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A BAJOCIAN (MIDDLE JURASSIC) MARINE GASTROPOD ASSEMBLAGE FROM THE BADAMU FORMATION, CENTRAL IRAN

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Abstract. Nine species of gastropods are reported from the Bajocian (Middle Jurassic) part of the Badamu Formation of Central Iran. This is the first report of a gastropod assemblage of this age from the shelves of the Kimmerian Continent. Seven species belong to the Vetigastropoda and two to the Caenogastropoda. Two new species, the pleurotomariid *Bathrotomaria iranica* sp. nov. and the eucyclid *Eucycloidea badamuensis* sp. nov., are described. The remaining species are left in open nomenclature owing to poor preservation. The composition of the gastropod association is strongly reminiscent of other Tethyan gastropod faunas, in particular those from the southern shores of the Tethys (India and Arabia) and from southern Europe. This indicates a relatively uniform distribution of gastropod faunas along the Middle Jurassic shores of the western Tethys.

Key words: Gastropoda, Middle Jurassic, systematics, palaeobiogeography, Badamu Formation, Central Iran.

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INTRODUCTION

Although Middle Jurassic gastropods have been researched intensively in the last three decades, a vast part of the information comes from Europe (Conti and Szabó, 1987, 1988; Conti, 1989; Conti *et al*., 1993; Fischer and Weber, 1997; Gründel, 1997, 2000, 2001a, 2003, 2005; Kaim, 2004, 2008, 2012; Szabó, 2009; Gründel *et al*., 2012; Gründel and Mitta, 2013; Monari and Gatto, 2013, 2014; Schulbert and Nützel, 2013), while the faunas from other regions are much less known. The Asian Middle Jurassic gastropods are known mostly from India (e.g., Das *et al*., 1999, 2005; Jaitly *et al*., 2000; Szabó and Jaitly, 2004) and Saudi Arabia (Fischer *et al*., 2001), the north-eastern shores of Gondwana at that time. Very few are known from the other regions of Asia and only a single species has been reported from Iran to date (Cox, 1936). The gastropod material presented in this paper comes from central Iran, which in the Middle Jurassic was a part of the Kimmerian Continent, a collage of microplates that collided with the Eurasian Plate during the Late Triassic; it was surrounded by a basin connected to the west with the Mediterranean, along the northern rim of the Tethys. As a consequence, the Jurassic faunas of Iran (ammonoids and bivalves in particular) bear a close resemblance to those from the Western Europe (Cox, 1936; Fantini-Sestini, 1966; Seyed-Emami *et al*., 2000; Fürsich and Pan, 2014). Gastropods from the Middle Jurassic of Iran are much less common and they have never been researched systematically, except for a single specimen of Bajocian *Pseudomelania* cf. *procera* (Eudes-Deslongchamps, 1842), described by Cox (1936) from the vicinity of Ravar (approx. 100 km north of the locality considered here). The aim of this paper is to describe a gastropod assemblage from the Middle Jurassic of the Badamu Formation in Central Iran collected by one of the authors (TB) and to compare its composition with that of other Middle Jurassic gastropod faunas from the Tethys Ocean and other Asian regions.

GEOLOGICAL SETTING

The study area is located in the central part of the Central-East Iranian Microcontinent (Fig. 1), which together with Central Iran and the Alborz Mountains form the Iran Plate of the Middle Eastern Tethysides (Wilmsen *et al*., 2009). The Badamu Formation is a marine unit within the thick molasse-type deposits of the Shemshak Group. It crops out along the Zarand Trough in the northern Kerman region of Central Iran (Fig. 1). The Badamu Formation reveals great lithological variation with a maximum thickness

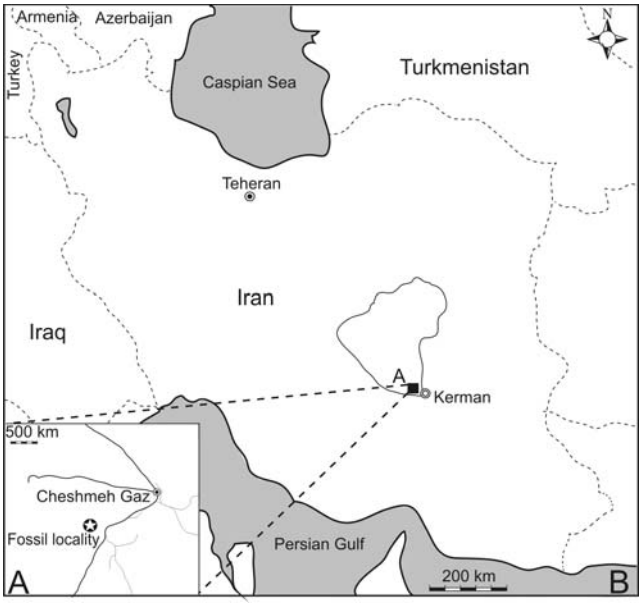

Fig. 1. Location maps. **A**. Location map of the study area, showing the fossil locality situated about 1 km west of the village Cheshmeh Gaz on the western side of the main Kerman-Zarand road. **B**. Map of the Central-East Iranian Microcontinent, showing the Kerman region.

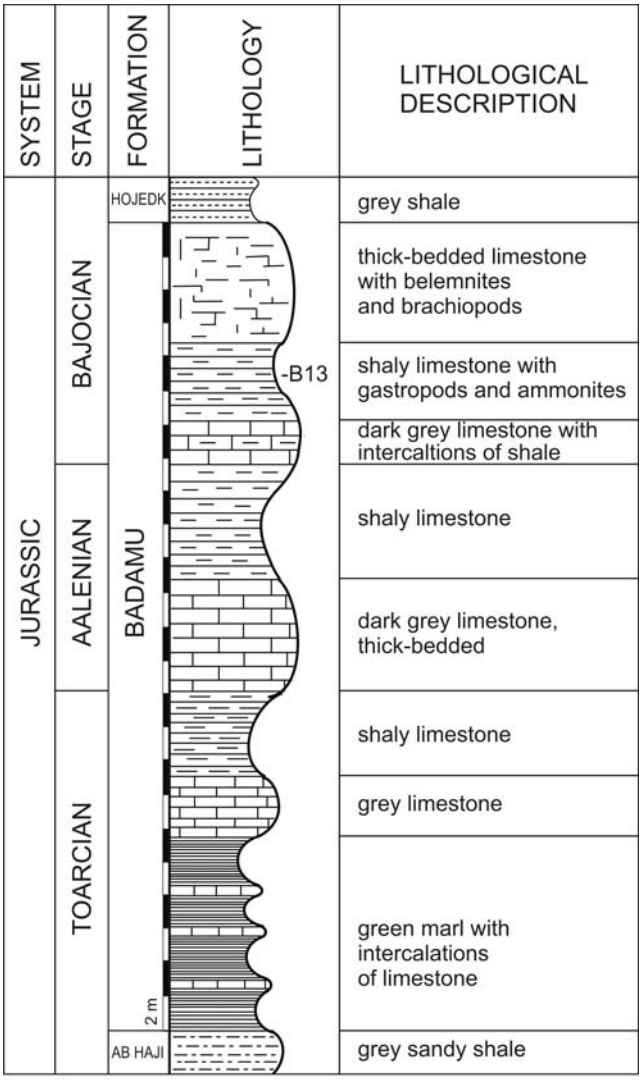

Fig. 2. Stratigraphical section of the upper part of the Badamu Formation, where the gastropods were found; B13 indicates lower Bajocian (*Otoites sauzei* Zone).

of 150 m and both lithology and thickness varying widely over the region, owing to different depositional conditions and differential subsidence in the Zarand Trough. The depositional environments to the north and along the trough axis were characterized by unstable conditions and repeated marine transgressions and regressions. In the southern part of the area, along the margin of the trough, more stable conditions and relatively uniform sedimentation predominated (Seyed-Emami, 1971).

