

NEW REPTILE FOSSIL RECORDS FROM CORUND (EASTERN TRANSYLVANIA, ROMANIA) AND THEIR PALEOENVIRONMENTAL SIGNIFICANCE

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Abstract. The carbonate deposit, located in Corund (Romania) area is well-known by the 19th century, because of the spectacular, colored carbonates found in three outcrops. The reptile fossils found in these carbonates are unique, not only because these are first occurrences for the studied area, but also because such type of reptile fossils were not described in the literature related to Europe Pleistocene – Quaternary reptile fauna. The identification of reptile fossils on casts or molds is highly facilitated by comparison with present forms – which could be a more comfortable charge for a "neoherpetologist", than a paleoherpetologist. In this paper, the authors describe two specimens of Anguidae (*Anguis fragilis*) and one specimen of Colubridae (*Coronella austriaca*, *Zamenis longissimus*). This entire species has a broad distribution range and shows a high ecological tolerance. In view of reptile's identity and based on a palinological study, an attempt of paleoenvironmental reconstruction is also presented.

Keywords: carbonate deposits, reptiles, Anguidae, Colubridae, palynology, paleoenvironment, Pleistocene, Quaternary, Transylvania, Romania

1. INTRODUCTION

The paleoherpetologists are familiar mainly with the skeleton, dentition or other particular bony elements (as osteoderms) of extinct or extant members of paleoherpetofauna. Holman (1998) spectacularly highlights the importance of bony elements for paleoherpetologists. According to him: "a single frog ilium or snake vertebra, unbroken and free from matrix, will be a much more relevant piece of diagnostic than an entire frog or snake embedded in rock". It is a favorable coincidence that the skeleton elements (e.g. vertebrae) have a good diagnostic character, as they are generally the only parts of vertebrates that fossilize. Although in rare cases, fully petrified herps as cast or molds could also be found (e.g. Młynarski & Ullrich, 1975). In those cases, the same outer shape could help us identify the species. The fossilization of head, limbs, tail has high information value. In reptiles, the scale pattern, shape

and the number of scale rows are the characters that also have an information value regarding the family, genus or species identity. The identification of species based on these types of fossils is difficult, mainly because of lack of such "type of material". The situation is positively changing when the presence of extant species is listed from similar geological time and geographical region. In this work, we had the chance to describe three snakes like reptile fossil, fossilized in a carbonated environment in the Eastern part of the Transylvanian Basin.

2. LOCATION AND GEOLOGICAL BACKGROUND

The studied carbonate deposits are situated in the Eastern part of the Transylvanian Basin, Romania, and have been well-known since the 19th century. These carbonates could be found in three outcrops, located North from Corund village, on the right side

of the 13A Corund – Praid road. Geological formations from the studied area represented by the Neogene calc-alkaline volcanic activity products of the Gurghiu Mountains (volcanoclastites and lava flows), by sedimentary rocks such as Pannonian salty clays, and Miocene salt diapires from Praid area (Fig. 1) (Gheorghiu et al., 1962). The carbonate deposits were precipitated from salted - bicarbonated springs (Gheorghiu et al., 1962; Tóth 2002).

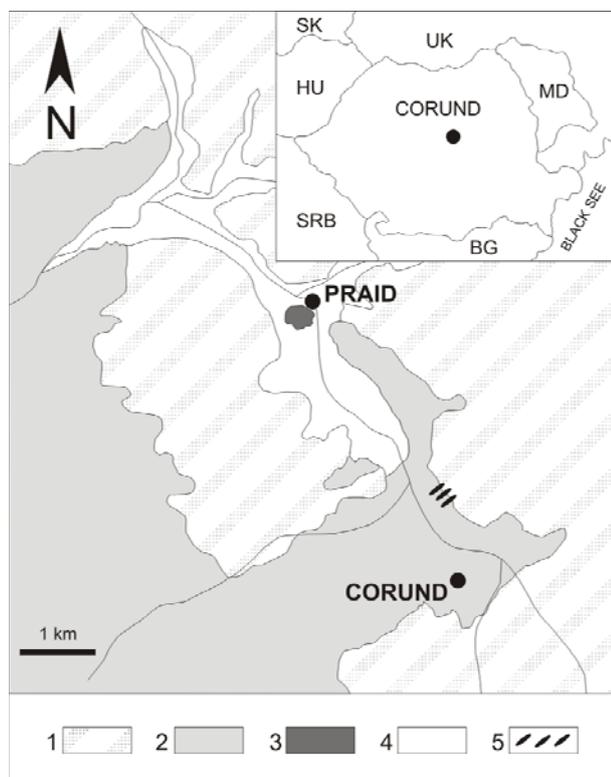


Figure 1. Geological sketch map of the studied zone (after Geological map of Romania, Odorheiu Secuiesc sheet, 1:200,000): 1 volcanoclastites and lava flows; 2 Pannonian sedimentary rocks; 3 Miocene salt diapire; 4 Quaternary sedimentary rocks; 5 spring carbonates.

