

## Crocodile remains from the Middle Miocene (Late Badenian) of the Vienna Basin (Sandberg, Western Slovakia)

JÁN SCHLÖGL and PETER HOLEC

Department of Geology and Paleontology, Faculty of Sciences, Comenius University in Bratislava, Mlynská dolina, SK-842 15 Bratislava, Slovakia

**Abstract.** Remains of crocodiles belonging probably to the genus *Gavialosuchus* are described from the western part of the Vienna Basin for the first time. Although they can not be determined more precisely at the species level, they enhance our knowledge about the spatial distribution of these ectothermal animals during the Middle Miocene. Moreover, they rank among the northernmost Late Badenian crocodile occurrences in the Central Paratethys area.

**Key words:** Reptilia, Crocodylia, ectotherms, Miocene, Badenian, palaeobiogeography, Vienna Basin, Central Paratethys

### Introduction

Spatial distribution of the ectothermal vertebrates provides the information about local ecological conditions. Recently this approach has been used by Böhme (2003) to reconstruct the migration and extinction events of this group in relation to climate changes in the Central Paratethys.

Crocodile remains are very rare in the whole Vienna Basin. The new material described here comes from its northeastern part from Western Slovakia (Fig. 1). Only a few fossil assemblages containing crocodile remains have been mentioned in the literature from the Austrian part of the basin. Toula & Kail (1885) introduced the name *Gavialosuchus* for the long-snouted crocodile from the Early Miocene deposits of the locality Eggenburg. Zapfe (1984) figured two large teeth assigned to *Crocodylus* sp. from the Middle Badenian deposits from the localities Müllendorf and Maustrenk, and three small and slender teeth of *Diplocynodon* sp. from the Badenian basal breccia from Kaiserstenbruch. All these localities are situated in the NE Austria. No more detailed stratigraphical position was given.

### Geological Setting

The described crocodile remains were collected at the locality Sandberg near Devínska Nová Ves village, which is situated on the western slope of the Devínska Kobyla hill. It belongs to Malé Karpaty Mts., the easternmost core mountain of the Central Carpathian system (Fig. 1).

The sediments are represented by sand and sandstones, sandy limestones and algal limestones, deposited in the littoral zone (Fig. 2, Sandberg Member, Baráth et al., 1994). The rich autochthonous marine assemblages are mixed with rarer allochthonous remains, originated from streams ending in the deposition area actually represented by Sandberg Member or brought occasionally by storm currents from the emersed neighborhood. Over 300 dif-

ferent invertebrate or vertebrate taxa have been described from the Badenian sediments of the Devínska Kobyla area, but despite more than 100 years of the palaeontological research in the locality, the crocodile remains have never been mentioned. Vertebrates were recently revised by Holec & Sabol (1996, see also Sabol, 2000; Sabol & Holec, 2002).

### Age of the fauna

The deposits were dated according to different fossil groups as well as radiometrically. Late MN6 Zone (*sensu* Steininger, 1999) is actually accepted by most of the authors working in the area. Assemblages of calcareous nannoplankton from Sandberg indicate Late Badenian NN6 Zone. Rich foraminiferal assemblages from Devínska Nová Ves clay pit studied by Hudáčková & Kováč (1993) indicate the *Bulimina-Bolivina* Zone (*sensu* Grill, 1941; 1943). Here uncovered dark pelitic sediments (Studienka Formation) are considered to be the outer shelf equivalent of the Sandberg Member. The value of 13.51 Ma (13.70 – 13.39 Ma) was obtained based on the radiometric Sr-dating on the foraminiferal tests (Hudáčková & Král', 2002) which correlates well with the Late MN6. Similar time interval (MN 6) was assumed by Sabol & Holec (2002) based on large mammals.

### Systematic Palaeontology

Order CROCODYLIA Laurenti, 1768  
Suborder EUSUCHIA Huxley, 1875  
Family CROCODYLIDAE Cuvier, 1807  
Subfamily TOMISTOMINAE Kälin, 1955  
Genus *Gavialosuchus* Toula & Kail, 1885

*Gavialosuchus* sp.

