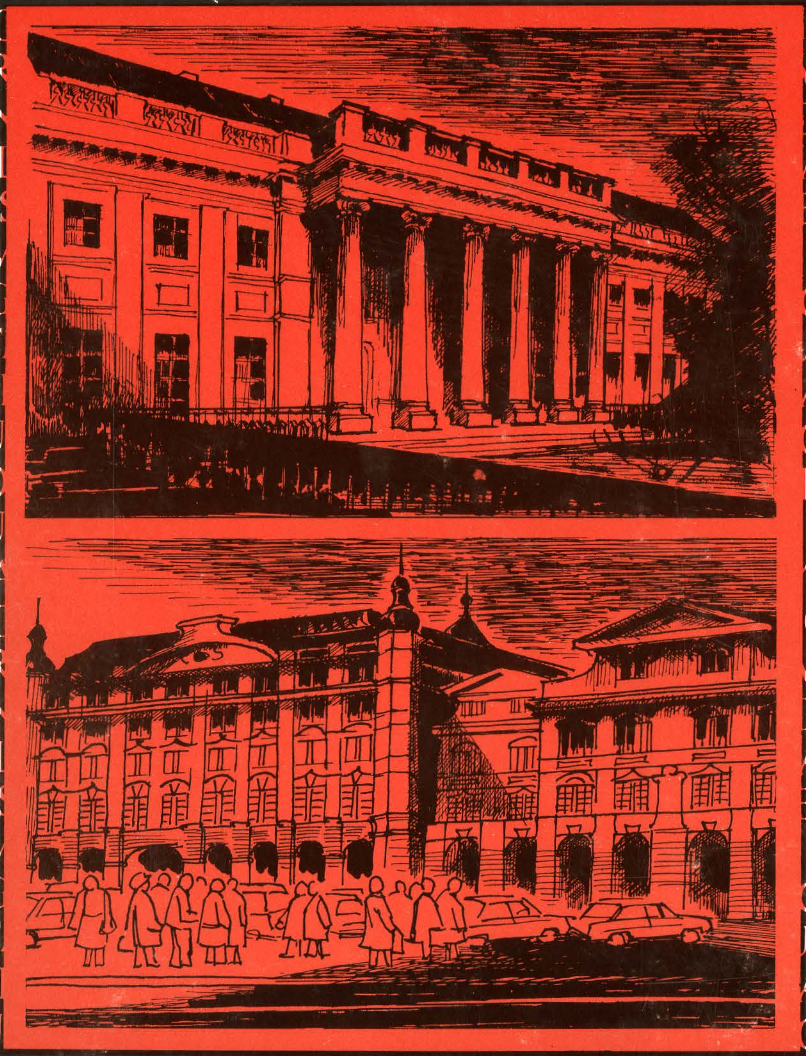

THIRTY YEARS OF GEOLOGICAL COOPERATION BETWEEN AUSTRIA AND CZECHOSLOVAKIA

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Reviewer:
JAN PETRÁNEK

Festive Volume edited to the occasion of the 30 Years Anniversary of the "Agreement between the Federal Government of Austria and the Government of the Czechoslovak Republic on the principles of cooperation in the field of geology between the Republic Austria and the Czechoslovak Republic" from January 23, 1960.

Festive
Volume

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THIRTY YEARS OF GEOLOGICAL COOPERATION BETWEEN AUSTRIA AND CZECHOSLOVAKIA

Federal Geological Survey,
Vienna

Geological Survey,
Prague

1990

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FOREWORD

Due to historical development, the fundaments of the Bohemian, Slovakian, and Austrian geology were laid in a corporate state formation, the Austrian Empire, in the 19th century.

Establishment of the Geological Survey in Vienna in 1849 resulted from the pressure of business circles put on creating conditions for a broader exploitation of domestic raw materials. Bohemia, Moravia, and Slovakia represented significant resources of these raw materials. Beside ores with many hundred years standing mining tradition, also non-metallic minerals and finally even coal and crude oil were explored. For their better utilization it was necessary to organize a systematic geological mapping and later on also closely related regional exploration.

Already in about the middle of the last century, when Joachim Barrande (1799—1883) published his fundamental results on the Palaeozoic of Bohemia, geoscientific relations were established between Prague, Vienna, and Bratislava.

Many other famous names are connected with this relationship, such as Johann Babtist Cžjžek (1806—1855) and August Emanuel Reuss (1811—1873) from Bohemia, Albin Heinrich (1785—1864) from Moravia, and from Austria Ferdinand Hochstetter (1829—1884), Carl Ferdinand Peters (1825—1881), Viktor L. Zapharovich (1830—1890), Franz X. M. Zippe (1791—1863) and last but not least Eduard Suess (1831—1914) the seventy-fifth anniversary of whose death we commemorate in 1989. Amongst other geologists, paleontologists, and mineralogists, these scientists prominently took part in the very first geological surveying of the regions nowadays subject of the common interest of Austrian and Czechoslovakian geoscientists.

Later on the history of the geological investigation of these areas is linked with the names of Josef Emanuel Hibsch (1852—1940), Josef Knett (1869—1946), Franz Eduard Suess (1867—1941), and Wilhelm Heinrich Waagen (1841—1900).

After the K.-K. Geologische Reichsanstalt had been founded in 1849, a number of staff members of the young Geological Survey of the Austrian Empire also took part in the geological investigations going on during the second half of the 19th century, amongst whom Jan Krejči (1825—1887), Ferdinand Lidl and Heinrich Wolf (1825—1882) should be mentioned.

FOREWORD

Doubtlessly one of the most outstanding personalities who should be quoted as a typical representative of the intimate historical connection between Austria and Czechoslovakia in the field of geology is Dionýs Štúr. He was born in Beckov, Slovakia, on April 2, 1827. As a staff member of the K.-K. Geologische Reichsanstalt, he became its third director in 1885, after W. v. Haidinger (1849—1865) and F. Hauer (1866—1884). He led the Geological Survey of the Austrian Empire for seven years until he retired in 1892, and died on the 9th of October, 1893 in Vienna.

In 1919, the Geological Survey was established in Prague and continued in geological mapping and investigation of all kinds of raw materials. Short time after World War II, geology in Austria and Czechoslovakia, similarily as in many other countries in the world, began to boom. Common raw material and regional geological problems led up to contracts which were ratified by a joint intergovernmental agreement in 1960. This agreement permitted further collaboration in geology on a long-term and planned basis.

In 1989, the thirtieth meeting of the official delegations of both Geological Surveys took place in the framework of the agreement on the principles of the geological cooperation between both countries. Three decades of work on common subjects of geological interest have passed in an atmosphere of mutual understanding and friendship. Year by year about seventy items of cooperation were discussed for the yearly programmes, regulating the exchange of experts and geological materials including scientific literature and the organization of fieldwork as well as meetings and symposia in either of the two countries. The cooperation covers a wide range of subjects, from pure geoscientific investigations of geological formations to the common exploitation of frontier-crossing oil and gas fields. There is no doubt about the great advantage this cooperation has brought about for the geological knowledge in both countries. As examples, the increase in understanding of the geological features of the Bohemian Massif or the Tertiary basins may be quoted. The publication in hand is an expression not only of the studious work of the geoscientists of both countries and of the multiplicity of the treated subjects, but it especially reflects the sense and spirit of cooperation in good neighbourly relationship.

It can be called a "European challenge" to preserve and promote this sense and spirit for further decades of fruitful common geological research.

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in Prague

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in Vienna

EDITORS' INTRODUCTION

On January 23, 1960 "Agreement between the Federal Government of Austria and the Government of Czechoslovak Republic on the principles of cooperation in the field of geology between the Republic Austria and the Czechoslovak Republic" was signed.

The main lines of the Agreement are as follows:

Considering the circumstance that a closer cooperation between Austria and Czechoslovakia in the field of geology would be beneficial to both countries,

and also considering the fact that such a cooperation appears to be of special importance in cases where common deposits of mineral raw materials occur on the territories of the two countries,

the Governments of both countries have made the following agreement:

Cooperation in the field of geology in the sense of this agreement is firstly the exchange of geological data and documents and the joint evaluation and coordination of the geological research in the border regions.

The programme of the geological mapping in the border region will be harmonized, if possible, so as to facilitate simultaneous mapping of the border sections of the two countries.

In individual cases, where the results of geological research accomplished by each contracting party on its own territory will differ due to subjective approaches, it will be possible to conduct joint inspections and measurements by the geologists of the two countries along the state border. Border-crossing will be facilitated for this purpose for the persons involved by the contracting parties.

Calibration of gravimetric and geomagnetic maps for the geological and geophysical work is a common goal.

If, within a distance of three kilometres from both sides of the border line results appear that would indicate the presence of useful minerals or of a deposit of a useful mineral raw material, the authorities of the two contracting parties will exchange the relevant geological information obtained during current work and they will, as far as possible, comply with request of the opposite party for such information.

If the researches result in finding common utilizable deposits, the two contracting parties will either, in due course, exchange information on such deposits according to the type of mineral substance found and coordinate the technical and juristical measures connected with the planned mining activities according to the agreement signed today on the exploitation of the common natural gas and crude oil deposits, or according to an agreement to be made separately.

To promote geological cooperation, the contracting parties will facilitate comparative studies of Czechoslovak geologists at Austrian classical localities and vice versa.

The realization of this agreement is the responsibility in Austria of the Geologische Bundesanstalt (Federal Geological Survey), Vienna in accordance with the Bundesministerium für Handel und Wiederaufbau — Oberste Bergbehörde (Supreme Mining Authority) and in Czechoslovakia of the Ústřední geologický úřad (Central Geological Office) in Prague.

On the same day, the Agreement between the above Governments concerning the exploitation of common natural gas and crude oil deposits was signed.

Survey of principal cooperation themes

On the basis of the above Agreement a geological cooperation of the two states was organized. In Austria the cooperation was coordinated by Geologische Bundesanstalt and in Czechoslovakia by the Central Geological Office up to 1969. From 1969 it has been taken over by the Czech Geological Office in Prague and the Slovak Geological Office in Bratislava.

On the Austrian side, the following organizations participated in the research: Geologische Bundesanstalt Wien, ÖMV Aktiengesellschaft Wien, Bundesversuchs- und Forschungsanstalt Arsenal Wien, Bundesministerium für wirtschaftliche Angelegenheiten Wien, Bundesministerium für Wissenschaft und Forschung Wien, Naturhistorisches Museum Wien, Universität Wien, Universität Graz, Universität für Bodenkultur, Montanuniversität Leoben, Institut für Geothermie und Hydrogeologie Forschungsgesellschaft Joanneum Graz, Zentralanstalt für Meteorologie und Geodynamik Wien, Amt der O. Ö. Landesregierung.

On the Czechoslovak side, the following organizations participated in the research: Ústřední ústav geologický Praha, Geologický ústav Dionýza Štúra Bratislava, Moravské naftové doly Hodonín, Geofyzika Brno, Geoindustria Praha, Inženýrsko-geologický a hydrogeologický prieskum Žilina, Geologický prieskum Spišská Nová Ves, Unigeo Ostrava, Československá akademie věd.

The extent of cooperation significantly increased after ratification of an agreement about the foreign currency exchange-free cooperation in June 1980. According to the main articles of the intergovernmental agreement the collaboration was concentrated into three chief areas — the exchange of literature, exchange of comparative material, and specialists' visits for the purpose of study.

The exchange of literature was carried out in the form of mutual supplying of geological publications, periodics and printed geological maps issued by the Geologische Bundesanstalt and Geological Survey, Prague or the Geological Survey of Dionýz Štúr and delivering requested materials issued by other geological institutions of both countries.

The exchange of comparative material was focussed predominantly on paleontologic samples especially from the territory of the Vienna Basin, Flysch Belt and foredeep and geological and geophysical profiles and borehole data from the area of crude oil and gas prospecting in frontier territories. Further exchange was carried out in the field of engineering geology and hydrogeology and was concerned with documentation of waterworks on the Danube river and mechanics of soils and landslides.

Visits for the purpose of study and comparative studies were focussed namely on (1) stratigraphy and paleogeography of sediments, (2) research of the crystalline complexes, (3) prospecting for hydrocarbons, (4) geophysics, (5) metallic and non-metallic deposits, (6) paleontology, and (7) geological mapping of frontier areas. To a lesser extent, the comparative studies were concerned with (8) hydrogeology and (9) engineering geology. Recently, cooperation included also geochemical and mineralogical laboratories (10). Geological cooperation between the two countries permitted also a study of special materials in museums and archives (11) and helped to expand the collaboration in the framework of Carpetho-Balkanian Geological Association (CBGA or KBGA) and IGCP (12).

(1) Comparative studies in stratigraphy and paleogeography include the investigation of sediments from the Paleozoic to the Quaternary. The greatest attention was paid to the area along the Czechoslovak-Austrian border and the studies were especially centred on bio- and lithostratigraphy of the sediments of the Foredeep, Flysch Belt, Vienna Basin and its basement. Investigation of the Quaternary sediments was focussed on the correlation of the Dyje and Morava rivers systems with the system of the Donau.

Recently, an intensive cooperation developed between Slovak and Austrian geologists in the field of facies research and correlation of namely Paleozoic and Triassic series of the West Carpathians and the Eastern Alps.

The scope of collaboration in the above fields is documented by the number and extent of articles in the Festive Volume.

(2) Comparative studies of the crystalline complex dealt especially with the deep structure and distribution of the Bohemian Massif units, namely with the Moldanubicum and its lithostratigraphy and tectonics. In the last decade, attention has been focussed on determination of the abso-

lute age of the Moldanubicum rocks and a comparative research into the West Carpathian and Eastern Alps crystalline complexes was started. These problems are also documented by papers in this Volume.

(3) Cooperation in hydrocarbon prospecting has been very successfully carried out over the whole 30 years. Besides prospecting for crude oil and gas a number of geological problems of the Alpine-Carpathian system was studied, e. g. deep structure, tectonics and facies. An overview of the cooperation results is presented in the article of Thon — Wessely. The range of cooperation is documented by manuscripts in the thematic group "Petroleum geology" and "Structural geology and geophysics".

Alongside with geological problems, various aspects of organic and gas geochemistry were also studied in the framework of the research into crude oil and gas genesis. Last year, a collaboration in the investigation of organic geochemistry of bituminous shales has been initiated.

(4) Similarly as prospecting for hydrocarbons, geophysics has also been incorporated into the cooperation from its beginning. Geophysicists of both countries participated in exchange meetings organized in yearly intervals. The major topic was the exchange of experience in application of geophysical methods for hydrocarbon prospecting and collaboration during measurements campaigns in frontier territories; this resulted in cooperation in the research into the deep structure of the Earth crust.

Beside the above major field of interest, questions of paleomagnetism and geophysical measuring for the investigation of landslides were also studied.

(5) In the course of the whole period of cooperation there were made rather frequent exchange visits concerned with the problematics of deposits. However, these visits had only random character from either side. Only in the past several years the cooperation in this field became systematic and included research of non-metallic raw materials, namely kaolin. Other comparative studies were focussed on tin, tungsten, nickel, molybdene, lead and zinc deposits, less frequently on non-metallic raw materials (beside already mentioned kaolins on magnesite, siderite, ceramic clays, graphite, and lignite). The use of aerial geophysical methods and their interpretation in metallogenesis was studied, too. The problems of metallogenesis were investigated also in collaboration with IAGOD working group.

(6) Paleontology (with palynology) represents a branch which was continuously studied during the whole period of cooperation. Comparative studies dealt especially with the research of Tertiary (namely Neogene, less frequently Paleogene) fossils and are documented by papers in the thematic group "Paleontology". Comparative study in the Barrandian area, the results of which are published in the informative reports of Chlupáč et al. and Kříž, represents another significant contribution.

(7) In the framework of geological mapping of frontier territories the crystalline areas along the Austrian-south Moravian border were mapped. The results and overview of the mapped territory are given in the informative report of Matějovská.

(8) Cooperation in hydrogeology was predominantly concerned with the study of geothermal energy. Measuring techniques, hydrogeology of lignite deposits, fault zones of the Bohemian Massif and hydrogeologic problems in frontier areas were investigated, too.

(9) Cooperation in engineering geology was aimed especially at problems of methodics (soil mechanics, geoacoustic methods in landslide research, maintenance of landslide slopes) connected with motorway and tube construction.

(10) Cooperation between geochemical and mineralogic laboratories has been developing namely in the past five years. It has been focussed on the exchange of information between the BVFA Arsenal and GBA on the Austrian side and Geoindustria Praha and Geological Survey on the Czechoslovak side, encompassing especially multi-element analyses (RFA, ICP, AAS, OES, INAA) with a view to calibration of apparatuses, preparation of geological standards and reference materials, checking the accuracy of laboratory works, laboratory automation and isotope analyses. It is concerned with environmental geology, raw material research, geochemistry and geochronology.

With this problematics is linked also the employment of mathematical methods in geology where collaboration was initiated during the last five years, too.

(11) Museums were visited especially for the purpose of study of paleontologic collections in the Naturhistorisches Museum in Vienna and National Museum in Prague. Archival studies (Hofkammerarchiv, Geofond, libraries) were concerned with ancient mining and history as well as with organization of documentation services and databanks.

(12) Cooperation with KBGA was carried out especially in the form of exchange of specialists from individual KBGA commissions, namely from the tectonic, metamorphic, stratigraphic, and sedimentologic commissions and the commission for geological maps.

Cooperation in the framework of IGCP included the projects nos. 5 (Correlation of Prevariscan and Variscan events of the Alpine-Mediterranen Mountain belts), 199 (Rare events in geology), 198 (Evolution of the northern margin of the Tethys), 203 (Permo-Triassic events of the Eastern Tethys and their intercontinental correlation), 254 (Metalliferous black shales), 262 (Tethyan Cretaceous correlation), 276 (Paleozoic in the Tethys).

In addition guest-lectures of well-known specialists from Austria and Czechoslovakia took place (Prof. Ronner, Prof. Gattinger, Prof. Maheľ, Prof. Fusán, Associate Prof. Štemprok, Dr. Kukal and others) and two joint seminars were organized. The first seminar took place in the Geological Survey (Prague, February 1987) and dealt with environmental problems. The second seminar (Brno, March 1988) was concerned with geology of the Bohemian Massif and its Carpathian cover with a view to prospecting for crude oil and gas. It was organized by the Geological Survey, Brno and attended by Moravian Oil Company Hodonín and ÖMV and Geologische Bundesanstalt in Vienna.

The Austrian and Czechoslovak specialists jointly cooperated in organization or participated in numerous international scientific meetings, conferences, symposiums etc. which took place in both countries in the course of years.

The future cooperation necessarily has to be focused on the important input of geology to the steadily growing problem of environmental protection. In this context as a first step, an intensive cooperation in the frame of the project "Deep Structure of the Bohemian Massif and Carpathians" is envisaged. Besides a contribution of data concerning the mineral deposit potential, geothermal energy, groundwater resources and gas, this project will provide the basis for landuse planning including a wide assay of ecologically relevant data material.

Particularly also the cooperation in the border area, including field mapping, basic geological research and geophysical and geochemical methods should be coordinated as efficiently as possible. The joint lithologic and tectonic evaluation of various units of the Bohemian Massif and other crystalline massifs in the subsurface should become one of the main topics. Of equal importance is the coordination of the Alpine with the Carpathian System and within the Vienna Basin.

Efforts should also be made in joint development of analytical methods and their standardization. This implies *a permanent and open exchange of opinions and experiences. In order to maintain the flux of information as efficient as possible, joint green desk and field seminars and workshops in a wide field of scientific and applied topics should be stressed. Results of these investigations should be documented in joint publications. As already in the past in many fields, the highest level of basic research should be maintained also in the future in as many topics of cooperation as possible.*

The different educational and geopolitical background of the experts of our two Republics should not coincide with a gap of understanding in the future, but should be understood as a challenge to bring together ideas from different points of view. Already in the past, this bridge of ideas between two states of different political understanding was easy to cross by the geological community, as impressively evidenced by thirty years of uninterrupted successful cooperation in an atmosphere of friendship. And in future this bridge could play the role of a catalysator of ideas and hopefully will bring together mental power and scientific capacity from different points of view. The steady competitive improvement of quality of basic scientific research is the only possible serious basis for successful practical work, which is the prerequisite for economic growth and higher standard of life. With this perspective in mind and in the context of the steadily growing importance of geoscientific research all over the world, Austria and Czechoslovakia should intensify their joint efforts in geoscientific cooperation for the benefit of their populations.

Editors' note

The Festive Volume contains 42 original manuscripts and 3 informative reports. The manuscripts were arranged into six thematic sections: (1) structural geology and geophysics, (2) stratigraphy and paleogeography, (3) petroleum geology and geochemistry, mineral deposits, (4) paleontology, (5) magmatism and metamorphism, (6) miscellaneous. In each group the articles were arranged alphabetically according to the names of their authors. The only exception to this rule is the contribution of Thon — Wessely which summarizes the results of cooperation in the research into crude oil and gas and thus was placed as an introductory article of the thematic group devoted to petroleum geology. All manuscripts are written in English with abstracts in German and Czech or Slovak. Only the paper by Aric is in German because it contains large passages in Old German the translation of which in practice would be not adequate.

Several manuscripts have a wider scope covering more fields and thus their assignment into groups is only approximate. The contributions do not cover the cooperation over the whole 30 years; they discuss recent results predominantly from the past ten years. Informative reports which close the Volume, provide a survey of results reached in the given field and have been already published elsewhere.

The names of institutes of individual authors are given in the original form. Their English translation, abbreviation and addresses are published in the appendix of the Volume.

The authors are responsible for the content and language correctness of their publication.

The deadline for presentation of contributions was the end of 1988, the final reviews were accepted by the publishers on March 3, 1989.

Considering the printing technology used the rules of word division could not be strictly observed.

We wish to thank the authors for working out original papers and instructive illustrations. We believe that the volume shows the wide scope of collaboration between Austria and Czechoslovakia and that it will contribute to a more profound knowledge of geology of Central Europe.

NEW FINDINGS ON THE DEEP STRUCTURE OF THE SOUTHEASTERN SLOPES OF THE BOHEMIAN MASSIF ("SOUTHERN SECTION" — NĚMČIČKY BLOCK)

Josef Adámek, Moravské naftové doly, Hodonín, Czechoslovakia

1. Introduction

Drilling and geophysical operations have revealed new facts on the geological structure and the functions of some significant faults on the southeastern slopes of the Bohemian Massif in the area of the Němčičky blocks, in the inner part of the Nesvačilka depression and on the adjoining slopes of the Ždánice crystalline high. New data have also been obtained on the extension of individual sedimentary complexes of the Variscan and Neoid levels. The studies conducted permit to determine the southwestern margin of the Variscan area of sedimentation preserved on the deep-seated Němčičky blocks and to define the structure of this region near the limits of the Variscan tectogene. NW-SE-striking tectonic elements were determined in the region under study; they step-like divide the whole area between the Waschberg ridge and the Ždánice high into numerous blocks with faults that evidently disturb the Devonian and Lower Carboniferous carbonate complexes. In the early Namurian, subsidence markedly accelerated on the margins of the Němčičky blocks and in the inner parts of the Uhřice blocks on the southwestern slope of the Ždánice high. Within the Němčičky blocks, subsidence accounts for the enormous thickness of the conglomerates (Němčičky — 2 and 5 boreholes) with pebbles from the Moldanubic zone and from the Dyje or the Brno Massifs. The overlying complexes, composed primarily of sandstones of the coal-bearing Namurian-A, have been compared to the Ostrava sequences. The blocks constitute a slightly asymmetric graben (Fig. 1). The directions of the tectonic lines agree, to a certain extent, with those of significant magnetic anomalies in the broader region (Fig. 4). After a hiatus during the Permian, resedimentation took place in Jurassic time (Lias-Malm) and was terminated by the Kurdějov and/or Ernstbrunn Malm limestones. In pre-Paleogene time, the Mesozoic sediments were removed from the major part of the present (Vranovice and Nesvačilka) depressions, leaving only relics there. Paleogene sediments, filling the Nesvačilka and Vranovice depressions, covered the heavily eroded pre-Tertiary relief. After subsequent Miocene sedimentation, delimited by the fronts of the flysch units on the southeast, the outer flysch nappes were finally overthrust. The structures of the nappes incorporated sediments of the underlying autochthonous Paleogene and the Mesozoic Carpathian Foredeep in the form of more or less separated tectonic fragments.

The development of the region studied can be characterized by three stages of basin development commonly known. The least number of data is available on the "pre-graben stage". The principal period of basinal development — the "graben fill basin" — seems to have started in the Upper Carboniferous. The third stage — the "interior sag graben" — can be associated with the period of Paleogene sedimentation.

The paper presented evaluates new data on the geological structure and development of the Variscan areas of sedimentation in the Němčičky and Uhřice blocks on the opposite slope of the Ždánice high. These data were obtained by deep drilling and reflexion seismic techniques. The development of this area in the transverse direction, i. e. perpendicularly to the bordering faults and the courses of young copying structures (the Nesvačilka and Vranovice depressions filled with Paleogene sediments) was also studied. These depressions, called the Vranovice and Nesvačilka grabens, were the subject of studies by numerous authors, and were evaluated, from other view-points, in a number of papers: V. Homola et al., 1961; F. Němec, 1973; F. Pícha, E. Hanzlíková, J. Cahelová, 1978; F. Pícha, 1979; and R. Jiříček, 1987. Problems related to the Variscan level were treated mainly by J. Dvořák, 1978; J. Hladil, 1983; J. Kalvoda, 1981; and J. Kalvoda, P. Kostelníček, 1981. Questions concerning the geological development were studied, in a more complex way, by geologists of the Moravian Oil Company, Hodonín and of the Central Geological Survey, Prague and Brno, e. g. by V. Špička, 1971; J. Adámek, 1981; P. Kostelníček, V. Ciprys, 1981. Recent studies by Soviet experts (V. I. Chnykin et al., 1986) have also dealt with these problems.

2. Geologic setting

The rock complexes encountered in the region studied belong to three — Cadomian, Variscan and Neoid — levels that were overthrust by the nappes of the outer flysch units of the western Carpathians.

The Cadomian level, composed of granitoid rocks and metamorphites, was encountered on the slopes of the Ždánice crystalline high, in the Vranovice depression filled with Paleogene sediments and in the Nikolčice blocks. Owing to the great thickness of the sediments (more than 5,000 m), the Cadomian level has not yet been reached by drilling in the Němčičky blocks.

The Variscan level (or its sedimentary cycle) begins with diversified and prevailingly coarse-grained clastic sediments in the broader region. Grey-black silty and clayey shales of Middle Devonian to Eifelian age have also been identified in the cores of Němčičky—3 and 6 boreholes (M. Vavrdová, 1987); their thickness has not yet been determined by drilling in the Němčičky blocks. In the Měnín and Nikolčice areas, the thicknesses of the mostly coarse-grained clastic sediments vary, attaining a maximum of more than 1,700 m in Měnín—1 borehole (J. Adámek, 1975). They are smaller by an order of magnitude in the Nikolčice boreholes. This difference appears to be due to the morphology of the basement and to different block subsidence. In the Upper Eifelian, the prevailingly terrigenous Old Red facies was transgressively covered by the Macocha carbonate sequence containing limestones of the Čelechovice cycle. The carbonates of this cycle yielded limestones of the "Býčí skála", Ochoz and Mokrá cycles (J. Hladil, 1983). Carbonate sedimentation was affected by block movements during the Givetian and, more markedly, during the Upper Frasnian and Lower Famennian. Biofacial investigations of Famennian and Lower Carboniferous limestones that terminated carbonate sedimentation, indicated a shallow area of sedimentation in the Němčičky-Nítkovice platform (J. Kalvoda, 1981, J. Kalvoda in J. Kalvoda, P. Kostelníček, 1981). Tuffite layers, characterized by increased values of natural radioactivity (Gamma Ray Log), are the typical, regionally proved correlate for determining the Famennian) Visean boundary. A significant regression related to a marked hiat lasting until the lower part of the Uper Visean occurred in the period between the Devonian and Carboniferous. The sedimentation of the Myslejovice sequence composed of dark shales, locally with limestone intercalations, continued in the upper part of the Upper Visean. The subsidence of the western marginal Němčičky block accelerated in the early Namurian. The blocks were sinking somewhat more slowly in the present Nesvačilka depression. The rapid subsidence is reflected in the thicknesses of the conglomerates found in Němčičky—2 (150 m) and, recently, Němčičky—5 boreholes (more than 1,000 m) that contain pebbles originating in the Moldanubic zone and the Dyje and or Brno Massifs (J. Polický, V. Fialová, 1980; M. Zádrapa, 1988). The prevailingly sandstone-containing complexes of the coal-bearing Namurian-A are situated at a higher level. Their upper parts display cyclic sedimentation with coal seams with predominating continental (fluvial and lacustrine) facies and transitions to marine facies. After a hiatus beginning from the Upper Carboniferous (Namurian-A), the development of the Neoid level started with the Jurassic and the sedimentation of basal prevailingly clastic Jurassic facies (Lias-Dogger) took place (locally with the redeposition with older Upper Carboniferous material — J. Adámek, 1986). These sediments leveled the peneplaned pre-Jurassic relief. This is obvious from the relatively small, not much varying thicknesses of the basal Jurassic clastic sequence (Gresten sandstones and claystones, Nikolčice sandstones and dolomites). The sedimentation of the Klentnice pelitecarbonate sequence indicates the deepening of the area of sedimentation. This is evidenced by the facies development of the base of this sequence, characterized by the decreasing thickness of the Vranovice carbonates and the increasing thickness of the Mikulov marlstones. The upper part of the Mesozoic, consisting of Kurdějov limestones and marlstones in the Němčičky blocks, is indicative of basin stabilization characterized by slight oscillations. Jurassic sedimentation was closed with Ernstbrunn limestones. The relief was repeneplaned in the subsequent period-practically up to Tertiary time. The development of Mesozoic (Jurassic to Upper Cretaceous) sediments in the broader region could be demonstrated, in a more complete range, south of the region described and in Lower Austria (F. Brix, A. Kröll, G. Wessely, 1977; J. Adámek, 1986). In the Nesvačilka depression, most of the Mesozoic sediments were removed, leaving only relicts on the slopes, much like in the Vranovice depression. The heavily eroded pre-Tertiary basement was transgressed by the sea in the Paleogene. Paleogene sediments gradually filled not only both depressions, but also the adjoining uplifted areas between the depressions (Němčičky area — Němčičky 5 and 6 boreholes) and the area south of the Vranovice depression. Their present extent is much smaller as a result of subsequent denudation and tectonic abrasion by the nappes. The Miocene sediments (Eggenburgian-Karpatian) that are confined to the Nikolčice blocks were substantially affected by tectonic abrasion coupled with faulting tectonics. This fact is evidenced by their fragments incorporated into the fronts of the flysch nappes (I. Zapletalová, 1975). Miocene sediments are absent farther southeast, that means in the area of the Němčičky blocks. Paleogene and Jurassic sediments were also integrated into the structures of the nappes.

The interrelations in the development of blocks following the NW-SE course of the Jurassic Nikolčice-Kurdějov ridge have been described already (J. Adámek, J. Dvořák, J. Kalvoda, 1980), but no adequate data were available, at that time, that would allow to divide the region perpendicularly to the two depressed areas filled with Paleogene sediments. New findings from recently drilled wells and reinterpretations of older wells and geophysical (mainly reflexion seismic) measurements permit to evaluate the development of the Variscan and Neoid levels and the nature of the southwestern contact between the Variscan and Cadomian levels. The region described includes places where the Paleozoic (Devonian — Upper Carboniferous) sedimentary cover has been preserved. Jurassic sediments have been preserved, to a varying extent, on both margins of the cover, i. e. in the Nikolčice-Němčičky area on the one side, and in the Ždánice-Uhřice area on the other side. Due to the inverted development of the individual blocks and subsequent erosion, the geological structure of the pre-Tertiary basement is rather complex in this region. In addition to Jurassic sediments, it comprises also those of the Variscan level and even crystalline rocks of the Cadomian level. Their major parts are covered with autochthonous Paleogene rocks. The autochthonous formations are overthrust by nappes of the West Carpathian flysch belt (Fig. 1). The structure of the Variscan level bears the character of an asymmetric graben trough bounded by faults, markedly

Fig. 1

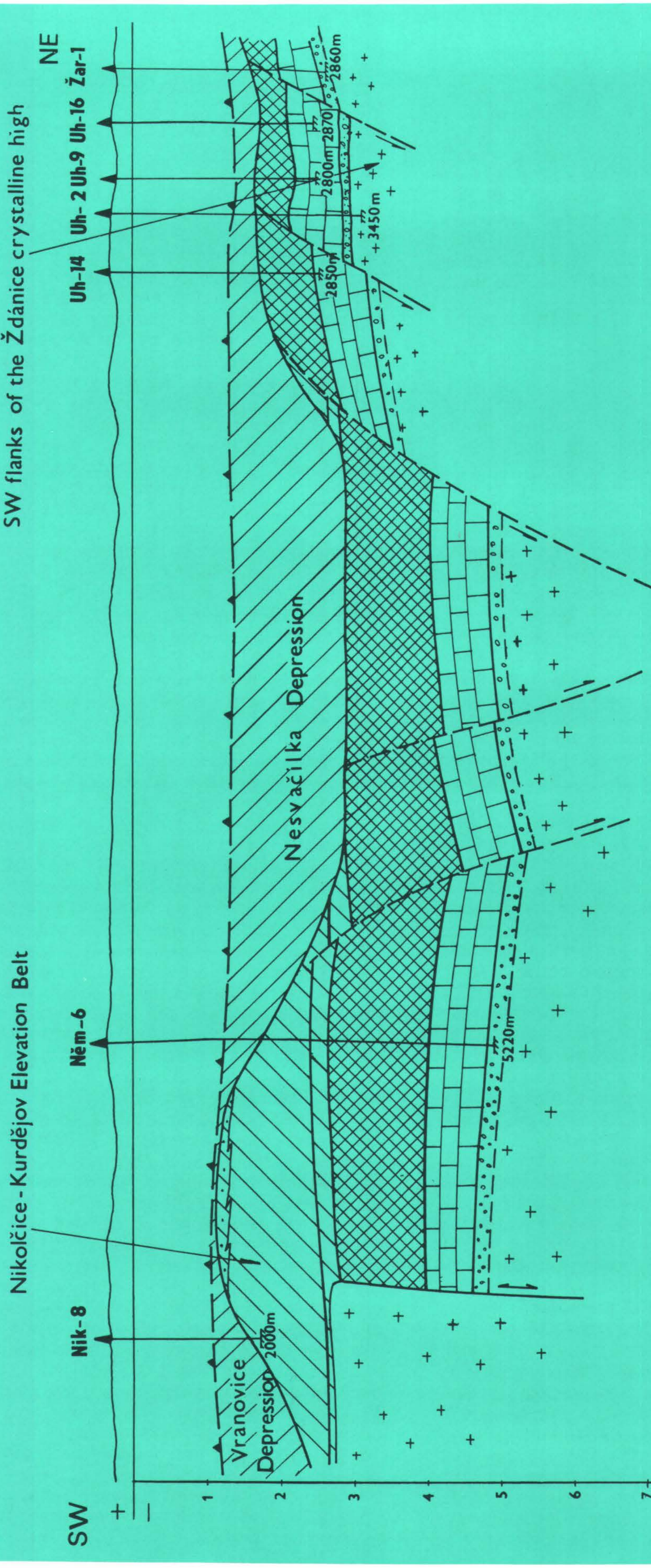
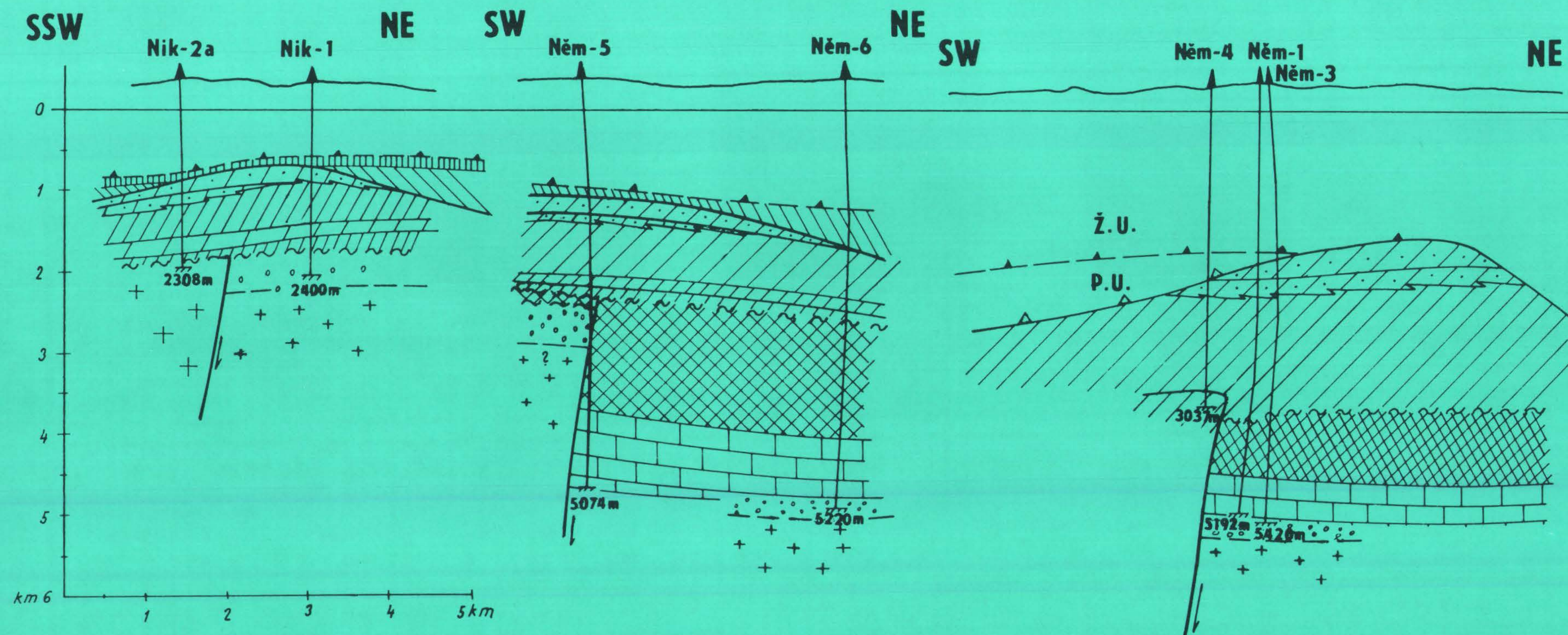


Figure 1
Part of the geological cross section along seismic reflection profiles No 169/78 and 119/80

Author: J. Adámek (1988)

Fig. 2

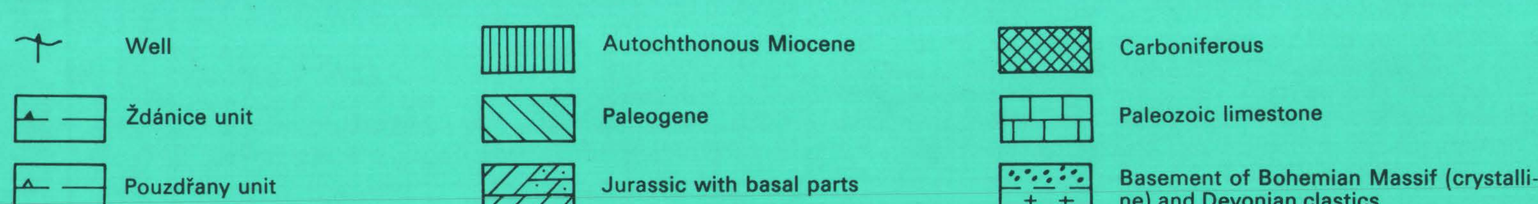


A. Geological cross section through Nikolčice - 2a and Nikolčice - 1 boreholes

B. Geological cross section through Němčičky-5 and Němčičky-6 boreholes

C. Part of the geological cross section along seismic reflection profile No 168/74

EXPLANATION FOR FIGURE NO. 1 AND 2



deepened, with almost completely preserved sequences of the higher parts of the Variscan level (Upper Carboniferous — Namurian-A) in the southwestern part of the region (Němčičky blocks). As a result of inversion and erosion, the thicknesses of the Upper Carboniferous sediments decrease towards the northeast along the step-like faults. On the southwestern slope of the Ždánice crystalline high, the Paleozoic rocks are covered with Jurassic sediments, or the latter rest immediately on the Cadomian basement. Farther northeast (on the Ždánice high), the Cadomian level forms the pre-Tertiary relief. The Variscan level is covered with thick Jurassic sediments in the area of the Němčičky and Nikolčice blocks. The tectonic character of the southwestern boundary of the Paleozoic sediments is evedenced by three profiles (Fig. 2). The whole structure, however, is much more complex; the tectonic recurrence of carbonate sequences, e. g. in Němčičky—1 borehole, can be explained by the effects of a disturbance zone with nearly vertical faults. The primary spatial distribution of the Variscan level was substantially larger (e. g. Nikolčice—5 borehole with clastics of the Old Red facies, occurrence of Frasnian carbonate pebbles in the Upper Carboniferous complex in Němčičky—5 borehole — J. Kalvoda, personal communication). All the above indicates that, in the Devonian, the extent of the carbonate platform was larger than it is at the present time. In the uplifted blocks, platform carbonates have been preserved as denudation remnants only in downdip intermediate blocks. Lithostratigraphic correlations of the top of the carbonate complex (Famennian — Visean) suggest that their epigenetic disturbance most likely occurred during a pronounced subsidence in the lower part of the Upper Carboniferous (Namurian-A), mainly at the southwestern margin of the Němčičky blocks (as opposed to the Cadomian level) and on the slopes of the Ždánice crystalline high (Figs. 1 to 3). At that time, subsidence was isostatically compensated by the uplifting of blocks situated beyond the present principal Upper Carboniferous area of sedimentation. During the sedimentation of the top parts of the Upper Carboniferous, the Němčičky block area appears to have been tectonically more active than the slopes of the Ždánice high. After the sedimentation of the Upper Carboniferous had terminated, the area was peneplaned and the basal clastic Jurassic sequence was deposited after a long-lasting hiatus. Tectonic activity apparently reappeared only during the sedimentation of the pelitic part of the Klentnice sequence. As a result, the thicknesses of the pelites and the pelite-carbonate cycle increased and the base of the latter changed in facies. The uper parts of the Jurassic sedimentary cycle were denuded, in part, probably owing to an inversion on the slopes of the Ždánice high. In the region under study, Jurassic sediments have been preserved practically only on the incised blocks.

3. Conclusions

The investigations conducted in the area of interest have yielded new facts on the Paleozoic, Mesozoic and Paleogene lithostratigraphic complexes present in the Nesvačilka depression. The development of the region permits two evolutional stages to be determined: the main "graben fill basin" stage active in the Lower Carboniferous and the "interior sag graben" stage in the Paleogene. The age of the "pre-graben stage" cannot be determined because of lacking data. On the basis of the development of the region, the principal unconformities were identified on which suitable reservoir rocks could have formed in the periods between the Upper Carboniferous and Jurassic (Lias-Dogger) and between the Mesozoic (Tithonian) and Tertiary (Paleogene). Oil-bearing capacity can be attributed to the clastic sediments of the Upper Carboniferous covered, deep below the nappes, with Jurassic marlstones (Mikulov marlstones). In the shallower part of the region, the upper levels of the Upper Carboniferous are connected with clastic facies at the base of Jurassic sedimentation. Oil traps can be formed in clastic sequences of the overlying Jurassic sediments or at the base of Jurassic pelite-carbonate layers (Vranovice carbonates). The period between the Mesozoic and Tertiary is more suitable with respect to the formation of reservoir rocks, mainly in the old Tertiary (Paleogene) basin fill. The regionally distributed facies of the underlying Mesozoic in the deeper parts of the Jurassic area of sedimentation (generally facies of a more pronounced pelitic nature) are less suited to form oil traps. Oil and gas deposits on the slopes of the Ždánice high are associated with the Paleogene basin fill (sandy facies). Of less importance are the carbonate layers (Visean) and the Famennian pure limestones layers. The carbonate facies are sealed, at the top, by Upper Visean shales of the Myslejovice sequence. In the Uhřice area, oil traps are present in these carbonates, the distribution of the traps being closely related to the lithological development of the carbonates. In addition to the factors mentioned above, tectonic development is of decisive importance to the formation of oil and gas traps.

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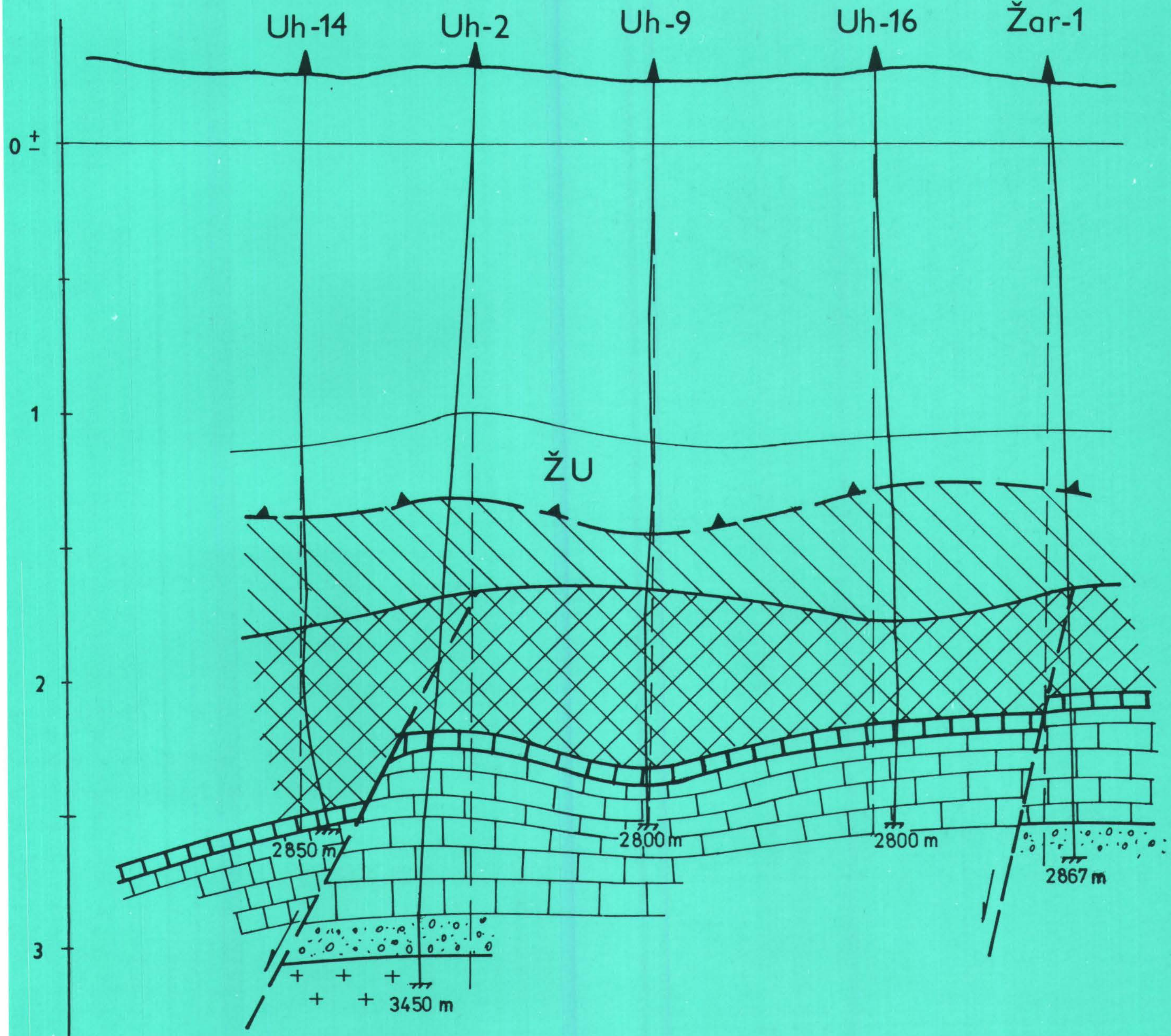

GEOLOGICAL CROSS SECTION THROUGH UHŘICE-14, 2, 9, 16 AND ŽAROŠICE-1 BOREHOLES

(CORRELATION OF PALEOZOIC SEDIMENTS)

Lower Carboniferous
Visean (Limestones)

Devonian
Givetian - Famennian (Limestones)

Fig. 3

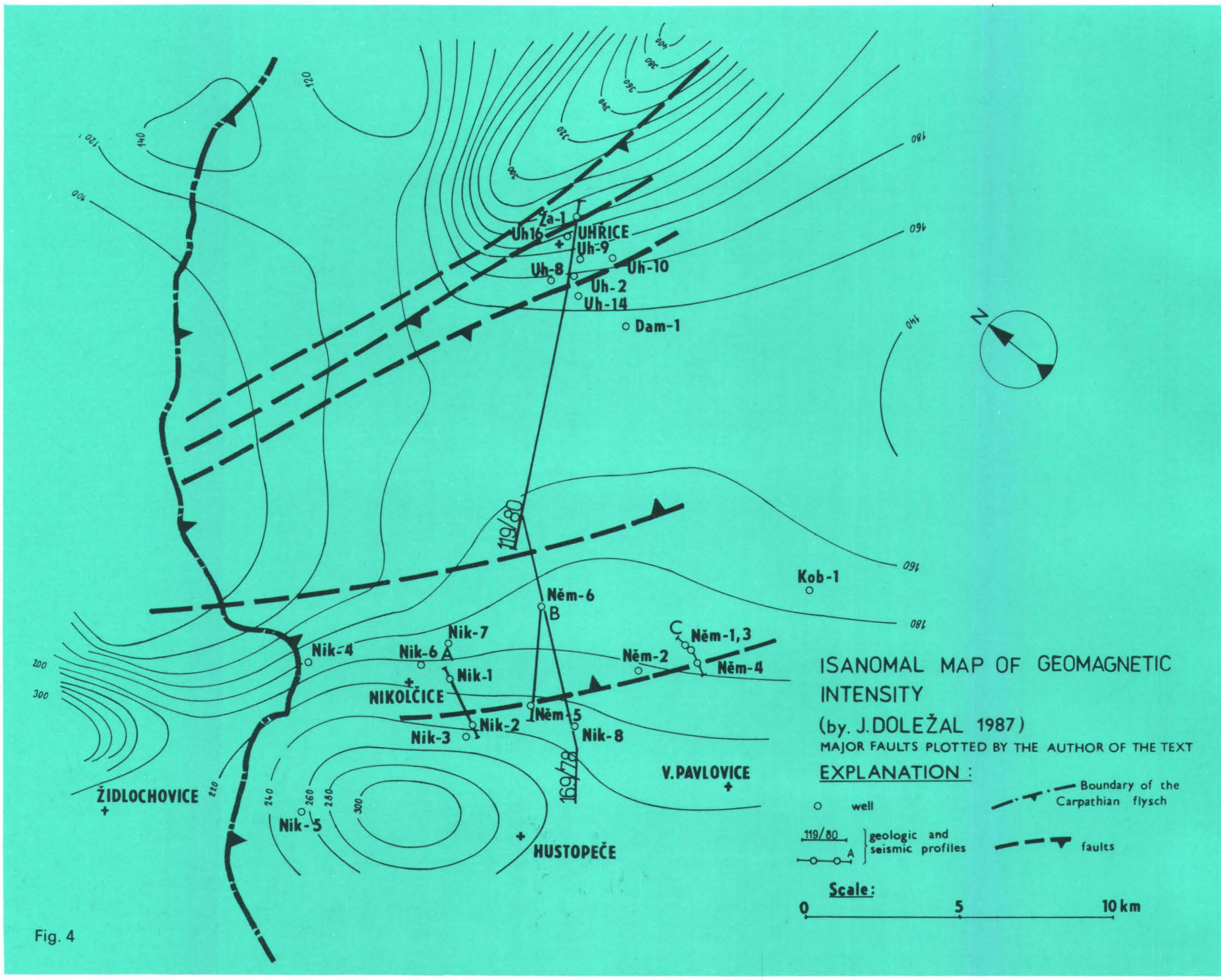

Fig. 4

Abstrakt

Na jv. svazích Českého masívu, v prostoru němčičských ker, stejně jako v interní části nesvačilské deprese a na přiléhajících svazích ždánické krystalinické elevace, byly vrtními a geofyzikálními pracemi zjištěny nové poznatky o geologické stavbě a o funkci zlomů SZ—JV průběhu. Zlomy člení stupňovitě celý prostor mezi waschberskou krou a ždánickou elevací na řadu ker a porušují evidentně karbonátové komplexy devonu a sp. karbonu. Na základě širšího zpracování je také možno vymezit jz. okraj zachovaného variského sedimentačního prostoru a určit stavební styl této pro variský tektogén okrajové oblasti. Kry tvoří mírně asymetrický příkop a směry tektonických linií jsou přitom v jistém souladu se směry významných magnetických anomálií. Vývoj tohoto studovaného prostoru je možno charakterizovat třemi známými etapami vývoje pánví, přičemž o stadiu tzv. „pregrabenu" máme nejméně údajů. Hlavní období vývoje pánve, tj. během výrazné funkce zlomů („graben fill basin"), začalo nejspíše ve spodní části svrchního karbonu a třetí stadium, vázané na období sedimentace po ukončení výrazné zlomové činnosti („interior sag graben"), je možno vázat na paleogenní cyklus.

Zusammenfassung

An SO-Hängen der Böhmischen Masse, im Raum der Němčičky-Schollen sowie im inneren Teil der Nesvačilka-Mulde, und an anliegenden Hängen der Ždánice-Kristallinerhebung sind durch geophysikalische und Bohrarbeiten neue Erkenntnisse vom geologischen Bau und von der Funktion der von NW nach SO streichenden Brüche erworben worden. Durch diese Brüche wird der ganze Raum zwischen der Waschberg-Scholle und der Ždánice-Erhebung in mehrere Schollen aufgeteilt und die Karbonatkomplexe des Devons und Unterkarbons offensichtlich gestört. Aufgrund einer weiteren Auswertung der Forschungsergebnisse kann auch der SW-Rand des erhaltenen variszischen Sedimentationsraums abgegrenzt und der Baustil dieses Randgebiets des variszischen Tektogens bestimmt werden. Die Schollen bilden einen mäßig asymmetrischen Graben, wobei die Streichrichtungen der tektonischen Linien in gewissem Einklang mit den Richtungen bedeutsamer magnetischer Anomalien stehen. Die Entwicklung des Untersuchungsgebiets kann durch drei bekannte Beckenentwicklungsetappen charakterisiert werden, wobei uns die wenigsten Angaben über das Stadium des sog. „Prägrabens" zur Verfügung stehen. Die Hauptperiode der Beckenentwicklung, d. h. die Periode von ausgeprägter Funktion der Brüche („graben fill basin"), begann höchstwahrscheinlich im unteren Teil des Oberkarbons, und das dritte Stadium, das an die Sedimentationsperiode nach dem Abschluß ausgeprägter bruchtektonischer Vorgänge gebunden ist („interior sag graben"), kann mit dem paläogenen Zyklus in Zusammenhang gebracht werden.

DEEP CRUSTAL STRUCTURE AT THE CONTACT OF THE BOHEMIAN MASSIF AND WEST CARPATHIANS

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Geophysical and drilling investigations brought new opinions on the contact of the Bohemian Massif and West Carpathians. Since the beginning of investigations in the 1930s there have been two concepts. Firstly, it was contended that in the deeper structure the contact is formed by an old consolidated unit only partially affected by Hercynian and Alpine tectonometamorphic processes (Zapletal 1931 — Brunnia, Roth 1964 — Brno unit, Dudek 1980 — Brunovistulicum, Jantski 1976 — Moravo-Silesian Massif) and having its own metamorphic structure (Štelcl, Weiss 1983). Secondly, the existence of a deep weak zone at the contact was assumed, composed of rocks from the Precambrian to the present time. It is, for instance, the Moravian zone (Zoubek 1946, 1948), the Moravo-Silesian lineament (Stille 1951), the Svojanov-Dyje corridor (Mísař 1961, 1967), the Peripieninian lineament (Máška 1960), the aseismic zone (Beránek, Zátopek 1981), the Lednice zone (Beránek, Weiss 1979). This "deep weak zone" is situated in the margin of the Bohemian Massif, in the axis of the oldest part of the Carpathian foredeep, in the axis of the Carpathian low, in the western part of the Carpathian foredeep, in the western part of the Klippen Belt, or is identified with the Peripieninian lineament.

In recent years, deep boreholes were drilled in Outer Carpathians, the first reflection seismic profiles were interpreted (Štelcl et al. 1981, Blížkovský et al. 1986, Tomek 1985) and abundant geological and petrological data were collected (Štelcl et al. 1986, Dudek 1980, Weiss 1982).

According to the latest data the Brno unit forms a separate structural basement consolidated during Cadomian orogeny, and present in both the basement of the Bohemian Massif Hercynides in the west, and the basement of the Carpathian foredeep, of the Vienna Basin, and of Carpathian nappes in the east. In the west the Brno unit appears to continue as far as Moravské Budějovice (Weiss et al. 1983), as far as the Přibyslav zone (Dudek 1980), or more accurately as far as the Jihlava line which in gravity maps (Blížkovský et al. 1986) separates the negative gravity Moldanubicum — Kłødzko area from the positive Moravo-Silesian area. According to refraction seismic data the Brno unit exhibits an anomalous distribution of velocities (Beránek et al. 1980) in the deep structure of the Moravicum. Reflection seismic data as well indicate the continuation of the Brno unit towards the Boskovice Furrow (Štelcl et al. 1986), and towards the Svratka dome (Tomek, Ibrmajer 1988).

In the east, the continuation of the Brno unit cannot be reliably traced. According to data from boreholes north of Brno (north of the Holešov-Štiavnica fault) the unit extends not only beyond the assumed Lednice zone (Jablůnka 1, Jablůnkov 1 boreholes), but probably farther to the east across the Klippen Belt (Roth, Grecula 1978). In this area, data from deep boreholes are in agreement with seismic data.

In the southern part of the Vienna Basin basement the extent of the Brno unit has not been clearly interpreted. It can be followed along the metabasite zone which is documented by detail interpretations of gravity and mainly magnetic residual anomalies (Doležal 1974, Bucha et al. 1988). In agreement with data from boreholes (basic rocks in boreholes Mušov 1, Mušov 2, Strachotín 1, Dudek 1980) the continuation of the Brno unit towards the line Břeclav—Skalica—Starý Hrozenkov is evidenced. In the Vienna Basin the line is indicated by the Lanžhot or Farský fault and corresponds with the assumed extent of the Klippen Belt in the basement of the Vienna Basin (Tomek, Budík 1981) and reaches beyond the Lednice zone as it was documented by deep drilling (Thon, Kostelníček 1980, Menčík 1983).

The Carpathian gravity low, often regarded as one of the factors delimiting the contact of the Bohemian Massif and West Carpathians, differs both in direction and intensity from surrounding segments, and according to Ibrmajer et al. (1969) is due to the Neogene filling of the foredeep and of the Vienna Basin. If the influence of the filling is excluded, the low disappears and a positive area emerges, connecting the basement of the foredeep and of the Vienna Basin with the Danube basin basement.

Magnetic data indicate continuous plunging of the Brno unit boundary in the deep structure of the Vienna Basin to a depth of more than 20 km (Praus et al. 1984, Bucha et al. 1988). It means a great horizontal reduction of crystalline units and of younger West Carpathian and Alpine units in the area of origin of the Vienna Basin. The comparatively fast plunging of the Brno unit contrasts with the conception of stretching of a "transformed platform" as far as the Inner Carpathians.

This concept and data from new seismic profiles (Tomek, or. c.) imply that the basement of the eastern part of the Vienna Basin beyond the Klippen Belt is built of the same type of crust as the basement of the Danube basin and therefore is of the Pannonian type containing volcanites. It sharply differs from both the Brno unit and from the Malé Karpaty crystalline complex which cannot be regarded as a horst uplift of the basement at the border-line Vienna Basin — Danube basin because the new data support the concept of its nappe position (Mahel' 1980). The role of the Klippen Belt as a border zone was also confirmed by other geological criteria (Zoubek 1960, Marschalko 1979, Mišík 1979).

An even more intricate problem is the continuation of Hercynides to the east of the Bohemian Massif and its link to the Hercynides on the northern coast of Black Sea.

Deep drilling in the basement of Outer Carpathians in northern Moravia (Jablůnka 1, Jablůnkov 1, Krásná 1, Zadní Lomná 1) confirmed the continuation of Hercynides towards the east as far as the West Carpathians. Data about the Hercynian age of folding and metamorphism in some West Carpathian units show that the Hercynian orogene belt extends along the border-line of the North European Platform to the North Dobrudja Lowland (Zwart, Dornsiepen, 1978, 1980). Also the continuation of Hercynides from the Bohemian Massif to Eastern Alps was confirmed (Suess 1931, Wieseneder 1966, etc.). It means that the basement of Eastern Alps, West Carpathians and Bohemian Massif in Central Europe uderwent the same geological development until the end of Hercynian orogeny.

As in the Bohemian Massif, the uniform development ended in different regions in different periods, e. g. in the Brno unit in the Upper Carboniferous, in the Hrubý Jeseník Mts. in the Lower Carboniferous, in eastern Moravia in the Middle Permian. Similar differentiation holds for the West Carpathians where not only the marine Carboniferous rocks belonging to the Hercynian structural basement, but in the Choč and Vepor units also the Upper Carboniferous units and Permian strata are lithofacially and by their volcanic character associated with the Mesozoic development (Vozárová, Vozár 1975). Confirmed were:

a) the arcuate shape of Hercynian tectogen with deformation of the Brno unit elevations similar to the Alpine-Carpathian arc,
b) the existence of an independent Alpine rift development in West Carpathians since the Middle Permian,
c) the secular character of the collision zone between Laurasia and Gondwana and the Permian origin of the Tethys in Central Europe.

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Abstrakt

V práci je diskutován rozsah prekambrického a hercynského podkladu v suprakrustální struktuře Českého masívu a Západních Karpat z hlediska nových výsledků geofyzikálních, geologických a vrtných výzkumů na styku Českého masívu a Západních Karpat. Potvrdil se obloukový průběh zón hercynského tektogénu s obdobným porušením prekambrickou elevací brněnské jednotky na Moravě, jaké má i oblouk alpsko-karpatský, samostatný (riftogenní) vývoj v Západních Karpatech od středního permu, sekulární ráz kolizní zóny mezi Laurasií a Gondwanou a v důsledku toho prekambrický původ Tethydy ve střední Evropě.

Zusammenfassung

Im vorliegenden Beitrag wird die Ausdehnung des präkambrischen und herzynischen Untergrunds in der suprakrustalen Struktur der Böhmischen Masse und der Westkarpaten mit Rücksicht auf neue Ergebnisse geophysikalischer und geologischer Forschungs- und Bohrarbeiten an der Berührung der Böhmischen Masse und der Westkarpaten erörtert. Es wurden der bogenförmige Zonenverlauf des herzynischen Tektogens mit einer zur Störung des Alpen-Karpaten-Bogens analogen Störung durch die präkambrische Erhebung der Brno-Einheit in Mähren, eine selbständige, vom mittleren Perm an sich entwickelnde Riftzone in den Westkarpaten, der säkulare Charakter der Kollisionszone zwischen Laurasien und Gondwana und infolge dessen der präkambrische Ursprung der Tethys in Mitteleuropa bestätigt.

DEEP-SEATED STRUCTURES OF THE BOHEMIAN MASSIF IN THE REGION BETWEEN THE VRANOVICE GRABEN AND THE CZECHOSLOVAK-AUSTRIAN FRONTIER

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In recent years, a new important stage of the survey of the deep-seated structure of the Vienna Basin has been undertaken, which is focused on autochthonous formations of mantle units of the Bohemian Massif, underlying flysch nappes. The first important results of the survey come from Austria, where two very deep boreholes (Zistersdorf ÜT 1a and 2a) have been drilled, whose depths are 7,544 and 8,553 m, respectively. Though they have not fully met the expectations, they have confirmed the perspective of autochthonous formations.

Geological and geophysical studies have proven an analogous structure of deep-seated autochthonous formations in the territory of Czechoslovakia. At the same time, one can reasonably expect the depths of platform formations to be lower than the Austrian ones.

Two basic tectonic units play a key part in the surface setting of the promising region, namely the Neogene filling of the Vienna Basin and the Carpathian nappes.

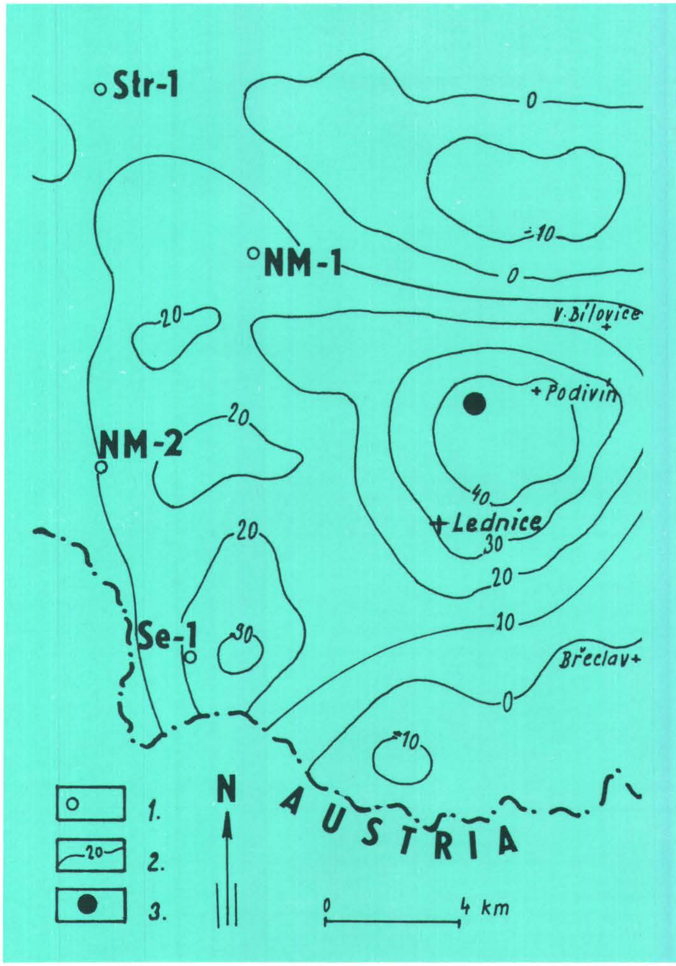

Fig. 1. Residual gravity map (Čekan V., Geofyzika Brno, 1987). ▲
1 — wells penetrated crystalline rocks; 2 — contours of gravity data; 3 — projected well.

The Neogene is represented by the following stages: Eggenburgian — Ottnangian, Badenian, Sarmatian, Pannonian, Pontian — Dacian and Rumanian; on the other hand, the Carpathian nappes are represented by the Ždánice Unit with an inner development zone known as the Čejč — Zaječí Zone, and the Rača Unit of the Magura Nappe situated in their tectonic overlayer.

The autochthonous base of the Carpathian nappes is built by the deeply immersed platform of the southeastern slopes of the Bohemian Massif, composed of crystalline rocks and their sedimentary mantle represented by Mesozoic to Paleozoic rocks. In depressions, mainly in the Vranovice Graben, autochthonous Paleogene rocks occur as well. No deep borehole has hitherto been drilled in the immediate vicinity of the region under study. As far as its broader surroundings are concerned, there are Sedlec 1, Nové Mlýny 1 and Bulhary 1 wells and boreholes falling into the area of the Němčičky Structural Unit.

The region under study was covered by a basic network of gravimetric and geomagnetic measurements. During the seventies, these measurements were supplemented by seismic measurements. Owing to the low resolution of the old seismic measurements, it was impossible to outline the structural setting of the region. Consequently, new seismic measurements making use of progressive techniques and instrumentation have been undertaken during the eighties.

Several authors (Tomek Č. — 1976, Čekan V. — 1978) have dealt with the evaluation of the gravimetric measurements. V. Čekan has made use of a modification of the so-called band filtration method for this purpose. In a map showing the 2—4 km zone which illustrates best the relationship between the overlying flysch and the underlying crystalline rocks (Fig. 1), a significant anomalous zone can be observed in the area between Lednice and Podivín.

The depth of the anomaly is estimated at 4.6 km and the anomaly is likely to be related to the presence of thick layers of heavier rocks.

Fig. 2 shows a section of the map of vertical magnetic in-

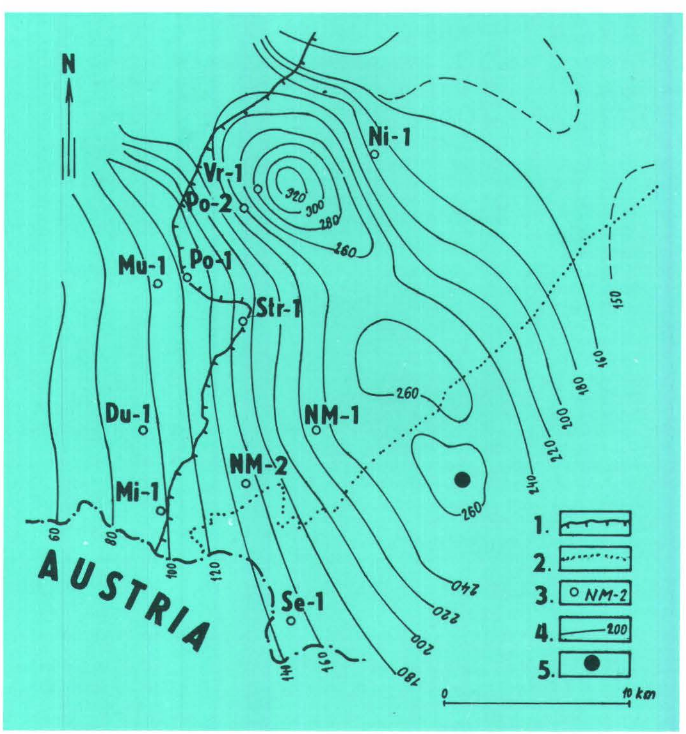

Fig. 2. Vertical magnetic intensity map (Doležal J., Geofyzika Brno, 1972).
1 — front of the flysch belt; 2 — NW margin of the Vienna basin; 3 — wells penetrated crystalline rocks; 4 — values of magnetic data; 5 — projected well.

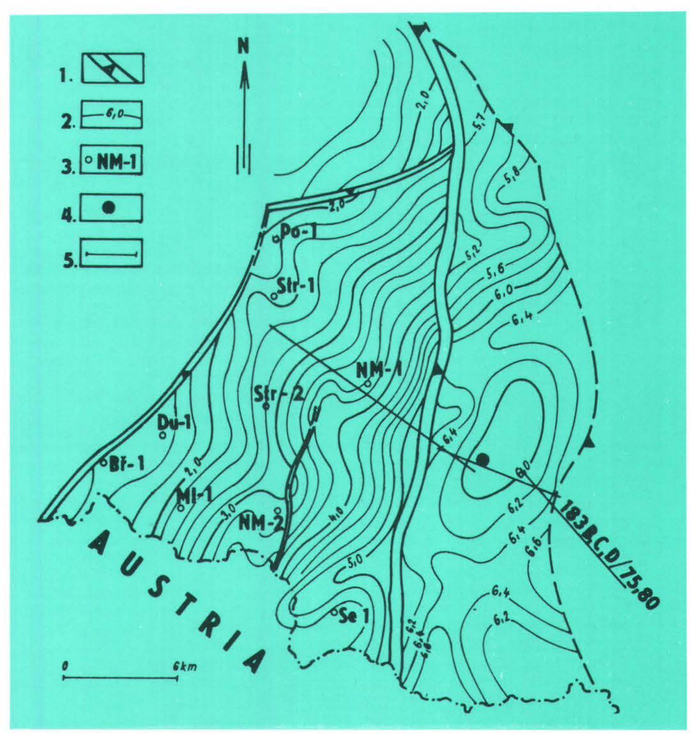

Fig. 3. Depth map at the top of crystalline basement (Ciprys V., Thon A., MND Hodonín, 1986).
1 — main faults; 2 — contours of crystalline basement; 3 — wells penetrated crystalline rocks; 4 — projected well; 5 — seismic line.

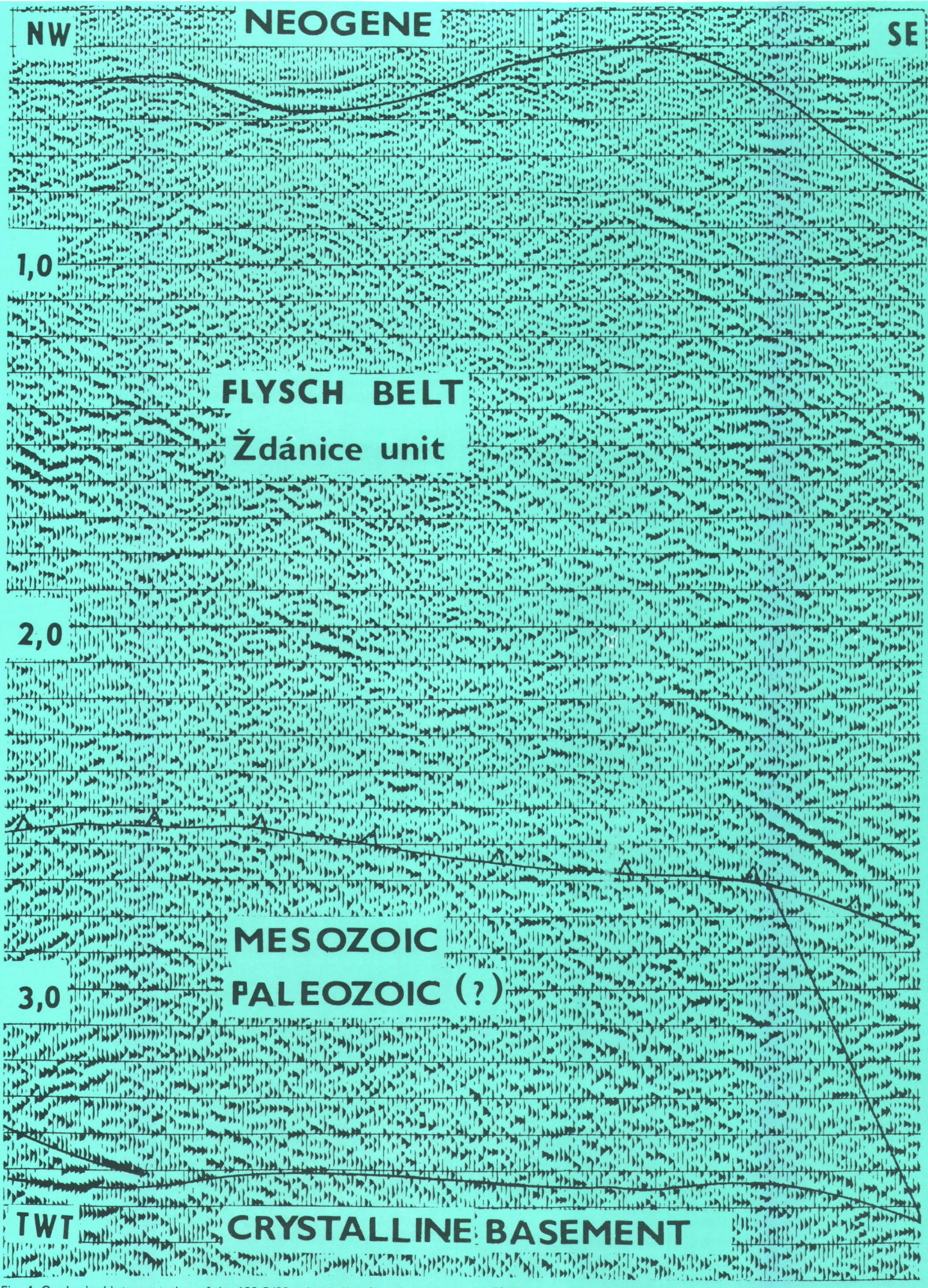

Fig. 4. Geological interpretation of the 183 C/80 seismic line (unmigrated version). (Ciprys V., Thon A., MND Hodonín, 1986).

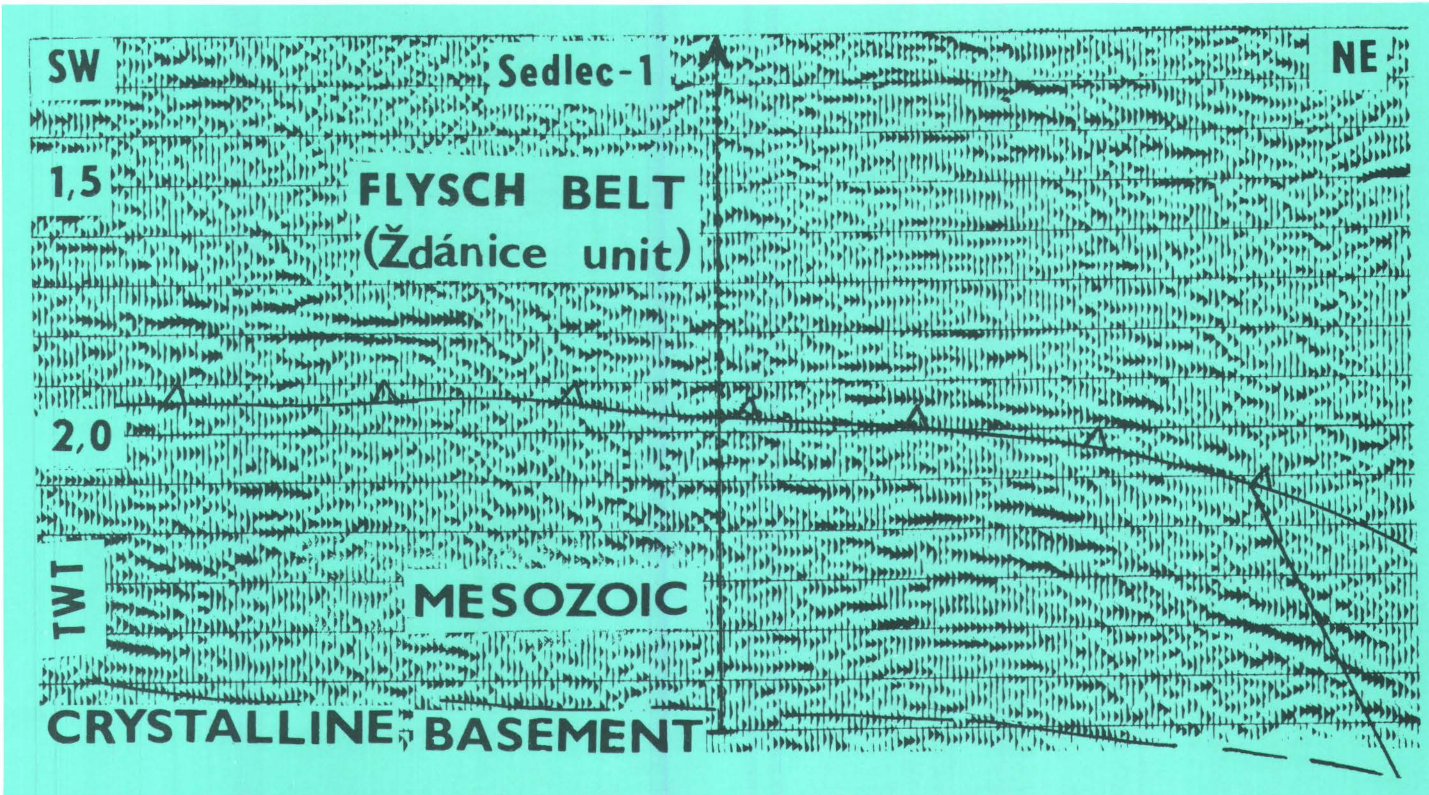

Fig. 5. Geological interpretation of the 238/80 seismic line through the Sedlec-1 well (unmigrated version), (Ciprys V., Thon A., MND Hodonín, 1986).

Fig. 6. Residual magnetic map (Pícha B., Geofyzika Brno, 1986).
1 — main faults; 2 — values of residual magnetic data; 3 — projected well.
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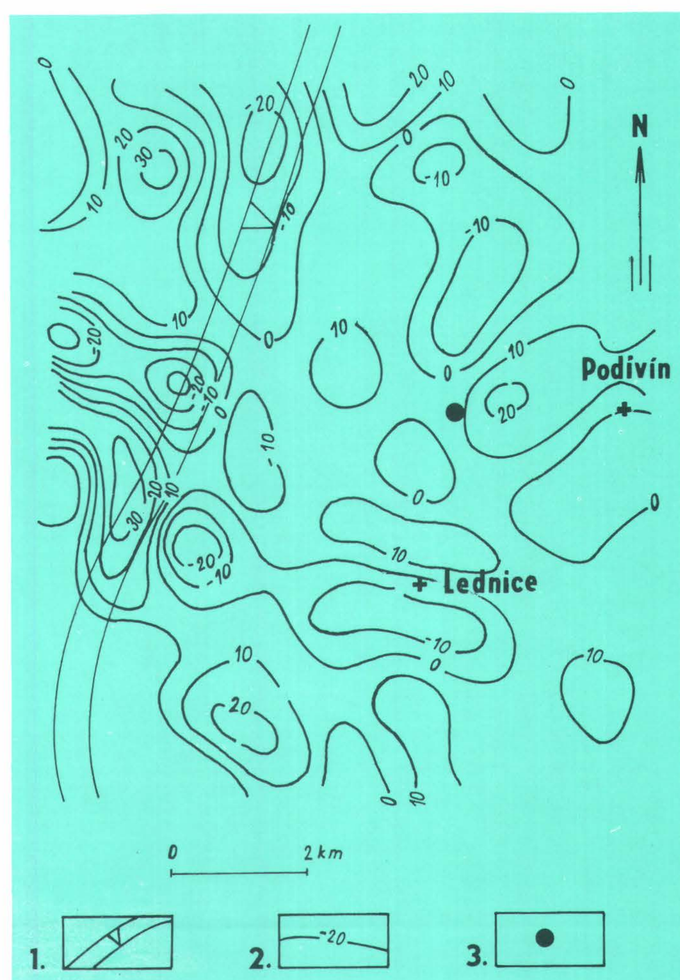

tensities of the area between Brno and Břeclav (B. Pícha, 1984). The contour line map shows a significant magnetic anomaly. Most experts agree with the initial opinion of R. Běhounek (1943, 1956), namely that the anomaly is due to rocks similar to those of the central basic zone of the Brno Massif. B. Pícha has also made an attempt aimed at a quantitative interpretation of the depth of the crystalline rocks occurring in the southern part of the anomaly. The depth of the crystalline rocks has been measured to be equal to 3,500 m in the anomaly peak. The crystalline rocks submerge down to 5,000—8,000 m to the south and east.

The dominant element resulting from the interpretation of the seismic measurements in the broader surroundings of the area of interest is an important, almost S—N trending fault line dividing the region into two blocks, one elevated, one submerged. As far as the latter is concerned, no deep exploration has been carried out so far. Its dominant element is an extensive zone of elevations with three distinctive peaks, one in the area of Břeclav, one (the most important) in the zone between Lednice and Podivín, one located west of the Němčičky Structural Unit (Fig. 3). The interpretation and quality of the seismic data are illustrated in Figs. 4 and 5. Fig. 4 shows the area of the Lednice — Podivín peak (a standard, non-migrated variant of Section 183 C/80) of the submerged block, while Fig. 5 shows a part of Section 238/80 of the elevated block, including the deep borehole Sedlec 1.

The existence of the distinctive N—S fault, which plays one of decisive roles with respect to the evaluation of the area in terms of promising hydrocarbon accumulations, has also been confirmed by a detailed quantitative analysis of magnetic data (B. Pícha — 1986) in the region of a significant geomagnetic anomaly. A map of residual anomalies (Fig. 6) shows that the submerged block displays less intensive residual anomalies and less steep and lower gradient contour lines in comparison with the elevated block.

An analysis of all geophysical and geological supporting data shows that even several deep boreholes drilled into

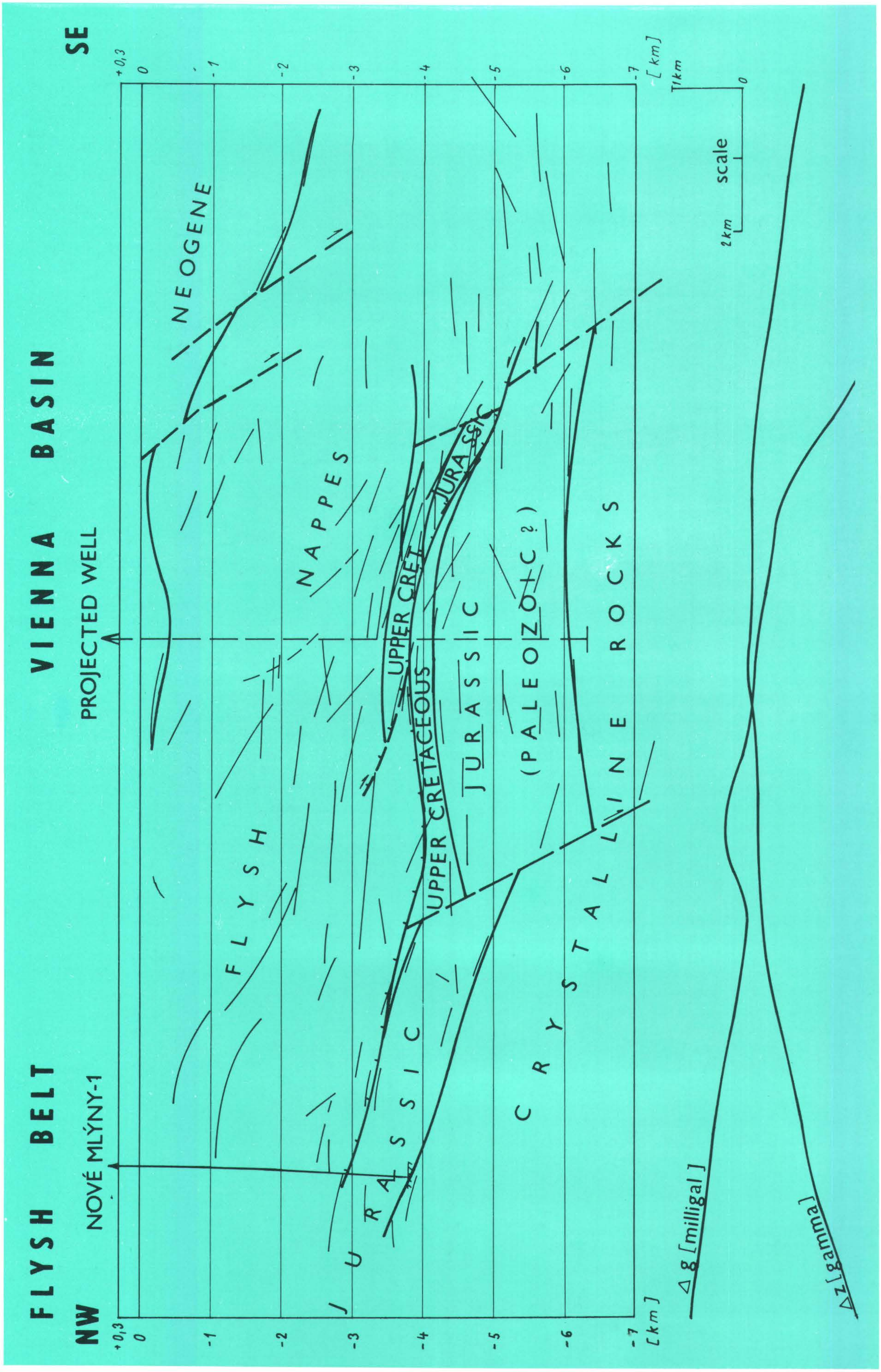

Fig. 7. Geological cross section through the seismic line 183 B + 183 C, D/75, 80.

the shallower block have not brought any results which should justify an essential change of the earlier opinion on the structural setting. This means that germanotype tectonic elements, sometimes and under specific circumstances accompanied by Carpathian activization, are considered chief deposit-forming elements. The structural-tectonic model shown in a structural map of the crystalline basement (Fig. 3) and a geological cross-section (No. 183, Fig. 7) is conceived in this way as well.

Objective problems arise when interpreting depths of the platform foundation and its geological composition. This mainly results from insufficient data and variable-quality seismic measurements.

Consequently, an alternative approach to the study of the western marginal zone of the Vienna Basin has been selected. Both variants include a delineation of basic structural and tectonic elements with the distinctive elevation bulge between Lednice and Podivín. This region presently seems to be best prepared for verification by drilling. However, there are still problems to be solved, namely those of the basic deep setting of the structure, of its tectonic position and preservation of promising hydrocarbon accumulations. Another alternative is offered by F. Chmelík (1985) who assumes lower depths of the platform units.

One way or another, the beginning of the exploration of the structural region in the vicinity of Lednice marks the beginning of an economically and technically very demanding project. Consequently, considerable attention must be paid to its preparatory stage, i. e. to the implementation of most progressive seismic measurements and their evaluation. On the other hand, the extent of structures of this type suggests that such projects are very important for the national economy. In this respect, close cooperation with our Austrian colleagues is extremely important, in the framework of which the areas of interest are being extensively explored. In these terms, the results achieved so far in both countries draw from the long-term and qualified cooperation.

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Abstrakt

V předloženém článku je hodnocena perspektivita vysoce pokleslých jv. svahů Českého masívu v prostoru západního okraje vídeňské pánve. Na základě zhodnocení geologických a geofyzikálních podkladů byla v prostoru Lednice vymezena rozsáhlá elevační struktura autochtonních útvarů vázaná na výraznou zlomovou linii S—J směru. Zahájení průzkumných prací v oblasti Lednice bude úkol z hlediska ekonomického i technického velmi náročný, na druhé straně však rozsah struktur tohoto typu naznačuje značný národohospodářský význam. Z tohoto pohledu má značný význam spolupráce s rakouskými geology, v rámci které dochází k široce pojatému plošnému zpracování oblasti.

Zusammenfassung

Im vorliegenden Beitrag wird die mögliche Erdölhöffigkeit tief eingesunkener SO-Hänge der Böhmischen Masse im Raum des Westrandes des Wiener Beckens eingeschätzt. Aufgrund einer Auswertung der geologischen und geophysikalischen Unterlagen wurde im Raum von Lednice eine ausgedehnte Elevationsstruktur aus autochthonen Gesteinskomplexen abgegrenzt, die an eine von N nach S streichende, ausgeprägte Bruchlinie gebunden ist. Die Aufnahme der Erkundungsarbeiten im Gebiet von Lednice wird eine in ökonomischer sowie technischer Hinsicht sehr anspruchsvolle Aufgabe sein, andererseits wird allerdings durch die Flächenbearbeitung der Strukturen von diesem Typ ihre beträchtliche volkswirtschaftliche Bedeutung angedeutet. Von diesem Gesichtspunkt aus ist die auf eine breit aufgefaßte Flächenbearbeitung des Untersuchungsgebiets orientierte Zusammenarbeit mit österreichischen Geologen von ziemlich großer Bedeutung.

CZECHOSLOVAK-AUSTRIAN COOPERATION IN GEOPHYSICAL STRUCTURAL EXPLORATION IN THE VIENNA BASIN

V. Čekan[1], A. Kocák[1], Č. Tomek[1], G. Wessely[2], D. Zych[2]
[1] Geofyzika, Brno, Czechoslovakia
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Under the long-term agreement on cooperation in geological sciences between Czechoslovakia and Austria a team was formed with the aim to upgrade prospection for hydrocarbons in the Czechoslovak and Austrian parts of the Vienna Basin. In order to solve particular geological and geophysical problems professional staff members from Geofyzika Brno and ÖMV Vienna met annually in Brno or Vienna. Predominantly seismic beside the other geophysical methods like gravity, log service and its substituted disciplines with regard to geological problems were discussed. Discussions concerning methodology of data acquisition, processing and interpretation obtained and demonstrated by the two parties in general and involving the border area in particular were very helpful.

Geophysical data and other materials from the Czechoslovak-Austrian border areas have been exchanged between Czechoslovak and Austrian geophysicists.

When the cooperation started in the sixties, the gravity potential field method had an essential meaning next to the seismic reflection method, especially concerning deep situated structures. At that time it was very difficult for the seismic measurement to solve the above mentioned problems without complex interpretation. Still single fold seismograms were used and the last good addressable horizon f. e. within the Vienna Basin has been the Aderklaa conglomerate. Only parts of weak reflection from the base Neogene could be used for the correlation of a phantom horizon.

In 1968 an agreement was prepared to connect the two independent gravity nets from ÖMV and Geofyzika Brno. At this point we remember Mr. Břetislav Beránek not only as a mentor in many technical discussions, but also for his assistance for this project.

The connection of the gravity net involved measurements on both sides of the border executed by ÖMV Geophysics and Geofyzika Brno in 1969—1974.

BOUGUER GRAVITY ANOMALY MAP VIENNA BASIN

$\sigma = 2{,}67 g\ cm^3$

V. Čekan, J. Ibrmajer, Geofyzika Brno
D. Zych, ÖMV Vienna

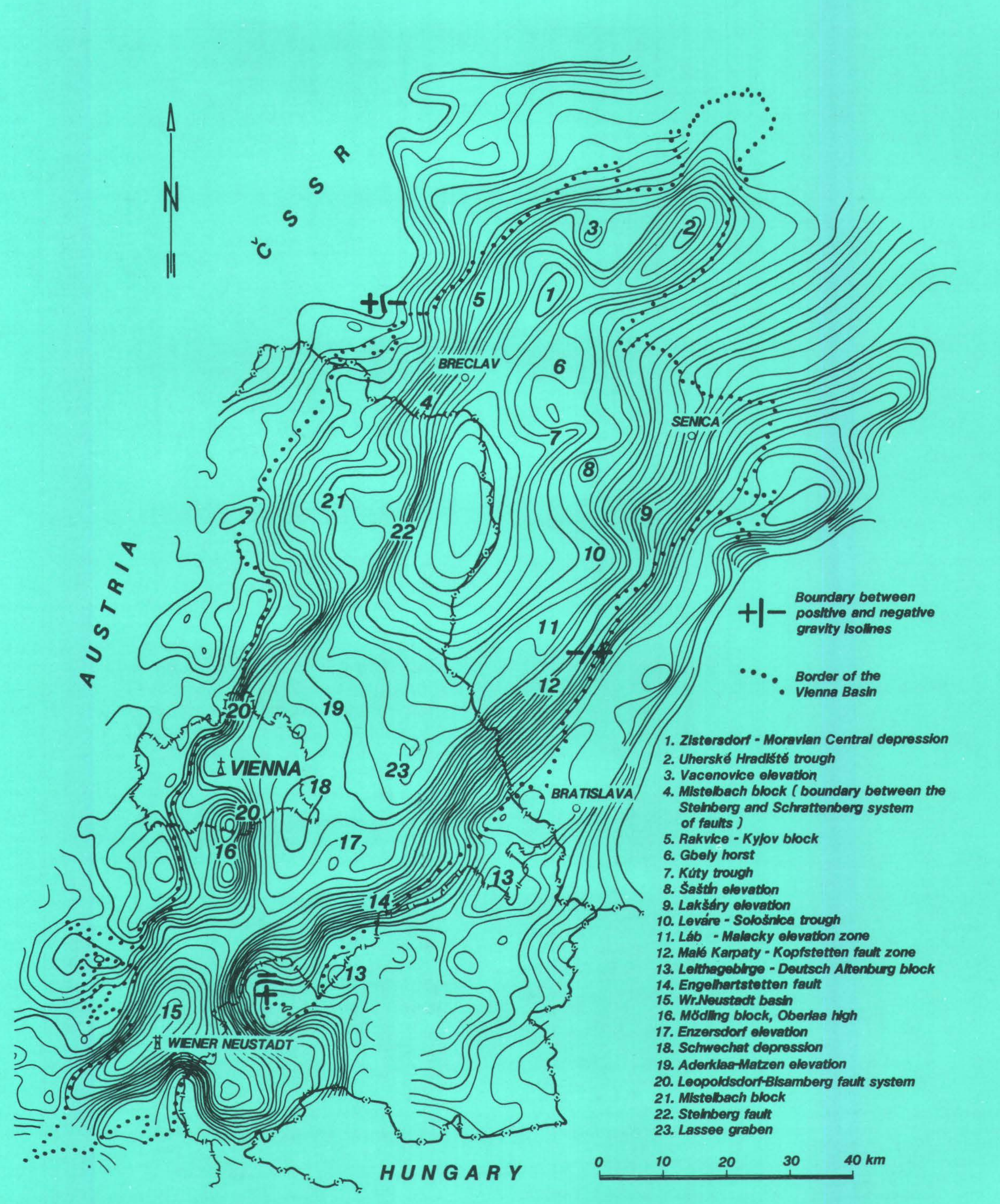


Fig. 1

STRUCTURAL MAP OF THE VIENNA BASIN ON THE SURFACE OF THE PANNONIAN-SARMATIAN

state in 1988

Authors:

J.Hromec
A.Kocák *GEOFYZIKA sp BRNO*
R.Jiříček et al MND HODONIN

H.Unterwelz et al ÖMV WIEN

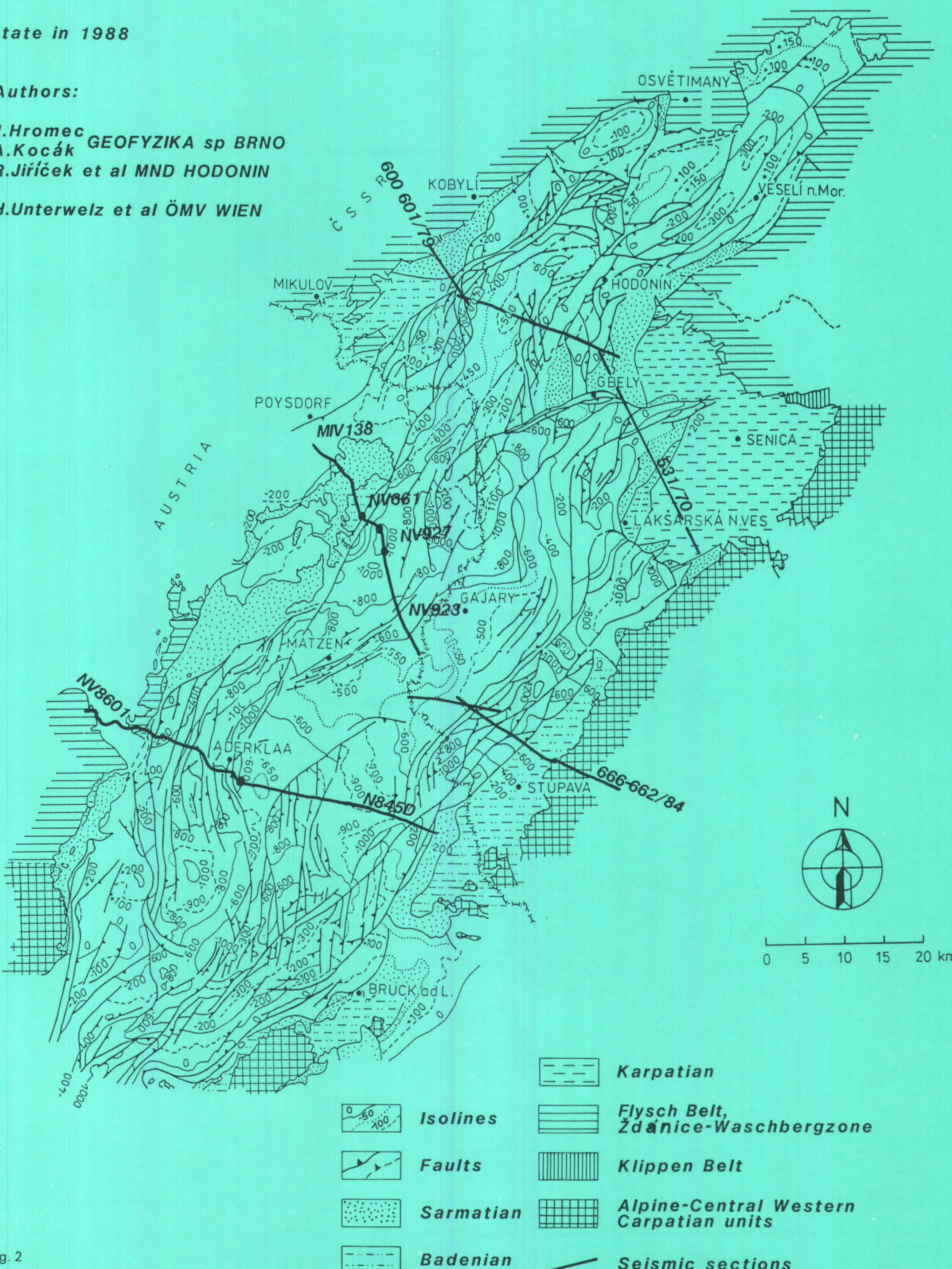


Fig. 2

STRUCTURAL MAP OF THE VIENNA BASIN ON THE SURFACE OF NEOGENE BASEMENT

state in 1988

Authors:

A.Kocák
S.Mayer GEOFYZIKA sp BRNO
R.Jiříček et al MND HODONÍN

G.Wessely
A.Kröll et al ÖMV WIEN
D.Zych

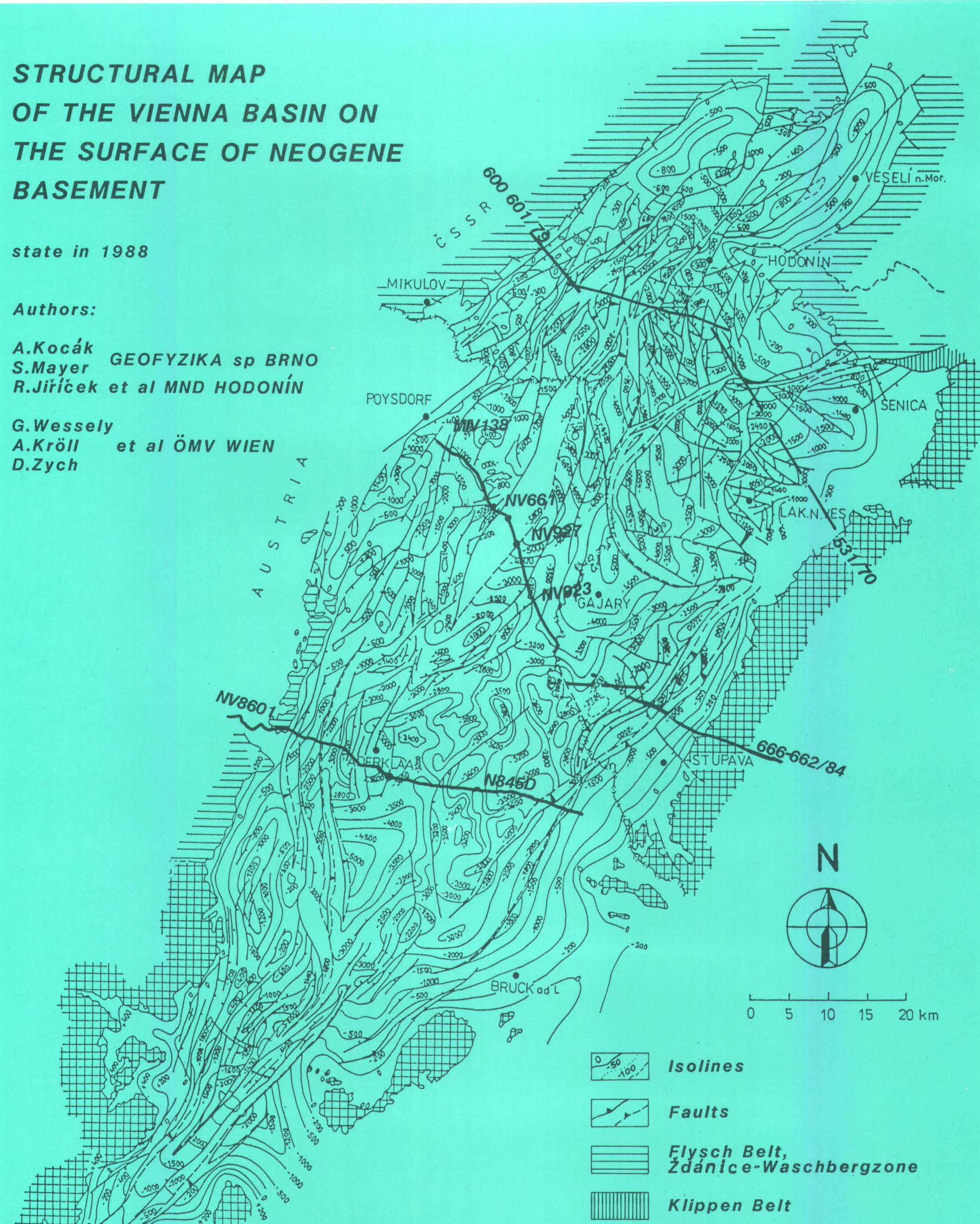


Fig. 3

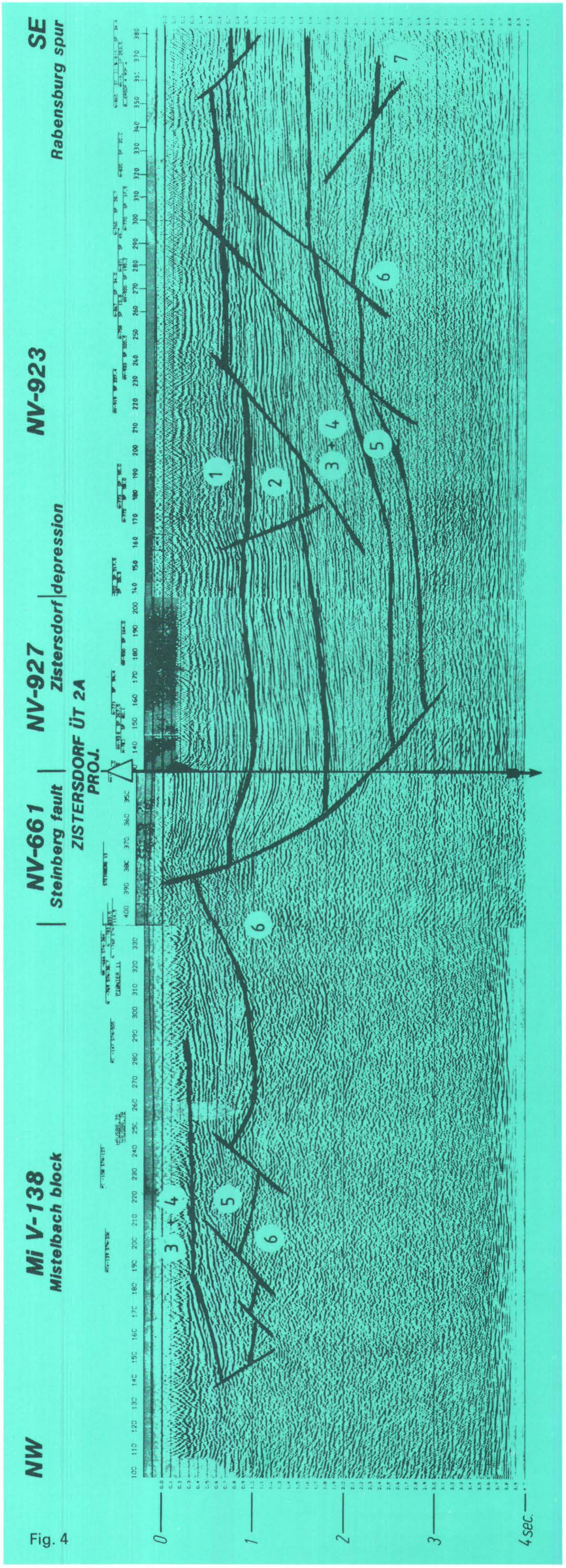


Fig. 4

Both institutions determined gravity differences at the base points of the Czechoslovak and Austrian gravimetric networks.

All the measured data were processed in Geofyzika Brno (Čekan and Odstrčil 1974). Relative differences of 12.1—14.8 μ s⁻ were detected between the basic networks. A constant correction of 13.0 μm s⁻ was used for processing the data. A unified Bouguer anomaly map was constructed in a 6 km wide band along the border, from which residual maps (Saxov-Nygaard and Baranov s = 0,25 km) were derived. Detailed gravimetry has yielded a comprehensive pattern of geologic structures in the border areas, which stimulated the forthcoming geologic-geophysical activity. The joint correlation of gravimetric networks made it possible to construct Bouguer anomaly map for the whole basin. For the Czechoslovak part of the Vienna Basin the maps constructed by J. Ibrmajer (1978) and by Č. Tomek (1976) and for the Austrian part by D. Zych (1988) were used.

The gravity scheme shows depression-type of the structure of the NE-SW elongated basin, which is characterized by a central and adjoining minima. The basin is further divided by longitudinal and transversal elements into partitional structural units related to inhomogeneities in both the basin fill and its fundament. The striking gradients of the gravity field correspond with significant fault systems.

The following systems represent the marginal limitation of largest subsidence in the Vienna Basin:

In the NW near the towns of Poysdorf and Břeclav the Steinberg-Schrattenberg fault system can be observed.

Following this system to the SW the Steinberg fault and the Schrattenberg fault split apart. The directions and character of the Steinberg fault changes near Wolkersdorf and is replaced by other faults, especially the Bisamberg fault and the Leopoldsdorf fault system.

In the SE, along the Bruck-Senica line, the Kopfstetten-Engelhartstetten fault system bordering the Malé Karpaty- and Leithagebirgsblocks (Fig. 1) are indicated.

In the seventies the influence of the gravity method as a whole was nearly neglected in favour of the evolution in seismic field work and processing technics (E. Geutebrück et al., 1984).

Methodology and technology of CDP reflection seismic surveys have gradually improved, which has reflected adequately in the data output quality. Both dynamite and Vibroseis technologies have been applied along profiles (2D survey). Registration was accomplished with the use of 96 channel recording units and 40 fold coverage with the same frequency ranges for generating the waves and for their registration. The obtained seismic data enabled a mutual tie between the Czechoslovak and Austrian results and interpretation of structures along the border.

Numerical processing of seismic data has been performed in a conventional way. Both parties have used identical hardware. Their data processing systems have differed only in details. The Czechoslovak party has used the Geofyzika Brno system while the Austrian one the CGG system, which has resulted in differences in the wavefield patterns in the respective time sections. A greater (2 mm as compared with 1 mm used by the Czechoslovak party) interval of CDP traces along the Austrian profiles is responsible for a clearer course of seismic tracing maxima and minima. To a certain extent, though, overall dynamic character of time sections appears relatively worse. Disturbant waves that occur in some Czechoslovak time sections are well attenuated in Austrian time sections.

As a result of compilation of geophysical and borehole data a map of the Neogene basement topography and that of the Pannonian-Sarmation boundary was constructed in cooperation with the Austrian and Czechoslovak hydrocarbon exploration groups (A. Kröll, G. Wessely 1973, A. Kröll 1980, F. Němec, R. Jiříček, A. Kocák et al. 1983, G. Wessely 1984, A. Kocák, S. Mayer et al. 1986).

The contour maps (figs. 2 and 3) show a distinct system of structural elements as longitudinal fault systems (NE-SW) in some cases transversal ones (NW-SE) and often in en echelon arrangements, which delimit horsts, inter-blocks, troughs, as well as ridges, depressions and monoclines. The main structural elements and their terms were described in another paper (W. Hamilton, R. Jiříček, G. Wessely) in this volume.

Main elements are documented in several seismic sections crossing the northern Vienna Basin. The pair of sections 600—601/79 and 531/70 (Fig. 4) extending North of the state boundary passes from West to East the Rakvice block, the converging of the Schrattenberg-Steinberg fault systems, the Moravian Central depression, the Lanžhot-Lužice fault system, the Hodonín—Gbely horst, the Hodonín—Gbely faults, the Kopčany depression, the Holíč block area, the Štefanov elevation, the Farské fault system, the Kovalov depression. The second pair of sections MiV138—NV661—NV927—NV923, 666—662/84 combines the Lower Austrian and the Slovakian part of the Vienna Basin. The section crosses the Steinberg fault in the part of the largest displacement between the Mistelbach block (Steinberg high) and the Zistersdorf depression. Towards the border the submerging Rabensburg spur as the continuation of the Hodonín—Gbely spur is to be noticed, in Slovakia flanked by the Suchohrad trough. The Zohor-Plavecký Mikuláš graben is bordered to the West by the Láb faults and to the East by the Kopfstetten-Engelhartstetten fault system, the main faults separating the graben from the Malé Karpaty marginal block. The southernmost sections NV8601 ND845D show to the West the western margin of the basin, the Bisamberg fault, the Gross-Engersdorf depression, the Aderklaa en echelon fault system, the Aderklaa elevation, the Markgrafneusiedl faults, the Marchfeld depression, the Lasseegraben (corresponding to the Zohor-Plavecký Mikuláš graben) and the Kopfstetten Engelhartstetten fault system.

The data on depths in the pre-Neogene basement, subsidence and amplitudes of faults are obvious in the maps.

In order to make the seismic and geologic data in the proximity of the border more accurate both parties agreed to conduct a joint 3D seismic survey. The first joint 3D survey was conducted in 1987 in the area of 23.3 km^2 between the towns of Lanžhot and Rabensburg under very complicated field conditions. This is why an irregular 3D system

LEGEND TO MIGRATED TIME SECTIONS

(1) PANNONIAN - PLIOCENE

(2) SARMATIAN

(3) UPPER BADENIAN

(4) LOWER BADENIAN

(4a) ADERKLAA CONGLOMERATE

(5) LOWER MIOCENE (KARPATIAN - EGGENBURGIAN)

(6) FLYSCH BELT

(7) KLIPPEN BELT

(8) INTERNAL ALPINE - CARPATHIAN UNITS

(9) MOLASSE

(10) AUTOCHTHONOUS MESOZOIC

(11) CRYSTALLINE BASEMENT

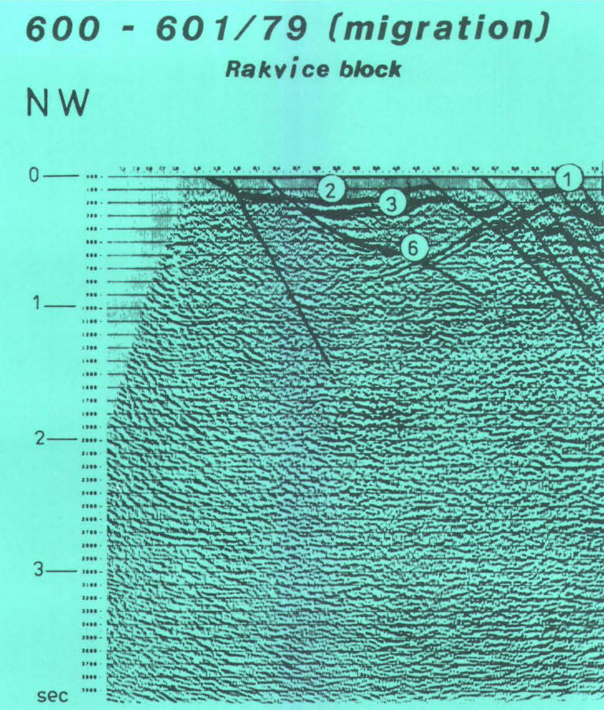


Fig. 4

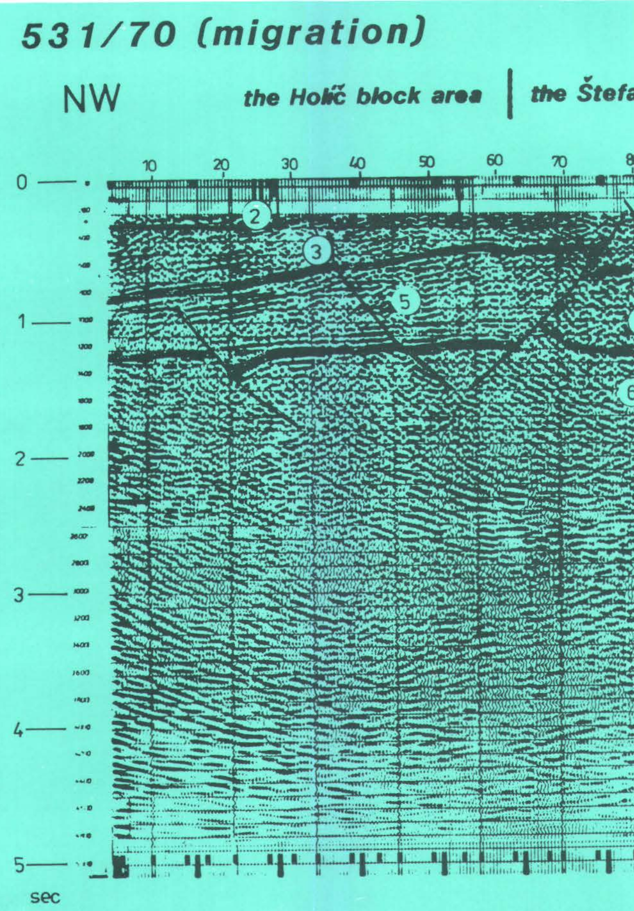
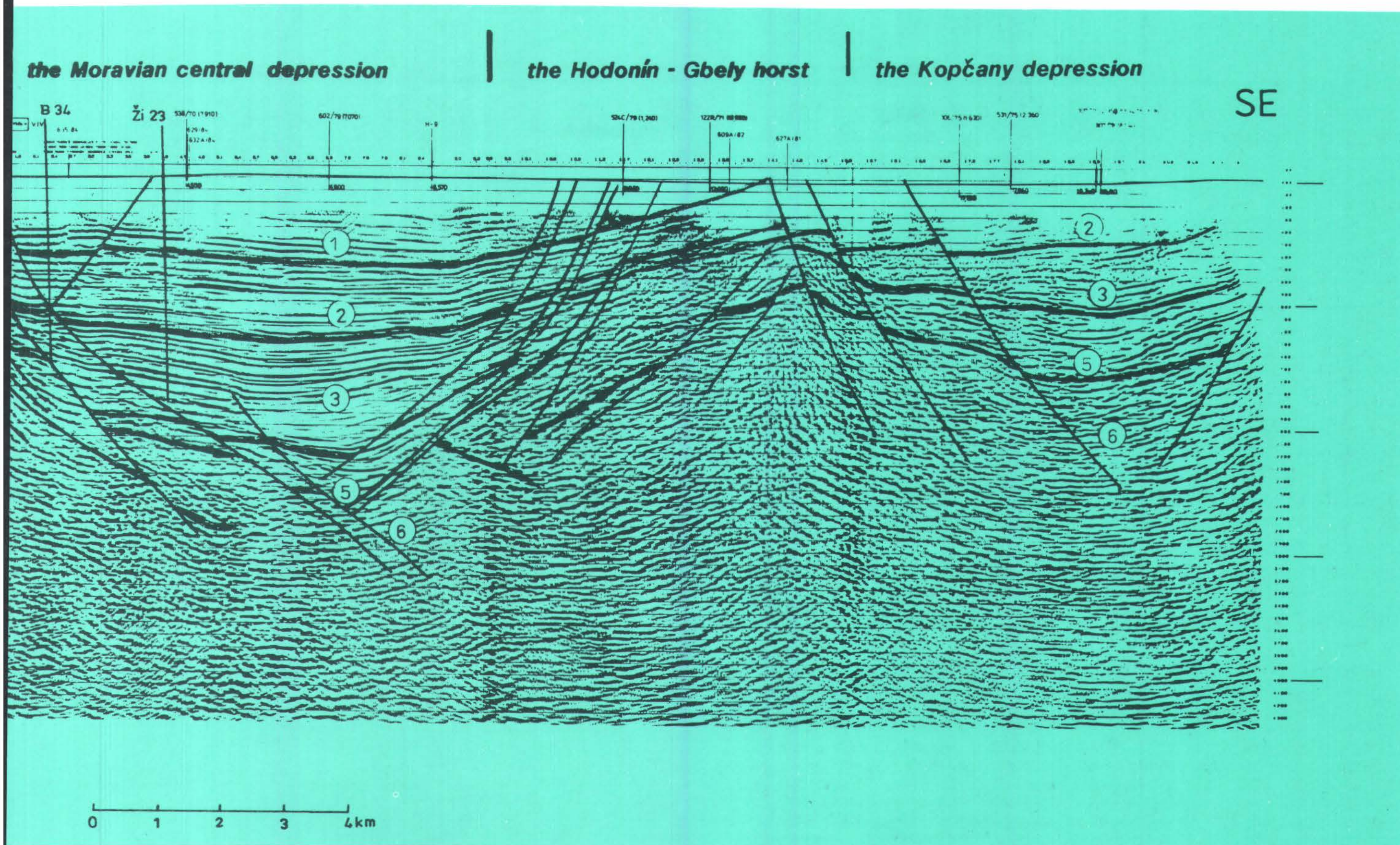
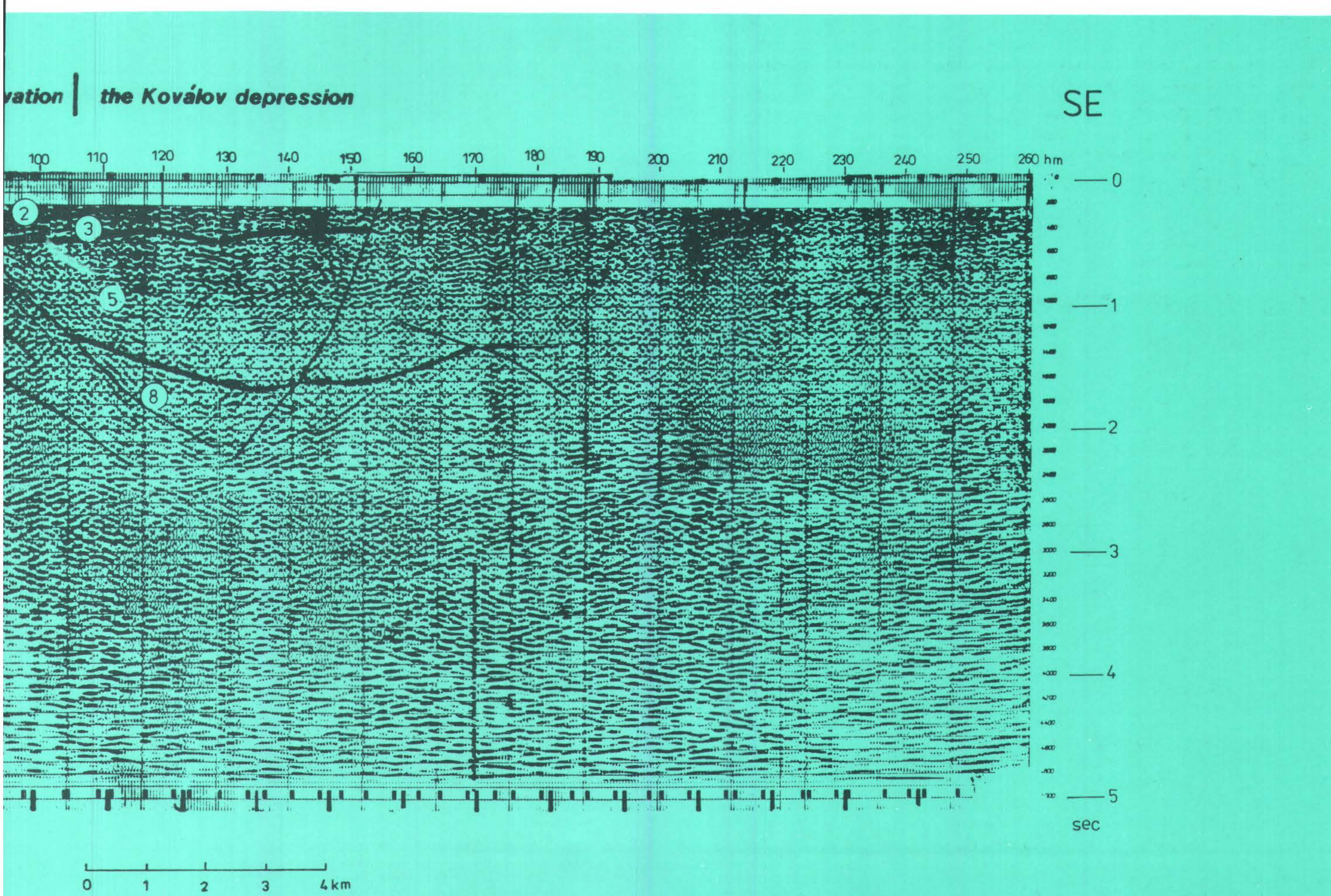


Fig. 4


the Moravian central depression
the Hodonín - Gbely horst
the Kopčany depression
SE
B 34
Ži 23
1
2
3
5
6
0 1 2 3 4km


vation
the Kovålov depression
SE
100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250 260 hm
2
3
5
8
0
1
2
3
4
5
sec
0 1 2 3 4km

was used along with the dynamite technology.

To carry along this survey a detailed preplaning with a team of specialists from both sides was necessary. The simulation of shot point location and layout was prepared by the Austrian geophysicists with their experience obtained in preceeding 3D-campagnes, the technical department of Geofyzika Brno performed the preparation and execution or the radio communication between the two crews.

Both parties had 192 recording channels available which makes 384 channels altogether. The size of reflection elements was 30 x 30 m. On average, 6—8 fold coverage was attained. The seismic data were processed by the Austrian party on the system GEOMAX 2.

Seismic sections and time slice sections were processed for interpretation to prepare a detailed map of this area.

The joint geophysical activities in general contributed largely to the geologic information in the border areas and are useful tools for further exploration.

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Abstrakt

Tento příspěvek podává souhrnný přehled o spolupráci státního podniku Geofyzika, Brno, a ÖMV, akc. spol., Vídeň, v oboru geofyziky. Tato činnost je součástí dohody o spolupráci v geologických vědách mezi Československem a Rakouskem.

Předmětem zájmu byla společná gravimetrická a seizmická měření, jakož i výměna geologicko-geofyzikálních poznatků a materiálů z pohraničních oblastí. Korelace gravimetrických sítí umožnila získat detailní výsledky měření lokálního gravitačního pole v pohraničních oblastech a sestavit mapu Bouguerových anomálií celé pánve. Seizmická měření byla kompilována a umožnila tak zhotovení strukturních schémat celé pánve. V rámci spolupráce se v po-

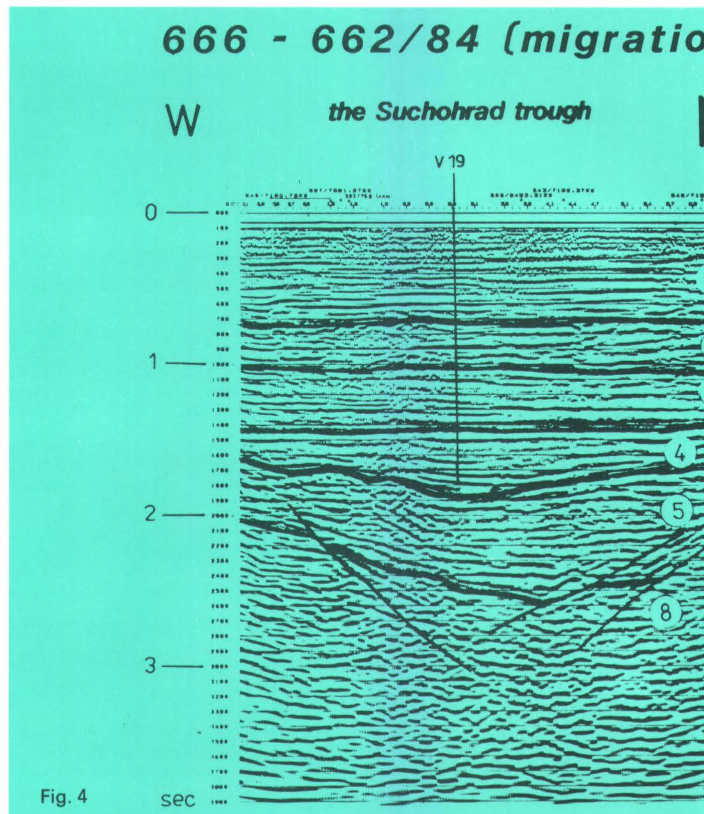


Fig. 4

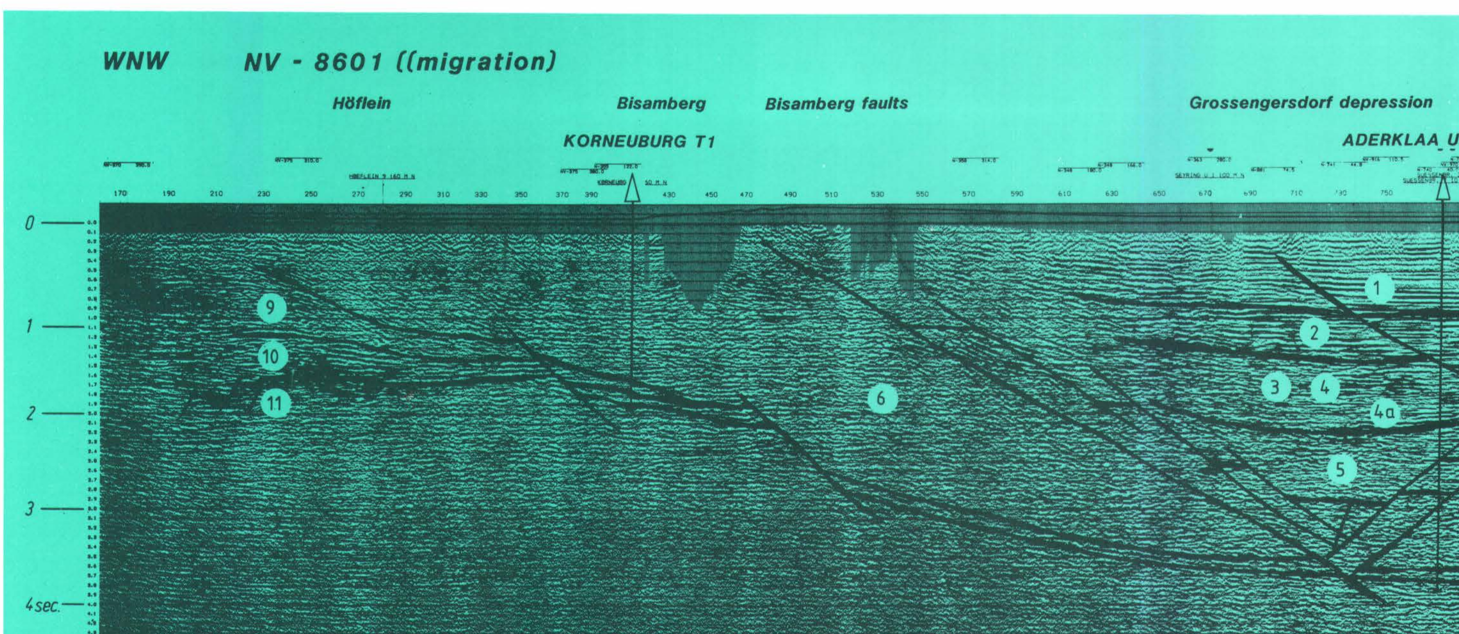


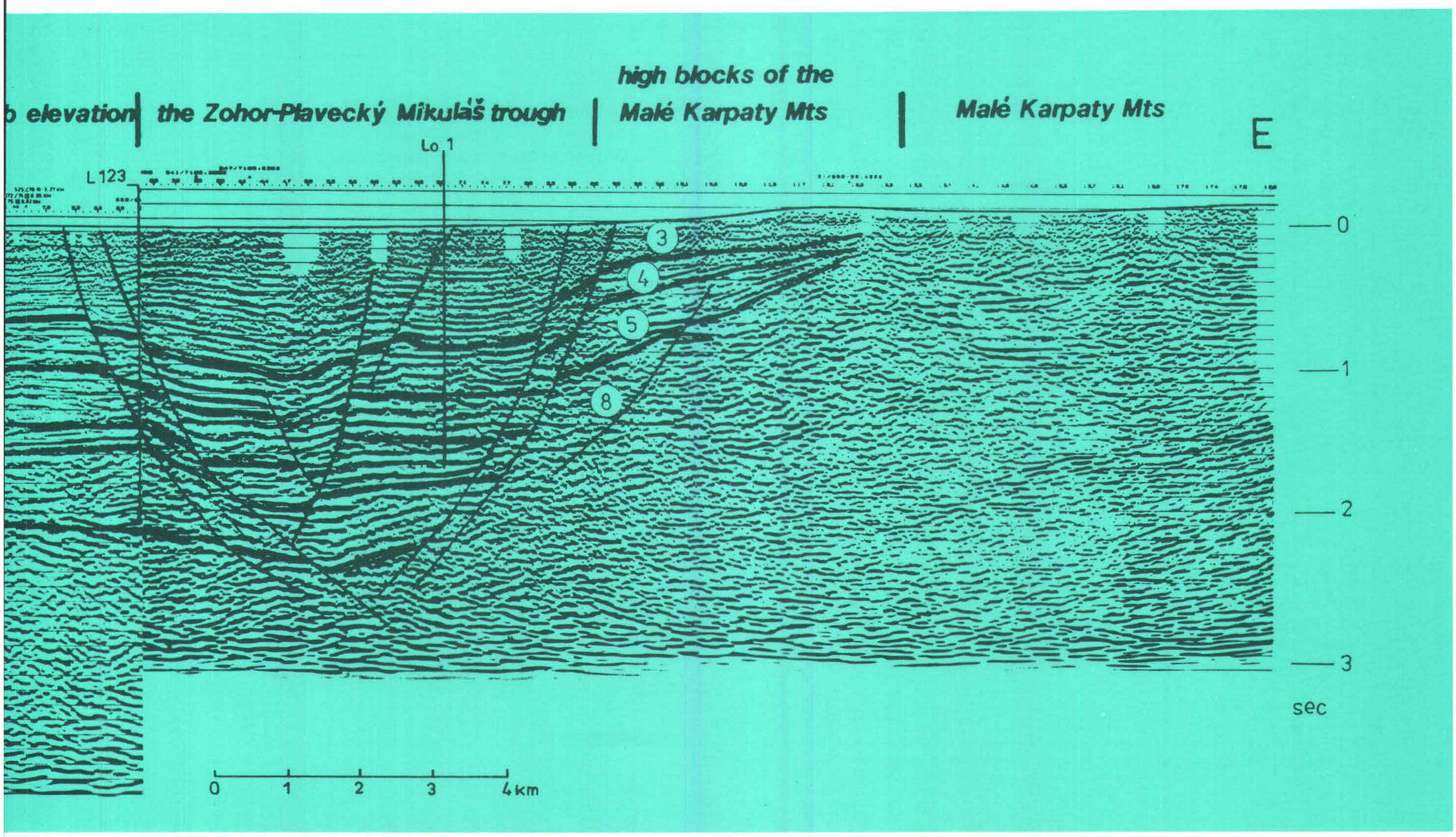
Fig. 4

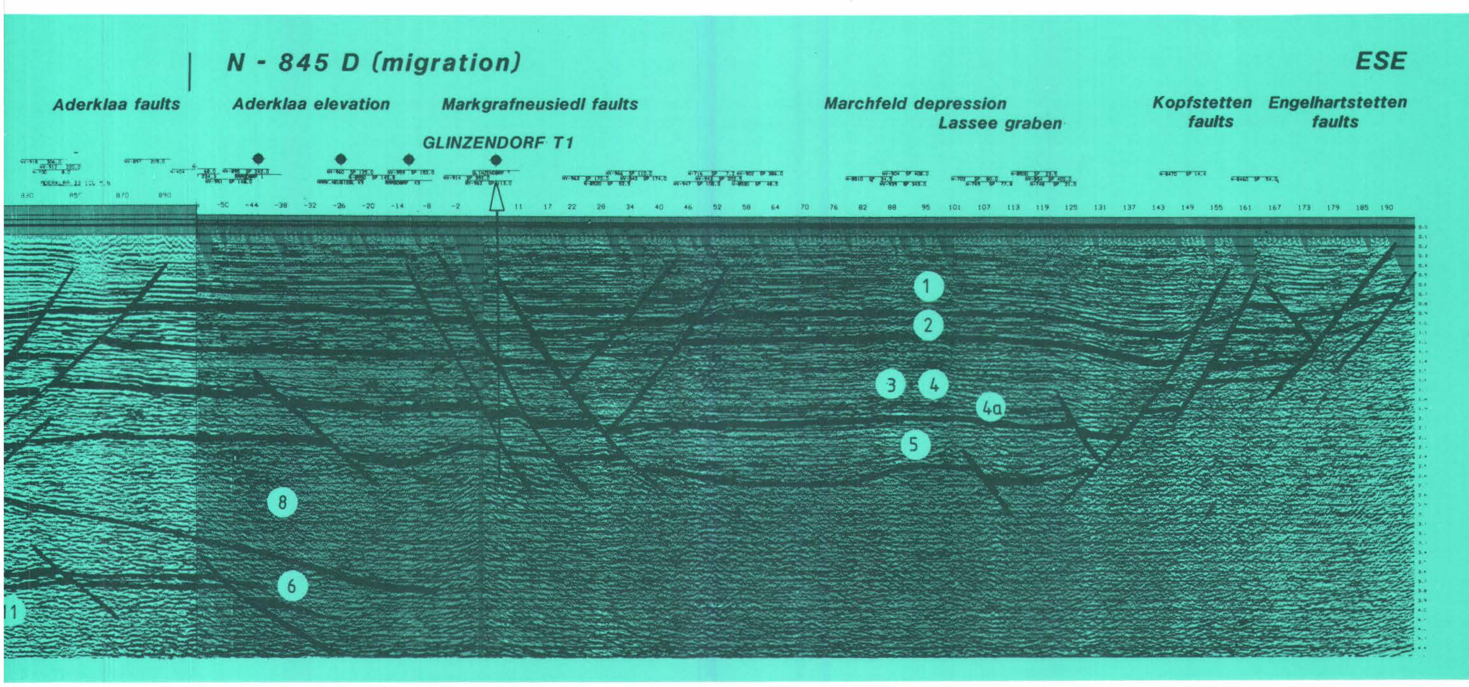
slední době konala společná měření v okolí Lanžhota — Rabensburgu, kde bylo použito trojrozměrné seizmiky.

Zusammenfassung

Dieser Beitrag gibt eine zusammenfassende Übersicht über die Zusammenarbeit des Staatsbetriebes Geofyzika Brno und der ÖMV Aktiengesellschaft Wien in geophysikalischer Hinsicht. Diese Tätigkeit ist ein Bestandteil des Abkommens über die Zusammenarbeit in den geologischen Wissenschaften zwischen der Tschechoslowakei und Österreich.

Gegenstand des Interesses waren gemeinsame gravimetrische und seismische Messungen und der Austausch der geologisch-geophysikalischen Erkenntnisse und Materialien aus den Grenzgebieten. Die Korrelation der gravimetrischen Netze hat ermöglicht, die Detailergebnisse des Lokalschwerefeldes in den Grenzgebieten zu gewinnen und eine Karte der Bouguer-Anomalien des ganzen Beckens herzustellen. Die seismischen Messungen wurden kompiliert und haben so die Herstellung von Strukturschemen des ganzen Beckens ermöglicht. Im Rahmen der Zusammenarbeit erfolgten in letzter Zeit gemeinsame Messungen in der Umgebung von Lanžhot — Rabensburg, wo 3D-Seismik angewendet wurde.





EXPLANATION OF THE ANOMALOUS ENERGY PROPAGATION OF EAST ALPINE TRANSVERSAL QUAKES

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1. Introduction

In the 19*th* century at the latest it was known that the energy of strong earthquakes in the Northeastern Alps propagates preferably to the north and northwest, which means transverse to the mountain-range of the Alps. Due to this fact Eduard Suess (1873, 1875) and his contemporaries designated these earthquakes as „Transversal Quakes". They tried to explain the anomaly of energy propagation by a „Shock-line hypothesis". As a rule, shock-lines were identical with the major axes of the extended shaken areas, the shapes of which are nearly elliptical, and the epicentres lie nearby the southern foci. — Not least the circumstance that the energy of strong East Alpine earthquakes propagates far into the Bohemian Massif is a reason for a cooperation of Czechoslovak and Austrian seismologists for many years.

2. Description of the problem

The foci of strong transversal earthquakes are mainly located on steeply incident faults of the Peripieninic Lineament (cf. Zátopek and Beránek, 1975), that means, along the Mur-Muerz-Line, in the Semmering region as well as in the Vienna Basin, but also on the East Alpine Northern Rim Fault (cf. Drimmel, 1980a) and on faults running about parallel to and lying in between the fault systems mentioned before (cf. Drimmel and Procházková, 1985; Heritsch, 1918; Procházková and Drimmel, 1983). The macroseismic focal depths of strong transversal quakes mostly lie within the interval of 8 to 12 km, in the Semmering region also between 15 and 20 km (cf. Drimmel, 1980a).

(Remark: The „macroseismic focal depth" is the depth of the virtual seismic point source which in calculations frequently takes the place of the finite source size. The macroseismic focal depth is always smaller than the depth of the centre of gravity of a steeply incident fault-plane.)

Transversal quakes do not only have the characteristic to radiate their energy mainly to the north and northwest, but they also cause a distinct increase of the seismic intensity in larger epicentral distances, so that, for example, in Southern Bohemia, far away from the epicentral damaged area, local damages occur again (cf. Kárnik et al., 1957; Procházková, 1974).

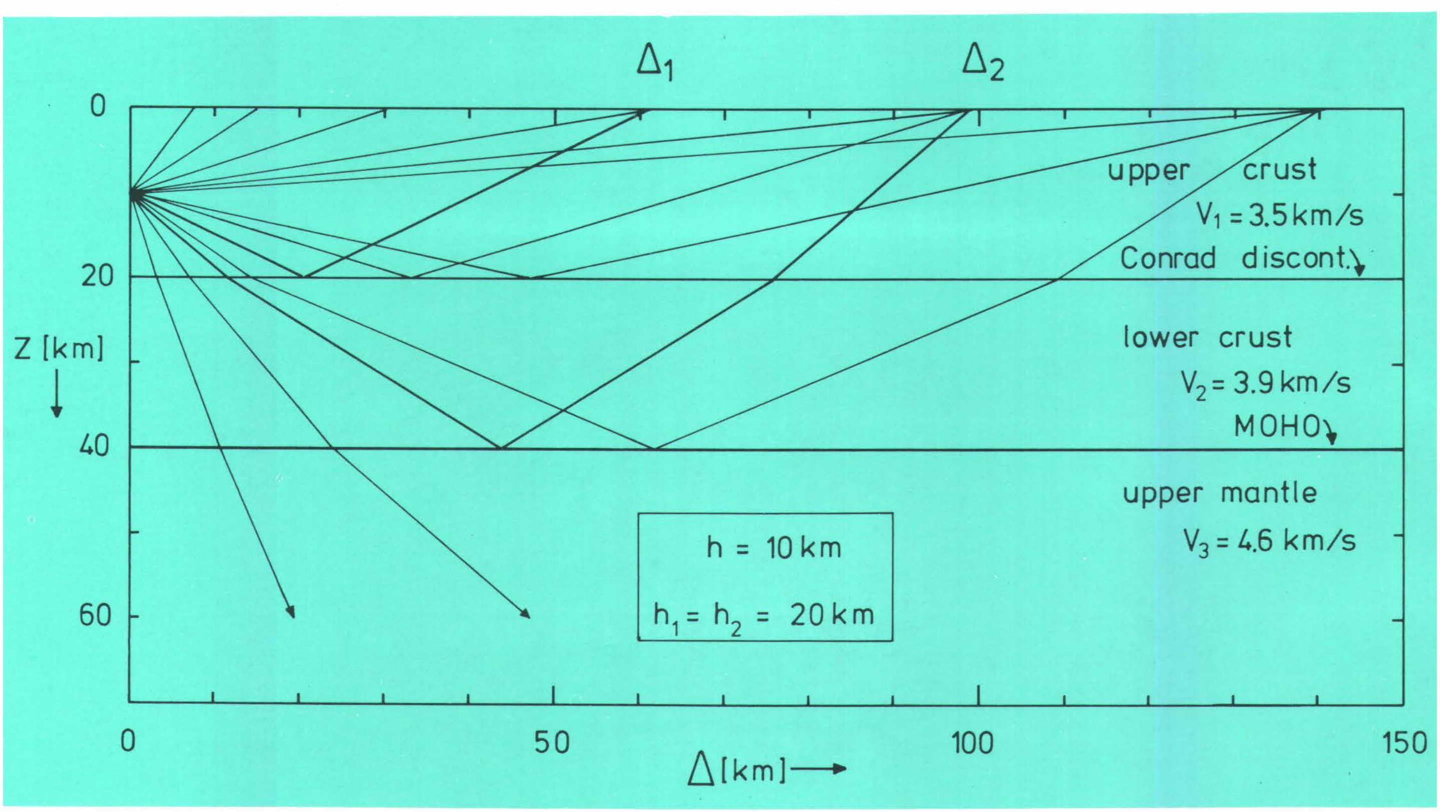
Whereas our predecessors had worked with the shock-line hypothesis, our generation tried to explain the propagation anomaly of transversal quakes by the aid of new findings about structure of the Earth's crust and the depth-dependence of seismic wave velocities; especially the discovery of low-velocity layers has influenced our reasoning enduringly. — The assumption of a channel for seismic energy can certainly explain special cases of anomalous energy propagation (cf. Drimmel and Duma, 1974), as model seismic experiments have also proved (cf. Drimmel et al., 1973), but the general case of transversal quakes can definitely be explained without this assumption. The proof for this allegation follows in the next section.

3. The reason for transversal quakes

Before we can explain the propagation anomaly of transversal quakes we have to study the regular propagation of seismic waves in a two layer model of the crust. — As the S-wave energy of near earthquakes is about 100times bigger than the P-wave energy (cf. Duda, 1965), we can neglect the P-wave energy in our investigation.

We take into consideration the increase of the velocity of seismic waves with growing depth by assuming an upper

Fig. 1: Two-layer model of the Earth's crust with a seismic point-source within the upper crust; paths of directly running as well as totally reflected shear-waves



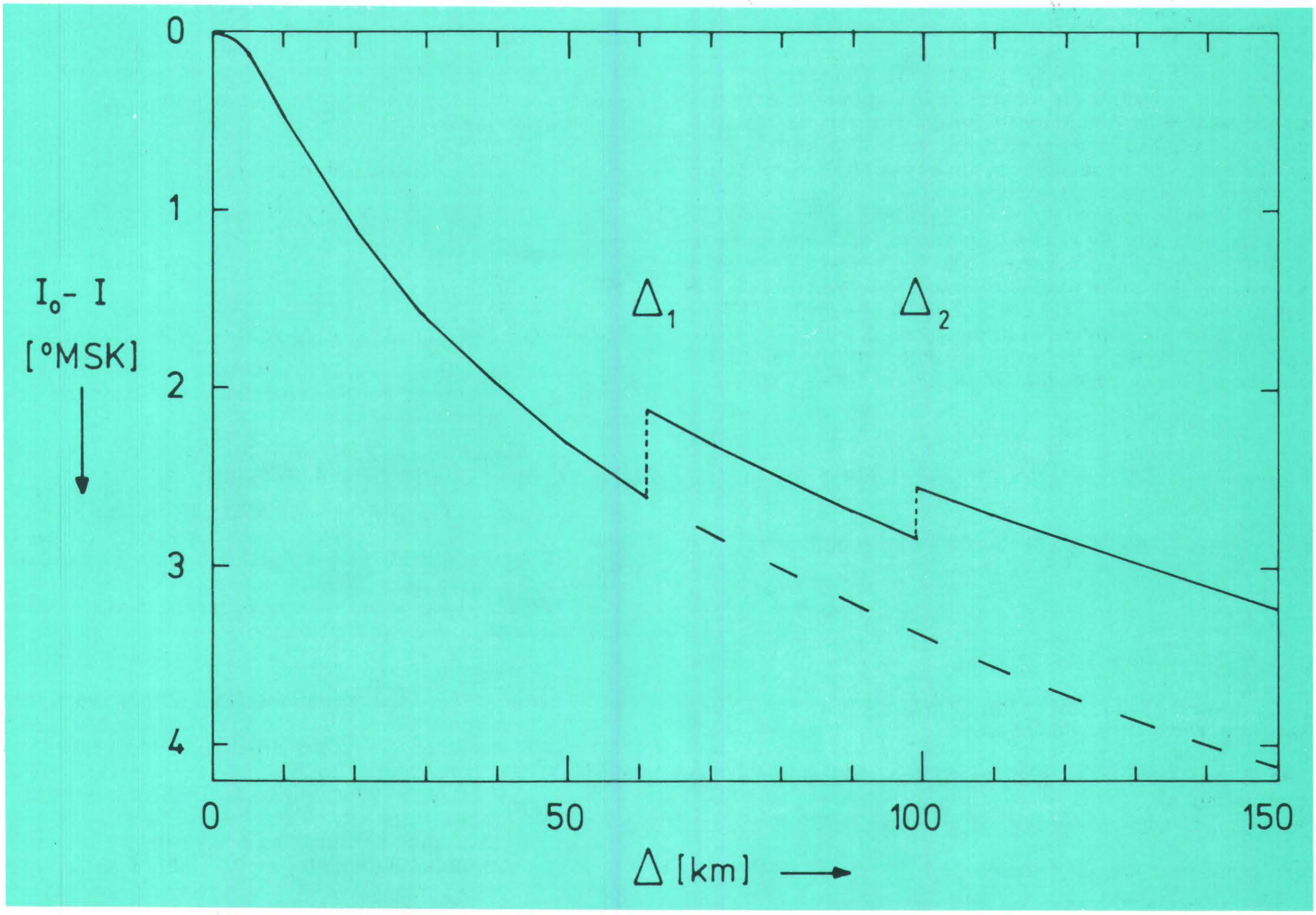
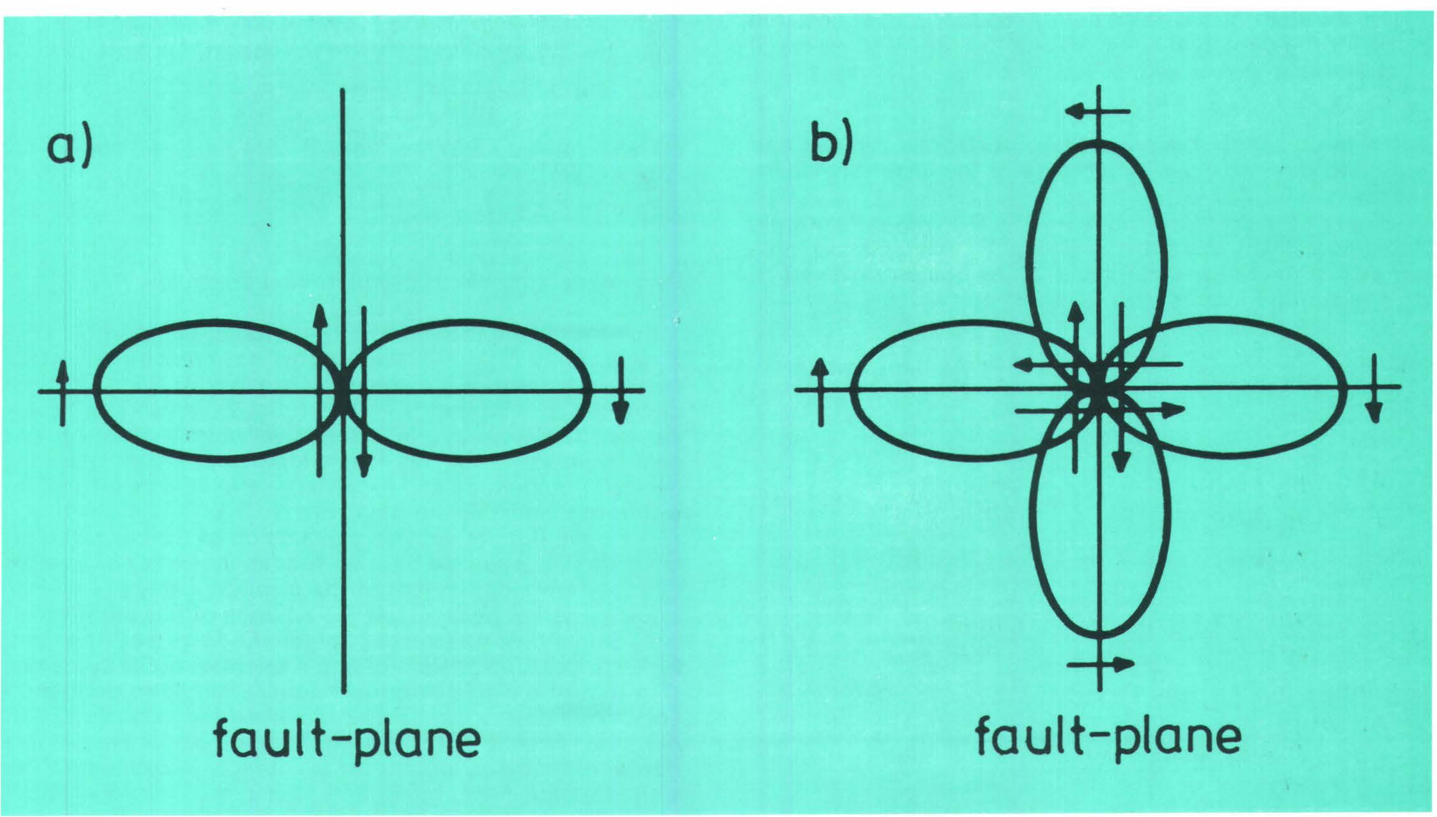


Fig. 2: Intensity-distance curve for the example reproduced in fig. 1., with $\kappa \doteq \bar{\kappa} \doteq 10^{-2}$ [km^{-1}]

▼ Fig. 3: Radiation of shear-waves
a) from a dipole with moment (single force couple);
b) from a double dipole (double couple) with zero net moment



and a lower crust with constant physical properties. The upper and the lower crust are separated by the „Conrad discontinuity", and the lower boundary of the crust is the „Mohorovičić discontinuity" (= MOHO). The seismic point source (with depth h) is located in the upper crust, corresponding to East Alpine earthquakes. The seismic rays originating from the focus obey to the laws of ray optics. In figure 1 the paths of seismic rays in case of horizontal boundaries of the crust are described.

As it can be learned from fig. 1, in epicentral distances $\Delta < \Delta_1$, only directly running Sg-waves reach the surface, in distances $\Delta \geqslant \Delta_1$, however, also $S_{Co}S$-waves (= by the Conrad discontinuity totally reflected Sg-waves) reach the surface. In addition, there are S_MS-waves (= by the MOHO totally reflected Sg-waves) in distances $\Delta \geqslant \Delta_2$. The following relations apply to the travel-times and epicentral distances of these waves (cf. Drimmel and Trapp, 1975):

$$t_{Sg} = (\Delta^2 + h^2)^{1/2}/v_1$$

$$t_{S_{Co}S} = [\Delta^2 + (2h_1 - h)^2]^{1/2}/v_1, \text{ with } \Delta = (2h_1 - h).\ \tan\alpha_1,$$

α_1 = angle of incidence at the Conrad discontinuity,
h_1 = thickness of the upper crust;

$$t_{S_MS} = (2h_1 - h)/v_1\cos\alpha_1 + 2h_2/v_2\cos\alpha_2\ , \text{ with}$$

$$\Delta = (2h_1 - h)\tan\alpha_1 + 2h_2\tan\alpha_2;$$

α_2 = angle of incidence at the MOHO,
h_2 = thickness of the lower crust.

The following formulae apply to α_2^*, the „critical angles" of total reflection.

$$\alpha_1^* = \arcsin(v_1/v_2),\ \alpha_2^* = \arcsin(v_2/v_3);$$

this yields the „critical distances"

$$\Delta_1 = (2h_1 - h).\tan\alpha_1^* \text{ and } \Delta_2 = (2h_1 - h).\tan\alpha_1' + 2h_2.\tan\alpha_2^*, \text{ with } \alpha_1' = \arcsin(v_1/v_3).$$

The duration of the maximum phase, δt_m, is almost the same for the directly running and for the reflected waves; if at observation points with $\Delta \geqslant \Delta_1$ the time differences $t_{S_{Co}S} - t_{Sg}$, $|t_{S_MS} - t_{Sg}|$, and $|t_{S_MS} - t_{S_{Co}S}|$ are smaller than or equal to δt_m, then a superposition of directly running and reflected waves causes an increase of the local seismic intensity.

In case of a spherical focus (radius R_1) with an isotropic radiation pattern, the seismic energy E_Δ, which is available per unit of the horizontal surface at the epicentral distance Δ, is given by the following relations:

$$(1)\quad E_\Delta = \frac{E_s}{4\pi\,(R/R_1)^2}\cdot\frac{h}{R}\cdot e^{-\kappa R}, \text{ for } \Delta < \Delta_1 \text{ [km], with } R = (\Delta^2 + h^2)^{1/2} \text{ [km]};$$

$$(2)\quad E_\Delta = \frac{E_s}{4\pi}\left[\frac{(h/R_1)}{(R/R_1)^3}\cdot e^{-\kappa R} + \frac{(2h_1-h)/R_1}{(R'/R_1)^3}\cdot e^{-\kappa R'}\right], \text{ for}$$

$$\Delta_1 \leqslant \Delta < \Delta_2 \text{ [km], with } R' = [\Delta^2 + (2h_1-h)^2]^{1/2} \text{ [km]};$$

$$(3)\quad E_\Delta = \frac{E_s}{4\pi}\left[\frac{(h/R_1)}{(R/R_1)^3}\cdot e^{-\kappa R} + \frac{(2h_1-h)/R_1}{(R'/R_1)^3}\cdot e^{-\kappa R'} + \frac{[2(h_1+h_2)-h]/R_1}{(R''/R_1)^3}\cdot e^{-\bar\kappa R''}\right],$$

for $\Delta \geqslant \Delta_2$ [km], with $R''\{\Delta^2 + [2(h_1 + h_2) - h]^2\}^{1/2}$ [km];

E_s = total seismic energy, R = hypocentral distance
κ [km^{-1}] = absorption coefficient within he upper crust,
$\bar\kappa$ [km^{-1}] = mean absorption coefficient within the crust.

It is plausible that the seismic effects at the surface, W, are proportional to the available seismic energy, E_Δ (cf. Drimmel, 1980b; 1984):

$$(4)\quad W \sim E_\Delta/E_1 \qquad (E_1 = \text{unit of energy});$$

for the macroseismic intensity, I, is the logarithm of W, we get

$$(5)\quad I = \log_{10}(E_\Delta/E_1) + \text{const}.$$

For epicentral distances $\Delta < \Delta_1$ with equation (1) we get

(6) $I = \log_{10}(E_sE_1) - 3.\log_{10}(R/R_1) + \log_{10}(h/R_1) - 0.4343q.\kappa.R + \text{const}$; for R = h follows the epicentral intensity I_0:

(7) $I_0 = \log_{10}(E_s/E_1) - 2.\log_{10}(h/R_1) - 0.4343.\kappa.g + \text{const}$;
the difference of equ. (7) and (6) yields

(8) $I_0 - I = 3.\log_{10}(R/h) + 0.4343.\kappa.(R-h)$, for $\Delta < \Delta_1$ [km].

This is a slightly modified Kövesligethy formula (cf. Kövesligethy, 1907; Sponheuer, 1960).

If we replace the seismic energy E_s by the surface-wave magnitude M_s, by using the relation

(9) $\log_{10}(E_s/E_1) = 1.5.M_s + \text{const}$,
(cf. Richter, 1958), the equations (6) and (7), valid for $\Delta < \Delta_1$, turn into

(6′) $I = 1.5.M_s - 3.\log_{10}(R/R_1) + \log_{10}(h/R_1) - 0.4343.\kappa.R + \text{const}$ and

(7′) $I_0 = 1.5.M_s - 2.\log_{10}(h/R_1) - 0.4343.\kappa.h + \text{const}$.

In case of East Alpine earthquakes it is valid

$$\text{magn}(\kappa) \doteq \text{magn}(\bar\kappa) \doteq 10^{-2}\ [km^{-1}]$$

and

$$\text{const} \doteq 1.9 \text{ for a twelve-grade intesity scale.}$$

Analogous to the intensity formulae for direct running waves we get the following intensity formulae for a distinct superposition of direct running and reflected waves:

$$(10)\quad I = 1.5.M_s + \log_{10}(F_1 + F_2) + \text{const, for } \Delta_1 \leqslant \Delta < \Delta_2$$

[km], with $F_1 = \dfrac{h/R_1}{(R/R_1)^3}\cdot e^{-\kappa R}$ and $F_2 = \dfrac{(2h_1-h)/R_1}{(R'/R_1)^3}\cdot e^{-\kappa R'}$;

(11) $I = 1.5.M_s + \log_{10}(F_1+F_2+F_3) + \text{const}$, for $\Delta > \Delta_2$ [km],

with F_1, F_2 as before and $F_3 = \dfrac{[2(h_1+h_2)-h]/R_1}{(R''/R_1)^3}\cdot e^{-\bar\kappa R''}$.

By that we are able to calculate real examples.

For the example which is reproduced in figure 1, with $\kappa \doteq \bar\kappa \doteq 10^{-2}$ [km^{-1}], we receive an intensity—distance curve with steplike increases of intensity at the epicentral distances $\Delta = \Delta_1$ and $\Delta = \Delta_2$ (cf. fig. 2), which are, however, practically always smoothed over certain distance-ranges. (Remark: From this result follows that macroseismic values of magnitude and focal depth should only be evaluated from macroseismic data with $\Delta < \Delta_1$.)

We have not yet won an explanation of transversal quakes with this, because the two sudden increases of seismic intensity are independent of the azimuth if there is an isotropic radiation pattern, but the solution of our problem results immediately from our former findings and the fact, that the radiation pattern of a real seismic source coincides with that of a single or double couple (single or double dipole; the latter is probably predominating; see fig. 3; cf. Aki, 1967; Schick, 1972), that the fault-planes of East Alpine transversal quakes altogether are steeply incident south to southeast (cf. Prey, 1980), and finally, that the local topo-

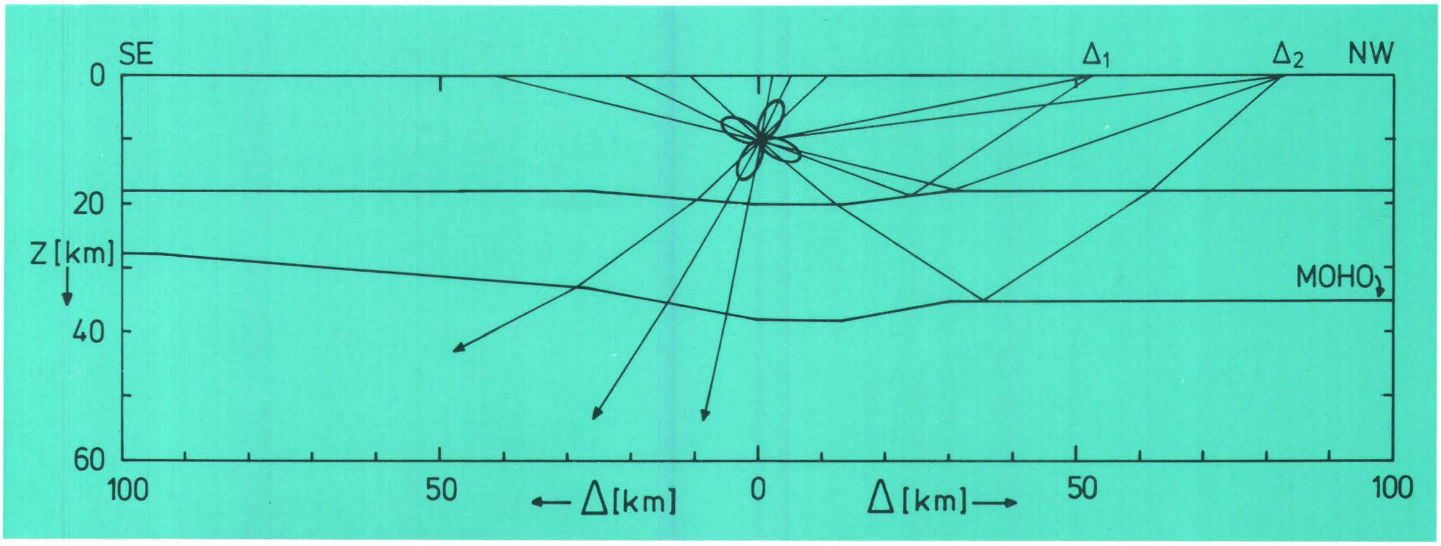
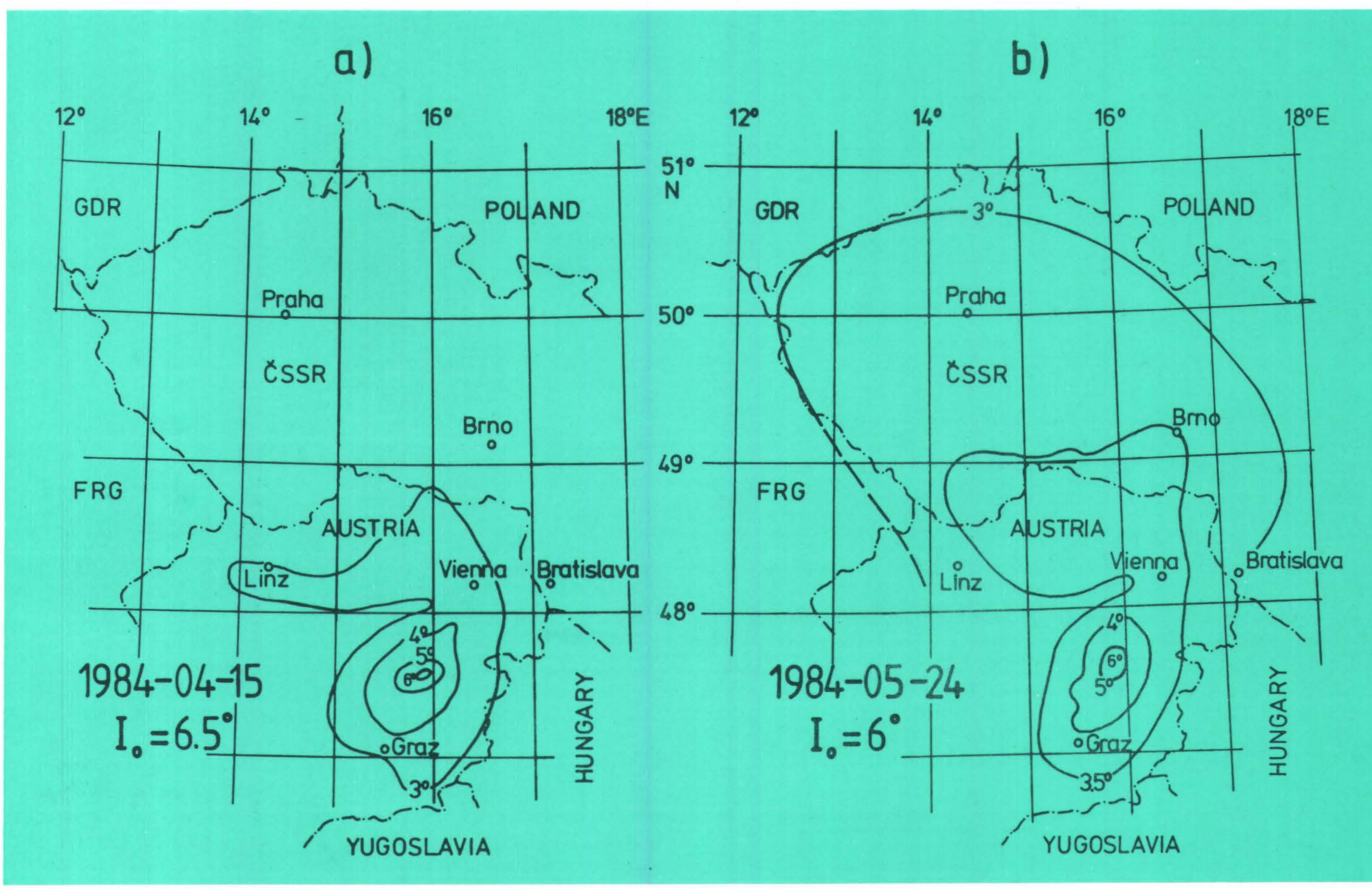


Fig. 4: Profile transverse to the Northeastern Alps (very simplified) with a seismic point source within the upper crust and the paths of directly running as well as reflected shear-waves

Fig. 5: Two earthquakes in the Semmering region with conspicuous differences in the shapes of their isoseismals
a) April 15, 1984: h = 5...7 km, I_0 = 6.5° MSK, M = 4.0 (macro);
b) May 24, 1984: h = 10...12 km, I_0 = 6° MSK, M = 4.1 (macro) ▼



graphy of the MOHO, in a profile transverse to the Northeastern Alps, has the shape of an asymmetric trough (cf. Posgay et al., 1988). In the northwest quadrant this constellation leads to a predominating radiation of shear-wave energy from the focus slanting downwards into the Bohemian Massif, where it suffers a total reflection on the Conrad and Mohorovičić discontinuity, if the angles of incidence exceed certain values; it emerges not before Bohemia, where it causes a distinct increase of seismic intensity. Owing to the fact that the maximum phases of direct running and reflected S-waves are overlapping only partially, an elongation of the effective maximum phase results and therefore resonance effects are possible there, too. — In the direction of Hungary, however, there is a normal decrease of seismic intensity because the seismic energy radiated from the focus slanting downwards carries through the Conrad and Mohorovičić discontinuity (see fig. 4). That's why the southern part of the shaken area has a normal shape. — Herewith we have the requested explanation of transversal quakes.

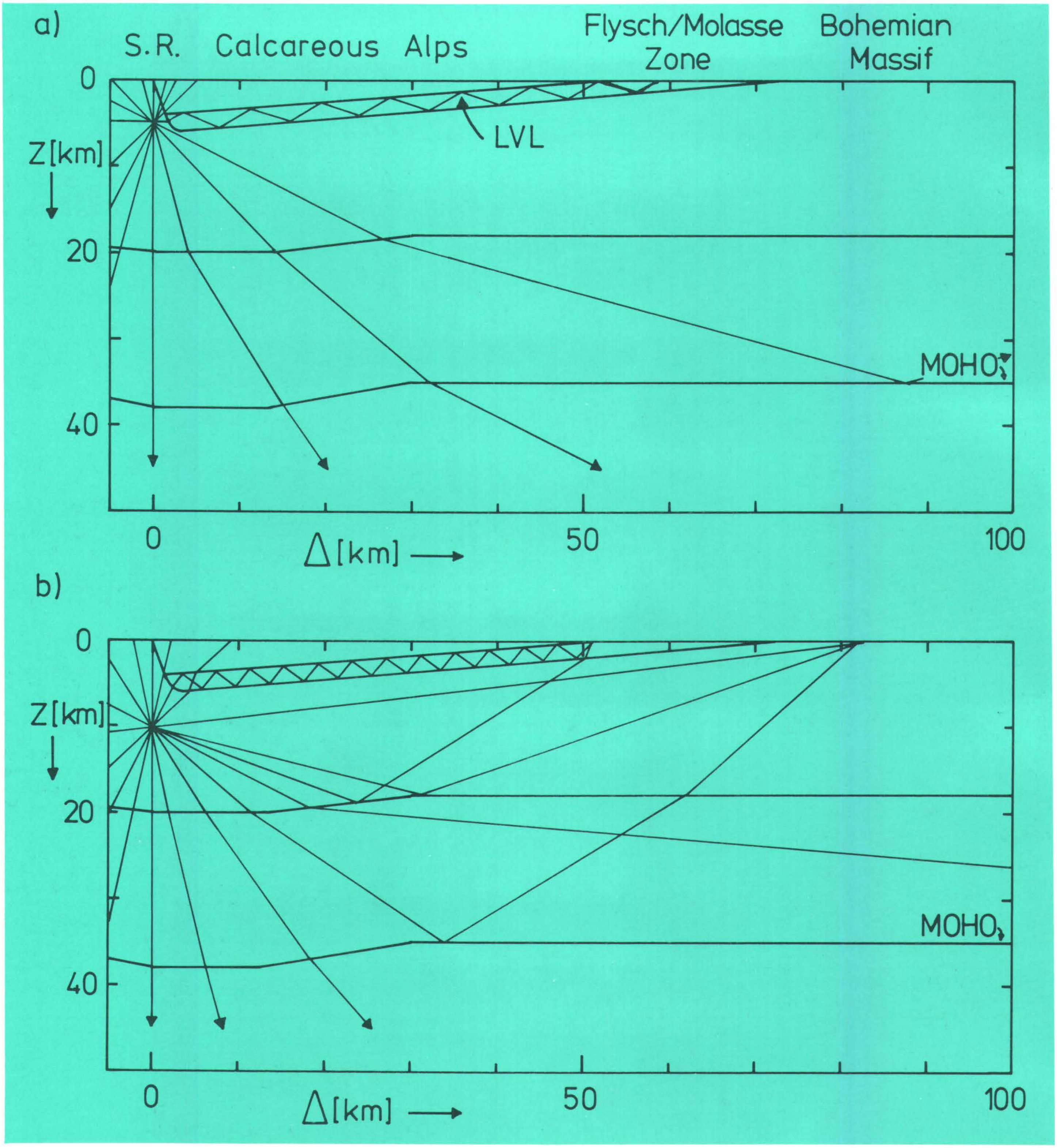


Fig. 6: Explanation of the different propagation of the investigated earthquakes (see fig. 5); a) h = 5 km; b) = 10 km

4. An Experimentum Crucis

A sequence of earthquakes happened in the Semmering region in 1984, two of which (April 15th, May 24th) caused slight damages in the epicentral area. The macroseismic investigation of these quakes yielded identical epicentral coordinates and nearly equal magnitudes, but conspicuous differences in the focal depths as well as in the propagation of the seismic energy to the north (see fig. 5). These differences of propagation could not be explained up to now, and at first sight, it looks as if our theory on transversal quakes failed, too. Therefore the attempt to explain the differences in the energy propagation of these earthquakes carries the weight of an „experimentum crucis".

From the first it can be stated that the earthquake on May 24, 1984 (fig. 5b) corresponds to a transversal quake, the propagation anomaly of which can principally be explained. Therefore it remains to explain the question why the quake of April 15, 1984 was not perceptible in Bohemia though it had the magnitude of the quake of May 24th.

If we suppose that our explanation of transversal quakes is true, then we will have to look for the reason for the propagation differences only in the different focal depths and in the marked deviation of the local geology from our very simple model of the crust.

As it turns out, it is enough to vary our model only in one detail, namely by the introduction of a thin low-velocity layer (= LVL) slightly dipping from north to south (see fig. 6). This LVL corresponds to a stratum of Molasse and Flysch between the Calcareous Alps (above) and the crystalline of the Bohemian Massif. The shear-wave velocity within the LVL is considerably smaller (ca. $v_1/2$) than that of the other geological units within the upper crust (ca. v_1), therefore in this connection we can calculate with only two different shear-wave velocities within the upper crust.

How to draw from figure 6a, in case of earthquakes in the Semmering region with small focal depths (5 km ±) the seismic energy radiated from the focus slanting downwards to the north will be captured by the LVL and led to the surface in the Molasse zone. For this reason reflections don't take place at the Conrad discontinuity and at the MOHO, which are preconditions for transversal quakes.

If, however, the focal depth is greater than the depth of the LVL ($h \geqslant 10$ km ±) the energy radiated from the focus slanting downwards to the north will be reflected by the discontinuities within the Bohemian Massif and so get up to Bohemia and farther, quite in the manner of transversal quakes (see fig. 6b). On the other hand, the energy radiated from the focus slanting upwards to the north gets into the LVL and reaches the surface in the Molasse zone and increases the local seismic intensity there. — With that the individual differences of earthquakes in the Semmering region are clarified, and our explanation of transversal quakes is fully confirmed.

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Abstrakt

Energie silných zemětřesení v sv. Alpách se šíří především k severu a severozápadu; přibližně eliptické oblasti otřesů jsou protaženy podél hlavních os probíhajících napříč k alpskému směru. Proto se taková-to zemětřesení od minulého století nazývají „příčná" neboli „transverzální". Anomální šíření energie alpských zemětřesení nebylo dosud uspokojivě vysvětleno žádným z autorů, kteří se o to pokusili. V této práci se nyní na základě výzkumů dokazuje, že anomální šíření energie transverzálních zemětřesení je důsledkem pouze zvláštní lokální topografie Mohorovičićovy diskontinuity, jakož i k J až JV strmě upadajících zlomových ploch uvnitř svrchní kůry. Hlavní část seizmické energie šířící se z ohniska zemětřesení šikmo dolů se v sz. kvadrantu zcela odráží od Conradovy a Mohorovičićovy diskontinuity, kdežto v jv. kvadrantu těmito rozhraními proniká. Tím lze tedy nyní rovněž bez jakýchkoliv pochyb vysvětlit nápadné rozdíly v šíření dvou zvláštních semmerinských zemětřesení.

Zusammenfassung

Die Energie starker Erdbeben in den nordöstlichen Alpen pflanzt sich bevorzugt nach Norden und Nordwesten fort; die näherungsweise elliptischen Schüttergebiete haben große Achsen, die transversal zum Streichen der Alpen verlaufen. Solche Beben werden daher seit dem vorigen Jahrhundert als „Transversalbeben" bezeichnet. Bis jetzt war noch kein Erklärungsversuch der anomalen Energieausbreitung befriedigend. In der vorliegenden Untersuchung wird nun nachgewiesen, daß die Ausbreitungsanomalie der Transversalbeben allein eine Folge der speziellen lokalen Topographie der Mohorovičić-Diskontinuität sowie der steil süd- bis südostwärts einfallenden Bruchflächen innerhalb der oberen Kruste ist: der Hauptanteil der vom Bebenherd schräg nach unten abgestrahlten seismischen Energie wird im Nordwestquadranten an der Conrad- und Mohorovičić-Diskontinuität total reflektiert, während sie im Südostquadranten diese Grenzflächen durchdringt. Es können nunmehr auffallende Unterschiede in der Ausbreitung von zwei speziellen Semmeringbeben ebenfalls zweifelsfrei erklärt werden.

COMPARISON OF THE FLYSCH ZONE OF THE EASTERN ALPS AND THE WESTERN CARPATHIANS BASED ON RECENT OBSERVATIONS

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1. Preface

Making comparisons between the Flysch Zone of the East Alps and the West Carpathians has a long-standing tradition, as earliest researchers investigated both sides

Tectonics and Facies of the Flysch Zone of the Eastern Alps and the Western Carpathians

M. ELIÁŠ, W. SCHNABEL, ZD. STRÁNÍK 1989

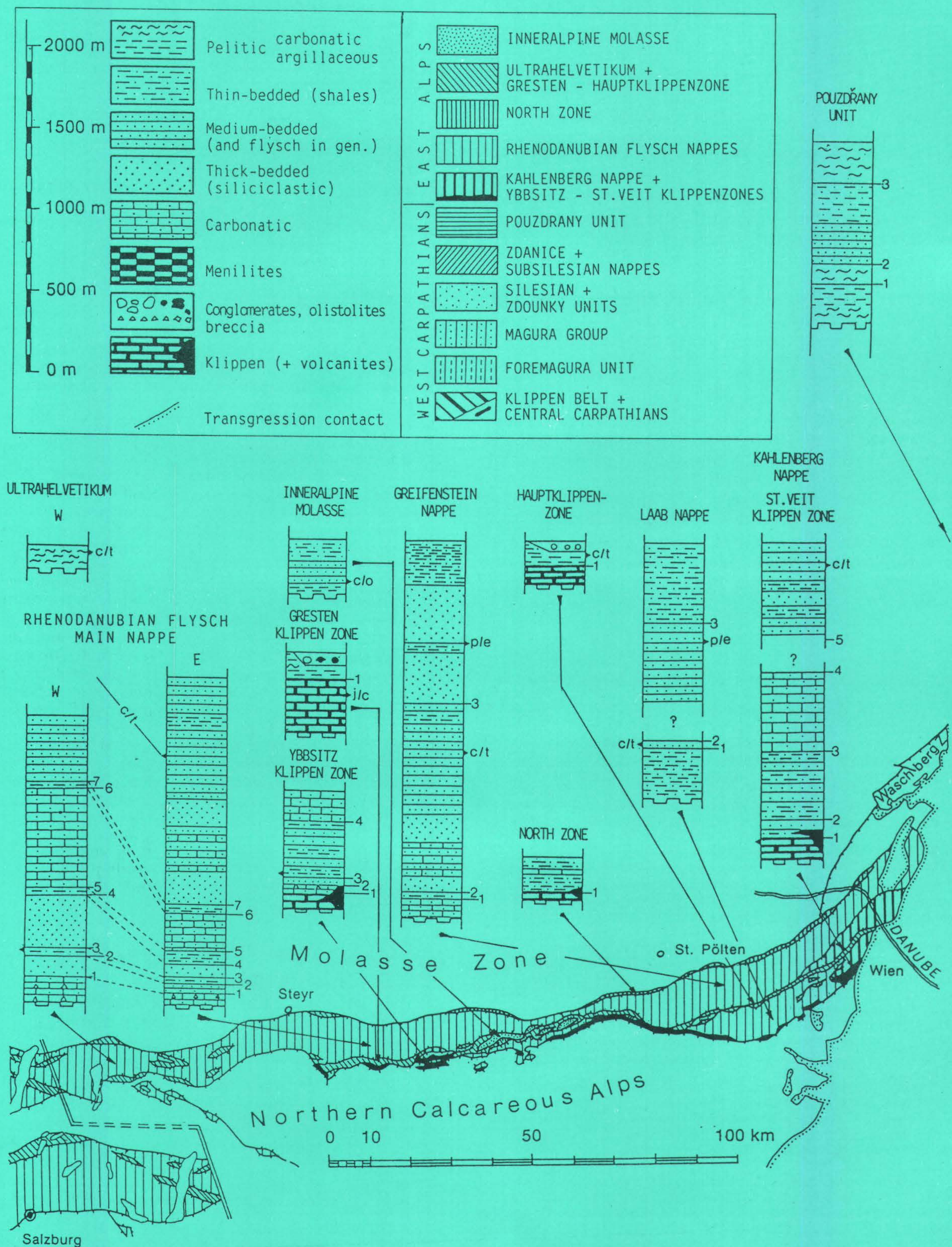
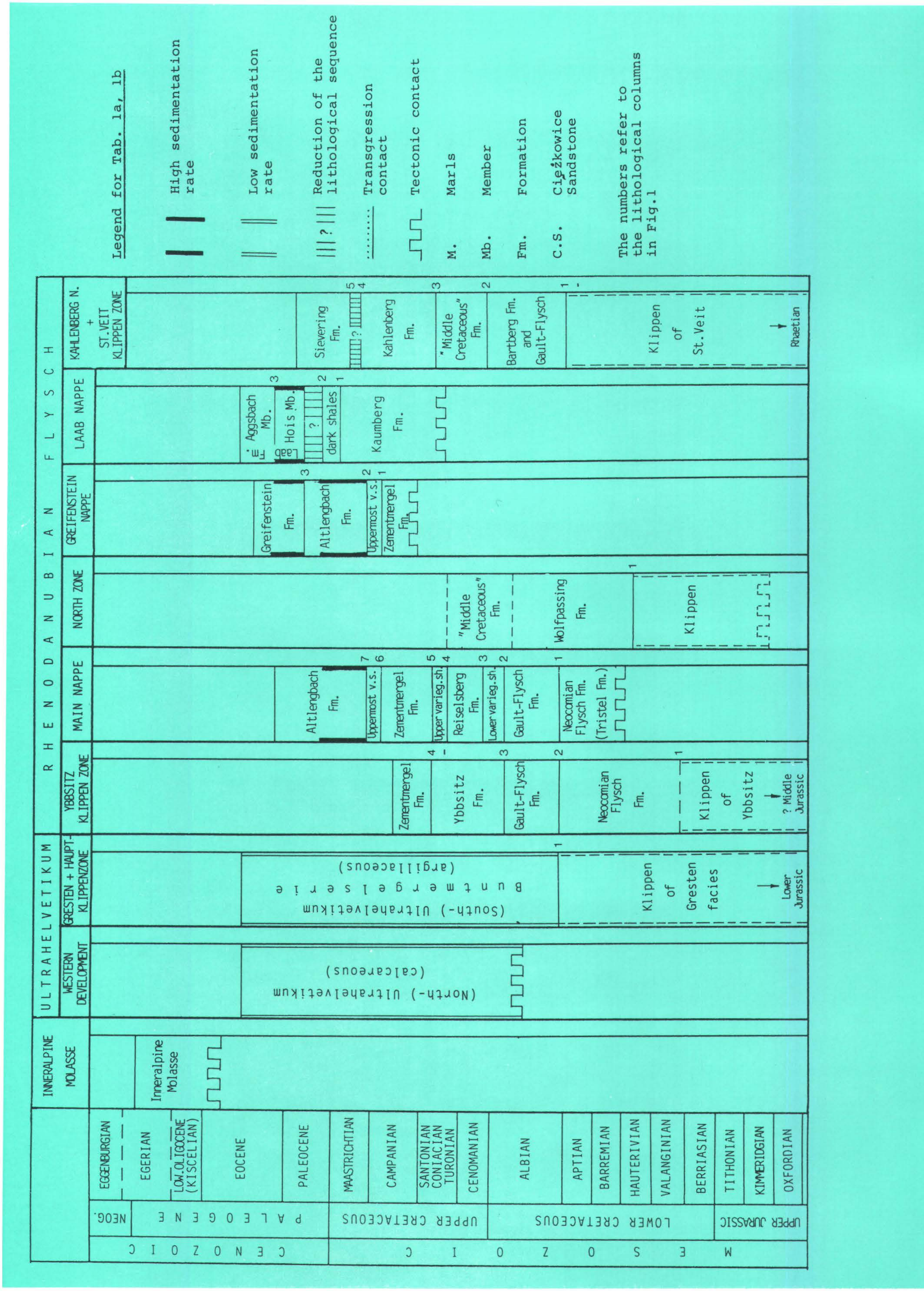
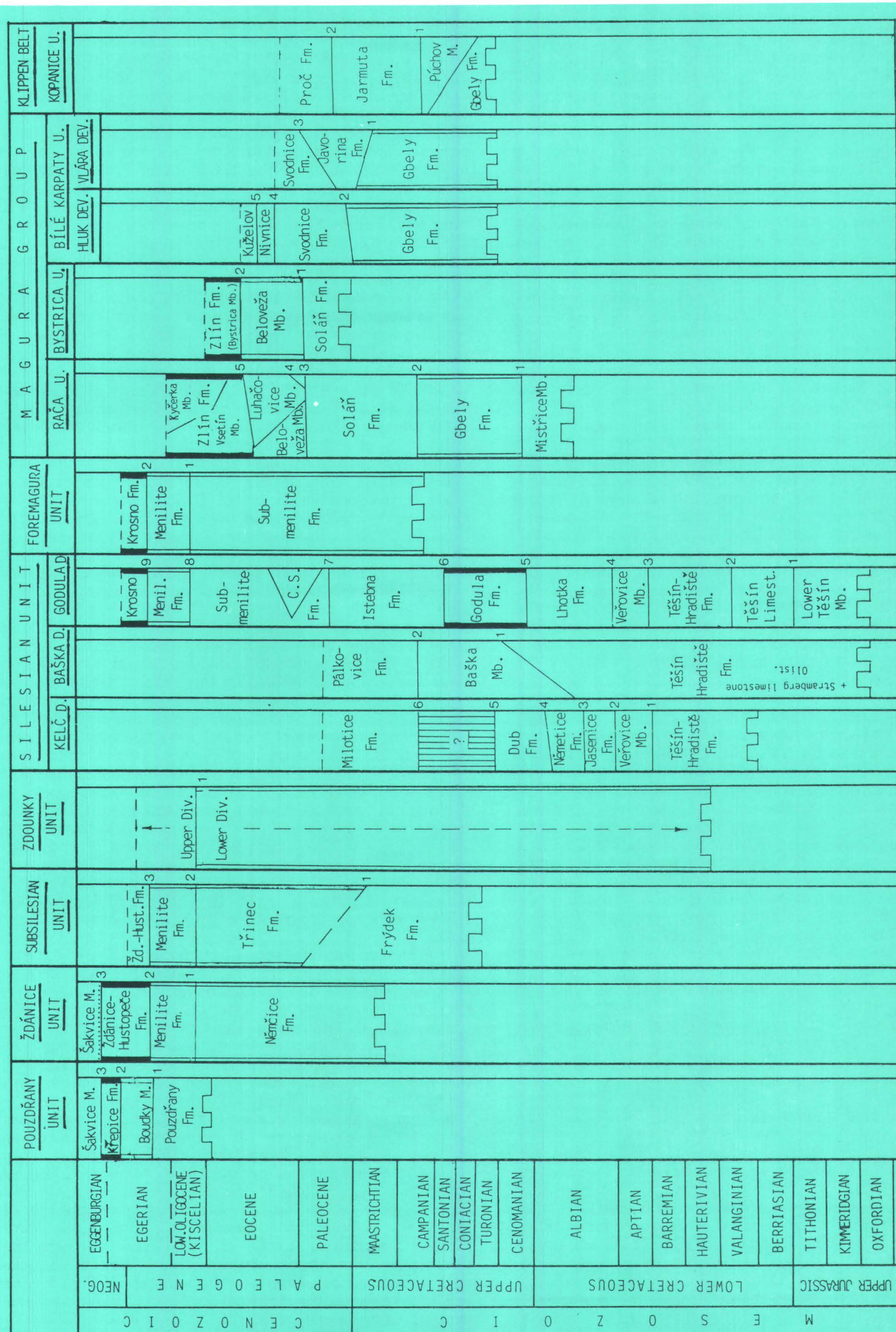


Fig. 1


ŽDÁNICE UNIT
SUBSILESIAN UNIT
ZDOUNKY UNIT
BAŠKA DEVELOPMENT
KELČ DEVELOPMENT
FOREMAGURA UNIT
GODULA DEVELOPMENT
RAČA UNIT
BYSTRICA UNIT
BÍLÉ KARPATY UNIT
KOPANICE UNIT
Ostrava
Olomouc
Brno
Gottwaldov
Žilina
Bratislava
DANUBE
Carpathian Foredeep
Vienna Basin
e/o
c/p
j/c



Tab. 1a: Age and Stratigraphic Names in the Flysch Zone of the Eastern Alps in its Eastern Sector.



Tab. 1b: Age and Stratigraphic Names in the Flysch Belt of the West Carpathians in Moravia.

themselves and where therefore naturally acquainted with both (e.g. Hauer, Stur, Uhlig, Paul). No principle differences became apparent to them. Even a cursory glance at the geological map shows clearly, that the zone along the northern rim of the Northern Calcareous Alps and the Central Carpathians, dominated by flysch deposits, must play a very similar role in the Alpine-Carpathian orogeny.

The salient coincidences are
- the flysch deposits which essentially characterize the zone in the Cretaceous and the Palaeogene,
- the presence of rootless nappes in a frontal position in the orogeny.

There is therefore no doubt that, when considering the Alpine orogeny in its entirety, the term: Alpine-Carpathian Flysch Zone (or Belt) is justifiably applied.

However, the strikingly evident differences are:
- the different width and the difference in stress and history during the young alpidic orogenesis
- The distribution by age of the Cretaceous and Palaeogene beds, which indicate a juvenation of the predominant flysch sequences from West to East. Such a juvenation can also be seen in the Carpathians to occur from the inner to the outer units (see Tab. 1b).

Intensive researches on both sides during the last forty years (Andrusov 1968, Fuchs 1976, Chmelík 1971, Mahel' et al. 1974, Oberhauser 1968, Prey 1965a, Roth 1967, 1980, Tollmann 1971) have produced new basis for making specific comparisons. The results obtained are accordingly more important, as the Neogene of the Vienna Basin interrupts the continuity at the surface. It is for this reason that indications can only be obtained indirectly of the the Alpine and Carpathian sphere, the proof lies hidden under the Vienna Basin. The more importance is therefore due to the evaluation of the flysch from the manifold drill-holes in the Vienna Basin, for which the result has not yet been finally summarized. The indications obtained from the drilling pertain to the flysch and its tectonic units, as well as their direct relationship with these visually evident units, as well as the "Helvetikum" in the Eastern Alps, the Klippen Zone and the Inner Alpine and peripheral Molasse Zones, whose assignment to the Flysch Zone is subject to diverse opinion as is already evident in the different concepts held here as well as there.

This article summarizes the current state-of-knowledge and underlines the essence of the agreements obtained and the differences held. During the last few years many points of view were gained in joint field excursions to obtain comparisons held within the framework of the Treaty on Geological Cooperation between Austria and Czechoslovakia, in which not only the authors, but also many other geologists from both countries were involved. Special thanks are due to Messrs. Bachmayer, Brix, Faupl, R. Fuchs, Grill, Grün, Marschalko, Mišík, Nemčok, Oberhauser, Prey, M. E. Schmid, Seifert, Wessely, as well as many others not only for guidance in the field, but also for numerous discussions.

A careful review by John Meyer helped to improve the exposition of the English version of the manuscript.

2. The East Alpine Flysch Zone

2.1. Major Tectonic Units and Definition

The narrow peripheral zone of the East Alps between the Molasse Zone to the North and the Northern Calcareous Alps in the South is formed by two tectonic systems, the Helvetikum — essentially Helvetikum and Ultrahelvetikum and the Flysch Nappes, for which, after Oberhauser 1968, the designation "Rhenodanubian Flysch" has generally become accepted.

The "typical Helvetikum" is located in the western sector of the East Alps along the northern rim of the Rhenodanubian Flysch and it is linked with the Swiss Helvetikum via a sequence of Upper Jurassic to Eocene. Towards Bavaria it is facially and tectonically substituted by the Ultrahelvetikum. The easternmost continuous domains of the Helvetikum North of the Flysch occur in the area of Salzburg. Normally, these continuous areas of the Helvetikum are not assigned to the Flysch Zone.

Farther toward the East the flysch nappe has overthrust the Ultrahelvetikum completely, which is then present in Upper Austria in the form of northerly vergent thrust-sliced windows within the flysch nappe. This was verified by drilling through the base of the flysch nappe. The almost exclusively pelitic sequence of variegated marls is of modest thickness and is restricted to the Upper Cretaceous-Palaeogene (to middle Eocene), thus being in glaring contrast to the Rhenodanubian Flysch of almost equal age, which attains thicknesses to 2000 m and shows the classic flysch development.

Approximately from the river Enns onwards, SW of the city of Steyr, these marls become noticeably more clayey, forming the cover of the Gresten Klippen Zone (Lower Jurassic — Middle Eocene) thus assuming an ultrahelvetic position. This cover is termed the Buntmergelserie (Albian — Middle Eocene, Prey 1957). The majority of the Rhenodanubian Flysch occurs North of this Gresten Zone, but also as minor occurrences to the South, whereby the Gresten Klippen Zone is also a window within the Flysch Zone.

Exactly South of the very prominent spur of the Bohemian Massif, in the Lower Austrian sector, occurs the so-called „Inneralpine Molasse" (Upper Eocene — Oligocene), which is framed by the Gresten Klippen with the Buntmergelserie, thus forming a double window within the Flysch Zone. It is assumed by W. Fuchs (1976), that the Inneralpine Molasse is the normal sedimentary continuation of the Buntmergelserie, but this remains open to discussion.

However, from the river Enns eastwards, there are still other Mesozoic klippen within the Flysch Zone assemblage, apart from the Gresten Klippen the Ybbsitz Klippen Zone. They are marked by a distinct deep-water facies, containing radiolarites and remnants of basic volcanics (Schnabel 1979). The Zone noticeably widens near the locality of Ybbsitz, where the cover of these klippen consists of flysch of the Middle Cretaceous and Lower Upper Cretaceous, which is comparable with the normal bed-sequence of the Rhenodanubian Flysch, despite several peculiarities, e.g. the distinct chromite content. The zone along the northern margin of the Calcareous Alps, referred to in the literature as the Kieselkalkzone, forms certainly part of this and is shown so by the most recent mapping (Schnabel et al. 1988). Because this clearly shows its inherently distinct characteristics, the Zone is termed the Ybbsitz Klippen Zone in order to differentiate it from the Gresten Klippen Zone.

The Flysch Zone broadens noticeably in the Wienerwald and the Bisamberg Range; we also find there several clearly distinguishable flysch nappes. Midway through these runs the strike of the so-called "Hauptklippenzone" (Main Klippen Zone). The marker beds of the Jurassic — Lower Cretaceous and the Buntmergelserie are comparable with the Gresten Zone, which is why it is also termed "Helvetic", this despite its tectonically different character, since it is, unlike the Gresten Zone, no window-like structure but a distinct „separator" inside the flysch nappes. Incorporated in it are also slices of the Laaber and Kahlenberg Nappes. („Schottenhofzone" Brix 1970).

The St. Veit Klippen Zone occurring in the southern sector of the Flysch Zone in the Wienerwald, was for some time considered as the normal stratigraphic base of the Rhenodanubian Flysch (Tollmann 1963; Prey 1975). As the Klippen themselves as well as their flysch cover are comparable with the Ybbsitz Zone, they can both be regarded as the primary basis of the Rhenodanubian Flysch. From this point of view the different views expressed are reconcilable, even though the original palaeogeographic position is considered differently (Tollmann 1987).

It is therefore not possible to give a tectonic, but only a general regional definition of the East Alpine Flyschzone, which is as follows:

The East Alpine Flysch Zone is that zone at the northern periphery of the Eastern Alps, which ranges from the south edge of the Molasse Zone to the northern edge of the Northern Calcareous Alps. In it dominates the penninic Rhenodanubian Flysch, in which the Ultrahelvetikum and the Inner Alpine Molasse is partially exposed in windows.

It thus shows the following generalized tectonic buildup:

above: Rhenodanubian Flysch with Ybbsitz and St. Veit Klippen-Zones
middle: Ultrahelvetikum with Gresten- and Hauptklippenzone
below: Inner Alpine Molasse.

The Waschberg Zone and the neighbouring Alpine tectonically affected units of the Molasse Zone are not considered as being part of the East Alpine Flysch Zone. This should be particularly emphasized when making comparisons with the Carpathian Flysch Zone.

2.2. The Rhenodanubian Flysch

Tectonic Setting, Stratigraphy and Facies Analysis (Fig. 1, Tab. 1a).

The dominating element in the Flysch Zone is the Rhenodanubian Flysch. Associated with it are all those formations, from the upper part of the Lower Cretaceous to the Lowermost Upper Eocene, in which flysch deposition is predominant. It is assumed that they are laid down in a palaeogeographic position, which is correlatable with the Valais Trough towards the Western Alps (Trümpy 1960). The rootless Rhenodanubian Flysch is therefore considered to be native to the North Penninic realm.

