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Paleoecology and Isotopic Analysis of Eggenburgian Molluscs from the SW Part of the Carpathian Foredeep in Moravia (Czech Republic)

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With 4 Text-Figures and 5 Tables

Tschechische Republik
Mähren
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Eggenburgien
Mollusken
Paläoökologie
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Contents

Paläoökologie und Isotopenanalyse von Eggenburg-Mollusken aus dem SW-Teil der Karpatenvortiefe in Mähren (Tschechische Republik)

Zusammenfassung

Der Artikel faßt die Ergebnisse einer ausführlichen paläoökologischen Analyse der Molluskengemeinschaften (Bivalvia, Gastropoda) aus dem Eggenburgien (7 Bohrungen, 6 Aufschlüsse) des SW-Teiles der Karpatenvortiefe in Mähren, Tschechische Republik, zusammen. Für diese Analyse wurden Ergebnisse der Paläobiologie der Mollusken, Sedimentologie und Geochemie (die Isotopenanalyse von C und O der karbonatischen Molluskenschalen) ausgewertet.

Es wurden 2 Molluskengemeinschaften nachgewiesen, und zwar die *Congeria* sp.-*Nematurella* sp. (+*Hydrobia* sp., *Staliopsis* sp., *Clithon* aff. *pictus*) Gemeinschaft und *Pirenella moravica*-*Cerastoderma* sp. (+*Ostrea* sp.) Gemeinschaft. Diese artenarmen Gemeinschaften substituieren einander in der vertikalen und lateralen Richtung abhängig von den Milieubedingungen wie Wassertiefe und -dynamik, Licht, Aeration und Salinität, die im untersuchten Bereich sehr veränderlich waren. Besonders die Salinität repräsentierte offenbar einen sehr wichtigen Milieufaktor. Mit paläobiologischen, als auch isotopischen Analysen wurde nachgewiesen, daß die Salinitätswerte meistens von den normalen Meerwasserwerten abgewichen sind. Die Salinitätsänderungen in Zeit und Raum wurden als die Folge der unterschiedlichen Verbindungen der einzelnen Sedimentationsräume mit dem offenen Meeresraum interpretiert.

Die Studie zeigt besonders die Aussagekraft von paläontologischen Analysen in enger Verbindung mit stabilen Isotopenanalysen bei paläoökologischen Rekonstruktionen auf.

Abstract

This article summarizes the results of a detailed paleoecological analysis of the Eggenburgian mollusc communities (Bivalvia, Gastropoda) from seven boreholes and six natural exposures from the SW part of the Carpathian Foredeep in Moravia, Czech Republic. For this analysis, the results of paleobiology, carbon and oxygen isotopic analysis of the carbonate molluscan shells and sedimentology were used.

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Two basic communities, namely the *Congeria* sp.-*Nematurella* sp. (+*Hydrobia* sp., *Staliopsis* sp., *Clithon* aff. *pictus*) community and the *Pirenella moravica*-*Cerastoderma* sp. (+*Ostrea* sp.) community were found. These communities are generally relatively very poor in species and they substitute each other vertically as well as laterally in dependence on environmental conditions, as water depth, water dynamics, light, aeration, salinity, that were highly variable in the investigated area. Namely water salinity proved to be a very important environmental factor. Both paleobiological and isotopic analyses of molluscs proved that the salinity values differed mostly from normal marine values. The salinity changes were interpreted as a consequence of the changes in the communication of individual sedimentation areas with the open sea.

The comparison of individual possibilities of paleobiology and stable isotope analysis for paleoecological reconstructions proved the importance of their narrow cooperation.

1. Introduction

1.1. Regional Geology and Paleontology

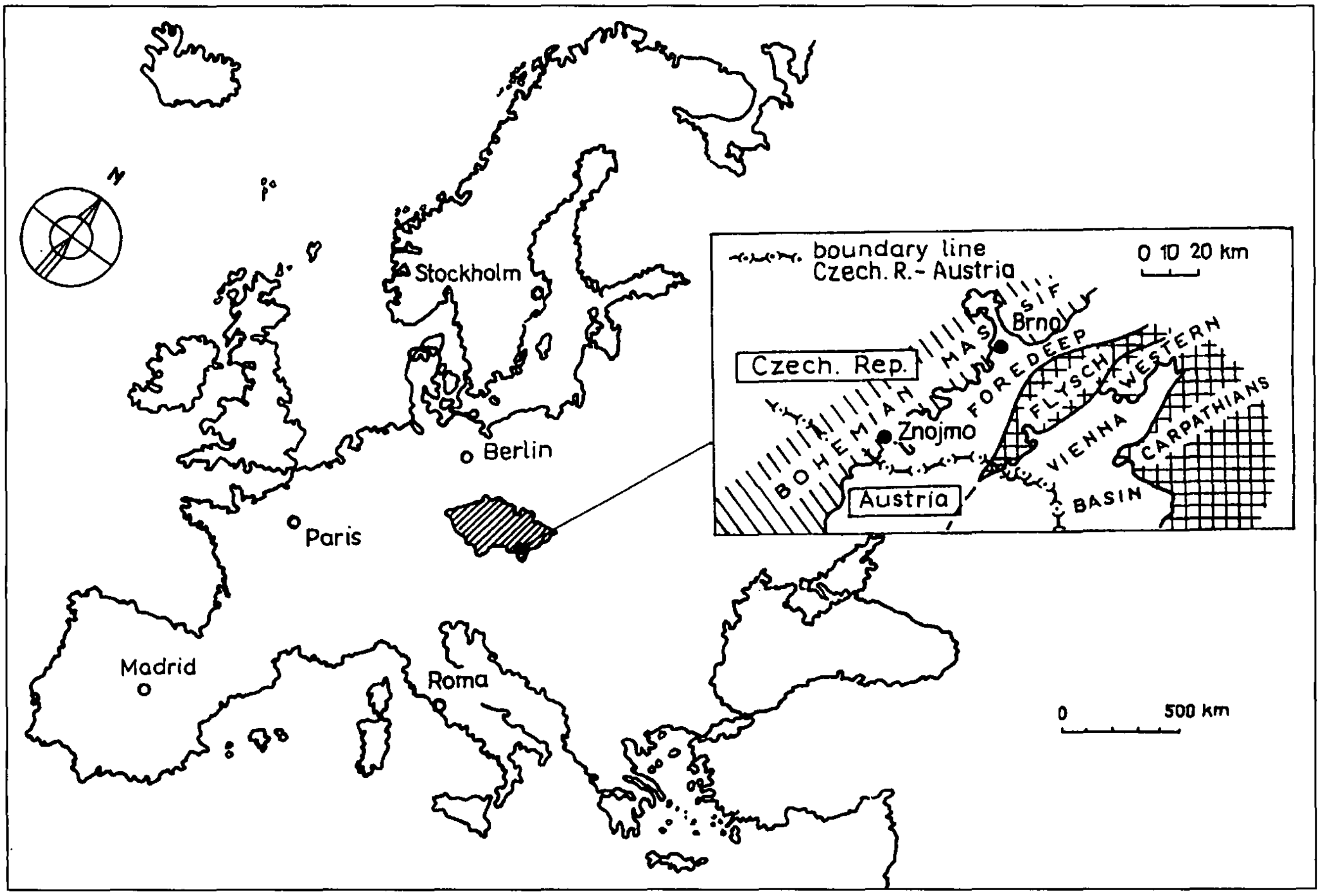
The Western Carpathians are a part of the northern branch of the Alpides and extend mostly in the territory of Eastern Moravia (Czech Republic) and in Slovakia (Text-Fig. 1). Paleogeographically the region belonged in the Neogene to the Central Paratethys realm. The Neogene basin formation in the Western Carpathian area is in close relation to the geodynamical development of the orogene. From this point of view the foreland, foredeep, residual flysch and piggy-back, intramountain, backland and backdeep basins are distinguished (KOVÁČ et al., 1989; CICHA & KOVÁČ, 1990).

For the definition of the regional chronostratigraphic stages in the Central Paratethys see the papers by BÁLDI, SENEŠ et al., 1975; STEININGER, SENEŠ et al., 1971; PAPP, RÖGL, SENEŠ et al., 1973; CICHA, SENEŠ & TEJKAL, 1967; PAPP, CICHA, SENEŠ, STEININGER et al., 1978.

The Miocene filling of the Western Carpathian Foredeep is formed by molasse sediments reaching 2000 m in thickness. In Moravia they are known today in autochthonous and allochthonous positions and they are of Egerian–Badenian ages. They overlay the pre-Neogene platform basement in front and below the Carpathian nappes, or they form slices and nappe units of the Western Carpathians.