Fig. 3(1–2)

**Material.** Two isolated teeth (housed in Slovak National Museum, SNM Z 26 503, Z 26 504).

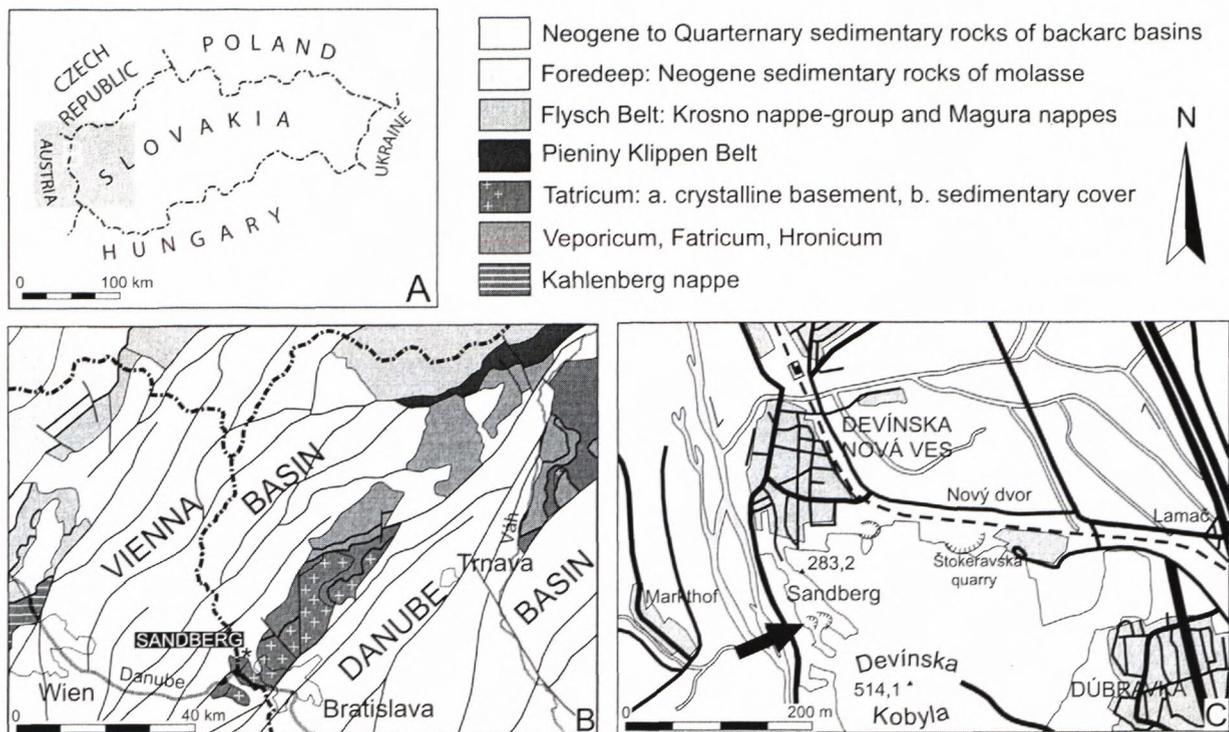


Fig. 1. Geological and geographical setting of the described fauna.

A, C. Geographical position of the locality Sandberg. B. Geological sketch map of the Vienna Basin and surrounding areas.

**Description.** The first tooth (SNM Z 26 503, Fig. 3(1)) is represented by a crown part, the root is broken off. It is conical with bluntly pointed apex and almost circular cross section. There are two sharp, distinct mesial and distal keels, extending from the apex to the edge of the tooth breakage. The tooth is slightly recurved. The mesiodistal diameter is only slightly greater than the linguobuccal (11,7 mm to 10,8 mm). The enamel is thin, variably transparent, light brown colored. Its ornamentation consists of dense and fine longitudinal wrinkles.

The second tooth (SNM Z 26 504, Fig. 3(2)) is badly preserved but it is markedly more robust. The mesiodistal diameter at the enamel limit is not measurable, linguobuccal diameter is approx. 14 mm. The lateral keel is marked on one side only; the other side is heavily corroded. The tooth is also slightly recurved as it is seen on its lingual side. The preserved enamel is thin and dark brown colored. The ornamentation is identical to that of the first tooth.

