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

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ABSTRACT/ZUSAMMENFASSUNG

Silty fossiliferous grey marls, including „black shales“, with subordiate sandstone and marly limestone intercalations dominate the sequence of the Eisenbach Lower Gosau Subgroup. Samples from Eisenbach are generally poor of foraminifers without stratigraphic significance. Only the occurrence of *Marginotruncana schneegansi* in sample EB 8 gives evidence to include this assemblage to planktonic zone Marginotruncana schneegansi sensu Robaszynski and Caron (1995). The foraminiferal assemblages from other samples belong, by the character of assemblage, to the Turonian-Coniacian. Shallow-water condition of open sea with the influence of boreal realm (presence of agglutinated species *Gaudryina, Dorothia*, etc.) is characteristic for the environment of all studied samples. Shallow marine conditions with low oxygen content and the local change of salinity characterize the „black shale“-type sediments EB 1 and EB 2. Nannofossil species *Eiffellithus eximius* and *Lucianorhabdus quadrifidus* give evidence for zone UC8b that is correlated with the Middle Turonian. The nannofossil genus *Lucianorhabdus* and fragments of *Braarudosphera bigelowii* reflect shallow-marine sedimentation. Moreover, poor nannofossils and rare occurrence of species which formed the component of Turonian assemblages may reflect a pioneer character of nannoflora during marine transgression. First occurrence of angiosperm pollen *Trudopollis* is correlated to the Middle Turonian age (sample EB 8). The composition of the dinoflagellate assemblage and the presence of microforaminifers indicate shallow marine conditions. Reworked gymnosperm pollen of Permian age (from „Haselgebirge“) were observed in the „black shale“-type sample EB 1. Also the ostracod fauna indicates a shallow marine environment. The bivalve assemblage 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.

Die Untere Gosau-Subgruppe der „Eisenbach-Gosau“ wird von einer Schichtfolge von grauen siltigen Mergeln mit markanten fossilreichen Schwarzschiefer-Zwischenschaltungen sowie Sandstein- und mergeligen Kalkstein-Zwischenlagen dominiert. Kalkiges Nannoplankton erlaubt eine stratigraphische Einstufung unseres Probenmaterials in die tiefste Gosau-Subgruppe, und zwar in das Mittelturonium. Die Palynomorphen und die Ostracoden-Fauna bestätigen diese stratigraphische Einstufung sowie bedingt auch die spärlichen und schlecht erhaltenen Foraminiferen-Assoziationen, die auch einen Coniacium-Anteil nicht ausschließen. Alle untersuchten Fossilgruppen deuten auf ein marines Seichtwasser-Environment, wobei sowohl die hellgrauen, insbesondere aber die schwarzen Kalkmergel („Schwarzschiefer“) einen hohen Anteil an inkohltem Pflanzenhäcksel aufweisen. Die Muschelfauna ist vergleichsweise artenarm und dürfte auf ein Trübwasser-Environment hindeuten.

I. INTRODUCTION

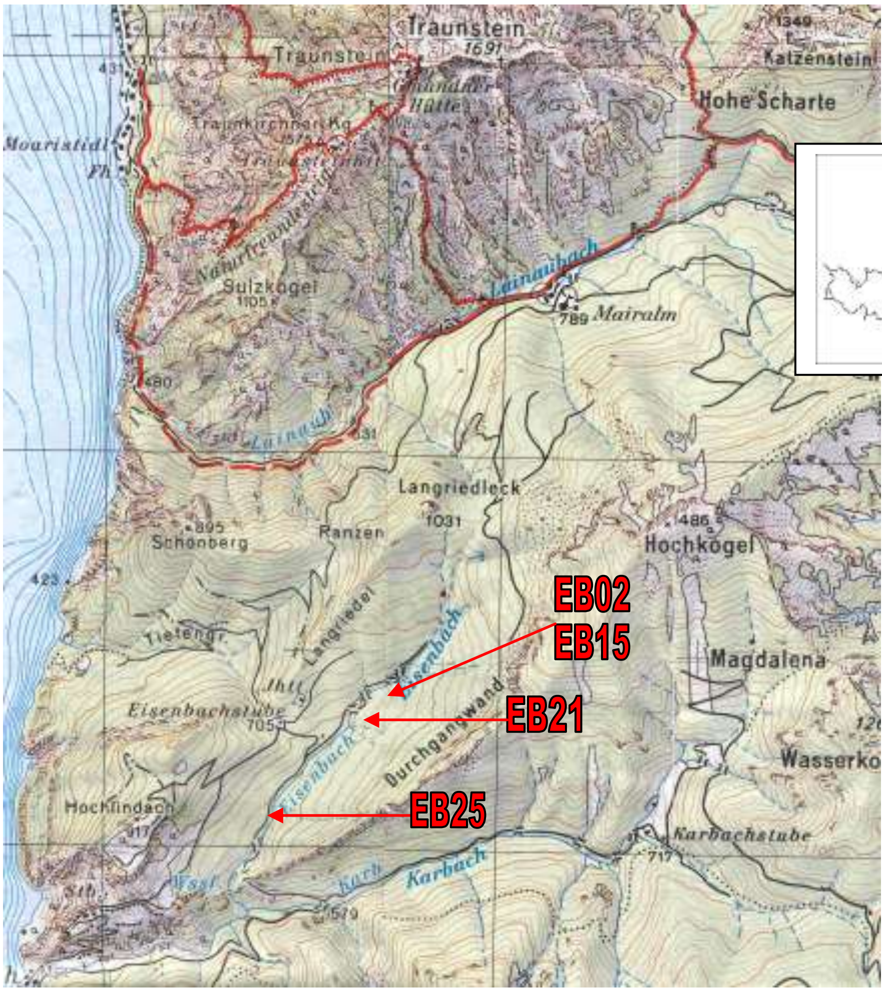
The purpose of our study of the sediments from locality Eisenbach (Lower Gosau Subgroup) is, that there exist no modern biostratigraphic data on these extensive and in part highly fossiliferous outcrops. Therefore our results fill a gap in the knowledge on the occurrences of Gosau Group sediments in between Lake Wolfgangsee in the west and Lake Traunsee in the east. In addition, the palaeoenvironment of the „black shale“ intercalations, which are well known to fossil collectors, were a main target of our investigations.