This phenomenon is still active at present. The structure of the carbonate deposits is formed of vertical to nearly vertical banded carbonate veins in the middle part, covered by travertine in the top. From mineralogical point of view this spring deposit is formed by calcite and aragonite. The color of these is very variable, from white to black, but they also present green, brown, dark-yellow, reddish-brown colors. This wide spectrum of colors is related with the presence of iron sulphide and iron oxy-hydroxide (Metta, 1928; Gheorghiu et al., 1962; Tóth, 2002).

3. MATERIALS AND METHODS

Comparative measurements were made on lizard and snake carcass and on moulded skin (Sós,

personal collection).

For the detailed morphological study, we used Nikon SMZ-800 stereo microscope equipped with Nikon Coolpix-950 camera at the Lithosphere Fluid Research Lab, Department of Petrology and Geochemistry, Eötvös University - Budapest.

The palynological studies were performed on separated pollen and spore samples made by dissolving reaction of the carbonates in HCl at the Department of Geology and Paleontology, Babeş-Bolyai University, Cluj-Napoca. The remaining material was washed in demineralized water and centrifuged several times (5 min, 3000 rpm). The solution was filtered and dried on glass lamellae. After the separation procedure using a Zeiss-Axiolab microscope the taxa were determined.

4. RESULTS

4.1. Sample description

The studied samples are from two different collections. Sample 1 is exhibited in the Paleontological Museum of the Babeş-Bolyai University from Cluj-Napoca (Romania), while sample 2 is in a private collection, belonging to Papucs András at Sfântu Gheroghe.

4.1.1. *Sample 1.* In a 50 cm long and 26 cm width (measured in the middle section) carbonate block, two fossils could be identified (Fig. 2).

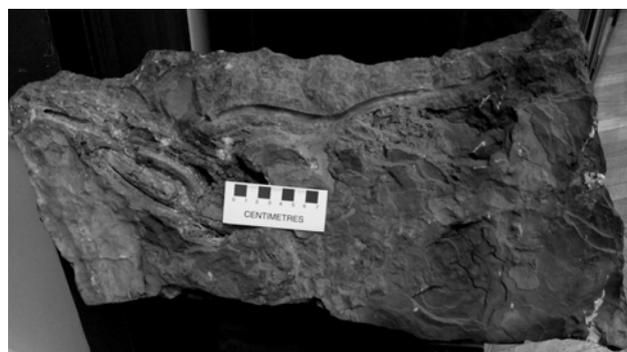


Figure 2. Carbonate block with the two *Anguis* sp. (f1, f2) fossils.

The first fossil (f1) appears as a fossilized snake-like trunk section, which is approximately 7.5 cm long, situated in the left part of the rock bed. The fossil occurs near a fossilized log. One end of the fossil looks like burrowed in the rock (Fig. 2, 3) while the second end of the fossil is broken into an angle near to 90 degree. The trunk section is embedded in the rock less than half of the circumference of the body. In the largest free part of the trunk section, 11 scale rows could be counted. The shape of the scales is rhombus like. After the

broken part, only the mold of the reptile could be traced in about 11 cm long sections (Fig. 3).



Figure 3. The f1 *Anguis* sp. fossil.

At the proximate part, the mold/imprint is covered by the rock and shows a 1.5 cm long tube-like form where the outer part of the reptile (scales) is petrified but the inner part such as vertebrae, etc are missing (Fig. 4).



Figure 4. The imprint part of f1 *Anguis* sp. fossil.

The position of scales and the tapering trunk shape indicate that the frontal part of the reptile is the burrowed part (the right end of the fossil), thus even the fossilization of the head could be suspected (Fig. 3). In the middle of the preserved part, an injury could be supposed, although the trunk seems to be fossilized in natural shape.