The basement of the autochthonous sediments of the Western Carpathian Foredeep in Moravia consists mostly of the rocks of the Bohemian Massif (pre-Variscan metamorphites and granitoid rocks covered in the greater part by the Paleozoic–Devonian, Lower and Upper Carboniferous and Permian, and by the Mesozoic sediments, especially Jurassic).

In the studied part of the Carpathian Foredeep in Moravia, sediments of Eggenburgian age are schematically di-



Text-Fig. 1.
Geographic map and geologic position of localities studied.
Geologic units on insert map: hatched = Bohemian Massif; white = Molasse Zone (foredeep) and Vienna Basin; cross hatched = Flysch nappes in front of the Western Carpathian unit.

vided into two bio- and lithofacies developments: basinal and shallow-water ones (ČTYROKÝ, 1982, 1991).

The basinal development is situated in the southern part of the territory concerned, near the Austrian border, between Šatov in the west and Mikulov in the east. It begins with chloritic and glauconitic sands and sandy gravels with *Glycymeris cor* (LAMARCK), *Glycymeris fichteli* (DESHAYES), *Protoma cathedralis* BRONGNIART and *Turritella vermicularis* BROCCHI. These sediments are overlaid by fine-grained sands and calcareous clays with *Cibicidoides budayi* (CICHA et ZAPLETALOVÁ), *Thracia* cf. *pubescens* (PULTENEY) and *Laevicardium* cf. *cingulatum* (GOLDFUSS). The uppermost parts of the profiles are formed by montmorillonitic clays with volcanic glass.

The shallow-water development is described from outcrops and boreholes at the western margin of the Carpathian Foredeep adjacent to the Bohemian Massif, from the Austrian border south of Šafov as far as the neighbourhood of Ivančice. Its basal parts are represented by coarse and fine-grained gravels, sands, sandstones, often kaolinic or with layers of redeposited secondary kaolin. In higher parts of the profiles sands, sandy clays, silts, calcareous as well as noncalcareous clays and coaly clays occur. The uppermost parts of this sequence are formed by layers of rhyolite tuffite and tuffaceous montmorillonitic and bentonitic clays. For this marginal shallow-water development, rhythmically alternating layers with marine and brachyhaline faunas are typical. The marine rhythms contain the species *Nucula* sp., *Glycymeris* sp., *Glycymeris fichteli* (DESHAYES), *Glycymeris cor* (LAMARCK), *Barbatia* cf. *barbata* LINNAEUS, *Pholas dactylus* (LINNAEUS), *Timoclea ovata minor* DOLLFUSS & DAUTZENBERG, Cardiidae div. sp., *Hinia edlaueri* BEER-BYSTRICKY, *Calyptraea* sp., *Ocinebrina* sp., *Pirenella moravica* (HÖRNES). In the brachyhaline rhythms, there are very abundant oyster accumulations with large shells of *Crassostrea gryphoides* (SCHLOTHEIM), *Pirenella moravica* (HÖRNES), accompanied by the species *Clithon (Vittoclithon) pictus* (FÉRUSSAC), *Hydrobia*, *Nematurella*, *Ctyrokya*, *Congeria* and *Cerastoderma*. These assemblages are comparable with molluscan faunas described in the underlying of a coal seam at Langau in Lower Austria (ZAPFE, 1953, 1956 in ČTYROKÝ, 1991).

1.2. Carbon and Oxygen Stable Isotopes of Molluscan Shells

The carbon and oxygen isotopic composition of carbonate shells have been widely used for paleoecological purposes since the beginning of the fifties (e.g. UREY et al., 1951; BOWEN, 1966; SAVIN, 1977). It is well known that water temperature, the oxygen isotopic composition of water and the carbon isotopic composition of dissolved bicarbonate are the major factors which control the carbon and oxygen isotopic composition in mollusc shell carbonate (HUDSON, 1977). On the other hand, if we know the carbon and oxygen isotopic composition of molluscan shells we can discuss the above mentioned factors which characterized the aquatic environment at the time of the deposition of the shells.

However, before applying stable isotopes of fossils for paleoenvironmental studies it is necessary to evaluate if the found isotopic values really reflect the conditions of formation. It means that it is necessary to determine the degree of diagenetic alteration of shells and the extent in what the isotopic compositions of shells were affected by the metabolism of the living organism (so called "vital effect"). It is generally agreed that the molluscs grow in good isotopic equilibrium with their aquatic environment and exert only minimal "vital effects" (MILLIMAN, 1974). Diagenetically altered shell carbonates, of course, cannot be used for paleoecological studies because their original isotopic composition could be changed during diagenesis. According to HUDSON (1977) and STAHL & JORDAN (1969) the primary isotopic composition is preserved if the original carbonate mineralogy of the shell was not changed. Therefore the preservation of metastable aragonite, which is secreted by most of the molluscs (MILLIMAN, 1974), infer that the measured carbon and oxygen isotopic composition of the aragonite shell can characterize the environment in which the organism grew.

2. Methods of Work

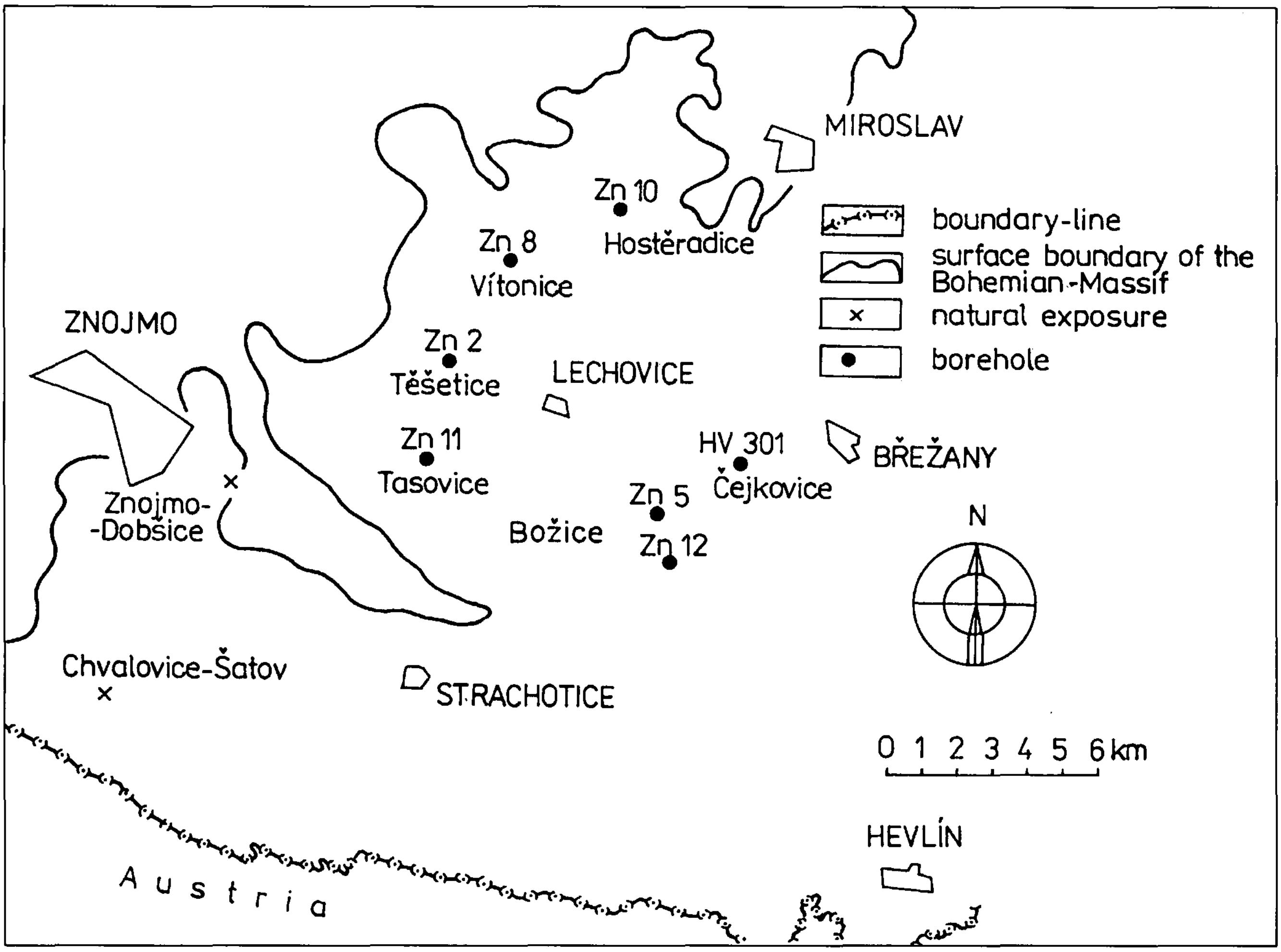
A detailed paleoecological analysis of the Eggenburgian molluscan fauna from seven boreholes (Zn-2 Těšetice, Zn-5 Božice, Zn-8 Vítonice, Zn-10 Hostěradice, Zn-11 Tasovice, Zn-12 Božice, HV-301 Čejkovice) and six natural exposures (Znojmo-Dobšice: 4 surface exposures, Chvalovice-Šatov: 2 surface exposures) was made in the SW part of the Carpathian Foredeep in Moravia (Czech Republic) (Text-Fig. 2).

