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Taxonomic composition and palaeoecological features of the Early Badenian (Middle Miocene) bivalve fauna of Szob (Börzsöny Mts, Hungary)

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Abstract – Taxonomic composition and palaeoecological features (life habit, feeding type, preferred substrate, depth range) of the Early Badenian bivalves of Szob were examined. The fauna is quite diverse at higher taxonomic levels, but at the same time very poor at lower taxonomic levels. The taxonomic composition of the fauna (Heterodonta subclass: 76%; Pteriomorpha subclass: 23%) corresponds to the taxonomic structure of other faunas of the Miocene sandy facies. The bivalve fauna connected with a seagrass community and dominated by suspension feeder infaunal elements (mostly corbulids). Seagrass is generally advantageous for byssally attached species but on the other hand the movement of vagile infaunal elements is hampered by the roots of seagrass. Bivalves refer to infralittoral depth in the photic zone. The soft, mixed, sandy-muddy bottom was fixed by the roots of seagrass. The bottom sediment was very poor in organic matter because it was rapidly decayed due to the high oxygen content of the sea-water inside the seagrass meadows. Some species indicate the Early Badenian age of the fauna. With 10 figures.

INTRODUCTION

Hungary and the Carpathian Basin belonged to the Central Paratethys during the Middle Miocene, therefore a significant part of the basin contains marine Miocene formations. There are many localities in Hungary, where rich Miocene mollusc faunas can be found. One of the most famous of them is Szob in the Börzsöny Mts (Fig. 1).

The Börzsöny Mts are situated at the northern border of Hungary. This is the westernmost part of the so-called "Inner Carpathian Volcanic Arc". The main mass of the mountains consists of volcanic rocks and sedimentary formations are present only at the margins of the mountains. The andesite – which is 1000 m thick at some places – developed in the Early Badenian during a relatively short time (BÁLDI & KÓKAY 1970). The andesite is overlain by also Early Badenian Leitha Limestone and some other sedimentary rocks, including the examined sand from Szob.

This locality is situated at the SW slopes of the Börzsöny Mts. The old sandpit is NW of Szob on the left bank of the Ipoly River. The fossils of the yellowish-grey sand were already studied from the mid 19th century, owing to its rich mollusc fauna.

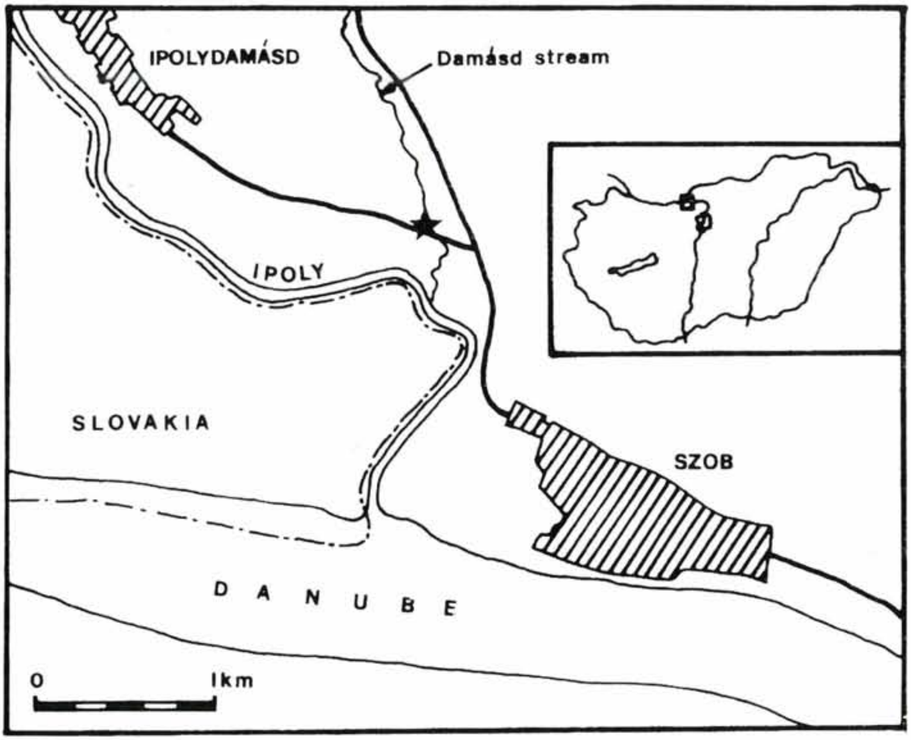


Fig. 1. Sketch map showing the location of the studied sand pit

Several Austrian and Hungarian geologists dealt with molluscs. For example 73 gastropod and 20 bivalve species were mentioned from here in HÖRNES's famous works (1856, 1870). STACHE (1866) listed 214 mollusc species, then HOERNES & AUINGER (1879) described 2 new forms from Szob. Among Hungarian geologists KRENNER (1865) listed 29 gastropod and 5 bivalve species, while HALAVÁTS (1881) mentioned 14 *Conus* species from the locality. Some rare species and 30 species of pleurotomes were described by CSEPREGHY-MEZNERICS (1952, 1953).

After these smaller papers the mollusc fauna was examined monographically by CSEPREGHY-MEZNERICS (1956). A total of 267 gastropod and 74 bivalve species were listed in her work and 143 of them were described briefly. However, this monograph dealt only with taxonomic questions and the age of the fauna.

MATERIAL

In the framework of the research project on the Middle Miocene mollusc fauna of the Börzsöny Mts, a palaeoecological work was made on the described material, which can be found in the Hungarian Natural History Museum, Budapest. As this material was collected by several workers during a century between 1848 and 1952, the composition of this collection may be not very representative for the locality. For this reason a new collection was made by the author. This second material is derived by washing from the coarse fraction of 10–12 kg sand collected from the locality. Further on only the bivalves will be discussed here and the taxonomic compositions and the ecological characters of the two collections are compared.

Since the classification of bivalves is significantly changed soon after the CSEPREGHY-MEZNERICS (1956) monograph, the detailed systematic position of the species is given below based on the adequate volumes of "Treatise on Invertebrate Palaeontology" (MOORE 1969). Palaeoecological characters and distributions are also given for all species. In some cases the referred literature deals only with the palaeoecological features of the genus or another species of the genus, it is indicated by the words "genus" or "other species".

Abbreviations: a: abundance in the museum collection (number of specimens); b: dominance in the museum collection (percentage of specimens); c: abundance in the washed material; d: dominance in the washed material.

Class Bivalvia LINNÉ, 1758

Subclass Palaeotaxodonta KOROBKOV, 1954
Order Nuculoida DALL, 1889
Superfamily Nuculacea GRAY, 1824
Family Nuculidae GRAY, 1824
Genus *Nucula* LAMARCK, 1799

Nucula (Nucula) nucleus (LINNÉ, 1758) – a: 6, b: 0.37, c: 7, d: 0.16. – Palaeoecological characters (BERNASCONI & ROBBA 1993): – life habit: vagile infauna; feeding type: detritus feeder; preferred substrate: mixed bottom; depth range: infralittoral-circalittoral. – Distribution: Early Miocene – Recent (STUDENCKA 1986)

Superfamily Nuculanacea ADAMS et ADAMS, 1858
Family Nuculanidae ADAMS et ADAMS, 1858
Genus *Nuculana* LINK, 1807
Subgenus *Saccella* WOODRING, 1925

Nuculana (Saccella) fragilis (CHEMNITZ, 1784) – a: 10, b: 0.61, c: 3, d: 0.07. – Palaeoecological characters (DAVITASHVILI & MERKLIN 1966; genus): – life habit: vagile infauna; feeding type: detritus feeder; preferred substrate: mixed bottom. – Distribution: Early Miocene – Recent (STUDENCKA 1986).

Nuculana cf. **emarginata** (LAMARCK, 1819) – a: 1, b: 0.06, c: –, d: –. – Palaeoecological characters (DAVITASHVILI & MERKLIN 1966; genus): – life habit: vagile infauna; feeding type: detritus feeder; preferred substrate: mixed bottom. – Distribution: Early Miocene – Pliocene (BOHN-HAVAS 1973).

Subclass Pteriomorpha BEURLEN, 1944
Order Arcoida STOLICZKA, 1871
Superfamily Arcacea LAMARCK, 1809
Family Arcidae LAMARCK, 1809
Subfamily Arcinae LAMARCK, 1809
Genus *Barbatia* GRAY, 1842

Barbatia (Barbatia) barbata (LINNÉ, 1758) – a: 5, b: 0.31, c: 47, d: 1.05. – Palaeoecological characters (FRENEIX *et al.* 1987*a*): – life habit: attached epifauna; feeding type: suspension feeder; preferred substrate: hard bottom; depth range: infralittoral – abyssal. – Distribution: Early Miocene – Recent (STUDENCKA 1986).

