

The Lower Badenian (Middle Miocene) Hartl Formation (Eisenstadt – Sopron Basin, Austria)

Andreas KROH¹, Mathias HARZHAUSER², Werner E. PILLER¹, Fred RÖGL²

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Abstract: For the Lower Badenian (~Langhian) sandy sediments in the area north-east of Eisenstadt, Burgenland/Austria, formerly known as “Hartl sands” or “Terebratelsand” the formal lithostratigraphic unit Hartl Formation is proposed. The current study documents two important sections within this area: Hartlucke and Johannesgrotte. The former is chosen as type section for the Hartl Formation. For the first time log descriptions and detailed descriptions of the sediments of these sections, as well as an environmental interpretation are hereby made available.

Zusammenfassung: Für die unter den Namen „Hartl-Sand“ oder „Terebratelsand“ bekannten Sedimente des Unteren Badenium (~Langhium) im Raum nordöstlich Eisenstadt, Burgenland, wird eine neue lithostratigraphische Einheit, die Hartl-Formation eingeführt. In der vorliegenden Arbeit werden zwei bekannte Aufschlüsse dieser Region, die Hartlucke und die Johannesgrotte, beschrieben und erstmals auch in Form von Profilen dargestellt. Das Profil der Hartlucke dient gleichzeitig als Typusprofil der Hartl-Formation.

Keywords: Lithostratigraphy, Lower Badenian, Middle Miocene, Hartl Formation, Eisenstadt, Leitha Mountains.

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¹ Institut für Geologie und Paläontologie, Universität Graz, Heinrichstr. 26, A-8010 Graz, discometra@gmx.at, werner.piller@uni-graz.at

² Naturhistorisches Museum Wien, Burgring 7, A-1014 Wien, mathias.harzhauser@nhm-wien.ac.at, fred.roegl@nhm-wien.ac.at

1. INTRODUCTION

The locality Hartl, named after the hillside in the north-east of Eisenstadt, is a classical locality for Lower Badenian (Langhian) bryozoans. The extraordinarily diverse bryozoan fauna includes more than 150 species, about one third of which have their type-locality here (PILLER & VÁVRA, 1991). Despite the large number of publications on fossils from this locality, including systematic papers on the bryozoans (e.g., REUSS, 1848, 1874; MANZONI, 1877, 1878; CANU & BASSLER, 1924; DAVID & POUYET, 1974; VÁVRA, 1979; SCHATTLLEITNER, 1990) and brachiopods (DREGER, 1889), little information is available on the lithology, sedimentology, microfacies, and palaeoecology. The aim of this paper is to give a detailed description of the outcrops, including for the first time also log descriptions. Additionally, a new lithostratigraphic unit, the Hartl Formation, is proposed to accommodate the Lower Badenian sandy sediments formerly informally referred to as "Hartl sands" or "Terebratelsand".

2. STUDY AREA AND GEOLOGICAL SETTING

The investigated sections and localities are situated in the vicinity of Eisenstadt in Burgenland/Austria (ÖK 50 map, sheet 77) (Fig. 1). The locality Hartl is named after the hillside in the north-east of Eisenstadt. Palaeogeographically, the study area belongs to the Eisenstadt-Sopron Basin.

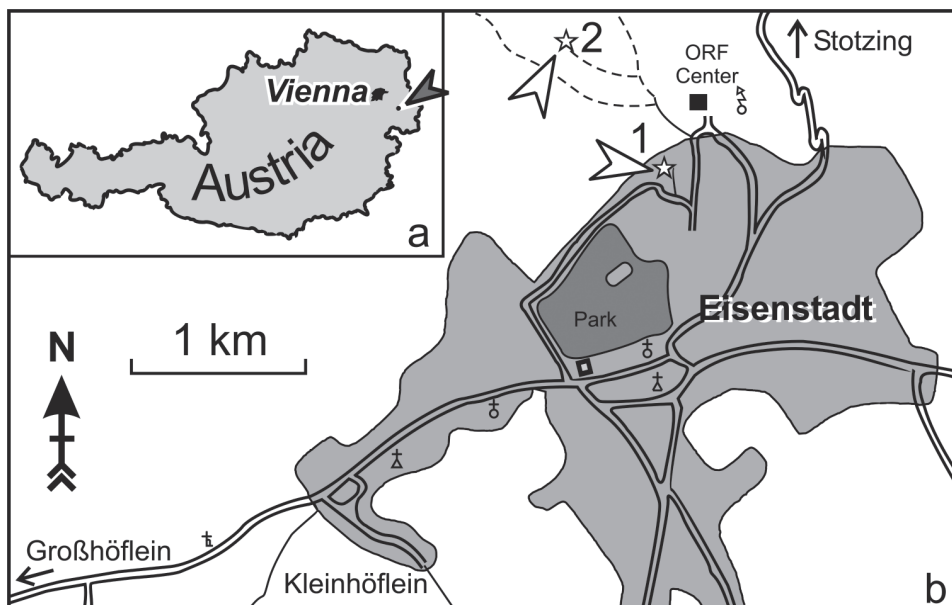


Fig. 1: a: Location of the study area within Austria; b: Study area and location of the studied sections (indicated by arrows; 1: section Hartllucke, 2: section Johannesgrotte).

This small basin is a strongly asymmetrical subbasin of the Vienna Basin complex. It displays a more or less trigonal size of about 20 x 20 km width (PILLER & VÁVRA, 1991). In the north it is limited by the NE-SW trending Leitha Mountains and the associated SE dipping Eisenstadt fault (FODOR, 1992). In the east, the basin is limited by the N-S trending Rust faults. The Rust-Fertőrákos Mountains separate the basin from the Danube Basin in the east. The southern margin is defined by a crystalline ridge, covered by Lower Miocene gravel which reaches from the Rosalia Mountains in eastern direction to the Brennborg. This relief separates the Eisenstadt-Sopron Basin from the Styrian Basin complex tectonically and palaeogeographically.

The subsidence history of the Eisenstadt-Sopron Basin started during the Early Badenian. At that time the first marine ingression reached the area, whereas fluvial deltaic environments predominated during the Early Miocene Ottnangian and Karpatian ages. The subsidence of the basin started in the western part of the basin in the Mattersburg depression and affected the eastern and north-eastern part not before the Middle Badenian. Therefore the greatest depth is developed in the SSE of the basin in the Mattersburg depression where a subsidence of more than 2,400 m along the Forchtenstein Fault is recorded by KRÖLL & WESSELY (1993) and BELOCKY et al. (2000). In contrast, in the eastern part of the basin the Neogene sediments do not exceed 600 m.

An open, relatively deep connection into the southern Vienna Basin is warranted through the Wiener Neustadt Gateway, furnishing evidence that the development of the Eisenstadt-Sopron Basin is strongly linked with that of the Vienna Basin.

3. MATERIAL AND METHODS

The logs of the sections were taken in spring 2001 and spring 2002. These are the last sections of the Hartl Formation which are still outcropping. Due to a current geotope protection program of the provincial government of Burgenland these outcrops have a high potential to be preserved for the future and are thus chosen as type and reference sections respectively. Besides these two sections only several isolated outcrops are currently available which were studied and sampled during this survey.

In the field, both unconsolidated and consolidated sediments were sampled. Of the unconsolidated samples 250 g were first dried and then disintegrated using H_2O_2 . Subsequently the samples were washed using standard sieve-sets (0.063 mm, 0.125 mm, 0.25 mm, 0.5 mm, 1 mm, 2 mm, 4 mm, 8 mm). For quantitative component analysis thin sections of the consolidated sediments were prepared. Unconsolidated sediments were embedded in resin and also thin-sectioned to produce comparable results. Both, the washed samples and the thin-sections were subject to quantitative analysis to assess the distribution of biogenic components within the sections. The samples are kept at the Geological-Palaeontological Department of the Natural History Museum Vienna and the thin-sections at the Institute of Geology and Palaeontology of the University of Graz.

4. LITHOSTRATIGRAPHY AND LOG DESCRIPTION

4.1. Hartl Formation

Type area: NE Eisenstadt to NE St. Georgen, Burgenland (ÖK 50/Sheet 77 Eisenstadt), along the Hartl Hill, Burgstall Hill, Scheiben Hill, Hoch Hill, and Hummelbühel Hill (also known as Hummelbuchberg) (Figs. 1, 2).

Type section: Hartlucke, NE Eisenstadt (Austrian Cave Register No. 2911/38) (Figs. 3, 4)

Co-ordinates: N 47° 51.38', E 016° 31.63'

Derivation of the name: The name "Hartl" is used for that part of Eisenstadt, where the sections are located. It is a name for the hill/mountain flank. The name was also used for a path leading from Eisenstadt into the Leitha Mts., termed "Hartlsteig" and for the sandpit of Eisenstadt, "Gemeindesandgrube am Hartl" (HABERLEHNER, 1938: 3), which was located about 200 m to the south-west of section Hartlucke and was closed in the 1970's.

Remarks: The type section was chosen, because it is the largest of the outcrops remaining today and protected as "natural" cave.

Synonymy: "Hartlsande", "Terebratelsande von Eisenstadt" (HABERLEHNER, 1938), "Eisenstädter Terebratelsand" (TOLLMANN, 1955: 20). This lithological unit was first mentioned by ČÍŽEK (1852) and ROTH VON TELEGD (1879), who published the first geological maps of the area.