Field work included the lithological documentation of the localities and the taphonomic analysis of the macrofauna. The state of preservation of the fossils, the character of their surface and degree of their rolling and sorting, the position of the shells in the sediments and their orientation were studied (sensu JANIN, 1983).

Laboratory work included first of all the preparation and determination of fossils from boreholes and localities. Further, the following characteristics were ascertained (first of all for molluscs, but roughly also for other fossils): absolute and relative number of individuals, number of genera and species in individual layers, species diversity according to SIMPSON and SHANNON-WEAVER, species dominance, coordination index (Agrell's index – LOSOS, 1980), presence, species identity (Jaccard's number – LOSOS, 1980).

On the basis of published data (AGER, 1963; BAGDASARJAN et al., 1966; BÁLDI, 1973; BAYNE, 1976; ČTYROKÝ, 1972; EBERZIN, 1960; KINNE, 1970, 1971, 1972; LADD, 1963; MARKOVSKIJ, 1966; MOORE, 1958; ODUM, 1977; REMANE & SCHLIEPER, 1971; SENEŠ, 1953, 1956, 1960; SCHLICKUM, 1960, 1961, 1962, 1963, 1964, 1965, 1966, 1967; STANLEY, 1970; TATISHVILI, BAGDASARJAN & KAZACHASHVILI, 1968; VALENTINE, 1973; VERMEIJ, 1978; ZENKEVICH et al., 1968), the mode of life of individual genera (species) and the ways of their food ingestions were analysed in detail. The orientation of the shells and taphonomic observations were evaluated and it was concluded whether the position of fossils is autochthonous or allochthonous. All the ascertained characteristics were presented in tables and graphs.

For a complex paleoecological evaluation results of older sedimentological analyses were used (KRYSTEK et al., 1980). A new sedimentological analysis was made at the Chvalovice-Šatov profiles (MINAŘÍKOVÁ in HLADILOVÁ, 1985). In addition to this paleobiologic and sedimentologic analysis, stable isotope geochemistry was applied on this material and the carbon and oxygen isotope composition of carbonate molluscan shells of the genera *Cerastoderma*, *Congeria*, *Pirenella* and *Nematurella* was determined. For this isotopic analysis, shell carbonates were reacted



Text-Fig. 2.
Map of borehole locations and surface exposures in the surroundings of Znojmo (Moravia, Czech Republic).

with 100 % H_3PO_4 in a vacuum at 25°C (McCrea, 1950). The evolved CO_2 was measured in a Finnigan MAT 251 mass spectrometer. Results are expressed in the usual way as δ values in ‰ versus PDB standard. The reproducibility of the measurement on a single carbon dioxide sample is better than ±0.1 ‰ for $\delta^{18}O$ and ±0.05 ‰ for $\delta^{13}C$ values. Most shells were analyzed as a whole. Only in some well-preserved shells of pirenells the isotope analyses both of the spire and of the basal part of the last whorl were made.

X-ray analysis (Guinier's method) was used for the determination of carbonate mineralogy. Isotopic data of aragonitic samples were corrected for reported fractionation differences between aragonite and calcite structure (Tarutani et al., 1969; Rubinson & Clayton, 1969).

By the combination of paleoecological and isotope study following paleoenvironmental factors were determined:

- ☐ water dynamics: it was reconstructed according to water dynamics demands of individual genera, sediment character, state of preservation and position of shells, analysis of food ingestion types and modes of life;
- ☐ water depth: character of sediments, depth demands of individual taxa;
- ☐ light: individual demands of fossils, character of sediments, depth, water dynamics and turbidity;
- ☐ temperature: temperature demands of individual genera;
- ☐ oxygen content: demands of genera, character of substrate, water dynamics;
- ☐ salinity: qualitative and quantitative composition of faunistic and floristic associations, their salinity demands, diversity of assemblages, isotopic analysis of C and O of shell carbonates.

3. Results and Discussion

The majority of the studied surface exposures and boreholes belonged sensu above mentioned conception (Čtyroký, 1982, 1991) to the marginal shallow-water facies of Eggenburgian age, only the Chvalovice-Šatov natural exposures belonged to the basinal development.

In the studied boreholes and natural exposures, the state of preservation of molluscan shells is mostly rather bad, incomplete shells and fragments are prevailing. Fragments are mostly sharply angular. Among bivalves, both valves were sometimes found together. Shell surfaces were mostly undamaged. Almost in all cases the position of the shells in the sediments could be interpreted as subautochthonous. The cases of allochthonous positions were excluded from further paleoecologic consideration. A slightly preferred orientation of organic remnants was ascertained at the locality Znojmo-Dobšice and together with some assorting of shells by water also in the boreholes Zn-11 and Zn-12 (Hladilová, 1985, 1987).

Table 1.
Bivalvia recovered from Early Miocene-Eggenburgian sediments of the boreholes Zn-2, Zn-5, Zn-10, Zn-11, Zn-12, HV-301 and of the natural exposures Znojmo-Dobsice and Chvalovice-Satov.

borehole / species	Zn-2	Zn-5	Zn-10	Zn-11	Zn-12	HV-301	Dobšice (nat. expos.)	Chvalovice-Šatov(nat. expos.)
?*Nucula* sp.		+	+					
Nucula nucleus LINNAEUS				+				
?*Anadara* sp.				+				
?*Atrina* sp.		+						
Ostrea sp.	+		+	+	+	+	+	
Crassostrea gryphoides (SCHLOTHEIM)	+	+						
Congeria sp.	+	+	+	+	+	+	+	
Anodonta sp.						+		
Polymesoda sp.	+	+	+	+	+			
Cavilucina cf. *schloenbachi* (KOENEN)								+
?*Thyasira* sp.				+				
Cerastoderma sp.	+	+	+	+	+	+	+	+
Laevicardium aff. *cingulatum* (GOLDFUSS)								+
Limnocardium sp.						+		
? *Limnopagetia* sp.				+				
?*Pitar* sp.			+					
? *Macoma* sp.				+				
?*Tellina* sp.		+						
Gastrana fragilis LINNAEUS				+				
Abra sp.						+		
Solemya sp.				+				
Aloidis sp.							+	+
Aloidis cf. *gibba* (OLIVI)				+		+		
Thracia cf. *pubescens* (PULTENEY)								+
?*Thracia* sp.				+				
Venus sp.	+	+		+				
Bivalvia indet.		+				+	+	

Genera and species numbers, numbers of individuals, as well as values of species diversity and dominance of individual taxons vary conspicuously in all studied boreholes and natural exposures. In all cases, only associations with a relatively low diversity were found.

The bad state of preservation of the molluscan fauna complicated its precise determination, making it sometimes impossible. Among molluscs, taxons with a broad stratigraphic range were ascertained (Tab. 1, 2). From this point of view, the microfauna – foraminifers and ostracodes – was more conclusive. The Eggenburgian ostracode *Naumannia (Neocyprideis) fortisensis* (KEY), an index fossil of NO4 zone, sensu JIŘÍČRICEK, 1983, was found at the locality Znojmo-Dobsice (HLADILOVÁ, 1987). Therefore, the Eggenburgian age of the studied sediments was accepted mostly on the basis of their superposition, micropaleontological contents and with regard to the outstanding similarity and/or identity of their faunistic and floristic associations with those from the wider area, ranged to the Eggenburgian (ČTYROKÁ, 1979; BRZOBOHATÝ, 1980; BATÍK & ČTYROKÝ, 1982; ČTYROKÝ 1982, 1991).

Our study of vertical successions of molluscan faunas from individual profiles demonstrates that two main communities were ascertained:

1) the *Congeria* sp.-*Nematurella* sp. (+ *Hydrobia* sp., *Staliopsis* sp., *Clithon* aff. *pictus*) community, prevailing in Zn-5, Zn-12, HV-301 boreholes and in the lower part of the cross-section at Znojmo-Dobsice;
2) the *Pirenella moravica*-*Cerastoderma* sp. (+*Ostrea* sp., *Crassostrea* sp.) community, prevailing in the Zn-2, Zn-8, Zn-11 boreholes and in the upper parts of the Zn-10 borehole and of the natural exposure Znojmo-Dobsice.