The scale types (the presence of the central differentiated scale rows) and the body shape (compressed in dorsal-ventral direction) confirm that in this section the dorsal part of the trunk is preserved. The second fossil (f2) is represented by an approximate 21 cm long mold in the upper section of rock bed (Fig. 2, 5). The position of the scales shows that the proximal part of the reptiles is in the left part.

In both samples, the presence of the legs or the differentiated ventral scales is missing. These facts such as the scale type and the elongated, legless shape make it belong to a similar species as the first fossil.



Figure 5. The f2 *Anguis* sp. imprint.

4.1.2. *Sample 2*. The imprint is preserved in a 7 cm long section in a piece of carbonate rocks (Fig. 6). These carbonates covered the initial cylindrical, snake-like trunk where the fibrous carbonate crystals have radial distribution around the imprint surface.



Figure 6. The imprint of snake (presumably *Coronella austriaca* or *Zamenis longissimus*).

The estimated circumference of the trunk is 4.5 cm. In the largest circumference of the mold, 9 scale rows could be counted. The mold/imprint presents the signs of differentiated ventral scales (Fig. 7) which enable us to identify the reptile mold/imprint as belonging to a snake species.



Figure 7. The imprint of snake - closer view with the ventral scales (presumably *Coronella austriaca* or *Zamenis longissimus*).

This fossil mold/imprint does not show a real scale form (Fig. 6, 7), the tip and the edge of the scale are embedded in the rock. Thus, only the upper part of the scale imprint (from the scale base until

the largest transversal width) could be used in the identification process.

Although we can conclude from the fossil imprint that, we are looking for a relative robust scale type with almost similar length and width. In the outer part of the sample, a well-preserved petrified leaf could be found as well.

4.2. Palynological study

As both the studied samples contain fossilized plant rests (log, leaf), a palynological study was performed on the samples for the better understanding of the paleoenvironment where this reptiles lived.

The pollen content is usually very poor in carbonate sediments. The arboreal pollen is represented by a few grains of *Picea*, *Pinus* and *Betula*. The non-arboreal pollen (NAP) is represented by a few grains of Poaceae and Ranunculaceae. The ferns are present by a few spores of *Polystichum* and *Pteridium*.

5. DISCUSSIONS

5.1. Comparison and systematic study

As the presence of vertebrae or cranial elements is missing in the studied samples (petrified trunk and trunk molds/imprints), the only traces in the diagnostic of the reptile fossil were the shape, number and the distribution patterns of the scales.

6.1.1. Sample 1. In the list of extant European Pleistocene herpetofaunistical elements only the members of Scincidae, Anguidae and Typhlopidae show similar scales. This type of scales represents an adaptation to a fossorial life style, which is (more or less) general in these reptile families.

In the comprehensive work of Holman (1998) one fossil record of Scincidae is listed in undesignated Pleistocene period in Spain (*Chalcides* sp. indet.; Holman, 1998), thus in the present distribution areal (Salvador & Pleguezuelos, 2001). Despite this, we compared the cast (f1) and the molds (f1, f2) with the present forms of scincids, e.g. the limbless *Ophiomorus punctatissimus* (Bibron & Bory de Saint-Vincent) and the reduced legged *Chalcides chalcides* (Linnaeus) and *C. striatus* (Cuvier). The other members of the family shows a well-developed legs and short, robust trunk thus were inappropriate to compare with the elongated form of present fossil. The cast and molds (f1, f2) differs in scales shape, which show a degree of differentiation from the top of the trunk to the lateral sides (the middle row shows mostly a different scale

type), in contrast with the scales of similar shape in scincids (at least in the dorsal part of the trunk).

From the second part of Pleistocene just two members of Anguidae are documented: the *Pseudopus* Merrem, (earlier *Ophisaurus* Daudin) and the *Anguis* Linnaeus (Klembara, 1981). The only extant member of *Pseudopus*, *P. apodus* (Palla) differs from fossils by its characteristic bold scales, which are distributed transversally in a nearly perpendicular bar. The presence or the absence of the lateral prominent grooves was not proved.

The only genus with similar scales and distribution pattern was the *Anguis* genus (Fig. 8.).

