Brief report

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Boine snake *Bavarioboa* from the Oligocene/Miocene of eastern Turkey with comments on connections between European and Asiatic snake faunas

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Fossil remains of the extinct boine snake *Bavarioboa*, thus far known exclusively from several localities of western and central Europe, are reported for the first time outside Europe. The new fossil record is from the Mendikdere Formation in easternmost Turkey, dated Late Oligocene to Early Miocene. The finding provides strong evidence of links connecting ophidian faunas of Europe and southwestern Asia in the past, and confirms the supposition that Anatolia may have had close terrestrial connections with Europe around the Oligocene/Miocene boundary.

Introduction

Living members of the subfamily Boinae (family Boidae) are distributed mainly in the tropical Americas, while in the Old World their range is restricted to Madagascar and some western Pacific islands. In the past, however, they dominated in European and perhaps also Asiatic snake faunas. The genus *Bavarioboa*, an extinct member of the subfamily Boinae, was one of the most common and most recognizable snakes of the European Oligocene and Early Miocene.

This extinct genus was first described, as *Bavarioboa hermi*, from the late Early Miocene (MN 4) of Petersbuch 2 in southern Germany (Szyndlar and Schleich 1993). Subsequent studies (Szyndlar and Rage 2003) identified numerous remains of *Bavarioboa* in 14 fossil sites located in several European countries (mainly France and Germany) and ranging in age from the Middle Oligocene (MP 25) to early Middle Miocene (MN 5); altogether, the genus is represented by seven species.

Although it was speculated that the Asiatic continent was the most probable place of origin of *Bavarioboa*, this was not supported by any fossil record. Here we report *Bavarioboa* in the Mendikdere Formation in easternmost Turkey, near the Iranian frontier. At the same time, this is the first record of the genus in the Asiatic continent. The finding provides strong evidence of similarities (hence, exchanges) between snake assemblages inhabiting western Europe and southwestern Asia around the Oligocene/Miocene boundary.

The fossil remains were discovered during field work undertaken by IH in April 2010. The entire fossil material of vertebrates in the Mendikdere Formation is limited, consisting of two trunk vertebrae of *Bavarioboa* sp., described in detail below, two hardly identifiable trunk vertebrae of anguine lizards (probably two different forms), and two fragmentary dentaries of *Myotis*-like bats. Remains of Oligocene/Miocene terrestrial vertebrates are practically unknown from eastern Turkey. The only exception is the find of a few mammals and a crocodile of similar age reported recently from the Kağızman-Tuzluca Basin (Sen et al. 2011), located near the Armenian frontier, north of the Mendikdere Formation.

Institutional abbreviation.—AUNHL, Ankara University Natural History Laboratory.

Geological setting

The study area is situated in the Hınıs-Muş-Van Basin. This is an intermontane basin, 80 km long and 20 km wide, located in the eastern part of the North Anatolian Fault zone. The snake fossils were found near the village Kurucan, in the Saray district of Van province, near the Turkish-Iranian frontier (Fig. 1).

One stratigraphic section located east of Kurucan was measured and sampled during field work in 2010. This measured stratigraphic section is 115 m thick approximately and mostly composed of clastic lithologies. The Mendikdere Formation is located at the bottom of the section and is characterized by green, well-sorted, thick-bedded sandstone and conglomerate at the bottom and interfingering with clayey limestone, siltstone, greyish to green sandstone-shale intercalations at the top (Fig. 2). The fossil remains were deposited in a green-brown, roughly laminated siltstone, consisting of quartz, pyrite, and some glauconite (54m–S10AT1).

No reliable age estimates of the formation are available from the literature. The very shallow marine to brackish facies is generally difficult to date because of the absence of planktonic foraminifera. Age correlation ranges broadly from the Late Oligocene to Early Miocene (Şenel et al. 1984). The most characteristic and most abundant macrofossils occurring at the base of the Mendikdere Formation from the Kurucan section are oysters, in particular *Crassostrea cyathula* (Lamarck, 1806) (IH, unpublished material), widely recognised as an important stratigraphic marker for the Oligocene (Hoşgör and Okan 2009). Their presence generally points to a Rupelian–early Chattian age, enabling at least the lower stratigraphic boundary to be defined. Hence, lacking any other biostratigraphic tools, the oyster faunas are used to estimate the age of the overlying deposits.

