Swiss J Palaeontol (2013) 132:129–139
DOI 10.1007/s13358-013-0060-4

The fossil record of *Glypturus* (Decapoda: Axiidea: Callianassidae) revisited with additional observations and description of a new species

Matúš Hyžný · Ali Bahrami · Adiël A. Klompmaker · Mehdi Yazdi · Roger W. Portell · Christian Neumann

Received: 13 May 2013 / Accepted: 16 August 2013 / Published online: 22 September 2013

Abstract The extent of propodal tuberculation is considered taxonomically important for species of the callianassid genus *Glypturus* (Decapoda: Axiidea). Based on cheliped material from the Middle-Late Miocene of Iran, *Glypturus persicus* n. sp. is described here. It possesses no tuberculation on the outer surface of the major propodus, whereas its inner surface is moderately to heavily tuberculated in terms of its extent. It resembles extant *Glypturus armatus*, but this species is completely smooth on both propodal surfaces. A reappraisal of *Glypturus toulai* from the Early and Late Miocene of Panama is presented. Additionally, the type material of *Glypturus fraasi* from the Late Eocene of Egypt is figured. In the nature of tuberculation, an evolutionary trend is observable in *Glypturus* with the most tuberculated forms from the Palaeogene and less tuberculated forms from the Neogene. This trend is clearly seen in the possible West Atlantic lineage of the genus.

Keywords Decapoda · Axiidea · Callianassidae · *Glypturus* · Eocene · Miocene · New species

M. Hyžný (✉)
Department of Geology and Paleontology, Faculty of Natural Sciences, Comenius University, Mlynská dolina G1, SVK-842 15 Bratislava, Slovakia
e-mail: hyzny.matus@gmail.com

A. Bahrami · M. Yazdi
Department of Geology, Faculty of Science, University of Isfahan, PO Box 81746-73441, Isfahan, Islamic Republic of Iran
e-mail: Bahrami_geo@yahoo.com

M. Yazdi
e-mail: Meh.yazdi@gmail.com

A. A. Klompmaker · R. W. Portell
Florida Museum of Natural History, University of Florida, 1659 Museum Road, PO Box 117800, Gainesville, FL 32611, USA
e-mail: adielklompmaker@gmail.com

R. W. Portell
e-mail: portell@flmnh.ufl.edu

C. Neumann
Museum für Naturkunde, Leibniz-Institut für Evolutions- und Biodiversitätsforschung, Invalidenstrasse 43, 10115 Berlin, Germany
e-mail: christian.neumann@mfn-berlin.de

Introduction

Callianassid ghost shrimp remains are among the most commonly found decapod crustacean fossils, and, as Glaessner (1969: R435) noted, their “chelae are almost ubiquitous in Tertiary sediments”. Yet, our understanding of the fossil record of ghost shrimps is comparatively poor because most extinct taxa have not been re-examined with respect to modern classifications and much material remains to be discovered and described. Recently, in several contributions, fossil callianassid taxa attributable to the subfamilies Eucalliacinae Manning and Felder, 1991 (Hyžný 2012; Hyžný and Hudáčková 2012) and Callichirinae Manning and Felder, 1991 (Schweitzer and Feldmann 2002; Hyžný and Müller 2010, 2012; Hyžný and Karasawa 2012; Hyžný and Muñiz 2012) were revised and discussed in detail. Much of this work was stimulated by the pioneering work of Manning and Felder (1991).

The genus *Glypturus* Stimpson, 1866 (subfamily Callichirinae) was documented at length by Hyžný and Müller (2012). Since then, however, additional material has been collected from the Miocene of Iran allowing description of a new species. Moreover, because of a lack of material, *G. toulai* (Rathbun, 1919) was discussed only cursorily by Hyžný and Müller (2012). Recently, part of the original material of Toula (1911) was rediscovered at the Naturhistorisches Museum Vienna, Austria, which, together with additional comparative material from the Miocene of Panama, allows a reappraisal of *G. toulai*. Additionally, the type material of *G. fraasi* (Noetling, 1885) is figured. Thus, this work provides a more complete understanding of the fossil record of *Glypturus*.

