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New family, genus, and species of Carpilioidea (Decapoda, Brachyura) from the upper Cretaceous of Saudi Arabia

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Abstract

Arabicarcinus arumensis new genus, new species, is only the second fossil decapod from the Arabian Peninsula. Its Late Cretaceous age makes it one of the older members of the Carpilioidea but it does not expand the geographic range of the superfamily. Carpilioidea is one of the most diverse groups of Brachyura in the Eocene, dwindling to only one extant genus.

Key words: Decapoda, Achelata, Scyllaridae, Eocene, Oregon, USA

Introduction

Fossil decapod crustaceans from the Arabian Peninsula are very rare. Chablais *et al*. (2011) reported a Triassic anomuran from the United Arab Emirates; thus, this Cretaceous brachyuran from Saudi Arabia is only the second report of a fossil decapod from the region. A few fossil decapods are known from nearby Iran (Glaessner, 1933; Feldmann *et al*., 2007; Vega *et al*., 2012; Yazdi *et al*., 2010, 2013), and many are known from Lebanon (i.e., Glaessner, 1946; Garassino, 1994); thus, future work at such time as it is possible may reveal a high diversity of these animals in the region.

Geologic Setting

The sole specimen is reported to have been collected from the Aruma Formation. Although the label and time of collection of the specimen are old (1937), the specimen was collected by and referred to the Aruma Formation by two of the namers of the Aruma Formation (Steinecke and Bramkamp, 1952; Steinecke *et al*., 1958); thus, we consider the collecting locality information reliable. The Aruma Formation crops out in a northwest-southeast trending belt northwest of Riyadh (Skelton and El-Asa'ad, 1992) and is composed of limestone, dolomite, and calcareous shale (Steinecke *et al*., 1958). The unit was originally reported as Maastrichtian in age based upon ammonites and other fossils (Steinecke *et al*., 1958). Powers *et al*. (1966) considered the Aruma Formation as Campanian to Maastrichtian based upon foraminiferans. The lowermost member, the approximately 65 m thick Khanasir Limestone Member (Al-Kahtany *et al*., 2016), was later reported to be Coniacian to Campanian in age, based upon ammonites and rudists (El-Asa'ad, 1983a, b; Skelton and El-Asa'ad, 1992). This was confirmed by Al-Kahtany *et al*. (2016). The crab was reported as having been collected about 17 m from the base of the formation, suggesting a likely Coniacian age as only the top few meters of the Khanasir Member were considered as Campanian in age (Skelton and El-Asa'ad, 1992). The unit has been interpreted as having been deposited in a lagoonal to back reef area inhabited by rudists and dasycladacean algae (Al-Kahtany *et al*., 2016).

Collecting locality: Aruma Plateau, 40.5 km S72° W of Ain Er Rumahiya; about 17 m above the base of the Aruma Formation, from brown to tan and white fine to medium grained crystalline limestone. This information is directly from a United States National Museum Field Label dated April 1, 1937, and numbered S-397 as part of the Aramco Collection, Field Designation 3602. A town called Rumhiyah appears to be about 80 miles just east of north from Riyadh and is very likely the town referred to on the label, as proceeding 40.5 km S72° W would place the location within the formation (Skelton and El-Asa'ad, 1992, fig. 1).

Systematics

Institutional abbreviations: KSU D, Kent State University

Comparative Collection; MGSB, Museo Geológico del Seminario de Barcelona, Barcelona, Spain; USNM, United States National Museum of Natural History, Smithsonian Institution, Washington, DC.

Infraorder Brachyura Linnaeus, 1758
Section Eubrachyura de Saint Laurent, 1980
Subsection Heterotremata Guinot,1977

Superfamily Carpilioidea Ortmann, 1893

Included families: Arabicarcinidae new family; Carpiliidae Ortmann, 1893; Palaeoxanthopsidae Schweitzer, 2003; Tumidocarcinidae Schweitzer, 2005; Zanthopsidae Vía, 1959.

Discussion: Superficially the new specimen (Fig. 1) resembles members of Dakoticancroidea Rathbun, 1917, especially *Ibericancer* Artal *et al*., 2008, in terms of the dorsal carapace. The four-lobed front, the forward projected orbits, and the ovate carapace are very similar to those of the type species, *Ibericancer sanchoi* Artal *et al*., 2008 (Fig. 2). However, the sternum of the new crab from the Arabian Peninsula is markedly different from that of Ibericancridae Artal *et al*., 2008, and also Dakoticancridae Rathbun,1917, both of Dakoticancroidae, in several important regards. The sternum of *Ibericancer* is narrow and very deep axially. In Ibericancridae, strong vertical projections are present on sternite 4 along the articulation with coxa 1, and the episternal projections are short and weakly developed. In *Dakoticancer*, the type and best known genus of Dakoticancridae, the sternum is much wider than that of Ibericancridae, as in the new taxon. However, in *Dakoticancer* Rathbun, 1917, sternite 4 has a ridge bordering the anterior edge of the sternite 4, absent in the new taxon, and each sternite has transverse ornamentation, especially well-developed in males, not seen in the new taxon. Episternal projections are weak, and the pleonal cavity is very deep in males, and moderately and broadly excavated in females. None of these features are seen in the new taxon.

