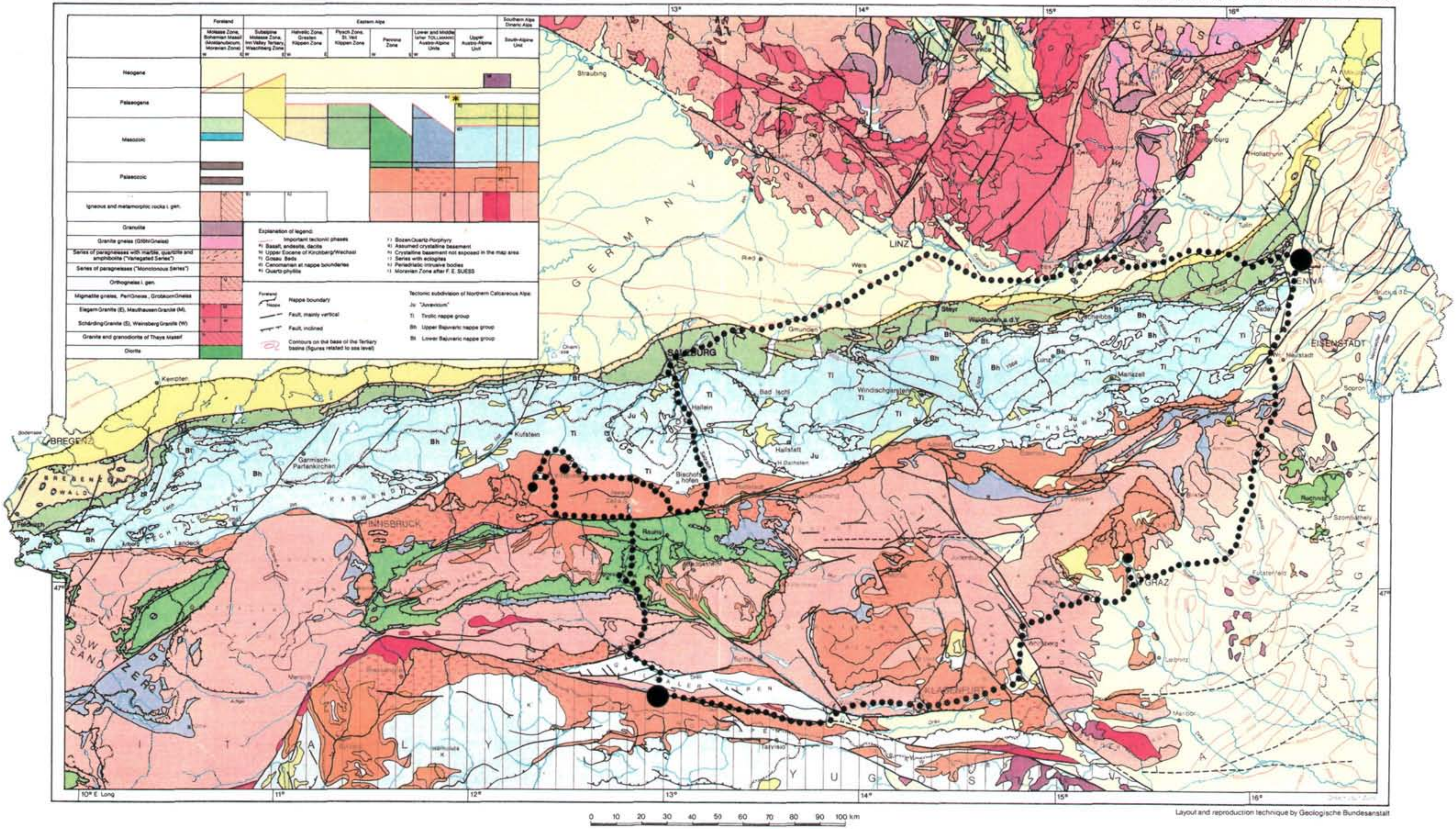
GEOLOGICAL MAP OF AUSTRIA with indication of the excursion route for the SSS Field Meeting '94

(WITHOUT QUATERNARY)

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



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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

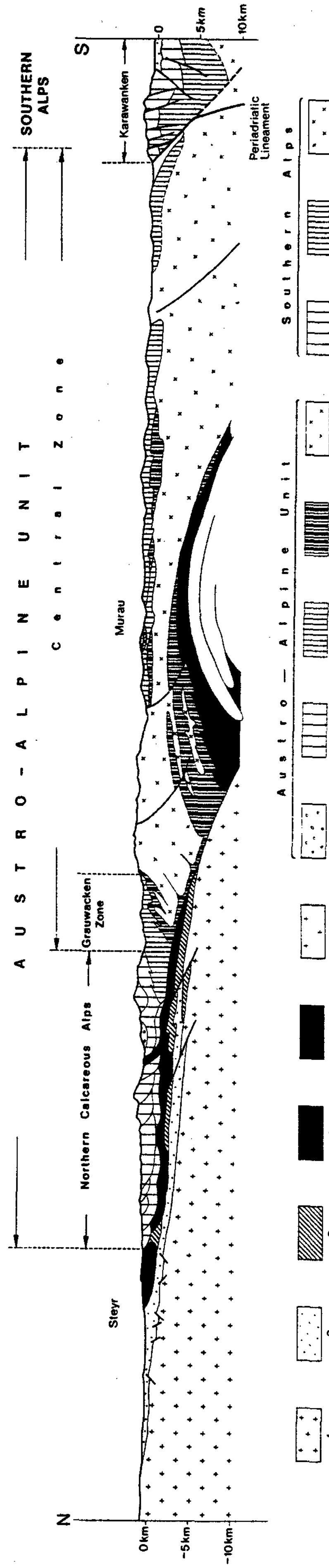

Fig. 1

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 = Paleozoic (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):

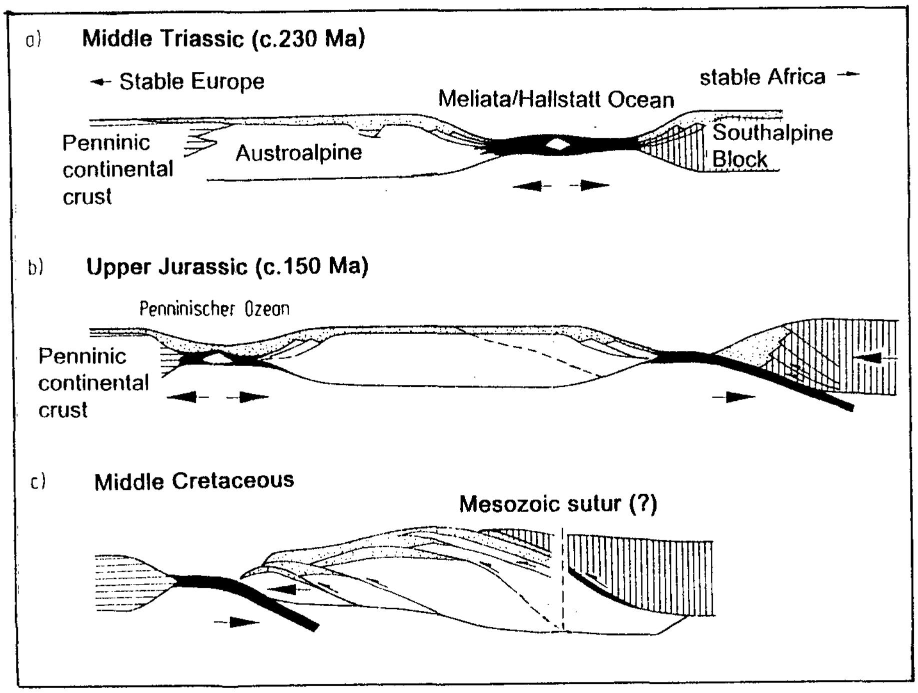

Fig. 2: Model of the early Alpine tectonic evolution of the Eastern Alps and Western Carpathians (modified after NEUBAUER 1994).

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.

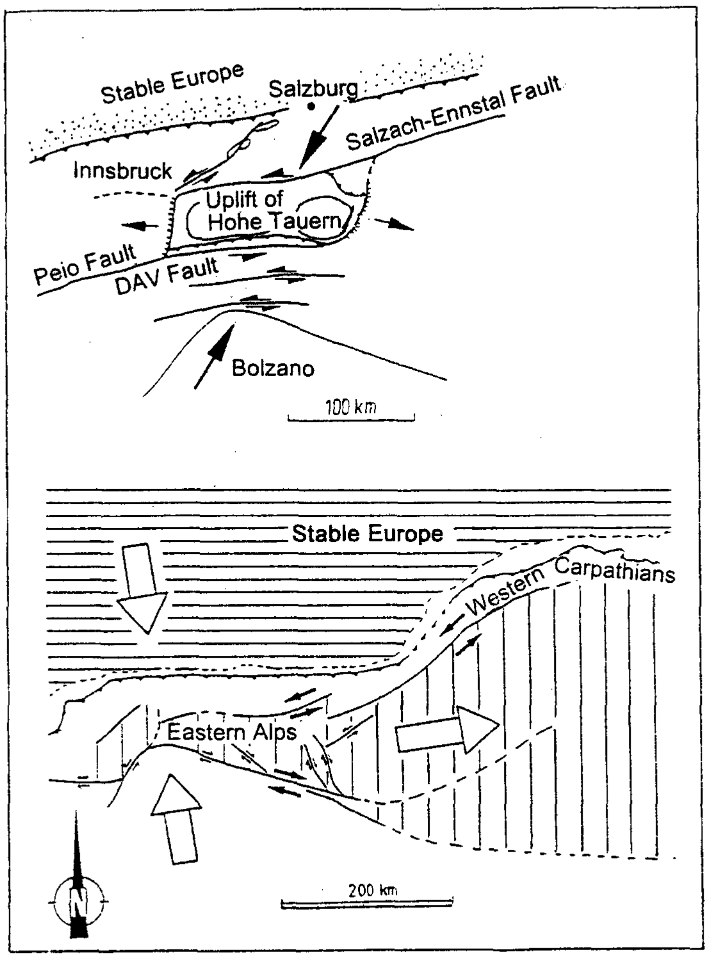

Fig. 3: Post collisional evolution of the Eastern Alps; explanation see text (modified after NEUBAUER 1994).

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)

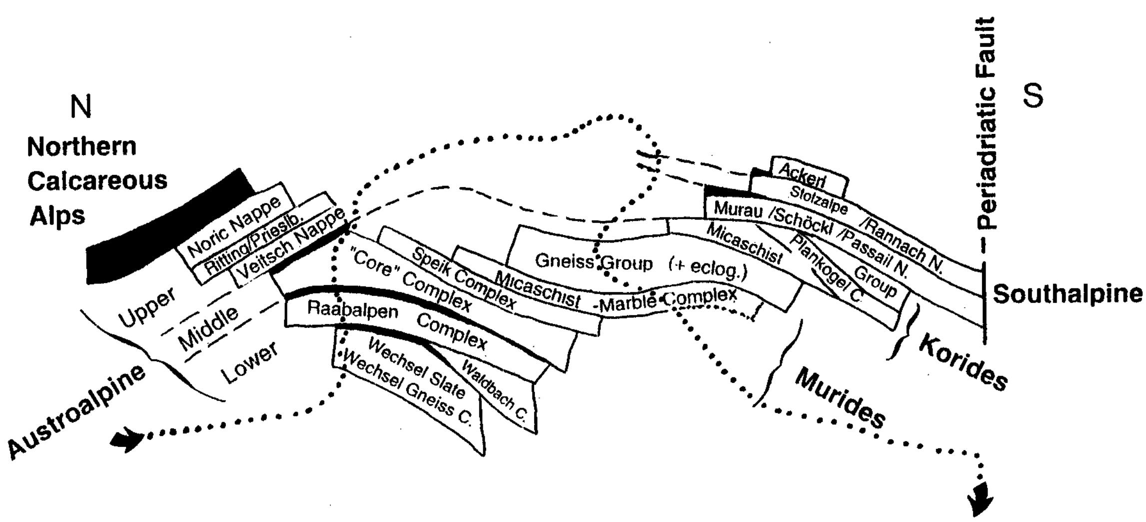

Fig. 4: Tectonic subdivisions of the Eastern part of the Alps after FRISCH et al. 1990

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.