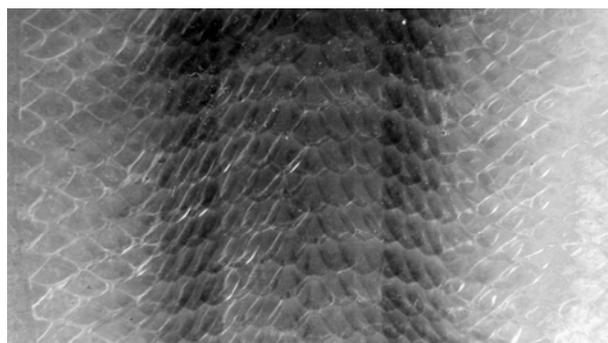


Figure 8. Moulded skin of *Anguis colchica incerta*.

The comparison was made on basis of a preserved *A. colchica incerta* Krynicki and several moulded skins of the subspecies. The genus *Anguis* appears at present with four modern species (Gvoždik et al., 2010): *A. fragilis* Linnaeus has an estimated occurrence in Western and Central Europe, in North-Western Balkans, with possibly isolated populations in the Eastern Balkans, and presumably also in Western Scandinavia and Italy; this species was recently identified in north-western Romania, Carei Plain (Covaciu-Marcov et al., 2009); *A. colchica* (Nordmann) has a distribution from the Eastern Czech Republic and the Baltic region eastward to Northern Iran, presumably also in Eastern Scandinavia and the North-Eastern Balkans; *A. graeca* Bedriaga is considered restricted to the Southern Balkans, and partially sympatric with the fourth species, *A. cephalonica* Werner, which is restricted to Greece (Peloponnese, Cephalonia, Zakynthos and Ithaca; Valakos et al., 2008).

Anguis genus has rich Upper Pleistocene fossil records and is listed under the name of *A. fragilis*. Fossils were found in territories of Britain, France, Spain, Germany, Poland, Hungary and Serbia, although the most common *A. fragilis* fossils found are vertebrae and osteoderms (Holman, 1998). Another extinct member of the genus, which was described in the Middle and Upper Pleistocene, is *A. stammeri* Brunner. This fossil form differs from *A.*

fragilis with a more robust and more sharply pointed teeth (Holman, 1998). Some authors agree with the validity of this species (e.g. Estes, 1983), others consider that it belongs to other taxa (*Ophisaurus/Pseudopus*; Mlynarski, 1962). According to Holman (1998), the validity of this species is doubtful and is considered a robust variant of *A. fragilis*.

The only member of Typhlopidae, *Typhlops vermicularis* Merrem, has a single fossil record listed by Holman (1998), in the Middle Pleistocene of Greece, similarly in its present distribution area (Valakos et al., 2008). The scales of this worm-like snake differ from the fossil in a similar way as described in scincidae.

In conclusion, the cast (f1) and the mold (f2) were identified as belonging to the *Anguis fragilis* species complex. Our study area lies in the distribution of *A. colchica* (Nordmann). This species was also recently divided in three subspecies: the Caucasian nominat form, the East-European *A. c. incerta* Krynicki and the Caspian *A. c. orientalis* Anderson (Gvoždík et al., 2010). Consequently, we are in the territory of *A. c. incerta*. Nevertheless, the species or even subspecies origin of the cast, remain unknown forasmuch as the recent classification is based mostly on genetic studies.

Classification: Class Reptilia – Order Squamata – Suborder Sauria – Family Anguidae – Genus *Anguis* Linnaeus.

6.1.2. *Sample 2*. Only the upper part of the scale mold (from the scale base until the largest transversal width) could be used in the identification process. However, we can conclude from the fossil mold that we are looking for a relative robust scale type with almost similar length and width. In colubrids, the scales belonging to the middle dorsal rows differ in form and size from those distributed in rows near the ventral scales. In this fossil record, the scales show similar sizes and shapes.

The fact that the scales are smooth and without the keels helped us draw the conclusion that the snake mold does not belong to the *Elaphe quatuorlineata* (Bonnaterre) or *E. sauromates* (Pallas), Genus *Natrix* Laurenti or to the Family Viperidae. The fossil mold looks similar with the scale type of members of the genus *Eryx* Daudin, which occur in the European Pleistocene (in Holman, 1998). However, compared with the estimated body circumference of the snake, the scales are much bigger than e.g. in the case of extant *Eryx jaculus* (Linnaeus). In the sand boas, the number of scale rows at mid-body is ranging between 41–57 (Valakos et al., 2008) which is impossible to achieve in case of such scale size and

this circumference as in the fossil mold. At the same time, the Pleistocene fossil records of the *E. jaculus* do not exceed their present distribution (e.g. appear in Middle Pleistocene, “Upper Quaternary” of Greece; in Holman, 1998).

