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Дигитални репозиторијум Рударско-геолошког факултета Универзитета у Београду

[ДР РГФ]

A new evidence for pachyostotic snake from Turonian of Bosnia-Herzegovina | Dragana Đurić, Dragoslav Radosavljević, Dragana Petrović, Miloš Radonjić, Petar Vojnović | Geološki anali Balkanskoga poluostrva | 2017 | |

10.2298/GABP1778017D

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A new evidence for pachyostotic snake from Turonian of Bosnia-Herzegovina

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Abstract. Records of Cretaceous marine snakes from Bosnia and Herzegovina have been known for nearly a hundred years. This paper presents a new finding of a pachyostotic snake from the local quarry Dubovac, three kilometers northwest of Bileća. The specimen consists of 29 vertebrae, seven of which are detached from the slab. The two best preserved vertebrae are almost square-shaped resembling *Simoliophis rochebrunei* but neural arches are much more swollen. Vertebrae and ribs are extremely pachyostotic as in *Pachyophis woodwardi*. Since there are no three-dimensional vertebrae of this species preserved from Bosnia and Herzegovina, precise identification was limited to a certain extent.

Key words: Turonian, Bileća, hind-limbed snake, pachyostosis, *Pachyophis*.

Апстракт. Фосилни налази морских змија из кредних седимената Босне и Херцеговине познати су од пре скоро сто година. У овом раду је приказан нови налаз пахиостотичне змије пронађене у локалном каменолому Дубовац, око три километра северозападно од Билеће. Примерак чини низ од 29 кичмених пршљенова од којих су седам изоловани из седимента. Међу изолованим пршљеновима два најочуванија су својим скоро четвртастим обликом слична пршљеновима *Simoliophis rochebrunei* али су неурални луци више отечени. Пршљенови и ребра показују висок степен пахиостозе као код *Pachyophis woodwardi*. Прецизна идентификација је у одређеној мери била ограничена јер не постоје сачувани тродимензионални пршљенови ове врсте из Босне и Херцеговине.

Кључне речи: турон, Билећа, змије са ногама, пахиостоза, *Pachyophis*.

Introduction

Cretaceous marine snakes represent a significant link in the interpretation of the phylogeny of Squamata and they are important for the understanding of snake origins (ZAHER & RIEPPEL, 1999, 2002; LEE & SCANLON, 2002; CALDWELL et al., 2015). Until today several taxa of pachyostotic snakes have been collected and all of them come from Cenomanian coastal regions of the Mediterranean Tethys (RAGE & ESCUILLE, 2003). Among these finds are fossils with preserved hind limbs (*Eupodophis*, *Haasiophis* and *Pachyrhachis*), as well as others in which the existence of hind limbs cannot be confirmed (*Mesophis*, *Pachyophis* and *Simoliophis*). Around one hundred years ago, the fossil

remains of two pachyostotic (non-pathological increase in bone thickness (HOUSSAYE, 2013) snakes were found in the Cenomanian sediments of Bosnia and Herzegovina (SLIŠKOVIĆ, 1970). Both species, *Pachyophis woodwardi* (NOPCSA, 1923) and *Mesophis nopcsai* (BOLKAY, 1925) come from the same locality of Selišta, north of Bileća. The holotype of *Pachyophis woodwardi* (NHMW 1912-I8) is housed in the Naturhistorisches Museum Vienna (NHMW) while for *Mesophis nopcsai* there is no clear evidence whether it was preserved or lost (LEE et al., 1999; RAGE & ESCUILLE, 2003; BARDET et al., 2008; HOUSSAYE, 2010).

The specimen presented in this paper undoubtedly belongs to the ancient marine squamate (Pachyophiidae) with the unsolved phylogenetic position. There is

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no consensus on whether Pachyophiidae present the sister group to all other snakes (CALDWELL & LEE, 1997; LEE & CALDWELL, 1998), or they belong to advanced macrostomatan snakes, which is of no relevance to the origins of snakes (ZAHER, 1998; ZAHER & RIEPPEL, 1999). This report will briefly describe the main morphological features of the specimen.