[1] Geol. Institut der Montanuniversität A-8700 Leoben

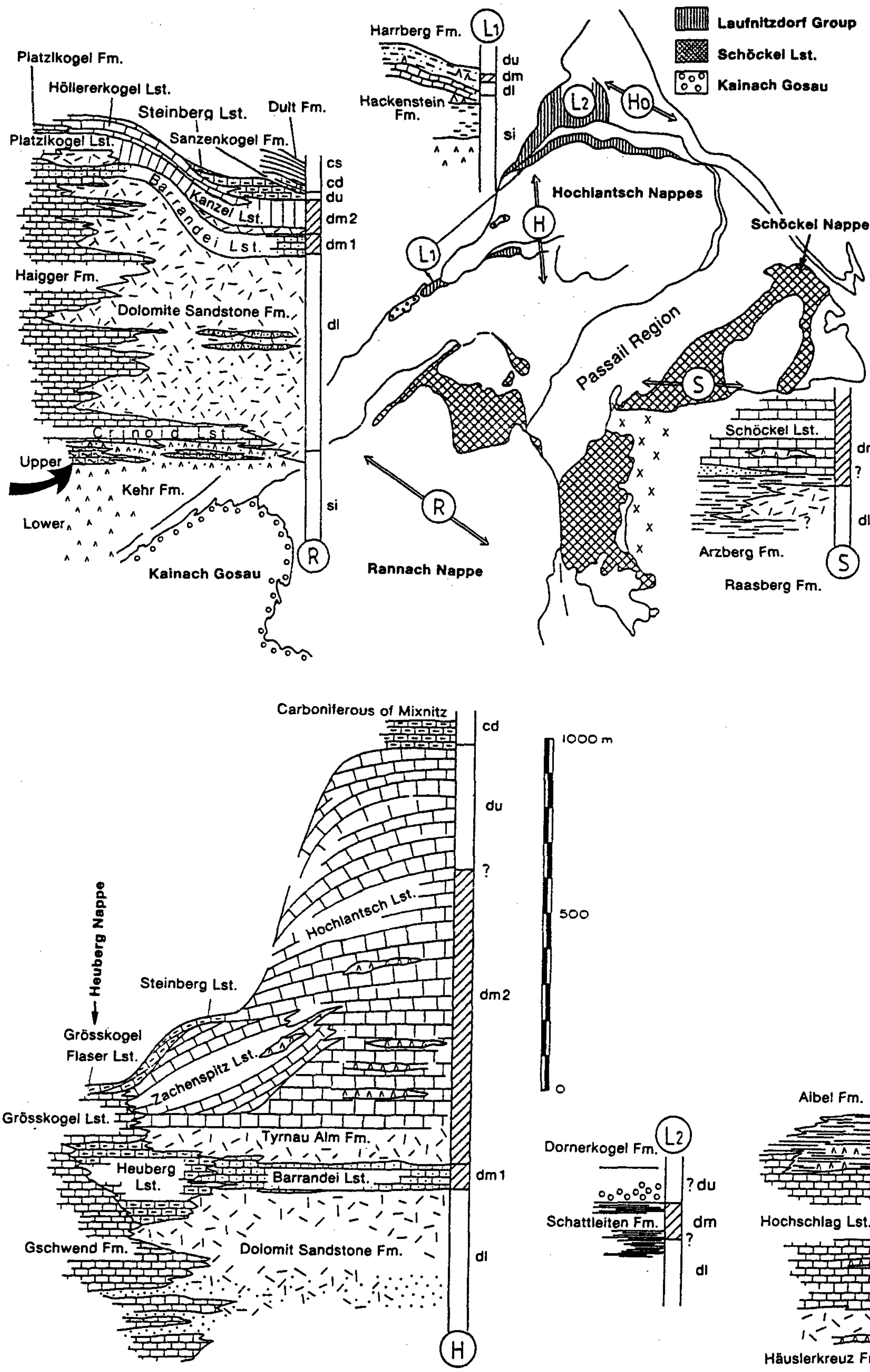

Fig. 5: Stratigraphy of the thrust system of the Paleozoic of Graz. Letters of the stratigraphic columns indicate: *R* Rannach Group; L_1, L_2 Laufnitzdorf Group; *Ho* Hochschlag Group; *S* Schöckel Group. (FLÜGEL & NEUBAUER 1984).

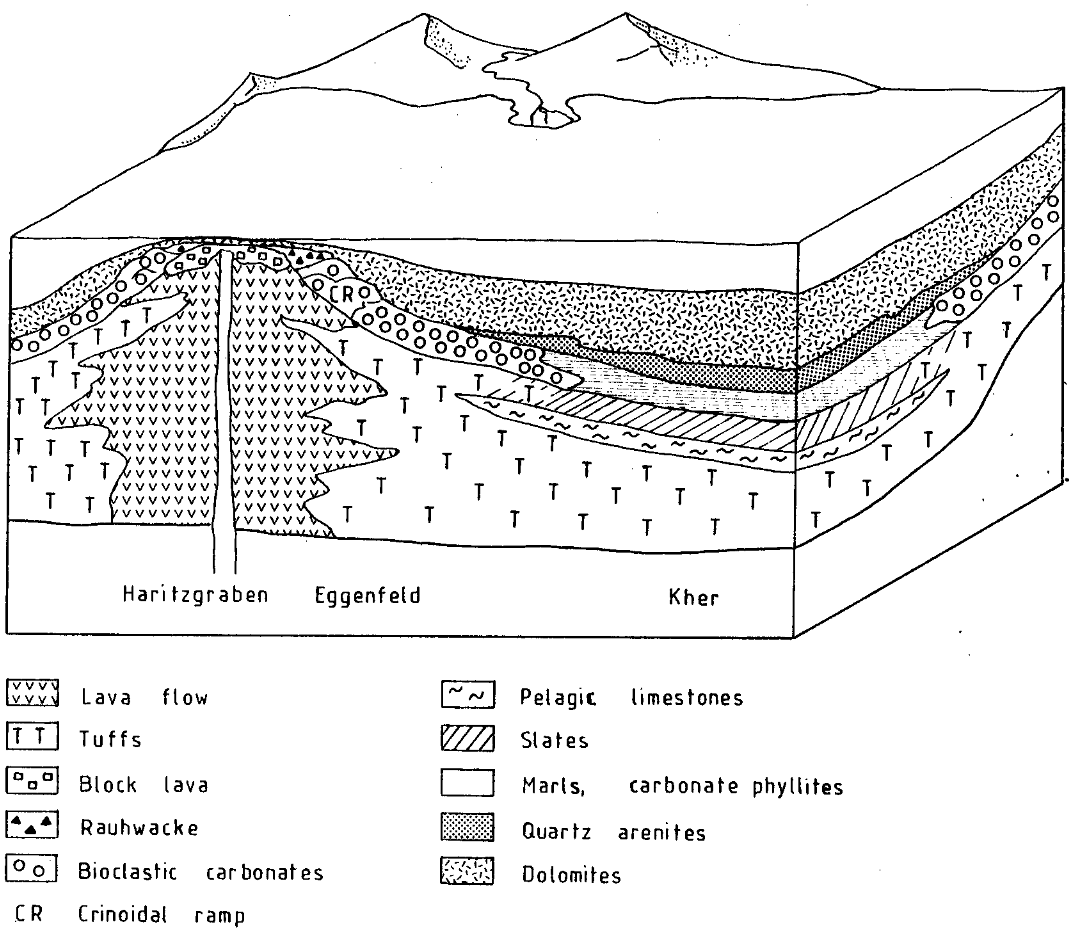

Fig. 6: Diagram showing the Middle Silurian Volcanic centers (after FRITZ & NEUBAUER 1988)

"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.

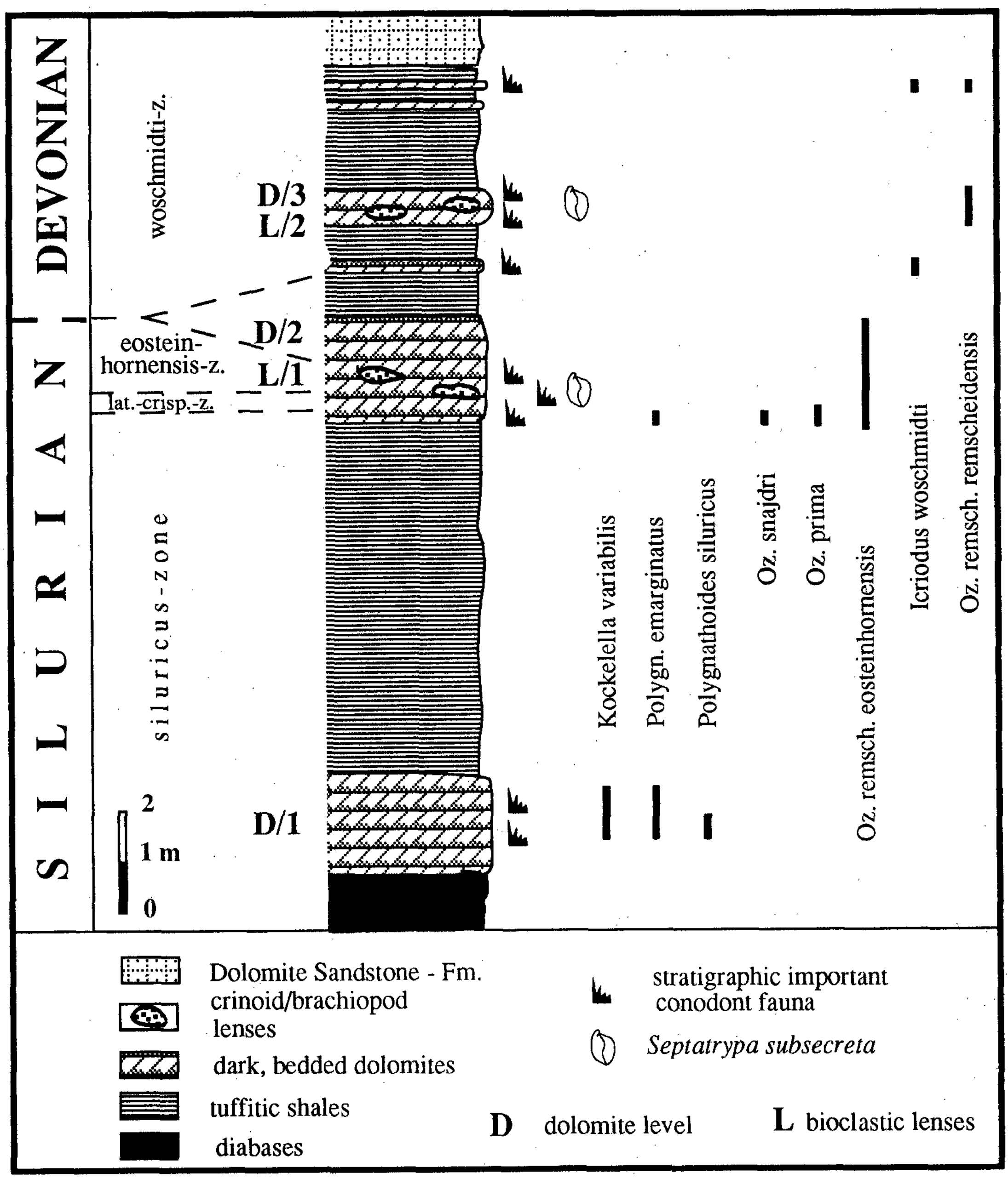

Fig. 7: Bio- and Lithostratigraphy of the Eggenfeld Section

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.

