Section 2

Cellon Section

(figs. 8A-D)

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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 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.

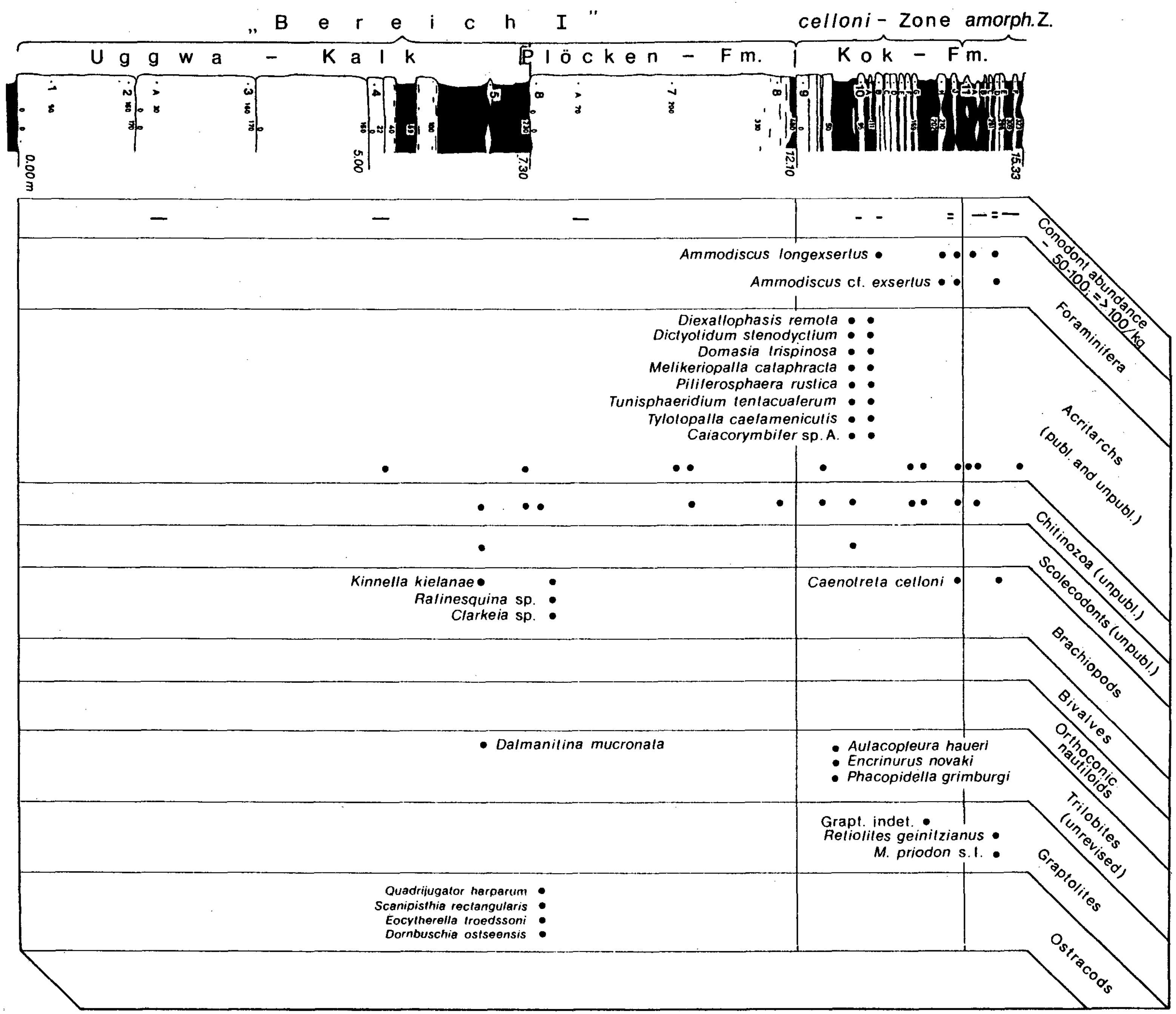
Stable Isotope Data (H.P. Schönlaub)

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.

