BIOSTRATIGRAPHY AND PALAEOENVIRONMENT OF THE LOWER GOSAU SUBGROUP OF EISENBACH BROOK IN SALZKAMMERGUT (UPPER AUSTRIA)

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The Eisenbach locality is situated on the eastern side of Lake Traunsee, approximately opposite the Traunkirchen peninsula. The outcrops occur along the Eisenbach brook, which rises on the foothills of Mt. Hochstein on mapsheet 67 Grünau im Almtal and flows to the southwest into the Karbach stream, entering the area of mapsheet 66 Gmunden. Silty fossiliferous grey marls, including „black shales", with subordiate sandstone and marly limestone intercalations dominate the sequence. Sediments for mineralogical and microfossil analyses were sampled in, respectively on the slopes of the Eisenbach brook. However, the study of the bivalve fauna and of the foraminifers were focused so far only on the grey marls of locality No. EB 8.

Samples EB 15A, B: 30 cm thick black marly limestone layer with mollusks and „black shales", mapsheet 66. Thin sections show a floatstone with extremely reduced content of microfossils.

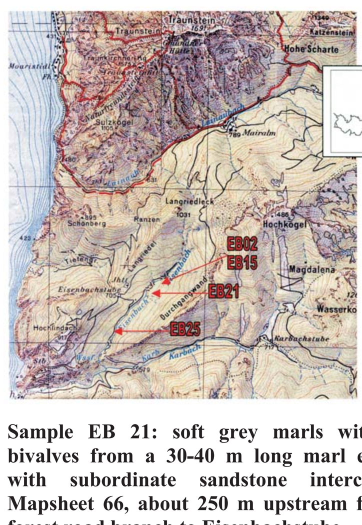


Fig. 1: Topographic situation of Eisenbach sample points, 5km NNE of Ebensee.

Sample EB 21: soft grey marls with some bivalves from a 30-40 m long marl exposure with subordinate sandstone intercalations. Mapsheet 66, about 250 m upstream from the forest road branch to Eisenbachstube.

Sample EB 25: lilac red sequence of hard sandstones and subordinate marly sandstones, about 70 m upstream from the first bridge crossing the Eisenbach brook after the tunnel. Mapsheet 66.

Sample EB 1: fossil collecting point (mainly gastropods) in „black shales" below a bridge crossing the Eisenbach stream on the border of mapsheet 66 and 67.
Sample EB 2: fossiliferous „black shales" with gastropods and bivalves with thick fossil-rich layers of bituminous limestone (?tempestites); downstream from sample point EB 1, already on mapsheet 66.
Sample EB 8: grey marls in the higher part of the Eisenbach creek, about 895 m above sea level.
Samples EB 9A, B: see paper by Schlagintweit et al. (2003). A thin section of sample EB 9A shows mudstone with a finely dispersed pyrite content; no microfossils.

Sample EB 9B can be classified as green algae wackestone with *Halimeda paucimedullaris* Schlagintweit & Ebli, *Neomeris circularis* Badve & Nayak, *Dissocladella*? *pyriformis* Schlagintweit and most abundant the dasycladale *Thrysoporella eisenbachensis* Schlagintweit.
Sample EB 10: light grey, fossil-rich marls with bivalves, gastropods, corals. Upstream from sample point EB 8 on mapsheet 67.
Samples EB 11A, B: as locality EB 10, however, hard marly limestones. Thin sections show bioturbate wackestone with fine clastic debris. Benthic foraminifera include *Vidalina hispanica* Schlumberger and other miliolids. In addition some echinoid spines, ostracodes, debris of the green alga *Halimeda* and isolated fertile ampullae of *Neomeris circularis* Badve & Nayak.