Subfamily Anadarinae REINHART, 1935
Genus *Anadara* GRAY, 1847

Anadara (Anadara) diluvii (LAMARCK, 1805) – a: 100, b: 6.14, c: 20, d: 0.45. – Palaeoecological characters (BERNASCONI & ROBBA 1993): life habit: free-lying semiinfauna; feeding type: suspension feeder; preferred substrate: muddy bottom; depth range: infralittoral – circalittoral. – Distribution: Late Oligocene – Recent (STUDENCKA 1986).

Anadara (Anadara) turoniensis (DUJARDIN, 1837) – a: 2, b: 0.12, c: –, d: –. – Palaeoecological characters (STANLEY 1970; genus): life habit: free-lying semiinfauna; feeding type: suspension feeder; preferred substrate: sandy bottom. – Distribution: Early Miocene – Middle Miocene (BOHN-HAVAS 1973).

Family Noetiidae STEWART, 1930
Subfamily Striarcinae MACNEIL, 1938
Genus *Striarca* CONRAD, 1862

Striarca lactea (LINNÉ, 1758) – a: 2, b: 0.12, c: –, d: –. – Palaeoecological characters (FRENEIX *et al.* 1987*a*): life habit: attached epifauna; feeding type: suspension feeder; preferred substrate: hard bottom; depth range: infralittoral – abyssal. – Distribution: Early Miocene – Recent (STUDENCKA 1986).

Genus *Arcopsis* KOENEN, 1885

Arcopsis (Arcopsis) papillifera HÖRNES, 1874 – a: 1, b: 0.06, c: –, d: –. – Palaeoecological characters (STANLEY 1970; genus): life habit: attached epifauna; feeding type: suspension feeder; preferred substrate: hard bottom. – Distribution: Early Miocene – Middle Miocene (KOJUMDGIEVA & STRACHIMIROV 1960).

Superfamily Limopsacea DALL, 1895
Family Limopsidae DALL, 1895
Genus *Limopsis* SASSI, 1827

Limopsis (Limopsis) anomala (EICHWALD, 1830) – a: 3, b: 0.18, c: 4, d: 0.09. – Palaeoecological characters (DI GERONIMO *et al.* 1982): life habit: free-lying infauna; feeding type: suspension feeder; preferred substrate: sandy bottom. – Distribution: Early Miocene – Recent (BÁLDI 1973).

Family Glycymerididae NEWTON, 1922
Subfamily Glycymeridinae NEWTON, 1922
Genus *Glycymeris* DA COSTA, 1778

Glycymeris (Glycymeris) obtusata (PARTSCH in HÖRNES, 1870) – a: 5, b: 0.31, c: 2, d: 0.04. – Palaeoecological characters (FRENEIX *et al.* 1987*a*; other species): life habit: free-lying infauna; feeding type: suspension feeder; preferred substrate: sandy bottom. – Distribution: Early Miocene – Middle Miocene (BÁLDI 1962).

Glycymeris (Glycymeris) pilosa deshayesi (MAYER, 1868) – a: 11, b: 0.68, c: 8, d: 0.18. – Palaeoecological characters (FRENEIX *et al.* 1987*a*): life habit: free-lying infauna; feeding type: suspension feeder; preferred substrate: sandy bottom; depth range: infralittoral. – Distribution: Early Miocene – Middle Miocene (BÁLDI 1962).

Superfamily Pinnacea LEACH, 1819
Family Pinnidae LEACH, 1819
Genus *Pinna* LINNÉ, 1758

Pinna (Pinna) tetragona BROCCHI, 1814 – a: 4, b: 0.25, c: –, d: –. – Palaeoecological characters (STANLEY 1970; other species): life habit: attached semiinfauna; feeding type: suspension feeder; preferred substrate: sandy bottom. – Distribution: Early Miocene – Middle Miocene (CSEPREGHY-MEZNERICS 1950).

Order Pterioida NEWELL, 1965
Suborder Pteriina NEWELL, 1965
Superfamily Pectinacea RAFINESQUE, 1815
Family Pectinidae RAFINESQUE, 1815
Genus *Amusium* RÖDING, 1798

Amusium cristatum badense (FONTANNES, 1879) – a: 12, b: 0.74, c: 8, d: 0.18. – Palaeoecological characters (BERNASCONI & ROBBA 1993): life habit: vagile epifauna; feeding type: suspension feeder; preferred substrate: muddy bottom; depth range: infralittoral – circalittoral. – Distribution: (Early Miocene ?) – Middle Miocene [(Ottnangian ?) – Late Karpatian – Badenian] (STEININGER *et al.* 1978).

Genus *Chlamys* RÖDING, 1798
Subgenus *Aequipecten* FISCHER, 1886

Chlamys (Aequipecten) angelonii (DE STEFANI et PANTANELLI, 1878) – a: 1, b: 0.06, c: –, d: –. – Palaeoecological characters (BENIGNI & ROBBA 1990): life habit: vagile epifauna; feeding type: suspension feeder; preferred substrate: sandy bottom; depth range: infralittoral – circalittoral. – Distribution: Early Miocene – Pleistocene (STUDENCKA & STUDENCKI 1988).

Chlamys (Aequipecten) elegans (ANDRZEJOWSKY, 1830) – a: 10, b: 0.61, c: 2, d: 0.04. – Palaeoecological characters (DAVITASHVILI & MERKLIN 1966; genus): life habit: vagile epifauna; feeding type: suspension feeder; preferred substrate: sandy bottom. – Distribution: Middle Miocene (Badenian) (STEININGER *et al.* 1978).

Chlamys (Aequipecten) malvinae (DUBOIS, 1831) – a: 1, b: 0.06, c: –, d: –. – Palaeoecological characters (BERNASCONI & ROBBA 1993): life habit: vagile epifauna; feeding type: suspension feeder; preferred substrate: sandy bottom; depth range: infralittoral. – Distribution: Early Miocene – Middle Miocene (STUDENCKA 1986).

Chlamys (Aequipecten) scabrella (LAMARCK, 1819) – a: 177, b: 10.87, c: 87, d: 1.94. – Palaeoecological characters (BENIGNI & ROBBA 1990): life habit: vagile epifauna; feeding type: suspension feeder; preferred substrate: sandy bottom; depth range: infralittoral – circalittoral. – Distribution: Early Miocene – Pliocene (STUDENCKA 1986).

Subgenus *Macrochlamis* SACCO, 1897

Chlamys (Macrochlamis) tournali (DE SERRES, 1829) – a: 1, b: 0.06, c: –, d: –. – Palaeoecological characters (BERNASCONI & ROBBA 1993): life habit: vagile epifauna; feeding type: suspension feeder; preferred substrate: sandy bottom; depth range: infralittoral – circalittoral. – Distribution: Middle Miocene [(Karpatian ?) – Badenian] (STEININGER *et al.* 1978).

Genus *Pecten* MÜLLER, 1776
Subgenus *Flabellipecten* SACCO, 1897

Pecten (Flabellipecten) besseri ANDRZEJOWSKY, 1830 – a: 2, b: 0.12, c: –, d: –. – Palaeoecological characters (DAVITASHVILI & MERKLIN 1966; genus): life habit: vagile epifauna; feeding type: suspension feeder; preferred substrate: sandy bottom. – Distribution: Middle Miocene (Badenian) (STEININGER *et al.* 1978).

Pecten (Flabellipecten) solarium (LAMARCK, 1819) – a: 1, b: 0.06, c: –, d: –. – Palaeoecological characters (DAVITASHVILI & MERKLIN 1966; genus): life habit: vagile epifauna; feeding type: suspension feeder; preferred substrate: sandy bottom. – Distribution: Early Miocene – Middle Miocene (STUDENCKA & STUDENCKI 1988).

Subgenus *Oppenheimopecten* VON TEPPNER, 1922

Pecten (Oppenheimopecten) revolutus MICHELOTTI, 1847 – a: 1, b: 0.06, c: –, d: –. – Palaeoecological characters (DAVITASHVILI & MERKLIN 1966; genus): life habit: vagile epifauna; feeding type: suspension feeder; preferred substrate: sandy bottom. – Distribution: Early Miocene – Middle Miocene (STUDENCKA & STUDENCKI 1988).

Family Plicatulidae WATSON, 1930
Genus *Plicatula* LAMARCK, 1801

Plicatula (Plicatula) mytilina PHILIPPI, 1836 – a: 1, b: 0.06, c: 1, d: 0.02. – Palaeoecological characters (STANLEY 1970; other species): life habit: attached epifauna; feeding type: suspension feeder; preferred substrate: hard bottom. – Distribution: Early Miocene – Middle Pliocene (STUDENCKA & STUDENCKI 1988).

