DIPLOMARBEIT

Titel der Diplomarbeit

The molluscan – dominated benthic assemblages of the estuarine and shallow marine Upper Burdigalian deposits of the Korneuburg Basin in Lower Austria

Verfasserin

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Contents

Contents

4

1 Introduction

1.1 A historical summary

Since the middle of the 19th century many records of fossil deposits of the Korneuburg Basin (16.5 Ma) are known (Harzhauser et al., 2009), but the first was made by M. Hoernes in the year 1848 (Sovis, 1998). At the beginning of the 20th century the first series of drillings took place in the basin. The drillhole "Korneuburg 1" in 1943/1944 for example provides 18 cores and the longest profile in the Korneuburger sediments by then (Wessely, 1998). In 1975 a group of collectors made the first detailed scientific studies which were the base for the project named "Teiritzberg" (Harzhauser et al., 2009). This project was scientifically supported by the Institute of Palaeontology of the University of Vienna and the Natural History Museum of Vienna (NHMV). The data, collected from 1982 to 1995 and handled by 36 scientists, was finally summarized in the two volumes of "Das Karpat des Korneuburger Beckens", published in 1998 and 2002 (Harzhauser et al., 2002). In that, Wolfgang Sovis (1998) described the history of the Korneuburg sediments and listed more than 64 outcrops from 15 localities. More than 650 taxa including invertebrata, vertebrata and plants were included into palaeoenvironmental reconstruction of the basin (Harzhauser et al., 2002). Since the year 2005 an oyster-biostrome in Teiritzberg was successively excavated and now forms the main attraction of the Geopark "Fossilienwelt Weinviertel" since the year 2009 (Harzhauser et al., 2009; Kern et al., 2010). Therefore the Korneuburg Basin is one of the best-described basins of Europe and crucial for the palaeobiogeographical and palaeoecological understanding of the Karpatian (Upper Burdigalian) of the Central Paratethys (Harzhauser and Wessely, 2003).

1.2 Research question

The purpose of this thesis is to get more quantitative information about the faunal composition of the Korneuburg Basin, especially about its southern, estuarine part. For the first time it was possible to achieve continuous quantitative palaeontological data along an 1.8 km long transect and to put this information into a detailed sedimentological and stratigraphical context. It is of special interest to see how the palaeoenvironmental reconstruction of this outcrop fits into the estuary-hypothesis of the Korneuburg Basin of previous authors.

2 Regional setting

2.1 The Karpatian stage

The "Karpatian", named after a mountain range in Central Europe, was first mentioned by Cicha and Tejkal (1959) and formally defined by Cicha et al. (1967) in "Chronostratigraphie and Neostratotypen" (Piller et al., 2007). It is a chronostratigraphic unit for the uppermost Lower Miocene and corresponds to the latest Burdigalian of the international timescale (Cicha and Rögl, 2003) (Fig. 2.1). The Paratethys is a biogeographic entity (Laskarev, 1924; Piller et al., 2007) whose correlation with the Mediterranean is difficult and therefore resulted in a regional chronostratigraphic classification (Cicha and Rögl, 2003). The stratotype section for the Karpatian is located in Slup in the Carpathian Foredeep (southern Moravia, Czech Republic) (Cicha and Rögl, 2003). It was selected because of its rich mollusc-fauna (Cicha and Rögl, 2003) and is characterized by bedded, fine-grained and coarse sands (Piller et al., 2007). Assemblage and abundance biozones were used for more detailed definitions of the Karpatian stage (Piller et al., 2007). The base of the Karpatian is defined by the FAD (first appearance datum) of the benthic foraminifer *Uvigerina graciliformis* (Papp et al., 1971). The top is marked by the Badenian-base and the FAD of the planktonic foraminifer *Praeorbulina* (Cicha and Rögl, 2003). Thus, the Karpatian/Badenian is completely equivalent to the Burdigalian/Langhian boundary (Cicha and Rögl, 2003; Piller et al., 2007).

2.2 The Paratethys and Central Paratethys

The definition of the "Paratethys" derived from Laskarev (1924). The Paratethys, an epicontinental sea, was formed during the Late Eocene to Oligocene, ranged from the Rhone Basin (France) in the west towards the Transcaspian area (Inner Asia) in the east (Rögl, 1998) and was separated into three different units: a
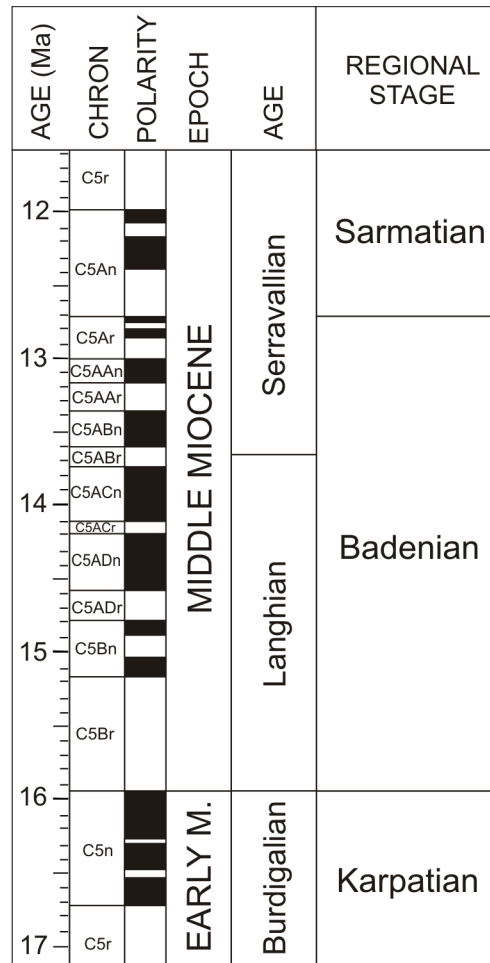
Figure 2.1: Regional Lower and Middle Miocene stages of the Central Paratethys (after Harzhauser and Piller, 2007).

western, central and eastern part (Piller et al., 2007). The Central Paratethys consists of the Eastern Alpine (southern Germany) - Carpathian Foreland basins and the Pannonian Basin System (Piller et al., 2007). After Senes and Marinescu (1974) and Rusu (1988) there are four distinct stages within the development of the Paratethys (Proto-, Eo-, Meso- and Neo-Paratethys) and the Korneuburg sediments are part of the Meso-Paratethys (late Early to early Middle Miocene) (Piller et al., 2007).

2.3 The Karpatian of the Central Paratethys

In the Karpatian the small Paratethys had a connection to the Mediterranean Sea in the south (Piller et al., 2007), the Slovenian "Trans-Tethyan Trench Corridor" (Bistricic and Jenko, 1985) (Fig. 2.2). There was a transgression at the beginning and a rise of temperature in the upper part of the Karpatian, which was recognized in the mollusc faunas of the shallow-water zones. All these signs finally led to an invasion of new marine faunal elements in the Central Paratethys (Rögl et al., 2003).

The climate was subtropical with humid conditions (Rögl et al., 2003). The annual mean temperatures were about 17 °C and the winter was frost-free. The annual precipitation was about 2000 mm and the water temperature did not sink below 15 °C (Harzhauser et al., 2002).

In the course of the Karpatian stage, tectonic activity led to pull-apart movements which formed the Korneuburg, Vienna and Styrian basins in the Central Paratethys (Harzhauser and Rögl, 2005).

Figure 2.2: The Paratethys during the late Burdigalian/Karpatian with the marked Korneuburg section (SPK) (after Zuschin et al., 2011).
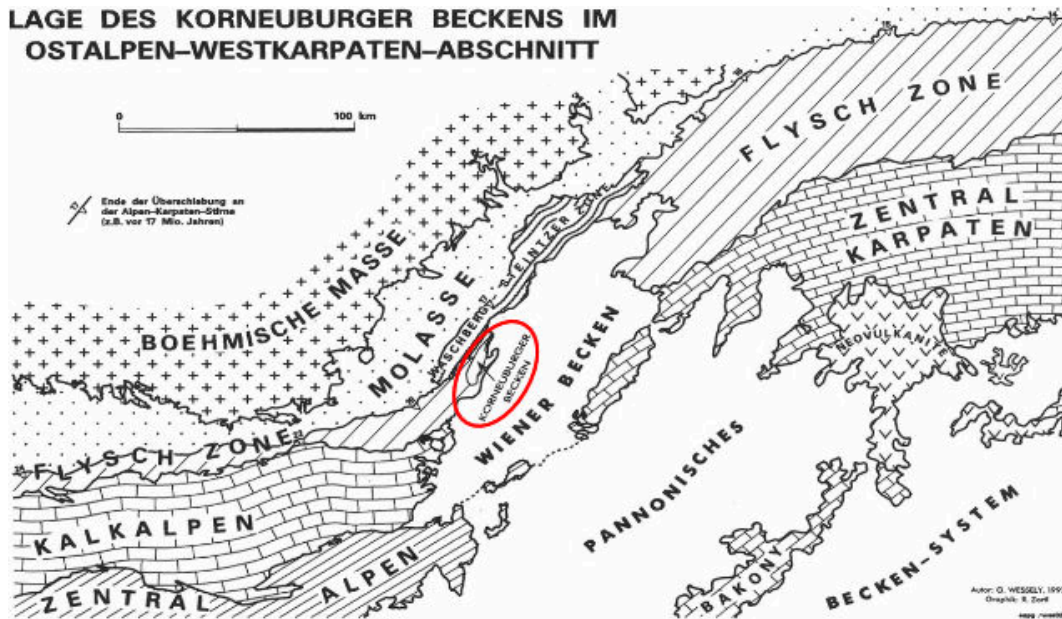
2.4 The Korneuburg Basin

