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Badenian Palaeoenvironment, Faunal Succession and Biostratigraphy: A Case Study from Northern Vienna Basin, Devínska Nová Ves-Bonanza site (Western Carpathians, Slovakia)

by

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Abstract

Three important Badenian sites (Devínska Nová Ves-Fissures, Devínska Nová Ves-Bonanza, Devínska Nová Ves-Sandberg) are situated in NE margin of the Vienna Basin. Based on their fossil and sedimentary contents the localities can be biostratigraphically positioned in the Middle to Late Badenian (MN 6). Fossil assemblages show a faunal succession, which is determined by palaeoenvironmental changes. These changes were caused by a palaeogeographic turnover, representing gradual transition from terrestrial to marine conditions. The palaeoenvironmental changes follow the development of a mountain landscape and river net, as well as gradual transgression during the Late Badenian. The marine flooding was beside tectonics also most likely controlled by orbitally forced cycles. From this viewpoint, Bonaza site plays a key role, connecting the sites of Devínska Nová Ves-Fissures and Devínska Nová Ves-Sandberg with respect to the biostratigraphy as well as the palaeoenvironmental changes.

Keywords: Faunal succession, Palaeoenvironment, Biostratigraphy, Badenian, Vienna Basin

Zusammenfassung

Drei wichtige Fundstellen des Badeniums (Neudorf-Spalte, Neudorf-Bonanza, Neudorf-Sandberg) liegen am NE-Rand des Wiener Beckens. Aufgrund ihrer biostratigraphischen und sedimentologischen Beschaffenheit werden sie in das mittlere bis spätere Badenien gestellt (MN 6). Die Fossilgesellschaften zeigen eine Faunensukzession, die durch Umwelteinflüsse gesteuert war. Diese Veränderungen waren die Folge von starken paläogeographischen Umstellungen, nämlich des Wechsels von terrestrischen zu marinen Bedingungen. Die Änderungen des Paleoenvironments folgten der Heraushebung einer Bergkette und dem dazugehörigen Flussnetz wie auch der schrittweisen Transgression während des späten Badeniums. Neben tektonischen Ursachen waren wohl vor allem Schwankungen der Erdumlaufbahn Ursache dieser Transgression. Unter diesem Gesichtspunkt fällt der Fundstelle Bonanza eine Schlüsselrolle bei der Verbindung der Fundstellen Neudorf-Spalte und Neudorf-Sandberg hinsichtlich Biostratigraphie und Umweltveränderungen zu.

1. Introduction

Three important Badenian sites are situated at the NE margin of the Vienna Basin – Devínska Nová Ves-Fissures (former Neudorf a. d. March), Devínska Nová Ves-Sandberg and the recently discovered Devínska Nová Ves-Bonanza. The latter is located in the eastern part of the former Stockerau limestone quarry, situated on the northern slope of Devínska Kobyla Hill near the village of Devínska Nová Ves (geographic co-ordinates of the site are 48° 12' N and 17° 01' E) (Fig. 1). Although limestone was extracted in the quarry from 1891 to the 1970s (BIZUBOVÁ & MINÁR, 2005), the site was only discovered in 1984 by the amateur palaeontologist Štefan Meszároš (HOLEC et al., 1987).

Meszároš' collection of the first known vertebrate fossils from the site was listed by HOLEC et al. (1987) and today, it is housed in the Slovak National Museum – Natural History Museum. This first list of Bonanza's vertebrates was reviewed by HOLEC & SABOL (1996, 2004, 2005), HOLEC (1997), SABOL & HOLEC (2002), and SABOL et al. (2004).

A description of the remains of the postcranial skeleton, together with the preserved ilium of the *Ophisaurus* specimen in its original position, were the first published vertebrate fossils from the site (KLEMBARA, 1986). Two years later, HODROVÁ (1988) alluded to the Miocene frog assemblage from the site and this was partly revised by ŠPINAR et al. (1993). They also described a new narrow-headed toad species (*Bufo priscus*) on the basis of an almost complete skeleton, several isolated bones, and part of the vertebral column. The snake assemblage of the site

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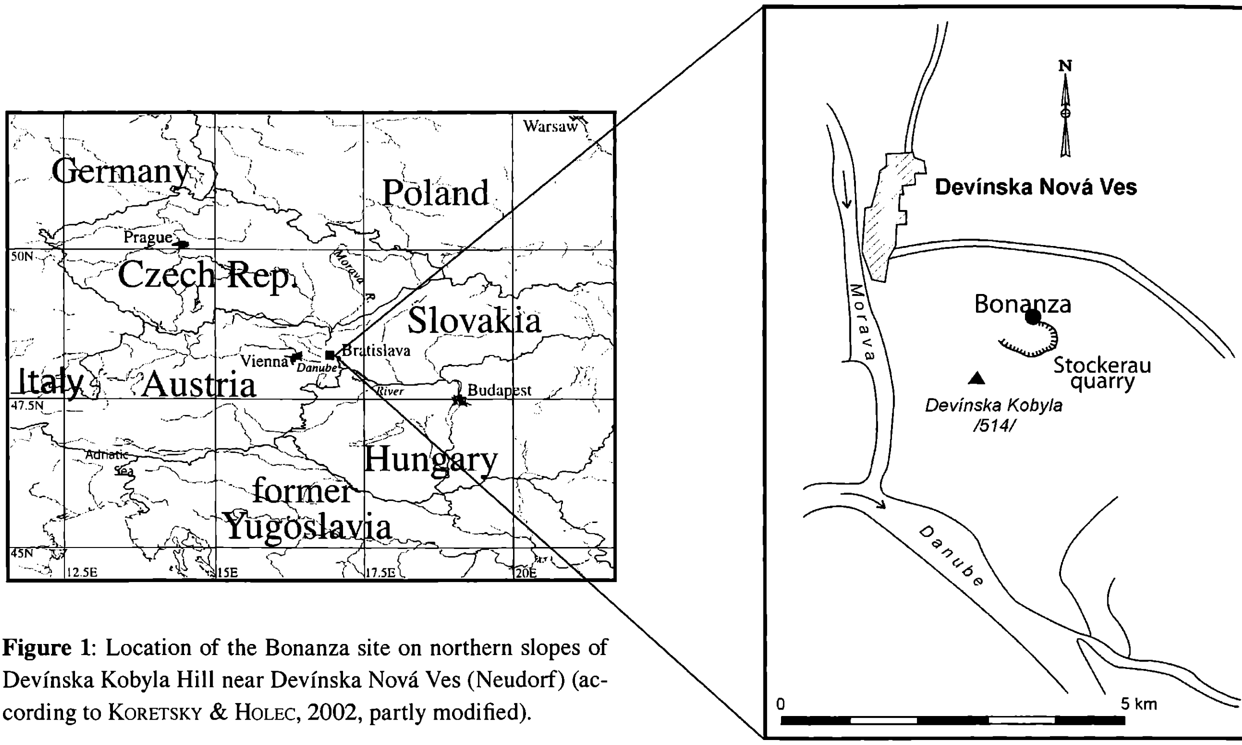

