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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.

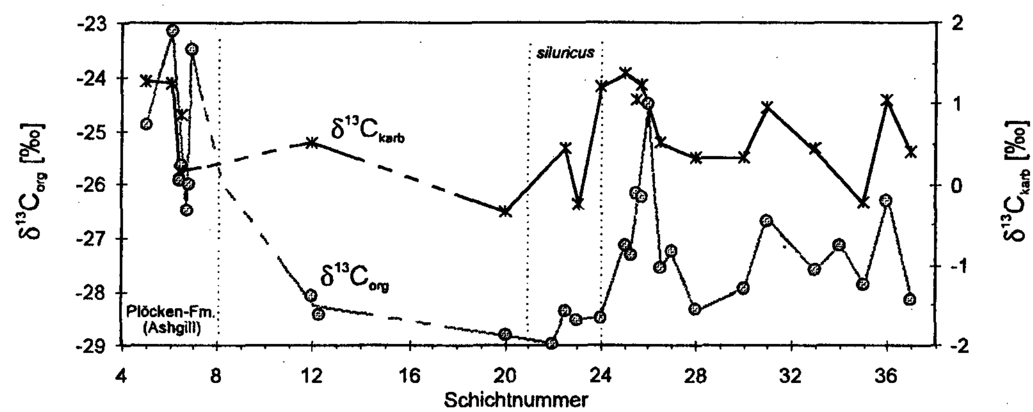

Fig. 8. $\delta^{13}C_{carb}$ and $\delta^{13}C_{org}$ data for the Cellon section. For sample numbers compare Fig. 7. Note that positive $\delta^{13}C_{org}$ excursions are paralleled by positive $\delta^{13}C_{carb}$ excursions for the Ashgillian, the latialata Zone of the upper Ludlow and within the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

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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).