The faunal composition of the Badamu Formation varies with the lithology and basically each locality differs with regard to fauna. Most of the fossils found in the study area are confined to the limestone beds. The most common marine invertebrate fossils include belemnites, ammonites and bivalves, while gastropods are much less common and poorly known so far.

The Badamu Formation begins with several metres of green marl containing intercalations of thin layers of limestone. Higher up, the marls are replaced by grey limestone with cephalopods of Middle-Upper Toarcian age, as indicated by the ammonoid *Hammatoceras speciosum* Janensch. The end of the Toarcian to the beginning of the Bajocian is represented by alternations of shaly limestone or limestone with shale intercalations. These beds yield ammonite, gastropod, belemnite and bivalve fossils. The uppermost part of the succession consists of about 9 m of massive limestone, yielding belemnites, ammonoids and scarce brachiopods. Most of the gastropods described come from the upper part of the Badamu Formation, from a shaly limestone yielding gastropods and ammonoids of the *Otoites sauzei* Zone (Fig. 2; lower Bajocian, B13). Another part of the collection was found in a scree from the Badamu Formation and should be treated as Toarcian-Bajocian in age. The gastropod composition of the latter sample, however, does not differ in composition and therefore the authors decided to treat the entire collection from Cheshmeh Gaz (Fig. 1) as a single supersample in the following general considerations.

The gastropod-bearing outcrop is located in the central part of the Badamu Mountains, about 1 km west of the village Cheshmeh Gaz on the western side of the main Kerman-Zarand road (coordinates: N30°24′26″; E56°42′12″; Fig. 1). The section at the Cheshmeh Gaz locality is composed of siliciclastic deposits in its lower (Ab-e-Haji Fm; lower Toarcian) and upper (Hojedk Fm; upper Bajocian) parts and contains mostly calcareous sediments in the central part (Badamu Fm; Toarcian to Bajocian).

MATERIAL AND METHODS

The large- and medium-sized gastropods were whitened with ammonium chloride and photographed in the photolab of ZPAL and the small gastropods were mounted

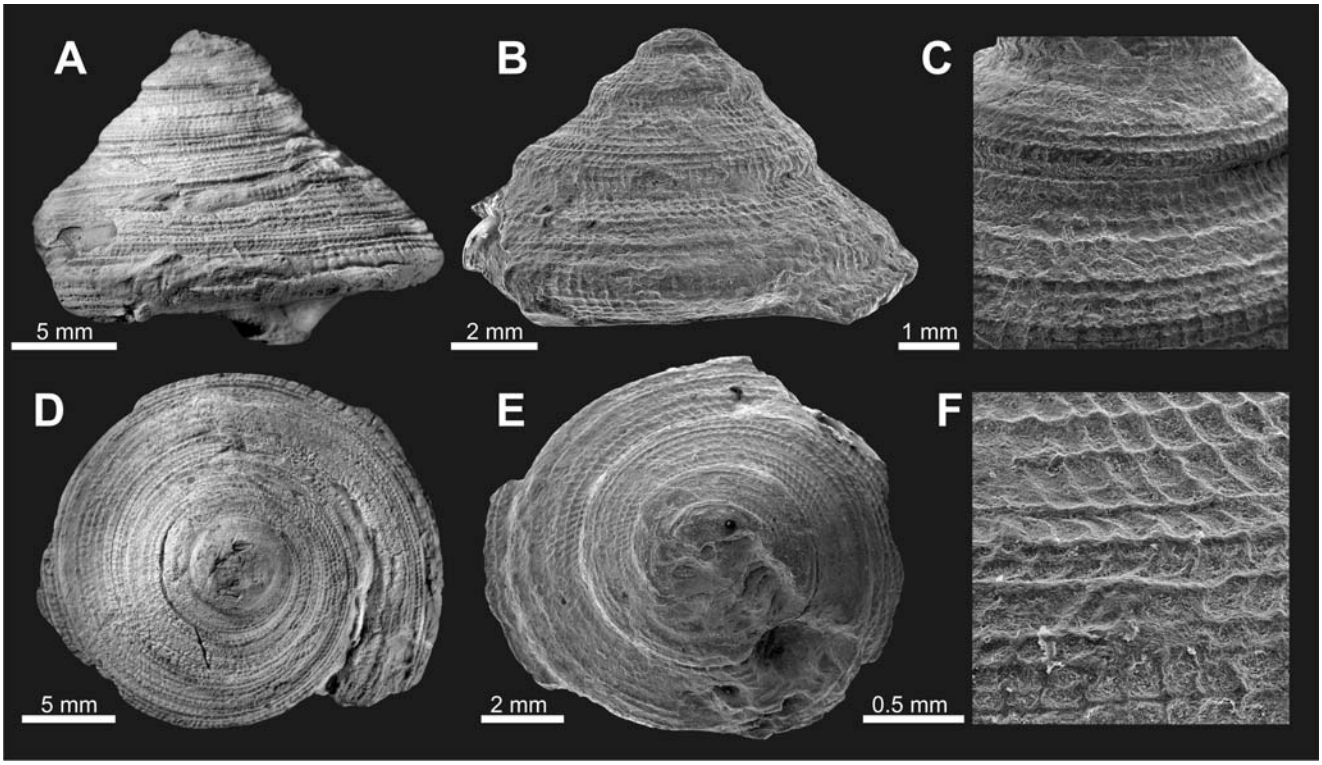

Fig. 3. *Bathrotomaria iranica* sp. nov. **A, D**. Holotype, ZPAL Ga. 19.1; A – lateral view; D – apical view. **B, C, E, F**. Paratype, ZPAL Ga. 19.2; B – lateral view; C – ornament detail; E – apical view; F – selenizone detail.

on stubs, coated with platinum, and examined on a Philips XL20 scanning electron microscope at ZPAL.

The specimens are housed at the Institute of Paleobiology, Polish Academy of Sciences, Warszawa, Poland (abbreviated ZPAL).

SYSTEMATIC PALAEONTOLOGY

Class Gastropoda Cuvier, 1795
Order Vetigastropoda Salvini-Plawen, 1980
Family Pleurotomariidae Swainson, 1840
Genus *Bathrotomaria* Cox, 1956

Type species: *Trochus reticulatus* Sowerby, 1821, from the Upper Jurassic (Kimmeridgian), England.
Occurrence: Early Jurassic to Late Cretaceous of Europe, Asia and Africa.

