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Paleoecology and biostratigraphy of the section Mühlbach (Gaindorf Formation, lower Middle Miocene, Lower Badenian, Austria)

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(With 4 text-figures)

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Abstract

The Gaindorf Formation comprises siliciclastics of the Early Badenian (~Langhian). Genetically, it seems to be related to the late 3rd order first Transgressive Systems Tract of the Vienna Basin sensu WEISSENBÄCK (1996). Poor outcrop conditions and major erosion have hindered detailed analyses of the paleoecology and biostratigraphy of this formation up to now. A short-lived artificial outcrop at Mühlbach am Manhartsberg (Lower Austria) offered first opportunities to study more than 270 terrestrial and marine taxa, thus revealing this section as a tie point for the continental/marine correlation in the Middle Miocene Molasse Basin.

Various paleoenvironments surrounding a steep, tectonically initiated coast could be reconstructed based on the fairly rich fossil assemblage. Cool bottom waters and nutrient enrichment of the surface waters either by riverine influx or by local upwelling occurred.

The biostratigraphic dating of the section based on foraminifera points to an absolute age of about 15.1 ma, corresponding to the top of Zone M5b/Mt5b. In terms of mammal zonation the section is correlated with the late MN 5.

Keywords: Central Paratethys, Gaindorf Formation, Middle Miocene, Badenian, steep coast, terrestrial paleoenvironment, marine paleoecology

Zusammenfassung

Die Gaindorf-Formation umfaßt siliziklastische Sedimente des älteren Badenium (~Langhium). Sequenzstratigraphisch dürften sie mit dem späten 1. Transgressive Systems Tract des Wiener Beckens (sensu WEISSENBÄCK 1996) korrelierbar sein. Schlechte Aufschlussbedingungen und weitreichende Erosion der miozänen Sedimente erschwerten bisher jede detaillierte biostratigraphische und paläoökologische Interpretation dieser Ablagerungen.

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Ein künstlicher Aufschluß in Mühlbach am Manhartsberg (Niederösterreich) erbrachte nun über 270 marine und terrestrische Taxa, die die Lokalität als bemerkenswerten Bezugspunkt für die kontinentale/marine Korrelation erweisen. Die Vergesellschaftungen erlauben die Rekonstruktion verschiedener Biotope, die sich im Badenium entlang einer tektonisch angelegten Steilküste bildeten. Fluviatiler Eintrag und/oder lokale Upwelling Bedingungen führten zu relativ kühlen Bodenströmungen und einer Nährstoffanreicherung der höheren Wasserschichten.

Die Alterseinstufung anhand von Foraminiferen in die späte M5b/Mt5b Zone deutet auf ein absolutes Alter von ca. 15.1 Millionen Jahren. Die Säugetiervergesellschaftung ist typisch für die späte MN 5 Zone.

Schlüsselworte: Zentrale Paratethys, Gaindorf-Formation, Badenium, Mittel Miozän, Steilküste, terrestrische Ökosysteme, marine Paläoökologie

1. Introduction

This paper is a synthesis of all data concerning the section Mühlbach, collected and published in the present volume of the "Annalen des Naturhistorischen Museums in Wien ser. A vol. 104".

Due to the efforts of Reinhard ROETZEL and Gudrun DAXNER-HÖCK, a large amount of material has been collected at a seemingly unexciting Middle Miocene section at Mühlbach in Lower Austria. This previously unstudied site in the Molasse Basin comprises a short pelitic to sandy section with few macrofossils. The sediment belongs to the Gaindorf Formation - a lateral equivalent of the better-studied Grund Formation, which is famous for its highly diverse mollusc fauna.

Two large bulk samples for the micro-mammal washing procedure and several smaller samples for the study of sedimentology and marine microfossils were taken. These samples soon turned out to yield a rich but ecologically completely inconsistent fauna of foraminifera, ostracods, balanids, molluscs, fishes, reptiles, and smaller mammals.