Figure 1: Location of the Bonanza site on northern slopes of Devínska Kobyla Hill near Devínska Nová Ves (Neudorf) (according to Koretsky & Holec, 2002, partly modified).

was studied by Ivanov (1998), who distinguished three taxa of European colubrid snakes.

The site, however, is especially famous for the findings of mammals, particularly those of primitive Miocene seals. The occurrence of their cranial fossils initiated thorough excavations by a scientific team consisting of palaeontologists from the Comenius University, the Slovak National Museum (Bratislava), and also from the Smithsonian Institution (Washington). A desciption of a new seal taxon (Koretsky & Holec, 2002) was the main result of this bi-annual research (1997-1998). During the excavations, a poor assemblage of sharks was also found (Holec, 2001).

The last sampling from fossiliferous deposits of the site focused on small mammals. It was connected with a revision of former micromammalian records, and it was completed in 2001-2002. As with the previous research, it also yielded a description of a new species of small talpid – *Storchia meszaroshi*, and other taxa of micromammals thus far unknown from the site (Sabol, 2005, *in press*). Furthermore, other interesting fossils are still under study (e.g., unique cranial remains of terrestrial carnivores studied by M. Wolsan and P. Lupták).

The richness of the whole fossil assemblage of Devínska Nová Ves-Bonanza, dating to the Badenian (Holec et al., 1987; Fejfar, 1990), makes the site important for interregional correlations from both biostratigraphic and palaeoenvironmental points of view.

2. Geological settings

Badenian deposits of the NE Vienna Basin margin are represented by the Middle Badenian Devínska Nová Ves Member (Vass et al., 1988), consisting of talus and alluvial fan sediments, transported in aquatic environment by slumps and gravity flows. The Studienka Formation was deposited towards the overlying strata (Špička, 1966). The basin margin of the Upper Badenian formation contains mostly grey calcareous clays, passing into shallow water sandy deposits with algal limestones of the Sandberg Member (Baráth et al., 1994). This sediment type was also found at the studied site.

The Bonanza locality consists of a broad fissure in a WNW – ESE direction, and it is situated in a rock wall of Lower Jurassic limestone breccia with fragments of underlying Triassic dolomite (Mišík, 1997). The Mesozoic rock surface indicates a cliff position affected by wave surf action (Holec et al., 1987).

The width of the fissure varies from 2.6 to 3.5 metres and its exposed part is more than five metres high. It is filled with limestone debris, boulders and marine sandy deposits (Fig. 2).

The sedimentary record of the fissure infill, as well as faunal remnants in individual layers' document an apparent cycle associated with changes in position of the coastal line. Shifts of the Late Badenian seashore towards the land or seawards could be caused by relative sea level changes of the Milankovich type, but also by intensive storm events. The sea-level rise led firstly to penetration of wave activity onto rocky cliff fissures, causing erosion of older sediments (mostly terrestrial fill) and the development of lag deposits containing fossil remains of terrestrial vertebrates. These were sometimes mixed with marine organisms (layers 17, 16, 13, 7-11, and layer 4). During the following period of sea flooding, littoral sediments containing marine fossils were deposited (layers 14-15, 12, 5-6, and probably layers 1-3). The aggradational part at the end of the sedimentary cycle changed to progradational infill of fissures, due to the bypass of coarse clastics from the seashore towards the basin (layers 5 and 1). The sediment transport may have been induced by the sea level fall, storms or other events.

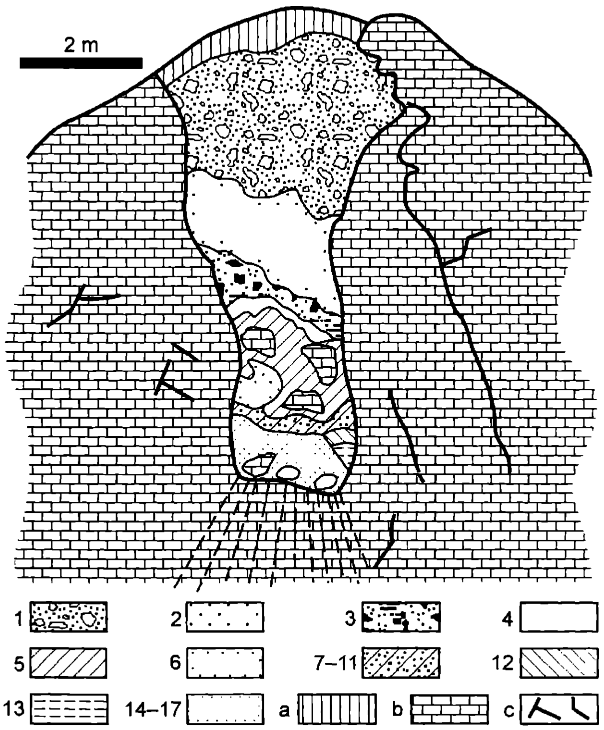

Figure 2: Generalised section through the sediments of Bonanza (according to IVANOV, 1998).

