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Miocene Argonautidae (Octopoda) from the Persian Gulf area and their palaeogeographic distribution

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ABSTRACT:

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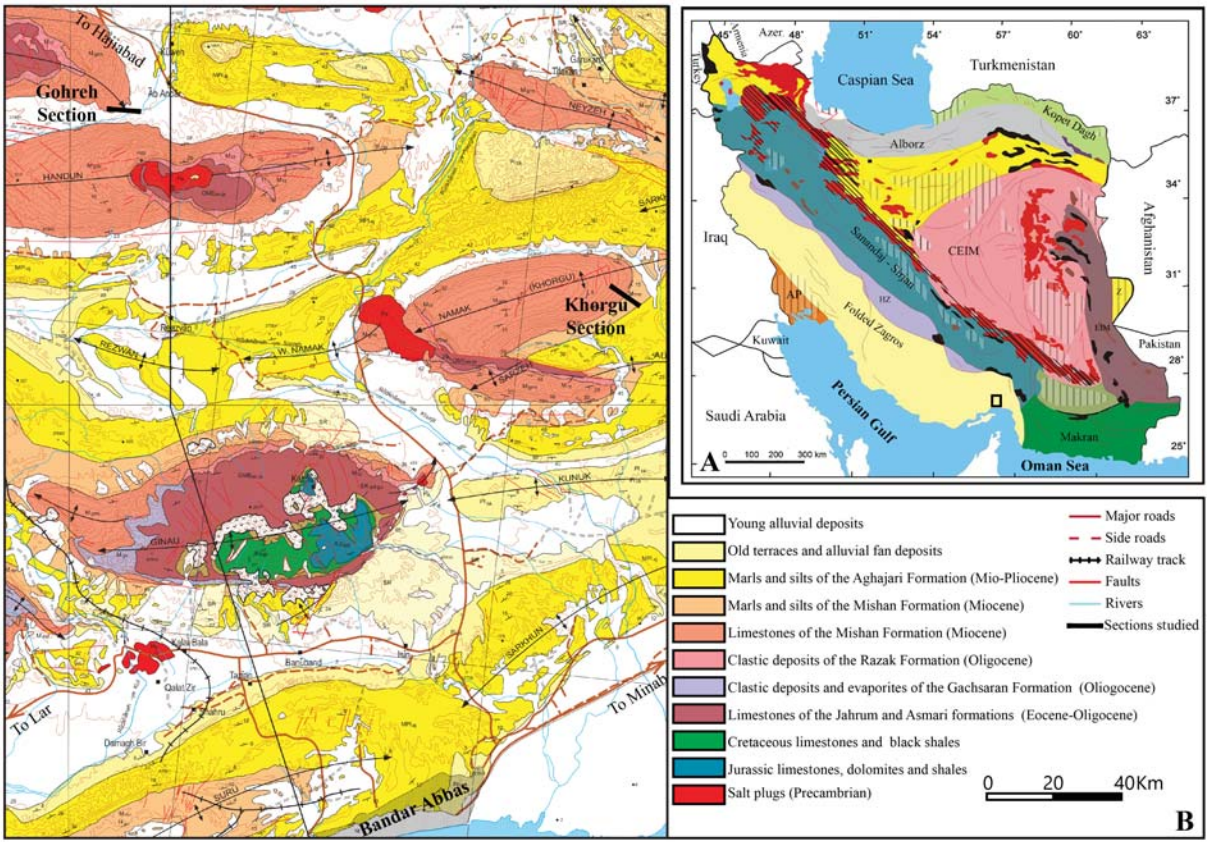
Cephalopod specimens assigned to the Argonautidae (*Obinautilus pulchra* Kobayashi, 1954 and an unknown taxon) from two localities of the Mishan Formation in Gohreh and Khorgu sections, Bandar Abbas, southern Iran, are reported for the first time from the Persian Gulf area. The co-existing foraminifera confirm the middle Miocene age of the strata. Based on micropalaeontological data, the previous Oligocene age of *Obinautilus pulchra* is extended to the middle Miocene. The palaeobiogeographic distribution of the reported Argonautidae shows that the presence of these faunas is limited to the West Pacific, Indo-Pacific and the East Pacific. The present-day distribution of the Argonautidae is similar to the ancient one and seems to be inherited from their ancestors.

Key words: Argonautidae; *Obinautilus*; Miocene; Mishan Formation; Iran.

INTRODUCTION

Neogene deposits of the Neo-Tethys Ocean in the Zagros Structural Zone include various lithostratigraphic units, especially the Mishan (early to middle Miocene) and Aghajari (late Miocene to Pliocene) formations showing an upward marine regression trend. The lower and middle part of the Mishan Formation consists of limestones and marls deposited in a moderately deep oceanic basin. The upper part of this formation gradually passes into the clastic deposits of the Aghajari Formation. These deposits are exposed in almost all anticlines of the Zagros Structural Zone. The Mishan Formation with large thickness and extensive exposures in the Zagros area includes rich and diverse micro and macro fauna, including echinoids, molluscs (bivalves, gastropods and cephalopods), bryozoans, arthropods, foraminifers and ostracods, of which most have been studied recently. For example, Kroh *et al.* (2011) analysed Miocene echinoids and pectinid bivalves of the Mishan Formation in Bandar Pohl (west of Bandar Abbas). Gholamalian *et al.* (2015) reported spatangoid and clypeasteroid echinoids from the north of Bandar Abbas. Yazdi *et al.* (2009), Vega *et al.* (2010, 2012) and Heidari *et al.* (2012) studied decapods from selected beds in the Bandar Abbas and Ahram areas. In addition, Vega *et al.* (2010, 2012) introduced several new crab species from these beds. The foraminiferal microbiostratigraphy of the Mishan Formation in the Bandar Abbas Hinterland was elaborated by Heidari *et al.* (2013), Hosseinipour (2013), Rezaee Ruzbahani *et al.* (2013), Daneshian *et al.* (2016), Yusofi (2016), Shiva-Korkaj (2017) and Hassani and Hosseinipour (2018). The present research focuses on the cephalopods, so far not studied from the Mishan Formation. This paper



Text-fig. 1. Location of the study area. A – Geological map of Iran (after Aghanabati 2004), small quadrangle in lower part of image shows the study area enlarged in B. B – Geological map of the study area and location of sections (after Fakhari 1994)

is the first report of Cenozoic Argonautidae from the Miocene of the Middle East.

