The Field Trip Programme

Stop 1: Cellon Section

by
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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-minute walk from Plöcken Pass.

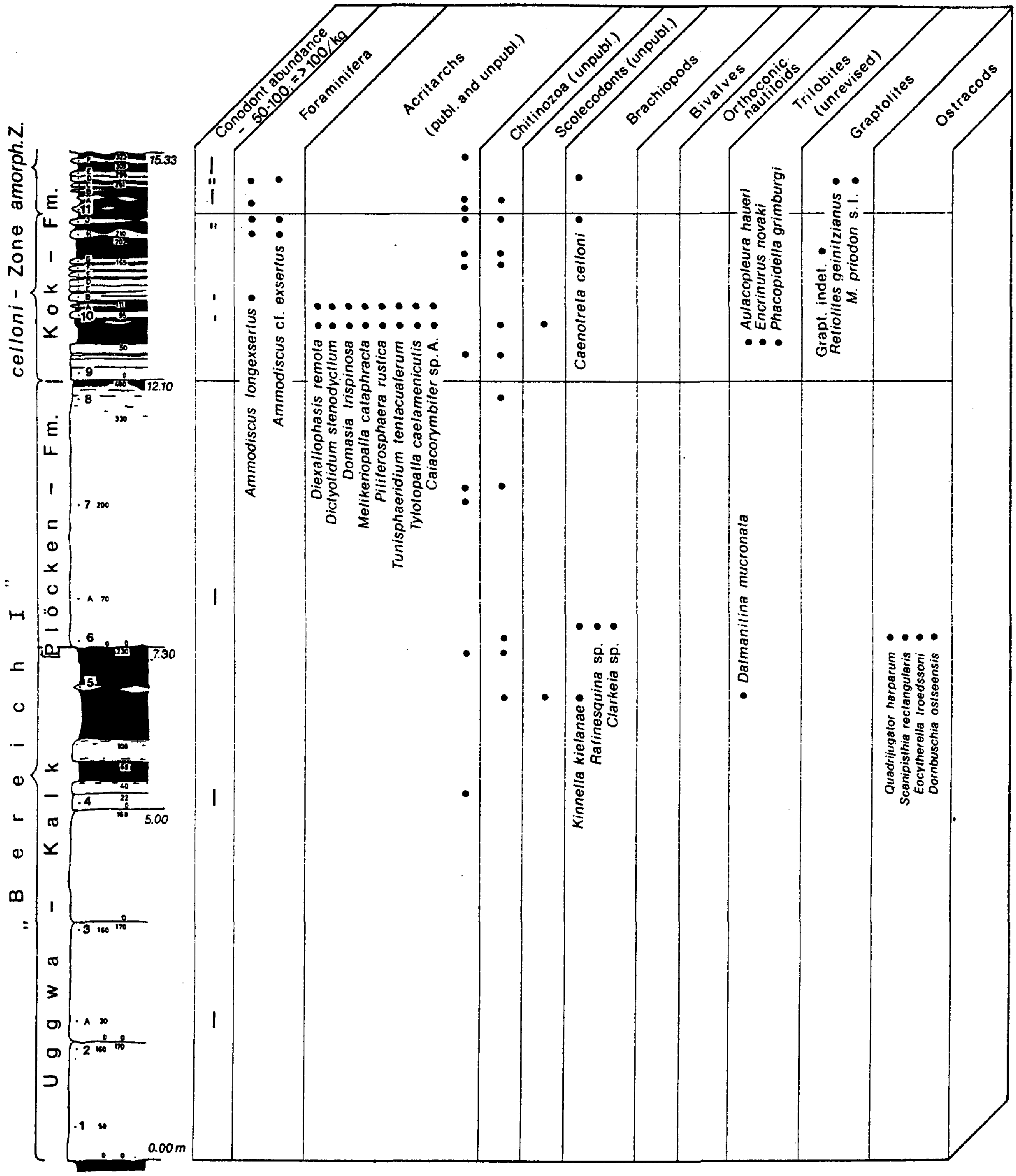
The Silurian part of the Cellon section is best exposed in a narrow gorge cut by avalanches. Thus, the German name for the section is "Cellonetta Lawinenrinne".

The Cellon section represents the stratotype for the Silurian of the Eastern and Southern Alps. Nowhere else in the Alps has a comparably good section been found. It has been famous since 1894 when G.GEYER first described the rock sequence. In 1903 it was presented to the 9th IGC which was held in Vienna. According to H. R. v. GAERTNER (1931) who studied the fossils and rocks in great detail, the 60 m thick continuously exposed Upper Ordovician to Lower Devonian section could 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 shallow-water environment. From top to base the following formations can be recognized (see Figs. 1A-D on the following pages):

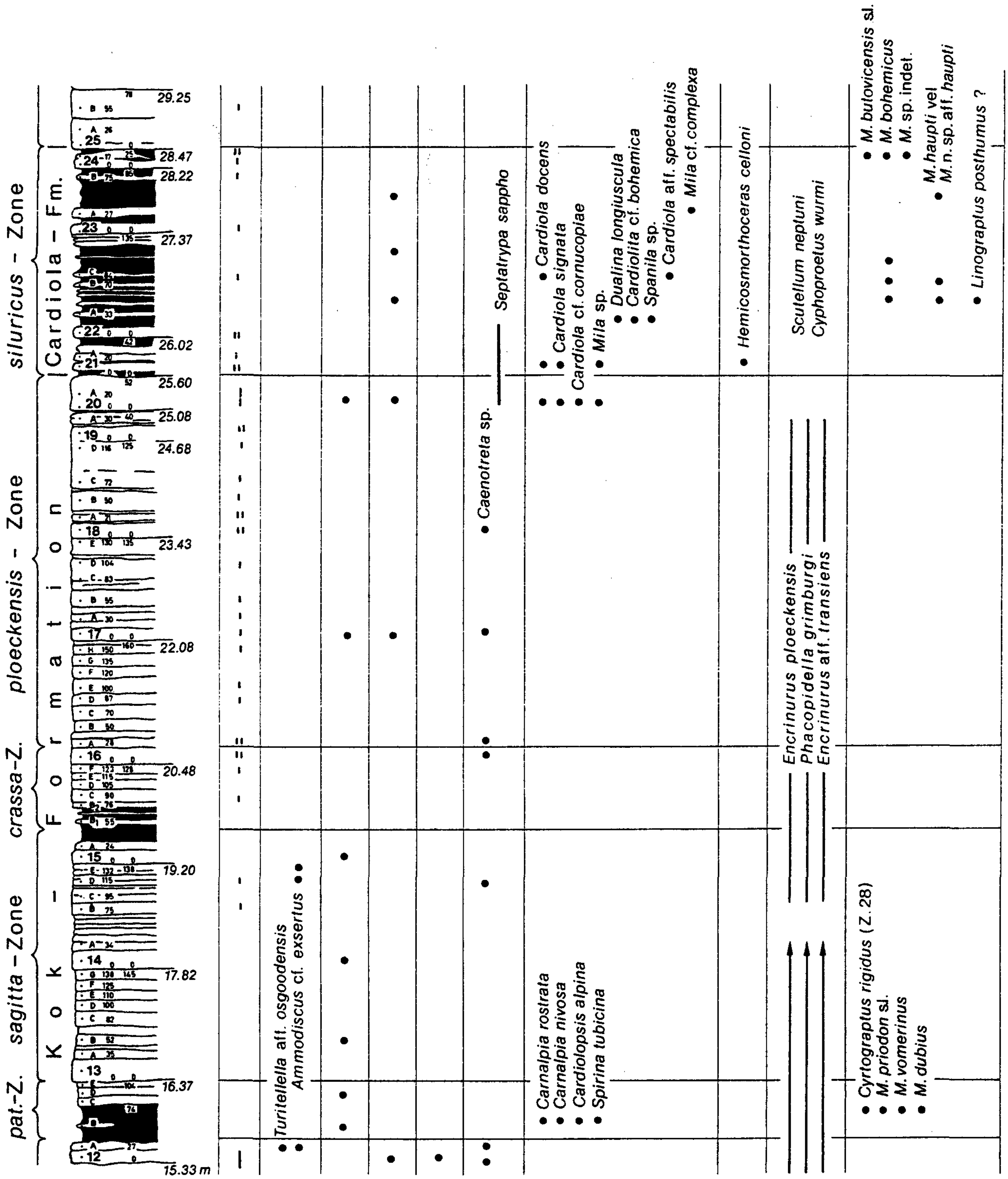
Top:

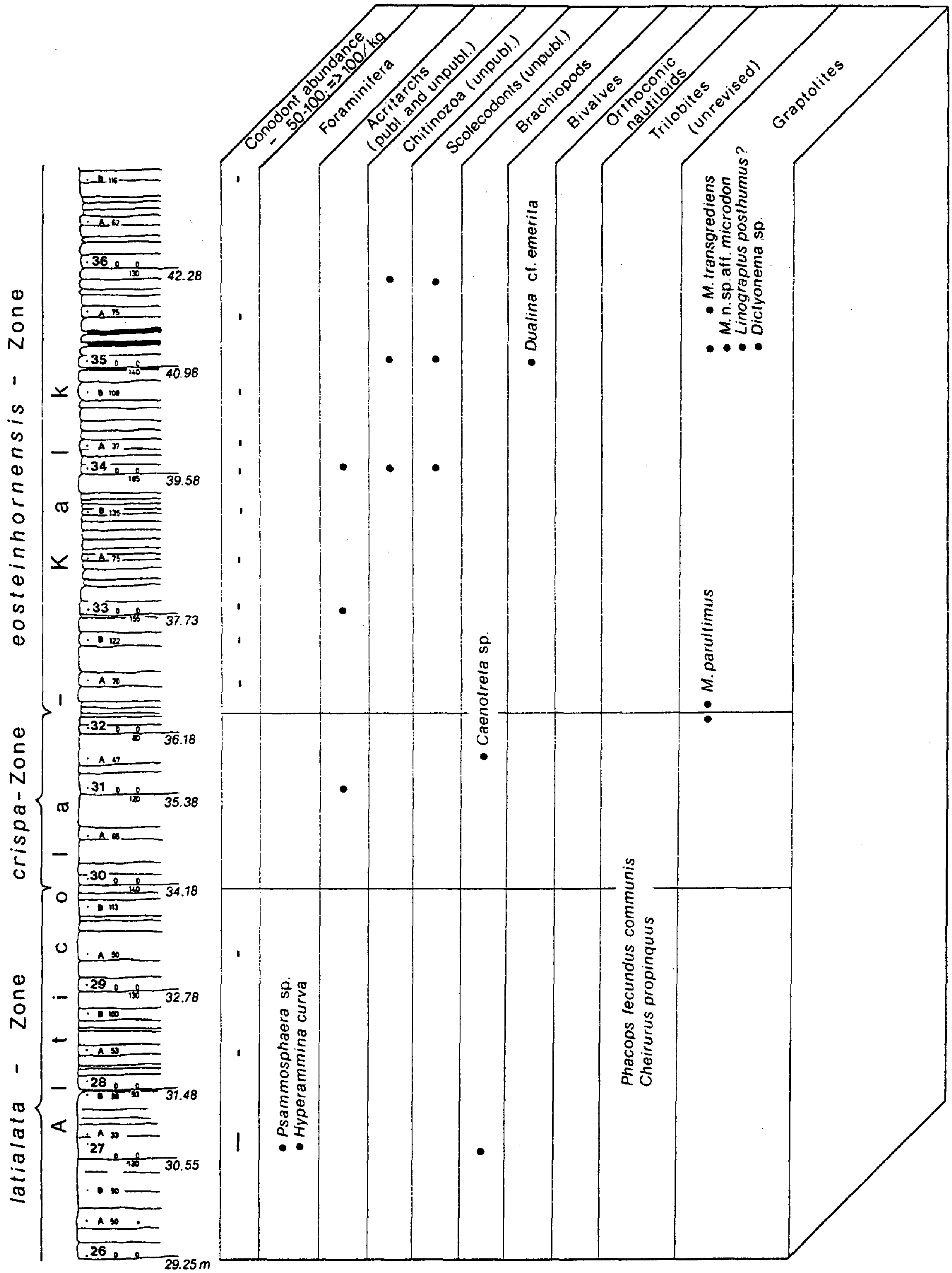
- 80.0 m Rauchkofel Limestone (dark, platy limestone; Lochkovian)
- 8.0 m Megaerella Limestone (greyish and in part fossiliferous limestone; Pridoli)
- 20.0 m Alticola Limestone (grey and pink nautiloid bearing limestone; Ludlow to Pridoli)
- 3.5 m Cardiola Formation (alternating black limestone, marl 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

