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Bufo aff. *viridis* (Anura: Bufonidae) from the Middle Miocene diatomite of Szurdokpüspöki, northeastern Hungary

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The excellently preserved toad fossil was found the Middle Miocene (Badenian) lower freshwater-brackish diatomite layers in Szurdokpüspöki, Mátra Mountains, northern Hungary. This is the first amphibian fossil of the locality. This specimen is the only toad skeleton from Hungary and possibly from the Miocene of Europe. The toothless premaxilla and maxilla denote the family Bufonidae and the ossification of the frontoparietal, prootic and exooccipital indicates the toad species *Bufo viridis*. The difference from other bufonid toads is the presence of a small bulge on the ventral side of the well-preserved right ilium; thus it is referred to as *Bufo* aff. *viridis*. The size of the bones of the fossil anura suggests it was probably a young specimen. Detailed taxonomic description is given.

Key words: Amphibia, Anura, Bufonidae, Miocene, Badenian, diatomite, northeastern Hungary

Introduction

A unique anura skeleton in a diatomaceous earth slab can be found in the collection of the Eötvös Museum of Natural History. On the label of the fossil remains, only the indication "…püspöki" refers to Szurdokpüspöki. From the Middle Miocene (Badenian) quarry at Szurdokpüspöki, several vertebrate fossils were extracted from pyroxene andesite-tuff bedrocks: turtles, remains of deer, rhinos and proboscideans (deinotheres and gomphotheres). The tuff is covered by freshwater and marine diatomite beds. Besides articulated specimens of fishes and isolated shark teeth (Hajós 1968), remains of amphibians also turned up from the diatomite layers from other occurrences of this formation (Venczel 2004). This new specimen is the first fossil frog to have been found in the Szurdokpüspöki

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locality. The correct stratigraphic position of the fossil was unknown; thus a study of the diatoms of the slab was necessary. In the present work, the detailed study of the diatom flora of the locality by Hajós (1968) was a very important support. The Middle Miocene vertebrate localities of Hungary (Hasznos, Szentendre, Sámsonháza 3, Mátraszőlős 1 and 3/2) yielded at least seven different anuran taxa but most of them are isolated, fragmentary bones. Only a few fragmentary ilia indicated the presence of toads from the Hasznos and Sámsonháza 3 localities (Venczel 1997; Gál et al. 2000; Hír et al. 2001; Venczel 2004). This nearly complete skeleton is the best-preserved toad skeleton from the Miocene of Hungary (Venczel 2004) and possibly also represents one of the most complete toad remains from the Miocene of Europe (Sanchíz 1998; Rage 2003). In this paper a detailed description of this unique toad specimen from the locality of Szurdokpüspöki is provided.

Geologic setting

The Szurdokpüspöki diatomite mine is situated at the western slope of the Mátra Mountains in the Gyöngyöspata Basin, northeastern Hungary. The basement of the Gyöngyöspata Basin consists of Carpathian–Badenian pyroxene-andesite, andesite tuff and agglomerate. The irregular surface of this igneous rock is covered by Badenian sediments. The Badenian diatomaceous sediments were deposited in small basins and depressions within these volcanic events (Kis Kocsis 1954; Varga 1977). The diatomea of this locality were intensely studied by Hajós (1968).

The volcanic deposits contained various vertebrate fossils, including a terrestrial turtle species, *Testudo strandi* Szalai 1936 (Schréter 1953), deer (*Paleomeryx* or *Eoceros*) and rhinoceros remains (*Brachypotherium*) (Vígh 1939; Kretzoi and Pálfalvy 1969; Kordos 1985).

The diatomite beds of the locality consist of lower freshwater-brackish and upper marine diatomaceous earth deposits (Fig. 1) (Hajós 1968). The base of the lower bed is a clayey diatomaceous earth which often contains bentonite and montmorillonite strata as well as pyrite and gypsum. The upper part of these strata contains hydroquarzite and limnoopalite beds as well. These layers are covered by rifle-green calcareous and clean diatomaceous earth deposits with Hydrobia and ostracod remains. The overlying layer is again a clayey diatomaceous earth covered by diatomaceous earth deposits of varying color. Small fishes (*Clupea* and *Leuciscus*) were unearthed from the latter deposits. The cover of the lower freshwater-brackish diatomaceous strata is light grayish-white rhyolite tuff with pumice and mollusk shell remains (Hajós 1968). The upper, marine layers are built up by diatomaceous earth mixed with tuff, tuffy diatomaceous earth and calcareous-marly diatomaceous earth deposits. These beds provided many marine diatoms, sponge, mollusk, and fish remains as well as shark teeth (Halmai 1981). The upper marine diatomaceous earth strata are