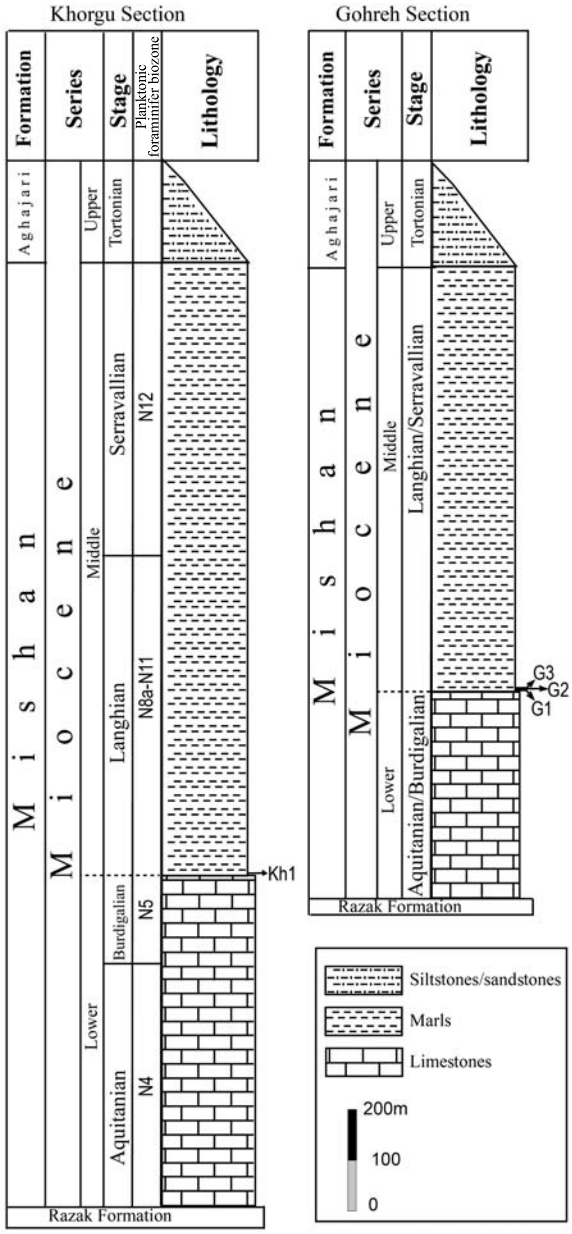
GEOLOGICAL OUTLINE

The south-eastern part of the Zagros Folded Zone around the Hormuz strait named as the Bandar Abbas Hinterland (Motiei 1993). The presence of numerous salt plugs in addition to the large thickness of the Miocene–Pleistocene Fars Group (Gachsaran/Razak, Mishan, Aghajari and Bakhtiari formations) and the specific trends of anticlines are the most important features of this area (Motiei 1993). The sedimentary and igneous Ediacaran–Cambrian Hormuz Series is the oldest stratigraphic unit in this area that underlies the Pre-Cretaceous, Cretaceous and Palaeogene to Neogene strata (i.e., Daryian, Kazhdumi, Jahrum and Asmari formations and the Fars Group respectively). The Neogene sequence of this area (Fars Group) begins with red terrigenous beds of the Razak Formation and continues with carbonate-clastic Mishan and Aghajari formations, which widely crop out in this area and build most of the plains (Text-fig. 1B).

LOCALITIES STUDIED AND THEIR STRATIGRAPHY

The argonautid specimens were collected from strata of the Mishan Formation in Gohreh and Khorgu sections in the north and northeast of Bandar Abbas, SE of the Zagros Structural Zone, southern Iran (Text-fig. 1). Gohreh section is located 76 km to the north of Bandar Abbas near Gohreh village (56º02’54”E, 27º43’26”N) and Khorgu section is located 50 km to the northeast of Bandar Abbas (56º28’37”E, 27º35’07”N) (Text-fig. 1B).

The total thickness of the Mishan Formation in Gohreh section is 1250 m. The lower 420 m comprises medium to thin-bedded limestones with intercalations



Text-fig. 2. Simplified stratigraphic and lithological logs of the studied sections and the position of the cephalopod-bearing beds (G1 and Kh1). G1–G3 are limestone beds in the lower part of the marly member

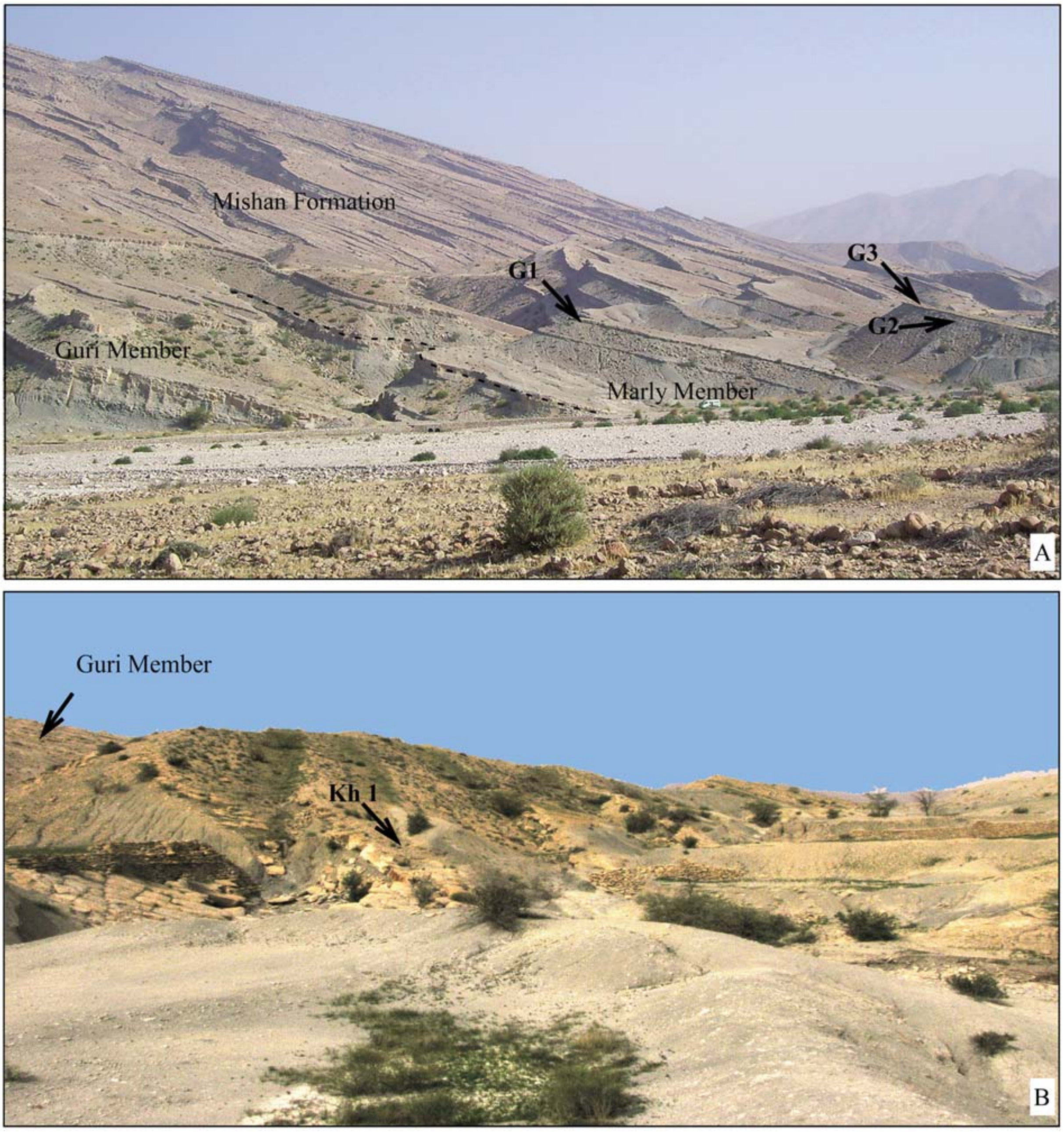
of marls at the top. The middle and upper parts of the Mishan Formation in this section comprise 830 m of green to grey marly beds, which gradually change to siltstones, marls and sandstones of the basal part of the Aghajari Formation (Text-fig. 2). According to Fanati-Rashidi (2014), planktonic foraminifers prove a Burdigalian to Langhian age for the lower limestone member (Guri Member) and a Langhian to Serravallian age for the upper marly member in this area. In addition, Gholamalian *et al.* (2015) identified an assemblage including *Amphistegina lessoni* d'Orbigny, 1826, *Dendritina rangi* d'Orbigny, 1826, *Globigerinoides trilobus* Reuss, 1850, *Neorotalia viennoti* (Greig, 1935), *Orbulina universa* d'Orbigny, 1839, *Operculina complanata* d'Orbigny, 1826, *Triloculina tricarinata* d'Orbigny, 1826, *T. trigonula* Lamarck, 1804, *Bigenerina* sp., *Reusella* sp., *Spirolina* sp. and *Textularia* sp. in the lower part of the marly member, which points to a Langhian to Serravallian age. Three limestone beds (G1, G2 and G3) occur in the lower part of the marly member, and these contain bivalves, gastropods and crustaceans. The cephalopods studied were collected from bed G1 (Text-fig. 2).