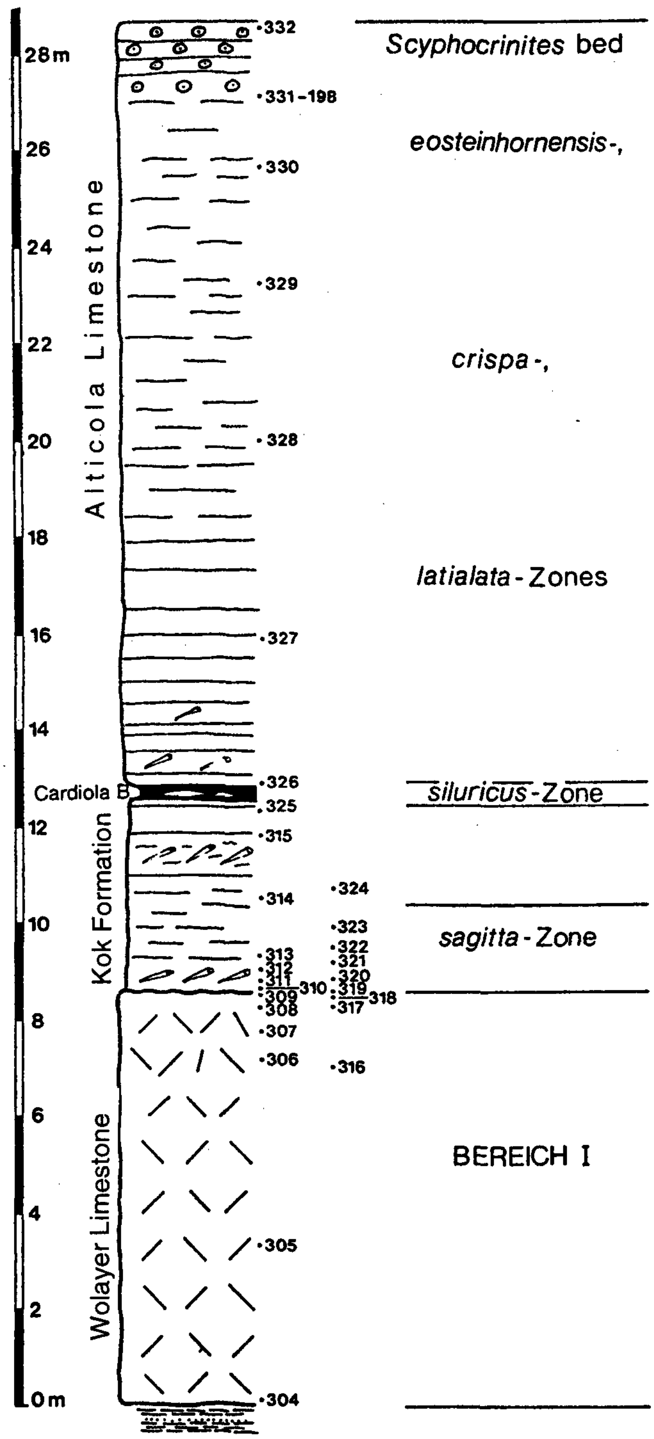

Fig. 9. The Rauchkofel Boden section (Upper Ordovician to Silurian part) after H.P. SCHÖNLAUB et al. (1980).

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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. According to W. C. DULLO 1992 it was deposited in a shallow water environment with low energy in a 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.
"Odontopieura" ovata
Eodrevermannia n.subg. n.sp.
Otarion (0.) sp.
Scharyia n.sp.
Leonaspis cf. *minuta*
Xanionurus n.sp.
Koneprusia n.sp.

In the middie part he found:

Kosovopeltis n.sp.
Otarion (0.) sp.
Leonaspis cf. *minuta*
Raphiophorus rouaulti

The upper part of the cephalopod limestone contains:

Raphiophorus rouaulti
Prionopeltis striatus
Otarion (0.) sp.
Leonaspis cf. *minuta*

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

Cardiola docens BARR.
Cardiola consanguis BARR.
Cardiola cf. *signata* BARR.

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Mila complexa BARR.
Spanila aspirans BARR.

W. HAAS found in the Cardiola Fm. *Aulacopieura* cf. *muensteri.* The fauna above the Cardiola Fm. has not been restudied in detail yet. H. R. v. GAERTNER and F. HERITSCH 1943 reported the following taxa:

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

Spirigera canaliculata BARR.
Spirigera obovata SOW.
Retzia ? umbra BAAR.
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.

Sample nos. 329-332:

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

According to W. HAAS (unpubl.) the following 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 occurs from the base of the *Orthoceras* Lst. up to sample no. 313, i.e. 1.20 m above the base (fig. 12). Although richly 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 J. KRIZ et al. 1993).