In total, 271 taxa were recorded in the samples (without reworked pre-Badenian taxa). These are composed of 28 species of calcareous nannoplankton (ĆORIC 2003), 162 planktonic and benthic foraminifera (RÖGL & SPEZZAFERRI 2003), 25 molluscs (MANDIC & HARZHAUSER 2003), 16 ostracods (ZORN 2003), 2 decapod crustaceans (unstudied), 1 balanid species (unstudied), 5 species of arborescent bryozoans (unstudied), 11 fish taxa (SCHULTZ 2003), 8 reptiles (MIKLAS-TEMPFER 2003) and 13 species of mammals (DAXNER-HÖCK 2003; ZIEGLER 2003; BOON-KRISTKOIZ 2003).

The habitat requirements of the elements present in the assemblages range from terrestrial environments down to the upper bathyal (marine). Even for the marine taxa, most authors attest a mixing of shallow and deeper marine species (ZORN 2003; MANDIC & HARZHAUSER 2003; RÖGL & SPEZZAFERRI 2003).

The aim of this study is to discuss a paleoecological scenario which might have produced this strange mixture of elements.

2. Geological setting

The geological setting of the Gaindorf Formation and the sedimentology of the section Mühlbach are discussed in detail by ROETZEL (2003). Geologically, the section Mühlbach lies at the south-eastern margin of the Bohemian Massif. The composite section

comprises about 4 m of Ottnangian and Badenian sediments. During this study the focus was laid on the Badenian part, which attains only about 2 m thickness. It consists of badly sorted sandy pelites which display a slight fining upward trend. In the lower part of the Badenian section, sandy layers, mollusc coquinas, and numerous vertebrate remains and terrestrial gastropods have been recorded (samples M6, M5, M4, M2, Mü1, Mü2).

3. Biostratigraphy of the Gaindorf Formation (Figure 1)

The integrated approach allows an exceptionally well-collateralised biostratigraphic dating. Therefore, the small fauna of Mühlbach serves as a reference point for the marine/continental correlation in the Central Paratethys.

Generally, the Gaindorf Formation corresponds to the regional ecostratigraphic foraminiferal zone Lower Lagenidae Zone. Its deposition is interpreted by RÖGL & SPEZZAFERRI (2003) to span the upper part of the planktonic foraminifera Zone M5b with *Praeorbulina glomerosa circularis* up to Zone M6/Mt6, indicated by the occurrence of *Orbulina suturalis*. The section Mühlbach, however, is even more precisely dated based on the evolutionary level of *P. glomerosa circularis* and is placed at the top of Zone M5b/Mt5b. The co-occurrence of *Sphenolithus heteromorphus* and *Helicosphaera waltrans*, indicating the nannofossil Zone NN5 (ĆORIC 2003), agrees well with this dating.

A calibration of the section Mühlbach with the continental zonation is warranted by the occurrence of smaller mammals. According to DAXNER-HÖCK (2003), the rodent fauna with *Cricetodon meini* is representative for the late mammal Zone MN5, and is definitely older than the Ries event, which is dated roughly at ~14.9 ma. Thus, the datings point to an absolute age of about 15.1 ma (RÖGL & SPEZZAFERRI 2003).

4. Section Mühlbach – Paleoenvironments of a rough gneiss peninsula

Due to the surprisingly rich material deriving from only 8 Badenian samples from the section Mühlbach, a rather detailed paleoecological interpretation is possible. The mixed character of the assemblages warrants a glance into at least 5 different paleoenvironments which developed at the Paratethys Sea-European continent interface during the Early Badenian.

4. 1. Terrestrial environments

As emphasised by DAXNER-HÖCK (2003), the predominance of burrowing cricetids and gophers among the rodents, coinciding with the absence of glirid-eomyid-petauristid-castorid assemblages, points to rather dry woodland and a low groundwater level. Rodents of moist woodland, as typical for the Karpatian of the Korneuburg Basin, are almost completely missing (DAXNER-HÖCK 1998; 2003). The insectivora fauna is strongly predominated by the Erinaceidae genus *Schizogalerix*, which is also indicative for a woodland habitat but hints at closeby freshwater habitats (ZIEGLER 2003). Among the reptiles, only *Lacerta* sp. prefers dry, rocky areas, whereas the terrapin *Mauremys* and the natricine snake indicate the presence of standing water bodies or slowly flowing

