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 ⩾ 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 südbis 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

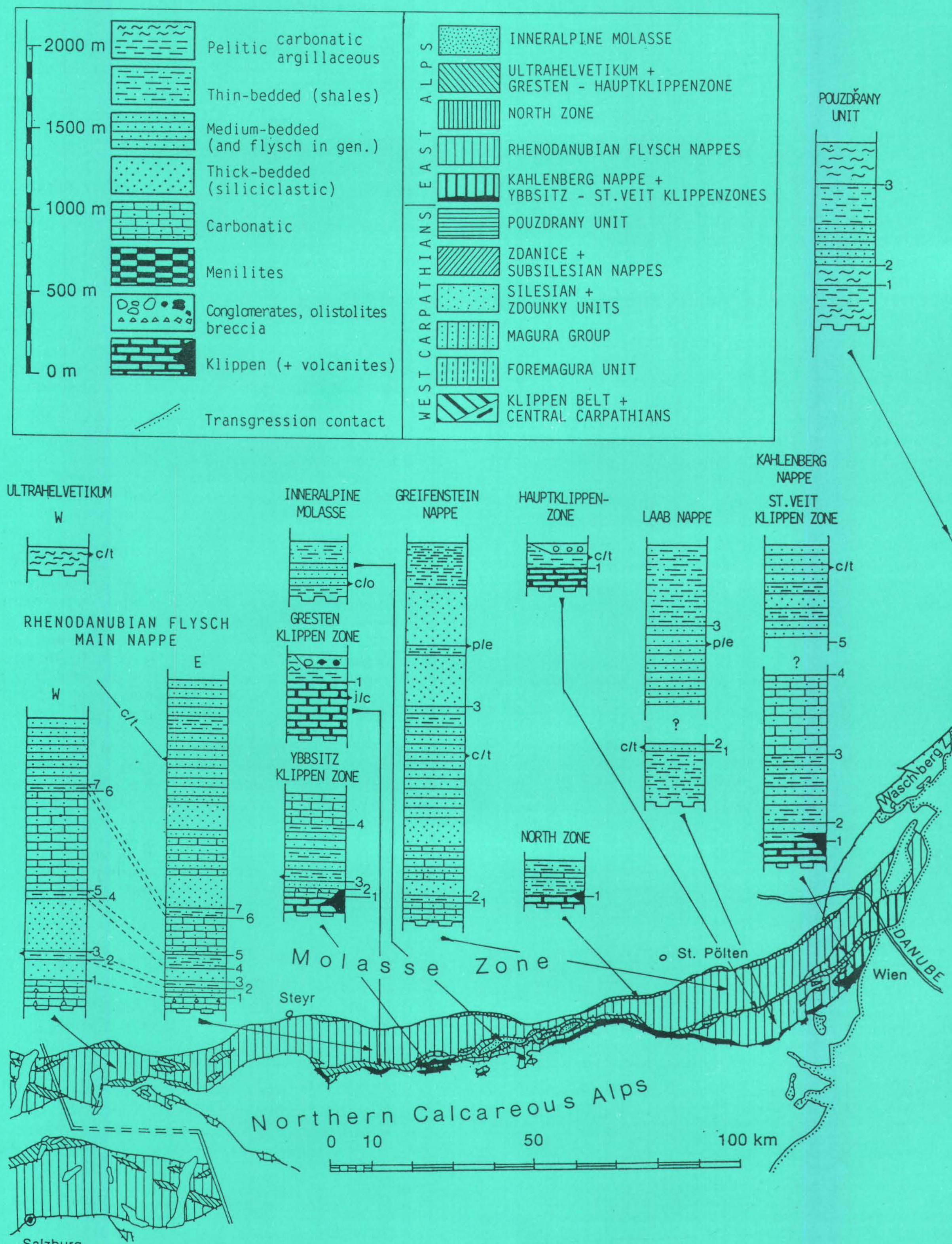
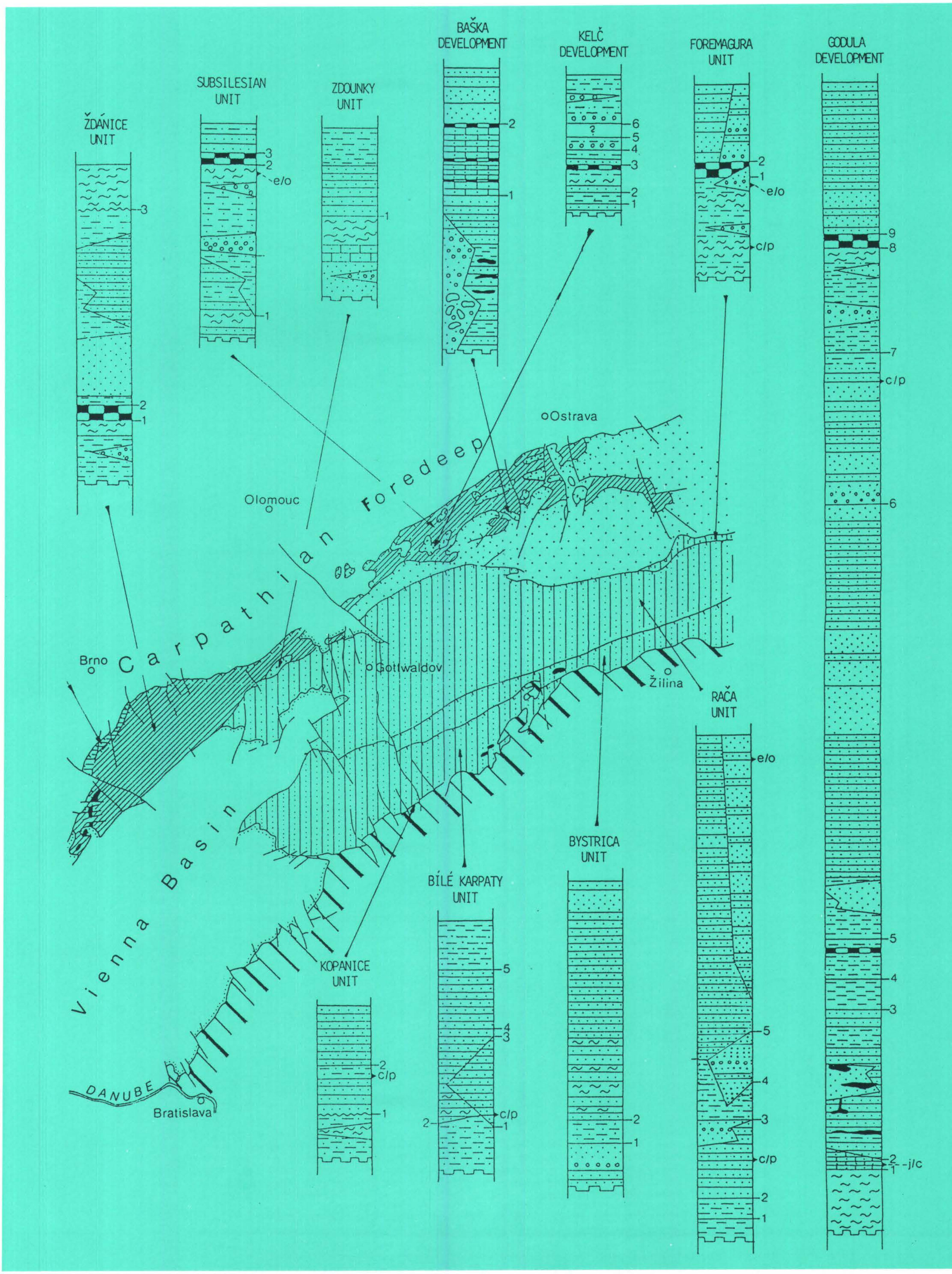
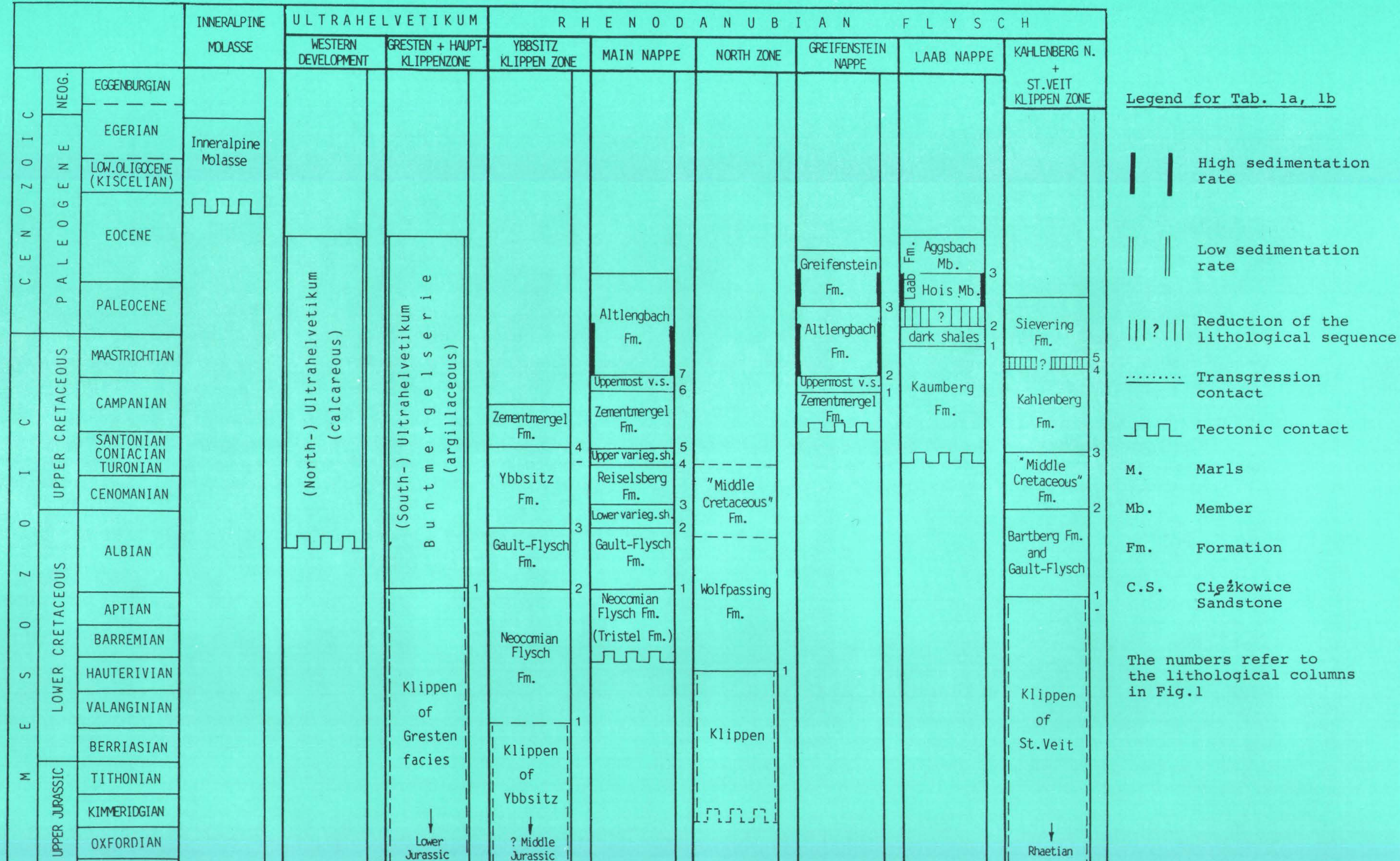