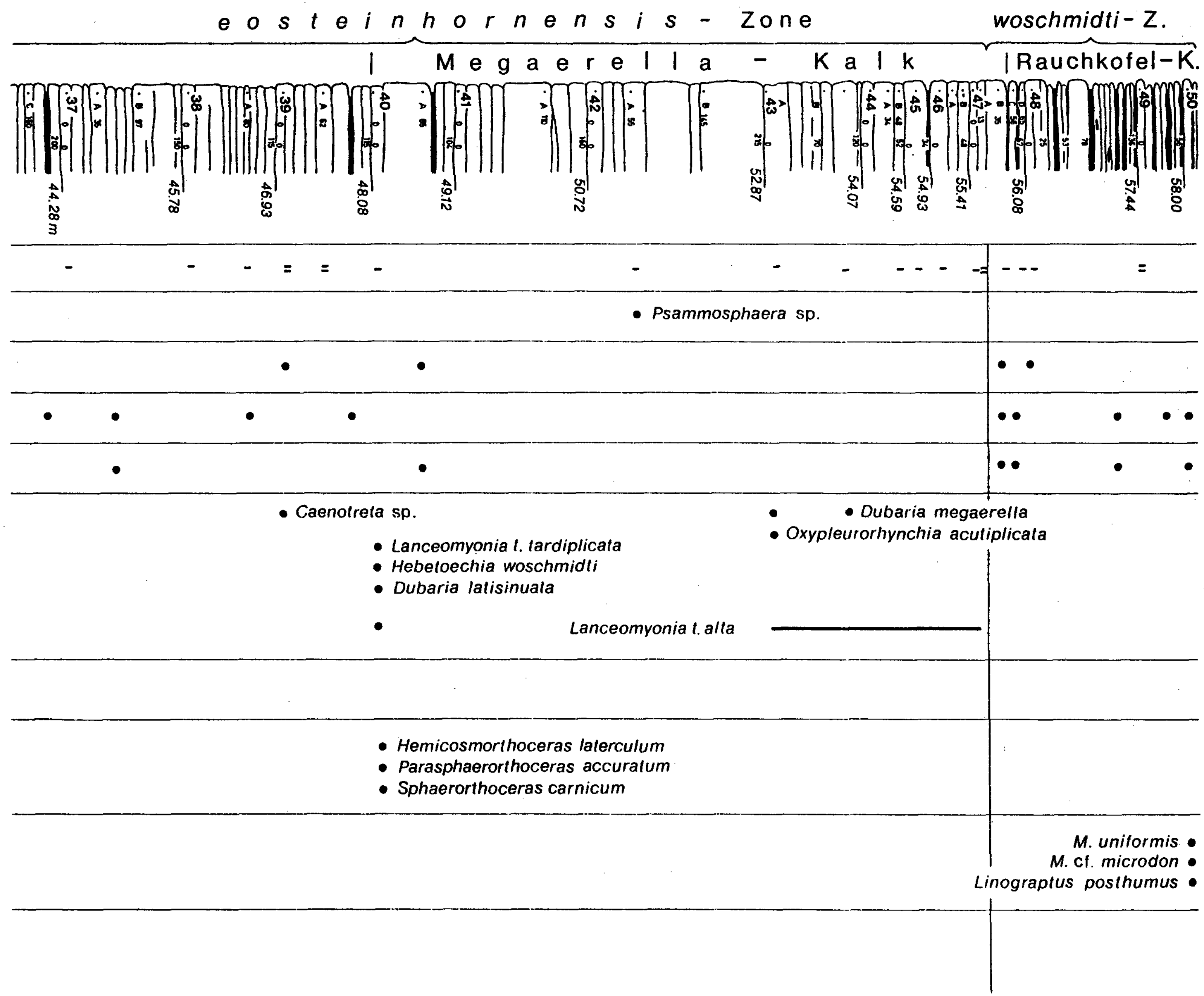


Figs. 1A - B. The Upper Ordovician to Lower Devonian portion of the Cellon section (after H. P. SCHÖNLAUB 1985, modified).


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.
15.33 m
16.37
17.82
19.20
20.48
22.08
23.43
24.68
25.08
25.60
26.02
27.37
28.22
28.47
29.25
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. bulovicensis sl.
M. bohemicus
M. sp. indet.
M. haupti vel
M. n. sp. aff. haupti
Linograptus posthumus ?



Figs. 1C - D. The Upper Ordovician to Lower Devonian portion of the Cellon section (after H. P. SCHÖNLAUB 1985, modified).


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

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 equivalence 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 5m 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 and chitinozoans can be found in the paper by H. PRIEWALDER in this volume.

Cephalopod Limestones

(Kathleen Histon)

General Remarks on the Silurian Nautiloid Fauna from the Carnic Alps.

The *'Orthoceras'* Limestones from the Silurian of the Carnic Alps and the nautiloid fauna have been well documented by various workers at the start of the century when the geology of the area began to be studied in detail: TIETZE (1870),

STACHE (1879), FRECH (1887, 1894), GEYER (1894, 1903), von GAERTNER (1931) but these works consist principally of faunal lists.The only systematic study was done by HERITSCH (1929) who described some of the earlier material collected together with his own from Dienten, Kokberg (Mt. Cocco) and Cellon giving clear stratigraphic data for the species. A total of 52 species were described by these early workers and these were revised by HERITSCH (1943) who also gave the stratigraphic occurrence of the species (as listed in Fig. 2) . A more recent generic assignment of the species is tentatively given where known). TARAMELLI (1870, 1881, 1895), GORTANI & VINASSA DE REGNY (1909), VINASSA DE REGNY & GORTANI (1910), VINASSA DE REGNY (1908, 1913) are the most important Italian works on the area in which these *'Orthoceras'* limestones are mentioned in detail and a total of 18 nautiloid species were described (GNOLI & HISTON, in prep.).

RISTEDT (1968, 1969, 1971) included material from the Cellon and Rauchkofelboden sections (Carnic Alps, Austria) in his study of the Orthoceratidae and early ontogenetic features in orthoconic nautiloids and described 12 new species from the area: *Merocycloceras declivis, Sphaerorthoceras carnicum, Sphaerorthoceras* sp. A (sensu RISTEDT), *Sphaerorthoceras* sp. F (sensu RISTEDT), *Parasphaerorthoceras accuratum*, *Parasphaerorthoceras* sp. A (sensu RISTEDT), *Parasphaerorthoceras* sp. C (sensu RISTEDT), *Parasphaerorthoceras* sp. D (sensu RISTEDT), *Parasphaerorthoceras* sp. E (sensu RISTEDT), *Parasphaerorthoceras* sp. L (sensu RISTEDT), *Hemicosmothoceras laterculum, Hemicosmothoceras celloni.*

The biostratigraphic potential of the nautiloid fauna was proposed as early as 1894 by FRECH who suggested *Orthoceras potens* BARRANDE as an index fossil for the lower red "orthoceras" limestones and *Orthoceras alticola* BARRANDE for the upper red "Orthoceras" limestones.

In 1943 HERITSCH proposed the following zonation:

Orthoceras apollo BARRANDE -	Kok Kalk
Orthoceras electum BARRANDE -	Kok Kalk and Alticola Kalk
Orthoceras neptunium BARRANDE-	Alticola Kalk

However, he states that it is difficult to define zones based on the nautiloid fauna as most species are found in both the Kok and Alticola Kalk.

RISTEDT (1969) suggests that the following species may be useful as marker fossils as they are found as mass occurrences at these horizons in the Carnic Alps:

Merocycloceras declivis	- Upper Wenlock / Lower Ludlow
Hemicosmothoceras celloni	- Base of the Cardiola Fm.
Hemicosmothoceras laterculum	- Base Megaerella Kalk

New detailed collecting from both the Cellon and Rauchkofel sections together with a revision of the older collections will test the biostratigraphic potential of the nautiloid fauna from the Carnic Alps which may allow a more precise comparison to be made with the nautiloid assemblages proposed by GNOLI (1991) from Sardinia. There are close affinities particularly between the Carnic Alps nautiloid fauna and the Bohemian fauna but also with the Sardinian fauna though with the latter some differences have been noted.