1 – fine limestone debris; 2 – white lime sand; 3 – disaggregating sandstone with a higher content of muscovite; 4 – solid, light yellow marlstone with a great quantity of fossils; 5 – big boulders with white lime matter; 6 – greenish sand with interbeds of white lime matter; 7-11 – layers with coarse-grained, disaggregating sandstone without fossils to the fossiliferous marl, rich in fossils; 12 – white calciferous sandstone; 13 – yellowish-white sand with a large quantity of fauna; 14-17 – greenish to light sandstone, the biggest quantity of fossils are contained in the layer No. 17; a – Holocene humus-carbonate soil; b – Lias limestone; c – tectonic faults.

It is also important to note that the erosion could have been repeated many times, and therefore it is impossible to connect the individual cycles separated by a hiatus of unknown duration.

The detailed description of Bonanza's fissure sedimentary fill and its individual seventeen layers can be found in HOLEC et al. (1987).

3. Taphonomy

The described fossil assemblage of Devínska Nová Ves-Bonanza comes mostly from two main fossiliferous layers – 11 (terrestrial fauna) and 13 (mixed marine and terrestrial fauna). Fossil remains of vertebrates are rarer in other fossiliferous layers. The fossils were collected either during the excavations at the site or by sorting of screen washing residues. Whereas findings from loose sand consist mainly of isolated teeth, bones or other skeleton fragments, the record from cemented rock (sandstone or laminated carbonate) is mostly unbroken, less disturbed, and almost entirely preserved.

Results of basic taphonomic analysis indicate several modes of animal bone accumulation at Devínska Nová Ves-Bonanza. There are undisturbed remains of terrestrial vertebrates from cemented rock fossilized in a low energy sedimentary environment without apparent water transport. However, isolated fossils from the loose sandy deposits indicate an increase of disturbance during the deposition of the uncemented fossiliferous sediments. Post-mortem processes (natural and/or forced disarticulation of skeletal remains and short-distance transport) also played a definite role. So far, no evidence of post-depositional modification of assemblage from fossiliferous sediments has been found. The accumulation of fossils was associated with the deposition of marine sandy deposits in coastal conditions with sea level changes.

From a taphonomic viewpoint, fossils of micromammals and seal coprolites full of fish remains are also interesting. In the case of small mammals, a greater occurrence of juveniles was discovered. Their presence in the fossil assemblage is probably connected with a role of the fissure/-s in a karstic area representing a trap during sea level falls, mainly for young, callow animals. On the other hand, the assumed karstic area may have been partly flooded during a rise in sea level, and serving as a shelter for seals and other marine animals.

4. Palaeoenvironmental Aspects of the Bonanza's Fauna

Invertebrates: Thus far, the studied invertebrate fauna consists of marine lamellibranches and terrestrial gastropods (Tab. 1).

The diversity of bivalve species is very low – only shells and/or ichnofossils of five taxa have been found. Despite this, the discovered bivalve taxa allow their separation into three distinct habitats from which they originated:

1. An autochthonous bivalve palaeo-community with *Loripes* (*Microloripes*) *dentatus* living in a muddy sublittoral environment and representing a pioneer-phase of bottom re-colonisation after environmental changes (MANDIC & HARZHAUSER, 2003);
2. A stenohaline bivalve palaeo-community with byssate pectinids *Chlamys fasciculata* and *Pecten aduncus* in a deeper rocky sublittoral environment less exposed to wave action. According to ŠVAGROVSKÝ (1976), the bivalves cannot characterize their palaeoenvironment because they can be transposed for long distances by marine currents;
3. A bivalve palaeo-community with sessile oysters *Ostrea* cf. *digitalina*, which indicates the presence of a wave-exposed rocky coastline with a water depth to 10 m (this palaeoenvironment is also supported by abundant ichnofossils of the boring bivalve *Lithophaga*).

Hitherto undetermined fossils of terrestrial gastropods do not allow a more detailed palaeoenvironmental interpretation. They probably represent an assemblage living

Taxon	Layer	Taxon	Layer
Evertebrata		Anura indet.	4, 11b
Loripes (M.) cf. *dentatus*	12	*Salamandra sansaniensis*	13
Chlamys (M.) *fasciculata*	12	Caudata indet.	?
Pecten aduncus	17	**Reptilia**	
Ostrea cf. *digitalina*	12	*Ophisaurus* sp.	4, 8, 10, 13
Gastropoda indet.	4, 11a	*Neonatrix* sp.	13
Chondrichthyes		Colubrinae D	13
Aetobatis arcuatus	12, ?	Colubrinae indet.	13
Dasyatis sp.	12, 15	Serpentes indet.	11b
Raja sp.	12-17	**Mammalia**	
Miliobatidae indet.	13	*Spermophilinus bredai*	4, 13
Rajidae indet.	5, 13, ?	Sciuridae indet.	13, 17
Carcharias cuspidatus	?	*Eumyarion* sp.	4, ?
Carcharias sp.	?	?*Megacricetodon* sp.	17
Negaprion eurybatrodon	?	*Democricetodon vindobonensis*	13, 17, ?
Osteichthyes		*Neocometes brunonis*	13, ?
Holocentrus sp.	12-17	?Cricetidae indet.	?
Holocentridae indet.	12-17, ?	*Bransatoglis astaracensis*	13
Acanthuridae indet.	12-17	Gliridae indet.	?
Labridae indet.	12-17	?Eomyidae indet.	?
Lates sp.	12-13, 17	Rodentia indet.	4, 10, ?
Epinephelus sp.	12-13, 15-17	Viverridae indet.	11a
Serranus sp.	?	*Trocharion albanense*	11a
Serranidae indet.	12-13, 15-17, ?	Mustelidae indet.	11a, 17
Sparidae indet.	12-17, ?	*Devinophoca claytoni*	5, 13, 17
Percoidei indet.	?	Phocidae indet.	13, 16, 17
Sphyraena? sp.	12-17	*Lantanotherium* aff. *sansaniense*	13
Trichiurus miocaenicus	?	Erinaceidae indet.	?
Trichiurus sp.	12	*Talpa minuta*	?
Perciformes indet.	12, 17	*Storchia meszaroshi*	13
Trigla sp.	12-17	*Plesiodimylus chantrei*	11b
Triglidae indet.	12	*Dinosorex* cf. *zapfei*	11b
Tetraodontidae indet.	12-17	Soricidae indet.	?
Osteichthyes indet.	6, 12-17	?Lipotyphla indet.	?
Amphibia		*Lagomeryx parvulus*	11b
Bufo priscus	11b	*Lagomeryx* sp.	16
Bufo sp.	13	Ungulata indet.	17
Eopelobates bayeri	13	*Zygolophodon turicensis*	13
Eopelobates sp.	12	Mammalia indet.	13
Hyla sp.	13		