The Mishan Formation in Khorgu section is 1845 m thick and consists of 635 m of basal limestone (Guri Member) in the lower part and 1210 m of marls in the upper part. About 120 m of the basal limestone member is exposed in the field, whereas the rest was observed in an exploratory well of the National Iranian Oil Company (Fakhari 1994). According to Hassani and Hosseinipour (in press), the exposed part of the basal limestone member contains *Globigerinoides trilobus* Reuss, 1850, *G. quadrilobata* (d'Orbigny, 1846), *G. subquadratus* Broennimann, 1954 and *Globorotalia mayeri* Cushman and Ellison, 1939. This assemblage is equivalent to the N4 and N5 global planktonic foraminifera biozones and indicates an Aquitanian to Burdigalian age for the lower limestone member. Hassani and Hosseinipour (in press) attributed a Langhian–Serravallian age (zones N8–N12) to the upper marly member (Text-fig. 2).

In both sections, the cephalopod-bearing thin limestone bed occurs in the basal part of the marly member, directly after the uppermost strata of the Guri Member (Text-figs 2 and 3). Apart from cephalopods, diverse specimens of spatangoid echinoids, gastropods and crabs have also been recovered from these beds.

OCTOPUSES IN GEOLOGICAL TIME

Most of the octopus families generally do not have any external fossilizable carbonate shell and there are only a few reports of Lagerstätte-type preservation of this group in some areas, e.g., Lebanon (Fuchs *et al.* 2009; Fuchs and Weis 2009; Jattiot *et al.* 2015). Based on these data, Young *et al.* (1998) and Fuchs *et al.* (2009) assume that the time of appearance for this group is the Late Cretaceous, but some researchers attribute their emergence to the Cenozoic (Doyle *et*

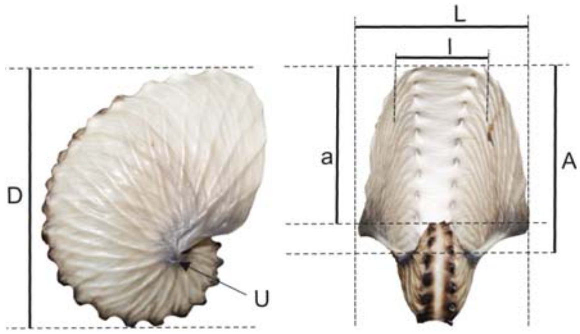


Text-fig. 3. Location of the cephalopod-bearing beds in the field. A – Limestone beds in the lower part of the marly member in Gohreh section; view to the north. G1 is the cephalopod-bearing bed. B – Cephalopod-bearing bed (Kh1) in Khorgu section; view to the north-east

al. 1994). Because of these limitations, most of the statements are based only on the few accessible specimens indicated above, but there is an exceptional phenomenon among the Argonautidae that increases their preservation potential. The female individuals of some genera of this family (*Argonauta* Linnæus, 1758; *Izumonauta* Kobayashi, 1954; *Kapal* Martin, 1929; *Mizuhobaris* Yokoyama, 1913 and *Obinautilus* Kobayashi, 1954), secret calcitic egg-cases or temporal shelter shells. The outline of these egg-cases is similar to the nautilid shell, but they are secreted by arms and do not have any septa or siphuncle (Donovan 2012). Fossil specimens of such shells are very rare and poorly reported worldwide.

MATERIAL AND METHODS

Twelve specimens of argonautid cephalopods were studied, two from Gohreh section and ten from Khorgu section. Most of specimens were covered by sediment and gently cleaned with a slender drill. Two specimens were cut and polished to find any possible internal structure (chambers, septa and siphuncle). Photographs of the shells in all aspects and biometric measurements of important dimensions are used for comparison of the collected specimens with the species holotype. The common shape of the shells and their whorls are the same as in living Argonautidae, therefore similar structural terms are used herein: D = diameter, A = maximum height of aperture, a = minimum height of aperture, U = umbilicus, L = maximum width of aperture, l = minimum width of aperture (Text-fig. 4).