DASYCLADALES

Thrysoporella eisenbachaensis n. sp. from Lower Gosau Group of Eisenbach

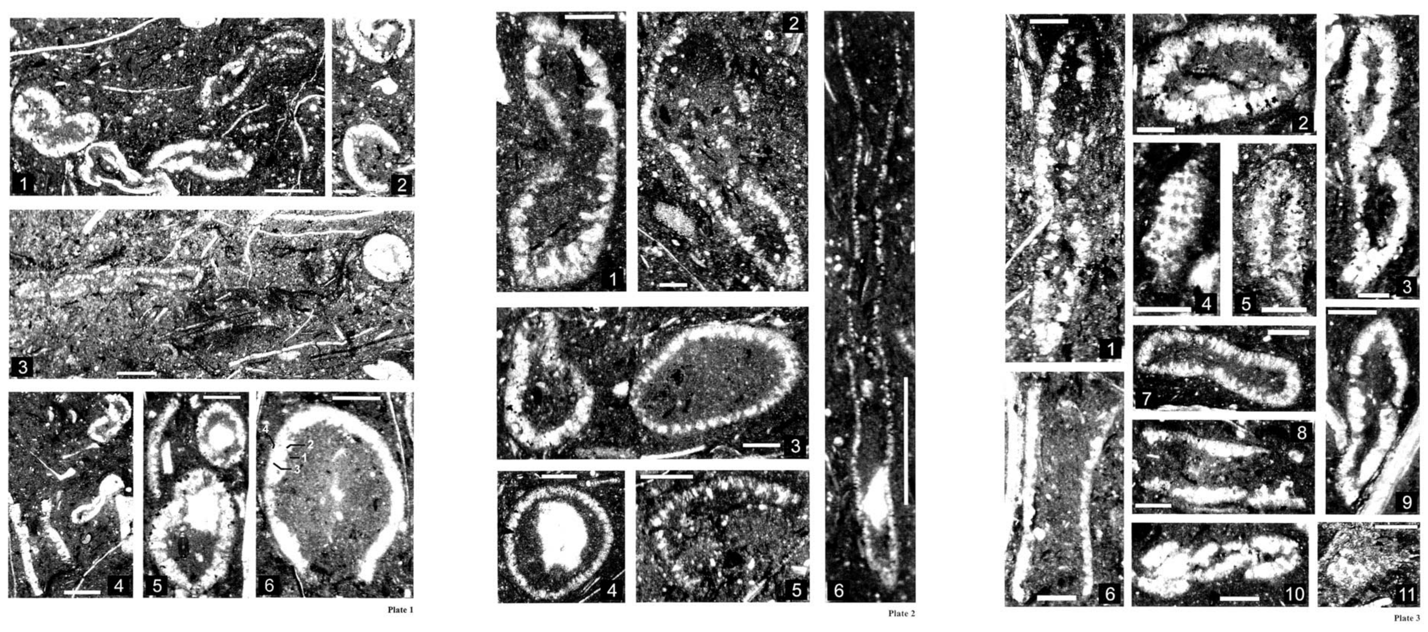


Plate 1 Plate 2 Plate 3

From the Middle Turonian of the lower Gosau Group of Eisenbach a new dasycladale is described as *Thrysoporella eisenbachensis* n. sp. The new taxon occurs within a marly limestone bed intercalated within a series of marls. The microfacies represents a lagoonal wackestone where the new species occurs together with pelecypod remains, ostracodes, *Neomeris circularis* Badve & Nayak, *Dissocladella? pyriformis* Schlagintweit& Ebli and miliolids, e.g. *Vidalina hispanica* Schlumberger. The new species is distinguished from other representatives of *Thrysoporella* above all by its high number of primary branches.