Table 1: Faunal list of Bonanza evertebrates and vertebrates and layers of their finding.

on plants and trees in adjacent woodland or in a fluvial habitat. In general, the discovered molluscan assemblage indicates a shallow water environment in direct contact with a seashore, which probably also had a sporadic supply of fresh water.

Chondrichthians: Bonanza's chondrichthian fauna includes taxa of rays and sharks (Tab. 1). Whereas sharks represent the cosmopolitan inhabitants of ocean tropical areas, the rays found here belong to taxa living today in shallow litoral parts of tropical and subtropical seas which are rich in both bentic fauna and marine vegetation needed for the fixation of their eggs (Van de Bosch et al., 1975). On the other hand, shark carcasses could also have been transported from pelagic to littoral parts, and/or cast ashore by marine currents.

Osteichthyes: In contrast to chondrichthians, the assemblage of bone fish, as determined by Prof. Hensel (unpublished), is more varied, and it consists of ten actinopterygian families (Holocentridae, Acanthuridae, Labridae, Latidae (Centropomidae), Serranidae, Sparidae, Sphyraenidae, Trichiuridae, Triglidae, and Tetraodontidae) (Tab. 1).

The found bony fishes inhabitated subtropical and tropical seas, although some taxa could also have appeared in temperate habitats (Labridae, Serranidae, Sparidae) or could

Mammalian Taxa	FAD	LAD	Ecology
Sciuridae			
Spermophilinus bredai	MN 4	MN 10	probably fossorial, soft ground of the humid forest
Sciuridae gen. et spec. indet.			
Cricetidae			
Eumyarion sp.	MN 4	MN 9	ground dweller, wet habitats in proximal areas of alluvial fans
?*Megacricetodon* sp.	MN 4	MN 9	ground of the forest-open country
Democricetodon vindobonensis	MN 6	MN 6	ground dweller, humid and warm probably forested habitat
Neocometes brunonis	MN 5	MN 7/8	arboricol, frugivor, granivor, drier habitat (open forest)
?Cricetidae gen. et spec. indet.			
Gliridae			
Bransatoglis astaracensis	MN 4	MN 9	arboricol/scansorial, sub-canopy to canopy of humid forests
Gliridae gen. et spec. indet.			
Eomyidae			
?Eomyidae gen. et spec. indet.			
Viverridae			
Viverridae gen. et spec. indet.			
Mustelidae			
Trocharion albanense	MN 5	MN 9	omnivore, terrestrial
Mustelidae gen. et spec. indet.			
Phocidae			
Devinophoca claytoni	MN 6	MN 6	invertebrate eater, semiaquatic
Phocidae gen. et spec. indet.			
Erinaceidae			
Lantanotherium aff. *sansaniense*			meat eater, subtropical forests close to water
Erinaceidae gen. et spec. indet.			
Talpidae			
Talpa minuta	MN 2	MN 9	not very informative for paleoenvironmental questions
Storchia meszaroshi	MN 6	MN 6	meat eater, semiaquatic
Dimylidae			
Plesiodimylus chantrei	MN 4	MN 11	insectivorous, probably habitat close to water
Soricidae			
Dinosorex cf. *zapfei*	MN 4	MN 6	not very informative for paleoenvironmental questions
Soricidae gen. et spec. indet.			
Cervidae			
Lagomeryx parvulus	MN 4	MN 6	browser, subtropical forests with much undergrowth
Lagomeryx sp.	MN 4	MN 6	browser, subtropical forests with much undergrowth
Mammutidae			
Zygolophodon turicensis	MN 3	MN 10	brachyodont browser, subtropical woodland
Mammalia			
Rodentia gen. et spec. indet.			
?Lipotyphla gen. et spec. indet.			
Ungulata gen. et spec. indet.			
Mammalia gen. et spec. indet.			

Table 2: Bonanza mammalian faunal list.

even have spread into brackish and fresh waters (Latidae, Tetraodontidae). Their occurrence was mainly associated with coral reefs in shallow water (to a depth of about 40 m, although some taxa, such as *Trichiurus* or *Trigla*, also indicate the presence of a more pelagic habitat). They also inhabited sporadic rocky crevices and ledges on the sandy and muddy bottom, covered by marine algae and grasses. The whole assemblage consists of planktonivorous (e.g. some of Labridae), herbivorous (e.g. Acanthuridae) and carnivorous species; including apex predators, such as *Epinephelus* and *Sphyraena*.

