STOP 2. Sittendorf (Schrambach and Tannheim Formations; Aptian)

THE PENNINIC OCEAN SUBDUCTION: NEW DATA FROM PLANKTONIC FORAMINIFERA

Compendium from Oleg Mandic and Alexander Lukeneder (2008)

Introduction

The biostratigraphic data on the transition between the Schrambach and the Tannheim Formation of the northeastern Northern Calcareous Alps (Upper Austroalpine) are remarkable scarce (Weidich 1990, Wagreich 2003). This fact reflects the absence of identifiable ammonoid macrofossil fauna as well as the absence or bad preservation of relevant microfossils. The corresponding boundary however has an extraordinary importance for the reconstruction of Austroalpine geodynamics as marking the initial siliciclastic input into the basin reflecting the starting point of the Penninic Ocean subduction beneath the Upper Austroalpine (Wagreich 2003). Therefore the newly discovered outcrop NW of Sittendorf in the southwestern Vienna Woods, should now fill that gap. In that section the critical interval has been found for the first time in an environment comprising extraordinarily rich accumulations of planktonic foraminifera.

Penninic Ocean and Austroalpine Shelf

The Penninic Ocean (Fig. 1) was initiated in the Late Triassic by rifting and disjunction of the Austroalpine microcontinent from the southern European Plate margin. It was the eastern prolongation of the North Atlantic Rift-System effecting the final disintegration of the Permotriassic Pangea Supercontinent (e.g. Faupl 2003). The formation of the oceanic crust and the sea floor spreading lasted from the Middle Jurassic to the Early Cretaceous, terminating with the introduction of its southward-directed subduction beneath the northern Austroalpine plate margin (Faupl and Wagreich 2000). The active plate margin including the transpressional accretionary wedge and the northern parts of the Austroalpine microplate thereby underwent accelerated uplift and erosion; this is reflected in the beginning siliciclastic input into the southern, adjoining marine environments (Wagreich 2003).

The Northern Calcareous Alps, originally encompassing the southern part of the Austroalpine microplate, are positioned today at the northern margin of the Austroalpine nappe complex (Faupl and Wagreich 2000). In the Early Cretaceous the complex started to drift northwards, overriding progressively the northern parts of the Austroalpine plate (Fig. 2). At the front of the overthrust a piggyback basin developed, supplied from the north by a marine slope apron deposition (Wagreich 2003). The pelagic carbonate sedimentation, which already started in the Late Jurassic, therefore changes within several meters of the section into a siliciclastic dominated sedimentation. The gradual convergence of the slope apron depositional front and filling of the piggyback basin is reflected by a coarsening upward sequence ending with coarse sand and conglomerate intercalations at the top of the succession.

Depositional and tectonic setting

The studied section at Sittendorf includes the slope-apron succession of the Frankenfels Nappe representing the NNE part of the Northern Calcareous Alps and the Bajuvaric Unit nappe-system. The Lower Cretaceous pelagic sediments of the Bajuvaric Unit represent its major sedimentation cycle. The significant depositional change from the carbonate to the siliciclastic depositional system is reflected in the boundary between the Schrambach and the Tannheim Formations. Accordingly, the Schrambach Formation represents the phase of autochthonous pelagic sedimentation with the light-colored, aptychi-bearing nannoconid limestones and marly limestones. The Tannheim Formation, on the other hand, features typically dark, laminated pelagic marls and marly limestones whose formation was triggered by erosion and intensive redeposition (Wagreich 2003). The macro-invertebrate fauna of the succession is very sparse, comprising ammonoids, aptychi, belemnites, brachiopods and rare bivalves. The micro-fauna is in contrast abundant, with dominating radiolarians in the Schrambach Formation and planktonic foraminifera blooms within the Tannheim Formation.