In the western part the build-up of nappes is less well pronounced. Only one nappe is present from the West-East Alpine boundary far to the East to the river Traisen over a distance of 450 km (Flysch Main Nappe). However, this is intensively folded and thrust-sliced and is disturbed by numerous faults (Prey 1980). The special features of the westernmost sector will not here be dealt with any further. The older formations (Neocomian to Campanian) show considerably thicker development in the West, the younger Altlengbach Formation (Maastrichtian to Palaeocene) increases toward the East in thickness as well as in stratigraphic range toward the top.

There are three nappes present in the Wienerwald, which differ also markedly in facies and age: from N to S, they are the Greifenstein Nappe, the Laab Nappe, and the Kahlenberg Nappe. It is the Greifenstein Nappe, which despite differences in facies in the higher Paleocene, can most nearly be considered as the continuation of the Zone to the West. However, the correlation of these two is not yet entirely resolved.

The particularity of the Laab Nappe is the thin-bedded variegated flysch of the Upper Cretaceous (Kaumberg Formation); at the Cretaceous-Tertiary boundary there are glauconitic quartzites and black shales. After an apparent gap in strata-sequence follows the Laab Formation with siliciclastic Hois Member (Upper Palaeocene) and the clayey Aggsbach Member of the Lower to Middle Eocene (Prey 1965b).

The Kahlenberg Nappe is characterized by an extensive disintegration of the original sequence (Jurassic-Lower Paleocene), caused by progressive sliding as a result of tectonic movements and the present-day distribution of the originally correlatable parts over tectonic structures. In essence, the older parts are accumulated in the South, the younger in the North, only the "Middle Cretaceous" is present everywhere, acting as a lubricant and is thus the common link which allows with good reason the supposition of considering them as of common origin. Remnants of the stratigraphic base are the Klippen of St. Veit (Prey 1975). The existence of a synsedimentary picritic volcanism in the "Middle Cretaceous" is worthy of note.

The Ybbsitz Klippen Zone with its flysch cover forms a nappe of its own and which could justifiably also be referred to as Ybbsitz Nappe. It shows characteristics similar to the Kahlenberg Nappe with the St. Veit Klippen Zone both by its stratigraphic range and its tectonic setting. It is marked by frequently occurring remnants of basic to ultrabasic rocks (? ophiolites, Schnabel 1979, Ruttner & Schnabel 1988).

The so-called Northern Zone forms a tectonic element of its own (Grün et al. 1972), extending in the eastern sector roughly from the Erlauf river to the Vienna Basin. The beds, which consist only of the younger part of the Lower Cretaceous to the Lower Albian, with small remnants of Upper Jurassic and Neocomian (?) Klippen contact basic rocks near the locality of Kilb (Prey 1977) and therefore show marked parallels with the Ybbsitz and St. Veit Klippen Zones.

It is difficult to unravel these tectonic units palinspastically and to reconstruct the original sequence of the depositional expanses, as the formational sequences are mostly torn out of their original assemblage. In general the younger members show a tendency of gliding to the North, leaving the older beds behind in the South, a process which can lead up to the complete disintegration of the original sequence right up to diverticulation, where older members of the sequence are overthrust in an upright position over their own younger caprocks. Such processes are conjectured to have occurred in the Wienerwald (Prey 1972). Similar features are recognizable in the underlying Helvetic.

These tectonic complications make a comparison with the Carpathians more difficult, as the tectonic units there can be set up sequentially in accordance to their present setting from N to S to reconstruct their original palaeogeographic position. The Carpathian Flysch Zone was just not overthrust by the Central Carpathians, like the East Alpine Flysch Zone was by the Northern Calcareous Alps. It is for this reason, that a comparison of the formation sequence with the Carpathians can produce clarifying indications.

3. The Flysch Belt of the West Carpathians

3.1. Tectonic Setting

The Carpathian Flysch Belt is situated between the Neogene Carpathian Foredeep to the West and the Klippen Belt to the East. The Flysch Belt has been divided, from the inside to the outer margins, into the Magura Group comprising the Bílé Karpaty, Bystrica or Rača Unit, Fore-Magura Unit, the Silesian Unit with the Godula, Baška and Kelč Developments, and the Zdounky, Subsilesian, Ždánice and Pouzdřany Units (see Fig. 1). In the western section of the Carpathians, the Flysch Belt is some 60 km wide. Its units, overthrust over one another toward the outer periphery of the Carpathians, are tectonically better individualized than the units of the East Alps, which is due to relatively less intensive compression. For this reason, the palaeogeography of the West Carpathians can be interpreted more easily (Książkiewicz 1956). The Alpine-Carpathian contact is obscured by the Vienna Basin covering the Magura Group and the inner parts of the Ždánice Unit and Waschberg Zone. The latter units are surface structures linking the West Carpathians with the East Alps.

3.2. Stratigraphy (Fig. 1,Tab. 1b)

In the Flysch Belt of the West Carpathians, sedimentation can be traced continuously from the Malm to the Lower Miocene. The presence of older sediments (Middle Triassic to Lower Cretaceous) can only be assumed from the pebbles contained in the conglomerates of the Flysch Belt (Soták 1986, Andrusov 1959, Eliáš, Eliášová 1984, Řehánek

1987). The Pouzdřany Unit (Upper Eocene — Eggenburgian) is the lowermost tectonic structure. It is developed in a prevailingly pelitic facies. With respect to lithofacies and palaeogeography, it is the link connecting the autochthonous Palaeogene cover of the Bohemian Massif with the Tethyan area (Stráník 1983).

The front of the Carpathian nappes consists of the Ždánice —Subsilesian Unit (Upper Cretaceous — Lower Miocene) with incorporated Upper Jurassic tectonic fragments (Klippen) and have their continuation in the Waschberg Zone in Austria. Features common to the whole unit are the Uppermost Cretaceous to Upper Eocene pelitic facies and the overlying Menilite Formation. The Subsilesian sector is characterized by the Upper Cretaceous Frýdek Formation, the Ždánice Unit and the Waschberg Zone by the Ždánice-Hustopeče Formation and superimposed Lower Miocene beds (Eggenburgian — Karpatian; Pokorný 1962; Cicha, Pícha 1964).

The Silesian Unit is characterized by the deposits of the Upper Jurassic to Oligocene. The Kelč, Baška and Godula Developments have lithofacially been distinguished in this unit. The Kelč Development (Valanginian-Paleocene) represents a prevailingly pelitic slope facies with slump bodies. The Baška Development (Oxfordian — Palaeocene) represents, particularly in the Lower Cretaceous, a base-of-slope facies comprising block accumulations of the Štramberk Limestones and a basinal facies with carbonate flysch of the Baška Member (Albian — Senonian). The Godula Development (Oxfordian — Oligocene) in characterized, in Jurassic to Cretaceous times, by the carbonate flysch of the Těšín Limestone and, in the Lower Cretaceous, by dark-grey pelite sedimentation, accompanied by the intensive growth of a teschenite volcanic association. Upper Cretaceous to Palaeocene sedimens have developed in a sandy flysch facies (Godula and Istebna Formations). Locally developed Ciężkowice sandstone-bodies are typical of the Palaeocene to Lower Eocene. The Menilite Formation and the flysch facies of the Krosno Formation are the uppermost parts of the sequence. Owing to the lithofacies development of the Cretaceous beds, the Zdounky Unit (Lower Cretaceous — Oligocene) in central Moravia is considered to be the equivalent to the Kelč Development of the Silesian Unit. It is the most SW occurrence of the Silesian Unit, proving that this continues SW from the mobile fault zone of Hornomoravský úval (Matějka, Roth 1956; Roth et al. 1962a, 1962b; Eliáš 1979; Menčík 1983).

At the front of the Magura nappe slices of the Foremagura Unit, characterized by Upper Cretaceous to Eocene variegated pelites, are situated (Hanzlíková, Menčík, Pesl, 1962).

In the Magura Group, the most extensive flysch unit in the West Carpathians, the Rača, Bystrica or Bílé Karpaty Units are distinguished (Matějka, Roth 1949, 1956). The Rača Unit (Lower Cretaceous to Lower Oligocene) displays a considerable variation in lithofacies (Pesl 1968). Its outer part is characterized by thick sandstone bodies, particularly in the Palaeocene. The Palaeocene to Middle Eocene sediments exhibit thin-bedded rhythmic flysch development with variegated claystones (Beloveža Member). In the inner part of the unit, the Beloveža Member is partly replaced by sandstone sedimentation (Luhačovice Formation) which fades out towards the Carpathians. The Middle Eocene to Lower Oligocene series are represented by the typical flysch of the Zlín Formation characterized by glauconite sandstones (Vsetín Member) in the outer part and by dominant arkose and muscovite sandstones (Kyčerka Member) in the inner part. The latter are lithologically and stratigraphically equivalent to the Magura Sandstone of the Flysch Carpathians in Poland.

The Bystrica Unit (Palaeocene—Upper Eocene) is the axial fill of the Magura basin. The Lacko Marls are typical of its Middle to Upper Eocene Zlín (Bystrica) Formation.

The Bílé Karpaty Unit has been divided into the Hluk and Vlára facies-developments (Matějka, Roth 1956; Stráník, Krejčí, Menčík in print). The Hluk Development (Upper Cretaceous — Middle Eocene) is characterized, in the Palaeocene to Lower Eocene, by flysch with prevailing pelites (Svodnice and Nivnice Formations, Stráník et al. in print). Klippen of the Lower Cretaceous Hluk Member with alodapic limestones (carbonate turbidites) are incorporated into the Upper Cretaceous to Paleocene variegated beds. The Vlára Development (Upper Cretaceous — Lower Eocene) is characterized, particularly in the Palaeocene, by sandy flysch sedimentation of the Javorina Formation, wedged as a lenticular body between the Upper Cretaceous variegated Gbely Member and the overlying Svodnice Formation. The Kopanice Development (Stráník, Krejčí, Menčík in print), determined along its contact with the Klippen Belt, is characterized by flysch beds originating from the Campanian to Lower Eocene with abundant clastic carbonate material (Jarmuta and Proč Formations). It is not entirely clear whether it should be assigned to the Bílé Karpaty Unit or to the Klippen Belt.

The stratigraphy of the individual facies units in the Flysch Belt gets younger towards the foreland. In the Bílé Karpaty Unit, the youngest sediments are Middle Eocene, in the Bystrica Unit they are Upper Eocene and in the Rača Unit Lower Oligocene in age. In the outer units, the upper boundary of the sequence (Krosno and Ždánice-Hustopeče Formations) was placed into the Egerian or Lower Miocene (tab. 1b).

4. Comparisons and conclusions

The field excursions carried out to make correlative studies are the basis for making the following comparisons. In this connection, it should be pointed out that the conclusions are not based on detailed research on the objects, but are based on visual inspections in the field and discussions on the general tectonics. However, the exposures visited were chosen selectively, the criteria being that they had been examined recently on other occasions. Corresponding literatur references are quoted.

4.1. Molasse, Ždánice-Waschberg Unit and the Helvetic

The Waschberg Zone (Grill 1953, 1968) is the only zone where the junction of the East Alps with the West Carpathians can be traced on the surface. A relationship of the Waschberg Zone with the Ždánice Unit is evident by their lithostratigraphic and facial development. There is commonality of the Ždánice-Hustopeče Formation and Menilite Formation. The sequence grouped together as the "Submenilite Formation" in the Carpathians is different to a degree. There are differences by the presence of the Jurassic and Cretaceous klippen, as well as the tectonically more compressed structure in the Waschberg Zone South of the Dyje river (Matějka in Kalášek et al. 1962). The Třinec Formation (Uppermost Cretaceous — Uppermost Eocene) has striking similarity with the equivalents of the Helvetic of equal age (Książkiewicz 1956, Prey 1965a, Eliáš 1981).

The connection of the Inneralpine Molasse with the Ždánice Unit and the Waschbergzone as well as the Molasse at the northern periphery of the Flysch Zone near the village of Kilb (Schnabel et al. 1988) and tectonic window of Rogatsboden based on the similarity with the Ždánice-Hustopeče Formation became evident.

For resolving the relationship between the Helvetic (Buntmergelserie) and the Inneralpine Molasse, the conditions in the Carpathians should therefore be taken more into consideration than previously.

4.2. North Zone

This is a conspicuous element with its Lower to Middle Cretaceous remnants of klippen and basic volcanics, at the northern edge of the Alpine Flysch Zone in its eastern sector. A continuation of this zone in the Carpathians in this form is not known. Possibly the Jurassic and Lower Cretaceous of the klippe of Kurovice at the front of the Magura Nappe (Benešová et al. 1968) is lithogically comparable to a degree.

4.3. The relationship of the Magura Group to the Rhenodanubian Flysch

The relationship of the Magura Group to the nappes of the Wienerwald is an essential component of the problem of determining the interconnection of the entire Alpine-Carpathian Flysch Belt. In the first place it is clearly the Magura Group which finds its continuation in the Wienerwald, firstly because of its spatial proximity and secondly because of its stratigraphic extent. In both areas the Upper Cretaceous, Paleocene and Eocene show comparable developments. In contrast thereto, Prey (1965a) has drawn parallels between the Greifenstein Nappe and the Silesian Nappe, which is attributable to his particular emphasis of the Cretaceous. On the other hand, this author also does not want to separate the Greifenstein and Laab developments palaeogeographically, because of their facial transitions. For comparison with the Carpathians, preference should in any case be given to the Palaeogene, as there is a distance of at least 400 km between the typically developed Cretaceous of the Main Flysch Nappe in the western sector of the East Alps and the eastern extremity of the Silesian Unit. It is only the Magura Group which is relevant in establishing a direct connection.

An open question is only how the nappes of the Wienerwald can be linked with the particular units of the Magura Group in Moravia and how they can be traced underground in the Vienna Basin, where such speculations can be confirmed. It is for this reason that drilling into flysch has great significance.

The comparison given here is based on the observations made during the excursions and the present state of the art of present knowledge.

4.3.1. Greifenstein Nappe — Rača Unit

A connection between the Greifenstein Nappe and the Rača Unit is based on the lithological comparison of the sequence of beds in the inner part of the Rača Unit (Luhačovice Zone, Pesl 1968) and the classic exposures of the Greifenstein Formation near Greifenstein (Brix 1969) and Bisamberg (Hekel 1968). The identical lithological sections as in Greifenstein are found underground within the Vienna Basin, in the area of the Hodonín-Gbely Horst (Eliáš 1981b) and can be traced underground (Grill 1968).

It is possible to compare directly the Luhačovice Formation with the Greifenstein Formation in accordance with lithology, sedimentary petrography and stratigraphy. It is possible to correlate on both sides a lower part, dominated by thick-bedded quartz sandstone (Upper Palaeocene to Lower Eocene) and a thin to medium-bedded flysch of the Upper part of the formation. This correlation follows the ideas of Zapletal (1930, 1931) and also Götzinger (1945, 1954), despite the fact that the "Ciezkowice Sandstone" of the localities observed by the latter author is really Luhačovice Sandstone (see also Prey 1965a, p. 90).

Based on this findings it is the authors' opinion that it is not possible to draw a parallel between the Greifenstein Sandstone and the Ciężkowice Sandstone, as is done by Prey (1965a). The Silesian Unit has no connection with the East Alpine Flysch Zone.

4.3.2. Laab Nappe — Bílé Karpaty Unit

The connection between the Laab Nappe and the Bílé Karpaty Unit is also evident from the lithological sequence in outcrops and wells. The clearest indication is the relationship seen between the Laab Beds with both its developments, the Hois Formation and the Aggsbach Formation (Prey 1965b). Both these two facies find their stratigraphic and lithological equivalents in the Svodnice Formation (Paleocene-Eocene). In the Upper Cretaceous it is possible to compare the Kaumberg Formation with the Gbely Formation, both are characterized by their variegated shale facies. They have already been found underground in the Vienna Basin. In this respect first comparisons were made by Götzinger (1945). Both units are completely identical in their entirety, stratigraphically as well as lithologically.

4.4. Kahlenberg Nappe

The Kahlenberg Nappe seems to have no equivalent in the Carpathians at least at the surface. This statement concerns the Middle to Upper Cretaceous flysch sequences as well as the Klippen Zone of St. Veit. Due to the well-founded suspicion of Prey (1975, p. 65) the St. Veit Klippen Zone can also not be compared with the Pieniny Klippen Belt, as it was argued before (e. g. Birkenmajer 1962). A direct connection of the flysch sequences of the West Carpathians with their former base has not yet been observed.

5. References

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Abstrakt

Upozorňujeme na rozdíly v časovém a obsahovém chápání flyše ve Východních Alpách a v Západních Karpatech. V Západních Karpatech jsou vnější jednotky (podslezská, ždánická a pouzdřanská) integrující složkou flyšového pásma, zatímco srovnatelné jednotky Východních Alp nejsou paleogeograficky spojovány s flyšem. Řadí se k helvetiku a k molase.

Tektonické jednotky Vídeňského lesa mohou být srovnány s dílčími jednotkami magurského flyše. Greifensteinský příkrov odpovídá jednotce račanské, jak je možno dokázat i z vrtů, které dostihly flyšové podloží neogénu vídeňské pánve. Greifensteinský pískovec může být přímo srovnáván s pískovci luhačovického souvrství.

Vrstevní sled laabského příkrovu je srovnatelný se sledem bělokarpatské jednotky, kaumberské vrstvy s gbelským souvrstvím a laabské vrstvy se svodnickým souvrstvím.

Pro slezskou jednotku nebyl v alpském flyšovém pásmu nalezen žádný ekvivalent. Rovněž tak severní zóna a kahlenberský příkrov Vídeňského lesa nemá žádné pokračování v Karpatech, minimálně v povrchové stavbě.

Bude následovat detailní zpracování vrstevních sledů jednotlivých tektonických jednotek a jejich korelace.

Zusammenfassung

Basierend auf den Beobachtungen der Exkursionen in die Flyschzone der Ostalpen und der Westkarpaten werden die tektonischen Einheiten und wichtige Formationen verglichen.

Die Unterschiede im altersmäßigen Umfang der Flyschfolgen und die Abfolgen sowie die unterschiedlichen Begriffsfassungen werden aufgezeigt. Es geht hervor, daß in den Karpaten die externen Einheiten (Subsilesische, Ždánice- und Pouzdřany-Einheit) integrierter Bestandteil der Flyschzone sind, während vergleichbare Einheiten der Ostalpen paläogeographisch nichts mit dem Rhenodanubischen Flysch zu tun haben. Sie gehören zum Helvetikum und zur Molasse.

Die tektonischen Einheiten des Wienerwaldes können mit denen der Magura-Gruppe verglichen werden. Die Greifensteiner Decke ist mit der Rača-Einheit parallelisierbar, was auch aus Bohrungen im Wiener Becken ersehen werden kann. Der Greifensteiner Sandstein kann direkt mit dem Luhačovice-Sandstein verglichen werden.

Die Schichtenfolge der Laaber Decke ist mit der Bílé Karpaty-Einheit vergleichbar, und zwar die Kaumberger Schichten mit der Gbely-Formation und die Laaber Schichten mit der Svodnice-Formation.

Die Silesische Einheit hat offensichtlich kein Äquivalent in der alpinen Flyschzone. Umgekehrt finden die Nordzone und die Kahlenberger Decke des Wienerwaldes in den Karpaten, zumindest an der Oberfläche, keine Fortsetzung.

Eine detaillierte Bearbeitung der Schichtprofile der tektonischen Einheiten und die stratigraphische Korrelation werden angeregt.

THE ALPINE-CARPATHIAN FLOOR OF THE VIENNA BASIN IN AUSTRIA AND ČSSR

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1. Introduction

The Alpine nappe system underneath the Neogene of the Vienna basin connects the Austrian Alps and the Czechoslovakian Carpathians. Of course, on the strike, some tectonical units are replaced by others or end in the Vienna basin. Especially the nappes of the Flysch and the Calcareous Alps are objects of intensive exchange of information between Austria and Czechoslovakia for common interests of finding hydrocarbons. These contacts are relevant for better knowledge of source and reservoir rocks in this area. Especially the fields in the Calcareous Alps in Austria and Czechoslovakia (Aderklaa, Schönkirchen, Baumgarten, Závod, Borský Jur) deepened the contacts of ÖMV and MND Hodonín.

The source of the information are wells and seismic surveys. The wells reached depths of more than 6 000 m. The penetrated sequence of the Alpine—Carpathian system was in some cases several thousand meters. The seismic surveys very often did not offer the wanted information; one can use seismics in this area only for the determination of the Preneogene relief. If stratigraphic or tectonic planes

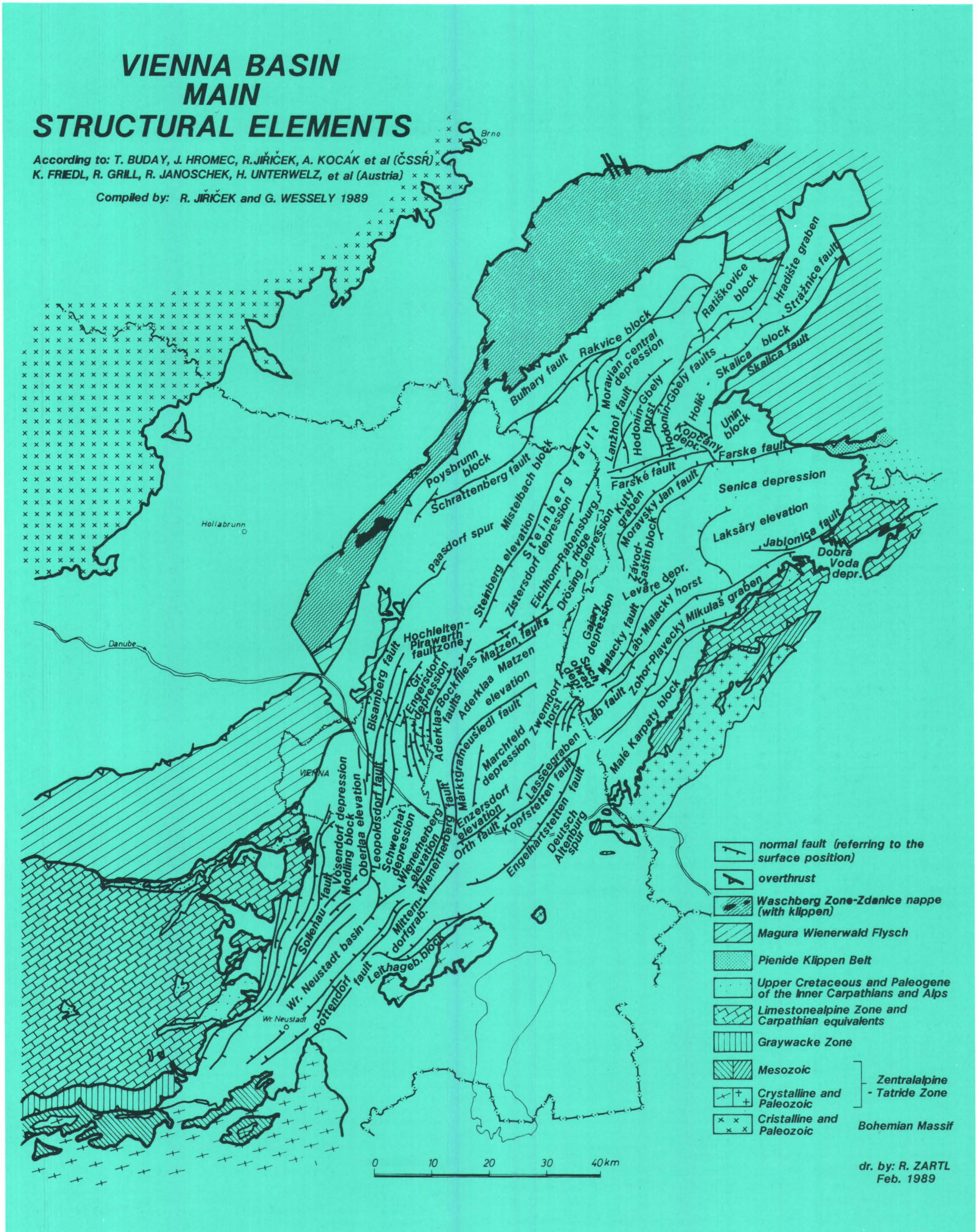

VIENNA BASIN
MAIN
STRUCTURAL ELEMENTS
According to: T. BUDAY, J. HROMEC, R. JIŘIČEK, A. KOCÁK et al (ČSSR)
K. FRIEDL, R. GRILL, R. JANOSCHEK, H. UNTERWELZ, et al (Austria)
Compiled by: R. JIŘIČEK and G. WESSELY 1989
Brno
Hollabrunn
Danube
VIENNA
Wr. Neustadt
Rakvice block
Bulhary fault
Moravian central depression
Ratiškovice block
Hradište graben
Strážnice fault
Skalica block
Skalica fault
Holíč - Skalica
Hodonín-Gbely faults
Hodonín-Gbely horst
Lanžhot fault
Kopčany depr.
Unín block
Farske fault
Farské fault
Senica depression
Laksáry elevation
Jablonica fault
Dobrá Voda depr.
Poysbrunn block
Schrattenberg fault
Mistelbach block
Steinberg fault
Paasdorf spur
Steinberg elevation
Zistersdorf depression
Eichhorn-Rabensburg ridge
Drösing depression
Kúty graben
Moravský Ján fault
Závod-Šaštín block
Leváre depr.
Gajary depression
Malacky fault
Lab-Malacky horst
Zohor-Plavecky Mikuláš graben
Hochleiten-Pirawarth faultzone
Matzen faults
Matzen elevation
Bisamberg fault
Gr. Engersdorf depression
Aderklaa-Bockfliess faults
Aderklaa
Marchfeld depression
Markgrafneusiedl fault
Zwerndorf horst
Lab fault
Malé Karpaty block
Lassee graben
Kopfstetten fault
Engelhartstetten fault
Deutsch Altenburg spur
Enzersdorf elevation
Orth fault
Leopoldsdorf fault
Wienerherberg fault
Wienerherberg elevation
Schwechat depression
Oberlaa elevation
Mödling block
Vösendorf depression
Sollenau fault
Wr. Neustadt basin
Mitterndorf grab.
Leithageb. block
Pottendorf fault
0 10 20 30 40km
normal fault (referring to the surface position)
overthrust
Waschberg Zone-Zdanice nappe (with klippen)
Magura Wienerwald Flysch
Pienide Klippen Belt
Upper Cretaceous and Paleogene of the Inner Carpathians and Alps
Limestonealpine Zone and Carpathian equivalents
Graywacke Zone
Mesozoic
Crystalline and Paleozoic
Zentralalpine - Tatride Zone
Cristalline and Paleozoic
Bohemian Massif
dr. by: R. ZARTL
Feb. 1989

Fig. 1.

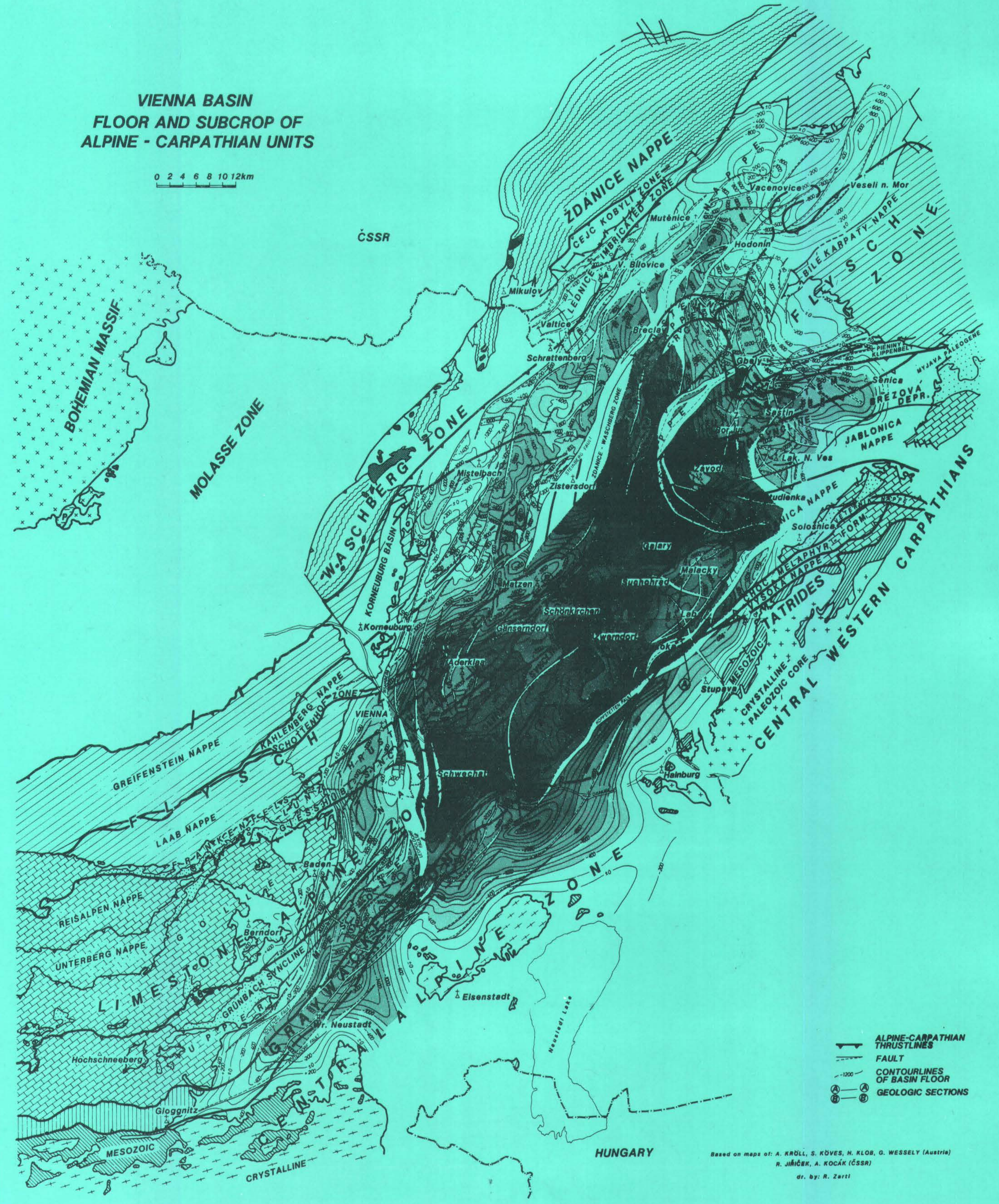

VIENNA BASIN
FLOOR AND SUBCROP OF
ALPINE - CARPATHIAN UNITS
0 2 4 6 8 10 12km
ČSSR
BOHEMIAN MASSIF
MOLASSE ZONE
WASCHBERG ZONE
ŽDÁNICE NAPPE
FLYSCH ZONE
BÍLÉ KARPATY NAPPE
JABLONICA NAPPE
BREZOVÁ DEPR.
CENTRAL WESTERN CARPATHIANS
TATRIDES
CRYSTALLINE PALEOZOIC CORE
GREIFENSTEIN NAPPE
KAHLENBERG NAPPE
LAAB NAPPE
REISALPEN NAPPE
UNTERBERG NAPPE
GRÜNBACH SYNCLINE
LIMESTONE ALPINE ZONE
CENTRAL ALPINE ZONE
MESOZOIC
CRYSTALLINE
HUNGARY
Mikulov
Valtice
Břeclav
Hodonín
Mutěnice
Veseli n. Mor
Schrattenberg
Gbely
Senica
Mistelbach
Zistersdorf
Matzen
Gänserndorf
Korneuburg
VIENNA
Schwechat
Baden
Berndorf
Wr. Neustadt
Eisenstadt
Hochschneeberg
Gloggnitz
Hainburg
Stupava
Malacky
ALPINE-CARPATHIAN THRUSTLINES
FAULT
CONTOURLINES OF BASIN FLOOR
GEOLOGIC SECTIONS
Based on maps of: A. KRÖLL, S. KÖVES, H. KLOB, G. WESSELY (Austria)
R. JIŘIČEK, A. KOCÁK (ČSSR)
dr. by: R. Zartl

Fig. 2

within the Calcareous Alps are very steep, no believable seismic reflections are seen.

2. Structure of the Vienna Basin

For delineating structural elements in the Neogene floor of the Vienna basin it is necessary to define the reference surfaces. The structural subdivisions in shallower parts (fig. 1) differ mainly from those at the base of Neogene because in deeper stratigraphic sections older structures are preserved in addition to the younger ones often divergent in striking. In the shallower positions only younger structures are present, which may disappear with depth like narrow grabens or which may be shifted.
Nevertheless an attempt of generalisation of the structural picture and fault systems will be undertaken.

The marginal blocks are separated by large synsedimentary faults from deep depression zones. Beside complex arrangements of subsided and elevated blocks a median high zone in a sigmoidal shape is extending along the axis of the basin.

The most extensive marginal blocks along the western border of the basin are the Ratiškovice and Rakvice blocks, the Poysbrunn, Mistelbach and Mödling blocks. By the Schrattenberg-Steinberg-Bisamberg-Leopoldsdorf fault systems these marginal blocks are separated from a system of depressions consisting of the Uherské Hradiště graben, the Moravian central depression, the Zistersdorf, Groß-Engersdorf and Schwechat depressions.

A median highzone extends from the Hodonín-spur s. l., which is limited to the Moravian central depression by the Lanžhot and Lužice faults, along the Rabensburg-Eichhorn ridge to the Matzen-Aderklaa highzones. Isolated in the Southern Vienna basin the Wienerherberg-Enzersdorf high is situated. The Hodonín spur s. l. consists of the Hodonín Gbely horst s. s., the Holič-Skalica block, the Kopčany depression and the Unín block. These structures are cut towards the South by the large Farske fault. South of this fault large depressions are extending: the Kúty-Drösing depression, continuing to the South into the Gajary and Suchohrad depressions, the Senica depression and the Leváre depression, interbedded between these depressions is the Závod-Šaštín block and to the East these depressions are bordered by the Láb-Malacky horst and the Lakšáry elevation. In Austria the median high zone is separated by the Markgrafneusiedl fault from the Marchfeld depression. Between the latter one and the Gajary-Suchohrad depressions the Zwerndorf-Tallesbrunn high is situated.

Along the Eastern flank of the Vienna basin a system of grabens is arranged consisting of the Wiener Neustadt basin, the Mitterndorf graben, the Lassee graben and the Zohor Plavecký graben. The extension of these grabens lasted to very young times. They are separated by large faults (Pottendorf fault, Kopfstetten-Engelhartstetten fault-system) from the Eastern marginal blocks, as the Leithagebirge block, Deutsch Altenburg spur and the Malé Karpaty block.

The faults mentioned above are synsedimentary, often with large displacements (Steinberg fault 5 000—6 000 m, Leopoldsdorf faults up to 4 000 m), mostly active since Badenian time. But there are also structural elements and faults, which indicate tectonic movements in Prebadenian age. These elements are known in the northern parts of the Vienna basin. The rhomboidal shape of the basin, the bending of structures and faults in an often right stepping en echelon arrangement and the known depocenters are the indications for a specific mechanism of tension. This mechanism was caused by the further overthrusting of the Carpathian nappes in the Miocene and the stop of the Alps at the same time. By its subsiding tendency the crystalline basement was controlling these tectonic events which created the Vienna basin.

For the hydrocarbon exploration in the Flysch zone at the base of the Vienna basin the Steinberg highzone in Austria and the Gbely-Hodonín in the ČSSR are of large importance.

The hydrocarbon exploration in the dolomitic reservoirs of Alpine zone at the base of the Vienna basin in Austria was performed on the high zones of Aderklaa (ca. 2 650 m deep), Schönkirchen (ca. 2 600 m deep) and Baumgarten (ca. 2 500 m deep) with detection of gas or oil in Schönkirchen. Other elevations are known in Oberlaa-Laxenburg (Mödling block) and along the line Markgrafneusiedl-Gänserndorf, but no hydrocarbons were found in these positions. In the ČSSR the elevations of Závod (4 000 m deep), Borský Jur (3 000 m) and Šaštín (2 000 m) are gas-bearing. Other prominent high positions are the Láb-Malacky and Lakšáry highs.

3. Overview of the Geologic Alpine-Carpathian Units

3.1 Austria

Below the Neogene of the Vienna basin nappes of the Flysch, the Calcareous Alps, the Graywacke zone and the Centralalpine Zone are striking from the western basin margin into the area of Slovakia. The Flyschzone is subdivided into the Harrersdorf (= Rača) unit, the Greifenstein nappe (Gösting and Zistersdorf subunit), the Kahlenberg nappe (Sulz subunit) and the Laab nappe. The Calcareous Alps consist of 3 groups of nappes: The lowermost (northwesternmost) one is the Frankenfels-Lunz unit (Bajuvaricum), overthrust by the Göller nappe (Tirolicum), which in turn is overthrust by the Upper Limestone Alpine nappes (Juvavicum). These nappes are separated by troughs of Gosau sediments (Gießhübl and Glinzendorf depressions). Both troughs are overthrust in northwestern direction by the respective higher nappe.

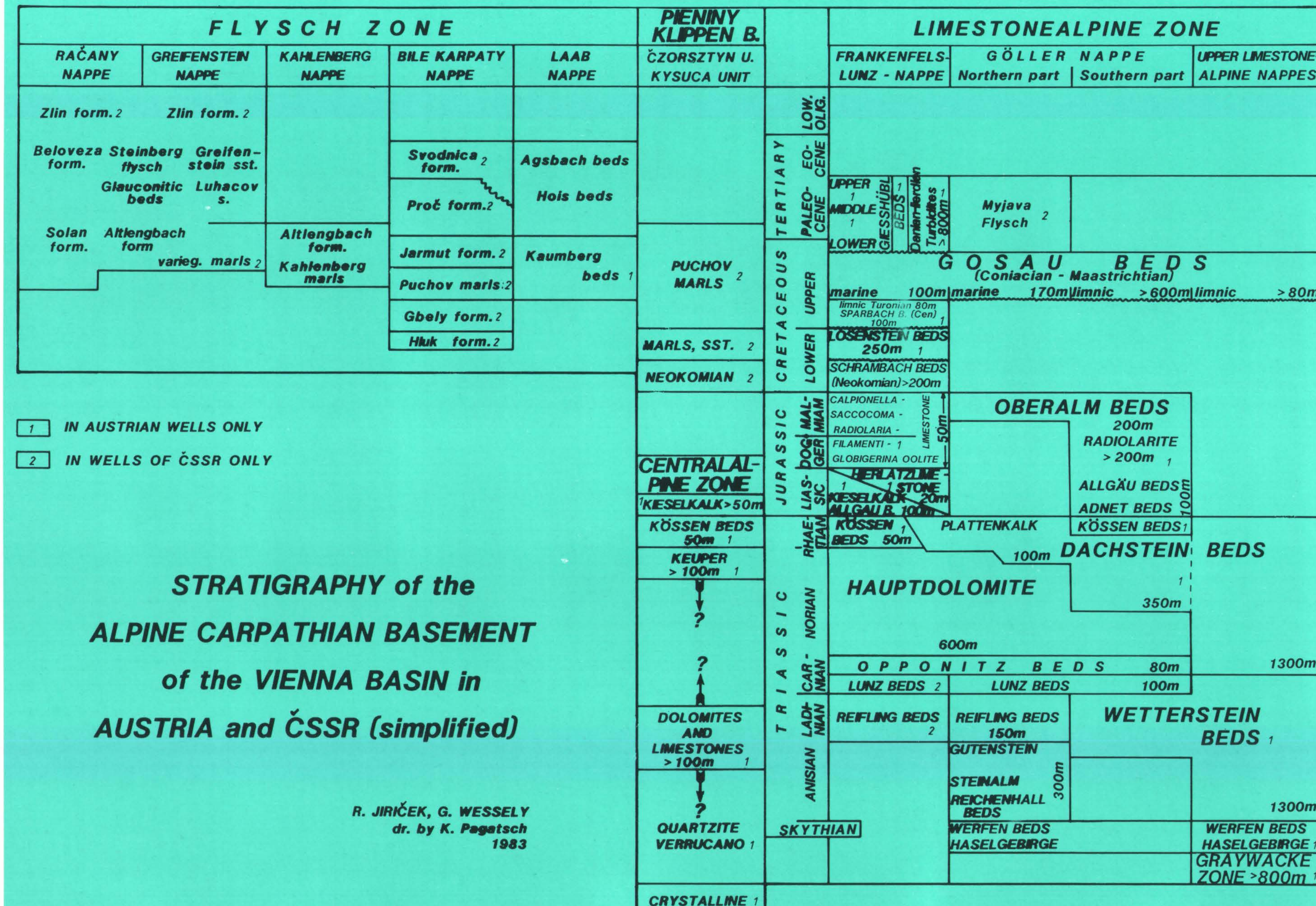
The Preneogene relief of the Flysch covers an area of 1 240 km^2. It has been explored by numerous wells. Hydrocarbon deposits are restricted to sandstones of Paleocene-Eocene age in the area of the Steinberg high (Greifenstein nappe), but some occurrences of oil were found in disturbed rocks of the Kahlenberg nappe (Pirawarth-Hochleithen).

The Preneogene Limestone Alpine relief covers an area of 1 450 km^2. More than 200 wells penetrated this surface enabling the investigation of the limestone Alpine floor. Many of them are concentrated in areas of oil and gasfields. On the other hand 30 wells explored longer sections in this floor giving evidence of the interior structure of nappes. The most knowledge was obtained in the Frankenfels-Lunz System (80 wells) and the Ötscher nappe (100 wells), less explored are the Upper limestone alpine nappes with 28 wells.

3.2. ČSSR

In the Preneogene basement of the Czechoslovakian part of the Vienna basin the Flyschzone and the Northern Limestone Alpine nappes continue towards NE, partly to the Carpathian mountains. The Flyschzone contains the Lower Magura nappe system (Račany-, Greifenstein-, Kahlenberg nappe) and the Upper Magura nappe system (Bílé Karpaty-Laab nappe). Between the Flyschzone and the Limestone Alpine nappe runs in SW—NE direction the narrow zone of the Pieniny klippen belt with the Czorstyn and Kysuca units. Towards the NW the Flyschzone is bordered by the Ždánice unit.

The Limestone Alpine nappes of the ČSSR part of the Vienna basin are as in Austria subdivided into a northwestern unit corresponding to the Frankenfels-Lunz nappe system (Bajuvarikum), the middle zone of the thrust units (equivalent to the Tirolicum containing the Göller nappe) and the Veternik, Havran and the Jablonica nappes which appear on the Carpathian border on surface. The Brezová Gosau depression is extending from the surface into the



1 IN AUSTRIAN WELLS ONLY

2 IN WELLS OF ČSSR ONLY

STRATIGRAPHY of the ALPINE CARPATHIAN BASEMENT of the VIENNA BASIN in AUSTRIA and ČSSR (simplified)

R. JIRIČEK, G. WESSELY
dr. by K. Pagatsch
1983

Table 1.

basin. The southernmost zone can be compared with the Upper Limestone Alpine nappes (Juvavikum).

This zone as well as its underlying Paleozoic base, the Graywackezone, dissappears within the basin, the Central-Alpine Zone is replaced by the Tatride zone.

The Preneogene surface of the Flysch in the ČSSR part of the Vienna basin occupies an area of 1 600 km^2. 200 wells were drilled into the Flysch, but in Moravia most wells have been finished in the Zlín formation, 15 wells encountered the Pieniny klippen belt.

The Limestone Alpine surface below the Vienna basin comprises an area of 1 385 km^2. Till now 50 wells, nearly all located on high zones, were spudded within this zone.

4. Stratigraphy and Facies (ČSSR and Austria)

4.1 Flysch and Klippenzone

4.1.1 Lower Magura Nappe System

The sedimentary sequence of the Račany nappe starts with the Soláň formation (Senonian to Lower Paleocene). The lower part consists of variegated marls and sandstones, the upper part of sandstones and conglomerates. The Beloveža Formation (Upper Paleocene to Middle Eocene) and the Zlín Formation (Upper Eocene to Lower Oligocene) are superimposed. The Račany unit is overlain by the Týnec slice with Altlengbach beds (Senonian to Lower Paleocene), overlain by the Zlín beds. This slice can be compared with the Greifenstein nappe. The Kuty slice, which is not well known, can be correlated with parts of the Kahlenberg Flysch, some picrites also have been detected.

In the lower system of Flysch units in the Austrian part of the Vienna basin (from NW to SE Harrersdorf-, Gösting-, Zistersdorf thrust slices) a rather unique succession is to be observed: turbiditic sandstones and marls of the Upper Cretaceous Altlengbach beds are followed by a Paleocene to Eocene series of 3 or more glauconitic sandstone complexes, each of them with considerable thicknesses (hundreds of meters) and interpreted as deep sea fans with different stages of progradation in the different units. On top of them the Eocene "Steinbergflysch" was deposited, a more distal element of a turbiditic complex, with dominating marls interbedded with a series of sandy layers (up to 18 horizons).

The Harrersdorf unit is a frontal nappe similar to the northern (Rača) unit in ČSSR. The Gösting- and Zistersdorf units are to be combined with the Greifenstein nappe (M. Rammel 1988, Diss. phil.: "Die Glaukonitsandsteinserie im Untergrund des Nördlichen Wiener Beckens").

The stratigraphy of the Sulz unit, which corresponds to the Kahlenberg nappe is not as explored as the deeper units. The well Maustrenk ÜT 1a and wells of the Sulz-Pirawarth-Hochleiten area proved turbiditic sediments from Upper Cretaceous to Paleogene in a tectonically more complicated succession.

4.1.2 Upper Magura Nappe System

This system consists of the Bílé Karpaty Nappe and Laab Nappe. The lowermost beds of the Bílé Karpaty Nappe are the Gbely beds (Cenomanian to Turonian), which are overlain by the variegated Púchov Marl (Upper Coniacian to lower Campanian to Maastrichtian). The youngest deposits are the Proč formation with Flysch rocks (Paleocene to Middle Eocene). Beds of the Laab Nappe have been drilled presumably in Slovakia.

The upper Flysch complex in the Austrian part of the Vienna basin is subsumed under the term Laab nappe. A continuous sequence of this unit was drilled by the well Aderklaa ÜTla with Upper Cretaceous Kaumberg beds, a series of thick sandstone complexes of Paleogene age (Hois beds) covered by a more pelitic series of Eocene age (Agsbach beds). Many wells in the Bockfließ-Raggendorf-Matzen-Spannberg area encountered Upper Cretaceous turbiditic sandstones predominating the pelites. Within these sections also red or violet shales occur. In some cases complexes of diabase were found. Sedimentary components of these rocks in red shales point to synsedimentary intrusions of the diabases in Upper Cretaceous time. By the well Ringelsdorf 3 the Laab nappe is followed towards the State boundary by the occurrence of Kaumberg beds or their sandy equivalents.

4.1.3 The Pieniny Klippen Belt

This Klippen belt is genetically connected with the Magura Unit and consists of the Czorstyn- and Kysuca Unit in the Vienna basin. Rocks of Neocomian to Senonian age have been deposited.

4.2 Limestone Alpine Zone

4.2.1 Frankenfels-Lunz Nappe System — Bajuvaricum

Pregosauic Sediments

In Austria there is a tectonical reduction of the middle and lower Upper Triassic in the exposed parts of the Calcareous Alps as well as in the Calcareous Alps in the Vienna basin, however, the sedimentary sequence starts with the Middle Triassic Reifling limestone (Upper Anisian to Upper Ladinian). These limestones have been drilled 480 m thick in Kuklov 3 — Partnach beds can attain a thickness of up to 150 m. Aon-beds and Lunz beds, about 600 m thick, are occurring in Lower Carnian. In Austria, the sedimentary sequence starts with the Opponitz beds, a dolomitic-evaporitic facies of low thickness. They represent a good sliding horizon. The Norian Hauptdolomit (gray and granular, sometimes with shale interbeds), is the main reservoir rock of the Calcareous Alps in the Vienna basin with a thickness of 500 to 1 000 m. At the end of the Triassic the Kössen beds (up to 100 m thick) were deposited; they are replaced toward south by a Plattenkalk-facies.

In the Liassic time Hierlatz limestone, a shallower water facies, changes toward the north and south to a basin facies, siliceous limestones and spotted limestones, respectively. The Klaus limestone occurs till Dogger time, followed upwards by a radiolarite bed and variegated limestones of Malmian age.

In the Lower Cretaceous, marls and marly limestones predominate in the Neocomian, marls and sandstones in the Upper Aptian and Albian, sometimes with exotic gravels. The transgressive upper Cenomanian is represented by a marly facies, on the margins, however, by clastic sediments. Finally, brackish to limnic fluviatile marls, sandstones and coal limestones, partly including conglomeratic layers, occur in the Middle Cretaceous. Strata of this age, have not been drilled in Czechoslovakia.

The Gosau Beds (Upper Cretacous to Paleocene — Gießhübl Syncline)

In Austria, the Coniacian and Santonian consist of basal breccias and sandstones, the Campanian comprises variegated marl limestones and marls with several intercalated clastic layers, pointing to a subsidence. A turbidite facies with a basal coarse layer is developed between the Upper Maastrichtian and the Middle Paleocene. Lower, Middle and Upper Gießhübl beds can be differentiated. The Lower and Upper Gießhübl beds are characterized by quartz-rich layers and variegated calcarous clays, the middle Gießhübl beds by carbonate rich clastics and grey marls. The sequences of Cretaceous are 100 m, those of the Paleocene up to 1 300 m thick. In Czechoslovakia rocks of the Gießhübl syncline have not yet been drilled, but they should be present in the area Suchohrad-Jakubov-Gajary-Malé Leváre.

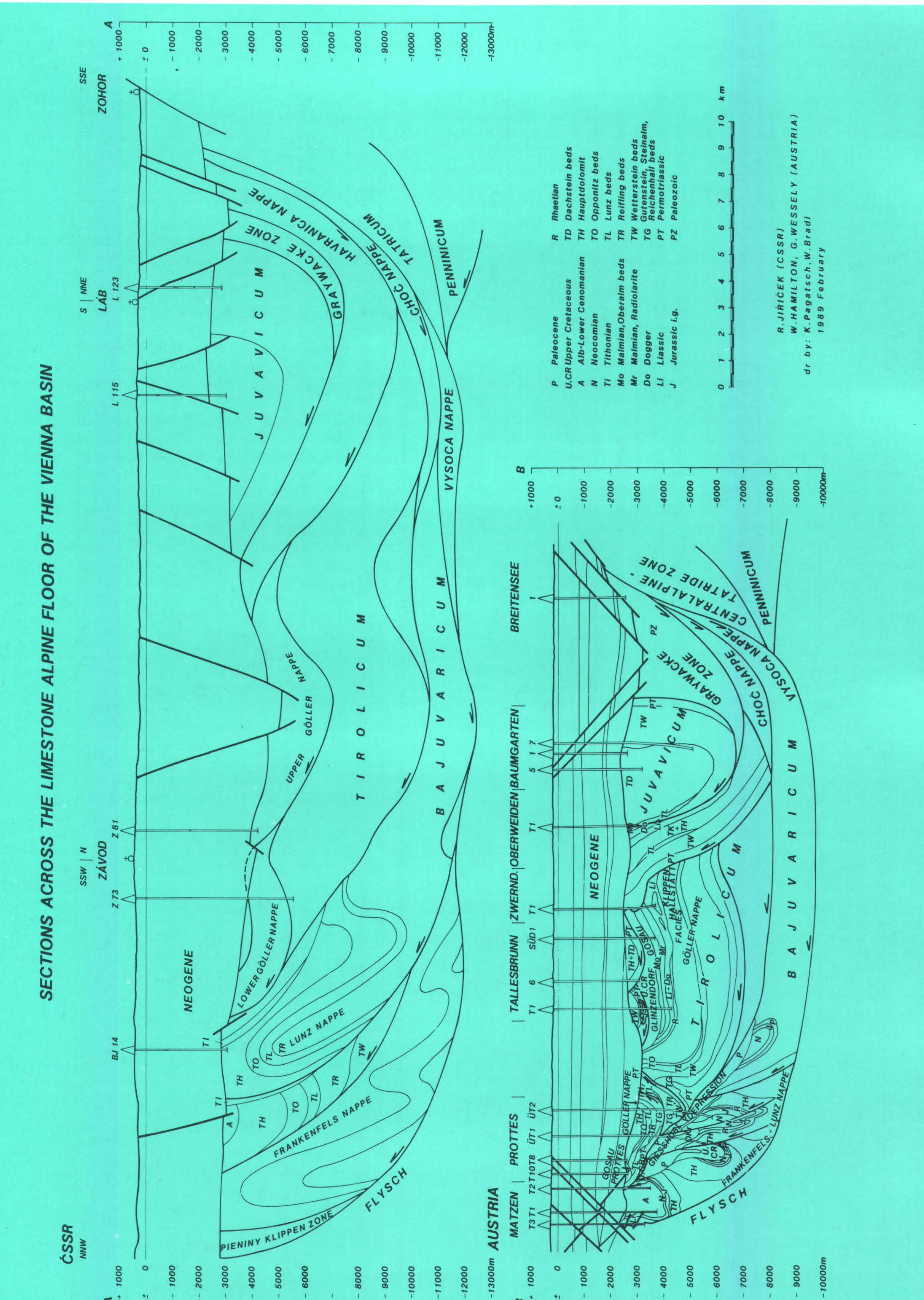

SECTIONS ACROSS THE LIMESTONE ALPINE FLOOR OF THE VIENNA BASIN
ČSSR
NNW
SSE
ZOHOR
LÁB
ZÁVOD
AUSTRIA
MATZEN
PROTTES
TALLESBRUNN
ZWERND.
OBERWEIDEN
BAUMGARTEN
BREITENSEE
NEOGENE
FLYSCH
PIENINY KLIPPEN ZONE
FRANKENFELS NAPPE
LUNZ NAPPE
LOWER GÖLLER NAPPE
UPPER GÖLLER NAPPE
TIROLICUM
BAJUVARICUM
JUVAVICUM
GRAYWACKE ZONE
HAVRANICA NAPPE
CHOČ NAPPE
TATRICUM
VYSOCA NAPPE
PENNINICUM
CENTRALALPINE - TATRIDE ZONE
P Paleocene
U.CR Upper Cretaceous
A Alb-Lower Cenomanian
N Neocomian
Ti Tithonian
Mo Malmian, Oberalm beds
Mr Malmian, Radiolarite
Do Dogger
Li Liassic
J Jurassic i.g.
R Rhaetian
TD Dachstein beds
TH Hauptdolomit
TO Opponitz beds
TL Lunz beds
TR Reifling beds
TW Wetterstein beds
TG Gutenstein, Steinalm, Reichenhall beds
PT Permotriassic
PZ Paleozoic
0 1 2 3 4 5 6 7 8 9 10 km
R. JIŘIČEK (CSSR)
W. HAMILTON, G. WESSELY (AUSTRIA)
dr by: K. Pagatsch, W. Bradl
1989 February

Fig. 3.

4.2.2 Göller Nappe — Tirolicum Pregosauic Sediments

In the entire Vienna basin two lithofacies can be differentiated in the Göller Nappe:

The Northwestern Part

The sequence starts with Haselgebirge (Permian) and Werfen beds (Permo-Scythian), including also anhydrites and dolomites. In the drillholes Závod-Studienka the Haselgebirge appears as a slide horizon of the nappes. Anisian Gutenstein limestone (Studienka) is following. In the Ladinian, the Reifling beds with cherts and greenish tuffs are typically developed, additionally marls and shales occur. In the area of Závod the Reifling beds are connected with Wetterstein carbonates of low thickness. The Lunz beds locally are up to 400 m thick (Stillfried 2) and the Opponitzer beds (limestones and shales) are overlain by the Hauptdolomit up to 1 700 m thick. At the top the Hauptdolomit can be replaced by the Plattenkalk. In the drillhole Závod 81 nodulose Hallstatt limestone of low thickness is tectonically intercalated into Permo-Skythian. In the northern part of the Göller Nappe Jurassic beds are not known.

The Southeastern Part

The facies of the Reifling beds in the northwest changes to Wettersteindolomit in the southeastern part of the Göller Nappe Gänserndorf, (Lakšarska Nová Ves). The Hauptdolomit, resting upon the Lunz beds, is replaced by a facies of Dachsteinkalk-Plattenkalk, up to 500 m thick. On top layers of Kössen beds occur (Laxenburg 2). In Jurassic time Enzesfeld limestone, spotted limestone, radiolarite and Oberalm beds have been deposited. Jurassic beds have not been drilled in the Czechoslovakian part.

The Gosau Beds

Marine Facies (Frontal Part of the Göller Nappe)

In the Prottes area dolomitic breccias and dolomitic sandstones, intermitted by carbonates and marls, are transgressing. These beds belong to Campanian, their base perhaps may be older (Santonian to Coniacian). A marly fine-clastic sequence in the Heidenberg area could represent an intermediate facies between the frontal part of the Gosau and the Glinzendorf Gosau, described subsequently. In the Czechoslovakian part the Gosau beds mainly occur in the Jablonica Nappe (Brezová depression). High-marine Senonian sediments, more than 900 m thick, have been pentrated in Závod 68 and 57, north of the Závod gas deposit. This Závod Syncline represents the continuation of the Brezová depresssion. Coniacian sediments are missing in the drill holes. Flyschoid sandy marls were deposited during Santonian time. Dolomitic calcarenites including layers of breccias, belong to the Santonian-Campanian. In the lower Campanian variegated marly limestones and marls were deposited. Thick flysch sequences (marls, sandstones) occur in the Middle and Upper Campanian. In the upper Campanian and Maastrichtian organic-detritic limestones and marls were deposited, hitherto found only in the Brezová Depression. Orbitoids bearing Campanian of the shallow marine Gosaufacies is transgressively overlying the Lunz beds in the Studienka area (Studienka 83).

Limnic Facies (Glinzendorf Syncline)

Up to nearly 1 000 m thick Upper Cretaceous, predominantly in limnic facies, is unconformably resting upon Triassic and Jurassic sediments. The sequences are partly very rich in breccias and contain exotic components (Markgrafneusiedl 1, Záhorská Ves). Intervals containing shales and calcareous clays (Glinzendorf T1) also occur.

Paleogene of the Myjava Syncline

The Myjava syncline consists of Paleogene flysch sequences, several hundred meters thick and was perhaps once connected with the Gießhübl syncline. Conglomerates and calcitic sandstones of the Nummulites bearing Eocene are following. The Eocene is similarly developed as in the Kuklov Depression. The Paleogene is presumably continuing into the Vienna basin.

4.2.3 The Upper Limestone Alpine Nappes — Juvavicum

The structurally highest parts of the Limestone Alpine Nappes are showing a rather uniform facies of Triassic carbonates (Baumgarten-Zwerndorf-Schönfeld). In the Ladinian (perhaps including Anisian parts) Wetterstein limestone and Wetterstein dolomite are developed. Lunz beds were deposited above them to the North (Oberweiden T1). In other drill holes the Wetterstein beds show a continuous transition into Dachstein limestone, sometimes dolomitized (Baumgarten 7). The beds continue into the Vysoká-Láb-Malacky area in the ČSSR. An occurrence of dark marls, variegated Upper Triassic limestones and light Steinalm beds in the well Zwerndorf T1 may be explained as slide mass of Hallstatt facies into a Liassic trough overlain by a thick series of Dogger, Malmian radiolarites and Oberalm beds of the Göller nappe.

4.2.4 Differentiation of Limestone Alpine Facies

Reconstructing the original positions of the areas of Mesozoic and Tertiary sedimentation by backstripping of the tectonic units, changes in facies from North to South are evident, and in some cases also from East to West. Within Middle Triassic sequences a change of a basin facies in the Northwest (Gutenstein-Reifling-Partnach beds) to a platform facies in the South (Steinalm-Wetterstein beds) takes place within the Göller nappe, for example documented in the well Kuklov 3 (ČSSR), but also in the Gänserndorf area in Austria. The Wetterstein facies is dominant in the Veternik, Havranica and Jablonica nappes. The continuation of the Wetterstein facies is to be found in the Upper Limestone Alpine nappes.

The Lower Carnian Lunz beds were encountered in the Bajuvaricum (only in the ČSSR area) and in the Tirolicum, whereas in the Upper Limestone Alpine Nappes they are rare (Láb, Oberweiden T1).

In the Upper Carnian a change of an evaporitic-carbonatic development in the Frankenfels-Lunz system to carbonatic facies in the Tirolicum is visible.

In the Norian a gradual transition from a slightly continental influenced Hauptdolomit (richness in thin interbedded green shales) in the Frankenfels-Lunz system to a more "clean" Hauptdolomit in the northern part of the Tirolicum takes place, to the South the Hauptdolomit is more and more replaced by Dachstein beds. In the Rhätian time Kössen beds change to "Plattenkalk" or to Dachstein beds.

The succession of facies in the Jurassic is mostly an Austrian object of investigation. In Liassic time repetitions in changing of facies from North to the South are to be observed: A gray basinal facies in the northernmost Frankenfels-Lunz system (Allgäu-Kieselkalk beds) pass into a shallower environment ("Hierlatzkalk") and again a transition into a deeper depositional development (Allgäu beds, Adnet-Enzesfeld beds) occurs in the Tirolicum. A similar behavior show Dogger deposits: continuation of gray marly carbonates in subsiding areas and thin Bositra limestones or Globigerina oolites on shoals.

In southern parts of the Göller nappe megabreccias with Lower Jurassic and Upper Triassic block masses can be observed (Wittau ÜT1) in this member.

The Malmian facial succession is characterized by thin variegated sequences in the North (radiolarites, Saccocoma and Calpionella limestones) and thick cherty Ruhpolding and Oberalm beds in the southern nappes of the Tirolicum. The Neocomian (Aptian and Albian) and Cenomanian sediments, present in the synclines of the Bajuvaricum of Austria and the ČSSR are missing in the units of the Tirolicum and Juvavicum.

In the Gießhübl syncline the Cenomanian is passing into the Turonian and Senonian without significant interruption. In the Upper Cretaceous Gosau formation clearly a change from South to North is obvious. A shallow limnic-continental environment (Glinzendorf Gosau) grades into a shallow marine one (Heidenberg, Studienka). As a next step in Prottes and in the Brezova depression mostly a slope facies is represented and finally a deep marine development, especially in Campanian and Maastrichtian in the Gießhübl syncline. All the known Paleocene deposits are deep marine turbidites.

4.3 Graywacke Zone

The sedimentary (?) base of the Juvavicum are the Paleozoic dark calcareous schists, shales and terrigeneous sediments of the Graywacke zone. In the Czechoslovakian part of the Vienna basin this zone may be eroded towards east, it was not encountered till now.

4.4 Tatride-Centralalpine Zone

In some Austrian wells Mesozoic members belonging to a Centralalpine-Tatride sedimentary cover were encountered: Permoskythian quartzites, Middle Triassic platform carbonates, Upper Triassic Keuper with variegated shales, some quartzite and some dolomite, Rhätian with dark limestones and Liassic with sandy limestones. The crystalline base of these sediments, which could define any affiliation to the Austroalpine or Tatride main unit, has not been drilled till now.

5. Tectonics

5.1 General View

The Alpine Carpathian tectonic units on the floor of the Vienna basin (fig. 2) show a relatively constant strike across the Austrian-Czechoslovakian border. This uniform behavior changes near the Central Western Carpathians on the one hand and the Carpathian Flysch-Klippenbelt on the other hand. An axial rise near the Tatride core area causes an erosion of upper Limestone Alpine units together with the Graywacke zone and the only presence of Tirolicum and Bajuvaricum both forming in general a complex syncline between the Little Carpathians and the Myjava Klippenbelt. In contrary to the Austrian Limestone Alpine zone the real basal nappes appear also in the southeastern flank of this syncline in the case of the Križná-Vysoká nappe, which is dipping towards northwest tectonically superposing the Tatrides of the Little Carpathians (fig. 1,2). In the Flysch-Klippenbelt a change in the tectonical style beginning NE of the Gbely area is obvious: a broadening of the Flysch zone in connection with a diminished tectonical differentiation can be followed from the Wienerwald area nearly through the whole basin. The Pieniny klippen belt starting south of the Gbely area was not encountered southwestward.

5.2 External Alpine-Carpathian Units (Flysch, Klippen Belt)

Only to a minor extent the most external Alpine-Carpathian tectionc units as the Waschberg-Ždánice zone, perhaps also the "Helvetic" Schottenhofzone are part of the Preneogene surface of the Vienna basin. And only the wells Zisterdorf ÜT1a, ÜT2a, Maustrenk ÜT1a and Aderklaa ÜT1a penetrated these units below the Flysch. They contain mostly pelitic Paleogene layers, in some cases (Zistersdorf ÜT1a, 2A) in a menilitic facies, in distinct sections with variegated marls. Malmian klippen were established in the Zistersdorf and Maustrenk wells. Beside these sections some wells, which penetrated the fault plane of the Steinberg fault in deeper positions detected pelitic sequences obviously belonging to the same unit (Palterndorf T1, Mühlberg T1).

From the outcropping Wienerwald Flysch three main units can be followed into the basin: the Greifenstein-, the Kahlenberg- and the Laab nappes. North of the Danube the Račany nappe becomes import additionally (Harrersdorf unit in the Austrian term). In the Zistersdorf area the Harrersdorf unit, the Greifenstein nappe with 2 thrust slices (Gösting unit and Zistersdorf unit) and finally the Kahlenberg nappe, represented by the Sulz unit, were established. Harrersdorf-, Gösting-, Zistersdorf- and Sulz units were all together identified in the profile of Maustrenk ÜT1a. The Laab nappe is documented in its whole sequence by the well Aderklaa ÜT1a and in restricted sections in many wells of the Bockfließ-, Matzen-, Raggendorf-, Spannberg area as well as in the well Ringelsdorf 3.

In the Czechoslovakian area a continuation of this subdivision of the Flysch is to be followed. The Greifenstein nappe is covering the Zlín beds of the Račany nappe (Tynec 30) and the Kahlenberg nappe is developed to the Southeast in drill holes of Brodské-Lanžhot. The Gbely and Kúty Flysch belongs to the same complex. All these units are subsumed under the term "outer nappe system of the Magura unit". This system is overthrust by the "Inner nappe system of the Magura unit" along a planar and subhorizontal thrust plane. This inner system consists essentially of the Bílé Karpaty nappe with several thrust slices (the Hluk lower Cretaceous and the Hradiště and Gbely middle Cretaceous near Kúty are part of these thrust complexes). The southern part of the Bílé Karpaty nappe has a large affinity to the Pieniny klippen belt.

5.3. Limestone Alpine Zone

5.3.1 Frankenfels-Lunz System (Bajuvaricum)

The Frankenfels Lunz system is extending below the Neogene as a narrow belt from Vienna to Senica, where it is overthrust by higher units. Along its whole extent it is characterized by steep or overturned folds and thrust slices. In many cases the cores of the folds are Hauptdolomit. Near Vienna two chains of folds are known under the term Höllensteinantiklinale and Teufelsteinantiklinale, separated from each other by the Flössel syncline with its Neocomian filling. The first mentioned anticline may partly be involved in the strongly disturbed frontal thrust zone to the east, the second one seems to be buried under Gießhübl beds by eastward dipping of the axis near Prottes. Further structures were followed underneath the cover of Cretaceous-Paleogene of the Gießhübl depression and below the Göller nappe in Aderklaa, Schönkirchen and Prottes. Folds similar to the Höllen- and Teufelsteinanticline with cores of Hauptdolomit appear in the area of Kuklov 4 and separated by the Kuklov syncline in the Borský Jur ridge. The Kuklov syncline may be filled by Lower Cretaceous sediments like the Flössel syncline. Towards Northeast these structures are cut by the Klippenbelt, where the frontal, first anticline disappears near Šaštín and the second one near Senica. Below the Tirolic nappe system evaporites of the Frankenfels Lunz system were encountered in wells of Závod and Lakšárská Nová Ves.

In Austria the Gießhübl depression, filled with Cretaceous and mainly Paleogene is extending from Gießhübl towards Prottes and overthrust by the Göller nappe, in the area of Schönkirchen-Prottes completely covered by the latter one. The thickness of the Paleocene sediments diminishes towards the NE, but they are expected to continue into the ČSSR area of the Vienna basin.

5.3.2 Göller-, Veternik-, Havranica-, Jablonica Nappe Systems (Tirolicum)

The Göller nappe, extending from the eastern Limestone Alps to the western Carpathian border, exhibits a more quiet tectonical character than the Bajuvaricum, but nevertheless contains several subunits, especially in the Czechoslovakian area where it splits into the Veternik, Havranica and Jablonica nappes. In Austria a more complex frontal part may be distinguished from a more simply structured main body. There exist frontal slices in the Aderklaa field and a remarkable frontal syncline in the Schönkirchen-Prottes field with Hauptdolomit in its core resting upon Opponitz-, Lunz-, Reifling-, Gutenstein- and Werfen beds. New considerations about the possibilities of backstripping led to the conclusion, that this syncline must be a backthrusted portion of the frontal part of the nappe. Southeast of Ebenthal this element raises towards NE, therefore the Hauptdolomit is eroded and the Lunz beds reach the Preneogene surface. Towards the ČSSR a decline of the axis could occur and possibly the anology of this frontal syncline could be found in Závod.

The frontal syncline in Prottes carries a coarse slope development of Gosau beds diverging in thickness towards the North. This wedge of Gosau could represent the transported Southern part of the Gießhübl Gosau trough.

Again the analogy to the Závod area is remarkable where the continuation of the Brezová Gosau is to be assumed with its coarse facies and thick sedimentation of Upper Cretaceous in contrast to the Gießhübl development. On surface the Brezová Cretaceous sequence is resting as a northward thickening wedge upon the Jablonica nappe.

The main complex of the Göller nappe in Austria is known by several deep wells, especially in the Wittau-Markgrafneusiedl-Gänserndorf-Tallesbrunn-Zwerndorf areas.

According to the wells in the Markgrafneusiedl and Gänserndorf area this main complex shows a steep southward decline of its Triassic members and a flattening under a thick Jurassic sequence extending below the syncline of the Glinzendorf Gosau. From here a slight rise in southern direction till the thrust plane of a higher nappe is observed (fig. 2).

The Glinzendorf Gosau depression is a dominant trough extending from the Grünbach area through the whole Austrian perhaps also Czechoslovakian part of the Vienna basin (remnants of limnic Gosauic sediments were found in the Neogene Jablonica Conglomerates). The northern border of the Glinzendorf Gosau is steep or overturned. Outliers of higher nappes (Tallesbrunn outlier) cover the syncline in the Eastern part to a large extent.

The Tirolicum in ČSSR seems to show a similar structural style as in Austria (fig. 2). In general a system of thrust units form a kind of synclinorium. Elements of the Göller nappe in the northwestern zone can be identified. This outer complex may be divided by the expressed Studienka ridge from an inner one. Two synclines are expected in this zone according to seismic investigation: the continuation of the Glinzendorf syncline and the Leváre syncline, perhaps a southern element of the Gießhübl syncline.

5.3.3 Upper Limestone Alpine Units (Juvavicum), Graywacke Zone

These units are not as well known by drilling as the zones mentioned before. Only in distinct areas well density is higher (Zwerndorf-Baumgarten, Láb-Malacky). In general the Grünbach-Glinzendorf-Gosau Zone borders the Upper Limestone Alpine nappes towards NW. Outliers may cover parts of the Gosau (Tallesbrunn). Structures and subdivisions are difficult to be reconstructed because of only isolated informations by wells, but in the Baumgarten-Láb area a syncline was established by a sufficient well density with thick Dachstein beds in the core to the Southeast bordered by Wetterstein dolomites (Schönfeld 1, T1). The northwestern flank of the syncline is cut off, so that in Oberweiden T1 no Wetterstein dolomites were encountered, but Lunz beds were gliding upon Malmian radiolarites. According to observations in the Southern Limestone Alpine area not only thrusting events of Cretaceous to Tertiary age are proven but also motions by gliding of Triassic blocks or whole rock systems during Jurassic times into a deepening basin must be taken into consideration (Mandl, personal communication). So the tectonical situation of the Baumgarten-Láb complex will be investigated under these new aspects.

This phenomenon could explain also the occurrence of rocks with Hallstatt facies in the area of the Tirolicum, which were detected in the Zwerndorf T1 well in the lower part of a Liassic sequence. The final underlying of the Hallstatt complex by Jurassic sediments unfortunately has not been proven in this well. This explanation fits with the block sedimentation observed in the Jurassic of the well Wittau ÜT1.

The distribution of the Upper Limestone Alpine nappes in connection with the Graywacke zone points to a primary association of both complexes and to a superposition of the Graywacke zone upon Tirolicum. The facies of the Paleozoic of the Choč Melaphyre formation is quite different to that of the Graywacke zone.

5.4 Central Alpine-Tatride Zone

It is evident, that the Limestone Alpine-Graywacke nappe system has been thrust over the Central Alpine-Tatride nappe system. Till now no crystalline rocks of these units were drilled. The wells, which entered the Mesozoic mantle of this system underneath the Vienna basin brought no clear evidence about a tectonic differentiation between the Centralalpine and Tatride tectonic complexes.

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Abstrakt

Podloží vídeňské pánve je rozděleno SV linií na dvě základní zóny: vnější flyšovou a vnitřní vápencovoalpskou. Magurský flyš se dále skládá ze dvou jednotek. Vnější z nich má v moravské části račanský příkrov, který je na struktuře u Týnce překryt greifensteinským příkrovem. Týlová část je v rakouském území zastoupena kahlenberským příkrovem a jeho šupinami. Vnitřní část flyšové zóny je charakterizována bělokarpatským a laabským příkrovem. Týl tvoří pieninské bradlové pásmo. Vápencovoalpskou zónu lze rozdělit na tři jednotky. Vnější s frankenfelsko-lunzským šupinovým systémem je oddělena gießhübelskou paleogenní depresí od střední zóny s ötscherským (göllerským) příkrovem. Vnitřní zóna s vyššími alpínskými příkrovy je ohraničena glinzendorfskou křídovou depresí.

Zusammenfassung

Der alpin-karpatische Untergrund des Wiener Beckens erstreckt sich über österreichisches und tschechoslowakisches Gebiet mit den Einheiten der Waschberg-Ždánice-Zone, des Flysches, der Kalkalpen und der zentralalpin-tatriden Zone. Seit der Erschließung desselben ab den 60er Jahren wurde getrachtet, die Gegebenheiten im Untergrund einerseits mit den Beckenrändern und andererseits über die Grenze hinweg zu verbinden. Das Ergebnis dieser Kompilation wird in vorliegender Arbeit zusammengefaßt. Es werden die wesentlichen Strukturelemente und Brüche an der Neogenbasis in Zusammenhang gebracht, der Verlauf der alpin-karpatischen Teileinheiten in einer gemeinsamen Karte und in Profilen dargestellt und eine Analyse der Stratigraphie und tektonischer Zuordnungsmöglichkeiten vorgenommen. Damit wurden die Ansatzpunkte weiterer Untersuchungen und Explorationsmöglichkeiten im Untergrund des Wiener Beckens gegeben.

PALEOMAGNETIC INVESTIGATIONS IN THE CENTRAL PART OF THE BOHEMIAN MASSIF (Barrandian)

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Introduction

During the IAGA-meeting in Praha, three institutes agreed on a comparison program on red silicites of the central part of the Bohemian Massif; so called Barrandium. These institutes were Rennes in France, Geofyzika Brno in Praha and Gams, Mining University Leoben, Austria. The target was a reliability test of individual investigations on the same material. The silicites of the Barrandium were chosen, since earlier investigations of M. KRS (1976) had established a multicomponent origin of the natural remanent magnetization (NRM). The new development of thermal cleaners in Praha and Gams seemed to be a good start of testing this equipment.

Geology of the Investigated Area

The central part of the Bohemian Massif the Barrandian, is divided into at least three different basins. These basins were formed during the cadomian orogeny. A complete sequence of Ordovician, (Tremadocian to Ashgillian) volcano-sedimentary rocks from these basins was described by V. HAVLÍČEK (1980). The age of the rocks is dated by micro- as well as macrofossils. From this sequences the Upper Tremadocian Milina formation was chosen for this work. The rocks are light to dark red silicites, of different grain sizes. Haematite of different particle size and concentration can easily be found in the ore microscope. Beside haematite, goethite and magnetite can be found, and particularly proved by rockmagnetic tests.

Sampling

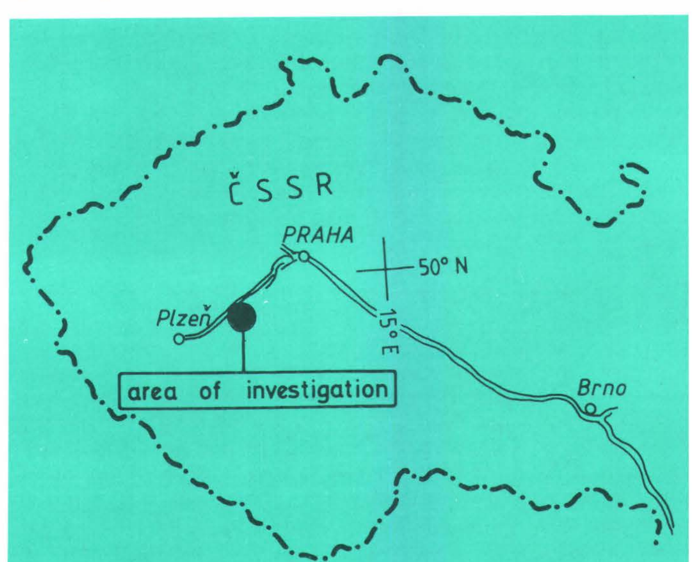
The sampling was done by drilling machines in three occurences. The first was a quarry, north of the road from Komárov to Jivina. 13 cores were taken.

The second was an outcrop along the river Jalový, close to a small bridge. Four sites with six cores each were taken. The third outcrop was near the school in the village Zaječov. Three sites with six cores each were taken there. The cores were very difficult to drill because of the hardness, and were cut into 22 mm long samples.

Rockmagnetic experiments

It was decided from the beginning to demagnetize every individual sample stepwise, in order to find as many details as possible of the magnetization. Since M. KRS's (1976) paper it was well known that a more-component magnetization had to be expected. All that one needs is a thermal cleaner with a magnetic vacuum as good as possible. For the laboratory in Gams, a new system was developed. The samples are placed around a reference sample in a MU-metal shield, which is placed in a Helmholtz coil system. The oven is moved in and out of the shield. The advantage is the permanent position of the samples in the shield, throughout the whole heating and cooling procedure. Up to

Fig. 1: Geographical sketch map of the sampling area.



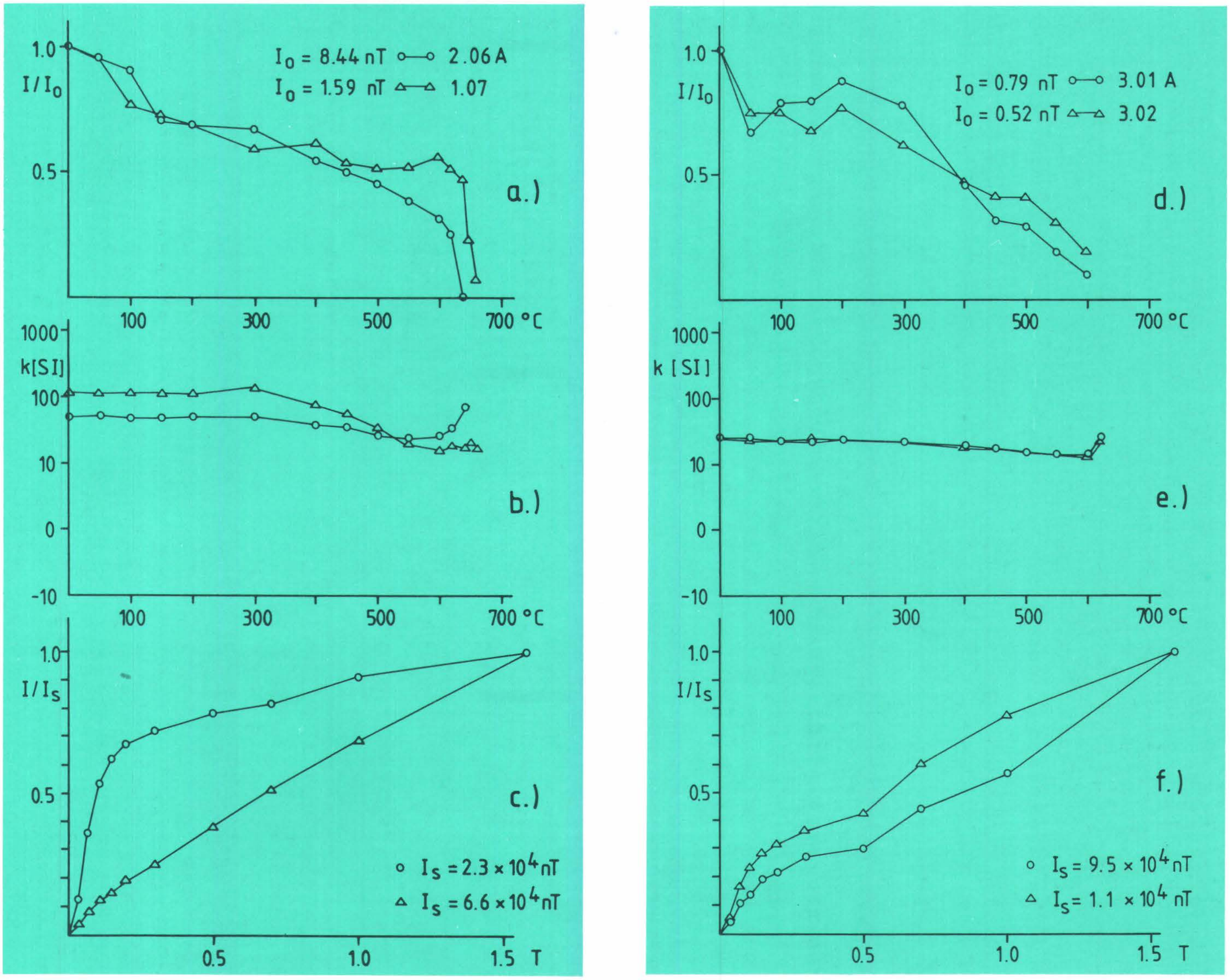


Fig. 2: *a.* normalized intensity of group 1, *b.* susceptibility of group 1, *c* saturation acquisition of group 1, *d.* normalized intensity of group 2, *e.* susceptibility of group 2, *f.* saturation acquisition of group 2, *g.* normalized intensity of group 2, *h.* susceptibility of group 2, *i.* saturation acquisition of group 2.

30 samples can be cleaned at once in a restfield of ± 2 nT.

Similar to M. KRS (1986) this cleaning procedure established 4 groups of cleaning behaviours: In the normalized intensity curves the first group (Fig. 2a–c) shows a small influence of Goethite up to 150 °C. Above that, there exists a plateau up to about 550 °C in case of sample 1.07. The susceptibilities show an oxidizing effect above 450 °C, in case of sample 2.06 A an increase above 600 °C. This is thought to be due to a new formation of magnetite during boiling off the oxygen in this temperature range. Similar to the intensity curves, the saturation acquisition curves show a strong dependence on the particle size of haematite. In the curve for sample 2.06 A, there could also be a weak influence by magnetite up to about 0.3 T.

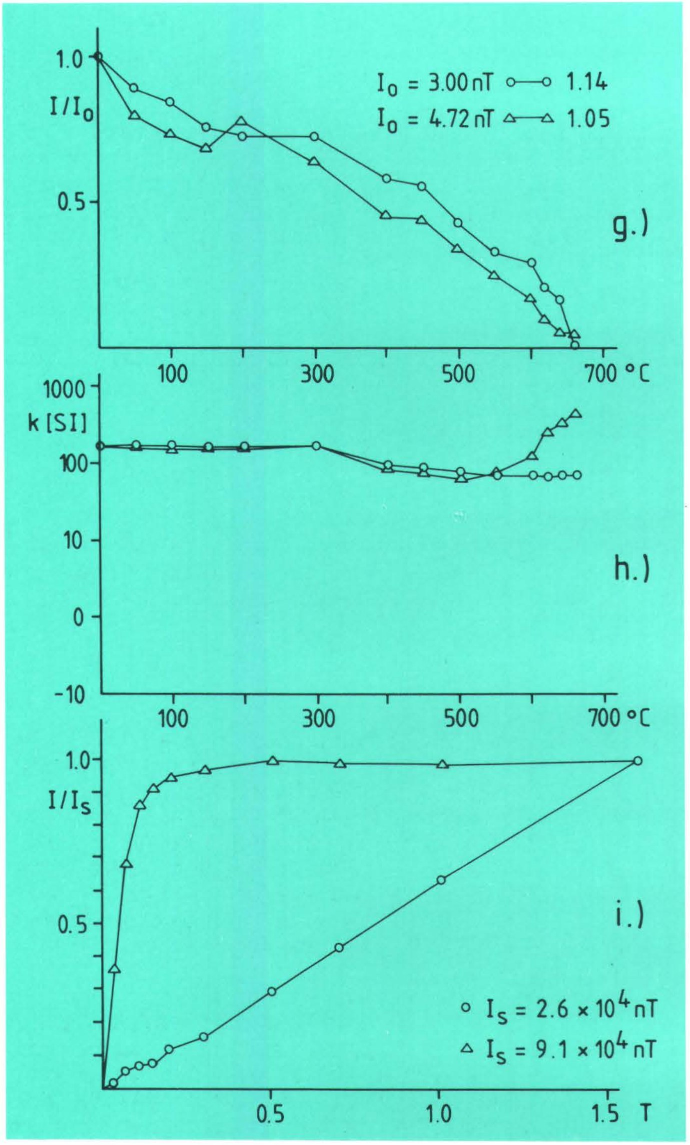
The second group is characterized by a stronger influence of magnetite. After a weak influence of Goethite the intensity curves (Fig. 2d–i), show magnetite up to about 450 °C–550 °C. The susceptibility remains stable up to 600 °C. The saturation curves prove the influence of magnetite, beside the dominating behaviour of haematite. In the case of sample 1.05, magnetite is obviously dominating. Above 600 °C this sample shows again a new formation of magnetite from the small haematite content shown in Fig. 2g and Fig. 2h.

The third group shows a characteristic influence of Goethite at the beginning, and a flat plateau up to the blocking temperature for haematite. Again in sample 2.02 A an increase of the susceptibility (Fig. 3) above 450 °C can be seen. The decrease of the susceptibility in the other cases, indicates a weak oxidizing process, which is thought to be due to a small content of secondary magnetite.

The fourth group demonstrates a stable plateau up to about 300 °C. Above a drop down in the intensity can be noticed and understood as wide range of blocking temperatures. Whereas the intensity curves don't show very clearly the presence of magnetite, this is proved by the saturation acquisition.

With these rockmagnetic properties of the rocks in mind one can start to interpret the remanence directions. To show these NRM-directions, a modified Zijderveld diagram (1967) was used. Instead of plotting x, y and z the declination and the inclination were plotted in dependence on the normalized intensity.

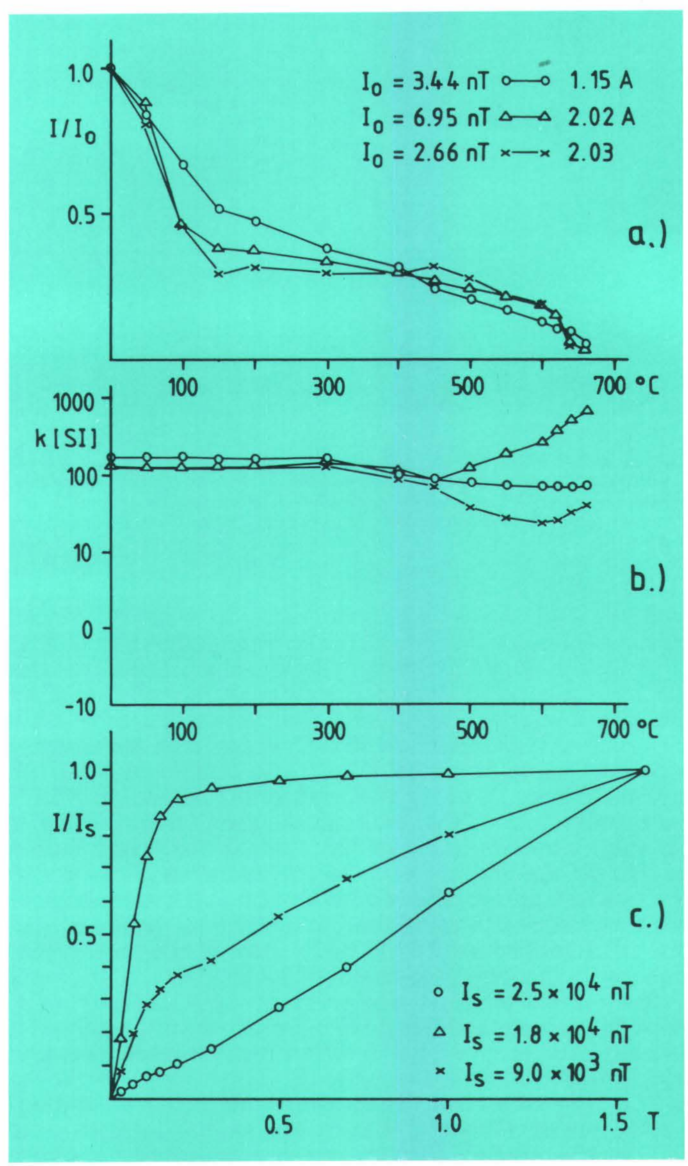
The two diagrams for the group one clearly demonstrate the distinct difference in the magnetization history, even when rockmagnetic results are very similar. The example of sample 1.07 in Fig. 4a, shows a four component magnetization; from NRM–100°; 100°–400°; 400°–600° and 600°–660°. Sample 2.06 A, the example of sampling site 2, shows



Name	Treatment °C	F_{Dec}	F_{Inc}	B_{Dec}	B_{Inc}	Int.
1.08A	NRM	204.1	-38.4	200.3	-37.4	1.11
1.08A	T 50	210.5	-29.6	207.7	-29.2	0.91
1.08A	T100	210.9	-38.2	207.0	-37.8	0.84
1.08A	T150	205.4	-41.3	201.1	-40.5	0.77
1.08A	T200	200.0	-44,2	195.4	-42.8	0.67
1.08A	T300	166.2	-52.4	162.2	-48.7	0.44
1.08A	T400	95.4	-7.2	95.6	-2.8	0.33
1.08A	T450	82.8	-1.1	82.7	+2.7	0.30
1.08A	T500	66.6	-7.4	67.1	-4.6	0.22
1.08A	T550	32.3	+22.3	30.2	+22.2	0.26
1.08A	T600	40.4	+2.7	38.3	+23.2	0.27
1.08A	T620	24.0	+26.1	21.6	+25.2	0.29
1.08A	T640	23.9	+39.2	19.9	+38.3	0.25
1.08A	T650	31.3	+17.3	29.7	+17.1	0.14

Tab. 1: Demagnetization steps of a typical sample of site 1 (Fig. 6a).

Fig. 3: *a.* normalized intensity of group 3, *b.* susceptibilities of group 3, *c.* saturation acquisition of group 3, *d.* normalized intensity of group 4, *e.* susceptibility of group 4, *f.* saturation acquisition of group 4.



more or less a two component magnetization; NRM — 550° and 550°—640°. The scatter in the declination results from the very steep inclination in the bedding corrected state.

The samples of group two, 1.05, 1.14, 3.01 A, 3.02 show again very different magnetization histories. Sample 1.05 in Fig. 4c shows a two component magnetization from NRM to 300 °C, resp. 620 °C.

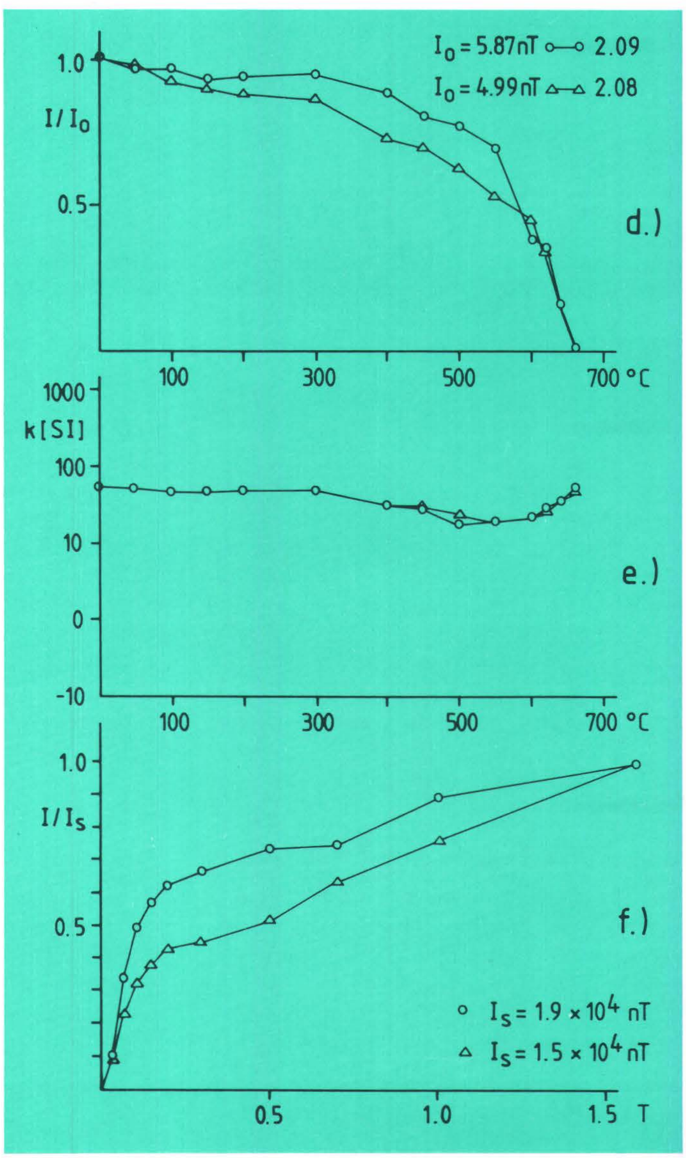
Sample 1.14, from the same site than the previous ones, shows a three component magnetization; from NRM to 300°; 300°—620° and 620°—660°. Whereas the first two components show positive inclinations, which are due to overprints, the high temperature component becomes negativ. The very last vector seems to be primary since it is in a suitable arrangement with other reliable samples.

Group three, represented by the samples 1.15, 2.02 and 2.03, again proves the multicomponent magnetization. All samples show at least three components. Whereas 1.15 in Fig. 5a and 2.03 in Fig. 5c show a very soft viscous component at the beginning, sample 2.02 in Fig. 5b remains stable up to about 200 °C. The viscous component is thought to be carried by very coarse grained magnetite since the saturation acquisition curve clearly indicates magnetite at the beginning. An exception is sample 1.15 where only haematite can be seen. The viscous influence in this case seems to be due to Goethite.

The high temperature component, comes close to upper Paleozoic directions in the Variscan of Europe except the last one or two points.

Study	Lithology	Geographic Coordinate		Paleomagnetic Direction tectonic corrected		α'_{95}	k	n	Paleomagnetic Poleposition	
		Lat	Long	Dec	Inc				Lat	Long
Krs et al. 1986	red silicites	49.75	13.63E	126.7°	-41.7°	3.63°	24.8	64	41.52S	91.82° E
this study calculated	red silicites	49.75	13.83E	131.0	-32.0	11.7	13	13	38.8S	82.1E
large circle reconstruction				150	-22					
overprinted direction for sampling site 2	red silicites	49.75	13.83E	56.0	58.0	16.5	11.5	8	49.3N	97.1E
site 2 at 600° C		49.75	13.83E	126.1	-36.7	10	31.7	8	38.55N	89.33E

Tab. 2: Calculated paleomagnetic directions for the Milina formation (sampling site 1).
The direction, observed by large circle reconstruction is shown as well as the overprinted direction of sampling site 2.



The fourth group with hard magnetic properties is represented by the samples 2.08 and 2.09. Again a three component magnetization can be seen (Fig. 5d and 5e), from NRM to 300°, 300° – 550° and 550° – 660°. The low temperature component could be carried by magnetite, which is proved as well in intensity as in the saturation acquisition curve. Haematite, mostly finegrained, carries the high temperature components. These components are very close to present earth field again. A recent overprint has therefore to be expected.

Summarizing these results, one can clearly notice that sampling sites 2 and 3 are strongly to completely overprinted. Whereas in site 2 mainly the direction close to the present earth field can be seen, site 3 shows random distribution within this small occurence. All samples clearly show large circle behaviour (Tab. 1) during cleaning, which again proves multicomponent magnetization (Fig. 6b). Furthermore it can be seen, that a certain cleaning temperature for all samples would be unsuccessful. In looking carefully through all individual samples, one can find two main directions, one in the first quadrant with positive inclination and one in the second with negative inclinations (Tab. 2).

Tab. 3: Chosen vectors which are thought to be primary.

Name	Temperature range	F_{Dec}	F_{Inc}	B_{Dec}	B_{Inc}
1.01	0 – 300°	105	–17	105	–11
1.06')	450 – 600°	149	–41	147	–35
1.08	0 – 300°	166	–52	162	–49
1.10	0 – 300°	135	–28	135	–23
1.11')	200 – 550°	124	–60	124	–55
1.12')	100 – 300°	133	–47	132	–42
1.14	660°	178	–23	173	–18
1.18	100 – 450°	123	–12	123	0
1.22')	100 – 550°	132	–52	129	–40
1.23')	500 – 620°	121	–42	121	–30
1.24')	400 – 450°	128	–26	127	–14
1.25')	300 – 450°	114	–54	115	–42
1.26')	300 – 500°	113	–44	114	–32

') The direction always remains in the second quadrant with negative inclinations.

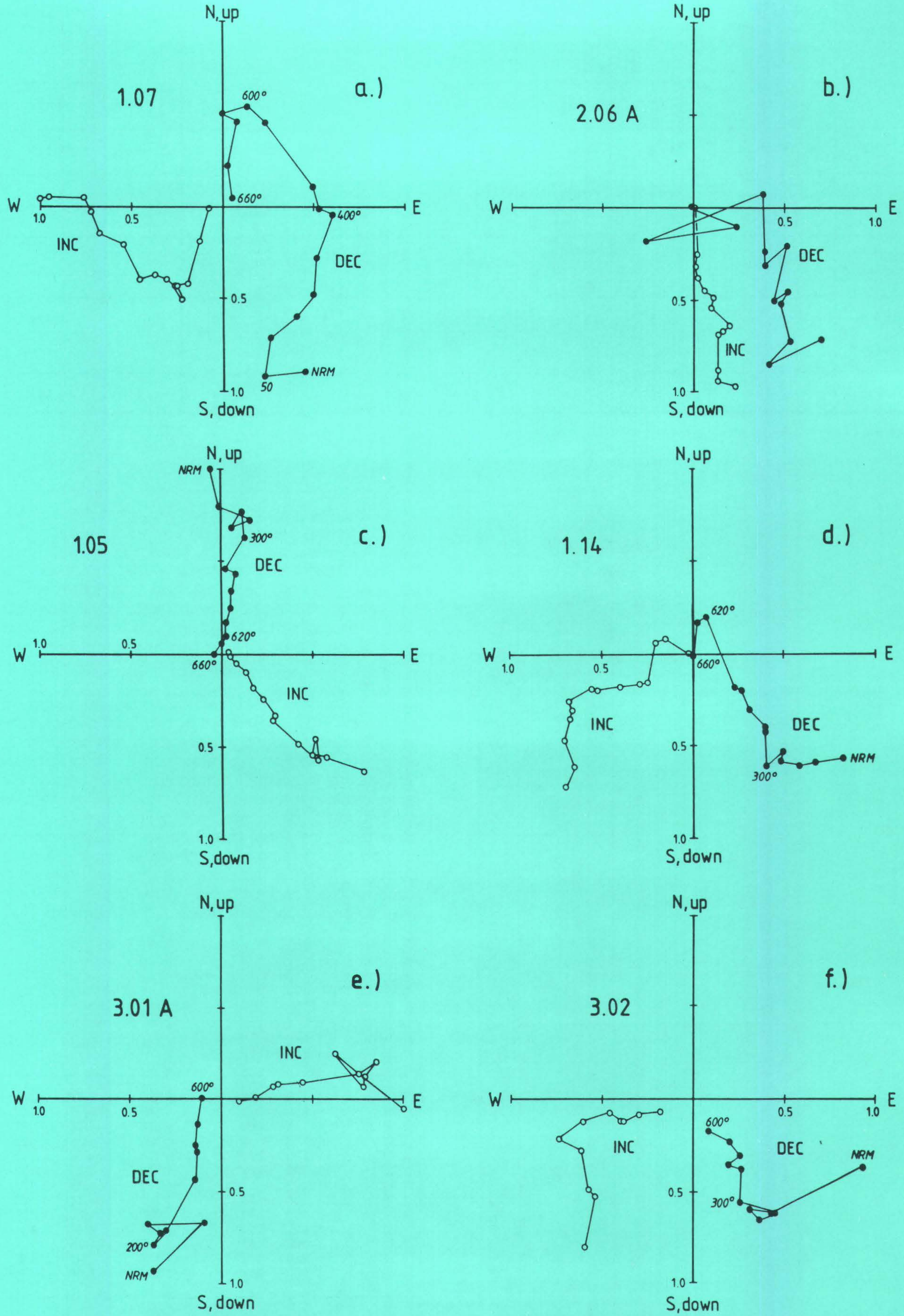


Fig. 4: Modified Zijderveld diagrams of group 1 and 2.

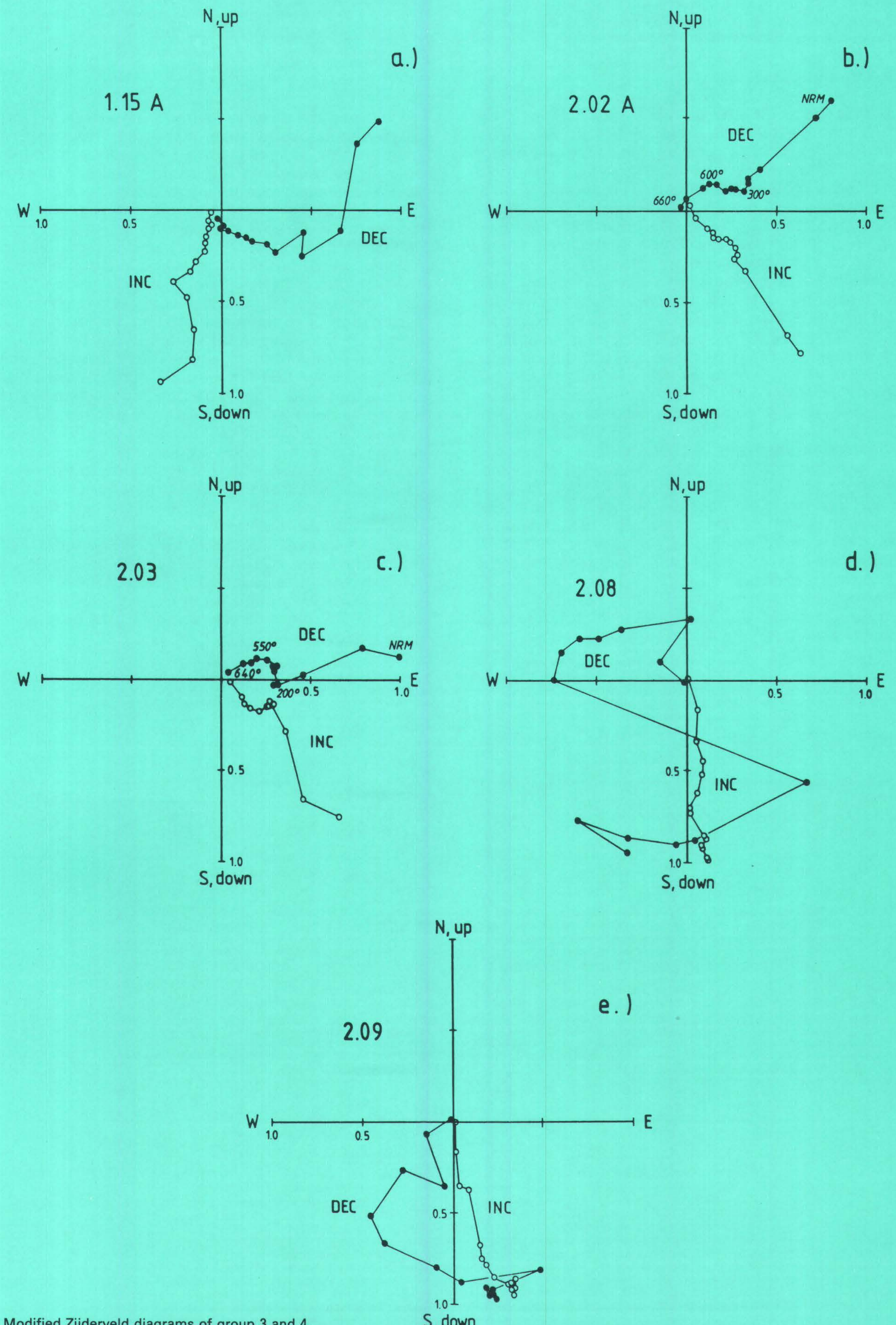


Fig. 5: Modified Zijderveld diagrams of group 3 and 4.

Whereas the directions in the first quadrant seem to show a certain affinity to the present earth field in the field coordinate system, the second group is well documented to be of possible primary origin.

Interpretation and conclusion

Starting with the worst outcrop this is outcrop 3 near the school in Zajecev. In this case 3 sites with 6 samples were drilled. The samples within an site as well as the site means between each other, show random distribution. No meaningful average direction was found. The sampling point 2 occurs strongly overprinted in a recent earth field. Again no primary information was found. Only sampling spot one, the quarry north of the road from Komarov to Jivina, seems to be suitable to carry some primary information.

The interpretation was tried in two ways; firstly by great circle reconstruction and secondly by collecting direction intervals of the individual sample. The large circle reconstruction (Fig. 6b) gives the primary direction as pole of the large circle through all the large circle poles of the individuals. The scatter of the individual poles is quite high, because of the different extent of overprinting in the individuals. This depends on the chemical composition and in particular on the grain size distribution in case of monomineralization of haematite. The observed magnetite is understood as secondary mineralization, occurring through the variscan orogeny. As one can easily see (Tab. 2), the direction observed by large circle distribution, occurs shallower and more clockwise deviated, compared with the calculated one and M. KRS's direction. The reason may be, that short vectors are lost in this reconstruction. That was the same with the line find technique.

Individual collected vectorparts (Tab. 3) resulted a reliable mean direction for sampling site 1, which is more or less indentical with M. KRS's result.

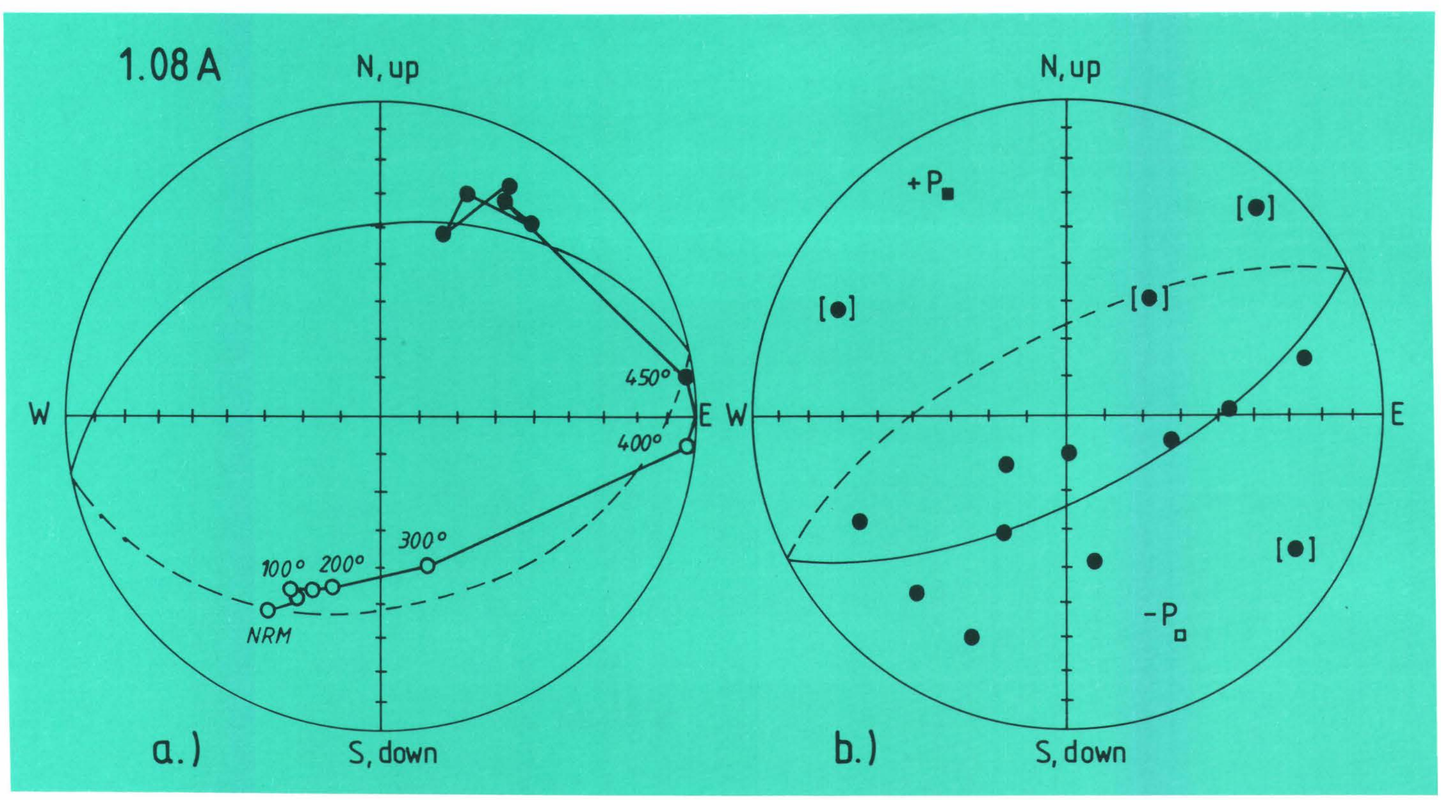
Fig. 7: Tectonic corrected sample directions during cleaning for all three sampling sites. In the right column just the field corrected directions are given. T 50—620 means cleaning temperature. F_{corr}- means directions in the field coordinate system; B_{corr}-means directions after tectonic correction. ▶

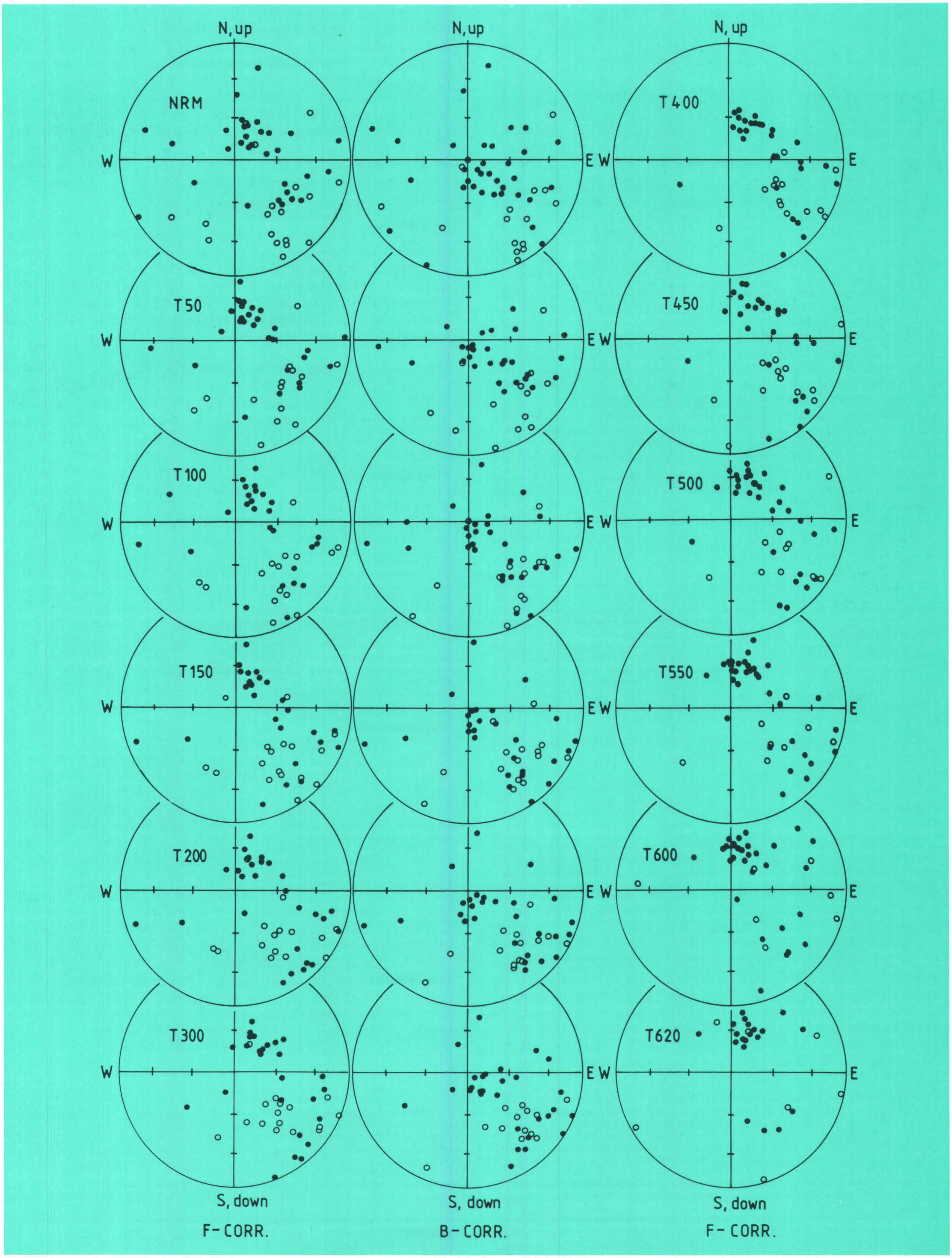
Whereas the direction without an asterisk (Tab. 3) occur a bit speculative because of the short interval and the low temperature, the ones with an asterisk seem to be very reliable. They remain in the same quadrant throughout the whole cleaning procedure (Fig. 6).

Looking at the poleplots, where all three occurences are shown, a decrease in scatter with increasing temperatures can easily be noticed. The grouping of negative inclinations belong to site 1, the ones with positive inclinations to site 2. The scattering points belong mainly to site 3. At about 300 °C the scatter of the inverse directions seem to be a minimum i. e. after eliminating softer overprints. The scatter in the positive directions is further decreasing and reaches a minimum at about 600 °C. In this range it can easily be seen that the direction groups very well around the present earth field in the field coordinate system, whereas the tectonic correction deteriorates the result. An overprint in the present earth field is proved. The stable inverse direction of site 1 keeps around a fixed position, but with increasing scatter, which is again due to the broad variety of particle sizes of the carrier mineral. One can conclude that multicomponent magnetization can deliver reliable paleomagnetic results, if one has the opportunity to use a reliable thermal demagnetizier. Not automatic interpretation techniques, but individually collected vector directions are the basis of a successful interpretation.

The paleogeographic interpretation was given by M. KRS et al. in 1986, since he was using 26 sites instead of three as in this comparison.

Fig. 6: *a.* Typical large circle behaviour of a sample of site 1. *b.* Large circle reconstruction of a primary magnetization




N, up
N, up
N, up
W
E W
E W
E
NRM
T50
T100
T150
T200
T300
T400
T450
T500
T550
T600
T620
S, down
S, down
S, down
F-CORR.
B-CORR.
F-CORR.

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Abstrakt

V předložené studii jsou odvozeny paleomagnetické parametry vzorků spodnoordovických červených silicitů, odebraných ze tří lokalit mílinských vrstev. Použité laboratorní postupy demagnetizace a vícesložková analýza magnetizace byly aplikovány na celé kolekci vzorků. Podařilo se odvodit složky paleomagnetizace, vypočtené paleomagnetické parametry z různých laboratoří jsou shodné a dokazují správnost použitých postupů.

Zusammenfassung

Drei Vorkommen der Mílina-Formation, rote Quarzite bis Quarzschiefer aus dem Barrandium, ČSSR, wurden bearbeitet. Durch den Vergleich der Ergebnisse von drei Laboratorien sollte die Verläßlichkeit von paläomagnetischen Ergebnissen bei komplizierter Magnetisierungsgeschichte überprüft werden. Die Vielkomponentennatur der Magnetisierung war in diesen Vorkommen bekannt und daher ein ausgezeichneter Testfall für moderne Abmagnetisierungsapparaturen. Der Vergleich fiel zur vollsten Zufriedenheit aus.

CORRELATIONS OF PALEOMAGNETIC DATA FROM EASTERN ALPS AND WESTERN CARPATHIANS — DISCUSSION

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Introduction

Our knowledge obtained from the Late Paleozoic of the West Carpathians, presented summarized in this contribution, is a fundament to solution of problems of paleotectonic development of Alpine-formed units. The results of paleomagnetic investigations from the Eastern Alps, West Carpathians and Transdanubian Central Mts., presented in the last time (Selli, R. 1981, Márton, E., 1981, Márton, E. et al. 1987, Muška, P. — Vozár, J. 1987), contribute to solution of problems of paleogeographical development and Alpine tectonics, but at the same time point to different possibilities of their interpretation. One of the main problems is establishing of competence of the principal tectonic units to the northern or southern margin of the Tethys region (confr. Rakús, M. et al. 1989 in press). Assignment of the individual units of the East Alpine-West Carpathian belt to the northern or southern margin of the Tethys region is decisive in correlation of paleodirections with directions of the North European platform or African block (confr. Márton, E. et al. 1987). In our up to present works we correlated all the results of paleomagnetic investigations of Alpine-formed units of the West Carpathians with the statistically processed results from the North European platform only (Krs, M. 1982).

In interpretation of Late Paleozoic paleomagnetic directions of the West Carpathians the results from the correlation project IGCP-198 (Rakús, M. et al. 1989 in press) are determining for us. The units of the Inner West Carpathians are correlated with Austroalpine and ranged to North part of Apulia-African platform in sense of the quoted study. General paleotectonic development of the Eastern Alps and West Carpathians in the Mesozoic, the north-vergent shift of nappe units and pressing of spaces at the contact with units of the northern Tethys margin (Manín and Klippen belts in the West Carpathians) logically tempt to correlation of main paleodirections in relation to the North European platform (Fig. 1). From the whole complex of the observed units and their developments in the Alpine stage we choose the results achieved from Late Paleozoic sequences for correlation, which represent the Late Variscan stage and also were the basis for development of Mesozoic sedimentation areas. The Late Paleozoic, particularly in the West Carpathians, from the point of view of paleomagnetic investigation methods, is a suitable environment, mainly for the reasons of sufficient representation of well stratified volcanic-sedimentary formations.

Inner west Carpathian tectonic units

Tatricum — lithofacial analysis of the studied areas (Považský Inovec Mts. (2) and Malá Fatra Mts. (1)) assumes that both occurrences of the Upper Permian are associated with the formation of separate smaller sedimentation basins in the northern part of the Tatra-Veporide block (Vozárová, A. — Vozár, J. 1988). Declination deviations reflect the primary orientation of the basins. The different inclination deviations are likely to be due to vertical movements of individual sections of the Tatricum.

Veporicum — rather large values of angle α_{95} make difficult the interpretation of results from the northern part of Veporicum. If it is assumed that the studied occurrences of northern Veporicum units, NW-part of Veporské vrchy Mts. (5), Tríbeč Mts. (3), Staré hory Mts. (4), Branisko Mts. (6), reflect the facial evolution in smaller basins, the facies in the south exhibit negative and in the north positive declination deviations (Muška, P. 1987). Substantially larger inclination differences have been observed in south Veporicum units Slovenské rudohorie Mts.) where the "characteristic" orientation attains strikingly large values due to a greater mobility of the margin of the Tatra-Veporide block.

Hronicum — the original sedimentation space on southern margin of the Tatra-Veporide block (or between this block and Gemeride block) in the Upper Paleozoic underwent positive i. e. clockwise rotation. The unit was studied mainly in Malá Fatra Mts. (10), Malé Karpaty Mts. (9), Tríbeč Mts. (11), Nízke Tatry Mts. (12, 13) (Muška, P. 1985).

Gemericum — the differences in the lithostratigraphic development of the Upper Paleozoic of North (14, 15) and South Gemericum (16) units are characterized by a complex pattern of paleomagnetic directions due to different paleogeographic conditions in the two separate sedimentation areas (Muška, P. 1987). The data from both Gemeric units indicate a generally positive rotation in the Permian. The data from the upper parts (Permian-Triassic) (14, 16) reflect a negative rotation of the Gemericum as a whole. This motion is associated with the nappe vergence movement of the Gemericum to the north, especially with its thrust on the southern part of the Veporicum.

Eastern Alps

With taking over the results from units of the Eastern Alps (Márton, E. et al. 1987) similarly as in evaluation of the West Carpathians we set out from the results of IGCP-198 Project (Rakús, M. et al. 1989 in press). In correlation of the paleodirections are certain problems resulting from unequal processing of the units of the Eastern Alps. Sporadical, well correlable data are represented by Permian sediments from the area of Christofberg and Saalfelden (in Márton, E. et al. 1987). Other data from the quoted work

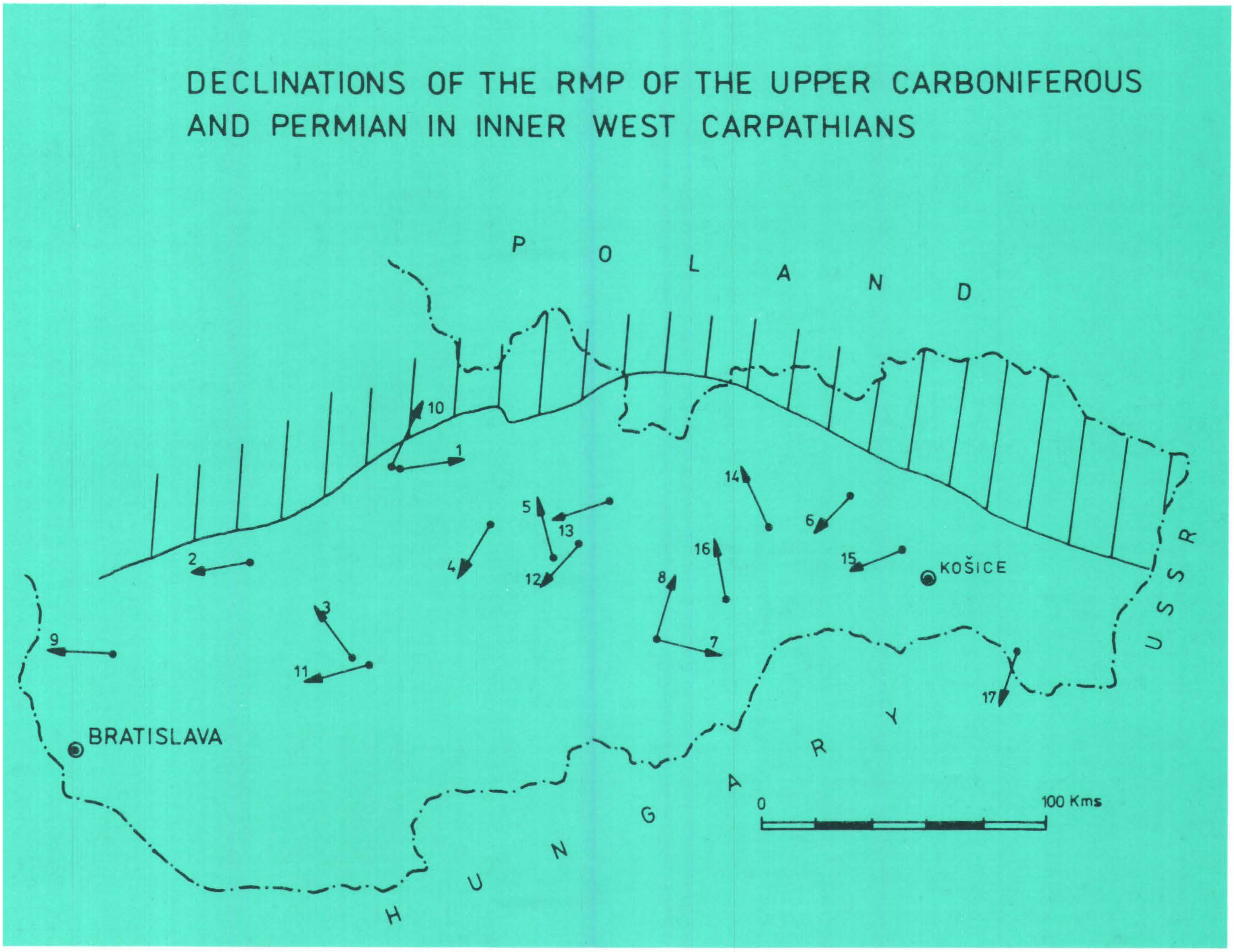

Fig. 1: Declination of remanent magnetic polarization (RMP) of the Upper Carboniferous and Permian of the Inner West Carpathians. Striped zone separates part of the Inner from Outer Carpathians. Numbers 1—17 mark studied orographic units of the West Carpathians and they are identical with numbers in the text (chapter Tectonic units of the Inner West Carpathians). Arrow marks the direction of declination RMP from present direction to the north.

cannot be used for correlation of the Eastern Alps-West Carpathians as they reflect proximity of the contact with the Southern Alps.

Tectonic breaking up (segmenting) of the Austroalpinicum units and their present-day position render the analysis of the measured paleodirection values difficult. From the values obtained from sporadical Permian sequences (Agnoli, Reisinger, Sopfel in Márton, E. et al. 1987) the prevailingly negative deviation of declination in the interval 80—90° in relation to the statistically calculated direction of the North European platform results.

In the West Carpathians the Permian sequences always display a positive deviation of declination, but the intervals of rotation are various for the individual tectonic units (Muška, P. — Vozár, J. 1987). This knowledge distinctly contributed to the paleogeographical analysis of the Late Paleozoic in the West Carpathians and to explanation of some phenomena of the Alpine nappe structure (Vozárová, A. — Vozár, J. 1988).

Particularly it may call attention to the identical direction of declination of Upper Permian sediments from the locality Saalfelden (Northern Alps) and locality Kamenná Poruba (Hronicum nappe) in the Malá Fatra Mts. (West Carpathians). Both display the direction of paleodeclination close to the calculated direction of the Permian of the North European platform. The mutual difference of their declinations is 3° and inclinations 3° too.

When compared with the Eastern Alps essentially more paleomagnetic data also with their interpretation are known from Hungary, from the Late Paleozoic of the Transdanubian Central Mts. (Márton, E. et al. 1987). The obtained values (confr. in lit. l. c.) display a systematic deviation of paleodeclination in the interval 40—80° in counter clockwise direction to the calculated direction of the Permian of the North European platform. Márton, E. (1981) compares this region with the calculated directions of the African platform and considers the Transdanubian Central Massif as a fragment of the African plate. From this view the mentioned directions (in Márton, E. et al. 1987) are manifested as positive deviations of paleodeclinations.

The paleodeclination directions of the West Carpathian Permian, compared with the values from the Transdanubian Central Mts., are shown considerably dispersed, corresponding to the complicated structure of the Alpine units.

Conclusion

In the analysis of paleodirections in the Eastern Alps, West Carpathians, Transdanubian Central Mts., obtained from Permian sequences, it may be pointed to the considerable dispersion of values, mainly in areas with a complicated nappe structure. The Transdanubian Central Mts. are manifested as the most compact whole in relation to the units of the Eastern Alps and West Carpathians (Fig. 2). It is questionable whether comparison of the paleodirections from the Transdanubian Central Mts. in relation to the African platform is purposeful when we compare the units of the Eastern Alps and West Carpathians with the North European platform. For the analysis of the whole wider region of the Alpine-Carpathian belt unification of the methodical approach in interpretation may be recommended. A particularly sensitive approach is required at the north-vergent nappe units of the Eastern Alps and West Carpathians.

From our view we propose to carry out a confrontation of the results of paleomagnetic investigations from equivalent tectonic units of the Eastern Alps and West Carpathians on the basis of equal stratigraphic horizons and with general evaluation of the results to introduce also cooperation with Hungary, especially with stress laid on the particular tectonic position of units in the Szendrö, Bükk, Mecsék, Villány and Transdanubian Central Mts.

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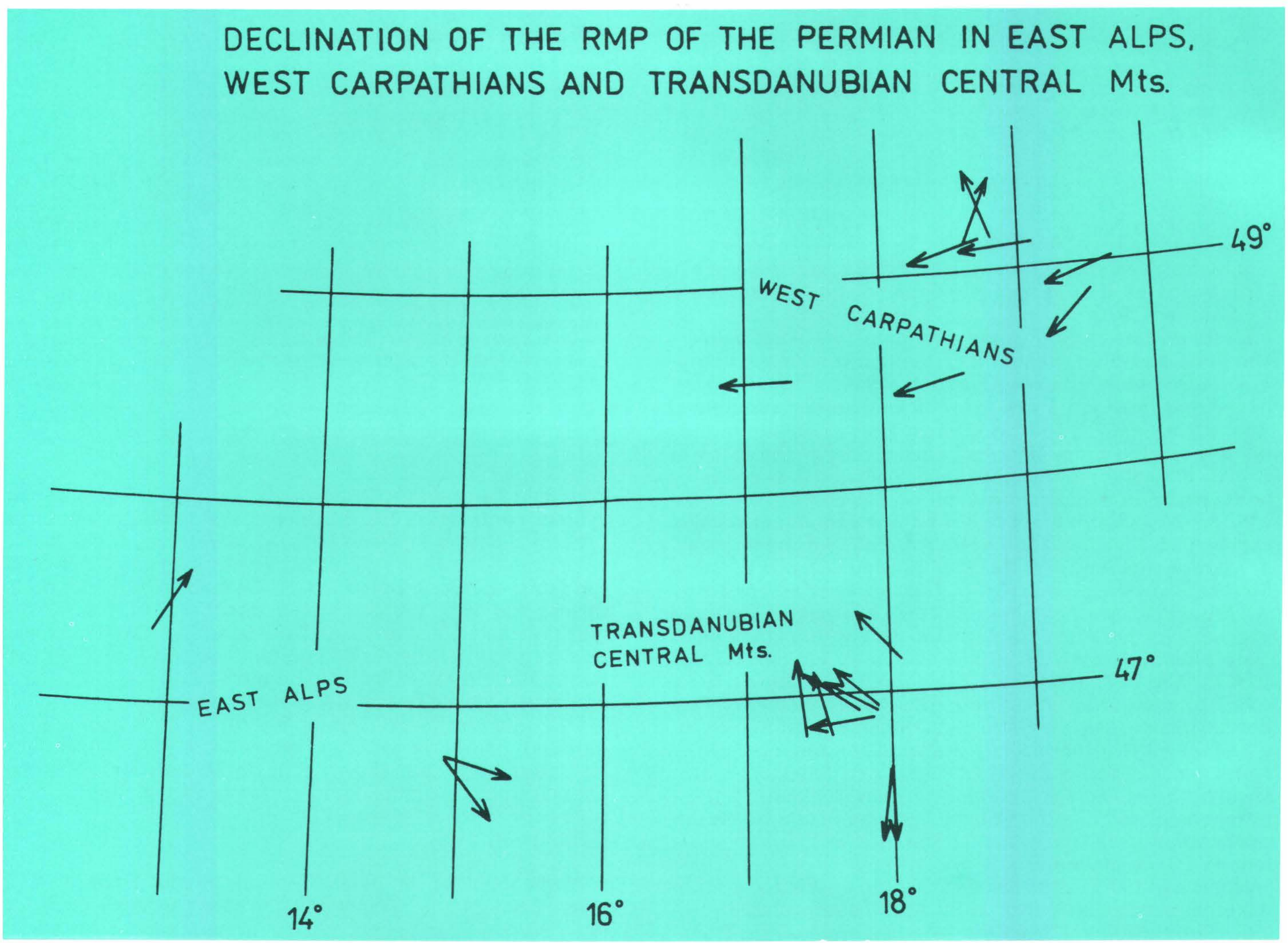
Abstrakt

Predložený článok diskutuje výsledky paleomagnetického výskumu z Východných Álp, Západných Karpát a transdanubického centrálneho masívu. Cieľom je prispieť k riešeniu otázok paleogeografického vývoja a alpínskej tektoniky, ktoré sú interpretované rôznymi autormi (Selli, R. 1981; Marton, E. 1981; Marton, E. et al. 1987; Muška, P. — Vozár, J. 1987).

Zusammenfassung

Im vorliegenden Beitrag werden Ergebnisse paläomagnetischer Untersuchungen in den Ostalpen, Westkarpaten und im Donau-Zentralmassiv erörtert, womit zur Lösung der Fragen der paläogeographischen Entwicklung und der alpinen Tektonik ein Beitrag geleistet werden soll, die von verschiedenen Autoren behandelt wurden (Selli, R. 1981; Marton, E. 1981;

Fig. 2: Declination RMP of the Permian in the Eastern Alps, West Carpathians and the Transdanubian Central Mountains. Arrows mark the direction of declination RMP from present direction to the north (from Marton, E. et al. 1987).



Hlavný problém pri ich interpretácii predstavuje príslušnosť hlavných tektonických jednotiek k severnému, alebo južnému okraju Tethys. Dôsledkom toho je potom aj korelácia smerov remanentnej magnetickej polarizácie so štatisticky spracovanými smermi príslušnej stratigrafickej úrovne severoeurópskej, alebo africkej platformy. Mladopaleozoické jednotky Západných Karpát sú vzťahované k severnému okraju Tethys a logicky korelované s paleosmermi severoeurópskej platformy a vykazujú rotácie v smere hodinových ručičiek, na rozdiel od výsledkov z transdanubického centrálneho masívu, ktorých rotácie v smere hodinových ručičiek sú vzťahované k africkej platforme.

Marton, E. et al. 1987; Muška, P. — Vozár, J. 1987). Das Hauptproblem der Interpretation besteht in der Zugehörigkeit tektonischer Haupteinheiten entweder zum Nord- oder zum Südrand der Tethys. Demnach werden auch Richtungen der remanenten Magnetisierung mit statistisch bearbeiteten Richtungen vom entsprechenden stratigraphischen Niveau der Nordeuropäischen bzw. der Afrikanischen Plattform korreliert. Die jungpaläozoischen Einheiten der Westkarpaten werden auf den Nordrand der Tethys bezogen, und ihre Rotationen im Uhrzeigersinn mit den Paläorichtungen der Nordeuropäischen Plattform korreliert, zum Unterschied von Ergebnissen aus dem Donau-Zentralmassiv, dessen Rotationen im Uhrzeigersinn auf die afrikanischen Richtungen bezogen werden.

THE MIROSLAV HORST — MOLDANUBIAN KLIPPE OR AUTOCHTHONOUS MASSIF

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Introduction

An old enigma exists in the tectonic interpretation of the Miroslav (Misslitzer) horst at the eastern boundary of the Bohemian Massif (Fig. 1). The horst itself is in its southern part formed by typical Moldanubian granulites and amphibolites (Dudek, 1963; Němec, 1980). In the northern continuation of the Miroslav horst mostly Moravian and probably also Brunnian rocks crop out.

Three totally different units (terranes) existing at the eastern boundary of the Bohemian Massif — catazonal Moldanubicum, mesozonal Moravicum and Brunnia deformed and sheared basement — occur in the very small and complicated territory of the Miroslav horst together. The Miroslav horst is bounded by the Diendorf (Boskovice) fault in the west and by the Miroslav fault in the east.

Because the horst is situated east of the Boskovice furrow, tectonic problems of the emplacement of the Moldanubian and Moravian complexes have existed since the end of the last century. Suess (1912) considered Moldanubian relicts as tectonic remnants of the huge "Moldanubische Überschiebung". Following the Austrian and Czech workers (Preclik, Zapletal etc) the Miroslav horst was interpreted in a similar manner until Dudek (1963) proposed that the Moldanubicum could be autochthonous in the Miroslav horst.

Several years ago we prolonged one Carpathian foredeep seismic line (287A/84) to the West and passed the Miroslav horst (Figs. 1 and 2). The field technique employed to obtain the seismic reflection data examined at Geofyzika Brno was standard VIBROSEIS practices used for oil exploration. The compressional wave source in this survey consisted of three vibrators operating synchronously and transmitting a sweep signal with the frequency varying linearly from 15 to 60 Hz. The duration of each sweep was 11 s with the total recording time of 14 s, resulting in 3 s of correlated reflection data. A 48-channel recording system was used with a 25-metre station spacing, producing offset of 1 175 m. Vibrating every second station resulted in nominal 12-fold data.

Interpretation

The section displayed (Fig. 3) is not migrated, and so dipping reflections on the time sections are not in their true positions. A final geologic section (Fig. 7) is constructed using hand migrations of more than 40 reflections. In this short contribution I will concentrate on the Miroslav horst itself between km 3.8 (the Diendorf fault) and km 8 (the Miroslav fault).

In Fig. 3 we see the line drawing of the unmigrated time section. Reflections B and C are strongly inclined (35° — 38°) after hand migration. I consider them thrust faults features (duplexes) beneath the 1 km Moldanubicum overthrust fault. These duplexes are typical of deformed Brunnia rocks elsewhere in the Brno Massif. Because south of the horst the Culm rocks have been drilled (Batík, Skoček 1981), which are always deformed together with the Brunnia rocks, this hypothesis seems to be reasonable.

In the upper part of the section I interpret the easterly dipping reflections D as Moldanubian overthrust over the Brunnia complex. This hypothesis is supported by migration of seismic data, gravity interpretation and mainly by structural geologic observations.

The hand migration of the reflections enabled us also to observe that no reflections cross steeply the Diendorf and Miroslav faults. These faults behaved probably during the post-collisional Upper Carboniferous — Lower Permian times as left lateral strike-slip faults bringing southern blocks to the North.

In that case, the Miroslav horst was probably present during the collisional thrusting between the Moldanubicum and the Brunnia in the direction opposite to the central part of the Thaya window. Němec (1980) noted that the Miroslav granulites are more similar to the Austrian than to the Moravian ones, which is in favour of our hypothesis.

Conclusion

The final simple geologic section (Fig. 4) illustrates the view presented above. Amphibolite bodies have been interpreted from the gravity data. Beneath the Moldanubian overthrust, the Brunnia (with Devonian and Culm sediments) rocks are strongly sheared and tectonized, and form typical duplexes mapped geologically in other places. The western and eastern segments west and east of the Diendorf and Miroslav faults are similar. Significant thrusting

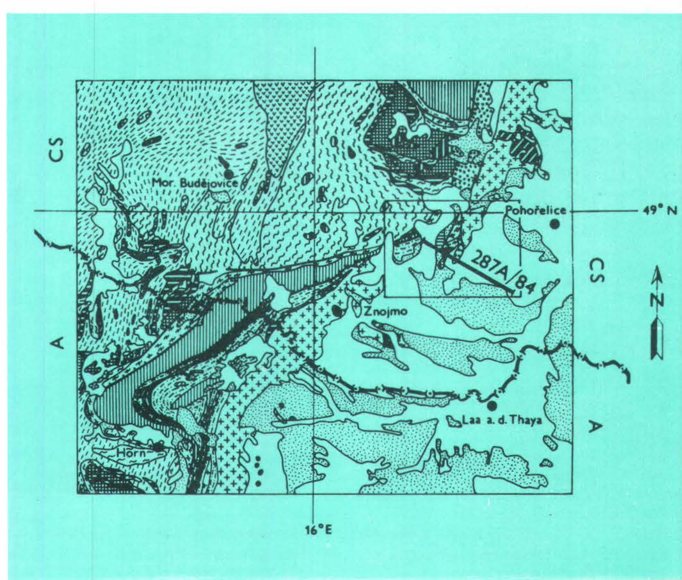

Fig. 1: Simplified geological map of the eastern boundary of the Bohemian Massif between Horn and Pohořelice with the position of the seismic line 287A/84.

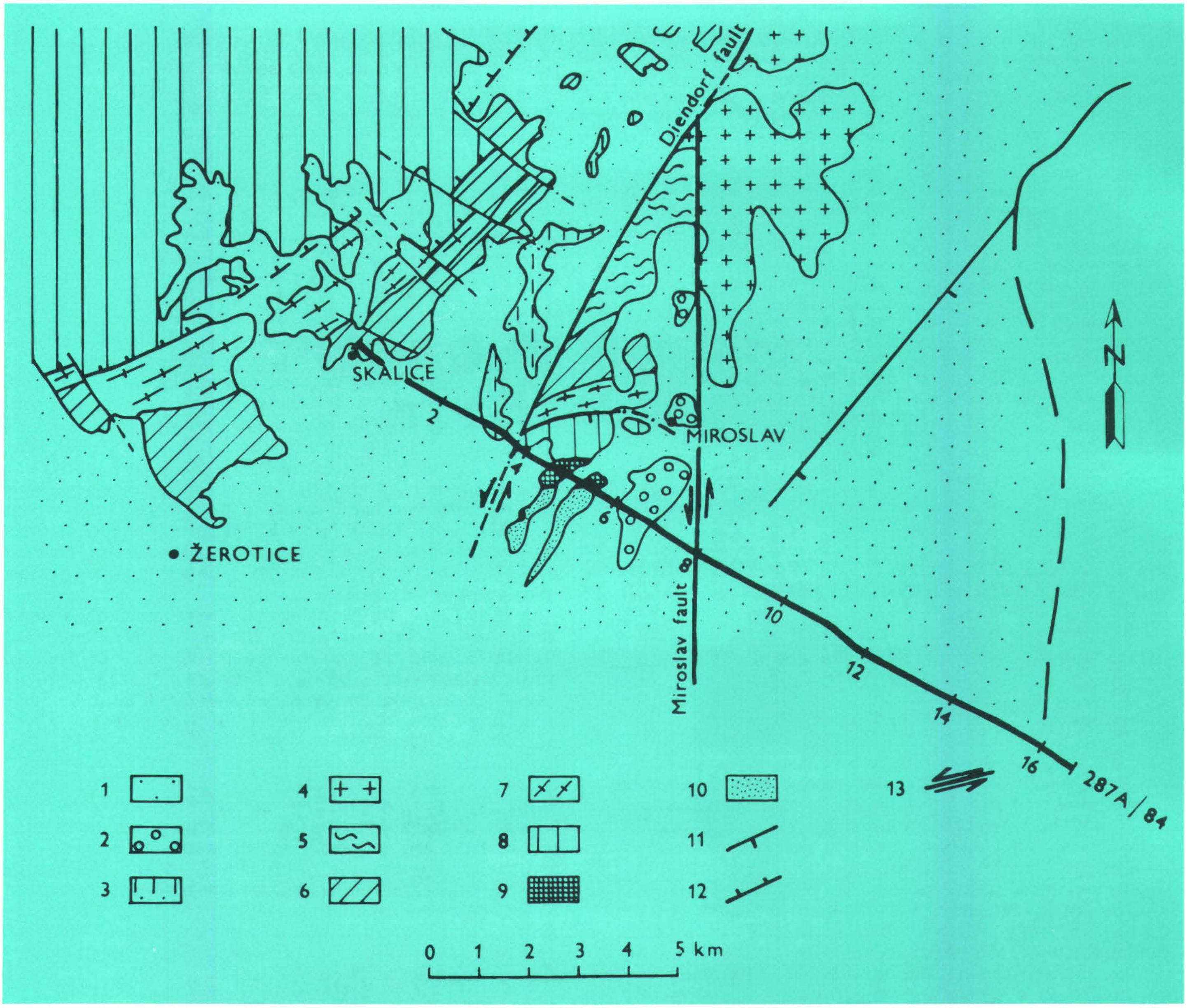

Fig. 2: Detailed geologic map of the Miroslav horst and its surroundings with the position of the seismic line 287A/84. Explanations:
1 — Neogene sedimentary rocks, 2 — Permian, 3 — Culm, 4 — Brno Massif (deformed and sheared Brunnia), 5 — Brno Massif (?) — Moravicum (?), 6 — Moravicum (biotitic phyllites), 7 — Moravicum (two-mica orthogneisses), 8 — Moldanubicum (garnet-sillimanite gneisses), 9 — Moldanubicum (garnet-pyroxene amphibolites), 10 — Moldanubicum (granulites), 11 — normal fault, 12 — thrust fault, 13 — strike-slip fault.

and shearing of the Brunnia rocks can also be observed there. Detailed interpretation of tho whole line is presented synchronously elsewhere.

In principle, the seismic data support the old statement by F. E. Suess. The Moldanubian rocks in the Miroslav horst are, most probably, of an allochthonous character and caused the tectonization of the less metamorphosed Brunnia basement complexes during the thrust sheet movement.

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Abstrakt

Krátký seizmický reflexní profil 287/84 změřený pro účely naftové a plynové prospekce v karpatské předhlubni velmi pomohl pro pochopení povahy a tektonické pozice miroslavské hrástě na jižní Moravě. Seizmické reflexní údaje, geologická pozorování a interpretace ostatních geofyzikálních údajů hovoří spíše pro moldanubický alochton (hypotéza F. E. Suesse) než pro moldanubický autochtonní masív na východní straně boskovické brázdy. Pod moldanubickým (morávním) alochtonem leží silně porušené a střižené horniny brunnie s jejich devonským a kulmským sedimentárním pokryvem. Boskovický a miroslavský zlom jsou velmi pravděpodobně téměř vertikálními pozdně paleozoickými horizontálně směrnými posuny.

Zusammenfassung

Das kurze reflexionsseismische Profil 287/84, das im Rahmen der Erdöl- und Erdgaserkundung der Karpatenvortiefe gemessen worden war, trug

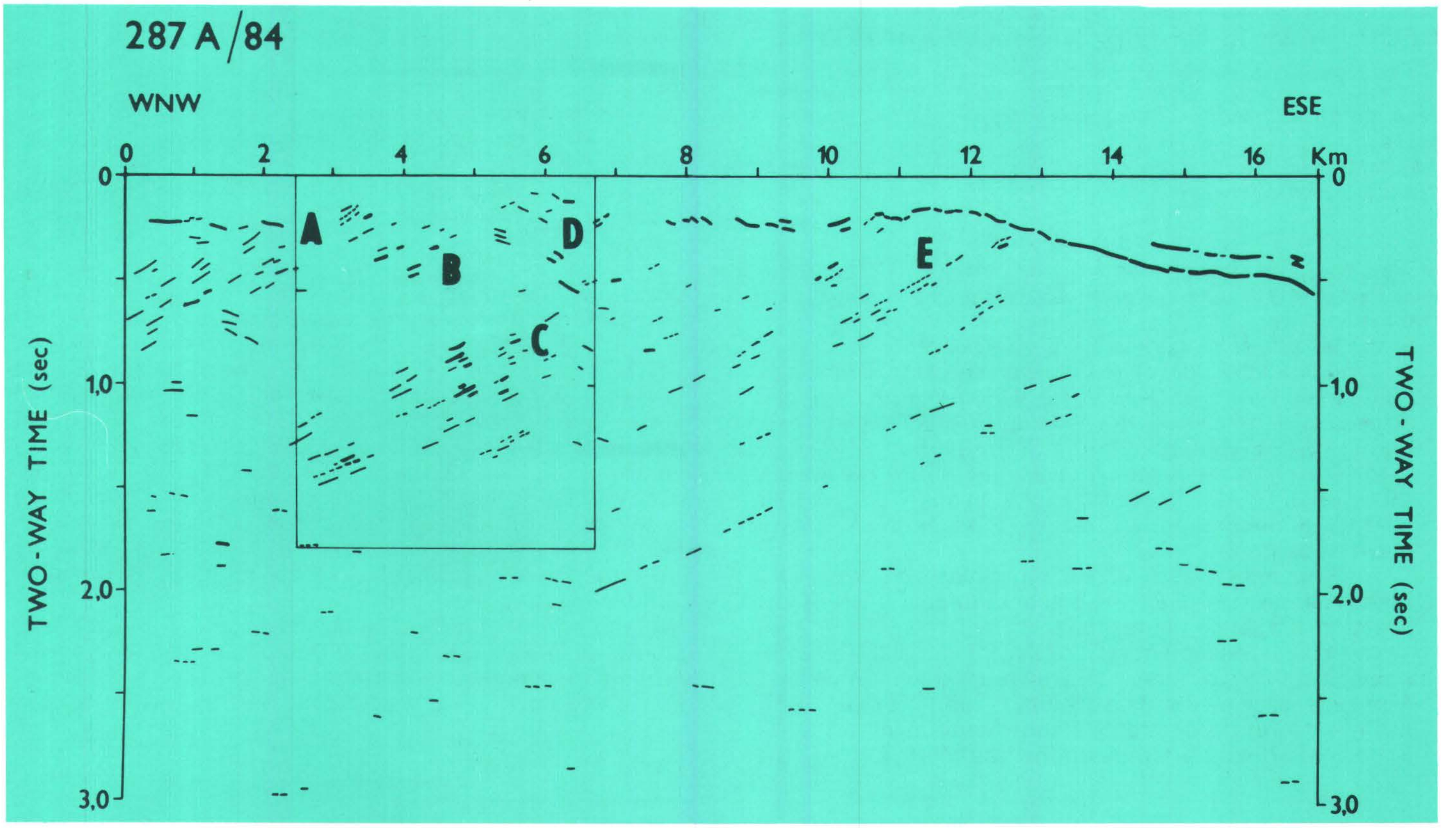
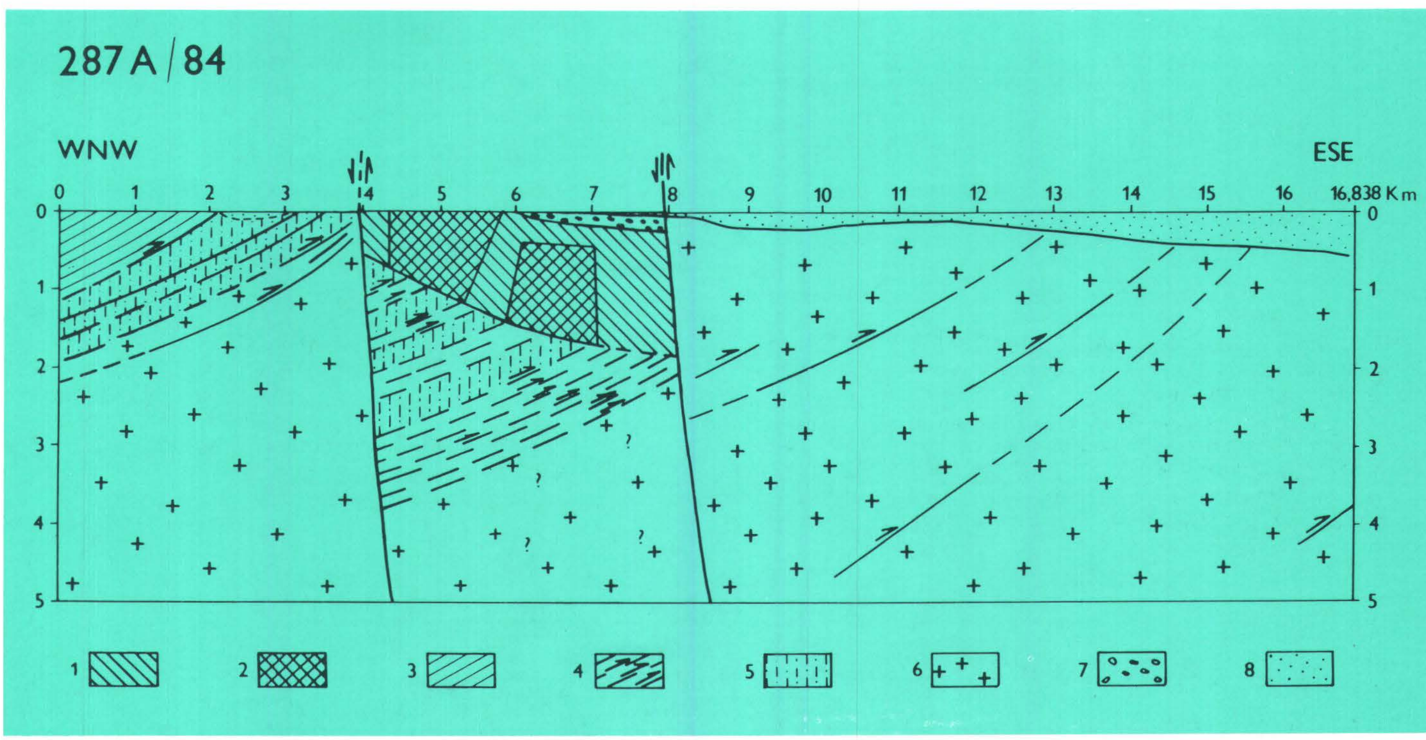


Fig. 3: Selected reflections of the unmigrated time section 287A/84. Significant reflection events described by lettres (see the text).

Fig. 4: Hypothetical geologic section along the 287A/84 profile. Explanations: 1 — Moldanubian granulites, 2 — Moldanubian amphibolites, 3 — Moravicum, 4 — deformed and sheared Brunnia rocks, 5 — Culm, 6 — Brno Massif, 7 — Permian, 8 — Neogene. ▼



zur Auffassung des Charakters und der tektonischen Stellung des Miroslav-Horstes in Südmähren bei. Reflexionsseismische Angaben, geologische Erkenntnisse und die Interpretation anderer geophysikalischer Angaben bezeugen eher das moldanubische tektonische Allochthon (Hypothese von F. E. Sueß) als das moldanubische autochthone Massiv an der Ostseite der Boskovice-Furche. Unter dem moldanubischen (moravischen) Allochthon lagern stark gestörte, durch Scherflächen begrenzte Gesteinskomplexe der Brunnia mit sedimentären Deckformationen des Devons und Kulms. Der Boskovice- und Miroslav-Bruch stellen höchstwahrscheinlich fast vertikale spätpaläozoische, horizontal streichende Längsverwerfungen dar.

NEOGENE CLIMATIC CHANGES AND GEODYNAMICS OF THE CENTRAL PARATETHYS

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The Neogene development of the Western Carpathians as a part of the Alpine-Carpathian suture zone is characterized as follows:

In the area of the Western Carpathian outer units –

– gradual extinction of the former flysch throughs accompanied by a change of flysch sedimentation into molasse one (e. g. during the Egerian in the Ždánice unit, during the Eggenburgian in the Skola unit);

– extension of the foredeep over the platform and from the area of former flysch throughs on the fronts of the overriding nappes (e. g. basins in position of "piggy back" type);

– folding and thrusting of the outer Western Carpathian flysch nappes over the foredeep and gradual uplift of the Western Carpathian outer units;

– overthrust movements in the Carpathian collision zone fading out from the inner units toward the outer ones and from the west to the east (Buday, Cicha, Seneš, 1965).

In the area of the Central Western Carpathians –

– formation of the arc-shape of the Western Carpathians associated with formation and development of shear zones;

– horizontal displacement and rotation of individual blocks inside the Western Carpathian segment;

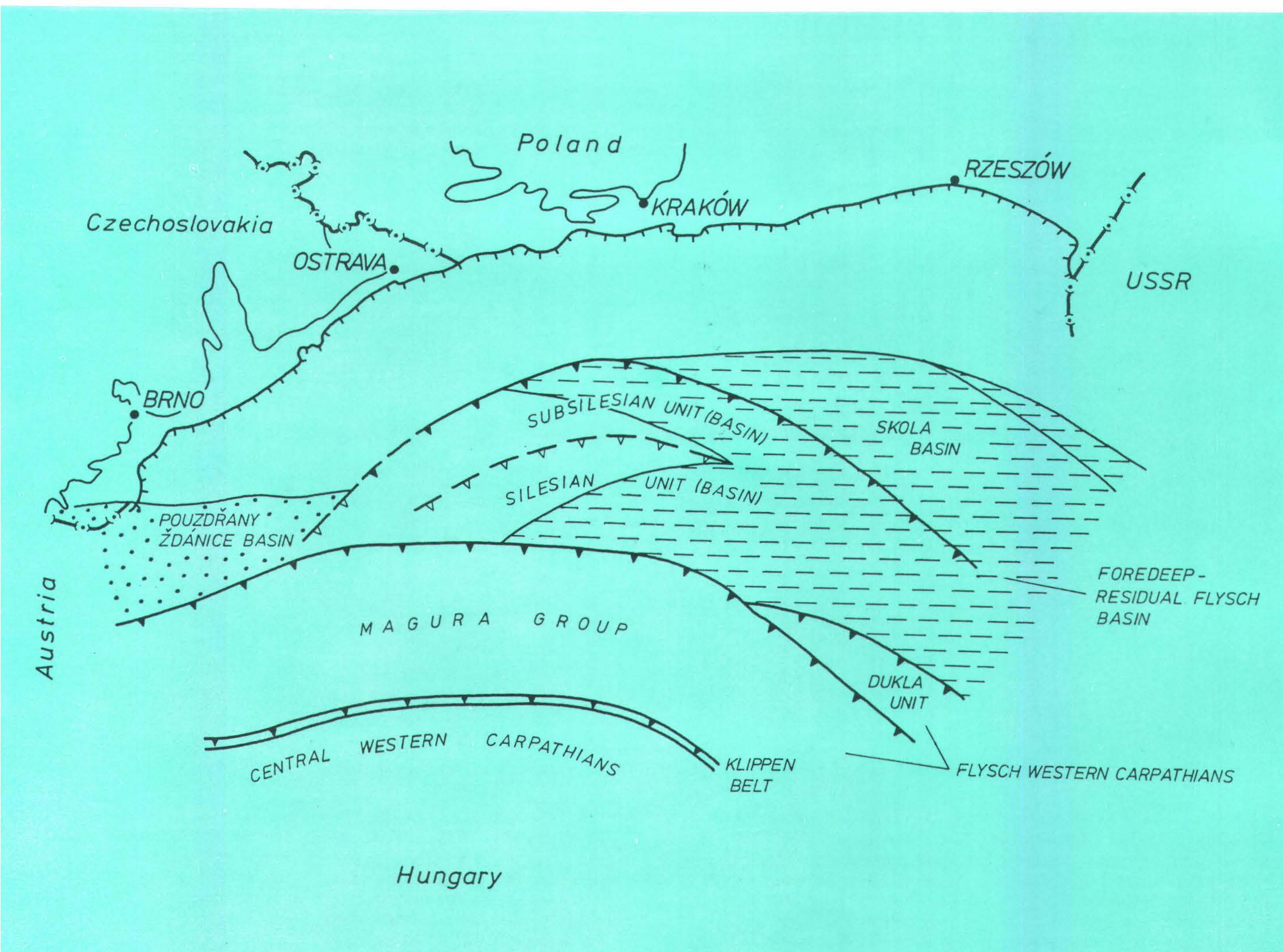
– formation and development of the Pannonian mantle diapir (mantle astenolith) (Stegena, Geczy, Horváth, 1975);

– Neogene volcanism resulting from subduction, formation and development of the mantle diapir (Lexa, Konečný, 1974).

It should be pointed out that in the Lower Oligocene a separate sedimentary area was formed in the Tethys northern branch which markedly differed both from the older, mostly flysch, and the younger molasse basins (Cicha, Krystek, 1986). This period ranges within the new regional stage – the Kiscellian (Baldi, 1979). Contrary to the Eocene, it gets colder, several anoxic phases accompanied by deposition of menilitic beds repeate, and during the Kiscellian marl deposition it gets warmer again. This fact based on the study of marine assemblages corresponds even to the character of floras and faunas from the continental basins deposits of the Bohemian Massif (e. g. Fejfar, personal communication).

At the end of the Oligocene and onset of the Miocene considerable changes in the development of the Western Carpathian sedimentary areas took place. The space reduction in the outer units was manifested by further folding

Fig. 1: Palinspastic reconstruction of the Western Carpathians during the Egerian.



and thrusting of Alpine and Western Carpathian flysch units. In the northern Alps, the main overthrust on the foreland took place in the Egerian (Tolmann, 1978). In this period, the flysch deposition in the Pouzdřany and Ždánice sedimentary areas in the front of the Magura Group of nappes changed into molasse one (Cicha, Pícha, 1964). Eastwards, in the sedimentary basins of the Subsilesian, Silesian, Skola and Fore-Magura units the flysch deposition of the Krosno Fm. continued till the Eggenburgian. The basin extended eastwards, to the Eastern Carpathians.

Folding and overthrust of the nappes in the front of the folded belt was in the backland area of the Western Carpathians compensated by movement along the transform faults (fault zones) Rába-Rožňava, Balaton-Darnó, Zagreb-Zemplín, according to Hungarian geologists by dextral strike-slip displacement toward the NE (Baldi, 1986). By the end of the Oligocene these displacements led to disintegration of the Paleogene Buda Basin in the backland of the Western Carpathians and to their uplift.

In the Egerian (Bůžek, Kvaček, 1985) the flora of the Central Paratethys region was changing due to numerous factors both of global and local character — it was not only the prevailing wind direction or precipitation spread that played a role. The Egerian floras and faunas occurring more southerly comprised more thermophillous elements than those occurring northerly (e. g. at Bechlejovice — the Bohemian Massif, Krumvíř-Ždánice unit, Veröcemaros-Csörög — the Buda Basin). It was caused by former position of the Buda Basin which was at least 100—150 km more to the south than we find it today.

Based on the macro- and microflora study (Planderová, 1975) in the Egerian the lower and middle subtropic parts and the upper part indicating a certain drop of temperature, as it contains "Arctic-Tertiary" elements, can be distinguished. This cooling was probably of Miocene date, when the Western Carpathian sedimentary basins underwent structural changes (sea regression, uplift of the internides). The cooling, however, might not coincide with the Oligocene-Miocene boundary in the Upper Egerian — in the opinion of Bůžek and Kvaček (1985) the Miocene set on with a short-term climatic optimum favouring perennially green wood species. The fauna from the Miogypsina tanigunteri Zone signalises a warmer climate as well. Penetration of warm-water indicators — the foraminifers — into northern parts of the Buda Basin and the Carpathian Foredeep in the Egerian also evidences the warming. The mollusc fauna found at many localities in Western Carpathian basins exhibits both boreal and Mediterranean elements. (Seneš, 1958).

Eggenburgian — Ottnangian

During the Eggenburgian, the southern margin of the sedimentary area in the front of the Western Carpathians shifted due to compression northwards. Deposition took place both in the foredeep and in the residual flysch basins. In the western part, the Silesian and Subsilesian units

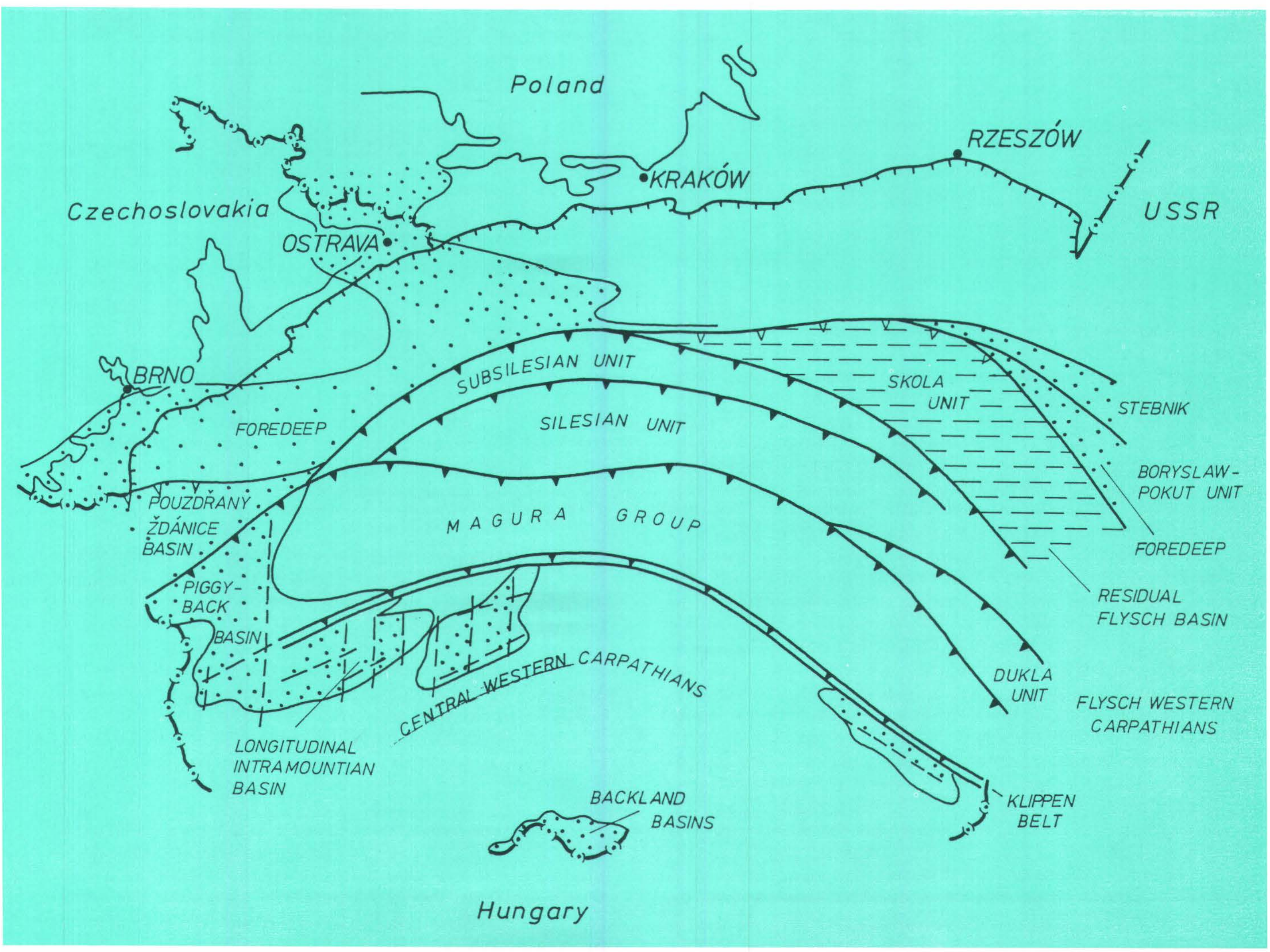


Fig. 2: Palinspastic reconstruction of the Western Carpathians during the Eggenburgian.

emerged, while in the eastern part the flysch deposited in the Skola and molasse in the Boryslaw-Pokuty Basin. By the end of the Eggenburgian, sediments of molasse character containing evaporites (Vorotyshche Fm.) were deposited in the Boryslaw-Pokuty Basin.

During the Ottnangian the Eggenburgian foredeep deposits from central and north Moravia underwent denudation. The sedimentation continued in southern Moravia and in Poland, Sucha Fm. was deposited in the west and in the east sedimentation in the area of the Stebnik unit took place the eastern continuation of the Stebnik unit in the Western Carpathians is the Sambor-Rozniatov unit. Due to compression, by the end of the Ottnangian the Skola unit was thrust over the Borislaw-Pokuty unit (Oszczypko, Slaczka, 1986).

In the Eggenburgian a shear zone was formed in the periklippen belt area on the central Western Carpathian basement in which by sinistral strike-slip displacement a longitudinal intramountain basin was opened. This sedimentary area followed the boundary between the outer flysch and central Western Carpathians from where it penetrated along the rejuvenated mobile zones into Paleoalpine consolidated inner units.

In the Ottnangian the marine sedimentary areas of the central Western Carpathians were reduced, in the backland they were replaced by terrestrial deposition.

In the Eggenburgian the first temperature optimum of the Miocene comparable to the Lower Badenian — the Moravian one appeared. Beside the large foraminifers (Miogypsina) known also from the Alpine foredeep from the "Hall schlier" sediments the association of large pectinides considerably evolved. The mollusc fauna showed affinity either to the Atlantic or the Mediterranean bioprovince. Both the flora and fauna recorded brand-new elements. However, we point out that there was not much difference between the Lower Eggenburgian and the Upper Egerian flora. In the Tertiary basins of the Bohemian Massif and on the area of the today's G. D. R. (Bůžek, Kvaček, 1985) there were mixed forests in the Egerian with frequent deciduous wood species. Overwhelming part of the Eggenburgian belonged to the most varied, prevailingly evergreen forest formations of the Neogene.

Palynological investigations (Planderová, 1978) have revealed that the Eggenburgian had overwhelmingly subtropic to tropic climate. The presence of "Arctic-Tertiary" forms by the end of the Eggenburgian indicated a gradual decrease of temperature. However, this can be connected with sea regression in the area of the Western Carpathians. The Ottnangian palynological spectra point to a warm period with a certain extension of "Arctic-Tertiary" elements. The Ottnangian floras of the Central Paratethys were very close to the Eggenburgian. But new species of deciduous plants start to appear (Bůžek, Kvaček, 1985) which may signalize cooling, aggravation of climatic conditions. From the viewpoint of the development of the Paratethys sedimentary areas, the Ottnangian stage represents an important Miocene period. During it the connection between the Western Paratethys and the Rhone basin was interrupted and the Paratethys was getting still more isolated from the marine regime of the Mediterranean region s. s. This process culminated by formation of a sedimentary area extending from the molasse zone in Switzerland as far as the Caspian region (including Ustjurt) with brackish fauna of Rzehakia association strongly reduced as to the species variety. During the Ottnangian the coal seams of the Salgótarján Fm. were formed in the Western Carpathian backland area. The coal deposition was reported also from the marginal parts of the Alpine-Carpathian foredeep Langau-Šafov, south Moravia, from the underlier of the Rzehakia beds in Braunau "schlier" of the molasse zone in Austria (Rögl 1971) and in the underlier of the Salgótarján Fm. (Vass et al. 1987) a rudimentary foraminiferal fauna with Uvigerina was detected being later on typical of the Karpatian. The movements associated with a gradual isolation of the Paratethys from the Mediterranean s. s. were the reason of a short-lasting activation of the marine regime, with penetration of marine fauna which later in the Karpatian, under fully euhaline conditions, creates the assemblages of Acme-zones. The data on an extremely close relation between the Eggenburgian and Ottnangian floras to a certain degree contradict the world-wide cooling supposed for this period by Barron 1985, Rögl, Steininger, 1984.

Within the Ottnangian humudity gradually lowered and climate became drier with continental features (Bůžek, Kvaček, 1985). The activation of tectonic movements and uplift of sedimentary areas led to reduction of the swamp system typical of the Lower Ottnangian. Even higher temperatures cannot be excluded as indicated by the evaporite deposition in the Lower Karpatian in the East Slovakian Basin.

Karpatian

Styrian orogenetic movements resulted in further space reduction in the frontal part of the orogene in the Karpatian. The sedimentary area of the foredeep extended along the whole front of the Western Carpathians. The preserved remains of the foredeep deposits (Krystek, 1983) prove the transgression reaching the Bohemian Massif. The tectonic reduction of the foredeep sedimentary fill supposed later on is indicated also by a considerable thickness of the sediments in the basin "schlier" facies — from the area between Mikulov and Vranovice trench in southern Moravia (1 200 m), where the thick "schlier" sequence is cut off by the nappes front. Gradual overthrust of the nappes into the foredeep area during the Karpatian is documented by flysch material found in conglomerates ahead the nappe front (Krystek, 1983) and olistolithes in the Polish Zamarov Fm. (Oszczypko, Tomáš, 1985). At the end of the Karpatian the foredeep was overriden by the Pouzdřany and Ždánice units in southern Moravia and the Silesian and Subsilesian units in northern Moravia and Poland. In the northeastern part of the Western Carpathian front (in today's Poland) part of the foredeep sediments was detached and created the nappe of the Stebnik unit (Ney et al. 1974).

In the central Western Carpathians formation of orogene arc-shape was completed. (Styrian orogenetic movements.) In the western part in a sinistral strike-slip zone intramountain basins opened in the area of the present Vienna Basin and northern part of the Danube lowland. Namely the area of the Vienna Basin with the central Carpathian basement display an increased sedimentation rate. In the eastern part of the Western Carpathians the uplift in the beginning of the Karpatian contributed to the shallowing of the East Slovakian Basin. Evaporites were deposited. In the Upper Karpatian the basin formation was controlled by a dextral strike-slip displacement. Rapid deposition of the variegated shales documents an increase of terrigenous input.

Lower Miocene basin formation culminated at the end of the Karpatian and new Middle Miocene cycle started. The Karpatian can be considered a turning point in the evolution of fauna and flora. It was stressed in the paper by Cicha et al. 1975 that from the Eggenburgian-Ottnangian, the Karpatian flora and fauna markedly changed. The "Middle-Miocene" type of organisms' evolution coincides with this period chronostratigraphically assigned to the terminal part of the Burdigalian s. l. of the global Miocene time scale.

Badenian

Compared with the Lower Badenian (Moravian) — Langhian the basic difference was the appearance of the planktonic foraminifers association Praeorbulina-Orbulina. However, from the phylogenetical viewpoint the organisms are the closest in the Karpatian sequence with the appearance of Globigerinoides bisphaericus.

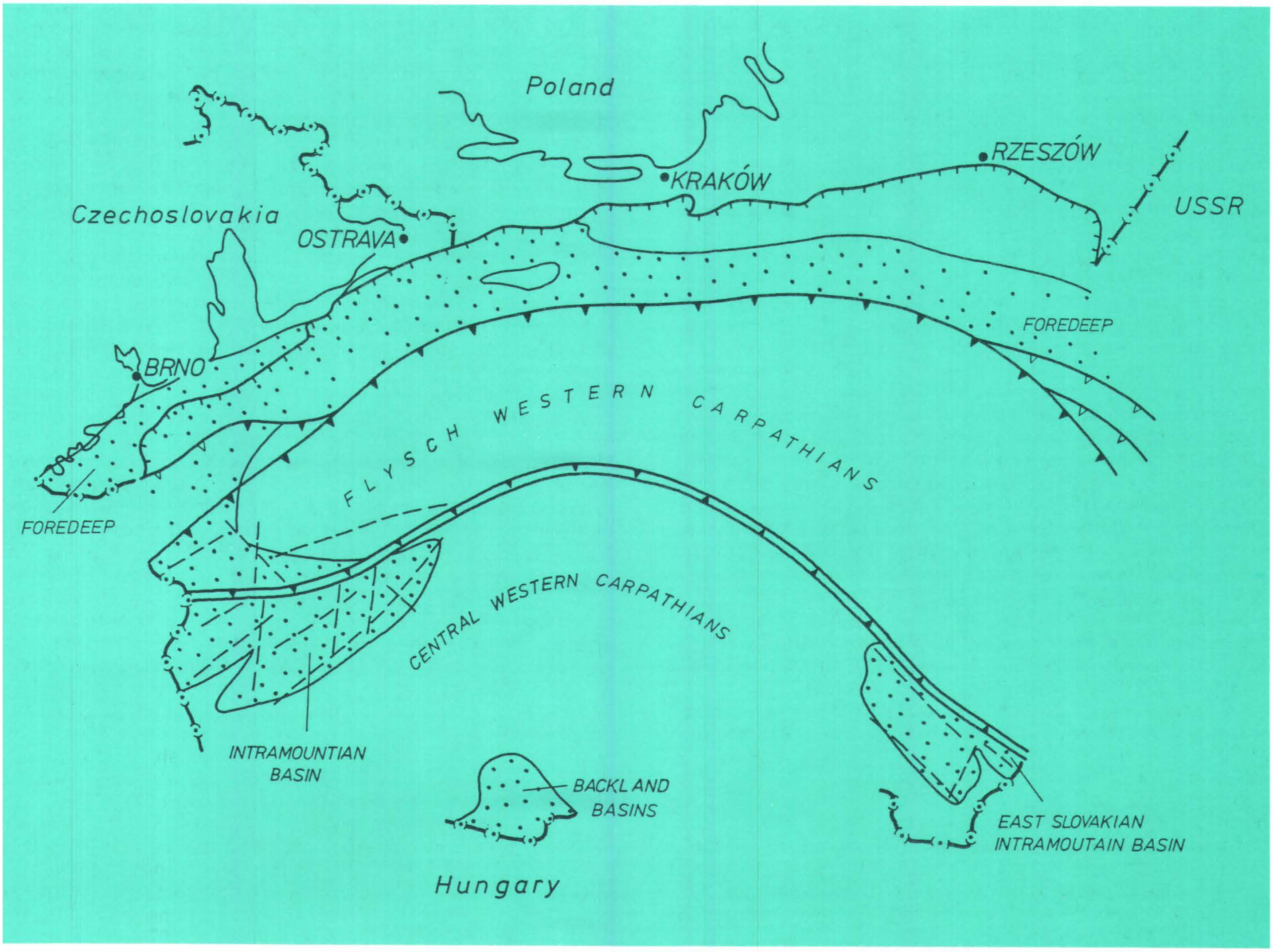


Fig. 3: Palinspastic reconstruction of the Western Carpathians during the Karpatian.

The mollusc fauna and the benthic foraminifers (Cicha, Seneš, Tejkal, 1967) document the subtropic climate. According to Planderová (1978) the Karpatian flora is rich in humid and thermophilous elements; southwards (the North Hungarian Basin) even in the tropic elements. The salinity crisis indicates a drier climate with equivalents even in the Vienna Basin. We cannot exclude that e. g. in the Carpathian foredeep this phase of the Karpatian development was accompanied by faunal reduction and prevalence of sponges which can be documented by predominance of megascleres in fossil association of these sediments. Knobloch 1969 and particularly Bůžek, Kvaček 1985 suppose that a certain change in the general character of flora, namely reduction of thermophilous wood species in the northernmost part of the Central Paratethys in the Karpatian may be attributed to regressions with the following radical change in the basin configuration. However, the Karpatian climate was for the most part subtropic and the evolution of benthic faunas points to warming toward the Badenian. Strong orogenetic movements caused an extensive break in sedimentation in the Upper Karpatian. The G. bisphericus Zone occurs only in the southern part of the Central Paratethys, not in its northern part. Here the Lower Badenian has prominently transgressive character.

The Lower Badenian sea transgression extended from the foredeep far to the Bohemian Massif. The highest subsidence in the foredeep was between the rivers Danube and Odra. Sinking of the platform margin was connected with the nappes overthrust. The overthrust on the area of the ČSSR in the Badenian was not so long as that in the Karpatian. Probably due to transverse tectonics (as a result of oblique collision) the overthrust of the flysch nappes front was restricted only to the northern Moravia region (NM of the Maliník horst) with anti-clockwise rotation (in fact "en block" — Jurková 1976). After deposition of the Balice Fm. Sambor-Rozniatov unit was overthrust with the Boryslaw-Pokuty unit in the outer Carpathians (Oszczypko, Slaczka, 1986).

After the end of nappes overthrust movements, in the Middle Badenian, the marine deposition in the foredeep on the territory of ČSSR was finished maintaining only in the Opava region. Eastwards, the Silesian and Subsilesian nappes overriden the Slavkov-Těšín Ridge and the last overthrust of the Magura Group was documented in Poland (Oszczypko, Tomáš, 1985). The compression in frontal part of the Carpathian orogene was associated with a regional uplift of the mountain chain. This is evidenced also by an increased supply of detritus from the Carpathian front into the foredeep. In the foredeep evaporite crisis took place. By the end of the salinity crisis the northern Carpathian margin was uplifted and eroded, this resulted in redeposition of eroded clastic material to the foredeep in the Wieliczka region in Poland.

In the Upper Badenian the flysch front had overriden the NE part of the foredeep partly due to gravity tectonics evoked by the uplift of the Western Carpathians (Poltovitz, 1978). The foredeep deposits were folded and detached forming the Vojnice unit (Badenian) in the front of the Carpathians.

In the Middle Miocene regional uplift of the Western Carpathians started. Intramountain basin formation was accompanied mainly by the shear zones development. The basin opening in the orogene and the maximum sedimentation rate in them, migrating from W to the E, can be well correlated with the last overthrusts in the front of the Western Carpathians.

In the course of synsedimentary activity of faults in the Lower and Middle Badenian the today's Vienna Basin was opened. In the contrary to the Lower Miocene depocentres, the Badenian ones migrated southwestwards. The Vienna Basin was formed in a sinistral strike-slip zone (Roth 1980, Kováč 1985, Royden 1985), in the same way the Middle and Upper Badenian basins were opened in the northern margin of the Danube lowland — the Trnava-Dubník depressions. In the eastern part of the Western Carpathians the East Slovakian Basin was opened in a dextral strike-slip zone (Vass et al. 1988). Here, in the Lower Badenian the connection with the foredeep through the today uplifted flysch nappe units is supposed. Middle Badenian salinity crisis can be here a consequence of partial areal uplift. The subsidence in the East Slovakian Basin culminated in the Upper Badenian (Kolčov Fm. 2 000 m thick)) to the Lower Sarmatian. In the western part of the orogene in this time the subsidence decreased. In central part of the Western Carpathians small intramountain basins with lacustrine and river deposition were formed in the Badenian.

The backland area of the Western Carpathians had since the Badenian a similar development as the Pannonian intermountain region, controlled by origin and formation of the mantle diapir (Vass 1979, Stegena et al. 1985).

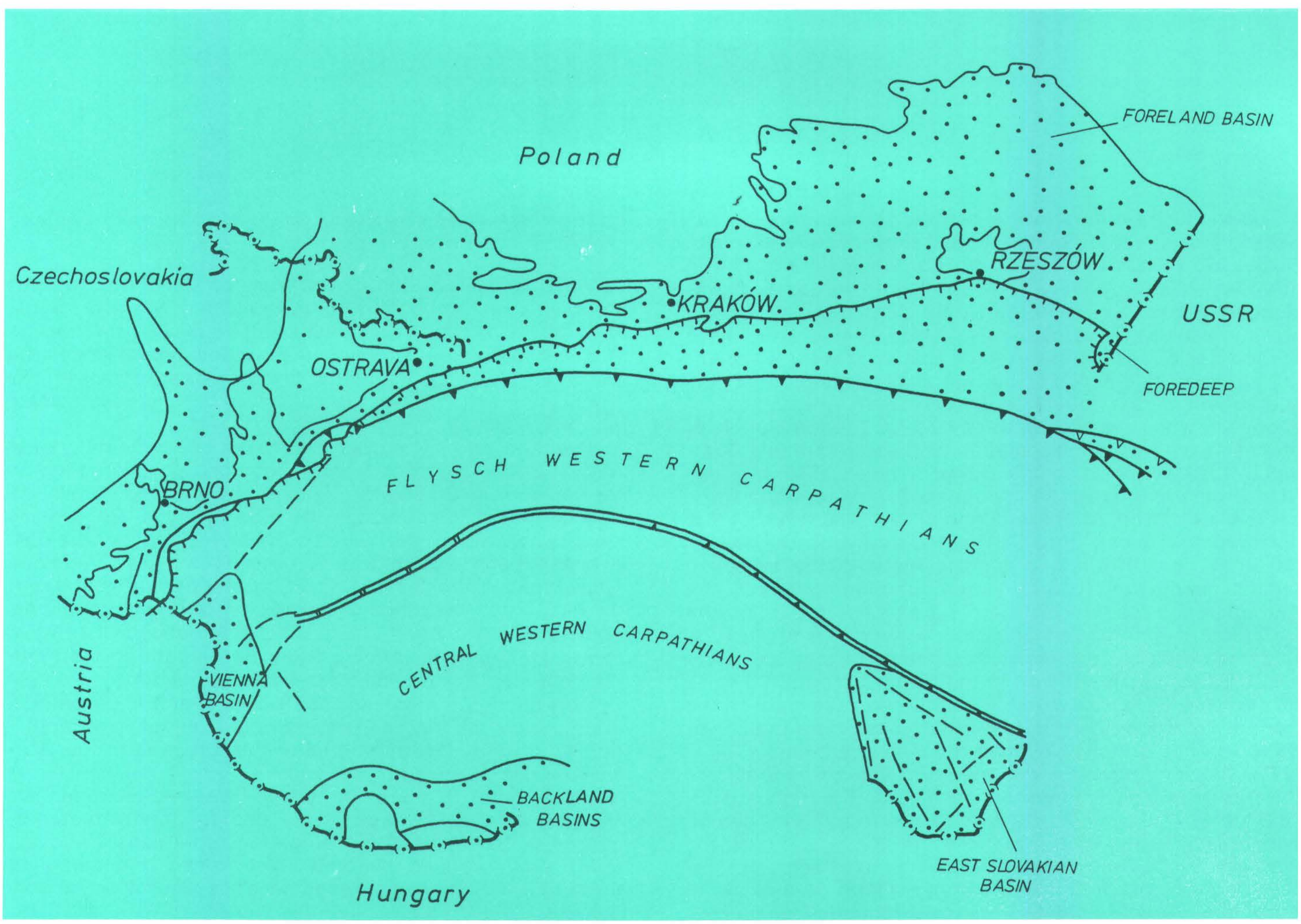
As to the species diversity (of mollusc and other assemblages), the Lower Badenian represents the optimum phase in the evolution of Neogene marine faunas. Benthic faunas are virtually identical with the Lower Karpatian ones.

The evolution of foraminiferal plankton indicates the prevalence of subtropic to tropic climate accompanied by formation of minor reefs even in more northernly situated parts of the Carpathian foredeep.

As to the flora evolution, in the northern part of the Central Paratethys, the period of the last extension of mastixioid floras sets on. Perennially green wood species gradually recede (Bůžek, Kvaček, 1985). In the Middle and Upper Badenian the annual average temperature lowers. The evaluation of conditions of evaporite deposition reveals that it was passing on in mild climate of the Opava region whereas in the Polish part of the foredeep xerophilous elements dominated — the halophyte genus Limnocarpus (Knobloch in Cicha et al. 1975). In the Kosov cooler oscillations prevailed already.

The palynological analysis (Planderová 1978) indicates that a very hot and humid Lower Badenian period in the Middle and Upper Badenian changes into cooler and drier. Warming up is recorded by the end of the Badenian and the onset of the Sarmatian. Warm and humid climate with low occurrence of tropic and subtropic flora species was suitable for coal deposition, e. g. in the area of the Nitra Valley Basin and the western part of the Opava Basin. In the south of the Carpathian foredeep in Moravia the deposition of the so called Brno basal sands and their equivalents was followed by deposition of thin evaporite layers, shortly before another transgression phase accompanied by deepening and "tegl" deposition. Comparing the devel-

Fig. 4: Palinspastic reconstruction of the Western Carpathians during the Lower Badenian.



opment in the front of the Western Carpathian mountain chain with that inside and in the backland area, differences in the Badenian are obvious. In the backland area on the Hungarian territory elements of tropic flora were represented throughout the Badenian, in the intramountain basins tropic elements occurred only in the Lower Badenian, whereas in the front of the Carpathians the Lower Badenian is characterized by elements typical prevailingly only of the subtropic climate. Gradual cooling of the climate from the Lower till the Middle Miocene is probably associated with the Western Carpathians shifting to the N and NE.

Sarmatian

At the and of the Lower Sarmatian, development and sedimentation of the northeastern section of the Western Carpathian foredeep in Poland terminated. The last overthrust of the nappe front on the Lower Sarmatian sediments east of Rzeszow was already influenced by the development of the Eastern Carpathians. In the mountain chain the development of intramountain basins came to the end. The Sarmatian sediments are known from the area of the Vienna Basin, the Danube lowland and the numerous small intramountain basins. In the East Slovakian Basin, where the Lower Sarmatian sediments reach maximum

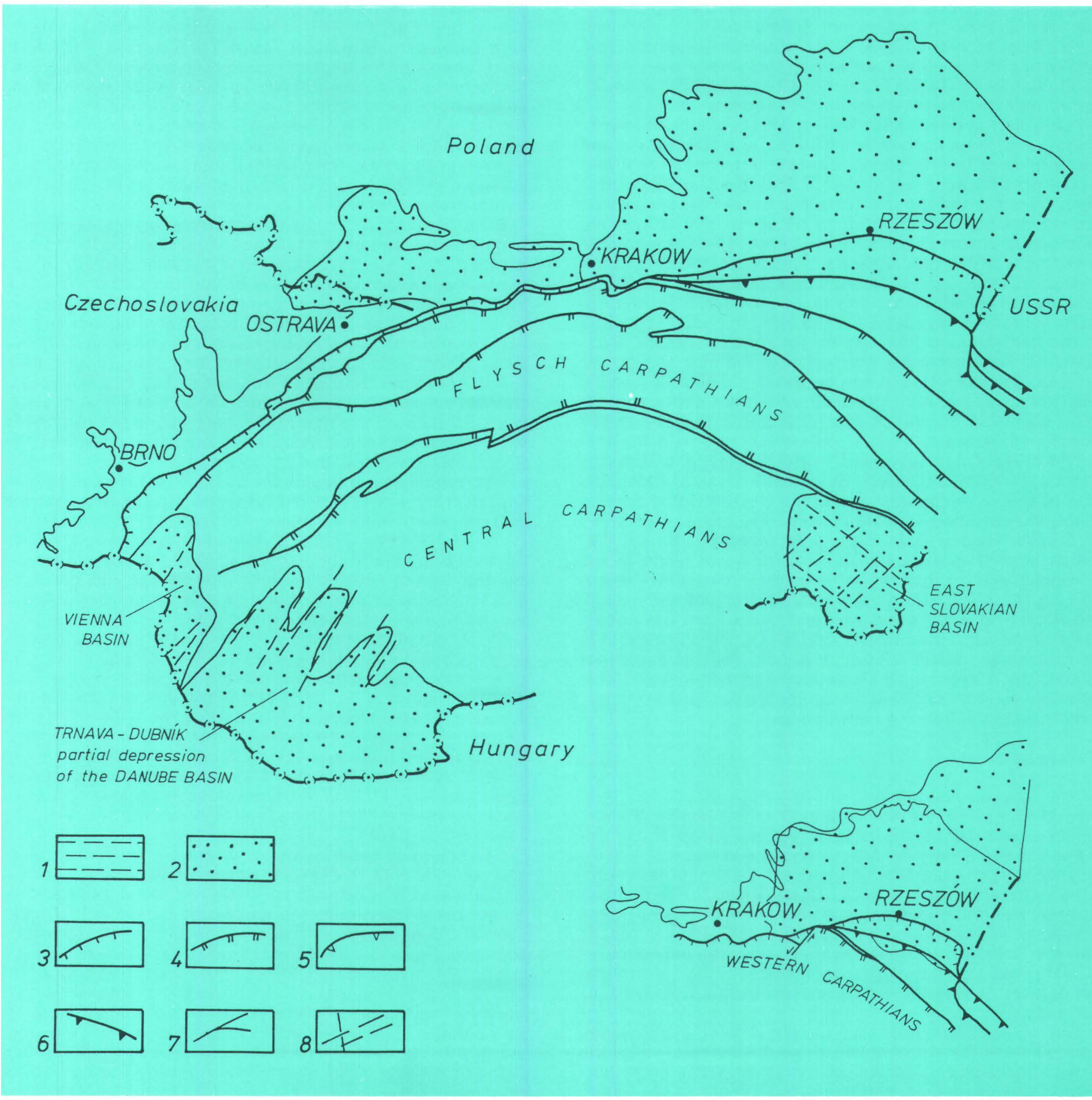


Fig. 5: Palinspastic reconstruction of the Western Carpathians during the Upper Badenian
1 — Flysch sedimentation; 2 — Molasse sedimentation; 3 — Present front of the Western Carpathian nappes; 4 — Passive fronts of individual groups of the Western Carpathian nappes; 5 — Border of folded autochthonous sediments; 6 — Active thrust front of the Western Carpathian nappes; 7 — Boundary of basins (subbasins); 8 — Faults.

Fig. 6: Palinspastic reconstruction of the Western Carpathians during the Sarmatian.

thickness, the centre of deposition moves toward the SE. The axis of the basin was NW-SE oriented, i. e. along the Eastern Carpathian segment.

The Sarmatian flora evolved from that of the Badenian. In Central Europe the environmental differentiation was still more marked. At the beginning of the Sarmatian, the climate had humide, subtropic character, whereas it was much cooler at its upper part. The climate at the end of the Sarmatian becomes drier. At the Sarmatian/Pannonian boundary the climatic conditions were aggravated showing further temperature fall (Planderová 1978).

Upper Miocene — Pliocene

In the Upper Miocene and Pliocene the compression manifestations in the orogene front faded out, the Western Carpathian uplift became slowlier than the Mid-Miocene, the fault activity weakened. Intensive subsidence was focussed in the backland area. The Pannonian region was influenced here by the collapse of the mantle diapir (Stegena et al. 1975, Horváth 1984). The Carpathian intramountain and backland basins in fact formed systems of bays of the Pannonian basin. In the Pontian the basin became more isolated and freshwater environment prevailed.

According to Kovar-Eder 1987, mixed mesophytic forests dominated in the Pannonian while the evergreen trees and conifers were in full retreat. There is no unequivocal evidence on the presence of xerophilous flora of Mediterranean type, nor the steppe or savanna assemblages can be proved. Herbs, on the other hand, were common in the Pannonian. A humid phase with formation of brown-coal seams falls within the Lower Pannonian, i. e. the time of the Hipparion fauna onset. Mild climate free from utterly dry seasons prevailed. According to Kovar-Eder 1985, the extinction of yew-tree species in the Pontian meant reduction of the coal-forming flora. As to the Pontian climate, Planderová (1978) supposes alternation of warmer and cooler periods. Comparatively warm period is indicated by kaolin weathering in southern Slovakia, a humide and warm climate supported formation of coal seams in the Vienna and Gabčíkovo Basins.

The present data obtained from the Pleistocene of the Central Paratethys (Dacian, Rumanian) speak of extension of mesophyte deciduous woods. Phases of global cooling in the Pliocene had their equivalents also in the Rumanian of Central Europe (e. g. Nyssa, Ampelepsis). Boreal elements started to appear. The occurrence of loess of the Rumanian age at Stranzendorf along the margin of the Bohemian Massif signified extremely cool climatic phases in the Alpine-Carpathian arc foreland. Data from the uppermost Rumanian (Reuverian) of the Upper Moravia Vale bring evidence about a humide phase. We can state that namely the Rumanian was characterized by numerous pronounced climatic oscillations signalizing the onset of enormous cooling within the Pleistocene.

Conclusion

The Pyrenean orogenetic movements united the sedimentary areas of the northern part of the Tethys Realm, which was under the influence of a global phase of cool climate. On the Bohemian Massif and the Western Carpathians territory the regional influences did not manifest. Activation of marine regime in the Upper Kiscellian and Lower Egerian was accompanied by prominent warming of global character, without climatic zoning, in the Bohemian Massif and the Western Carpathians. Similarly, the influence of global cooling of the world ocean (Müller 1985) in the Upper Egerian is well documented even in the Western Carpathians.

The onset of temperature optimum in the marine regime observable in the world ocean since the Burdigalian till the Lower Serravallian can be correlated with the Eggenburgian-Middle Badenian temperature optimum in the Western Carpathians. The regional influence of Savian and Styrian orogenetic movements in the Alpine-Carpathian region is documented by the relation between the large Miocene transgressions and their climatic optima. The Eggenburgian transgression caused by the Savian orogenetic movements took place in tropic to subtropic climate. The onset of Styrian orogenetic movements is associated with the Karpatian transgression with a new climatic optimum culminating in the Lower Badenian with regime of subtropic to tropic character.

Unlike the drastic cooling of the world ocean in the Upper Serravallian lasting till the Lower Tortonian (Müller 1985), in the Western Carpathian basins since the Middle Badenian till the Panonnian, the temperature lowers only gradually devoid of distinctive temperature boundaries.

The deposition of evaporites accompanied tectonic activity during the orogenetic movements in the area of the forming orogene of the Western Carpathians. Activation of a marine regime in the sedimentary areas of the Upper Kiscellian and Egerian was in the marginal parts associated with evaporites formation (southern Slovakia, Pouzdřany unit). The separation of the eastern part of the Carpathian foredeep in the Eggenburgian conditioned by Savian orogenetic movements resulted in the deposition of evaporites. Similarly, the Styrian movements in the Karpatian led to isolation of the sedimentary basin with evaporites deposition in eastern Slovakia. The Middle Badenian origin of the evaporites coincides with the culmination of Styrian orogenetic movements.

Disintegration of large sedimentary areas into individual basins by the end of the sedimentary cycles led to coal deposition. This is well documented by disintegration of Eggenburgian sedimentary areas during the Ottnangian (the Eggenburgian-Ottnangian sedimentary cycle) accompanied by coal deposition. The Styrian orogenetic movements initially caused changes in extension and sea ways connections of the Badenian sedimentary area, later, during their disintegration in the Upper Badenian, they caused formation of coal seams in the Western Carpathians. The coal deposition at the Sarmatian/Pannonian boundary associated with formation of a brachyhaline facies, and that at the Pannonian/Pontian boundary had similar reasons.

The orogenetic movements in the Western Carpathian sedimentary areas have the following consequence on the marine environment changes: the anoxic regime in Oligocene basins following the Pyrenean movements, the brachyhaline regime of the Rzehakia sea in the Ottnangian after the Savian orogenetic movements and the onset of a brachyhaline regime in Sarmatian sedimentary areas after the Styrian orogenetic movements.

The Miocene development of the Western Carpathian orogene considerably influenced the morphological division of the mountain chain area. During the Eggenburgian the climatic regime in the front of the orogene still did not differ from that in its backland area. With the onset of Styrian orogenetic movements in the Karpatian the N-S climatic zoning started to be manifested. Since the Badenian zoning caused by the uplift of the Western Carpathian mountain chain, forming a climatic barrier between the sedimentary areas in the front, inside and in the backland of the mountains was expressive.

