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Green toad (Anura: Bufonidae) skeleton from the Upper Pleistocene of Hungary (Nagyharsány Crystal Cave, Villány Hills)

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Abstract – The Nagyharsány Crystal Cave is a new, probably Late Pleistocene palaeovertebrate locality, from where this is the first report on the herpetofauna. The study revealed the presence of *Bufo viridis* (Anura) and *Natrix* sp., the appearance of which taxa suggests that the fossiliferous sediments were probably accumulated at the beginning of an interglacial phase in a steppe or woody steppe environment. With 2 figures.

Key words – Anura, palaeoecology, Pleistocene, Serpentes, taphonomy, Villány

INTRODUCTION

The Villány Hills are very rich in Pleistocene fossil vertebrate localities. There are more than 50 occurrences where the fossil fauna may be correlated with the Lower and/or Middle Pleistocene ages (e.g. Kormos 1937; Kretzoi 1956; Jánossy 1986; Kordos 1991; Hír 1998).

The Nagyharsány Crystal Cave is situated on Szársomlyó Hill, north of the village Nagyharsány (Fig. 1). The cave was discovered in April 1994, but the anthropogenic deposits near the entrance suggest this event could have happened earlier by miners or amateur collectors or cavers (Vigassy & Leél-Őssy 2001). Katalin Takács-Bolner and her colleagues explored and mapped the cave, and established that it is 550 m long, vertically 60 m, and consists of two storeys. The upper storey contains great chambers covered by dripstone streamings, stalagmites and botryoids. The lower floor consists of calcite layers covered with hot water mineral calcite crust and stalactites. The Nagyharsány Crystal Cave is strictly protected by the Nature Conservation Act (Vigassy & Leél-Őssy 2001).

The Nagyharsány Crystal Cave has developed in the tectonic rifts of the Cretaceous Nagyharsány Limestone. The host rock consists of 99.5% calcium carbonate. In the cave deposits, besides carbonate minerals quartz, sericite/illite, chlorite, smectite, ankerite and anorthosite are detected, resulting from transport of materials from outside the cave (Vigassy & Leél-Őssy 2001).

The deposits of the cave are very rich in fossil bones; these are mainly isolated frog remains. Piroska Pazonyi collected the first samples in 1999, which were studied by László Kordos, who suggested the Late Pleistocene–Holocene ages for these specimens as preliminary results (see Vigassy & Leél-Őssy 2001). Some years later Pazonyi (pers. comm.) revised this age determination for Late Pleistocene based on fossilised mammal teeth.

