

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

HOSSEIN GHOLAMALIAN<sup>1</sup>, MOHAMMAD-JAVAD HASSANI<sup>2\*</sup> and FATEMEH HOSSEINIPOUR<sup>3</sup>

<sup>1</sup> Department of Geology, Faculty of Sciences, University of Hormozgan, Bandar Abbas, Iran.

<sup>2</sup> Department of Ecology, Institute of Science and High Technology and Environmental Sciences, Graduate University of Advanced Technology, Kerman, Iran.

<sup>3</sup> Department of Geology, Payame Noor University (PNU), Tehran, Iran.

\* Corresponding author: mjhassani887@gmail.com

## ABSTRACT:

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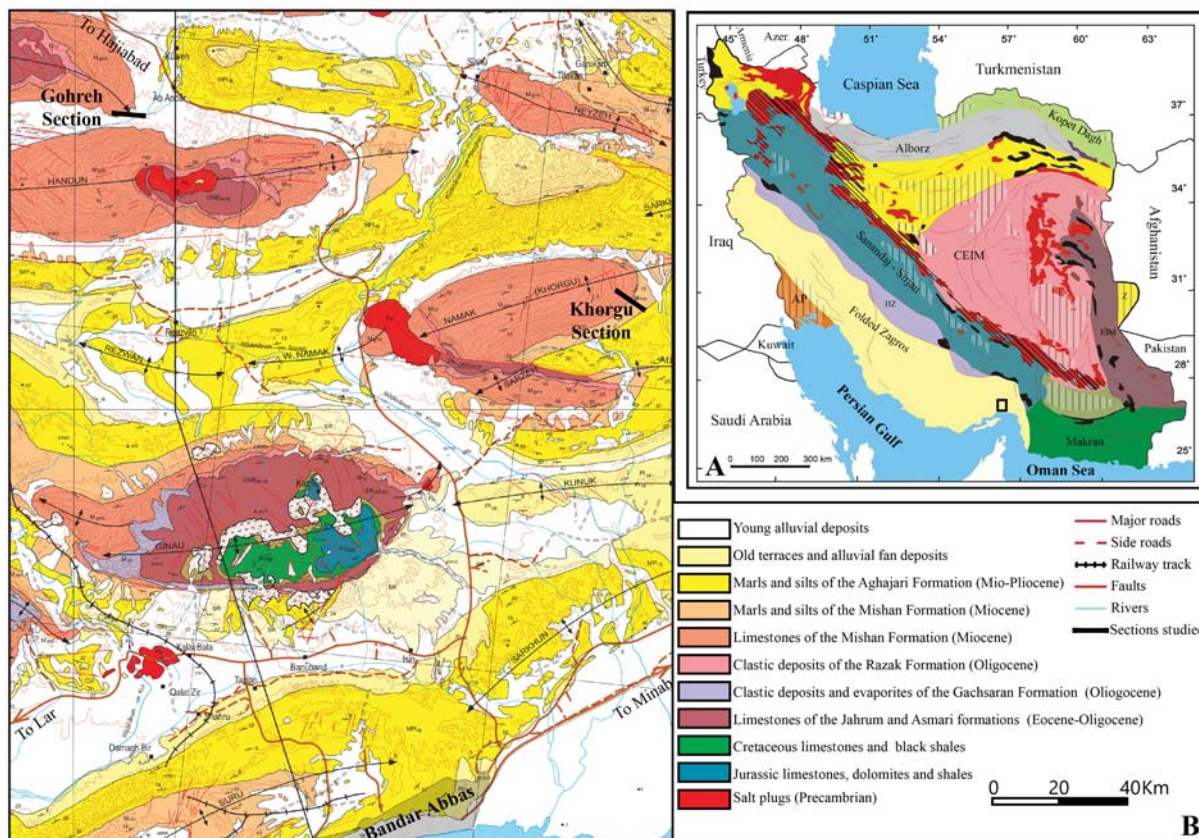
Cephalopod specimens assigned to the Argonautidae (*Obinautilus pulchra* Kobayashi, 1954 and an unknown taxon) from two localities of the Mishan Formation in Gohreh and Khorgu sections, Bandar Abbas, southern Iran, are reported for the first time from the Persian Gulf area. The co-existing foraminifera 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), Hosseini pour (2013), Rezaee Ruzbahani *et al.* (2013), Daneshian *et al.* (2016), Yusofi (2016), Shiva-Korkaj (2017) and Hassani and Hosseini pour (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**