The sea level changes of the world ocean (Müller 1985) still coincide with the Egerian transgression in the Western Carpathians. Marine regime of the Miocene sedimentary areas was influenced by the orogenetic movements. An expressive Eggenburgian transgression in the Western Carpathians (from the Rhone Basin to the Caspean region) does not correspond to the supposed drop of the world ocean level. A regional isolation and sea regression within the Ottnangian in the Paratethys area is, on the other hand, in the frame of the world ocean manifested by rising sea level (the uplift of the Alpine-Carpathian orogene). Gradual rising of the world ocean sea level from the Burdigalian till the Upper Serravallian can be in the Western Carpathians

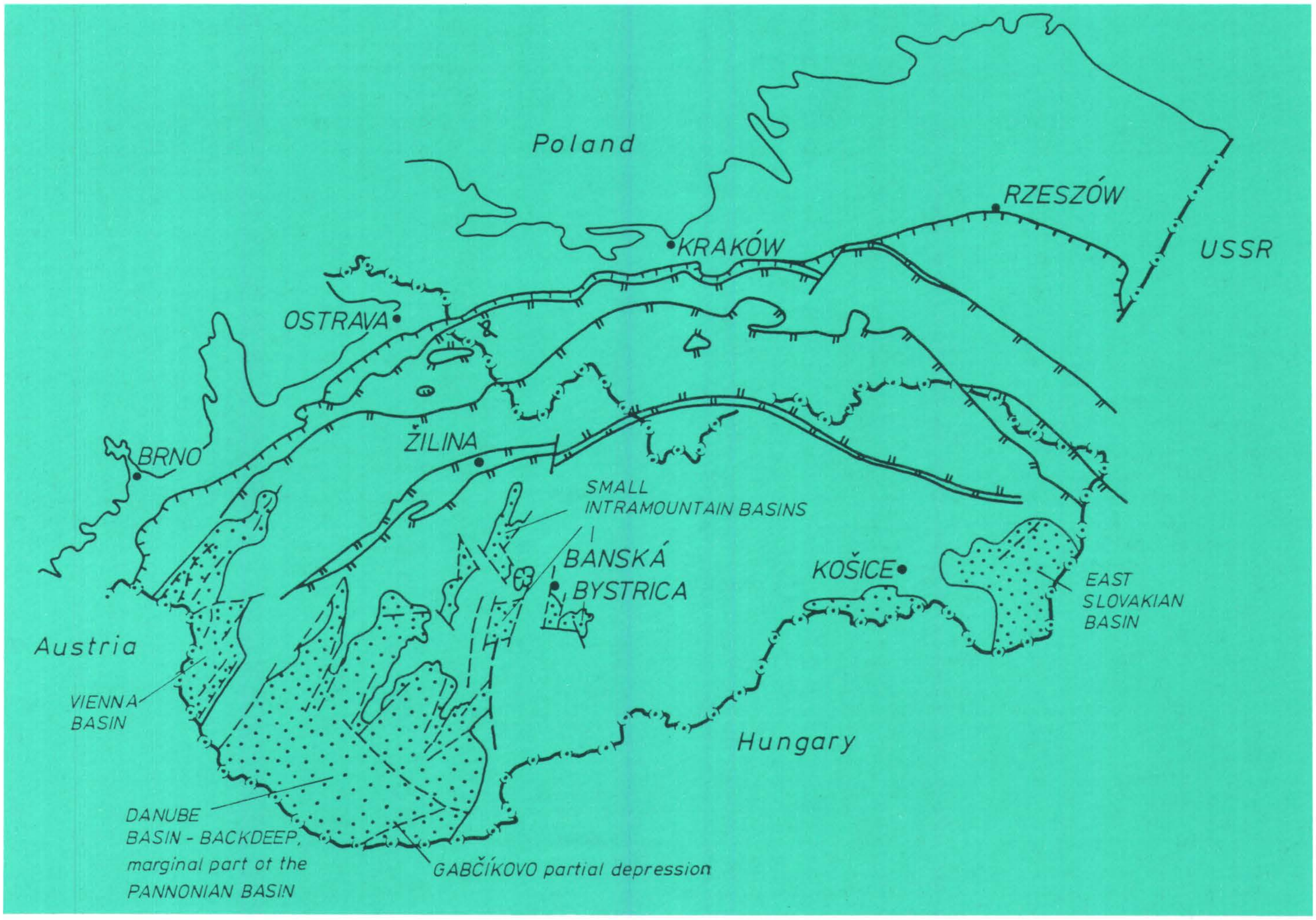


Fig. 7: Palinspastic reconstruction of the Western Carpathians during the Pannonian.

identified with the regional transgressions of the Karpatian and Lower Badenian induced by orogenetic movements. The global drop of the world ocean level in the Upper Serravallian coincides with eustatic changes in the Upper Badenian in the Western Carpathian region. The activation of the world ocean sea regime in the Meotian has its equivalent in the Euxinic-Caspean region.

The sedimentary record of the Western Carpathians Neogene shows, besides the global changes, also a large number of regional ones. The changes reflect the geodynamics of the orogene. The global changes took place especially in the earlier period of orogene development, while the role of regional changes increased in the later period of mountain chain formation.

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Abstrakt

Pyrenejské horotvorné pohyby sjednotily sedimentační prostory v severní části tethydní oblasti, která byla pod vlivem globální fáze chladného klimatu. Na území Českého masívu a Západních Karpat se v oligocénu neuplatnily regionální vlivy.

Nástup teplotního optima v mořském režimu, pozorovatelný od burdigalu do staršího serravallu ve světovém oceánu, můžeme korelovat s teplotním optimem eggenburg—střední baden v Záp. Karpatech. Regionální vliv sávských a štýrských horotvorných pohybů v alpsko-karpatské oblasti dokládá vztah velkých miocenních transgresí a jejich klimatických optim.

Na rozdíl od výrazného ochlazení světového oceánu v mladším serravallu, trvajícího do staršího tortonu, sledujeme v pánvích Západních Karpat od středního badenu do panonu jen postupné ochlazování, bez výrazných teplotních rozhraní.

Důsledkem horotvorných pohybů v Západních Karpatech byly: anoxický režim oligocenních pánví po doznění pyrenejských pohybů, brachyhalinní režim rzehakiového moře v ottnangu po doznění sávských horotvorných pohybů a nástup brachyhalinního režimu sarmatských sedimentačních prostorů po ukončení štýrských horotvorných pohybů.

V eggenburgu se ještě klimatický režim čela orogénu neliší od jeho týlových částí. S nástupem štýrských horotvorných pohybů v karpatu začíná S-J zonace, která je už v badenu velmi výrazná.

Zusammenfassung

Durch die pyrenäischen gebirgsbildenden Bewegungen wurden Sedimentationsräume im Nordteil der Tethys vereinigt, die von einer globalen kalten Klimaperiode beeinflußt wurden. Im Bereich der Böhmischen Masse und der Westkarpaten kamen im Oligozän keine regionalen Einflüsse zum Vorschein.

Der Beginn des Temperaturoptimums im marinen Regime, das vom Burdigal bis zum älteren Serravall im Weltozean zu beobachten ist, kann mit dem Temperaturoptimum vom Eggenburg bis zum mittleren Baden in den Westkarpaten korreliert werden. Der regionale Einfluß der savischen und steirischen gebirgsbildenden Bewegungen im Alpen-Karpaten-Bereich wird durch die Beziehung großer miozäner Transgressionen zu den Klimaoptima bezeugt.

Zum Unterschied von einer ausgeprägten Erkaltung des Weltozeans im jüngeren Serravall, die bis zum älteren Torton andauerte, ist in den westkarpatischen Becken vom mittleren Baden bis zum Pannon nur eine allmähliche Erkaltung, ohne einen ausgeprägten Temperaturwechsel, zu verzeichnen.

Die gebirgsbildenden Bewegungen in den Westkarpaten hatten ein sauerstoffarmes Regime in den Oligozänbecken nach dem Abklingen der pyrenäischen Bewegungen, ein brachyhalines Regime im Rzehakia-Meer im Ottnang nach dem Abklingen der savischen Bewegungen und den Beginn eines brachyhalinen Regimes in den sarmatischen Sedimentationsräumen nach dem Abschluß der steirischen Bewegungen zur Folge.

Im Eggenburg unterschied sich das Klimaregime der Orogenfront noch nicht von dem der Rückteile des Orogens. Mit dem Beginn der steirischen gebirgsbildenden Bewegungen im Karpat begann eine nördlich-südliche Zonenanordnung, die im Baden bereits sehr ausgeprägt war.

THE AUTOCHTHONOUS MESOZOIC ON THE EASTERN FLANK OF THE BOHEMIAN MASSIF — AN OBJECT OF MUTUAL GEOLOGICAL EFFORTS BETWEEN AUSTRIA AND ČSSR

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Introduction

The exploration of the Autochthonous Mesozoic along the Eastern flank of the Bohemian Massif led to contacts between ÖMV and ÚÚG Praha and later MND Hodonín as well as Geofyzika Brno in order to investigate the stratigraphy, paleogeography and structure of this geological unit, which was unknown until the early sixties.

It became evident soon, that the encountered Pretertiary deposits on both sides of the state boundaries belong to the same basin and form nearly the same vertical and horizontal sequences. The industrial results of the exploration in the basement of the foredeep and of the frontal part of the Alpine-Carpathian nappes are manifested by the discoveries of Dolní Dunajovice, Pottenhofen, Roseldorf, Höflein etc. Up to this activity only the outer, western part of an area prospective for hydrocarbons has been explored. There is to be expected, that in case of more apt economical situation for the future the exploration will advance into deeper positions, where larger accumulations of hydrocarbons may be possible because of more favourable maturity conditions of a very potential source rock.

The results of deep wells in the Carpathian frontal areas (for example Němčičky 1, Sedlec 1, Falkenstein 1) as well as in underground of the Vienna basin (Zistersdorf ÜT2, Maustrenk ÜT1, Aderklaa ÜT1) give evidence of the importance of a further cooperation.

1. History of exploration and investigation

Before the Autochthonous Mesozoic was explored by wells indications of a Jurassic-Cretaceous basin on the southeastern flank of the Bohemian Massif already existed in form of Jurassic carbonates in the vicinity of Brno (Eliáš 1962) and of klippen tectonically shorn off from this basin

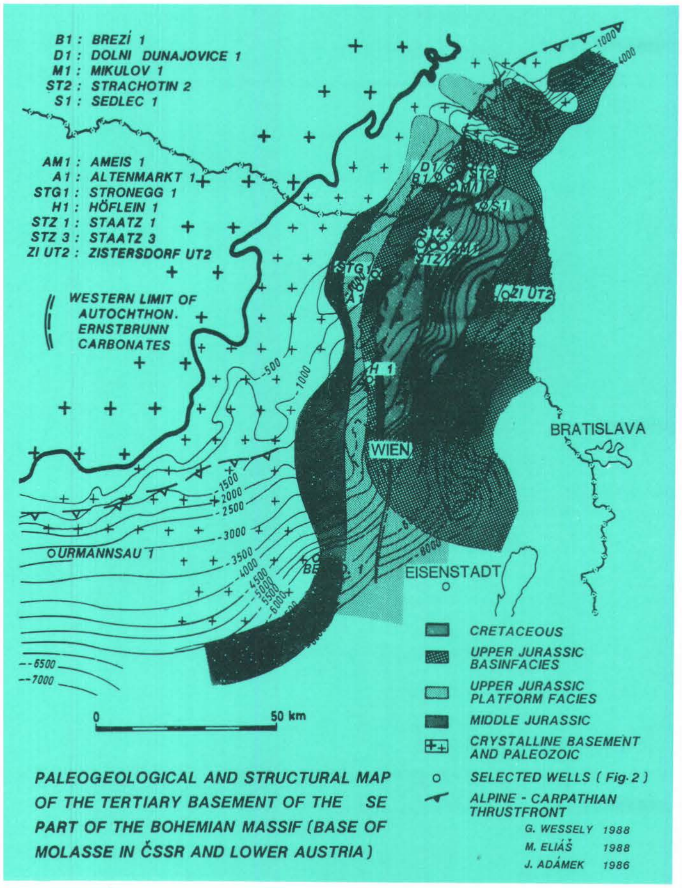


Fig. 1.

by the Carpathian external nappes. These klippen consist of Klentnitz beds (Abel 1899, Jüttner 1933), Ernstbrunn limestones (Boué 1829) and Klement beds (Glaessner 1931).

The carbonate platform of this basin was encountered in continuation of the Brno Jurassic in the fourties and early fifties (Pasohlávky 1, Novosedly 1, Hrušovany 1). But these wells documented only partial sections of the platform facies.

The first step of major importance for the knowledge of the Autochthonous Mesozoic sedimentary cover of the Bohemian Massif was made 1959 by the well Staatz 1, which exposed a continuous sequence of upper Cretaceous, Malmian in a thick mainly pelitic basin development and Dogger with its delta sediments (G. Wessely 1988). A whole series of wells in Austria and ČSSR were necessary until the extension, vertical sequences, facial distributions and thicknesses of this sedimentary basin could be established (fig.1,2).

A new dimension arose in exploring the Pretertiary basement of the Molasse below the Carpathian external zone and finally in the deepest underground section of the Vienna basin.

The step downwards into this deepest autochthonous etage of the Vienna basin was done by the wells Zistersdorf ÜT1a, ÜT2A, Maustrenk ÜT1a and Aderklaa ÜT1a in the period of 1977–1987. Depths from 6560–8553 m were reached (G. Wessely 1984, 1988).

The geological result of this deep exploration gave an important contribution to the reconstruction of the Western Carpathian-Eastern Alpine belt. The continuation and enlarging subsidence of these Mesozoic layers far towards the East were confirmed (fig.1). By following the Autochthonous Mesozoic towards the South under the Eastern Alps, the well Mauerbach 1 was drilled and finally the gas-condensate field Höflein was discovered.

In the ČSSR the exploration activity in Dolní Dunajovice, Nové Mlýny, Sedlec, Němčičky and Uhřice brought a substantial contribution to the knowledge of Autochthonous Mesozoic in northern and northeastern direction.

The history of investigation may be divided in several phases. At the beginning ideas of the stratigraphic identifications and subdvisions were developed separately in Austria (J. Kapounek, A. Kröll, A. Papp, K. Turnovsky 1967) and ČSSR (Eliáš 1971).

An intensification of exchange of experiences began with a meeting of experts in May 1971 in Bratislava. For this meeting new stratigraphic concepts had been prepared on the base of cores, cutting strips and logs. An agreement was found concerning lithostratigraphy and diverging opinions of Austrian and ČSSR paleontologists about the age of the Malmian basin marls (the former was located by ÖMV into the Lower Cretaceous on the base of foraminifera).

A series of meetings of the competent specialists of ÖMV and ÚÚG-Praha brought a final correlation of all lithostratigraphic units. The paleontologic criteria were ammonites, defined by Z. Vašiček (ČSSR) and L. Krystyn (Austria). Beside these macrofossils, pollen and nannofossils brought a useful support for the correlation. Documentations of microfacies were completed especially by the ČSSR side and led to the establishment of a series of formations in the Dogger and Malmian (Eliáš 1977).

In order to keep open the possibility of differentiation and typifying facial variations in the stratigraphic sections a neutral lithological nomenclature was further used in Austria (G. Wessely in F. Brix et al. 1977). Classical terms were taken as comprehensive definitions.

A complete compilation and comparision of all terms, separated for all facial complexes was made by J. Adámek, 1986. Later the attention for further investigations in the autochthonous basement of the Molasse has been shifted to structural and paleogeographic questions in connection with the exploration for hydrocarbons and therefore the cooperation took place between ÖMV and MND Hodonín as well as Geofyzika Brno. Structural maps, seismic sections and well-logs were compared. New results as well as core material of deep wells were always exchanged and led to a uniform picture necessary as starting point for further exploration.

2. Recent stage of investigation in stratigraphy and facies

The data obtained by wells in both countries enabled to point out a general picture of the Autochthonous Mesozoic complex (figs. 2,3).

Upon the Hercynian basement (Devonian-Lower Carboniferous and partly Permo-Carboniferous sediments) rests unconformably a deltaic series of Dogger sediments, subsumed by the superior term „Gresten beds". The full facial variety in different tectonical settings influencing the thickness and lithology is clearly visible in the Austrian territory. Facies depends on the one hand on the position within the deltaic complex, on the other hand on the position within a synsedimentary tilted fault block system. In the subsided parts of the fault blocks large thicknesses (up to 1000 m) are observed in contrary to reduced thicknesses on elevated positions (about 100 m). The subdivisions of lithological groups, environments, directions of sedimentation etc. are object of a recent study. Until its result the term „Gresten group" should be used. The basal transgressive member „Untere Quarzarenitserie" consists of ?Aalenian arkoses, quartz-arenites containing intercalations of coaly shales and coals. Traces of roots point to a sedimentation in a continental part of the delta system. In prodeltaic positions and in areas of larger subsidence an intercalation of Bajocian dark shales appears („Untere Tonsteinserie"). It seperates the lower continental from a marine deltaic series of sandstones with shaly intercalations, the „Obere Quarzarenitserie" relating to the Upper Bajocian. The deltaic sequence is finally overlain by a further prodeltaic horizon of shales, the „Obere Tonsteinserie" of Bathonian age. In littoral positions the shales are replaced by glauconitic or

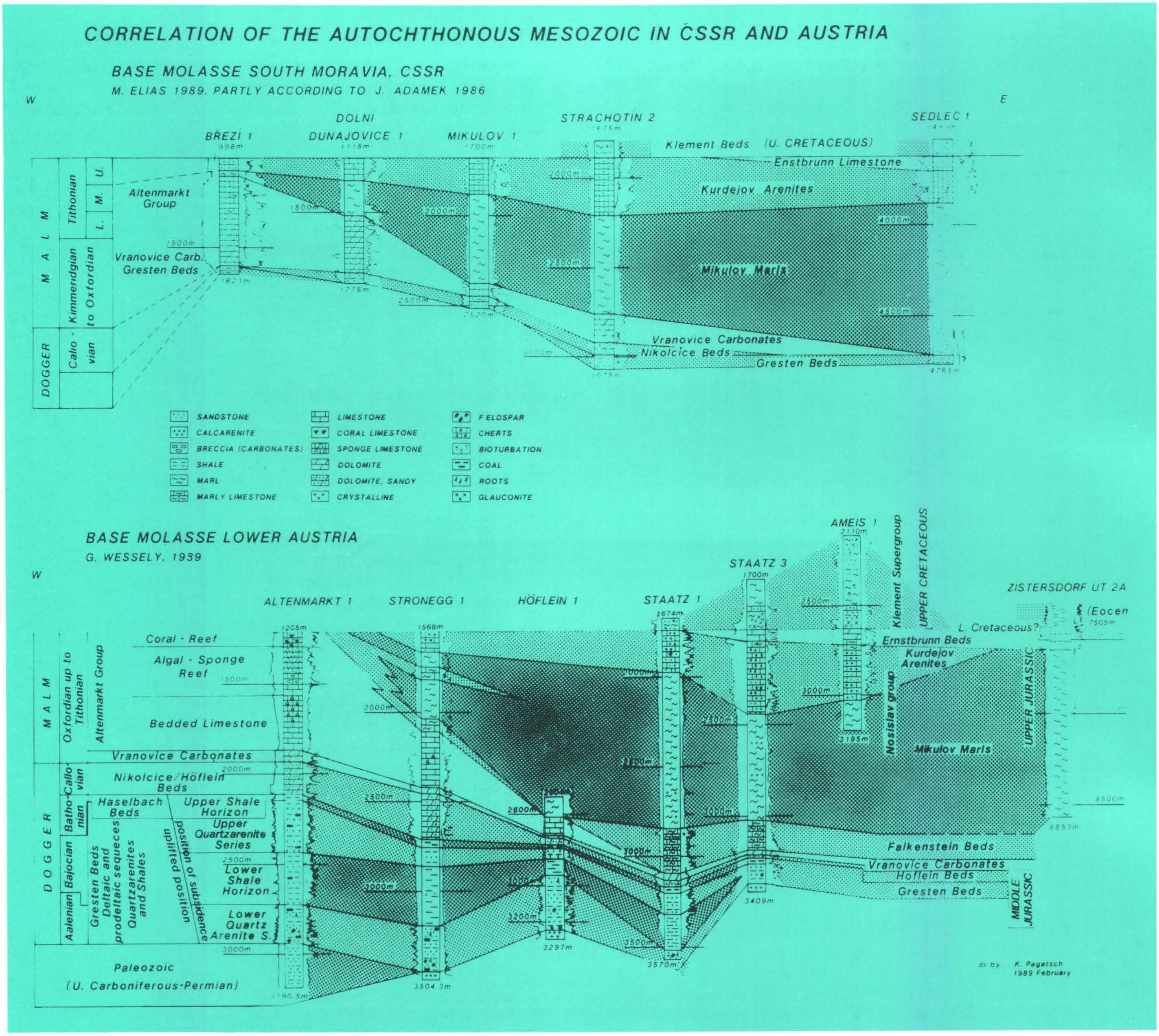


Fig. 2.

phosphorite bearing sandy beds (Haselbach, Höflein). These will find its nomenclatoric consequences in near future. A correlation to equivalent sediments in CSSR is to be found. In that context, after Adámek, 1986, the relevance of the term „Diváky beds" and „Bořetice beds" established 1971 by M. Eliáš, should be revised. Bořetice beds are proofed to be Lower Carboniferous according to the finds of trilobites.

In Callovian time starts a new and unique cycle (as a result of the global eustatic cycle). It is marked by unconformable superpositions on former tectonics and even sediments. The basal beds of this cycle are characterized by a beginning carbonatic influence of the extinguishing terrigenous sedimentation and are well defined by the term „Nikolčice beds" in ČSSR, in Austria represented by „Dolomitische Quarzarenitserie". Thickness range between 70–300 m. A facies differentiation of these deposits was described by Eliáš (1981). Obviously the specific development of Höflein (R. Sauer, 1984) requires an additional definition.

The Malmian complex of sedimentation is generally to be divided into an area of a throughgoing marginal carbonatic platform in the west and an area of mainly basinal development in the east, only near the bottom and on top replaced by platform carbonates and wedges of carbonate clastics.

Before the facial division takes place in Oxfordian time an overall carbonatic, mostly dolomitized member covers the Nikolčice beds in a restricted thickness towards east (some tens of meters). It is well defined with the term „Vranovice beds" corresponding to „Untere Karbonatserie" in Austria.

The starting carbonate platform on top of these lower carbonates in the western marginal area was first investigated and documented as a continuous series by W. Ladwein, 1976 („Altenmarkt beds"). The 750 m thick sequence begins with bedded limestones partly cherty, upwards grading into bioclastic limestones. These are overlain by algal-sponge-and finally coral patch-reefs. Laterally reef complexes may be replaced by oolitic-bioclastic series. The large facial variety within the platform complex may result in different local formations as „Pasohlávky limestones", „Novosedly" and „Hrušovany" limestones and dolomites, „Iváň"-beds and presumable further more.

The carbonate facies is fringed basinward by 150 m, max.

400 m thick marly limestones („Mergelkalkserie") with an upwards rising marly content and with intercalated slope clastics. The age of this member is running through the whole Malmian stages according to its updip replacement of successive older and younger sediments. According to lithology and logshape it is clear to be identified and it is proposed to separate it from the proper basin facies by a new formation name — „Falkenstein formation".

The basinal development of the Malm is represented by dark marls, which laterally replace the platform facies respectively its slope deposits. The age of these marls is Kimmeridge (in ČSSR Oxford) to lower Tithonian. The member in Austria called „Mergelsteinserie" is well defined by the formation term „Mikulov marls". Their thickness, often tectonically enlarged by duplications ranges at 500 m and exceeds in some cases 1000 m.

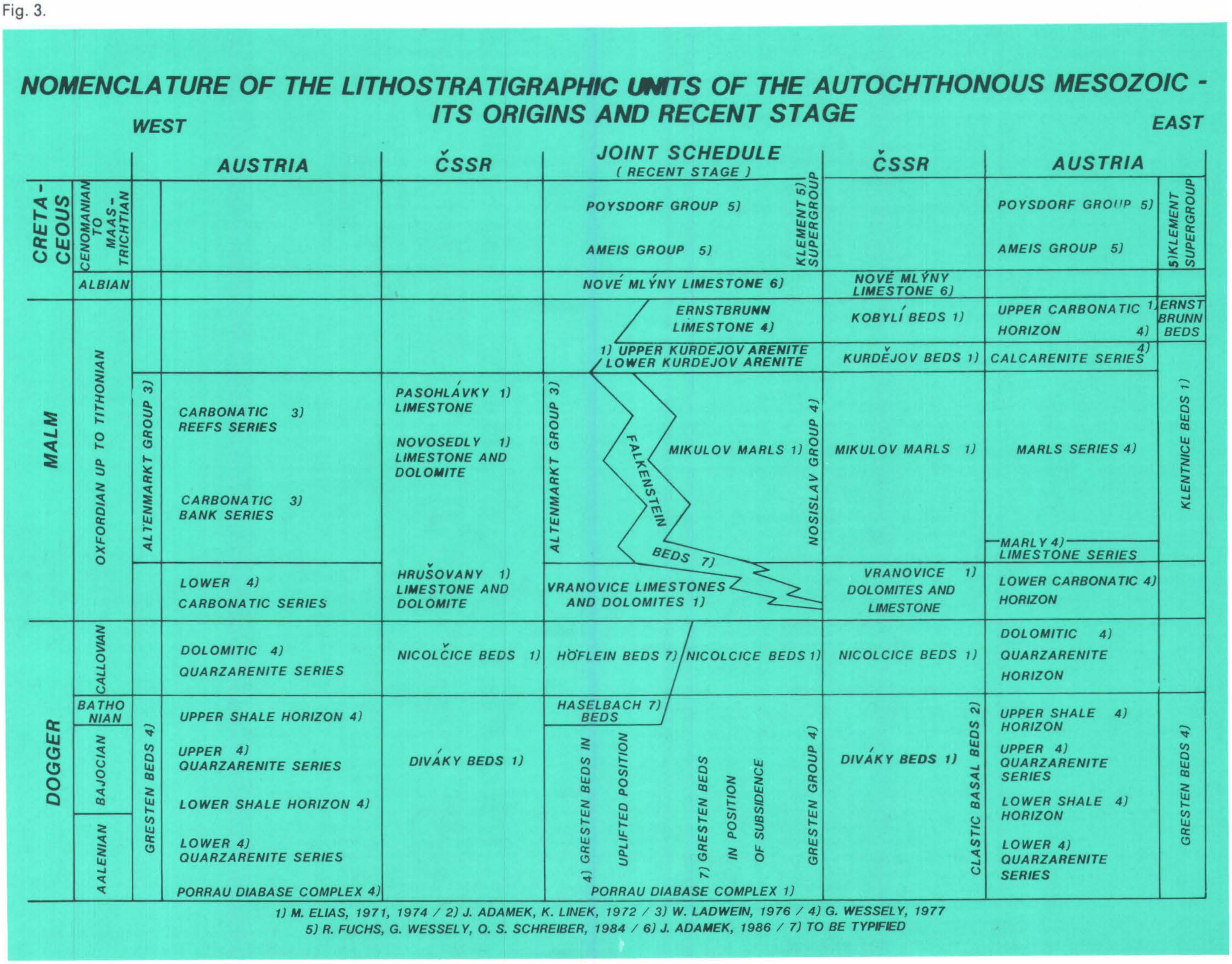
During the Upper Tithonian the basin got shallower again manifested by a basinward progradation of upward coarsening terrigenous and bioclastic carbonates. These up to 400 m thick, generally dark deposits developed by an upward transition from the Mikulov marls and show in some portions further marly influence. According to its detrital character these sediments were defined as „Kalkarenitserie" in Austria. The formation name is „Kurdějov limestone", after Eliáš, 1971. There can be distinguished a lower part with fine-grained carbonatic quartz sandstones from an upper part with upwards coarsening carbonate detritus. It is therefore proposed to change the term „Kurdějov limestones" into „Kurdějov arenites" and to divide these into „Lower" and „Upper Kurdějov arenites". The bulk of basin facies formations may be subsumed under the term „Nosislav group".

The regression within the Uppermost Tithonian resulted in a development of a new Upper Tithonian carbonatic platform perhaps covering the whole basin but preserved only in more eastern parts of it. The carbonate platform consists of many types of carbonatic environments, which as in the klippen of the external Carpathian nappes we subsumed as „Ernstbrunn beds". Similarities in lithofacies and in basal development of this member in boreholes and on surface suggest to use a uniform term for the carbonates in the autochthonous and allochthonous position. The names „Obere Karbonatserie" and „Kobyly limestones and dolomites" are therefore not necessary.

Lower Cretaceous seemed for a long time to be missing, until Upper Albian was reported at first by Krystek, I., Samuel, O., 1978 and than from the well Nove Mlýny 2 by Řehánek 1983, 1984. These „Oncoidic limestones" were defined as „Nové Mlýny limestones" by J. Adámek 1985 (published 1986). Possibly the whole part of the carbonatic section in Zistersdorf ÜT2A does not belong to the Ernstbrunn beds, the higher part shows boulders of mixed carbonates of the Ernstbrunn type in a carbonatic matrix. But no relevant indications for Cretaceous were found.

The Upper Cretaceous has been encountered by a large number of wells. But there are especially two of them, Ameis 1 and Poysdorf 2 which allow to establish a combined section from Cenomanian to Maastrichtian. It con-

Fig. 3.



tains marine glauconitic marls, sandy marls and at the Turonian/Coniacian boundary zone a horizon of sandy limestones. The whole section is subsumed under the term „Klement super group" and is to be divided into an Ameis group (Cenomanian to Santonian) and a Poysdorf group (Campanian to Maastrichtian) (R. Fuchs and G. Wessely 1977).

The unique situation of an existing Mesozoic basin crossing the Austrian — Czechoslovakian border requires a common nomenclature which stands for stratigraphic units well defined by a representative occurrence on surface or in boreholes and by representative paleontologic, micro- and macrofacial, bio-and lithostratigraphic characteristics. The structure of nomenclature should be open for further infillings or additions if future investigations lead to the necessity for that. A summary of the existing terms and their validity is presented by J. Adámek 1986. In the following there is shown a compilation of the different terms to one at that time valid joint schedule (fig.3).

3. Paleogeographic and structural results

Wells and seismic data brought a general view of the distribution of the different members and facial complexes of the Autochthonous Mesozoic.

The arrangement of the formations under Molasse along the southern flank of the Bohemian Massif (fig.1) is different in ČSSR and in Austria.

In Austria a uniform succession from W to E is to be seen with a rim of Dogger deltaic sediments, followed by platform carbonates and finally basin development of the Malm. The western limit of the latest carbonatic development (Ernstbrunn beds) can be traced only along a short extension. A not everywhere preserved Upper Cretaceous cover is restricted to the more eastern area of the Jurassic complex and rests unconformably over its substratum.

In the northernmost part of Lower Austria the Malmian western platform zone seems to cover the margin of the Dogger and to rest directly upon the basement. The arrangement of the sediments in Czechoslovakia in the border zone with Austria is similar, but towards the north it is stronger influenced by tectonical and erosional affects especially in the area of the „Vranovice" and „Nesvačilka" graben (Adámek 1965, plate 8). The Upper Cretaceous is restricted to the southern part of Czechoslovakia. The less importance of the areal extent of the Dogger in comparison to Austria is due to a more expressed and thicker development of a deltaic system in Austria.

The internal geometry of the Autochthonous Mesozoic mantle is devided into a Precallovian and a Postcallovian part formed within two different cycles. The first one is characterized by a stronge differentiation in sedimentation, thickness of deposits, mainly caused by synsedimentary tectonics. In Austria halfgrabens probably caused by inner Alpine-Carpathian rifting events contain a thick sedimentary infill in their subsided positions and a thin developed one on their uplifted parts. The Callovian seals this tectonic sedimentary conditions and initiate a second cycle with tectonically more uniform sucessions where the main dominant feature is the boundary of the marginal carbonatic platform to the eastward thickening basin facies in the Malm. The different, mainly postmesozoic tectonics are object of specific regional geological and geophysical investigations in combination with the search for trapping positions of hydrocarbons.

4. Aspects of investigations for the exploration of hydrocarbons

The exploration of hydrocarbons has to be based on a broad spectrum of knowledge about reservoir rocks, source rocks, maturity of sediments, structural possibilities for trapping. The ambiguous exchange of information enables both sides to get a maximum of information to diminish risks and costs especially with respect to very deep targets.

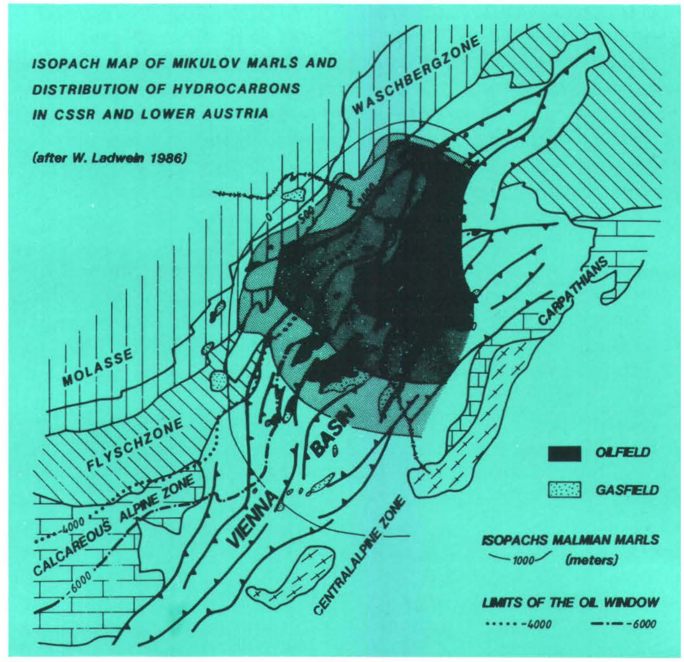


Fig. 4

Reservoir rocks are to be found in deltaic sequences of the Dogger (Klement, Höflein), in sandy dolomites with cherts in the uppermost Dogger (Höflein), in carbonates of the platform facies (Roseldorf) and in calcarenites, partly dolomitized of the Kurdějov beds (D. Dunajovice, Pottenhofen). Possibly Mikulov marls can have reservoir properties if they are fractured by effects associated with hydrocarbon genesis causing high pressure (W. Ladwein). A large thickness of the layer would be necessary in this case (Zistersdorf ÜT2a).

The information on rock thicknesses in both countries led to a construction of an isopach map of the Mikulov marls, the most important source rock of the Autochthonous Mesozoic mantle because of its high content in organic matter (Ladwein, 1988) and its large volume. The thickness exceeds in the deepest parts 1000 m (fig. 4). The history of subsidence and the thermal history of the Jurassic basin lead to the conclusion, that a large amount of hydrocarbons must have been generated. Even if the amount of hydrocarbons, migrated and accumulated in the Vienna basin, is substracted from this volume, large possibilities remain in the lowermost section of the Vienna basin and underneath the external zones of the Alpine-Carpathian nappes. Additionally prodeltaic shales of the Dogger may act as source rocks.

Experiences in structural possibilities for trapping are important for exploring the Autochthonous Mesozoic plays: updoming, blockfaulting, upthrusting, onlapping, pinchout, facial changing in carbonate complexes (reefs, dolomitisations, karstifications) and possibly thick fractured complexes of marls.

All these features have been realized already in this tectonic—sedimentary environment and give chance for future exploration.

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Abstrakt

Ropařské vrty provedené v Rakousku a v ČSSR v oblastech karpatské a alpské předhlubně (molasy), flyšového pásma a vídeňské pánve přinesly důkazy, že krystalinikum a paleozoikum na jv. svazích Českého masívu pokrývají uloženiny mezozoika. Výskyty téměř identických litologických a stratigrafických jednotek v Rakousku a Československu po obou stranách státní hranice podmínily stálou spolupráci při jejich výzkumu. Společný výzkum se soustředil na definování a doložení nejdůležitějších litostratigrafických jednotek. Přiložené tabulky dokumentují současný stav výzkumů. Podáváme přehled paleogeografických a strukturních poměrů. Uvádíme dosavadní výsledky detekce uhlovodíků a možné aspekty jejich vyhledávání ve vztahu ke kolektorským, zdrojovým a strukturním podmínkám.

Zusammenfassung

Bohrungen für Kohlenwasserstofferkundung in Österreich und der ČSSR haben den Nachweis eines autochthonen mesozoischen Sedimentmantels an der Ostflanke des Kristallin-Paläozoikumspornes der Böhmischen Masse unter Molasse, unter der alpin-karpatischen Externzone und unter dem Wiener Becken erbracht. Die nahezu identischen stratigraphisch-faziellen Einheiten beiderseits der Grenze bedingten eine kontinuierliche Kooperation beider Länder. Es wurden die wichtigsten dieser Einheiten stratigraphisch definiert und dokumentiert. Der neueste Stand dieser Gliederung wurde in einem gemeinsamen Schema dargestellt.

Ebenso werden die paläogeographischen und strukturellen Ergebnisse übersichtsmäßig wiedergegeben. Die Ergebnisse der Kohlenwasserstofferkundung und die künftigen Aspekte werden im Zusammenhang mit Speicher- und Muttergesteinsfragen sowie den strukturellen Gegebenheiten erörtert.

PALEOGEOGRAPHY AND STRATIGRAPHY OF THE AUTOCHTHONOUS PALEOGENE ON THE SOUTHEASTERN FLANK OF THE BOHEMIAN MASSIF

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The Nesvačilka and Vranovice canyons, filled with autochthonous Paleogene sediments, were discovered in the south Moravian part of the Bohemian Massif in the late sixties. Natural gas was found in Paleogene sandstones in the early eighties, which put this formation into the centre of attention of the Moravian Oil company. In this region, the author (R. Jiříček, 1981, 1986) studied the stratigraphic and facies division of sediments in relation to gradually transgression and troughs evolution. Autochtonous Paleogene rocks were identified in 42 boreholes from which 233 cores and some cuttings correlated by means of electric logging (Table 1) were recovered for lithological and micropaleontological purposes. Seismic sections were used not until in the paper presented that gives more precission to previous results. For some of the boreholes, the presumed autochthonous Paleogene rocks were placed into the autochthonous Eggenburgian or into the overthrusted Nikolčice Unit of the parautochthone.

1. The age of the autochthonous Paleogene is seen individually. Originally, the Paleogene sediments of Arta-H2 borehole were classified as Aquitanian to Burdigalian (K. Friedl, 1937). Later they were assigned, together with the equal layers of the adjoining Brno-1 borehole, to the Lower Oligocene (M. Dlabač, 1946,; R. Grill, 1947). In accordance with the bethos foraminifers present, they were determine as ranging from the Upper Eocene to the Lower Oligocene or Rupelian in Nesvačilka-1 borehole (M. Holzknecht, in V. Homola et al., 1961). The occurence of Nummulites and Discocyclines at Uhřice placed them into the Middle Eocene (E. Benešová, 1969). J. Krhovský (1988) basing on a revision of the benthos forams, concluded, after all, that age was Paleocene to Oligocene.

According to the author (R. Jiříček, 1986), the problem of disagreement consist in the fact that the abundant benthos fauna is of deepwater nature similar to that of the Upper Eocene to Lower Oligocene faunas of eastern Europe reported by M. Holzknecht (1961), but that is also resembles Paleocene faunas of western Europe, described under other species names, by J. Krhovský (1988). The occurrence of Eocene age, indicates the possible survival of a large part of the faunas from the Paleocene to the Eocene. Typical faunas including Bulimina parisiensis („B. trigonalis") extend from Lower Eocene into Paleocene pelites. In addition, a number of mollusc faunas are present there that resemble those in the Lower Oligocene Pouzdřany Unit not altered throughout the Paleogene. For this reason, the upper part of the Paleogene seems to be composed of Upper Eocene perhaps to Lower Oligocene sediments linking up with the primary molasse extending from the Perialpine region into southern Moravia (R. Jiříček, 1981). The lower part of the Paleogene is regarded as Middle and Lower Eocene and Paleocene (M. Holzknecht—J. Krhovský, 1988; B. Hamršmíd, 1988).

2. The determination of the internal stratigraphy of the autochthonous Paleogene was equally difficult as that of the age of the sediments. On the basis of well cores, V. Homola et all. (1961) identified several horizont; a few of them could be correlated with the aid of electric logs to the closest proximity of the Nesvačilka boreholes (F. Němec, 1973), but not to regions more distant. Presently the clastic Těšany formation, westwards replaced by darkgrey claystones of the Lower Nesvačilka Member, can be identified in the centre of the Nesvačilka canyon. The two units are covered by grey-green claystones of the Upper Nesvačilka Member. Brown Uhřice marls, present mainly near Uhřice, have developed in the terminal part. Black bituminous Vranovice claystones, divided into several subhorizons in conformance with the results of GK and RAG logging, have been racognized throughout the cross section (R. Jiříček, 1986)

Age		Vranovice canyon	Nikolčice ridge	Nesvačilka canyon	
EOCENE	Upper	Vranovice claystones	Vranovice claystones	Uhřice marls	
	Middle				
	Lower			Upper Nesvačilka clayst.	
Paleocene		?	—	Lower Nesvačilka claystones	Těšany clastic Formation

The biostratigraphic division of the Paleogene into several foraminiferal horizons for Nesvačilka-1 borehole (M. Holzknecht, 1961) could not be applied to other boreholes. Later, when comparing the forams and ostracods from the two canyons, several regional horizons could be defined (R. Jiříček, 1981, 1986). The nanoplankton zones NP 1—20 of the Paleocene to the Upper Eocene were defined in the Nesvačilka canyon (B. Hamršmíd, in the press). However, their correlation pose many problems in the boreholes. That is why we can adjust the original biostratigraphy of forams to the Paleogene stages in the following table:

Age	Zones	Horizons
Upper Eocene	Bolivina aenariensis-Bolivina fastigia	Uvigerina costellata Uvigerina jacksonensis Uvigerina (cut-off shells) Globigerapsis index
Middle Eocene	Uvigerina hantkeni	Bulimina rugirefa Discocyclina-Nummulites
Lower Eocene	Bulimina parisiensis-Bulimina rugifera	four fluctuation of both Bulimina species
Upper Paleocene	Bolivinopsis spectabilis	Bulimina parisiensis-rugifera Höglundina — Gyroidina Bulimina rugifera — Clavulina—Plectina Trochammina pacifica

The correlation of the Vranovice and Ždánice (Uhřice boreholes) Paleogene is easy to be made, but it is problematic with respect to the centre of the Nesvačilka canyon.

The Upper Paleocene of M. Holzknecht — J. Krhovský (1988) can we correlated with the biozone of Bolivinopsis spectabilis of R. Jiříček (1986). In the centre of the Nesvačilka canyon, it comprises the Těšany clastic formation, up to 500 m thick, grading into Lower Nesvačilka claystones. The basal levels of the Trochammina pacifica horizon are typical of zone A in the electric-log division. The middle levels comprise a horizon with Plectina apicularis-Bulimina rugifera of zone B-C. The upper levels represent a horizon with Gyroidina girardana-Höglundina elegans-Serpula spec. of zone D. Zone E with Bolivinopsis spectabilis and Bulimina rugifera-Bul. parisiensis represents the Upper Nesvačilka claystones. A pelitic facies was identified within zones D-E on the Nikolčice ridge. In the Vranovice canyon the Paleocene begins with Bolivinopsis spectabilis too. Its occurence with Uvigerina hantkeni characterizes more likely the connection with the Middle Eocene.

The Lower Eocene (M. Holzknecht — J. Krhovský, 1988) begins with the Bulimina parisiensis-Bulimina rugifera zone of the Upper Nesvačilka Claystones (R. Jiříček, 1986). This pelitic section of zones F-H extends to the terminal parts of the Paleogene in the Nesvačilka boreholes. The species B. parisiensis Kaaschietter (= Bul. trigonalis Ten Dam) and B.rugifera Flaessner (= Bul. „jarvisi" Nuttal) alternate in four fluctuation horizons there. The highest brown marls of zone H may belong to the Middle Eocene. When correlating this Lower Eocene from the centre of the Nesvačilka canyon, to the Ždánice slope, the whole Bulimina section within zones F-G was found to be absent near Uhřice. The brown marls of zone H rest discordantly on the pelites of zone E (R. Jiříček, 1981), or the Bulimina zone facially alternates with the Bolivina one and the higher parts of the Uhřice or Vranovice Paleogene correspond to zone F only (R. Jiříček, 1986). The first supposition appears to be probable if considering the seismic data.

The Middle Eocene is developed on the Ždánice slope of the Nesvačilka canyon. The basal sandstones and limestones with Discocyclina and Nummulites or Lithothamnium (Uhřice-1)are typical (L. Švábenická, 1980). The upper pelites have no typical rare fauna with Bolivinopsis spectabilis and Bulimina rugifera. In the Vranovice canyon this fauna related to the Uvigerina hantkeni zone.

The Upper Eocene is developed on the Ždánice slope and in the Vranovice canyon with the Bolivina aenariensis-Bolivina fastigia zone. They are the very typical Uvigerina spec. cut-off shells on a discordant base. Two horizons with Globigerapis index there occur there. The middle part is characterized by Uvigerina aff. jacksonensis and the top of the Upper Eocene by an Uvigerina costellata horizon. The Lower Oligocene with psychrosphaeric ostracods have been found in the parautochthonous Pouzdřany Unit, only.

3. The genesis of the canyons in the autochthonous Paleogene has been explained in a variety of ways by many authors. A. Dudek (1980) related the Nesvačilka section to the tectonic parting of the crystalline basement into a „southern" and „central" section. This type of tectonics was interpreted by J. Dvořák (1987) as a boundary responsible for the diversified evolution of the Paleozoic. R. Jiříček (1982), however, classified the faults as Jurassic and resulting from the remote rifting of the Tethys. V. Homola et al. (1961) and F. Němec (1973) considered the Nesvačilka and Vranovice grabens to be bounded by Paleogene tectonic faults. According to M. Dlabač — E. Menčík (1964), erosive action showed up in addition to faulting tectonics during the Paleogene. F. Pícha (1978) related Paleogene and Mesozoic development to the aulacogene that predisposed the formation of submarine canyos moddeled by turbidity currents. F. Čech (1984) talks about pseudoaulacogens of the grabens. F. Chmelík et. al. (1981) means that the existence of submarine canyons on the margin of Tethys is douptful. R. Jiříček (1981) demonstrates, the canyons originate initial on the continent.

Actually quite different structural levels from various periods are involved. Their elevations and depressions cannot be combined into a single geological structure. The oldest of them is the **Měnín depressed area** with the centre of the 1,500 m thick Old Red clastics in Měnín-1 borehole. From Nikolčice-4 borehole Southwards the pseudothickness of its clastics is reduced from 676 m to 34 m in Nikolčice-3 borehole. Similar is the case northeastwards, in Těšany-1 borehole, where 150 m thick clastics are present that reduce their thickness to a minimum at Uhřice. They completely disappear in Kobeřice-1 a 4 boreholes (J. Brzobohatý, 1986), and Devonian carbonate rocks occur on the uplifted slope. The axis of the depression runs roughly westwards to the deep basin below the thrusted Moravian Moldanubic complex that separates the high elevations of the Dyje and Svratka domes (Moravikum). This relief is a pre-Devonian one, possibly generated during the Caledonian folding.

In the course of Hercynian folding new structures were formed, e.g. the overthrust of the Moldanubic complex over the Moravic one, and its thrusting over the superficial nappes of Paleozoic sediments overlying the disturbed Brno massif. Primary early molasse, possibly belonging to the Myslejovice sequence with Račice and Luleč conglomerates of Upper Visean to basal Namurian rocks, was formed ahaed of the fronts of the nappes (J. Dvořák, 1978). The last **Namurian A molasse** only terminated geosynclinal sedimentation in the region under study. Its beds, up to 1,000 m thick, extend from the Němčičky boreholes in the depression zone probably towards Příbor and Ostrava and, thus, they have nothing in common with the S-N elongated structure of the Nesvačilka area.

The Epihercynian platform, disturbed by rift tectonics during the formation of the Boskovice furrow in Permo — Carboniferous time, was generated after Hercynian folding. A second stage of faulting tectonics occured in Lias and Middle Dogger, when the margins of the Bohemian Massif were broken into blocks as a result of remote Tethyan rifting. The Lednice fault-zone appeared at that time and should be rotated to a NE-SW direction across Lednice to Hollabrunn (R. Jiříček, 1982). Up to 2,000 m of the Gresten Formation were deposited on the **sunken Waschberg block** (F. Brix et.al., 1977). Upper Jurassic (Kelloway — Tithon) sediments transgressed over this tectonics structure on the crystalline of the **Lifted South Moravian block.** The tectonically bounded Nesvačilka graben was formed there in perpendicular NW-SE direction. The whole horst between the Nikolčice fault and that of the Boskovice furrow became a source area from which Paleozoic sediments almost disappeared. The rest of the Devonian sediments, together with the crystalline, were unconformably covered with Jurassic beds. On the lifted Nikolčice block, basal Devonian layers wedge out towards the SW, whereas, on the sunken Nesvačilka block, Old Red to Namurian A have been preserved with sediments wedging out northeasterly below Jurassic and Paleogene layers.

A Jurassic unconformity in the early Kelloway covered the tectonic blocks and generated an **unfaulted depressed area** from the faulted Nesvačilka graben, and a **fault-free** slope facing the Waschberg depression from the Lednice fault-zone. Both depressed areas lasted from the Kelloway to the Lower Cretaceous, with marine Albian sediments at Nové Mlýny-2 (J. Řehánek, 1984) and at Kuřim locality north of Brno (I. Krystek — O. Samuel, 1979). A repeated transgression changed the Blansko trough into a channel connecting the Clement and the Bohemian Cretaceous from Upper Cenomanian to Senioan time. Relics of the Clement Cretaceous have been preserved on the Jurassic sediments in the large area from Mikulov to Vienna. They obliquely crop out to the basin of Neogene levels in a belt crossing Ameis-1 with Coniacian-Santonian and in a belt crossing Poysdorf-2 with Campanian-Maastrichtian sediments (R. Fuchs et. al., 1984).

The whole Mesozoic area of sedimentation seems to have been bordered by the upliftied slopes of the Moldanubic and Moravic zones on the southwestern side. The marine sediments of the Bohemian and Moravian Cretaceous ended on the Moldanubic slope, with the denudation rests on the Svratka-Polička crystalline. The Blansko Cretaceous, Kuřim Albian and Olomučany Jurassic ended near the Svratka Moravicum. The Clement Cretaceous and Jurassic, perpendiculary passing below the Vienna basin to the town Baden, had their end on the Dyje and Tulln Moravicum, before the Moldanubic slope (Berndorf-1 borehole). The Silesian nappe with Štramberk-type Tithonian limestones has its origin on a Helvetic slope (on a gravimetric low?).

Towards the end of the Cretaceous, the Bohemian Massif rapidly began to emerge, which resulted in an enormous lowering of the erosin level of the rivers at its margin. In the early Paleocene, this event led to the formation of deep **erosion canyons** following an intensive drainage pattern oriented from the Bohemian Massif to the South Moravian and partly also in the Lower Austrian regions. The Blansko channel became a river valley for the main stream following SSW into the Boskovice furrow. Near Kuřim a secondary channel branched-off that crossed Brno to incise the Nesvačilka depression as an erosion canyon cut to a depth of 1,500 m in its Mesozoic and Paleozoic rocks. Another channel branched-off from the Boskovice furrow at Moravský Krumlov crossing the SE slopes towards Hustopeče to form there deep erosion walls of the Vranovice canyon incised into Jurassic carbonate and crystalline rocks. The two erosion canyons were separated by the narrow and high Nikolčice ridge. On the southern and southeastern sides, the canyons were disturbed by secondary erosion trenches of the Hustopeče, Rašovice and Žarošice channels. The incission of the erosion canyons was accompanied by the disintegration of the Jurassic platform which can be compared to the geomorphological relief of present „Bohemian-Saxon Switzerland". The Tulln erosion channel generated (perhaps from Třeboň syncline) in the Moosbierbaum drilling district at the today's Danube in the Krems-Tulln area (Fig.1).

The Nesvačilka canyon extended southeasterly below the present Carpathian flysh and Neogene of the Vienna basin probably as far as the Little Carpathians. It submerged to the present depth of about 8—10 km between the Týnec and Skalica elevations. The Vranovice canyon, by contrast, turned towards Břeclav and its slopes were situated roughly at Maustrenk-ÜT1 and Zistersdorf-ÜT2 boreholes.

Three evolutional stages of Paleogene canyons appear to have existed: In the **first stage,** V-shaped southeasterly erosion canyons, more than 100 km long, 10—15 km wide and 1,5 to 2 km deep, were incised. Their upper parts, 40—50 km long, are localised on the present SE flank of the Bohemian Massif below the Neogene molasse and below the nappes of the Ždánice and Pouzdřany Units. The middle parts occupy the deep basement below the Alpine orogene in the Vienna basin. On a gravimetric low or as far as the Little Carpathians, Helvetis slopes are thought to have existed, where the erosion canyons turned into submarine canyons, with turbidity erosion in the basement of the Submenilite Paleogene of the Subsilesian (Ždánice) nappes. This is evidenced by the in tense mixing of Cretaceous and Paleogene faunas.

An immense amount of clastics derived from rocks that disappeared from the two canyons should extend into flysch trough at the foot of the bathyal zone. Pebbles of Jurassic limestones and marlites, Namurian sandstones, Culm shales, greywackes, conglomerates, Devonian limestones and conglomerates, and crystalline rocks are thought to have their origin in the Nesvačilka canyon. Pebbles of Jurassic limestones and marlites, with granodiorites of the Brno massif could be derived from the Vranovice canyon.

If putting back the overthrust flysch nappes to Egerian time, i.e. beyond Berndorf-1 borehole and if considering the rotation related to the bending of the nappes around the SE extremity of the Bohemian Massif, we can suppose a W-E direction of the front of the Magura flysch (R. Jiříček, 1986). In Upper Austria and Bavaria, the Rupelian molasse too follows this direction along the SW flank of the Bohemian Massif. The Tulln, Vranovice and Nesvačilka canyons are oriented in the same way.

It is possible, therefore, that the distal cones of these canyons could be situated, as conglomerates of the Upper Soláň Member of the Paleocene, at the margins of the Račany flysch. The flysch of the Vsetín region actually comprises pebbles of Jurassic and Carboniferous rocks, Culm greywackes and shales, Devonian quartz limestones, me-

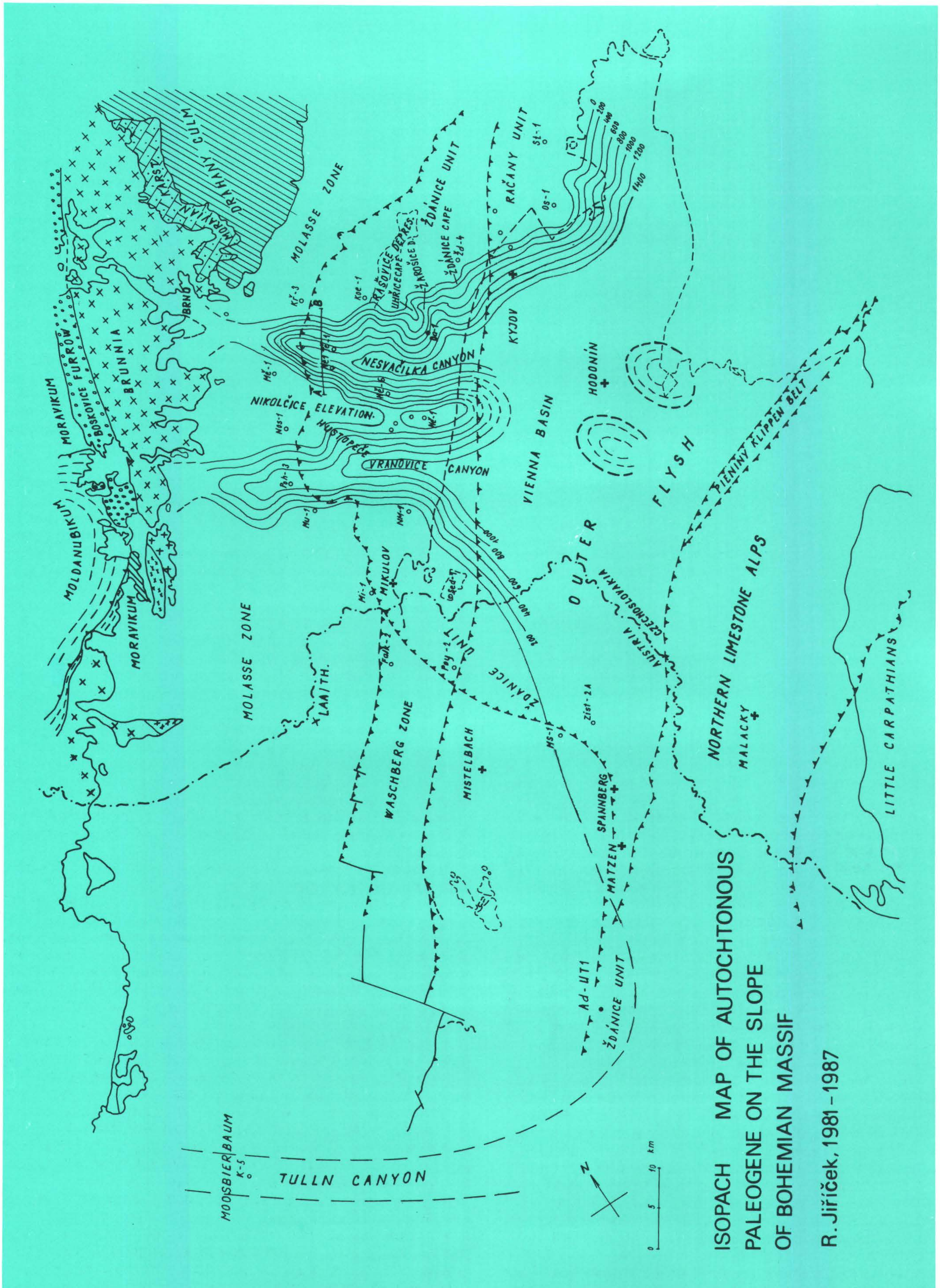
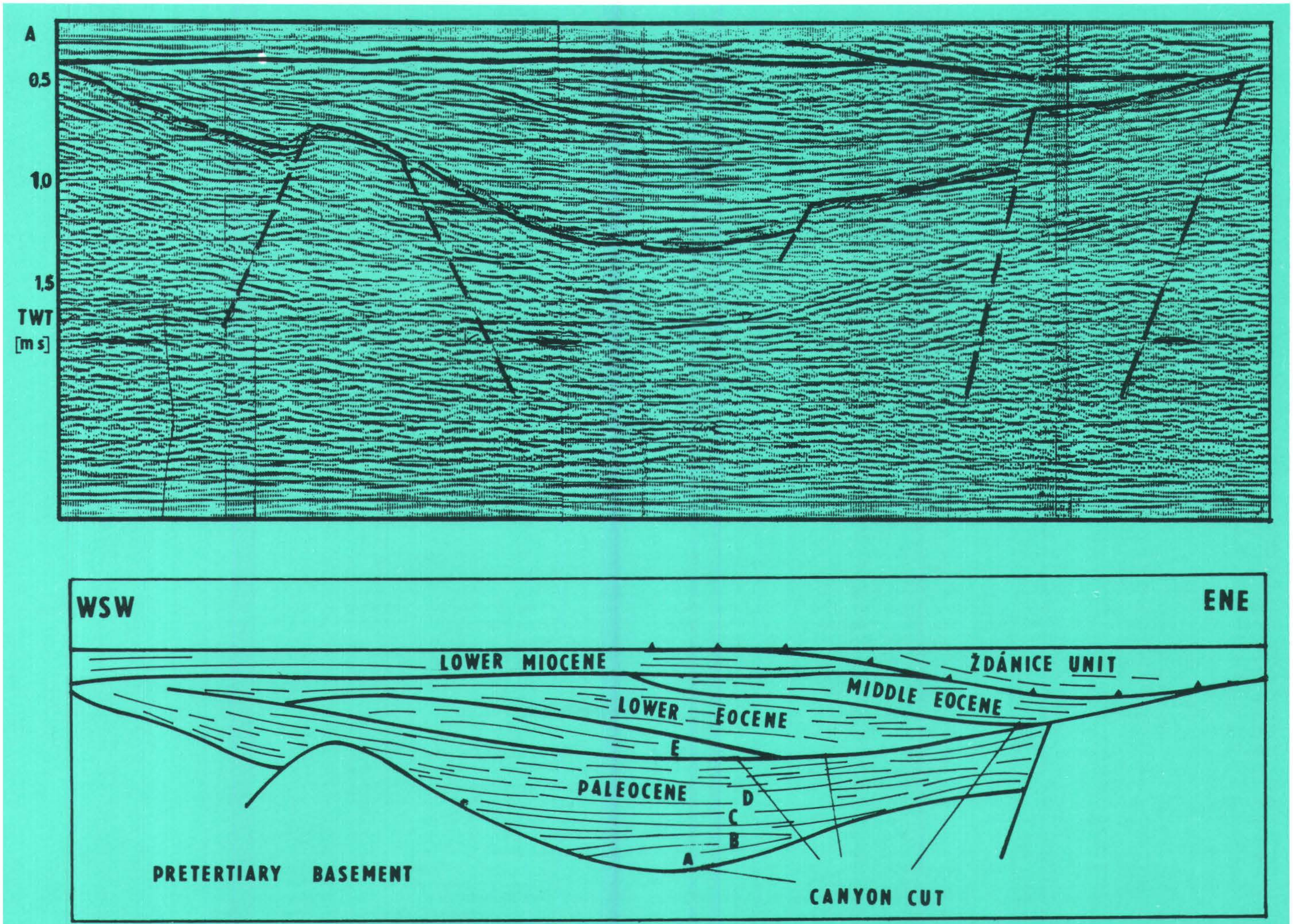

ISOPACH MAP OF AUTOCHTONOUS
PALEOGENE ON THE SLOPE
OF BOHEMIAN MASSIF
R. Jiříček, 1981-1987
MOLDANUBIKUM
MORAVIKUM
BOSKOVICE FURROW
BRUNNIA
MORAVIAN KARST
DRAHANY CULM
BRNO
MOLASSE ZONE
ŽDÁNICE UNIT
RAČANY UNIT
ŽDÁNICE CAPE
KYJOV
HODONÍN
NESVAČILKA CANYON
NIKOLČICE ELEVATION
HUSTOPEČE
VRANOVICE CANYON
VIENNA BASIN
OUTER FLYSH
PIENINY KLIPPEN BELT
MIKULOV
LAAITH.
WASCHBERG ZONE
MISTELBACH
ŽDÁNICE UNIT
AUSTRIA
CZECHOSLOVAKIA
NORTHERN LIMESTONE ALPS
MALACKY
LITTLE CARPATHIANS
SPANNBERG
MATZEN
TULLN CANYON
MOOSBIERBAUM
0 5 10 km

Fig. 1.



SEISMIC PROFILE AND LINE-DRAWING INTERPRETATION OF PALEOGENE SEDIMENTS (ZONE A-E) TROUGH THE NESVAČILKA CANYON R. JIŘÍČEK, 1988

Fig. 2.

tamorphites and granodiorites closely resembling thouse of the Brno massif. However, the large olistolith Brno granitoids with hexagonal biotites at Bílava near Holešov demonstrates only short transport many of pebbles perhaps from the Silesian cordillera (or front of nappes) of the Helveticum.

In the second stage, the river-eroded valleys were transgressed, from the SE, by Paleogene sea that first filled the axial sections of the canyons and then spread laterally. Up to 500 m of clastic rocks were deposited in the axis of the Nesvačilka canyon. Their structures indicate the downslope transportation of debris by gravity rather than turbidity currents (turbidity currents were supposed by F. Pícha, 1978, to have excavated the submarine canyons). Bottom currents transported coarse clastic breccias and conglomerates, debris flows, grain flows, mudflows, etc. These rocks are frequently accompanied by sandstones and conglomerates with graded bedding or laminated claystones closely resembling deposits derived from turbidity currents as documented well by F. Pícha (l.c.). On no account, however, they do not represent flysh rocks with distal and proximal cones. The pebbles contain fragments of granites, diorites, gneises, greywackes, conglomerates, arkose sandstones and some Devonian and Jurassic limestones from which abundant redeposited rhaxes of Spongiae originate. All these rocks deposited from the canyon walls and higher-seated channel-ways, because the bottom of the Nesvačilka trough had already been covered with clastics. Lower pebble contents are supposed for the extension of the Vranovice canyon below the Lednice slope. The clastics of the Tulln canyon comprise metamorphites (F. Brix et. al., 1977). Silty claystones were deposited in non-active channels only. The repeated transportation of clastics alternated with calm periods during which laminated claystones were deposited.

In the third stage, the sea level extended beyond the erosion margins of the canyons, flooding the neighbourhood with a shallow shelf with abundant minor Cibicides faunas indicating algal growth. The erosion walls became slopes of **submarine canyons,** in which some mudflows, slips and paraconglomerates were generated in the Eocene. After the sea level and ceased to rise and stabilized, the Nikolčice slope prograded eastwardw moving thereby the bottom of the Nesvačilka canyon to the same direction, which caused lateral and bottom erosion and a hiatus with respect to the older Paleogene. This suggests that prograding had brought into contanct, from the W to the E, zones F/E (Nesvačilka-1 borehole), G/E (Těšany-1), H/E near Uhřice-13. A horizon with Bulimina parisiensis wedges out eastwards as a downlap on the dipping slopes. The nature of the later was recognized on seismic profile 250/86 (Fig. 2.).

A similar hiatus was also found in the Vranovice canyon (R. Jiříček, 1986). We suppose, that existe the same progradation there. A horizon with Bulimina parisiensis wedges out too as a downlap on the slopes. The layers of

DEPTH AND THICKNESS OF AUTOCHTHONOUS PALEOGENE LAYERS ON SE SLOPE OF THE BOHEMIAN MASSIF

Well	Top-off	Basis	Thickn.	Top-wall	Underground	Final Depth
Poh-1	508	890	382	Eggenb?	Crystall.	1000 m
Poh-3	692	1358	666	Eggenb?	Crystall.	1425 m
Iv-1	556	652	96	Carpath.	Jurassic	1250 m
Pou-1	986	1202	216	Eggenb.	Paleogene	1202 m
Str-1	1298	1391	93	Eggenb.	Jurassic	2600 m
Pop-1	1605	2242	637	Pozdř.	Crystall.	2450 m
Pop-2	1188	1702	514	Ždánic.	Crystall.	1805 m
Vr-1	812	1173	361	Ždánic.	Jurassic	1750 m
Nik-3	1145	1156	11	Eggenb.	Jurassic	1392 m
Nik-7	1184	1356	172	Eggenb.	Jurassic	1504 m
Nik-8	1678	1801	123	Eggenb.	Jurassic	2000 m
Něm-6	1641	2112	471	Ždánic.	Jurassic	5220 m
Necfl	367	473	106	Eggenb.	Paleogene	473 m
Ne-1	417	1571	1154	Carpath.	Devonian	1589 m
Ne-2	417	1275	858	Carpath.	Paleogene	1275 m
Ne-3	286	1385	1099	Eggenb.	Culm	2484 m
Ar H2	186	650	464	Eggenb.	Paleogene	650 m
Brn-1	245	607	362	Eggenb.	Culm	658 m
Br-41	236	304	68	Carpath.	Paleogene	304 m
Új-1	298	645	347	Carpath.	Culm	2300 m
Tě-1	849	1905	1056	Eggenb.	Culm	4500 m
Žar-1	1522	1862	340	Ždánic.	Culm	2867 m
Dam-1	2018	2710	692	Ždánic.	Namurian	4482 m
Uh-1	2208	2763	555	Ždánic.	Carbonif.	3960 m
Uh-2	1705	1992	287	Ždánic.	Carbonif.	3450 m
Uh-3	1512	1543	31	Paraut.	Jurassic	2595 m
Uh-5	1529	1644	115	Ždánic.	Devonian	2050 m
Uh-7	1369	1438	69	Ždánic.	Carbonif.	3101 m
Uh-8	1533	1840	307	Ždánic.	Carbonif.	2800 m
Uh-9	1688	1880	192	Ždánic.	Carbonif.	2800 m
Uh-10	1903	2410	507	Ždánic.	Carbonif.	2911 m
Uh-11	1317	1394	77	Paraut.	Jurassic	1711 m
Uh-13	867	1498	631	Ždánic.	Carbonif.	2700 m
Uh-14	1777	2065	288	Ždánic.	Carbonif.	2850 m
Uh-16	1640	2060	420	Ždánic.	Carbonif.	2800 m
Uh-17	1659	1908	249	Ždánic.	Jurassic	3320 m
Uh-18	1520	1812	292	Ždánic.	Jurassic	3300 m
Uh-19	1855	2183	328	Ždánic.	Jurassic	3623 m
Uh-20	1820	2188	368	Ždánic.	Jurassic	3700 m
Uh-21	1444	1865	421	Ždánic.	Carbonif.	1900 m
Uh-22	1281	1575	294	Ždánic.	Carbonif.	1800 m
Jež-2	2150	2240	90	Ždánic.	Jurassic	3000 m

The boreholes: Pohořelice, Iváň, Pouzdřeny, Strachotín, Popice, Vranovice, Nikolčice, Němčičky, Nesvačilka, Arta, Brno, Újezd, Těšany, Žarošice, Dambořice, Uhřice, Ježov.

Middle Eocene are in contact with the Upper Paleocene beds. The main progradation is again between the Middle and Upper Eocene sediments. Perhaps in the Eocene actívised the small secondary channels as Hustopeče, Rašovice and Žarošice, ones. The displace of channels was accompanied by redeposition and mixing of faunas.

4. In conclusion it may be stated that the enormous decline of the sea level from the Senonian to the Paleocene seems to be related, in this region too, to a global decline emphasized by Laramide deformation of nappes in the Carpathians. The decline was followed by a rise in sea level with a consecutive transgression of Paleogene sediments into the canyons.

If relating the D/E or E/F boundary to the Paleocene/Eocene boundary in the Nesvačilka centrum, the argument would be that a global sea level decline with partial stabilisation, emphasized by Illyrian deformation in the Carpathians, could have occured. It could be associated with prograding slopes a hiatus between the Paleocene and Lower Eocene sediments in both of canyons. The same global decline of level was between the Lower and Middle Eocene and the Middle and Upper Eocene, when migrated the main channels, where the new channels activised.

Primary molasse was formed in front of the flysh nappes in the Alpine-Carpathian realm in the flysh nappes in the Alpine-Carpathian realm in the late Priabonian to Lower Oligocene. The Globigerina marls of the Submenilite Upper Eocene Formation appeared in the Helvetic zone overlain by cherts of the Lower Oligocene Menilite Formation troughout the Carpathians. The appearence of cherts could to have resulted from the shift of the carbonate-compensation-depth lysocline to shallower depths owing to global cooling. Indications of cooling can also be found in the Lower Oligocene brown Pouzdřany marls, in which V. Pokorný (1981) determined psychrospaeric ostracodes. These marls pass into the Upper Eocene brown Uhřice marls from which they were separated during the overthrusting of nappes.

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Abstrakt

V autochtonním paleogénu na JV svazích Českého masivu byla vymezena 3 pásma a 8 zón. Spodní část s Bolivinopsis spectabilis lze korelovat s paleocénem, střední část s Bulimina rugifera — Bulimina parisiensis se spodním eocénem a svrchní část s Bolivina aenariensis — Uvigerina hantkeni se středním až svrchním eocénem. V autochtonním paleogénu jsou vymezeny vranovický a nesvačilský příkop. Jejich vznik byl původně spojován se zlomovou tektonikou nebo s podmořskými kaňony. Pomocí zonací bylo prokázáno, že marinní sedimenty paleogénu transgredovaly do už existujících erozívních kaňonů.

Zusammenfassung

Im autochthonen Paläogen an den SO-Hängen der Böhmischen Masse in Südmähren wurden aufgrund der Foraminiferen und E-log-Diagramme 3 Komplexe und 8 Zonen abgegrenzt. Der untere Teil mit Bolivinopsis spectabilis ist dem Paläozän, der mittlere Teil mit Bulimina rugifera — Bulimina parisiensis dem unteren Eozän und der obere Teil mit Bolivina aenariensis — Uvigerina hantkeni dem mittleren und oberen Eozän gleichzustellen. Im autochthonen Paläogen wurden der Vranovice- und der Nesvačilka-Graben abgegrenzt. Ihre Entstehung wurde ursprünglich mit der Bruchtektonik oder mit den submarinen Cañons in Zusammenhang gebracht. Mittels der Verteilung auf Zonen wurde klargelegt, daß die marinen Sedimente des Paläogens in bereits bestehende erosive Cañons transgredierten.

PALEOGEOGRAPHY OF THE NEOGENE IN THE VIENNA BASIN AND THE ADJACENT PART OF THE FOREDEEP

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Introduction

The Vienna basin is the NW-part of the Pannonian intracarpathian basinsystem and is situated in the external zone of the Alpine — Carpathian thrust belt, covering 200 km length in the NE-SW extension and 60 km in width. Separated by the Alpine — Carpathian thrust sheets of the Waschberg — Ždanice zone the Molasse foredeep extends parallel to the Vienna Basin along the SE-flank of the Bohemian Massif with a width of 8 km near Brno up to 30 km in the Austrian part (see fig. 1 below).

Several geologists dealt with the paleogeography of the Neogene sediments of the Vienna Basin and the adjacent Alpine-Carpathian foredeep. In the Austrian part of the Molasse zone, paleogeography was provided by Braumüller (1961), Grill (1953, 1961), and Brix (1977), in the Vienna Basin by Krobot (1977) and Turnovsky (1976). In the Czechoslovakian part, paleogeography of the Molassezone was investigated by Buday (1965) and Jiřiček (1983), of Ždanice unit by Špička (1971) and Chmelík (1981) and in the Vienna Basin by Buday (1960), Špička (1967) and Jiříček (1977—1983). The last two authors studied the paleogeography during the construction of the formation thickness maps. Jiříček (1978, 1986) worked on the Neogene paleogeography in the whole Vienna basin and its surroundings in the Lower Austrian to South Moravian areas in the classical and in the palinspastic view as well.

The existing paleogeographic and isopach maps, which were worked out before 1975, can no longer be used. Because of the introduction of the neostratotypes in the Central Paratethys (1968), the range of the stratigraphic units changed and was again modified later on in the different basins.

It was clearly incorrect to assume, as some geologists did, that it would be enough to define the new stages by a convergence chart in which the former Chattian and Aquitanian were compared with today's Egerian, the former Lower Burdigalian with the Eggenburgian, the Upper Burdigalian and Helvetian (Lower Helvetian) with the Ottnangian, the Upper Helvetian with the Karpatian, the Tortonian with the Badenian and the Sarmatian, Pannonian and Pontian with the same stages nowadays (Cicha et al., 1971).

With the modification of the neostratotypes their range, revised in hundreds of wells in some basins, was also changed (see fig. 2). The thickness maps of the Neogene in the Czechoslovakian part of the basin (Špička 1967) included in the former Lower Burdigalian not only Eggenburgian sediments of Hodonín-Lužice in the wells, but also the Ottnangian of Tynec-Gbely and the Karpatian of Malacky Lab.

The coloured Kúty beds with 400—1 000 m thickness were also placed in the Lower Badenian, although they actually belong to the Upper Karpatian. Because there existed no division of Badenian in an upper, middle and lower part like nowadays, the boundary was placed between the Lanzendorf and the Devin series in the midst of the middle Badenian. Sometimes the boundary Badenian-Sarmatian is situated 500 m deeper than the former boundary between Tortonian and Sarmatian. As now has been proved, the coloured series between them belongs to the Sarmatian and not to the Badenian. The coal series of Zone F, which was classified into the upper Pannonian, was included in the Pontian. The coloured series on its top, which used to be compared with the Pontian or Dacian earlier, belongs to the

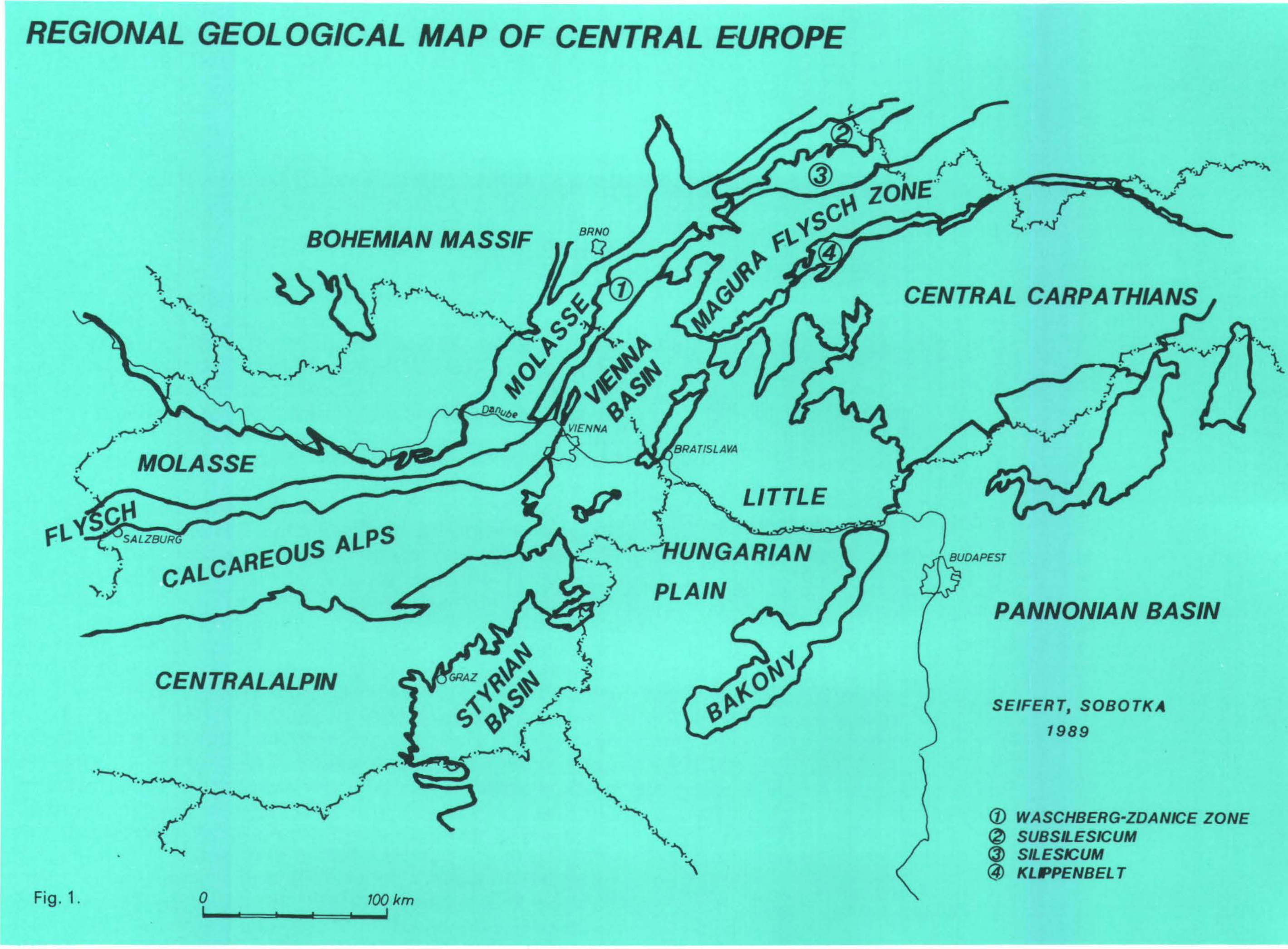


Fig. 1.

Pontian now. At last the sediments of the Levantian or Rumanian were compared previously with the early Pleistocene.

Some stratigraphic questions still remain unanswered. The Rzehakia beds, for example, are classified in Austria as Oncophora beds into the Ottnangian, in Moravia into te Karpatian. This poses some problems when attempting to arrange a homogeneous structural and tectonic map of the described area. For this reason we are forced to accept a uniform stratigraphic system based on a conclusive fauna, on electric logs and seismic or geologic profiles, as we attempt to demostrate in this paper.

The paleogeographic maps in this paper show the extension of different formations from a static point of view. The palinspastic position of the Vienna Basin on the back of the progressing Alpine-Carpathian nappe system at different times was described by Jiříček in 1986 (see also Kováč 1989). The structural evolution and the geodynamic development of the Vienna Basin and its basement were described by Wessely (1987) and Jiříček & Tomek (1981).

1. Oligocene

The perialpine Molassezone extends in a W—E direction from Switzerland to Bavaria and Austria, where the successive later beginning of the sedimentation on the flanks of the Bohemian Massif to the east is well documented (Brix 1977).

In Upper Austria the Molasse basis has an Upper Eocene age. In the area east of Steyr, we find Lower Oligocene on the basis; in the area of Melk/Danube, the sequence starts with limnic sediments of the Rupelian, which are manifest as residuals in the area of Vienna as well (Roetzel 1983).

The sediments of the Egerian transgressed extensively on the Bohemian Massif and are found far to the south below the alpine nappes, e. g. in the exploration well Berndorf 1 30 km south of the front of the nappes (Fuchs et al 1980).

The Egerian transgression followed northwards the Variscan determined graben system extending NNE—SSW along the Mailberg fault and reaches a thickness of nearly 300 m in the exploration well Grossharras 1 (fig. 3). It ended in the region of Wildendürnbach near the Czechoslovakian border.

In South Moravia the Molasse sequence starts with the Eggenburg. The supposed Egerian of the well HV 102 near Pohořelice (Cicha 1975—1988) represents perhaps the autochthonous Lower Oligocene of Vranovice graben.

In Lower Austria the extension of Egerian sediments in the Mailberg graben is limited by the NNE—SSW running Hagenberg swell (fig. 3). From it the Egerian sedimentation area extended far to the east. It included differrent facies environments: from the shallow areas in the west to the deeper ones in the east. This eastern part was incorporated into the external zone of the Alpine-Carpathian nappe system and was thrusted to the northwest. In the Waschberg-zone we can find folded Michelstetten beds and Thomasl beds (Papp 1978), in the Pouzdřany unit the Boudky beds (Upper Pouzdřany beds) and the problematic Křepice beds (Cicha 1965, Stráník 1980). These sediments were detached from their autochthonous, probably clastic basis.

The Melk beds transgressed only in the Austrian part on the flank of the Bohemian Massif. In the opposite direction rose the front zone of the Alpine and Magura flysch in the

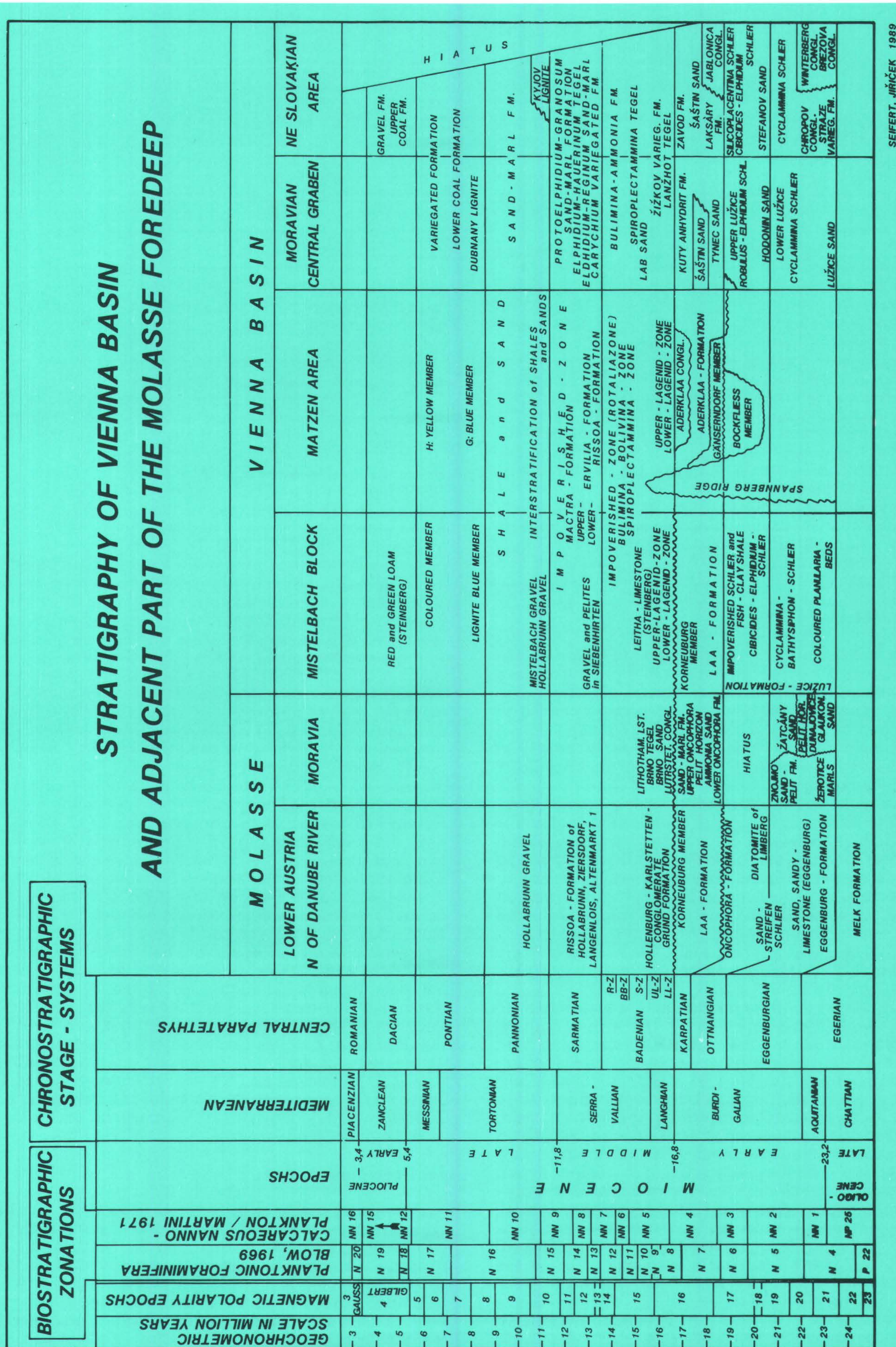

STRATIGRAPHY OF VIENNA BASIN
AND ADJACENT PART OF THE MOLASSE FOREDEEP
BIOSTRATIGRAPHIC ZONATIONS
CHRONOSTRATIGRAPHIC STAGE - SYSTEMS
GEOCHRONOMETRIC SCALE IN MILLION YEARS
MAGNETIC POLARITY EPOCHS
PLANKTONIC FORAMINIFERA BLOW, 1969
CALCAREOUS NANNO - PLANKTON / MARTINI 1971
EPOCHS
MEDITERRANEAN
CENTRAL PARATETHYS
MOLASSE
VIENNA BASIN
LOWER AUSTRIA N OF DANUBE RIVER
MORAVIA
MISTELBACH BLOCK
MATZEN AREA
MORAVIAN CENTRAL GRABEN
NE SLOVAKIAN AREA
PLIOCENE
MIOCENE
OLIGO - CENE
PIACENZIAN
ZANCLEAN
MESSINIAN
TORTONIAN
SERRA - VALLIAN
LANGHIAN
BURDI - GALIAN
AQUITANIAN
CHATTIAN
ROMANIAN
DACIAN
PONTIAN
PANNONIAN
SARMATIAN
BADENIAN
KARPATIAN
OTTNANGIAN
EGGENBURGIAN
EGERIAN
HIATUS
SPANNBERG RIDGE
SEIFERT, JIŘIČEK 1989

Fig. 2.

south-east. On its back the presence of Lepidocyclinidae and Miogypsinidae was found in wells near Reinthal and Rabensburg in the northern part of the Vienna Basin (see fig. 3). The question whether this deposition is autochthonous or integrated in the thrust sheets has not yet been solved.

The Egerian sediments of the Waschberg — Ždanice unit are proven to be in an allochthonous position in the Austrian ultradeep wells Maustrenk ÜT 1a and Zistersdorf ÜT 2a below the Vienna Basin and the Alpine-Carpathian nappe system, as well as in the Moravian Pouzdřany and Ždanice units. East of this area sediments remained in an autochthonous position.

The south part of the Egerian Molasse transgressed on the Helveticum nappe both in the Austrian and in the Moravian parts (Jiříček 1982). In the investigated area folded Egerian sediments were found together with Helveticum below the external Flysch nappes in the exploration well Urmannsau 1 west of Vienna (Kröll, Wessely 1967).

In the region from north of Vienna to South Moravia occured the transgression of the sandy-shaley Ždanice-Hustopeče Egerian, while in the remaining part of the Carpathian belt mainly Krosno sandstones transgressed on the Oligocene Menilit beds and partly on the Upper Eocene Submenilit beds. These sediments built the basis of the Ždanice unit, which was detached from the Subsilesian unit of the Helveticum (Jiříček 1982).

The Egerian sediments in the region of the Vienna basin occur mainly in the Waschberg Ždanice zone, which developed out of the main sedimentary basin during Oligocene — Lower Miocene from Eastern Austria to Western and Southern Slovakia.

2. Lower Miocene

Originally, the Lower Miocene included the stages of Aquitanian to Lower Helvetian. In today's interpretation these stages correspond with the Upper Egerian to Ottnangian (fig. 2). The upper limit of Lower Miocene was shifted to the termination of the Karpatian according to a decision of the International Stratigraphic Commission (RCMNS) in 1975. In the Lower Miocene we can place the last thrust tectonic in this region.

The broad perialpine Molasse zone, which extends from Switzerland to Bavaria and Austria, continues to Moravia in the pericarpathian foredeep. During the shortening of the sedimentation area we can notice not only a shift of the Molasse axis onto the flanks of the Bohemian Massif in front of the nappes, but also a pass of the sedimentation over the partly sunken front zone of the nappes into the area of the Vienna Basin towards the SE.

2.1 Eggenburgian

During the Savian Phase in the Eggenburgian the Alpine-Carpathian nappes moved over the ridge of the southern Egerian Molasse more and more to the foreland and built a new foredeep. Its sediments not only transgressed forward northwest along the flank of the Bohemian Massif, but they also passed southeast over the sunken front range of the Magura Flysch zone into the forming Vienna Basin. At the contact of these two units, where the Eggenburgian sediments hold an autochthonous position on the basement, today the Waschberg-Ždanice unit is located. In this unit sediments of the same age were folded and incorporated into the nappes. When we flatten this folded zone in the palinspastic map, we can realize the original sedimentation area (Jiříček, 1986). The Molasse zone extended NE to Ostrava. From there a subbasin in the direction to the Klippenbelt zone turns with the last Eggenburgian presence near Žilina into the Vienna Basin.

On the southeastern flank of the Bohemian Massif we can follow the Eggenburgian sediments from Krems in Lower Austria via Retz to the Litenčice hills in northern Moravia (fig. 4). On the border region clastic sediments are developed with coarse grained sandstones or coloured clays, which transgress on the crystalline. This is where the locations of Maissau, Loibersdorf, Eggenburg, Šatov, Chvaletice and Slup belong. The maximum extension occurred with the 30 km distant transgression into the Horn subbasin in Lower Austria (Kapounek et al. 1965), (fig. 4). The inner part of this plateau is covered by glauconitic sandstones and fish debris containing claystones which transgressed on the autochthonous Upper Jurassic, Upper Cretaceous and Egerian basement. This facies has been proven in wells in Lower Austria and South Moravia. On this whole above mentioned nearshore plateau, the Lower Eggenburgian with Neocyprideis fortisensis (KAY) is almost exclusively present, while the Upper Eggenburgian and Ottnangian was, as far as accessible, eroded as a result of the Karpatian unconformity (Jiříček 1978, 1983). In the later folded Waschberg-Ždanice zone, the sedimentation took place in the outer shelf to the slope area in water depths of some hundred meters. Sometimes in this sequence flyschoid sediment structures were observed in outcrops and cores of wells in the Waschberg zone.

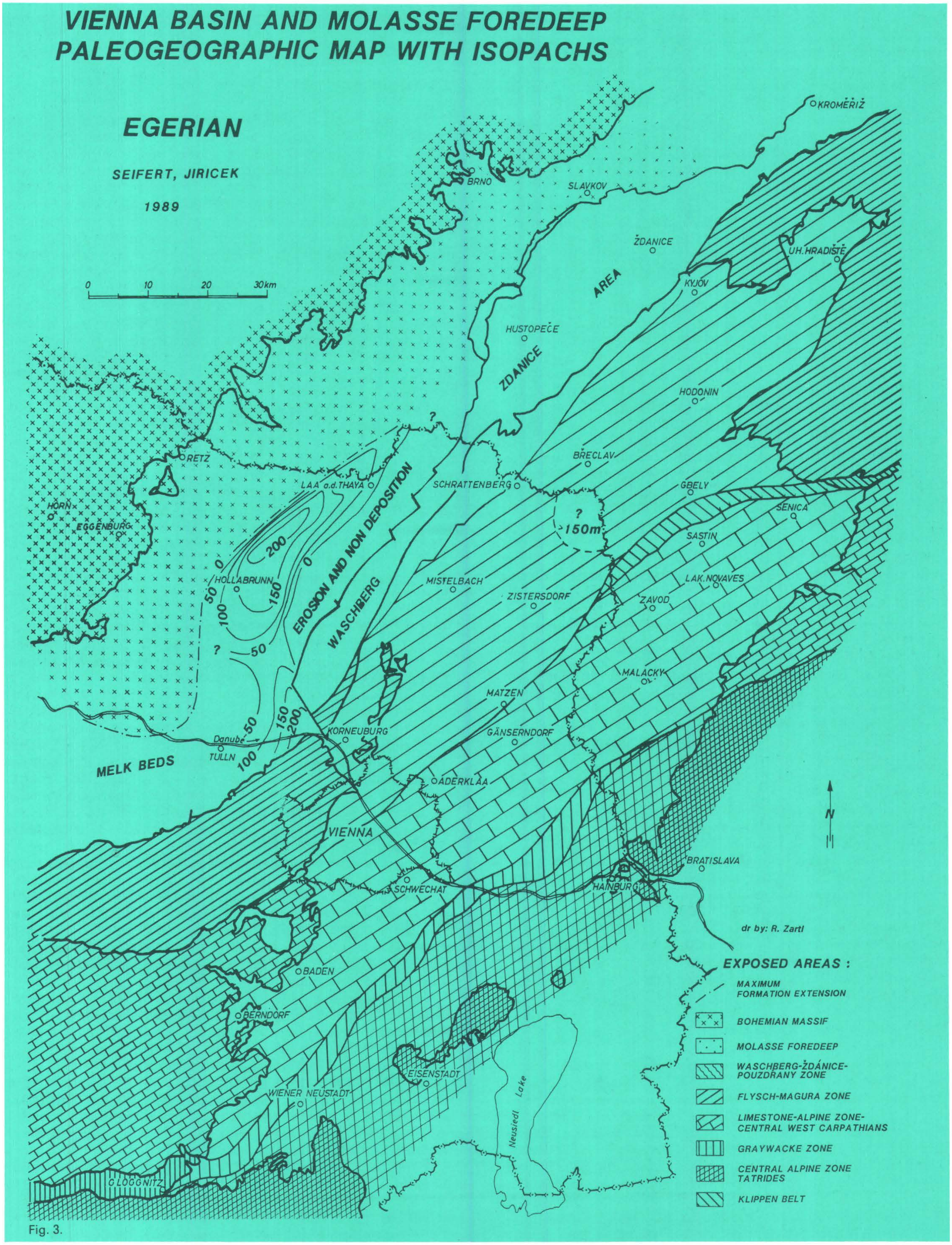
This sediment type developed to the south to the "Sandstreifenschlier" of the autochthonous and allochthonous Molasse north and west of Vienna (Brix et al. 1977). A similar development with a Cibicides fauna was found in the Šakvice marls in the Pouzdřany and Ždanice unit (Stráník 1980). We can follow this type up to Mikulov, Valtice and Lednice, where distal influence of delta sedimentation with Silicoplacentina fauna was noticed (Jiříček 1983).

From the foredeep the Eggenburgian sedimentation passed over into the forming Vienna Basin between Mistelbach, Schrattenberg and Mikulov and advanced to the line Mistelbach — Zistersdorf to the south (fig. 4). In the northern part the sedimentation was concentrated in four depressions, e. g. Lužice, Kopčany, Štefanov and Senice.

In the Luzice depression the Eggenburgian sequence developed in front of the Týnec-Steinberg flanks of the Kahlenberg Flysch nappe. We can follow Eggenburgian sediments in the wells from Hodonin to Lužice, to Břeclav and to Reinthal to the southwest up to the Mistelbach block. In this region the formation reaches its greatest thickness of nearly 600 m northwest of Mistelbach. Towards the east it decreases and pinches out near Rabensburg at the Czechoslovakian border. Through the traverse extending Kopčany channel to the east the Eggenburgian reached the area near the Klippenbelt (fig. 4). On its outside Eggenburgian has been proven in the Štefanov depression in numerous exploration wells in the area of Štefanov and Petrova Ves. At the inner side of the area near the Klippenzone it was recorded in the Senice depression in the wells of Šastin, Kovalov, Lakšárska Nová Ves and in Studienka 95 in the Levare depression. In the whole region the Eggenburgian is represented by basal conglomerates with Flysch or Trias carbonate components. The breccias in the area of Stillfried might be the terrestric southernmost equivalent. Large Pectinids exist in the lower part of Eggenburgian, whereas the upper part consists of a huge sequence of Schlier sediments with Cyclammina praecancellata (see fig. 2). The paleogeographic maps of Cicha (1965) and Kovač (1986) show that a connection of this sedimentation area with the Tethys existed during Lower Eggenburgian and was subsequently interrupted.

2.2 Ottnangian

The main problem of the correlation of sequences emerges in the in the Ottnangian, because Karpatian sediments might be partly included. In the Neostratotype area of Upper Austria the Ottnangian is represented by the Innviertel series (Papp et al, 1968). Here we find the following sequence from the bottom to the top: marine Vöckla beds with Schlier sediments and sands with Cibicides-Elphidium, Atzbach sand, Ottnang Robulus Schlier, Ried Rotalia Schlier, glauconitic series with Mehrnbach, Braunau and Treubach sands with reduced marine fauna and finally


VIENNA BASIN AND MOLASSE FOREDEEP
PALEOGEOGRAPHIC MAP WITH ISOPACHS
EGERIAN
SEIFERT, JIRICEK
1989
0 10 20 30km
BRNO
SLAVKOV
KROMĚŘÍŽ
ŽDANICE
UH. HRADIŠTĚ
KYJOV
AREA
HUSTOPEČE
ZDANICE
HODONIN
BŘECLAV
RETZ
LAA a.d. THAYA
SCHRATTENBERG
GBELY
SENICA
HORN
EGGENBURG
150m
SASTIN
EROSION AND NON DEPOSITION
HOLLABRUNN
WASCHBERG
MISTELBACH
ZISTERSDORF
LAK. NOVAVES
ZAVOD
MALACKY
MATZEN
GÄNSERNDORF
KORNEUBURG
Danube
TULLN
MELK BEDS
ADERKLAA
VIENNA
BRATISLAVA
HAINBURG
SCHWECHAT
BADEN
BERNDORF
EISENSTADT
WIENER NEUSTADT
GLOGGNITZ
Neusiedl Lake
N
dr by: R. Zartl
EXPOSED AREAS :
MAXIMUM FORMATION EXTENSION
BOHEMIAN MASSIF
MOLASSE FOREDEEP
WASCHBERG-ŽDÁNICE-POUZDRANY ZONE
FLYSCH-MAGURA ZONE
LIMESTONE-ALPINE ZONE-CENTRAL WEST CARPATHIANS
GRAYWACKE ZONE
CENTRAL ALPINE ZONE TATRIDES
KLIPPEN BELT
Fig. 3.

brackish Rzehakia beds (Braumüller 1961). Below this sequence Hall Cyclammina Schlier emerges, whereas above it the "Obere Süßwassermolasse" occurs, which is ascribed to Karpatian by Cicha (1967). If we correlate this region with the Vienna Basin, Hall Schlier corresponds to the sediments of Lower Lužice Eggenburgian Schlier (Jiříček 1978). On top of it the 10 to 150 m thick Štefanov and Hodonín sands appear, which could be compared with the Vöckla and Atzbach beds. Above them in the whole area of Hodonín and Lužice, Robulus Schlier of Upper Lužice beds follows, which is replaced laterally by the Cibicides — Elphidium Schlier near Týnec.

In the uppermost part of the Ottnangian, "Fischschlier" and the Silicoplacentina horizon are developed, which could be equivalent to the Ried Schlier because of the uncertain classification of the glauconitic series in the Vienna Basin. However, on top of the Silicoplacentina horizon marine Karpatian occurs here.

In the Molasse zone the Ottnangian on the SE—flank of the Bohemian Massif is represented by the Robulus Schlier (fig. 5). Its deposition area extends to the north up to Wildendürnbach — Mikulov, where the complete Eggenburgian is still present. In South Moravia the Rzehakia beds, which contain a Lower Karpatian fauna (Jiříček 1983), appear above the glauconitic sands and clays of the Lower Eggenburgian. Therefore, a hiatus is presumed which includes the rest of the Eggenburgian, the Ottnangian and sometimes also the Lower Karpatian on the northwest basin termination (Jiříček, 1983). Both, the sedimentologic development and the formation thickness allow the combination of the Oncophora beds and the Rzehakia beds to one unit (fig. 6). Therefore we realize the problem of formation classification as a palaeontologic one.

Along the line Mistelbach, Schrattenberg, Mikulov there was a broad connection of the foredeep with the Vienna Basin.

The paleogeography of the Ottnangian Upper Lužice beds concentrates in the Vienna Basin on the four above mentioned depressions. In the area near the Klippenzone, thin Ottnangian appears in the depression of Senice with Štefanov sands and thin pelite sediments on top. The same sediments obtain a thickness of 600 to 700 m in the Štefanov depression on the opposite outer side of the Klippen zone up to Gbely. In this development the Ottnangian advances through the transverse Kopčany channel into the Lužice depression, where the Lužice Schlier is separated by the Hodonin sands into an Eggenburgian Schlier with Cyclammina and an Ottnangian Schlier with Robulus. From this depression, which extends to the Mistelbach block (fig. 5), the Ottnangian transgresses along the Tynec-Steinberg line on the Flysch of the risen front of the Greifenstein nappe (Jiříček 1978). There it reaches the maximum thickness with 800—900 m. In the opposite direction to the northwest, the marine Ottnangian is proven in wells near Lednice east of Mikulov, where it overlies thick Eggenburgian Schlier. A distinct regression appears towards the end of the Ottnangian. It is most probable that the uppermost part of the Šakvice marl in the Pouzdřany and Ždanice unit and the upper part of the Ždanice-Hustopeče beds in the Waschberg-zone belong to the Ottnangian.

2.3 The Bockfliess Beds

A great delta complex is situated south of the Central Vienna Basin with a thickness up to 800 m east of Matzen (fig. 6). It developed out of the Lužice basin over the eroding relief of the Alpine-Carpathian nappes, first across the Flysch, then onto the Limestone Alps. A river system brought the sediment input from the south. The water depth did not exeed 250 m, the facies was brackish; salinity decreased towards the top of the formation, where total regression and an unconformity can be observed. Because of its microfauna, it was thought to be Upper Ottnangian. However, a new investigation of the fauna is now underway. Regarding the paleogeographic view, it is provisionally parallelized with the Lower Karpatian in Czechoslovakia (fig. 6), although they might be identified as two different units in modern seismic profiles.

2.4 Karpatian

The beginning of the Karpatian is characterized by the prominent Older-Styrian folding, which caused the overthrust of the Alpine-Carpathian flysch of the Penninicum on to the Eggenburg-Ottnang Molasse in Lower Austria and South Moravia. In connection with this tectonic movement the Pouzdřany, Waschberg and Ždanice zones were formed as the northwestern external zone of the mountain belt. On this occasion an enormous relief inversion developed; the flanks of the Bohemian Massif were tilted to the southeast, and progressively younger sediments of the marine Karpatian and Rzehakia beds transgressed to the northwest. After a decrease of the pressure of the Pannonian plate and the termination of the thrust movement from the southeast against the Bohemian Massif, the whole region reacted with an uplifting. This movement caused the regression of the sea from west to east and to northeast. It was in this way that the "Obere Süßwassermolasse" in Upper Austria was formed. In Lower Austria the sea regressed to the line Tulln-Eggenburg and covered most of the Waschberg, Ždanice and Flysch units (fig. 7). This sequence is partly preserved in the Korneuburg basin, in the area up to the Austrian-Czechoslovakian border and in the Southern Moravian graben region. Towards the end of the Karpatian, sedimentation moved back to the northeast and continued in the Laa basin and the connected northern Vienna Basin.

On the base of the Karpatian we can place the Rzehakia beds of the foredeep (fig. 6). Their brackish sediments reach in some areas the basis of the Lower Badenian as equivalent to the marine, more then 1 000 m thick beds of the Laa formation. In the wells close to Dunajovice near the Austrian-Czechoslovakian boundary the Rzehakia beds develop into Congeria beds and Ammonia sands, in whose marly layers a fauna of Karpatian age with Cyclammina carpatica and Uvigerina primiformis was found.

Similar confusions of Rzehakia beds with marine Karpatian sediments are known also from the Southern Slovakian area, the Salgotarjan basin, Lwow area (Lemberg, USSR) and from Georgia (USSR). It was for this reason that Jiříček (1975—1988) proposed to classify these deltaic and lagoonal sediments as equivalent to the marine Karpatian. In this case the assumption of a hypothetical brackish sea, extending from Switzerland to the Aral region, is no longer valid (Papp 1948—1975, Schlickum-Strauch 1968, Cicha 1967—1987, Čtyroký 1972—1982).

The progressive Karpatian transgression in the foredeep of Lower Austria and South Moravia in the northwest direction can be observed because of the disappearance of the different units, first of the thick Rzehakia beds (fig. 6). Then the Congeria and Ammonia sands disappear, which were recorded on top of the Eggenburgian in the wells near Laa, Wildendürnbach, Nový Přerov, Březí, Dolní Dunajovice, Mikulov up to Nesvačilka.

From Hrušovany and Židlochovice to the basin termination pelitic sediments of the marine Middle Karpatian are in contact with this Eggenburgian. On the border of the foredeep, the Upper, Uvigerina bearing sandy-shaly Karpatian almost touches the underlying Eggenburgian (fig. 7). In its continuation to Moravský Krumlov and Brno-Líšeň, only the Rzehakia beds appear. In the past these were thought to be of the same age. The greatest subsidence and sedimentation rate took place east of Laa where the predominantly shaly sequence reached a thickness of around 1 100 m.

In the northern part of the Vienna Basin, sedimentation continued from the regressive Ottnangian to the Karpatian. The Karpatian started with a transgression and is divided into three substages. The sediments of the lower stage cover nearly the whole western part, the area of the Mistel-

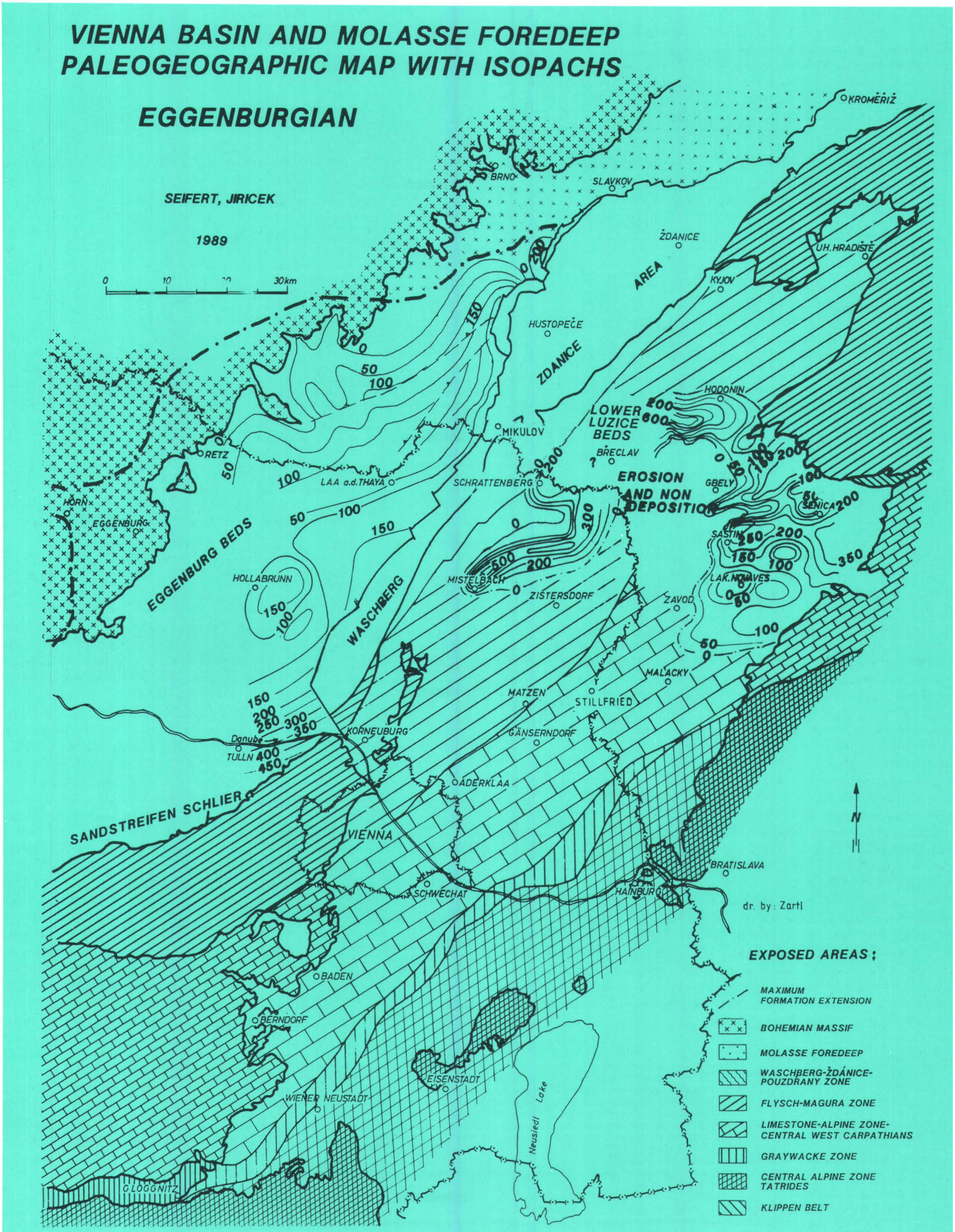

VIENNA BASIN AND MOLASSE FOREDEEP
PALEOGEOGRAPHIC MAP WITH ISOPACHS
EGGENBURGIAN
SEIFERT, JIRICEK
1989
0 10 30km
KROMĚŘÍŽ
BRNO
SLAVKOV
ŽDANICE
UH. HRADIŠTĚ
KYJOV
AREA
HUSTOPEČE
ZDANICE
HODONIN
LOWER LUZICE BEDS
MIKULOV
BŘECLAV
RETZ
EROSION AND NON DEPOSITION
GBELY
SENICA
LAA a.d. THAYA
SCHRATTENBERG
HORN
EGGENBURG
EGGENBURG BEDS
SASTIN
HOLLABRUNN
MISTELBACH
ZISTERSDORF
LAK. NOVAVES
ZAVOD
WASCHBERG
MALACKY
MATZEN
STILLFRIED
KORNEUBURG
GÄNSERNDORF
Danube
TULLN
ADERKLAA
SANDSTREIFEN SCHLIER
VIENNA
N
BRATISLAVA
SCHWECHAT
HAINBURG
dr. by: Zartl
EXPOSED AREAS:
MAXIMUM FORMATION EXTENSION
BOHEMIAN MASSIF
MOLASSE FOREDEEP
WASCHBERG-ŽDÁNICE-POUZDRANY ZONE
FLYSCH-MAGURA ZONE
LIMESTONE-ALPINE ZONE-CENTRAL WEST CARPATHIANS
GRAYWACKE ZONE
CENTRAL ALPINE ZONE TATRIDES
KLIPPEN BELT
BADEN
BERNDORF
EISENSTADT
WIENER NEUSTADT
Neusiedl Lake
GLOGGNITZ

Fig. 4

VIENNA BASIN AND MOLASSE FOREDEEP PALEOGEOGRAPHIC MAP WITH ISOPACHS

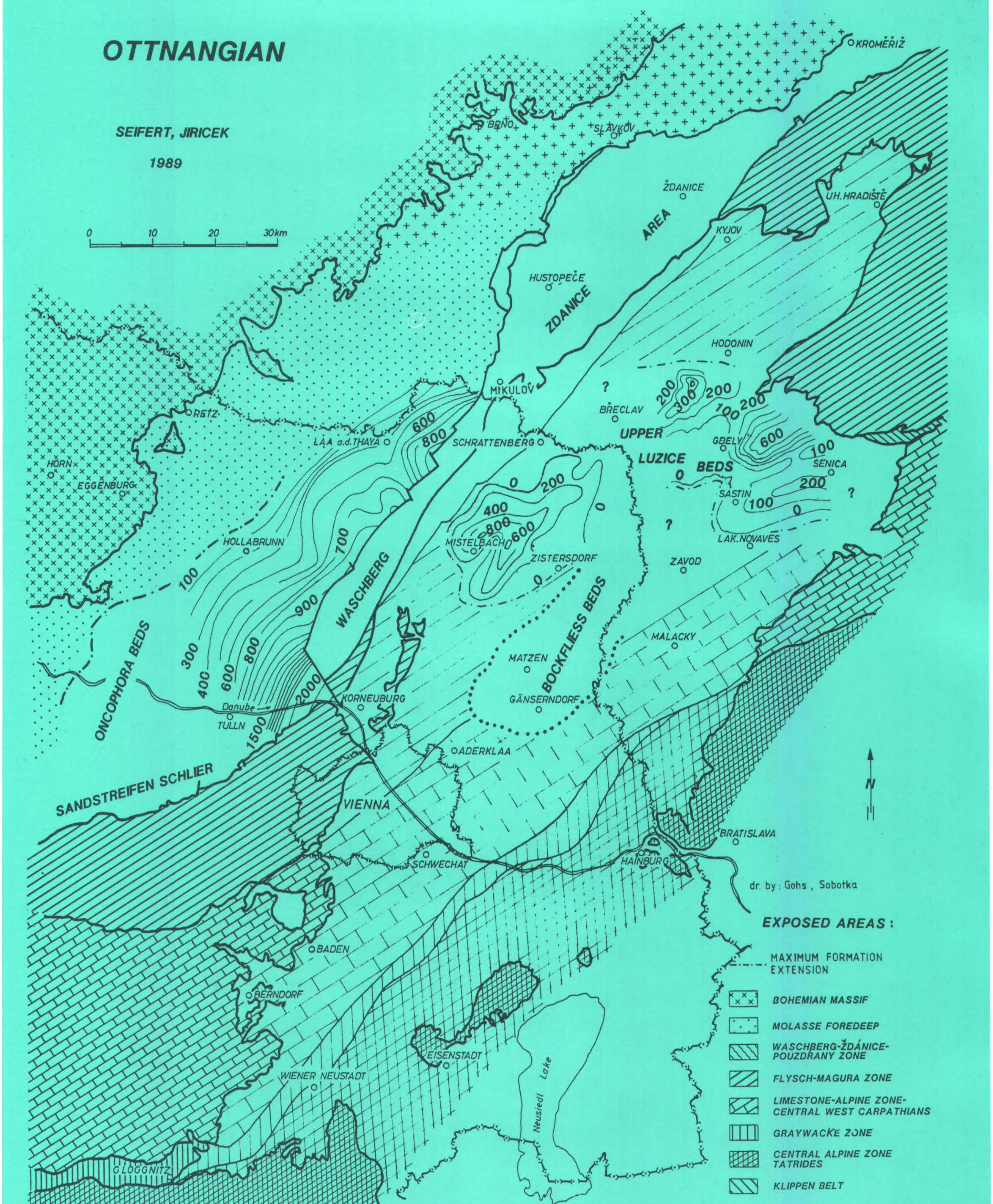


Fig. 5

bach block, and extend from the north to the Levare graben to the southeast (fig. 7). In the western part the Laa sandfacies is developed, which advances to Moravia as Tynec sand. On the Tynec-Gbely elevation it is replaced by marine Schlier sediments, which surround the whole northern part of the basin into the depression of Senice. Near the Little Carpathians the marine Schlier sediments of the Lakšáry beds are underlain by the Jablonica conglomerate.

In the Middle Karpatian thick delta sequences were developed, which surrounds the Slovakian part of the basin from Gbely to Studienka as Šaštín sands. The course of the rivers was directed from south to north.In the Upper Karpatian nearly the whole area of today's Vienna Basin was coverred with sediments. The largest basin subsidence shifted during the Karpatian from the eastern part of the basin to the middle part near the Austrian-Czechoslovakian border (compare fig. 6 and 7). The western part was uplifted and erosion and non deposition took place from Matzen to Zistersdorf in the area NW of the Spannberg ridge (fig. 7).

The vertical profile in the Slovakian part shows a sequence of 600—900 m Lakšáry Schlier sediments of the Lower Karpatian, then the 100—400 m thick brackish to limnic Šaštín sands of the Middle Karpatian and at last the marly-sandy 1 000 m thick marine to brackish Zavod formation of the Upper Karpatian (fig. 7).

The Bockfließ beds in the Austrian part of the basin correspond perhaps with the Lower Karpatian in Slovakia (fig. 6). The younger Gänserndorf beds are a limnic-terrestric sequence south of the central region of the basin with a thickness of 400 m near Rabensburg in the northeastern corner of the Austrian part and more then 500 m near Gänserndorf. Sandstones, conglomerates, coloured claystones with evaporite layers together with a limnic-terrestric fauna and Characeae bearing layers are characteristic and can be compared with the Middle Karpatian in the Slovakian part.

The Aderklaa beds developed continuously from the underlying Gänserndorf beds and transgressed 30 km to the south. The sand-shale sequence presents a delta complex with the terrestric part between Schwechat and Hainburg in the south, the delta plain area in the region east of Vienna up to the Matzen field, the delta front in the Matzen Závod area and the delta slope in the central, Slovakian part of the basin. The limnic brackish facies and fauna in the southern part correlates with the limnic-brackish Lab (ostracode) beds of Upper Karpatian in the south Slovakian part of the basin.

On top of the Lower Miocene sequence, in a period of nearly total regression in the basin, the fluviatile Aderklaa conglomerates appeared in the area east of Vienna up to Gänserndorf and the Little Carpathians. It covered an area of 350 km^2 and filled the relief mainly with components of the Limestone Alps from southwest up to a thickness of 350 m. Little conglomerate complexes on the western and southeastern border of the basin correspond to it.

3. Middle Miocene

At the beginning of this period the tectonic style changed from thrusting and normal faulting to strike slip movement. Because of the oblique collision of the Alpine-Carpathian nappe system with the Variscan Bohemian Massif, the thrust movement ended from west to east (Jiříček 1979).

In the Molasse zone west of Vienna, the latest overthrust is found in the Ottnangian, in the Waschberg zone in Lower Austria during the Karpatian, in the Ždanice unit in South Moravia at the end of the Karpatian, in North Moravia in the Lower Badenian.

The Waschberg, Pouzdřany and Ždanice units rose and began to be eroded. In the remaning Molasse foredeep, the last sedimentation period began for a short time. From the Mediterranean region across the Styrian Basin and Burgenland, the north part of the Vienna Basin with continuous sedimentation was again connected with the Tethys from the beginning of Badenian.

In the Vienna Basin an enormous relief inversion took place as a consequence of the change of the tectonic style. At the same time the major fault systems — Schrattenberg, Steinberg-Zistersdorf, Lanžhot, Kúty and Lakšáry — were created.

3.1 Lower Badenian

The Lower Lagenid zone sequence started with block breccias and conglomerates, which document the uplift of the neighbouring Alpine-Carpathian Flysch and Waschberg Ždanice zone and their erosion. The predominantly sandy beds are interbedded with shales mainly in the area southwest of Laa. Across the region between Mistelbach up to Hustopeče, the Vienna basin was connected with the sedimentation area of the reamining Molasse foredeep across the Wachberg — Ždanice unit (Grill 1958, 1961), (fig. 8). The sedimentation area extended in Lower Austria to the southwest near Krems, where the outcropping sediments are called Grund beds. The sequence started with basal sands overlain by lithothamnium limestones. The main part is built by Tegel. From the Lower to the Upper Lagenid zone the change of the tectonic style continued. The Molasse Basin, the Waschberg — Ždanice zone and the western and northern part of Vienna Basin were uplifted and began to be eroded after regression of the sea took place. The sedimentation followed the new fault-formed NNE—SSW basin axis and transgressed to the north and to the south (see fig. 8). Towards the end of the Karpatian, sedimentation in the northern part was marine, in the southern part limnic. During the Lower Badenian a reversal happened. Limnic sedimentation took place in the north and marine in the south. We can observe the progressive transgression of younger and younger beds northwards on the older Lower Miocene. The thick sequence of the central Moravian deep consists mainly of "Tegel". To the south a delta complex developed in the region Aderklaa, Matzen, Gajary west of Malacky.

3.2 Middle Badenian

The uplift of the western region — Molasse foreland, Waschberg-Ždanice zone and the western and northern border of the Vienna Basin — still continued and the area became dry land, except the northern part around Opava. The width of the Vienna Basin reached its maximum extension in the Austrian part, which can be seen still today (fig. 8). This is a result of the high stand of the global eustatic sea level (Kreutzer 1986).

A river system, the so-called "Ur-Donau", proceeded along the dry Molasse zone from the west through the Zaya-Graben into the Vienna Basin and established a large delta system. The Zaya Graben was developed above an old west-east Variscan graben structure of the underlying Bohemian Massif, which showed subsidence activity again from this time up to the Pannonian. The great delta complex progressed from west to east and covered nearly 30 percent of the whole basin in marine facies in the area of Pirawarth, Matzen, Gänserndorf, Suchohrad, Jakubov, Vysoká and Gajary to the southeast.

In the northern part a regression took place, and a delta complex advanced southwards into the basin (Jiříček 1975). In the lower part the lagoonal Žižkov beds were deposited and the sequence was finished with the Lab sands.

Lithothamnium limestones are characteristic sediments in the shallow water areas at this time. They were built at the upthrown side of the Mistelbach block at Schrattenberg and Lednice in the north and at the Steinberg in the middle part of the basin, as well as on the Matzen anticline. In the southeast 100 m thick bioherms overlain by claystones grew in the Lab area south of Malacky. The Hainburg and the Leitha mountains north of Eisenstadt are covered with tens of meters of this limestone.

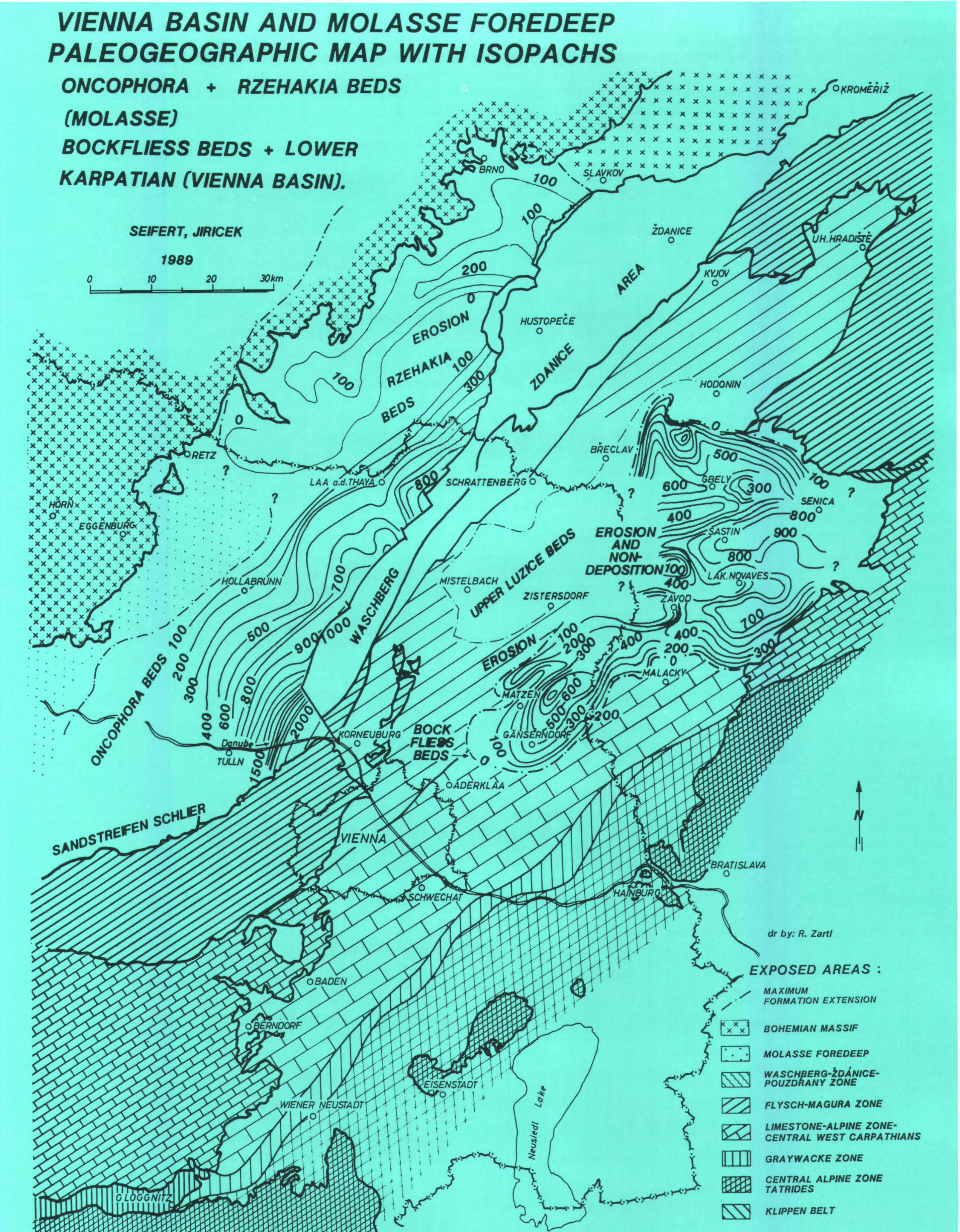

VIENNA BASIN AND MOLASSE FOREDEEP
PALEOGEOGRAPHIC MAP WITH ISOPACHS
ONCOPHORA + RZEHAKIA BEDS
(MOLASSE)
BOCKFLIESS BEDS + LOWER
KARPATIAN (VIENNA BASIN).
SEIFERT, JIRICEK
1989
0 10 20 30km
BRNO
SLAVKOV
KROMĚŘÍŽ
ŽDANICE
UH.HRADIŠTĚ
KYJOV
HUSTOPEČE
ŽDANICE
AREA
EROSION
RZEHAKIA
BEDS
HODONIN
RETZ
BŘECLAV
LAA a.d.THAYA
SCHRATTENBERG
GBELY
SENICA
HORN
EGGENBURG
ŠAŠTIN
EROSION
AND
NON-
DEPOSITION
UPPER LUZICE BEDS
LAK.NOVAVES
HOLLABRUNN
WASCHBERG
MISTELBACH
ZISTERSDORF
ZÁVOD
ONCOPHORA BEDS
EROSION
MALACKY
MATZEN
GÄNSERNDORF
KORNEUBURG
BOCK
FLIESS
BEDS
Danube
TULLN
ADERKLAA
SANDSTREIFEN SCHLIER
VIENNA
N
BRATISLAVA
SCHWECHAT
HAINBURG
dr by: R. Zartl
BADEN
BERNDORF
EISENSTADT
WIENER NEUSTADT
Neusiedl Lake
GLOGGNITZ
EXPOSED AREAS :
MAXIMUM
FORMATION EXTENSION
BOHEMIAN MASSIF
MOLASSE FOREDEEP
WASCHBERG-ŽDÁNICE-
POUZDRANY ZONE
FLYSCH-MAGURA ZONE
LIMESTONE-ALPINE ZONE-
CENTRAL WEST CARPATHIANS
GRAYWACKE ZONE
CENTRAL ALPINE ZONE
TATRIDES
KLIPPEN BELT

Fig. 6

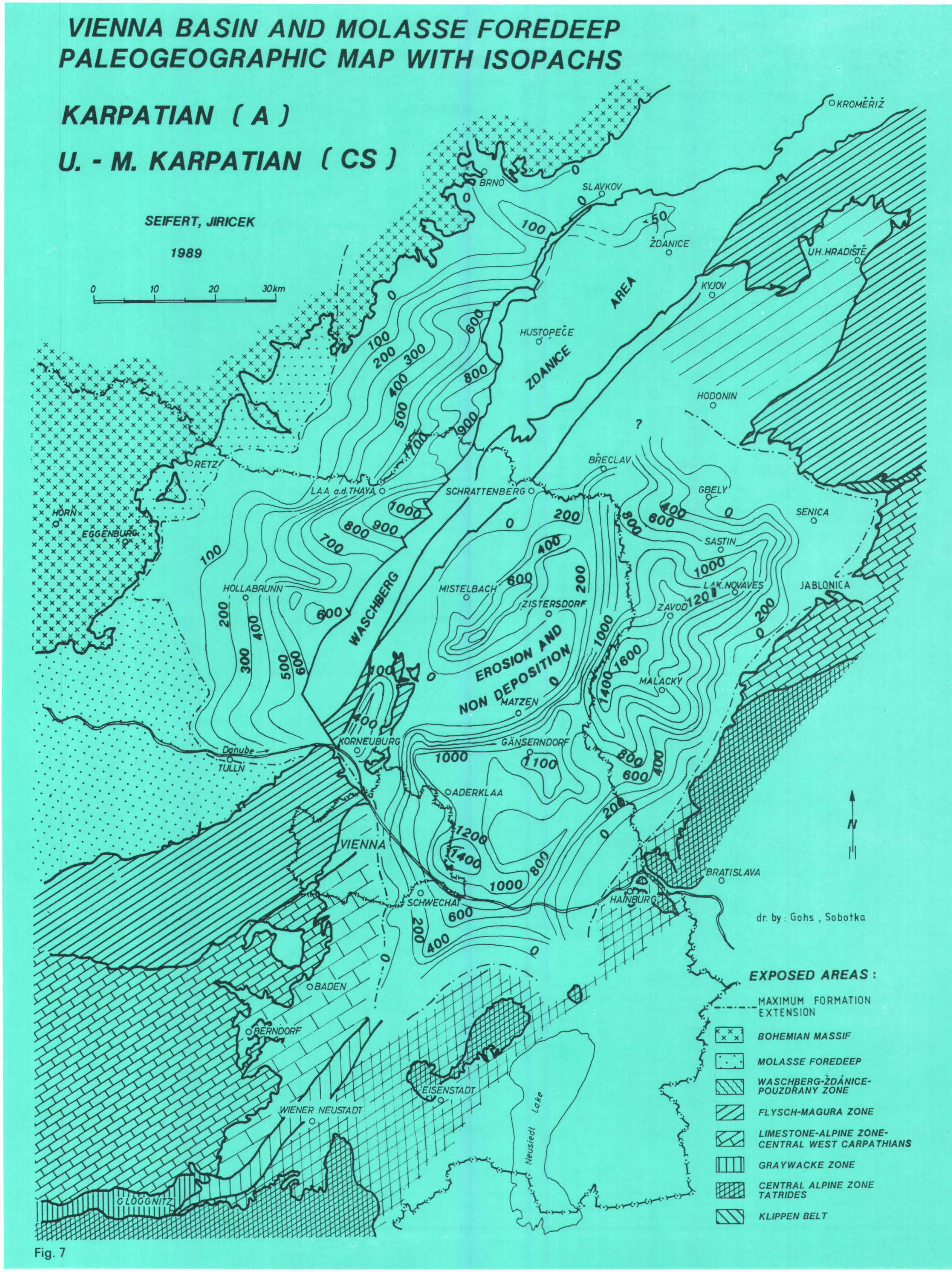
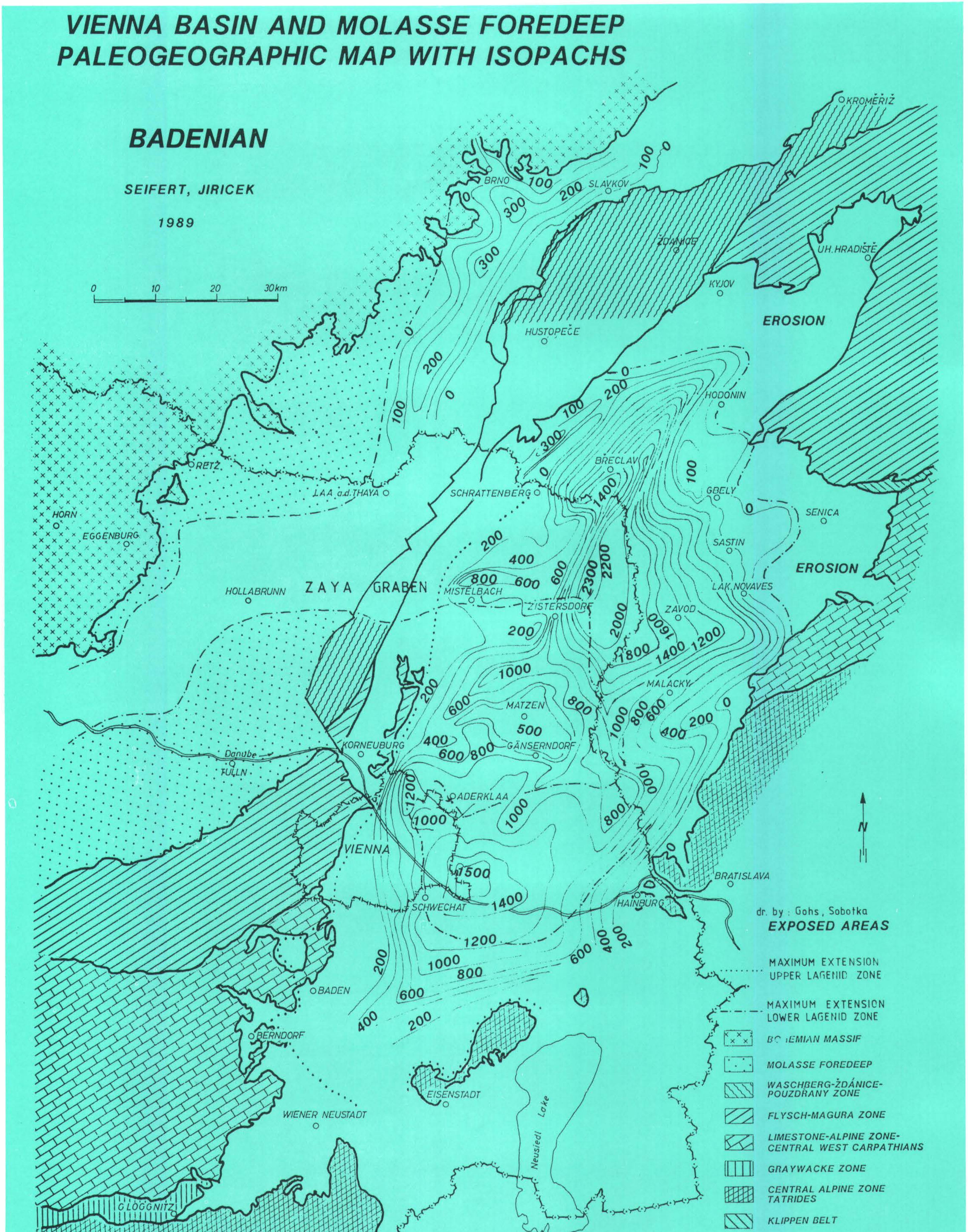
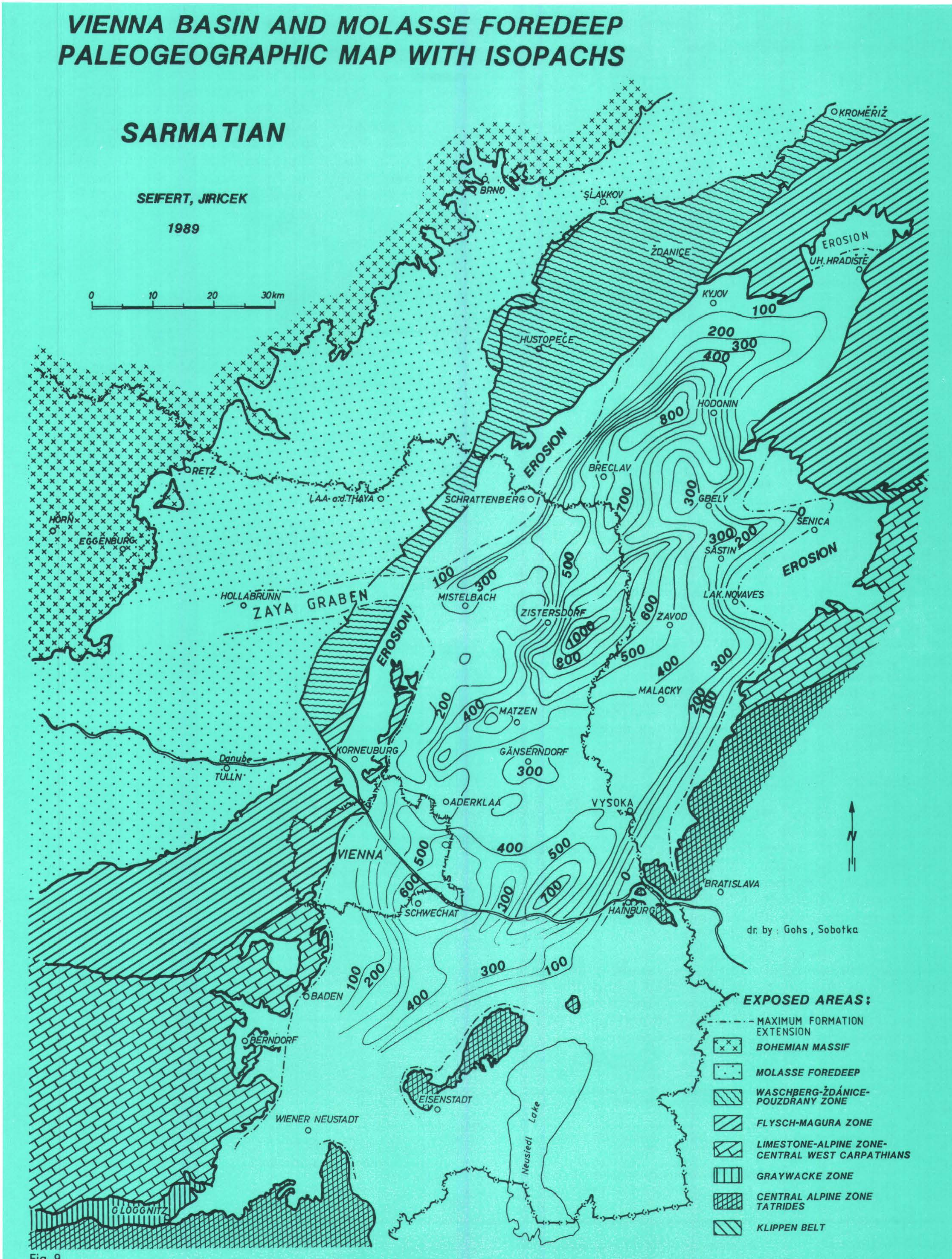

VIENNA BASIN AND MOLASSE FOREDEEP
PALEOGEOGRAPHIC MAP WITH ISOPACHS
KARPATIAN (A)
U. - M. KARPATIAN (CS)
SEIFERT, JIRICEK
1989
0 10 20 30km
BRNO
SLAVKOV
KROMĚŘÍŽ
ŽDANICE
UH. HRADIŠTĚ
KYJOV
HUSTOPEČE
ŽDANICE
AREA
HODONIN
BŘECLAV
GBELY
SENICA
SASTIN
LAK. NOVAVES
JABLONICA
ZAVOD
MALACKY
RETZ
HORN
EGGENBURG
LAA a.d. THAYA
SCHRATTENBERG
HOLLABRUNN
MISTELBACH
ZISTERSDORF
WASCHBERG
EROSION AND
NON DEPOSITION
MATZEN
KORNEUBURG
GÄNSERNDORF
Danube
TULLN
ADERKLAA
VIENNA
SCHWECHAT
HAINBURG
BRATISLAVA
BADEN
BERNDORF
EISENSTADT
WIENER NEUSTADT
GLOGGNITZ
Neusiedl Lake
N
dr. by: Gohs, Sobotka
EXPOSED AREAS:
MAXIMUM FORMATION EXTENSION
BOHEMIAN MASSIF
MOLASSE FOREDEEP
WASCHBERG-ŽDÁNICE-POUZDŘANY ZONE
FLYSCH-MAGURA ZONE
LIMESTONE-ALPINE ZONE-CENTRAL WEST CARPATHIANS
GRAYWACKE ZONE
CENTRAL ALPINE ZONE TATRIDES
KLIPPEN BELT

Fig. 7


VIENNA BASIN AND MOLASSE FOREDEEP
PALEOGEOGRAPHIC MAP WITH ISOPACHS
BADENIAN
SEIFERT, JIRICEK
1989
0 10 20 30km
ZAYA GRABEN
EROSION
EROSION
VIENNA
BRNO
SLAVKOV
KROMĚŘIŽ
ŽDANICE
UH. HRADIŠTĚ
KYJOV
HUSTOPEČE
HODONIN
BRECLAV
RETZ
LAA a.d. THAYA
SCHRATTENBERG
GBELY
SENICA
HORN
EGGENBURG
SASTIN
HOLLABRUNN
MISTELBACH
LAK NOVAVES
ZISTERSDORF
ZAVOD
MALACKY
MATZEN
KORNEUBURG
GÄNSERNDORF
Danube
TULLN
ADERKLAA
BRATISLAVA
SCHWECHAT
HAINBURG
BADEN
BERNDORF
EISENSTADT
WIENER NEUSTADT
Neusiedl Lake
GLOGGNITZ
N
dr. by: Gohs, Sobotka
EXPOSED AREAS
MAXIMUM EXTENSION UPPER LAGENID ZONE
MAXIMUM EXTENSION LOWER LAGENID ZONE
MOLASSE FOREDEEP
WASCHBERG-ŽDÁNICE-POUZDŘANY ZONE
FLYSCH-MAGURA ZONE
LIMESTONE-ALPINE ZONE-CENTRAL WEST CARPATHIANS
GRAYWACKE ZONE
CENTRAL ALPINE ZONE TATRIDES
KLIPPEN BELT
Fig. 8


VIENNA BASIN AND MOLASSE FOREDEEP
PALEOGEOGRAPHIC MAP WITH ISOPACHS
SARMATIAN
SEIFERT, JIRICEK
1989
0 10 20 30km
KROMĚŘIŽ
BRNO
SLAVKOV
ŽDANICE
EROSION
UH. HRADIŠTĚ
KYJOV
HUSTOPEČE
HODONIN
BŘECLAV
RETZ
LAA a.d. THAYA
SCHRATTENBERG
GBELY
SENICA
HORN
EGGENBURG
ŠASTIN
HOLLABRUNN
ZAYA GRABEN
MISTELBACH
ZISTERSDORF
LAK. NOVAVES
ZAVOD
MALACKY
MATZEN
KORNEUBURG
Danube
TULLN
GÄNSERNDORF
ADERKLAA
VYSOKA
VIENNA
BRATISLAVA
SCHWECHAT
HAINBURG
dr. by: Gohs, Sobotka
BADEN
BERNDORF
EISENSTADT
WIENER NEUSTADT
Neusiedl Lake
GLOGGNITZ
N
EXPOSED AREAS:
MAXIMUM FORMATION EXTENSION
BOHEMIAN MASSIF
MOLASSE FOREDEEP
WASCHBERG-ŽDÁNICE-POUZDRANY ZONE
FLYSCH-MAGURA ZONE
LIMESTONE-ALPINE ZONE-CENTRAL WEST CARPATHIANS
GRAYWACKE ZONE
CENTRAL ALPINE ZONE TATRIDES
KLIPPEN BELT
Fig. 9

The transgression reached the southernmost part of the basin, from where another delta complex advanced to the north to the region Schwechat-Hainburg.

3.3 Upper Badenian

In this time the transgression reached the northernmost part of the basin, where it covered the Ottnangian and Eggenburgian beds. The lower part, especially in the south, is characterized by marine claystones, sands and lithothamnium limestone beds of the Bulimina zone. In the upper part marine and brackish sands of the Rotalia zone dominate. Towards the end of the Badenian a reduced fauna appeared together with a partial regression, which can be observed at the line border of the basin.

4. Upper Miocene

In this period the separation of the Paratethys from the Mediterranean Sea and the transformation to a brackish continental sea occured.

4.1 Sarmatian

The lowest part is characterized by the above-mentioned regression and the locally developed coloured limnic beds (Carychium beds). They cover nearly the whole Czechoslovakian part of the basin up to Malacky, Lab and Vysoka (Jiříček 1975).Here we can observe the transition to the brackish beds, which are developed mainly in the Austrian part.

In the central part of the basin we assume continuous sedimentation across the Baden/Sarmat boundary. The brackish sand-shale sequence transgressed across the underlying different facies areas (zone with large Elphidiae). Above that the sandy zone with Elphidium hauerinum followed and then the sand-clay sequence with Protoelphidium granosum (fig. 2). The sediment input was brought mainly by the big delta system out of the Zaya graben, where residual Sarmat sediments were found up to Hollabrunn in the west (fig. 9). Two smaller deltas filled the basin from the north near Uherské Hradiště and the south near Wiener Neustadt. At the end of this sequence a partial regression occured. The three depocentres occur near Hodonin, Zistersdorf and east of Schwechat.

4.2 Pannonian

After the regression phase at the Sarmatian/Pannonian boundary, which can be observed at the basin border, a last transgression took place. The Paratethys was divided into the western kaspibrackish to limnic Pannonian Basin, the central halfbrackish Pannonian Basin and the eastern brackish area. At this period the Vienna Basin was a bay, situated northwest of the Pannonian Basin, and filled by the former delta systems especially by the Zaya graben delta (fig. 10).

The uplift and erosion of the Alpine orogene caused block-breccias in the south and thick sand-gravel sequences in the centre of the basin. The Pannonian sequence consists also of sand, shale, silt and marly beds. In the northern part of the basin, in Hradiště graben the sediments transgressed directly on the flysch.

The depocentres near Zistersdorf and Schwechat were shifted to the west from Sarmatian to Pannonian time (compare fig . 9 and 10).

4.3 Pontian

This period is characterized by the regression of the half-brackish sea to Hungary. The sedimentation concentrated in a new axis near the southeastern borderline of the basin. south of Malacky, east of Schwechat and north of Wiener Neustadt (fig. 11). At the bottom, mainly in the Czechoslovakian part, the Dubňany lignite and above that the coal series of zone F are developed, which reach also the the Austrian part. On top the transition to the bluegrey marl of the zone G followed, and finally the coloured, yellow brown clays of zone H. These are limnic to terrestric sediments, which originated in marshes. In the past zone F was classified with the Upper Pannonian and zones G—H into the Pontian (Buday 1960). The stage boundary was placed deeper, because of the discovery of the brackish Pontian Ostracods. The coloured series of zone H were classified into the Dacian (Jiříček 1975). The Pontian was expanded at the whole zones F to H because of the division in three parts in the Dacian Basin and the discovery of vertebrate fossils in the coloured series in the Austrian part (Papp 1975).

5. Pliocene

The lake sedimentation withdrew from the Vienna Basin to the southeast towards Hungary. In spite of the continuous uplift of the Alpine-Carpathian orogene with the Vienna basin, some areas in this basin were still sinking. Therefore, the drainage system of the Alpine Molasse zone — the Danube river — formed, away from the Zaya graben, a new channel in today's southeern position. In the Vienna basin 200 m thick, coloured claystones were classified into the Dacian, the sands and coal bearing clays above zone H near Studienka and the river gravels, sands and lignites near the Little Carpathians in the Rumanian (Jiříček 1975).

6. Pleistocene

This has left fluviatile gravels and sands near the rivers, Loess and aeolian sands elsewhere, and alluvial fans near the Eastern Alps, the Leitha mountains and the Little Carpathians.

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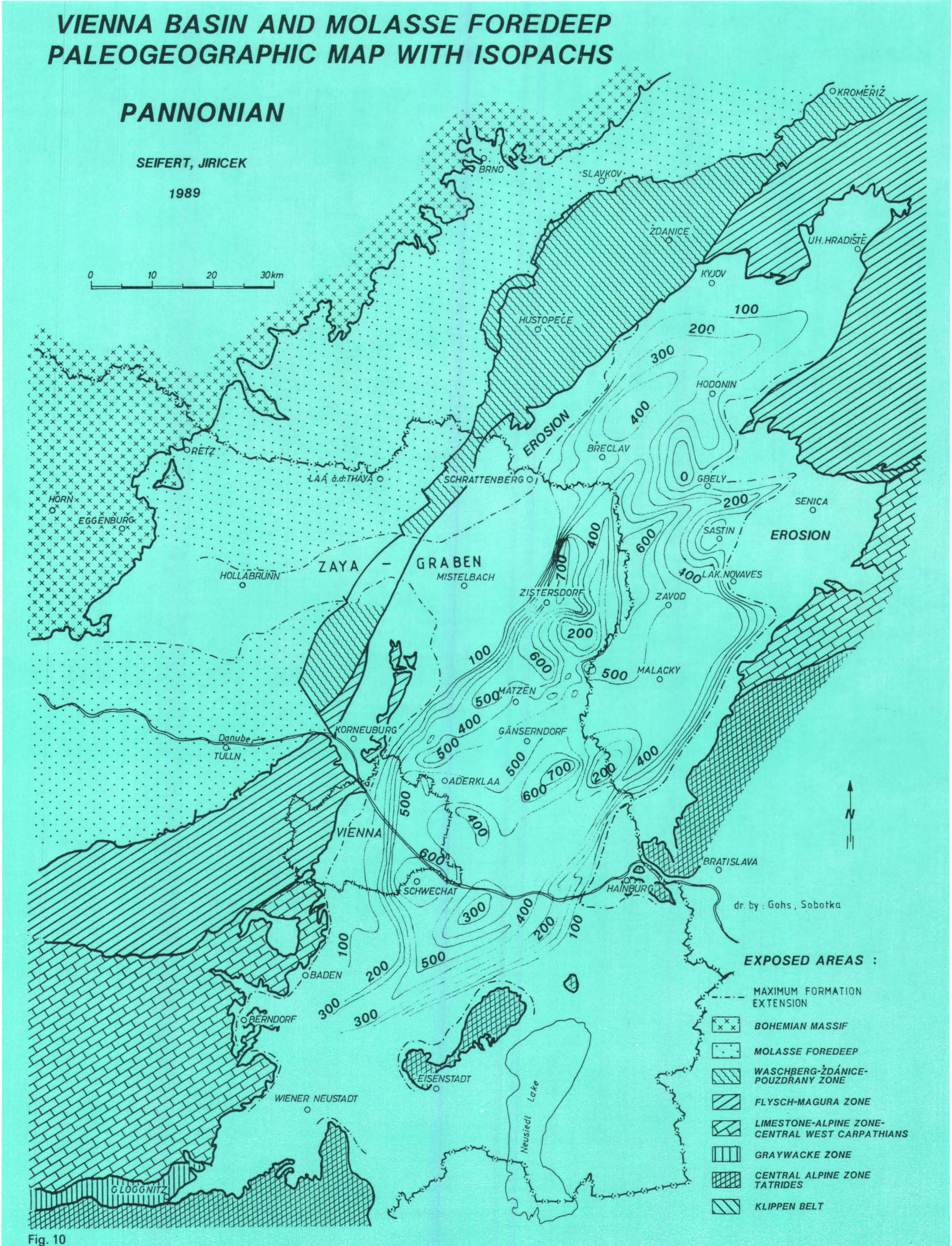
VIENNA BASIN AND MOLASSE FOREDEEP
PALEOGEOGRAPHIC MAP WITH ISOPACHS
PANNONIAN
SEIFERT, JIRICEK
1989
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SLAVKOV
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KYJOV
HUSTOPEČE
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BŘECLAV
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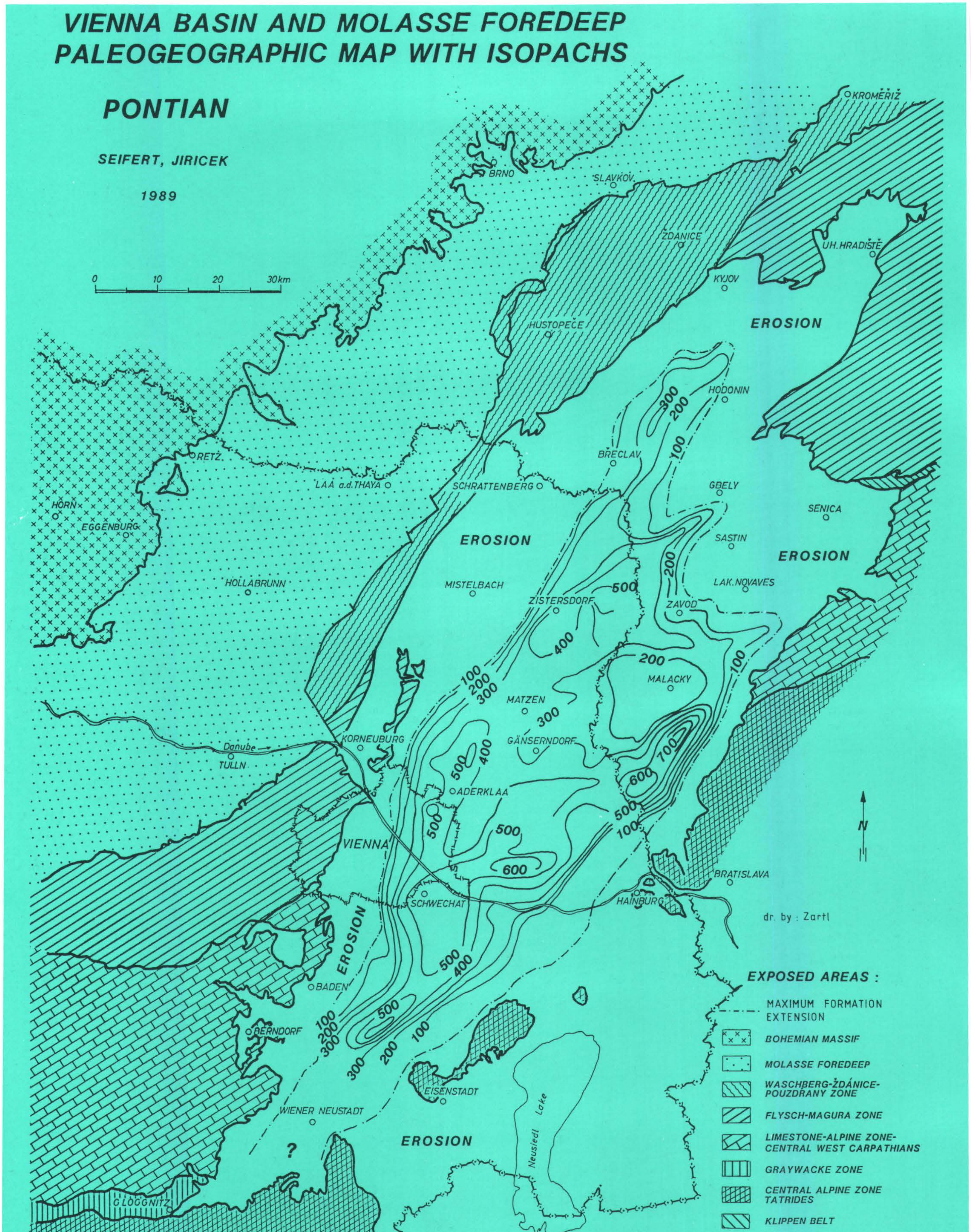
LAA a.d. THAYA
SCHRATTENBERG
GBELY
SENICA
HORN
EGGENBURG
SASTIN
EROSION
ZAYA - GRABEN
MISTELBACH
HOLLABRUNN
LAK. NOVAVES
ZISTERSDORF
ZAVOD
MALACKY
MATZEN
KORNEUBURG
GÄNSERNDORF
Danube
TULLN
ADERKLAA
VIENNA
BRATISLAVA
SCHWECHAT
HAINBURG
dr. by: Gohs, Sobotka
BADEN
BERNDORF
EISENSTADT
WIENER NEUSTADT
Neusiedl Lake
GLOGGNITZ
N
EXPOSED AREAS :
MAXIMUM FORMATION EXTENSION
BOHEMIAN MASSIF
MOLASSE FOREDEEP
WASCHBERG-ŽDÁNICE-POUZDŘANY ZONE
FLYSCH-MAGURA ZONE
LIMESTONE-ALPINE ZONE-CENTRAL WEST CARPATHIANS
GRAYWACKE ZONE
CENTRAL ALPINE ZONE TATRIDES
KLIPPEN BELT
Fig. 10


VIENNA BASIN AND MOLASSE FOREDEEP
PALEOGEOGRAPHIC MAP WITH ISOPACHS
PONTIAN
SEIFERT, JIRICEK
1989
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KROMĚŘÍŽ
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EROSION
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WIENER NEUSTADT
EROSION
Neusiedl Lake
GLOGGNITZ
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EXPOSED AREAS :
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BOHEMIAN MASSIF
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WASCHBERG-ŽDÁNICE-POUZDŘANY ZONE
FLYSCH-MAGURA ZONE
LIMESTONE-ALPINE ZONE-CENTRAL WEST CARPATHIANS
GRAYWACKE ZONE
CENTRAL ALPINE ZONE TATRIDES
KLIPPEN BELT

Fig. 11

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Abstrakt

V práci jsou předloženy prvé mapy mocností miocénu pro celou vídeňskou pánev a sousední molasovou zónu. Autochtonní eger je jen na rakouském území. Jeho alochtonní část tvoří šupiny ve waschberské zóně, pouzdřanské a ždánické jednotce. Sedimenty eggenburgu jsou typické jak ve vídeňské pánvi, tak i v molase. Pouze s ottnangem jsou těžkosti, neboť rzehakiové vrstvy jsou spíše korelovatelné s karpatem. Ve spodním badenu bylo jasné spojení mezi vídeňskou pánví a molasou. Od středního badenu do pontu existovalo toto spojení pouze s rakouskou molasovou zónou.

Zusammenfassung

Die vorliegende Arbeit beschäftigt sich mit der paläogeographischen Entwicklung des miozänen Wiener Beckens. Diese Region zählt zu den ältesten Erdölprovinzen Europas und zu den am intensivsten untersuchten. Die Verbreitung, die Mächtigkeit und die fazielle Ausbildung der einzelnen Formationen stehen in direktem Zusammenhang mit der tektonischen Entwicklung des Alpen-Karpatenbogens in diesem Abschnitt. Drei Stufen können unterschieden werden: Im älteren Miozän entstand das Wiener Becken am Rücken des nordwärts wandernden Dekkensystems und war ein Teilbereich der nördlich davon sich erstreckenden Molassevortiefe. Der Wechsel zwischen mariner, brackischer und limnisch-fluviatiler Sedimentation spiegelt die bewegte tektonische Entwicklung des Untergrundes wider. Ab dem Mittelmiozän war die Deckenbewegung beendet und es folgte das Pull-apart-Stadium der Beckenentwicklung. Dies war von starker Absenkung und hoher Sedimentationsrate gekennzeichnet. Große Deltasysteme füllten langsam das Becken, dessen Ablagerungsmilieu sich von vollmarin zu brackisch änderte. Im oberen Miozän verursachte die starke Hebung der Alpen und Karpaten grabenähnliche Bruchstrukturen. Die verstärkte Erosion des Reliefs bewirkte Grobschüttungen, die das gesamte Becken mit limnisch-fluviatilen Sedimenten bedeckten.

THE LOWER PANNONIAN SANDS AND THE PANNONIAN-SARMATIAN BOUNDARY IN THE MATZEN AREA OF THE VIENNA BASIN

N. Kreutzer, ÖMV Aktiengesellschaft, Wien, Austria

Based on the paleoecology of foraminifera and on geology, investigations by R. JIŘÍČEK (1978, 1985) in the czechoslovakian (and austrian) part of the Central Vienna basin resulted in a predominant deltaic nature of the gas bearing Upper Sarmatian and Lower to Middle Pannonian sand (gravel) — shale (clay) succession. A fingerlike distribution of several distinct NW-SE and N-S oriented sand and gravel beds of the Pannonian attaining a maximum thickness on the ends, has been compared by R. JIŘÍČEK with the modern birdfoot delta of the Mississippi river. These Pannonian fluctuating deltaic sand lobes of an ancient Danube river mouth are characterized by a fauna pointing to a lower salinity or fresh water in the sands than in the surrounding lagoonal shales or clays, eroding sometimes deeper shale layers, for instance of the Pannonian — Sarmatian boundary. On the contrary, other oriented sandbars containing the same faunal content as the surrounding shales, are not of deltaic origin. By compaction of the shales during burial, structural highs have been developed in the sand lobes and gas reservoirs, now gas storage deposits, have been created with different gas-water contacts (R. JIŘÍČEK, 1978, 1985).

A possible deltaic origin of the brachyhaline Sarmatian in the Matzen area has been indicated by N. KREUTZER (1974). Three conspicuous channellike trends of sands with basal extraformational alpine carbonate gravels, laterally and basally sharp bounded, exist in the 3rd/4th, 6th and 7th Sarmatian which are characterized by transgressive SP-log shapes (L. KÖLBL, 1953, H. WIESENEDER, 1959, N. KREUTZER, 1974). These partly meandering trends with a pendulum effect point to a sediment transport from the northwestern Molasse zone to south into the Central Vienna basin. The Lower Pannonian sand lobes in the Matzen area show a similar pendulum effect of the several NW-SE oriented and lensoid-shaped sand-and gravel beds, separated by shale or clay layers (Fig. 1,2). The variation of the gross-and the net thicknesses is considerable in the flanks of the 5th, 4th and 3rd Lower Pannonian, accompanied by erosional effects on the basis of the 5th and 4th, but decreases upwards in the 2nd and 1st Lower Pannonian. The boundary between Pannonian and Sarmatian, also very sharp within 1 m due to the faunal content, is generally a conformity within shale (clay) beds, containing numerous and regionally correlatable E-log resistivity markers. If sand lobes of both the 5th and the 4th Lower Pannonian become very thick and sharp based (channels), they have both eroded this boundary in numerous but small places in the whole Matzen area similar as in Czechoslovakia (Fig. 3—8). The 4th Pannonian could erode this boundary, however, only in the shaly flanks of the 5th Pannonian! In other places resedimented shales seem deposited below the 4th and 5th Pannonian. Erosional effects on the basis of the 3rd, 2nd or 1st Lower Pannonian, however, could not be detected. Important gas reservoirs, now gas storage deposits, are contained in the 3rd and 4th Lower Pannonian of the Matzen field. Based on the investigations by R. JIŘÍČEK, these sand lobes in the Matzen field should be also of deltaic origin,

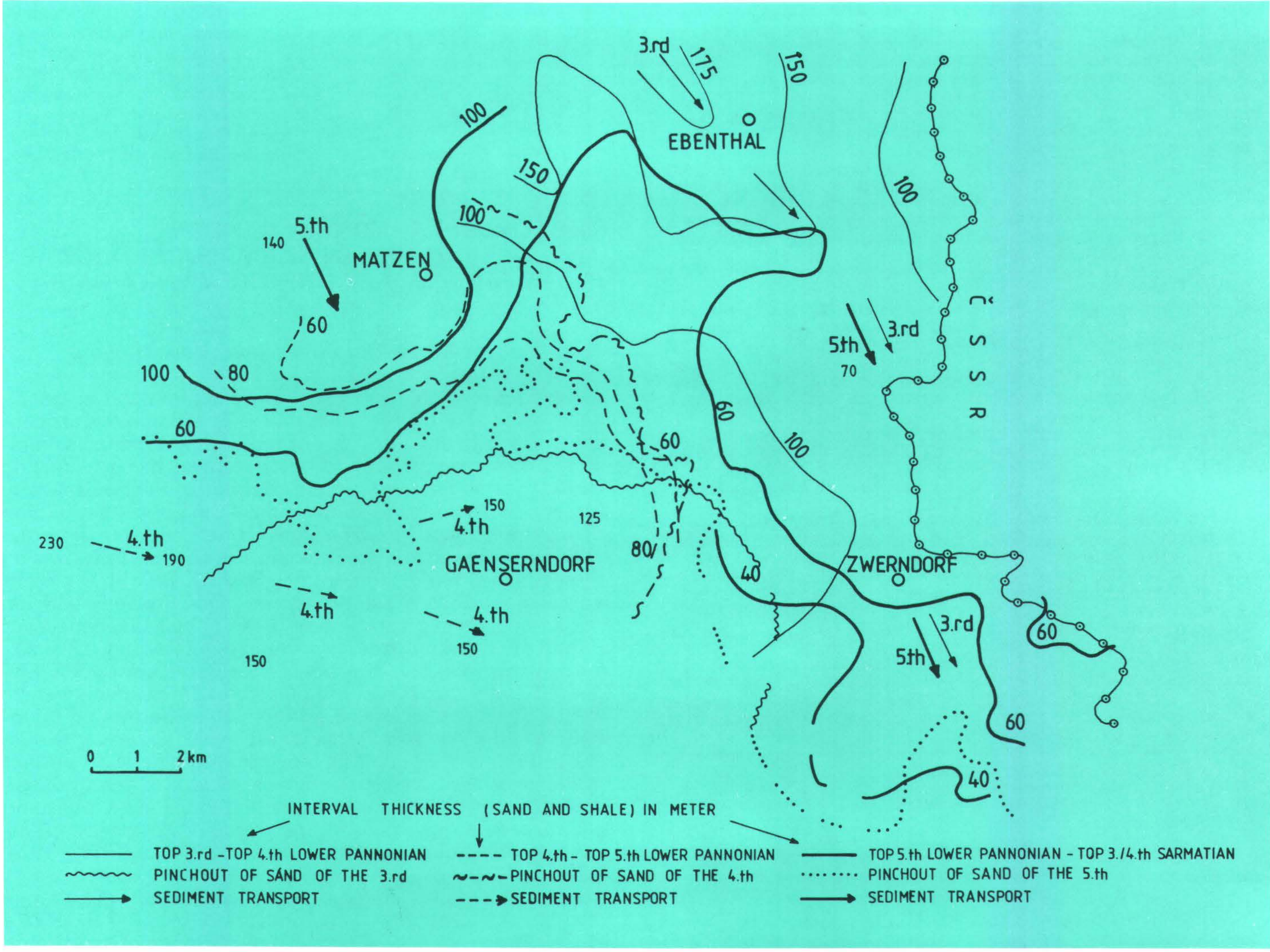

Fig. 1: Areal trends of the 3rd, 4th and 5th Lower Pannonian in the Matzen area (deltaic lobes).

constituting parts of a subaqueous bird foot delta of the ancient Danube river in the austrian part of the Central Vienna basin. The fluviatile sediments of the Lower Pannonian Danube river are represented by the well known Hollabrunn-Mistelbach-gravel-cone, seen in outcrops from west of the coast at Zistersdorf through the Zaya furrow northwest of Mistelbach into the Molasse zone at Hollabrunn.

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Abstrakt

Písčitá tělesa spodního panonu, orientovaná ve směru SZ-JV, jež se nacházejí v okolí lokality Matzen, vykazují kyvadlový efekt se značnými výkyvy mocností spodního panonu 5, 4 a 3. Dosahují-li písčitá tělesa spodního panonu 4, resp. 5, velkých mocností s ostře omezeným spodním rozhraním, mají na hranici panonu se sarmatem na mnoha místech erozní styk. Spodní panon 4 může však na této hranici vykazovat erozní kontakt pouze v jílovitých křídelních oblastech spodního panonu 5. Důležitá ložiska zemního plynu, využívaná nyní jako podzemní zásobníky plynu, jsou ve spodním panonu 3 a 4. Ve smyslu R. Jiřička snad tato písčitá tělesa rovněž představují podvodní deltové sedimenty Dunaje.

Zusammenfassung

Die NW-SO orientierten Sandkörper des Unterpannons im Raume Matzen zeigen einen Pendeleffekt mit beträchtlichen Mächtigkeitsschwankungen des 5., 4. und 3. Unterpannons. Wenn die Sandkörper des 4. bzw. 5. Unterpannons sehr mächtig werden und eine scharf begrenzte Unterkante aufweisen, erodieren sie die Pannon-Sarmatgrenze an zahlreichen Stellen. Das 4. Unterpannon kann diese Grenze jedoch nur in den tonigen Flankenbereichen des 5. Unterpannons erodieren. Wichtige Gaslagerstätten, jetzt Gasspeicher, sind im 3. und 4. Unterpannon vorhanden. Im Sinne von R. JIŘÍČEK sollten diese Sandkörper ebenfalls subaquatische Donau-Deltasedimente darstellen.

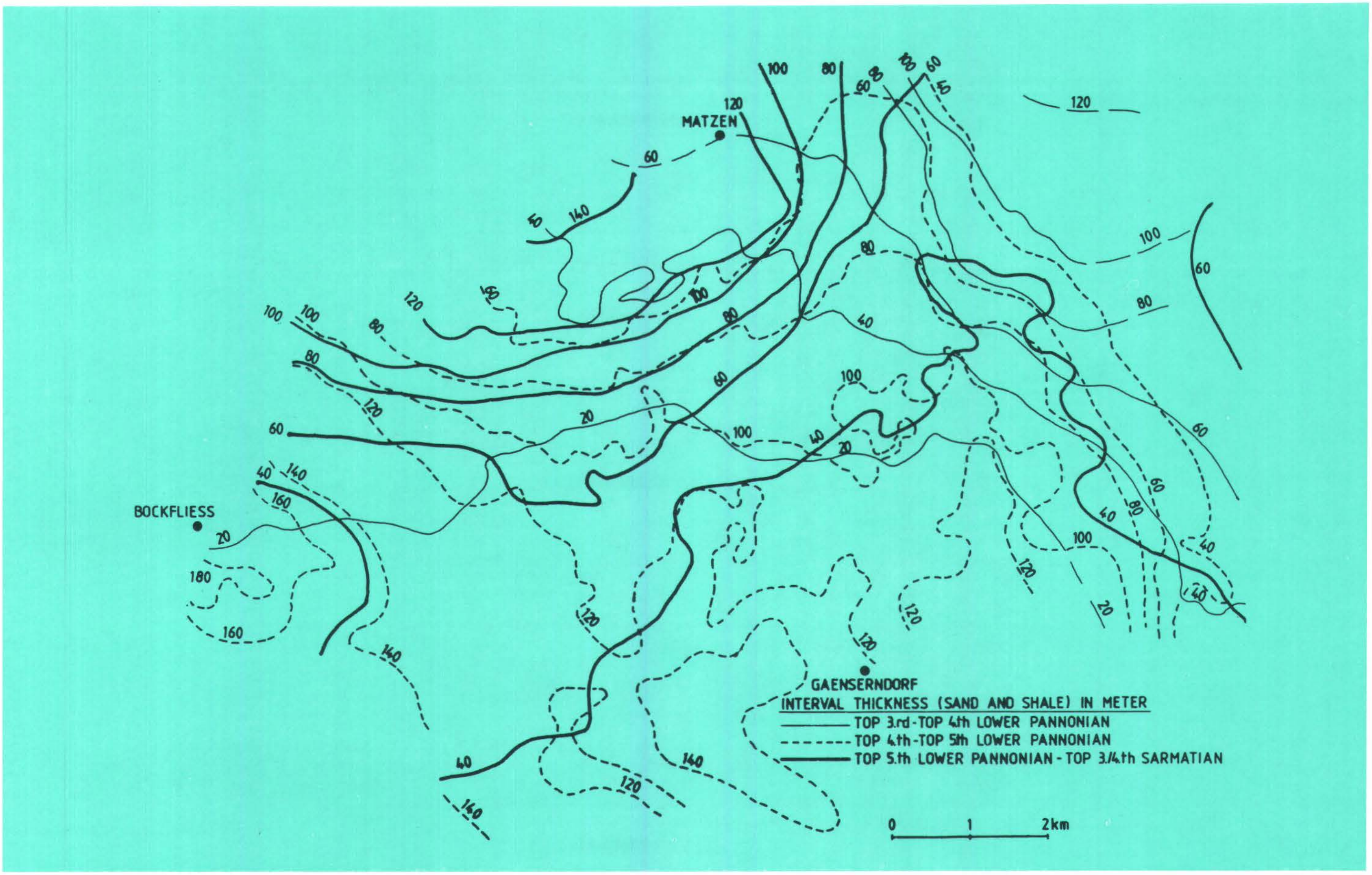
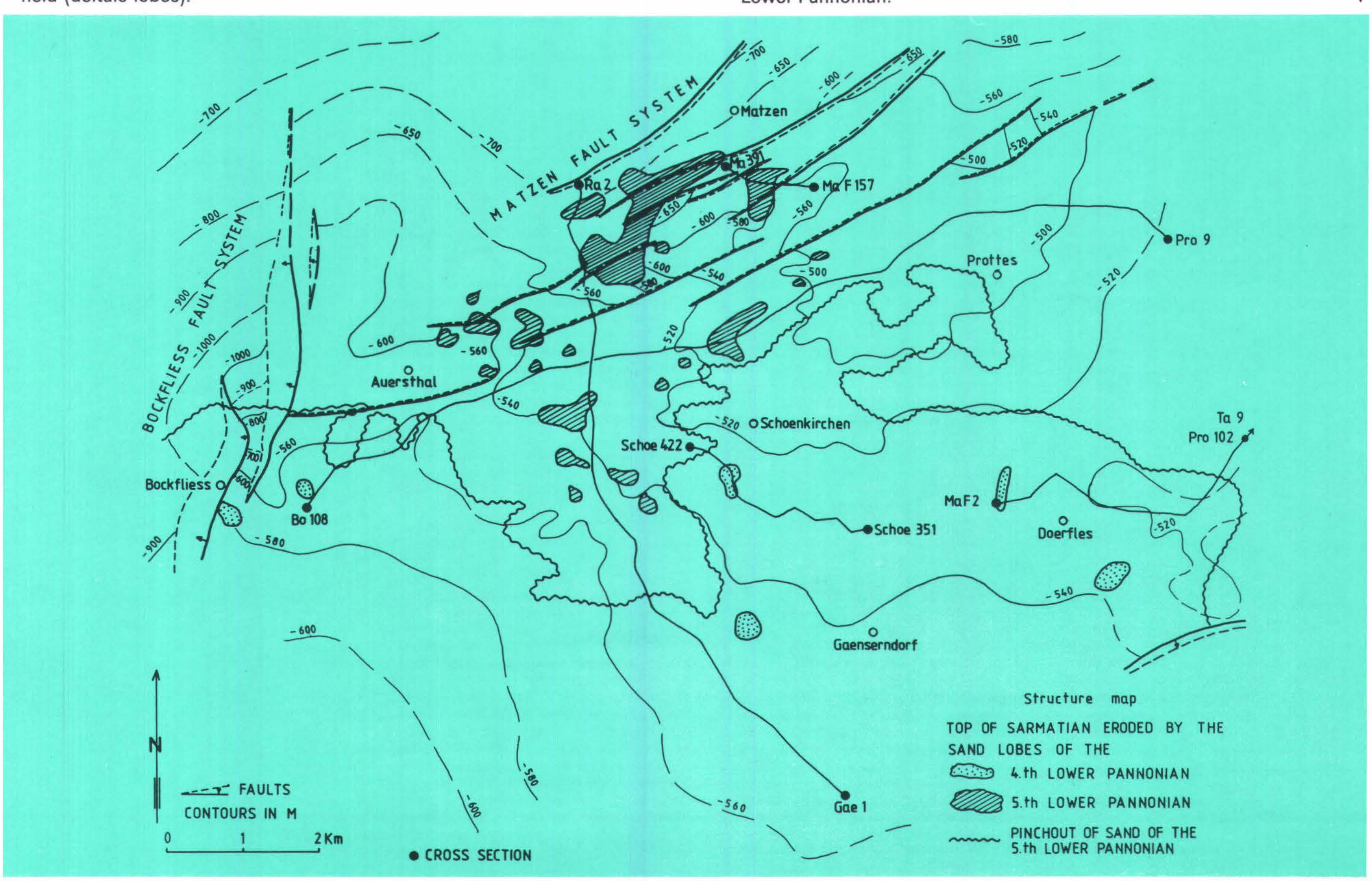


Fig. 2: Areal trends of the 3rd, 4th and 5th Lower Pannonian in the Matzen field (deltaic lobes).

Fig. 3: Structure map of the top of Sarmatian, eroded by sandlobes of the Lower Pannonian. ▼



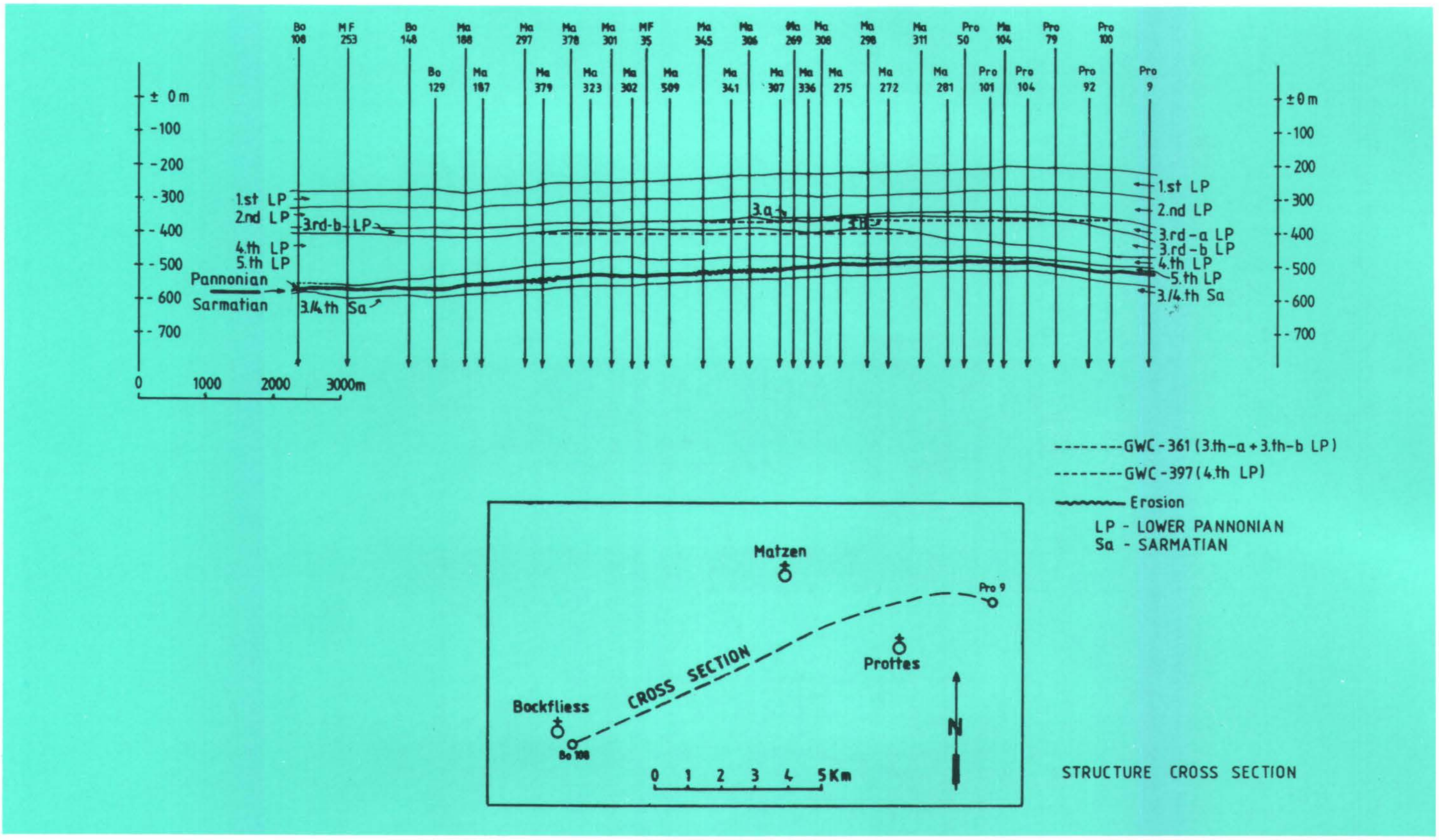
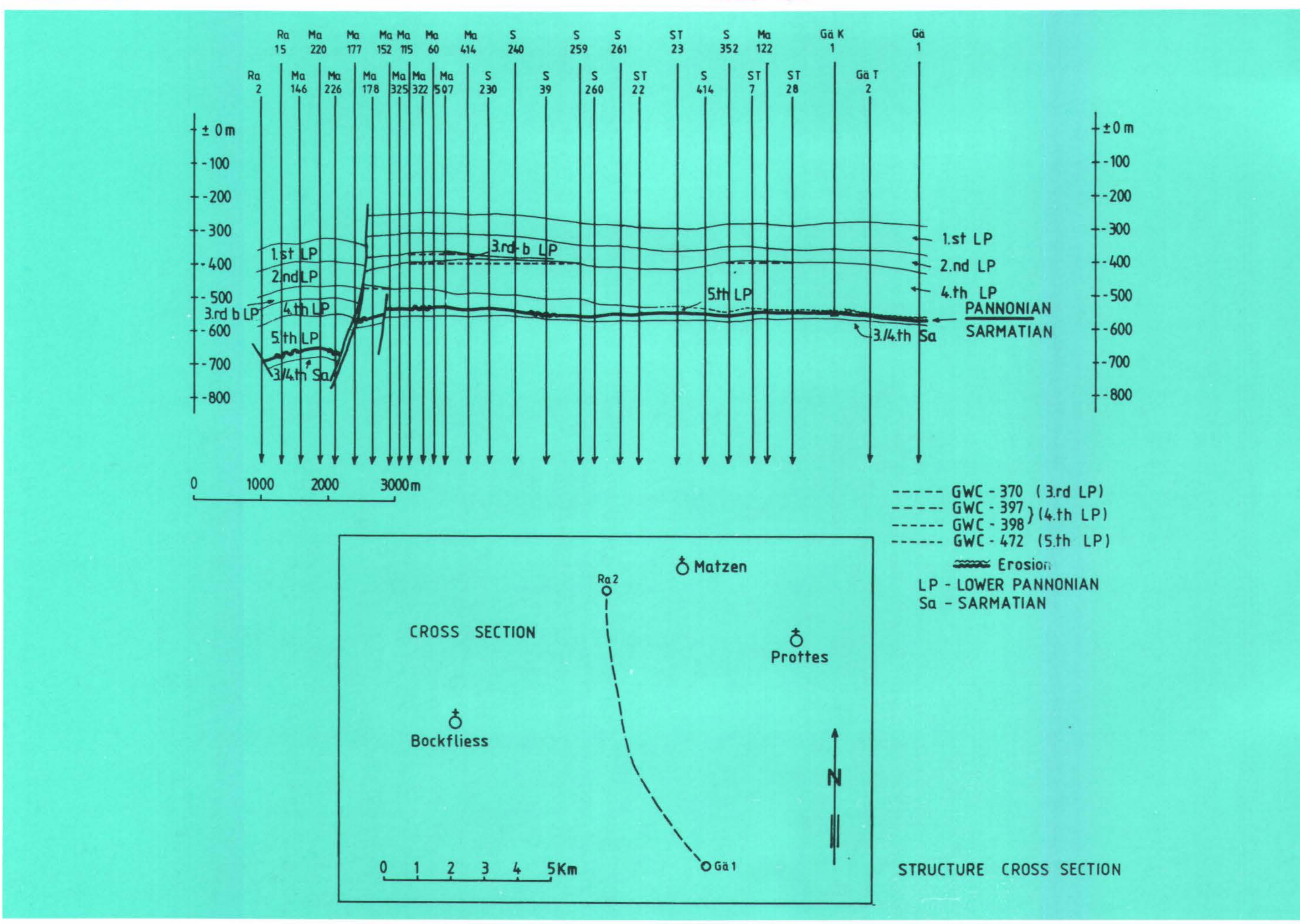


Fig. 4: Simplified cross-section of the Lower Pannonian sandlobes in the Matzen field.

Fig. 5: Simplified cross-section of the Lower Pannonian sandlobes in the Matzen field. ▼



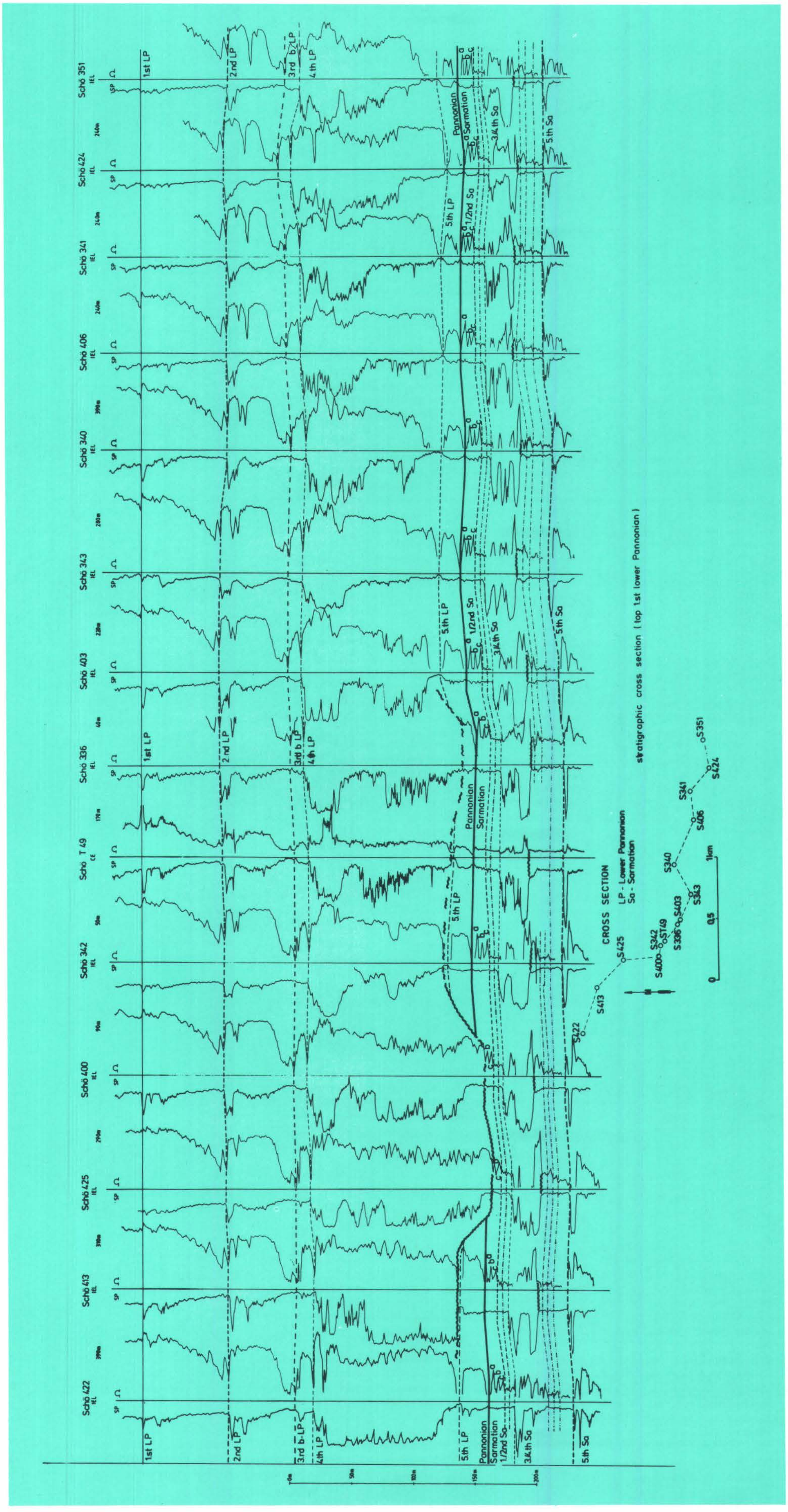


Fig. 6: Stratigraphic cross-section. The top of Sarmatian and the shaly 5[th] Pannonian can be eroded by the 4[th] Lower Pannonian sand-lobe.

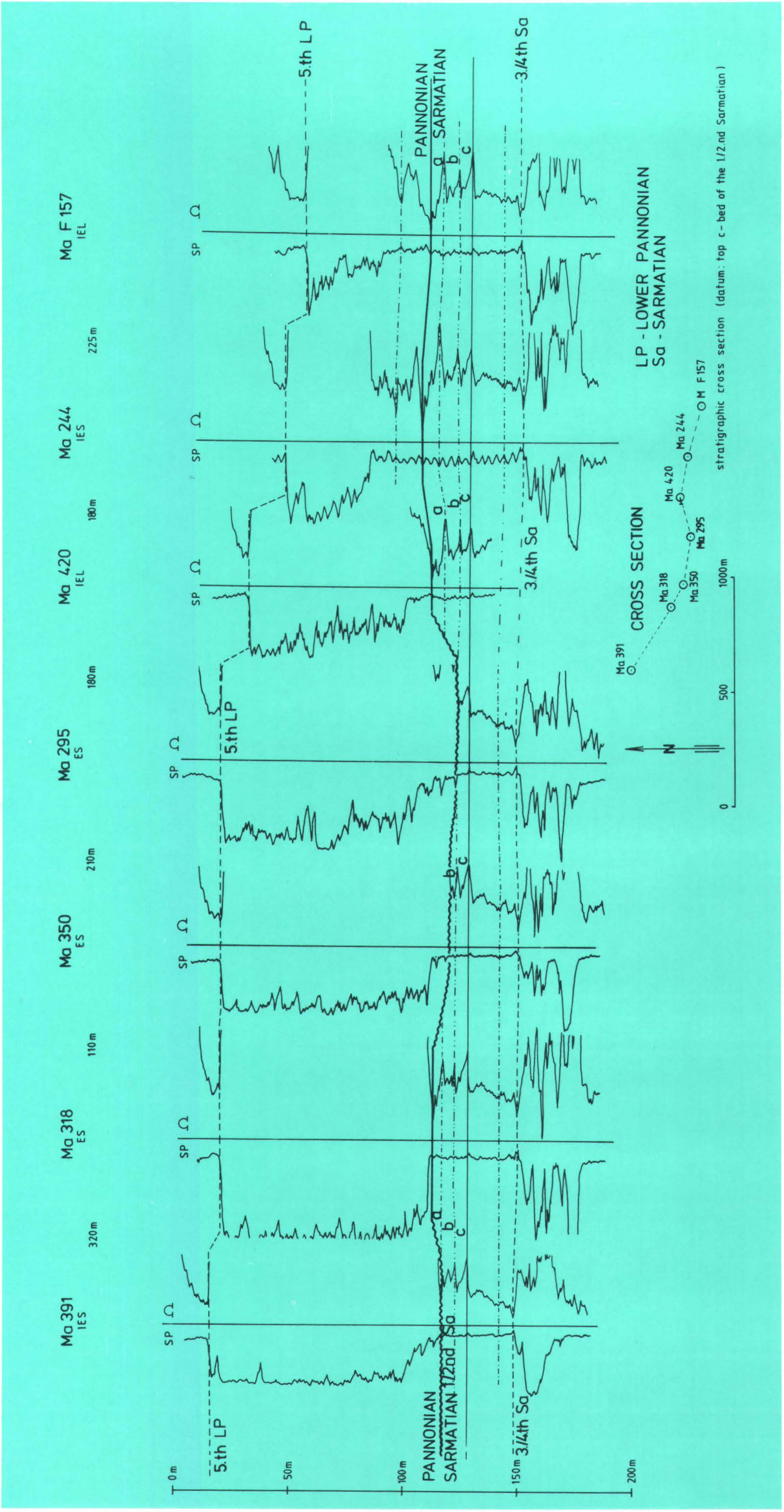


Fig. 7: Stratigraphic cross-section. The top of Sarmatian can be eroded by the 5th Lower Pannonian sandlobe.

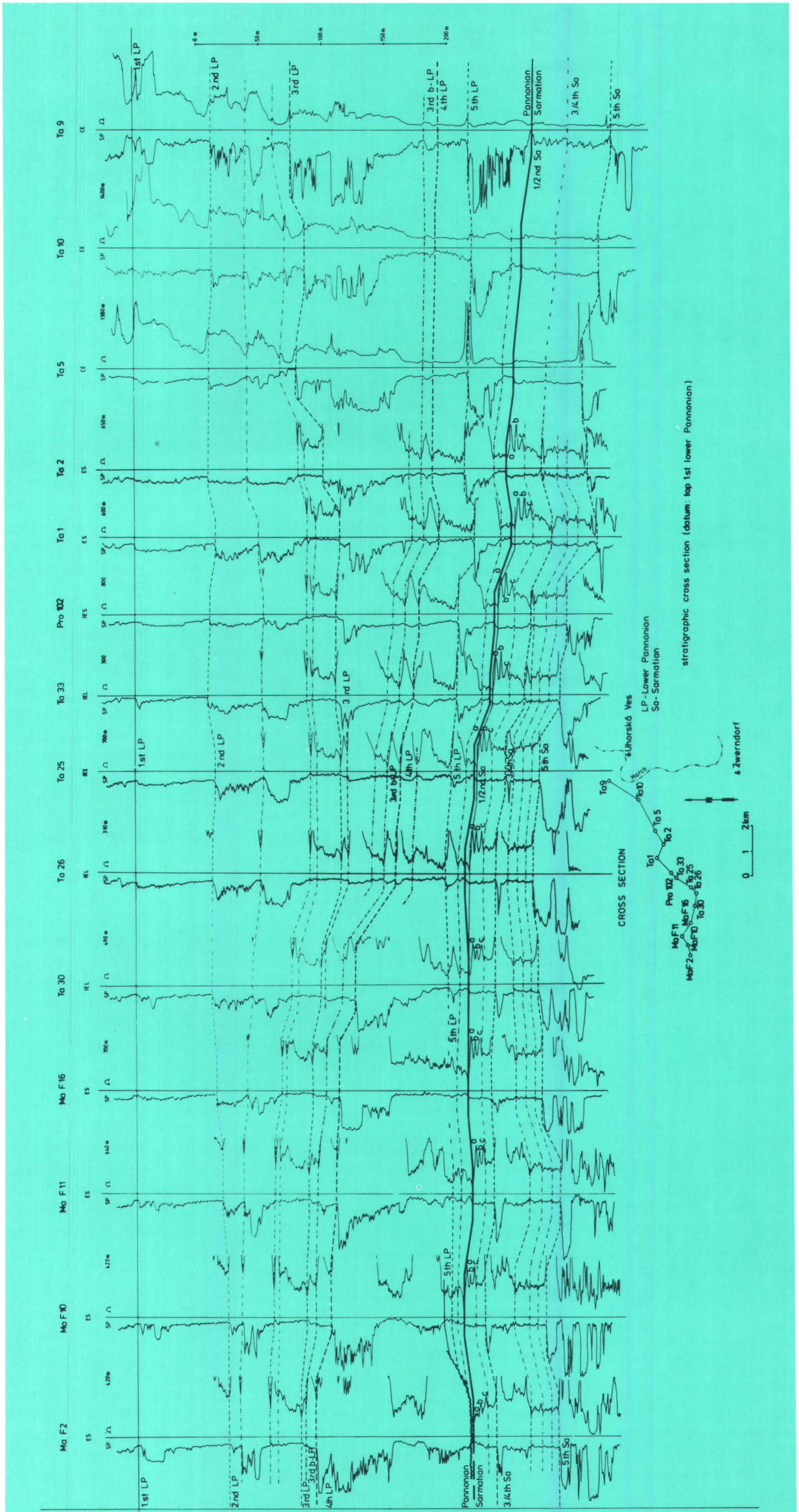


Fig. 8: Stratigraphic cross-section. The top of Sarmatian and the shaly 5th Pannonian can be eroded by the 4th Lower Pannonian sand-lobe.

SEDIMENTS OF THE MIOCENE (MAINLY BADENIAN) IN THE MATZEN AREA IN AUSTRIA AND IN THE SOUTHERN PART OF THE VIENNA BASIN IN CZECHOSLOVAKIA

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Matzen area

Transgressive — Regressive facies — Cycle wedges

The 2000 — 2800 m Miocene basin fill of the Matzen field can be divided, on the basis of well data and some seismic data, into different geological units, bounded mostly by erosional and angular unconformities or at least some paleontological or lithological criteria (Fig. 1). These geological units mostly correspond to depositional sequences (R. M. MITCHUM et.al, 1977), in a lower scale, as well as to transgressive-regressive faciescycle wedges (Fig. 1,2,3) (D.A. WHITE, 1980), in a higher scale. In the following the latter model will be treated first. Although at places bounded by regional unconformities, the cycle wedges as fundamentally facies-defined bodies will be bounded by nonmarine tongues. The study of D. A. WHITE is based on stratigraphic cross-sections through the main producing areas of 80 basins of the western world (including Vienna basin, but without a published cross-section), as well as on WALTHER's law of facies (the vertical succession of facies commonly is the same as the lateral order of their depositional environments, shifted by transgression and regression of the coast). The ideal wedge represents a transgressive-regressive cycle of deposition including, from base to top, the vertical succession of facies from nonmarine to coarse- and fine- to coarse textured marine and back to nonmarine (Fig. 2).

The Miocene basinfill of the Vienna basin can be divided into a various number of sand-shale cycle wedges, depending on the occurrence of the pre-Karpatian sediments. In the Miocene basinfill of the Matzen field 4 sand-shale cycle wedges can be recognized more or less distinctly (Fig. 1). 1. Lower parts of a wedge base: The terrestrial-limnic and conglomeratic Gänserndorf beds, the fluviatile Aderklaa conglomerate, the deltaic conglomeratic Auersthal beds, the gravel beds at the Badenian — Sarmatian boundary. Upper parts of a wedge base: the transgressive sands of the Lower Bockfliess beds, the transgressive Matzen sand of the Lower Badenian, the upper part of the Lower Sarmatian (8th). 2. Wedge-middle: the sand-shale succession in the middle part of the brachyhaline Bockfliess beds, of the limnic Aderklaa beds, of the brachyhaline to marine Badenian, of the brachyhaline Sarmatian and of the brackish Lower to Middle Pannonian. 3. Wedgetop: the sand-rich beds of the uppermost Badenian (1st—4th) and the fresh water gravelbeds of the Pontian. Because of erosional and angular unconformities on the top of the Bockfliess beds (D2) and Aderklaa beds (D3), a wedge-top does not exist or is incomplete and will not be represented by the overlying Gänserndorf conglomerate (D2) or Aderklaa conglomerate (D3).

1. Cycle

In the mostly lenticular sands of the brachyhaline Bockfliess beds the oldest and first distinct trangressive-regressive sand-shale facies cycle wedge is developed. A thick transgressive wedge-base of coarse sandstones (B16) onlaps unconformably the flanks of the Spannberg Flysch ridge in the north, dolomite debris and conglomerates (complexes B11—B16) onlap the buried hills of the Calcareous Alps in the south, respectively. The transgressive-regressive wedge-middle comprises sandstones and thicker shale intervals and perhaps also overlying sand-rich beds (B9—B11 in the north, B9, B10 in the south), although truncated by a regional unconformity (D2) (Fig. 1).

2. Cycle

Therefore the overlying terrestrial limnic Gänserndorf beds (TL3, TL4) with a basal conglomerate correspond to the nonmarine part of the wedge-base of the second cycle and not of the wedge-top of the first cycle. The limnic Aderklaa beds (Marker M18—25) belong to the wedge-middle, although truncated on the top by the regional erosional and angular unconformity (D3 (Fig. 1). Both, the Gänserndorf-and the Aderklaa beds, consist also of mostly lenticular sands.

3. Cycle

The overlying Aderklaa conglomerate again probably corresponds to the nonmarine part of the wedge-base of the Badenian and not of the wedge-top of the second cycle. The Lower Lagenida zone (far in the south of the field), the Upper Lagenida zone (Auersthal beds) and the Matzen sand belong to the marine part of the wedge-base of the third cycle. The transgressive-regressive sand-shale facies-cycle wedge of the Badenian in the Matzen field is almost completely developed and is especially clear recognized (Fig. 1, compare Fig. 2 and Fig. 3) (N. KREUTZER, 1986).