Bathrotomaria iranica sp. nov.
Fig. 3A–F

Material and types: Two specimens consisting of the holotype and paratype. Holotype: ZPAL Ga.19.1 (Fig. 3A, D), a recrystallized teleoconch. Paratype: ZPAL Ga.19.2 (Figs. 3B, C, E, F), a recrystallized teleoconch. Cheshmeh Gaz locality, lower Bajocian (Middle Jurassic), lower level B13, Badamu Formation, Central Iran.
Etymology: Referred to the Iranian region, where the material was found.
Diagnosis: Shell small-sized, trochiform, distinctly gradate; periphery delimited by a strong, spiral keel; ornament reticulated; selenizone narrow, concave at mid-whorl of the ramp; lunulae crossed by a median weak spiral cord; base flat; aperture subtrapezoidal-elliptical.
Dimensions (mm): ZPAL Ga.19.1, holotype: height, 11.3; width, 17.8; aperture height, 3.4; aperture width, 5.7. ZPAL Ga.19.2, paratype: height, 7.7; width, 9.7.
Description: Dextral, anomphalous, trochiform, strongly conical, small-sized and moderately low-spired shell. The protoconch is not preserved. The teleoconch consists of 5 angular whorls. The ramp of whorls is flat and inclined 45°. The periphery of whorls is delimited by a very strong, spiral keel. Some specimens (ZPAL Ga.19.3/4) have developed a convex peripheral shoulder, which delimits the ramp with the outer face. Suture is weakly incised. The shell surface is ornamented by a reticulated pattern of spiral and axial elements; small and rounded nodes appear at the crossing points. On the sutural ramp of whorls, the axial ribs are strongly prosocline and intercepted by spiral cords. Spiral cords are stronger than axial elements, more or less regularly spaced and present in number of 5. The selenizone is situated at mid-whorl of the ramp, just above the strong, peripheral spiral keel; it is narrow and concave and bears fine and weak lunulae, which are crossed by a weak, median spiral cord. Abapically to the selenizone, just below the peripheral spiral keel (or shoulder), the axial ribs become opisthocline to opisthocyrt. At the outer face, the axial ribs become straight and orthocline. The base is very flat to concave and ornamented by axial and spiral elements. The spiral cords on the base are equally developed as in the shell surface; axial ribs are strongly prosocline on base and weaker than spiral cords. At the crossing points, small and rounded nodes appear. The aperture is subtrapezoidal-elliptical and the slit is visible on the outer lip at mid-whorl.
Remarks: According to the characterization of Harasewych and Kiel (2007), species of *Bathrotomaria* can be distinguished by its large and trochiform shells, with a spire elevated or depressed. The

umbilicus may be broad or completely absent. The whorl profile is usually angulated and non-tuberculate, with a broad ramp and a second carina or angulation just covered by the following whorl. The selenizone is situated below the ramp angle. The surface is sculptured by spiral cords and threads, commonly cancellate at the intersection with the collabral threads. The selenizone is moderately broad and the labral slit short. Following the diagnosis of Harasewych and Kiel (2007), the specimens described here are identified as a species of *Bathrotomaria*.

Bathrotomaria martiae Szabó, 2009 (p. 52, fig. 45), from the Early Jurassic of Hungary, resembles the Iranian form, although *B. martiae* has a more conical and higher-spired shell, and the periphery of whorls are slightly more convex. *Bathrotomaria reticulata* (Sowerby, 1921) (p. 128, pl. 272, fig. 2; Fischer and Weber, 1997, p. 186, pl. 33, fig. 3 a, b; Kaim, 2004, pp. 158, 159, fig. 136 B), from the Middle Jurassic (Bajocian) of Europe and Late Jurassic (Oxfordian) of Russia, is also very similar to *B. iranica* sp. nov; but in Sowerby's species the selenizone forms a sharply delimited, rounded rib on the upper angulation of whorls and the outline of the spire is conoidal to strongly cyrtoconoidal. *Bathrotomaria mandoki* Szabó, 1980 (p. 61, pl. 2 figs. 2–4), from the Middle Jurassic (Bajocian) of Hungary, is larger than *B. iranica* nov. sp., has a more gradate shell outline, a higher spire and more convex whorls. *Bathrotomaria gangtaensis* Alberti *et al*., 2013 (p. 283, fig. 5 A–O), from the Late Jurassic (late Oxfordian) of India differs from *B. iranica* sp. nov. in having a selenizone distinctly elevated, forming a sharp, cord-like bulge on the angulation of whorls, and a more gradate shell. *Bathrotomaria buddhai* Das *et al*., 2005 (p. 336, fig. 5 A, B, E–G; Alberti *et al*., 2013; p. 285, fig. 6A–H), from the Late Jurassic (Oxfordian) of India, is also similar to *B. iranica* sp. nov.; but the Indian form is lower-spired and has a more convex ramp and rounded periphery. *Bathrotomaria dhosaensis* Das *et al*., 2005 (p. 337, fig. 6 G–I; Alberti *et al*., 2013; p. 287, fig. 7D–I), from the Late Jurassic (Oxfordian) of India differs from *B. iranica* sp. nov. in having a more gradate shell and a wider selenizone forming a prominent band just on the angulation of whorls. *Bathrotomaria aitkeni* Cox, 1965 (p. 138, pl. 22, fig. 6, pl. 23, fig. 1a, b) from the Late Jurassic (Kimmeridgian) of Africa, differs from the Iranian species in having a more gradate shell, the selenizone developed on a rounded spiral cord at the periphery of whorls, a narrow and deep umbilicus, and the ornament, consisting of numerous regularly spaced, spiral cords lacking a reticulate pattern.

The genus *Bathrotomaria* is well represented in the Middle Jurassic of Europe (Fischer and Weber, 1997; Gründel, 2003; Gründel *et al*., 2012). Here, the first occurrence of *Bathrotomaria* in the Bajocian of Iran (Fig. 7) is described.

Occurrence: Cheshmeh Gaz locality, lower Bajocian (Middle Jurassic), Badamu Formation, Central Iran.

Pleurotomariidae indet. sp. 1
Fig. 4C, D

Material: One fragmentary and recrystallized teleoconch, ZPAL Ga.19.6 (Fig. 4C, D).

Dimensions (mm): ZPAL Ga.19.6: height, 35.8; width, 46.6.

Description: Dextral, trochiform- gradate, cyrtoconical shell, with a strongly depressed spire. The protoconch is not preserved. The fragmentary teleoconch consists of 4 convex whorls. Suture is weakly incised. The selenizone is not preserved. The outer rim between last whorls and base is angular. The base is weakly convex and smooth (ornament not preserved). Umbilical area and aperture obscured by poor preservation.

Remarks: The single specimen described here seems to be a pleurotomariid. However, the poor preservation does not allow assigning it to any particular genus and species. In gross shell morphology, the Iranian material is similar in shape to *Pleurotomaria faberi* Monari and Gatto, 2013 (p. 769, fig. 12), from the Middle Jurassic (early Bajocian) of Luxemburg; but the authors decided to keep the specimen in open nomenclature as Pleurotomariidae indet. sp. 1. The gross shell shape of the current specimen (ZPAL Ga. 19.6) differs from *Bathrotomaria iranica* sp. nov. in having a more depressed spire.

Occurrence: Cheshmeh Gaz locality; lower Bajocian (Middle Jurassic), Badamu Formation, Central Iran.

Pleurotomariidae indet. sp. 2
Fig. 4A, B

Material: One fragmentary and recrystallized teleoconch, ZPAL 19.5 (Fig. 4A, B).

Dimensions (mm): ZPAL 19.5: height, 62.8; width, 83.8; aperture height, 19.3; aperture width, 43.2.

Description: Dextral, conical, trochiform, moderately high-spired and large-sized shell. The protoconch is not preserved. The fragmentary teleoconch consists of 4 to 5 strongly convex whorls. The suture is weakly incised in the spiral furrow. The whorls are moderately convex. The selenizone is not preserved. The surface is smooth. The base is nearly flat, and the umbilicus and aperture are not preserved.

Remarks: The single specimen available is most likely a representative of Pleurotomariidae, though the diagnostic characters of the family (see Monari and Gatto, 2013) are not preserved. This species is characterized by the highest spire among the Iranian pleurotomariid-like gastropods presented in this paper.

Occurrence: Cheshmeh Gaz locality; lower Bajocian (Middle Jurassic), debris, Badamu Formation, Central Iran.

Pleurotomariidae indet. sp. 3
Fig. 4E–J

Material: Three recrystallized and fragmentary teleoconchs, ZPAL Ga.19.7; ZPAL Ga.19.8; ZPAL Ga.19.9 (Fig. 4E–J).

Dimensions (mm): ZPAL Ga.19.7: height, 23.1; width, 43.3; aperture height, 11.0; aperture width, 16.2. ZPAL Ga.19.8: height, 62.8; width, 83.8; aperture height, 19.3; aperture width, 43.2. ZPAL Ga.19.9: Height, 17.0; width, 30.1.