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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.

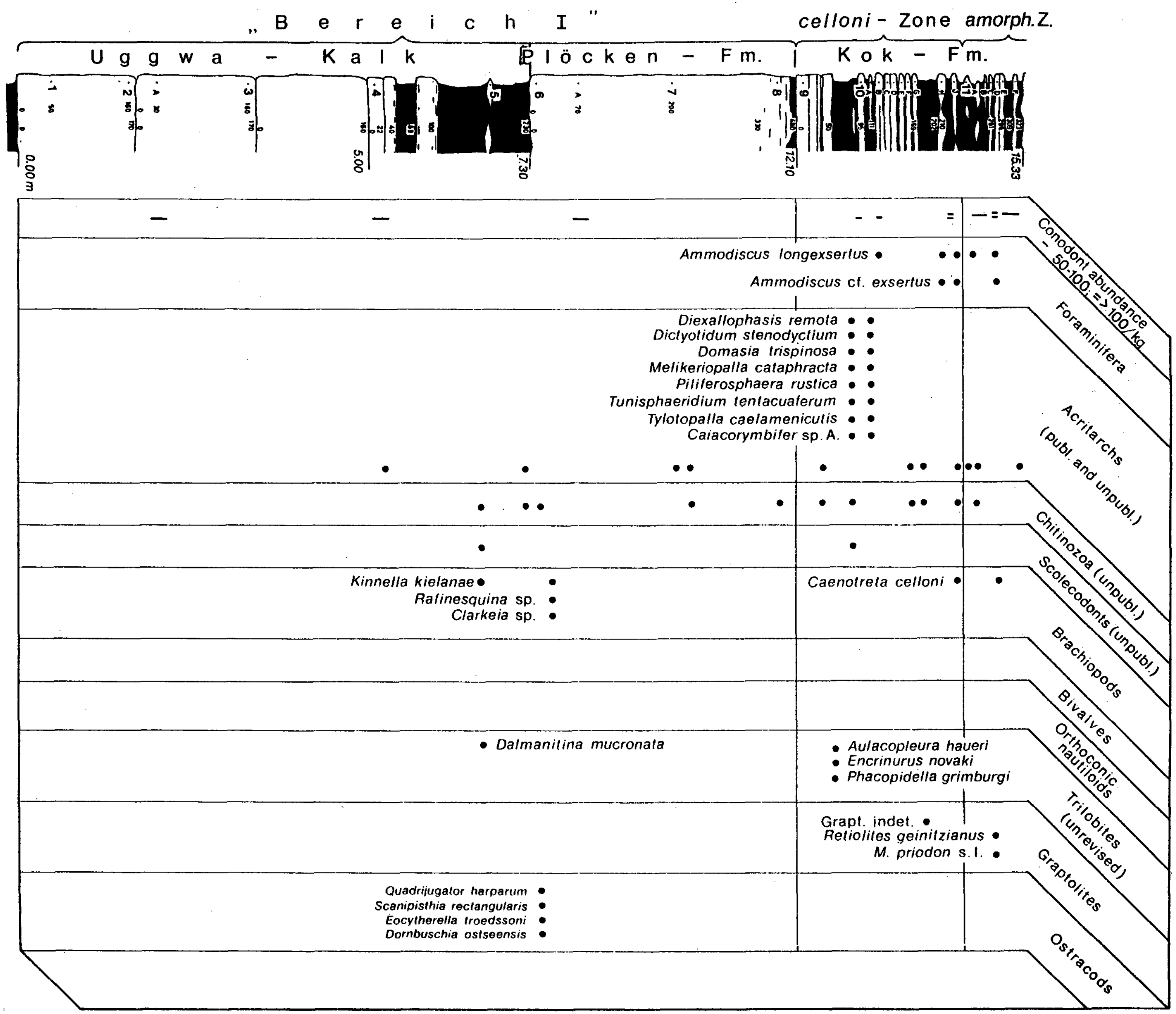
Stable Isotope Data (H.P. Schönlaub)

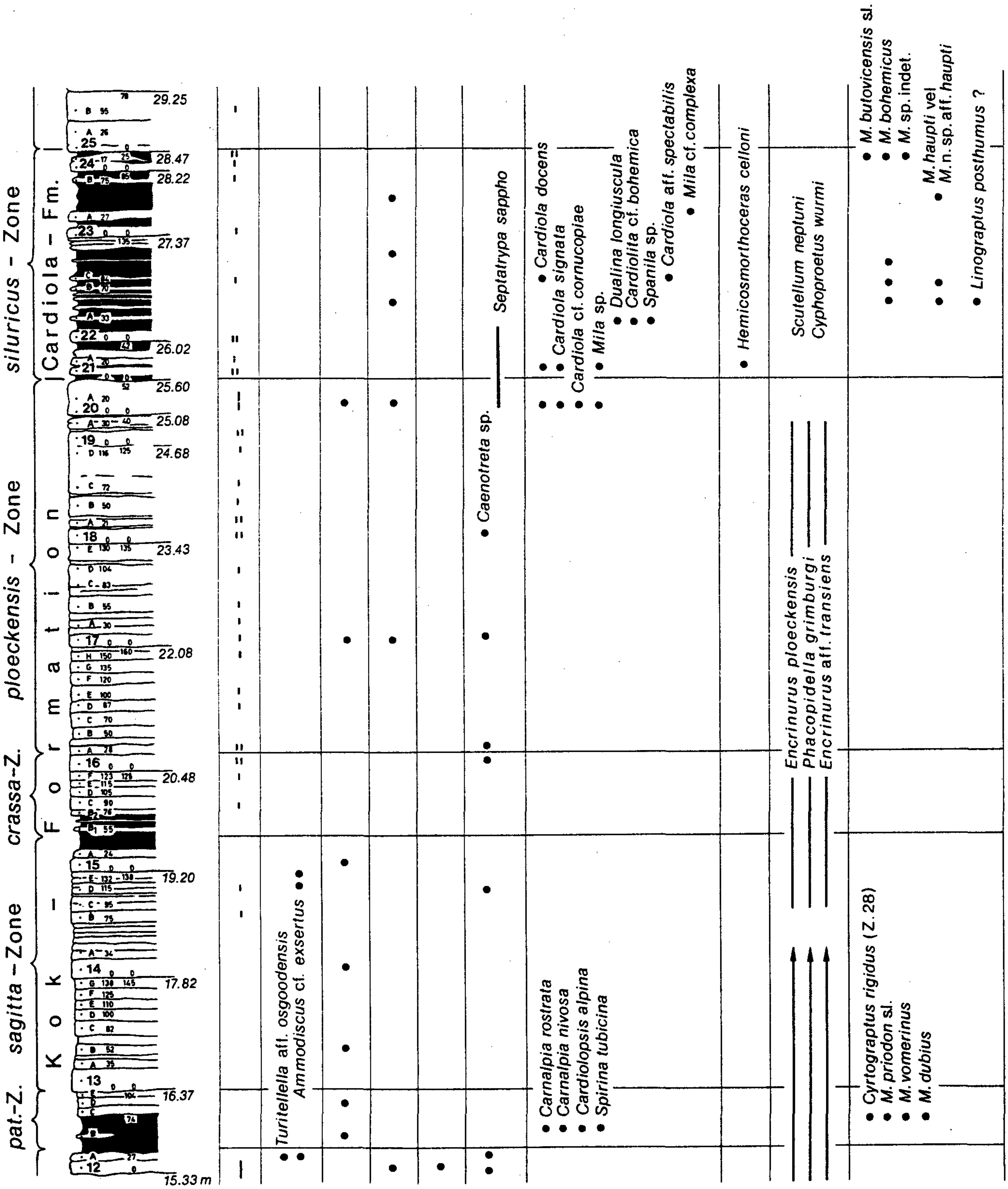
A preliminary record of carbon-13 variations (delta-^{13}C) from the Cellon section is based on some 80 samples which were kindly analyzed by W. BUGGISCH & M. JOACHIMSKI from Erlangen University. The curve shows not very prominent fluctuations although three minima apparently coinciding with shale horizons 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.

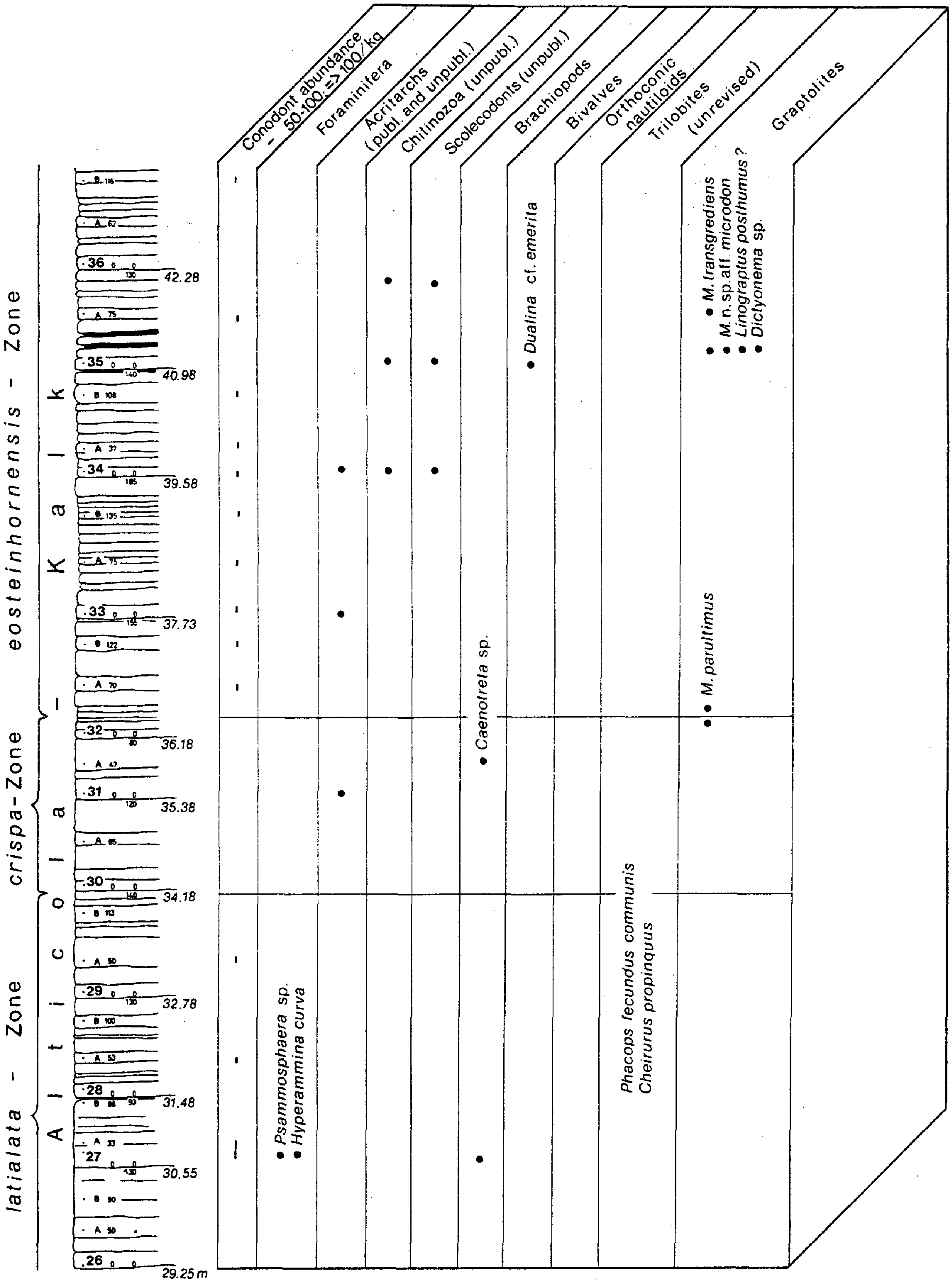
With reference to the oxygen isotopes the delta-^{18}O ratios seem to increase from low-levels in the Upper Ordovician and Lower Silurian (-9) to values about -6,5 in the interval from beginning of the Wenlock to the end of the Pridoli (measurements provided by W. BUGGISCH & M. JOACHIMSKI).