Species	Kok Fm.	Cardiola Fm.	Alticola Lst.	Megaera Lst.
Orthoceras apollo Barr.	*			
O.argus Barr.		*	*	*
O.currens Barr. (Michelinoceras ?)	*			
O.extenuatum barr.	*			
O.firmum Barr.	*	*	*	
O.germanum Barr.	*			
O.gruenewaldti Barr. (Plagiostomoceras?)	*			
O.littorale Barr.	*		*	
O.lineare Barr.			*	
O.michelini Barr. (Michelinoceras?)	*		*	
O.migrans Barr.	*			
O.potens Barr.	*	*		
O.praevalens Barr.	*			
O.truncatum (Sphooceras?)	*			
Geisonoceras alticola Frech (non Barr.)	*		*	
G.amoenum Barr.	*	*	*	*
G.arion Barr.		*		
G.carinatum Münster			*	
G.cavum Barr.		*		
G.transiens Barr (Pseudocycloceras?)	*			
G. reductum Barr.			*	
G.pelagium Barr.	*		*	
G.placens Barr.			*	
Kionoceras cf. bacchus Barr.	*			
K.dorulites Barr.			*	*
K.aff. electum Barr.	*		*	
K.neptunium Barr.			*	
K.pulchrum Barr			*	
K.striatopunctatum Münster			*	
K.tiro Barr.	*		*	*
Protobactrites acuarium Münster			*	
P.acus Barr.			*	
P.perlongum Barr.	*			
P.pleurotomum Barr.	*	*	*	
Dawsonoceras aff. agassizi Barr.	*			
D.dulce Barr	*	*	*	
D.aff.inchoatum Barr.	*			
D.lunaticum Barr.	*			
D.lynx Barr. (Orthocycloceras?)			*	
D.cf.pauper Barr.		*		
D.praecox Barr.		*		
D.subannulare Münster	*	*	*	*
D.venustulum Barr.	*			
Paractinoceras cf.severum Barr.			*	
Cyrtoceras circumflexum Barr.			*	
C.cycloideum Barr.			*	
C.imbelle Barr.	*			
C. sp.	*	*	*	*
Trochoceras carinthiacum Stache	*			
Barrandeoceras sacheri Barr.	*			
Total - 52 species	32	11	26	6

Fig. 2

Taphonomy. A detailed study of the taphonomy of the nautiloid fauna from the Kok Fm. has been carried out and the field observations are illustrated in Fig 3. The abundance, dimension, orientation, preservation, morphology and structural strenghts of the fauna have been observed for each level as defined by WALLISER (1964) in his study of the conodonts from this section. In some cases these divisions have been subdivided on the basis of the taphonomy of the fauna observed.The study is still in progress and will be continued during 1997 with main emphasis on the Cardiola Fm. and the remaining Upper Silurian.

Kok Formation

Base of the Silurian sequence - Bed 9

At the level of the Ordovician/Silurian boundary the transition from the greenish silts - shales of the Plöcken Fm to the carbonate sequence of the Upper Llandovery is marked by the occurence of flattened nodules approximately 3-5cm in diameter which appear to be micritic, dark grey-black in colour, quite dense and showing iron weathering: The overlying shales and carbonate layers are badly deteriorated: Fossil content not apparent:

Bed 10

Again a series of shales and thin carbonate beds: level E is the best preserved and shows trace fossil features at the base and the first development of 'crust' like shales otherwise fossil content not apparent although a trilobite fauna has been described from this level.

Bed 11 Llandovery - Wenlock Transition

The base is marked by micritic lenses or nodules with 'crusts' . The overlying shales have a crinoid, trilobite and brachiopod fauna towards the top of the sequence:
The first occurence of nautiloids is at the base of the Wenlock with levels of alternating shales and of reddish-grey micritic carbonate levels which have upper and lower crusts. There is a nautiloid fauna both in the shales and limestones. The shales show flow features around the lenses and the nautiloids are enclosed within the shales. They are small to medium in dimension with an abundance of medium nautiloids towards the top of the sequence.They are parallel to bedding with both body chamber and apexes preserved and have an outer oxidised coating only in the carbonates. A change may be noted up the sequence in that the nautiloids become relatively more abundant in the carbonate levels whereas previously they were more abundant in the shales.

Bed 12

Again a series of shales and limstone levels with more carbonate levels than before.There is an abundant trilobite fauna of large dimensions at the base with associated brachiopods and nautiloids. A crinoid fauna is more apparent higher in the sequence. Nautiloids are parallel to bedding with both body chamber and apexes preserved. There are upper and lower 'crusts' around the carbonate levels. Nautiloids are relatively abundant in the carbonate levels towards the top of the sequence whereas previously they were more abundant in the shales.

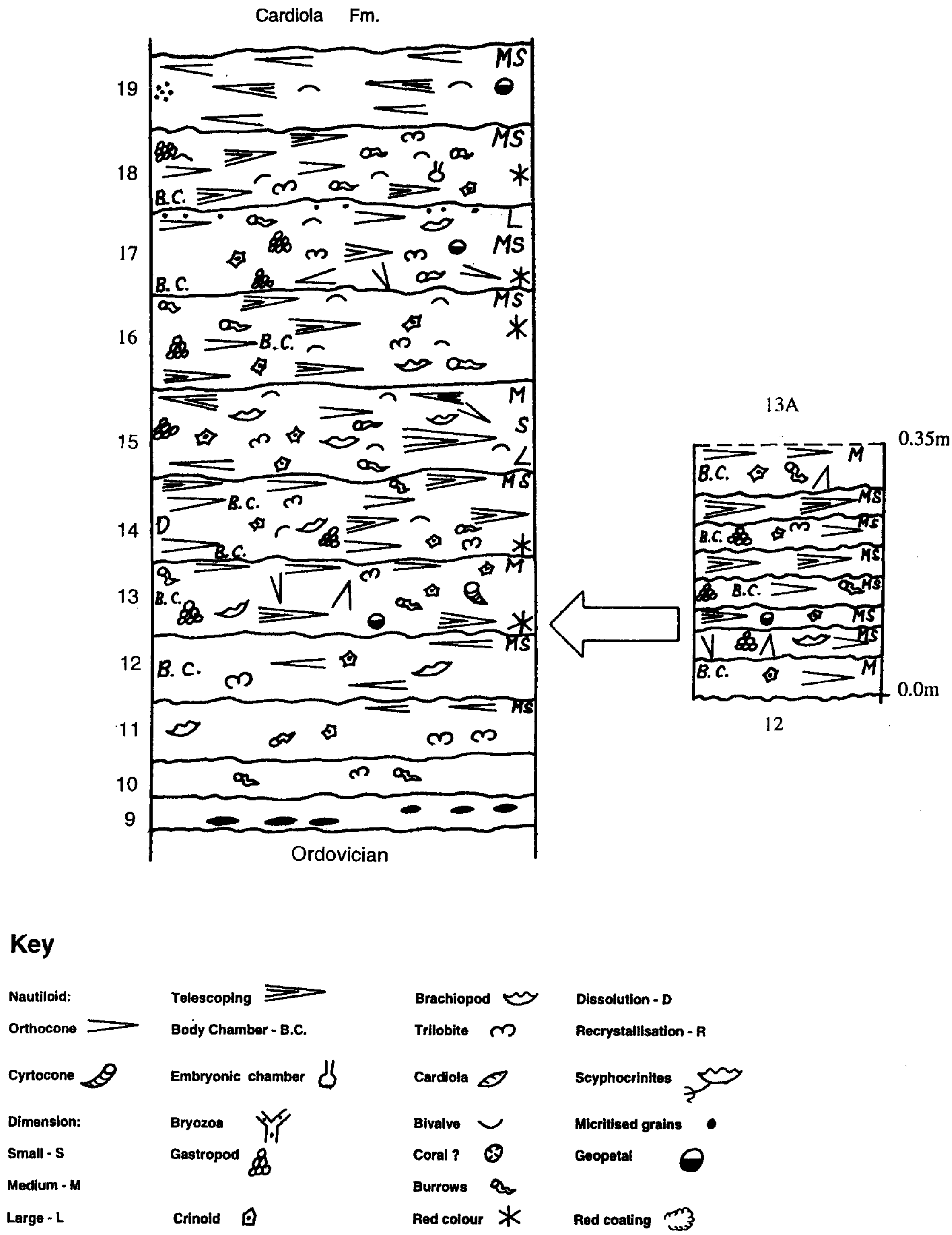


Fig. 3. Cellon section: Taphonomy - preliminary field observations. Bed numbers after WALLISER (1964).