BIVALVIA

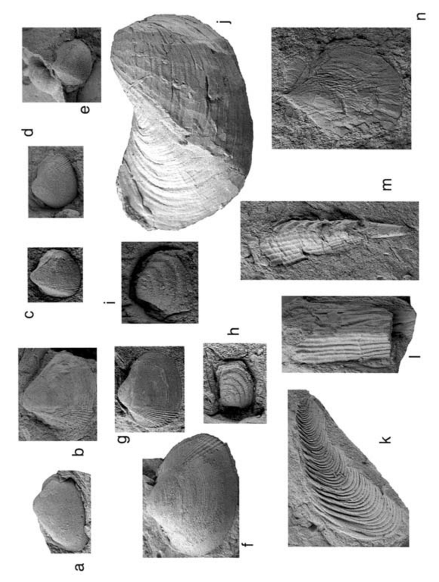
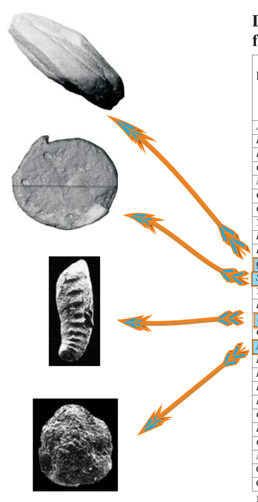


Plate 1; Bivalves from the locality EB 8: Fig. a: *Nucula* sp. 2x; Fig. b-g: *Protocardia (P.) hillana* (J. Sowerby, 1813), b: 1.5x, c,d:2x, e:1.5x, f:1x, g:1.6x; Fig. h, i: *Astarte*? sp. h: 5.6x, i: 4x; Fig. j: *Pholadomya* sp. 1.2x; Fig. k: *Inoperna flagellifera* (Forbes, 1846), internal surface of a left valve, 1.5x; Fig. l, m: *Pinna* cf. *cretacea* (Schlotheim, 1813), both 1.8x; Fig. n: *Entolium* sp. 3x.

The beds of locality EB 8 are largely represented by in situ, but loose blocks and have yielded a bivalve fauna consisting of 9 taxa. The bivalve shells are usually more or less chalkified. Almost 200 specimens were identified in the field in order to characterise the assemblage quantitatively. Only small-sized solitary corals and internal moulds of gastropods were encountered as associated macro-faunal elements.

FORAMINIFERA



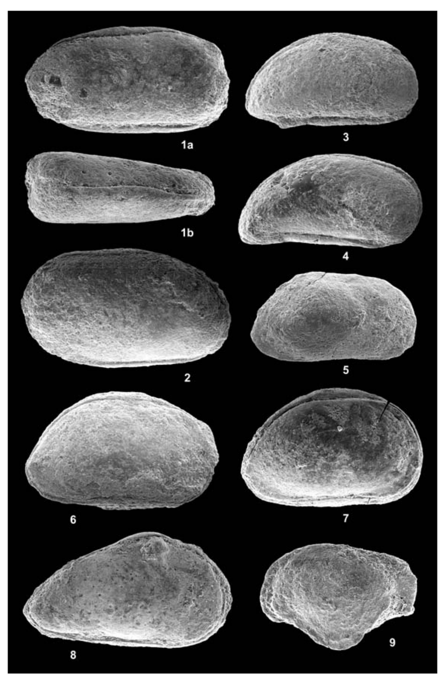
Distribution of foraminifera
f = frequent c = common r = rare

Eisenbach am Traunsee	Turonian-Coniacian	?	Middle-Upper Turonian		?	Turonian	Santonian ?
	?	?	M.schneegansi Z.	?	?	?	?
	EB 1	EB 2	EB 8	EB 10	EB21	EB 25	EB 26
Ammobaculites sp.	r		r				
Haplophragmoides cf. *latidorsatum*			r				
Bigenerina sp.			r				
Gaudryina rugosa				f			
Marssonella oxycona				f		r	
Gaudryina trochus				f			
Gaudryina laevigata							
Trochammina sp.			r				
Dorothia filiformis ?					f		
Pseudotextularia sp. ?							
Quinqueloculina angusta	r	r	f	r			
Spirillina cretacea	f	f	f				
Triloculina sp. ?	r	r					
Lenticulina sp.	r						r
Vaginulina trilobata			r				
Gavelinella sp.						r	
Marginotruncana schneegansi			r				
Hedbergella planispira					r		
Hedbergella simplex						r	
Hedbergella delrioensis							
Heterohelix globulosa				r			
Globigerinelloides ultramicra ?	r						
Praeglobotruncana sp.			r				
Globotruncana stuartiformis ?							r
Marginotruncana angusticarinata ?	r						
Ostracoda	c	c	c	c	c		
Gastropoda	c	c	c	c	c		r