The sternum of the new taxon is much more like that of heterotreme crabs, particularly those of families within Carpilioidea, although the carapace is less reminiscent of members of that superfamily. In the new taxon, sternite three is triangular and separated from sternite four by a notch in the margin. Sternite 4 is wide, with strong episternal projections with which pereiopod 1 articulates. Episternal projections are also clearly present on sternites 5 and 6, the only other sternites clearly visible on the specimen. The pleonal cavity is broad and not particularly depressed (Fig. 1-3).

Most importantly for excluding placement of this taxon into Dakoticancroidea, there is no evidence of gonopores on coxae 3 or 5. Dakoticancroidea is a podotrematous crab, meaning that gonopores in females are located on coxae 3 and males are located on coxae 5. Both right and left coxae three are preserved on the current specimen, with the proximal regions preserved as well as the lower margins. In our experience, this is where gonopores are typically located. In *Dakoticancer overanus* Rathbun, 1917, for example, they are on the lower inner portion of the coxa (Jones, 2013, fig.14-1, 4); that portion is preserved on both the right and left coxae three in the new specimen. In a different family, Xandarocarcinidae, the gonopores are located entirely on the distal margin (Schweitzer *et al*., 2012). In addition, one coxa 5 is preserved, not as entirely as the coxae three. There is no evidence of a gonopore. The specimen is difficult to assign to sex, with a moderately wide pleon with parallel sides and free somites, appearing most likely to be an immature female.

Another common feature of less derived crabs is presence of reduced 4th and/or 5th pereiopods or subdorsal 4th and/or 5th pereiopods. The fifth coxa preserved on the specimen is smaller than 1 through 4 but is not markedly smaller. It is carried laterally and visible in dorsal view; however, examination of specimens of the blue crab *Callinectes sapidus* Rathbun, 1896, indicates that it holds its fifth pereiopod in much the same manner. Thus, whereas the fifth pereiopod seems somewhat smaller and is visible dorsally, this seems not out of line with that seen in other heterotreme crabs.

Thus, there is not one single line of evidence placing this specimen within a podotrematous family other than a superficial carapace resemblance. The front and orbits appear less derived than that seen in many heterotrematous crabs; however, the sternum and pleon appear to belong to a heterotreme family based upon the evidence at hand. In addition, examination of the dorsal carapace suggests that carapace region development is not atypical of heterotreme groups such as Carpilioidea, Goneplacoidea MacLeay,1838, and Portunoidea Rafinesque, 1815. The specimen has weakly developed regions, not usual in podotrematuous crabs. The axial regions are weak, and there is a weakly developed arcuate epibranchial region that is very commonly seen in the Carpilioidea, Goneplacoidea, and Portunoidea. Thus, because the specimen bears an unusual combination of characters, we place it in a new family, provisionally with Carpilioidea.

The specimen is placed within Carpilioidea due to its possession of an ovate carapace, weakly developed regions, carapace widest about half the distance posteriorly, four-lobed front, fronto-orbital width about 60% maximum carapace width; free pleonal somites, and

relatively narrow pleon, all diagnostic for the superfamily (Karasawa and Schweitzer, 2006). Goneplacoids tend to have much wider orbits and a pleon that extends to the anterior end of sternite 4 (Karasawa and Schweitzer, 2006); these are not present in the new specimen. Portunoids almost always have spinose anterolateral margins, whereas those of the new specimen are entire, and the carapace is nearly always angular and wider than long, not seen in the new specimen (Karasawa *et al*., 2008). Thus, the most parsimonious placement for the new family seems to be within Carpilioidea at this time.

Arabicarcinidae new family

Diagnosis: as for sole genus.

Sole included genus: *Arabicarcinus* new genus.

Discussion: The specimen is placed within a new family due to its unique combination of characters. It fits well into the diagnosis for the superfamily Carpilioidea as discussed above, but existing families cannot accommodate the new taxon well. Carpiliidae are strongly vaulted longitudinally and widest posterior to the midlength of the carapace, eliminating this family. Palaeoxanthopsids have wider than long carapaces with bulbous carapace ornamentation and very strong anterolateral spines in addition to strong orbital fissures, not seen in the new specimen. The new specimens are not unlike members of Tumidocarcinidae in lacking orbital fissures and having relatively smooth carapaces but tumidocarcinids, as the name suggests, are very strongly vaulted longitudinally. Zanthopsidae may be the closest fit, but this taxon has strong swellings on sternite 4 in males and females and pleonite 3 in males, not seen in the new taxon. Thus, although the new taxon exhibits many features of the superfamily, it does not present an array of characteristics that fit any particular family within it. A new family is herein erected for it.