Material

Details of all specimens studied are supplied under each taxon in the systematic palaeontology section.

Repositories. Geological Museum of the Department of Geology, University of Isfahan, Iran (EUIC); Museum für Naturkunde, Leibniz-Institut für Evolutions- und Biodiversitätforschung, Humboldt-Universität, Berlin, Germany (MB.A); Naturhistorisches Museum Wien, Austria (NHMW); Florida Museum of Natural History at the University of Florida, Gainesville, Florida, USA (UF).

Systematic palaeontology

Higher classification of decapods follows De Grave et al. (2009).

Order Decapoda Latreille, 1802
Infraorder Axiidea de Saint Laurent, 1979
Family Callianassidae Dana, 1852
Subfamily Callichirinae Manning and Felder, 1991
Genus *Glypturus* Stimpson, 1866

Type species. *Glypturus acanthochirus* Stimpson, 1866, by monotypy.

Included species. See Table 1.

Diagnosis. See Manning (1987: p. 390) and Manning and Felder (1991: p. 778).

Remarks. The propodal spination with usually three distinct spines positioned on the upper margin and directed distally immediately identifies specimens of the genus (Manning 1987; Manning and Felder 1991).

Hyžný and Müller (2012) provided a systematic revision of extant and fossil species of *Glypturus*. They based their revision on the morphology of the major cheliped, with emphasis on spination and tuberculation. They considered the extent of tuberculation on both lateral surfaces of the major propodus to be important in species assignment.

Recently, Beschin et al. (2012) re-assigned *Callianopsis microspineus* Beschin, De Angeli, Checchi and Zarantonello, 2005, to *Glypturus*. Hyžný and Schlögl (2011) already cast doubt on the generic assignment of *C. microspineus*. Generic re-assignment of this taxon to *Glypturus* looks similarly unwarranted. Beschin et al. (2005) based a new species on two fragmentary propodi. The authors mentioned the presence of one small spine distally on the upper propodal margin. However, Beschin et al. (2012) indicated the presence of two spines and noted that the dorsal margin is broken distally, which implies that a third spine could be present. Indeed, a line drawing in Beschin et al. (2012: fig. 13) showed a broken distalmost portion of the upper margin. However, in the original figure this portion appears complete in both the line drawing (Beschin et al. 2005: fig. 7) and the photograph of the holotype (Beschin et al. 2005: pl. 2, fig. 1). Moreover, even in the case of three propodal spines in *C. microspineus*, their position would be very strange for *Glypturus*. All members of the genus exhibit a proximalmost spine positioned approximately at the mid-length of the upper margin of the propodus, which is not the case in *C. microspineus*. Because of the fragmentary nature of the material and until new material is discovered, we refrain from referring *C. microspineus* to *Glypturus*.

Table 1 Synopsis of species of *Glypturus* known to date. *G.* sp. = *G. rabalaisae* sensu Sakai (2005, 2011); *nomen nudum*. For map of areal extent of Recent species see Hyžný and Müller (2012: fig. 11)

Taxon	Age	Occurrence
G. fraasi	Middle–Late Eocene	Egypt, Spain, Hungary, Italy, ?Namibia
G. spinosus	Late Eocene	Hungary
G. berryi	Oligocene	USA (Mississippi)
G. pugnax	Early Miocene	Java
G. munieri	Middle–Late Miocene	Hungary, Austria, Malta
G. persicus n. sp.	Middle–Late Miocene	Iran
G. toulai	Late Miocene	Panama
G. armatus (=*G. motupore*)	Pliocene–Recent	Vanuatu (fossil); Indian Ocean + West Pacific
G. acanthochirus	Late Pleistocene–Recent	Jamaica (fossil); Caribbean (Recent)
G. laurae	Recent	Red Sea
G. sp.	Recent	Gulf of Mexico

Glypturus fraasi (Noetling, 1885)

*1885 *Callianassa Fraasi* Noetling, p. 492, pl. 4, figs 4–6.
1929 *Calianassa* [sic] *pseudo-Fraasi* Lőrenthey *in* Lőrenthey and Beurlen, p. 55, pl. 1, fig. 12.
1969 *Calianassa fraasi* (Noetling); Vía Boada, p. 34, text-fig. 1; pl. 1, figs 1–8.
2012 *Glypturus fraasi* (Noetling); Hyžný and Müller, p. 976, figs 4F,7A–C.
2012 *Glypturus fraasi* (Noetling); Beschin, De Angeli, Checchi, and Zarantonello, p. 17, fig. 12, pl. 2, figs 1–3.