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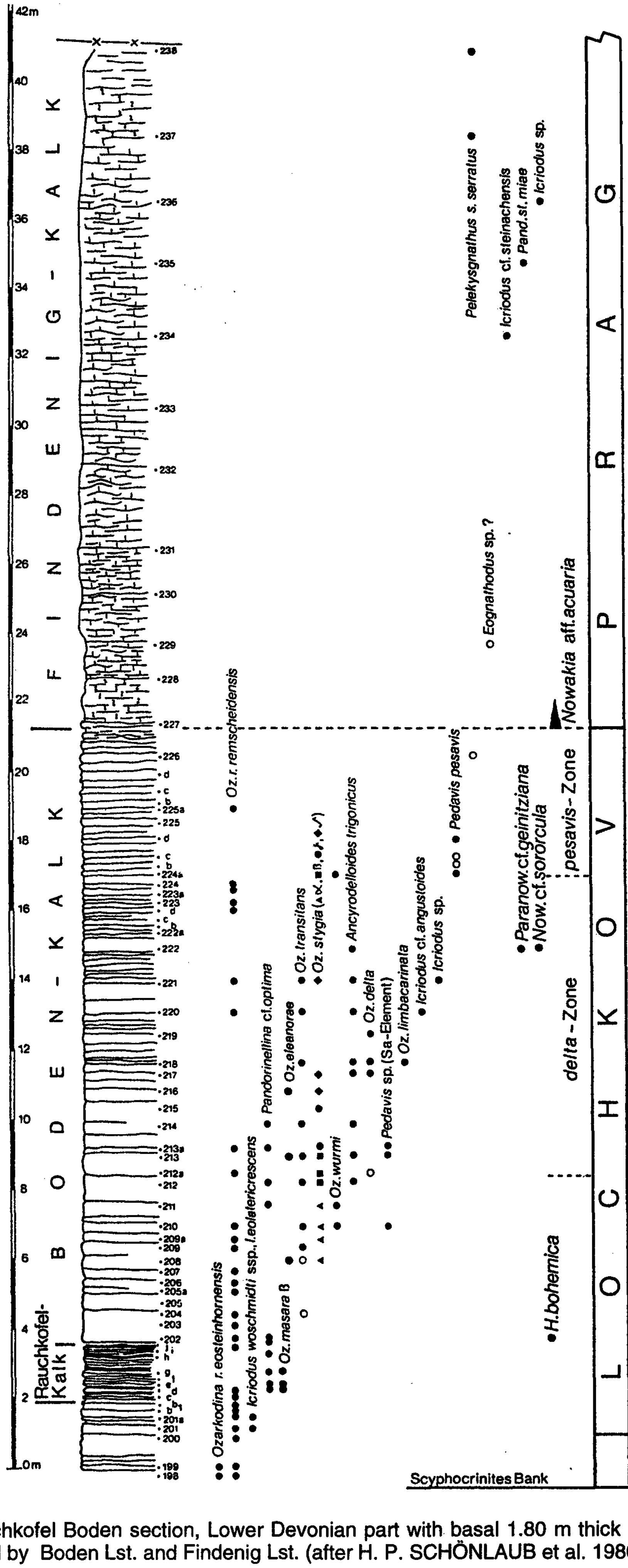

Fig. 10. Rauchkofel Boden section, Lower Devonian part with basal 1.80 m thick pelagic Rauchkofel Lst., followed by Boden Lst. and Findenig Lst. (after H. P. SCHÖNLAUB et al. 1980, modified).

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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 (sample nos. 330. 331) belong to the apparatus of *Oz. r. eosteinhornensis.* In addition, *Oz. ortuformis and Oz. jaegeri* occur at 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 occurrences of *Oz. r. eosteinhornensis* and, more frequently, *Oz. r. remscheidensis.*

The basal part of the overlying Lochkov sequence (Fig. 10) seems to be extremely condensed. This interval is represented by well bedded, thin and blackish limestone beds with shaly intercalations (sample 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 have graptolites yet been recorded.

With regard to the Lower Devonian part of this section we refer to Fig. 10 showing its lithology and faunal content. The exposed 40 m thick undisturbed section is subdivided into the following formations:

1.80 m pelagic Rauchkofel Lst. comprising black limestones interbedded with marls (Lower Lochkovian);

c. 17 m Boden Lst. comprising greyish coarsely bedded nautiloid bearing limestones rich in conodonts but rare in dacryoconarids and orthoconic and coiled nautiloids (Upper Lochkovian);

20 m nodular pink Findenig Lst. rich in dacryoconarids.

Cephalopod Limestones

(Annalisa Ferretti & Kathleen Histon)

Microfacies and Taphonomy. The Rauchkofel section offers pictoresque expositions of Silurian cephalopod limestones, among which different limestone types may be recognised. A global study of the Silurian strata at this section by a research team (O. BOGOLEPOVA, A. FERRETTI, K. HISTON, J. KRIZ & H. P. SCHÖNLAUB) is in progress based on observations of the abundance, dimension, orientation, colour and the preservation of all organisms composing the fauna, in particular the nautiloid fauna, together with lithologic and sedimentological data. The data here reported and summarised in Fig. 11 are just preliminary results by two members of the group. A distinction of the outcrop into three parts was attempted (Inner trench, exposed towards the south, median trench and outer trench, exposed to the north) and a correlation made between them. Iron-oolitic concentrations which may mark the limit of depositional cycles have been identified at certain levels. A brief outline of previous work on these limestones in the Carnic Alps and the taphonomic parameters used in this study is given in this volume in the chapter on the Cellon Section.