Planktonic foraminifera patterns

The Cretaceous record of planktonic foraminifera generally shows a threefold pattern with periods of rapid diversifications alternating with periods of stasis (Premoli Silva and Sliter 1999). The investigated section represents the first diversification phase defined by latter authors lasting from the Early Valanginian to the latest Aptian. The continuous diversification therein is briefly interrupted only during the "Selli" event, where a smaller-scale turnover event occurred. The diversification phase begins with the rise of the first hedbergellids in the Early Valanginian followed in the Early Hauterivian with the first occurrence of small planispiral *Blowiella*. Intensification of taxonomic diversification, abundance increase together with the increase of the overall test size started within the Barremian. Finally with the Aptian the planktonic foraminifera blooms became frequent (cf. Premoli Silva and Sliter 1999). The assemblage prior to the Selli Event is still dominated by relatively small-sized, thin-walled and simple morphotypes (e.g. Coccioni et al. 1992). Following the Selli Event, medium-sized, clavate *Leupoldina* become typical, followed by the first occurrence of the thick-walled *Globigerinelloides*. Whereas *Leupoldina* soon retreats, *Globigerinelloides* goes through a remarkable evolution characterized by size and chamber number increase (Moullade et al 2005). This culminated in the Late Aptian, with *G. algerianus* being the first large-sized planktonics in the evolutionary history of the genus, attaining maximum diameters of ~700µm (Leckie et al. 2002). Synchronously, the same evolutionary trend is followed by the hedbergellids, with the remarkably large and massive *Hedbergella trocoidea* arising from the more primitive *Praehedbergella* *praetrocoidea* (Moullade et al. 2002). The brief global cooling (Herrle and Mutterlose 2003; Skelton 2003) by the end of Aptian initialized enhanced ocean mixing and thermocline destruction, triggering extinctions and the final drop in plankton diversity.

Lithology and facies distribution

The N-S striking section was measured from 11 m below and 12 m above the lithostratigraphic boundary between the Schrambach and the Tannheim Formation (Fig. 6). The layers dip at a very high angle toward the north (2nd section's meter: 326/70, 340/60; 16th section's meter: 000/70, 353/90).

The base of the measured section overlies a smaller-scale fault within the Schrambach Formation. Upsection, up to the 9 m mark, the Schrambach Formation exposes a monotonous series of hard, finely (at 10 cm scale), wavy bedded, micritic limestones. These mudstones to wackestones are typically light gray and contrast with the more strongly weathered and more marly portions (from 2 to 4 m, and around the 8 m mark), which are dark gray to olive green. Small-scale bioturbations are common in places, forming cm-thick horizons. Typical features include about 1-mm-thick, small, dark-colored, tube-shaped burrows unevenly distributed in the sediment.

The 9 m to 13 m level marks the transitional interval between the Schrambach and the Tannheim Formation. The boundary is defined with the top of the uppermost light gray bed at 10.9 m. The interval is characterized by a gradual upsection increase of the siliciclastic, clayey component. Nine 20- to 40-cm-thick limestone interlayers are intercalated – their boundaries show occasional minor fault structures. The lower 4 intercalations are light gray mudstones to packstones. The intervening marly intervals are light gray in the first meter, thereafter becoming dark gray laminated marls to marly limestone up to the top of the transitional interval; an exception is one 5-cm-thick dark clay horizon at 12.4 m. The other 5 micritic limestone intercalations are dark gray, laminated (first two) or homogeneous, bioturbated wackestones to packstones.

From 13 m to the top of the section, dark gray to greenish gray marls and marly limestones are present. These mostly wackestones can be laminated or bioturbated. Between 16 m and 17 m, at 18 m and at 22 m, 40- to 100-cm-thick, more limy, less weathered intervals are intercalated. At about 14.5 m and 20 m, steep fault structures occur. Above the uppermost limestone bed the outcrop situation becomes unclear. Except for one small bivalve shell, no microfossils were found.

Biostratigraphy

For the 23-m-long section in Sittendorf, 5 planktonic foraminifera Zones were detected. The Zones span from the Late Barremian to the older part of the Late Aptian (Gargasian sub-age in Ogg at al. 2004). Moreover, the occurrence of *Praehedbergella occulta* already within the first meter of the section points to the Early Aptian (Bedoulian sub-age in Ogg et al. 2004) for the lowermost part of the section. The studied sequence therefore correlates largely with the Aptian.

Interpretation of the section

The biostratigraphic analysis proved that the lower part of the section, including the investigated lithostratigraphic boundary between the Schrambach and Tannheim Formations, is continuous. In contrast, the upper part the section shows two distinct stratigraphic discontinuities. Moreover the biostratigraphy clearly demonstrates that the package between the two faults is a tectonically inverted block with a stratigraphically older strata overlying the younger one.

The gamma-log curve supports the biostratigraphic data very well. The gamma response becomes gradually stronger in the lower, undisturbed part of the section. The inverted block from the upper part of the section shows the highest gamma responses, remaining vertically at about the same mean intensity level. The uppermost package of the section, however, shows an upsection decreasing gamma response. The curve pattern therefore shows a vertically inverted picture of the corresponding biostratigraphic interval of the lower part of the section. This strongly suggests that the package from the uppermost part of the section represents an inverted block as well.