Lithology: Coarse calcareous sands to fine gravels, with variable, but generally low fine sand and silt content (Pl. 1); terrigenous bryozoan-coralline algal limestones (Pls. 1, 2). Generally, quartz, quartzite, mica schist and other lithic fragments are present. Cementation is common, especially in the upper part of section Hartlucke and throughout section Johannesgrotte. The lower part of section Hartlucke and small outcrops in the vicinity (e. g., locality 3) are characterised by intense cross-bedding.

The direct transition towards the top of the Formation is obscured by soil cover. However, the top is formed by medium grained sandstones and sandy marls with intercalations of terrigenous bryozoan-coralline limestones (Pl. 2). The sandstones and sandy marls yield a rich fauna of benthic and planktic foraminifers. The limestones are predominantly terrigenous bryozoan-coralline rudstones with abundant planktic and benthic foraminifera, locally containing glauconite. Some of the limestones are particularly rich in the larger foraminifera *Amphistegina* and *Planostegina* (Pl. 2, Figs. 5–7). In the woody northern and north-eastern parts of the type area, where few outcrops exist, these sediments have formerly been mapped as limestones only (TOLLMANN, 1955; SCHMID, 1968). However, road cuts along the dirt roads within this area clearly show that the limestone facies is subordinate and restricted to single beds of 10 cm to few dm thickness only. The preferential weathering of the terrigenous sediments, which leaves the floor of the woods and vineyards covered with limestone blocks, create the impression that the limestone is the dominant facies.

Fossils (Pl. 3): Bryozoa and brachiopods are the typical biota of the Hartl Fm. The bryozoan fauna is very diverse (about 150 species) and the Hartlucke is the type locality for about 50 bryozoan species (PILLER & VÁVRA, 1991). It can be considered to belong to the most important bryozoan localities in the Neogene of Europe. Encrusting species on the inner side of brachiopod shells are especially well preserved and diverse. Throughout

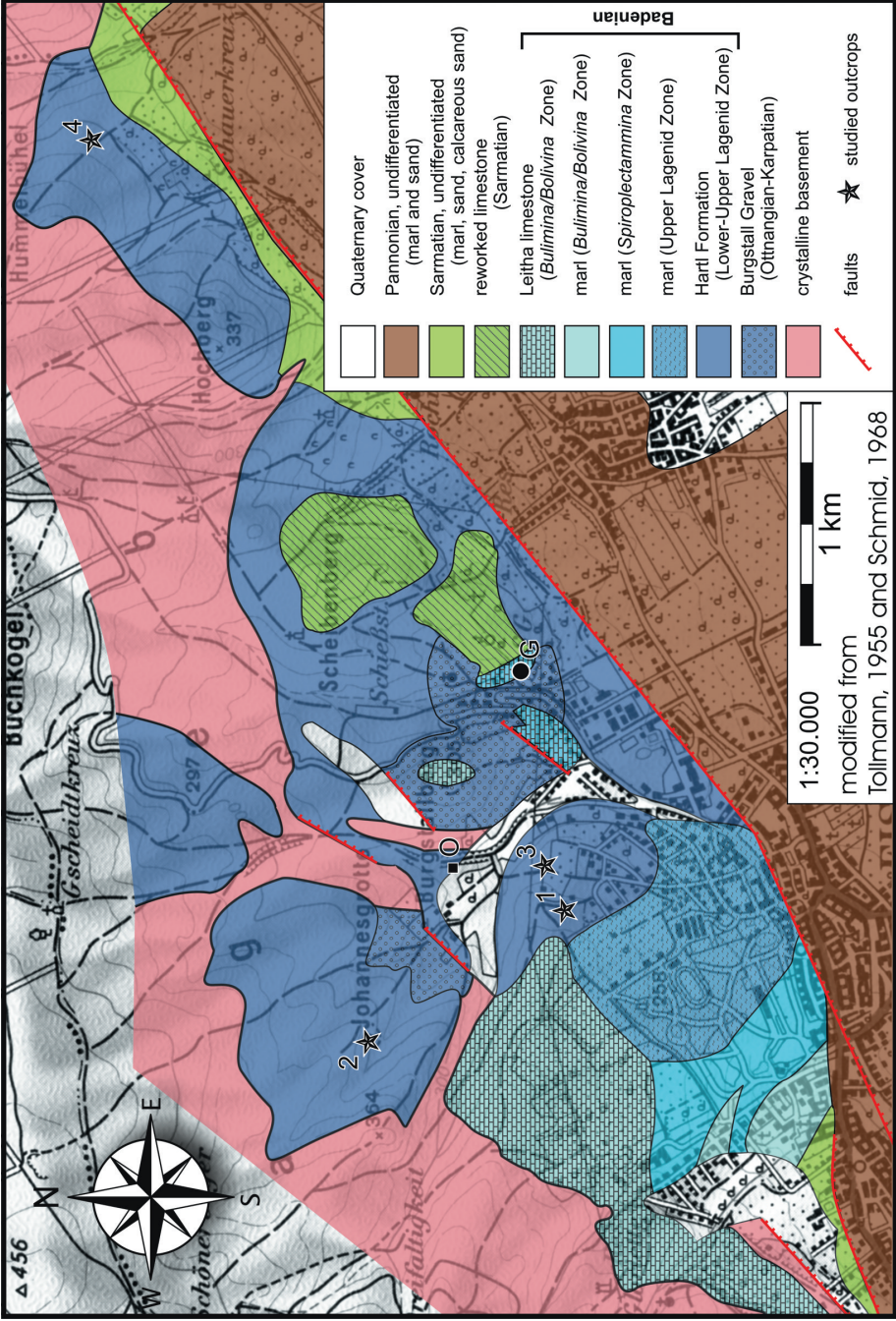


Fig. 2: The distribution of the Hartl Formation (modified after TOLLMANN, 1955 and SCHMID, 1968) and location of the studied localities (indicated by asterisks; 1: section Hartlucke, 2: section Johannesgrotte, 3: locality 3).

the sections globular bryozoan macroids (bryoids) made up mostly by celleporids are common. They are conspicuously abundant and large (up to 10 cm in diameter) in locality 3 (Fig. 2), where they were partly encrusting pagurized gastropod shells (Pl. 3, Figs. 5–7) and corals, which are otherwise leached. The bryozoan fauna of the Hartl Fm. was investigated by REUSS (1874), MANZONI (1877, 1878), CANU & BASSLER (1924), HABERLEHNER (1938), BOBIES (1958), DAVID & POUYET (1974), and SCHATTLITNER (1990). The brachiopod fauna was studied by DREGER (1889) and is dominated by *Pliothyrida macrescens* (DREGER), a large terebratulid (Pl. 3, Figs. 8–10), which occurs in form of isolated valves mostly. These shells can locally form small shell beds and act as secondary hardgrounds for bryozoans, serpulids, barnacles, and oysters. Less commonly the micro-morphic brachiopod *Megathiris detruncata* (GMELIN) is found in bulk samples.

Another very abundant group are the echinoderms, which are found as isolated ossicles mostly. Except of holothurians, all echinoderm classes are present in the samples. Echinoids are represented by spines and isolated plates of *Prionocidaris* sp., *Eucidaris zeamays* (SISMONDA), diadematids, and the temnopleurid *Arbacina* sp., as well as whole coronas of the tiny clypeasteroid *Echinocyamus stellatus* CAPEDE and the cassiduloid *Echinolampas manzonii* POMEL. Spatangoids are rare and found as fragments of indeterminate spines and plate fragments only. Ophiuroids are very common, they are represented by isolated vertebrae of gorgonocephalids, which occur throughout the section in large numbers. Other ophiuroid remains are rare and poorly preserved. Asteroids and crinoids are less common, the former being represented by marginal plates of *Astropecten* sp., *Luidia* sp. and goniasterids, the later by indeterminate brachial and cirral ossicles, and rare calyxes of comatulids.

Foraminifera are generally rare in the predominantly terrigenous sediments and poorly preserved, most common are abraded tests of *Amphistegina* sp. and *Planostegina* sp. (section Hartlucke). In one of the sandy outcrops (along the road to the ORF-Center) a considerably rich fauna (56 taxa) was detected containing benthic and planktic taxa (Appendix 1). In the calcareous sediments foraminifera may become abundant, particularly in the topmost limestones of the formation. From there textulariids, *Triloculina/Quinqueloculina*, *Borelis*, large lagenids (Pl. 2, Fig. 3), *Amphistegina*, *Planostegina*, *Sphaerogypsina*, ammoniids, elphidiids, cibicidids, *Asterigerinata*, uvigerinids and a relatively diverse fauna of large planktics, including *Orbulina*, are recorded. Sessile foraminifera are represented by *Acervulina* and *Carpenteria*. A rich foraminiferal fauna (> 130 taxa) originates from sandy marls of the Hummelbühel Hill (see below and Appendix 2).

Among molluscs, only groups with calcitic shells are preserved in the studied sections, because of aragonite dissolution during diagenesis. An exception are pagurized gastropod shells, which are preserved as casts through encrusting bryozoans (celleporids) (Pl. 3, Figs. 6, 7). *Aequipecten macrotis* and *Aequipecten malvinae* are common, as are small oysters (*Ostrea digitalina*). Anomiids (*Anomia ephippium*) are rare and poorly preserved, as well as casts of *Glycymeris pilosoa*.

Balanids are commonly found as isolated plates and encrusting on brachiopod shells. Less commonly *Creussia miocaenica* (Pl. 3, Figs. 3, 4) and *Creussia costata*, two pyrgomid cirripeds, a group living in association with anthozoans, occur. Annelids are represented by several different forms. Among these "*Serpula*" div. sp., *Protula protensa*, and *Ditrupea cornea* are most important.