Bed 13

Grey-red iron rich limestone with abundant nautiloids dominantly parallel to bedding. There are various cycles within this bed which show minor changes in the energy levels of the depositional environment (A detail of the base of the base of bed no. 13 is given in the illustration). Telescoping is prevalent at the base then progressing to random orientation followed by parallel orientation at the top of the sequence. Geopetals parallel to bedding have been noted at the base. The internal sediment of the nautiloids sometimes appears finer grained than the surrounding matrix so there may be some reworking of this fauna. Nautiloids have both internal and outer iron rich coating. Burrowing is also seen at the base and top of the sequence. The associated fauna consists of both coiled and spired gastropods, crinoids (articulated stem fragments), brachiopods and a cyrtocone at the base with trilobites becoming common upwards in the sequence. A certain amount of recrystallisation and gradation may also be noted up the sequence. Crusts occur between each cycle and iron rich 'layers' which have an uneven lateral development - sometimes appear to be only a surface feature: sometimes shows internal sedimentary layering.

Bed 14

This is similar to bed 13 but the cycles are less frequent and there is less iron in the bed overall with some dissolution effects. There is a slight developement of a juvenile brachiopod-bivalve-nautiloid fauna in one layer midway in the bed. Burrows only seem to occur in the iron-rich layers. Nautiloids start to be 'trapped' within crusts at top of cycles and are mainly medium in size.

Beds 13 and 14 represent a series of brown ferriginous limestones, a grey-red iron rich limestone with abundant nautiloids dominantly parallel to bedding. There are various cycles within these beds which show minor changes in the energy levels of the depositional environment. Telescoping is prevalent at the base then progressing to random orientation followed by parallel orientation at the top of the sequence. Geopetals parallel to bedding have been noted at the base. However, sediment within the nautiloids sometimes appears finer grained than the surrounding matrix so there may be some reworking of this fauna. Nautiloids have both an internal and outer iron rich coating.

Crusts occur between each cycle and iron rich 'layers' which have an uneven lateral development - sometimes appear to be only a surface feature: but sometimes also show internal sedimentary layering. As we go up the section the cycles are less frequent and there is less iron in the bed overall with some dissolution effects being evident

Bed 15

This bed shows a definite change in lithology with less iron content and development of an encrinitic level and a small fauna level as seen previously.The base is marked by the presence of large nautiloids within cycles as seen before and a juvenile fauna layer. Then there is the development of shales and the crinoid levels which also have a rich nautiloid fauna parallel to bedding.Towards the middle of the formation there is a definite change in lithology with less iron content and development of an encrinitic level above which, as at the Rauchkofel section, the nautiloid fauna is again abundant.

The top levels of the bed return to the previous cycles seen in beds 13 and 14 - iron rich and with medium nautiloids forming the top of the level showing telescoping.

Bed 16

This bed shows an increased frequency of cycles and of faunal abundance: iron layers and crusts are also developed together. There are also juvenile fauna layers which are quite distinctive and are easy to trace. Telescoping occurs at both the base and top of the bed but there is no concentration of larger dimensions at the top of the bed as seen previously. There is an increase in burrows and also in their dimension.

Bed 17

This bed is similar to bed 16 in the frequency of cycles and the faunal content but we start to have gradation up the cycles and the appearance of micritised grains particularly at the top of this bed. There is also a concentration of large nautiloids towards the top of the bed. A small fauna layer is apparent also near the top of the bed.

Bed 18

The fauna and cyles are as before but there is a definite increase in the variety of nautiloid fauna as we see large siphuncles, variety of apical angles and width of septa and embryonic chambers. Both the body chambers and apexes are preserved. There is a concentration of medium nautiloids at the top of the bed. This is probably a slightly deeper environment than the beds before.

Bed 19

There is a gradation upwards in the bed and more frequent development of crusts between thin carbonate levels. Faunal content not apparent but nautiloids parallel to bedding at top of bed and trapped between crust layers in the middle part of this bed. Burrows not evident in this bed. At the top of the bed the carbonate layers have an undulating appearance between thinly laminated shales similar to Bed 12.

Summary. In general in the Kok Formation in both the Cellon and Rauchkofel Boden sections we can note the changing energy and oxygen levels within the sequence and that there are many accumulated levels with intermittent changes in sea level particularly towards the top of the sequence. The data for the structural limits of the nautiloids is quite general at this stage of the study based on a ratio of conch diameter to septal spacing but the indications are for a mixed fauna in the lower beds of the formation becoming dominated by stronger fauna higher in the formation. A detailed study of the septal strengths of the nautiloids using the methods of HEWITT & WESTERMANN (1996) will be done when sampling of the sections is completed.

This study is still in its preliminary stages but it is hoped by comparing the results of the taphonomy and bathymetric indications for the nautiloid fauna from both sections to identify various taphofacies as has been done by BRETT (1989, 1990, 1991, 1995) for the Silurian of North East America.

The preliminary data for the nautiloid fauna at the Cellon section indicates a possible placement for the lower beds of the Kok Formation in Taphofacies 4 and the upper beds in Taphofacies 2 but this is still work in progress.

The depositional environment

(Lutz H. Kreutzer & Hans P. Schönlaub)

The first facial investigation at the Cellon section was carried out by H. FLÜGEL (1965). K. BANDEL (1972) studied the facies development of the Lower and Middle Devonian in the central part of the Carnic Alps. Middle and Upper Devonian and Lower Carboniferous strata (exposed as steep cliffs and on top of Cellon) were investigated by L. H. KREUTZER (1991). Photomicrographs with detailed interpretation from the Ordovician to Lower Carboniferous sequences comprising the whole Cellon section was published by L. H. KREUTZER (1992b).

In this volume a revised analysis of 64 thin sections of the Cellon gorge is presented. The following list shows the facial characteristics of each formation with the sample numbers according to O. H. WALLISER (1964).

Ordovician: Uggwa Formation
Age: Ashgill
Facies: Uggwa Facies
Character: (a:) grey to coloured pelagic Flaser limestone with (b:) ostracod-echinodermal debris layers.
Skeletal grains: brachiopods, 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, Hirnantian Stage
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: Upper Llandovery 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 Limestone
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 Limestone
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
SM F-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 and shales with shell debris and 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

Single beds can be characterized as follows (see Figs. 1A-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, parathuram- minacea
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 echinoderms 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

The remaining part of the Variscan carbonate succession at Cellon and the surrounding area is described in L. H. KREUTZER 1992b.

The bathymetric environment for the Silurian sequence can be described as follows (see Fig. 4):

As early as in the Ordovician a facial differentiation can be recognized for the carbonates. The Cellon section with its Uggwa Limestone development (sample 1-5) represents the late Ordovician Uggwa facies which is time-equivalent to the Wolayer Limestone of the Himmelberg facies exposed, e. g., at the Rauchkofel-Boden section. Based on conodonts the Uggwa Limestone is well dated as being Ashgillian in age. According to W. C. DULLO (1992), the two formations represent the near-shore parautochthonouos cystoid facies (Wolayer Limestone) and an off-shore basinal debris facies (Uggwa Limestone), respectively.