In case of other colubrids with smooth scales such as *Hierophis gemonensis* (Laurenti), *H. viridiflavus* Lacépède, *Hemorrhoids hippocrepis* (Linnaeus) and *Malpolon monspessulanus* (Hermann), the scarce Upper Pleistocene fossil records of this species do not exceed their present distribution areas (see listed also in other reptiles in Table 1), except in one case. *H. gemonensis* appear in Upper Pleistocene of Italy (in Holman, 1998) and one extralimital record from Bulgaria (Szyndlar, 1991). *H. hippocrepis* occur only in the Upper Pleistocene of Spain (in Holman, 1998). *H. viridiflavus* and *M. monspessulanus* occur in the Upper Pleistocene of France (in Holman, 1998). However, *H. viridiflavus* as part of the West European species-group (*in sensu* Szyndlar, 1984) is the only one snake species which penetrated into the Carpathian Basin (Venczel, 1998). The Upper Pleistocene (Toringian) snake fauna from sixteen fossil localities situated on the territory of Bihor county (W-Romania) are composed by only contemporaneous snake species (Venczel, 2000). In conclusion, the above-mentioned species were not considered.

A comparison with the scales of extant *Dolichophis caspius* (Gmelin), species with no fossil record in Upper Pleistocene of the Carpathian Basin (Venczel, 2000), but a species with closer distribution area (Nagy et al., 2004), revealed that the fossil scales mold markedly differ in shape from the scales of the *D. caspius*. The scales of mold are less elongated and more angled. The mold shows similar characteristic with the scales types of members of genus *Coronella* Laurenti and *Zamenis* (Laurenti).

At present, the genus *Coronella* has two species. *C. girondica* (Daudin) is restricted to Mediterranean areas (Iberia, Southern France, Italy, Sicily, and North-Western Africa; Arnold & Ovenden, 2007). The Upper Pleistocene records of this species do not exceed their present distribution area (e.g. Upper Pleistocene of Spain; in Holman, 1998). *C. austriaca* Laurenti has a wide distribution in Europe (Arnold & Ovenden, 2007) and is also present in the Carpathian Basin (Ghira et al., 2002). This species has a considerable Upper Pleistocene fossil record; it was found in the Upper Pleistocene of Germany, Poland, Serbia, etc. (in Holman, 1998). The identification of *Coronella* fossils is performed on cranial elements and vertebrae (e.g. Szyndlar, 1984, 1991).

Table 1. The Upper Pleistocene fossil records of Anguinae family and Serpentes of Central and Eastern Europe as listed in Holman (1998). In case of Hungary the snake records are mostly indeterminate or undesignated. Completed with data from Bolkay (1913)* and Szyndlar (1991)**.

Country \ Species	Ang. fra.	Pse. apo.	Typ. ver.	Cor. aus.	Hie. gem.	Ela. qua.	Zam. sit.	Zam. lon.	Nat. nat.	Nat. tes.	Vip. amm.	Vip. ber.
Upper Pleistocene												
Germany (33)	12			5				7	8			4
Poland (15)				1				4	2			3
Hungary (11)	3											
Romania*				1								
Croatia (6)		1				2		2	1	1		
Bulgaria** (1)					1	1					1	
Greece (5)			1		1		2	1		1		
Holocene												
Germany (5)	5			5				3	5	3		4
Poland (3)	1							1	1			1
Serbia (2)	1	1		1				1			1	1

In this species, similarly as in the fossil mold, the scales from the dorsal and lateral rows show less differentiation in shape and size than in other colubrid species (Fig. 9), although the scales from the dorsal rows are more elongated and less angled (personal obs.).

Z. longissimus, member of *Zamenis* genus also actually live in the Carpathian basin (Ghira et al., 2002) and has a rich Upper Pleistocene fossil records (in Holman, 1998). The scales of the fossil mold show similar characteristics only in young subadults snakes (Fig. 10).

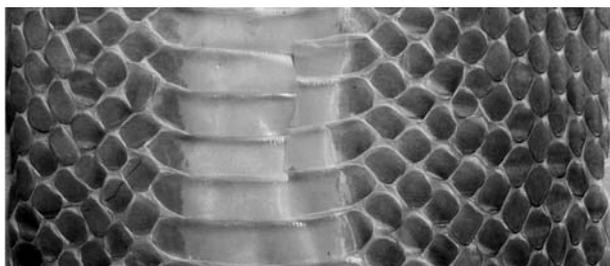


Figure 9. Moulded skin of *Coronella austriaca* with ventral scales in the center.