The **Matzen sand** is a typical basal time transgressive sand of the Badenian, corresponding to the transgressive wedge-base of the third facies cycle. This sand onlaps, with increasing erosional and angular unconformity from south to north, various older beds, first the conglomeratic Auersthal beds of the Upper Lagenida zone, then the Aderklaa- and Gänserndorf beds of the Karpatian, the Bockfliess beds of the Ottnangian or Lower Karpatian and at last the Upper Cretaceous Flysch of the Spannberg ridge (Fig. 3). The within the field up to 80 m, outside up to 140 m thick diachronous Matzen sand is a high quality reservoir (average porosity 26%, average permeability 1000 md) with a cumulative oil production of about 34 million tons since 1949.

The facies change between the Matzen sand and the overlying marine shale wedge occurs progressively farther marginward toward the island of the Spannberg ridge (or the basin margin in the northwest, respectively) in successively younger strata, representing a transgressive or up-to-margin pattern (N. KREUTZER, 1986) (Fig. 1,3). The inner neritic Matzen sand (Chr. RUPP, 1986) (Fig. 5) fines upward, apart from the conglomeratic and deltaic Auersthal beds in channellike topographic lows at the base, from coarse sands into fine-grained clastics in response to a sea level rise and changes from a high to a low energy environment. The SP-log profil is typically cylinder-shaped in the lower and middle part and more bell-shaped in the upper part, as the sand grades into the overlying marine shales of the outer neritic environment (Chr. RUPP, 1986) (Fig. 5). The thickness of the basal transgressive sand is dependent on the gradient of the depositional surface (W. O. ABBOTT, 1985). Because of high sediment influx and the moderate to steep gradient of the flanks of the eroded Spannberg ridge (Fig. 3) the transgression was slow and unusually thick sands are deposited in the topographic lows, whereas over the topographic highs with a low to moderate surface gradient and a limited supply of source material, the transgression was relatively fast and thin sands are preserved, in some places only shales have been deposited. This situation of the Matzen sand agrees well with the many examples of basal transgressive sands from North-and South-America, Australia, described and illustrated by W. O. ABBOTT, 1985.

All the other sheetlike (and in some places lenticular) oil and gas sands in the Badenian (15th—5th) above the Matzen sand belong to the wedge-middle plays (Fig. 1,3). Numerous sand tongues, alternating with shale interbeds,

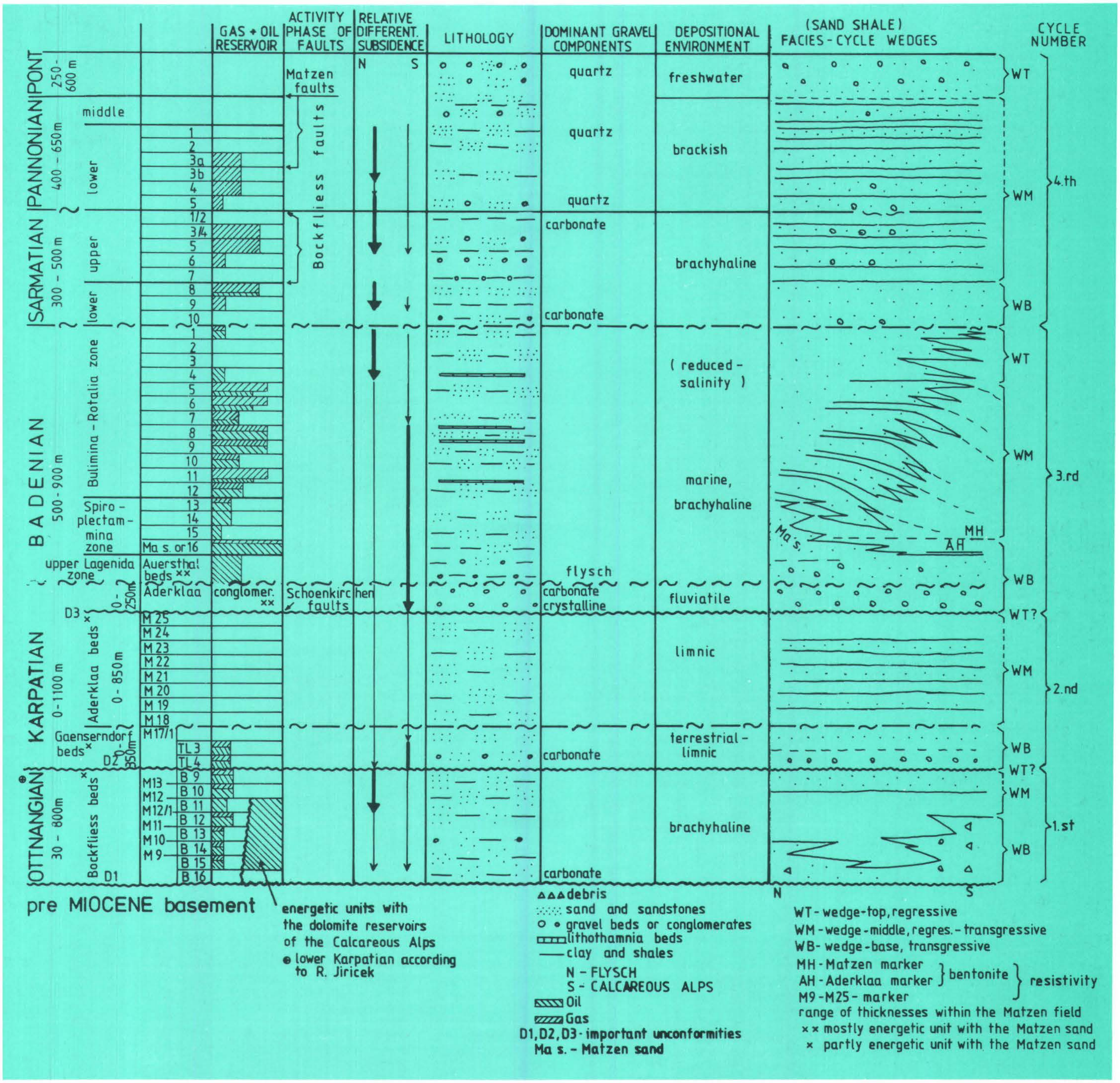


Fig. 1: Stratigraphy, tectonics, gas- and oil reservoirs of the Miocene basin fill in the Matzen field.

probably representing on the one side the transgressive fully marine parts, on the other side the regressive marine parts of deltas (deltafront and prodelta). These sand tongues extent, first (15th, 14th) from the northeast around and then also from the north and northwest over the subsided Spannberg ridge, into the wedge-middle part progressively farther south —and basinward in successively younger strata. The lower and upper segments of such tongues commonly have up-to-center (regressive) and up-to-margin (transgressive) facies patterns and funnel-shaped or bell-shaped SP-log patterns, respectively. The oil and gas reservoirs of the Badenian (15th — 5th) follow this trend, they occur in an up-to-center progression. The wedge-middle plays in the Matzen field are typically associated with marked depositional slopes and interval thickening (Fig. 1,3,4) (N. KREUTZER, 1986).

The regressive wedge-top of the uppermost Badenian (4th-1st) consists of sand- rich beds with a poor marine fauna and is truncated locally by an erosional unconformity in synsedimentary highs in the southern part of the field, marked by extraformational alpine carbonate gravelbeds at the Badenian-Sarmatian boundary (Fig. 1,3,4).

4. Cycle

Sand-rich beds of the Lower Sarmatian (10th-8th) correspond to a new transgressive wedge-base, transitional to an Upper Sarmatian thick shale interval (between 8th and 7th), followed again by sand-rich fining- or coarsening upward beds (7th-3rd/4th) including 3 channelized sharp-based sands with extraformational alpine carbonate gravels (3rd/4th, 6th and 7th Sarmatian) as well as several thicker shale intervals. It seems that the transgressive-regressive wedge-middle part comprises not only the lower thick shale interval but also the overlying sand (gravel) and shale

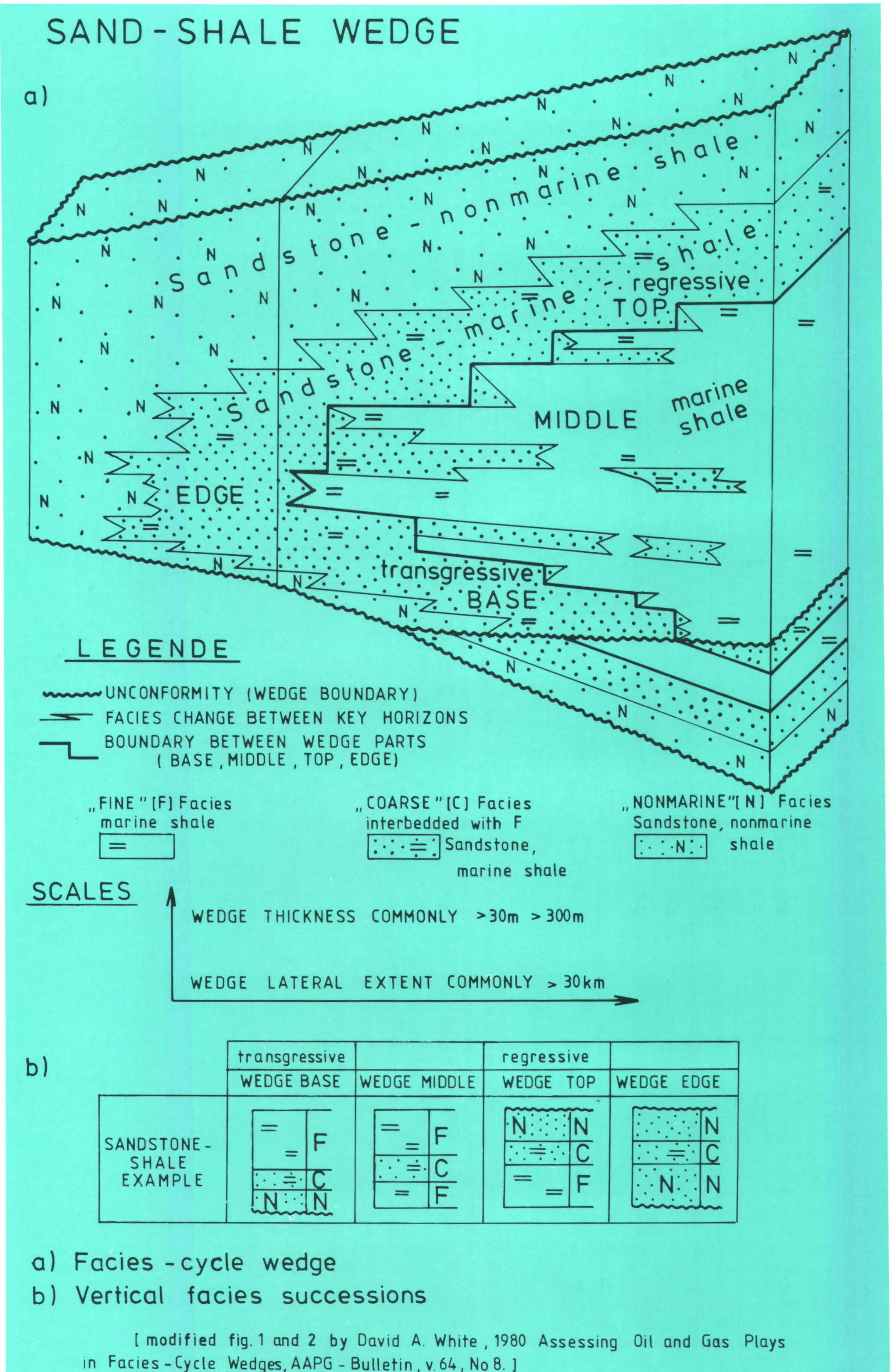


Fig. 2: Sand-shale wedge (modified) (According to D. A. White, 1980).

beds of the deltaic Upper Sarmatian, together even with the brackish and deltaic Lower and Middle Pannonian sand, (gravel) and shale or clay succession (Fig. 1). The Lower Pannonian sands (1st-5th) are characterized by an upward-coarsening facies (L. KÖLBL, 1953, H. WIESENEDER, 1959, N. KREUTZER, 1974) with regressive Sp-log shapes, except in the cylinder-shaped channelized parts of very thick sand lobes. The wedge-top would be represented by the sands and gravelbeds of the fluviatile-lacustrine Pontian (Fig. 1).

The Miocene basin fill has been subdivided into three sedimentary cycles already by L. KÖLBL, 1953 (internal report), 1957, 1959. Because all his cycles begin with the thick shale intervals and end with the sand-rich beds, the wedge bases of the 4th and 3rd cycle still belong to his 2nd and 1st cycle, respectively. The 2nd and 1st cycle correspond to his 1st cycle, but the pre-Badenian sediments have been only little known at this time and therefore could have not been differentiated by L. KÖLBL.

The depositional sequences

The Miocene geological units of the Matzen field generally also correspond to despositional sequences (R. M. MITCHUM et al, 1977: „A depositional sequence is a stratigraphic unit composed of a relatively conformable succession of genetically related strata and bounded at its top and base by unconformities or their correlative conformities“). Because depositional sequences are recognized by the geometry of their bedding planes, it was necessary to divide the **Badenian** of the Central Vienna basin into two completely different geological units or depositional sequences, a lower transgressive unit or sequence of the Lower Badenian and an upper alternating regressive-transgressive unit or sequence of the Upper Badenian (Fig. 3,4) (N. KREUTZER, 1986).

The lower transgressive sequence of the Badenian in the Matzen field (Fig. 3), showing an increasing base discordant onlap and hiatus towards north, comprises the Matzen sand as well as the overlying parallel to slightly divergent bedded and rather homogeneous and bentonite bearing shales, which have a facies change with the sand and are increasing in thickness southward. This situation of the lower sequence indicates probably a deposition (sedimentation rate lower than subsidence rate) after a relative fall of sea level followed by a rise in sea level („lowstand deposits“ of VAIL et al., 1977) (N. KREUTZER, 1986).

On the contrary, the upper sequence of the Badenian in the Matzen field above the regional Matzen bentonite marker, overlying the lower sequence with increasing apparent base-discordant downlap and apparent hiatus towards south, (Fig. 3,4), is characterized by cyclic beds of lower regressive (coarsening-upward) and upper transgressive (fining-upward) sands and rather heterogeneous clays and shales. The upper and middle sands are thicker and laterally more extensive than the lower sands. Up to 1 m thick calcareous sandstones with a marine macrofauna are frequent on the top of such sandcomplexes and are, together with the overlying shales, marine transgressive sediments. These shales, 5—20 m thick and repeatedly intercalated, separate the sandcomplexes and reservoirs. Slightly increasing SP- and resistivity values as well as silt-or sand-content of the shales indicate marine prodelta sediments, transitional to the marine deltafront sands of such sandcomplexes. The upper sequence (Fig. 3) exhibits a sigmoid to oblique progradation or offlap with a paleo-topographical differentiation into a northern upper platform (topset) zone with gently dipping and rather parallel bedded segments of a sand-rich facies, a middle (foreset) zone with thicker more steeply dipping (up to 6°) segments locally

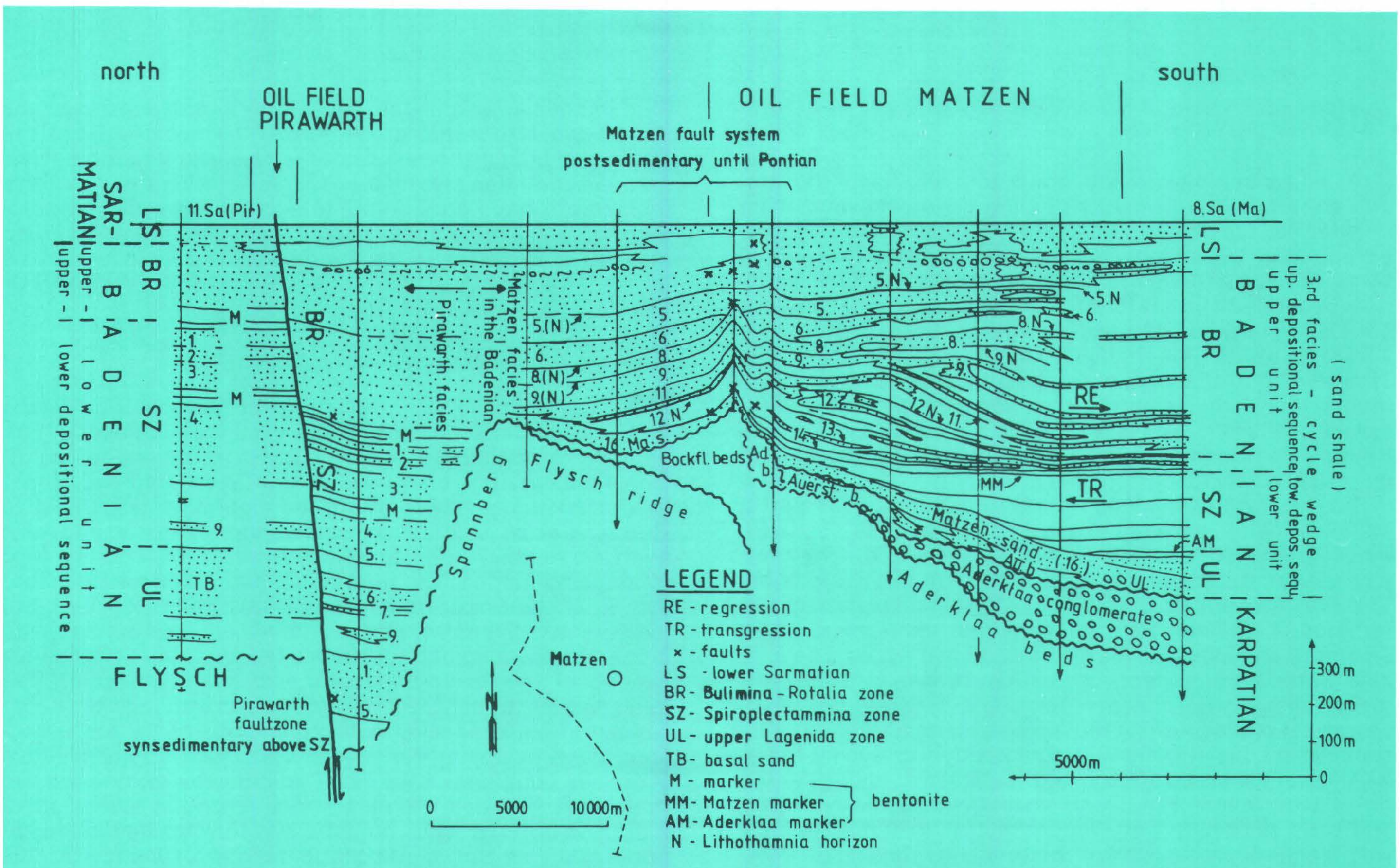


Fig. 3: Stratigraphic cross-section of the Badenian in the Matzen field with a facies-cycle wedge (south of the Spannberg ridge) and depositional sequences (according to N. Kreutzer, 1986, modified).

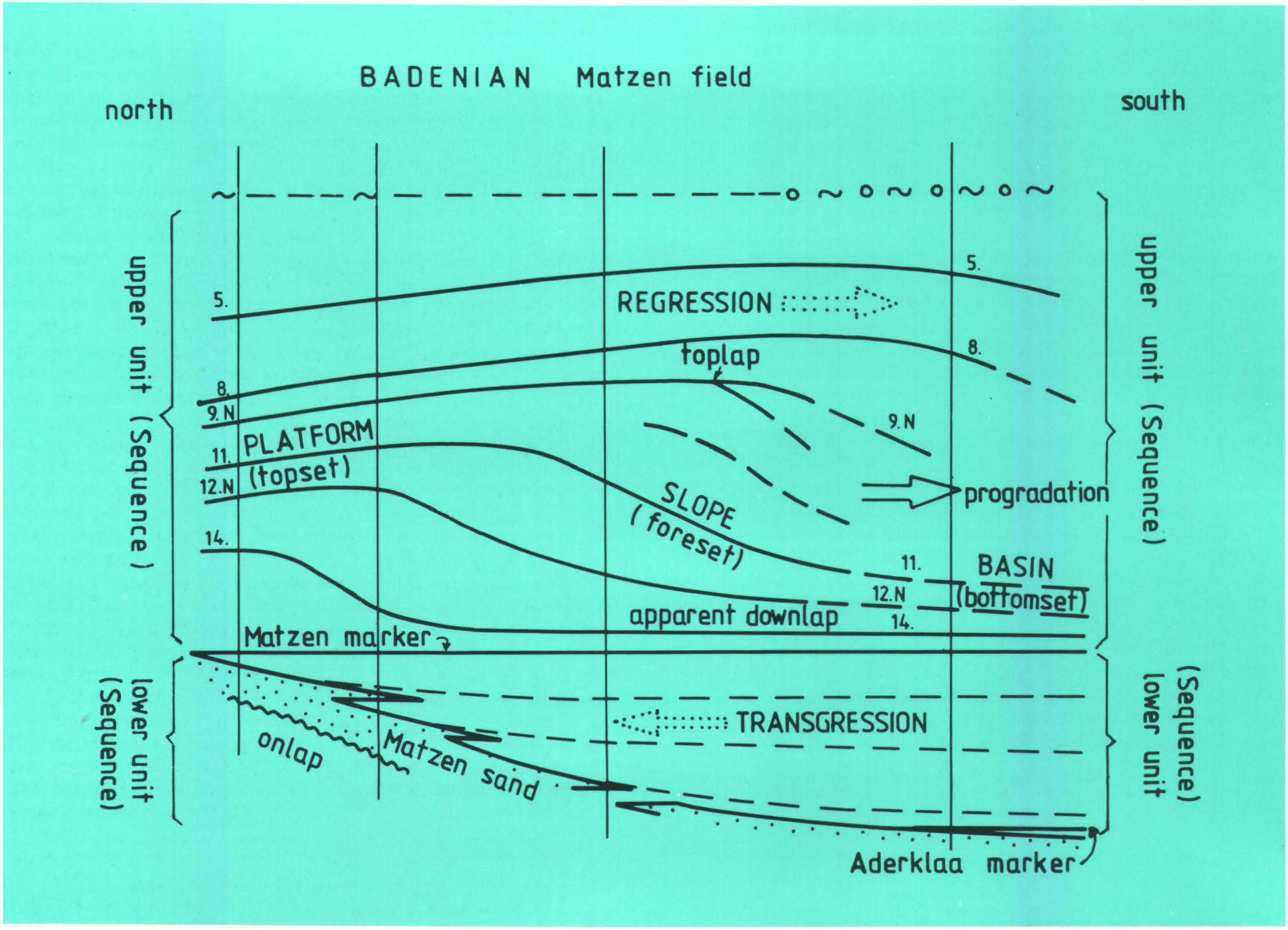


Fig. 4: Schematic cross-section of the depositional units or sequences of the Badenian in the Matzen field.

terminating updip by toplap, and a southern lower (bottomset) zone again with gently dipping segments of a shale-rich facies, terminating downdip by apparent downlap on an apparent „nondepositional unconformity". The depositional environments generally have been shifted by regression southwards, therefore the platform facies of the beds, containing large oil and gas reservoirs, is overlying the basin facies of the older beds („Walther's law of facies") (Fig. 3). The strata of the upper sequence (sedimentation rate higher than subsidence rate) indicate probably a relative rise of sea level, leading to the complete inundation of the Spannberg ridge („highstand deposits" of VAIL et al., 1977) (N. KREUTZER, 1986).

Several lines of evidence point to a subaqueous part of an ancient Danube delta of the upper sequence of the Badenian in the Matzen field (N. KREUTZER, 1986): The cyclic succession, the geometrical configuration of the strata and the investigations by Ch. RUPP, 1986, (Fig. 5) resulting in alternated shale intervals of fully marine „deeper water" foraminifera and sandcomplexes of dominant hyposaline shallow water foraminifera, indicating proximity to a river mouth system (for instance Textularia earlandi, the recent species of it is typical for the Mississippi mouth facies). The sediments consist generally of unbedded or evenly (parallel) to wavy bedded (flaser and lenticular bedding) sometimes bioturbated sands and shales with common lignitic and plant debris. In the „deeper water" fully marine intervals frequent up to several meters thick layers of Lithothamnia nodules, embedded in a matrix of calcareous clays and micritic limestone, are repeatedly intercalated from the 5th to the 14th Badenian. Although the occurrence of the red algae indicates episodes of very shallow marine water over a submarine swell (50 — 150 m water depth), the composition of the matrix points to a low-energy environment. The extent of these Lithothamnia beds and the distribution of their thicknesses is for the most part influenced by the synsedimentary structures (L. KÖLBL, 1953, H. WIESENEDER, 1956, 1964, N. KREUTZER, 1978).

The seismic facies

The seismic facies in the marginal parts of the Matzen field and in the surrounding area is variable, depending on lithologies and stratal configurations. In the bedded sand-shale successions of the Pannonian Sarmatian and Upper Badenian the principal stratal configuration is parallel to subparallel or slightly divergent, sometimes hummocky, with continuous to discontinuous reflections and weak to strong amplitudes. The prograding and predominantly shaly part of the Upper Badenian is almost reflection-free, but sometimes distinct sigmoid and oblique clinoforms with apparent downlap and toplap are recognizable. In the shale wedge of the lower Badenian, also nearly reflection-free (seismically „transparent"), however, an although weak developed parallel to slightly divergent seismic facies is indicated and onlapping reflections upon the strong reflective Aderklaa conglomerate exist. The lenticular and on the top truncated Aderklaa beds are characterized by rather indistinct and discontinuous reflections with weak amplitudes or reflection-free zones. The conglomeratic Gänserndorf beds and the Bockfliess beds indicate sometimes stronger ref-

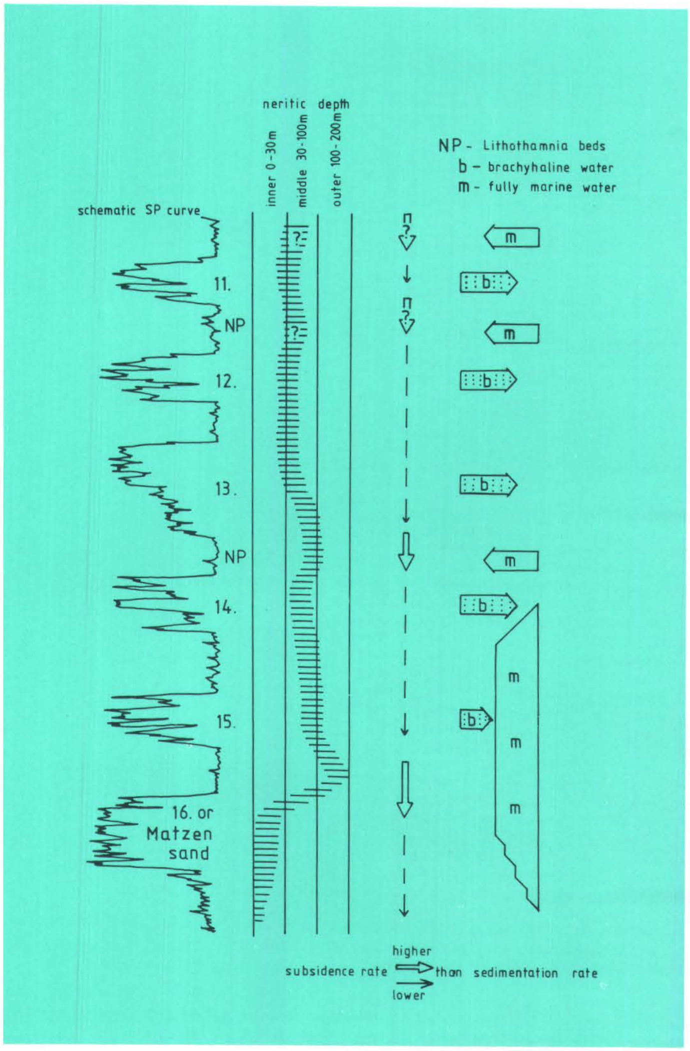


Fig. 5: Paleoenvironment and foraminiferal paleoecology between the Matzen sand and the 11th Badenian, by Chr. Rupp, 1986 (modified). Foraminiferal groupings in the sand complexes are made up of hyposaline shallow water foraminifera, in the shale intervals of fully marine "deeper water" foraminifera.

lections, those of the latter beds onlapping the older sedimentary basement.

The Gänserndorf beds probably represent delta plain sediments, equivalent beds in Czechoslovakia, as shown by R. JIŘÍČEK, indicate delta front and prodelta sediments, which distinctly prograde and updip to east in the seismic sections.

Structural development and faults

The structural development in the Miocene basin fill of the Matzen field predominantly is governed by the differential subsidence of the sedimentary basement, that is the generally SW-NE striking Spannberg Flysch ridge in the north and the N-S striking ridge of the Calcareous Alps in the south (Fig. 1). This development, by use of isopach maps, has been investigated in the Pannonian, Sarmatian and Badenian by N. KREUTZER, 1971, in the Aderklaa, Gänserndorf, Bockfliess beds by S. KÖVES, 1971 and HLADEČEK et al., 1971. A southward convergence of E-log markers suggests a less subsidence of the Calcareous Alps during the sedimentation of the upper Bockfließ beds (B 11—9) as well as of the upper Badenian (above 5th), Sarmatian and Pannonian (a short interruption of this tendency in the lowest Pannonian is caused apparently by the rapid deposition of some delta lobes). A northward convergence suggests a less subsidence of the flysch ridge generally during the sedimentation of the Gänserndorf beds, the Aderklaa conglomerate and until upper Badenian (8th). The rather parallel markers of the intervening intervals point to a balanced subsidence in the lower Bockfliess beds (B16-12), the Aderklaa beds and the upper Badenian (between 8th and 5th) (Fig. 1).

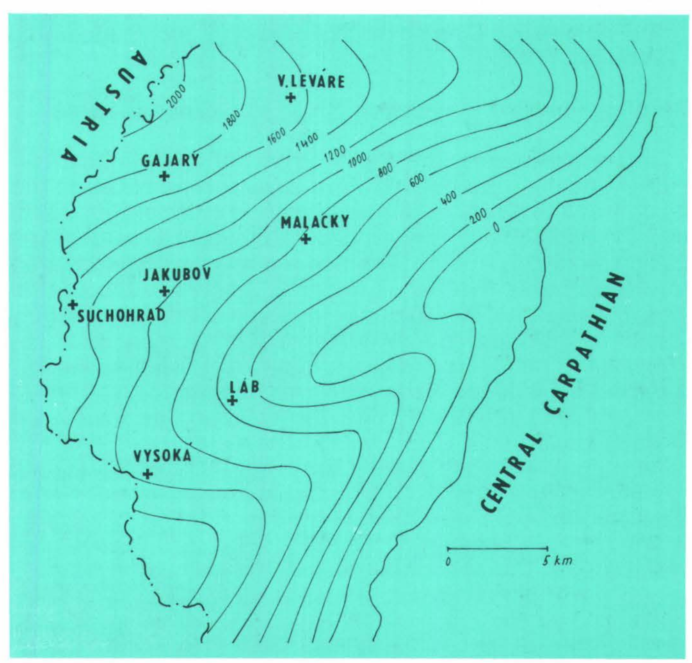
The structural development in the upper regressive-transgressive depositional sequence of the Badenian is influenced not only by the differential subsidence but also by the progradation of the strata. The more steeply dipping segments of the individual foreset zones (5th — 15th Badenian) establish sedimentary structural flanks shifting laterally to southwest, south and southeast from the older to younger beds (Fig. 3 and 4).

A final important change occurs in the Pontian owing to the origin of a new (postsedimentary) structure in the northern part of Matzen field, together with the Matzen fault system. Numerous old synsedimentary structure elements are preserved, however.

In the Matzen field three genetically unrelated fault systems can be recognized in the Miocene basin fill (Fig. 1).

1) the oldest is the north to south striking postsedimentary Schönkirchen fault system above the ridge of the Calcareous Alps in the southern part of the field. Its activity began after the sedimentation of the Aderklaa beds and ended pre-Badenian, the vertical throw is up to about 50 m (S. KÖVES, 1971, K. HLADECEK et al., 1971) (Fig. 1).
2) The north — south striking and west dipping synsedimentary Bockfliess fault system, consisting of en echelon fault segments, on the western field margin with a vertical throw of up to 400 m. Upthrown and downthrown blocks are directly connected by steeply dipping narrow strips between two faults. A large difference in the thickness of the Miocene sediments of the upthrown and downthrown blocks and increase in thickness within the narrow strips accentuate the synsedimentary character (G. WESSELY, 1988). There are two activity phases, the one from the 7th Badenian up to the top of Sarmatian, the other from the 3rd Lower Pannonian up to the top of Middle Pannonian, repectively (N. KREUTZER, 1971) (Fig. 1).
3) the southwest to northeast striking postsedimentary Matzen fault system in the northern part of the field, consisting of northwest and southeast- dipping rotational

Fig. 6: Map of total thicknesses of the Badenian in the southern part of the Vienna Basin. After D. Jiráček 1969.



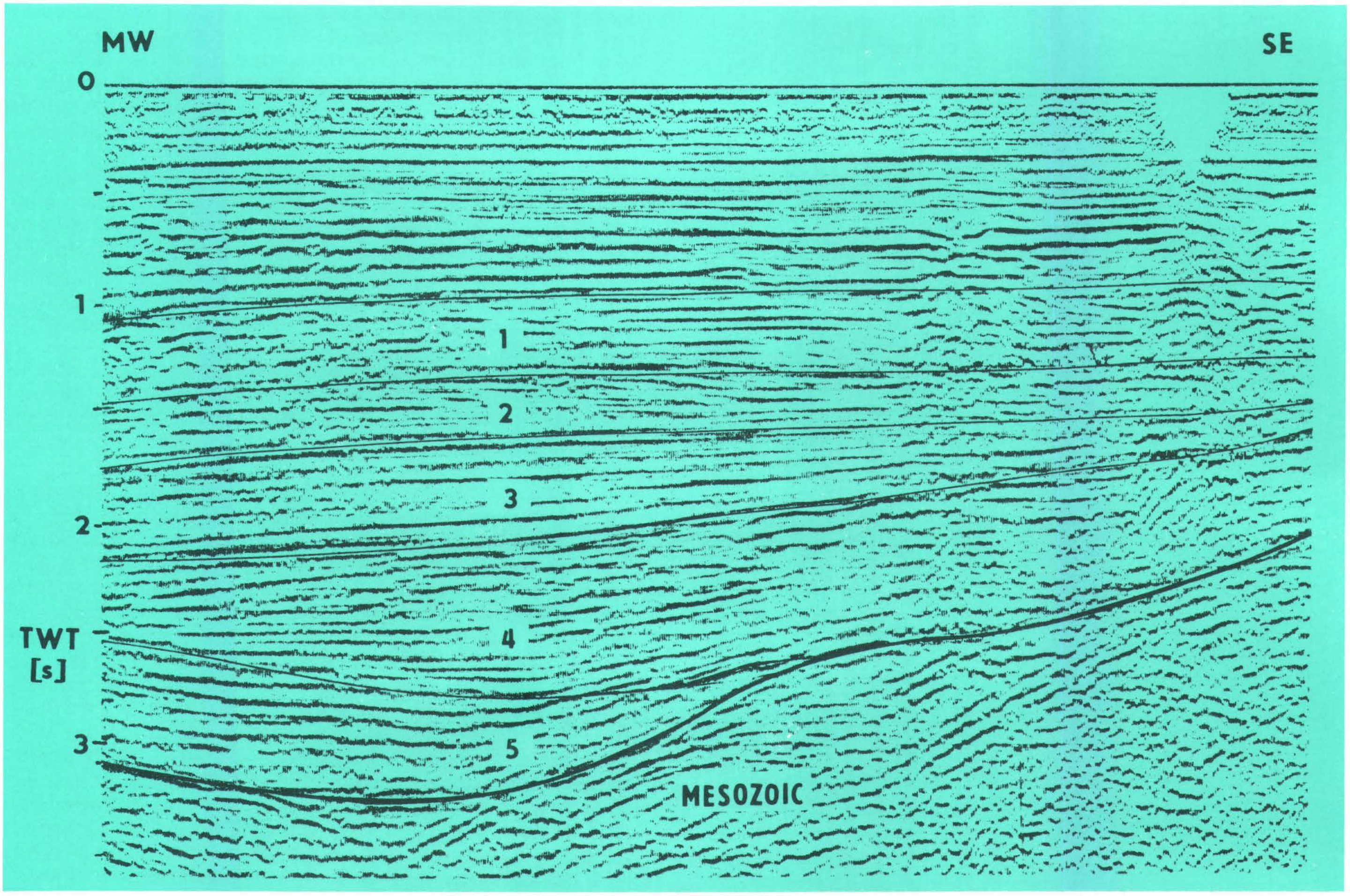


Fig. 7: Seismic line No. 651/84
1 — UB; 2 — MB; 3 — LB; 4 — Aderklaa + Láb Ostracoda Beds; 5 — Gänserndorf + Bockfliesser Beds.

faults (Fig. 1.). It is post-Pannonian in age (N. KREUTZER, 1971), the faults show a maximum vertical throw of 80 m and may be explained by tension above an updoming of the deeper however still undrilled autochthonous basement, which causes the Matzen-Spannberg elevation (G. WESSELY, 1988). By displacing southeast dipping faults the northwest dipping faults prove to be younger (G. WESSELY, 1988).

Southern part of the Vienna Basin in Czechoslovakia

In Czechoslovakia, the southern part of the Vienna Basin comprises the area between the Leváre depression on the north and the Czechoslovak/Austrian frontier on the south (fig. 6). Geologically it is related to the central part of the basin situated in Austria. The two regions developed during the Neogene as two opposite flanks dipping to the central Gajary deep and the Suchohrad depression. Minor differences in the development of the individual sequences recognized in the course of exploration work are the result of different subsidence rates. However, the most pronounced changes occurred during the development of the Lower Miocene sediments. The results of exploratory drilling and seismic profiles have shown that, for the Bockfliess and Gänserndorf Beds which form the basic part of the Lower Miocene, the centre of basinal sedimentation was situated within the Austrian part of the Vienna Basin. On Czechoslovak territory, the sedimentation of these sequences appears to have extended into the area of the Suchohrad depression and the Gajary deep only, or to the lower-lying parts of the Láb and Malacky elevations. They could not be identified by drilling in the higher levels of the slopes of the elevations mentioned above. After the deposition of the Bockfliess and the Gänserndorf Beds, the whole western flank was uplifted and the centre of sedimentation shifted eastwards to the bases of the slopes of the Láb and Malacky elevations. (fig. 7—10). The Láb Beds with ostracodes (Aderklaa Schichten) were deposited in this new area of sedimentation and overlain by a sand-and- clay complex —the so-called Upper Karpatian Variegated Beds — on the northeastern margin. These beds are the terminal part of the Lower Miocene.

Cycle 1

The comparison of the above data with the division into cycles according to N. Kreutzer has shown that, in the Czechoslovak southern part of the Vienna Basin, cycle 1 can be present only with its top part (the top of the Bockfliess Beds) which is spatially related to the depression zones along the western margin of the region under study (figs. 7,8,10). By their bedding, the sediments onlap the relief of the underlying beds in the Suchohrad depression.

Cycle 2

The bedding of the transgressive part of cycle 2 — the Gänserndorf Beds — appears to be nearly conformable with the Bockfliess Beds as apparent along the western margin of the Czechoslovak part of the basin. by contrast, a marked unconformity can be recognized between the Gänserndorf Beds and the overlying limnic Láb Beds with ostracodes (Aderklaa Schichten) that form the wedge middle. The wedge base onlaps the lower-lying slopes of the elevation zones. The wedge top is missing in the western part, because it was eroded away by the transgressive part

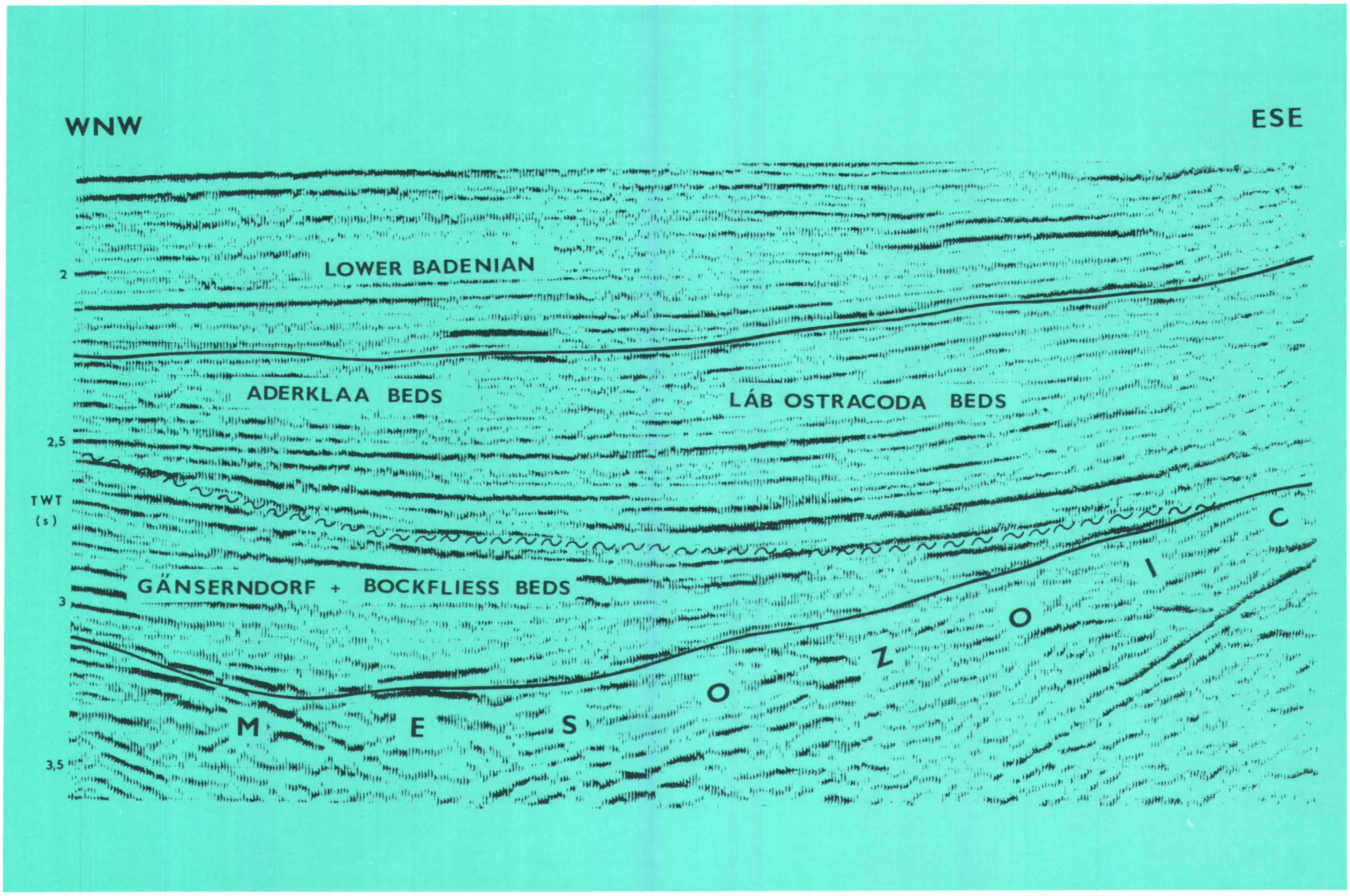


Fig. 8: A section of the seismic line No. 539/81 showing the discordant contact of the Aderklaa + Láb Ostracoda beds with Gänserndorf beds. Wave line = unconformity.

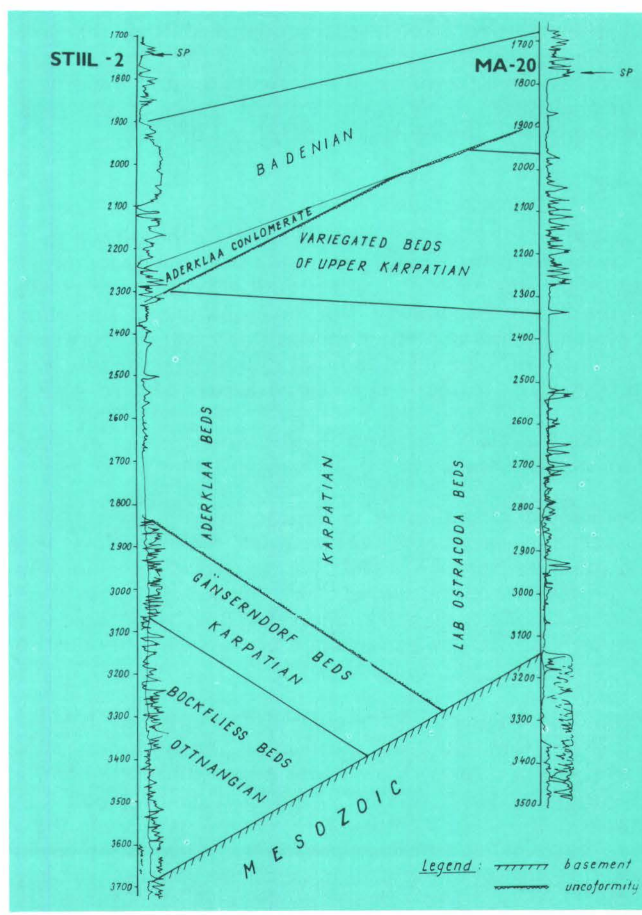
of cycle 3, but it is present in the higher-lying slopes and elevation tops with a 300 m thick sand-and-clay complex comprising the Upper Karpatian Variegated Beds.

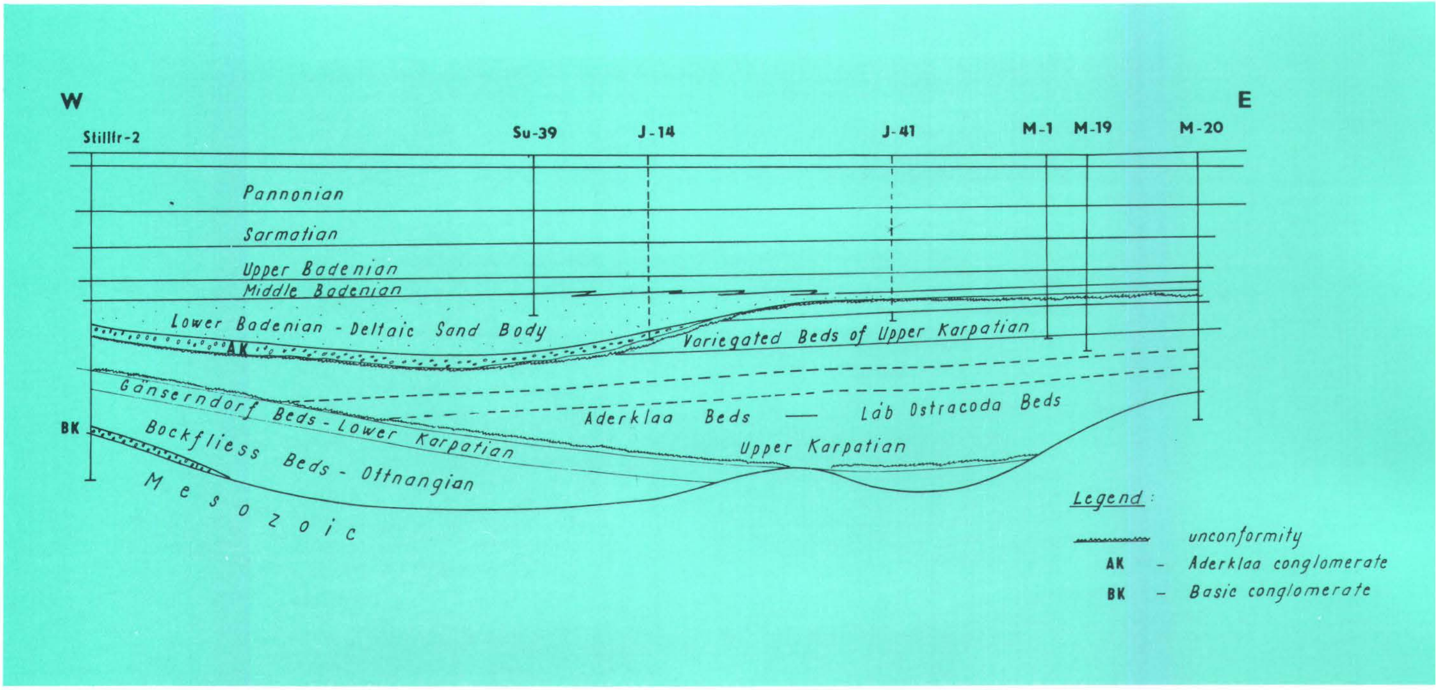
Cycle 3

This cycle corresponds to cycle 1 which is completely and clearly developed throughout the region investigated. The transgressive wedge base consists of fluvial conglomerates equivalent to the Aderklaa conglomerate from the Austrian part of the Vienna Basin. They are overlain by thick layers of sandy sediments of deltaic origin that can also be attributed to the wedge base. In the Láb and Malacky elevation zones, the wedge base is reduced to the presence of transgressive marine sand termed the Láb horizon. In all of the region the wedge middle consists of marine pelites of the Agglutinantia zone, an equivalent to the Sandschaler ozone in the Austrian portion of the basin. The regressive top is composed of sand layers of the Upper Badenian Rotalia zone.

The development of the Upper Miocene can be considered to constitute a separate cycle (cycle 4 of N. Kreutzer), or this sequence can be regarded as the upper regressive part of a multiple wedge (D. A. White, 1980) whose transgressive part is formed by the sedimentation of cycle 3. One of the reasons supporting this view is the fact that, beginning with the terminal part of the Upper Badenian, the flattening and freshening of the sea continued until its complete regression.

Fig. 9: Correlation profile of the boreholes Malacky-20 and Stillfried-2. ▶





▲ Fig. 10: Geological profile between the boreholes Malacky-20 and Stillfried-2

In consequence, the development of the Vienna Basin as a whole can be characterized by the following three evolutional stages:

Stage 1

This stage includes the Lower Miocene, i. e. cycles 1 and 2 in the sense of the division by N. Kreutzer. This period is characterized by dynamic basin development and continuous changes in the shape and extent of the sedimentary basin. Basin growth and the southward shift of the sedimentation centre are accompanying features. This stage of development culminated in a full inversion and the formation of a new area of sedimentation the shape of which can be recognized in the Middle and Upper Miocene.

Stage 2

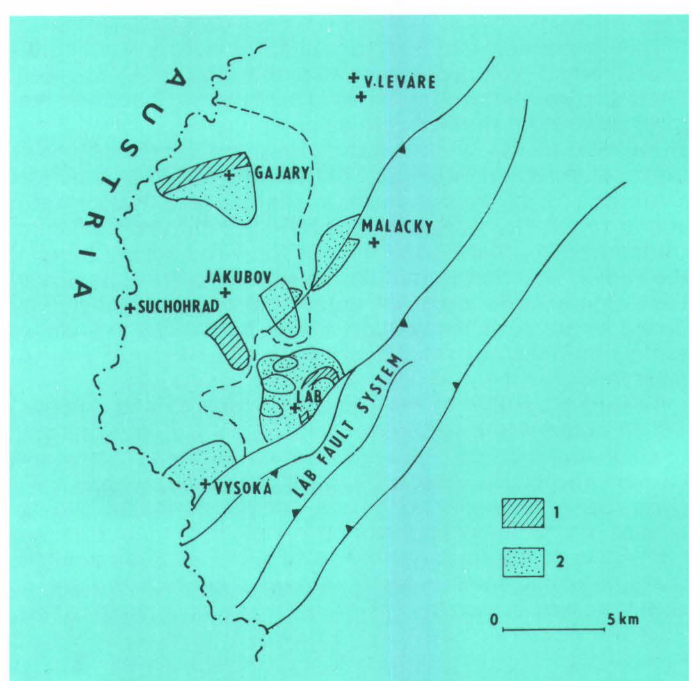
A Badenian sequence (cycle 3) covered the new area of sedimentation after a long-lasting hiatus. The Badenian sedimentation was a certain consolidation period in the history of the basin. Essentially, the development of the upper part of this Badenian sequence was the onset of regression that, jointly with sea level fluctuations, characterized **stage 3 until the complete regression of the sea.**

Lithologic Development and Stratigraphic Division of the Badenian Sequence

The Badenian sequence is composed of a complex of sand and clay sediments whose total thickness has been found to range from 400—600 m in the elevation zones. Seismic profiles have suggested this thickness to attain about 2,000 m in the Gajary central deep (fig. 6). The contact with the underlying Karpatian is unconformable; in the Suchohrad depression this unconformity is of erosional nature (fig. 10).

Three lithologic units identical with the stratigraphic division can be distinguished throughout the sequence. The first of them is a sandy facies with a conglomerate layer at the base. Its extent is related to the lows of the Suchohrad depression and Gajary central deep to their flanks. In these zones, the thickness may exceed 600 m. Abundant Cibicides faunas were identified in clay bands in the drill cores (R. Jiříček, 1979). The whole complex is thought to be a product of deltaic sedimentation. On the basis of his sedimentological studies, N. Kreutzer has reached the same conclusion. The unit has stratigraphically been classed as Lower Badenian with the exception of the terminal part which can be placed into the Middle Badenian. The entire sequence is associated with an erosion valley by the major part of its thickness (fig. 10).

Fig. 11: Location of the Badenian oil and gas deposits in the southern part of the Vienna Basin.
1 — oil deposits; 2 — gas deposits. ▼



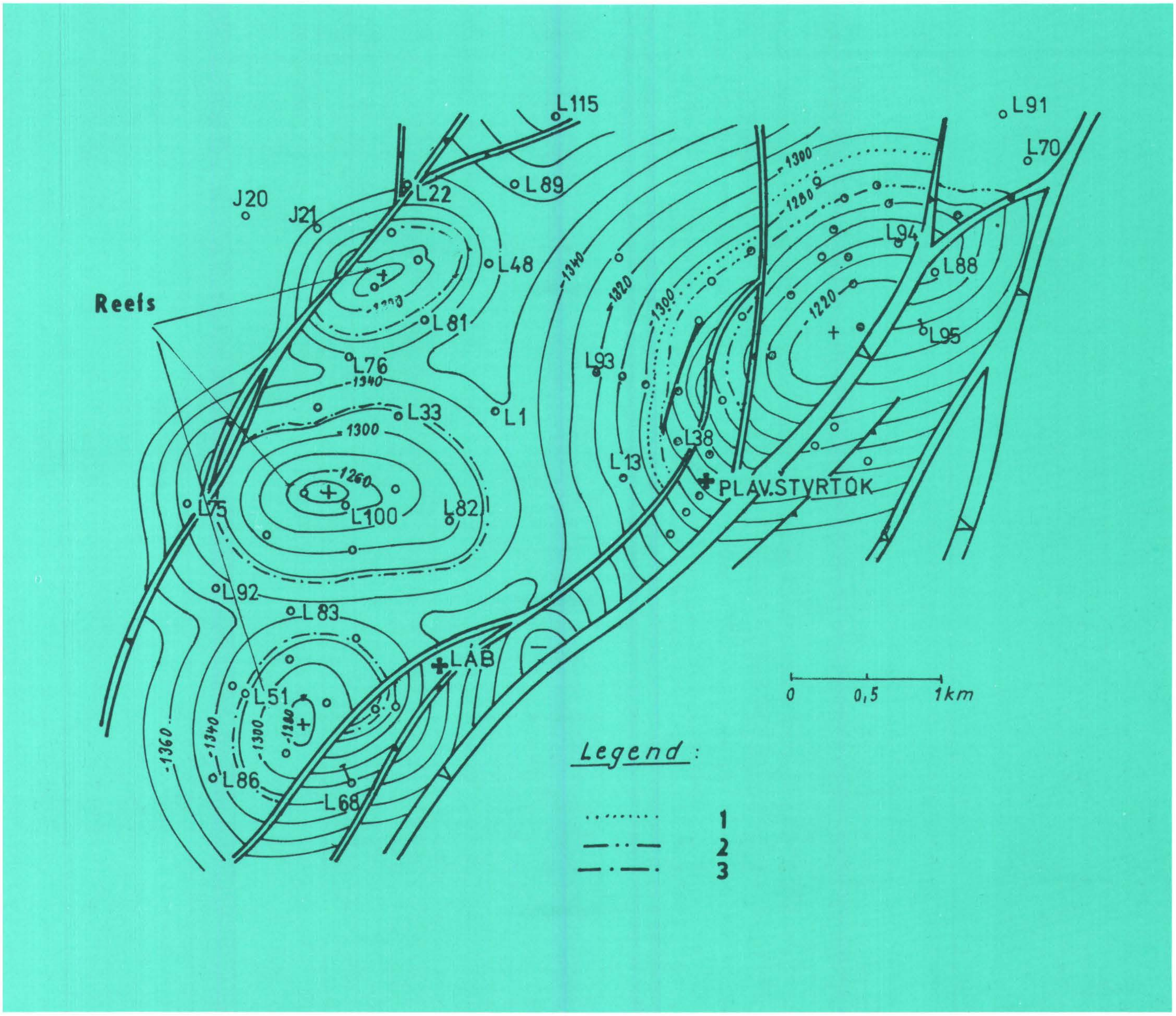


Fig. 12: Oil and gas-bearing deposits Láb. A map reflecting the geological structure of the Láb horizon (eastern part) and the surface of the lithothamnion rifts (western part).
1 — contact of oil and water; 2 — contact of oil and gas; 3 — contact of gas and water (after Bílek and Hlavatý).

The second lithologic unit consists of a pelitic zone replacing marine sedimentation characterized by deep-sea faunas — Cyclamina pleschakovi and Bathysiphon filiformis (R. Jiříček 1979). The beds have been known as the „Agglutinantia zone", they are distributed throughout the basin maintaning their constant thickness which varies in the range from 220—240 m in the southern part of the basin. This sequence was the sealing element during the formatin of oil and gas traps. Associated with this zone are three domal bioherms developed in the beds overlying the transgressive Láb horizon on the western slope of the Láb elevation (fig. 11,12).

The third unit is composed of a sand and clay sequence of a relatively constant thickness of 350—380 m. With regard to the faunas present and lithological differences, this sequence can be divided into a loweer level with pelites predominating over sands (Bolivina-Bulimina zone) and an upper level with prevailing sands. The latter level is characterized by Rotalia faunas and combines with deltaic sedimentation in the western part. The distribution and the shapes of some horizons display the properties of channel fill in delta systems.

Tectonic setting

From the viewpoint of fault tectonics, the southern part of the basin can be divided into a tectonized eastern section represented by the Láb and Malacky elevations and a tectonically undisturbed western section comprising mainly the depression zones and the lower-lying parts of the slopes of the elevations mentioned above. The principal tectonic feature of the whole region is represented by the Láb fault system that disturbs the eastern slopes of the Láb and Malacky elevations (fig. 11,12). It consists of two main faults with vertical throws of 200 and 100 m, respectively. These principal fault lines are related to a greater number of disturbances with which several deposits on the above elevations are associated.

This fault system is striking from the northeast to the southwest in parallel to the Lesser Carpathians. Together with the Litava reverse marginal fault it forms a distinct tectonic graben system — the Zohor-Plavec graben. The faults are of Upper Miocene age.

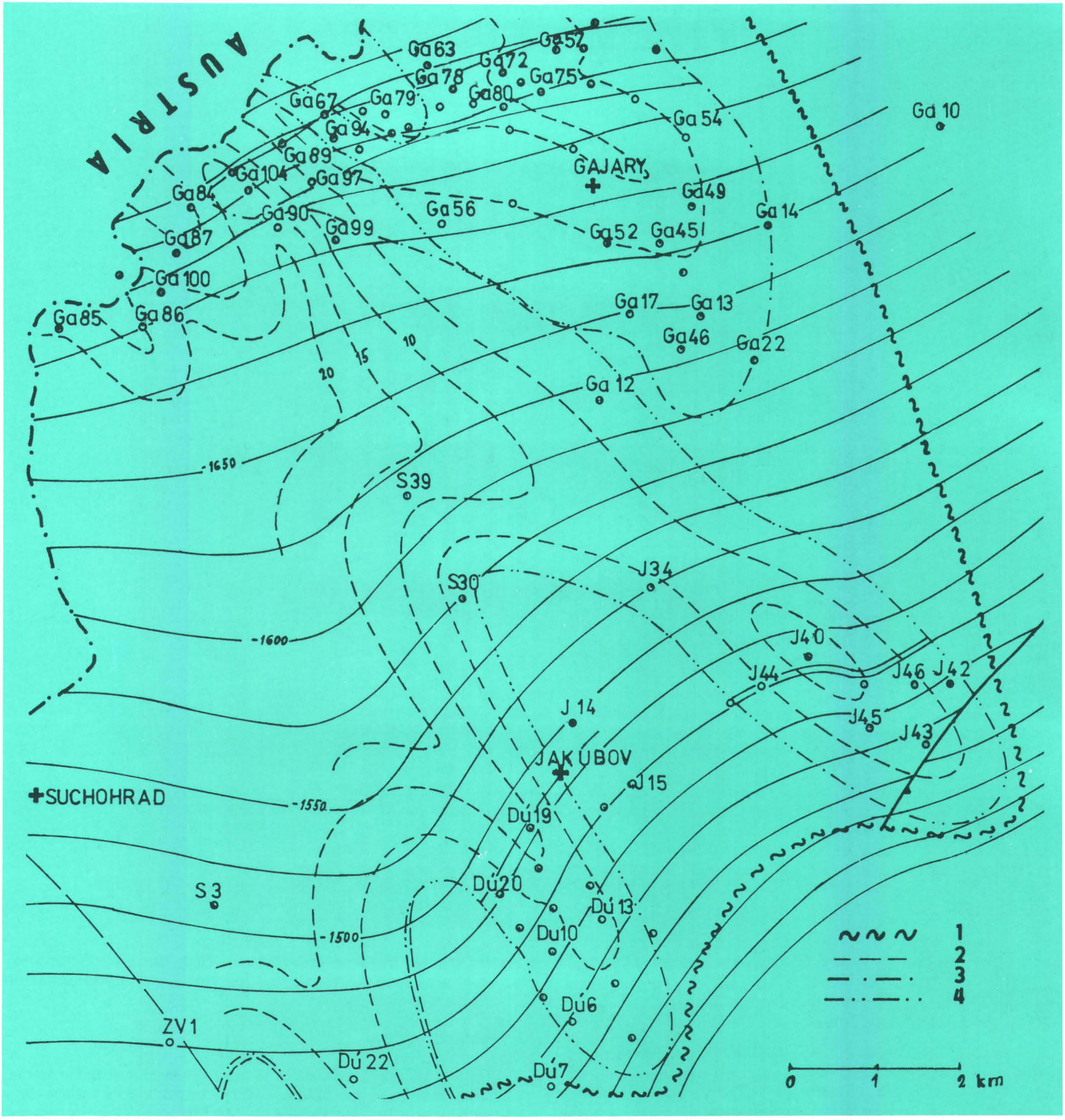


Fig. 13: Oil and gas deposits connected with terminal part of the deltaic sand body (after Hlavatý, Ralbovský, Šalyová).
1 — boundary of deltaic body; 2 — isolines of thickness; 3 — boundary of extension of the first sand; 4 — boundary of extension of the second sand.

Types of oil and gas traps in the Badenian sequence

The unconformable contact with the underlying Lower Miocene and the regional distribution of the sand base of the Badenian sequence provided advantageous conditions allowing the basal part of the sequence to act as a reservoir rock sequence. Another favourable element is the pelitic „Agglutinantia zone" that overlies the basal sand beds. By its regional extent, this zone acts as a seal for the whole basin. The terminal parts of the deltaic sandy body, developed as delta fronts to prodelta, played an essential role in the formation of Badenian oil and gas deposits.

In the course of exploration drilling several types of deposits were discovered in the southern part of the Vienna Basin.

The following deposits are considered to be of particular interest:

Láb and Malacky deposits:

Both deposits are associated with high-lying levels of the Láb and Malacky elevations. The individual reservoir sands are sealed by the faults of the Láb fault system (fig. 12).

Bioherms of the Láb deposit:

They have formed on the western slope of the Láb elevation, in a plece where the Láb horizon forms a relatively wide platform. They constitute three plug domes the largest of which is 3 km long in its axis. Superelevation attains 100 m. The plugs consist of Lithothamnia limestones with favourable physical properties and with gas accumulated in them. They are hydrodynamically realted to the Láb horizon (fig. 12).

Gajary, Jakubov, Dúbrava deposits:

The three deposits are associated with wedging-out sandy tongues of the deltaic sedimentary body. The sand tongues are considered to be the channel fill of the channel system in the delta. The Gajary deposit is a gas-capped oil deposit, Jakubov is a natural gas deposit and oil has accumulated in the Dúbrava deposit (fig. 13).

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Abstrakt

Na podklade hojných údajov vrtného prieskumu, doplnených seizmickými profilmi, je možné v miocénnej výplni viedenskej panvy v oblasti Matzen rozlíšiť 4 transgresívno-regresívne faciálne cykly. S určitými odchýlkami v spodnom miocéne možno toto členenie uplatniť i v južnej časti panvy na čs. území, ktorá tvorí protiľahlý svah rakúskej strednej časti panvy. Rozdiely oboch svahov v úložných pomeroch a litologickom členení jednotlivých súvrství boli spôsobené rôznymi hodnotami subsidencie a vlivom deltovej sedimentácie. Hlavné tektonické línie porušujú oba svahy len vo vyšších polohách.

Súvrstvie bádenu je v oboch častiach panvy najbohatšie na akumulácie ropy a zemného plynu.

Zusammenfassung

Die miozäne Beckenfüllung kann im Feld Matzen in verschiedene geologische Einheiten gegliedert werden, die meist Ablagerungssequenzen sowie transgressiv-regressiven Fazies-Zyklus-Keilen entsprechen. Ein solcher Keil stellt im Idealfall einen transgressiv-regressiven Ablagerungszyklus dar, der von unten nach oben eine vertikale Faziesfolge von grobkörnigen kontinentalen über grob-, fein- und wieder grobkörnige marine zu erneut kontinentalen Schichten umfaßt. Im Feld Matzen können vier Sand-Ton-Zyklus-Keile erkannt werden: 1. Zyklus — Bockfließer Schichten, 2. Zyklus — Gänserndorfer und Aderklaaer Schichten, 3. Zyklus — Badener Serie (einschließlich Aderklaaer Konglomerat), 4. Zyklus — Sarmat, Pannon und Pont.

Da sich Ablagerungssequenzen durch die Geometrie ihrer Schichtflächen unterscheiden, mußte die Badener Serie des zentralen Wiener Beckens in zwei völlig verschiedene geologische Einheiten oder Ablagerungssequenzen unterteilt werden, eine untere, transgressive Einheit oder Sequenz des unteren Badens und eine obere, abwechselnd regressiv-transgressive Einheit oder Sequenz des oberen Badens.

Die strukturelle Entwicklung der miozänen Beckenfüllung des Feldes Matzen wird vorherrschend durch die differenzierte Absenkung des Beckenuntergrundes, des Spannberger Flyschrückens im Norden und des kalkalpinen Rückens im Süden, bestimmt. Die S-Konvergenz von Leithorizonten in den oberen Bockfließer Schichten, im oberen Baden, Sarmat und Pannon läßt auf eine geringere Absenkungstendenz der Kalkalpen, die N-Konvergenz innerhalb der Gänserndorfer Schichten, des Aderklaaer Konglomerates und bis ins obere Baden auf eine geringere Absenkung des Flyschrückens schließen. Die ziemlich konkordanten Leithorizonte der dazwischen liegenden Intervalle weisen auf eine gleichmäßige Absenkung in den unteren Bockfließer Schichten, den Aderklaaer Schichten und dem oberen Baden hin.

Im Feld Matzen sind drei genetisch unabhängige Bruchsysteme in der miozänen Beckenfüllung erkennbar:

1) Das N-S-streichende postsedimentäre Schönkirchner Bruchsystem im Süden des Feldes, nach der Sedimentation der Aderklaaer Schichten

und vor jener des Badens wirksam.

2) Das N-S-streichende und W-fallende synsedimentäre Bockfließer Bruchsystem am W-Rand des Feldes mit zwei Aktivitätsphasen.

3) Das SW—NO streichende postsedimentäre Matzner Bruchsystem im N des Feldes, aus NW- und SO-fallenden Brüchen bestehend, nach dem Pannon entstanden.

ADDITION TO STRATIGRAPHY OF BORINKA LIMESTONE IN THE HAINBURG MOUNTAINS

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The Borinka limestone is considered as a lithostratigraphic unit characteristic of the Malé Karpaty Mts. with stratigraphic assignment to the Liassic.

It is found in the SW and S part of the Malé Karpaty Mts. where it represents the Tatric unit. The most extensive occurrence of the Borinka limestone is observed in the area of the village Borinka (Propadlé valley) and continues in SW direction to the southernmost spur of the Malé Karpaty Mts. The Hainburg Mts. on Austrian territory are prevailingly built up of carbonates of Middle Triassic age. The lithological character of Middle Triassic carbonates occurring here is identical with carbonates found in the area of the villages Devín and Borinka in the underlier of the Borinka limestone. The carbonates found here have stratigraphic assignment to the Triassic.

The rock filling and stratigraphic assignment of the Borinka limestone changed in the course of several decades. Under the term Borinka limestone various lithological types of limestones were included (grey limestones, dolomitic limestones, laminated limestones of brecciated texture, organodetrical limestones) with assignment to Triassic — Liassic age. The works of M. Mahel' (1986), D. Plašienka (1987), M. Mišík (1986) and A. Kullmanová (1971, 1988) have contributed to solution of the problem of age of the Borinka limestone. D. Plašienka (1987) designates with the name Borinka unit the complex of Mesozoic sedimentary rocks of the Tatric unit in the Malé Karpaty Mts. According to this author the term Borinka unit represents a lithostratigraphic as well as tectonic unit. On the contrary, A. Kullmanová (1988) redefines the lithostratigraphic unit with the name Borinka limestone. On the basis of the results of lithological investigation the Borinka limestone contains thick-layered clastic, mostly organoclastic limestones with the stratigraphic range Lotharingian — Carixian. The macrofauna (lamellibranchs, brachiopods and belemnites) was studied at the locality Borinka (road cut of the Propadlé valley) and at the locality in the village Devín (castle rock and SW slope of elev. p. Devínska Kobyla).

The superposition relations of the Borinka limestone to the underlier and overlier were pursued in surficial outcrops and boreholes. In the underlier of the Borinka limestone dark — grey compact limestones, dolomitic limestones often with quartz spherolithes — Gutenstein limestones, grey dolomites and dolomitic limestones of brecciated texture are found. Stratigraphic assignment of the mentioned carbonates to the Middle Triassic is proved by algae (outcrop S slope of Devínska Kobyla) and foraminifers (Propadlé valley, outcrop 70 A).

At the outcrop in the Propadlé valley in the overlier of the Borinka limestone grey marly shales, sandstones — the Korenec formation (D. Plašienka, 1987) or Somár breccias are found. In the area of the village Devín, in the overlier of the Borinka limestone, grey marly shales with belemnites are found (railway cut Devínska Nová Ves).

The Hainburg Mts. on Austrian territory are prevailingly built up of dark-grey micrite limestones, dolomitic limestones of brecciated texture and grey fine-grained organodetrical limestones. The Austrian geologists designate the above mentioned lithofacies with the term Borinka limestone. The organoclasts present in limestones in the Hainburg Mts. are represented by determinable crinoids, which enable to stratify the investigated rocks into the Middle Triassic, Anisian (Kristan-Tollmann-Spendlingwimmer, 1987). On our territory we observe identical rocks in the Propadlé valley (borehole 70 A) rock below castle ruins). The rocks studied at the mentioned locallity are of Middle Triassic age. In micrite matter Trochammina almtalensis Koehn-Zaninetti; Diplotremmina sp., Glomospira sp., Agathammina austroalpina Kristan-Tollmann, Meandrospira sp. are present. Similarly the southern and southwestern slope of Devínska Kobyla is bult up of the mentioned lithofacies. The present Dasycladacea sp. and Physoporella disita (Gümbel) enable to stratify the investigated carbonates as Anisisan (M. Mišík 1986).

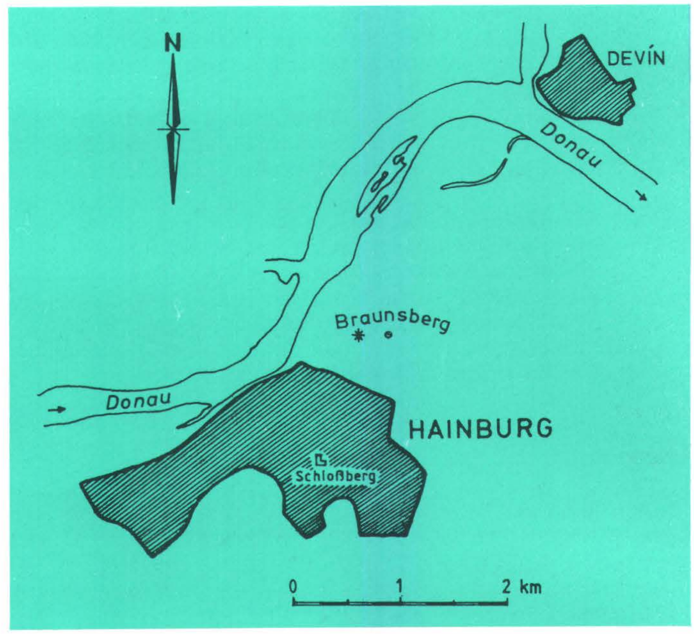
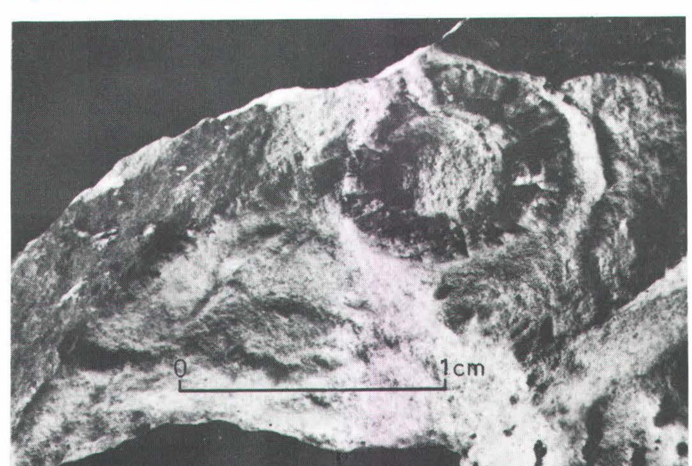


Fig. 1: Schematic situation of occurrence of belemnites at the locality of Braunsberg.

* Belemnite occurrences.

Fig. 2: Belemnites from joint filling, western slope of Braunsberg.



The Borinka limestone (redefined lithostratigraphic unit) is characterized by dark-grey thick-layered clastic, prevailingly organoclastic limestone, which is found in the Propadlé valley (village Borinka). The Middle Liassic age of the Borinka limestone is proved by macrofauna. Lamellibranchs were found in dark-grey organoclastic limestones in the Propadlé valley — cut of the road to the cottage Košariská (Kochanová M. in Mahel' M., 1962). Brachiopods were investigated from the outcrop west of the rock below the Borinka castle (Pevný J. in Mahel' M., 1962). Belemnites determined by Činčurová M. (in Mahel' M., 1962) come from the locality mentioned.

In the area of the village Devín the Borinka limestone occurs in the upper part of the Devín castle rock and at the abandoned quarry at the western slope of Devínska Kobyla. Fragments of ammonites from the group Arietitidae are mentioned from the locality Devínska Kobyla by Mišík M. (1986).

The Borinka limestone in the Hainsburg Mts. is found in joint fillings of dolomitic limestones with brecciated texture. At the outcrop west of Braunsberg in joints of Middle Triassic brecciated dolomitic limestones belemnites are found (figs. 1,2).

It results from the mentioned that the masses of grey limestones, dolomitic limestones and brecciated limestones in the Hainburg Mts. are of Middle Triassic age. They are identical with the Middle Triassic limestones, dolomitic limestones with quartz spherolithes and brecciated limestones in borehole 70 A in the Propadlé valley and at outcrops at the S slope of Devínska Kobyla, which form the underlier of the Borinka limestone. The Borinka limestone has greatest thickness in the Propadlé valley (about 200 m) and in southern direction its thickness diminishes. At outcrops in the village Devín it attains thickness of about 60 m, in the Hainburg Mts. it is found in form of relicts in joint filling.

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Abstrakt

Borinský vápenec, redefinovaná litostratigrafická jednotka liasového veku, vystupuje na JZ a J svahoch pohoria Malé Karpaty, kde predstavuje charakteristický litologický člen tatrickej jednotky pohoria Malé Karpaty.

Najväčšieho plošného rozšírenia dosahujú borinské vápence v oblasti obce Borinka (dolina Propadlé). Južnejším smerom borinský vápenec sa vyskytuje v oblasti obce Devín (J a JZ svah k. Devínska Kobyla), kde má menšie plošné rozšírenie.

Západný svah Hainburských vrchov je budovaný prevažne tmavosivými dolomitovými vápencami brekciovitej štruktúry a dolomitami. Totožné horniny sú v oblasti obce Borinka a Devín, kde tvoria podložie borinského vápenca.

Borinský vápenec (detritický a organodetritický vápenec) sa v Hainburských vrchoch (pravdepodobne v dôsledku erózie) vyskytuje vo výplni puklín strednotriasových dolomitových vápencov brekciovitej štruktúry. Liasový vek je potvrdený výskytom belemnitov. V odkryve Z od kóty Braunsberg, vo výplni puklín tvorenej organodetritickými vápencami, sa vyskytujú úlomky belemnitov a krinoidové články.

Zusammenfassung

Der Borinka-Kalk, eine redefinierte lithostratigraphische Einheit liassischen Alters, tritt an den SW- und S-Hängen des Gebirges der Kleinen Karpaten auf, wo er ein charakteristisches lithologisches Glied der tatrischen Einheit darstellt.

Die größte flächenmäßige Verbreitung erreicht der Borinka-Kalk im Raume der Ortschaft Borinka (Propadlé-Tal). In südlicher Richtung kommt der Borinka-Kalk im Raume der Ortschaft Devín (S- und SW-Hang der K. Devínska Kobyla) vor, wo er von geringerer flächenmäßiger Ausdehnung ist.

Der Westhang der Hainburger Berge ist überwiegend von dunkelgrauen dolomitischen Kalken von brekzienartiger Struktur und Dolomiten aufgebaut. Dieselben Gesteine sind im Gebiete der Ortschaften Borinka und Devín, wo sie das Liegende des Borinka-Kalkes bilden.

Der Borinka-Kalk (ein detritischer und organodetritischer Kalk) kommt in den Hainburger Bergen (wahrscheinlich infolge der Erosion) in der Spaltenfüllung von mitteltriassischen dolomitischen Kalken brekzienartiger Struktur vor. Das liassische Alter is durch Vorkommen von Belemniten bestätigt. Im Aufschluß W der K. Braunsberg, in einer von organodetritischen Kalken gebildeten Spaltenfüllung, kommen Bruchstükke von Belemniten und Krinoidenstielglieder vor.

"TISOVEC LIMESTONE" — AN EXAMPLE OF THE PROBLEMS OF LITHOSTRATIGRAPHIC CORRELATION BETWEEN THE NORTHERN CALCAREOUS ALPS AND THE CENTRAL WEST CARPATHIANS

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1. Introduction

The unification of stratigraphic nomenclature is an important prerequisite for the coordination of geological events on an international scale. This is especially true for the Alps and the Carpathians. The similarities in facies and geodynamic development have been hidden by a mass of local names. Thus our joint goal must be to work out the similarities and differences in stratigraphy and lithofacies of this large area. This is only possible using an accepted and convenient stratigraphic nomenclature. One of the prerequisites for such a venture is the detailed review of the current lithostratigraphic terminology. The following new investigation of the Tisovec Limestone in its type locality is to be seen in this respect. This unit was set up in the central West Carpathians and used later in the Calcareous Alps. It seems, however, that this term has been used in a different sense in both regions. One part of the problem is the different use of the term „Dachstein Limestone" in both regions. In the West Carpathians this term has been used primarily for the Upper Norian — Rhaetian lagoonal facies of the Dachstein Formation.

2. Historical outline: the installation of the term "Tisovec Limestone" in the Central West Carpathians

The existence of unnamed light-grey massive limestones of Upper Triassic age in the southernmost zones of the Western Carpathians was known for a long period (STÜRZENBAUM 1879, UHLIG 1903, ZOUBEK 1932, and others; compare review in ANRUSOV 1959). It was supposed that parts of these limestones were Carnian in age, what was confirmed (or ought to be confirmed) by fossils in numerous localities (Slovakian karst: BALOGH 1940, 1948, BALOGH & PANTÓ 1953, ANDRUSOV & KOVACIK 1955, BYSTRICKY 1955, 1957, 1960; Stratenská hornatina Mts.: MAHEL 1957; Murán Plateau: POUBA 1951, KOLLAROVA-ANDRUSOVOVA 1959). However, localities with occurrence of Norian fossils were even more abundant. BYSTRICKY and KOLLAROVA-ANDRUSOVOVA (in: KOLLAROVA-ANDRUSOVOVÁ 1960: p. 106) decided to name the Carnian part of the grey, massive, biogenic limestones with scattered corals, bivalves, and "Grossoolithes" of the Murán Plateau as the Tisovec Limestone; the Norian part was designated as the Furmanec Limestone. These limestones were described before by POUBA (1951) and BYSTRICKY (1959). POUBA attributed them Carnian and partly Norian age.

In spite of this delimitation and definition there was no reliable possibility to distinguish Tisovec Limestone from Furmanec Limestone during geological mapping. This was the reason for using the term Tisovec-Furmanec Limestone for light-grey massive limestones by mapping geologists on the Murán Plateau (mainly by BIELY 1960—1965 unpubl. rep., and later). Overlying bedded limestones were designated as Dachstein Limestone.

Later on BYSTRICKY (1965: p. 33, 1972, 1982), BYSTRICKY & BIELY (1966) and others used the term Tisovec Limestone for all bright limestones which resemble Wetterstein Limestone but Carnian in age (Slovakian karst, Stratenská hornatina Mts., Strázovské vrchy Mts., etc.; compare BYSTRICKY 1985: p. 270).

2.1. Problems of the "Tisovec Limestone": limits and dating in the past

The separation of a Carnian part of the bright massive limestones brought forth some troubles especially in the past. ROTH (1939), BALOGH (1940, 1948, 1950, 1953), and HOMOLA (1951) attributed those — not very precisely defined — parts of these bright limestones to Carnian age which are unfossiliferous and are overlain by presumed Norian limestones with *Gyroporella vesiculifera* GÜMBEL. HOMOLA (1951) even supposed a hidden disconformity between the Ladinian and the upper part of the Upper Triassic. This presumption was based on the occurrence of an endostratic breccia in Gombasek quarry which he interpreted as "regressive sediment". (Today we know that in Gombasek quarry only Wetterstein reef limestones are present).

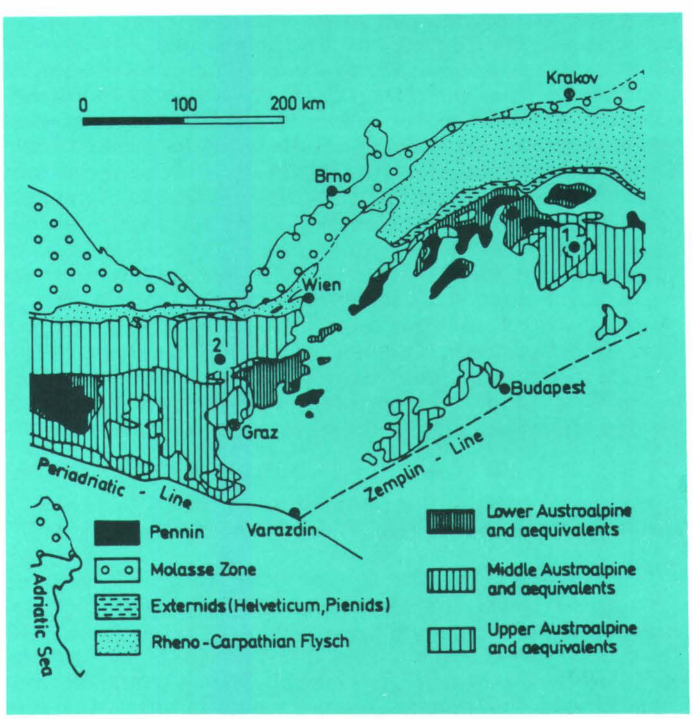


Fig. 1: Tectonic sketch map (according to Tollmann 1969) with the position of the studied area of the "Tisovec Limestone": 1) Tisovec quarry (Muran plateau), 2) Kl. Waxeneck (Mürztal Region).

The problems of a lithostratigraphic subdivision of Upper Triassic massive limestones in the Stratenská hornatina Mts. and the separation of its Carnian part (Tisovec Limestone) are discussed in detail by BYSTRICKY et al. (1982).

The Carnian age of the Tisovec Limestone on the Murán Plateau, including the type locality in the Tisovec quarry, was established by means of ammonites from the Tisovec quarry (*Anatomites* cf. *fischeri* MOJS., *Megaphyllites jarbas* (MUENST.), *M. jarbas jarbasides* KUEHN, *Placites placodes* (MOJS.) and from Dedov vrch hill (*Placites placodes* MOJS., *Megaphyllites jarbas* (MUENST.), *Sirenites* cf. *senticosus* (DITTMAR)) (e.g., KOLLAROVA-ANDRUSOVOVA 1959: p. 92, 1960, 1961, 1962, 1967, BYSTRICKY & BIELY 1966, BYSTRICKY 1973, KOLLAROVA-ANDRUSOVOVA & BYSTRICKY 1974).

However, the ammonite community from these two localities — originally considered as being Julian in age — became "younger" step by step:

- Upper Julian: Ellipticus-zone (BYSTRICKY & BIELY 1966: p. 42).
- Tuvalian (BYSTRICKY 1973: p. 72).
- Middle Tuvalian: Subbulatus-zone (KOLLAROVA-ANDRUSOVOVÁ & BYSTRICKY 1974: p. 132).
- Uppermost Tuvalian (KRYSTYN 1983: p. 262, BYSTRICKY 1986: p. 313). KRYSTYN (1974: p. 50) expressed some doubts about the stratigraphic position of the ammonite fauna from the Tisovec quarry. He took the occurrence of *Placites* for the base of the Norian stage. Later (KRYSTYN 1983: p. 262) he reported *Placites placodes* from the "Uppermost Tuvalian". This view was accepted by BYSTRICKY (1986: p. 313). He additionally has taken this locality as upper boundary of the taxon range zone of *Andrusoporella duplicata* (op. cit.: p. 312). Nevertheless, *A. duplicata* occurs very frequently in the Tisovec as well as the Furmanec Limestone (Tuvalian — Alaunian, sensu BYSTRICKY loc. cit.) of the Murán Plateau. It also occurs in the Tisovec quarry (BYSTRICKY 1986: fig. 3).

Among conodonts only Norian forms were reported from the Murán Plateau (MOCK 1971).

3. "Tisovec Limestone" in the Northern Calcareous Alps

LEIN (1972: p. 30—32) was the first to use the term "Tisovec Limestone" in the Northern Calcareous Alps for Carnian dasycladacean limestones followed by TOLLMANN (1972: p. 195). Before, these limestones had been included within the Dachstein Formation. The detailed description in the standard work "Analyse des klassischen Mesozoikums" (TOLLMANN 1976: p. 166—169) led to the factual establishment of the term Tisovec Limestone in the Northern Calcareous Alps.

The main occurrence of Upper Carnian dasycladacean limestones named Tisovec Limestone is concentrated to the southeastern part of the Northern Calcareous Alps within the Mürzalpen region (Styria, Fig. 1). Further occurrences have been reported from Carinthia in the area of the Krappfeld and the Mountains of St. Paul (GRUBER et al. 1980). The Triassic sequence of the Carinthian localities belongs to the tectonic unit of the Upper-Austroalpine Gurktal Nappe.

The North-Alpine Tisovec Limestone exhibits its characteristic development in the Mürzalpen Nappe where it is very well exposed in the Waxeneck Plateau (NE of Mürzsteg, Styria). Because these limestones represent shallow water facies, stratigraphically important fossils, such as ammonites and conodonts, which would be necessary for exact dating, are not present. Therefore, according to VEGH-NEUBRANDT et al. (1986) only a general Carnian age can be assigned to these beds by the occurrence of the megalodontid bivalve *Cornucardia hornigii* (BITTNER) described by LEIN & ZAPFE (1971) and ZAPFE (1972). This is also true for the mass occurrence of the calcareous alga *Poikiloporella duplicata* (PIA)[1], which is mentioned as Carnian guide by OTT (1972) and BYSTRICKY (1986).

A stratigraphically clearly defined upper boundary of the "Tisovec Limestone" in the Mürztal Alps is given by the overlying Hallstatt Limestone containing Lower Norian conodonts. More difficult is the stratigraphic fixation of the lower boundary. In this case only lithologic comparisons in term of sequence stratigraphy can be made. The data collected up till now from the platform-basin transition zones of the south of the Northern Calcareous Alps suggest that the installation of the new carbonate platform above the terrigenic interval of the Raibl Beds s. l. occurs at the Julian/Tuvalian boundary.

The exact stratigraphic position of the "Tisovec Limestone" in Carinthia is not fully explained, due to considerable tectonic complications. Here time equivalent reef- and fore-reef limestones occur next to lagoonal dasycladacean limestones with *Poikiloporella duplicata* (PIA) (GRUBER et al. 1980, DULLO & LEIN 1982). Following the data, the conodont bearing fore-reef sediments of Lower Carnian age can, at least partially, be assigned to the Wetterstein Limestone. Another till now not well dated part of these limestones may be Upper Carnian in age. In conclusion it must be stated that those rocks of the Northern Calcareous Alps designated as "Tisovec Limestone" are clearly of **Carnian** age. This is in contrast to the now proven Lower to Middle Norian age range of the type locality in Tisovec (see chapter 4.2.). It is thus necessary to establish a new formation name for the Upper Carnian dasycladacean limestones of the Upper-Austroalpine, which obviously differ from the type locality of the Tisovec Limestone in age as well as in facies. The name **Waxeneck Limestone** is proposed for the above mentioned lightly colored Carnian shallow water carbonates with calcareous algae and frame-building organisms in the area of the Waxeneck-Schönhaltereck-Plateau (Schwarzkogel, Jausenstein, Donnerswand, Kl. Waxeneck; LEIN & ZAPFE 1971: Fig. 2). The profile in the region of the Kl. Waxeneck (Fig. 2) is designated as type locality because of its completeness and good exposure. The Waxeneck Limestone at the type locality is lithostratigraphically clearly separated from the underlying terrigenous influenced limestones/marls of the Leckkogel Beds, as well as from the micritic Hallstatt Limestones above.

A lithostratigraphic separation may be difficult in the case of a "continuous" shallow water carbonate development from the Ladinian up to the Norian. However, when the lithostratigraphic marker ("Lunz event") is missing the boundary to the underlying Wetterstein Limestone is often marked by an emersion horizon (e.g., profile Bärenlochgraben, E Schönhaltereck; LEIN 1972: Fig. 6). The boundary to the overlying Dachstein Limestone exhibits commonly a facial change.

At the type locality, the light coloured, thick bedded Waxeneck Limestone consists mainly of well washed dasycladacean grainstones. The bio- and intraclasts often show oncolithic incrustation. Interbedded are scattered layers of ooliths and beds with megalodontid bivalves. Very rare are coral fragments. The lithological affinities of this facies to some parts of the Wetterstein Limestone are evident.

In the upper part of the type locality sedimentation was more quiet, because instead of the coarse biosparites of the lower part biopelsparites and -micrites containing coquinas of thinly shelled bivalves (filaments) dominate.

The following microfacies types could be identified in the type locality of the Waxeneck Limestone:

a) Algal-foraminiferal Detritus Facies (partly with clasts of frame-building organisms),

b) Oncoid Facies (with up to 5 cm large *Girvanella*-oncoids),

c) Grapestone Facies

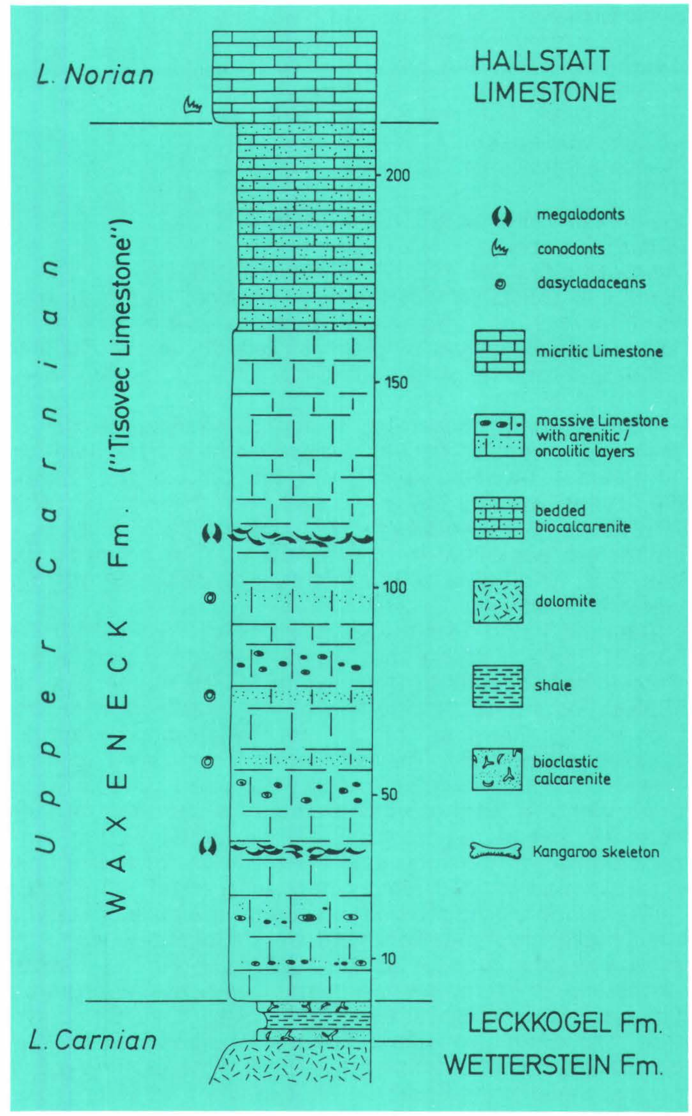


Fig. 2: Type section of the Waxeneck Limestone. The range of lithology of the limestone in its type locality is clearly seen. The rocks occurring below and above show clear differences in their facies.

d) Grapestone Facies with fixed sediment (representing a bindstone, probably built by subtidal microbial mats).

Following this microfacial spectrum the depositional environment of the Waxeneck Limestone can be reconstructed as open platform with a bathymetric range from dominating shallow subtidal to depths of a maximum of a few tens of metres.

The macrofauna of the Waxeneck Limestone consists on the one hand of frame-building organisms dominated by calcisponges (not yet investigated), on the other hand of megalodontid bivalves *(Cornucardia hornigii* (BITTNER), *Megalodus* cf. *triqueter* (WULF.)) and gastropods *(Omphaloptychia* cf. *rosthorni* (HOERNES), *Purpuroidea* aff. *excelsior* (KOKEN)).

The dasycladacean flora contains *Poikiloporella duplicata* (PIA), *Teutloporella herculea* (STOPP.), and *Clypeina besici* (PANTIC).

In the type section (Fig. 2) the following foraminifera were identified:

Glomospirella sp.

"Pilaminella" falsofriedli SALAJ, BORZA & SAMUEL

Agathammina austroalpina TOLLMANN & KRISTAN-TOLLMANN

Agathammina cf. *iranica* ZANINETTI, BRÖNNIMANN, BOZORGNIA & HUBER

Reophax sp.
Spiroplectammina sp.
Trochammina sp.
Endothyra sp.
various Duostominidae gen. et spec. indet.
Ophthalmidium sp.
Quinqueloculina sp.
"Sigmoilina" sp.
Aulototrus friedli (KRISTAN-TOLLMANN)
Aulototrus sinuosus (WEYNSCHENK)
Aulototrus tumidus (KRISTAN-TOLLMANN)
various Lagenina *(Nodosaria, Frondicularia, Lenticulina)*

4. New investigation of the type locality of the Tisovec Limestone and its surroundings

The summary concerning stratigraphy and tectonics of the surroundings of Tisovec is given by the map of the Murán plateau of KLINEC (1976). The data base of the Triassic part of this map largely originated from the work of BYSTRICKY. In this map the Tisovec and the Furmanec Limestones are combined in one signature. This is due to the fact that up till now a differentiation of these formations was not possible.

Compiling data from the surroundings (BYSTRICKY 1959, KLINEC 1976), it seems that a thinly developed terrigenous Carnian sequence is present in the Murán region (e.g., in Tisovec, at the northeastern flanks of Hradova; in the region of Ciganka; south of Cervena Skala), but mostly tectonically suppressed. The presence of such a terrigenous Lower Carnian horizon can also be assumed by facial analogies with the Northern Calcareous Alps (northern Juvavicum: Dachstein region; southern rim of Tirolicum: Tennengebirge). In these regions the thickness of the terrigenous Carnian interval ranges between 20 and 150 metres.

The tectonically disturbed position of the base of the Upper Triassic carbonate rocks at the type locality is also suggested by the map of KLINEC (1976). Here the Tisovec Limestone is in anomalous contact with the Wetterstein Limestone in a northwestern as well as southeastern direction. The character of the tectonics responsible for this complication is not sufficiently shown in the existing maps. Further detailed stratigraphic investigations are thus necessary within the area.

4.1. Indications for the tectonic situation in the quarry

The tectonic complications of the quarry, as well as the short time studying and sampling the outcrop, determine the preliminary character of the following contribution. A continuation of these investigations is clearly necessary. Additionally, these studies have to be expanded in order to refine our knowledge of the composition and structure of the Murán Plateau. Only by using this knowledge can the considerable but until now underestimated tectonic deformation of this region be elucidated. Within the framework of our limited studies, only age and facies of selected parts of the quarry were investigated:

1) the southwest corner of the quarry on the lowermost platform (samples A 1350 – A 1353 and 14A 100–101),
2) the middle part of the quarry on the main platform (samples A 943 – A 945; 14A 1–7),
3) the eastern part of the quarry between the main platform and the two overlying floors (samples A 1355, A 1362; 14A 102–103).

In spite of the wide-spaced sampling the quarry could be subdivided into three parts of different age and/or into four different facies units (Fig. 4), which are separated from one another through faults or large exploratory gaps.

In 1960, when the term "Tisovec Limestone" was established, the outcrop situation in the quarry was quite different from today. Recently, at the western outermost margin we found a thin (5 m), indistinctly bedded – up to now undescribed – sequence of crinoidal limestones. By its conodont fauna (sample A 1353) with *Gondolella polygnathiformis* BUD. & STEF. and *G. nodosa* (HAYASHI) this sequence has to be placed into the Upper Carnian (Tuval 3). In 1960 this limestone was not exposed in the quarry (see Fig. 4).

This sequence is separated by a fault from the massive carbonate rocks – Lower to Middle Norian in age – of the main part of the quarry. Outside the quarry bright algal limestones are connected to this fault, which should be classified with the Wetterstein formation following the map of KLINEC (1976). The exact direction of this fault, which separates the marginal Wetterstein Limestone from the Carnian crinoidal limestone, is not fully understood up till now. On the other side of this fault, in the central area of the quarry, red colored carbonate rocks are exposed, which seem massive but are strongly fractured. The red color partly originates from the faults.

An additional very steep large fault crosses the quarry. This fault recognizable for the main part of the quarry causes the immediate contact of the rocks differing in facies and age (Fig. 4).

The Norian carbonate rocks in the quarry can be roughly subdivided into three clearly separated facies units:

1) On the lowermost platform, grainstones with abundant frame-building organisms are present. These are irregularly intercalated with strongly bioturbated, skeletal rich, partly colored wackestones, which represent slope deposits (samples A 1350 – A 1352). Basing on their conodont fauna they are Middle Norian in age.
2) Above, in the western part of the main platform of the quarry, follow bioclastic grainstones to rudstones with associations of frame-building organisms of typical Norian character (samples A 943 – A 945; 14A 1–7). The rocks of the slope facies grade into grainstones, and breccias of the fore-reef facies (sample 14A 100–101).
3) The rocks east of the main fault of the quarry are made up by peloidal grainstones. Inserted are isolated small patches of a Norian reef-fauna showing somewhat of a Carnian character (14A 103). In spite of some foraminifers, which seem to reflect a lagoonal environment, the occurrence of a – Lower Norian – conodont fauna point to a slope position.

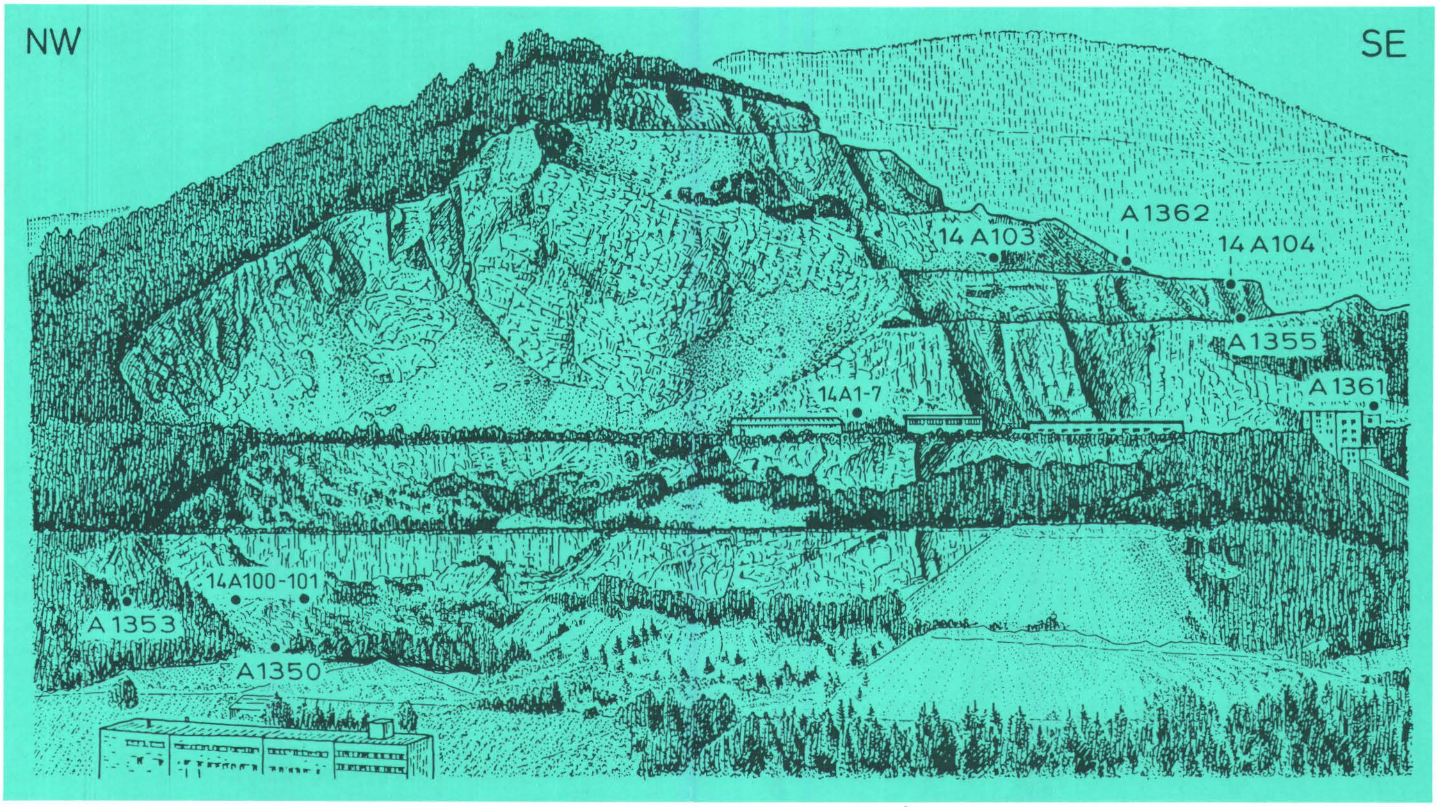
Interpreting the different facies units in terms of a stratigraphic sequence is very difficult, because the bedding relationships are widely unclear. A clarification is needed, for example, whether the mega-bedding in the eastern part of the quarry at the uppermost platform and the similarly dipping parallel "fractures" at the main platform, dipping in a SE direction (150/30–45), represent a sedimentary bedding. Our first attempts to explain the bedding relationships with the help of geopetal structures were not successful. To answer these questions work will be continued on oriented samples.

4.2. Age and fauna of the Tisovec quarry

At present accurate dating of marine Triassic rocks is possible by using either ammonoids or conodonts. Both groups, though normally rare in shallow water deposits, are represented in Tisovec. Ammonites are well-known since the early sixties (KOLLAROVA-ANDRUSOVOVA 1959, 1960, 1962); conodonts, previously undescribed from the quarry, have recently been found by us. The fitting of the ammonoid and conodont ages should guarantee a well-established and precise dating of the rocks under study.

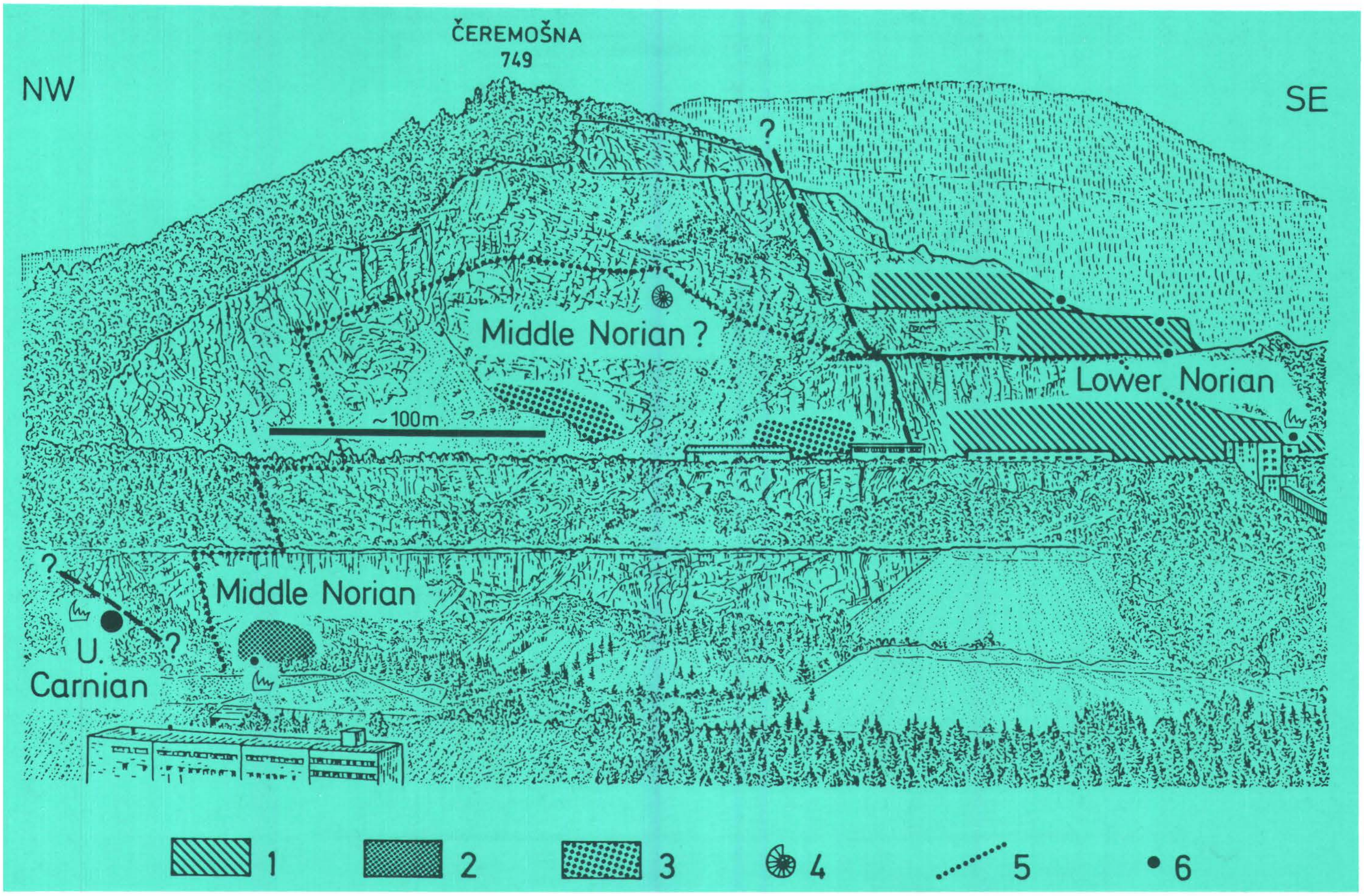
Ammonites

KOLLAROVA-ANDRUSOVOVA (1962) described ammonites from two localities at Tisovec. In the quarry itself she found *Anatomites* cf. *fischeri* MOJSISOVICS and *Megaphyllites jarbas jarbasides* KUEHN. Several specimens of *Placites placodes* MOJSISOVICS originate from above the quarry (op. cit.: p. 78). Concerning the last locality, however, there is some incertainty about its exact position, as



▲ Fig. 3: View of the Tisovec quarry seen from the northeastern slope of Hradova hill with indication of the sample sites.

Fig. 4: Stratigraphy and preliminary facies distribution of the Tisovec quarry. 1) peloidal grainstones with isolated patches, 2) bioclastic grainstones with intercalated wackestones, 3) bioclastic grain- and rudstones, 4) ammonite site, 5) border of the quarry around 1960, 6) Crinoidal limestone (Tuval). ▼



on p. 80 the same *Placites* specimens are labelled with "Tisovec quarry". According to Mrs. ANDRUSOVOVA (pers. comm.) the fossils have been collected by BYSTRICKY in 1959 and unfortunately no information is available on the original sampling sites. Since Triassic cephalopods are normally not common in fore-reef environments, we suggest a single rather than two localities for all the Tisovec ammonites and locate them with some uncertainty to the top of the quarry in its 1960 outline (see Fig. 4). Nevertheless, the opposite may also be possible in that the ammonites have been found in the lower part of the quarry near our samples A 1350 and A 1351 containing Middle Norian conodonts.

Because of the partly unsatisfying reproduction quality of the figures in KOLLAROVA-ANDRUSOVOVA (1962), a direct examination of the topotypes stored in the Slovakian Academy at Bratislava was inavoidable. This study led to serious changes in nomenclature which may be seen from different aspects. Taxonomic revision of Tethyan Upper Triassic ammonites is still at its beginning with only few new investigations (TATZREITER 1981, KRYSTYN 1982). Modern stratigraphic classification of the Upper Triassic started with TOZER (1965, 1967) for North America and was followed later in Europe (KRYSTYN 1973, 1980). KOLLAROVA-ANDRUSOVOVA published her paper long before basing her conclusions on the 80 years old monograph of MOJSISOVICS. This, however, includes a stratigraphic standard with extraordinary long or often missing ranges of most of the ammonite species. Thus relying on MOJSISOVICS (1873—1902), KOLLAROVA-ANDRUSOVOVA had no chance of avoiding the incorrect (Lower) Carnian age assignment to her Tisovec fauna. Another serious problem has to be seen in the relatively bad state of preservation of the material as well as in the small amount of specimens both making specific determinations rather difficult.

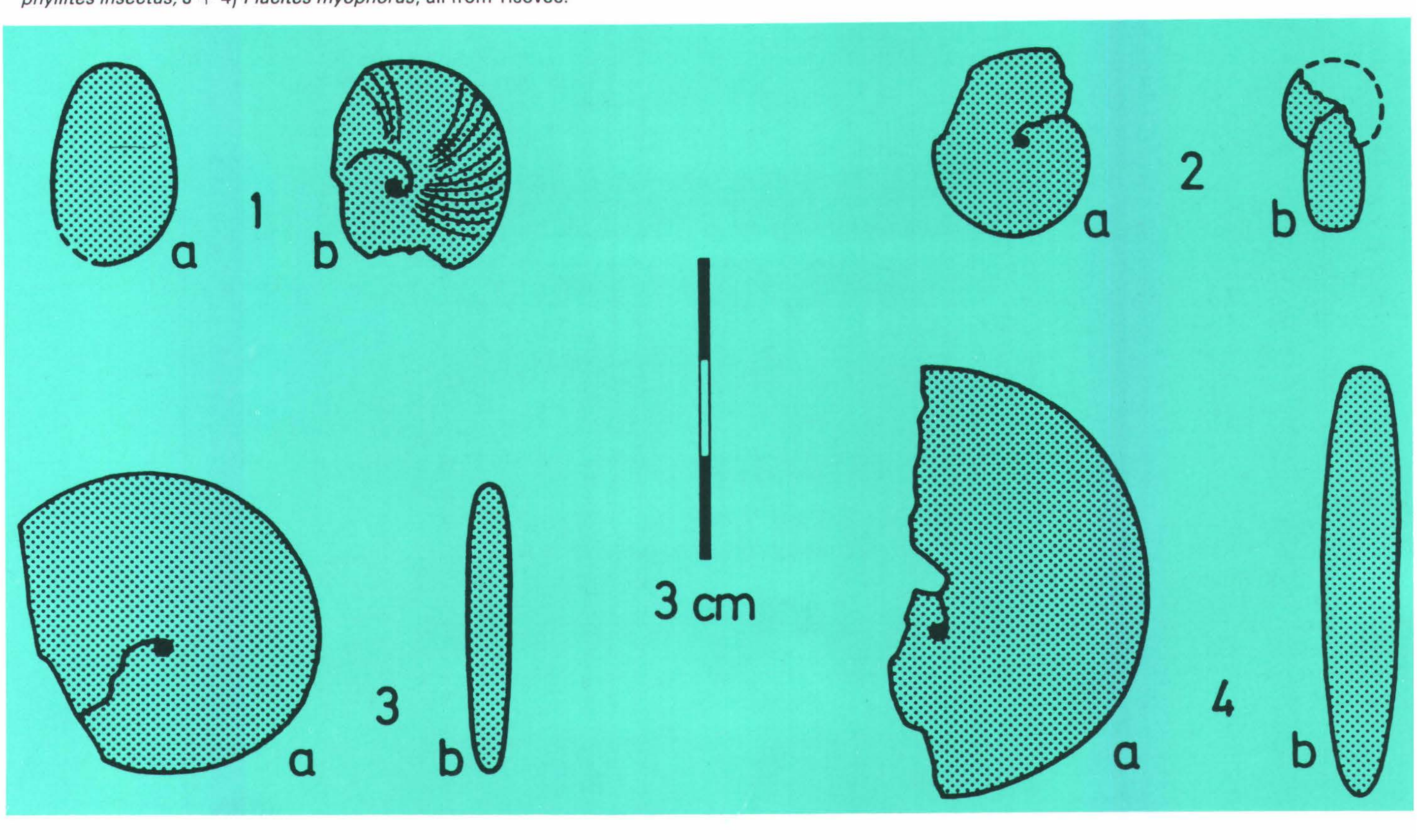
The lateral as well as the frontal or ventral outline drawings on Fig. 5 are based on the photographic figures of Pl. 4 and 5 in KOLLAROVA-ANDRUSOVOVA (1962). They are refigured here for demonstrating features which are interpreted as species-diagnostic. Those are, for example, the umbilical egression with the *Halorites* or the umbilicus size and the cross-section with the *Megaphyllites* and the *Placites* species.

KOLLAROVA-ANDRUSOVOVA 1962	this paper
Anatomites cf. *fischeri* (MOJS.)	*Halorites* sp. indet.
Megaphyllites jarbas jarbasides KUEHN	*Megaphyllites insectus* (MOJS).
Placites placodes MOJS.	*Placites myophorus* (MOJS.)
Placites sp.	*Placites myophorus* (MOJS.)

Halorites sp. indet. (Fig. 5—1) is identical with the specimen figured by KOLLAROVA-ANDRUSOVOVA (1962: Pl. 4, Fig. 9). The specimen is relatively badly preserved. It shows the sculpture sporadically and on one side only the umbilicus. The latter is closed till the beginning of the last half whorl but suddenly egresses afterwards (Fig. 5—1b). This adult feature is most diagnostic for haloritins and some tropidids but has never been found with juvavitins s. str. Tropidids can be ruled out by the lack of a ventral keel as may be seen from Fig. 5—1. In cross-section the last whorl is compressed oval with gently curved flanks and a broadly rounded venter, the greatest whorl width close to the umbilicus. As far as the sculpture is preserved it consists of numerous relatively delicate multiple branching ribs which cross the venter without interruption. A constriction was mentioned and also figured on Pl. 5, Fig. 9 by KOLLAROVA-ANDRUSOVOVA (1962). Since it is weekly developed and moreover restricted to a very small area at one flank only, it may well be the result of diagenetic overprint.

With respect to the adult umbilical egression in combination with the missing keel, the specimen can be closely compared with the Middle Norian genera *Halorites* MOJSI-

Fig. 5: Lateral and frontal outline drawings of 1) *Halorites* sp. ind., 2) *Megaphyllites insectus,* 3 + 4) *Placites myophorus*; all from Tisovec.



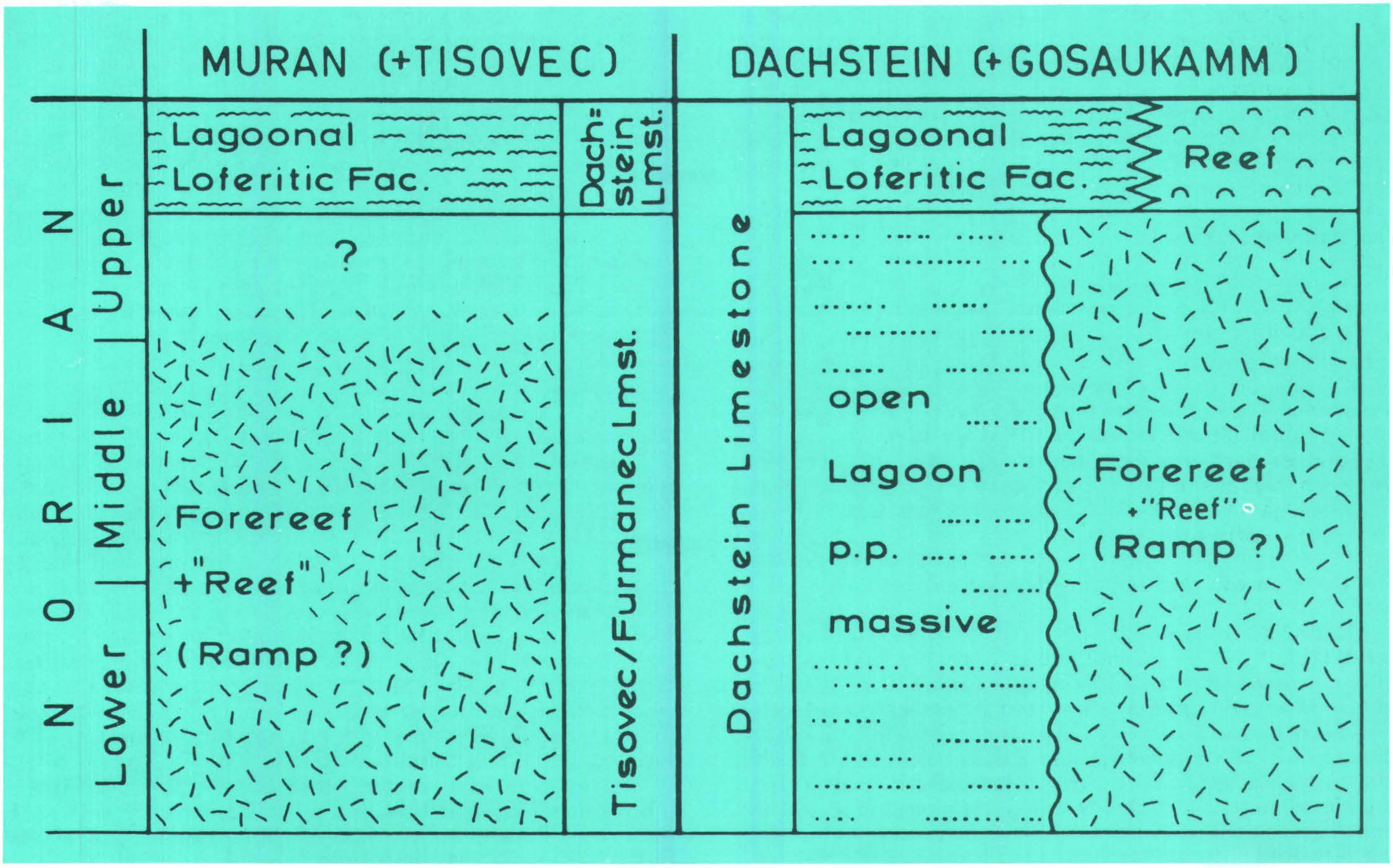


Fig. 6: Comparison of the lithostratigraphic nomenclature between the Dachstein region and the Muran plateau. Note the different extent of the use of the term Dachstein Formation within these two areas. The terminological range of the Dachstein Formation is restricted to the lagoonal facies in the type region of the Tisovec/Furmanec Limestone.

SOVICS, 1892, and *Episculites* SPATH, 1951. The last genus has a clearly different final whorl section of rectangular shape through subparallel and less convex flanks and a relatively flat venter. *Halorites* according to TATZREITER (1981) is stratigraphically restricted to the Upper Middle Norian *Halorites macer* zone and is very common in this time interval.

Megaphyllites insectus (MOJS.) (Fig. 5–2): Described originally as *Megaphyllites jarbas jarbasides* KUEHN by KOLLAROVA-ANDRUSOVOVA (1962: Pl. 5, Fig. 4) the specimen in question can be clearly attributed to the above cited species by its subcircular whorl section with well-rounded flanks (Fig. 5–2b). *Megaphyllites insectus* starts in the Upper Middle Norian and ranges well to the top of the Triassic. A Rhaetian representative of the species has been described by POMPECKY (1892) as *"Megaphyllites Joannis Böhmi* n. sp.".

Placites myophorus (MOJS.) (Fig. 5–3, 4): The specimen in Fig. 5–3 is identical with KOLLAROVA-ANDRUSOVOVA's *Placites placodes* MOJS. of Pl. 4, Fig. 8, specimen Fig. 5–4 with her *Placites* sp. of Pl. 5, Fig. 2. Both are marked by a closed umbilicus and by thin whorls. There are two species with a similarly slender whorl section in question: *Placites myophorus* to which the specimens belong in our view and *Placites placodes* which differs by having an open umbilicus (see MOJSISOVICS 1873).

According to unpublished data from the Hallstatt facies of Timor and the Alps *Placites myophorus* ranges from Middle Norian to Lower Rhaetian.

Conodonts

Altogether six samples have been collected in the quarry. Four close to the western corner (A 1350 to A 1353) and two (A 1361, A 1362) above the main platform in the eastern part of the quarry (Fig. 3). Between two and three kilograms have been dissolved per sample, resulting in, if productive, rich and time-diagnostic faunas (see below).

Samples A 1352, a peloidal mudstone and A 1362, a bioclastic grainstone, were barren. Sample A 1353 taken at the quarry's western border represents a crinoidal limestone of Carnian age. This differs in lithology as well as microfacies from the Tisovec Limestone and is therefore treated in chapter 4.1. The remaining three samples indicate a stratigraphic two-fold division of the rocks of the Tisovec quarry as discussed below.

A 1350: wackestone with echinoderms, filaments (halobiids?) and foraminifers

Gondolella steinbergensis (MOSHER)	52×
Epigondolella postera (KOZUR & MOSTLER)	42×
ramiform elements	15×

A 1351: wackestone with echinoderms

Gondolella steinbergensis (MOSHER)	5×
Epigondolella postera (KOZUR & MOSTLER)	32×
ramiform elements	8×

The *Epigondolella* specimens are identical within the two samples and are morphologically close to the *"Epigondolella postera* population" of ORCHARD (1983: p. 186, Fig. 11). Typologically they also include *"Gladigondolella abneptis"* sensu HUCKRIEDE (1958) and *Metapolygnathus zapfei* sensu KOZUR (1973).

Compared with *Epigondolella* populations from Timor they are restricted to the Middle and basal Upper Middle Norian (Alaun 2 to Alaun 3/1).

A 1361: wackestone to packstone

Gondolella navicula (HUCKRIEDE)	4×
Epigondolella "triangularis" (BUDUROV)	2×
ramiform elements	15×

Epigondolella "triangularis" is used here in a very informal way for *Epigondolella* populations with an asymmetrically expanding posterior platform similar to the *"Epigondolella abneptis* subsp. B population" of ORCHARD (1983: p. 182). A Middle Lower Norian age (Lac 2) is estimated by comparison with ammonoid bearing sequences in the Alps (Feuerkogel) and Timor. The Lower Norian age of the sample is further supported by *Gondolella navicula.*

Conodont biofacies

Gondolella and *Epigondolella* dominated Triassic samples clearly reflect basinal facies influence (CARR et al. 1984, CAREY 1984). If they are not reworked (and there are no signs of reworking within the studied samples) they provide a valuable tool for characterizing the sedimentary environment. The conodont bearing rocks of Tisovec are of typical basinal character including lower slope deposits or the deeper part of a carbonate ramp (sensu READ 1982). The rich representation of platform conodonts excludes high-energetic shallow water environments like the platform rim (reef) or the upper slope.

Remarks on the reef-building and dwelling fauna

Most of the macrofauna of the Tisovec quarry is not determinable. The organisms, most probably inozoans and spongiomorphids, have been dissolved. In a following stage the molds have been coated by several generations of yellow palisade cements. Remaining cavities have been closed in a later stage by white sparry calcite. Due to this kind of preservation of most reef builders it is difficult to decide which have been the important members of the constructor guild.

Compared with the Dachstein Limestone of the Northern Calcareous Alps (FLÜGEL 1981) the fauna and flora of the limestones of the Tisovec quarry shows a lower diversity. Common elements of the reef facies of the Dachstein Limestone like corals, tabulozoans, hydrozoans, red algae, and many of the secondary reef builders (e.g., *Follicatena irregularis* SENOWBARI-DARYAN & SCHÄFER) were not observed.

The typical Dachstein reef foraminifers, like *Galeanella,* are present. Spiriamphorellids, comparable to those described from the Norian Hohe Wand near Vienna (SADATI 1981) and the Norian reefs of Sicily (SENOWBARI-DARYAN 1982), occur in the Tisovec quarry as well. These taxa are not identical with those of the Carnian!

4.3. Facies of the Tisovec quarry

Depending on the small number of thin sections the limestones in the quarry can be classified into two main facies types, a slope facies and a reef facies s. l.

Slope facies

The slope facies is reflected by mudstones and wackestones, containing very fine grained shell debris and mud intraclasts. Only a few filaments and tiny clasts of echinoderms occur. Besides that crinoidal grain- to packstones were observed. The sediment of the latter consists of peloids, echinoderm clasts, lithoclasts, fine grained shell debris, and thin shells of bivalves. Sometimes fecal pellets (Ø 1 mm) occur. Nodosariid and textulariid foraminifers, ostracods, and gastropod shells are rare. The echinoderm clasts (Ø 0.5 mm) have micritic envelopes and many of the bivalve shells show thin algal crusts. Sometimes graded bedding can be observed within this normally massive limestones.

Reef facies s. l.

By far most of the samples have to be placed into this group which consists of various microfacies types. Most common are peloidal grainstones and rudstones, but also bafflestones are frequently found. Reef building organisms in situ are very seldom, only in some places small patches (Ø 0.5 m) of reef organisms in growth position were observed. Sometimes large clasts of reef builders (up to several cm) occur. Peloidal sediment and fine grained shell debris are found in between the reef building organisms. In some places clasts of dasycladaceans are common co-occurring with broken reef builders and unbroken encrusters.

Main reef building organisms are inozoans and probably spongiomorphids whereas corals, hydrozoans, and sphinctozoans are very rare. The reef builders are encrusted by spongiostromata. Only in some cases tabulozoans and foraminifers *(?Alpinophragmium perforatum* FLÜGEL) encrust other organisms. An important and frequent secondary reef builder is *Radiomura cautica* SENOWBARI-DARYAN & SCHÄFER.

Characteristic elements of the dweller guild are foraminifers, especially miliolids (*Ophthalmidium* sp., *Spiriamphorella* sp., *Galeanella* sp.) and textulariids (*Kaeveria fluegeli* (ZANINETTI, ALTINER, DAGER & DUCRET) and *Palaeolituonella majzoni* BERCI—MAKK), ostracods, and microproblematica *(Microtubus communis* FLÜGEL, *Baccanella floriformis* PANTIC, *Muranella sphaerica* BORZA). Echinoderm clasts, sea-urchin spines, and mollusk shells are rare.

Some peloidal grainstones and packstones contain a foraminiferal fauna with *Glomospira* sp., *Duostomina* sp., and *Aulotortus* sp.; other components are fine grained shell debris, mollusks shells, and rare echinoderm fragments. Micritic coatings are infrequently found.

These microfacial data suggest an interpretation of the depositional environment of the limestones of the Tisovec quarry as follows: In the upper part of a slope or carbonate ramp in shallow, agitated water patches of reef building organisms formed small buildups. The inter-reef or — perhaps — back-reef deposits are created by destructive processes causing coarse to fine clastic sediments with reworked reef builders. In a more downslope position the sediments are dominantly fine grained, poor in fossils, and partly show an influence by shallow water material, transported down by gravity transport mechanisms.

5. Tisovec Limestone as part of Dachstein Formation

From the very beginning (SIMONY 1847) the term "Dachstein Limestone" has always been understood in its complete facial differentiation in the literature concerning the Eastern Alps (ZAPFE 1959, FLÜGEL 1963, SCHLAGER 1967, ZANKL 1969, TOLLMANN 1976). In the surroundings of the type locality of the Dachstein Formation at the Gosaukamm reef complex, these facies units are arranged in more or less distinct zones representing, roughly speaking, fore-reef, reef, back reef, and lagoonal deposits (Fig. 7). Neither in lateral nor in vertical direction do these zones remain constant during the Norian-Rhaetian. The development of these facies also changes through time.

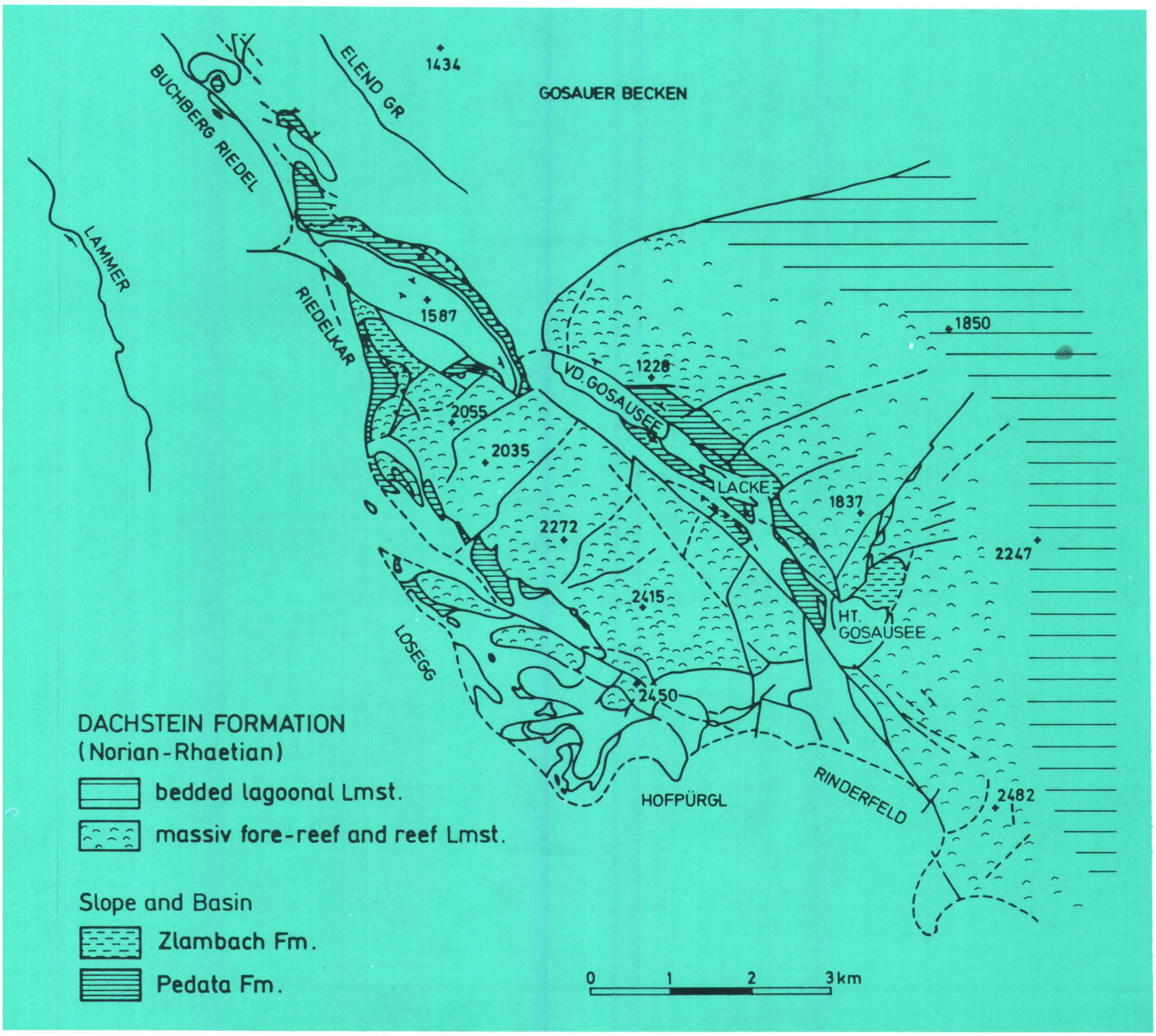
The facies migrations are best observable at the platform margins because of the narrower zones (fore-reef, reef, backreef). Intercalated into these marginal types of Dachstein Limestone are beds of colored wackestones to mudstones (SCHAUER 1983). The occurrence of these fine grained limestones also expresses the facies migration. They are well dated by pelagic faunal elements (conodonts, halobiid bivalves) reflecting the adjacent basinal sedimentation. Changes not only in the position but also in the development of the facies units are recognizable, for example, in the western part of the Dachstein plateau. Here the reef facies of the lower part of the sequence is overlain by bedded Dachstein Limestone in "Lofer facies". Additionally differences occur in the reef types itself as well as in the back reef sediments (Fig. 6).

This use of the term Dachstein Limestone in the Eastern Alps has been totally ignored during the last three decades in the Western Carpathians. In this area only the bedded limestones, expressing lagoonal depositions by the occurrence of "Lofer cycles", were named "Dachstein Limestone". This followed an overinterpretation of UHLIG's (1903) remarks. For other facial variations new terms like Tisovec and Furmanec Limestone were introduced (KOLLAROVA-ANDRUSOVOVA 1960, 1961). The introduction of these new terms was encouraged by the supposed Carnian age of the Tisovec Limestone being in contrast to the Norian-Rhaetian age of the Dachstein Formation. Following the new stratigraphic range (chapter 4.2) and the facial data (chapter 4.3) it has to be stated that the Tisovec Limestone in its type locality fully corresponds with the Dachstein Limestone of the Eastern Alps. Thus the Tisovec Limestone has to be renamed into Dachstein Limestone. However, future discussions will show the necessity to divide the Dachstein Formation into individual members based on the different facial variations.

Acknowledgements

The research was supported by grants of the Deutsche Forschungsgemeinschaft (Projekt "Evolution von Riffen" FL 42/49—2 under the direction of Prof. E. Flügel) and by grants of the IGCP, Project 198. We wish to thank for the preparation of the drawings (N. Frotzler, L. Leitner) and the thin sections (Hammermüller, Karisch). The examination of the English text was done by J. Nebelsick.
The thin section and samples on which this work is based are stored on following sites:
1) Ammonites (coll. BYSTRICKY, det. KOLLAROVA-ANDRUSOVOVA): Geologicky ústav Slov. akad. vied
2) Thin sections and conodont samples of the sample set A . . .: Geological Institute of the University, Vienna
3) Thin sections of the sample set 14A . . .: Paleontological Institute of the University, Erlangen.

Fig. 7: Upper Triassic facies distribution in the western Dachstein region (according to MANDL 1984: fig. 2). Note, that the original use of the term "Dachstein Formation" in its type region includes the forereef, reef and back reef development.



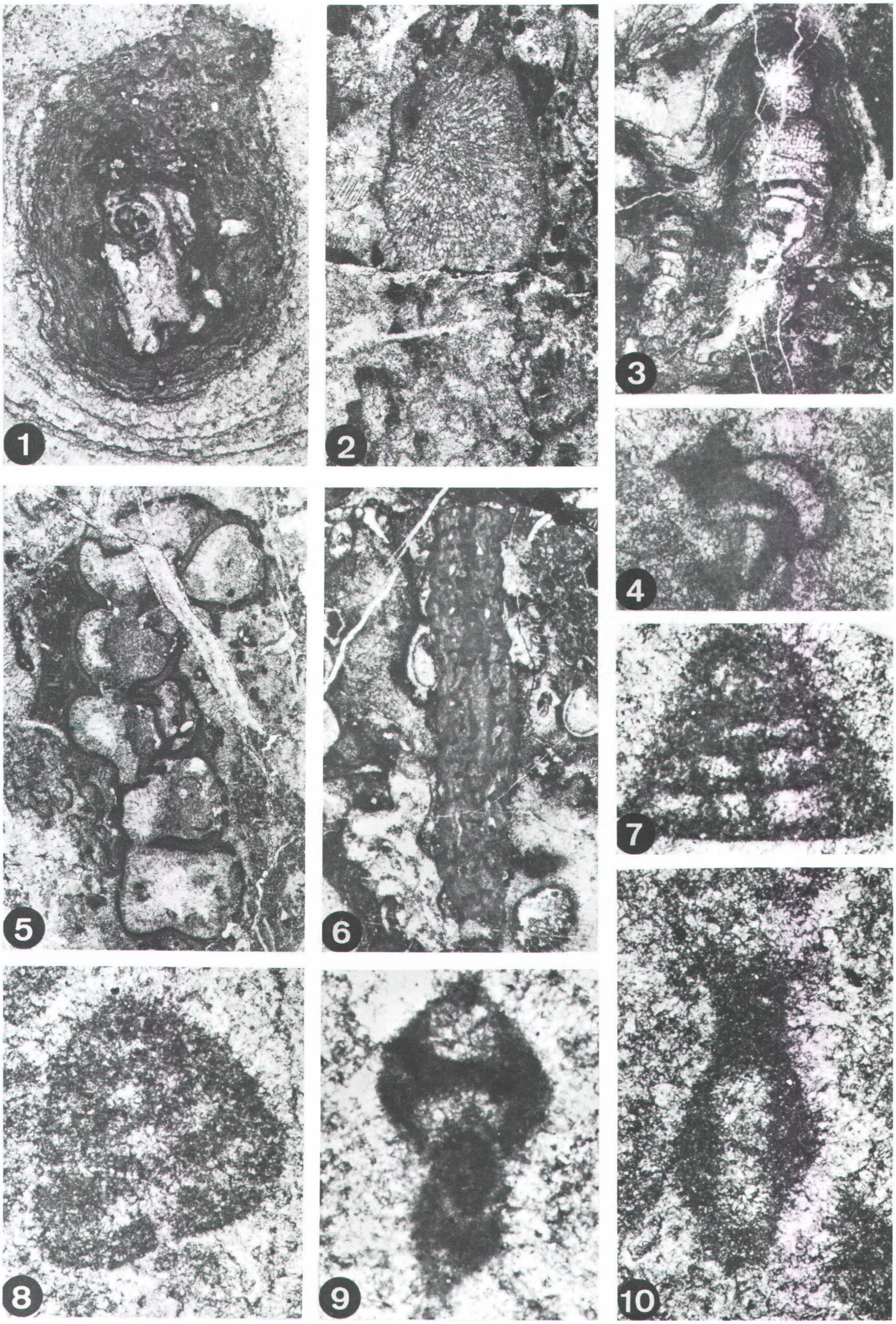

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Fig. 1: Thick algal-bacterial layers surround this bioclast. Thin tubes within this crust proof the fixing activity of algae.
Tisovec Quarry, Norian, thin section 14A4/3, scale 6.5 ×.

Fig. 2: Diverging tubes and irregularly arranged tabulae within the tubes are characteristic of red algae.
Tisovec Quarry, Norian, thin section 14A7, scale 14 ×.

Fig. 3: ? *Paradeningeria* sp. The younger chambers of this sphinctozoan sponge are encrusted by thick algal crusts.
Tisovec Quarry, Norian, thin section 14A4/1, scale 3.5 ×.

Fig. 4: *Spiriamphorella* districta? BORZA & SAMUEL is a common dweller of the reef facies of the Tisovec quarry.
Tisovec Quarry, Norian, thin section 14A1/2, scale 70 ×.

Fig. 5: *Radiomura cautica* SENOWBARI-DARYAN & SCHÄFER is an important secondary reef builder. The shape of this microproblematic resembles of sphinctozoan sponges.
Tisovec Quarry, Norian, thin section 14A7, scale 6.5 ×.

Fig. 6: *Vesicocaulis* cf. *alpinus* OTT is a rare member of the constructor guild in the reef facies. This sphinctozoan sponge is a characteristic Ladinian/Carnian faunal element which normally does not occur in Norian reefs.
Tisovec Quarry, Norian, thin section 14A3, scale 4 ×.

Fig. 7: *Palaeolituonella majzoni* BERCI-MAKK is a common member of the foraminiferal association of Norian reef limestones.
Tisovec Quarry, Norian, thin section 14A7, scale 100 ×.

Fig. 8: ? *Palaeolituonella majzoni* BERCI-MAKK is an abundant element of the foraminiferal assemblage of Norian reefs.
Tisovec Quarry, Norian, thin section 14A1/2, scale 110 ×.

Fig. 9: *Spiriamphorella districta?* BORZA & SAMUEL is also known from the Norian limestones of the Hohe Wand near Vienna (Austria).
Tisovec Quarry, Norian, thin section 14A1/2, scale 210 ×.

Fig. 10: *Spiriamphorella* sp. Spiriamphorellids are characteristic foraminifera of the reef facies.
Tisovec Quarry, Norian, thin section 14A1/2, scale 150 ×.

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[1] There are some new indications that this taxon has a longer range and may well reach the (?Middle) Norian.

Abstrakt

Nové výskumy v tisovskom lome, teda na typovej lokalite rovnomenných tisovských vápencov, považovaných za karnské, priniesli prekvapujúci poznatok o ich spodno- a stredno-norickom veku. Dostatočne to preukazuje fauna konodontov a amonitov.

Z litologického hľadiska je možné v lome odkryté vápence zaradiť do dvoch hlavných faciálnych zón: k svahovej fácii a k rífovému vývoju v širšom zmysle.

Z litologického ako aj stratigrafického hľadiska v tisovskom lome odkryté masívne norické vápence zodpovedajú východoalpskému dachsteinskému vápencu a v dôsledku toho by sa tak mali aj nazývať (obr. 6). Označenie „tisovský" vápenec by sa teda na označovanie takýchto vápencov nemalo používať.

Z toho dôvodu je na označenie skutočných vrchnokarnských riasových vápencov, ktoré boli dosiaľ v literatúre týkajúcej sa vápencových Álp označované ako „tisovské", potrebné zaviesť nové pomenovanie. Navrhuje sa pre ne pomenovanie waxenecké vápence (Waxeneck-Kalk) (typový profil Kleines Waxeneck, mürzalpský príkrov, obr. 2).

Zusammenfassung

Die Bearbeitung des Steinbruches in Tisovec, der Typuslokalität des gleichnamigen, für karnisch gehaltenen Kalkes, erbrachte das überraschende Ergebnis eines norischen Alters. Dieses ist durch Conodonten und Ammoniten hinreichend abgesichert.

In lithologischer Hinsicht können die im Steinbruch aufgeschlossenen Gesteine zwei Hauptfaziesbereichen zugeordnet werden: einer Slope-Fazies und einer Riffentwicklung im weitesten Sinne.

In lithologischer wie auch in stratigraphischer Hinsicht entsprechen die im Steinbruch Tisovec aufgeschlossenen massigen norischen Kalke vollkommen dem ostalpinen Dachsteinkalk und sind folglich auch so zu benennen (Abb. 6). Die Bezeichnung „Tisovec-Kalk" ist dagegen einzuziehen.

Aus diesem Grund war eine Neubenennung jener echten oberkarnischen Algenkalke nötig, die bisher in der Literatur über die Kalkalpen unter der Bezeichnung „Tisovec-Kalk" geführt wurden. Für sie wird die Bezeichnung Waxeneck-Kalk (Typusprofil Kleines Waxeneck, Mürzalpendecke, Abb.2) vorgeschlagen.

COMPARATIVE STUDY OF WETTERSTEIN CARBONATE PLATFORMS OF THE EASTERNMOST NORTHERN CALCAREOUS ALPS AND WEST CARPATHIAN MOUNTAINS: PRELIMINARY RESULTS

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Introduction

Most of the fieldwork on which this paper is based was carried out in the frame of the respective Austrian and Slovak regional mapping programmes. Field mapping is still in progress and detailed paleontological work will be a future task. The calcisponges collected so far in the Austrian working area (leg. LOBITZER) at present are under study by colleagues from Erlangen University. The comparatively scarce and often poorly preserved coral fauna will be evaluated by Mrs. Doc. E. Roniewicz, Warsaw. Therefore, in order not to confuse the literature by inadequate fossil determinations, we do not refer to our preliminary determinations in the frame of this paper.

We also have to state that all the poor English in this paper is in the responsibility of the Austrian/Slovak authors, Sal Mazzullo did not forget his mother language!

For the sake of brevity, in the remainder of this paper we often refer to the Anisian to Cordevolian sequence as "Middle Triassic". In the study area, Middle Triassic rocks include diverse lithologic types, each with a distinct faunal assemblage.

Wetterstein carbonate platforms of the easternmost Northern Calcareous Alps

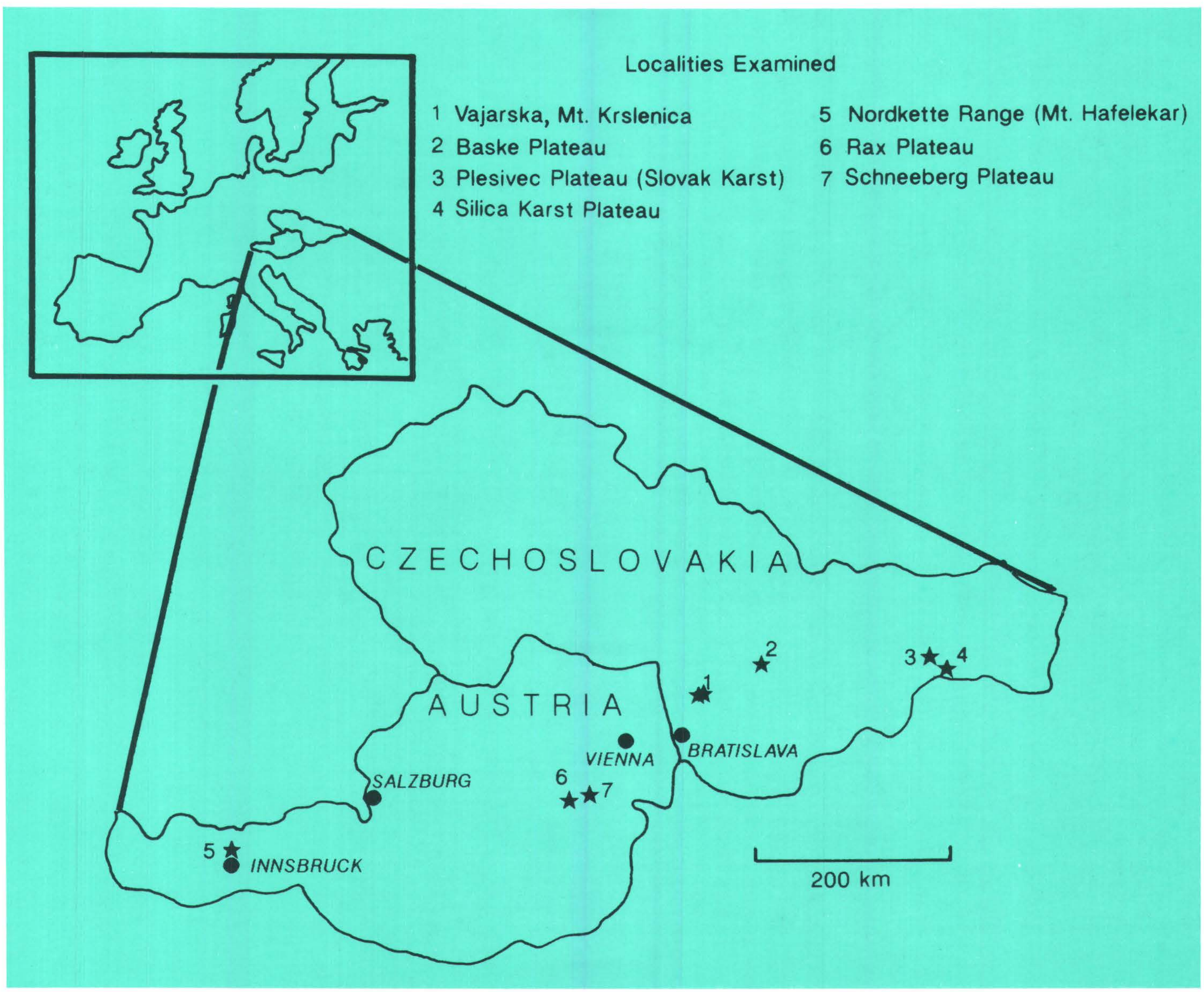
Published data on the facies distribution in the Wetterstein Limestone of the easternmost Northern Calcareous Alps are scarce and the only documentation so far is the unpublished map in the PhD-Thesis by LOBITZER (1971), followed by several short accounts by LOBITZER (1972—1988) and MANDL (1985—1987). In the following paragraphs we shortly summarize the results of our field investigations concerning Wetterstein Limestone in the Schneeberg nappe.

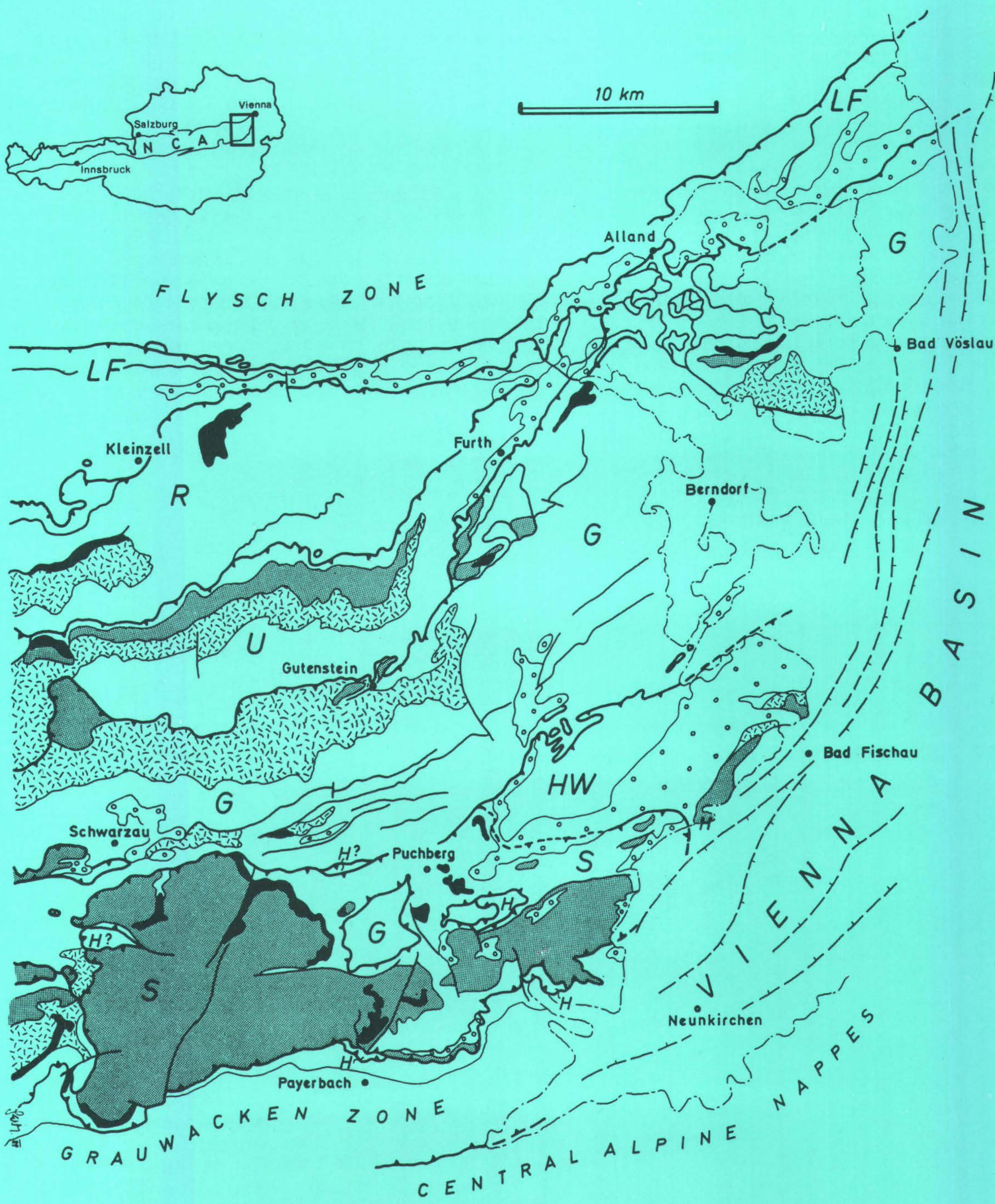
Details on the biota and their communities will be worked out in a joint effort with colleagues from Erlangen University (particularly the calcisponges) in cooperation with experts from various other institutions.

The Schneeberg nappe as part of the Higher Alpine Nappe System provides excellent exposures both on larger karst plateaus (Rax and Schneeberg) and in scattered smaller exposures, isolated either by tectonics or erosion, which stretch eastward towards the easternmost margins of the Northern Calcareous Alps (Figs. 2,3). Equivalents of the Schneeberg nappe have been cored also in the subsurface of the Vienna Basin (e.g. Tattendorf drill hole with Wetterstein reef-facies) by ÖMV AG.

The Rax Plateau provides excellent exposures of a prograding carbonate platform over slope sediments. In the southwest an extensive platform edge reef (the Heukuppe-Predigtstuhl reef complex) interfingers in its lower parts towards the south with upper slope limestones and towards the northeast with near-reef lagoonal, in part peritidal, limestones. The slope sediments (Plate 1, Figs. 6,8,9; Plate 2, Figs. 1,2,6) comprise various allodapic limestones and variegated micrites, often with pronounced deeper water biota, including ammonites, conodonts, „filaments" and radiolarians. The „reef-belt" clearly stretches from the uppermost slope to a considerable distance into the platform. In the field the intensive cementation by radiaxial fibrous calcite, often of grossolithic character, is most conspicuous. Larger biota are rather scarce and maximum in the decimeter size range. A variety of calcisponges (inozoans and sphinctozoans), *Tubiphytes* and more scarcely corals predominante. Brachiopods are the most important reef-dwellers. Small lenses of pinkish micritic limestone of Hallstatt-type, occasionally with „zebra"-neptunian dykes or stromatactis-shaped fabrics occur within the reef. They clearly show deeper-water biota (Plate 2, Figs. 3,4,5) and also contain stratigraphically valuable conodonts and foraminifera (LOBITZER 1986, LOBITZER et al. 1988). Towards the north, or northeast, the reef belt interfingers either with grainstones or with birdseye limestones, both of them contain the characteristic dasycladacean alga *Teutloporella herculea* and very often abundant solenoporaceans and/or porostromate algae. In a transitional zone „mixed" biota, such as *Teutloporella,* solenoporaceans/porostromate algae and sphinctozoans and/or corals may occur together. Patchy dolomitization affects as well the reef and also the lagoonal sediments.

Fig. 1. Situation map of studied exposures





Location map of Wetterstein carbonate platforms and coeval basin deposits in the eastern part of the Northern Calcareous Alps, Austria. Compiled from AMPFERER & SPENGLER 1931, CORNELIUS 1936, 1951, PLÖCHINGER 1982, TOLLMANN 1976, WESSELY 1983, FUCHS 1984 and own mapping (MANDL 1983 - 1986 unpubl.).

Northern Calcareous Alps:

- Cretaceous
- mainly Triassic, local Jurassic
- Wetterstein dolomite — Lower Carnian to Upper Anisian
- Wetterstein limestone — Lower Carnian to Upper Anisian
- H Hallstatt limestones — Lower Carnian to Upper Anisian
- Reifling Formation — Lower Carnian to Upper Anisian

Main nappe boundaries

- LF Lunz/Frankenfels nappe system
- R Reisalpen nappe
- U Unterberg nappe
- G Göller nappe
- HW Hohe Wand / Mürzalpen nappe
- S Schneeberg nappe

Fig.

Towards the east, respectively northeast the plateaus of the Schneeberg and Gahns (Fig. 3) show again a complex patchwork of various carbonate platform sediments which are very similar to the Rax plateau. The reefs interfinger in their lower parts with various slope sediments (MANDL 1987, LOBITZER 1986). One gets the impression, that deeper water steep fjord-like channels cut into the carbonate platforms.

Also further towards the east (Fig. 3) Wetterstein Limestone in reef-facies (Schacherberg, Asandberg, Kehr) and lagoonal environments (Hinterberg, Dürrenberg, Talberg, Kienberg) are well exposed as documented by LOBITZER 1986; LOBITZER-PIROS 1987; MANDL 1985, 1986).

Many excellent papers on the Wetterstein depositional system of the western Northern Calcareous Alps have been published, among them BRANDNER-RESCH (1981), DONOFRIO et al. (1979), FLÜGEL (1982), GERMANN (1960,1971), HENRICH (1982), OTT (1967,1973), SARNTHEIN (1965,1967), SCHNEIDER (1964), TOSCHEK (1968), and WOLFF (1973).

Wetterstein carbonate platforms (WCP) of the Inner West Carpathians (IWC)

The WCP are the most widespread in the eastern part of the IWC (Fig. 6), less in the western part (Fig. 5) and relatively scarce are in the central portion of the IWC (not illustrated). This is due to the fact that WCP are mainly bind with Silicic (before „Gemeric") tectonic unit which is preserved mainly in these two areas. In the middle part of the IWC the Silicic unit is present only in small overliers, but encroaching of the WCP into tectonic and paleogeographic area of Hronic (the Choč nappe) is of interest.

In the western part of IWC however still remains the problem if WCP are really part of higher nappes of Silicic, or presence of WCP is due to facial change of Hronic (the Choč nappe) in westward direction.

WCP of the western part of IWC (Fig. 5)

If we push aside occurrences of Wetterstein limestones in deep drillings of Vienna basin, the nearest outcrops of WCP to Northern Calcareous Alps (NCA) in IWC are in White Hills of Malé Karpaty Mts. between Vajarská and Trstín (Fig. 5, Fig. 8) and in neighbouring Brezovské Karpaty Mts. (the Veterling, Havranica and Jablonica nappes).

Structural correlation with NCA is rather controversial, because distinguished tectonic units (the Choč and higher nappes) are older than Gosau sediments, while in NCA tectonic units are upper Jurassic to Paleogene in age.

On the other hand, there are no problems in facial and lithostratigraphic correlation - it is a direct continuation and prolongation of facial zones from NCA with analogical sequences in the underlier and overlier.

Further to the North rests of WCP are preserved in Čachtické Karpaty Mts. and Strážovská hornatina Mts. in higher nappes (Nedzov and Strážov nappe) with interference to the Choč nappe (into Bebrava Group of M. Maheľ 1979a).

Wetterstein carbonate platforms are here mostly of prograding (regressive) type - they are growing towards the basins over basinal sediments. These are mostly represented by the Reifling, less by the Schreyeralm limestones. Higher up slope facies of the Raming limestones, often with turbidites, forereef breccias, limestones of reef barrier follow and the cycle is terminated with back-reef and lagoonal facies, often dolomitized.

More detailed data about individual Wetterstein carbonate platforms of this region may be found mainly in the works by M. Maheľ (1979a, 1979), J. Bystrický (1972, 1973, 1982), J. Bystrický — M. Maheľ (1970), J. Michalík (1984), J. Hanáček (1976), G. Kolosvary (1958—1967), E. Jablonský (1973), M. Peržel (1966), S. Buček (1988), P. Masaryk (in press) and J. Salaj et al. (1987).

For more detailed illustration of the Wetterstein limestone facies two areas have been chosen: Baske reef complex S of Omšenie in Strážovská hornatina Mts. (Fig. 7) and Veterlin and Havranica nappes in Malé Karpaty Mts. (Fig. 8).

Mt. Baske is rest of a huge reef area: back-reef and lagoonal parts of complex are scattered amidst dolomites. In Veterlín nappe almost exclusively reefal limestones and fore-reef breccias (demonstrated kindly by J. Michalík) are represented, for Havranica nappe lagoonal Wetterstein limestones are typical (J. Bystrický 1973, S. Buček 1988).

Wetterstein carbonate platforms in the inner part of the West Carpathians, eastern Slovakia (Fig. 6).

In this region Wetterstein limestones form widespread karst plateaus of Slovak Karst, Muráň plateau and Stratenská hornatina Mts. The most detailed data on facies distribution of Wetterstein carbonate platforms are available from the Slovak Karst (J. Bystrický 1964, 1972, J. Mello 1974, 1975a, 1975b, 1975b, 1977, Ľ. Gaál 1982, E. Jablonský 1973a, 1973b, 1973c, M. Kochanová-J. Mello-M. Siblík 1975). On Muráň plateau mainly dasycladacean zones of back-reef and lagoonal area were studied (J. Bystrický 1986). In Stratenská hornatina Mts. both reefal (Veľký Sokol, Geravy) and lagoonal (Pelc, Glac) facies of Wetterstein limestones are richly represented, but they have not been studied in detail until now.

For illustration of facial relations of this region WCP of Silica nappe on Zádiel and Jasov karst plateau (of Slovak karst) have been chosen (Fig. 9). WCP is cut here in two partial units which are dipping slightly to the south. Basinal facies are represented on the northern side by Nádaska and Reifling limestones. Reefs are concentrated also near to the northern margin of the plateaus (in the overlier of the basinal facies) in both subunits. Back-reef and lagoonal facies are developed in overlying parts of reef (with some patch-reefs) southwards.

Middle Triassic depositional system in the area studied

Sedimentary facies

Four principal depositional facies units are recognized in platform carbonates of the Wetterstein Limestone: (1) peritidal, (2) lagoonal, (3) reef, and (4) associated grossoolite-breccia facies. Distal-slope and basin deposits comprise fore-platform facies.

Accordingly, a brief treatment of Middle Triassic facies is presented herein as background for the sections on depositional systems and diagenesis that follow.

Peritidal facies. This facies includes rocks deposited in intertidal and supratidal environments.

Syndepositional marine cements are characteristic features of these rocks. Evidence of periodic hypersalinity and locally, subaerial exposure, during the deposition of these beds is indicated in several outcrop sections, particularly in central and western Austria (BRANDNER & RESCH 1981). Similar facies are known in Tethyan Upper Triassic (i.e., LOBITZER 1974) as well as Permian rocks in the Guadalupe Mountains of New Mexico-Texas (MAZZULLO & HEDRICK 1985), the United Kingdom (SMITH 1981; HARWOOD 1986; KALDI 1986) and Southern Alps (NOE 1987).

Lagoonal facies. Rocks of this facies are generally massive bedded, locally bioturbated and partly dolomitic limestones with a diverse biota of various dasycladacean (prominently including the genus Teutloporella), solenoporacean and codiacean algae, molluscs, echinoderms, sponges, corals, brachiopods, bryozoans, foraminifera and ostracods. Textures vary from wackestone to grainstone, the latter lithology being particularly abundant in transitional zones between lagoonal and reef facies (the „reefflat calcarenite" facies of BRANDNER & RESCH 1981). Patch reefs up to approximately one cubicmeter in size occur very

Facies distribution within the Wetterstein limestone of Schneeberg nappe. Compiled after CORNELIUS 1936, 1951 LOBITZER 1971 - 1988, MANDL 1984 - 1987.

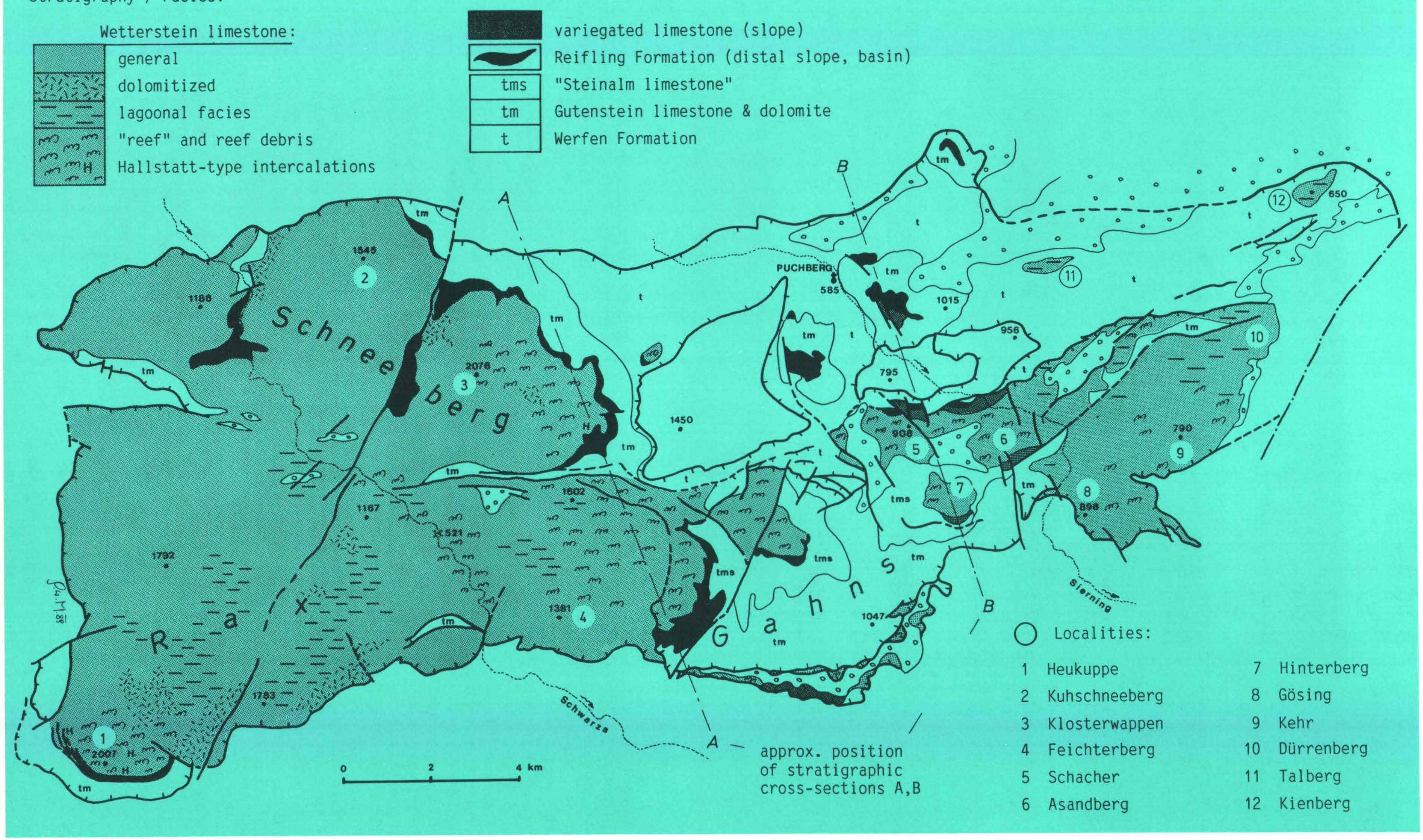


Fig. 3.

scarcely in the lagoon. They consist of buildups made up by branching corals of „Thecosmilia"-type. Brachiopods are conspicuous reef dwellers, their clams can be observed in considerable quantity entrapped between the coral branches. The immediate transitional area „behind" the reef – the near-reef lagoon platform – is often characterized by grainstones, boundstones or birdseye-limestones with mixed biota consisting of reef debris and *Teutloporella* as typical element of the near reef lagoon. In some cases flats with abundant in situ growth of solenoporaceans are most characteristic; they are either represented by grainstones or by birdseye-limestones.

Reef facies. The most intensely studied facies of the Wetterstein is by far, reefal limestones (Plate 1, Fig. 3). These buildups are composed of diverse biotic assemblages of sphinctozoan and other calcisponges, corals (*„Thecosmilia", „Montlivaltia", „Thamnasteria"), Tubiphytes,* bryozoans, codiacean and solenoporacean algae (and possible squamariaceans), foraminifera, echinoderms, molluscs, and brachiopods (MELLO 1975a; BRANDNER & RESCH 1981). *Tubiphytes* alone locally occurs as relatively thick platform-margin reef buildups such as in the Vajarska-Mt. Krslenica outcrops area of Slovakia (Fig. 5). This organism similarly is a major faunal constituent of Permian rocks throughout the world (MAZZULLO & CYS 1977; FLÜGEL 1981a; SMITH 1981). Rock textures of reefal deposits generally are wackestones and packstones; boundstones resulting in large part, from syndepositional marine cementation, are also very common in this facies.

MAZZULLO & LOBITZER (1988) compared the biotic compositions, settings, and diagenetic attributes of Upper Permian (Guadalupian, Capitan) and Tethyan Triassic reefs, noting the persistence and similarity of major reef-forming organisms in these Permian and Middle Triassic limestones.

Notwithstanding evolutionary changes in specific taxa, the biotic compositions of the Capitan (and other Permian sections in the world: FLÜGEL 1981a; SMITH 1981; HARWOOD 1986; KALDI 1986; NOE 1987) and Middle Triassic reefs are very similar at several phyllogenetic levels, and are clearly distinct from those of Tethyan Upper Triassic reefs. Both the Permian and Middle Triassic reefs are composed mainly of calcisponges, *Tubiphytes* and lesser numbers of corals (rugosans in the Permian, scleractinians in the Triassic). Spongiostromata and possible squamariacean algae are important contributors to the Middle Triassic reefs, whereas organisms of similar encrusting habit, namely the problematical alga *Archaeolithoporella,* apparently occupied the same ecologic niche in the Capitan (MAZZULLO & CYS 1978) and other Permian reefs (FLÜGEL 1981a; SMITH 1981). In contrast, Tethyan Upper Triassic reefs are dominated by scleractinian corals (*Thecosmilia* types). Phylloid algae are known as a minor constituent in the Capitan reef (BABCOCK 1977), and REID (1986) noted their persistence into the Mesozoic, describing occurrences in Upper Triassic (Norian) reef carbonates in Canada. To date, however, we have not found phylloid algae in any of the Triassic reefs examined in the study area. In addition to their biologic makeup, Permian and Middle Triassic reefs are also similar in terms of their diagenetic histories, both having been extensively syndepositionally cemented in the marine environment (MAZZULLO & CYS 1977, 1978; FLÜGEL 1981a; SMITH 1981). In Upper Triassic reefs, syndepositional marine cements are relatively uncommon (MAZZULLO & LOBITZER 1988).

According to our opinion a biogenic reef framework in the sense of a wave-breaking structure- as e.g. in the Latest Triassic Steinplatte reef crest – did not exist in the Wetterstein reefs of the eastern Northern Calcareous Alps. Practically all „reef"-organism are of comparatively small dimensions of several centimeters only. Coral-buildups of giant dimensions are missing as well as also other potential wave breaking organisms. One gets the impression, however, that a rigid „framework" could be constructed by a combination of pervasive submarine early diagenetic cementation and various encrusting organisms. The remarkable fact of immediate interfingering of the „reef"-proper with lagoonal birdseye limestones is considered as prove for platform-edge reefs and not an upper slope situation. Typical assemblages of a deeper water slope, as silicisponges, ammonites, radiolarians and relevant foraminifera are missing. Scattered very small lenses of variegated – pinkish, yellowish or grey – micritic limestones with conspicuous cement growth of „zebra"-type and stromatactis-like features can be seen within the reef of Heukuppe on Rax-Plateau and even more scarcely on Schneeberg-Plateau as well. We call them „lenses of Hallstatt-type limestone". Similar features are well documented also in the Dachsteinkalk reefs (Hoher Göll: Zankl 1969; Mitteralpe/Hochschwab-Plateau: Lobitzer 1971, Hohenegger- Lobitzer 1971; and Gosaukamm/Dachstein-Plateau). The biofacies indicates a deeper water environment and in many cases also allows a stratigraphic dating. The biota comprise conodonts, „filaments" (thin pelecypod shells), spicules of siliceous sponges, and ammonites.

Grossoolite facies. A conspicuous feature of platform-edge facies in the Wetterstein Limestone is the development of coarse breccias (Plate 1, Fig. 5) and locally, in reef and outer-lagoonal (reef-flat aprons) sand facies, coarse skeletal rudites with interparticle „grossoolite" cements. The term „grossoolite" (or „grossoolith") refers to thick, laminated, isopachous coatings of coarsely crystalline calcite cement (generally radiaxial-fibrous fabrics) and calcite-replacive dolomite around lithoclasts and skeletal particles (LEUCHS 1928; SANDER 1936 [and 1951 translation]; GERMANN 1971). Although SANDER (1936) initially interpreted these crystalline coatings as being of organic origin, they are now regarded as inorganic cements (GERMANN, 1971; MCKENZIE & LISTER 1983). The term „grossoolite facies" is herein also applied in the textural sense, to those coarse, reef-associated breccias („grossoolite-breccias") and skeletal calcirudites that are lithified by grossoolitic cements. The component clasts in the grossoolite-breccia facies are commonly angular and generally poorly sorted through a vertical section of such rocks, ranging in size from a few centimeters to several decimeters in diameter. Within individual beds, however, the clasts typically are relatively well sorted such that the interparticle matrix is occluded nearly entirely by coarse crystalline cements rather than fine particulate detritus (Plate 1, Fig. 4). In the outcrops examined, the clasts within the grossoolite-breccia facies are composed exclusively of shelf-margin reefal lithologies (Plate 1, Fig. 4); reefal and some lagoonal organisms similarly comprise the associated calcirudites lithified by grossolitic cements. In places, grossoolite-breccias are the only remaining evidence of the former presence of in-situ, shelf-margin reefs.

We concur with BRANDNER & RESCH (1981) in interpreting the grossoolite-breccias to have been deposited in both shelf-margin as well as uppermost slope environments, although we believe they are best developed on the shelf margin throughout most of the study area. Although the origin of these breccias in the Nordkette Range of Tyrol has been attributed by BRANDNER & RESCH (1981) to syndepositional block-faulting of the underlying Goetheweg reef, equivocal evidence of similar faulting has not been noted by us in other outcrop areas. However, it is likely that syndepositional tectonism, oversteepening of the platform margin, slope instability, or combinations of these processes, must have been causative factors in the formation of such widespread breccia deposits in this region.

Slope and basin facies. Rocks of transitional nature between Middle Triassic platforms and basins are relatively rarely exposed in the Northern Calcareous Alps and West Carpathians due to structural complexities. Basinal facies often are tectonically isolated from formerly contiguous platform deposits.

In general we know two different types of Anisian to Cordevolian carbonatic basinal sediments, the Reifling Formation and Hallstatt Formation. The Reifling Fm. consists of light to dark grey, well bedded, nodular micritic limestone with chert nodules, occasionally green tuffits and a sparse fauna dominated by radiolarians, filaments, conodonts and locally ammonites. In central and western part of NCA it passes lateraly into the dark shales of Partnach Formation. The Hallstatt Formation comprises a lot of different lithologies mostly of variegated (violet, red, pink, yellowish-grey, white) micritic limestones with abundant conodonts and ammonites. Hallstatt Limestones are almost restricted to the uppermost respectively southernmost tectonic units and represent the sediment of outer shelf and/or local uplifts, far away from continental influences and may pass into oceanic conditions (Meliata Fm. in Slovak Karst area).

Transitional strata between Wetterstein and Reifling Limestone is known as Raming Limestone (TOLLMANN 1976). It is a sequence of medium bedded, light coloured micritic limestone with graded lithoclastic beds and occasionally chert nodules. Clasts are mainly slope-derived semiconsolidated micritic sediments, locally platform debris occurs too.

Investigations of the last 15 years have shown much more types of slope and basin facies (HOHENEGGER &LEIN 1977, MELLO 1975) which do not fit very well to the established formations mentioned above. This should be a main topic of further comparative investigations. Therefore we use in this article preferably descriptive lithological terms.

Basinal facies and eventually distal slope too is represented in the Schneeberg area by grey nodular limestone of Reifling type and black even bedded cherty limestone with fine grained graded allodapic composition. The latter has been named Grafensteig Limestone by HOHENEGGER & LEIN 1977. It is overlain at Mt. Schneeberg by grossoolite-breccia facies of upper slope.

A second type of transitional facies is a variegated limestone which resembles Hallstatt Limestone at a macroscopic view. But gradual transition into Wetterstein reef limestone, resedimentation structures, „stromatactis"-cavities and fine grained platform debris do not fit to typical Hallstatt facies in a strict sense. It contains lenticular cavities lined with alternating generations of isopachous, radiaxial-fibrous calcite cements and red, internal sediments. Whether these filled cavities represent the products of marine or meteoric diagenesis is presently uncertain. These textures and crystalline fabrics of these rocks are the focus of a detailed study by MAZZULLO, who notes their resemblance to similar features described by KENDALL (1985) from Devonian fore-reef carbonates in Australia.

A variegated limestone of slope origin has also been described by BALOGH & KOVACS 1981 as „Nadaska" Limestone. But as far as published, influence of a nearby reef has not been noticed and therefore it does not show the special characteristics of our slope type.

Another type of transitional facies has been reported from the Slovak Karst as „Wetterstein bedded limestone" by MELLO 1975. Similar lithology is known from Northern Calcareous Alps, Dachstein region (MANDL et al. 1987) in position between Hallstatt Limestones and Wetterstein reef limestone.

Slope and basinal facies of the Tethyan Upper Triassic and Permian (such as in the southwestern United States and the United Kingdom) do not differ greatly from those in the Middle Triassic. Upper Triassic fore-platform deposits in the study area are variously lithoclastic (Aflenz Limestone: LOBITZER 1974), calcarenitic (Steinplatte reef complex: PILLER 1981) or micritic (LOBITZER 1974, 1980).

Analogous Permian distal-slope and basinal facies in the United States and United Kingdom similarly consist variously of lithoclastic (non-grossoolitic), calcarenitic, and micritic limestones as well as sandstones, shales, and evaporites (KING 1948; HARWOOD 1986).

The foraminifera assemblages of the Wettersteinkalk and age-equivalent slope- and basin facies are much lesser diverse and poorer in individuals compared to the Norian/„Rhaetian" Dachstein Limestone (HOHENEGGER — LOBITZER 1971). In addition the ecologic distribution of taxa assemblages is not yet studied in sufficient detail though some preliminary results are already available (BRANDNER-RESCH 1981, LOBITZER et al. 1988).

In Carnian time a conspicuous break in biotic distribution is evident. Most of the Permian/Mid-Triassic holdovers disappear and new highly diverse faunas bloom. Land floras show extreme generic diversity and pronounced provincialism (DOBRUSKINA in LOBITZER et al. 1988). The reason for this regressive Carnian event is still unclear (STANLEY 1988). And as pointed out by KRYSTYN et al. (this volume), the Tisovec Limestone at its classical locality cannot be longer considered as „missing link" between the reef developments of the Wetterstein and Dachstein Formations.

Depositional Models

Interpreted platform-to-basin depositional models of the Middle Triassic are generally similar throughout the study area (Figures 3 and 4). Platforms in Austria and Slovakia both evolved from incipient shallow-shelf and skeletal bank deposits of the subjacent Steinalm Limestone (Fig. 2). Likewise, the Middle Triassic everywhere in the study area accreted rapidly into thick, basinward progradational sequences (MELLO 1974; BRANDNER & RESCH 1981). The ubiquitous occurrence of coarse grossoolite-breccias in Austria (Figures 3A and B), and deposition of coarse, dolomitized reef-derived megabreccias in Czechoslovakia (Fig. 4A), suggest that platform-edges in these areas were, at least periodically, destructional. Insofar as the Tethyan region was structurally active during the Triassic (BRANDNER & RESCH 1981), it is likely that these destructional phases of platform development were related, at least in part, to periodic tectonism. Except for some areas on the platforms in Austria (sand-shoal and peritidal facies in the Hafelekar complex: BRANDNER & RESCH 1981) and Czechoslovakia (Plesivec Plateau), we have not found evidence of subaerial exposure of the Middle Triassic reefs in the study area. Upper Triassic reefs particularly those of the Norian-Rhaetian in Austria, however, contain abundant evidence for repeated episodes of subaerial exposure and meteoric diagenesis related presumably, to eustatic fluctuations (MAZZULLO, in prep.).

A major aspect of facies systems development in the Middle Triassic concerns the nature of the platform-to-basin depositional profile (i.e., READ 1985). In this regard, the depositional setting of the reefs is critical in interpreting platform profiles.

A depositional setting mainly in upper slope environments is considerd for the Late Permian Capitan reef (PRAY 1977, MAZZULLO & LOBITZER 1988). Of course, ecologic displacement in the Late Triassic of calcisponges by scleractinian corals, from shallow platform-marginal to reef-slope environments, must also be considered as an alternative interpretation for such biotic variations in Middle to Upper Triassic depositional systems. Notwithstanding this alternative explanation, there is some apparent sedimentological corroboration for an upper slope interpretation for Middle Triassic calcispongal reefs, as suggested by the distribution of facies in these rocks. This evidence is predicated on the following three assumptions: (1) that shallow, seaward facing shelf-margin environments are areas of maximum wave and current energy and therefore, (2) shelf-margin deposits should be dominated by carbonate sands or mud-poor reefs (although the latter is not necessarily a valid assumption for all reef buildups: FRIEDMAN 1985), and; (3) that syndepositional marine cementation in many modern and ancient platform-margin environments is most pervasive in upper fore-reef deposits and the seawardfacing margins of reefs (GINSBURG & JAMES 1973; GOREAU & LAND 1974; MAZZULLO & CYS 1977;

Stratigraphic scheme (Anisian to Lower Carnian) of Schneeberg nappe. Note lateral variability of platform to basin transition. For location of cross-sections A,B see textfigure of facies distribution.

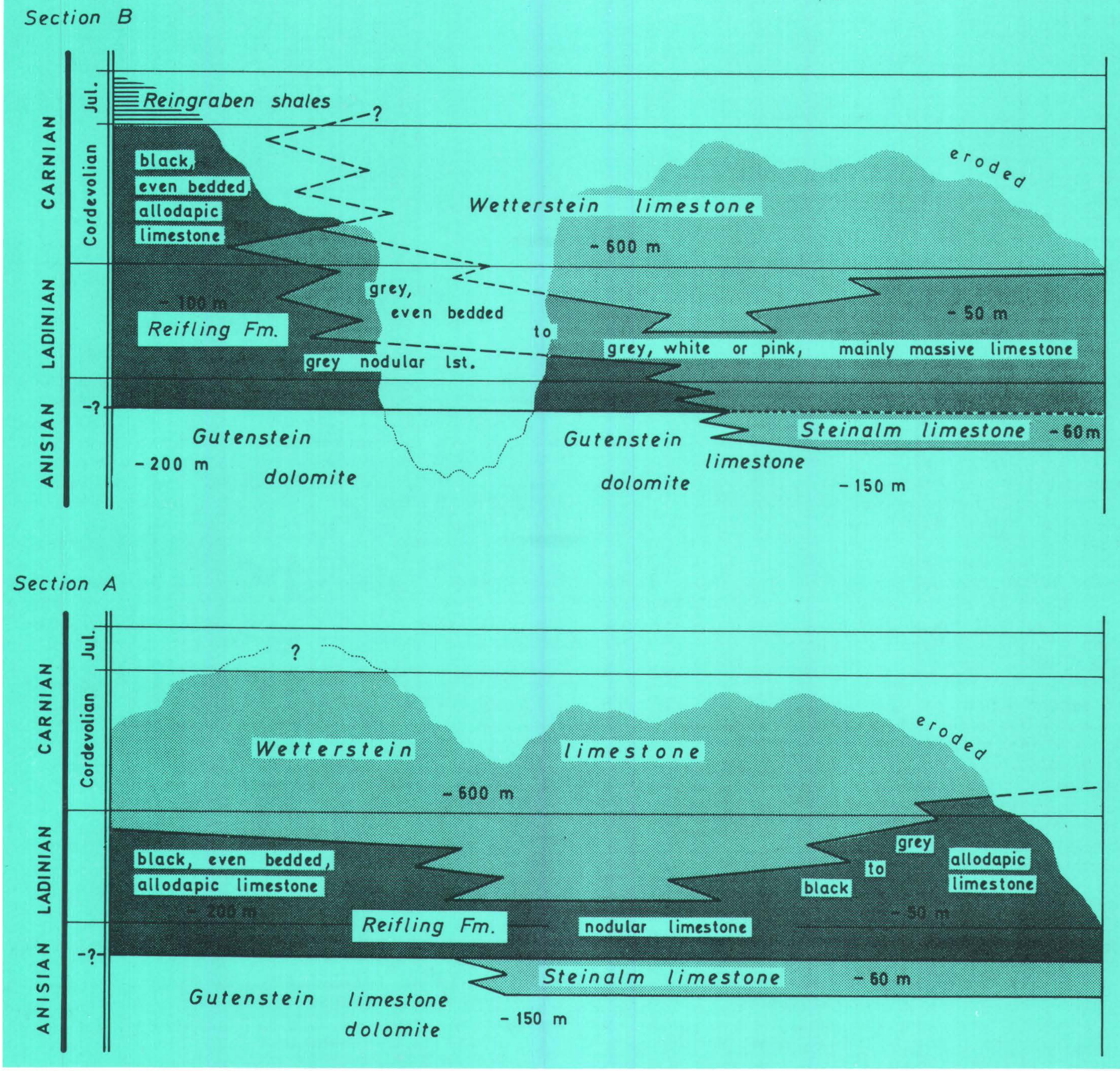


Fig. 4.

JAMES & GINSBURG 1979; PURSER & SCHROEDER 1986).

On the Schneeberg Plateau in Austria (Fig. 2), for example, in-situ calcisponge reef facies are poorly represented, occurring mostly as small lenses within middle and lower beds of the grossoolite-breccias. Pervasively cemented grossoolite-breccias not only comprise most of the upper slope facies of the present platform-margin, but they pass directly into outer-lagoonal, marine-cemented biograinstones without an intervening in-situ reef buildup. These grainstones contain conspicuous *Teutloporella,* and locally associated with only small, marine-cemented calcispongal patch-reefs. These facies pass further shelfward into micritic limestones with a typical quiet-water lagoonal biota. A similar belt of biograinstones occurs updip of the extensively marine-cemented Upper Permian Capitan sponge-algal reef (MAZZULLO & HEDRICK 1985); these grainstones are composed of typical outer-shelf rather than reef biotic assemblages. In the Hafelekar complex of the Nordkette Range in Tyrol the grossoolite-breccias similarly comprise much of the upper slope and shelf-margin facies. In-situ calcispongal reefs make up only a minor portion of this depositional environment, instead occurring most notably in distal-slope settings. The platformedge facies here pass updip into high-energy, reef-flat and skeletal sands composed of a mixed reefal and lagoonal biota (BRANDNER & RESCH 1981). Middle Triassic reefs in Czechoslovakia also appear to have been deposited in similar environments. In the Plesivec-Silica Karst Plateau area for example, micritic reef facies seemingly occur between basinal facies of the

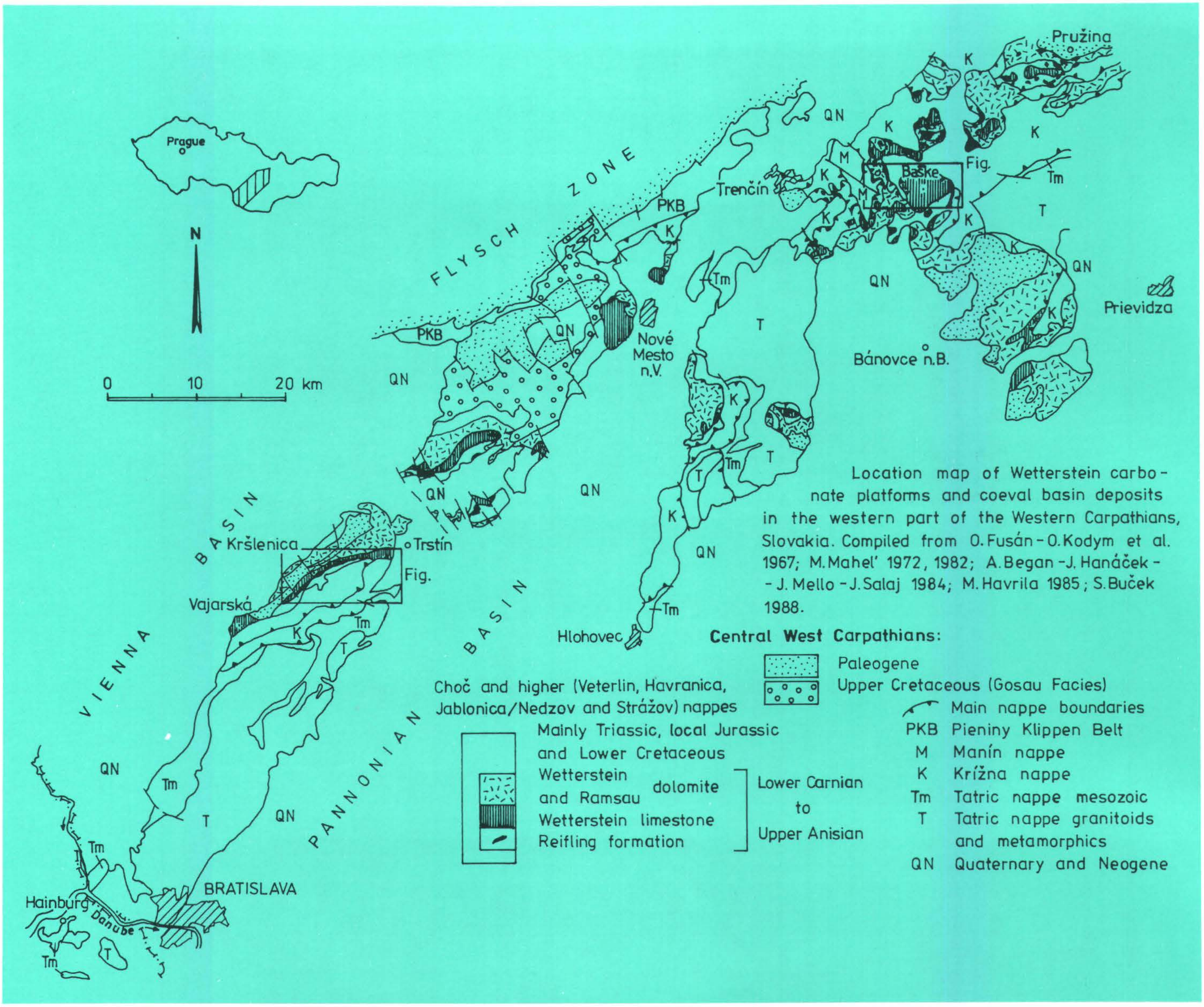


Fig. 5.

Reifling and an updip belt of biograinstones that define the zone of maximum depositional energy.

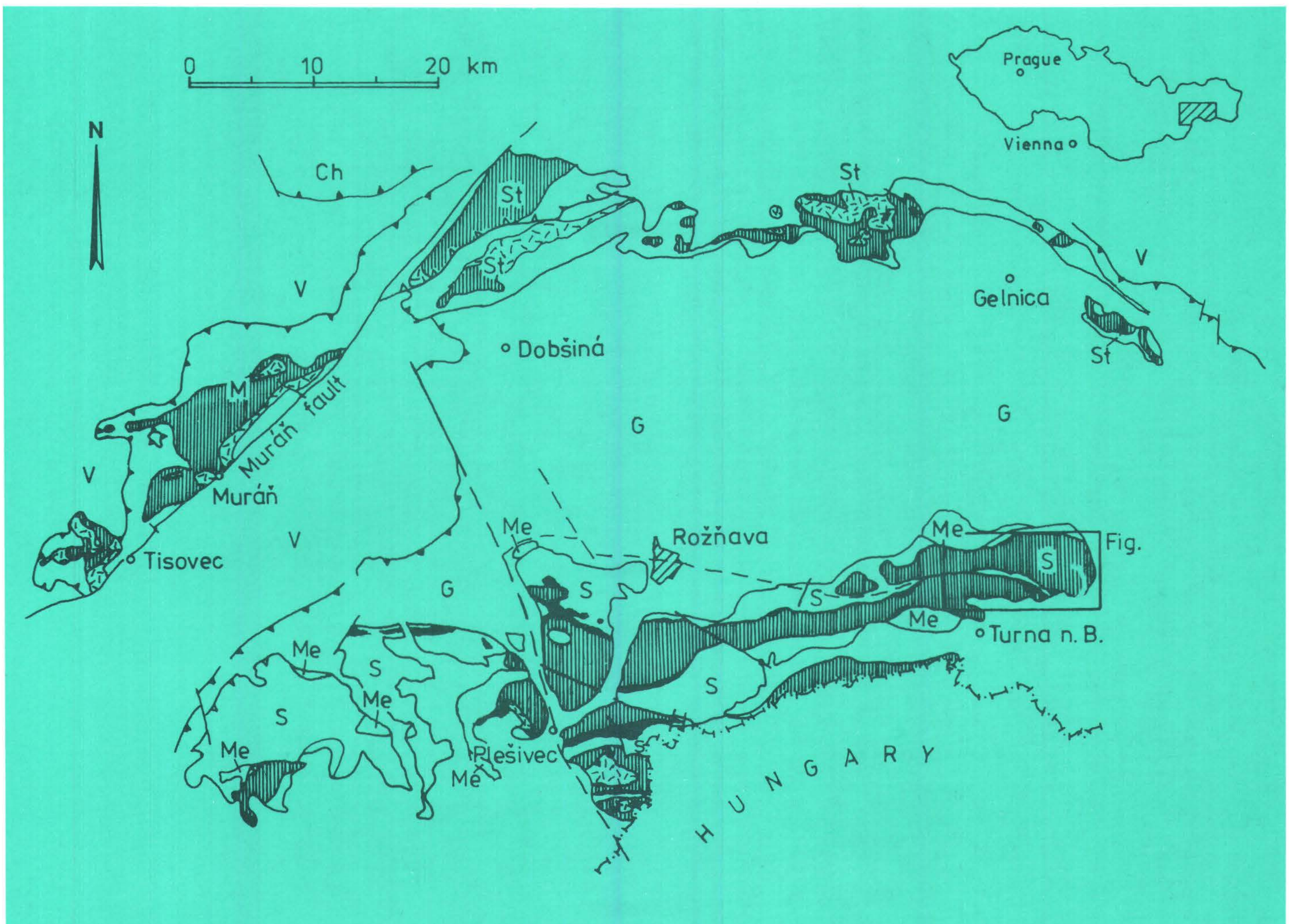
Diagenesis of Middle Triassic carbonates

The diagenetic history of Middle Triassic platform carbonates is similar throughout the study area, and is analogous in many respects to those of the Capitan reef complex and other Permian platform carbonates. Syndepositional marine cementation of platform deposits appears to have been a pervasive theme in both the Permian and Middle Triassic (MAZZULLO & CYS 1977, 1978; FLÜGEL 1981; SMITH 1981). Peritidal, lagoonal, and reef facies in the Wettersteinkalk all typically contain abundant marine cements represented principally by isopachous rims of radiaxial-fibrous calcite surrounding component allochems in the rocks (Plate 6, Figures 1—3). KENDALL & TUCKER (1973) originally interpreted radiaxial-fibrous crystalline fabrics as being replacive of aragonite, although current studies (KENDALL 1985) suggest that it may instead be a primary fabric of precursor marine high-magnesian calcite or possibly, calcite cements. The Capitan reef and some associated shelf grainstones also were pervasively marine-cemented, but apparently by aragonite in most cases rather than calcite (MAZZULLO & CYS 1977, 1978). A similar precursor mineralogy is considered for Permian reefs elsewhere (FLÜGEL 1981; SMITH 1981). The reasons for apparent changing marine cement mineralogies in the Permian and Triassic are unknown, although they may relate to differences in seawater chemistry through time. The Upper Triassic platform carbonates that we have examined in the study area contain little to no readily recognizable syndepositional marine cement fabrics (MAZZULLO & LOBITZER 1988; MAZZULLO in prep.). Because of the micritic texture of the rocks, we are unable to recognize with any certainty, marine cements in the distal-slope and basinal deposits of the Middle Triassic.

The coarse crystalline calcite cements in the grossoolite-breccia facies in Austria are similarly composed of radiaxial-fibrous calcite and locally, some replacive dolomite (Plate 6, Fig. 4). That these cements were not precipitated during actual subaerial exposure of the breccias is suggested by the lack of corroborative evidence in the rocks of such exposure. BRANDNER & RESCH (1981) and MCKENZIE & LISTER (1983) suggested that lithification of the grossoolite-breccias in Tyrol occurred in the early burial environment as a consequence of interaction with refluxing meteoric and hypersaline fluids. We don't entirely agree with a burial-diagenetic origin for these cements everywhere in the study area for the following reasons: (1) in the other Austrian grossoolite occurrences that we've examined, there is ample evidence of multiple episodes of cementation, brecciation and resedimentation (Plate 6, Fig. 4), some of which may suggest pre-burial lithification; (2) coarse crystalline, radiaxial-fibrous cements in reefal limestones associated with the breccias represent syndepositional lithification, and these cements are identical petrographically to those in the grossoolite-breccia deposits (Plate 6, Fig. 3); (3) grossoolitic cements are characteristically laminated and contain numerous internal discontinuities (Plate 6, Figure 4), indicating long-term cement precipitation. It is therefore possible that cementation of the grossoolite-breccia deposits was initiated syndepositionally, and that it continued into the shallow-burial environment; accordingly, the nature of the precipitating fluids would likely have changed during the course of cementation. MAZZULLO and his colleagues are presently studying the petrography and geochemistry of these cement fabrics in order to identify their precursor mineralogy, timing and sites of lithification, and geochemistry of involved waters.