These data allow a precise reconstruction of the tectonic setting of the studied section. Accordingly, the best fit tectonic interpretation for the section's stratigraphic pattern is a position in a laterally (N-S) compressed, isocline, slightly overturned, syncline fold as illustrated in Fig. 8. The interpolation of the successional biostratigraphic horizons beyond the large inverted package in the upper part of the section yields the most reasonable reconstruction. Therefore, the latter block must have been pushed out from the southern fold wing apex due to the pressure from progressing lateral compression. The reconstructed offset is about 5 to 6 m.

Conclusions

The Schrambach Formation comprises the lower 10.9 m of the section. Those pelagic limestones and marly limestones are mudstones to wackestones whose matrix is dominated by large nannoconid phytoplankton. Among the microplankton, radiolarians are often abundant, especially in the topmost portions. Planktonic foraminifera are, except for the topmost part, scattered; in the lower part they are still small sized, becoming distinctly larger upwards. The assemblage is dominated by small, five-chambered *Praehedbergella*, particularly by *P. infracretacea*. The presence of *Blowiella blowi* together with *Praehedbergella occulta* already in the lower part of the section allows the section to be placed into the upper part of the *B. blowi* Interval Zone and to be correlated with the uppermost Barremian and lowermost Aptian.

The uppermost part of the Schrambach Formation (10 m to 10.9 m) displays already marly intercalations, and therein also the C_{org} values suddenly drop from previously enhanced values (1-2%) to distinctly lower ones (<1%). Except for one sample close to the dark clay intercalation, the lowered C_{org} values persist upward throughout the Tannheim Formation. The planktonic foraminifera also undergo a radical change, not only in taxonomic composition, size and wall thickness, but particularly in abundance. From here upwards, zooplankton blooms characterize the succession up to its top. The planktonic foraminiferal assemblage is characterized by the common *Leupoldina* and large specimens of *Blowiella blowi*, defining its stratigraphic position within the *Leupoldina cabri* Acme Zone. The base of the latter Zone superimposes the Early Aptian Oceanic Anoxic Event "Selli" and has an inferred age of about 124 Ma. Up to now, the presence of a planktonic foraminiferal assemblage with *Leupoldina* was unknown from the investigated depositional cycle (Schrambach - Tannheim - Losenstein Formation).

The larger part of the succession within the lower portion of the Tannheim Formation (between 10.9 m and 14 m) is characterized by the common occurrence of *Leupoldina*. For the upper part of the Acme Zone, a characteristic feature is the occurrence of *Praehedbergella luterbacheri* and *Globigerinelloides ferreolensis*. The last occurrence of *Leupoldina* in the section approximates the base of the *Globigerinelloides ferreolensis* Interval Zone, correlating roughly with the Early/Late Aptian boundary. The presence of the upper part of the Interval Zone is indicated by the introduction of *Globigerinelloides barri*. This species with 9 chambers in the last whorl represents the limb in the gradual evolution from *G. ferreolensis* (7-8) to *G. algerianus* (10 to 12).

The uppermost part of the Sittendorf exposure (14 m to 23 m) follows a fault structure and comprises another fault at the 20 m of the section. Except for those two faults, the succession comprising the Tannheim Formation has been originally presumed for being principally continuous. Yet, the biostratigraphic analysis together with the analysis of the gamma-log curve trend proved clearly highly complicated tectonic setting.

Hence the samples above the fault showed distinctly younger planktonic foraminifera assemblage than the ones below the fault. The large, thick-walled *Hedbergella trocoide*a with 8 chambers in the last whorl, along with the absent *Globigerinelloides algerianus*, underpinned the Late Aptian *H. trocoidea* Interval Zone.

Further upsection, up to the next fault, the reverse succession has been detected. Then not only the extremely large specimens of *G. algerianus* in that samples proved the exact correlation with the Late Aptian *G. algerianus* Taxon Range Zone, but also the *Hedbergella trocoide*a has been found therein present exclusively by the distinctly smaller, primitive, 7-chambered morphotypes. Hence, this particular part of the section has been clearly proved for being a tectonically inverted block.

The latter block is delimited from the topmost part of the section by the second fault positioned at its 20 m. The reoccurrence of *Leupoldina cabri* Acme Zone in those topmost samples is highly significant. Hence it proves the stratigraphically reversed position of the uppermost section part. It proves, as well, the significant tectonic movement at the fault causing the stratigraphic gap of one planktonic foraminifera zone (i.e. *G. ferreolensis* IZ). The decreasing gamma log values together with the characteristic pattern, which is reversely symmetrical to the corresponding pattern in the lower, undisturbed part of the section, correspond well with the interpretation of that block as a tectonically inverted structure.