Arabicarcinus new genus

Type species: *Arabicarcinus arumensis* new species, by original designation and monotypy.

Diagnosis: Carapace not much wider than long, length about 94% width; widest about one-half the distance posteriorly on carapace; moderately vaulted longitudinally; front extended beyond orbits, with 4 blunt spines including inner-orbital spines; front about 23% maximum carapace width; orbits rectangular, directed forward, upper-orbital margin entire; outer-orbital spine curving slightly axially; anterolateral margin convex, entire save small anterolateral spine extending from arcuate epibranchial region; dorsal carapace regions very weakly defined; sternal suture 3/4 incomplete, sutures 4/5 and 5/6 parallel; sternite 7 barely visible in ventral view in female, sternite 8 not visible; telson about as long as somite 6 in female; female pleon reaching middle of sternite 4.

Etymology: The generic name is derived from Arabia, the peninsula and region from which the specimen was collected and Carcinus, a common stem in the group, meaning crab. The gender is masculine.

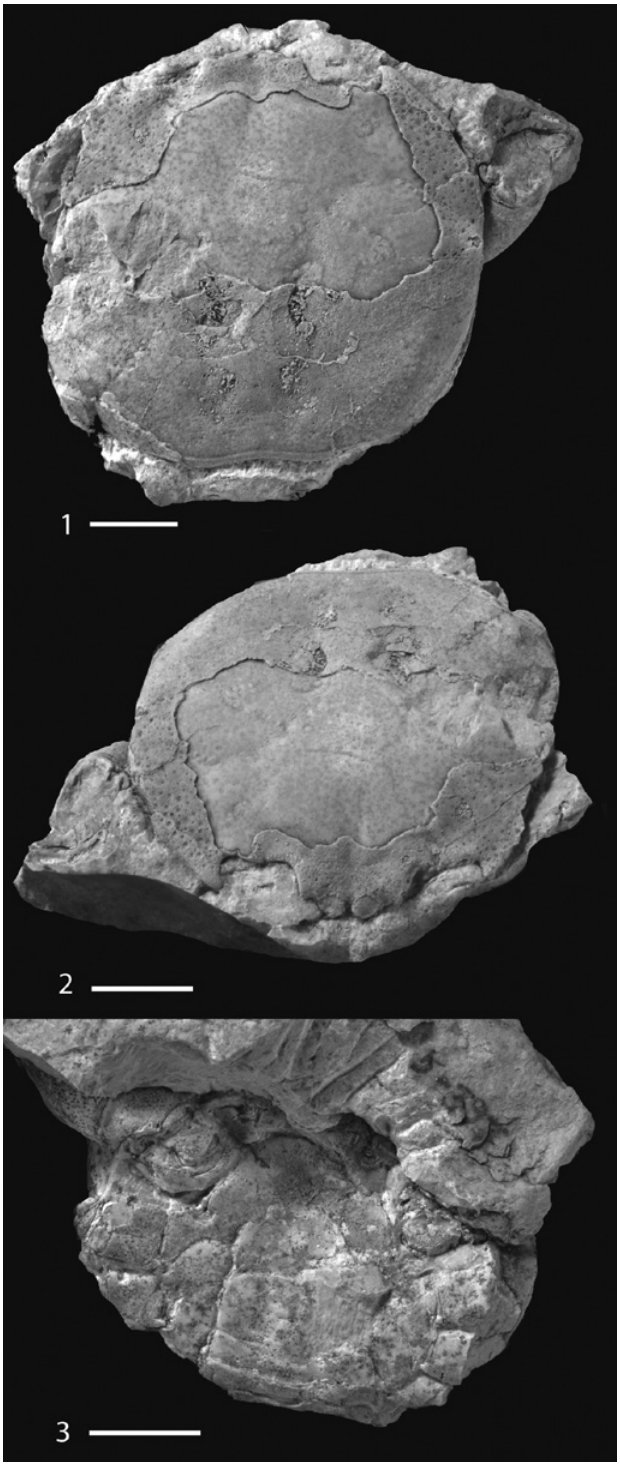

Fig. 1. *Arabicarcinus arumensis* new species, holotype, USNM 636369. 1, dorsal carapace, 2, oblique anterior view showing orbits; 3, sternum and pleon of ?immature female. Scale bars = 1.0 cm.

Arabicarcinus arumensis new species

(Fig. 1)

Diagnosis: as for genus.

Description: Carapace about as wide as long, L/W about 94%; ovate; widest one-third the distance posteriorly on carapace; weakly vaulted transversely and moderately vaulted longitudinally.