Superfamily Anomiacea RAFINESQUE, 1815
Family Anomiidae RAFINESQUE, 1815
Genus *Anomia* LINNÉ, 1758

Anomia (Anomia) ephippum rugulosostriata BROCCHI, 1814 – a: 8, b: 0.49, c: 14, d: 0.31. – Palaeoecological characters (BERNASCONI & ROBBA 1993): life habit: attached epifauna; feeding type: suspension feeder; preferred substrate: hard bottom; depth range: infralittoral – circalittoral. – Distribution: Early Oligocene – Recent (BÁLDI 1973).

Suborder Ostreina FÉRUSSAC, 1822
Superfamily Ostreacea RAFINESQUE, 1815
Family Ostreidae RAFINESQUE, 1815
Subfamily Ostreinae RAFINESQUE, 1815
Genus *Cubitostrea* SACCO, 1897

Cubitostrea digitalina (EICHWALD, 1830) – a: 30, b: 1.84, c: 7, d: 0.16. – Palaeoecological characters (DAVITASHVILI & MERKLIN 1966; genus): life habit: attached epifauna; feeding type: suspension feeder; preferred substrate: hard bottom. – Distribution: Middle Miocene – Late Miocene (STUDENCKA 1986).

Subclass Heterodonta NEUMAYR, 1884
Order Veneroida ADAMS et ADAMS, 1856
Superfamily Lucinacea FLEMING, 1828
Family Lucinidae FLEMING, 1828
Subfamily Lucininae FLEMING, 1828
Genus *Linga* DE GREGORIO, 1884

Linga (Linga) columbella (LAMARCK, 1818) – a: 12, b: 0.74, c: 2, d: 0.04. – Palaeoecological characters (STANLEY 1970; other species): life habit: vagile infauna; feeding type: suspension feeder; preferred substrate: muddy bottom. – Distribution: Late Oligocene – Recent (BÁLDI 1973).

Subgenus *Bellucina* DALL, 1901

Linga (Bellucina) agassizi (MICHELOTTI, 1839) – a: 1, b: 0.06, c: –, d: –. – Palaeoecological characters (STANLEY 1970; other species): life habit: vagile infauna; feeding type: suspension feeder; preferred substrate: muddy bottom. – Distribution: Early Miocene – Late Miocene (BOHN-HAVAS 1973).

Linga submichelotti (SACCO, 1901) – a: 2, b: 0.12, c: –, d: –. – Palaeoecological characters (STANLEY 1970; other species): life habit: vagile infauna; feeding type: suspension feeder; preferred substrate: muddy bottom. – Distribution: Late Oligocene – Middle Miocene (STEININGER *et al.* 1971).

Genus *Megaxinus* BRUGNONE, 1880

Megaxinus (Megaxinus) bellardianus (MAYER, 1864) – a: 13, b: 0.80, c: –, d: –. – Palaeoecological characters (BERNASCONI & ROBBA 1993; other species): life habit: vagile infauna; feeding type: suspension feeder; preferred substrate: sandy bottom. – Distribution: Late Oligocene – Middle Miocene (STEININGER *et al.* 1971).

Megaxinus (Megaxinus) incrassatus (DUBOIS, 1831) – a: 1, b: 0.06, c: –, d: –. – Palaeoecological characters (BERNASCONI & ROBBA 1993; other species): life habit: vagile infauna; feeding type: suspension feeder; preferred substrate: sandy bottom. – Distribution: Late Oligocene – Middle Miocene (TEJKAL *et al.* 1967).

Megaxinus (Megaxinus) subgibbosulus (D'ORBIGNY, 1841) – a: 3, b: 0.18, c: –, d: –. – Palaeoecological characters (BERNASCONI & ROBBA 1993; other species): life habit: vagile infauna; feeding type: suspension feeder; preferred substrate: sandy bottom. – Distribution: Miocene (CSEPREGHY-MEZNERICS 1956).

Genus *Parvilucina* DALL, 1901
Subgenus *Microloripes* COSSMANN, 1910

Parvilucina (Microloripes) dentata (DEFRANCE, 1823) – a: 44, b: 2.70, c: 48, d: 1.07. – Palaeoecological characters (BERNASCONI & ROBBA 1993): life habit: vagile infauna; feeding type: suspension feeder; preferred substrate: sandy bottom; depth range: infralittoral. – Distribution: Early Miocene – Late Pliocene (STUDENCKA 1986).

Subfamily Myrteinae CHAVAN, 1969
Genus *Myrtea* TURTON, 1822

Myrtea (Myrtea) spinifera (MONTAGU, 1803) – a: 5, b: 0.31, c: –, d: –. – Palaeoecological characters (BERNASCONI & ROBBA 1993): life habit: vagile infauna; feeding type: suspension feeder; preferred substrate: mixed bottom; depth range: infralittoral – bathyal. – Distribution: Early Miocene – Recent (STUDENCKA 1986).

Genus *Lucinoma* DALL, 1901

Lucinoma borealis (LINNÉ, 1767) – a: 19, b: 1.17, c: 3, d: 0.07. – Palaeoecological characters (BERNASCONI & ROBBA 1993): life habit: vagile infauna; feeding type: suspension feeder; preferred substrate: sandy bottom; depth range: infralittoral – circalittoral. – Distribution: Early Oligocene – Recent (STUDENCKA 1986).

Family Ungulinidae ADAMS et ADAMS, 1857
Genus *Diplodonta* BRONN, 1831

Diplodonta (Diplodonta) holubicensis FRIEDBERG, 1929 – a: 1, b: 0.06, c: –, d: –. – Palaeoecological characters (BERNASCONI & ROBBA 1993; other species): life habit: vagile infauna; feeding type: suspension feeder; preferred substrate: muddy bottom. – Distribution: Miocene (CSEPREGHY-MEZNERICS 1956).

Superfamily Chamacea LAMARCK, 1809
Family Chamidae LAMARCK, 1809
Genus *Chama* LINNÉ, 1758
Subgenus *Psilopus* POLI, 1795

Chama (Psilopus) gryphoides LINNÉ, 1758 – a: 1, b: 0.06, c: –, d: –. – Palaeoecological characters (FRENEIX *et al.* 1987*b*): life habit: attached epifauna; feeding type: suspension feeder; preferred substrate: hard bottom. – Distribution: Early Miocene – Recent (STUDENCKA 1986).

Superfamily Carditacea FLEMING, 1820
Family Carditidae FLEMING, 1828
Subfamily Carditinae FLEMING, 1828
Genus *Cardita* BRUGUIÉRE, 1792

Cardita (Cardita) crassa vindobonensis (SACCO, 1899) – a: 1, b: 0.06, c: –, d: –. – Palaeoecological characters (FRENEIX *et al.* 1987*b*): life habit: attached epifauna; feeding type: suspension feeder; preferred substrate: small hard bottom. – Distribution: Middle Miocene (Late Karpatian – Early Badenian) (STEININGER *et al.* 1978).

Subfamily Carditamerinae CHAVAN, 1969
Genus *Cardiocardita* ANTON, 1839

Cardiocardita (Cardiocardita) partschi (GOLDFUSS, 1840) – a: 12, b: 0.74, c: –, d: –. – Palaeoecological characters (STANLEY 1970; other genus): life habit: vagile infauna; feeding type: suspension feeder; preferred substrate: sandy bottom. – Distribution: Middle Miocene (Badenian) (STEININGER *et al.* 1978).

Cardiocardita (Cardiocardita) schwabenaui (HÖRNES, 1870) – a: 1, b: 0.06, c: –, d: –. – Palaeoecological characters (STANLEY 1970; other genus): life habit: vagile infauna; feeding type: suspension feeder; preferred substrate: sandy bottom. – Distribution: Middle Miocene [(Karpatian ?) – Early Badenian – Middle Badenian)] (STEININGER *et al.* 1978).

Genus *Cyclocardia* CONRAD, 1867
Subgenus *Scalaricardita* SACCO, 1899

Cyclocardia (Scalaricardita) scalaris (SOWERBY, 1825) – a: 6, b: 0.37, c: –, d: –. – Palaeoecological characters (BERNASCONI & ROBBA 1993): life habit: vagile infauna; feeding type: suspension feeder; preferred substrate: sandy bottom; depth range: infralittoral. – Distribution: Early Miocene – Late Pliocene (STUDENCKA 1986).

