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in memoriam Hermann Jaeger

Guidebook + Abstracts

edited by

Hans Peter Schönlaub & Lutz Hermann Kreutzer

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Preface

This volume is dedicated to the late and unforgettable Hermann Jaeger (1929 - 1992) to honour his contribution for the knowledge of the Silurian stratigraphy of the Alps. In all three areas which will be visited during the SSS Field Meeting 1994, i.e. the surroundings of Graz, the Carnic Alps and the Northern Graywacke Zone, Hermann Jaeger was the leading person to revise the older stratigraphic framework and to establish a modern one based on a solid and well documented graptolite zonation. This will be shown at several occasions in the Carnic Alps but also in a section of the Graywacke Zone of Tyrol.

It was Professor Helmut Flügel of Graz University, this year celebrating his 70th birthday who invited Hermann Jaeger for graptolite studies in 1965. Of course he accepted this challenge and in 1966 started field work in the famous "Graptolithengraben" (graptolite gorge) near the Upper Bischofalm. The author was one of the many students of that time who accompanied the "chief" and thus was able to learn the basic principles of biostratigraphy in the field. Since his beginning in 1965 Hermann Jaeger repeatedly visited Austria and continued his studies at several other localities in the forementioned regions but also revised older collections which are mainly stored at Graz University. The whole campaign resulted in 10 publications, many citations and comparative remarks in the literature and numerous "personal communications" to various people, in particular to the author. Those who were in closer contact with Hermann Jaeger know that his conclusions were always based on well established evidences. When necessary they were defended in lively but never polemic discussions.

After many years of joint research in the Alps I got the feeling that the Carnic Alps became Hermann Jaeger's favourite study area for Silurian and Lower Devonian graptolites. Other colleagues may forgive me if they do not believe me. However, the physical and mental input into his work in general and in particular into the Carnic Alps are the main reasons for such a statement. He revisited the steep and strongly faulted graptolite gorge and the Cellon section of the central Carnic Alps many times until the year 1982 when he had the last opportunity to accept our welcome greetings. In particular at these two locailties the members of the field meeting should acknowledge Hermann Jaeger's fundamental work.

In addition to the foregoing honourable acknowledgment I wish to express my gratitude to many other persons who contributed to this volume. In their "order of appearance" these are Lutz H. Kreutzer, C. Hauser, Helga Priewalder, Riki Scevik and the driver from the Geological Survey, Prof. Fritz Ebner from Leoben University, Prof. Werner Buggisch and Michael Joachimski from Erlangen University and Prof. Helfried Mostler from Innsbruck University.

Hans Peter Schönlaub
(Director, Geologische Bundesanstalt)

Vienna, August 1994

Contents

The Classic Fossiliferous Palaeozoic Units of the Eastern and Southern Alps[1]

with 18 figures

by

Hans-Peter Schönlaub and Helmut Heinisch

Summary

In this report we review the present knowledge about the stratigraphy, the development of facies and the tectonic evolution of the Variscan sequences of the Eastern and Southern Alps. In the Eastern Alps outcrops of fossiliferous rocks of Lower Palaeozoic age are irregularly distributed. They form a mosaic-like pattern of dismembered units incorporated into the Alpine nappe system. Such areas include the Gurktal Nappe of Middle Carinthia and parts of Styria, the surroundings of Graz, a small area in southern Burgenland and the Graywacke Zone of Styria, Salzburg and Tyrol. South of the Periadriatic Line Variscan sequences are represented in the Carnic and Karawanken Alps where they form the basement of the Southern Alps. As regards the regions occupied by quartzphyllitic rocks of presumably Palaeozoic age the reader is referred to the article by Neubauer and Sassi (this volume).

Based on a comprehensive set of data a distinct geological history on either side of the Periadriatic Line is inferred. Main differences concern the distribution of fossils, the development of facies, rates of subsidence, supply area, amount of volcanism and the spatial and temporal relationship of climate sensitive rocks from north and south of the Periadriatic Line (H.P.Schönlaub 1992).

The Ordovician of the Southern Alps is characterized by mainly clastic rocks with minor participation of volcanics. This facies agrees well with other areas in the Mediterranean. Also, the widespread glacial event at or close to the Ordovician/Silurian boundary can be recognized. It is followed by different Silurian deposits ranging from shallow water carbonates to graptolitic shales. Thicknesses are overall similar and do not exceed some 60 m. Due to extensional tectonics and highly different rates of subsidence the facies pattern changed considerably during the Devonian. This is documented by more than 1200 m of shallow water limestones which are time equivalent to some 100 m of condensed cephalopod limestones. After the drowning of the reefs uniform limestones were deposited in the Famennian and early Dinantian followed by an emersion and a widespread karstification phase near the end of the

[1] Extended version of a paper published in: RAUMER, J.F. v. & NEUBAUER, F. (Eds., 1993): Pre-Mesozoic Geology in the Alps.- Springer Verl., 395-422; Heidelberg

Tournaisian. The final collapse of the Variscan basin started in the Visean and resulted in more than 1000 m of flysch deposits indicating an active margin regime at the northern edge of the Southern Alps plate, which culminated in the main deformation of the Southern Alps in the Westphalian. The transgressive cover comprisis Late Carboniferous and Lower Permian sediments at the end of the Variscan sedimentary cycle.

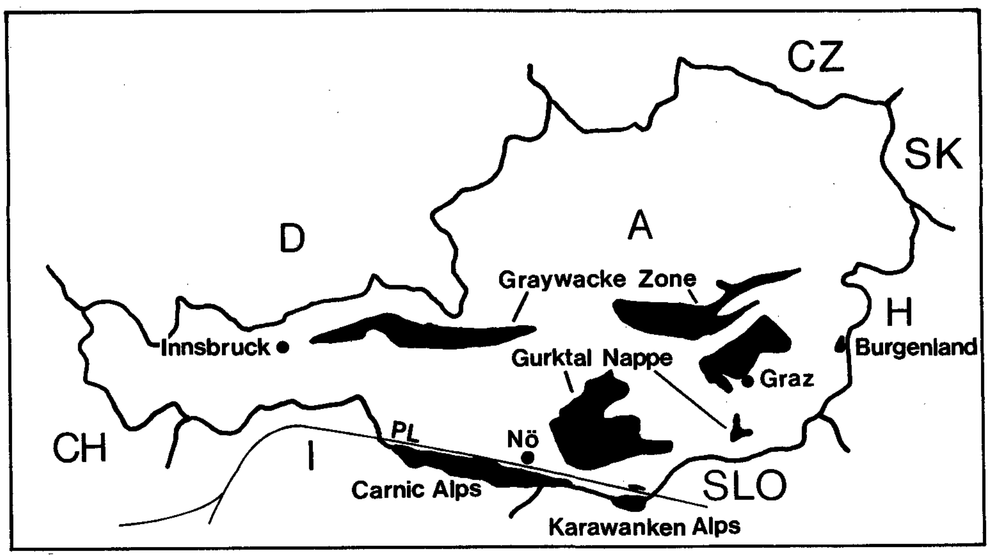


Fig. 1: Main regions with fossiliferous Paleozoic strata in the Eastern and Southern Alps (PL = Periadriatic Line, Nö = Nötsch)

The area north of the Periadriatic Line has only few rocks in common with the Southern Alps. In short, its geological history is significantly different. This concerns thick piles of siliciclastic rocks in the interval from the Ordovician to the Devonian, a contemporaneous local reef and warm water development during the Silurian and the Devonian, basic magmatism in the Middle (?) Ordovician, Lower Silurian and in the Middle Devonian (s.l.). The increased input of clastic material suggests a close proximity to a land area; the intense volcanism may be related to crustal extension starting already in the Ordovician. For some degree volcanism may also be responsible for the variation of facies which occurred in most areas north of the Periadriatic Line during the Silurian and particularly in the Lower and Middle Devonian.

In the Graywacke Zone the oldest sediments are of Tremadocian age; the second oldest fossils occur north of Klagenfurt and correspond to the Llandeillan Stage of the Middle Ordovician. They are underlain by basic volcanics and several hundred meters of metapelitic rocks of presumably Lower Ordovician age. Consequently, a continuous sedimentation from the base of the Ordovician to the top of the Variscan sequence is suggested, for example, in the surroundings of Graz, the Graywacke Zone and in Middle Carinthia until the Namurian or Westphalian. Thus, in the Alps a Caledonian orogenetic event as proposed by other authors, seems highly speculative. On the other side motion of individual areas ("microplates", "terranes") may have played a significant role and may help unravelling and explaining the observed differences between the Southern and the Northern Alps during the Palaeozoic.

Introduction

The term 'classic Palaeozoic' has generally been applied to those areas of the Eastern Alps in which fossiliferous strata of Palaeozoic age have been well known since the last century. They were recognized soon after foundation and designation of the individual Palaeozoic Periods in Great Britain following the pioneering phase of geology. For example, the world famous Carboniferous deposits of Nötsch (Carinthia) have been known since Mohs (1807) and were later visited by the highly reputated L v Buch in 1824; the equivalents of the Devonian Period were found in the surroundings of Graz as early as 1843, i.e., 4 years after the erection of the system by Murchison & Sedgwick in Devonshire; the discovery of Silurian strata date back to 1847 when F.v.Hauer found cardiolids of this age near the village of Dienten in the Graywacke Zone of Salzburg. Finally, Permian and Ordovician fossils were first described from the Carnic Alps by Stache in 1872 and 1884, respectively.

Accordingly, until about the year 1955 dating of sedimentary rocks of Palaeozoic age was mainly based upon macrofossils. The majority of fossils were derived from the Southern Alps, i.e, the Carnic and Karawanken Alps, yielding abundant and well preserved representatives of various faunal and floral groups for each period. The Palaeozoic of Graz too, furnished rich collections of corals, stromatoporoids and brachiopds mainly from the Middle Devonian. In the Graywacke Zone, Middle Carinthia and Burgenland, however, most macrofossils are badly preserved and generally occur less abundantly due to greenschist grade metamorphism and foliation.

Since the introduction of microfossil research methods in the mid-1950s, in particular conodont biostratigraphy, the knowledge about sedimentary sequences considerably increased. In fact the high-resolution biostratigraphy of conodonts in spite of lack of other fossils provided the basis for accurate dating and interregional correlation of poorly known almost 'unfossiliferous' sequences. In the meantime many reference sections in the Carnic Alps, the Graywacke Zone and the Palaeozoic of Graz have been studied which confirmed the conodont zonations from other parts of the world and/or supplied additional informations. Thus, together with sedimentological, microfacies, geochemical and structural data a very detailed subdivision of the geological record of the Eastern Alps has been established. Based on this multi-lined framework the Palaeozoic history of the Alps can be better inferred than ever before and hence, seems well constrained in today's geology of the Alps.

The occurrences of fossiliferous Palaeozoic outcrops represent different tectonic units. South of the Gailtal Fault they form the Variscan basement of the Southern Alps; to the north they belong to a huge thrust sheet named Upper Austroalpine Nappe. As far as their original palaeolatitudinal settings are concerned analysis of faunas and climate sensitive rock data has revealed fundamental differences between both major occurrences (Schönlaub, this volume). In addition, the intra-Alpine facies development varies to a certain degree. For example, the Palaeozoic record from Middle Carinthia is lithologically more close related to certain areas occupied by quartzphyllites than to any other region; the Graywacke Zone of Styria shows more similarities with the Carnic Alps than to the nearby Palaeozoic of Graz; this development reflects its own distinct setting suggesting an intermediate position between the Southern and Central Alps. Finally, in the Palaeozoic sequences of the Alps the participation of volcanic rocks varies considerably. They have been assigned to different geotectonic settings that characterized the Ordovician, Silurian and Devonian Periods (Loeschke & Heinisch, this volume).

The Carnic and Karawanken Alps

The Carnic Alps of Southern Austria and Northern Italy represent one of the very few places in the world in which an almost continuous fossiliferous sequence of Palaeozoic age has been preserved. They extend in West-East direction over 140 km from Sillian to Arnoldstein. In the following Western Karawanken Alps the Variscan sequence is almost completely covered by Triassic rocks. To the east Lower Palaeozoic rocks are excellently exposed in the Seeberg area of the Eastern Karawanken Alps south of Klagenfurt. Different from the Carnic Alps in this region Lower Palaeozoic rocks are distributed on either side of the Periadriatic Line (Gailtal Fault). They were subdivided into a northern and a southern domain, respectively. The latter extends beyond the state border to Northern Slovenia.

Historical Notes

In both regions systematic research started after foundation of the Geological Survey of Austria in the middle of the last century. Interestingly, the equivalents of the Lower Palaeozoic were first found in the Karawanken Alps and not in the Carnic Alps (Suess 1868, Tietze 1870). In this latter area main emphasis was laid on marine Upper

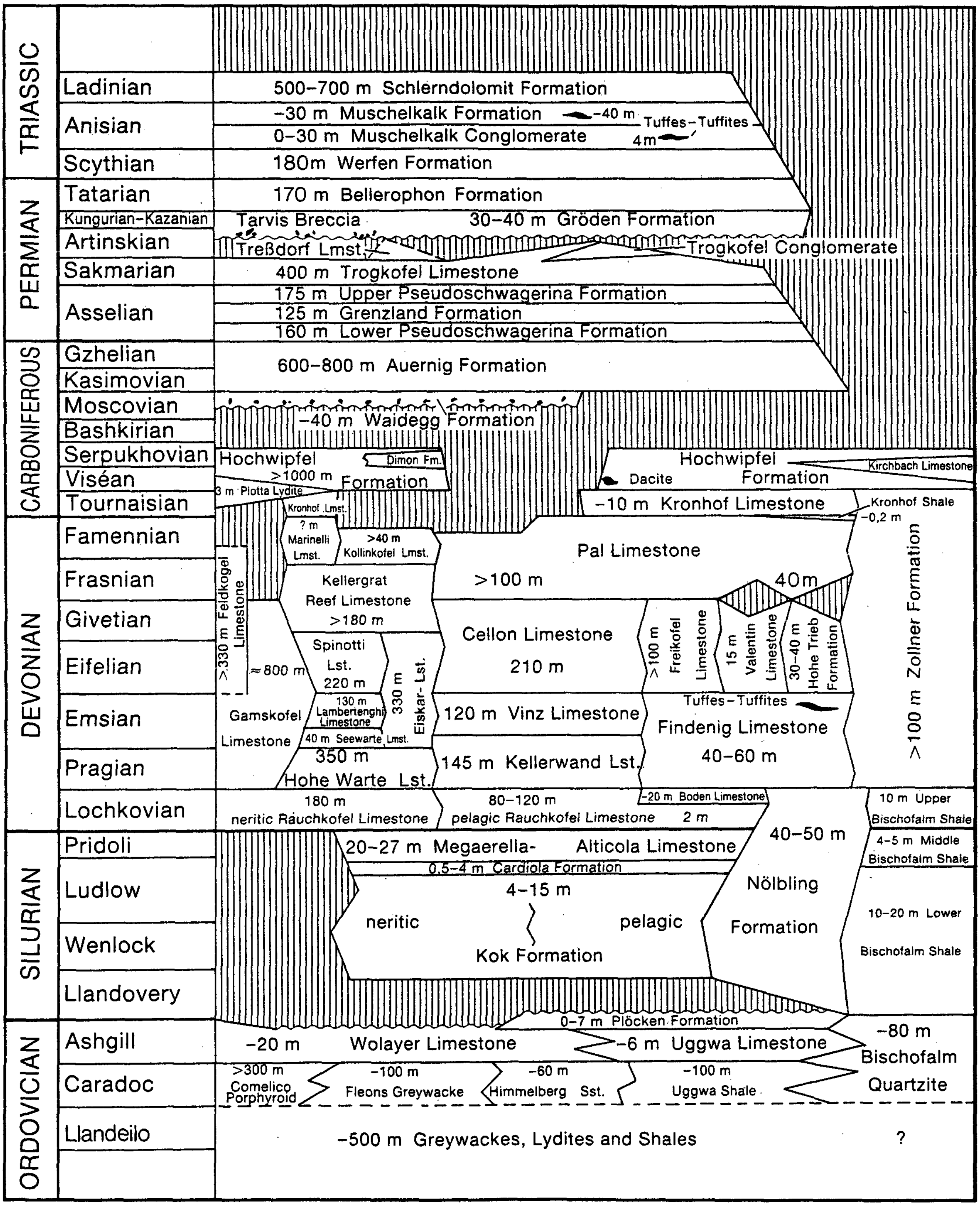


Fig. 2: Biostratigraphic scheme of the Palaeozoic sequence of the Carnic Alps. With only minor modifications this subdivision can also be applied in the Karawanken Alps (after Schönlaub 1985, amended by KREUTZER 1992a, 1992b).

Palaeozoic rocks. At the end of the 19th century this initial phase was followed by a second mapping campaign carried out mostly by Geyer and detailed studies of the Devonian by Frech. During the first half of this century Heritsch and his co-workers from Graz University refined the stratigraphy on the Austrian side while Gortani from Bologna University and others worked on the Italian side of the mountain range. One of the outstanding contributions of that time from the Lower Palaeozoic was provided by Gaertner (1931). The detailed knowledge of Upper Carboniferous and Permian rocks resulted mainly from studies by Kahler beginning in the early 1930s. Since then many students of geology started visiting both areas. During this third campaign after World War II study of different microfossil groups began and other techniques were as well introduced. It culminated in the publication of detailed maps, the refinement of the stratigraphy, and revisions of old and discoveries of new faunas and floras (see Schönlaub 1979, 1980, 1985a).

Review of Stratigraphy

Figure 2 summarizes the stratigraphy and facies relationship of various rocks of the Carnic Alps. With minor modifications this scheme is also valid for the Karawanken Alps (Schönlaub 1980, Moshammer 1989). Traditionally the sequence is subdivided into the Variscan basement rocks and its post-Variscan cover. The oldest fossiliferous rocks are Caradocian in age (Upper Ordovician) and comprise thick acid volcanics named Comelico Porphyroid and volcaniclastics of the Fleons Formation which laterally and vertically grade into the Uggwa Shale and the Himmelberg Sandstone. According to Dallmeyer & Neubauer (1994) detrital muscovites from the sandstones are characterized by apparent ages ($^{40}Ar/^{39}Ar$) of c. 600 to 620 Ma and may thus be derived from a source area affected by late Precambrian (Cadomian) metamorphism. They are succeeded by bioclastic limestones, i. e. the massive Wolayer Lst. and the corresponding quiet-water Uggwa Lst., respectively. The global regression during the Hirnantian Stage (Late Ashgillian) is documented by arenaceous limestones of the Plöcken Formation. It resulted in channeling, erosion and local non-deposition. Thus basal Silurian strata generally disconformably overlie the Late Ordovician sequence.

Ordovician fossil groups include rich collections of bryozoans, brachiopods, trilobites, pelmatozoans and hyolithes occurring with varying abundances in the Uggwa Shale, and abundant conodonts in the limestones (Schönlaub, see summary in this volume).

In the Carnic Alps the Silurian transgression began at the very base of the Llandovery, i.e., in the graptolite zone of *Akidograptus acuminatus*. Its forerunner from the latest Ordovician, *Gl.persculptus*, was reported from the Western Karawanken Alps. Due to the unconformity separating the Ordovician from the Silurian a varying thick pile of sediments is locally missing, which correspond to several conodont zones in the Llandovery and Wenlock in both the Carnic and Karawanken Alps. At some places even basal Lochkovian strata may disconformably rest upon Upper Ordovician limestones.

Silurian lithofacies is split up into four major facies reflecting different depth of deposition and hydraulic conditions. A shallow marine environment represents the Plöcken Facies characterized in succeeding order by the pelagic Kok Formation, the Cardiola Fm. and the Megaerella-Alticola Limestones. The typical section is the 60 m thick Cellonetta profile well known for its merits for the Silurian conodont zonation established by Walliser in 1964.

The Wolayer Facies represents an even shallower environment. It is characterized by fossiliferous limestones with abundant orthoconic nautiloids, trilobites, small brachiopods and crinoids. Due to a period of non-deposition at the base this facies is represented by only 10 to 15 m thick limestones. The main occurrences are in the Lake Wolayer region of the Central Carnic Alps.

The Findenig Facies represents an intermediate facies between the shallow water and the starving basinal environment. It comprises interbedded black graptolite shales, marls and limestone beds. At its base a quartzose sandstone may locally occur.

The stagnant water graptolite facies is named the Bischofalm Facies. It is represented by 60 to 80 m thick black siliceous shales, black cherty beds ("lydite") and clayish shales which contain abundant graptolites. Their distribution has been clearly outlined by the thorough work of Jaeger in the past 25 years (see Jaeger 1975, Flügel et al 1977, Jaeger & Schönlaub 1980, Schönlaub 1985).

The four Silurian lithofacies reflect different rates of subsidence. During the Llandovery to the beginning of the Ludlow sedimentation suggests a steadily subsiding basin and a transgressional regime. This tendency decreased and perhaps stopped during the Pridoli to form balanced conditions with uniform limestones being widespread deposited. Simultaneously, in the Bischofalm Facies black graptolite shales were replaced by greenish and grayish shales ("Middle Bischofalm Shale").

At the base of the Devonian in the Bischofalm Facies the deep-water graptolite environment was restored until the end of the Lochkovian Stage. The succeeding strata named Zollner Formation, also represent a deep-water off-shore setting that lasted to the end of the Devonian or early Carboniferous.

In comparison with the Late Ordovician and the Silurian subsidence and mobility of the sea-bottom significantly increased in the Devonian. This is documented in a Lower Devonian transgressional sequence including the up to 180 m thick Rauchkofel Limestone which corresponds to some 20 m of pelagic limestones ("Boden Lst."). During the Pragian and Emsian Stages the differences even increased. Within short distances of less than 10 kilometers (Kreutzer 1992a, b) a strongly varying facies pattern developed indicating a progressive but not uniform deepening of the basin. It was filled with thick reef and near-reef organodetritic limestones including different intertidal lagoonal deposits of more than 1000 m thickness in the Carnic Alps and some 300 m in the Karawanken Alps. They are time equivalent to some 100 m of pelagic cephalopod limestones and the pelitic Zollner Formation.

In the Carnic and Karawanken Alps reef growth started in the Lower Emsian. Main reef builders were stromatoporoids, tabulate corals and calcareous algae like *Renalcis*. For the Karawanken Alps Rantitsch 1990 concluded an arrangement of reefs resembling present-days atolls as opposed to the Carnic Alps with its barriere-type reefs (Kreutzer 1990, 1992a, b). Depending on adequate subsidence the location of the reef belt shifted spatially and temporarily during the Devonian. Different from the Carnic Alps with its 150 m thick reefs of Givetian age in the Karawanken Alps there are no good records from the Middle Devonian. In both areas the reef development ended in the Frasnian when the former shallow sea subsided and the reefs drowned and were partly eroded (Bandel 1972, Tessensohn 1974,1983, Pohler 1982 and Kreutzer 1990). Subsequently, with few exceptions, e.g., the Kollinkofel Lst., uniform pelagic goniatite and clymeniid limestones were deposited lasting from the Frasnian/Famennian boundary to the Late Tournaisian Stage. They were named Pal and Kronhof Lst., respectively. Generally, these wackestones contain abundant cephalopods, trilobites, radiolarians, foraminifera, ostracods, conodonts and even fish teeth.

The nature of the transition from the above mentioned limestones to the following clastics of the Hochwipfel Formation raised a long lasting controversy about the significance of tectonic events in the Lower Carboniferous. It now has been settled after recognizing a wide variety of distinct palaeokarst features in the Karawanken Alps (Tessensohn 1974) and in the Carnic Alps (Schönlaub et al 1991) including an extensive palaeorelief with related collapse breccias, fissures, strata-bound ore deposits and a silcrete regolith at the surface ("Plotta Lydite"), and caves with cave sediments, formation of speleothems and palaeokarst-related cements in the subsurface. The palaeokarst was caused by a drop in sea-level during the Late Tournaisian. Rise of sea-level and/or collapse of the carbonate basin promoted the transgression of the Hochwipfel Formation which presumably started as early as the Tournaisian/Visean boundary.

On account of its characteristic lithology and sedimentology Tessensohn 1971, 1983, Spalletta et al. 1980, v Amerom et al. 1984, Spalletta & Venturini 1988 and others interpreted the 600 to more than 1000 m thick Hochwipfel Formation as a flysch sequence. In modern terminology the Kulm sediments indicate a Variscan active plate margin in a collisional regime following extensional tectonics during the Devonian Period. The main lithology comprises arenaceous to pelitic turbidites with intercalations of several tens of metres thick pebbly mudstones, disorganized debris flows and chert and limestone breccias in its lower part. They may represent submarine canyon fillings or inner fans. Widespread although less abundantly are up to 10 m thick massive sandstone beds. Vertically, and locally also laterally, the flysch grades into volcaniclastites and volcanics of the Dimon Formation.

Except for trace fossils the palaeontological content of the flysch series is very poor. According to v Amerom et al 1984 and v Amerom & Schönlaub (in prep.) plant remains are fairly common suggesting a Middle Visean to Namurian age for the formation of parts of the flysch. Other stratigraphic data are derived from the underlying limestone beds and a few scattered limestone intercalations, i.e., the Kirchbach Limestone which provided index conodonts of the Visean/Namurian boundary (Flügel & Schönlaub 1990). Moreover, of great interest are limestone clasts within the debrites. They comprise a broad spectrum of shallow water carbonate shelf types with stratigraphically important fossils like the coral *Hexaphyllia mirabilis*, the algae *Pseudodonezella tenuissima*, the foraminifera *Howchinia bradyana* and the early fusulinids. Apparently, these clasts together with the turbidites were supplied from a source area located originally to the north of the present Southern Alps.

In the Southern Alps the Variscan orogeny reached the climax between the Late Namurian and the Late Westphalian Stages. This time corresponds to the interval from the Early Bashkirian to the Middle or Late Moscovian Stages. According to Kahler (1983) the oldest post-Variscan transgressive sediments are Late Middle Carboniferous in age and, more precisely, correspond to the *Fusulinella bocki* Zone of the Upper Miatchkovo Substage of the Moscovian Stage (Moscow Basin). In particular between Straniger Alm and Lake Zollner they rest with a spectacular angular unconformity upon strongly deformed basement rocks including the Hochwipfel Formation, the Silurian-Devonian Bischofalm Formation or different Devonian limestones. This basal part named Waidegg Formation consists of mainly basal conglomerates, disorganised pebbly siltstones and arenaceous and silty shales with thin limestone intercalations. Even meter-sized limestone boulders reworked from the basement were recognized at the base of the transgressive sequence (Fenninger et al 1976) and named Malinfier Horizon by Italian geologists. The Bombaso Formation of the Naßfeld region, i.e., the Pramollo Member, has also long been regarded as the base of the Auernig Group in this area (Venturini et al 1982, Venturini 1990). Based on new field evidence, however, for this member a clear relationship with the Variscan Hochwipfel Formation is suggested.

South of Naßfeld its transgressive molasse-type cover comprises the 600 to 800 m thick fossiliferous Auernig Group. Although the oldest part biostratigraphically may well correspond to the Late Moscovian Stage (Pasini 1963) the majority of sediments belong to the Kasimovian and Ghzelian Stages.

In the Lower Permian the Auernig Group is followed by a series of almost 900 m thick shelf and shelf edge deposits (see HOLSER et al 1991, Krainer, this volume). They characterize a differentially subsiding carbonate platform and outer shelf settings which from the Westphalian to the Artinskian Stages were affected by transgressive-regressive cycles. This cyclicity may be explained as the response to the continental glaciation in the Southern Hemisphere (see Schönlaub, this volume).

Upper Permian sediments rest disconformably upon the marine Lower Permian or its equivalents, and farther to the west, on quartzphyllites of the Variscan basement. They indicate a transgressive sequence beginning with the Gröden Formation and followed by the Bellerophon Formation of Late Permian age (Boeckelmann 1991, Holser et al 1991).

Upper Carboniferous and Permian molasse-type sediments also occur in the Seeberg area of the Eastern Karawanken Alps (Tessensohn 1983, Bauer 1983). Although strongly affected by faults the general lithology and the fossil content resemble that of the Auernig Group of the Carnic Alps being dominated by interbedded fusulinid and other fossil bearing marine limestones, arenaceous shales, sandstones and massive beds of quartz-rich deltaic conglomerates. Equivalents of the Permian are represented by the Trogkofel Lst., the coeval detritic Trogkofel Beds and the Gröden Formation. The Bellerophon Dolomite is only locally preserved.

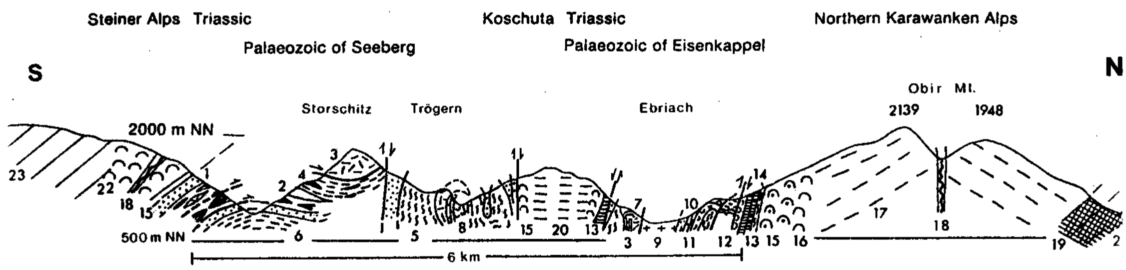


Fig. 3: N-S directed section through the Eastern Karawanken Alps. Numbers indicate (1) post Variscan Permian and Late Carboniferous, (2) banded limestone slices, (3) Devonian limestones, (4) undated volcanics, (5) Hochwipfel Fm., (6) Seeberg Shale, (7) Upper Ordovician and Silurian rocks, (8) volcanics of the Upper Ordovician, (9) granite of Eisenkappel, (10) pillow lava of the "Diabaszug of Eisenkappel", (11) sills, (12) Werfen Fm., (13) Muschelkalk Fm., (14) Partnach Fm., (15, 16, 17) Wetterstein Lst., (18) Raibl Fm., (19) Rhätian to Jurassic deposits, (20) Schlern Dolomite, (21) Tertiary, (22, 23) Dachstein Lst. (from Schönlaub 1979).

In the Eastern Karawanken Alps north of the Periadriatic Line rocks of Palaeozoic age have long been known. They belong to the so-called "Diabaszug von Eisenkappel" (Fig. 3). This narrow belt extends in W-E direction from Zell Pfarre via Schaidasattel to east of Eisenkappel and continues further east to Slovenia. In Austria this zone has a length of more than 25 km and a maximum width of 3,5 km. The 650 m thick Palaeozoic sequence comprises up to 350 m of volcanic and volcaniclastic rocks and sediments. According to Loeschke (1970-1977, 1983) the first group is dominated by basic tuffs and tuffitic rocks, massive pillow lavas and basic sills of hawaiitic composition with ultrabasic layers. Sills and pillow lavas represent spilites which differentiated from alkali olivine basalts, the original geotectonic setting of which is yet not known. Subsequent low-temperature metamorphism associated with devitrification and metasomatic replacement processes caused the spilitic mineral composition in these rocks. The sedimentary rocks are monotonous gray shales and slates with intercalations of conglomeratic graywackes, quartzitic and graphitic sandstones and thin limestone beds. The definite age of this succession is yet not exactly known although some poorly preserved single cone conodonts recovered from the limestone intercalations are rather in favour of an Ordovician than any younger age (Neubauer, pers. comm.).

Tectonic Remarks

The Palaeozoic sequence of the Carnic and Karawanken Alps represent a strongly compressed WNW-ESE running thrust sheet complex composed of isoclinally folded anchi-to epimetamorphic Palaeozoic rocks. This style of deformation developed during the Variscan orogeny in the Late Namurian or Early Westphalian. It is sealed by the post-Variscan cover overlying the deformed basement with a distinct angular unconformity. Paraconformities occur at different levels within the Palaeozoic sequence, for example, at the end of the Ordovician, in the late Middle and early Upper Devonian and in the Lower Carboniferous. Supposedly, they were caused by sea-level changes related to the glaciation of parts of Gondwana at the end of the Ordovician, to seismic shock events, and to a palaeokarstic event, respectively. Lowering of sea-level and/or block faulting may also have acted at the end of the Trogkofel Stage being responsible for extensive erosion and accumulation of reworked limestones, stratigraphic gaps, formation of fissures and local karstification.

For many years the complicated tectonics of the Carnic Alps was explained in terms of 9 nappes produced during the Variscan orogeny. Each north verging nappe consisted of a more or less continuous Ordovician to Devonian sequence and was separated from the next by the clastics of the Hochwipfel Formation. The extent of Alpine overprints on this pile of nappes was difficult to decide. With respect to the less deformed post-Variscan cover, however, it was concluded that the intensity of the Variscan tectonics was much stronger than the Alpine deformation. Nevertheless, the latter resulted in interferences between both and was responsible for a complex deformative pattern in the Southern Alps (Castellarin & Vai 1981)

According to Vai 1979 the horizontal shortening of the Carnic Alps during the Variscan deformation is estimated to 75-80% of its original width. This value does not consider the assumed detachment from pre-Ordovician basement rocks.

Based on new field data from mainly the Naßfeld area the old concept was challenged by Venturini (1990, 1991) who proposed a new structural model. He speculated on three distinct and interacting phases that resulted in different systems of asymmetric folds and faults distributed along N 120° - 140° E direction (Fig. 4):

1. Middle or early Upper Carboniferous compressional tectonics caused a huge SSW-verging fold that affected the whole belt. Syncinematically a back fold system with clear northern vergence developed on its back side. Such smaller-scale syn-and anticlinales can be recognized, for example, on Roßkofel, at Hoher Trieb, at Plöckenpaß-Kleiner Pal-Piz Timau. Perhaps even the fold structure separating the Cellon subnappe from the Kellerwand-subnappe (Kreutzer 1990) can be attributed to this deformation.

2. In response to uplifting brittle deformation occurred with development of flat fault planes along shale horizons. As a result the huge asymmetrical fold was cut into smaller tectonic slices.

3. The third phase occurred during further uplift. It produced huge open antiforms following new thrust planes and older folded structures. They were later reactivated during the Alpine compression.

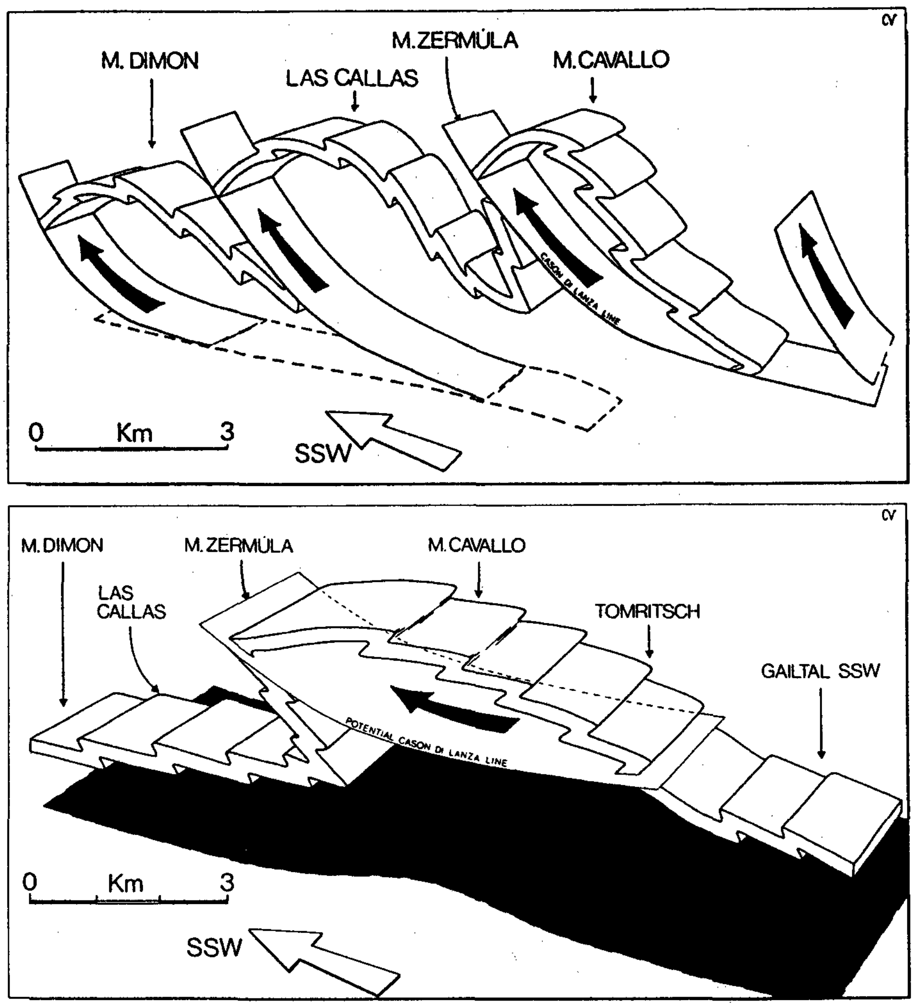


Fig 4: Hercynian deformation of the Carnic Alps. Figured are the 1st and 3rd (Figure above) deformative phases. The huge asymmteric fold affected the whole Palaeozoic belt. The 3rd phase formed thrusts with open folds which re-folded the older structures of the 1st and 2nd deformative stages (from Venturini 1990).

The formation of sedimentary basins in the Upper Carboniferous was governed by extensional tectonics (Venturini 1990). They were related to 120° to 130° directed fault zones forming thus an elongated trough with an original width of not more than 15 km shortened today to a narrow zone of some 10 km.

According to Venturini (1990) three different stress directions controlled the Alpine deformation pattern. An early NE-SW directed stressfield produced N 120°E trending thrust which, for the Carnic Alps, have mainly been destroyed by the younger N-S compression. The main structures are running in E-W direction. They include close folds, steep thrust planes, vertical faults and conjugate faults. Also, older faults were rejuvenated, for example the Bordaglia Line and the But-Chiarso-Line along which sinistral movements probably occurred during the Neogene. The third phase acted during the Plio to Quaternary time and had a stress direction from NW to SE. During this event older fault zones were reactivated.

As noted already by Heritsch (1936) the post-Variscan cover was affected by strong Alpine deformation which even produced nappes composed of flat lying Upper Carboniferous to Lower Permian limestones thrust upon the Gröden Formation. In the region west of Naßfeld Eichhübl (1988) distinguished two tectonic units, i.e., the allochthonous Trogkofel Unit and the autochthonous Stranig Unit. Evidently, thrusting of the Trogkofel Unit occurred towards southeast. This direction has clearly been inferred from numerous southeast verging folds, fold axes, kinkfolds with rounded hinges and conjugate folds recognized along the thrust plane. Thrusting is estimated to have a magnitude of more than 3 km. The NW-SE directed orientation of the maximum stress resulted from the interaction between Alpine N-S directed shortening within the Southern Alps and the developing dextral wrench fault of the Periadriatic (Gailtal) Line. After stress release a system of shear zones developed during the Oligocene (Schwarzwipfel Fault, Hochwipfel Fault, Mölltal Line and other) followed by repeated NW-SE directed shortening in the Middle Miocene during which folds en échelon facing mostly to southeast and reverse faults of the same polarity were established. At this shear faults (flower structures) large vertical displacements and uplifting occurred. Subsequently the stress field changed to N-S direction leading to the final overthrust of the Karawanken Alps over the foreland during the Pannonian and Pontian, and to the southward thrusting of the Steiner Alps in Slovenia.

The tectonic framework of the Eastern Karawanken Alps is characterized by the north verging anticlinal structure of the central and southern part (Fig. 5). Its axis dips gently towards southwest. The whole area may be subdivided into two superposed allochthonous units. In addition, north of the Seeberg anticline the folded Trögern area further complicates the deformation style.

1. In the area around the Seeberg Pass the uppermost unit is represented by the Reef Unit. Near the Pass rocks of the core are well exposed. They comprise reef and near-reef limestones, e.g., north of Plasnik (P.1257), at Rapold, Pasterk, Storschitz and at the Grintoutz localities. Laterally this facies grades into forereef and pelagic deposits. Generally, the sequence within this unit consists of different limestone of Devonian age, followed locally by the Carboniferous Hochwipfel Formation and transgressive sediments of Late Carboniferous and Permian age..At the the southern limb the well known localities of Paulitschwand, Leßnik and Sadnikar are occurring, while on the northern side such famaous outcrops as Sadonighöhe, Stanwiese, Grintoutz and Hirschfelsen are located. The lateral movement of the Reef Unit is estimated to be some 4,5 km.

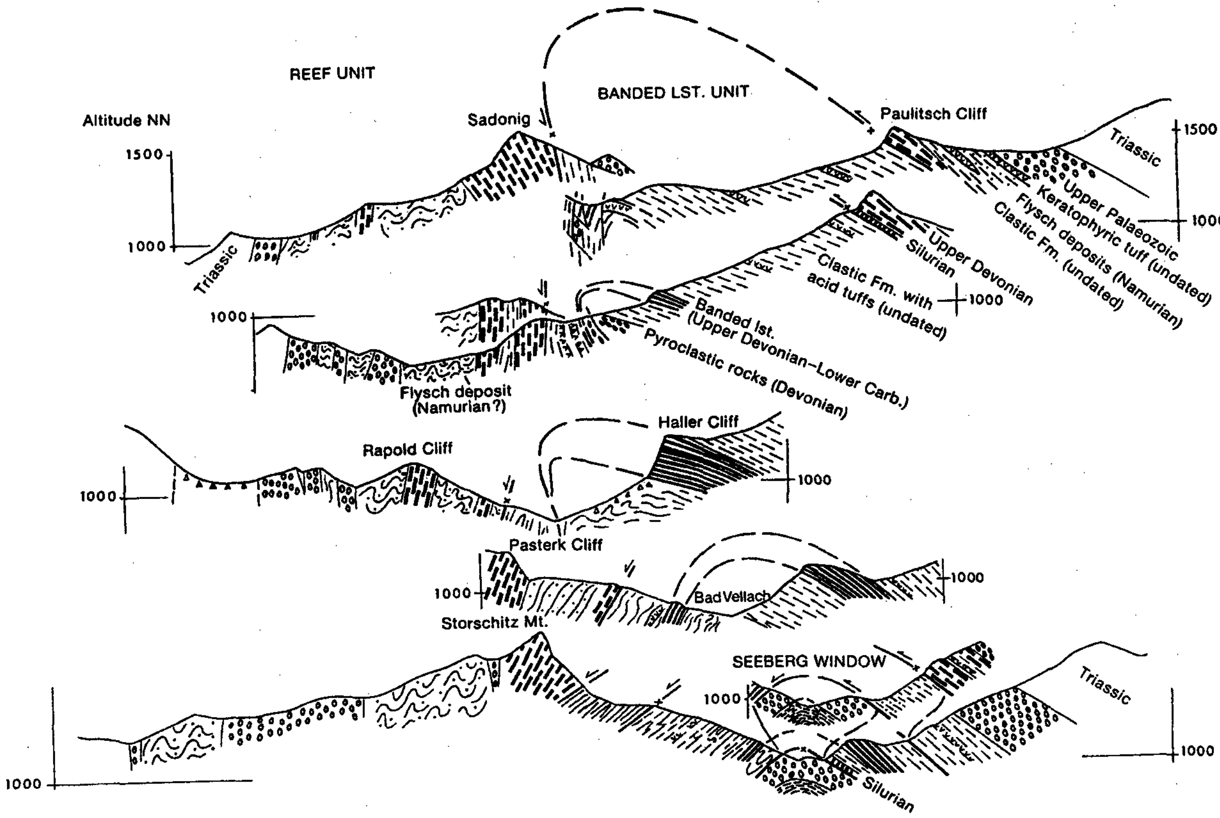


Fig. 5: N-S running sections through the Palaeozoic of the Seeberg area of the Eastern Karawanken Alps (after Rolser & Tessensohn 1974)

2. The above mentioned uppermost unit is underlain by the Bänderkalk Unit ("Striated banded limestone Unit"). It is dominated by banded limestones and over and underlying clastics. Locally, at its base nautiloid bearing Silurian limestones and Lower Devonian tentaculite bearing limestones occur. The amount of thrusting in this unit does not exceed 1,5 km.

3. The Basal Unit is well distributed between the village of Bad Vellach und the locality "Steiner". Structurally, this unit can be regarded as a tectonic window (Fig. 6). Its sequence consists of the so-called "Seeberg Shale" the age of which has yet not been ascertained and its transgressive cover formed by the equivalents of the Auernig Group, i.e., fusulinid bearing limestones, shales, sandstones and quartz-rich conglomerates.

To unravel the complicated tectonic deformation of the Eastern Karawanken Alps the above mentioned Late Carboniferous sediments are of critical importance as they provide clear evidence of the age of nappe-forming processes. Due to the fact that the post-Variscan molasse-type sediments are also involved in the nappe pile the main deformation in this are must be assigned to the Alpine tectonism.

North of the anticline formed by the above mentioned nappes the folded zone of Trögern occurs. It is characterized by steep to vertical dipping of the sequence dominated by clastic rocks of the Hochwipfel Formation. Locally also the Devonian substratum and the post-Variscan cover is exposed showing a mushroom and drop-like appearance due to squeezing of competent rocks between clastic layers. This zone may locally attain a width of more than 3 km.

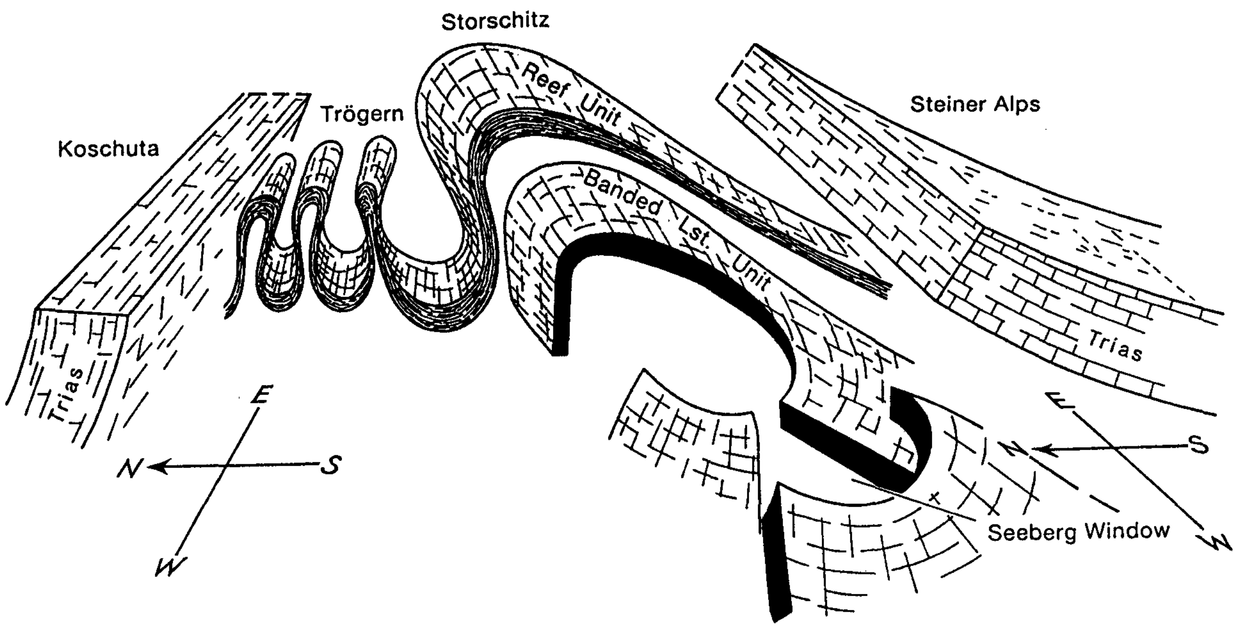


Fig. 6: Diagram showing the main tectonic units of the Seeberg area of the Estern Karawanken Alps (from Rolser & Tessensohn 1974).

In addition to the huge fold structures with amplitudes of several hundreds of meters small-scale folding is very common in the Seeberg area. It mainly affects those regions which are occupied by shales, i.e. the Seeberg Shale and the Hochwipfel Formation. Finally, steep faults have further subdivided the whole area into numerous small blocks. During the uplift of the whole area the Triassic cover of the Koschuta belt and the Steiner Alps detached from the underlying Late Carboniferous and Permian rocks.

The narrow belt of the "Diabaszug of Eisenkappel" from north of the Periadriatic Line is fault bounded to the north and the south (Fig. 3). It represents a highly compressed folded and faulted north verging zone showing several repetitions. To the north this belt of Palaeozoic rocks is thrust upon Late Permian and Triassic rocks. Most probably they formed the original cover of the Lower Palaeozoic volcaniclastic sequence suggesting thus a Variscan deformation for this Palaeozoic series. The southern boundary is formed by the north thrusting Karawanken Granite. According to radiometric dating it was formed during Late Variscan times (Cliff et al. 1975). During intrusion the Diabase of Eisenkappel and its accompanying rocks were marginally affected by contact metamorphism (Exner 1972).

The Carboniferous of Nötsch

The famous fossiliferous outcrops of Carboniferous age are located in the Gail Valley between Windische Höhe and the Villacher Alpe. It culminates in the peak called Badstube (1369 m) and is crossed by the Nötsch River. The name-bearing village of Nötsch, however, is situated in the Gailtal Crystalline Complex follwing to the south of the Carboniferous deposits (Fig. 7).

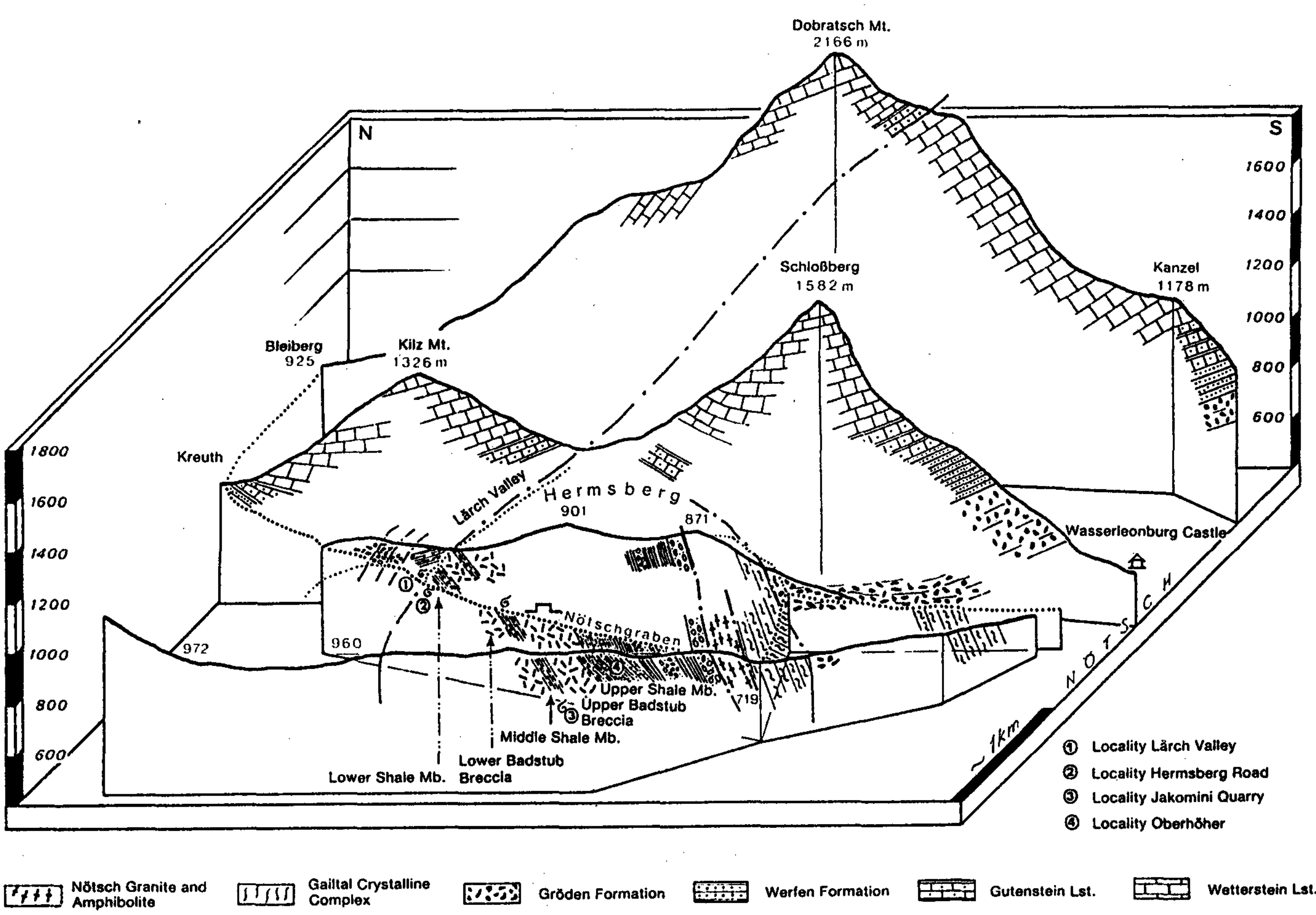


Fig. 7: Diagrammatic sketch of the eastern part of the Carboniferous of Nötsch showing the south dipping succession along the river Nötsch bounded to the north and south by faults. To the east the Carboniferous deposits are overlain by Permian and Triassic rocks of the mountain Dobratsch (=Villacher Alpe). From Schönlaub 1985.

Since the beginning of the last century the Carboniferous of Nötsch has been famous for its abundance of fossils and thus has attracted many geologists and palaeontologists. The east-west directed exposures extend as narrow fault-bounded wedge over a distance of 8 km the maximum width of which is 2 km in the east. Further to the west the Carboniferous rocks are squeezed out between the above mentioned rocks and are also covered by Quaternary deposits, respectively.

The tectonic significance of these Carboniferous rocks has raised many controversial statements in the past. In fact the true relationship between the Carboniferous sediments and the surrounding units of the Gailtal Crystalline Complex and the Drauzug has long been a matter of debate and has yet not been solved satisfactorily. One of the main problem concerns the northern boundary of the Carboniferous deposits (see Fig. 7): Some authors consider it as a distinct fault zone separating the Carboniferous from the Permian and Triassic while some others assume an originally transgressive relationship between Upper Carboniferous rocks and the overlying Permian clastics. A conclusive decision about one of the two options has significant implications for the tectonic framework of the greater part of the Eastern Alps.

Based on a revised map and additional palaeontological work carried out in the last few years knowledge about most rocks and fossils considerably increased. In the south dipping sequence which was affected by several NNE-SSW trending distinct faults the oldest part occurs in the north and is named Erlachgraben Formation. Towards south it is followed by the Badstub Breccia and the Nötsch Formation. Erlachgraben and Nötsch Formation display similar lithologies such as grayish blackish shales, micaceous siltstones, sandstones and quartz-rich conglomerates. Locally, fossils occur very abundantly. The disorganized Badstub Breccia is composed of mainly subrounded and rounded crystalline clasts such as amphibolites, ortho- and paragneisses, schists, micaschists, quartz, quartzites, marbles and few limestone clasts embedded in a dense green matrix of tholeiitic composition. From sedimentological evidence Schönlaub (1985b) and subsequently Krainer & Mogessie (1991) inferred a sedimentary origin of the breccia. Previously a volcanic source was favoured for the explanation of this rock. Conodonts recovered from limestone clasts indicate a formation after the *Paragnathodus nodosus* Zone. In terms of the presently used chronostratigraphical subdivision of the Carboniferous this time correpsonds to the latest Visean or more probably, to the early Serpukhovian.