But from the vertical succession of the molluscan communities in the HV-301 Cejkovice borehole, where the Eggenburgian sediments were ascertained in their relatively greatest thickness, it follows that these two communities substitute each other vertically as well as laterally in dependence on the environmental conditions (HLADILOVÁ, 1988).

A quite different molluscan community was described from the locality Chvalovice-Satov, as for the species structure as well as for the state of preservation of the fossils (TEJKAL, 1958; HLADILOVÁ, 1985). This locality differs from the others in its type of sediments as well as in higher salinity values (HLADILOVÁ, 1985).

It can be shown that practically all environmental factors were highly variable in the area investigated (Fig. 3).

The depth of the sedimentation area was highly variable in the studied boreholes and natural exposures, but mostly it did not reach over 40 m. Therefore, the water dynamics was also very changeable. It influenced partly the transport of shells, partly it was the reason of the preferred orientation and assorting of molluscan shells.

The water turbidity and light penetration into the water changed slightly in dependence on the water depth and dynamics, but it can be supposed that they did not represent any limiting factors for organisms.

The water aeration (oxygen content) in individual profiles also changed, first of all in dependence of water dynamics. Some signs of reduction (occurrence of pyrite, a higher sulphur content in sediments, presence of dark-grey to black clays) were ascertained in the Zn-2, Zn-5, Zn-8, Zn-10 and HV-301 boreholes.

In some intervals of the profile of the Zn-8 borehole a possibility of eutrophication in connection with a higher amount of phytoplankton cannot be entirely excluded. But in all cases these declines of aeration were slight and

Table 2.
Gastropoda recovered from Early Miocene-Eggenburgian sediments of the boreholes Zn-2, Zn-5, Zn-11, Zn-12, HV-301 and of the natural exposure Znojmo-Dobšice.

borehole species	Zn-2	Zn-5	Zn-10	Zn-11	Zn-12	HV-301	Dobšice (nat. exp.)
Clithon pictus FÉRUSSAC				+	+	+	+
?*Eulimella* sp.							+
?*Hydrobia* sp.		+				+	+
Hydrobia aff. *ventrosa* (MONTAGU)							+
Bythinia sp.							+
Staliopsis sp.				+	+	+	+
Nematurella sp.		+		+	+	+	+
?*Ctyrokia* sp.		+		+		+	+
Pirenella moravica (M. HOERNES)	+	+	+	+		+	+
Bittium reticulatum COSTA						+	
Turritella aff. *vermicularis* BROCCHI				+			
Turritella sp.					+		
Melanopsis sp.					+		
Melanopsis impressa (KRAUSS)		+					
Natica sp.							+
Nassa sp.			+				
Hinia sp.						+	
Dorsanum cf. *nodosocostatum* HILBER				+			
Dorsanum sp.	+		+				
Dorsanum haueri MICHELOTTI						+	
?*Gyraulus* sp.						+	
Gastropoda indet.		+	+			+	+

short-dated only, not exceeding the tolerance limits of the organisms.

The temperature reconstructions confirmed the existence of subtropical climate without any fluctuations in the time and the area investigated.

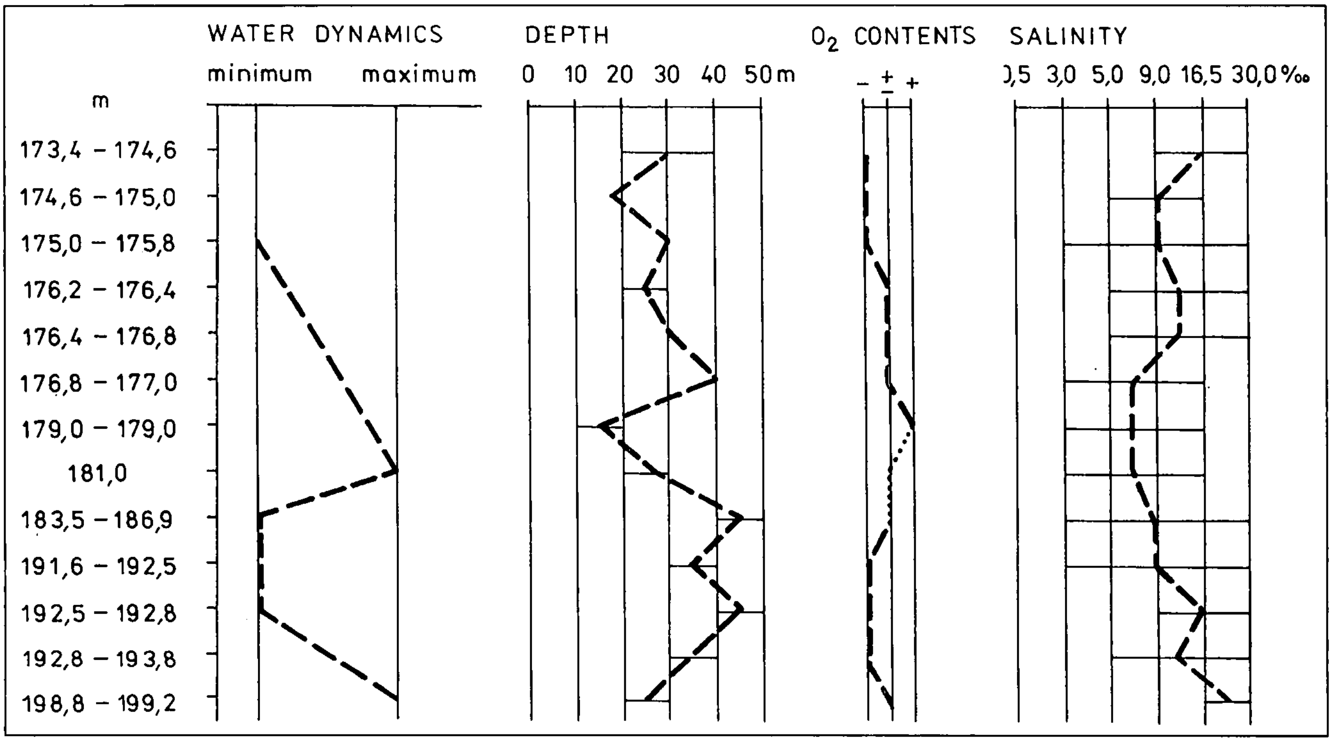
The salinity proved to be a very important environmental factor influencing the character and the evolution of faunas and floras in the area investigated. The paleobiological analysis shows that, in general, salinity values deviate from normal marine ones; only in the Zn-11 and Zn-12 boreholes and at Chvalovice-Šatov did some values correspond with the normal marine environment. The salinity changes were interpreted as a result of the changes in the communication of the individual basin areas of sedimentation with the open sea.

To describe such an unstable environment by carbon and oxygen stable isotopes and to compare the results of all of the above mentioned methods was very useful. The results of carbon and oxygen isotope analyses of carbonate molluscan shells of the genera *Cerastoderma*, *Congeria*, *Pirenella* and *Nematurella* are given at Tab. 3, 4 and in Text-Fig. 4. The results of the isotope analyses both of spire and of the basal part of the last whorl in some well-preserved shells of pirenells can be found in Tab. 5.

According to X-ray analyses all analysed molluscan shells consisted of aragonite and therefore it is possible to assume that their original isotopic composition was not changed.

It is well known that $\delta^{18}O$ values of carbonates are determined by temperature as well as by the oxygen isotopic composition of the surrounding water (CRAIG, 1965). Besides, there is also a relationship between salinity and $\delta^{18}O$ values of seawater (FAURE, 1986). By means of the paleotemperature equation (CRAIG, 1965) from the measured $\delta^{18}O$ values of carbonates it is possible to calculate either the temperature or the $\delta^{18}O$ values of the surrounding water.

The highest $\delta^{18}O$ value found in our set of molluscs is +2.2 ‰, the lowest $\delta^{18}O$ value is −4.5 ‰. In the case that oxygen isotopic composition of seawater was constant, the mentioned differences in $\delta^{18}O$ values of carbonate shells would be the result of the temperature fluctuation only, then the highest $\delta^{18}O$ value would correspond to the temperature of 3°C and the lowest one to the temperature of 32°C. According to our results of paleoecologic analysis corresponding to the opinion of other authors (DORF, 1964; STEININGER et al., 1971; PLANDEROVÁ, 1978; CICHA & KOVÁČ, 1990) there was a subtropical climate in the time of the formation of the Eggenburgian molluscs. Therefore, such changes of water temperature are unreal for seawater with a depth of about 40 metres. For example, at Bermudy, where subtropical climate prevails, the surface water temperature ranges between 16–30°C (EPSTEIN & LOWENSTAM, 1953). The measured temperatures of the Adriatic seawater in the depth of 50 m vary from 15.5 to 18.5°C and from 10 to 13°C in the depth of 100–250 m (SENEŠ, 1973). If we assume the surface temperature 25°C and the temperature 15°C in the depth of 40 m, then the difference in the $\delta^{18}O$ values of carbonate arising due to this temperature fluctuation would be only 2.3 ‰. For this



Text-Fig. 3.
Environmental analysis of borehole HV-301 CČejkovice – comparison of some environmental factors in section 173.4-210.0 m – according to HLADILOVÁ (1988).

reason, and in accordance with the paleontological conclusions, we supposed that the mentioned differences in the $\delta^{18}O$ values of carbonate shells were largely the results of the variability in the oxygen isotopic composition of the water. In such a case the salinity of water had been evidently changed and marine, freshwater and estuarine environments could have been in existence during the formation of the studied fossils. Therefore, the calculated

Table 3.
reason, Carbon and oxygen isotopic composition of various molluscs from Early Miocene-Eggenburgian sediments of the borehole HV-301 Č»ejkovice.
$\delta^{13}C$ and $\delta^{18}O$ values are expressed in ‰ (PDB).