#### Remarks and comparisons.

In majority of cases the isolated teeth are only rarely classifiable into the species level. Our determination is based on the comparison with the taxa known from the European Miocene deposits.

The large size of the new described material is sufficient to exclude *Diplocynodon*, taxon comprising crocodiles of small size. The teeth of this genus are generally smaller and more slender. The mesiodistal diameter is below 10 mm (e.g. Murelaga et al., 2002, Ginsburg & Bulot, 1997; Scherer, 1978; 1981; Antunes & Guinsburg, 1989; Böhme, unpublished data). *Diplocynodon styriacus*

(Hofmann) is the only species of this genus known from the MN4, MN5 and probably also MN6 (*D. cf. styriacus*, Ginsburg & Bulot, 1997) of Europe.

Long-snouted *Gavialis* has never been reported from the Central Europe, moreover its dentition with pointed and very slender long teeth (e.g. see Antunes, 1994) differs completely from the robust-teethed genera.

Another crocodiles known from the European Miocene are *Tomistoma* and *Gavialosuchus*. They show very similar cross-section and also enamel ornamentation, consisting of faint, irregular longitudinal wrinkles. According to several authors (e.g. Böhme, 2003, Myrick, 2001) both the North-American and European fossil crocodiles assigned to the genus *Tomistoma* are distinctly different from its single modern representant *Tomistoma schlegelii* Müller and they propose to use the name *Gavialosuchus*, or *Thecachampsia*. The mesiodistal diameter is between 16 and 20 mm (Antunes & Guinsburg, 1989; Antunes, 1994; Toula & Kail, 1885), in some cases between 12 and 14 mm (Rossmann et al., 1999). On the basis of shape and dimensions, our material ranges among the smaller sized *Gavialosuchus*.

Zapfe (1984) described several crocodile teeth from the Northern Austria. Besides three *Diplocynodon* teeth, there are two robust and conical teeth with the oval cross-section designated as *Crocodylus* sp., showing the same shape and ornamentation as *Tomistoma* or *Gavialosuchus*. Moreover the presence of the genus *Crocodylus* in the European Miocene has been recently questioned (Antunes, 1994).

**Stratigraphic and geographical position.** Sandberg, Vienna Basin, Slovakia, Late Badenian, Late MN 6.



Fig. 2. Northern outcrop of the Late Badenian sandstones in the locality Sandberg. Arrows indicate the finding places of tooth SNM Z 26 504 and the bone plate (black) and tooth SNM Z 26 503 (white) (Photo by L. Slíva).

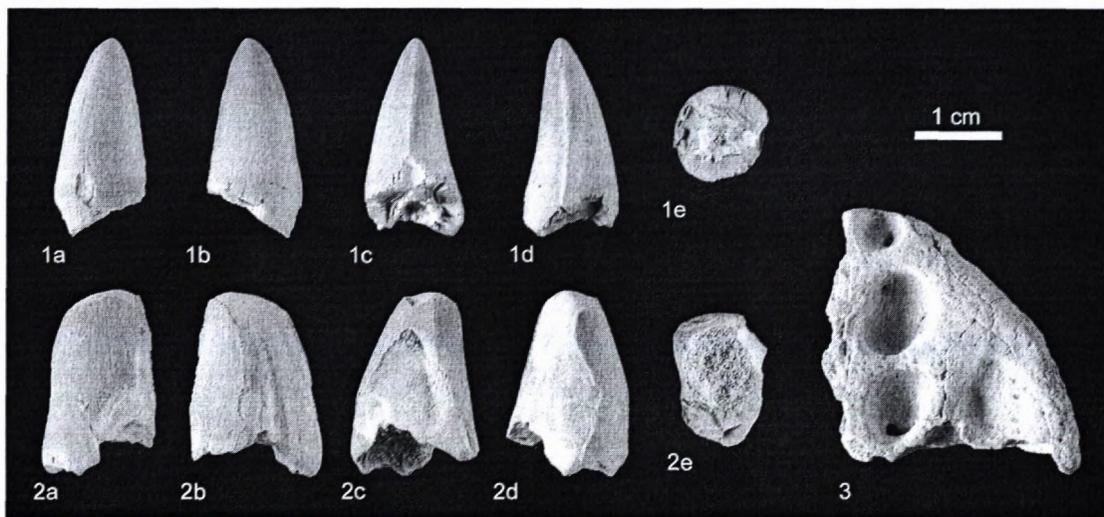


Fig. 3. 1, 2. *Gavialosuchus* sp., Late Badenian, Sandberg. 1. SNM Z 26 503. 2. SNM Z 26 504 (a – labial, b – lingual, c – distal, d – mesial, e – basal view). 3. *Crocodylia*: incertae sedis, bone plate fragment, SNM Z 26 505, Late Badenian, Sandberg.