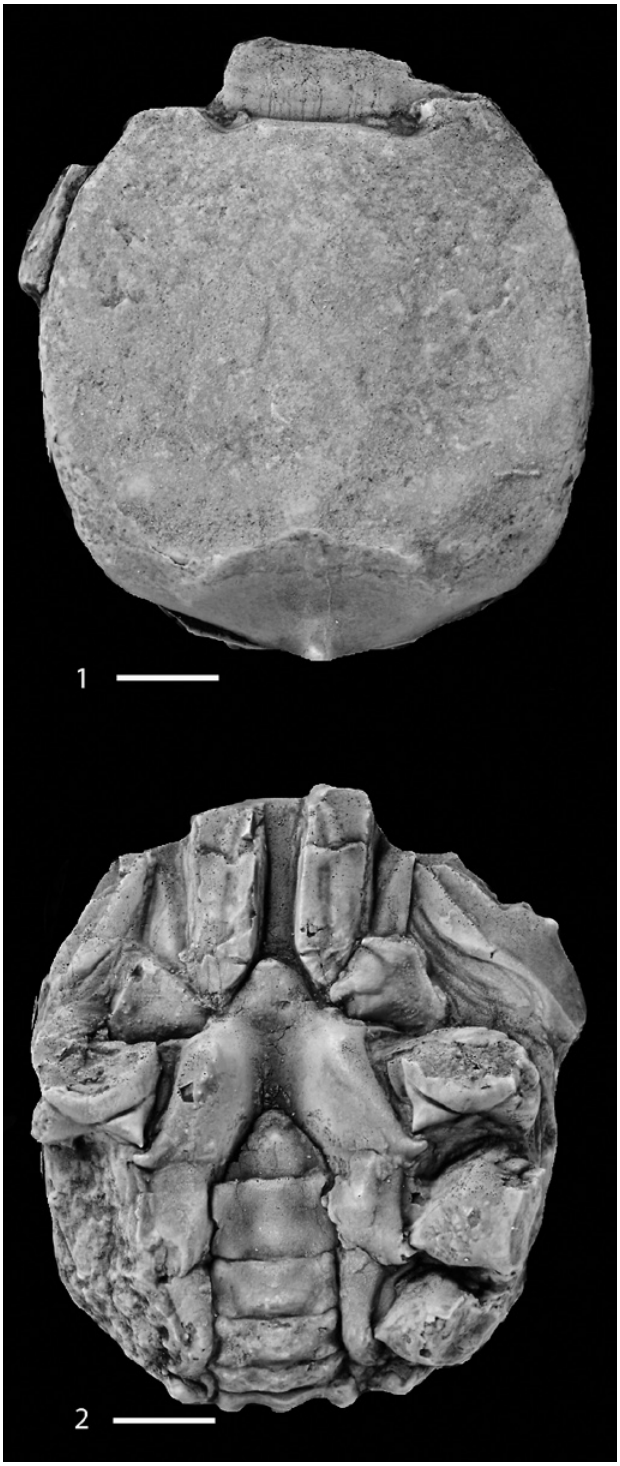

Fig. 2. *Ibericancer sanchoi* Artal *et al*., 2008, KSU D 446, cast of holotype MGSB 68572. 1, dorsal carapace, 2, ventral surface showing narrow sternum, deeply excavated pleonal cavity, and male pleon. Scale bars = 1.0 cm.

Front extending moderately beyond orbits, quadrilobed, axial two lobes extending furthest, blunt, separated by blunt notch; inner two lobes set further posteriorly, forming inner orbital angles, sharp; front about 23% maximum carapace width. Orbits rectangular, directed forward, upper orbital margin sinuous, with broad convex forward axial projection along upper orbital margin; outer-orbital spine curving very slightly axially; fronto-orbital width about 58% maximum carapace width.

Anterolateral margin convex, appearing to have been entire, curving into slightly less convex posterolateral margin; transition marked by small anterolateral spine; posterior margin sinuous; axially concave, rimmed.

Dorsal surface of carapace preserved mostly as mold of interior. Mesogastric region poorly developed; protogastric region broadly inflated, especially so along anterior margin; hepatic region depressed; epibranchial region arcuate, convex anteriorly, with spine or tubercle forming anterolateral spine. Metagastric and urogastric regions bounded laterally by deep branchiocardiac groove; cardiac region also bounded by deep groove; mesobranchial and metabranchial regions confluent, flattened and depressed along axial regions, inflated laterally; cuticle where present pitted.

Sternite 3 narrowed anteriorly, widening posteriorly, then narrowing again to posterior margin, separated from sternite 4 by short incision along margin. Sternite 4 wide, broadly depressed axially, with marked episternal projections, longer than wide; sternite 5 about as wide as long, with long episternal projections; sternite 6 somewhat shorter than long; sternites 7 and 8 poorly known; pereiopods articulating with episternites.

Pleon of immature female? relatively broad, parallel sided; all somites free, becoming longer posteriorly; somite 6 longest of all somites except telson; telson about as long as somite 6, telson bluntly rounded, reaching about middle of coxa of pereiopod 1.