Description: Dextral, gradate, moderately low-spired trochiform, medium-sized shell. The protoconch is not preserved. The teleoconch consists of 5 nearly flat whorls in the most complete specimens (ZPAL Ga.19.8). The outer face is nearly flat to weakly convex. The suture is moderately incised. The surface is smooth, owing to abrasion. The selenizone is not preserved. The base is nearly flat with a wide umbilicus. The aperture is subtrapezoidal.

Remarks: The material analyzed shows the general shell morphology, characteristic of Pleurotomariidae (see diagnosis in Monari and Gatto, 2013). However, like Pleurotomariidae indet. sp. 1 and sp. 2, it lacks any ornament pattern and the selenizone owing to preservation. Pleurotomariidae indet. sp. 3 differs from Pleurotomariidae indet. sp. 2 in having a less high-spired and less convex outer face. Pleurotomariidae indet. sp. 1 differs in having a much more depressed spire.

Occurrence: Cheshmeh Gaz locality; lower Bajocian (Middle Jurassic), upper level B13, debris, Badamu Formation, Central Iran.

Family uncertain
Turbiniform gastropod indet.
Fig. 5A, B

Material: One fragmentary and recrystallized teleoconch, ZPAL Ga.19.10 (Fig. 5A, B).

Dimensions (mm): ZPAL Ga.19.10: height, 33.8; width, 30.8.

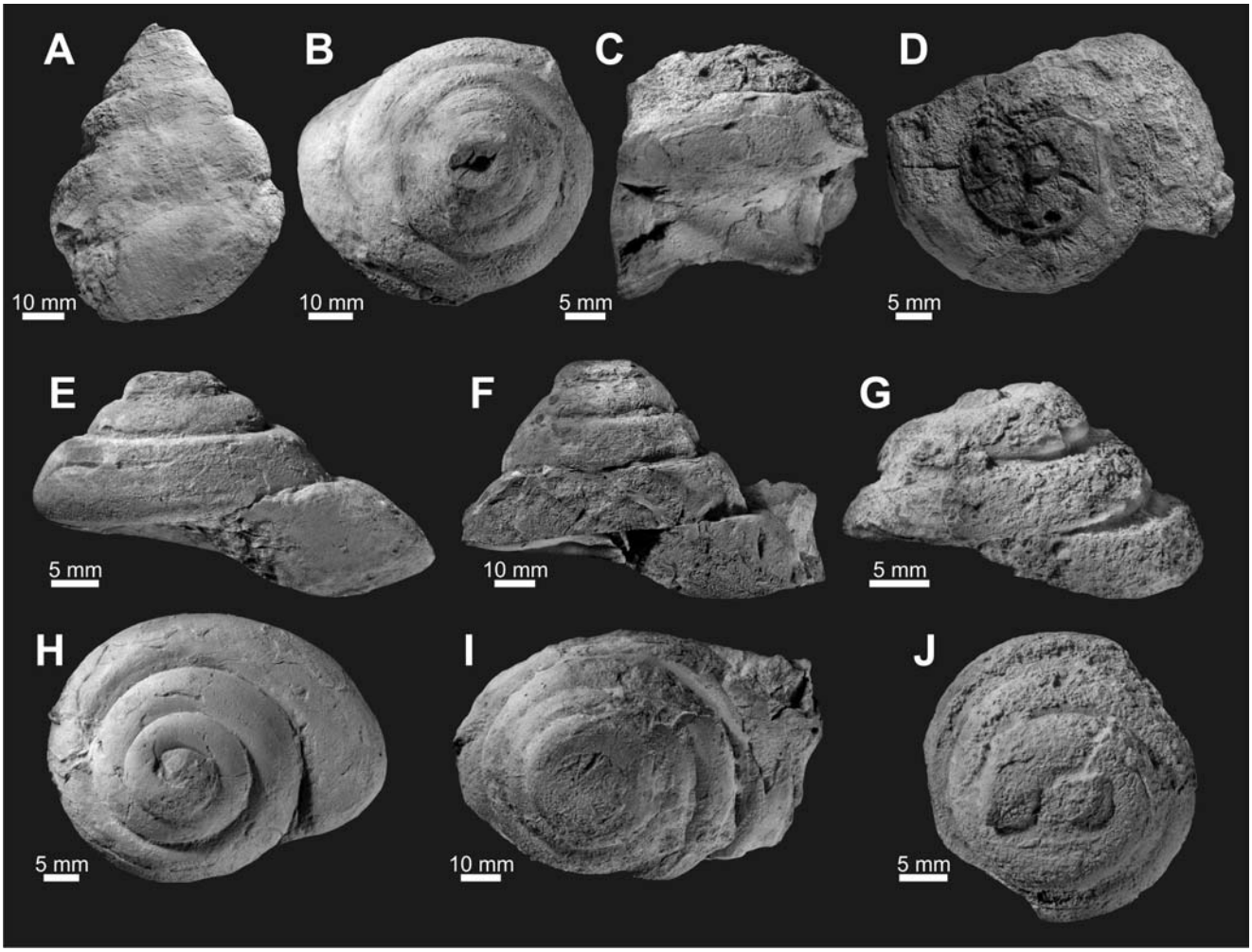

Fig. 4. Pleurotomariidae spp. **A**, **B**. Pleurotomariidae indet. sp. 2, ZPAL Ga. 19.5; A – lateral view; B – apical view. **C**, **D**. Pleurotomariidae indet. sp. 1, ZPAL Ga. 19.6; C – fragmentary teleoconch in lateral view; D – apical view. **E**, **H**. Pleurotomariidae indet. sp. 3, ZPAL Ga. 19.7; E – lateral view; H – apical view. **F**–**J**. Pleurotomariidae indet. sp. 3. F, I, ZPAL Ga. 19.8; F – lateral view; I – apical view; G, J – ZPAL Ga. 19.9 (G – lateral view; J – apical view).

Description: Dextral, turbiniform, medium-sized and moderately high-spired shell. The protoconch is not preserved. The inner mould of the shell consists of 3.5 strongly convex whorls. The suture is strongly incised. The last teleoconch whorl is slightly more expanded than the spire. The surface is smooth and lacks any ornament. There is no demarcation between lateral flank and the base. The base is strongly convex with a wide umbilicus. The aperture is not preserved.

Remarks: The single inner mould available may represent a wide array of taxa. The turbiniform shell shape may point to a possible vetigastropod affinity. None of the specimens in collection of the present authors is similar in shape to the mould under consideration.

Occurrence: Cheshmeh Gaz locality; lower Bajocian (Middle Jurassic), upper level B13, Badamu Formation, Central Iran.

Family Discohelicidae Schröder, 1995
Genus *Asterohelix* Szabó, 1984

Type species: *Discohelix spinicosta* Stoliczka, 1861, Early Jurassic (early Sinemurian), Northern Alps.

Age range: Early Jurassic (Sinemurian) to Middle Jurassic (middle Callovian).

Remarks: According to the characterization of Szabó (1984) and Gründel (2005) *Asterohelix* shells are small to medium sized, discoidal, with few whorls, lower side and upper side concave with depressed quadrangular whorl sections; umbilicus wide; both lateral keels with nodes; spiral lirae cover the shell surface; growth lines strengthened and opisthocline, rather prosocyrt on the umbilical side and opisthocyrt on the outer face; protoconch smooth. The type species of the genus is known from the early Sinemurian of the Northern Calcareous Alps and members of *Asterohelix* are also common in the Middle Jurassic (Bathonian–Callovian) of Saudi Arabia (see Fischer *et al*., 2001).

?Asterohelix sp.
Fig. 5E, F

Material: One fragmentary and recrystallized teleoconch, ZPAL Ga.19.12 (Fig. 5E–F).