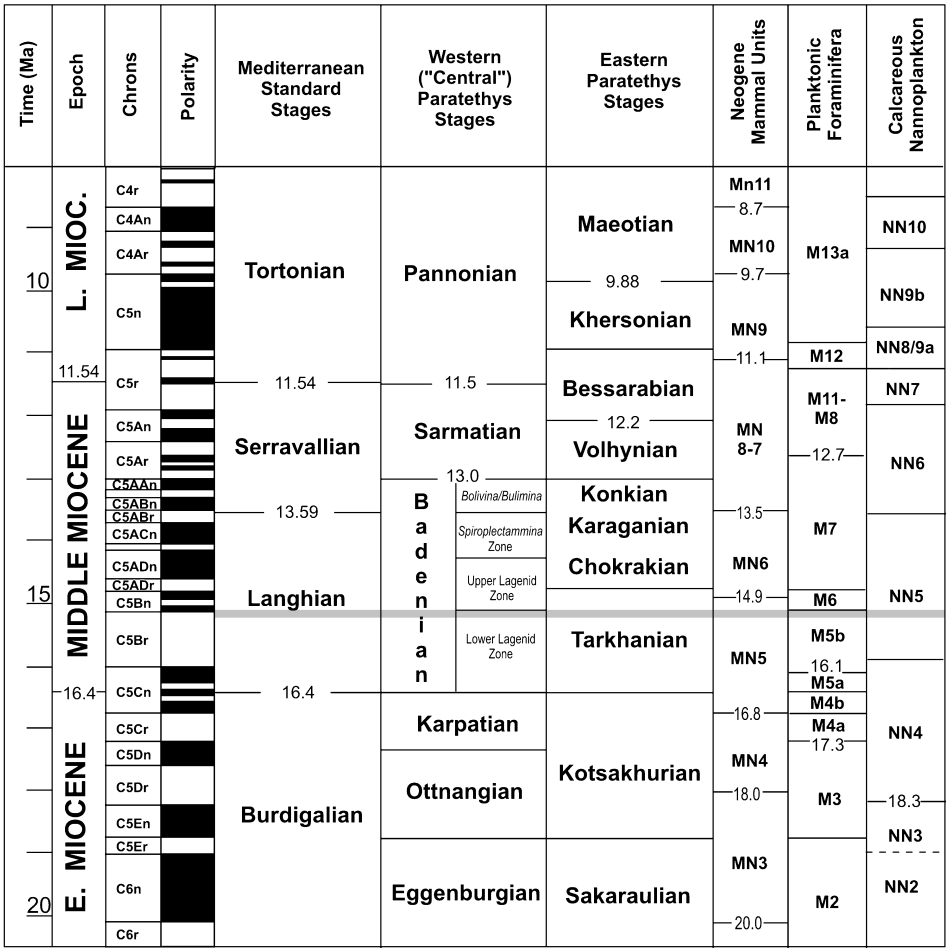

Fig: 1: Early to Late Miocene geochronology and biostratigraphy modified after RÖGL (1998). Langhian/Serravallian and Serravallian/Tortonian boundaries according to FORESI & al. (2002a; b).

The shaded area indicates the stratigraphic position of vertebrate-bearing samples of the section Mühlbach am Manhartsberg. The Gaindorf Formation spans the upper part of the Planktonic Foraminifera Zones M5b and M6.

rivers (MIKLAS-TEMPFER 2003). Amphibians, however, are absent from the investigated samples, emphasising the generally dry conditions. Another freshwater index is documented by SCHULTZ (2003), who reports the chub *Palaeoleuciscus* sp. This fish is recorded from lacustrine settings but might have also populated riverine environments (see SCHULTZ 2003 for discussion).