See Hyžný and Müller (2012) for full synonymy list.

Material. The type material of *Glypturus fraasi* consists of three fragmentary propodi deposited under numbers MB.A 1571–1573. Noetling (1885) did not designate a holotype; instead the type collection represents three syntypes. Specimen MB.A 1571 is designated herein as the lectotype; the two paralectotypes are MB.A 1572 and 1573. Noetling (1885), as shown in Fig. 1, accurately depicted the specimens, instead of figuring idealised reconstructions. Nevertheless, the paralectotype MB.A 1573 does not really fit the original figure (Noetling 1885: pl. 4, fig. 6; refigured herein as Fig. 1k–l). We assume that the specimen was damaged sometime after the publication of Noetling's report.

Occurrence. Middle Eocene of Spain (Vía Boada 1959, 1969), Late Eocene of Egypt (Noetling 1885) and Hungary (Lőrenthey 1897, 1898; Hyžný and Müller 2012) and, possibly, Eocene of Namibia (Böhm 1926).

Diagnosis. Strongly tuberculated *Glypturus*; lateral tuberculation on propodus confined to lower two-fifths of outer surface and nearly entire inner surface (after Hyžný and Müller 2012: 978).

Remarks. Hyžný and Müller (2012) revised the species. They also synonymised *Callianassa pseudofraasi* Lőrenthey *in* Lőrenthey and Beurlen, 1929, from the Eocene of Hungary to *C. fraasi*. Numerous specimens have been recovered from the Middle Eocene strata of Spain (Vía Boada 1969; see also Hyžný and Müller 2012 and references therein).

Interestingly, in paralectotype MB.A 1572 (Fig. 1e, g) the number of spines on the upper propodal margin exceeds three and in this respect it is reminiscent of a specimen of *G. acanthochirus* depicted by Hyžný and Müller (2012: fig. 2A–C). Similarly, *Eoglypturus* Beschin, De Angeli, Checchi and Zarantonello, 2005, from the Middle Eocene of Italy, possesses five spines (Beschin et al. 2005, 2012). In this respect, it is worth noting the presence of *G. fraasi* at the same locality as *E. grolensis* Beschin, De Angeli,