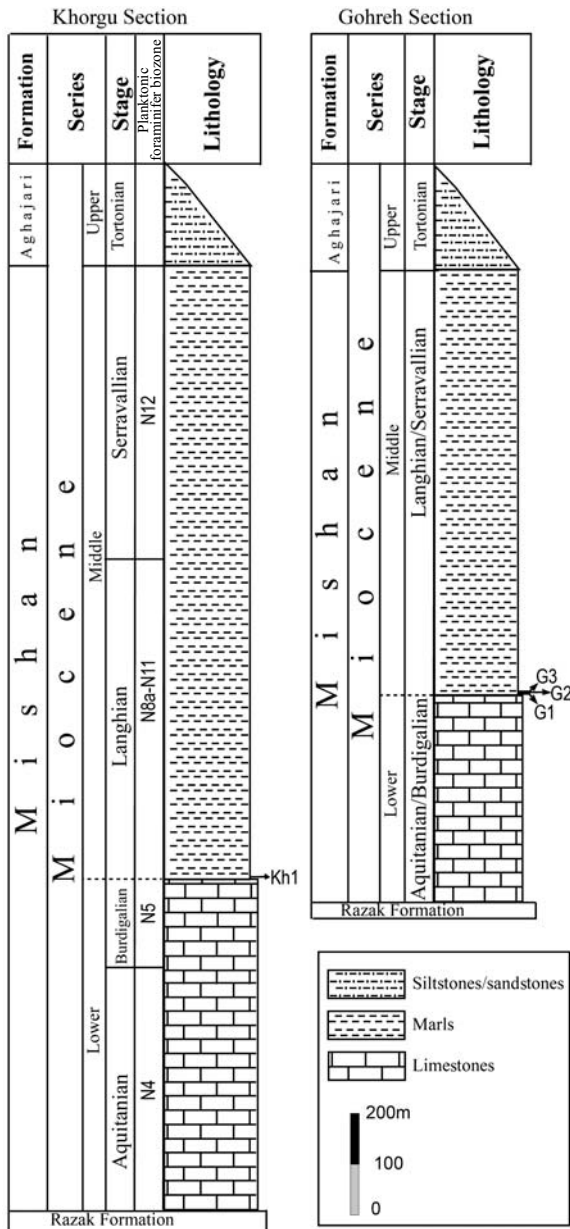
The south-eastern part of the Zagros Folded Zone around the Hormuz strait named as the Bandar Abbas Hinterland (Motiei 1993). The presence of numerous salt plugs in addition to the large thickness of the Miocene–Pleistocene Fars Group (Gachsaran/Razak, Mishan, Aghajari and Bakhtiari formations) and the 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 (56°02'54"E, 27°43'26"N) and Khorgu section is located 50 km to the northeast of Bandar Abbas (56°28'37"E, 27°35'07"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