New and revised fossil data (see Schönlaub, this volume) suggest an overall Late Visean to Early Westphalian age for the molasse-type Carboniferous sediments. The dominating fossil groups are brachiopods, followed by bivalves, trilobites, gastropods, corals, crinoids, bryozoans, very few cephalopods and plants; microfossils include foraminifera, ostracods and few conodonts. In addition in the clastics trace fossils are fairly common.

Yet the basement of the transgressive Carboniferous sequence has not been found. It may either be formed by an amphibolite-grade crystalline complex or less probably, by the Gailtal Quartzphyllite. Interestingly, at several places north of the village of

Nötsch there is clear evidence of a transgressive relationship between the latter and overlying Permian clastics (Schönlaub 1985b). It may thus be concluded that the present outline of the Carbonifeous basin was formed during the Alpine orogeny which affected and rejuvenated older faults and created new ones parallel to the Periadriatic Line. Extensive N-S shortening was mainly responsible for the closely neighbouring different tectonic units observed today; additionally vertical movements promoted the preservation of Carboniferous deposits distributed today in an apparently distinct and almost exotic setting.

The Palaeozoic of the Gurktal Nappe

Since the first half of this century fossils of Lower Palaeozoic age have been known from Middle Carinthia. They were first recognized by Petraschek (1927) who recorded *Orthoceras* sp. from the area between Feldkirchen and Lake Ossiach. According to Haberfelner (1936) who studied the Aich quarry near Althofen and north of St.Veit an der Glan, the clastic part of the section tentatively was subdivided into Ordovician and Silurian cherts, siliceous slates and quartzites. They are overlain by platy stromotoporoid bearing limestones which he assigned to the Lower Devonian. A few years later Seelmeier (1938, 1940) and Murban (1938) discovered even older fossils at the locality Bruchnig on Christofberg from north of Klagenfurt. They occurred in tuffaceous rocks at the top of a thick volcanic series studied later by Riehl-Herwirsch (1970) and Loeschke (1989) in great detail. Yet the brachiopods from this locality represent the oldest macrofauna ever been recorded from the Alps; according to Havlicek et al (1987) the fauna is equivalent to the Llandeilo Stage of the British succession and thus represents a Middle Ordovician age. Below the volcanics badly preserved conodonts may also indicate this age (Neubauer & Pistotnik 1984, Pistotnik 1989).

For a long time these few fossil localities were the only database in this region. It changed after introduction of research methods for microfossils, in particular conodonts. Since then many new data have been obtained:

-- A conodont based subdivision of the Magdalensberg Group of Kahler (1953) was first established by Strehl (1962) on the western margin of the Saualpe between Eberstein and Klein St.Paul. He recognized a 400 m thick clastic sequence with intercalations of limestones ranging from almost the base of the Silurian to the Upper Devonian. It succeeds basic volcanics and pyroclastic rocks assigned to the Upper Ordovician. Interestingly, one of the lowermost limestone lenses of the Silurian contains abundant tabulate corals and other fossil debris (crinoids, brachiopods) suggesting a bioclastic or patch-reef origin. Buchroithner (1979) confirmed this conclusion and extended the biostratigraphic information to the Upper Ordovician (Ashgillian). From the same area of Klein St. Paul Neubauer and Pistotnik (1984) recorded basic volcanics of Lower Silurian age.

-- Clar et al (1963) supplemented these data and provided additional biostratigraphic evidence from the area between Althofen-Mölbling and the Magdalensberg region including the western part of the Saualpe.

-- From limestone intercalations within phyllitic slates of the southeastern part of the Saualpe Kleinschmidt & Wurm (1966) recorded Upper Silurian (Ludlowian) conodonts.

-- Neugebauer (1970) discovered spiriferid brachiopods from marbles within the "Phyllit Group" of the Saualpe region suggesting a Devonian age.

-- The Aich quarry near Althofen was further subdivided by Schönlaub (1971). It displays a 50 m thick limestone succession ranging from the Lower Emsin to the early Famennian. Parts of the Middle Devonian, however, are missing. The limestone sequence is overlain by shales and cherts which yielded conodonts assignable to the Late Tournaisian or the Tournaisian/Visean boundary (Neubauer & Herzog 1985).

-- At Mölbling some 5 to 10 m thick limestones and dolomites provided conodonts of Late Silurian age. According to Buchroithner (1979) these carbonate rocks may well represent the extended base of the nearby Aich quarry section. In addition, Upper Ordovician conodonts were found near Mölbling (Neubauer & Pistotnik 1984) suggesting an overall continous long ranging Ordovician to Carboniferous section in this region.

-- Additional biostratigraphic information was derived from Drasenberg near the village of Meiselding and from Schelmberg east of Guttaring (v Gosen et al 1982, Neubauer & Herzog 1985). Based on conodonts some limestone lenses were assigned to the Lower and Upper Devonian, respectively. They occcur within a siliciclastic sequence which according to Neubauer & Herzog (1985) suggests similarities with the flysch-type Hochwipfel Formation of the Southern Alps.

In conclusion, the facies development of the Gurktal nappe system varies between a carbonate dominated and a carbonate-poor facies (Tollmann 1977, Buchroithner 1979 and Ebner et al 1990, see Fig.8). The first represents the pelagic "Facies of Althofen" and corresponds to the Pridolian, the whole Devonian and the Lower Carboniferous. It is opposed by the "Facies of Magdalensberg" representing a more than 500 m thick clastic-volcanic sequence with intercalations of 2 to 8 m thick limestone horizons. It spans the interval from Middle (?) Ordovician to the Middle Devonian (Buchroithner 1979, Pistotnik 1989).

The above mentioned facies variation has also been documented from the north and northwest of Middle Carinthia, i.e., the Murau and Turrach areas (Höll 1970, Ebner et al 1977, Buchroithner 1978, 1979, Neubauer 1979, Neubauer & Pistotnik 1984, Ebner et al 1990, Neubauer & Sassi, this volume). In these regions the oldest part of the sequence (?) is formed by the "Metadiabase Formation" of presumably Lower or Middle Ordovician age (according to Schnepf 1989 they may be assigned to the Silurian). This thick mafic volcanics are overlain by the more than 100 m thick Golzeck Sandstone containing conodont bearing Upper Ordovician limestone lenses, the 7 m thick Golzeck Quartzporphyry and the 6 m thick Lower Auen Dolomite indicating most probably an Ashgillian age. After a sedimentary break lasting from the Lower to the Middle Silurian the following part of the sequence is represented by the 20 m thick Middle Auen

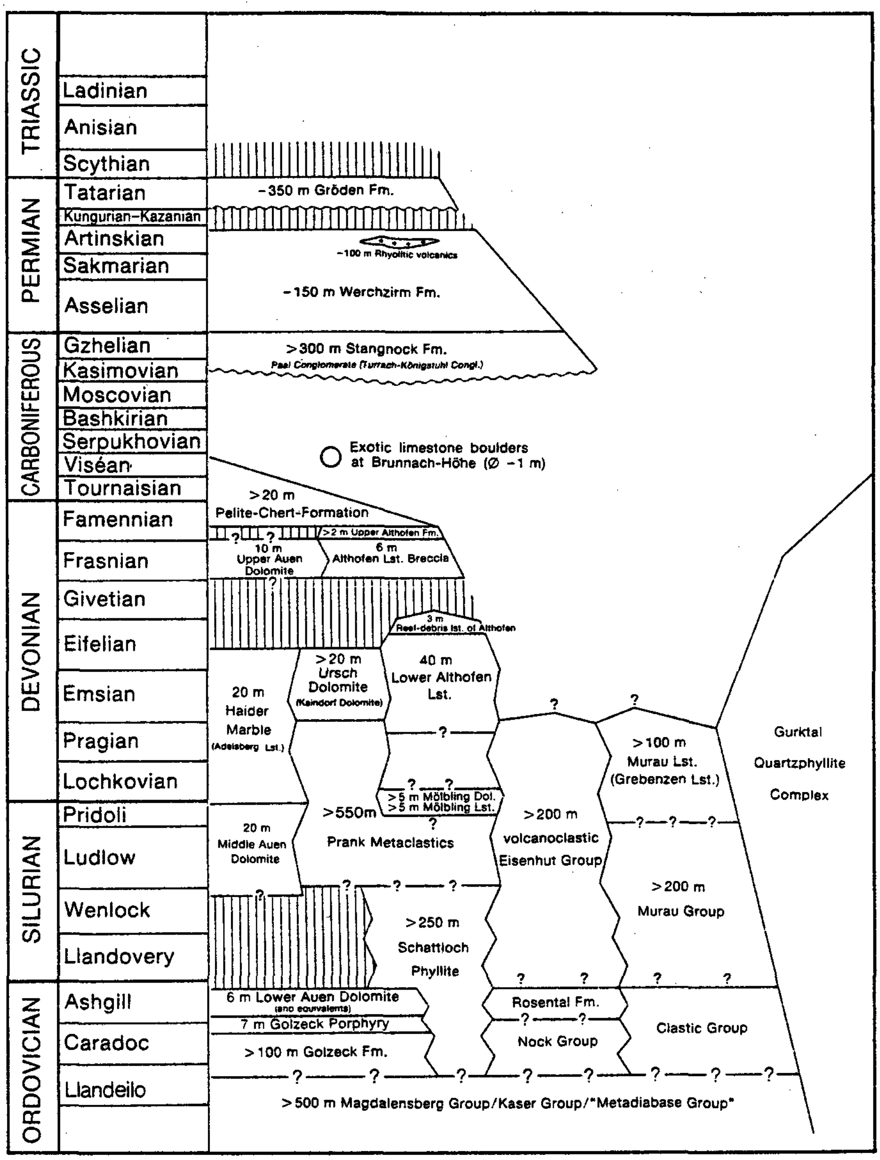


Fig. 8: Stratigraphy of the Variscan sequence of the Gurktal Nappe of Middle Carinthia and the surroundings of Murau (SW Styria). Modified from Buchroithner (1979) and Neubauer & Pistotnik 1984.

Dolomite in the Upper Silurian and the 20 m thick Haider Marble of Lower to Middle Devonian age. The 10 m thick Upper Auen Dolomite represents the uppermost portion of the sequence indicating a Frasne age.

The concurrent clastic facies displays marked differences (Neubauer 1979, Neubauer & Pistotnik 1984). For example, at locality Prankerhöhe distinct lithologies comprise more than 500 m of sandstones, quartz wackes and quartz arenites underlying the Emsian to Eifelian Ursch Dolomite. Also, in the surroundings of Turrach similar lithologies are distributed.

In addition, the Lower Palaeozoic sequences of the Gurktal nappe system are characterized by volcanic activities. Volcanism occurred at different times, varying intensity and differing geochemical behaviour depending grossly on its paleotectonic setting. For further details the reader is referred to the respective articles of this book (Loeschke and Heinisch; Neubauer and Sassi).

The Palaeozoic of Graz

Introduction

The Palaeozoic sequence in the surroundings of Graz has long been famous for its varied lithology and its abundance of fossils of mainly Devonian age. The Palaeozoic outcrops cover an area of approx. 50 x 25 km to the east and the west of the Mur river (Fig. 9). Even within the city of Graz Silurian and Devonian oucrops are widely distributed. Close to the southwestern edge the "Gosau of Kainach" transgressively overlies the Lower Palaeozoic sequence. Its eastern and northern frame is formed by crystalline rocks attributed to the Middle Austroalpine tectonic complex. To the south the Palaeozoic is covered by Tertiary rocks and thus mask the assumed continuation to the Sausal and Remschnig counterparts of southwestern Styria.

Shortly after Anker (1828) recognized the "Übergangsgebirge" in the vicinity of Graz the equivalents of the Devonian Period were discovered by Unger (1843). Although the first subdivision of the rock sequence was presented by Suess as early as 1868 a stratigraphic scheme based on fossils was not established till Stache (1884) and Pennecke (1894). This latter work constituted the base for all future studies, in particular that of Heritsch who published the first comprehensive monographs about the Palaeozoic of Graz in 1915 and 1917.

For a long time in the Palaeozoic of Graz the existence of nappes was not realized. Schwinner (1925) was the first who assumed lateral movements which explained some of the problems in stratigraphy raised by the old concepts. Following the newly proposed tectonic framework and additional field data provided by Heritsch, Clar, Waagen and others Heritsch (1943) and Flügel (1953) further improved the stratigraphic database. In the 1950s a new study campaign started. Preliminary it was completed in 1960 when Flügel (1960, 1961) presented a new map and explanatory notes based on revised and supplemented data on fossils and rocks. Since that time research in different fields has continued and the knowledge about the facies development, the macro and microfauna content, distribution of ores and the deformation features have considerably increased. For recently published summaries we refer to Flügel (1975), Schönlaub (1979), Ebner et al (1981, 1990), Flügel and Neubauer (1984) and Weber (1990).

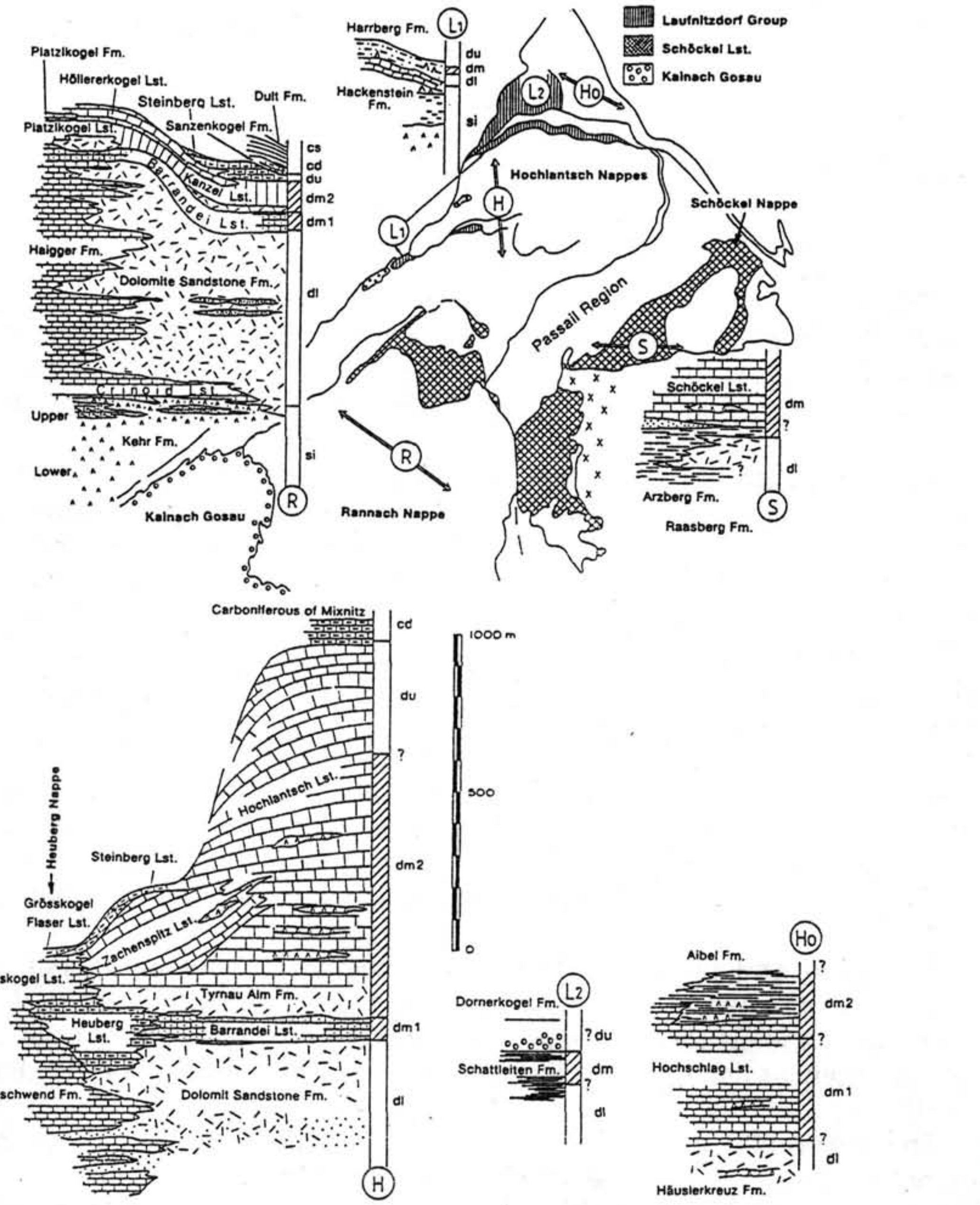


Fig. 9: Stratigraphy of the thrust system of the Palaeozoic of Graz. Letters of the stratigraphic colums indicate: R=Rannach Group, L_1, L_2=Laufnitzdorf Group, H=Hochlantsch Group, Ho=Hochschlag Group, S=Schöckel Group (from Flügel and Neubauer 1985).

Recently Fritz et al (1986, 1991) subdivided the nappe system into lower and upper nappes (Fig. 10). The first type is represented by the metamorphic Schöckel Nappe and the 'Angerkristallin', the latter by the anchi to epimetamorphic Hochlantsch, Rannach, Heuberg, Laufnitzdorf and Kalkschiefer Nappes. In comparison with the former these higher nappes lack a Variscan ductile structural imprint.

Fig.9 summarizes the lithology, stratigraphic range and regional distribution of the main facies developments of the Rannach and Hochlantsch Nappes supplemented by additional data from other units. This sketch clearly demonstrates that the individual nappes represent facies nappes.

Review of Stratigraphy

The Palaeozoic history of the Graz area is best displayed in the sequence of the Rannach Nappe. The oldest parts comprise basic metavolcanics of Ludlovian age followed by Upper Silurian to Lower Devonian clastics and limestones. Sedimentation of different carbonates dominated from the Middle Devonian to the beginning of the early Upper Carboniferous.

New field data from the Silurian Kehr Formation indicates a sedimentation pattern controlled mainly by volcanism (Fritz and Neubauer 1988, Neubauer 1989). The eastern area is characterized by a proximal shallow water setting with lavas and coarse lapilli tuffs while the western sections represent the distal facies displaying cinerites with intercalated lapilli-rich beds, agglomerates, shales and pelagic limestones. Beside other components the Kehr Agglomerate consists to 1-3% of quartzites, dolomites, cherts and reworked limestones. During the succeeding Lochkovian and Pragian Stages sedimentation of the 0 to 100 m thick Crinoid Beds and time-equivalent quartz-arenites followed the inherited topography. However, in the course of the Lower Devonian the clastic input progressively ceased in favour of carbonate sedimentation, and finally in the Emsian gave way to an almost uniform formation of dolomites, i.e, the 500 to 1000 m thick Dolomit-Sandstein Formation (Fenninger and Holzer 1978). Still, in its lower part a weak volcanic activity is indicated by the intercalation of pyroclastic rocks.

New field and biostratigraphic data obtained from other nappes suggest overall similar environmental conditions for the Upper Silurian portion of the respective sections of the Schöckel Nappe and the Laufnitzdorf Group. In the latter, however, pelagic nodular limestone sedimentation persisted during the Devonian (Gollner et al 1982).

The lower 300 m thick Sandstone Member of the Dolomit-Sandstein Formation comprises thick sandstone beds, dolomitic shales and bioclastic dolomites; the succeeding Dolomite Member consists of lower grayish and and upper blackish dolomites. In the gray dolomites Fenninger and Holzer (1978) recognized stromatolites, sheet cracks, fenestral fabrics, tepee structures, pseudomorphs of gypsum indicating a supra and subtidal environment; the black types are rich in amphiporids suggesting a setting in a protected lagoon. As far as these types and the extent of the basal sandstone member are concerned lateral and vertical variations are quite common (see Gollner and Zier 1985).

In the Eifelian the thick Dolomit-Sandstein Formation is succeded by the Barrandei and the Kanzel Limestone. The first are represented by 80 to 100 m thick grayish packstones and bioclastic limestones rich in corals, stromatoporoids, brachiopods and crinoids indicating a shallow water environment (Flügel 1975). Locally, they are interbedded with graphitic shales and brownish marls (e.g.,"Chonetenschiefer"). In the Heuberg Nappe the Heuberg Limestone represents a lateral equivalent of the Barrandei Lst. The main difference is its increased content of clastic detritus suggesting a more coastal setting.

The upper portion of the Barrandei Lst., represented by black *Amphipora*-bearing limestones is succeeded by the coarse-bedded and massive up to 100 m thick Kanzel Limestone. It comprises mudstones and wackestones with only few corals and other fossils indicating a middle or upper Givetian age. Presumably, they were formed in a protected and low agitated moderately deep environment. Time equivalent deposits are named Platzkogel Lst. and Größkogel Lst., respectively, which may also pass to platy limestones, thin bedded clayish limestones and even sandstones. Most probably they represent a near-shore shallow water environment close to or shortly after the Middle/Upper Devonian boundary.

In the Hochlantsch Nappe the 140 t0 500 m thick Tyrnau Alm Formation grossly corresponds to the Kanzel Lst. and its equivalents; previously it was named "Calceola Beds". This formation comprises dolomitic rocks, sandstones, dolomitic sandstones, limestones, shales and rauhwackes in the lower part followed by a volcanic horizon and an upper limestone member. This latter contains abundant corals and stromatoporoids forming small biostromal accumulations. For details see Gollner and Zier (1982, 1985), Zier (1982) and Gollner (1983).

The Tyrnau Alm Formation is overlain by the 350 m thick mostly well bedded Zachenspitz Limestone, previously named "Quadrigeminum Lst.". They are characterized by abundant fossils like tabulate and rugose corals, bioherms of stromatoporoids, amphiporids, crinoids and other fossil debris suggesting a subtidal quiet water environment with local reef growth. Locally, at the base volcaniclastic intercalations are common.

The lateral equivalent of this formation is the more than 800 m thick Hochlantsch Limestone. The lithology comprises massive grayish to reddish limestones which have been interpreted as shallow water back-reef deposits. They provided only few fossils like, for example, conodonts, tabulate corals and *Amphipora* indicating a Givetian to Frasnian age.

In the Hochlantsch Nappe the uppermost beds are represented by 15 m thick styliolinid limestones resembling the Steinberg Lst. of the Rannach Nappe. According to conodonts a Frasnian age of these limestones has been concluded. Disconformably they are succeeded by a limestone breccia forming the base of the cephalopod bearing "Carboniferous of Mixnitz". These pelagic deposits are up to 100 m thick and correspond to the Upper Tournaisian, Visean and basal Namurian B.

In the Rannach Nappe the Upper Devonian is represented by the grayish to yellowish or reddish and between 20 and 70 m thick Steinberg Limestone. The transition from the underlying Kanzel Lst. is gradational starting in the varcus conodont zone of the Late Givetian and ending at different time levels of the Famennian. In general, these limestones closely resemble cephalopod limestones distributed widely in the Variscan region, e.g, the Rhenish Slate Mts., the Carnic Alps or southern France. The fauna (cephalopods, trilobites, ostracods, foraminifera, conodonts) indicate a pelagic setting of moderate depths between 60 and 300 m. Corresponding units occur in the western part of the Rannach Nappe at Platzlkogel and at Höllererkogel (Höllererkogel Lst.) but also in southern slices of the Hochlantsch Nappe (Größkogel Lst.).

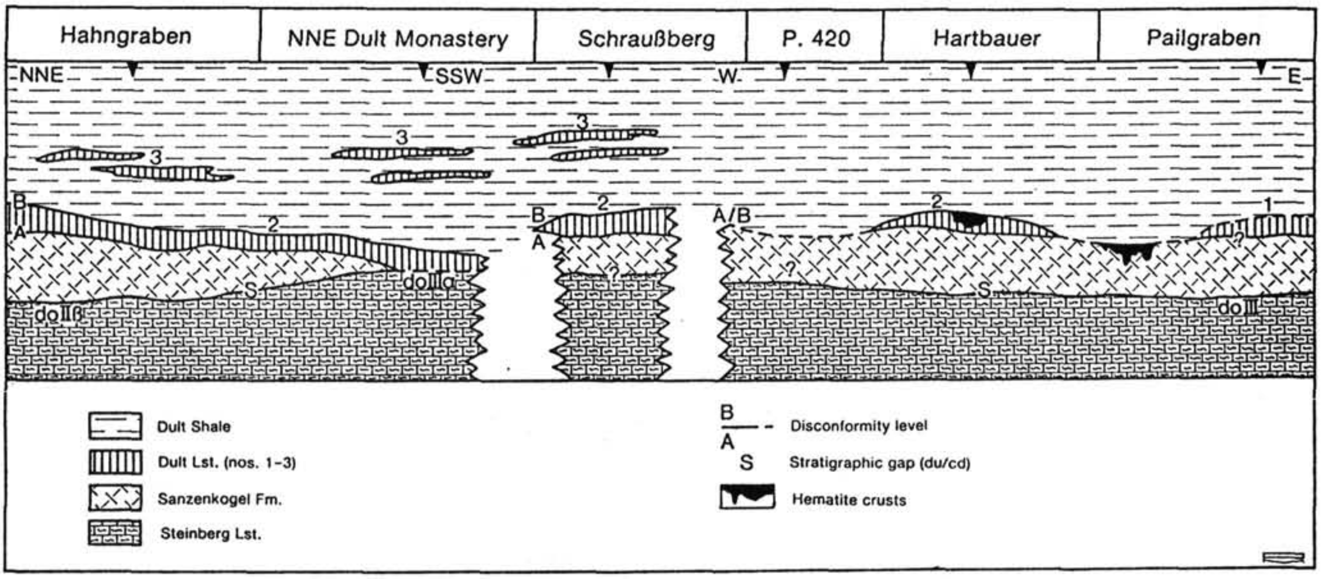


Fig. 10: Upper Devonian and Lower Carboniferous sediments of the Graz Palaeozoic. Note unconformity at the D/C boundary (letter S) and between the Sanzenkogel and the Dult Formations (A, B). From Ebner 1976.

The 20 to 25 m thick Sanzenkogel Formation represents the Lower Carboniferous part of the limestone succession of the Rannach Nappe (Fig. 10). This unit comprises grayish bedded limestones with intercalations of chert, phosphorite and shales in the lower part. They disconformably overly various levels of the Steinberg Lst. suggesting significant erosion and non-deposition in the Tournaisian. As a result the Lower Sanzenkogel Limestone ranging from the equivalents of the sulcata Zone to the Upper Tournaisian anchoralis-latus zone, does not exceed 2.20 m in thickness; frequently it is even completely missing. Formation of fissures, a distinct micro and macrorelief, internal sediment accumulations, hematite crusts, hardgrounds and mixed conodont faunas most probably indicate local emersion and karstification at the end of the

Tournaisian (Ebner 1978, Fig. 10). Subsequently, limestone sedimentation continued and the Upper Sanzenkogel Limestone was deposited.

In the Rannach Nappe the more than 70 m thick predominantly clastic Dult Formation represents the youngest rock. At its base the 10 to 15 m thick Dult Limestone is developed which disconformably overlies the Sanzenkogel Limestone (Fig. 10). Based on conodonts these basal parts represent shallow water limestones corresponding to the Namurian B. Due to the relief at the base these limestones only locally have been deposited and preserved (Ebner 1976a,b 1977a,b, 1978a,b, 1980a,b). Hence, these deposits too suggest local emersion which accords well with data from other parts of Central Europe (Schönlaub 1991). Yet the range of the Dult Formation is not precisely known; it may extend to the Westphalian as has been inferred from few conodonts and some plants.

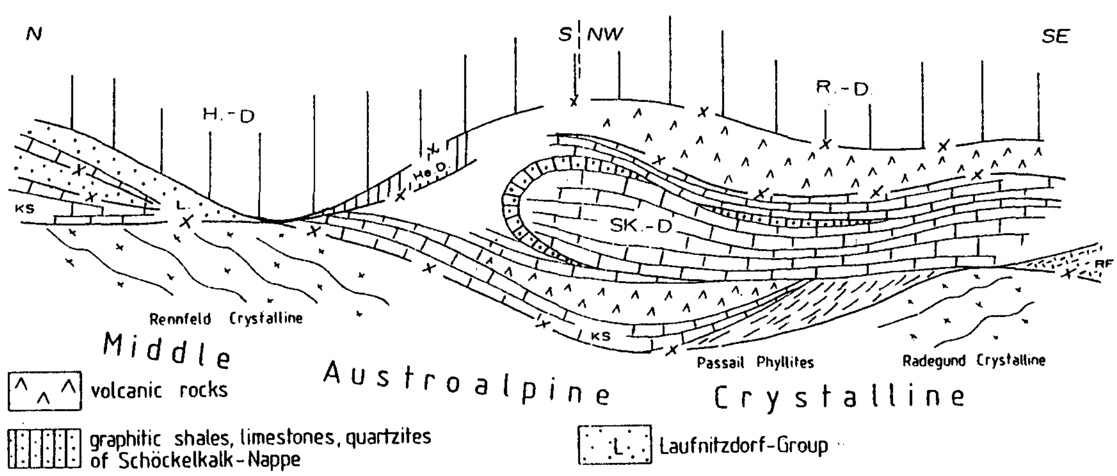


Fig. 11: Tectonic sketch of the Palaeozoic of Graz. Abbreviation: H.-D. Hochlantsch Nappe, He.D. Heuberg Nappe, R.-D. Rannach Nappe, KS Kalkschiefer unit, RF Raasberg Group (unknown age, underlying Silurian strata). From Ebner et al 1990.

In the surroundings of Graz the deepest tectonic unit is represented by the Hochschlag Group. However, the stratigraphy is only poorly known due to tectonic complications, metamorphic overprints and scarcity of fossils. It comprises the basal Häuslerkreuz Formation composed of arenites, marbles, dolomitic rocks and metavolcanics. Few conodonts indicate an Upper Silurian to Lower Devonian age. It is followed by the Hochschlag Formation composed of interbedded platy and shaly limestones, graphitic quartzites, black shales, dolomitic rocks and local occurrences of metavolcanics. Locally the limestones yielded Middle Devonian conodonts. The Hochschlag Fm. may be overlain by the Aibel Formation comprised mainly of siltstones and shales (Thalhammer 1982) with less abundantly occurring limestones, cherts, sandstones and basic metavolcanics of unknown age. Similar rocks are widely distributed near the western margin of the Palaeozoic of Graz and north of the Hochlantsch mountain. Generally they have been described as "Kalkschiefer". According to Thalhammer and Tschelaut (1983), Flügel (1984), Tschelaut (1984) and Hubauer (1983) this lithology includes interbedded mudstones to wackestones, bioclastic limestones, sandstones, arenaceous shales, marls and intercalations of volcaniclastic rocks. Thickness of these strata varies between several 100 metres and more than 800 metres. Based on conodonts the Kalkschiefer Group may range from the Upper Silurian (or Lower Devonian) to the late Middle Devonian.

Tectonic Remarks

The Palaeozoic of Graz is subdivided into a number of thrust sheets which are composed of Silurian to Carboniferous sequences of distinct facies (Figs. 9, 11). The metamorphic overprint varies from amphibolite facies at the tectonic base, i.e. the Anger Crystalline Complex, and greenschist facies of the Schöckel Nappe s.l. to nearly unmetamorphosed sequences in the Rannach and Hochlantsch trust sheets at the tectonic top of this pile. The middle portion of the nappe pile displays a multiple imbrication of the Laufnitzdorf Nappe with Kalkschiefer nappes in the northern part of the Palaeozoic of Graz. Age of metamorphic overprint is Cretaceous; Variscan metamorphism is restricted to the deepest thrust sheets. Ductile deformation along thrust surfaces and in the interior of sheets is related to Alpidic thrusting and subsequent low angle normal faulting, which reactivated thrust surfaces during exhumation (Fritz et al., 1991).

The Palaeozoic of Burgenland

In southern Burgenland rocks of Palaeozoic age have been known since the last century (Hoffmann 1877). The Devonian age was inferred from corals and crinoids which were found in massive limestones intercalated in a predominantly shaly sequence. Such occurrences ar located between the villages of Hannersdorf and Burg, near Kirchfidisch and in the surroundings of Güssing (see Pollak 1962, Schönlaub 1984, 1990).

According to Toula (1878) the small fossil collection comprises tabulate and rugose corals, badly preserved brachiopods and crinoid stems. Based on this fauna Toula concluded a Middle Devonian age. Recently new findings of tabulate corals, amphiporas, crinoids and few conodonts , i.e. icriodids, confirmed the old age assignment. Lithologically these carbonates suggested a close relationship to coeval formations in the nearby Palaeozoic of Graz. Such an affinity seems well founded by subsurface data from the area in between (Ebner 1978c, 1988, Flügel 1988).

According to new stratigraphic data interbedded shales and limestones of the Blumau Formation are dominating in the Silurian. The Lower Devonian Arnwiesen Group is characterized by dolomitic rocks which are mainly occurring in the subsurface of the Tertiary Basin of Eastern Styria. Its Middle Devonian part, however, is widely exposed in Southern Burgenland. Ebner (1988) and Flügel (1988) suggested a correlation of these carbonates with the Dolomit-Sandstein Formation of Graz. Less certain are other possible equivalents, for example, the parallelization with the Barrandei Formation or the Dult Formation. Other affinities may exist to to the Palaeozoic outcrops of North Hungary, i.e., the Szendrö-Uppony Mountains which show a very similar lithologic succession.

The Graywacke Zone

Introduction

The Graywacke Zone forms the Palaeozoic basement of the Northern Limestone Alps. The WSW-ENE directed belt of Palaeozoic rocks extends over a length of some 450 km and a maximum width of 23 km from the Rhätikon of Vorarlberg to the town of Ternitz east of the Semmering Pass. In the Vienna Basin the eastern continuation is covered by Tertiary rocks.

The Graywacke Zone and its transgressive cover, i.e. the Northern Limestone Alps, belong to the Upper Austroalpine Nappe system. It is thrust upon crystalline complexes of the Central Alps following to the south. Generally all rocks of the Graywacke Zone are moderately metamorphosed ranging as far as the upper greenschist grade, and display a certain degree of foliation. Consequently, most fossils have been either destroyed or are badly preserved.

In the eastern part the Lower Palaeozoic sequence locally starts with a conglomeratic horizon named Kalwang Gneiss Conglomerate (Daurer and Schönlaub 1979). Based on its position below fossil bearing strata for the conglomerate an age within the Ordovician can be inferred. In the surroundings of the town Bruck an der Mur it rests upon a crystalline basement complex (Neubauer 1985) which by some authors has been referred to an enigmatic intra-Ordovician collision-subduction process (Frisch et al 1984, Becker et al 1987, Neubauer and Frisch 1988, Neubauer et al 1989, Frisch et al 1990).

In the provinces of Styria and Lower Austria the Graywacke Zone is subdivided into two major tectonic units, i.e. the Veitsch Nappe below and the Noric Nappe System above (Figs.12, 15). The first comprises shallow water limestones and molasse-type clastics of Lower to Upper Carboniferous age (see article of Krainer, this volume) while the latter forms a series of strongly deformed nappes and smaller tectonic slices ranging from the Middle or Upper Ordovician to the Carboniferous. Overthrusting of the Noric and Veitsch nappes occurred during the Alpine orogeny; both nappes are separated by the so-called "Noric Thrust Line". For the Noric Nappe System, however, a strong Variscan deformation is indicated by the transgressive "sealing" redbeds of the Permian Präbichl Formation (Schönlaub 1982, Neubauer 1989).

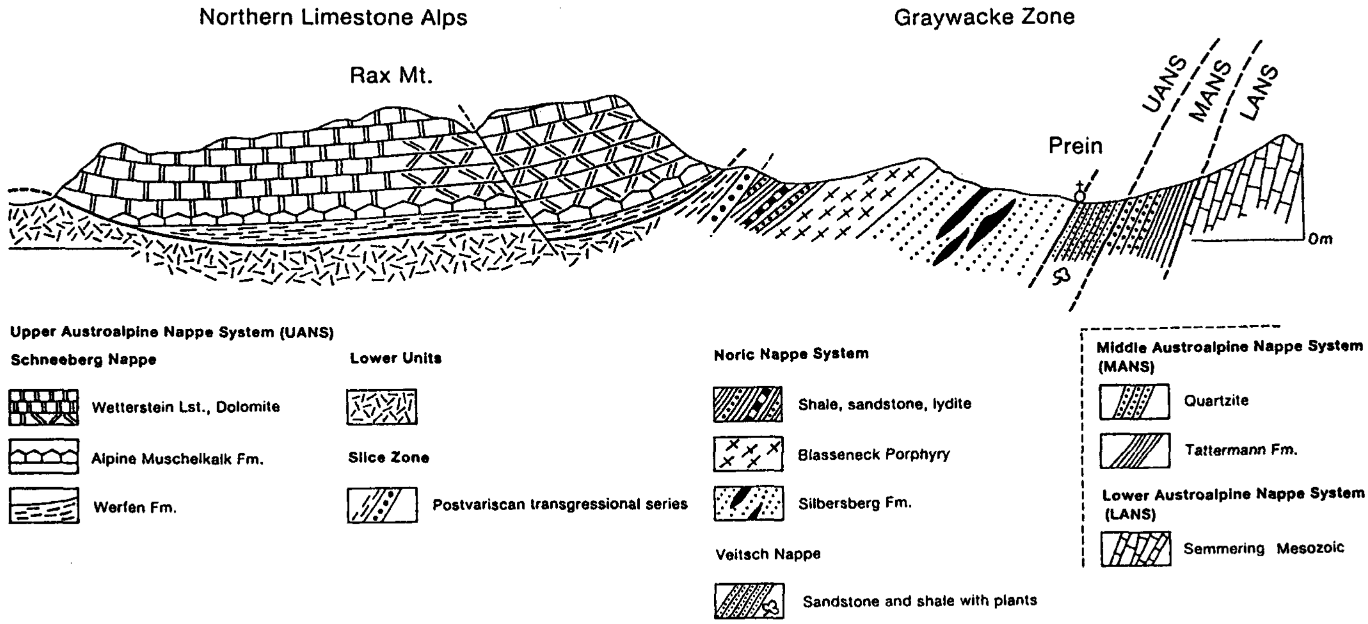


Fig. 12: NW-SE directed cross section of the Semmering area showing the tectonic relationship between the Lower, Middle and Upper Austroalpine Units. Note bipartation of the Graywacke Zone into the Veitsch Nappe below and the Noric Nappe System above. The latter is unconformably overlain by the Limestone Alps (from Tollmann).

Historical Notes

Prior to the discovery of fossils all schists of the Graywacke Zone collectively were named "graywacke". This term emphasized the separation from the "Urgebirge" of the Alps and designated as well the dominating rock type of this zone. Also it indicated the importance of mining in the Graywacke Zone during the 19th century; presently, however, only the siderite mine of Eisenerz is being mined. Following v Hauer's (1847) recognition of a Silurian fauna at Dienten the Graywacke Zone was generally regarded to represent a Lower Palaeozoic rock sequence.

For a long time knowledge of rocks and fossils of the Graywacke Zone of Styria and Salzburg was promoted by and benefited much from the mining industry. Research and progress of stratigraphy was equally concentrated in the Dienten-Mitterberg and the Eisenerz areas where a first subdivision of rocks was established by v Pantz and Atzl as early as 1814. Later, the first fossils were found including crinoids, bivalves, corals, trilobites, brachiopods and nautiloids from the localities Nagelschmiedpalfen near

Dienten and the Sauberg Limestone quarry of Eisenerz, the Polster region and a few more places (see Schönlaub 1979, 1982). At the beginning of this century subsequent work provided additional material from other regions near Kitzbühel and Fieberbrunn in Tyrol, the Entachenalm south of Hintertal in Salzburg and the Eisenerz area of Styria. As a result of the new and revised old collections Heritsch (1932, 1943) published a first biostratigraphically founded subdivision of the different lithologies of the Graywacke Zone. This scheme was further improved by correlating some of the rocks of the Graywacke Zone with coeval strata of the Southern Alps (HABERFELNER, K.METZ).

Yet, the main step towards the modern needs of a detailed biostratigraphic framework was not achieved until the early 1960s when conodont studies started in the Graywacke Zone. Such pioneering methods were first employed by Flajs for the Styrian part of the Graywacke Zone and by Mostler for the Salzburg and Tyrolian segment. Since then a great variety of new biostratigraphic data were recognized accompanied by analysis of facies, geochemistry work on volcanics and new maps (for more details the reader is referred to Schönlaub 1979, 1982, Heinisch 1986, 1988, Heinisch et al 1987, Schlaegel-Blaut 1990, Ebner et al 1990).

The Eastern Graywacke Zone of Styria

Review of Stratigraphy

The Eastern Graywacke Zone comprises a series of nappes and tectonic slices which display a certain variation of facies development of the Lower Palaeozoic rock sequence. A pre-Caradocian age is suggested for a more than 1000 m thick unfossiliferous sequence of greenschists, arenaceous shales, a thin marble bed, metaclastics and metapyroclastic rocks underlying the Blasseneck Quartzporphyry in the Southern Eisenerz Alps north of Kalwang (J.LOESCHKE et al. 1990, Fig. 13). Near the base the Kalwang Gneiss Conglomerate forms a distinct debris flow horizon interbedded in greenschists. Its age remains open.

The succeeding Blasseneck Quartzporphyry ("Blasseneck-Porphyroid") varies in thickness between a few meter or less and more than 1500 m (Heinisch 1981). In the Präbichl area the quartzporphyry is underlain by some up to 30 m thick limestone lenses which produced a rich conodont fauna of Late Caradocian or Early Ashgillian age (Flajs and Schönlaub 1976). The volcanics represent different types of recrystallized massive ignimbrites (pumice flow deposits), unwelded tuffs and other pyroclastics. According to its chemistry alcali-rhyolitic and rhyolitic compositions are dominating over rhyodacitic, dacitic and trachyandesitic rocks. These latter types mainly occur in the surroundings of Eisenerz. In this northern area the quartzporphyry is overlain by some 60 m thick quartzarenites named "Polster Quartzite" and the 13 m thick Cystoid Limestone both belonging to the Ashgillian Series (Fig. 13). In the southern part, however, the corresponding rocks may be represented by slates with intercalations of quartzarenites, greenschist and black shales comprising a thickness of a few hundred meters. Limestone intercalations in the upper part indicate a Late Llandovery or Early Wenlock age.

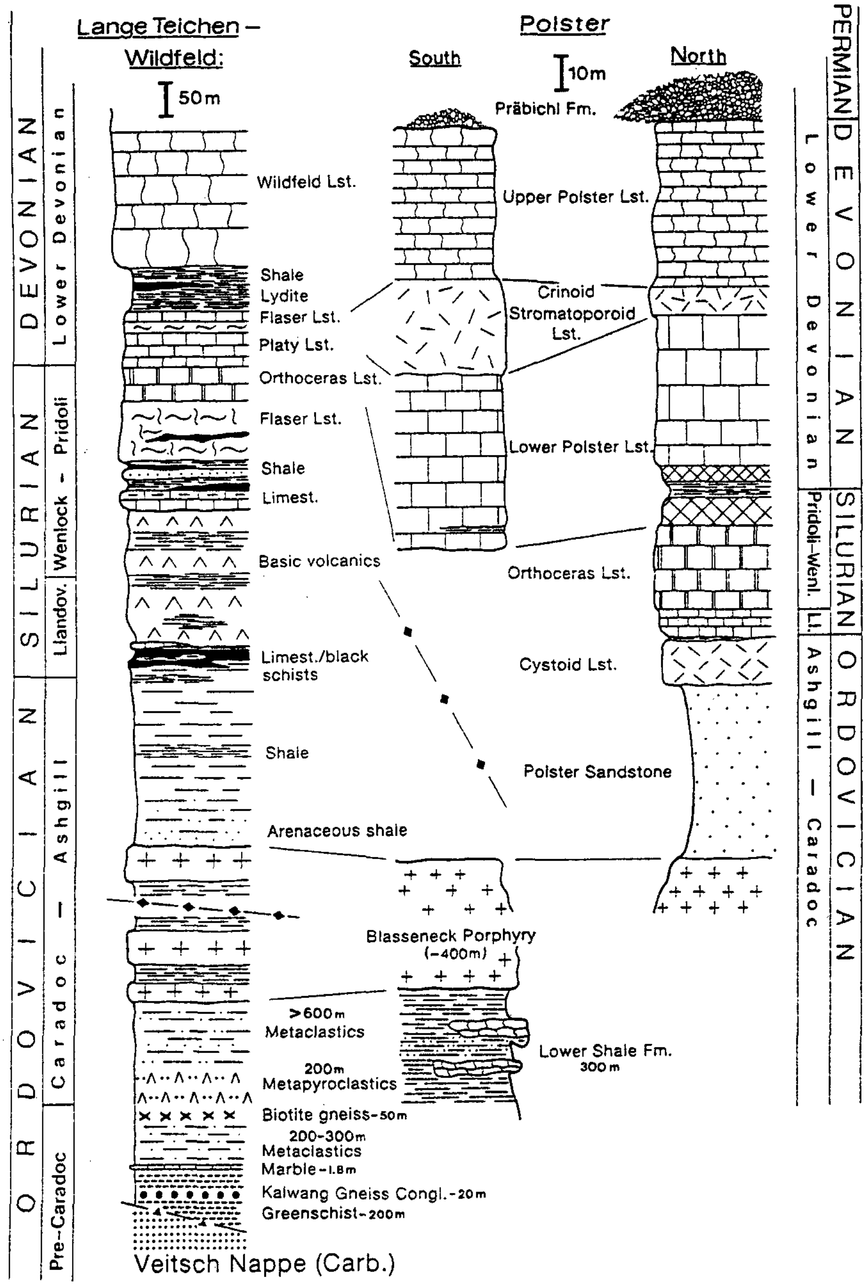


Fig. 13: Stratigraphy and facies variation of the Lower Palaezoic sequence of the Graywacke Zone in the southern and northern Eisenerz Alps (from Schönlaub 1979, modified)

During the Silurian the facies pattern varied from some 50 m thick crinoid and nautiloid bearing limestones in the northernmost part to black graptolitic shales in a more southern area. Upwards and also laterally they grade into interbedded limestones and shales followed by a pure limestone development during the Late Ludlow and Pridoli. Thus far intercalations of basic volcanics of Llandovery age have only been found near the southern margin of the Graywacke Zone (Schönlaub 1976, 1982).

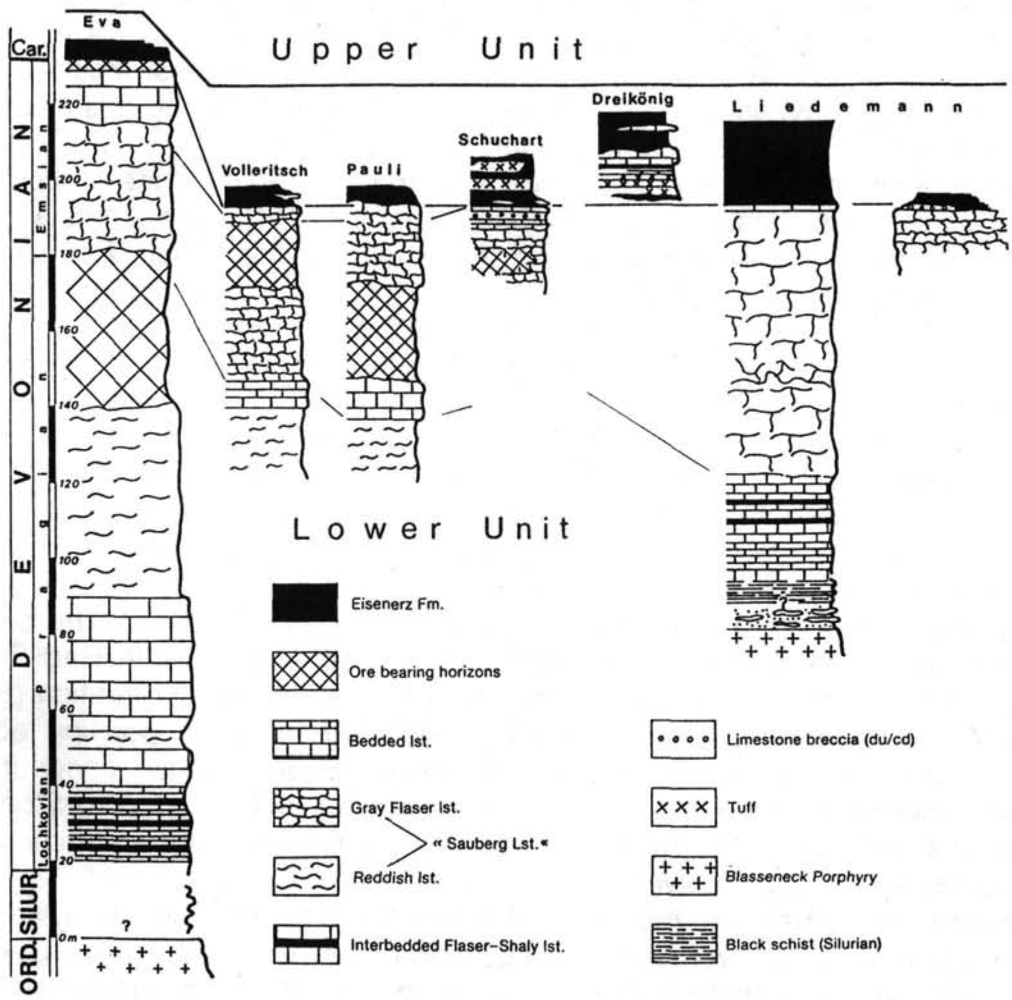


Fig. 14: Composite stratigraphic sections of the iron-mine at Erzberg/Eisenerz. Note unconformity relationship between the Devonian sequence and the overlying clastic Eisenerz Formation ("Zwischenschiefer") with a limestone breccia at the base (from Schönlaub 1979, modified).

In the Eastern Graywacke Zone limestone sedimentation continued during the Devonian. Different from other areas of the Alps, however, splitting of facies is less pronounced during this time. The Lochkovian Stage is characterized by platy limestones which may pass laterally into variegated limestones with intercalations of shales and organodetritic limestones. Locally they range into the Pragian and Emsian Stages (Fig. 13). Also, during this time nodular dacryoconarid bearing limestones and reddish limestones are very common.

In this part of the Graywacke Zone the majority of sections end at or close to the Lower/Middle Devonian boundary. At few places, however, some unfossiliferous limestones above may represent a Middle Devonian age as can be inferred from overlying rocks of Frasnian and even Famennian age. They demonstrate that limestone sedimentation may have lasted through the entire Devonian. During this time between 200 and 300 m of limestones were deposited.

Disconformably the Devonian sequence is overlain by a limestone breccia and the 100 to 150 m thick clastic Eisenerz Formation (Fig. 14). The breccia produced reworked and mixed conodonts spanning the time from the Middle Devonian to the Dinantian. Most probably the breccia was formed during a karstification event in the Visean (Schönlaub 1982). At the end of the Dinantian the paleokarst was covered by the clastic Eisenerz Formation ranging perhaps into the lower parts of the Upper Carboniferous.

A partly modified stratigraphic framework is inferred from more eastern areas of the Styrian Graywacke Zone. According to Nievoll (1983, 1987) the lowermost part is represented by the more than 300 m thick unfossiliferous Silbersberg Formation comprising metaclastites with intercalations of quartzarenites, metaquartz-conglomerates, greenschists, cherts and acid volcanics (Fig. 12). Analogous to the Eisenerz region they are overlain by the Blasseneck Quartzporphyry. The succession above is represented by the 300 to 1000 m thick metapelits of the Rad Formation. Although fossils are almost lacking for the lower part of the Rad Formation (Rad Unit) an Upper Ordovician and Silurian age is concluded from the position above the quartzporphyry and mainly below the occurrence of ferruginous conodont bearing Devonian limestones. Whether or not the overlying pelites of the Stocker Unit correspond to the clastic Eisenerz Formation of the Carboniferous or may represent tectonic repetitions is yet unsolved.

In the Enns valley between the towns of Admont and Radstadt the Graywacke Zone is tectonically reduced or even eliminated between crystalline rocks of the Central Alps to the south and the Limestone Alps to the north. The former continuation, however, has been confirmed by small outcrops near the village St.Martin south of Grimming (Böhm 1988) and from northeast of the town of Schladming (Schönlaub, unpubl.). At the first site black graphitic phyllites are associated with conodont bearing marbles of early Famennian age; previously, this sequence was regarded as part of the Veitsch Nappe. East of Schladming yellowish-brownish limestones overlying a metapelitic sequence produced conodonts of probably Upper Silurian age.

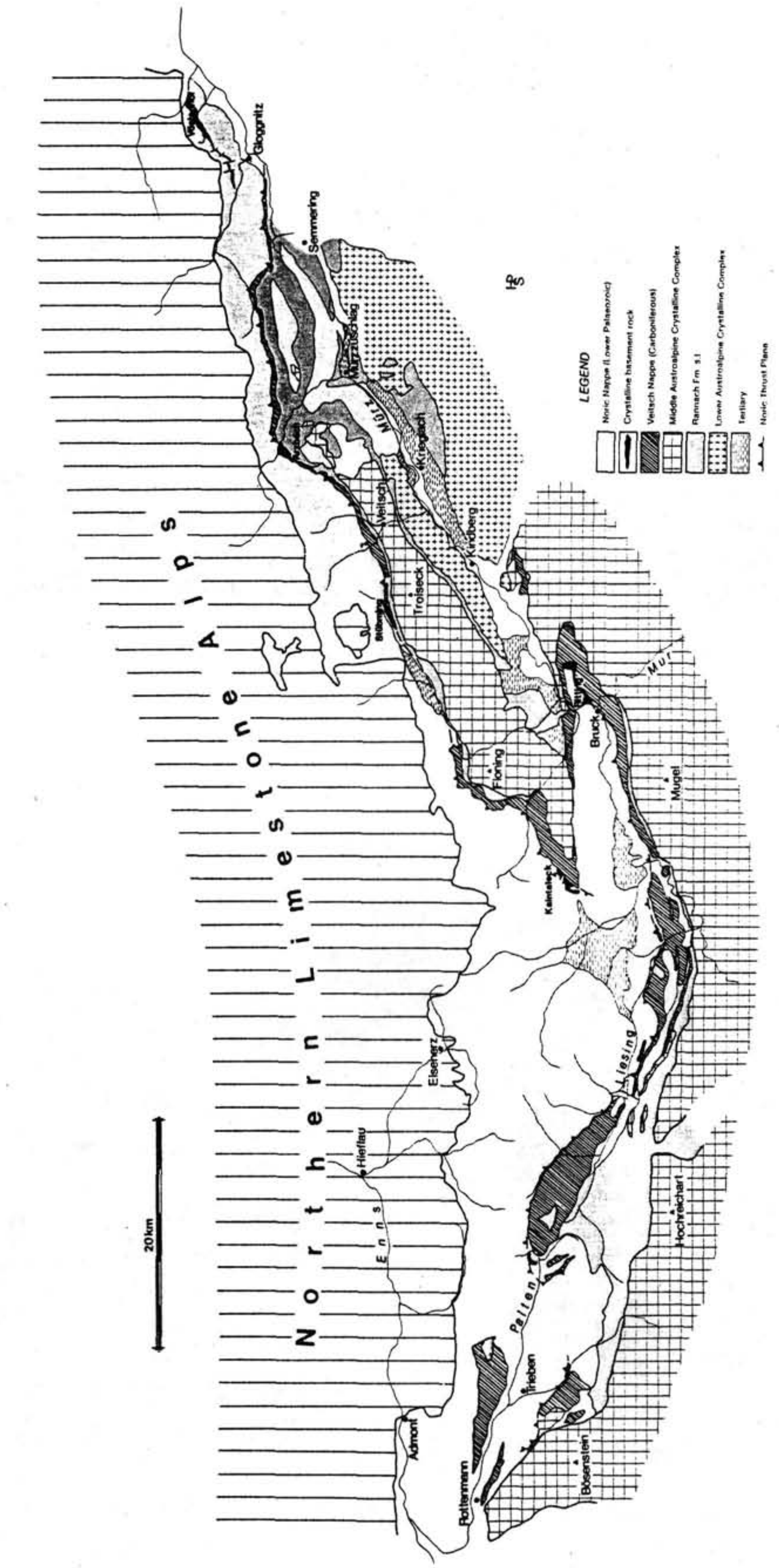


Fig. 15: Main subdivision of the eastern part of the Graywacke Zone of Styria and Lower Austria (from Schönlaub 1979, modified).