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Kok Formation (Bed nos. 310 to 315 and 319 to 325)

The Kok Formation consists of a of dark grey-reddish micritic limestone showing a variety of bed thickness which in general decreases upwards.Possible dropstones have been noted at the Ordovician - Silurian boundary on the upper surface of the Ordovician Cystoid limestone. The contact with the lighter Ordovician limestone is easily recognizable in all the exposures being marked by an iron-oolitic concentration. The lowermost samples are mostly represented by a bioclastic wackestone to packstone with cephalopods inside a sorted matrix of small bioclasts (trilobites, crinoid fragments, simple valves of bivalves, ostracods and gastropods). Recrystallisation is common. The base of the formation is relatively barren in nautiloid fauna with respect to the upper beds. The majority of them are apparently oriented parallel to bedding and some telescoping is seen although there seems to be a very regular cyclicity to the occurence of telescoping of specimens, usually occuring at the top of individual beds. Body chambers have not been observed but the apex is usually present. In some cases the nautiloids are seen to have an outer dark red oxidised coating of the shell which may represent dissolution of the shell wall itself as in some cases the nautiloid may be removed from this external casing.

An encrinitic packstone of crinoid debris is present towards the middle of the formation (level 323/314). Above it what may be called "an abundant nautiloid fauna" occurs for the first time in this formation (base 324/ mid 314).

This level is followed by thinly developed cyclic micritic limestone beds of bioclastic accumulations separated by thinly laminated iron-rich layers or 'crusts' with sometimes iron-oolitic concentrations. These crusts may represent sedimentation breaks or hardgrounds in the carbonate sequence. A rich nautiloid fauna is preserved, the nautiloids sometimes being apparently trapped within the crusts. The nautiloids are varied in dimension from 1 - 5cm diameter but larger diameters are also seen in vertical orientation and these sometimes traverse the bedding layers.

The orientation of the nautiloids varies within individual beds but alternating trends from parallel to random may be noted with telescoping also occurring in certain beds. Dissolution of the conch wall is also often evident where specimens are enclosed within the "crusts".

Higher in this series of beds the external red oxidised coating of the lower beds is not so obvious but an iron-rich lining of cameral chambers and siphuncle is often seen. Pyrite development also occurs towards the top of this sequence.

Concentrations of apparently juvenile and equidimensional articulate brachiopods and nautiloids and small gastropods alternating with the nautiloid beds occur from about mid-way to the top of the sequence (top 324 / 315). and have a distinctive red-pink appearance. These bio-accumulations seem to have major thickness in front of the middle trench.

At the top of the formation bordering the war trench, spectacular cephalopod limestone beds are exposed and may be distinguished from the previous nautiloid layers by the greyer appearance of the limestone and the obvious variety of the nautiloid fauna (325 /315). The limestone is represented by a cephalopod wackstone to packstone with gastropods, echinoderms, trilobites and ostracods. No sorting or