Pereiopod 1 large, ischium stout; merus longer than high, very stout; carpus poorly known. Only bases of pereiopods 2–5 known, becoming smaller posteriorly, pereiopod 5 slightly smaller than others, visible in dorsal view but not appearing to be held dorsally or subdorsally. Coxae of pereiopods 3 and 5 with no evidence of gonopores.

Etymology: The specific name is derived from the Aruma Plateau amd Aruma Formation, from which the specimen was collected.

Type: The holotype and sole specimen is USNM 636369.

Measurements: Measurements (in mm) taken on the holotype and sole specimen USNM 636369: maximum carapace length, 47.8; fronto-orbital width, 27.6; frontal

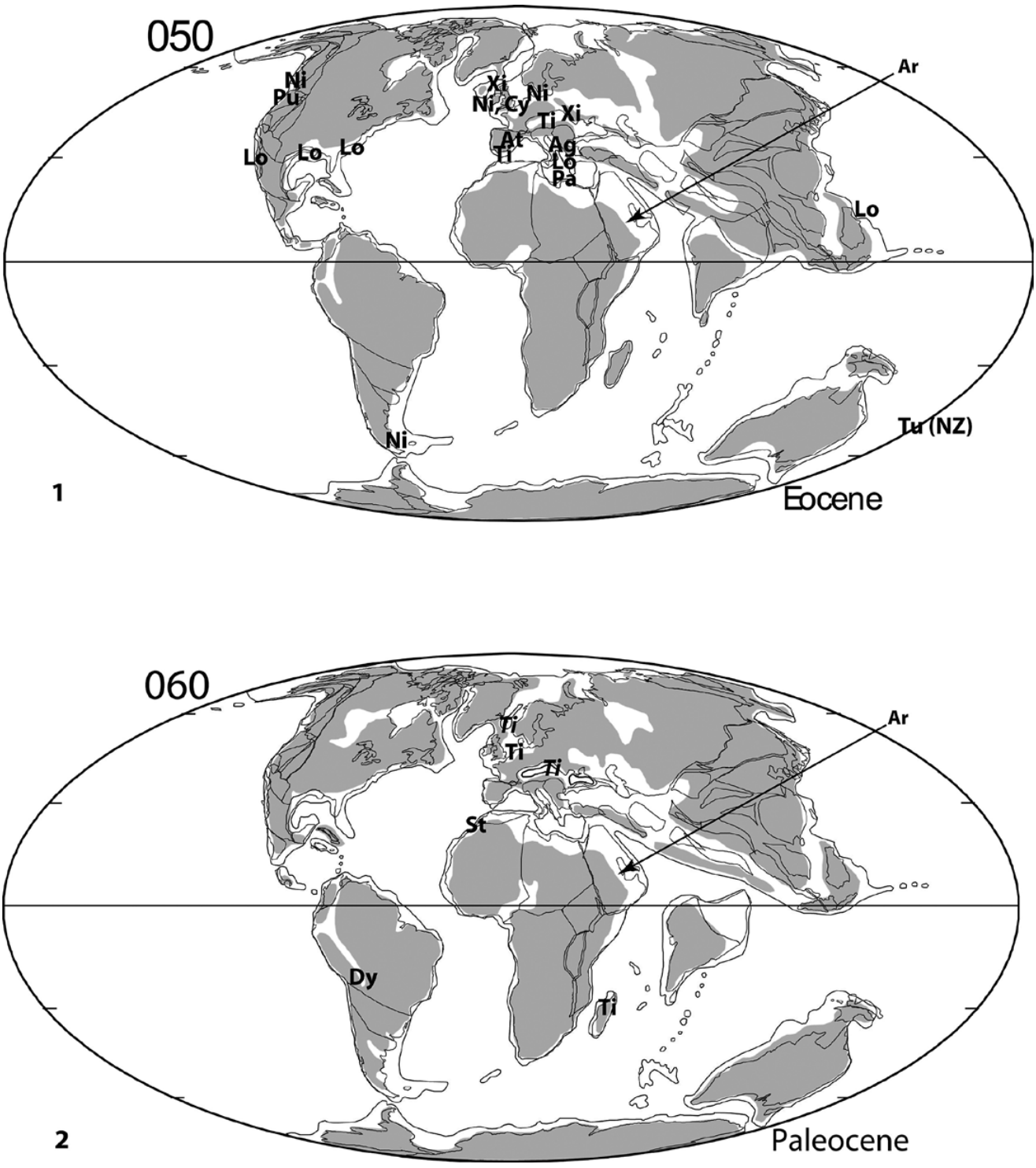

Fig. 3. Occurrences of Tumidocarcinidae. A. Eocene occurrences: At, *Agostella*; Ag, *Agnocarcinus*; Cy, *Cyclocorystes*; Ni, *Nitotacarcinus*, l, *Lobonotus*, Ni, *Nitotacarcinus*; Pa, *Paronacarcinus*; Pu, *Pulalius*; Ti, *Titanocarcinus*; Tu, *Tumidocarcinus*; Xi, *Xanthilites*; NZ, New Zealand. B. Cretaceous and Paleocene occurrences, the latter in italics, plotted on a Paleocene map. Dy, *Dynomenopsis*; St, *Styracocarcinus*; Ti, *Titanocarcinus*. Ar = *Arabicarcinus* occurrence for biogeographic reference. Base maps from Scotese (2006).