Text-fig. 4. Biometric characters of the Argonautidae shown on an *Argonauta* egg-case shell (specimen from the personal collection of H. Gholamalian). D = diameter, A = maximum height of aperture, a = minimum height of aperture, U = umbilicus, L = maximum width of aperture, l = minimum width of aperture

SYSTEMATIC PALAEONTOLOGY

Class Cephalopoda Cuvier, 1797
Subclass Coleoidea Bather, 1888
Order Octopoda Leach, 1818
Famiy Argonautidae Cantraine, 1841
Obinautilus Kobayashi, 1954

TYPE SPECIES: *Obinautilus pulchra* Kobayashi, 1954, OD.

DISCUSSION: The general characteristics of the specimens studied are common in two genera of the Argonautidae, i.e., *Argonauta* and *Obinautilus*. In *Argonauta*, the shell is involute and the whorl rapidly rises towards the aperture. The umbilicus is very small. There are two objected keels with large tubercles on the venter. Rigid ribs can be seen on the lateral sides of the shell. *Obinautilus* does not have any keel and tubercles. This genus was previously included to the Nautilida because of superficial similarities (Kobayashi 1954a); but the lack of internal structures such as septa and siphuncle confirms that it is an argonautid (Tomida 1983). Comparing the outline and biometric characteristics of eleven of the collected specimens confirms that these fossils represent *Obinautilus*.

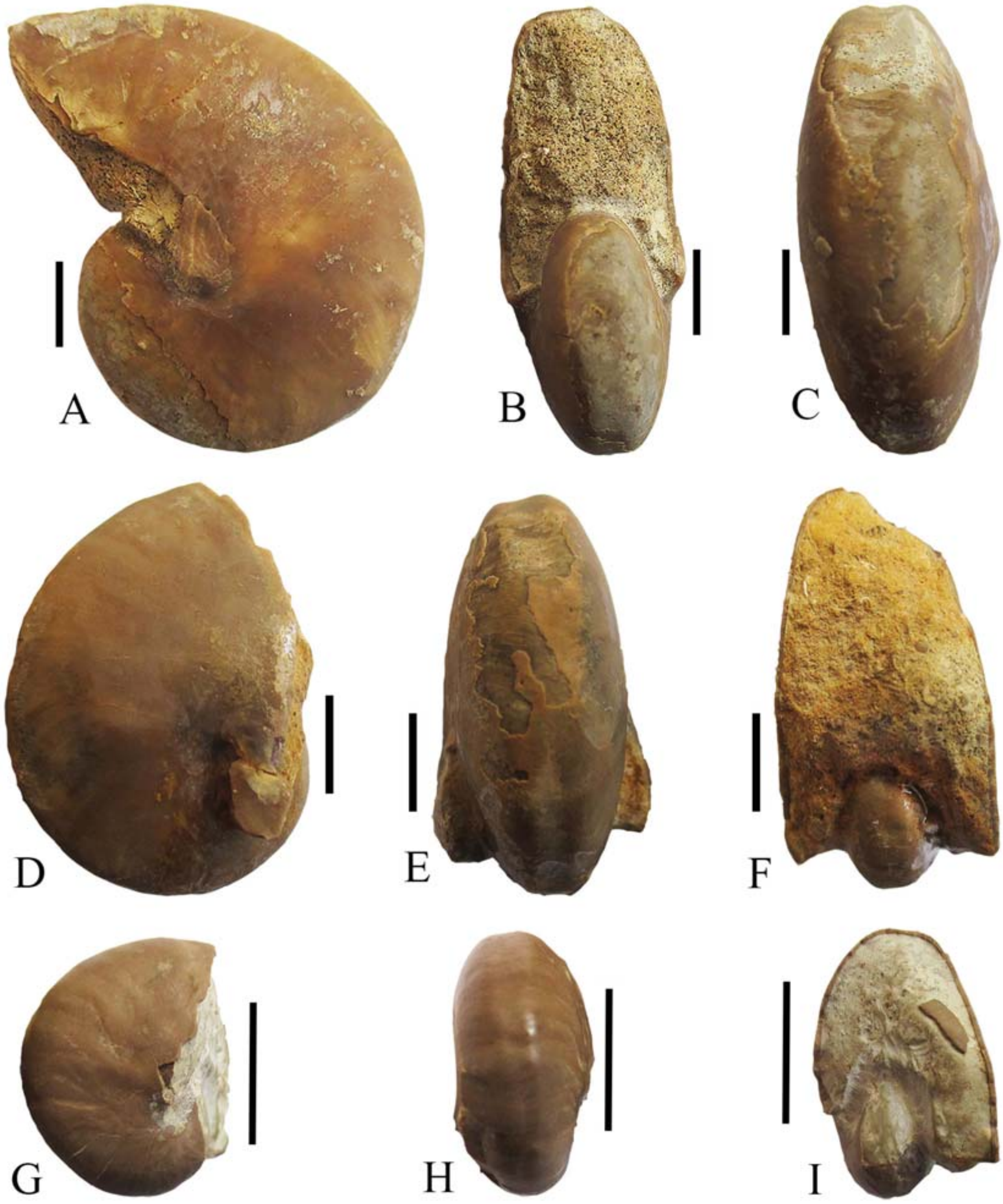
Obinautilus pulchra Kobayashi, 1954
(Text-figs 5A–I, 6A–G)

MATERIAL: Ten specimens from bed Kh1 (Khorgu) and one from bed G1 (Gohreh).

DESCRIPTION: All of the specimens are medium in size, with diameters ranging from 22 to 59 mm. The shell is lenticular in general shape with nautiliform involute spirality. Neither septa nor chamber can be seen in the structure of the conchs. The wall is composed of a thin aragonitic layer. The outer surface of the conch is smooth, but a few delicate growth lines may be seen in some specimens. Two weakly rounded peripheral keels with a shallow wide depression between them are present on the venter. There are no sculptural ribs, nodes and spines on the surface. The maximum aperture height (A) ranges from 17 to 33 mm; its ratio to the minimum aperture height (a) is 1.21 to 1.43, indicating a very high aperture with semi-parallel sides. The umbilicus is closed and could not be observed in any of the specimens studied. The range of the A/D ratio in the specimens studied is 0.622 to 0.883 (Table 1).

REMARKS: The range of the A/D ratio in the specimens studied is the same as in specimens of *O. pulchra* described by Kobayashi (1954a, p. 22, figs 3, 4) from the Oligocene of Japan, indicating that the final whorl covers most of the previous ones. *Obinautilus pulchra* can be distinguished from the closest species, *O. awaensis* Tomida, 1983 from the Pliocene of Japan by the absence of weak and short ribs on the lateral sides of the shell. The presence of two ventral weak keels with a shallow depression between them is the most important difference with specimens of *Mizuhobaris lepta* Saul and Stadum, 2005 from the upper Miocene of California, which have a completely rounded venter.