Genus *Glans* MEGERLE, 1811

Glans rudista (LAMARCK, 1819) – a: 2, b: 0.12, c: 1, d: 0.02. – Palaeoecological characters (BERNASCONI & ROBBA 1993; other species): life habit: vagile infauna; feeding type: suspension feeder; preferred substrate: sandy bottom. – Distribution: Middle Miocene [(Karpatian ?) – Badenian] (STEININGER *et al.* 1978).

Subfamily Venericardiinae CHAVAN, 1969
Genus *Megacardita* SACCO, 1899

Megacardita jouanneti BASTEROT, 1825 – a: 5, b: 0.31, c: –, d: –. – Palaeoecological characters (BERNASCONI & ROBBA 1993): life habit: vagile infauna; feeding type: suspension feeder; preferred substrate: sandy bottom; depth range: infralittoral. – Distribution: Middle Miocene (Badenian) (STEININGER *et al.* 1978).

Superfamily Crassatellacea FÉRUSSAC, 1822
Family Crassatellidae FÉRUSSAC, 1822
Subfamily Scambulinae CHAVAN, 1952
Genus *Crassinella* GUPPY, 1874

Crassinella moravica HÖRNES, 1870 – a: 8, b: 0.49, c: –, d: –. – Palaeoecological characters (BERNASCONI & ROBBA 1993; other species): life habit: vagile infauna; feeding type: suspension feeder. – Distribution: Early Miocene – Middle Miocene (BOHN-HAVAS 1973).

Superfamily Cardiacea LAMARCK, 1809
Family Cardiidae LAMARCK, 1809
Subfamily Cardiinae LAMARCK, 1809
Genus *Parvicardium* MONTEROSATO, 1884

Parvicardium minimum (PHILIPPI, 1836) – a: 1, b: 0.06, c: 30, d: 0.67. – Palaeoecological characters (ŠVAGROVSKY 1984): life habit: vagile infauna; feeding type: suspension feeder; preferred substrate: mixed bottom. – Distribution: Middle Miocene – Recent (STUDENCKA 1986).

Subfamily Laevicardiinae KEEN, 1936
Genus *Laevicardium* SWAINSON, 1840

Laevicardium cyprium (BROCCHI, 1814) – a: 7, b: 0.43, c: –, d: –. – Palaeoecological characters (STANLEY 1970; other species): life habit: vagile infauna; feeding type: suspension feeder; preferred substrate: mixed bottom. – Distribution: Late Oligocene – Middle Miocene (STEININGER *et al.* 1978).

Laevicardium spondyloides (HAUER, 1847) – a: 2, b: 0.12, c: –, d: –. – Palaeoecological characters (STANLEY 1970; other species): life habit: vagile infauna; feeding type: suspension feeder; preferred substrate: mixed bottom. – Distribution: Early Miocene – Middle Miocene (STEININGER *et al.* 1978).

Superfamily Mactracea LAMARCK, 1809
Family Mactridae LAMARCK, 1809
Subfamily Lutrariinae ADAMS et ADAMS, 1856
Genus *Lutraria* LAMARCK, 1799

Lutraria oblonga (CHEMNITZ, 1782) – a: 1, b: 0.06, c: –, d: –. – Palaeoecological characters (BERNASCONI & ROBBA 1993): life habit: vagile infauna; feeding type: suspension feeder; preferred substrate: sandy bottom; depth range: infralittoral. – Distribution: Early Miocene – Pliocene (KÓKAY 1966).

Family Mesodesmatidae GRAY, 1839
Subfamily Erviliinae DALL, 1895
Genus *Ervilia* TURTON, 1822

Ervilia miopusilla BOGSCH, 1937 – a: 56, b: 3.44, c: 11, d: 0.25. – Palaeoecological characters (DAVITASHVILI & MERKLIN 1966; genus): life habit: vagile infauna; feeding type: suspension feeder; preferred substrate: sandy bottom. – Distribution: Middle Miocene (TEJKAL *et al.* 1967).

Superfamily Tellinacea DE BLAINVILLE, 1814
Family Tellinidae DE BLAINVILLE, 1814
Subfamily Tellininae DE BLAINVILLE, 1814
Genus *Tellina* LINNÉ, 1758
Subgenus *Moerella* FISCHER, 1887

Tellina (Moerella) donacina LINNÉ, 1758 – a: 1, b: 0.06, c: –, d: –. – Palaeoecological characters (ŠVAGROVSKY 1984): life habit: vagile infauna; feeding type: detritus feeder; preferred substrate: sandy bottom. – Distribution: Early Miocene – Recent (STUDENCKA 1986).

Subgenus *Serratina* PALLARY, 1922

Tellina (Serratina) serrata RENIER, 1804 – a: 1, b: 0.06, c: –, d: –. – Palaeoecological characters (ŠVAGROVSKY 1984; other species): life habit: vagile infauna; feeding type: detritus feeder; preferred substrate: sandy bottom. – Distribution: Miocene – Recent (MOORE 1969).

Family Solecurtidae D'ORBIGNY, 1846
Subfamily Solecurtinae D'ORBIGNY, 1846
Genus *Solecurtus* DE BLAINVILLE, 1824

Solecurtus candidus (RENIER, 1804) – a: 1, b: 0.06, c: 2, d: 0.04. – Palaeoecological characters (BERNASCONI & ROBBA 1993; other species): life habit: vagile infauna; feeding type: suspension feeder; preferred substrate: sandy bottom. – Distribution: Middle Miocene – Recent (KAUTZKY 1925).

Superfamily Arcticacea NEWTON, 1891
Family Kelliellidae FISCHER, 1887
Genus *Lutetia* DESHAYES, 1860
Subgenus *Spaniodontella* ANDRUSSOV in GOLUBIATNIKOV, 1902

Lutetia (Spaniodontella) nitida REUSS, 1867 – a: 3, b: 0.18, c: 1, d: 0.02. – Palaeoecological characters (HOFFMAN 1977; genus): life habit: vagile infauna; feeding type: suspension feeder . – Distribution: Middle Miocene (Badenian) (ŠVAGROVSKY 1984).

Superfamily Corbiculacea GRAY, 1847
Family Pisidiidae GRAY, 1857
Genus *Pisidium* PFEIFFER, 1821

Pisidium (Pisidium) priscum EICHWALD, 1830 – a: 1, b: 0.06, c: –, d: –. – Palaeoecological characters: fresh water species (MOORE 1969). – Distribution: Miocene (CSEPREGHY-MEZNERICS 1956).

Superfamily Veneracea RAFINESQUE, 1815
Family Veneridae RAFINESQUE, 1815
Subfamily Venerinae RAFINESQUE, 1815
Genus *Venus* LINNÉ, 1758

Venus (Venus) tauroverrucosa SACCO, 1900 – a: 10, b: 0.61, c: 5, d: 0.11. – Palaeoecological characters (DAVITASHVILI & MERKLIN 1966; other species): life habit: vagile infauna; feeding type: suspension feeder; preferred substrate: sandy bottom. – Distribution: Early Miocene – Middle Miocene (KOJUMDGIEVA & STRACHIMIROV 1960).

Subgenus *Ventricoloidea* SACCO, 1900

Venus (Ventricoloidea) multilamella (LAMARCK, 1818) – a: 53, b: 3.26, c: 116, d: 2.59. – Palaeoecological characters (BERNASCONI & ROBBA 1993): life habit: vagile infauna; feeding type: suspension feeder; preferred substrate: muddy bottom; depth range: infralittoral – circalittoral. – Distribution: Late Oligocene – Recent (STUDENCKA 1986).

Genus *Circomphalus* MÖRCH, 1853

Circomphalus subplicatus (D'ORBIGNY, 1847) – a: 41, b: 2.52, c: 82, d: 1.83. – Palaeoecological characters (BERNASCONI & ROBBA 1993; other species): life habit: vagile infauna; feeding type: suspension feeder; preferred substrate: sandy bottom. – Distribution: Early Miocene – Early Pliocene (STUDENCKA 1986).

Circomphalus vindobonensis (MAYER, 1858) – a: 2, b: 0.12, c: –, d: –. – Palaeoecological characters (BERNASCONI & ROBBA 1993; other species): life habit: vagile infauna; feeding type: suspension feeder; preferred substrate: sandy bottom. – Distribution: Middle Miocene (Badenian) (STEININGER *et al.* 1978).

Subfamily Circinae DALL, 1896
Genus *Gouldia* ADAMS, 1847

Gouldia (Gouldia) minima (MONTAGU, 1803) – a: 26, b: 1.60, c: 28, d: 0.63. – Palaeoecological characters (BOSENCE 1979): life habit: vagile infauna; feeding type: suspension feeder. – Distribution: Early Miocene – Recent (STUDENCKA 1986).