Among coralline algae *Spongites albanensis*, *Lithothamnion ramosissimum* and *Lithophyllum* were identified. They occur mainly as fragments, but branches as well as crusts, the later alternating with bryozoans, are also recorded. Coralline algae are missing in section Hartllucke. This lack seduced KAPOUNEK (1938: 68) and other authors to the conclusion that the depositional depth of these sediments must have been below the photic zone, an interpretation rejected by TOLLMANN (1955: 20), PILLER & VÁVRA (1991: 199–200), and PILLER (2000: 87).

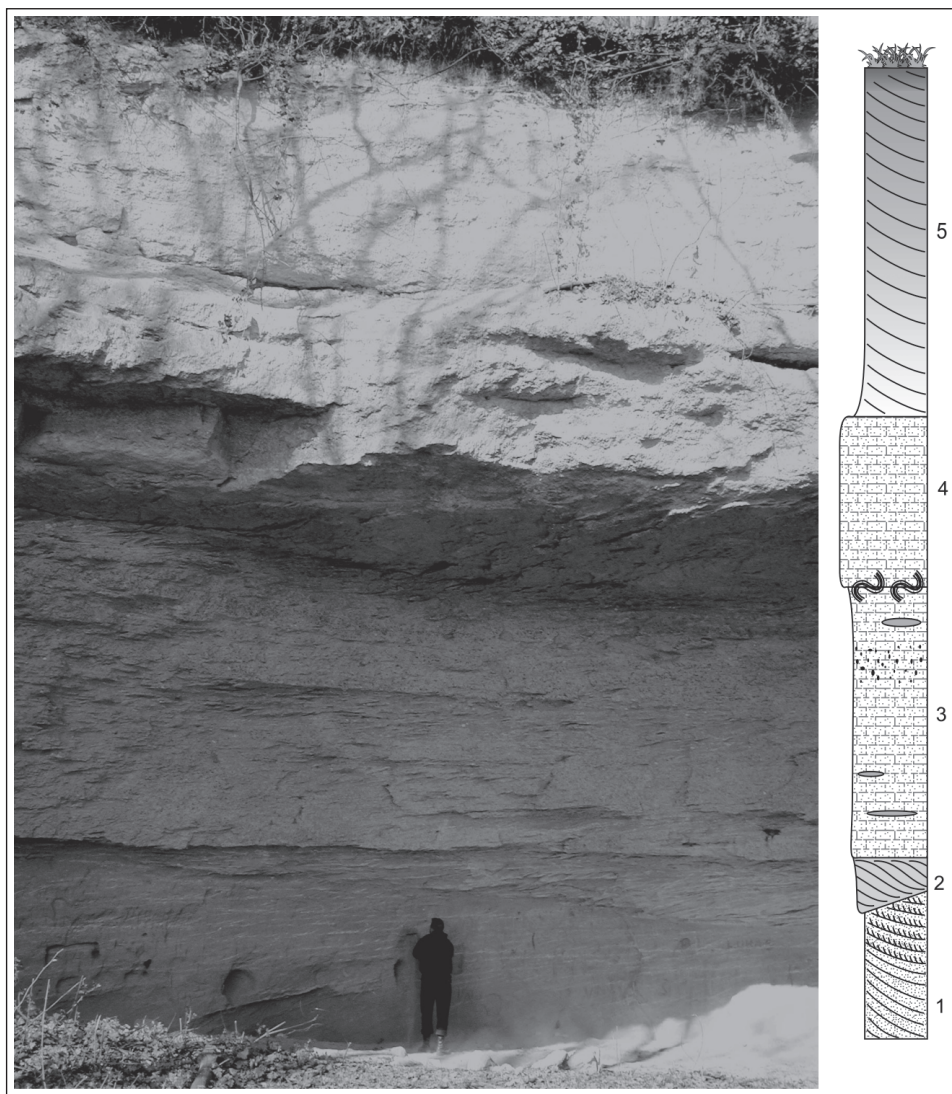


Fig. 3: Hartllucke, outcrop view of the type locality of the Hartl Formation and approximately corresponding section (not to scale; see Fig. 4).

Facies: Sedimentological data suggest a current dominated foreshore regime for the lower part of section Hartlucke and for locality 3, which are characterised by intense cross stratification. The upper part of section Hartlucke and other small localities show grain size distributions typical for submarine sand waves, incorporating reworked sediment (compare SINDOWSKI, 1957). The preserved echinoderm-, brachiopod-, bryozoan-assemblage is typical for a very shallow, coarse sandy habitat with seagrass and/or coral patches, indicating the presence of moderately strong currents, which were facilitated by the suspension feeding taxa.

The sample of the Hummelbüchel Hill reflects a diverse shallow-water microfauna. The assemblage is dominated by the genera *Cibicidoides* and *Heterolepa*, which have an epifaunal life-style. *Lobatula*, which lives on marine plants is also common. Among larger foraminifera, *Amphistegina mammilla* is abundant. Recently HOHENEGGER et al. (1999) showed that the similar extant species *A. radiata* occurs between 10 and 50 meters water depth, with an optimum at about 20 meters. Based on the observation, that juvenile specimens of several shallow-water taxa were missing in the sample, a transport from a shallower environment is inferred. Since taxa characteristic for a shelf environment, as e.g. *Lenticulina* and *Uvigerina* are only present in low numbers and since planktic foraminifera are not uncommon, a depositional depth of about 30 to 50 meters is assumed for these marly sediments.

Chronostratigraphy: Lower Badenian (Upper Langhian, Middle Miocene) (TOLLMANN, 1955: 20, Tab. 8).

Biostratigraphy: Lagenid Zone – Lower Lagenid Zone to approximately the boundary between Lower and Upper Lagenid Zone.

TOLLMANN (1955: 20, Tab. 8), in contrast, placed these sediments into the Upper Lagenid Zone on the base of few, poorly preserved foraminifera. Unfortunately, he did not list the species on which this biostratigraphic dating is based.

Generally, the planktic foraminifera have a typical Badenian composition. In the typical sand facies near the base of the formation the frequent occurrence of *Paragloborotalia? mayeri* clearly indicates Lower Badenian. The co-occurrence of *Amphistegina bohdanowiczi* and *A. mammilla* (Appendix 1) refines this position since it is to date only known from the Lower Lagenid Zone (RÖGL & BRANDSTÄTTER, 1993). This fits also well the origination of the sample close to the base of the formation.

Despite considerable efforts, none of the studied samples from the sections Hartlucke and Johannesgrotte yielded a biostratigraphically useful microfauna. Foraminifera were rare, poorly preserved and identifiable only to a limited extent in thin-sections such as textulariids, *Amphistegina*, *Planostegina*, *Sphaerogypsina*, nodosariids, ammonias, elphidiids, and buliminids.

A sample from yellowish sandy marls outcropping at the south-eastern slope of the Hummelbüchel Hill, about 3 km north-west of St. Georgen, yielded a rich microfauna. The sample was collected at a road cut along the dirt road leading from the "Schauerkreuz" to the summit of the Hummelbüchel Hill, about 50 meters north-east of the boundary between vineyards and wood (N 47° 52,43', E 016° 34,02'). It comes from near the top of the formation and yielded more than 130 taxa (see Appendix 2). The benthic taxa yield only an imprecise dating of the sample, since many species typical for the Lower Badenian, reach up into the *Spiroplectammina* Zone. *Lenticulina echinata*, *Vaginulinopsis hauerina* and *V. pedum*, however, are restricted to the Lagenid Zone.

The sole occurrence of *Amphistegina mammilla* is typical for the Upper Lagenid Zone whereas in the Lower Lagenid Zone this species co-occurs with *Amphistegina bohdanowiczi* BIEDA (see above; Appendix 1). The identification of just two *Bolboforma* species (*B. reticulata* and *B. moravica*) is also characteristic for the Lower Badenian (SPIEGLER & RÖGL, 1992). Among planktic foraminifera the co-occurrence of *Praeorbulina glomerosa circularis* and *Orbulina suturalis* is noteworthy, since it is usually observed in the uppermost part of the Lower Lagenid Zone. *Globigerinoides bisphericus*, also a species ranging up to the Lower Lagenid Zone, was documented by a single specimen. A similar common occurrence of *Globoturborotalita woodi* and large specimens of *Globigerina concinna* is observed in the "Baden Tegel" at the type locality (Upper Lagenid Zone). Taking all facts together, a position at the boundary of the Lower/Upper Lagenid Zone for this sample – close to the top of the formation – is strongly indicated.

A biostratigraphic correlation with the ecostratigraphic zonation of the Vienna Basin is not applicable since the importance of uvigerinids for a zonation of the basinal facies (PAPP & TURNOVSKY, 1953; PAPP, 1963) was widely rejected by the studies of HAUNOLD (1995).

Sequence stratigraphy: The general transgressive character of the Hartl Formation correlates well with a deepening upward trend, indicated by the increase in planktic foraminifera in the top units (Pl. 2, Fig. 4). The biostratigraphic dating close to the boundary between the Lower and the Upper Lagenid Zone of this top unit thus allows a correlation with the sequence stratigraphic model introduced by WEISSENBACK (1996) for the adjacent Vienna Basin. According to this model the deposition of the Hartl Formation falls into a late Transgressive Systems Tract called TST1 by WEISSENBACK (1996). The closeness of the maximum flooding surface (MFS 1) which was defined just below the Upper/Lower Lagenid boundary by WEISSENBACK (1996) is probably reflected by the high percentage of planktic foraminifera. A further indicator might be represented by glauconite.