Depth (m)	*Nematurella*		*Congeria*		*Cerastoderma*		*Pirenella*	
	$\delta^{13}C$	$\delta^{18}O$	$\delta^{13}C$	$\delta^{18}O$	$\delta^{13}C$	$\delta^{18}O$	$\delta^{13}C$	$\delta^{18}O$
173.4-173.9			-3.4	-0.6	-2.3	-1.1	-1.5	-0.7
173.9-174.8	-3.3	-1.1	-3.3	-0.3	-2.9	-1.2	-0.1	-1.2.
174.6-175.0	-4.3	+1.2	-2.4	-0.6				
175.0-175.3	-4.5	-2.5	-6.2	-1.4				
175.5-175.7	-4.1	-0.1	-2.5	-0.9			-1.5	-1.7
176.2-176.4	-2.1	-0.9	-1.6	-2.7				
176.4-176.8	-6.7	-2.3	-3.5	-1.5	-2.2	-1.1		
176.8-177.0	-2.3	-1.5	-2.1	-2.2				
179.0-179.7	-4.5	-1.9	-3.7	-0.1				
ca 181	-3.9	-2.7	-5.3	-4.5				
183.5-184.0	-3.2	-0.6	-2.8	-0.1	+0.3	-0.1		
185.0-185.7	-5.1	-1.6	-4.2	+0.2				
192.0-192.5	-3.1	+0.1	-1.3	+1.1	-2.5	+0.8	-3.6	-0.1
192.5-192.8	-5.5	-1.0	-2.6	+0.9	-1.9	-1.2	-2.2	+0.1
192.8-193.3	-3.4	+0.4	-1.2	+0.6	-1.8	+0.9		
193.3-193.8	-5.1	-0.4			-3.5	-0.7	+0.5	-0.6
207.0-210.7							-3.4	-1.6

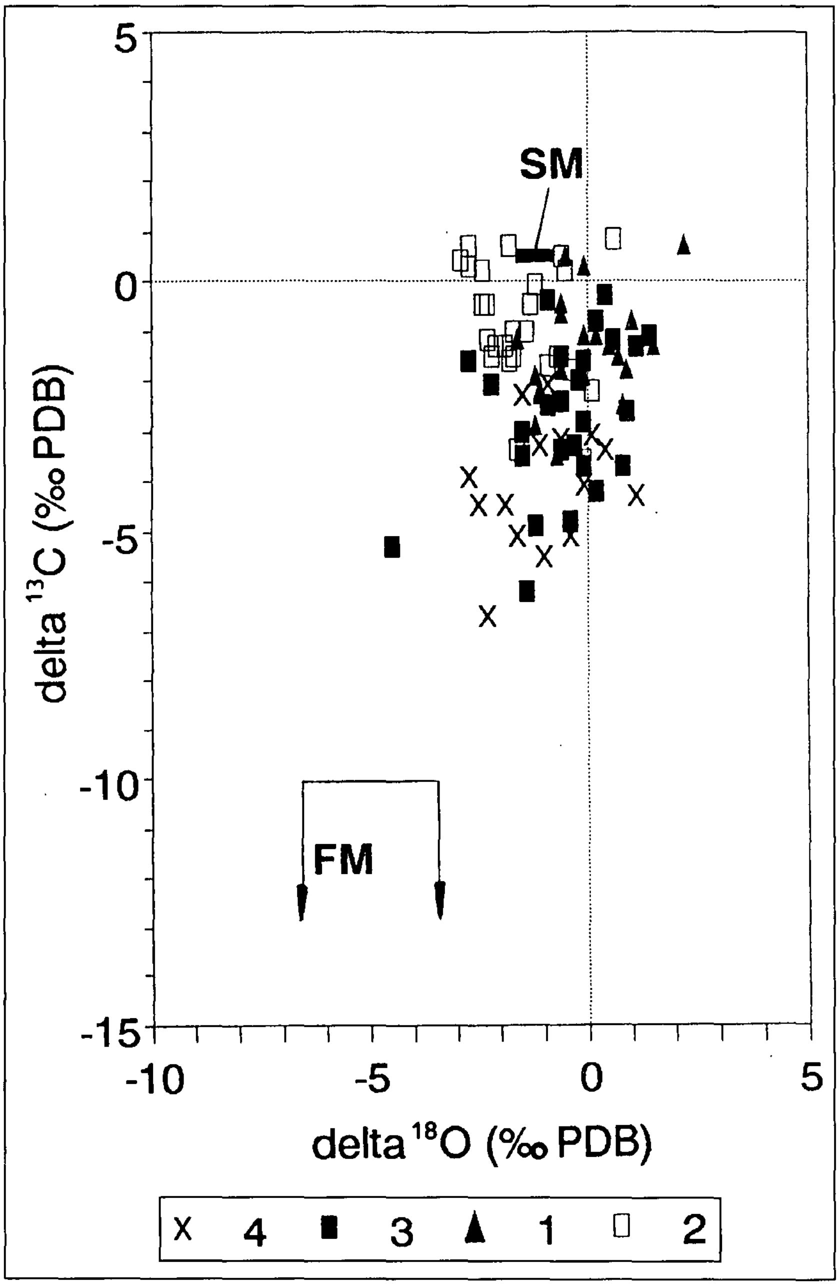
Table 4.
Carbon and oxygen isotopic composition of various molluscs from Early Miocene-Eggenburgian sediments of the boreholes Zn-2 Těšetice, Zn-5 Božice, Zn-8 Vítonice, Zn-10 Hostěradice, Zn-11 Tasovice, Zn-12 Božice and the natural exposure Znojmo-Dobšice.
$\delta^{13}C$ and $\delta^{18}O$ values are expressed in ‰ (PDB).
Pirenella: s - spire, b - base.

borehole	depth (m)		*Pirenella*		*Cerastoderma*		*Congeria*	
			$\delta^{13}C$	$\delta^{18}O$	$\delta^{13}C$	$\delta^{18}O$	$\delta^{13}C$	$\delta^{18}O$
Zn-2	57.2-58.0		-1.8	-0.4	-1.3	+1.5		
	58.0-60.0		-1.6	-1.8				
	58.5-59.0		-1.5	-2.2				
	59.0-59.8		-0.5	-1.3				
	59.8-63.4		-0.5	-2.3				
	60.5	s	-1.0	-1.7	-0.7	-0.6		
		b	-1.0	-1.4				
	63.4-65.0		+0.7	-2.7				
Zn-5	80.5-81.0		+0.7	-1.8	-1.2	-1.6	-0.4	-0.9
	81.0-81.5						-3.0	-1.5
	81.9-82.5						-1.5	-0.6
	82.0-83.0						-0.8	+0.2
Zn-8	undet.				-1.3	+0.5		
Zn-10	92.0-93.0		-1.7	-0.9	-1.5	+0.7		
	94.6-94.8	s	+0.2	-2.4			-1.6	-0.1
		b	-0.5	-2.4				
Zn-11	93.0-94.0		-1.3	-1.9	+0.7	+2.2	-1.1	+1.4
	99.0-100.0		-1.3	-2.1	-1.8	-0.6		
	100.0-101.0				-1.9	-0.1		
	102.0-104.0				-1.1	+0.2	-4.9	-1.2
	108.0-109.0	s	-1.2	-2.3	+0.5	-0.5		
	109.0-110.0	s	+0.2	-0.5	-0.5	-0.6		
		b	+0.8	+0.6				
	undet.	s	+0.3	-2.7			-4.8	-0.4
		b	+0.4	-2.9				
Zn-12	101.0-102.0				-0.8	+1.0	-3.7	+0.8
	127.0-129.0				-1.1	-0.1		
	129.0-129.5						-2.0	-0.2
	130.0-130.5						-0.3	+0.4
	131.0-131.5						-3.4	-0.6
Dobšice	layer							
(nat.ex.)	A		-0.4	-0.1	-1.7	-1.4		
	B		-1.9	-0.1	-2.0	+0.8		
	B		-0.4	+0.1	-2.8	-1.9		
	C		-1.9	+0.4	-4.2	-1.1		
	D		-4.6	+0.3	-2.5	-1.3	-3.3	0.0