Subfamily Pitarinae STEWART, 1930
Genus *Callista* POLI, 1791

Callista (Callista) italica (DEFRANCE, 1818) – a: 3, b: 0.18, c: –, d: –. – Palaeoecological characters (BERNASCONI & ROBBA 1993): life habit: vagile infauna; feeding type: suspension feeder; preferred substrate: sandy bottom; depth range: infralittoral. – Distribution: Early Miocene – Late Pliocene (STUDENCKA 1986).

Genus *Pelecyora* DALL, 1902
Subgenus *Cordiopsis* COSSMANN, 1910

Pelecyora (Cordiopsis) gigas (LAMARCK, 1818) – a: 2, b: 0.12, c: –, d: –. – Palaeoecological characters (BERNASCONI & ROBBA 1993): life habit: vagile infauna; feeding type: suspension feeder; preferred substrate: sandy bottom; depth range: infralittoral. – Distribution: Middle Miocene (Badenian) (STEININGER *et al.* 1978).

Pelecyora (Cordiopsis) islandicoides (LAMARCK, 1818) – a: 14, b: 0.86, c: 2, d: 0.04. – Palaeoecological characters (BERNASCONI & ROBBA 1993): life habit: vagile infauna; feeding type: suspension feeder; preferred substrate: muddy bottom; depth range: infralittoral – circalittoral. – Distribution: Early Miocene – Late Pliocene (STUDENCKA 1986).

Subfamily Tapetinae ADAMS et ADAMS, 1857
Genus *Paphia* Röding, 1798

Paphia waldmanni KAUTZKY, 1936 – a: 1, b: 0.06, c: –, d: –. – Palaeoecological characters (BERNASCONI & ROBBA 1993; other species): life habit: vagile infauna; feeding type: suspension feeder; preferred substrate: sandy bottom. – Distribution: Early Miocene – Middle Miocene (STEININGER *et al.* 1978).

Subfamily Chioninae FRIZZEL, 1936
Genus *Timoclea* BROWN, 1827

Timoclea (Timoclea) ovata minor (DOLLFUS et DAUTZENBERG, 1903) – a: 1, b: 0.06, c: –, d: –. – Palaeoecological characters (DAVITASHVILI & MERKLIN 1966; other genus): life habit: vagile infauna; feeding type: suspension feeder. – Distribution: Middle Miocene – Pliocene (BOHN-HAVAS 1973).

Order Myoida STOLICZKA, 1870
Suborder Myina STOLICZKA, 1870
Superfamily Myacea LAMARCK, 1809
Family Corbulidae LAMARCK, 1818
Subfamily Corbulinae GRAY, 1823
Genus *Corbula* BRUGUIÉRE, 1797
Subgenus *Varicorbula* GRANT et GALE, 1931

Corbula (Varicorbula) carinata (DUJARDIN, 1837) – a: 253, b: 15.54, c: 1134, d: 25.32. – Palaeoecological characters (BERNASCONI & ROBBA 1993; other species): life habit: attached infauna; feeding type: suspension feeder; preferred substrate: mixed bottom. – Distribution: Late Oligocene – Middle Miocene (BOHN–HAVAS 1973).

Corbula (Varicorbula) gibba (OLIVI, 1792) – a: 610, b: 37.47, c: 2651, d: 59.20. – Palaeoecological characters (BERNASCONI & ROBBA 1993): life habit: attached infauna; feeding type: suspension feeder; preferred substrate: mixed bottom; depth range: infralittoral – circalittoral. – Distribution: Late Eocene – Recent (STUDENCKA 1986).

Corbula (Varicorbula) revoluta (BROCCHI, 1814) – a: 6, b: 0.37, c: –, d: –. – Palaeoecological characters (BERNASCONI & ROBBA 1993; other species): life habit: attached infauna; feeding type: suspension feeder; preferred substrate: mixed bottom. – Distribution: Middle Miocene – Pliocene (BOHN-HAVAS 1973).

Suborder Pholadina ADAMS et ADAMS, 1858
Superfamily Pholadacea LAMARCK, 1809
Family Pholadidae LAMARCK, 1809
Subfamily Xylophagainae PURCHON, 1941
Genus *Xylophaga* TURTON, 1822

Xylophaga dorsalis (TURTON, 1819) – a: 1, b: 0.06, c: –, d: –. – Palaeoecological characters (DAVITASHVILI & MERKLIN 1966; genus): life habit: boring infauna; feeding type: suspension feeder; preferred substrate: drift-wood. – Distribution: Early Miocene – Recent (MOORE 1969).

Subclass Anomalodesmata DALL, 1889
Order Pholadomyoida NEWELL, 1965
Superfamily Clavagellacea D'ORBIGNY, 1844
Family Clavagellidae D'ORBIGNY, 1843
Genus *Clavagella* LAMARCK, 1818
Subgenus *Stirpulina* STOLICZKA, 1870

Clavagella (Stirpulina) sp. indet. – a: –, b: –, c: 1, d: 0.02. – Palaeoecological characters (SAVAZZI 1982): life habit: tube-dwelling; feeding type: suspension feeder; preferred substrate: soft bottom

TAXONOMIC COMPOSITION OF THE FAUNA

At the museum collection (Fig. 2a) gastropods are the most frequent (74%), bivalves are important (23%) and the other groups are in insignificant minority. At the washed material (Fig. 2b) bivalves are the most frequent (46%), gastropods are significant (26%), but more than one-quarter of the fossils are composed of the other groups (worm tubes, bryozoans, vertebrates, decapods, scaphopods).

The specimen number is nearly three times larger at the washed material, than at the museum collection, but at the same time the species number is more than twice as much at the museum collection. The difference in abundance continuously decreases between the two collections at higher taxonomic levels (genus, family and superfamily) and the washed material is more diverse at the level of orders due to the small fragment of *Clavagella* (*Stirpulina*) in the washed material (Table 1) (DULAI in prep.). The most frequent bivalves are generally nearly equal in the two collections or slightly more abundant at the museum collection, except the two most frequent species – *Corbula gibba* and *Corbula carinata* – at which the percentage of these species is much larger at the washed material (Fig. 3). The amount of these two species is about 84% in the washed fauna, while only 53% in the museum collection. At the other species there are no such significant differences.

Table 1. Taxonomic composition of the two collections (1: collection of the museum; 2: washed material)

1	2
1628 specimens	4478 specimens
66 species	29 species
45 genera	25 genera
26 families	18 families
20 superfamilies	16 superfamilies
5 orders	6 orders

The taxonomic structure of the fauna is given in Table 2. The bivalve fauna is very diverse at higher taxonomic levels but at the same time very poor at lower taxonomic levels. 18 families contain only one genus each in the museum collection. Four families

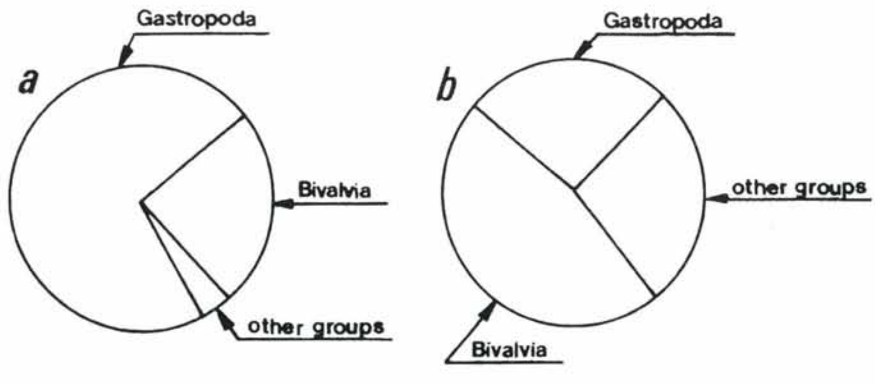
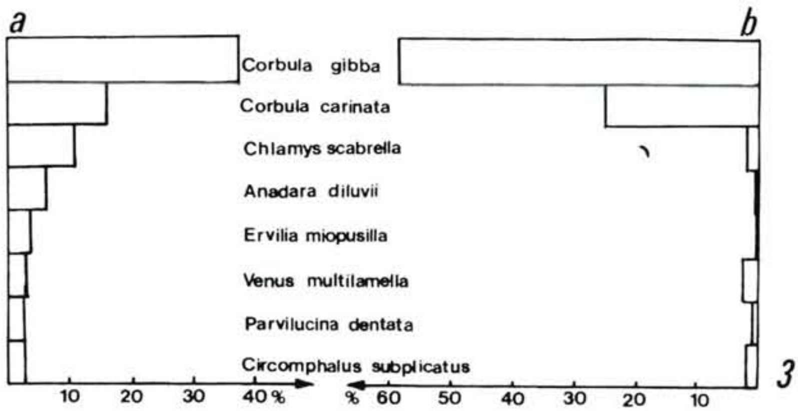
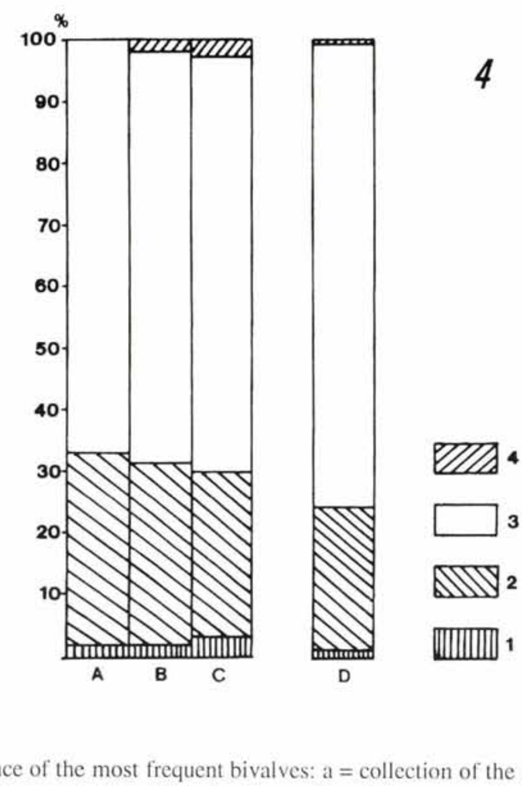