f = frequent c = common r = rare

In the assemblages from the light grey marls (EB 8 in part, EB 10, EB 21, EB 25), agglutinated species as *Gaudryina, Marssonella* and *Dorothia* are dominating. Calcareous benthos and plankton occur rarely and their tests are usually recrystallized. The foraminiferal assemblage of the red coloured sediments of sample EB 25 is very poor of species, only a few badly preserved, recrystallized tests of foraminifers were found. Samples from „black shales" contain mostly Miliolidae as *Spirillina cretacea* and *Quinqueloculina angusta*.
The character of foraminiferal assemblage is similar to that one of Weißenbachalm locality near Bad Aussee (samples WB 1, 1A, Hradecká et al. 1999) but the Eisenbach assemblage is much more poorer (see distribution table).

OSTRACODA



Sample EB 8 provided following taxa: *Brachycythere* sp., *Cytherella parallela* Reuss, 1844, *Cytherella* sp., *Dolocytheridea* aff. *crassa* Damotte, 1971, *Dordoniella turonensis* Damotte, 1962, *Dordoniella* aff. *strangulata* Apostolescu, 1955, *Schuleridea neglecta* (Reuss, 1854), *Schuleridea* sp. and several other indeterminable faunal elements.
Sample EB 21 yielded only two ostracod species, namely *Cytherella* aff. *dordoniensis* Damotte, 1971 and *Cytherella* sp.

Ostracoda from the locality EB 8:

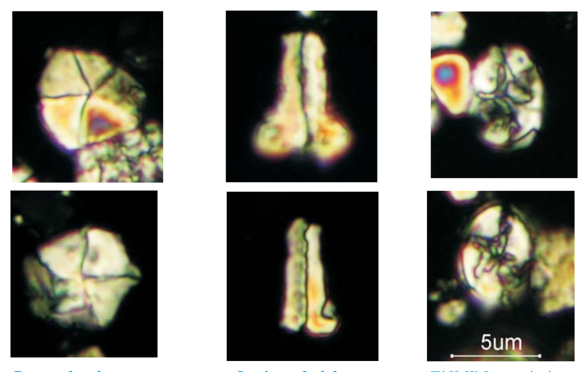
Fig.1a-b: *Cytherella parallela* Reuss, 1844, 1a: carapace from the left, 1b: dorsal view, coll.Nr. 2003/5/3, x 125, Fig. 2:*Cytherella* sp., coll. Nr. 2003/5/5 , x 85, Fig. 3: *Dolocytheridea* aff.*crassa* Damotte, 1971, coll. Nr. 2003/5/7, x 85, Fig. 4: *Dolocytheridea* aff. *crassa* Damotte, 1971, coll. Nr. 2003/5/9, x 110, Fig. 5: *Dordoniella turonensis* Danotte, 1962, coll. Nr. 2003/5/10, x 100, Fig.6: *Dordoniella* aff. *strangulata* Apostolescu, 1955, coll. Nr. 2003/5/11, x 100, Fig. 7: *Dordoniella* aff. *strangulata* Apostolescu, 1955, coll. Nr. 2003/5/12, x100, Fig.8: *Schuleridea neglecta* (Reuss, 1854), male, coll. Nr. 2003/5/14, x85, Fig. 9: *Brachycythere* sp. coll. Nr. 2003/5/1, x 100.