The presented data underpin well the rather complicated, structural geological interpretation of the section. Hence the studied exposure is apparently positioned within a slightly northwards overturned, isoclinal syncline fold. The discontinuity in the upper section is a product of the lateral pressure, block escape movements in the southern wing of the syncline.

In conclusion, the range of the section is estimated to be about 10 m.y. and to include five Aptian planktonic foraminifera zones. The terrigenous input bounded to initial subduction of the Penninic Ocean under the Austroalpine Microplate started at about 123 Ma (Early Aptian). This date corresponds with that determined for the lithostratigraphic boundary between the Schrambach Formation and the Tannheim Formation. Although the section is discontinuous in its upper part (Tannheim Formation), the studied lithostratigraphic boundary is positioned within the continuous part of the section, making it suitable for the present investigation. Finally, thin section biostratigraphy of planktonic foraminifera proved, also in the Northern Calcareous Alpidic shelf, to be a powerful tool for stratigraphic dating of Aptian deep-water successions.

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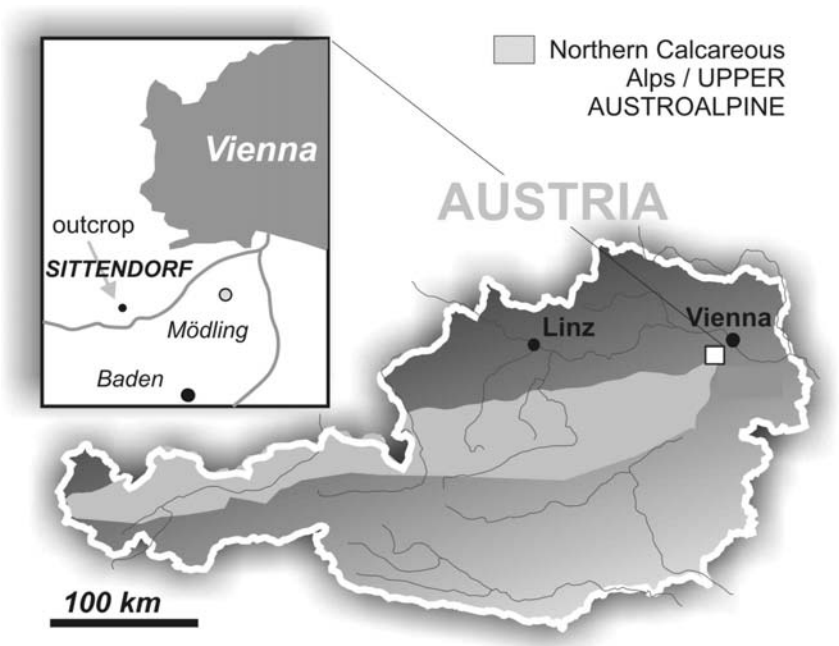

Fig. 1. Geographic position and regional geologic setting of the studied outcrop at Sittendorf.