In adult snakes, the scales from the dorsal and lateral rows markedly differ; the scales from dorsal rows develop in more elongated scales. In addition, the adults' exhibit keeled scale rows in the dorsal part of body. Although similar scale types could also be found in adults in the posterior trunk section, close to the tail (Fig. 11.). Here also the keeled scales could be identified. In conclusion, we suppose that this mold

belongs either to the *C. austriaca* or to a young subadult *Z. longissimus*, although the possible presence of cryptic species or other morphologically closer species could not be neglected (Borkin et al., 2004).



Figure 10. Moulded skin of *Zamenis longissimus* with ventral scales in the center.

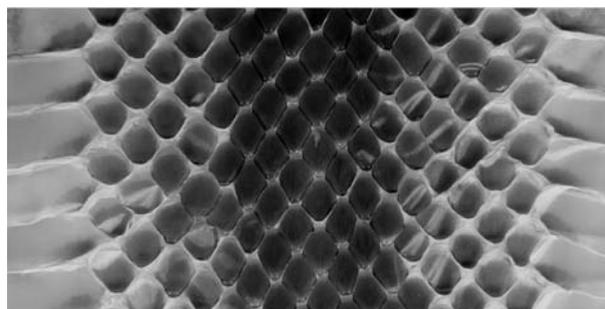


Figure 11. Moulded skin of *Zamenis longissimus* trunk close to the tail base.

Nevertheless, new data regarding a recent snake fossilization event confirm the *C. austriaca* in such situation. As one can see in the (Fig. 12), a juvenile

C. austriaca died and started to fossilize only a few months ago, in the same conditions as the other fossils are believed to have done.

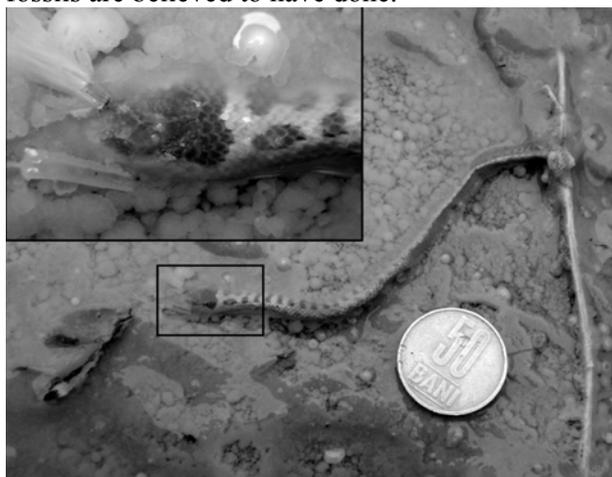


Figure 12. Juvenile *Coronella austriaca* in the first stage of fossilization (the diameter of the coin is 2.4 cm).

Classification: Class Reptilia – Order Squamata – Suborder Serpentes – Family Colubridae: *Colubridae* sp. indet. Supposed origin: Genus *Coronella* Laurenti: *Coronella austriaca* Laurenti; Genus *Zamenis* Wagler (earlier *Elaphe* Fitzinger): *Zamenis longissimus* (Laurenti).

5.2. Paleoecology, paleoenvironment

Holman (1998) concluded that “herpetological species may not determine the chronological age of a Pleistocene deposit, but they are certainly of great use in determining the type of stage (warm or cold) and, considering the central European model above [*in sensu* Böhme (1996), who listed certain herpetological species or assemblages of species that are specific to portions of Quaternary climatic cycles in Central Europe], in determining even the specific phase of that stage (e.g., late warm, early cold, etc.)” He drew this conclusion based on the evolutionary stasis of the Pleistocene herpetofauna of Britain and Europe through the epoch (virtually unchanged for the last 1.64 million years!).

Still, the analysis of herpetofaunal assemblages shows a good deal of potential in the following areas: paleoenvironmental reconstruction and correlation of certain Pleistocene interglacial sites, the recognition and distinction of interglacial, the climatic changes, in biogeography, in drawing the land bridges and colonization routes (Gleed-Owen, 1999).