These somewhat contradictory data witness a freshwater environment surrounded by a rather narrow, moist and vegetated belt. This zone gave shelter to taxa such as the wormlizard *Blanus*, the terrapin *Mauremys*, the European glasslizard *Ophisaurus*, and the chub *Palaeoleuciscus*. Due to the absence of any clearly riverine taxa and based on the sedi-

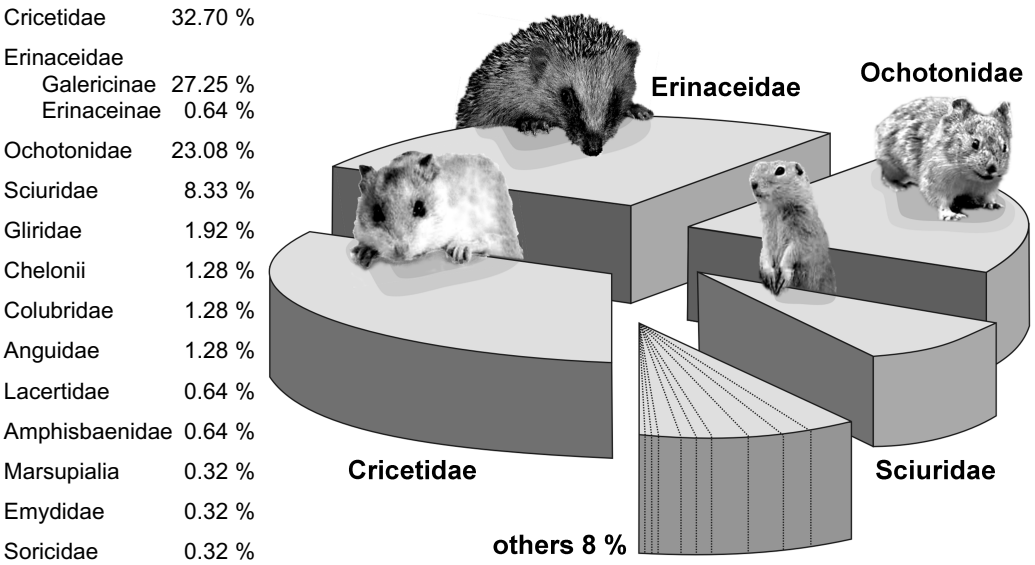

Fig. 2: Percentages of terrestrial vertebrates represented in the investigated samples from Mühlbach am Manhartsberg (1 specimen = 0.32 %). The numbers are based on all identified specimens (skeletal fragment or tooth) and do not represent estimations of individuals. The graph illustrates the strong predominance by Cricetidae, Erinaceidae, Ochotonidae, and Sciuridae, pointing to a generally rather dry hinterland with low groundwater level. Furthermore, this distribution indicates a taphonomic bias by predation of nocturnal birds, as most of these smaller mammals are chiefly nocturnal animals. Aquatic taxa and species with preference for moist habitats are present but of subordinate importance. These elements are interpreted to derive most probably from a nearby rivulet.

mentological data, a noteworthy fluvial system is unlikely; we rather suggest that a small lake or a slowly running rivulet formed in the hinterland adjacent to the coast. The formation of extensive coastal swamps, however, can be ruled out because the rodent fauna as well as the gastropods point to a generally moderately dry area. The comparison of the ratios of the various terrestrial vertebrate remains as shown in figure 2 documents the predominance of Crictidae, Erinaceidae, Ochotonidae, and Sciuridae in the assemblages, attaining about 92% of the total fauna. By contrast, the humidity indices such as the Emydidae, Colubridae, and Amphisbaenidae make up less than 2.5% of the spectrum and should thus not be overemphasised in the local environment analysis.

However, the unusual composition of the mammal assemblage is probably taphonomically biased. Only 5 mammal species predominate the spectrum: *Schizogalerix pristinus, Spermophilinus besanus, Cricetodon meini*, *Democricetodon mutilus,* and *Prolagus oeningensis.* The actualistic interpretation suggests these species to most likely represent nocturnal animals. Consequently, nocturnal birds such as owls with some degree of predation preferences might be responsible for the bias. In this case, the mammal assemblage would largely derive from disintegrated bird pellets, which include isolated teeth and bone fragments, but no jaws or articulated limb-bones.

4. 2. The shoreline

Little information is available from the littoral zone. Fragments of *Balanus* sp. are common in the samples, indicating the presence of littoral hardgrounds acceptable for balanid settlement. Aside from balanids, which favour the upper littoral zone, *Ostrea digitalina* might have been an important hardground-dwelling species in the lower littoral zone down to few metres depth (Fig. 3). This species is quite frequently recorded in the samples but displays a conspicuous left/right valve ratio discrepancy. This fact is interpreted by MANDIC & HARZHAUSER (2003) to point to a distinct taphonomic loss. Only the "free" valve was transported to the depositional environment, whilst the majority of the attached valves remained at the shoreline where they were cemented to the rocks.