Amphibians and Reptiles: It is possible to distinguish two ecological groups in the Bonanza's amphibian assemblage. These consist of anurans and tailed amphibians (Tab. 1). Whereas hylids and salamadrids are rather typical of a wet lowland habitat, representatives of located pelobatids and bufonids are not immediately dependent on the proximity of water, and their presence may point to seasonal changes of wet and dry periods. Additionally, bufonids, represented by the primitive narrow-headed toad (*Bufo priscus*), may also have adapted to life in highlands (MARTIN, 1972). This assumption, however, can not be proven. The discovered reptiles indicate a vegetated environment (*Ophisaurus*) and/or an open forest habitat (Colubrinae D) with the presence of marsh and moist areas (*Neonatrix*). However, some recent South American insular species of anguids inhabit the seashore, feeding on marine crustaceans.

Mammals: Mammals represent the largest portion of Bonanza's fossil assemblage (Tab. 1). Besides their biostratigraphic value, most of them also serve as relatively good indicators of the reconstruction of palaeoenvironmental conditions. Based on their environmental requirements (Tab. 2), three main ecological groups can be distinguished:

1. A humid forest with a probably very soft underground;
2. Open woodland to open land;
3. Water areas (small ponds, rivers, sea).

Mammals from humid forested habitats form the dominant part, and these include ground dwellers (e. g. erinaceids, some sciurids and cricetids, or cervids), arboreals (sciurids, glirids) and gliding species (eomyids). The forest habitat is also presumed for indifferent taxa (such as carnivores, talpids or soricids) although these could inhabit more open areas as well. The second group consists of taxa living exclusively in open woodland to open land (e.g. some cricetids), and these are only sporadically represented at this site. The last ecological group of mammals consists of semiaquatic to aquatic species, such as pinnipeds, watermoles and probably also dimylids, located in salt and/or fresh water areas.

Generally, the composition of the whole Bonanza's faunal assemblage (Tab. 1) indicates a predominance of a subtropical forested humid habitat close to fresh water. It had sporadic open areas in the vicinity of a rocky and/or sandy coast of shallow sea, with a coral reef ecosystem. This assumption is supported by the records of terrestrial (reptiles, land mammals and gastropods), freshwater (frogs) and semimarine (seals) to marine (sharks, fishes, clams) animals.

5. The Age of the Bonanza fauna

So far, the Devínska Nová Ves-Bonanza site has yielded a relatively diverse fauna of invertebrates and vertebrates, consisting of more than 70 taxa (5-6 taxa of molluscs, 8 taxa of chondrichthians, 18 taxa of bone fishes, 8 taxa of amphibians, 5 taxa of reptiles, and 29 taxa of mammals) (Tab. 1). Since it has not yet been possible to exactly date this locality using magnetostratigraphy or radioisotopic methods, the Bonanza's age was mainly determined on biostratigraphic correlations of mammalian species (Tab. 2).

The stratigraphic range of *Spermophilinus bredai* is from MN 6 to MN 7/8, although the slightly smaller *S.* aff. *bredai* is also known from MN 4 and MN 5 sites (Ziegler & Fahlbusch, 1986). Slightly larger forms are also known from later periods (MN 10) (Bachmayer & Wilson, 1970). The smaller form probably represents an ancestor of *S. bredai*, whereas the larger one may represent a descendant of the Middle Miocene populations. The Bonanza´s finds belong to the typically Middle Miocene form.

Democricetodon vindobonensis is so far known only from the type locality Devínska Nová Ves-Fissures, which is placed in the lower part of MN 6.

Neocometes brunonis is known from the European Miocene, from MN 6 to MN 7/8, although allied relative forms (e.g., *N.* aff. *brunonis*) are already known from the MN 5 sites (e.g., Schellenfeld 2) (Ziegler, 1995). They probably represent an ancestor of the Astaracian species.

Stratigraphically *Bransatoglis astaracensis* ranges from the Early Miocene (MN 4) to the Late Miocene, with the last occurrence in Spain (MN 9) (Daams & De Bruijn, 1995).

Devinophoca claytoni is thus far only known from Devínska Nová Ves-Bonanza. The record of mustelid *Trocharion albanense* is relatively useless for correlation, because of its wide stratigraphic range (MN 5 to MN 9).

The stratigraphic range of *Lantanotherium sansaniense* is from MN 6 to MN 7/8, but the slightly smaller *L.* aff. *sansaniense* occurs in MN 5 sites in Germany. This smaller form apparently represents an ancestor of *L. sansaniense* (Ziegler, 1999). However, the Bonanza's find represents a larger form than *Lantanotherium* fossils from the type locality Sansan (MN 6).

Talpa minuta is one of the most common Miocene talpids, and its fossils are known from many sites in Western and Central Europe, ranging from MN (2)3 to MN 9 (Ziegler, 1999). The desmanine *Storchia meszaroshi* is so far only found in Devínska Nová Ves-Bonanza.

Plesiodimylus chantrei is also one of the most common Miocene insectivore species.

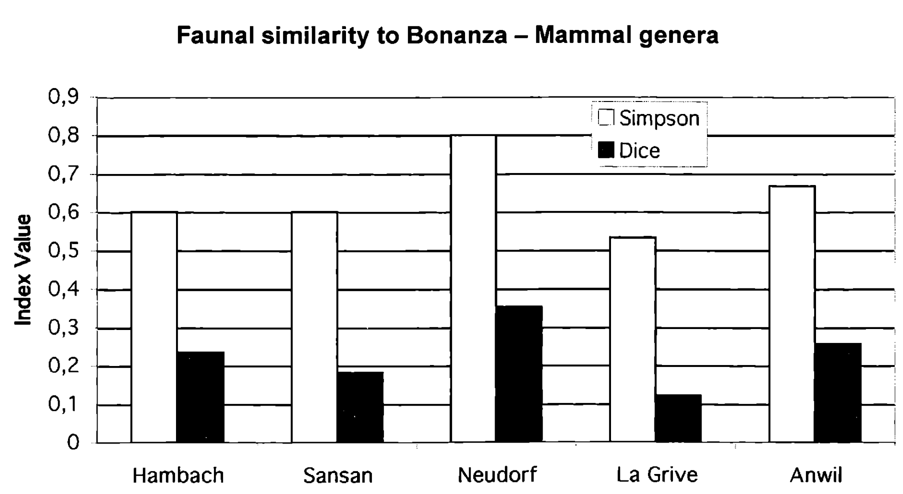

Figure 3: Genus mammal resemblance index (SIMPSON's and DICE's) among Devínska Nová Ves-Bonanza and 5 other Middle Miocene European sites (Neudorf = Devínska Nová Ves-Fissures).