Tectonic Remarks

The main deformation of the Lower Paleozoic sequence of the Eastern Graywacke Zone occurred in the Upper Carboniferous. It resulted in southwest facing axial surface planes accompanied locally by a foliation at very low grade metamorphic conditions. During that time also an extensive system of nappes with flat lying thrust surfaces formed. This is documented by coarse clastic sediments of the Permian Präbichl Formation which unconformably overly different Variscan nappes, folds and faults (Flajs and Schönlaub 1976, Schönlaub 1982, Neubauer 1989).

In the Eisenerz Alps of the Eastern Graywacke Zone from south to north the following Variscan nappes and tectonic slices can be distinguished (Schönlaub 1982, Figs. 15, 16): Zeiritzkampl Nappe, Wildfeld Nappe, Reiting Nappe, Slice Zone and Northern Zone. Each nappe is composed of a rock sequence of mainly different stratigraphic extent and lithology. During the Alpine Orogeny this pile of basement rocks of the Northern Alps was thrust upon a lower unit comprised of the Carboniferous of the Veitsch Nappe. Both major tectonic units are separated by the Noric thrust plane.

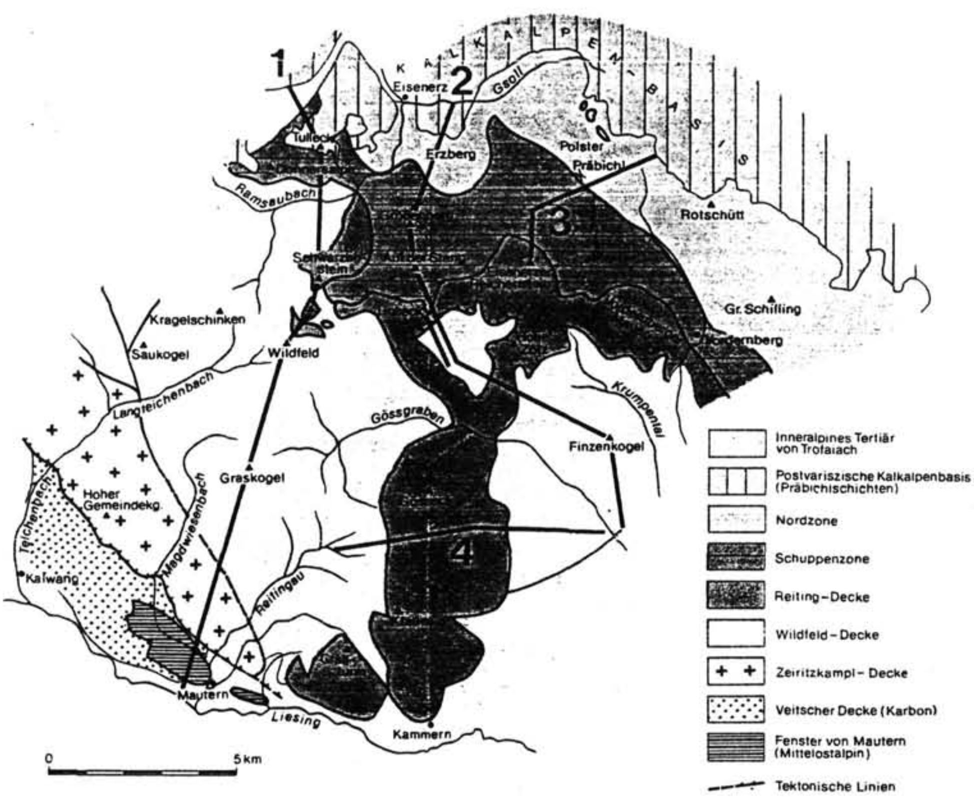


Fig. 16: Tectonic map of the Graywacke Zone of the Eisenerz Alps (from Schönlaub 1982).

The Veitsch Nappe represents the lowermost unit of the Upper Austroalpine thrust sheet. It is thrust upon the Middle Eastalpine thrust system exposed in the tectonic window of Mautern (Schönlaub 1982). The lithology within the window resembles the Rannach Formation and the Lower Triassic "Scythian Quartzite" well known from the Semmering area. In the region south of the Eisenerz Alps such clastics form the Permotriassic cover of the Variscan Seckau Crystalline Complex (Fig. 15).

The Western Graywacke Zone of Salzburg and Tyrol

Review of Stratigraphy

In the early sixties in the Western Graywacke Zone a team from Innsbruck University headed by Mostler started the re-examination of the stratigraphy and tectonic evolution of the Lower Palaeozoic sequences of Salzburg and Tyrol. The result was a well founded new biostratigraphic scheme based mainly on conodonts, supplemented by detailed sedimentological, petrographical and geochemical analysis (e.g. Mostler 1966, 1968, 1970, 1984, Al-Hasani and Mostler 1969, Mavridis and Mostler 1970, Emmanuilidis and Mostler 1970, Colins et al 1980, Fig. 17). Subsequently, detailed mapping of the Kitzbühel-Saalbach area was carried out by a working group of Munich University focusing on sedimentology, stratigraphy, volcanology, petrography and structural geology (Heinisch 1986, 1988, Heinisch et al 1987, Schlaegel 1988, Schlaegel-Blaut 1990).

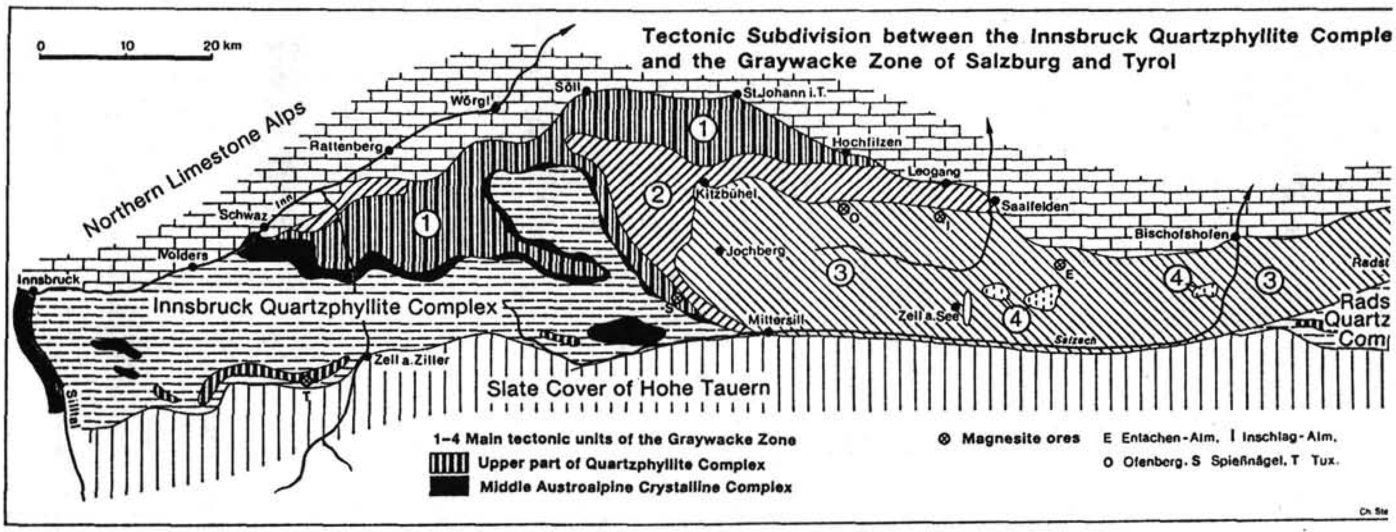
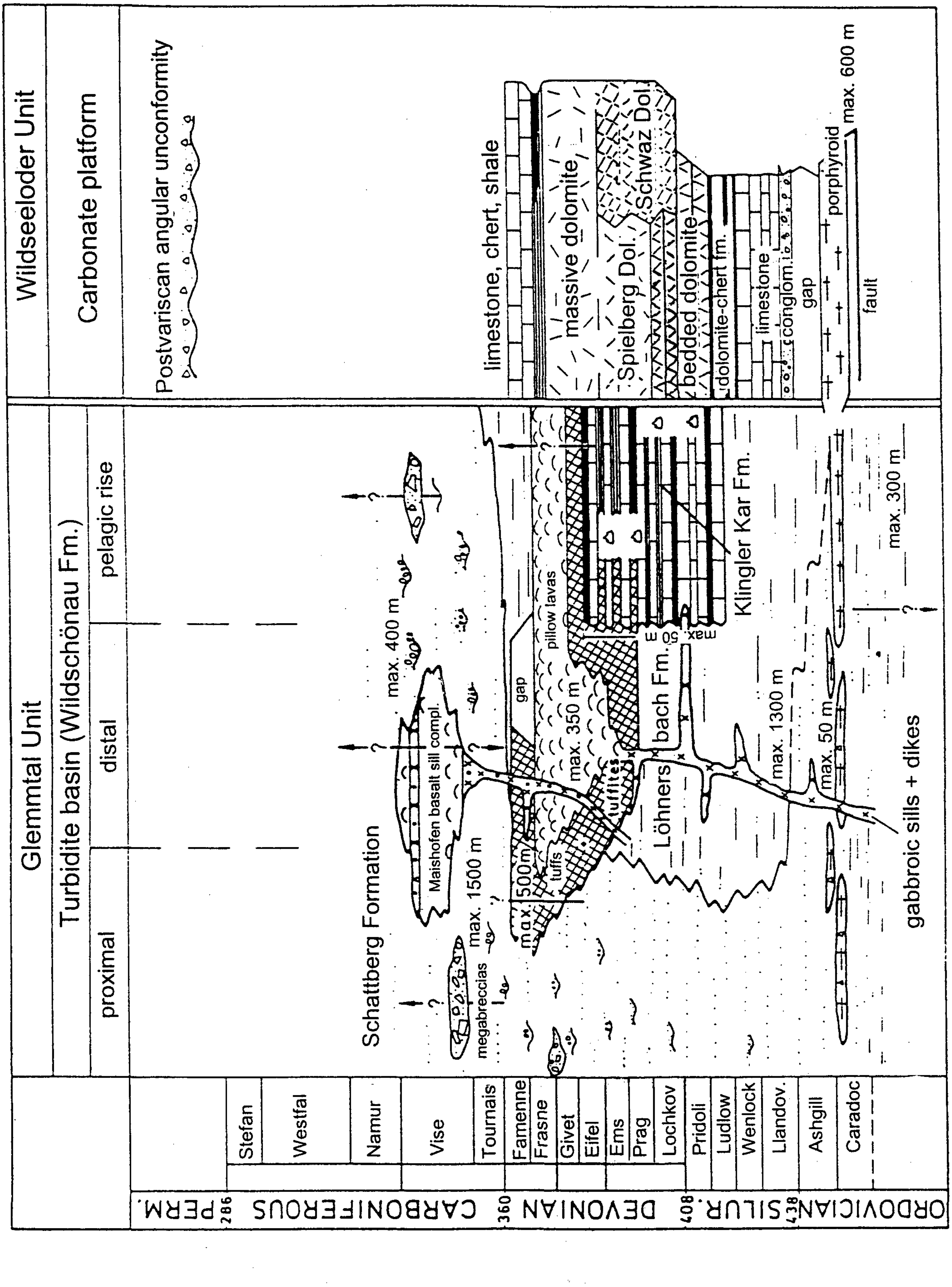


Fig. 17: Main structural subdivision of the Graywacke Zone of Salzburg and Tyrol (from Mostler 1973, modified).



Glemmtal Unit
Turbidite basin (Wildschönau Fm.)
proximal
distal
pelagic rise
Wildseeloder Unit
Carbonate platform
Postvariscan angular unconformity
Schattberg Formation
megabreccias
Maishofen basalt sill compl.
max. 1500 m
max. 400 m
max. 500 m
tuffs
tuffites
gap
pillow lavas
max. 350 m
Löhners bach Fm.
max. 50 m
Klingler Kar Fm.
max. 1300 m
max. 50 m
max. 300 m
gabbroic sills + dikes
limestone, chert, shale
massive dolomite
Spielberg Dol.
Schwaz Dol.
bedded dolomite
dolomite-chert fm.
limestone
conglom.
gap
porphyroid
fault
max. 600 m
PERM.
286
CARBONIFEROUS
360
DEVONIAN
408
SILUR.
438
ORDOVICIAN
Stefan
Westfal
Namur
Vise
Tournais
Famenne
Frasne
Givet
Eifel
Ems
Prag
Lochkov
Pridoli
Ludlow
Wenlock
Llandov.
Ashgill
Caradoc

Based on the comprehensive set of new and refined old data from the two groups mentioned above between Kitzbühel and Zell am See an obvious heterogenity of facies of the Paleozoic rock record has been recognized. Within short distances two distinct facies can be distinguished (Heinisch 1988; Fig. 18). They are preserved in two nappes named Wildseeloder and Glemmtal Unit, respectively, which are separated by a polyphase composite shear zone.

The Wildseeloder Unit covers the northern part of the studied area. It is characterized by thick piles of Upper Ordovician Blasseneck Quartzporphyry and pelagic carbonates that developed during the Silurian and the Devonian (Fig. 18).

In this unit the oldest rocks are represented by the Blasseneck Quartzporphyry. Although in this part of the Graywacke Zone fossils are missing there are good reasons to assume the same Upper Ordovician age for these volcanics as in the Eastern Graywacke Zone. According to Mostler (1970, 1984) and Heinisch (1981, 1988) the up to 600 m thick rhyolitic ignimbrites extruded under subaerial to shallow marine conditions. Due to intense thrusting, any rocks older than the Blasseneck Quartzporphyry are not preserved.

Conglomeratic horizons at the top of the volcanics might mask a considerable gap in sedimentation. In addition, mudstones, debris flows and sandstones partly interfinger with volcaniclastic layers. At some places the Blasseneck Quartzporphyry is overlain by limestones of Llandovery age (Mostler 1967, 1970). During the Silurian facies differentiation was a common feature ranging from black shales with occasional occurrences of graptolites to cherts, siliceous pelagic limestones, condensed cephalopod limestones and even to dolomitic rocks. Starting in the Upper Silurian a carbonate platform developed until the early Upper Devonian. It comprises shallow water lagoonal dolomites, a local reef development and pelagic limestone of Frasnian age (Mostler 1970, Schönlaub 1979, 1980).

The Glemmtal Unit covers the southern part of the area. It comprises several thousand meters of siliciclastic sediments named Wildschönau Group. Locally intercalations of condensed pelagic limestones with interbedded cherts and siliceous shales are found. They are named Klingler Kar Formation. Of further importance are intercalations of basic magmatites ranging from a few meters to several 100 m thickness.

The monotonous siliciclastic rocks of the Wildschönau Group consist of interbedded shales, siltstones and sandstones, with locally occurring microconglomerates, conglomerates and breccias. Relics of sedimentary features (i.e., grading, cross laminations, plane parallel laminations, convolute bedding, Bouma sequences) demonstrate a turbidite origin. Within short distances two intergrading facies can be distingiushed (Heinisch 1986, Fig. 18):

-- the Schattberg Formation displays characteristics of proximal turbidites, e.g., coarse grained m-thick graded sandstones, channeling microconglomerates and breccias; and

-- the Löhnersbach Formation shows features indicating distal turbidites, e.g., dm-thick medium to fine grained sandstones with higher amounts of siltstones and shales.

In general facies relations are diachronous although a certain degree of coarsening upwards can be recognized. Following the basic volcanism in the Middle Devonian the Schattberg Formation was distributed over the entire Glemmtal Unit. Whether or not this formation extends into the Carboniferous is yet not known because of lack of fossils.

Olistholithic megabreccias of the Schattberg Formation comprise a varying spectrum of partly well rounded boulders of garnet or hornblendegneisses, amphibolites, quartzites, sericitic gneisses and granitoids. According to heavy mineral analysis the sandstone composition, i.e.subgraywackes, indicates a continental source area (Heinisch 1988).

In conclusion during the Lower Palaeozoic the Graywacke Zone of Kitzbühel and Saalbach may have acted as a marginal basin to a continent. It was supplied by turbidites connected with fan and channel deposits. The adjacent eroded continent was characterized by a metamorphic zoning and by intruded granitoids. This passive margin regime persisted from at least the Upper Ordovician to the Middle Devonian.

The up to 50 m thick Klingler Kar Formation represents a marine hemipelagic deeper water setting which lasted from the Upper Silurian to the Middle Devonian. It comprises condensed cephalopod limestones, marls, greenish and black shales, chert horizons ("lydites") and basaltic layers. The only fossils yet discovered are conodonts which indicate different levels within the Upper Silurian and the Lower to Middle Devonian. In addition they provide precise age assignments for some of the intercalated volcanic horizons (Heinisch et al 1987, Heinisch 1986, 1988).

Intercalated in the metasediments a huge amount of basic rocks occur (Schlaegel 1988, Schlaegel-Blaut 1990). During a short time span all facies zones except the carbonate platform were affected by strong magmatic events. According to conodonts volcanism apparently started in the late Lower Devonian Emsian Stage (Heinisch et al 1987); its end has not been dated yet. The volcanism produced lavas, pyroclastic rocks and tuffites described in great detail by Schlaegel-Blaut (1990). Based on trace elements the basaltic volcanism is of intraplate type (transitional basalts and alkali basalts) and may be linked to seamounts reaching temporary a subaerial stage (see Loeschke and Heinisch, this volume).

In the past the extensive basalt-sill complex of Maishofen has been interpreted as Ordovician ocean floor basalt (Colins et al 1980, Mostler 1984). It differs from the volcanics mentioned above by the tholeiitic pillow lavas and the sills which were generated within the deeper water. Yet the exact age has not been based on fossils.

Originally, the stratigraphic base of the clastic sedimentation was supposed to be in the Lower Ordovician (Mostler 1970). Recently, this idea was supported by acritarchs of Tremadocian age recovered from metapelites near Kitzbühel (Reitz and Höll 1989). Whether or not some of the basaltic volcanics are also Ordovician in age as suggested by Mostler (1970, 1984) is presently difficult to decide due to lack of fossil evidence.

In summary, during the Silurian and Devonian in the Western Graywacke Zone the shallow water platform facies of the Wildseeloder Unit existed contemporaneously with the turbiditic basin facies of the Glemmtal Unit. The connecting link between both facies is the Blasseneck Quartzporphyry although this rock too reflects two different settings: The Wildseeloder Unit is characterized by subaerial ignimbrites; in the Glemmtal Unit the dominating rock type is an epiclastic volcanic debris washed into the basin by sediment flows. Presently the distance between these two depositional areas is not known.

Conclusions

Based on the data from the classic fossiliferous Palaeozoic regions of the Eastern and Southern Alps in the authors opinion there is no unequivocal evidence for a Caledonian collision of parts of the early Alps as proposed by Frisch et al (1984), Frisch and Neubauer (1989) and Loeschke (1989). In fact, neither an angular unconformity has been recognized in the geological record of the Alps nor any significant hiatus in sedimentation. The widespread Upper Ordovician acid volcanism as documented by the Blasseneck Quartzporphyry needs not necessarily be related to a subduction process. Rather, its partly calc-alkaline chemistry can be interpreted as anatectic melts of a thick continental crust formed during the "Pan-African tectonothermal event" (Almond 1984, Sacchi 1989).

The angular unconformity advocated by Neubauer (1985) as evidence for a Caledonian event from the base of the Palaeozoic sequence of the Eastern Graywacke Zone is undoubtely older than Upper Ordovician. Furthermore, the basally occurring conglomerate corresponding perhaps to the Kalwang Gneiss Conglomerate has not been dated yet.

There is no true time relationship between these hypothetical events in the Alps and the Caledonian collision and closure of the Iapetus ocean in Northern Europe during the Late Silurian followed by the Old Red sedimentation. Consequently, in the Alps the term "Pan-African" should be applied when describing Cambrian and/or Ordovician accretionary events. The affinities with Gondwana seem to justify such an approach.

Also, during the Ordovician to Devonian there is definitely no proof of a well developed ocean floor characterized by oceanic crust in the Alps. The majority of the basic rocks neither displays a relationship to an active plate margin nor to a mature oceanic ridge segment, but instead shows intraplate geochemistry. Any model dealing with the plate tectonic evolution of the early Alps must consider this fact.

Variation of facies is a widely occurring phenomenon and has been demonstrated for the Graywacke Zone and for other areas in the Alps characterized by Lower Palaeozoic strata. However, biostratigraphic data yet available are not always as sufficient as are required as base of a highly sophisticated evolutionary model. In particular this regards fossil data from the early Ordovician and in greenschist grade metamorphosed strata.

Crustal extension is the most common and distinct feature during the early Palaeozoic history of the Alps. It strongly controlled the sedimentation and the kind of volcanism from the Ordovician to the middle of the Dinantian. During the following time this changed in favour of subduction and collision related processes which mainly occurred in the Southern Alps.

References

AL-HASANI N, MOSTLER H (1969) Zur Geologie der Spießnägel südlich Kirchberg (Nördliche Grauwackenzone, Tirol). Veröff Univ Innsbr 9, Alpenkdl Stud 5: 5-26

ALMOND DC (1984) The concepts of "Pan-African episode" and "Mozambique Belt" in relation to the geology of E and NE Africa. Bull Fac Earth Sci Abdulaziz Univ 6: 71-87

AMEROM van HWJ, FLAJS G, HUNGER G (1984) Die "Flora der Marinelli Hütte" (Mittleres Visé) aus dem Hochwipfelflysch der Karnischen Alpen (Italien). Med Rijks Geol Dienst 37-3: 1-41

ANKER MJ (1828) Gebirgskarte der Steiermark. Tafeln zur Stratigraphie der österreichischen Monarchie. Wien

BANDEL K (1972) Palökologie und Paläogeographie im Devon und Unterkarbon der Zentralen Karnischen Alpen. Palaeontographica Abt A 141: 1-117

BAUER FK (1983) Perm der Vellacher Kotschna. In: Erläuterungen zur Geologischen Karte der Karawnken 1:25.000, Ostteil, 46-47. Geol BA

BECKER LP, FRANK W, HÖCK V, KLEINSCHMIDT G, NEUBAUER F, SASSI FP, SCHRAMM JM (1987) Outlines of the pre-Alpine metamorphic events in the Austrian Alps. In: Flügel HW, Sassi FP, Grecula P (eds) Pre-Variscan and Variscan Events in the Alpine-Mediterranean Mountain Belts. Alfa Publs Bratislava, p 69-106

BOECKELMANN K (1991) The Permian-Triassic of the Gartnerkofel-1 Core (Carnic Alps, Austria): Lithology, Sedimentology and Microfacies of Sediments. In: W.T. HOLSER, HP SCHÖNLAUB (eds) The Permian-Triassic Boundary of the Carnic Alps, Southern Austria. Abh Geol BA 45

BÖHM F (1988) Geologie des Grimming-Westabschnittes. Mitt Ges Geol Bergbaustud Österr 34/35: 151-184

BUCH L v (1824) Über die Karnischen Alpen. Leonhards Miner Taschenb 18, 2.Abt: 396-437

BUCHROITHNER MF (1978) Biostratigraphische Untersuchungen im Paläozoikum der Steiermark. Mitt naturw Ver Steiermark 108: 77-94

BUCHROITHNER MF (1979) Biostratigraphie und fazielle Untersuchungen im Paläozoikum von Mittelkärnten. Carinthia II 169: 71-95

CASTELLARIN A, VAI GB (1981) Importance of Hercynian tectonics within the framework of the Southern Alps. J Struct Geol 3: 477-486

CLAR E, FRITSCH W, MEIXNER H, PILGER A, SCHÖNENBERG R (1963) Die geologische Neuaufnahme des Saualpen-Kristallins (Kärnten), VI. Carinthia II 153/73: 23-51

CLIFF RA, HOLZER hF, REX DC (1975) The Age of the Eisenkappel Granite, Carinthia and the History of the Periadriatic Lineament. Verh Geol BA 1974: 347-350

COLINS E, HOSCHEK G, MOSTLER H (1980) Geologische Entwicklung und Metamorphose im Westabschnitt der Nördlichen Grauwackenzone unter besonderer Berücksichtigung der Metabasite. Mitt Österr Geol Ges 71/72: 343-378

DAUER A, SCHÖNLAUB HP (1979) Anmerkung zur Basis der Nördlichen Grauwackenzone. Mitt Österr Geol Ges 69: 77-87

EBNER F (1976a) Die Schichtfolge an der Wende Unterkarbon/Oberkarbon in der Rannachfazies des Grazer Paläozoikums. Verh Geol BA 1976: 65-93

EBNER F (1976b) Das Silur/Devon-Vorkommen von Eggenfeld - ein Beitrag zur Biostratigraphie des Grazer Paläozoikums. Mitt Abt Geol Paläont Bergb Mus Joanneum 37: 1-33

EBNER F (1977a) Die Gliederung des Karbons von Graz mit Conodonten. Jb Geol BA 120: 449-493

EBNER F (1977b) Die Transgression der Folge der Dult (Oberkarbon, Paläozoikum von Graz). Mitt naturw Ver Steiermark 107: 35-53

EBNER F (1978a) Die sedimentäre Entwicklung des Unterkarbons in Österreich. Österr Akad Wiss Schriftenreihe Erdwiss Komm 3: 179-190

EBNER F (1978b)Stratigraphie des Karbon der Rannachfazies im Paläozoikum von Graz, Österreich. Mitt Österr Geol Ges 69: 163-196

EBNER F (1978c) Der paläozoische Untergrund in der Bohrung Waltersdorf I (S Hartberg, Oststeiermark). Mitt Österr Geol Ges 68: 5-11

EBNER F (1980a) Conodont localities in the surroundings of Graz/Styria. In: HP SCHÖNLAUB (ed) Second European Conodont Symposium (ECOS II), Guidebook Abstracts. Abh Geol BA 35: 101-127

EBNER F (1980b) Steinbergkalk und Sanzenkogelschichten im Kalvarienbergzug E von Gratwein. Mitt naturw Ver Steiermark 110: 47-54

EBNER F (1988) Das Paläozoikum in den RAG-Bohrungen Blumau 1, 1a und Arnwiesen 1 (Oststeirisches Tertiärbecken). Jb Geol BA 131: 563-573

EBNER F, FENNINGER A, GOLLNER H, HOLZER HL, NEUBAUER F, NIEVOLL J, RATSCHBACHER L, STATTEGGER K, TSCHELAUT W, THALHAMMER O, ZIER C (1990) Stratigraphic Correlation Forms of Paleozoic units in Austria. In: SASSI FP, ZANFERRARI A (eds) Pre-Variscan and Variscan Events in the Alpine-Mediterranean Belts, Stratigraphic Correlation Forms. Rend Soc Geol It 12: 213-239

EBNER F, NEUBAUER F, PISTOTNIK J (1977) Vorbericht über stratigraphische Untersuchungen im Altpaläozoikum südlich und westlich von Murau. Sitz Ber Österr Akad Wiss math-naturw Kl 1977: 21-25

EBNER F, FENNINGER A, HOLZER HL, NEUBAUER FR, STATTEGGER K (1981) Stratigraphic Correlation Forms (SCF) of the Austrian aprt of Geotraverse B. In: SKARAMATA, FP SASSI (eds) IGCP No 5. Newsletter 3: 58-60

EICHHÜBL P (1988) Groß- und Kleintektonische Untersuchungen zum alpidischen und variszischen Gebirhsbau in den Östlichen Karnischen Alpen (Österreich/Italien). Diplomarbeit Naturwiss Fak Univ Wien, 1-123

EMMANUILIDIS G, MOSTLER H (1970) *Zur Geologie des Kitzbühler Horns und seiner Umgebung mit einem* Beitrag über die Barytvererzung des Spielberg-Dolomites (Nördliche Grauwackenzone, Tyirol). Festband Geol Inst 300 Jahr Univ Innsbruck: 547-569

EXNER C (1972) Geologie der Karawankenplutone östlich Eisenkappel, Kärnten. Mitt Österr Geol Ges 64: 1-108

FENNINGER A, HOLZER H-L (1978) Die Genese der Dolomitsandstein-Folge des Grazer Paläozoikums. Mitt Österr Geol Ges 69: 109-162

FENNINGER A, SCHÖNLAUB HP, HOLZER H-L, FLAJS G (1976) Zu den Basisbildungen der Auernigschichten in den Karnischen Alpen (Österreich). Verh Geol BA 1976: 243-255

FLAJS G, SCHÖNLAUB HP (1976) Die biostratigraphische Gliederung des Altpaläozoikums am Polster bei Eisenerz (Nördliche Grauwackenzone, Österreich). Verh Geol BA 1976:257-303

FLÜGEL E, SCHÖNLAUB HP (1990) Exotic limestone clasts in the Carboniferous of the Carnic Alps and Nötsch. In: Venturini C, Krainer K (eds) Field workshop on Carboniferous to Permian sequence of the Pramollo-Nassfeld Basin (Carnic Alps). Proceedings, p 15-19

FLÜGEL H (1953) Die Neuaufnahme des Grazer Paläozoikums 1952/1953. Anz Akad Wiss math-naturw Kl91: 232-236

FLÜGEL H (1961) Die Geologie des Grazer Berglandes. 1.Aufl. Mitt Abt Geol Paläont Bergb Landesmus Joanneum 23:1-212

FLÜGEL HW (1975a) Erläuterungen zur Geologischen Wanderkarte des Grazer Berglandes 1:100.000. Geol B-A, p 1-288

FLÜGEL HW (1975b) Einige Probleme des Variszikums von Neo-Europa. Geol Rdsch 64: 1-62

FLÜGEL HW (1984) Das Grazer Paläozoikum. In: FLÜGEL HW, NEUBAUER F (eds) Steiermark - Geologie der österreichischen Bundesländer in kurzgefassten Einzeldarstellungen. Geol BA p.44-54

FLÜGEL HW (1988) Geologische Karte des prätertiären Untergrundes. In A KRÖLL, HW FLÜGEL, W.SEIBERL, F WEBER, G WALACH, D ZYCH (eds) Erläuterungen zu den Karten über den prätertiären Untergrund des Steirischen Beckens und der Südburgenländischen Schwelle. Geol BA, 1-49

FLÜGEL HW, JAEGER H, SCHÖNLAUB HP, VAI GB (1977) Carnic Alps. In: A. MARTINSSON (ed) The Silurian-Devonian Boundary. IUGS Series A No 5: 126-142

FRISCH W, NEUBAUER F (1989) Pre-Alpine terranes and tectonic zoning in the eastern Alps. Geol Soc Amer Spec Pap 230: 91-100

FRISCH W, NEUBAUER F, SATIR M (1984) Concepts of the evolution of the Austroalpine basement complex (Eastern Alps) during the Caledonian-Variscan cycle. Geol Rdsch 73: 47-68

FRISCH W, NEUBAUER F, BRÖCKER M, BRÜCKMANN W, HAISS N (1987) Interpretation of geochemical data from the Caledonian basement complex. In: Flügel HW, Sassi FP, Grecula P (eds) Pre-Variscan and Variscan events in the Alpine-Mediterranean mountain belts. Alfa Publ Bratislava, p 209-226

FRISCH W, MÉNOT R-P, NEUBAUER F, RAUMER von JF (1990) *Correlation and evolution of the Alpine* basement. Schweiz Mineral Petrogr Mitt 70: 265-285

FRITZ H, NEUBAUER F (1988) Geodynamic aspects of the Silurian and Early Devonian sedimentation in the Paleozoic of Graz (Eastern Alps). Schweiz Mineral Petrogr Mitt 68: 359-367

FRITZ H, GSELLMANN H, NEUBAUER F, RATSCHBACHER L, AGNOLI F, FLÜGEL HW, REISINGER J, SCHLAMBERGER J (1986) Strukturanalyse in einem heterogen deformierten Terraine: Das Grazer Paläozoikum (Ostalpin). Abstract Workshop Strukturgeologie, Kristallingeologie, Tektonik, Tübingen

FRITZ H, NEUBAUER F, RATSCHBACHER L (1991) Compression versus extension in the Paleozoic of Graz (Eastern Alps, Austria). Zbl Geol Paläont Teil I 1991 (in press)

GAERTNER HR v (1931) Geologie der Zentralkarnischen Alpen. Denkschr Österr Akad Wiss Wien math-naturw Kl 102: 113-199

GOLLNER H (1983) Die Geologie des Hochlantschstockes (Grazer Paläozoikum, Steiermark). Diss Univ Graz: 1-251

GOLLNER H, ZIER C (1982) Stratigraphic Correlation Forms of the Hochlantsch facies (Hochlantscheinheit, Harrbergerformation) in the Paleozoic of Graz (Austria), Geotraverse B. In: FP SASSI, I VARGA (eds) IGCP Project No 5, Newsletter 4: 38-40

GOLLNER H, ZIER C (1985) Zur Geologie des Hochlantsch (Grazer Paläozoikum, Steiermark). Jb Geol BA 128: 43-73

GOLLNER H, THALHAMMER O, TSCHELAUT W, ZIER C (1982) Die Laufnitzdorf-Gruppe. Eine pelagische Fazies im Grazer Paläozoikum. Mitt naturw Ver Steiermark 112: 63-73

GOSEN W v, HAIGES K-A, THIEDIG F (1982) Fossilführendes Paläozoikum am Ostrand der Gurktaler Alpen (Steiermark/Kärnten- Österreich). Mitt Geol Paläont Inst Univ Hamburg 53: 151-168

HABERFELNER E (1936) Das Paläozoikum von Althofen am Krappfeld in Kärnten. Cbl Min Geol Paläont 1936B: 395-408

HAUER F v (1847) Versteinerungen von Dienten in Salzburg. Haidingers Ber 1:10

HAVLICEK V, KRIZ J, SERPAGLI E (1987) Upper Ordovician brachiopod assemblages of the Carnic Alps, Middle Carinthia and Sardinia. Boll Soc Paleont It 25: 277-311

HEINISCH H (1981) Zum ordovizischen "Porphyroid"-Vulkanismus der Ost- und Südalpen-Stratigraphie, Petrographie, Geochemie. Jb Geol B-A 124: 1-109

HEINISCH H (1986) Die Geologie der Nördlichen Grauwackenzone zwischen Kitzbühel und Zell am See und ihre Bedeutung für die Rekonstruktion der altpaläozoischen Geodynamik des Ostalpenraumes. Habilitationsschrift Univ München

HEINISCH H (1988) Hinweise auf die Existenz eines passiven Kontinentalrandes im Altpaläozoikum der Nördlichen Grauwackenzone - Ostalpen. Schweiz Mineral Petrogr Mitt 68: 407-418

HEINISCH H, SPRENGER W, WEDDIGE K (1987) Neue Daten zur Altersstellung der Wildschönauer Schiefer und des Basaltvulkanismus im ostalpinen Paläozoikum der Kitzbühler Grauwackenzone (Österreich). Jb Geol B-A 130: 163-173

HERITSCH F (1915) Untersuchungen zur Geologie des Paläozoikums von Graz I. Die Fauna und Stratigraphie der Schichten mit *Heliolites Barrandei*. Denkschr Österr Akad Wiss Wien math-naturw Kl 92: 551-614

HERITSCH F (1917) Untersuchungen zur Geologie des Paläozoikums von Graz II. Die geologische Stellung der Schichten mit *Heliolites Barrandei* in der Umgebung von Graz (mit Ausschluß des Hochlantschgebietes). Denkschr Österr Akad Wiss Wien math-naturw Kl 94: 53-112

HERITSCH F (1932) Zur Tektonik des Gebietes um Eisenerz. Verh Geol BA 1932: 103-108

HERITSCH F (1936) Die Karnischen Alpen. Monographie einer Gebirgsgruppe der Ostalpen mit variszischen und alpidischem Bau. Geol Inst Univ Graz, Graz p 1-205

HERITSCH F (1943) Das Paläozoikum. In: Die Stratigraphie der geologischen Formationen der Ostalpen I. Borntraeger Berlin

HOFFMANN K (1877) Aufnahmsbericht über das Jahr 1876. Verh Geol RA 1877: 14-23

HÖLL R (1970) Die Zinnober-Vorkommen im Gebiet der Turracher Höhe (Nock-Gebiet/Österreich) und das Alter der Eisenhut-Schieferserie. N Jb Geol Paläont Mh 1970: 201-224

HOLSER WT, SCHÖNLAUB HP, BOECKELMANN K, MAGARITZ M (1991) The Permian-Triassic of the Gartnerkofel-1 Core (Carnic Alps, Austria): Synthesis and Conclusions. In: WT HOLSER, HP SCHÖNLAUB (eds) The Permian-Triassic Boundary of the Carnic Alps, Austria. Abh Geol BA 45:

HUBAUER N (1983) Bericht 1982 über geologische Aufnahmen auf Blatt 134 Passail. Jb Geol BA 126:315

JAEGER H (1975) Die Graptolithenführung im Silur/Devon des Cellon-Profils (Karnische Alpen). Carinthia II 165/85: 111-126

JAEGER H, SCHÖNLAUB HP (1980) Silur und Devon nördlich der Gundersheimer Alm in den Karnischen Alpen (Österreich). Carinthia II 170/90: 403-444

KAHLER F (1953) Der Bau der Karawanken und des Klagenfurter Beckens. Carinthia II Sh 16: 1-78

KAHLER F (1983) Fusuliniden aus Karbon und Perm der Karnischen Alpen und der Karawanken. Carinthia II SH 41: 1-107

KLEINSCHMIDT G, WURM F (1966) Paläozoikum und epizonale Serien zwischen St. Andrä im Lavanttal und Griffen. Carinthia II 156/76: 108-140

KRAINER K, MOGESSIE A (1991) Composition and significance of resedimented amphibolite breccias and conglomerates ("Badstubbreccia Complex") in the Carboniferous of Nötsch (Eastern Alps, Austria). Jb Geol B-A 134

KREUTZER LH (1990) Mikrofazies, Stratigraphie und Paläogeographie des Zentralkarnischen Hauptkammes zwischen Seewarte und Cellon. Jb Geol B-A 133: 275-343

KREUTZER LH (1992a) Palinspastische Entzerrung und Neugliederung des Devons in den Zentralkarnischen Alpen aufgrund von neuen Untersuchungen. Jb Geol BA 134

KREUTZER LH (1992b) Photoatlas zu den Variszischen Karbonat-Gesteinen der Karnischen Alpen - Photo-Atlas of the Variscan Carbonate Sequences in the Carnic Alps. Abh Geol BA 47

LOESCHKE J (1970) Zur Geologie und Petrographie des Diabaszuges westlich Eisenkappel (Ebriachtal/Karawanken/Österreich). Oberrhein Geol Abh 19: 73-100

LOESCHKE J (1977) Kaledonischer eugeosynklinaler Vulkanismus Norwegens und der Ostalpen im Vergleich mit rezentem Vulkanismus unterschiedlicher geotektonischer Positionen: Eine Arbeitshypothese. Z dt Geol Ges 128: 185-207

LOESCHKE J (1983) Diabaszug von Eisenkappel westlich der Vellach. In FK BAUER et al: Erläuterungen zur Geologischen Karte der Karawanken 1:25.000, Ostteil. Geol BA: 24-30

LOESCHKE J (1989a) Lower Palaeozoic volcanism of the Eastern Alps and its geodynamic implications. Geol Rdsch 78: 599-616

LOESCHKE J (1989b) Die paläotektonische Stellung der Vulkanite der Magdalensberg-Serie (Ober-Ordovizium, *Gurktaler Decke, Kärnten, Österreich). Carinthia II* 179: 491-507

LOESCHKE J, KRETZSCHMAR T, LANGER V, STRECK M (1990) Zur Geologie der Norischen Decke nordwestlich von Kalwang (Eisenerzer Alpen, Steirische Grauwackenzone/Österreich). Jb Geol BA 133: 345-363

MAVRIDIS A, MOSTLER H (1970) Zur Geologie der Umgebung des Spielberghorns mit einem Beitrag über die Magnesitvererzung. Festband Geol Inst 300 Jahr Feier Univ Innsbruck: 523-546

MOHS F v (1807) Die Villacher Alpe, und die dieselbe zunächst umgebenden Gegenden. Molls Efemeriden Berg-Hüttenkunde 3: 161-228

MOSHAMMER B (1989) Das südalpine pelagische Eisenkappeler Paläozoikum (Trögener Gruppe) der Ostkarawanken. Carinthia II 179/99: 611-640

MOSTLER H (1966) Zur Einstufung der "Kieselschiefer" von der Lachtal-Grundalm (Fieberbrunn, Tirol).Verh Geol BA 1966:157-170

MOSTLER H (1967) Conodonten aus dem tieferen Silur der Kitzbühler Alpen (Tirol). Ann Naturhist Mus Wien 71: 295-303

MOSTLER H (1968) Das Silur im Westabschnitt der Nördlichen Grauwackenzone (Tirol und Salzburg). Mitt Ges Geol Bergbaustud Österr 18: 89-150

MOSTLER H (1970) Struktureller Wandel und Ursachen der Faziesdifferenzierung an der Ordoviz/Silur-Grenze in der Nördlichen Grauwackenzone (Österreich). Festbd Geol Inst 300 J Univ Innsbr, p 507-522

MOSTLER H (1984) Erfassung basischer Massengesteine im Raum Mittersill-Zell a. See-Salzburg. Arch Lagerstforsch (Ostalpen) 5: 105-115

MURBAN K (1938) Brachiopoden aus dem Caradoc vom Christoffberg bei Pischeldorf. Anz Österr Akad Wiss Wien math-naturw Kl

NEUBAUER F (1979) Die Gliederung des Altpaläozoikums südlich und westlich von Murau (Steiermark/Kärnten). Jb Geol B-A 122: 455-511

NEUBAUER F (1984) Das Murauer und Gurktaler Paläozoikum. In: Flügel HW, Neubauer F Steiermark-Geologie der österreichischen Bundesländer in kurzgefassten Einzeldarstellungen. Geol B-A p.55-58

NEUBAUER F (1985) Eine präoberordovizische Transgression in der Grauwackenzone (Ostalpen) und ihre Bedeutung für paläozoische Geodynamik und alpidischen Deckenbau. N Jb Geol Paläont Mh 1985: 46-64

NEUBAUER F (1988) The Variscan orogeny in the Austroalpine and Southalpine domains of the Eastern Alps. Schweiz Mineral Petrogr Mitt 68: 339-349

NEUBAUER F (1989) Late Variscan structures of the Eastern Greywacke Zone (Eastern Alps). N Jb Geol Paläont Mh 1989: 425-432

NEUBAUER F, PISTOTNIK J (1984) Das Altpaläozoikum und Unterkarbon des Gurktaler Deckensystems (Ostalpen) und ihre paläogeographischen Beziehungen. Geol Rdsch 73: 149-174

NEUBAUER F, HERZOG U (1985) Das Karbon der Stolzalpendecke Mittelkärntens - Implikationen für die variszische Paläogeographie und Orogenese im Ostalpin. Anz Österr Akad Wiss math-naturw Kl 1985: 105-109

NEUBAUER F, FRISCH W (1988) Ordovician-Silurian geodynamic evolution of the Alps - the orogeny back-arc basin model. Schweiz Mineral Petrogr Mitt 68: 351-357

NEUBAUER F, FRISCH W, SCHMEROLD R, SCHLÖSER H (1989) Metamorphosed and dismembered ophiloite suites in the basement units of the Eastern Alps. Tectonophysics 164: 49-62

NEUBAUER F, DALLMAYR R D (1994) $^{40}Ar/^{39}Ar$ Age of Detrital Muscovite, Carnic Alps: Evidence for Cadomian Basement in the Eastern Alps. J. Geol. Soc. London

NEUGEBAUER J (1970) Altpaläozoische Schichtfolge, Deckenbau und Metamorphoseablauf im südwestlichen Saualpen-Kristallin (Ostalpen). Geotekt Forsch 35: 23-93

NIEVOLL J (1983) Stratigraphische und strukturgeologische Untersuchungen in der Grauwackenzone bei Veitsch (Steiermark). Unpubl Diss Univ Graz: 1-150

NIEVOLL J (1987) The Lower Paleozoic of the Noric Nappe at Veitsch (Eastern Alps, Austria). In: FLÜGEL HW, SASSI FP, GRECULA P (eds) Pre-Variscan and Variscan Events in the Alpine-Mediterranean Mountain Belts. IGCP Project No 5 Regional Volume, Miner Slov Monogr: 379-386

PANTZ VIR v, ATZL AJ (1814) Versuch einer Beschreibung der vorzüglichsten Berg- und Hüttenwerke des Herzogthumes Steyermark. 1-374 Wien

PASINI M (1963) Alcuni Fusulinida della serie del Monte Auernig (Alpi Carniche) e loro significato stratigrafico. Riv Ital Paleont 69: 337-382

PENNECKE KA (1894) Das Grazer Devon. Jb Geol RA 43: 567-616

PETRASCHEK W (1927) Zur Tektonik der alpinen Zentralzone. Verh Geol BA 1927: 151-164

PISTOTNIK J (1989) Die Phyllitgruppe und Magdalensbergserie auf ÖK-Blatt 186 St.Veit/Glan. In: Arbeitstagung der Geol.B.-A. 1989, Blatt 186 St.Veit an der Glan: 42-44

POHLER S (1982) Die Entwicklung der Flachwasserkarbonate im Mittel- und Oberdevon der Zentralen Karnischen Alpen (Seewartesockel zum S-Abfall der Hohen Warte). Diplomarbeit Paläont Inst Univ Bonn: 1-134

POLLAK W (1962) Untersuchungen über Schichtfolge, Bau und tektonische Stellung des österreichischen Anteils der Eiseneberggruppe im südlichen Burgenland. Diss Phil Fak Univ Wien: 1-108

RANTITSCH G (1990) Fazies und Diagenese devonischer Riffkalke des Seeberger Aufbruches (Kärnten, Österreich). Diplomarb Inst Geol Paläont Univ Graz, p 1-120

REITZ E, HÖLL R (1989) Unterordovizische Acritarchen aus der Nördlichen Grauwackenzone (Ostalpen). Jb Geol B-A 132: 761-774

RIEHL-HERWIRSCH G (1970) Beitrag zur Altersstellung der Magdalensbergserie (Altpaläozoikum-Mittelkärnten). Mitt Ges Geol Bergbaustud Österr 19: 195-214

ROLSER J, TESSENSOHN F (1974) Alpidische Tektonik im Variszikum der Karawanken und ihre Beziehung zum Periadriatischen Lineament. Geol Jb A25: 23-53

SACCHI R (1989) Pan African Rejuvenation. 28th Intern Geol Congr Washington, Abstracts 3:2-3

SCHLAEGEL P (1988) Geotektonische Neuinterpretation des basischen Magmatismus der Nördlichen Grauwackenzone, Ostalpen - ein Überblick. Schweiz Mineral Petrogr Mitt 68: 419-432

SCHLAEGEL-BLAUT P (1990) Der basische Magmatismus der Nördlichen Grauwackenzone, Oberostalpines Paläozoikum. Abh Geol B-A 43: 1-149

SCHNEPF HG (1989) Vulkanismus und Sedimentologie im Murauer Paläozoikum (Gurktaler Decke, Oberostalpin, Österreich). Arb Inst Geol-Paläont Univ Tübingen A2: 1-183

SCHÖNLAUB HP (1971) *Palaeo-environmental studies at the Ordovician/Silurian boundary in the Carnic Alps. In:* Colloque Ordovicien-Silurien Brest 1971. Mem Bur Rech géol minières 73: 367-377

SCHÖNLAUB HP (1979) Die Nördliche Grauwackenzone. In: Das Paläozoikum von Österreich. Abh Geol B-A 33: 76-97

SCHÖNLAUB HP (1980) *Carnic Alps. Field Trip A. In: Schönlaub HP (ed) Second European Conodont Symposium* ECOS II, Guidebook-Abstracts. Abh Geol B-A 35: 5-57

SCHÖNLAUB HP (1982) Die Grauwackenzone in den Eisenerzer Alpen (Österreich). Jb Geol BA 124: 361-423

SCHÖNLAUB HP (1984) Das Paläozoikum von Sulz bei Güssing im Südburgenland. Jb Geol BA 127: 501-505

SCHÖNLAUB HP (1985a) Das Paläozoikum der Karnischen Alpen. In: Arbeitstagung der Geologischen Bundesanstalt 1985. Geol B-A 1985: 34-52

SCHÖNLAUB HP (1985b) Das Karbon von Nötsch und sein Rahmen. Jb Geol.B-A 127: 673-692

SCHÖNLAUB HP (1990) The collapse of the Carboniferous flysch trough in the Carnic Alps. In: Venturini C, Krainer K (eds) Field workshop on Carboniferous to Permian sequence of the Pramollo-Nassfeld Basin (Carnic Alps). Proceedings, p 14

SCHÖNLAUB HP, KLEIN P, MAGARITZ M, RANTITSCH G, SCHARBERT S (1991) Lower Carboniferous Paleokarst in the Carnic Alps (Austria, Italy). Facies 25: 91-118

SCHWINNER R (1925) Das Bergland nordöstlich von Graz. Sitz Ber Österr Akad Wiss math-naturw Kl 134: 219-276

SEELMEIER H (1938) Die stratigraphische Eingliederung der Diabase und Diabastuffe des Christophberges bei Klagenfurt. Anz Österr Akad Wiss Wien math-naturw Kl 75: 110-113

SEELMEIER H (1940) Geologische Beobachtungen in der Umgebung des Chrisoph Berges und des St.Magdalens Berges bei Klagenfurt. Z Dt Geol Ges 92: 430-441

SPALLETTA C , VENTURINI C (1988) Conglomeratic Sequences in the Hochwipfel Formation: A New Paleogeographic Hypothesis on the Hercynian Flysch Stage of the Carnic Alps. Jb Geol BA 131: 637-647

SPALLETTA C, VAI GB, VENTURINI C (1980) Il flysch ercinico nella geologia dei Monti Paularo e Dimon (Alpi Carniche). Mem Soc Geol It 20: 243-265

STACHE G (1874) Die paläozoischen Gebiete der Ostalpen. Jb Geol RA 24: 135-272

STACHE G (1872) Entdeckung von Graptolithenschiefer in den Südalpen. Verh Geol RA 1872: 234-235

STACHE G (1884) Über die Silurbildungen der Ostalpen, nebst Bemerkungen über die Devon-Karbon- und Permschichten dieses Gebietes. Z Dt Geol Ges 36: 277-378

STREHL E (1962) Die geologische Neuaufnahme des Saualpen-Kristallins. IV. Das Paläozoikum und sein Deckgebirge zwischen Klein St.Paul und Brückl. Carinthia II 152: 46-74

SUESS E (1868) Über die Äquivalente des Rothligenden in den Alpen. Sitz Ber Österr Akad Wiss math-naturw Kl Abt I 57: 230-277

TESSENSOHN F (1971) Der Flysch-Trog und seine Randbereiche im Karbon der Karawanken. N Jb Geol Paläont Abh 138: 169-220

TESSENSOHN F (1974) Zur Fazies paläozoischer Kalke in den Karawanken (Karawankenkalke II). Verh Geol BA 1974: 89-130

TESSENSOHN F (1983) Eisenkappler und Seeberger Paläozoikum. In: FK BAUER et al Erläuterungen zur Geologischen Karte der Karawanken 1:25.000, Ostteil. Geol BA: 32-45

THALHAMMER O (1982) Das Paläozoikum nördlich der Breitenau. Unpubl Diss Univ Graz: 1-251

THALHAMMER O, TSCHELAUT W (1983) Some remarks on the northern parts of the Graz Paleozoic (Austria, Geotraverse B). In: SASSI FP, SZEDERKENYI T (eds) IGCP Project No 5. Newsletter 5: 187-190

TIETZE E (1870) Beiträge zur Kenntnis der älteren Schichtgebilde Kärntens. Jb Geol RA 20: 259-272

TOLLMANN A (1977) Geologie von Österreich. Band 1. Deuticke Wien: 1-766

TOULA F (1878) Über Devon-Fossilien aus dem Eisenburger Comitate. Verh Geol RA 1878: 47-52

TSCHELAUT W (1984) Die Geologie des Gebietes zwischen Röthelstein und Gams bei Frohnleiten (Grazer Paläozoikum, Steiermark). Unpubl Diss Univ Graz: 1-155

UNGER F (1843) Geognostische Skizze der Umgebung von Grätz. In: G SCHREINER (ed) Grätz: 69-82.

VAI GB (1979) Una palinspastica permiana della Catena Paleocarnica. Rend Soc Geol It 1: 25-27

VENTURINI C (1990) Geologia delle Alpi Carniche Centro Orientali. Comune Udine Ed Mus Friul St Nat 36: 1-220

VENTURINI C, FERRARI A, SPALLETTA C, VAI GB (1982) La discordanza ercinica, il tardorogeno e il postorogeno nella geologia del Passo di Pramollo. In: A CASTELLARIN, GB VAI (eds) Guida alla geologia del Sudalpino centro-orientale. Guide Geol Reg Soc Geol It: 305-319

WALLISER OH (1964) Conodonten des Silurs. Abh hess L-Amt Bodenf 41: 1-106

WEBER L (1990)

ZIER C (1982) Die Geologie des Gebietes zwischen Bärenschützklamm und Tyrnauergraben (Grazer Paläozoikum, Steiermark). Unpubl Diss Univ Graz: 1-364

The Faunal Relationship of the Silurian of the Alps[1]

with 1 figure

by Hans Peter Schönlaub

In the Alps the Silurian Period is characterized by a wide range of different lithofacies (H.P. SCHÖNLAUB 1979). The respective rocks are locally very fossiliferous and have long been known from the Carnic Alps of southern Carinthia and its eastern continuation, the Karawanken Alps, the Graywacke Zone of Styria, Salzburg and Tyrol, the surroundings of Graz, the Gurktal Nappe of Carinthia and Styria and from a few other places within the quartzphyllite complexes of the Eastern Alps.