STRATIGRAPHIC RANGE: Langhian to Serravallian (Text-fig. 2).

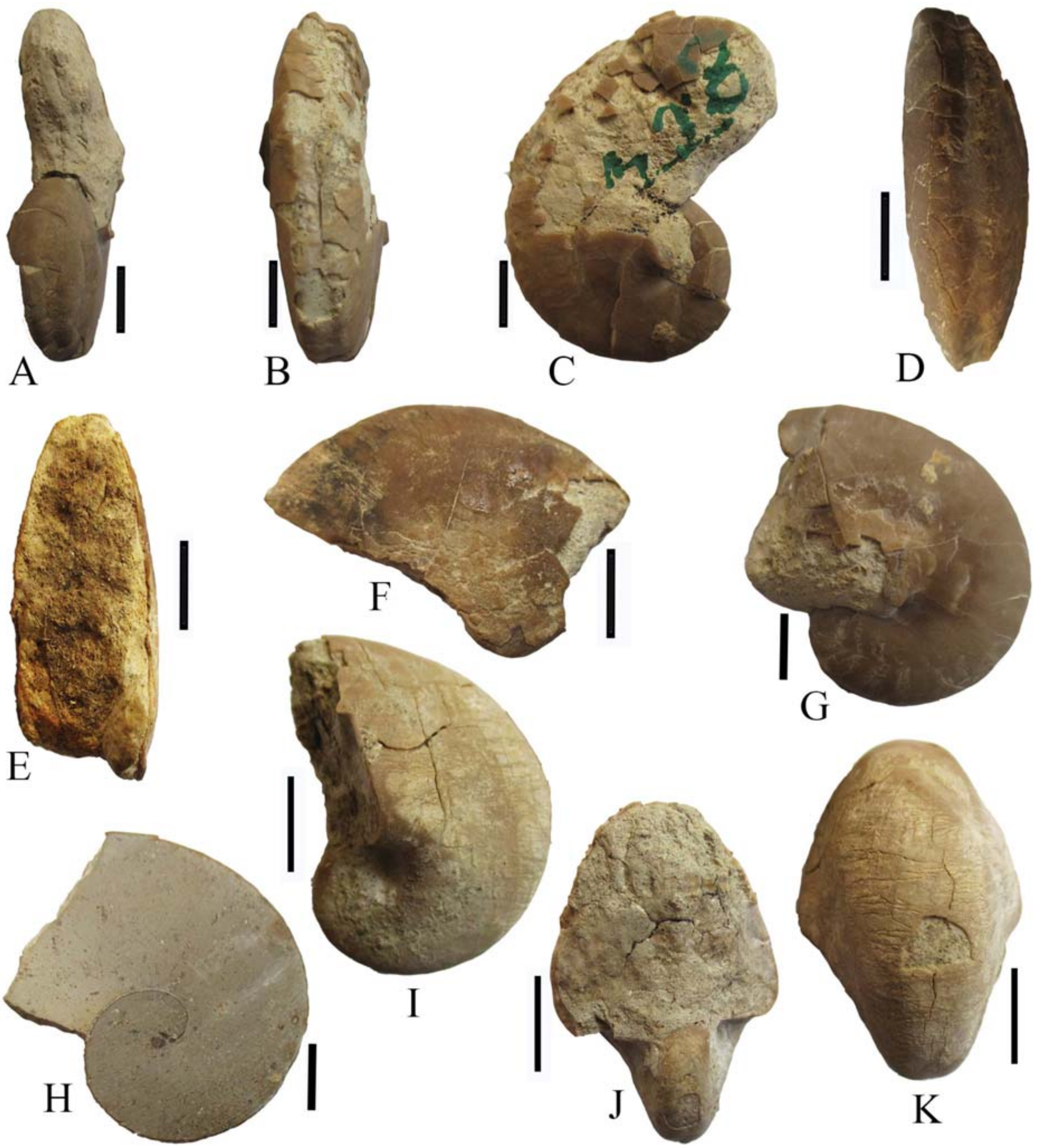


Text-fig. 5. *Obinautilus pulchra* Kobayashi, 1954 from the Miocene of southern Iran. A-C – Lateral, anterior and posterior views of specimen HUIM184, bed Kh1, Khorgu section; D-F – Lateral, posterior and anterior views of specimen HUIM186, bed Kh1, Khorgu section; G-I – Lateral, posterior and anterior views of specimen HUIM192, bed G1, Gohreh section. Scale bars equal 10 mm

Argonautidae gen. et sp. indet.
(Text-fig. 6H–K)

MATERIAL: One specimen from bed G1 (Gohreh section).

DESCRIPTION: One of the collected argonautid specimens possesses a lenticular shape with nautiliform involute whorl. This specimen is medium in size (D = 48 mm). The shell surface is smooth without any sculpture. There is not any keel developed at the venter. The aperture is trapezoidal in shape. The maximum and minimum heights of the aperture are equal. The umbilical area is filled with sediment and



Text-fig. 6. Argonautids from the Miocene of southern Iran. **A-H** – *Obinautilus pulchra* Kobayashi, 1954 from bed Kh1, Khorgu section. A-C – Anterior, posterior and lateral views of specimen HUIM190; D-F – Posterior, anterior and lateral views of specimen HUIM188; G-H – Lateral and polished transverse section of specimen HUIM185. **I-K** – Argonautidae gen. et sp. indet., lateral, posterior and anterior views of specimen HUIM193, bed G1, Gohreh section. Scale bars equal 10 mm

cannot be seen. The venter is rounded. There are no traces of septa and siphuncle (Table 1).

REMARKS: The lack of internal structures (septa, siphuncle, chamber, etc.), a smooth and non-ornamented surface and an involute shell confirm that this specimen belongs to the Argonautidae, but the wide, extended and trapezoidal aperture of this specimen with equal maximum height and width have not seen in any of the reported Argonautidae. The

Species	D	A	a	A/D	A/a	L	l	Repository no.	Sampled bed
Obinautilus pulchra	39	26	21	0.66	1.238	13	9	HUIM183	Kh1
	52	33	23	0.63	1.434	19	10	HUIM184	Kh1
	37	27	19	0.729	1.421	-	-	HUIM185	Kh1
	43	38	28	0.883	1.357	21	12	HUIM186	Kh1
	30	22	17	0.733	1.294	11	7	HUIM187	Kh1
	34	24	18	0.705	1.333	18	9	HUIM188	Kh1
	25	18	13	0.720	1.384	–	7	HUIM189	Kh1
	45	28	23	0.622	1.217	–	–	HUIM190	Kh1
	22	17	13	0.772	1.307	–	–	HUIM191	Kh1
	23	19	14	0.826	1.357	13	9	HUIM192	G1
Argonautidae gen. et sp. indet.	48	28	28	0.583	1	31	14	HUIM193	G1