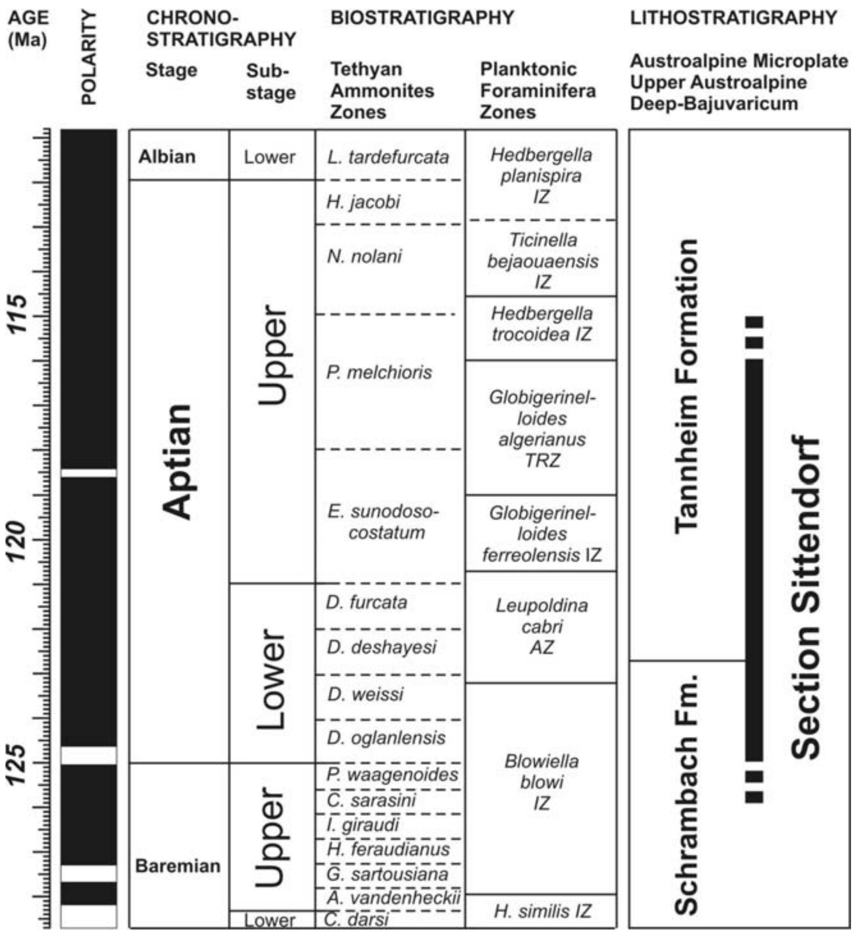

Fig. 2. Stratigraphic Correlation Table (modified after Ogg et al. 2004)

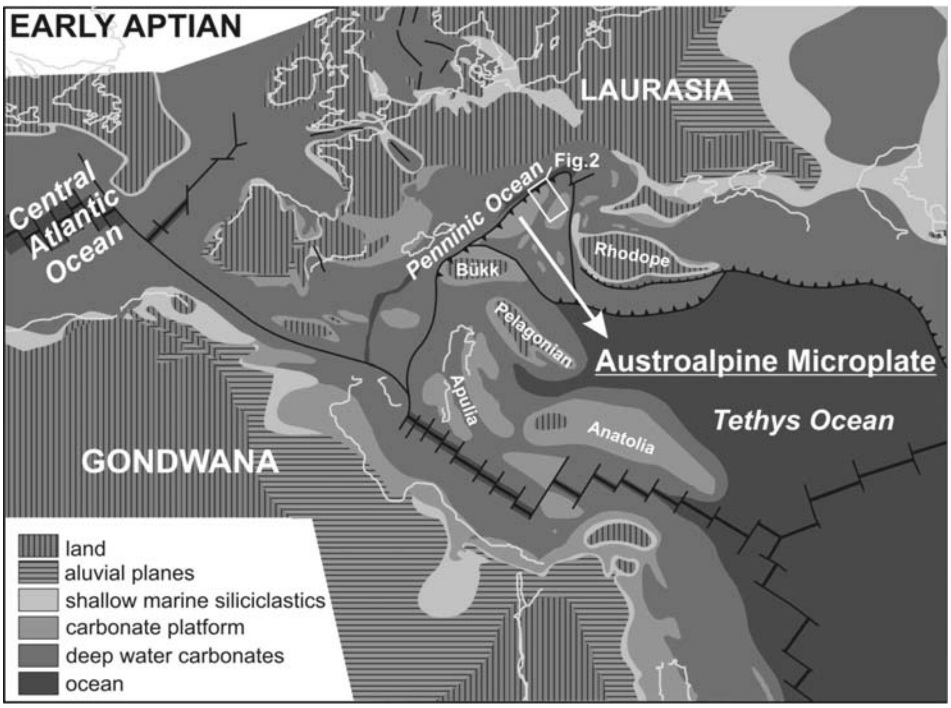

Fig. 3. Palinspastic setting and position of the Penninic Ocean subduction (modified after Masse et al. 2000)