Dimensions (mm): ZPAL Ga.19.1: height, 5.96; width, 15.3.

Description: Dextral, depressed, discoidal, biconcave, planispiral, medium-sized shell. The protoconch is fragmentary. The earliest teleoconch whorls are convex; toward the adult shell the whorls become concave and ornamented by two spiral bumps located in the adapical and abapical positions. The abapical spiral bump is strong with pointed nodes; the adapical spiral bump is weaker and

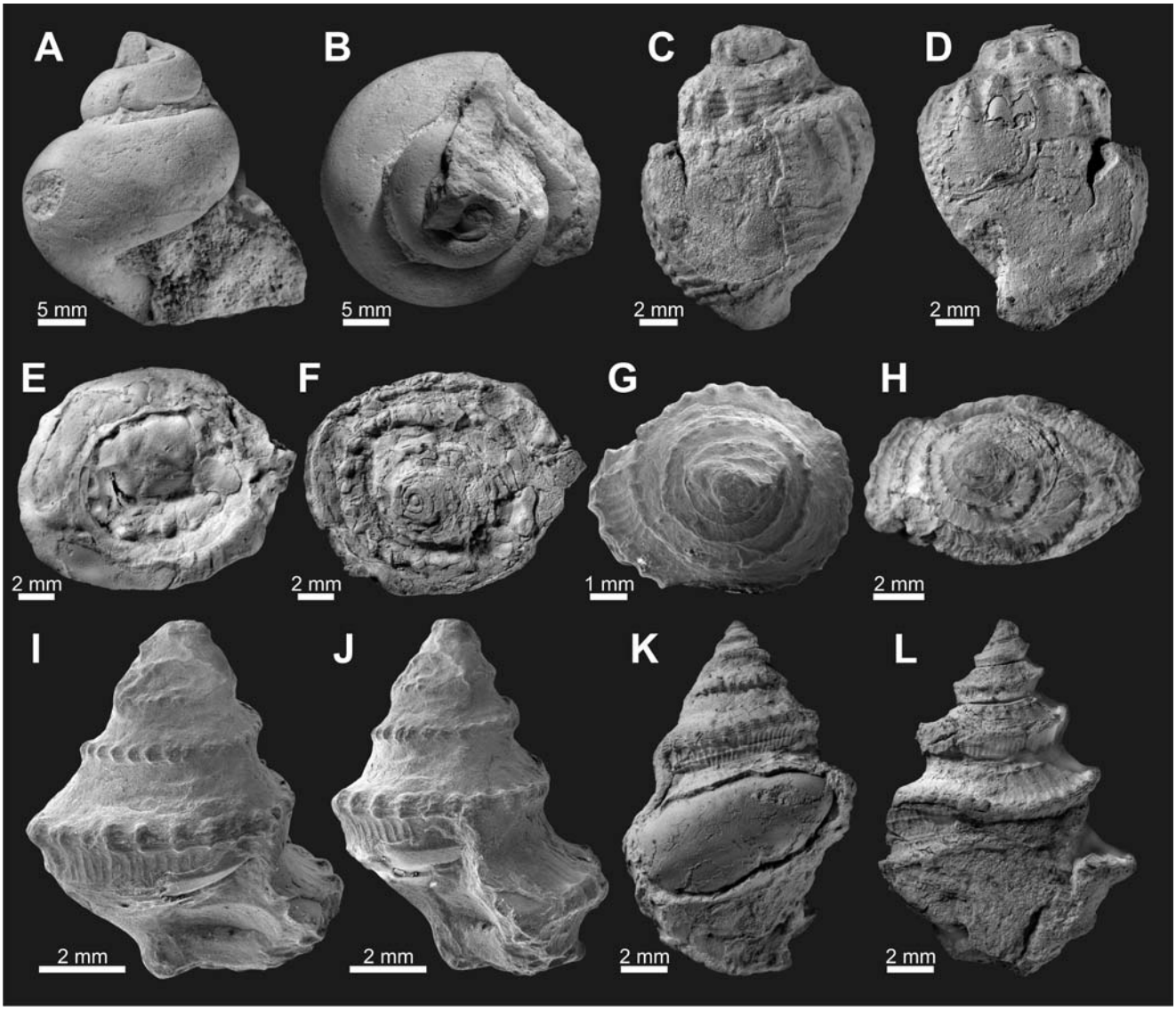

Fig. 5. Other gastropods from the Badamu Formation. **A**, **B**. Turbiniform gastropod, ZPAL Ga. 19.10; A – lateral view; B – apical view. **C**, **D**. *Purpurina* sp., ZPAL Ga. 19.11, lateral views. **E**, **F**. ?*Discohelix* sp., ZPAL Ga. 19.12; E – basal view; F – apical view. **G**, **L**. *Eucycloidea badamuensis* sp. nov. G, I-J, ZPAL Ga. 19.13, paratype; G – apical view; I, J – lateral views. H, L – ZPAL Ga. 19.14, holotype (H – apical view; L – lateral view; K – ZPAL Ga. 19.15, paratype, lateral view).

has smaller nodes. Spiral and axial elements are visible on the shell surface. The lateral side of the last whorl is angular and smooth. The base is strongly concave and excavated, delimited at the periphery by a strong spiral keel with pointed nodes, oriented abapically. On the base, there is a second weaker, spiral cord with smaller nodes. The aperture is fragmentary and oblique.

Remarks: According to the characterization of Szabó (1984) and Gründel (2005), the specimen described here may represent a member of *Asterohelix*. *Asterohelix spinicosta* (Stoliczka, 1861) (p. 185, pl. 3, fig. 15; Szabó, 1984, p. 68, fig. 2), from the Sinemurian of Northern Calcareous Alps, differs from the Iranian species in having the angulation of whorls with periodically repeating parabolic spines, a regular row of small, collabrally elongated tubercles, and strongly developed opisthocyrt growth lines on the outer face of whorls. *Asterohelix* (*A.*) *tenuisiensis* (Cox, 1969; p. 245, pl. 1, fig. 1a–d), from the middle Callovian of Saudi Arabia (Fischer *et al*., 2001, p. 74, figs 3a–c, 4) resembles ?*Asterohelix* sp.; however, the Arabian form has a clearly visible reticulate ornament pattern on the outer face, consisting of 15 spiral cords crossed by collabral and prosocline ribs; the periphery of the last whorl is three-keeled; the umbilical side is also ornamented with a reticulate pattern, and the aperture is sub-quadrangular. *Asterohelix (Bifidobasis) hourcqi* (Delpey, 1948) (p. 8, pl. 1, figs 2–4), from the early Bathonian of Saudi Arabia (Fischer *et al*., 2001, p. 74, pl. 1, figs 5a–c, 6 a, b, 7) differs from ?*Asterohelix* sp., in having the upper face of the whorls ornamented with five to seven granulated, spiral cords, which are crossed by prosocline and regularly spaced ribs; a large umbilicus limited by a sutural keel, and the aperture subovoid and inclined 55 from the coiling axis.

The species of *Asterohelix* are rare gastropods in the Jurassic worldwide, but it has been retrieved from the Early Jurassic of Europe (Szabó, 1984, 2009; Gründel, 2003) and from the Middle Jurassic of Saudi Arabia (Fischer *et al*., 2001).?*Asterohelix* sp. represents the first (although doubtful) record of the genus in the Bajocian of Central Iran (Fig. 7).

Occurrence: Cheshmeh Gaz locality; lower Bajocian (Middle Jurassic), Badamu Formation, Central Iran.