ranges of the isotopic composition of carbonates formed under these environmental conditions were added to the measured $\delta^{13}C$ and $\delta^{18}O$ values of the Eggenburgian molluscs given in Text-Fig. 4. As it was mentioned above, there was a subtropical climate in the time of the deposition of the Eggenburgan molluscs and therefore we calculated the theoretical $\delta^{18}O$ carbonate values for the temperature range between 15 and 25°C. According to SAVIN (1977) the Early Miocene ocean water was depleted in $\delta^{18}O$ isotope in comparison with the present ocean water and this is why we used –1 ‰ (SMOW) for the $\delta^{18}O$ value of the Miocene seawater. The theoretical $\delta^{13}C$ value for the marine carbonate (0.60±0.11 ‰) is the average value for the Tertiary marine carbonate (VEIZER, HOLSER & WILGUS, 1980) and $\delta^{13}C$ values for freshwater carbonates are those values which are used by MOOK (1982). The $\delta^{13}C$ and $\delta^{18}O$ values of brackish water are largely determined by mixing ratio of fresh water and seawater. However, it is difficult to calculate concrete numbers for $\delta^{18}O$ values of the Miocene fresh (river) water. Direct measurements do not exist but TAYLOR (1971) measured the δD and $\delta^{18}O$ values of kaolinites from the Tertiary soils and he concluded that those values for the Tertiary meteoric waters showed the similar temperature dependence as recent meteoric waters. Considering TAYLOR's conclusions and the data on the isotopic composition of recent and paleowaters given by ROZANSKI (1983) and by SIEGENTHALER & MATTER (1983) we used the range between –4 and –6 ‰ (SMOW) for theoretical $\delta^{18}O$ values of the Tertiary fresh water in the studied area.

The carbon and oxygen isotopic composition of euryhaline molluscs from the Dutch coastal waters was studied by EISMA, MOOK & DAS (1976). These authors found a positive correlation between $\delta^{13}C$ and $\delta^{18}O$ values and salinity. It means that carbonate shells formed in water with a low salinity had lower $\delta^{13}C$ and $\delta^{18}O$ values than those formed in water with a higher salinity. Also YIN (1991) used carbon isotope data of the Jurassic shells from southern China for paleosalinity reconstruction. Both cases represent the simple mixing of two waters (i.e. seawater and river water) with different carbon and oxygen isotopic composition and then the correlation between carbon and oxygen isotope data must exist.

It is evident from Text-Fig. 4 that the molluscs under study were formed under various environmental conditions but the correlation between the $\delta^{18}O$ and $\delta^{13}C$ values was not found and, in addition to this fact, there are isotopic data which could be hardly explained by the mentioned mixing of two water types. For example, some shells with positive $\delta^{18}O$ values show negative $\delta^{13}C$ values (e.g. –4.2 ‰). Carbonate shells with positive $\delta^{18}O$ values probably were formed in lagoonal environments where the



Text-Fig. 4.
The relation between $\delta^{18}O$ and $\delta^{13}C$ values of shell carbonate from different Eggenburgian molluscs: 1: *Cerastoderma*; 2: *Pirenella*; 3: *Congeria*; 4: *Nematurella*.
SM and FM: calculated isotopic composition of seawater and freshwater molluscs.

increased evaporation of water played an important role. How to explain the negative ^{13}C value in combination with the positive $\delta^{18}O$ value? It is necessary to mention that not only marine and freshwater carbonates, but also carbon dioxide formed during photosynthesis or during decomposition of organic matter could exist in the studied environments. This carbon dioxide shows $\delta^{13}C$ values from −10 to −25 ‰ (BUCHARDT & FRITZ, 1980). And just this third source of carbonate carbon could be present in lagoons as well as in other environments rich in flora. This is the possible way of explaining why the $\delta^{13}C$ values of shell carbonates are lower than the $\delta^{13}C$ values given by VEIZER, HOLSER & WILGUS (1980) for the Tertiary marine carbonates.

Due to its relatively greatest thickness of the Eggenburgian sediments, the Čejkovice HV-301 borehole was the best profile for the comparison of results of paleoecological and isotopic analyses. From all environmental factors, only changes of salinity and temperature could affect the oxygen isotope composition of carbonate shells. It means that lower temperature values (a deeper water) and higher salinity values resulted in the increasing of the $\delta^{18}O$ values of carbonate shells and vice versa. The depth of water in most parts of the HV-301 borehole varied between 25 and 45 m (Text-Fig. 3). We suppose that these differences in water depth were connected with an insignificant variability in temperature. Only the range between 177 and 187 m was characterized by a distinct shallowing of water depth and due to the higher temperature the $\delta^{18}O$ values of carbonate shells could increase of about 2 ‰. The water salinity varied between 9 and 16 ‰ in most of the intervals of this borehole, the lowest salinity was found in the interval 177–181 m (Text-Fig. 3). The magnitude of lowering of the $\delta^{18}O$ values of carbonate shells due to mixing with fresh water depends on the oxygen isotopic composition of this fresh water. If the above mentioned assumption on the oxygen isotopic composition of the fresh water is valid, the $\delta^{18}O$ values of freshwater carbonates formed under 20°C will vary between −3.3 and −5.3 ‰. Only *Congeria* and *Nematurella* occurred in the whole profile, therefore all changes in the oxygen isotopic composition could be studied on these molluscs. It is evident (Tab. 3) that the differences between the highest and the lowest $\delta^{18}O$ values are higher than the calculated differences corresponding to temperature changes. It is also evident that the lowest $\delta^{18}O$ values of both molluscan genera are in the interval with the lowest salinity. Even the $\delta^{18}O$ value for *Congeria* in 181 m is close to the $\delta^{18}O$ value for freshwater carbonate. Therefore, it is reasonable to assume that the changes in salinity affected the $\delta^{18}O$ values of carbonate in a greater extent than temperature fluctuations.

In most cases different genera were analysed from one given depth interval of boreholes (Tab. 3, 4) and only in some cases the identical $\delta^{18}O$ values were found for shells of 2 or 3 genera (e.g. borehole HV-301, depth 173.9–174.8 m and borehole Zn-12, 101–102 m). In the majority of the other sections the $\delta^{18}O$ values as well as $\delta^{13}C$ values are different for different genera. The maximum difference between $\delta^{18}O$ values of different fossils (i.e. 3.3 ‰) was found for borehole Zn-11, depth 93–94 m, the maximum difference between $\delta^{13}C$ values (i.e. 5.1 ‰) was found for borehole Zn-11 (depth undetermined) – Tab. 4.

The mentioned variations of $\delta^{18}O$ and $\delta^{13}C$ values in given parts of boreholes may be explained by means of the following factors:

a) various life habitats of different genera;
b) subautochthonous position of fossils in sediments;

Table 5.
Variations of oxygen and carbon isotopic ratios during the growth of *Pirenella* (boreholes Zn-2, Zn-10, Zn-11).

borehole	Zn-2		Zn-2		Zn-10		Zn-10		Zn-11		Zn-11		Zn-11	
depth (m)	58.5-59.0		60.5		94.6-94.8 a		94.6 - 94.8 b		undet.		93.0-94.0		109.0-110.0	
	δC	δO	δC	δO	δC	δO	δC	δO	δC	δO	δC	δO	δC	δO
spire	-1.2	-0.4	-1.0	-1.7	-0.9	-0.7	+0.2	-2.4	+0.3	-2.7	-0.4	-1.4	+0.2	-0.5
centre									-0.4	-2.6				
base	-1.6	-1.2	-1.0	-1.4	+0.1	-0.5	-0.5	-2.4	+0.4	-2.9	0.0	-1.0	+0.8	+0.6

c) variability in $\delta^{18}O$ values of water and $\delta^{13}C$ values of dissolved carbonate carbon at the period when the studied section of the borehole was deposited.

By evaluating these three factors we conclude that the various habitats of different fossil genera could not be the main factor causing the variations in the $\delta^{13}C$ and $\delta^{18}O$ values of carbonate shells because all analysed organisms were able to live in water with different salinity. Besides, if we calculated the differences between the highest and the lowest $\delta^{18}O$ values of individual fossil genera, we obtained practically the same values (i.e. 3.5; 3.8; 3.9 ‰) for *Pirenella*, *Cerastoderma* and *Nematurella* but this difference for *Congeria* was 5.9 ‰. The lowest $\delta^{18}O$ value from the whole set of data (–4.5 ‰) was found for *Congeria* (borehole HV-301, depth 181 m). This fact seems to be in accordance with the paleoecological data about the genus *Congeria*.