It is widespread especially in Western and Central Europe, and its fossils have been recognized in many sites dating from MN 4 (aff., cf.) to MN 11 (ZIEGLER, 1999).
The stratigraphic range of *Dinosorex zapfei* is restricted to MN 6, although closely relative (aff.) or insufficiently known forms (cf.) are also inferred from MN 4 and MN 5 sites in Germany (ZIEGLER & MÖRS, 2000) and Austria (RABEDER, 1998).
The known distribution of *Lagomeryx parvulus* is from MN 4 to MN 6 (GENTRY et al., 1999), whereas the biostratigraphic occurrence of *Zygolophodon turicensis* is wider, it being recorded from the Early to Late Miocene (MN 3b to MN 10) (GÖHLICH, 1999).
A synthesis of the stratigraphic ranges of the determined mammalian species from Devínska Nová Ves-Bonanza supports the MN 6 age of the site. However, based on lithological conditions, Devínska Nová Ves-Bonanza represents a site from a later period (Late Badenian) than the nearby Devínska Nová Ves-Fissures locality (HOLEC et al., 1987). The fauna of the latter assemblage is placed in the Middle Badenian, in an earlier part of MN 6 (FEJFAR, 1990, 1997). This is also indirectly supported by the Sr-dating of foraminifer skeletons from the nearby Late Badenian outer shelf deposits of the Devínska Nová Ves-clay pit, which is dated at 13.54 Ma (HUDÁČKOVÁ & KRÁĽ, 2002).

6. Discussion

The fauna of Devínska Nová Ves-Bonanza accumulated during late MN 6 near the shoreline of the Late Badenian sea. Despite the scarcity of fossils, it shows relatively high diversity of vertebrates, especially mammals. This is observed also in other European Miocene mammalian faunas. In general, this diversity is much higher than that of the extant mammalian fauna of Europe, which is impoverished, lacking some extinct and/or exotic taxa (e.g., eomyids, anomalomyids, flying squirrels, plesiosoricids, dimylids, or mastodonts) in comparison with the fossil record. However, the number of taxa and the composition of individual fossil assemblages frequently vary in space and time. Despite the incompleteness of the fossil record (taphonomic events), this compositional variability is also evoked by various factors, mainly by environmental and climatic changes.
Using the downloaded dataset from the NOW database (available online at the website: www.helsinki.fi/science/now) and available literature data (DE BRUIJN et al., 1992; ENGESSER, 1972; MÖRS et al., 2000), the Devínska Nová Ves-Bonanza site was compared with other five important mammalian European Miocene localities (MN 5 MN 7/8) at the genus level (Fig. 3). The Bonanza assemblage displays its strongest resemblance to the nearby Devínska Nová Ves-Fissures site (early MN 6). This strong similarity of the Devínska Nová Ves sites suggest a temporal and spatial affinity for this geographical region. In contrast, the mammal assemblage of the site under study is different at the genus level from other compared sites, especially from France (Sansan and La Grive). However, detailed comparisons are more or less limited, as mammal fossils from Bonanza are very scarce.
On the other hand, some faunal differences (especially of mammalian family diversity) can also be observed among separate Devínska Nová Ves sites (including also the assemblage of the Devínska Nová Ves-Sandberg, late MN 6) (Fig. 4). Apart from taphonomic influences, this contrast could also be caused by changes in climate or in the palaeoenvironment. However, a reconstruction of the Middle Miocene palaeoclimate conditions (Tab. 3), based on floral associations of neighbouring sites in the Vienna Basin (SITÁR & KOVÁČOVÁ-SLAMKOVÁ, 1999), suggests a subtropical climate with only small fluctuations in precipitation and temperature during this period in the studied area (KVAČEK et al., 2006). Thus, the differences in diversity of mammalian families are probably related to palaeoecological changes due to changes in palaeogeography, strongly influenced by tectonic activity during this time (KOVÁČ et al., 1998).
In the Middle Badenian, a dramatic change of the Western Carpathians landscape began due to tectonically controlled development of the mountain relief. This change is documented by the sedimentary record (coarse clastic sediments of the Devínska Nová Ves Mb.) as well as by the development of wide deltaic systems (KOVÁČ et al., 2004). The Late Badenian pollen spectra already document a vegetation containing plant elements of both lowlands and mixed forests as well as an important portion of high mountain taxa (KVAČEK et al., 2006).
The fill of fissures and caves in the karstic system of the southern tip of the Malé Karpaty Mts. (in the Devínska Nová Ves area under study) also mirrors this landscape development. The oldest deposits can be observed in Devínska Nová Ves-Fissures. They are filled with terra fusca and terra rossa, probably representing sediments of an environmental system covered by subtropical forest vegetation together with open land territories with a minimally developed river net.
Due to the noticeable development of mountain relief, areas of open land were continuously replaced by forest, which started to prevail in the landscape at the beginning of the

Mean annual temperature (MAT)	15.6 - 18.4 °C
Coldest month temperature (CMT)	5.0 - 12.5 °C
Warmest month temperature (WMT)	24.7 - 27.9 °C
Mean annual precipitation (MAP)	1 194.0 - 1 520.0 mm
Wettest month precipitation (WtMP)	204.0 - 245.0 mm
Driest month precipitation (DMP)	21.0 - 37.0 mm
Warmest month precipitation (WMP)	118.0 - 175.0 mm

Table 3: Paleoclimatic values based on primary pollen data from the Late Badenian sediments in the Vienna Basin (KOVÁČ et al., 2006).

