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# A PAPER NAUTILUS (OCTOPODA, *ARGONAUTA*) FROM THE MIOCENE PAKHNA FORMATION OF CYPRUS

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**Abstract:** The fossil organic trace of an argonaut shell from the Pakhna Formation (Serravillian, Middle Miocene) of southern Cyprus is described. The new find represents one of only a very few argonaut egg cases reported from the fossil record of the Tethyan region and is the first to be reported from the eastern Mediterranean. It is assigned to a new species of *Argonauta* as *A. absyrtus* sp. nov.

**Key words:** Cephalopoda, *Argonauta*, Miocene, Cyprus.

Argonauts are extant cephalopod molluscs lacking both an internal and external phragmocone that utilise ammonia metabolism for buoyancy (Robson 1932). They are distinctive for producing very delicate, thin, calcitic shells that are rapidly expanding planispiral and involute, with a tabular venter and usually ornamented with ribs and/or nodes (Holland 1988). They superficially resemble the shells of some Triassic and Cretaceous ammonites (Lewy 1996) and nautiloids but are not septate and their morphogenesis also differs in that they are secreted by the dorsal arms rather than the internal mantle shell sac of coleoids (Naef 1923; Hewitt and Westerman 2003). These shells, composed of calcite (Kelly 1901; Kobayashi 1971; Hewitt *et al.* 1983) rather than aragonite (Noda *et al.* 1986), appear to be multifunctional in that they serve as an incubatory chamber for eggs, a protective retreat and support during jet swimming for the female and, with trapped air bubble, as an aid to buoyancy when near the surface (Stephens 1965; Boletzky 1983). Argonauts are placed within the Octopoda based on their soft tissue morphology (Naef 1921–28; Voight 1997) and have a fossil record that begins in the Oligocene (Engeser 1990). Fossil argonauts appear to be more diverse in the Pacific region (Yoshiwara 1900, 1901; Yokoyama 1913; Kobayashi 1954; Tomida 1983; Noda *et al.* 1986; Saul and Stadum 2005). Their egg cases are produced in large numbers during the breeding cycle and may often be cast onto beaches in large numbers (Okutani and Kawaguchi 1983). It is somewhat surprising therefore that argonauts are rare fossils, given that thin-shelled aragonitic ammonites can be so abundant. Here we describe the occurrence of an argonaut shell in deep-water carbonate turbidites of the Eastern Mediterranean region and comment on its biogeographical significance.