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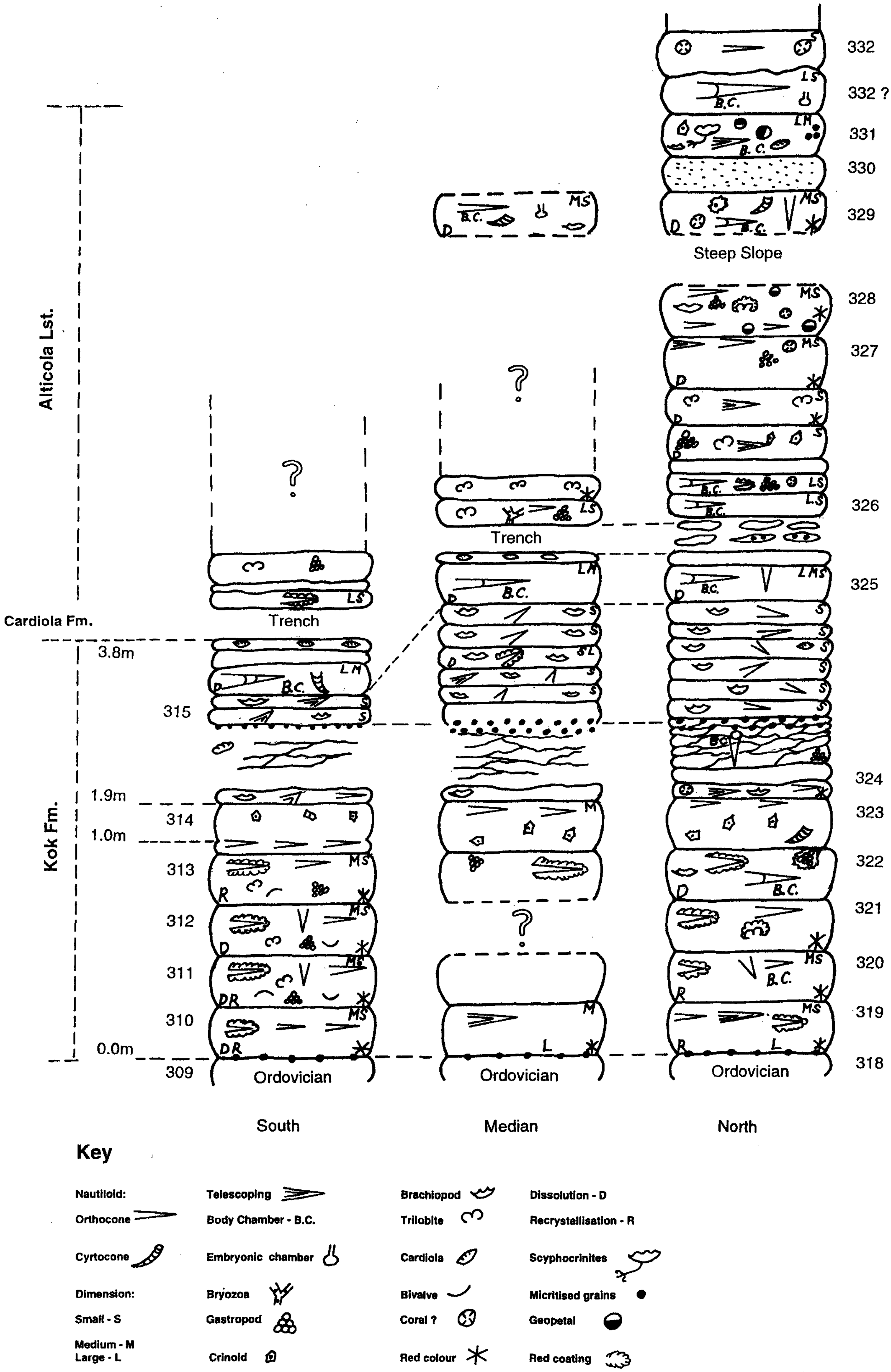

Fig. 11. Rauchkofel Boden section: Microfacies and Taphonomy - preliminary field observations. Bed numbers after SCHÖNLAUB et al. (1980).

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gradation was observed. The abundance of the nautiloid fauna is at first deceptive due to the undulating exposure of the underlying layers but the fauna is nevertheless quite rich particularly with regard to form and dimension. Dimensions range from 1-5cm in diameter in general with the smaller forms being dominant. They are usually oriented parallel to bedding with some vertically oriented specimens also being present. The specimens are also less fragmented in these upper levels.

Dissolution of the conch wall and body chamber has also been noted and is particularly shown by the contrast of the relief of the remaining secondary cameral and siphuncle deposits on the bedding surface.