CALCAREOUS NANNOPLANKTON

Sediments provided very rare calcareous nannofossils (1-2-5 specimens in maximum per one field of view of the microscope; calcium carbonate material of anorganic origin is the major component). Specimens are poorly preserved and mostly in fragments.
Nannofossil assemblages are characterized by following phenomena (see distribution tab.):
Presence of species they first appear in the Turonian, such as *Eprolithus octopetalus, Quadrum gartneri, Eiffellithus eximius, Lucianorhabdus maleformis,* and *L. quadrifidus.*
Presence of long-ranging species known in the interval from Jurassic or Lower Cretaceous up to Campanian-Maastrichtian.
Reworked species the first occurrence of which is known in the Aptian or Albian and they disappear during the Upper Cretaceous.
Reworked nannofossils fixed on the ?Aptian-Albian-Cenomanian interval exclusively.
Reworked nannofossils fixed on the Cenomanian stage exclusively (*Corollithion kennedyi* – sample EB 8C).
Reworked Jurassic and lower Lower Cretaceous species.
Deposits of sample EB 2 and EB 25 provided mostly calcium carbonate detritus of anorganic

Eisenbach-Traunsee			?Albian to Turonian	Turonian							Coniacian
				Lower	Middle						Middle
		nannofossil zones (Burnett 1998)		UC7	UC8b						UC10
		sample No.	EB10	EB1	EB 8	EB 8A	EB 8B	EB 8C	EB 8D	EB21	EB26
		abundance of nannofossils	VL	L	L	VL	L	VL	L	L	M
		nannofossil preservation	VP	VP	VP	VP	VP	VP	VP	VP	VP
FO Cenomanian-Turonian-Coniacian	species they may form Turonian or Coniacian nannofloral assemblages	*Braarudosphaera bigelowii* *		R	R				R	R	
		Calculites ovalis					R		R		
		Eiffellithus eximius			R	R	R		R		
		Eiffellithus turriseiffelii-eximius					R	R	R		
		Eprolithus octopetalus								R	
		Lucianorhabdus maleformis					F	R			
		Lucianorhabdus quadrifidus			R	R	F	R	R	R	
		*Micula staurophora***									R
		Prediscosphaera cretacea		R	F		R	R	F		R
		Quadrum gartneri-gothicum		?						?	
		Quadrum gartneri		R	R		R			R	
		Quadrum intermedium (7 elements)*		R				R			
		*Rhagodiscus plebeius**					R				
FO Aptian-Albian		*Amphizygus brooksii*			R				R		
		Broinsonia signata							R		
		Cribrosphaerella ehrenbergii		R	R				R	R	R
		Eiffellithus turriseiffelii		f	F	R	R		F	R	R
		Eprolithus floralis		R	R		R	F	F	R	
		Helicolithus trabeculatus			R					R	
		Microrhabdulus belgicus					R				
		Prediscosphaera columnata	R		F	R	R	R	F	R	
		Prediscosphaera ponticula							R		
		Prediscosphaera spinosa		R	R						
		Radiolithus orbiculatus		R	R			?			R
		Rhagodiscus angustus	R	R	R				R		
		Rhagodiscus splendens		R							
		Zeugrhabdotus bicrescenticus		R			R			R	
Jurassic and Cretaceous long-ranging species		*Braarudosphaera regularis*	?	?	?						
		Chiastozygus litterarius		R				R	R		
		Cretarhabdus conicus		R	R	R		R	R	R	
		Cyclagelosphaera margerelii					R		R		
		Helenea chiastia		R							
		Lithraphidites carniolensis		R	R		R		F	R	
		Manivitella pemmatoidea								f	f
		Nannoconus elongatus			R				R		
		Retacapsa angustiforata	R	R							R
		Retacapsa crenulata		R	R	R	R	R	R	R	R
		Tegumentum stradneri		R	R						
		Watznaueria barnesae	F	F	F	F	F	F	F	C	F
		Watznaueria britannica		R	R		R	R		R	R
		Zeugrhabdotus diplogrammus		R	F		R	R	R	R	R
		Zeugrhabdotus embergerii		R	R	R			R	R	
		Zeugrhabdotus noeliae			R						
Cen.	reworked nannofossils	*Corollithion kennedyi*						r			
Apt.-Cen.		*Braarudosphaera africana*						r		r	
		Cretarhabdus striatus			r						
		Isocrystallithus compactus					r	?	r		
		Lithraphidites acutus								?	
		Nannoconus cf. *vocontientis*					r				r
lower Lower Cretaceous		*Cruciellipsis cuvillieri*		r	r				r	r	
		Discorhabdus striatus						r			
		Lithraphidites bollii		r							
		Micrantholithus hoschulzii	r	f	r	r	r	r	r	r	
		Micrantholithus obtusus			r					r	
		Nannoconus globulus minor						r			
		Nannoconus kamptneri							r		
		Nannoconus steinmanii		r	r					r	r
		Nannoconus truittii		r						r	
Tithon.		*Conusphaera mexicana*							r	r	
		Watznaueria manivitae						r			