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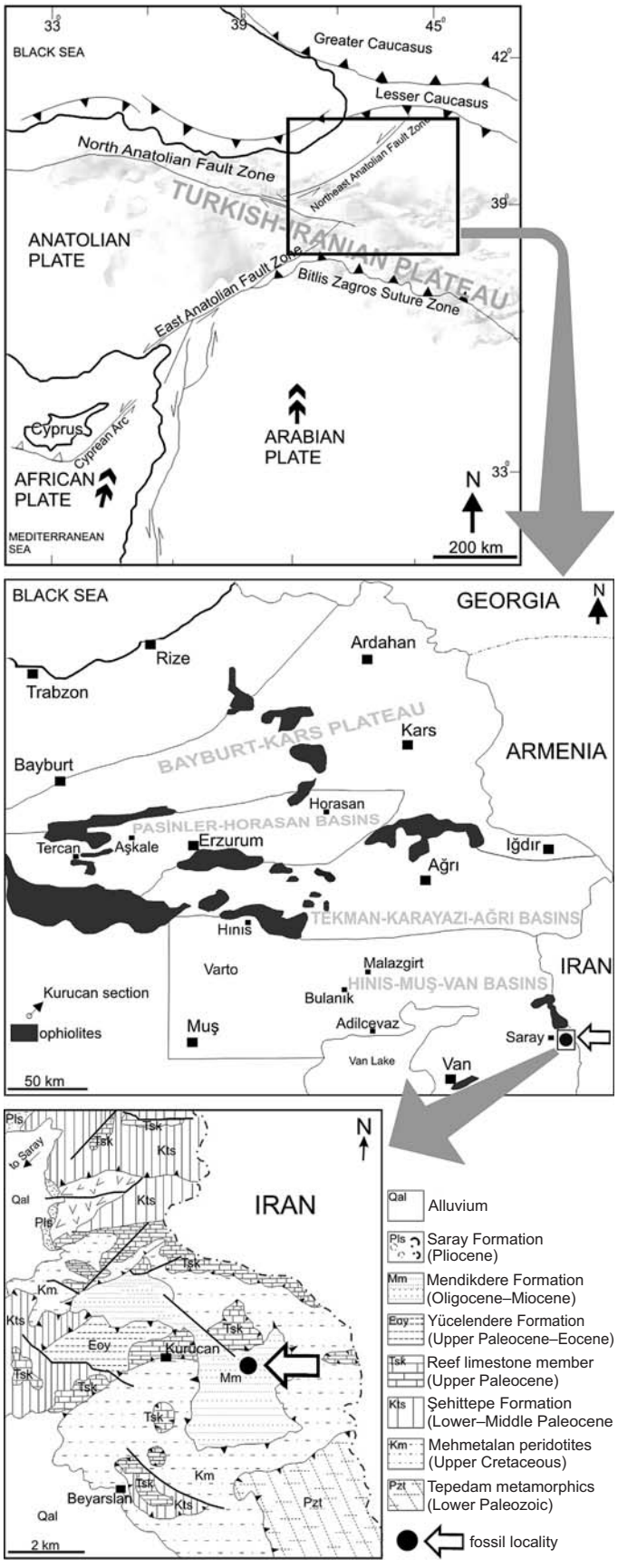

Fig. 1. Map of the Eastern Anatolia subbasins, and the location of snake fossil site (modified from Şenel et al. 1984; Bozkurt 2001; Sancay et al. 2006).

Systematic paleontology

Reptilia Laurenti, 1768

Squamata Oppel, 1811

Serpentes Linnaeus, 1758

Boidae Gray, 1825

Boinae Gray, 1825

Genus *Bavarioboa* Szyndlar and Schleich, 1993

Type species: *Bavarioboa hermi* Szyndlar and Schleich, 1993 from Petersbuch 2, Germany; Early Miocene (MN 4).

Bavarioboa sp.

Fig. 3.

Material.—AUNHL IZ100401a, anterior trunk vertebra (Fig. 3A); AUNHL IZ100401b, middle trunk vertebra (Fig. 3B).

Description.—The vertebra from the middle trunk portion of the column (AUNHL IZ100401b) is almost completely preserved except for slightly eroded tips of the prezygapophyseal processes and posterior surface of the condyle. The centrum length (measured as the distance between the cotyle lip and the end of the condyle) is 5.0 mm approximately; the centrum width (the width of the interzygapophyseal constriction) is 7.1 mm.