The subautochthonous position of fossils could be the reason of the $\delta^{18}O$ and $\delta^{13}C$ values in such environments. The individual original microenvironments probably differed mutually and the shells originating in such conditions held their isotopic composition even during the postmortal transport.

The main factor affecting the variability of $\delta^{18}O$ values in the discussed fauna was probably the fluctuation of salinity which is also confirmed by paleontological methods. However, it is necessary to state that the effect of temperature differences arising between deeper and shallower waters on the $\delta^{18}O$ values could not be omitted as discussed above.

In some shells of the genus *Pirenella* we analysed both the spire part and the basal part of the shell (Tab. 5). This analysis proved that the spire (e.g. the part of shell which formed first) grows in general in an environment with a lower salinity, than does the youngest part of the shell. This fact seems to be in accordance with the recent ecologic observations (MOORE, 1958; VALENTINE, 1973 etc.) that juveniles usually prefer water with lower salinity. The found differences in the isotopic composition of individual shells during their growth are at the same time smaller than the differences in the whole set of fossils. This fact evidently corresponds with the commonly high dynamics of the environment under study and with the subautochthonous deposition of fossils.

4. Conclusions

① In the SW part of the Carpathian Foredeep in Moravia, a detailed paleoecologic analysis of Eggenburgian molluscan communities from seven boreholes and six natural exposures was made. For this analysis, the results of paleobiology, carbon and oxygen isotopic analysis of the carbonate shells of molluscan genera *Congeria*, *Cerastoderma*, *Pirenella* and *Nematurella* as well as sedimentology were utilized.

② The state of preservation of studied molluscan shells is mostly rather bad, incomplete shells and fragments are prevailing. Almost in all cases the position of shells in sediments could be interpreted as subautochthonous. Practically all the quantitative and qualitative characteristics of molluscan assemblages vary conspicuously in time and space.

③ The two main characteristic molluscan communities, namely *Congeria* sp.-*Nematurella* sp. (+*Hydrobia* sp., *Stalіopsis* sp., *Clithon* aff. *pictus*) community and *Pirenella moravica*-*Cerastoderma* sp. (+*Ostrea* sp., *Crassostrea* sp.) community were ascertained. Both of these communities are generally relatively poor and they substitute each other vertically as well as laterally in dependence on variable environmental conditions.

④ It was confirmed that – except temperature – practically all environmental factors (water depth and dynamics, light, aeration, salinity) were highly variable in all of the studied localities and boreholes. Therefore, the local marine environment as a whole was relatively very unstable during the Eggenburgian time. A shallow-water sedimentation (~40 m) dominated generally.

⑤ Namely the water salinity represents a very important environmental factor for the studied area. According to both paleobiological and isotopic analyses, the salinity values differed mostly from normal marine ones. These salinity fluctuations were interpreted as consequences of changes in the communication of individual sedimentation areas with the open sea.

⑥ The results of this complex paleoecological analysis confirmed the hitherto opinions regarding the Eggenburgian sedimentation area in the SW part of the Carpathian Foredeep in Moravia as highly differentiated. Its variability is caused by a transgression on a weathered, very pronounced basement relief, giving rise to a number of partial basins with highly complicated contours of their shorelines and with a variable mutual communication as well as a communication with the open sea.

⑦ The comparison of the individual possibilities of paleontology and stable isotopic analysis in these paleoecological reconstructions proves their narrow cooperation to be very useful. However, it is necessary to have in mind that paleontological and isotopic methods of investigation are different. Conclusions made from a paleontological study are based on statistical treatment of data whereas conclusions made from an isotopic study are supported by analyses of individual shells.

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References

Ager, D.V.: Principles of Paleoecology. An Introduction to the Study of How and Where Animals and Plants Lived in the Past. – 371 pp., New York (Mc Graw Hill Book Co. Inc.) 1963.

Bagdasarjan, K.G., Tatishvili, K.G., Kazachashvili, Zh.R., Muschelishvili, L.V. et al.: Spravochnik po ekologii morskich dvustvorok. – 353 pp., Moscow (Nauka) 1966.

Báldi, T.: Mollusc fauna of the Hungarian Upper Oligocene (Egerian). – 511 pp., Budapest (Akadémiai Kiadó) 1973.

Báldi, T. & Seneš, J.: Chronostratigraphie und Neostratotypen. Miozän OM – Egerien. – 580 S., Bratislava (Veda, SAV) 1975.

Batík, P., Čtyroký, P. et al.: Vysvětlivky k základní geologické mapě ČSSR 1:25 000 34–131 Šatov. – 62 pp., Praha (ÚÚG) 1982.

Bayne, B.L.: Marine mussels, their ecology and physiology. – 506 pp., Intern. Biol. Programme 10, Cambridge – New York – London – Melbourne (Cambridge Univ. Press) 1976.

Bowen, R.: Paleotemperature Analysis – Methods in Geochemistry and Geophysics, 265 S., Amsterdam (Elsevier) 1966.

Brzobohatý, R.: Mikrofauna některých hydrogeologických vrtů v jihozápadní části karpatské předhlubně na Moravě. – Zem. Plyn Nafta, **25**, 2, 153–160, Hodonín 1980.

Buchardt, D. & Fritz, P.: Environmental isotopes as environmental and climatological indicators. – Handbook of Environmental Isotope Geochemistry, 1–236, Amsterdam (Elsevier) 1980.

Cicha, I., Seneš, J. & Tejkal, J.: Chronostratigraphie und Neostratotypen. Miozän M3 – Karpatien. – 316 S., Bratislava (Veda, SAV) 1967.

Cicha, I. & Kováč, M.: Neogene climatic changes and geodynamics of the Central Paratethys. – In: Minaříková, D. & Lobitzer, H.: Thirty years of geological cooperation between Austria and Czechoslovakia, 70–78, Praha 1990.

Craig, H.: The measurements of oxygen paleotemperatures. – Proc. Spoleto Conf. Stable Isotopes Oceanogr. Stud. Paleotemp., **3**, 1965.

Čtyroká, J.: Mikrobiostratigrafie neogénu v průzkumných hydrogeologických vrtech Geotestu v jižní části karpatské předhlubně. – MS Arch. ÚÚG Praha 1979.

Čtyroký, P.: Die Molluskenfauna der Rzehakia-(Oncophora)-Schichten Mährens. – Ann. Naturhist. Mus. Wien, **76**, 41–141, Wien 1972.

Čtyroký, P.: Spodní miocén (eggenburg a ottnang) jz. části čelní hlubiny na Moravě. – Zem. Plyn Nafta, XXVII (1982), **4**, 379–394, Hodonín 1982.

Čtyroký, P.: Division and correlation of the Eggenburgian and Ottnangian in the southern Carpathian Foredeep in southern Moravia. – Západ. Karpaty, Sér. Geol., **15**, 67–109, Bratislava 1991.

Dorf, E.: The use of fossil plants in paleoclimatic interpretation. – In: Nairn, A. (ed.): Problems in Paleoclimatology, 13–31, London – New York (Interscience) 1964.

Eberzin, A.G.: Osnovy paleontologii. Molljuski – pancirnye, dvustvorchatye, lopatonogie. – 303 pp., Moscow (Akademia Nauk) 1960.

Eisma, D., Mook, W.G. & Das, A.: Shell characteristics, isotopic composition and trace element contents of some euryhaline molluscs as indicators of salinity. – Palaeogeogr., Palaeoclimatol., Palaeoecol., **19**, 39–62, Amsterdam 1976.

Epstein, S. & Lowenstam, H.A.: Temperature-shell growth relations of Recent and interglacial Pleistocene shoal water biota from Bermuda. – J. Geol., **61**, 424–438, Chicago 1953.

Faure, G.: Principles of isotope geology. – 2nd ed., 439 pp., New York 1986.

Hladilová, Š.: Paleoekologické vyhodnocení populací měkkýšů eggenburgu JZ části karpatské předhlubně na Moravě. – Thesis, MS Arch. MU, Brno 1985.

Hladilová, Š.: Paleoekologické výzkumy v eggenburgu na lokalitě Znojmo-Dobšice (in Czech). – In: 3. pracovní seminář z paleoekologie, Sborník konference, Kat. geol. a pal. PřF UJEP, 107–123, Brno 1987.

Hladilová, Š.: Paleoecology of the Eggenburgian molluscs (Bivalvia, Gastropoda) from the borehole HV-301 Čejkovice, Moravia. – Čas. Mineral. Geol., **33**, 3, 299–309, Praha 1988 (English summary).