Thus, only a very low diverse fauna can be reconstructed for the shore. This is probably due to rather unfavourable conditions prevailing along an unprotected coast which lacked noteworthy shallow, sandy sublittoral zones suitable for settlement by infaunal taxa. Consequently, any littoral taxa preferring muddy protected coasts such as potamidid and batillariid gastropods – ubiquitous in synchronous closeby faunas – are completely missing.

4. 3. Out into the sea

The slope

Below the tidal zone, a diverse mollusc fauna proliferated. Epifaunal and byssally attached species predominate here among the bivalves, represented by various thin-shelled, byssate pectinids and anomiids (Fig. 3). These settled either on primary hardgrounds, such as the gneiss rocks forming the coastal morphology, or were attached to various algae or bryozoans in the sublittoral zone. Thus, the few recorded arborescent bryozoans might also derive from this rocky, less wave-exposed environment. The frequent wentletrap *Epitonium miofrondiculoides* is suspected to derive from this shallow sublittoral zone (Fig. 3). Most recent wentletraps are specialised on parasitic or commensal relationships with sea anemones (see MANDIC & HARZHAUSER 2003 for references). These animals depend on hardgrounds for settlement and might rather be expected along the rocky slope than in the muddy bottom of a depositional environment. Thus, the agitated shallow marine coastal zone of the Mühlbach peninsula was probably settled by abundant, but unpreserved sea anemones which were intensively exploited by wentletraps.

This paleoenvironment interpretation fits well to the ostracod data reported by ZORN (2003). Among the ostracods, too, an ecologically twofold grouping is observed by ZORN (2003).

Of these two groups, the first one with *Callistocythere, Cytheridea, Loxoconcha,* and *Aurila* among others derives from the littoral and shallow sublittoral zone. In contrast to the bivalves, the ostracods prefer softbottoms; *Aurila,* for example, commonly lives on sandy substrate. Some phytal covering is also documented by the occurrence of *Xestoleberis* which dwells on or between algae.