In the Wetterstein rocks examined, neither we nor BRANDNER & RESCH (1981) have found any evidence of

Fig. 6.



Location map of Wetterstein carbonate platforms and coeval basin deposits in the inner part of the West Carpathians, eastern Slovakia.
Compiled from O. Fusán - O. Kodym et al. 1967; J. Bystrický 1964, 1982, 1986; Ľ. Gaál 1982; M. Mahel' 1957; J. Mello 1988; Š. Bajaník et al. 1984.

Central and Inner West Carpathians:

Silica (S), Muráň (M) and Stratená (St) nappe
Mainly Triassic, local Jurassic
Wetterstein dolomite
Wetterstein limestone
Reifling, Schreyeralm and Nádaska formation — Lower Carnian to Upper Anisian

Main nappe boundaries
Partial nappe boundaries
G Gemeric unit
Me Meliata unit
V Veporic unit
Ch Choč nappe

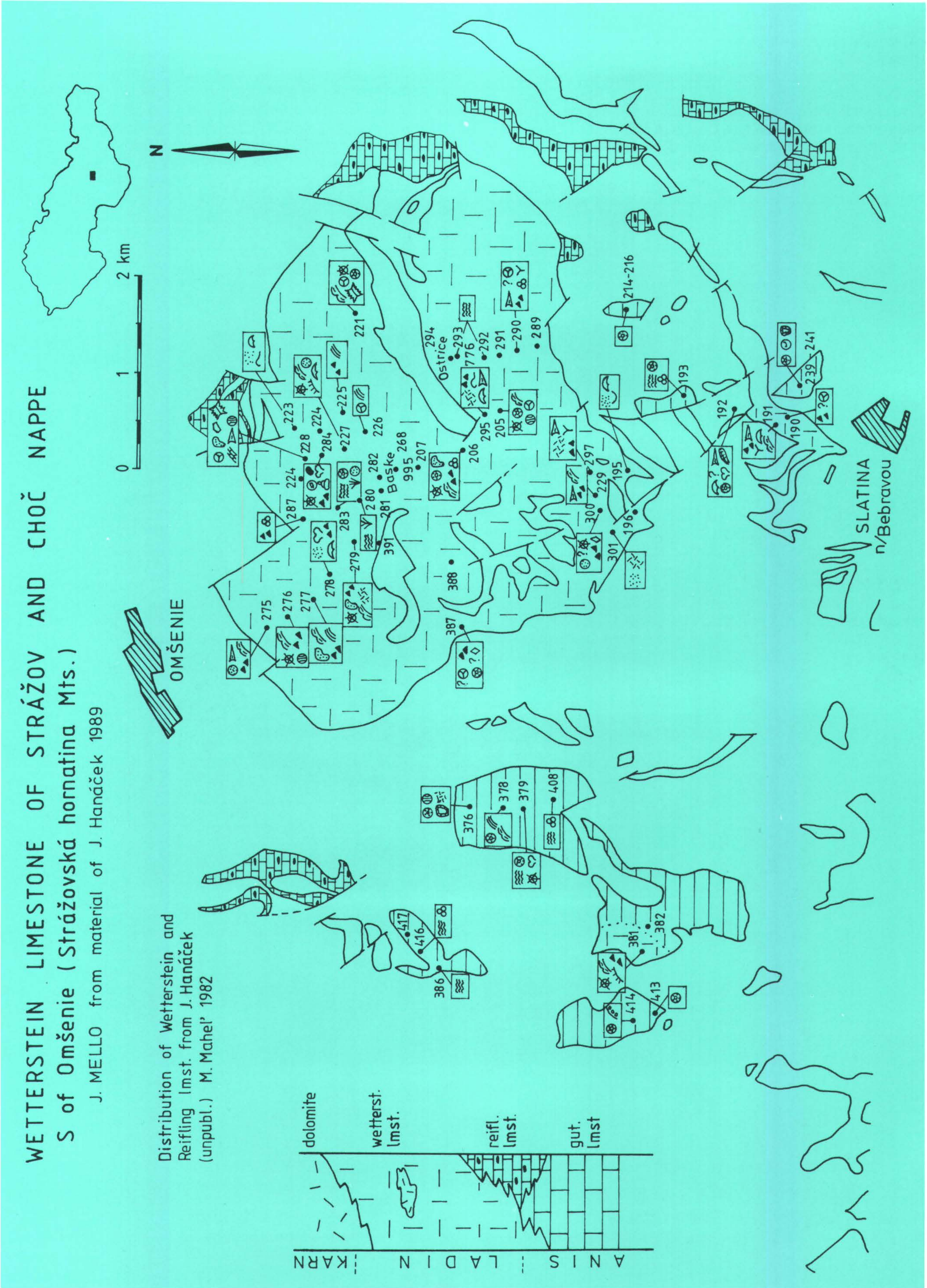
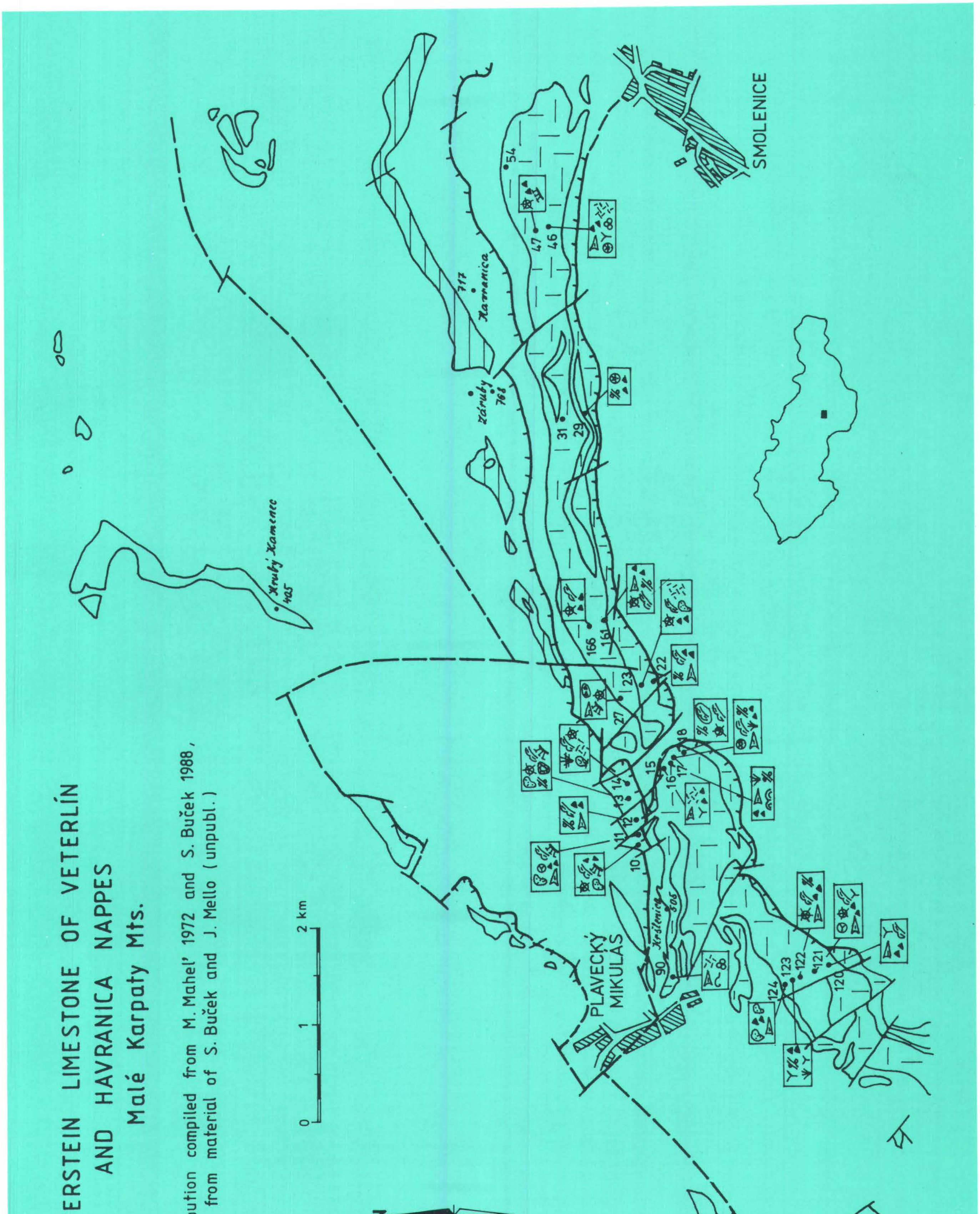

WETTERSTEIN LIMESTONE OF STRÁŽOV AND CHOČ NAPPE
S of Omšenie (Strážovská hornatina Mts.)
J. MELLO from material of J. Hanáček 1989
Distribution of Wetterstein and Reifling lmst. from J. Hanáček (unpubl.) M. Mahel' 1982
N
0 1 2 km
OMŠENIE
Ostrice
Baske
SLATINA n/Bebravou
dolomite
wetterst. lmst.
reifl. lmst.
gut. lmst
KARN
LADIN
ANIS

Fig. 7.

Fig. 8.


WETTERSTEIN LIMESTONE OF VETERLÍN
AND HAVRANICA NAPPES
Malé Karpaty Mts.
Distribution compiled from M. Mahel' 1972 and S. Buček 1988,
facies from material of S. Buček and J. Mello (unpubl.)
0
1
2 km
N
SMOLENICE
PLAVECKÝ MIKULÁŠ

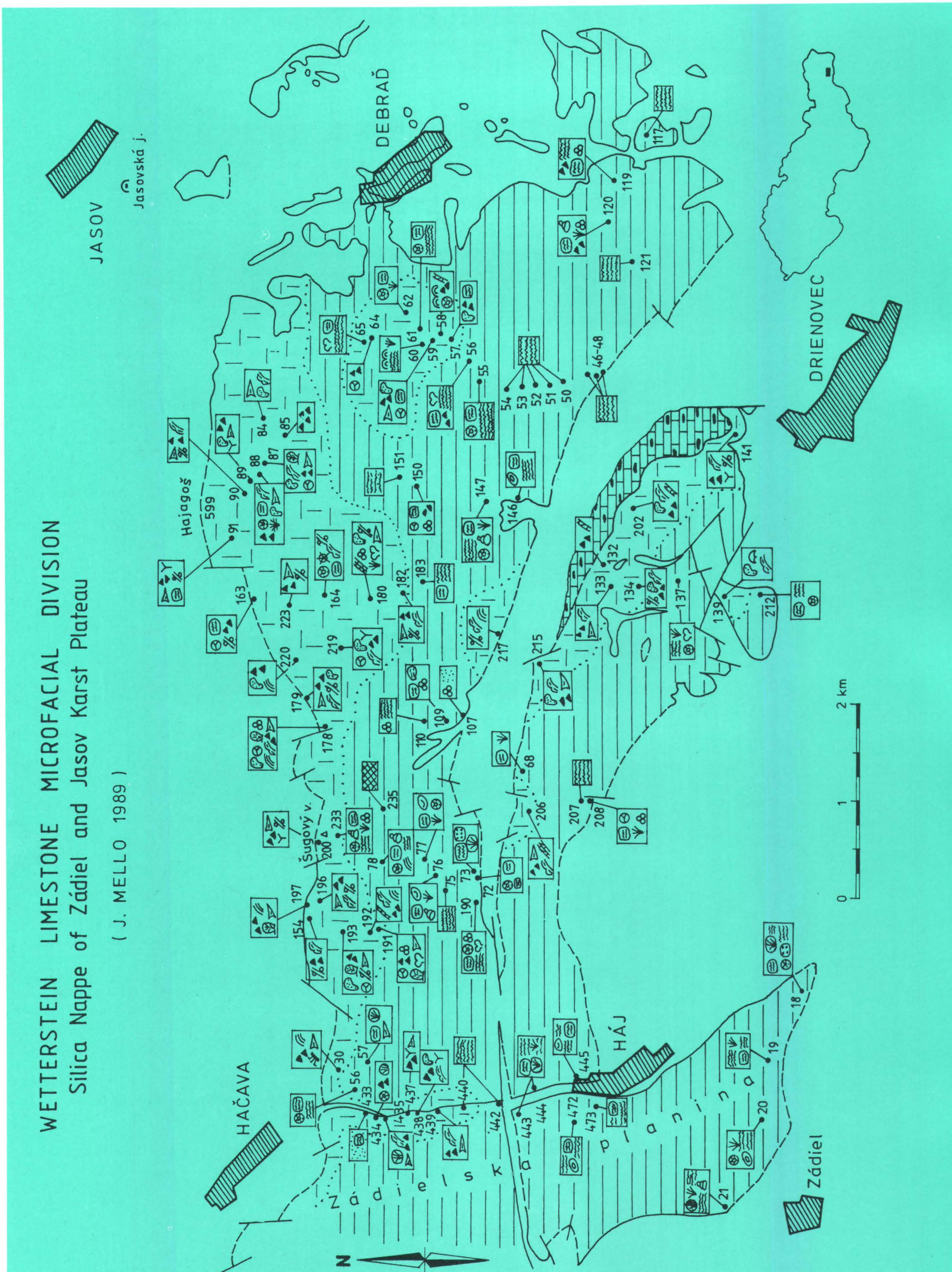

WETTERSTEIN LIMESTONE MICROFACIAL DIVISION
Silica Nappe of Zádiel and Jasov Karst Plateau
(J. MELLO 1989)
JASOV
Jasovská j.
DEBRAĎ
DRIENOVEC
HAČAVA
Hajagoš
Šugový v.
HÁJ
Zádiel
Z á d i e l s k á p l a n i n a
0 1 2 km

Fig. 9.

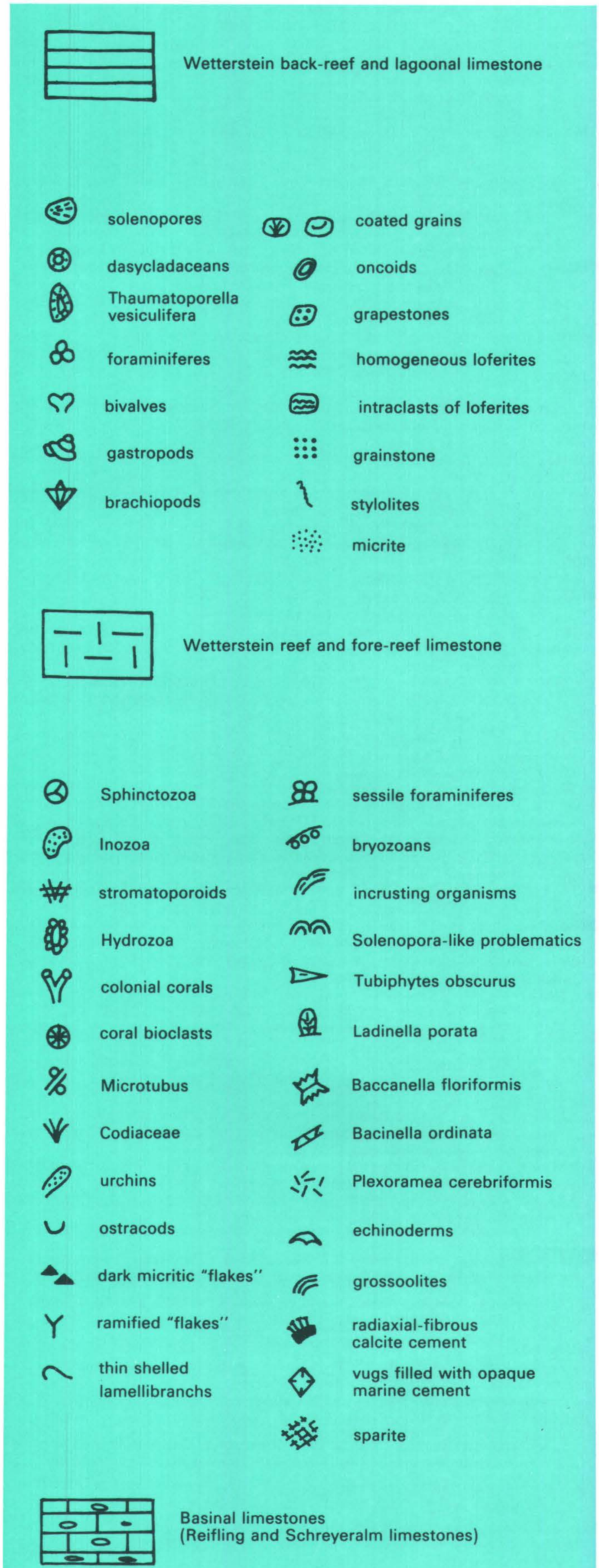


Fig. 10.

subaerial meteoric diagenesis of reef facies, except for scattered zones with red internal sediment on the Plesivec Plateau of Slovakia. BRANDNER & RESCH (1981) did, however, recognize subaerial diagenetic textures and fabrics in lagoonal facies of the Hafelekar reef complex in Tyrol, and similar evidence of exposure is known to us in Wetterstein peritidal facies at several localities in the study area. The apparent lack of subaerial exposure of these Wetterstein reefs throughout most of Austria and Czechoslovakia compares with that of the Upper Permian Capitan reef, but contrasts with the Tethyan Upper Triassic reef and platform sections we've examined (i.e., the Norian-Rhaetian Steinplatte reef complex near Salzburg: MAZZULLO in prep.), which contain abundant solution molds filled with red internal sediments and cements.

The possible relationships between sealevel changes and diagenesis in Triassic rocks are presently important unresolved topics in Tethyan sedimentology, and warrant further study.

Particularities of Wetterstein reefs in comparison with Late Permian and Late Triassic ones

Summarizing it simply can be stated, that biota-wise the Wetterstein Formation still shows an extremely intensive connection with the Late Permian Capitan Formation (LOBITZER 1971, FLÜGEL 1981, MAZZULLO & LOBITZER 1988, STANLEY 1988). This statement is also particularly true for the diagenetic aspects. The shelf profile, however, seems to have changed from prevailing upper slope reefs in the Late Permian to predominatly shelf margin location of reefs in the Middle Triassic. This development marks the transition to the „modern" reef-rimmed platforms of the Tethyan Dachstein Limestone in the Norian/„Rhaetian".

Compared to the biota of the Capitan Formation the diversity after the Early Triassic break in reef growth in the early stages of Wetterstein reef development was very low. However all important groups survived as „Lazarus" (STANLEY 1988) and constructed buildups in the Middle Triassic very much similar to the Permian ones. Archaeolithoporella, however, up to present has not yet been identified in European Middle Triassic reefs. In the Middle Triassic reefs and in part in the associated grossoolites we do recognize abundant syndepositional marine cement, in particular radiaxial fibrous calcite (see, however, critical evaluation in the chapter on „grossoolite facies").

Following the strongly clastic influenced Carnian extinction-event and reorganization the „modern" types of reef-rimmed platforms with tremendous framework of scleractinian corals evolved (Hoher Göll: ZANKL 1969; Steinplatte: OHLEN 1959, LOBITZER 1980, PILLER 1981, a.o.). Also we feel difficulties in following the ideas expressed by STANTON & FLÜGEL 1981, in particular that a biogenic framework should be absent even in the Latest Triassic reefs and other statements by these authors which were already discussed by STANLEY (1988).

Also on the platforms the change between the Wetterstein and Dachstein Formations is most remarkable as evidenced by the Lofer cyclothems (FISCHER 1964) and the dominant role of the megalodonts. In general, marine cements are present in much lesser amounts than in the Middle Triassic and unconformities are very abundant (e.g. Steinplatte). In the Wetterstein Limestone the near reef lagoon with its peritidal sediments indicates sedimentation repeatedly interrupted by sea level low stands of short duration.

CONCLUSIONS

Tethyan Middle Triassic carbonates in Austria and Czechoslovakia comprise a complex mosaic of peritidal, lagoonal, reef and reef-derived breccia (Wettersteinkalk), and distal slope to basinal facies. Interior platform deposits consist of loferitic dolomites (peritidal facies) and biopackstones to grainstones with local patch-reefs (lagoonal facies), all of which were extensively lithified in the marine environment. Proximal portions of some of these plattforms were periodically subaerially exposed and altered in the meteoric diagenetic environment. Platform-edges were constructed by marine-cemented calcispongal reefs that were deposited in shallow shelf-margin environments. The reefs of the Middle Triassic thus define rimmed platforms and locally, subdued rimmed platforms. The biotic composition, setting, and abundance of syndepositional marine cements are strikingly similar in Permian and Middle Triassic reefs, although there was a change in the mineralogy of the marine cements from aragonite to calcite. A major biotic change in Late Triassic time heralded the dominance of framebuilding coral reefs in shelf-margin environments.

This biotic change followed the development of rimmed platforms as a prominent depositional motive that persists into the Recent. Reef-derived breccias were deposited in shelf-margin and slope settings seaward of many of the Wetterstein reefs, and originated during destructional phases of platform-edge evolution probably related to Middle Triassic tectonism and inherent slope instability. These deposits were rapidly cemented, perhaps in the syndepositional marine and shallow burial environments, by coarse crystalline, radiaxial-fibrous cements.

Acknowledgements

This comparative study would not have been possible without the financial and logistic background of the Austrian-Czechoslovak geoscientific exchange programme. LOBITZER, MANDL and MELLO wish to express their gratitude to the directors of Geologische Bundesanstalt in Vienna and of Geologicky Ustav Dionyz Stur in Bratislava for supporting mutual field trips. The authors acknowledge the assistance of Dr. Inna A. DOBRUSKINA, Geological Institute of the U.S.S.R. Academy of Sciences, Moscow, and Dr. Olga PIROS, Hungarian Geological Institute, Budapest, for their contributions to the field study of various Triassic sections in Austria. Mrs. PIROS alco contributed to the determinations of dasycladaceans of the Austrian material. Appreciation is extended to Dr. Josef MICHALIK, Slovak Academy of Sciences, Bratislava, for guidance to the Small Carpathians. We also want to extend our thanks to Dr. Rainer BRANDNER, University Innsbruck, for introducing us to the geology of the classical Wettersteinkalk exposures at Hafelekar, Tyrol. Financial and logistic support to MAZZULLO for field work in Austria for the summers of 1986 and 1987 was provided by the Geologische Bundesanstalt, Vienna. Support for his field studies in Slovakia during the summer of 1988 was provided by IGCP Project 198. MAZZULLO particularly wishes to thank the LOBITZER family for their kind hospitality during his stay in Vienna.

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▶

Fig. 1: Near-reef lagoonal Wetterstein Limestone in birdseye-facies with solenoporaceans. Between Friedrich Haller Haus and Feichterberg.

Fig. 2: Lagoonal Wetterstein Limestone with abundant solenoporaceans. South of Haslitz-Adriganbauer.

Fig. 3: Wetterstein Limestone in reef-facies with sphinctozoan sponges, "tubes in the reef-debris" sensu OTT.
Strong biogenic encrustation. Schacherberg.

Fig. 4: Wetterstein Limestone in reef-facies with abundant *Tubiphytes obscurus*. Asandberg, top-plateau.

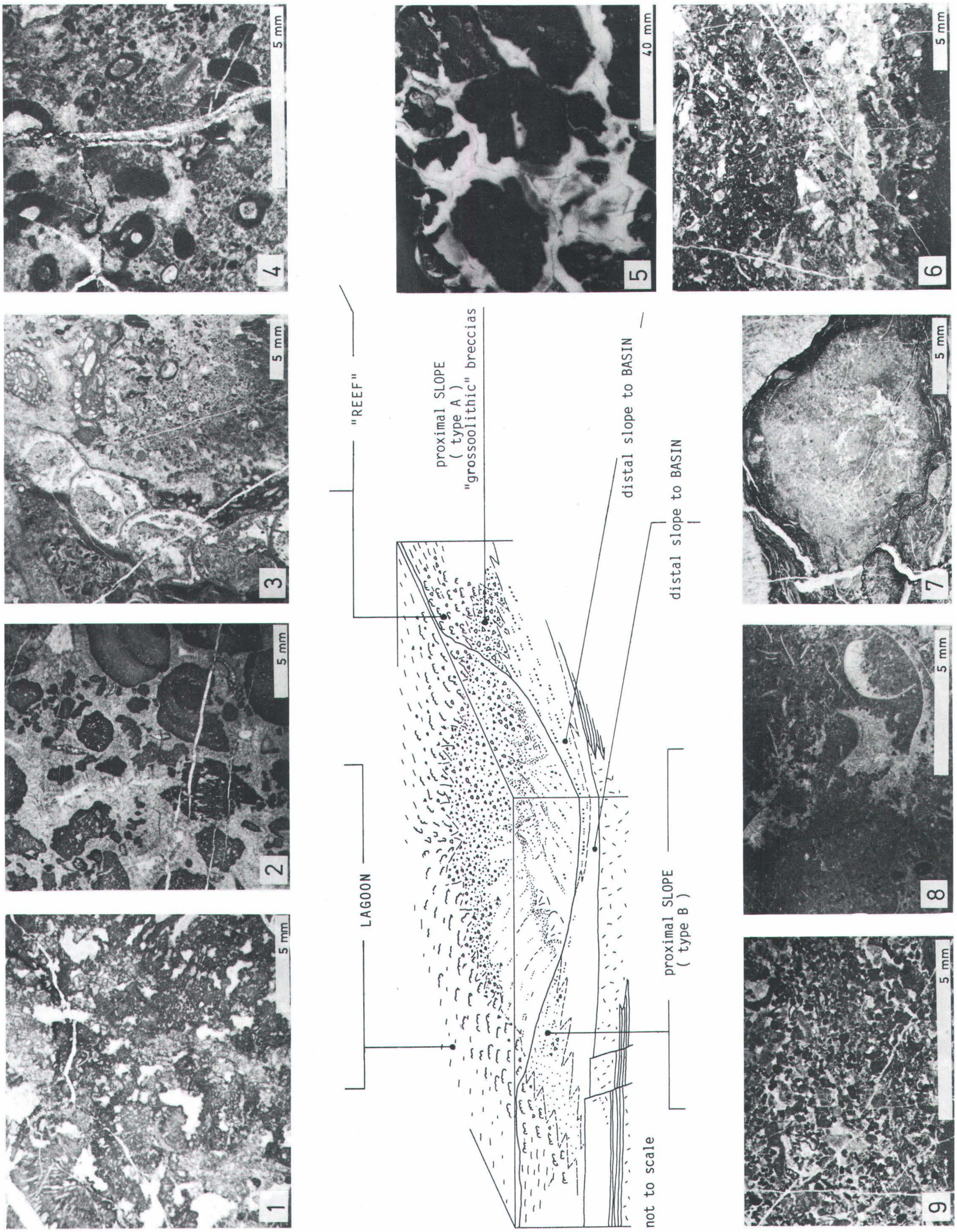
Fig. 5: Grossoolite-facies of Wetterstein Limestone. Clasts (dark) composed of marine-cemented calcispongal reef lithology. Schneeberg plateau.

Fig. 6: Grafensteig Limestone: graded allodapic intercalations of platform-derived debris within black micritic basinal limestone. Himberg.

Fig. 7: Reifling Limestone. Light grey nodular limestone of pelmicritic composition, abundant "filaments" between but also within the nodules. Sierningtal.

Fig. 8: Variegated limestone, mainly fine-grained pelmicritic limestone with filaments and sparse platform debris (*Tubiphytes*). Himberg.

Fig. 9: Variegated limestone, arenitic layer of platform debris. Himberg.



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5 mm
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LAGOON
"REEF"
proximal SLOPE
(type A)
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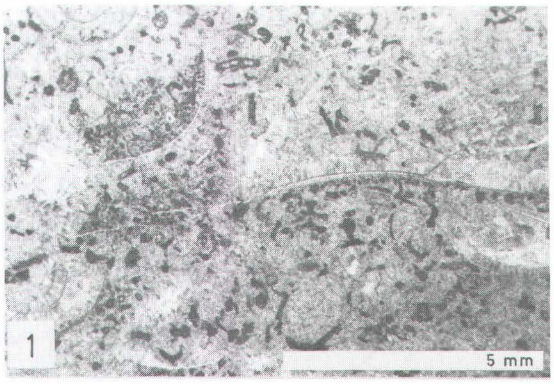
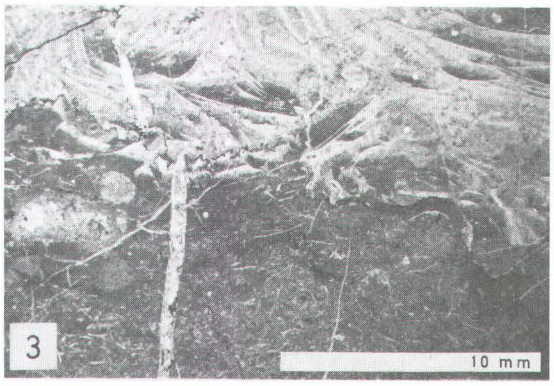
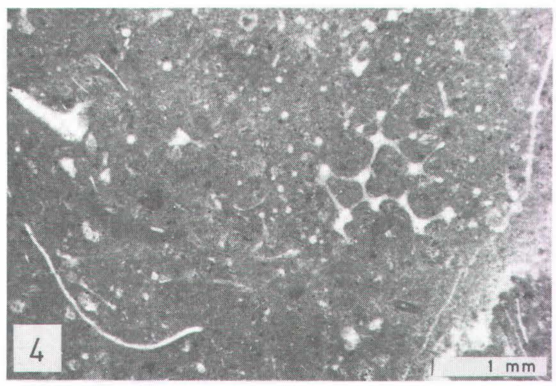
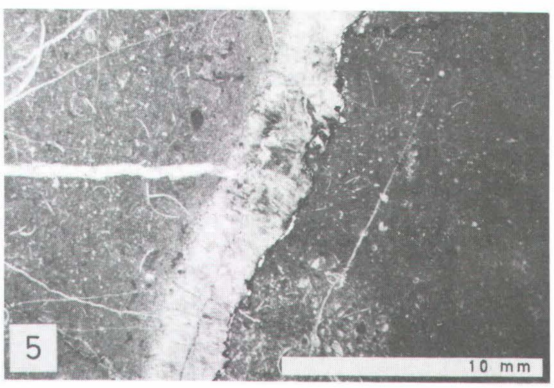
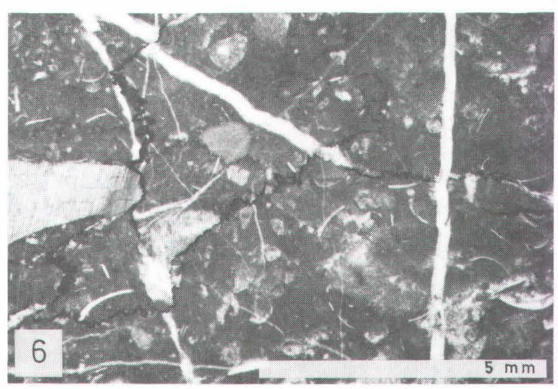
distal slope to BASIN
proximal SLOPE
(type B)
not to scale











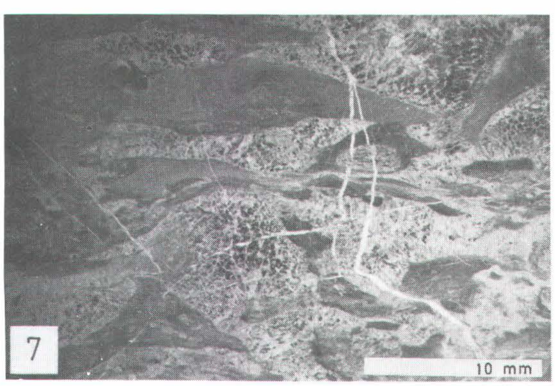


Fig. 1: Variegated limestone of slope facies in part with reef-derived debris ("tubes in reef debris" sensu OTT) and "filaments" (probably delicate pelecypod shells). Sierningtal.

Fig. 2: Grafensteigkalk of distal slope environment; allodapic layer of reef-derived debris and brachiopods within black micritic limestone. Himberg, northern terrain.

Fig. 3: Grey micritic limestone of Hallstatt-type with abundant "filaments" and pelecypod-coquina. Rax Plateau, Heukuppe.

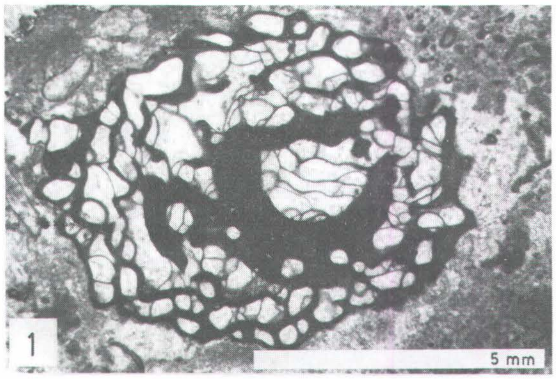
Fig. 4: Pinkish micritic limestone of Hallstatt-type (intercalation within reef facies) with "filaments", skeletal elements of siliceous sponges and pelecypod shells. Rax Plateau, Heukuppe.

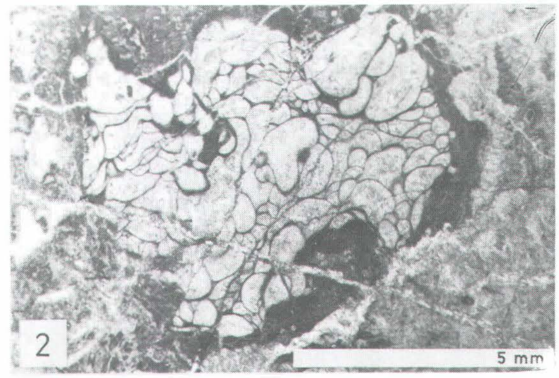
Fig. 5: Pinkish micritic limestone of Hallstatt-type intercalation within reef facies with "filaments" and larger pelecypod shells; conspicuous zebra-fissure. Rax Plateau, Heukuppe.

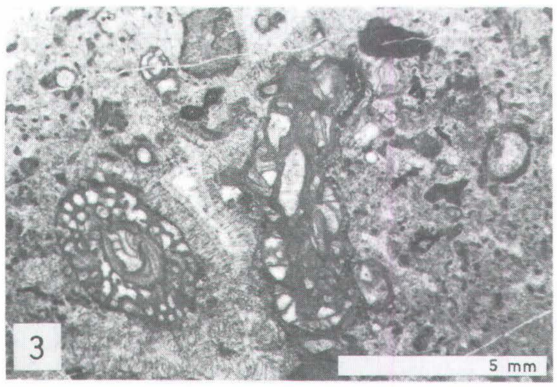
Fig. 6: Pinkish micritic limestone of Hallstatt-type as intercalation in basal Wetterstein Limestone reef. "Filaments" and debris of echinoderms; stylolites. Upper trail from Karl Ludwig Haus in direction to Preiner Gscheid.

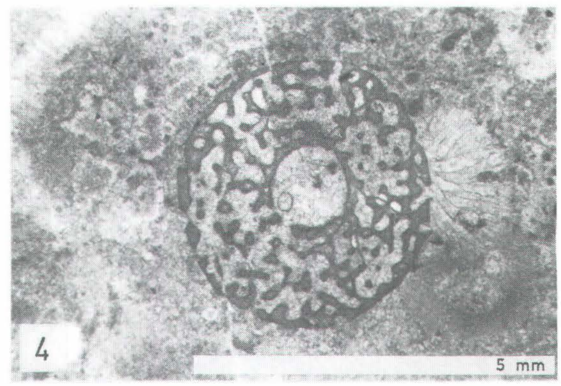
Fig. 7: "Schlierenkalk", flasered, recrystallized; the biota is preserved as "ghost-structures" only. Probably former, strongly altered Wetterstein Limestone of reef facies. As informal working name we use "Gösing Limestone" for this type of sediment. Mt. Gösing.

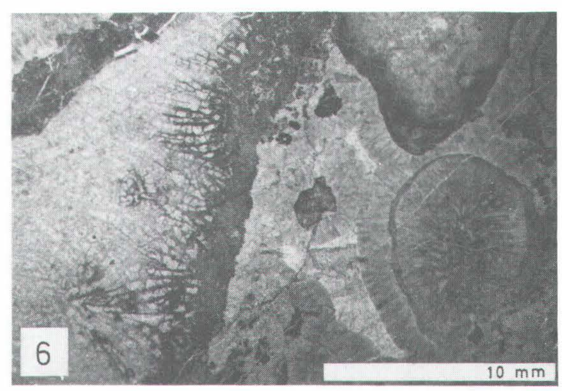
Fig. 8: Wetterstein Limestone in reef facies. Pervasively cemented boundstone with sphinctozoan sponges encrusting shell debris. Trail from Haller Haus to Promiskagraben.

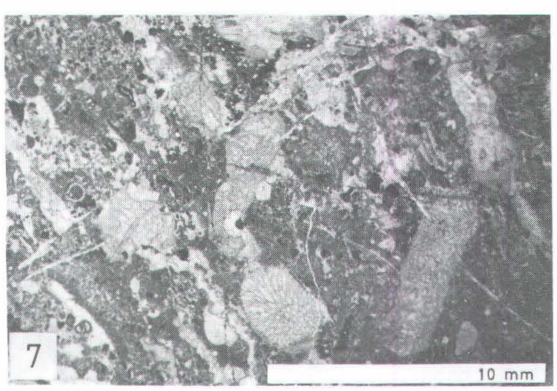












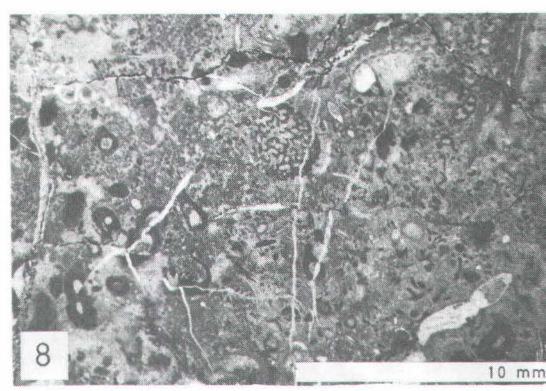


Fig. 1: Wetterstein Limestone in reef-facies with sphinctozoan sponge. Schacherberg summit.

Fig. 2: Wetterstein Limestone in reef-facies with sphinctozoan sponge. Southern Gahns area.

Fig. 3: Wetterstein Limestone in reef-facies with sphinctozoan sponges, "tubes in the reef debris" sensu OTT, and *Tubiphytes obscurus*. Schacherberg.

Fig. 4: Wetterstein Limestone in reef-facies with cross section of calareous sponge and *Baccanella floriformis*. Second generation biogenic growth on sponge. Wiege.

Fig. 5: Coral patch-reef in lagoonal Wetterstein Limestone. Besides branches of corals and sphinctozoan sponges, clams of brachiopods which seem to be the most important dwellers in lagoonal patch-reefs. Trail from Preiner Wand to Neue See-Hütte/Rax-Plateau.

Fig. 6: Coral buildup in lagoonal Wetterstein Limestone. West Preinerwand, Rax-Plateau.

Fig. 7: Wetterstein Limestone with abundant reef debris, comprising also bryzoans. Wassersteig, Krummbachstein.

Fig. 8: Wetterstein Limestone in reef-facies with *Tubiphytes obscurus*, debris of calcisponges, brachiopods and "tubes in the reef-debris" sensu OTT. Asandberg.

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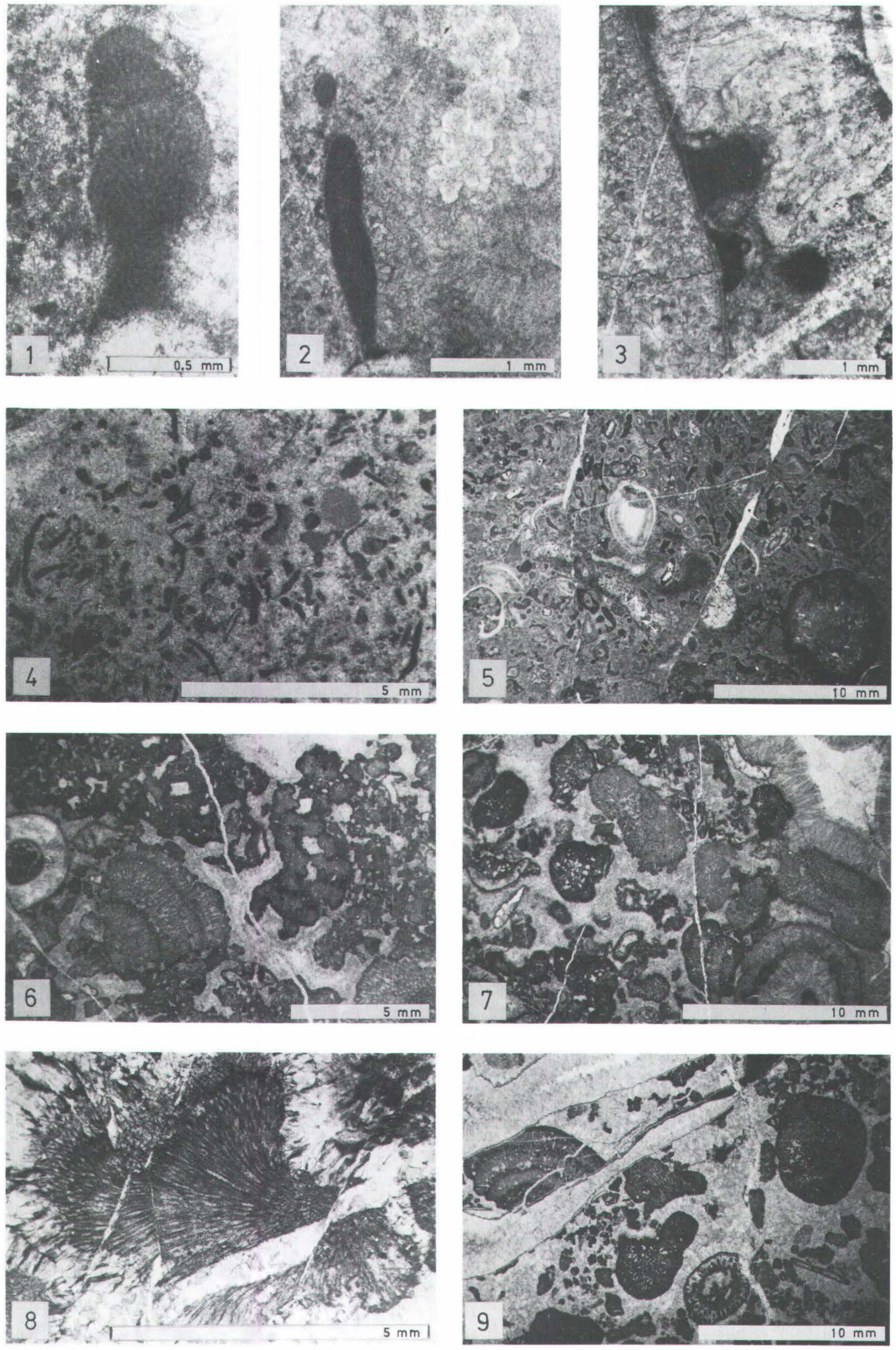

Fig. 1: Wetterstein Limestone in reef-facies with superb Ladinella porata. Wiege.

Fig. 2: Wetterstein Limestone in reef-facies with elongate growth-form of *Ladinella porata* and *Baccanella floriformis*. Wiege.

Fig. 3: Wetterstein Limestone in reef-facies with *Ladinella porata*. Trail from Hallerhaus to Promiskagraben.

Fig. 4: Wetterstein Limestone in reef-facies with abundant "tubes in the reef-debris" sensu OTT and peloids. Waxriegel/Hochschneeberg.

Fig. 5: Wetterstein Limestone in reef-facies with debris of calcareous sponges, corals and brachiopods, "tubes in the reef-debris" and gastropod hash. Predigtstuhl/Rax-Plateau.

Fig. 6: Lagoonal Wetterstein Limestone in birdseye-facies with solenoporaceans. Saubersdorfer Wald, north "Kehr".

Fig. 7: Lagoonal Wetterstein Limestone. Grainstone with *Teutloporella herculea*, solenoporacean and codiacean algae. North of Scheibwaldhöhe/Rax.

Fig. 8: Lagoonal Wetterstein Limestone. Solenoporacean alga surrounded by pervasive generations of fibrous cement. Creek west Johannesbachklamm.

Fig. 9: Lagoonal Wetterstein Limestone. Grainstone with solenoporaceans and dasycladaceans. Trail from Otto Haus to Wachthüttelkamm, Rax-Plateau.

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Abstrakt

Pri faciálnom porovnávaní východoalpských a západokarpatských wettersteinských karbonátových platforiem a priľahlých pánvových oblastí sa podľa očakávania ukazuje množstvo spoločných znakov.

Wettersteinské karbonátové platformy majú prevažne progradačný (regresívny) charakter. Ich vývoj začal od vrchného anisu postupným narastaním do pánvových oblastí (reiflinské a schreyeralmské vápence). Vývoj viedol cez svahové (grafensteigské, raminské a iné vápence) a predrífové brekcie k „rífovej" fáze wettersteinských vápencov. Tieto sú prekryté lagunárnou fáciou wettersteinských vápencov, často dolomitizovaných.

Rífový vývoj wettersteinských vápencov má z biologického hľadiska ešte mnoho spoločných znakov s vrchnopermskými rífmi (napr. s guadalupskou formáciou) s prevládaním bindstones a bafflestones. Na rozdiel od prevažne vo vrchnej časti svahu situovaných vrchnopermských rífov sú však hubovo-tubifytové nárasty wettersteinských vápencov situované prevažne na okraj karbonátovej platformy (tým vykazujú značnú analógiu s pozdejším vývojom dachteinského vápenca v noriku a v „réte"). Poukazuje na to často pozorované prstovité prelínanie rífov s peritidálnymi lagunárnymi sedimentami, napr. so stromatolitmi. Na druhej strane tiež často pozorovaná synsedimentárna cementácia morským radiaxiálnym fibróznym kalcitom (včítane cementácie s veľkými oolitmi) poukazuje ešte na úzku afinitu k permskému charakteru rífov.

Wettersteinským rífom teda prislúcha dôležitá „sprostredkovateľská" úloha medzi paleozoickými typmi rífov a modernejšími rífmi na okrajoch šelfov s dominujúcou stavbou typu framestone.

Zusammenfassung

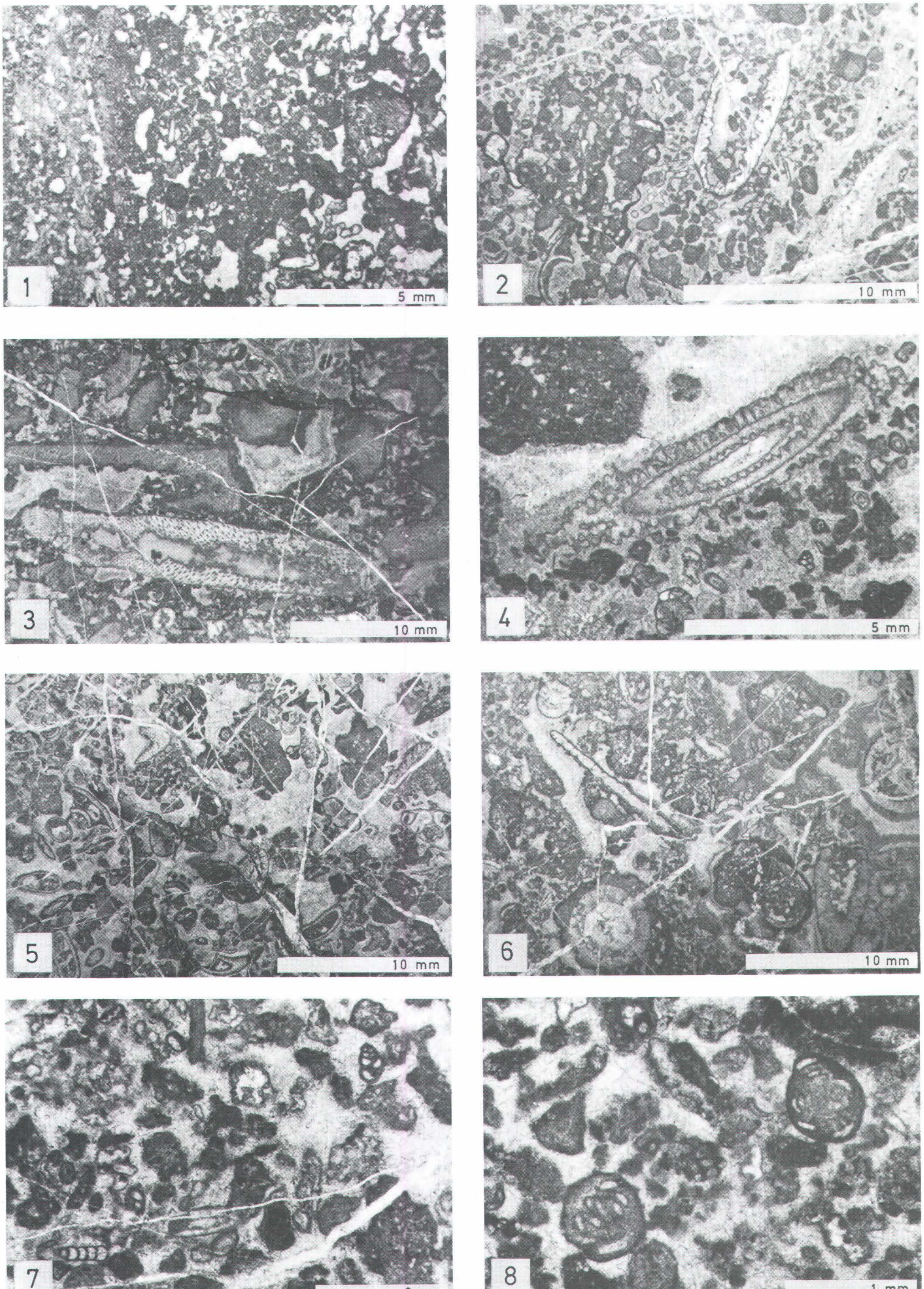
Ein Faziesvergleich zwischen den ostalpinen und westkarpatischen Wettersteinkalk-Karbonatplattformen zeigt erwartungsgemäß größte Übereinstimmung. Die progradierende regressive Wetterstein-Karbonatplattformentwicklung setzte im Oberanis über eine Beckenentwicklung ein und führte über Slope-Sedimente (Grafensteigkalk, Raminger Kalk u.a.) zu einer „Riff"-Phase, die wiederum von einer lagunären Entwicklung abgelöst wird mit häufig auftretender Dolomitisierung.

Die „Riff"-Entwicklung des Wettersteinkalks ist in biologischer Hinsicht noch stark an das Oberperm (z.B. Guadalupe-Formation) angelehnt, mit einer Dominanz von Bindstones und Bafflestones. In Gegensatz zu den überwiegend am oberen Slope situierten Oberperm-Riffen sind die Spongien/Tubiphyten-Bauten des Wettersteinkalks als deutlicher Anklang an die folgende Dachsteinkalk-Entwicklung im Nor/„Rhät" zu verstehen und überwiegend am Plattformrand gelegen. Dafür spricht die oftmals beobachtete Verzahnung der Riffe mit peritidalen lagunären Sedimenten, etwa mit Birdseye-Kalken. Sehr häufig zu beobachtende synsedimentäre marine radiaxial fibröse Kalzit-Zementation (inkl. der Großoolith-Zementation) weist noch auf enge Bindung an den permischen Riffcharakter hin.

Den Wettersteinkalk-Riffen kommt also eine wichtige „Vermittlerrolle" zwischen dem paläozoischen Rifftyp und den modernen Framestone-dominierten Schelfrandriffen zu.

▶

Fig. 1: Lagoonal Wetterstein Limestone; biointrapelsparite, birdseye-facies. Trail from Otto Haus to Wachthüttelkamm/Rax-Plateau.
Fig. 2: Lagoonal Wetterstein Limestone. Grainstone (peloidal, grapestone-lumps) with fragments of dasycladaceans (*Teutloporella herculea*), solenoporaceans, molluscs and abundant biogenic incrustations. Northwestern slope of Dürrenberg.
Fig. 3: Lagoonal Wetterstein Limestone with *Teutloporella herculea* and partly micritized grains. Dürrenberg.
Fig. 4: Lagoonal Wetterstein Limestone with dasycladaceans (*Poikiloporella duplicata*), solenoporaceans and codiaceans, foraminifera. North of Feichterberg.
Fig. 5: Lagoonal Wetterstein Limestone. Grainstone with *Aciculella*, fragments of dasycladaceans and gastropods. Most grains are micritized. Entrance of Kesselgraben, northern slope of Rax.
Fig. 6: Lagoonal Wetterstein Limestone. Grainstone with dasycladaceans (*Teutloporella herculea* and *Poikiloporella duplicata*). 400 meters west of Raxgmoa Hütte.
Fig. 7: Lagoonal Wetterstein Limestone. Grainstone with foraminifera (nodosariids and textulariids) and debris of solenoporaceans and gastropods. Peloids and intraclasts in part micritized. Trail from Haller Haus to Kaiserbrunn, approximately 1 120 meters above sea level.
Fig. 8: Lagoonal Wetterstein Limestone. Biointrapelsparitic grainstone with involutinid foraminifera (Permodiscids) and often micritized clasts of solenoporaceans. Location as Fig. 7: 1 160 meters above sea level. Diagenetic fabrics in Middle Triassic limestones.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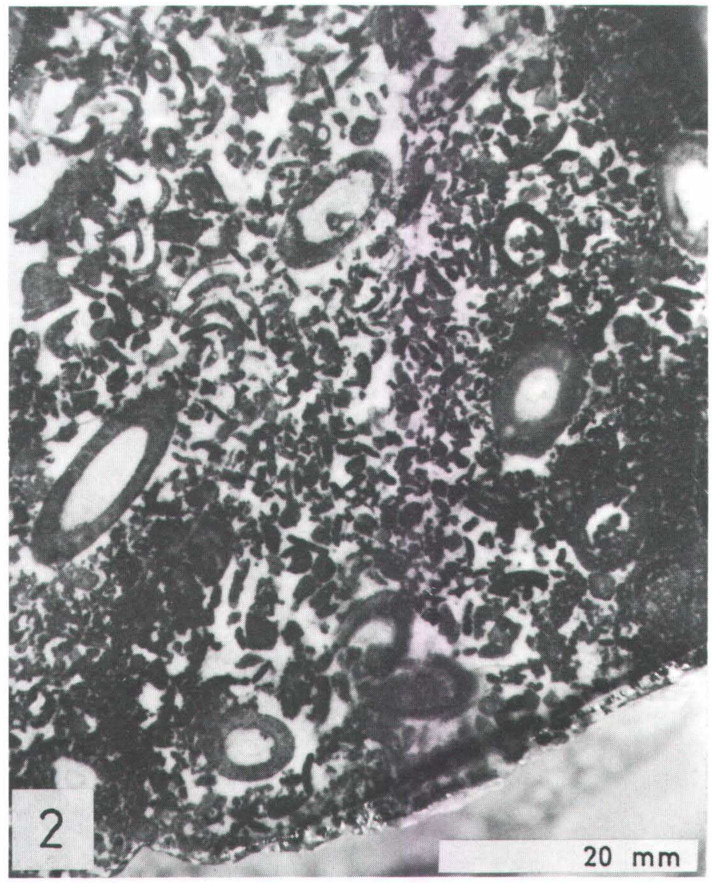

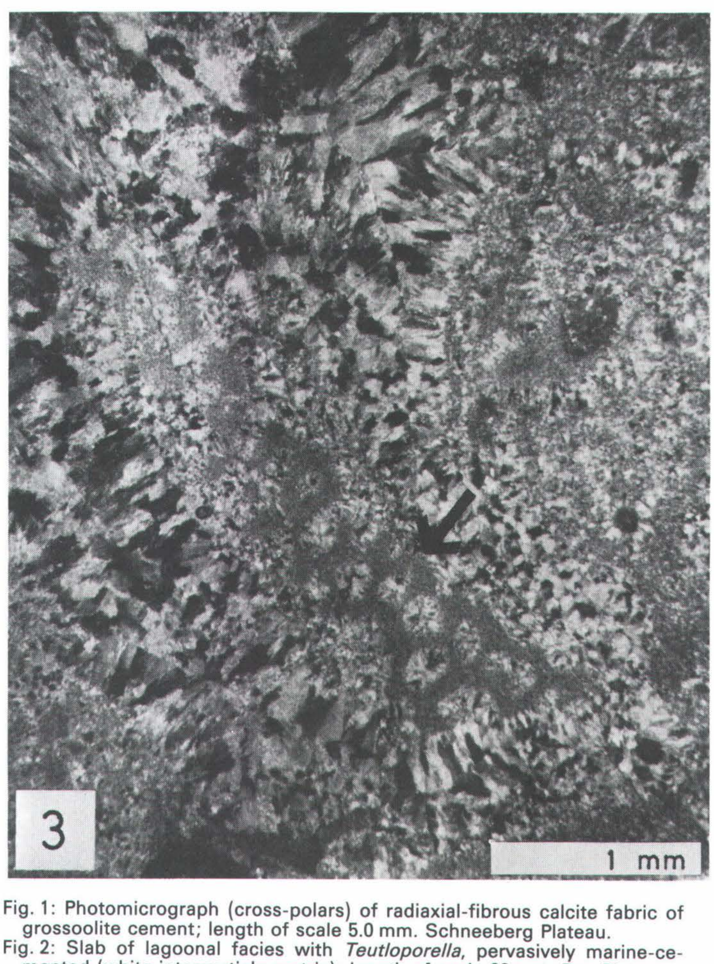

Fig. 1: Photomicrograph (cross-polars) of radiaxial-fibrous calcite fabric of grossoolite cement; length of scale 5.0 mm. Schneeberg Plateau.

Fig. 2: Slab of lagoonal facies with *Teutloporella*, pervasively marine-cemented (white interparticle matrix); length of scale 20 mm. Rax Plateau.

Fig. 3: Photomicrograph (cross-polars) of syndepositional marine cements in reef facies; note recrystallized sponge (arrow); length of scale 1.0 mm. Rax Plateau.

Fig. 4: Slab of grossoolite-breccia facies, showing truncated earlier generation of laminated radiaxialfibrous cement (arrows) overlain by later generation of cement (white); length of scale 25 mm. Schneeberg Plateau.

CORRELATION OF FLUVIAL SEDIMENTS OF THE DYJE AND MORAVA RIVERS ALONG THE CZECHOSLOVAK-AUSTRIAN BORDER

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Detailed research of Quaternary sediments of southern Moravia (Ústřední ústav geologický, Praha) and western Slovakia (Geologický ústav Dionýza Štúra, Bratislava) was carried out in the sixties through eighties. In 1984 and 1985, in the framework of cooperation between the Ústřední ústav geologický and Geologische Bundesanstalt the present authors visited several localities of terrace accumulations on Austrian territory in the Mitterhof area and along the Dyje river between Bernhardsthal and Gerichtsfeld. Samples from the visited fluvial accumulations were correlated with fluvial accumulations from the Czechoslovak territory by means of field study and petrographic analyses.

To enable comparison, first a brief overview is given concerning the main results of the terrace accumulation research from the area of Hevlín (Laa a. T. on the Austrian side) and Břeclav, Lower Moravian Basin and western and southern part of the Záhorská nížina Lowland. Correlation of the Danube terraces between Wien and Bratislava with Quaternary sediments from the Bratislava area and Podunajská nížina Lowland is discussed at lenght in the paper of Halouzka and Minaříková (1977). For stratigraphic evaluation of individual terrace accumulations the Alpine system is being used for the sake of continuity with earlier works.

The studied area (Fig. 1) has been considerably affected by neotectonic activity which resulted in hydrographic changes of river courses, postsedimentary vertical differentiation of river terraces and generation of Quaternary depressions. For the above reasons petrographic research (gravel and heavy mineral analyses, grain-size analyses) proved very useful. Table 1 and 2 give results of pebble analyses (fraction 16—18 mm) and heavy mineral analyses (separated from 0.25—0.063 mm fraction using acetylenetetrabromide) from several typical localities of southern Moravia. Around 500 analyses from fluvial sediments were performed from the above given Czechoslovak localities.

Table 1. Composition of pebbles in the Dyje and Jevišovka river sediments (fr. 16—8 mm)

	quartz	metaquartzite	crystalline schists	granitoids	orthoquartzite	sandstones	silicites
Valtice, Dyje r. (Pliocene-Pleistocene)	91,2	1,4	0,3	0,8	—	6,0	0,3
Valtice, Dyje r. (Günz)	61,0	0,8	13,1	18,0	1,1	5,2	0,5
Dyjákovice, Dyje r. (Günz)	40,8	2,0	25,0	30,1	0,7	—	—
Poštorná, Dyje r. (Mindel)	49,2	1,3	25,4	12,1	4,1	6,8	1,2
Hevlín, Dyje r. (Riss)	65,1	1,1	18,7	13,3	0,9	0,4	0,4
Travní Dvůr, Jevišovka r. (Riss)	47,0	1,2	26,8	25,0	—	—	—
Poštorná, Dyje r. (Riss)	46,1	1,0	24,5	17,8	2,1	6,7	1,8
Poštorná, Dyje r. (Würm)	45,8	2,1	22,9	16,6	2,3	8,5	2,1

Crystalline schists: muscovite gneiss, two-mica gneiss, granulite, amphibole gneiss, fine-grained biotite paragneiss, amphibolite, rarely green schists
Sandstones: flysch sandstones (glauconitic sandstone, graywacke sandstone, arcose sandstone) and sandstones of the Bohemian Cretaceous Basin from the confluence of the Dyje and Svratka rivers (silicified sandstone, rarely orthoquartzite)
Silicites: different types of cherts

A special attention was given to the presence and amount of grains which underwent an eolian transport, since it has been found out that these grains occurred in the terrace sediments as late as the beginning of the Mindel and were frequent especially in the Riss and Würm deposits. The corrosion of amphibole and garnet grains had also been

Table 2. Composition of heavy minerals in the Dyje and Jevišovka river sediments

	garnet	opaque minerals	green amphibole	brown amphibole	zoisite-epidote group	staurolite	disthene	apatite	zircon	rutile	tourmaline	altered minerals
Valtice, Dyje r. (Pliocene-Pleistocene)	23,9	36,0	4,8	0,3	15,1	2,4	1,5	0,3	6,0	2,1	0,5	3,6
Valtice, Dyje r. (Günz)	17,6	25,9	26,7	3,8	8,8	1,9	1,5	0,4	1,9	1,2	1,1	6,1
Dyjákovice, Dyje r. (Günz)	25,4	13,1	32,2	14,3	3,6	1,2	0,3	0,3	0,3	0,3	0,3	6,6
Poštorná, Dyje r. (Mindel)	15,6	27,2	21,5	16,1	5,1	2,5	0,8	1,7	2,0	1,7	0,2	3,4
Hevlín, Dyje r. (Riss)	44,7	17,8	12,6	8,9	7,5	1,7	0,3	0,6	1,4	2,0	—	1,7
Travní Dvůr, Jevišovka r. (Riss)	65,1	15,3	6,2	2,8	2,3	3,9	0,3	—	1,0	0,2	0,3	1,8
Poštorná, Dyje r. (Riss)	24,3	22,5	29,3	4,6	6,1	0,7	1,8	1,8	1,8	1,8	0,3	2,9
Poštorná, Dyje r. (Würm)	35,5	26,4	11,9	1,6	5,0	5,3	0,9	1,6	4,1	4,1	0,6	1,9

Andalusite, sillimanite and titanite represent less than 1 %; pyroxenes, chromite, xenotime, monazite, spinel and anatase are rare.

Table 3. Composition of pebbles in samples from Austrian territory (fraction 16—8 mm)

	quartz	metaquartzite	crystalline schists	granitoids	orthoquartzite	sandstones	silicites
Mitterhof, Dyje r. (Riss)	36,6	1,8	37,5	18,7	5,4	—	—
Bernhardsthall 1, Dyje r. (Mindel)	55,1	2,9	22,9	9,5	4,3	4,2	1,0
Rabensburg, upper part, Dyje r. + local material (Mindel or older)	61,9	2,6	12,3	10,6	4,7	3,5	3,5
Rabensburg, lower part, Dyje r. + local material (Mindel or older)	69,5	9,5	8,4	4,2	2,1	5,3	1,0
Gerichtsfeld, Zaya r.? (Mindel or older)	84,9	3,6	1,1	—	8,3	2,2	—
Mühlberg, „Oil-field", fine-grained gravel (Pliocene)	83,3	1,8	0,7	1,8	1,8	3,6	4,2
Mühlberg, „Oil-field", lens of gravel (Pliocene)	91,6	1,6	0,3	0,9	0,6	0,6	4,4
Mühlberg, upper level — 220 m (Pliocene)	91,6	—	0,3	1,1	0,4	3,3	2,9

studied; from other regions of Czechoslovakia it is known (Tyráček — Minaříková — Kočí 1985) that garnet is usually slightly corroded in sediments older than the Mindel and similar corrosion of amphibole (namely of the green variety) has been observed in the Mindel and older sediments.

The Dyje river catchment area between Hevlín and Břeclav (Minaříková 1983, Havlíček — Kovanda 1985, Havlíček — Zeman 1986). In this area the Dyje river formed accumulations from the Lower Pleistocene to the Holocene. Remains of gravels in Valtice are the earliest sediments laid down on the Pliocene — Pleistocene boundary (relative height of the base is 63—66 m, height above sea level 223—226 m). This accumulation is of sheet nature and therefore cannot be considered a typical terrace from the morphologic point of view (Zeman 1973). Its sediments are strongly weathered, considerably mature (see Table 1) and amphibole and garnet grains are corroded. The Dyje Günz accumulation which can be observed also in Valtice surroundings (relative height of the base is about 30 m, height above sea level around 190 m) exhibits more varied composition (see Tables 1, 2); amphibole and garnet grains are slightly corroded. The Mindel sediments cover an extensive plateau west of Poštorná near Břeclav (relative height of the base is 15 to 24 m, height above sea level 158 to 164 m, maximum thickness 10 m). Their composition does not significantly differ from that of the Günz deposits but their sand contains occasional eolian grains and the corrosion of amphibole grains is very weak; garnet grains show no corrosion. The Riss terraces skirt along almost entire course of Dyje river in the described area. They form two accumulations which in some places can be distinguished only with the help of boring (relative height of the base R1 at Hevlín is 5—6 m and R2 0 to —3 m; the base at Poštorná is 0 to —1 m). Their composition is similar to that of the Mindel and Günz sediments of the Dyje river (see Tables 1, 2), but they exhibit much higher degree of roundness of sand grains which testifies of an intensive eolian activity. The amphibole grains are not corroded.

The floor of the Dyje river valley is rather flat, without significant depressions. The thickness of sandy gravel in the flood plain is 7 to 12.5 m and their composition is practically the same as that of the Riss sediments. Often there were found coalified pieces of wood which permitted dating of the sediments by radiocarbon analysis. Pieces of wood from the Dyje gravel base south of Břeclav gave the age 16,170 ± 480 BP (Hv—9728), further dating 7,990 ± 75 BP (Hv—9729) from the middle of gravels at Poštorná confirmed our hypothesis of gravel sedimentation or resedi-

Table 4. Composition of heavy minerals in samples from Austrian territory

	garnet	opaque minerals	green amphibole	brown amphibole	zoisite-epidote group	staurolite	disthene	apatite	zircon	rutile	tourmaline	altered minerals
Mitterhof, Dyje r. (Riss)	43,3	9,7	18,3	13,7	1,3	3,3	0,7	1,0	0,3	0,7	0,3	4,3
Alt Prerau, Dyje r. (Riss)	35,3	26,2	10,1	8,2	3,2	1,9	1,9	2,2	4,1	0,6	0,3	2,5
Bernhardsthal 1, Dyje r. (Mindel)	44,2	26,2	11,9	5,8	2,3	1,2	0,6	—	3,2	1,5	0,6	1,7
Bernhardsthal 2, Dyje r. (Mindel)	39,9	13,3	18,3	9,9	5,2	1,3	2,9	1,0	1,0	0,8	0,5	4,7
Rabensburg, upper part Dyje r. + local material (Mindel or older)	22,6	38,0	6,6	4,4	4,8	3,7	1,5	1,2	7,7	1,9	1,2	3,1
Rabensburg, lower part Dyje r. + local material (Mindel or older)	27,5	29,3	11,5	9,2	4,5	2,1	2,3	2,1	5,0	1,0	0,3	2,6
Gerichtsfeld, Zaya r.? (Mindel or older)	27,2	39,7	7,8	1,4	7,5	2,3	1,8	0,5	3,2	2,7	0,7	2,1
Mühlberg, „Oilfield" fine-grained gravel (Pliocene)	3,9	43,9	2,3	5,1	10,1	5,1	2,8	1,1	6,2	5,1	2,8	6,5
Mühlberg, „Oilfield" lens of gravel (Pliocene)	6,2	53,2	1,7	2,6	10,0	1,9	2,1	0,6	8,3	4,1	2,4	3,4
Mühlberg upper level — 220 m (Pliocene)	3,9	53,2	0,8	1,4	7,4	5,2	4,4	0,3	10,2	3,6	3,9	2,8

Andalusite, sillimanite and titanite represent about 1 % or less; pyroxenes, chromite, spinel, brookite and anatase are rare.

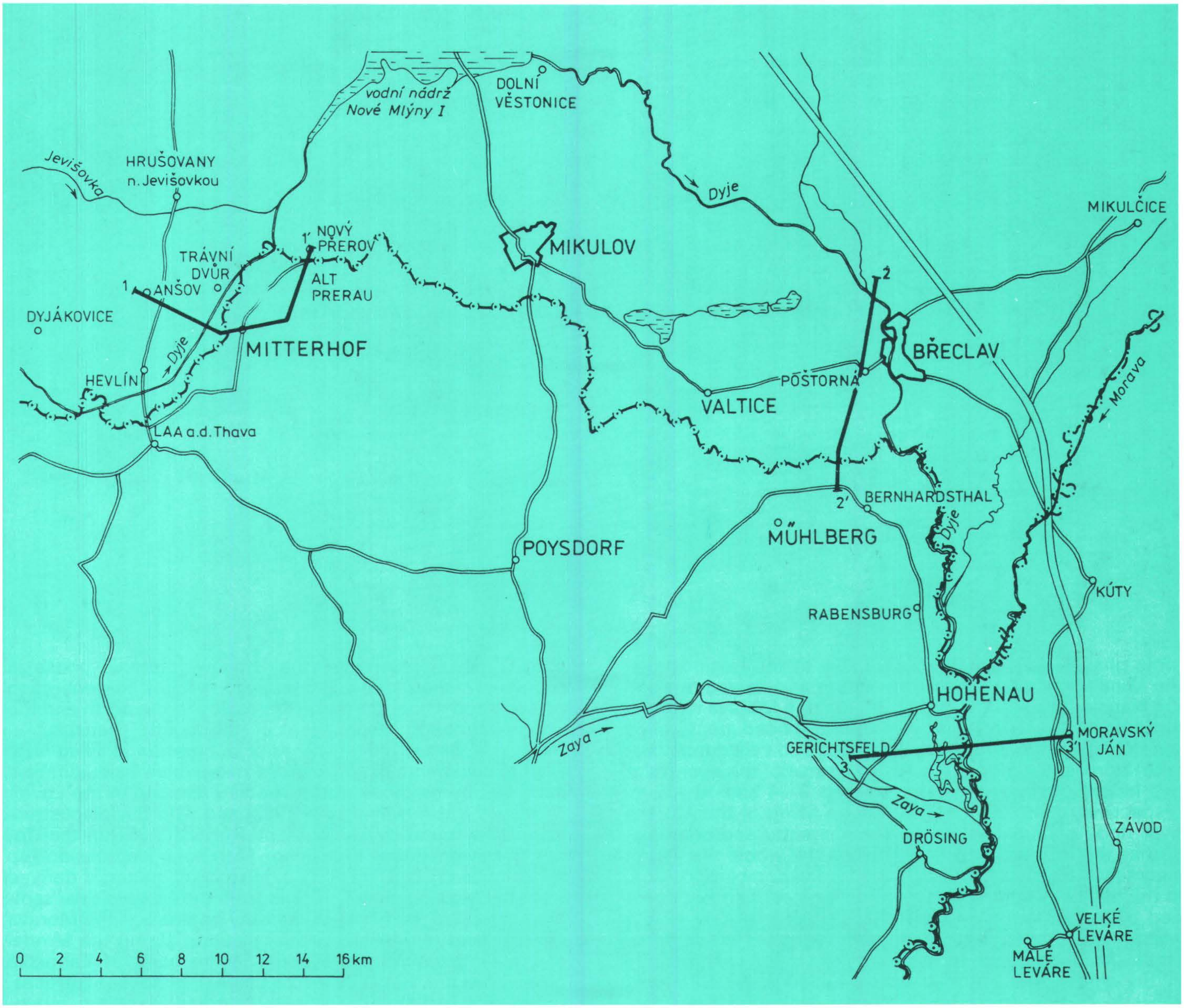


Fig. 1: Sketch map of the studied area with schematic geological sections.

mentation even in the Holocene (the Atlantic). The beginning of the deposition of gravels filling the flood plain at the Dyje and Morava rivers confluence occurred most probably in the Late Glacial (i. e. after deposition of pieces of wood dated 16, 170 ± 480 BP (Hv—9728) and 22,400 ± 3,650 BP (Hv—7150)).

Numerous dunes blown up from the near fluvial sediments originated on the surface of gravels in the Dyje flood plain. They make conspicuous elevations which had been settled probably as early as in the Mesolithic (Dolní Věstonice, Pohansko, Mikulčice, Kalousek 1966), during the Neolithic-Bronze Age (south of Pohansko, Klíma 1970) and especially in the 8th to 12th centuries A. D. (Na pískách, Vysoká zahrada near Dolní Věstonice, Pohansko, Mikulčice, etc.).

The surface of the Dyje flood plain is composed mainly of 2 to 5 m thick flood loams with the beginning of sedimentation dated 3,720 ± 60 BP (Hv—9727) — the Subboreal up to 1,970 ± 80 BP (Hv—9731) — the Subatlantic.

The Lower Moravian Basin (Havlíček 1980, Minaříková 1982, Zeman et al. 1980, Havlíček — Zeman 1986). The terrace accumulations on this territory were formed by various rivers. Relics of higher terraces of Lower Pleistocene age (relative height of the bases ranges between 30 and 70 m) are to be linked with local streams only. The Morava river did not flow through the Lower Moravian Basin territory in the Lower Pleistocene. It flowed through the more northerly situated Vyškov Gate to the west, towards the town of Brno (Zeman 1973). The change in the Morava river course was caused by tectonism (the Drahany neotec-

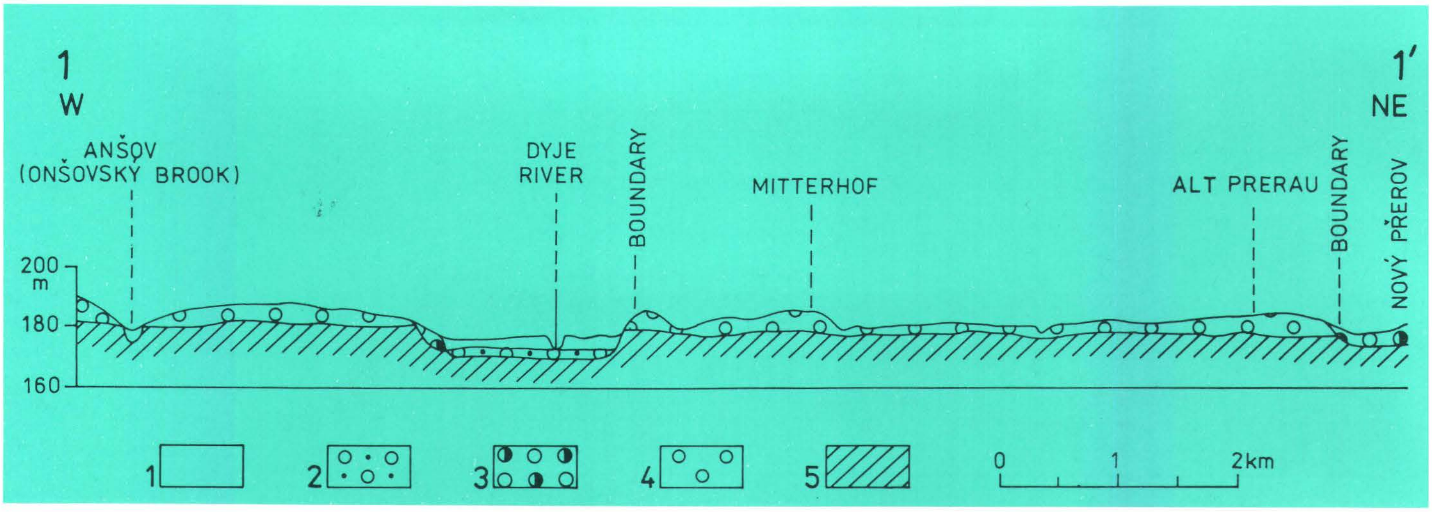


Fig. 2: Schematic section 1—1′
1 — flood loam; 2 — fluvial sandy gravel (Würm-Holocene); 3 — fluvial sandy gravel (Riss 2); 4 — fluvial sandy gravel (Riss 1); 5 — pre-Quaternary basement.

tonic phase — Zeman 1973) probably at the beginning of the Mindel when it turned to the south and flowed through the Napajedla Gate. During the Mindel the Morava river did not make terraces on this territory but its sediments filled the Hradiště Graben. The Riss terrace (also called main terrace) skirts along almost the whole course of the river (relative height of the base and surface is 2—4 and 10—12 m, respectively). The Würm to Holocene filling of the Morava river flood plain exhibits a similar character and composition as the Riss accumulation, but on the whole the Würm sediments are coarser and show more varied composition. In the base of valley-floor accumulation near Lanžhot coalified pieces of wood dated 22,400 ± 3,650 BP (Hv—7150) were found. The earliest flood loams with one to two burried soil horizons began to deposit in the Middle and namely in the Upper Holocene (Strážnice, 1,950 ± 90 BP (Hv—7152) — Subatlantic). South-east of Moravská Nová Ves and SE of Týnec a zone of 24 to 30 m deep narrow closed depressions trending NNE—SSW and filled with Würm sediments of the Morava river was recognized.

Western and southern parts of the Záhorská nížina Lowland (Minaříková 1969, 1973, 1983). Fluvial accumulations of the Záhorská nížina Lowland were made by various rivers, similarly as the accumulations of the Lower Moravian Basin. Neotectonic movements which conditioned an increased erosion and denudation caused that terrace accumulations older than the Riss are preserved only as relics. Relative heights of the terraces of identical age significantly vary. The Lower Pleistocene terraces are represented by two levels and their relics occur always side by side, irrespective of the distance from the Morava river and relative heights. Their bases are situated 73 and 65 m the highest (north of Studienka) and 32 and 11 m the lowest (near Závod) in the subsidence area of the Kúty Graben. Their mutual correlation was possible only on the basis of petrographic composition which showed that the Lower Pleistocene accumulations were formed by the Dyje river but they contained also resedimented material from the basement (the Pannonian, Pontian). However, these terraces are lacking any clastic material typical of the Morava river sediments.

At the beginning of the Mindel the entire area of the Záhorská nížina Lowland was afflicted by an intensive tectonic activity which resembled the Drahany tectonic phase in Moravia (Zeman 1973). This activity resulted in generation of two depression: the Kúty depression in the north and the Zohor-Marchegg depression in the south (Baňacký — Harčár — Sabol 1965). The Kúty depression is filled with Mindel sediments of the Morava river which have identical composition as those of the Hradiště Graben in the Lower Moravian Basin (Minaříková 1982) and with fluviolacustrine sediments found by Macoun and Růžička (1967) in the Upper Moravian Basin. The Zohor-Marchegg depression (up to 80 m deep) is filled with a mixture of material derived from the Malé Karpaty Mts. and from the Morava river sediments. Beside the filling of the Kúty depression the Morava river formed two terrace accumulations during the Mindel and their relics were preserved in the north of Záhorská nížina Lowland. Similarly as the Lower Pleistocene terraces, they were afflicted by postsedimentary tectonic movements so that the relative height of their bases fluctuated between 13 and 30 m in the younger Mindel and 26 to 50 m in the older Mindel. The Riss accumulations skirt along the today's Morava river and their position shows that the course of the river significantly shifted to the west. On the composition of the sediments participate both the Dyje and Morava rivers. Also bases of the Riss terraces significantly fluctuate and this proves that the entire area was tectonically active throughout the whole Pleistocene.

The Lower Pleistocene catastrophic sediment, occurring in pockets made in the Pannonian clays in the basement of the Würm Morava river terrace, testifies of a considerable sinking of the territory between Moravský Ján and Malé Leváry. The sediment is composed of coarse pebbles to boulders which are little worn and exhibit varied petrographic composition. The rocks come from the SE part of the Bohemian Massif; beside resistant rocks there were found also fresh phyllites and epidotites (Minaříková 1969). The boulders are accompanied by many bones of elephantids, determined by Musil (1960) and ranged with the Lower Pleistocene, and by pieces of wood and peat. The character of flora (Krippel 1965) and fauna indicates typical periglacial environment. The sedimentation was very rapid, chaotic and blocks of rocks were transported probably in ice floes. Similar blocks were reported by Eppensteiner et al. (1973) from terrace bases of various ages from Marchfeld in Austria. The Austrian autors believe that these blocks were deposited by braided rivers in the glacial period in the periglacial zone and transported in ice floes.

It was found that the highest Lower Pleistocene accumulations preserved as tiny relics in the southern part of the Záhorská nížina Lowland in the Devín (Hainburg) Gate were deposited by local Carpathian streams and not by the Danube river (Halouzka — Minaříková 1977). The Danube sediments in this area occurred as late as in the Mindel, when the Danube river formed a terrace near Devínska Nová Ves and two accumulations in the Bratislava area which correspond with the upper and lower Seyring in Marchfeld. Before deposition of these terraces, in the Lower Pleistocene, the Danube river had probably flowed through the Bruck Gate (Fink 1955, Küpper 1955). The change of the Danube course probably occurred in the same period as the change of the Morava river course towards south via the Napajedla Gate, i. e. probably at the beginning of the Mindel. In this period tectonic movements are reported from great part of western and central Europe (Šibrava 1972).

Results of the study of terrace accumulations on Austrian territory and their correlation with Czechoslovak terraces

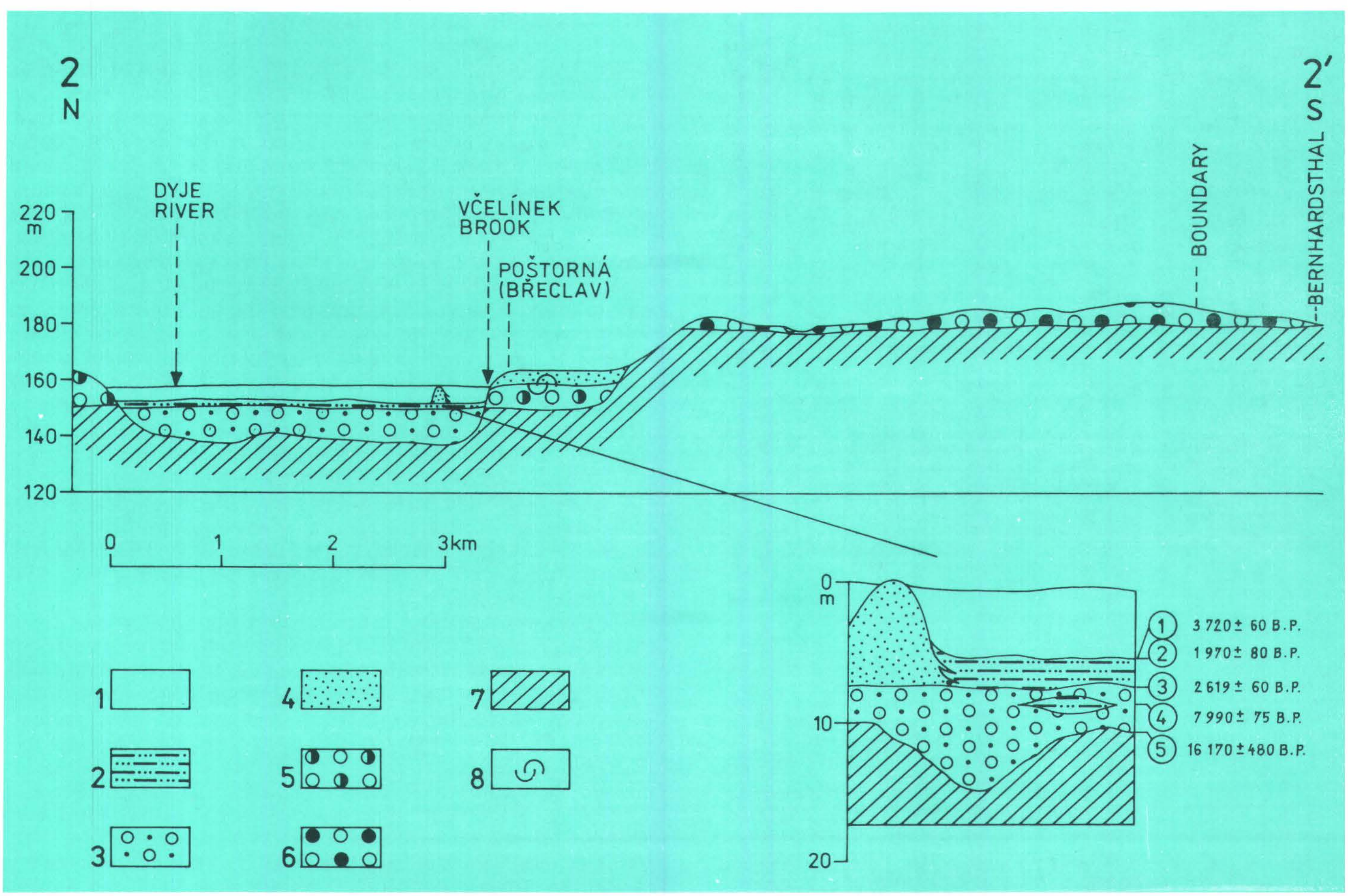
Mitterhof region

The Mitterhof accumulation forms an extensive terrace on the right bank of the Dyje river north of Laa a. T. towards Alt Prerau. Its surface is situated 184—185 m above sea level, i. e. approximately 10 m above the Dyje flood plain. The accumulation is composed predominantly of sand with medium-grained gravel lenses and micaceous silt intercalations. On the surface of the accumulation the sediments are cryoturbated in some sites. The gravel contains (see Table 3) typical rocks of the Dyje provenance, heavy fraction (see Table 4) exhibits prevalence of garnet over amphibole and opaque minerals. According to Austrian geologists (see Grill 1968) the terrace belongs to the Riss.

On the Czechoslovak territory this terrace can be correlated with the Dyje accumulation NE of Hevlín. Its surface gradually ascends from 4 to maximum 10 m above the Dyje flood plain. On the basis of borehole data we can distinguish the Riss 1 and Riss 2 according to different base heights (see schematic section 1—1'). The accumulation is also prevailingly sandy, in the composition of pebbles and heavy fraction (see Tables 1, 2) is similar to that of the Mitterhof terrace. In the vicinity of Travní Dvůr there were found Riss sediments of the Jevišovka river which can be well distinguished from the Dyje Sediments on the base of heavy minerals. In the Jevišovka river sediments a dominant heavy mineral is garnet (see Table 2). The presence of the Jevišovka sediments (nowadays the Jevišovka river empties into the Dyje river approximately 7 km to the NE) suggests that in the Riss period the Jevišovka mouth into the Dyje was situated further to the south, probably on Austrian territory.

In the wider surroundings of Laa a. d. Thaya, about 200 m above sea level (relative height 25 m above the Dyje flood plain) occurs a level covered only by dispersed gravels. Only in some sites a small residue of accumulation has been

Fig. 3: Schematic section 2—2'
1 — flood loam; 2 — fluvial sand (Holocene); 3 — fluvial sandy gravel (Würm-Holocene); 4 — eolian sand; 5 — fluvial sandy gravel (Riss 2); 6 — fluvial sandy gravel (Mindel); 7 — pre-Quaternary basement; 8 — cryoturbation.



preserved. Austrian geologists (see Grill 1968) assign this level to the Lower Pleistocene. Dispersed gravels are composed predominantly of quartzose rocks with admixture of flysch rocks.

On Czechoslovak territory this level probably corresponds with the Dyje accumulation with the surface 200—203 m above sea level and thickness about 2.5 m which forms a conspicuous ridge of E—W direction between Hevlín and Dyjákovice. The accumulation is formed by loamy consolidated limonitized medium-grained gravels (for compostion see Table 1). The sand shows no eolian grains and amphibole and garnet grains are corroded. On the basis of composition and character of the sediment the present authors presume that the accumulation is of the Lower Pleistocene (Günz) age.

The territory north of Bernhardsthal

North of Bernhardsthal lies a terrace with the surface 185 m above sea level (about 30 m above the Dyje flood plain) which is formed of medium-grained sandy gravel containing typical Dyje rocks (see Table 3). Heavy fraction exhibits prevalence of garnet; opaque minerals and amphiboles (see Table 4) occur in a smaller amount. Amphibole grains are slightly corroded. Eolian grains are rare. Austrian geologists classify the accumulation as Lower Pleistocene (see Grill 1968).

On Czechoslovak territory, this accumulation can be probably compared with terrace situated on an extensive plateau between Poštorná and Valtice (see schematic section 2—2′) with its surface lying 180—184 m above sea level. The base of this Dyje accumulation was determined at the height of about 164 m above sea level. Compared with Bernhardsthal, the pebble component contains more flysch sandstones at the expense of quartzose rocks (see Table 1). Also the composition of heavy fraction is slightly different (see Table 2), but the corrosion of mineral grains is similar and also eolian grains are present. In spite of the above differences in representation of certain rocks and minerals it is presumed that the accumulations correspod to each other. On the Czechoslovak territory this terrace is assigned to the Middle Pleistocene — Mindel.

A sample of sands from the gravel pit at "Zollhaus" (Bernhardsthal 2) was taken NE of Bernhardsthal. Composition of its heavy fraction (see Table 4) is similar to that of other sediments of the Dyje river, the wear and corrosion of grains is identical with Bernhardsthal 1. This led the present authors to conclusion that the sample also belongs to the Mindel sediments of the Dyje river.

The terrace west of Rabensburg

An extensive accumulation with the surface about 163 m above sea level and up to 10 m thickness has been preserved west of Rabensburg. The accumulation is doubled, divided by a layer of strongly cryoturbated silty loam. The upper part is built of whitish fine- to medium-grained sandy gravel which is considerably consolidated; the lower part is sandy with an admixture of quartz pebbles showing a slight wear. Austrian geologists (see Grill 1968) correlate this accumulation with the terraces "west of Seyring" assigned to Mindel. Although the level corresponds to Riss terrace, the nature of clastic material suggests an older age. Table 3 shows representation of rocks. Compared with Bernhardsthal 1 the terrace contains more quartz, siltstone and silicite and less metamorphites and granitoids. Quartzose pebbles are less worn than those of the Dyje accumulations. Glauconitic sandstones are strongly silicified with corresponding very irregular shapes of pebbles. Silicites are represented by various types of cherts including even blackbrown cherts with white patina which are very frequent in the sediments near Mühlberg. Crystalline schists and granitoids are of the same type as in the Dyje sediments. They exhibit strongly kaolinized feldspars. Opaque minerals (partly formed by authigenic pyrite) are the most frequent in heavy fraction, garnet and amphiboles are less represented (see Table 4). Amphibole grains are slightly corroded. Rounded eolian grains are not present. Compared with the typical Dyje sediments, zircon is more frequent.

The present authors presume that the above described accumulation may belong to the Dyje terrace which was significantly enriched with local material brought from the west, probably from the Pliocene gravels. As the Rabensburg accumulation lies in the subsidence area either Mindel or an older age can be ascribed to it.

The terrace south of Hohenau — Gerichtsfeld

On the left bank of the Zaya river lies about 10 m thick accumulation with the surface about 160-165 m above sea level, i. e. 10 m above the flood plain (see schematic section 3—3′). The accumulation is composed of medium-grained quartzose sandy gravel with rare sand lenses. It exhibits very well rounded quartz pebbles. Surface of the accumulation is cryoturbated. Austrian geologists (see Grill 1968) correlate it to the level "west of Seyring". The composition of pebbles is given in Table 3. The sediments show a marked maturity, contain prevailingly quartz and very resistant quartzose rocks. Heavy fraction shows prevalence of opaque minerals (formed frequently by authigenic pyrite) and garnet the grains of which are only rarely corroded; amphibole grains are little corroded. It follows from the above characteristics that the sediment is of local origin (probably of Zaya river) and is composed of resedimented, probably Pliocene deposits. It may be dated as Mindel or older.

The sediments near Mühlberg

South of Mühlberg, in "Oilfield", we studied sediments which were presumed by Austrian geologists (see Grill 1968) to be of Lower Pleistocene age. The sediments attain up to 20 m in thickness and are composed of light-ochreous sand with occasional intercalations of fine-grained gravel. The sediments show horizontal deposition with conspicuous inclined bedding and cross-bedding. Surface of the sediments lies about 185 m above sea level, i. e. approximately in the same height as the near-by Dyje terrace at Bernhardsthal. However, pebble composition (Table 3) is completely different, the pebbles are composed solely of quartz and silicites. Silicites represent about 30 % in fraction over 16 mm and consist of predominantly black chert. Sandstones are also very resistant and silicified. Heavy fraction exhibits different composition from that of the Dyje sediments; garnet and amphibole represent a small fraction only. Besides predominating opaque minerals, minerals of zoisite-epidote group and stable minerals such as zircon and rutile (see Table 4) are significantly represented.

The sediments near Mühlberg situated in the height of 220 m above sea level exhibit identical composition and character (see Table 3, 4).

The present authors presume that the above mentioned sediments from "Oilfield" as well as from the level of 220 m above sea are pre-Quaternary, namely of Pliocene age. On Czechoslovak territory similar sediments were never found cropping out on the surface.

Conclusion

Results of petrographic analyses showed that the traditional method of terrace classification according to their relative heights is not appropriate for the studied territory since the heights of terraces significantly fluctuate due to

STRATIGRAPHICAL CORRELATION TABLE OF FLUVIAL SEDIMENTS OF DYJE AND MORAVA RIVERS ALONG THE CZECHO-SLOVAK-AUSTRIAN BORDER

				DYJE RIVER		MORAVA RIVER	unknown rivers (Zaya)	neotectonic phases
				Czechoslovakia	Austria	Czechoslovakia Austria	Austria	ČSSR Austria
QUARTERNARY	HOLOCENE	upper		base of flood loams and eolian sands at Poštorná; base 154m (-4 to -5m)				
QUARTERNARY	HOLOCENE	middle / lower		base of fluvial sandy gravel of the flood plain at Hevlín: 170m (-6m); at Poštorná: 140 m (-7 to -13m)	base of fluvial sandy gravel at the confluence of Dyje and Morava rivers 138m (-10 m)	base of fluvial sandy gravel of the flood plain (136 m) (-14 to -15m)	?	tectonic movements (Záhorská Lowland, Marchfeld)
QUARTERNARY	PLEISTOCENE	Upper	WÜRM				?	
QUARTERNARY	PLEISTOCENE	Middle	RISS 2	Hevlín: base 174 m; Poštorná: base 150m (0 to -3m)				
QUARTERNARY	PLEISTOCENE	Middle	RISS 1	Hevlín: base 180m (5 to 6m)	Mitterhof: base 179 to 180 m (4 to 5m)	Záhorská Lowland: base (16 to -2 m)	Gerichtsfeld: base 156m (7 to 8 m)	
QUARTERNARY	PLEISTOCENE	Middle	MINDEL	Poštorná: base 170 to 178m (15 to 24 m)	Bernhardsthal base 176 m (18 m)	Záhorská Lowland: base 13 to 30m; base 26 to 50m		Drahany phase
QUARTERNARY	PLEISTOCENE	Lower	GÜNZ	Valtice: base 190 m (30 m)	?	Záhorská Lowland: base (11 to 73m)		
QUARTERNARY	PLEISTOCENE	Lower	DONAU	Valtice: base 223 to 226m (63 to 66 m)	?	Malé Leváre: relicts of catastrophic sediments in pocket in Pannonian clays base 134 to 135m (-15 to -16 m)		
TERTIARY	PLIOCENE							

Table 5.

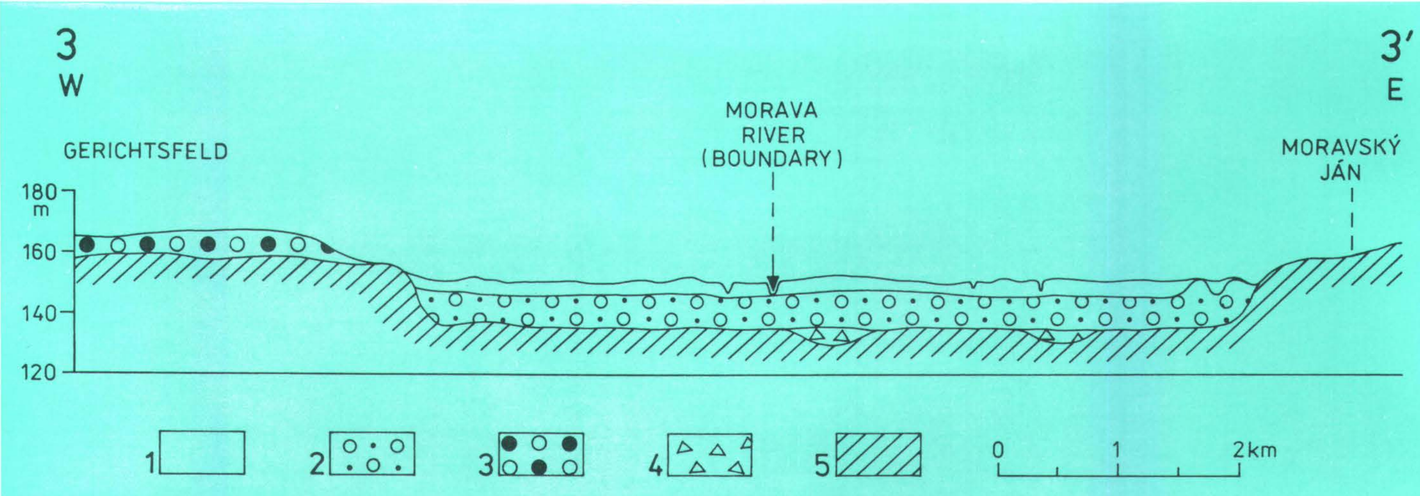


Fig. 4: Schematic section 3—3′
1 — flood loam; 2 — fluvial sandy gravel (Würm-Holocene); 3 — fluvial sandy gravel (Mindel); 4 — catastrophic sediment (minimum Lower Pleistocene); 5 — pre-Quaternary basement.

neotectonic movements (see stratigraphical correlation table). Petrographic investigation proved very successful for mutual correlation of the sediments and their stratigraphic classification. Besides composition of pebbles and heavy minerals, roundness of sand grains and the degree of corrosion of amphibole and garnet grains were applied for correlation purposes.

Data on absolute dating (from the area of southern Moravia 14 analyses were performed) supplied important information for the study of flood plains development.

The achieved results show that further cooperation of Czechoslovak and Austrian geologists will be highly profitable, especially for sake of correlation of the continental and Alpine glaciations for which the studied territory is of essential importance.

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Abstrakt

Studovaná oblast je součástí území, které má klíčový význam pro korelaci kontinentálního zalednění na s. Moravě a alpského zalednění v Rakousku. Toto území bylo postiženo intenzívní neotektonikou, která způsobila změny říčních toků a postsedimentární vertikální diferenciaci říčních teras. Nelze zde proto použít klasických morfologických metod pro stratigrafické zařazení teras na základě jejich relativních výšek. Petrografické analýzy poskytly řadu poznatků, které vzájemnou korelaci teras a jejich stratigrafické zařazení umožnily. V práci jsou uvedeny hlavní výsledky výzkumu kvartérních sedimentů j. Moravy a z. Slovenska v pohraniční oblasti a výsledky studia teraso-

Zusammenfassung

Das Untersuchungsgebiet an den Flüssen Thaya und March entlang der tschechoslowakisch-österreichischen Staatsgrenze ist ein Teil des Gebiets von entscheidender Bedeutung für die Korrelation der Kontinentalvereisung in Nordmähren und der Alpenvereisung in Österreich. Das erwähnte Gebiet wurde durch eine intensive Neotektonik betroffen, die Änderungen der Wasserläufe und eine postsedimentäre vertikale Differenzierung der Flußterrassen verursachte. Daher können hier klassische morphologische Methoden zur stratigraphischen Einstufung der Terrassen aufgrund ihrer Relativhöhen nicht angewendet werden. Petrographische Analysen liefervých akumulací na území Rakouska a jejich korelace s terasami na území Československa.

ten eine Reihe von Kenntnissen, durch die eine gegenseitige Korrelation und stratigraphische Einstufung der Terrassen ermöglicht wurden. Im vorliegenden Beitrag werden wichtigste Ergebnisse der Erforschung von Quartärablagerungen im Grenzgebiet Südmährens und der Westslowakei sowie der Untersuchung von Terrassenaufschotterungen auf dem Gebiet Österreichs und ihrer Korrelation mit den Flußterrassen auf dem Gebiet der Tschechoslowakei zusammengefaßt.

THE NOETSCH-VEITSCH-NORTH GEMERIC ZONE OF ALPS AND CARPATHIANS: CORRELATION, PALEOGEOGRAPHY AND SIGNIFICANCE FOR VARISCAN OROGENY

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Introduction

The correlation of basement zones between the Alps and Carpathians have strong significance for the definition of microplates involved in the Alpine orogen, and, naturally, for the evolution of the pre-Alpine basement. Late Paleozoic depositional sequences with strong shallow water affinities have a distinct significance among basement units because they contrast all other lithotectonic units in regard to the depositional environment, the age of deposition as well as to the age and degree of metamorphism.

Late Paleozoic deposits of a shallow marine environment occur within the North Gemeric Zone, e. g. at the locality Ochtina and related localities of the Western Carpathians, within the Veitsch nappe (Greywacke zone) and at Noetsch of the Eastern Alps (Fig. 1). The North Gemeric Zone and the Veitsch nappe are situated along the same structural zone which separates a strong metamorphosed basement in the footwall from weakly metamorphosed Early Paleozoic rocks in the hangingwall (see TOLLMANN, 1986, and references cited therein). The tectonic position of Noetsch in the Eastern Alps is rather obscure. It forms the core of a fault-controlled window below Mesozoic rocks of the Drauzug.

The aim of this paper is

— to correlate the individual formations of these three structural units,

— to evaluate their geodynamic evolution,

— to elucidate their significance for the Variscan geodynamic evolution of the Alpine and Carpathian belt.

Sections

1. Noetsch Group

SCHÖNLAUB (1985) redefined the sedimentary sequence from the locality Noetsch (Noetsch Group). The Noetsch Group consists of three formations, from the base to the top, of the Erlachgraben Fm., die Badstub-Breccia Fm. and the Noetsch Formation. The stratigraphic base of the Noetsch Group is not known up to now.

The Erlachgraben Formation is composed of sandy siltstones, and slates which are intercalated by up to ten metres thick conglomerate lenses. Some rich faunas including brachiopods, bivalves, corals and plants favour a shallow marine environment of deposition. The age of deposition is not known exactly. SCHÖNLAUB (1985) discusses a Late Visean and/or Early Namurian age.

The up to 400 m thick Badstub Breccia Formation is formed by a greenish breccia of a mysterious, strongly discussed origin and a marly siltstone („Zwischenschiefer"). The breccia bears predominantly components of a metamorphic origin (e. g., amphibolites, marbles and orthogneisses), and rare pelagic limestones of Late Visean age. The recent interpretation of SCHÖNLAUB (1985; see discussion in that paper) favours a volcanic origin for this breccia, an eruptive breccia. TEICH (1982) found a tholeiitic basaltic chemistry evaluating the major elements.

The 400—600 m thick Noetsch Formation is composed of grey slates, siltstones and conglomerates. Some localities are rich in fossils typical of a shallow marine environment, as like bivalves, gastropods, brachiopods, corals. The age of deposition is Namurian to Westphalian (?).

It is worth being noted that all three formations bear predominantly strongly metamorphosed components like amphibolites, marbles, orthogneisses. Unmetamorphosed plutonic rocks are rather rare (EXNER, 1983). KODSI and FLÜGEL (1970) described the light and heavy mineral content of the sandstones which suggest likewise a metamorphic source region. SCHÖNLAUB (1985) notes the occurrence of pelagic limestones with conodonts hardly older than the age of redeposition. These limestones contrast the sedimentary environment of the Noetsch Group. Own observations on components show the predominant existence of components strongly sheared during metamorphic conditions. The age of metamorphism of the metamorphic components is not known up to now.

2. Veitsch Group

The sedimentary sequences of the Veitsch nappe (Veitsch Group) are rearranged recently by NIEVOLL (1983), RATSCHBACHER (1984, 1987) and RATSCHBACHER and NIEVOLL (1984). RATSCHBACHER gives a new subdivision in three formations for the western part of the Veitsch nappe. The correlation with the eastern area of the Veitsch nappe bears some uncertainties (RATSCHBACHER and NIEVOLL, 1984). In the western Veitsch nappe, there are the Steilbachgraben Formation, the Triebenstein Formation and the Sunk Formation from bottom to the top. For the eastern Veitsch nappe, the Graschnitz Formation is introduced new by this paper (see below; see also FLÜGEL, HÖTZL and NEUBAUER, in press).

Recently, a highly metamorphosed basement slice (paragneisses and discordant aplitic veins (plagiogranitic composition) of the Prieselbauer Complex are found together with low grade metamorphosed sediments of the Veitsch Group (NEUBAUER et al., 1987). U/Pb zircon data (lower intercept age of paragneiss: 391 ± 2 Ma; upper intercept age of aplite: 363 ± 20 Ma) favour an intra-Devonian age of metamorphism and magmatism. But it is important to note, that the relationship between Prieselbauer slice and the Veitsch sediments is based on an interpretation because a mylonite zone separates actually both units.

The Steilbachgraben Formation (up to 230 m thick) consists of arkosic sandstones, shales and limestones which bear siliciclastic components. Tuffaceous rocks of basic composition are rare. Dolomite, magnesite and sulphates are intercalated between clastic sediments. Some shallow marine fossils like brachiopods, trilobites, gastropods and corals indicate a Late Visean age of deposition (HAHN and HAHN, 1977; NIEVOLL, 1983; RATSCHBACHER, 1987, and references cited therein).

The 10 to 300 m thick Triebenstein Formation consists of pure limestones bearing some corals and crinoids which indicate a Late Visean age of deposition. Greenschists of a tuffaceous and lava flow origin are intercalated within the

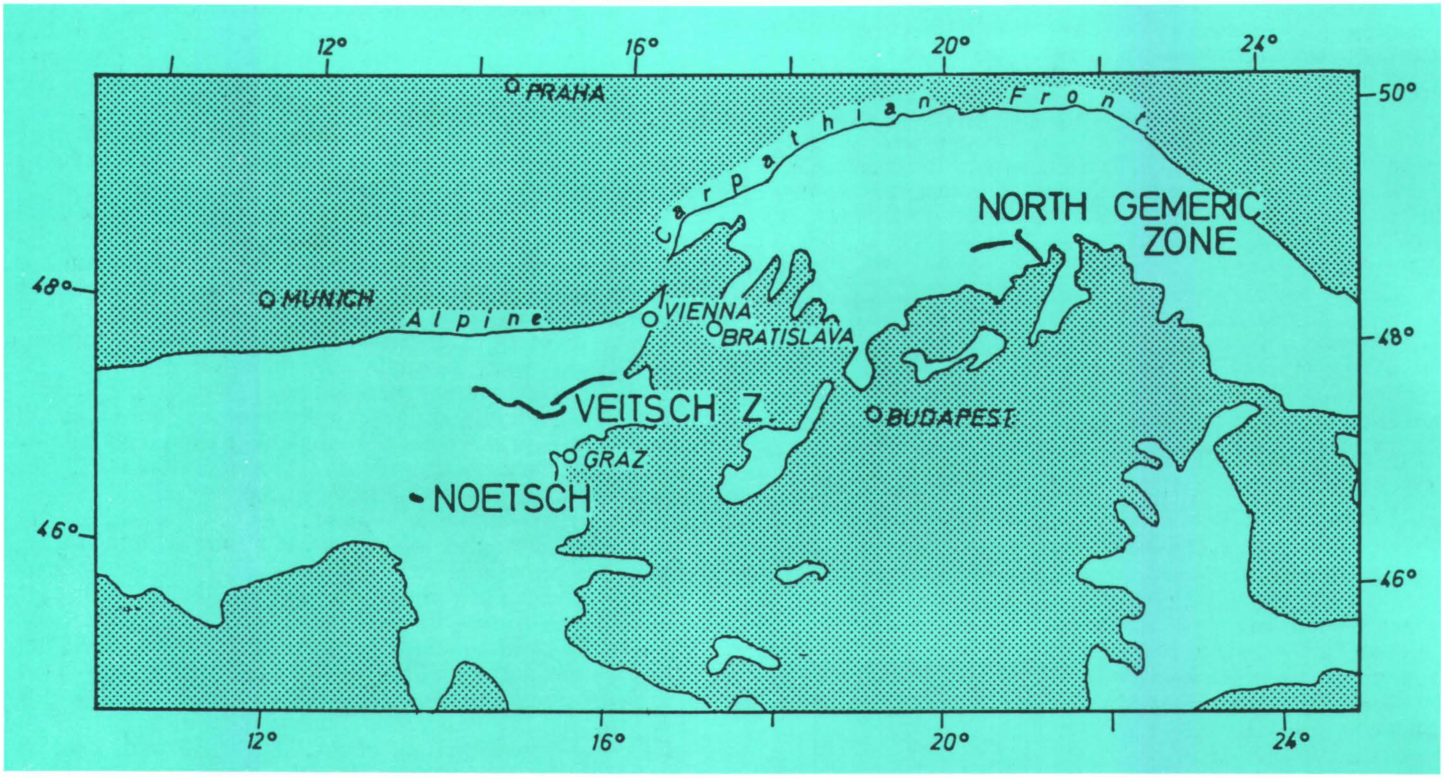

Fig. 1: The Noetsch-Veitsch-North Gemeric Zone within the Alpine-Carpathian belt.

limestones in some sections. The thickness of these greenstones varies between 0.1 to aproximately 10 metres. About the chemistry and geodynamic significance of this volcanic episode is known nothing up to now.

The 50 to 150 m thick Sunk Formation is composed of cyclic carbonate and clastic deposits. A cyclus range from limestones at the base to shales, siltstones, sandstones and conglomerates suggesting a coarsening upwards trend. Graphite occurs together with conglomerates. As a rule, the clastic rocks of the Sunk Formation exhibit a dark pigment. Plant fossils of the Sunk Formation suggest a Westphalian A–C age (TENCHOV, 1980).

The Graschnitz Formation appears east of the locality Bruck/Mur. The boundary to the Sunk Formation is defined by the change from dark into reddish to yellow clastic rocks (NEUBAUER, 1983). The Graschnitz Formation consists of slates and siltstones which are intercalated by thin quartz breccias and fanglomerates. The presence of acid tuffaceous rocks containing phenocrysts of quartz and alkali feldspar as well as red-coloured quartz pebbles prefer a Permian age interpretation by lithostratigraphic comparison with other Permian sections of the Eastern Alps.

In contrast to the Noetsch Group, the clastic content of Veitsch Group rocks is dominated by nearly undeformed and unmetamorphosed plutonic rocks. Besides quartz pebbles, granite pebbles dominate the clastic spectrum. Heavy minerals suggest a similar source region (RATSCHBACHER and NIEVOLL, 1984).

3. North Gemeric zone

The filling of Late Paleozoic basins preserved in the Alpine structure of the North Gemeric zone reflects the final stages of the Variscan orogeny. The Late Paleozoic formations are represented by Early and Late Carboniferous volcanosedimentary complexes of the Dobšiná– and the Črmeľ Groups and by Permian continental sediments and volcanics of the Krompachy Group.

3.1 Dobšiná Group

The Dobšiná Group consists of four formations (from the bottom to the top): the Ochtiná, Rudňany, Zlatník and the Hámor Formations (BAJANÍK, VOZÁROVÁ and REICHWALDER, 1981).

The Ochtiná Fm. (about 1200 m thick) is in the western part of the Gemericum. Its stratigraphic basement is not known. The formation rests in a nappe position upon the lower tectonic unit – the deformed envelope series of the Veporic crystalline complexes. The lower part of the Ochtiná Fm. consists of a complex of cyclic, metamorphosed fine-grained conglomerates and sandstones with phyllite intercalations. The complex is overlain by phyllites alternating with fine-grained metasandstones and intercalations of metavolcanics and metavolcaniclastics (tholeiite basalts, their tuffs and tuffites). Minor bodies of magnesites and ultrabasic rocks occur sporadically. The Tournaisian-Visean age of the lower part of the Ochtiná Formation is indicated by sporomorphs (BAJANÍK and PLANDEROVÁ, 1985). A Visean sporomorph assemblage (PLANDEROVÁ, 1982) was found in a horizon with basic volcaniclastic material. The upper part of the Ochtiná Fm. consits of a horizon of magnesite spatially associated with heavy-bedded dolomites and black graphite slates. The Uppermost Visean-Serpuchovian age of the magnesite horizon is proved by conodonts (KOZUR, MOCK and MOSTLER, 1976). Clastic sediments of the Ochtiná Formation contain besides quartz, feldspar and scarce clastic mica grains also clasts of dark phyllites, metasandstones, lydites and sporadical aplite granites.

The Rudňany Formation is only preserved in the northwestern northern and eastern parts of the Gemericum. In the northwestern and northern parts of the Gemericum, the Rudňany Fm. overlies with an unconformity the low-grade metamorphosed Paleozoic rock complex of the Rakovec Group (former phyllite-diabase series) and the gneiss-amphibolite complex (the Klátov Group). In the eastern part of the Gemericum the Rudňany Fm. overlies unconformably the low-grade metamorphosed Early Carboniferous rocks of the Črmeľ Group. The coarse-clastic Rudňany Fm. tends evidently to fining upwards. It consists of coarse-grained conglomerates, its upper parts comprise sandstone and slate intercalations. Its thickness shows extreme regional variability (10—150 m). The clastic material consists of metabasalts, their tuffs and tuffites, various types of phyllites, actinolite schists, metasandstones, hematite quartzites and phyllites, lydites, plagioaplites, granitic and tonalitic magmatic rocks, biotite-, two mica-, biotite-hornblende-, garnet-hornblende and injected gneisses, amphibolites.

Crystalline dolomite clasts occur sporadically. The clastic material is very similar to rock complexes of the basement of the Rakovec Group, the Črmeľ Group and of the gneiss—amphibolite complex (Klátov Group). The Westphalian A—B age of the Rudňany Fm. is proved by macrofauna and macroflora (RAKUSZ, 1932; VACHTL, 1938; NĚMEJC, 1946).

The Zlatník Formation (max. thickness 400 m) overlies the Rudňany Fm. It is mostly preserved in the northern part of the Gemericum (around Dobšiná-Rudňany) and consists of a rather monotonous complex of slates and fine-grained metasandstones with basic volcaniclastic layers and thin tholeiite basalts. In the lower part of the Zlatník Fm. sporadical carbonate bodies contain plentiful macrofaunas (loc. Dobšiná). The fauna is indicative of the Westphalian C—D age (RAKUSZ, 1932) or the uppermost Westphalian B age (BOUČEK and PŘIBYL, 1960). The macroflora indicates the Westphalian A—B (NĚMEJC, 1953). The conodonts are indicative of the Westphalian A (KOZUR and MOCK, 1977). A complex of dark phyllites and light crystalline limestones with interbeds of basic volcaniclastic material (the Dúbrava beds in the sense of FUSÁN, 1959) overlying the Ochtiná Fm. at the locality Ochtiná and partly SW of the locality, is also correlated with the Zlatník Fm.

Cyclical paralic sediments denoted as the Hámor Formation (150—370 m thick) represent the youngest formation of the Dobšiná Group. Sedimentary cycles composed of conglomerates, sandstones and slates contain local anthracite coal sheds. The Hámor Fm. was dated Westphalian D — Stephanian A (ILAVSKÁ, 1964) according to a sporomorph assemblage. Clastic material of the Hámor Fm. conglomerates contains various types of phyllites, metaquartzites, lydites, scarce granitoids and acid volcanics. Because of pre-Permian erosion and Alpine tectonic reduction, the Hámor Fm. is only preserved in relics.

3.2 Črmeľ Group

The Črmeľ Group is the lithological and stratigraphical equivalent of the lower part of the Ochtiná Fm. in the eastern part of the Gemericum. The Črmeľ Group mostly consists of low-grade metamorphosed sediments, basic volcaniclastics and sporadical acid volcaniclastics. The basal part of the Črmeľ Group tends to fining upwards and consists of a complex of medium— to fine-grained metasandstones alternating with phyllites, and sporadical acid volcaniclastics. The major part of the Črmeľ Group is formed by cyclical fine-grained metasediments associated with basic volcanics and volcaniclastics (tholeiites s. l. according to BAJANÍK in BAJANÍK et al., 1986). The intensity of volcanism decreases towards the upper part of the Črmeľ Group to be replaced by thin lenses of carbonates (partly alterated to magnesites) and occasional lydites. The top parts of the entire complex display coarsening of sediments again.

Sediments and volcanics of the Črmeľ Group underwent Variscan metamorphism (Sudetian phase). The grade of their metamorphism corresponds to the lower part of the greenschist facies of the low-pressure type (SASSI and VOZÁROVÁ, 1987).

The Črmeľ Group was dated as Tournaisian-Visean on the basis of a sporomorph assemblage (BAJANÍK, VOZÁROVÁ and SNOPKOVÁ, 1986).

When reconstructing the evolution of Carboniferous formations in the North-Gemeric zone we must consider at least two prominent breaks in sedimentation. The bed sequence is devoid of the Namurian B—C sediments and of the most part of the Stephanian sediments. Various lithological members of Carboniferous sequences of the Dobšiná and Črmeľ Groups are uncorformably overlain by Permian basal sediments of the Krompachy Group. They are represented by violet-red alluvial, polymict conglomerates. Radiometrical dating of a volcanogenic horizon overlying the basal conglomerates indicate the Upper Autunian-Saxonian age $^{206}Pb^{238}U$ — 263 Ma; $^{207}Pb/^{235}U$ — 274 Ma; NOVOTNÝ and ROJKOVIČ, 1981).

Data concerning the age of metamorphism of rock complexes from the basement of the Rudňany Fm. are most frequently indicative of the Devonian /Carboniferous boundary (CAMBEL et al., 1980; KANTOR, 1980 — K/Ar method; gneisses and amphibolites of the Klátov Gr.).

In the eastern part of the Gemericum, the Rudňany Fm. overlies unconformably the low-grade metamorphosed rock complex of the Črmeľ Group. Its age is Tournaisian-Visean. The Rudňany Fm. conglomerates contain pebbles of low-grade metamorphosed rocks from the Črmeľ Group. So the Lower Carboniferous formations of the North-Gemeric zone must have been metamorphosed in final phases of the Variscan orogeny under the condition of low temperature and low pressure. The grade of metamorphism of the Ochtiná Formation in the western part of the Gemericum is analogous, i. e. the lower part of the greenschist facies of the low-pressure type (SASSI and VOZÁROVÁ, 1987).

Discussion

Sedimentary formations of the Noetsch and Veitsch Groups in the Eastern Alps, and sedimentary formations of the Črmeľ and Dobšiná Groups in the North-Gemeric zone of the West Carpathians display following common features:

1) an approximately equal age,

2) marine shallow-sea depositional environments relatively well defined by fauna,

3) syngenetic basic volcanism, prominent in West-Carpathian Carboniferous formations (because they are better preserved) showing the character of tholeiite basalts of the orogenic type (VOZÁR in VOZÁROVÁ and VOZÁR, 1988),

4) clastic detritus originating from metamorphic and magmatic rocks as well as from low-grade metamorphosed or almost nonmetamorphosed volcanics and sediments,

5) general upward coarsening of clastic facies, associated with gradual shallowing and transition into paralic and continental depositional environments,

6) Permian continental volcanosedimentary formations (overlying unconformably the Carboniferous complexes of the North-Gemeric zone of the West Carpathians),

7) the basement whose metamorphism is radiometrically dated as Devonian or Devonian-Carboniferous.

8) In the Eastern Alps, the zone of Early Carboniferous shallow water sedimentation is contrasted by flysch-like deep water deposits in the south and a metamorphic-batholithic belt situated in the north. A similar configuration occurs in the Western Carpathians. For both, Carpathians and Eastern Alps, this zonation is explained in terms of terranes or microplates (VOZÁROVÁ and VOZÁR, 1988; FRISCH and NEUBAUER, 1989; NEUBAUER, 1988) which were differentiated after their basement evolution and evolution in Early Carboniferous times.

Bed complexes of Carboniferous formations are generally better preserved in the North-Gemeric zone of the Western Carpathians. Although they are incorporated in the Alpine nappe structure in this area, their basement and their relation to overlying Permian complexes may be defined almost completely. The complexes have been interpreted as remnants of depositional basin fillings, associated with the collision type orogeny (VOZÁROVÁ and VOZÁR, 1988). De-

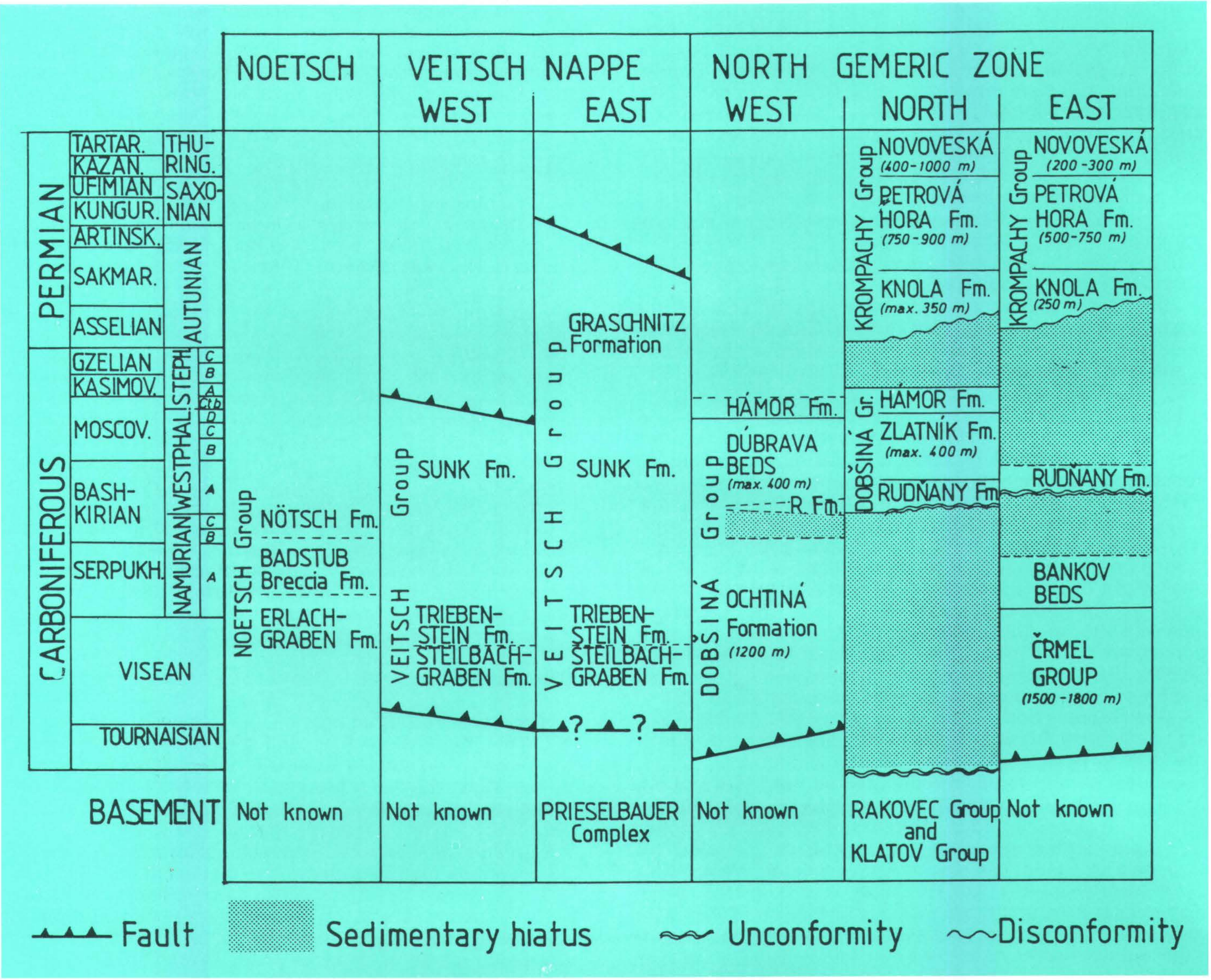

Fig. 2: The lithostratigraphic frame of sections of the Noetsch-Veitsch-North Gemeric Zone. For location of sections, see Fig. 1.

vonian metamorphism of the basement in both areas compared, and detritus originating from geotectonically different source areas — continental microplates and orogenic zone — are significant for the reconstruction of the evolution of the entire depositional zone.

Conclusions

Shallow-sea Carboniferous depositional formations of the Noetsch and Veitsch Groups of the Eastern Alps, and of the North-Gemeric zone in the West Carpathians represent remnants of depositional basins bordering the Variscan suture zone. Their origin was closely associated with the evolution of the entire orogenic zone. Tournaisian-Visean basins in the West Carpathians (the Črmeľ Group and the lower part of the Ochtiná Fm.) had the character of a remnant basin. The basinal filling was refolded and slightly metamorphosed (VOZÁROVÁ and VOZÁR, 1988). Upper Visean-Namurian and Westphalian peripheral basins bordered the new-formed suture zones. The basins are characterized by a shallow-sea depositional environment, variegated lithofacies and frequent breaks in sedimentation.

The final phase of the Variscan orogeny, characterized mainly by intense fault tectonics and gradual consolidation trend in the entire orogenic zone, resulted in Permian continental volcanosedimentary formations followed by Permian — Triassic evaporite formations.

Acknowledgements

The first author (F. N.) thanks the collegues from the Dionýz Štúr Institute of Geology for the impressive guidance through the Slovakian Ore Mountains.

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Abstrakt

Mladopaleozoická sedimentácia z výskytov v oblasti Nötsch a Veitsch vo Východných Alpách je zrovnávaná s obdobnými sedimentačnými podmienkami z oblasti Ochtinej, príp. ostatných ekvivalentných častí severogemeridnej zóny v Západných Karpatoch. Uvažovaný je jednotný plytkomorský sedimentačný priestor s morskou molasovou sedimentáciou, s narastajúcimi rífmi (alebo časťami s vývojom plytkovodných organizmov), ktoré boli prekrývané vrchnokarbónskymi, regresívnymi deltovými, deltovo-riečnymi sedimentárnymi fáciami a miestami i permskými fanglomerátmi. Pre jednotlivé časti tohoto sedimentačného priestoru bol diskutovaný devónsky metamorfný podklad. Toto sedimentačné prostredie charakterizuje sutúru medzi dvoma rozdielnymi mikroplatňami, menovite medzi metamorfovanou vnútornou zónou variskeho orogénu a vonkajšou zónou so spodnokarbónskou hlbokovodnou sedimentáciou.

Zusammenfassung

Die jungpaläozoischen Ablagerungen von Nötsch, Veitsch der Ostalpen werden mit solchen von Ochtiná und vergleichbaren Abfolgen der Nordgemeriden der Westkarpaten korreliert. Ein einheitlicher mariner Flachwasserraum mit mariner Molassesedimentation und dazwischen sich aufbauenden Riffen (oder Tells mit Flachwasserorganismen) wird postuliert, die von oberkarbonischen regressiven Delta- und Flußablagerungen und von vermutlich permischen Fanglomeraten überlagert werden. Ein devonisch metamorphosiertes Fundament von Teilen dieses Ablagerungsraumes wird diskutiert. Dieser Sedimentationsraum charakterisiert die Sutur zwischen zwei verschiedenen Mikroplatten resp. Terranes, nämlich einer metamorphen Internzone des variszischen Orogens und einer Externzone mit unterkarbonischen Tiefwassersedimenten.

BIOSTRATIGRAPHICAL EVALUATION OF WEAKLY METAMORPHOSED SEDIMENTS OF WECHSEL SERIES AND THEIR POSSIBLE CORRELATION WITH HARMÓNIA GROUP IN THE MALÉ KARPATY MTS.

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Introduction (A. Pahr)

The Wechsel mountain group in the Central Eastern Alps has aroused the attention of geologists for a long time. The reason for this may have been a particular rock assemblage and problems with its tectonic position.

After the fundamental works by H. Mohr (1911—1919) detailed studies by Faupl, Vetters, Huska, Halbmayer, Lemberger (1968—1970) have brought about important new results. Mohr's litho-stratigraphic division of the Wechsel rocks into (top to bottom) Wechsel schists and Wechsel gneiss (with the Permoskythian transgression on top) could be improved by the studies of P. Faupl (1970). His new division (Fig. 1) shows the sequence of the Wechsel gneisses at the bottom, followed by the Underlying (= Liegende) and the Overlying (= Hangende) Wechsel schists, and then, after a gap, by the ABP- (= Arkose-Breccia-Porphyroid) series (= Rotliegendes) and the Semmering quartzite (Skythian).

Recent conclusions concerning the tectonic position of the Wechsel unit have shown it as a deeper part of the Lower Austro-Alpine nappe system after a variety of attempts to find its right position in the tectonic scheme of the Eastern Alps (Fig. 2). This was possible after it had turned out that the Wechsel nappe is not restricted to the Wechsel mountain group proper but is widely spread under the overthrusted Grobgneis nappes of the Central Alpine

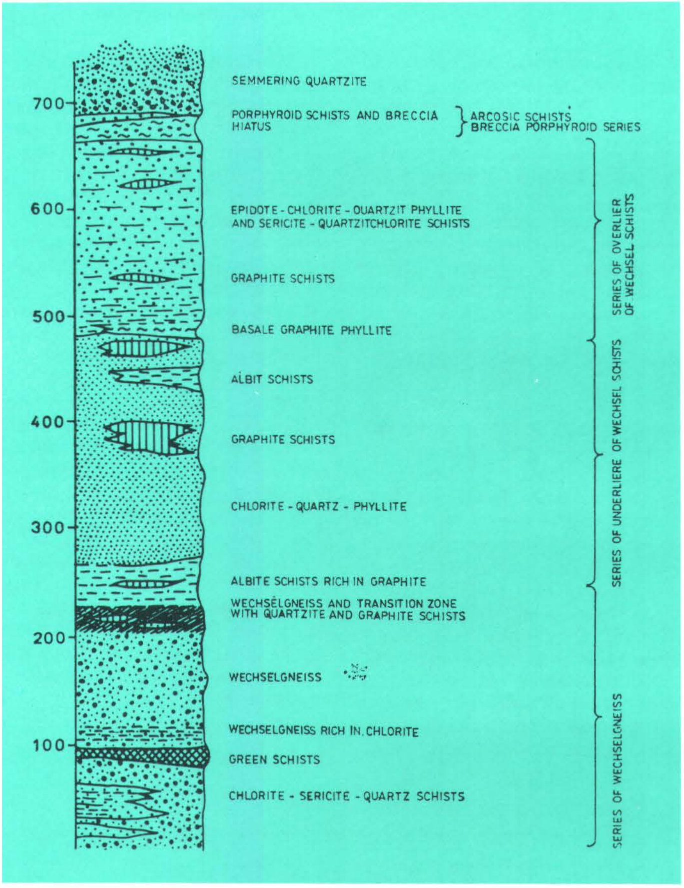


Fig. 1: Lithostratigraphic profile of the Wechsel series (after Faupl, 1970).

Zone in Austria, overlapping the Penninic in the East and emerging in several tectonic windowss below the Grobgneis nappes in the Northeast and North (Pahr 1972, Tollmann 1976).

The problem of the stratigraphic position of the Wechsel Series

Whereas there were no problems about the lithostratigraphic ranging of the overlying Permoskythian, there have only been assumptions about the stratigraphic position of the underlying Wechsel schists due to the lack of fossils. In 1907 G. A. Koch announced the discovery of Carboniferous plants north of the village Mariensee (near Aspang), but this turned out to be a mystification as H. Mohr found out and published in 1922 (on the place mentioned by Koch there is only albitic gneiss and a quartz vein cropping out!).

On the other hand H. Mohr stressed the possibility of a (late) Carboniferous age of the graphite-bearing Wechsel schists (1913). His opinion was shared by L. Kober (1912) and K. Bistritschan (1939).

In 1970 P. Faupl considered the Early Paleozoic the most probable age of the Wechsel schists after comparing them to similar Early Paleozoic rocks in the Eastern Alps and the Carpathians. His opinion is based, above all, on the basic tuffaceous intercalations in the Wechsel schists.

A. Tollmann (1957) supported the theory of an Early Palaeozoic age, whereas H. Wieseneder (1971) insisted on Late Carboniferous, because the underlying and overlying Wechsel schists were not metamorphosed (in the Quartz-Albite-Muscovite-Chlorite subfacies of the greenschist facies) before the Alpidic orogenesis. According to H. W. Flügel (1976) Wieseneder's view fits his idea of a Palaeozoic sedimentation trough of the Northern Alpine Variscan belt.

To H. P. Schönlaub (1977) the dark quartzites indicate Silurian age and so in his geological column we find the Wechsel schists ranged in the Silurian for the most part, with the top just going up into the early Devonian.

The fact, that the Wechsel unit extends much farther to the East than the "traditional" Wechsel mountain group (Pahr 1970) widened the scale of Wechsel schists and Wechsel gneisses, but could not as yet provide any proof for a stratigraphic ranging either. The occurrence of (elongated) quartz pebbles in graphitic quartzites around Bernstein could be interpreted as a hint for a (late) Carboniferous age of these rocks.

Palynological evaluation of epizonally metamorphosed sediments
(E. Planderová)

Since metasediments of the Wechsel series and of the Harmónia group in the Malé Karpaty Mts. have similar lithological characters (A. Pahr, M. Mahel', O. Miko), both complexes were palynologically studied for the purpose of age correlation.

The study was aimed at information on the age of metasediments of the Wechsel series, more precise age data on dark graphitic schists of the Harmónia group and at their correlation.

Biostratigraphical evaluation of epizonally metamorphosed sediments was based on sporomorphs and acritarchs from chloritic and sericitic phyllites and graphitic schists.

Rich palynomorph assemblages were obtained from about 50 samples from the whole Wechsel series and the Harmónia group in the Malé Karpaty Mts.

The preservation of palynomorphs shows that changes in temperature and dynamometamorphosis had only partial influence upon exines of sporomorphs. So it was possible to determine the genera, and in many cases also species of palynomorphs. Graphitization damaged exines to 40—70 %. Most sediments were affected by temperatures ranging up to 200 °C, on the locality Weinweg to 170—180 °C. Samples of sediments affected by higher metamorphosis contained palynomorphs with exines with dark graphite remains and they were regarded sterile with respect to their age.

The degree of preservation of palynomorphs indicated approximately the same degree of metamorphosis as of palynomorphs resedimented in Wechsel series and in the Harmónia group and a higher degrees of metamorphosis in chloritic and sericitic schists from the locality E of Bad Schönau (HM—1, 2).

The determination of palynomorphs was based on the modern systematic-morphological publications by A. Eisenack (1973), F. H. Cramer (1964), J. Doubinger, D. C. Raucher (1962), J. Doubinger (1968), D. C. McGregor (1973), D. C. McGregor (1977), A. Moreau-Benoit (1980), J. B. Richardson — R. Lister (1969), E. V. Tchibrikova (1972).

Wechsel area

For the above mentioned reasons the samples from the Wechsel area were repeatedly treated to get assemblages so rich in species as to enable age determination of sediments from the following cross sections:
A. Weinweg (samples 1—8)
B. Bernstein (samples 1—3)

In cross section Weinweg and Bernstein were 80 % of autochthonous Late Paleozoic palynomorphs and 20 % of palynomorphs redeposited from the Early Paleozoic rocks.

A. Cross section Weinweg

It is on a road cut N of the village Trattenbach. The cross section is in darkgrey sericitic phyllites (Fig. 3).

The sporomorph composition is as follows:

Locality 1: Wilsonia pseudopraetecta Inosova, frequent in the Upper Carboniferous (Stephanian C — Autunian base). Frequent were species of Thymospora tiessenii (Kos.) Alp, Lycospora punctata Kos. — mainly in the Stephanian — Lower Permian: and species of the genus Verrucatosporites, Florinites antiquus (Schopf.) Alp, Torispora securis Alp., Colluminisporites ovalis Peppers, Dictyotriletes reticulocingulum (Loose) Schmidt, and various species of the genus Cordaitina. The above mentioned spore assemblage is typical of the Stephanian — Lower Permian. Since the percentage of monosaccate pollen was not higher than that of trilete spores. The sediments are ranged to the Stephanian C.

Sample 3—4 contained poorly preserved sporomorphs representing the following species: Cordaitina ornata Samoil., Scabratisporites scabratus Teteriuk, Torispora securis Alp., Raistrickia sp., Florinites luberae Samoil. — species frequent in the Stephanian — Lower Permian. There were also spores of the genus Potonieisporites, Punctatisporites punctatus (Kos.) Alp. and unidentifiable species of the genus Pityosporites. Sediments from this locality are also ranged to the Stephanian C — Lower Permian.

Locality 5: Sediments of this locality did not contain any monosaccate nor bisaccate pollen; they only contained spores of Spermophyta: Punctatisporites cingulatus Alp., Apiculatisporites irregularis Alp., Punctatisporites granifer Pot. Kr., Spinosporites aff. peppersi Alp., Densosporites crassipterus (Waltz) Schwartzm., Spinosporites peppersi Alp., Punctatosporites sp., Aumancisporites sp. All the species are indicative of the Upper Stephanian.

Locality 6: The sporomorph assemblage is well preserved and diversified in species. The effect of metamorphosis on exines are minimal. The assemblage comprised Triquitrites triturgidus (Looze) Wils. et Ven. occurring in the Stephanian, Lophotriletes commisuralis (Kos.) Pot. Kr. occurring in the Stephanian B—C, Punctatosporites cingulatus Alp. occurring in the Stephanian B—C, Cordaitina sp. — in the Stephanian — Lower Permian, Wilsonia pseudopraetecta Inos. in the Stephanian C, and especially in the Lower Permian; Thymospora thiessenii (Kos.) Alp., Colluminisporites ovalis Peppers., Torispora sp. occurring mostly in the Stephanian C—D, cf. Dictyotriletes bireticulatus (Ibr.) Pot. — in the Westphalian B.

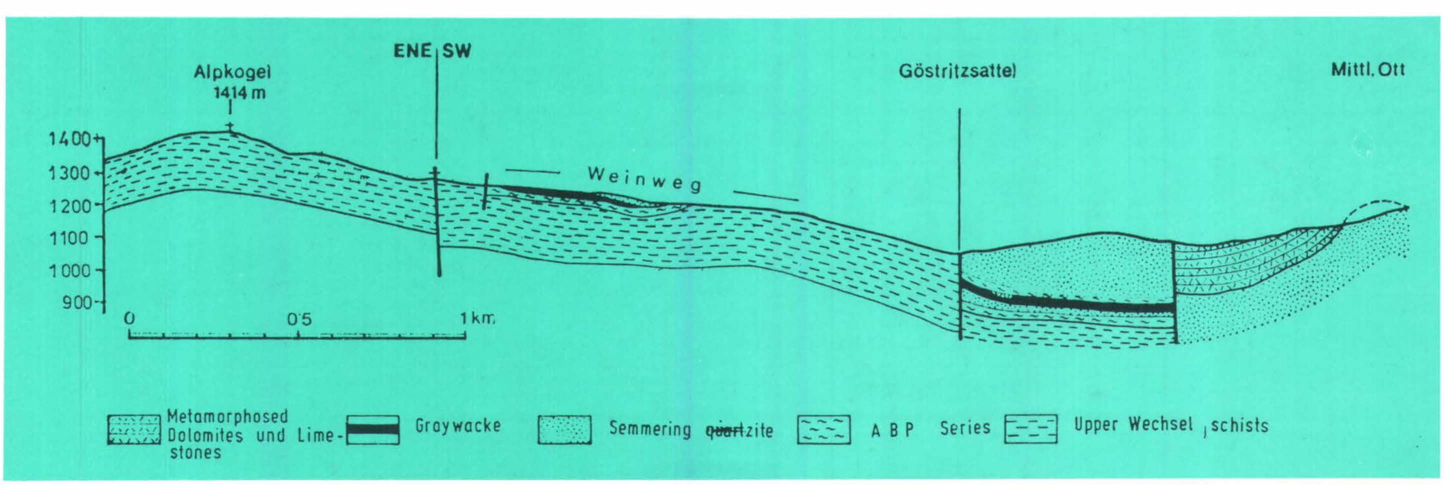
The composition of the spore-pollen assemblage and its stratigraphic range are indicative of the Stephanian — Lower Permian.

Locality 7: The sample contained well preserved sporomorphs: Lycospora cf. granulata Kos., Triquitrites peronnatus Radondy-Doub., Tripartites sp., Endosporites globiformis (Ibr.) S. W. B., Densosporites sp., Lycospora sp., Cymatiosphaera sp., Acritarcha indet. These species occur in the Upper Stephanian.

Fig. 2: Geological situation around the Wechsel group (after Tollmann, 1977).

Locality 8 is the last one in the cross section through the schistose formation at the end of the forest road to Weinweg. The sporomorph assemblage consists of Punctatosporites sp., Punctatosporites cingulatus Alp., Punctatosporites punctatus Kos. and Colluminisporites ovalis Peppers Stephanian C — Lower Permian. Limitisporites sp., Potonieisporites sp. are more frequent in the Permian. The species Illinites unicus Kos. and Colluminisporites ovalis Peppers are frequent in the Stephanian C — Lower Permian. Sediments of this locality contain mostly Lower Permian microfloral elements indicative of the Lower Permian (Fig. 4).

Fig. 3: Geological profile of Weinweg (after Faupl, 1970).

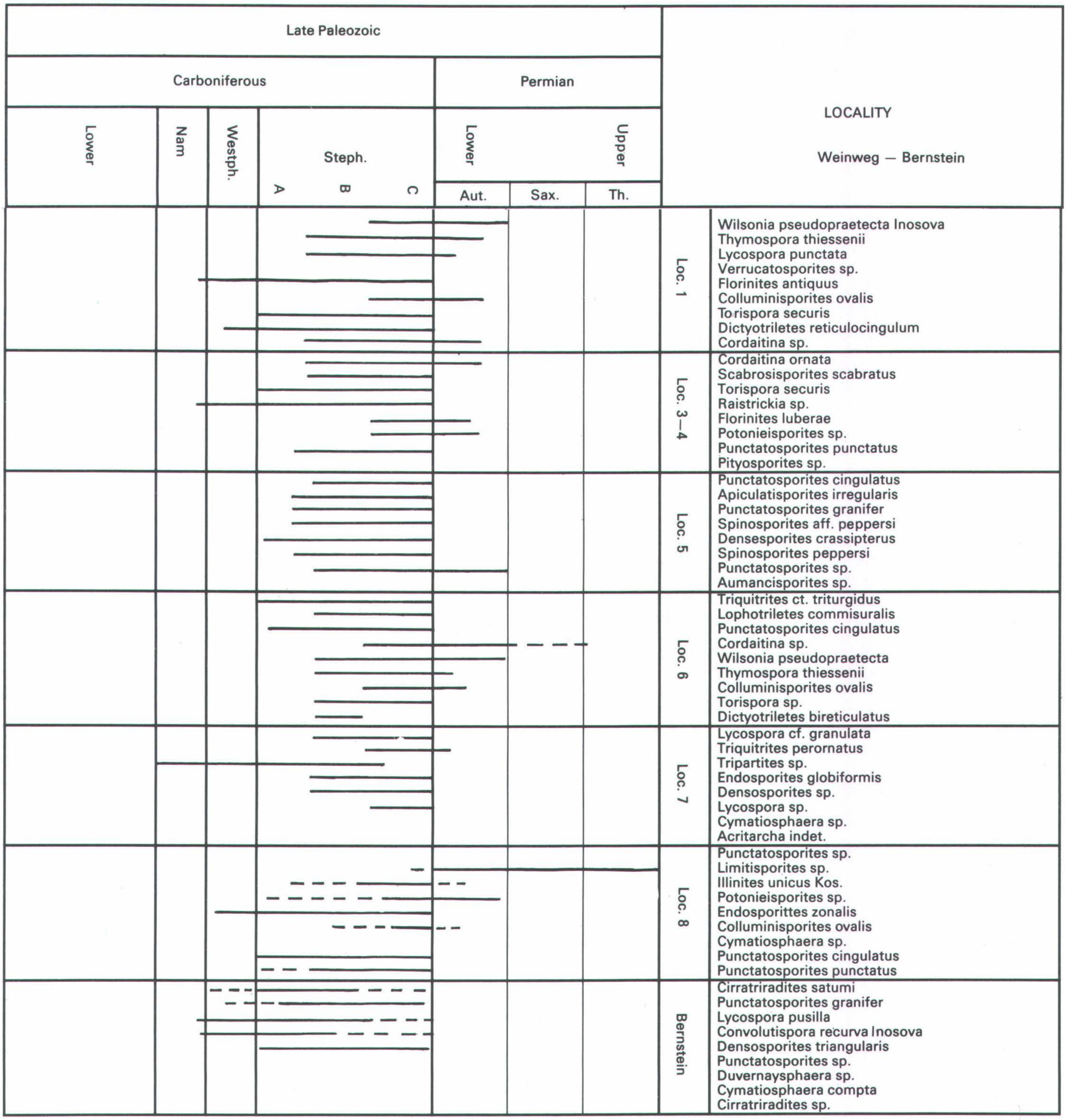


B. Locality Bernstein

The locality is in a road cut near the village Bernstein. It is in graphitic schists (Fig. 5). The degree of preservation of organic remains shows that graphitization was not extensive. The samples contained the following palynomorph species: Cirratriradites saturni (Ibr.) S. W. B., frequent in the Upper Carboniferous, mainly in the Stephanian; Punctatosporites granifer (Pot. Kr.) Alp., occurring in the Stephanian, Lycospora pussilla Alp., — occurring in the Stephanian, Convolutispora recurva Innosova — in the Stephanian B—C, Densosporites triangularis (Kos.) Alp., occurring in the Stephanian B—C, Punctatisporites sp., Cirratriradites sp. The sea plankton was represented by Duvernaysphaera sp. and Cymatiosphaera compta resedimented from the Early Paleozoic. These species are indicative of the Stephanian age of sediments of this locality. They are related microfloristically to samples from Weinweg loc. 5.

The biostratigraphical evaluation of sediments from cross section Weinweg and Bernstein proves that they were deposited in the Late Paleozoic time. According to microflora the Upper Permian and the uppermost part of the Lower Permian age is excluded, and the sediments from the localities 1—7 are Stephanian B — Stephanian C in age. Sediments from the locality 8 might already be ranged to the base of the Permian.

Fig. 4: Abundance of palynomorphs in the samples of profile of Weinweg and Bernstein.



From paleoecological viewpoint these sediments were deposited most likely in a shallow marine environment. Spores of Spermophyta are indicative of a humid swamp zone. The low percentage of cordaite and bisaccate pollen indicates a higher relief distant from the sedimentation area. The locality E of Bad Schönau (Fig. 2 point 4) was also palynologically studied.

Area of the Malé Karpaty Mts. (Harmónia group)

Locality Pezinok. Palynological data on the Harmónia group resulted from the study of many samples from several localities. Most important are the localities of a quarry near the road to Pezinská Baba. Čorná (1968) studied samples from localities in Lamač and presented biostratigraphical data also on the Harmónia group. On the basis of study of cuticles, she ranged the rocks to Silurian — Devonian.

Detailed examination of samples from the Harmónia group revealed a rich palynomorph assemblage mostly composed of acritarchs. It consisted of the following species: Rhabdosporites langi (Eis.) Rich., occurring in Lower — Middle Devonian, Dictyotriletes emsiensis (Alen) McGregor — in Lower — Middle Devonian, Dibolisporites echinaceous (Eis.) Rich., Lower — Middle Devonian, Dibolisporites sp., Verrucosisporites pseudospinosus Streel — Middle Devonian, Retusotriletes triangulatus Streel — end of Middle Devonian, Stenozonotriletes extensus Naum. — Middle Devonian, Emphanisporites minutus Allen — Lower Devonian, Hymenozonotriletes sp. Raucher — Lower Devonian, Azonomonoletes usitatus Tschibr. — end of Lower Devonian, Acritarchs were represented by the species Micrhystridium lapellum Loebl., Wic. from Upper Silurian — Lower Devonian, Cymatiosphaera nebulosa Downie — end of Silurian and base of Devonian, Cymatiosphaera leonensis Cramer — end of Silurian, Cymatiosphaera sp. Raucher — end of Silurian — Lower Devonian, Quadratidium fantasticum Cramer — Lower — Middle Devonian, Discina asperella Tschibr. — Lower Devonian, Acantodiacrodium sp. "2" Martin — Upper Devonian, Duvernaysphaera tennuicingulata Stapl. — Lower Devonian, Dictyopsophosphaera polygona (Stapl.) Tschibr. — Lower Devonian, Pulvinosphaeridium deunffi Moreau-Benoit — Lower — Middle Devonian, Ammonidium loriferum Deunff. — Lower Devonian, Ammonidium rigidum (Deunff.) Lister, Ammonidium sannemani Deunff. — Lower Devonian, Ammonidium cf. allciteaui (Deunff.) Moreau-Benoit — end of Silurian — Lower Devonian, Baltisphaeridium tuberosum Sanneman — Lower — Middle Devonian, Tunisphaeridium cf. tentloculoferum (Martin) Eis. — Lower — Middle Devonian, Pterospermella pernambucensis (Britto) Eis. — Lower — Middle Devonian, Onandogella deunffi Cramer — Upper Silurian — Lower Devonian, Riculosphaera fissa Loebl. et Drugg — Upper Silurian — Lower Devonian, Moyera uticansis Thusu — Upper Silurian — Lower Devonian, Evittia granulatispinosa (Down.) Lister — Upper Silurian — Lower Devonian, Multiplicisphaeridium raspa (Cramer) Eis. — Silurian — Lower Devonian, Multiplicisphaeridium ramusculosum (Deunff.) Eis. — Lower — Middle Devonian, Multiplicisphaeridium cf. rabiosum Cramer — Upper Silurian — Lower Devonian, Lagenochitina — Silurian — base of Devonian. On the basis of the plentiful palynomorphs and their age dispersion we can range the metamorphosed sediments of the Harmónia group to the Lower Devonian.

On the age of epizonally metamorphosed sediments

The existing opinions about the age of sericitic, chloritic and graphitic schists of the Wechsel series were contradictory, not reasoned by paleontological data. Metamorphosed sediments were regarded as unfossiliferous "barren". We have collected palynomorphic material by palynological method and on the basis of the material we can determine the age of the sediments under study. The age determination of metasediments was complicated by the character of rocks, by destruction of palynomorph exines by metamorphosis, and particularly by a high percentage of resedimented palynomorphs in some cross sections. Repeated sampling and treatment of probes, determinations on the basis of plentiful palynological literature showed that cross sections Weinweg and Bernstein are most suitable for the age determinations of sediments.

a) Samples from the profiles contained well preserved Stephanian — Lower Permian sporomorph assemblages and a low percentage of redeposited palynomorphs from the Silurian — Lower Devonian (mainly plankton).

The Upper Permian age is denied by the sporomorph assemblage without typical Upper Permian species especially monosaccate and bisaccate pollen.

b) Weakly metamorphosed sediments of the Harmónia group in Malé Karpaty Mts. are ranged to the Lower Devonian on the basis of the palynomorph assemblage.

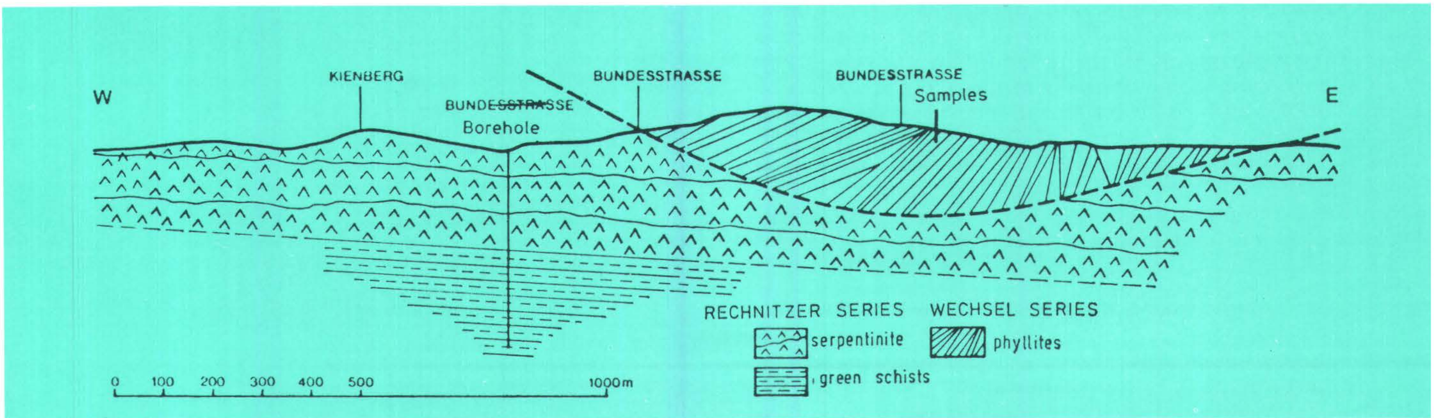
Possible correlation between sediments of Wechsel series and of Harmónia group in Malé Karpaty Mts.

The results of our study show that in spite of the possibility of lithological correlation, the existing data are not sufficient for biostratigraphical correlation between metasediments of the Wechsel series and of the Harmónia group.

Redeposited Silurian-Devonian palynomorphs from cross section E of Bad Schönau (HM—1, 2, WS—8, WS—9) may be correlated with palynomorphs of the Harmónia group; i. e. the original Silurian-Devonian sediments may be correlated to phyllites of the Harmónia group.

The question remains open for further lithological, petrographical and palynological investigations.

Fig. 5: Geological profile of Bernstein East (after Pahr, 1983).



Biostratigraphical study of sediments in these areas may result in new data on age and enlighten the relationship between the Alpine and Carpathian systems. At the present state of our knowledge it would be better to correlate the Harmónia group with the Gemeric Paleozoic (perhaps the Gelnica group).

Paleoecological evaluation

With respect to paleoecology we take into conciderationthe depositional environment, i. e. a) the water environment, and b) the terrestrial environment with plants producing pollen and spores transported to the places of sedimentation by wind and water. Significant are the distance of the respective localities from dry land and climate (temperature, humidity).

Palynological research of metasediments also revealed paleoecological conditions

a) Silurian — Lower Devonian period in Malé Karpaty Mts. There was a marine depositional environment with dominant marine plankton of Dinoflagellata and Acritarcha, and less terrestrial plants. The deposition proceeded further from dry land. Destruction of spore exines and of Acritarcha shows that the degree of metamorphosis must have been higher in the Malé Karpaty Mts. than in the Graz Paleozoic.

b) Upper Carboniferous Stephanian C to lowest Permian. Cross section of the Wechsel series contained palynomorph assemblages with dominant spores and pollen of terrestrial plants, mostly Pteridophyta growing on humid swampy substrata in favourable climatic conditions. It is likely, that the localities of the Wechsel series — although deposited in a marine environment — were not far from dry land with plentiful Pteridophyta and Arthrophyta. The lack of coniferous saccate pollen indicates flat dry land relief.

Redeposition of Early Paleozoic palynomorphs into sediments of the Wechsel series may indicate restless depositional environment.

Palynological conclusions

Palynological research of lithologically similar, epizonally metamorphosed sediments results in the following conclusions:

a) The Late Paleozoic (Stephanian C — the lowest Permian) age of sericitic, chloritic and graphitic schists of the Wechsel series was determined reliably for the first time.

b) The age of the Harmónia group is Lower Devonian.

c) It is not yet possible to correlate metasediments of the Wechsel series with the Harmónia group.

Biostratigraphical research of weakly metamorphosed sediments by palynological methods may result in reliable information on the age of sediments so far referred to as fossilless. The study is enabled by exine resistance to all kinds of metamorphosis except that of high degree. This is proved by our results, and by data collected in the Carpathians in the past decade. The relation of metamorphism to preservation of fossil organisms in sediments is now studied all over the world with respect to chemical structure of sporopollenine and to biostratigraphical and geological facts.

The submitted results are the first and will be further complemented and precised by detail palynological research of a complete cross section in the Malé Karpaty Mts. and of some units of the Alpine system.

Geological conclusions (A. Pahr)

A geological evaluation of the palynological results shows that we have Late Carboniferous — Lower Permian schists in the topmost branch of the Wechsel schists in the "traditional" Wechsel mountain group (Nr. 3, Weinweg), and we also have palynomorphs of the same age outside of it (Nr. 5 east of Bernstein).

The occurrence of early and late Paleozoic in this profile can be explained in two ways:

1) There are schists of early Paleozoic age in (deeper) parts of the Wechsel schists and the sequence is tectonically piled up in the profile.

2) We have late Paleozoic (Upper Carboniferous — Lower Permian) age in the whole sequence, with a lot of early Paleozoic palynomorphs resedimented in the younger formation.

Both possibilities may occur in different places. At present no decision in this problem is available, further detailed investigation will have to decide it.

The authors are quite aware that all the work done by them up to now, is just a first step in the research of a region, which was, for the most part, devoid of fossils, but nevertheless seems important for structural problems in this part of the Eastern Alps and Little Carpathians.

As to the correlation of the Wechsel group with the Harmónia group in the Little Carpathians detailed geological and petrological correlation is necessary and is being planned.

In this respect it should be mentioned that recently the Borinka limestones and Marianka schists are thought to represent the Penninic zone of the Eastern Alps (without ophiolites) and that they are overthrust by the rocks of the Pezinok — Pernek unit or by the Bratislava granitoids and their cover schist respectively (Pahr 1983). D. Plašienka (1986) gave a refined picture of the Borinka unit: He subdivided it into four lithostratigraphic subunits: Prepadlé — Korenec — Marianka — and Somar formations, all of Jurassic to Lower Cretaceous age. He assumes that the sedimentation of these units occurred in southern marginal zones of the Penninic oceanic trough. In this publication the granitoids of Bratislava are shown in overthrusting position in profiles and maps.

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Abstrakt

V práci sa jedná o palynologickom výskume slabometamorfovaných sedimentov wechselskej série v Rakúsku a sedimentov harmónskej skupiny v Malých Karpatoch. Litologicky majú obe série veľa spoločných znakov. Palynologickým výskumom sa mala potvrdiť aj ich veková identita. Zistili sme, že metasedimenty wechselskej série obsahujú sporomorfy mladopaleozoického veku stefan C — spodný perm (Torispora securis Alp., Colluminisporites ovalis Pepp., Cordaitina div. sp. a iné). Palynomorfy z harmónskej skupiny Malých Karpát obsahovali rody a druhy hlavne zo skupiny Acritarcha veku vrchný silúr — spodný devón (Emphanisporites minutus Allen, Cymatiosphaera nebulosa Down., Duvernaysphaera tenuicingulata Stapl. a iné). Tým sa preukázalo, že vek metasedimentov wechselskej série neodpovedá veku metasedimentov z harmónskej skupiny Malých Karpát.

Zusammenfassung

Die vorliegende Arbeit behandelt die palynologische Untersuchung von gering metamorphen Ablagerungen der Wechsel-Serie in Österreich und der Ablagerungen der Harmónia-Serie in den Kleinen Karpaten. Lithologisch betrachtet gibt es viele Ähnlichkeiten in den beiden Serien. Durch palynologische Untersuchung sollte man auch deren Altersidentität bestätigen. Wir haben festgestellt, daß die Metaablagerungen der Wechsel-Serie die Sporomorphen des jungpaläozoischen Alters Stefan C — Unterperm (*Torispora securis* Alp., *Colluminisporites ovalis* Pepp., *Cordaitina* div. sp. und andere) beinhalten. Die Palynomorphen der Harmónia-Serie der Kleinen Karpaten enthielten Familien und Arten vor allem aus der Gruppe Acritarcha des Alters Obersilur — Unterdevon (*Emphanisporites minutus* Allen, *Cymatiosphaera nebulosa* Down., *Duvernaysphaera tenuicingulata* Stapl. und andere). Dadurch wurde festgestellt, daß es nach derzeitiger Kenntnis keine Altersübereinstimmung zwischen den Metasedimenten der Wechsel-Serie und denen aus den Kleinen Karpaten gibt.

BIOSTRATIGRAPHY OF THE VLÁRA DEVELOPMENT OF THE BÍLÉ KARPATY UNIT ON THE BASIS OF CALCAREOUS NANNOFOSSILS

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The Bílé Karpaty Unit is situated in the area of the Bílé Karpaty Mts., on the boundary between Moravia and Slovakia. The sediments are characteristic by conspicuous facial changes both in the transverse and longitudinal direction. On the basis of these changes Matějka and Roth (1956) defined two lithostratigraphic units from the bottom to the top: 1. the lower part of the Paleogene represented namely by variegated beds; 2. the upper part of the Paleogene represented by flysch beds with noncalcareous claystones and flysch beds with calcareous claystones. In the upper part of the Paleogene they delimited three developments: the Vlára, the transitional and Hluk developments. Micropaleontologic part in the work of Matějka and Roth was written by E. Hanzlíková.

The concept of the Bílé Karpaty Unit structure of Stráník, Krejčí and Menčík (1988) is based on the classical division of Matějka and Roth. They proposed some changes in the upper part of the Paleogene and gave up the theory of an independent status of the transitional development. They delimited a new lithofacial member — the Kopanice development — along the Klippen Belt (Fig. 1).

This contribution deals with the biostratigraphy according to the calcareous nannofossils in the Vlára development of the Bílé Karpaty Unit.

Matějka and Roth (1956) defined the Vlára development as the beds of the upper part of the Paleogene with finely to medium rhythmic flysch with prevalence of sandstones. Stráník, Krejčí and Menčík (1988) include into the Vlára development the Gbely variegated beds as the oldest component, which according to Hanzlíková (1984) and Švábenická (1986) belong to the Cenomanian till lower Paleocene. Above them lie finely to medium rhythmic flysch beds which were established as a new stratigraphic member — the Javorina Formation — by Stráník, Krejčí and Menčík (1988). The flysch beds with calcareous claystones — the Svodnice Formation — are the youngest component (Pesl 1968).

Calcareous nannofossils were determined in all calcareous sediments of the Vlára development of the Bílé Karpaty Unit. Taphocenoses usually showed a greater species diversity and contained forms which permitted to asses the relative age within stages to zones precision (see Fig. 2). Only on the basis of nannofossils it was possible to distinguish which sediments were of Cretaceous and which of Paleogene age. Parallelly studied microfauna contained agglutinated foraminifers and very rarely minute plankton. Their species composition usually indicated a wider stratigraphic range from the upper Senonian to the Paleogene.

The Gbely Member is marked by a dominant development of red-brown noncalcareous claystones. The red and greenish calcareous claystones and marlites of the Santonian and the Campanian to Maastrichtian which form thin layers and intercalations, testify of fading of the variegated calcareous sedimentation of the Gbeľany Member towards NW, with the growing distance from the Klippen Belt. The age of the Gbely Member was determined on the basis of agglutinated foraminifers as the Cenomanian to upper Senonian with a possible overlap to the lower Paleocene (Stráník, Krejčí and Menčík 1988).

In the variegated calcareous claystones of the Gbely Member (Vlára development of the Bílé Karpaty Unit) there were determined nannofossil taphocenoses of Santonian — Campanian — Maastrichtian age without Paleogene indications. The oldest nannoplankton assemblage with Reinhardtites anthophorus, Lithastrinus grillii, Micula decussata, Marthasterites furcatus and Einffellithus eximius corresponds to the lower Santonian CC15 Zone (sensu Sissingh 1977). In the Campanian and Maastrichtian a gradual appearance of the following stratigraphically important species can be observed: Aspidolithus parcus parcus, A. parcus constrictus, Arkhangelskiella specillata, Ceratolithoides aculeus, Quadrum sissinghii, Q. trifidum, Arkhangelskiella cymbiformis, Prediscosphaera grandis, Lithraphidites quadratus, Micula murus, Nephrolithus frequens and very rarely Micula prinsii. The youngest established sediments of the Gbely Member belong to the CC26 Zone (the highest part of the Maastrichtian).

The Javorina Formation is a complex of finely to medium rhythmic flysch sediments characterized by blue-grey, fine- to coarse-grained calcareous greywacke sandstones and green-grey to grey, usually noncalcareous and variably sandy claystones. This formation exhibited nannoplankton taphocenoses of Campanian to Maastrichtian age without Paleogene indications (the same as in the Gbely Member). In the flysch sediments of the Td and Te intervals (sensu Bouma 1962) altogether 65 species were determined (Švábenická, in press).

According to the fossil record the sedimentation of the Javorina Formation started in the lower Campanian (Aspidolithus parcus Biozone – see fig. 2) and continued together with the Gbely Member to the upper Maastrichtian including the Nephrolithus frequens CC26 Biozone. Simultaneously studied microfauna contained only agglutinted foraminifers of a broader stratigraphic range the Upper Cretaceous – Paleocene.

In the Gbely Member and the Javorina Formation the classical Sissingh's (1977) zonation could not be applied in its full extent due to their divergent biofacial development. In both these lithotypes the calcareous nannoplankton taphocenoses exhibit the following common features: 1. They have no Paleogene indications; 2. Within the Campanian – Maastrichtian the species composition is almost identical; 3. There can be delimited identical nannoplankton biochrons; 4. The topmost Maastrichtian CC26 Zone Nephrolithus frequens with rare Micula prinsii has been documented.

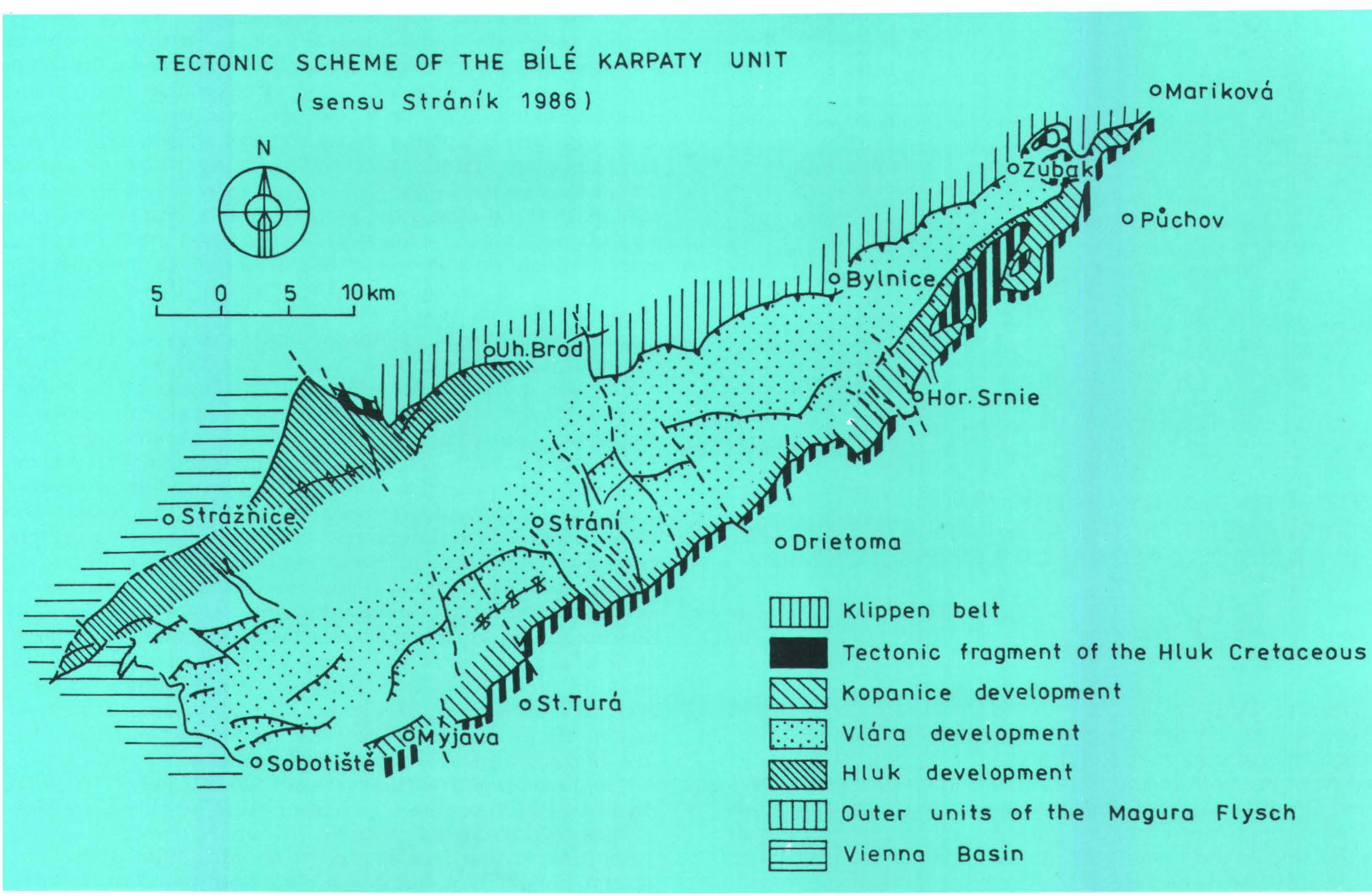
The Svodnice Formation is stratigraphically the uppermost member of the Bílé Karpaty Unit. It is formed by flysch beds with blue-grey fine-grained calcareous, often convolutedly laminated sandstones and by calcareous claystones similar to the Vsetín type of the Zlín Formation and marlites of the Lackov type (Pesl 1968). The Svodnice Formation exhibited a different microfauna and calcareous nannoplankton development compared with the Javorina Formation and Gbely Member. The microfaunas contained, beside agglutinated foraminifers, occasionally also calcareous plankton and benthos and attested to the similar relative age of the rocks as the calcareous nannofossils.

Calcareous nannoplankton (47 species) documents lower Paleocene to lower Eocene age of the Svodnice Formation. The taphocenoses contain species of standard nannoplankton Zones ?NP1 – NP2 to NP11 (sensu Martini 1971). The beginning of the sedimentation is characterized by a very poor nannofossil association with a small and big forms of Cruciplacolithus primus, Markalius inversus, Thoracosphaera operculata, Placozygus sigmoides, Braarudosphaera bigelowii and in the NP2 Zone Cruciplacolithus edwardsii, C. tenuis and Ericsonia subpertusa. Biantholithus sparsus has not been determined yet in these sediments. The sedimentation continued probably without a significant interruption to the lower Eocene. The nannofossil taphocenoses of the Svodnice Formation are characteristic by numerous redepositions from the Upper Cretaceous. Redeposited Paleogene material is very rare in the Paleocene and lower Eocene.

According to the micropaleontologic data we may expect sedimentation without any significant interruption at the Cretaceous/Tertiary boundary in the sediments of the Vlára development of the Bílé Karpaty Unit. In the upper Maastrichtian CC25b Lithraphidites quadratus and CC26 Nephrolithus frequens nannoplankton Zones (sensu Sissingh 1977) were documented and already in the lower Paleocene the ?NP1 – NP2 biochrone (sensu Martini 1971) with Cruciplacolithus primus, C. edwardsii, C. tenuis, Thoracosphaera heimii, T. saxea and Ericsonia subpertusa were found.

The Cretaceous/Tertiary boundary is "survived" by five species in the Bílé Karpaty Unit: Braarudosphaera bigelowii, Markalius inversus, Cyclagelosphaera reinhardtii, Placozygus sigmoides and Thoracosphaera operculata.

Fig. 1: Tectonic scheme of the Bílé Karpaty Unit



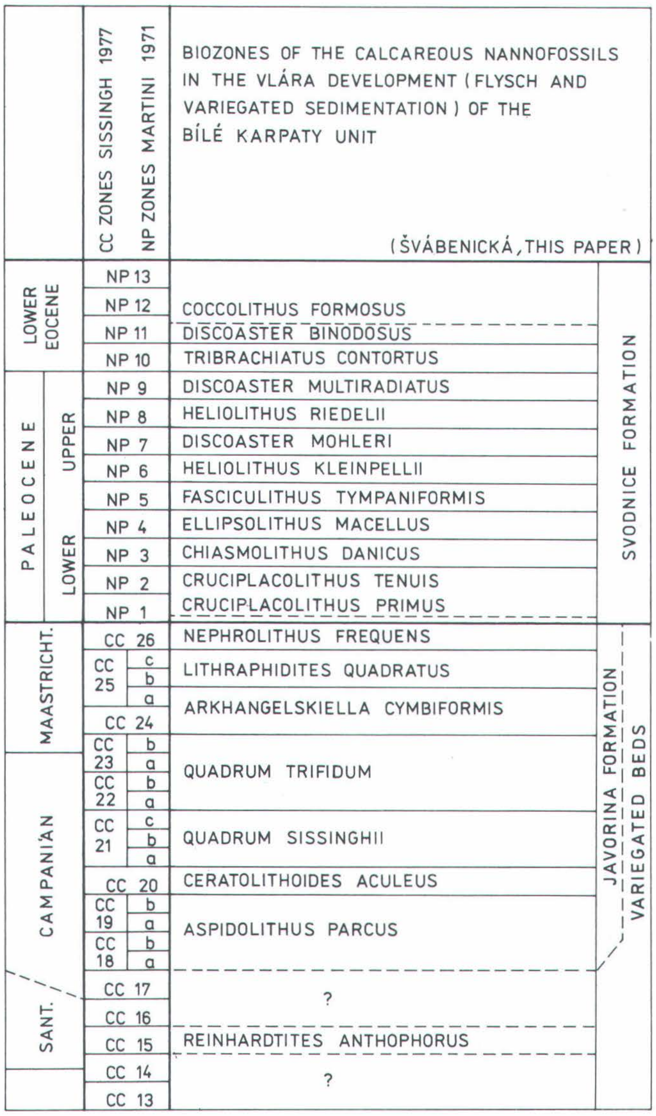


Fig. 2: Biozones of the calcareous nannofossils in the Bílé Karpaty Unit.

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Abstrakt

V sedimentech vlárského vývoje bělokarpatské jednotky (flyšové sedimenty a pestré vápnité jílovce) byla zjištěna relativně dobře zachovaná společenstva vápnitého nanoplanktonu s vyšší druhovou diverzitou. Tafocenózy nanofosilií obsahují stratigraficky důležité druhy, pomocí kterých můžeme stanovit relativní stáří s přesností na stupně až zóny v rozmezí santon—spodní eocén. Na hranici křída/terciér předpokládáme sedimentaci bez velkého přerušení.

Zusammenfassung

In Sedimentgesteinen der Vlára-Entwicklung der Bílé Karpaty- (Weißkarpaten-) Einheit (Flyschablagerungen und bunte Kalktonsteine) wurden verhältnismäßig gut erhaltene Vergesellschaftungen des kalkigen Nannoplanktons von einem größeren Artenreichtum ermittelt. Die Taphozönosen der Nannofossilien enthalten stratigraphisch wichtige Arten, aufgrund deren das relative Alter mit einer Genauigkeit auf Stufen bis Zonen in der Zeitspanne von Santon bis zum Untereozän bestimmt werden kann. An der Kreide/Tertiär-Grenze nehmen wir die Sedimentation ohne eine größere Unterbrechung an.

GRANITOID CLASTICS ON THE SE MARGIN OF THE VIENNA BASIN AND BASIN GENESIS

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Breccias and conglomerates on the southeastern margin of the Vienna Basin — on the foothill of the Malé Karpaty Mts. — mostly consist of granitoid material. They crop out at the village Borinka and between the villages Stupava and Lozorno. They were revealed in a surprising thickness by the borehole DNV—1 near Devínska Nová Ves (Vaškovský et al. 1988). Other boreholes show their wedging-out over a shorter distance towards the inside of the Vienna Basin i. e. southwestwards of their outcrops.

The borehole DNV—1 near the brick-kiln of the village Devínska Nová Ves (Fig. 1) drilled the granitoid conglomerates and breccias in total thickness of about 330 m and offered thus biostratigraphical scissors for the determination of age of the clastics studied (Fig. 2). Granitoid clastics are overlain by calcareous friable siltstones and claystones including sandstone layers. The sediments are equivalent to the Studienka Formation of the Vienna Basin and contain Upper Badenian (Kosovian) foraminifers of the Bulimina — Bolivina and Rotalia zone, including the species Bulimina elongata, Bolivina dilatata, Uvigerina venusta liesegensis (Kyjovská — Kučerová 1986). The calcareous nannofloral assemblage comprises species most frequent in Upper Badenian: Cyclococcolithus macintyrei, Cycloperfolithus carlae, Helicosphaera wallichi, H. walsberdorfensis, H. selli, H. obliqua, Sphenolithus abies. The index species of the zone NN 6 — Discoaster exilis is scarce as well as the index species of the zone NN 7 denoted as Discoaster cf. kugleri (Lehotayová 1986) in the upper part of the formation.

The granitoid clastics are underlain by conglomerates with plentiful pebbles of Mesozoic carbonates with pelite layers containing calcareous nannoflora including the index form of the zone NN 5: Sphenolithus heteromorphus, and Discoaster variabilis and Coronosphaera sp. (Lehotayová l. c.). So the age of the granitoid clastics may be Middle Badenian.

Detailed lithological and sedimentological study of the clastics was performed on two natural exposures near Borinka and Lozorno, and in the borehole DNV—1 near Devínska Nová Ves.

On the northern periphery of the village Borinka — in a gorge — with a forest path and a tourist route to the

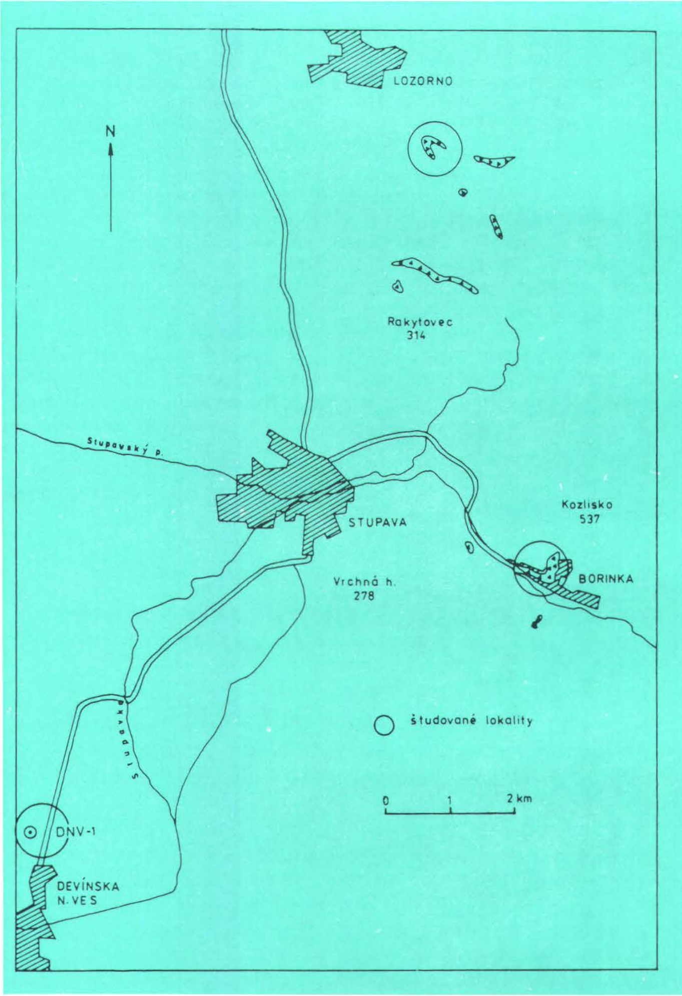


Fig. 1: Sketch of localities of Devínska Nová Ves Formation. Localities studied are in circles.

Pajštún castle ruins, and in gorges cutting the piedmont terrace NE of Stupava there are monomict granite breccias consisting of chaotical angular granitoid blocks.

In the mentioned forest road cut on the northern periphery of the village Borinka the breccias consisting (in about 95 %) of granitoid material are exposed. The diameter of largest blocks ranges to 1.5 m. The granitoid blocks are angular and their distribution is chaotic (Fig. 3). Usually the blocks are unsupported and matrix represents the supporting structure. Blocks of muscovite-biotite- and of two-mica granodiorites are dominant. Frequent are blocks of muscovite-biotite granites whereas blocks of biotite granites and fragments of aplite muscovite granites are infrequent. Vein varieties like muscovite aplites and pegmatites occur sporadically. Granitoid blocks and fragments underwent medium- to intrusive cataclastic metamorphosis. They are intensely weathered. Feldspars are intensely sericitized, kaolinized; epidotization was less intensive.

Metamorphites are represented by sporadical metapelites and metapsammites, biotite mica-schist gneisses and paragneisses. Clasts of these rocks are intensely weathered.

Matrix is silty-sandy, with a high muscovite content, noncarbonatic or partly carbonatic, unsorted, visually resemblant to granite material. It represents the washed material of fossil weathering crust on crystalline, mostly granitoid rocks.

In the entire profile studied near Borinka the granitoid blocks and pebbles are intensely weathered. The strength of considerably friable matrix and of the most part of weathered granite blocks and of crystalline schists is practically equal.

The exposure near the village Lozorno is now inundated with water of an artificial water reservoir. There are two layers of coarse clastics separated by a coarse-sandy layer containing well-rounded granitoid pebbles up to 2 cm in size (Fig. 4). The coarse clastics resemble the granitoid clastics from Borinka. Blocks range up to 80 cm in diameter. They are angular or poorly rounded. The composition of clasts is somewhat more variable than in Borinka. Besides dominant granitoids there are also metamorphic rocks (10 %), Lower-Triassic quartzites clasts (5 %). Among granitoids most frequent are medium- to coarse-grained muscovite-biotite- and biotite granodiorites. Medium-grained, two-mica and aplitoid muscovite granites are also frequent. Metamorphic rocks are mostly represented by clasts of metapelites-phyllites, sandy metawackes and mica-schist gneisses with indications of periplutonic metamorphism.

Lower Triassic quartzite fragments are epimetamorphosed. There is a unique occurrence of most likely Neogene fine-sandy siltstone with clastic mica. The siltstone clast is an evidence of intraformational cannibalism — common in rocks of the analogous type. The grain-supporting matrix surrounding the blocks, is gravelly-sandy, nonsorted, composed of granitoid material with infiltrations of Fe-oxides.

Clastic material is distributed chaotically, without indications of imbrications or arrangement of blocks. Blocks are smaller there than at the locality Borinka. The material is less weathered in lower parts of the exposure, in upper parts the extent of weathering is similar to that at Borinka.

Weathering of blocks and pebbles of granitoids and crystalline rocks is typical of both localities described.

Intensely weathered angular granitoid blocks must inevitably disintegrate to sand and fine debris when falling down the rock cliffs during their transport of any kind. The weathering process must have followed the deposition of breccias. It is also proved by the results of a comparison of mineral composition of the clay fraction of weathered granitoid blocks and of matrix from both localities studied.

Clay minerals of grain-size fraction < 0.002 mm from weathered granitoid blocks at Borinka are represented by kaolinite and illite. In some samples kaolinite evidently dominates over illite. Kaolinite has also been found in the clay fraction from granitoid blocks from the locality Lozorno with dominant illite. It is absent at both localities or montmorillonite is present there in a small amount.

Mineral composition of the clay fraction of matrix from both localities is different from the composition of clay minerals from weathered granitoid blocks. Montmorillonite and illite predominate at the locality Borinka. Kaolinite with partly ordered structure is actually an admixture. Mineral composition of clay fraction of matrix from Lozorno is analogous. Minerals from weathering crusts preserved on granitoids and crystalline schists of the Malé Karpaty Mts. (Kraus 1986, Kraus in Vass et al. 1988) have a similar composition.

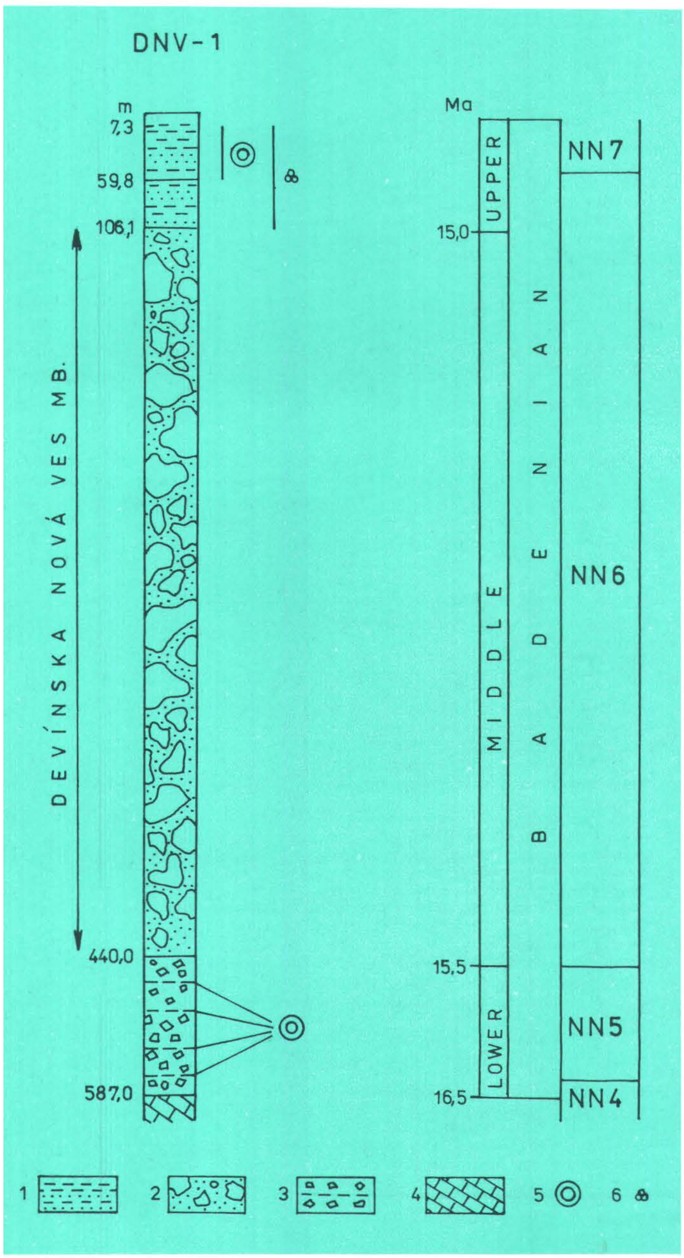
So the weathering crusts preserved on crystalline complexes of the Malé Karpaty Mts. are fossil. They most likely formed before the Middle Badenian time. Clay minerals of weathering crusts and of matrix of Badenian clastics have a similar composition, mostly containing montmorillonite. Redeposition of granitoid blocks of Badenian clastics was followed by exposure and weathering resulting in preferred formation of kaolinite. Granitoid clastics buried, for example, in borehole DNV—1 protected with a 100 m thick layer of mostly impermeable sediments, were not affected by weathering processes.

About 330 m thick granitoid clastics were drilled by borehole DNV—1 near Devínska Nová Ves. Blocks and pebbles of Malé Karpaty Mts. granitoids, and of analogous types like in Borinka and Lozorno are dominant (85—90 %). Pegmatite fragments are interestingly variable. The clastic material contains almost all types of pegmatites known from the Malé Karpaty Mts.

Among metamorphites are common metapelites and metapsammites, frequently affected by metamorphism — biotite mica-schist gneisses to paragneisses, phyllites, metamorphosed wackes and metabasites, metatuffs — mainly various types of amphibolites and actinolite phyllites. Less frequent are clasts of contact-metamorphosed rocks of the Harmónia Group and sporadical graphite metaquartzites. At present similar rocks only occur on the north around Kuchyňa (Putiš 1987) in the Bratislava Massif.

An approximately 200 m thick upper part of the Devínska Nová Ves member consists excludingly of crystalline rock clasts. Fragment of Lower Triassic quartzites appear in the borehole at the depth of about 300 m and their amount in-

Fig. 2: Schematical section of Devínska Nová Ves member in borehole DNV—1, and position of biostratigraphically dated layers in their overlier and underlier. 1 — calcareous clays and sands, 2 — granitoid clastics, 3 — polymict clastics, 4 — underlying Mesozoic sediments, 5 — calcareous nannoflora, 6 — foraminifers. ▼



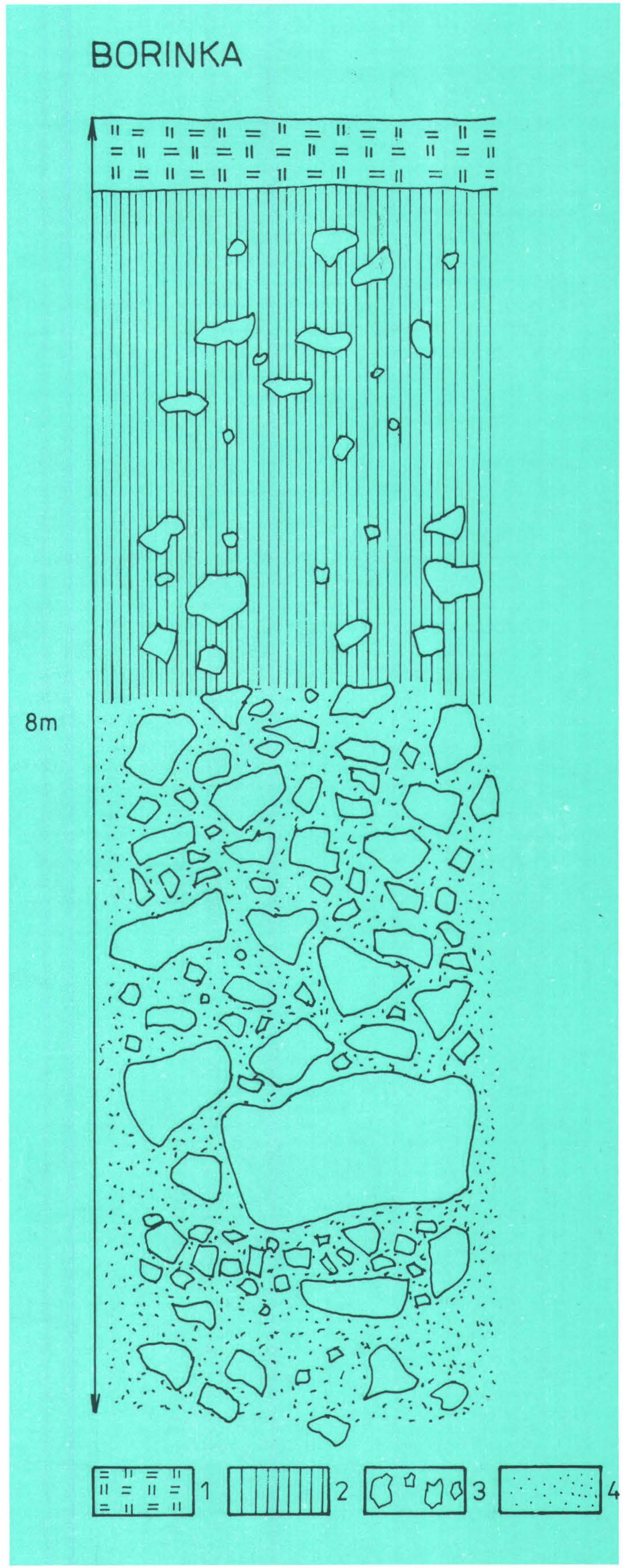


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Fig. 3: Profile of Devínska Nová Ves member at locality Borinka. 1 — soil, 2 — loam, 3 — boulders and granitoid clasts, 4 — matrix.

creases with the depth. They are partly recrystallized like quartzite clasts from Lozorno. At the depth of 365 m carbonate clasts appear in the borehole and the lower part of the Devínska Nová Ves Formation shows a polymict character.

The composition of clastics changed markedly at the depth of about 440 m. Mesozoic rock clasts dominate over granitoids fading out completely at the depth of about 490 m. At the level of 505—515 m the Lower Triassic quartzites fade out and the interval down to 575 m consists of conglomerates from Mesozoic carbonates. The interval 575—595 m consists of "tectonic breccia" from underlying, probably Jurassic limestones and the final interval 595—618 m consists of Jurassic limestones.

The Devínska Nová Ves Member has the siltstone-sandstone matrix in the borehole DNV—1. Blocks and fragments in the upper part are unrounded or poorly rounded (breccia). In the lower part the clastic material is medium-rounded (transition to conglomerates). Clastic material beneath the Devínska Nová Ves Member is medium to well rounded.

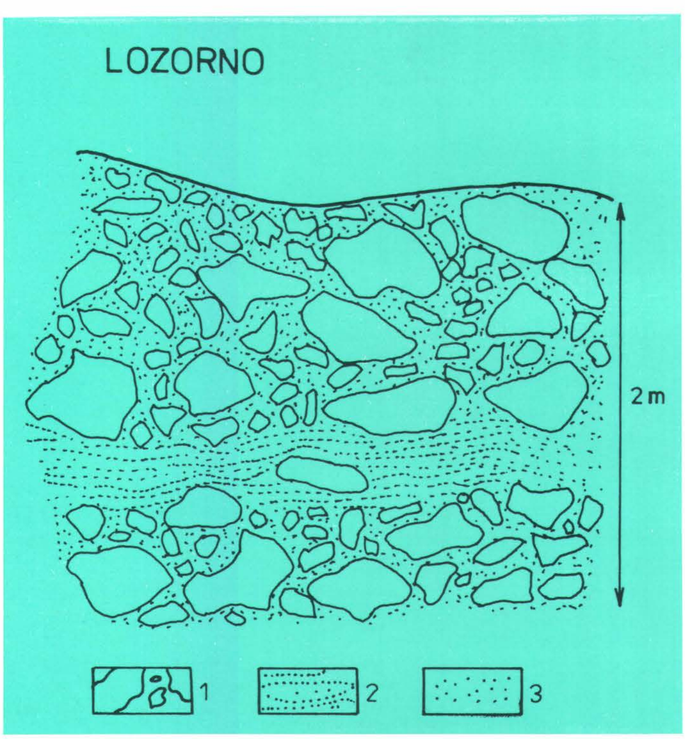
There are differences in the composition of clasts — upper part: 90 % granitoids, 10 % metamorphites, lower part: 75 %—80 % granitoids, 10 %—15 % metamorphites and 5 %—10 % Mesozoic rocks.

A detailed analysis of clastics in the borehole DNV—1 shows that their lower part is polymict, although granitoid material is dominant. This may be explained in two ways:

1. At the beginning of the Middle Badenian the uplift of the Malé Karpaty Mts. was slow. Transport to the basin was more extensive, the clastics have polymict character. Gradually, after the removal of the Mesozoic envelope (partial unloading) the uplift rate increased and only crystalline rock clasts, mainly granitoids got into the basin.
2. The primary source area with dominant Mesozoic material got to a greater distance from the accumulation of the Devínska Nová Ves member — owing to the sinistral strikeslip fault of the Malé Karpaty block (Fig. 5). In the new source area the crystalline rocks, mainly granitoids, dominated.

The material of conglomerates and breccias is not weathered. This is a striking difference from granitoid clastics at Borinka and Lozorno.

Fig. 4: Profile of Devínska Nová Ves member at locality Lozorno. 1 — boulders, fragments and granitoid pebbles, 2 — sandy layer, 3 — matrix.



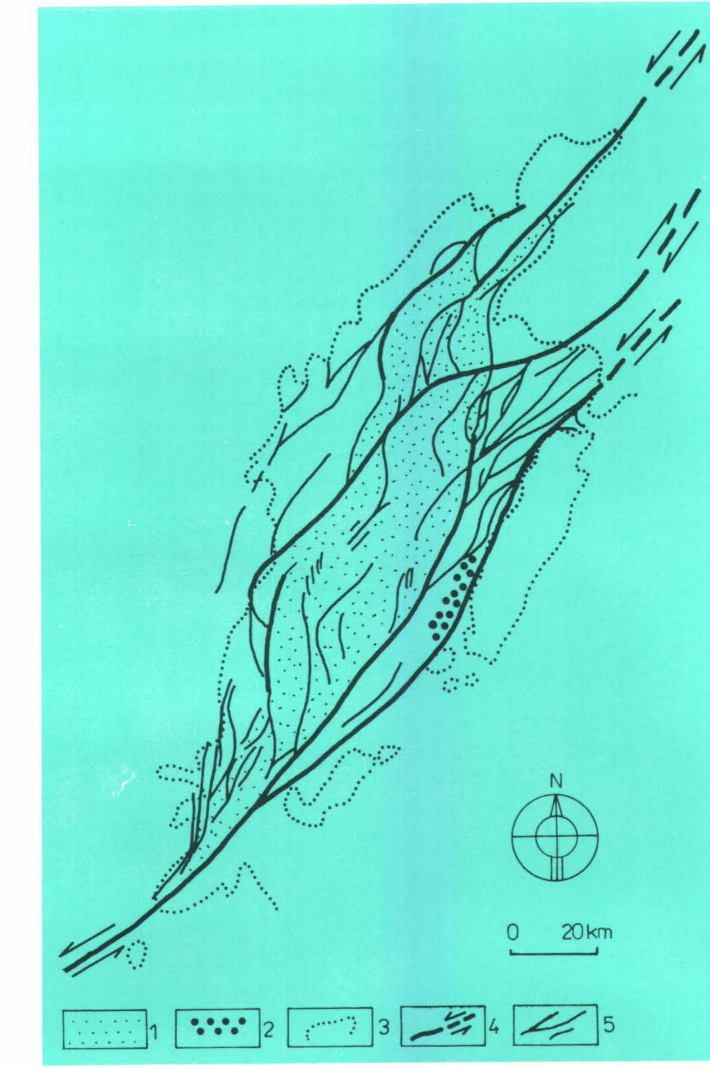


Fig. 5: Position of Devínska Nová Ves member on SE periphery of Vienna Basin and course of main faults with significant lateral movement. 1 — area of rapid Badenian sedimentation, 2 — olistostromes and piedmont clastic cones (Devínska Nová Ves member), 3 — present basin contours, 4 — main faults and presumable movement direction, 5 — other faults.

The granitoid clastics resemble olistostromes. According to Raymond (1978) the term olistostrome generally denotes clastic beds or formations, or mélange of sedimentary origin. Middle Badenian granitoid clastics on the SE periphery of the Vienna Basin show the following characters identical with typical features of olistostromes:

— chaotic ordering
— lens shape (clastic bodies rapidly wedge-out into the basin)
— lack of true bedding
— position among marine bedded sequences (proved by DNV—1 well log).