Previous studies

The Eisenbach (or „Eisenau“) Gosau occurrence is in the focus of scientists already since the dawn of Austrian geology, as documented by the papers by Partsch (1826), Lill von Lilienbach (1830) and Boué (1832), and is also well known to local fossil collectors. Some of the studies deal with the fauna (e.g. Morlot 1847, Zekeli 1852, Zittel 1865-1866, Kollmann in Weber 1960, Oberhauser 1963, Kühn 1965, Szente 2003) or with the dasycladacean green algae (Schlagintweit et al. 2003). Other papers are focused on the occurrences of coal seams (Ehrlich 1850, 1854; N.N. 1880, Koch 1898; Rantitsch et al. 1995) or on the findings of amber together with the coal (Reuss 1851, Ehrlich 1850, 1854). The regional geology of the Eisenbach Gosau occurrence was studied in detail by Geyer (1911) and mapped by Geyer and Abel (1922) respectively Abel and Geyer (1922). The last profound study of the geology and also (micro-)palaeontology of the Eisenbach-Gosau was published by Weber (1960). Mandl and Hofmann (1993) studied the nearby Gosau outcrops of the Hochlindach limestone quarry in Karbach. Ostracoda from the surroundings of Eisenbach are mentioned in Weber (1960); they were determined by K. Kollmann. Calcareous nannofossils and palynomorphs have not been studied yet.

Sample localities and lithological remarks

The Eisenbach Gosau occurrence is situated on the eastern side of Lake Traunsee, approximately opposite to 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 (Fig. 1). 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.



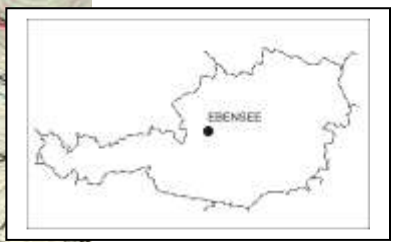


Fig. 1: Topographic situation of Eisenbach sample points, 5km NNE of Ebensee.

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 and Ebli, *Neomeris circularis* Badve and 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 and Nayak.
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.
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.

II. METHODS

The mineralogy of samples EB1, EB2, EB8, EB10, and EB21 was studied by means of X-ray diffraction (XRD) using a Philips 1710 diffractometer with automatic divergent slit, 0.1° receiving slit, Cu LFF tube 45 kV, 40 mA, and a single-crystal graphite monochromator. The measuring time was 1s in step-scan mode and stepsize of 0.02°. The bulk sample as well as the clay fraction (<2µm) was analysed. Sample preparation generally followed the methods described by Whittig (1965) and Tributh (1989). Dispersion of clay particles and destruction of organic matter was achieved by treatment with dilute hydrogen peroxide. Separation of clay fraction was carried out by using centrifugation methods. The EXCHANGE complex of the sample (<2µm) was saturated with Mg and K using chloride solutions by shaking. Similar to the methods of Kinter and Diamond (1956) the preferential orientation of the clay minerals was obtained by suction through a porous ceramic plate. To avoid disturbance of the orientation during drying, the sample was equilibrated during 7 days above saturated NH_4NO_3 solution. Afterwards expansion tests were made, using ethylenglycol, glycerol and DMSO as well contraction tests heating the sample up to 550°C. After each step the sample was X-rayed from 2-40°2θ.
The clay minerals were identified according to Thorez (1975), Brindley and Brown (1980), Moore and Reynolds (1997) and Wilson (1987). Semiquantitative estimations were carried out using the corrected intensities of characteristic X-ray peaks (Riedmüller 1978). Semiquantitative mineral composition of the bulk samples was estimated using the method described by Schultz (1964).

For nannofossil study, suspension slides were prepared using a decantation method (gravity settling, separated fraction of ca. 3-30 µm) and inspected under the light microscope Nikon at 1.000 x magnification. Biostratigraphic data were corellated with the UC zones by Burnett (1998). The slides are stored in the Czech Geological Survey in Prague.

Samples for the study of Foraminifera and Ostracoda were washed in the Laboratory of the Czech Geological Survey using standard washing methods (size of sieve 0,063 mm). Foraminifers and ostracods were separated under binocular microscope. The foraminifers are deposited in the Czech Geological Survey in Prague and the ostracods in the collections of the Geological Survey of Austria in Vienna with the collection number 2003/5 (EB 8) and 2003/7 (EB 21) with subnumbers.

A standard palynological procedure involving mineral acid treatment (10% HCl, 40% HF, acetolysis, 30% HNO_3) was used. The residues were mounted in glycerine jelly. The slides are stored at the Institute of geology of Czech Academy of Sciences in Prague.

III. RESULTS

III-1. MINERALOGY

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.

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

Clay minerals
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.

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

III-2. MACROFOSSILS

III-2A. BIVALVIA

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.

Following bivalve taxa have been identified:

Nucula sp. (Plate 1, Fig. a)
Three internal moulds of smooth surface, partly covered by shell and displaying traces of taxodont dentition are identified as belonging to *Nucula* Lamarck, 1799. Due to their incomplete state of preservation they can not be assigned to any of the *Nucula* species described from the Gosau beds by Zittel (1865).

Protocardia (P.) hillana (J. Sowerby 1813) (Plate 1, Fig. b-g).
Represented by 108 specimens, this species is by far the most frequent one occurring at the locality. The shape of the valves is rather variable, ranging from oval to subtriangular or subcircular. Thus, the species concept of *P. hillana* accepted here includes *Protocardia* sp., types 1 and 2 of Smettan (1997, p. 128, pl. 6, figs. 11 and 13, respectively)

Cardiidae, gen. et sp. indet.
Some very poorly preserved small-sized specimens bearing fine radial striae are assigned to Cardiidae.