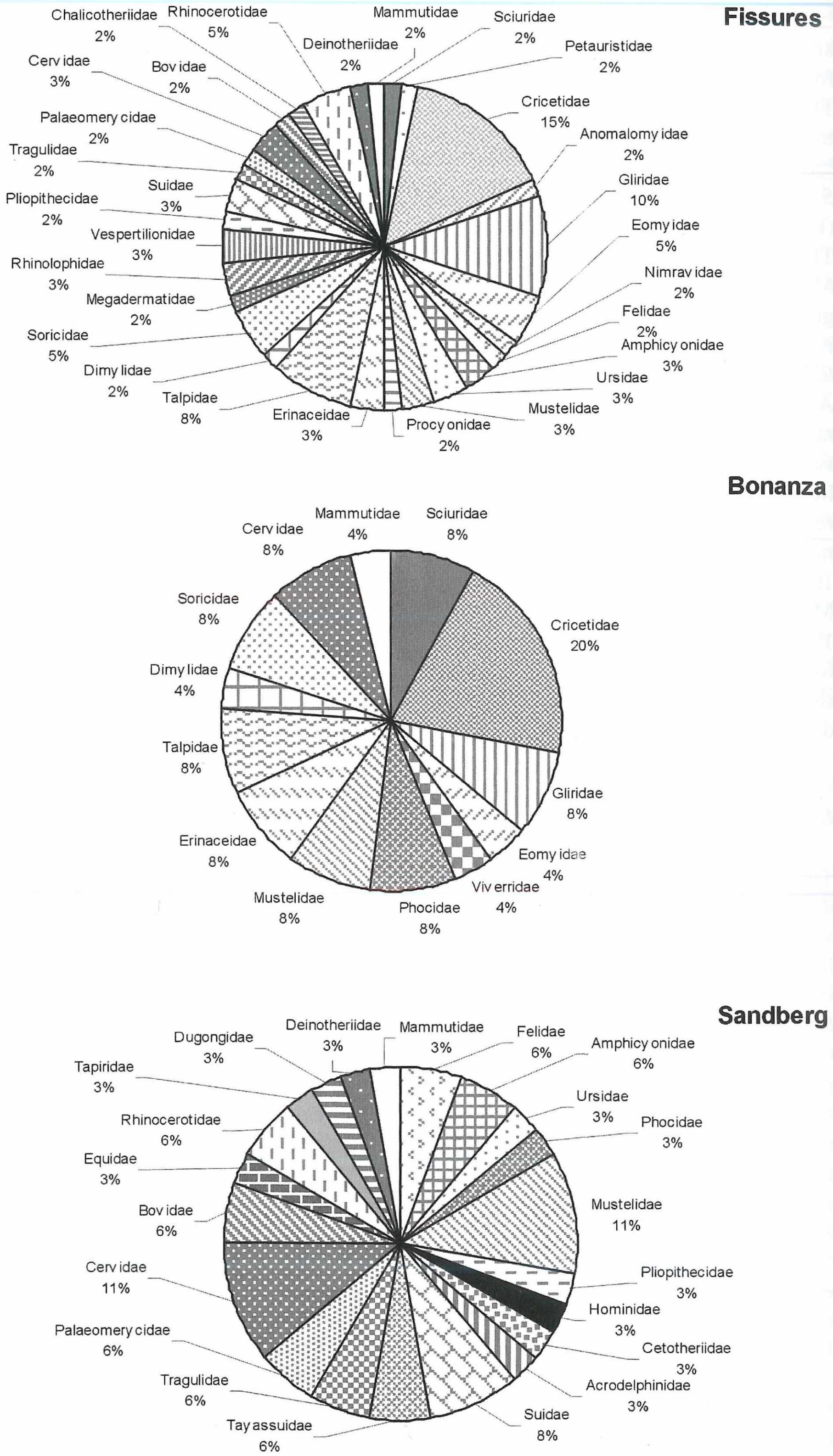

Figure 4: Pie-diagrams of the mammalian family composition of Devínska Nová Ves sites (modified according to Sabol et al., 2004).

Late Badenian (Fig. 5). This assumption is also supported by the enlargement of a river and ephemeral lake system. This is documented by the fossil faunal assemblage of Devínska Nová Ves-Bonanza, which contains taxa related to a fresh water environment, as well as a sedimentary record containing terrestrial deposits of gravity flows mixed with lag and shallow marine sediments. The presence of several, possibly orbitally driven cycles refers to changes in the sea-level. Here, the coastal line moved towards the land several times, flooding the valleys between the rocky cliff seashore.

During the Late Badenian transgression, the sea penetrated towards the land – sediments of this period are represented by shallow water littoral deposits and they contain predominantly fossil remnants of seashore and littoral inhabitants (e.g. in the locality of Sandberg). The coast-line led through sandy or gravelly beaches divided by rocky cliffs and this is documented by the diversity of sea animal fossils. Wave or current actions can account for the occasional presence of open marine taxa. Similarly, the presence of taxa living in rivers or lakes, and of animals living on dry land can be assumed to be the result of occasional short transports of their remains towards the coastal marine depositional environment by running water. The diagram (Fig. 5) documents well the seashore flooding by the Late Badenian transgression along valleys, where open land and fresh water environments retired in front of the advancing sea.