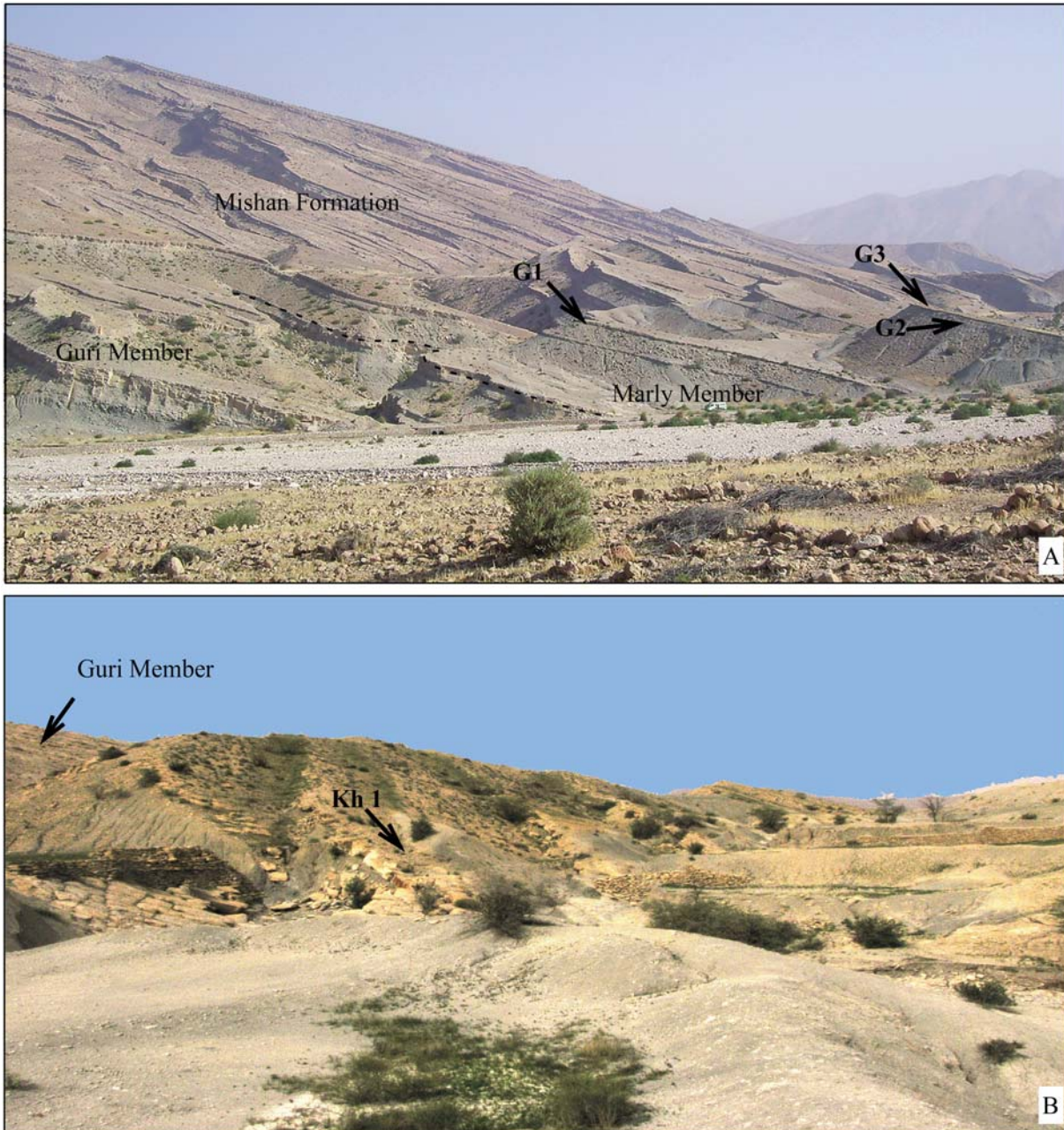
Serravallian age for the upper marly member in this area. In addition, Gholamalian *et al.* (2015) identified an assemblage including *Amphistegina lessoni* d’Orbigny, 1826, *Dendritina rangi* d’Orbigny, 1826, *Globigerinoides trilobus* Reuss, 1850, *Neorotalia viennoti* (Greig, 1935), *Orbulina universa* d’Orbigny, 1839, *Operculina complanata* d’Orbigny, 1826, *Trilocolina 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), secrete 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).

## SYSTEMATIC PALAEOLOGY

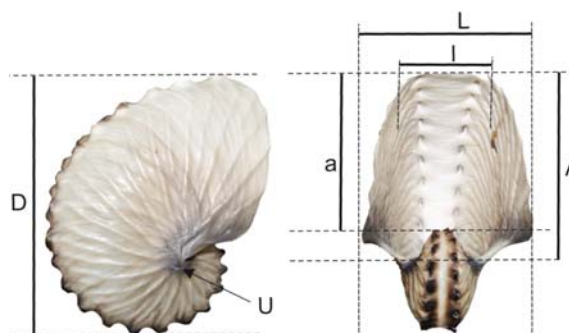
Class Cephalopoda Cuvier, 1797  
 Subclass Coleoidea Bather, 1888  
 Order Octopoda Leach, 1818  
 Family Argonautidae Conrath, 1841  
*Obinautilus* Kobayashi, 1954

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).