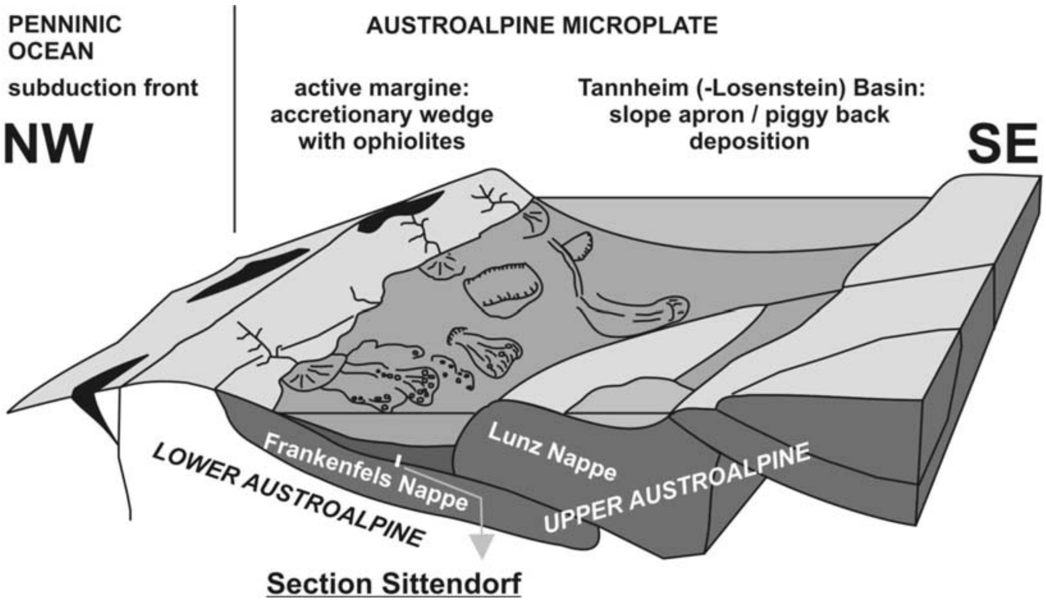

Fig. 4. Schematic paleogeographic reconstruction of the Tannheim Basin with indicated position of the Sittendorf Section (modified after Wagreich 2003)

Fig. 5. Outcrop Sittendorf with indicated sample positions, including lithostratigraphic and chronostratigraphic results of the present study.