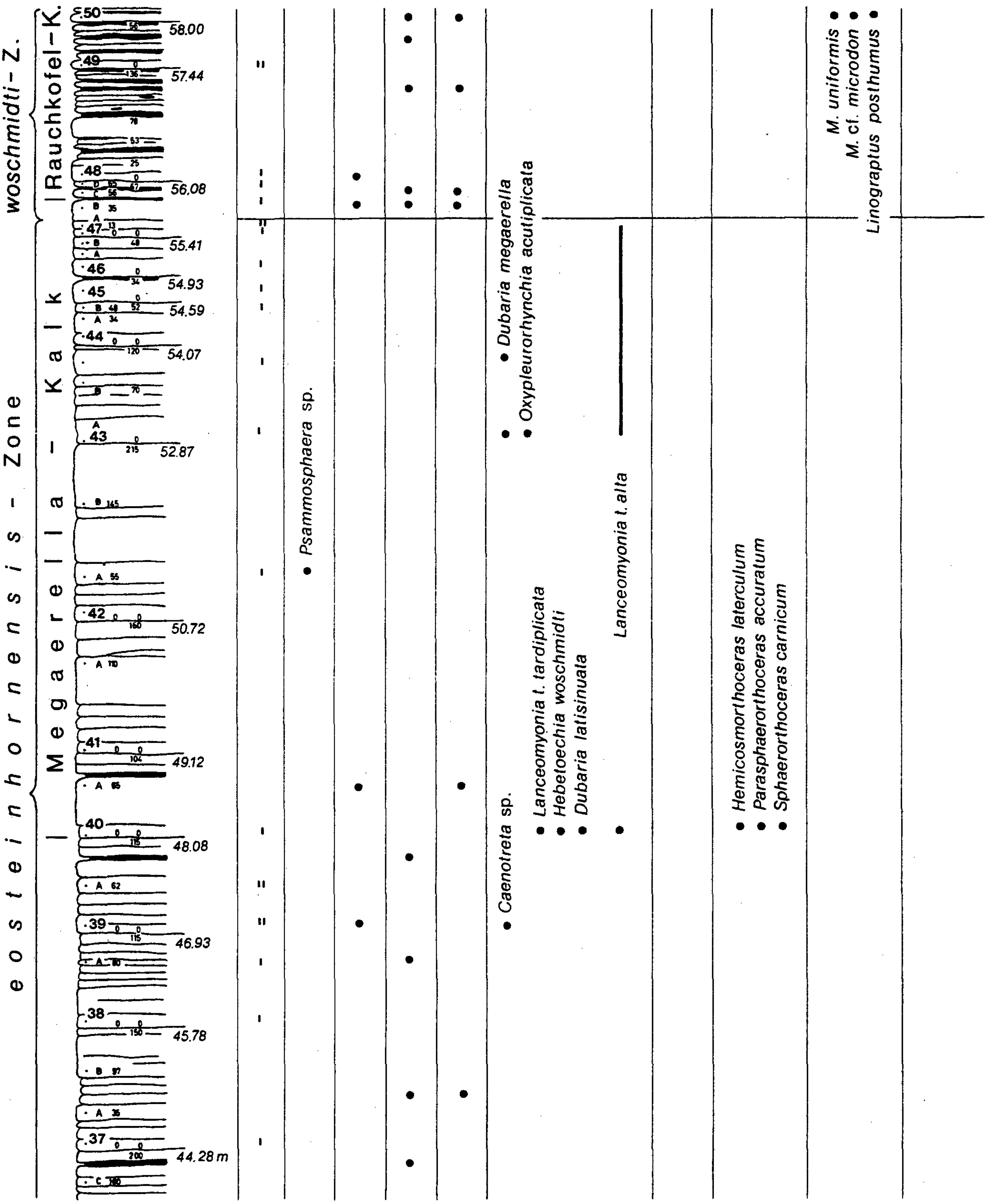
This major positive shift may either indicate decreasing temperatures or increasing delta ^{18}O of ocean water. Anyway, a similar global trend has been observed for marine cements during the interval from the late Ordovician to the end of the Silurian (see ANDERSON 1990, fig.3 in BRIGGS & CROWTHER (eds.),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


siluricus - Zone
ploeckensis - Zone
crassa-Z.
sagitta - Zone
pat.-Z.
Cardiola - Fm.
Kok - Formation
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
Cardiola docens
Cardiola signata
Cardiola cf. cornucopiae
Mila sp.
Dualina longiuscula
Cardiolita cf. bohemica
Spanila sp.
Cardiola aff. spectabilis
Mila cf. complexa
Carnalpia rostrata
Carnalpia nivosa
Cardiolopsis alpina
Spirina tubicina
Hemicosmorthoceras celloni
Scutellum neptuni
Cyphoproetus wurmi
Encrinurus ploeckensis
Phacopidella grimburgi
Encrinurus aff. transiens
M. butovicensis sl.
M. bohemicus
M. sp. indet.
M. haupti vel
M. n. sp. aff. haupti
Linograptus posthumus ?
Cyrtograptus rigidus (Z. 28)
M. priodon sl.
M. vomerinus
M. dubius


Conodont abundance
– 50-100; => 100/kg
Foraminifera
Acritarchs
(publ. and unpubl.)
Chitinozoa (unpubl.)
Scolecodonts (unpubl.)
Brachiopods
Bivalves
Orthoconic
nautiloids
Trilobites
(unrevised)
Graptolites
M. transgrediens
M. n.sp. aff. microdon
Linograptus posthumus ?
Dictyonema sp.
Dualina cf. emerita
M. parultimus
Caenotreta sp.
Phacops fecundus communis
Cheirurus propinquus
Psammosphaera sp.
Hyperammina curva
eosteinhornensis - Zone
crispa-Zone
latialata - Zone
Alticola Kalk
36
42.28
35
40.98
34
39.58
33
37.73
32
36.18
31
35.38
30
34.18
29
32.78
28
31.48
27
30.55
26
29.25 m


eosteinhornensis - Zone
woschmidti - Z.
Megaerella - Kalk
Rauchkofel-K.
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
Psammosphaera sp.
Caenotreta sp.
Dubaria megaerella
Oxypleurorhynchia acutiplicata
Lanceomyonia t. tardiplicata
Hebetoechia woschmidti
Dubaria latisinuata
Lanceomyonia t. alta
Hemicosmorthoceras laterculum
Parasphaerorthoceras accuratum
Sphaerorthoceras carnicum
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.

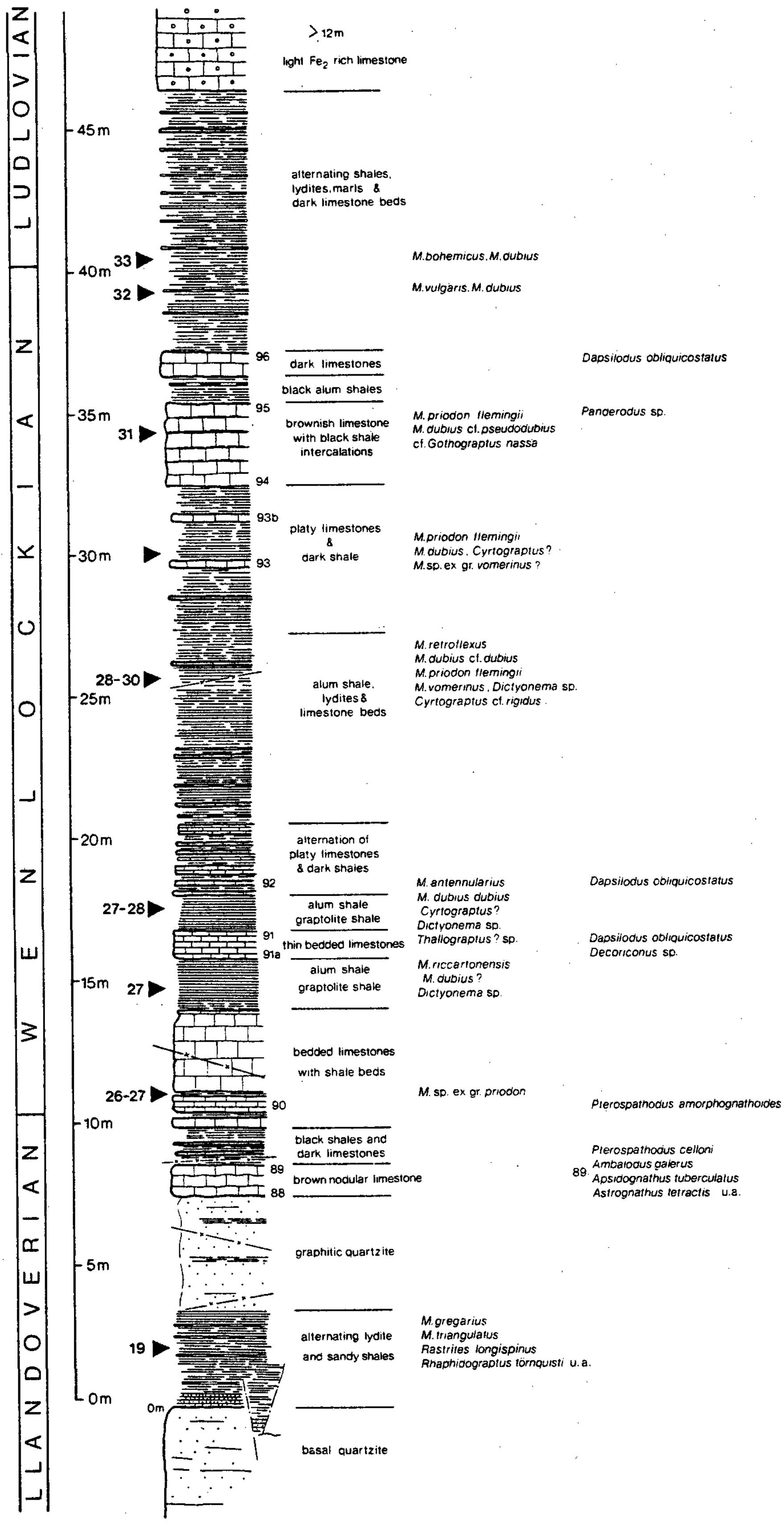


Fig. 9: The Silurian Section Oberbuchach 1. From JAEGER & SCHÖNLAUB (1980)

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.