Fig. 2. Taxonomic composition of the studied Szob material:
a = collection of the museum, b = washed material

Table 2. Abundance of bivalve subclasses and families in the fauna of Szob (1: percentage in the museum collection; 2: number of genera in the museum collection; 3: number of species in the museum collection; 4: percentage in washed material; 5: number of genera in washed material; 6: number of species in washed material)

	1	2	3	4	5	6
Palaeotaxodonta						
Nuculidae	0.37	1	1	0.16	1	1
Nuculanidae	0.67	1	2	0.07	1	1
	1.04	2	3	0.23	2	2
Pteriomorpha						
Arcidae	6.57	2	3	1.50	2	2
Noetiidae	0.18	2	2	–	–	–
Limopsidae	0.18	1	1	0.09	1	1
Glycymerididae	0.99	1	2	0.22	1	2
Pinnidae	0.25	1	1	–	–	–
Pectinidae	12.58	3	9	2.16	2	3
Plicatulidae	0.06	1	1	0.02	1	1
Anomiidae	0.49	1	1	0.31	1	1
Ostreidae	1.84	1	1	0.16	1	1
	23.14	13	21	4.46	9	11
Heterodonta						
Lucinidae	6.20	6	10	1.18	3	3
Chamidae	0.06	1	1	–	–	–
Carditidae	1.66	5	6	0.02	1	1
Crassatellidae	0.49	1	1	–	–	–
Cardiidae	0.61	2	3	0.67	1	1
Mactridae	0.06	1	1	–	–	–
Mesodermatidae	3.44	1	1	0.25	1	1
Tellinidae	0.12	1	2	–	–	–
Solecurtidae	0.06	1	1	0.04	1	1
Kelliellidae	0.18	1	1	0.02	1	1
Pisididae	0.06	1	1	–	–	–
Veneridae	9.39	7	10	5.20	4	5
Corbulidae	53.38	1	3	84.52	1	2
Pholadidae	0.06	1	1	–	–	–
	75.77	30	42	91.90	13	15
Anomalodesmata						
Clavagellidae	–	–	–	0.02	1	1





Figs 3–4. 3 = Abundance of the most frequent bivalves: a = collection of the museum, b = washed material. 4 = Taxonomic composition of bivalve faunas from Miocene sandy facies: 1 = Palaeotaxodonta subclass, 2 = Pteriomorpha subclass, 3 = Heterodonta subclass, 4 = Anomalodesmata subclass. A = Kinberk (from STUDENCKA & STUDENCKI 1988), B = Niskowa (from STUDENCKA & STUDENCKI 1988), C = Nawodzice and Rybnica (from STUDENCKA & STUDENCKI 1988), D = Szob (this paper)

have two or three genera (Arcidae, Noetiidae, Pectinidae and Cardiidae) and only three families can be considered as diverse (Veneridae: 7 genera; Lucinidae: 6 genera; Carditidae: 5 genera). 31 genera are represented by one species each and 9 genera are represented by two species each (*Nuculana, Anadara, Glycymeris, Cardiocardita, Laevicardium, Tellina, Venus, Circomphalus, Pelecyora*). Five genera are more or less diverse (*Chlamys*: 5 species; *Pecten*: 3 species; *Linga*: 3 species; *Megaxinus*: 3 species; *Corbula*: 3 species). These facts are more striking in the washed material: 18 families contain only one genus each and only four families are represented by more genera (Veneridae: 4 genera; Lucinidae: 3 genera; Arcidae: 2 genera; Pectinidae: 2 genera). 21 genera from 25 are represented by only one species each and two species can be found at the others (*Glycymeris, Chlamys, Venus, Corbula*).

The Palaeotaxodonta subclass is insignificant in both collections (1.04% and 0.23 %). The dominance is slightly larger in the museum collection, but the numbers of genera and species are very similar. The Pteriomorpha subclass is much more important in the museum collection (23.14%) than in the washed material (4.46%). At the same time the number of genera is hardly different (13 and 9) and the difference of the number of species is also not very significant between the two collections (21 and 11). The Heterodonta subclass is the most important in both collections (75.77% and 91.90%). However the high dominance is derived from the high proportion of Corbulidae (84.52%) and only 7.38% is represented by the other seven families in the washed material while the high proportion of Corbulidae and the relatively high diversity of the heterodont bivalves are equally responsible for the dominance of the Heterodonta subclass in the museum collection (53.38% Corbulidae and 22.39% of the other 13 families). The Anomalodesmata subclass is missing in the museum collection and represented by only a small fragment in the washed material.

STUDENCKA & STUDENCKI (1988) compared the taxonomic structure of seven bivalve faunas and they found that the compositions of the faunas from sandy facies are clearly different from the structures of the faunas from carbonate deposits. Bivalves in carbonate deposits are characterized by a high proportion of the Pteriomorpha subclass (37–42%) and a relatively low proportion of the Heterodonta subclass (53%). On the contrary in sandy facies the Pteriomorpha subclass is less important (30%) however the Heterodonta subclass is more abundant (67%). The taxonomic structure of the Szob fauna from sandy facies confirms these conclusions because in the museum collection Heterodonta are very significant (75.77%) and Pteriomorpha are less important (23.14%) (Fig. 4).

PALAEOECOLOGICAL FEATURES OF THE FAUNA

The palaeoecological examination is based on the autecological data of bivalves focussing on life habit, feeding type, substrate preference and depth range. Life habit and feeding type are interpreted at all species, but substrate preference and depth range are not mentioned everywhere because a significant part of the fauna consists of extinct species and their palaeoecological features are not known. (Moreover sometimes these characters are uncertain at the Recent species, too).

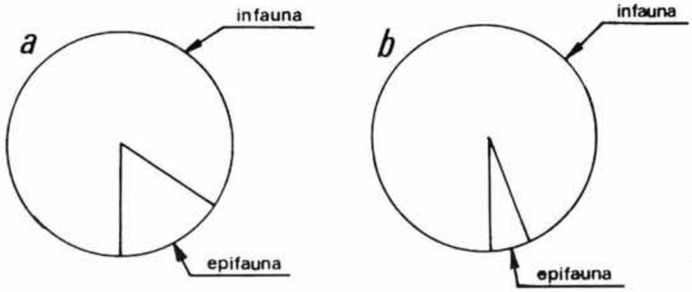
Life Habit

The life habit is very varied at bivalves. Some groups of them are epibenthic, a bigger part of bivalves belong to the infauna and a few groups live at the interface of the water and the sediment (semiinfauna). From the point of view of movement bivalves may be attached, vagile or free-lying. At some groups the life habit is changing during the life. The high variability of life habit of bivalves is clearly reflected in the Szob material. Several life habit groups are represented by the following genera in the examined material:

- vagile infauna: *Nucula, Nuculana, Linga, Megaxinus, Parvilucina, Myrtea, Lucinoma, Diplodonta, Cardiocardita, Cyclocardia, Glans, Megacardita, Crassinella, Parvicardium, Laevicardium, Lutraria, Ervilia, Tellina, Solecurtus, Venus, Circomphalus, Gouldia, Callista, Pelecyora, Paphia, Timoclea*
- free-lying semiinfauna: *Anadara*
- free-lying infauna: *Limopsis, Glycymeris*
- attached semiinfauna: *Pinna*
- attached infauna: *Corbula*
- boring infauna: *Xylophaga*
- tube-dwelling infauna: *Clavagella*
- vagile epifauna: *Amusium, Chlamys, Pecten*
- attached epifauna: *Barbatia, Striarca, Arcopsis, Plicatula, Anomia, Cubitostrea, Chama, Cardita*

At the life habit there is a characteristic difference between the two collections (Fig. 5). Namely, the percentage of the epifaunal elements is nearly three times smaller at the washed material (15.58% in the museum collection and 6.03% in the washed material). Life habit groups are also showed in Figure 6 but in more detail. In order to show a clear picture the free-lying infauna and free-lying semiinfauna as well as attached infauna and attached semiinfauna are figured as a single group. For the same reason the poorly represented boring infauna and tube-dwelling fauna are missing in the figures. As it can be seen not only the percentage of infaunal elements increased on the account of epifaunal elements, but the rates changed among infaunal groups, too. In spite of the high diversity of vagile infaunal elements, the infauna is dominated by attached corbulids.