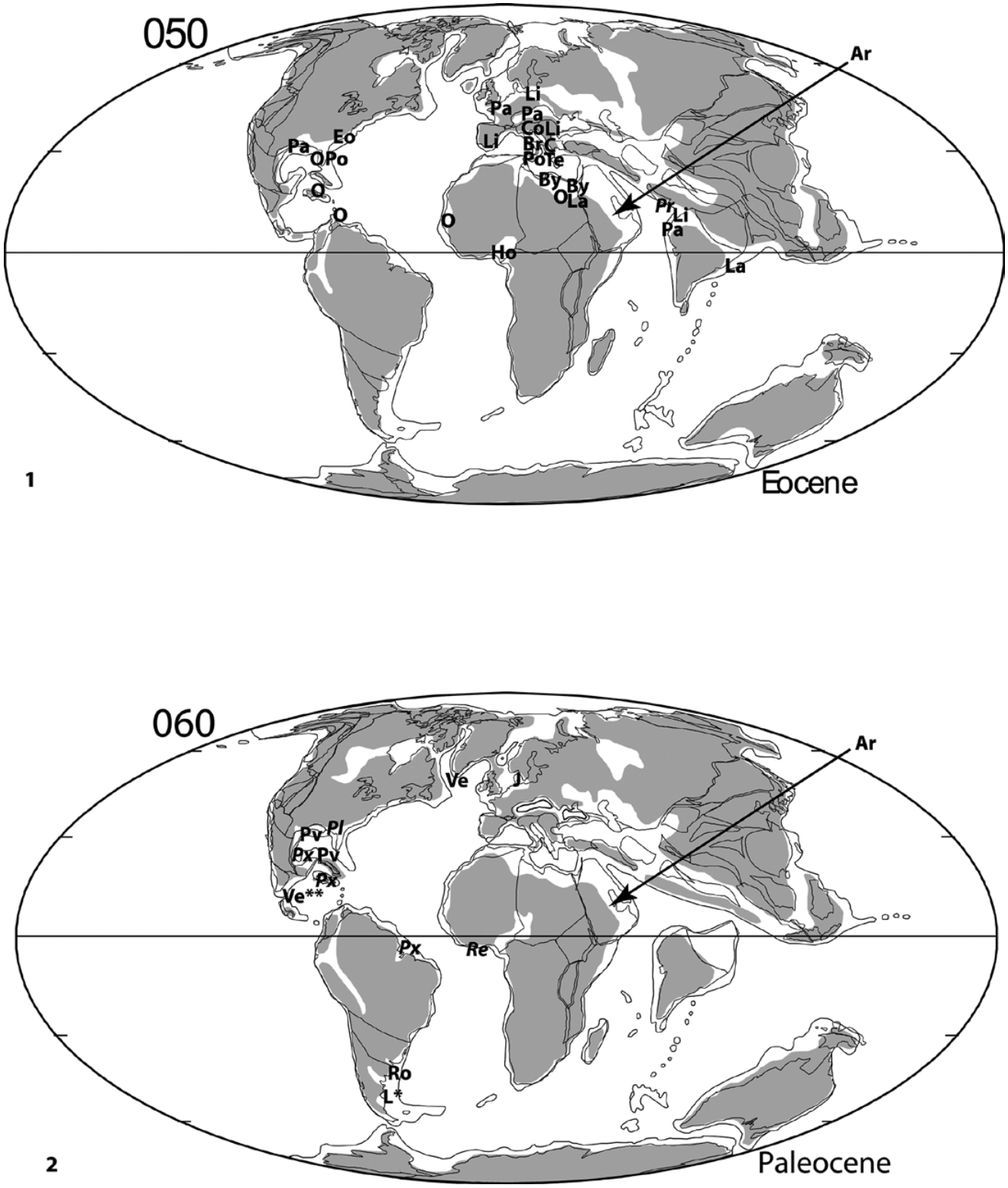

Fig. 4. Occurrences of Carpiliidae and Palaeoxanthopsidae. A. Eocene Carpiliidae: Br, *Braggiocarcinus*; By, *Bryocarpilius*; C, *Carpilius*; Co, *Corallicarpilius*; Eo, *Eocarpilius*; Ho, *Holcocarcinus*; La, *Laticarpilius*; Li, *Liopsalis*; Lo, *Lovaracarpilius*; O, *Ocalina*; Pa, *Palaeocarpilius*; Po, *Paraocalina*; Pr, *Proxicarpilius* (Paleocene); Te, *Tethyscarpilius*. B. Palaeoxanthopsidae: J, *Jakobsenius*; L, *Lobulata*; Pl, *Palaeoxantho*; Px, *Palaeoxanthopsis*; Pv, *Paraverrucoides*; Re, *Remia*; Ro, *Rocacarcinus*; Ve, *Verrucoides*. * =Maastrichtian – Danian; ** Eocene. Ar = *Arabicarcinus* occurrence for biogeographic reference. Base maps from Scotese (2006).