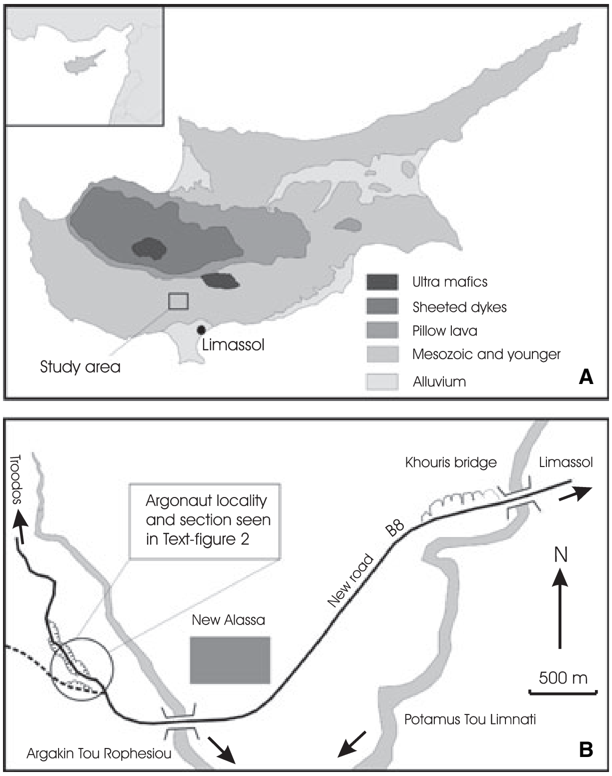
## LOCALITY

The argonaut egg case described here was discovered *in situ* during palaeontological excavations at a roadside exposure of the Miocene Pakhna Formation on the main road between Limassol and Troodos, southern Cyprus, in 1992 (Text-fig. 1). The site was excavated as a consequence of a discovery of fossil fishes the previous year by a party of students from the University of Portsmouth (Gaudant *et al.* 2000). The exposure comprises a series of cuttings on both sides of the B8 road close to the junction with the road to Lofou (Text-fig. 1B). At the time of the discovery the exposures were clean, well exposed and of relatively easy access to most levels.

## GEOLOGICAL SETTING, STRATIGRAPHY AND AGE

The Pakhna Formation forms part of an extensive carbonate ramp sequence on the southern flank of the ophiolitic Troodos Massif (Text-fig. 1A). The sedimentary sequence here is nearly continuous from the Late Cretaceous Campanian–Maastrichtian umbers and bentonites to the late Late Maastrichtian to Miocene Lefkara and Pakhna formations, which comprise a sequence of mainly stacked distal carbonate mud turbidites with interbedded hemipelagites (Robertson and Hudson 1974). The




**TEXT-FIG. 1.** A, schematic geological map of Cyprus. B, sketch map of the study area showing exposures of the Pakhna Formation fossil locality.

sequence was probably deposited at some depth on the Mediterranean seafloor as shallow-water benthos is scarce, although younger parts of the succession develop into reefoid facies and evaporites that became important later during the Messinian (McCallum and Robertson 1990).

The Pakhna Formation is a carbonate-dominated sequence that reaches several hundred metres thickness in places. Formal stratigraphic subdivision of the formation has proven difficult, largely as a result of the vertical monotony of the sequence. Deposition occurred in several subbasins around the active margins of the Troodos ophiolite and consequently lateral variation can be considerable (Eaton 1987). The argonaut described here comes from a locality that lies some 8·3 km from the southern border of the Troodos Massif. Here the Pakhna Formation occurs in the Alassa Sub-basin and is of considerable thickness. Five subunits of the formation were recognised by Greitzer and Constantinou (1969) in this sub-basin, and the argonaut was found in the lowest of these units called the Lophos Beds, which has an estimated thickness of 400 m (Text-fig. 2).

The age of this unit is considered to be Early–Mid Serravallian (13·65–11·61 Ma) (N10 zone of Blow 1969) based on the occurrence of the foraminiferan *Globorotalia peripherodonda*, the nannoplankton *Helicosphaera carteri*, *H. walbersdorfensis*, *Calcidiscus macintyrei*, and *C. premacintyrei*, and characteristic pteropods (see Gaudant *et al.* 2000 for details).

## PALAEONTOLOGY

Fossils are not abundant in the Pakhna Formation at the locality described here, but several levels do contain high concentrations. In particular, at least three hemipelagic marl horizons yield an abundant fauna of syngnathid fishes (*Syngnathus* cf. *albyi* Sauvage), with rarer *Sardina* sp. and *Lepidopus* sp. and the nautiloid *Aturia* sp. (Text-fig. 3), while in the turbiditic chalks small (diameters *c.* 50–100 mm) examples of the *Aturia* and the spatangoid echinoid ?*Pygospatangus* occur. An assemblage of benthic and planktonic foraminiferans has been reported by Gaudant *et al.* (2000). Preservation of the vertebrates is exceptional, with good preservation of original biominerals and some degree of articulation. Most aragonitic fauna is represented by internal moulds or as periostracal films. Calcitic foraminiferans are present, but not well preserved. Some plant debris occurs as carbonaceous films but is not well preserved, though some angiosperm leaves do show venation.