Table 1. Biometric characteristics of the collected specimens. All dimensions are in millimetres. See Text-fig. 4 for explanation of abbreviations

Taxon	Reference	Age	Location
Argonauta argo	Linnæus (1758)	Pleistocene	Red Sea
Argonauta boettgeri	Maltzan (1881)	Recent	Tropical Indo-west Pacific
Argonauta cornutus	Conrad (1854)	Recent	Panama, Mexico
Argonauta hians	Lightfoot (1786)	Pliocene, Recent	Italy, Tropical cosmopolitan
Argonauta hians	Tomida *et al.* (2004)	Pliocene	Japan
Argonauta itoigawai	Tomida (1983)	Pliocene	Japan
Argonauta joanneus	Hilber (1915)	Middle Miocene	Austria
Argonauta nodosus	Lightfoot (1786)	Recent	Indo-west Pacific
Argonauta nouryi	Lorois (1852)	Recent	USA, Peru
Argonauta oweri	Fleming (1945)	Early Pliocene	New Zealand
Argonauta sismondai	Bellardi (1873)	Pliocene	Italy
Argonauta pacificus	Dall (1871)	Recent	Peru, southern California
Argonauta tokunagai	Yokoyama (1913)	Middle Miocene	Japan
Izumonauta kaganus	Kaseno (1955)	Late Miocene	Japan
Izumonauta kasataniensis	Kaseno (1955)	Late Miocene	Japan
Izumonauta latus	Kobayashi (1954b)	Middle Miocene	Japan, New Zealand
Kapal batavus	Martin (1929)	Miocene	Sumatra
Mizuhobaris izumoensis	Yokoyama (1913)	Middle Miocene	Japan
Mizuhobaris lepta	Saul and Stadum (2005)	Late Miocene	USA
Obinautilus awaensis	Tomida (1983)	Miocene–Pliocene	Japan
Obinautilus pulchra	Kobayashi (1954a)	Oligocene	Japan
Obinautilus pulchra	this study	Middle Miocene	Iran

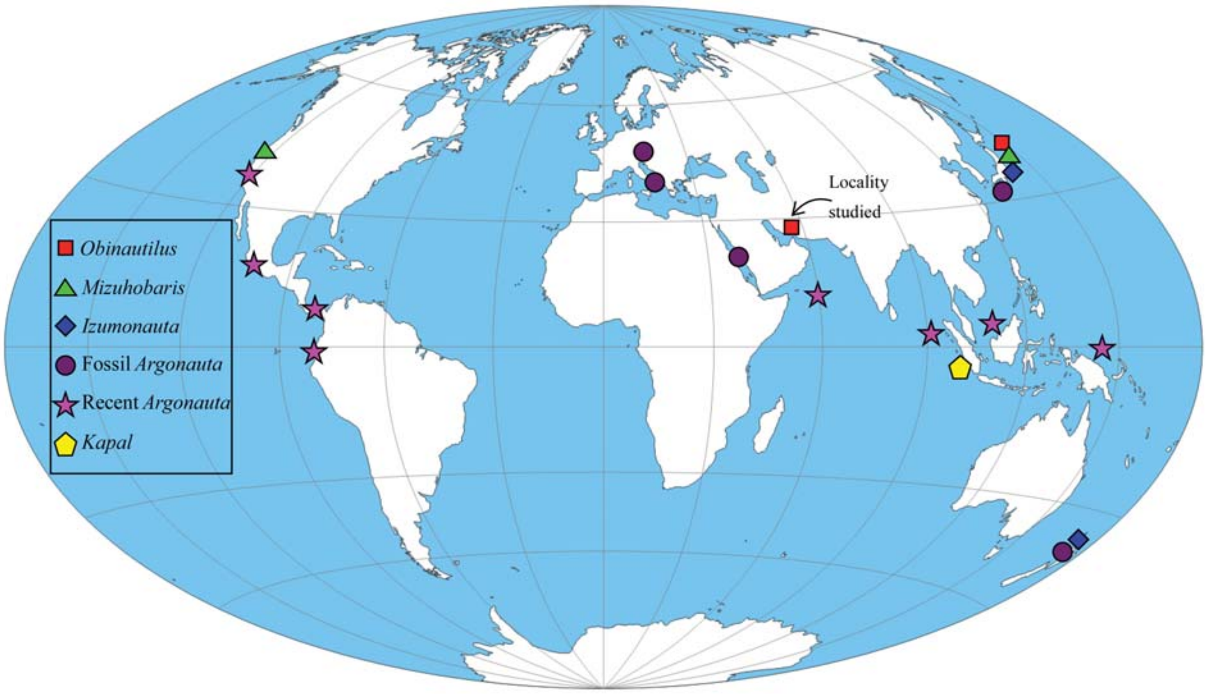
Table 2. Age and distribution of all reported fossil and recent Argonautidae

material is too sparse to allow establishing of a new taxon.

STRATIGRAPHIC RANGE: Langhian to Serravallian (Text-fig. 2).

PALAEOGEOGRAPHIC DISTRIBUTION

Individuals of the family Argonautidae live in recent seas, but their egg-cases have been recorded from the Cenozoic sequences of North America, Europe and East Asia (Tomida 1983; Saul and Stadum 2005; Martill and Barker 2006; Strugnell and Allock 2010; Table 2). Most of the reported Argonautidae were collected from post-Oligocene strata. It could be assumed that the ability of secreting solid egg cases in this family could have originated in the Oligocene. Among the recorded Argonautidae, *Argonauta* is the most common and the only living taxon. In turn, other Argonautidae, including *Obinautilus*, are recorded only as extinct genera, mainly recovered from the eastern hemisphere, in the Tethyan and Indo-Pacific realms (Text-fig. 7). Although the puzzling palaeobiogeographic distribution of the fossil Argonautidae may be attributed to the lack of proper studies, the complete absence of this group in the Atlantic Realm may also point to the limited



Text-fig. 7. Global biogeographic distribution of fossil and living Argonautidae in the West and East Pacific, Indo-West Pacific and Tethyan Ocean

dispersal of ancient Argonautidae from the Tethyan and Indo-Pacific oceans. Nesis (2003) studied the distribution of recent and Plio-Pleistocene cephalopods and presented conclusions on the relationship between the faunal and latitudinal zonal geographic distribution. He outlined that the West Pacific, Indo-West Pacific and the East Pacific realms include the most endemic cephalopods. Accordingly, the distribution of recent Argonautidae is also limited to the East and West Pacific, the west Indian Ocean and the Indo-West Pacific realms (Text-fig. 7). The study of fossil Argonautidae proves also that their endemic distribution was limited to the eastern Pacific, west Indian Ocean and Indo-West Pacific at least from the Oligocene to Recent. On the other hand, among 150 living cephalopod genera and more than 718 species, the Argonautidae family includes just one genus and seven species (Nesis 2003), which shows their limited diversity and distribution in recent and maybe also in late Cenozoic seas.