The granitoid clastics have not a heterogeneous composition and this perhaps is not the general feature of olistostromes. For example, olistostromes with huge olistoliths in the contact zone between Tjan-Shan and Pamir (Pridarvazie) have a monomict composition (Shcherba 1975).

Piedmont clastic cones, talus cones, mure cones (Borinka) and alluvial cones with material partially rounded during a short transport in aqueous environment (Lozorno) represent another genetic type of sediments ot he Devínska Nová Ves Member.

This member has been formed of debris, mostly granitoid material, either accumulated on the margin of the Vienna Basin, or slumped down as chaotic mass — a mixture of rigid rock blocks and mud in the form of submarine gravitational slides over a certain distance into the opening Vienna Basin inundated with the sea (Fig. 5).

The Devínska Nová Ves Member represents one of the largest known coarse-clastic accumulations in the West Carpathians (e. g. maximum thickness of Badenian detritus from Foredeep near Ostrava is about 300 m). Perhaps only clastics of the alluvial fan from the Spišsko-gemerské rudohorie Mts. sedimented in the Košická kotlina basin (Košice gravel formation) may be thicker than the Devínska Nová Ves Member. The genesis of the clastic formation from the Spišsko-gemerské rudohorie Mts. lasted long: it commenced in the Badenian and continued during the entire Sarmatian time, i. e. about 4 m. y. The genesis of the Devínska Nová Ves Member had a shorter duration: Middle Badenian period lasted for only about 0.5 m. y. (Fig. 6). No wonder that the clastics show the features of olistostromes. The formation of olistostromes in the zone of contrast vertical movements may easily be explained:

— The steep relief on the margin of the Vienna Basin tended to rockfall and to gravitational sliding into the subsiding basin inundated with the sea.

— Seismic shocks cannot be excluded (a geophysically indicated segment of the Záhorie—Humenné seismoactive fault is running along the western margin of the Malé Karpaty Mts.).

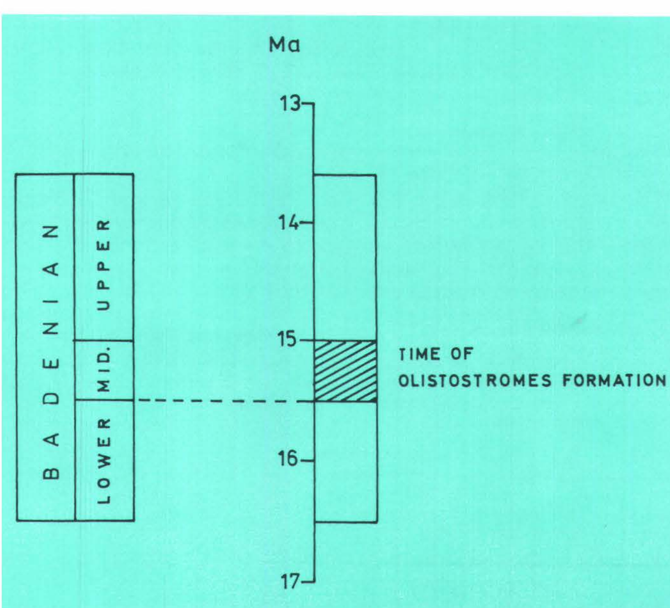
The seismic shocks might have triggered disintegration of rock massifs and activation of debris masses to submarine gravitational slides.

The origin of the beds decribed was associated with differentiated movements on the margin of the opening Vienna Basin in the Middle Badenian time. According to the recent opinions, the basin was opening as a "pull-apart" basin. But in respect of new facts about its structure a particular model has been suggested for the basin: faults, along which the horizontal block movements proceeded controlling the basin opening, were rather shallow (thin-skinned pull-apart, Royden 1985). The Vienna Basin shows some features typical of pull-apart basins (rapid episodical subsidence, quick basin deepening, a. o.) although some of them do not characterize excludingly this basin type.

1. The formation of a steep topographic relief on margins of such basins resulted (Reading in Ballance — Reading 1980, p. 13, 14; Christie — Blick — Biddle 1985, p. 22, 25; Mitchell — Reading in Reading 1978, p. 512) in:

— coarse-detrital facies along the basin margin and sudden lateral facies change towards the basin centre

Fig. 6: Time of origin of Devínska Nová Ves member.



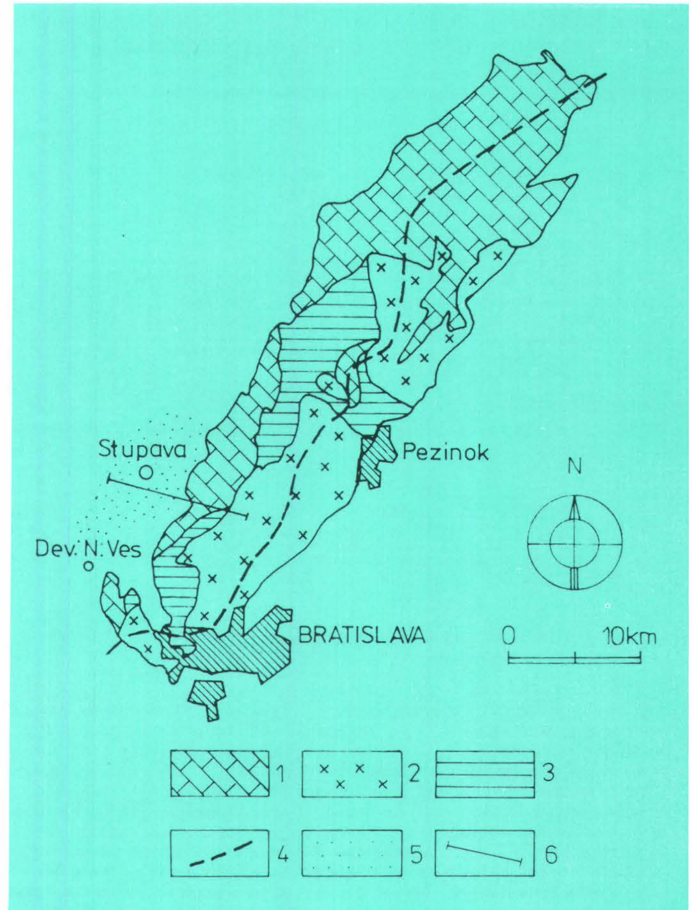


Fig. 7: Scheme of distribution of rocks forming Malé Karpaty Mts. (present situation). The figure shows that the NW slopes of the Malé Karpaty Mts. consist mostly of Mesozoic, less of Paleogene rocks and of pre-Mesozoic metamorphites. The present mountain range and its SE slopes consist of granitoids. 1 — Mesozoic, partly Paleogene sediments, 2 — granitoids, 3 — pre-Mesozoic metamorphites, 4 — axis of highest peaks of Malé Karpaty Mts., 5 — presumable extent of Devínska Nová Ves member, 6 — schematic section line with Middle Badenian reconstruction of NW slope of Malé Karpaty Mts.

— coarse-detrital sediments: conglomerates and breccias form piedmont clastic cones including slumped blocks (olistoliths) and debris flow

— coarse-grained detrital sediments show the features of a very proximal source (poor roundness, monomict petrographic composition).

The Devínska Nová Ves Member proves the existence of a steep relief on the basin margin in the Middle Badenian time and corresponds to the criteria applied on coarse-grained clastics usually accumulating on the periphery of an opening basin of the pull-apart type.

To complete the tectonic background of the Middle Badenian opening of the Vienna Basin it should be mentioned that in this period the megaanticlinoria or horst megaanticlinoria of the present core mountain ranges formed in the West Carpathians. The beginning of the Badenian uplift is dated by fission tracks of apatites from crystalline cores of the core mountain ranges (Kráľ 1977). The Middle Badenian uplift of the Carpathian Arch caused a crisis of salinity in the Carpathian Foredeep (Wieliczka) and in intramontane basins in the Transcarpathian b. (evaporites of the Zbudza Formation in East Slovakia) and in the Transylvanian b. (salt diapirs).

The analysis of the Devínska Nová Ves Member and particularly the evidence of its almost monomict composition with absolutely dominant clastic material of the Malé Karpaty granitoids contribute to the explanation of dynamics of the origin and evolution of the Vienna Basin and to the elucidation of ancient structure of the Malé Karpaty Mts.

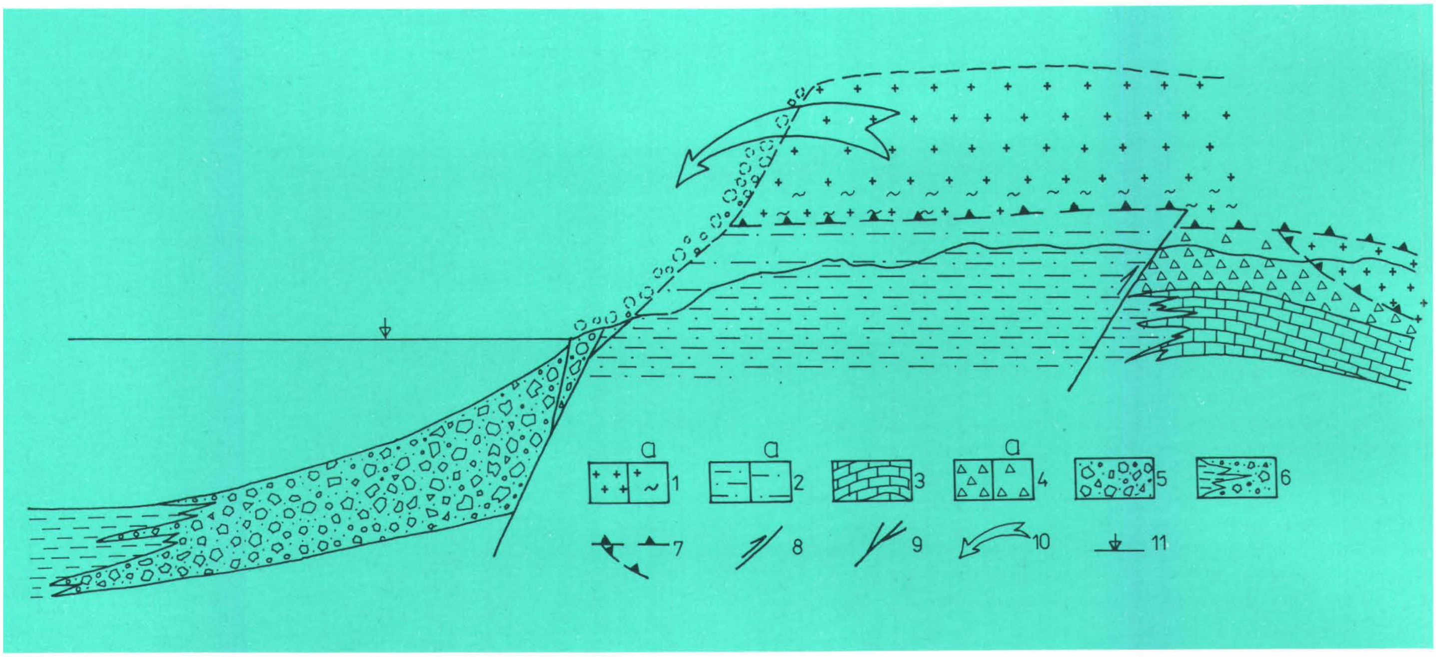


Fig. 8: Reconstruction of Middle Badenian NW slope of Malé Karpaty Mts. in area of Prepadlé—Kozlisko — no scale. For situation of section see Fig. 7 (modified after Plašienka). 1 — Malé Karpaty crystalline complexes, mostly granitoids — Bratislava nappe, a) denuded, 2 — Borinka sequence (mostly in flyschoid facies), a) denuded, 3 — Borinka limestones, 4 — Somár breccia, a) denuded, 2—4 Borinka sequence (Jurassic), 5 — Devínska Nová Ves member, 6 — transition of Devínska Nová Ves member to basinal facies, 5—6 Middle Badenian, 7 — overthrust planes of Bratislava nappe, 8 — reverse fault, 9 — significant strike-slip fault in Badenian, 10 — rockfall from steep paleorelief, 11 — Badenian sea level in Vienna Basin

Direct evidence of allochthoneity of the Malé Karpaty granitoids was presented by Kullman (1957), new data are postulated by Plašienka and Putiš (1987), a. o. Thick coarse granitoid clastics on the northwestern foothill of the Malé Karpaty Mts. represent indirect evidence of their allochthoneity: almost monomict composition of the Devínska Nová Ves Member indicates that their source area — NW slopes of the Malé Karpaty Mts. uplifting in the Middle Badenian — must have consisted of the Malé Karpaty granitoids in the tectonic overlier of Mesozoic series forming the present NW slopes of the Malé Karpaty Mts. (Fig. 7).

In respect of presumable sinistral strike-slip fault of the Malé Karpaty block during the opening of the Vienna Basin, the material of the lower part of the Devínska Nová Ves Member originated from the Malé Karpaty range which is now distant on NE from the granitoid clastics occurrence (Fig. 5).

If we presume that the strike-slip fault of the Malé Karpaty blocks terminated in the Middle Badenian, then the material of the upper part of the Devínska Nová Ves Member (composed excludingly of crystalline material in the borehole DNV—1) originates from a crystalline nappe whose deeper part is exposed in the Prepadlé valley W of Stupava (Fig. 8.)

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Abstrakt

Svedkami dynamického procesu otvárania viedenskej panvy sú úpätné kužele, suťové kužele a olistostromy. Hruboklastické sedimenty sú složené prevažne z malokarpatských granitoidov a tvoria akumulácie na jv. okraji viedenskej panve.

Zusammenfassung

Den dynamischen Ablagerungsprozeß des Wiener Beckens bezeugen Schuttkegel an Hangfüßen und Olisthostrome. Grobklastische Sedimente sind vorwiegend aus Granitoiden der Kleinkarpaten zusammengesetzt und bilden Anhäufungen am SO-Rand des Wiener Beckens.

COMPREHENSIVE RESULTS OF CZECHOSLOVAK-AUSTRIAN COOPERATION IN OIL AND NATURAL GAS SURVEYING

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The Austrian and Czechoslovak geological schools are traditionally interdigitated. This has its deep historical roots and logical reasons. In this respect oil geology is a relatively young field, dynamically developing since 1913, the year we date the start of systematic oil and natural-gas surveying in the Vienna Basin. But expensive and systematic cooperation did not begin until after the second world war. The legislative platform was the Agreement of the 23rd of January 1960 between the government of the Czechoslovak Socialist Republic and the Austrian federal government on principles of geological cooperation between the Czechoslovak Socialist Republic and the Austrian Republic. The Czech Geological Office in Prague and the Federal Geological Institute in Vienna were charged with the practical implementation of the agreement. The agreement covered the entire sphere of cooperation between the two sovereign countries in geological sciences, in particular in deposit application. A significant part of the agreement, though, was assigned to oil geology and geophysics. Thus a significant legislative base for cooperation was established, enabling for the first time a systematic development of mutually advantageous collaboration and later also cooperation.

The field of data exchange and cooperation between CSSR and Austria is a broad one, because the main zones important for exploration of hydrocarbons are extending from one country into the other: the Vienna Basin, the Molasse Zone, the external Zone of the Carpathians, the Calcareous Alpine nappes buried underneath the Vienna Basin and finally the autochthonous sedimentary cover of the Bohemian Massif, extending from the Molasse eastward far underneath the Vienna Basin. In the sixties and the beginning of the seventies the cooperation proceeded predominantly in the form of a mutual exchange of documentation and geoogical-geophysical information. The exchange of maps of the progress of exploration work became the foundation. Thus a state of progressive collaboration was achieved, gradually changing into cooperation. This desirable condition was reached at the end of the seventies and in the eighties. Here it is necessary to mention the prominent personalities who deserve credit for this desirable situation. They are Dipl. Ing. Dr. H. Spörker and Dr. Kröll from the national enterprise ÖMV Wien and the chairman of the Czech geological Office Prague, Dr. Pravda, whose purposive work led to very open and mutually advantageous relations. We now return to at least the main aspects of the cooperation and the achieved results.

As it has already been mentioned the mutual exchange of information was the first and very important stage of cooperation. The conditions for the mutual coordination of exploration work were thus established. Already this basic factor indisputably led to a considerable increase of the efficiency of the exploration work in both countries, consistent in the gradual elimination of mutual duplicities. With regard to the advanced state of the exploration of the Neogene filling of the Vienna Basin a great quantity of information was obtained in this area. Both parties paid great interest to the exploration of the basal Miocene and to observing the industrial accumulation in the vicinity of the state border in the entire Neogene sequence. On the method of solution of the Neogene problems, primarily with regard to structural, stratigraphical and other aspects, it was necessary to elaborte joint stratigraphical and logging-interpretation criteria as a foundation for drawing up joint structural maps. It was indisputably a very exacting complex of work, a successful accomplishment of both parties.

Finally, it was possible to proceed with the drawing up of joint structural maps, e. g. for the upper boundary of the Sarmatian fot the boundary between the Badenian and Karpatian, etc. Gradually a state was reached when also the problems of the course of main tectonic line were solved, e. g. the Steinberg Fault, the Hrušky-Lanžhot Fault, the Farský Fault, etc.

The gradual modernization of seismic measuring was logically succeeded by the phase of a systematic tracing of lithologically limited deposits. A significant representative of such deposits is the Gajary oil field in the upper Badenian. This result enabled the development of seismic and drilling work on the Austrian side of the state border, which proved that this deposit does not continue on Austrian territory, but at the same time this result led to the intensified tracing of such deposits in Austria, and after mutual consultations, interpretational procedures of seismic data for the solution of complicated structural types of traps were established.

Undoubtedly further significant cooperation progressed with the exploration of the Alpine substratum of the Vienna Basin. In this respect remarkable results were achieved in Austria already at the close of the fifties and beginning of the sixties in the exploration of the morphological structures of the Limestone Alpine Zone and in their inner structure. Surveying of this type belongs in all respects to the most demanding, not excluding economic aspects. In particular the discovery of the Schönkirchen deposit is an excellent example of the complex solution and mastery of these problems. In Czechoslovakia this type of surveying was started later — it was only developed at the close of the seventies and in the eighties. The best results so far were on the morphological and litologically combined structure Závod in the surface of the Limestone Alpine Zone. Encouraging results wre also achieved in the inner litologically limited dolomite bodies on the Závod and Šaštín structures. At this stage of exploration it was possible to proceed with the drawing up of joint structural maps of the pre-Neogene relief with coordination of the tectonic elements, including deep tectonics, and with the composition of joint geological cross-sections.

Another extensive sphere of cooperation is in the exploration of the autochthonous sedimentary mantle of the Bohemian Maasif the Neogene frontal and Mesozoic platform cover. Here it is particularly necessary to mark out the exploration of the Steinberg dome in Austria, the wells in Zistersdorf UT—1 (7544 m) and 2A, where the deepest oil-well drilling in Europe (8573 m) was achieved. Beside the exploration of this structure exploration of other areas progressed, e. g. Maustrenk UT—1 in Austria, Sedlec 1, Nové Mlýny — 1 and 2 in Czechoslovakia and some others. But important, economically interesting results have not yet been achived, because of the fact that the reservoir rocks, that have been established underneath the Czechoslovakian and Austrian Foredeep of the Carpathians were not encountered till now. An isopach map drawn on the base of deep wells in both countries of the main source rock, the autochthonous Malmian Basin marls with their large thickness and their high oragnic content encourages to a continuation of deep exploration in the Vienna Basin in future time.

For the development of the systematic exploration of the Mesozoic platform it was necessary to elaborate also a joint stratigraphical nomenclature, the principles of which were accepted by both parties as the basic norm.

A similar procedure was used in the exploration of the Molasse Zone of Carpatian Fordeep where a discovery was made of a not very extensive common gas accumulation in the Rzehakia (Oncophorn) beds (Alt Prerau — Nový Přerov). Joint structural maps and geological cross-sections were also drawn up of these areas.

Seismic measuring became a very significant factor of the cooperation. Here, coordination was led in two directions — on the one hand by the subcomittee for geophysical work between Geophysics ÖMV and Geophysics Brno, on the other hand between MND Hodonín and the department of geology of the ÖMV Vienna. The result of this activity was the establishment of a network of regional and, in some areas, of detailed seismic measuring. Thus, after the jointing of also the methodic and interpretation principles, a long-term foundation was laid for the orientation of surveying work with marked effectiveness for both parties. Today, consequently, there is a network of seismic cross-sections, constituted without regard to the course of the state borders.

The most recent example of cooperation in seismic investigation in the borderzone between Austria and CSSR is the common 30 acquisition in the area of Rabensburg – Lanžhot which will be followed by a common interpretation of the data obtained.

Today, mutual cooperation concerns practically all the spheres of the process of tracing deposit traps. Here we must mention, for instance, other cooperation in the methodology of tracing deeply deposited structures and also the solution of the technical problems involved with such surveying. Jointly solved are problems concerning the genesis of hydrocarbon in laboratories in Czechoslovakia and in Austria, an intensive exchange of rock core samples is being carried out for checking analyses, there is an exchange of geophysical drilling data, both parties enabled excursions of specialists, there is an exchange of some supporting projects and attendance at professional seminars and symposiums is made possible.

The achieved standard of cooperation is indisputably a good promise also for the coming years. Both parties express sincere interest to further develop professionally established principles of coordination, bringing indisputable effect in the sphere of application and economic rationalization.

A further intesification of the cooperation also has its material reasons. It will certainly touch upon methodic problems, geological studies and the critical assessment of significant projects. We see, without doubt, considerable resources in the sphere of natural-gas storage and the relevant geological deposit work, etc. In retrospect, the past years of cooperation have fully confirmed the justification to continue to build our mutual relations on the highest concrete professional principles that bring both parties the greatest effect.
At the same time they are also an expression of the good relations between two neighbouring countries.

Abstrakt

V příspěvku je podán ucelený přehled a výklad ke spolupráci mezi ČSSR a Rakouskem v oblasti naftového průmyslu. Jsou zde vzpomenuty hlavní výsledky této spolupráce, která postupně přecházela od vzájemné výměny informací do fáze sestavování společných geologických map a profilů včetně interpretace strukturních a tektonických elementů.

Obzvláště vysokého stupně spolupráce bylo dosaženo v lokalitách společných ložisek, resp. v oblastech potenciální existence společných perspektivních strukturních objektů pro průmyslové akumulace přírodních uhlovodíků.

Zhodnocena je též oblast metodiky a interpretace seizmických prací, metodiky vyhledávání velmi hluboko uložených struktur a akumulačních podmínek.

Zusammenfassung

Im Beitrag wird eine in sich abgeschlossene Übersicht und Erörterung der Zusammenarbeit zwischen der ČSSR und Österreich auf dem Gebiet der Erdölindustrie geboten. Es werden hier Hauptergebnisse dieser Zusammenarbeit erwähnt, die sich allmählich von einem gegenseitigen Informationsaustausch zur Phase der Zusammenstellung gemeinsamer geologischer Karten und Profile einschl. der Interpretation von Struktur- und tektonischen Elementen entwickelte.

Ein besonders hohes Niveau der Zusammenarbeit wurde an Fundorten erreicht, wo sich gemeinsame Lagerstätten bzw. mögliche gemeinsame perspektivische Strukturobjekte vorfinden, die förderwürdige Akkumulationen natürlicher Kohlenwasserstoffe enthalten können.

Eingeschätzt wird auch das Gebiet der Methodik und Interpretation seismischer Arbeiten, der Methodik zur Ermittlung sehr tief gelagerter Strukturen und Akkumulationsbedingungen.

FACIES DEVELOPMENT OF MIOCENE FORMATIONS IN THE SOUTHWESTERN PART OF THE CARPATHIAN FOREDEEP AND ITS OIL AND GAS PROSPECTS

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1. Introduction

On the basis of reflection-seismic prospecting conducted by the CGG Company with the aid of Vibroseis techniques in 1979, Altprerau-2 borehole in the Altprerau region in Austria brought evidence, in 1981, of a natural gas deposit in Karpatian sandstone horizons and in the Oncophora Beds of the undisturbed molasse. The extension of the gaseous hydrocarbon deposit into Czechoslovakia was confirmed by Nový Přerov-3 borehole.

The common Czechoslovak and Austrian Nový Přerov – Altprerau natural gas field is situated in the southeastern part of the Carpathian Foredeep, southeast of the village of Nový Přerov on Czechoslovak territory and southeast of the village of Altprerau in Austria (Fig. 1). The geologic structure of the region comprises Quaternary and Karpatian sediments in its upper sections and, in the west, with Lower Badenian sediments on the top. The gas accumulations lie in Karpatian sandstone horizons of basal clastic development in Oncophora horizons NNo 1, 2, 4 (in Austria, the whole basal sedimentary complex has been assigned to the Ottnangian – Oncophora Beds) and in the schlier (clay marl) development of the Karpatian. The geological data obtained as a result of geophysical prospecting and exploratory drilling were evaluated by Austrian and Czechoslovak geologists and, by agreement, Oncophora horizons 1, 2, 4 were defined as the common gas-bearing formation.

During the subsequent stage of reflection-seismic prospecting in the Neuruppersdorf and Pottenhofen areas in Austria, additional structures in Miocene sediments were discovered and delineated. The presence of gas in these structures was proved by Neuruppersdorf-1, Pottenhofen 2 and Pottenhofen-3 boreholes. The gas accumulations occur in Karpatian sandstone horizons (Oncophora Beds). The upper part of a Jurassic formation composed of light to dark grey limestones deposited in a favourable tectonic setting was found to be gas-bearing in Pottenhofen-2 borehole.

2. Stratigraphy and lithology

The Nový Přerov-Altprerau, Pottenhofen and Neuruppersdorf gas occurrences are localized in the southeastern part of the Carpathian Foredeep. The surface formations include Quaternary, Karpatian and Lower Badenian sediments; the Miocene sedimentary basin is underlain by Mesozoic, particularly Jurassic sediments represented by a carbonate facies gradually passing into a pelite-carbonate facies east of the localities mentioned above. The fill of the Carpathian Foredeep consists, from the underlying to the overlying formations, of Egerian, Eggenburgian, Ottnangian, Karpatian and Lower Badenian sediments.

GEOLOGICAL MAP OF THE REGION STUDIED

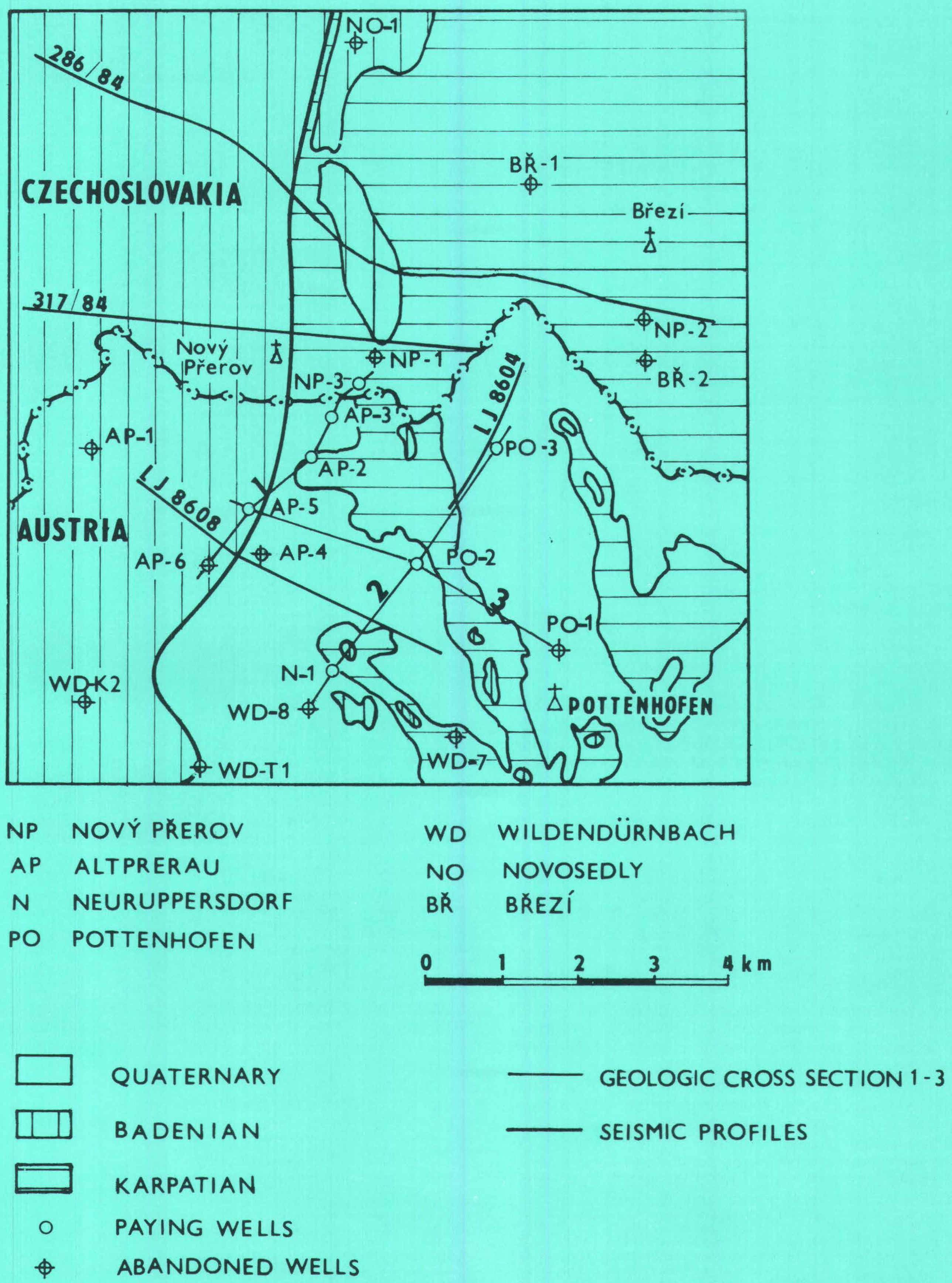

Fig. 1.

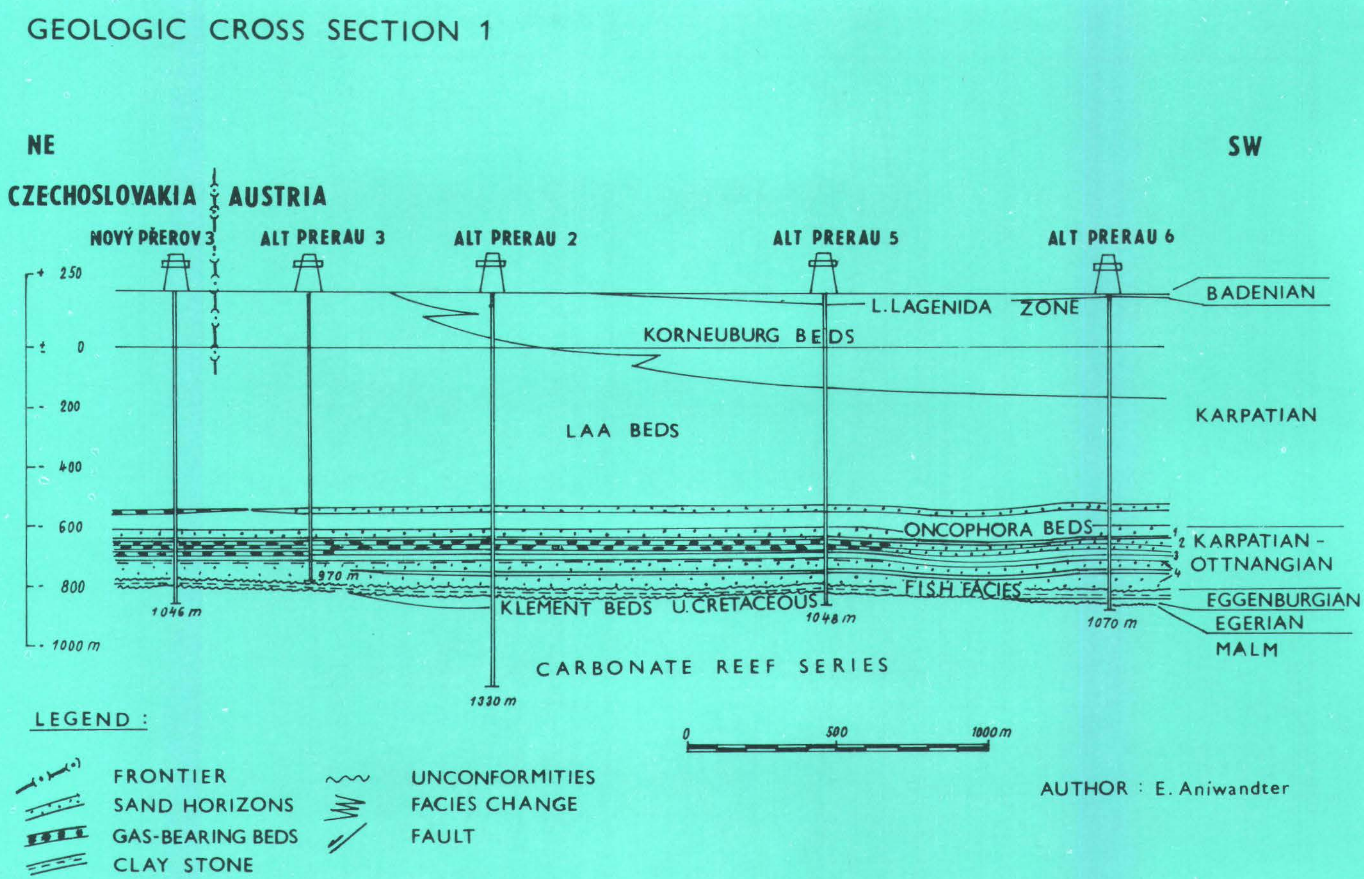

Fig. 2.

In the western part of the region, molasse sedimentation began with **Egerian** sediments in Melk sandstone development and dark grey calcareous claystone development identified with a thickness of 49 m in Altprerau-1 borehole and with 7 m in Altprerau-6 borehole. The sediments were classified in accordance with R. Fuchs analyses of the microfaunas of a marine littoral facies.

As stated by Austrian geologists, **Eggenburgian** sedimentation started with a transgressive foraminiferal facies unconformably deposited on the Mesozoic underlying formation in the eastern part of the region under study. The following thicknesses were determined in the boreholes: Neuruppersdorf-1 — 14 m, Pottenhofen-2 — 7 m and Pottenhofen-3 — 27 m. By their lithology, the sediments are dark-grey thin-bedded non-calcareous claystones rich in microfaunas. In the western part of the region, the Eggenburgian sediments are developed as a marine fish facies unconformably overlying the Mesozoic base (Fig. 2), while they are conformably deposited on a foraminiferal facies on the east. (Fig. 3). The fish facies is up to 20 — 35 m thick, lithologically it is identical with the foraminiferal facies. Micropalaeontological analyses have found sporadic representatives of fauna and flora. Bone fragments of teleosts are abundant, shark teeth and small poorly developed foraminiferal shells occur sporadically.

The **Eggenburgian** sediments are unconformably overlain by a complex of prevailingly clastic sediments termed **Oncophora Beds.** Their thickness increases from 106 m on the west (Altprerau-1 borehole) to 714 m on the east (Pottenhofen-1 borehole). In the latter borehole, the Oncophora Beds include a pelite complex 400 m thick, underlying the clastic development. The characteristic development of this sequence is present throughout the region studied and very well evidenced by the drill cores recovered. As to lithology, light grey micaceous, fine-to medium-grained sandstones with thin lignite layers alternating with layers of grey-greenish fine-micaceous, calcareous silty claystones have been recognized. The fauna is severely impoverished owing to clastic sedimentation. Coalified plant remains, sparsely occurring small ammonoids, fish bones, pyritized diatoms and minute mollusc remains can be found in the sediments. The problem involved in the stratigraphical classification of this complex is whether it can unambiguously be assigned to the Karpatian or to the Ottnangian. The Austrian geologists have placed the Oncophora Beds into the Ottnangian. On the basis of palynological analyses conducted by I. Draxter on rock samples from Pottenhofen-3 borehole, Czechoslovak geologists have assigned the whole complex to the Karpatian considering it to represent its basal clastic development. The stratigraphic definition as Karpatian is based on the presence of two specimens of Ostracoda Senesia aff. vadászi (Zalányi) in drill core No 3 from Dunajovice-1 borehole (depth: —997 m). This ostracode species has appeared in the Paratethys since the Karpatian (R. Jiříček, 1974). Further evidence has been provived by the occurrence of small foraminifers of the genus Bathysiphon that are not characteristic of the age of the sediments, but are fully identical with similar occurrences in the overlying clay marl (schlier) development of the Karpatian. The sequence is related to the overlying schlier development by lithologic and faunal transitions.

The Oncophora Beds are overlain by **Karpatian** sediments of schlier and aleurite-pelite development. Typical of

GEOLOGIC CROSS SECTION 2

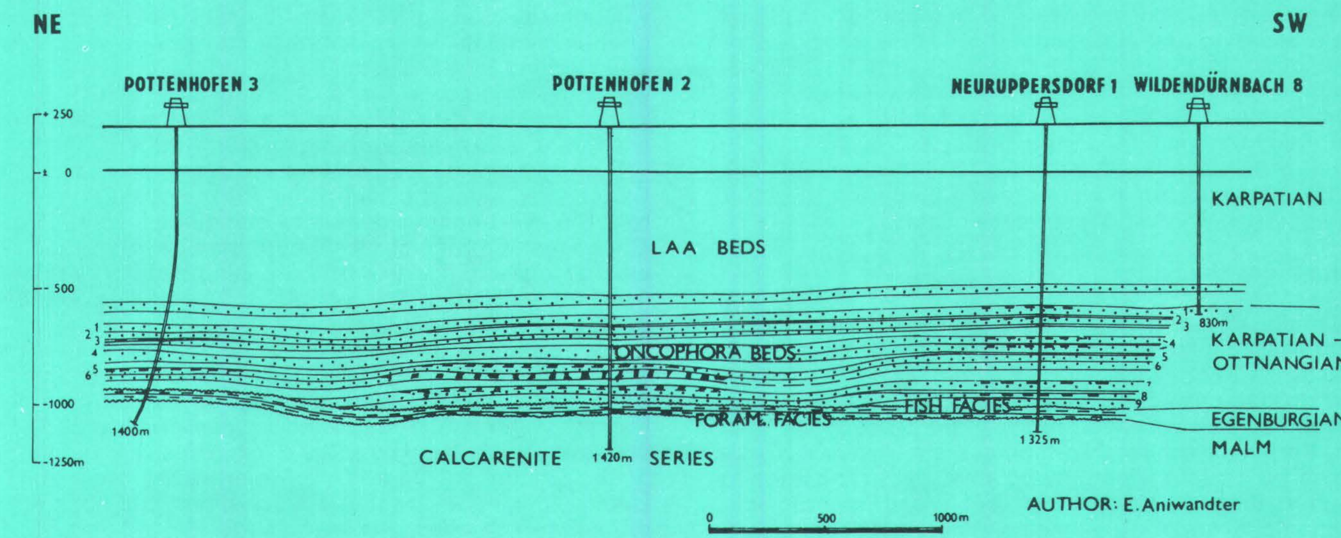

Fig. 3.

the schlier development are greenish-grey, brownish, grey fine-micaceous calcarecus claystones with silty and sandy admixtures, alternating with laminae, lenses and, locally, layers of light grey micaceous, calcareous, slightly consolidated sandstones and siltstones. The upper part of the Karpatian exhibits aleuritepelite development. Present are prevailingly light grey, grey micaceous calcarecus silty clays and claystones grading, by intervals, into sand. Palaentological analyses of rock samples from these complexes have shown the presence of plaktonic foraminifers, cryophile agglutinating foraminifers and fish otoliths characterizing the Karpatian in its deep-sea development. This sequence has been termed Laa Beds (Laaer Schichten) in Austria. In Altprerau- 1, 2, 4, 5, 6 boreholes, the Laa Beds are overlain by a marine-brackish facies of Karpatian sediments represented by the Korneuburg Beds. Their thickness increases from zero in the east to 354 m in the west (Altprerau-6 borehole, Fig. 4). Lithologically they consist of layers of grey-greenish calcareous clays alternating with layers of slightly consolidated light grey calcareous sandstones.

The Badenian stratigraphic stage is represented by sediments of the Lower Lagenida zone. Lower Badenian sediments occur at the top of the geologic structure in the western part of the region studied (Fig. 1). Their greatest thickness, attaining 80 m, was identified in Altprerau-1 borehole. The marine sediments form gravels and gravel sands at the base with layers of grey, fine- to medium-grained slightly consolidated sand. They are overlain by greenish-grey, blueish-grey, slightly fine-grained, slightly micaceous calcareous clays with intercalations of fine-grained calcareous sands and silts.

3. Tectonic setting

The results of drilling operations and the interpretation of reflection-seismic surveys have shown the Věstonice fault to be a significant tectonic element in the geologic setting of the region investigated. The existence of the fault has been evidenced by reflection seismic profiles taken through the areas of Dolní Dunajovice, Březí, Nový Přerov (profiles No 317/84 and No 286/84) and through the Altprerau — Pottenhofen area in Austria. The Věstonice fault strikes NE-SW and, southwesterly, it can be traced from the village of Strachotín to Dolní Dunajovice, where it splits into two branches. The western branch continues through Dobré Pole to Nový Přerov and to Altprerau in Austria. The fault dips westward, its vertical throw is 100—120 m to the surface of Mesozoic carbonates in the Nový Přerov area, as evidenced by reflection profiles 317/84 (Fig. 6) and 286/84. The fault throw decreases westwards near Altprerau and gradually dies out in the area of Altprerau-5 and 6 boreholes. The eastern branch of the Věstonice fault extends from Dolní Dunajovice to Březí and southwestwards into the region west of Pottenhofen-2 and 3 boreholes in Austria, where it gradually dies out. The fault throw is 160—200 m to the Jurassic surface in the area of the gas deposit near Dolní Dunajovice (J. Adámek, 1977; J. Adámek, A. Petr, 1977). The fault throw gradually decreases towards Austria. The results of exploratory drilling and geophysical prospecting point to probable Miocene age of the fault which, in vertical direction, terminates on the upper boundary between the Oncophora Beds and the base of the Karpatian schlier development.

As reported by Austrian geologists, in Austria the eastern branch of the Věstonice fault shows up particularly in the Mesozoic basement. They assume that, in the Oncophora Beds, the fault had formed flat synclines that have led to the formation of gas-bearing anticlinal structure (Pottenhofen area). This structural type is documented by reflection-seismic profile LJ 8680 (Fig. 7).

The Nový Přerov — Altprerau structure very distinctly appears in the reflection-seismic maps (see Fig. 6). In this structure, the Věstonice fault is an important lateral seal that seems to have decisively affected the accumulation of natural gas in the sand horizons of the Oncophora Beds.

The processing and evaluation of reflection seismic profiles accomplished, since 1986, by means of a digital interpretation system has resulted in the assessment of hydrocarbons on the Pottenhofen seismic structure, which is demonstrated by reflection-seismic profile LJ 8604 (Fig. 8). In the area of Pottenhofen-2 borehole, additional indications of hydrocarbon presence were obtained by using the root-mean-square method and interval velocities.

4. Natural gas deposits

Accumulations of gaseous hydrocarbons are associated with Jurassic limestones, sand horizons of the Oncophora Beds and the Karpatian schlier development.

Light to dark grey fine- to medium-grained sandy limestones are Jurassic reservoir rocks. In the Oncophora Beds and in Karpatian schlier development, the reservoir rocks consist of calcareous, fine-grained, partly silty sandstone to sand alternating with poorly permeable and impermeable laminae and layers of claystones or siltstones.

Nový Přerov — Altprerau natural gas deposit

The deposit was discovered by Altprerau-2 borehole in 1981. In the subsequent stage, Altprerau-3, 4, 5, 6 boreholes and Nový Přerov-1, 3 boreholes were drilled. Nový Přerov-3 borehole demonstrated the extension of the gas field into Czechoslovak territory. Altprerau-4, 6 and Nový Přerov-1 boreholes were dry, because the traps were found to be water-saturated in these wells. Oncophora horizons NNo 1, 2, 4 and a Karpatian sandstone horizon of schlier development are potential deposits in this field. The individual sandstone horizons are vertically isolated from one another by pelite layers. Laterally the gasbearing horizons are bounded by the Věstonice fault in the west and by the water-gas contact in the east, south and north. The gas field stretches SW-NE along the Věstonice fault over a length of 2.7 km and with a maximum width of 700 m.

Oncophora horizon No 4 lies in the lower part of the Oncophora Beds. The sandstone horizon constitutes a narrow SW-NE-trending domal to semidomal uplift (Fig. 9). The gas-water contact was determined by interpreting the electric logs and the results of pumping tests to a structural depth of −735 m in Altprerau-2, 3, 5 boreholes. The average porosity of the sandstone is 18.5 %.

The formation pressure related to the gas/water interface (−735 m) is 9.4 MPa and the formation temperature is 37° C at this depth. The average net pay is 3.92 m and the average water saturation of the reservoir rock is 52 %.

Oncophora horizon No 2 occupies the middle part of the Oncophora Beds. Upon interpreting the results of electric logging and well-log correlations, the horizon was divided into two sections — A and B. (Fig. 10 and Fig. 11).

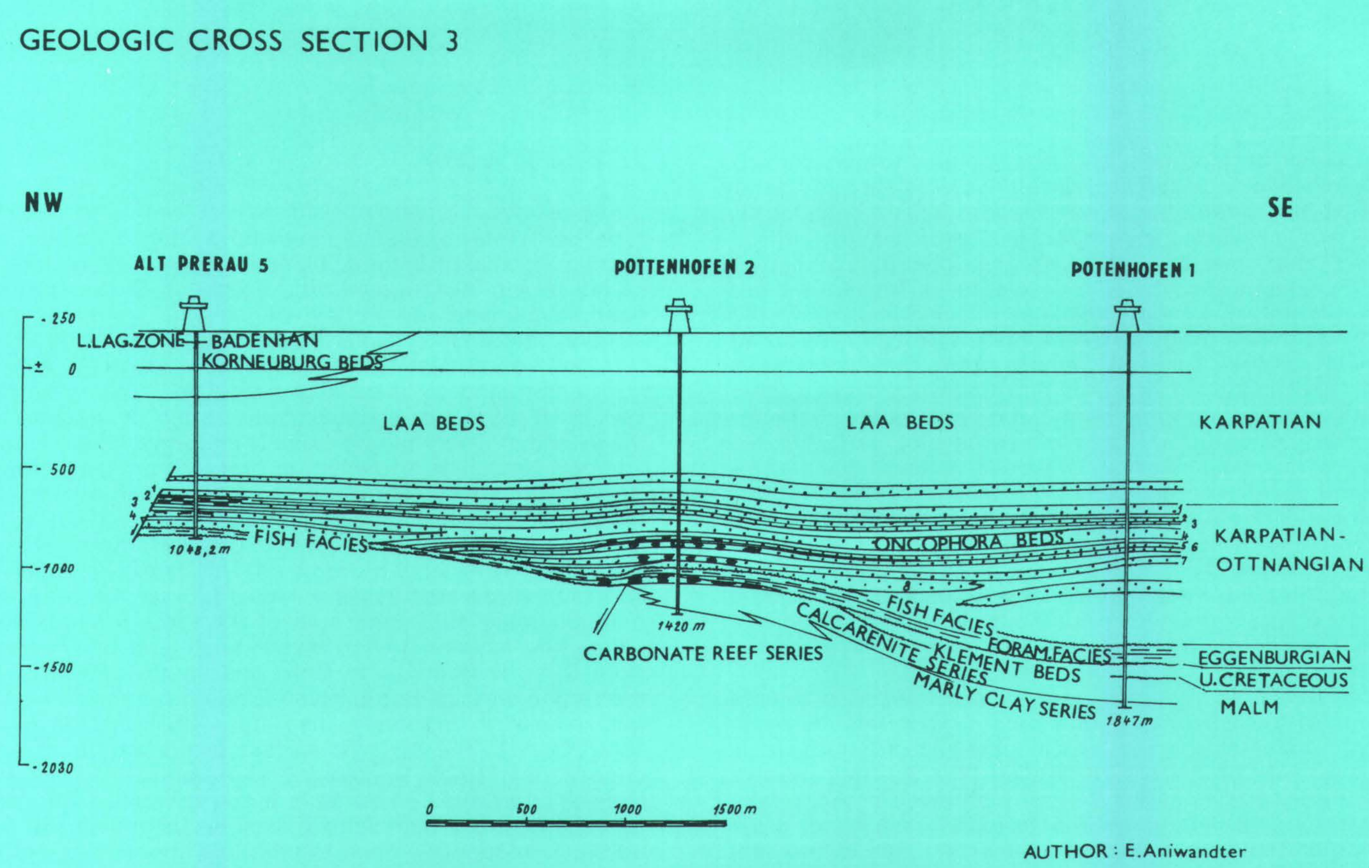

Fig. 4.

The two sections of the horizon form a SW-NE-trending narrow semidomal uplift. The gas-water contacts were interpreted at the structure depth of −662 m (layer A) and −681 m (layer B), respectively, on the basis of the results of electric logging and pumping tests in Altprerau-2, 3, 5 boreholes. Average porosity attains 21 %, the average net pay of layer A is 3.46 m and that of layer B 3.7 m. Average water saturation of the reservoir rock amounts to 50 %. The formation pressure related to the gas-water contact is 8.7 MPa in layer A (−662 m) and 8.9 MPa in layer B (−681 m). The rock temperature is 35 °C for both of the layers (A and B) at the depths mentioned.

Oncophora horizon No 1 forms the upper part of the Oncophora Beds. According to the structural map constructed for the surface of this sand horizon, it is a SW-NE-trending domal to semidomal uplift (Fig. 12). In accordance with the results of electric logging and pumping tests in Nový Přerov-1, 3 and Altprerau-2, 3, 5 boreholes, the water-gas contact was located at a structure depth of −612 m. The formation pressure related to the gas-water contact is 8.2 MPa and the formation temperature 33° C at this depth. The average net pay of the horizon is 1.29 m, average porosity attains 19 %.

The highest-lying deposit of the structure is a Karpatian sandstone of schlier development whose gas-bearing capacity was confirmed by drill-stem testing in Nový Přerov-3 borehole. In the cross-section through Nový Přerov-1 borehole, the results of the pumping test from this horizon and the evaluation of the well logs have suggested the water-gas contact to lie at a structure depth of −556 m. In Alprerau-3 borehole the water-gas contact has been placed at a structure depth of −546 m. Due to the differences in interpreting the depth of the water-gas contact, the horizon is supposed to be divided into two separate units by a facies boundary. The formation pressure related to the water-gas contact at a depth of −556 m is 6.93 MPa and rock temperature is 33° C at this depth. The average net pay of the horizon is 2 m, average porosity attains 19 %.

Natural gas samples were recovered from the Nový Přerov-1, 3 and Altprerau-2, 3, 5 boreholes. The average composition of the natural gas in the individual horizons is as follows:

Oncophora horizon No 4

Methane 98.77 % by vol, ethane 0,23 %by vol., propane 0.02 % by vol, CO_2 0.14 % by vol., azote 0,82 % by vol.

Oncophora horizon No 2

Methane 99.08 % by vol., ethane 0.13 % by vol., propane 0.01 % by vol., CO_2 0.04 % by vol., azote 0.8 % by vol.,

Oncophora horizon No 1

Methane 99.02 % by vol., ethane 0.13 % by vol., propane 0.01 % by vol., CO_2 0.04 % by vol., azote 0.8 % by vol.

The formation waters are highly mineralized (11.77−21.56 g/l), of the chloride sodium type, calcic hydrocarbonate subtype. The iodide content ranges from 33.05 − 90.2 mg/l.

Pottenhofen deposit

The structure was discovered as a result of reflection seismic survey and drilling of Pottenhofen-2 borehole in 1985. The presence of gas was confirmed by an open-hole test in the Oncophora Beds (Oncophora horizon No 5 with a 7.1 m thick gas-bearing section) and in the Upper part of the Jurassic formation. The evaluations of electric logging

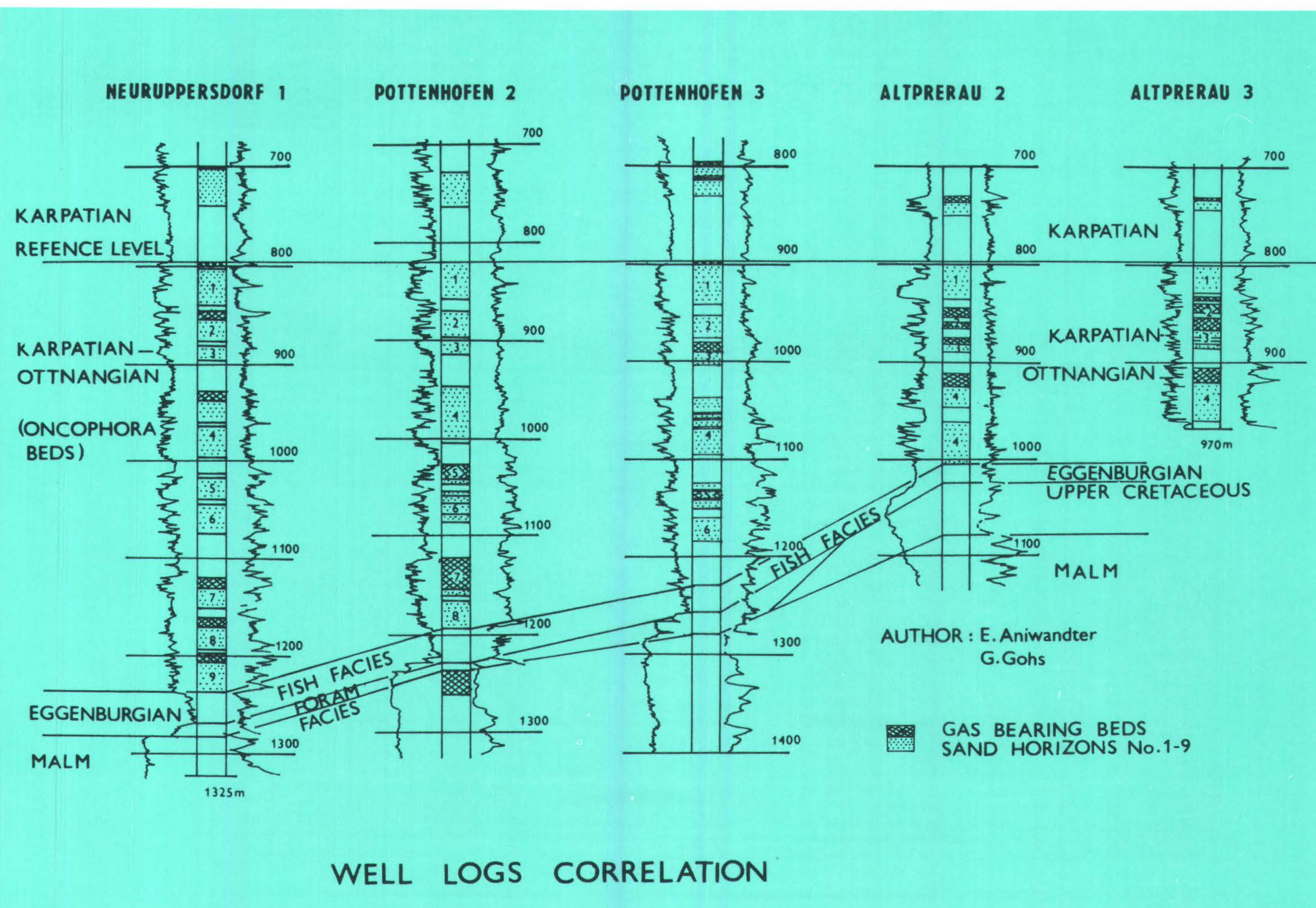

Fig. 5.

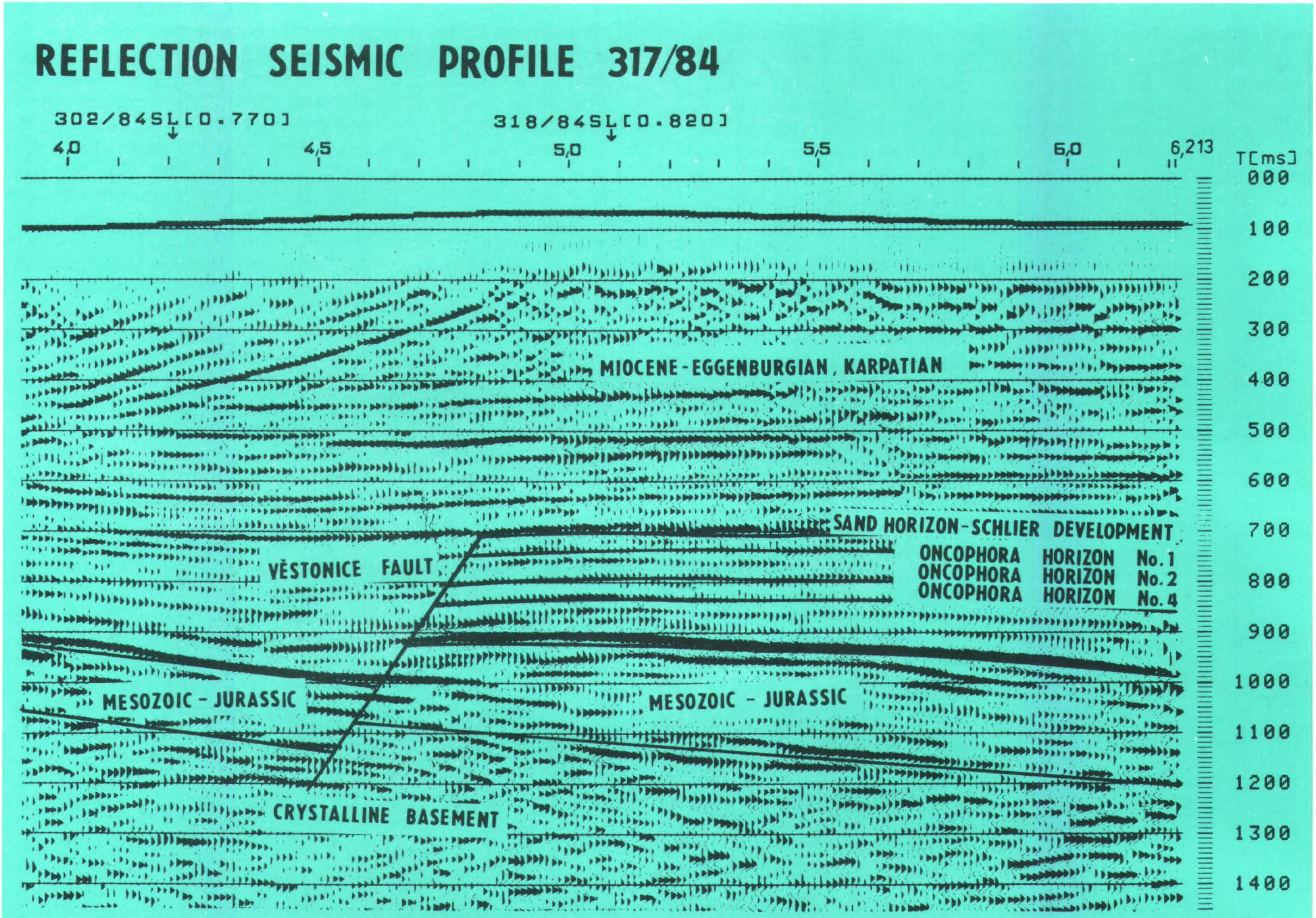
REFLECTION SEISMIC PROFILE 317/84
302/84SL[0.770]
318/84SL[0.820]
4,0
4,5
5,0
5,5
6,0
6,213
T[ms]
000
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
MIOCENE-EGGENBURGIAN, KARPATIAN
SAND HORIZON-SCHLIER DEVELOPMENT
ONCOPHORA HORIZON No.1
ONCOPHORA HORIZON No.2
ONCOPHORA HORIZON No.4
VĚSTONICE FAULT
MESOZOIC-JURASSIC
MESOZOIC - JURASSIC
CRYSTALLINE BASEMENT

Fig. 6.

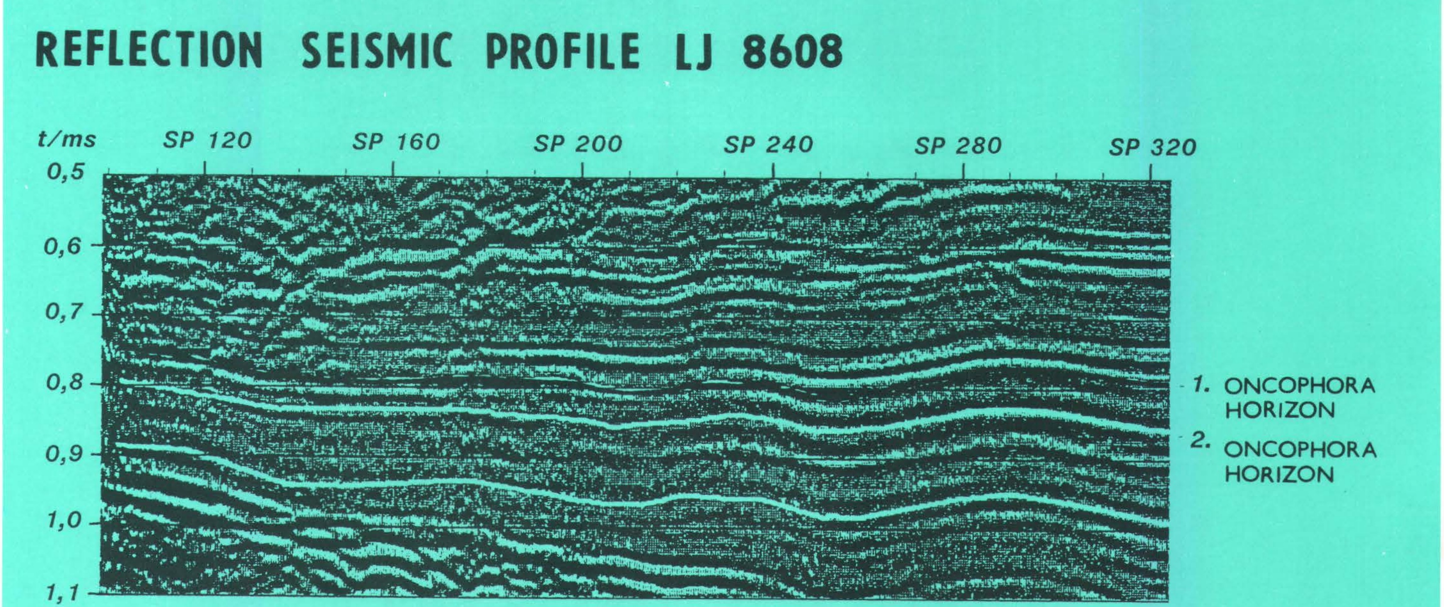
REFLECTION SEISMIC PROFILE LJ 8608
t/ms
SP 120
SP 160
SP 200
SP 240
SP 280
SP 320
0,5
0,6
0,7
0,8
0,9
1,0
1,1
1. ONCOPHORA HORIZON
2. ONCOPHORA HORIZON

Fig. 7.

in Oncophora horizons NoNo 6 and 7 suggest the presence of additional gas accumulations. The structure is built of a SW-NE-trending flat anticline bounded by the gas-water contact on all sides. The maximum length of the structure is 1.5 km, its maximum width – 800 m. Average porosity was found to be 21.9 % and water saturation 56–59 %.

A similar gas-bearing structure was discovered by Pottenhofen-3 borehole in 1988. In this structure, the deposits lie in Oncophora horizons No 3 and No 5 (the gas-saturated sections of the reservoir rock attain thicknesses of 3.1 m and 9.1 m, respectively). The flat NE-SW-trending anticline is 1.2 km long with a maximum width of 550 m. It is separated from the structure drilled by Pottenhofen-2 borehole by a flat NW-SE-trending syncline.

Another minor structure was discovered by Neuruppersdorf-1 borehole in 1987. This structure is situated north of the Wildendürnbach gas deposit (Fig. 3). Drill-stem testing in the open hole resulted in gas flow from Oncophora horizon No 1. Measurements of the formation pressure did not evidence a relationship of the structure to the Wildendürnbach deposit. As indicated by reflection seismic data, the structures appear to be separated from each other by a transverse W-E striking depression. Regarding the evalutions of electric logging, additional natural gas accumulations are supposed to exist in Oncophora horizons NoNo 2, 4, 5 and 7.

Summary

Petroleum-geological prospecting conducted in the southeastern part of the Carpathian Foredeep in the regions of Nový Přerov, Altprerau, Pottenhoffen and Neuruppersdorf in the period from 1981 to 1988 has yielded positive results evidencing the gas potentials of the Miocene sandstone horizons of the Oncophora Beds and the schlier development of the Karpatian. The Nový Přerov-Altprerau natural gas deposit was discovered. The exploration of the gas field was terminated and the geological reserves of gaseous hydrocarbons of this deposit have been estimated to be of the order of magnitude of hundreds of millions of cubic metres.

Additional gas-bearing structures were identified and proved by drilling in the Pottenhofen and Neuruppersdorf regions, where exploration goes on at the present time. The favourable exploration results recently obtained point to the fact that the survey of the Miocene sediments in the Carpathian Foredeep should not be regarded as completed. In view of the results obtained, we can express the realistic hope that similar structures may be found in Miocene sediments in the near future.

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Bimka J. (1978): Naleziště zemního plynu Nový Přerov – Altprerau. Zemní Plyn, Nafta, XXXII (3), 317–338, Hodonín.
F. Brix. A. Kröll, G. Wessely (1977): Die Molassezone und deren Untergrund in Niederösterreich. Erdöl-Erdgas-Zeitschrift, 93.Jg. Sonderausg.
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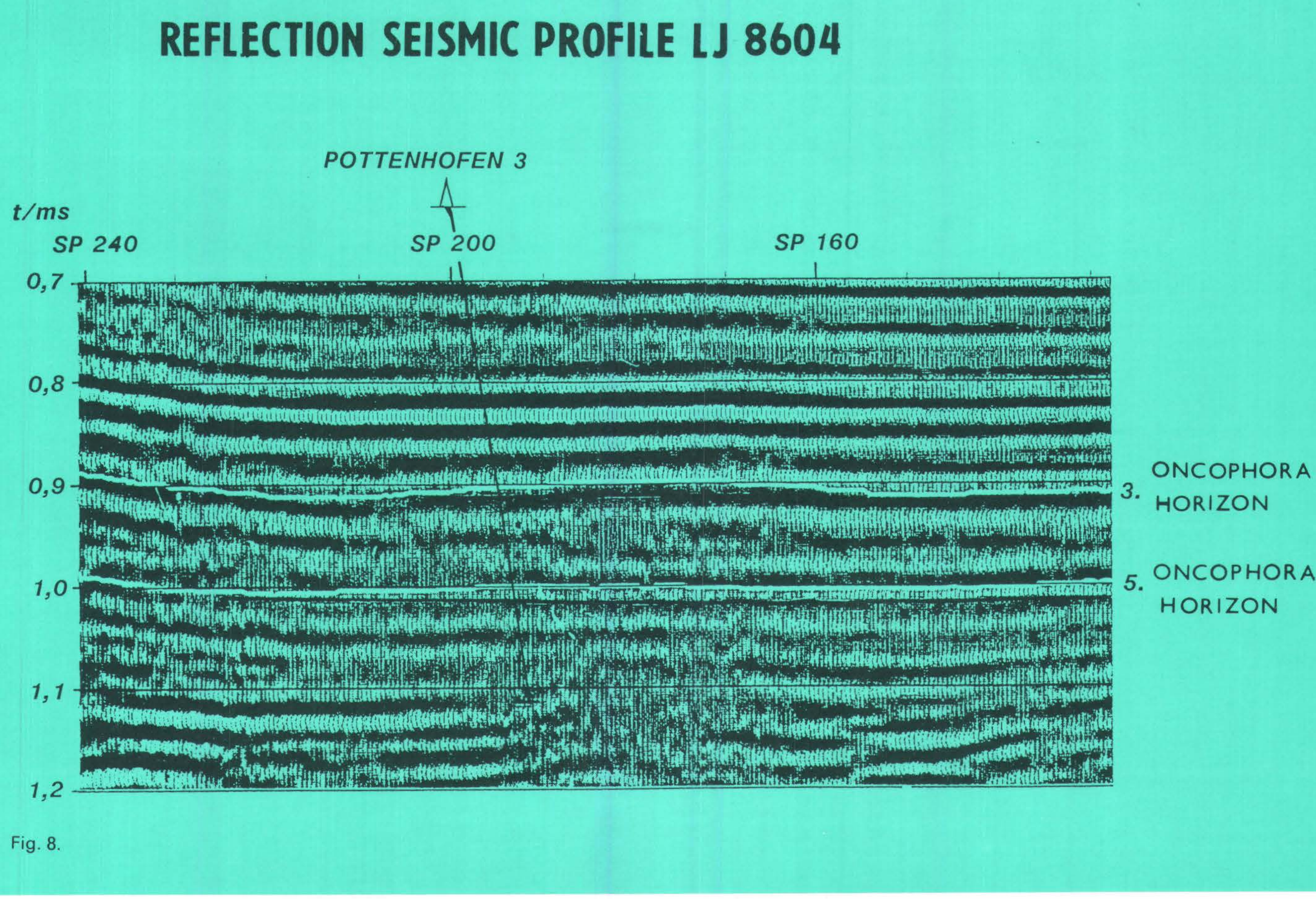


Fig. 8.

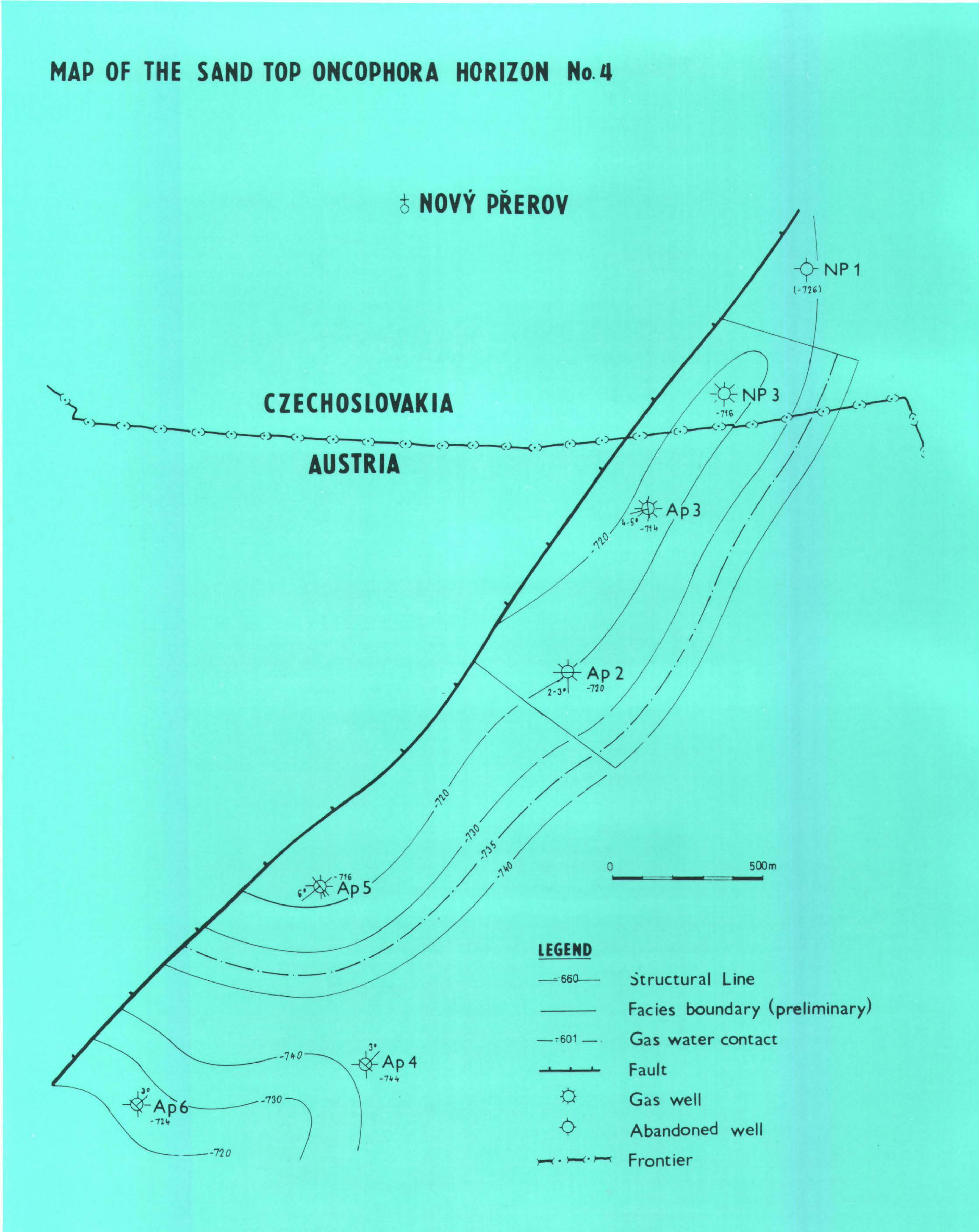

MAP OF THE SAND TOP ONCOPHORA HORIZON No. 4
NOVÝ PŘEROV
NP 1
(-726)
NP 3
-716
CZECHOSLOVAKIA
AUSTRIA
Ap 3
4-5°
-714
-720
Ap 2
2-3°
-720
-720
-730
-735
-740
0
500m
Ap 5
6°
-716
Ap 4
3°
-744
-740
Ap 6
3°
-724
-730
-720
LEGEND
660
Structural Line
Facies boundary (preliminary)
601
Gas water contact
Fault
Gas well
Abandoned well
Frontier

Fig. 9.

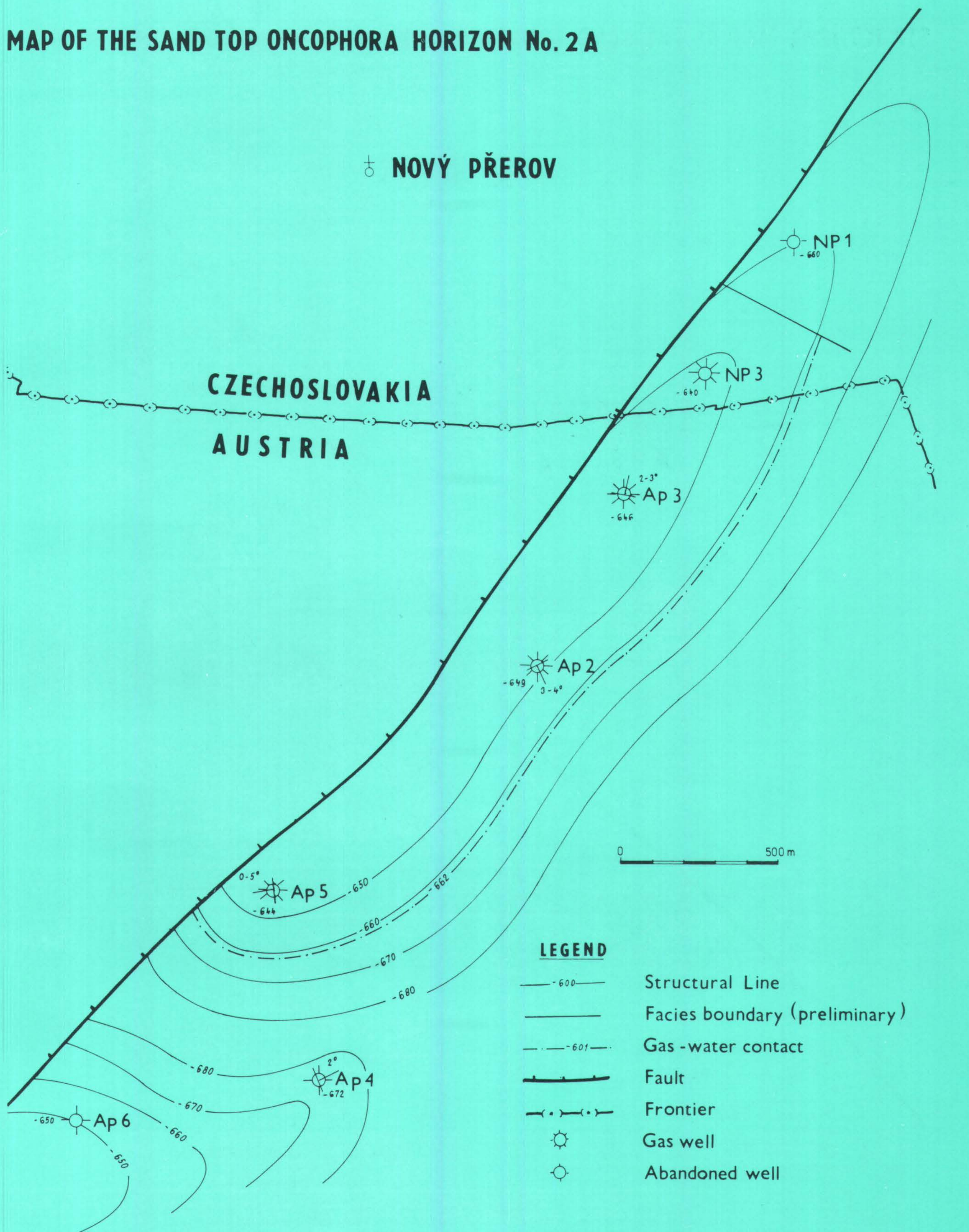

MAP OF THE SAND TOP ONCOPHORA HORIZON No. 2 A
NOVÝ PŘEROV
CZECHOSLOVAKIA
AUSTRIA
NP 1
NP 3
Ap 3
Ap 2
Ap 5
Ap 4
Ap 6
0
500 m
-650
-660
-662
-670
-680
LEGEND
Structural Line
Facies boundary (preliminary)
Gas-water contact
Fault
Frontier
Gas well
Abandoned well

Fig. 10.

STRUCTURAL MAP OF THE SAND TOP ONCOPHORA HORIZON No. 2 B

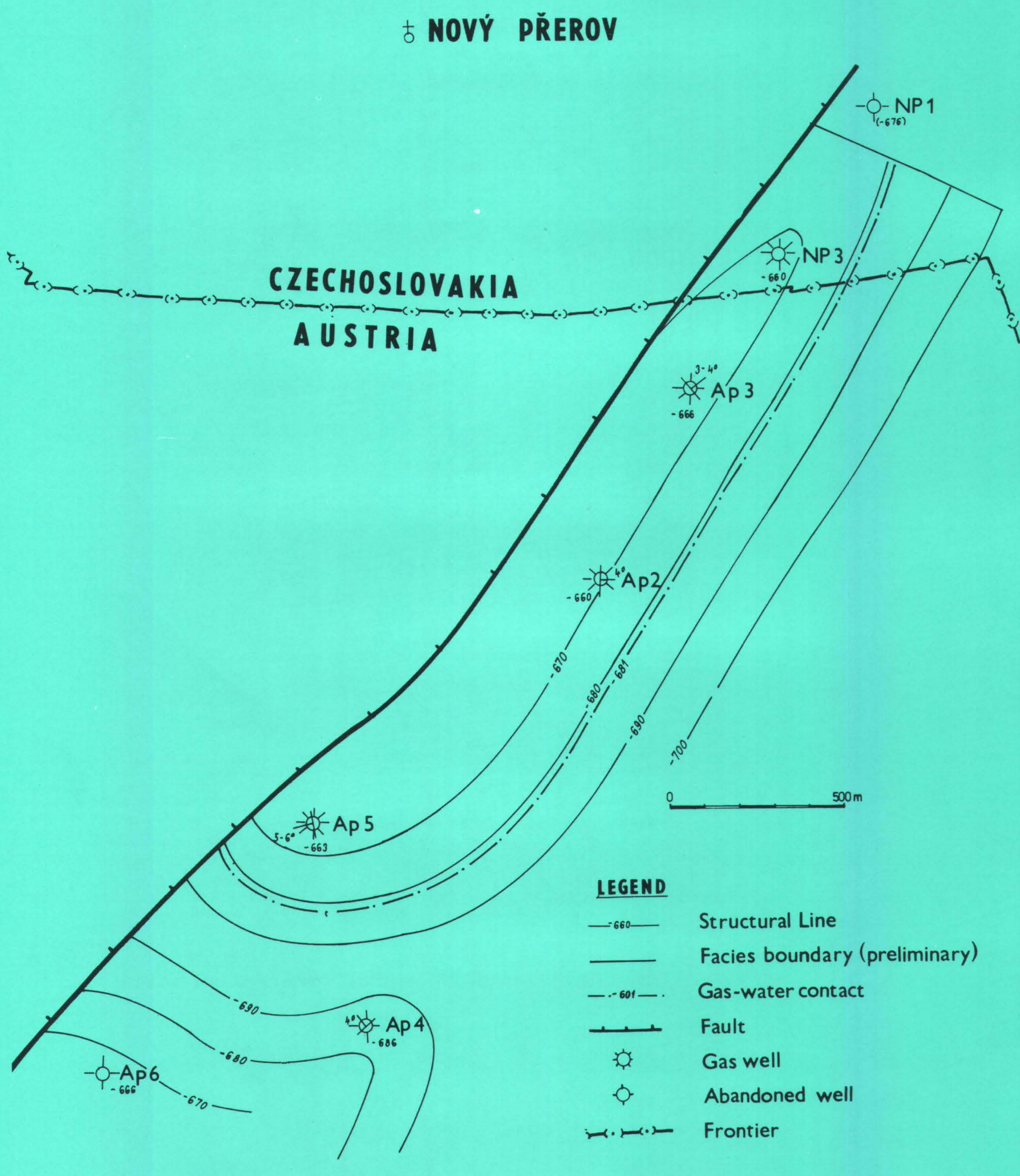


Fig. 11

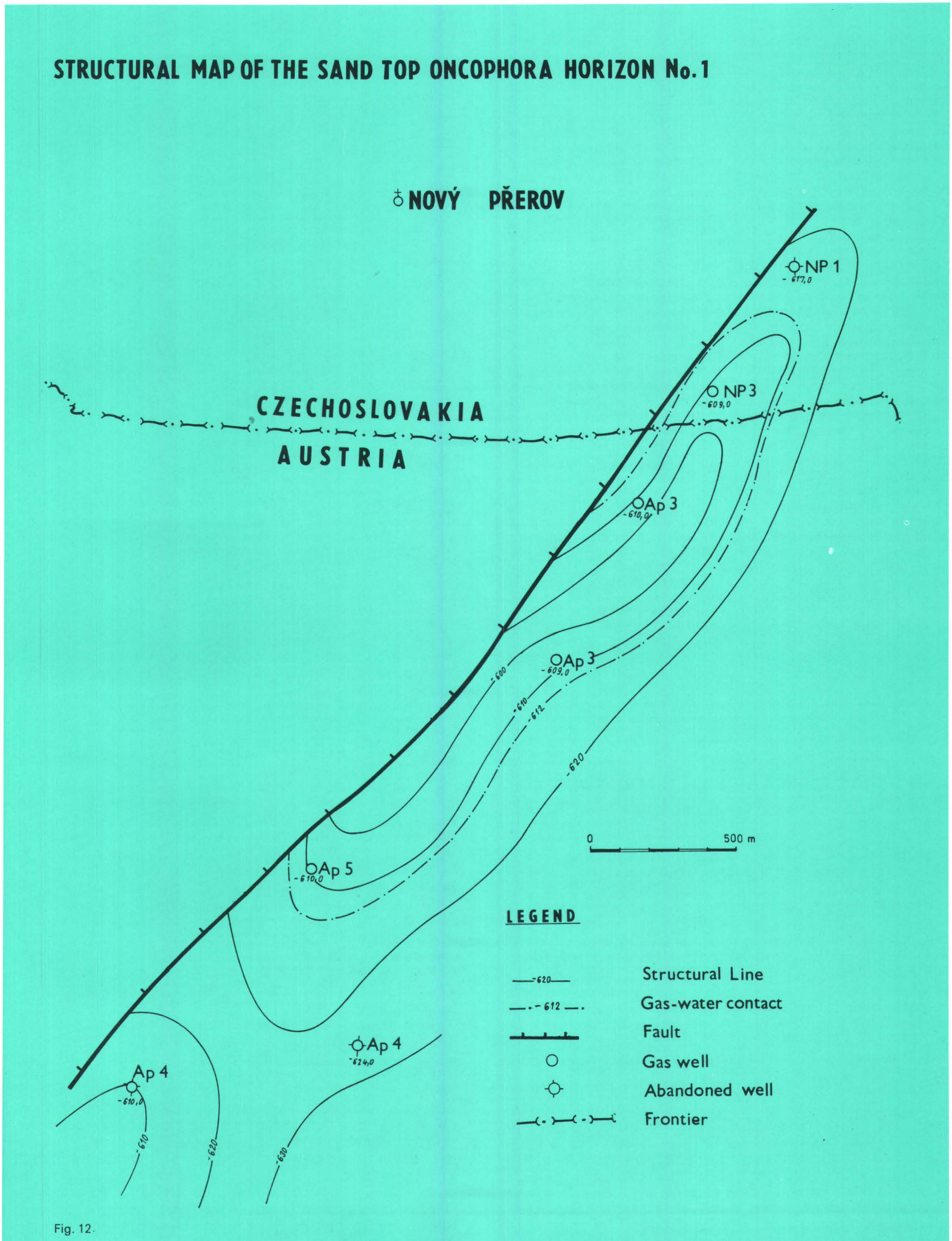

STRUCTURAL MAP OF THE SAND TOP ONCOPHORA HORIZON No. 1
NOVÝ PŘEROV
NP 1
NP 3
-609,0
CZECHOSLOVAKIA
AUSTRIA
Ap 3
-610,0
Ap 3
-609,0
600
610
612
620
Ap 5
-610,0
0
500 m
LEGEND
620
Structural Line
612
Gas-water contact
Fault
Gas well
Abandoned well
Frontier
Ap 4
-624,0
Ap 4
-610,0
610
620
630

Fig. 12.

Abstrakt

Naftově geologickým průzkumem prováděným v období 1981—1988 v jihovýchodní části karpatské předhlubně byla prokázána plynonosnost miocenních pískovcových obzorů v oncophorových vrstvách a ve šlírovém vývoji karpatu. Bylo objeveno společné československo-rakouské naleziště zemního plynu Nový Přerov — Altprerau. Plynné uhlovodíky na tomto nalezišti jsou vázány na 1., 2., 4. oncophorový horizont a na pískovcový obzor ve šlírovém vývoji karpatu. Průzkum naleziště byl ukončen a stanoveny geologické zásoby.

V další etapě průzkumu byly objeveny další plynonosné struktury v oblasti Pottenhofenu a Neuruppersdorfu. Akumulace zemního plynu jsou vázány na svrchní část karbonátů jury (vrt Pottenhofen—2) a na pískovcové obzory oncophorových vrstev (1. — 9. oncophorový horizont). Průzkum na těchto strukturách v současné době pokračuje. Na základě těchto příznivých výsledků, získaných vrtným průzkumem v molasových sedimentech, je možno předpokládat objevení dalších analogických struktur vázaných na miocén karpatské předhlubně.

Zusammenfassung

Durch die im Zeitraum 1981—1988 durchgeführte erdölgeologische Erkundung wurde im südöstlichen Teil der Karpatenvortiefe die Gasführung der miozänen Sandsteinhorizonte in den Oncophora-Schichten und in der Schlierentwicklung des Karpats nachgewiesen. Es wurde eine gemeinsame tschechoslowakisch-österreichische Erdgaslagerstätte Nový Přerov — Altprerau entdeckt. Die gasförmigen Kohlenwasserstoffe sind an den 1., 2. und 4. Oncophora-Horizont und an den Sandsteinhorizont in der Schlierentwicklung des Karpats gebunden. Die Erkundung der Lagerstätte ist beendet und es wurden ihre geologischen Vorräte berechnet.

In der darauffolgenden Etappe der Erkundungsarbeiten wurden weitere gasführende Strukturen im Raum Pottenhofen und Neuruppersdorf entdeckt. Die Erdgasakkumulationen sind an den oberen Teil der Jurakarbonate (Bohrung Pottenhofen-2) und an die Sandsteinschichten der Oncophora-Horizonte (1. — 9. Oncophora-Horizont) gebunden. Die Erkundung der genannten Strukturen wird gegenwärtig fortgesetzt. Aufgrund dieser günstigen Ergebnisse, die durch Bohrerkundungsarbeiten in Molassesedimentgesteinen erzielt wurden, kann die Entdeckung weiterer, an das Miozän der Karpatenvortiefe gebundener analogischer Strukturen vorausgesetzt werden.

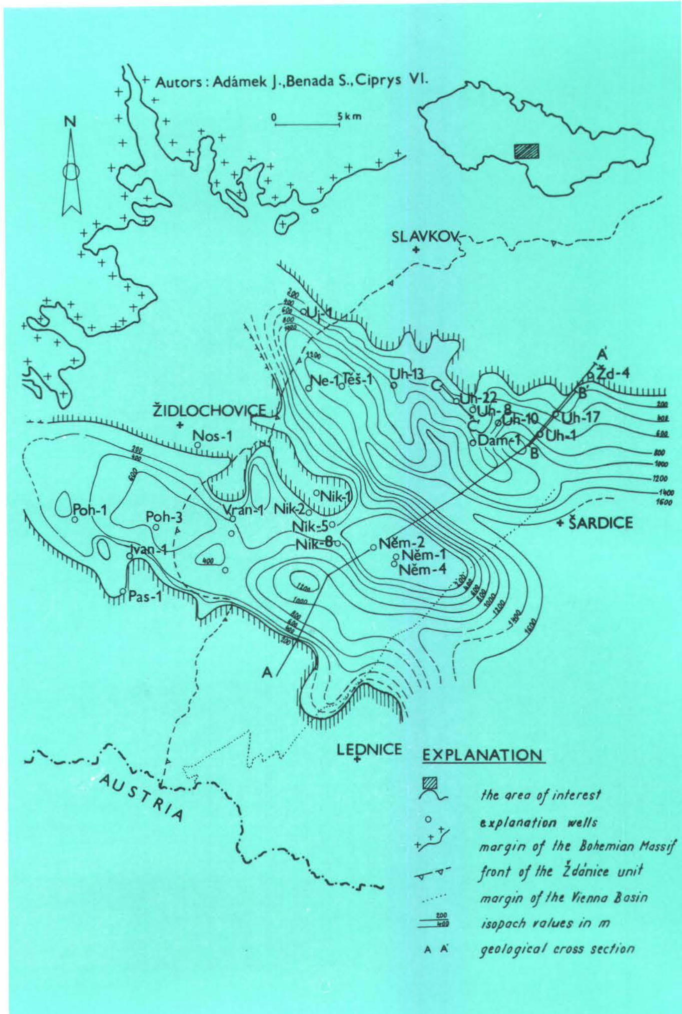


Fig. 1: Isopach map of Paleogene sediments.

NEW DATA ON THE EXTENT, STRUCTURE AND DEPOSITS OF THE AUTOCHTHONOUS PALEOGENE IN THE NESVAČILKA GRABEN

Stanislav Benada, Vladimír Ciprys, Petr Kostelníček, Moravské naftové doly, Hodonín, Czechoslovakia

Recently new results have been obtained when prospecting for oil and natural gas in Paleogene sediments preserved on the southeastern flanks of the Bohemian Massif. Autochthonous Paleogene sediments have widespread occurrence, above all, in two extensive depressions in the Nesvačilka and Vranovice grabens, the axes of which are perpendicular to the margins of the Bohemian Massif. In the northern part, the Paleogene sediments are covered with Neogene sediments of the Carpathian Foredeep while they are overlain by overthrust flysch nappes of considerable thickness in the southern part.

The extent of the Paleogene sediments is obvious from Fig. 1 depicting thicknesses of the autochthonous Paleogene rocks. Both the Nesvačilka and the Vranovice grabens penetrate deep into the Bohemian Massif and, locally, Paleogene sediments even extend beyond the margins of the grabens. The original extent of Paleogene sediments on the flanks of the Bohemian Massif is generally believed to have been a much broader one; however, a part of these sediments was eroded and a part removed by the flysch nappes. Paleogene sediments are included in the basal parts of the Ždánice unit, but they also form separate para-autochthonous slices.

Paleogene sediments were incountered in more than 40 deep wells; in regions not explored by exploratory drilling these sediments can be correlated by a comparatively closely-spaced network of seismic profiles. A maximum thickness of 1,000 to 1,500 m has been assumed for the axial part of the Nesvačilka graben. The interpretations base on the results of the Těšany-1, Nesvačilka-1 and Pohořelice-3 boreholes. In the southern part, the identification of Paleogene sediments in seismic materials is limited by the margin of the Vienna basin, where the quality of seismic data considerably decreases. In this area, the surface of Paleogene sediments is thought to occur at depths greater than 4,000 m and these sediments are strongly reduced by overthrust nappes.

Stratigraphy of Paleogene sediments has been studied in detail, at the present time, by the geologists of the Moravian Oil Company (MND), Hodonín, of the Central Geological Survey, Prague and of Charles University, Prague. The conception of a consecutive transgression of the sea has been generally accepted. Two somewhat differing opinions on the age of the autochthonous sediments have been presented. Jiříček (1987) places these sediments into the Upper Eocene — Lower Oligocene, whereas Hamršmíd, Krhovský, Švábenická (1988), basing on nannoplankton investigations, believe these sediments to be of Paleocene to Oligocene age. Most probably the older sediments were redeposited, in great part, during the last and most important transgression in the Upper Eocene — Lower Oligocene.

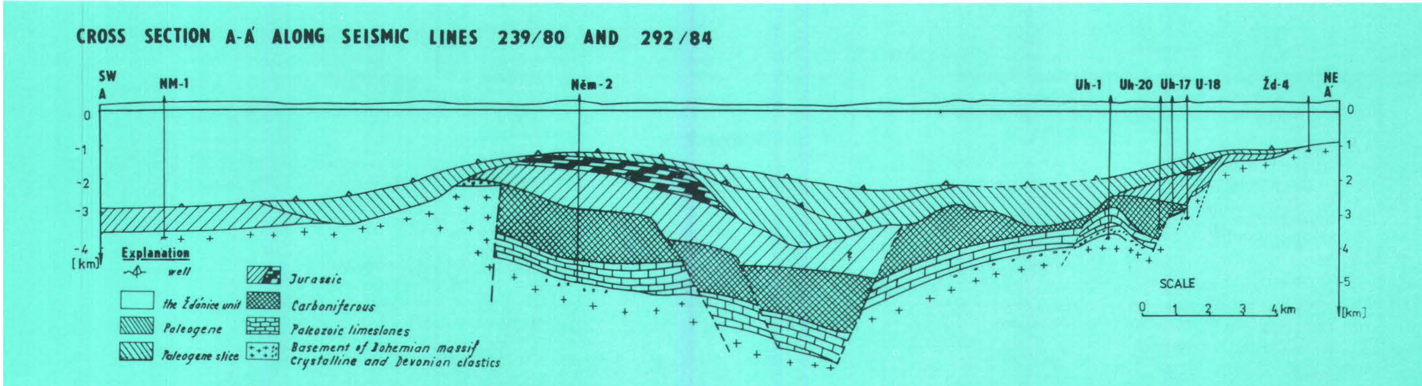


Fig. 2: Cross section A—A' along seismic lines 239/80 and 292/84.

This is documented by a great number of redeposited microfaunas present in Oligocene sediments. Upper Oligocene sediments have been known mainly from tectonic slices emplaced in the lower parts of the Ždánice nappe. Their original area of sedimentation was situated farther southeast below the present-day nappes.

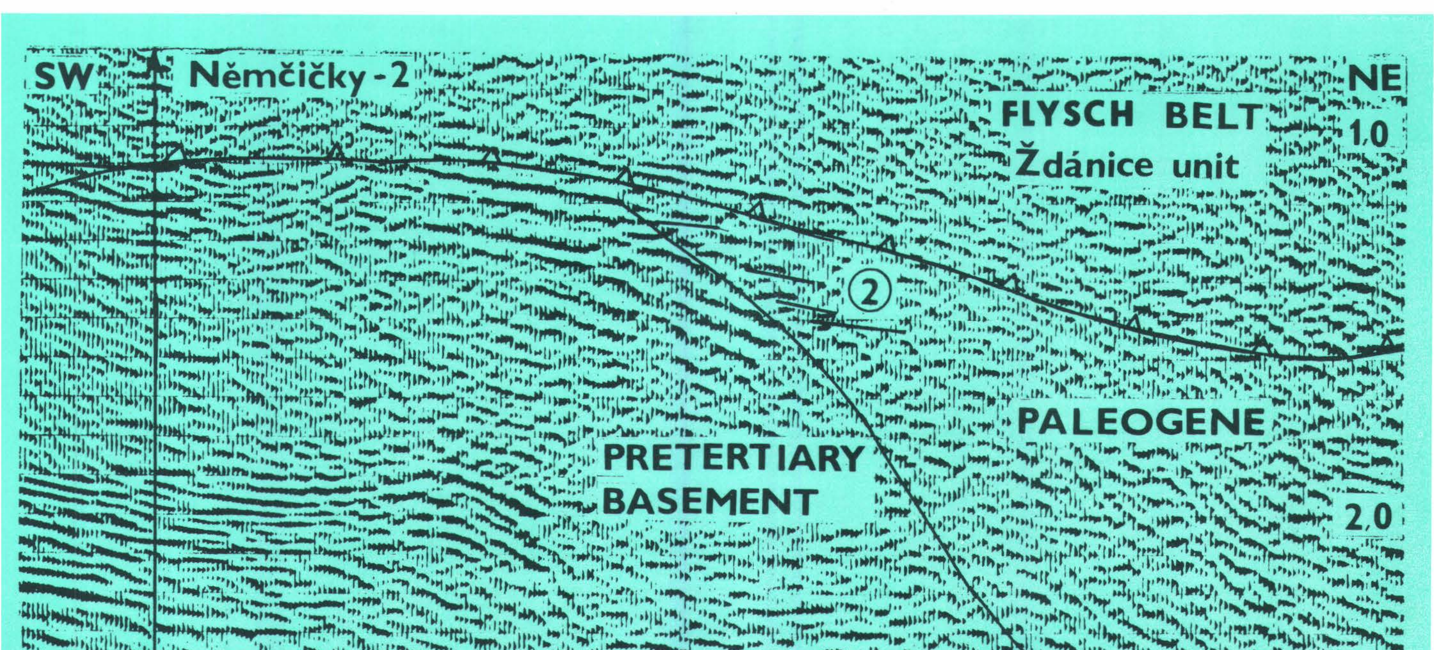
The Nesvačilka and Vranovice grabens are supposed to have been founded to old faults. Their activity was revived in dand after Jurassic time. The two young depressions filled with Paleogene sediments appear to have originated due to erosion which was the dominating element mainly during the last stage of their modelling.

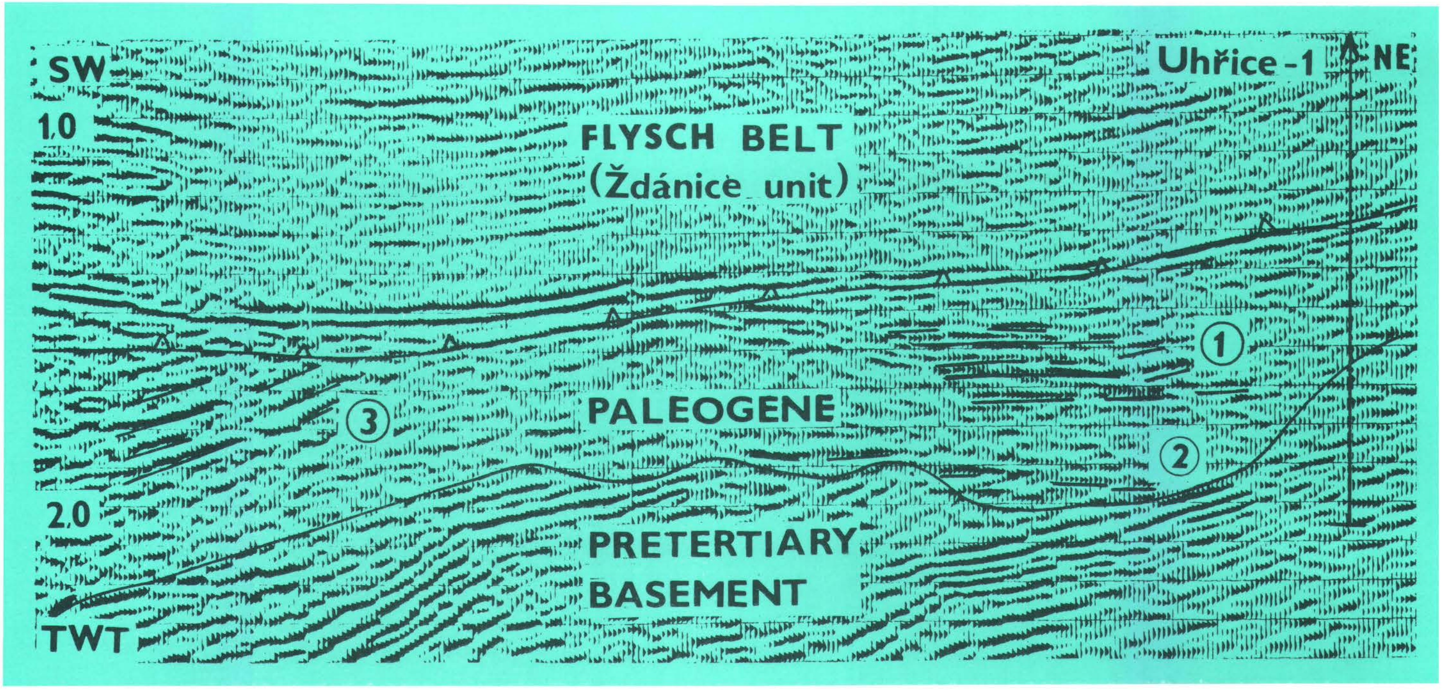
Fig. 2 illustrates a geological cross-section along seismic profile 292/85 — 239/80 running SW—NE and crossing the Nové Mlýny-1, Němčičky-2, Uhřice-1, 20, 17, 18 and Ždánice-4 boreholes. It displays the principal geological features of the whole region. The basement consists of plutonic rocks of the Pavlov-Waschberg block in the south and of the central Moravian block in the north. A thick Paleozoic rock complex was deposited in the tectonically active zone between these blocks. Sediments of the clastic Devonian (Old red facies), carbonates (Devonian — Lower Carboniferous) and clastic facies of the Lower to Upper Carboniferous have been recognized in this region.

The original Paleozoic basin was rebuild and reduced after Variscan folding that had also affected the margins of the Bohemian Massif. Another transgression of the sea occurred in the region under study in Jurassic time. After the revival of tectonic activity some blocks were incised and the majority of Jurassic sediments, mainly those in the central parts of the Nesvačilka and Vranovice grabens, were eroded.

In the time section of seismic profile 239/80 (Figs 3, 4), the Paleogene interval is characterized as a prevailingly reflection-free zone. Several anomalous reflection groups can be interpreted at different time levels in some points of this interval. The reflection groups are defined as seismic facies and denoted 1, 2 and 3. Two of these facies are dominating,

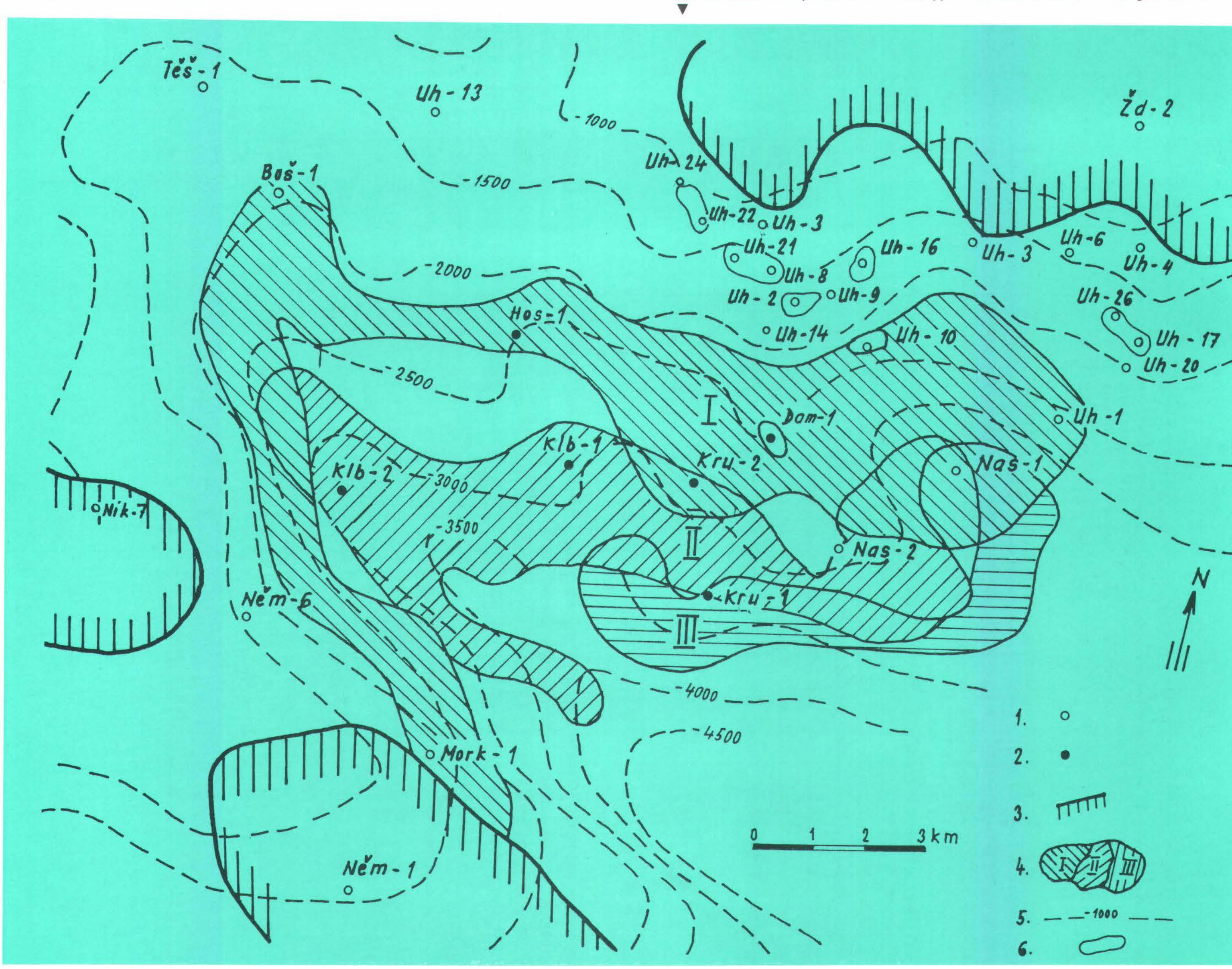
Fig. 3: True amplitude seismic section 239/80 (left part) across the Nesvačilka graben showing the distribution of seismic facies in the Palaeogene. 2 — seismic facies.





▲ Fig. 4: True amplitude seismic section 239/80 (right part) across the Nesvačilka graben showing the distribution of seismic facies in the Palaeogene. 1, 2, 3 — seismic facies.

Fig. 8: Hypothetical distribution of clastics in the Nesvačilka graben. 1 — well; 2 — projected well; 3 — boundary of Paleogene sediments; 4 — the clastics complexes; 5 — isohypse values in m; 6 — oil-gas field. ▼



one of them is characterized by short, low-to-medium-amplitude, subhorizontal reflections that also occur at the base of the Paleogene complex. The other facies is distinguished by steep, relatively pronounced reflections occurring within the Paleogene complex. In some places of the slope of the Nesvačilka graben, these anomalous reflections (seismic facies) can be correlated to the clastic complexes encountered in some boreholes (Dambořice-1, Těšany-1).

The classtic complexes are thought to have been deposited as sand bars and sand belts along the shore in the course of repeated marine transgressions during the Paleogene.

Most of the Paleogene sediments consist of calcareous, sandy and silty claystones. Sandstones and conglomerates commonly appear in the lower parts of the Paleogene interval. Dominant are the following types of clastic rocks:

1. Basal conglomerate with abundant crystalline, limestone and Carboniferous pebbles,
2. Coarse-grained quartz sandstone with well-rounded quartz grains, and
3. Sandstone and conglomerate alternating with claystone and limestone and dolomite blocks.

This group of clastics comprises abundant Mesozoic redeposited material.

The quartz sandstones are the most important of these three types. They are excellent reservoir rocks with a porosity of 15—25 % and permeability of 200 to 2,000 mD.

Prospecting for oil and natural gas on the northwestern slope of the Nesvačilka graben was started in the seventies, initially with regard to Paleozoic carbonates. When testing Paleozoic deposits, favourable oil and gas indications were established in Paleogene sediments, too. Fig. 5 displays the rather complex geological setting in the Uhřice-east oil deposit (discovered by Uhřice-17 borehole). Oil accumulations occur in Devonian carbonates. It is obvious that the Uhřice-20 borehole has reached a small gas-bearing sand horizon in Paleogene rocks not far from its wedging-out. A number of similar horizons have been determined on the northwestern slope of the Nesvačilka graben. Non-commercial gas reserves have also been proved in Dambořice-1 borehole.

Fig. 6 illustrates the correlation of resistivity logs in the boreholes Uhřice-25, 22, 21 and 8. The former two boreholes have reached an ol field and the latter two a gas field. Both deposits are situated in the Uhřice-west section, also on the northwestern slope of the Nesvačilka graben. Fig. 7 shows the structural positions of the boreholes in these deposits, indicating water, oil and gas saturation. The depth of the deposit ranges from 1,600 to 2,000 m; its reservoir rocks consist of coarse-grained Paleogene quartz sandstone. The thickness of the deposit varies from 60 to 110 m. Jurassic pelites in the deeper parts of the Nesvačilka graben are regarded as the oil source rocks sealed-of by overlying impervious Paleogene pelites. Hydrocarbon migration most probably took place in Miocene time during which the source rocks became submerged to great depths and affected by high temperatures and pressures.

Fig. 7 is a geological cross-section demonstrating the situation of the Paleogene deposits in the Uhřice-west area.

The commercial reserves of the oil deposit have been estimated at 230,000 tons of low-gravity paraffinic oil and at 150 million cubic m of gas in the gas deposit. the gas contains about 95 % methane, 3 % higher hydrocarbons and 2 % nitrogen combined with CO_2.

The Paleogene sediments with layers of clastics in the Nesvačilka and Vranovice grabens are considered to be highly promising with respect oil and gas exploration. Fig 8 illustrates the distribution of clastics as assumed in the Nesvačilka graben. This interpretation bases on the evaluation of seismic data and the boreholes drilled. Presently an extensive project is under way for exploring the clastic horizons that form stratigraphic traps in various places and at different depth levels of the Nesvačilka graben.

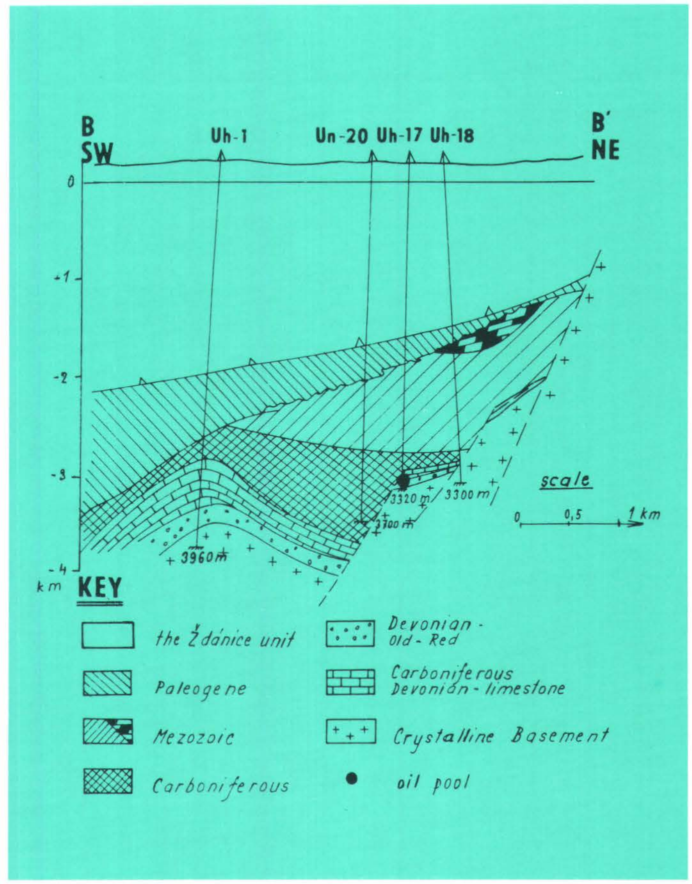
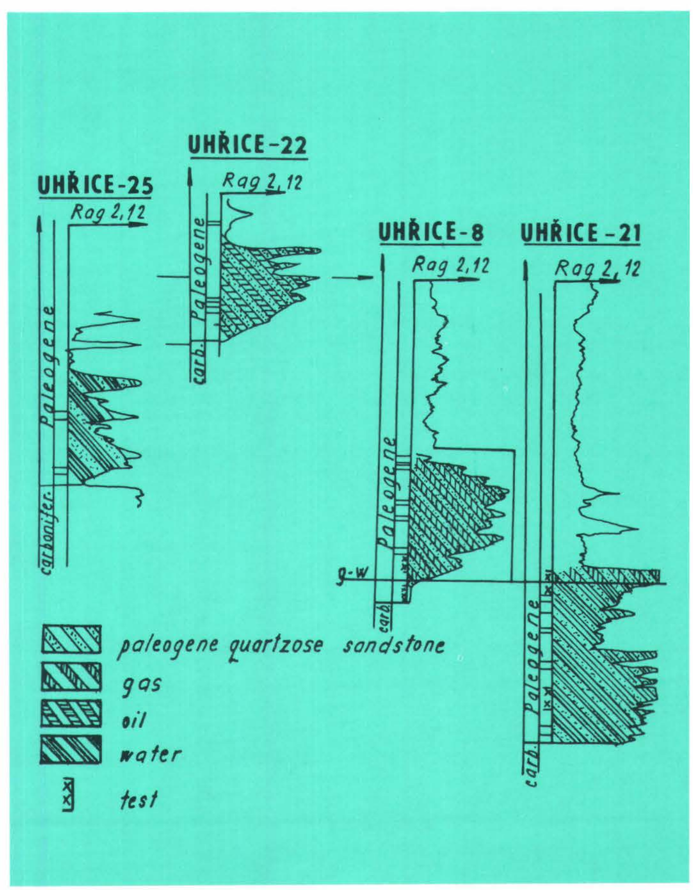


Fig. 5: Geological section BB' across Uhřice-east oil field.

Fig. 6: Comparison resistivity logs in Uhřice west fields.



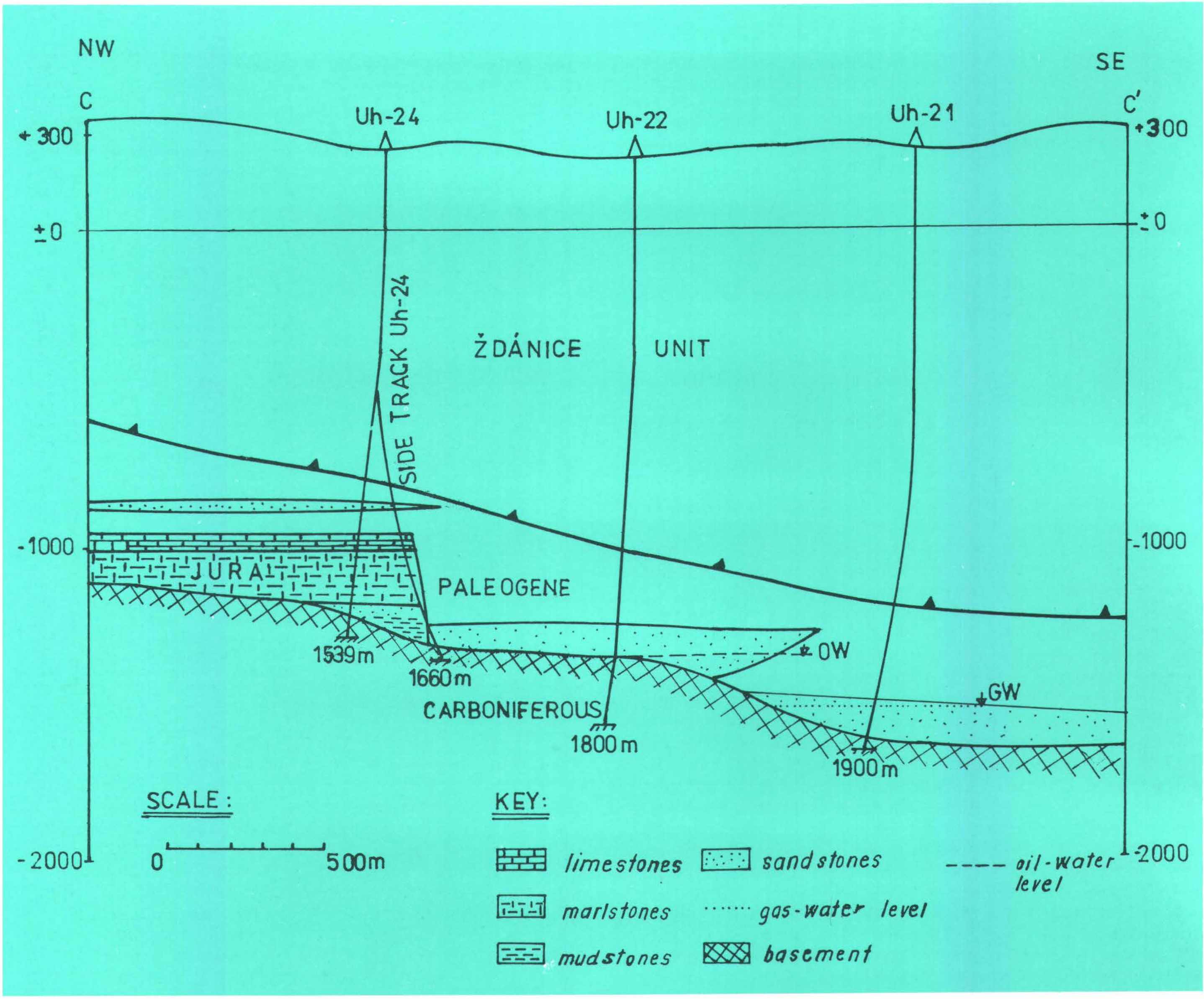


Fig. 7: Geological section C—C' across Uhřice-west oil and gas fields.

There is a good chance that, on the northwestern slope, in the central part and on the southeastern steeper slope of the Nesvačilka graben, oil and gas deposits resembling those found by the Uhřice-22, 21 8, Dambořice-1 and Uhřice-20, may be discovered.

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Abstrakt

V poslední době byly získány nové poznatky při naftovém průzkumu nesvačilského a vranovického příkopu.

Na základě více než 40 vrtů, kterými byly sedimenty paleogénu zachyceny, je sestrojena mapa mocností a geologické řezy. Stáří těchto sedimentů postupně přechází od paleocénu, eocénu do sp. oligocénu. V časových řezech seizmických profilů byly vyčleněny anomální skupiny reflexů, které jsou charakterizovány jako seizmické facie. Po srovnání s litologickými profily vrtů lze konstatovat, že ve většině případů tyto facie zobrazují vrstvy nebo komplexy klastik v jinak převážně pelitickém vývoji paleogénu. Pískovce a slepence, které se v paleogénu vyskytují, lze rozdělit do 3 základních skupin, z nichž křemenné pískovce jsou vynikajícími kolektory. Ložiska přírodních uhlovodíků byla nalezena na jz. svahu nesvačilského příkopu v oblasti Uhřice-západ. Jednotlivé plynonosné obzory byly zjištěny i na vrtech Uhřice-20 a Dambořice-1.

Zusammenfassung

In letzter Zeit wurden bei den Erdölerkundungsarbeiten im Nesvačilka- und Vranovice-Graben neue Erkenntnisse gewonnen. Aufgrund von mehr als 40 Bohrungen, welche die Sedimente des Paläogens durchbohrten, wurden eine Mächtigkeitskarte und einige geologische Profile zusammengestellt. Das Alter dieser Sedimente geht allmählich vom Paläozän und Eozän bis zum unteren Oligozän über. In seismischen Profilen wurden einige Gruppen anomaler Reflexionen unterschieden, die als „seismische Fazies" charakterisiert werden können. Nach einem Vergleich mit lithologischen Bohrprofilen kann festgestellt werden, daß diese „Fazies" meistens Schichten oder Komplexe von Trümmergesteinen in der sonst überwiegend pelitischen Entwicklung des Paläogens darstellen. Die im Paläogen vorkommenden Sandsteine und Konglomerate kann man grundsätzlich in 3 Gruppen unterteilen, von denen die Quarzsandsteine hervorragende Speicher-

gesteine darstellen. Lagerstätten natürlicher Kohlenwasserstoffe wurden am SO-Hang des Nesvačilka-Grabens im Raum Uhřice-West gefunden. Einzelne gasführende Horizonte wurden auch in den Bohrungen Uhřice-20 und Dambořice-1 ermittelt.

ZONES OF POSSIBLE OCCURRENCE OF NON-ANTICLINAL DEPOSITS IN THE VIENNA BASIN

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Prognostication of and research for non-anticlinal types of deposits are the fundamental problems of present-day petroleum geology in the Vienna basin. This interest is the result of the high grade of exploration on all elevations known. The character of non-anticlinal traps suggests that can be expected to occur anywhere in an oil-bearing basin. However, biofacies, lithofacies and palaeotectonic analyses of a basin permit zones of the possible occurrence of certain non-anticlinal trap types be determined. Such a prognosis was made for the Vienna basin in the framework of COMECON theme No 7.1.2. „Methods for determining non-anticlinal oil and gas traps and their improvement regarding the experience gained in highly industrialized contries" (Kolářová M., Buchta Š. Ralbovský E., 1987). As this study has yielded results relevant to the potencial occurrence of non-anticlinal traps, the paper presented it in abbridged and modified form.

The research work started by revising the entire fund of deposits from the viewpoint of non-anticlinal traps. This revision has shown that all principal types of traps are present in the Vienna basin, including traps formed by domal uplift of the cover, traps with lateral sealing and lithologic traps sealed on all sides. The classification by V. J. Ratner (Ratner et al., 1982) was used in order to class them. In our opinion, this classification based on trap morphology fully complies with the requirements of oil and gas exploration. I addition to traps bounded tectonically, lithologic, stratigraphic and biogenic traps, traps in erosional elevations and traps closed on all sides occur in the Vienna basin. Combined traps, mostly lithologic-tectonic ones, are relatively abundant (Fig. 1).

The non-anticlinal deposits ascertained were subdivided into groups on accordance with the trap type stratigraphic age of the reservoir rock. This analysis has shown that certain stratigraphic levels comprise several oil and gas deposits in traps of the same or similiar types (Table 1). This accumulation of deposits can be regarded as the primary indication of a zone with a certain type of non-anticlinal traps (Lab horizon, 8. Pannonian horizon, etc.). The subsequent investigations consisted in determining the courses of the zones indicated with aid of lithofacies analyses using electric logs and seismic profiles. The results obtained are depicted in a map delinesting the zones of the potential occurrence of non-anticlinal deposits (Fig. 2).

The zones with the occurrence of a certain type of non-anticlinal deposits can be subdivided from two points of view. The first group includes linear and areal zones. The linear ones are zones regionally wedging out, reducing their marl content, uncoformities and organogenic barrier reefs. They can follow any course, but are characterized by traps positioned like pearls on a string. An areal zone implies the irregular spatial arrangement of non-anticlinal traps, e. g.

Zones of the potential occurrence of non-anticlinal deposits in the Vienna basin

Zone	Age	Trap type (see Fig. 1)	Deposit	Description on the map
A	Triassic	I. a	Borský Jur Závod	A1 A2
B	Ottnangian	II. c	Mikulčice — H 1 Lužice — H 1	B1 B2
C	Karpatian	II, b, d	Hrušky — Karpatian	C1
D	Lower Badenian	II. a, c	Hrušky — L. Badenian Lanžhot — horizon 26	D1 D2
E	M. Badenian	II. a	Gajary — horizon 1 Gajary — horizon 3 Jakubov — horizon 2 Dúbrava — horizon 2 Dúbrava — horizon 5 Vysoká — horizon E	E1 E2 E3 E4 E5 E6
F	M. Badenian (Láb — horizon)	II. a, c	Poddvorov Josefov Hrušky Brodské — lifted block Závod Studienka	F1 F2 F3 F4 F5 F6
G	M. Badenian	I. b III. c I. b	Láb — reefs Kostice Lednice	G1 G2 G3
H	U. Badenian	II. a, c	Poddvorov Hrušky Závod — south	H1 H2 H3
I	Pannonian	III. a, b	Suchohrad — Gajary Jakubov — Pannonian 8 Láb — Pannonian 8 Vysoká — Pannonian 8	I1 I2 I3 I4

erosional elevations or deltaic deposits. The second group is related to the number of reservoir beds countoured by the boundary of the zone. A single horizon (Lab horizon, bioherms) or a whole sequence of sandy layers (Middle Badenian delta), i. e. a set of reservoir rocks, can be concerned. The two types are shown in the occurrence of individual traps. Their correspondence to a certain zone is indicated by code numbera in accordance with Table 1. A lithological trap is denoted by the hatched zone boundary.

The spatial arrangement of non-anticlinal trap zones in the Neogene sediments of the Vienna basin reflects their complex lithofacies structure and locally the questionable nature of our present-day views on the lithostratigraphical classification of reservoir rocks and the spatial interrelations between zones of lithologic changes. Nine zone (A—I) for the potencial occurrence of non-anticlinal traps have been distinguished and are listed in Table 1. Five of these zone are areal ones with areal trap distribution and four zones are linear ones.

The zones of the potential occurrence of non-anticlinal traps (hereinafter referred to as NAT) can be characterized as follows:

A) Areal NAT zones in erosional elevations of the Mesozoic basement

The occurrence of traps in erosional elevations in the Mesozoic frontal nappes in the basement of the Vienna basin was established in analogy to the Austrian portion of the Vienna basin was based on the interpretation of seismic profiles and the geological results from deep boreholes. Structural maps depicting the relief of the basement of the Vienna basin were constructed and elevation zones determined. As to the discovery of commercial occurrences, exploratory drilling was successful in the tops of these elevations. However, merely elevations with a sealing cover are significant for exploration. The Karpatian pelites can be regarded as a suitable cover. Erosional elevations lacking such a cover were found to be dry (Láb, Malacky, etc.). Reservoir rocks are represented by Upper Triassic dolom-

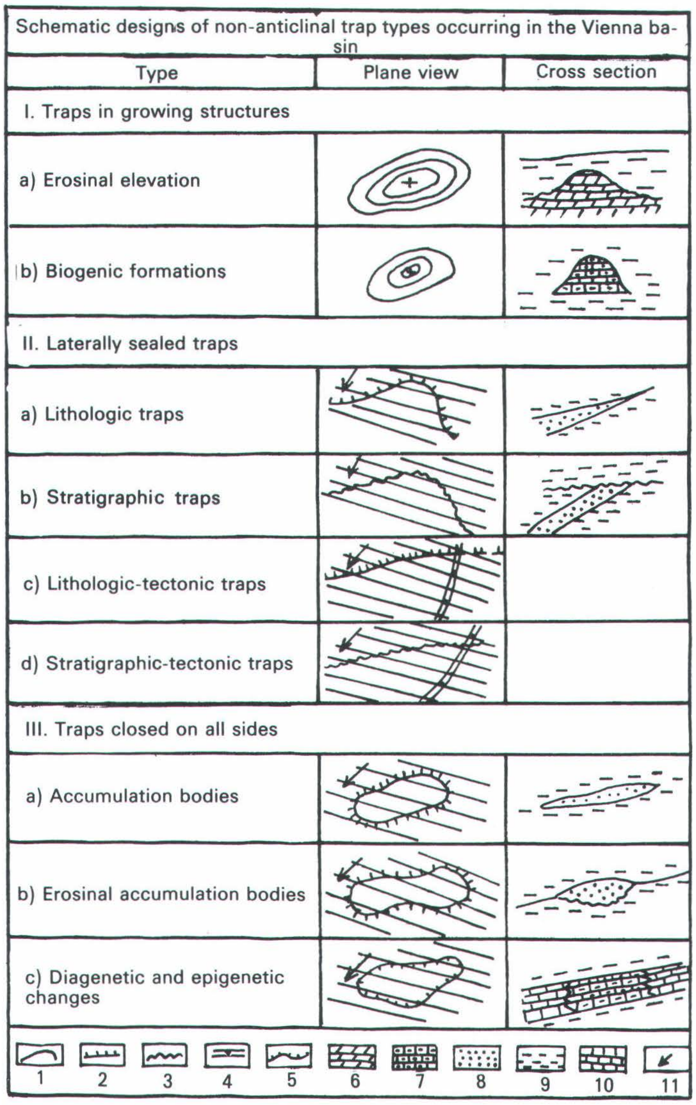


Fig. 1: Explanatory notes
1 — structural line; 2 — thinning, reduction of marl content; 3 — unconformity; 4 — faults; 5 — delineation of a region of secondary changes; 6 — dolomite; 7 — permeable limestone; 8 — sand, sandstone; 9 — clay, claystone; 10 — impervious limestone; 11 — direction of dip.

ites of low and medium secondary porosity. The types of the traps present are schematically illustrated in Fig. 1, Ia. The Borský Jur and Závod deposits only were found in this zone, but the discovery of analogous deposits is expected for the future.

B) Areal NAT zone at the Ottnangian base

This region includes porous rocks comprising Ottnangian basal clastics. The irregular areal development is due to sedimentary conditions — the partial depression sof the pre-Ottnangian relief apper to have been filled first, after which sedimentation continued in the broader region. In terms of sedimentology, the basal clastics consist of a broad group of psamitic sediments ranging from coarse-grained conglomerates to medium — and fine — graines sandstones. Generally the rock bodies are lenticular in shape; the boundaries of the individual traps are influenced both by thinning beds and tectonics (types IIa, c). With regard to the unconformable bedding of the overlying sediments, the occurrence of stratigraphic or stratigraphic — tectonic deposits (types II b, d) is also possible. In view of the results obtained in the Lužice and Hodonín areas, relatively small deposits with low hydrocarbon reserves can be present. Traps of this zone are exemplified by the Mikulčice and Lužice deposits accumulated in the Ottnangian basal sand locally designated as H 1.

C) Areal NAT zone in Karpatian basal clastics

This zone of trap occurrence associated with an unconformable boundary of sand hodies in the Lower Karpatian could be proved merely on the western sloope of the Týnec hign in the Hrušky area. In addition to the unconformity, the trap is also bounded by slip faults. The reservoir consists mainly of coarse — to fine — grained sand of low porosity and permeability. As the Karpatian sediments are poorly explored, a short section of this zone only could be identified so far. The deposits in the Karpatian of the Hrušky field are examples of a morphogenic trap type with combined stratigraphic-tectonic sealing (II d). They have accumulated in several horizons (sands) of the basal Karpatian Týnec sand complex; their main sealing element is a partial surface of unconformity between the Upper and Lower Karpatian.

D) NAT zone at the Lower Badenian base

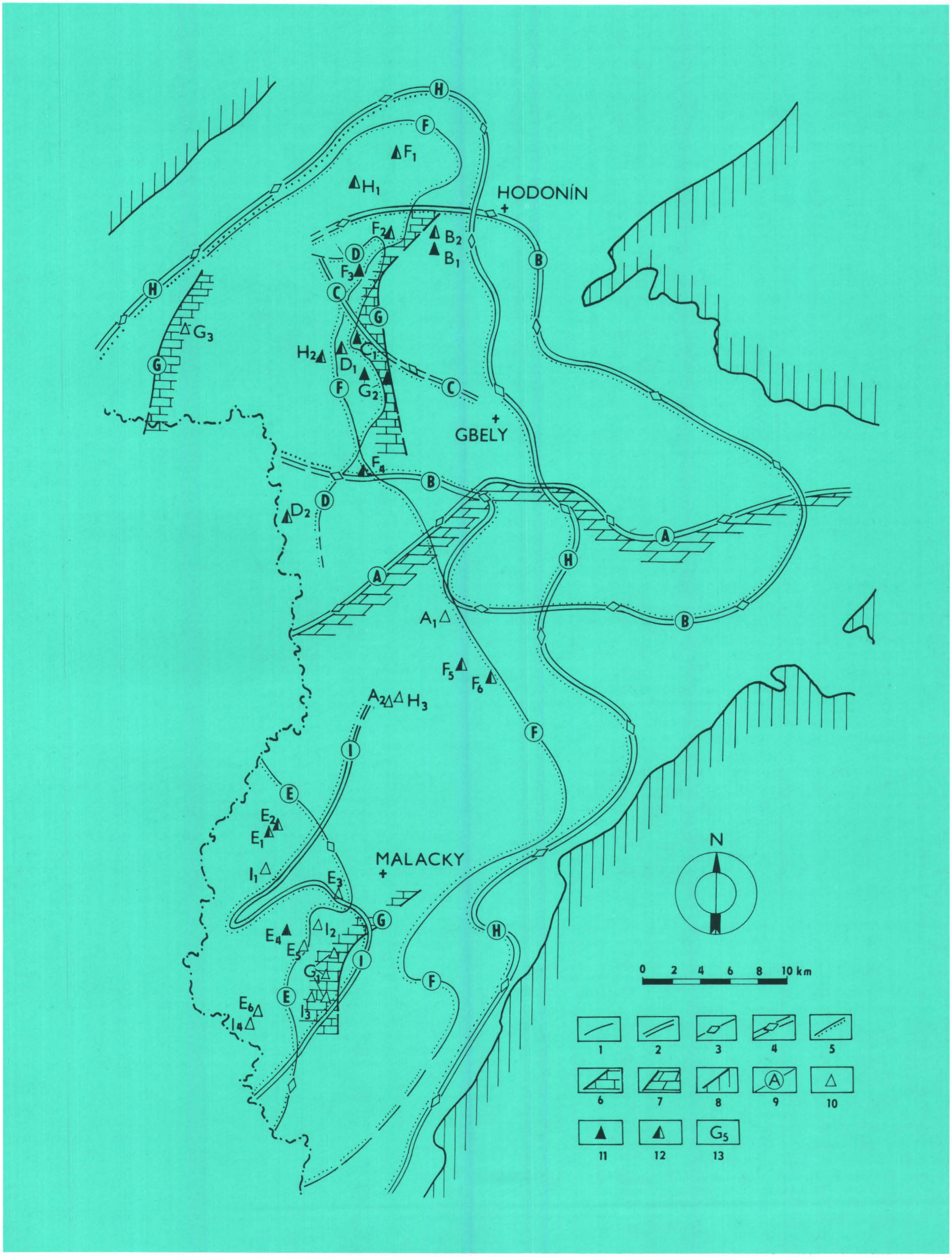
Within the Hodonín-Gbely horst, Lower Badenian basal clastics have developed in the Lanžhot, Brodské and Hrušky areas, where they gradually wedge out on the slopes of the Týnec high. Commonly they consist of medium — grained sandstones, but coarse — grained sandstone conglomerates are present too. The traps are seales lithologically, to a lesser degree also tectonically (type II a, c). The potencial extension of this zone into other parts of the Vienna basin will be the subject of further study. The traps of this zone are exemplified by the deposit in horizon No 26 of the Badenian in the Lanžhot field. It can be characterized as a trap formed at the place where the sand body is wedging out up-hill. Other deposits placed into this zone were found on the lifted block of the Lanžhot—Hrušky faultin the Hrušky field.

E) NAT zone in deltaic sand bodies in the Middle Badenian

The traps are tongue-shaped with simple lithologic lateral sealing (type II a). They form a well-outlined zone passing to the southeastern corner of the Vienna basin in Austria. Five deposits have been discovered so far, the largest of them being the Gajary oil and gas deposit in horizon No 1. The Jakubov gas deposit and the Dúbrava oil deposit in horizon No 2 and the Gajary oil deposit with a small gas cap accumulated in horizon No 3 are of minor size. The fifth deposit forming a gas accumulation discovered by Dúbrava-16 borehole in horizon No 5 is of an extent so far unknown. The individual productive horizons exhibit monoclinal bedding and wedge out roughly southeasterly. Greygreen calcareous sandstones of excellent permeability in the central parts of the deposits are the reservoir rocks. They are overlain by Middle Badenian sealing pelites. Analogous conditions can be expected to exist also in the area north of Gajary, into which the northern branch of the Danube palaeodelta is thought to have extended. The Gajary deposit is a typical example of traps occurring in this zone.

▸

Fig. 2: Vienna basin
Map depicting the zones of the possible occurrence of non-anticlinal deposits.
Explanatory notes: 1 — linear zone for one natural reservoir; 2 — areal zone for one natural reservoir; 3 — linear zone for a complex of natural reservoirs; 4 — areal zone for a complex of natural reservoirs; 5 — sand and sandstone reservoir rocks; 6 — limestone reservoir rocks; 7 — dolomite reservoir rocks; 8 — boundaries of the Vienna Basin; 9 — indication of a zone (see text and table); 10 — gas deposit; 11 — oil deposit; 12 — oil deposit with gas cap; 13 — description of the deposit (see table).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F) NAT occurrence in the zone of regional thinning of the Láb horizon

The Láb horizon, an extensive sand complex developed at the base of the Agglutination zone in the Middle Badenian, has been considered the principal reservoir rock of the Vienna basin in Czechoslovak territory. It extends almost over the entire basin. Besides a number of fields with anticlinal and tectonic traps, non-anticlinal trap deposits, commonly of the lithologic and lithologic-tectonic types (II a, c) have been found. The horizon is composed of several gradually thinning sand bodies. This fact has been proved for the Závod and Borský Jur fields and also for the Poddvorov field. For this reason, the zone outlined on the map should be regarded as a relatively broad belt bordering the boundary of the thinning Láb horizon. The lithology ranges from medium — to very fine — grained consolidated sands to sandstones, generally well graded. The major part of the oil and gas reserves of the Neogene sediments in the Vienna basin have accumulated in the sands of this horizon. Therefore, primary attention should focus on the exploration of natural hydrocarbon accumulation in this reservoir rock. The deposit at Brodské (lifted block) is a typical example of the traps in this zone.

G) NAT zones in biogenic formations of the Middle Badenian

Biogenic accumulations of the shallow-water shelf have formed in Middle Badenian sediments and are present at three locations in the Vienna basin — on the southwestern slope of the Láb high, on the western slope of the Týnec high and in the Mistelbach block. The three occurrences (fragments) may be related to a single zone charakterized by the presence of Lithothamnion limestones that form two kinds of traps in the Vienna basin: (1) conic bioherms and (2) biostromes — beds of common thickness lithologically grading into clays of low permeability. The bioherms (biogenic highs) form three separate accumulation traps (type I b) developed in the Láb horizon and covered by the marls of the Agglutination zone in the Láb region. An extensive biostrome was found on the Týnec high, borgering its western slope. Two minor oil deposits in the Kostice area have been discovered there. The reservoir rocks are probably the result of secondary changes in carbonates. The traps are irregularly shaped and sealed on all sides (type IIIc). The third occurence of biogenic carbonates in the Lednice area resembles that on the Hodonín-Gbely horst where it forms a relatively extensive biostrome. A minor gas deposit was found in the uplifted position of the biostrome near Lednice — 6 borehole. The trap is the result of a semibrachyanticlinal closure at the Schrattenberg fault. Its sealing appears to be a purely tectonic one.

H) Areal zone of NAT occurrence in Upper Badenian thinning sands

Upper Badenian sediments have been deposited almost on all of the surface of the Vienna basin; at some locations they lie unconformably on Eggenburgian, Ottnangian and Karpatian sediments. The main reservoir beds are the sands of the Rotalia and Bulimina zones. The formation of lithological and combined traps (II a, c) can be assumed for the entire distribution of the Upper Badenian sand facies. Generally the reservoir beds are fine-grained sands, mostly consolidated in the lower parts of the horizons. A number of deposits from various oil and gas fields both in the Moravian and Slovak parts of the Vienna basin can be associated with this zone. Typical examples are some Upper Badenian deposits in the Hrušky field (horizons No 5 C, 6 and 10).

I) Areal NAT zone in deltaic accumulations at the Pannonian base

The deltaic development of Pannonian horizon No 8 was proved by exploratory drilling in the southwestern part of the Vienna basin within the Vysoká, Láb, Jakubov, Suchohrad and Gajary oil and gas fields. The bird-ffoot delta extends into Austria. Within this zone, the sand of Pannonian horizon No 8 forms extensive lenses lithologically sealed on all sides. The basal parts of the sand bodies are downwarped and usually fill the erosive depressions in the underlying Upper Sarmatian pelites. The lithology of the reservoir rock comprises grey crumbling calcareous sand of several grain sizes. The oil — and gas bearing characteristics of the sand are very favourable. Gas accumulations occur at the top of Pannonian horizon No 8 where they form a series of irregularly distributed major or minor gas deposits. The largest of them are those at Suchohrad-Gajary and Jakubov. These trap types are schematically illustrated in Fig. 1, III a, b. The interpretation of the seismic profiles permits an analogous development of Pannonian horizon No 8 to be assumed for the whole frontier zone from Gajary to Kúty. The Suchohrad-Gajary deposit is a typical example of this kind of deposits.

The map depicting zones of the possible occurrence of non-anticlinal deposits is the first step in predicting of and searching for such deposits. Detailed facies analyses of the Neogene sequences in the Vienna basin and of its Mesozoic basement will follow. The results of the analyses will reflect in the delineation of new areal or linear zones and in the subdivision of the zones outlined into several subzones. We belive that the construktion of a similar map for the Austrian part of the Vienna basin could supply data on the existence of zones that cannot be found on Czechoslovak territory. On the other hand, the map of the Czechoslovak section can yield information on zones that could not be outlined in the Austrian portion of the basin. A combination of these maps could produce a basic document for the future search for non-anticlinal deposits.

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Abstrakt

Problematika prognózování výskytu a vyhledávání neantiklinálních typů ložisek se stává základním problémem průzkumu vídeňské pánve. Ve zkrácené verzi jsou v článku předloženy výsledky analýzy výskytu těchto ložisek. Bylo zjištěno, že podle typu pasti a stratigrafické příslušnosti kolektoru je zde možné tato ložiska rozdělit do několika zón. Vymezení plošného rozšíření těchto zón umožňuje prognózovat výskyt dalších neantiklinálních ložisek, a tím určit směry dalšího průzkumu ve vídeňské pánvi.

Zusammenfassung

Die Problematik der Prognostizierung des Vorkommens und Aufsuchens nichtantiklinaler Lagerstättentypen wird zum Hauptproblem der Forschungsarbeiten im Wiener Becken. Im vorliegenden Beitrag werden kurzgefaßte Ergebnisse einer Analyse des Vorkommens dieser Lagerstätten geboten. Es wurde festgestellt, daß hier möglich ist, diese Lagerstätten entsprechend dem Fallentyp und der stratigraphischen Zugehörigkeit des Speichergesteins in mehrere Zonen zu teilen. Durch die Abgrenzung der Flächenausdehnung dieser Zonen wird die Prognostizierung des Vorkommens weiterer nichtantiklinaler Lagerstätten und somit die Bestimmung der künftigen Forschungsorientation im Wiener Becken ermöglicht.

OIL WATERS OF SE SLOPES OF THE BOHEMIAN MASSIF

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In the framework of oil prospecting in SE slopes of the Bohemian Massif the chemical and isotopic composition of gas and oil field waters was investigated. The study should have clarified the relations between the chemical and isotopic composition of waters reflecting the physico-chemical development in the system water-oil or gas source rock, of the paleoclimate and of paleohydrological conditions.

Experimental procedures

Prevailing part of water samples was taken from pilot boreholes during the pumping tests. An exception were the oil producing wells and iodine-bromine thermal waters with overflow. Chemical composition of the waters was analysed in laboratories of Moravské naftové doly, k.p. Hodonín, gas analyses were carried out in labs of the Geological Survey, Brno branch, and isotopic analyses in the isotopic laboratories of the Geological Survey and Bundesversuchs- und Forschungsanstalt Arsenal, Vienna.

Geology of the sites

The location of wells (Fig.1) of deep oil waters analysed reflects at once also their regional geological pertinence. Water samples Nos. 2,24,25,31,42 derive from the Miocene aquifers of the Vienna Basin, from the Miocene of the Carpathian Foredeep section North are waters Nos. 3,4,5,18,19,20,21,33,34,37, from the underlying Paleozoic — Culm (Lower Carboniferous) the water No.1, from the crystalline complex of the section North the water No.43. In the southern and middle part of SE slopes of the Bohemian Massif the geological pertinence of the waters is wider — to the Miocene of the Carpathian Foredeep refer the waters Nos. 12,13,35,36,39 and 23, to the autochthonous Lower Oligocene the waters Nos. 14,22,27,45,46, to the autochthonous Mesozoic of the Bohemian Massif — the Jurassic — the waters Nos. 9,10,28,29,30,44, to the autochthonous Paleozoic of the Devonian and the Carboniferous the waters Nos. 7,26,40. The allochthonous Paleogene of the Carpathian Flysch Belt is in our set represented only by waters Nos. 41,15,16 and 17. From the basement of the crystalline rocks of the section South and Centre are the waters Nos. 8,11,38, whereas the waters Nos. 47—60 are Miocene. The oil iodine-bromine water from the southern Slovak Oligocene No.32 and the mineral water from the central Carpathian Mesozoic No.6 were involved for comparison.

The deposition of lithographical horizons during the Miocene, Paleogene, Mesozoic and Paleozoic in SE slopes of the Bohemian Massif was mainly marine. The deposition of the Middle Badenian and Sarmatian of the Vienna Basin corresponded to the salinity of 18—30 g/l. Fresh water development was proved in the Lower Carpathian overlying the nappes of the Middle Carpathian Mesozoic of the Slovak part of the Vienna Basin.

Discussion

In accordance with Janák's theory (Janák 1955) proved by Michalíček (Michalíček 1965), the oil field waters studied are regarded as synsedimentary marine-brackish, sodium-chloride waters metamorphosed in the water-rock system with dispersed organic substances which transform to gaseous and liquid hydrocarbons. The alteration processes of marine to brackish oceanic waters are always accompanied by a change in water chemistry. It is mainly a very low concentration of sulphates, a difference in the ratio of Na/Ca, Mg/Ca, HCO_3^-/Cl^-, Cl^-/Br^- and the Cl^-/I^-. A high concentration of iodides of biogenic origin is typical. In the waters investigated Cl^-/I^- ratio varies from 100 to 400 whereas in the case of marine water the value of the Cl^-/I^- ratio is about 380 000. The Cl^-/Br^- ratio is being considered as the genetical coefficient (Valjaško 1956, Rittenhouse 1967). Numerous authors have proved the coefficient to deal with the presence of the organic substances. In Bars'opinion (Bars 1957) the Cl^-/Br^- ratio oscillating around 180 indicates the contact with some oil deposit, someone (Kölbl 1967) suggests that the brine bromides of the Middle Mesozoic basement of the Vienna Basin have an organogenic origin. These presumptions were verified by Michalíček (Michalíček 1978, 1986).

Along with the chemical composition also the isotopic composition of the studied waters was analyzed. Simultaneous knowledge of δD and $\delta^{18}O$ distribution enables us to determine the origin and mixing of the waters. Fig.2a shows the interdependence of D and ^{18}O contents in a common sedimentary basin. It illustrates the dependence of δD on $\delta^{18}O$ for meteoric water — meteoric water line, the Standard Mean Ocean Water, changes in isotopic composition resulting from fractionation processes during the interaction with rocks, evaporation, hyperfiltration and resulting mixtures of formation brines with meteoric waters. Fig.2b gives the dependence of δD on $\delta^{18}O$ for the water samples studied.

On this dependence, several typical water groups may be distinguished: at first, the low-mineralized waters Nos. 1,6,7,8,9 and 10. These are infiltrated meteoric waters the deuterium excess of which $d = \delta D - 8\delta^{18}O$, is lower than 10. (The value of 10 is typical of recent meteoric waters but of 30—50 thousand years old waters as well (Rozanski 1985)). Higher value of d indicates a drier continental climate than the today's. The value of the He/Ar coefficient speaks of the pertinence of these waters to exposed (or opened) hydrogeological zones with a direct water exchange (Michalíček 1987).

The straight line connecting water samples Nos.35,42,36 crosses the meteoric water line at the present value of δD, $\delta^{18}O$ ($\delta D = -70$ ‰, $\delta^{18}O = -10$ ‰). The next group of water samples linearly dependent in δD vs $\delta^{18}O$ plot are samples Nos. 12,16,24,25,23,37,14,29 and 2. The line connecting these points crosses the meteoric water line at values corresponding to a warmer climate ($\delta D = -54$ ‰, $\delta^{18}O = -8$ ‰). Such linearly depending groups of samples are usually interpreted as mixtures of the original brines with infiltrated meteoric water (Clayton et al. 1966). The marginal points — samples 29 and 2 — can be taken as the "original" primary brines in the first approximation — at least as to the value of δD and their mineralization. Based on these values primary brines may be considered as marine-brackish water with a 60—70 per cent marine water content.

Above the linearly depending "mixed" waters there is a large group of oil and gas accompanying waters with narrow-ranged δD values and markedly variable $\delta^{18}O$. In their values these waters resemble oil field waters from other areas (Kharaka, Carothers 1986). Considerably wide-ranged $\delta^{18}O$ values result from equilibrium isotopic exchange of water with the surrounding carbonate rocks. Their typical $\delta^{18}O$ values vary from -4 to -7 ‰ on PDB scale (i.e. approx. 26.5-24 ‰ on SMOW scale).If one considers the geothermal gradient as one degree centigrade per a 30—33 m depth, then the temperature of waters at a 1 000 m depth is about 45 °C, at 2 000 m about 80 °C, at 3 000 m about 110 °C. The $\delta^{18}O$ values of water in isotopic equilibrium

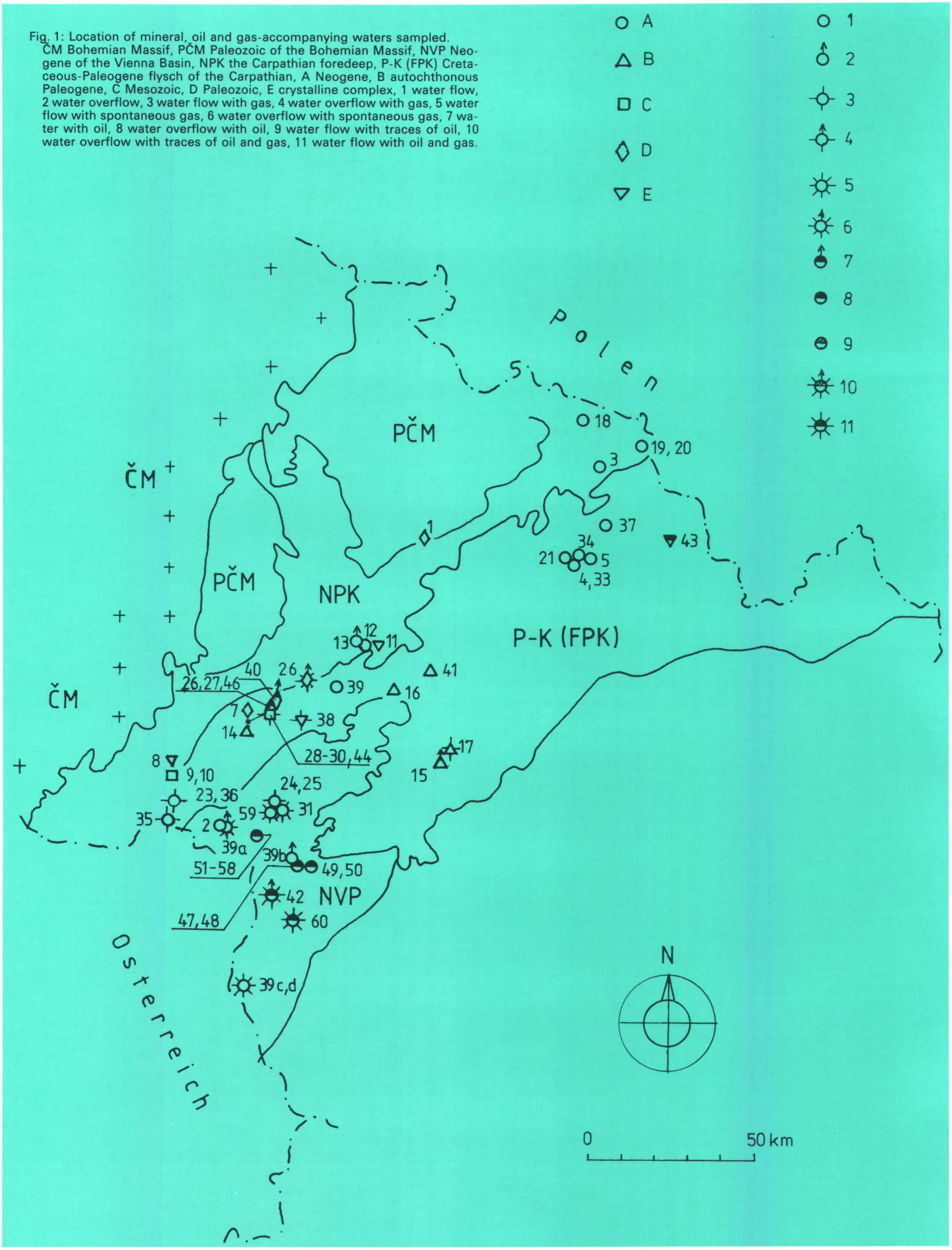
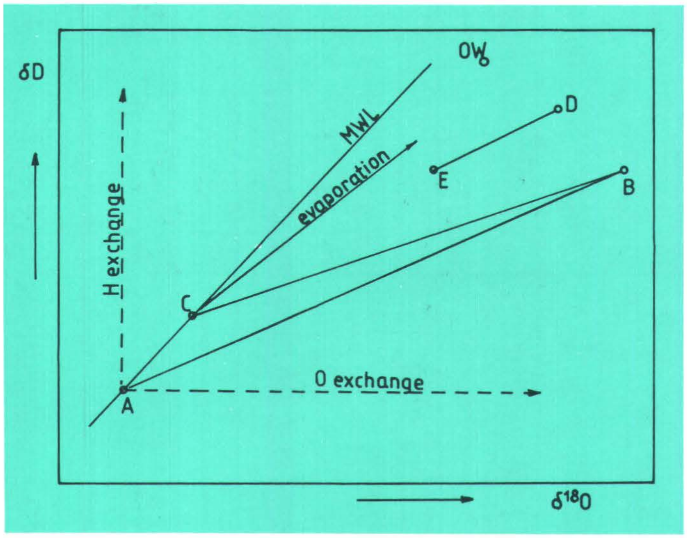


Fig. 1: Location of mineral, oil and gas-accompanying waters sampled. ČM Bohemian Massif, PČM Paleozoic of the Bohemian Massif, NVP Neogene of the Vienna Basin, NPK the Carpathian foredeep, P-K (FPK) Cretaceous-Paleogene flysch of the Carpathian, A Neogene, B autochthonous Paleogene, C Mesozoic, D Paleozoic, E crystalline complex, 1 water flow, 2 water overflow, 3 water flow with gas, 4 water overflow with gas, 5 water flow with spontaneous gas, 6 water overflow with spontaneous gas, 7 water with oil, 8 water overflow with oil, 9 water flow with traces of oil, 10 water overflow with traces of oil and gas, 11 water flow with oil and gas.

Fig. 2a: Schematic dependence of δD upon $\delta^{18}O$ illustrating fractionation processes and mixing of different water types in sedimentary basin.
A — local meteoric waters; B — primary formation solution; C — local meteoric waters in the past (warmer) climate; D — solution before hyperfiltration; E — solution after hyperfiltration; OW — recent ocean water; MWL — recent meteoric water line (Craig 1961).

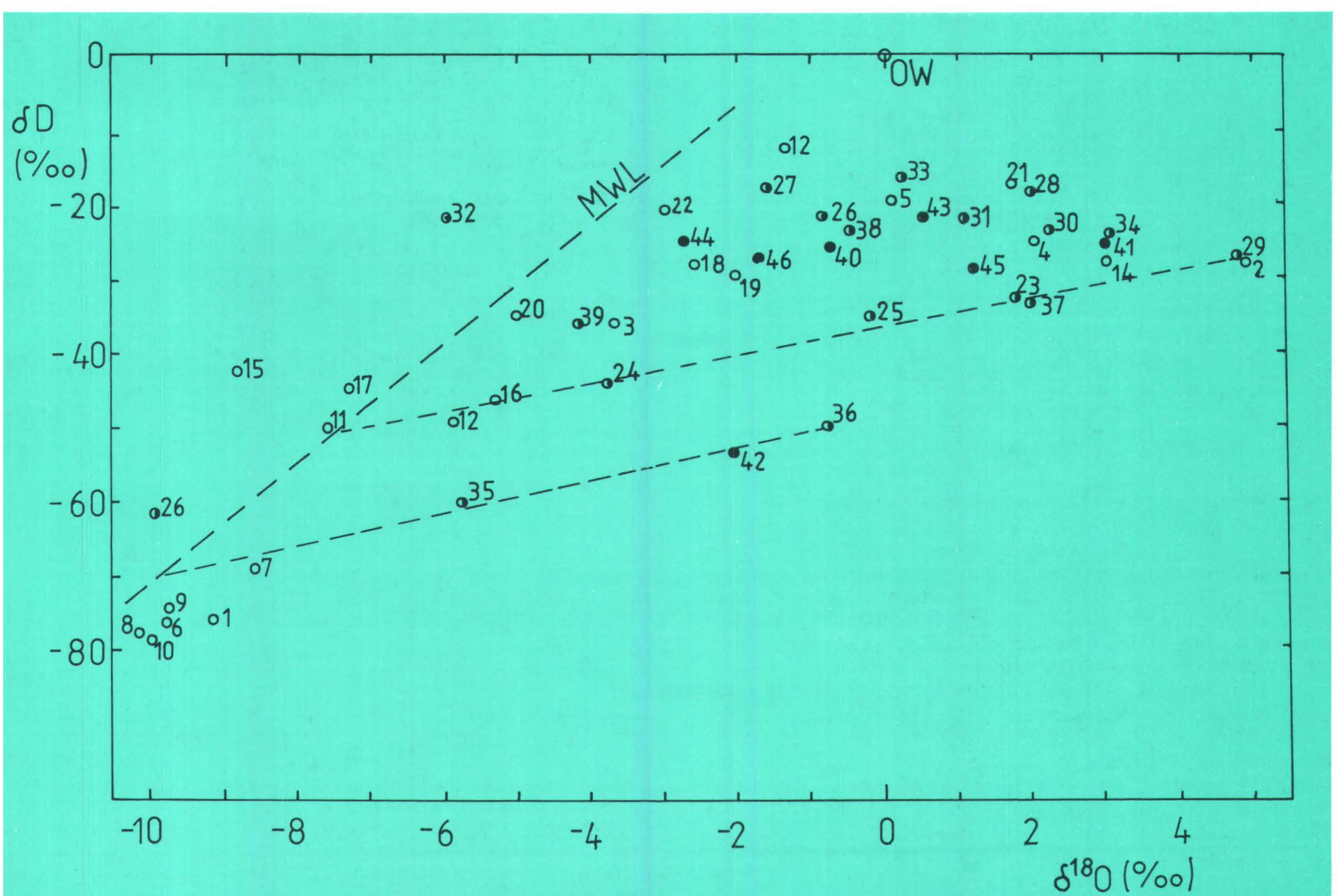


with the carbonates fluctuate at these temperatures from 0 to 6 ‰ on SMOW scale (Clayton et al. 1966).

For the further discussion relations between the isotopic composition (particularly δD which is not so much influenced by the interaction with rocks and keeps the original value) and water mineralization should be taken into consideration. For Na-Cl water type the chloride contents is important. Fig.3 shows chloride concentrations in dependence upon the bromide contents.

The sampled brines were originally considered as secondary, that means of an infiltration origin (Michalíček 1971) resulting from infiltration of the metamorphosed Tertiary brackish to fresh waters into the Mesozoic evaporites. The Cl/Br ratio of the primary brines is similar as in the marine water and makes about 300. The concentration of Br in the solution rises at the beginning of halite crystallization. Dissolving the evaporites, the solutions get richer in chlorides and the Cl/Br ratio increases. In Fig.3 virtually all samples (except for No.42) do not exceed the line of evaporite dissolving. It means the waters are the secondary saline waters in which salt precipitation did not take place, only concentration and dilution of the primary solution. The sample No.42 was mineralized evidently due to evaporites dissolving. Although the hypersaline development with evaporite formation has been proved in the area under study, the searched samples display primary salinity. All of them are

Fig. 2b: Dependence of δD upon $\delta^{18}O$ for the deep waters studied.



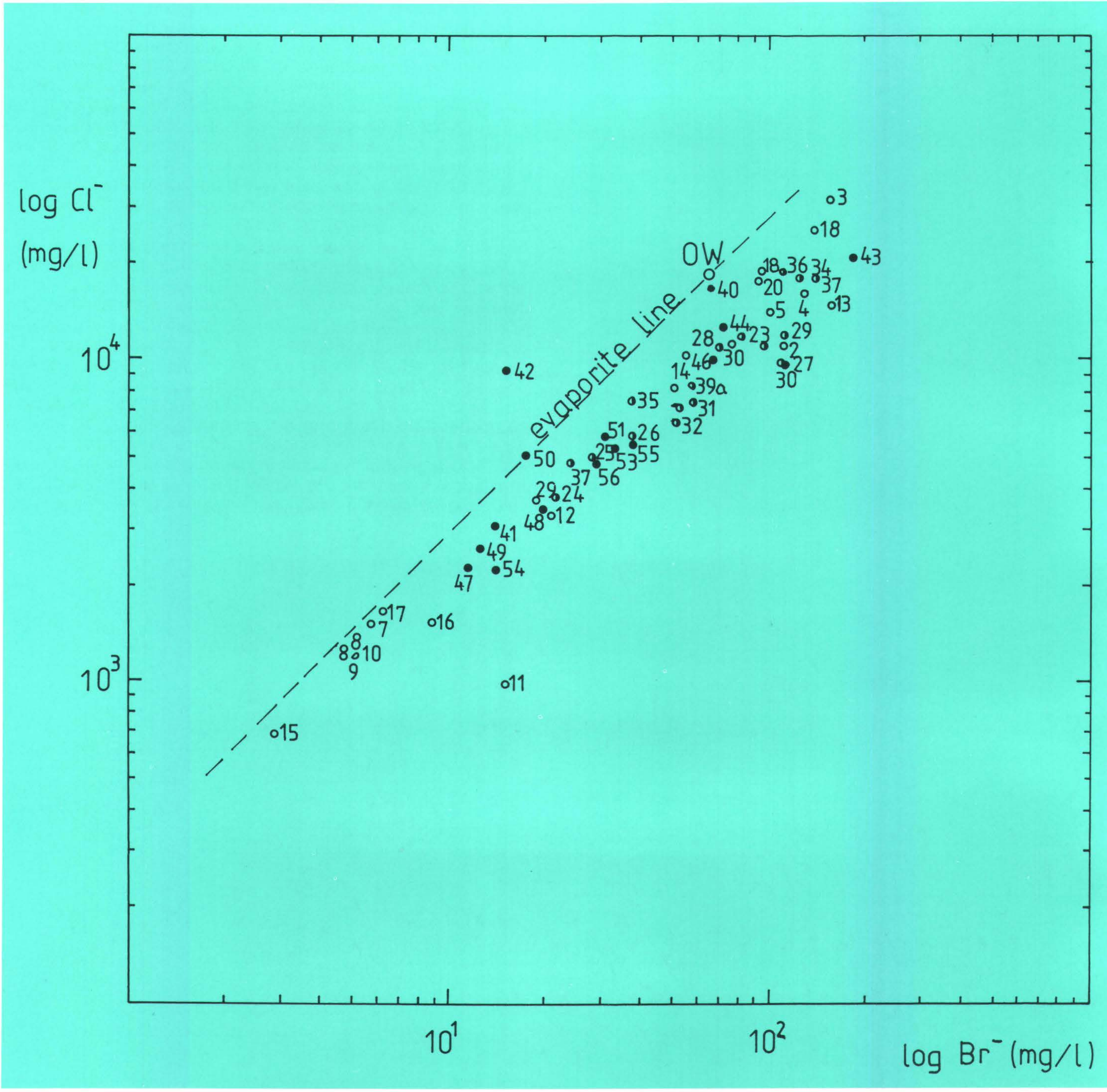


Fig. 3: Dependence of log Cl^- upon log Br^- for the studied waters.

in good linear dependence being under the level of the evaporites. In the periods of non-deposition they might have been altered by infiltration into marine-brackish waters — the secondary saline waters. These are, however, only hardly distinguishable by chemism.

For the discussion on the relationships between the isotopic composition of waters and the chloride contents the dependence of %Cl on %D was inferred. It should better characterize the problems of mixed waters than the simple dependence of Cl^- upon δD. %Cl and %D speak of the marine water contents in the given sample calculated from the balance of hypothetic mixture of marine and meteoric water. The equations 1—3 give balance relations for %D.

$$x_D \cdot \delta D_{OW} + (1 - x_D) \cdot \delta D_{MW} = \delta D_{SAMPLE} \quad (1)$$

$$x_D = \frac{\delta D_{SAMPLE} - \delta D_{MW}}{\delta D_{OW} - \delta D_{MW}} \quad (2)$$

$$\%D = x_D \cdot 100\,\% \quad (3)$$

x_D is the marine water content in a theoretic mixture, δD_{OW}, δD_{MW} and δD_{SAMPLE} are the isotopic composition of marine water, meteoric water, and of the given sample, respectively. A similar balance relation holds also for %Cl. For simplicity, the recent value of δD_{MW} was taken as -70 ‰, being later recalculated with more accuracy e.g. from the value of the intersection on the meteoric water line in Fig.2b. The %Cl dependence upon %D is illustrated in Fig.4. The diagram is centred by the proportionality line with

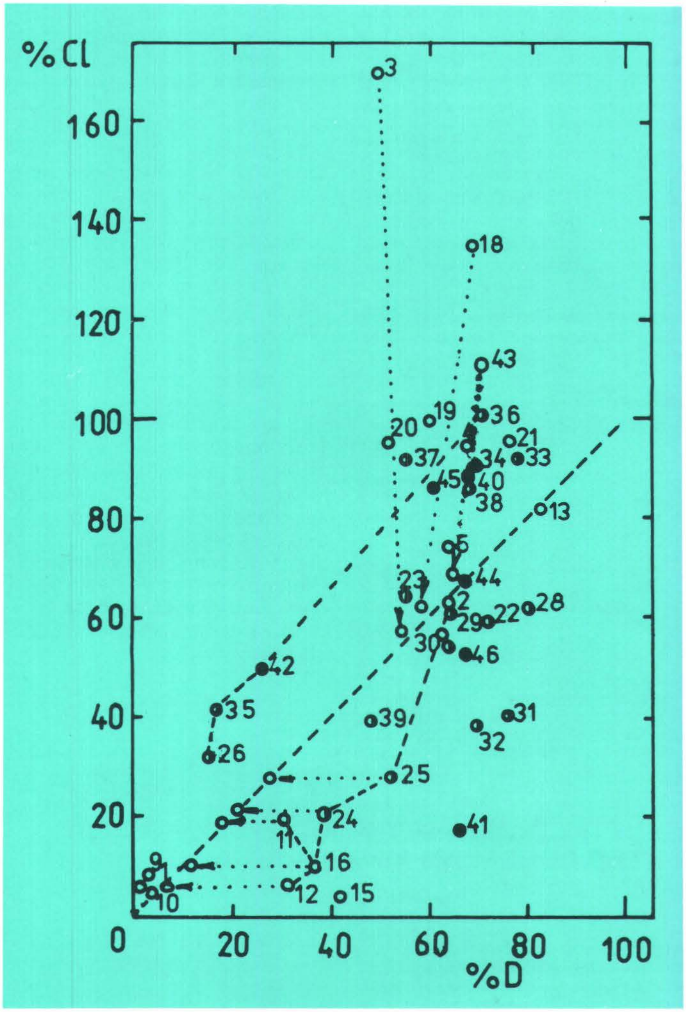


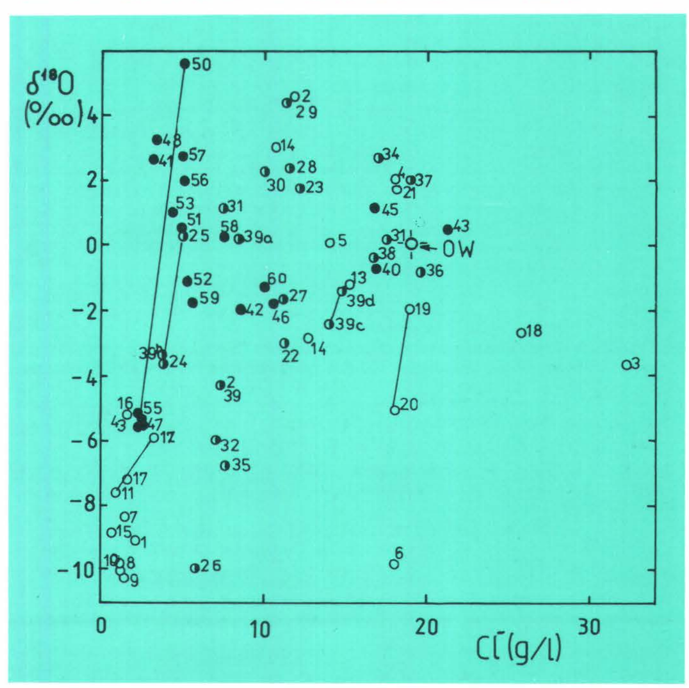
Fig. 4: Percentage of Cl^- and δD of studied waters calculated for theoretic mixtures of meteoric and marine waters.

points having identical %Cl and %D values and corresponding to an ideal mixture of ocean and meteoric water. A surprisingly large number of samples in this dependence has the %D values in the range of 60—80 %D. As during the alteration processes δD of the formation water does not change considerably, the original composition of brackish solutions may be supposed. For example, the samples Nos. 2,29 of mixed waters discussed before, are on the proportionality line in the proximity of these values.

How do the fore-discussed mixed waters in this dependence look like? The straight line connecting the samples Nos. 26,35,42,36 parallels the proportionality line in the area of higher Cl contents. It proves that the original solution (sample No.36 ?) was more mineralized than the marine water — e.g. due to evaporation before the secondary dilution. Sample 42 might be assigned to this line accidentally due to the possible present meteoric water contents. Next group of mixed waters (samples Nos. 11, 12, 16, 24, 25, 23, 37, 29, 2) in the dependence illustrated on Fig.4 cannot be unequivocally interpreted. But as %Cl vs %D plot was calculated for the present meteoric water (δD = -70 ‰) all we have to do is to apply the value δD_{MW} = -54 ‰ from Fig.2b. After that a majority of the points will approach the proportionality line, too. Sample No.37 is the only exception. It has higher chloride contents and its involvement was improper (it differs in chemical composition having high HCO_3^- contents — 2 646 mg/l and SO_4^{2-} — 394 mg/l). The recalculation shifts of points are indicated by lines paralleling %D axis.

The high variability of chloride contents in samples with %D values attaining to 60—80 % of marine water is hardly explainable. Samples with mineralization higher than corresponds to the marine water contents — above the proportionality line — can be interpreted by dilution of originally hypersaline solutions by meteoric water. For instance, evaporation of the NaCl solution to 0.4 of the initial water phase volume, leads to a shift of δD by 30—40 ‰ to more positive values according to the humidity of the surrounding atmosphere (Sofer, Gat 1975). Dilution of such solutions by meteoric waters to about 30 % causes shifting of brines Nos. 3 and 18 roughly parallel to the %Cl axis. The Cl contents changes and %D gets closer to the proportionality line. Also $\delta^{18}O$ values of the saline waters correspond to possible shifts of original values due to evaporation. Significant changes in $\delta^{18}O$ should be considered as resulting mainly from equilibrium isotope exchange with carbonates. These changes are obvious from the $\delta^{18}O$ vs Cl^- plot — see Fig.5. The lines connect the samples deriving from the same location, which differ in sampling depth only. Changes of mineralization do not take place virtually, however, there are remarkable shifts toward positive values of $\delta^{18}O$ according to the higher temperature of the exchange reaction with carbonate. Samples under the proportionality line in Fig.4 exhibit lower chloride contents than would correspond to their δD values. Some of them can approach the proportionality line by choosing more suitable meteoric water composition — as was done in the case of samples Nos. 11,12?16,24,23,25,29,2. However, this is not valid for samples with strikingly lower salinity as e.g. No. 41. Moreover, this sample it is not even in the range of linear dependence in δD, $\delta^{18}O$ diagram. Low mineralized oil field waters with rather positive values of δD are usually interpreted as condensation waters accompanying gas deposits (Kharaka, Carothers 1986, Kato, Kijiwara 1986). Otherwise they can be interpreted as "hyperfiltrated" waters squeezed from sediments under strong geopressures. In the case of the deposit No.41 the capacity is not large enough to allow the formation of sufficient amount of the condensate. The sample, however, was taken at a 3 000 m depth, where the pressures are even twice higher than the hydrostatic one. Hyperfiltration is reliable.

Fig. 5: $\delta^{18}O$ dependence upon Cl^- contents for the water studied.



The occurrence of clays in sedimentary complexes is significant namely in the Miocene, Paleogene, Carpathian flysch, autochthonous Oligocene, Jurassic, and Lower Carboniferous. Exceptionally high tectonic pressures were proved in Miocene trenches of the Vienna Basin, and are supposed also in allochthonous Paleogene complexes of the Flysch Carpathians and the Lower Carboniferous — the Culm. In the whole area of SE slopes of the Bohemian Massif hydrostatic pressures can be observed throughout the sedimentary complexes. It indirectly points to vertical — capillary connection of fluids closed in sediments. The theory of ions balance and chemical alteration of deep waters was based on Janák (1955). Diffusion processes give rise both to low- and higher-mineralized solutions, which differ in shift of δD values from the evaporated ones.

Conclusions

From the discussion several types of water can be presumed. The low-mineralized brines were primarily brackish waters with approx. 60—70 % marine water contents. The brines with mineralization of 35—50 g/l were originally marine waters concentrated by evaporation without any salt precipitation. Later these primary brines were diluted by infiltration of meteoric waters at different climatic stages. The low-mineralized brines with more positive δD values may in fact be hyperfiltrated primary brines. Only one of the waters studied was mineralized by evaporite dissolution.
Translated by G. Vladyková

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Abstrakt

V rámci prospekce ropoplynonosnosti JV svahů Českého masívu byly vzorkovány vody doprovázející ropu a plyn. Vody byly analyzovány chemicky a izotopicky (D,^{18}O). Podle mineralizace jde o formační vody naředěné srážkovými vodami. Rozsah zředění primárních solanek byl určen ze závislosti δD na $\delta^{18}O$. Porovnáním obsahů chloridů a izotopického složení deuteria bylo určeno složení primárních formačních roztoků. Jde o brakické solanky s obsahem cca 70 % mořské vody. Více mineralizované roztoky byly nakoncentrovány pouze odparem, ne rozpouštěním evaporitů. Zřeďování primárních solanek probíhalo v různých klimatických obdobích.

Zusammenfassung

Im Rahmen der Erdöl- und Erdgaserkundung an der SO-Abdachung der Böhmischen Masse wurden Proben von Erdöl- und Erdgasbegleitwässern entnommen. Es wurden ihre chemische Zusammensetzung und ihre Isotopenverhältnisse untersucht. Aufgrund des Mineralgehaltes handelt es sich um durch Niederschlagswasser verdünnte Formationswässer. Das Ausmaß der Verdünnung ursprünglicher Salzwässer wurde aus der Beziehung δD — $\delta^{18}O$ bestimmt. Aus dem Vergleich von Chloridgehalt und Wasserstoffisotopenverhältnis wurde die Zusammensetzung der ursprünglichen Formationswässer ermittelt. Es handelt sich um Brackwasser mit einem Meerwasseranteil von etwa 70 %. Für die Entstehung stärker mineralisierter Wässer sind ausschließlich Verdampfungsprozesse verantwortlich, nicht die Auflösung von Evaporiten. Die Verdünnung der ursprünglichen Salzwässer erfolgte während unterschiedlicher Klimastadien.

GENETIC TYPES OF THE KAOLIN DEPOSITS IN THE BOHEMIAN MASSIF

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Introduction

The deposits of kaolins of the Bohemian Massif (B. M.) belong (with exception of some non-economic occurrences of kaolins of hydrothermal or chemogenic origin) to the weathering type and, apart from the kaolins in the Inner Phyllites of Moravikum, have originated by kaolinization of the rocks rich in feldspars. The majority of these deposits are primary, however a very important volume of kaolins are redeposited. These secondary kaolins, represented by only two deposits (Kaznějov and Horní Bříza) probably experienced a short transport. Parent rocks of the primary kaolins of the B. M. are granitoids, metamorphites (orthogneisses to granulitic gneisses, paragneisses, phyllites), sediments (arkosic sandstones to arkoses, feldspar sands) and occasionally volcanites (Permo-Carboniferous). Kaolinization has occurred in two periods: 1, Carboniferous (Westphalian C — Stephanian) and 2, (Jurassic-) Cretaceous — Paleogene (-Middle Miocene). KÖSTER (1980) also mentioned kaolinization of Triassic age from the w. border of the B. M.

Geological summaries of the kaolin deposits of the ČSSR, were presented by KUŽVART (1969) and KUŽVART et al. (1983). Characteristics of the particular types of the deposits summarized in our paper come from the publications cited below. Newly, mineralogical studies (XRD, EDX, SEM) of 16 samples of kaolins taken from exploited or opened deposits of ČSSR were performed in the laboratories of the Institut für Baugeologie, Vienna. The results were studied from the point of view of the genesis of the deposits (Plates 1—4). Comparative material was taken from the Horná Prievrana deposit near Lučenec, the Carpathian Mts.

The location of the kaolin deposits of the B. M. are shown in Fig. 1. In the following text, the deposits are described according to particular genetic type, parent rock and regional geological positions. The proportion of different types with the raw material reserves and the extraction amount, production of the washed kaolins are shown in Fig. 2.

1.0 Primary (residual) kaolins of climatic weathering origin

1.1 Kaolinitic residuals of granitoids

1.1.1 The Karlovy Vary Massif

The Karlovy Vary region is a classical area of kaolins used for the production of porcelain. The kaolins represent residual kaolinitic weathering products of the surface portions of granites in the Sokolov Basin, with preserved original granitic texture. The climatic weathering origin is documented by the dependence of the depth of kaolinization to the fossil river course (KUŽVART et al., 1983). Kaolins originated in both the basic granite types — so called normal (or Mountain) type, and the finer autometamorphic (Erzgebirge) type. The type of the parent granite substantially influences the quality of the resulting kaolin. The deposits of the best quality originated from fine to medium-grained bright autometamorphic granite and the medium-grained two-mica facies of the normal granite. The parent granites are of Carboniferous age and the kaolinization has occurred continuously before and during the Paleogene; always with the same intensity (BABŮREK, 1970). The tectonically controlled extent of the preserved fossil weathering crust is 85 km^2. Kaolinization potentially reaches 50 m, occasionally 100 m, however the zone of completely kaolinitized phenocrysts of K-feldspar reaches only 20—30 m (KUŽVART et al., 1983). On the top of kaolins redeposited kaolinitic clays locally occur along with quartz sands and quartzites as well as Upper Oligocene to Miocene sediments.

In the whole region the complete typical kaolinitic weathering profile is preserved. Three zones of kaolinization are recognized (from top to bottom): 1, all feldspars are kaolinized, 2, cores of phenocrysts remain preserved, 3, cores of feldspars in the matrix are preserved. With depth the total porosity of the rock and the content of organic substance diminish. The relative polarity of the organic compounds (FALC, 1968) as well as the character of accessory minerals (KONTA, 1969) and trace elements (BABŮREK, 1971) also change. The very pronounced vertical zonality is disturbed locally by the intercalations of kaolins of lesser quality with illite and chlorite, within the profile. Primarily, different types of parent granites are concerned.

In the area, about 30 deposits of kaolins are known. Today, only the deposits Osmosa (Božíčany), Jimlíkov, Podlesí, Katzenholz (Otovice) and Hájek (Bystřice-Hroznětín) are extracted. From the non-extracted ones, the deposits of Bohemia, Brázda, Čankovská-Rybáře, Marta-Epiag, Mírová, Zátiší, Čapí Hnízdo, Ruprechtov, Smolnice, Nová Role, Vintířov, Ztracený rybník, Počerny-Stará Role etc., are mentioned. Most of the deposits are presently being geologically investigated. Kaolin from the terminated deposit Zettlitz (Sedlec) is a world standard of kaolin for the production of fine ceramics since 1924.

The petrography and geochemistry of the main parent rock of the kaolins were described by NEUŽIL and KONTA (1965), the petrography of kaolins from the particular deposits by BABŮREK et al. (1959), KONTA and MRÁZ (1965), KONTA (1968), KONTA and KOSCELNÍK (1968), KONTA (1975) etc. KONTA and KOSCELNÍK (l. c.) described nine petrographical types of primary kaolins that can be distinguished macroscopically: coarse-grained with biotite + muscovite; or only with muscovite; medium-grained with biotite + muscovite; or only with muscovite; fine-grained with rare muscovite (without tourmaline); fine-grained with frequent muscovite and tourmaline; very fine-grained (with muscovite); large feldspar pseudomorphs after feldspar; and fine-grained type without micas (only with quartz). The redeposited kaolin in the top is fine-grained and contains quartz and muscovite. The kaolinitic residuals in the Karlovy Vary region contain 20—30 %, occasionally (Ti-kaolins) up to 35—40 % of the washable kaolin amount.

The raw kaolins contain, apart of the clay fraction, grains of the primary minerals of parent granites: quartz (in the top portions of the deposits chemically corroded and rounded), muscovite and biotite. Siderite originates from the cement. From accessory minerals, the most frequent ones are primary tourmaline and zircon, and secondary pyrite, anatas, rutile and oxidic Fe minerals (maghemite, hematite, goethite). With the depth of kaolinization, siderite prevails over pyrite, and, within the Ti minerals, rutile diminishes; tourmaline, with the colour reduced to green one in the upper parts, remains brown (KONTA, 1969).

Among the clay minerals kaolinite (95 %) prevails. It is nearly the pM type, rarely the T type (in the Jimlíkov deposit; KONTA, 1975). Illite is omnipresent (5—10 %) and its amount rises with depth. Montmorillonite is always absent, but is an accessory mineral at the base of the profile.

XRD	TOTAL MINERAL CONTENT		CLAY MINERAL CONTENT <2 μm	
Božíčany-Osmosa				
Kaolin A	Quartz	+++	Kaolinite	81 %
	Muscovite	++	Fire Clay	19 %
	Kaolinite	+++	Illite	Tr.
Weathered Granite	Quartz	+++	Kaolinite	78 %
	Feldspar	+++	Fire Clay	22 %
	Muscovite	+	Illite	Tr.
	Kaolinite	+		
Granite	Quartz	+++	Kaolinite	74 %
	Feldspar	+++	Fire Clay	26 %
	Muscovite	+	Illite	Tr.
Aplite	Quartz	+++	Kaolinite	70 %
	Feldspar	+++	Fire Clay	30 %
	Muscovite	+	Illite	Tr.
	Kaolinite	+		
Jimlíkov				
Weathered Granite	Quartz	+++	Kaolinite	76 %
	Muscovite	+++	Fire Clay	24 %
	Kaolinite	+++	Illite	Tr.
Kaolin B	Quartz		Kaolinite	97 %
	Muscovite		Fire Clay	3 %
	Feldspar		Illite	Tr. %
	Kaolinite			
Podlesí				
Kaolin C	Quartz		Kaolinite	83 %
	Muscovite		Fire Clay	17 %
	Feldspar		Illite	Tr. %
	Kaolinite			
Otovice-Katzenholz				
Kaolin D	Quartz		Kaolinite	75 %
	Muscovite		Fire Clay	25 %
	Kaolinite		Illite	Tr.
Hájek (Hroznětín)				
Kaolin E—1	Quartz		Kaolinite	92 %
	Muscovite		Fire Clay	8 %
	Kaolinite		Illite	Tr.
Kaolin E—2	Quartz	+++	Kaolinite	90 %
	Kaolinite	+++	Fire Clay	10 %
	Muscovite	Tr.	Illite	Tr.
			Halloysite	Tr.

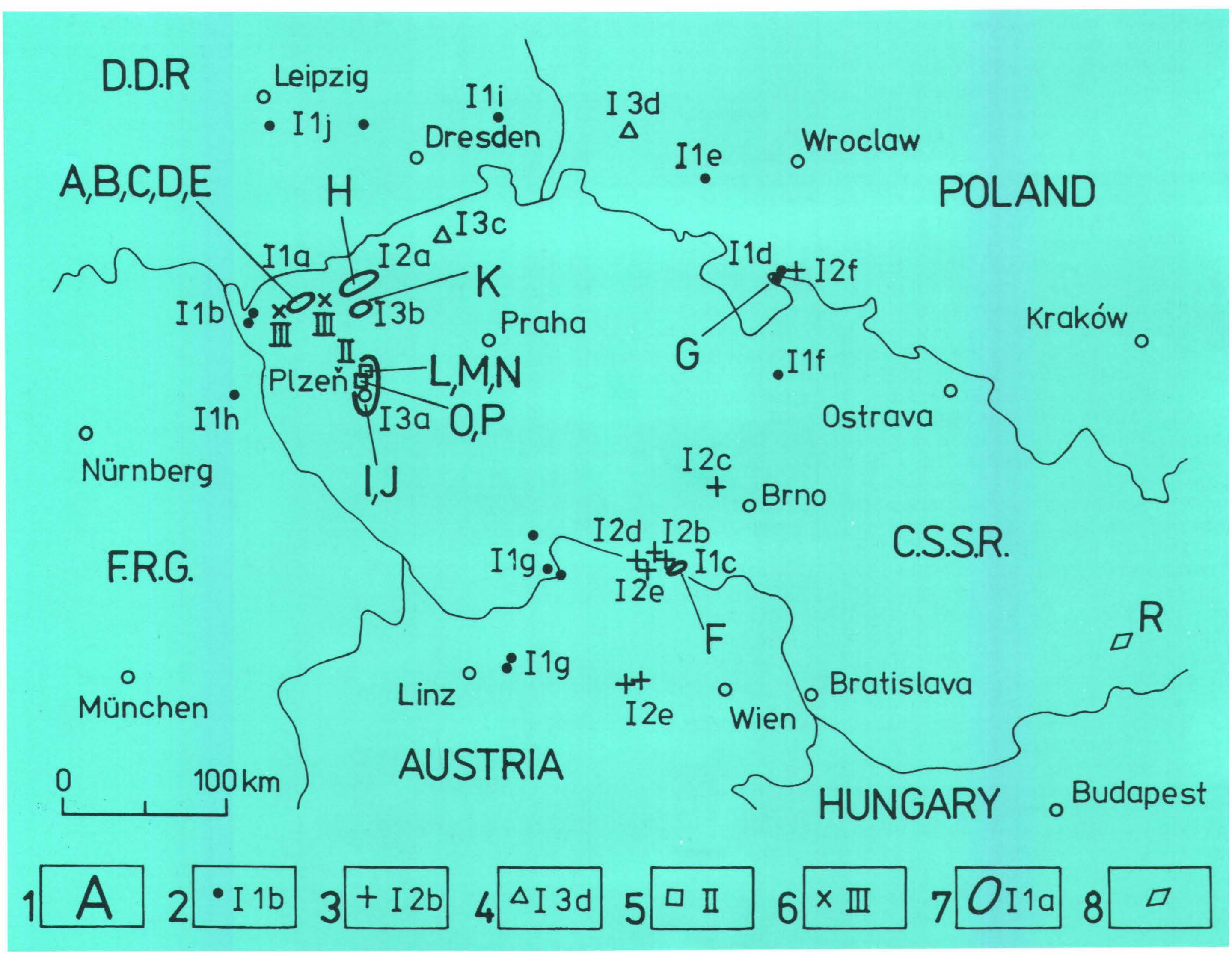
Mineralogically (XRD, SEM) we have newly studied samples of all the deposits exploited (Božíčany-Osmosa, Jimlíkov, Podlesí, Otovice-Katzenholz, Hájek). (Plates 1—1 to 1—6 and 2—1 to 2—4.)

The parent granites of the Karlovy Vary kaolins are poor in colouring oxides (Fe_2O_3, FeO, TiO_2). This is a very important condition of the origin of very good quality kaolins. FeO is present in illite, Fe_2O_3 in oxidic Fe minerals. Industrially, two types of kaolins are distinguished: kaolin for fine ceramics with TiO_2 below 0.4 %, and the so-called titanic kaolin with TiO_2 = 0.4—0.7 %. The parent rock of the kaolins was primarily rich in Ti (in biotite). We must distinguish among them kaolins that are perfectly kaolinized and highly white ones, and the little kaolinized ones with illite and chloritized biotite (FRANČE et al., 1973). The source of trace elements within the kaolins was principally biotite of the parent granites. The amount of the elements Ti, V, Cu, Sr, Ba etc. rises with the grade of kaolinization (BABŮREK, 1970, 1971). Mn was concentrated in oxidizing conditions of the upper parts of the profiles (Božíčany, Hroznětín) while Cr in reduction conditions of the lower parts (Sedlec).

A most characteristic feature of the Karlovy Vary kaolins from the technological point of view is the high strength in green state (after drying), excellent moulding properties, white colour after firing and transparency of the fired products — all this is appreciated in fine ceramics (porcelain). Ti kaolins of an enormously high whiteness in green state, exceeding 90 % of the ideal scale, can be used as a filler in paper industry as well as in rubber, cosmetics, plastics etc., as a raw material to produce mullite grog, in electroceramics and sanitary ceramics. When used as coating kaolins in the paper industry, they show rather worse rheological properties in comparison with the kaolins from Kaznějov (2.1.1). They are exploited only in the Otovice-Katzenholz deposit even if they represent great portion of the reserves of kaolins in the area.

1.1.2 The Smrčiny Massif (Fichtelgebirge)

The muscovite granite of the massif with a low content of colouring oxides, also of Carboniferous age, similar to the granites of the Karlovy Vary massif, suffered climatic kaolinization in the Cretaceous to Paleogene age. In comparison with the former, we know here only a limited number of



1. Sketch location of kaolin deposits of the Bohemian Massif
1 — samples under study; 2 — kaolins over granites (I1b — Smrčiny, Fichtelgebirge Massif; I1d — Žulová Massif; I1e — Strzegom Massif; I1f — Šumperk Massif; I1g — Moldanubian Pluton; I1h — Falkenberg Massif; I1i — Lužice, Lausitzer Massif; I1j — rhyolites); 3 — kaolins over metamorphites (I2b — Bíteš, Bitescher Orthogneiss; I2c — Svratka Orthogneiss; I2d — Inner Phyllites of Moravicum; I2e — Orthogneisses and granulites of Moldanubicum; I2f — Mantle of the Žulová Massif); 4 — kaolins over feldspar sediments (I3c — Zálezly; I3d — North-Sudetian Depression); 5 — secondary (redeposited) kaolins (Kaznějov, Horní Bříza); 6 — other genetic types (Sokolov Basin, Kyselka); 7 — greater kaolin areas (I1a — Karlovy Vary Massif; I1c — Dyje, Thaya Massif; I2a — Krušné hory, Erzgebirge Crystalline Complex; I3a — Plzeň Basin; I3b — Podbořany area); 8 — Carpathian kaolins (Horní Prievrana)

deposits: in the outcropping part of the massif, the deposits were denuded and served as a source material of the Tertiary sediments of the Cheb basin, which may cover some unknown deposits. Deposits are known from the border of granites with basin sediments, a finished deposit at Lomany near Cheb and several deposits near Plesná and Velký Luh. The primary position of the kaolins is documented by the existence of a zonal kaolin profile (BYLOVÁ et al., 1976, ŠINDELÁŘ, 1979) of a 30—60 m thickness. Maximum thickness of the quality kaolins is only 4 m.

The kaolin raw material is petrographically sandy- to clayey-sandy residual (ŠINDELÁŘ, 1979). Apart from the clay substance, it contains quartz and relics of feldspars, in the lower portions sericite (originated from feldspars), and of the accessories, tourmaline, secondary calcite, andalusite, sphene, zircon and chlorite. Washed kaolin amount varies from 10—25 %. In the clay substance kaolinite prevails over a mica mineral whose quantity rises with depth (BYLOVÁ et al., 1976). The crystallinity of kaolinite represents nearly the T type (index according to Hincley = 1.04—1.50). The kaolin of the Plesná deposit was appreciated as a filler material for paper industry.

1.1.3 The Dyje (Thaya) Massif

Deposits of kaolins are kaolinitic residuals of granitoids of the Proterozoic age, mostly of the mylonitized and partly cleaved leucocratic biotite-(muscovite) granodiorite. To a lesser extent the relics of the cover of the massif (hornblende diorite, migmatitized para- and orthogneisses) were also kaolinized. A kaolin of higher quality has originated from pegmatites and aplites. The kaolinization happened before Tertiary sedimentation (Cretaceous-Paleogene). Its intensity rapidly diminishes with depth (a primary weathering profile). The kaolinization process was made easier by the Variscan dynamometamorphosis (cataclasis, mylonitization). Young tectonics influenced the preservation of the deposits in depressed blocks. The preserved portions represent mostly only the lower parts of the kaolin profile (thickness of 5—13 m). The kaolins of the upper parts were redeposited in the Paleocene to Eocene. The cover of the deposits form Oligocene to Lower Miocene sediments (1—18 m) and Quarternary loess (4—6 m).

Deposits are concentrated in the surroundings of Únanov and Mašovice (Únanov, Tvořihráz, Liščí Díra, Mašovice, Mašovice-Hradiště, Přímětice, Podmolí etc.). Only the deposit Únanov-North is being exploited. In Austria lies the deposit Niederfladnitz, covered by redeposited kaolinitic sands (WIEDEN, 1978).

Petrographically, the kaolins are feldspar-quartz-kaolinite residual (BATÍK et al., 1979). They contain in average 33 % quartz, 12 % (6—20 %) alkali feldspar, and 55 % of the clay substance. Locally, biotite is present. The spectrum of accessoric heavy minerals is very varied thanks to the varied parent substrate; nevertheless, their contents are very low (pyroxenes, amphiboles, zircon, monazite, kyanite, sillimanite, andalusite, chlorite, muscovite, ilmenite, rutile, brookit, anatase, garnet, pyrite, sphene, tourmaline, staurolite, baryte, apatite, hematite, spinel, epidote, limonite, Mn-oxides, leucoxene, siderite, and other carbonates). Washed kaolin amount reaches 15—49 %.

In the clay substance, kaolinite prevails (37.5—87 %) apart from an admixture of illite (2-18.5 %) which unfortunately raises the FeO content. In various samples, halloysite was identified, and sometimes chlorite. Montmorillonite is present only in the upper redeposited kaolins (up to 9 % of the total content of clay minerals; PAVLÍK, 1987). The kaolinite is of low crystallinity (the 1 pM type). The crystallinity index after Hincley rises with the intensity of kaolinization (0.24—0.78; NEUŽIL and KUŽVART, 1972; NEUŽIL et al., 1980). Newly, we have mineralogically (XRD, SEM) studied a sample from the Tvořihráz deposit (Plate 2—5).

Tvořihráz

Kaolin F	Quartz	Kaolinite	73 %
	Muscovite	Fire Clay	17 %
	Feldspar	Illite	10 %
	Kaolinite	Halloysite	Tr. %
		Mixed Layer	Tr. %

The modes of use of the kaolins of the Thaya massif are substantially limited by the variability of the parent rocks. The reserves of kaolins with relics of non-kaolinized feldspars exceed the reserves of perfectly kaolinized rocks by 15 times. The latter can be used — after dressing — as a filler in paper industry (Únanov, Mašovice-Hradiště). Most of the feldspar kaolins (even if their washed kaolin amount is high enough) do not suit the norms not only because of their elevated contents of Fe which elevates the colouring and reduces whiteness, but also because of their low strength in green state (after drying), low refractoriness, and high content of the rubber poisons (Cu, Mn). In the green state, without dressing, they can be used after milling and homogenization in sanitary and utility ceramics.

1.1.4 The Žulová Massif

A deposit of kaolin originated by weathering of the Carboniferous medium- to coarse-grained biotite granite is known from Vidnava, and from Biskupów in Poland. The Vidnava deposit was exploited in the past; recently, an investigation is being performed. The deposit is very variable and apart from the white kaolins, it is composed of the red (with admixture of goethite) and the green ones (with admixture of chlorite). Thickness of kaolinization reaches 40 m while thickness of industrial kaolins only 13 m. In the cover, Miocene clays (up to 10 m) and Quarternary sands (redeposited granite eluvials, up to 20 m) are developed. The washed kaolin amount is 16-25 %. We have mineralogically (XRD, SEM) studied a sample of white kaolin from Vidnava (Plate 2—6).

Vidnava

White kaolin G	Quartz	Kaolinite	95 %
	Muscovite	Fire Clay	5 %
	Kaolinite	Illite	Tr. %

The Vidnava kaolins are good products. The white kaolins can be used in the paper industry (filling as well as coating kaolin) and rubber industry, the coloured types can be used in ceramics (refractories, tiles).

1.1.5 The Strzegom Massif

In Poland, several kaolin deposits are known from the surroundings of Zarów and Bolesławice, originated from the Carboniferous two-mica granite of the Strzegom-Sobótka Massif. The thickness of kaolinization is 50—80 m. The age of the kaolinization is Paleogene. In the cover of the kaolins Upper Miocene clays are present (GAWRONSKI and KOZYDRA, 1968).

A primary position is documented by the preserved original granitic textures. The kaolins are used for the production of refractories.

1.1.6 The Šumperk Massif

The biotite granodiorite of the Carboniferous age was kaolinized near Bludov. The resulting kaolin is of a low quality. The washed kaolin amount reaches occasionally 13 % (KAMENSKÝ, 1973).

1.1.7 The Moldanubian Pluton

The supposed kaolin weathering crust developed on the Moldanubian block was denuded after its uplift by the end of Miocene. Some relics covered by younger sediments are preserved (e. g. by the Klikov group of beds of the Senonian age). Kaolinization occurred probably in the Carboniferous or Lower Cretaceous.