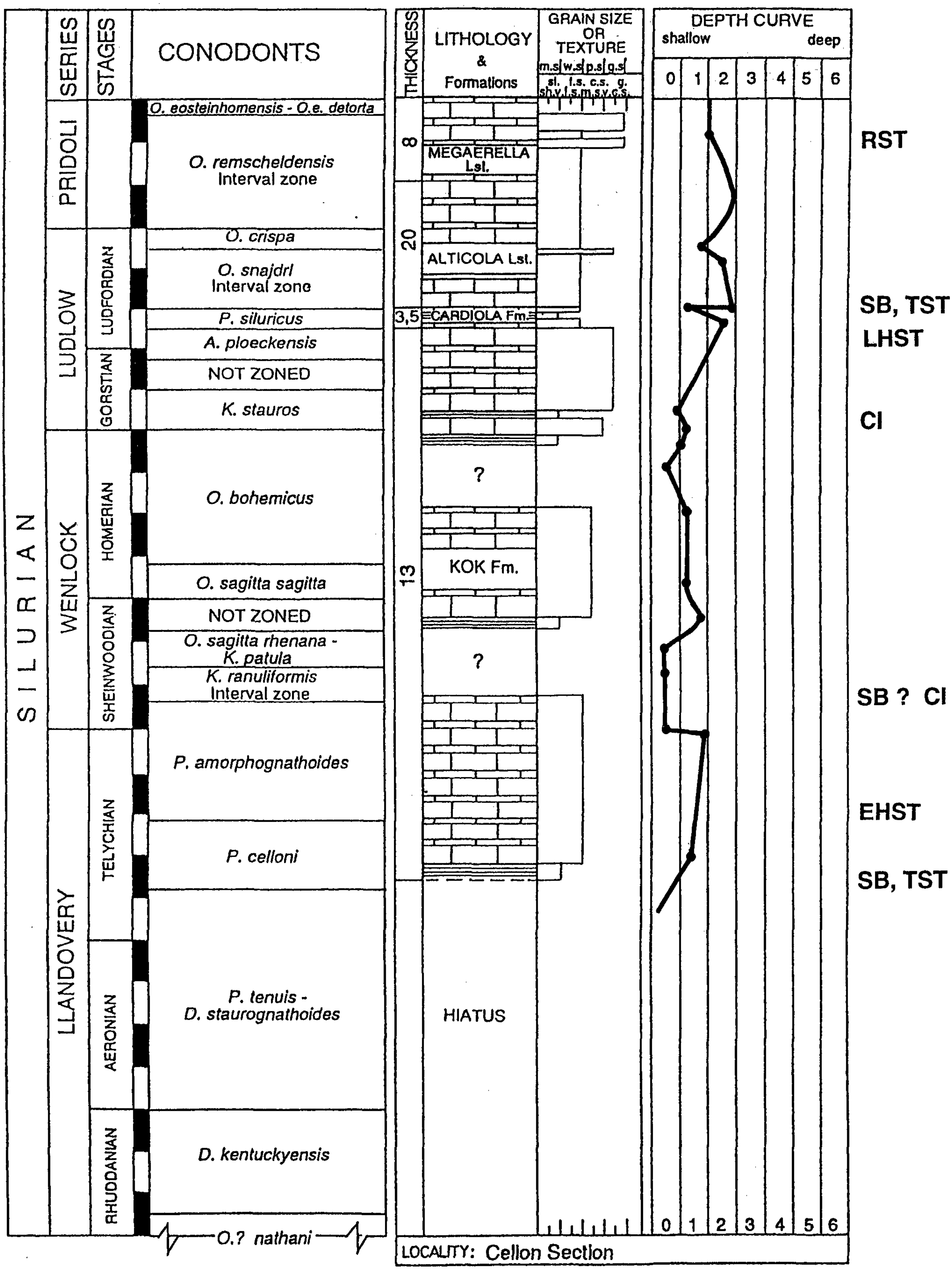


Fig. 4. Conodont stratigraphy, lithology, grain size and depth curve of the Silurian portion of the Cellon section (CI - condensed interval, EHST - early highstand system tract, LHST - late highstand (regressive) system tract, RST - regressive system tract, TST - transgressive system tract, SB - sequence boundary).

At the end of the Ordovician in the Carnic Alps a regression occurred. The Uggwa limestone bed nos. 1 - 4 characterized by pelagic faunal elements, are followed by limestones composed of subtidal components of the Plöcken Formation (bed nos. 5 - 8). A significant unconformity separates the Plöcken Fm. from the overlying Kok Fm..

Transgression of the Kok Formation started in the Cellon section in the Upper Llandovery (bed no. 9). In contrast to the Cellon section the Rauchkofel section located some 8 km to the northwest exhibits a considerably reduced sequence. At Cellon the basal Silurian succession represents a moderately shallow environment which may have lasted until the Llandovery/Wenlock boundary or until the very beginning of the Wenlock. Sample 11 exhibits a very shallow to intertidal environment thus confirming the biostratigraphic considerations of an extrem condensation or more probably a gap in sedimentation. Based on lithofacies criteria for the remaining part of the Wenlock a sea-level rise is indicated. However, at the Wenlock/Ludlow boundary (bed nos. 15A - F) some strata may also be missing reflecting either submersion or another level of reduced sedimentation.

During deposition of the Cardiola Formation (bed nos. 21 - 24) contemporrary non-deposition (due to currents ?) may have occurred. Black limestone and shale beds with radiolarians alternate with pelagic limestone beds indicating an offshore environment of a late highstand system (RST - regressive system tract).

In terms of sequence stratigraphy the boundary between the Cardiola Fm. and the overlying Alticola Lst. represents a sequence boundary (SB) with a sharp erosive contact between the two formations. At the base of the Alticola Lst. a "transgressive systems tract" (TST) of the following deepening cycle is developed. The succeeding beds up to no. 39 reflect overall stable conditions in a pelagic environment which was interrupted by a short-term regressive pulse (bed no. 40). With the onset of the Megaerella Limestone (nos. 41-47A) a further transgressive trend followed by a regressive (late) highstand system can be inferred.

Starting in the Lochkovian Stage (bed 47B and >; Rauchkofel Limestone) and ranging to the Upper gigas Zone of Frasnian age (top region of the Cellon cliff) the Devonian transitional facies represents a fore-reef facies. While this slope facies accumulated at Cellon, only a few kilometers to the palinspastic SSW (today seen at the Kellerwand region) more than 1000 meters of Devonian shallow-water limestones were deposited (Fig. 5). Moreover, coeval carbonates of pelagic origin, i. e. pelagic limestone facies of the Rauchkofel nappe) with a markedly reduced thickness of not more than 100 meters were deposited within short distances to the NNE (SCHÖNLAUB 1979, 1985; KREUTZER 1990, 1992a, b).

During the crepida Zone of the Famennian a short-lasting regression occurred. In the Upper Famennian and Lower Carboniferous uniform cephalopod limestones were deposited (Pal and Kronhof Limestone, respectively). At the beginning of the Viséan the flysch of the Hochwipfel Formation transgressed upon the Kronhof Limestone and limestone deposition ended.