Generally, three types of lithofacies, each with a distinct faunal assemblage, can be recognized :

1. Fossiliferous carbonate facies: The dominating lithologies are limestones and less frequently dolomites with a thickness of at most some 60 m. Although the equivalences of the Lower Llandovery are missing, for the remaining of the Silurian the fossil record from many sections of the Carnic Alps and the Graywacke Zone has indicated a complete but slightly condensed sequence. Fossil assemblages consist of varying abundances of nautiloids, trilobites, bivalves, brachiopods and scarce graptolites as well as of conodonts, foraminifera, acritarchs, chitinozoans, scolecodonts and ostracods. During the last decades most but by far not all groups have been revised or are being studied presently. This facies is best represented by the Plöcken and Wolayer Groups of the Silurian of the Carnic Alps.
2. Graptolitic facies: It is characterized by black siliceous shales, cherts (lydites) and alum shales which prevail over quartzitic sandstones and greenish mudstones at the base and in the basal Pridolian, respectively. The thickness approximates that in the pure limestone facies. A continuous record of graptolites starting with the name bearer of the *Akidograptus acuminatus*-Zone of the basalmost Llandovery and ending in the Upper Lockovian has indicated continuous sedimentation during the Silurian and across its boundary with the Devonian. In particular this is true for the Carnic Alps; in other areas, e,g., the Graywacke Zone such a continuous record has as yet not been demonstrated and it seems uncertain to assess it due to the bad preservation of all collections. During the last 25 years all graptolite faunas were revised by H.JAEGER and numerous new ones have been collected; the corresponding strata were named by him Bischofalm-Formation.
3. Transitional facies: It comprises a mixture of the above mentioned two main rock types, i.e. an alternation of black shales and marls with black or darkgrey limestone beds. Its faunal content is very poor and consists of grapolites and few conodonts and nautiloids. In the local stratigraphic scheme of the Carnic Alps this facies was named Findenig Facies.

All three main facies may intergrade to varying degrees depending on its setting in a distinct paleogeographical and paleotectonic environment with different amount of limestone production and fossil support. In particular this regards the region occupied

[1] Revised section from the paper by: SCHÖNLAUB, H.P. (1992): Jb. Geol. B.-A., 135/1, 381-418; Wien

by the Gurktal Nappe in Carinthia and parts of Styria with its dolomite and marble rich facies which is equivalent to a several 100 m thick clastic development in the same area (F.NEUBAUER 1979, F.NEUBAUER & J. PISTOTNIK 1984). Moreover, in some other fossiliferous sequences basic volcanics and tuffs are intercalated which indicate rifting associated with intracontinental volcanism at various times during the Silurian (for summary remarks see H.P.SCHÖNLAUB 1979, 1982, R. HÖLL 1970, F. EBNER 1975, M. F. BUCHROITHNER 1979, F. NEUBAUER 1979, F. NEUBAUER & J. PISTOTNIK 1984, U.GIESE 1988, H. FRITZ & F.NEUBAUER 1988, J.LOESCHKE 1989a,b).

Silurian faunas following the terminal-Ordovician mass extinction event are generally regarded as cosmopolitan and hence provide only little evidence to determine the latitudinal position of individual plates (D.JABLONSKI 1986). This evaluation, however, may change if a varied high diversified fossil association is considered together with lithic data from the host rock.

According to S.M. BERGSTRÖM 1990 most if not all post-Ordovician conodont localities ly between 40°S and 40°N paleolatitude. In the Wenlockian continental Europe was located at the margin of this belt consistent with our conclusions drawn for the Late Ordovician. For this time conodont evidence from the Carnic Alps and other areas of the Eastern Alps suggests close affinity to coeval faunas from central, southern and southwestern Europe. Comparable faunas from Britain and Gotland which occupied a more equatorial position seem, however, more diversified. These differences diminished towards the end of the Silurian. S.M.BERGSTRÖM 1990 concluded that the Pridolian was a time of minimal conodont provincialism during which coeval faunas from the Alps, Bohemia and Nevada showed striking similarities at the generic level.

In the Silurian the distribution of phyto- and zooplankton, i. e., acritarchs and chitinozoans displays a broad latitude-parallel-zonation. However, plotted on the new world maps of C.R.SCOTESE & W.S. McKERROW 1990 the old phytoplankton data of F.H.CRAMER 1971 seem to reflect local environmental conditions rather than a biogeographic pattern (G.K. COLBATH 1990).

Yet, from the Silurian of the Alps only few appropriate data are available (A. BACHMANN & M.E. SCHMID 1964, H. PRIEWALDER 1976, 1987, F. MARTIN 1978). Accordingly, acritarchs from the Cellon section of the Carnic Alps suggest an intermediate position between the high latitude *N.carminae* and the tropical *Domasia-Deunffia* biofacies (J.B. RICHARDSON et al. 1981, H. PRIEWALDER 1987). This paleolatitudinal setting is well constrained by other data presented here. On a worldwide scale F. PARIS (1981, 1989) concluded that the distribution of Silurian acritarcs is essentially cosmopolitan.

According to H. PRIEWALDER (pers. comm.) the chitinozoans of the Cellon section show close relationships to those from Bohemian deposits of the same age which is especially pronounced in the upper Ludlow to lower Lochkov sequence (DUFKA, 1992; KRIZ, 1992; KRIZ et al. 1986; PARIS & KRIZ, 1984; PARIS et al., 1981).

On the other hand in the Cellon section samples from the base of the Wenlock to the lower Ludlow yielded no chitinozoans whereas in Bohemia diverse faunas could be obtained from sediments of this period (KRIZ, 1992; KRIZ et al., 1993). This phenomenon might be caused by unfavorable conditions for preservation (e.g.oxidation) in the depositional environment of the Cellon section.

Silurian trilobites from the Carnic Alps are closely related to Bohemia and other central European regions (W.HAAS 1969, G.K.B.ALBERTI 1970). Affinities to Morocco may exist but are as yet not studied in detail. Interestingly, in the succeeding Devonian the apparent distinction with North Africa continued; instead, there appears a closer relationship with the Ural and Tienshan (G.K.B. ALBERTI 1969).

According to T. KOREN 1979 most if not all Silurian to Lower Devonian graptolites occur within paleolatitudes of some 30-40^{0}N and 30^{0}S. As noted by W.B.N. BERRY 1979 Silurian graptolites show only very little endemism suggesting that interplate dispersal was possible and apparently occurred during the Silurian and Lower Devonian. Presumably, its distribution was mainly controlled by the character of the surface water plus ocean currents that overlied the site at which graptolites are found. The distribution of graptolites may thus have very much depended on the size, shape and position of certain plates.

In 1962 C. ROMARIZ introduced the name "Mediterranean Province" for those graptolites which are characterized by large robust rhabdosoms and have been recorded from middle and late Wenlockian strata of Portugal, Spain, Sardinia and the Carnic Alps (see also M. GORTANI 1922 and C. ROMARIZ et al.1971). Many of these giant specimens are, however, tectonically deformed and did not represent a distinct biofacies (H. JAEGER 1968, 1975, H. JAEGER & D. MASSA 1965).

During the Ludlow and Pridoli an essentially uniform graptolite fauna developed in Europe. As pointed out by H. JAEGER 1976, 1989 the changing environment of this time is portrayed in strikingly similar and closely contemporaneous shifting lithofacies between northern Africa and Baltica which exhibit - with minor local modifications - a characteristic and continuous range from black graptolite shales to limestones, e.g., the well known "Ockerkalk" of Thuringia. According to H. JAEGER 1975 and G.K.B. ALBERTI 1980 this change in facies was controlled by simultaneous sea-level rise and fall that affected a hypothesized single block along its passive margins.

Distribution of extinct cephalopds corresponds widely to their living habitats (J.A. CHAMBERLAIN et al. 1981) and was limited by the same physical barriers as the recent *Nautilus*. In the absence of a planctonic larva stage (N.H. LANDMAN et al.1983) dispersal took place as part of the vagrant benthos on shallow shelfes or over shallow open marine environments and not as part of the oceanic nekton. Structural studies of the shell (R.E. CRICK 1988) have indicated that they were restricted to limits between 300 and 500 m water depths. This may explain why Ludlowian faunas from North Africa and Laurentia show such striking differences suggesting that an exchange across the wide mid-European ocean was largely impossible (R.E. CRICK 1990).

In the Alps the oldest yet not described nautiloids occur in the Ashgillian Uggwa Lst. of the Carnic Alps. From the Late Llandovery onwards nautiloids became the dominating organisms in the carbonate facies of the Southern Alps with rich abundances of orthocerids in the Late Wenlock and Early Ludlow (H.RISTEDT 1968, 1969). The diversified fauna seems closely related to Bohemia and Sardinia. With decreased numbers nautiloids continue into the Pridolian and Lower Devonian.

According to O.K. BOGOLEPOVA (pers. comm. 1994) the Silurian cephalopod biofacies of the Carnic Alps reflects a close relationship with coeval deposits from Bohemia and the Tajmyr Peninsula of northern Siberia. The affinities between these faunas and supposedly with those from other localities in southern Europe may have resulted from the South Equatorial Current that operated during the Silurian and Devonian along the southern margin of Siberia and Laurussia.

In contrast to the Carnic Alps in the Graywacke Zone and in the Gurktal Nappe of Carinthia very few nautiloids have been found despite the occurrences of very similar lithologies. This remarkable feature is yet difficult to explain.

The distribution of other molluscs, in particular bivalves corresponds grossly to that of orthoconic nautiloids. According to J. KRIZ 1979 the Silurian cardiolids from the Southern Alps and the Graywacke Zone inhabited the warm equatorial zone or were dispersed through south equatorial currents. However, plotted on the modified base maps proposed by C.R.SCOTESE & W.S.McKERROW 1990 the central and southern European faunas must either have occurred in slightly higher southern latitudes or the position of the respective plates is too high. In our opinion a position around 35°S would be the best estimate for the Silurian occurrences in the Alps.

This view is strongly supported from other evidence: In the Silurian corals were prominent constituents of the shallow water environment in the tropical belt. After a crises at the end of the Ordovician several order among the Tabulata and the Rugosa diversified in the early Silurian. During this time only weak provincialism is apparent at the generic level (J.W.PICKETT, 1975, R.A.McLEAN 1977, 1985, D.L.KALJO & E.KLAAMANN 1973, W.A.OLIVER 1977). An explanation might be the assumed larval life-style of rugose corals so that long-living teleplanic larvae were capable of being transported by ocean currents 1000 km or more (R.S. SCHELTEMA 1968, 1971, 1972, A.E.H.PEDDER & W.A.OLIVER 1990).

Remarkably, rugose and tabulate corals abundantly occur in the Late Llandovery of Middle Carinthia (E.STREHL 1962, M.F. BUCHROITHNER 1979), in the Upper Silurian (Ludlowian) of Graz (H.MENSINK 1953, H.W.FLÜGEL & H.P.SCHÖNLAUB 1972, F.EBNER 1976) and very rare in shallow water and locally superficial ooid bearing limestones in the Late Llandovery of the Graywacke Zone of Tyrol (H.MOSTLER 1966, N. AL-HASANI & H. MOSTLER 1969), but apparently are missing in coeval strata of the Southern Alps. The inferred Silurian age of F. HERITSCH 1929 is actually Lower Devonian (Lochkovian).

We hardly believe that these coral bearing bioclastic limestones represent the fossil counterpart of modern cold-water coral reefs such as the common *Lophelia* reefs found presently as far north as beyond the Polar Circle, in the Barents Sea and on the shelf off Mid-Norway at depths between 250 and 300 m and at water temperatures of 6°C (T.STROMGREN 1971, N. MIKKELSEN et al.1982). Rather they display excellent environmental indicators controlled by such physical factors like light, temperature, suspended sediment, salinity, water agitation and other agents (D.J.J.KINSMAN 1964, T.P.SCOFFIN et al.1989 and others). Modern and ancient builtups cannot exist beyond the "Darwin Point" of about 35°-latitude (R.GRIEG 1982), which is also the northernmost limit of corals in the present-day Pacific (G.W.TRIBBLE & R.H. RANDALL 1986) and, more generally, carbonate production is light-limited to within 35° latitudes (R.A.ZIEGLER et al.1984). There is no objective reason against the consideration that the Silurian of the Central Alps was positioned within these limits. This conclusion was already drawn by A.J. BOUCOT 1975 and lately 1990 who subdivided the Silurian World into two main realms. The Carnic Alps correspond to the warm water North Silurian Realm characterized by limestones and rich shelly faunas in contrast to the cool and cold water high southern latitude Malvinokaffric Realm.

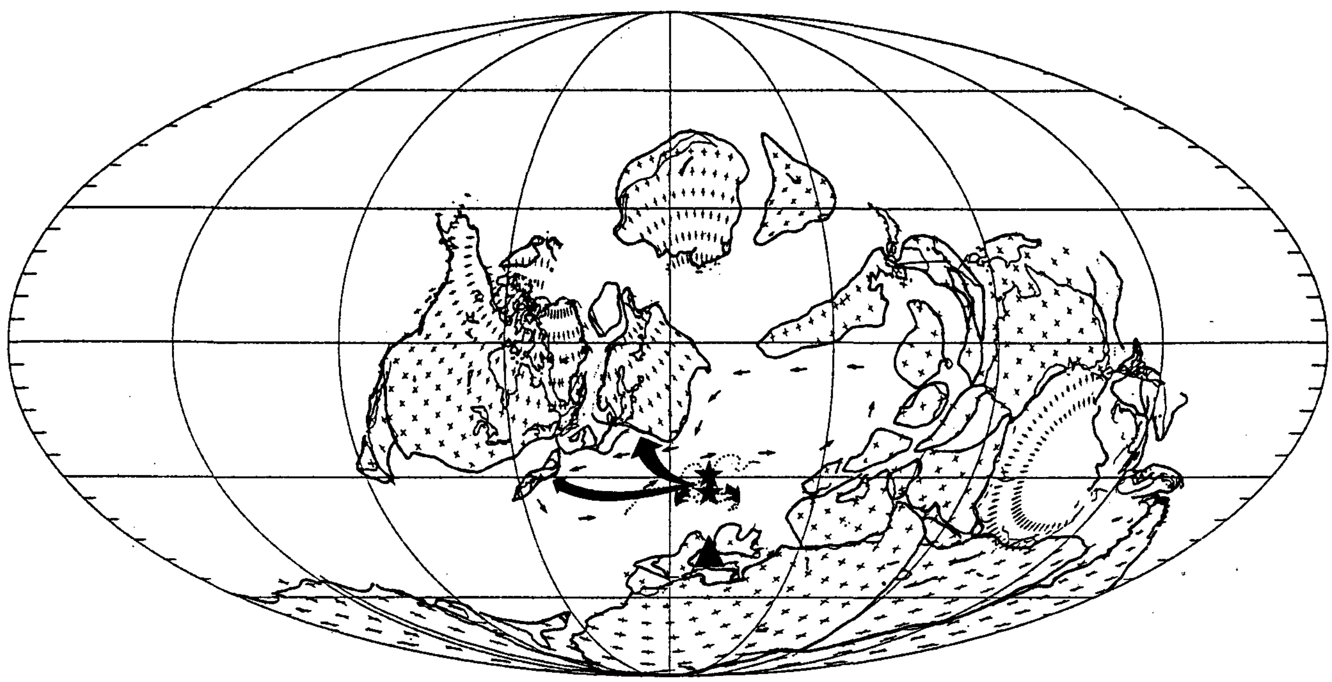


Fig. 1
Middle Silurian (Wenlockian) paleogeography.
Triangle indicates position of the Alpine Silurian as suggested by C.R. SCOTESE & W.S. MCKERROW (1990). The author's latitudinal setting is shown by two stars for the Silurian of the Southern and Central Alps, respectively. Faunal relationships are shown by heavy arrows, the oceanic current system in the mid-European ocean by small arrows.
Modified from C.R. SCOTESE & W.S. MCKERROW (1990).

Conclusions

During the Silurian Period the Alpine occurrences of Silurian strata continued to shift into lower latitudes. Based on the evidences presented above the best position is estimated at approximate 30-35° southern latitude. Faunal relationships existed to southern Europe but apparently were closer to northern Europe. The affinities to southwestern Europe and northern Africa, however, decreased.

Paleomagnetic data from Gondwana seem to support the assumption of a rapid northward movement. It is associated with rifting-related volcanism through much of the Silurian. Interestingly, the Southern and Central Alps differ in two main aspects: The Silurian of the Central Alps, i.e., the development north of the Gailtal Fault, is characterized by warm water occurrences of rugose and tabulate corals in an environment which locally also contains superficial ooids, but these sequences yield only few cephalopods as opposed to the Southern Alps with the opposite relationship suggesting most plausibly a farther south and slightly cooler environment. These differences may indicate two separate terranes or microcontinents prior to the Variscan deformation in the Alps.

References

ALBERTI GKB (1969) Trilobiten des jüngeren Siluriums sowie des Unter- und Mitteldevons.I. Abh Senck Naturf Ges 520: 1-692

ALBERTI GKB (1970) Trilobiten des jüngeren Siluriums sowie des Unter- und Mitteldevons. II. Abh Senck Naturf Ges 525: 1-233

ALBERTI GKB (1980) Zur lithofaziellen Entwicklung, Fauna (Trilobiten, Tentaculiten) und Biostratigraphie des Paläozoikums (Silur-Devon) von Beni Afeur (Kleine Kabylei, Tell-Atlas, Algerien). N Jb Geol Paläont Mh 1980: 277-286

AL-HASANI N, MOSTLER H (1969) Zur Geologie der Spießnägel südlich Kirchberg (Nördliche Grauwackenzone, Tirol). Veröff Univ Innsbr 9, Alpenkdl Stud 5: 5-26

BACHMANN A, SCHMID ME (1964) Mikrofossilien aus dem österreichischen Silur. Verh Geol B-A 1964: 53-64

BACHTADSE V, BRIDEN JC (1990) Palaeomagnetic constraints on the position of Gondwana during Ordovician to Devonian times. In: McKerrow WS, Scotese CR (eds) Palaeozoic Palaeogeography and Biogeography. Geol. Soc Mem 12: 43-48

BARCA S, JAEGER H (1990) New geological and biostratigraphical data on the Silurian in SE-Sardinia. Close affinity with Thuringia. Boll Soc Geol It 108 (1989): 565-580

BERGSTRÖM SM (1990) Relations between conodont provincialism and the changing palaeogeography during the Early Palaeozoic. In: McKerrow WS, Scotese CR (eds) Palaeozoic Palaeogeography and Biogeography. Geol Soc Mem 12: 105-121

BERRY WBN (1979) Graptolite biogeography: A biogeography of some Lower Palaeozoic plancton. In: Gray J, Boucot AJ (eds) Historical Biogeography, Plate Tectonics, and the Changing Environment. Proceedings 37th Annual Biology Colloquium, Oregon State Univ Press Corvallis Oregon p 105-115

BOUCOT AJ (1975) Evolution and Extinction Rate Controls. Development in Palaeontology and Stratigraphy 1. Elsevier, Amsterdam Oxford New York

BUCHROITHNER MF (1979) Biostratigraphie und fazielle Untersuchungen im Paläozoikum von Mittelkärnten. Carinthia II 169: 71-95

CHAMBERLAIN JA Jr, WARD PD, WEAVER JS (1981) Post-mortem ascent of *Nautilus* shells: implications for cephalopod paleobiogeography. Paleobiology 7: 4594-509

COCKS LRM (1979) New acrotretacean brachiopods from the Paleozoic of Britain and Austria.- Palaeontology, 22, 93-100, London

COLBATH GK (1990) Palaeobiogeography of Middle Palaeozoic organic-walled phytoplancton. In: McKerrow WS, Scotese CR (eds) Palaeozoic Palaeogeography and Biogeography. Geol Soc Mem 12: 207-213

CRAMER FH (1971) Distribution of selected Silurian acritarchs. Rev Espan Micropal Num Extraord, p 1-203

CRICK RE (1988) Buoyancy regulation and macroevolution in nautiloid cephalopods. Senckenbergiana lethaea 69: 13-42

CRICK RE (1990) Cambro-Devonian biogeography of nautiloid cephalopods. In: McKerrow WS, Scotese CR (eds) Palaeozoic Palaeogeography and Biogeography. Geol Soc Mem 12: 147-161

DUFKA,P.: Lower Silurian Chitinozoans of the Prague Basin (Barrandian, Czechoslovakia). Preliminary Results.- Rev.Micropaléont., 35/2, 117-126, 1 Abb., 3 Tab., 3 Taf., Paris, 1992.

EBNER F (1975) Ein Beitrag zum Altpaläozoikum des Remschnigg (Steiermark). Verh Geol B-A 1974: 281-287
EBNER F (1976) Das Silur/Devon-Vorkommen von Eggenfeld - ein Beitrag zur Biostratigraphie des Grazer Paläozoikums. Mitt Abt Geol Paläont Bergb Mus Joanneum 37: 1-33
FLÜGEL HW, SCHÖNLAUB HP (1972) Nachweis von tieferem Unterdevon und höherem Silur in der Rannach-Fazies des Grazer Paläozoikums. Mitt Österr Geol Ges 63: 142-148
FRITZ H, NEUBAUER F (1988) Geodynamic aspects of the Silurian and Early Devonian sedimentation in the Paleozoic of Graz (Eastern Alps). Schweiz Mineral Petrogr Mitt 68: 359-367
GIESE U (1988) Lower Paleozoic volcanic evolution at the northwestern border of the Gurktal nappe, Upper Austroalpine, Eastern Alps. Schweiz Mineral Petrogr Mitt 68: 381-396
GORTANI M (1922) Faune Paleozoiche della Sardegna. I. Le graptoliti di Goni. II. Graptoliti della Sardegna Orientale. Palaeontogr Italica 28: 51-67, 85-111
GRIGG RW (1982) Darwin Point: A threshold for atoll formation. Coral Reefs 1: 29-54
HAAS W (1969) Trilobiten aus dem Silur der Karnischen Alpen. Carinthia II SH 27:23
HERITSCH F (1929) Faunen aus dem Silur der Ostalpen. Abh Geol B-A 23/2: 1-183
HILL D (1959) Distribution and sequence of Silurian coral faunas. Journ Proc Roy Soc N.S.W. 42 NS 70: 151-173
HÖLL R (1970) Die Zinnober-Vorkommen im Gebiet der Turracher Höhe (Nock-Gebiet/Österreich) und das Alter der Eisenhut-Schieferserie. N Jb Geol Paläont Mh 1970: 201-224
JABLONSKI D (1986) Background and mass extinctions: The alternation of macroevolutionary regimes. Science 270: 129-133
JAEGER H (1968) Vorbericht über graptolithenstratigraphische Untersuchungen in den Karnischen Alpen, insbesondere an der Bischofalm. Anz Österr Akad Wiss Wien Math-Naturw Kl 1968/7: 155-159
JAEGER H (1975) Die Graptolithenführung im Silur/Devon des Cellon-Profils (Karnische Alpen). Carinthia II 165/85: 111-126
JAEGER H (1976) Das Silur und Unterdevon vom thüringischen Typ in Sardinien und seine regionalgeologische Bedeutung. In: Franz-Kossmat-Symposium. Nova Acta Leopoldina NF 224: 263-299
JAEGER H, MASSA D (1965) Quelques données stratigraphiques sur le Silurien des confins algéro-marocains (Ben Zireg, Djebel Grouz et régions voisines). Bull Soc Géol France 7: 426-436
KALJO DL, KLAAMANN E (1973) Ordovician and Silurian corals. In: Hallam A (ed) Atlas of Palaeobiogeography. Elsevier Amsterdam, p 37-45
KENT DV, VAN DER VOO R (1990) Palaeozoic plaaeogeography from palaeomagnetism of the Atlantic-bordering continents. In: McKerrow WC, Scotese CR (eds) Palaeozoic Palaeogeography and Biogeography. Geol Soc Mem 12: 49-56
KINSMAN DJJ (1964) Reef coral tolerance of high temperatures and salinities. Nature 202: 1280-1282
KOREN T (1979) Late monograptid faunas and the problem of graptolite extinction. Acta Paleont Polon 24: 79-106
KRIZ J (1979) Silurian Cardiolidae (Bivalvia). Sb Geol VED Paleont 22: 1-157
KRIZ, J. (1992): Silurian Field Excursions. Prague Basin (Barrandian), Bohemia.- Geol. Ser. Nation. Mus. Wales, 13, 111p., Cardiff.
KRIZ, J., DUFKA, P., JAEGER, H. & SCHÖNLAUB,H.P. (1993): The Wenock/Ludlow Boundary in the Prague Basin (Bohemia).- Jb.Geol.B.-A., 136/4, 809-839, Wien.
KRIZ, J., JAEGER, H., PARIS, F. & SCHÖNLAUB, H.P. (1986): Pridoli - the Fourth Subdivision of the Silurian.- Jb.Geol.B.-A., 129/2, 291-360, 44 Abb., 1 Tab., 6 Taf., Wien.
LANDMAN NH, RYE DM, SHELTON KL (1983) Early ontogeny of *Eutrephoceras* compared to recent *Nautilus* and Mesozoic ammonites: evidence from shell morphology and light stable isotopes. Palaeobiology 9: 269-279
LOESCHKE J (1989a) Lower Palaeozoic volcanism of the Eastern Alps and its geodynamic implications. Geol Rdsch 78: 599-616
LOESCHKE J (1989b) Die paläotektonische Stellung der Vulkanite der Magdalensberg-Serie (Ober-Ordovizium, Gurktaler Decke, Kärnten, Österreich). Carinthia II 179: 491-507
MARTIN F (1978) Sur quelques Acritarches Llandoveriens de Cellon (Alpes Carniques Centrales, Autriche). Verh Geol B-A 1978: 35-42
MACDONALD KC (1990) A slow but restless ridge. Nature 348: 108-109
McLEAN RA (1977) Biostratigraphy and zoogeographic affinities of the Lower Silurian Corals of New South Wales, Australia. Mém Bur Rech Géol Min 89: 102-107
McLEAN RA (1985) New Early Silurian rugose corals from the Panuara area, central New South Wales. Alcheringa 9: 23-34
MENSINK H (1953) Eine tektonische Detailuntersuchung im Raum nördlich Gratkorn. Mitt Naturw Ver Steiermark 83: 123-129
MIKKELSEN N, ERLENKEUSER H, KILLINGLEY JS, BERGER WH (1982) Norwegian corals: radiocarbon and stable isotopes in *Lophelia pertusa*. Boreas 11: 163-171

MOSTLER H (1966) Zur Einstufung der "Kieselschiefer" von der Lachtal-Grundalm (Fieberbrunn, Tirol).- Verh. Geol. B.-A., 1966, 157-170 Wien

MOSTLER H (1970) Struktureller Wandel und Ursachen der Faziesdifferenzierung an der Ordoviz/Silur-Grenze in der Nördlichen Grauwackenzone (Österreich). Festbd Geol Inst 300 J Univ Innsbr, p 507-522

NEUBAUER F (1979) Die Gliederung des Altpaläozoikums südlich und westlich von Murau (Steiermark/Kärnten). Jb Geol B-A 122: 455-511

NEUBAUER F, PISTOTNIK J (1984) Das Altpaläozoikum und Unterkarbon des Gurktaler Deckensystems (Ostalpen) und ihre paläogeographischen Beziehungen. Geol Rdsch 73: 149-174

OLIVER WA Jr (1977) Biogeography of Late Silurian and Devonian rugose corals. Palaeogeography, Palaeoclimatology, Palaeoecology 22: 85-135

PARIS F (1981) Les Chitinozoaires dans le Paléozoique du Sud-Ouest de l'Europe. Mém Soc Géol Minér Bretagne 26: 1-412

PARIS F (1990) The Ordovician chitinozoan biozones of the Northern Gondwana Domain. Rev Palaeobotany and Palynology 66: 181-209

PARIS F (1981): Les Chitinozoaires dans le Paléozoique du sud-ouest de l'Europe.- Mém. Soc. géol. minéral. Bretagne, 26 , 412 S., 134 Abb., 45 Tab., 41 Taf., Rennes,

PARIS F & KRIZ J (1984): Nouvelles especes de chitinozoaires a la limite Ludlow/ Pridolien Tchecoslovaquie.- Rev. Palaeobot. Palynol., 43, 155-177, 8 Abb., 3 Taf., Amsterdam

PEDDER AEH, OLIVER Jr WA (1990) Rugose coral distribution as a test of Devonian palaeogeographic models. In: McKerrow WS, Scotese CR (eds) Palaeozoic Palaeogeography and Biogeography. Geol Soc Mem 12: 267-275

PICKETT J (1975) Continental reconstructions and the distribution of coral faunas during the Silurian. J Proc Roy Soc New South Wales 108: 147-156

PLODOWSKI, G. (1971) Revision der Brachiopoden-Fauna des Ober-Siluriums der Karnischen Alpen, 1: Glattschalige Atrypacea aus den Zentralkarnischen Alpen und aus Böhmen.- Senck. Lethaia, 52, 285-313 Frankfurt

PLODOWSKI, G. (1973) Revision der Brachiopoden-Fauna des Ober-Siluriums der Karnischen Alpen, 2: Rhynchionellacea aus den Zentralkarnischen Alpen.- Senck. Lethaia, 54, 65-103 Frankfurt

PRIEWALDER H (1976) in PRIEWALDER H, SCHUMACHER R Petrographisch-tektonische Untersuchungen in den Ennstaler Phylliten (Niedere Tauern, Steiermark) und deren Einstufung in das Silur durch Chitinozoen. Verh Geol B-A 1976: 95-113

PRIEWALDER H (1987) Acritarchen aus dem Silur des Cellon-Profils, Karnische Alpen, Österreich. Abh Geol B-A 40: 1-121

RICHARDSON JB, RASUL SM, AL-AMERI T (1981) Acritarchs, miospores and correlation of the Ludlovian-Downtonian and Silurian-Devonian boundaries. Rev Palaeobot Palynol 34: 209-224

RISTEDT H (1968) Zur Revision der Orthoceratidae. Abh Akad Wiss Mainz Math Naturw Kl 1968 Nr 4: 213-287

RISTEDT H (1969) Orthoceren als Leitfossilien des Silurs. Carinthia II SH 27: 25-28

ROMARIZ C (1962) Graptoloides des formacoes ftaniticas do Silurico portugues. Bol Soc Geol Portugal 14: 1-135

ROMARIZ C, ARCHE A, BARBA A, GUTIERREZ ELORZA M, VEGAS R (1971) The Mediterranean graptolitic fauna of the Wenlockian in the Iberian Peninsula. Bol Soc Geol Portugal 18: 57-61

SCHELTEMA RS (1968) Dispersal of larvae by equatorial ocean currents and its importance to the zoogeography of shoal-water tropical species. Nature 217: 1159-1162

SCHELTEMA RS (1971) The dispersal of the larvae of shoal-water benthic invertebrates over long distances by ocean currents. In: Crisp DJ (ed) 4th European Marine Biology Symposium Bangor. Univ Press Cambridge, p 7-28

SCHELTEMA RS (1972) Dispersal of larvae as a means of genetic exchange between widely separated populations of shoal-water benthic invertebrate species. In: Battaglia B (ed) 5th European Marine Biology Symposium Venice. Piccini Editore Padua, p 101-114

SCHÖNLAUB HP (1979) Die Nördliche Grauwackenzone. In: Das Paläozoikum von Österreich. Abh Geol B-A 33: 76-97

SCOFFIN TP, TUDHOPE AW, BROWN BE (1989) Corals as environmental indicators, with preliminary results from South Thailand. Terra Nova 2: 559-563

SCOTESE CR, McKERROW WS (1990) Revised World maps and introduction. In: McKerrow WS, Scotese CR (eds) Palaeozoic Palaoegeography and Biogeography. Geol Soc Mem 12: 1-21

STREHL E (1962) Die geologische Neuaufnahme des Saualpen-Kristallins. IV. Das Paläozoikum und sein Deckgebirge zwischen Klein St.Paul und Brückl. Carinthia II 152: 46-74

STROMGREN T (1971) Vertical and horizontal distribution of *Lophelia pertusa* (LINNE) in Trondheimsfjorden on the West Coast of Norway. Kong Norsk Vitensk Selsk Skr 6: 1-19

TRIBBLE GW, RANDALL RH (1986) A description of the high-latitude shallow water coral communities of Miyaka-jima, Japan. Coral Reefs 4: 151-159

ZIEGLER AM, HULVER ML, LOTTES AL, SCHMACHTENBERG WF (1984) Uniformitarianism and palaeoclimates: Inferences from the distribution of carbonate rocks. In: Brenchley PJ (ed) Fossils and Climate. John Wiley & Sons Chichester, p 3-25

Chitinozoans of the Cellon Section (Upper Ordovician - Lower Devonian).- A Preliminary Report

with 1 figure

by Helga Priewalder

Introduction

The investigations of the chitinozoans from the Cellon-section were part of a project with the goal of examining the geographic and stratigraphic distribution of the palynomorphs within the different facies of the upper Ordovician to lower Devonian strata in the Carnic Alps.

These are: the shallow water facies with mainly calcareous deposits, the siliciclastic basin facies and the transitional facies mediating between them.

In none of these facies *spores* could be observed. The *acritarchs* showed to be strongly influenced by the local environments. Their only remarkable occurrence was in the lower Silurian of the Cellon-section which belongs to the calcareous facies (PRIEWALDER, 1987). The *chitinozoans* however proved to be the geographically and stratigraphically widest distributed group of the palynomorphs.

Concerning the chitinozoans 79 samples from the siliciclastic and transitional facies have been examined so far only by spot checks: 60% of them proved to be fossiliferous.

From the upper Ordovician to lower Devonian sequence of the Cellon-section 92 samples have been studied. 48 (= 52%) yielded chitinozoans.

As the chitinozoans were opaque to transmitting light the investigations had to be done mainly under SEM. About 4.300 micropalaeontological objects (chitinozoans as well as chitinozoan-like and/or problematic particles) have been examined in this way. Approximately 12.600 SEM-photos have been taken.

It has to be pointed out that the names of the chitinozoans in this report are provisional because they are based only on gross determinations of the fossils. Detailed studies have yet to be carried out and will result in more diverse chitinozoan associations at many horizons of the section.

In the Cellon-section the chitinozoans are restricted to four sequences (fig.1):

- to the Plöcken Formation (upper Ashgill);
- to the lower part of the Kok Formation (upper Llandovery);

- to the sequence from the uppermost Kok Formation to the top of the Cardiola Formation (upper Ludlow);
- to the sequence from the upper part of the Alticola Limestone to the lowermost Rauchkofel Limestone (Ludlowi/Pridolian boundary - lowermost Lochkov).

Chitinozoans of the upper Ordovician

In the Uggwa Shales and Uggwa Limestones no chitinozoans were found. Instead black and glossy particles with chitinozoan-like contours (probably consisting of graphite) were frequently present. In the light-microscope they could be confused with badly preserved chitinozoans.

Stratigraphically the chitinozoans occur for the first time at the base of the Plöcken Formation (sample ***126***) with a few representatives of *Conochitina* EISENACK 1931 and probably also *Tanuchitina* JANSONIUS 1964. Further numerous melanosklerits with a strong resemblance to chitinozoans were observed , as well as the chitinozoan-like graphitic particles.

In the uppermost part of the Plöcken Formation a few samples (***128*** , ***129*** , ***45***) contain taxa which are diagnostic for the upper Ashgillian: *Armoricochitina nigerica* (BOUCHE 1965) and *Tanuchitina elongata* (BOUCHE 1965). Furthermore *Desmochitina minor* EISENACK 1931 (which is limited to strata of Ordovician age) and representatives of *Conochitina*, *Rhabdochitina* (?) EISENACK 1931, *Spinachitina* SCHALLREUTER 1963 and the first specimen of the *Ancyrochitininae* with broken processes were extracted.

The Ashgillian samples yielded only very few chitinozoans in a rather bad state of preservation: most specimens are preserved threedimensionally, but broken.

Chitinozoans of the upper Llandovery

Sample ***46A*** at the very base of the Kok Formation (= upper Llandoverian), which after a long hiatus follows the Plöcken Formation in a conformable position, yielded a completely different chitinozoan fauna with a great number of individuals: numerous representatives of the *Lagenochitinidae* and *Ancyrochitininae*, which cannot be determined absolutely ; *Ancyrochitina cf.diabolo* (EISENACK 1937), *A.gr.ancyrea* (EISENACK 1931), *Cyathochitina caputoi* DA COSTA 1971 and *Eisenackitina sp.A* which is very characteristic of this sample.

Samples ***47*** , ***130*** , ***131*** and ***49*** contain many specimens of *Bursachitina* TAUGOURDEAU 1966 and *Conochitina* (e.g. *C.cf.emmastensis* NESTOR 1982), further *Eisenackitina sp.A*, *Angochitina aff.longicollis* EISENACK 1959, as well as *A.cf.nigerica* and *Laufeldochitina ? sp.*, which are reworked and of upper Ordovician age.

In the upper part of the Llandoverian layers of the Kok Formation (samples ***50, 132***) chitinozoans appear which are very similar to *Conochitina proboscifera* EISENACK 1937, a typical species of the upper Telychian/lower Sheinwoodian; *Conochitina spp.*(e.g.*C.cf.armillata* TAUGOURDEAU & JEKHOWSKI 1960), *Eisenackitina sp.* and *Lagenochitina sp.* occur at minor amounts.

The uppermost Llandoverian sample (***133***) yielded only badly preserved individuals resembling *Angochitina longicollis* (= typical of the upper Telychian/lower Sheinwoodian), as well as *Conochitina sp.*, *Cyathochitina sp.*, *Eisenackitina sp.* and *Sphaerochitina sp.*.

The chitinozoans from this part of the section are entirely or partly flattened and frequently folded. In cases of intense folding or variable flattening of the vesicles (e.g. thinner-walled necks are more, thicker-walled body chambers less strongly deformed) their contours may be altered to an extent that the original taxon is difficult to recognize.

Throughout the Wenlock and lower Ludlow associations of determinable chitinozoans are missing; only sporadic and badly preserved fossils are present: sample ***135***: one fragment of *Belonechitina sp.*; sample ***54***: the internal moulds of *Conochitinidae indet.*; sample ***136***: fragments of *Conochitinidae indet.* and *Lagenochitinidae indet.*, sample ***56***: *Bursachitina sp.*, *Lagenochitinidae indet.*, *Conochitinidae indet.*.

Chitinozoans of the upper Ludlow

From the uppermost layer of the Kok Formation (sample ***63***) to the top of the Cardiola Formation (sample ***145***) a great variety of chitinozoans occurs.

At the base of this sequence (sample ***63***, ***141***) abundant and diverse *Angochitina* EISENACK 1931, *Sphaerochitina* EISENACK 1955 (e.g. similar to *S.impia* LAUFELD 1974), *Conochitina* and a few *Bursachitina sp.* and *Eisenackitina sp.*, as well as some *Ancyrochitina sp.* appear.

Above it a fragment of *Linochitina* (sample ***142***) was found. Some *Cingulochitina cf.convexa* (LAUFELD 1974), *Sphaerochitina spp.* and *Angochitina spp.* (like in samples ***63*** , ***141***) and a few *Ancyrochitininae indet.*could be extracted from sample ***64***.

The middle part is dominated by numerous *Conochitina*. *C.aff.tuba* EISENACK 1932 occurs in sample ***143***. Sample ***66*** yielded *C.aff.latifrons* EISENACK 1964 and rare *Sphaerochitina sp.*.

Finally in the last sample of this sequence (***145***) a few *Cingulochitina sp.* and *Ancyrochitininae indet.* are present.

Here an other - unusual - state of preservation could be observed: the vesicles of thin-walled taxa from limestones collapsed threedimensionally similar to a deflated rubber ball. This feature probably developed at an early stage of diagenesis when the internal cavities of the chitinozoans became dehydrated before mineral fillings could grow (these fillings are common in fossils from limestones and responsible for their threedimensional preservation).

From the lower part of the Alticola Limestone up to the end of the Ludlowian no chitinozoans were found.

Chitinozoans of the Pridoli and lower Lochkov

A rich development of chitinozoans is documented by sample ***73*** from the Ludlow/ Pridoli boundary area and persists throughout the Pridolian to the end of the section in the lower Lochkov (sample ***89***). It comprises the upper part of the Alticola Limestone, the Megaerella Limestone and the lowermost part of the Rauchkofel Limestone.

Three samples (***73***, ***74***, ***75***) at the base of this succession contain *Eisenackitina barrandei* PARIS & KRIZ 1984 and *Urnochitina* group *urna* (EISENACK 1934).

The two taxa occur together within a very short interval also at the Ludlow/Pridoli boundary of some sections in the Bohemian type area of the Pridoli series (KRIZ et al., 1986).

There *E.barrandei* is characteristic of upper Ludlow strata but in a few cases it extends some cm into the basal Pridoli before it becomes extinct.

U.gr.*urna* appears directly at the boundary or a few cm above it. It develops quickly to the dominant and diagnostic taxon (= *U.urna*) of the Pridoli.

In the Cellon-section the situation is a little different. As the upper Ludlow strata above the Cardiola Formation did not yield any chitinozoans (except sample ***73*** from the topmost Ludlow layer) samples ***73***, ***74*** and ***75*** are the only horizons where *E.barrandei* is present. It seems that this important taxon ranges higher into the Pridol than it is the case in Bohemia.

Further taxa in the above samples are: some *Bursachitina* sp. (sample ***73***); numerous *Eisenackitina granulata* (CRAMER 1964) and *E.interme-dia* ? (EISENACK 1955), a few *Sphaerochitina cf.sphaerocephala* (EISENACK 1932), *Angochitina sp.*, *Gotlandochitina sp.* and *Ancyrochitina gr.ancyrea* (EISENACK 1931) (samples ***74*** , ***75***).

Sample ***149*** shows a very low fossil content: only some *Eisenackitina sp.*, *Angochitina sp.* and *Ancyrochitina ? sp.*.

The development of the typical *Urnochitina urna* (= a worldwide occurring diagnostic fossil of the Pridoli) starts suddenly and with a great number of individuals in sample ***76***. As already described in the literature the fauna here too is almost monospecific, only rare *Desmochitinidae indet.*occur in addition.

Also the next sample (***149A***) shows a special feature: *U.urna* becomes numerically unimportant, whereas large quantities of *Bursachitina krizi* (PARIS & LAUFELD 1980) are present (the residue consisted almost entirely of representatives of this taxon).

Sample ***150*** again is dominated by *U.urna*, while only very few individuals of *B.krizi* and *Desmochitinidae indet.* occur.

The next three samples (***151***, ***152***, ***153***) yielded insignificant associations with various *Lagenochitinidae indet.*, a fragment of *B.krizi* (?), some *Angochitina aff.chlupaci* (PARIS & LAUFELD 1980) and *Sphaerochitina sp.*.

In the following sample ***78*** the only taxon is *E.granulata* with a few well preserved individuals. It is still present in sample ***154***, but there accompanied by rare *B.krizi*, *Linochitina klonkensis* PARIS & LAUFELD 1980 and *Ancyrochitina sp.*.

The chitinozoan fauna now starts to rearrange: *U.urna* occurs with more and more decreasing numbers of individuals, while *Angochitina* EISENACK 1931, *Cingulochitina* PARIS 1981, *Gotlandochitina* LAUFELD 1974, *Linochitina* EISENACK 1968, *Sphaerochitina* EISENACK 1955 and especially *Ancyrochitina* EISENACK 1955 become frequent.

The most frequent taxon in sample ***81***, from which large quantities of chitinozoans could be extracted, is *Ancyrochitina sp.A* (simple processes with very broad basis).Other taxa are *L.klonkensis*, *Calpichitina corinnae* JAGLIN 1986, *Sphaerochitina cf.sphaerocephala* (EISENACK 1932), *Gotlandochitina ? sp.* and *U.urna* with very few specimens.

Samples ***82*** and ***83*** contain poor associations: very few *U.urna*, *Ancyrochitina sp.A* and *S.cf.sphaerocephala*.

Sample ***84*** from the lowermost Lochkovian layer yielded a rich fauna: comparatively numerous *U.urna* (the last documented occurrence in the section), many well preserved and diverse *Angochitina*, *Gotlandochitina*, *Sphaerochitina* (e.g. *S.sphaerocephala*) and a few *Ancyrochitina* with unusual processes.

The fossil content of sample ***85*** (the number of individuals is rather low) is dominated by *Eisenackitina bohemica* (EISENACK 1934) which is an index-fossil typical of the Lochkov. Accompanying taxa are a few *Angochitina aff.chlupaci*, *Cingulochitina sp.*, *Desmochitinidae indet.* and *Lagenochitinidae indet.*.

In sample ***156*** *A.chlupaci* is now present with several unequivocal individuals together with a few *Angochitina sp.* and *Desmochitinidae indet.*.

The remaining samples in the section (***157*** , ***87*** , ***88*** , ***158*** and ***89*** with a large quantity of chitinozoans) are dominated by numerous *Ancyrochitina* (at least 5 species). Moreover they yielded numerous diverse *Angochitina*, *Sphaerochitina*, *Gotlandochitina*, *Linochitina* and *Cingulochitina* [e.g.*C.ervensis* (PARIS 1979)] .

The chitinozoans of the Pridoli/Lochkov sequence are usually preserved threedimensionally (especially thicker-walled taxa), thinner-walled individuals are often more or less strongly collapsed.

Conclusions

In contrast to the acritarchs which are mainly restricted to the upper Llandovery to lower Wenlock strata the chitinozoans are present in almost all series of the upper Ordovician to lower Devonian succession of the Cellon-section.

In several samples (*46A, 141, 74, 76, 149A, 150, 81, 84, 89*) they occur with large numbers of individuals and usually great diversity.

Environmental conditions obviously were more favourable for the chitinozoans in the upper part of the section. Starting with the topmost layer of the Kok Formation (upper Ludlow) up to the lower Lochkov they show greater diversities and larger numbers of individuals and also better preservation than in the lower part.

The chitinozoan associations of the upper Ashgill and upper Llandovery strata which after a gap of two stages follow in a conformable position are easily to distinguish.

The boundaries between the Llandovery and Wenlock and the Wenlock and Ludlow, respectively, are hardly to determine by the aid of chitinozoans as these fossils are missing throughout the Wenlock and also in the lower Ludlow. The bases of the Pridoli and the Lochkov, however, are well documented by diagnostic chitinozoan associations.

The chitinozoans of the Cellon section show close relationships to those from Bohemian deposits of the same age which is especially pronounced in the upper Ludlow to lower Lochkov sequence (DUFKA, 1992; KRIZ, 1992; KRIZ et al. 1986; PARIS & KRIZ, 1984; PARIS et al., 1981).

On the other hand in the Cellon-section samples from the base of the Wenlock to the lower Ludlow yielded no chitinozoans whereas in Bohemia diverse faunas could be obtained from sediments of this period (KRIZ, 1992; KRIZ et al., 1993). This phenomenon might be caused by unfavorable conditions for preservation (e.g. oxidation) in the depositional environment of the Cellon section.

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References

ACHAB,A., BERTRAND,R. & VAN GROOTEL,G.: Chitinozoan Contribution to the Ordovician and Lower Silurian Paleobiogeography.- J.Geol., 100, 621-629, 5 Abb., Chicago, 1992.

DUFKA,P.: Lower Silurian Chitinozoans of the Prague Basin (Barrandian, Czechoslovakia). Preliminary Results.- Rev.Micropaléont., 35/2, 117-126, 1 Abb., 3 Tab., 3 Taf., Paris, 1992.

EISENACK, A.: Neotypen baltischer Silur-Chitinozoen und neue Arten.-N .Jb. Geol. Paläont.: Abh., 108, 1-20, 4 Abb., Taf.1-3, Stuttgart, 1959.

EISENACK, A.: Neotypen baltischer Silur-Chitinozoen und neue Arten.- N. Jb. Geol. Paläont.: Abh., 114, 291-316, 8 Abb., 1 Tab., Taf.14-17, Stuttgart, 1962.

EISENACK, A.: Mikrofossilien aus dem Silur Gotlands, Chitinozoen.- N. Jb. Geol. Paläont.: Abh., 120, 308-342, 9 Abb., 7 Tab., Taf.26-30, Stuttgart, 1964.

EISENACK, A.: Über Chitinozoen des baltischen Gebietes.- Paläontographica, A 131/5-6, 137-198, 13 Abb., 2 Tab., Taf.24-32, Stuttgart, 1968.

EISENACK, A.: Beiträge zur Chitinozoen-Forschung.- Paläontographica, A 140/4-6, 117-130, 1 Abb., Taf.32-37, Stuttgart, 1972.
GRAHN, Y.: Chitinozoan stratigraphy in the Ashgill and Llandovery.- In COCKS, L.R.M. & RICKARDS,R.B. (eds.): A Global Analysis across the Ordovician-Silurian boundary.- Bull.Br.Mus.nat.Hist.(Geol.), 43, 317-323, 27 Abb., London, 1988.
JENKINS,W.A.M. & LEGAULT,J.A.: Stratigraphic ranges of selected Chitinozoa.- Palynology, 3, 235-264, 6 Abb., Dallas, 1979.
KRIZ, J.: Silurian Field Excursions. Prague Basin (Barrandian), Bohemia.- Geol. Ser. Nation. Mus. Wales, 13, 111S., 86 Abb., 4 Taf., Cardiff 1992.
KRIZ, J., DUFKA, P., JAEGER, H. & SCHÖNLAUB,H.P.: The Wenock/Ludlow Boundary in the Prague Basin (Bohemia).- Jb.Geol.B.-A., 136/4, 809-839, 18 Abb., 1 Tab., 3 Taf., Wien, 1993.
KRIZ, J., JAEGER, H., PARIS, F. & SCHÖNLAUB, H.P.: Pridoli - the Fourth Subdivision of the Silurian.- Jb.Geol.B.-A., 129/2, 291-360, 44 Abb., 1 Tab., 6 Taf., Wien, 1986.
LAUFELD, S.: Silurian Chitinozoa from Gotland.- Foss. and Strata, 5, 130 S., 78 Abb., Oslo, 1974.
LAUFELD, S.: Biogeography of Ordovician, Silurian and Devonian Chitinozoans.- In GRAY,J. & BOUCOT,A.J. (eds.): Historical Biogeography, Plate Tectonics, and the Changing Environment, 75-90, 14 Abb., (Oregon State University Press), o.O., 1979.
NESTOR; V. & K.: Correlation of the East-Baltic and Gotland Silurian by Chitinozoans.- In KALJO,D & KLAAMAN,E. (eds.): Ecostratigraphy of the East Baltic Silurian.- Acad. Sci. Estonian S.S.R., 89-96, 3 Abb., Tallinn, 1982.
NESTOR, V.: Silurian Chitinozoans.- In KALJO, D. & NESTOR, H.N.(eds.): An excursion guidebook, 80-83, Abb. 15, Taf.14, 15, Tallinn, 1990.
NESTOR, V.: Chitinozoan diversity dynamics in the east Baltic Silurian.- Proc. Estonian Acad.Sci.Geol., 41/4, 215-224, 5 Abb., 2 Tab., Tallinn, 1992.
PARIS, F.: Les Chitinozoaires dans le Paléozoique du sud-ouest de l'Europe.- Mém.Soc.géol.minéral.Bretagne, 26 , 412 S., 134 Abb., 45 Tab., 41 Taf., Rennes, 1981.
PARIS, F.: Chitinozoans.- In HOLLAND, C.H. & BASSETT, M.G. (eds.): A Global Standard for the Silurian System.- Geol.Ser.Nation.Mus Wales, 9, 280-284, Abb.174, 175, Cardiff, 1989.
PARIS, F.: Evolution paléogéographique de l'Europe au Paléozoiqe inférieur: le test de Chitinozoaires.- C.R.Acad.Sci.Paris, t.316, Ser.II, 273-280, 4 Abb., Paris, 1993.
PARIS, F. & KRIZ, J.: Nouvelles especes de chitinozoaires a la limite Ludlow/Pridolien Tchecoslovaquie.- Rev.Palaeobot.Palynol., 43, 155-177, 8 Abb., 3 Taf., Amsterdam, 1984.
PARIS, F., LAUFELD, S. & CHLUPAC, I.: Chitinozoa of the Silurian-Devonian boundary stratotypes in Bohemia.- S.G.U., Avh.,Ser.Ca., 51, 1-28, 10 Abb., 3 Taf., Uppsala 1981.
PARIS, F. & ROBARDET,M.: Early Palaeozoic palaeobiogeography of the Variscian regions.- Tectonophysics, 177, 193-213, 5 Abb., 1990.
PRIEWALDER; H.: Acritarchen aus dem Silur des Cellon-Profils, Karnische Alpen, Österreich.- Abh.Geol.-B.-A., 40, 121 S., 39 Abb., 24 Taf., Wien, 1987.
RAUSCHER, R.: Recherches micropaléontologiques et stratigraphiques dans l'Ordovicien at le Silurien en France. Etude des Acritarches, des Chitinozoaires et des Spores.- Mém.Sci.Géol., 38, 224 S., 46 Abb., 31 Tab., 12 Taf., Strasbourg, 1973.
SCHÖNLAUB,H.P.: Das Paläozoikum der Karnischen Alpen.- In: Arbeitstagung der Geologischen Bundesanstalt, 1985, 34-52, Abb.10-15, Wien, 1985.
SCHWEINEBERG, J.: Silurische Chitinozoen aus der Provinz Palencia (Kantabrisches Gebirge, N-Spanien).- Göttinger Arbeiten zur Geologie und Paläontologie, 33, 94 S., 24 Abb., 13 Taf., Göttingen, 1987.
VERNIERS, J.: The Silurian of the Mehaigne Valley (Brabant Massif, Belgium): Biostratigraphy (Chitinozoa).- Rev.Palaeobot.Palynol., 34, 165-174, 1 Abb., 2 Taf., Amsterdam 1981.
VERNIERS, J.: The Silurian Chitinozoa of the Mehaigne Area (Brabant Massif, Belgium).- Prof.Pap.Geol.Dienst Belgie, 1982/6, 192, 76 S., 10 Abb., 9 Taf., Gent, 1982.
WRONA, R.: Upper Silurian - Lower Devonian Chitinozoa from the Subsurface of Southeastern Poland.- PalaeontPolonica, 41/1980, 103-165, 111 Abb., 13 Tab., Taf.24-37, Warschau, 1980.