## SYSTEMATIC PALAEONTOLOGY

CEPHALOPODA Cuvier, 1798
COLEOIDEA Bather, 1888
OCTOPODA Leach, 1818
INCIRRATA Grimpe, 1917
ARGONAUTOIDEA Cantraine, 1841
ARGONAUTIDAE Tryon, 1879

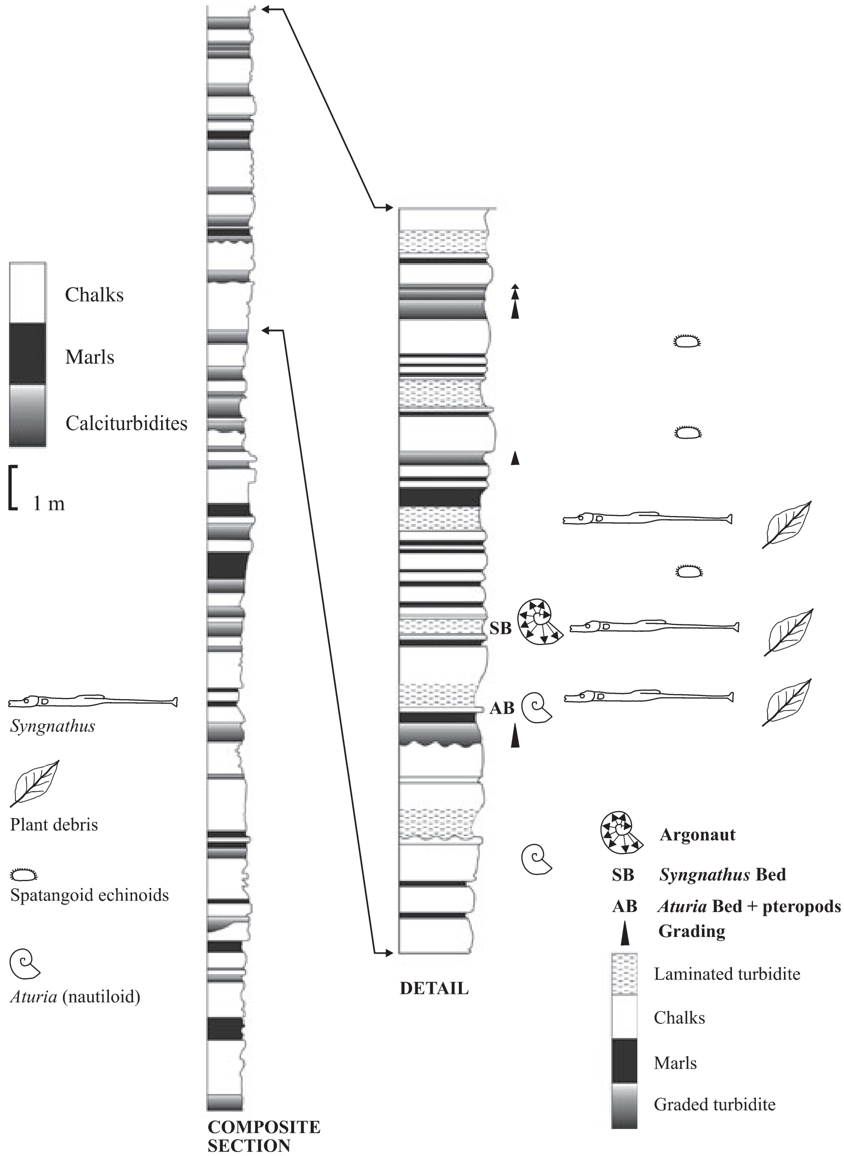
Genus ARGONAUTA Linnaeus 1758

*Argonauta absyrtus* sp. nov.
Text-figure 3

*Derivation of name.* After Absyrtus, brother of Medea, who was a lover of Jason of the Argonauts.

*Holotype.* A near complete shell as part and counterpart from the Pakhna Formation, southern Cyprus, preserved as a slightly obliquely flattened organic trace on laminated marl: Text-figure 3. Accessioned into the collection of the Natural History Museum, London, specimen number BMNH C 93790a, b.