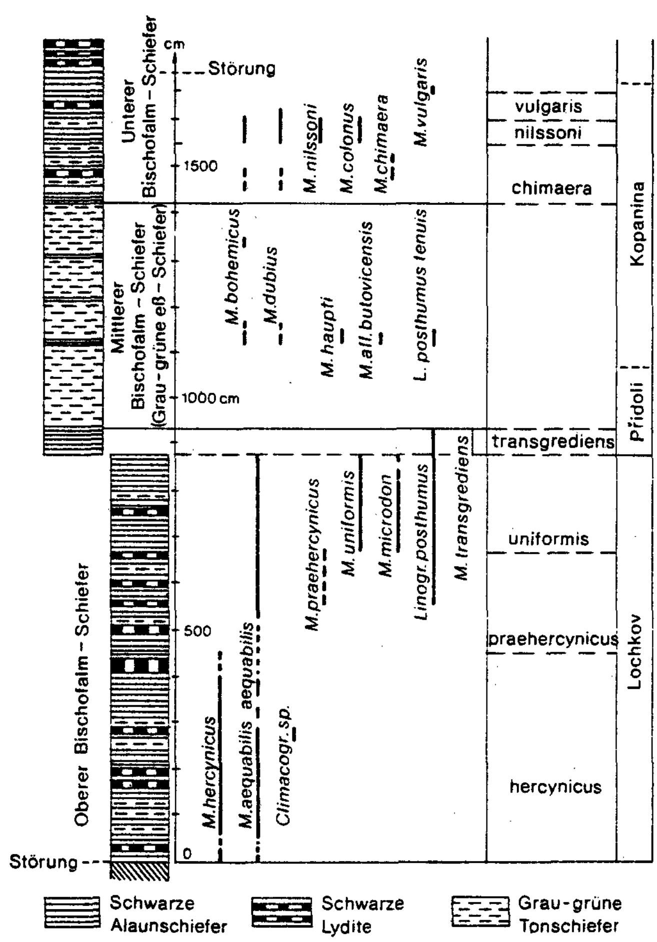


Fig. 10: Type section of the Silurian to Lower Devonian Bischofalm facies north of the upper Bischofalm ("Graptolithengraben"). After JAEGER in FLÜGEL et al. 1977, modified.

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

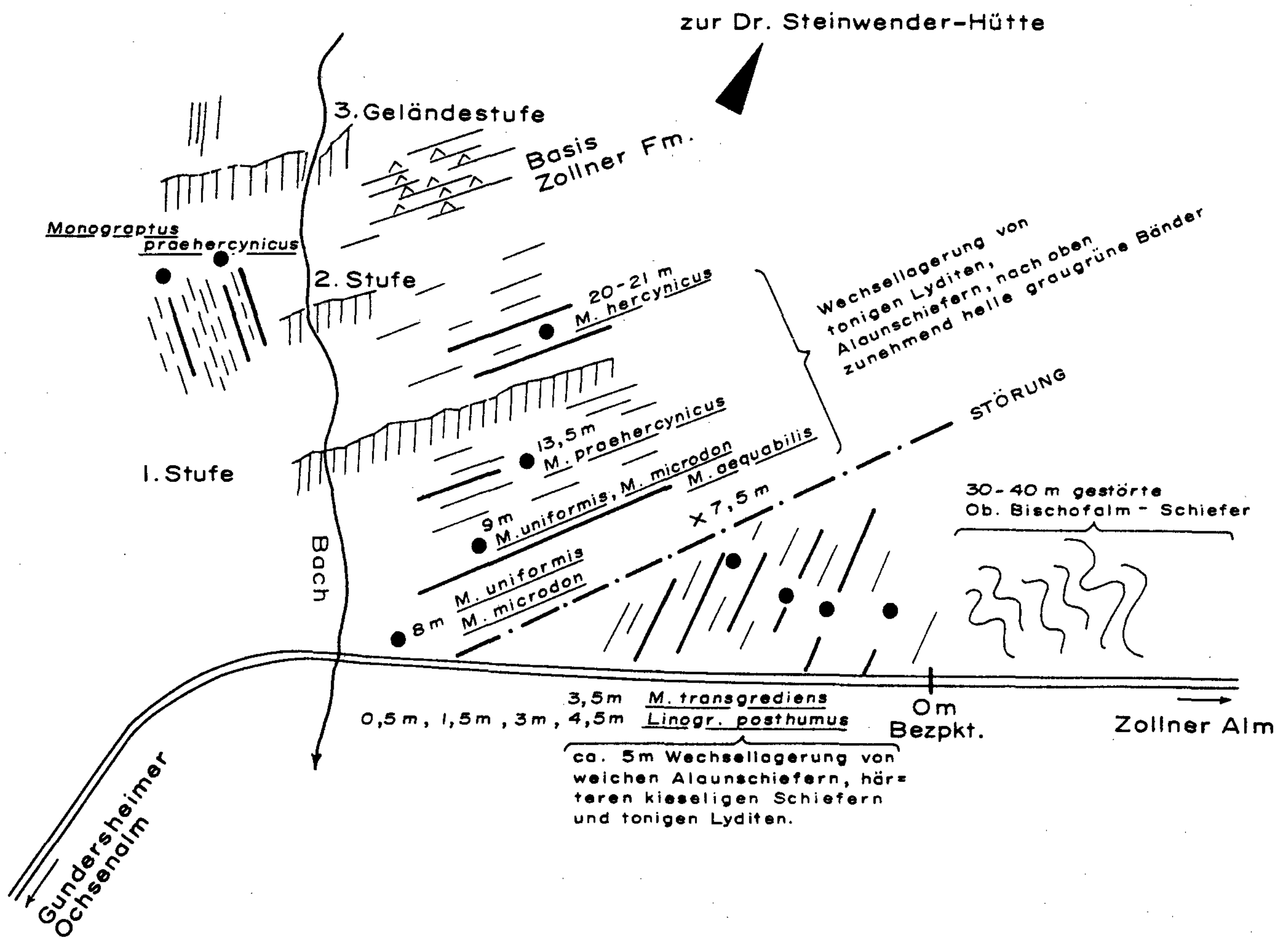


Fig. 11: The upper part of the Waterfall Section between the street and the Alpine Hut "Dr. Steinwender-Hütte" after JAEGER 1985.

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*

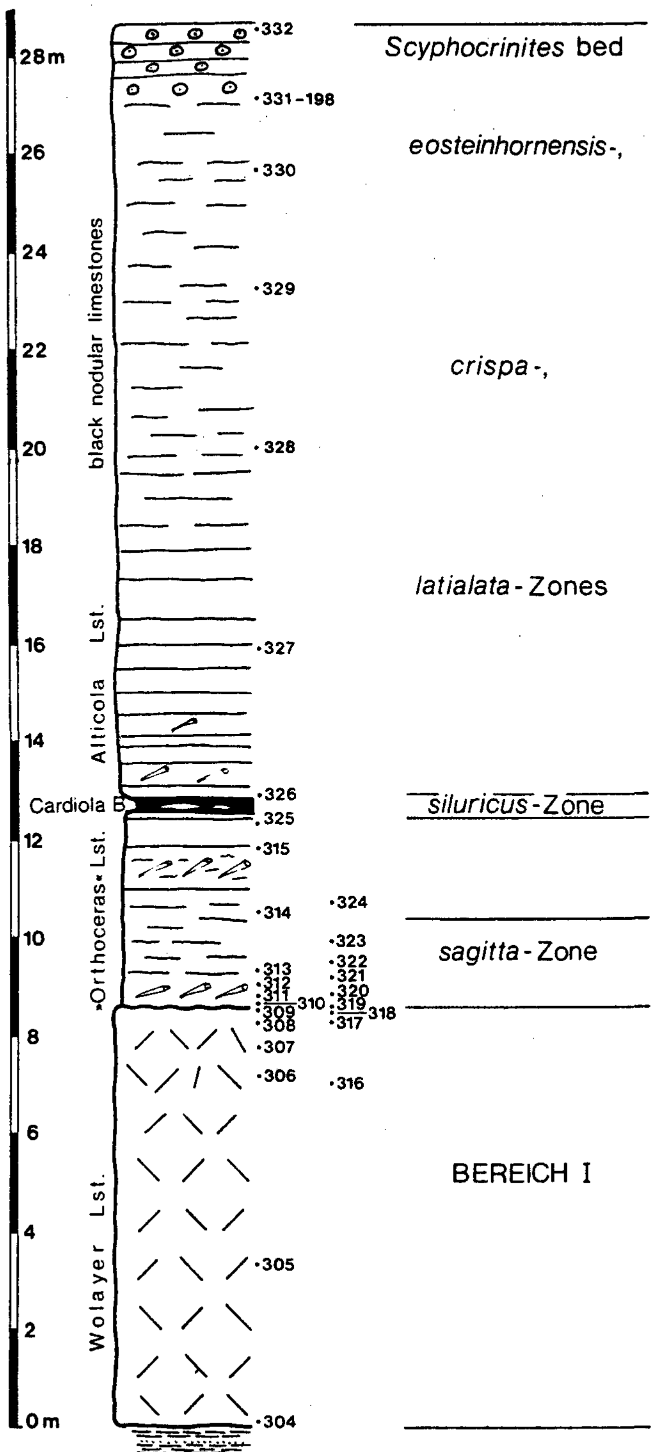


Fig. 12: The Rauchkofel Boden Section (Ordovician - Silurian part) after SCHÖNLAUB et al. 1980.

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.