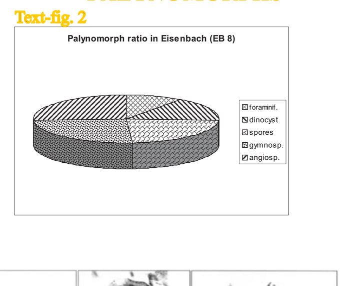
Distribution of calcareous nannofossil taxa
Abundance of nannofossil taxa: F = few (>5 specimens per 20 fields of view), R = rare (<5 specimens per 20 fields of view); ? = questionable taxon, f = fragments, r = reworked. Estimates of the abundance of nannofossils in samples: M = medium (>5 specimens per 1 field of view), L = low (1-5 specimens per 1 field of view), VL = very low (<1 specimen per 1 field of view). Preservation of nannofossils: VP = very poor (etching and especially mechanical damage is intensive making identification of some specimens difficult).
FO = first occurrence, * = taxon the first occurrence of which is known from Cenomanian.



Braarudosphaera sp. *Lucianorhabdus* sp. *Eiffellithus eximius*

PALYNOMORPHS

Text-fig. 2



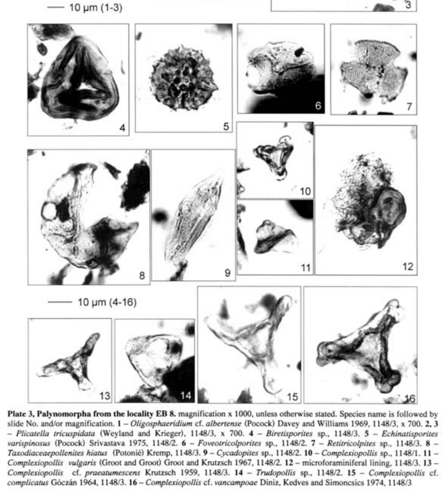


Plate 3, Palynomorpha from the locality EB 8, magnification x 1000, unless otherwise stated. Species name is followed by slide No. and/or magnification. 1 – *Oligosphaeridium* cf. *albertense* (Pocock) Davey and Williams 1969, 1148/3, x 700. 2, 3 – *Plicatella tricuspidata* (Weyland and Krieger), 1148/3, x 700. 4 – *Biretisporites* sp., 1148/3. 5 – *Echinatisporites varispinosus* (Pocock) Srivastava 1975, 1148/2. 6 – *Foveotricolporites* sp., 1148/2. 7 – *Retitricolpites* sp., 1148/3. 8 – *Taxodiaceaepollenites hiatus* (Potonié) Kremp, 1148/3. 9 – *Cycadopites* sp., 1148/2. 10 – *Complexiopollis* sp., 1148/1. 11 – *Complexiopollis vulgaris* (Groot and Groot) Groot and Krutzsch 1967, 1148/2. 12 – microforaminiferal lining, 1148/3. 13 – *Complexiopollis* cf. *praeatumescens* Krutzsch 1959, 1148/3. 14 – *Trudopollis* sp., 1148/2. 15 – *Complexiopollis* cf. *complicatus* Góczán 1964, 1148/3. 16 – *Complexiopollis* cf. *vancampoae* Diniz, Kedves and Simoncsics 1974, 1148/3