Astarte? sp. (Plate 1, Fig. h, i)
Represented by nearly 70 specimens rarely exceeding 4 mm in length, this form is the second most frequent one in the assemblage.

Pholadomya sp. (Plate 1, Fig. j)
A single complete internal mould with traces of shell is assigned to *Pholadomya* G. B. Sowerby, 1823 *sensu stricto*. The specimen differs from *P. nodulifera* Muenster in Goldfuss, 1841, as figured by Zittel (1865, pl. 2, figs. 1,2 as *P. rostrata* Matheron, 1843) and by Dhondt (1987, pl. 5, figs. 4,5) from the Gosau beds by bearing considerably fewer radial plicae.

Inoperna flagellifera (Forbes 1846), (Plate 1, Fig. k)
Three incomplete specimens represent this form already well documented from the Upper Cretaceous of Northern Calcareous Alps by Zittel (1866, p. 82, pl. 12, figs a-c); Dhondt (1987, p. 55, pl. 1, figs 11-13) and Smettan (1997, p. 110, pl. 2, fig. 4).

Pinna cf. *cretacea* (Schlotheim, 1813): Plate 1, Fig. l ,m
Problems distinguishing Upper Cretaceous species of *Pinna* were discussed by Dhondt (1987, p. 59) and Smettan (1997, p. 110). Here, the oldest available name is applied to the two specimens found.

Glycymeris sp.
A single small-sized, well inflated internal mould is assigned to *Glycymeris* Da Costa, 1778.

Entolium sp. (Plate 1, Fig. n)
A single right valve with smooth disc and well-defined anterior auricle is assigned to *Entolium* Meek, 1865.

III-3. MICROFOSSILS

III-3A. 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 Tab. 3):
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 origin and rare specimens of *Watznaueria barnesae, Radiolithus orbiculatus, Micrantholithus hoschulzii,* and Lower Cretaceous nannoconids.
Sample EB 9B did not contain any calcareous nannofossils.

Table 3; 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.

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. *vocontiensis*					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			

II-3B. FORAMINIFERA

Samples from Eisenbach are generally poor of foraminifers. Foraminiferal tests are badly preserved that is why their determination was sometimes difficult. Organic material of washed samples is composed, first of all, by small gastropods, ostracods, relicts of spines and pelecypods. The foraminiferal tests from the „black shales“ (EB 1, EB 2), and of sample EB 8 in part are stained by carbon substance and their calcareous tests are very often secondarily decalcified.

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 (samples WB 1, 1A, Hradecká et al. 1999) but the Eisenbach assemblage is much more poorer (see distribution table).

Table 4; distribution of foraminifera: **f** = frequent, **c** = common, **r** = rare

range		age / nannofossil zone (Burnett 1998)	Middle Turonian UC8b				
		sample No.	EB 8	EB 8A	EB 8B	EB 8C	EB 8D
		abundance of nannofossils	L	VL	L	VL	L
		nannofossil preservation	VP	VP	VP	VP	VP
FO Turonian	taxa they may be a component of the Turonian assemblage	*Braarudosphaera bigelowii* *	R				R
		Calculites ovalis			R		R
		Eiffellithus eximius	R	R	R		R
		Eiffellithus turriseiffelii-eximius			R	R	R
		Lucianorhabdus maleformis			F	R	
		Lucianorhabdus quadrifidus	R	R	F	R	R
		Quadrum gartneri	R		R		
		Quadrum intermedium *				R	
		Rhagodiscus plebeius *			R		
FO Aptian-Albian		*Amphizygus brooksii*	R				R
		Broinsonia signata					R
		Cribrosphaerella ehrenbergii	R				R
		Eiffellithus turriseiffelii	F	R	R		F
		Eprolithus floralis	R		R	F	F
		Helicolithus trabeculatus	R				
		Microrhabdulus belgicus			R		
		Nannoconus ex gr. *truittii*	R	R		R	R
		Prediscosphaera cretacea	F		R	R	F
		Prediscosphaera columnata	F	R	R	R	F
		Prediscosphaera ponticula					R
		Prediscosphaera spinosa	R				
		Radiolithus orbiculatus	R			?	
		Rhagodiscus angustus	R				R
		Zeugrhabdotus bicrescenticus			R		
Cretaceous long-ranging species		*Braarudosphaera* cf. *regularis*	R				
		Chiastozygus litterarius				R	R
		Cretarhabdus conicus	R	R		R	R
		Cyclagelosphaera margerelii			R		R
		Lithraphidites carniolensis	R		R		F
		Nannoconus elongatus	R				R
		Retacapsa crenulata	R	R	R	R	R
		Tegumentum stradneri	R				
		Watznaueria barnesae	F	F	F	F	F
		Watznaueria britannica	R		R	R	
		Zeugrhabdotus diplogrammus	F		R	R	R
		Zeugrhabdotus embergeri	R	R			R
		Zeugrhabdotus noeliae	R				
Cen.	reworked nannofossils	*Corollithion kennedyi*				r	
Apt.-Cen.		*Braarudosphaera africana*				r	
		Cretarhabdus striatus	r				
		Isocrystallithus compactus			r	?	r
		Nannoconus cf. *vocontientis*			r		
Lower Cretaceous		*Conusphaera* sp.					r
		Cruciellipsis cuvillieri	r				r
		Discorhabdus striatus				r	
		Micrantholithus hoschulzii	r	r	r	r	r
		Micrantholithus obtusus	r				
		Nannoconus globulus minor				r	
		Nannoconus kamptneri					r
		Nannoconus steinmanii	r				
		Watznaueria cf. *manivitae*				r	

III-3C. OSTRACODA

The only reference to ostracods from the Eisenbach Gosau was given by K. Kollmann (in Weber 1960), who differenciated following ostracods from clay marls of the higher part of the Gosau deposits between Traunsee and Almtal: *Cythereis* sp., *Cytherella* sp., *Cytherelloidea* sp., gen. indet. aff. *truncata* (Bosquet 1847), *Schuleridea* sp., *Krithe* sp., *Bairdia* sp. and *Pterygocythere* sp. An interesting ostracod fauna has been found also in our samples EB 8 and EB 21. 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.