*Crocodylia*: incertae sedis  
Fig. 3(3)

**Material.** Fragment of bony plate (SNM Z 26 505, Fig. 3(3)).

**Description.** The inner side is slightly convex with almost smooth surface. The outer side bears many oval depressions with foramina in their bottoms.

**Remarks.** The bony plate fragment cannot be precisely determined because of considerable similarity of the bony plates of many crocodylian taxa and also due to scarcity and bad preservation of the material.

**Stratigraphic and geographical position.** Sandberg, Vienna Basin, Slovakia, Late Badenian, Late MN 6.

**Palaeobiogeographical and palaeoecological remarks.**

Crocodyles ranks among the best ecological indicators, especially concerning palaeotemperatures. Böhme (2003, see also Markwick, 1998) recently documented a southward disappearance of the ectotherms during the Middle and early Late Miocene. In the Central Europe it succeeded the long phase of Miocene Climatic Optimum (from about 18 to 14.0-13.5 Ma, see Böhme, 2003). The drop of the mean annual temperature (cooling) led to a regional extinction of the most thermophilic groups in Central Europe. According to this author the crocodiles (*Diplocynodon*) have disappeared from the palaeolatitudes 38-45° N to 30-37° N between Late MN6 (Late

Badenian) and Late MN9 (Middle Pannonian). The Late Badenian palaeogeographical position of the Vienna Basin is not known, but recent palaeomagnetic data indicate the Early Miocene position of the Carpathian-North Pannonian domain much more southward than it was thought before (around 31°, Márton & Kováč, 2004), and the fast northward shift of the domain started close to the end of the Early Miocene. Recent latitude of the Vienna Basin is around 48°. Therefore the change of palaeoclimatic conditions were probably not only due to global cooling, but also due to tectonic movement of Alcapa microplate northwards (Csontos et al., 1992, Kováč et al., 1994).

Rivers, lakes, and freshwater swamps are preferred habitat of the recent representatives of the genus *Crocodylus*, although some taxa show a certain tolerance for salinity, being found in brackish waters around the coastal areas, in coastal lagoons and in river estuaries. The *Gavialosuchus* remains are found mainly in coastal marine sediments (Antunes, 1994) with only one exception (Buffetaut et al., 1984). This could suggest a rather fluvio-deltaic to coastal marine habitat for this genus, making these animals more independent from continental climate changes. Similar habitat is assumed for the *Gavialosuchus*, which inhabited the eastern margin of the Vienna Basin.

Occurrence of the thermophilic taxa on the eastern margin of the Vienna Basin agrees with the assumed local Late Badenian environmental conditions and is consistent with the data from other fossil groups. Palynological assemblages from the Studienka Formation show great portion of hydrophilous to swamp vegetation elements, but thermophilic taxa *Magnolia*, *Engelhardia*, *Platycarpa*, *Castanea*, *Ilex*, *Distylium*, *Tamarix* or *Myrica* are still abundant (Sitár & Kováčová-Slamková, 1999, Hudáčeková et al., 2002), indicating subtropical climate. Chondrichthyes reported from the Sandberg locality suggest at least moderately warm waters, expressed by dominance of the genera such as *Carcharhinus*, *Galeocerdo*, *Scyliorhinus*, *Myliobatis* or *Aetobatus* (Holec, 2001).

## Conclusions.

The crocodile remains collected from the marginal deposits of the Slovak part of the Vienna Basin probably belong to an indeterminate species of the genus *Gavialosuchus*. Described occurrence ranks among the northernmost Late Badenian occurrences of the Crocodylia in the Central Paratethys.