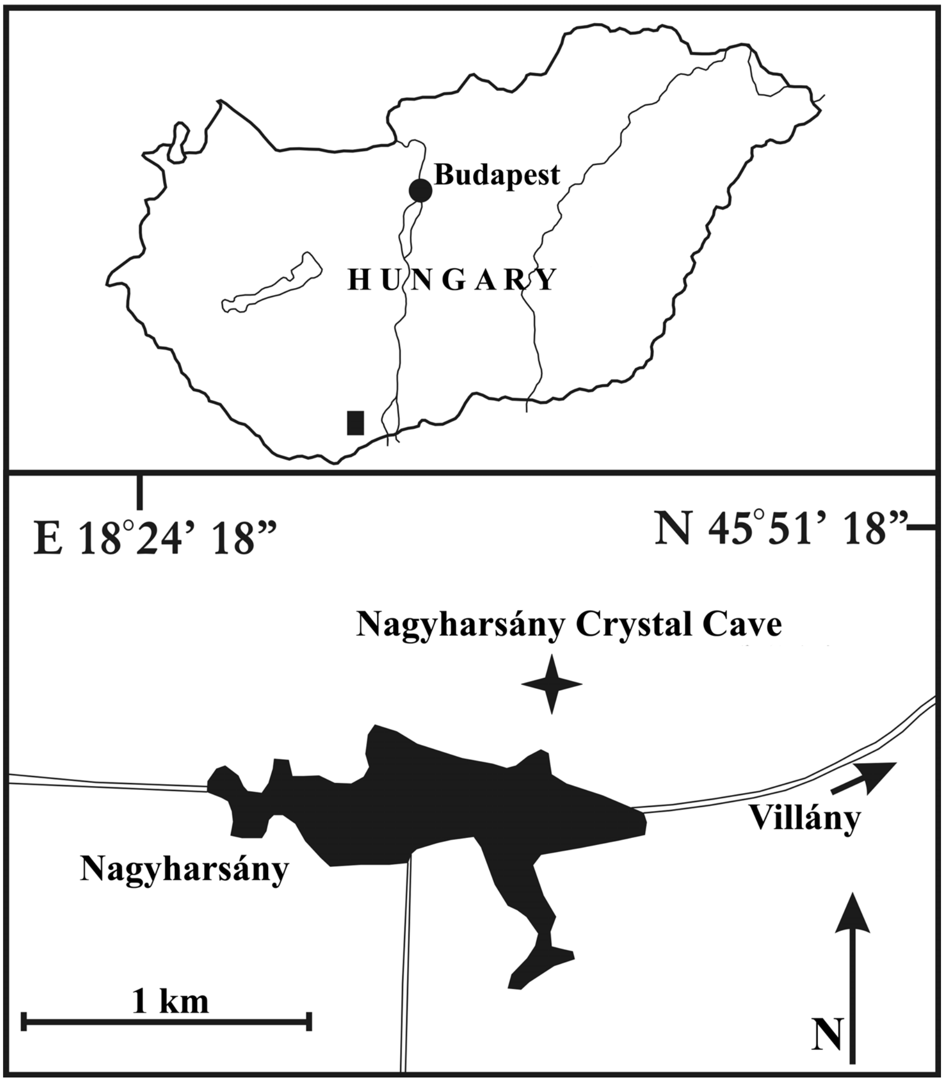

Fig. 1. Map showing the geographic location of the Pleistocene Nagyharsány Crystal Cave palaeovertebrate locality

In this paper a partial toad skeleton is described, which was preserved on a clay slab with some other fossil bones.

MATERIAL AND METHODS

The studied sample (PAL 2014.1.) is a partial green toad skeleton with other toad and snake fossils deposited in the collection of the Hungarian Natural History Museum, Budapest. These fossils are embedded in a piece of red clay slab. The preparation was carried out under light microscope (Nikon SMZ445).

Bailon's (1999) taxonomy was used for the classification of Neozoic anurans and morphological terminology, while the taxonomic nomenclature of frogs is based on Sanchíz (1998) and Martín *et al.* (2012). Rage's (1984) work was used for the classification of snakes and their morphological terminology.

SYSTEMATIC DESCRIPTION

Class Amphibia Linnaeus, 1758
Subclass Lissamphibia Haeckel, 1866
Superorder Salientia Laurenti, 1768
Order Anura Fischer von Waldheim, 1813
Family Bufonidae Gray, 1825
Genus *Bufo* Garsault, 1764

Bufo viridis Laurenti, 1768
(Figs 2/1, 3–7)

B. viridis is represented on the slab by a partial skeleton and some isolated bones. The partial skeleton is exposed in ventral view (Fig. 2/1). Only a few skull bones are preserved from this specimen, as well as the almost complete vertebral column.

Cranium – The frontoparietal is always fused with the prootic and the exooccipital in *Bufo viridis* (e.g. Bailon 1999; Venczel 2001; Blain *et al.* 2010). An extinct species with close affinities to *B. viridis*: *Pseudepidalea prisca* (Špinar, Klembara et Meszároš, 1993) is known (originally as *B. priscus*) from the Middle Miocene site (MN6) of Devínska Nová Ves and probably from the French Middle Miocene, too (Sanchíz 1998, and references therein). However, it should be noted that the type material of *Pseudepidelea prisca* was originally assigned to *Bufo* cf. *viridis* by Hodrova (1988, Fig. 4), while Martín *et al.* (2012) reclassified it as a member of the "*Bufo viridis* group". The genus name *Pseudepidalea* is not acceptable because this name suggests the "*Bufo viridis* group" belongs to another taxon than all other European toads (e.g. *Bufo bufo* or *B. calamita*).

Vertebral column – It is composed of eight discrete procoelous vertebrae, which are partially disarticulated. The atlas is ring-like with two anterior cotyles and with a pinch between the cotyles. The presacral vertebrae (II–VII) maintain transverse processes preserved to varying degrees. On the second vertebra the transverse processes project anteriorly, while on the others slightly laterally or posteriorly (e.g. IV). The sacrum has an anterior cotyle and two posterior condyles. The transverse processes extend moderately laterally and flare distally. The slender, posteriorly tubular urostyle has two anterior cotyles.