The preservation of the ostracods is relatively good and most of the specimens are present as carapaces. Few details of the inner characters of the valves and finer sculptural elements could be obtained. This partly makes it difficult not only to determine the species but also to do a clear classification of the genus. The shape of the carapace remains the most important criteria for the determination of the smooth specimens.

Some smooth specimens of ostracods, especially genera *Schuleridea* and *Dordoniella* could not be easily distinguished. The specimen on plate 2, figure 8 is supposed to be a male individual of *Schuleridea neglecta* (Reuss 1854) which in the Grabenbach Formation of the Weißenbachalm area had been found in samples assigned to the stratigraphical interval from Late Turonian to Early Santonian (Zorn in Hradecká et al. 1999). Eye spots are present which are not developed in *Dordoniella*. A second small *Schuleridea* sp. was found but is not figured. The shape of the right valve was taken into consideration to differentiate between *Schuleridea* and *Dordoniella*. In *Schuleridea* it is subtriangular and in *Dordoniella* it is subquadrangular. In both genera the left valve is larger than the right. In *Dordoniella* the overlap of the left valve is overall whereas in *Schuleridea* the overlap is most pronounced dorsally and ventrally but a strong overlap overall is also known (Morkhoven 1963). The specimens of *Dordoniella* at hand do not show a very strong overlap. The specimens on plate 2, figures 6, 7 remind on *Dordoniella strangulata* Apostolescu, 1955 but the overlap is not that extreme. Therefore the material is named *Dordoniella* aff. *strangulata* Apostolescu, 1955. The anterodorsal depression which is typical for *Dordoniella strangulata* Apostolescu, 1955 exists but is not visible on the scanning photos. *Dordoniella turonensis* Damotte, 1962 had originally been described from the Lower Turonian of the Touraine area in France. Only one right valve (plate 2, fig. 5) had been found which is typically subquadrangular. *Dordoniella* is reported from brackish and shallow marine environments (Morkhoven 1963).

The specimens of *Dolocytheridea* possibly belong to more than one species. Several specimens remind on *Dolocytheridea crassa* Damotte, 1971 from the Cenomanian of France but the ventral concavity of the outline is additionally strengthened through secondary compression. The posterior end of the present specimens is rounded very narrow like in *Dolocytheridea crassa* Damotte, 1971 but the anterior half of the shell is not that high. Provisionally the material described herein is named *Dolocytheridea* aff. *crassa* Damotte, 1971. *Dolocytheridea* is known from brackish and shallow marine environments (Morkhoven 1963). *Cytherella parallela* Reuss 1844 is a common species in the European Upper Cretaceous. *Cytherella dordoniensis* is known from the Cenomanian of France.

III-3D. PALYNOMORPHS

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. *Atlantopollis* sp. and *Trudopollis* sp. rarely appear. Other early angiospermous types are represented by tricolpate reticulate *Retitricolpites* sp., foveolate *Foveotricolpites* sp., tricolporate psilate *Perucipollis minutus*, reticulate *Retitricolporites* sp. and polyporate *Bohemiperiporis zaklinskae*. A part of reticulate pollen grains is arranged in tetrahedral tetrads.

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 i.e. *Cicatricosisporites* sp., *Echinatisporites varispinosus*, *Vadaszisporites urkuticus*, *Biretisporites* sp.
The gymnosperms are represented by abundant inaperturate *Taxodiaceaepollenites hiatus*, *Cycadopites* sp., and *Corollina torosa*, associated with occasionally present disaccate *Alisporites* sp. and *Pinuspollenites* sp.
Palynofacies includes rich yellow- to red-brown-striped tracheidal phytoclasts and other membranous tissues, although palynomorphs are generally uncommon.
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. Conditions of lowered oxygen level is documented in „black shale“ sample EB 1 by the presence of pyrite which is frequently found inside the spores and pollen grains. Pyrite is abundant in marine to brackish peats (Cohen et al. 1984). The composition of gymnosperms with abundant taxodiaceous and cheirolepidiaceous pollen (pollen *Corollina* characterizes marginal marine deposits), corresponds to marsh environment. Palynofacies of „black shales“ sample EB 2 characterizes abundant yellow structured and non-structured plant tissues with a few miospore specimens (*Taxodiaceaepollenites, Corollina, Complexiopollis*) and dinocyst of *Coronifera oceanica.* Rare dinoflagellate cysts (*Achomosphaera ramulifera*, *Palaeohystrichophora infusorioides*), scolecodonts, pteridophyte spores and pollen *Complexiopollis* were observed in sample EB 10.

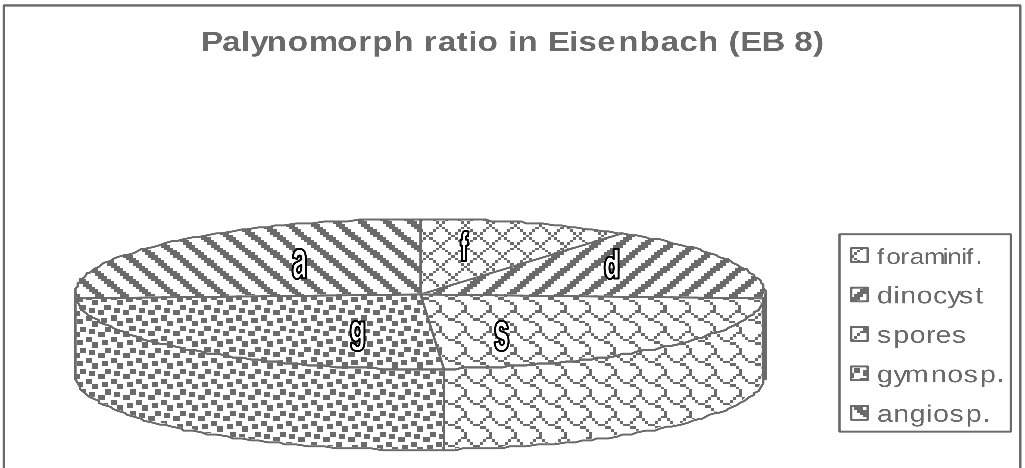


Table 5: Proportions of palynomorph groups in the sample EB 8

IV. BIOSTRATIGRAPHY

All the nannofossil species mentioned in Tab. 3 may be a component of the Turonian assemblage except those their occurrence is known in Jurassic or Lower Cretaceous exclusively or their stratigraphic short range is known from the Cenomanian. An interesting phenomenon of samples is the relative high number of redeposited species their first occurrence is known from the Aptian-Albian.
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 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 and Caron (1995).
The occurrence of ostracod species *Dordoniella turonensis* Damotte, 1962 supports the Turonian age of sample EB 8.