Their presence on the eastern margin of the Vienna Basin indicates the existence of fluvio-deltaic or coastal marine environments providing suitable life conditions for these ectothermal reptiles. Moreover it completes the existing palaeoclimatic data based on other fossil groups and agree well with warm subtropical climate assumed for the Vienna Basin during the Late Badenian.

## Acknowledgement.

Authors are grateful to Prof. M. Mišík from the Department who provided a part of the described material, to Dr. M. Böhme, Prof. J. Klembara and Prof. M. Kováč for important comments and to Peter Richter for language corrections. The research was supported by VEGA grant 1/0002/03.

## References.

- Antunes, M. Telles, 1994: On Western Europe Miocene Gavials (Crocodylia) their Paleogeography, Migrations and Climatic significance. *Comun. Inst. Geol. e Mineiro*, 80, 57 – 69.
- Antunes, M. T. & Ginsburg, L., 1989: Les Crocodiliens des faluns miocènes de l'Anjou. *Bull. Mus. natn. Hist. nat., Paris*, 4<sup>e</sup> sér., 11, 79 – 99.
- Baráth, I., Nagy, A. & Kováč, M., 1994: Sandberg Member – Late Badenian Marginal Sediments on the Eastern Margin of the Vienna Basin. *Geologické práce, Správy* 99, 59–66. [in Slovak].
- Böhme, M., 2003: The Miocene Climatic Optimum: evidence from ectothermic vertebrates of Central Europe. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 195, 389 – 401.
- Buffetaut, E., Crouzel, F., Juillart, F. & Stigliani, F., 1984: Le crocodylien longirostre *Gavialosuchus* dans le Miocène moyen de Polastron (Gers, France). *Geobios*, 17, 113 – 117.
- Cope, E. D., 1867: An Addition to the Vertebrate Fauna of the Miocene Period with a Synopsis of the Extinct Cetacea of the United States. *Proceedings of the Academy of Natural Sciences of Philadelphia*, 1867, 136 – 156.
- Csontos, L., Nagymarosy, A., Horváth, F. & Kováč, M., 1992: Tertiary evolution of the intra-Carpathian area: a model. *Tectonophysics*, 208, 221 – 241.
- Ginsburg, L. & Bulot, C., 1997: Les *Diplocynodon* (Reptilia, Crocodylia) de l'Orléanien (Miocène inférieur à moyen) de France. *Geodiversitas*, 19, 1, 107 – 128.
- Grill, R. 1943: Über mikropaläontologischen Gliederungsmöglichkeiten im Miozän des Wiener Becken, Mitteilungen des Reichsamts für Bodenforschung, 6, 33–44.
- Grill, R. 1941: Stratigraphische Untersuchungen mit Hilfe von Mikrofaunen im Wiener Becken und den benachbarten Molasse-Anteilen. *Oel und Kohle* 37, 595–602.
- Holec, P., 2001: Chondrichthyes and Osteichthyes (Vertebrata) from Miocene of Vienna Basin near Bratislava (Slovakia). *Mineralia Slovaca*, 33, 111 – 134.
- Holec, P. & Sabol, M., 1996: Tertiary vertebrates (Vertebrata) of the Devínska Kobyla. *Mineralia Slovaca*, 28, 519–522. [in Slovak]
- Hudáčeková, N. & Kováč, M., 1993: Changes of sedimentary environment in the eastern part of Vienna Basin in Late Badenian and Sarmatian. *Mineralia Slovaca*, 25, 202 – 210. [in Slovak].
- Hudáčeková, N. & Král, J., 2002: Radiometric dating. In: Kováč, M. (ed.), *Tectonogenesis of the Western Carpathian sedimentary basins – The Vienna Basin*. Manuscript, Geofond, Bratislava, 50 – 52. [in Slovak].
- Hudáčeková, N., Zlínská, A., Halásiová, E. & Slamková, M., 2002: Comparison of the Upper Badenian sediments in the Danube and Vienna Basins (Central Paratethys area) on the basis of foraminifera and calcareous nannoplankton. In: Michálek, J., Hudáčeková, N., Chalupová, B. & Starek, D. (eds.), *Paleogeographical, Paleoclimatological, Paleoclimatological development of Central Europe, ESSEWECA/EEDEN Workshop*, Bratislava, 57 – 58.
- Kováč, M., Král, J., Márton, M., Plašienka, D. & Uher, P., 1994: Alpine uplift history of the Central Western Carpathians: geochronological, paleomagnetic, sedimentary and structural data. *Geologica Carpathica*, 45, 2, 83–96.
- Markwick, P. J., 1998: Fossil crocodylians as indicators of Late Cretaceous and Cenozoic climates: implications for using palaeontological data in reconstructing palaeoclimat. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 137, 205 – 271.
- Márton, E. & Kováč, M., 2004: Palaeomagnetic contribution to a realistic palaeogeographic - palinspastic model of the Central Paratethys during the Tertiary. *ESSEWECA Conference, Bratislava 2004, Abstracts*. Available from: <<http://www.fns.uniba.sk/~kpgp/esse/esse.htm>>
- Murelaga, X., Pereda Suberbiola, X., Lapparent de Broin, F. de, Rage, J.-C., Duffaud, S., Astibia, H. & Badiola, A., 2002: Amphibians and reptiles from the Early Miocene of the Bardenas Reales of Navarre (Ebro Basin, Iberian Peninsula). *Geobios*, 35, 347 – 365.
- Myrick, Jr. A. C., 2001: *Thecachampsia antiqua* (Leidy, 1852) (Crocodylidae: Thoracosaurinae) from Fossil Marine Deposits at Lee Creek Mine, Aurora, North Carolina, USA. *Smithsonian Contributions to Paleobiology*, 90, 219 – 225.