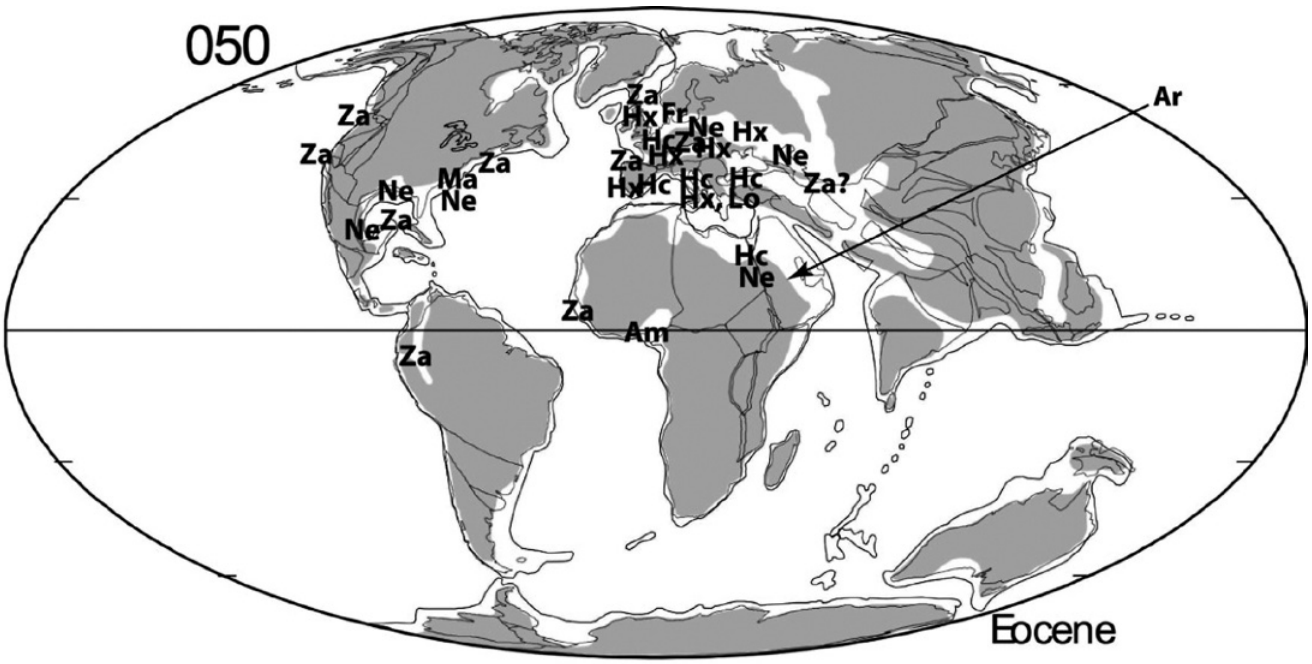

Fig. 5. Eocene occurrences of Zanthopsidae. Am, *Amekicarcinus*; Fr, *Fredericia*; Hc, *Harpactocarcinus*; Hx, *Harpactoxanthopsis*; Lo, *Lovaracarcinus*; Ma, *Martinetta*; Ne, *Neozanthopsis*; Za, *Zanthopsis*. Ar = *Arabicarcinus* occurrence for biogeographic reference. Base maps from Scotese (2006).

width, 11.1; maximum length, 45.0; length to position of maximum width, 15.2.

Occurrence: Collecting locality as discussed above.

Discussion

Biogeography: Referral of the new taxon to Carpilioidea does not extend the geologic range, as several members of Tumidocarcinidae and Palaeoxanthopsidae were already known from the Late Cretaceous (Figs. 3, 4.2). Tumidocarcinidae, Carpiliidae, and Zanthopsidae all display Tethyan distributions (Figs. 3–5); however, no members of Carpilioidea, nor in fact, any other Decapoda in the fossil record, are known from Saudi Arabia. Carpiliids have been well reported from Egypt, Libya, and western India (Fig. 4.1), and zanthopsids are also reported from Egypt (Fig. 5). All families except Palaeoxanthopsidae are well-represented in the Mediterranean; Palaeoxanthopsidae are Atlantic in distribution. Thus, it was perhaps simply a matter of finding specimens in the Arabian Peninsula as related taxa were already known from all around the area.