Family Eucyclidae Koken, 1897
Genus *Eucycloidea* Hudleston, 1888

Type species: *Turbo bianor* d'Orbigny, 1850, Bajocian, France.
Age range: Early Jurassic to Middle Jurassic.
Remarks: Bandel (2010) has characterized the species of *Eucycloidea* as having angled whorls and resembling in shell shape species of *Eucyclus* Eudes-Deslongchamps, 1860, as well as modern *Lischkeia* Fischer in Kiener and Fischer (1879). The type species, *Turbo bianor* d'Orbigny (as *Eucycloidea bianor* by Gründel, 1997, pl. 4, figs 1, 2) definitely represents a member of the Vetigastropoda in that its shell has a nacreous layer. Also the change from the axially ribbed, rounded early teleoconch to an angular conical shell, characteristic of *Eucycloidea*, is very similar to that observed in the modern *Pagodatrochus* Herbert, 1889 (see Bandel, 2010). Following Bandel's (2010) characterization, the material described below is assigned to the genus *Eucycloidea*.

Eucycloidea badamuensis sp. nov.
Fig. 5G–L

Material and types: Three specimens consisting of holotype and two paratypes. Holotype: ZPAL 19.14 (Fig. 5H, L), a recrystallized teleoconch. Paratypes: ZPAL 19.13 and ZPAL 19.15 (Fig. 5G, I–J, K); both are recrystallized teleoconchs, Cheshmeh Gaz locality; lower Bajocian (Middle Jurassic), lower level B13, Badamu Formation, Central Iran.
Etymology: Referred to the Badamu Formation, where the material was found.
Diagnosis: Conical, pagodiform, gradate shell; axial ribs straight and orthocline on the outer face; periphery delimited by a nodular keel; nodes rounded and elongated abapically; four to five spiral cords on the periphery of the shell; a second weaker spiral cord with small nodes borders the suture; base convex with five nodular spiral cords; aperture holostomatous and oval.
Dimensions (mm): ZPAL Ga.19.14, holotype: height, 14.8; width, 10.6. ZPAL Ga.19. 13, paratype: height, 11.1; width, 7.4. ZPAL Ga.19.15, paratype: height, 14.8; width, 10.4.
Description: Dextral, anomphalous, conical, slender pagodiform, strongly gradate, small- to medium-sized and moderately high-spired shell. The protoconch is not preserved. The teleoconch consist of 6 strongly angular whorls. The sub-sutural ramp is very narrowly horizontal and suture is incised in a spiral furrow. The ramp is flat to strongly concave toward mature growth stages and inclined approximately 45°; it is ornamented with prosocline axial ribs on the upper portion, becoming opisthocyrtic toward the lower portion at the periphery. The outer face becomes straight and slightly inclined abaxially. The axial ribs are straight and orthocline on the outer face. The periphery of the shell is delimited by a strong spiral and nodular keel; nodes are rounded, clearly separated from each other and slightly elongated abapically; 30 nodes are present per whorl. Four to five fine and regularly spaced, spiral cords are visible on the periphery of the shell and cross the nodes at the periphery. A second adapical, weaker spiral cord borders the adapical suture and bears nodes smaller than those of the peripheral keel. The base is strongly convex and ornamented with 5 nodular spiral cords, which are crossed by fine straight to opisthocline axial ribs. The aperture is holostomatous and oval.
Remarks: *Eucycloidea badamuensis* sp. nov. is the first record of the genus in the Middle Jurassic (Bajocian) of Central Iran. *Eucycloidea tenuistria* (Münster in Goldfuss, 1844) (p. 16, pl. 169, fig. 9; Schulbert and Nützel, 2013; p. 731, fig. 8), from the Middle Jurassic (early Aalenian) of Germany, is very similar to *E. badamuensis* sp. nov., but it differs from the Iranian form in having slightly weaker and less rounded nodes at the peripheral keel and a less reticulate ornament pattern on the outer face of the whorls. *Eucycloidea bianor* (d'Orbigny, 1850; d'Orbigny, 1851, pl. 331, figs 13–15; Gründel, 1997, p. 85, pl. 4, figs 1–2; Gründel, 2003, p. 63, pl. 6, fig. 1–4), from the Middle Jurassic (Bajocian–early/middle Bathonian) of France, differs from *E. badamuensis* sp. nov. in being smaller, having more developed nodes at the intersections of spiral and axial elements on the ramp and outer face, and smaller nodes at the peripheral keel. *Eucycloidea granulata* Hébert and Eudes-Deslongchamps, 1860 (p. 180, pl. 7, fig. 9; Gründel, 1997, p. 86, pl. 4, figs 3–8, pl. 8, fig. 13), from the Middle Jurassic (Callovian) of France, has also a stronger reticulated pattern than the Iranian species, with small and rounded nodes at the intersections of axial and spiral elements, and nodes at the peripheral keel are more pointed and slightly elongated adapically. {plain *Eucycloidea verrucosa* Gründel, 2000 (p. 217, pl. 3, fig. 12–16), from the Bathonian of Germany differs from *Eucycloidea badamuensis* sp. nov. in having three fine, spiral cords at the periphery of whorls intersected by more conspicuous and spinose nodes. *Eucycloidea madagascarensis* Bandel, 2010 (p. 455, figs 8E–I, 9A) from the Middle Jurassic of Madagascar, seemingly also belongs to this genus, but its shell is a juvenile specimen and only its earliest whorls are present.

The species of *Eucycloidea* are rare, but they have worldwide distribution during the Middle Jurassic and they have been reported in the early Aalenian of Germany (Schulbert and Nützel, 2013), and in the Callovian–Bajocian of France (Gründel, 1997, 2003). Bandel (2010) described a species of *Eucycloidea* from the Middle Jurassic of Madagascar. Here, the authors report its first occurrence in the Bajocian of Iran (Fig. 7).
Occurrence: Cheshmeh Gaz locality, lower Bajocian (Middle Jurassic), Badamu Formation, Central Iran.

Order Caenogastropoda Cox, 1960
Family Pseudomelaniidae R. Hörnes, 1884
Genus *Pseudomelania* Pictet and Campiche, 1862

Type species: *Pseudomelania gresslyi* Pictet and Campiche, 1862, by subsequent designation of Wenz, 1938; from the Lower Cretaceous (Neocomian) of Switzerland.
Remarks: The type species of *Pseudomelania* is based on internal moulds. The genus and the family unite more or less high-spired, smooth-shelled, non-nerineid, mostly Mesozoic gastropods. The status of the family and genus remains uncertain.
Occurrence: Triassic to Cretaceous (Kaim, 2004) of Europe, Asia, Africa, Madagascar, New Zealand and the Americas.

?Pseudomelania spp.
Fig. 6A–D

Material: Four fragmentary and recrystallized teleoconchs, which may belong to different species and genera, ZPAL 19. 16–19 (Fig. 6A–D).
Dimensions (mm): ZPAL Ga.19.16: height, 38.3; width, 15.5. ZPAL Ga.19.2: height, 42.6; width, 15.1. ZPAL Ga.19.18: height, 58.7; width, 17.1. ZPAL Ga.19.19: height, 51.8; width, 21.6.
Description: Dextral, turriculate, medium-sized and high-spired shell. The fragmentary teleoconch consists of 5–7 convex whorls in the best preserved specimens. Suture is incised in a spiral furrow. The shell is smooth or lacks ornament pattern. Nerineid plaits are absent. The base is strongly convex without ornamentation, and in some specimens a narrow umbilical notch is visible. The aperture is oval with the outer lip convex.
Remarks: Turriculated gastropods with poorly developed ornament and no plaits are commonly assigned to *Pseudomelania* (see also the genus concept in Kaim, 2004). The material here analyzed is tentatively classified as ?*Pseudomelania* spp.. *Pseudomelania*