The locality and depositional environment

In the beginning of 2017, the authors of this paper received a piece of a thin limestone slab with fossil remains. The specimen was found in a local quarry Dubovac (Fig. 1c), three kilometers northwest of Bileća (Bosnia and Herzegovina). The surrounding area of Bileća (Fig. 1) is made of Cretaceous sediments which belong to the deposits of the Adriatic Carbonate Platform of the peri-Mediterranean realm. The overall paleogeographic conditions of the northeastern part of the Adriatic Carbonate Platform during the Late Cretaceous were controlled by syndimentary tectonics, eustatic sea level changes and increases of the amount of carbonate material production (VLAHOVIĆ et al., 2005). Such conditions led to local emergences of the platform and shallow-water depositional environments (VLAHOVIĆ et al., 2005). The Late Cretaceous sedimentary succession near Bileća consists mainly of limestones and dolomites which were deformed into large-scale open folds, locally truncated by thrusts during the Cenozoic uplift of the Dinarides.

No detailed analysis of the site was performed, while its stratigraphic position according to the Basic Geological Map of Yugoslavia is within lower Turonian sediments (NATEVIĆ & PETROVIĆ, 1970). The mapped lower Turonian lithostratigraphic unit is composed of thin bedded limestones with interbedded dolomites and is positioned above Cenomanian dolomites and below sediments in which the bivalve *Chondrodonta occur* appear (middle Turonian). The specimen is situated in the Natural History Museum in Belgrade (NHMBEO MV 280).

Description

The specimen is represented by a string of 29 vertebrae associated with the corresponding ribs (Fig. 2). The majority of vertebrae are complete and embedded in the sediment with the exception of the last two represented only by their imprints on the slab.

The first three vertebrae that are exposed in dorsal view are heavily damaged. Most of the following vertebrae are exposed with their lateral side on the slab. The last seven vertebrae in the string (two of which are best preserved) are detached from the slab and their lateral and ventral surface can be observed. In dorsal view (Fig. 3b) the vertebrae are slightly wider

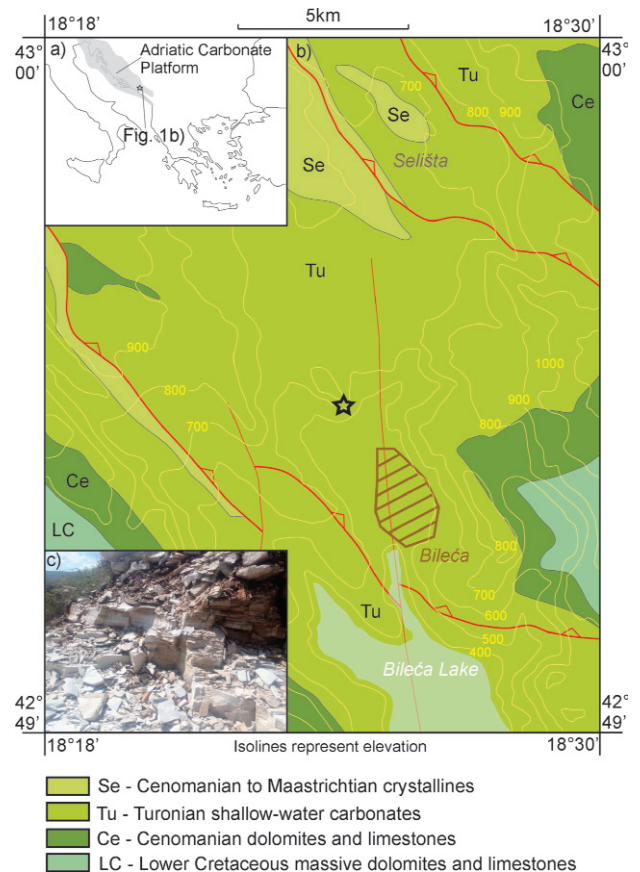


Fig 1. **a.** Overview map of the Balkan Peninsula with the position of the Adriatic Carbonate Platform deposits (modified after VLAHOVIĆ et al., 2005). **b.** Simplified geological map of the vicinity of Bileća (modified after NATEVIĆ & PETROVIĆ, 1970). The star symbol represents the original location of the specimen described in this paper. Note that Selišta toponym is placed according to the position taken from the map sources and that it could possibly be the same locality mentioned in NOPCSA (1925). **c.** Quarry in the Lower Turonian carbonates located on the hill Dubovac in which the specimen was found.