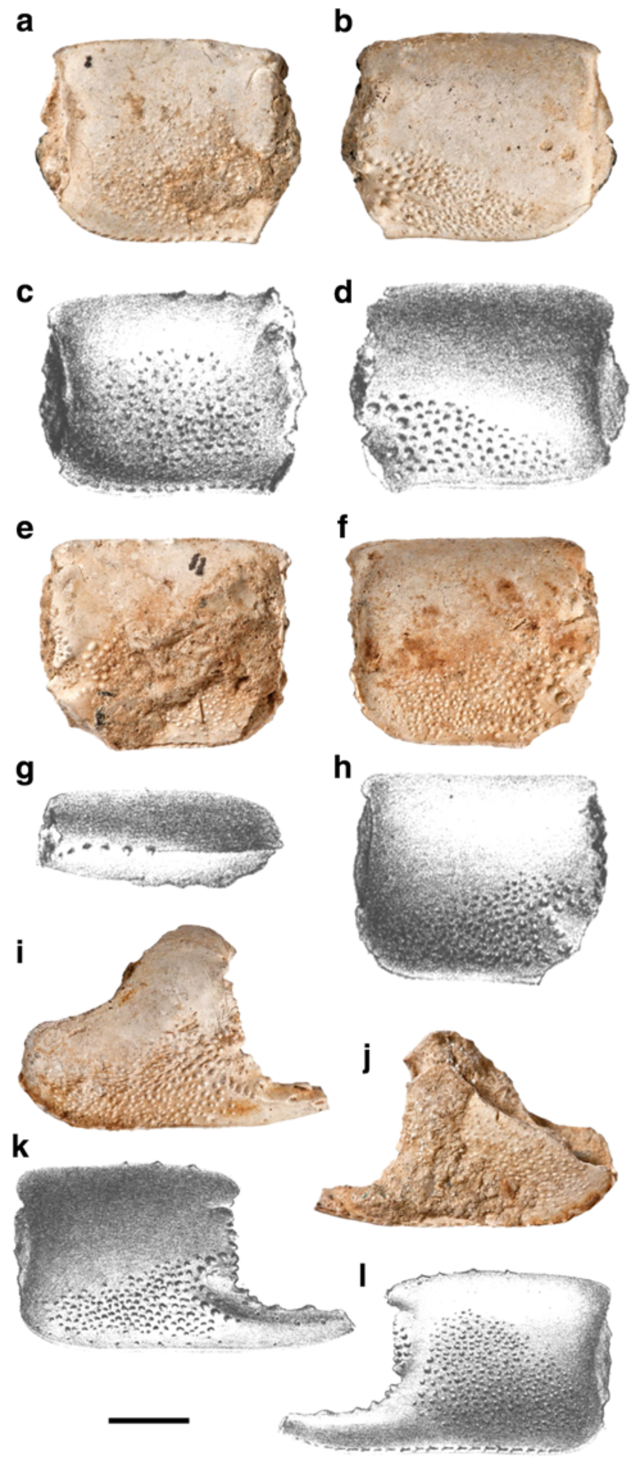

Fig. 1 *Glypturus fraasi* (Noetling, 1885) from the Late Eocene of Egypt. **a–d** major left propodus (lectotype MB.A 1571), inner lateral surface (**a**, **c**), outer lateral surface (**b**, **d**), **e–h** major right propodus (paralectotype MB.A 1572), inner surface (**e**), outer surface (**f**, **h**), upper view (**g**), **i–l** major right propodus (paralectotype MB.A 1573), inner surface (**j**, **l**), outer surface (**i**, **k**). *Scale bar* 5 mm

Checchi and Zarantonello, 2005. Taking into account the variability in the number of propodal spines as discussed by Hyžný and Müller (2012: p. 970), *Eoglypturus* may be found synonymous to *Glypturus* in the future when more complete material is recovered.

Glypturus persicus new species
Figures 3, 7

Material. Major left propodus (holotype EUIC 101825), major right propodus (paratype EUIC 101826), major left propodus (paratype EUIC 101827), major right dactylus (EUIC 101828). Numerous fragmentary chelae (propodi) deposited under collective numbers EUIC 101829–101831.

Occurrence. Middle-Upper Miocene of the Mishan Formation, Iran. The Mishan Formation consists of alternating marls and sandy limestones (James and Wynd 1965). Ghost shrimp remains originate from two sandy limestone horizons above the Guri Member (Kashfi 1982) in the upper part of the Mishan Formation exposed at the Konar-Takhteh and Ahram sections (Fig. 2). Both sections are situated in the folded zone of the oil field of the Zagros Basin, southwestern Iran. The Konar-Takhteh section is located approximately 45 km east from Konar-Takhteh city (co-ordinates 29.3317°N/51.2845°E); the Ahram section is located approximately 20 km east from Ahram city (co-ordinates 28.4739°N/51.2053°E). Details on the geology and sedimentology of the Mishan Formation were provided by Vega et al. (2010) and Heidari et al. (2012).

Diagnosis. Glypturus with lateral tuberculation on inner surface of propodus covering central portion of manus and also extending distally; outer surface of propodus smooth.

Etymology. The specific epithet refers to Persia, which is a former name for Iran, the country where the type material comes from.