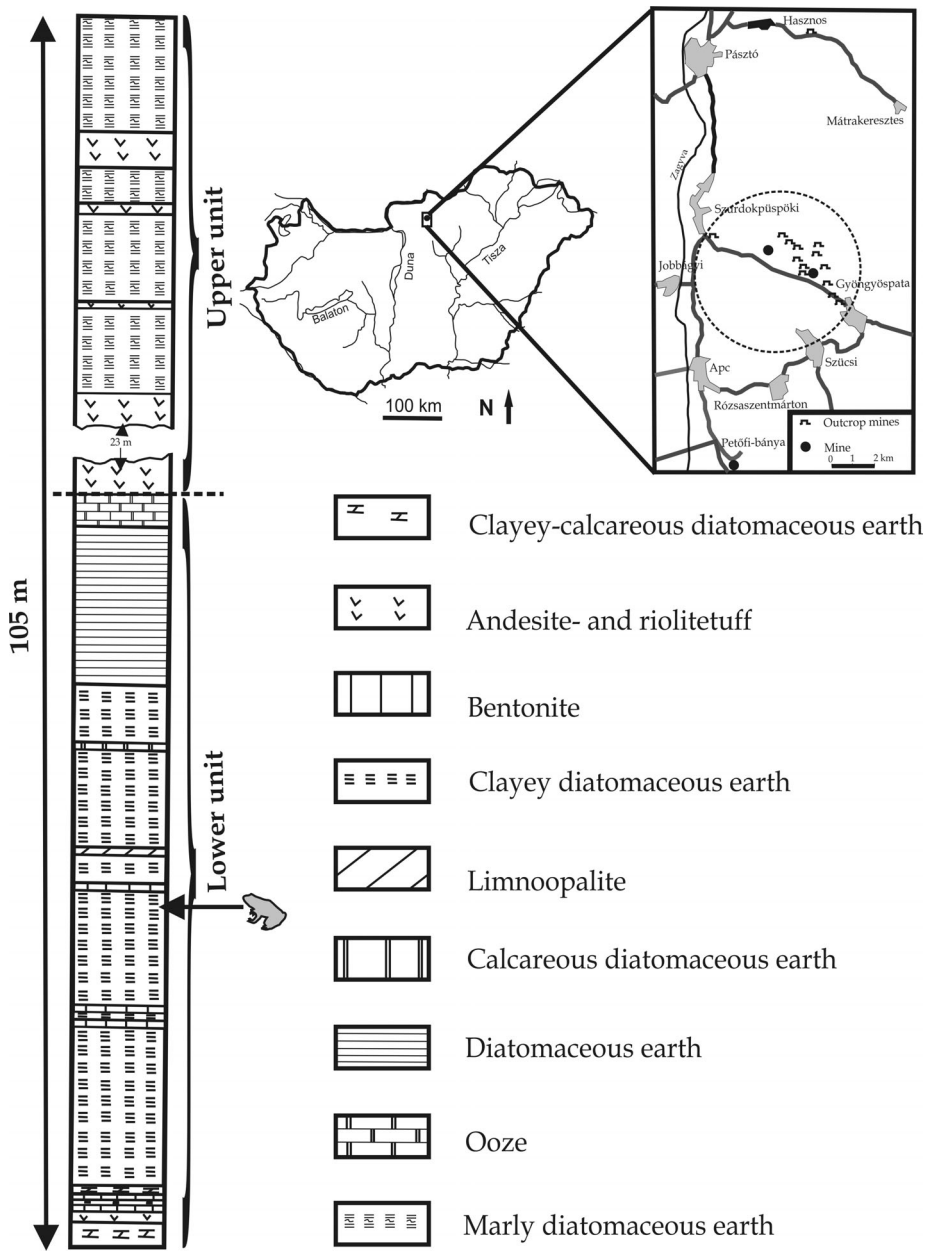

Fig. 1
Geographic position and stratigraphic column of the locality, modified after Hajós (1968)

covered by tawny, laminated, spongy and porous limestone. The eroded surface of these deposits is covered by Pleistocene-Holocene debris, loessy black volcanic clay soil and brown forest soil (Hajós 1968).