Detailed micropalaeontological analysis of sample EB 8 disclosed a relatively well preserved but not rich assemblage of spores, pollen grains, organic-walled microplankton, and microforaminifers. The palynomorph ratio (Text-fig. 2) consists of 23% of pteridophyte spores, 25% of gymnosperm pollen, 26% of angiosperm pollen, 16% of non-calcareous marine microplankton (dinoflagellate cysts), and 10% of planispiral type of inner microforaminiferal linings.
The spore-pollen flora is diverse and has a slightly predominant angiosperm component. Mostly triporate angiosperm pollen grains of Normapolles group - *Complexiopollis*, i.e., *Complexiopollis* cf. *christae*, *C. vulgaris*, *C.* cf. *praeatumescens* and *Complexiopollis* spp. prevail.
The lower land plants (pteridophyte spores) are particularly well represented by abundant large striate spores with long appendices – *Plicatella tricuspidata* (Schizaeaceae) and other trilete spores.
The gymnosperms are represented by abundant inaperturate *Taxodiaceaepollenites hiatus*, *Cycadopites* sp., and *Corollina torosa*.
Palynofacies includes rich yellow- to red-brown-striped tracheidal phytoclasts.
Palynomorph assemblage of „black shale" sample EB 1 consists of abundant gymnosperm pollen of *Taxodiaceaepollenites hiatus*, *Cycadopites* sp. and *Corollina torosa.* Triporate angiosperm pollen from the Normapolles group - *Complexiopollis* spp. and large tricolporate pollen - are common. Marine elements are rare, mostly microforaminiferal linings, some broken dinocysts, i.e., *Spinidinium* sp. and acritarchs *Micrhystridium* sp. occasionally occur. Miospores contain reworked Permian disaccate pollen of *Lueckisporites* sp.

MINERALOGY

Table 2: Semiquantitative clay mineral composition in the clay fraction (<2µm) in mass-%

Sample		Smectite	Vermiculite	Mixed Layer	Kaolinite	Illite	Chlorite	Unweath. vs. weathered
5799	EB1	8	0	4	4	66	18	84:16
5800	EB2	7	0	2	11	64	16	80:20
5386	EB8	tr.	0	tr.	5	76	19	95:05
5801	EB10	11	0	3	3	72	11	83:17
5802	EB21	12	0	6	9	57	16	73:27

tr.: traces

Table 1: Semiquantitative bulk mineral composition (in mass-%)

Sample		Quartz	Layer silic.	Feldspar	Calcite	Dolomite	Pyrite
5799	EB1	18	31	2	39	7	3
5800	EB2	20	32	1	36	5	6
5386	EB8	14	38	0	39	6	3
5801	EB10	15	32	1	42	7	3
5802	EB21	16	28	1	48	4	3

Bulk minerals

The mineralogical composition of the black shale samples EB 1 and EB 2 shows a quartz content of 18 to 20 mass-% whereas the marls contain less quartz in the range of 14 to 16 mass %. The feldspar content is generally very low 0-2 mass %). Layer silicates (mica, chlorite etc.) are a dominant (28-38 mass %) mineral group in all samples. Carbonate minerals are represented mainly by calcite in a range from 36 to 48 mass %, dolomite can only be found in rather low amounts. The marls EB 10 and EB 21 consist of 49-52 mass % carbonate minerals. The content of pyrite is in all samples around 3 mass % except in the black shale EB2 which contains 6 mass % of this mineral.

The clay mineralogical composition of the <2µm-fraction is dominated by illite which occurs in a range from 57-76 mass %. Furthermore, moderate amounts of chlorite can be found. Kaolinite is present only in small amounts except in the black shale EB 2, the kaolinite content in this sample reaches a value of 11 mass %.
The swellable clay mineral smectite is present in the black shales in amounts of 7-8 mass % and in the marls as well. The content in EB 10 and EB 21 is 11-12 mass %, only traces of this mineral could be found in EB 8. Vermiculites are completely absent. Small amounts of a mixed layer mineral illite/smectite regularly ordered could be found in all samples. Illite and chlorite represent more or less the unweathered clay minerals in the samples, whereas smectite, the mixed layer mineral and kaolinite represent the weathered clay minerals. From this point of view the sample EB 8 is the less weathered sample (95 mass % unweathered clay minerals), and EB 21 is the most weathered sample with 73 mass % unweathered and 27 mass % weathered clay minerals.