In lateral view, the vertebra is slightly higher than long. The neural spine is approximately as high as long, with anterior and posterior margins vertical, occupying one half the length of the neural arch, and beginning above the zygosphenal articular facets. The anterodorsal portion of the neural spine is slightly rounded. The lateral foramina are small but distinct. The paradiapophyses are subsquare in shape, somewhat higher than long anteroposteriorly, with indistinct subdivision into para- and diapophyseal portions. The subcentral ridges are prominent. The haemal keel is distinct, with its ventral margin straight.

In dorsal view, the vertebra is distinctly wider than long. The notch in the posterior border of the neural arch is moderately deep. The interzygapophyseal constriction is well expressed. The neural spine is moderately thick. The zygosphene is provided with three indistinct and wide lobes. The long axis of prezygapophyseal facets is weakly oblique. The prezygapophyseal articular facets are subtriangular in shape. The prezygapophyseal processes are not visible.

In ventral view, the centrum is distinctly wider than long. The haemal keel looks like a biconcave lens owing to the presence of a distinct constriction, at the level of the subcentral foramina, and prominent broadenings at the anterior and posterior ends; it is triangular in cross section. The subcentral grooves are relatively deep. The subcentral foramina are small but distinct. The postzygapophyseal articular facets are subtriangular in shape. The prezygapophyseal processes are weakly developed (their tips are lost).

In anterior view, the zygosphene is slightly concave dorsally. It is as wide as the cotyle, the latter being moderately flattened dorsoventrally. The prezygapophyses are located clearly above the floor of the neural canal and are weakly inclined. The

paradiapophyses project downwards slightly beyond the cotyle lip. The paracotylar foramina are absent.

In posterior view, the neural arch is weakly vaulted. The neural spine is moderately thick. The condyle is slightly flattened dorsoventrally.

The other vertebra (AUNHL IZ100401a), as characteristic of the cervical region of the column, is distinctly higher than long, the neural arch is more vaulted in comparison with the middle trunk vertebra, the neural spine is shorter and higher, and the haemal keel is replaced by a hypapophysis. The distal portion of the latter structure is broken off, but the preserved base indicates that the hypapophysis was prominent.

Remarks.—To some extent, the Mendikdere fossils resemble trunk vertebrae of the Erycinae (another subfamily of the family Boidae), in particular those of the living *Eryx–Gongylophis* complex. However, vertebral centra of the latter snakes are (usually) relatively shorter, neural arches much more depressed, prezygapophyseal processes longer, and haemal keels either underdeveloped or (if distinct) uniform in width (ZS, unpublished observations).

The fossil remains display clearly diagnostic features of the extinct genus *Bavarioboa*—see Szyndlar and Rage (2003) for detailed diagnoses of members of *Bavarioboa* and comparisons with other, extant and extinct, genera of the Boinae. More specifically, the vertebrae from the Mendikdere Formation most resemble several Late Oligocene and Miocene members of the genus, in particular *B. crocheti* from the French Late Oligocene (MP 28). Especially, the Turkish *Bavarioboa* and *B. crocheti* share the peculiar biconcave-lens-like haemal keel, the feature not observed in other species of the genus; besides, both snakes are characterized by weakly vaulted neural arches. However, the material from the Mendikdere Formation, consisting of two vertebrae only, is neither sufficient for the identification to specific level nor for the description of a new species. What is more, precise comparisons of the Turkish fossils with *B. crocheti* make great difficulties, considering that the latter is characterized by a very broad spectrum of intraspecific variation in its vertebral morphology (Szyndlar and Rage 2003).

Discussion

Our knowledge of the extinct snakes of Asia Minor is limited. There are only four published reports of ophidian fossils from the Asiatic part of Turkey. The snake fauna from the youngest (mid-Pleistocene) locality of Emirkaya-2 (Kessler and Venczel 1993; Venczel and Sen 1994) consists of several extant (or presumably extant) species. The Late Pliocene fauna of Çalta contains erycines (*Eryx–Gongylophis* complex), *Naja* (originally reported as *Palaeonaja*) as well as unidentifiable members of Scolecophidia and Colubridae (Rage and Sen 1976). The oldest locality of Bes-Konak seems most interesting, considering its age estimated as Early or Middle Miocene; unfortunately, its snake remains are badly preserved and offer little information (identified as "Colubroïde"; Paicheler et al. 1978). Members of the Boinae have never been reported from Turkey.