Thickness: To evaluate the thickness of the Hartl Fm. is difficult, because neither the lower nor upper boundary are outcropping today. The minimum thickness is 10 m, as seen in section Hartlucke. In the old sandpit a thickness of 9 m was outcropping in the first half of the 20th century (HABERLEHNER, 1938: 3). For the whole unit a thickness of about 30 m can be reconstructed, on the basis of the mapped occurrence (Fig. 2). This thickness, however, is due to a backstepping of the sediments during transgression and is not represented in a vertical column.

Regional distribution: As erosional relic the Hartl Formation is restricted to its type area along the Burgstall Hill at Eisenstadt and the southern slopes of the Leitha Mountains north of St. Georgen (Fig. 2). An equivalent might be represented in the sandpit St. Georgen close to Eisenstadt located in the SE of the distribution area of the unit (described by SAUER et al., 1992). There, medium to coarse grained sands with conglomerate layers crop out. Samples from this pit yielded a very similar assemblage of echinoderms as is typical for the Hartl Formation. Unfortunately no exact biostratigraphic dating of this sequence is available and the outcrop is now filled with waste. Thus the relation to the Hartl Formation is unclear. The limestones with coralline algal fragments, which lie discordantly on top of the sands are of younger age (Lower *Spiroplectamina* Zone, compare SCHMID, 1968: 21) and do not belong to the Hartl Formation.

Underlying units: According to TOLLMANN (1955: 20–21) this unit lies directly on the crystalline basement of the Leitha Mts. (Lower Austroalpine units), only in the south-

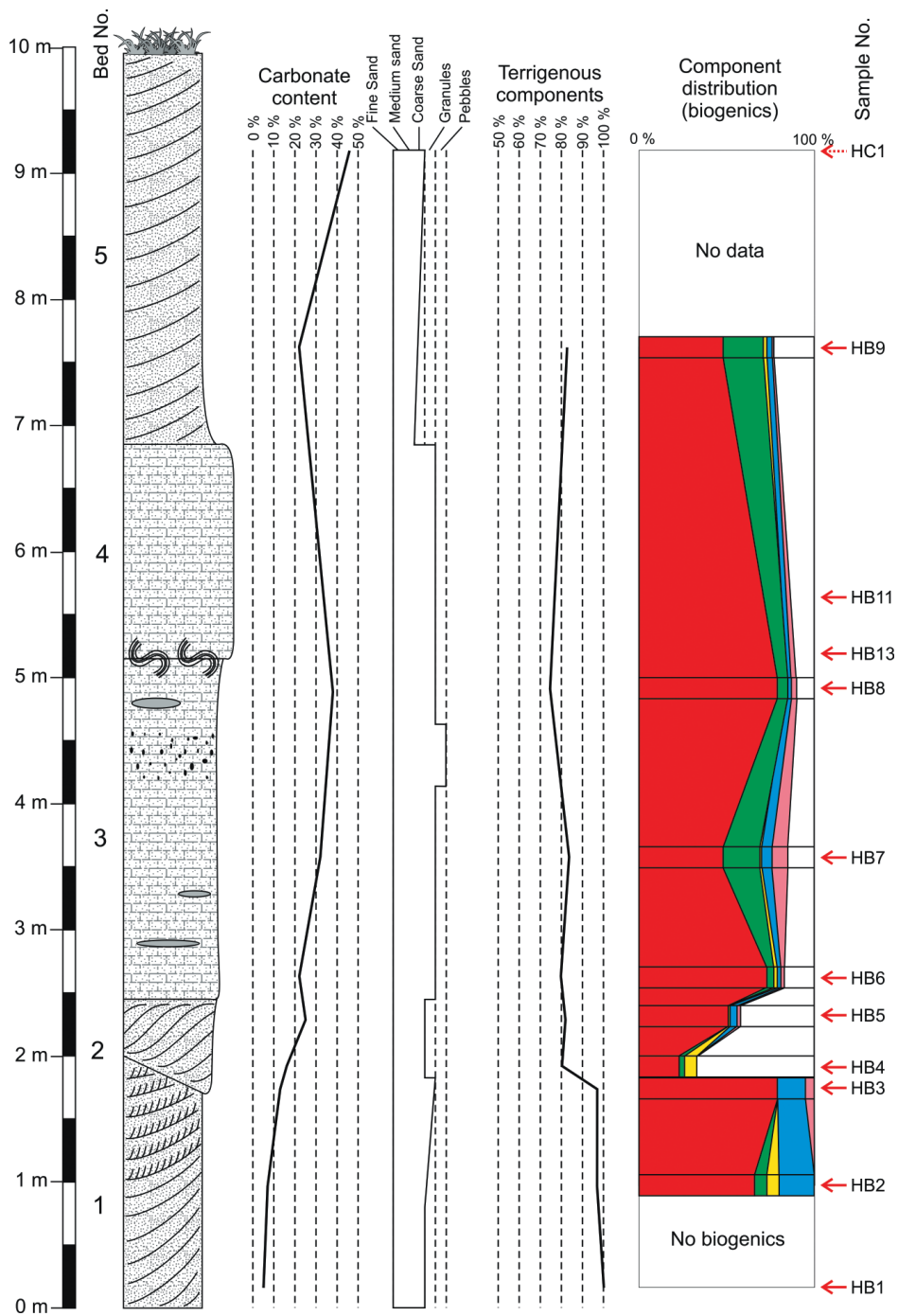


Fig. 4: Section Hartlucke (type-section of the Hartl Formation) with component distribution (for explanation see Fig. 5).

eastern part of the type area, it lies on top of the "Burgstall-Schotter" which crop out in the forest along the hillside below the Hartl Fm. The main part of the "Burgstall-Schotter" represents a lateral equivalent of the "Ruster-Schotter" (fluvial gravels of Ottnangian to Karpatian age), the reworked uppermost part of the "Burgstall-Schotter", however, is the basal unit of the Hartl Formation and represents a transgressional conglomerate. The heavy mineral spectrum of the "Burgstall-Schotter" was analysed by LUEGER (1977), who detected 14.4 % garnet, 17.5 % zirconium, 58.5 % apatite and 9.6 % other heavy minerals.

The statement of ČIŽEK (1852: 51), KAPOUNEK (1939: 67), and HABERLEHNER (1938: 4), that the Hartl Fm. is intercalated within the Leitha Limestone was already rejected by TOLLMANN (1955: 20–21).

Lower boundary: The contact with the crystalline basement is currently not exposed, whereas the contact to the "Burgstall-Schotter" can be observed along the dirt roads leading from the north-eastern end of Eisenstadt to the Johannesgrotte. The outcrop situation is, however, not very good and thus no logs of this transition could be measured.

Overlying units: In the south of the type area the Hartl Fm. is overlain by Leitha Limestone (TOLLMANN, 1955: 21). Foraminifera of the *Spiroplectammina* Zone indicate that these limestones belong to the following Badenian sequence and thus cannot be correlated with the limestone facies in the very top of the Hartl Formation.

Upper boundary: Currently not exposed in the south and in the northern distribution area the topmost beds are eroded. The upper boundary was exposed in the St. Georgen sandpit (described by SCHMID, 1968, and SAUER et al., 1992), where Leitha Limestone of the Lower *Spiroplectammina* Zone, lies discordantly on top of sands of the Upper Lagenid Zone.

Lateral boundary: Not exposed; nevertheless the – at least partly – synchronous lateral, basinal facies is represented by pelitic sediments in the centre of Eisenstadt which are dated into the Upper Lagenid Zone.

Geographic distribution: Only in the type area (Fig. 2).

4.2. Section Hartlucke (type section) (Figs. 3, 4)

Bed 1: > 200 cm coarse sand to fine gravel, moderately well sorted, showing a slight coarsening upwards trend. The bed shows low-angle cross-bedding and the bedding planes within the bed are covered with coarse biogene components (mainly bryozoans, both whole and fragmented terebratulid brachiopods, small cellemorph macroids, aequipectinids, small oysters and anomids, and echinoderm ossicles). Most bivalve and brachiopod shells display a convex-side-up position. The sediment between the bedding planes is nearly devoid of macrofossils. In the upper half of the bed, cross-bedding-planes are less inclined and are internally structured by steep foresets with coverings of bryozoan debris.

Bed 2: 0–90 cm coarse sand to fine gravel with sigmoidal cross-bedding. The bedding-planes are covered with biogene debris as in bed 1. Within the bed a marked increase in carbonate content is observable which is due to an increase in biota (Fig. 4). This bed is wedge-shaped and is thickest in the north-eastern part of the outcrop (Fig. 3).

Bed 3: 270 cm coarse sand to fine gravel, moderately lithified. The bed is intensely cross-bedded by small-scale, low-angle cross-bedding. Locally, there are lense-shaped bodies

of coarse sand with sigmoidal cross-bedding similar to bed 2. At 170 cm above the base of the bed is a distinct pebble-layer of quartz, quartzite and micaceous schist lithoclasts. Macrofossils are very common, including terebratulid brachiopods (both single- and double-valved), pectinids, bryozoans, cellemorid macroids, and echinoderm debris.

Bed 4: 170 cm well lithified calcareous coarse sandstone. This bed is rich in bryozoans, cellemorid macroids, echinoderm debris, and brachiopods. Coralline algal-debris is rare but present. According to HABERLEHNER (1938) the base of the bed showed a dense pattern of meandering trace fossils. Today the base of the bed is strongly weathered and these traces are only faintly visible.