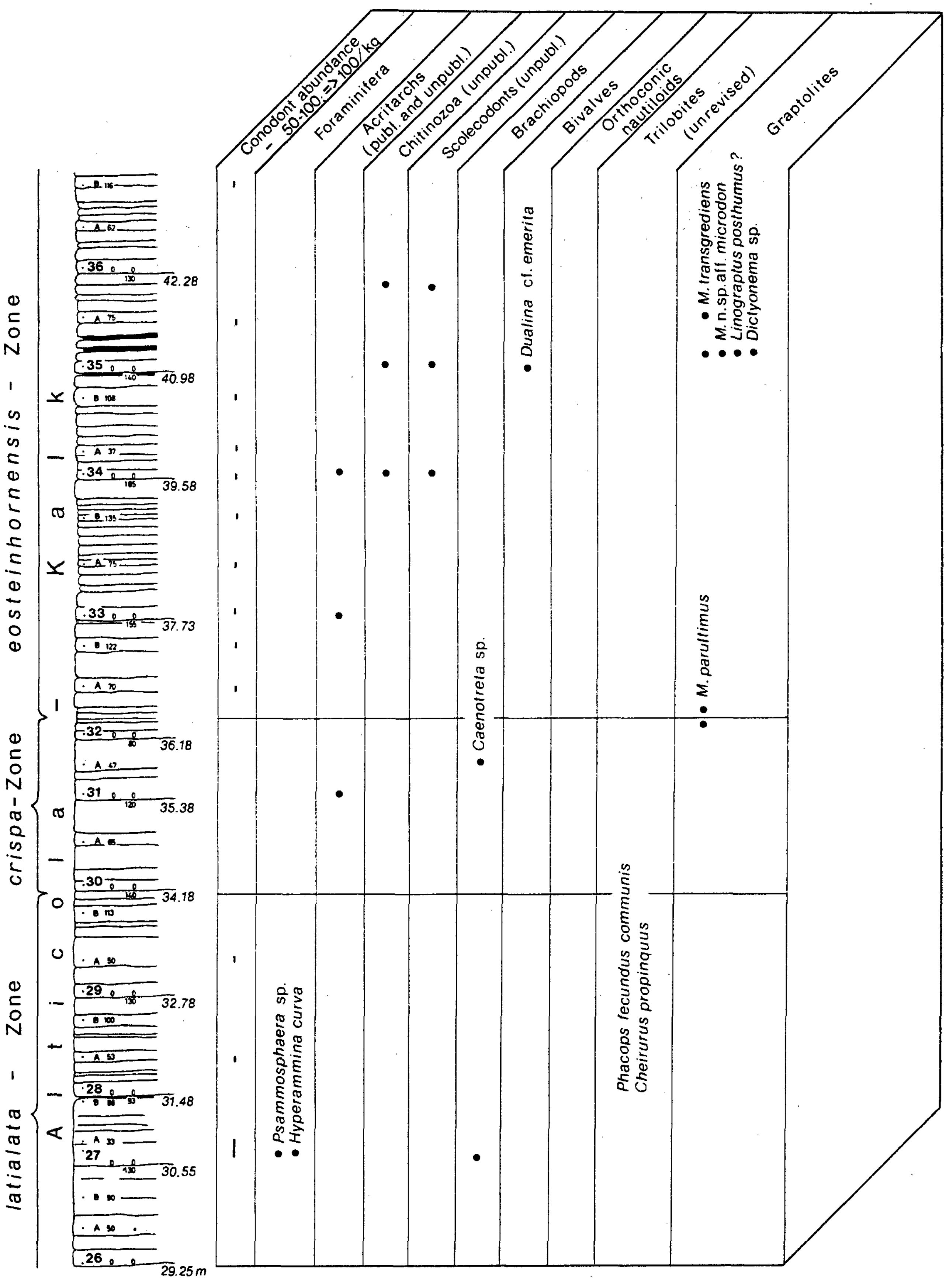
With reference to the oxygen isotopes the delta-^{18}O ratios seem to increase from low-levels in the Upper Ordovician and Lower Silurian (-9) to values about -6,5 in the interval from beginning of the Wenlock to the end of the Pridoli (measurements provided by W. BUGGISCH & M. JOACHIMSKI).

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).