Diversity: We examined the diversity patterns of other members of Heterotremata with rather similar body plans and environmental preferences. This body plan includes a generally wider than long or as wide as long carapace; regional definition moderate to weak; weakly projecting front or rostrum; carapace flattened or vaulted in anterior one-third; and generally large, stout first pereiopods that are often heterochelous. We therefore included Portunoidea; Xanthoidea MacLeay, 1838; Eriphioidea MacLeay, 1838; Pilumnoidea Samouelle, 1819; Goneplacoidea; and Cancroidea Latreille, 1802. This grouping is based upon body plan similarity only; a molecular phylogeny of Brachyura indicates that Carpiliidae is sister to a clade composed of a quite different array of families (Tsang *et al*., 2014). All superfamilies with body plans similar to Carpilioidea inhabit a broad array of environments ranging from siliciclastic to carbonate and coral associated. Carpilioidea originated during the Late Cretaceous and was most diverse during the Eocene (Fig. 6). Eighteen carpilioid genera are now known to have coexisted during the Lutetian, and after the Priabonian, the number of genera within Carpilioidea continuously dwindled until the Holocene, when only one genus, *Carpilius*, is reported. This report adds another family to the superfamily during Cretaceous time. Among the other superfamilies, Portunoidea, Xanthoidea, and Goneplacoidea originated in the Early Cretaceous and were also quite diverse in the Eocene. However, they have remained diverse in the Holocene with Xanthoidea and Portunoidea being dominant superfamilies among Heterotremata. Comparison of Carpilioidea to phylogenetically derived related clades is part of an ongoing project.

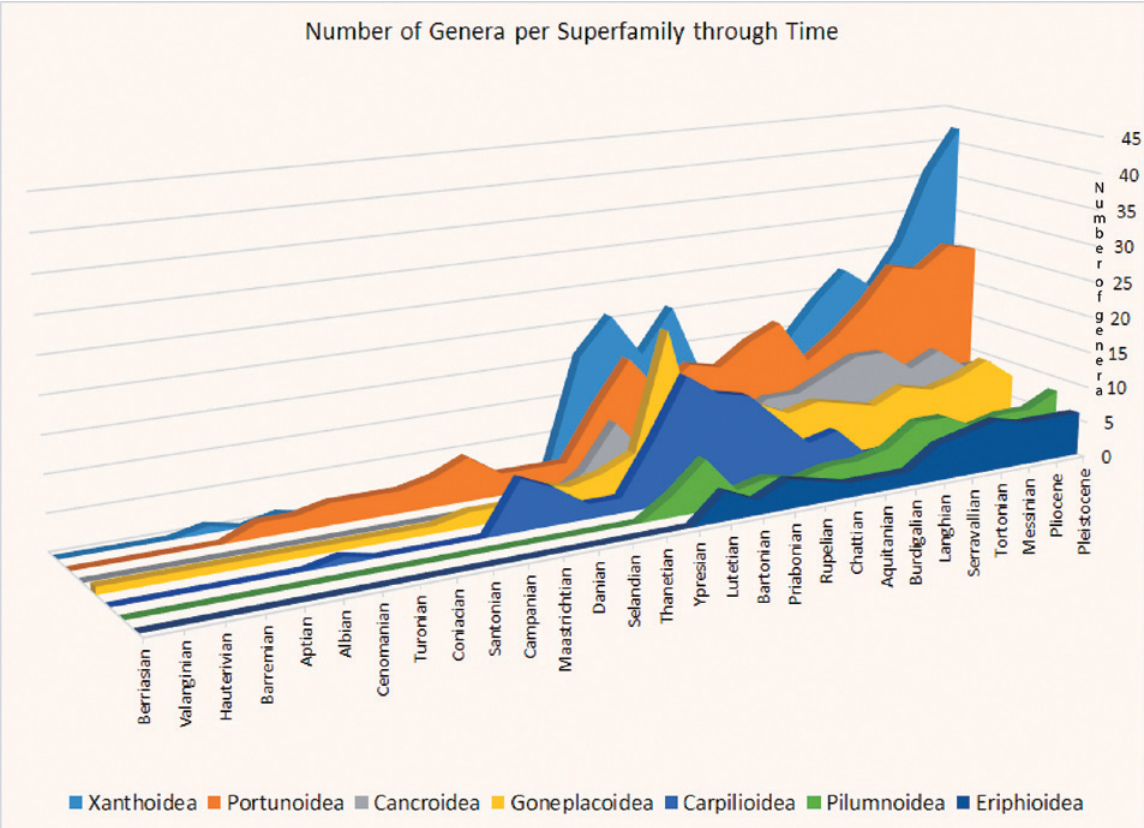

Fig. 6. Diversity of Carpilioidea and superfamilies of Brachyura with similar body plans from Cretaceous to Pleistocene. X-axis not to scale.

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