2.4.1 Geology and history of the Korneuburg Basin

The Korneuburg Basin is located in Lower Austria. It has a length of 20 km and a width of 7 km. In its N-S extension it shows two depressions, reaching a depth of 530 m in the north and 880 m in the south, which are separated by a swell near Obergänserndorf (Wessely, 1998). The basin is bordered in the north by the Waschberg Zone and in the south by the Rhenodanubian Flysch Zone (Harzhauser and Wessely, 2003; Kern et al., 2010). It is an asymmetrical basin with a synsedimentary fault called "Schliefbergbruch" (Sovis and Steininger, 1987) on its west side, while the east side seems to be nearly undisturbed (Wessely, 1998) (Fig. 2.3 & 2.4).

Its history of development is intimately connected with the creation of the Northern Vienna Basin (Wessely, 2009). The Korneuburg Basin was formed during the last Alpine activities by pull-apart movements within the Alpine-Carpathian thrustbelt about 19 million years ago in the Burdigalian (latest Early Miocene) (Wessely, 1998). The autochthonous basement consists of Cretaceous and Jurassic deposits and the crystalline of the Bohemian Massif (Malzer et al., 1993). Based on previous studies the basin fill shows a sediment sequence from the Eggenburgian to the Karpatian stage (Wessely, 2009). A part of the basement belongs to the Waschberg and Flysch Zone but the main part of the fill is formed by the Karpatian "Korneuburg Formation" (Harzhauser and Wessely, 2003). This formation consists of an alternating sequence of pelitic and sandy deposits with occasional occurrences of coal intercalations and shows reworking of coastal sediments on its borders. Consistent "piggy back" movements in the basin caused shifts and faults like the Schliefbergbruch (Wessely, 2009). After Scholger (1998) the basin rotated about $20°$ counter-clockwise since the Karpatian.

The fossil faunal composition shows that the Korneuburg Basin was divided into a southern, estuarine and a northern, marine part (Harzhauser et al., 2002). This knowledge supports the assumption that the Korneuburg basin once had a fluvial influence coming from a river system of the neighbouring Vienna Basin in the south (Weissenbäck, 1996; Seifert, 1996) and a connection to the Paratethys Sea into the Alpine-Carpathian Foredeep in the north (Harzhauser and Wessely, 2003; Harzhauser et al., 2002) (Fig 2.5).

Figure 2.3: The position of the Korneuburg Basin (after Wessely, 1998).

2.4.2 The stratigraphy of the Korneuburg Basin

Because of palaeomagnetic studies and the stratigraphic classification of the nannoplankton to the Zone NN4 (Martini, 1971) and the mammal fauna to the Zone MN5 (16.5 - 16.7 Ma) (Daxner-Höck, 1998; Harzhauser et al., 2002), the deposits of the Korneuburg Basin can be dated to the Karpatian (Uppermost Lower Miocene) (Harzhauser and Wessely, 2003).

2.4.3 The palaeoenvironment of the Korneuburg Basin in the Karpatian

In the Karpatian the Korneuburg basin was dominated by an estuary (Harzhauser et al., 2002; Latal et al., 2005) (Fig 2.5). After Kaiser et al. (2005) an estuary can be defined as an inlet of the sea into a river valley, which can be divided into 3 sectors (low, middle and upper). It displays an important role between two aquatic environments, freshwater and marine. It shows an own environment and ecology but with influences from both systems. From a geological point of view, an estuary is short-lived with high sediment deposition-rates. It is a very stressful, dynamic system, which shows variations of important ecological factors like salinity, temperature or tidal influence and therefore consequences for
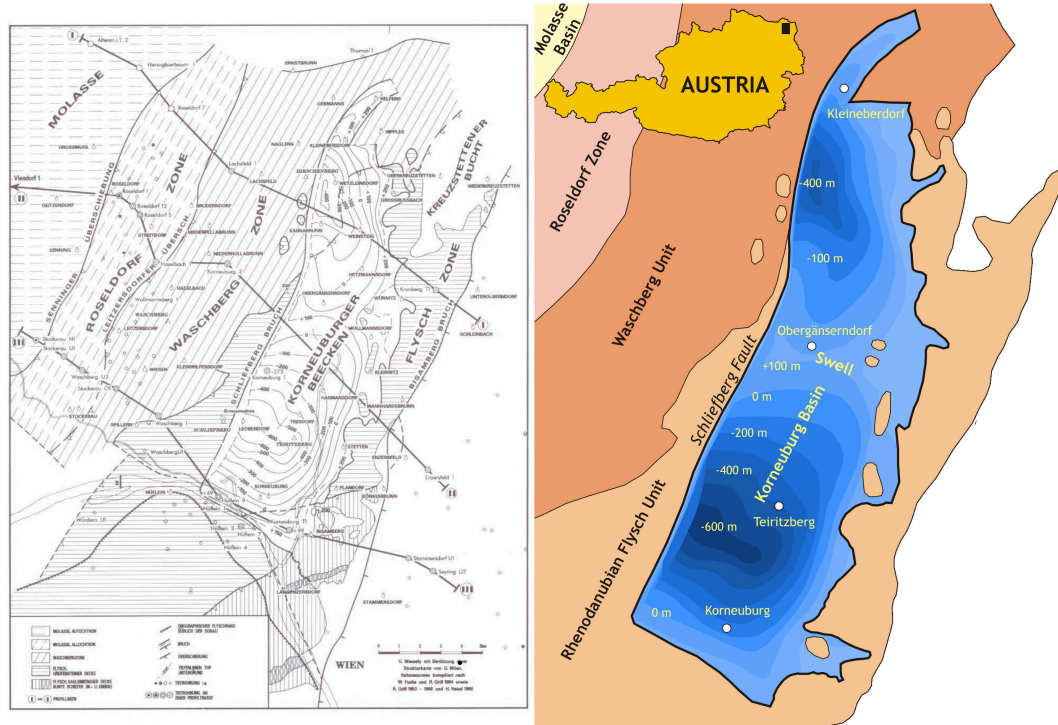
Figure 2.4: Structural geology and sediment fill of the Korneuburg Basin (left: after Wessely, 1998; right: after Harzhauser et al., 2009).

its inhabitants. Taxa which live in an estuary are for example oligochaetes, pulmonate molluscs and fish from freshwater or polychaetes, crustaceans, fish and bivalves from marine habitats. Mudflats and large bivalve-beds with mussels and oysters can also occur, mangroves or seagrass beds are rare. It is possible that an estuary shows a higher diversity than other marine systems, especially in such habitats like seagrass- or bivalve beds (Kaiser et al., 2005).

2.4.4 Localities in the basin

Stetten: Stetten is a small village located in the south of the Korneuburg Basin near the town Korneuburg which gives name to the whole basin in Lower Austria. The transect for this thesis was studied near Stetten in the course of road constructions (Wiener Außenring Schnellstraße (S1)) in the year 2008 and is no longer accessible (Fig. 2.6).