Biostratigraphically important is the angiosperm pollen *Trudopollis*, 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. Similar *Complexiopollis* types were recorded by Pacltová (1981) in the Middle Turonian marine epicontinental deposits of the boreholes Lipová and Jeleč in the Bohemian Cretaceous Basin in Czech Republic. Dinocyst taxa contain mostly „long-ranging forms". The presence of *Oligosphaeridium* cf. *albertense* is interesting because it mostly characterizes the Lower Cretaceous deposits and its last occurrence is in the Cenomanian (Rotalipora cushmani Zone sensu Mao and Lamolda 1998). A redeposition from older sediments cannot be excluded. Reworked Permian disaccate pollen of *Lueckisporites* sp. were found in the „black shale" sample EB 1.

V. PALAEOGEOGRAPHIC INTERPRETATION

From the palaeogeographic and further interpretation point of view, attention should be paid to the reworked nannofossils the occurrence of which is fixed on the Aptian-Albian-Cenomanian interval or on the Cenomanian exclusively. They may be redeposited from nearby marine ?Aptian-Cenomanian sediments of the „Ultrahelvetic" zone („Buntmergelserie", Egger 1996). Habitus of nannofossil species *Lucianorhabdus quadrifidus* and the remarkably small size of other nannofossil specimens remember development of assemblages of the same age from the Grabenbach Formation, locality Weißenbachalm (Švábenická in Hradecká et al. 1999) and from the other sites of Hochmoos Formation (Hradecká et al., in prep.). Also redeposited dinocysts with the last occurrence in the Cenomanian (maybe from the „Buntmergelserie", Egger 1996) and sporomorphs of the Permian age (Haselgebirge) are recorded.

VI. 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 frequent dark colour can be attributed to bituminous organic material, but also coaly plant remains and pyrite pseudomorphs are present. Within the reduced matrix content between the shells generally no microfossils occur but a fine siliciclastic content has to be noted. In thin-section EB 2A only one test the foraminifer *Vidalina hispanica* Schlumberger has been observed.

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 diversity proves to be especially low if it is expressed by the evenness index ($D=1/\Sigma p_i^2$, where p_i is the relative frequency of the *i*th species). The calculated value (D= about 2), as well as the abundance of *P. (P.) hillana*, suggest abnormal bottom conditions.

Genus *Protocardia* Beyrich 1845 can be well considered among Mesozoic bivalve genera of the widest environmental distribution. It 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*. According to Barnes (1989), the dominance of organisms commonly attributed to brackish-water environments can also indicate an unusually soft, soupy nature of the substrate. This explanation seems to be plausible for the sediments exposed at the EB 8 locality as well.

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. Poor preservation of nannofossil specimens is probably result of carbonate dissolution caused by the release of carbon dioxide during oxidation of organic matter.

Habitus of nannofossil species *Lucianorhabdus quadrifidus* and the remarkably small size of other nannofossil specimens remember development of assemblages of the same age from the Grabenbach Formation, locality Weißenbachalm (Švábenická in Hradecká et al. 1999) and from the other sites of Hochmoos Formation (Hradecká et al., in prep.). Sediments of the above mentioned lithostratigraphic units of the Lower Gosau Subgroup are interpreted as shallow-water deposits probably of a transgressional character.

Also on the basis of the character of foraminiferal assemblages we could suppose shallow-marine live conditions. Abundance of benthonic 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). According to Koutsoukos and Hart (1990) these species represent active deposit feeders belonging to an epifauna and shallow burrowers, dwelling in fine-grained calcareous or siliceous muds of inner-middle neritic biotopes. Due to small juvenile tests of *Heterohelix* the water depth of the light grey marls was probably deeper with good oxygen condition of an open sea. The occurrence of *Gavelinella* shows a middle neritic environment with water depth of 30-100 m (Wagreich and Faupl 1994).

The assemblage of ostracods with *Brachycythere*, *Cytherella, Dolocytheridea*, *Dordoniella* and *Schuleridea* indicates a shallow marine environment.

Marine influence is documented by the presence of dinoflagellate cysts and faunal chitinous foraminiferal linings. Dinocysts consist predominantly of shallow water types, i.e. *Palaeohystrichophora infusorioides*, *Dinogymnium* sp., *Subtilisphaera* sp. associated with chorate forms, such as *Oligosphaeridium* cf. *albertense* and *Spiniferites ramosus* which characterize neritic sea conditions. Low species diversity and the presence of inner linings of microforaminiferal tests also correspond to shallow marine environment. Conditions of lowered oxygen level („black shale-type" sample EB 1) are documented by the presence of pyrite which is frequently found inside the spores and pollen grains. Pyrite is abundant in marine to brackish peats (Cohen et al. 1984).

VII. CONCLUSIONS

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.