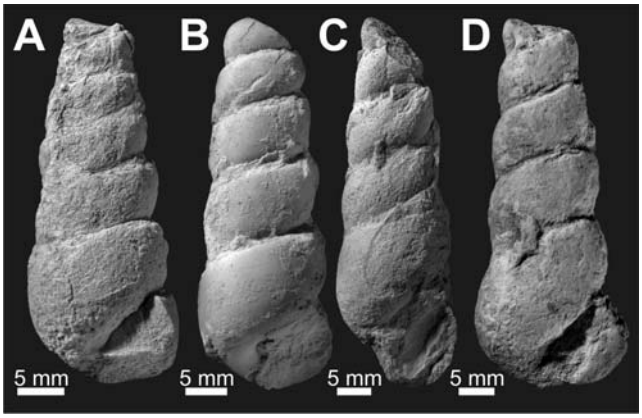

Fig. 6. ?*Pseudomelania* sp. **A**. ZPAL Ga. 19.16, lateral view. **B**. ZPAL Ga. 19.17, lateral view. **C**. ZPAL Ga. 19.18, lateral view. **D**. ZPAL Ga. 19.19, lateral view.

calloviensis (Hébert and Eudes-Deslongchamps, 1860; p. 187, pl. 7, fig. 8), from the Middle Jurassic (Callovian) of India (Szabó and Jaitly, 2004, p. 14, pl. 2, figs 9–10) resembles the Iranian form in shell shape; however, *?Pseudomelania* sp. is larger and has a narrow umbilical notch. *Pseudomelania remtaensis* Cox, 1969 (p. 249, pl. 1, figs 13a–b) from the Bathonian of India (Szabó and Jaitly, 2004, p. 14, pl. 2, figs 1–5) differs from *?Pseudomelania* sp. in having the last teleoconch whorls slightly more expanded than the earlier whorls, and a wide and V-shaped inner lip. *Pseudomelania calloviensis* (Hébert and Deslongchamps, 1960; p. 35, pl. 7, figs 8a, b), also from the Bathonian of India (Szabó and Jaitly, 2004, p. 14) has the mature teleoconch whorls slightly more fattened, and whorls are separated by a flush suture.

Pseudomelania (in the wide sense) had a cosmopolitan distribution during the Jurassic. Szabó and Jaitly (2004) mentioned representatives of the genus in the Callovian of India, and Cox (1965) in the Oxfordian of Africa. *Pseudomelania* has also been recovered commonly from the Bathonian marine deposits of Europe (Kaim, 2004) and India (Cox, 1969; Szabó and Jaitly, 2004) (Fig. 7). Szabó (1983) recorded a doubtful occurrence of the genus in the Bajocian of Hungary, as did Gründel (2001b) in the Bajocian of Chile. Possible pseudomelanids have been also reported by Hikuroa and Kaim (2007) from the Antarctic. Cox (1936) reported *Pseudomelania* cf. *procera* from the Bajocian of the Ravar locality at northern of the Kerman region in Central Iran. Cox's (1936) specimen is very similar in shell shape to the pseudomelanid specimens described above. However, the present authors refrain from classifying the specimens documented here to a named species owing to their fragmentary preservation.

Occurrence: Cheshmeh Gaz locality; lower Bajocian (Middle Jurassic), upper level B13, Badamu Formation, Central Iran.

Suborder Neogastropoda Thiele, 1929
Family Purpurinidae Zittel, 1895
Genus *Purpurina* d'Orbigny, 1850

Type species: *Purpurina bellona* d'Orbigny, 1850, by subsequent designation of Piette (1860), and Eudes-Deslongchamps (1860). Bajocian (Middle Jurassic), Bayeux, Calvados, France.

Age range: Late Triassic (Carnian) to Late Jurassic (Oxfordian).

Remarks: Zittel (1895) established the new family Purpurinidae to incorporate *Purpurina*-like gastropods. Kaim (2004) suggested that the obtusely conical shape and large size of the protoconch of *Purpurina* recollect the representatives of the family Maturifusidae and included both families in Neogastropoda. According to Kaim (2004), species of *Purpurina* share a moderately large- to medium-sized shell, with a broad low spire, angulated with an adapical ramp. The ornament consists of numerous axial and spiral ribs. The body whorl is very large, and the base rounded with a predominantly spiral sculpture. The aperture is large and ovate. Following the characterization of Kaim (2004), the material analyzed below is assigned to *Purpurina*.

Purpurina sp.
Fig. 5C, D

Material: One fragmentary and recrystallized teleoconch, ZPAL Ga.19.11 (Fig. 5 C, D).

Dimensions (mm): ZPAL Ga.19.11: height, 16.2; width, 12.9.

Description: Dextral, trochiform, gradate to step-like shell, anomphalous, medium- sized and moderately low-spired shell. The protoconch is not preserved. The fragmentary teleoconch consist of 4 gradate whorls. The sutural ramp is markedly horizontal and relatively wide. The outer face is straight and vertical, becoming slightly convex toward last whorl. The ornament is predominantly spiral, consisting of 5 or 6 regularly spaced spiral cords on the spire whorls and increasing to 12 toward the last teleoconch whorl. Strong and orthocline axial ribs cover the outer face and intercept the spiral cords; the orthocline axial ribs become slightly opisthocyrtic toward last whorl. Rounded and weak nodes appear at the crossing point of the axial and spiral elements. A strong, spiral keel appears at the periphery of whorls, bearing stronger nodes on last whorl. The base is convex and ornamented with several regularly spaced, spiral cords. The aperture is holostomatous and strongly oval with an abapical channel.

Remarks: According to the emended diagnosis of the genus (see Kaim, 2004, p. 107), the single specimen described here might be classified as a species of *Purpurina*. *Purpurina* sp. shows close resemblance to *Purpurina coronata* Hébert and Eudes-Deslongchamps, 1860 (p. 177, pl. 1, fig. 8), from the Middle Jurassic (Callovian) of Poland (Kaim, 2004, p. 107, fig. 86); however, the latter species is smaller, the spiral cords are present in numbers of 4 or 5 per whorl, and the sub-sutural ramp of whorls is wider than in the Iranian species. *Purpurina formosa* (Eichwald, 1868; p. 946, pl. 31, fig. 7), also from the Middle Jurassic (Callovian) of Poland (Kaim, 2004, p. 108, fig. 87), differs from *Purpurina* sp. in having a more slender shell, more pointed nodes on the angulations of whorls, and orthocline axial ribs on the last whorl. *Purpurina pagoda* Hudleston, 1888 (p. 89, pl. 1, fig. 7), from the Middle Jurassic (late Bajocian/mid Bathonian) of Southern Germany (Gründel, 2003, p. 78, pl. 10, figs 1–6), has a more acute and less broad shell outline, a higher spire and more acute and spinose nodes at the periphery of the whorls. *Purpurina serrata* (Quenstedt, 1856; p. 485, pl. 65, fig. 7; Gründel, 2003, p. 79, pl. 10, figs 7–10), from the Middle Jurassic (late Bajocian/middle Bathonian) of Southern Germany, differs from *Purpurina* sp. in having a less horizontal and more inclined sub-sutural ramp and a more acute shell outline.

Purpurina is common in the Middle Jurassic of Europe, as it has been frequently reported in the Callovian of Poland (Kaim, 2004) and in the Bajocian/Bathonian of Southern Germany and France (Gründel, 1997, 2003). *Purpurina* sp. represents the first occurrence of the genus in the Bajocian of Iran (Fig. 7).

Occurrence: Cheshmeh Gaz locality; lower Bajocian (Middle Jurassic), lower level B13, Badamu Formation, Central Iran.