In more detail the Devonian to Lower Carboniferous succession is subdivided into the following units (L. H. KREUTZER 1992). It represents the transitional facies between the southwestern shallow-water realm and the eastern to northeastern deep-water settting:

80 m well-bedded pelagic Rauchkofel Lst.: dark grey and black plate limestones with occasional organodetritic interbeds (Lochkov);
120 - 150 m Kellerwand Lst.: well-bedded yellowish tentaculite limestones alternating with skeletal debris layers (Pragian to Lower Emsian);
120 m Vinz Lst.: well-bedded dark grey platy limestone interbedded with detritic layers (Emsian);
150 - 200 m Cellon Lst.: grey massive limestone beds composed of pelagic biogenes, bioclasts and debris layers (Eifelian - Givetian);
50 - 100 m Pal Lst.: greyish to reddish and also pinkish cephalopod limestone (Frasnian to Famennian);
1 - 3 m Kronhof Lst.: greyish to reddish cephalopod limestone (Tournaisian).

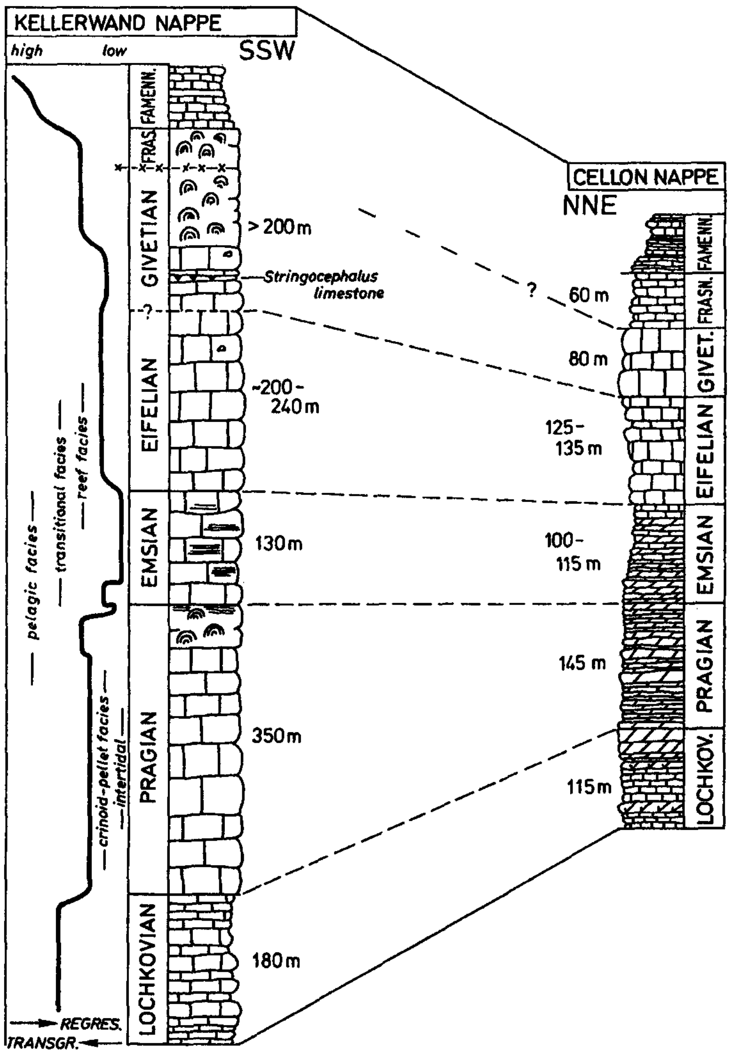


Fig. 5. Comparison of the Devonian sequences between the Kellerwand and the Cellon Nappes (after L. H. KREUTZER 1990).

A short distance to the west of the peak of Cellon at the famous Grüne Schneid section the Devonian/Carboniferous boundary beds are excellently exposed (Fig. 6). The detailed distribution of conodonts, goniatites and trilobites as well as the lithology and major and trace element content has recently been studied by an international working group (see H. P. SCHÖNLAUB et al. 1992).

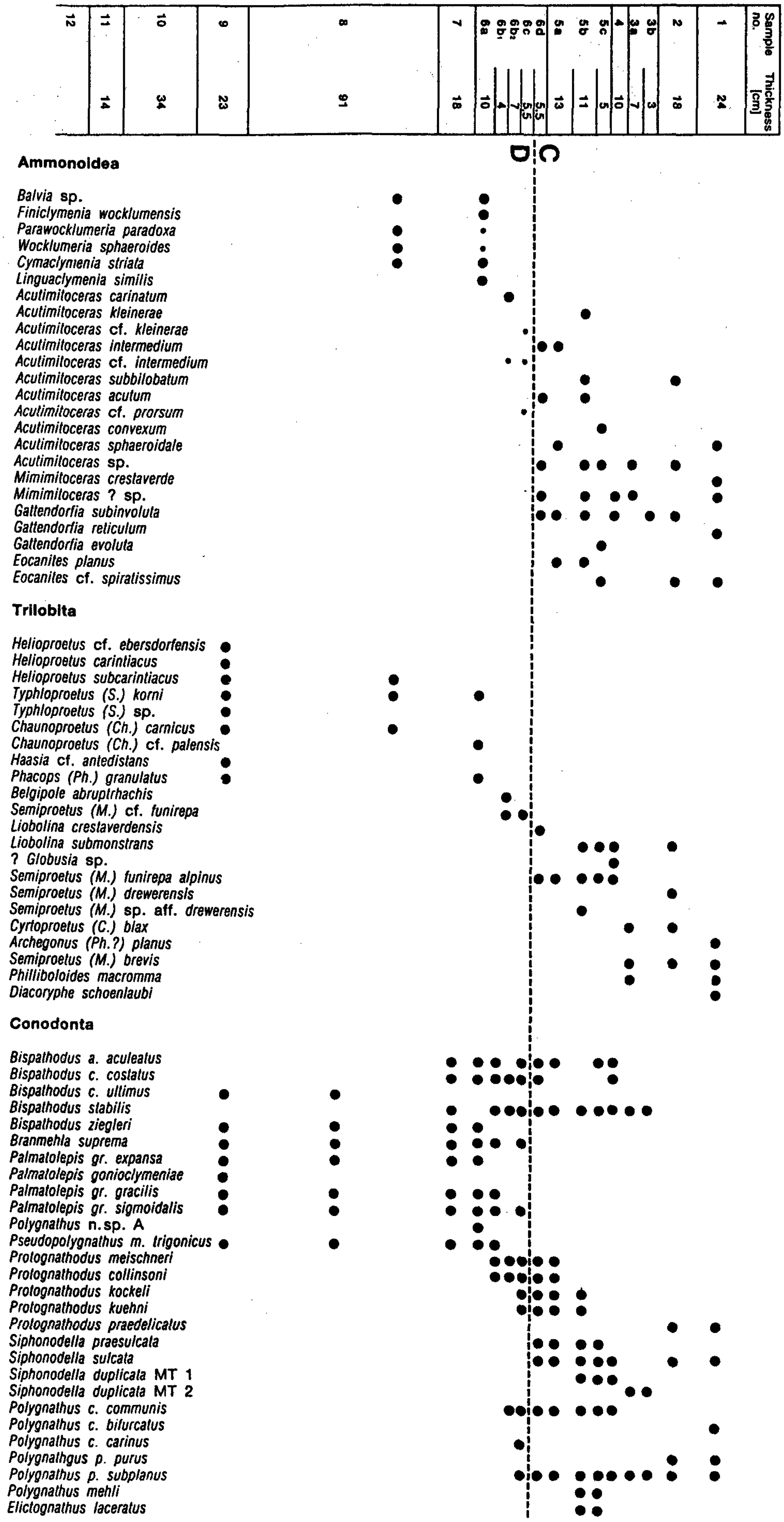


Fig. 6.
Distribution of conodonts, ammonoids and trilobites at the Grüne Schneid section.