Material and methods

The studied specimen (V-290) is in the collection of the Eötvös Museum of Natural History, Budapest. This fossil was embedded in a piece of diatomaceous earth slab, relatively well exposed. The preparation was carried out under light microscope (Zeiss 477460).

The extraction of the diatoms was made on the basis of the work of Anantha Padmanabha Setty (1966). The study of diatoms demonstrated five freshwater diatom genera: *Amphora, Fragilaria, Melosira, Nitzschia* and *Surrirella*. The age of these diatoms is Badenian (Middle Miocene). Based on the work of Hajós (1968) the taxa and their ratio showed a strong similarity to the layer number 22 (freshwater-brackish) and distinctly differ from the flora of the other layers of the locality. It is therefore probable that the studied fossil toad came from this layer (Fig. 1).

Systematic paleontology

For the classification of Neozoic anurans and for morphological terminology, the work of Bailon (1999) was used. Nomenclature for wear facet is after Sanchíz (1998).

Class: Amphibia Linnaeus, 1758
Subclass: Lissamphibia Haeckel, 1866
Superordo: Salientia Laurenti, 1768
Order: Anura Rafinesque, 1815
Family: Bufonidae Gray, 1825
Genus Bufo Laurenti, 1768
Type species: Bufo bufo Linnaeus, 1758
Bufo aff. *viridis* Laurenti, 1768

Material

V-290, the specimen studied here is exposed in ventral view (Fig. 2). Most of the bones are complete, but some can only be inferred from their imprints.

Anatomical description

Cranium

Most elements of the skull are well preserved. The skull is wider than long (length = 18 mm, width = 22 mm).

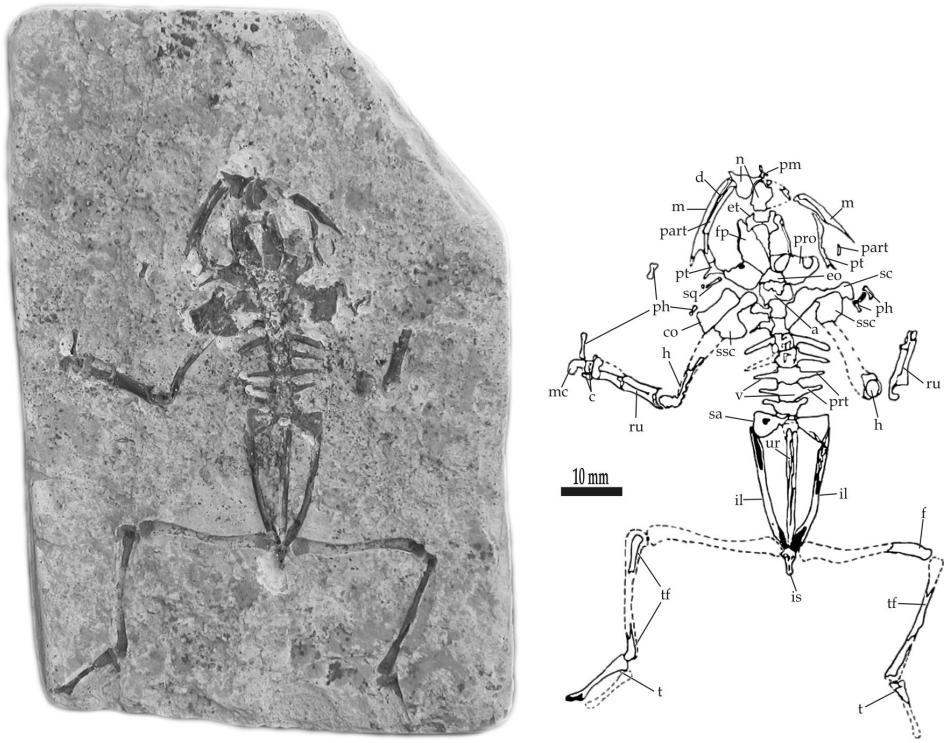

Fig. 2
Bufo aff. *viridis* partial skeleton (V-290) from Szurdokpüspöki in ventral view. Abbreviations: a: atlas; c: carpale; co: coracoid, d: dentary; eo: exoocipital; et: ethmoid; f: femur; fp: frontoparietal; h: humerus; il: ilium; is: ischium; m: maxilla; mc: metacarpal; n: nasal; part: prearticular; ph: phalanx; pm: premaxilla; pro: prootic; prt: transverse process; pt: pterygoid; ru: radioulna; sa: sacral vertebra; sc: scapula; sq: squamosal, ssc: suprascapula; t: tarsal; tf: tibiofibula; ur: urostyle; v: vertebra