- Rossmann, T., Berg, D. E. & Salisbury, S., 1999: Studies on Cenozoic crocodiles: 3\*. *Gavialosuchus* cf. *gaudensis* (Eusuchia: Tomistomidae) from the Lower Miocene of South Germany. *Neues Jahrbuch für Geologie und Paläontologie Monatshefte.*, 6, 321 – 330.
- Sabol, M., 2000: Neogene carnivores of Slovakia. *Slovak Geological Magazine*, 6, 2-3, 124 – 126.
- Sabol, M. & Holec, P., 2002: Temporal and spatial distribution of Miocene mammals in the Western Carpathians (Slovakia). *Geologica Carpathica*, 53, 4, 269 – 279.
- Scherer, E., 1978: Krokodilreste aus der miozänen Spaltenfüllung Appertshofen nördlich von Ingoldstadt. *Mitteilungen der Bayerischen Staatssammlung für Paleontologie und historische Geologie*, 18, 65 – 91.
- Scherer, E., 1981: Die mittelmiozäne Fossil-Lagerstätte Sandelzhausen 12. *Crocodylia* (abschließender Bericht). *Mitteilungen der Bayerischen Staatssammlung für Paleontologie und historische Geologie*, 21, 81 – 87.
- Sitár, V. & Kováčová-Slámková, M., 1999: Palaeobotanical and palynological study of the Upper Badenian sediments from the NE part of the Vienna basin (locality Devínska Nová Ves). *Acta Palaeobotanica, Proceedings 5<sup>th</sup> EPPC, Krakow, Suppl. 2*, 373 – 389.
- Steininger, F. F., 1999: Chronostratigraphy, geochronology and biochronology of the Miocene „European Land Mammal Mega-Zones“ (ELMNZ) and the Miocene „Mammal-Zones (MN-Zones)“. In: Rössner, G. E. & Heissig, K. (eds.), *The Miocene land mammals of Europe*. Verlag Dr. Friedrich Pfeil, München, 9 – 24.
- Toula F. & Kail, J. 1885: Über einen Krokodil-Schädel aus den Tertiärablagerungen von Eggenburg in Niederösterreich. *Denkschriften der Kaiserlichen Akademie der Wissenschaften, mathematisch-naturwissenschaftliche Klasse*, 50, 299 - 356.
- Zapfe, H., 1984: Krokodile im Mittelmiozän des Wiener Beckens. *Sitzungsberichten der Österreichische Akademie der Wissenschaften, mathematisch-naturwissenschaftliche Klasse, Abt. I*, 193, 161-169.