Teiritzberg: Near to the profile of Stetten, the locality Teiritzberg is famous for its huge oyster biostrome characterized by the giant euryhaline species

Figure 2.5: The Korneuburg Basin reconstructed as an estuary with separation in northern and southern part (after Harzhauser et al., 2009)

Crassostrea gryphoides SCHLOTHEIM, 1813 (Čtyroký, 2002; Harzhauser et al., 2002). The biostrome was also developed in the Karpatian (about 16.5 million years ago) and shows the impact of an increase of the sea-level and of storm activity in the shallow subtidal zone of the estuarine area (Harzhauser et al., 2009). Among the oysters many other fossils like crocodiles and pollen of mangrove plants were found and finally taken for palaeoenvironmental reconstruction (Harzhauser et al., 2002) (Fig. 2.7 & 2.8).
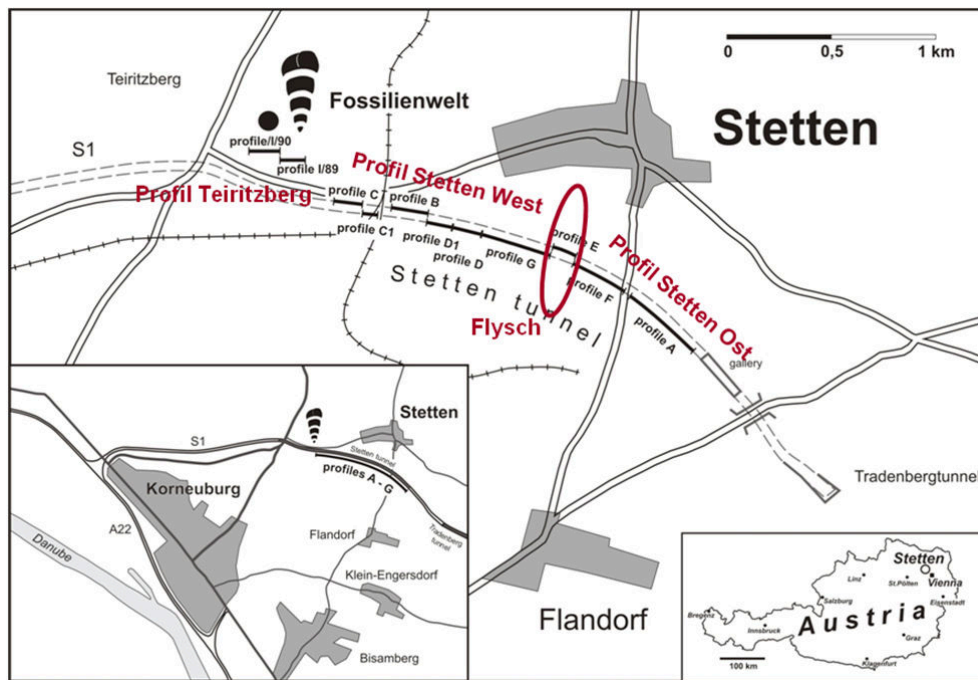
Figure 2.6: Position of the profile along the road construction project near Stetten (map provided by Reinhard Roetzel).

Figure 2.7: Field work at the oyster-biostrome in Teiritzberg in the year 2005.

Figure 2.8: Representative slab of the oyster-biostrome in Teiritzberg (NHMV).

3 Material and methods

3.1 Field work

All samples were taken along roadcuts from a huge highway tunnel project near the village of Stetten. The total transect had a length of 1.8 km and was divided into ten sections. Each section was logged depending on the accessibility during construction work (Fig. 2.6).

The siliciclastic succession consisted of pelitic and sandy sediments and sandstones which diped about 25° westwards (Fig.3.1). Some fossils like thin coal deposits, washed-in snails (Planorbidae) and river snails (Melanopsidae) occurred occasionally during the fieldwork (Fig. 3.2 & 3.3).

Parallel to the sampling for this thesis, the study of pollen, formaminifers or calcareous nannoplankton were made by members of the Natural History Museum of Vienna (NHMV) and the Geologische Bundesanstalt (GBA).

3.2 Sample preparation

A total of 118 bulk-samples with a weight of about 1 kg each were brought to the laboratory. The sediment was wet sieved with 4 mm, 2 mm and 1 mm mesh size, air dried and finally split for an efficient work under a binocular microscope. Because of the poor condition of the material each identifiable component of several different species was counted as an individual and finally registered in spread sheets of Microsoft Excel.

3.3 Statistical methods

All statistical analyses were performed with the program PRIMER version 6.1.6 (Clarke and Gorley, 2006; Clarke and Warwick, 1994). Samples containing less than 20 fossils were removed from the final data matrix. To standardize samples,

Figure 3.1: Layers of siliciclastic sediments of the profile, dipping westwards.

percentages of the abundances were calculated and "square-root transformed to de-emphasise the influence of the most abundant taxa" (e.g. Zuschin et al., 2007). Two multivariate methods were used: cluster analysis and the ordination method nonmetric mutidimensional scaling (NMDS, Kruskal 1964) for detecting ecological gradients (e.g. Springer and Bambach 1985, Olszewski and Patzkowsky 2001, Zuschin et al. 2001). Both methods are based on the Bray-Curtis similarity coefficient (Bray and Curtis, 1957; Clarke and Warwick, 1994).

Figure 3.2: Example for coal deposits in the studied transect.

Figure 3.3: Example for terrestrial influence: the land snail *Tropidomphalus*.

4 Results

4.1 Basic structure of the assemblages

A total of 160 species was determined from about 20,500 shells of 118 bulk samples. The fossil content includes sponges, corals, serpulids, molluscs, balanids, echinoderms, crustaceans and fish. Quantitatively the invertebrates, most notably the molluscs, clearly dominate the fauna (Table 4.1). Particular attention was given to the molluscs.

Taxa	Number of fossils
Demospongea	166
Scleractinia	540
Polychaeta	19
Cirripedia	395
Crustacea	34
Echinoderms	3
Fish	266
Molluscs	35765

Table 4.1: Fossil content in overview

The Demospongea-taxon *Cliona* is the only evidence for sponges and recorded by characteristic bioerosion (Fig. 4.1a). The corals are represented by the Scleractinia-families Faviidae, Poritidae and Siderasteridae; Poritidae with the species *Porites* dominate (461 fragments) (Fig. 4.1b). Polychaeta are represented by rare serpulid-tubes. Two species of balanomorpha are present, *Balanus amphitrite* and *Balanus tintinnabulum* (Wöhrer, 1998); *B.amphitrite* is quantitatively more important. Crustaceans occur with claws from decapoda (Müller, 1998) (Fig. 4.1c). The echinoderms are represented by only 3 fragments; two of them are marginal-plate-fragments, which belong to asteroids of the family Goniasteridae (Fig. 4.1d). Vertebrates are represented by only few fish-fossils: teeth and otoliths from Chondrichthyes-families (Dasyatidae, Mylio-

batidae and Odontaspididae) as well as from Osteichthyes-families (Atherinidae, Gobiidae, Haemulidae, Myctophidae, Sciaenidae and Sparidae); Gobiidae and Sparidae show more than 50 fragments each (Fig. 4.1e+f).
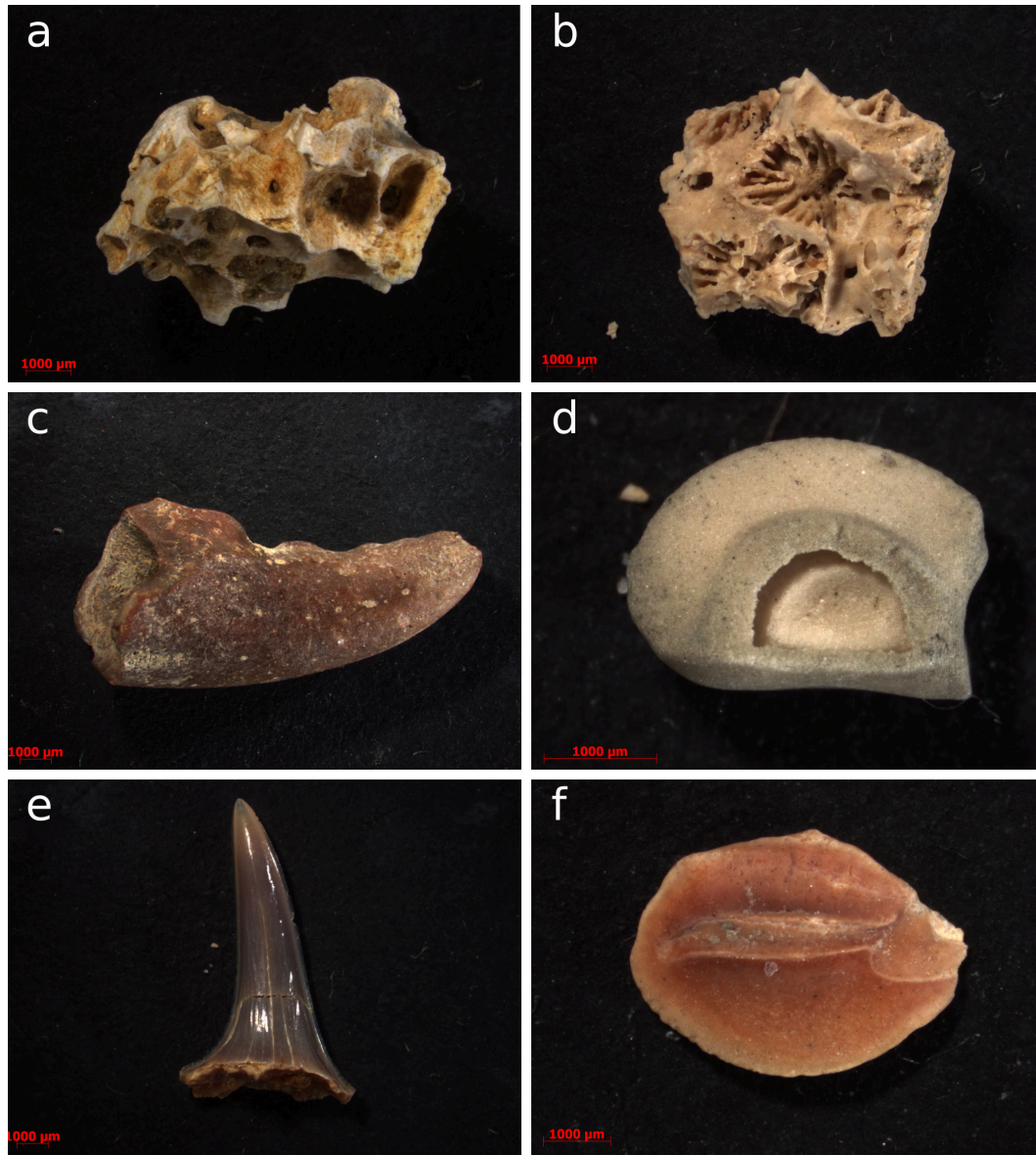
Figure 4.1: Fossils from the studied quantitative material: a.*Cliona*-bioerosion, b.corals, c.crustacean-claw, d.marginalplate from goniasterid seastar, e.shark-tooth, f.fish-otolith.