Premaxilla – Only the right premaxilla is preserved and slightly displaced from its original place. The frontal process is cylindric and thin. The premaxilla is toothless.

Maxilla – Both maxillae are preserved, but the right maxilla is incomplete. The maxillae are slender and toothless. The posterior process is pointed.

Nasal – A pair of laminar bones are preserved, but the left nasal is incomplete. The shape of the bones suggests that the nasals were in contact with each other along their medial margins. The anterior process of the right nasal is sharp and it points to antero-lateral direction. The medial margin is straight, the parachoanal process is rounded and the paraorbital process is missing.

Sphenethmoid – The sphenethmoid is so fragmentary that it does not provide any information about osteological features.

*Frontoparietal*s – The frontoparietals are ossified with the prootic and the exoccipital. They were slightly overlapped by the posterior part of the

sphenethmoid. The pars frontalis is well-preserved and more scalloped than the pars parietalis. The otic capsule is incompletely preserved on both sides. The prootic process is broken.

Squamosal – Only the right squamosal is known, and that is incomplete. Its zygomatic arch has an elongated cone shape.

Pterygoid – The pterygoids are incompletely preserved on both sides. These bones are Y-shaped. Anteriorly the right pterygoid is covered by the maxilla and the angular.

Postcranial skeleton

Vertebral column

Presacral vertebrae – The vertebral column is composed of seven discrete vertebrae, which are disarticulated. The transverse processes are consistently long and strongly curved posterolaterally on the presacrals II–IV, strongly curved anterolaterally on the presacrals VI–VII, and oriented laterally on the presacral V. Only the fifth vertebra is well-preserved, the ventral side of the other vertebrae being damaged. The opisthocoelus morphology is obvious in the fifth vertebra.

Sacrum – The sacrum is broken but the transverse processes are well-preserved and their shape is triangular.

Urostyle – The urostyle is incompletely preserved. The anterior end and the dorsal crista of the urostyle are broken (the length of 18 mm).

Pectoral girdle and forelimb

Scapula – Only the left scapula is preserved but broken.

Suprascapula – Both suprascapulae are preserved, but the left one is incomplete. The anterior and distal margins of the suprascapulae are straight. Anteriorly, the right suprascapula is covered by the coracoid. The distal end of the suprascapula is twice as wide as the proximal one. This proximal part of the bone was cartilaginous during the life of the toad (Bailon 1999). The distal part of the left suprascapula is fused with the fractured scapula; the proximal part is missing.

Coracoid – The right coracoid is preserved, but incomplete. The anterior and posterior margins of the coracoid are concave; it is even in its cross-section. The glenoideal process is absent and the epicoracoidal part of the coracoid is splayed.

Humerus – Only the distal parts of humeri are preserved. The condyle of the humerus is ball-shaped. The ulnar epicondyle of the left humerus is slightly curved.

Radioulna – The radioulnae are preserved, the right one is almost complete. The length of the radioulna is 14 mm. The olecranon is strongly concave and the bone is splayed here. The capitulum of the radioulna is pointed.

Carpals and phalanges – The carpals are preserved only on the right side. The ulnare is curved laterally and it is concave medially. The radiale is exfoliated and the posterior part of this bone is nearly straight. The shape of the centrale is

spherical. The metacarpals are broken on the right side and are not separable. Only some digital elements are preserved. The second basal knuckle is preserved in its original place. This bone is hourglass-shaped and broken proximally. The other digital elements are dispersed around the skull. A distal phalange is next to the right coracoid. This bone tapers distally and the end of the bone is ball-shaped. Four basal phalanges are close to the left scapula. The base of these bones is wide. The frame of the basal phalanges is tapering and these bones are rounded laterally.