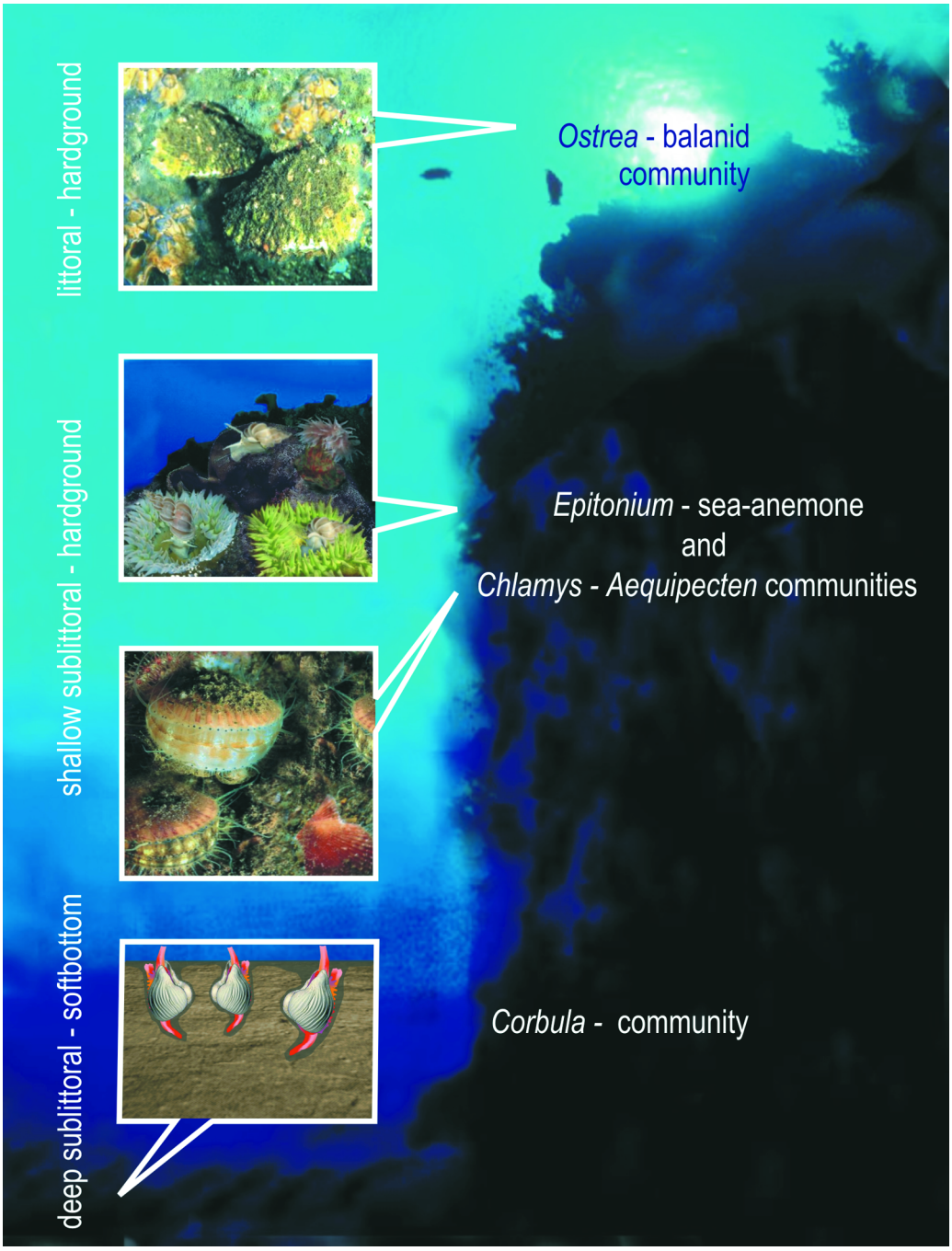

Fig. 3: Simplified sketch to illustrate the various origins of the documented mollusc assemblage from at least four different paleocommunities. These span environments from the well-agitated rocky littoral via the shallow sublittoral down to muddy bottoms of the deep sublittoral under unstable environmental conditions.

The sea-floor

The in-habitat fauna of the muddy bottom is represented especially by foraminifera, ostracods and infaunal bivalves. Among the latter the basket-shell *Corbula* (*Varicorbula*) *gibba* predominated the assemblage aside from *Gouldia minima* and *Loripes* (*Microloripes*) *dentatus* (MANDIC & HARZHAUSER 2003). These species could settle on rather unstable environments and were especially adapted to oxygen crises (Fig. 3). Correspondingly, RÖGL & SPEZZAFERRI (2003) postulate a muddy sea-floor in the outer shelf to upper bathyal with slight oxygen depletion or an oxic sea-floor with a dysoxid layer down to about 6 cm within the sediment based on the benthic foraminifera. MANDIC & HARZHAUSER (2003) discuss periodic algal blooms as a possible trigger for the oxygen depletion at the sea-floor, which would match with upwelling conditions as postulated by RÖGL & SPEZZAFERRI (2003).

The oxygenation of the sediments was highest in layers with high terrestrial input, which might account for a secondary oxygenation by remobilization (RÖGL & SPEZZAFERRI 2003). The same authors suggest cool bottom waters based on the occurrence of taxa such as *Sphaeroidina bulloides*, *Amphicoryna* spp. and *Pseudoparella exigua*. Among the ostracods, ZORN (2003) could identify few specimens of deeper-water taxa, such as *Parakrithe*, *Pterygocythereis* and *Cytheropteron,* which are considered to represent the autochthonous bottom fauna. ZORN (2003) discusses the upper circalittoral as a depositional environment of this ostracod fauna because of the co-occurrence of *Acanthocythereis hystrix*. This species is indicative of a warm-temperate environment.

Based on the foraminifera data, a considerable water depth of about 200 m is suggested. This indicates a very steep coast with a 200 m relief, resulting in a very quick succession of different environments, which is responsible for the extreme faunal mixing at the sampling locality.