The iron-rich coatings and infillings of the fauna in certain levels together with the observed dissolution of shell material indicate the changing oxygen levels in the environments. The iron-rich crusts seen between the beds in the upper part of the formation have also been noted in condensed beds in the Devonian of Morocco (WENDT 1988) and have been interpreted there as hardgrounds or breaks in sedimentation. BRETT (1995) discusses the importance of these condensed beds and sedimentation breaks for sequence stratigraphy and how the overall cycles may be used for correlation purposes. The data for the structural limits of the nautiloids is quite general at this stage of the study but the indications are for a mixed fauna in the lower beds of the formation becoming dominated by stronger fauna or deeper water fauna higher in the formation. Therefore for the Kok Formation at the Rauchkofel section we see that the fauna becomes dominantly abundant and larger in size up the sequence with iron content also decreasing but dissolution being more evident.

In general we can note the changing energy and oxygen levels of the formation from the data given and from the preservation and orientation of the fauna that there are many accumulated levels with intermittent changes in sea level particularly towards the top of the sequence. The orientation of the conchs to bedding and the presence of telescoping may be used as an indication of the energy of the environment in which they were deposited; telescoping being an indication of high energy. Thus a high energy environment may be indicated for bed nos. 319, 324 and some levels of 315. The preservation of the conchs where they are relatively intact with body chambers and apexes present may indicate little or no transport of the fauna as may be the case for bed nos. 320, 322, some levels of 315 and 325.

It is still too early in the study to make more conclusive comments on the environmental setting of the formation.

Cardiola Formation

The overlying Cardiola Formation, Ludlow in age, is comparable with the well-known cephalopod limestone which was deposited in Bohemia and along the North Gondwana margin. It is represented by a thinly developed dark limestone which is badly exposed in the war trench and shows lateral variation in its outcrop. It overlies the Kok Fm. appearing now as loose blocks or lenses which are buried in an earthy deteriorated layer. Cephalopods are the dominant fauna in this micritic limestone. Iso-oriented bioclasts, frequently coated by micrite, are quite common in the matrix.

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Below the Cardiola Fm., just at the top of bed 315 at one side of the trench, a 10cm thick level with an upper undulate surface was exposed. This horizon is rich in Cardiolids and was distinguished from the true Cardiola Fm. of the trench.

With regard to the nautiloids there is an abundant fauna apparently oriented parallel to bedding which acts as a fixed substrate for the *Cardiola* bivalve fauna. The specimens are generally small in size with diameters of 1-3cm and are longiconic in form. The specimens in general are well preserved with body chambers and apexes being present. Geopetal structures have been noted in the body chambers of some specimens oriented parallel to bedding and an opposed orientation of conchs on the bedding plane is also indicated. An interesting level overlies the Cardiola Fm. which bears a spectacular concentration of large nautiloids. Determinations and measurements of the specimens are in progress.

Alticola Limestone (Bed nos. 326 to 331)

The Alticola Lst., Pridoli in age, is a fine grey micritic limestone the beds of which vary in thickness and colour becoming darker and thinner towards the top but with an abundant nautiloid fauna throughout the formation. The preservation of the nautiloid fauna is similar to that of the Kok Formation. The associated fauna includes trilobites, brachiopods, echinoderms and relatively big gastropods. Solitary corals are visible in bed nos. 327 and 328 - lamination of the matrix and bioturbation were observed - the limestone becomes more micritic towards the top. A *Scyphocrinites* bed bearing complete specimens caps the formation. Micritised bioclasts are abundant in the matrix.

As may be seen from the data given (Fig. 2) this formation has a rich and varied fauna both of nautiloid and other groups. The base and top of the formation are marked by the occurrence of large orthocones oriented both parallel and perpendicular to bedding but which also show definite trends on the bedding surface itself. Telescoping and orientation to bedding are again good indicators of energy levels as is the fragmentation of the associated crinoid and trilobite fauna in some levels of bed nos. 326, 327 and 331. The amount of dissolution of the fauna appears to be quite significant in some beds particularly nos. 326 and 327 as is the development of thin crusts within these beds: these may be indicative of changing sea and oxygen levels. The nautiloid fauna is quite well preserved throughout the formation even where a higher energy environmental setting is indicated by telescoping, with body chambers being intact and sometimes showing geopetal structures parallel to bedding which is a good indication of little transport of the fauna. The data for the structural limits of the fauna, even though quite general, show a mixed fauna throughout the formation dominated by weaker fauna in bed 327 and comprised almost entirely of weak fauna in bed 331 at the top of the sequence. This latter indicates the shallowest fauna in the formation. The presence of Oncocerid nautiloids in Bed 329 also indicates a quite shallow setting.