The molluscs dominate with overall 40 superfamilies and 139 species, determined from about 19,500 shells. The bivalves occur with 19 superfamilies and 28 families (Table 4.2), the gastropods with 21 superfamilies and 34 families

(Table 4.3). Among the bivalves the Veneridae dominate, followed by the families Lucinidae, Cardiidae and Corbulidae which all have more than 1000 shells (Table 4.2).

Scaphopoda occur with a single species (*Antalis quindeciesstriata*) of the dentaliid family (Harzhauser, 2002).

Among the gastropods the Neritidae, the Hydrobiidae, the Potamididae and the Turritellidae dominate, each with more than 1000 shells (Table 4.3).

Superfamilies (number of shells)	Families (number of shells)
Nuculanoidea (1)	Nuculanidae (1)
Nuculoidea (39)	Nuculidae (39)
Arcoidea (807)	Arcidae (223)
	Noetiidae (584)
Mytiloidea (60)	Mytilinae (58)
	Crenellinae (1)
	Isognomonidae (1)
Pectinoidea (24)	Pectinidae (24)
Anomioidea (6)	Anomioidae (6)
Ostroidea (296)	Ostreidae (296)
Lucinoidea (1691)	Lucinidae (1661)
	Ungulinidae (30)
Chamoidea (7)	Chamidae (7)
Galeommatoidea (130)	Galeommatidae (2)
	Sportellidae (128)
Carditoidea (1)	Carditidae (1)
Cardioidea (1071)	Cardiidae (1071)
Mactroidea (1)	Mactridae (1)
Solenoidea (17)	Solenidae (17)
Tellinoidea (151)	Donacidae (62)
	Psammobiidae (1)
	Semelidae (19)
	Tellinidae (69)
Veneroidea (1814)	Petricolidae (1)
	Veneridae (1813)
Myoidea (1041)	Corbulidae (1041)
Gastrochaenoidea (23)	Gastrochaenidae (23)
Hiatelloidea (18)	Hiatellidae (18)
Dentaliida (168)	Dentaliidae (168)

Table 4.2: Superfamilies and families of bivalves and scaphopods in systematic order.

Superfamilies (number of shells)	Families (number of shells)
Fissurelloidea (6)	Fissurellidae (6)
Trochoidea (12)	Turbinidae (5)
	Skeneidae (1)
	Vitrinellidae (6)
Neritoidea (10667)	Neritidae (10667)
Rissooidea (2315)	Hydrobiidae (1632)
	Rissoidae (678)
	Rissoinidae (5)
Cerithioidea (11762)	Cerithiidae (1853)
	Melanopsidae (42)
	Potamididae (8717)
	Turritellidae (1150)
Vermetoidea (5)	Vermetidae (5)
Strompoidea (3)	Aporrhaidae (3)
Crepiduloidea (16)	Crepidulidae (16)
Naticoidea (248)	Naticidae (248)
Muricoidea (3334)	Columbellidae (79)
	Muricidae (128)
	Nassariidae (3125)
	Vasidae (2)
Cancellaroidea (6)	Cancellariidae (6)
Conoidea (224)	Terebridae (16)
	Turridae (208)
Cerithiopsoidea (2)	Cerithiopsidae (2)
Epitonoidea (2)	Epitoniidae (2)
Pyramidelloidea (24)	Pyramidellidae (24)
Valvatoidea (4)	Valvatidae (4)
Philinoidea (81)	Acteonidae (69)
	Cylichnidae (5)
	Retusidae (2)
	Ringiculidae (4)
	Scaphandridae (1)
Helicoidea (11)	Helicidae (11)
Planorbidea (4)	Planorbidae (4)

Table 4.3: Superfamilies and families of gastropods in systematic order.

Two gastropod species, *Agapilia pachii* (Neritidae) with more than 10,000 shells and *Granulolabium bicinctum* (Potamididae) with more than 8,000 shells, together make up more than 53% of the total molluscan composition (Fig. 4.2). Another 11 mollusc-species (the gastropods *Nassarius edlaueri, Bittium spina,*

Loripes dujardini, Hydrobia spp., Cyllenina ternodosa, Turritella gradata and the bivalves *Corbula gibba, Paphia subcarinata Cerastoderma praeplicata, Striarca lactea, Sandbergeria perpusilla*) contribute each more than 1% to the assemblage (Fig. 4.3). All other 126 species are quantitatively unimportant.
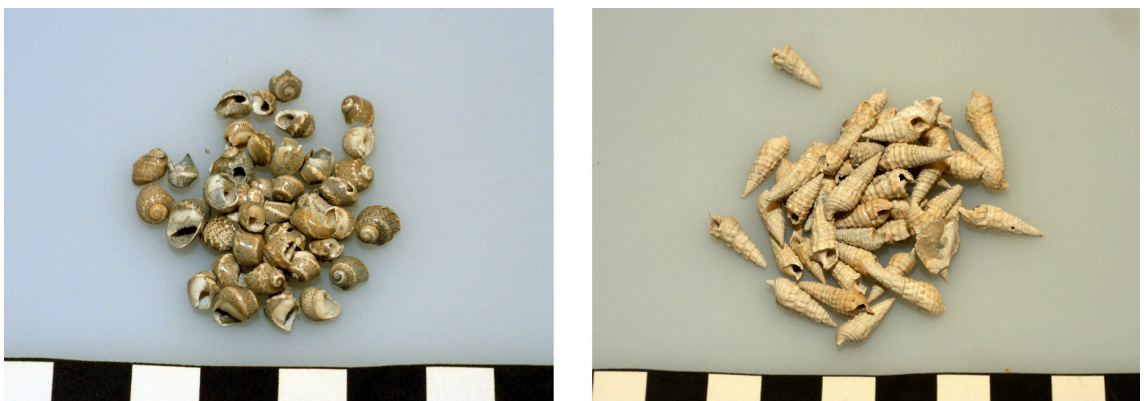
Figure 4.2: The two most important gastropod-species: *Agapilia pachii* (left) and *Granulolabium bicinctum* (right).
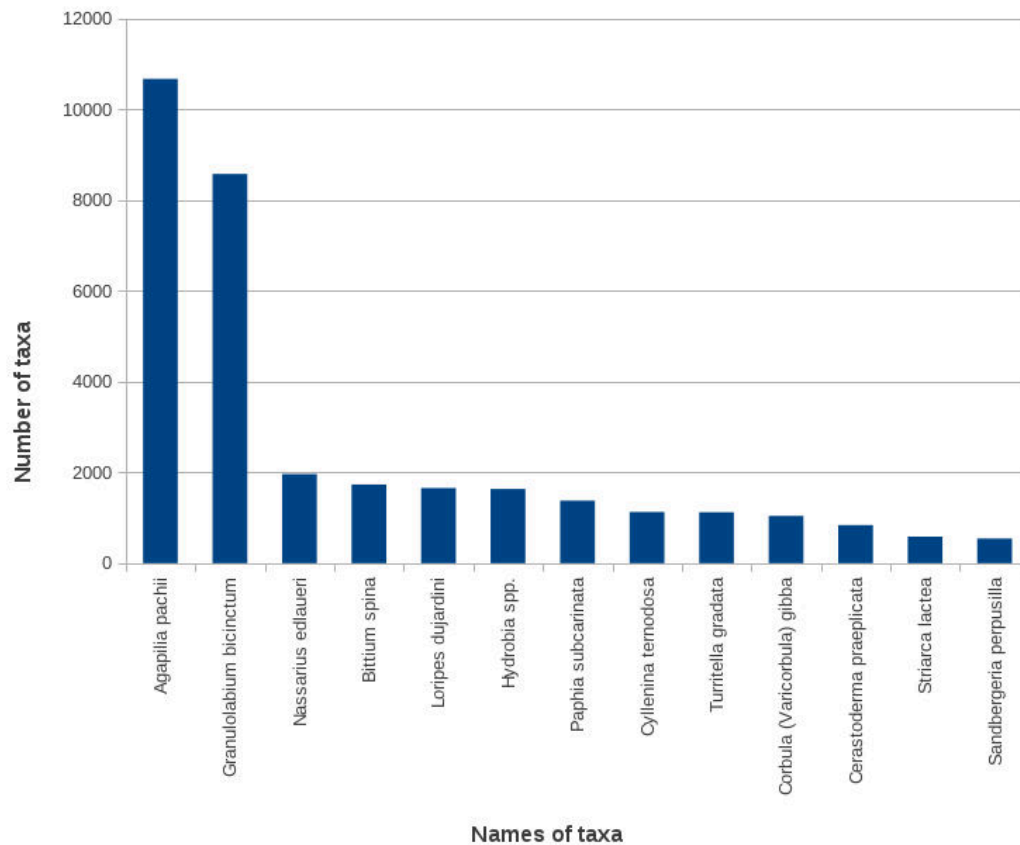
Figure 4.3: The 13 quantitatively important mollusc-species of the data-matrix.