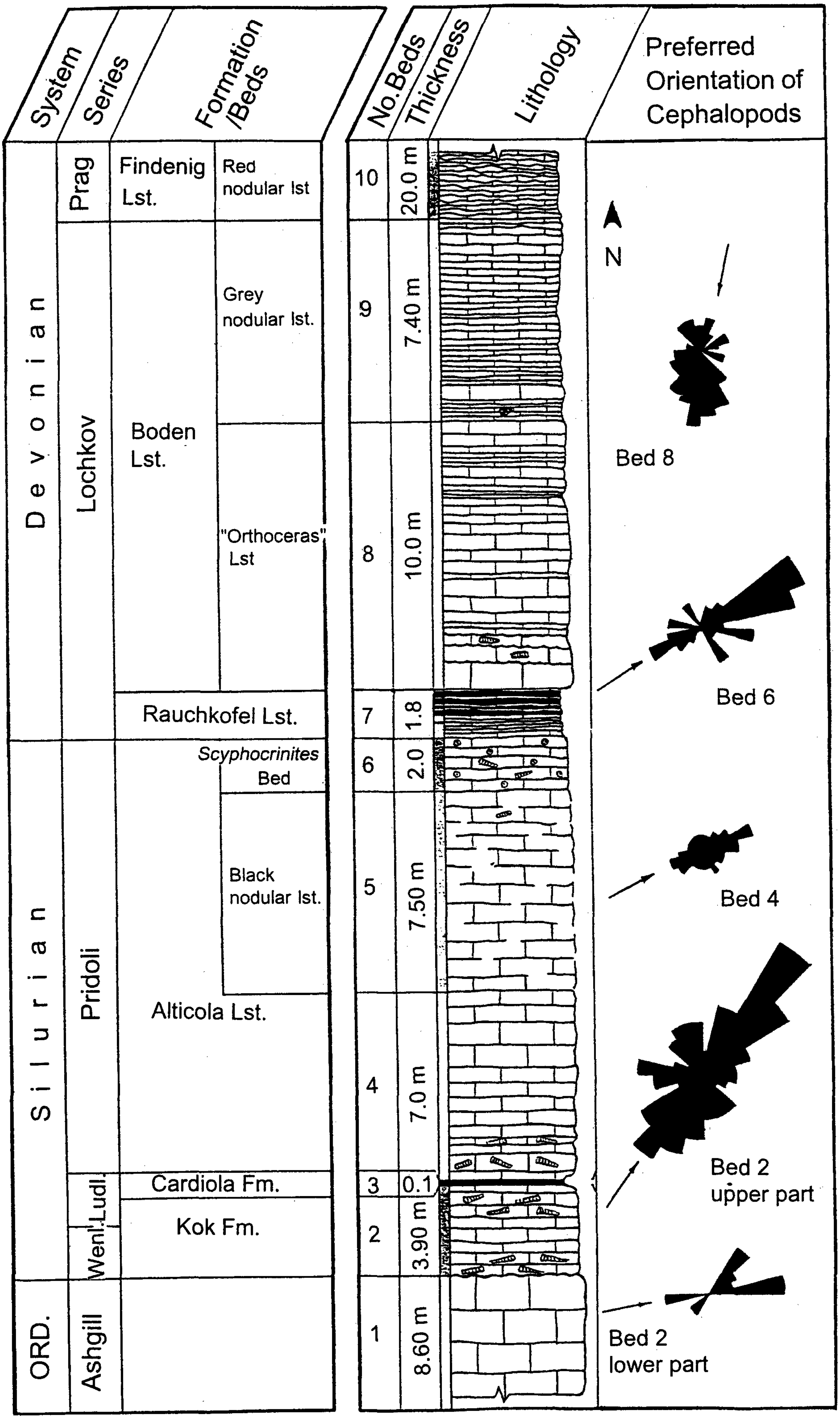
In the late Wenlock and the Upper Silurian conodonts are fairly abundant. A rich fauna representing the *O. sagitta* Zone occur from the base of the *Orthoceras* Lst. up to sample no. 313, i.e. 1.20 m above the base (fig. 12). Although resampled not a single specimen of *Ozarkodina bohemica* has yet 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
Silurian
ORD.
Prag
Lochkov
Pridoli
Wenl.
Ludl.
Ashgill
Findenig Lst.
Red nodular lst
Boden Lst.
Grey nodular lst.
"Orthoceras" Lst
Rauchkofel Lst.
Scyphocrinites Bed
Black nodular lst.
Alticola Lst.
Cardiola Fm.
Kok Fm.
10
9
8
7
6
5
4
3
2
1
20.0 m
7.40 m
10.0 m
1.8
2.0
7.50 m
7.0 m
0.1
3.90 m
8.60 m
N
Bed 8
Bed 6
Bed 4
Bed 2 upper part
Bed 2 lower part

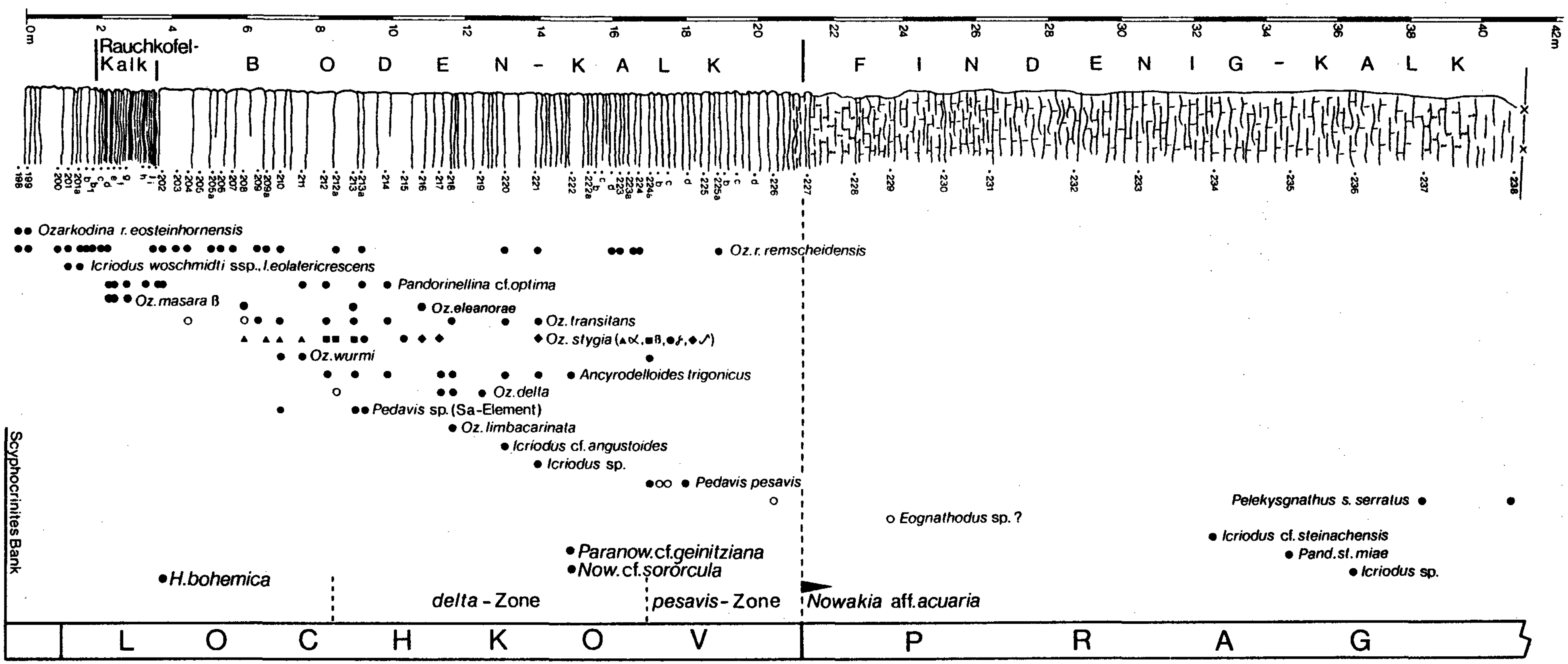


Fig. 14: Rauchkofel Boden Section, Lower Devonian part with basal 1.80 m thick Rauchkofel Limestone, above Boden Limestone and Findenig Limestone (after SCHÖNLAUB et al. 1980, modified)

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.

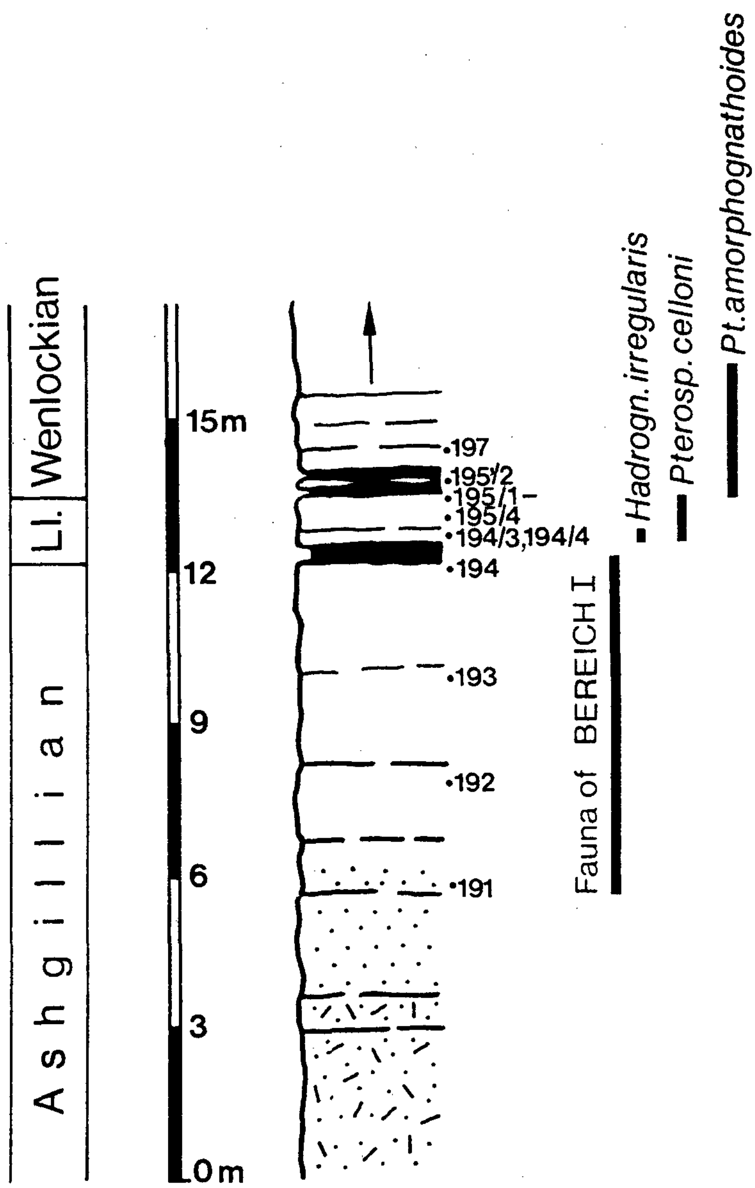


Fig. 15: Ordovician/Silurian boundary section at the base of Mount Seewarte from SCHÖNLAUB 1971.