Fig. 2. Pachyostotic snake (Pachyophiidae NHMBEO MV 280) from Bosnia and Herzegovina.

than long and somewhat “butterfly-shaped” (LEE et al., 1999). The prezygapophyses are oval in shape and do not markedly project laterally like in *Simoliophis* (RAGE et al., 2016). Prezygapophyseal processes are lacking. The neural arches are distinctly swollen and their posterior border is strongly concave (Fig. 3b). The dorsal margin of the neural spine is swollen, elongated and almost triangular in shape. Its anterior border is somewhat inclined posteriorly. The exposed zygospheneal roof has concave edge.

the neural arches are convex. The centrum is thick and surrounding condyle. The neural canal is ogival in shape. Its size is approximately equal to condyle.

Ribs are associated with corresponding vertebrae, but are not visibly articulated to them because they are covered with sediment. They are well exposed along the entire left side of the vertebral column. Proximal ends of the ribs are so swollen that the intercostal space is practically absent. Their thickness increases moderately throughout this vertebral segment, while

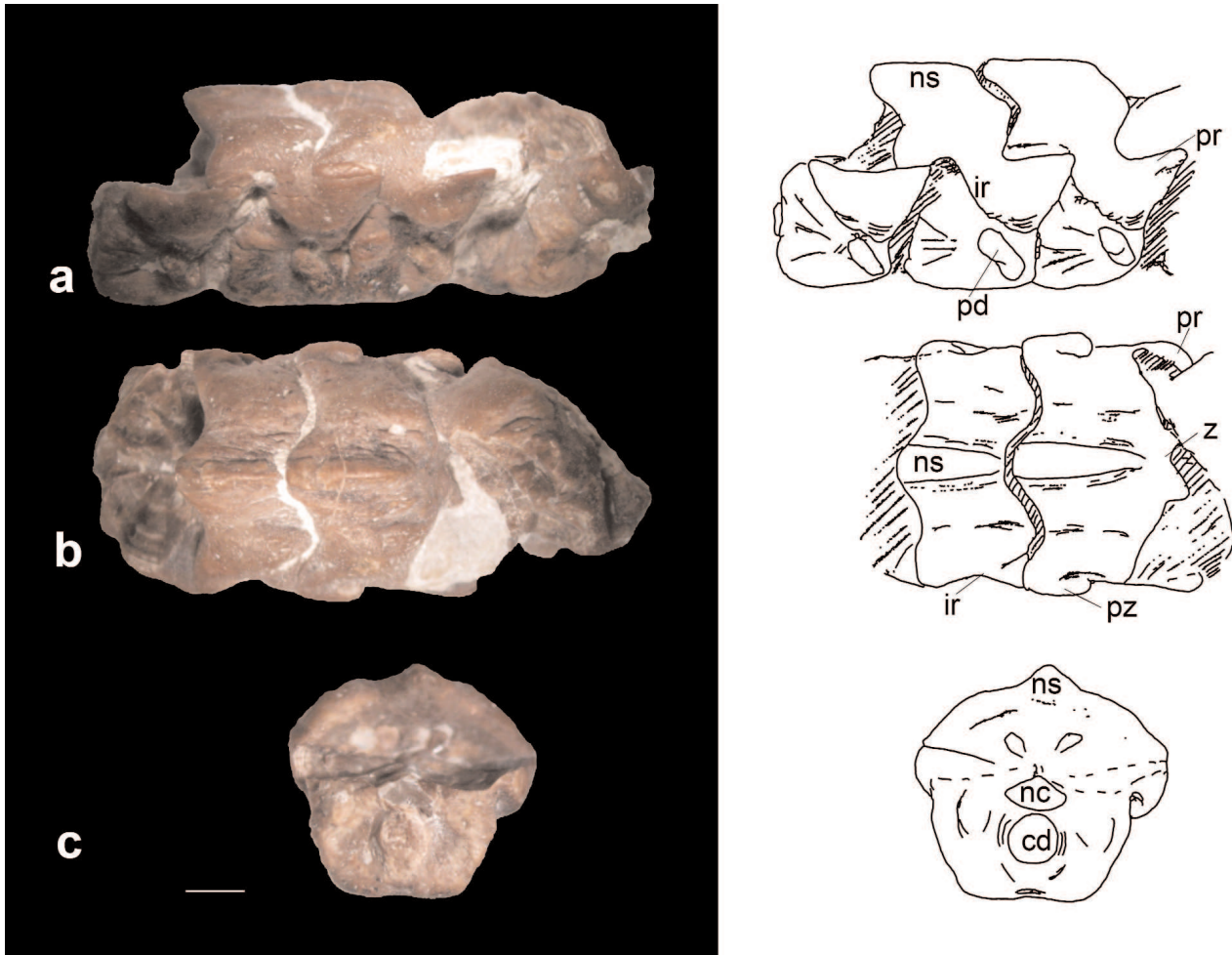


Fig. 3. Pachyostotic snake (Pachyophiidae) from Bosnia and Herzegovina: detached vertebrae (NHMBEO MV 280) in right lateral (a), dorsal (b) and posterior (c) views. Abbreviations: cd - condyle; ir - interzygapophyseal ridge; nc - neural canal; ns - neural spine; pd - paradiapophysis; pr - prezygapophysis; pz - postzygapophysis; z - zygosphene. Scale bar equals 2 mm.

In lateral view (Fig. 3a) the vertebrae are visibly higher than long. The neural spine is twice as long then high and slightly overhanging posteriorly. The interzygapophyseal ridge is thick and extremely swollen. The paradiapophyses are almost rectangular and inclined anteroventrally to posterodorsally. In ventral view the centrum appears plate-like, wider than long. The hemal keel is absent. Mid region of the ventral surface of centrum is occupied by a shallow groove with small unequal triangular extensions on anterior and posterior side. In posterior view (Fig. 3c)

the distal tip remains very slender. The vertebrae and ribs are strongly pachyostotic. Their size and level of pachyostosis increase gradually from anterior to posterior region of the specimen.

Discussion

The specimen consists of 29 articulated vertebrae with adjoining ribs. Although the sediment was broken in a few fragments, it has been determined that all