The same figure (Fig. 5) also shows the predominance of taxa living in subtropical forests within the Badenian mammalian assemblages from Devínska Nová Ves sites. However, the main observable difference is in the proportion of the next ecological groups – the open land and the aquatic environments. It probably mirrors a different taphonomy of the sites, though it also can be evidence for the palaeogeographic turnover and for the consequent palaeoenvironmental changes during Middle to Late Badenian (14 - 13 Ma). In this event, Devínska Nová Ves-Bonanza could represent a kind of "connecting link" between the Devínska Nová Ves-Fissures and Devínska

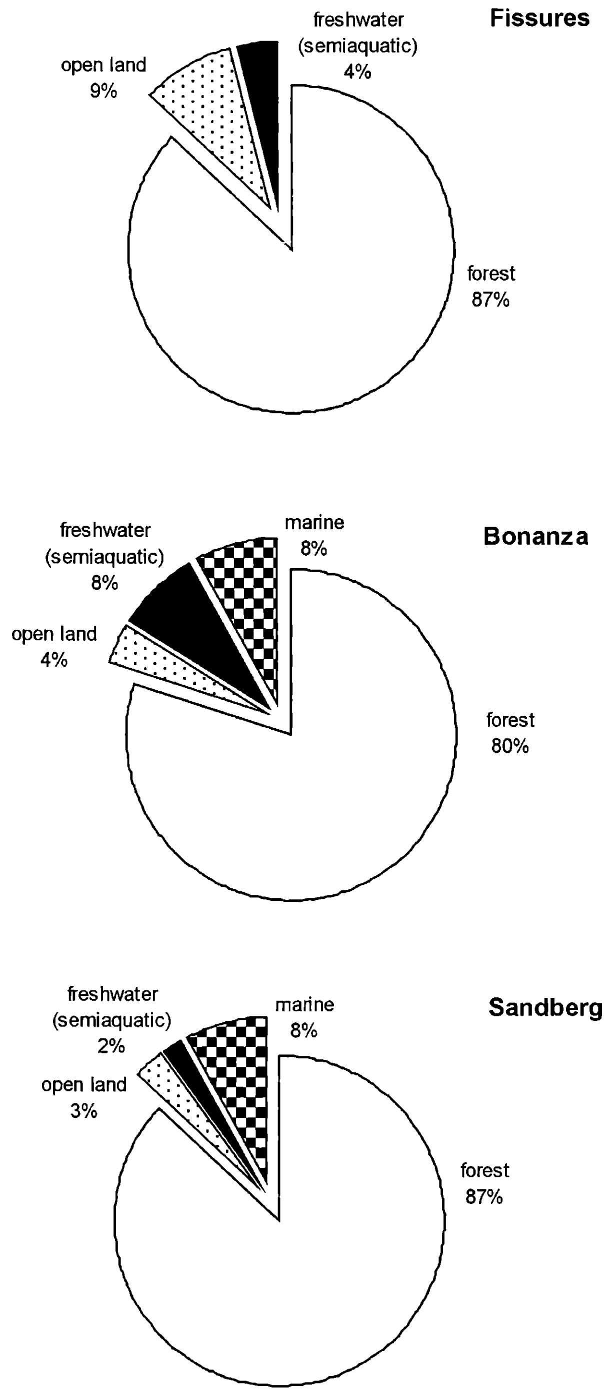

Figure 5: Pie-diagrams of main ecological groups of Devínska Nová Ves sites based on their mammalian assemblages.

Nová Ves-Sandberg sites. Although it is environmentally similar to the latter one, its assemblage rather resembles that of Devínska Nová Ves-Fissures from a faunistic viewpoint.

Thus, all three Devínska Nová Ves sites present a close faunal succession in the Vienna Basin and its surroundings during the Badenian. The fossiliferous sediments of Devínska Nová Ves-Fissures were deposited still before the Late Badenian transgression (early MN 6) in a subtropical karst environment, situated at southern slopes of the Western Carpathians. The present locality was situated at south-western tip of the antecessor of the Malé Karpaty Mts. horst structure, located between two bays of the Central Paratethys (Vienna and Danube Basins). Later on, marine sediments of Devínska Nová Ves-Bonanza and their fossil contents (late MN 6) were deposited during palaeogeographic and palaeoecological changes at the beginning of the Late Badenian. The locality represents a sedimentary environment close to the seashore with changing coastal line and probably with larger freshwater systems in the subtropical forested inland. Finally, marine sediments of Devínska Nová Ves-Sandberg (late MN 6) were deposited on the Late Badenian coastal line, where advancing sea flooded the seashore along valleys of a subtropical area during the transgression culmination.

7. Conclusions

The Devínska Nová Ves-Bonanza site belongs together with the two adjacent ones (Devínska Nová Ves-Fissures and Devínska Nová Ves-Sandberg) among the important palaeontological localities situated in the NE margin of the Vienna Basin, on the slopes of Devínska Kobyla Hill. Based on their fossil and sedimentary contents, the conclusions are as follows:

1) The Devínska Nová Ves sites provide a detailed vision of palaeoenvironmental changes during the period from the Middle to Late Badenian, caused by palaeogeographic turnover. Gradually, with the transition from terrestrial to marine conditions, the subtropical karst environment was replaced by an environment of subtropical seashore with forested inland. Later, the system was flooded along valleys during the Late Badenian transgression. In addition, changes of coastal line position associated with several (possibly orbital) cycles were the first documented in the sedimentary fill of a fissure site (Bonanza).

2) The faunal assemblages of the sites represent the only MN 6 faunal succession in the territory of the Vienna Basin. Besides different taphonomic events, the Devínska Nová Ves fossil record probably also reflects the palaeogeographic and palaeoenvironmental changes during Middle to Late Badenian in the area under study.

3) The difference of Devínska Nová Ves assemblages from the Badenian faunas of the Western Europe can be more or less caused by different palaeoenvironment (forested area near the shoreline of the advancing Late Badenian sea). Thus, the fossil assemblages of the Devínska Nové Ves sites, which also include Bonanza, make them important for interregional correlations from both the biostratigraphic and from the palaeoenvironmental points of view.

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