CONCLUSIONS

Fossil argonautid (Octopoda) egg-case shells were recovered from the Mishan Formation (Miocene) in Gohreh and Khorgu sections (SE Zagros, Bandar Abbas, Persian Gulf). The collected Argonautidae include eleven specimens of *Obinautilus pulchra* and one specimen of an unidentified taxon. The present paper is the first record of this group from the Miocene of the Middle East and the Neotethys area. *Obinautilus pulchra* was reported only from the Oligocene of Japan and the appearance of this species in the middle Miocene of southern Iran suggests an Oligocene to middle Miocene biostratigraphic range for this taxon. The palaeobiogeographic distribution of the Argonautidae is similar to that of recent forms and is limited to the West Indian Ocean, Indo-West Pacific and the East Pacific realms. Such a limited palaeo- and recent biogeographic distribution may point to the endemism of these taxa during their whole life history at least throughout the Cenozoic.

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REFERENCES

Bather, F.A. 1888. Shell growth in Cephalopoda (Siphonopoda). *Annals and Magazine of Natural History*, **6**, 421–427.

Bellardi, L. 1873. I molluschi del terreni tertziari del Piemonte e della Liguria, 1. Cephalopoda, Pteropoda, Heteropoda, Gasteropoda (Muricidae et Tritonidae). *Memorie della Reale Accademia delle Scienze di Torino*, **27**, 1–264.

Conrad, T.A. 1854. Monograph of the genus *Argonauta* Linne, with description of five new species. *Journal of the Academy of Natural Sciences of Philadelphia*, **2**, 331–333.

Brönnimann, P. 1954. Probable Occurrence of Oligocene in Saipan. *American Journal of Science*, **252** (11), 680–682.

Cantraine, E.J. 1841. Malacologie Méditerranéenne et littorale, ou description des mollusques qui vivent dans la Méditerranée ou sur le continent de l'Italie, ainsi que des coquilles qui se trouvent dans les terrains tertiaires Italiens, avec des observations sur leur anatomie, leurs moeurs, leur analogie et leur gisement. *Nouveaux Mémoires, Académie Royale des Sciences et Belles-Lettres de Bruxelles*, **13**, 1–173.

Cushman, J.A. and Ellisor, A.O. 1939. New species of foraminifera from the Oligocene and Miocene. *Contribution of Cushman Lab. Foraminifera research*, **15**, 1–14.

Cuvier, G. 1797. Tableau Élémentaire de l'Histoire Naturelle des Animaux, 710 p. Baudouin; Paris.

Dall, W.H. 1871. Descriptions of sixty new forms of mollusks from the west coast of North America and the North Pacific Ocean, with notes on others already described. *American Journal of Conchology*, **7**, 93–160.

Daneshian, J., Daneshian, M. and Moallemi, A. 2016. Relative dating of the Mishan Formation based on foraminifera and Strontium isotope in the northwest and west of Bandar Abbas, south Iran. *Journal of Stratigraphy and Sedimentology Researches*, **32** (2), 35–54. [In Persian, with English abstract]

Donovan, D.T. 2012. Treatise Online Part M, Ammonites and Octopuses, 363 p. Kansas University Press; Kansas.

Doyle, P., Donovan, D.T. and Nixon, M. 1994. Phylogeny and systematics of the Coleoidea. *The University of Kansas Paleontological Contributions*, **5**, 1–15.

Fakhari, M. 1994. Geological quadrangle map of Bandar Abbas 1/250000, sheet no. I-13. National Iranian Oil Company.

Fanati-Rashidi, R. 2014. Lithostratigraphy and biostratigraphy of Mishan Formation in North and West of Hormozgan Province, Ph.D. thesis, 263 p. Islamic Azad University, Sciences and Researches Branch; Tehran. [In Persian, with English abstract]

Fleming, C.A. 1945. Some New Zealand Tertiary cephalopods. *Transactions of the Royal Society of New Zealand*, **74**, 411–418.

Fuchs, D., Bracchi, G. and Weis, R. 2009. New octopods (Cephalopoda: Coleoidea) from the Late Cretaceous (upper Cenomanian) of Hâkel and Hâdjoula, Lebanon. *Palaeontology*, **52**, 65–81.

Fuchs, D. and Weis, R. 2009. A new Cenomanian (Late Cretaceous) coleoid (Cephalopoda) from Hâdjoula, Lebanon. *Fossil Record*, **12**, 175–181.

Greig, D.A. 1935. *Rotalia viennoti*, an important foraminiferal species from Asia Minor and western Asia. *Journal of Paleontology*, **9**, 523–526.

Gholamalian, H., Fanati-Rashidi, R. and Sajadi, S.H. 2015. Miocene (Mishan Formation) Echinoidea from Gohreh section, North of Bandar Abbas, Hormozgan Province. *Geosciences*, **25**, 73–82. [In Persian, with English abstract]

Hassani, M.J. and Hosseinipour, F. 2018. Lithostratigraphy and microbiostratigraphy of the Neogene deposits (the Mishan and Aghajari formations) in the Northeast of Bandar Abbas. *Paleontology Journal*, **7**, 86–114. [In Persian, with English abstract]

Heidari, A., Feldmann, R.M. and Moussavi-Harami, S.R. 2012. Miocene Decapod Crustacean from the Guri Member of Mishan Formation, Bandar Abbas, southern Iran. *Bulletin of Mizunami Fossil Museum*, **38**, 1–7.

Heidari, A., Mahboubi, A., Moussavi-Harami, S.R., Gonzales, L. and Moalemi, S.A. 2013. Biostratigraphy, sequence stratigraphy and paleoecology of the Lower–Middle Miocene of northern Bandar Abbas, southeast Zagros basin in South of Iran. *Arabian Journal of Geosciences*, **7**, 1829–1855.

Hilber, V. 1915. Der alteste bekannte und erste Miozäine Argonauta. *Mitteilungen des Naturwissenschaftlichen Verein*, **51**, 107–110.