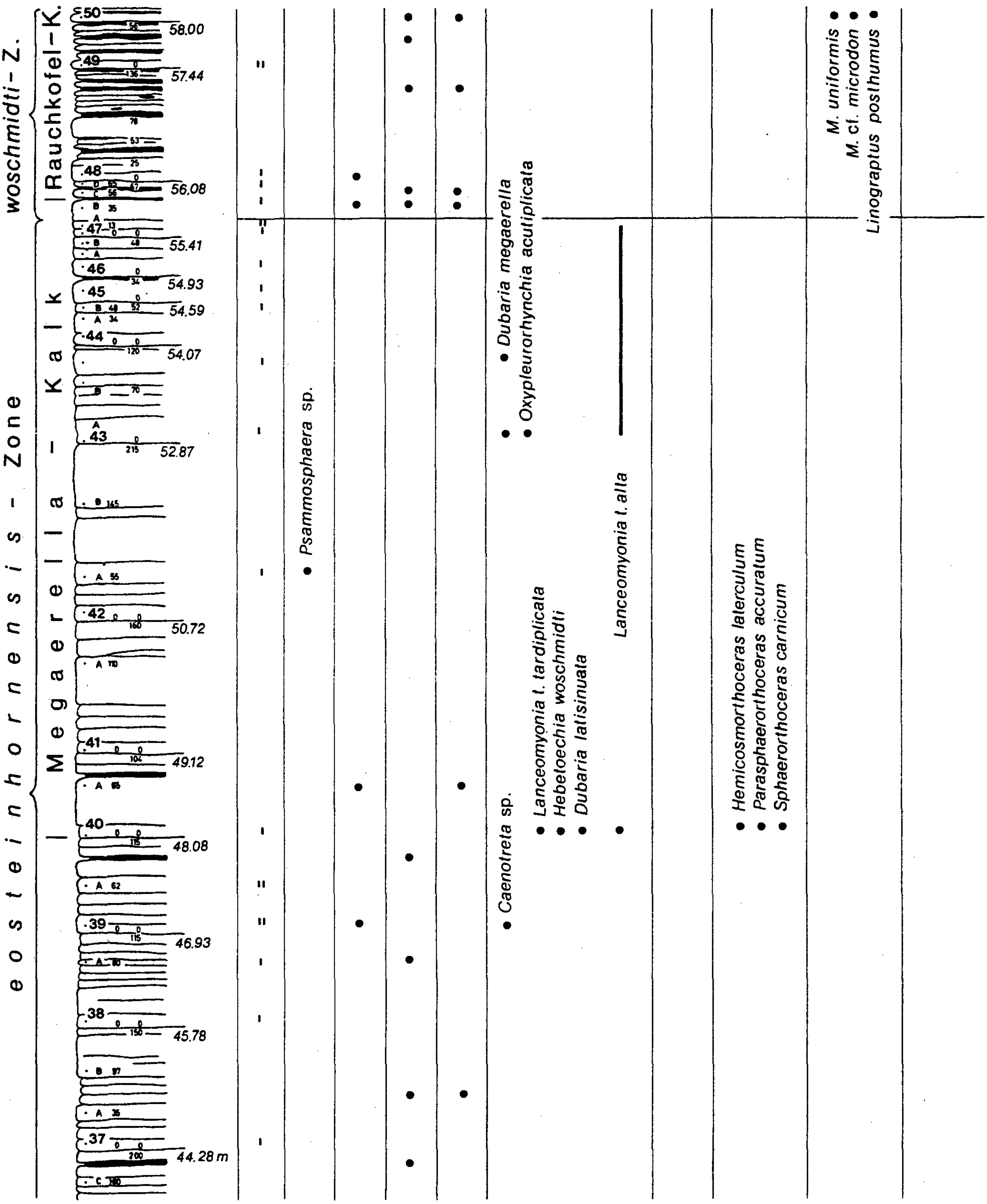
Fig. 8A-D (p. 90-93):The Cellon Section after SCHÖNLAUB 1985, slightly modified


„ 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
Ammodiscus longexsertus
Ammodiscus cf. exsertus
Diexallophasis remota
Dictyotidium stenodyctium
Domasia trispinosa
Melikeriopalla cataphracta
Pililerosphaera rustica
Tunisphaeridium tentacualerum
Tylotopalla caelamenicutis
Caiacorymbiler sp. A.
Kinnella kielanae
Ralinesquina sp.
Clarkeia sp.
Caenotreta celloni
Dalmanitina mucronata
Aulacopleura haueri
Encrinurus novaki
Phacopidella grimburgi
Grapt. indet.
Retiolites geinitzianus
M. priodon s. l.
Quadrijugator harparum
Scanipisthia rectangularis
Eocytherella troedssoni
Dornbuschia ostseensis
Conodont abundance
- 50-100; = > 100/kg
Foraminifera
Acritarchs
(publ. and unpubl.)
Chitinozoa (unpubl.)
Scolecodonts (unpubl.)
Brachiopods
Bivalves
Orthoconic nautiloids
Trilobites
(unrevised)
Graptolites
Ostracods


pat.-Z.
sagitta - Zone
crassa-Z.
ploeckensis - Zone
siluricus - Zone
Kok - Formation
Cardiola - Fm.
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 ?



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


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