Bed 5: >310 cm medium to coarse sand, poorly sorted. The bed shows low-angle cross-bedding and a slight coarsening upwards. The biogenic content is similar to the bed below, but coralline algal-debris is more common. Additionally, whole tests of *Echinolampas manzonii* POMEL occur within this bed. The upper bedding plane of this bed is not exposed.

4.3. Section Johannesgrotte (Fig. 5)

The section Johannesgrotte (also known as Johannisgrotte) is located in an abandoned quarry at the southern flanks of the Leitha Mountains, north-east of Eisenstadt, Burgenland (Co-ordinates: N 47° 51.82', E 016° 31.21'; Austrian Cave Register No. 2911/25). The section comprises calcareous sandstone to sandy limestone. In comparison to the other outcrops of the Hartl Fm., this outcrop is much more rich in coralline algae, which are distinctly less abundant or even absent in the other sections. The quarrying of the less well lithified layers has led to the formation of a cave in the north-western part of the abandoned quarry.

Bed 1: > 60 cm quartzose bryozoan-coralline algae rudstone to grainstone with many lithoclasts up to 8 mm in diameter. The bed is well cemented and its base is not exposed. The composition of the lithoclasts (in decreasing abundance): quartz, quartzite, feldspar and micaceous schists. Biota are abundant and besides bryozoans and coralline algae, foraminifera (textulariids, *Triloculina*/*Quinqueloculina*, *Amphistegina*, cibicidids, elphidiids, buliminids, nodosariids), ostracods, bivalves, serpulids, balanids, and echinoderms occur.

Bed 2: 80 cm terrigenous bryozoan-coralline algae rudstone to floatstone with many arborescent bryozoans and macroids of cellemorid bryozoans. The terrigenous content is high and lithoclasts are common. The components of the lithoclasts are the same as in bed 1, but their diameter is slightly smaller (up to 5 mm); the biogenic content is very similar.

Bed 3: 100 cm coralline algae rudstone with planar bedding on a 10 cm-scale. Arborescent bryozoans and macroids of cellemorid bryozoans are very common and accumulated in distinct layers. Lithoclasts of up to 5 mm in diameter are abundant. Single valves of terebratulid brachiopods are rare.

Bed 4: 140 cm terrigenous bryozoan-coralline algae rudstone to grainstone with many arborescent bryozoans and bryoids as well as low-angle cross-bedding. Locally terebratulid brachiopods, aequipectinids and cellemorid macroids are accumulated in thin layers. The terrigenous content is rather high and well rounded quartz-grains of up to 3 mm diameter are common. In the uppermost third of the bed, several shellbeds of terebratulid brachiopods are found.

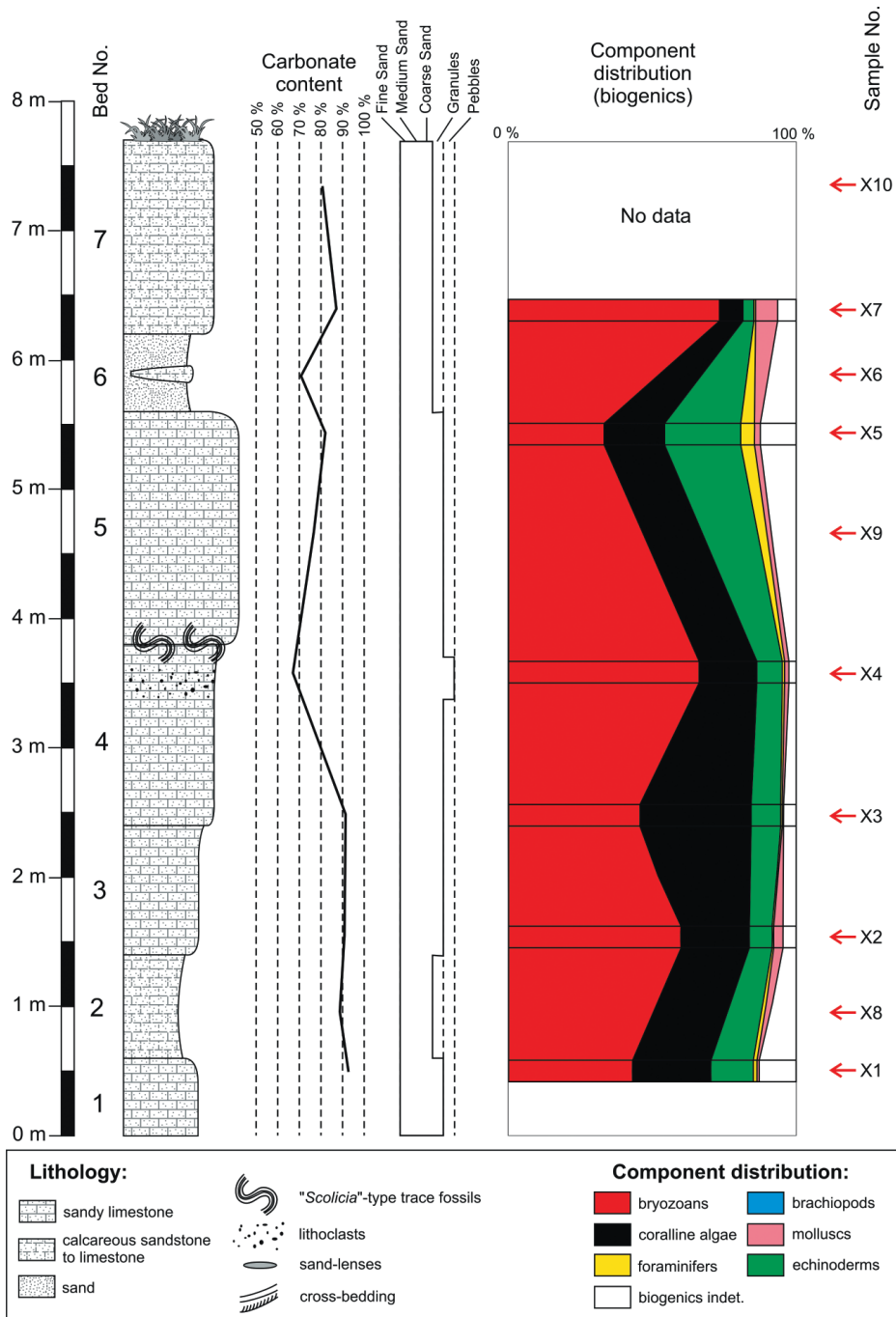


Fig. 5: Section Johannesgrotte with component distribution.

Bed 5: 180 cm bryozoan-coralline algae rudstone to floatstone with high terrigenous content and indistinct bedding at a 20 cm-scale. The base of the bed is intensely bioturbated; a dense pattern of meandering *Scolicia*-type trace fossils, presumably produced by spatangoid sea-urchins covers the exposed lower bedding plane of this bed. It seems that there are several horizons, showing this intense bioturbation by echinoids within this bed, but the situation is obscured by surface weathering. Lithoclasts of up to 10 mm diameter are very common. This bed forms the "roof" of the cave in the north-western part of the quarry.

Bed 6: 60 cm coarse bryozoan sand, badly sorted. Coralline algae, aequipectinids, cellopod macroids, terebratulid brachiopods, and lithoclasts of up to 10 mm diameter are very common. The coralline algal content is very variable laterally.

Bed 7: > 150 cm coarse bryozoan sandstone to rudstone, well lithified. Arborescent bryozoans, terebratulid brachiopods, aequipectinids and lithoclasts of up to 40 mm diameter are accumulated in layers within this bed. The lithoclasts are very well rounded and often encrusted by bryozoans and thin crusts of coralline algae. Coralline algae are present, but are less abundant than in the lower part of the section. The upper bedding plane of this bed is not exposed.

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References

- BELOCKY, R., SEIBERL, W. & WALACH, G., 2000: Der prätertiäre Untergrund. – In: SCHÖNLAUB, H. P. (ed.): Burgenland, Erläuterung zur Geologischen Karte des Burgenlandes 1 : 200.000. – 69–74, Wien (Geological Survey of Austria).
- BOBIES, C. A., 1930: Über bryozoenführende Sedimente des inneralpinen Wiener Beckens. – Mitt. Geol. Ges. Wien **21** (1928): 24–34, Wien.
- BOBIES, C. A., 1958: Bryozoenstudien III/2, Die Horneriden (Bryozoa) des Torton im Wiener und Eisenstädter Becken. – Sitzber. Österr. Akad. Wiss. Wien, math.-naturw. Kl., Abt. I **167/3–4**: 119–137, Wien.
- CANU, F. & BASSLER, R. S., 1924: Contribution à l'étude des Bryozoaires d'Autriche et de Hongrie. – Bull. Soc. Géol. Fr., Sér. 4, **24**: 672–690, Paris.
- CZÍŽEK, J., 1852: Geologische Verhältnisse der Umgebung von Hainburg, des Leithagebirges und der Ruster Berge. – Jb. k.-k. Geol. R.-A. **3/4**: 35–55, Wien.
- DAVID, L. & POUYET, S., 1974: Révision des Bryozoaires Cheilostomes miocènes du Bassin de Vienne, Autriche. – Doc. Lab. Géol. Fac. Sci. Lyon **60**: 83–257, Lyon.
- DREGER, J., 1889: Die tertiären Brachiopoden des Wiener Beckens. – Beitr. Paläont. Österr.-Ung. Orient. **7**: 179–192, Wien.
- FODOR, L., 1992: Tectonic Setting of the Eisenstadt Area. – In: SAUER, R., SEIFERT, P. & WESSELY, G. (eds.): Guidebook to Excursions in the Vienna Basin and the Adjacent Alpine-Carpathian Thrustbelt in Austria. – Mitt. Geol. Ges. Wien **85**: 124–126, Wien.
- HABERLEHNER, H., 1938: Palaeobiologische Studien an den Terebratelsanden bei Eisenstadt im Burgenland. – ph. D. thesis (unpublished), University of Vienna, 57 pp.
- HAUNOLD, T. G., 1995: Zur Taxonomie, Systematik und stratigraphischen Bedeutung uvigerinider Foraminiferen im Neogen des Wiener Beckens und benachbarter Gebiete – 40 Jahre nach Papp & Turnovsky (1953). – Jb. Geol. B.-A. **138/1**: 67–87, Wien.