The spatial distribution of vagile infaunal forms is very varied in the sediment, therefore presumably the competition for space was moderate. *Nucula*, cardiids and *Lutetia* live very near to the sediment-water interface. *Nuculana*, *Laevicardium* and *Ervilia* are shallow burrowers, *Venus* and *Circomphalus* can be found at intermediate depths, while *Linga*, *Lucinoma* and *Parvilucina* are deep burrowers. *Corbula gibba* lives shallowly buried in the sediment, attached to gravel or shell fragments with a single byssus thread. Taking the eight most frequent species into consideration (Fig. 3) it can be seen that *Chlamys scabrella* is epifaunal element (on the surface or in the water mass), *Anadara diluvii* lives at the sediment-water interface, *Corbula gibba*, *Corbula carinata* and *Ervilia miopusilla* are shallow burrowers, *Venus multilamella* and *Circomphalus subplicatus* are intermediate burrowers, while *Parvilucina dentata* is deep burrower. In spite of



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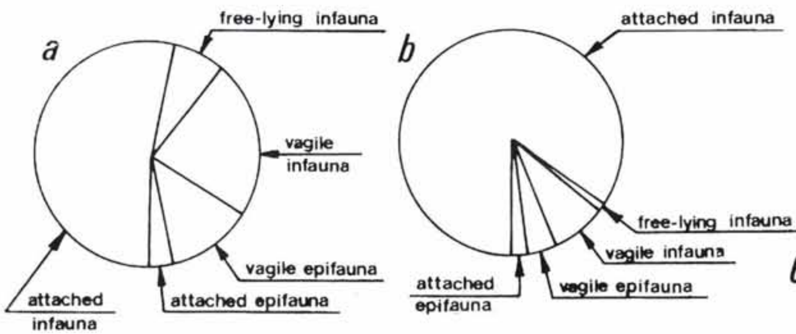

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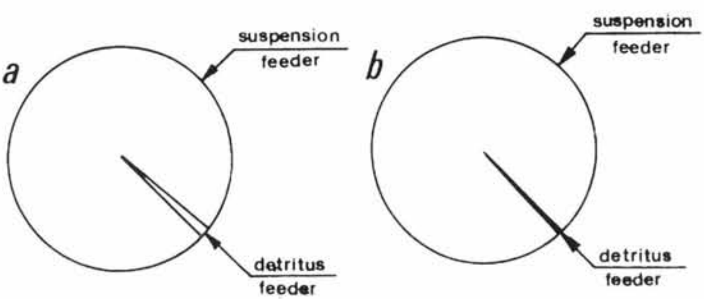

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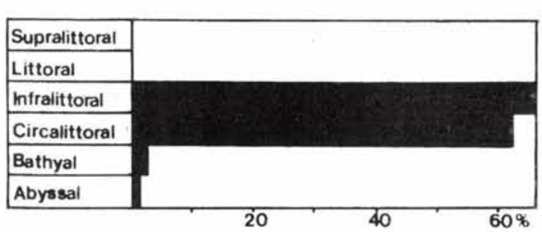

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Figs 5–8. 5 = Life habit groups of the bivalve fauna: a = collection of the museum, b = washed material. 6 = Life habit groups of the bivalve fauna (in more detail): a = collection of the museum, b = washed material. 7 = Feeding type groups of the bivalve fauna: a = collection of the museum, b = washed material. 8 = Depth range of the bivalve fauna this spatial division corbulids are the predominant elements of the fauna. According to LEWY & SAMTLEBEN (1979) *Corbula gibba* is a long- and wide-ranging species with remarkable tolerance to environmental changes. It is associated with faunas of relative low-energy environments.

FEEDING TYPE

The classification and terminology of feeding types of benthic invertebrates for palaeoecological analysis is given by WALKER & BAMBACH (1974). All bivalves are heterotrophic organisms and belong to suspension feeders and deposit feeders. Suspension feeders remove food from suspension in the water mass, while deposit feeders obtain food from sediment either selectively or nonselectively.

At the feeding type practically there is no difference between the two collections (Fig. 7) because deposit feeders (*Nucula*, *Nuculana*, *Tellina*) belong to the rare elements of the fauna, which are nearly equally represented in the two collections. The extremely low rate of deposit feeders refer to the fact that the bottom sediment was very poor in organic matter.

Predominant part of the fauna is suspension feeder and the two most frequent species also belong to this group. Epifaunal elements (for example *Anomia* and Pectinids) acquire their food high in the water mass, while at infaunal elements (for example *Anadara*, *Limopsis*, *Glycymeris*, *Loripes*, cardiids, *Venus*, *Lutetia*, *Corbula*) the location of the food acquisition is low in the water mass.

WATER DEPTH

The preferred water depth is not known at each species, because data about depth preference are rare in the literature. It is frequent that different species of the same genus live at different depth, therefore in the case of depth range only those species were interpreted which have found in the literature. In this way 21 species in the museum collection and 12 species in the washed material were taken into consideration. In both cases the interpreted species represent approximately two-third of the fauna (66.65% and 67.24%). So in spite of the small number of interpreted species, the obtained data probably give realistic results. Some species point to a wide depth range (Fig. 8) (infralittoral – abyssal: *Barbatia barbata*, *Striarca lactea*; infralittoral – bathyal: *Myrtea spinifera*). Several species point to the infra- and circalittoral depth-range (*Nucula nucleus*, *Anadara diluvii*, *Amusium cristatum badense*, *Chlamys angelonii*, *Chlamys scabrella*, *Chlamys tournali*, *Anomia ephippum*, *Lucinoma borealis*, *Venus multilamella*, *Pelecyora islandicoides*, *Corbula gibba*). Some species point to only the infralittoral environment (*Glycymeris pilosa deshayesi*, *Chlamys malvinae*, *Parvilucina dentata*, *Cyclocardia scalaris*, *Megacardita jouanneti*, *Lutraria oblonga*, *Callista italica*, *Pelecyora gigas*). So, the examined sand probably deposited at infralittoral depth.

SUBSTRATUM

In the respect of the substratum, approximately 95% of the fauna was interpreted. At certain species the preferred substrate is not known, but data for near relatives can be found in the literature. Some bivalves prefer the muddy bottom (*Anadara diluvii, Amusium cristatum badense, Venus multilamella, Pelecyora islandicoides*). More species refer to sandy bottom (*Glycymeris obtusata, Glycymeris pilosa deshayesi, Chlamys angelonii, Chlamys malvinae, Chlamys scabrella, Chlamys tournali, Parvilucina dentata, Lucinoma borealis, Cardiocardita partschi, Cyclocardia scalaris, Megacardita jouanneti, Lutraria oblonga, Tellina donacina, Callista italica, Pelecyora gigas*). Some species prefer the mixed, sandy-muddy bottom (*Nucula nucleus, Nuculana fragilis, Myrtea spinifera, Parvicardium minimum, Corbula gibba*).

The majority of the fauna belongs to the infauna therefore the upper layers of the sediment must have been unconsolidated. As it was mentioned above at life habits, vagile infaunal elements inhabited different depths of the substratum, some of them were deep burrowers. The great number of corbulids confirms the idea that the Szob fauna lived on mixed, soft bottom.

The attached epifaunal elements of the fauna (*Barbatia barbata, Striarca lactea, Arcopsis papillifera, Plicatula mytilina, Anomia ephippum rugulosostriata, Chama gryphoides, Cubitostrea digitalina, Cardita crassa vindobonensis*) point to some amount of hard substratum on the essentially soft sand. *Cubitostrea digitalina* specimens are generally very small and fragmentary but a very nice specimen in the museum collection shows a nest of 7–8 specimens grown on the surface of a large fragment of bivalve shell.