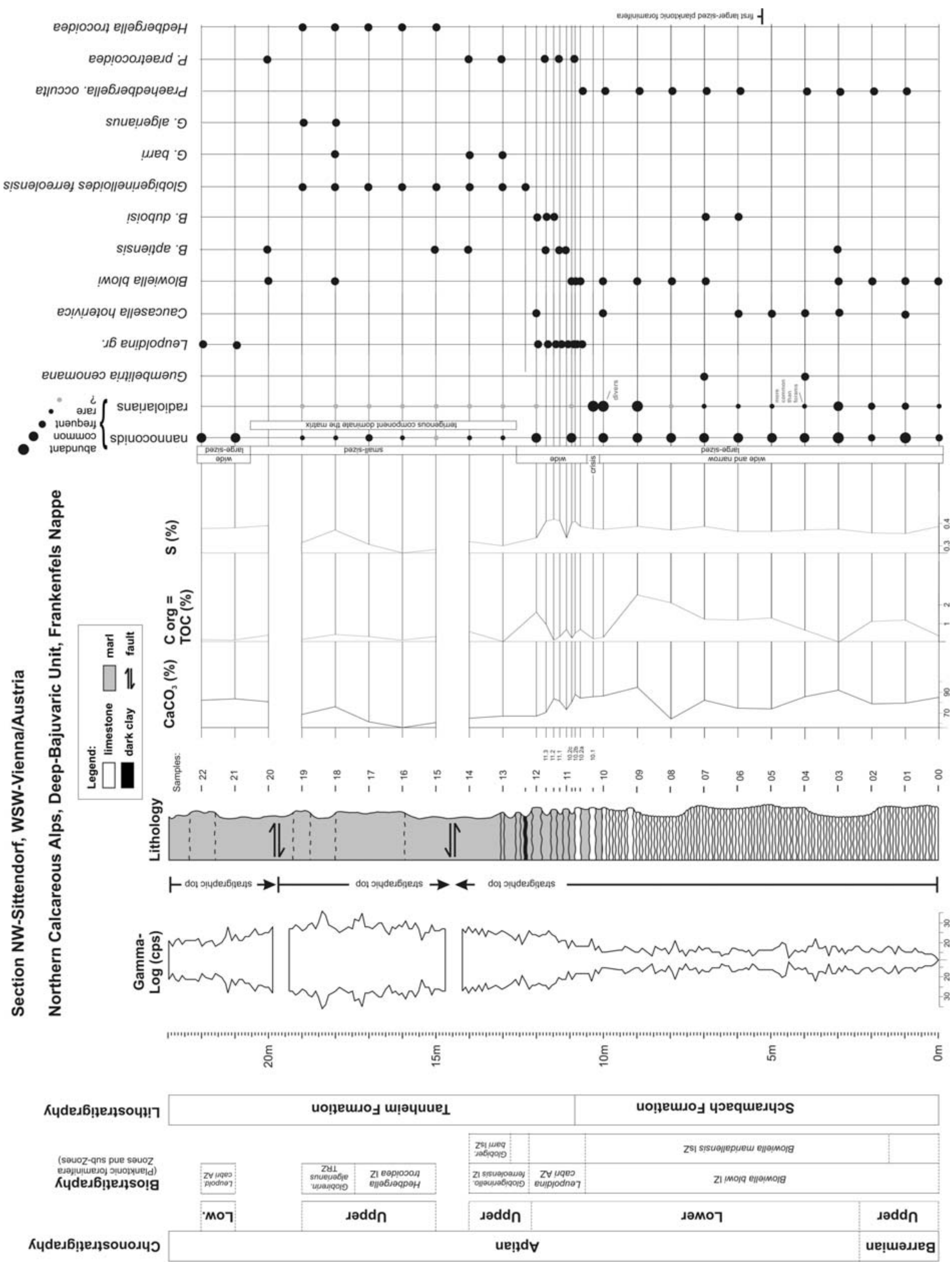

Fig. 6. Section Sittendorf showing the lithostratigraphic, biostratigraphic and chronostratigraphic interpretation. Indicated are lithologies, sampling positions, distribution of radiolarians, nannoconids and selected planktonic foraminifera as well as results of geochemical and geophysical investigations.