4.2 Cluster analysis

A cluster analysis shows 5 main sample groups at a similarity level of 25% (Fig. 4.4). On closer examination some of these clusters can be subdivided into smaller groups at a similarity level of 35% (Fig. 4.5).
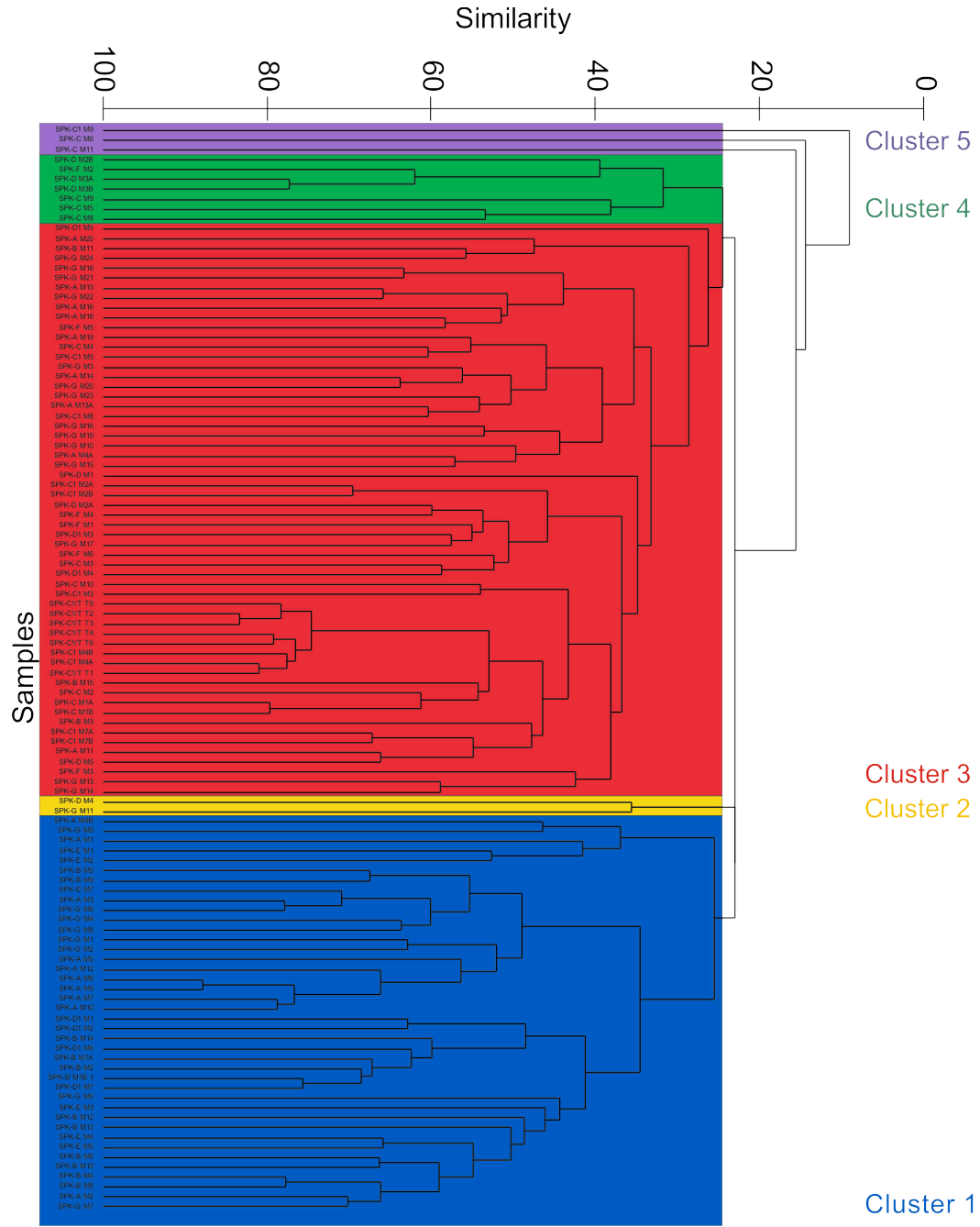
Figure 4.4: Results of cluster-analysis with 5 main sample groups at similarity level of 25%.

Figure 4.5: Results of cluster-analysis at a similarity level of 35%.
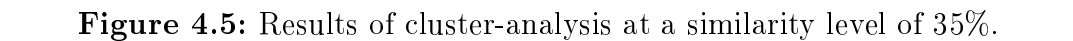
4.3 Cluster description

Cluster 1 is one of the largest clusters, consisting of 40 samples and almost 26,000 shells. *Granulolabium bicinctum* (Batillariidae) and *Agapilia pachii* (Neritidae) together make up more than 50% of the faunal composition. The third most abundant species is the scleractinian coral *Porites* (Poritidae). Subcluster 1a contains most of the samples and shells and is clearly dominated by *Granulolabium* and *Agapilia*. Subcluster 1b is small (5 samples, 912 shells) and is dominated by *Porites* (47%). Trace fossils of the genus *Entobia* indicating the activity of the demosponge *Cliona* appear occasionally. The third most abundant species is *Granulolabium bicinctum*.

Cluster 2 contains only 2 samples (45 shells) and is dominated by the gastropod species *Agapilia pachii* (Neritidae), *Turritella gradata* (Turritellidae) and *Terebralia bidentata* (Potamididae).

Cluster 3 shows the highest number of samples (58). *Nassarius edlaueri* (Nassariidae) makes up 20% of the cluster, followed by *Turritella gradata* (Turritellidae) and the bivalve *Paphia subcarinata* (Veneridae), each less than 10%. Subcluster 3a is composed of various gastropod species: *Nassarius edlaueri* (Nassariidae), *Agapilia pachii* (Neritidae) and *Turritella gradata* (Turritellidae). The most abundant species of subcluster 3b is the bivalve *Paphia subcarinata* (Veneridae), followed by *Nassarius edlaueri* (Nassariidae) and *Granulolabium bicinctum* (Potamididae), which is quantitatively unimportant (8%). Subcluster 3c is small and dominated by the bivalve *Corbula gibba* from the family Corbulidae (Myoidea), which makes up 70% of the composition. The second most abundant species is *Nassarius edlaueri* and the third is *Paphia subcarinata* (Veneridae), another bivalve. Subcluster 3d consists of only one sample which is characterized by two bivalve-species, *Panopea menardi* (Hiatellidae) and *Paphia subcarinata* (Veneridae), and the gastropod *Agapilia pachii* (Neritidae).

Cluster 4 is dominated by the bivalve *Loripes dujardini* (Lucinidae) which makes up nearly 50% of the composition. *Nassarius edlaueri* (Nassariidae) and another venerid bivalve, *Timoclea marginata*, each have less than 10%. Subcluster 4a is composed of the bivalve *Loripes dujardini* (Lucinidae) and two gastropod-species, *Nassarius edlaueri* (Nassariidae) and *Agapilia pachii* (Neritidae). The bivalve *Loripes dujardini* is clearly dominating subcluster 4b, accounting for

more than 70% of the molluscs. The other two bivalve species, *Paphia subcarinata* and *Timoclea marginata*, both Veneridae, each contribute less than 5% to the total composition.