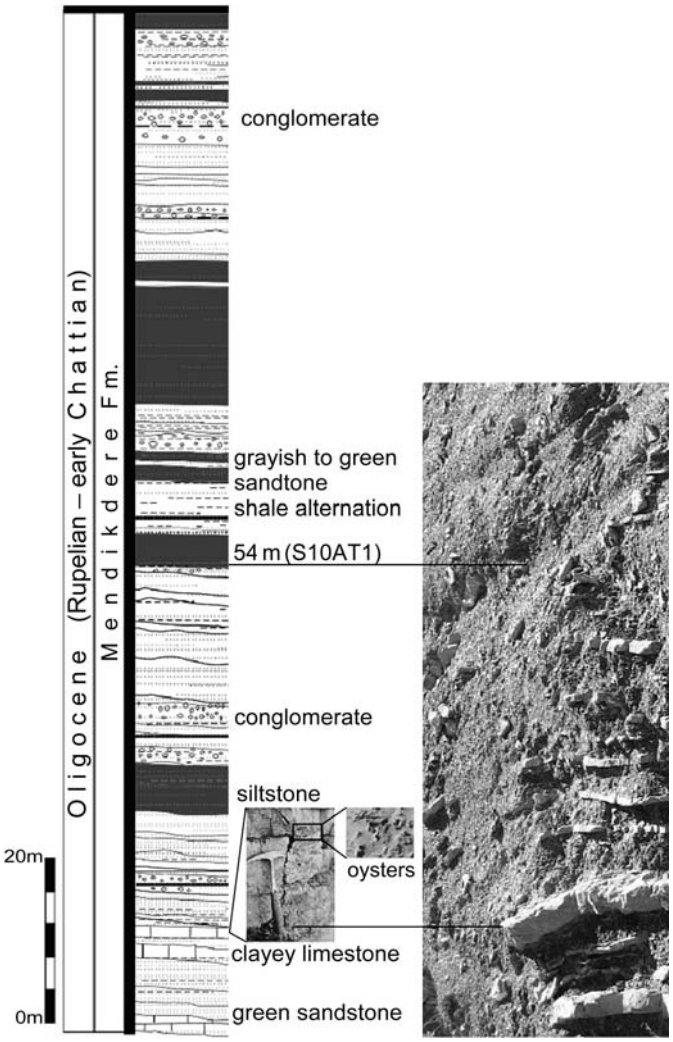

Fig. 2. The Kurucan section and sample location.

Most fossil remains of "Booidea" from Asia were referred to either erycines or pythons (Szyndlar and Rage 2003, and references therein; Head 2005; Böhme 2007). There is only one credible report of a member of the Boinae from Asia, a single (but well preserved) vertebra from the late Middle or early Late Miocene of Togay (Balkay Lake; Rage and Danilov 2008). The vertebra resembles those of *Bavarioboa* but differs from them by having a short (anteroposteriorly) neural spine. Another presumed member of the Boinae was reported from the Early Oligocene of the Zaisan Basin in Kazakhstan (Chkhikvadze 1985); unfortunately, this fossil has never been described or illustrated.

Most snakes inhabiting Europe before the Oligocene became extinct at the Eocene/Oligocene boundary. The existing fossil record indicates that Early Oligocene ophidian faunas were represented exclusively by several forms of very small dimensions; larger snakes, including *Bavarioboa*, appeared in Europe around the Middle Oligocene (Szyndlar and Rage 2003; Szyndlar et al. 2008). Where did the snakes in Europe arrive from? The most obvious answer was Asia, in particular its southwestern part, but thus far there has not been any fossil record in favour of this hypothesis. Interestingly, *Bavarioboa* disappeared from the European conti-