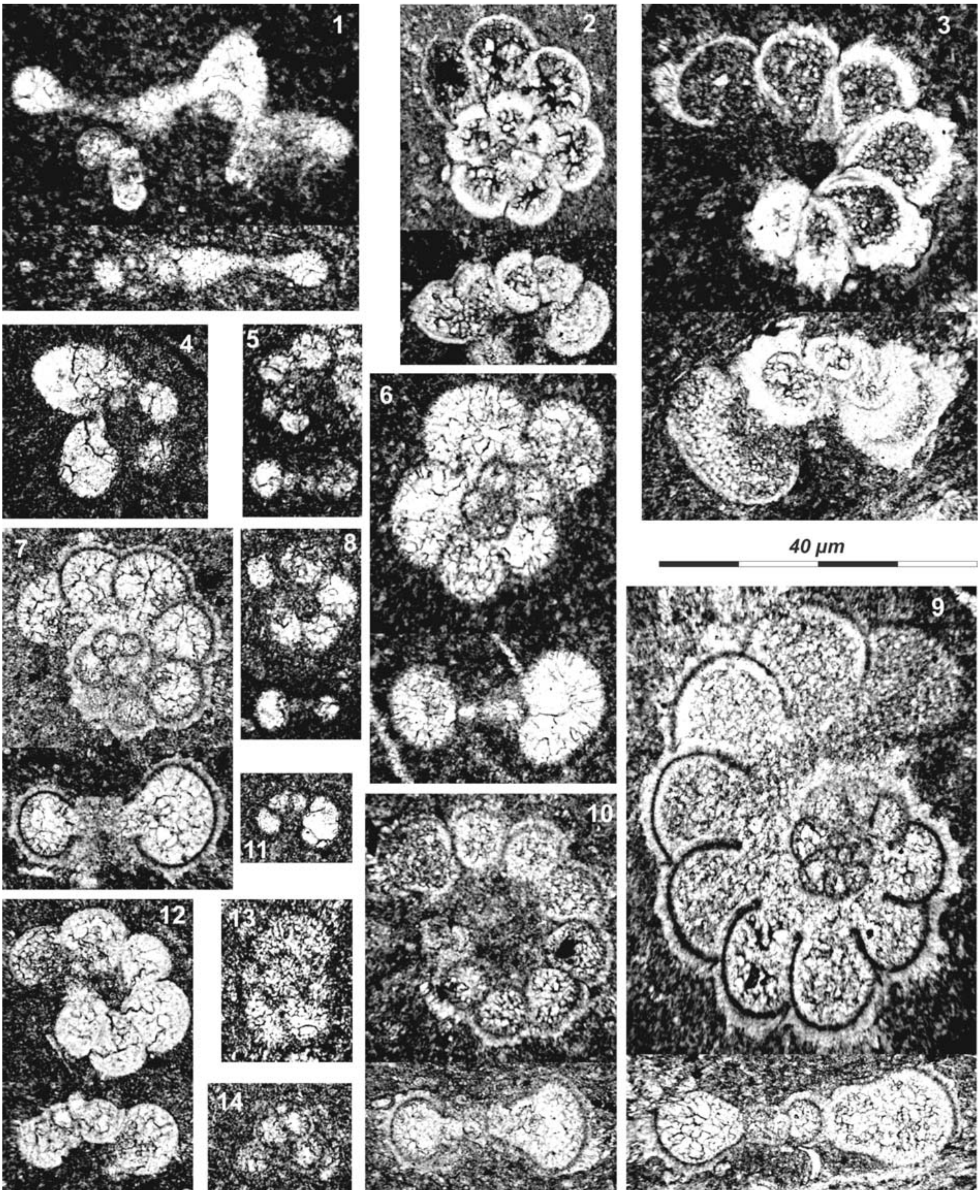

Fig. 7. 1, *Leupoldina cabri - pustulans* Group, Sittendorf (SI) 10.2b. 2-3, *Hedbergella trocoidea*. 2, SI 18. 3, SI 16. 4, *Blowiella duboisi*, SI 06. 5, *Blowiella aptiensis*, SI 03. 6, 8, *Blowiella blowi*, 6, SI 10.2b. 8, SI 01. 7, *Globigerinelloides ferreolensis*. 7, above, SI 13. 7, below, SI 14. 9, *Globigerinelloides algerianus*. 9, above, SI 18. 9, below, SI 19. 10, *Globigerinelloides barri*, SI 14. 11, *Praehedbergella occulta*, SI 04. 12, *Praehedbergella praetrocoidea*, SI 13. 13, *Caucasella hoterivica*, SI 13. 14, *Guembelitria cenomana*, SI 04.

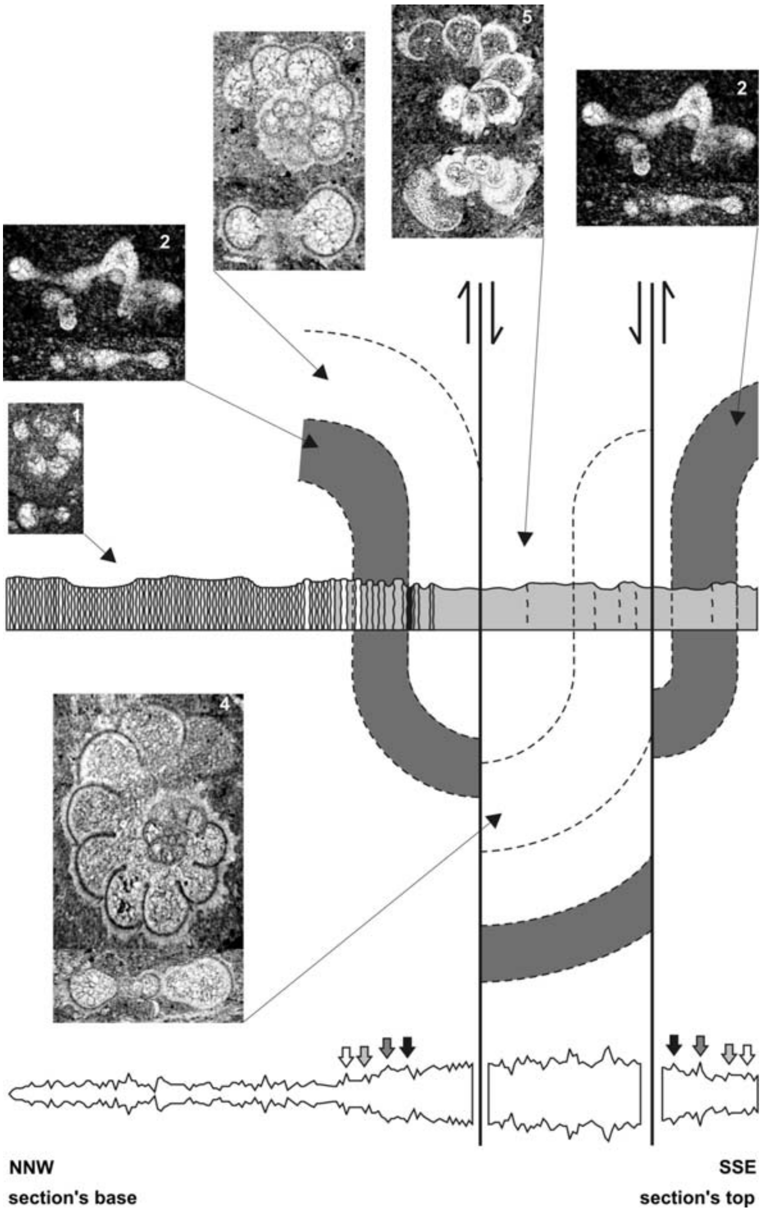

Fig. 8. Tectonic interpretation of the Section Sittendorf based on the evaluation of biostratigraphic and geophysical data. Each thin section photograph represents the name-giving taxon of the indicated biozone: 1: *B. blowi* Interval Zone (IZ), 2. *L. cabri* Acme Zone, 3. *G. ferreolensis* IZ, 4. *G. algerianus* Taxon Range Zone, 5. *H. trocoidea* IZ.