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APPENDIX I: NANNOFOSSIL TAXA MENTIONED IN THE TEXT

Amphizygus brooksii Bukry
Braarudosphaera bigelowii (Gran and Braarud) Deflandre
Braarudosphaera regularis Black
Broinsonia signata (Noël) Noël
Calculites ovalis (Stradner) Prins and Sissingh
Chiastozygus litterarius (Górka) Manivit
Conusphaera mexicana Trejo
Corollithion kennedyi Crux
Cretarhabdus conicus Bramlette and Martini
Cretarhabdus striatus (Stradner) Black
Cribrosphaerella ehrenbergii (Arkhangelsky) Deflandre
Cruciellipsis cuvillieri (Manivit) Thierstein
Cyclagelosphaera margerelii Noël
Discorhabdus striatus Moshkovitz and Ehrlich
Eiffellithus eximius (Stover) Perch-Nielsen
Eiffellithus turriseiffelii (Deflandre)
Eprolithus floralis (Stradner) Stover
Eprolithus octopetalus Varol
Helenea chiastia Worsley
Helicolithus trabeculatus (Górka) Verbeek
Isocrystallithus compactus Verbeek
Lithraphidites acutus Verbeek
Lithraphidites bollii (Thierstein) Thierstein
Lithraphidites carniolensis Deflandre
Lucianorhabdus maleformis Reinhardt
Lucianorhabdus quadrifidus Forchheimer
Manivitella pemmatoidea (Deflandre) Thierstein
Micrantolithus hoschulzii (Reinhardt) Thierstein
Micrantholithus obtusus Stradner
Microrhabdulus belgicus Hay and Towe
Micula staurophora (Gardet) Stradner
Nannoconus elongatus Brönnimann
Nannoconus globulus minor Brönnimann
Nannoconus kamptneri Brönnimann
Nannoconus steinmanii Kamptner
Nannoconus truittii Brönnimann
Nannoconus vocontientis Deres and Achéritéguy
Prediscosphaera columnata (Stover) Perch-Nielsen
Prediscosphaera cretacea (Arkhangelsky) Gartner
Prediscosphaera ponticula (Bukry) Perch-Nielsen)
Prediscosphaera spinosa (Bramlette and Martini) Gartner
Quadrum gartneri Prins and Perch-Nielsen
Quadrum intermedium Varol
Radiolithus orbiculatus (Forchheimer) Varol
Retacapsa angustiforata Black
Retacapsa crenulata (Bramlette and Martini) Grün
Rhagodiscus angustus (Stradner) Reinhardt
Rhagodiscus plebeius Perch-Nielsen
Rhagodiscus splendens (Deflandre) Verbeek
Tegumentum stradneri Thierstein
Watznaueria barnesae (Black) Perch-Nielsen
Watznaueria britannica (Stradner) Reinhardt
Watznaueria manivitae Bukry
Zeugrhabdotus bicrescenticus (Stover) Burnett
Zeugrhabdotus diplogrammus (Deflandre) Burnett
Zeugrhabdotus embergerii (Noël) Perch-Nielsen
Zeugrhabdotus noeliae Rood

APPENDIX II: PALYNOMORPH TAXA MENTIONED IN TEXT

Miospores

Alisporites sp.
Atlantopollis sp.
Biretisporites sp.
Bohemiperiporis zaklinskae Pacltová 1971
Cicatricosisporites sp.
Complexiopollis cf. *christae* (van Amerom) Kedves sensu Médus et al. 1980
Complexiopollis cf. *complicatus* Góczán 1964
Complexiopollis cf. *praeatumescens* Krutzsch 1959
Complexiopollis cf. *vancampoae* Diniz, Kedves and Simoncsics 1974
Complexiopollis vulgaris (Groot and Groot) Groot and Krutzsch 1967
Complexiopollis spp.
Corollina torosa (Reissinger) Klaus emend. Cornet and Traverse 1975
Cyathidites minor Couper 1953
Cycadopites sp.
Echinatisporites varispinosus (Pocock) Srivastava 1975
Foveotricolporites sp.
Parvisaccites radiatus Couper 1953
Pinuspollenites sp.
Plicatella tricuspidata (Weyland and Krieger)
Perucipollis minutus Pacltová 1971
Trudopollis sp.
Retitricolpites sp.
Retitricolporites sp.
Taxodiaceaepollenites hiatus (Potonié) Kremp
Vadaszisporites urkuticus (Deák) Deák and Combaz 1967
Varirugosisporites sp.

Dinoflagellate cysts

Achomosphaera ramulifera (Deflandre) Evitt 1963
cf. *Apteodinium* sp.
Clestosphaeridium ? *multispinosum* (Singh) Brideaux 1971
Coronifera oceanica (Cookson and Eisenack) May 1980
Dinogymnium sp.
Oligosphaeridium cf. *albertense* (Pocock) Davey and Williams 1969
Palaeohystrichophora infusorioides Deflandre 1935
Spiniferites ramosus (Ehrenberg) Mantell 1854
Subtilisphaera sp.

Miscellaneous

microforaminiferal linings
Pluricellaesporites psilatus Clarke (fungal spores)
scolecodonts