*Diagnosis.* Aseptate, involute planispiral shell with tabulate peripheral margin. The margin ornamented with non-dividing ribs (true costae) commencing as faint ribs

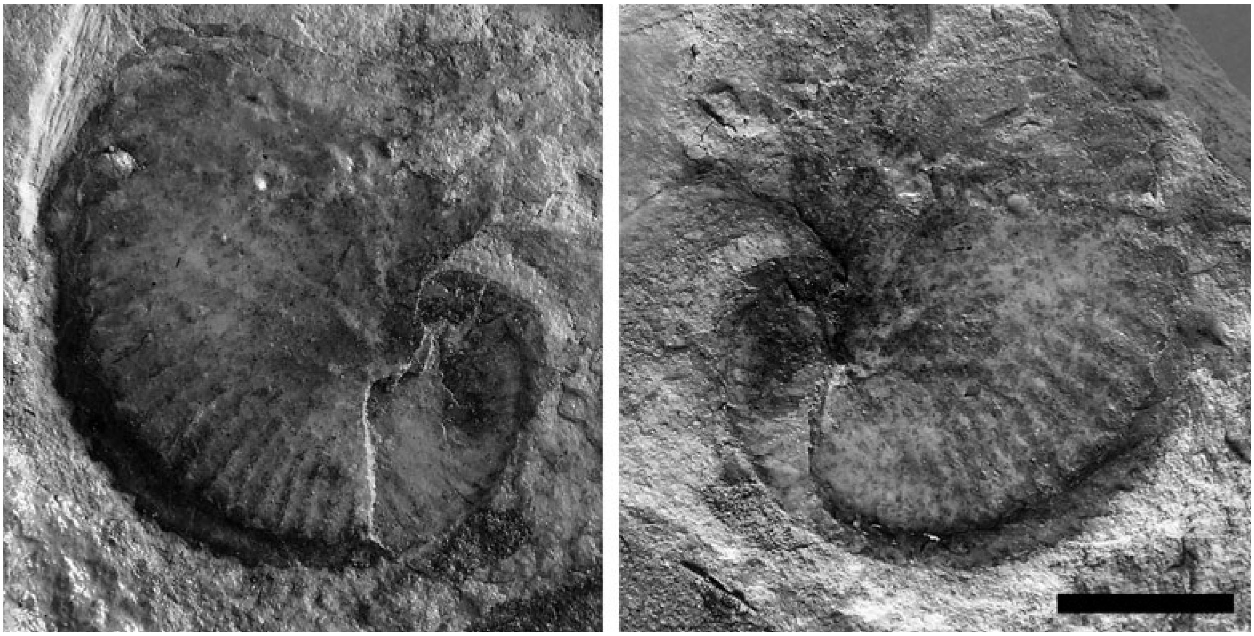



**TEXT-FIG. 2.** Stratigraphy of the Pakhna Formation at Alassa, Cyprus, with the argonaut horizon indicated (based on Gaudant *et al.* 2000).

some distance from the umbilicus and becoming stronger toward the periphery, and terminating in small nodes at the shoulder. Apertural margin expanded to produce a broad, lappet-like structure. Ribs rectiradiate in early ontogeny, becoming rursiradiate later. No intercalatory ribs present.

*Description.* The specimen shows an aseptate, rapidly expanding, planispiral shell with tabulate margin ornamented by radial ribs, each terminating in a node at the peripheral margin. Nodes of each side are paired. Slightly oblique compaction of the specimen reveals the noded peripheral margin of the left-hand side indicating a relatively narrow width to the peripheral margin of 3 mm. The shell of this species would thus have been relatively laterally compressed in life as in *Argonauta argo* Linnaeus, 1758. Faint, slightly rursiradiate growth lines, confluent with the aperture, are discernible in the youngest part of the shell. Maximum diameter of shell 33 mm, height of aperture 22 mm from coiling axis/inner edge of aperture.