CONCLUDING REMARKS

The gastropod association described in this paper is dominated by vetigastropods comprising four pleurotoma-

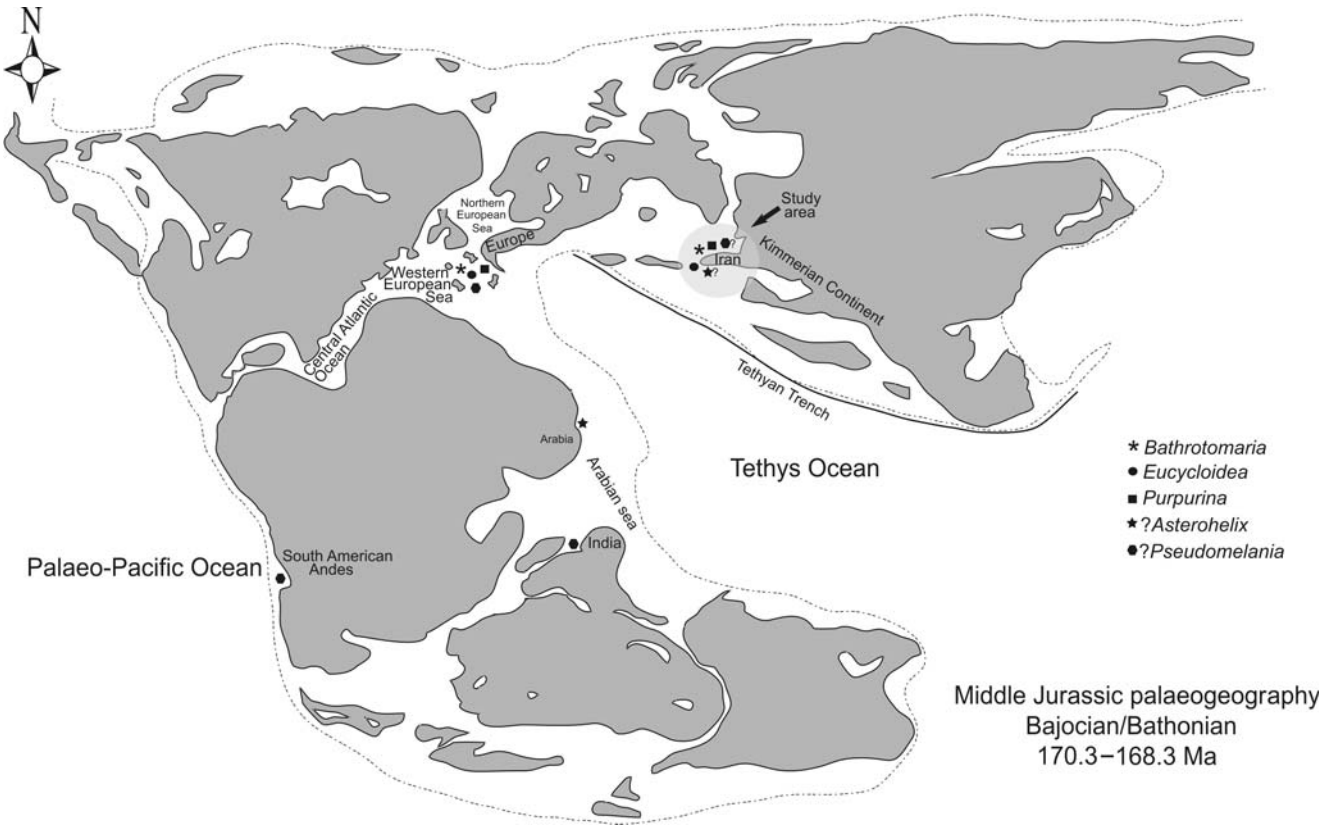

Fig. 7. Middle Jurassic (Bajocian/Bathonian) palaeobiogeographical map, showing the distribution of the gastropod genera described here (compiled from various sources).

riids, one eucyclid, one discohelicid and one unidentified turbiniform. Caenogastropods are represented only by one purpurinid and an unknown number of pseudomelaniid-like species. All these gastropods have their counterparts in coeval European and Arabian parts of the Tethys (e.g., Szabó, 1984; Gründel, 1997, 2003; Fischer *et al*., 2001; Gründel, *et al*., 2012; Monari and Gatto, 2013; Schulbert and Nützel, 2013; see Fig. 7). This faunal composition supports earlier suggestions based on ammonites (Seyed-Emami, 1971) that Kimmerian waters were in permanent connection with the Tethys Sea during the Jurassic.

Although the fossil record of Early and Middle Jurassic gastropods shows that the majority of taxa had rather cosmopolitan distribution, nevertheless several palaeogeographical regions can be distinguished, even in the western Tethys alone (see e.g., Conti and Fischer, 1984; Conti and Monari 1991, 2001; Szabó *et al*., 1993; Gatto and Monari, 2010). It is beyond the scope of this study to perform an exhaustive pala- eogeographical and/or palaeoecological analysis, despite the fact that the fauna from Iran dominated by vetigastropods is reminiscent of other Tethyan faunas known from calcareous or mixed calcareous-siliciclastic facies (Gründel, 2003; Monari and Gatto, 2013) rather than the north European faunas. The latter occur mostly in the clastic facies and are dominated by soft-bottom dwellers or tiering gastropods (Kaim, 2004, 2012) with a predominance of caenogastro- pods and heterobranchs (e.g., cerithioids, zygopleurids and mathildids).

The Middle Jurassic gastropod assemblages, known from the southern hemisphere (Jaworski, 1925; Weaver, 1931; Cox, 1956; Gründel, 2001b; Ferrari and Damborenea, 2015), show close affinities with both Tethyan and north European faunas. The Middle Jurassic gastropods from South America are dominated by the balanced co-occurrence of vetigastropods and caenogastropods, while heterobranchs, very common in fine-grained siliciclastics of northern Europe, are much less common. The latter might be at least a partially preservational artifact, as heterobranchs are usually small and brittle and less likely to be preserved in calcareous and coarse-grained siliciclastics. Further collection effort on Middle Jurassic South American gastropods should be undertaken in order to elucidate this question. The palaeobiogeographical affinities between the South American faunas and the ones from the Tethyan and northern European regions might be explained by the existence of shallow, marine connections between the western Tethys and the Palaeo-Pacific Ocean, which were related to the opening of a mid-Atlantic seaway, the Hispanic Corridor (Damborenea *et al*., 2013; see fig. 7). This resulted in an oceanic route of dispersal for benthic faunal exchange between the European and Palaeo-Pacific seas during the Jurassic.

Mesozoic marine gastropods from Iran are poorly known so far, with the exception of the fauna from Late Triassic (Norian–Rhaetian) of the Nayband Formation in Central Iran (Douglas, 1929; Fallahi *et al*., 1983; Nützel and Senowbari-Daryan, 1999; Nützel *et al*., 2003, 2010, 2012). These authors described numerous species, which showed a close resemblance to coeval Late Triassic faunas from the Alps (Cassian Formation), Burma and Southern China, and, in contrast, they show very little resemblance to the Late

Triassic faunas from South America (Pucará Group). The Late Triassic Iranian gastropod assemblages contain some genera, representatives of which are more common in the Jurassic. Nützel and Senowbari-Daryan (1999) suggested that the Late Triassic gastropods from the Nayband Formation, as well as the coeval Tethyan faunas, could have been the precursors of several Jurassic lineages. Another gastropod fauna from the Middle East was reported from the Early Triassic of Salt Range, Pakistan by Kaim *et al*. (2013). This fauna, however, showing an early stage in recovery from Permian-Triassic extinction, consists of taxa typical and cosmopolitan for this time slice. In turn, the Jurassic marine gastropods from northern shores of Tethys in the Middle East region were basically unknown so far. The present paper shows that this fauna was similar to the ones known from southern shores of the Tethys, i.e. Arabia (Fischer *et al*., 2001) and India (e.g., Das *et al*., 1999; Jaitly *et al*., 2000; Szabó & Jaitly, 2004), though more effort in collection is necessary to substantiate this assumption.

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