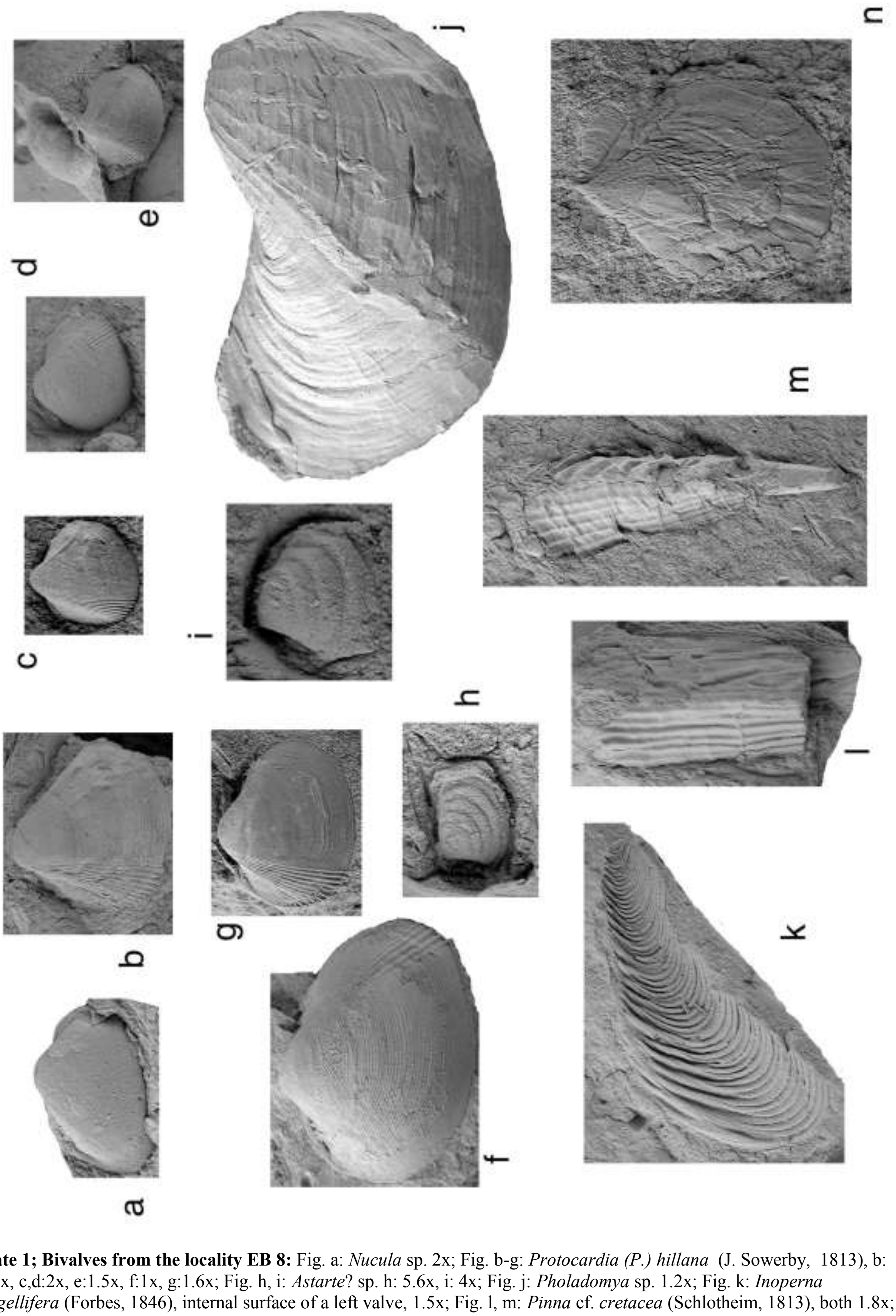

Plate 1; Bivalves from the locality EB 8: Fig. a: *Nucula* sp. 2x; Fig. b-g: *Protocardia (P.) hillana* (J. Sowerby, 1813), b: 1.5x, c,d:2x, e:1.5x, f:1x, g:1.6x; Fig. h, i: *Astarte*? sp. h: 5.6x, i: 4x; Fig. j: *Pholadomya* sp. 1.2x; Fig. k: *Inoperna flagellifera* (Forbes, 1846), internal surface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