belong to one individual as shown in Fig. 2. Pachyostosis is well developed on all vertebrae and ribs and gradually increases anteroposteriorly. Since pachyostosis is the most prominent in the middle-trunk region (LEE et al., 1999), we can propose that this preserved segment belongs to anterior trunk and/or middle trunk part of the snake. The entire column is mostly exposed laterally and dorsally. Several of the last vertebrae display the highest degree of pachyostosis and the greatest similarity with the described holotype of *Pachyophis* (LEE et al., 1999). The last seven preserved vertebrae are completely isolated from the sediment with visible ventral surface. The general shape of the vertebrae is almost rectangular as in *Simoliophis* (RAGE et al., 2016). Centrum is slightly concave and shows clear absence of the hemal keel. The plate-like centrum, absence of hemal keel, shallow groove on ventral surface of centrum is common with *Simoliophis*. The prezygapophyses do not markedly project laterally and the interzygapophyseal constriction is little expressed as in *Simoliophis* (RAGE et al., 2016). The neural arches are much more swollen than in *Simoliophis* and their posterior border is strongly concave in dorsal view. The latter is much more similar to *Pachyophis* (LEE et al., 1999). The neural spines rise from the zygosphenes and attain their highest point at the posterior end as in *Pachyophis woodwardi* (LEE et al., 1999; HOUSSAYE, 2010). Unlike *Simoliophis* the neural spine is very low, twice as long than high and extends over the condyle. The paradiapophysis almost rectangular inclined anteroventrally to posterodorsally. In *Simoliophis* they are rather vertically (RAGE et al., 2016). The vertebrae are extremely swollen. The neural arches display the higher degree of pachyostosis than centrum, while the centrum is more pachyostotic than arches as in the case of *Simoliophis*.

The ribs are extremely swollen, circular in cross section and abruptly curved proximally, continuing more straight and tapering to distal ends. It suggests that this snake was laterally compressed, and therefore, probably was living in a marine environment (LEE et al., 1999). This conclusion is supported by a previously mentioned shallow-water depositional environment of the Adriatic Carbonate Platform where the specimen was found.