The parsimonious assumption is that extant Pleistocene species have the same ecological preferences and requirements of their present day counterparts (Holman, 1998). In case of extant species, we have a real, clear data set, which is built

upon the results of scientific research regarding the ecology of live animals. The value of this information differs from one species to another. In case of species with restricted distribution range, resulted from particular ecological preferences and tolerances or even habitat preferences, the reconstruction of environmental conditions is supposed that mostly match the reality. In case of species which has a broad distribution range, and which can live in warm and as well as very cold climates, the picture is ambiguous.

All the 3 species (*Anguis* sp., *Coronella austriaca*/*Zamenis longissimus*) have a broad distribution range and show a high ecological tolerance. In the Southern distribution range they tend to occur in mountainous, in more humid habitats often at higher elevations (e.g. Valakos et al., 2008). In the North of range, they are confined to favorable localities such as sheltered, South-facing slopes. One main factor which could restrict the distribution of reptiles in colder climate and at higher elevations is the length of warm period needed for egg hatching in egg-laying species. This also applies to ovoviviparous species, whose females could find a more appropriate temperature range for eggs developing even in less favorable climate although they are still under the pressure of the captured high temperature amounts.

The *Anguis* sp. and *C. austriaca* are ovoviviparous. This biological adaptation makes them able to occur more in North. The *C. austriaca* is considered part of a cold trio (together with *Natrix natrix* and *Vipera berus*). *Z. longissimus* is listed as a paramediterranean form (Venczel, 2000). All the 3 species prefer the habitats with heterogeneous structure. *Anguis* sp. prefers rather moist and well-vegetated habitats with extensive ground cover and its presence in Pleistocene deposits indicate a moist terrestrial habitat (Holman, 1998). It occurs in pastures, glades in woods, in lush scrubland, etc. It is a semi-fossorial form that usually spends most of its time hiding in vegetation, under stones, among the roots of plants or in the leaf litter.

The two snake species live in a variety of dry, sunny habitats, which provide a diversity of thermal environments, as open woodlands mainly deciduous ones, sun-exposed forest margins, shrubby vegetation, rocky bushy slopes and also is hedgerows, wood-edges, open woods, bushy slopes (Arnold & Ovenden, 2002). They are heliophilous species and favor habitats with large diurnal amplitude both in atmospheric water vapor content (which is low on average) and in air temperature (high on average), although both species avoid excessive heat (Böhme et al., 2006). They are

secretive animals, but tend to be active during the daylight hours.

According to Böhme (1996), *Anguis* sp. and *C. austriaca* belong to the group of “invaders during the early part of a warm stage” and *Z. longissimus* to the “species characteristic of warm climatic optima”. In conclusion, the presence of *Anguis* sp. and either *C. austriaca* or *Z. longissimus* indicate a forested area with transitional vegetation types, from open, thus dry, to well vegetated, thus humid parts in a warm climatic stage. The type of forest could be deciduous or mixed.

The incidence of the two *Anguis* sp. so close to each other could be explained in 2 ways (although there might be further explanations):

1. the favorable hiding places are used frequently by more animals. The inundation of this kind of shelter could cause this double casualty;

2. during hibernation time the favorable hibernation places are occupied by more animals (often with specimens of other species). Similarly, the inundation of this kind of burrows could cause this double casualty.

The palynological evidence found in the reptile fossils host level suggests the presence of *Pinus-Picea* dominated woodland during the formation of these sediments, with low percentages of *Betula*. The composition of the forest vegetation, corresponding to this level, is characteristic to a warmer period of the Pleistocene - an interstadial. The presence of the fern spores indicates also moist conditions. Similar palynological associations were described from several sequences studied in Romanian Carpathians and attributed to the Late Glacial Interstadial (13000-11000 yr BP) (Feurdean & Bennike, 2004; Tanțău 2006; Tanțău et al., 2006; Feurdean et al., 2007). A few grains of *Tilia* and *Corylus* were identified in an upper level above the layer containing the reptile fossils. Based on the presence of these taxa we can assign this level to the Holocene.

6. CONCLUSIONS

It is the first time when such a fossilized reptile associations from these part of Romania were described. Also, from the conservation and variety of reptile forms point of view, this association is unique.

The palynological results are in good correlation with the life and climatic conditions of the studied species. In the absence of absolute age determination (e.g. U-Th chronology method) and based on the palynological analysis, it is suggested that the studied fossils could have lived during the Late Glacial Interstadial (13000-11000 yrs BP).

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