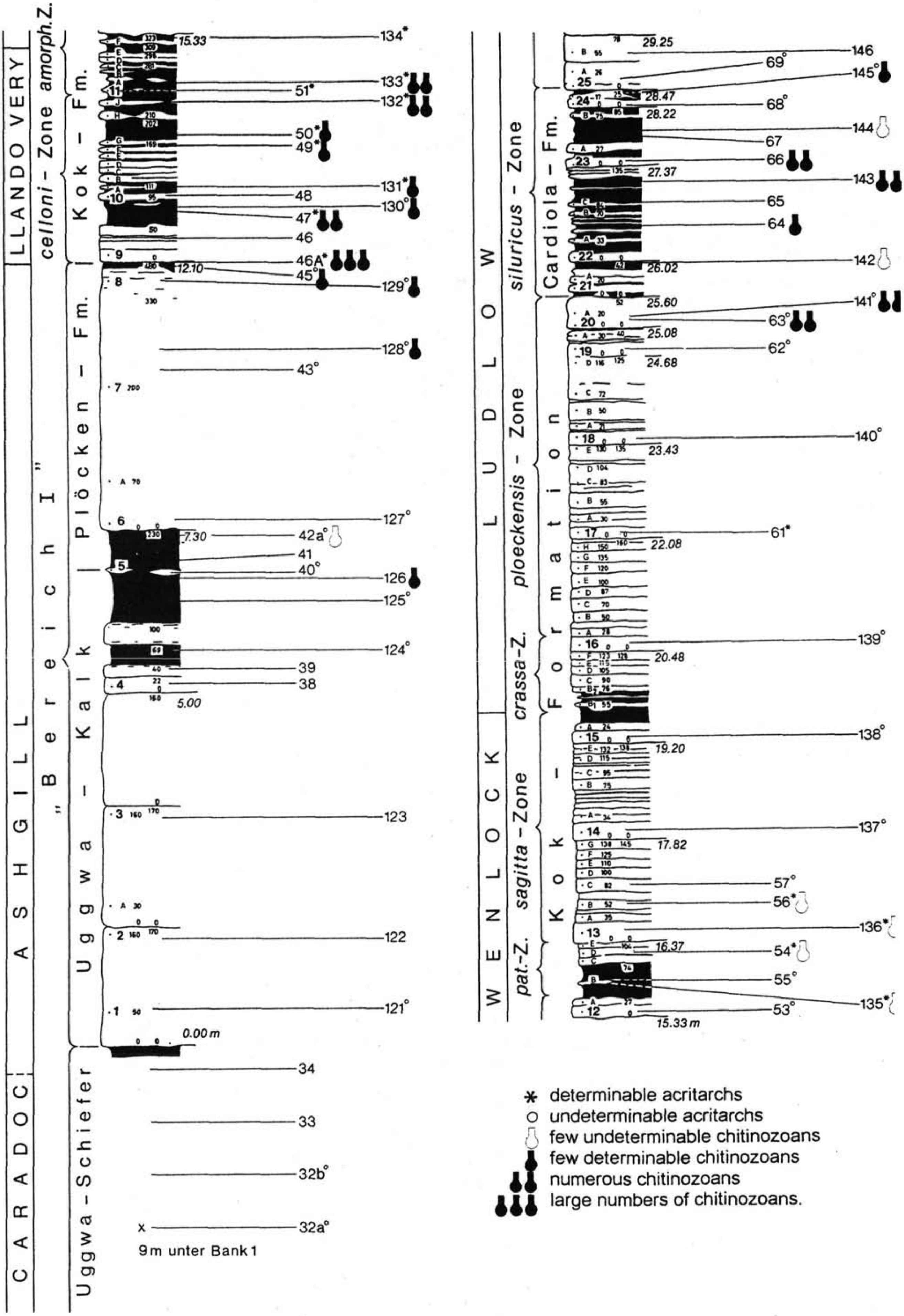
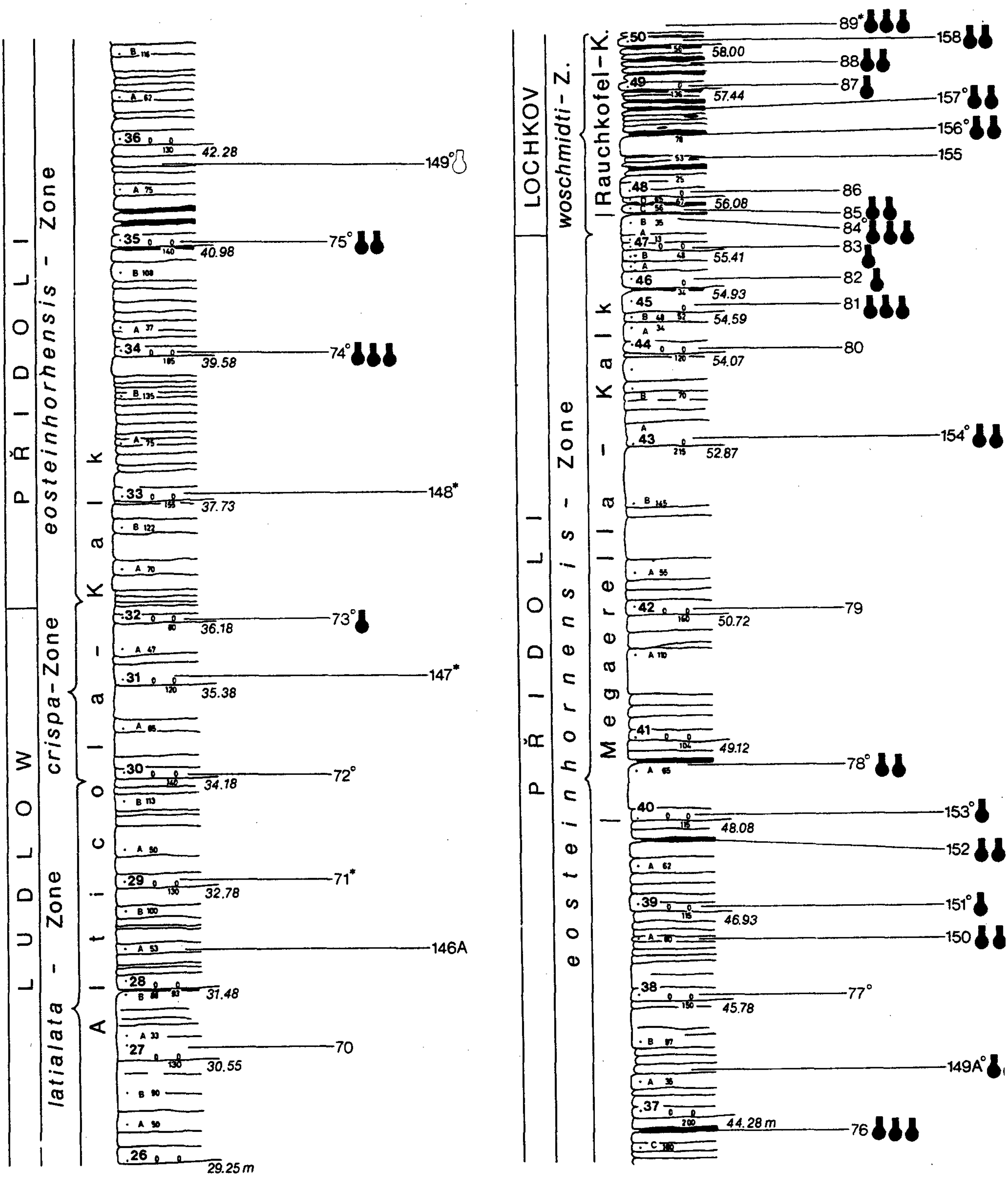


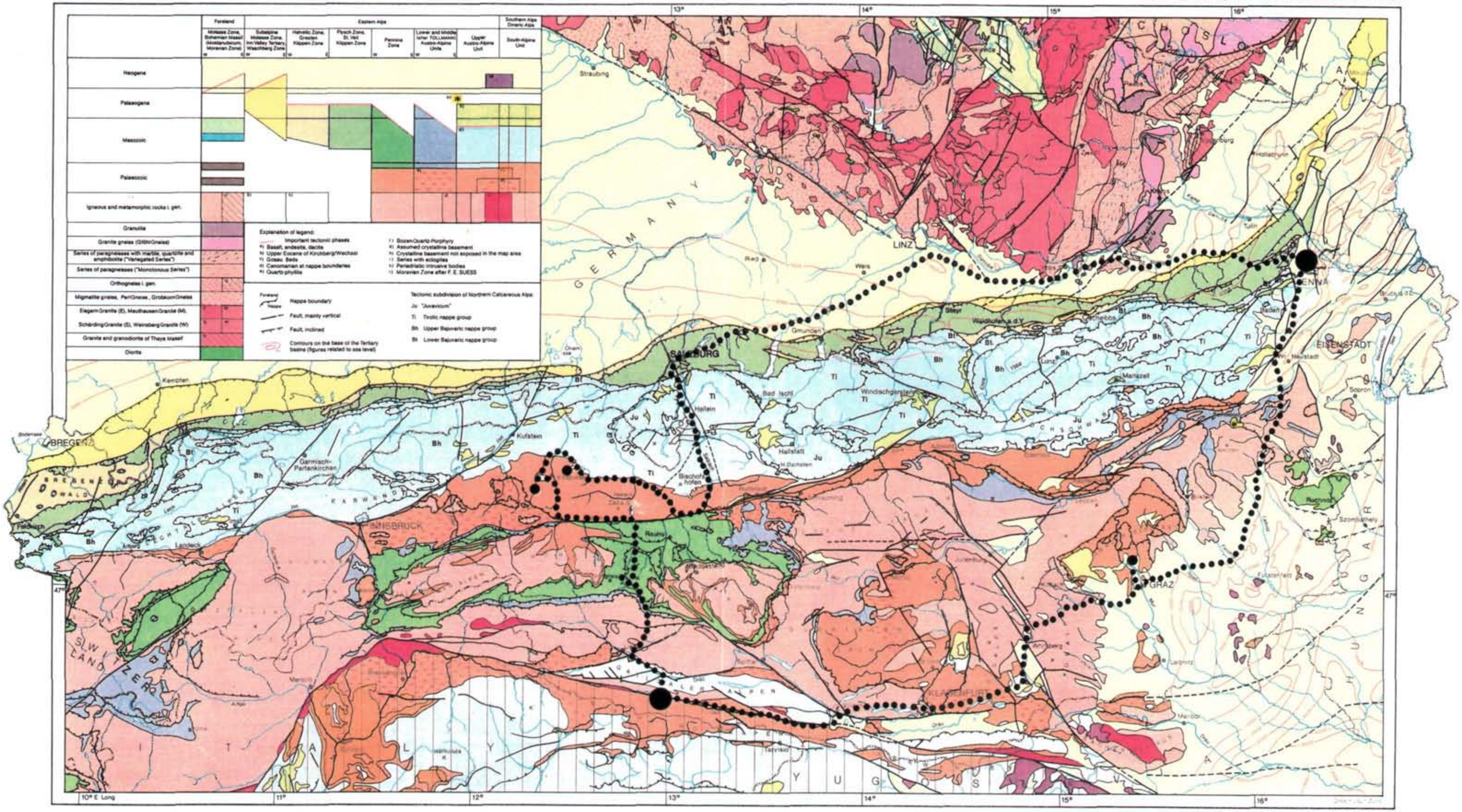
Fig.1: The location of the samples in the Cellon-section (drawing of the section after SCHÖNLAUB 1985).


LUDLOW
PŘIDOLI
latialata - Zone
crispa-Zone
eosteinhornensis - Zone
Alticola - Kalk
29.25 m
42.28
40.98
39.58
37.73
36.18
35.38
34.18
32.78
31.48
30.55
149°
75°
74°
148*
73°
147*
72°
71*
146A
70
LOCHKOV
PŘIDOLI
woschmidti - Z.
eosteinhornensis - Zone
Rauchkofel - K.
Megaerella - Kalk
58.00
57.44
56.08
55.41
54.93
54.59
54.07
52.87
50.72
49.12
48.08
46.93
45.78
44.28 m
89*
158
88
87
157°
156°
155
86
85
84°
83
82
81
80
154°
79
78°
153°
152
151°
150
77°
149A°
76

GEOLOGICAL MAP OF AUSTRIA with indication of the excursion route for the SSS Field Meeting '94

(WITHOUT QUATERNARY)

Compiled by P. BECK-MANNAGETTA (Eastern Alps) and A. MATURA (Bohemian Massif)
Edited by Geologische Bundesanstalt, Vienna 1980



0 10 20 30 40 50 60 70 80 90 100 km

Layout and reproduction technique by Geologische Bundesanstalt

Introduction

The main objective of the excursion program, the Carnic Alps of Southern Austria, represent the Paleozoic basement of the Southern Alps. The area has long been famous for its almost continuous and fossiliferous sequences ranging in age from the Caradoc to the Middle Carboniferous when the Variscan orogeny reached the climax. The intensively folded Lower Paleozoic rocks are conformably overlain by molasse-type sediments. The transgression started in the Moscovian Stage of the late Middle Carboniferous and continued during the Permian. Although these late Paleozoic series were affected by the Saalic Phase of the Lower Permian, the complicated structure of the Carnic Alps was mainly caused by intense Alpine deformation. It resulted in an imbricate nappe system, several thrust sheets, and dislocations in both the Variscan and post-Variscan series.

The fossiliferous marine Upper Ordovician to Serpukhovian sediments have been studied since the second half of the 19th century, e.g., by G. STACHE, F. FRECH, M. GORTANI, P. VINASSA, F. HERITSCH and H.R.v. GAERTNER who initiated systematic field work and provided numerous outstandig contributions to stratigraphy on which modern research has been based. Since World War II the nature of the faunas and lithofacies has further been analyzed and elaborated by the introduction of microfossil and other research methods and by a comprehensive mapping program carried out by the Geological Survey of Austria.

Towards the south the Carnic Alps are linked with the South Alpine Mesozoic strata, the so-called Southern Calcareous Alps. To the north they end abruptly at the Gail Valley which marks a prominent dextral fault zone. As a result of the Alpine Orogeny north of this fault the Central Eastern Alps form a complex tectonic nappe system (see fig.1). In recent years much progress has been achieved to document and better explain

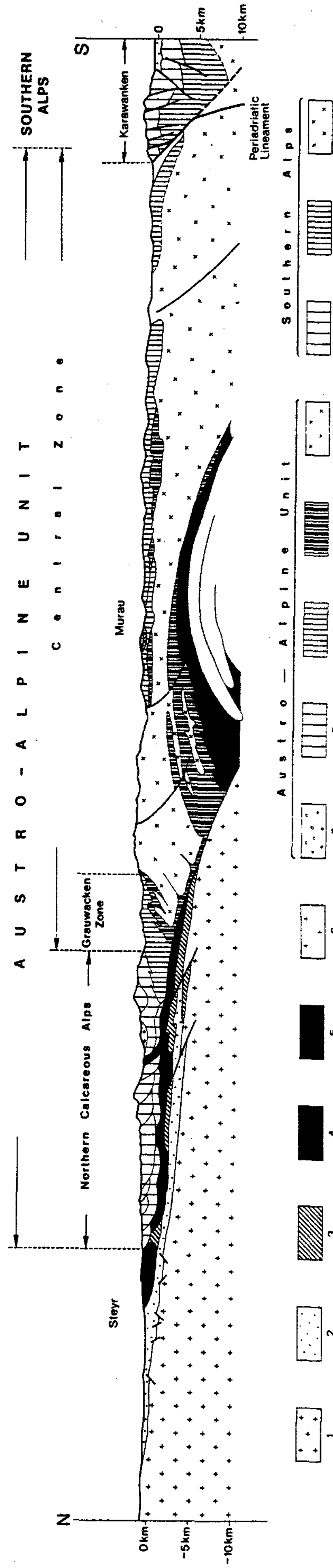


Fig. 1

Schematic cross section of the Eastern Alps along the line Linz–Klagenfurt (modified after S. PREY 1976, from W. JANOSCHEK & A. MATURA 1980).
1 = Extra-Alpine basement of the Bohemian Massif; 2 = Molasse Zone and intra-Alpine Tertiary (post-upper-Eocene); 3 = Helvetic Zone and Klippen Zone; 4 = Flysch Zone; 5 = Metasedimentary rocks of the Penninic Zone; 6 = Crystalline basement of the Penninic Zone; 7–11 = Austro-Alpine Unit: 7 = Gosau Formation; 8 = Permomesozoic (unmetamorphic) in North-Alpine facies; 9 = Palaeozoic (low-grade metamorphic); 10 = Permomesozoic (low-grade metamorphic) in Central Alpi-

the geological evolution and the individual mountain building processes of this part of the Alps. According to F. NEUBAUER and others its post-Variscan history can be described in terms of a two-stage collisional model which is briefly reviewed below (see fig.2):

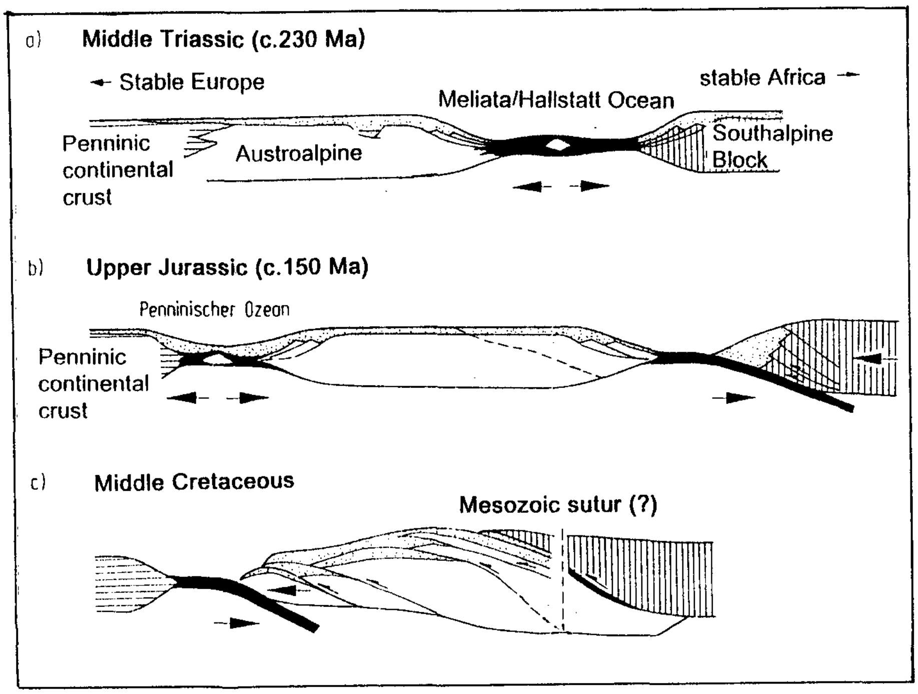


Fig. 2: Model of the early Alpine tectonic evolution of the Eastern Alps and Western Carpathians (modified after NEUBAUER 1994).

New radiometric data have shown that rifting processes started already in the Permian and affected the Variscan basement rocks. Finally, in the Middle Triassic continuous rifting led to the opening of the "Hallstatt-Meliata Ocean". To the north this fairly narrow ocean was bordered by the passive southern margin of the Austroalpine Realm and to the south by the Southalpine block.

During Early to Middle Jurassic times "somewhere" in the north of this realm a second ocean opened, i.e. the Penninic Ocean, which bordered stable Europe along another passive margin. As a consequence, the Austroalpine microplate drifted off and to the south and closure of the former ocean started in the Late Jurassic, i. e., approx. between 160 and 150 Ma; it was associated with subduction of the major part of the oceanic crust.

From the Late Jurassic to the Middle Cretaceous (approx. between 140 - 90 Ma) collision occurred between the Southalpine and Austroalpine microplates causing the so-called "Early Alpine" or "pre-Gosauan" overriding tectonics and nappe stacking within the Austroalpine block which consisted of pre-Variscan and Variscan basement and post-Variscan cover sequences the latter considerably varying in thicknesses. During the next step this mass which may be compared with an accretionary wedge, was loaded onto the Penninic extension of stable Europe. At the end of the Eocene the former Penninic Ocean was finally closed and subducted. For a long time it has been known that this process was accompanied by flysch-type sedimentation. As the result a second collision occurred, however, this time between the Austroalpine block and stable Europe.

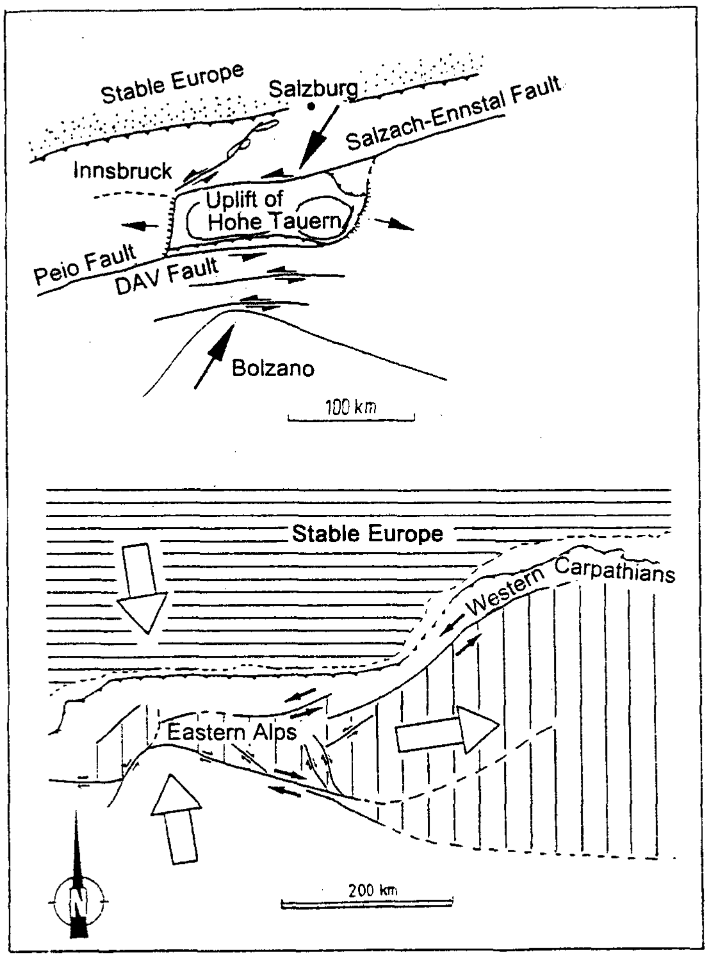


Fig. 3: Post collisional evolution of the Eastern Alps; explanation see text (modified after NEUBAUER 1994).

Post-collisional processes (fig.3) include additional N-S lithospheric shortening by contraction between the Adriatic "intender" and the Alpine foreland, uplift of metamorphic core complexes with following exhumation like in the Tauern Window, and simultaneous but differential eastward escape of different tectonic units along a sinistral wrench corridor and along the dextral Periadriatic fault system of which the Gail Valley Fault is a part of it. The corresponding lateral displacement may be in the order of up to 450 kilometers. Such processes may have started as early as the Oligocene and continued during the Miocene until the present. Due to crustal extension several sedimentary basins such as the Vienna and Pannonian basins were formed during the Neogene period.

THREE HISTORICAL NOTES ABOUT THE ALPS:

1. THE NAME: APPARENTLY, IT WAS INTRODUCED BY THE GREEK WRITER POLYBIOS IN THE 2ND CENTURY BC, ALTHOUGH HERODOT HAS ALREADY NAMED A RIVER "ALPIS" NORTH OF THE PROVINCE OF UMBRIA RUNNING TO THE DANUBE.

IT HAS BEEN SUGGESTED THAT THE IMMIGRATING INDOGERMANIC TRIBES HAVE OVERTAKEN THE NAME "ALP" FROM AN OLDER POPULATION AND TRANSLITERATED IT TO "ALBH" WHICH HAS THE MEANING OF WHITE. IF SO, IT SEEMS QUITE POSSIBLE THAT THIS INDOGERMANIC WORD DESIGNATES THE WHITE, I.E. SNOW COVERED MOUNTAINS. THE MEANING OF THE WORD "CARNIC" (ALPS) GOES BACK TO 'KARR" WHICH MEANS ROCK; THE CARNIC ALPS MAY HENCE BE TRANSLATED TO "WHITE ROCKY MOUNTAINS".

2. THE ROMAN WRITER TITUS LIVIUS SHORTLY CHARACTERIZED THE ALPS AS BEING "UGLY".

3. IN 1754 SAMUEL JOHNSON FROM ENGLAND DESCRIBED THE ALPS AS "UNNATURAL OUTBURSTS OF THE EARTH'S CRUST" - AN INDEED UNJUSTIFIED DISQUALIFICATION IN TODAYS VIEWS OF THIS MAGNIFICENT MOUNTAIN CHAIN!

Sections

Travel from Vienna to the Carnic Alps (Kötschach-Mauthen)

(fig. 4)

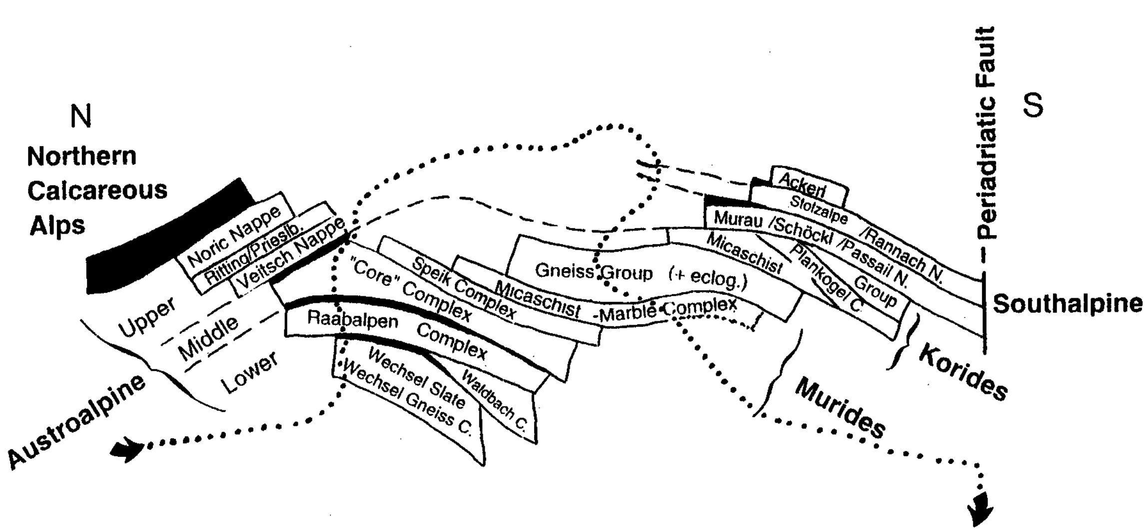


Fig. 4: Tectonic subdivisions of the Eastern part of the Alps after FRISCH et al. 1990

Route:
Vienna via Autobahn A 2 to Graz, capital of Styria (approx. 200 km); in the afternoon continuation via Autobahn to Klagenfurt, along the Wörthersee and further on through the Gail Valley to Kötschach-Mauthen (approx. 250 km).

Program:
Visit of the Upper Silurian Eggenfeld section near Gratkorn (guide F. Ebner, Leoben University). After lunch visit of the open-air museum at Stübing, Austria's finest collection of old farmhouses and the life on the countryside in older times.

Short route description:
In the introductory part of the excursion program it was outlined that the Vienna Basin has a locally more than 5000 m thick clastic Neogene sediment filling which hosts the majority of Austria's oil and gas occurrences. At present, however, only some 1.2 Mio t

oil and 1.2 Mio m^3 gas/year are exploited in Austria. In the Vienna Basin the majority of the oil-bearing horizons is in a depth between 900 and 2000 m.

For the formation of the basin a non-uniform extension model is applied. All drillings have shown that subsidence started simultaneously at 17.5 Ma, i.e. approx. at the lower/middle Miocene boundary. This event corresponds to the first strike-slip phase of the model. Renewed subsidence is reflected in a second strike-slip phase while locally also a third subsidence event can be recognized which presumably took place at the boundary betwen the Pontian and Pliocene Stages.

After leaving the Vienna Basin some 60 km south of Vienna the autobahn crosses the northeastern end of the Alps. In the sketch below the route is schematically indicated (fig.4). Due to Alpine contraction and N-S shortening in this segment the Austroalpine tectonic block represents a thick pile of nappes which consists of different low to high-grade metamorphosed pre-Variscan and Variscan basement rocks and their Permian and Mesozoic cover. The highest position is occupied by the Northern Calcareous Alps; the Wechsel unit on the other side represents a deep tectonostratigraphic unit. With regard to the formation of this nappe stacking we refer to the introduction.

Section 1

Silurian/Devonian boundary section of Eggenfeld/Paelozoic of Graz
(fig. 5, 6, 7)

by Fritz Ebner[1]

Location
Approx. 13 km NNW of Graz at the eastern side of the Mur Valley N of the village Eggenfeld. The bad exposures are located at the edge of the forest area of Eggenfeld at an altitude of 440 m.

Geological and paleontological informations
EBNER 1976, 1983, PLODOWSKI 1976, FRITZ & NEUBAUER 1988, NEUBAUER 1989, FRITZ et. al. 1992.

Geodynamic/paleogeographic evolution
The Silurian/Lower Devonian basal units of the uppermost nappe (Rannach nappe, fig. 5) of the Graz Thrust Complex are differentiated in account of their paleogeograhic/geodynamic evolution. The Silurian is dominated by alkaline mafic lavas and pyroclastics which are interpreted as initial rift sequences. These volcano- and siliciclastics are followed by progressive carbonate production during the Devonian.

In the Eggenfeld area the distribution of Upper Silurian/Lower Devonian sediments is controlled by the Silurian volcanism (fig. 6). It is suggested that the volcanic island of Eggenfeld was buried by Late Silurian/Lowermost Devonian fossiliferous carbonates. Within the Lower Devonian block rotation occurred due to extensional tectonics. This caused a weak angular unconformity between the Late Silurian/Lower Devonian carbonates ("Crinoid-Fm.") and the Lower Devonian Dolomite Sandstone-Fm. The latter is starting with a 5-10 m thick yellow rauchwacke member (FRITZ & NEUBAUER 1988, NEUBAUER 1989).

Lithostratigraphic sequence (fig. 7)
In spite of the bad outcrops the following lithostratigraphic sequence (from S-N = bottom - top) may be reconstructed (EBNER 1976).

Diabas Fm. of Eggenfeld (Silurian)
1) Massive green diabases interfingering with violett to greenish/grey tuffs. Syngenetic hematitic layers and crusts are concentrated at the tuffs and the upper contact of the diabases to dark dolomites.

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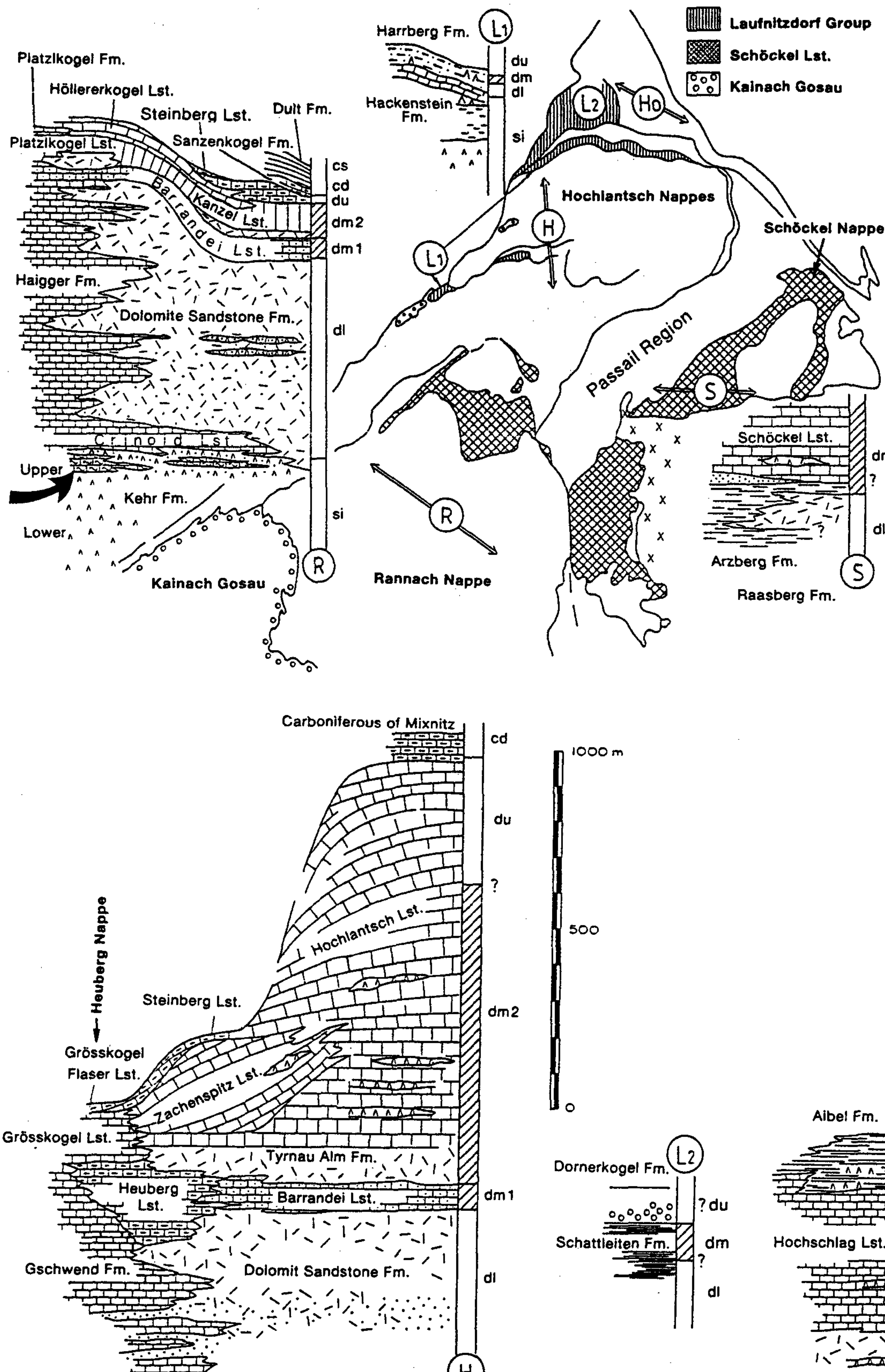


Fig. 5: Stratigraphy of the thrust system of the Paleozoic of Graz. Letters of the stratigraphic columns indicate: *R* Rannach Group; L_1, L_2 Laufnitzdorf Group; *Ho* Hochschlag Group; *S* Schöckel Group. (FLÜGEL & NEUBAUER 1984).

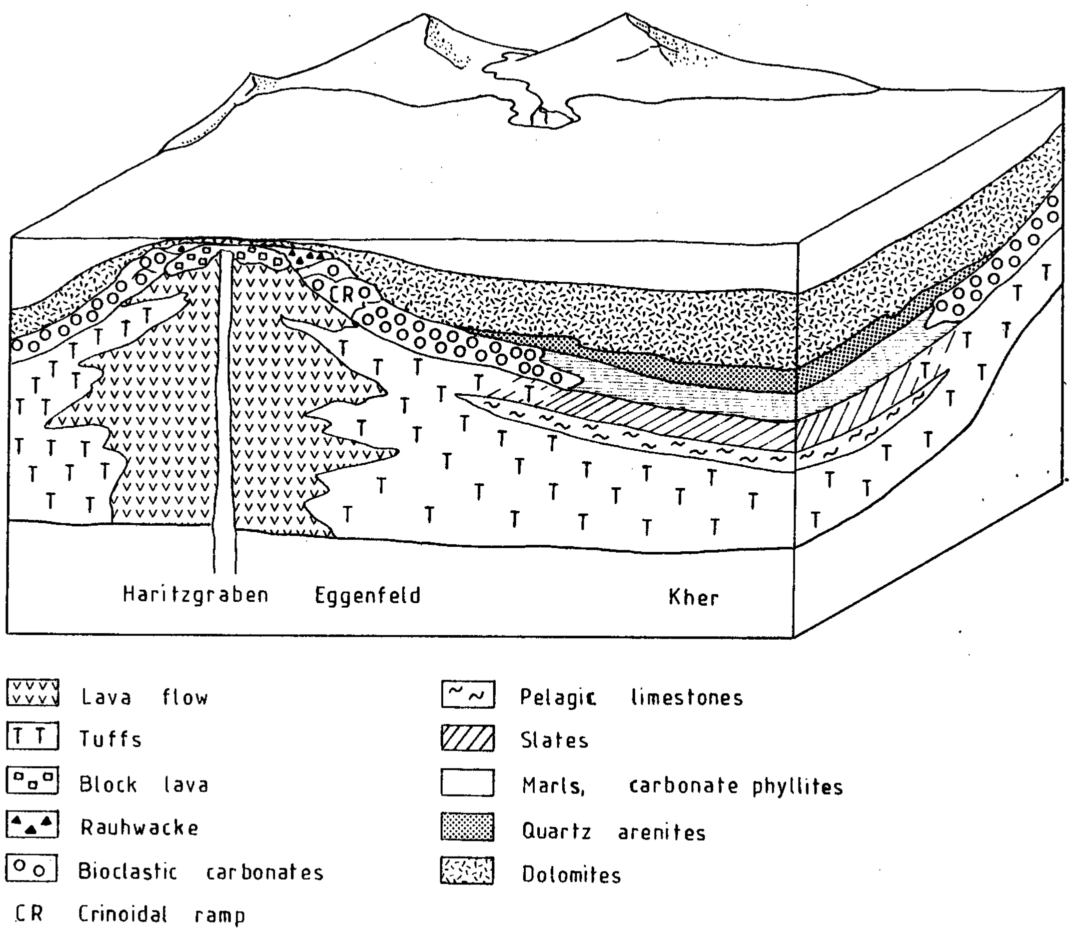


Fig. 6: Diagram showing the Middle Silurian Volcanic centers (after FRITZ & NEUBAUER 1988)

"Crinoid"-Fm. (Late Silurian - Lochkov)
2) 200 cm dark, bedded dolomites (D/1)
3) 700 cm tuffs and tuffitic shales
4) 200 cm dark, bedded dolomites (D/2) with lenses of bioclastic (crinoids, brachiopods) dolomitic limestones (L/1)
5) 350 cm tuffs and tuffitic shales including some layers of dark dolomites (D/3) with lenses and layers of bioclastic (crinoids, brachiopods) limestones (L/2).

The microfacies of the dolomites (D/1-3) is characterized by a fine grained sparitic fabric and a content of biogens (filaments, brachiopods, crinoids, trilobites, orthoceratids) up to 15 %. The bioclastic limestone lenses (L 1/2) are dolomitized biosparitic limestones rich in crinoids and brachiopods (often with geopetal internal sediments).

Dolomite Sandstone-Fm. (Late Lower Devonian)
6) light dolomites
The yellow rauchwacke member at the base of the Dolomite Sandstone-Fm. is badly exposed at the path from the parking place to the Silurian/Devonian boundary section.

Fossil record and biostratigraphy
Macro- and micofossils (conodonts) are restricted to the carbonatic levels D/1-3 and bioclastic lenses (L1/2).

D 1: common: crinoids; rare: small indet. brachiopods, orthoceratids, *Favosites* s p.

D 2: common: crinoids, rare: orthoceratids, corals (*Syringaxon* sp.)

D 3:common: crinoids

L1/L2: common *Septatrypa subsecreta* PLODOWSKI, 1976.

The brachiopods deriving from L1/L2 were described by PLODOWSKI 1976 as the new dimorphic species *Septatrypa subsecreta* (with formae "typica" and "trapezoidalis"). Due to accompaning conodonts the brachiopod levels are dated as *eosteinhornensis*- and *woschmidti* Zone of Latest Silurian and Earliest Devonian age.

A few brachiopods (Uncinulidae and cf. *Dubaria hircinaeformis*) were found as loose materials but can not be related to a distinct carbonatic level.

Conodonts are relatively fequent in all carbonatic levels. Due to the dolomitization they are relatively well preserved and show CAI 5. Beside conodonts agglutinated foramaminifera (*Hyperammina, Lagenammina, Tolypammina, Psammosphaera cava, Sorosphaera tricella*, indet. ostracods) and some microproblematics were found.

All carbonatic levels were dated by conodonts (quoted only stratigraphic important taxa):

D/1: Ludlow (*P. siluricus* Zone): *Kockelella variabilis, Polygnathoides emarginatus, Polygnathoides siluricus.*

D/2: Basal parts of D/2 indicate the *O. snajdri* horizon of the *P. siluricus* Zone by *Ozarkodina snajdri* and *Poygnathoides emarginatus.* The first occurrence of *Ozarkodina remscheidensis eosteinhornensis* was also recorded inside this level.
The bioclastic lenses approximately 65 cm above the base of D/2 with *Ozarkodina remscheidensis eosteinhornensis* are related to the *O. eosteinhornensis* Zone. In between these levels index condonts of *P. latialata*- and *O. crispa* Zone were not recorded.

D/3: The base of the Devonian (*I. woschmidti* Zone) was proved by *Icriodus woschmidti* from the lowermost carbonatic level of the upper band of tuffitic shales followed by *Ozarkodina remscheidensis remscheidensis* in the nextfollowing carbonatic level.

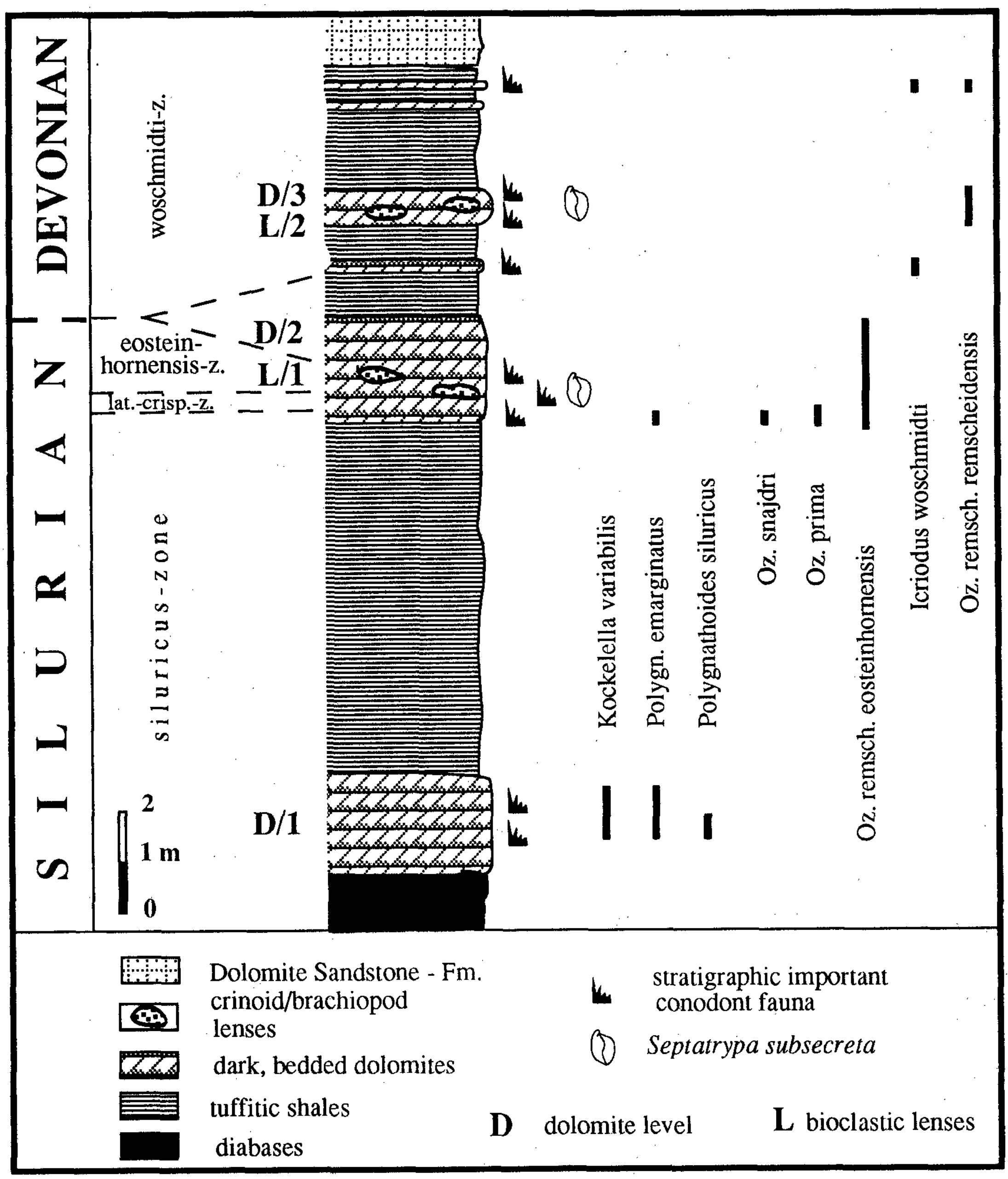


Fig. 7: Bio- and Lithostratigraphy of the Eggenfeld Section

Importance of Eggenfeld section
* Proof of Silurian volcanism which is typical for the Eastern Alps.
* Continuation of the volcanic activities to the Lower Devonian.
* Geodynamic implications (block rotation) deduced from biostratigraphy and field mapping.
* One of the best biostratigrahic records of Upper Silurian and Lowermost Devonian in the Eastern Alps. All paleontological materials are stored in Graz at the Landesmuseum Joanneum, Dept. of Geology and Paleontology.
* Position of the Silurian/Devonian boundary between the conodont bearing levels of D/2 and D/3 within a vertical sequence of approx. 2 m.
* Locus typicus of *Septatrypa subsecreta* PLODOWSKI, 1976.

What to see in the field ?
* Silurian diabases behind the house at the path from the parking place to the Silurian/Devonian section. o Along the path to the forest bad exposures and debris of tuffitic shales and yellow rauckwacke.
* In the forest righthand the path the outcrop in which the "Crinoid"-Fm. is overlain by the rauchwacke member of Dolomite Sandstone-Fm. by a weak unconformity (according to FRITZ & NEUBAUER 1988, NEUBAUER 1989).
* The lithostratigraphic section above the diabases and the Silurian/Devonian boundary section described before includes the locus typicus of *Septatrypa subsecreta* (EBNER 1976, PLODOWSKI 1976).

  In the field the carbonatic levels are indicated by red letters. Collection of conodont samples and perhaps some brachiopods is possible.

References

EBNER, F.: Das Silur/Devon-Vorkommen von Eggenfeld - ein Beitrag zur Biostratigraphie des Grazer Paläozoikums.- Mitt. Abt. geol. Paläont. Bergb. Landesmus. Joanneum, 37:3-33, Graz 1976.

EBNER, F.: Erläuterungen zur geologischen Basiskarte 1:50.000 der Naturraumpotentialkarte "Mittleres Murtal".- Mitt. Abt. Geol. Paläont. Bergb. Landesmus. Joanneum, 44, 32 p., Graz 1983.

FRITZ, H., EBNER, F. & NEUBAUER, F.: The Graz Thrust-Complex (Paleozoic of Graz).- ALCAPA-Field Guide, 83-92, Graz (IGP/KFU) 1992.

FRITZ, H. & NEUBAUER, F.: Geodynamic aspects of the Silurian and Early Devonian Sedimendation in the Paleozoic of Graz (Eastern Alps).- Schweiz. Mineral. Petrogr. Mitt., 68:359-367, Zürich 1988.

NEUBAUER, F.: Lithostratigraphie und Strukturen an der Basis der Rannachdecke im zentralen Grazer Paläozoikum (Ostalpen),. Jb. Geol. B.-A., 132:459-474, Wien 1989.

PLODOWSKI, G.: Die Brachiopoden des Silur/Devon-Grenzprofils von Eggenfeld (Grazer Paläozoikum).- Mitt. Abt. Paläont. Bergb. Landesmus. Joanneum, 37:35-51, Graz 1976.

Section 2

Cellon Section

(figs. 8A-D)

by Hans Peter Schönlaub, Lutz Hermann Kreutzer & Helga Priewalder

Lithology, Paleontology and Stratigraphy (H.P. Schönlaub)

The section is located between 1480 and 1560 m on the eastern side of the Cellon mountain, SSW of Kötschach-Mauthen and close to the Austrian/Italian border. It can be reached within a 15 minutes walk from Plöcken Pass.

The Silurian part of Cellon section is best exposed in a narrow gorge cut from avalanches. Thus, the German name for the section is "Cellonetta Lawinenrinne".

The Cellon section represents the stratotype for the Silurian of the Eastern and Southern Alps. Nowhere else in the Alps a comparable good section has been found. It has been famous since 1894 when G.GEYER first described the rock sequence. In 1903 it was presented to the 9. IGC which was hold at Vienna. According to v. GAERTNER 1931 who studied fossils and rocks in great detail, the 60 m thick continuously exposed Upper Ordovician to Lower Devonian section can be subdivided into several formations. Since O.H. WALLISER's pioneering study on conodonts in 1964 it still serves as a standard for the worldwide applicable conodont zonation which, however, has been further detailed and partly revised in other areas during the last two decades. Although the conformable sequence suggests continuity from the Ordovician to the Devonian, in recent years several small gaps in sedimentation have been recognized which reflect eustatic sea-level changes in an overall shelf-water environment. From top to base the following formations can be recognized (see figs. 8A-D on the following pages):

Top:
80.0 m Rauchkofel Limestone (dark, platy limestone; Lochkovian)
8.0 m Megaerella Limestone (greyish and in part fossiliferous limestone; Pridoli)
20.0 m Alticola Limestone (grey and pink nautiloid bearing limestone; Ludlow to Pridoli)
3.5 m Cardiola Formation (alternating black limestone, marl and shale; Ludlow)
13.0 m Kok Formation (brownish ferruginous nautiloid limestone, at the base alternating with shales; Upper Llandovery to Wenlock)
4.8 m Plöcken Formation (calcareous sandstone; Ashgill, Hirnantian Stage)
7.3 m Uggwa Limestone (argillaceous limestone grading into greenish siltstone above; Ashgill)

According to H.P.SCHÖNLAUB 1985 the Ordovician/Silurian boundary is drawn between the Plöcken and the Kok Formations, i.e. between sample nos. 8 and 9. In the Plöcken Fm. index fossils of Hirnantian age clearly indicate a latest Ordovician age. These strata represent the culmination of the end-Ordovician regressive cycle known from many places in the world (H.P. SCHÖNLAUB 1988).

According to conodonts and graptolites from the basal part of the overlying Kok Fm. the equivalences of at least six graptolite and two conodont zones are missing in the Lower Silurian. Renewed sedimentation started in the Upper Llandovery within the range of the index conodont *P. celloni*.

At present the precise level of the Llandovery/Wenlock boundary can not be drawn. Graptolites and conodonts, however, indicate that this boundary should be placed between sample nos. 11 and 12. Consequently, the rock thickness corresponding to the Llandovery Series does not exceed some three meters.

According to H.P. SCHÖNLAUB in J. KRIZ et al. 1993 the boundary between the Wenlock and the Ludlow Series can be drawn in the shales between sample nos. 15 B1 and 15 B2. Apparently, this level most closely corresponds to the stratotype at quarry Pitch Coppice near Ludlow, England. We thus can assume an overall thickness of some 5 m for Wenlockian sedimentation. By comparison with the Bohemian sections the strata equivalent to the range of *Ozarkodina bohemica* are at Cellon extremely condensed suggesting that during the Homerian Stage sedimentation occurred mainly during the lower part. With regard to the foregoing Sheinwoodian Stage it may be concluded that at its base the corresponding strata are also missing or represented as the thin shaly interval between sample nos. 12 A and 12 C. At this horizon the *M. rigidus* Zone clearly indicates an upper Sheinwoodian age.

By correlation with Bohemian sequences and the occurrence of index graptolites for the base of the Pridoli, the Ludlow/Pridoli boundary is drawn a few cm above sample no. 32 (H.P. SCHÖNLAUB in J. KRIZ et al. 1986). This horizon lies some 8 m above the base of the Alticola Lst.. The corresponding sediments of the Ludlow have thus a thickness of 16.45 m.

At Cellon the Silurian/Devonian boundary is placed at the bedding plane between conodont sample nos. 47 A and 47 B at which the first representatives of the index conodont *Icriodus woschmidti* occur. It must be emphasized, however, that the first occurrences of diagnostic graptolites of the Lochkovian is approx. 1.5 m higher in the sequence. H. JAEGER 1975 recorded the lowermost occurrences of *M. uniformis, M.* cf. *microdon* and *Linograptus posthumus* in sample no. 50. The Pridolian part of the sequence may thus represent a total thickness of some 20 m.

Data about acritarchs und chitinozoans can be found in the paper by PRIEWALDER in this volume, p.61 ff.

Facial differentiation and bathymetric environment (L.H. Kreutzer)

The first facial investigation at the Cellon section was done by FLÜGEL 1965. BANDEL (1972) made facial analyses about the Lower and Middle Devonian in the middle part of this mountain chain. The Middle, Upper Devonian and Lower Carboniferous (steep cliffs and top of Cellon) was investigated by KREUTZER (1991). Photomicrographs with detailed interpretation from the Cellon section can be found in KREUTZER 1992b.

For this volume a revised analysis of 64 thin sections of the Cellon gorge was done. The following list shows the facial characteristics of each formation with the sample numbers according to WALLISER (1962, 1964).