Hosseinipour, F. 2013. Biostratigraphy, microfacies and chemical stratigraphy of the Asmari, Jahrum and Mishan formations in the southeast of the Haji Abad and northeast of the Bandar Abbas. Ph.D. thesis, 312 p. Shahid Bahonar University of Kerman, Kerman, Iran. [In Persian, with English abstract]

Jattiot, R., Brayard, A., Fara, E. and Charbonnier, S. 2015. Gladius-bearing coleoids from the Upper Cretaceous Lebanese Lagerstätten: diversity, morphology, and phylogenetic implications. *Journal of Palaeontology*, **89**, 148–167.

Kaseno, Y. 1955. Neogene Argonautinae from Kahoku-gun, Ishikawa Prefecture, Japan. *Kanazawa University Science Reports*, **3**, 339–344.

Kobayashi, T. 1954a. A new Paleogene paracenoceratoid from southern Kyushu in Japan. *Japanese Journal of Geology and Geography Transactions*, **24**, 181–184.

Kobayashi, T. 1954b. *Izumonauta*, a new genus of the Argonautinae, with a note on their rare but gregarious fossil occurrence. *Japanese Journal of Geology and Geography Transactions*, **25**, 21–34.

Kroh, A., Gholamalian, H., Mandic, O., Ćorić, S., Harzhauser, M., Reuter, M. and Piller, W.E. 2011. Echinoids and pectinid bivalves from the Early Miocene Mishan Formation of Iran. *Acta Geologica Polonica*, **51**, 419–439.

Lamarck, J.B. 1804. Suite des mémoires sur les Fossiles des environs de Paris. *Annales de Museum National d'Histoire Naturelle*, **5**, 28–36.

Leach, W.E. 1817. Synopsis of the orders, families, and genera of the class Cephalopoda. *The Zoological Miscellany, being descriptions of new or interesting animals*, **3**, 137–141.

Lightfoot, J. 1786. A Catalogue of the Portland Museum, lately the property of the Duchess of Portland, deceased; which will be sold at auction, by Mr. Skinner and Co. on Monday the 24th of April, 1786, 194 p. Skinner; London.

Linnæus, C. 1758. Systema Naturae per regna tria naturae. Editio decima, reformata, Regnum Animale, vol. 1, 824 p. Laurentii Salvii; Holmiae.

Lorois, E.L. 1852. Description d'une nouvelle espèce du genre Argonaute. *Revue et Magasin de Zoologie, série 2*, **4**, 9–10.

Maltzan, H. von 1881. Description de deux espèces nouvelles. *Journal de Conchyliologie*, **29**, 162–163.

Martill, D.M. and Barker, M.J. 2006. A paper nautilus (Octopoda, *Argonauta*) from the Miocene Pakhna Formation of Cyprus. *Palaeontology*, **49**, 1035–1041.

Martin, K. 1929. Ein neues Argonautiden Geschlecht von Sumatra. *Leidse Geologische Mededelingen*, **3**, 221–226.

Motiei, H. 1993. Stratigraphy of Zagros, 543 p. Geological Survey of Iran; Tehran.

Nesis, K.N. 2003. Distribution of recent Cephalopoda and implications for Plio-Pleistocene events. *Berliner Paläobiologische Abhandlungen*, **3**, 199–224.

d'Orbigny, A. 1826. Tableau methodique de la classe des Foraminiféres. *Annales des Sciences Naturelles*, 7, 245–314.

d'Orbigny, A. 1839. Foraminiferes des Iles Canaries. *Histoire Naturelle des iles Canaries*, **2**, 119–146.

d'Orbigny, A.D. 1846. Foraminiféres fossiles du Bassin tertiaire de Vienne (Autriche), 312 p. Gide et Comp; Paris.

Reuss, A.V. 1850. Neues Foraminiferen aus den schichten des Osterreichischen Tertiarbeckens. *Denkschriften der Akademie des Wissenschaften Wein*, **1**, 365–390.

Rezaee Ruzbahani, P., Baharvand, S. and Qanavati, M. 2013. Lithostratigraphy and biostratigraphy of the Mishan Formation in the Maroon Oil Field. In: 17th Conference of the Geological Society of Iran, pp. 91–95. [In Persian, with English abstract]

Saul, L.R, and Stadum, C.J. 2005. Fossil argonauts (Mollusca: Cephalopoda: Octopodida) from Late Miocene siltstones of the Los Angeles Basin, California. *Journal of Paleontology*, **79**, 520–531.

Shiva-Korkaj, A. 2017. Biostratigraphy, microfacies and electric facies of the Guri Member of the Mishan formation, the southern Gashu Anticline, northwest of the Bandar Abbas. M.Sc. thesis, 137 p. Kharazmi Univercity, Tehran, Iran. [In Persian with English abstract]

Strugnell, J. and Allcock, A.L. 2010. Co-estimation of phylogeny and divergence times of Argonautoidea using relaxed phylogenetics. *Molecular Phylogenetics and Evolution*, **54**, 701–708.

Tomida, S. 1983. Two new fossil *Argonauta* and firstly discovered *Aturia coxi* Miller from the Late Tertiary of Boso Peninsula, Japan. *Bulletin of the Muzunami Fossil Museum*, **10**, 107–116.

Tomida, S., Shiba, M. and Nobuhara, T. 2004. First post-Miocene Argonauta from Japan and its Palaeontological Significance. *Cainozoic Research*, **4**, 19–25.

Vega, F.J., Gholamalian, H. and Bahrami, A. 2010. First record of Miocene crustaceans from Hormozgan Province, Southern Iran. *Paläontologische Zeitschrift*, **84**, 485–493.

Vega, F.J., Gholamalian, H., Hassani, M.J., Sajadi, S.H. and Schaaf, P. 2012. Miocene Crustacea from northern Bandar Abbas, South Iran. *Neues Jahrbuch fur Geologie und Paläontologie, Abhandlungen*, **265**, 221–234.

Yazdi, M., Bahrami, A. and Vega, F.J. 2009. Albian decapod Crustacea from Southeast Esfahan, Central Iran-Kolah-Qazi area. *Bulletin of the Mizunami Fossil Museum*, **35**, 71–77.

Yokoyama, M. 1913. On two new fossil Cephalopoda from the Tertiary of Izumo. *Geological Society of Tokyo Journal*, **20**, 1–3.

Young, R.E., Vecchione, M. and Donovan, D.T. 1998. The evolution of coleoid cephalopods and their present biodiversity and ecology. *African Journal of Marine Science*, **20**, 393–420.

Yusofi, L. 2016. Biostratigraphy and microfacies of the Mishan formation in the underground section of the Bostaneh Anticline, northwestern Bandar Lengeh, M.Sc. thesis, 187 p. Kharazmi University, Tehran, Iran. [In Persian, with English abstract]

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