The isolated bones probably represent one or more specimens of green toads on this slab because they are significantly smaller than the bones of the above described partial skeleton. Differences in bone size and immaturity of these isolated

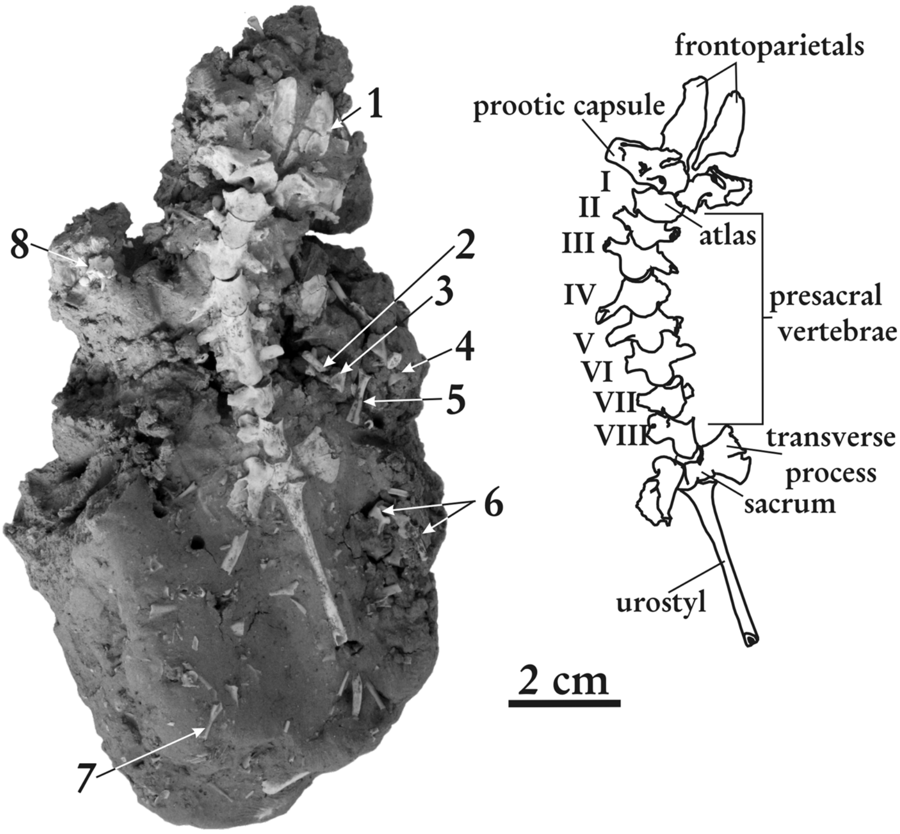

Fig. 2. Anuran and snake remains from the Pleistocene Nagyharsány Crystal Cave (PAL 2014.1.). 1 = *Bufo viridis* partial skeleton in ventral view; 2 = Anura indet. os cruris (tibiofibula); 3–7 = *Bufo viridis* right ilium in posterolateral, os antebrachii (radioulna) in lateral, coracoid in dorsal and vertebrae in anterior and ventral views; 8 = *Natrix* sp. trunk vertebra in posterior view

bones suggest that these fossils belong to one or more younger specimens. The dorsal crest, similarly to other toads (e.g. Holman 1998; Sanchíz 1998), is absent on this ilium (Fig. 2/3), and on the basis of the two-lobed dorsal protuberance this specimen belongs to *Bufo viridis*. The pars epicoracoidalis on the relatively elongated coracoid (Fig. 2/4) is flat-rounded dorsoventrally while the bends of the margo fenestralis and posterior are similar. The deep, rounded fossa under the capitulum and laterally under the rim of the joint on the radio-ulna (Fig. 2/5) is typical of *Bufo viridis* (e.g. Bailon 1999) just like the distally well-defined sulcus longitudinalis (Fig. 2/5–7). The two isolated vertebrae (Fig. 2/6) are similar to those described above on the partial skeleton. These are vertebrae IV and V of the vertebral column of a green toad.

Anura indet.
(Fig. 2/2)

The red clay slab also contains many fragmentary bones of Anura indet. by an angulosplenial, frontoparietals and mainly shin-bones, e.g. os cruris.