Ordovician: Uggwa Formation
Age: Ashgill
Facies: Uggwa Facies
Character: (a:) grey to coloured pelagic Flaser limestone with (b:) ostracod-echinodermal debris layers.
Sceletal grains: brachipods, filaments, ostracods, parathuramminaceae, cephalopods, styliolinids, trilobites, acritarchs
Thickness: 7,3 m
Outcrop: Cellon section, layer 1-5 (WALLISER 1964)
DUNHAM (1962): a: wackestone; b: pack-/grainstone
SMF-type acc. to WILSON (1975): (a:) 9; (b:) 12

Ordovician: Plöcken Formation
Age: Ashgill
Facies: Uggwa Facies
Character: echinodermal and bivalve debris
Skeletal grains: echinoderms, ostracods, bivalves, algae
Thickness: 4,8 m
Outcrop: Cellon section, layer 6-8 (WALLISER 1964)
DUNHAM (1962): grainstone
SMF-type acc. to WILSON (1975): 12

Silurian: Kok Formation
Age: Wenlock to Middle Ludlow
Facies: Plöcken Facies
Character: grey to greyish black micritic limestones with many stylolites
Skeletal grains: filaments, trilobites, ostracods, gastropods, brachiopods, echinoderms, algal crusts
Thickness: 13 m
Outcrop: Cellon section, layer 9-20 (WALLISER)
DUNHAM (1962): Mud-/wackestone
SMF-type acc. to WILSON (1975): 9

Silurian: Cardiola Formation
Age: Upper Ludlow
Facies: Plöcken Facies
Character: grey limestones with marly layers
Skeletal grains: nautiloids, ostracods, trilobites, parathuramminaceae, radiolarians
Thickness: 3,5 m

Outcrop: Cellon section, layer 21-24 (WALLISER 1964)
DUNHAM (1962): wackestone
SMF-type acc. to WILSON (1975): (3/9)

Silurian: Alticola Formation
Age: Ludlow to Pridoli
Facies: Plöcken Facies
Character: dolomitic grey to greyish pink micrites
Skeletal grains: nautiloids, filaments, trilobites
Thickness: 20 m
Outcrop: Cellon section, layer 25-39 (WALLISER 1964)
DUNHAM (1962): wackestone
SMF-type acc. to WILSON (1975): 3

Silurian: Megaerella Formation
Age: Pridoli
Facies: Plöcken facies
Character: a) light to grey micrites with b) biosparites
Skeletal grains: a) ostracods, filaments, trilobites; b) ostracods, filaments, echinoderms
Thickness: 8 m
Outcrop: Cellon section, layer 40-47A (WALLISER 1964)
DUNHAM (1962): a) wackestones; b) pack-/grainstones
SMF-type acc. to WILSON (1975): a) 3; b) 2

Devonian: Rauchkofel Limestone
Age: Lochkov
Facies: Transition facies (KREUTZER 1992a)
Character: a) dark grey to black platy limestone shales with shell debris ans layers of b) crinoidal debris grainstones
Skeletal grains: a) tentaculites, cephalopods, ostracods, parathuramminaceae, filaments, trilobites, few echinoderms; b) rounded echinodermal fragments, bivalves
Thickness: 80 m
Outcrop: Cellon section, layer 47B and >
DUNHAM (1962): a) wacke-/packstone; b) grainstone
SMF-type acc. to WILSON (1975): 9

In detail the sampled layers give the following microfacial remarks (see figs. 8A-D):

51:	Peloid-grainstone with echinodermal fragments and lumachelles
50, 49:	Laminated Peloid-shell-grainstone
48A, 48:	Laminated grainstone with lumachelles
47C:	Laminated grainstone with echinodermal fragments and lumachelles
46B:	Peloid-grainstone with lumachelles
46, 45:	Laminated grainstone with lumachelles
44A, 44:	Bioclastic wackestone with nautiloids, trilobites and filaments
43:	Grainstone with lumachelles
42B, 42, 41A:	Bioclastic wackestone with nautiloids, filaments, parathuramminacea
41:	Wacke-/packstone, dolomitized, bioturbated
40A:	Mud-/wackestone, few echinodermal fragments
40:	Laminated grainstone with lumachelles
39:	Wackestone with parathuramminacea, dolomitized
38:	Wackestone with , nautiloids, parathuramminacea

37, 36, 35, 34, 33, 32:	Bioturbated wackestone, parathuramminacea, nautiloids, filaments, trilobites, ostracods
31:	Bioclastic wackestone, partly dolomitic matrix, trilobites
30:	Graded bedding (pack-/wackestone, above secondary dolomite) in a wackestone
29:	Iron-rich pack-/grainstone with nautiloids, dacryoconarids, filaments
28:	Iron-rich bioclastic packstone, trilobites, surrounded by algal crusts, filaments, ostracods
27:	Bioclastic wacke-/packstone, nautiloids, filaments, ostracods
26:	Secondary dolomite, bioclastic wackestone
25:	Bioclastic wackestone, nautiloids, trilobites, filaments
24:	Finely laminated lithoclastic shaly limestone, pyrite
23:	Bioturbated shaly limestone with radiolarians, above shell grainstone with ostracods
22:	Bioclastic wackestone with nautiloids, filaments, trilobites
20:	Laminated grainstone with lumachelles, pyrite
19:	Bioclastic wackestones with nautiloids
18C:	Packstone, nautiloids, brachiopod shells, conodonts
18:	Lithoclastic layer with shells
17:	Bioclastic wacke-/packstone with trilobites, nautiloids, bioturbated
16:	Pack-/grainstone with lumachelles
15B:	Grainstone, lumachelles, pyrite
15, 14, 13, 12:	Bioclastic wacke-/packstone with nautiloids, trilobites, ostracods, filaments, iron rich
11D:	Strongly bioturbated wackestone with algae, lumachelles, quartz
7:	Packstone with edged echinoderm fragment clasts, few shells and bryozoan fragments
6:	Grainstone with ehinoderms and shells
5:	Grainstone with ehinoderms and shells changing with clay rich laminated clast layers, pyrite
4:	Lithoclastic pack-/floatstone with reworked components from layer 3
3, 2, 1:	Bioclastic wackestone with nautiloids, trilobites, filaments

Microfacial detaills about the whole Variscan carbonate layers in the area are presented in KREUTZER 1992b.

The bathymetric environment for the Silurian sequence can be described as follows:

As early as in the Ordovician a facial differentiation can be recognized for the carbonates. The Cellon section with it´s Uggwa Limestone (sample 1-5) represents the late Ordovician Uggwa facies and corresponds to the the Wolayer Limestone in Himmelberg facies at the Rauchkofel section. The Uggwa Limestones are well dated based on conodonts. According to DULLO (1991), the two formations represent the near-shore parautochthonouos cystoid facies (Wolayer Limestone) and an off-shore basinal debris facies (Uggwa Limestone).

At the end of the Ordovician in the Carnic Alps a regression occurred. The Uggwa limestone layers (nos. 1-4) show pelagic faunal elements and are followed by high energy limestones with subtidal components of the Plöcken Formation (nos. 5-8). Between the nos. 8 and 9 there is a gap.

Transgression of the Kok Formation started in the Cellon section in the Upper Llandovery (no. 9). At the 8 km distant Rauchkofel section the Silurian is considerably reduced. At Cellon the Kok Formation begins with a moderate shallow environment which may have lasted until the very beginning of the Wenlock. Sample 11 shows a very shallow to intertidal environment. During the Wenlock there is a progressing transgressive tendency. At the Wenlock/Ludlow boundary (nos. 15A-F) some strata may be missing.

During deposition of the Cardiola Formation (nos. 21-24) we see also the possibility of interrupted sedimentation. Black limestone shale layers with radiolarians change with pelagic limestone beds indicating offshore environment. The Alticola Limestone (nos. 25-39) reflects stable conditions in a pelagic environment which terminates in a regressive pulse (no 40). With the beginning of the Megaerella Limestone (nos. 41-47A) a further transgressive influense can be assumed.

From the Lochkovian (layer 47B and >; Rauchkofel Limestone) to the Frasnian Upper *gigas* Zone (top region of the Cellon cliff) the Devonian transition facies of a fore-reef area is developed. A few kilometers to the palinspastic SSW (today situated in the west: the Kellerwand region) more than 1000 meters of Devonian shallow-water limestones were deposited corresponding to the slope environment of the Cellon region. Coeval pelagic carbonates (pelagic limestone facies of the Rauchkofel nappe) of markedly reduced thickness of not more than 100 meters (SCHÖNLAUB 1979, 1985; KREUTZER 1990, 1992a, b) are situated a few hundred meters to the NNE.

In the Famennian a regression occurred which was briefly interrupted during the *crepida* Zone. In the Lower Carboniferous all facies were covered by a thin cephalopodal limestone facies (Kronhof Limestone). Hence, during the Lower Carboniferous a subdivision of facies cannot be recognized. At the beginning of the Viséan the flysch of the Hochwipfel Formation transgressed upon the Kronhof Limestone and stopped the limestone sequence of the Lower Paleozoic of the Carnic Alps.

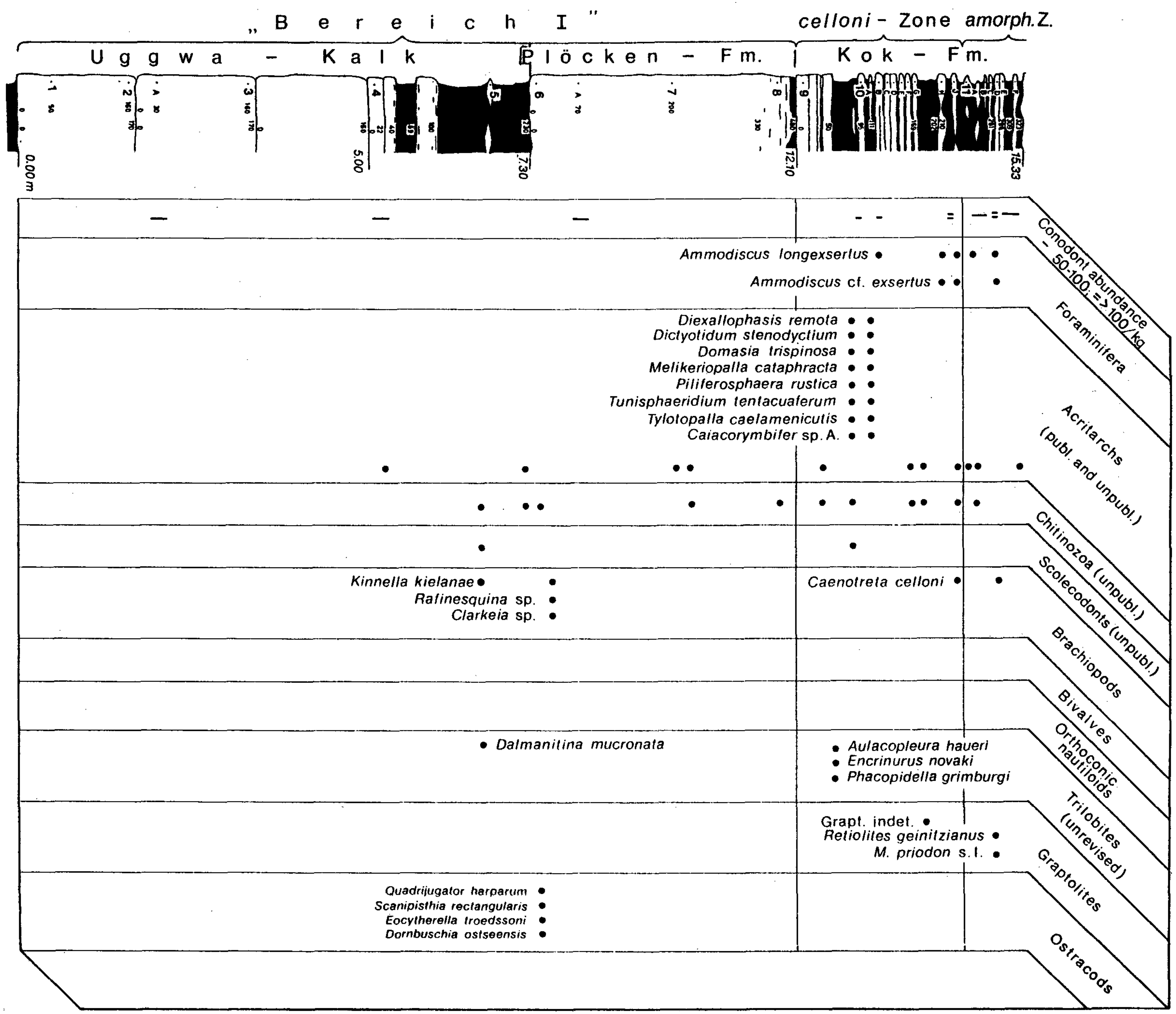
Stable Isotope Data (H.P. Schönlaub)

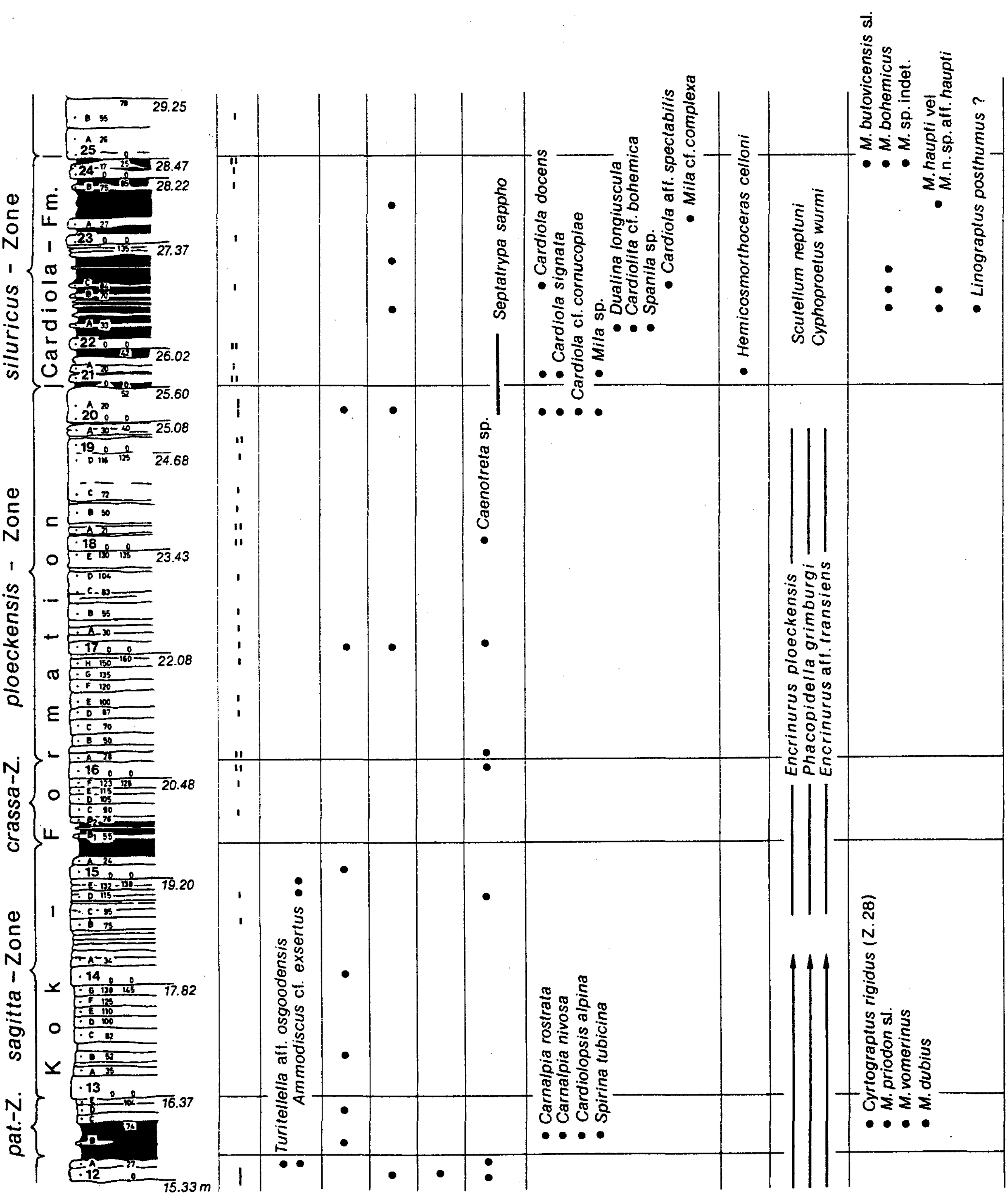
A preliminary record of carbon-13 variations (delta-^{13}C) from the Cellon section is based on some 80 samples which were kindly analyzed by W. BUGGISCH & M. JOACHIMSKI from Erlangen University. The curve shows not very prominent fluctuations although three minima apparently coinciding with shale horizons seem to characterize (1) the Llandovery/Wenlock boundary, (2) the Cardiola Fm. and (3) the lower Pridoli. The latter represents a marked deviation from positive signals recorded in both the lower Alticola Lst. and the overlying beds of the latest Pridoli. It is beyond the scope of this study to interpret our provisional results in common terms of mirrowing the oceans productivity but there seems a general trend in the present record from positive signals of the late Ordovician to delta-^{13}C minima during the interval from the Llandovery to the early to middle Ludfordian. The following generally positive signals are shortly interrupted in the lowermost Pridoli.

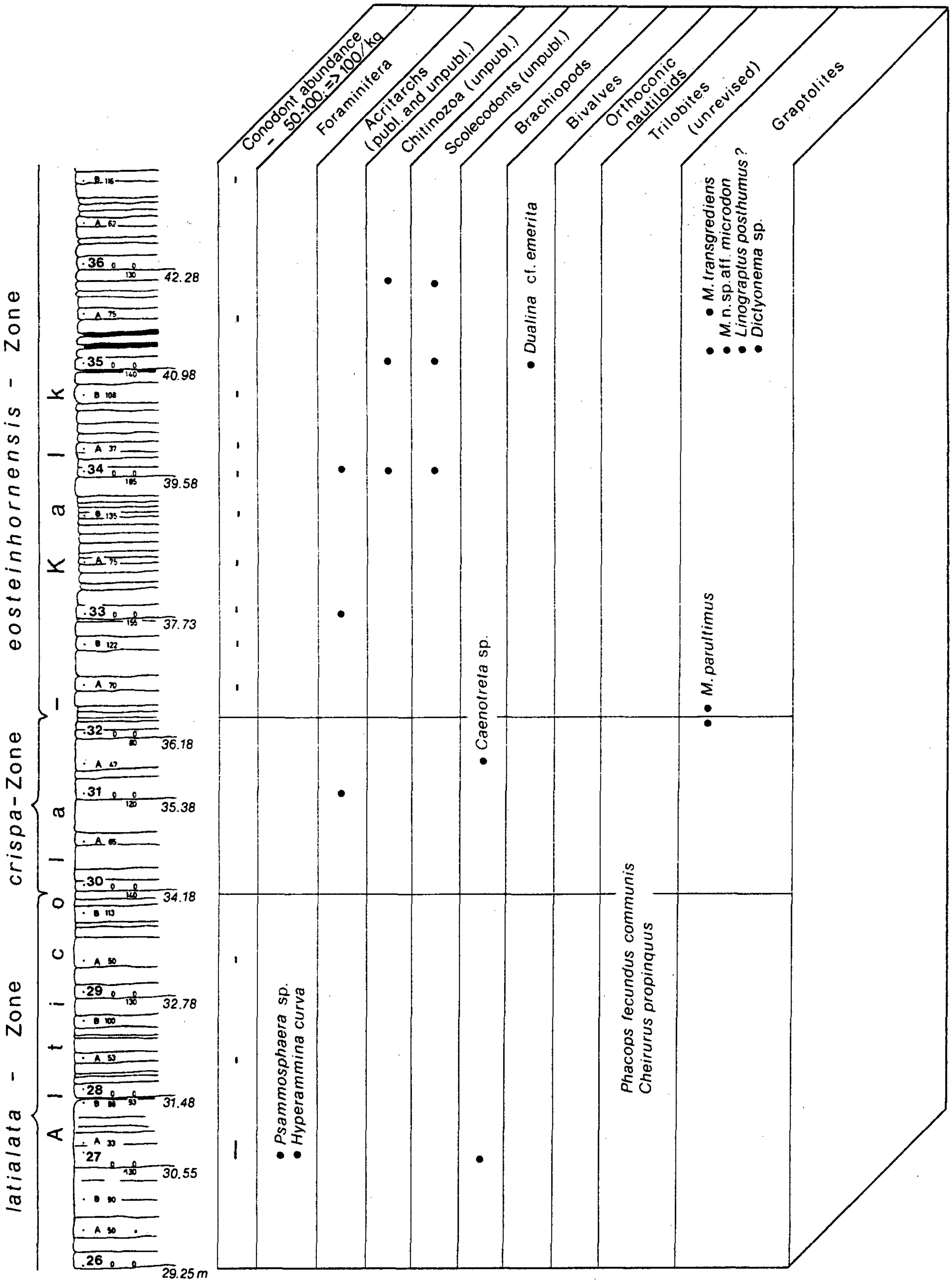
With reference to the oxygen isotopes the delta-^{18}O ratios seem to increase from low-levels in the Upper Ordovician and Lower Silurian (-9) to values about -6,5 in the interval from beginning of the Wenlock to the end of the Pridoli (measurements provided by W. BUGGISCH & M. JOACHIMSKI).

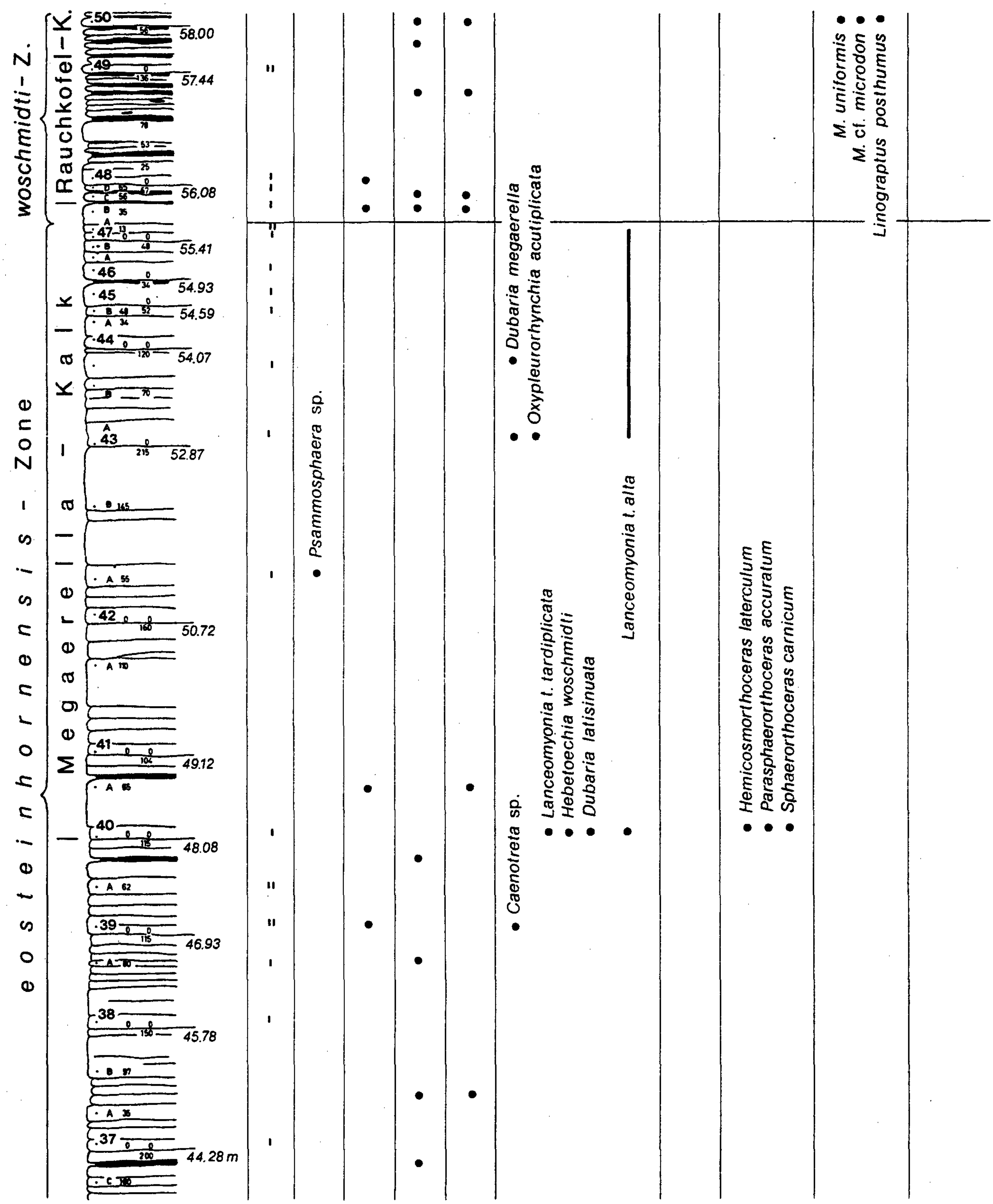
This major positive shift may either indicate decreasing temperatures or increasing delta ^{18}O of ocean water. Anyway, a similar global trend has been observed for marine cements during the interval from the late Ordovician to the end of the Silurian (see ANDERSON 1990, fig.3 in BRIGGS & CROWTHER (eds.), Palaeobiology, Blackwood Sc. Publ., Oxford).

Fig. 8A-D (p. 90-93):The Cellon Section after SCHÖNLAUB 1985, slightly modified


„ B e r e i c h I "
celloni - Zone
amorph.Z.
U g g w a - K a l k
P l ö c k e n - F m.
K o k - F m.
0.00 m
5.00
7.30
12.10
15.33
Conodont abundance
- 50-100; = > 100/kg
Foraminifera
Ammodiscus longexsertus
Ammodiscus cf. exsertus
Acritarchs (publ. and unpubl.)
Diexallophasis remota
Dictyotidium stenodyctium
Domasia trispinosa
Melikeriopalla cataphracta
Piliferosphaera rustica
Tunisphaeridium tentacuaferum
Tylotopalla caelamenicutis
Caiacorymbifer sp. A.
Chitinozoa (unpubl.)
Scolecodonts (unpubl.)
Brachiopods
Kinnella kielanae
Rafinesquina sp.
Clarkeia sp.
Caenotreta celloni
Bivalves
Orthoconic nautiloids
Trilobites (unrevised)
Dalmanitina mucronata
Aulacopleura haueri
Encrinurus novaki
Phacopidella grimburgi
Graptolites
Grapt. indet.
Retiolites geinitzianus
M. priodon s.l.
Ostracods
Quadrijugator harparum
Scanipisthia rectangularis
Eocytherella troedssoni
Dornbuschia ostseensis


pat.-Z.
sagitta - Zone
crassa-Z.
ploeckensis - Zone
siluricus - Zone
K o k - F o r m a t i o n
C a r d i o l a - F m.
29.25
28.47
28.22
27.37
26.02
25.60
25.08
24.68
23.43
22.08
20.48
19.20
17.82
16.37
15.33 m
Turitellella aff. osgoodensis
Ammodiscus cf. exsertus
Caenotreta sp.
Septatrypa sappho
Carnalpia rostrata
Carnalpia nivosa
Cardiolopsis alpina
Spirina tubicina
Cardiola docens
Cardiola signata
Cardiola cf. cornucopiae
Mila sp.
Dualina longiuscula
Cardiolita cf. bohemica
Spanila sp.
Cardiola aff. spectabilis
Mila cf. complexa
Hemicosmorthoceras celloni
Encrinurus ploeckensis
Phacopidella grimburgi
Encrinurus aff. transiens
Scutellum neptuni
Cyphoproetus wurmi
Cyrtograptus rigidus (Z. 28)
M. priodon sl.
M. vomerinus
M. dubius
M. butovicensis sl.
M. bohemicus
M. sp. indet.
M. haupti vel
M. n. sp. aff. haupti
Linograptus posthumus ?


latialata - Zone
crispa-Zone
eosteinhornensis - Zone
Alticola - Kalk
42.28
40.98
39.58
37.73
36.18
35.38
34.18
32.78
31.48
30.55
29.25 m
Conodont abundance
- 50-100; => 100/kg
Foraminifera
Acritarchs
(publ. and unpubl.)
Chitinozoa (unpubl.)
Scolecodonts (unpubl.)
Brachiopods
Bivalves
Orthoconic nautiloids
Trilobites
(unrevised)
Graptolites
Psammosphaera sp.
Hyperammina curva
Caenotreta sp.
Dualina cf. emerita
Phacops fecundus communis
Cheirurus propinquus
M. parultimus
M. transgrediens
M. n. sp. aff. microdon
Linograptus posthumus ?
Dictyonema sp.


eosteinhornensis - Zone
woschmidti - Z.
Megaerella - Kalk
Rauchkofel-K.
.37
.38
.39
40
41
.42
.43
44
45
46
47
.48
49
.50
44.28 m
45.78
46.93
48.08
49.12
50.72
52.87
54.07
54.59
54.93
55.41
56.08
57.44
58.00
Caenotreta sp.
Lanceomyonia t. tardiplicata
Hebetoechia woschmidti
Dubaria latisinuata
Lanceomyonia t. alta
Hemicosmorthoceras laterculum
Parasphaerorthoceras accuratum
Sphaerorthoceras carnicum
Psammosphaera sp.
Dubaria megaerella
Oxypleurorhynchia acutiplicata
M. uniformis
M. cf. microdon
Linograptus posthumus

Section 3

The Oberbuchach 1 Section
(fig.9)

by Hans Peter Schönlaub

Section Oberbuchach 1 is exposed some 10 km east of Kötschach-Mauthen in a roadcut at an altitude of 1150 m. The small road runs from the Gail Valley near Gundersheim to Gundersheim Alm. Due to a new roadcut the lower portion of the sequence has been excellently exposed but was as yet not studied in detail. It comprises the whole Uggwa Limestone and the equivalents of the Plöcken Fm. described here as "basal quartzite".

At this locality the Silurian strata represent the mixed argillaceous-calcareous Nölbling Fm. The almost 50 m thick rocks of Llandovery to Ludlow age are underlain by the 16 m thick Uggwa Lst. succeeded by 10 m of the clastic Plöcken Fm. This horizon is overlain by inderbedded laminated pyritic standstones, black bedded cherty layers and black argillaceous shales containing a rich graptolite fauna of the zone of *M. gregarius,* subzone of *M. triangulatus* (see fig. 9).

This member is followed by a second horizon of graphitic sandstones. Its Llandoverian age is inferred from the occurrence of diagnostic conodonts of the *P. celloni* Zone in limestones immediately above the upper sandstone member (sample no.89).

The limestones are overlain by an alternating sequence of dark argillaceous limestones, black argillaceous graptolite shales and lydites ranging through the Wenlock and the lower Ludlow. Near the base the *P. amorphognathoides*-conodont zone was recognized. The conodonts are associated with graptolites of uppermost Llandovery or early Wenlock age (zones 25 to 26 according to H. JAEGER). In the shales above graptolites occur at various levels starting off with the zone of *M. riccartonensis* and ending up with the zone of *M. nilssoni* or with a slightly younger age. Some 40 m above the base of the graptolite bearing sequence the Wenlock/Ludlow boundary may thus be placed.

In this part of the sequence other fossils than graptolites are very rare. The dark limestone beds intercalated in the black graptolite sequence are dominated by simple tooth-shaped conodonts like *Dapsilodus* and *Decoriconus*; yet only few ramiform conodonts have been found.

The corresponding rocks of the Ludlow and Pridoli Series consist of lithologically very characteristic and up to 20 m thick grey limestones showing a distinctly weathering surface which suggests solution processes. Comparable limestones are known from many areas in the Eastern and Southern Alps. Presumably, this horizon is coeval with the "Ockerkalk" of Thuringia and Sardinia.

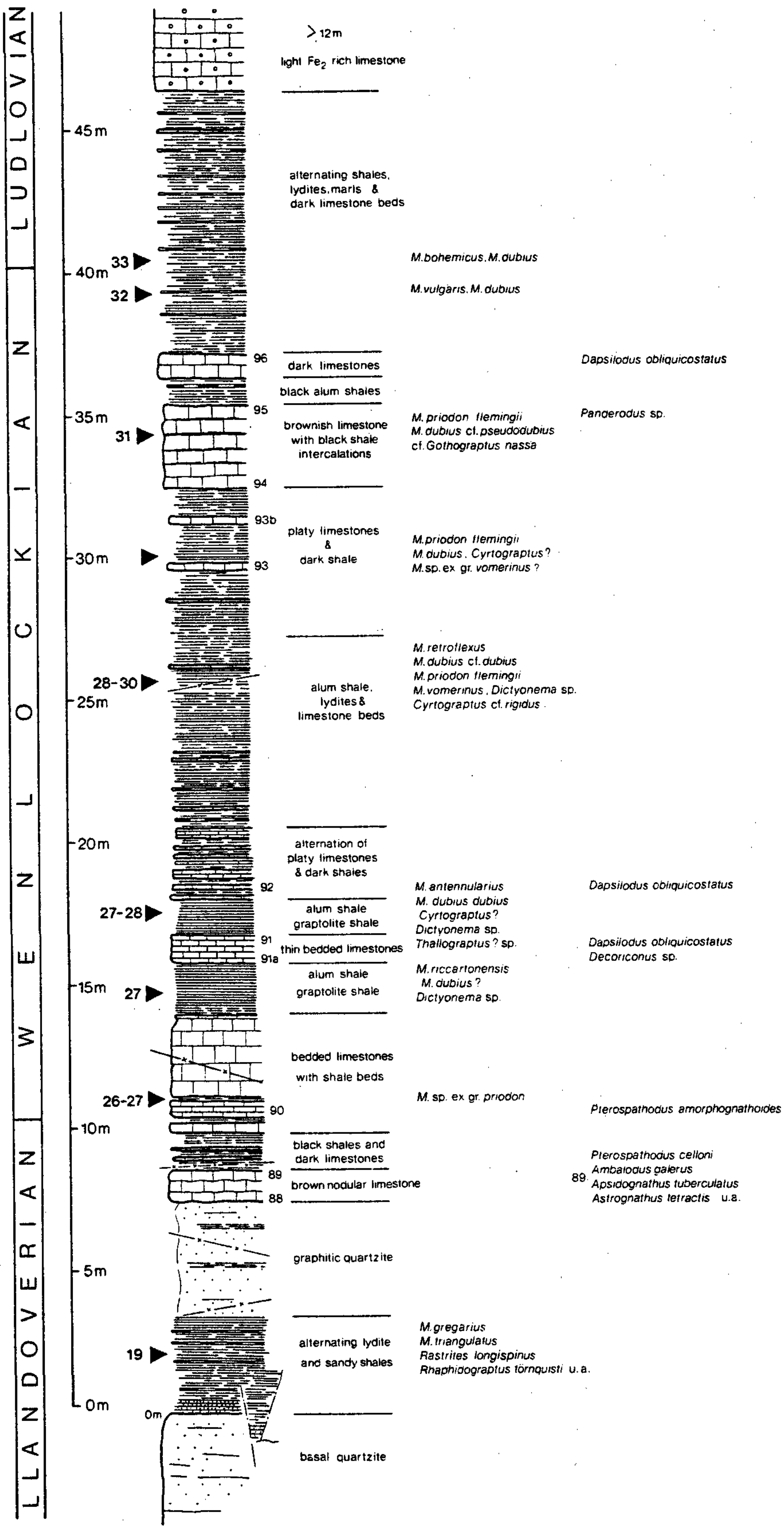


Fig. 9: The Silurian Section Oberbuchach 1. From JAEGER & SCHÖNLAUB (1980)

After the turn of the road the section continues into the Lockkov Series of the Lower Devonian. In this part only few conodonts have yet been found. Among others, the fauna includes *Ozarkodina r. remscheidensis* and *Pandorinellina optima*. They are associated with graptolites of the *M. praehercynicus* or *M. hercynicus* Zone but state of preservation does not permit a definite identification.

Section 4

"Graptolithengraben (graptolite gorge) north of Upper Bischofalm

(fig.10)

by Hermann Jaeger ✝ & Hans Peter Schönlaub

The graptolitic facies of the Carnic Alps has its main distribution in the middle part of the range on both sides of the Austrian/Italian border. Typically, the individual outcrops are in tectonic contact with other rocks.

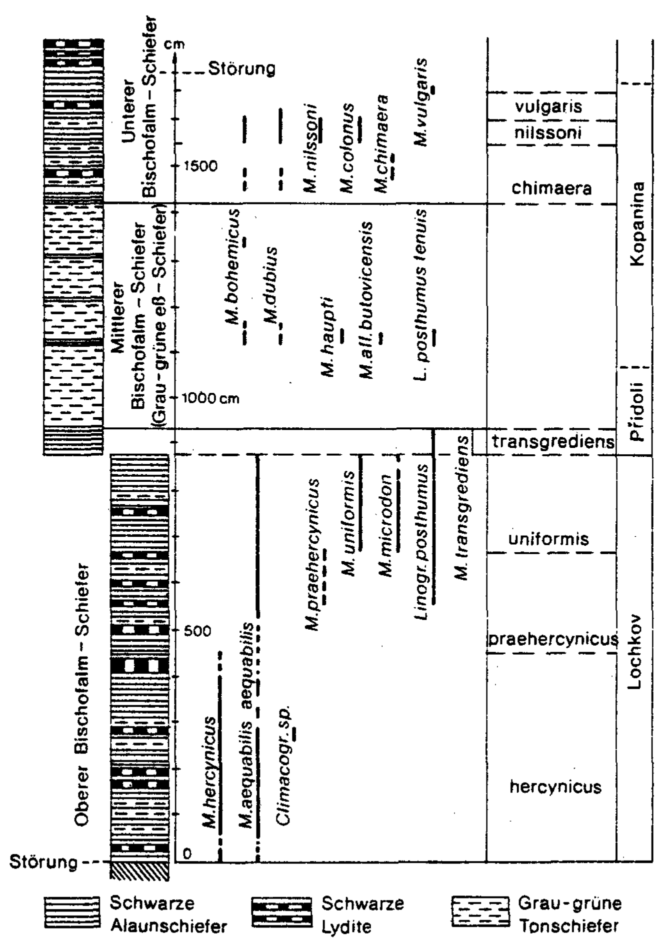


Fig. 10: Type section of the Silurian to Lower Devonian Bischofalm facies north of the upper Bischofalm ("Graptolithengraben"). After JAEGER in FLÜGEL et al. 1977, modified.

The black shale facies well known since the first finds of Silurian graptolites by Stache 1872 is supposed to range from the base of the Silurian through most of the Devonian though fossil evidence for the Lower Devonian and Middle Devonian are scarce. However, Upper Devonian and Lower Carboniferous cherts contain locally abundant conodonts.

Lithologically, the graptolitic rocks form a monotonous sequence of interbedded radiolarian cherts and alum shales. The chert beds dominate in the Llandovery and Wenlock part of the sequence, whereas higher up the alum shales prevail. The occurrence of grey-green shales that do not contain graptolites except in rare black bands results in a natural tripartite division of the whole graptolitic sequence as shown in fig. 10.

The composite thickness for all the graptolitic Silurian plus Lochkovian is certainly not less than 50 m and not more than 100 m. It is thus an extremely condensed sequence. The condensation is due to a very low but continuous rate of deposition, not to hiatuses. Such is indicated by the very complete graptolitic zonal succession. The environment was extremely euxinic except during deposition of the grey-green middle part of the Bischofalm Shales.

Graptolites (and rare conodonts) are the only fossils to be found. Planktic microfossils and nannofossils that are to be expected, have not been looked for yet. The graptolites are common in many layers both in the alum shales and the chert beds. But there are beds one metre thick or more that do not yield any graptolites. Due to the intense alpine type of tectonics also thicker portions of the sequence may locally not yield graptolites. For the same reason larger undisturbed sections are rare.

The boundary beds are exposed at a number of sites in a two kilometer long area between Zollner See and Bischofalm. By far the best exposed and least disturbed section is the "Hauptprofil" (main section) in the *Graptolithengraben* north of Obere Bischofalm (fig. 10).

It is located 8 km northeast of Plöcken-Paß and 5 km southeast of the village of Würmlach. The "Hauptprofil" is in about the middle of the *Graptolithengraben*. It is in a tectonic block not quite 20 m thick. The beds dip 45° degrees to the northeast. The section covers the stratigraphic interval from the *hercynicus* Zone to the *vulgaris* Zone. The rocks are overturned, with the *hercynicus* Zone below and the *vulgaris* Zone on top. At the base of the section the *hercynicus* Zone is in fault contact with dark shales of unknown age; these disappear under slope debris. The upper fault is half a metre above a 5 cm thick compact bed with *M. vulgaris*. On the other side of that fault are a few metres of disturbed and poorly exposed alum shales and cherts which are succeeded by shales with early Wenlock graptolites.

The "Hauptprofil" is virtually undisturbed except for a fault at the critical place between the *uniformis* Zone and the *transgrediens* Zone, i. e. at the Silurian-Devonian boundary. There the beds of the *uniformis* Zone are disturbed, and they disappear upwards under slope debris, whereas the section continues two metres to the left, beginning with the *transgrediens* Zone. The *transgrediens* Zone and the grey-green e-beta Shales form a cliff.

For visitors to the section it may be helpful to note that in about the middle of the Lochkovian part, at 400 - 436 cm, an unusually thick chert bed forms a distinctive marker in these extremely uniform rocks.

From comparison with other sections and general experience with this type of graptolitic rocks it is deduced that there is no substantial loss of strata at the fault between the *transgrediens* Zone and the *uniformis* Zone. It is estimated that not more than 1 m of strata be missing.

The following points of more than local interests may be made:

(1) The Silurian-Devonian boundary is within a homogeneous black shale facies. There was no obvious physical event at the boundary. The choice of the base of the *uniformis* Zone as a system boundary is thus supported.

(2) A distinct change in facies from grey-green shales to black shales preceded the faunal change at the boundary by one zone.

(3) Also in the Carnic Alps is no evidence for possible overlapping ranges between *M. transgrediens* and *M. uniformis*.

(4) The non-graptolitic e-beta Shales have exactly the same stratigraphic position as the non-graptolitic *Ockerkalk* in the graptolitic sequence of Thuringia some 400 km to the north and (less precisely dated) the *Ockerkalk* in the graptolitic black shale sequence of southeastern Sardinia 900 km to the south.

All the graptolite species collected in the section are listed in Fig. 10, and their ranges are shown. In addition, *Abiesgraptus* was found in the *praehercynicus* Zone in a section some 30 m to the left of the "Hauptprofil" .

Monograptus aequabilis aequabilis that elsewhere has been found only in the *uniformis* Zone, ranges here through all three Lochkovian zones.

As a great surprise a sole rhabdosome of a *Climacograptus* of *scalaris* type (sketch in Jaeger 1973, Fig.1) was found in the *hercynicus* Zone. It occurs together with *hercynicus* specimens on the same slab and on the same bedding plane. Two possibilities that might be envisaged to account for this faunal anomaly appear unlikely.

(1) There is no lithological or other faunal evidence for a presumed redeposition of Llandovery rocks in this extreme euxinic environment.

(2) Being familiar with many graptolites etched out of the rock and having seen many growth aberrancies, one might think of interpreting this *Climacograptus* as a growth anomaly. However, there is no Lochkovian monograptid that through

aberrant biserial growth could develop to a *Climacograptus* of simple generalized morphology without undergoing improbably drastic transformations.

Consequently, this *Climacograptus* may be considered as an extremely rare relict of the Ordovician-Llandovery graptolite fauna, a truely living fossil in Lower Devonian times.

Section 5

The Waterfall Section near Dr. Steinwender Hütte
(fig.11)

by Hans Peter Schönlaub

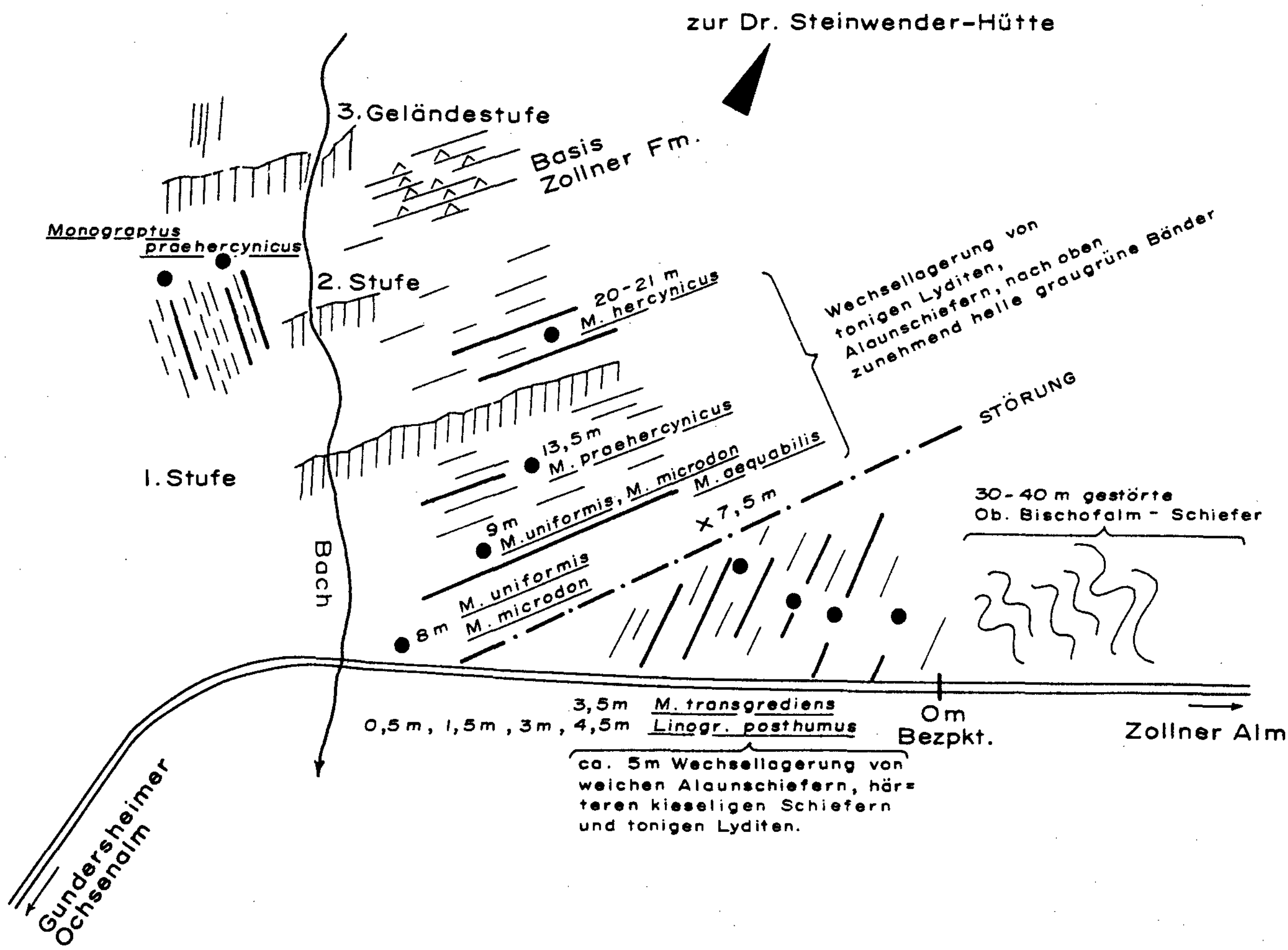


Fig. 11: The upper part of the Waterfall Section between the street and the Alpine Hut "Dr. Steinwender-Hütte" after JAEGER 1985.

In the gorge northeast of the hut a sequence of predominantly black cherts of the Bischofalm facies is exposed which ranges from the base of the Silurian to the Devonian. Conodonts from greyish radiolarites of the Zollner Fm. even suggest its continuation into the Lower Carboniferous. The graptolite-bearing strata correspond to those rocks which were visited north of the Upper Bischofalm. In the stratigraphic framework of the Carnic Alps they represent the Bischofalm Formation which can further be subdivided into three members, i.e. lower, middle and upper Bischofalm Shales.

Based on the comprehensive study of H. JAEGER in the waterfall section several graptolite-bearing horizon were found (see fig. 11). Although the general succession of strata has more or less been preserved, the section was affected by some faults. In particular such faults can be seen along the road crossing the brook below the upper waterfall. At this level the Silurian/Devonian boundary beds are exposed.

The base of the section is exposed some 50 m below the road. This part is accessible by steep downward climbing along a meadow on the western side of the lower and estern waterfall. At its base an overturned section occurs in which sandstones of presumably Upper Ordovician age are succeeded by black shales. According to H. JAEGER in black cherty shales 1 m below the sandstone the index graptolite for the base of the Silurian, *Akidograptus acuminatus* was discovered. Some 30 m above the normal sequence starts. This level corresponds to the middle Bischofalm Shales which in JAEGER's terminology were named eß-shales. They are best exposed along the northern margin of the road some 80 m to the west of the brook crossing the road.

Section 6

Rauchkofel Boden Section
(figs. 12-14)

by Hans Peter Schönlaub & Olga Bogolepova

This section is exposed on the southwestern slope of Mount Rauchkofel west of p.2175 m. It represents a continuously exposed and conformable limestone succession ranging from the Ashgillian to the Lower Devonian (Pragian). The major part of Lower Silurian strata, however, are missing at this section (fig. 12).

The Rauchkofel Boden section is one of the best known and most fossiliferous Upper Silurian sections of the Carnic Alps corresponding to the "Wolayer facies". A detailed description was published by H.R. v. GAERTNER 1931 and H.P. SCHÖNLAUB 1970, 1980. The fauna was studied by H. RISTEDT 1968 (orthoconic nautiloids), W. HAAS (trilobites, unpubl.), J. KRIZ (bivalves), and H.P. SCHÖNLAUB (conodonts).

The Upper Ordovician is represented by a 8.60 m thick cystoid bearing massive limestone horizon, the so-called Wolayer Limestone. Its lithology was recently studied by C. DULLO 1992 who suggested for its formation a shallow water environment with low energy in an moderate climatic setting. Besides undescribed cystoids and trilobites conodonts are fairly abundant suggesting a late Ordovician age within the Ashgillian Series.

The Wolayer Lst. is disconformably overlain by 3.90 m thick grey fossiliferous cephalopod limestones ("*Orthoceras* Lst."). The macrofauna includes the following nautiloids and bivalves (sample nos. 310-315, 319-324):

Michelinoceras (?) sp.
Sphaerorthoceras n.sp.
Merocycloceras declivis RISTEDT
Parasphaerorthoceras sp.
Isiola lyra KRIZ (nos. 319, 322, 325-65 cm)
Slava fibrosa (no.325-105 cm)
Cardiola aff. *signata* BARR. (322)
Cardiola contrastans (no. 325-105 cm)
Spanila sp. (322)

W. HAAS from Bonn University reported the following trilobites from the basal part (approx. 1.5 m) of the cephalopod limestone:

Aulacopleura haueri
Kielania n.sp.
"*Odontopleura*" *ovata*

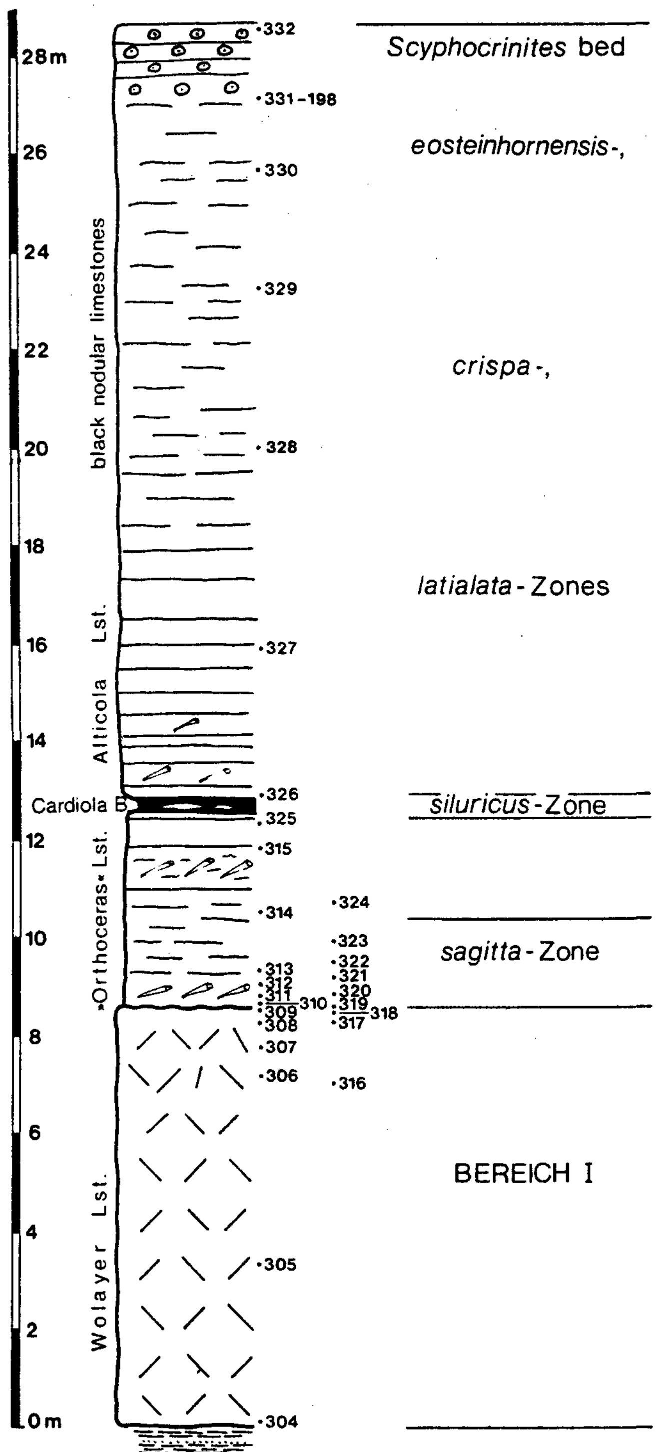


Fig. 12: The Rauchkofel Boden Section (Ordovician - Silurian part) after SCHÖNLAUB et al. 1980.

Eodrevermannia n.subg. n.sp.
Otarion (O.) sp.
Scharyia n.sp.
Leonaspis cf. *minuta*
Xanionurus n.sp.
Koneprusia n.sp.

In the middle part he found:

Kosovopeltis n.sp.
Otarion (O.) sp.
Leonaspis cf. *minuta*
Raphiophorus rouaulti

The upper part of the cephalopod limestone contains:

Raphiophorus rouaulti
Prionopeltis striatus
Otarion (O.) sp.
Leonaspis cf. *minuta*

The 10 cm thick black limestones bed above no. 325 (now badly exposed in the trench from the war) yielded the following bivalves (J. KRIZ):

Cardiola docens BARR.
Cardiola consanguis BARR.
Cardiola cf. *signata* BARR.
Mila complexa BARR.
Spanila aspirans BARR.

W. HAAS found in the Cardiola Fm. *Aulacopleura* cf. *muensteri*. The fauna above the Cardiola Fm. has not been restudied in detail yet. H.R. v. GAERTNER and F. HERITSCH reported the following taxa:

Base of Alticola Lst. (nos. 326-328):

Spirigera canaliculata BARR.
Spirigera obovata SOW.
Retzia ? umbra BARR.
Maminca italica GORT.
Dualina plicata MSTR.
Dualina cf. *sedens* BARR.
Tenka cf. *bohemica* BARR.
Loxonema commutatum PER.
Holopella compressa MSTR.

Holopella trochleata MSTR.
Platyceras otiosum BARR.
Platyceras praepriscum BARR.

Nos. 329-332:

Encrinurus transiens BARR.
Proetus romanicus GAERTNER
Petraia laevis POCTA
Holopella subcompressa MSTR.
Orthoceras tiro BARR.
Scyphocrinus sp.

According to W. HAAS (unpubl.) the follwing trilobites occur at the edge of the steep slope (sample no. R 5):

Goldillaenus nilssoni
Cornuproetus (C.) cf. *vertumnus*
Encrinurus subvariolaris
Encrinurus ploeckensis
Bohemoharpes n.sp.
Bohemoharpes cf. *crassifrons*
Cerauroides cf. *propinquus*
Phacopidella n.sp.
Ananaspis grimburgi
Ceratonurus sp.