The open sea

Both the planktonic foraminifera as well as the calcareous nannoplankton point to a drastic nutrient enrichment of the surface water. These conditions account for the predominance of the algae *Coccolithus pelagicus* and *Reticulofenestra minuta* (ĆORIC 2003) and the mass occurrence of five-chambered globigerinids (RÖGL & SPEZZAFERRI 2003). All these authors agree that these blooms may result from two different scenarios. On the one hand, high continental input by rivers would enhance nutrient enrichment. On the other hand, upwelling of cool waters frequently coincides with the proliferation of *Globigerina* s.s. and *Coccolithus pelagicus* (see RÖGL & SPEZZAFERRI 2003 and ĆORIC 2003 for references).

Both scenarios are supported equally by data: in respect to the paleomorphology of a rather steep gneiss slope and the cool bottom waters, as suggested by the benthic foraminifera, a "local upwelling" is quite reasonable. By contrast, strong fluvial influx is witnessed by the adjacent Hollenburg-Karlstetten Formation. These coarse siliciclastic deposits are interpreted to derive from a huge submarine delta which covered the region to the south of the investigation area (ROETZEL & al. 1999). Thus, nutrient enrichment by a larger river shedding its load some 10-20 km into the basin is also confirmed.

This deltaic complex is probably the origin for most reworked foraminifera and calcareous nannoplankton from the Calcareous Alps and the Flysch Zone identified by RÖGL & SPEZZAFERRI (2003) and ĆORIC (2003).

Despite the cool bottom water and the possible local upwelling zone, the sparse occurrence of warm-water species such as *Sphenolithus heteromorphus* and *Discoaster variabilis* among the nannoplankton and e.g. *Globigerinoides* and *Praeorbulina* among the foraminifera indicate warm surface waters coinciding with the generally warm early Middle Miocene temperatures. Sea surface temperatures of the warm temperate zone – at least – are also documented by the occurrence of the surgeonfish *Acanthurus*, described by SCHULTZ (2003).

5. Conclusions

The artificial outcrop Mühlbach is in a very close position to a tectonically displaced area of Gföhl gneiss of the Bohemian Massif, which formed a small, strongly structured peninsula protruding into the Paratethys Sea during the Early Badenian (Figure 4). In eastern and north-eastern direction, the Early Badenian Molasse Sea surrounding the investigated area displays a broad connection to the main waterbody of the Central Paratethys. Towards the south-east, the crystalline basement displays a small extension into the area of Fels am Wagram which probably acted as a submarine shoal during the Badenian transgression. Adjacent to this submarine elevation the sphere of influence of a large river becomes noticeable in the SSW, represented by delta fans of the Hollenburg-Karlstetten Formation.

This neighbouring deltaic system caused a high input of nutrients. Furthermore, the steep coast with a relief of about 200 m favoured the development of local upwelling zones. Both result in a remarkable proliferation of planktonic organisms such as globigerinids and coccoliths. Cool bottom waters and phases of low oxygenation of the seafloor are reflected in the benthic foraminifera fauna as well as in the bivalve communities, whilst warm surface waters can be reconstructed based on thermophilic discoasterids and sphenolithids and planktonic foraminifera.

The occurrence of terrestrial gastropods and vertebrates in the deep, marine environment might be explained at first glance by debris flows. Such an interpretation, however, can be definitively excluded based on the sedimentological data (ROETZEL 2003). Instead, the coarser sediment was probably transported by repeated storm events. The extremely poor sorting of the pelites is interpreted by ROETZEL (2003) to be secondary, resulting from intense bioturbation which obscured the originally distinct coarser layers. These storm events could have introduced the terrestrial elements such as egg shells of reptiles and the gastropods. In addition, the freshwater fish *Palaeoleuciscus* alongside the rare terrapin *Mauremys* point to the influx of a small rivulet which might have introduced the disintegrated bird pellets containing the low diversity mammal assemblage.

Overall, the faunal mixture which accumulated a few hundreds of meters in front of the steep coast points to a more or less local origin contributed by elements from the surrounding hinterland. A transport by currents from the Hollenburg-Karstetten Delta, as reasonable for most reworked Cretaceous microfossils, seems to be unlikely based on the sedimentology and the absence of any fluvial molluscs.