- HOHENEGGER, J., YORDANOVA, E., NAKANO, Y. & TATZREITER, F., 1999: Habitats of larger foraminifera on the upper reef slope of Sesoko Island, Okinawa, Japan. – *Marine Micropaleontology* **36**: 109–168.
- KAPOUNEK, J., 1939: Geologische Verhältnisse der Umgebung von Eisenstadt. – *Jb. Geol. B.-A.* **87 (1938)**: 49–103, Wien.
- KRÖLL, A. W. & WESSELY, G., 1993: Strukturkarte Basis der tertiären Beckenfüllung. Geologische Themenkarte der Republik Österreich. Wiener Becken und angrenzende Gebiete 1 : 200.000. – Vienna (Geological Survey Austria).
- LUEGER, J. P., 1977: Der Fölligsschotter – Ablagerung eines mittelpannonischen Flusses aus dem Leithagebirge im Burgenland. – *Mitt. Ges. Geol. Bergbaustud. Österr.* **24**: 1–10, Wien.
- MANZONI, A., 1877: Briozoi fossili del Miocene d'Austria ed Ungheria. II. – *Denkschr. k. Akad. Wiss., math.-naturwiss. Cl.* **37**: 49–78, Wien.
- MANZONI, A., 1878: Briozoi fossili del Miocene d'Austria ed Ungheria. III. – *Denkschr. k. Akad. Wiss., math.-naturwiss. Cl.* **38/2**: 1–24, Wien.
- PAPP, A., 1963: Die biostratigraphische Gliederung des Neogens im Wiener Becken. – *Mitt. Geol. Ges. Wien* **56/1**: 225–289, Wien.
- PAPP, A. & TURNOVSKY, K., 1953: Die Entwicklung der Uvigerinen im Vindobon (Helvet und Torton) des Wiener Beckens. – *Jb. Geol. B.-A.* **46/1**: 117–142, Wien.
- PILLER, W. E., 2000: Eisenstadt – Johannesgrotte. – In: SCHÖNLAUB, H. P. (ed.): Erläuterungen zur geologischen Karte des Burgenlandes 1:200.000. – 86–87, Wien (Geological Survey Austria).
- PILLER, W. E. & VÁVRA, N., 1991: Das Tertiär im Wiener und Eisenstädter Becken. – In: ROETZEL, R. & NAGEL, D. (eds.): *Exkursionen im Tertiär Österreichs*. – 170–216, Gmünd (Österreichische Paläontologische Gesellschaft).
- REUSS, A. E., 1848: Die fossilen Polyparien des Wiener Tertiärbeckens. Ein monographischer Versuch. – *Naturwissenschaftliche Abhandlungen, durch Suskription herausgegeben und zusammengestellt von Wilhelm Haidinger* **2**: 1–109.
- REUSS, A. E., 1874: Die fossilen Bryozoen des österreichisch-ungarischen Miocäns. – *Denkschr. k. Akad. Wiss., math.-naturwiss. Cl.* **33/1**: 141–190, Wien.
- RÖGL, F. & BRANDSTÄTTER, F., 1993: The foraminifera genus *Amphistegina* in the Korytnica Clays (Holy Cross Mts., Central Poland) and its significance in the Miocene of the Paratethys. – *Acta Geol. Pol.* **43/1–2**: 121–146, Warszawa.
- ROTH VON TELEGD, L., 1879: Geologische Skizze des Kroisbach-Ruster Bergzuges und des südlichen Theiles des Leitha-Gebirges. – *Föld. Közl.* **1879/3–4**: 1–12, Budapest.
- SAUER, R., SEIFERT, P. & WESSELY, G., 1992: Guidebook to Excursions in the Vienna Basin and adjacent Alpine-Carpathian thrustbelt in Austria. – *Mitt. Österr. Geol. Ges.* **85**: 5–239, Wien.
- SCHATTLLEITNER, M., 1990: Systematik und Taxonomie der inkrustierenden Cyclostomata (Bryozoa) aus dem Badenium (Mittel-Miozän) von Eisenstadt (Burgenland, Österreich). – ph. D. thesis (unpublished), University of Vienna.
- SCHMID, H., 1968: Das Jungtertiär an der SE-Seite des Leithagebirges zwischen Eisenstadt und Breitenbrunn. – *Wiss. Arb. Burgenland* **41**: 1–74, Eisenstadt.
- SINDOWSKI, K.-H., 1957: Die synoptische Methode des Kornkurven-Vergleichs zur Ausdeutung fossiler Sedimentationsräume. – *Geologisches Jahrbuch* **73**: 235–275, Hannover.
- SPIEGLER, D. & RÖGL, F., 1992: *Bolboforma* (Protophyta, incertis sedis) im Oligozän und Miozän des Mediterran und der Zentralen Paratethys. – *Ann. Naturhist. Mus. Wien* **94A**: 59–95, Wien.
- TOLLMANN, A., 1955: Das Neogen am Nordwestrand der Eisenstädter Bucht. – *Wiss. Arb. Burgenland* **10**: 1–74, Eisenstadt.
- VÁVRA, N., 1979: Die Bryozoenfauna des österreichischen Tertiärs. – *N. Jb. Geol. Paläont. Abh.* **157/3**: 366–392, Stuttgart.

Appendix 1: Foraminiferan fauna from an outcrop along the road to the ORF-Center (sample coll. N. Vávra 1976).

Textulariina:

Pseudogaudryina sturi (KARRER)
Semivulvulina deperdita (D'ORBIGNY)
Textularia sp.

Miliolina:

Quinqueloculina sp.
Miliolidae indet.

Lagenina – Rotaliina:

Alfredosilvestris levinsoni ANDERSEN?
Amphistegina bohdanowiczi BIEDA
Amphistegina mammilla (FICHTEL & MOLL)
Asterigerinata mamilla (WILLIAMSON)
Asterigerinata planorbis (D'ORBIGNY)
Cassidulina margareta KARRER
Cibicidoides lopjanicus (MYATLYUK)
Cibicidoides vortex (SEGUENZA)
Elphidium crispum (LINNÉ)
Elphidium fichtelianum (D'ORBIGNY)
Elphidium macellum (FICHTEL & MOLL)
Eponides umbonatus (FICHTEL & MOLL)
Fissurina laevigata REUSS
Fissurina pseudoorbignyana (BUCHNER)
Glabratella cf. *erecta* SIDEBOTTOM
Glabratella spp.
Globocassidulina subglobosa (BRADY)
Guttulina communis D'ORBIGNY
Guttulina elongata KARRER
Hanzawaia boueana (D'ORBIGNY)
Heterolepa dutemplei (D'ORBIGNY) s.l.
Lenticulina clericii (FORNASINI)

Lenticulina inornata (D'ORBIGNY)
Lenticulina orbicularis (D'ORBIGNY)
Lenticulina spinosa (CUSHMAN)
Lenticulina cf. *vortex* (FICHTEL & MOLL)
Lingulina sp.
Lobatula lobatula (WALKER & JACOB)
Neoconorbina sp.
Pararotalia aculeata (D'ORBIGNY)
Pullenia bulloides (D'ORBIGNY)
Reussella laevigata CUSHMAN
Rosalina obtusa D'ORBIGNY
Siphonodosaria consobrina (D'ORBIGNY)
Sphaerogypsina globulus (REUSS)
Stilostomella sp.
Stomatorbina concentrica (PARKER & JONES)
Trifarina bradyi CUSHMAN
Uvigerina aculeata ČIŽEK

Globigerinina:

Globigerina praebulloides BLOW
Globigerina bollii CITA & PREMOLI SILVA
Globigerina diplostoma REUSS
Globigerinella regularis (D'ORBIGNY)
Globigerinoides quadrilobatus (D'ORBIGNY)
Globigerinoides trilobus (REUSS)
Globigerinita cf. *glutinata* (EGGER)
Globigerinita uvula (EHRENBERG)
Globorotalia transsylvanica POPESCU
Globoturborotalita woodi (JENKINS)
Paragloborotalia? inaequiconica (SUBBOTINA)
Paragloborotalia? mayeri (CUSHMAN & ELLISOR)

Appendix 2: Microfossils from the south-eastern slope of the Hummelbühel Hill (N 47° 52.43', E 016° 34.02').