Section 8

The Rauchkofel Bodentörl Section
(fig. 16)

by Hans Peter Schönlaub

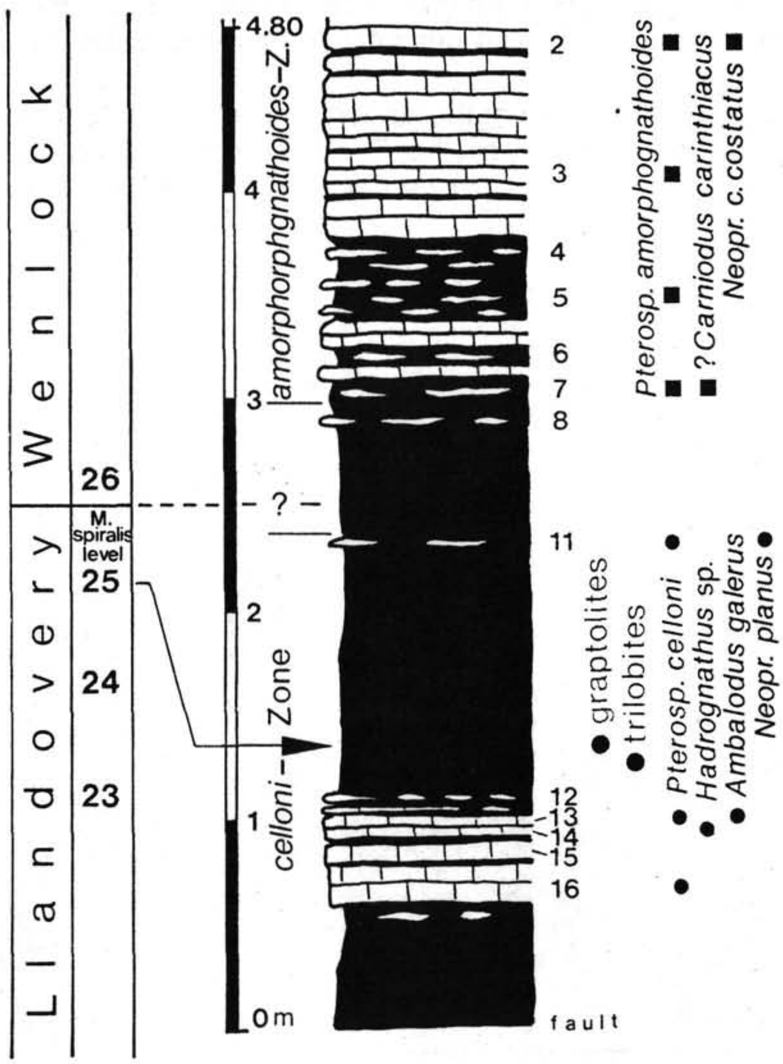


Fig. 16: The Rauchkofel Bodentörl Section after JAEGER & SCHÖNLAUB 1970, modied

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.

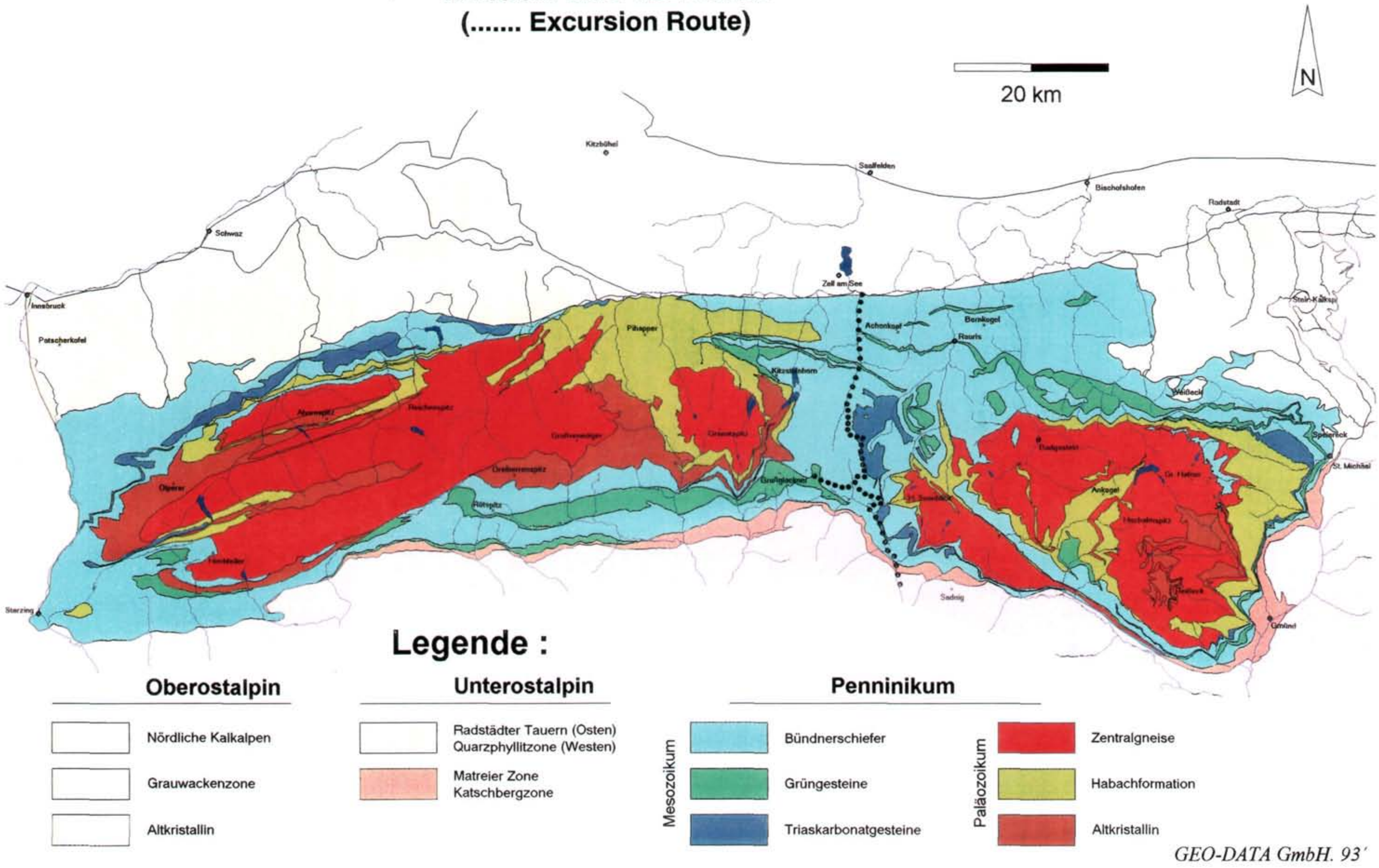
In comparison with the Western Alps in the Eastern Alps of Austria the Helvetic as well as the Penninic unit are markedly reduced. As far as the Hohe Tauern region is concerned it is surrounded by the overlying Austroalpine unit which forms a higher nappe upon the lowermost tectonic unit, i.e. the Penninic 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)



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.

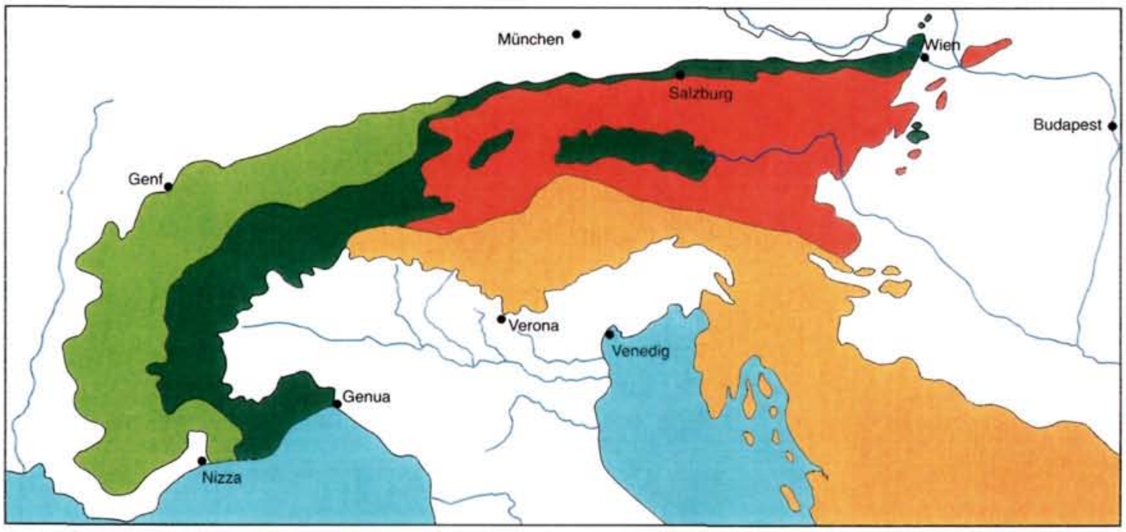


Fig. 18. Main geological subdivision of the Alps (from northwest to southeast with the Helvetic, Penninic, Austroalpine and Southalpine Zones)

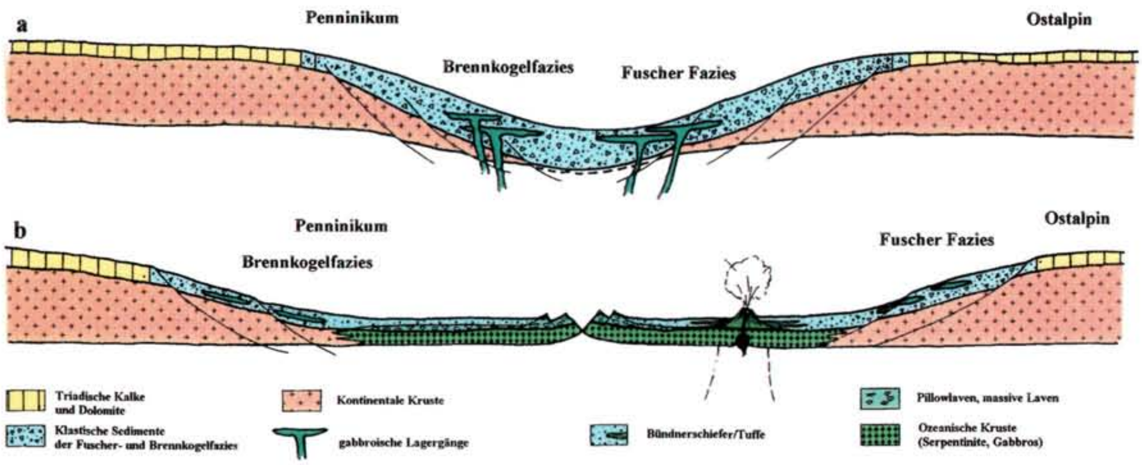


Fig. 19. Section a shows the rifting of the continental crust and opening of the Penninic Ocean at the beginning of the Jurassic with deposition of clastic sediments (Brennkogel facies and Fusch facies, respectively) with initial intrusion of basaltic dykes); section b shows the advanced oceanic stage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

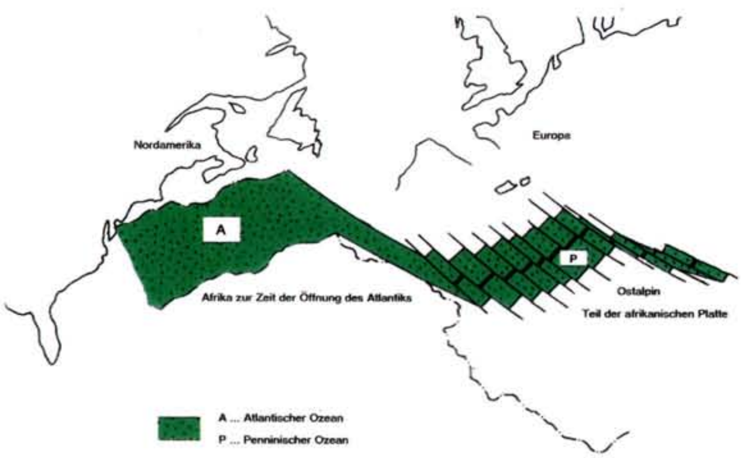


Fig. 20. Relationship between the opening of the Atlantic Ocean and the formation of the Penninic Ocean.