BIOSTRATIGRAPHY

- Nannofossil species *Prediscosphaera columnata* of which one specimen was found in the extremely poor assemblage of sample EB 10 allows to state stratigraphic range of sediments from the Albian up to Turonian (sensu Burnett 1998). Presence of *Quadrum gartneri* supports the lower part of Lower Turonian, zone UC7 (sample EB 1). Nannofossil species *Eiffellithus eximius* and *Lucianorhabdus quadrifidus* give evidence for zone UC8b that is correlated with the Middle Turonian (samples EB 8, EB 8A-D, EB 21).
- The occurrence of ostracod species *Dordoniella turonensis* Damotte, 1962 supports the Turonian age of sample EB 8.
- Biostratigraphically important is the angiosperm pollen *Trudopollis* (sample EB 8), which firstly appear in Middle Turonian (Góczán et al. 1967, Méon et al. 2004). Moreover, the palynofacies is characterized by the prevalence and diversity of *Complexiopollis* pollen. Such a level of angiospermous pollen diversification/composition accords with that found in other microfloras of the Middle Turonian age.
- The determination of stratigraphic age of studied samples on the basis of foraminifers is very difficult because stratigraphically important planktonic species are absent.Only the presence of *Marginotruncana schneegansi* in sample EB 8 makes it possible to include this sample to planktonic zone Marginotruncana schneegansi sensu Robaszynski & Caron (1995).

PALAEOENVIRONMENTAL INTERPRETATION

- Most of the grey silty marls show a typical biota of shallow marine, partly maybe muddy water, environment. However, a minor part of the sequence - in particular part of the „black shale" intercalations - could also represent brackish water influenced, probably prodelta environment deposits. Many of the marly limestone intercalations represent bioclastic packstones to rudstones consisting of densely packed shells (mainly of gastropods) and can be interpreted as tempestites (storm deposits) leading to the shell enrichment within distinct coquina beds.
- The bivalve fauna is clearly dominated by infaunal shallow-burrowing forms and consists of relatively few taxa if compared to other benthic assemblages of the Lower Gosau Subgroup (see e. g. Szente 2003). The abundance of *P. (P.) hillana*, suggest abnormal bottom conditions.
- Marine influence is documented by the presence of dinoflagellate cysts and faunal chitinous foraminiferal linings. Dinocysts consist predominantly of shallow water types.
- The assemblage of ostracods with *Brachycythere*, *Cytherella*, *Dolocytheridea*, *Dordoniella* and *Schuleridea* indicates a shallow marine environment.
- Poor nannofossils and especially the rare occurrence of species they formed component of the Turonian assemblages may indicate a pioneer character of nannoflora during marine transgression. Moreover, presence of genus *Lucianorhabdus* and fragments of *Braarudosphera bigelowii* reflects shallow-water sedimentation.
- Abundance of benthonic foraminiferal species *Quinqueloculina angusta* and *Spirillina cretacea* especially in the „black shale" samples EB 1 and EB 2 points to an environment with about 10 m depth of water with low oxygen content and also with low salinity (? brackish water).
- Genus *Protocardia* Beyrich, 1845 is a common element in brackish-water bivalve assemblages (Fürsich 1994), however, it has also been recorded from black shales deposited in dysoxic conditions (e. g. Wignall 1990). Both salinity and dissolved oxygene content can be excluded, on the basis of the presence of stenohaline organisms as well as of the macroscopically bioturbated nature of the sediments, as the governing factor causing the mass occurrence of the *Protocardia.*

CONCLUSION

The grey marls and also the „black shale-type" intercalations are considered as sediments of the Middle Turonian marine transgression of the Eisenbach Lower Gosau Subgroup. Because a larger part of the marls is characterized by a high amount of small coalified plant particles, most probably a near shore, maybe in part a delta-influenced, nutrient-rich muddy water depositional environment existed. Sediments of the above mentioned lithostratigraphic units of the Lower Gosau Subgroup are interpreted as shallow-water deposits probably of a transgressional character.