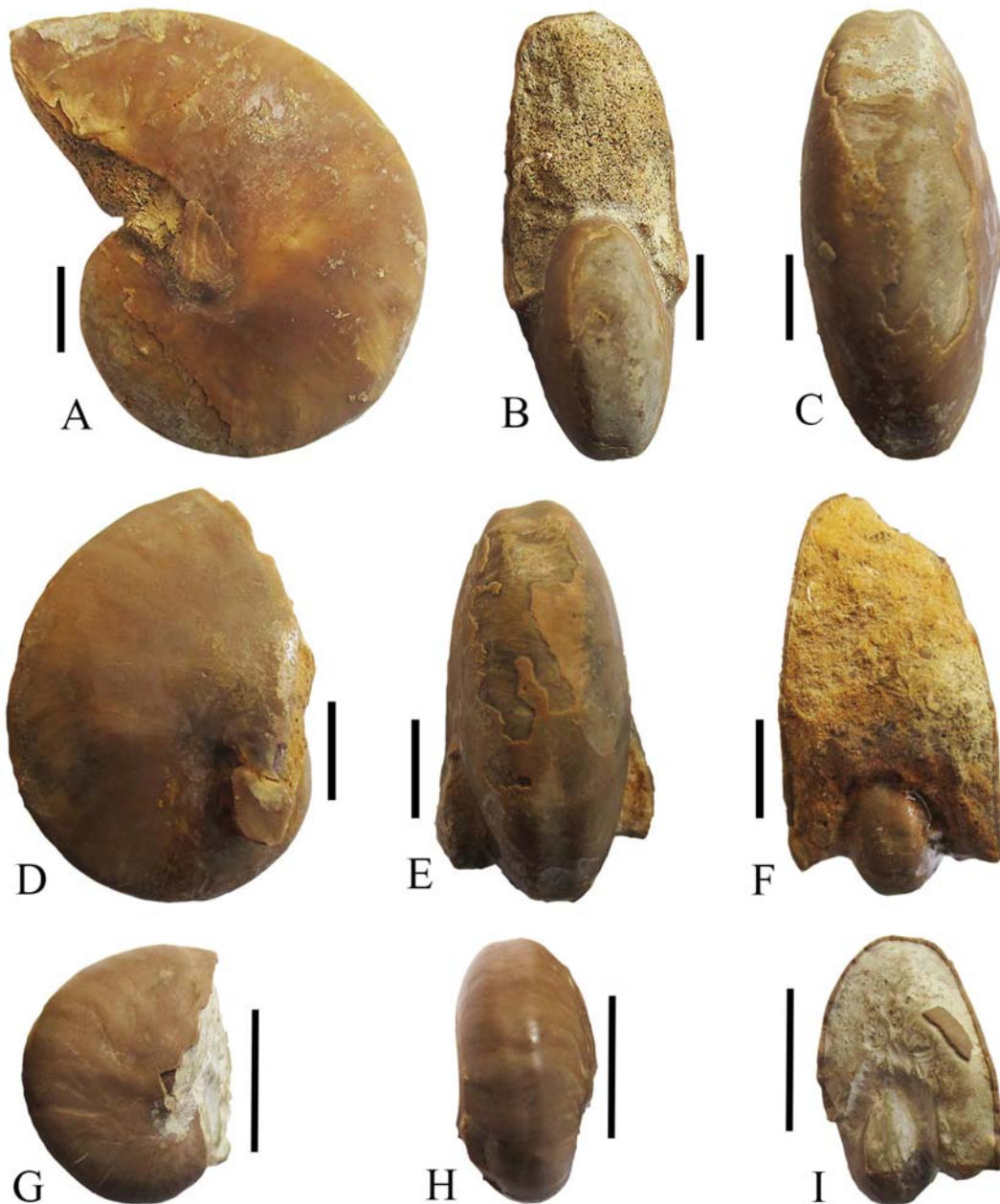


Text-fig. 4. Biometric characters of the Argonautidae shown on an *Argonauta* egg-case shell (specimen from the personal collection of H. Gholamalalian). D = diameter, A = maximum height of aperture, a = minimum height of aperture, U = umbilicus, L = maximum width of aperture, l = minimum width of aperture

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).