Conclusions

Opinion of the authors is that the studied specimen is most similar to *Pachyophis woodwardi* primarily because of the conspicuous pachyostosis of neural arches, their strongly concave posterior border and considerably low neural spine. *Pachyrhachis* and *Eupodophis* do not show that strong pachyostosis (RAGE & ESCUILLIE, 2003; HOUSSAYE, 2010). Regarding the similarities with *Simoliophis*, the plate-like centrum, shallow groove on ventral surface of the

centrum and the absence of hemal keel, they couldn't prevail in comparison with the observed characters that determine *Pachyophis woodwardi*. Since there are no three-dimensional vertebrae of this species preserved from Bosnia and Herzegovina, precise identification was limited to a certain extent.

Acknowledgments

The authors would like to express their deepest gratitude to the Editor-in-chief Professor NEVENKA ĐERIĆ for her editorial support. We would also like to thank to ALEXANDRA HOUSSAYE (Muséum National d'Histoire Naturelle, Paris, France) and RANDALL L. NYDAM (Midwestern University, Glendale, USA) for their helpful revisions and constructive guidelines in their respective comments.

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Резиме

Нови налаз пахиостотске змије из турона Босне и Херцеговине

Морске змије из креде представљају значајну карику за тумачење филогеније Squamata као и порекла змија. До данас је познато више таксона пахиостотичних змија са “задњим ногама”. Код неких су задњи екстремитети видљиви у фосилним остацима (*Eupodophis*, *Haasiophis*, и *Pachyrhachis*), док код других нема доказа њиховог постојања (*Mesophis*, *Pachyophis*, и *Simoliophis*). Пре скоро сто година у седиментима ценомана у околини Билеће (Босна и Херцеговина) пронађене су две змије из ове групе, *Pachyophis woodwardi* и *Meso-*

phis nopcsai (SLIŠKOVIĆ, 1970). У овом раду описан је нови налаз пахиостотичне змије пронађене у локалном каменолому Дубовац, три километра северозападно од Билеће.

Примерак чини низ од 29 пршљенова са ребрима у кречњачком седименту. Према HOUSSAYE (2013) пахиостоза (непатолошко повећање волумена костију које добијају отечен изглед) је веома изражена на пршљеновима и ребрима и расте од предњег ка задњем делу сачуваног дела тела. Како је пахиостоза најизраженија средином трупног региона (LEE et al., 1999) можемо закључити да сачувани примерак представља предњи до средњи део трупа змије. Последњих седам пршљенова је изоловано из седимента, од којих су два најбоље очувана. Ови пршљенови уједно показују и на већи степен пахиостозе и имају облик налик лептиру, као код холотипа *Pachyophis woodwardi* (LEE et al., 1999). Презигапофизе су овалне и нису превише истурене бочно. Презигапофизни наставци не постоје. Неурални луци показују већи степен пахиостозе од *Simoliophis*, а њихова постериорна ивица је изразито конкавна као код *Pachyophis woodwardi*. Неурални гребен је такође пахиостотичан и бочно гледано прелази дужину кондила. Такође се на овим пршљеновима може уочити да са вентралне стране центрум изгледа заравњено, кроз средину са плитким жљебом који се неједнако левкасто шири ка предњем и задњем крају и има скоро правоугаони облик као и *Simoliophis* (RAGE et al., 2016). Ребра су издужена, у проксималном делу изразито пахиостотична, а међуребарни простор скоро да не постоји, као што је то случај код *Pachyophis woodwardi* (LEE et al., 1999). У проксималном делу нагло се савијају вентрално, што змији даје бочно спљоштен изглед, типичан за становнике морских станишта.

Проучавани примерак показује највише сличности са *Pachyophis woodwardi*, нарочито у погледу изражене пахиостозе неуралних лукова, њихове конкавне задње ивице, као и изразито ниског и веома отеченог неуралног гребена. Насупрот овоме одсуство хемалног гребена на вентралној страни центрума, заравњен и скоро четвртаст облик веома су слични као код *Simoliophis rochebrunei* (RAGE et al., 2016). Такође, постојање веома плитког канала кроз средину центрума са неједнаким левкастим проширењима на оба краја пршљена, овај примерак повезује са *Simoliophis rochebrunei*. Без обзира на све сличности са *Simoliophis rochebrunei* аутори су мишљења да је ова пахиостотична змија најсличнија *Pachyophis woodwardi*. Међутим, узимајући у обзир да до сада нису познати изоловани пршљенови ове врсте из Босне и Херцеговине, прецизна идентификација је била делимично ограничена.