Near Kolenec-Pecák, medium- to finely-grained two mica granite of the Mrákotín type (a facies of the Eisgarn type granite) was kaolinized up to the depth of 10 m. The age of the parent granite is Carboniferous. The thickness of cover (the Klikov group of beds) is 20 m. The kaolin has a low whiteness and refractoriness (KUŽVART et al., 1983). A similar but smaller deposit is known below the cover of the Klikov group of beds near Klikov. Medium-grained Číměř facies of the Eisgarn type granite was kaolinized in this case. The kaolins of both the deposits are suitable for ceramic production. WIEDEN (1978) mentioned kaolinization of the Eisgarn granite a short distance from here, in Gramastetten near Gmünd in Austria. The deposit is covered by redeposited clays.

A tectonically depressed block of the Pre-Oligocene weathering crust over the Variscan Mauthausen type granite, with a cover of Oligocene sands and clays, is known from Kriechbaum and Weinzierl near Schwertberg, Austria (KIRNBAUER, 1965; WIEDEN, 1978). A preserved transition into non-kaolinized granite prooves the primary position of the kaolins and the climatic weathering origin. The thickness of kaolins reaches 4—30 m, the deposits are up to 1.3 km long. Because of the thick Tertiary cover (up to 120 m), the deposit is mined by means of galleries. Indices of kaolins are known also from the neighbouring Weinsberg type granite. The raw kaolin from Kriechbaum is formed (WIEDEN, l. c.) by quartz, relics of feldspars, muscovite, accessoric heavy minerals, and up to 47 % of the clay substance (kaolinite + 1—3 % of illite). An admixture of halloysite was confirmed. The washed kaolin amount (in this case represented by the fraction below 35 μm) is 50 %. The 80 % of the kaolins are used as a filler in the paper industry (whiteness of up to 79 % of MgO), the rest in ceramics.

1.1.8 The Falkenberg Massif

Deposits of kaolin originated by kaolinization of the biotite-muscovite granite of the Moldanubicum of the Český Les Mts., are known from Tirschenreuth and Schönheid in the F.R.G. (KÖSTER, 1974, 1980). While plagioclase and biotite were kaolinized completely, the K-feldspar and muscovite remain rather fresh. This result is being caused by climatic weathering in situ. The heavy minerals, tourmaline, andalusite and ilmenite, and, in a smaller amount beryl, apatite and spinel are present. The clay substance contains (apart from kaolinite) an admixture of a I—M mixed layer mineral. From traces, rather elevated amounts of Pb, Cu, Cr, Ni, P and Ti were confirmed. The kaolinite — K-feldspar raw material is being used as so called "pegmatite" in the ceramic industry.

1.1.9 The Lužice (Lausitzer) Massif

Granodiorite of the massif was kaolinized near Caminau (n. of Bautzen) in the G.D.R. and the Rumburk-type granite near Turów in Poland. The age of the kaolinization is probably Tertiary (STÖRR et al., 1968 a, b). The clay substance is formed by 90 % kaolinite and 10 % illite. The kaolin is used in the building ceramics and refractories.

1.1.10 Rhyolites

Kaolinization (or better clayey weathering) of rhyolites of Carboniferous age is known from the nw. periphery of the B. M. from Saxonia (G.D.R.). The age of the weathering is probably Tertiary (STÖRR et al., 1968 a). The rhyolite from Kemmlitz (the Rochlitz body) gives rise to a kaolin of about 50—79 % kaolinite and 5—30 % of a IM mixed layer mineral. The raw material of the Seilitz deposit near Meissen (the Dobritz body) can hardly be called a "kaolin": it contains 43 % of a IM mixed layer mineral and only 38 % kaolinite (apart from quartz). The kaolinized rhyolites are used in the building and refractory ceramics.

1.2 Kaolinitic residuals of metamorphics

1.2.1 The Krušné hory (Erzgebirge) Crystalline Complex

A kaolin weathering crust is preserved only in the depressed area of the North Bohemian Tertiary basins, where it was covered by their sediments. The outcrops of kaolin deposits are known only from the nw. border of the Chomutov-Pětipsy Basin, and from the Střezov ridge that separates the Kadaň and Pětipsy local basins. The deposits form two parallel belts in SW—NE direction. Parent rocks of the kaolin were various metamorphics rich in feldspars, mostly the fine-grained biotite granulitic orthogneiss of the Ohře (Eger) type (Kadaň, Klášterec n. Ohří, Mikulovice, Pruněřov, Kralupy u Chomutova, Horní Ves, Chomutov, Vlkáň, Krásný Dvoreček, Rokle) and leaky orthogneiss (Zásada, Černovice, Spořice-Brány, Prahly, Tušimice-Libouš) and mica schist (Jirkov, Březenec, Vysoká Pec). The parent metamorphics are of the Precambrian age and were kaolinized in several periods (CÍLEK, 1964): before the Carboniferous, during the Carboniferous, Cretaceous, Oligocene and Miocene. Kaolinization reaches the depth of 10—30 m (occasionally up to 64 m), but the upper 4 m are formed by a secondary coloured red kaolin (below a cap of Tertiary volcanoclastics). The primary position is proved by a preserved weathering profile with a 5 m thick transition zone. Weakened kaolinization is accompanied by diminishing washed kaolin amounts (NEUŽIL, 1970). A part of the kaolins was redeposited during Lower Turonian, Medium Oligocene, and Miocene (CÍLEK, l. c.).

The deposits of Klášterec, Mikulovice, Kralupy, Pruněřov, Zásada, Černovice, Spořice-Brány, Chomutov, Horní Ves and Jirkov have originated in the n. belt (border of the basin); the deposits of Vlkáň, Krásný Dvoreček, Rokle, Kadaň, Prahly and Tušimice-Libouš in the s. belt (the Střezov ridge). The deposits of Klášterec and Prahly were exploited in the past. Today the deposit Kadaň is nearly worked out and the deposit Rokle is being prepared for extraction.

The granulitic orthogneiss of the Ohře type, the parent rock of all the most important deposits of the area, is very rich in feldspars (56,6 % including 3/4 parts of K-feldspars), that is a very important pre-condition for rich kaolins (washed kaolin amount = 25—40 %). The raw kaolin contains about 35 % quartz, whitened biotite, and, in the lower parts, relics of feldspars. Among the accessories, kyanite, rutile, garnet, zircon and apatite are present. The clay substance is formed by well crystallized kaolinite (nearly the T type) with an admixture of illite (from biotite) and chlorite (from garnet).

Newly, we have mineralogically studied (XRD, SEM) kaolin from the Rokle deposit (Plate 3—1).

Rokle

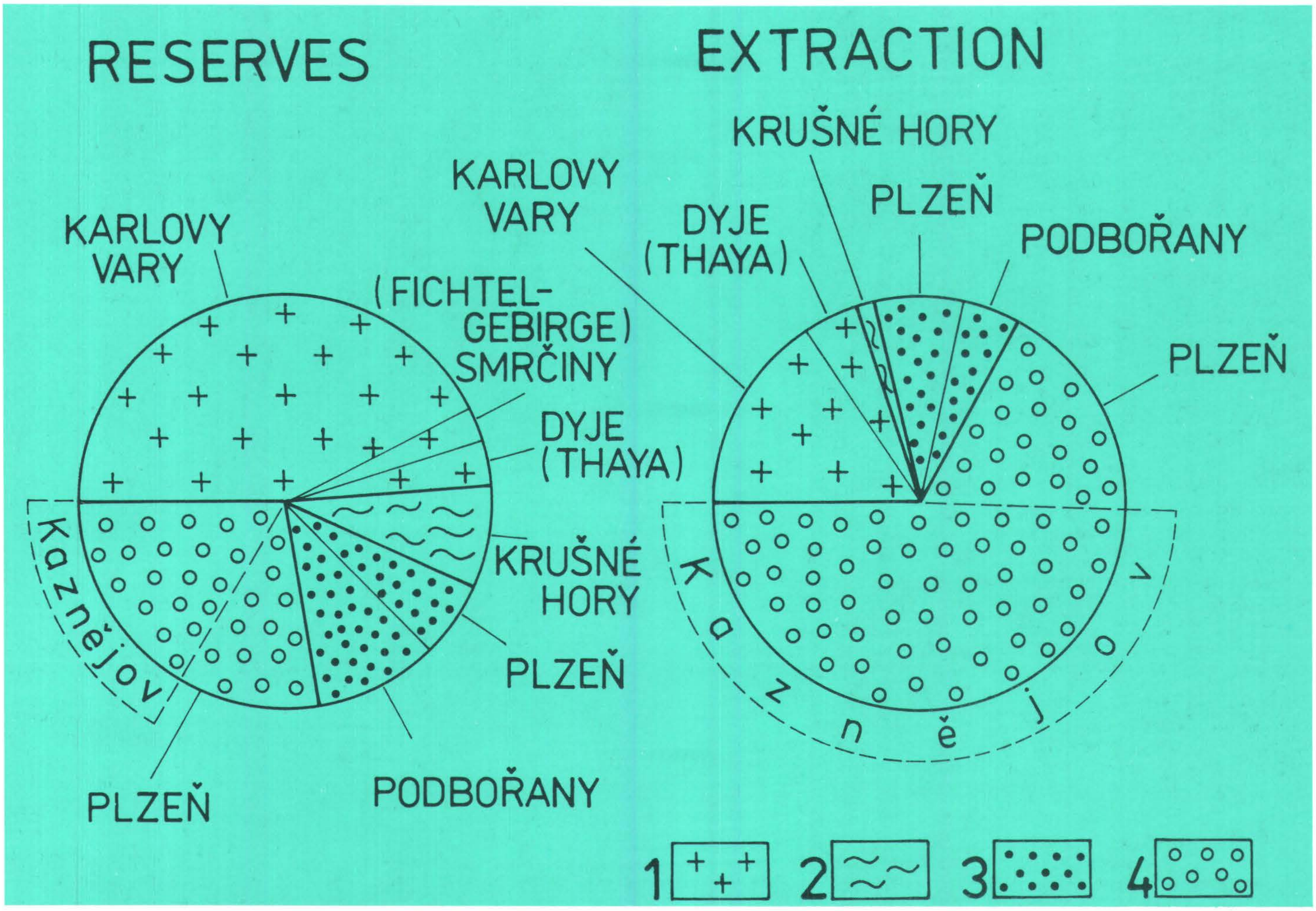
Kaolin H	Quartz	+ + +	Kaolinite	81 %
	Muscovite	+	Fire Clay	19 %
	Kaolinite	+ +	Illite	Tr. %
	Alunit	(?)		

Kaolin of the Kadaň area is mostly used as a filler in the paper industry, somewhat for ceramics. The kaolin from Vlkáň, thanks to its high whiteness and excellent rheological properties, can be used as a coating paper kaolin.

Recently, a new kaolin occurrence was encountered in a borehole near Budov, some 27 km s. of Kadaň. The parent rocks of the kaolin are mica-schists to paragneisses of the Barrandian Proterozoic. The kaolinite is close to the T type.

1.2.2 The Bíteš (Bitescher) Orthogneiss

Weathering crusts, developed on the Bíteš Orthogneiss of the Proterozoic age, are preserved as small relics in the area of ČSSR and Austria. In Czechoslovakia, only the deposit Plenkovice, and several occurrences near Žerůtky, Horní Břečkov and Hluboké Mašůvky, are known (KUŽVART et al., 1983). In Austria, only the deposit Mallersbach,



2. Proportion of reserves (left) and annual extraction (right) of the kaolins of the Bohemian Massif according to the particular genetic types and main areas of their occurrences
1 — kaolins over granites; 2 — kaolins over metamorphites;
3 — kaolins over feldspar sediments; 4 — secondary (redeposited) kaolins

formed by two small lenses of kaolins, exists (SCHERMANN, 1968; WIEDEN, 1978). The kaolins keep their original structure inherited from the parent rocks and, similarly as the deposits of the Thaya Massif, they are of in situ weathering origin. Equally, the age of kaolinization is Cretaceous to Paleogene. The underlying rock of the deposit Plenkovice is a mylonitized to phyllonitized orthogneiss; that is the reason why the kaolinitization grade seems to be of higher intensity in depth. WIEDEN (l. c.) considers the origin of the deposit Mallersbach as hydrothermal; evidently, it is also of the climatic weathering origin (montmorillonite forms only thin fillings of faults). Both the deposits have the NE—NNE direction and they are limited by the faults of the same direction accompanied by mylonitization. The origin of the Plenkovice deposit was enabled by tectonical fracturation of the parent rock in the tectonic contact with the Inner Phyllites (thickness of kaolin 10—50 m, max. up to 81 m).

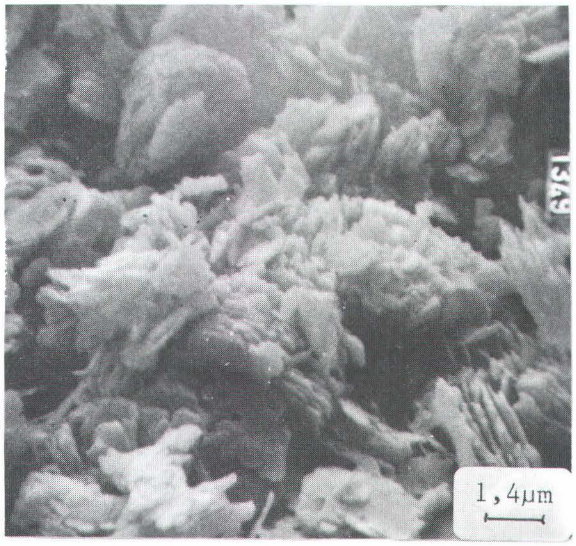
The raw kaolin is formed by 42 % quartz and relics of fresh feldspars, 8 % micas (partly newly formed), accessories, and 50 % clay substance. In the clay substance kaolinite prevails with an admixture of halloysite and mixed layer mineral. The finest fraction of the kaolins (below 1 μm) is constantly rich in CaO in the form of a calcite admixture (KLEMENT and BABŮREK, 1968). Washed kaolin amount reaches 26 % (Plenkovice) up to 51 % (Mallersbach). The kaolin from Mallersbach is occasionally used in ceramics while that of Plenkovice forms reserves for refractory production.

1.2.3 The Svratka Orthogneiss

Kaolinization of phyllonitized granodiorite is known from the contact with the Inner Phyllites. A small deposit extracted in the past near Lažánky (w. of Brno) originated by weathering of phyllonitized Proterozoic metagranites (cataclastic biotite orthogneiss) in a tectonic contact with Devonian limestones. The thickness of kaolins is 10—40 m, covered by 5—8 m of Miocene clays. The total thickness of the zone of kaolinization exceeds 113 m. Apart from kaolinite (nearly the PM type), illite and admixtures of montmorillonite and IM mixed layer mineral are present, more quartz and sericite in the raw material (NEUŽIL and KUŽVART, 1976). The washed kaolin amount reaches 25 %. The kaolin was used in paper and stoneware production.

1.2.4 The Inner Phyllites of Moravicum

REICHELT and NEUŽIL (1973) mentioned three occurrences of kaolins near Kasárny, w. of Únanov. Genetical relations to the deposits of the Thaya massif, Bitescher and Svratka orthogneisses, are evident. The parent rock is sericite- to chlorite-sericite phyllite. The age of kaolinization is probably Tertiary. The thickness of the residual kaolins is 20—40 m. They contain well crystallized T type kaolinite (originated from sericite!), chlorite, pyrite, and accessoric rutile and tourmaline. Washed kaolin amount varies between 22 and 58 %, but the quality of the kaolin is very low



Osmosa (Božíčany) deposit, 1.1.1

Fig. 1: Typical in situ weathering evidenced by kaolin books; single plates show rounded and thickened rims (kaolin A).

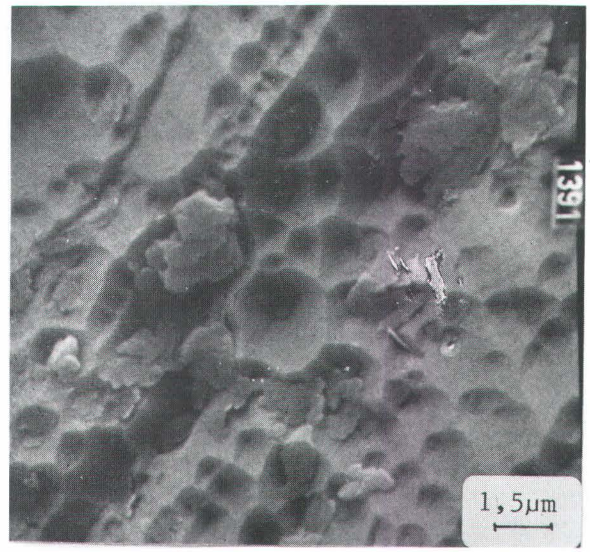


Fig. 2: Surface of strongly weathered quartz grain showing etched pits (kaolin A).

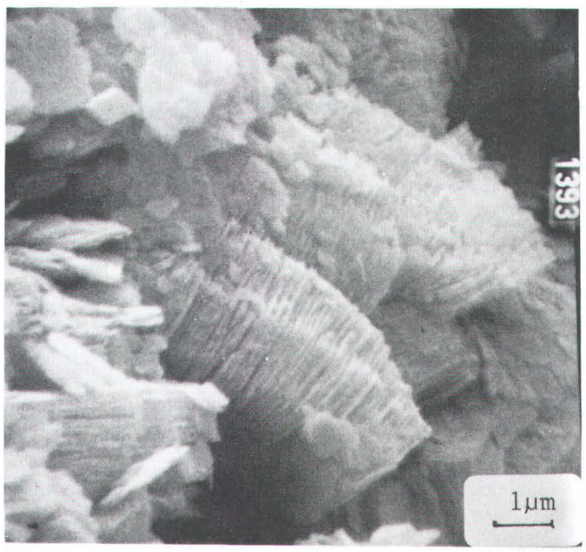


Fig. 3: Kaolinite with vermicular and booked growth (weathered granite).

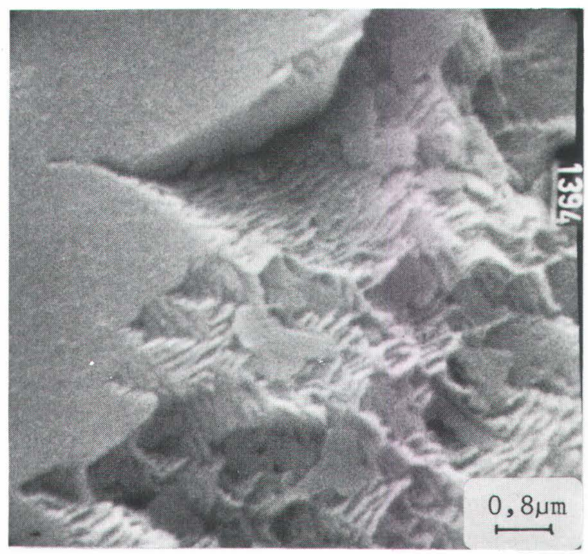


Fig. 4: Twinned feldspar grain with heringbone pattern formed by pseudomorphs of kaolinite (parent granite).

Fig. 5: Stacks of kaolinite with idiomorphic pseudohexagonal crystals (parent granite).

Jimlíkov deposit, 1.1.1.

Fig. 6: The microfabric indicates irregular distribution of predominating single plates together with some aggregates of kaolinite (rounded and thickened rims are characteristic similar to the Osmosa samples, see Fig. 1) (kaolin B).

because of high content of colouring oxides and pyrite that weathers to limonite.

1.2.5 Orthogneisses and granulites of Moldanubicum

Kaolinitic weathering crust after the uplift of the Moldanubian block in the Upper Miocene is preserved only in relics in bordering tectonically elongated blocks, for example in the border of Moldanubicum and Moravicum near Petřín and Lančov, where orthogneisses of the Gföhl type (KUŽVART et al., 1983) are developed.

Pure kaolinitic weathering products of granulites in situ are known from Unter Wölbling in Austria. They are purplish kaolins with limonitic spots, used as moulding clays in foundries. As a cover, Tertiary redeposited clays and sands with a bed of coal occur.

South of the Danube River, a new deposit was discovered near Karlstetten, ne. to St. Pölten, originated also by in situ climatic weathering from granulites (MÜLLER, SCHERMANN, SCHWAIGHOFER, 1983). The deposit is covered by Upper Oligocene sediments. Mineralogically, the clay substance is formed exclusively by halloysite. The washed halloysite amount (below 20 μm) is 97—100 %; an admixture forms illite (3 %) and traces of kaolinite.

1.2.6 Mantle of the Žulová Massif

In Poland, near Wyszonowice, the Devonian paragneiss of the mantle of the Carboniferous Strzelin-Žulová Massif is kaolinized to a depth of 40—50 m (GAWRONSKY and KOZYDRA, 1968). As in the case of the kaolins developed on the granites (Vidnava, 1.1.4), the kaolins are also of varying colours: red, greenish and white. The age of the kaolinization is Paleogene; the deposits are covered by the Upper Miocene sediments (10—80 m).

1.3 Kaolinized feldspar sediments (arkoses)

1.3.1 Kaolinized arkoses and arkosic sandstones of the Plzeň Basin

The sediments of the Middle-Bohemian Upper Carboniferous (Westphalian B—C — Stephanian C) represent an innermountain molasse of the Variscan mountains in the stream- and river-lake facies, typical for its mass occurrence of arkosic sediments. Great part of feldspars of the sediments are rather weathered and partly kaolinized (mostly plagioclase). The kaolin deposits have originated only in the westernmost Plzeň basin and sourrounding separated small basins (Tymákov, Kyšice). Indices of kaolins are also known from the Manětín basin. The thickness of the kaolins of this type reaches about 30 m. The deposits occur in all the four formations of the basins: the Kladno F. (but only in its upper beds — the Nýřany Beds, Westphalian D: Orlík, Ledce, Chlumčany, Obora and Tymákov deposits), the Týnec F. (Stephanian A: Chotíkov, Sokolka, Lité, Lomnička, Mrtník, Nekmíř, Žilov, Nevřeň), the Slaný F. (Stephanian B: the Ledce-Chotíkov area) and the Líně F. (Stephanian C: Chotíkov A and B deposits, Líně-Moguntia). Most of the deposits are situated in the Týnec Formation where some portions of them were redeposited to give rise to new deposits (type 2.1.1: Kaznějov, Horní Bříza). Some redeposition might have occurred also in other deposits; they are not exploited. All the deposits of the Týnec Formation occur in the n. part of the basin in the axes of two confluencing ancient streams (PEŠEK, 1968). The occurrence of pseudomorphs of kaolinite after feldspar (Lomnička, Mrtník, Kaznějov, Nekmíř, surroundings of Horní Bříza) are not unambiguous proofs because their kaolinitization might occur even after sedimentation of a clastic material with kaolinite cement. The kaolinization of feldspars was surely going on in the course of transport and sedimentation as well as after sedimentation (both directly after the deposition and during the Cretaceous-Miocene period in the outcrops of the rocks).

Because in this type of kaolin deposits no weathering profile can be developed (opposite to the type of granitic kaolins), the mode of genesis is very difficult to ascertain. The primary position can be confirmed only where outcrops of arkosic sediments were kaolinized in younger periods so that the underlying kaolins pass through the zone of kaolins with preserved feldspars to fresh arkoses. This postsedimentary kaolinization gave origin to the deposits in the Kladno Formation (Chlumčany: KNAPP et al., 1968; Chotíkov, Ledce, Líně-Moguntia). In the uppermost parts of the Chlumčany deposit however some redeposition of the kaolinized material already occurred, as shown from the SEM photographs (Plate 3—3), probably on a short distance. A new proof of the late postsedimentary kaolinization gives a small occurrence near Kyšice where arkoses of the Kladno Formation formed a small island during the Tertiary lake sedimentation (exploited deposit of ceramic clays) and were kaolinized to highly white kaolins; the intensity of their kaolinization substantially decreases with depth. Other proofs of the postsedimentary kaolinization are given by KUŽVART et al. (1975): preserved relics of kaolinized rocks and leucoxenic rims of ilmenite — both of them could not suffer a long transport; an occurrence of a kaolinized bed of tuff in fresh arkoses near Řevničov, etc.

Today, only the Chlumčany deposit is exploited. In some deposits extraction was terminated in the past (Ledce, Orlík). The rest of the deposits are not extracted, although small scale extraction may have occurred in the past.

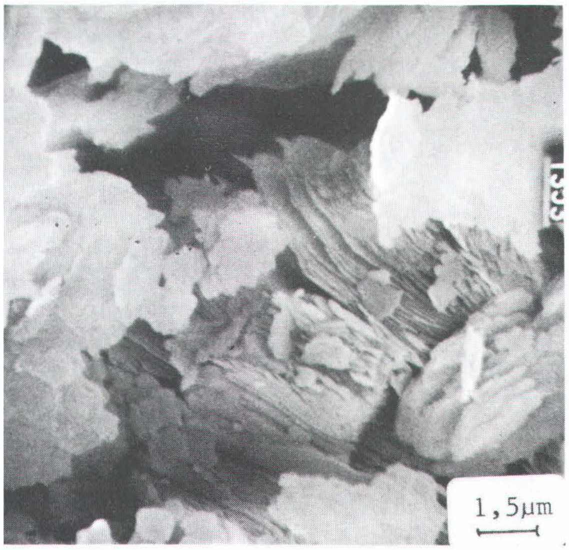
The primary kaolins of the Plzeň basin petrographically represent kaolinized arkosic sediments (arkoses, arkosic conglomerates, sandstones and siltstones). They contain 50—60 % quartz. The provenance area of the sedimentary material was very wide and it resulted in mixing of material of varied origin. The best proof of the provenance of the sedimentary material is the character of heavy minerals (andalusite, kyanite, staurolite, epidote, garnet, ilmenite, rutile, anatas, leucoxen, siderite, zircon, monazite, xenotime) and of the fragments of rocks in coarser fractions (granitoids, hornfelses, quartzites, silicites). The feldspar material mostly comes from adjacent Pre-Carboniferous granitoids (the Louny- and the Stod massifs).

In the clay substance, kaolinite prevails (well crystallized, type T; KUŽVART et al., 1975), locally with a small admixture of illite. In the Ledce kaolin, BABŮREK and STÖRR (1966) identified — apart from kaolinite — illite, I—M—CH mixed layer mineral, montmorillonite, chlorite, feldspar, quartz, and an amorphous silica form. The washed kaolin amounts vary between 15 and 25 %.

We performed a new mineralogical study (XRD, SEM) with two samples from the Chlumčany deposit — one sample from the base of the deposit (so called feldspar kaolin), and the other from the uppermost exploited part (Plate 3—3 to 3—6).

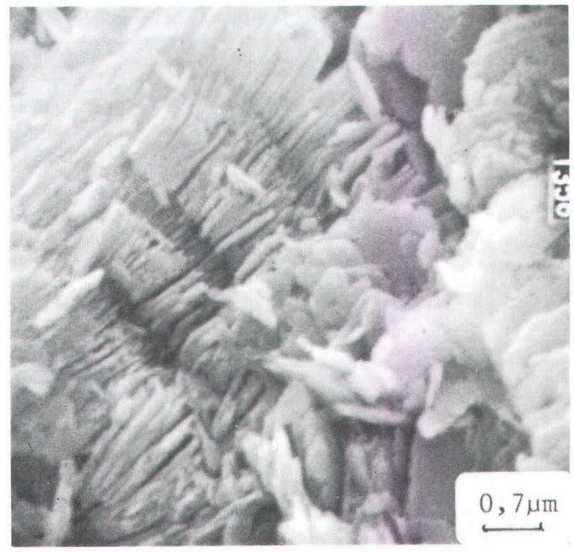
Chlumčany				
Kaolin I	Quartz	+++	Kaolinite	78 %
	Muscovite	+	Fire Clay	22 %
	Kaolinite	++	Illite	Tr.
	Feldspar	Tr.		
Feldspar kaolin J	Quartz	+++	Kaolinite	71 %
	Muscovite	+	Fire Clay	29 %
	Kaolinite	+	Illite	Tr.
	Feldspar	++		

The kaolins of the primary deposits of the Plzeň basin are used thanks to their high whiteness as fillers in paper industry; some part is used in ceramics (tiles). A special type of the raw material is represented by the "feldspar kaolins" or "pegraf" from the bases of the kaolin profiles (Chlumčany, Tymákov).



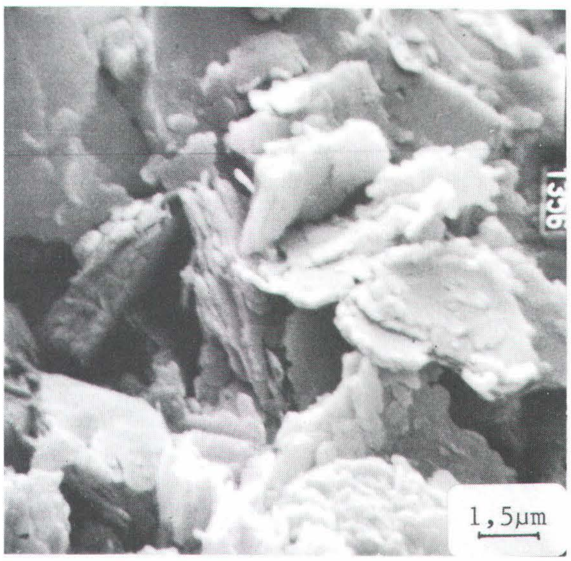
Podlesí deposit, 1.1.1.

Fig. 1: Stacks of kaolinite together with strongly rounded and thickened single plates (kaolin C).



Otovice (Katzenholz) deposit, 1.1.1.

Fig. 2: Book-like aggregates with rounded single plates of kaolinite (kaolin D).



Hájek (Hroznětín) deposit, 1.1.1.

Fig. 3: Typical development of Karlovy Vary kaolin deposits with chemically corroded and rounded kaolinite plates (kaolin E).

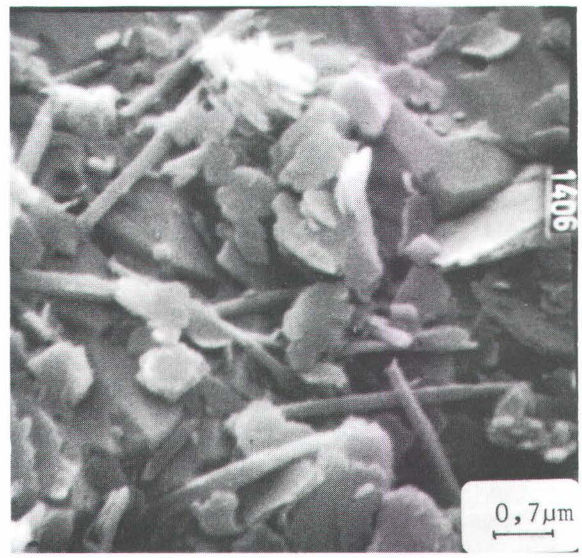
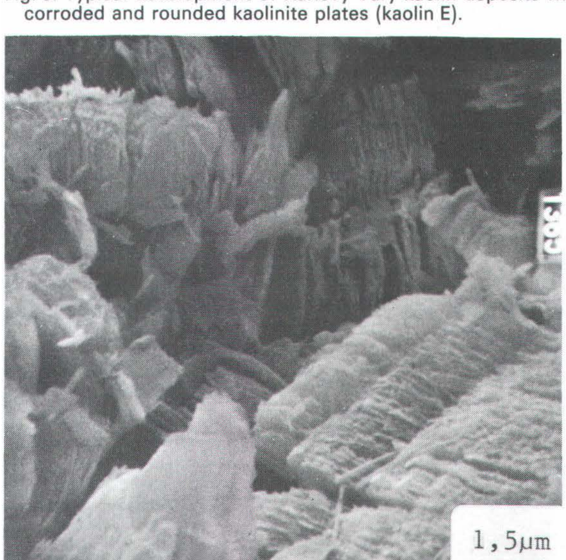
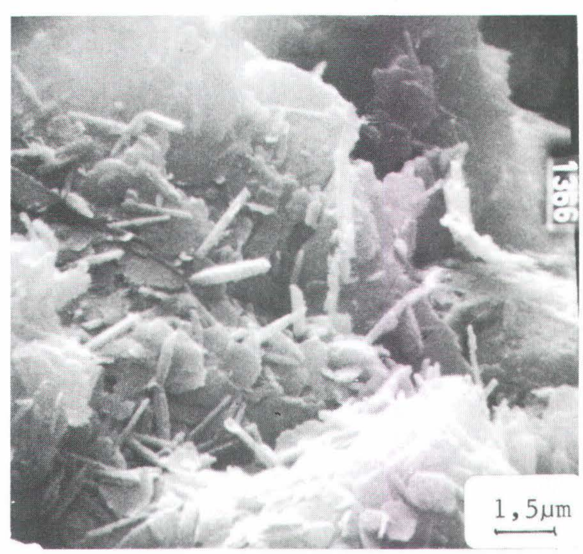


Fig. 4: Secondary components of tubular halloysite beside flakes of platy kaolinites (kaolin E).



Tvořihráz deposit, 1.1.3.

Fig. 5: Aggregates of tubular halloysite and single plates of kaolinite (kaolin F).



Vidnava deposit, 1.1.4.

Fig. 6: Vermicular kaolinite aggregates and rounded platy flakes (kaolin G).

1.3.2 Kaolinized arkosic sandstones of the Podbořany area

In the surroundings of Podbořany, several kaolin deposits are known that originated by in situ climatic weathering of arkosic sandstones of Carboniferous age (the Líně Formation). Their primary position is proved by the presence of the kaolinite pseudomorphs after feldspars. With depth, the number of nonkaolinized feldspar grains increases while the corrosion of quartz grains decreases. The supposed provenance area of the sediments is the crystalline complex of the Krušné hory Mts. (Erzgebirge) to the NW. The sedimentation of the arkosic material took place in stream- and delta-lake facies. The kaolinization is supposed to have occurred during two periods: in the Permo-Carboniferous, directly after the sedimentation (proved by the presence of clay interbeds), and during Cretaceous to Paleogene (before the Oligocene). The thickness of the quality kaolins is about 30 m, but the transitional zone is up to 100 m thick (MILICKÝ et al., 1968).

In the present time, two deposits are exploited: Krásný Dvůr and Dětáň. Other deposits of the region are: Blšany, Hlubany, Skytaly-Vrbička, Dvérce, Nepomyšl, Rybnický mlýn.

The raw kaolins have a high admixture of quartz, in the lower parts also of non-kaolinized feldspar, and admixture of a mica mineral and accessoric heavy minerals (tourmaline, staurolite, garnet, rutile, ilmenite, anatase, leucoxene, limonite, hematite, siderite, magnetite; KUŽVART et al., 1983). In the clay substance, kaolinite of the T-type prevails, while with the depth the admixture of illite, montmorillonite and chlorite rises. The washed kaolin amount is between 22 and 28 %.

We have newly studied the mineralogy (XRD, SEM) of the Krásný Dvůr deposit (Plate 3—2).

Podbořany (Krásný Dvůr)

Kaolin K	Quartz	+++	Kaolinite	84 %
	Muscovite	+	Fire Clay	16 %
	Kaolinite	++	Illite	Tr.
			Mixed Layer	Tr.

The most characteristic technological properties of the Podbořany kaolins are (according to KŘELINA, 1970): high whiteness, low content of the colouring oxides, high strength in a green state, and bad liquefaction which can be optimalized by an activation according to a Czechoslovak patent. About 85 % of the Podbořany kaolins are used as fillers in the paper industry, the rest in ceramics and electro-porcelain production (after activation, they can be used also for the porcelain production).

1.3.3 Kaolinitic sands from Zálezly (Ústí nad Labem)

The deposit originated by kaolinization of quartz-feldspar sands of an unknown age (Oligocene ?, Emscherian ?) after deposition, partly during the sedimentation (KUŽVART et al., 1983). It is covered by the Miocene volcanoclastics and volcanites. The washable kaolin amount is 7—15 %.

1.3.4 Kaolinitic sandstones of the North-Sudetian Depression

STOCH (1986) mentiones kaolinitic sandstones of the Santonian age from the Bolesławiec Trough in Lower Silesia (Poland), covered by younger Tertiary and Quaternary sediments. From the SEM studies (STOCH, l. c.) it follows that the origin of kaolinite is postsedimentary and clearly diagenetic. The kaolins are mined by means of galleries and they are dressed at Ołdrzychów. Petrographically they are sandstones with a kaolinite cement and with mica (muscovite). The kaolinite content reaches only about 5 %. The kaolinite has a high grade of crystallinity (the crystallinity index = 0.7).

2.0 Secondary (redeposited) kaolins of climatic weathering origin

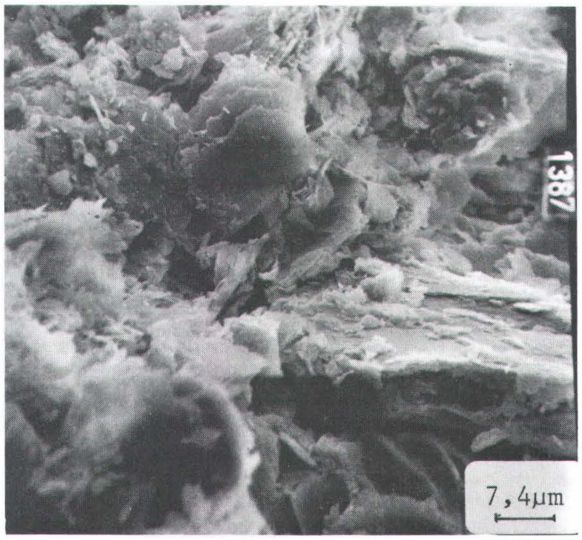
2.1. Kaolinitic conglomerates, sandstones and siltstones

2.1.1 The Plzeň Basin

Even if most of the deposits of the Plzeň basin are of primary deposition (1.3.1), we have segregated this group of deposits that is genetically specific within the kaolins of the B.M.; nevertheless, their genesis does not suit this particular origin entirely. A part of the source material was kaolinized during transport, during sedimentation and shortly after it. Because the explanation of such a transport of kaolinitic clastics without separation of the clayey — and coarse-grained clasts is difficult, the distance of transport was probably not long. We suppose that redeposition of pebbles and blocks occurred in a dense mud suspension. The most striking arguments for the presedimentary kaolinization are: 1, alternations of kaolins and non-kaolinized arkoses in dm-m beds in the base of the deposits; intercalations of red rocks (clays, kaolinitic siltstones and kaolinitic conglomerates) within the white kaolin sequence; 2, intercalations of white clays and kaolinitic siltstones that represent a redeposited material of pre-existing kaolinitic rocks; 3. fresh feldspar grains in highly kaolinitic rocks (JIRÁNEK, 1976, 1977): 4, geochemical characteristics that do not correspond to that of the primary weathering profiles, with an irregular distribution of the main as well as trace elements in the vertical direction, a common increase of trace elements as well as alkalies and alkali earths in the kaolin outwash accompanied by decrease of the kaolinite content (JIRÁNEK, 1982). The proofs of the postsedimentary kaolinization in the area of the Plzeň basin were summarized by KUŽVART et al. (1975); none of their proofs deal with the deposits that we have put into this group. The new SEM photographs (Plate 4—1 to 4—6) confirm that kaolinites of both modes of origin are present. The deposits have originated in the oxidizing conditions (Mn:Cr = 3:1 to 15:1). They are characterized further by a considerable vertical and horizontal variability and by an absence of any regular variations with depth. All the established changes are connected with changes of the petrographical (or granulometrical) character of the rocks. The age of the kaolinization is Carboniferous, the sedimentation occurred in Stephanian A (the Týnec Formation). The limits of the deposits are mostly tectonic, but intertongueing with economically unsuitable portions is present, too. The faults served also as tracks for deferrizing solutions in later periods (Cretaceous-Miocene?) that enabled natural whitening and improving of the raw material (JIRÁNEK, 1976). In the cover of the deposits, Quaternary soils of thicknesses up to 20 m are developed.

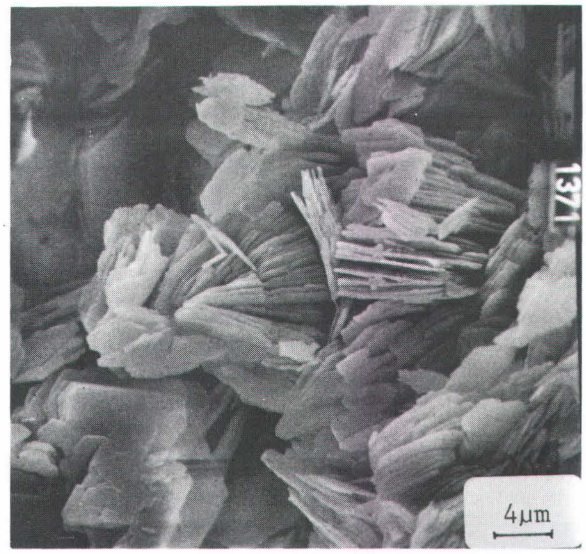
Even if the number of the deposits put in this group is small, the most important kaolin deposits of the B.M. are concerned, reaching up to 3.9 × 1.2 km and thicknesses up to 140 — 200 m (Kaznějov, Horní Bříza).

The kaolins of this group represent products of the fluviolacustrine sedimentation, mostly of the stream and river-lake facies types. Petrographical names of the rocks of the deposits are based on their granulometric composition. According to the KONTA's (1973) classification limits, they include groups of conglomerates with kaolinite cement and varying grain sizes (sandy-silty, silty-sandy, and clayey-sandy c.), silty-conglomeratic to conglomeratic-silty kaolinitic sandstones (with macroscopically well distinguishable end members that represent the best type of the kaolins of the deposit), and clayey-silty to silty-clayey kaolinitic sandstones. Occurrence of other types (e.g. clayey-conglomeratic kaolinitic sandstone) is limited (JIRÁNEK, 1977). Non-economical interbeds form sandy to clayey-sandy siltstones („šlika") with a considerable admixture of fine quartz and mica, and sandy clays, both white and coloured. The kaolin contains up to 30 % washable kaolin (the long-



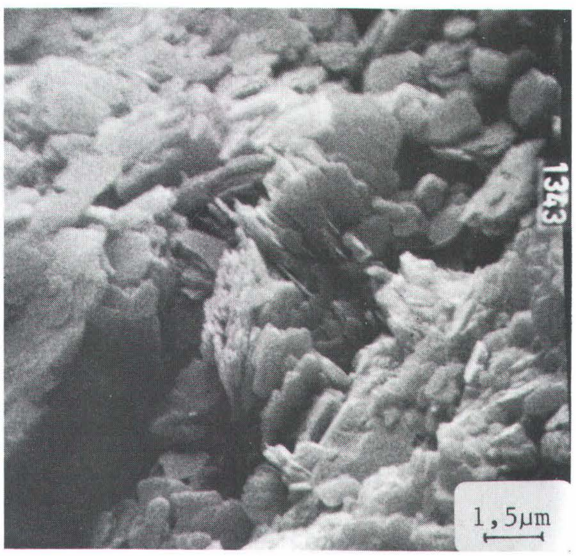
Rokle deposit, 1.2.1.

Fig. 1: The microfabric indicates irregular distribution of predominating flakes of kaolinite (kaolin H).



Podbořany (Krásný Dvůr) deposit, 1.3.2.

Fig. 2: Stacks of idiomorphic pseudohexagonal kaolinite plates (kaolin K).



Chlumčany deposit, 1.3.1.

Fig. 3: Predominating single plates of kaolinite (kaolin I).

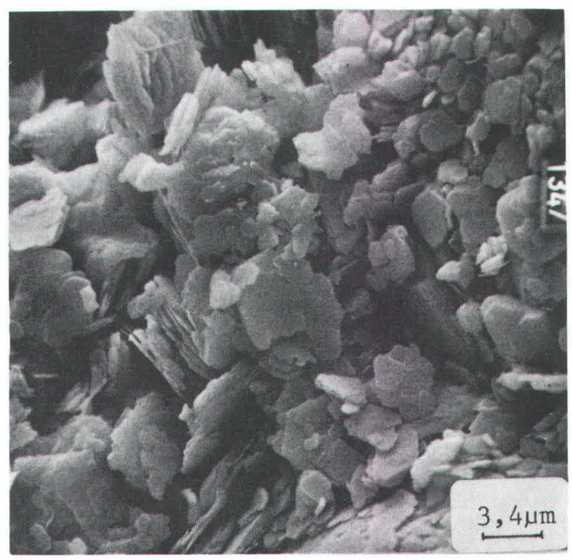
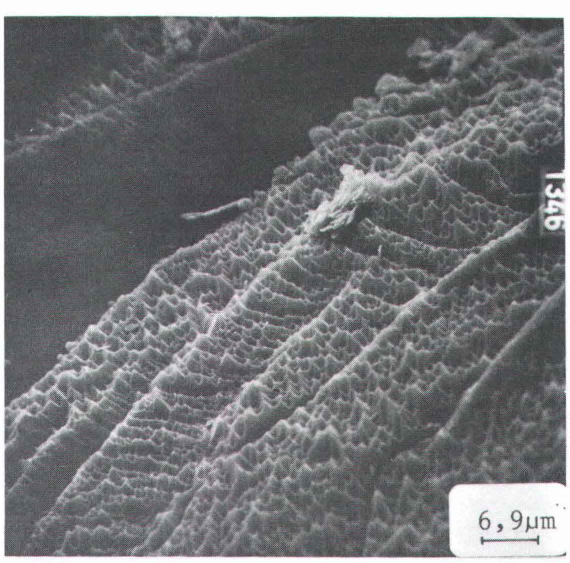


Fig. 4: Individual platy kaolinite crystals have well-defined boundaries (feldspar kaolin J).



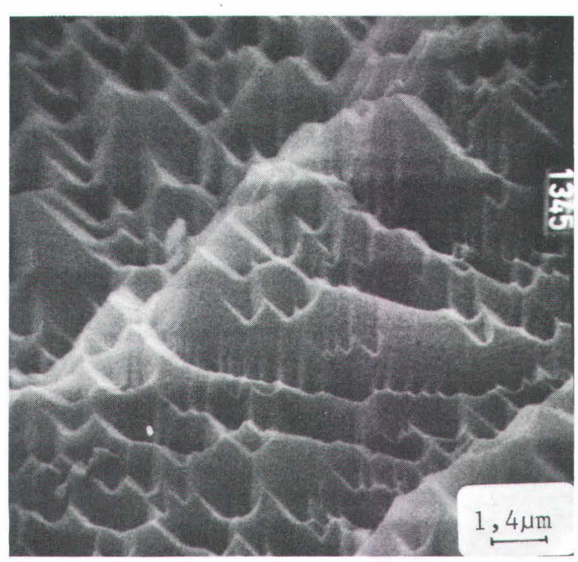


Fig. 5, 6: The surface of feldspar grains indicates chemical weathering (feldspar kaolin J).

term average is 18.5) and 50 — 60 % quartz, the rest are rock fragments and micas. With the total coarseness of the sediment, the relative coarseness of washed kaolin proportionally rises (JIRÁNEK, 1988). The washable kaolin amount decreases rapidly in the end members of the granulometric scale (conglomerates and siltstones).

Within the heavy minerals, the wide provenance area is reflected (granitoid massifs, Proterozoic sediments and volcanics, mesozonal to katazonal crystalline complexes). Rutile and zircon prevail (over 25 %) over monazite, staurolite and leucoxene (over 10 %). Tourmaline and anatase (over 1 %) and accessoric minerals (hematite, ilmenite, kassiterite, kyanite, magnetite, muscovite, pyrite, sphene, black spinelide, topaz and gold) are present as well.

The clay substance is formed — apart from the admixture of fine quartz — by well crystallized well ordered kaolinite of the T type (index of crystallinity = 1.0 — 1.2) with an admixture of mica (illite-sericite), rare montmorillonite, mixed layer mineral and alunite (?).

Mineralogically (XRD, SEM), we have newly studied three different samples from the Kaznějov deposit: silty-conglomeratic kaolinitic sandstone („coarse-grained kaolin" L), clayey-silty kaolinitic sandstone („medium-grained kaolin" M) and kaolinitic siltstone („šlika" N). Furthermore, two samples from the Horní Bříza deposit (the uppermost and lowermost exploiting portions) were examined (Plate 4—1 to 4—6).

Kaznějov				
Coarse-grained Kaolin L	Quartz	+++	Kaolinite	85 %
	Muscovite	Tr.	Fire Clay	15 %
	Kaolinite	++	Illite	Tr.
Medium-grained Kaolin M	Quartz	+++	Kaolinite	95 %
	Muscovite	+	Fire Clay	5 %
	Kaolinite	+	Illite	Tr.
Siltstone („šlika") N	Quartz	+++	Kaolinite	86 %
	Muscovite	Tr.	Fire Clay	14 %
	Kaolinite	+	Illite	Tr.
Horní Bříza				
Top kaolin 0	Quartz		Kaolinite	87 %
	Muscovite		Fire Clay	8 %
	Kaolinite		Illite	5 %
Bottom kaolin P	Quartz		Kaolinite	92 %
	Muscovite		Fire Clay	8 %
	Kaolinite		Illite	Tr.

In the Kaznějov deposit, a relative increase of most of the trace elements analyzed (mainly Ni, Sr, V) was established, along with a correlation of their contents with the geochemical composition of the parent rocks (granitoid K-feldspar: Ba, Pb, Sr; weathering products of the Proterozoic sediments and volcanics: Cr, Ni, V, Zn etc.).

Because of the fine granulometric composition of the washed kaolins, the crystallinity as well as derived rheological and technological properties, the kaolins from Kaznějov and Horní Bříza are used mainly in the paper industry as filler and coating kaolin, and, furthermore, as filler of rubber, plastics etc. A part of them is used in the fine ceramics, and a small part for other purposes (glass fibres, pharmaceutical industry, insecticides, cosmetics, etc.).

2.1.2 Overlying beds of the other deposits

The redeposited kaolins to kaolinitic clays are evidently known from the overburden of some of the described types of deposits (1.1.1, 1.1.3, 1.1.6, 1.2.1, 1.2.2, 1.2.5). They have been mentioned above.

2.2 Kaolinitic clays and claystones

Kaolinitic clays and claystones forming part of the sedimentary filling principally of the Carboniferous, Cretaceous and Tertiary of the B.M. (where also climatic kaolinization was confirmed), represent a redeposited weathering crust and prove the mentioned case of the separation of the clayey fraction during transport (the Plzeň basin, the Cheb basin, the Sokolov basin, the North-Bohemian basin, Kyšice, s. Bohemia, Maiersch in the Horn basin, etc.). In central Europe, the secondary clays of this type are not considered as kaolins. There is a great number of such deposits and they are not the subject of this work.

3.0 Other Genetic types

Kaolins of other types of genesis than the climatic weathering ones described above do not represent in the B.M. an economical genetic type. Some occurrences of kaolinite of the hydrothermal origin are known from the ore deposits and faults. Non economical is also the occurrence of kaolinite in a granite in association with rising hot mineral waters described by ŠANTRŮČEK (1980) from boreholes reaching the underlying rocks of the Sokolov basin. The kaolinite occurs in association with montmorillonite and newly formed calcite and pyrite. The temperature probably does not exceed 45° C.

KUŽVART et al. (1983) also mention kaolinization of the granite of the normal („Mountain") type of the Karlovy Vary Massif, and of a basalt in its neighbourhood, in a contact with a cool mineral water with $NaHCO_3$ near Kyselka (Kysibel). A sheer kaolin body 25 m thick and 500 m long is known to the depth of about 100 m.

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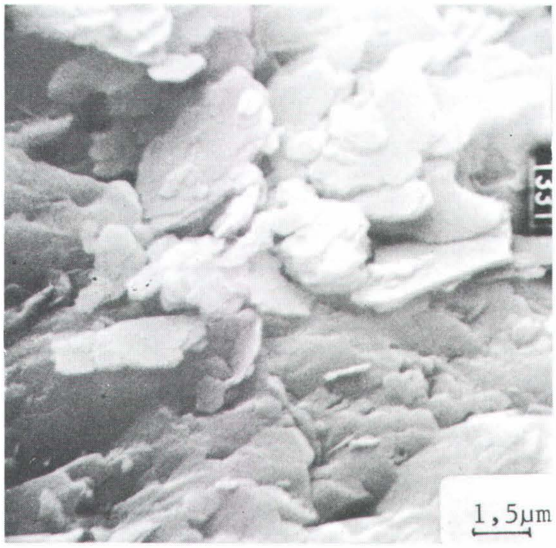
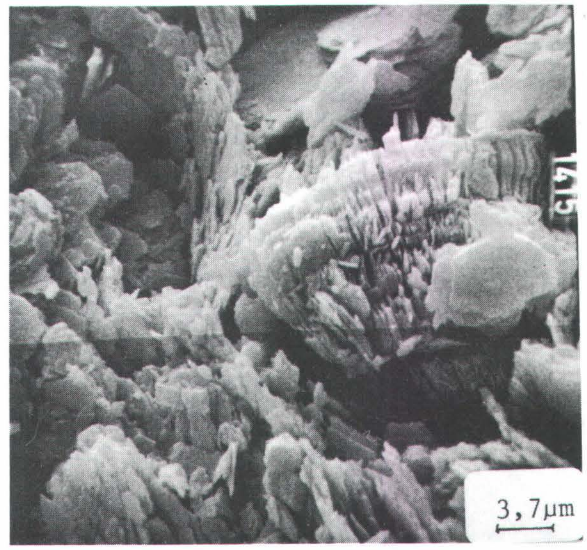




Kaznějov deposit, 2.1.1.

Fig. 1, 2: Predominating single pseudohexagonal kaolinite plates and small stacks (coarse-grained kaolin L).

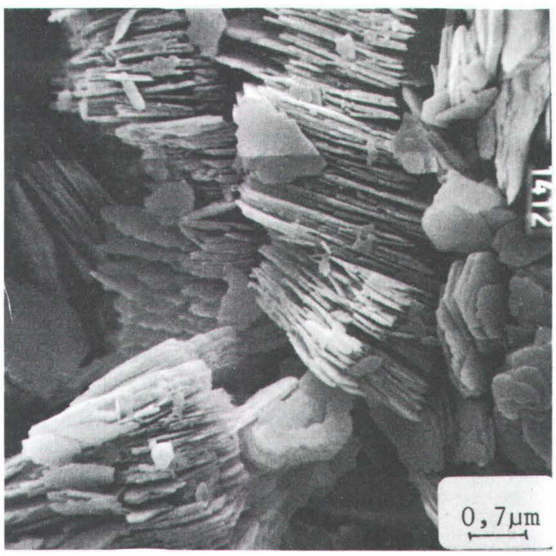


Fig. 3: Stacks of idiomorphic pseudohexagonal kaolinite plates (siltstone, "šlika" N).

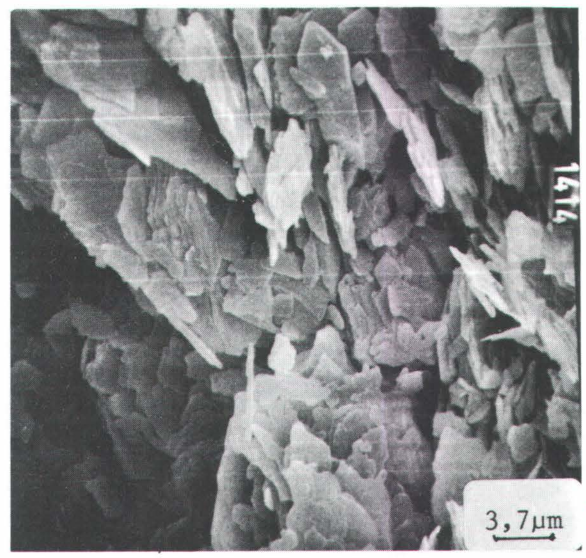
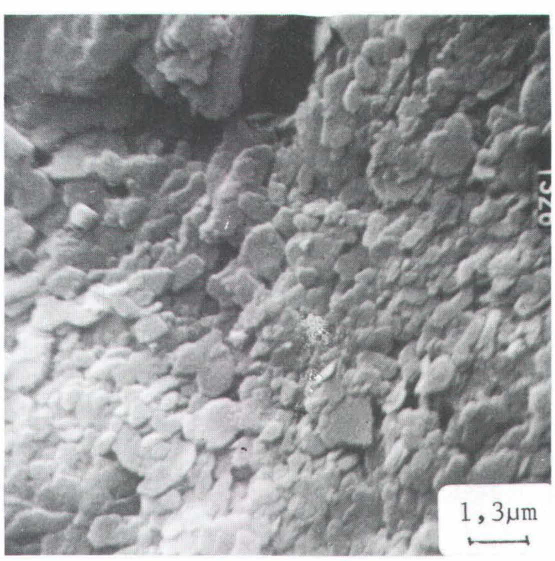
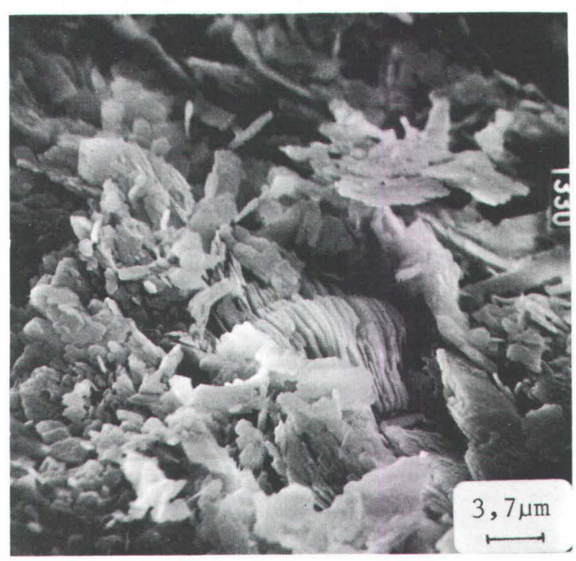


Fig. 4: Single flakes of kaolinite indicate the sedimentary bonding (siltstone, "šlika" N).





Horní Bříza deposit, 2.1.1.

Fig. 5: Single plates of kaolinite redeposited (top kaolin O).

Fig. 6: Stacks of kaolinite and redeposited single flakes (bottom kaolin P).

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Abstrakt

Byly shrnuty poznatky o genezi kaolínových ložisek Českého masívu na území ČSSR a sousedních států. Ložiska jsou přiřazena k jednotlivým genetickým typům a vlastnosti jejich kaolínů stručně charakterizovány. Nově provedená mineralogická studia (SEM) potvrzují primární pozici kaolinitu ve většině hornin. U objemově i průmyslově velmi významných ložisek v s. části plzeňské pánve (Kaznějov, Horní Bříza) byl vedle in situ kaolinizovaných zrn živců potvrzen významný podíl sedimentovaného kaolinitu. Znamená to, že tato ložiska vznikla redepozicí již dříve kaolinizovaného materiálu z neznámé vzdálenosti; po usazení byla dodatečně kaolinizována dosud relativně čerstvá zrna živců. Ostatní ekonomicky významná ložiska kaolínů v Českém masívu jsou vesměs zvětrávacího původu a představují kaolinitická rezidua granitoidů, metamorfitů a živci bohatých sedimentů in situ.

Zusammenfassung

Die Entstehung der Kaolinlagerstätten der Böhmischen Masse in der ČSSR und ihren Nachbarstaaten wird zusammenfassend dargelegt. Die Vorkommen werden getrennt nach genetischen Typen beschrieben und kurz charakterisiert. Aufgrund neuer mineralogischer Untersuchungen (Röntgendiffraktometrie, Rasterelektronenmikroskopie) konnte die primäre Entstehung der meisten Lagerstätten bestätigt werden. Bezüglich der großen, wirtschaftlich bedeutenden Vorkommen im nördlichen Teil des Beckens von Plzeň (Kaznějov, Horní Bříza) konnte festgestellt werden, daß abgesehen von in situ kaolinisierten Feldspatkörnern hauptsächlich sedimentierte Kaolinite vorliegen. Diese Vorkommen entstanden durch Umlagerung. Anschließend wurden die relativ frischen Feldspatkörner kaolinisiert. Die übrigen wirtschaftlich bedeutenden Kaolintone sind Verwitterungslagerstätten und stellen Residualtone von Granitoiden, Metamorphiten und feldspatreichen Sedimenten dar.

MONITORING OF EXPLORATORY WELLS AND HIGH-PRESSURE DETECTION IN POLYGENETIC STRUCTURED AREAS

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1. Introduction

Registration and interpretation of well data have become increasingly important to ÖMV exploration.
During drilling it's necessary to collect all data available, which are useful to get information about porosities, porepressures and formations.

For these reasons every well drilled is connected to a data unit, to get all the information needed.

Which drilling parameters are being used and which geological conclusions may be drawn, will be presented and discussed based on selected examples.

The following data were registered during drilling:

Drilling parameters:
- Time (minutes)
- Depth (meters)
- Weight on hook (tons)
- Rate of penetration (meter/hour)
- Torque
- RPM — Rotary per minute
- Pumpstrokes (strokes/minute)

Mud parameters:
- Mud weight in/out
- Temperature in/out
- Flow
- Pit volume
- Gas readings

Several sensors which transfer the data directly to the data unit were mounted on the rig-site.
There these data were digitally registered and permanently transferred on to „strip charts". Furthermore, the P.C. stores and evaluates all data on a discette.

Therefore, the aim is the registration and interpretation of all drilling parameters.
The data can be used as a helpful tool for logging-DST and casing decisions before entering a high pressure environment.

2. Criteria to predict high pressure zones and some genetic aspects

To identify transition-zones, the following criteria are decisive:

I. D-exponent
II. Gas readings
III. Shape of cuttings

IV. Increase in hook load
V. Increase in torque

I. D-exponent

This is the main criterion where lithological influences are expecially strong. In general a relationship between penetration rate, weight on bit, rotary speed, bit diameter, matrix strenght constants and effective circulating density has to be assumed.

$$D = \frac{\text{Log}\left(\frac{ROP}{RPM} . 0.0547\right)}{\text{Log}\left(\frac{BITWT}{BITDIAM} . 0.672\right)}$$

$$Dcs = \frac{D . 1.08}{ECD}$$

ROP = Rate Of Penetration (m/h)
RPM = Rotation Per Minute (U/min)
BITWT = Bit Weight (tons)
Bit Diameter (inch)
ECD = Equivalent Circulation Density (kg/l)

Some basic remarks on high pressure prediction:

In a normal case i.e. in a basin with increasing compaction, drillability decreases and D-exponent increases with depth. In shales and marls under which high pressure zones may be expected exactly the opposite is to be observed i.e. a very clear decrease of the Dcs.

As a classical example „Zistersdorf ÜT" can be mentioned, where the „transition-zone" was exceptionally thick, i.e. about 450 m (see fig. 2)

As genetic explanation „sedimentary loading" must be assumed.

High rates of sedimentation in connection with rapid burial — the fluid within the pores could not escape and took over a supporting function within the sediment against the overburden pressure.

This results in an essential increase in the rate of penetration although WOB is reduced as soon as the transition-zone is reached.

Two reasons for this are to be mentioned:

1) Increase in porosity with increasing depth (overcompacted shale section).
2) Decrease in differential pressure. The fact of increase in ROP can technically be explained through the decrease in differential pressure between formation and mud column. Formation pressure may increase significantly in transition-zones — gradients from 1.80 bar/10 m have often been registered in the northern part of the Vienna basin.
   This example only demonstrates the simplest case in which, based on drilling parameters and under consideration of lithology, exceptional high formation pressures could be concluded.

Following advantages result from an analysis of Dcs:

1) High pressure zones can be identified before an eventual kick and mud weight may be increased during drilling in this zone.
2) Another advantage to be mentioned is the correlation of the Dcs with SP or a resistivity log. This fact provides optimum information about lithology, porosity and formation changes during drilling.

In the Neogene, especially in the northern part of the Vienna basin, in the area of Mühlberg, Rabensburg and Ringelsdorf, transition-zones could be predicted only based on anomalies in the Dcs and required measures, like setting of a casing, could be taken.

II. Gas Readings:

If a transition-zone is drilled into, there will be a very obvious increase in trip-, connection- and backgroundgas, caused by the fast increasing formation pressure.

III. Shape of cuttings:

Due to higher formation pressure, which will come very close to mud pressure, or even supersede the later, the cuttings are much easier cut out of the formation by the bit.

This determines their shape. They are bigger, somewhat arched and of lengthy shape.

IV. Increase of hook load:

Because of pressure increase in the formation, marls grow into the bore hole and drag results. This, too, is an essential indicator that transition-zones are being drilled. As a logical consequence, considerable ream time could result.

V. Increase in torque:

Since size of cuttings is increasing and more material is chipped off at the bottom, an increase in torque may result.

There are sufficient criteria from a theoretical point of view for identification of high pressure zones on an early stage. The main problem is, however, that somewhat reliable predictions can only be made based on a combination of these parameters. In practice only some of the indicators mentioned will arise as soon as a transition-zone is being drilled into, and it depends on the state-of the art of the interpreter to interpret correctly even if only one or two of the criteria mentioned occur.

The following examples will clarify this point:

Exact knowledge about the formation and/or stratigraphical or tectonical information must exist. Only if one knows about the complexity of the matter it is possible to identify abnormal high pressures especially in the subcrops of the Alpine system buried and even then sources of errors cannot be completely eliminated.

3. High pressure prediction in ultra deep projects

Project „Zistersdorf Ultra Deep"

„Zistersdorf Ultra deep" represented a model case in which — with the assistance of all drilling-parameters registered in the data-unit it was attempted to obtain as much information as possible, regarding rock-type, pressure conditions and content of drilled formation.

A geological cross section clearly shows the target, i.e. the Autochthonous Mesozoic in the area of the „Steinberg Fault" in Zistersdorf.

In additon to the drilling parameters like weight on bit (WOB), rotation per minute (RPM) and rate of penetration (ROP) — the Pressure Control Analysis also contains the D-exponent and the sigma-plot (see fig. 2)

The sigma-plot, routinely being used during ultra deep drilling procedures is a further development of the Dcs by AGIP. Just as in the case of the Dcs it is based on the conformity or a number of basic formation-drilling relationships.

In addition, parameters covering the intensity of the compaction of a certain rock-type will be taken into consideration.

Thus, it represents an extension in the direction of geological — lithological criteria.

Which conclusion can be drawn from this pressure-profile?

First we see, as mentioned in the beginning and based on the crossection (fig. 1), down to 4.150 m a normal sequence in the Neogene, i.e. increasing compaction with depth. The line of the sigma-plot thus corresponds to a normal compaction trend line.

At 4.150 m the top of the transition-zone in the „Sandschaler Zone shows clearly (i.e. undercompacted shales). This, by the way, seems to be stratigraphically connected to this horizon.

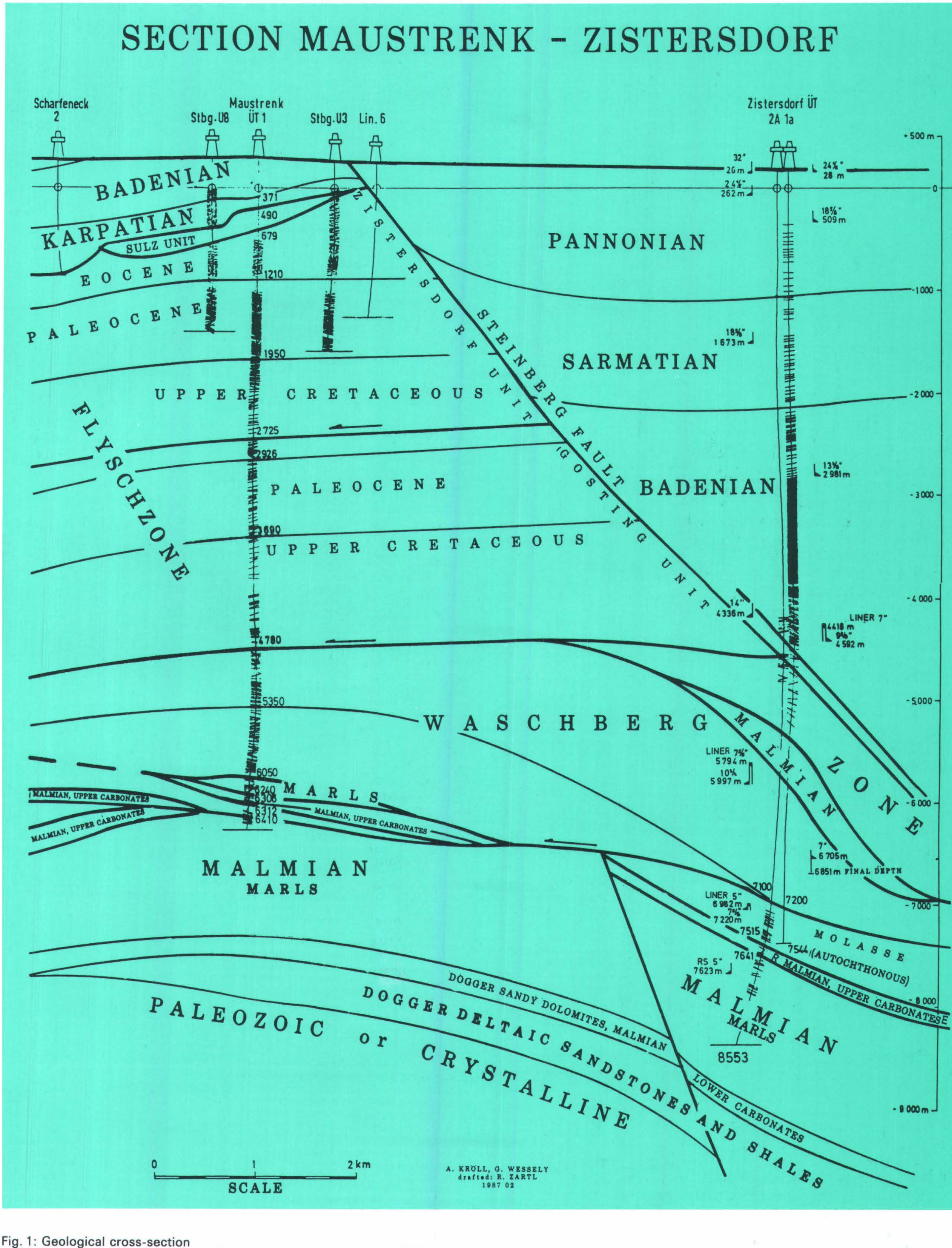


Fig. 1: Geological cross-section
Ultradeep projects "Zistersdorf ÜT 1, 1a, 2A" and "Maustrenk ÜT 1, 1a"
(G. Wessely, 1984).

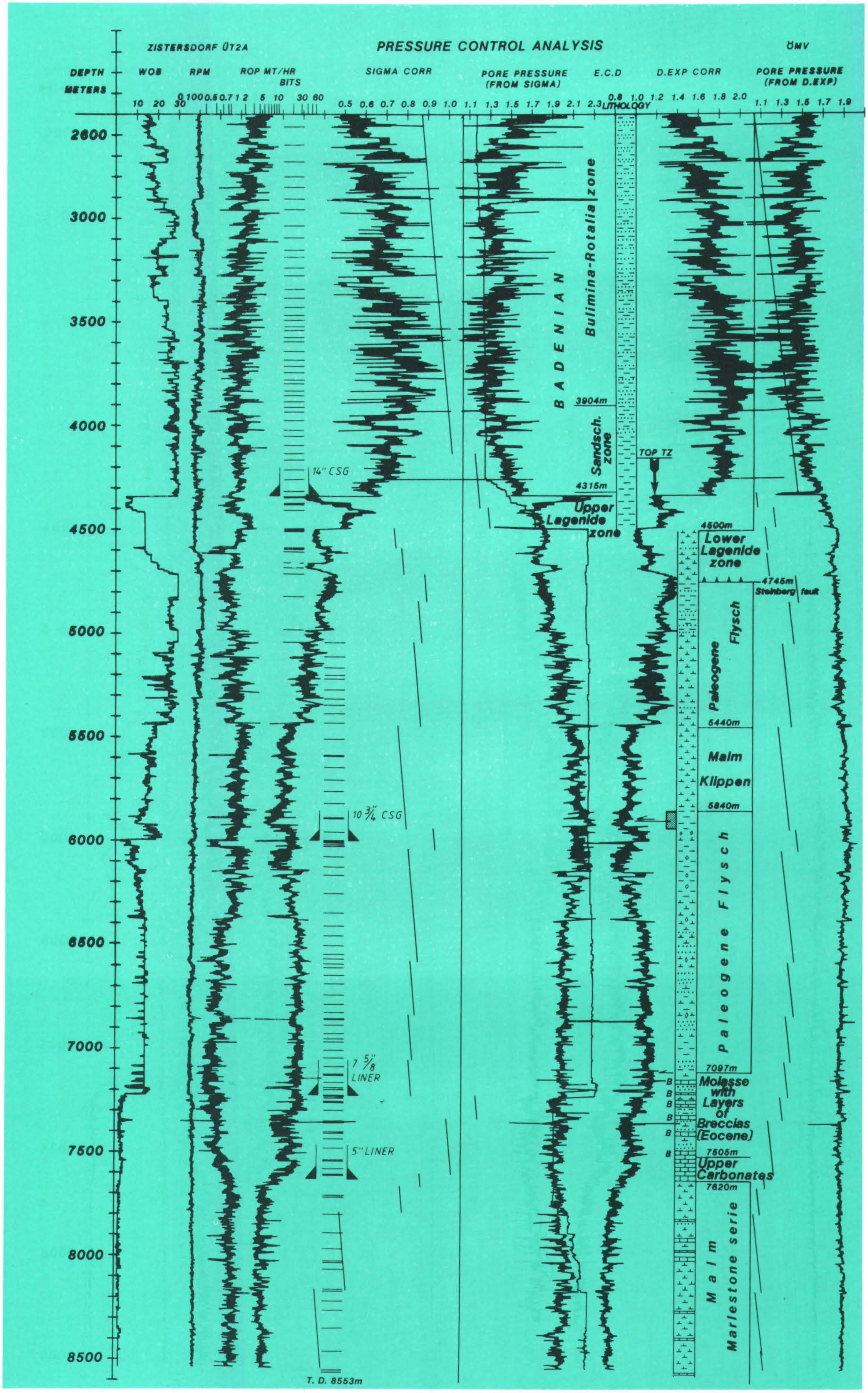


Fig. 2: Pressure Control Analysis, Project "Zistersdorf ÜT 2A" (W. Ringhofer 1986).

All projects drilled in the northern part of the Vienna basin have shown such anomalies in the „Sandschaler Zone".

The existence of transition-zone was also checked by logging methods as well as restivity and sonic-log.

1) Electric-log method:
   In normal pressured shales, there is an increase of resistivity with depth.
   In overpressured shales the resistivity curve shows a deviation from the normal trend, to lower than normal resistivities, indicating a higher water content and increasing porosity in the shales.
2) Acoustic log method:
   Plotting transit time against depth will give a normal compaction trend line.
   Pressure anomalies can be detected by an increase of transit time above the normal compaction trend (fig. 3).

Top of the transition-zone 4.150 m.

However, logging methods are „after the fact" techniques — after penetration of the bit. In the case of „Zistersdorf ÜT" only drilling parameters could help to detect „transition zones" immediately.

In accordance with pore pressure of the sigma-log, gradients of up to about 1,80 bar/10 m were detected in the Neogene.

The Paleogene flysch furthermore shows an increasing pressure up to approximately 2,0 bar/10 m.
From 5.840 m to 5.920 m the tectonically strongly influenced flysch, which was overthrusted by the „Malm-Klippe" has to be pointed out. It shows a significantly better drillability than the flysch sediments mentioned so far.

This tectonically severely disturbed area at the bottom of the „Malm-Klippe" also shows up very significantly in the sonic-plot (fig. 3).

The Molasse with its layers of breccias shows a very different course of the sigma-log, due to its differentiated lithology and is characterized by better drillability in connection with an increase of background gases in the calcareous breccial layers. Furthermore, the „Obere Karbonatserie" shows a better drillability which continues into the „Mergelsteinserie". Gradients of over 2,0 bar/10 m can be expected in these strata. The corresponding sonic-plot (fig. 3) substantiates the statement made with the assistance of the pressure control analysis also with regard to the top of the transition-zone at 4.150 m.

Project „Aderklaa Ultra Deep"

As previously discussed, it was the goal of this project, to prove the existence of Autochthonous Mesozoic below the flysch-nappes on the structural height in the Aderklaa area (fig. 4)

The sigma-plot shows normal pore pressures in the Neogene of the Vienna basin down to 3.160 m (fig. 5).

Starting at this depth the Calcareous Alpine Basin substratum was drilled, which made interpretation of pore pressure evaluation more difficult. The chart of the sigma-plot shows a drillability differing from the normal trend. This, however, cannot be interpreted as an increase in pore pressure, but has its reasons in the differentiated lithological composition of the Calcareous Alpine Basin substratum, consisting of limestones, dolomites and shales respectively. There were technical difficulties, when drilling through the shale layers embedded in between, as well as increase of torque and drag, indicating tectonically stressed zones, were registered. In this special case, the increase of background gas cannot be intepreted as an indicator for high pressure zones, since higher background gas levels may often be seen in overthrust areas.

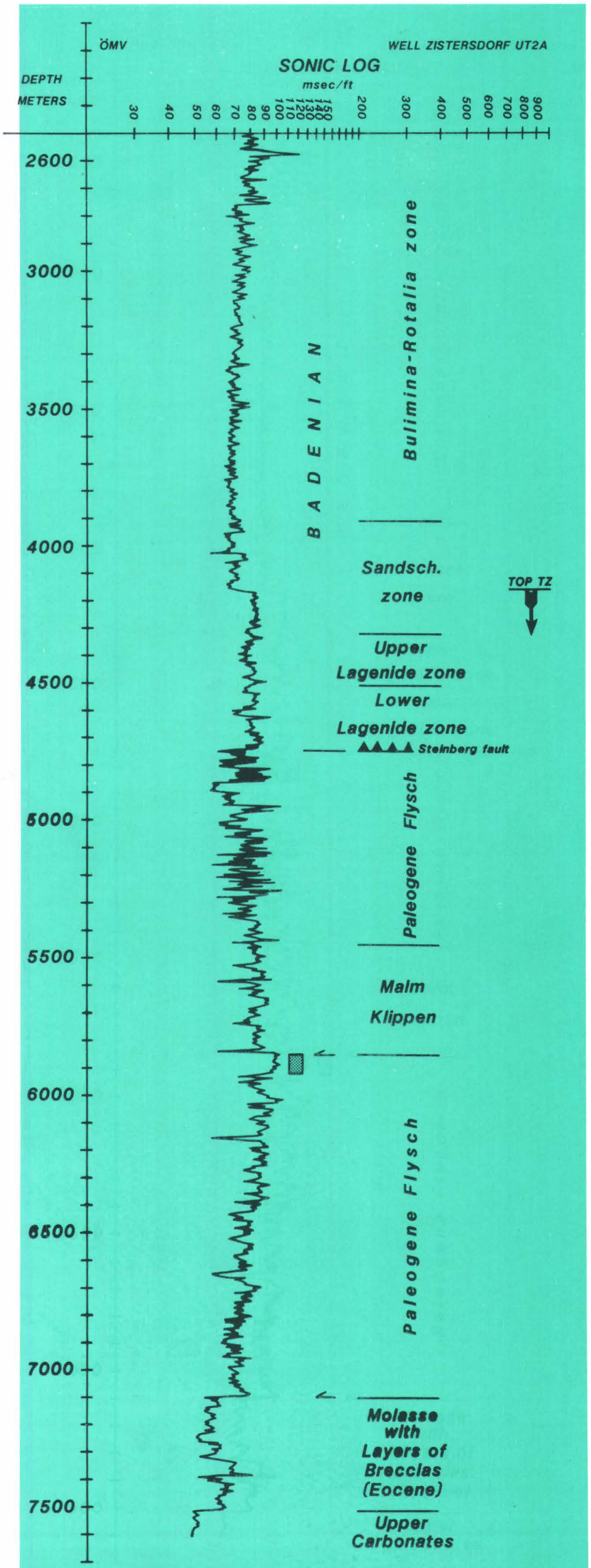


Fig. 3: Sonic-Plot of well "Zistersdorf ÜT 2A" (W. Ringhofer 1986). ▶

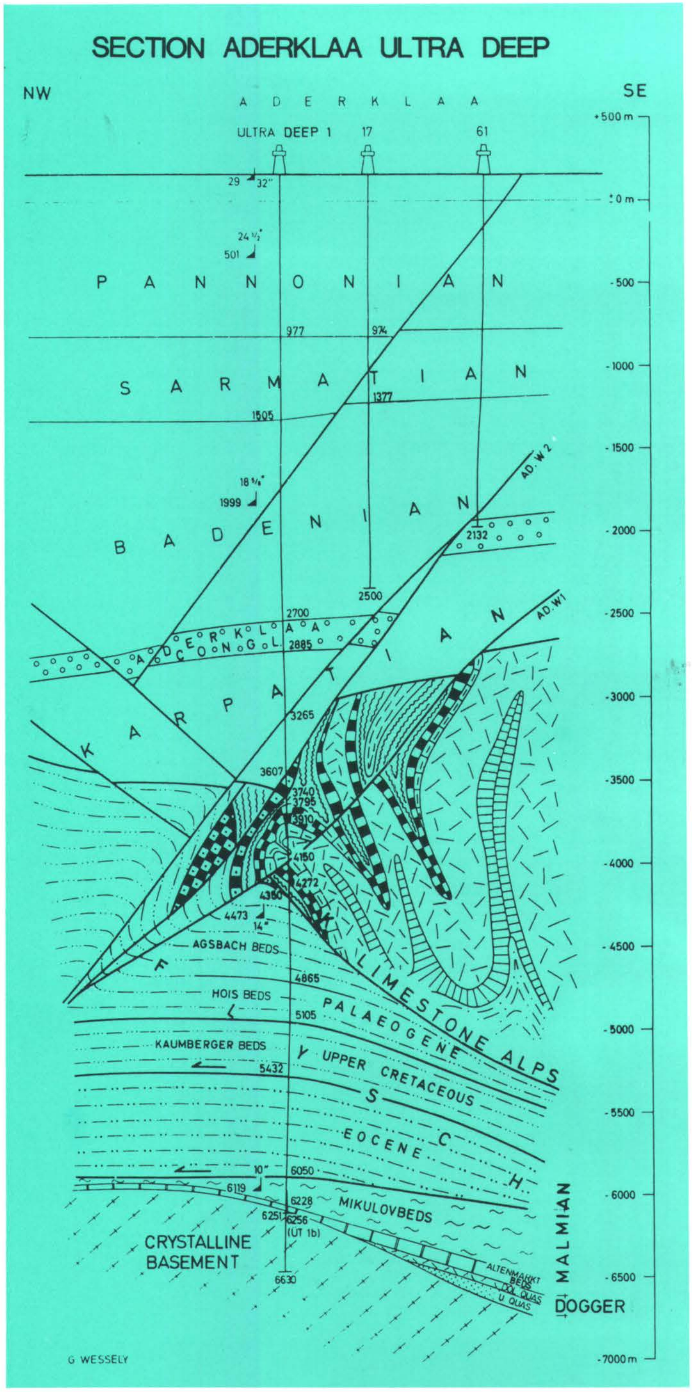


Fig. 4: Geological cross-section — Ultra deep project "Aderklaa UT 1, T 1a" (G. Wessely 1984).

Summarizing we found hydrostatic pressure conditions prevailing in this area with a few tectonic stress zones. Concerning this area it is important to point out that due to different WOB, the sigma-curve follows drilling rather than lithological criteria, i.e. is very much influenced by different drilling parameters.

This fact in addition renders the interpretation of the Calcareous Alpine Basin substratum more difficult. However, a partial loading of the limestone-alps within the contact-region to the Agsbach-nappes under highpressure conditions cannot be precluded completely.

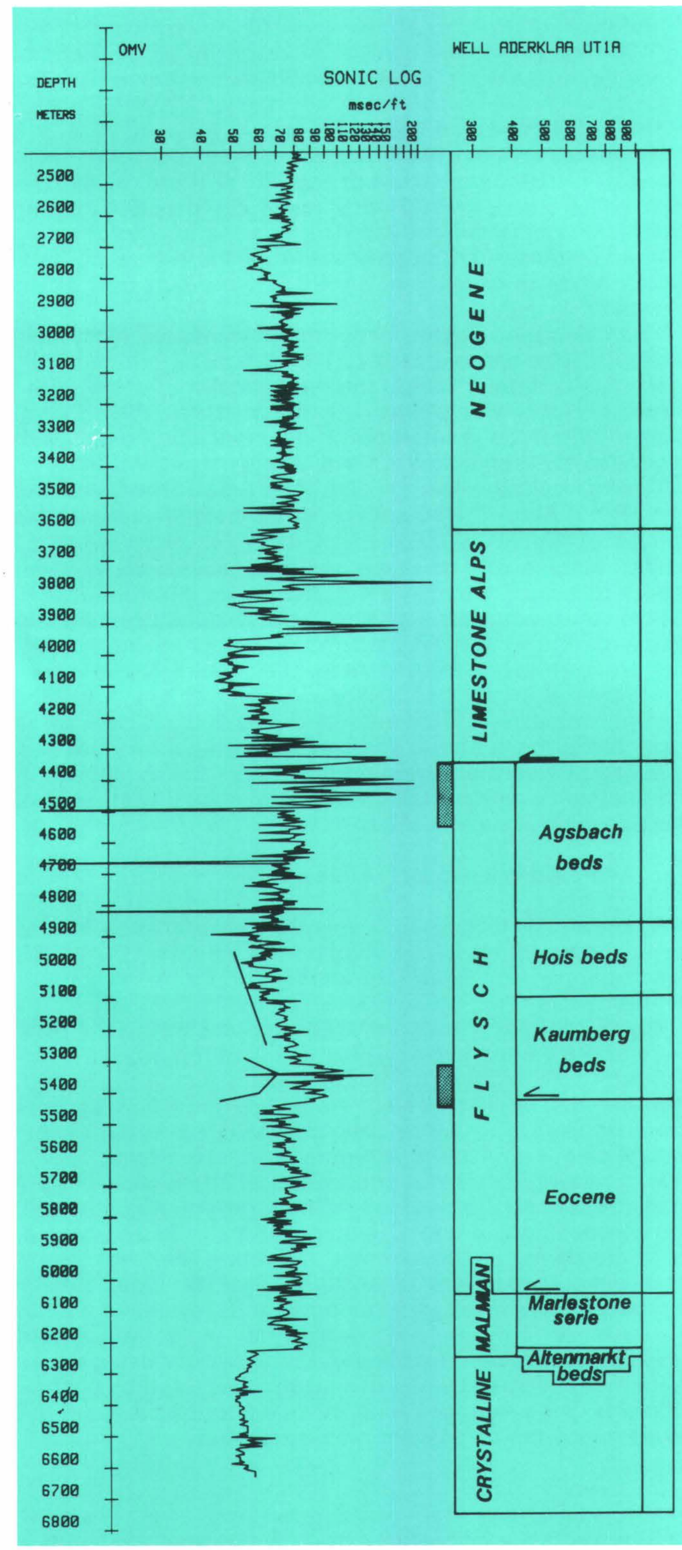
Especially prominent is the overthrust zone „Calcareous Alps over flysch sediment" (interval 4.350 — 4.550 m).

Because of varying velocities in this interval, the sonic-plot confirms statements made during drilling procedure.

The caliper log shows considerable cavings. This also points to tectonically stressed zones. Subsequently a 14" casing was run in. The first significant indication in the sigmalog showing the presence of a transition-zone, was detected about 4.550 m in the Agsbach-nappes, a dominately shaly-marly distal flysch environment. Based on their genesis, the Agsbach-nappes therefore have to be considered as a „seal".

The pressure curve of the sigma-plot in the Agsbach-nappes increased continuously. The transition from Ags-

Fig. 5: Pressure Control Analysis — Project "Aderklaa Ultra T 1, T 1a" (W. Ringhofer 1986). ▶



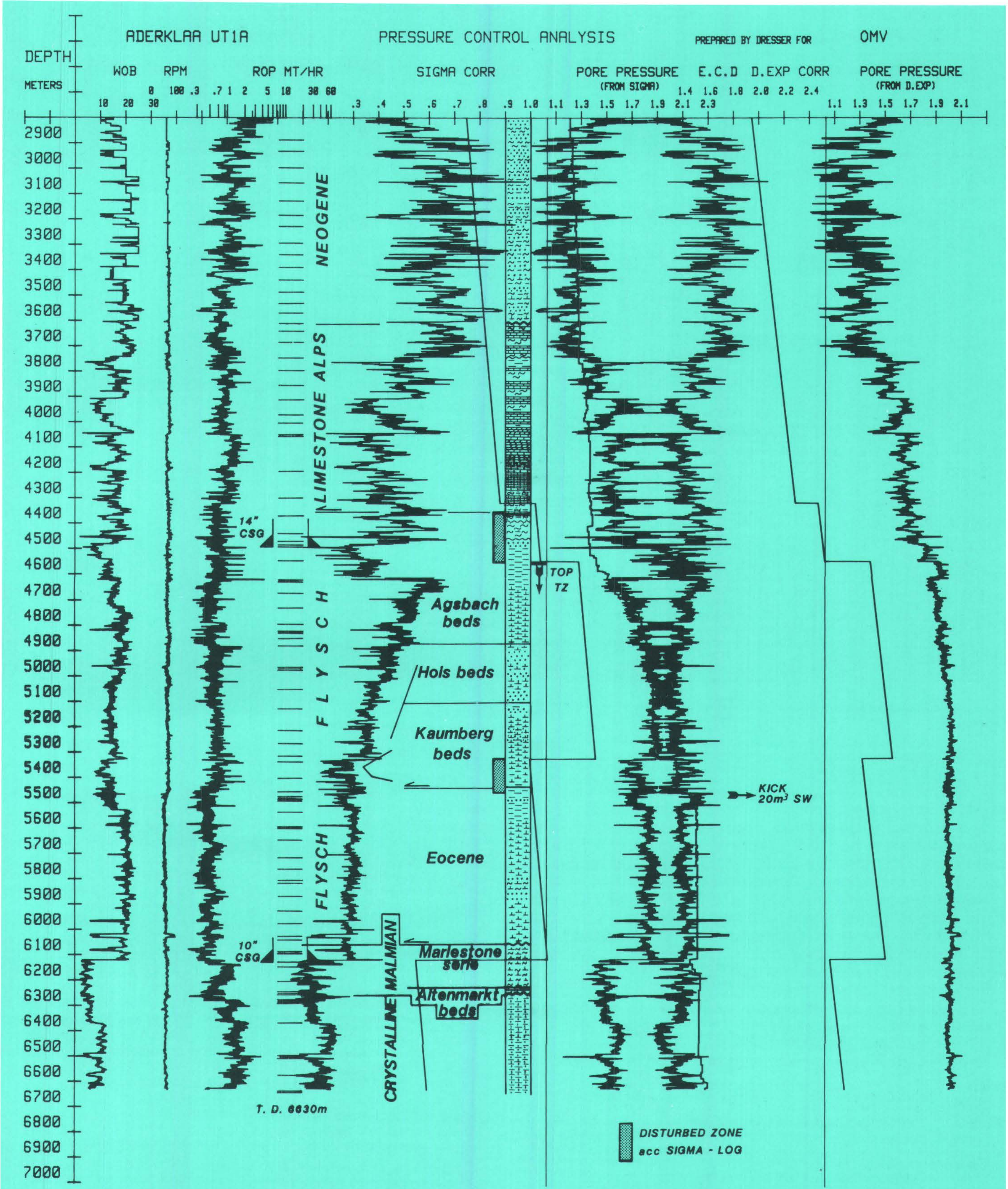


Fig. 6: Sonic-plot of well "Aderklaa UT 1a" (W. Ringhofer 1986).
◄

bach to Hoisnappes is of sedimentary origin. Therefore, no trend-anomalies show up in the sigma-log. The Kaumberg-nappes are the oldest formations in the normal sequence of this southern flysch environment. Down to 5.330 m, the sigma-log shows continuously increasing pressure conditions with gradients of about 1,90 bar/10 m. The interval from 5.330 to 5.460 m represents an area which even at first glance looks like a strongly disturbed zone.

This can be explained through the overthrust of Upper

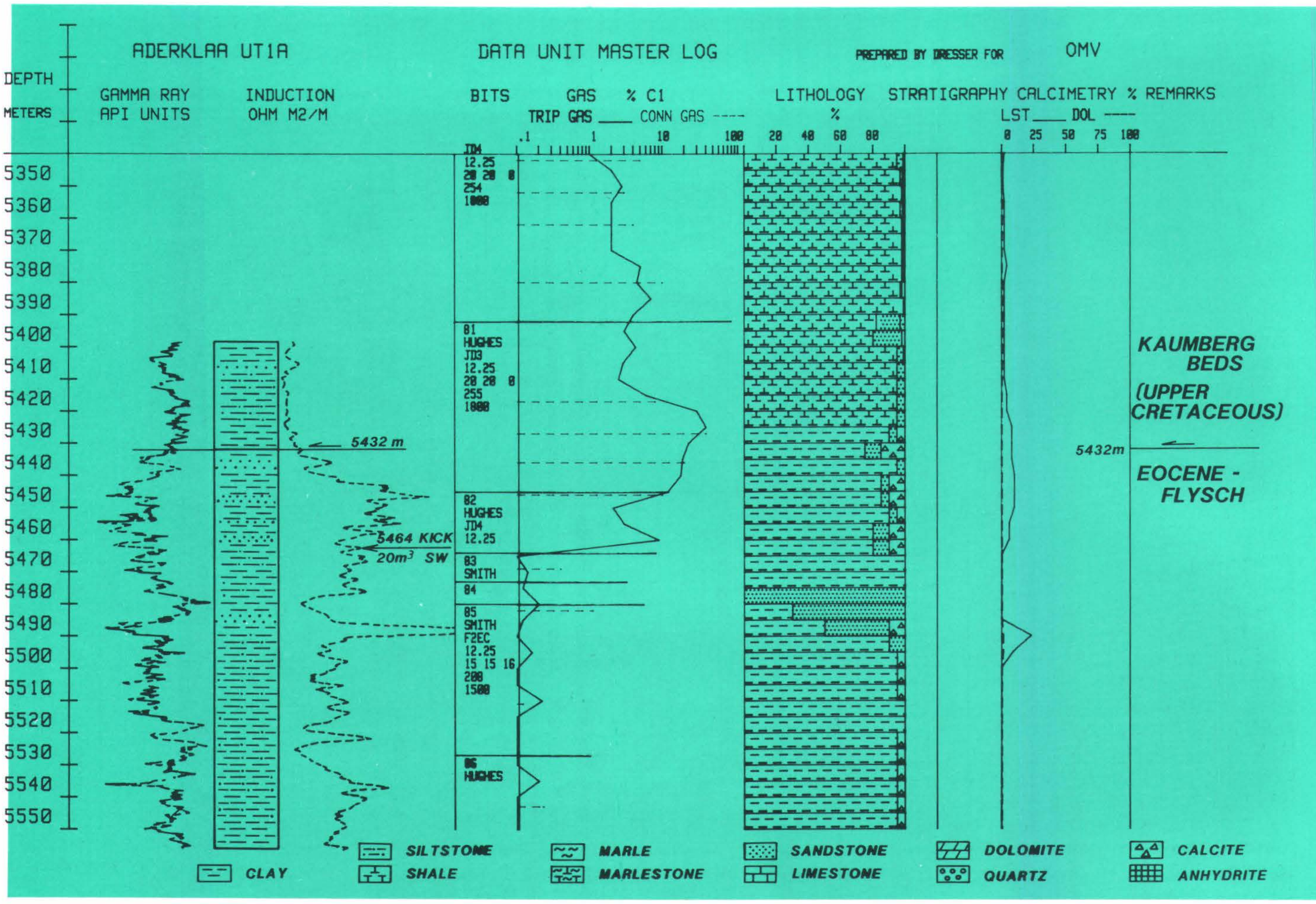


Fig. 7: DATA UNIT Master-Log of well "Aderklaa UT 1a" (W. Ringhofer 1986).

Cretaceous flysch-units onto younger Eocene-flysch.

At a depth of 5.464 m a kick occurred — about 20 m^3 saltwater entered the bore hole. A pressure gradient of 2.2 was calculated. This pressure environment in general remained constant for the whole drilling process.

Now to the analysis of the kick at 5.464 m, at which about 20 m^3 saltwater entered the bore hole (fig. 7)

The kick has occurred in the area Kaumberg-nappes (Upper Cretaceous) — Eocene flysch. The high drillability was documented by the sigma-log (see fig. 5).

Furthermore there occurred:

1. Extremely high gas readings were caused by connection gases (up to 40 %).
2. The background gas-level didn't decrease any longer, but remained at about the same amount as the connection gas did.
3. The massive presence of calcite also characterized this disturbed zone.

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Abstrakt

V souvislosti s intenzívní prospekcí autochtonního mezozoika se zvýšilo využívání vrtných parametrů, podle nichž lze usuzovat o geologicky významných horninových vlastnostech jednotlivých souvrství, jako např. o jejich pórovitosti, pórových tlacích atd.

Zvláštní význam se přikládá rozboru údajů o postupu vrtání a z něho vyplývajících údajů Dcs nebo Sigma-log vzhledem k jejich přímému vztahu k litologii. Dále se přistupuje k detailnímu včasnému zjišťování vysokých tlaků, jak je patrno z příkladů aplikace této metody např. na vrtech Zistersdorf ÜT 1a a Aderklaa Ultra T 1, 1a.

V kombinaci s údaji Sigma-log a s ohledem na geologická kritéria bylo tak možno rozpoznat „přechodné zóny" jak v neogénu, tak i v pánevním podloží, jež lze interpretovat značně obtížněji. D-exponent, resp. Sigma-log, se tak osvědčily jako mimořádně vhodné prostředky nejen ke včasnému zjišťování vysokých tlaků, nýbrž i k získání podrobných litologických informací v průběhu vrtání.

Zusammenfassung

In Zusammenhang mit einer intensivierten Prospektionstätigkeit auf das autochthone Mesozoikum hat sich die Auswertung von Bohrparametern, die für die Geologie wichtige Rückschlüsse auf Formationen, Porositäten, Porendrücke etc. ermöglichen, verstärkt.

Der Analyse des Bohrfortschritts, daraus resultierend des Dcs bzw. des Sigma-Logs, wird aufgrund ihrer direkten Beziehung zur Lithologie besondere Bedeutung beigemessen. Weiterhin wird eingehend auf die Hochdruckfrüherkennung anhand von angewandten Beispielen wie Zistersdorf ÜT 1a und Aderklaa Ultra T 1, 1a eingegangen.

Unter Berücksichtigung geologischer Kriterien, in Kombination mit dem Sigma-Log, ist es dadurch möglich geworden, „Transitionszonen" sowohl im Neogen als auch im wesentlich schwieriger interpretierbaren Beckenuntergrund anzusprechen. Der D-Exponent bzw. das Sigma-Log haben sich als äußerst probates Mittel, nicht nur für die Hochdruckfrüherkennung, sondern auch für detaillierte lithologische Informatio-

V této souvislosti je třeba zvláště zdůraznit možnosti korelace údajů odporového Dcs, resp. Sonic-log, se Sigma-log.

Navíc jsou uvedené metody, umožňující včasné rozpoznání kritických situací, důležitým příspěvkem nejen k hospodárnému, nýbrž především rovněž k bezpečnému hloubení vrtů.

nen während des Bohrvorganges erwiesen.

Besonders ist in diesem Zusammenhang die Korrelationsmöglichkeit Widerstand-Dcs bzw. Sonic-Log — Sigma-Log hervorzuheben.

Darüber hinaus wird durch das frühzeitige Erkennen von kritischen Situationen ein wichtiger Beitrag nicht nur zum wirtschaftlichen, sondern vor allem auch zum sicheren Niederbringen einer Bohrung geleistet.

PROBLEMS RELATED TO THE ORIGIN OF HYDROCARBONS IN THE VIENNA BASIN

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Although questions concerning the genesis of oil and natural gas in the Vienna Basin have received much attention, the problem has again come into prominence lately, when production from deposits located in sequences underlying the Tertiary basin fill was started. Intense studies on oil genesis in the Vienna Basin have been conducted, above all, by Austrian geologists and geochemists. The investigations made by D.H. Welte, H. Kratochvil et al. (1982), H. Kratochwil, H.D. Ladwein (1984) eliminate the generation of oil hydrocarbons in the Tertiary sediments of the basin. Basing on the results of Rock-Eval pyrolysis, microphotometry and chromatographic analyses of the hydrocarbon fraction of oils and rock (bitumen) extracts, they place the "oil window" to a depth of 4 to 6 km. They regard the organic matter of Tertiary rocks as of genetic type III, and that of the underlying sequences of the autochthonous Malm and Lias-Dogger as of genetic types II to III. These authors place the oils of the basin filling, the flysch basement and the basement of the Limestone Alps into a single genetic group. Most of the oils show features of biodegradation resulting in the complete absence of alkanes. The authors relate the variable oil composition (Klement boreholes) to a terrigenous organic parent matter. In their opinion, the source rocks of the hydrocarbons of the Vienna Basin are sediments of the autochthonous Malm (downdip blocks associated with the Steinberg fault system in the southwestern part of the basin); to some extent, also coal series of the autochthonous Lias-Dogger are thought to supply some hydrocarbons, mainly gaseous ones, at depths exceeding 4 km. The geological conditions of the basin apparently favour vertical migration. Recently, the Czechoslovak authors F. Chmelík and P. Müller (1987) have advanced their views on oil genesis in the Czechoslovak part of the Vienna Basin. They investigated the thermocatalytic alteration of dispersed organic matter (kerogen) that had not been examined by previous research (V. Šimánek, 1976). In their studies, they based upon the common parameters of thermocatalytic metamorphism of kerogen (maximum pyrolysis temperature T_{max}) and the S_1, S_2 indices derived, hydrogen and oxygen indices, production index, the reflectance of vitrinoid dispersinites, etc. They based their modelling of generative hydrocarbon zoning upon the summary temperature pulse method (L. A. Polster, 1984). This approach takes account of the principles of reaction kinetics and the dependence of the conversion of kerogen to oil hydrocarbons on the time and temperature of kerogen exposure during the geological history of the basin. The model development of the zonal generation of hydrocarbons in the Hrušky-Týnec area, illustrated in Fig. 1, can be extrapolated to the whole Moravian part of the Vienna Basin with regard to the geological setting of the region. The principal zones of possible oil-hydrocarbon genesis — "oil windows" — of mesokatagenesis 1 to 3 are situated at a depth of 2.7 to 6 km in this part of the basin. In accordance with paleotemperature history, indicated by the parameters of the pyrolysis temperature maximum T_{max} and reflectance R_o (Fig. 2) the kerogen of most of the rocks investigated was found to be „immature", even at depth intervals about 4 km. The reflectance of vitrinoid dispersinites assigns about half of the rocks examined to the lower part of the oil window and the other half to the protokatagenesis zone (PK_2-PK_3), that means to the zone, where early katagenic gas and incipient oil were formed. The results can be summarized as follows: as regards the level of katagenic kerogen conversion in the Moravian part of the Vienna Basin, kerogen can be assumed to convert to oil hydrocarbons at a depth of some 3 km and deeper. Katagenic hydrocarbon generation from kerogen in the Slovak part of the Vienna Basin is demonstrated in Fig. 3. During the most rapid subsidence in Sarmatian and Badenian time, Neogene sediments along the Kúty-Leváre-Suchohrad line lowered down as deep as 5 km in the early Badenian. At this depth, they were given the temperature pulse required for the conversion of kerogen to oil hydrocarbons. In this region, thermokatagenic kerogen metamorphism corresponding to the "oil window" starts in the late Sarmatian. In accordance with the summary-temperature-pulse theory, the top of the oil window, corresponding to protokatagenesis 3 to mesokatagenesis 1 zones in the Slovak part of the basin, is localized in Badenian sediments, whereas the bottom of the oil window, corresponding to mesokatagenesis 3 to mesokatagenesis 4 zones lies at about 6 km depth in the basement of the Neogene sediments. The katagenic metamorphism of the kerogen present in Neogene sediments in this part of the basin, established at a depth of about 4 km (Závod deposit), corresponds to the oil window bottom. The results of laborataory measurements and analyses are listed in Table 1 for the Moravian and for the Slovak part of the Vienna Basin.

The results obtained by the research on thermocatalytic metamorphism of dispersed organic matter in the rocks of the Czechoslovak part of the Vienna Basin have confirmed that kerogen conversion proceeds in rocks exhibiting favourable oil-generating properties at depths of about 3 to 6 km, as indicated by the level of thermocatalytic alteration and the summary temperature pulse. In the Czechoslovak part of the Vienna Basin, favourable geochemical properties and an adequate level of thermocatalytic alteration were established for the sediments of the autochthonous Mesozoic in the Mikulov marlstone facies and the autochthonous Paleogene, and, as far as gas genesis is concerned, probably also for Paleozoic sediments. The level of thermocatalytic metamorphism does not eliminate geochemically favourably developed Tertiary sediments deposited at adequate depth from the possible generation of oil hydrocarbons in the Vienna Basin* (p. 244).

Oils of rather varying physical and chemical composition have been recovered from deposits of the Tertiary fill of the Vienna Basin: very light paraffinic oils of a specific density less than 0.870 g/cm^3 at 20 °C, light to heavy oils of paraffinic-naphthenic and/or naphthenic-paraffinic type, density 0.870 to 0.940 g/cm^3, and rather heavy naphthenic oils of a density exceeding 0.940 g/cm^3 at 20 °C. The distribution of these oil types is differentiated horizontally and in the vertical section through the basin: very light oils of the paraffinic or paraffinic-naphthenic type are associated with the (Lower, Middle, Upper) Badenian and the Paleogene of the Magura flysch; very heavy naphthenic oils are related to the Sarmatian, and light to heavy oils of mixed paraffinic-naphthenic and naphthenic-paraffinic types to the Karpatian and Eggenburgian-Ottnangian (Table 2). The individual sequences exhibit a distinct dependence of the chemical oil composition on the tectonic framework of the reservoir rocks. Deposits associated with the Steinberg fault system and the Moravian central depression contain oils

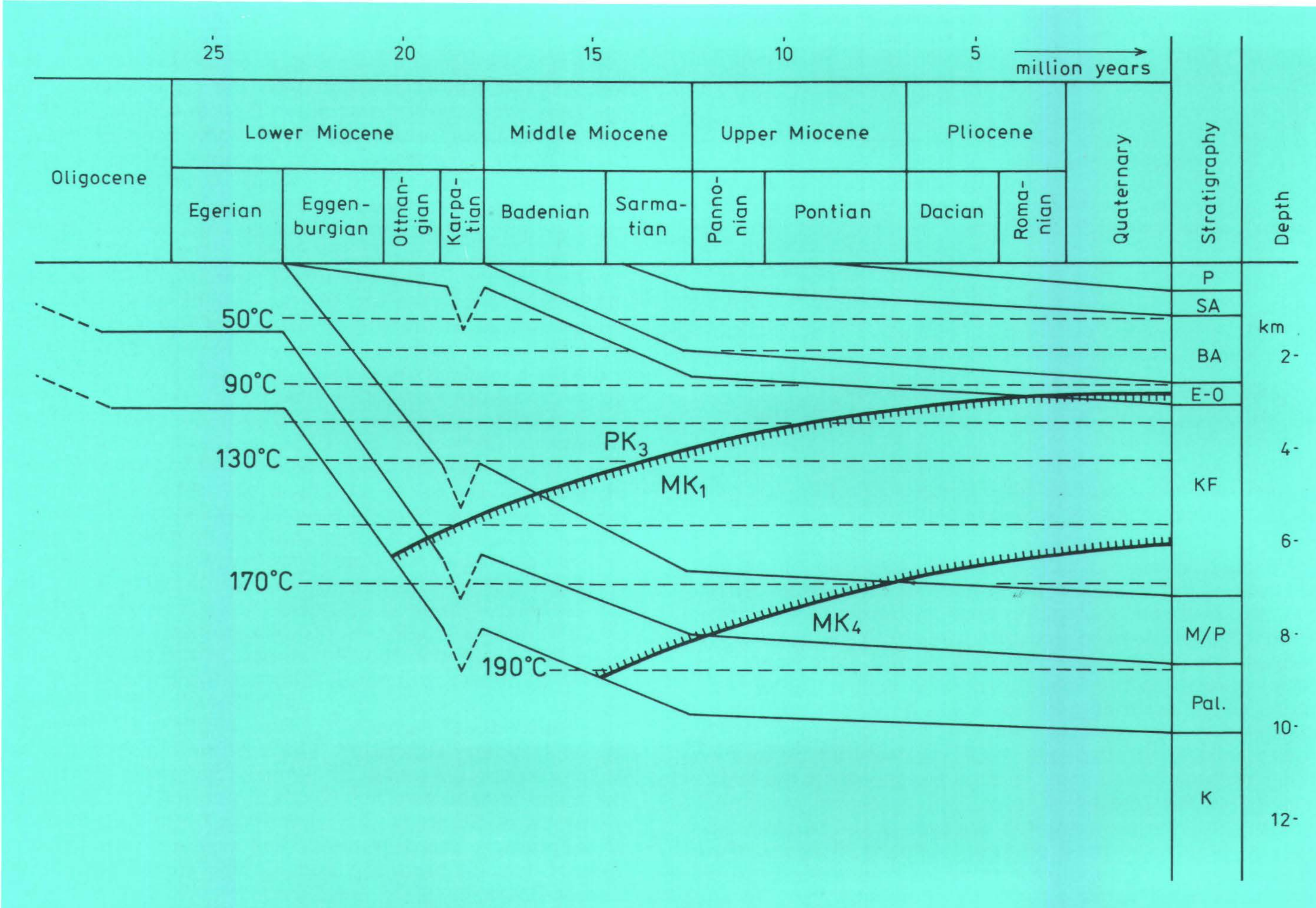
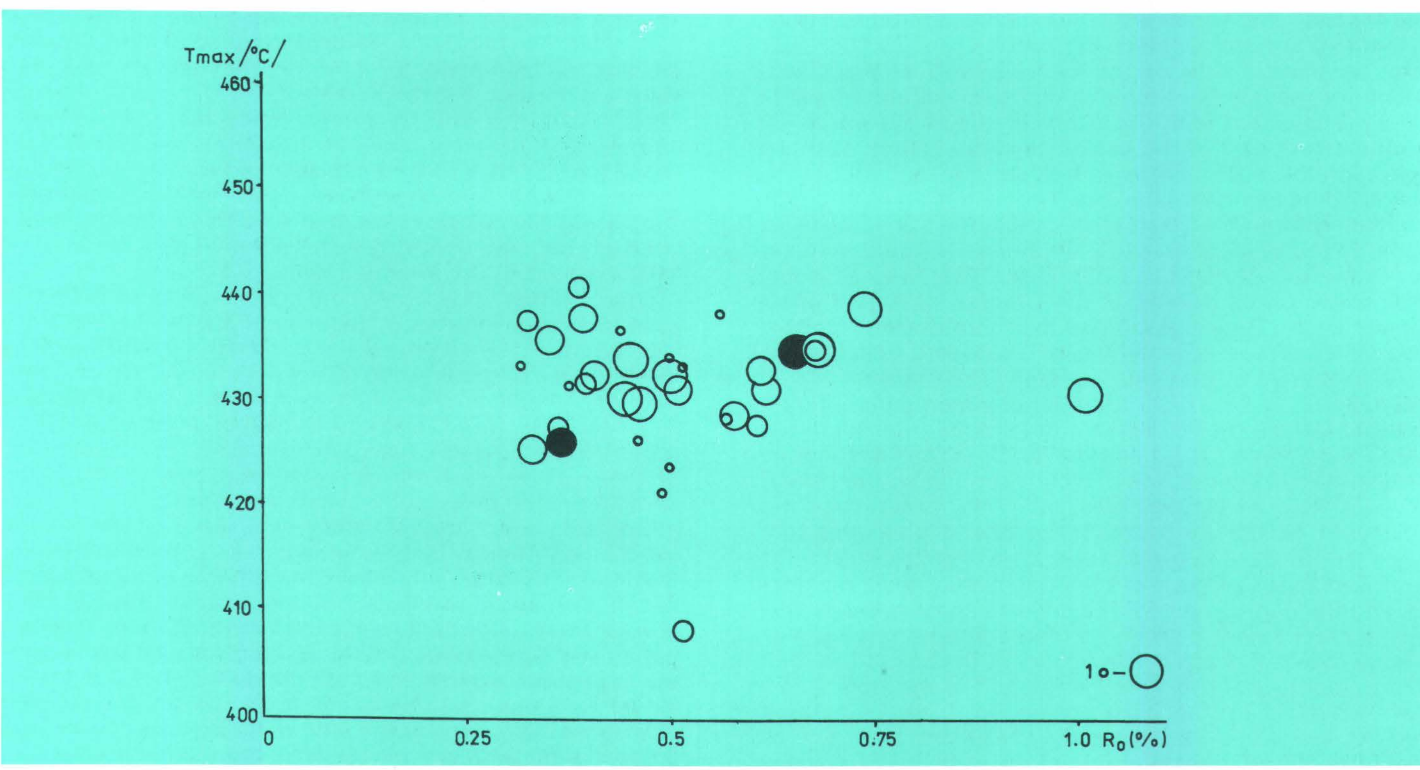


Fig. 1: Model development of the zoned origin of hydrocarbons in the Hrušky—Týnec area.

Fig. 2: Relationship T_{max}: vitrinite reflectance R_o.



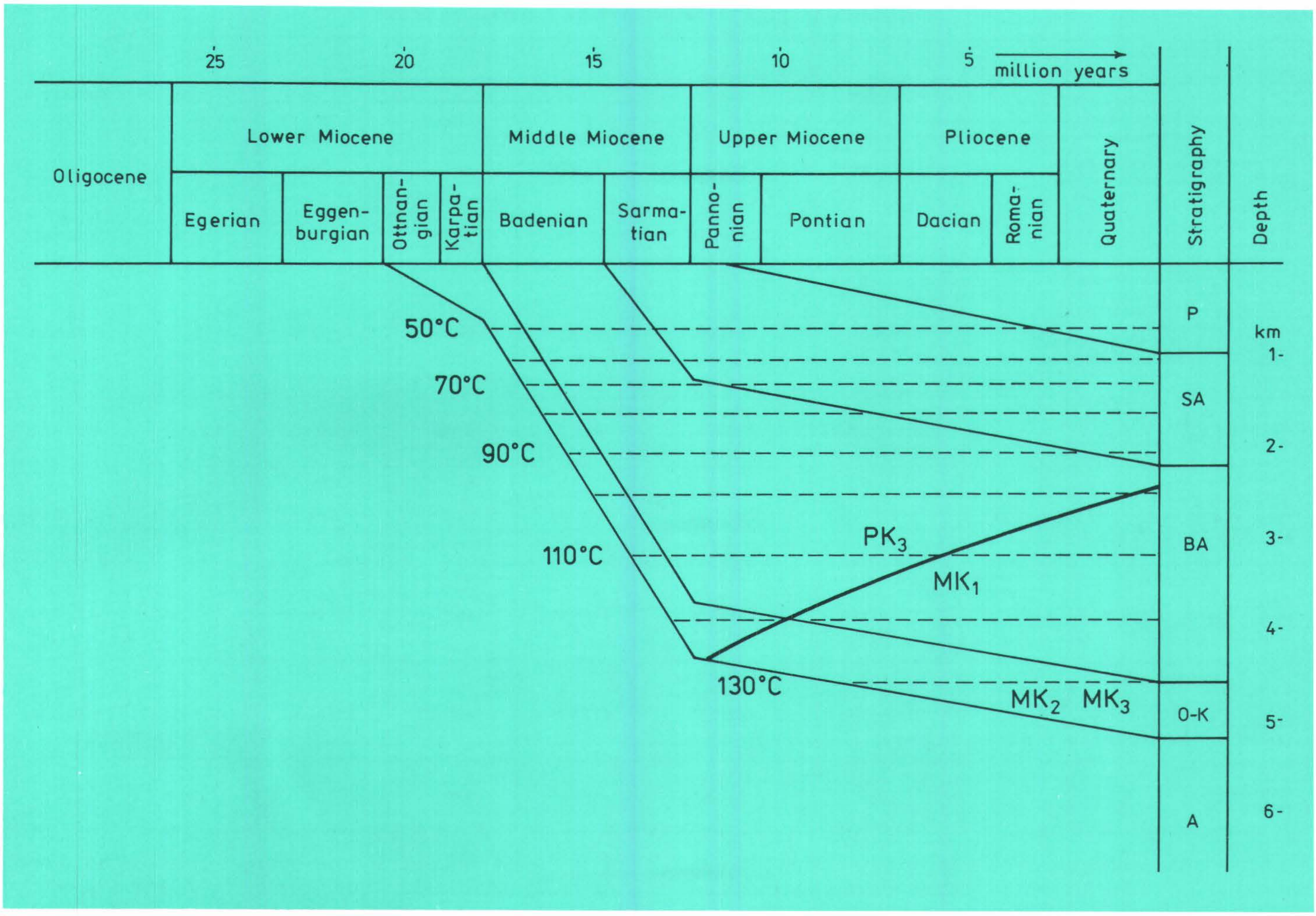


Fig. 3: Katagenic generation of hydrocarbons from kerogen in the Slovak part of the Vienna Basin.

related to the light group and exhibiting a more pronounced paraffinic character, while oils of deposits related to the Hodonín-Gbely horst or to the northern end of the Štefanov-Šaštín horst are commonly heavier, with a higher content of naphthenic hydrocarbons. The content in paraffinic hydrocarbons determined by structural type analysis varies, in reciprocal dependence on the content in naphthenic hydrocarbons. The oil composition displays a distinct tendency to a density decrease with the depth of deposition. At depth intervals from 100 to 2700 m, density decreases from about 0.950 to about 0.920 g/cm³ at 20 °C. At depths below 2 000 m distinct variations occur in the densities (Fig. 4). Particular consideration should be given to the stable physico-chemical composition of Sarmatian and Lower Badenian oils throughout the Czechoslovak part of the Vienna Basin, of Middle and Upper Badenian and Karpatian or Paleogene oils in tectonic subunits or structures, and to the rather variable physico-chemical composition of Eggenburgian and Ottnangian oils. Variations in oil composition within an identical horizon indicate the influence of the geological structure: upwards, i.e. to the structurally highest position, the oil densities decrease and the paraffinic character of the oil becomes more pronounced. Differences in oil densities at the oil/water contacts could not be determined. The concentration of n-alkanes in oils from Czechoslovak deposits ranges from several hundredths of percent by mass to several tens of percent by mass. The n-alkane concentration is consistent with the structural and chemical composition of the oils, but it is not a function of their specific and molecular mass. Saturated paraffinic hydrocarbons are missing in Sarmatian oils from 100 to 200 m depth. The oils of equivalent sequences at larger depths generally contain small to trace amounts of n-alkanes. In oils from older Neogene or Paleogene sequences, the content in n-alkanes attains more than 25 % by mass. Hydrocarbons with shorter chains — C_{14} to C_{20} — are absolutely prevailing members (see Table 3). The isoprenoid hydrocarbons of the oils in the Czechoslovak part of the Vienna Basin are generally represented by pristane and phytane which, however, do not exceed 2 % by mass. The pristane content is two to three times as high as the phytane content in the stratigraphical profile o the Tertiary sediments. The polyaromatic hydrocarbons, perylene, coronene and fluoranthene were determined. The coronene and fluoranthene contents do not exceed ppm, and perylene is bonded to oils of Neogene deposits in concentrations of some tens of ppm. In oils recovered from Paleogene, Mesozoic and/or Paleozoic sediments (Carpathian foredeep), perylene was found in trace concentrations or was absent.

Discussion

Undoubtedly genetical reasons are responsible for the differentiation in the physico-chemical composition of the oils in the Tertiary filling of the Vienna Basin. Microbial oil destruction under conditions of microbial activity certainly has played an important role, even though the stable densities of oils at the water/oil contact do not point to a substantial significance of this process: all types of oils are affected by underground aeration indicated by the absence of n-paraffines in shallower Sarmatian deposits and by "migration differentiation" dependent on migration distance.

Table 1 — **ORGANIC MATTER IN SEDIMENTS OF THE VIENNA BASIN**

Boreholes	Depth ⌀/median	% by mass C_{org}	Controlled pyrolysis				Reflecting microscopy
			IH	IO	IP	T_{max} °C	
Autochthonous Paleogene Hrušky-226, 229, Poddvorov-73	1898/1924	0,37/0,40	413/341	70/75	0,02/0,02	444/444	—
Magura flysch Břeclav-26, Lednice-8, Ježov-1	2474/3043	0,91/0,85	137/56	58/39	0,30/0,20	436/431	0,68/0,65
Limestone Alps and Inner Carpathian zones Závod-78, 75, 74, LNV-7, Kuklov-3, Studienka-83, Šaštín-12, Borský Jur-19	4405/4330	1,96/0,80	79/65	90/73	0,30/0,20	447/443	0,90/0,80
Eggenburgian Hrušky-33, 234, Šaštín-12	2592/2420	0,430/,50	95/77	89/89	0,06/0,02	433/432	0,57/0,61
Ottnangian Týnec-13A, 30, 4a, 82, 77, 83, Hrušky-228, 227, 230A, 84, 85, 86, 103, 106, 234	1122/831	0,87/0,90	492/399	73/69	0,30/0,11	403/431	0,46/0,46
Karpatian Hrušky-228, 45, 8, 220, Kuklov-3, 226A, 227, 2A, 72, 75	2379/1840	0,66/0,60	115/111	105/109	0,09/0,08	435/434	0,63/0,63
Badenian Hrušky-228, 188, 186, 152, Z-39, 35, 34, 223, 224, 231, 3, Břeclav-26, Lednice, 8, 9, Poddvorov-73	1955/1780	2,09/0,50	217/101	140/127	0,15/0,06	426/431	0,53/0,48
Sarmatian Hrušky-234	960	0,20	1854	541,0	—	442	—

In our opinion, processes of oil origin play a decisive role in the formation of the present physico-chemical composition of the oils. These processes are controlled by chemical reaction kinetics determined by thermodynamic laws. In this sense, the conversion of kerogen to oil hydrocarbons and the evolution of the latter imply the reduction of the available free energy of the molecules. Among the oil hydrocarbons, the energetically highest position is occupied by hydrocarbons of aromatic structure; an intermediate position has been assigned to cycloalkane (naphthene) hydrocarbons, while saturated paraffinic hydrocarbons dispose of the least amount of free energy. In accordance with thermodynamic calculations, aromatic hydrocarbons can be assumed to convert to cycloalkane hydrocarbons by way of hydrogenation as follows:

1. $C_6H_6 + 3H_2 \rightarrow C_6H_{12}$

   or, vice-versa, by dehydrogenation to high-molecular aromatics in accordance with equation

2. $2C_6H_6 \rightarrow C_6H_5 \rightarrow C_6H_5 + H_2$

   Reaction 1 yields cycloalkane hydrocarbons that, by way of hydrogenation give paraffinic hydrocarbons after equation 3:

Table 2 — **PRINCIPAL PHYSICO-CHEMICAL PARAMETERS OF THE OILS OF CZECHOSLOVAK DEPOSITS**

Stratigraphy	Depth	Number of analyses	Spec. gravity g/cm³ 20° C	Resins	Asphalt.	Composition by structure and type			Composition by fractions 200—350 °C					
				% by mass		CP%	CN%	CA%	200—300 °C			300—350° C		
									CP%	CN%	CA%	CP%	CN%	CA%
Sarmatian	68—1246	217	0,930	10,1	10,4	29,3	53,2	17,5	26,5	67,5	7,0	28,9	57,5	13,6
Middle-Upper Badenian	441—3147	307	0,860	3,8	5,4	50,4	35,1	14,5	45,7	54,4	8,9	49,7	38,3	12,0
Lower Badenian	1102—1834	25	0,840	2,7	6,3	58,9	30,0	11,1	62,0	33,3	4,7	59,0	35,5	5,5
Karpatian	356—2456	113	0,880	2,8	7,5	43,5	42,1	14,4	47,6	42,8	9,6	47,0	39,8	13,3
Eggenburgian Ottnangian	362—2599	35	0,891	6,5	2,0	41,7	40,9	17,4	41,0	45,2	13,8	41,0	43,2	15,8
Eggenburgian	696—2085	5	0,875	3,4	6,0	38,9	45,8	14,4	27,5	68,9	3,6	30,1	63,0	6,9
Carpathian Flysch	206—2193	28	0,843	6,4	6,6	56,8	28,2	16,0	61,4	27,2	9,3	59,5	27,1	13,4

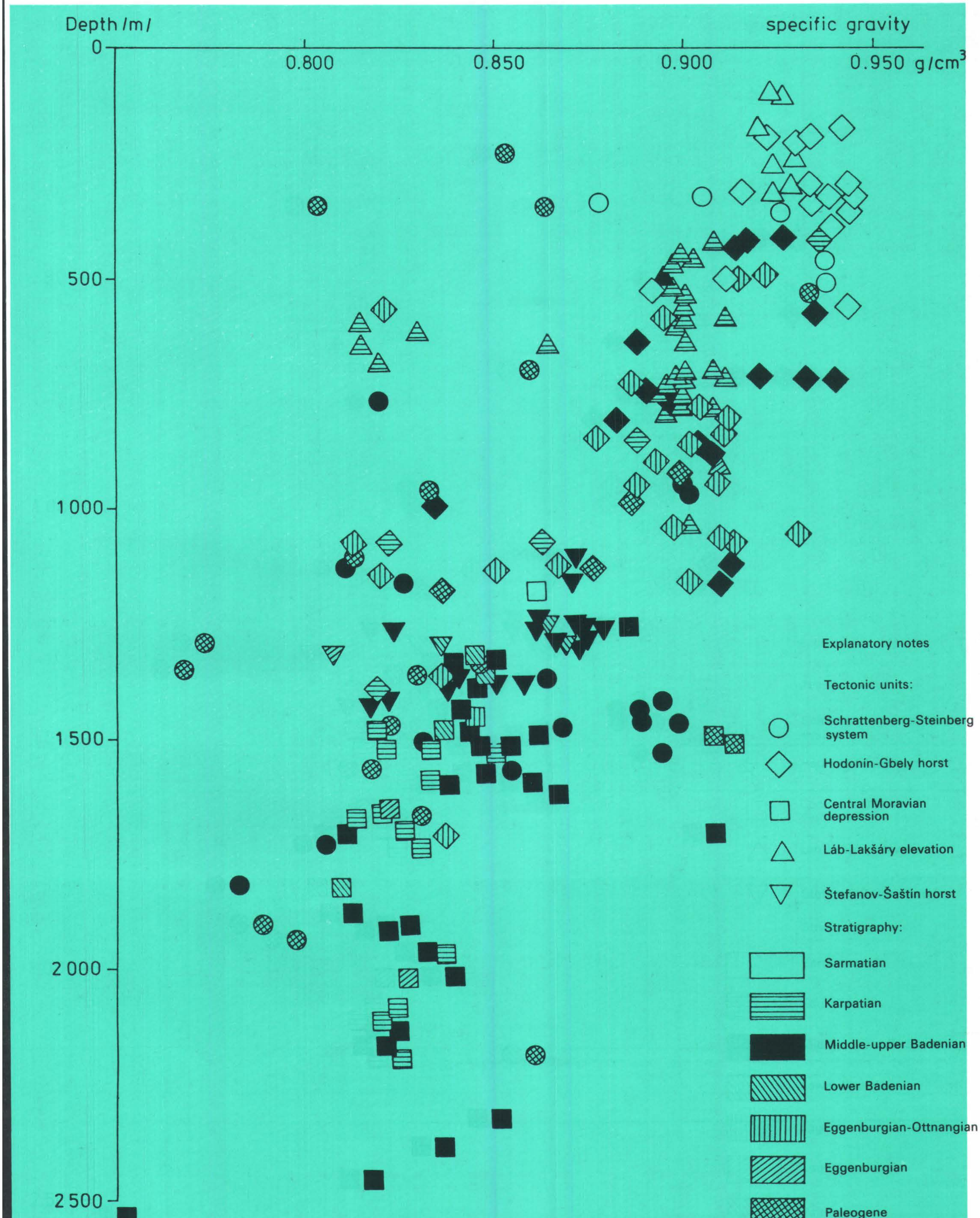


Fig. 4: Specific gravity values as a function of depth.

3. $C_6H_{12} + H_2 \rightarrow C_6H_{14}$

Dehydrogenation, in contrast with results in the condensation of aromatic cores, in the increasing number of C=C bonds and the generation of high-molecular aromatics and graphite formation in the final stage. Hydrogenation is conditioned by the supply of hydrogen released from dehydrogenated aromatics or by hydrogen disproportionation in hydrocarbon molecules.

Cycloalkane hydrocarbons (naphthenes) are, by their amount of free energy, nearer to paraffinic hydrocarbons (benzene 124.10^6J/mol, cyclohexane 24.10^6J/mol and hexane $4.3.10^6$J/mol). In accordance with the thermodynamic schemes, cycloalkane hydrocarbons cannot be generated by dehydrogenation of paraffinic hydrocarbons, as, for instance, demonstrated by equation 4:

4. $C_6H_{14} \rightarrow C_6H_{12} + H_2$

nor can they form in greater amounts by the hydrogenation o aromatics. The source of polycyclic cycloalkanes appears to consist in carbocyclic and heterocyclic structures derived from organic molecules of decayed biologic matter (proteins, carotenoids, pigments and other structures). By contrast, cycloalkane hydrocarbons readily lose hydrogen giving rise to aromatic hydrocarbons or, on the other hand, they yield paraffinic chains by hydrogenation. The strength of the C-C and C-H bonds rapidly declines with the increasing molecular mass of the individual members. The increase in energy level during the generation of aromatic cycles is offset, in the molecules, by decreasing the energy released owing to the decomposition of cycloalkane structures and the formation of paraffinic chains. Characteristic of the conversion (evolution) of paraffinic hydrocarbons is the decomposition of thermodynamically less stable high-molecular individuals to low-molecular hydrocarbons and carbon.

5. $C_nH_{2n+2} \rightarrow CH_4 + C + C_{n-2}H_{2n-2}$

The decomposition sequence of the individual hydrocarbon structures is governed by their bond strenght.

Considering the grade of katagenic metamorphism of dispersed organic matter, we may assume that most of the oils of the Vienna Basin have formed in the deeper-seated underlying strata. However, if accepting this affirmation, the explanation of the present chemistry of the oils in the stratigraphical profile of the Tertiary basin fill remains problematic. If admitting that the origin of oil hydrocarbons and their conversion were natural processes objectively governed by generally accepted laws, then the conversion of kerogen to oil hydrocarbons would be primarily controlled by the laws of the thermodynamic equilibrium of compounds; secondary effects accounting for the chemical composition of the oil hydrocarbons generated are migration differentiation controlled by the principles of frontal and displacement chromatography, microbial degradation, underground aeration, etc. The decisive factors of these processes are undoubtedly geological ones. The earlier concept of an autochthonous origin of oil in the deposits of the Tertiary basin fill presented by V. Šimánek (1976) is questionable. For deposits at shallower depths (3 to 4 km), owing to the results of new investigations that base primarily on the grade of katagenic metamorphism of organic matter. However, if accepting the origin of oil in the underlying sequences, we are not able to adequately explain their present physicochemical composition and, particularly, the formation of n-paraffines, the occurrence of the perylene type and their decomposition in the horizontal plane and in the depth section through the basin. Considering these facts, the questions related to oil origin in the Tertiary deposits of the Vienna Basin cannot be thought to have been answered in a satisfactory way. For this reason, this problem deserves our constant attention.

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Table 3

N-ALKANES IN THE OILS OF CZECHOSLOVAK DEPOSITS

Depth interval	n-alkanes in oils % by mass	% Cn H_{2n+2} in n-alkanes																							
		C_9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
Sarmatian 100—380	0,09	—	—	—	0,1	0,1	1,7	5,1	9,0	16,3	17,3	13,5	10,5	7,6	7,6	4,5	4,5	4,1	2,5	2,3	1,9	2,1	1,2	1,4	—
Upper Badenian 771—1856	20,4	0,8	2,4	3,7	5,0	5,6	6,8	8,4	7,8	7,3	6,7	6,4	6,4	5,0	5,0	4,4	3,7	3,1	2,8	2,2	1,9	1,6	0,9	0,7	0,5
Lower Badenian 1485—1578	19,0	0,4	1,2	2,1	3,0	3,5	4,2	6,9	8,5	8,0	7,7	6,7	5,8	5,5	5,0	4,5	3,9	3,5	2,8	2,4	2,3	1,2	1,0	0,5	—
Karpatian 1608—1917,5	10,0	—	—	—	5,2	7,3	7,9	7,6	8,5	7,2	6,3	6,5	5,8	5,0	4,7	4,5	4,2	3,9	3,1	2,9	2,2	2,0	1,6	1,4	0,7
Eggenburgian 865—1761,5	7,8	0,2	0,6	2,2	2,6	3,2	4,8	6,2	7,9	9,9	6,2	8,4	8,7	6,8	6,3	5,6	4,2	3,6	3,1	2,3	1,9	1,5	1,4	0,6	0,4
Paleogene 1070,5—1180	6,2	—	—	—	1,8	4,4	8,8	10,2	12,2	9,7	7,6	8,2	6,3	4,8	4,0	4,4	3,4	3,2	2,4	2,1	1,6	1,3	1,2	0,9	0,4

Abstrakt

Geneze ropy a zemního plynu v terciérních sedimentech čs. části vídeňské pánve je řešena na základě studia úrovně katagenní přeměny rozptýlené organické substance a chemického složení těžených rop. Jsou konfrontovány výsledky výzkumu těmito metodami. Úroveň katagenní metamorfózy oganické substance uvažovaných matečných hornin odpovídá ropnému oknu v hl. cca 3 — 6 km. Organická hmota je převážně III., v menším množství i II. genetického typu. Těžené ropy mají různorodé složení, vázané na jednotlivá stratigrafická souvrství; velmi lehké ropy parafinického, resp. parafinicko-naftenického typu jsou vázány na sedimenty badenu a paleogenní sedimenty magurského flyše, velmi těžké ropy naftenického charakteru na sarmat a ropy lehké až těžké, smíšeného parafinicko-naftenického a naftenicko-parafinického typu se vyskytují v karpatu a eggenburgu až ottnangu. V ploše jednotlivých souvrství je zřejmá závislost chemického složení rop na tektonické příslušnosti hornin. Termodynamika konverze kerogénu matečných hornin a sekundární diferenciace chemismu rop objasňuje přijatelným způsobem genezi ropných uhlovodíků v terciérní výplni pánve; předpoklad však zpochybňuje úroveň katagenní metamorfózy organické substance, kterou je třeba klást do podložních sérií, pravděpodobně do jury. Objasnění geneze přírodních uhlovodíků je třeba věnovat nadále patřičnou pozornost.

Zusammenfassung

Die Frage der Erdöl- und Erdgasgenese in tertiären Sedimenten des tschechoslowakischen Teils des Wiener Bekkens wird aufgrund der Untersuchung des Niveaus der katagenen Umwandlung verstreuter organischer Substanz und der chemischen Zusammensetzung des geförderten Erdöls gelöst. Im vorliegenden Beitrag werden Ergebnisse dieser Untersuchungsmethoden einander gegenübergestellt. Das Niveau der katagenen Metamorphose der organischen Substanz in betreffenden Muttergesteinen entspricht dem Erdölfenster in einer Tiefe von 3 bis 6 km. Die organische Substanz ist vornehmlich von III., in einer kleineren Menge auch von II. genetischem Typ. Das geförderte Erdöl weist eine verschiedenartige Zusammensetzung auf, die an einzelne stratigraphische Formationen gebunden ist; sehr leichte Erdölarten mit Paraffin- bzw. Paraffin- bis Naphthenbasis sind an die Baden- und Paläogensedimente des Magura-Flysches, sehr schwere naphthenbasische Erdölarten an das Sarmat gebunden, und schließlich leichte bis schwere Erdölarten von gemischtem paraffin-naphthen- bzw. naphthen-paraffinbasischem Typ kommen im Karpat und Eggenburg-Ottnang vor. In der Flächenausdehung einzelner Schichtenfolgen kommt eine Abhängigkeit der chemischen Erdölzusammensetzung von der tektonischen Zugehörigkeit der Gesteine zum Vorschein. Durch die Thermodynamik der Kerogenumwandlung in Muttergesteinen und die sekundäre Differentiation des Erdölchemismus wird die Genese der Erdölkohlenwasserstoffe in der tertiären Beckenfüllung auf eine annehmbare Weise gedeutet; die Annahme wird allerdings durch das Niveau der katagenen Metamorphose der organischen Substanz fraglich, das in unterlagernde Serien, wahrscheinlich in den Jura, zu stellen ist. Der Frage der Genese natürlicher Kohlenwasserstoffe soll auch weiterhin besondere Aufmerksamkeit zugewendet werden.

OCCURRENCES OF NATURAL HYDROCARBONS AT THE VARISCAN LEVEL OF THE CENTRAL AND ADJACENT SOUTHERN PARTS OF SOUTHEASTERN SLOPES OF THE BOHEMIAN MASSIF

Hedvika Thonová — Stanislav Benada
Moravian Oil Company

For many years now, the Moravian Oil Company has been prospecting for natural hydrocarbons at increasing depths and under increasingly complicated geological conditions. The exploration programme also includes deep boreholes on the southestern slopes of the Bohemian Massif, the purpose of which is to investigate the Variscan platform and its sedimentary mantle. These boreholes have recently discovered many deposits, some of them accumulated in Paleozoic sediments of the platform mantle.

The basement of the area of interest is composed of plutonites and metamorphosed sedimentary series. The Cadomian-consolidated basement is overlain by a Variscan platform mantle represented by Paleozoic rocks. As to younger formations, Mesozoic and Paleogene rocks are known to occur expecially in the southern part of the area. The northwestern part is occupied by the Carpathian Front Foredeep. Most of the area has been covered by flysch nappes of the Outer Carpathians.

Paleozoic sediments have been confirmed by boreholes especially on the high block of the longitudinal step parallel to the Carpathians, which is manifested very significantly in the central part of the slopes. According to the lateral classification of the Variscan Level, the area comprises the eastern edge of the Moravian Karst, Drahany Highland and Šlapanice Blocks (J. Dvořák 1978). The deeply submerged parts of the platform in the central section have not been verified, as the surface of autochthonous sediments is situated at depths from 4,000 to 5,000 metres there. Fairly high preserved thicknesses of Paleozoic rocks have been confirmed in sunken blocks perpendicular to the Carpathians, especially those of Nesvačilka, Měnín and Němčičky (J. Adámek, J. Dvořák, J. Kalvoda, 1980, J. Adámek — manuscript), where they constitute significant transversal elements of post-sedimentary tectonics.

Stratigraphic and lithologic development

The peneplained, highly complex relief composed of crystalline rocks is overlain by a basal clastic sequence of the Old Red facies (Eifelian-Givetian). It is represented by variegated terrestrial clastic sediments, in younger parts intercalated by variegated pelites. Its lithological development is relatively uniform, the thickness very variable, ranging from 10 to 1,700 m.

The sedimentary cycle continues by a carbonate facies during the Frasnian to Upper Fammenian, with local partial hiatuses. The transition between the basal clastics and pure carbonates is represented by reef dolomites and dolomitic limestones containing a terrestrial component (Eifelian — Givetian). A marine transgression during the Lower Frasnian is characterized by grey, massive, micritic and biomicritic limestones. Since the Upper Frasnian, the sea has been getting shallower, the process being associated with the deposition of light-coloured, sand- and clay-containing limestones, often with layers of clastics indicating an extensive sea regression. Between the Upper Fammenian and the Middle Viséan, there is a stratigraphic hiatus in most of the area, especially in deeper parts of the platform. A new transgression takes place from the Middle till Upper Viséan, manifested mainly by a carbonate facies, sometimes alternating with a Culm facies, sometimes the two facies laterally substituting each other. The carbonate facies

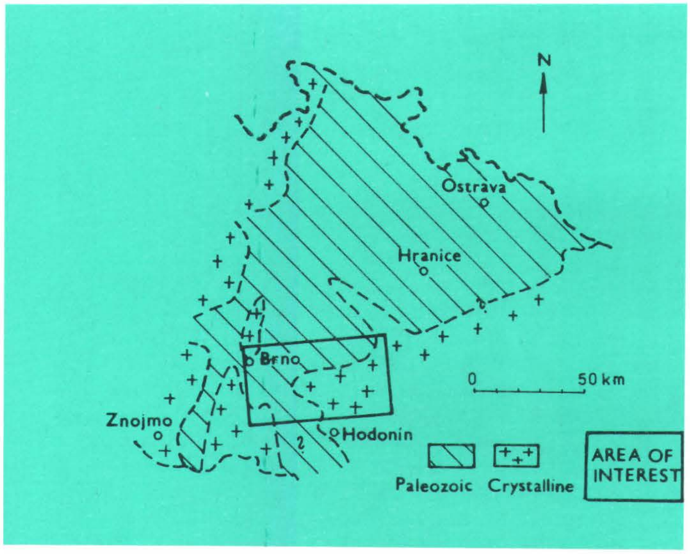


Fig. 1: Area of interest.

thickness is varied, from a few tens of metres to 1,800 m in Švábenice — 1 borehole and up to 1,200 m in the Nesvačilka Block (Těšany — 1 borehole).

The Viséan clayey-carbonatic facies passes over into a typical Lower Carboniferous culm facies (or even into Upper Carboniferous/Namurian A unit characterized by alternating clayey shales and subgraywackes). The highest thicknesses in excess of 1,700 m are in the western part of the Nesvačilka Block (Újezd — 1 borehole); Upper Carboniferous productive rocks (Namurian A) are known to occur in the central part of slopes of the Nesvačilka Block (420 metres in Dambořice — 1 borehole) and especially in the Němčičky Blocks (over 1,000 m).

Occurrences of natural hydrocarbons in the different stratigraphic-lithologic levels

Exploratory works focused on Paleozoic sediments proceeded from the northwest to the southeast in Czechoslovakia, i.e. from the shallow part of the platform into the deeper one. Boreholes in the shallow part sometimes encountered fairly thick Paleozoic sequences and were interesting from the viewpoint of areal and regional geology, but negative with respect to occurrences of natural hydrocarbons. As a rule, only weak- to medium-mineralized water with a low content of dissolved hydrocarbon gases was obtained from these boreholes. Favourable results increased as the exploration proceeded to deeper parts of the platform.

Owing to very variable, rather very poor hydrogen-accumulating properties, the Devonian basal clastics have always been regarded unpromising in terms of potential hydrocarbon occurrences. It is true that Ježov — 2, Koryčany — 3 and Žarošice — 2 boreholes have found surprisingly good hydrocarbon-accumulation properties of sandstones and conglomerates, but, generally, the remaining boreholes yielded only water with dissolved gaseous hydrocarbons, Těšany — 1 borehole giving gas-saturated, oil-type brines from fissure-type reservoir rocks. The first important occurrence of natural hydrocarbons was found on the hillside of the Ždánice elevation, by Uhřice — 6 borehole, in the upper part of the basal clastics. Despite difficult hydrocarbon-accumulating conditions of the sandstones, an inflow of gaseous hydrocarbons in an amount of 17,200 Nm^3/24 hours, with a small amount of heavy paraffin-naphtenitic crude was obtained. The gas is methane, containing no higher gaseous hydrocabons. The first economically important result was arrived at in the area of the Ždánice — West deposit (J. Krejčí, J. Brzobohatý, 1984). Ždánice — 14 and Ždánice — 55 boreholes have confirmed an accumulation of gaseous hydrocarbons in the Devonian basal clastics the thickness of which is 36 to 69 metres there. According to laboratory analyses, the rocks are classified as impermeable, their primary porosities ranging from 0.8 to 4.5%. Secondary porosity plays a key role there. The potential production, $Q_{pot.\ abs.}$, of Ždánice — 55 was measured at 27,000 Nm^3/24 hours, that of Ždánice — 14 equals 20,000 Nm^3/24 hours. After treating the reservoir rocks with acid, the production increased five times. As to Ždánice — 54 borehole, a hydrodynamic connection of heavily faulted, disintegrating basal clastics and the weathered surface of the crystalline rocks is assumed. Oil is accumulated in crystalline rocks while gas caps are likely to be associated with the Devonian sandstones. The productive zone thickness and economic parameters have not hitherto been verified.

Favourable conditions with respect to the formation and preservation of accumulations of natural hydrocarbons have also been proved in the carbonate Paleozoic sequence. Carbonates affected by epigenetic processes, especially by dolomitization, are best in this regard. Suitable reservoir rocks in the Givetian dolomites, significant oil impregnations along fissures and inlows of gas-saturated water have been found in many boreholes. Těšany — 1 borehole has encountered oiltype brines. In the area of the Měnín Block (Měnín — 1 borehole), a non-industrial inflow of viscous and oxidized oil is associated with Lower Frasnian, karstified and cavernous limestones situated at depths from 50 to 80 metres. During the 70s, the so far only deposit in the bedrock of the Carpathian Foredeep, Nítkovice — Hradisko, was discovered. The initial geological reserves of the deposit were estimated at 121.8 mill. Nm^3 of gaseous hydrocarbons (A. Petr 1983). The local gas accumulation is associated with a hemispherical structure of karstified limestones and dolomites of the Upper Devonian age (Frasnian — Fammenian) occurring at depths from 800 to 880 m, which represent a mixed-type reservoir rock. The gas-bearing zone thickness is up to 79 m. The reservoir pressure is subhydrostatic, its temperature 32°. The gas is methane (85.8% of volume), with traces of higher hydrocarbons and an increased content of nitrogen. Until now, the total production of the deposit has been 80 mill. Nm^3 of gas.

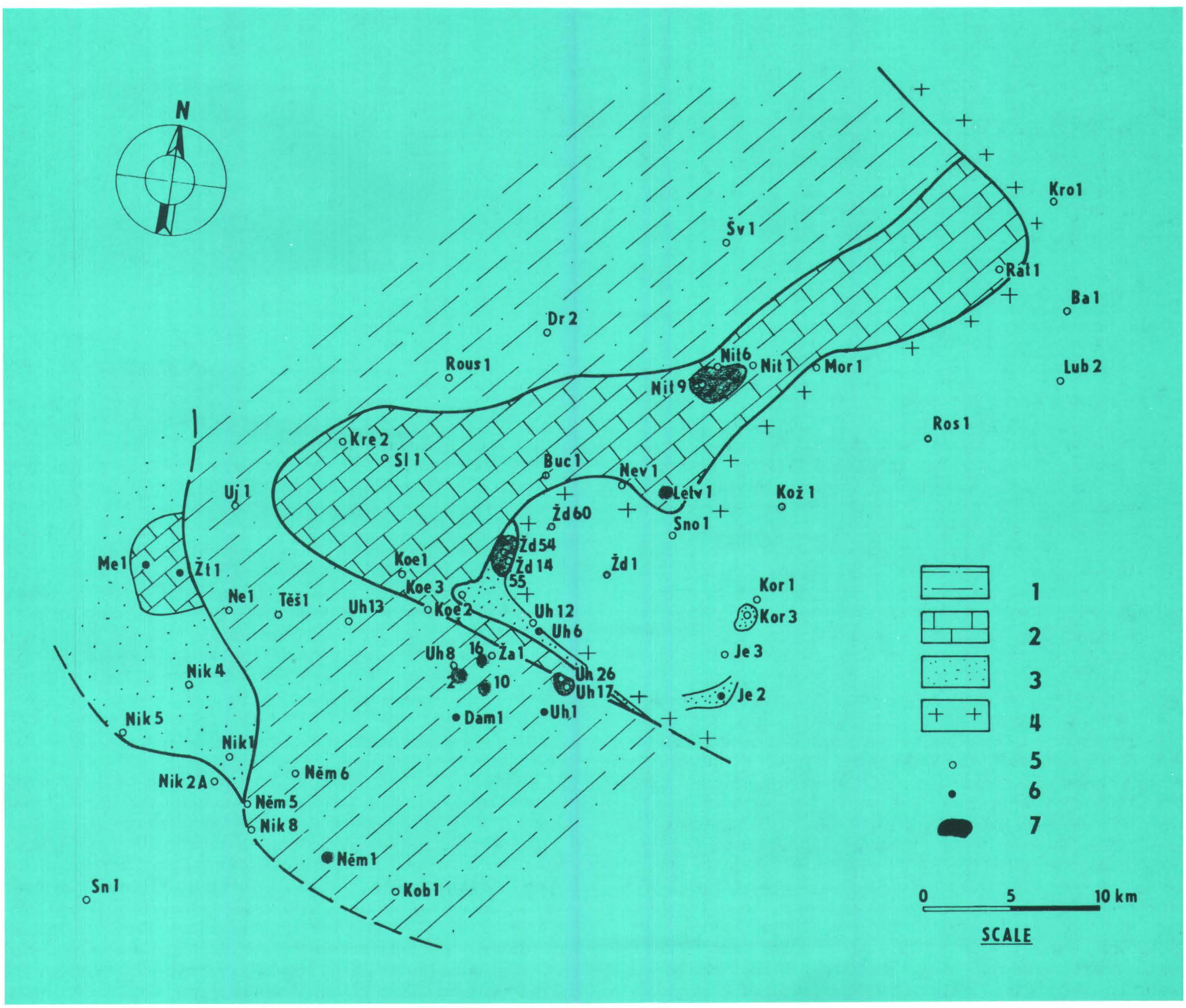
Last year, an interesting result was obtained in the area of the Ždánice crystalline elevation. Letošov — 2 borehole encountered a 220 m thick sequence of Devonian carbonates (Eifelian — Givetian — Lower Frasnian), so far unknown in the region. An interval of 14 metres in the upper part of the carbonates, at a depth of 930 m, was first treated by acid. Crude oil flowed out spontaneously from the borehole at intervals. Lithologically, the reservoir rocks are dolomitized, originally biomicritic Frasnian limestones, hydrodynamically communicating with overlying Miocene sediments. Apart from primary porosity, which is up to 7.1% in this area, secondary fissure-type porosity is also important. The crude oil extracted from the borehole is heavy, paraffin-naphtenitic, of a kerosene-oil character.

The first economically important inflow of natural hydrocarbons from Paleozoic sediments in Czechoslovakia was encountered by Němčičky — 1 borehole, in the area of the Němčičky Block, at a depth of 5,100 metres. The local gaseous condensate deposit is associated with epigenetically dolomitized, Frasnian — Famennian micritic limestones. The limestones are classified as impermeable, their maximum primary porosity being 6.6%. However, evaluations of logging measurements suggest total effective porosities up to 10%, which mainly result from fissures. The gas is methane, containing higher hydrocarbons. Light oil fractions (gasoline) extracted together with the gas contain paraffins and asphaltico-bituminous substances. The results suggest that there may be a contact with an oil-bearing zone. The deposit pressure is equal to hydrostatic. Extraction parameters were not obtained due to the poor technical condition of the borehole and the presence of underlying water beds. Owing to a collapse of casing, subsequent works were not possible. Additional boreholes in the area of Němčičky have not allowed for resolving the economic importance of the deposit and the problem still remains open.

For more than ten years, exploratory works have been going on under very difficult geological conditions on the northwestern slope of the Nesvačilka depression. Their result is a discovery of oil and natural gas deposits associated with the Paleogene filling of the depression and Paleozoic carbonates. The first local borehole, Uhřice — 2, encountered an accumulation of gaseous hydrocarbons and crude oil at a depth of 2,500 metres, in the upper part of Viséan micritic limestones. The primary porosity of the limestones is very low, the key role being played by secondary disturbances. Hydrodynamic tests resulted in an estimated permeability of 228 mD. A pumping test indicated a spontaneous inflow of a crude oil/natural gas mixture. The natural gas: oil ratio averaged 5,000 m^3 off gas to 1 m^3 of oil. The calculated actual gas production, $Q_{pot.act.}$, is 835,000 $Nm^3/24$ hours. The oil is very light, of a paraffin character, kerosene-like. The gas is methane, with a high content of higher hydrocabons, the initial deposit pressure being by 5% higher than the hydrostatic one. The borehole is now being conserved. The edge of the same deposit was encountered by Uhřice — 8 borehole, where a non-industrial inflow of crude oil and gas from Viséan limestones was obtained. Economic accumulations of gases occurring here are associated mainly with clastics dating back to Paleogene.

The western part of the Uhřice deposit also comprises oil accumulations of Uhřice — 16 and Uhřice — 10 boreholes. The surface of heavily tectonically faulted Viséan, massive, organodetritic limestones was encountered in a higher position in Uhřice — 16 borehole than in Uhřice — 2 borehole. The former borehole produced a weak inflow of light, paraffine character and kerosene-like oil. Intensification works

Fig. 2: Sketch of the top of Paleozoic on SE slopes of the Bohemian Massif
1 Carboniferous
2 Devonian — Lower Carboniferous
3 Devonian — Old Red
4 Crystalline Basement
5 wells
6 wells with hydrocarbon shows
7 Paleozoic oil and gas fields.



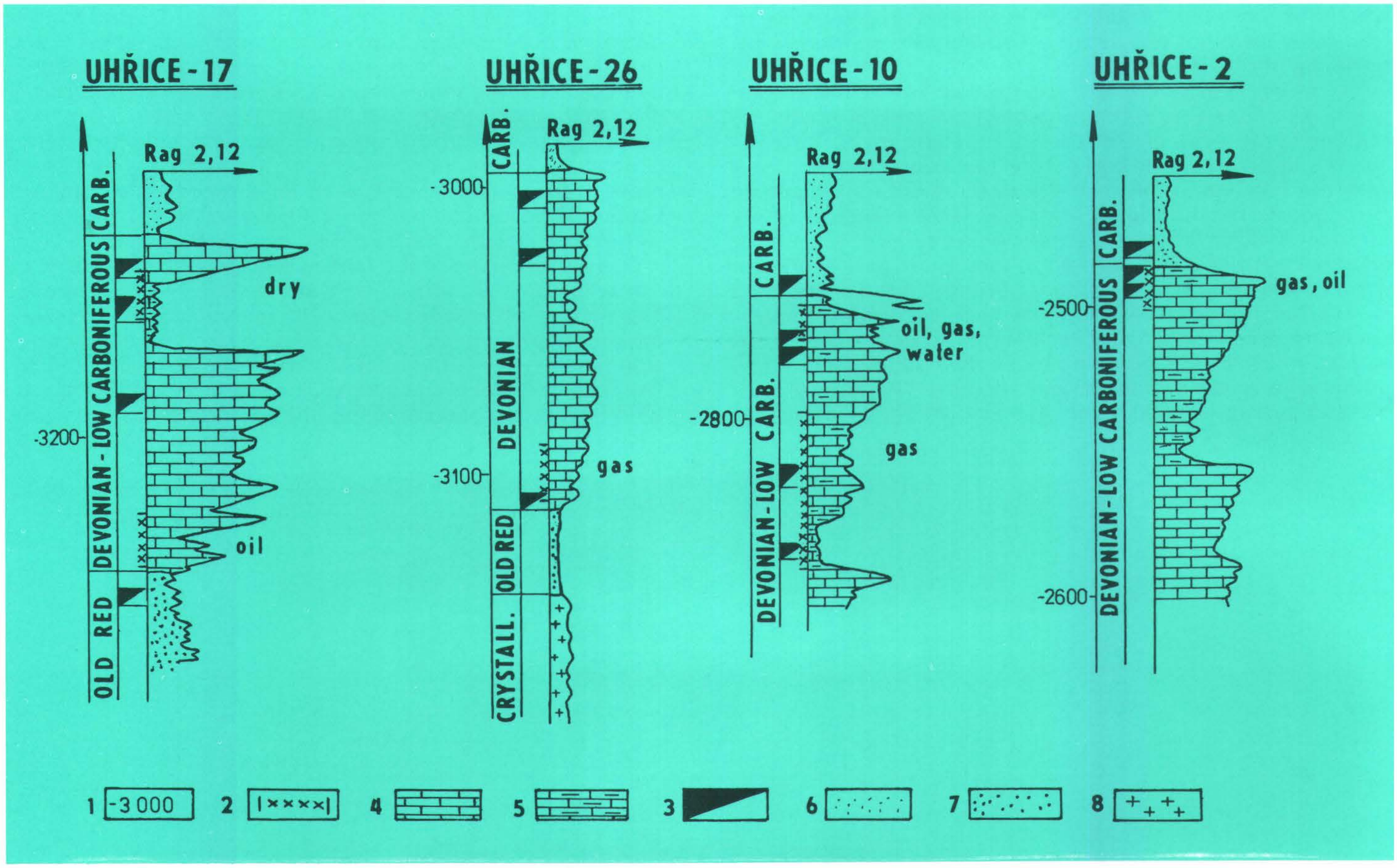


Fig. 3: Comparison resistivity logs in some Uhřice wells
1 depth
2 test
3 cores
4 limestones
5 argillaceous limestones
6 carboniferous sandstones
7 Old Red sandstones
8 Crystalline rocks

will be carried out at the borehole. The latter borehole has confirmed a separate crude oil accumulation, situated (structurally) much lower than that of Uhřice — 2. At a depth of 2,770 metres, the upper part of Upper Viséan biomicritic limestones yielded spontaneous, though irregular, inflows of crude oil containing some 5% to 10% of water. Hydrocarbon-accumulation properties, both primary and secondary, are characterized as very poor. The deposit pressure and temperature at 2,761 m are 31.8 MPa and 81° C, respectively. The oil is light, of a paraffion-oil character, with a high content of solid paraffin and a high point of congelation. The borehole is presently being conserved. The results achieved in the western part of Uhřice have confirmed the existence of partial hydrodynamically closed deposits associated with the same stratigraphic-lithologic complex at different levels.

In the eastern part of the Uhřice area, Uhřice — 17 borehole has succeeded in discovering a deposit of oil representing the hitherto deepest economic accumulation of oil in the Czechoslovak territory. Its gas part has been verified by Uhřice — 26 borehole. According to current knowledge, the minimum productive zone thickness is 200 metres. The deposit is associated with the lower part of Devonian carbonates, heavily dolomitized limestones or dolomites of the Lower Frasnian or Upper Givetian age. In terms of their hydrocarbon-accumulating properties, the dolomites are classified as unfavourable,both by laboratory tests and logging measurements. Consequently, intensification is planned. At Uhřice — 17 borehole, a spontaneous inflow of gas-saturated oil was encountered at 3,230 metres, the initial flow rate being 50 to 60 m^3 of oil /24 hours. The gas: oil ratio is 50 to 200 m^3 of natural gas per 1 m^3 of oil, the deposit pressure is 2.5% higher than the hydrostatic one. Chemical analyses indicate that the oil is light, paraffin-kerosene, with a high content of gasoline fractions. The borehole is presently being conserved. Uhřice — 26 borehole achieved a low inflow of gas with gasoline traces from a depth o 3,100 m, the calculated potential production of which, was 60,000 m^3/24 hours. After intensification works, the inflow increased several times. At the moment, only indicative exploitation parameters are known. It is planned that production (using a ø 9 mm nozzle) should be approximately 75,600 m^3/24 hours. The deposit pressure corresponds to the hydrostatic one. The gas is methane (over 90% of volume), with a certain amount of higher hydrocarbons. The boreholes will be used for production on a pilot scale.

Apart from the economic accumulations of natural hydrocarbons, much information has been obtained in the area of Uhřice on their potential occurrences. Uhřice — 1 and Dambořice — 1 boreholes in deeper parts of the Nesvačilka depression have found non-industrial inflows of dry gaseous hydrocarbons from Devonian limestones. Their hydrocarbon-accumulating properties have not been improved even by intensification measures. With respect to potential occurrences of promising hydrocarbon accumulations, it is not possible to rule out the clastic development of Lower and Upper Carboniferous rocks. The most signifi-

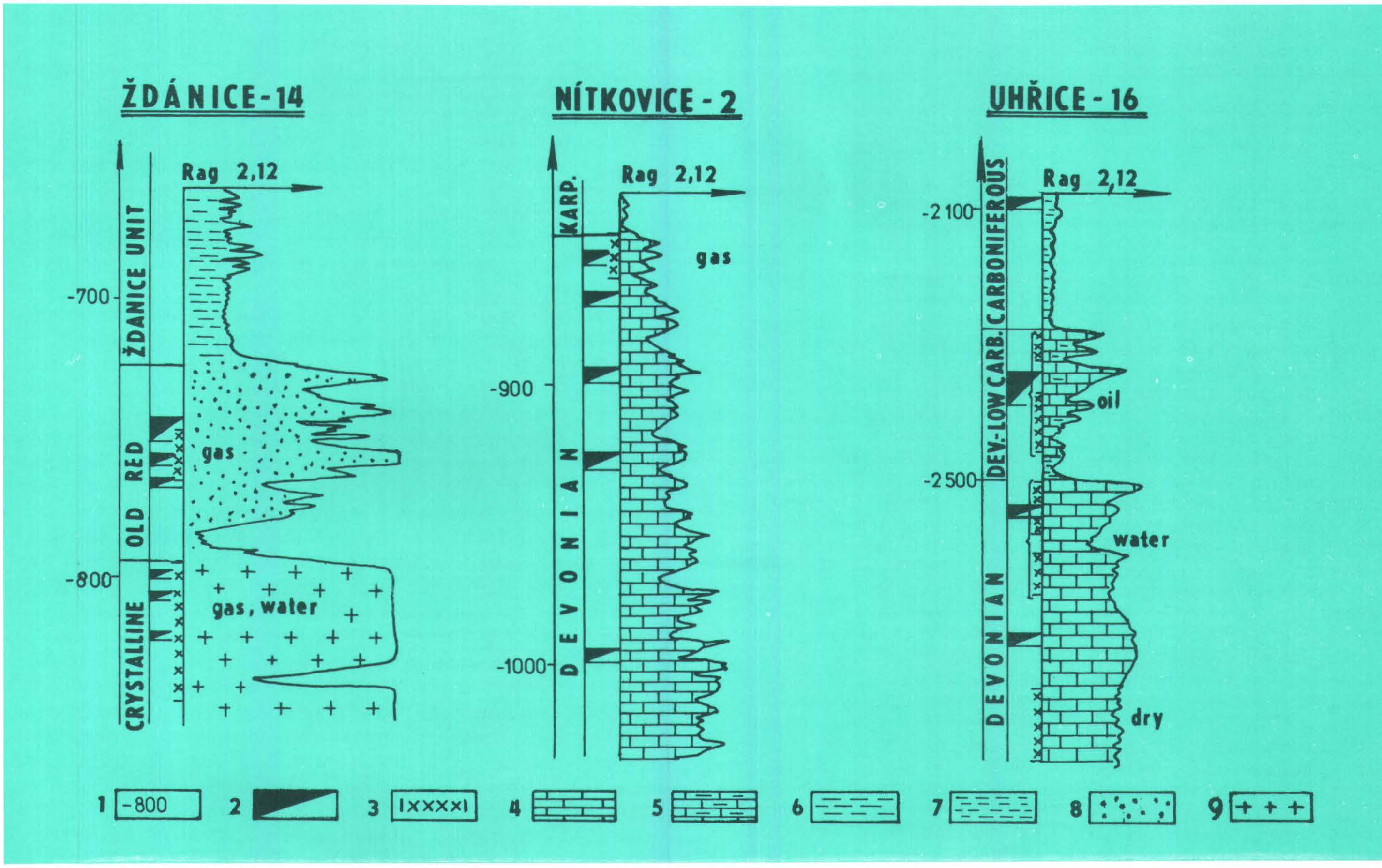


Fig. 4: Comparison resistivity logs in Ždánice, Nítkovice, Uhřice wells
1 depth
2 cores
3 test
4 limestones
5 argillaceous limestones
6 mudstones of Ždánice unit
7 carboniferous clayey shales
8 Old red sandstones
9 Crystalline rocks

cant result has been achieved in the area of the Nesvačilka depression by Uhřice — 9 borehole. Inflows of deposit water containing crude oil and gaseous hydrocarbons and of gaseous hydrocarbons with water (the measured flow rate is approx. 1,000 m^3 of gas/24 hours) have been drawn from porous subgraywackes. However, even this formation displays very variable hydrocarbon-accumulating properties. The clastic development of Upper Carboniferous rocks in many boreholes has been proven to manifest very good accumulation properties, but no significant proper accumulations have hitherto been found.

Conclusions

The results of the exploration of Paleozoic rocks in Czechoslovakia achieved so far permit to formulate the following conclusions:
- the formation is favourable with respect to the genesis and preservation of natural hydrocarbon accumulations,
- the formation is equivalent to other promising units
- the formation has specific properties resulting from its complicated lithologic and facial development, which influence both its accumulation conditions and requirements for drilling and horizon-tapping works
- the exploration of the formation is very demanding in terms of methodology and complexity, including seismic works and their evaluation. Especially the use of 3-D seismic measurements is envisaged.
- problems of the origin of hydrocarbons accumulated in Paleozoic rokcs still remain to be solved. Their age is dated back to Paleozoic or Mesozoic, and even Paleogene. However, the problem is undoubtedly associated with a relatively difficult problem of migration and structural-tectonic development.
- further exploratory works will increasingly focus on deep parts of the platform, where hydrodynamically closed horizons have been confirmed.

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Abstrakt

Na jihovýchodních svazích Českého masívu, v úseku Střed a přilehlých částech úseku Jih, je část průzkumných prací zaměřena na variské patro. V článku je v samostatných kapitolách zhodnocena stratigrafie, litologie a dále ložiska, významné přítoky a indicie přírodních uhlovodíků. Na bazální klastika devonu je vázáno ložisko v oblasti Ždánice. V karbonátovém vývoji paleozoika se akumulace ropy a zemního plynu vyskytují v tektonicky porušených a dolomitizovaných partiích karbonátů. V těchto horninách byla nalezena ložiska Nítkovice, Uhřice-západ, Uhřice-východ a průmyslových přítoků bylo dosaženo z vrtů Němčičky-1 a Letošov-1. I přes specifika, zvyšující nároky na metodiku průzkumu, technologii vrtných prací a otvírku jednotlivých horizontů, zůstává perspektivita variského patra pro nalezení dalších akumulací přírodních uhlovodíků nesporná.

Zusammenfassung

An SO-Hängen der Böhmischen Masse, im Abschnitt Mitte und in anliegenden Gebieten des Abschnitts Süd, ist ein Teil der Erkundungsarbeiten auf das variszische Stockwerk orientiert. In selbständigen Kapiteln werden Stratigraphie, Lithologie, ferner Lagerstätten, bedeutsame Zuflüsse und Anzeichen natürlicher Kohlenwasserstoffe behandelt. An basale Trümmergesteine des Devons ist die Lagerstätte im Gebiet von Ždánice gebunden. In der Karbonatentwicklung des Paläozoikums kommen Erdöl- und Erdgasakkumulationen in tektonisch gestörten und dolomitisierten Karbonatgesteinspartien vor. In diesen Gesteinen wurden die Lagerstätten Nítkovice, Uhřice-West und Uhřice-Ost entdeckt, und förderwürdige Zuflüsse wurden in den Bohrungen Němčičky-1 und Letošov-1 ermittelt. Trotz spezifischen Erscheinungen, durch welche die Ansprüche an die Erkundungsmethodik, Bohrtechnologie und Erschließung einzelner Horizonte erhöht werden, bleibt die Höffigkeit des variszischen Stockwerks in Hinsicht auf Entdeckung weiterer Akkumulationen natürlicher Kohlenwasserstoffe unstreitig.

*** In this line, the results of mathematical modelling of the conversion of kerogen to oil hydrocarbons conducted by M. Strnad are of interest. In the first version of a mathematical model using the parameters of the Rock-Eval temperature maximum pyrolysis T_{max} = 430—440 °C the author placed the oil window interval to a depth of 3.7 to 5 km in the Czechoslovak part of the Vienna Basin, the genesis of oil hydrocarbons culminating in the period of 15.5 — 17.6 million years after the commencement of sedimentation.**

PALEOGEOGRAPHIC ASPECTS OF THE STUDY OF OTOLITH FAUNAS IN THE MIOCENE BASINS OF THE CENTRAL PARATETHYS

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The hitherto assembled knowledge on the otolith faunas of the Miocene sediments of the Central Paratethys affords several remarks on the interpretation of the paleogeographic conditions of individual basins and on their changes with time. These remarks are mostly based on the fact that the epipelagic, mesopelagic and bathypelagic habitat of recent fish faunas has been formulated as early as in the Miocene in general characters (Brzobohatý 1981 inter alii) and that the composition of water and the character of surface water are decisive determinants in the composition of pelagic assemblages of fishes (Robison 1972).

In the sediments of the Eggenburgian, the finds of purely marine otolith faunas have been rather sporadic so far. This can be due to the small degree of investigation and possibly also to problems of fossilization. Biofacies deliberations of a broader scope are therefore not admissible. Recently, however, a very rich otolith fauna has been found near Maigen in the Horn Basin in Niederösterreich, the appreciation of which contributes to the better understanding of the relationships in the western part of the Central Paratethys of this time interval.

The Maigen otolith fauna is composed of 30 species of bony fishes that are represented in various parts of the Molt Beds and Loibersdorf Beds. Except for the Molt Beds, where more prominent brackish influences appear, it has a purely marine character of a very shallow sublittoral without any influence of deeper waters and it documents sedimentation in a very warm subtropical climate. It is mostly composed of Atlantic-Mediterranean and cosmopolitan elements with southward inclination (genus *Brachydeuterus*). It differs from the Lower Miocene faunas of the Aquitaine Basin and the Mediterranean area (Steurbaut 1981, Nolf et Cappetta 1980) by a substantially lesser proportion of Paleogene Indo-pacific relicts. This fact is obviously connected with the regressive tendencies in the Alpine-Carpathian region in the higher Egerian (Rögl et Steiniger 1983) and with the forming of new fish assemblages in this region at the beginning of the Miocene. The presence of an isolated Indo-Pacific representative (genus *Acropoma*) is evidently the result of direct migration from the Indo-Pacific region. The shallow-water assemblages of fishes of the marginal developments of the Eggenburgian at the SE margins of the Bohemian Massif are typical in the decrease of purely marine elements from the SW to the NE. This tendency, which is connected with the absence of Eggenburgian deposits in the region of the Vyškov depression, evokes here the idea of a relatively isolated bay which is closed from the W and the N, and which communicates S and southeastward with a more marine environment.

In the Eggenburgian of the Central Paratethys so far nowhere associations of otoliths of deep-sea fishes have been established. We may establish practically the same for the deposits of the Ottnangian. An individually poor assemblage of mesopelagic elements witnessed in the last-named level in the schlieren of Oberösterreich (vicinity of Ottnang) can be conceived as allochthonous (predators, currents, etc.). If not considering the state of the low degree of investigation, or taphonomic problems, we may interpret this fact so that the configuration of the basins in the Eggenburgian and Ottnangian (hydrographic or bathymetric conditions) was not suitable for the existence of deeper-living fish assemblages, or that the studied basins divided from seas represented for this type of fauna an unsurmontable barrier. Acceptable is the idea of relatively high sills between the Bohemian Massif and the Alpine arch on the connecting region of the present-day Austrian molasse (comp.Rögl et Steininger 1983).

In the sediments of the Karpatian and Badenian of the Central Paratethys, deep-sea fishes, whose assemblages form here a significant component of all fish fauna, can be encountered on the other hand. Their composition generally reminds of the so-called reduced deep-sea fish faunas (Marshall 1957) composed of the genera participating in the forming of ichthyocoenoses of the higher layers of oceanic waters and occurring also in the basins outside the free oceans but with a good communication with them.

In the Karpatian, these assemblages display a surprising coincidence in the representation of the most frequent elements with assemblages of the Gulf of California (Robison 1972). They inidicate the existence of a more or less semi-closed basin with a deep-seated communication with the free sea, with sufficient depth of the basin itself and evidently with the so-called estuarian type of circulation of water masses (sensu Schopf 1980). According to this interpretation, the transgression would procede from the Mediterranean region (comp. Rögl et Steiniger 1983) from the SW.The intrusion of the lower waters of the open sea (from the oxygen minimum zone) penetrated permanently into this basin near the bottom, propagated on it and caused low-oxygen conditions. The evaporation was evidently lower than the influence and the surface streams led away the warmer, and possibly even less salty water from the basin into the open sea. A sufficient dotation in organic matter from the dry land contributed to a relatively long-term regimen that was poor in oxygen. This concept is also supported by the character of microfauna of the Karpatian (relatively low diversity of assemblages, relatively great individual frequency, an indistinct and often dwarfish plankton, frequent occurrence of groups of benthic foraminifera or of elements tolerant with respect to low oxygen contents, which has, compared with the Badenian, a higher content of organic substance and a lower content of $CaCo_3$ in the sediments and a considerable content of laminated sediments. To the NE, the basin became generally more shallow and the influence of the open sea became less prominent.

In the Lower Badenian, the deep-sea component of the fish fauna became substantially more diversified and had a different composition. Over 20 genera of mesopelagic and archibenthic fishes occur in them which not only with respect to their composition, but also with respect to the frequency of their representatives correspond to the ecologically related ichthyocoenoses of the recent Mediterranean Sea. It may thus be assumed, that in the Lower Badenian the water regimen significantly changed compared with the Karpatian. The substantially more extensive Paratethys communicated in the W with the Mediterranean and in the SE with the Indopacific region. The communications between this region and the open sea did not necessarily attain greater depths than 300 m, the communication in the W, however, was decidedly deeper than in the SE. Inside the basin, however, partial basins must have existed with a depth reaching up to 1000 m. From the point of view of water circulation, the Central Paratethys became a Mediterranean type basin in the sense of Schopf (1980). Above all surface water of the free sea penetrated into them, partly they evaporated, subsided to the depth and flew out near the bottom. The supply of organic matter was evidently lower than in the Karpatian and the waters had a high oxygen content. In favour of this type of circulation of water witnesses not only the homogenized character of sediments generally rich in $CaCO_3$ and poor in organic matter, but also rich and highly diversified biotes of the bottom of various depths, considerably diversified plancton and evidently the most populated pelagial from all levels of the Central Paratethys.

In the Middle Badenian, the deep-sea component of the fish fauna is distinctly reduced and delimited above all to the western region of the Central Paratethys. The presence of some of the archibenthic fishes, however, still witnesses in favour of the considerable depth of the sedimentary region and of the communication paths into the Mediterranean region. The occurrence of otoliths of mesopelagic fishes in the Czechoslovak part of the Vienna Basin, the Dráva-Depresion, in the Polish Foredeep, belongs exclusively to the juvenile stages of fishes which are transported by streams over enormous distances.

In the Upper Badenian, the mesopelagic elements appear only sporadically in the otolith faunas of Roumania, in the western part of the Central Paratethys they are practically missing. This fact is controversary to the interpretation offered by Kókay (1984) on the communication of the Upper Badenian sedimentary region and they explain rather the interpretation offered by Rögl et Steininger (1983)-

More detailed data on the discussed problems are in the paper by Brzobohatý (1987).

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Abstrakt

Autochtonní asociace otolitů mezopelagických a archibentálních ryb byly v centrální Paratethydě prokázány dosud pouze v sedimentech karpatu a spodního a středního badenu. Jejich složení v konfrontaci s údaji mikrobiofaciálními, sedimentologickými a geochemickými umožňuje interpretovat hydrodynamický režim jednotlivých pánví. Během karpatu převládal estuáriový typ cirkulace vod s relativně nízkým stupněm prokysličení. Ve spodním a středním badenu převládal mediteránní typ cirkulace vod s vysokými obsahy kyslíku a výbornou komunikací s volným mořem.

Zusammenfassung

Autochthone Assoziationen der Otolithen mesopelagischer und archibenthaler Fische wurden in der zentralen Paratethys bisher nur in Sedimenten des Karpatiens sowie des unteren und mittleren Badeniens nachgewiesen. Der Vergleich ihrer Zusammensetzung mit mikrobiofaziellen, sedimentologischen und geochemischen Angaben ermöglicht eine Interpretation des hydrodynamischen Regimes in einzelnen Becken. Im Karpatien überwog der Ästuartyp des Wasserkreislaufs mit einem verhältnismäßig niedrigen Durchlüftungsgrad. Im unteren und mittleren Badenien überwog der mediterrane Typ des Wasserkreislaufs mit hohen Gehalten an Sauerstoff und einer ausgezeichneten Verbindung mit der hohen See.

NEW STUDIES OF THE OTOLITHS FROM THE MARINE OTTNANGIAN (LOWER MIOCENE, UPPER AUSTRIA)

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Preface

From the end of the 1970's onward, some coal cuttings were found in hydrocarbon wells, particularly north and west of the Hausruck region in Upper Austria. All of these coal occurrences are located in sandy beds of the predominantly muddy Robulus Schlier s.l. (Innviertel Group, Ottnangian) at depths ranging between 150 and 500 m.

In 1982, a cored hole (Kemating K 1) was drilled by the Geological Survey of Austria to explore the potential for coal occurrences; well logging was also done. Intensive sedimentological investigations were subsequently carried out; the total floral and faunal assemblage was examined by specialists for the purpose of environmental analysis. The fossil content of cuttings of hydrocarbon wells in the distant surroundings was also determined; field work on

Brief description of discussed wells (from the terrain surface to the top of Hall Formation, Eggenburgian)	
Pfaffstätt 4 (Pfaf 4, Rohöl-Auf suchungs G. m. b. H = RAG, 1979): **–20,5 m : Quaternary** **–67,0 m : Coal-Bearing Freshwater Beds** **–103,5 m : Ried Beds** **–591,5 m : Robulus Schlier s. l.**	**Kemating K 1 (Ktg K 1, Geological Survey of Austria, 1982):** **–0,5 m : Mehrbach Sands** **–142,0 m : Ried Beds** **–447,6 m (total depth): Robulus Schlier s. l.**
Hocheck 4 (He 4, RAG, 1974): **–3,0 m : Quaternary** **–185,0 : Coal-Bearing Freshwater Beds** **–235,0 m : Ried Beds** **–739,0 m : Robulus Schlier s. l**	**Pattigham Süd 1 (Pa S 1, RAG, 1979):** **–2,0 m : Quaternary** **–81,0 m : Ried Beds** **–620,0 m : Robulus Schlier s. l.**
Kemating 1 (Ktg 1, RAG, 1979): **–1,0 m : Quaternary** **–97,0 m : Ried Beds** **–615,2 m : Robulus Schlier s. l.**	**Eberschwang 1 (Esw 1, RAG, 1979):** **–1,0 m : Quaternary** **–108,0 m : Ried Beds** **–572,0 m : Robulus Schlier s. l.**
Kemating 3 (Ktg 3, RAG, 1979): **–0,3 m : Quaternary** **–88,0 m : Ried Beds** **–608,0 m : Robulus Schlier s. l.**	**Haag 2 (Hg 2, RAG, 1982):** **–8,0 m : Coal-Bearing Freshwater Beds** **–90,3 m : Ried Beds** **–549,0 m : Robulus Schlier s. l.**
Kemating 7 (Ktg 7, RAG, 1983): **–2,0 m : Quaternary** **–110,0 m : Ried Beds** **–620,0 m : Robulus Schlier s. l.**	**Wolf segg-Litzlfeld M 1/83 (Wolfsegg-Traunthaller Kohlenwerks AG, 1983):** **–0,5 m : Quaternary** **–50,4 m (total depth): Atzbach Sands**
Kemating Nord 1 (Ktg N 1, RAG, 1981/82): **–5,0 m : Mehrnbach Sands** **–42,0 m : Ried Beds** **–661,0 m : Robulus Schlier s. l.**	

the sedimentology of outcropping Atzbach Sands south and east of Hausruck was done (Heinrich et al. 1984).

The results of the programme of investigations indicate that the potential for finding in situ coal deposits in Ottnangian sediments of western Upper Austria is not large. However, the core drilling of Kemating K 1 meant the initiation of modern scientific investigations and geological mapping of Ottnangian sediments in the Innviertel (Faupl et Roetzel 1987).

This paper is concerned with otoliths and their ecological characteristics; the results of other fossil determinations (nannoplankton, spores, pollen, dinoflagellate cysts, lignite, Foraminifera, Anthozoa, Mollusca, Crustacea, Annelida, Echinoidea, Chondrichthyes) on Kemating K 1 have not been published yet.

Geological Review

The Molasse Zone of Upper Austria forms part of the Cenozoic foredeep that accompanies the Alpine and Carpathian ranges along their northern edge from the Rhône Basin to the Caspian Sea (Malzer 1980, Rögl et Steininger 1983). In Upper Austria, the Molasse Basin contains Late Eocene to Quaternary largely detrital sediments of predominantly alpine origin, overlying Mesozoic series and the crystalline basement of the Bohemian Massif (Malzer 1980, Nachtmann et Wagner 1986).

The marine sediments of Ottnangian stage in Upper Austria correspond to the younger part of Lower Miocene Paratethys transgression (Faupl et Roetzel 1987). Ottnangian deposits (Table 1) are showing almost uniform pelitic facies (Robulus Schlier s.s.) in the eastern part of Upper Austrian Molasse Zone, whereas in the western part the sedimentary record shows a more variable pattern. The fan — delta system of the Sand-Schottergruppe with coarse clastic deposits interfingers with the sandy and muddy sediments of a marine regime (Traub 1948, Aberer et Braumüller 1949, Aberer 1958, Faupl et Roetzel 1987). The plant- and coal-detritus bearing sand facies of Robulus Schlier s.l., shown by the wells north and west of Hausruck, especially in the Kemating region, is presumed to correspond with the outcropping Atzbach Sands (Fig. 1). The Atzbach Sands were deposited in a sand-rich subtidal shallow marine environment under strong tidal influences (Faupl et Roetzel 1987). They form a transitional contact with the underlying Vöckla Beds and are overlain by muddy shelf sediments of Ottnang Schlier.

Otoliths

The studied otolith fauna of the Ottnangian sediments of Upper Austria was obtained only from the sand facies of the Robulus Schlier s.l. (the first ten boreholes in table 2), or from its stratigraphic equivalent, the Atzbach Sands (borehole Wolfsegg-Litzlfeld M 1/83). It is an assemblage that is relatively poor in individuals and without exception composed of quite incompletely preserved otoliths (fragments, strongly corroded specimens). The systematic assignment of individual taxons is hence frequently incomplete or approximative. The assemblage, however, significantly extends the scope of our knowledge of the fish fauna of this time interval. It shows, that the Ottnangian fauna of the marine bony fishes was much richer and more diversified than hitherto published; the papers on these subjects had been mainly based on studies of brackish and freshwater facies (Schubert 1906, Brzobohatý et Schultz 1973). The identified taxons and their frequency in the sand facies of the Robulus Schlier s.l. in individual boreholes are listed in table 2.

From the paleoecologic point of view, the otolith assemblage of the studied boreholes is very clear. It is composed of purely marine species which require a stable normal salinity. The only exception might be the problematically evidenced gobiid in the borehole Pattigham Süd 1. A substantial part of the otoliths is constituted by representatives of the family Myctophidae (genera *Diaphus, Myctophum, Symbolophorus*), which can live mostly in the mesopelagic environment (200—1 000 m below water level) of tropical and subtropical oceans. They form the most important component of ichthyoplankton and therefore the basic component of the food chain of fish. They also migrate regularly in great shoals into the epipelagic environment, or up to the sea level. It is generally accepted that their mode of life in the Tertiary was analogous. The other groups of fishes are represented in the studied assemblage only sporadically. Macrouridae (genera *Coelorhynchus, Bathygadus*) are benthopelagic (archibenthal) fishes that occur preferably in the deeper region of the sublittoral and in the upper part of the continental slope. Gadidae (the genera *Raniceps* and *Palaeogadus*) and Ophidiidae (genus *Hoplobrotula*) also belong to the fishes which tend to live rather in open or deeper waters. Only the Gobiidae represent here distinctly shallow-water fishes that can live under both brackish and freshwater conditions.

A direct paleoenvironmental interpretation of this assemblage, however, would lead to false conclusions. The strong corrosion of the otoliths, a fragmentary preservance and composition of the fauna (prevalence of juvenile myctophids) together with the hitherto accomplished paleogeographic interpretations of the Ottnangian sedimentary area point to a typically allochthonous origin. The transport of the otoliths of various fish groups over relatively great distance by predators (other fishes, birds, sea mammals, etc.) is quite usual. Physical factors such as currents are not considered. Many recent assemblages of otoliths have passed through the digestive system of predators. The presence of a great number of sharks in the Ottnangian sediments of Upper Austria (Schultz 1969, Brzobohatý et Schultz 1973) is also in favour of this explanation of the assemblage studied.

In any case, the otolith Robulus-Schlier fauna points to a very good connection between the Upper Austrian region and the open sea as late as during the Lower Ottnangian. This connection was oriented to the W (besides cosmopoli-

		MOLASSE ZONE IN UPPER AUSTRIA AND SALZBURG					
		SW – and W – Part	Central Part			N–Part	E–Part
OTTNANGIAN	UPPER	Oncophora Beds	Oncophora Beds				
OTTNANGIAN	MIDDLE	Sand – Schottergroup	Innviertel-Group	Treubach Sands Braunau Schlier Mehrnbach Sands Ried Beds	Glauconitic Beds		
OTTNANGIAN	LOWER	Sand – Schottergroup	Innviertel-Group	Ottnang Schlier Atzbach Sands Vöckla Beds	Robulus Schlier s.l.	Robulus Schlier s.l. Enzenkirchen Sands Coarse Phosphoritic Sands	Robulus Schlier s.s.
UPPER	EGGENBURGIAN		Hall Formation				Hall Formation

Table 1: Stratigraphic table of Upper Eggenburgian and Ottnangian deposits of Molasse Zone in Upper Austria and Salzburg (by Faupl et Roetzel 1987).

tan and Mediterranean elements and/or even boreal elements — *Hoplobrotula, Raniceps?, Bathygadus, Palaeogadus* — are present there). This conclusion is in harmony with the present-day paleogeographic interpretations (Rögl et Steininger 1983) and with the detailedly evaluated otolith fauna of the Lower Miocene of Aquitania (Steurbaut 1979). The studied otolith assemblage is not competent to prove connection of the Bavarian-Austrian Molasse with the Mainz Basin and probably with the boreal region, which is considered by Martini (1981, 1983) based on the evaluation of shallow water and brackish fish.

The otolith fauna of the sand facies of the Robulus Schlier s.l. is stratigraphically almost indifferent. Apart from taxonomic problems, the identified or at least approximately determined species are currently present in the Miocene and show a considerable geographic distribution (*Diaphus debilis, D. austriacus, D. cahuzaci, Coelorhynchus toulai*). *Symbolophorus meridionalis* has occurred since the upper part of the Lower Miocene. A comparison with the Eggenburgian fish fauna of the Central Paratethys is not possible, because from the Eggenburgian deposits only very shallow and brackish assemblages not containing deeper water elements have been known. But the composition of the deep-water assemblages of the Karpatian differs already significantly in the dominant occurrence of otoliths of the species *Triphoturus carpaticus* (Brz.) and *Hygophum weileri* (Brz.), which seem to be specific for the Karpatian deposits of the Central Paratethys and which have not been established in the Ottnangian.

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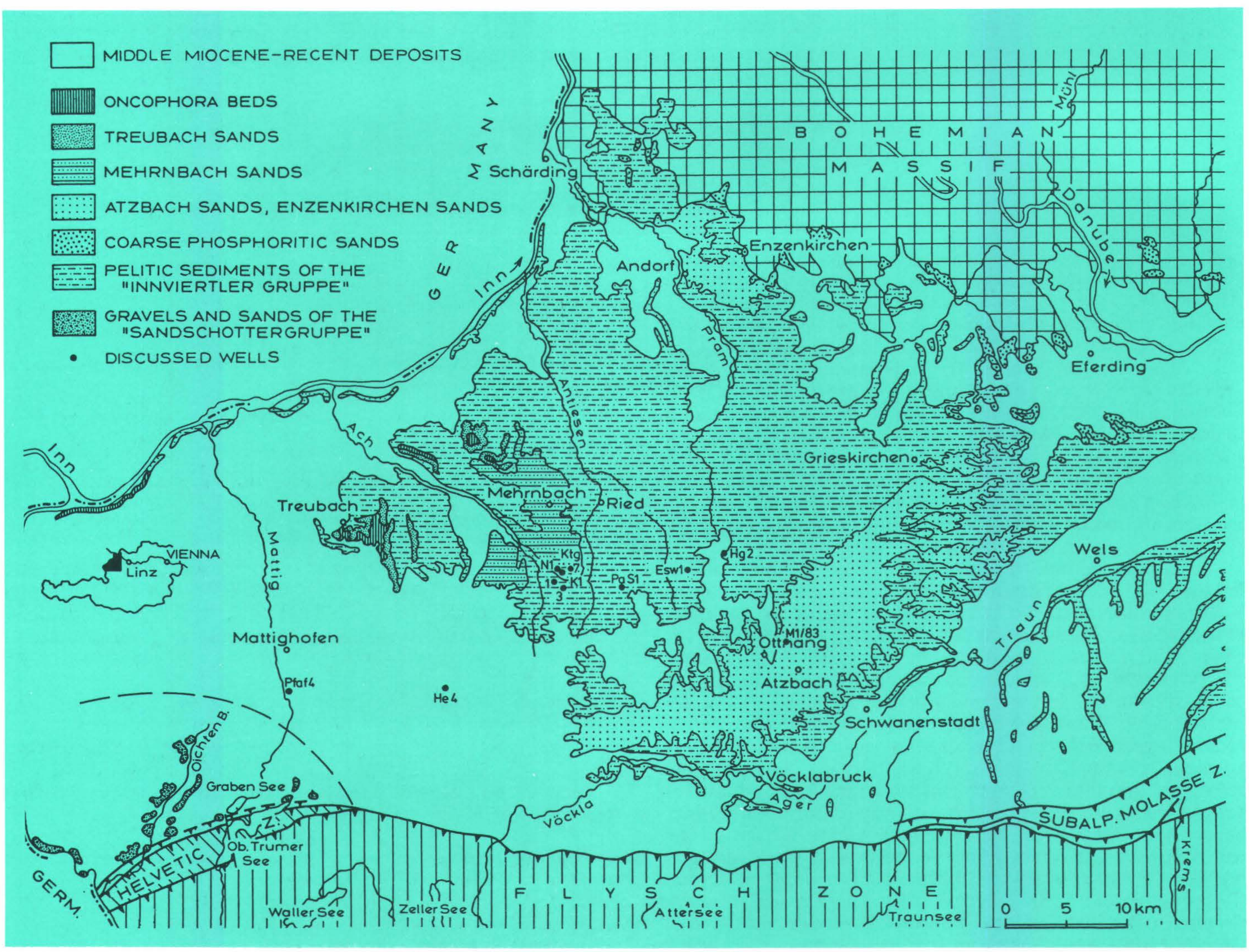
Table 2: Distribution of otolith species in sand facies of Robulus Schlier s. l. of discussed wells.

species \ wells	Pfaffstät 4	Hocheck 4	Kemating N 1	Kemating 1	Kemating 3	Kemating 7	Kemating K 1	Pattigham Süd 1	Eberschwang 1	Haag 2	Wolfsegg-Litzlfeld M 1/83
Myctophidae											
Diaphus debilis (Koken, 1891)		+	+			+				+	+
Diaphus austriacus (Koken, 1891)		+		+							
Diaphus sp.		+			+	+	+		+	+	
Diaphus cf. cahuzaci Steurbaut, 1979								+			
Myctophum sp.							+				
Symbolophorus cf. meridionalis Steurb., 1979				+	+					+	
Symbolophorus? sp.			+	+						+	
Myctophidae gen. et sp. indet.		+	+	+	+	+	+	+	+	+	
Macrouridae											
Coelorhynchus aff. toulai (Schubert, 1905)										+	
Coelorhynchus sp.			+	+						+	
Bathygadus sp.										+	
Macrouridae gen. et sp. indet.			+								
Gadidae											
Palaeogadus sp.										+	
Raniceps? sp.										+	
Gadidae gen. et sp. indet.	+							+			
Ophidiidae											
Hoplobrotula sp.										+	
Gobiidae											
Gobiidae gen. et sp. indet.								+			

Fig. 1: The Ottnangian sediments in Upper Austria and Salzburg (compiled by Faupl, Rohrlich et Roetzel, 1988) with the situation of discussed wells.



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Abstrakt

Otolitová fauna písčité facie robulových šlírů s.l. Horního Rakouska (spodní ottnang) je složena z čistě mořských druhů indikujících relativně značné hloubky původního životního prostředí. Silná koroze otolitů a úlomkovité zachování spolu s převahou juvenilních exemplářů ukazují na primárně allochtonní původ studované asociace, která však každopádně dokumentuje dobré spojení sedimentačního prostředí s otevřeným mořem. S touto představou je v souladu i přítomnost četných druhů žraloků (predátorů) i prokázaná existence relativně silných proudů a silné tidální aktivity během ukládání písčité facie robulových šlírů s.l.

Většina zjištěných druhů kostnatých ryb je ze sedimentů ottnangu uváděna poprvé.

Zusammenfassung

Die Otolithenfauna der Sandfazies des Robulus-Schliers s.l. in Oberösterreich (unteres Ottnangien) ist ausschließlich aus marinen Arten zusammengesetzt, die verhältnismäßig beträchtliche Tiefen des ursprünglichen Lebensmilieus indizieren. Eine starke Korrosion und bruchstückartige Erhaltung der Otolithen sowie ein Übergewicht juveniler Exemplare weisen auf einen primär allochthonen Ursprung der untersuchten Assoziation hin, durch die jedenfalls eine gute Verbindung des Sedimentationsraums mit der hohen See dokumentiert wird. Mit dieser Vorstellung stehen auch das Vorkommen zahlreicher Haifischarten (Raubfische) sowie die nachgewiesene Existenz verhältnismäßig starker Ströme und Gezeiten während der Ablagerung der Sandfazies des Robulus-Schliers s.l. im Einklang.

Die meisten ermittelten Arten der Knochenfische werden aus den Ablagerungen des Ottnangiens zum erstenmal angeführt.

CARBONIFEROUS CONODONTS FROM BRUSNÍK ANTICLINE (SOUTH SLOVAKIA)

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Geologic structure

The geologic structure and tectonic interpretation of the eastern part of the Slovenské rudohorie Mts. (Spišsko-gemerské rudohorie) are at present widely discussed in Czechoslovakia and abroad, especially in Hungary and Austria.

A structure test hole in the southern part of the Slovenské rudohorie Mts. on the periphery of the Rimavská kotlina basin (Vozár et al. 1986) had to solve the problem concerning the geologic structure of the Inner West Carpathians, i.e. the Silicicum as a nappe unit and its relation to the Gemericum s.s. The structure test hole was situated in the Brusník anticline consisting according to earlier ideas (Fusán 1957, Chmelík — Jablonský 1964, Snopko et al. 1970, Varga et al.1971, Mello et al. 1976, Vass et al. 1983) — of Early-Paleozoic complexes. These are lithologically correlated with the Gelnica Group, in the upper part — with Permian and Lower Triassic terrigencus complexes, and higher up with Lower-Middle Triassic limestones. The core of the anticline is ranged to the Devonian on the basis of lithological correlation with the data by Snopková — Snopko (1979). Mello (in Mello et al. 1976) regards the Early-Paleozoic complexes as the Gelnica Group, i.e. as the Gemericum, but he ranges the Late Paleozoic and the Mesozoic to the Silica nappe. According to the new interpretation by Mello — Vozárová (1984) the entire Brusník anticline is part of the Silicicum nappe unit, presumably underlain by the Meliata Group (Meliaticum). Later on (Vozárová — Vozár 1988) the presence of an Alpine granite intrusion in deeper parts of the anticline was presumed. All the opinions were, however, based on the idea of the Gelnica Group as the oldest member in the core of the Brusník anticline, and the anticline was regarded as part of the units in the eastern part of the Slovenské rudohorie Mts. and in the Slovak Karst, i.e. the Gemericum and Silicicum comprising Paleozoic complexes in their structure.

The structure test hole at Brusník (BRU-1) was situated in the core of the anticline. The lithological section of the 1 043 m deep hole offered new data enabling the new interpretation of the anticline, particularly in the relation of Paleozoic occurrences in Hungary.

Following are most significant data from the borehole BRU-1:

1. The borehole penetrated two tectonically related rock complexes as indicated by a prominent fault at the depth of about 600 m;

2. conodonts from the interval of 75—116 m of the upper rock complex were determined by Ebner and Straka and ranged to the Namurian B-C to Westphalian A;

3. the rock complex from the interval 0—598.8 m with its lithologic character and stratigraphic position is best correlatable with the Szendrö Fm. (described from the Szendrö Mts. in Hungary, Kovács — Péró 1983, Kovács 1987);

4. the lower rock complex below the fault sole has so far not been dated biostratigraphically but it may lithologically correspond to olistostromes of the Rudabánya Mts., described by Kovács (1987).

Lithological characteristics

The upper part of the borehole BRU-1 to the depth of 598.8 m consists of grey and black phyllites, metasiltstones, and intercalations of line-grained metasandstones, mostly refolded, showing a distinct cleavage. Metasediments display typical features of flysch sedimentation, including graded- and laminar bedding. Graded-bedded intraformation breccia appear amid the metasediments in the interval of about 497—541 m. Structures in the breccia correspond to the gravity current sediments. The fragments are angular ranging from 1 cm to 10 cm in size. They consist of shales, siltstones, acid volcanics, less lydites, and sporadical crystalline carbonates. Clastic detritus with quartz grains in metasandstones has the same composition. Metasandstones contain small amounts of plagioclase-, microperthite- and clastic mica grains. There are also metamorphosed volcanoclastic sandstones and rhyolite tuffs (maximum in the interval of 250—350 m). The volcanoclastic sediments consist of fragments of quartz-, microperthite-, plagioclase phenocrysts, of occasional K-feldspar and decomposed biotite. The microcrystalline volcanogenic matrix is recrystallized to quartz, sericite, ore pigment, tourmaline and rutile.

Layers of grey to black, bluish-grey carbonates are in the interval of 75—116 m. They are divided from one another by dark shale layers. The carbonates are either crystalline and contain fragments of organic detritus, or they are slightly recrystallized with a micrite or microsparite texture, formerly enriched with clay material and organic matter. In the same interval (75—116 m) conodonts were found, determined by Ebner.

The complex of metasediments from the interval 0—598.8 m underwent regional metamorphism to the initial degree of the green schist facies (the approximate temperature 370—400 °C).