Description. Manus as long as high, or slightly longer (length/height ratio $\sim$ 1.0–1.1); upper margin converging distally, proximally keeled, bearing three spines distally, keel terminating in blunt corner proximally; lower margin sharp with rows of setal pits on inner lateral surface; outer lateral surface completely smooth, unornamented; inner lateral surface covered with tubercles, the extent of tuberculation variable but usually covering the central portion of the manus and also extending distally. Fixed finger with distinct blunt tooth on occlusal margin (visible in Fig. 3b); tip of fixed finger not preserved. Dactylus stout; occlusal margin with large blunt tooth positioned proximally and smaller one distally.

Remarks. *Glypturus persicus* n. sp. possesses no tuberculation on the outer surface of the major propodus whereas its inner surface is moderately to heavily tuberculated in terms of its extent. Such combination is unknown in previously described *Glypturus* species. *Glypturus armatus* (Milne Edwards, 1870) is the only species without tuberculation on the outer surface of the major propodus, but its inner surface also lacks tuberculation. Thus, erecting a new species is warranted.

Glypturus toulai (Rathbun, 1919)
Figures 4, 5, 6, 7b

1911 "Krabbenscheren" Toula, p. 512 (26), pl. 30(1), fig. 14.
*1919 *Callianassa toulai* Rathbun, p. 146.
2005 *Glypturus toulai* (Rathbun); Todd and Collins, p. 63, pl. 1, fig. 1.
2009 *Glypturus toulai* (Rathbun); Collins et al., pp. 70–71.
2012 *Glypturus toulai* (Rathbun); Hyžný and Müller, p. 983, text-fig. 10A–D.

Type material. Toula (1911) described two chelae from the Late Miocene of Panama merely as "Krabbenscheren", illustrating one left major propodus and the dactylus. To accommodate this, Rathbun (1919) erected a new ghost shrimp species, *Callianassa toulai*, but did not select a type specimen. Later, Todd and Collins (2005), without re-examination of the actual specimen, designated the chela illustrated by Toula (1911, pl. 30(1), fig. 14) as a lectotype. The lectotype is, however, missing among the rediscovered Toula material. For the time being, it is considered lost. Rediscovered Toula material as presented herein (Fig. 4) is considered to represent paralectotypes and consists of one complete right major propodus (Fig. 4a–c) and three fragmentary fixed fingers (Fig. 4d–f), bearing the collective number NHMW 1933/0018/0160.

Additional material. One propodus and accompanying dactylus found at Sabanitas behind Las Lomas Suites, lower Gatun Formation, Colon Province, Panama (co-ordinates 9.35711°N/-79.8387°W, UF 203348) (Fig. 5); 13 propodi found at Lyrio Norte West 01, Paraiso area, Culebra Formation, Panama Province, Panama, co-ordinates 9.05814°N/-79.66479°W, UF 233762–233767 (Fig. 6a–d, i); and 3 specimens from Lirio East 01, Paraiso area, Culebra Formation, Panama Province, Panama, co-ordinates 9.0509°N/-79.6506°W, UF 233792–233794 (Fig. 6e–h, j–k).

Occurrence. Lower Miocene, Culebra Formation, Panama (herein); Upper Miocene, Gatun Formation, Panama (see Todd and Collins 2005; herein).

Emended diagnosis. Moderately tuberculated *Glypturus*; lateral tuberculation on outer surface of propodus extending from near base of fixed finger diagonally to lower margin and reaching proximal lower corner; lateral