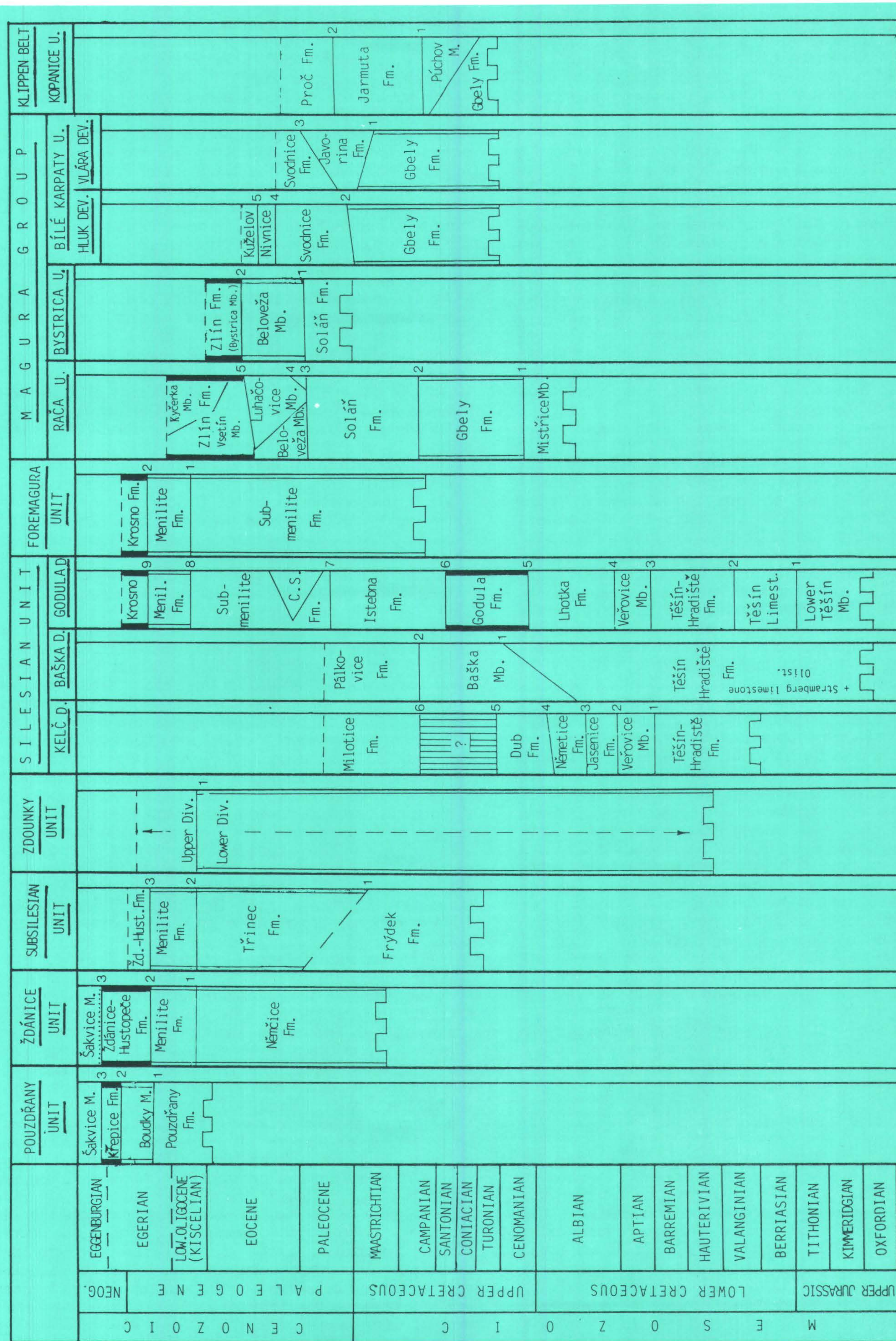
Fig. 1



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



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 (Ksiažkiewicz 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.

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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