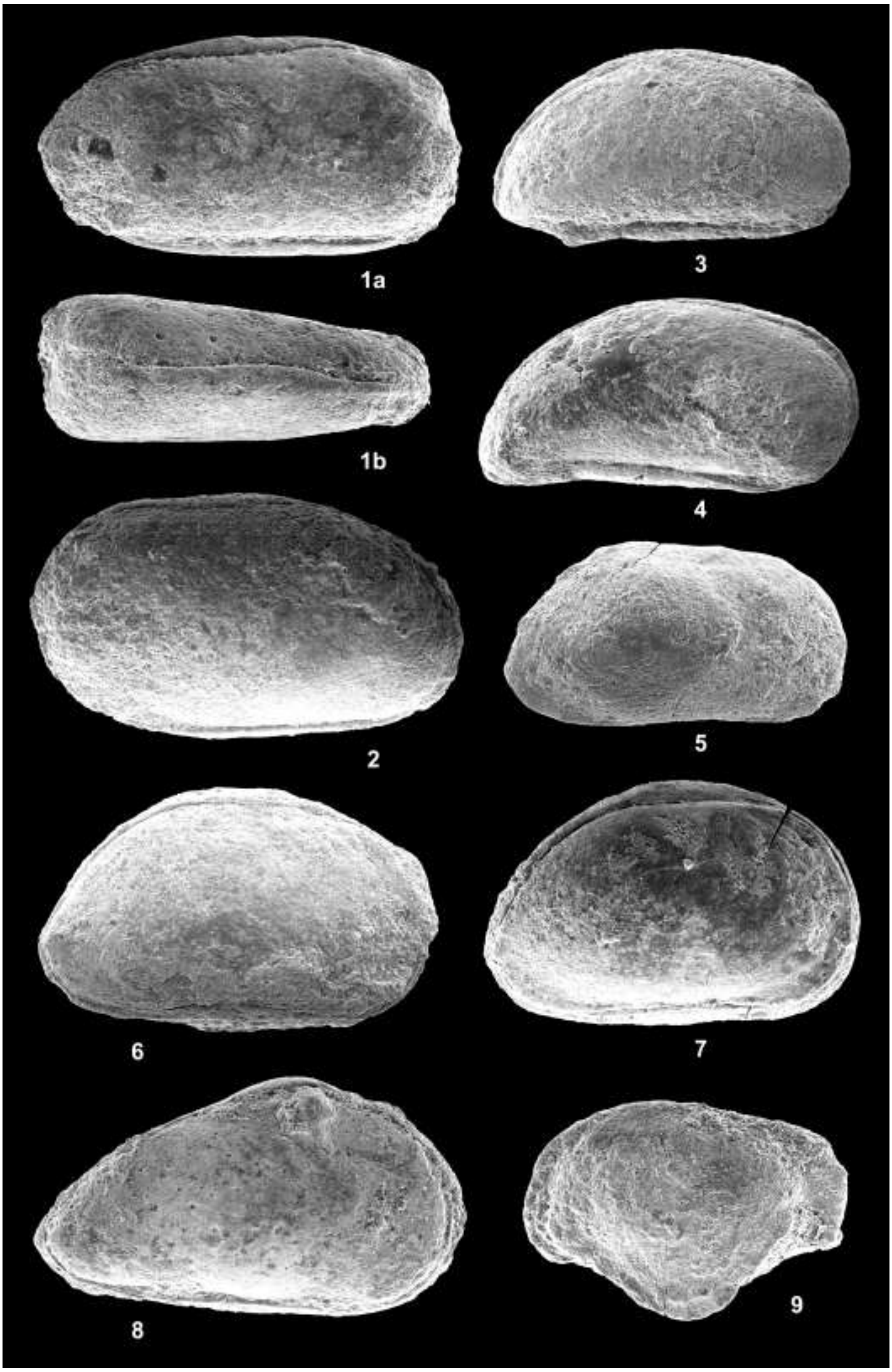

Plate 2; Ostracoda from the locality EB 8: Fig. 1a-b: *Cytherella parallela* Reuss, 1844, 1a: carapace from the left, 1b: dorsal view, coll. Nr. 2003/5/3, x 125, Fig. 2: *Cytherella* sp., coll. Nr. 2003/5/5, x 85, Fig. 3: *Dolocytheridea* aff. *crassa* Damotte, 1971, coll. Nr. 2003/5/7, x 85, Fig. 4: *Dolocytheridea* aff. *crassa* Damotte, 1971, coll. Nr. 2003/5/8, x 110, Fig. 5: *Dordoniella turonensis* Damotte, 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, x 100, Fig. 8: *Schuleridea neglecta* (Reuss, 1854), male, coll. Nr. 2003/5/14, x 85, Fig. 9: *Brachycythere* sp., coll. Nr. 2003/5/1, x 100.

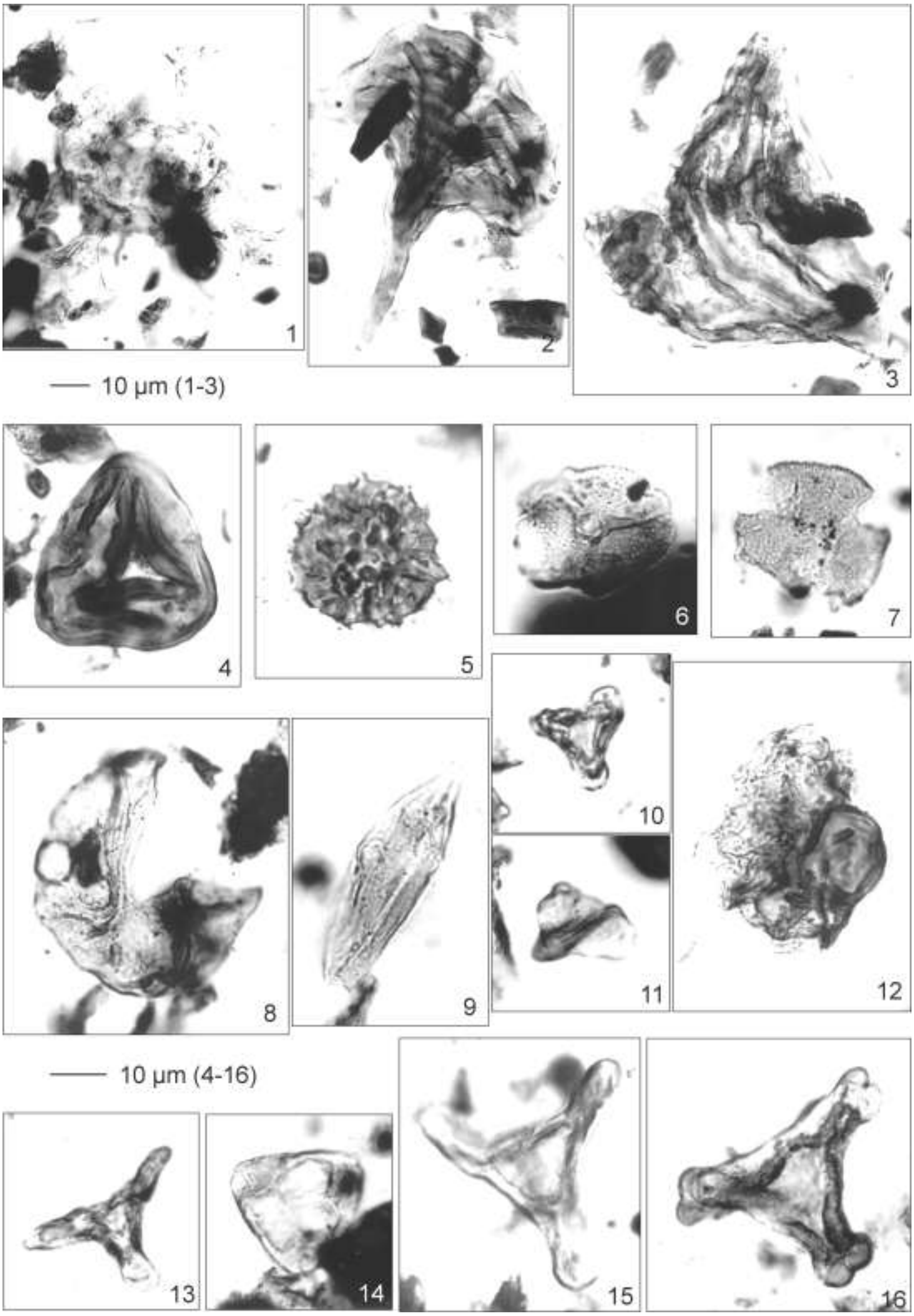

Plate 3, Palynomorpha from the locality EB 8. magnification x 1000, unless otherwise stated. Species name is followed by slide No. and/or magnification. **1** – *Oligosphaeridium* cf. *albertense* (Pocock) Davey and Williams 1969, 1148/3, x 700. **2, 3** – *Plicatella tricuspidata* (Weyland and Krieger), 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