Foraminifera

Textulariina:

Colominella paalzowi (CUSHMAN)
Pseudogaudryina karreriana (CUSHMAN)
Pseudogaudryina mayeriana (D'ORBIGNY)
Pseudogaudryina sturi (KARRER)
Semivulvulina acuta (REUSS)
Semivulvulina deperdita (D'ORBIGNY)
Spirorutilus carinatus (D'ORBIGNY)
Textularia gramen D'ORBIGNY
Textularia laevigata D'ORBIGNY
Textularia pala ČIŽEK

Spirillinina:

Spirillina vivipara EHRENBERG

Miliolina:

Pyrgo lunula (D'ORBIGNY)
Quinqueloculina pygmaea REUSS
Triloculina gibba D'ORBIGNY

Lagenina – Rotaliina:

Alabamina armellae POPESCU
Amphistegina mammilla (FICHTEL & MOLL)
Angulogerina angulosa (WILLIAMSON)
Anomalinoides cf. *badenensis* (D'ORBIGNY)
Asterigerinata mamilla (WILLIAMSON)

Asterigerinata planorbis (D'ORBIGNY)
Astrononion stelligerum (D'ORBIGNY)
Baggina cf. *californica* CUSHMAN
Bolivina aff. *simplex* PHLEGER & PARKER
Bolivina dilatata brevis CÍCHA & ZAPLETALOVA
Bolivina fastigia CUSHMAN
Bolivina papulata CUSHMAN
Bolivina plicatella CUSHMAN
Bolivina scalprata retiformis CUSHMAN
Bolivina viennensis MARKS
Bulimina striata mexicana CUSHMAN
Cancris auriculus (FICHTEL & MOLL)
Cassidulina margareta KARRER
Caucasina elongata (D'ORBIGNY)
Caucasina schischkinskayae SAMOYLOVA
Chilostomella ovoidea REUSS
Cibicidoides bogdanovi (SEROVA)
Cibicidoides haidingeri (D'ORBIGNY)
Cibicidoides lopjanicus (MYATLYUK)
Cibicidoides pachyderma (RZEHAČ)
Cibicidoides vortex (SEGUENZA)
Coryphostoma digitalis (D'ORBIGNY)
Dentalina acuta D'ORBIGNY
Dimorphina akneriana (NEUGEBOREN)
Ehrenbergina serrata REUSS
Elphidium crispum (LINNÉ)
Elphidium fichtelianum (D'ORBIGNY)
Elphidium macellum (FICHTEL & MOLL)
Elphidium subumbilicatum (CZIZEK)
Eponides umbonatus (FICHTEL & MOLL)
Fissurina laevigata REUSS
Fissurina pseudoorbignyana (BUCHNER)
Fursenkoina acuta (D'ORBIGNY)
Glabratella cf. *erecta* SIEDEBOTTOM
Glabratella effusa (KRASHENINNIKOV)
Glabratella platyomphala (REUSS)
Globocassidulina oblonga (REUSS)
Globocassidulina subglobosa (BRADY)
Globulina gibba D'ORBIGNY
Globulina spinosa D'ORBIGNY
Guttulina communis (D'ORBIGNY)
Gyroidinoides octocameratus (CUSHMAN)
Gyroidinoides soldanii (D'ORBIGNY)
Hanzawaia boueana (D'ORBIGNY)
Heterolepa dutemplei (D'ORBIGNY)
Heterolepa praecincta (KARRER)
Laevidentalina elegans (D'ORBIGNY)
Lenticulina austriaca (D'ORBIGNY)
Lenticulina calcar (LINNÉ)
Lenticulina meynae VESPERMANN
Lenticulina echinata (SOLDANI)
Lenticulina inornata (D'ORBIGNY)
Lenticulina orbicularis (D'ORBIGNY)

Lobatula laciniosa (KARRER)
Lobatula lobatula (WALKER & JACOB)
Melonis pompilioides (FICHTEL & MOLL)
Neononorbina terquemi (RZEHAČ)
Neoeponides schreibersi (D'ORBIGNY)
Nodosaria rudis D'ORBIGNY?
Nonion commune (D'ORBIGNY)
Nonionella karaganica KRASHENINNIKOV
Nonionella ventragranosa KRASHENINNIKOV
Orthomorphina sp.
Palliolatella arborea (MATTHES)?
Pararotalia aculeata (D'ORBIGNY)
Pappina parkeri (KARRER)
Planopulvinulina granulosa (KARRER)
Planostegina costata (D'ORBIGNY)
Planulina papillata (KARRER)
Praeglobobulimina ex gr. *pupoides* (D'ORBIGNY)
Pullenia bulloides (D'ORBIGNY)
Pullenia quinqueloba (REUSS)
Reussella laevigata CUSHMAN
Riminopsis boueanus (D'ORBIGNY)
Rosalina obtusa D'ORBIGNY
Rotorbis patella (REUSS)
Siphonodosaria consobrina (D'ORBIGNY)
Sphaerogypsina globulus (REUSS)
Sphaeroidina bulloides D'ORBIGNY
Stomatorbina concentrica (PARKER & JONES)
Trifarina bradyi CUSHMAN
Uvigerina aculeata CZIZEK
Uvigerina grilli SCHMID
Uvigerina laubeana SCHUBERT
Uvigerina pygmaea D'ORBIGNY
Uvigerina semiornata D'ORBIGNY
Uvigerina urnula D'ORBIGNY
Vaginulinopsis hauerina (D'ORBIGNY)
Vaginulinopsis pedum (D'ORBIGNY)

Globigerinina:

Globigerina praebulloides BLOW
Globigerina bollii CITA & PREMOLI SILVA
Globigerina diplostoma REUSS
Globigerina subcretacea LOMNICKI
Globigerina tarchanensis SUBBOTINA & CHUTZIEVA
Globigerina concinna REUSS
Globigerina bulloides D'ORBIGNY
Globigerina cf. *foliata* BOLLI
Globigerina cf. *ottnangiensis* RÖGL
Globigerinella regularis (D'ORBIGNY)
Globigerinoides bisphericus TODD
Globigerinoides immaturus LE ROY
Globigerinoides quadrilobatus (D'ORBIGNY)
Globigerinoides ruber (D'ORBIGNY)?

Globigerinoides trilobus (REUSS)
Globigerinita cf. glutinata (EGGER)
Globigerinita uvula (EHRENBERG)
Globorotalia bykovae (AISENSTADT)
Globorotalia transsylvanica POPESCU
Globorotaloides sp.
Globoturborotalita woodi (JENKINS)
Orbulina suturalis BRÖNNIMANN

Paragloborotalia? inaequiconica (SUBBOTINA)
Praeorbulina glomerata circularis (BLOW)
Tenuitella minutissima (BOLLI)
Turborotalita quinqueloba (NATLAND)

Protozoa, inc. sed.:
Bolboforma moravica REDINGER
Bolboforma reticulata DANIELS & SPIEGLER

Plate 1

Thin sections from the sections Hartlucke (Figs. 1–4) and Johannesgrotte (Figs. 5–8).

Fig. 1: Coarse grained sand (Hartlucke HB1, resin embedded loose sediment; magnification: 4x).

Fig. 2: Fossiliferous fine gravel with brachiopod shells and bryozoan (Hartlucke HB5, resin embedded loose sediment; magnification: 4x).

Fig. 3: Fossiliferous fine gravel with brachiopod and bivalve shells, balanids and bryozoan. The brachiopod shell (top center) is encrusted by bryozoans (Hartlucke HB7, resin embedded loose sediment; magnification: 4x).

Fig. 4: Detail of a punctate brachiopod shell fragment (Hartlucke HB3, resin embedded loose sediment; magnification: 25x).

Fig. 5: Branching bryozoan colony (Johannesgrotte X2, thin section; magnification: 8x).

Fig. 6: Bryozoan-coraline algae rudstone. Cross-sections of bryozoan branches: *Myriopora truncata* (GMELIN), sections of coraline algal branches and of serpulid tubes (Johannesgrotte X5, thin section; magnification: 4x).

Fig. 7: Bryozoan-coraline algae rudstone. One nearly circular bryozoan colony (left center) clearly points to encrustation of non-fossilized substrate, possibly seagrass or macroalgae. Besides coraline algal fragments echinoid particles (e. g., top center) are abundant showing syntaxial calcite overgrowth (Johannesgrotte X2, thin section; magnification: 8x).

Fig. 8: Terrigenous bryozoan-coraline algae rudstone with serpulid tubes encrusting on bryozoan colony (Johannesgrotte X4, thin section; magnification: 4x).