Stable Isotope Data of the Silurian of the Carnic Alps[7]

(Bernd Wenzel)

Carbon isotope data were obtained from carbonate whole rock samples and the sedimentary organic carbon content (TOC) for several Silurian sections of the Carnic Alps. The sampled sections comprise pelagic graptolite shales of the Bischofalm facies, the transitional Findenig facies of interbedded black shales and carbonates and the pelagic Plöcken as well as the neritic Wolayer facies. The isotope data can not only be used for stratigraphic correlation but permit also further implications for the depositional environment.

The Silurian part of the Cellon section (Fig. 7)

At Cellon the Silurian carbonates are characterized by more or less uniform $\delta^{13}C$- values. Slightly increased values occur in the late Ashgill (Hirnantian Stage) and in the lowermost part of the Alticola Lst. corresponding to the latialata conodont Zone of

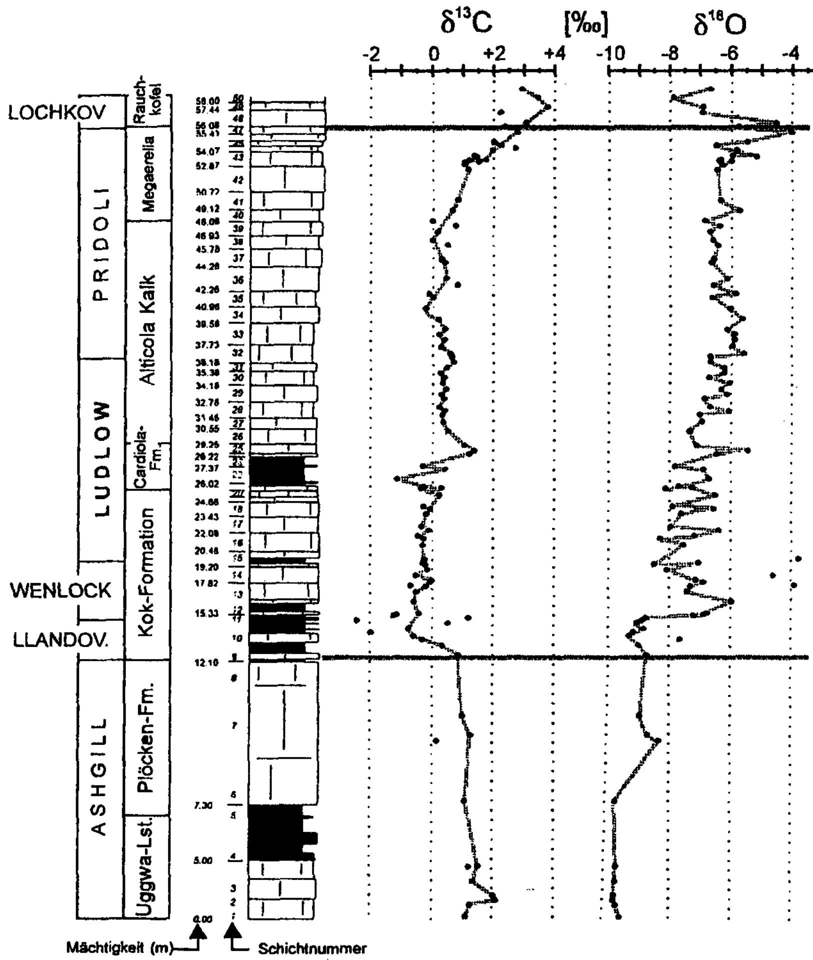


Fig. 7. Stratigraphy, lithology and isotope data for the Cellon section (Upper Ordovician to Lower Devonian). Black = C_{org} rich carbonates and shales. Isotope data from dolomitized horizones are excluded (after B. WENZEL, in press).

[7] The originally German text was provided by B. WENZEL (Erlanger Geol. Abh., 129, in press) and translated by Hans P. Schönlaub.

the Ludfordian Stage (upper Ludlow). However, these positive excursions are less pronounced than in the Baltic region. Moreover, the postive $\delta^{13}C$ signal in strata of the lower Wenlock riccartonensis graptolite Zone of Gotland can not be confirmed at Cellon suggesting either a gap or a strongly condensed interval in this part of the section. This suspicion is supported by data from the Oberbuchach 1 section a few kilometers to the east of Cellon in which a distinct positive signal has clearly been recognized in strata corresponding to the riccartonensis Zone presumably missing at Cellon.

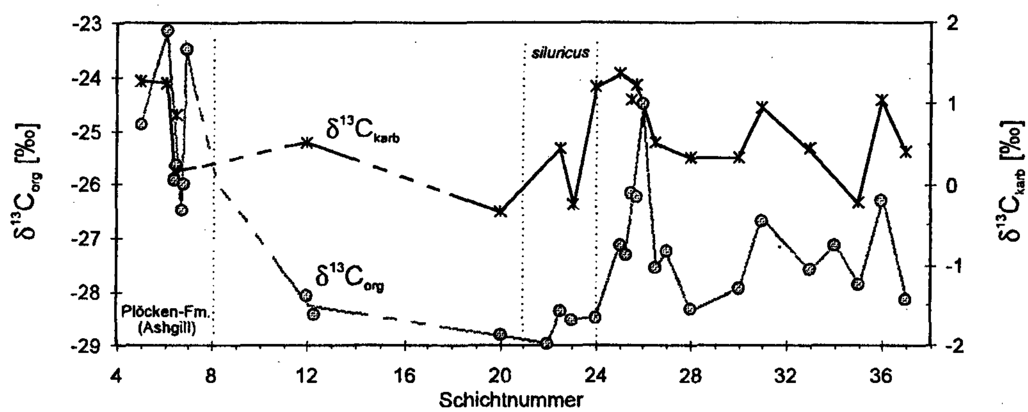


Fig. 8. $\delta^{13}C_{carb}$ and $\delta^{13}C_{org}$ data for the Cellon section. For sample numbers compare Fig. 7. Note that positive $\delta^{13}C_{org}$ excursions are paralleled by positive $\delta^{13}C_{carb}$ excursions for the Ashgillian, the latialata Zone of the upper Ludlow and within the Pridolian part of the sequence.

The measurements of the isotope signal of the organic carbon displays a parallel trend (Fig. 8). The Plöcken Fm. of the Hirnantian Stage is characterized by high $\delta^{13}C_{org}$-values similar to the Hirnantian of Estonia and South China. A second high signal is reflected in the lower latialata conodont Zone of the basal Alticola Lst. which can be correlated with the Eke and Burgsvik Beds of the Gotland succession. Similar to the $\delta^{13}C_{carb}$-signal the $\delta^{13}C_{org}$-values for the lower Wenlock suggest a break in sedimentation as the corresponding positive $\delta^{13}C$ excursions of the Baltic region (and of the Oberbuchach 1 section) are missing.

Stop 2: Rauchkofel Boden Section

by
Hans P. Schönlaub, Kathleen Histon, Annalisa Ferretti,
O. Bogolepova, Bernd Wenzel

Lithology and Paleontology
(Hans P. Schönlaub)

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. 9).