*Affinities. Argonauta absyrtus* sp. nov. has clear differences in ornamentation pattern from all of the extant species of *Argonauta* L. In particular, it differs from *A. argo* in that its costae are markedly rectiradiate to rursiradiate (prosiradiate in *A. argo*). *A. absyrtus* also appears to differ from fossil species of *Argonauta*. In *A. sismondae* Bellardi, 1873 from the Pliocene of Liguria, Italy, the shell is more inflated and has much stronger ribbing with larger nodes, while in the holotype of *A. joanneus* Hilber, 1915 from the Middle Miocene Grunderschichten of Wetzelsdorf, Austria, the ribbing is similar in that it is radial but the ribs are very strong (especially so as the holotype is a steinkern) and extend from the coiling axis/inner margin



**TEXT-FIG. 3.** Shell of female *Argonauta absyrtus* sp. nov., BMNH C 93790a, b, from the Pakhna Formation of southern Cyprus, part and counterpart of same individual. Scale bar represents 10 mm.

of the aperture to the periphery. Intercalatory ribs are also present. *A. oweri* Flemming, 1945 from the Pliocene of New Zealand, hardly differs from the Recent *A. hians* Lightfoot, 1786 in our opinion, and may simply be a variety of that taxon where the ribs are slightly reflexed distally as they are in *A. argo* L. In *Argonauta itoigawai* Tomida, 1983 from the Pliocene Senhata Formation of Japan, the ribbing is nodal as in the Recent *A. nodosa* and although *A. itioigawai* is more laterally compressed, these two species may be closely related.

The monotypic genus *Kapal* Martin, 1930 from the Lower Palembang shales of Sumatra is considerably more evolute than *Argonauta* with an open umbilical region and seems to lack the nodes seen in the new specimen. *Izumonauta lata* Kobayashi, 1954 from the Mid–Late Miocene of Japan and New Zealand (Marshall 1971) is a highly distinctive argonaut with a rounded peripheral margin and prominent ribs that appear to cross over the peripheral margin from one side to the other. The Japanese species of *Izumonauta* (*I. kasataniensis* Kaseno, 1955 and *I. kagana* Kaseno, 1955) both possess ribs that are divided into a series of small nodes, as in some specimens of the Recent *A. hians*. In the Late Oligocene and Miocene *Obinautilus* of Japan the peripheral margin is slightly tabulate and the shell flanks have lirae often strong enough to be called costae. The venter appears to be slightly sulcate and its low expansion rate resembles that of *Nautilus*. In *Mizuhobaris* from the Mid Miocene of Japan and California (Saul and Stadum 2005), the shell is smooth with faint growth lines and lacks any keels, ribs or nodes.

Thus the specimen described here appears to have more in common with members of the genus *Argonauta* than it does with other Neogene argonauts, in that it possesses a tabular peripheral margin and carries nodes at the shoulder. It differs from most extant species of *Argonauta* in that the ribs are not prosiradiate but rectiradiate as in *A. joanneus*.

## DISCUSSION

Argonauts are an enigmatic group of the Octopoda, today inhabiting tropical and subtropical waters around the globe. Some forms have been encountered at depths of up to 1000 m but most are pelagic. They have achieved some publicity on account of their beautiful, delicate brood pouches which may occur washed onto beaches in their thousands, and also because of their unusual reproductive strategy in which the diminutive male mates by proxy, releasing a sperm-filled hectocotylus that independently fertilises the female. Most authors consider there to be four extant species of argonaut: *Argonauta argo* Linnaeus, 1758, *A. hians* Lightfoot, 1786, *A. nodosa* Lightfoot, 1786 and *A. nouryi* Lorois, 1852, although some (e.g. Nesis 1982) consider *A. gruneri* (= *A. nouryi*), *A. corunata* Conrad, 1854 (? = *A. hians*) and *A. boettgeri* Maltzan, 1881 (? = *A. hians*) to be specifically distinct.