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Orientation of Cephalopods

(Olga Bogolepova)

With regard to the orientation of orthoceracone cephalopods in the Rauchkofel Boden section O. 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* bearing 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. 12). 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).

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On the illustrated figure the main results of this preliminary study are summarized showing 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 a 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 against the apex or in the 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 held 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).

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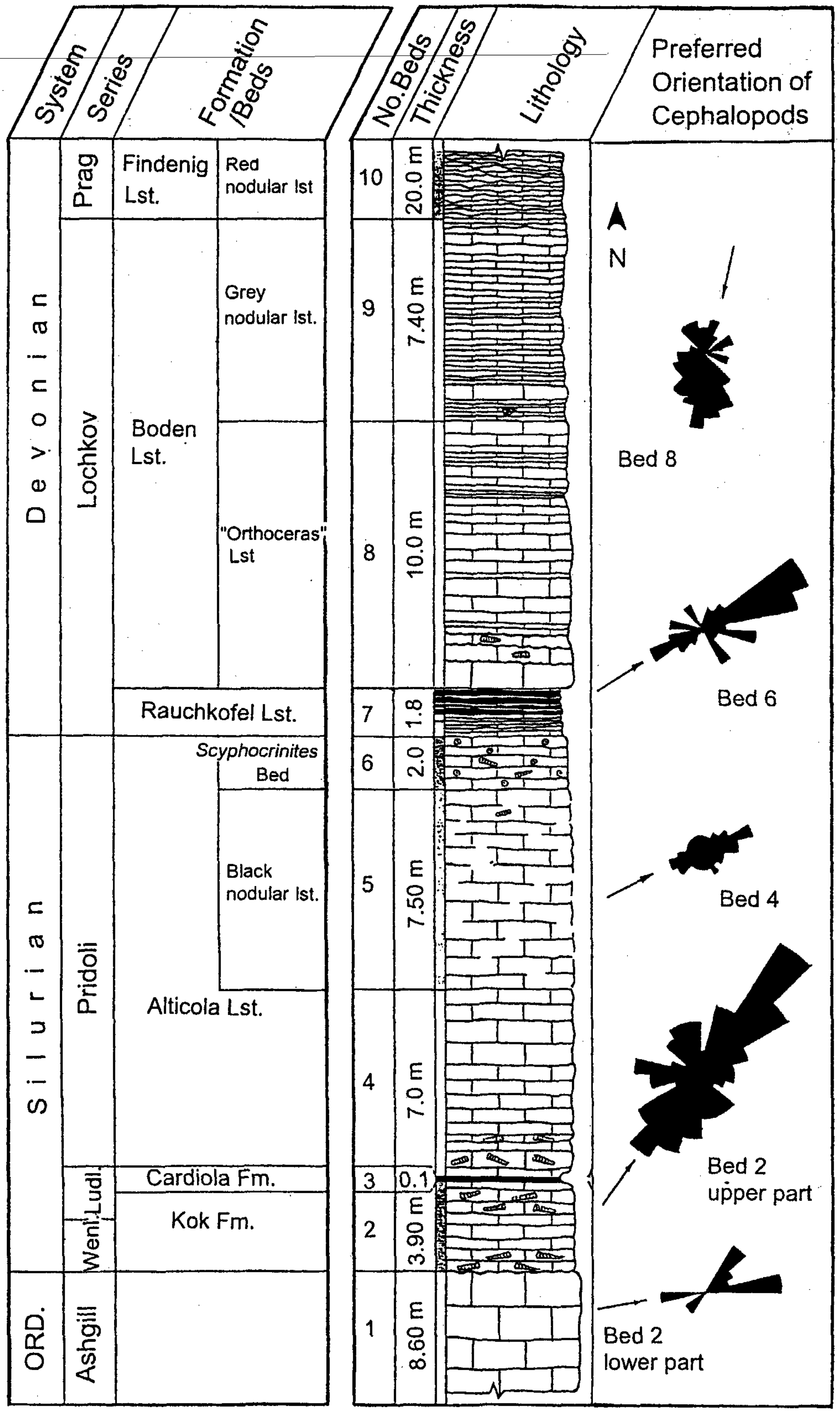