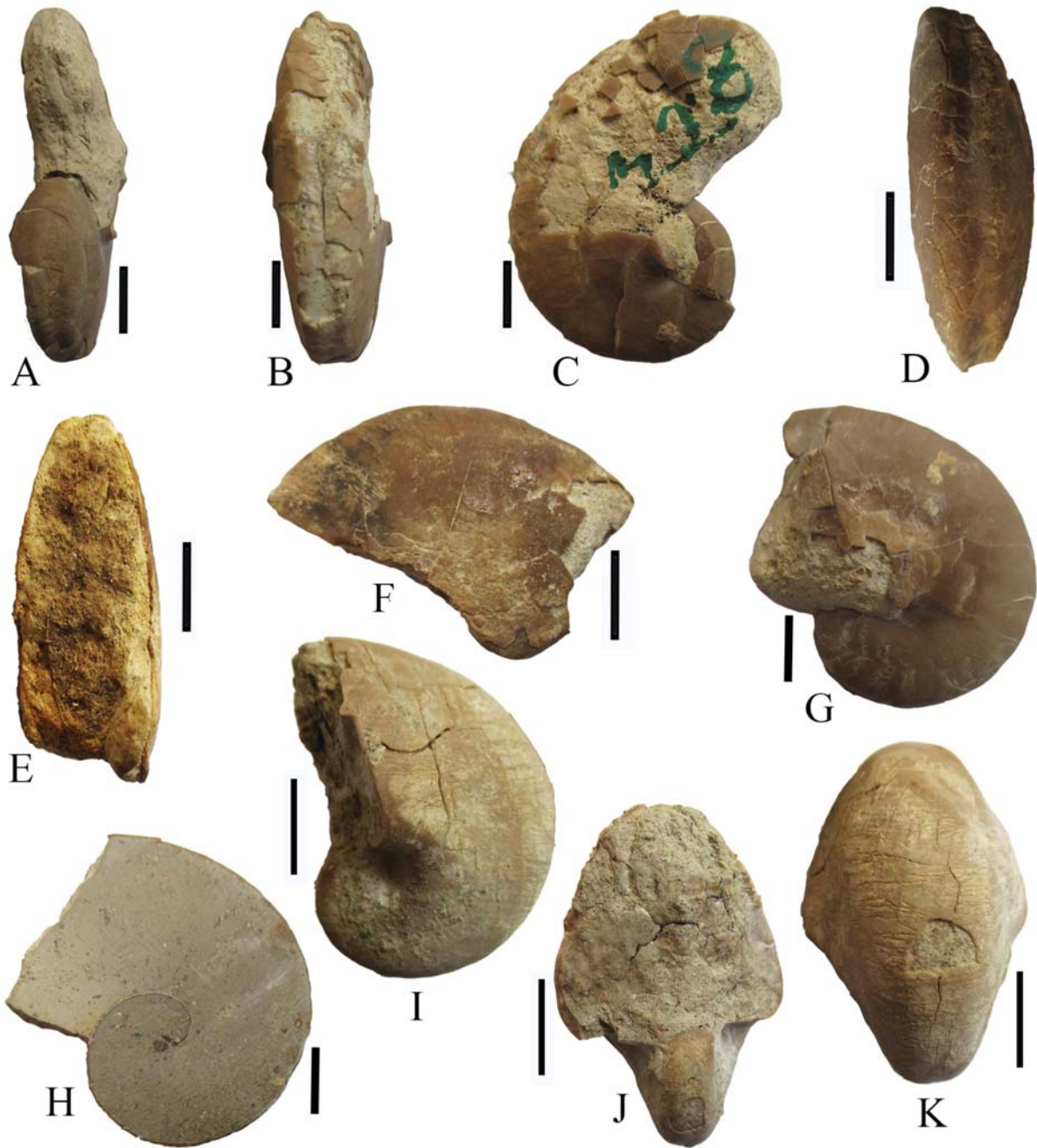
Text-fig. 5. *Obinautilus pulchra* Kobayashi, 1954 from the Miocene of southern Iran. A-C – Lateral, anterior and posterior views of specimen HUIM184, bed Kh1, Khorgu section; D-F – Lateral, posterior and anterior views of specimen HUIM186, bed Kh1, Khorgu section; G-I – Lateral, posterior and anterior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

mented 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 been seen in any of the reported Argonautidae. The