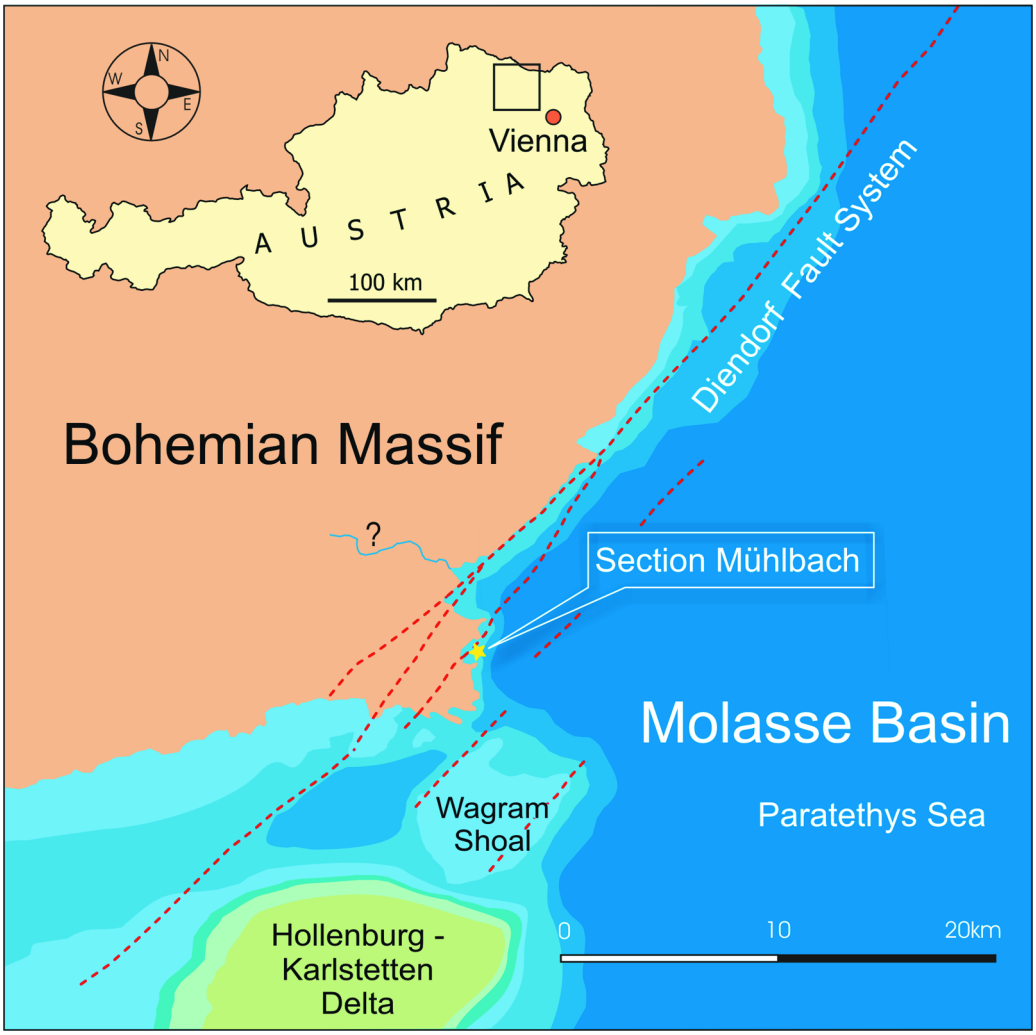

Fig. 4: Hypothetical paleogeography in the vicinity of Mühlbach during the Early Badenian (~15 ma), based on the geological map of ROETZEL in ROETZEL & al. 1999 (note that the former marine extension of the sea onto the Bohemian Massif is obscured by erosion of most Badenian sediments). The Diendorf Fault system caused the establishment of steep rocky coastal settings. Transportation of coarser deposits deriving from the southern Hollenburg-Karlstetten Delta was probably deviated by a submarine topographic elevation, termed Wagram Shoal herein. Therefore, a local river might have transported the documented freshwater elements such as the chub *Palaeoleuciscus* and the terrapin *Mauremys* along with parts of other terrestrial taxa into the depositional environment.

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