The small cluster 5 (3 samples) contains the bivalve *Gastrochaena* (Gastrochaenidae) and the gastropod *Tympanotonus cinctus* (Potamididae). The third most abundant species is the Cirripedia-taxon *Balanus amphitrite* (Balanidae). All these 3 species together make up more than 50% of the cluster (Table 4.4).

4.4 Nonmetric multidimensional scaling (NMDS)

The NMDS shows that the sample groups of the cluster-analysis are characterized by considerable overlaps. It was possible to filter out 5 main sample groups: 1a, 1b, 3a, 3b and 4. The remaining clusters (2, 3c, 3d, and 5) are quantitatively unimportant because of their small number of samples and are therefore outliers (Fig. 4.6).
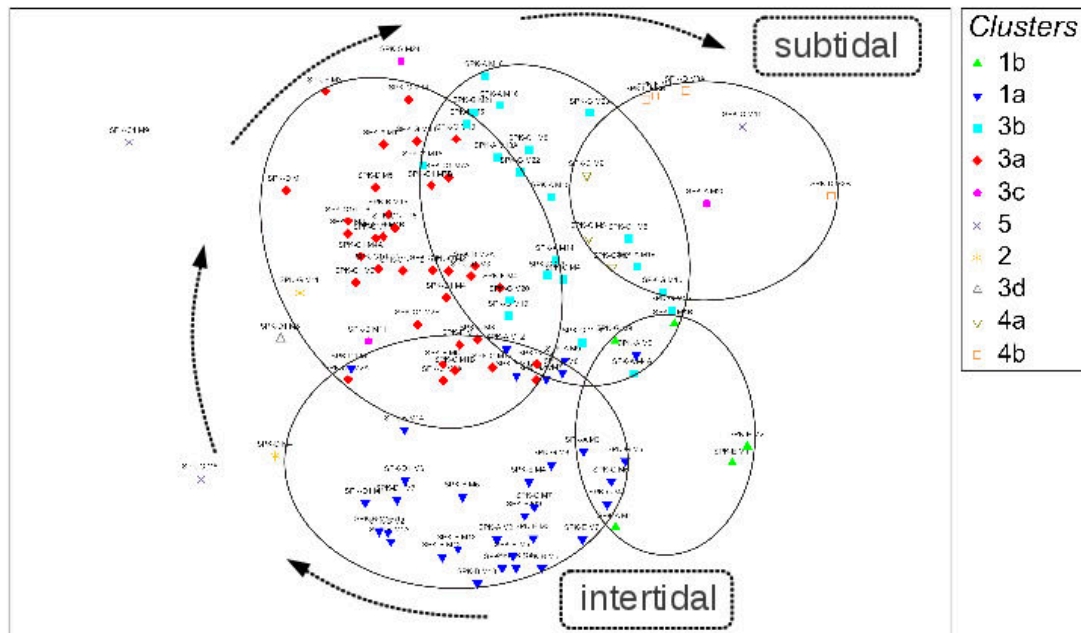
Figure 4.6: NMDS with 5 main clusters. Clusters 4a and 4b are united here for clarity. Samples close to each other are similar in faunal composition. Arrows indicate environmental gradient (from intertidal to subtidal).

Cluster	Number of samples	Number of fossils	3 most abundant taxa (%)
1	40	25846	*Granulolabium bicinctum* (33.0) *Agapilia pachii* (28.9) *Porites* (6.1)
1a	35	24934	*Granulolabium bicinctum* (36.8) *Agapilia pachii* (32.4) *Bittium spina* (5.6)
1b	5	912	*Porites* (47.3) *Cliona* (10.1) *Granulolabium bicinctum* (6)
2	2	45	*Agapilia pachii* (23.9) *Turritella gradata* (18.2) *Terebralia bidentata* (13.3)
3	58	7868	*Nassarius edlaueri* (20.6) *Turritella gradata* (10.2) *Paphia subcarinata* (9.3)
3a	33	5131	*Nassarius edlaueri* (23.2) *Agapilia pachii* (13.7) *Turritella gradata* (12.8)
3b	21	2460	*Paphia subcarinata* (21.5) *Nassarius edlaueri* (18.8) *Granulolabium bicinctum* (7.8)
3c	3	237	*Corbula gibba* (70.9) *Nassarius edlaueri* (10.6) *Paphia subcarinata* (4)
3d	1	40	*Panopea menardi* (20) *Paphia subcarinata* (17.5) *Agapilia pachii* (7.5)
4	7	3299	*Loripes dujardini* (49.1) *Nassarius edlaueri* (9) *Timoclea marginata* (4.4)
4a	3	2529	*Loripes dujardini* (19.8) *Nassarius edlaueri* (16.1) *Agapilia pachii* (9.5)
4b	4	770	*Loripes dujardini* (71.1) *Paphia subcarinata* (4.3) *Timoclea marginata* (3.8)
5	3	135	*Gastrochaena* (21.3) *Tympanotonus cinctus* (16.7) *Balanus amphitrite* (13.2)

Table 4.4: Number of samples/fossils and the 3 most abundant species for each cluster.

5 Discussion

5.1 Interpretation of the fossil content

5.1.1 Rare taxa

Clionids are mainly limestone-boring sponges (Goreau and Hartman, 1963; Rützler, 1975) and often dominate the sponge-content of shallow coral reefs (Rützler, 2002). *Porites* are among the main builders in modern coral reefs (e.g. Cortés et al. 1994, Grossman and Fletcher 2004, Macintyre et al. 1992). Serpulidae live fixosessil (Schneider et al., 2009) and mostly on hardsubstrate (Sanfilippo, 2009). Many serpulids are known from the Miocene which mainly occur in nearshore, shallow fully marine environments (Jäger and Schneider, 2009). *Balanus amphitrite* is an acorn barnacle (Desai and Anil, 2005) which lives in the intertidal (Thiyagarajan, 2010). The recent *B.amphitrite* is known from warm, tropical and *Balanus tinntinabulum* from temperate and tropical regions (Wöhrer, 1998). The unspecified decapod-claws could indicate a marine, soft-muddy environment (Müller, 1998). Starfish-fossils are rarely complete and marginal-plates like the two goniasteridae-plates found here have therefore taxonomic potential. Most goniasterids occur in shallow habitats (Villier et al., 2004). After Kroh (2007), the rare echinoderm-fossils from the Karpatian are often presented in shallow-water carbonates. The fish-fauna (e.g. Sparidae, Dasyatidae or Myliobatidae) could stand for shallow, tropical conditions with freshwater influence (Schultz, 1998). After Reichenbacher (1998) otoliths from littoral and sublittoral species (e.g. Gobiidae) from tropical and subtropical regions are dominating the Korneuburg fauna.

5.1.2 Abundant taxa

The most important fossils are neritid gastropods, which today are represented in different habitats worldwide but mostly in intertidal rock and mangrove re-

gions (subtropical and tropical) (Scott and Kenny, 1998). The important batil-lariid gastropods live also in the intertidal, in estuaries or sandy mudflats (Healy and Wells, 1998) and are known from temperate and tropical mudflats in the Indo-West Pacific (Ewers, 1963; Wells, 1984). Nassariid gastropods which occur globally from intertidal to shallow subtidal marine habitats (Cernohorsky, 1984) but mostly in estuarine and shallow marine (soft-substrate) environments of temperate and tropical zones (Harasewych, 1998) are also numerous. *Cyllenina ternodosa* is a brackish-marine Nassaridae which is known from intertidal mudflats to shallow habitats (Zuschin et al., 2004). Cerithiid gastropods ("sand creepers") are common in shallow marine water in subtropical and tropical zones globally and in different substrata like sand flats or mangroves (Healy and Wells, 1998). *Bittium* mainly occur in planted, marine environments (Bernasconi and Stanley, 1997; Olabarria et al., 1998; Schneider and Mann, 1991). The brackish and freshwater species Hydrobiidae occur in different habitats like rivers or estuarine mudlfats (Ponder and De Keyzer, 1998). Turritellidae are mostly common on muddy-sandy bottoms from the subtidal to deep water (continental slope) (Healy and Wells, 1998). Scaliolid gastropods like *Sandbergeria perpusilla* live in sandy-mud substrate in the intertidal and littoral (Healy and Wells, 1998) and are known from the subtropical and tropical Indo-West Pacific (Ponder, 1994a).

The most abundant bivalves are Lucinidae which are known from the intertidal to the shallow subtidal (Reid and Slack-Smith, 1998; Taylor and Glover, 2006) and many occur in seagrass environments (Barnes and Hickman, 1999; Johnson et al., 2002). Most lucinids have chemosymbionts (Berg and Alatalo, 1984; Reid and Brand, 1986; Reid and Slack-Smith, 1998) and live therefore in the marine suboxic zone (Ott et al., 2004) . The venerid bivalve *Paphia* (Tapetines) occurs worldwide in different environments but mostly in the intertidal of tropical (Indo-Pacific) to temperate regions (Harte, 1998) and is known from shallow subtidal habitats in the Mediterranean and the Red Sea (e.g. Poppe and Goto 1993, Zuschin and Oliver 2003). Corbulidae are shallow subtidal inhabitants in soft-bottom environments (Hrs-Brenko, 2006; Lamprell et al., 1998) and *Corbula gibba* lives in the coastal and estuarine subtidal (Holmes and Miller, 2006). Cardiidae ("heart cockles") live mostly infaunal in shallow habitats (Rufino et al., 2010) in subtropical and tropical regions (Wilson, 1998) and marine neotiid bivalves are common in the intertidal and shallow sub-littoral (Iredale, 1939;

Stanley, 1970; Oliver, 1985).