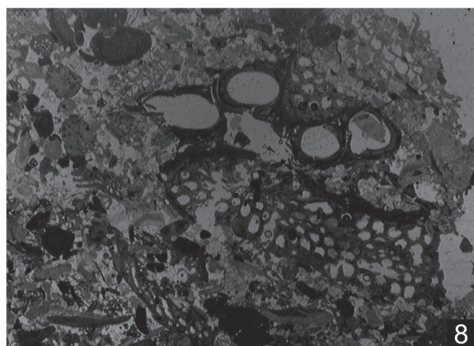
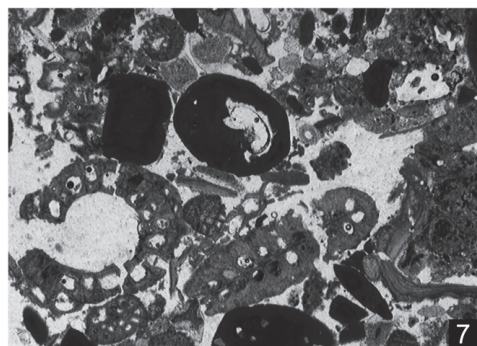
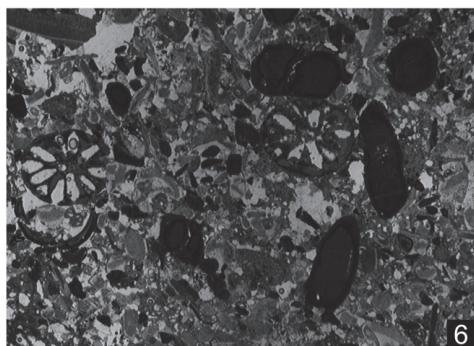
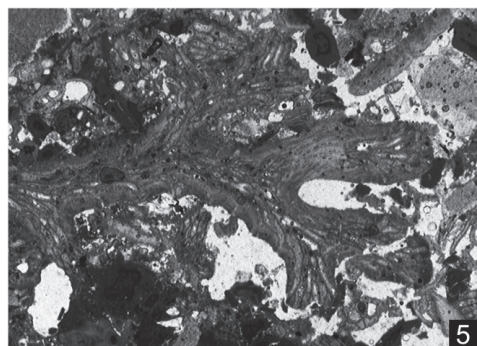
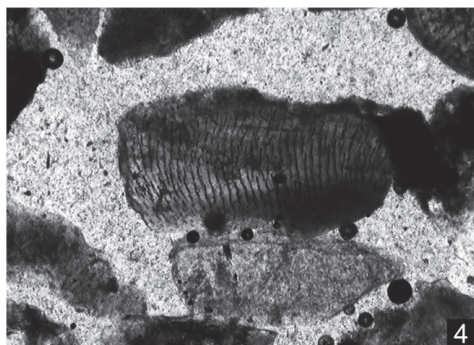
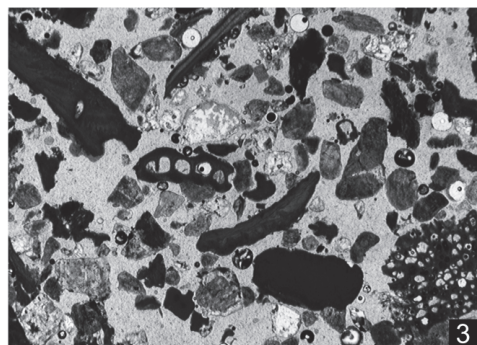
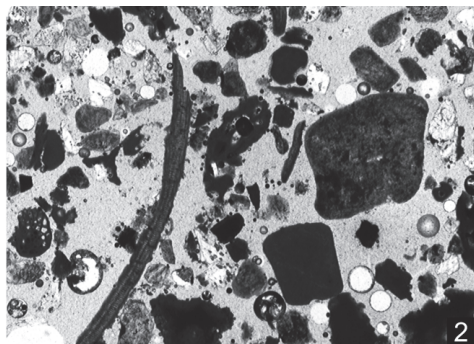
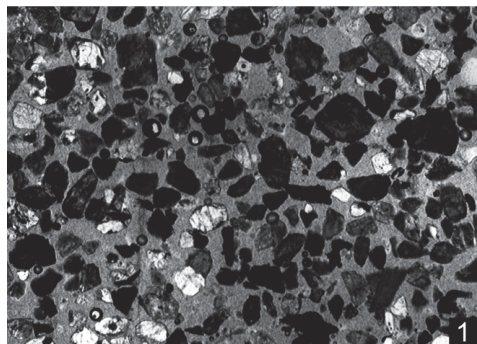


Plate 2

Thin sections from the sandstones and limestones of the Hartl Formation overlying the sediments of section Johannesgrotte.

- Fig. 1: Bryozoan-coralline algae rudstone. Branching bryozoan colony and abundant *Amphistegina* (O1, thin section; magnification: 8x).
- Fig. 2: Bryozoan-coralline algae packstone – floatstone (O2, thin section; magnification: 18x).
- Fig. 3: Detail of a corallinean-bryozoan rudstone with a large lagenid foraminifer and smaller benthic foraminifers (H1, thin section; magnification: 14x).
- Fig. 4: Biogenic quartz sandstone with abundant planktic foraminifers (H2, thin section; magnification: 18x).
- Fig. 5: Bryozoan-coralline algae rudstone with Celleporid bryozoan colony, coralline algal branch fragments and abundant *Amphistegina* (O1, thin section; magnification: 4x).
- Fig. 6: Detail of bryozoan-coralline algae rudstone with abundant foraminifers (*Amphistegina*, *Elphidium*, cibicidids) (O1, thin section; magnification: 14x).
- Fig. 7: Terrigenous *Planostegina*-bryozoan floatstone with various bryozoan growth forms and a subaxial *Planostegina* section (H3b, thin section; magnification: 12x).
- Fig. 8: Terrigenous bivalve-coralline algal rudstone with bryozoan (H3a, thin section; magnification: 4x).

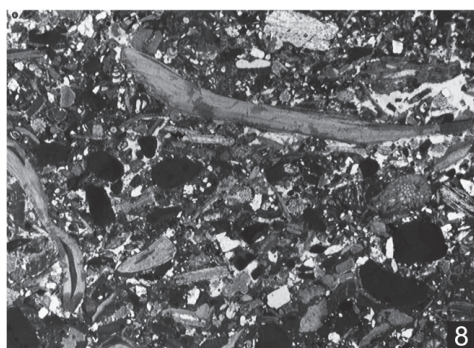
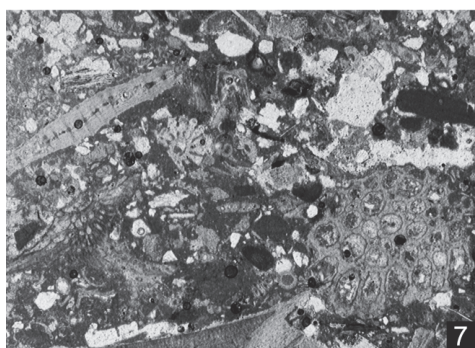
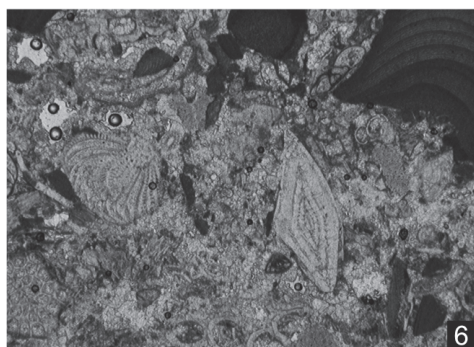
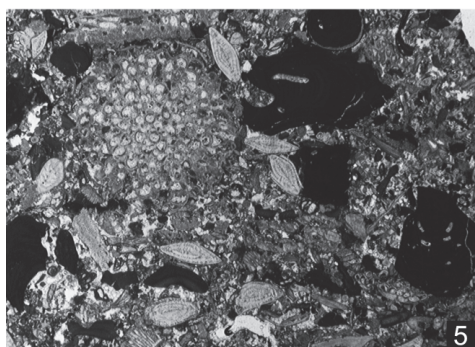
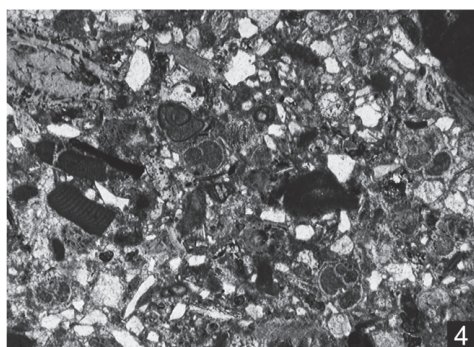
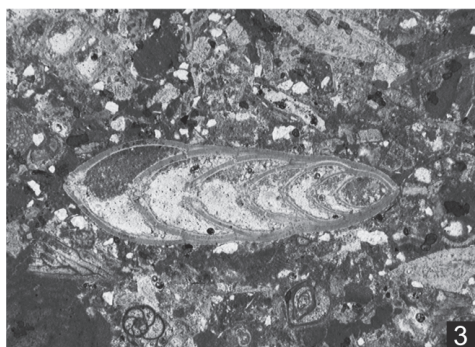
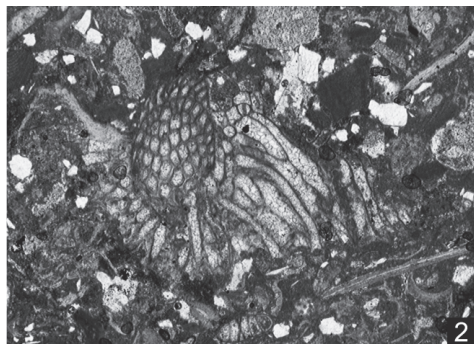
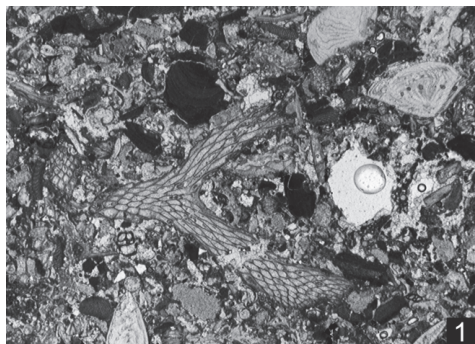


Plate 3

Characteristic fossils of the Hartl Formation.

Fig. 1: Corallinacean-bryozoan macroid.

Fig. 2: Nesting of brachiopod shells and bryoids.

Fig. 3: *Creussia miocaenica* PROCHÁZKA, 1893; dorsal view.

Fig. 4: *Creussia miocaenica* PROCHÁZKA, 1893; lateral view.

Fig. 5: Celleporid-bryozoan macroid with the mould of a pagurized gastropod.

Fig. 6: Celleporid-bryozoan macroid with the mould of a pagurized gastropod.

Fig. 7: Silicon cast of the gastropod mould in fig. 6.

Fig. 8: *Pliothyryna macrescens* (DREGER, 1889); ventral view

Fig. 9: *Pliothyryna macrescens* (DREGER, 1889); dorsal view

Fig. 10: *Pliothyryna macrescens* (DREGER, 1889); lateral view

All figures are in natural size, except figs. 3–4, which are double natural size.