The relationship of argonauts to other extant cephalopods is reasonably well understood but their evolutionary history remains mysterious (Engeser 1990). A majority of

**TABLE 1.** Stratigraphic occurrences of fossil argonaut taxa; data extracted mainly from Noda *et al.* (1986) and Engeser (1990)

| Taxon | Locality | Formation | Reference |
|---|---|---|---|
| **Pliocene** | | | |
| *Argonauta hians* Lightfoot, 1786 | Italy | Not recorded | Lightfoot 1786 |
| *A. itoigawai* Tomida, 1983 | Japan | U. Senhata Fm | Noda *et al.* 1986 |
| *A. oweri* Flemming, 1945 | NZ | Holotype not *in situ* | Flemming 1945 |
| *A. sismondae* Bellardi, 1872 | Italy | Not recorded | Bellardi, 1872 |
| *Obinautilus awaensis* (Tomida, 1983) | Japan | U. Senhata Fm | Noda *et al.* 1986 |
| **Late Miocene** | | | |
| '*Argonauta*' *awaensis* Tomida, 1983 | Japan | L. Senhata Fm | Tomida 1983 |
| *A. tokunagi* (Yokoyama, 1913) | Japan | Pumice-bearing sst | Kobayashi 1956 |
| *Izumonauta kagana* (Kaseno, 1955) | Japan | Otokawa Fm | Noda *et al.* 1986 |
| *I. kasateniensis* (Kaseno, 1955) | Japan | Yoshitaki Fm | Noda *et al.* 1986 |
| *I.* cf. *lata* Kobayashi, 1954 | NZ | No formation recorded | Marshall 1971 |
| **Mid Miocene** | | | |
| *Argonauta absyrtus* sp. nov. | Cyprus | Pakhna Fm | This paper |
| *Argonauta joanneus* Hilber, 1915 | Austria | Not recorded | Hilber 1915 |
| *A. tokunagai* Yokoyama, 1913 | Japan | Huzina Fm | Kobayashi 1954 |
| | | Bessho Fm | Kosaka and Taguchi 1983 |
| *Kapal batavus* Martin, 1930 | Sumatra | Lwr Palembang shales | Martin 1930 |
| *Izumonauta lata* Kobayashi, 1954 | Japan | ?Huzina Formation | Kobayashi 1954 |
| | | Fugina Fm | Sonoyama 1935 |
| *Mizuhobaris izumoensis* (Yokoyama, 1913) | Japan | Fujina Fm | Noda *et al.* 1986 |
| | | Hiuchiyama Fm | Noda *et al.* 1986 |
| | | Yoko-o Fm | Noda *et al.* 1986 |
| | | Bessho Fm | Noda *et al.* 1986 |
| **Early Miocene** | | | |
| *Mizuhobaris izumoensis* (Yokoyama, 1913) | Japan | Akeyo Fm | Itoigawa *et al.* 1982 |
| **Oligocene** | | | |
| *Obinautilus pulcher* Kobayashi, 1954 | Japan | Nichinan Fm | Noda *et al.* 1986 |

fossil argonauts are documented from the Cenozoic of the western Pacific Rim (Engeser 1990), with most reports coming from Japan, an isolated record from Sumatra (Martin 1930) and a couple of occurrences in New Zealand (Marshall 1971). In Japan most records are from the Upper Miocene (Noda *et al.* 1986), though Kosaka and Taguchi (1983) reported fossil argonauts from the Middle Miocene of Japan while Kobayashi (1954) reported an Oligocene example (Table 1).

In Europe fossil argonauts have only been reported from the Miocene of Austria (Paratethyan Realm) (Hilber 1915) and the Pliocene of Italy (Mediterranean Tethys) (Bellardi 1873; Bandel and Dullo 1985), while elsewhere in the Tethyan realm they have been reported from the Pliocene of Algeria (Roger 1942) and the Pleistocene of the Red Sea (Bandel and Dullo 1985). There have been no reports of fossil argonauts from the Atlantic Province, despite their occurrence off the coast of Morocco and in the Mediterranean today. That the taxon described here appears to belong within *Argonauta* is of some significance, in that none of the other argonaut genera known from the Pacific region, and especially Japan, has yet been reported in the western Tethyan region.

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