Hudson, J.D.: Stable isotopes and limestone lithification. – Jour. Geol. Soc., **133**, 637–660, Oxford 1977.

Janin, B.T.: Osnovy tafonomii. – 184 S., Moscow (Nedra) 1983.

Jiříček, R.: Redefinition of the Oligocene and Neogene ostracod zonation of the Paratethys. – Knih. Zem. Plyn Nafta, **4**, 195–236, Hodonín 1983.

Kinne, O.: Marine Ecology. Vol.I – Environmental Factors, Part I, 2, 3. – 681 pp., 561 pp., 503pp., London – New York – Sydney, Toronto (Wiley-Interscience) 1970, 1971, 1972.

Kováč, M., Cicha, I., Krystek, I., Slaczka, A., Stráník, Z., Oszczypko, N. & Vass, D.: Palinspastic maps of the Western Carpathian Neogene, scale 1:1 000 000, Geol. Surv., Praha 1989.

Krystek, I. et al.: Sedimentologický a sedimentárně-petrografický výzkum neogénu karpatské předhlubně – úsek "JIH". – MS Fac. of Science, Masaryk University, Brno 1980.

Ladd, H.S.: Treatise on Marine Ecology and Paleoecology. Vol. 2 – Paleoecology. – Mem. Geol. Soc. Amer., **67**, 1–1077, New York 1963.

Losos, B.: Ekologie živočichů. – 307 pp., Brno (UJEP) 1980.

Markovskij, B.P.: Metody biofacialnogo analiza. – 170 pp., Leningrad (Nedra) 1966.

McCrea, J.M.: On the isotopic chemistry of carbonates and paleotemperature scale. – J. Chem. Phys., **18**, 849–857, London 1950.

Milliman, J.D.: Marine Carbonates. – New York (Springer) 1974.

Mook, W.G.: Isotope geochemistry. – In: Natural stable isotopes for sediment transport studies, Delft Hydraulic Laboratory, **271**, Delft 1982.

Moore H.B.: Marine Ecology. – 493 pp., New York – London (Wiley & Sons) 1958.

Odum, E.P.: Základy ekologie. – 736 pp., Praha (Academia) 1977.

Papp, A., Cicha, I., Seneš, J., Steininger, F. et al.: Chronostratigraphie und Neostratotypen. Miozän M4 – Badenien. – 600 S., Bratislava (SAV) 1978.

Papp, A., Rögl, F., Seneš, J. et al.: Chronostratigraphie und Neostratotypen. Miozän M5 – Sarmatien. – 708 S., Bratislava (SAV) 1973.

Planderová, E.: Microflorizones in Neogene of Central Paratethys. – Západ. Karpaty, Geol., **3**, 7–34, Bratislava 1978.

Remane, A. & Schlieper, C.: Biology of Brackish Water. – 372 pp., Stuttgart (E. Schweitzerbartsche Verlagsbuchh.) 1971.

Rozanski, K.: Temporal and spatial variations of deuterium and oxygen-18 in European precipitation and groundwater. – ZFI Mitt.: Isotope in der Natur, 341–353, Leipzig 1983.

Rubinson, M. & Clayton, R.N.: Carbon-13 fractionation between aragonite and calcite. – Geochim. Cosmochim. Acta, **33**, 997–1002, Oxford 1969.

Savin, S.M.: The history of the Earth's surface temperature during the past 100 million years. – Ann. Rev. Earth. Planet. Sci., **5**, 319–355, 1977.

Seneš, J.: Príspevok k biocenózam mäkkýšov v morských litorálnych sedimentoch. – Geol. Sbor. Slov. Akad. Vied, **4**, 3–4, 883–892, Bratislava 1953.

Seneš, J.: Hojnosť niektorých druhov mäkkýšov vo fosílnych brakických sedimentoch. – Geol. Sbor. Slov. Akad. Vied, **7**, 214–221, Bratislava 1956.

Seneš, J.: Príspevok k problémom fosílnych brakických biotopov. – Geol. Práce, Spr., **19**, 27–58, Bratislava 1960.

Seneš, J.: Faciálne analýzy adriatického šelfu z aspektu potrieb geológie. – Manuscript, Bratislava 1973.

Schlickum, R.W.: Die Gattung *Nematurella* Sandberger. – Arch. Molluskenkde, **89**, 4–6, 203–214, Frankfurt a. M. 1960.

Schlickum, R.W.: Die Gattung *Euchilus* Sandberger. – Arch. Molluskenkde, **90**, 1/3, 59–68, Frankfurt a.M. 1961.

Schlickum, R.W.: Die Gattung *Limnopagetia* n. gen. – Arch. Molluskenkde, **91**, 1/3, 109–115, Frankfurt a. M. 1962.

Schlickum, R.W.: Die Molluskenfauna der Süssbrackwassermolasse von Ober- und Unterkirchberg. – Arch. Molluskenkde, **92**, 1/2, 1–10, Frankfurt a. M. 1963.

Schlickum, R.W.: Die Molluskenfauna der Süssbrackwassermolasse Niederbayerns. – Arch. Molluskenkde, **93**, 1/2, 1–70, Frankfurt a. M. 1964.

Schlickum, R.W.: Zur Gattung Euchilus Sandberger. – Arch. Molluskenkde, **93**, 3/4, 99–104, Frankfurt a. M. 1965.

Schlickum, R.W.: Die Molluskenfauna der Kirchberger Schichten des Jungholzes bei Leipheim/Donau. – Arch. Molluskenkde, **95**, 5/6, 321–335, Frankfurt a. M. 1966.

Schlickum, R.W.: Zur Molluskenfauna der Süssbrackwassermolasse Niederbayerns, 2. Gattung *Limnopagetia* Schlickum. – Arch. Molluskenkde, **96**, 3/6, 175–179, Frankfurt a. M. 1967.

Siegenthaler, U. & Matter, H.A.: Dependence of $\delta^{18}O$ and δD in precipitation on climate. – In: Paleoclimates and paleowaters: a collection of environmental isotope studies, IAEA, 37–51, Vienna 1983.

Stahl, W. & Jordan, R.: General consideration on isotopic paleotemperature determinations and analyses on Jurassic ammonites. – Earth Planet. Sci. Lett., **6**, 173–178, Amsterdam 1969.

Stanley, S.S.: Relation of Shell Form to Life Habits in the Bivalvia (Mollusca). – Mem. Geol., Soc. Amer., **125**, 1–296, Colorado (Boulder) 1970.

Steininger, F., Seneš, J. et al.: Chronostratigraphie und Neostratotypen. Miozän M1 – Eggenburgien. – 828 S., Bratislava (SAV) 1971.

Tarutani, H.P., Clayton, R.N. & Mayeda, T.K.: The effect of polymorphism and magnesium substitution on oxygen isotope fractionation between calcium carbonate and water. – Geochim. Cosmochim. Acta, **33**, 987–996, Oxford 1969.

Tatishvili, K.G., Bagdasarjan, K.G. & Kazachashvili, Zh.R.: Spravochnik po ekologii morskich bryuchonogich. – 169 pp., Moscow (Nauka) 1968.

Taylor, H.P.: Oxygen isotope evidence for large-scale interaction between meteoric ground waters and Tertiary granodiorite intrusions, Western Cascade Range, Oregon. – J. Geophys. Res., **76**, 7855–7874, Washington 1971.

Tejkal, J.: Spodnomiocenní (?) písky mezi Šatovem a Chvalovicemi a jejich fauna. – Čas. Morav. Muz. (Brno), Vědy přír., **43**, 85–94, Brno 1958.

Urey, H.C., Lowenstam, H.A., Epstein, S. & McKinney, C.R.: Measurements of paleotemperatures and temperatures of the Upper Cretaceous of England, Denmark, and the southeastern United States. – Bull. Geol. Soc. Am., **62**, 339–416, New York 1951.

Valentine, J.E.: Evolutionary Paleoecology of the Marine Biosphere. – 471 pp., New Jersey (Prentice-Hall) 1973.

Veizer, J., Holser, W.T. & Wilgus, Ch.K.: Correlation of $^{13}C/^{12}C$ and $^{32}S/^{34}S$ secular variations. – Geochim. Cosmochim. Acta, **44**, 579–587, Oxford 1980.

Vermeij, G.J.: Biogeography and Adaptation. – 332 pp., Cambridge, Massachusetts – London (Harvard Univ. Press) 1978.

Yin, J.: Stable carbon and oxygen isotopes in Jurassic shells as paleosalinity indicators. – N. Jb. Geol. Paläont. Mh., **3**, 163–176, Stuttgart 1991.

Zenkevich, L.A. et al.: Zhizn zhivotnych. Bespozvonochnye. 2. – 193 pp., Moscow (Prosveshchenie) 1968.

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