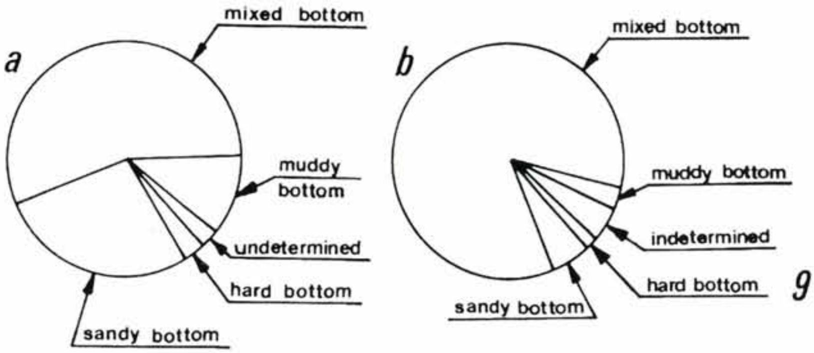
The presence of tube-dwelling *Clavagella* also fits to the idea of soft bottom. *Xylophaga dorsalis* refers to some drift-wood on the surface of the water, and the fresh water *Pisidium priscum* can travel also in this way to the marine environment. Some volcanic islands probably existed in the neighbourhood of the locality, but drift-wood can drift through long distances, too.

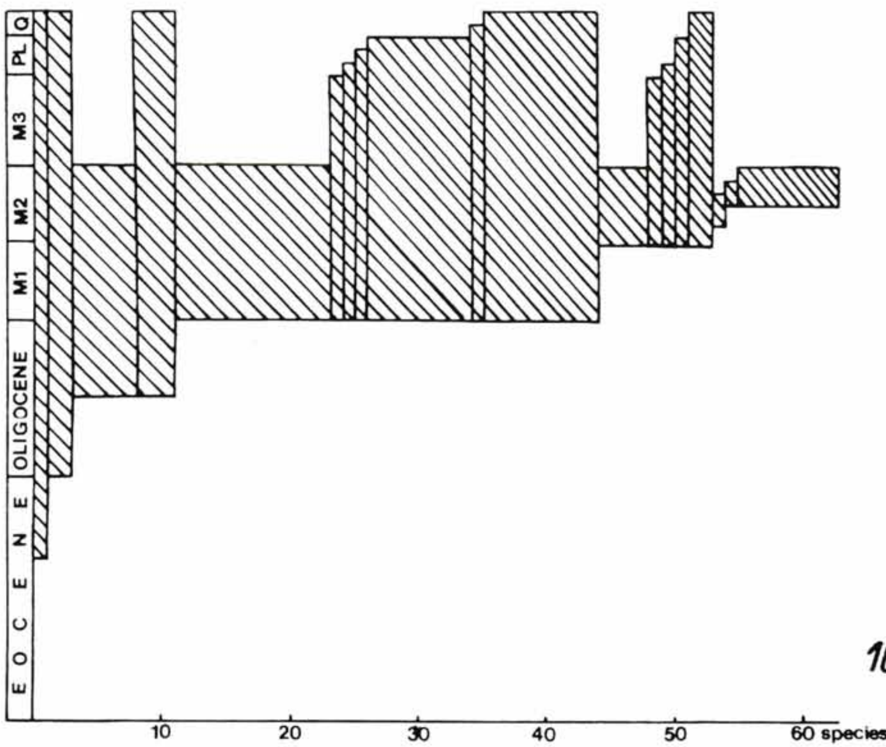
The two collections are quite different from the viewpoint of substratum (Fig. 9). More than half of the fauna prefers the mixed bottom in the museum collection (55.34%) but a significant part of the fauna prefers purely sandy (27%) or muddy (11.98%) substrate. The hard substrate preference is negligible (3.06%). On the contrary the species preferring mixed bottom are dominant in washed material (85.44%) and all the other groups are insignificant (sandy: 5.59%; muddy: 3.3%; hard: 1.54%).

AGE OF THE FAUNA

The age of the Szob material was determined as Tortonian by CSEPREGHY-MEZNERICS (1956) using the old and deficient nomenclature, which was derived from the false correlation between Italian "tortoniano" and Paratethyan Middle Miocene. New regional stages were initiated in the last few decades including the Badenian, which more or less correspond to the former Tortonian of Paratethys (PAPP *et al.* 1978).

Most bivalve species have very long range in the Szob material (Fig. 10). The most frequent *Corbula gibba* appeared in the earliest (Late Eocene – Recent). Several species live from the Oligocene or Miocene up to now (Early Oligocene – Recent: 2 species;





Figs 9–10. 9 = Preferred substrate of the bivalve fauna: a = collection of the museum, b = washed material. 10 = Distribution of the bivalve species: M1 = Early Miocene, M2 = Middle Miocene, M3 = Late Miocene, PL = Pliocene, Q = Quaternary

Late Oligocene – Recent: 3 species; Early Miocene – Recent: 11 species; Middle Miocene – Recent: 2 species). Similarly, a lot of extinct bivalve species have long range (Early Oligocene – Late Miocene: 1 species; Late Oligocene – Middle Miocene: 4 species; Early Miocene – Pleistocene: 1 species; Early Miocene – Late Pliocene: 7 species; Early Miocene – Middle Pliocene: 1 species; Early Miocene – Early Pliocene: 1 species; Early Miocene – Late Miocene: 2 species; Early Miocene – Middle Miocene: 12 species; Middle Miocene – Late Pliocene: 2 species; Middle Miocene – Late Miocene: 1 species; Middle Miocene: 4 species).

Eight species indicate Badenian age (*Chlamys elegans*, *Chlamys tournali*, *Pecten besseri*, *Cardiocardita partschi*, *Glans rudista*, *Megacardita jouanneti*, *Circomphalus vindobonensis*, *Pelecyora gigas*). *Cardita crassa vindobonensis* have been found in Late Karpatian and Early Badenian, while *Cardiocardita schwabenaui* in Early Badenian and Middle Badenian. These two latter species prove the Early Badenian age of the Szob bivalve fauna. This age was suggested by NAGYMAROSY (1980), who, based on nannoplankton examinations, determined the upper part of the Early Badenian (NN 6) from the locality.

CONCLUSIONS

The Early Badenian bivalve fauna of Szob is very diverse at higher taxonomic levels, but at the same time very poor at lower taxonomic levels (more diverse families: Veneridae, Lucinidae, Carditidae). The taxonomic composition of the fauna well corresponds to the taxonomic structure of other faunas of sandy facies (Heterodonta subclass: 76%, Pteriomorpha subclass: 23%).

On the basis of the palaeoecological examinations (life habit, feeding type, preferred substrate, depth range) the bivalve fauna of Szob is interpreted as member of a seagrass community (this statement is confirmed by gastropods: large number of browsers, great abundance of small gastropods). The bivalve fauna is dominated by infaunal elements. The competition for space below the sediment-water interface probably was not too intensive, because the dominant infaunal bivalves lived at different depths in the sediment. But in spite of the varied spatial distribution the fauna is highly dominated by corbulids. Supposing that the fauna is part of a seagrass community these dominance relations can be explained in the following way. Corbulids fixed themselves by a single byssus thread to a gravel or shell fragment in the sediment but the roots of seagrass also can be used for fixation, in this way the roots help the attachment of corbulids. The turbulence of water is strongly decrease inside the seagrass meadows, what is also advantageous for corbulids, which usually associate with faunas of low energy environments (LEWY & SAMTLEBEN 1979). On the contrary, movement of vagile infaunal elements is hampered by the roots of seagrass therefore large populations of vagile infaunal species were not able to develop, only some tolerant groups are frequent (for example lucinoids, pinnids, BRASIER 1975). Epifaunal elements can use the leaves of seagrass as a firm substrate (for example *Barbatia*, BRASIER 1975). The swimmer pectinids are represented only by small forms because smaller specimens can move easier in the dense seagrass meadows.

The fauna is highly dominated by suspension feeders because the organic matter is very rapidly decayed due to the high oxygen content of the sea-water inside the seagrass meadows, therefore the bottom sediment was very poor in organic matter (HOFFMAN *et al.* 1978). Bivalves refer to infralittoral depth in the photic zone. The soft, mixed, sandy-muddy bottom was fixed by the roots of seagrass.

The old museum collection contains more species, but the proportion of the species is anomalous at the most frequent bivalves, because the collectors keep in view only the diversity of the fauna and not the frequency of certain species. For this reason the museum collection is very good for the examination of palaeodiversity or taxonomy, but the above bias must be kept in mind in the case of palaeoecological studies based on the museum collections.

* * *

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