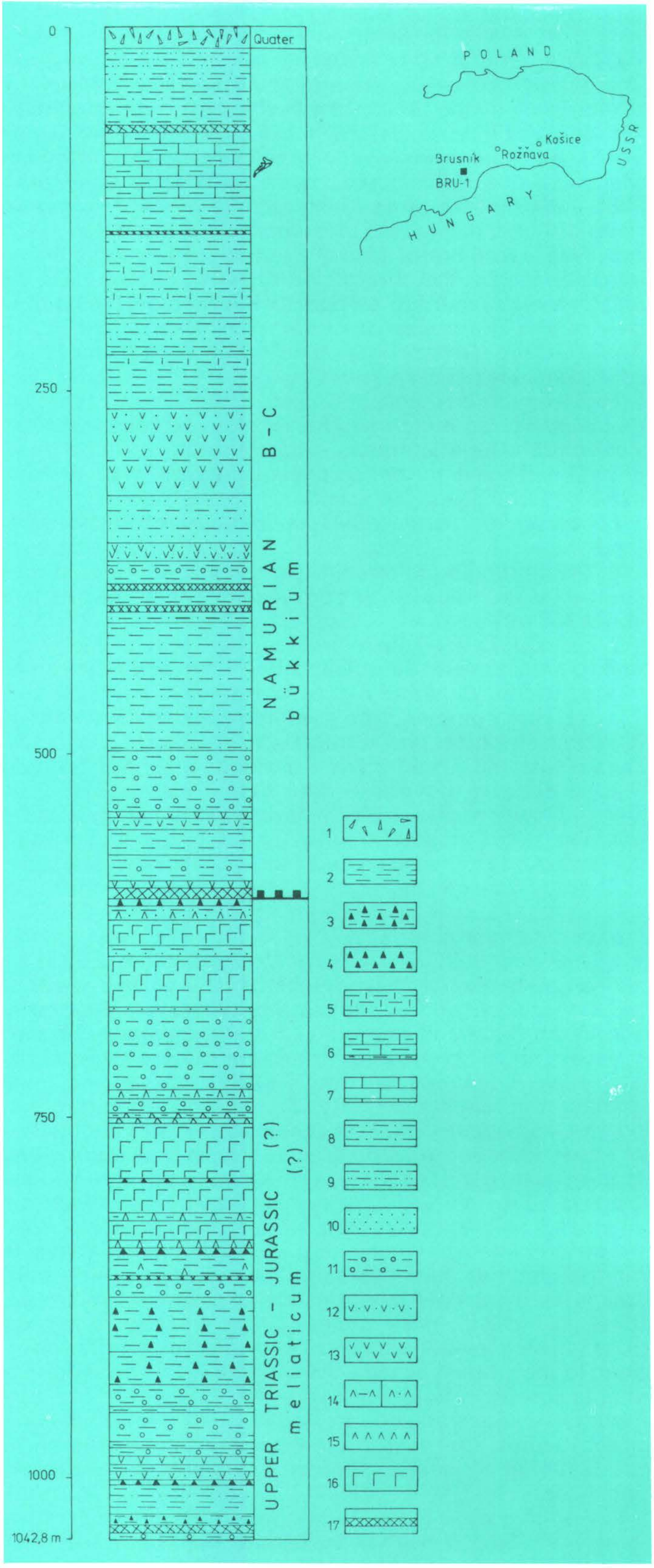


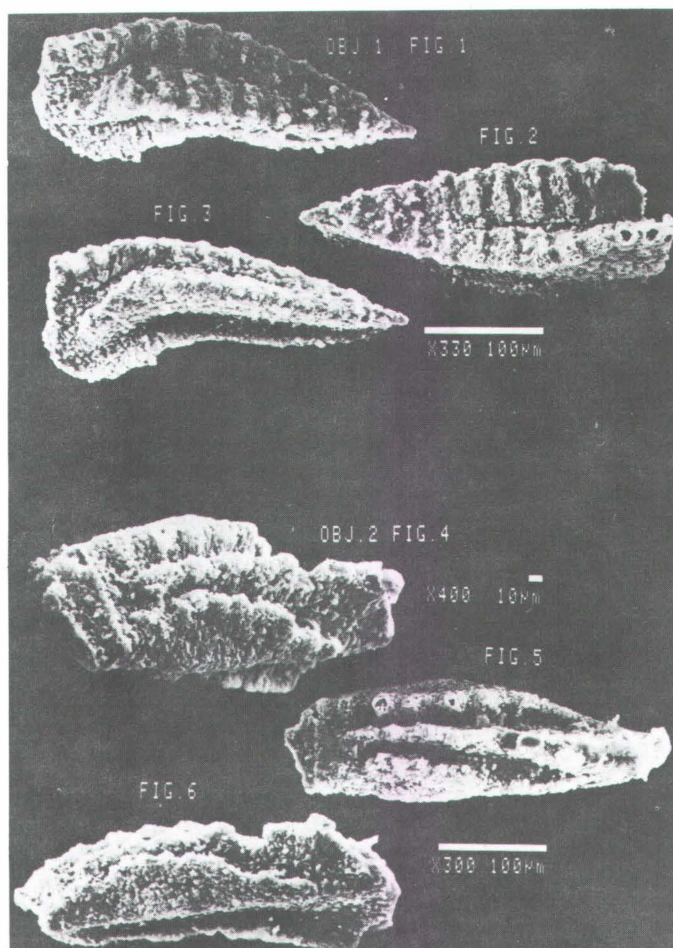
Fig. 1: Lithostratigraphical scheme of rock complexes of borehole BRU—1
1 — loamy stony debris (Quaternary); 2 — very low- and low-metamorphosed black pelites; 3 — very low-metamorphosed pelites with thin intercalations and laminae of silicites; 4 — black and grey silicites; 5 — low-metamorphosed pelites containing carbonate detritus; carbonate metapelites; 6 — low-metamorphosed clayey carbonates; 7 — grey, bluish-grey crystalline carbonates; 8 — laminated and graded-bedded metasiltstones and metapelites; 9 — metasandstones with intercalations of dark phyllites; 10 — very low- and low-metamorphosed sandstones; 11 — gravitational slides of breccia and conglomerates; 12 — volcanoclastic metawackes; 13 — metarhyolite tuffs; 14 — rhyolite volcanoclasts a) in metapelites, b) in metasandstones; 15 — detritus from basic volcanics; 16 — serpentinized picrite basalts; 17 — prominent zones of tectonic crushing.

Paragenesis of metamorphosed minerals: quartz + muscovite + albite ± semigraphite, rutile, chlorite. It was a low-pressure regional metamorphism, b_0 of muscovite = 8.994 Å, s = 0.005, n = 60 (in Mazzoli — Vozárová 1989).

A complex of low-grade metamorphosed sediments from the borehole BRU-1 (interval 0—598.8 m) cannot be compared to any occurrences in the Czechoslovak West Carpathians in its lithological character and stratigraphical range but it is comparable with the complex of Szendrö phyllites in Hungary (cf. Kovács — Péró 1983, Kovács 1986). Carbonate olistostromes containing conodonts and showing the flysch character of sedimentation like in the borehole BRU-1 (interval 0—598.8 m) were found in the Szendrö Mts. In the complex of the Szendrö phyllites rhyolite metatuffs, tuff sandstones, turbidite conglomerates with siliclastic intraformational detritus have not been described. In the regional sense the Middle-Carboniferous flysch from the Szendrö Mts. is compared to the Hochwipfel flysch from the Carnian Alps and from the Karawanken. There, also coarse-clastic turbidites and rhyolite-dacite volcanoclastic material have been described (Schönlaub 1979). It is to be emphasized that the Hochwipfel flysch was folded and an-

Plate 1
Object 1
Figures 1—3: *Idiognathoides* cf. *corrugatus* (HARRIS and HOLLINGSWORTH, 1933)
2 Upper view
3 lateral view

Object 2
Figures 4—6: *Idiognathodus* or *Streptognathodus*
5 upper view
6 lateral view



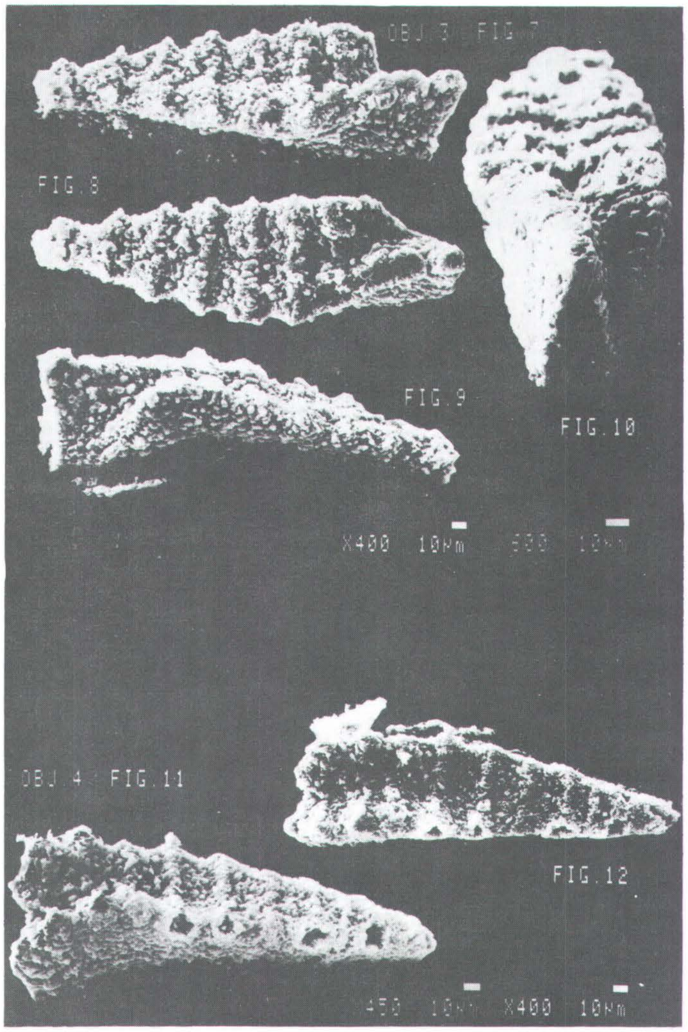


Plate 2
Object 3
Figures 7—10: *Idiognathoides* sp.
8 upper view
9 lateral view
Object 4
Figures 11—12: *Idiognathoides* sp.
11 upper view
12 lateral view

chimetamorphosed prior to the deposition of the Auerning formation ranged to the Upper Westphalian. This is in contradiction to the opinions about the Alpine age of metamorphosis of the Szendrö phyllites according to Árkai (1983), Kovács — Kozur — Mock (1983).

The lower rock complex penetrated by the borehole BRU-1 below the fault sole in the interval ranging to the depth of 1042.8 m consists of sediments and volcanics. Their characteristic features are: the presence of serpentinized picrite basalts, black silicites alternating with pelites, layers of polymict coarse-grained breccia with rhyolite volcanoclastic material. So far we have no biostratigraphical data about this rock complex.

Sediments and volcanics are very low metamorphosed — only the top part of the anchizone. The basic volcanics represent the porphyric types with ophite- or subophite texture and fine-grained varietes. Among original minerals only clinopyroxenes and plagioclases are preserved. Basalts are partly serpentinized. Thin basaltic intercalations are in the whole complex.

Coarse-grained polymict breccia are characterized by plentiful rhyolite detritus. Besides that the clastic material in breccia comprises various types of sericite shales, silicites, scarce micrite carbonates and carbonate shales and sporadical decomposed basic volcanics. There is a contact between clasts in breccia, in places without matrix. The structure of breccia is unsorted. In the borehole the coarse-clastic sediments are amid dark, formerly clayey-silicite sediments and their contact is sharp. They have the character of slumps amid fine-grained basinal sediments.

Analogous conglomerates were found in Jurassic olistostromes of the Rudabánya Mts. in Hungary (Kovács 1987). They also contain rhyolite detritus in a great amount, and limestone clasts. In the borehole BRU-1 the rhyolite detritus is mostly associated with siliclastic detritus (silicites, shales). No analogous complex has been found in Paleozoic and Mesozoic formations of the Czechoslovak West Carpathians.

Stratigraphic position

Basing on conodonts from the interval of 75—116 m we range the upper rock complex (to 598.8 m) to the Namurian B-C or up to the Westphalian A. We have no biostratigraphic data about the lower rock complex (at the level 600 m below the fault sole). So the opinion about the age of the oldest rocks in the core of the Brusník anticline must be changed. They were regarded as Devonian on the basis of lithological correlations with the upper part of the Gelnica Group (palynological dating by Snopková — Snopko 1979).

Conodonts found:
Idiognathoides cf. corrugatus (HARRIS-HOLLINGSWORTH, 1933) 1 ex. Idiognathoides sp. 2 ex.
Streptognathodus vel Idiognathodus sp. 1 Ex. div. ramiforme Elements 3 ex (Table 1)

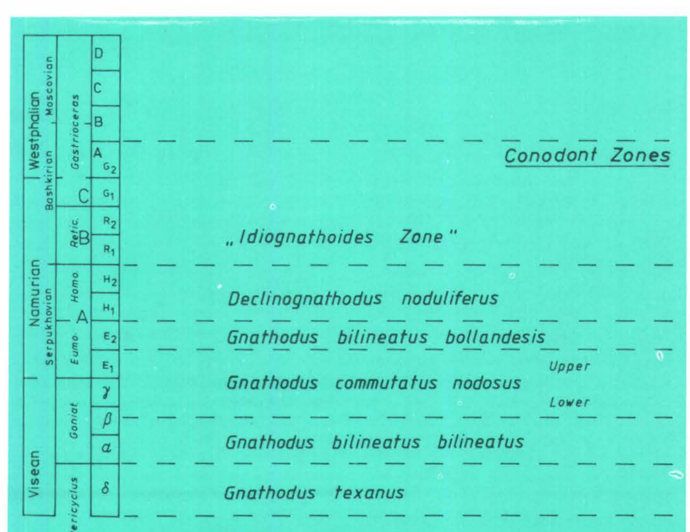
According to Ebner the determined forms may — in respect of a wider regional correlation — be ranged to Idiognathoides — „Zone" corresponding to the Namurian B — Westphalian A.

The existing data on the stratigraphy of the Gemeric Carboniferous particularly the conodonts from the Ochtiná Fm. (Kozur — Mock — Mostler 1976, Kozur — Mock 1977) and lithologic characteristics of the Ochtiná Fm. (Vozárová in Bajaník — Vozárová — Reichwalder 1981) prove that the borehole BRU-1 in the interval ranging to 598.8 m cannot be compared to any known occurrence of the Upper Carboniferous in the West Carpathians.

Conclusions

The borehole BRU-1 was realized in the core of the Brusník anticline. On the basis of lithological correlation the anticline core was regarded as an equivalent of the upper part of the Gelnica Group (Lower-Middle Devonian). The bore-

Table 1.



hole penetrated two rock complexes differing in lithology and metamorphism. The rock complexes are in tectonic contact with each other. The upper unit contained Namurian B-C to Westphalian A conodonts. The rock complex is correlated with the Szendrö phyllites Formation (the Bükkium). The lower rock complex is correlated with Jurassic olistostromal formations of the Rudabánya facies (Meliaticum). So the Brusník anticline is not part of the Gemericum s.s. It has the character of a nappe-imbrication zone comprising two higher-order tectonic units south of the Rožňava lineament.

The problem and its solution is dedicated to the 65th birthday of Profesor H. FLÜGEL from the Graz University.

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Abstrakt

Antiklinála pri Brusníku predstavuje jednu z problémových štruktúr južnej časti Slovenského rudohoria. Vrt BRU-1 (1 043 m) bol situovaný do jadra antiklinály, v ktorej sa doposiaľ predpokladalo vystupovanie gelnickej skupiny (spodný až stredný devón). Profil vrtu v skutočnosti zastihol dva odlišné súbory hornín, ktoré sú v tektonickom styku. Vrchný súbor, na základe konodontov z hĺbky 75—116 m, zaraďujeme k namuru B—C až vestfálu A. Litologicky i stratigraficky horniny v intervale do 598,8 m sú korelovateľné s formáciou Szendrö fylitov. Sporný súbor hornín (pod 598,8 m), zatiaľ bez biostratigrafických dôkazov a len na základe litológie, môže zodpovedať jurským olistostromovým sekvenciám rudabaňského vývoja. Týmto sa zásadne mení názor na doterajšie postavenie antiklinály pri Brusníku vo vzťahu k južným častiam gemerika.

Zusammenfassung

Die Brusník-Antiklinale stellt eine der problemreichen Strukturen im Südteil des Slowakischen Erzgebirges dar. Die Bohrung BRU-1 (1 043 m) wurde im Kern der Antiklinale angesetzt, in der man bisher das Auftreten der Gelnica-Gruppe (Unter- bis Mitteldevon) angenommen hatte. In Wirklichkeit wurden im Bohrprofil zwei unterschiedliche Gesteinskomplexe von tektonischer Berührung angetroffen. Der obere davon wird von uns aufgrund der Conodonten aus einer Tiefe von 75 bis 116 m dem Namur B-C bis Westfal A zugeordnet. Die Gesteine aus dem Tiefenbereich bis zu 598,8 m können lithologisch und stratigraphisch mit der Szendrö-Phyllitformation korreliert werden. Der strittige Gesteinskomplex (von 598,8 m an), bisher ohne biostratigraphische Belege, dürfte nur aufgrund der Lithologie den jurassischen Olisthostromaschichtenfolgen der Rudabánya-Entwicklung entsprechen. Durch diese Erkenntnisse wird die bisherige Ansicht über die Stellung der Brusník-Antiklinale in bezug auf die südlichen Teile des Gemerikums grundsätzlich geändert.

A. E. REUSS' IMPORTANCE FOR RESEARCH INTO NEOGENE OSTRACODA IN THE VIENNA BASIN AND THE TAXONOMIC REVISION OF HIS DETERMINATIONS

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The work of A. E. Reuss on the Ostracoda of the Neogene Austro-Hungarian Basins of the year 1850 ranks with the classic fundamental works devoted to ostracod fauna.

In his work, written in German, the author described a total of 90 ostracod species, the greatest part of which come from localities in the Vienna Basin. (In the supplements he described another 6 species from localities in Sicily, England and France.) The object of Reuss' investigations were 46 different localities, of which numbers of fossil Ostracoda were established in 28 places. They involve Baden, Möllersdorf, Vöslau, Atzgersdorf, Meidling, Döbling, artesian wells near Vienna, Heiligenberg, Brunn, Moosbrunn, Nussdorf, Gainfahren, Steinabrunn, Garschenthal, St. Nikolai, Wurzing, Grossing, Freibühl, Grinzing, Rust, Mauer near Vienna, one undefined locality in Austria, Sopron (- Oedenburg) in Hungary, Kyjov (- Gaya), Podivín (- Kostel), Rudoltice (- Rudelsdorf) in Czechoslovakia, Lapugiul de Sus (- Felsö-Lapugy) in Romania, Wieliczka in Poland. Of these localities, Nussdorf and Podivín in the facies of the Leitha limestones proved to be the richest in Ostracoda, then Brunn, Sopron, Grinzing and Rudoltice in the Teglian facies. Halite and "salt" clay of Wieliczka contained a lot of species, but as for the number of individuals, it was far behind the above-mentioned localities.

As far as the stratigraphic determination of layers of the investigated localities is concerned, they can be incorporated into the Badenian to the Pontian, the majority of them belonging to the Badenian. Reuss used the following, stratigraphically not very clear terms, rather facial terms: the Leitha limestone, which corresponds to the shallow-water facies of the Badenian, and the Teglian.

As stated by Reuss, at the time he wrote the work five genera of fossil Ostracoda were known: Cypridella de KONINCK, 1841, Cypris O. F. MÜLLER, 1776, Cytherina LAMARCK, 1818, Cypridina EDWARDS, 1840, Cyprella de KONINCK, 1841. The material investigated by Reuss only contained representatives of genera Cypridina and Cytherina. The author also mentioned that of all the species investigated by him, only 12 were more widely distributed: Cytherina subdeltoidea (MÜNSTER, 1830), C. Mülleri REUSS, 1850, Cypridina trigonella REUSS, 1850, C. punctata (MÜNSTER, 1830), C. Haueri (RÖMER, 1838), C. deformis REUSS, 1850, C. hastata REUSS, 1850, C. sulcato-punctata REUSS, 1850, C. Haidingeri REUSS, 1850, C. cornuta (RÖMER, 1838). C. plicatula REUSS, 1850, C. Edwardsi (RÖMER, List of ostracod fauna in REUSS (1850):

Original name	Revision
Cytherina subdeltoides v. MSTR.	Bairdia subdeltoidea (MÜNSTER, 1830)
Cytherina abscissa m.	Amplocypris abscissa (REUSS, 1850)
Cytherina lucida m.	unrevised, documentation material is missing
Cytherina semicircularis m.	Pseudocandona semicircularis (REUSS, 1850) — rev. JIŘÍČEK (1985)
Cytherina unguiculus m.	Candona (Serbiella) u. unguiculus (REUSS, 1850) — rev. KRSTIČ (1985) Caspiolla unguiculus (REUSS, 1850) — rev. JIŘÍČEK (1985)
Cytherina mytiloides m.	unrevised, documentation material is missing
Cytherina arcuata v. MSTR.	Phlyctenophora arquata (MÜNSTER, 1830)
Cytherina auriculata m.	Hungarocypris auriculata (REUSS, 1850)
Cytherina inflata m.	unrevised, documentation material is missing
Cytherina abbreviata	Cypria abbreviata (REUSS, 1850) — rev. JIŘÍČEK (1985)
Cytherina gracilis m.	unrevised, documentation material is missing
Cytherina neglecta m.	unrevised, documentation material is missing
Cytherina recta m.	Amplocypris recta (REUSS, 1850)
Cytherina longa m.	Cushmanidea longa (REUSS, 1850) — rev. BRESTENSKÁ, JIŘÍČEK (1978), genus appurtenance is debatable
Cytherina tenuis m.	Leptocythere tenuis (REUSS, 1850)
Cytherina compressa v. MSTR.	Cytherella compressa (MÜNSTER, 1830)
Cytherina sublaevis m.	unrevised, documentation material is missing
Cytherina Cytherella dilatata	(REUSS, 1850) — rev. BRESTENSKÁ, JIŘÍČEK (1978)
Cytherina ovulum m.	Xestoleberis ovulum (REUSS, 1850) — rev. OERTLI (1956)
Cytherina exilis m.	Bairdia exilis (REUSS, 1850) — rev. REUSS (1860), unrevised late, 1830
Cytherina Mülleri v. MSTR.	Cytheridea muelleri (MÜNSTER)
Cytherina salinaria m.	unrevised, documentation material is missing
Cytherina heterostigma m.	Cyprideis heterostigma (REUSS, 1850)
Cytherina subteres m.	a synonym to Cyamocytheridea leptostigma leptostigma (REUSS, 1850)
Cytherina obesa m.	Cyprideis heterostigma obesa (REUSS, 1850) — rev. KOLLMANN (1960)
Cytherina falcata m.	Bairdia falcata (REUSS, 1850) — rev. REUSS (1860), unrevised later, documentation material is missing
Cytherina leptostigma m.	Cyamocytheridea leptostigma (REUSS, 1850)
Cytherina tumida m.	Xestoleberis tumida (REUSS, 1850)
Cytherina crystallina m.	Parakrithe crystallina (REUSS, 1850) — rev. BRESTENSKÁ, JIŘÍČEK (1978)
Cytherina strigulosa m.	Haplocytheridea strigulosa (REUSS, 1850) — rev. KEY (1957)
Cytherina setigera m.	unrevised, documentation material is missing
Cytherina pilosella m.	Xestoleberis pilosella (REUSS, 1850)
Cytherina glabrescens m.	Xestoleberis glabrescens (REUSS, 1850)
Cytherina trichospora m.	unrevised, documentation material is missing
Cytherina seminulum m.	Cyprideis seminulum (REUSS, 1850)
Cytherina tribullata m.	unrevised
Cytherina expansa m.	Ilyocypris expansa (REUSS, 1850) — rev. KRSTIČ (1985)
Cypridina punctatella m.	Loxoconcha punctatella (REUSS, 1850)
Cypridina notata m.	Aurila notata (REUSS, 1850)
Cypridina Philippi m.	Aurila philippii (REUSS, 1850)
Cypridina trigonella m.	Aurila trigonella (REUSS, 1850)
Cypridina cinctella m.	Aurila cinctella (REUSS, 1850)
Cypridina galeata m.	Aurila galeata (REUSS, 1850)
Cypridina cicatricosa m.	Aurila cicatricosa (REUSS, 1850)
Cypridina Kostelensis m.	Urocythereis kostelensis (REUSS, 1850)
Cypridina angulata m.	Aurila angulata (REUSS, 1850)
Cypridina punctata v.M.	Aurila punctata (MÜNSTER, 1830)
Cypridina deformis m.	Pokornyella deformis (REUSS, 1850)
Cypridina hastata m.	Loxoconcha hastata (REUSS, 1850)
Cypridina sagittula m.	Loxoconcha sagittula (REUSS, 1850)
Cypridina lacunosa m.	Cytheromorpha lacunosa (REUSS, 1850) — rev. JIŘÍČEK (1985) Leptocythere (Amnicythere) lacunosa (REUSS, 1850) — rev. KRSTIČ (1985)
Cypridina Haueri RÖM.	Aurila haueri (RÖMER, 1838)
Cypridina reniformis m.	Hemicytheria reniformis (REUSS, 1850)
Cypridina opaca m.	Aurila opaca (REUSS, 1850)
Cypridina clathrata m.	unrevised, documentation material is missing
Cypridina loricata m.	Hemicytheria loricata (REUSS, 1850) — rev. JIŘÍČEK (1985)
Cypridina folliculosa m.	Hemicytheria folliculosa (REUSS, 1850)
Cypridina similis m.	probably a synonym to Aurila haueri (RÖMER, 1838)
Cypridina spinulosa m.	Falunia spinulosa (REUSS, 1850) — rev. BRESTENSKÁ, JIŘÍČEK (1978)
Cypridina hispidula m.	Aurila hispidula (REUSS, 1850)
Cypridina brunnensis m.	Hemicytheria brunnensis (REUSS, 1850)
Cypridina granifera m.	Loxoconcha granifera (REUSS, 1850)
Cypridina asperrima m.	Henryhowella asperrima (REUSS, 1850)
Cypridina coelacantha m.	unrevised, documentation material is missing
Cypridina hystrix m.	Acanthocythereis hystrix (REUSS, 1850)
Cypridina omphalodes m.	Hemicytheria omphalodes omphalodes (REUSS, 1850)
Cypridina sulcato-punctata m.	Tenedocythere sulcatopunctata (REUSS, 1850)
Cypridina canaliculata m.	Callistocythere canaliculata (REUSS, 1850)
Cypridina daedalea m.	Callistocythere daedalea (REUSS, 1850)
Cypridina carinella m.	Bosquetina carinella (REUSS, 1850)
Cypridina bituberculata m.	Occultocythereis bituberculata (REUSS, 1850) — rev. RUSSO (1968)
Cypridina rostrata m.	unrevised, documentation material is missing
Cypridina Haidingeri m.	Hermanites haidingeri (REUSS, 1850)
Cypridina transylvanica m.	Trachyleberis transylvanica (REUSS, 1850) — rev. SCHEREMETA (1961)
Cypridina Ungeri m.	Ambostracon ungeri (REUSS, 1850) — rev. KOLLMANN (1971) Pachycaudites ungeri (REUSS, 1850)
Cypridina corrugata m.	Mutilus corrugatus (REUSS, 1850) — rev. KOLLMANN (1971)
Cypridina truncata m.	Cnestocythere truncata (REUSS, 1850)
Cypridina verrucosa m.	Verrucocythereis verrucosa (REUSS, 1850)
Cypridina coronata RÖM.	the material from REUSS' collection probably corresponds to Pterygocythereis calcarata (BOSQUET, 1852) — sensu BRESTENSKÁ, JIŘÍČEK (1978)
Cypridina cornuta RÖM.	Pterygocythereis cornuta (RÖMER, 1838) — rev. KEY (1957)
Cypridina vespertilio m.	Cytheropteron vespertilio (REUSS, 1850)
Cypridina triquetra m.	Paracytheridea triquetra (REUSS, 1850)
Cypridina pygmaea m.	Eucytherura pygmaea (REUSS, 1850)
Cypridina denudata m.	unrevised, documentation material is missing
Cypridina plicata v. M.	Cythere plicata (MÜNSTER, 1830)
Cypridina polyptycha m.	Climacoidea polyptycha (REUSS, 1850) — rev. RUSSO (1968) Mutilus polyptychus (REUSS, 1850)
Cypridina plicatula m.	Falunia plicatula (REUSS, 1850), Olimfalunia plicatula (REUSS, 1850) — rev. CARBONEL P. (1985)
Cypridina Edwardsi RÖM.	Costa edwardsi (RÖMER, 1838)
Cypridina tricostata m.	Costa tricostata (REUSS, 1850)
Cypridina reticulata m.	Costa reticulata (REUSS, 1850).

1838). The occurrence of other species is confined to individual collecting localities or to a very small number of localities.

In the systematic part of the work, Reuss gave relatively detailed descriptions of both represented genera Cytherina and Cypridina. He characterized them and defined their mutual differences. The description of each species is preceded by a brief diagnosis in Latin, and the average size of the lengths of valves is given. The description proper is brief, as a rule, first the overall shape of the valve from the lateral view is given, further then the shape and size of the anterior and posterior margins, frequently also the shape of the dorsal and ventral margins. This is followed by a description of sculptural elements, such as ribs, pits, nodes, spines, etc., and of their positions on the valve surface, sometimes, a brief description of the hingement is included. The imperfection of optical microscopes of that time is most likely responsible for some inaccuracies in Reuss' descriptions, e.g. on the valve surfaces of some species, he describes short hairs, which are obviously normal pore canals. The description is followed by a list of the localities, where the respective species was found.

The work is supplemented with 4 tables which depict the valves or carapaces of each species from outer lateral, and ventral or dorsal views. Only with some few species the inner view is given, depicting first of all the selvage pattern. Singularly, there are details of valve surfaces. Although the level of the depictions is fairly good for that time, the resolution power in smooth, unsculptured forms is smaller.

Note to revisions: In some species I could not verify the genus classification. In such cases I refer by abbreviation „rev." (revised) to the respective work.

In his next work, Reuss (1860) presented a list of ostracod fauna of the Miocene deposits in the environs of Česká Třebová of localities Opatov, Třebovice and Rudoltice. With each species he only gave the occurrence frequency and another collecting locality. All the 26 ostracod species quoted here were already described by the author in his work of 1850. It is worth mentioning that the genus classification does not agree in any case with the original one, the species were re-classified to genera Cythere, Bairdia, Cytherella and Cytheridea.

List of the occurring species: Cythere galeata (REUSS), C. bituberculata (REUSS), C. plicata (REUSS), C. Edwardsi (RÖMER), C. cinctella (REUSS), C. cicatricosa (REUSS), C. angulata (REUSS), C. deformis (REUSS), C. hastata (REUSS), C. Haueri (RÖMER), C. similis (REUSS), C. hystrix (REUSS), C. canaliculata (REUSS), C. Haidingeri (REUSS), C. corrugata (REUSS), C. verrucosa (REUSS), C. polyptycha (REUSS), C. plicatula (REUSS), C. reticulata (REUSS), Bairdia subdeltoidea (MÜNSTER), B. arcuata (MÜNSTER), B. exilis (REUSS), B. falcata (REUSS), B. glabrescens (REUSS), Cytherella compressa (MÜNSTER), Cytheridea Mülleri (MÜNSTER).

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Abstrakt

Práce A. E. Reusse o ostrakodech neogenních pánví Rakousko-Uherska z roku 1850 patří mezi klasická, základní díla věnovaná ostrakodové fauně.

V této německy psané práci autor popsal celkem 90 druhů, z nichž převážná většina pochází z lokalit vídeňské pánve. Pokud se týká stratigrafického stáří vrstev zkoumaných lokalit, lze je zařadit do badenu až pontu, přičemž nejvíce jich patří badenskému stupni.

U všech Reussem popsaných druhů byla provedena taxonomická revize jejich rodového určení.

Zusammenfassung

Die von A. E. Reuß verfaßte Arbeit über Ostrakoden der neogenen Becken in Österreich-Ungarn vom J. 1850 gehört den klassischen, grundlegenden Werken an, die sich mit Ostrakodenfaunen befassen. In dieser in Deutsch erschienenen Arbeit beschrieb der Verfasser insgesamt 90 Arten, von denen die überwiegende Mehrheit aus Fundorten im Wiener Becken stammt. Was das stratigraphische Alter der Schichten an untersuchten Fundorten betrifft, kann man sie in das Baden bis Pont einstufen, wobei die meisten davon der Baden-Stufe angehören. An allen von Reuß beschriebenen Arten wurde eine taxonomische Revision ihrer Gattungsbestimmung durchgeführt.

METAMORPHIC EVOLUTION OF THE VEPORICUM (CONTRIBUTION TO POSSIBLE CORRELATION WITH THE EASTERN ALPS)

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Metamorphism in the West Carpathians should be considered from several aspects. First of all there is a close relation between metamorphism and tectonics — like in the Alps (M. Frey et al. 1974) and in other regions (e. g. G. B. Haxel et al. 1984). Recent investigations of crystalline complexes in the West Carpathians revealed fragments of a formerly uniform Hercynian system. The nature of Lower Paleozoic sediments and volcanics indicates that the system was formed upon Proterozoic continental crust. In respect of geotectonics it is the evolution of intracratonic orogen also described from other parts of the Hercynides (e. g. Dalmayrac et al. 1980). The results of the study of European Hercynides indicate the dynamical character of the Hercynina orogeny (P. Matte 1986). Recently it was proved by the research in the Veporicum of the West Carpathians (V. Bezák 1988). In the West Carpathians the Hercynian system was completely destroyed during the Alpine tectogenesis. Fragments of the Hercynian system and Precambrian elements are incorporated in the structure of new Alpine tectonic units (Tatricum, Veporicum) practically ignoring the Hercynian structure.

The Veporicum, mainly its southern part is most favourable for the analysis of metamorphism. On a relatively small area there are the elements of all the three structural and age levels, i. e. the Upper Paleozoic and Mesozoic (upper structural levels) units, Lower Paleozoic complexes (middle level) and the complexes of the lower level (their elementary classification was presented by V. Bezák 1988). Recently we advanced in the range of information about tectonic position of particular complexes, their lithological content and grade of metamorphosis, and in age determinations, mainly of Lower Paleozoic complexes.

In the Veporicum the lowest level is represented by gneisses and migmatites — perhaps products of Cadomian metamorphism. So far there is only indirect evidence of their age: change of metamorphosis in comparison with Lower Paleozoic complexes, different structural pattern, tectonic breccias of these rocks cemented by Hercynian granitoids, deformational structures (lineations, boudinage) occurring under the conditions of higher-rank metamorphism than Alpine. The primary metamorphosis ranged up to temperatures above 600 °C (according to the first records of the graphite and garnet-biotite thermometers), Hercynian metamorphism had diapthoritic effects upon the rocks.

Fragments of Early Paleozoic metamorphites (mica--schist complex of Ostrá and Klenovec complex of biotite albitized gneisses) underwent the Hercynian regional dynamic medium-pressure metamorphosis. The lower age limit of the metamorphosis is defined by the age of sediments (Silurian-Devonian), the upper age limit is indicated by the upper Carboniferous sedimentation (its metamorphosis and tectonic position are already different). The metamorphism was evidently the most intensive at the end of the Devonian and during the Lower Carboniferous. In analogy with the Bohemian Massif the process of metamorphosis might be longer (J. Cháb — M. Suk 1977). According to paragenetic analysis the conditions of metamorphism are close to the low grade/medium grade boundary in the sense of H. G. F. Winkler (1979) — to the almandine zone of the green schist facies with a stable chlorite + muscovite association. On the basis of petrogenetic lattice and geothermometric determinations (we have used the garnet-biotite and graphite thermometers and the results show a good accordance) the conditions of metamorphism may be determined to 450 — 530 °C and 400—500 MPa. Main differences between Lower Paleozoic complexes are not in the grade of metamorphosis but in lithology (the complex of Ostrá consists of pelites with a small portion of basic volcanics; the Klenovec complex consists of psammites with admixture of intermediary volcanic material). The products of the first — synkinematic stage of the Hercynian metamorphism were later overlain by the products of the static thermal phase, most likely associated with intrusions of Late Hercynian granitoids and with heat outlets in the form of thermal domes. Analogous evolution of Hercynian metamorphism is also described from other parts of European Hercynides (Ch. Pin — J. J. Peucat 1986). Local more intensive static metamorphosis of Cadomian metamorphites may be explained by the „basement effects" (in the sense of J. M. Fonteille — G. Guitard 1964).

The nature of the Alpine metamorphism may be studied on the rocks of the upper structural level (Upper Paleozoic and Mesozoic) overlying the complexes of the lower and middle levels. The rocks are only incorporated in the Alpine tectonic structures. The Upper Paleozoic complexes (mainly the Sinec complex) differ markedly from the Lower Paleozoic also in their lithological content (occurrences of magnesite, metaconglomerates, basic volcanics), and in the grade of metamorphosis (synkinematic metamorphosis did not surpass the chlorite zone). The Alpine metamorphism proceeded in two stages — with synkinematic crystallization of minerals in the chlorite zone, and with postkinematic crystallization of mainly biotite and garnet. In this stage also crystallization of disthene and chloritoid proceeded, for instance on the contact with the Gemericum (S. Vrána 1964). These minerals were also in other parts of the Veporicum and their origin is influenced by chemical composition of rocks. Rocks affected by pre-Alpine metamorphosis under similar conditions underwent hardly distinguishable alterations (isozonal recrystallization) whereas rocks affected by metamorphosis of higher rank, show effects of diaphthoresis.

According to K/Ar dating the Alpine metamorphism proceeded mainly during the Cretaceous (94 ± 18 Ma — J. Burchart et al. 1987) and its upper age limit is defined by the uplift of the Veporicum (fission tracks indicate its beginning about 75 Ma ago — J. Kráľ 1982). V. Hurai (1983) estimates the rate of uplift to 0,3 mm per year. So in contrast to the Alps the metamorphism in the Veporicum did not extend to the Neoalpine period. According to the records by the garnet—biotite and graphite thermometers the synkinematic metamorphosis proceeded at the temperatures 360 — 430 °C and pressure about 400 MPa (according to petrogenetic lattice). The postkinematic metamorphosis had a variable extent (the effects of granitoids) and proceeded under higher temperatures (formation of biotite and garnet). It is generally presumed that the Alpine metamorphism proceeded under the conditions of the thickness of overlying complex at least 5 — 10 km which is sought either in the denuded nappe of the Tatricum (S. Vrána 1980) or of the Gemericum (D. Plašienka 1984). The question concerning the role of the nappes of the basement is still unanswered.

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Abstrakt

V článku je analyzovaný metamorfný vývoj kryštalinika veporickej jednotky Západných Karpát na základe najnovších výskumov. V dnešnej stavbe veporika sú zakomponované elementy troch orogénov — najstaršieho (kadomského?), hercýnskeho a alpínskeho. Tomu odpovedá aj metamorfný vývoj veporika, ktorý prebiehal v niekoľkých etapách v súhlase s tektonickým vývojom. V práci sú charakterizované aj podmienky všetkých etáp metamorfózy.

Zusammenfassung

Im Artikel ist die metamorphe Entwicklung des Kristallins der Vepor-Einheit in den Westkarpaten auf Grund der neuesten Ergebnisse analysiert. Am heutigen Bau des Veporikums sind Elemente von drei Orogenen beteiligt, nämlich ?kadomische, herzynische und alpine. Dem entspricht auch die metamorphe Entwicklung des Veporikums, welche in einigen Etappen in Übereinstimmung mit der tektonischen Entwicklung verlief. In der Arbeit sind auch die Bedingungen aller Etappen der Metamorphose charakterisiert.

THE MOLDANUBICUM – AN OLD NUCLEUS IN THE HERCYNIAN MOUNTAIN RANGES OF CENTRAL EUROPE

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1. Introduction

For many years the Moldanubicum was accepted as the old core of the Bohemian Massif – a median mass (STILLE, 1951; ZOUBEK et al. 1960, SVOBODA et al. 1966 a. o.). For most geologists „Moldanubicum" was synonymous with Precambrian. There is a tendency now to leave this conservative view. THIELE (1976 a, b, 1984) takes the nappe structures of the Moldanubicum like those of the Moravicum as Hercynian in age. This view is supported by TOLLMANN (1982, 1985), who concludes on the observations of fold vergencies that the Moldanubian nappes are derived from 300 km to the W. Matte et al. (1985) also favour E-directed Hercynian nappes in the Moldanubicum of the Waldviertel on the basis of combined structural-geochronological studies. Siluro-Devonian microfossils discovered in the Varied Group of southern Bohemia provide a surprise: Parts of the Moldanubicum are Palaeozoic in age (ANDRUSOV & CORNA; 1976; PACLTOVA, 1980, 1986). The geochronological studies by van BREEMEN et al. (1982) bring the result that the granulite facies metamorphism, SE-directed thrusting and plutonism all occurred within the period of 345±5 and 331±4 ma.

Thus all recent research seems to support the concept of a uniform Hercynian orogene comprizing both the Moldanubicum and the Moravicum. Nappes directed ESE are the prominent structural elements in the south-eastern parts of the Bohemian Massif.

Certainly it does not mean „to be in", if one puts arguments in favour of the old view of a Moldanubicum representing a median block. However there are series of facts inconsistent with the assumption of a uniform homogeneous Hercynian mountain system in the Bohemian Massif. Therefore I contested this view in my 1986 paper. Since then the Wolfshof Syenite has been dated (pers. comm. by Prof. W. FRANK, Geol. Inst. Univ. Vienna), which provides another essential argument against the concept of Hercynian intra-Moldanubian nappe structures. In the following the problem is discussed particulary in respect to the Austrian portions of the Bohemian Massif.

2. The Moldanubian Rocks and Structures

The Variscian Moldanubian Pluton intruded a rock complex with characteristic rock associations, and orogenic zoning.

In **southern Bohemia** the zonal arrangement follows a SW-NE-strike, and the regional dip is NW. The lowest series are the monotonous Kaplice Micaschists followed by the Varied Series[1]) with its marbles, graphite schists, quartzites, paragneisses and amphibolites. Large bodies of hybrid orthogneiss resemble the Gföhl Gneiss of the Waldviertel. In the NW, thus apparently in the highest position, large granulite masses and associated ultramafites follow.

In the **Waldviertel** and **Moravia** the regional strike is SSW-NNE with dip towards the ESE. We find the same rock assemblages as in Bohemia and the same sequence of zones. The Monotonous Series is the lowest complex succeeded by the Varied Series. Then follow the Gföhl Gneisses and at the top the granulites with their associate series.

Thus in Bohemia as in the Waldviertel and Moravia we find the high-grade metamorphics, migmatites, and orthogneisses regularly overlying the metasedimentary series of lower grade of alteration. ZAYDAN & SCHARBERT (1983) found P/T conditions of ca. 630 °C/3 Kbs for the Monotonous Series, ca. 670 °C/5 Kbs for the Varied Series. HÖGELSBERGER (1987) examined the carbonates of the latter series and deduced ca. 700 °C/5.5–7.5 Kbs. PETRAKAKIS (1986) studied the gneisses of the same unit and suggested even 700–770° C/7–9 Kbs. HÖGELSBERGER (1987) notes that he did not find a change in metamorphism between the Varied Series and the overlying Gföhl Unit. The granulite series making up the upper portions of the named unit, however, were formed under > 760 °C/ > 11 Kbs (SCHARBERT & KURAT, 1974). Associated with the granulites we find pyrope peridotites and garnet pyroxenites derived from the upper mantle (DOBRETSOV et al. 1984; SCHARBERT & CARSWELL, 1983).

The inversion of metamorphic complexes, no doubt, was brought about by tectonics. In form of nappes the high-grade metamorphic complexes came in superposition on less altered rocks. The importance of thrust tectonics first emphasized by F. E. SUESS (1903, 1912) was extended to the internal parts of the Moldanubicum by FUCHS (1971, 1976), MATURA (1976) and THIELE (1974, 1976, 1984). Regarding the delimitation of the units, age and vergency of thrusting the opinions of the named authors are diverging. However it is evident that the Moldanubicum is characterized by certain rock association (granulite series, Gföhl Gneiss, Varied and Monotonous Series), nappe tectonics, typical zoning and the SW-NE-to-SSW-NNE-trend of orogenic belts.

3. The Relations between Moldanubicum and Bavaricum

It was usual in Austria and Bavaria to regard the Moravicum as an individual unit in the sense of F. E. SUESS and to take the rest of the Bohemian Massif as Moldanubicum. Thus the Hercynian belt of the Mühlviertel, Sauwald and Bavarian Forest was too named „Moldanubicum". FUCHS (1976) introduced the term Bavaricum for the named belt, because it represents a new orogenic zone, which has to be distinguished from the Moldanubicum typified in the preceding chapter.

FISCHER (1959), FISCHER & TROLL (1973), FUCHS (1962), FUCHS & THIELE (1968), a. o. describe the rotation of the NE-SW-trending structural elements of southern Bohemia into the Hercynian NW-SE-strike of the Bavarian Forest and the Mühlviertel. Parallel with the structural transformation the typical rock assemblage of the Moldanubicum is progressively overprinted by metablastesis and finally obliterated. A new crystalline formed with NW-SE orientated Hercynian granites and migmatites. In passage zones,such as the Böhmer Wald, or in the Kropfmühl area in Bavaria remains of the older complex are partly preserved.

Thus the well-dated Hercynian orogenic belt cuts the NE-SW-striking zones of a pre-existing mountain system at right angles. The old foliation and axes are rotated into the new direction and the old, very characteristic rock associations are obliterated by migmatization. Therefore it is documented that the crystalline complex of southern Bohemia – the Moldanubicum – is older than the Bavaricum, which was formed in Hercynian times. Definitely there are more than one structural and metamorphic phases (see also FISCHER & TROLL; 1973).

4. The Relations between the Moldanubicum and Moravicum[2])

A tectonic discordance is very conspicuous if two orogenic belts meet at right angles as along the Moldanubicum/Bavaricum contact. In the Waldviertel and Moravia both the Moldanubicum and Moravicum show similar regional NNE-SSW strike. There the structural unconformity is primarily expressed in the direction of dip: The rock series of the Moldanubicum predominantly dip ESE, whereas the Moravicum shows a regional plunge towards the W. The two complexes join along the Moldanubian Thrust (F. E. SUESS) a tectonic plane dipping towards the W. After thrusting this thrust plane was deformed – in culminations the Moravicum is exposed in tectonic windows (Thaya and Svratka Windows). Detailed mapping showed that the internal structures in the Moravicum are in conformity with the Moldanubian Thrust. Those of the Moldanubicum, however, are disconformable. The Moldanubian Thrust marks the western boundary of the Thaya Window. The Moravian rock series follow parallel to this line (Pl. 1). But the Moldanubian zones join the Moldanubian Thrust in a **discordant** way. The Varied Series strikes from the Jauerling via Krumau/Kamp to the area of Messern, where it comes in contact with the Moravicum. The Gföhl Gneiss meets the Moravicum at Horn. The Rehberg Amphibolites and paragneisses of the lower Kamp Valley border the Moravicum E of this valley. NW of the Messern Bow the Moravicum is approached by the Blumau Granulite from the W. Gföhl Gneisses from the NW, and the Varied Series from the N, from Drosendorf. Also in the CSSR various rock series of the Moldanubicum border the Moravicum.

When we follow the named Moldanubian series as they approach the Moravicum we observe increasing **retrogressive** metamorphism. The granulite facies rocks and series of the sillimanite zone are adapted to the kyanite or staurolite zones of amphibolite facies. There are also structural changes near to the Moldanubian Thrust: S of Messern the Varied Series shows huge recumbent folds in km-dimensions. The Gföhl Gneiss is deformed in E-directed isoclinal folds, which explain its peculiar areal extent and pseudosynclinal form in the Gföhl area. The Drosendorf Window is an E-directed antiform with overturned eastern flank. Thus the Moldanubian Thrust is followed by a zone several km wide, which is dominated by intensive E-vergent folding. It is a zone where the Moldanubian sequences are inverted (Pl 1,2). This type of deformation is accompanied by retrogressive metamorphism. The most conspicuous change is from the paragneisses to micaschists. SUESS (1908, 1912) therefore introduced the term Micaschist Zone to this belt and gave the right explanation of its origin. The retrogressive nature of the Micaschist Zone was further substantiated by KÖLBL (1922). Modern petrological studies all show two distinct metamorphic phases in the Moldanubicum (FUCHS & SCHARBERT, 1979; GÖTZINGER, 1981; ZAYDAN & SCHARBERT, 1983; HÖDL, 1985; HÖGELSBERGER, 1987).

It is evident that the internal structures of the Moldanubicum and its rock assemblages are older than the Moldanubian Thrust and the accompanying deformations and alterations. Following F. E. SUESS we may accept the latter as Hercynian in age. Though the Hercynian metamorphism affected the whole Moldanubicum, the preexisting rocks and structures remained predominantly metastable. Only in a several km wide marginal zone the rocks became adapted to the Hercynian metamorphism. This probably is due to the intensive Hercynian deformation in this marginal belt, where a new crystalline was formed.

Thus like in Bohemia there is evidence in the Waldviertel and Moravia that the Moldanubian rock associations and structures are older than the adjoining Hercynian orogenic zone.

5. The Relation of the Hercynian Intrusives to the Surrounding Crystallines

The sequence of Hercynian magmatites was investigated by WALDMANN (1951, 1958). Recently S. SCHARBERT (1987) has given geochronological dating of the main types of granitoids in the Austrian part of the Bohemian Massif. The Weinsberg Granite and Mauthausen Granite are about of the same age (349±4 resp. 353±5 m. a.). From field evidence the Weinsberg Granite always proves to be older. The Eisgarn Granite gave an age of 316±7 m. a.

In the **Waldviertel** all these granites show sharp contacts, migmatization is insignificant, and swarms of dikes occur occasionally. All evidence shows that the magmatites intruded a pre-existing crystalline complex. The rocks and the structures were already formed at the time of intrusion.

In the **Bavaricum** the older magmatites – the Weinsberg Granites and the Diorites I – are synorogenic (FUCHS, 1962). They are foliated and show elongate forms concordant to the surrounding gneisses. The Weinsberg Granite passes into the accompanying migmatites (Grobkorngneiss; Schlierengranite, FINGER, 1986). All observations point to syntectonic intrusion during regional metamorphism. The younger magmatites, Diorites II, Mauthausen Granite, and Eisgarn Granite exhibit predominantly sharp discordant contacts and insignificant migmatization. It is obvious that the crystalline was already cooling at the time of their intrusion.

The different appearance of the Weinsberg Granites in the Waldviertel and the Bavaricum indicates that at the time of regional metamorphism and tectogenesis in the Hercynian belt the Moldanubian complex was already existing.

6. The Age of the Moldanubian Rocks and Structures

In the preceding chapters it was documented that the Moldanubicum formed before the Hercynian zones of the Bavaricum and Moravicum. Therefore it shows imprints of polymetamorphism and several tectonic phases. Now the question arises whether these phases occurred in one orogeny (TOLLMANN, 1982) or may be attributed to different orogenies (FUCHS, 1976)?

6.1. Radiometric Data

S. SCHARBERT compiled the existing geochronological data in 1980: The characteristic Moldanubian rocks – the granulites and Gföhl Gneisses – gave ages of 485±11 (ARNOLD & SCHARBERT, 1973) and 491±24 m. a. (ARNOLD pers. comm.). Anatectic gneiss in Bavaria was dated 487±20 m. a. by GRAUERT et al. (1974). The age of the granulite metamorphism is dated with 446±36 m. a., and biotite ages indicate the cooling at the end of the Hercynian metamorphism. Also the Gföhl Gneiss indicates Hercynian alteration at 325±7 m. a. and the above named anatexites at 324±15 m. a.

These data document a strong Caledonian regional metamorphism and the activity of Hercynian metamorphism, which however was not able to homogenize the pre-existing rocks. Caledonian radiometric ages were found by various authors in different parts of the European Variscides (DAVIS & SCHREYER, 1962; GRAUERT et al. 1971; GEBAUER & GRÜNENFELDER, 1976; SCHMID, 1976; DORNSIEPEN, 1979; GEBAUER et al. 1981; BLÜMEL, 1982 a. o.).

ZWART & DORNSIEPEN (1979) and DORNSIEPEN (1979) discuss the problem of a Caledonian thermic event or regional metamorphism without contemporaneous folding in the suprastructural series. They are inclined to explain the Caledonian ages as a rejuvenation in Hercynian times. In my view the subfluence model (BEHR, 1978) provides a reasonable solution of this problem (see chapter 8).

Recently the **Wolfshof Syenite** of the eastern Moldanubicum has been dated (pers. comm. by Prof. Dr. W. FRANK, Geol. Inst. Vienna University), and a petrological study of this magmatite is under way by H. ALIASGARI. After my mappings in that area I pointed out that the geochronological examination of the Wolfshof Syenite would elucidate the age of the intra-Moldanubian nappe tectonics. This because of the following facts:

1) The syenite-gneiss occurs as one respectively few rather continuous, concordant layers in the huge syncline of St. Leonhard/HW. Its position is within the paragneisses and amphibolites between the Gföhl Gneiss below and the granulite at the top.

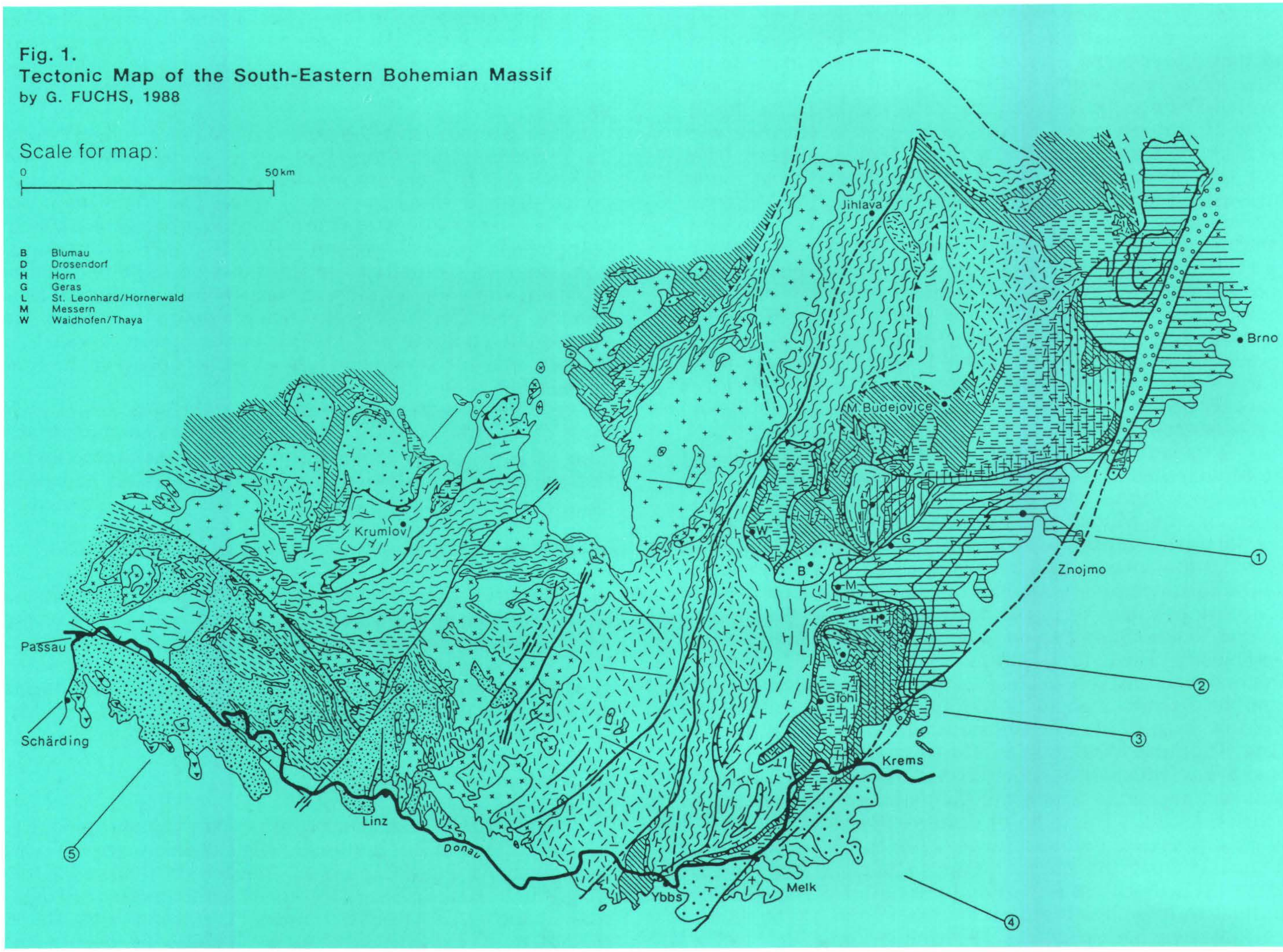


Fig. 1.
Tectonic Map of the South-Eastern Bohemian Massif
by G. FUCHS, 1988

2) The faint parallel structures and massive character of the syenite-gneiss contrasts to the schistosity of the intruded rocks. This is also observed in cases where the thickness of the syenite-gneiss is reduced to a few meters.
3) Inclusion of the country rock in the syenite and branching sills document the magmatic contact.

Consistent with these observations there is only the conclusion that the syenite intruded during the nappe tectonics and not yet in a solid state was sandwiched between the Gföhl Gneiss and the overthrust granulite series. Thus the age of the magmatite gives the age of the intra-Moldanubian thrusting.

The Wolfshof Syenite was examined by whole rock Rb/Sr method (8 samples) by FRANK (pers. comm.) and gave a good isochrone of 430 ± 15 m. a. (Silurian).[3]).

Contrary to the above indications of a Caledonian orogenesis van BREEMEN et al (1982) propose a basement formed in the Cadomian orogeny and rejuvenated in Hercynian times. In the very small time interval of ca. 15 m. a. the granulites formed at 345 ± 5 m. a., SE-to ESE-directed thrusting occurred at 338 ± 3 m. a., and granite plutonism took place at 331 ± 4 m. a. In the Visean Culm conglomerates of the Moravo-Silesian Zone we find already boulders of granulite.

It is very unlikely that all these processes occurred in such close succession. Between the formation of the granulite series with its associated rocks from the Mantle and the Hercynian plutons the conditions must have changed fundamentally. S. SCHARBERT (1987) dated the Weinsberg Granite with 349 ± 4 m. a., the Mauthausen Granite with 353 ± 5 m. a. which means that these intrusives formed earlier or approximately at the same time as the granulites! Again it should be stressed that the Bohemian SW-NE-trending zone containing granulites is cut and obliterated by the Bavaricum with its NW-SE-striking synorogenic intrusions of Weinsberg Granite-gneiss. Further South Bohemian granulites are penetrated by Rastenberg Granitoid (durbachite, FIALA et al. 1987, p. 11) which is generally accepted as earliest Hercynian intrusive. This indicates a pre-Hercynian age of the granulites. My interpretation of the geochronological data by van BREEMEN et al is that they show the cooling towards the end of the Hercynian metamorphism. Doubts concerning the results of van BREEMEN et al are also advanced by SUK (1986, p. 231).

6.2. Palaeontological Evidence

ANDRUSOV & CORNA (1976) claimed the discovery of microfossils in the Varied Group of southern Bohemia. PACLTOVA (1980, 1986) confirmed this by describing fragments of acritarchs, chitinozoans, and tracheid tissues belonging probably to vascular plants. These microfossils suggest Silurian and Devonian age. They were recovered from marbles, graphitic marbles and quartzites, erlans, paragneisses, and micaschists. Certainly Silurian and Devonian age of the Varied Series would prove the Hercynian age of the Moldanubian nappe structures. But the figured fossils are far from convincing. Further I doubt that the organic structures can be preserved in graphitized form in the rock series altered under conditions of the sillimanite zone The marbles and erlans show all signs of plastic flow, and the graphitic rocks are extremely deformed because of the gliding facilities of graphite. Though PFLUG & REITZ (1987) found doubtless spores in garnetiferous micaschists, it should be emphasized that the metamorphism of the Varied Group is much stronger. In this context it is to note that the fossils discovered in the Lam-Bodenmais area in Bavaria are derived from Hercynian metamorphites of the Bavaricum and not from the Moldanubicum as understood here.

7. The Intra-Moldanubian Nappes

FUCHS (1971, 1976) and SCHARBERT & FUCHS (1981) designate three major tectonic units in the Waldviertel (from bottom to top):

1) The **Ostrong Unit** is composed by the Monotonous Series (anatectic sillimanite-cordierite paragneisses) and very subordinate leucocratic orthogneisses, eclogitic rocks, and erlans. In the W the unit is intruded by the Hercynian granites. Towards the SSW the unit plunges beneath the Varied Series of the Drosendorf Unit, which overrides the Ostrong Unit in the E.
2) The **Drosendorf Unit** follows the Ostrong Unit tectonically. In the centre of a shear zone a thin layer of granulite formed along the thrust plane (FUCHS & SCHARBERT, 1979). This dm to a few meters thick granulite lamella was traced for approximately 30 km. The Drosendorf Unit is composed of the Dobra Orthogneiss and the succeeding Varied Series consisting of marbles, calcsilicate rocks, quartzites, graphite schists and amphibolites in a paragneiss matrix.
3) The **Gföhl Unit** rests as nappe on the above unit as documented by the Drosendorf Window. The Gföhl Unit is characterized by the Gföhl Gneiss, granulite, ultramafitites, migmatitic paragneiss often containing graphite quartzite, the banded Rehberg Amphibolite and anorthosite amphibolite. The lower boundary of the unit is not well-defined as amphibolites border on both sides and the migmatization of the Gföhl Unit influenced the uppermost portions of the Varied Series too. Within the Gföhl Unit we observe the following succession (from bottom to top):
   a) amphibolites, serpentinites and paragneisses
   b) Gföhl Gneiss (hybrid orthogneiss)
   c) amphibolites and paragneisses showing tendency towards granulite facies with the concordant intrusion of the Wolfshof Syenite
   d) Granulite and ultramafitites

This sequence represents at least two structural subunits: The Gföhl Gneiss and associated rocks and the Granulite Series. Thin layers of granulite along shear planes (e. g. at the base of the Gföhl Gneiss in the Taffa Valley) and granulite tendency in highly deformed portions of the Gföhl Gneiss indicate regional metamorphism of highest amphibolite facies close to granulite facies. This and the granulite lamella at the base of the Drosendorf Unit are evidence that the nappe movements occurred under strong amphibolite facies to granulite facies conditions. Also the migmatization reaching down across the Gföhl and Drosendorf Units boundary proves thrusting under „hot" conditions of regional metamorphism. These facts are the reason why FUCHS (1971, 1976) takes the eastern Waldviertel and Moravia as the root zone of the nappes. In the frontal position, as assumed by THIELE (1976, 1984) and TOLLMANN (1982, 1985), the above phenomena are not easy to understand. After a transport of ca. 300 km, as accepted by TOLLMANN, a crystalline nappe will be cool and no granulites will be produced along the thrust plane.

This brings us to the problem of the **direction of thrusting** and provenance of the nappes. As I accept the belt marked by Gföhl Gneiss and Granulite in the eastern Waldviertel and Moravia as the root zone and the Blumau-Waidhofen thrust mass as an outlier, the conclusion is W-directed tectonic transport (FUCHS, 1971, 1976). This was contested by THIELE (1976, 1984) and TOLLMANN (1982, 1985). TOLLMANN studied the dm– to decametric folds in various parts of the Waldviertel and found them all directed E or SE. This vergency is thought as caused by the overriding „Gföhl Nappe".

In the whole region W of the Gföhl Gneiss from the Danube to Waidhofen/Th, my mappings revealed W-vergent kilometric folds, unrealized by TOLLMANN. These huge, often isoclinal folds proved to be younger than the emplacement of the nappes, because they deform the ready pile of nappes (FUCHS & FUCHS, 1986).

Thus in the Waldviertel farther W from the Moldanubian/Moravian boundary there are W-directed km-folds younger than the nappe tectonics and the dm-to decametric folds directed E according to TOLLMANN. In the eastern marginal parts of the Moldanubicum all structures are uniform directed E.

In the dispute about the direction of the nappe movements I hesitated to use the small to medium scale folds as an argument, because they are not unequivocal as claimed by TOLLMANN. Further there are wide areas where the folds uniformly trend across the regional NNE-SSW-strike (e. g. around Spitz, where TOLLMANN (1982, p. 10 – 15) also claims SE-vergency).

It is the problem now whether the observed vergencies are related to the nappe movements? Most of the E-directed folds referred by TOLLMANN and shown in the figures are in marbles. In these rocks we find the most conspicuous fold patterns. However, in rocks so ready to plastic flow, can we expect there the preservation of older structures? It is a fact that the Moldanubicum is polyphase deformed, whether we accept early and late Hercynian phases (TOLLMANN, 1982) or different orogenies (FUCHS, 1976). Anyhow, the intra-Moldanubian nappes formed in the earlier phase. In my view TOLLMANN's E-directed folds are Hercynian like those dated by MATTE et al (1985) 323 ± 7 m. a. (39 Ar/40 Ar), but they are not related to the earlier intra-Moldanubian nappe tectonics. These older structures would not have survived the younger deformation in marbles.

What is now the **age** of the Intra-Moldanubian nappes? Granulites and Gföhler Gneiss dated. ca. 480 m. a. are integrated parts of the nappes, which therefore can not be older. On the other hand the Moldanubian structures are deformed and obliterated along the contacts to adjoining Hercynian fold belts (Bavaricum and Moravicum, see chapters 2, 3), and thus are older. As the thrusting occurred under conditions of high-grade regional metamorphism (sillimanite zone, granulite facies) it is very suggestive that the tectonics immediately followed the formation of the large granulite masses. All that indicates Caledonian age (FUCHS, 1976, 1986) wich is now proved by the 430 m. a. age of the Wolfshof Syenite. TOLLMANN (1982, 1985) accepts early Hercynian (Bretonic) Moldanubian nappe tectonics overprinted by the late Hercynian Moldanubian Thrust. This is very unlikely because in the Bavaricum two orogenic belts meet at right angles and the older is overprinted and obliterated. It is hard to believe that such a fundamental change in the tectonometamorphic pattern may occur within one orogeny.

8. The Moldanubicum in the Hercynides of Europe

TOLLMANN (1982, Pl. 2) shows the Bohemian Massif in the context of the Hercynian belts of Europe. The Moravicum is envisaged as the continuation of the Rhenohercynian Zone and thus belongs to the N-directed branch of the Hercynian orogene. The Moldanubicum represents the S-vergent branch. The ENE-striking divide between these branches bends to the S in Moravia. Thereby the vergency of the northern branch changes from NNW to NE and finally to ESE. Similarly it may be expected that in the southern branch the SE-vergency of Bohemia should swing around to the W in Moravia and the Waldviertel (like in the Ibero-

Amorican arc.) Contrary TOLLMANN accepts SE-vergency also in the Waldviertel.

The arc connecting the analogous zones of Bohemia with those of Moravia and the Waldviertel is explained by TOLLMANN (1982, Fig. 16) as the result of the axial NE-plunge of the anticlinorium of the Moldanubian Pluton. There the frontal portions of the „Gföhl Nappe" are connected with those parts of the nappe nearer to the roots. This view is **inconsistent with the bending of the whole orogene** (see above). FUCHS (1986) stresses that in accordance with the bending of the whole orogene the Moldanubian Zone swings around from the NE-strike in Bohemia to the S-to SSW-strike in Moravia and the Waldviertel. In this sharp bend the vergency changes from SE in Bohemia to W in the Waldviertel. There is no necessity to assume a thrust distance of 300 km (TOLLMANN, 1982, 1985).

It seems very suggestive to me that the Palaeozoic mountain building in Europe was a process of very long duration. It started with the Cadomian orogeny and persisted through the Caledonian to the Hercynian orogeny (BEHR, 1978, BEHR & WEBER, 1980). The Cadomian crust was rejuvenated along subfluence zones in the sense of BEHR's ensialic orogene model (1978). But in my view it is necessary to distinguish between subfluence zones active at different times. In the southern Bohemian Massif **Caledonian** subfluence zones are characterized by the Varied Series overthrust by the Gföhl Gneiss-granulite complexes. BEHR's Granulite-Garnet Peridotite-Migmatite Belts 5 and 6 (in 1978, Fig. 1, p. 289) seem to join up in the area N of Jihlava (Iglau). In Bohemia the subfluence is towards the NW (vergency of thrusting towards the SE), in Moravia-Waldviertel it is towards the ESE (vergency towards the WNW). The Caledonian subfluence zones and relictic Cadomian crust together formed a seed nucleus. Such consolidated masses acted as more or less rigid cores during the succeeding Hercynian orogeny. Their position in the Hercynian orogene is near the „Narbe" dividing the N-respectively S-directed belts. The Caledonian subfluences affected mainly the lower crust. In the suprastructure tectonics active during the sedimentation of the Ordovician-Devonian beds of the Prague Basin (HAVLICEK, 1981) are a synchronous phenomenon.

The **Hercynian** subfluence zones follow the margins of the Moldanubian nucleus. They cut the internal structures of this block discordantly and the subfluence is directed beneath the Moldanubicum. The **Moldanubian Thrust** represents a subfluence zone in its upper levels involving slightly altered sedimentaries (Devonian of the Moravian Windows). The metamorphism along the thrust was of the staurolite-to kyanite grade of amphibolite facies and is represented in the „Micaschist Zone".

The **Bavaricum** is a subfluence zone eroded to a deeper level. It is also of amphibolite facies grade, but with much anatectic mobilization and migmatization. These phenomena indicate rich supply in H_2O. In the Bavarian — as well as in the Moldanubian/Moravian subfluence belt no granulite or derivatives thereof have been found. The granulites of the Waldviertel and Moravia crop out close to the latter belt, but are not the products of this subfluence zone; they formed along the older E-dipping subfluence belt, which is cut by the W-heading Moldanubian Thrust. Granulites which may be attributed to the post-Caledonian subfluence are to be expected at deeper depth.

Index

Hercynian rocks

- Permo-Carboniferous sediments
- Brunovistulicum
- Moravian Zone
- Pearl gneisses of Bavaricum
- Eisgarn Granite
- Mauthausen-Freistadt Granitoids
- Schärding-Peuerbach Granites
- Weinsberg Granite massive; foliated
- Rastenberg Granodiorite, durbachite

Caledonian units of Moldanubicum

Gföhl Unit

- Granulite
- Gföhl Gneiss, recrystallized granulites, migmatites
- Gneisses, amphibolites and other rocks

Drosendorf Unit

- Varied Series

Ostrong Unit

- Monotonous Series

- Caledonian thrusts
- Caledonian thrusts, inverted
- Hercynian thrusts
- Late Hercynian mylonite zones, low angle shear zones
- Faults, steep mylonite zones
- Inversion zone of eastern Moldanubicum
- Dip
- Sections of Figs. 2, 3

Fig. 2.
Sections across the South-Eastern part of the Bohemian Massif.
Index same as for map Fig. 1.

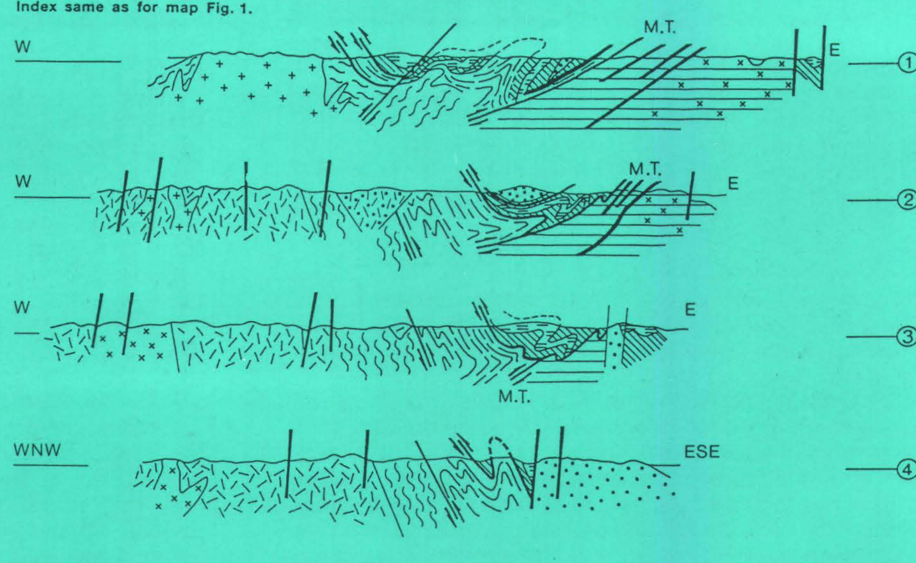
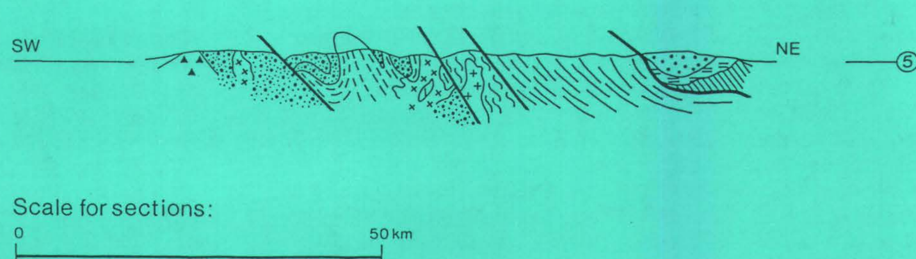


Fig. 3.
Section across the Bavaricum in Upper Austria.
Index same as for map Fig. 1.



MAGMATISM AND METAMORPHISM

The mobile Hercynian belts surround the Moldanubian block, but transformed only its marginal parts („Micaschist Zone", Mühl Zone, Böhmerwald Zone). The vast central portions of the Moldanubicum were invaded by the Hercynian granitoids accompanied by a wave of heating, but the rock assemblages and structures remained metastable. Along the margins of the Moldanubicum progressive structural overprinting and adaption to the new metamorphic conditions are observed.

Thus I come to the conclusion that the Moldanubicum formed by the reactivation of the Cadomian crust in Caledonian times. In agreement with BEHR (1978) and BEHR & WEBER (1980) this rejuvenation took place along subfluence zones in the internal zones of the Palaeozoic ensialic orogene. I explain the intra-Moldanubian nappe structures as Caledonian subfluence zones.

In Hercynian times the Moldanubicum was a consolidated core. New subfluence zones developed along its margins, their orientation however is different from the older ones. Though subfluence was a long lasting continuous process in the sialic crust of Europe (BEHR, 1978), successive thrust belts may be discerned.

The Palaeozoic orogeny of Central Europe affected the infracrust first, later the supracrust was involved (BEHR & WEBER, 1980). The orogeny started with the central zones of the mountain belt which grew outwards by the accretion of younger zones.

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[1]) I do not use the terms Monotonous and Varied Group of the Czechoslovakian geologists, because I am excluding the granulites, Gföhl Gneisses and their accompanying series from the Varied Group.

[2]) The term Moravicum is used in the sense of F. E. SUESS, who designates the Bitesch Gneiss as Moravicum, the Micaschist Zone as Moldanubian. JENCEK & DUDEK (1971) took eastern portions of the Moldanubicum (e. g. Vratenin Series = Varied Series of Drosendorf) as Moravicum, a view I can not follow.

[3]) Recently Prof. FRANK suspects that this age might be a mixed one.

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Abstrakt

Řada současných publikací interpretuje moldanubikum jako integrální část hercynského orogénu. To znamená, že vnitřní příkrovová stavba moldanubika je hercynská, stejně jako vnitřní stavba moravika.

Na rozdíl od tohoto názoru autor předkládá doklady, že moldanubikum představuje intramontánní blok evropských hercynid.

1. Moldanubická pásma v j. Čechách o průběhu SV-JZ jsou v pravém úhlu uťata bavarikem s celkovým trendem SZ-JV. V tomto hercynském pásmu jsou moldanubické struktury smazány a rotovány do nového směru.
2. Ve Waldviertlu a na Moravě je moldanubikum nasunuto na moravikum podél přesmyku hercynského stáří, upadajícího k Z.Tato plocha utíná vnitřní struktury moldanubika, upadající k V, diskordantně. V této okrajové části je moldanubikum postiženo retrográdní metamorfózou a převrásněním.
3. Starší intruzíva moldanubického plutonu jsou vůči moldanubickému komplexu posttektonická, v hercynském bavariku jsou synorogenní.
4. Granulity, které vznikly jako tektonity podél intramoldanubických střižných ploch, naznačují, že tyto pohyby probíhaly bezprostředně po vzniku velkých těles granulitů a gföhlských rul, které jsou datovány jako kaledonské.
5. Wolfshofský syenit byl zakliněn podél intramoldanubických přesmykových ploch v době, kdy nebyl ještě ve zcela pevném stavu. V současnosti byl datován 430 ± 15 milióny let, což dokumentuje kaledonské stáří příkrovové tektoniky.

Všechna tato fakta vedou k závěru, že moldanubikum představuje staré jádro, pouze okrajově přepracované v průběhu hercynské orogeneze. Domnívám se, že ve smyslu Behra (1978) byla kadomská kůra rejuvenována podél kaledonských zón subfluence, což vedlo ke vzniku moldanubika. To tvořilo zárodečný nukleus, pod který se ze všech stran podél okrajů podsunula mobilní hercynská pásma. Kaledonské subfluence se omezily na infrakrustální komplexy, kdežto hercynská orogeneze postihla i suprakrustální komplexy. Orogenní pásmo jeví akreci z vnitřních a starších částí přikládáním vnějších a mladších zón.

Zusammenfassung

In einer Reihe neuerer Arbeiten wird die Meinung vertreten, daß der interne Deckenbau des Moldanubikums variszisch wäre wie der des Moravikums.

Im Gegensatz dazu argumentiert der Autor dafür, daß das Moldanubikum eine Zwischengebirgsmasse in den europäischen Varisziden bildet:

1. Die NO-SW-streichenden Zonen des Moldanubikums Südböhmens werden von dem NW-SO-verlaufenden Bavarikum im rechten Winkel geschnitten. In dieser variszischen Zone wird der moldanubische Gesteinsbestand aufgelöst, umgewandelt, und die älteren Strukturelemente in die neue Richtung umgeregelt.
2. Im Waldviertel und in Mähren überschiebt das Moldanubikum das Moravikum an einer gegen W abtauchenden variszischen Bewegungsfläche – der moldanubischen Überschiebung. Diese Bewegungsfläche schneidet die ostfallenden internen Strukturen des Moldanubikums diskordant. Im Randbereich wird dabei das Moldanubikum umgefaltet und von rückschreitender Metamorphose betroffen.
3. Die älteren Intrusiva des variszischen moldanubischen Plutons erweisen sich als posttektonisch gegenüber dem moldanubischen Gneiskomplex. Im variszischen Bavarikum sind sie hingegen synorogen.
4. Entlang innermoldanubischen Bewegungsflächen bildeten sich Granulite als Tektonite. Dies spricht dafür, daß die Bewegungen während hochgradiger Regionalmetamorphose, wohl unmittelbar nach der Bildung der großen Granulit- und Gföhler Gneismassen erfolgten. Diese Gesteine wurden als kaledonisch altersbestimmt.
5. Der Wolfshofer Syenit wurde an innermoldanubischen Überschiebungen eingeschlichtet, als er noch nicht in festem Zustand war. Er wurde kürzlich mit 430 ± 15 m. a. datiert, woraus ein kaledonisches Alter der Überschiebung folgt.

Alle diese Tatsachen führen zu dem Schluß, daß das Moldanubikum einen älteren Kern darstellt, der während der variszischen Orogenese nur randlich überprägt wurde. Im Sinne von BEHR (1978) bin ich der Meinung, daß cadomische Kruste durch kaledonische Subfluenzzonen reaktiviert wurde, was zur Bildung des Moldanubikums geführt hat. Dieses bildete einen Kern in den Varisziden, der an seinen Rändern durch die mobilen variszischen Zonen unterschoben wird. Die kaledonischen Subfluenzen haben zunächst die Unterkruste betroffen, während die variszische Gebirgsbildung auch die Oberkruste erfaßt hat. Das Orogen wuchs von seinen inneren, älteren Teilen nach außen durch die Angliederung neuer, äußerer Zonen.

Rb-Sr SYSTEMATICS OF INTRUSIVE ROCKS FROM THE MOLDANUBICUM AROUND JIHLAVA

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We report here about the work of the last years that was performed in cooperation of GEOINDUSTRIA Jihlava with the Geologische Bundesanstalt. The study is the continuation of research work that has been started on the Austrian part of the Moldanubian pluton (SCHARBERT 1987, 1989). The area around Jihlava was of special interest because in its vicinity the Monotonous and Varied Groups are cropping out, accompanied by magmatites of very contrasting composition, which are the topic of this paper. The Jihlava and Třebíč Massifs are composed of melanocratic biotite, amphibole, and pyroxene rich rocks and the Central Moldanubian Pluton of light coloured biotite-muscovite bearing granites. Fig. 1 shows the situation of the massifs as well as the sample localities from which Rb-Sr data are presented below.

The Central Moldanubian Pluton (Eisgarn Massif)
The part of the pluton as shown in Fig. 1 extends over a distance of approximately 100 km in NE – SW direction. The maximun width of more than 20 km at the boundary between Austria and Czechoslovakia diminishes to the south and to the north to attain there the shape of apophyses not more than 3 km broad (Fig. 6). It crops out as a body of greater width (Massif of Melechov) NW of Havlíčkův Brod. According to MOTTLOVÁ (1982) the granite is of relatively small thickness in its central parts dipping to

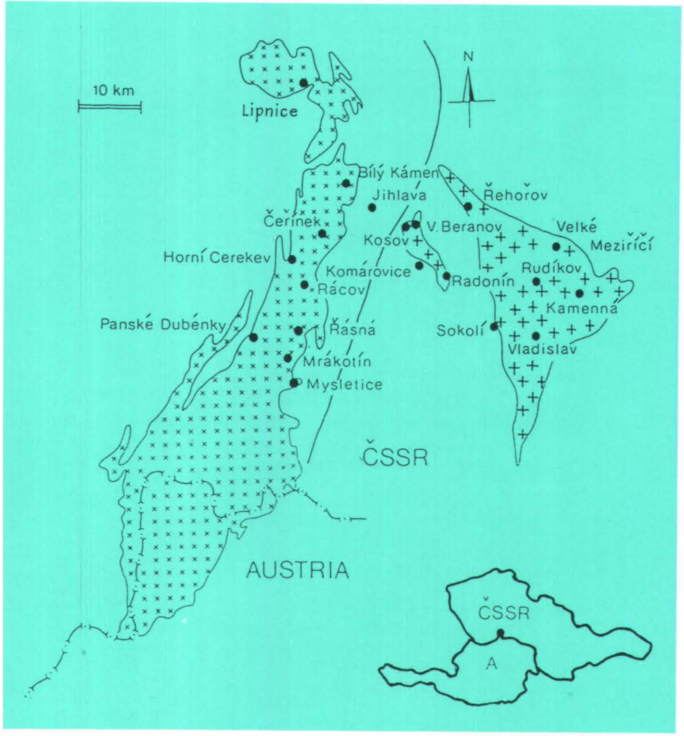
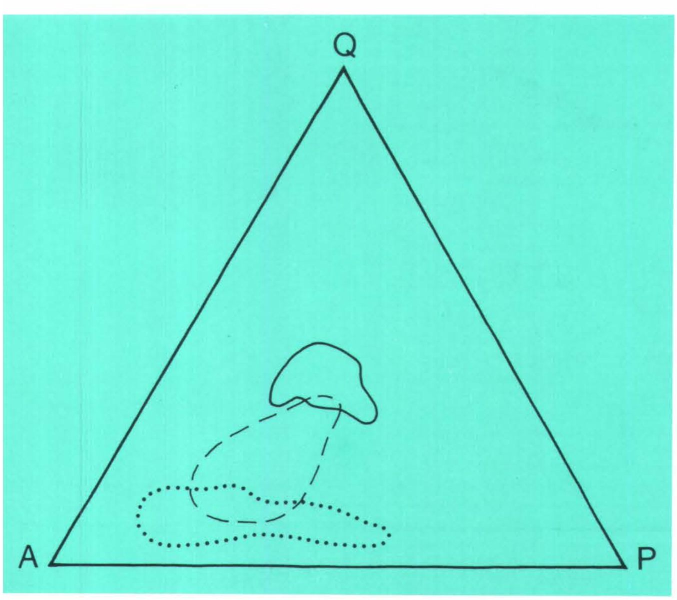


Fig. 1: Geological sketch map of the Central Moldanubian Pluton (oblique crosses) and the Jihlava and Třebíč Massifs (heavy crosses). Black dots are sample localities.

the west. The contacts are sharp and cut discordantly the country rocks of the Monotonous and Varied Groups.

The pluton is composed of Eisgarn type granite. This term comprises Eisgarn type granite s.str. (WALDMANN 1951) as it is exclusively exposed on Austrian territory, and at least three different types in Czechoslovakia: Mrákotín (KOUTEK 1925), Číměř, and Landštejn type (ZOUBEK 1949, DUDEK et al. 1962). The names are given to textural varieties which often cannot be separated clearly, the criteria being the size and amount of the tabular alkali feldspar phenocrysts and grain size (Plate 1). All types are identical in mineralogical and chemical composition (DUDEK et al.

Fig. 2: The composition of rocks investigated in the STRECKEISEN diagram. Full line: Central Moldanubian granites, dotted line: Jihlava Massif, broken line: Třebíč Massif.



1962, BENEŠ et al. 1963, D'AMICO et al. 1982, and SCHARBERT 1966). They contain perthitic microcline, oligoclase, quartz, biotite, muscovite, accessory zircon, apatite, ilmenite, and most typically andalusite, often sillimanite and in places cordierite or its pseudomorphs. Eisgarn type granite s.str. does not contain as much andalusite as Czech varieties and is free from sillimanite and cordierite. According to its composition the granite is ranged among the peraluminous granites (CLARKE 1981).

According to our concept the intrusion proceeded from SW to the NE rising also to higher crustal levels, the part of the massif SW of Jihlava belonging to the apical parts. From southwest to northeast the number and size of enclaves of paragneiss increases, best seen in the quarries of Mrakotín and Rácov. In the latter outcrop the granite grades into pegmatite when it gets in contact with an obviously cool block of cordierite bearing gneiss. In its youngest apical parts the intrusion is accompanied, beside a rich aureole of lamprophyric dykes (NĚMEC 1975), by numerous ore veins, which are part of the Pelhřimov and Jihlava ore district with Pb, Zn, Cu (± Ag, Au) mineralization. Other evidence for "high" level intrusion are muscovite — quartz — greisens, in places mineralized by scheelite, wolframite, and cassiterite, found SW, W and NW of Jihlava in a fine-grained variety (Bílý Kámen type). In the surroundings of Bílý Kámen, xenoliths of cordierite migmatite, granulitic gneiss and amphibolite are sunken into the granite (VESELÁ 1976) indicating its position close to the roof.

Table 1: Rb — Sr data from the Central Moldanubian Pluton

Sample	Locality	Rb ppm	Sr ppm	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$
3/88	Mysletice	297	79.0	10.9_8	.76483 ± 7
13/83	Mrákotín	267	83.4	9.33	.75782 ± 14
24/87	Mrákotín	291	71.4	11.9_0	.76913 ± 12
2/88	Panské Dubénky	320	67.8	13.8_3	.77802 ± 8
23/1/87	Řásná	319	60.7	15.3_7	.78424 ± 10
23/2/87	Řásná	307	65.9	13.6_3	.77583 ± 8
10/84	Rácov	317	74.4	12.4_4	.77159 ± 6
1/88	Horní Cerekev	345	69.1	14.5_9	.77895 ± 4
C 1	Čeřínek	364	47.4	22.4	.81359 ± 12
C 3	Čeřínek	355	46.7	22.2	.81363 ± 8
AB 135	Bílý Kámen	314	58.0	15.8_6	.78602 ± 15
45/85	Bílý Kámen	331	53.6	18.0_6	.79591 ± 8
46/85	Bílý Kámen	341	51.2	19.4_8	.80172 ± 8
47/85	Bílý Kámen, Sr enriched	355	73.0	14.2_2	.77453 ± 5
49/85	Bílý Kámen	345	72.3	14.3_7	.77542 ± 7
AB 136	Bílý Kámen	295	81.5	10.5_7	.75922 ± 20
AB 139	Bílý Kámen	289	108	7.82	.74462 ± 6
AB 138	Bílý Kámen	275	210	3.80_5	.72355 ± 20
AB 134	Bílý Kámen	259	260	2.89_6	.71862 ± 6
AB 137	Bílý Kámen	260	289	2.61_5	.71739 ± 13
50/85	Boršov	230	159	4.19_6	.72685 ± 6
26/1/87	Boršov	224	168	3.87_2	.72554 ± 8
26/2/87	Boršov	226	160	4.11_2	.72650 ± 10
26/3/87	Boršov	221	159	4.03_4	.72615 ± 5
27/87	Pavlov	201	493	1.187	.71068 ± 6
33/86	Lipnice	311	138	6.57_0	.74168 ± 9
34/86	Lipnice	307	80.3	11.1	.76619 ± 11

The homogeneity in chemical composition is reflected in the rather uniform distribution of the trace elements Rb and Sr (Table 1). All varieties of Eisgarn type granite are characterized by high Rb and low Sr content. Nevertheless, Eisgarn type granite s.str. and the other types show two distinct trends in the Rb vs. Sr diagram (Fig. 3), indicating two suites of granites.

For this reason the age of the Eisgarn type granite s. str. was recalculated, rejecting the samples C1 and C3 which obviously belong to the second suite (Scharbert 1987).

The newly calculated age is given now with 318 ± 7 m.y. with an initial Sr isotope ratio of .7143 ± 7. Samples from the northern part of the pluton (see Fig. 1 and 4), slightly lower in Rb, lie on an isochrone defining an age of 303 ±6 m.y., which is significantly different from the age of the southern portion of the pluton. The high initial Sr isotopic

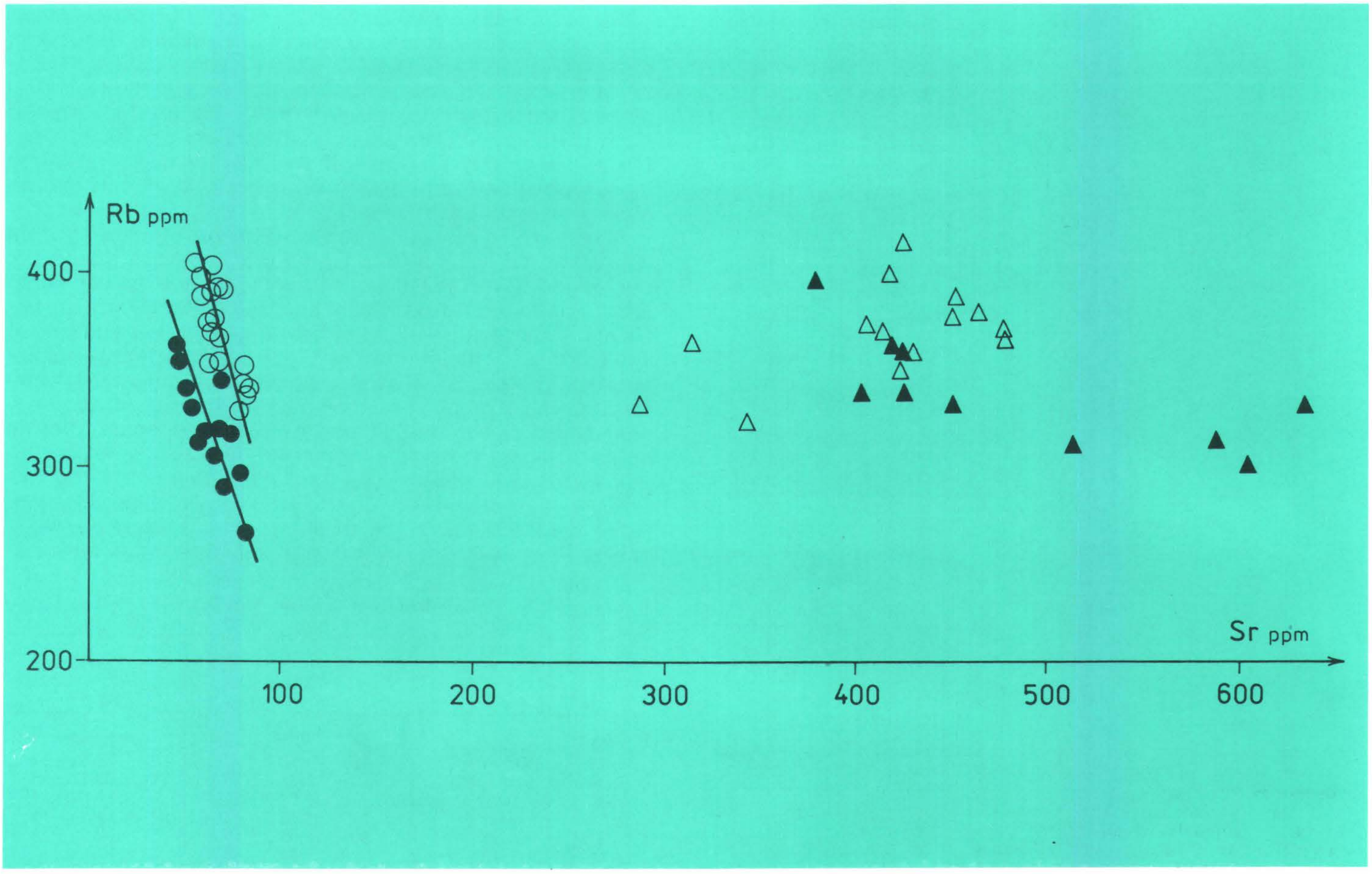


Fig. 3: Rb vs. Sr diagram. Eisgarn type granites from the Czech part of the Central Moldanubian Pluton (full circles) show a different trend than Eisgarn type granite s. str. (open circles). Rocks from the Jihlava Massif (full triangles) and the Třebíč Massif (open triangles) are highly enriched in Rb and Sr.

Fig. 4: Sr evolution diagram of Eisgarn type granite from the Czech part of the Central Moldanubian Pluton.

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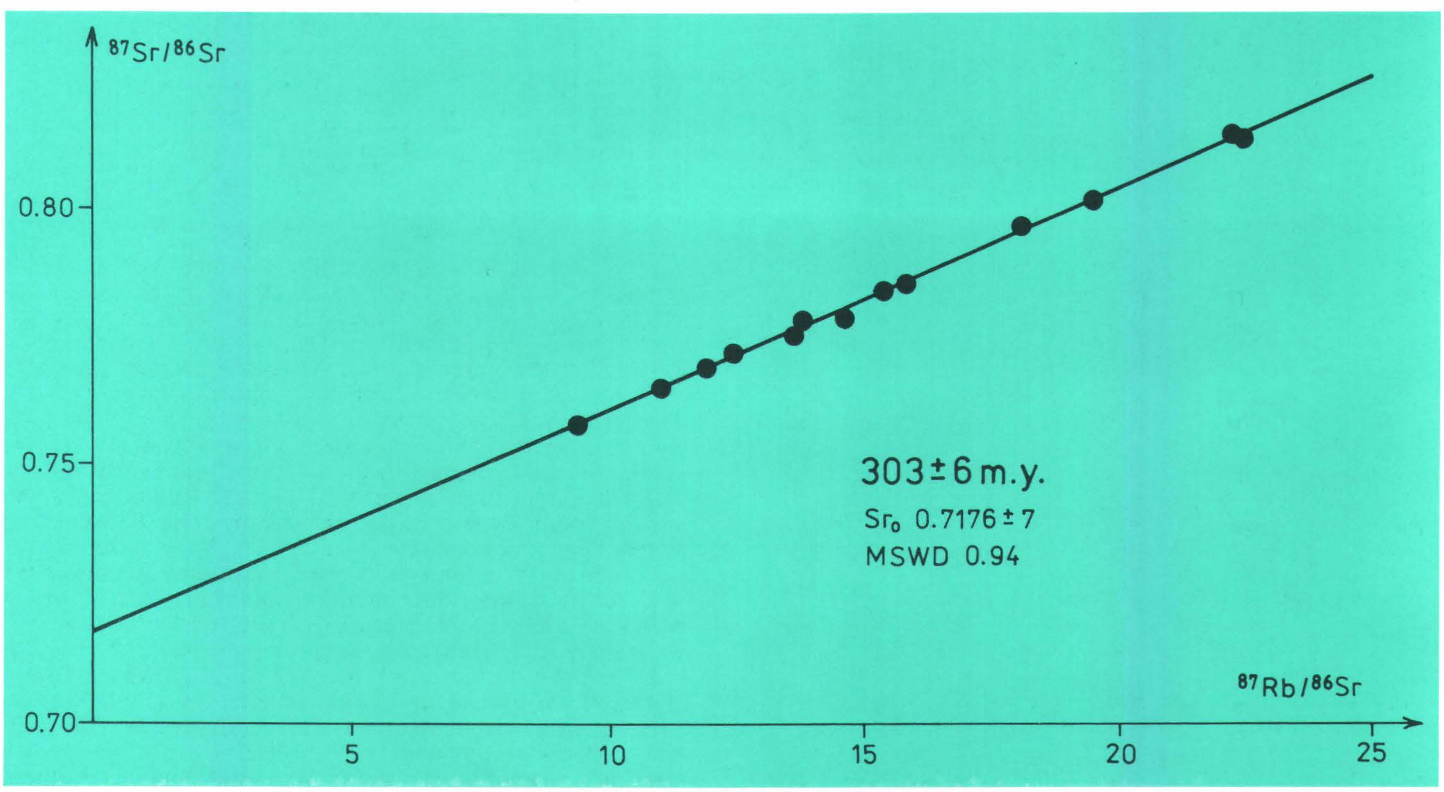

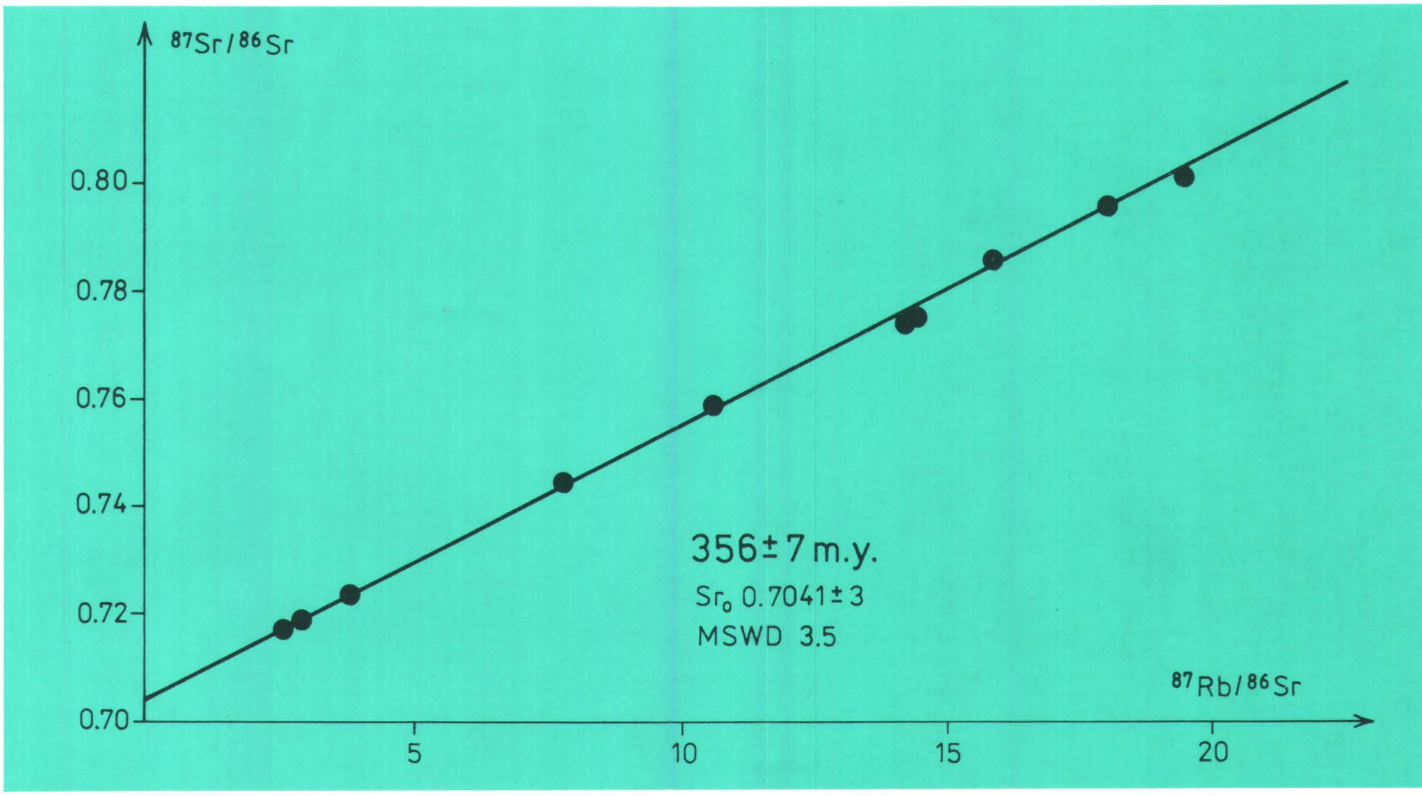

Fig. 5: Sr evolution diagram of biotite — muscovite-andalusite bearing granite from Bílý Kámen quarry. Most of the samples are enriched in Sr which leads to an unrealistic high age, that is, like the low initial Sr ratio erroneous. Three samples with the highest Rb/Sr ratios have been used for construction of the isochrone of Fig. 4.

ratio of .7176 ± 7, the Rb and Sr concentrations (Table 1) and the content of alumosilicates reflect the provenance from molten sedimentary gneisses and places these intrusives among S-type granites.

A peculiar case of disturbance in the Rb-Sr household could be found in the fine-grained granite from Bílý Kámen quarry. In places, the fresh looking samples show deviations from the average Rb and Sr content. In thin sections they exhibit altered feldspars. This hydrothermal alteration certainly is in connection with NW-SE and NE-SW striking faults along which the light granite changes to pinkish grey and greenish grey colour. Due to metasomatic alteration the Rb content slightly decreases, while Sr is highly enriched (Table 1). Nevertheless all samples are linearly arranged in a Sr evolution diagram (Fig. 5), and an age of 356 m.y. can be calculated, which is absolutely meaningless. Following points argue against a geological significance of this date: Eisgarn type granite has a uniformly low Sr content, the low initial Sr isotopic ratio of .7041 ± 3 which would point to low crustal or mantle origin, is in severe contradiction to the content of andalusite, sillimanite, and muscovite.

With the dating method applied we could not resolve age differences of varying textured granites. They are either too small or more likely the granites are contemporaneous and 15 million years younger than Eisgarn type granite s.str. in the southern part of the pluton. Even where texturally different granites are exposed like in Řásná quarry (Plate 1) we do not see a relative sequence of intrusion. There is a sudden change in texture from almost equigranular to porphyric.

Our data are in good agreement with the lead model age of 290 m.y., LEGIERSKY (1973) has given as the time of mineralization connected with the intrusion of the pluton. A great discrepancy arises if we compare our data with those given by GOROCHOV et. al. (1983). The isochrone they present obviously is a mixing line of different types of granitic rocks. From their data we identify fine-grained Lipnice, Pavlov and Boršov intrusives, which certainly come from sources with different Sr isotope compositions.

In the northern part of the pluton we sampled granitoids (Fig. 6) which — with the exception of one Lipnice sample — are geochemically different from Eisgarn type (Table 1). So far we have not been successful in dating these rocks.

Cordierite bearing anatectic migmatite

In the cover of the Central Moldanubian Pluton in the Jihlava area we find cordierite bearing migmatites of the phlebite-stromatite type. While blastic recrystallization occurred in the substratum, anatexis without separation of the mobile portions led to the formation of migmatites of granitic composition (hybrid granites after KRUPIČKA 1968). Sometimes — due to the increased plasticity of the environment — they are of intrusive character. In places they contain rotated inclusions of biotite bearing migmatites, cm to dm large xenoliths of fine-grained biotite and pyroxene bearing paragneisses, and of amphibolites. The xenoliths are oval with or without sharp boundaries (VESELÁ et al. 1988).

We sampled cordierite bearing anatectic migmatite with discordant contacts to the phlebite-stromatite type migmatite from the highway construction site W of the town of Jihlava (Fig. 6). It is macroscopically very similar to granite, but is a very irregularly granular rock. The texture is granitic, in places the feldspars tend to grow as porphyroblasts up to ten mm in size. Quartz and plagioclase form a granoblastic mosaic. Quartz varies from 30 — 50 %, plagioclase up to 20 %, potassium feldspar 3 — 8 %, muscovite 1 — 10 %, and biotite up to 10 %. Strongly pinitized cordierite is present up to 3 %. Accessory minerals are sillimanite, garnet, spinel, zircon, apatite, monazite and ore minerals.

ŠMEJKAL (1964) reported K-Ar ages of 348 m. y. on micas from a locality 30 km NW of Jihlava near Humpolec

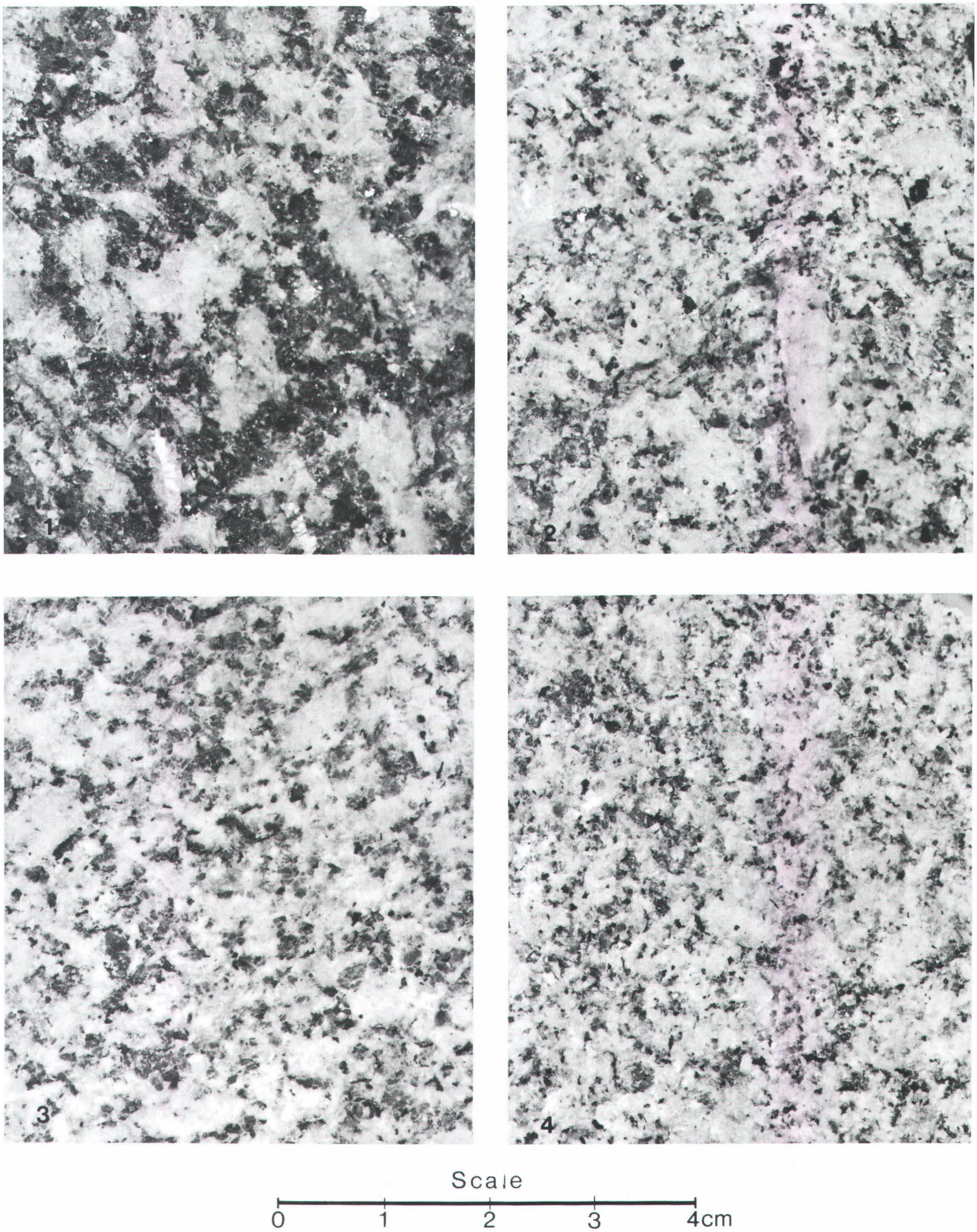

Plate 1: Textural variation of Eisgarn type granite. 1: Eisgarn type granite s. str. from Aalfang (Waldviertel, Austria), 2: sample from the quarry near Mrákotín, 3: "porphyric" variety, quarry near Řásná, 4: "nonporphyric" variety, quarry of Řásná.

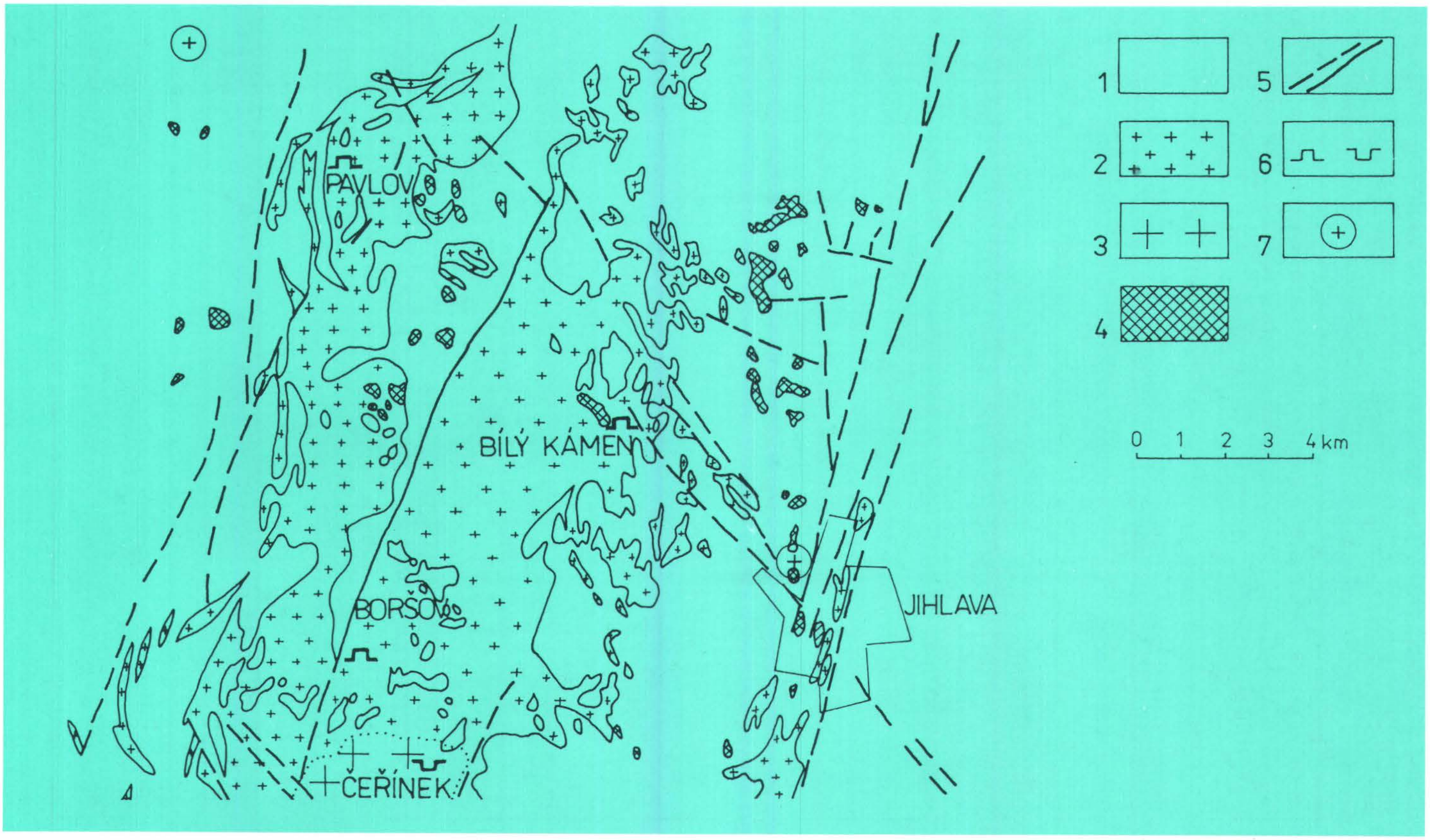

Fig. 6: Geological sketch map based on the new geological map 22—23 Jihlava 1:50 000 by M. VESELÁ 1988. 1: Moldanubian crystalline schists, undifferentiated. 2: Two-mica granites of the Central Moldanubian, Pavlov — Slavníč, and Bílý Kámen type. 3: Two-mica granite of Čeřínek type, texturally most closely related to Eisgarn type granite s. str. 4: Anatectic cordierite-bearing migmatite. 5: Significant faults. 6: Quarry in operation and abandoned. 7: Sampling site of anatectic cordierite-bearing migmatite.

(Fig. 6). Recalculation with the constants of STEIGER & JÄGER (1977) gives 335 m. y. Our Rb-Sr analyses on whole rock samples and an apatite from Jihlava yielded an age of 335 ± 3 m.y. (Table 2, Fig. 7). We interpret this age as the peak of Variscan metamorphism in this area.

The Jihlava Massif

The Jihlava Massif is situated in the Varied Group. It intruded an antiform structure of NW — SE direction, dipping to the E. The contact to the country rocks are sharp, in places discordant, partly concordant. At some sites the contact planes are tectonically rejuvenated. Notably at the eastern contact cordierite migmatites occur (VESELÁ 1988). Inclusions of basic diorite, dm to tens of meters in size are found in the central parts of the massif, also xenoliths of the metamorphic country rocks, sometimes indicated by relictic clusters of garnet and sillimanite. The melanocratic rocks are rich in biotite and pyroxene, sometimes amphibole bearing. They can be classified as quartz monzonites to syenites (Fig. 2). The rocks are massive, grey to greyish green in colour and fine grained. The texture is hypidiomorphic-granular, in places slightly porphyritic. The mineral content comprises andesine, potassium feldspar, quartz, hypersthene, diopside, amphibole and accessory apatite, zircon, sphene, rutile, orthite, and ore minerals. ŠMEJKAL (1964) reports K — Ar ages on biotite of 330 m.y., the age of the Jeclov pegmatite was determined (TONIKA 1970) to be 300 m.y.

Samples for Rb — Sr age determinations were taken from the quarry in Jihlava river valley 1.3 km NE of Kosov, from the excavation of water piping 0.5 km SW of Velký Beranov and from an outcrop in the river valley 1 km NNE of Radonín. The rock is characterized by high Rb and Sr contents (Table 3, Fig. 3). The spread in Rb/Sr ratios is poor and the samples scatter around an errorchrone (Fig. 8), that was constructed including one apatite sample. Due to the scatter it is not possible to determine a precise age, a best estimate is 325 m.y. with an initial Sr isotope ratio of ~.712.

In the quarry of Kosov dykes of tourmaline bearing aplite and of granitic composition had been sampled as well. Aplite yielded an age of 314 ± 3 m.y. with a high initial Sr ratio of .7180 (Fig. 9, Table 3). The granitic samples (Fig. 10, Table 3) produced an age that is older than the host rocks. This date of 357 m.y. and the Rb and Sr content point to a close relationship to Bílý Kámen type granite that was interpreted as being metasomatically altered, and thus is an erroneous age. From the vicinity of the Jihlava Massif, S of the community of Komárovice a sample of baryte was investigated, that accompanies the Pb, Zn, Cu mineralization. Nothing clear can yet be said about the provenance of the material with regard of the Sr isotope ratio.

Table 2: Rb — Sr data from the anatectic cordierite-bearing migmatite west of Jihlava

Sample number	Rb ppm	Sr ppm	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$
15/83	153	171	2.592	.72439 ± 10
16/83	111	149	2.175	.72237 ± 6
17/83	122	169	2.098	.72197 ± 7
18/83	143	182	2.287	.72285 ± 15
19/83	104	151	1.998	.72151 ± 7
19/83/Apatite	3.98	153	$.075_5$	.71236 ± 15

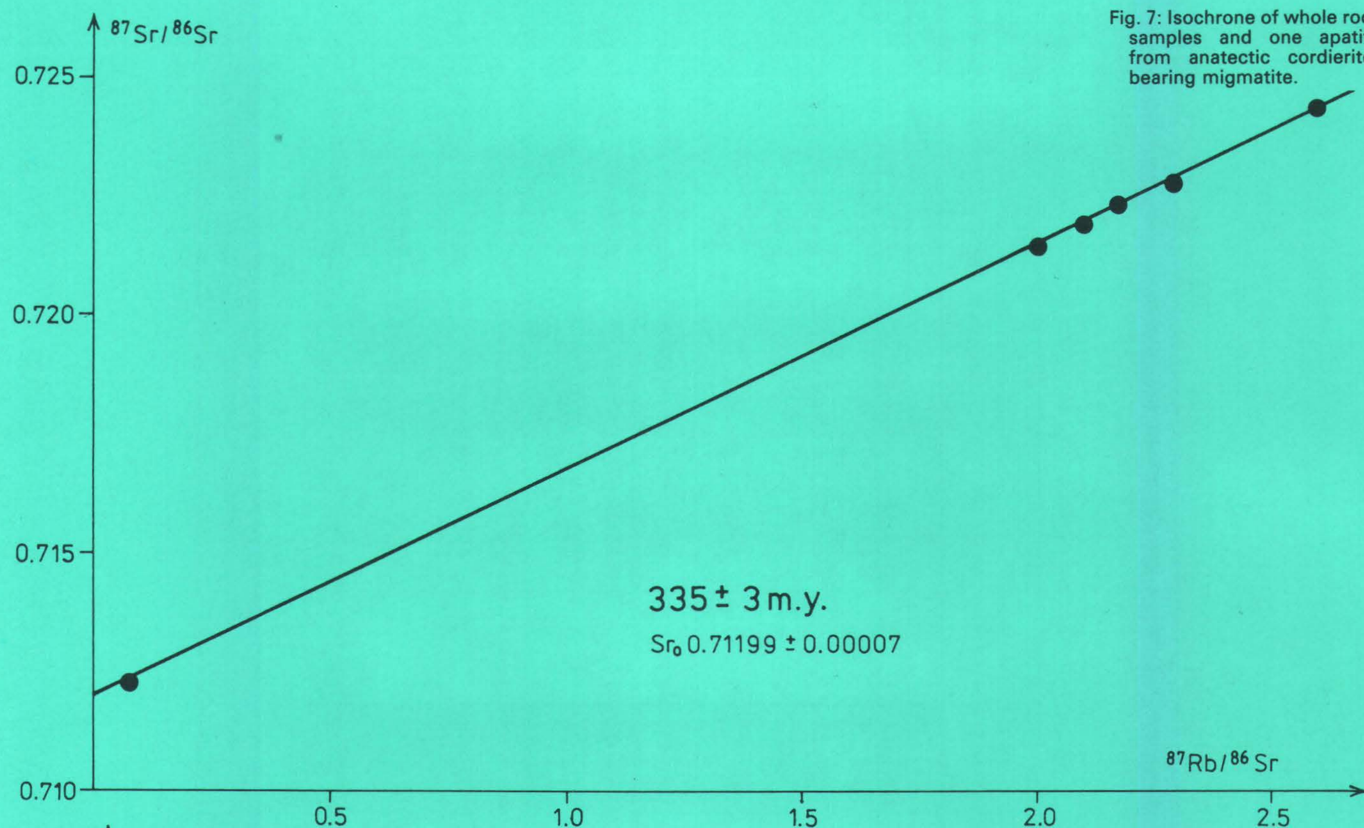

Fig. 7: Isochrone of whole rock samples and one apatite from anatectic cordierite-bearing migmatite.

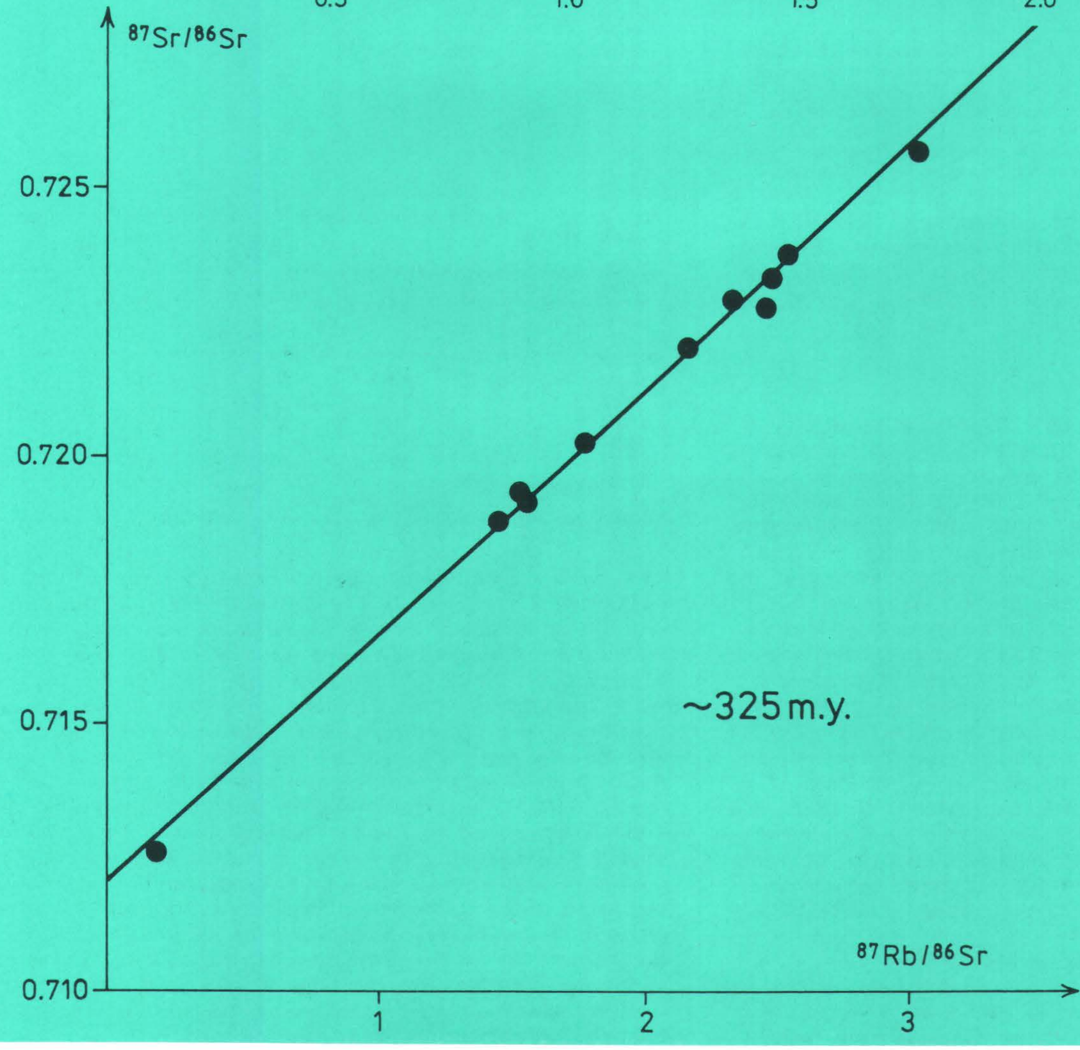

Fig. 8: Sr evolution diagram of ten whole rock and one apatite samples from the Jihlava Massif. The best estimate on age is 325 m. y., but must be regarded with reservation.

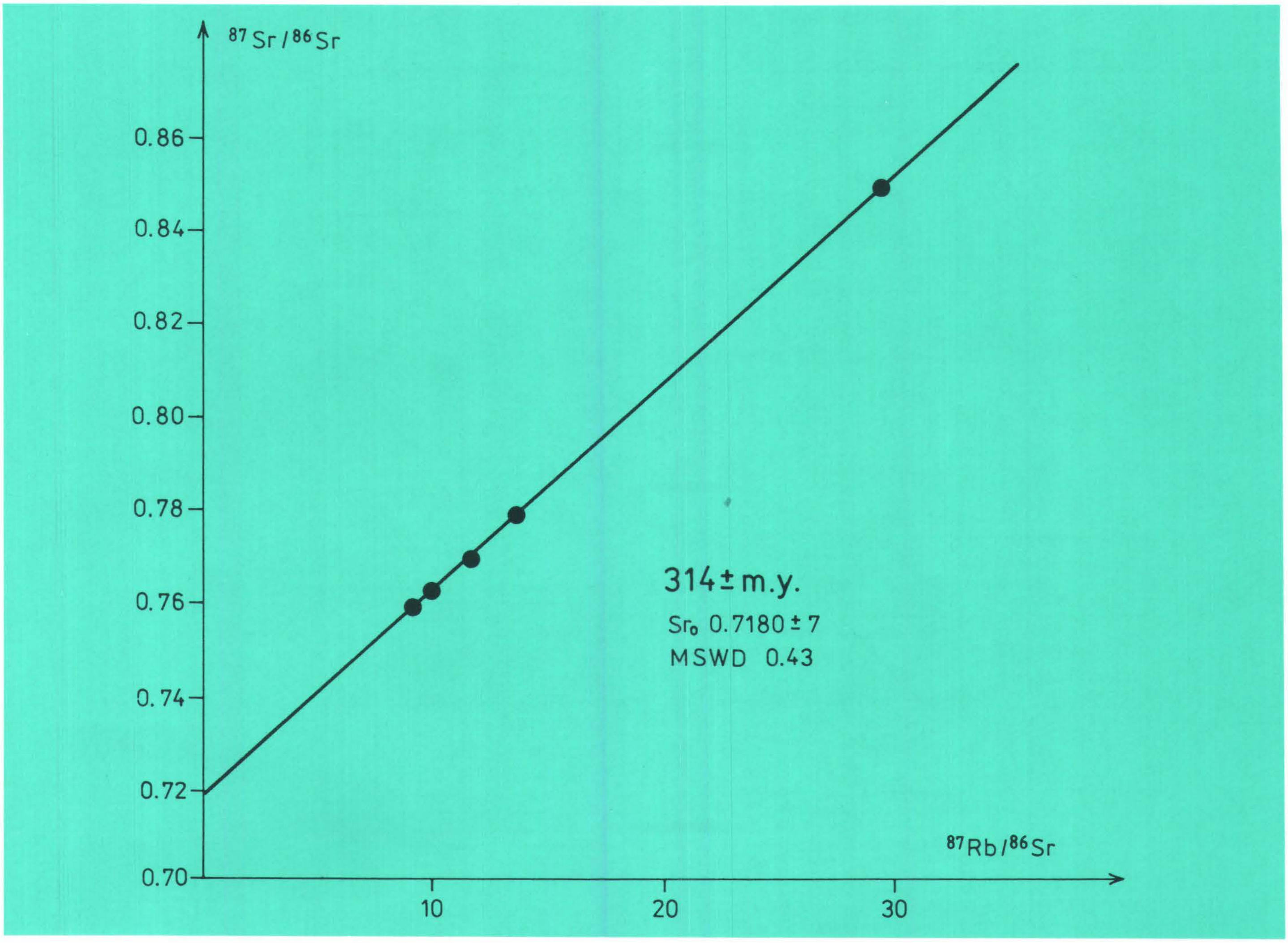

Fig. 9: Isochrone of tourmaline bearing aplites from the quarry of Kosov.

The Třebíč Massif

It forms a triangular shaped body, which discordantly penetrates at the western margin the rocks of the Varied Group (VESELÁ 1986). The bulk composition is very variable. Porphyric melanocratic amphibole and biotite bearing granites to melanocratic quartz syenites prevail. They consist of K-feldspar, plagioclase (oligoclase to andesine), quartz, biotite, and amphibole with accessory apatite, sphene, zircon, orthite, often epidote, and ore minerals. In places syenites with rare rhombic pyroxenes are frequent. The coarse-grained and porphyric granitic varieties contain feldspar phenocrysts up to four cm in size, more basic types of 1.5 — 2 cm size. In the border zones and inside the massif occurs a fine-grained facies with potash feldspars of mm size and isolated phenocrysts one cm long, and irregularly dispersed plagioclase grains. In the massif comparatively large blocks of crystalline schists along mylonite zones can be mapped. There occur also numerous dark streaks and schlieren which can not unequivocally be proved as being the rests of assimilated country rock material. Near the margins of the massif elongate, lenticular melanocratic inclusions of metabasite were observed, many of dioritic composition.

The geochemical composition of the Třebíč Massif varies. BUBENÍČEK (1968a, 1968b) reports a decrease in acidity from S to N and from W to E. He assumes that the northern and nothwestern halves belong to higher parts of the body, which have taken up and assimilated material, while S of the town of Třebíč uncontaminated and therefore more acid material crops out. We observe a similar trend in Rb — Sr geochemistry: samples close to the northern border are rich in Sr. Sr decreases going south to Rudíkov and Kamenná, being lowest in Vladislav. Rb obviously decreases only slightly (Table 4, Fig. 2).

We took samples from the following localities: Řehořov, road cut 1 km NNE (fine-grained basic facies and basic inclusion) and 3 km NNE of the community; Velké Meziříčí, road cut N of the city, quarry of Kamenná, boulders 1 km S of Rudíkov, and quarry of Vladislav, 3 km E of Třebíč. Isotope analyses of Sr failed to produce geochronological data (Fig. 11). From the geological description we know that the rocks are of most heterogeneous composition. Obviously many parts of the massif represent "mixed" rocks of basic composition low in radiogenic Sr and Rb (samples AB 184 — 187) and granitic material. The high concentration of Rb along with a high Sr content is a unique geological feature not often encountered within granitoid rocks. These rock types exposed in the Třebíč and also in the Jihlava Massif put the problem on the origin of granites which are highly enriched in Rb, K, and Mg (HOLUB 1988). In cases like these the Rb — Sr method has reached the limits of applicability, and other methods of dating must be envisaged.

Methods

Rb and Sr have been determined by isotope dilution techniques. $^{87}Sr/^{86}Sr$ was calculated from spiked samples. For isotope ratio measurements a VG MM 30 solid source mass spectrometer was used. For calculations the con-

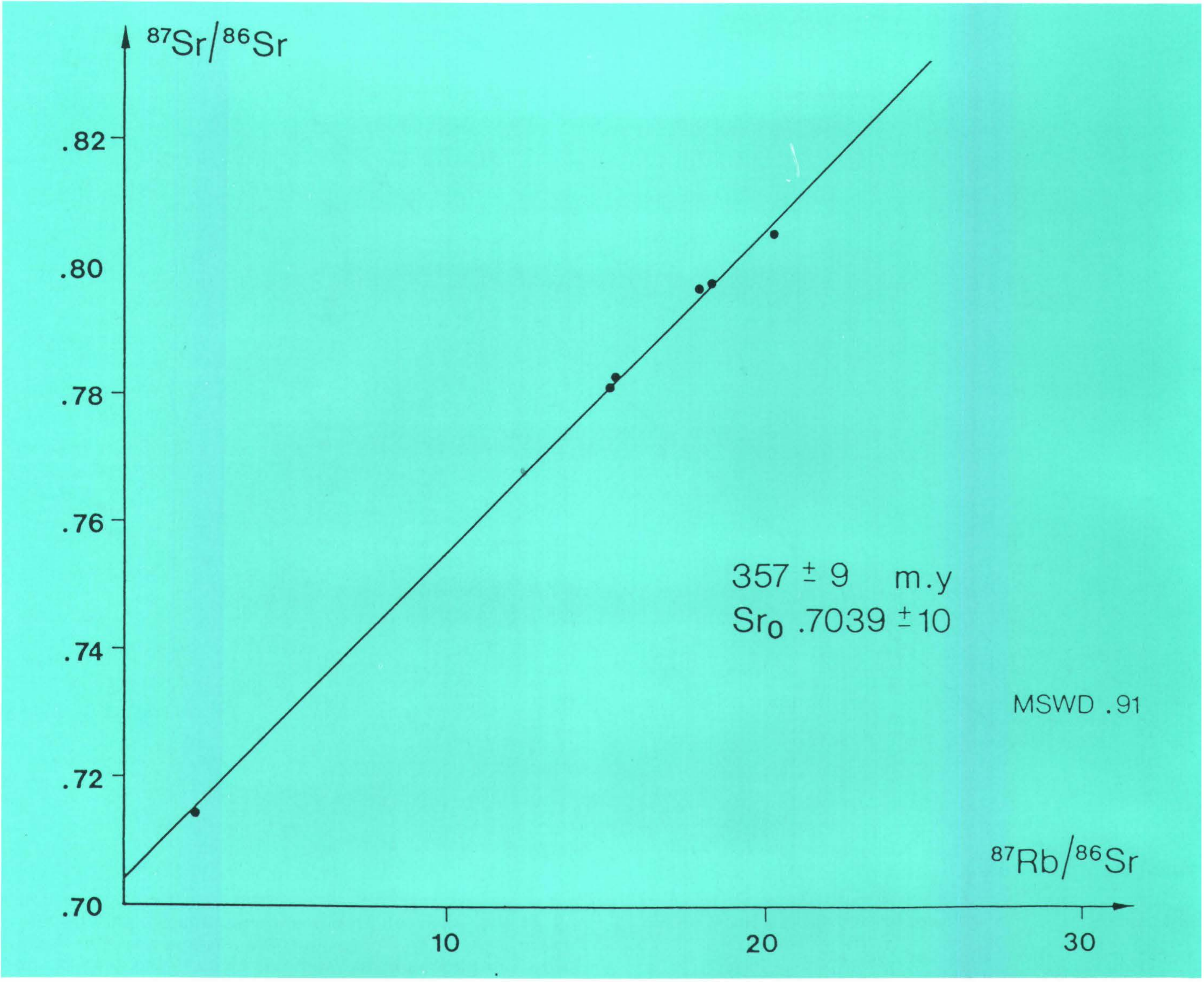

Fig. 10: Isochrone of granitic rocks from the quarry of Kosov, exhibiting the same peculiarities like Bílý Kámen type granite (Fig. 6). For the same reasons this "age" must be rejected.

stants given in STEIGER & JÄGER 1977 have been used, with $\lambda\ ^{87}/Rb = 1.42 \times 10^{-11} \times a^{-1}$. The isochrones are calculated by the method of YORK 1969 following the program of McSAVENNY in FAURE 1977, using model 1, where all sample points are weighted equally. All errors quoted are on the 95 % confidence level (2σ). Errors on $^{87}Rb/^{86}Sr$ are assumed to be 1 %, 2σ errors on $^{87}Sr/^{86}Sr$ are the standard error on the mean.

Acknowledgement

We would like to express our gratitude to Dr. P. Květon for continuing support of our work. Ing. M. Jelenc did a fine job in the chemical laboratory. S. Laschenko, A. Jilka and G. Schnürer had much patience in preparing the drawings and photographs.

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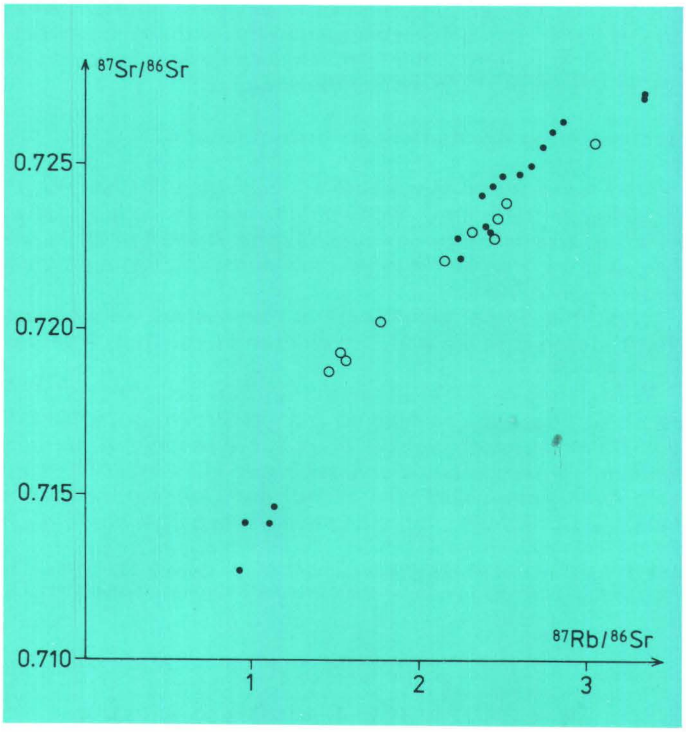

Fig. 11: Sr evolution diagram of rocks from the Třebíč Massif (black dots). The linear alignment of sample points is very poor and no age can be calculated. It seems that the rocks have originated by mixing of material with differing radiogenic Sr. For comparison samples from the Jihlava Massif (open circles) are plotted.

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Table 3: Rb — Sr data from the Jihlava Massif

Sample	Locality	Rb ppm	Sr ppm	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$
		Syenite			
AB 142	Kosov	315	586	1.55_7	.71908 ± 10
AB 143	Kosov	304	603	1.45_8	.71875 ± 11
AB 144	Kosov	334	634	1.52_9	.71927 ± 14
AB 145	Kosov	361	425	2.46_8	.72336 ± 6
AB 146	Kosov	339	425	2.321	.72296 ± 3
AB 179	Kosov	313	513	1.77_3	.72023 ± 8
AB 181	Kosov	363	419	2.51_8	.72381 ± 12
AB 183	Kosov	333	450	2.15_3	.72206 ± 14
7/84	Beranov	398	379	3.04_7	.72565 ± 21
36/86	Radonín	340	403	2.45_3	.72276 ± 14
AB 143/Apatite	Kosov	6.3_2	98.6	$.18_6$	.71261 ± 10
		Tourmaline-bearing aplite, Kosov			
G 1		152	32.6	13.6_3	.77921 ± 14
G 3		144	36.3	11.6_1	.76941 ± 10
G 4		137	43.0	9.2_7	.75957 ± 8
G 5		177	17.7_1	29.4_8	.84894 ± 21
AB 140		143	41.5	10.0_6	.76271 ± 15
		Granitic dykes, Kosov			
Gr 1		324	51.9	18.2_8	.79744 ± 14
Gr 2		314	59.7	15.3_8	.78242 ± 4
Gr 3		202	274	2.13_9	.71458 ± 5
Gr 4		312	59.8	15.2_7	.78160 ± 6
Gr 5		349	50.4	10.2	.80541 ± 13
Gr 6		325	52.9	18.0_2	.79665 ± 5
41/86/Barite	Komárovice	79_5	4438	.0005	.71407 ± 6

Table 4: Rb — Sr data from the Třebíč Massif

Sample	Locality	Rb ppm	Sr ppm	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$
VM 1	Velké Meziříčí	417	415	2.86_0	.72630 ± 7
VM 2	Velké Meziříčí	381	465	2.38_4	.72404 ± 10
VM 3	Velké Meziříčí	389	453	2.50_0	.72463 ± 19
VM 4	Velké Meziříčí	379	452	2.43_7	.72432 ± 15
VM 5	Velké Meziříčí	401	418	2.79_0	.72599 ± 8
AB 147	Řehořov	360	430	2.43_4	.72291 ± 20
VM 6	Řehořov	371	415	2.60_0	.72471 ± 12
VM 7	Řehořov	374	406	2.67_7	.72494 ± 13
8/84	Řehořov	372	478	2.25_6	.72214 ± 9
9/84	Řehořov	351	424	2.40_6	.72307 ± 15
52/85	Řehořov	367	479	2.22_8	.72273 ± 9
AB 184	Řehořov, basic inclusion	171	541	$.92_7$	.71272 ± 10
AB 185	Řehořov, basic inclusion	168	429	1.13_9	.71466 ± 12
AB 186	Řehořov, basic inclusion	131	395	$.96_1$	.71416 ± 13
AB 187	Řehořov, basic inclusion	171	447	1.11_3	.71415 ± 15
37/86	Rudíkov	365	315	3.36_5	.72701 ± 13
25/87	Kamenná	324	344	2.73_8	.72551 ± 11
38/86	Vladislav	333	288	3.36_1	.72704 ± 9

Abstrakt

Rb—Sr analýzy moldanubických hornin z širšího okolí Jihlavy přinesly tyto výsledky: Centrální moldanubický pluton je několikanásobnou intruzí, v níž peraluminiová žula eisgarnského typu vykazuje v severní části stáří 303 ± 6 mil. let s počátečním poměrem radiogenního Sr .7 176 ± 7, je tedy o 15 mil. let mladší než eisgarnská žula jižních částí na rakouském území. Lokálně metasomatickyměněná žula vykazuje abnormálně vysoké stáří (356 mil. let), jež nemá geologický význam. Vrchol variské metamorfózy byl u anatektického cordieritického migmatitu stanoven na dobu před 335 ± 3 mil. let. Neobvyklý Rb—Sr chemismus syenitoidních až granitoidních hornin jihlavského a třebíčského masívu ukazuje na jejich komplikovaný vznik, jehož dobu nelze určit pomocí užité metody. Turmali-

Zusammenfassung

Rb-Sr-Analysen moldanubischer Gesteine aus der weiteren Umgebung von Jihlava ergaben folgende Resultate: Der Zentralmoldanubische Pluton ist eine multiple Intrusion aus peraluminosem Eisgarner Granit, der im nördlichen Teil ein Alter von 303 ± 6 Mio. J. hat bei einem Sr-Initial von .7176 ± 7 und somit um 15 Millionen Jahre jünger ist als der Eisgarner Granit in den südlichen Teilen auf österreichischem Gebiet. Ein lokal metasomatisch veränderter Granittyp ergibt ein abnormal hohes Alter (356 Mio. J.), das geologisch bedeutungslos ist. Der Höhepunkt der Metamorphose wurde an anatektischen cordieritführenden Migmatiten mit 335 ± 3 Mio. J. bestimmt. Syenitische bis granitische Gesteine der Massive von Jihlava und Třebíč haben eine komplexe

nický aplit v jihlavském masívu vykazuje stáří 314 ± 3 mil. let s počátečním poměrem radiogenního Sr .7180 ± 7.

Entstehung und eine ungewöhnliche Rb- und Sr- Chemie. Sie können mit der angewandten Methode nicht datiert werden. Turmalinführende Aplite aus dem Jihlava-Massiv haben ein Alter von 314 ± 3 Mio. J. mit einem Sr-Initial von .7180 ± 7.

DAS HISTORISCHE BEBEN VON 1768 IN NIEDERÖSTERREICH NACH EINER MAKROSEISMISCHEN STUDIE VON K.U.K. HOFMATHEMATICUS JOSEF NAGEL

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Einleitung

Das Erdbeben vom 27. Februar 1768 ist das zweitstärkste Ereignis in Niederösterreich seit Beginn der Chroniken im Jahre 1201. Es wurde nachweislich in weiten Teilen Ungarns und der ČSSR wahrgenommen. Die Schwere des Ereignisses läßt sich auch daran messen, daß durch ein volles Jahrhundert, bis 1868, in Wiener Neustadt eine kirchliche Gedenkfeier abgehalten wurde.

Der primäre Gegenstand dieser Arbeit ist die Nachbearbeitung der Bebenmeldungen zur Darstellung der Isoseistenkarte und auch eine Würdigung der makroseismischen Arbeit des k. k. Hofmathematicus Josef Nagel und des k. k. Astronomen Dr. phil. Pater Hell. Nagel wurde 1749 zum Hofmathematiker ernannt. Er wurde 1772 Direktor der physikalischen und mathematischen Studien an der Wiener Hohen Schule und Präsidiumsmitglied der philosophischen Fakultät.

Bisherige Untersuchungen

Verschiedene Autoren haben sich bisher mit diesem Beben beschäftigt. Procházková und Drimmel, 1983, haben nach Sichtung des Archivmaterials in Prag, Bratislava und Wien die Isoseiste 4° MSK angegeben.

Im Atlas of Isoseismal Maps der Akad. d. Wiss., Prag 1978, wurden einige Intensitätsangaben in der ČSSR bis zum 51. Breitengrad dargestellt.

Die erste Maximalintensitätsangabe (I_0 = 8° MSK) und Angabe des Epizentrums findet sich bei Toperczer und Trapp, 1950. Suess, 1873, widmet diesem katastrophalen Naturereignis einen eigenen Abschnitt in seiner Arbeit über die Erdbeben in Niederösterreich. Hier wurde hauptsächlich die Uhrzeit und Lage des Hauptstoßes bestätigt, verschiedene Vor- und Nachbeben chronologisch festgehalten.

Radics, 1906, gibt nun detailliert den Inhalt des Berichtes von Nagel wieder, den er, wie auch Suess, 1873, als die Hauptquelle der bis dato erschienenen Schriften ansieht. Die Definition von Linien vergleichbarer Schadenwirkung (derzeitige Isoseistenkarten) wurde zum ersten Mal von Mallet, 1862, nach einer wissenschaftlichen Untersuchung des Neapelbebens von 1857 durchgeführt. Nahezu 90 Jahre vorher hat Josef Nagel wohl die erste „makroseismische Forschungsreise'' unternommen und seinen offiziellen Bericht am 22. Dezember des gleichen Jahres an die Kaiserin Maria Theresia erstattet (s. Abb. 1).

Dieser Bericht ist objektiv und fachmännisch verfaßt, gibt die damalige Denkweise und den Wissensstand wieder und ist unentbehrlich für die Beurteilung der Intensität. Nagel reiste damals von Ort zu Ort, suchte und befragte die „studierten" Leute, von denen er sich — berechtigterweise — die konkretesten Aussagen erwartete, stellte ihre Meinungen dar und kommentierte sie. Er besichtigte Schäden an Gebäuden und die Auswirkungen des Bebens, beschrieb und philosophierte über den Ursprung des Ereignisses, seiner Wesenheit und seiner Verbreitung.

Beschreibung der damaligen Untersuchung

Also wird dem Hofmathematicus Joseph Nagel *allergnädigst befohlen, sich dahin, wo es nöthig seyn möchte, zu verfügen, um zuverlässige Nachricht einzuziehen, was sich an einem oder dem anderen Orte eigentlich zugetragen hätte.*

Daraufhin begibt sich Nagel auf eine etwa vierwöchige Reise, deren Strecke und Ortschaften in der Abb. 2 dargestellt sind.

In Baden (I = 6° MSK) berichtet ihm der Landschaftsapotheker Herbst, *„so bald es Tag geworden, zu den dortigen Bädern geeilet, um die etwa vorgegangene Änderung wahrzunehmen; wo er dann auch das Wasser etwas trüb gefunden, einen häufigern Zufluß der Quellen und deren mehrere Schwängerung mit schwefelichen Theilen, folglich*

Abb. 1: Titelblatt des am 22. Dezember 1768 an die Kaiserin Maria Theresia erstatteten und veröffentlichten Berichtes des Hofmathematicus J. Nagel.

Ausführliche Nachricht

von dem

am 27ten Hornung dieses laufenden Jahrs 1768.

in und um Wien

erlittenen Erdbeben,

auf allerhöchsten Befehl

überall an Ort und Stelle eingezogen

von

Hrn. Joseph Nagel,

k. k. Hofmathematico,

und nunmehr dem wißbegierigen Leser mitgetheilet.

WIEN,

gedruckt bey Johann Thomas Edlen von Trattnern,

k. k. Hofbuchdruckern und Buchhändlern.

1768.

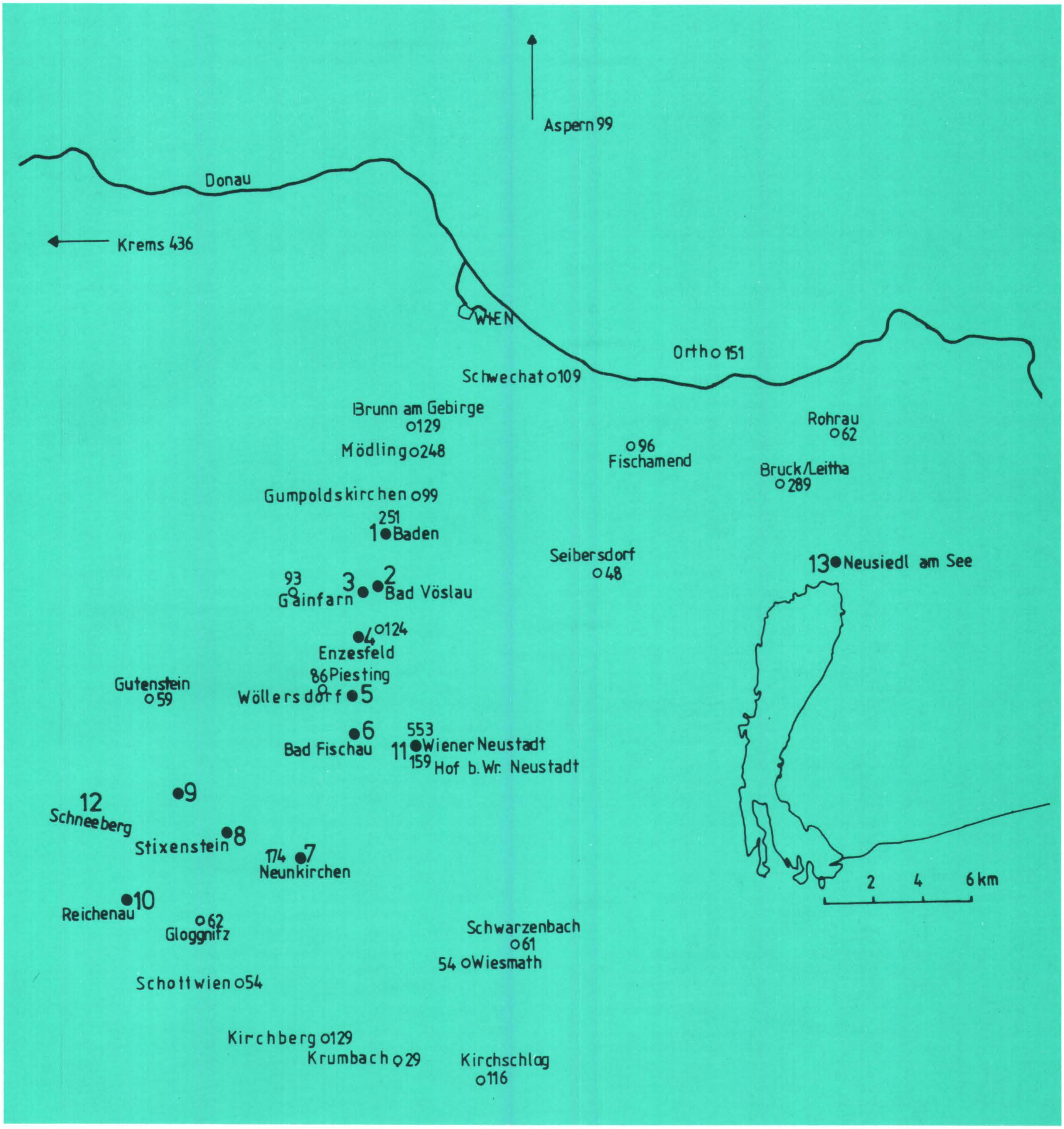


Abb. 2: Reiseetappen von Nagel (Punkte Nr. 1 bis 13). Die offenen Kreise sind Ortschaften mit der Anzahl der Häuser um 1789. (Altes Stadtbuch, Stadtarchiv Wr. Neustadt).

eine merklich größere Wärme wahrgenommen hätte; welches alles denn nicht anders als eine Wirkung dieser Erderschütterung anzusehen, und dermals wieder in seinen vorigen Stand zurückgetreten wäre". Nagel nahm die Quelle mit dem absonderlichen Namen „Ursprung" in Augenschein und stellt fest, daß das Wasser darin um einen Zoll höher, als sonst gewöhnlich stand.

In Gainfarn (I = 6,5° MSK) befragt er den Pfarrer, der ihn über Vor- und Hauptbeben ausführlich informiert: *„Nach Mitternacht einige Minuten vor 1 Uhr empfanden viele der damals schon munteren Bauersleute einen weiteren Stoß, insonderheit der Nachtwächter. Dieser lehnte sich kurz vorher an eine bis 8 Schuhe hohe Mauer eines Bauernhäusleins, um auszurasten, ward aber etliche Augenblicke lang samt seiner Stütze erschüttert, als ob selbe mit ihm umfallen wollte. Er machte sich davon, und ging den nächsten Blassenberg hinauf, um sich bey den hellen Strahlen des Mondes weiter umzusehen. Während dem Hinaufgehen hörte er, daß die Erschütterung in einen Knall, wie aus einem groben Geschütze, über den Blassenberg hin gegen*

Norden ausbrach. Ob dieser Knall nicht eine Öffnung am Gipfel des Berges nach sich gelassen, hat man noch zur Stunde wegen Tiefe des Schnees nicht nachspüren können. Den 27. Hornung Morgens um 3/4 auf 3 Uhren kam der fürchterlichste Stoß mit diesen mir wohl bewußten Umständen. Beyläufig 10 Minuten vor 3/4 auf 3 ließ sich ein Getöse hören, wie man in der Gegend einer auf 1/4 Meile entlegenen Hammerschmiede wahrnimmt. Auf solches fortdauernde Hämmern folgte ein so gewaltiger Stoß von unten auf, daß er mich, so wie einige andern von hier, beynahe aus dem Bette geworfen." Die Bevölkerung von Gainfarn, schon aufmerksam gemachte Inwohner, blieben die Nacht hindurch unter freyem Himmel, wo sie, im Garten des Pfarrers, gewachet und gebetet hat.

Bisher größte Schäden erlebt er im Schloß Brunn am Steinfeld (I = 8° MSK): *„Allda siehet man eine gänzliche Verwüstung; also daß, nach wiederhergestellter Erdruhe, fast keiner Herzhaftigkeit genug besessen hat, das Hausgeräthe herauszuholen und selbiges in Sicherheit zu bringen. Die heruntergestürtzten Rauchfänge haben theils die Dächer eingeschlagen, theils den Hof mit Schutt angefüllt, das äußere Hausgesims ward von seinem Lager getrennet und zum Falle gebracht; und die Gewölber, absonderlich in der Kapelle, wurden dermaßen auseinander getrieben, daß die Schlußsteine vielmehr schweben als hängen, der übrigen gräulichen Zerspaltungen nicht zu gedenken, welche das ganze Gebäude unwohnbar machen."*

Er fragte sich, weshalb Gebäude unterschiedlicher Bauart und Alter auf das Beben mit verschiedenen Zerstörungsgraden reagiert haben: *„Nicht weniger ist verwunderlich, daß die unterirdische Kraft, welche das Schloß so sehr mitgenommen hat, in dem kaum 50 Schritte von dar gelegenen neuen Gebäude nur sehr geringe Merkmale ohne die mindeste üble Folge zurückgelassen habe: da jedoch das alte Gemäuer, wie das am Schlosse, gemeiniglich fester als das neuere zu seyn pfleget."*

Obwohl Nagel im höchst baufälligen Gewölbe des Schlosses allen Anlaß einer Einsturzgefahr erkennt, möchte er die Ursache der unterschiedlichen Schäden eher an dem Wassergraben, ebenso wie bei der Burg in Wiener Neustadt, sehen. Er hält die alten Gemäuer für widerstandsfähiger als die Mauern der neuen Wirtschaftsgebäude.

In einer weiteren Etappe macht Nagel nun Beobachtungen, die mit dem Einfluß der lokalen Geologie, Gründungsart der Gebäude und Epizentralentfernung im Zusammenhang stehen: *„In Stixenstein* (I = 6,5° MSK), *einem Schlosse, welches dem Herrn Grafen von Hoyos zugehörig und auf einem sehr hohen Felsen zwischen noch viel höheren Bergen gelegen ist. Die erhabene Lage desselben und die Nachbarschaft des Schneeberges, falls sich der Sitz der Ursache in seinem Busen hätte befinden sollen, machen mich befürchten, allda noch ärgere Spuren der Verwüstung als anderswo anzutreffen: aber die Wuth der Erschütterung war wider mein Vermuthen allhier viel leidentlicher gewesen, als zu Brunn und zu Neustadt."*

Da das Epizentrum bis dato nicht bestimmt werden konnte, äußert sich Nagel mißbilligend über andere Berichterstatter: *„Bisher haben sich verschiedene geschmeichelt, den eigentlichen Feuerherd des Erdbebens entweder unter dem Neusiedlersee, oder in dem Busen des fürchterlichen Schneeberges ganz sicher entdeckt zu haben."* Daher nähert sich Nagel der Schneeberggegend mit der Befürchtung, *allda noch ärgere Spuren der Verwüstung als anderswo anzutreffen. Nichts als Elend und betrübte Überbleibsel eingestürzter Wohnungen und anderer Gebäude* erwartet der Forschungsreisende in Puchberg (I = 6,5° MSK), doch er findet *mit Vergnügen* kaum Beschädigungen. In Reichenau (I = 5,5° MSK), noch näher am Schneeberg gelegen, hatte *man noch weniger gelitten.*

„Ich war begierig, auch noch auf der anderen Seite des Schneeberges weitere Nachricht einzuholen, aber der damals in diesen Gegenden noch liegende tiefe Schnee machte mein Vorhaben sozusagen unmöglich."

Auf dem Weg zum Neusiedlersee wird Nagel in Wiener Neustadt unmittelbarer Zeuge des Nachbebens am 21. März 1768 um 9 Uhr. Das Beben war nicht stark und wurde nicht einmal in Neunkirchen verspürt. Das zeitliche Geschehen dokumentierte er mit folgenden Sätzen: *„Dieserwegen führe ich hier nur an, daß am oft gedachten 27. Hornung sechs verschiedene Erschütterungen allda sind beobachtet worden. Nämlich die erste und heftigste, welche all gegenwärtiges Übel nach sich gezogen hat, Morgens um 2 3/4 Uhr, die zweite um 4 3/4 und die dritte um 5 1/2 Uhr. Weiters die 4. Nm. um 3 Uhr, die fünfte um 6 Uhr und endlich die sechste um 9 Uhr Abends, welche letztere sich zwar mit wenigen, doch gewaltigen Stößen geäußert hat."*

Die Auswirkungen auf die Gebäude und Bewohner in einer großen Siedlung wie Wiener Neustadt (I = 7,5° MSK) erfahren wir neben Nagel auch vom k. k. Astronomen Pater Hell (Wienerisches Diarium, 9. 3. 1768). Beide führen vorher an, daß ein Vorbeben, kurz und schwach, sich am 26. Februar bereits um 23 Uhr 30 von einigen Personen gespürt worden ist.

„Den 27. um 3/4 auf 3 Uhr wurde die Stadt durch den ersten gewaltigen Stoß aus dem Schlafe erweckt. Nach Aussage der Schildwacht, die beim großen Thore der Burg, worin die Militärschule ist, Wache hielt, soll der erste Stoß von Süden gegen Norden, mit einem so entsetzlichen unterirdischen Brausen und einem so heftigen Winde begleitet geschehen sein, daß diese Erschütterung die Schildwache zu Boden geworfen und alle Schlafenden erweckt, welche ihre Betten und Zimmer verlassen und in den anliegenden Garten geflohen sind, wo sie bis den 28. Abends 7 Uhr verblieben.

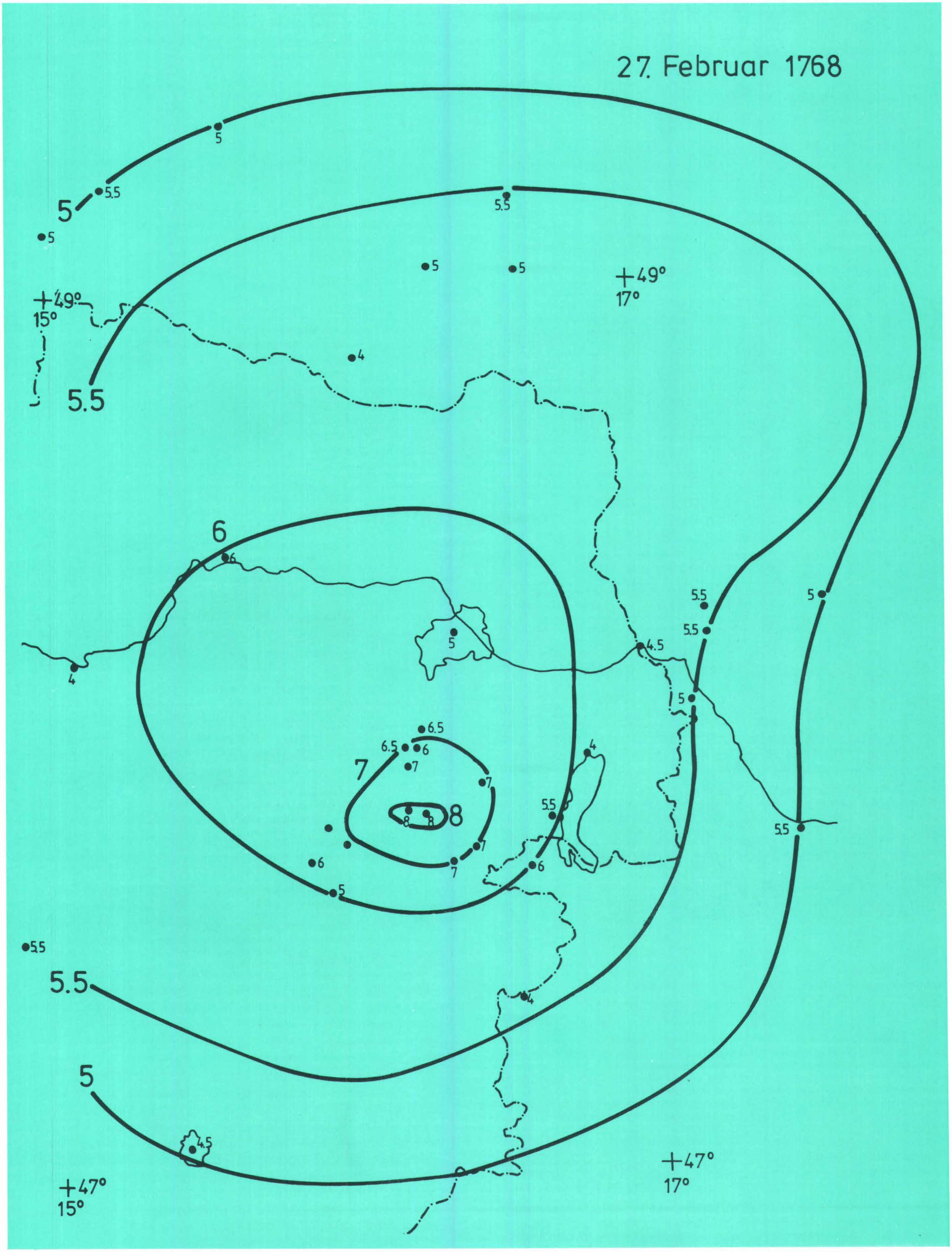
Die Hauptmauern spalteten sich, die an den vier Ecken stehenden Thürme wurden von oben bis unten nach der Ordnung, deren Fenster an allen drey Theilen zerrissen, die Dachfenster herabgeworfen, die Gewölbe aus ihren Widerlagern gehoben, abgebrochen und in viele Stücke gespalten, einige Schornsteine umgeworfen, mit einem Worte, das ganze Gebäude ist so entsetzlich zugerichtet worden, daß es nunmehr zur Wohnung unbrauchbar ist und folglich einen beträchtlichen Schaden erlitten hat. Auch die alte, auf gothische Art gebaute Kirche hat sowohl an den Gewölben als den Gesimsen, so ganz von Stein sind, verschiedene Merkmale dieser Erschütterung bekommen. Die übrigen Häuser in der Stadt sollen fast alle die traurigen Merkmale dieses erschröcklichen Erdbebens aufzuweisen haben; doch hat Gott der barmherzige die lieben guten Einwohner dieser guten Stadt von größeren Übeln bewahrt, sie müssen in Wahrheit der allmächtigen Güte Gottes den brünstigsten Dank sagen, daß keiner aus allen erschlagen oder sonst am Leibe beschädigt worden."

Als Vergleich hiezu ist es interessant zu erfahren, wie der k. k. Astronom seine eigenen Beobachtungen in Wien (I = 5° MSK) beschreibt: *„Nach 3/4 auf 3 Uhr fing der astronomische Thurm erschrecklich an zu beben. Die fünf Schellen gaben einen Klang von sich und alles wurde bewegt; man hörte ein unterirdisches Getöse, Sausen und Brausen, welches einem im Sode sprudelnden Wasser ähnlich schien. Die Erschütterungen waren nicht schwankend, sondern kamen von unten herauf schnell nacheinander, nicht anders als wenn unter der Erde eine mineralische Materie in voller Gärung stünde. Diese Erschütterung dauerte mehr als 30 Sekunden lang, in welcher Zeit etliche hundert der vorbeschriebenen Stöße mit erstaunender Geschwindigkeit folgten* (I = 5° MSK).

Die Leute aus der Gegend des Neusiedlersees (I = 5° MSK) berichteten, daß sie das Beben kaum verspürt haben. *„ . . . und was den See beträfe, so hätte man dabey nichts anders Außerordentliches bemerket, als daß in gedachter Nacht das bis 3 Schuh dicke Eis, womit eben damals seine ganze Oberfläche überzogen gewesen, durch die gelittene Erschütterung vielfältig zerrissen, und hier-*

▶

Abb. 3: Isoseistenkarte des Bebens vom 27. Februar 1768. Der Epizentralbereich liegt heute bei Bad Fischau (Brunn am Steinfelde)/Nö.


27. Februar 1768
+49°
15°
+49°
17°
+47°
15°
+47°
17°
5
5.5
6
7
8
5.5
5

durch ein entsetzliches Krachen und Getös verursachet worden wäre".

Nagel bestimmt, entgegen der Meinung anderer zeitgenössischer Wissenschafter (Pater Hell führt z.B. den Schneeberg als Zentrum an) aufgrund seiner Lokalaugenscheine das Epizentrum *„nicht weit von gemeldtem Brunn und vielleicht wohl allda, wo die Bäder zu Baden gewärmet werden".*

Über die Ursache des Bebens entwickelt Nagel seine eigene Theorie, wobei die Ausdehnung des Schüttergebietes von der Herdtiefe sowie die Intensitätsabnahme mit der Entfernung zur Sprache kommen.

„Hätten also diejenigen nicht einen größeren Beyfall zu gewarten, welche dafür halten, daß die Natur keiner so weitläufigen Gänge nöthig habe, sondern sich mit einer mäßigen Höhle zu ihrer Werkstatt begnüge, worin das unterirdische Feuer, welches aus der Vermischung gewährender Materien erzeuget wird, das Wasser in Dünste auflöse, und diese die eingeschlossene Luft so lang zusammen drücken, bis endlich die Erdenlast dieser Kraft nicht mehr widerstehen könne, und daß sothane Höhle so tief in die Erde versetzet sey, als nöthig scheinet, von daraus, als aus einem Punkte einen gewissen Theil des Erdbodens in Bewegung zu setzen, welcher bewegte Theil um so größer seyn wird, je tiefer sich die Höhle unter der Erde befindet. Nicht anders als wie eine mit Schießpulver gefüllte Mine um so mehreres Erdreich in der nämlichen Zeit über sich wirft, je tiefer dieselbe angelegt ist.

Solcher Gestalt ließ sich leicht begreifen, wie es möglich sey, daß bey einem Erdbeben mehrere weitläufige Länder in einem Augenblicke können erschüttert werden, und warum ein Ort mehr als der andere beweget werde: Nämlich, derjenige muß der Bewegung am meisten ausgesetzt seyn, welcher sich gerade über dieser Höhle befindet, die übrigen aber um so weniger, je mehr sie sich von dem Punkte entfernen, welcher auf der Oberfläche der Erde von einer Linie bestimmt wird, die durch die Höhle und Mittelpunkt der Erde gehet."

Vorläufige makroseismische Karte des Bebens

Die verfügbaren zeitgenössischen Dokumente aus den Gebieten des heutigen Österreichs, Ungarns und der Tschechoslowakei wurden nach der seismischen Intensitätsskala MSK 1964 ausgewertet. Analog zu vielen anderen späteren Beben zeigt die innere Isoseiste (Abb. 3) eine deutliche Ost-West-Erstreckung, die auch die Richtung der Herdfläche andeutet, die geringe Intensitätsabnahme nach Norden wird durch die äußeren Isoseisten (5° und 5,5°) angezeigt. Das Epizentralgebiet lag bei der Ortschaft Bad Fischau, westlich von Wiener Neustadt, die Maximalintensität betrug 8° MSK. Bestimmte Inseln kleinerer Intensitäten, wie z.B. der Bereich um Wien (Duma, 1988), wie in Abb. 3 dargestellt, werden noch untersucht.

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Abstrakt

Zemětřesení, ke kterému došlo 27. ledna 1768, je možno pokládat na základě kronik, které se datují od roku 1201, za druhé nejsilnější v Dolním Rakousku. Zemětřesení bylo zaznamenáno rovněž na velké části Maďarska a Československa. Epicentrum zemětřesení leželo ve vesnici Brunn a. Steinfelde, nedaleko Wiener Neustadt v Dolním Rakousku, jeho intenzita byla 8° MSK.

Hlavním cílem předkládaného článku bylo revidovat tehdejší zprávy o zemětřesení pro sestavení izoseizmické mapy a vzdát hold makroseizmické práci Josefa Nagela, císařského a královského dvorního matematika, a Dr. Maxmiliána Hella, císařského a královského dvorního astronoma.

Abstract

The earthquake of February 27th, 1768, was almost the strongest one in Lower Austria after chronicles started with the year of 1201. It is easy to show that it has been noticed also in large parts of Hungary and in Czechoslovakia, too. Its epicentre was in Brunn am Steinfelde, a village near Wiener Neustadt/Lower Austria, its intensity 8° MSK.

The main intention of this paper will be the reexamination of contemporary reports on the earthquake for drawing the isoseismic map as well as a homage to the macroseismic work of Josef NAGEL, Imperial and Royal court mathematician, and Dr. Maximilian HELL, Imperial and Royal court astronomer.

BIOGEOCHEMISTRY OF SMALL CATCHMENTS

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A small catchment is a well-defined drainage basin or watershed with the surface area usually of tens to hundreds of hectars but sometimes even substantially smaller or larger. The set of investigated processes can be greater if the basin contains one or more small lakes. Most often the catchment is situated in a comparatively undisturbed landscape i. e. in areas not affected by local environmental impacts. These areas could be typical for a larger region of a given biome. The ecosystems in the catchment are preferably in a late stage of ecological succession, e. g. forests.

By investigation of the biogeochemical processes the inputs and outputs of energy and matter to the catchment and out of it are studied: the atmospheric deposition of rain, snow, fog, particles or gases, evaporation and degassing, subsurface and surface runoff of water with dissolved and undissolved material, incoming solar radiation and outgoing infrared radiation fluxes. Biological processes comprise exchange of energy, water, and gases by photosynthetic and respirative processes and water transpiration. It is of key importance to investigate any man-caused flows of matter and energy.

These observations are complemented by the investigation of the processes within the catchment, such as rock weathering, chemical and mechanical erosion, soil processes including soil biology, limnological and hydrobiological processes, internal biogeochemical cycles within the forest and other ecosystems, the dynamics of living organisms and their biogeochemical role. Attention is paid not only to the more or less regular processes such as the accumulation of a certain compound in the soil but also to all sorts of seasonal or random episodes such as thaws, storms, floods, and remarkable biological events.

To improve our understanding of the functioning of the catchment's biogeochemistry, experiments could be performed. These include liming, fertilization, irrigation, biological manipulations, forest management, artificial acidification, and controlled release of chemicals including radioisotopes. Such studies could also be helpful in establish-

Table 1 — Characteristics of the catchments

Catchment		Location	Altitude m a.s.l.		Surface area ha	Vegetation cover	Bedrock	Mean annual precipitation mm	Mean annual temperature °C
Name	Code		Highest	Lowest					
Na Lizu	SUM	13°41′E 49°04′N	1 073	825	101	spruce forest 100 %	gneiss	950	4.8
Mlynářův luh	MLL	13°50′E 50°00′N	546	400	202	mixed forest 100 %	rhyolites andesites	535	6.8
Jezeří	KRH	13°28′E 50°33′N	924	475	261	demaged spruce forest 50 %	gneiss	850	5.8
Salačova Lhota	TRN	15°00′E 49°32′N	744	557	168	spruce and pine forest 100 %	gneiss	700	6.2

ing countermeasures against anthropogenic influences.

For more complex elucidation of various biogeochemical processes — e. g. hydrochemical ones — mathematical models may be applied. Models exists e. g. for short-term episodic simulation of stream water chemistry and for long-term prediction of future response to changes in environmental parameters such as atmospheric deposition patterns.

The concept of biogeochemical investigation enables us to integrate more or less isolated, divergent, or at least not directly connected studies. Main features of the new approach are:

i) The work of various specialists is tied up by the common objective to study the energo-material processes which could be expressed in terms of matter and energy fluxes. All studied processes are recognized as constituents of biogeochemical "metabolism" of the whole catchment.

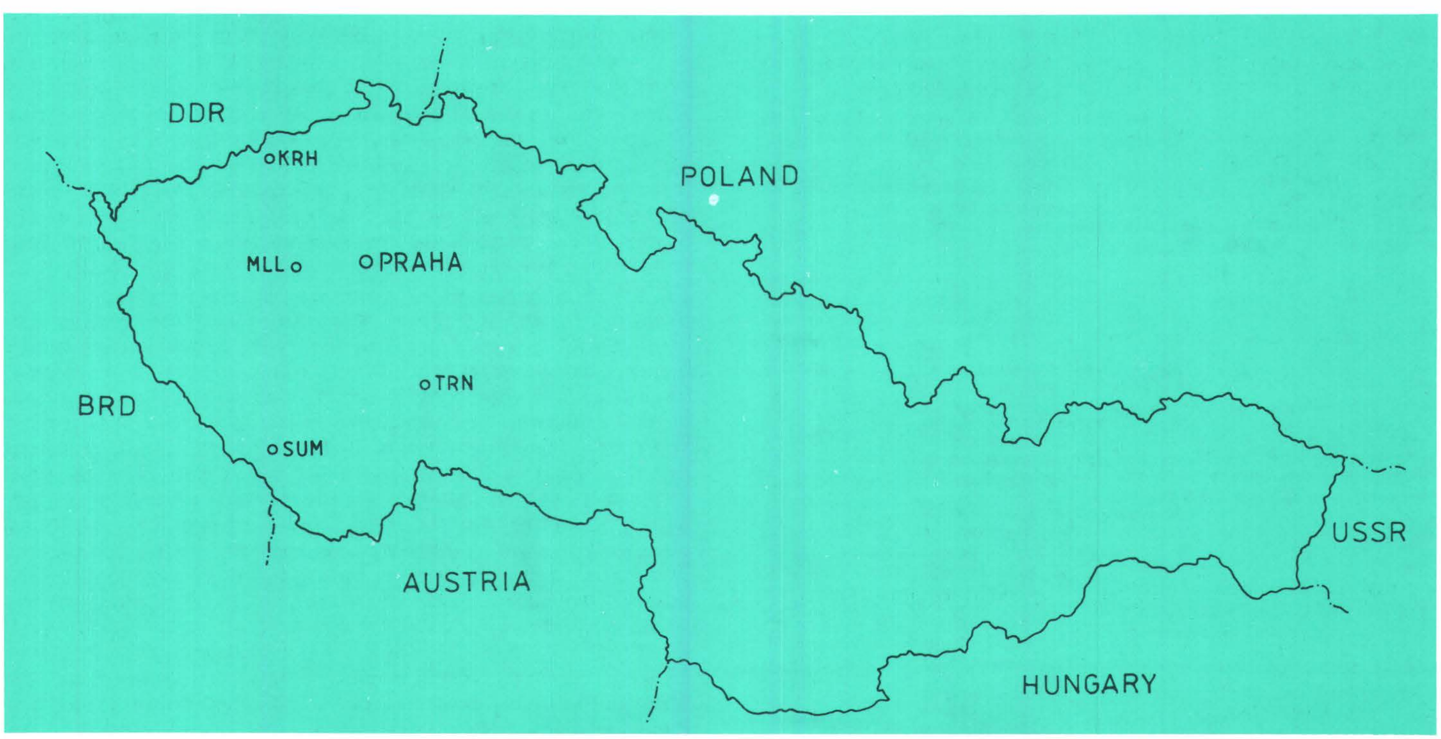
ii) The studies are located in one place and coordinated in time. The area of a small catchment can be regarded as a sort of nature laboratory. It has naturally delineated borders and the hydrological, geological, biological, and other conditions can be well defined. In the same time it is both a part of a real biome and a laboratory-like workplace equipped with hardware where measurements can be repeated and checked and experiments can be performed.

At present, small catchment research is going on in at least 20 different countries. Most of it is concentrated into temperate forest zone of Europe and North America but catchments in other biomes including tropical zones of South America are studied, too. In Europe, an informal network already exists covering the whole 'pollution gradient' from pristine landscape in Northern Scandinavia to heavily affected areas of Central Europe. A proposal for establishing a world-wide network of small catchments has already been formulated.

Our research group within the Geological Survey of Prague has been studying biogeochemical processes of small catchments since 1974. We started to measure main fluxes and other phenomena in about five forested and agricultural small catchments within the Trnávka River Basin (about 80 km southeast of Prague). At present, we are investigating catchments in Křivoklátsko Biosphere Reserve (40 km west of Prague), in Krušné hory Mts and in Šumava Mts in addition to Trnávka catchments (Fig. 1). The basic characteristics of the catchments are summarized in Table 1.

The areas where catchments are located represent different "pollution landscapes" of Bohemia. The differences are well documented by the level of the typical constituents of acidic atmospheric deposition, sulphur and hydrogen ions (Table 2).

Fig. 1: Geographical location of small catchments studied by Geological Survey, Prague.



Under development is the net of about 20 catchments covering the whole area of Czechoslovakia. We have collected basic information on 45 catchments out of which the final set will be carefully selected.

Long-term integrated biogeochemical research and monitoring of small catchments has proven to be a very valuable tool for assessing both natural and man-made changes in the environment. The list of environmental impacts reflected by processes in small catchments includes — among others — acidification of soils, surface and ground water, depletion of nutrients and accumulation of harmful substances in the soil, transport of atmospheric pollution, changes in physical and chemical parameters of climate, e. g. growing concentration of CO_2 or depletion of stratospheric O_3, effects of land-use on the geochemical balance, e. g. eutrofication. The monitoring can reveal the effects of the reduction of emissions of sulphur and nitrogen agreed by European countries.

The geochemical and integrated monitoring of small catchments and the investigation of biogeochemical processes within them is the main programme of the Environmental Geochemistry Group of the Prague Geological Survey. We recommend to our Austrian colleagues to start with similar research in their country. There, to our knowledge, no monitored small catchment exists yet. We offer our rather long experience. The results from Austria will be very valuable especially when related to the data from existing catchments in Switzerland, Federal Republic of Germany, and Czechoslovakia.

Table 2 — Atmospheric deposition into small catchments

Catchment	Substance	Wet deposition		Dry deposition	Total
		vertical	horizontal		
SUM	S	**18**	**8**	**11**	**37**
	H^+	0.5	0.2	0.9	1.6
MLL	S	15	0	39	54
	H^+	0.41	0	3.0	3.4
KRH	S	30	71	80	164
	H^+	0.79	0.4	9	6.1
TRN	S	12	0	13	25
	H^+	0.32	0	1.0	1.3

Units: kg $ha^{-1}yr^{-1}$. Wet vertical deposition: rain, snow.
Wet horizontal deposition: fog, rime-ice.
Dry deposition: absorption of acidic gases SO_2, NO_x.

Abstrakt

Malá povodí jsou vybraná území o rozloze okolo 1 km², situovaná většinou v přírodních oblastech, nesmějí být ovlivněna lokálními zdroji znečištění. Povodí jsou vybavena komplexem technických zařízení, jež umožňují integrovaný výzkum biogeochemických procesů. Jde především o látkové vstupy (například atmosférická depozice) a látkové výstupy (povrchový a podzemní odtok). Uvnitř povodí se sledují další procesy (půdní, biologické apod.). Výsledky přinášejí spolehlivé informace o celkovém stavu přírodního prostředí. Ústřední ústav geologický sleduje malá povodí ve čtyřech oblastech, v rámci ČSSR je budován systém Geomon. Rakouské straně se navrhuje zahájit obdobný výzkum.

Zusammenfassung

Kleine Einzugsgebiete (Flußbecken) sind ausgewählte Gebiete mit einer Flächenausdehnung von etwa 1 km², die meistens in Naturgebieten gelegen sind. Sie sind mit einem Komplex technischer Einrichtungen ausgestattet, die eine integrierte Erforschung der biogeochemischen Vorgänge ermöglichen. Dies betrifft vor allem die Stoffzufuhr (z. B. atmosphärische Niederschläge) und -abfuhr (ober- und unterirdischer Abfluß). Innerhalb des Einzugsgebiets werden weitere Vorgänge (Boden-, biologische Vorgänge usw.) untersucht. Die Untersuchungsergebnisse bieten eine verläßliche Auskunft über den Gesamtzustand der natürlichen Lebensumwelt. Die Geologische Zentralanstalt in Prag verfolgt kleine Einzugsgebiete in vier Regionen, im Rahmen der ČSSR wird das Geomon-System aufgebaut. Der österreichischen Seite wird vorgeschlagen, ähnliche Forschungen aufzunehmen.

THE LOCHKOVIAN-PRAGIAN BOUNDARY IN THE LOWER DEVONIAN OF THE BARRANDIAN AREA (CZECHOSLOVAKIA)

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Summary from: Jahrbuch Geol. Bundesanst., Bd. 128, Heft 1, p. 9—41. Wien, Mai 1985

Six selected sections of the Lochkovian-Pragian boundary beds in the Barrandian area of central Bohemia were subjected to investigations of mega- and microfossils. Joint occurrence of different stratigraphically important fossil groups, particularly dacryoconarid tentaculites, conodonts, chitinozoans, trilobites, brachiopods, graptolites a. o. allows a correlation from different viewpoints. The Lochkovian-Pragian boundary as originally defined is drawn in a conformable succession of marine carbonate rocks which include fine-grained pelagic up to shallow-water biodetrital facies. The faunal relationships and lineages suggest an uninterrupted development and evolution. The Lochkovian-Pragian boundary interval and the boundary proper is distinguishable by means of dacryoconarid tentaculites, conodonts, chitinozoans, trilobites, brachiopods, echinoderms, etc. A proposal for a conodont-based Lochkovian-Pragian boundary is presented.

LOWER PALEOZOIC IN THE RESEARCH COOPERATION BETWEEN AUSTRIA AND CZECHOSLOVAKIA

Jiří Kříž, Ústřední ústav geologický, Praha, Czechoslovakia

There are very close paleogeographic relationships between the Lower Paleozoic rocks of Czechoslovakia and Austria and this is an obvious reason for close research cooperation between the both countries. Recent cooperation started a little more than twenty years ago when after the world war the first Austrian geologists (H. Flügel et al.) realized first visits of Bohemian and Moravian Lower Paleozoic localities. In exchange J. Kříž (1969) and I. Chlupáč (1970), both from the Geological Survey, Prague, visited Austrian localities in the Carnic Alps, in Gratz Area and in the "Grauwacken Zone" where H. P. Schönlaub (Geologische Bundesanstalt, Vienna) mapped Lower Paleozoic rocks and studied conodonts for stratigraphic purposes. J. Kříž collected Silurian bivalves in the Carnic Alps during his first (1969) and further visits (1975 and 1982). Detailed study of the family Cardiolidae (Kříž 1974 and 1979) showed that bivalves represent one of important groups to correlate Silurian of Austria and Silurian of the Prague Basin. Since carbonate sedimentation occurred in the Silurian of the Carnic Alps earlier than in Bohemia, the first known Silurian epibyssate Bivalvia developed here earlier (in the middle Wenlock). Silurian bivalves of the Carnic Alps represent important ancestral forms of lineages which later (upper Wenlock, Ludlow and Přídolí) prospered in the Prague Basin as "Bohemian type" Bivalvia dominated communities (Kříž, 1984).

To correlate the Silurian and Devonian of Austria and Bohemia H.-P. Schönlaub visited several times geological sections in Bohemia to sample them for conodonts. In cooperation with J. Kříž particular attention was paid to the Ludlow and Přídolí sections and more than 250 large samples were processed for conodonts in Schönlaubs laboratory in the Geologische Bundesanstalt in period 1973—1982. Biostratigraphic results were submitted in 1981 and 1983 in a form of proposals to the International Subcommission for the Silurian Stratigraphy (I.U.G.S.) to establish Přídolí as internationally accepted highest subdivision of the Silurian System with its international boundary stratotype in Bohemia. Schönlaub's contribution on conodonts represented substantial part of these submissions. In 1984 the proposal of working group (Kříž, Jaeger, Schönlaub) was accepted internationally by the International Stratigraphic Commission at the International Geological Congress in Moscow. Later, the monograph on the Přídolí was published by Kříž, Jaeger, Paris and Schönlaub (1986).

During 1975 and 1982 field trips to the Carnic Alps also Upper Ordovician brachiopods were collected at the Hoher Trieb section in the Carnic Alps (Uqua Formation). They were studied in detail and results published by Havlíček, Kříž and Serpagli (1987). Another important study of uppermost Ordovician brachiopods from the Hoher Trieb section prepared in cooperation (Jaeger, Havlíček, Schönlaub 1975) should be mentioned at this place.

Conodont studies were also realized by Schönlaub in cooperation with I. Chlupáč during 1977—1979. Most of important Lower Devonian sections in the Prague Basin were sampled for conodonts. First results were published in the ECOS II Conodont Symposium guidebook (Chlupáč, Kříž, Schönlaub et al. 1980). In 1980—1984 the conodont biostratigraphic studies continued especially at the Lochkovian-Pragian boundary. The conodonts supported distinctly correlation of this boundary in Bohemia with other world regions and results were published by Chlupáč, Lukeš, Paris and Schönlaub in 1985.

In 1988 Chlupáč and Schönlaub participated in the discussions concerning Devonian — Carboniferous boundary as members of the working group (in Courtmacsherry, Ireland).

One of the important results of the research cooperation was joint organization of the Second Conodont Symposium (ECOS II) in Austria and Bohemia. The field trip to visit Prague Basin most important Silurian and Devonian sections and localities was prepared for the participants of the symposium and important results of the joint research in the Carnic Alps and Prague Basin were for the first time presented in the guide-book (Chlupáč, Kříž, Schönlaub et al. 1980).

Besides above mentioned results important studies concerning the correlation between the Paleozoic of Eastern Alps and the Paleozoic of the Moravo-Silesian region of Czechoslovakia summarized by Schönlaub (1979), should also be mentioned.

It may be concluded that research cooperation of the Lower Paleozoic rocks between the Geological Survey, Prague, and the Geologische Bundesanstalt, Vienna, contributed substantially to our knowledge on the Silurian and Devonian biostratigraphy, correlation and paleontology. During recent research also several interesting and important new questions arised concerning the Silurian and Devonian biostratigraphy and paleogeography. For this I am sure that a good cooperation which became traditional will continue in the future to be profitable for both sides.

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GEOLOGICAL MAPS FROM THE CZECHOSLOVAK-AUSTRIAN BORDER

Olga Matějovská, Ústřední ústav geologický, Praha, Czechoslovakia

A systematic geological investigation for the purpose of geological mapping on the scale of 1:25 000 has been carried out on the territory of SW Moravia near SE margin of the Bohemian Massif. Nineteen sheets of these geological maps have been already issued.

There exists a good cooperation between the Geological Survey in Prague and the Geologische Bundesanstalt in Vienna focussed on mapping of areas along the Czechoslovak-Austrian state border. In 1987 the first sheet of common Czechoslovak-Austrian maps, Gross Sieghardts, on the scale of 1:50 000 was released under editorship of Dr. O. Thiele. The second sheet, Geras, is being finished under editorship of Dr. G. Fuchs.

On the basis of petrochemical and petrological studies the distribution of metamorphic mineral facies in SW Moravia could be defined and more precise knowledge of the metamorphic development of the high-grade crystalline complex was gained.

Crystalline basement in this region is represented by two regional units: the Moldanubicum and Moravicum of the Dyje dome. The Moldanubicum exhibits a polyphase metamorphic development. The high regional metamorphism in conditions of granulite and high amphibolite facies was followed by an intensive regional migmatization of retrograde character which reworked the rocks and gave rise to advanced migmatites of orthogneiss appearance. The intensity of metamorphism in the Moravicum is lower: it changes from greenschist facies to upper amphibolite facies.

APPENDIX

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THIRTY YEARS OF GEOLOGICAL COOPERATION BETWEEN AUSTRIA AND CZECHOSLOVAKIA

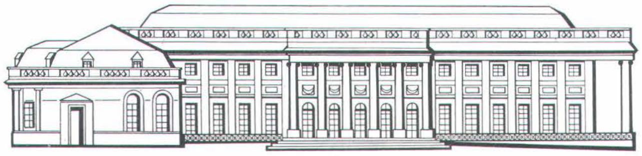
Editors: D. Minaříková, H. Lobitzer
Reviewer: J. Petránek
Translated by the authors and by
T. Hlavatá, E. Jassingerová, J. Mareš,
J. Pevný, G. Plíva, M. Radevová,
H. Šilarová, G. Vladyková (English),
A. Kříž (German)

Vydal Ústřední ústav geologický
Praha 1990

Grafická úprava: Jiří Matula
Obálka: Marie Zábranská

Vydání I. — 288 stran
52,37 AA — 53,80 VA
Náklad 2 000 výtisků
03/9 — R221 — 60—418—90
509/818
ISBN 80-7075-022-7

Grafická úprava a technická redakce:
Propagační tvorba, v. d., Praha
Sazba: Severografia, s. p., Ústí nad Labem
Tisk: Turnovské tiskárny



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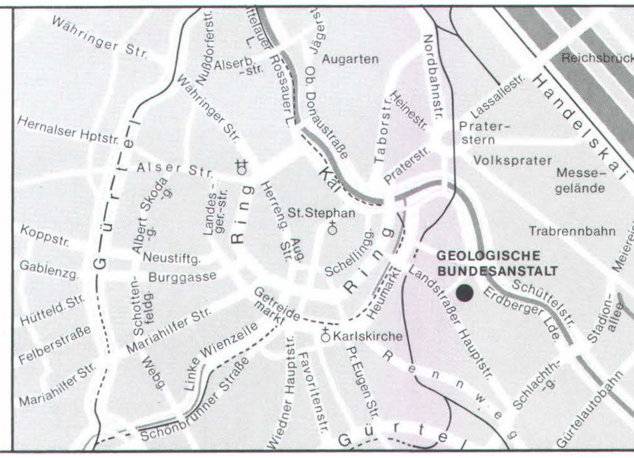

Historic Remarks

1835 Foundation of the Montanistic Museum in Vienna. Director from 1835—1839: Friederich Mohs († 1839). Director from 1840—1849: Wilhelm Karl Ritter von Haidinger.

1849 Foundation of the k. k. Geologische Reichsanstalt. Director from 1849—1866: Wilhelm Karl Ritter von Haidinger (†1871).

1851 Palais Rasumofsky becomes the new seat of the k. k. Geologische Reichsanstalt.

1918 Conversion of k. k. Geologische Reichsanstalt into Geologische Reichsanstalt.
From 28. 8. 1919 Geologische Staatsanstalt.
From 11. 8. 1921 Geologische Anstalt.
From 24. 1. 1922 Geologische Bundesanstalt.

1838—1945 Reichsamt für Bodenforschung Berlin — Zweigstelle Wien.
Bomb hits in the last days of the World War II cause severe destructions.

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1960 January 23rd, 1960; The governments of Austria and of Czechoslovakia conclude an agreement concerning the principles of geological co-operation.

1979 Reorganisation of the Geologische Bundesanstalt.

1989 The 30th mutual conference according to the governmental agreement between Austria and Czechoslovakia concerning geological cooperation is held in Austria.

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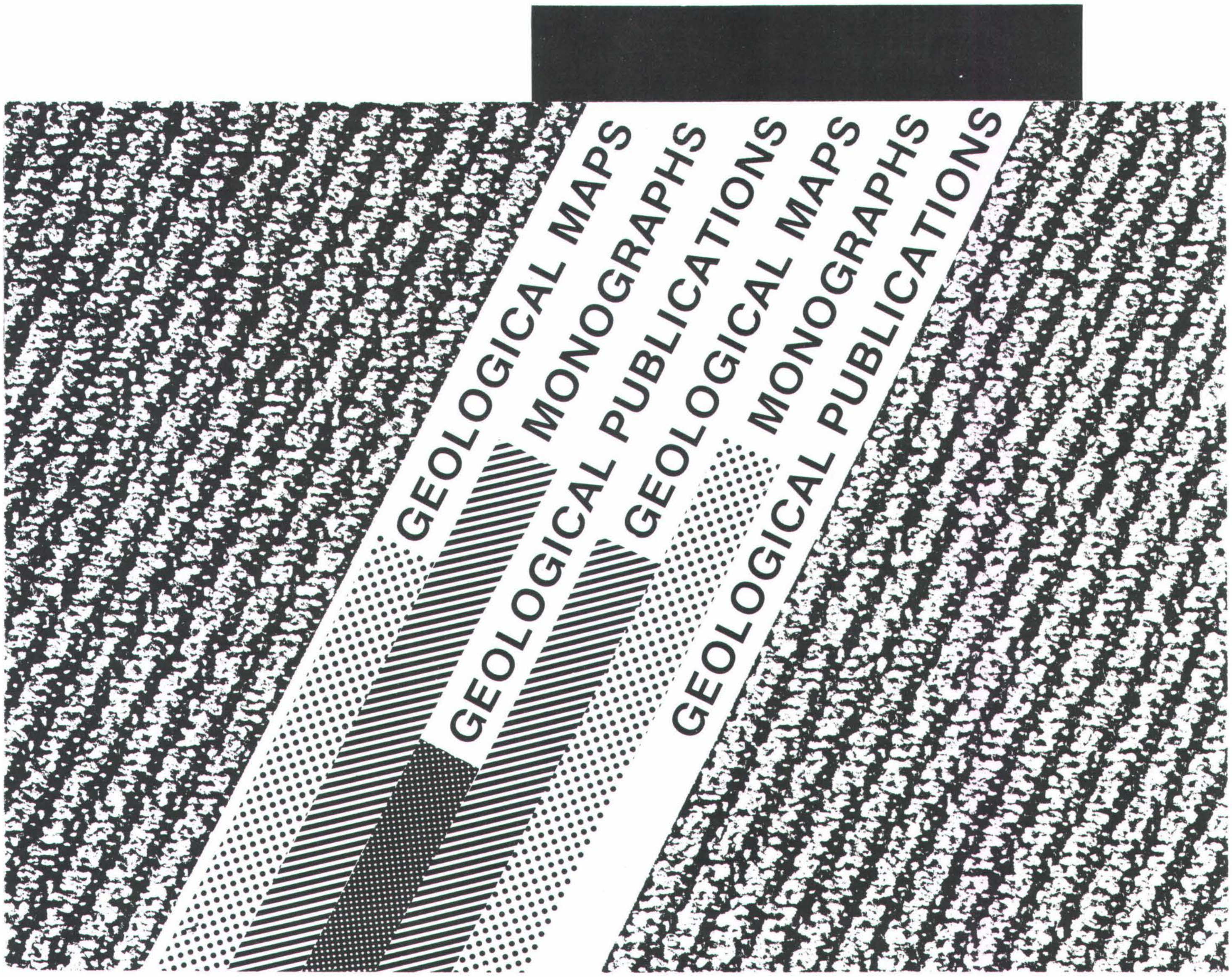

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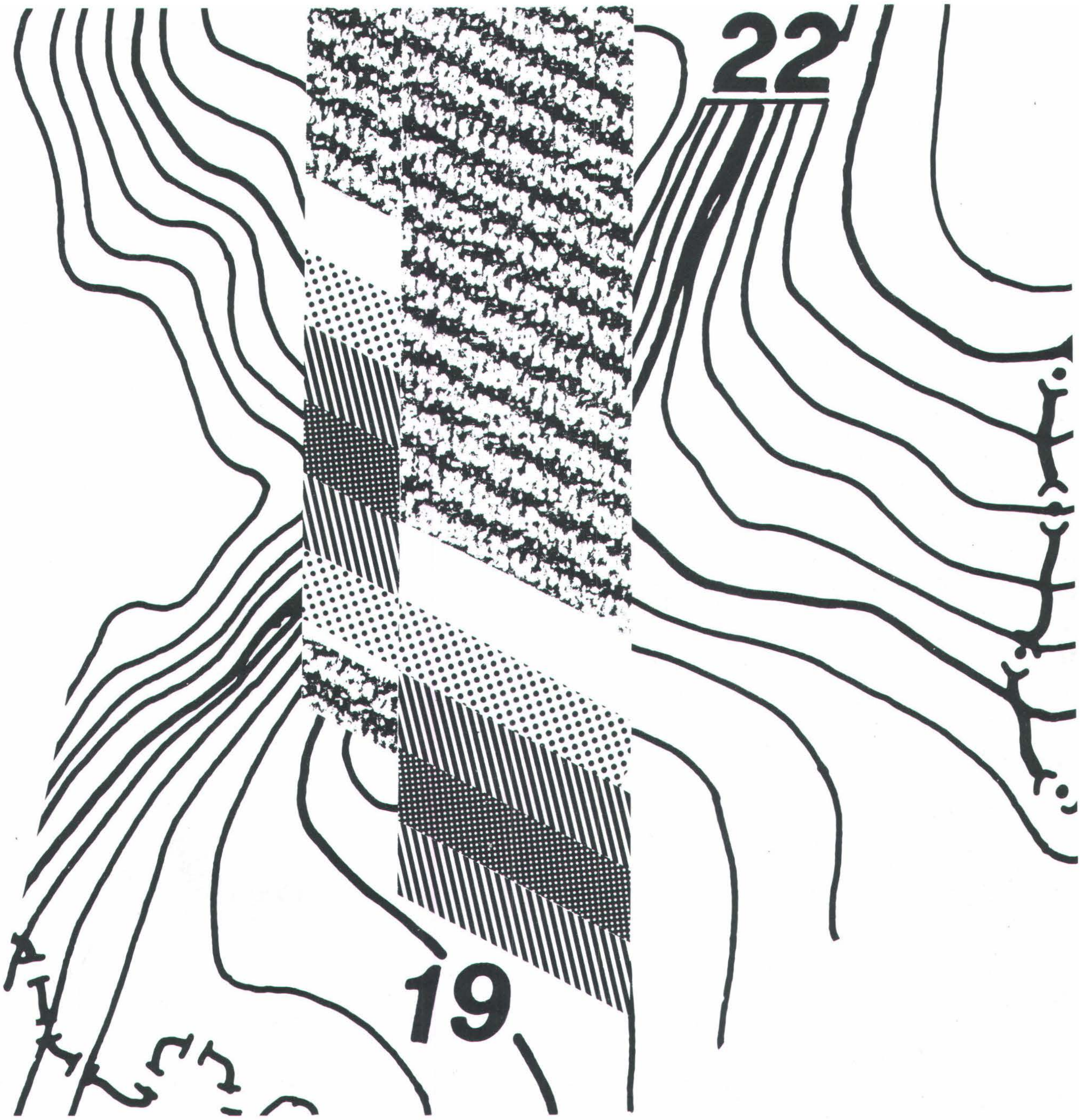
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