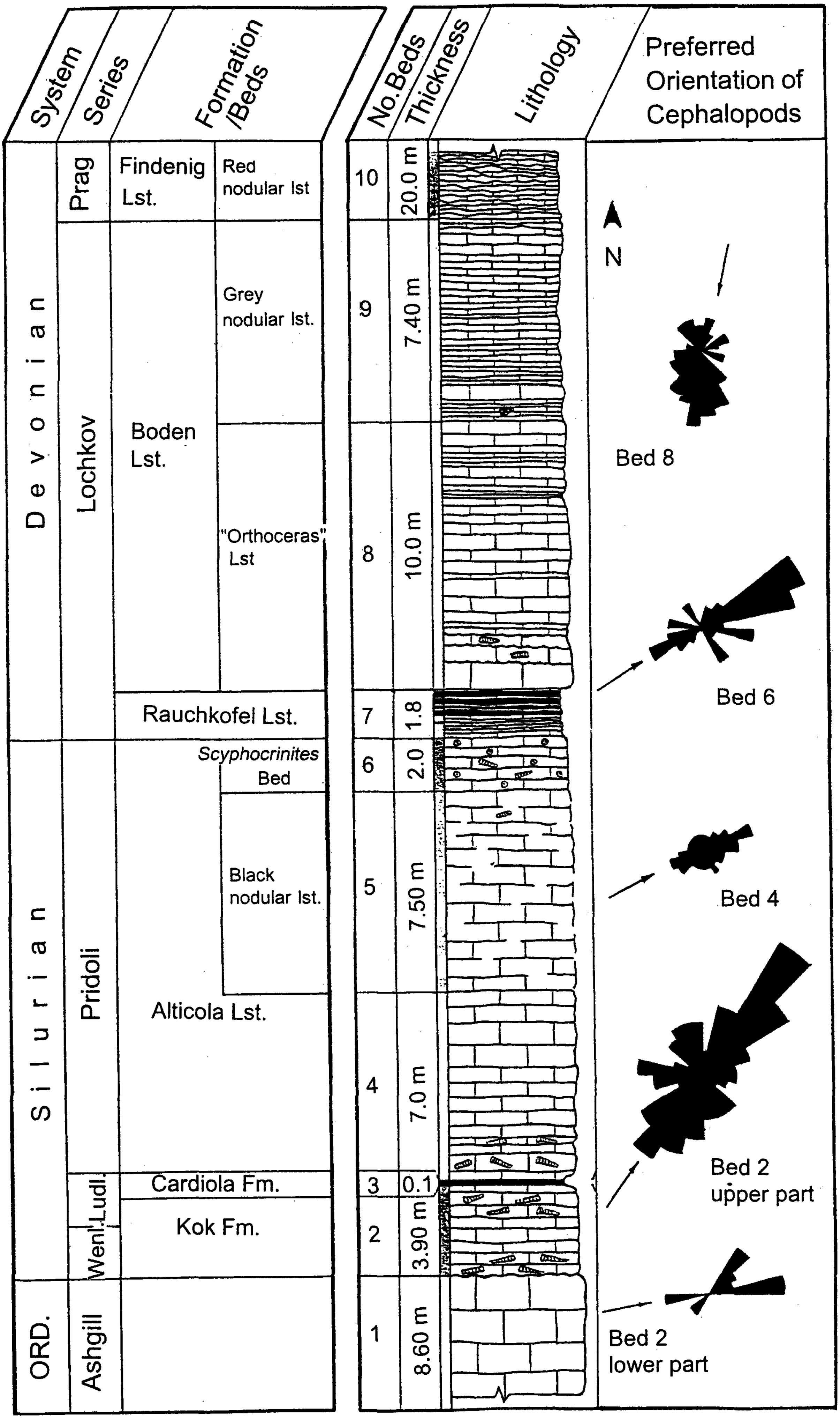
In the late Wenlock and the Upper Silurian conodonts are fairly abundant. A rich fauna representing the *O. sagitta* Zone occur from the base of the *Orthoceras* Lst. up to sample no. 313, i.e. 1.20 m above the base (fig. 12). Although resampled not a single specimen of *Ozarkodina bohemica* has yet been found in that interval.

In sample no. 314 Kockelella variabilis first occurs suggesting the base of the Ludlow Series by comparison with Bohemia (H.P. SCHÖNLAUB in I. KRIZ et al. 1993).

The following Cardiola Fm. corresponds to the *P. siluricus* Zone of the stratotype at Cellon. Conodonts from the uppermost part of the black nodular limestones (nos. 330. 331) belong to the apparatus of *Oz. r. eosteinhornensis*. In addition, *Oz. ortuformis* and *Oz. jaegeri* occur in this interval.

The Silurian/Devonian boundary is drawn at the base of grey and blackish platy crinoidal limestones containing *Scyphocrinites* (sample no. 331=198). At this horizon abundant loboliths of *Scyphocrinites* can be found. Bed no. 198 as well as the overlying sample no. 199 yielded common accurrences of *Oz. r. eosteinhornensis* and, more frequently, *Oz. r. remscheidensis*.

Fig. 13: The Orientation of orthocone nautiloids in the Rauchkofel Boden Section (O.K. BOGOLEPOVA)


System
Series
Formation /Beds
No.Beds
Thickness
Lithology
Preferred Orientation of Cephalopods
Devonian
Prag
Findenig Lst.
Red nodular lst
10
20.0 m
Lochkov
Boden Lst.
Grey nodular lst.
9
7.40 m
"Orthoceras" Lst
8
10.0 m
Rauchkofel Lst.
7
1.8
Silurian
Pridoli
Scyphocrinites Bed
6
2.0
Black nodular lst.
5
7.50 m
Alticola Lst.
4
7.0 m
Ludl.
Cardiola Fm.
3
0.1
Wenl.
Kok Fm.
2
3.90 m
ORD.
Ashgill
1
8.60 m
N
Bed 8
Bed 6
Bed 4
Bed 2 upper part
Bed 2 lower part

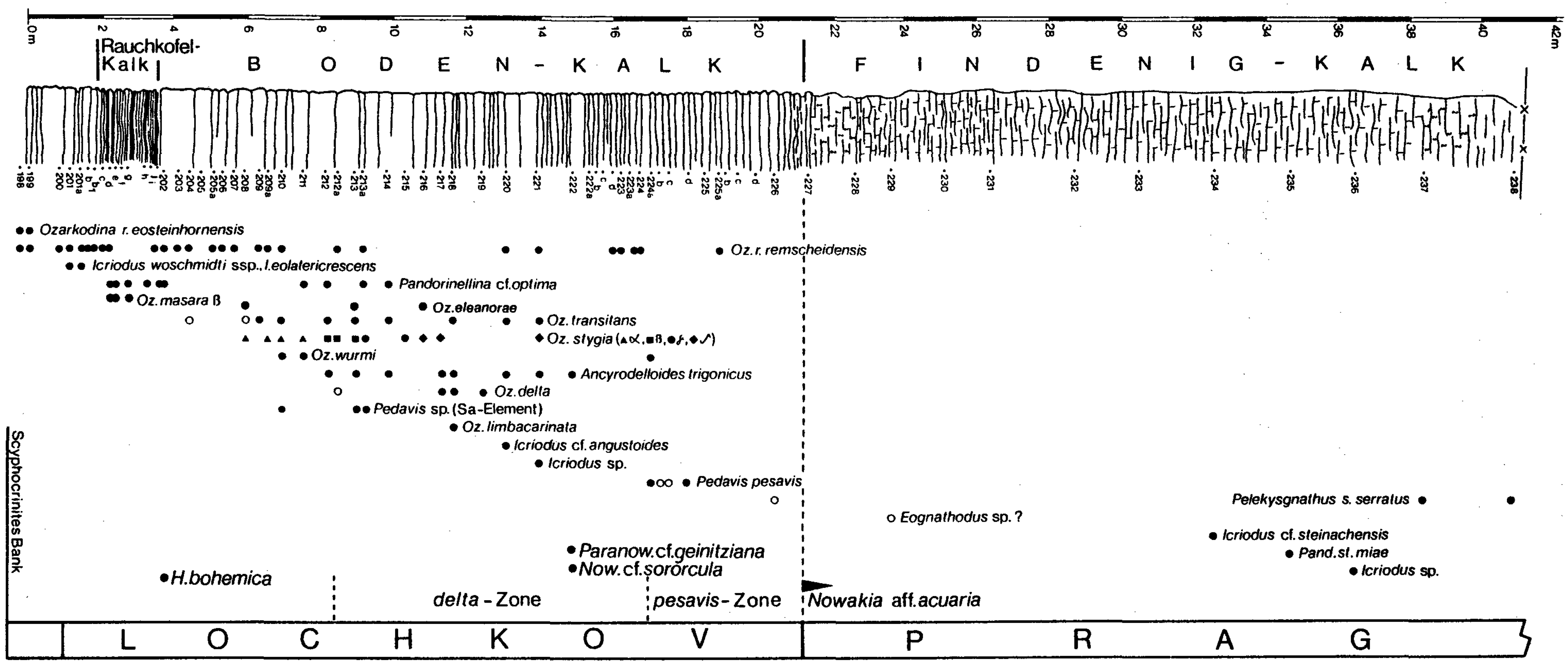


Fig. 14: Rauchkofel Boden Section, Lower Devonian part with basal 1.80 m thick Rauchkofel Limestone, above Boden Limestone and Findenig Limestone (after SCHÖNLAUB et al. 1980, modified)

The basal part of the overlying Lochkov sequence seems to be extremely condensed. This interval is represented by well bedded, thin and blackish limestone beds with shaly intercalations (nos. 201 b-201 j). The index conodont for the base of the Devonian, *Icriodus woschmidti*, was collected in sample nos. 201 and 201 a. However, as yet only juvenile specimens were found. Neither at this horizon nor in any other parts of the section graptolites have yet been recorded.

With regard to the orientation of orthoceracone cephalopods in the Rauchkofel Boden section O.K. BOGOLEPOVA is adding some preliminary data based on a study in 1993:

Many examples of orthoceracone cephalopod orientation and the use of the latter as indicator or paleocurrents have been published. Theoretical considerations indicate that orthoceracone cephalopods (like other elongate objects) are aligned parallel with a current. Though there are a number of publications based on the application of hydrodynamic modelling in experiments, which produce different and at times conflicting results, the author following the majority of the investigators, holds to the opinion that most orthocone shells of orthoceratids, tentaculites and high-spired gastropods found on bedding planes in mass accumulation are oriented by their apices against the current. A strong current orients orthocones in such a way that their apices point against the current. However, the discussion of the paleoflumenology problems, the merits and demerits of this method, the ways for different interpretation of the results and so on will be the subject of a future article. The task of the author here is to present preliminary data which were obtained as the result of measurements of cephalopod orientation at the Rauchkofel Boden section during a visit in 1993.

Orthoceracone cephalopods are abundant in the Kok Lst., the Cardiola Fm. and the Scyphocrinites bed of the Alticola Limestone. The highest concentration of orthocones occurs in bed 2 (lower and upper part) of the authors subdivision, bed 4 (lower part), bed 6 and bed 8 (see fig. 13). Orientations were measured on bedding planes (one or a few in each layer) and the condition of the majority of cones was noted. All measurements were done by the umbonal part of cephalopods. In each layer the orientation of each individual was plotted on the bar graph and then on the rose-diagram. All orientation measurements within 15 degrees were placed in one class.

Bed 2: In the lower part of the layer the orientation of 36 orthocones shows two trends, from SW to NE, and from W to E. The number of measurements does not allow to conclude any major preferable trend in the orientation of cephalopods. In the upper part of the bed on a different bedding plane the orientation of 187 orthocones was measured. The rose-diagram of layer 2, upper part shows the orientation of all measured cephalopods. There is one clear trend from SW to NE (between 30-45 degrees).

Bed 4: The orientation of 39 orthocones was measured. Most of the cones are oriented between 60 and 75 degrees indicating a direction from SW to NE.

Bed 6: The orientation of 82 orthocones was measured. They reflect one major trend from SW to NE (between 45 and 75 degrees) and minor secondary trends.

Bed 8 (Lower Devonian, Lochkov): The orientation is based on measurements of 85 cephalopods. The major direction runs from N-NE to S-SW (between 180 and 195 degrees).

Fig. 13 summarizes the main results of this preliminary study and shows the main tendency of preferred orientation of cephalopods in the Rauchkofel Boden section. C. HOLLAND (1984) noted many published examples of so-called "Orthoceras" limestones and wrote that "more observations could be quoted and new ones must be made, but the variety of situations is perhaps sufficient to inspire caution". Our data allow us to make the first very preliminary and careful conclusion about the existence of two major trends of the paleocurrent: a current running from south-west to north-east in the Upper Silurian and a Lower Devonian one prevailing a north-northeastward direction.

Comment by H.P. SCHÖNLAUB:

Regardless whether the current-direction hypothesis aginst the apex or in opposite direction is preferred, the statistics from orthocone cephalopod measurements from both the Carnic Alps and Bohemia show striking similarities with regard to shell alignement in the Silurian (J. KRIZ 1992, p. 24, 43, 55: Silurian Field Excursions, Prague Basin (Barrandian), Bohemia. National Mus. Wales, Geol. Series No.13, Cardiff). During the Lower Devonian the current direction suggests minor changes towards a north direction. This northern gyre may be related to the South Equatorial Current which according to M.S. OCZLON 1990 operated along the southern margin of Laurussia in the Middle Devonian. During the interval from the Silurian to the Devonian this system may be hold responsible for the distinct exchange of faunas between Siberia, the Urals and Central and Southern Europe. Also, it should be noted that during this time Siberia had an "upside-down position" with the Tajmyr Peninsula in a more southern position facilitating such an exchange (pers. comm. O.K. BOGOLEPOVA).

With regard to the Lower Devonian part of this section we refer to Fig.14 showing its lithology and faunal content.

Section 7

The Section at the Base of Mount Seewarte

(fig.15)

by Hans Peter Schönlaub

The oldest rocks of the Seewarte section are best exposed near the Valentin Törl (=Pass), a few meters to the west of the southern pass at an altitude of 2100 m (H.P. SCHÖNLAUB 1971, 1980).

The Ashgillian and Silurian part of this section represents a transitional facies between the Plöcken facies and the Wolayer facies. In the Ashgill neither the typical Uggwa Lst. nor the typical Wolayer Lst. are developed. Similarly, the Silurian is characterized by an intermediate facies of crinoid-brachiopod bearing limestones instead of the brownish nautiloid bearing Kok Lst.

At the base of the Silurian iron-manganese bearing black shales and Fe-Mn enriched hardground layers occur suggesting a condensation horizon which can also be inferred from the basal Silurian conodont fauna.

The fauna from the Ordovician limestone below indicate a coeval age with the Uggwa Lst. at Cellon as well as from other places in the Carnic Alps (E. SERPAGLI 1967). Although all elements of the multi-element of *Amorphognathus ordovicicus* have been found, the fauna is dominated by single cones such as *Acodus similaris, Oistodus niger* and *Distomodus europaeus.*

The basal Silurian conodont fauna is mentioned in fig. 15. Diagnostic elements indicate presence of the *P. celloni* Zone (Upper Llandovery, Telychian) and the following *P. amorphognathoides* Zone at the passage from the Llandovery to the Wenlock. As at Cellon the corresponding sediments of the Lower and the major part of the Middle Llandovery are missing.

As far as the thickness is concerned the succeeding Wenlock and Ludlow sequence resembles the Cellon section. For example the equivalent of the Kok Lst. reaches a thickness of 12 m in comparison to 13,5 m at the Cellon section.

The main difference, however, is the lithology which reflects a more shallow environment dominated by crinoids and small brachiopods.

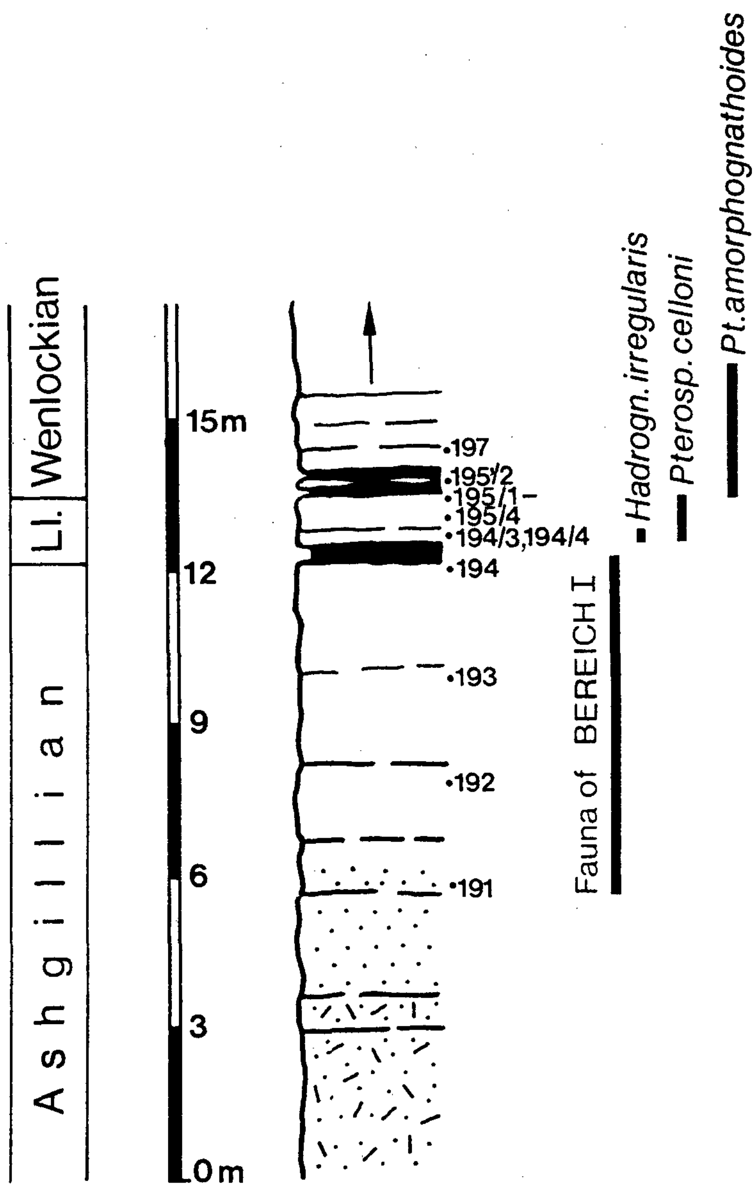


Fig. 15: Ordovician/Silurian boundary section at the base of Mount Seewarte from SCHÖNLAUB 1971.

Section 8

The Rauchkofel Bodentörl Section
(fig. 16)

by Hans Peter Schönlaub

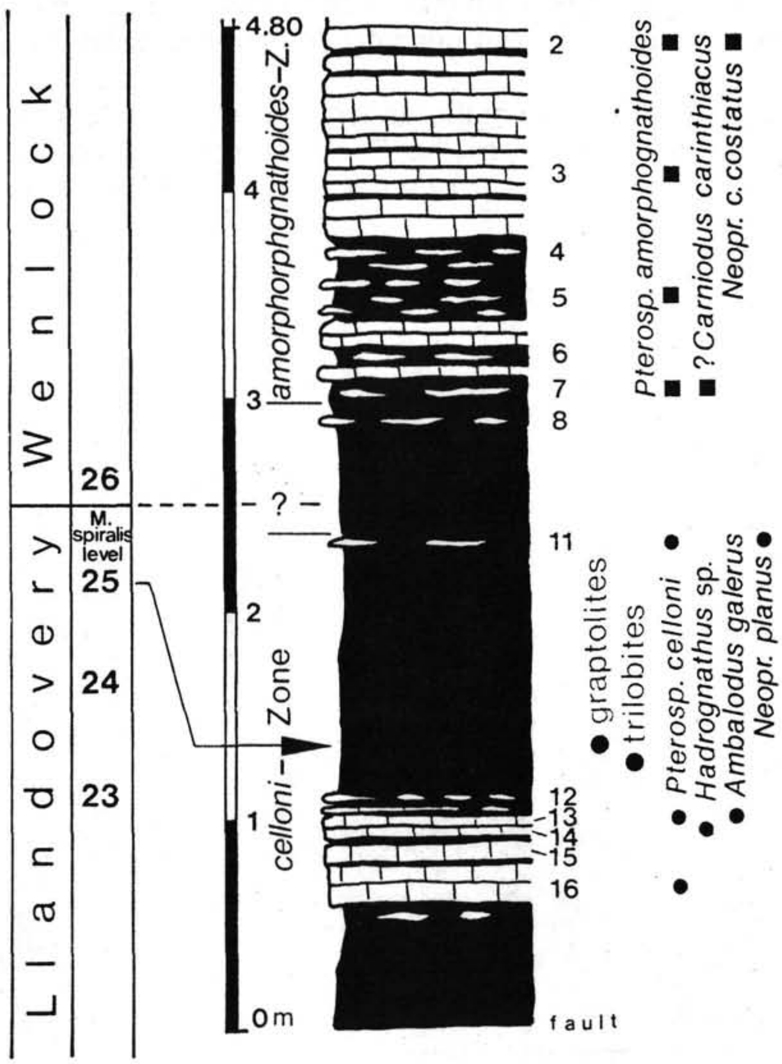


Fig. 16: The Rauchkofel Bodentörl Section after JAEGER & SCHÖNLAUB 1970, modied

The section at Bodentörl is exposed along the path from Lake Wolayer to Mount Rauchkofel; access is also possible from Valentin Törl. The short section comprises the lower part of the Kok Lst. named at Cellon previously the "Trilobite-Aulacopleura Beds".

The section has been famous for the common occurrences of graptolites, trilobites and conodonts. The graptolite fauna, found 1.30 m above the base, includes *M. curvus, M. priodon, M. retroversus, M. spiralis, M. grobsdorfiensis ?, M. vomerinus* ssp. indet. and *Ret. geinitzianus* cf. *angustidens.* According to H. JAEGER (in H. JAEGER et H.P. SCHÖNLAUB 1970) this fauna indicates the upper part of the *M. crenulatus* Zone of the late Llandovery.

The trilobites are poorly preserved. W. HAAS identified *Scharyia* n.sp., *Otarion* sp., *Phacops* sp.. *Encrinurus* sp., *Dalmanites* sp. and n.gen. ex aff. *Eodrevermannia.*

Diagnostic *P. celloni* Zone conodonts were found in the lower part of the section (see fig. 16, sample nos. 16-11). They are associated with the above mentioned macrofauna of Upper Llandovery age. The succeeding *P. amorphognathoides* Zone occurs in sample nos. 7-2.

Graptolite and conodont data from the Bodentörl section led to the conclusion that the boundary between the *P. celloni* and the *P. amorphognathoides* Zones comes near to the Llandovery/Wenlock boundary. This agrees well with British sections.

Travel across the Hohe Tauern along the route from the Gail Valley to Lienz, Iselsberg, Heiligenblut, Hochtor, Bruck (Großglockner Highway), Zell am See, Kitzbühel, Kirchberg to Aschau. - A short geological route description.

(figs. 17-23)

(based on V. HÖCK, F. KOLLER and R. SEEMANN 1994 and their figures)[1]

The Alps are generally subdivided into 4 major zones which from north to south have the following names (see fig. 17):

1. Helvetikum (Helvetic Zone or Unit)
2. Penninikum (Penninic Zone or Unit)
3. Ostalpin (Austroalpine Zone or Unit)
4. Südalpin (Southalpine Zone or Unit)

Distribution and style of deformation of these 4 tectonostratigraphic zones varies in the Alps. Unit 1-3 is thrust towards the north while the Southalpine unit is south directed. In addition, it is separated from the former by the distinct Periadriatic Fault.

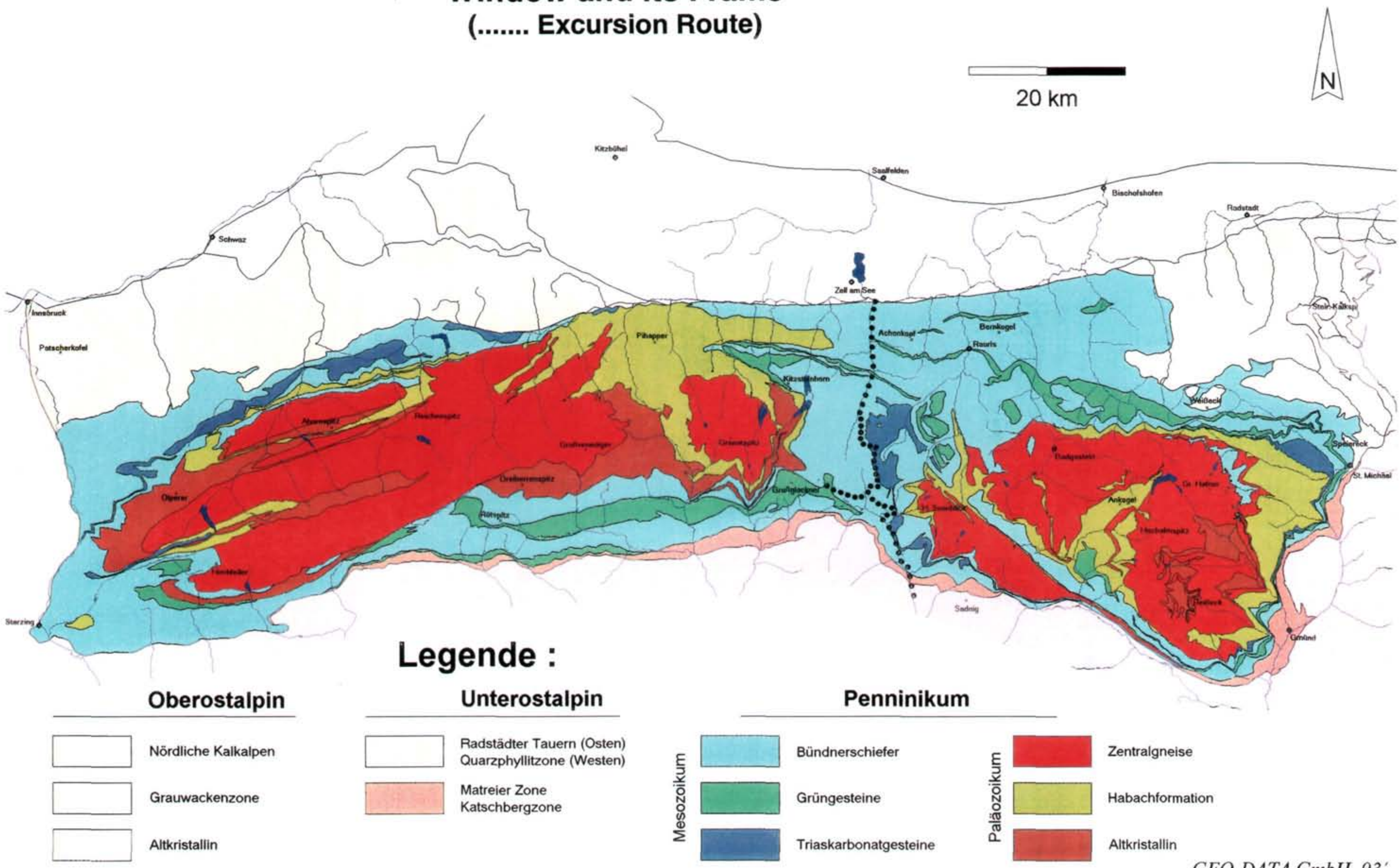
In comparison with the Western Alps in the Eastern Alps of Austria the Helvetic as well as the Penninic unit are markedly reduced. As far as the Hohe Tauern region is concerned it is surrounded by the overlying Austroalpine unit which forms a higher nappe upon the lowermost tectonic unit, i.e. the Penninic Unit (fig. 18). Due to Neogene uplifting and erosion the latter is exposed as a 120 km long and up to 60 km wide tectonic window - the so-called Tauern Window.

In the introductory part of the excursion program the evolution of the Penninic Ocean between stable Europe and the northern promontory of the Adriatic plate was outlined. Along the route from Vienna to Carinthia the main part of the Austroalpine unit was crossed. In the Hohe Tauern region the metamorphic Variscan basement rocks, the intruding late Variscan I-type-granites ("Zentralgneis") and the Permian to Mesozoic sedimentary filling of the former Penninic Ocean can be briefly shown. Due to a considerable N-S shortening and overburden all rocks have been affected by Alpine metamorphism of different ages which locally produced blueschists and even eclogites.

The Permian detritic Wustkogel Fm. is exposed along the peaks of the Großglockner Highway and represents the oldest sediments of the post-Variscan cover sequence figs. 22, 23). It grades into several 100 m thick arenaceous limestones, dolomites, rauhwackes and quartzites of Triassic age. In the Jurassic to Lower Cretaceous they were succeeded by the famous "Bündnerschiefer", a name which was introduced from

[1] HÖCK, V., KOLLER, F. & SEEMANN, R. (1994), Geologischer Werdegang der Hohen Tauern - Vom Ozean zum Hochgebirge. In: Mineral & Erz in den Hohen Tauern, p. 29-54, Naturhistorisches Museum Wien.

Fig. 17. Generalized Geological Map of the Tauern Window and its Frame
(....... Excursion Route)



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their main distributional area of Graubünden in Switzerland. Lithologically, this formation can be split into three main facies each representing a different setting in the Penninic Ocean (fig. 19). They range from the arenaceous Brennkogel and Fusch facies to the marly and ophiolitic Glockner facies. The latter is characterized by the occurrences of more than 500 m thick serpentinites (harzburgites), gabbros, tholeiitic basaltic rocks and volcanoclastics which are overlain and interbedded by different sedimentary rocks.

Due to contradictory biostratigraphic and radiometric data the Paleozoic history of the Hohe Tauern is yet not clear understood. The oldest available data suggest that rock formation started in the late Proterozoic. Continuous geological processes led to a thick continental crust which was intruded by acid magmatic rocks attributed to the Variscan orogeny. The Paleozoic rock sequence comprise a vaying amount of metamorphosed clastic rocks and those which were derived from ultrabasic and acid volcanics. Metamorphosed remains of an ophilitic rock sequence associated with island-arc volcanics, and the large volume of granitic rocks may testify that plate tectonic processes were responsible for the closure of a former Paleozoic ocean and that continent-continent-collision occurred during the Variscan orogeny.

The post-Variscan transgression started at or close to the Permian/Triassic boundary by deposition of the arcosic and arenaceous Wustkogel Formation. By that time the roof of most granites was already eroded to form the basement of the succeeding Mesozoic sequences. Interestingly, the equivalents of the Triassic resemble corresponding sediments in Germany suggesting a spatial and temporal relationship with this part of stable Europe; this contrasts with sediments from the southern frame of the Hohe Tauern Window and in particular with the lithologic development of the Australpine Realm further to the south which reflects no affinity to the north.

During the Jurassic Period rifting processes and crustal thinning in cunjunction with the opening of the Atlantic Ocean led to the formation of the Penninic Ocean (figs. 19, 20). The developing basin was filled with various clastic sediments such as sandstones, arcoses, shales and breccias characterizing the Brennkogel and Fusch facies, respectively. In the course of the Jurassic a true ocanic crust was formed including a mid-oceanic ridge and ophiolitic sequences. Closure of this ocean may have started in the Cretaceous by N-S shortening and subduction processes. During this stage locally blueschists and eclogites were formed indicating high-pressure events at considerable depths. At the end of the Eocene the former ocean was definitely closed and continent-continent-collision may have ended. As the result all sediments were overprinted to a varying degree and incorporated into a north directed deformation yielding wide and partly recumbent folds of kilometer-size (fig. 21). Some 30 Ma ago the whole Penninic area was covered by the Austroalpine nappe system causing another metamorphic overprint of greenschist to amphibolite facies-grade. Finally, in the Miocene some 15 Ma ago uplift and cooling began but the former has yet not ended. Recent crustal uplift in the Hohe Tauern Region (and in general in western Austria) are in the order of 1 to 2 mm/year.

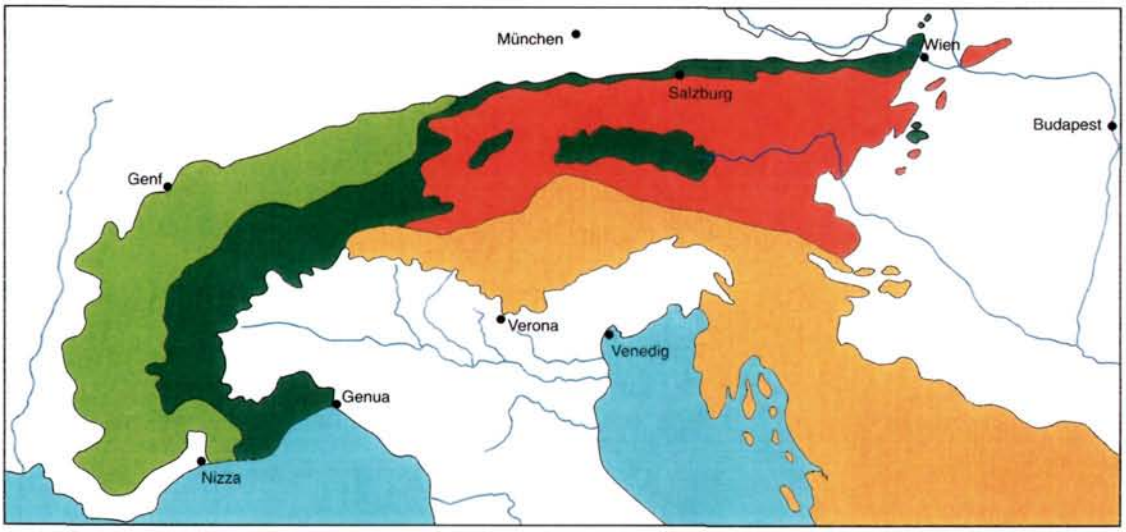


Fig. 18. Main geological subdivision of the Alps (from northwest to southeast with the Helvetic, Penninic, Austroalpine and Southalpine Zones)

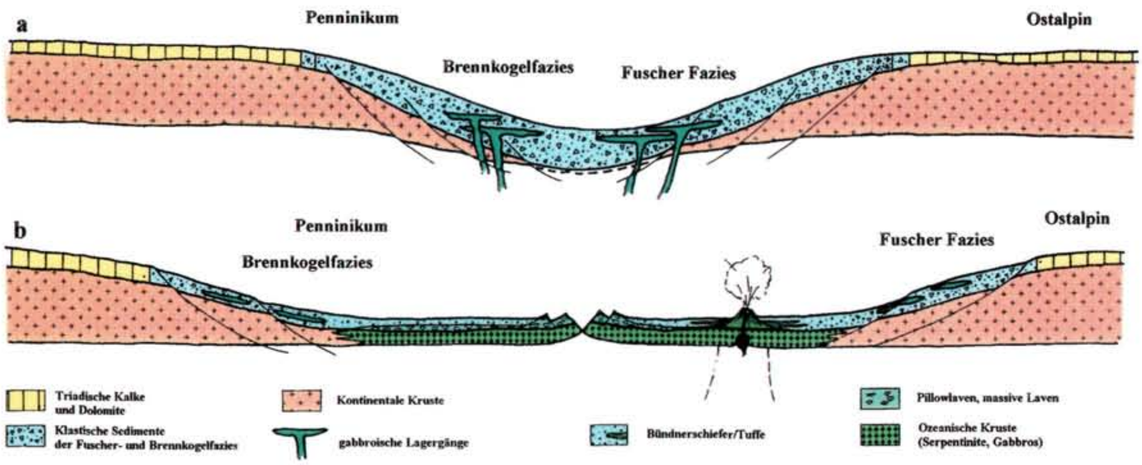


Fig. 19. Section a shows the rifting of the continental crust and opening of the Penninic Ocean at the beginning of the Jurassic with deposition of clastic sediments (Brennkogel facies and Fusch facies, respectively) with initial intrusion of basaltic dykes); section b shows the advanced oceanic stage with oceanic crust, mid-oceanic ridge and basic volcanics in the late Jurassic to early Cretaceous.

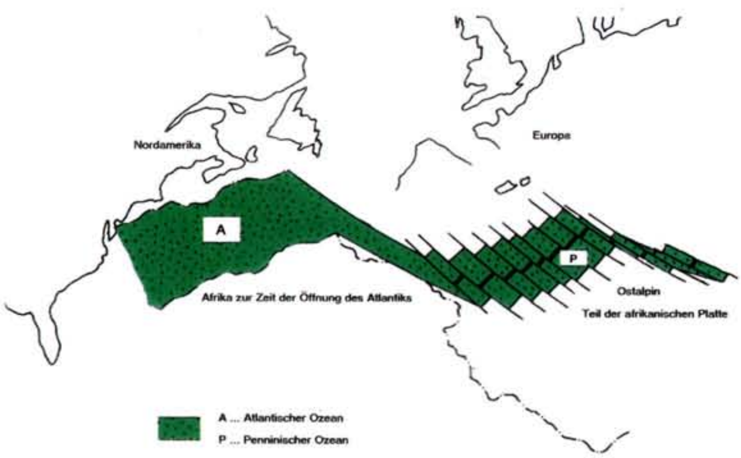


Fig. 20. Relationship between the opening of the Atlantic Ocean and the formation of the Penninic Ocean.

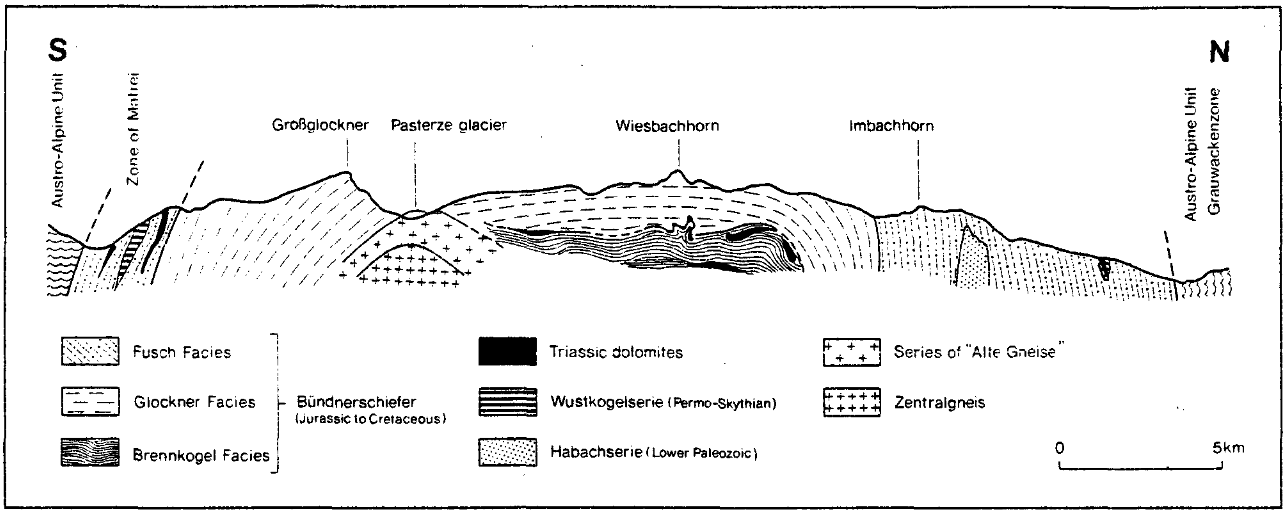


Fig. 21: Geological cross-section of the middle part of the Tauern Window after FRANK, 1965.

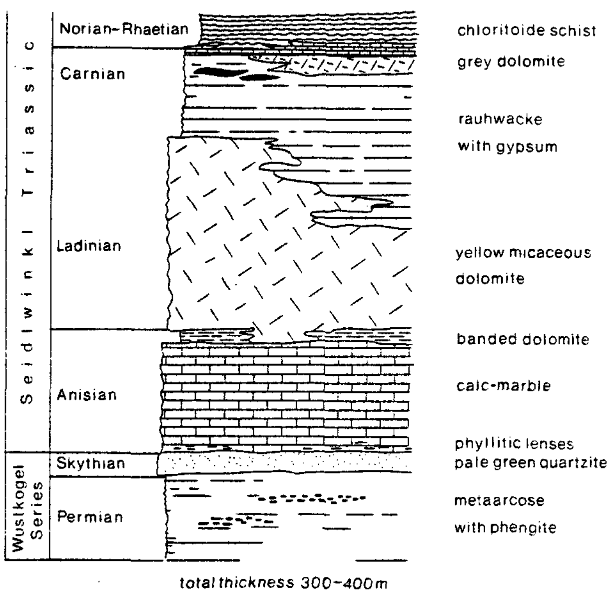
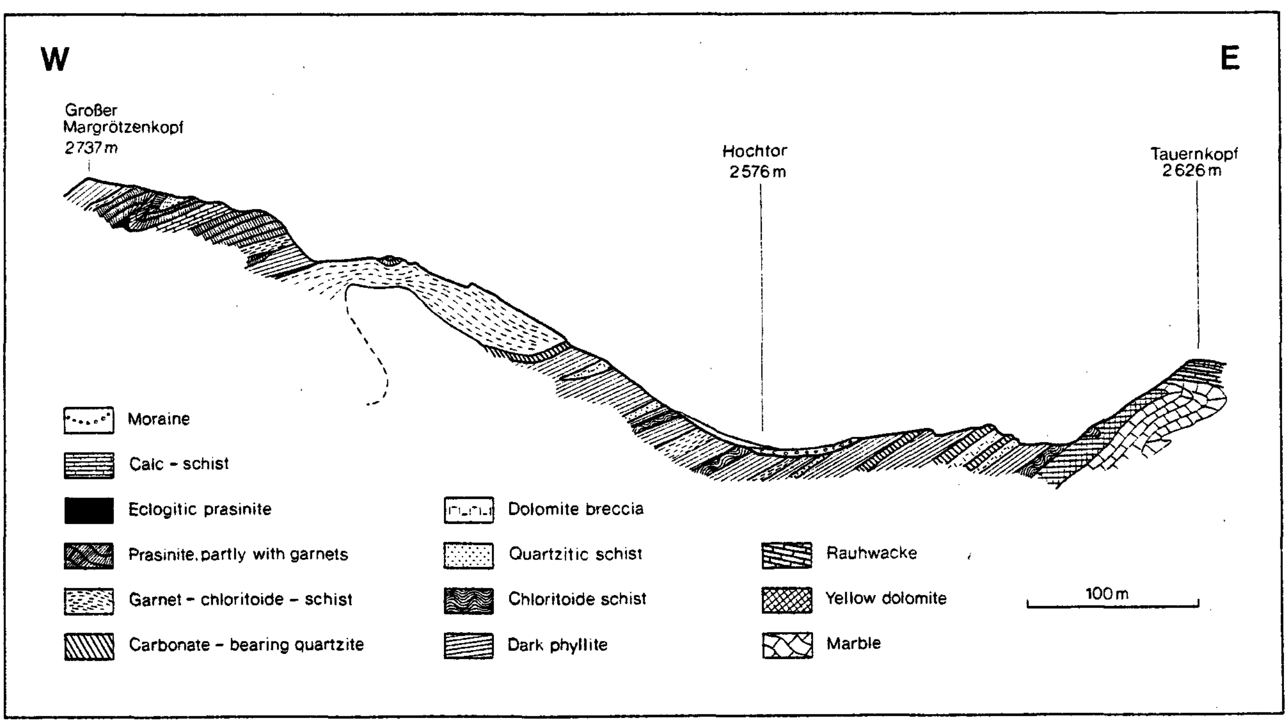


Fig. 22 (right): Columnar section of the Wustkogel Series and the Seidlwinkl Triassic (after Frank 1964).

Fig. 23 (below): Geological cross-section of the Brennkogel facies assemblage in the Hochtor area (after CORNELIUS & CLAR1993)



Section 9

The Spießnägel Section in the Graywacke Zone of Tyrol

(figs. 24, 25)

by Hans Peter Schönlaub

As far as general geology and stratigraphy of this part of the Graywacke Zone are concerned we refer to the introductory paper by H.P.SCHÖNLAUB & H. HEINISCH in this volume.

According to H. MOSTLER and his working team who have studied the Tyrolean part of the Graywacke Zone in great detail during the past 30 years, the area south of the line from Kitzbühel to Kirchberg und Brixen is dominated by an Ordovician shale sequence with intercalations of volcanoclastics (see fig. 24). In the Upper Ordovician they are followed by acid volcanics, the so-called Blasseneck Porphyroid. Although there are no data available concerning the precise position of the Ordovician/Silurian boundary in that area, the Silurian succession is fairly well known due to conodont occurrences and some other fossils such as graptolites.

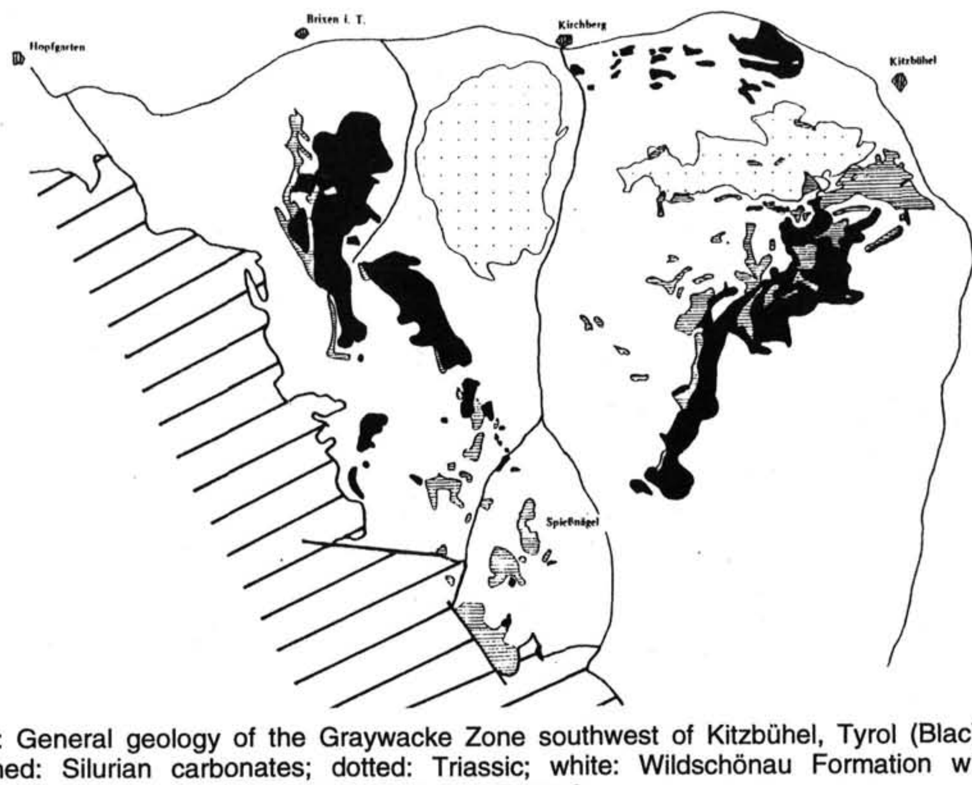


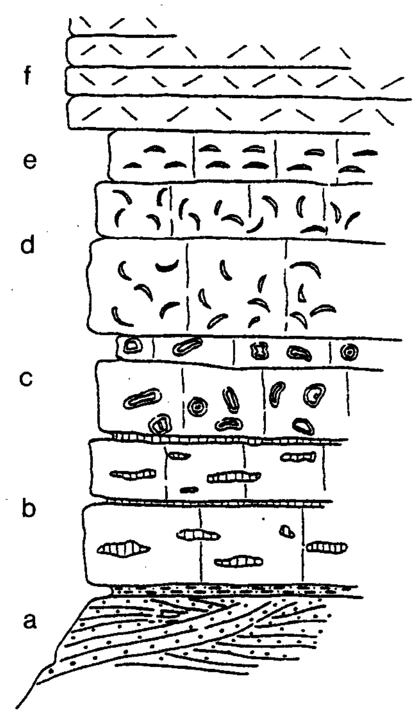
Fig. 24: General geology of the Graywacke Zone southwest of Kitzbühel, Tyrol (Black: Porphyroids; dashed: Silurian carbonates; dotted: Triassic; white: Wildschönau Formation with greenschist intercalations). After AL-HASSANI & MOSTLER 1969.

The section at the southern peak of the Spießnägel mountain is one of the most important successions in which a detailed transition from graywackes of presumably latest Ordovician age to basal Silurian strata has been documented (N. AL HASANI & H. MOSTLER 1969; fig. 25). The Silurian sequence starts with a 0.85 m thick bed of arenaceous and tuffitic limestones of the *P. celloni* Zone. Within this bed a 6 cm thick tuffitic interbed occurs which is followed by well bedded brownish bioturbated and crinoidal limestones. To a vaying degree these limestones are mineralized. The lower 0.65 cm portion of these limestones are bioturbated mudstones with varying amount of clastic and tuffaceous input. Starting with sample no. 75 some 0.70 m above the base of the limestone section fossil debris becomes significantly enriched forming wackestones. Of special interest is the occurrence of superficial ooids which can be found in the upper part of this bed. According to the authors these ooids consist of a crinoid nucleus or shell debris of bivalves which were superficially coated.

The basal part is succeeded by 1.10 m of brownish well bedded to noduliferous limestones with up to 0.25 thick shaly layers containing some limestone lenses. This part represents packstones with lumachelles-like debris of bivalves, brachiopods, ostracods and in particular echinoderms in the upper portion. Fairly abruptly, this sequence grades into greyish and yellowish laminated dolomitic rocks.

The limestone sequence below the dolomites correspond to the interval from the the *P. celloni* to the *P. amorphognathoides* Zone. Hence, they reflect the environment of the Upper Llandovery and the transition to the Wenlock. According to H. MOSTLER the base of the overlying dolomites represent the *K. patula* Zone of the early Wenlock.

Fig. 25: The Spießnägel Section after AL HASANI & MOSTLER (1969); a: Subgraywackes of Wildschönau Formation; b: Limestone with tuffaceous layers; c: Grainstone with coated grains; d: Bioclastic grainstone; e: Well sorted echinodermal limestone; f: laminated dolomite



Section 10

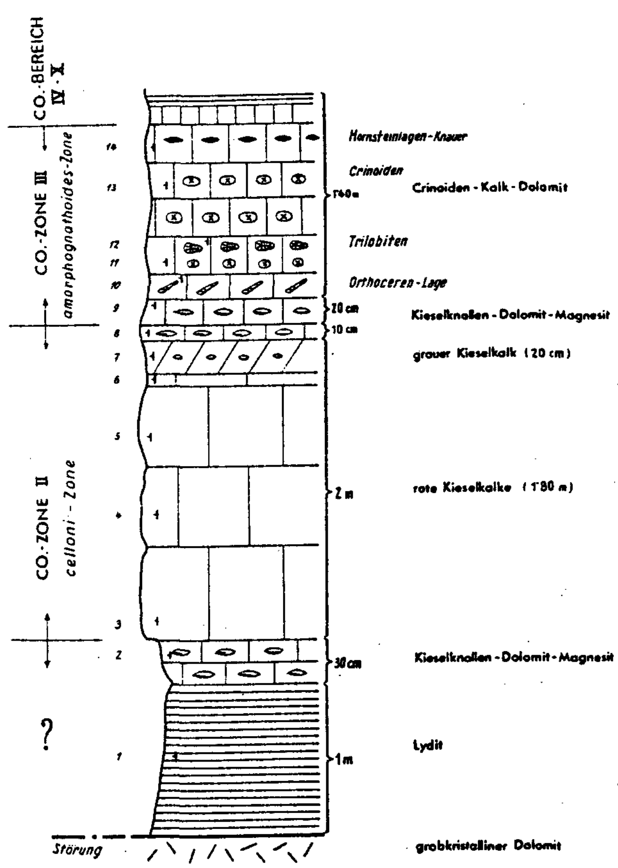
The Lachtal-Grundalm Section near Fieberbrunn

(figs. 26, 27)

by Helfried Mostler[1]

The section is exposed at an altitude of 1220 m in the Lachtal valley near the Lachtal-Grundalm. This graptolite bearing locality is one of the "classical" outcrops for the Silurian of the Graywacke Zone. The first records of graptolites date back as early as 1930. In fact, the sequence represents a mixed shale-limestone succession known in the literature as "Lydit-Kieselkalk-Komplex" at the base and the 5 m thick "Dolomit-Kieselschiefer-Komplex" above (H. MOSTLER 1966). However, due to intense faulting only short undisturbed sections can be found. The following description is based on an overturned section published by H. MOSTLER 1966 and H. JAEGER 1978.

Fig. 26: The basal part of the Lachtal-Grundalm Section after Mostler 1966 covering the cherty limestones of the *P. celloni* Zone and the dolomitic crinoidal limestone of the *P. amorphognathoides* Zone



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The stratigraphic base of the section comprises the "Lydit-Kieselkalk-Komplex". This cherty formation is formed by black massive cherts known as "lydites" in the Alpine terminology, radiolarian-bearing dolomites and reddish cherty limestones which grade into crinoidal limestones (fig. 26). The overall thickness does not exceed some 5 m. The accompanying microfauna consists of shell debris of ostracods, foraminifers, brachiopods, radiolarians, conodonts and echinoderms. In addition, shells of bivalves, solitary corals, trilobites and orthocone nautiloids sparsely occur the latter being concentrated at the base of the 1.40 m thick crinoidal limestone member.

Conodonts from the above described short section indicate the presence of the *P. celloni* Zone in the lower 2.10 m thick part (reddish cherty lst.) and the *P. amorphognathoides* Zone in the following 1.40 m thick part of the section.

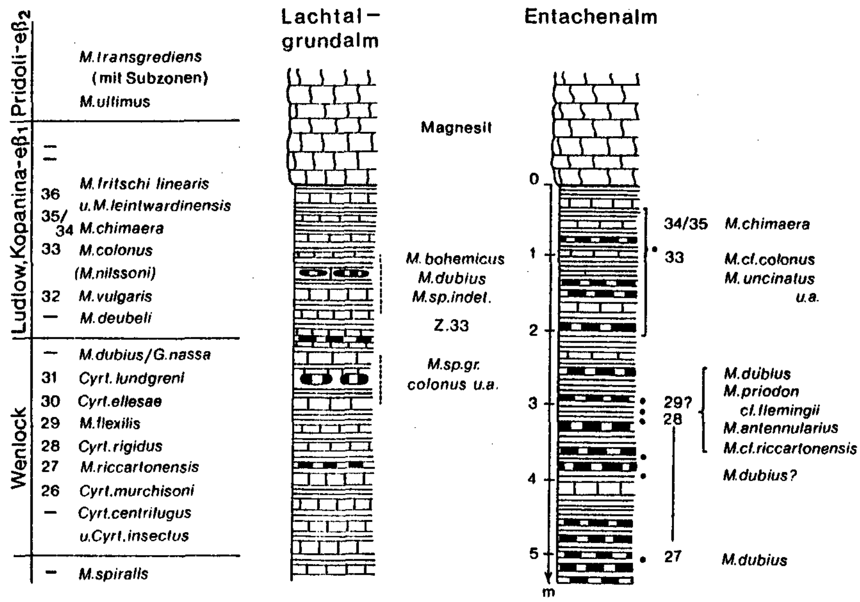

Fig. 27: The graptolite bearing upper part of the Lachtal-Grundalm Section of Tyrol and the Entachenalm Section of Salzburg (after JAEGER 1978). Both sections display the mixed facies of the dolomite-graptolitic shale Formation of the time span from the Wenlock to the Lower Ludlow.

According to H. JAEGER 1978 determinable graptolites only occur in the upper part of the section, i.e. in the "Dolomit-Kiesleschiefer-Komplex" (fig. 27). The lithology resembles the Cardiola Fm. of the Carnic Alps. Representatives of *M. bohemicus* are most abundant at a higher level. According to H. JAEGER they characterize the graptolite Zone 33. Based on the new definition for the Wenlock/Ludlow boundary this horizon corresponds to the basal Ludlow. Yet, co-occurring conodonts are non-diagnostic long ranging elements which permit no further age assignment. Other graptolites were identified as *M. dubius* cf. *frequens* and *M.* sp. indet. ex grege *colonus.*

A second occurrence of graptolites is in a creek adjacent to the main outcrop of the Lachtal brook. At this horizon *M. bohemicus* is missing; the remaining fauna seems identical with the one mentioned for the first outcrop. Hence, H. JAEGER concluded a slightly older age within the *M. vulgaris* Zone.