The rare dentaliid-taxon *Antalis quindeciestriata* is one of the most common scaphopod-species in the Karpatian of the Korneuburg Basin. It indicates fully-marine conditions and a shallow, sublitoral (silt – fine sand) environment (Harzhauser, 2002).

5.2 Cluster interpretation

The 5 main clusters (1a, 1b, 3a, 3b and 4) are characterized by ecological features of their fauna and and assigned to either intertidal or subtidal conditions (Table 5.1):

Cluster 1a is characterized by batillariid and neritid gastropods which are both known from intertidal tropical conditions (Healy and Wells, 1998; Scott and Kenny, 1998). Cerithiidae like *Bittium* do also fit into this environment (Ewers, 1963; Wells, 1984) .

Cluster 1b is clearly dominated by corals of the genus *Porites* which together with traces of sponge-bioerosion are indicators for a very shallow area and hard-substrate (Goreau and Hartman, 1963; Rützler, 1975; Rützler, 2002; e.g. Cortés et al. 1994, Grossman and Fletcher 2004, Macintyre et al. 1992). This cluster is the only cluster which indicates hardsubstrate. The batillariid *G.bicinctum* stands for intertidal but softsubstrate conditions (Healy and Wells, 1998).

Cluster 3a consists of nassariids, neritids and turritellids. *Nassarius edlaueri* is an intertidal gastropod (Mandic et al., 2008) and neritids live in shallow marine, tropical zones (Cernohorsky, 1984; Harasewych, 1998; Scott and Kenny, 1998). Turritellidae live also in softsubstrate but deeper in the subtidal (Healy and Wells, 1998).

In Cluster 3b, venerid bivalves like *Paphia* are indicators for shallow subtidal conditions (e.g. Poppe and Goto 1993, Zuschin and Oliver 2003), *N.edlaueri* and *G.bicinctum* for the intertidal (Mandic et al., 2008; Healy and Wells, 1998). Cluster 4 is dominated by Lucinidae which are common in the intertidal or shallow benthos (Reid and Slack-Smith, 1998), *Nassarius* stands for the intertidal and *Timoclea* is like *Paphia* mostly common in shallow subtidal zones (e.g. Poppe and Goto 1993, Zuschin and Oliver 2003).

Clusteranalysis and the NMDS indicate the presence of intertidal and shallow subtidal mollusc-associations. The NMDS also reveals that these groups are

Main clusters	Taxa	Mean percentage ± stdev	environment
1a	*Granulolabium bicinctum* *Agapilia pachii* *Bittium spina*	36.8 ± 28.8 32.4 ± 25.8 5.6 ± 12.1	intertidal
1b	*Porites* *Cliona* *Granulolabium bicinctum*	47.3 ± 23.3 10.1 ± 22.6 6.0 ± 2.1	shallow hardsubstrate
3a	*Nassarius edlaueri* *Agapilia pachii* *Turritella gradata*	23.2 ± 15.0 13.7 ± 18.1 12.8 ± 11.7	intertidal - subtidal
3b	*Paphia subcarinata* *Nassarius edlaueri* *Granulolabium bicinctum*	21.5 ± 12.5 18.8 ± 18.3 7.8 ± 10.2	shallow subtidal
4	*Loripes dujardini* *Nassarius edlaueri* *Timoclea marginata*	49.1 ± 30.9 9.0 ± 14.1 4.4 ± 4.7	subtidal

Table 5.1: Main clusters with most abundant species plus environmental affiliation.

not distinct but overlapping, which allows to create an ecological gradient from intertidal to subtidal settings (Fig. 4.6).

5.3 Palaeoenvironmental reconstruction

Based on many previous studies, for example on palaeomagnetostratigraphy, it is possible to draw a palaeoenvironmental picture of the Korneuburg Basin. The basin, especially the southern part, is reconstructed as an estuary: there was fluvial influence in the south but also marine influence from occasionally incoming floodings from the northern part of the basin, which was still connected to the Paratethys Sea. This division into 2 different habitats also influenced the evolution of the fauna (Harzhauser and Wessely, 2003; Harzhauser et al., 2002). This suggestion of estuarine conditions in the southern basin is confirmed in this study. The results of this thesis show fluviatile as well as marine input. The terrestrial, fluviatile part is represented by thin coal deposits and washed-in land (Planorbidae) and river snails (Melanopsidae). The rich fossil content is mainly built up by marine species which is dominated by molluscs. The main part of the molluscs are characterized by intertidal, softsubstrate and tropical

ecology like the two most abundant taxa *Agapilia pachii* and *Granulolabium bicinctum*. After Zuschin et al. (2011), these neritid and batillariid gastropods, which suggest tidal flat deposits, dominated the molluscan assemblages indicating the prevalence of nearshore conditions in the Karpatian. Some molluscs like *Nassarius edlaueri* or *Turritella gradata* are very common (Harzhauser, 2002), whereas others like *Agapilia pachii* show their first occurrence in the Karpatian (Harzhauser, 2003). But there are also some other characteristics which suggest the presence of other habitats in this special ecosystem. In only one cluster (cluster 1b) hardsubstrate exists, marked by big flysch-blocks (Fig. 5.1) and surrounded by *Porites*-and *Crassostrea*-layers (Fig. 5.2) which could form a secondary hardground for taxa like boring molluscs, balanids, clionid sponges (Harzhauser et al., 2002), whose etching marks are often found on *Ostrea*-shells (Binder, 2002), or serpulids which mostly need hardsubstrate (Sanfilippo, 2009). Another cluster (cluster 3a) is characterized by the appearance of the gastropod *Turritella gradata*, which suggests somewhat deeper marine settings (Harzhauser et al., 2002). Turritellids are the most abundant benthic molluscs (Healy and Wells, 1998). During the fieldwork a block of this *Turritella*-layer has been extracted (Fig. 5.3). There is also freshwater input, suggested by taxa like *Hydrobia* which are known from tidal mudflats (Harzhauser et. al., 2002). Typical estuarine inhabitants like Nassariidae (Harasewych, 1998), mangrove-inhabitants like Cerithiidae (Healy and Wells, 1998) and burrowers like corbulid (Lamprell et al., 1998; Yonge, 1946) or cardiid (Rufino et al., 2010; Wilson, 1998) bivalves are very common in the sediments.

It is also conspicuous that the molluscs occur in typical associations (Fig. 5.4) and indicate a gradual alternation between intertidal and subtidal conditions (Fig. 4.6). The intertidal is well-characterized by neritid and potamidid gastropods, the subtidal by decapods and fish remains. In the Korneuburg Basin, decapod-fossils indicate a waterdepth of about 10 to 20 m (Müller, 1998), whereas fish-fossils indicate a depth of about 10 to 50 m (Harzhauser et al., 2002).

Salinity is difficult to judge. The echinoderms, which could be affected by changes in salinity (Kroh, 2002) are too sparse to make a good statement. The low number of echinoderms, however, could also stand for brackish conditions (Kroh, 2002) but corals in shallow areas point to rather fully-marine conditions. The molluscs are numerous but no good indicators for salinity.

Figure 5.1: Flysch-blocks which mark hardsubstrate in the outgrop.

Figure 5.2: Hardsubstrate-layer with *Porites*- and *Crassostrea*-associations.

Figure 5.3: The recovered and prepared *Turritella*-block (NHMV).

Figure 5.4: Mollusc-associations (*Agapilia pachii* & *Granulolabium bicinctum*) during fieldwork.

6 Conclusion

The quantitatively analyzed fauna from the southern part of the Korneuburg Basin fits well into the expected picture of an estuary which points to a dynamic, subtropical ecosystem from the Lower Miocene:

1. The fauna is rich in species but dominated by only few taxa, mainly molluscs.

2. There is terrestrial as well as freshwater influence.

3. There are soft- as well as hardsubstrate sediments but the softsubstrate dominates.

4. The fossil content is rich, mainly of mollusc-associations, which can be assigned to two different environments, intertidal or subtidal.

5. The quantitative analyses resulted in 5 clusters of the fauna which show a gradual change from intertidal to subtidal conditions.