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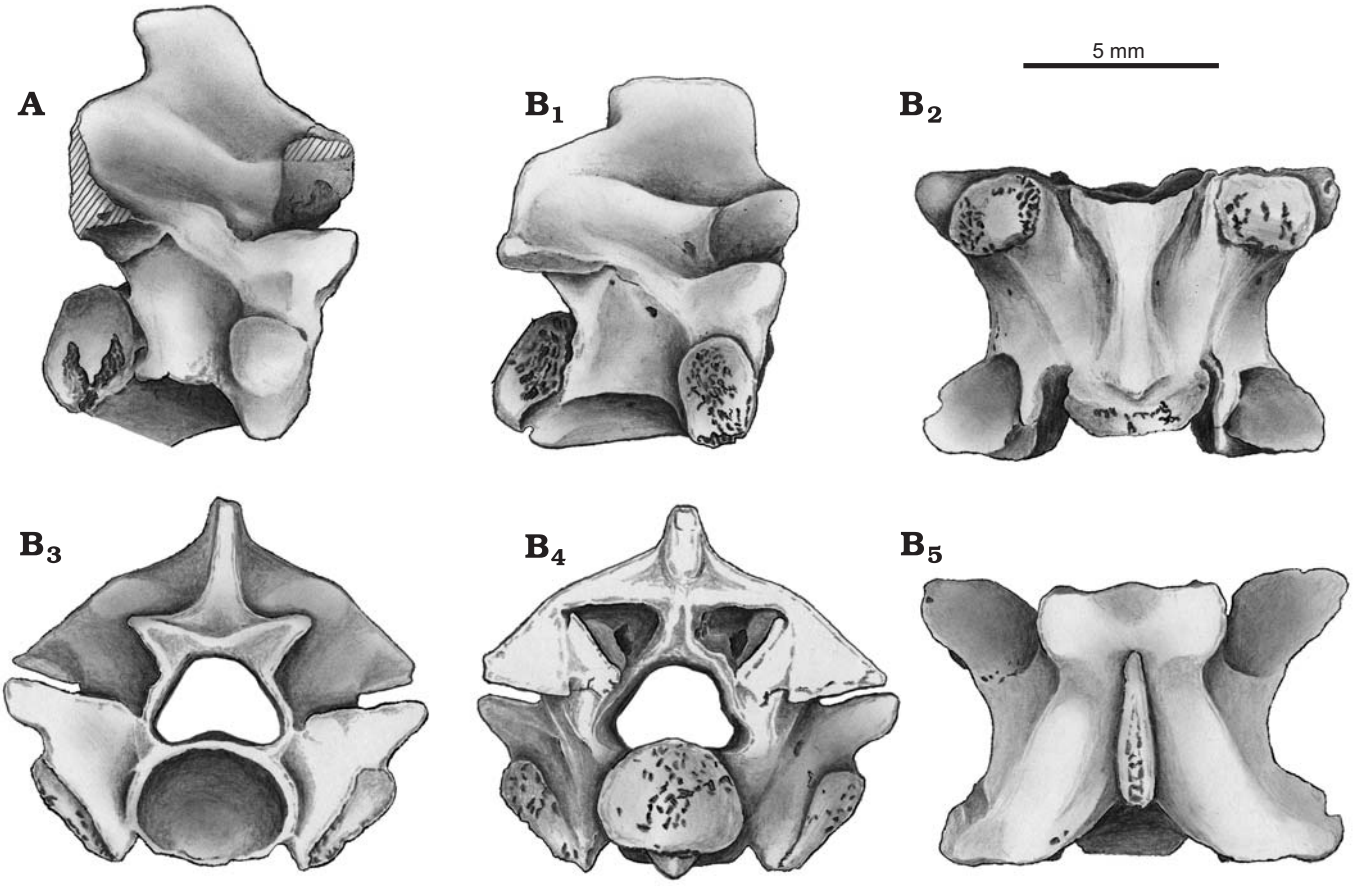

Fig. 3. Two vertebrae of boine snake *Bavarioboa* sp. from the Mendikdere Formation, Kurucan, Turkey, Oligocene/Miocene. **A**. AUNHL IZ100401a, anterior trunk vertebra in right lateral view. **B**. AUNHL IZ100401b, middle trunk vertebra, in right lateral (B_1), ventral (B_2), anterior (B_3), posterior (B_4), and dorsal (B_5) views.

nent before the end of the Oligocene (MP 28), perhaps following the growing aridization, and reappeared in the late Early Miocene (MN 3–4), arriving in Europe along with a wave of modern snakes, mainly colubroids. Apart from *Bavarioboa*, we know a number of other ophidians that, since the beginning of the Oligocene, invaded the European continent, withdrew from it, and then reappeared (Szyndlar et al. 2008). Again, also in such cases, southwestern Asia seems the most suitable place for survival and/or migratory route for the taxa that became extinct in Europe.

Recently published studies of Oligocene and Miocene rhinocerotoids and associated faunas from several Turkish localities (Antoine at al. 2008; Sen at al. 2011) indicate that Anatolia had close terrestrial connections with Asia and Europe during the Late Oligocene and Early Miocene. These observations contradict most palaeogeographic maps issued in the last decade (e.g., Popov et al. 2004), depicting marine barriers across the hypothetical migratory routes linking Anatolia with Asia and Europe. The present report of the occurrence of *Bavarioboa* in eastern Turkey brings additional evidence of links between terrestrial faunas of Europe and southwestern Asia.

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