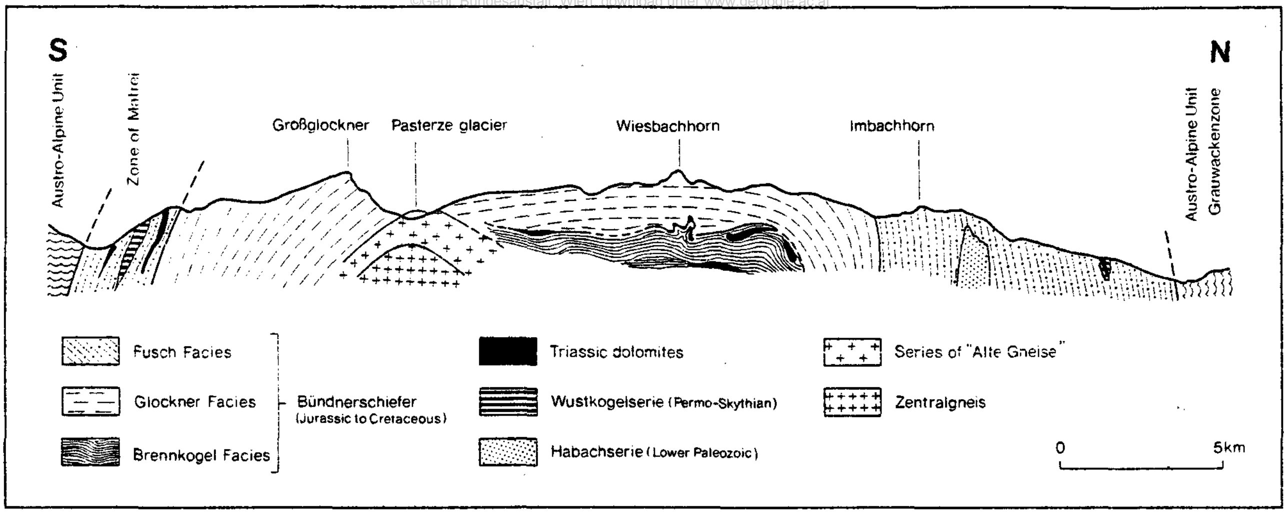


Fig. 21: Geological cross-section of the middle part of the Tauern Window after FRANK, 1965.

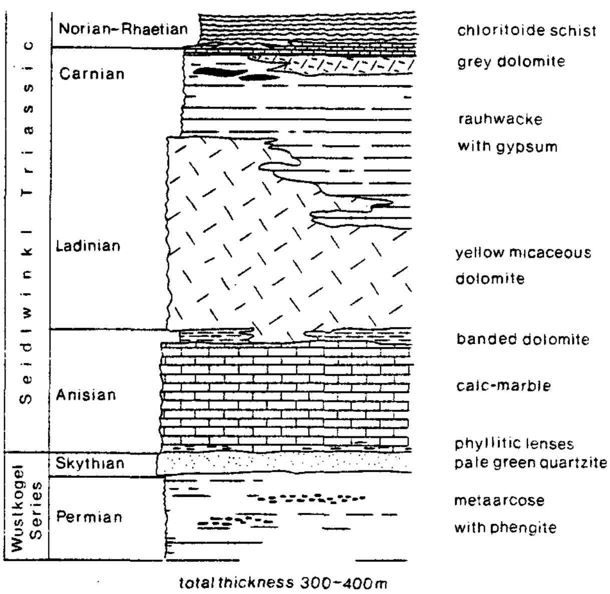
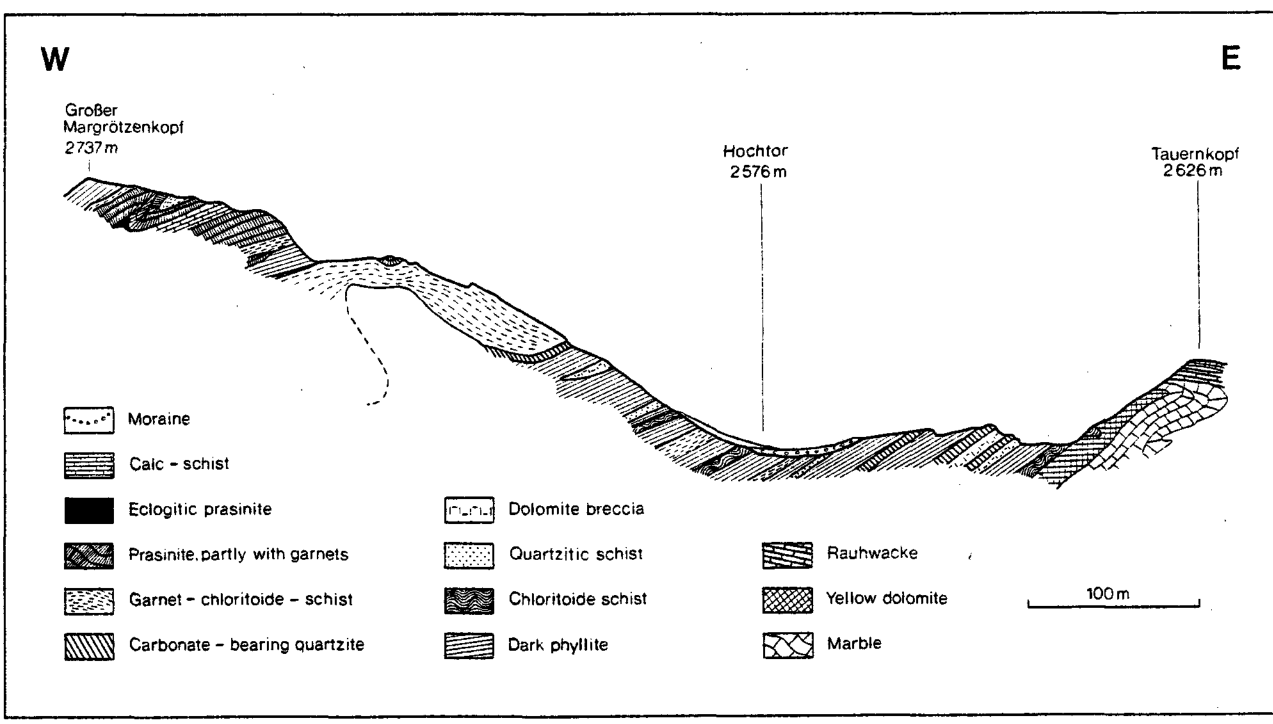


Fig. 22 (right): Columnar section of the Wustkogel Series and the Seidlwinkl Triassic (after Frank 1964).

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.

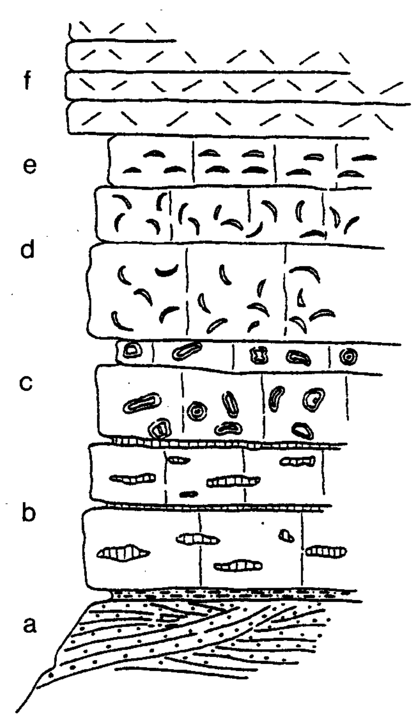
Fig. 24: General geology of the Graywacke Zone southwest of Kitzbühel, Tyrol (Black: Porphyroids; dashed: Silurian carbonates; dotted: Triassic; white: Wildschönau Formation with greenschist intercalations). After AL-HASSANI & MOSTLER 1969.

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

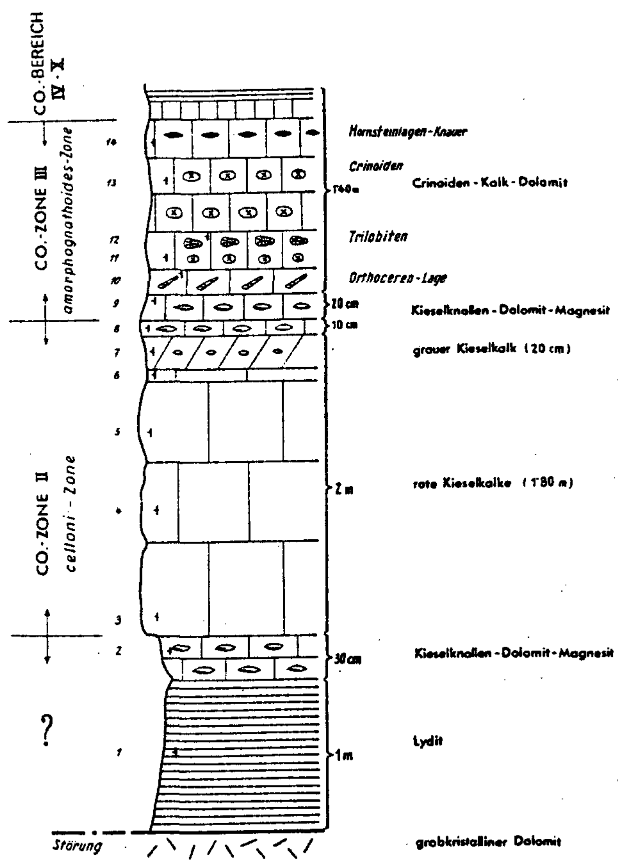
The Lachtal-Grundalm Section near Fieberbrunn

(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.

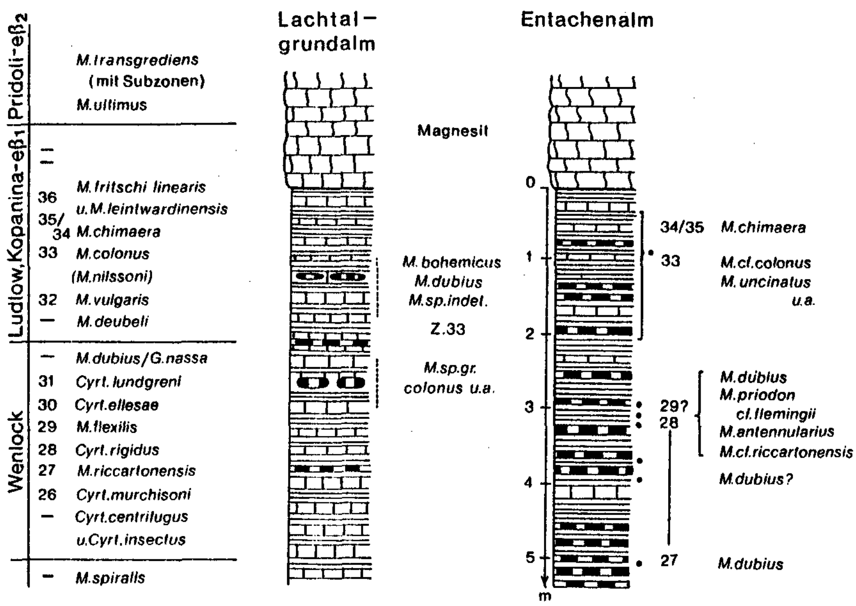

Fig. 27: The graptolite bearing upper part of the Lachtal-Grundalm Section of Tyrol and the Entachenalm Section of Salzburg (after JAEGER 1978). Both sections display the mixed facies of the dolomite-graptolitic shale Formation of the time span from the Wenlock to the Lower Ludlow.

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.