Pelvic girdle and hind limb

Pelvic girdle – Both ilia are preserved, but the anterior end of these specimens is broken. The preserved length of the ilium is 23 mm. The ilium is laterally compressed and ventrally curved. The pubis is missing; the ischium is preserved but ventrally broken. A small elongated bulge is visible on the ventral side of the right ilium which increases posteriorly. Dorsally, above the bulge, a small groove is visible, which tapers posteroventrally and curves back on the bulge.

Femur – Both femora are missing, only their imprints can be seen. The length of the imprint of the femur is about 20 mm.

Tibiofibula – Only the left tibiofibula is preserved, but it is incomplete. On the ventral side there is a small crest fragment. The length of this bone is 19 mm. The imprint of the right tibiofibula is apparent.

Tarsals – The tarsals are preserved, but fragmentary. The right tibiale is almost complete and only the imprint of the right fibulare is visible. The proximal part of the left tibiale is also preserved.

Comparison and discussion

The premaxilla and maxilla are toothless, the shape of the nasal is wedged, the vertebrae are procoelus, the middle part of the diapophysis of the sacrum is flared and the ilium is elongated and tubular. These features are typical of the family Bufonidae (Fejérváry 1917; Rocek 1993; Sanchíz 1998; Bailon 1999; Tempfer 2005). Remains of this family are known from the Early Miocene of numerous European localities (Venczel 2004).

The difference from other bufonid toads is the presence of a little protuberance on the ventral side of the right ilium. It is difficult to diagnose this bulge because this part of the left ilium is lost. It could be a pathological mutation because the surface of the bulge is slightly striated.

Three toad species are known in the European Miocene fossil material: *Bufo bufo* Linnaeus, 1758; *Bufo viridis* Laurenti, 1768 and *Bufo calamita* Laurenti, 1768. The Bufonidae characters of this specimen indicate that this toad fossil can belong to any one of these species. Laterally, between the olecranon and the capitulum on the proximal end of the radioulna there is a small but deep ditch which is typical of the genus *Bufo* (Rocek 1993). The frontoparietal is ossified with

the prootic and the exoocipital, which is characteristic only for *Bufo viridis*. The size of the bones (skull length and width, radioulna, ilium, urostyl, femur and tibiofibula length) of the V-290 specimen (Fig. 3) is very similar to the size observed in recent *Bufo viridis*, but bigger than *Bufo calamita* and much smaller than *Bufo bufo* in Boulanger (1898). The size of the specimen from Szurdokpüspöki is between the size of a female and male adult animal, so perhaps it was a young but developed toad.

mm	*Bufo bufo*		***Bufo viridis***		*Bufo calamita*		**V–290**
	♀	♂	♀	♂	♀	♂	♂?
Skull length	28	22	17	19	17	16	18
Skull width	39	30	23	25	22	18	22
Radioulna length	26	24	12	16	12	12	14
Ilium length	51	40	28	32	27	24	23
Urostyle length	34	28	20	21	17	16	18
Femur length	41	35	22	25	20	19	20
Tibiofibula length	38	33	22	24	20	18	19

Fig. 3
Comparison of bone size of the V-290 partial toad skeleton with *Bufo bufo*, *B. viridis* and *B. calamita* after Boulanger (1898)

Conclusions

Previously only fragmentary and isolated *Bufo* cf. *viridis* remains were known from the Miocene of Hungary (Sámsonháza and Hasznos localities) (Venczel 2004: p. 167–168, text-fig. 8A–B.). The specimen V-290 is the first amphibian remain from the Szurdokpüspöki locality and this is the first partial toad skeleton from Hungary. The study of diatoms of the embedding rock indicates that the skeleton originated from layer 22 of the lower freshwater-brackish diatomaceous earth sequence. The maxilla and premaxilla of the specimen are toothless, which is characteristic of bufonid toads. Features of the sacrum, urostyle and vertebrae

also confirm the affinities of the family Bufonidae. The frontoparietal is ossified with the prootic and the exoocipital which is a typical feature of *Bufo viridis*. On the basis of the presence of the small protuberance on the ventral side of the right ilium (which is not observed in *Bufo viridis*, or other bufonids), the specimen V-290 is referred to *Bufo* aff. *viridis*.

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