In the Tyrolean part of the Graywacke Zone the "Dolomit-Kieselschiefer-Komplex" is overlain by dolomitic rocks and magnesite. According to H. MOSTLER 1966 the onset of this carbonates can be placed within the *O. crassa* Zone or at the base of the following *A. ploeckensis* Zone, i.e. at or near the base of the Ludlow.

Summarizing the available data from the Lachtal-Grundalm section a composite succession through the major part of the Silurian can be established in this part of the Graywacke Zone. It starts in the Middle (?) or Upper Llandovery and can, although strongly affected by faults, well be followed through the Wenlock into the basal Ludlow. Yet, there are no positive records from the Pridoli Series of the Upper Silurian which, however, may be obliterated in the strongly recrystallized dolomites.

Abstracts

Field Meeting Eastern + Southern Alps, Austria 1994

Conodont Evidences from the "Ockerkalk" of Southeastern Sardinia (Silurian, Silius area)

S. Barca[1], C. Corradini[2], A. Ferretti[3], R. Olivieri, & E. Serpagli[4]

Two new Ockerkalk sections (Genna Ciuerciu and Silius I°) have been discovered in southeastern Sardinia (Gerrei), about 7 Km south of the classic graptolite locality Goni. They provided a rich Silurian conodont fauna of about 9000 conodont elements belonging to twenty species. A precise age (Ludlow- Pridoli) has been deduced, with a continuous record of all Silurian conodont Biozones from the *Ancoradella ploeckensis* to the *Ozarkodina remscheidensis eosteinhornensis.* The fauna allows to subdivide the studied interval into the following biozones (from the base to the top): *Ancoradella ploeckensis- Polygnathoides siluricus- Pedavis latialata- Ozarkodina snajdri- Pelekysgnathus index horizon - Ozarkodina crispa- Ozarkodina remscheidensis eosteinhornensis.*

The *latialata, snajdri* and *crispa* Biozones are reported for the first time in Sardinia.

The index species *Polygnathoides siluricus, Pedavis latialata, Ozarkodina snajdri* and *Ozarkodina crispa* appear in the sequence with no co-occurrence.

Pelekysgnathus index, newly recorded in Europe, appears in a horizon in the lowermost part of the *crispa* Zone, considerably before the North American range.

As already reported in SW Sardinia (Gnoli et al., 1988), *Pseudooneotodus bicornis* is present up to *eosteinhornensis* Zone, having therefore a longer range than in other previous reports.

The biosedimentologic analysis confirms the pelagic nature of the limestone, whose fauna, together with conodonts, is composed by small bivalves, ostracods, brachiopods, gastropods, trilobites, crinoids and rare small cephalopods as sparse bioclasts, only locally concentrated, inside a fine-grained sediment.

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Cephalopod Limestone Biofacies: Tajmyr (Eastern Siberia) - the Carnic Alps

O.K. Bogolepova[1]

Cephalopod biofacies were formed during the Silurian period at regular intervals that was in most cases of global character. Within the platforms such as Siberian and Chinese ones these are only known from the Early Silurian, that is related to stable tectonic regime of the platforms, whereas in more mobile regions such as Tajmyr and the Carnic Alps cephalopod limestones were more frequently deposited and they occur both the Wenlockian and Ludlowian.

In deep-seated deposits occurring in the north-western part of the Tajmyr (Mittendorf Caves section), cephalopod biofacies are confined to thin intercalations of black limestones within thick sequence of black graptolite shales of the Middendorf Formation. The depth of sediments deposition is also evidenced by the fact that the cephalopods virtually have no preffered orientation. Fauna: cephalopods *Hemicosmorthoceras semiannulatum, Geisonoceras sp., Kionoceras aff. doricum, Akrosphaerorthoceras aff. gregale, Michelinoceras sp., Anaspyroceras pseudocalamiteum, Parakionoceras originale*, bivalves *Cardiola signata, Cardiola aff. consangius, Dualina ? faba, Mila gyrans, Maminka cf. comata, Butovicella migrans, ostracodes "Entomis" (R.) migrans,* conodonts *Ozarkodina iclinata inclinata, Ozarkodina inclinata posthamata,* rare trilobites (Kriz, Bogolepova, in press). In the Carnic Alps (Rauchkofel Boden section) cephalopod biofacies are confined to rather shallow dark-grey and black limestones of the Kok and Cardiola Formations and are comparatively thick. The cephalopods are oriented and their orientation is applicable to the description of water dynamics. Fauna (the upper part of Kok Formation): cephalopods *Merocycloceras declevis, Parasphaerorthoceras sp., Sphaerorthoceras sp, Hemicosmorthoceras laterculum* (Ristedt, 1968), bivalves *Cardiola signata, Cardiola consanguis, Mila complexa* (Kriz, 1979), conodonts *of the interval of the crassa-ploeckensis* Zones (Schönlaub, 1980), trilobites, crinoids, rare gastropods.

The cephalopod fauna from Eastern Siberia suggests a close affinity with those from Bohemia and the Carnic Alps although in the latter region a revision is needed. Additional studies must be carried out to prove whether or not any further regions like the Montagne Noire, Morocco, Spain, Sardinia, Turkey, Caucasus, the South Urals, Tien Shan and Novaya Zemlya are comparably close related to the above mentioned areas. In any way, our preliminary data suggest the operation of an equatorial current system which facilitated the exchange of faunas between the "upside-down" Siberian plate and Central Europe during the Silurian.

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The "Cephalopod Limestone" of The Prague Basin (Silurian, Czech Republic)

A. Ferretti[1] & J. Kríz[2]

Silurian cephalopod limestones developed in the northern Gondwana region at the same stratigraphic horizons, as also revealed by the analysis of bivalve-dominated communities. The absence of a major tectonic overprint together with the presence of extensive outcrops make the Prague Basin one of the ideal areas to study this limestone.

Five sections (Braník, Cephalopod Quarry, Marble Quarry, Pankrác Section and Kosov Quarry) have been investigated both directly in the field and with oriented thin sections. Additional samples have been collected from Jinonice, Muslovka Quarry and Karlstein.

Two facies types have been recognized. A first type (Braník type), which is regarded as the "normal" sedimentation facies, is the result of a surface current which transported empty shells of cephalopods, larvae of bivalves and other fauna. This current was in connection with the Silurian equatorial current regime of other northern Gondwana areas. The second type (Kosov type) is the effect of storm event redepositions within the current itself in a local shallower and better ventilated environment.

Cephalopod shells have peculiar orientations in these two facies types. They share a preferred unidirectional SW-NE direction in the Braník type cephalopod limestone, while they have a NS direction but opposite orientations according to shell size in the Kosov type cephalopod limestone.

These two facies types must be regarded as perspectives of the same view, as they simply represent two depositional cases of different depths and hydrodynamic regime. In the deepest parts of the Prague Basin, black shales sedimentation and anoxic conditions continued undisturbed in Wenlock and Ludlow time.

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The Dynamics of Change in Composition of Silurian Gastropod Communities in the Siberian Basin

A.P. Gubanov[1]

An extensive marine basin existed on the Siberian Platform in the Silurian period. The basin was moderately deep judging from the results of facies analysis, and its depth was rarely over 200 m. Recompensated sedimentation in the basin, resting on rather rigid crust of continental type, is responsible for gradual shallowing and disruption of normal marine regime at the end of the Silurian period. The consequences of eustatic changes and related variation in fossil communities, which at that time, are rather well traceable due to relative stability at the base of the basin.

General tendency towards the shallowing of the basin resulted in specific change in gastropod communities. Revealed previously the dependance of gastropod shell shape upon hydrodynamics of the basin, under the conditions of weakly rugged topography, that directly associates with the basin depth, has been studied at species level and treated as intraspecies variability (Gubanov, 1984, 1985). The study of extensive material compiled on Silurian gastropods of the Siberian platform (Gubanov, 1988) allowed this association to be established at gastropod communities on the whole. Distribution of various living forms in gastropod communities was investigated. Living forms determined before on the basis of relative mobility have appeared to be related to a considerable extent to hydrodynamics of the basin and its depth.

In the Early Silurian in the Rhuddanian, when the basin depth was maximal, there were gastropods almost living forms existed at that time. Taxonomic composition of gastropod communities is most rich as well. These communities are dominated by gastropods with subspherical *Prosoptychus globulus* and similar to them, in the ratio of surface and volume, conical forms *Eotomaria kuondae, Holopea transversa.* The Aeronian is dominated by the species possessing the shell of more streamline shape - *Pararaphistoma qualteriatum, Trochonema transformis, Arjamannia cancellata, Gyronema multangulata.* In the Telychian predominant are the taxa with high-spired and subdiscoid shape of shell such as *Murchisonia insignis* and *Straparollus alacer*, which are numerous in the deposits of that time. The number of gastropods of another living forms decreases considerably. In Wenlock *Lophospira alta* and *Murchisonia cingulata* (replaced *Murchisonia insignis*) were in the foreground along with *Straparollus alacer*. During the Ludlow a considerable number of gastropods stop to exist and two specis only *Straparollus alacer* and *Murchisonia cingulata* persisted, which are monotaxonic communities.

The above patterns of gradual change in gastropod communities are characteristic of more deep northwestern areas of the basin. More shallow areas have a somewhat different picture because of great effect of eustacy. By the Late Llandovery persisted were gastropods only of two living forms, such as high-spired and subdiscoid. During

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the Wenlock transgression gastropod became more diverse and in the Ludlow their diversity gradually decreases and again up to two living forms. Eustatic changes more weak than those of Early Wenlock are well recorded due to the range on intraspecies variation of gastropods, but virtually had no effect on communities composition.

Bathymetry of the Silurian Nautiloid Fauna from the 'Orthoceratite Limestone', SW Sardinia

K. Histon[1] & M. Gnoli[2]

Various factors must be considered in order to determine the depositional environment of the Silurian 'orthoceratite limestones' of SW Sardinia. The work of Gnoli et al. (1980, 1990) suggests a depositional environment for the limestone facies in a normally oxygenated epicontinental sea of limited depth rich in an exclusively pelagic fauna in the upper part but occasionally toxic towards the bottom. A study by Ferretti (1989) of the microbiofacies of the Upper Silurian has determined two stages of deposition for the cephalopod limestone facies. During the Late Wenlock - Ludlow a shallow high energy (near wave-base) shelf environment is suggested. A deeper tranquil environment is suggested for the Pridoli of a shallow offshore basin occasionally affected by storm sedimentation.

However, nautiloids which are abundant in the limestone provide an independant means of assessing bathymetry. The chambered cephalopods i.e. living *Nautilus* and by inference fossil nautiloids, are unique in having developed a fixed volume phragmocone, with subatmospheric internal pressure as a buoyancy tank to minimise energy expense, thus their distribution is depth-dependent (Denton 1974; Chen & Lindstrom, 1991)

The maximum hydrostatic limit for mature *Nautilus* is known to be equivalent to a depth of about 800m, below which the shell implodes (Hewitt & Westermann, 1987). The calculated implosion depths therefore can be expected to provide reliable evidence of depositional depth of the fossil bearing stratum (Chen & Lindstrom, 1991).

A bathymetric study of twenty eight species of nautiloids from the 'orthoceratite limestone' of the Upper Silurian of SW Sardinia has implied a water depth in excess of 300m based on those septa that have imploded as they exceeded their calculated hydrostatic limits. The structural limit of the weakest elements of the fauna is <100m. The habitat depths for the species indicate an environment of <350m taking the data for the weaker species as the limiting factor.

Where a stratigraphical control was placed on the fauna, within three assemblages, the environments deduced from the habitat depths of each assemblage were somewhat deeper than the environments implied by the previous studies for the periods Wenlock to late ludlow and Pridoli. With the former having habitat depths between 100-500m and the latter between 200-700m.

The palaeoecological implications from the various morphologies of the nautiloid species that there were two distinct faunal elements, one mesopelagic and the other epipelagic inhabiting an environment of between 150-450m are supported by the calculated habitat depths for the species. The fact that specimens of all growth stages

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are found indicates that this was an in situ assemblage and not an accumulation due to postmortem drifting of the shells.

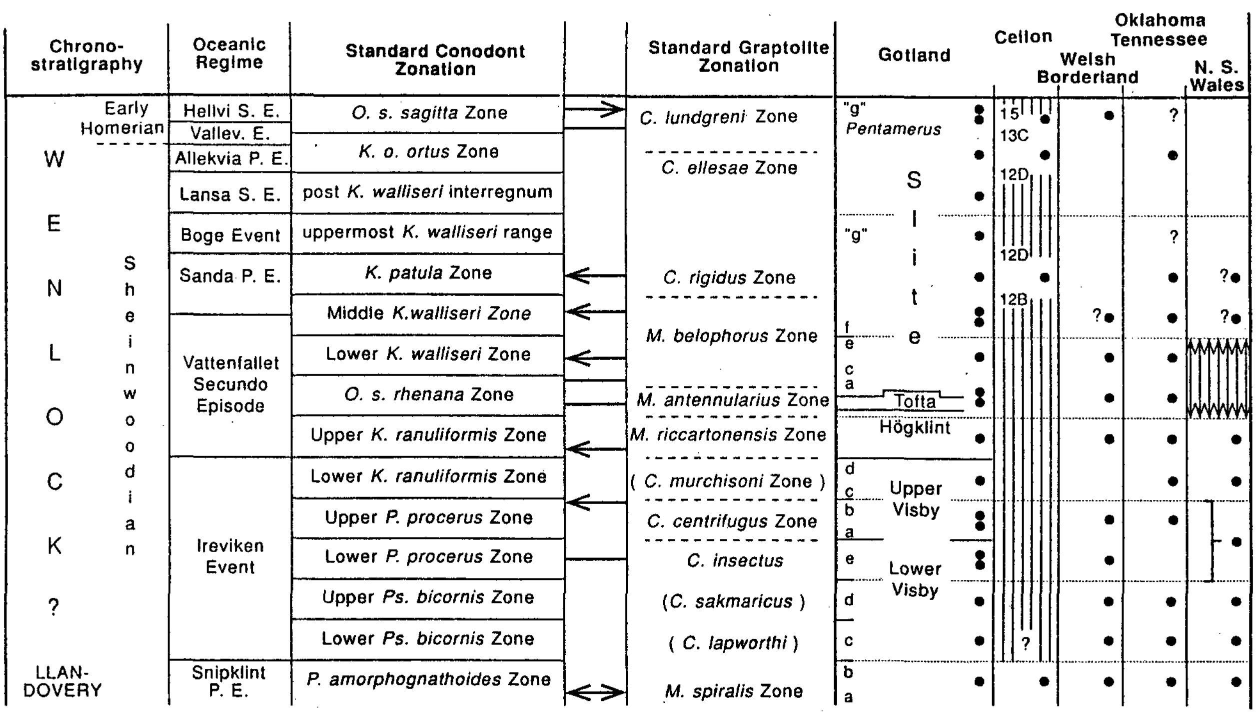
A new Standard Wenlock Conodont Zonation

L. Jeppsson[1]

A new standard conodont zonation fpr early and middle Wenlock is in manuscript. The late Homerian sequence too includes distinct faunas (the following text and tables should be read from below).

A full recovery occured in the early Ludlow with return of e.g. *P. recurvatus, P. gracilis, P. serratus* and *K. o. absidata.*

Conodonts		Graptolites	Oceanic state
O. c. densidentata etc, few coniforms		(*P. vulgaris*) (*P. deubeli*)	Klinte S.'E.
Temporary recovery, diverse fauna		*P. praedeubeli*	Mulde
Very low diversity faunas	*O. excavata* dominates	*G. nassa - P. dubius*	Secundo-Secundo Event
	P. equicostatus dominates	*M. d. parvus*	
	Pseudooneotodus abund.	No graptoloids?	
		Extinction	
	O. excavata dominates	Topmost (10% ?) *M. testis*	
Extinctions		Extinctions?	
O. s. sagitta, high diversity		*C. lundgreni*	Hellvi S.E.



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A Stepped Karst Unconformity as an Early Silurian Rocky Shoreline in Guizhou Province (South China)

Markes E. Johnson[1] & Rong Jia-yu[2]

Where succeeded by marine strata, karst unconformities signify a former rocky coastline. Such relationships may help sort out relative sea-level changes and aspects of local geography controlling facies distribution. An exceptional example of an early Silurian karst shore is well exposed near the village of Wudang in central Guizhou Province, not far from the capital city of Guiyang in South China. Here the Lower Silurian Kaochaitien Formation oversteps 63 m of paleotopographic relief over a distance of 0.8 km on limestones belonging to the Llanvirn Kuniutan Formation and Caradoc to early Ashgill Huanghuachong Formation (Ordovician). The corresponding rise in sea level took place coeval with tectonic uplift, as confirmed by a regionally diachronous relationship in the Ordovician-Silurian boundary across a 250 km track from central to northern Guizhou Province. In the north, there is no discernable time gap at the Ordovician-Silurian boundary but younger and younger Silurian strata rest on older and older Ordovician strata in the south. The change in sea level also fits with a global rise of sea level in late Aeronian (later Llandovery, early Silurian) time. Borings of the ichnofossil, *Trypanites,* are reported from the karst surface of the Huanghuachong Formation and Silurian fill defines sink holes in this unit over 5 m deep. The Silurian karst shoreline near Wudang is integrated with other regional data to construct a paleogeographic map covering the northern half of Guizhou Province.

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Stages, Substages and/or Chronozones and/or Standard Zones - What is Needed in the Silurian?

D. Kaljo[1]

A new version of the International Stratigraphic Guide lists stage and substage in the conventional hierarchy of formal chronostratigraphic terms. The first has been called the basic unit and one of the smallest units that in prospect may be recognized at a global scale (ISSC Circular No 85, 1992). The same source defines (differently from Hedberg, 1976) chronozone as a formal chronostratigraphic unit of unspecified rank, not part of the above hierarchy. Despite of shortness of the Silurian Period, it seems that stages might be subdivided at a global scale into units of lower rank - substages (preferable) and/or chronozones. Two main difficulties are obvious - tracing a lower rank unit in different provinces and crossing facies boundaries within a sedimentary basin. The latter might be sometimes more troublesome than interbasinal correlation in similar facies.

Standard graptolite zones (Koren, 1984) belong to the category of biostratigraphic zones with all their properties and possibilities (the procedure for establishing remains disputable). Their main idea is a better correlation of different graptolite-bearing rock sequences, but also to be used as a time scale for any kind of correlations (for the Silurian Subcommission map project etc.).

The latter goal is a step toward a chronostratigraphic unit (chronozone or substage). The main problem is here the same - the reliable tracing of zone boundaries through non-graptolite facies. It might be achieved by using different paleontological and non-paleontological tools (s.c. Meien's principle), but the number of standard zones has to be kept low (for graptolite facies another, more detailed set of zones might be used). If the correlation problem is solved, the standard zone can become a chronozone or substage.

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A Simplified Graptolite Zonal Sequence - Reliable Levels for Global Palaeogeographic Reconstructions

T. N. Koren[1]

The ongoing correlation chart project is a main objective of the SSS activity. It aims to a better reconstruction and analysis of the palaeogeographic, palaeobiogeographic and evolutionary development in the Silurian. The main aid for the correlation is the "left hand side biostratigraphical column" ("LBC"), which indicates graptolite and conodont time intervals, reliable for global correlation.

This LBC has to be based on all hitherto elaborated complete zonal sequences. But up to now, there is neither a general agreement about the principles of zonation, nor a generally accepted sequence itself. However, well established zonal graptolite sequences exist in several regions, such as the classic ones in Great Britain (there missing the upper part, i.e. Upper Ludlow and Pridoli) and Bohemia (there including the upper part), but also from other regions as, e.g., Poland, Bornholm, Arctic region of Canada, Central Asia).

However, correlation charts in many published papers show that not all of these zones are uniformly defined world-wide (Koren, 1984). This can be explained by the following: (1) in some cases different criteria were used in different regions to define the base of a single zone, (2) in particular parts of the type sequences, zones appear to be not well established, and (3) some intervals were subdivided in such a detail that these smaller units are presently applicable only at local or regional levels.

As a solution to the problems indicated above, it is proposed to use a simplified zonal sequence (Koren, 1984) for the LBS. There, all well traceable zones are named and used in their original biostratigraphic extent. But the parts of the zonal sequence which are not traceable world-wide in detail, or which are still questionable in their range or applicability, those are combined. In this combination (e.g. *parvus* to *deubeli*) all other zones between are included.

In the forthcoming discussion, corresponding compilations of regional zonal sequences, range charts and a LBC will be presented.

An additional task will be to discuss the principles of zonation. The present author pleads to distinguish strictly between the definition of a biostratigraphic zone and its characterization: A zone should be defined by the first occurrence of the zonal species, but characterized by the co-occurrence of other diagnostic species.

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Silurian Retiolitids from Poland

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Isolated retiolitids fauna from Upper Llandovery to Upper Ludlow of NE Poland deep boring and Baltic erratic boulders was investigated. The process of reduction of reticula and clathrium (ancora sleeve) as well reduction of edges of interthecal septa and central position of virgula started in the Wenlock. All Ludlow retiolitids possess central virgula in reduced rhabdosomes.

The appearance of the final growth phenomenon of the colony related to reduction the number of thecae in *Gothograptus* lineage started in Upper Wenlock and continued in the Ludlow. Classification and phyllogenetic relationships among subfamily Plectograptinae Boucek et Münch, 1952 are assumed.

Sokolovograptus polonicus sp.n. from *Cyrtograptus murchisoni* Biozone represents strongly reduced rhabdosom. Rhabdosome of *Plectodinemagrptus gracilis* gen. et sp.n. from *Cucullograptus hemiaversus/aversus* Biozone is the most reduced and startigraphicaly latest retiolitid.

The investigated retiolitids comprise genera: *Retiolites, Pseudoretiolites, Paraplectograptus, Pseudoplectograptus, Sokolovograptus, Eisenackograptus, Gothograptus, Neogothograptus* gen.n., *Holoretiolites, Spinograptus, Plectograptus, Semiplectograptus* gen.n., *Plectodinemagraptus* gen.n.

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Major Facial and Faunal Changes in the Silurian of the Prague Basin, Bohemia

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The general facial and faunal development of the Prague Basin was during the Silurian influenced by eustatic movements, water currents, volcanism and by synsedimentary tectonics.

After the lower Silurian transgression anoxic conditions in the basin persisted up to the upper Aeronian (middle Llandovery) when ventilated, shallow bottom conditions developed due to the volcanic activity. This caused the development of shallow water benthic communities formed of the new, most probably endemic species which originated by very quick adaptive radiation on the slopes of virgin volcanic island.

In the upper Wenlock and in the lower Ludlow the volcanic archipelago originated in the Prague Basin and the situation was analogous with that in the middle Llandovery. New shallow water brachiopod and trilobite dominated benthic communities developed by very quick adaptive radiation of immigrant species.

A different situation was in deeper parts of the basin which were ventilated only temporary by surface currents. The currents provided not only ventilation of the deeper parts of the basin but also transport of larvae and cephalopods. Here, during low stands of the sea level when currents were reaching the sea bottom, developed the cephalopod limestone biofacies with the Bivalvia dominated *Cardiola* Community Group (KRIZ 1993a MS). This group is composed of the recurring *Cardiola* dominated analogous and homologous communities. They are developed in several horizons which indicate low stands of the sea level stratigraphically. The communities are formed by cosmopolitan species with relatively long larval life which is favourable for long transport and which are known from many other basins within the reach of the South Tropical Current (Wilde, Berry and Quiby-Hunt 1991) - e.g. Morocco, Spain, Montagne Noire, Massif Armoricain, Welsh Borderland, Scane, Carnic Alps, Moesian Platform, Serbia, Sardinia, Australia, Caucassus and Tajmyr.

First major change in facies and fauna was in the middle Ludfordian (upper Ludlow) caused by high stand or transgression of the sea which influenced the whole basin, even the shallowest parts of it. In the basin developed new shallow water communities while old shallow water communities characterized by encrinurid trilobites extincted. There was no time and conditions for the deeper water communities to recover.

Shallowing of the basin during the higher Ludlow caused development of similar conditions in the basin which existed here before the middle Ludfordian. In the shallow parts of the basin, in the regions of former volcanic centres, brachiopod and trilobite dominated communities composed mainly from endemic species flourished. The deeper parts of the basin ventilated by currents were characterized by the Bivalvia dominated communities in which the majority of the species was cosmopolitan.

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A second major facial and faunal change was at the Ludlow - Prídolí boundary caused by another transgression of the sea. High stand of the sea-level killed all the Ludlow benthic communities and just few species survived. The new Bivalvia dominated communities composed mainly of infaunal and cosmopolitan species distributed as larvae together with cephalopods by surface currents developed in deeper water under somewhat restricted bottom conditions (mostly only little and temporary ventilated). These communities are known also from other regions (e.g. Morocco, Montagne Noire, Poland, Moesian Platform, Carnic Alps, Sardinia, Serbia). In the shallow bottom which persisted in the regions of former volcanic centres flourished the brachiopod dominated communities with a majority of endemic species. Parts of these shallow flats were protected against high energy by barriers of crinoid sand composed mainly of *Scyphocrinites* disarticulated stem plates and numerous loboliths.

Jarovian Stage and Bítovian Stage - a Proposal for the Prídolí Series Subdivisions (Silurian, Prague Basin, Bohemia)

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During the 1992 Prague Field Meeting of Subcommission on Silurian Stratigraphy it was recommended to Czech side to propose the international subdivision of the Prídolí in type area of the Prídolí Series - the Prague Basin. The Prídolí represents the last series of the Silurian System which was undivided into stages.

The Prídolí Series is in the Prague Basin developed as very monotonous series of alternating laminites and calcareous shales in whole thickness from the base up to the top, which is defined by the Silurian-Devonian global boundary stratotype. Only in the shallow environment carbonate sedimentation prevails in the upper parts and it is characterized by crinoidal limestones. Biostratigraphically the series is subdivided into six graptolite biozones and one graptolite interzone. Generally the whole series represents one conodont biozone and one chitinozoan biozone. Benthic fauna is mainly related to the facies distribution and cannot be used for detailed biostratigraphy.

When based on the graptolite biozonation, the subdivision must be based on the biozone which can be correlated internationally. Besides the basal biozones the *Monograptus bouceki* Biozone and the *Monograptus transgrediens* Interzone show the widest geographic distribution. *Monograptus bouceki* is recorded according to Jaeger (in Kríz et al. 1986) from many parts of the world but although a world-wide distribution of this species may be expected, this cannot yet be considered as safely established. What concerns *Monograptus transgrediens*, the species is known according to Jaeger (in Kríz et. all. 1986) from all continents except Antarctica and represents one of the most common Prídolian graptolite species in many areas.

There are just two alternative bases for the second stage when considered the wide geographic distribution of graptolite biozones. The base of the *Monograptus bouceki* Biozone and the base of the *Monograptus transgrediens* Interzone. Since the *Monograptus transgrediens* Interzone is defined as the part of the sequence above the *Monograptus perneri* Biozone in which *Monograptus transgrediens* occur almost exclusively and because *Monograptus transgrediens* ranges from the uppermost *Monograptus ultimus* Biozone through the *Monograptus lochkovensis, Monograptus bouceki* and *Monograptus perneri* Biozones to near the top of the Prídolí (Jaeger in Kríz et al. 1986) only the base of the *Monograptus bouceki* Biozone may be acceptable.

The *Monograptus bouceki* Biozone was recognized in the Prague Basin in the sections Pozáry, Marble Quarry, Hvizdalka, Budnany Rock, Certovy Schody, Kosov

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Quarry and others (KRIZ et al. 1986). The best accessible and most fossiliferous is the base of the *Monograptus bouceki* Biozone developed in the section Hvizdalka which was in detail described by KRIZ et al. 1986. The section is also protected by the State Law. For this we propose this section as the international boundary stratotype of the Bítovian Stage.

Jarovian Stage

For the first stage of the Prídolí Series we propose the name Jarovian Stage. The name is taken from Jarov Village, which is the part of Beroun Town in the western part of the Prague Basin. The base of the Jarovian Stage is coincident with the base of the Prídolí Series, which is defined on the International boundary stratotype at Pozáry near Praha - Reporyje.

Bítovian Stage

For the second stage of the Prídolí Series we propose the name Bítovian Stage. The name is taken from Bítov Village, south of Beroun in the western part of the Prague Basin. For the base of the Bítovian Stage we propose as the international stratotype the section Hvizdalka in Radotín Valley near Prague, on the base of the shale bed no. 27/28a. This point correlates with the base of the *Monograptus bouceki* Biozone and is marked by a mass occurrence of *Monograptus bouceki.*

Identification of the Llandovery-Wenlock Boundary in Welsh Graptolitic Sequences

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The decision of the Silurian Subcommission to place the Golden Spike for the Llandovery -Wenlock boundary at Hughley Brook in Shropshire, England has resulted in considerable uncertainties as to the position of the boundary in the graptolite biozonal scheme. Although it is widely stated that the Golden Spike correlates with the base of the *Cyrtograptus centrifigus* Biozone there is no direct evidence for this. Graptolites are absent from the boundary stratotype.

In order to resolve this problem the authors are involved in a study of graptolitic Llandovery-Wenlock boundary sections in Wales and the Welsh Borderlands with a view to using acritarchs/chitinozoans and/or bentonites to correlate these graptolitic sequences with the stratotype.

Within the Banwy River section in Powys we have recognised, for the first time in Britain, the existence of the *Cyrtograptus lapworthii* and *Cyrtograptus insectus* biozones, thus demonstrating once again the inadequacy of the so-called 'standard' graptolite biozonal scheme which places the *Monoclimacis crenulata* Biozone at the top of the Telychian. In Wales, as in Bohemia, the *crenulata* Biozone is succeeded by three biozones below the *centrifigus* Biozone.

Within the *lapworthii* and *insectus* biozones we have identified several graptolite taxa previously considered to be confined to the Wenlock. Indeed it seems almost that the only 'new' graptolite appearing at the base of the *centrifigus* Biozone is the eponymous taxon.

We hope that our study will enable greater precision in correlation of graptolitic sequences at this level and will encourage other workers to look again at their graptolitic faunas from around the Llandovery -Wenlock boundary.

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Some Additions to the Llandovery Conodont Zonation

P. Männik[1]

In the *D. kentuckyensis* Zone, originally defined by Nicoll and Rexroad (1968), three distinct faunas are recognized. Here the concept of the *D. kentuckyensis* Zone is used only for the oldest one of these faunas. It is followed by the *Ozarkodina excavata puskuensis* - *Kockelella manitoulinensis* interval and the *Pranognathus tenuis* Zone. The last one, identified by Aldridge and Schönlaub (1989) as a subzone, is distinct and widespread to be treated as a zone.

Based on the morphology of the zonal fossil the *Pterospathodus celloni* Zone can be divided into a lower and upper part. Further, the lower part includes three distinct intervals: the *Astropentagnathus irregularis*, the *Aulacognathus kuehni* and the *Apsidognathus tuberculatus* ssp. n. intervals. The upper boundary of the *P. celloni* Zone needs to be redefined, and an *P. amorphognathoides lithuanicus* interval is recognized between the *P. celloni* and *P. a. amorphognathoides* zones. The extinction of *O. polinclinata estonica* is an additional indication of the upper boundary of the *P. celloni* Zone.

The lower boundary of the *P. a. amorphognathoides* Zone is marked by the appearance of *P. a. amorphognathoides*. The appearance of *O. p. polinclinata, Apsidognathus ruginosus* and *Pseudooneotodus bicornis* are other indicators of this boundary. The upper boundary of the *P. a. amorphognathoides* Zone is drawnl according to Jeppsson (in press) and corresponds to the extinction level of *Nudibelodina sensitiva* (= the 1st datumplane of the Ireviken Event). For the Llandovery sequence above this level, and also for the lower Wenlock, a detaied conodont zonation is proposed by Jeppsson (in press).

The above listed conodont zones and intervals are recognizable in most known conodont sequences. Where only inadequate collections are available a less detailed zonation including the following "superzones" may be useful: *D. kentuckyensis, P. celloni* and *P. amorphognathoides*.

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On the *Loganellia taiti* Zone

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H.C. Stetson (1931) described *Loganellia (=Thelodus) taiti* from the Downton of Scotland. Now these beds are treated as belonging to the Wenlock Waterhead Group (Ritchie, 1985).

W. Gross (1967) and P. Turner & S. Turner (1974) also studied the fragments and scales of *L. taiti* from Scotland and Norway, correspondingly, but did not find in their material characteristic spiny scales figured by Stetson. Following them Märss (1982, 1986) described the scattered scales and established the *L. taiti* Zone in the Jaagarahu Stage of the East Baltic Wenlock. Later on the zone was used in the correlation of coeval strata of the West Baltic (Gotland), Norway, Timan-Pechora Region and Severnaya Zemlya.

Fredholm (1990) examined articulated, but not type specimens of *L. taiti* and showed that the Baltic species under discussion cannot be considered *L. taiti*. She distinguished *Loganellia grossi* n.sp. without revising the zonal scheme. Märss (1990) considered it preliminary to change the name of the zone before the revision of the genus Loganellia and redescription of *L. taiti*.

The results of the investigation of Scottish articulated thelodonts (Ritchie, Märss, in prep.) allow to presume the absence of *L. taiti* (Stetson) in the Baltic Wenlock. Nevertheless, similar tiny scales, which carry up to five longitudinal ridges, projecting over the posterior end of the crown as short spines and which could belong to *L. taiti*, are common in the Tahula Beds of the Kuressaare Stage, Ludlow of Estonia. The osteostracan *Procephalaspis* from the Paadla Stage, Ludlow, has the sculpture on the scales resembling *Ateleaspis*. Other vertebrates (*Birkenia* spp., *Lasanius* sp. and *Lanarkia* spp.) of Scotland, Waterhead Group, Wenlock, have not been found in the Baltic.

In the vertebrate zonal scheme the name *L. taiti* must be replaced by *L. grossi*. The *L. grossi* Zone corresponds to the *lundgreni* and lowermost *nassa-ludensis* standard graptolite zones and is recorded from the Baltic, Norway, Timan-Pechora Region and Severnaya Zemlya.

References

Fredholm D. 1990. Agnathan vertebrates in the Lower Silurian of Gotland, Sweden. Geol. För. i Stockholm Förh., 112, 1, 61-84.

Gross W. 1967. Über Thelodontier-Schuppen. Palaeontographica, Abt. A, 1-67.

Märss T. 1982. Vertebrate zones in the East Baltic Silurian. In: Kaljo D. and Klaamann E (eds). Ecostratigrapgy of the East Baltic Silurian. Tallinn, 97-105.

Märss T. 1986. Silurian vertebrates of Estonia and West Latvia. Tallinn, 104 pp.

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Märss T. 1990. Vertebrates. In: Kaljo D. and Nestor H. (eds). Field Meeting. Estonia 1990. An Exursion Guidebook. Tallinn, 93-95.
Ritchie A., Märss T. (in prep.). Silurian and Devonian thelodonts of Scotland.
Stetson C.H. 1931. Studies on the morphology of the Heterostraci. J. Geol. 39, 2. 141-154.
Turner P. and Turner S. Thelodonts from the Upper Silurian of Ringerike, Norway. Norsk Geol. Tidsskr., 54, 183-192.

Graptolite Extinction at the Llandovery-Wenlock Boundary

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Graptolites are diverse and well-documented through the Late Llandovery (Telychian) and Early Wenlock (Sheinwoodian) of the Canadian Arctic Islands, British Isles and Lithuania. Published data allow the subdivision of this time interval into 14 zones and subzones, eight in the Telychian, six in the Sheinwoodian, that are correlatable between the three regions. These areas show comparable species diversities through most of this time interval.

Combined graptolite range data through this time interval reveal that survivorship rates from one zone to the next are between 56 and 85%. The only exception is the Llandovery-Wenlock boundary, in which only 19% of the taxa of the upper *sakmaricus/crenulata* Zone (8 of 42) survive into the *centrifugus* Zone.

Global sea level curves for this interval show a very high eustatic sea level stand in the late Telychian dropping rapidly to a low stand in the earliest Sheinwoodian, followed by a transgression. This has been attributed by some authors to continuing fluctuation of glacial activity in Gondwana during this time interval. The high rate of graptolite extinction that accompanies these sea level changes, as with the Ashgill graptolite extinction, may be attributed to changing oceanic temperatures, circulation patterns, oxygenation and/or productivity associated with the onset of a glacial maximum event.

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Middle Ludfordian Event in Brachiopod Evolution in the European Province

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Ludfordian shallow water carbonates exposed at the north-eastern part of the European platform, Urals and Arctic islands contain rich brachiopod communities (BA-2) dominated by athyrids and atripids. Comparatively monotonous lithology in the sections studied (the Gerdju regional stage) allow to recognize complete stratigraphical ranges of genera that makes possible a reconstruction of their phylogeny. The *Greenfieldia-Didymothiris* lineage members associate with other anthyrid genera such as *Squamathyris* and *Homeathyris*, posessing by the complicate internal structure similar to *Didymothyris*. All above genera undergo a step-wise extinction at mid-Ludfordian time and they give rise to completely new brachiopod fauna, which includes rhynchospirinids, spiriferids and rhynchonellids alongside with a few advanced athyrids. The distinct diversification event at species level takes place among Ludfordian atrypids at the same time. These profound changes in taxonomic composition were used for drawing a boundary between the Gerdju and Greben regional stages.

Along the western and south-western margins of the European platform (Baltic and Podolia) the middle Ludfordian extincion event followed by radiation may be partly recognized within the shallow - water deposits because of uncomplete stratigraphical ranges of diagnostic brachiopod genera due to frequent facial changes. It seems that the diversity changes observed in brachiopod evolution have good potential for correlation of late Ludlow shelf deposits within the whole European province.

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The *P. acuminatus* Biozone in the Silurian of Barrancos Region (Ossa Morena Zone, South Portugal)

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The graptolite assemblage indicating the basal Silurian *P. acuminatus* Zone has been found in the Barrancos region (south Portugal) in the Ossa Morena Zone.

Badly tectonized lydites intercalated by black shales and, in the lowermost part of the sequence, with subordinate sandy levels, yielded determinable graptolites: *Parakidograptus acuminatus, Normalograptus trifilis, Normalograptus* cf. *medius*, and *Neodiplograptus* sp. (aff. *elongatus*).Owing to the presence of *Normalograptus trifilis* the assemblage may be refered to about the middle of the *P. acuminatus* Zone.

This is the first record of the *P. acuminatus* Zone in Portugal and the third one in the whole Iberian Peninsula. Wherever the graptolites of the *P. acuminatus* Zone were found, they were either at shaly intercalation near the top of the underlying sandstone unit. Both the graptolite assemblage of the *P. acuminatus* Zone and the facies development of the earliest Silurian of Barrancos region can be well compared with the corresponding sections in Spain, Germany, Bohemia, Bulgaria, Albania, Serbia, and Sardinia.

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Llandovery-Wenlock Boundary Interval in the Graptolite-rich Sequence of the Barrandian Area (Bohemia)

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In the Barrandian area continuous sections through the graptolite-rich Llandovery-Wenlock boundary strata have been examined bed by bed. *Stom. grandis, Cyrt. insectus, Cyrt. centrifugus,* and *Cyrt. murchisoni* zones have been studied and 43 graptolite taxa have been found in this interval. Graptolite taphocenoses account for gradual increase in species diversity, without any prominent radiation and/or extinction events.

Despite this statement several well determinable species of promising correlative potential appear at about the base of the *insectus* Zone (*M. kolihai, M. kodymi, M. pseudocultellus, Mcl.basilica, Mcl. chuchlensis, Cyrt. insectus*, and *Ps. giganteus*).The base of the succeeding *centrifugus* Zone lacks such distinct faunal change.

The base of the Wenlock Series was formally placed at the base of the *centrifugus* Zone. Graptolite evidence of the *centrifugus* Zone, however, is insufficient in the type area, being based on the presence of *Pr. watneyae* and *Mcl.* aff. *vomerina* the stratigraphic range of which is not well known.

In general the graptolites are neither common and diverse in the type Wenlock area and precise correlation with graptolite-rich sequences is difficult. Graptolite zones equal to the *grandis* and *insectus* Zones of Bohemia, for instance, have not yet been recognized in Britain.

According to the graptolite successions elsewhere (Bornholm, Arctic Canada, China, Poland) *Cyrt. insectus* occurs along with or in the lower part of stratigraphic range of *Cyrt. centrifugus.* In the Barrandian area *Cyrt. insectus* clearly precedes *Cyrt. centrifugus.* Here the first *Cyrt. insectus* is accompanied by a distinct change in the associated graptolite fauna as opposed to a very minor change at the base of the *centrifugus* Zone. The faunal change at the base of the *insectus* Zone in Bohemia is comparable with that observed at the base of the *centrifugus* Zone where the *insectus* Zone is not recognized. That is why in Bohemia the base of the Wenlock Series is placed traditionally at the base of the *insectus* Zone.

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Upper Silurian Graptolite Zonation of the Polish Part of the East European Platform

Lech Teller[1]

The Paleozoic sedimentary cover of the Polish part of the EEP was recognized on an area about 100.000 km^2. It did not underwent faulting during the Caledonian time. Their boundary with the Paleozoic platform runs obliquely along the Tornquist-Teisseyre lineament from Koszalin in the NW to Ruda Lubycka in the SE.

The sedimentary cover was penetrated by hundreds or so deep boreholes mainly in the 50-70s.The Silurian was pierced or only stated in most of the boreholes. Two main, almost fully cored wells the Mielnik IG.1 located in the Podlasie Depression and the Chelm IG.1 drilled in the Bug depression contains very rich Upper Silurian graptolites. The Mielnik IG.1 graptolites were worked out already in the 70s by Urbanek (1966,1970,1971) but the late Ludfordian assemblage was finished last year.The Chelm IG.1 graptolite zonation was published in 1964 (Teller 1964) but their revision has been undertaken also last year. Both sections and their graptolite content are standard one for Ludlow and Pridoli Series of the Polish biostratigraphical graptolite zonation. They can be correlated with almost all sections all over the world where the time equivalent sediments with graptolites are present (the Prag Basin, Podolia and Wolhynia, Tian-Shan, Kazakhstan, Arctic Canada). The following standard graptolite zonation is proposed for the Polish Ludlow and Pridoli Series:

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Standard Graptolite Zonation for the Polish Ludlow and Pridoli (L. Teller)		
PRIDOLI		TRANSGREDIENS
		PERNERI
		BOUCEKI
		SAMSONOWICZI
		CHELMIENSIS
		LOCHKOVENSIS
		ULTIMUS
		PARULTIMUS
LUDLOW	Ludford	SPINEUS
		ACER
		BALTICUS
		KOZLOWSKII
		INEXPECTATUS
		AURICULATUS
		LEINTWARDINENSIS
	Gorstian	SCANICUS
		NILSSONI

The Wenlock/Ludlow Boundary Based on Biostratigraphical and Geophysical Data of Poland

E. Tomczykowa[1] & H. Tomczyk[2]

Silurian deposits in Poland of the graptolite facies are some of the best developed in the world which has long entitled the authors to express their opinions on stratigraphy and further more to define the boundaries of stages.

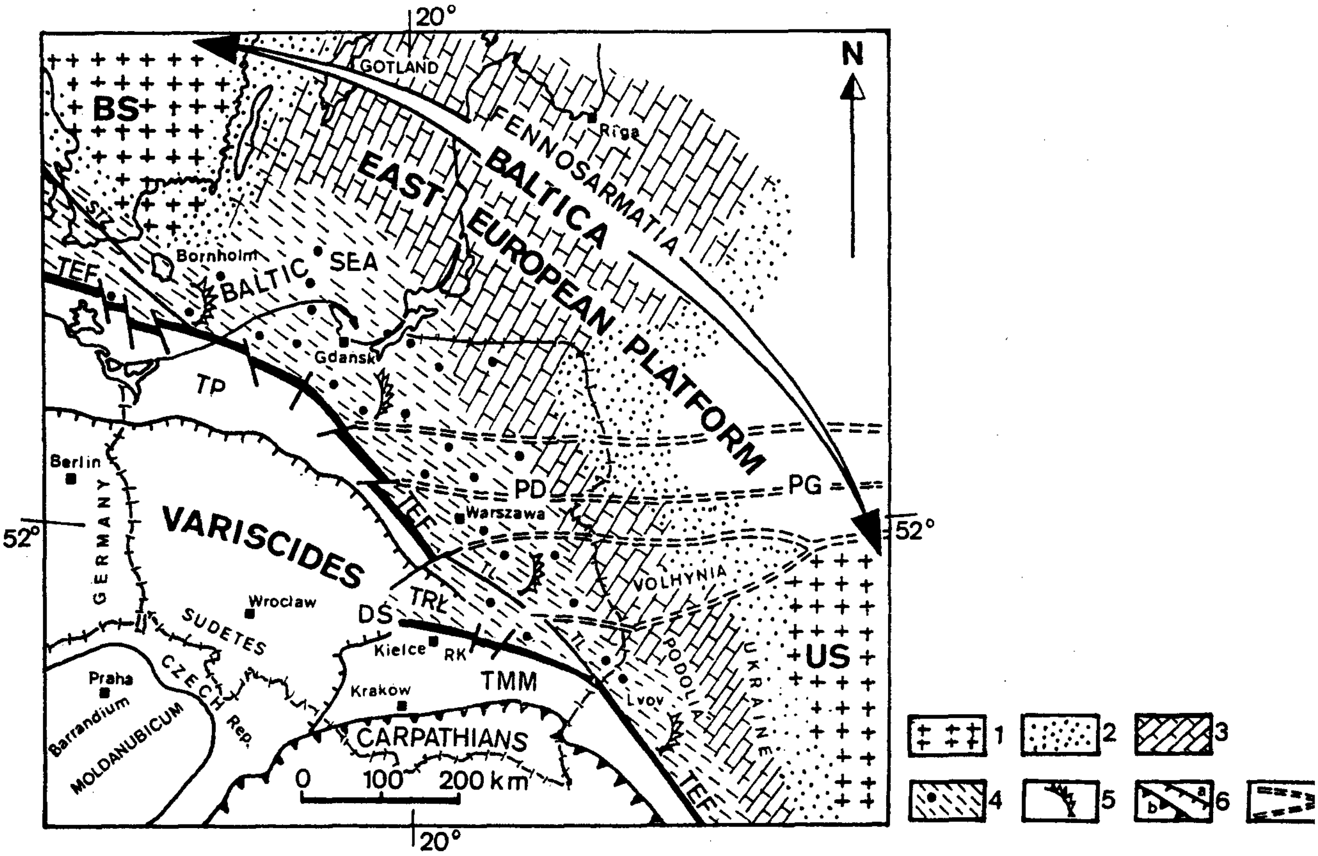

Fig. 1: The tectonic scheme and geological map of Silurian sediments of the Poland. 1: crystalline basement; 2: shelf deposits mainly terrigenous; 3: shelf deposits mainly carbonate; 4/5: clay deposits of graptolite sea or deeper continental slope with locations of the main boreholes; 6a: Front of the Variscides; 6b: Front of the Alpides; 7: Dip-slip fault and strike-slip zones of Bretonian phase movements. BS: Baltic shield; US: Ukrainian shield; TEF: Trans-European Faultbordered the East European Platform from the South-West; TL: Teisseyre Line; STZ: Sorgenfrei-Tornquist Zone; PD: Podlasie Depression; PG: Prypets Graben; TP: Pomeranian terrane; TRL: Lysa Góra Region terrane; DS: Swietokrzyska Holy Cross dislocation; TMM: Malopolska Massif terrane including RK: Kielce Region.

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The boundary between the Wenlock and the Ludlow at the base of *nilssoni* Zone which has recently been launched by the British geologists, is not commonly accepted. This boundary should be retained according to the criteria worked out by the outstanding British researchers G. Elles and E. Wood (1901-1918), namely between *Cyrtograptus lundgreni* and *Monograptus vulgaris* Zones (sensu lato).

Detailed studies of the *lundgreni* graptolite assemblage made possible the inclusion of *testis* Zone only in the Wenlock (Tomczyk, 1956-91). Towards to the end of its range the majority of graptolites mainly Wenlockian in age have dissappeared, bringing their stage of development to the end *Testograptus, Cyrtograptus, Monoclimacis; flexilis* and *flemingi* groups and others. These facts were also noticed by Jaeger (1959, 1976) who distinguished the interval of claystones above the top of *Cyrtograptus lundgreni* Zone called *"nassa-dubius interregnum"* to which the author has also lately attributed the term "big crisis" (Jaeger 1991).

The Polish Silurian profils entirely confirm this opinion, which was many times stressed and supported by the authors (Tomczyk 1970; Tomczykowa 1988, Tomczykowa and Tomczyk 1979 a,b). The big crisis of the organic world which happened at the boundary between the Wenlock and the Ludlow was marked by the decline of graptolites and by the occurrence of new taxons of benthic fauna (*Gothograptus, Spinograptus, Plectograptus, Holoretiolites* and *Neoretiolites* and others as well as trilobites and brachiopods).

This phenomenon is observed in very numerous core profils along the Fennosarmatia (Baltica) shelf over a distance of about 1000 km (Fig. 1) mainly in Poland: south-east from Bornholm up till the Lvov Basin in the western part of Ukraine (Pozaryski and Tomczyk, 1968, 1993). The Silurian profils of this area based on the graptolite fauna shed light on the stratigraphy of the classical Silurian of the shallower carbonate shelf on the Gotland Island, in the Baltic countries, in Volhynia and Podolia and also in the Holy Cross Mts., mainly Lysa Góra Region (Fig. 1). The changes which had taken place at that time are emphasized by the distinct anomalies in the geophysical measurements *gamma* and *neutron gamma* in the logging records ranging from 4 to 10 - 14 m occurring in the *G. nassa* Zone which is dominant within the argillo-marls deposits constituting the base of the Ludlow (Tomczyk 1956, 1970, 1991; Tomczykowa and Tomczyk 1979a,b). The term of the big crisis sensu H. Jaeger (1991) has connection with the global bioevents.

A Global Chitinozoa Biozonation for the Silurian

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A global biozonation of the Silurian with chitinozoa is proposed. Each biozone is an interval range biozone defined by the first occurrence of an index species, selected among well studied, unambiguous and easily identifiable species with a relative short time range. To prevent too local distribution, the selected index species have to be recorded at least in the major Silurian palaeocontinents where usable chitinozoa assemblages have been studied: i.e. Avalonia-Baltica (already linked in the Silurian), Laurentia, Gondwana, South China. Fifteen biozones are identified with, in ascending order, seven in the Llandovery: the *fragilis, postrobusta, electa, maennili, elongata, dolioliformis* and *longicollis* Biozones, four in the Wenlock: the *margaritana, clathrata, pachycephala* and *lycoperdoides* Biozones, three in the Ludlow: the *elongata, philipi* and *barrandei* Biozones and one in the Pridoli: the *urna* Biozone. This latter is divided into 3 subzones: the *kosovensis, elegans* and *superba* Biozones. The chronostratigraphic calibration is partly provided by direct reference to the range of the chitinozoa index species in the global stratotype sections (GSSP) of Silurian series: e.g. in Bohemia (Czech Republic) for the Pridoli and in the Welsh Borderland (United Kingdom) for the Ludlow and Wenlock. When this information was not available, independent stratigraphical control was given by calibration with the graptolite biozonation or in a few cases, by conodont or trilobite biozonation. The index species and most characteristic Silurian Chitinozoa species of each biozone are illustrated and their total stratigraphic range is provided.

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The Silurian of a Western Part of the Altai-Sayan Folded Area: A Recognition of Standard Boundaries and Geological Events

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New paleogeographic reconstruction have been recently made for the Ordovician-Devonian of a western part of the Altai-Sayan folded area (YOLKIN et al., 1994, in press). The Altai-Salair basin was shown to belong that time to marginal seas of the Siberian continent. This basin was developed on the Late Precambrian and Cambrian accretionary-collisional complexes of the eastern part of the Altai-Sayan area or on baikalids and early caledonids (salairids). Exposed Silurian is represented here mainly by shallow water deposits of outer and inner shelf environments. Such general geodynamic situation on the discussed area compells to analyze Silurian Altai-Salair sections from new positions.

Silurian succession of the Altai-Salair basin is complete and is represented by marine terrigeneous and carbonate deposits. They contain the cosmopolitic diverse pelagic and neritic fauna. Dark and green shales are common here for the Llandovery; limestone are characteristic for the Wenlock and Ludlow, and red colour clastics with a limestone member inside are provisionally named as Pridoli. All these rocks constitute four clear limited sedimentary T-R cycles. Turns from regressions to transgressions are located at the bases of the Silurian, *sedgwicki* Zone (inside Aeronian), Wenlock and Pridoli Series. The second-order cycles have not been recognized. Deepening events are sharply expressed at the bases of the Silurian, *sedgwicki* Zone and Wenlock Series. They are located within a carbonate platform (or outer shelf zone). Intraformational conglomerates start a normal transgressive succession of the Siberian Pridoli. Outlined sections´ characters permit to study sea-level fluctuations and to create a sea-level curve from a sedimentological process point of view. In this case the cross-section in Altai for the Wenlock interval through two shelf zones permits to see that the deepening and transgressive events could be aligned in time.

The standard series are treated here in regional schemes as stages. However, there is no alternative for the SSS scale as an international chronostratigraphical language. The main task now is to define a stratigraphical position of the boundary stratotype levels in local schemes.

In this aspect it could be said the following: The base of the Silurian boundary is defined in Altai sections within graptolite black shales just above their sharp contact with Upper Ordovician reef limestones. This boundary is documented by ranges of *G. persculptus* and *A. acuminatus*. Next two series (Wenlock and Ludlov) boundaries are supported only by shelly fauna and by deepening events as well. The base of the Pridoli Series is accepted provisionally as a start of the latest Silurian transgression. The main evidence was a benthic association recovered from normal marine bedded black limestones that are located within a red colour non-fossiliferous clastic sequence.

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This association (trilobites, brachiopods) certainly belongs to the Pridoli fauna. A clear angular unconformity is fixed at the Silurian/Devonian boundary.

Utility of Standard Stage scale for the Altai-Salair Silurian is still questionable. Here it is possible to recognize by graptolites both chronostratigraphical boundaries within Llandovery Series. However they are located within lithostratigraphic units and can't be traced without findings of these fossils. The Wenlock Series is subdivided into two units together by lithology and by shelly fauna. Possibly they are aligned to the Sheinwoodian and Homerian. The Siberian Ludlow is characterized by a single benthic faunal association. Noteworthy the members of this association are widely distributed including British Islands. The lithology of this Series is homogenous - black bedded limestones, with weakly expressed trend to upwards shallowing.

So, the more important features of the Altai-Salair Silurian are: a complete succession, well expressed sedimentary cyclicity for reconstruction of sea-level curve and a presence of reach worldwide distributed graptolites (for Llandovery) and shelly fauna (for Wenlock-Pridoli).

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