7 Acknowledgements

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9 Appendix

9.1 Abstract

In the course of highway constructions (Wiener Außenring-Schnellstraße (S1)) a detailed sedimentological transect of 1.8 km length consisting of the estuarine and shallow marine Karpatian (Upper Burdigalian) deposits of the southern Korneuburg Basin in the Central Paratethys was logged near the village of Stetten in Lower Austria.

The siliciclastic succession consists of pelitic and sandy sediments and sandstones and is rich in fossils. The fossil content includes sponges, corals, serpulids, molluscs, balanids, echinoderms and fish. A total of 324 sediment- and 118 molluscan samples was taken. Quantitatively the molluscs dominated and were studied in detail for this thesis. 139 molluscan species were determined from about 19,500 shells. Two gastropod species, *Agapilia pachii* and *Granulolabium bicinctum* make up more than 53% of the assemblage. Another 11 species each contributes more than 1% to the total molluscan composition, but all other 126 species are quantitatively unimportant. Cluster analyses show the presence of a conspicuous alternation between intertidal and shallow subtidal mollusc associations. The NMDS-method shows that the 5 main clusters are overlapping and indicate an ecological gradient from intertidal to subtidal settings. The intertidal is dominated by the superabundant *Agapilia pachii* and *Granulolabium bicinctum*, whereas the heavily bioturbated, fully-marine subtidal is characterized by a more diverse assemblage including *Turritella gradata, Nassarius edlaueri, Loripes dujardini, Anadara diluvii* and various venerids. Additionally, layers with large fragments of *Crassostrea* and thin coal deposits with *Terebralia bidentata* are quite abundant in the section. Washed in land snails (Planorbidae) and river snails (Melanopsidae) occur occasionally. This faunal composition, along with its typical alternation, points to a dynamic, subtropical ecosystem in the palaeo-estuary of the southern Korneuburg Basin.

9.2 Zusammenfassung

Im Zuge des Baus der Wiener Außenring-Schnellstraße (S1) wurde in der Nähe des Ortes Stetten (NÖ) ein detailliertes Profil über eine Länge von 1,8 km aufgenommen. Es handelt sich dabei um benthische Ablagerungen des Karpatiums (Oberes Burdigal) aus einem ästuaren Bereich des südlichen Korneuburger Beckens in der Zentralen Paratethys.

Die Sedimentzusammensetzung des Profils besteht aus Tonen, Sanden und Sandsteinen und ist reich an Fossilien. Der Fossilinhalt inkludiert Schwämme, Korallen, Serpuliden, Mollusken, Balaniden, Echinodermen und Fische. Insgesamt wurden 324 Sediment- und 118 Molluskenproben genommen. Die Mollusken dominieren und wurden im Detail bearbeitet. 139 Molluskenarten wurden von ca. 19 500 Schalen bestimmt. Zwei Gastropodenarten, *Agapilia pachii* und *Granulolabium bicinctum* machen zusammen mehr als 53% aller Individuen aus. Weitere 11 Arten tragen jeweils mehr als 1% zur Gesamtmolluskenfauna bei, alle anderen 126 Arten sind quantitativ unbedeutend. Clusteranalysen zeigen eine deutliche Wechselfolge von intertidalen und flach-subtidalen Molluskenassoziationen. Die NMDS-Methode zeigt, dass die 5 Hauptcluster sich überlappen und einen Umweltgradienten von intertidalen zu subtidalen Bedingungen aufweisen. Das Intertidal ist vorallem durch Taxa wie *Agapilia pachii* und *Granulolabium bicinctum* gekennzeichnet, während das vollmarine Subtidal mit viel Bioturbation durch Taxa wie *Turritella gradata, Nassarius edlaueri, Loripes dujardini, Anadara diluvii* und diverse Veneridae charakterisiert ist. Weiters sind im Profil häufig Lagen mit großen Fragmenten von *Crassostrea* und Kohlelagen mit *Terebralia bidentata* zu erkennen. Eingeschwemmte Landschnecken (beispielsweise Planorbidae) und Flussschnecken (Melanopsidae) kommen auch vor. Diese Faunenzusammensetzung mit ihrer typischen Wechselfolge weist auf ein dynamisches, suptropisches Ökosystem aus einem Paläoästuar des südlichen Korneuburger Beckens hin.

9.3 Profile
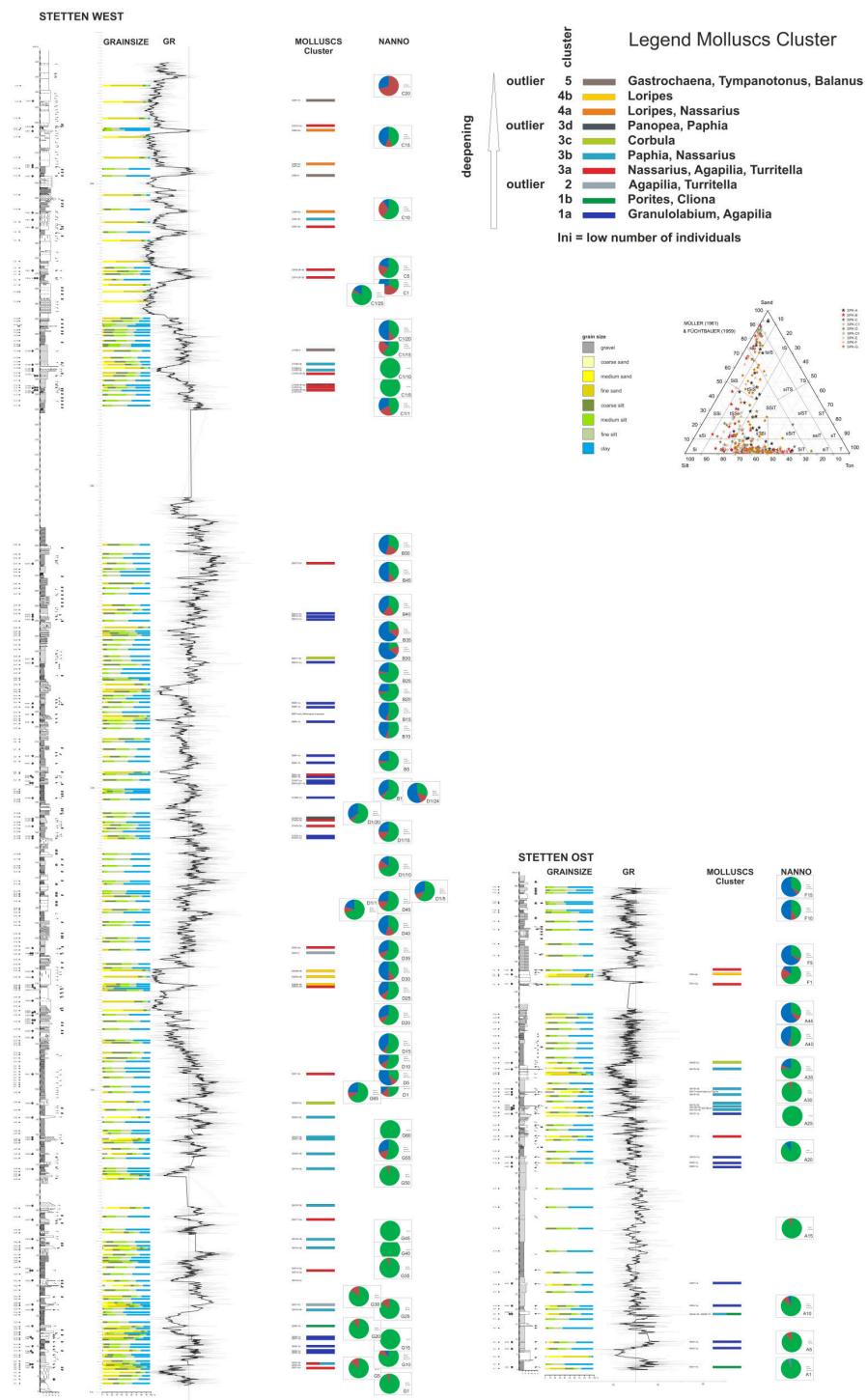
Figure 9.1: Profile of the studied transect (provided by Reinhard Roetzel).

9.4 Curriculum Vitae

Name	Babette Hengst
Date of birth	1983/03/03
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Previous education:

1989 − 1993	Elementary School in Stadt Haag
1993 − 2001	Öff. Stiftsgymnasium Seitenstetten with final examination (Matura)
2001 − 2002	Study of molecular biology at the University of Vienna
2002 − 2012	Study of biology with main subject in palaeobiology at the University of Vienna

Professional experience:

2007	Contract for services at the palaeontological department of the University of Vienna
2008 − 2009	Contract for services at the palaeontological department of the University of Vienna for assignment of mollusc-samples from the Korneuburg (SPK) sediment
2008 − 2011	Contract for services at the geological department of the Museum of Natural History Vienna (NHMV) for arrangement work in different fossil groups