Order Serpentes Linnaeus, 1758
Family Colubridae Oppel, 1811
Subfamily Natricinae Bonaparte, 1838
Genus *Natrix* Laurenti, 1768

Natrix sp.
(Fig. 2/8)

Only a trunk vertebra can be classified as that of a snake. The trunk vertebra, which could be studied dorsally and posteriorly, is small in size, the length of the centrum is about 4 mm. The neural spine is relatively thin. The zygosphene is straight, provided with two lateral tubercles. The hypapophysis is posteriorly more prominent, expanding to the anterior verge of the condyle. The appearance of this vertebra is similar to those of the living *Natrix natrix* (e.g. Čerňanský 2011, Fig. 8M-R) but the largest part of this bone cannot be studied.

TAPHONOMICAL OBSERVATIONS

The fossil remains were transported from the primary biocoenosis to the Nagyharsány Crystal Cave by water (probably by a stream or spring snowmelt) through the fissures of the Nagyharsány Limestone and deposited in the cave. This suggests periodic external filling in of the red clay, which also took place by gravitational movement (Vigassy & Leél-Őssy 2001). The mainly isolated small mammal bones and the numerous, mainly isolated frog bones accumulated during these sedimentary events (e.g. great seasonal rains). Pazonyi and her colleagues separated six stratigraphic levels on the basis of the sedimentation pattern of this cave (Pazonyi, pers. comm.).

The chaotic orientation of bones on the red clay slab also shows the signs of transportation by water and gravitational movement. The straight fractures of these bones show that these animals were transported to the site long after their death (e.g. Sóron & Virág 2009). Nevertheless, the partial green toad skeleton suggests another event. This animal probably slipped alive into a crevice of the limestone and perished there. On the basis of the preliminary studies the green toad was frequent in the fossil material of Nagyharsány Crystal Cave, but this conservation method was probably unique at this locality. The moving sediment transported the corpse to the cave before its total disintegration. Anuran skeletal elements, mainly the pectoral and pelvic girdle and limbs, have cartilaginous parts, which are hardly ever preserved in fossils even if these are deposited, moreover, these easily break off the transported body.

PALAEOECOLOGICAL ASSESSMENT

During the Late Pleistocene there were many climatic changes in the Carpathian Basin, which is well demonstrated by cluster analysis of the mammalian fauna (Pazonyi 2011). Her study segmented the Late Pleistocene–Holocene period into six small mammal fauna types. Two of these phases are cold, two are warm and two phases are "transitional". The age of this Nagyharsány site is not known exactly, though Pazonyi (pers. comm.), based on the study of small mammals, suggests that it belongs to Late Pleistocene when the palaeoarea of Nagyharsány was probably a steppe or woody steppe.

According to Holman (1998) at present *Bufo viridis* occurs in Europe (including southern Scandinavia), eastern Kazakhstan, the Altai Mountains, Mongolia and extreme western China, and it is also present at the northern coast of Africa. However, Stöck *et al.* (2006) suggest by mitochondrial analysis that the North African toads belong to *B. boulangeri*, while the Chinese toads belong to *B. pewzowi*. The green toad is essentially a lowland species that often lives in dry, sandy areas, but is not restricted to such environments. Böhme (1996) suggests *B. viridis* with *B. calamita* appeared during the latter part of a warm stage, while the presence of *Natrix natrix* indicates the early part of a warmer stage. However, Rage & Bailon (2005) claim that the occurrence of bufonid toads is more often associated with whole interglacial periods. It is known that herpetological species, which are ectotherms, compared with homoiotherms, lack those complex physiological mechanisms that would enable them to regulate their body temperature. It follows that amphibians and reptiles are more sensitive to temperature changes. However, it is not certain whether the green toad is also a good indicator of local temperature changes since toads and frogs are able to respond to minor climate variations, as the onset of their biological cycle depends on the weather (Hartel *et al.* 2007).

CONCLUSIONS

From the fossiliferous (probably Late) Pleistocene Nagyharsány Crystal Cave the presence of *Bufo viridis* (Anura) as a partial skeleton and *Natrix* sp. (Squamata: Serpentes) with other isolated bones of green toad were detected on a red clay slab.

The results of the taphonomical studies suggest that the fossils were deposited on the slab in two ways. The isolated bones were deposited similarly to the other vertebrate fossils in the Crystal Cave, while the partial skeleton of the green toad was deposited as a whole and its limbs and other bones were separated later.

Although *Bufo viridis* is a broadly tolerant species, it is essentially indicative of dry, sandy palaeoenvironments, which on this site was probably a steppe or woody steppe. The presence of the green toad and *Natrix* sp. equally suggest a warmer interglacial phase during the deposition of these fossils.

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