Species	D	A	a	A/D	A/a	L	l	Repository no.	Sampled bed
<i>Obinautilus pulchra</i>	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
<i>Argonauta argo</i>	Linnæus (1758)	Pleistocene	Red Sea
<i>Argonauta boettgeri</i>	Maltzan (1881)	Recent	Tropical Indo-west Pacific
<i>Argonauta cornutus</i>	Conrad (1854)	Recent	Panama, Mexico
<i>Argonauta hians</i>	Lightfoot (1786)	Pliocene, Recent	Italy, Tropical cosmopolitan
<i>Argonauta hians</i>	Tomida et al. (2004)	Pliocene	Japan
<i>Argonauta itoigawai</i>	Tomida (1983)	Pliocene	Japan
<i>Argonauta joanneus</i>	Hilber (1915)	Middle Miocene	Austria
<i>Argonauta nodosus</i>	Lightfoot (1786)	Recent	Indo-west Pacific
<i>Argonauta nouryi</i>	Lorois (1852)	Recent	USA, Peru
<i>Argonauta oweri</i>	Fleming (1945)	Early Pliocene	New Zealand
<i>Argonauta sismondai</i>	Bellardi (1873)	Pliocene	Italy
<i>Argonauta pacificus</i>	Dall (1871)	Recent	Peru, southern California
<i>Argonauta tokunagai</i>	Yokoyama (1913)	Middle Miocene	Japan
<i>Izumonauta kaganus</i>	Kaseno (1955)	Late Miocene	Japan
<i>Izumonauta kasataniensis</i>	Kaseno (1955)	Late Miocene	Japan
<i>Izumonauta latus</i>	Kobayashi (1954b)	Middle Miocene	Japan, New Zealand
<i>Kapal batavus</i>	Martin (1929)	Miocene	Sumatra
<i>Mizuhobaris izumoensis</i>	Yokoyama (1913)	Middle Miocene	Japan
<i>Mizuhobaris lepta</i>	Saul and Stadum (2005)	Late Miocene	USA
<i>Obinautilus awaensis</i>	Tomida (1983)	Miocene–Pliocene	Japan
<i>Obinautilus pulchra</i>	Kobayashi (1954a)	Oligocene	Japan
<i>Obinautilus pulchra</i>	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.

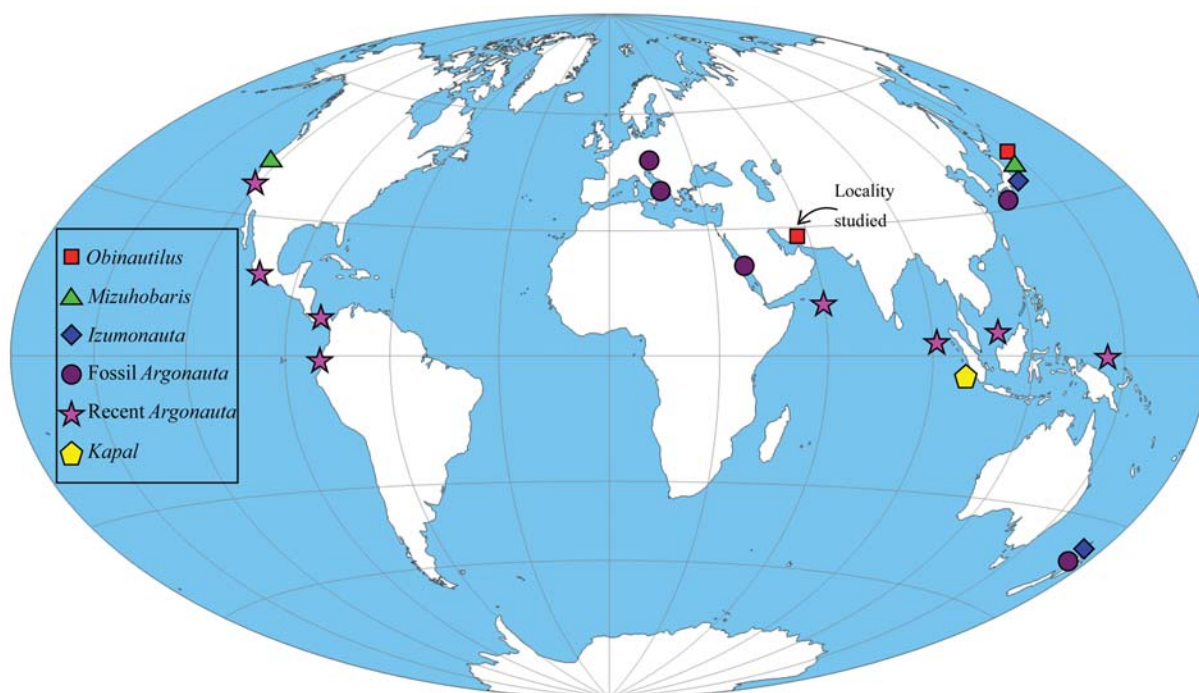
STRATIGRAPHIC RANGE: Langhian to Serravalian (Text-fig. 2).

#### 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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