Fig. 12. The orientation of orthocone nautiloids in the Rauchkofel Boden section (after O. BOGOLEPOVA 1994)

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Stable Isotopes at Rauchkofel Boden section

(Bernd Wenzel)

For the introduction part we refer to p.106. Not surprisingly, on either side of the contact between the Upper Ordovician Wolayer Lst. and the transgressive Kok Fm. of the Wenlock a sharp break in the $\delta^{13}C_{carb}$-values can be recognized (Fig. 13). The succeeding samples from the Kok Fm. are characterized by relatively uniform $\delta^{13}C$-values. In contrast in the overlying equivalents of the basal Alticola Lst. corresponding to the latialata conodont Zone of the upper Ludlow significantly enhanced $\delta^{13}C$-values occur which apparently reveal the same trend as observed at Cellon. Different from the Cellon section, however, the strongest signal occurs at the base of the *Scyphocrinites*-bearing bed and not at the base of the overlying Rauchkofel Lst. of lowermost Lochkovian age. In terms of thickness this level is 2 m below the base of the Rauchkofel Lst. at this section.

During the present study of C and O isotopes additional differences between the Cellon and Rauchkofel sections have been recognized (see Fig. 13): For example, the $\delta^{13}C$-values of the Wolayer Lst. are about 1‰ higher than those from the Plökken Fm. at Cellon. Similar differences have been found in samples from the Wenlock and the lower and upper Ludlow. Also, in the Upper Silurian of the Rauchkofel Boden section the variation of the $\delta^{13}C$-signal is significantly bigger than at Cellon.

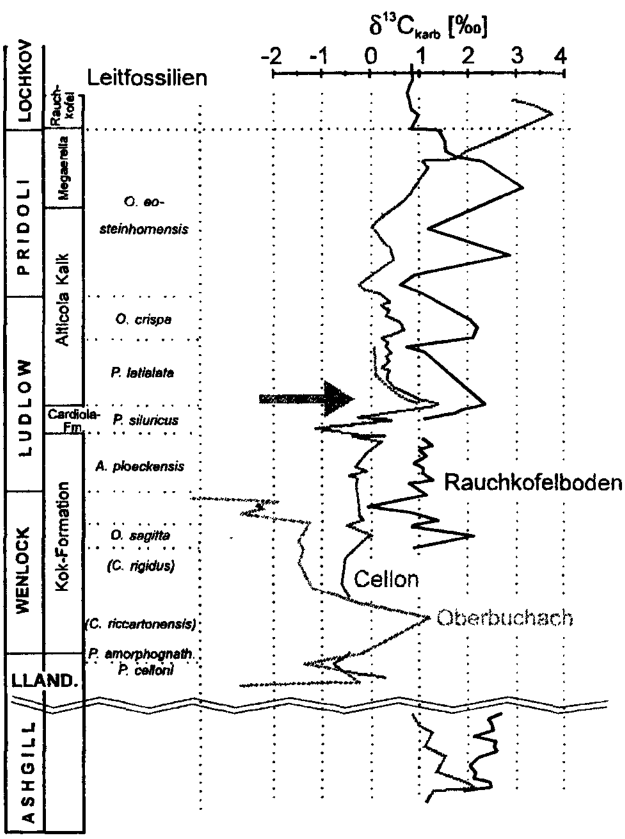

Fig. 13. $\delta^{13}C_{carb}$ curves for the sections Rauchkofel Boden, Cellon and Oberbuchach 1 correlated according to available biostratigraphic data. Note the upper Ludlow positive $\delta^{13}C$ excursion (arrow). After B. WENZEL (in press).

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