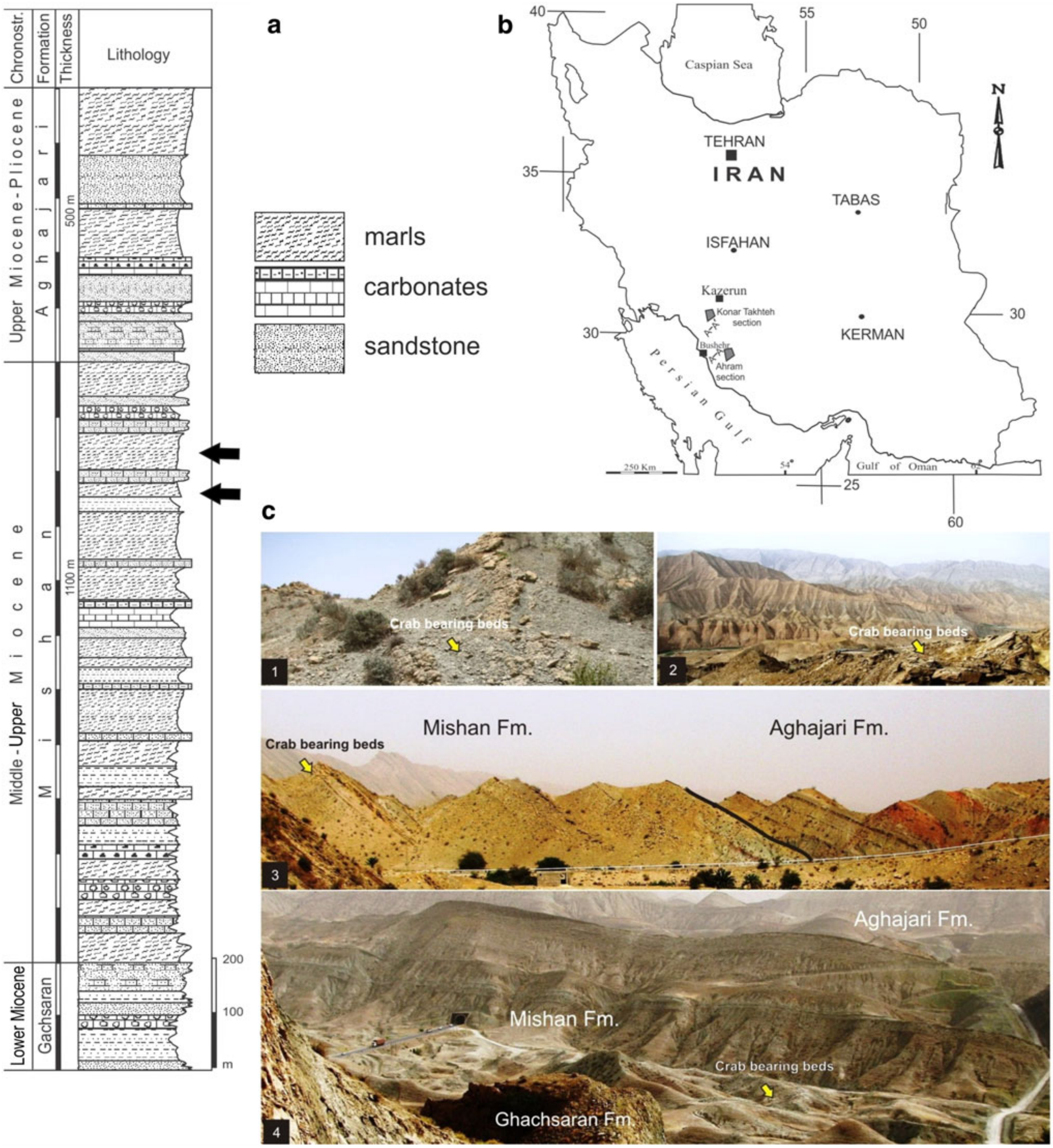

Fig. 2 Stratigraphy and locality of Miocene strata in Iran in which *Glypturus persicus* n. sp. was found. **a** Lithostratigraphic scheme of the Mishan Formation at the Konar-Takhteh section. Arrows indicate crab bearing beds with remains of *Glypturus persicus* n. sp.; **b** Generalised map of Iran with locations of the Konar-Takhteh and the Ahram sections; **c**: photographic documentation; (*1*) intercalated limestone horizons in green marls of the Mishan Formation at the Konar-Takhteh section; (*2*) panoramic view at the exposed parts of the Mishan and Aghajari formations at the Konar-Takhteh section; (*3*) panoramic view of the Ahram section; (*4*) a different view of the Konar-Takhteh section with indication of crab bearing beds. Photos by Mehdi Yazdi

tuberculation on inner surface of the propodus restricted mainly to area of articulation with dactylus in small specimens, but covering large lower part of manus in large specimens with lower margin of tuberculated area diagonally crossing from area of articulation of dactylus toward proximal lower corner.

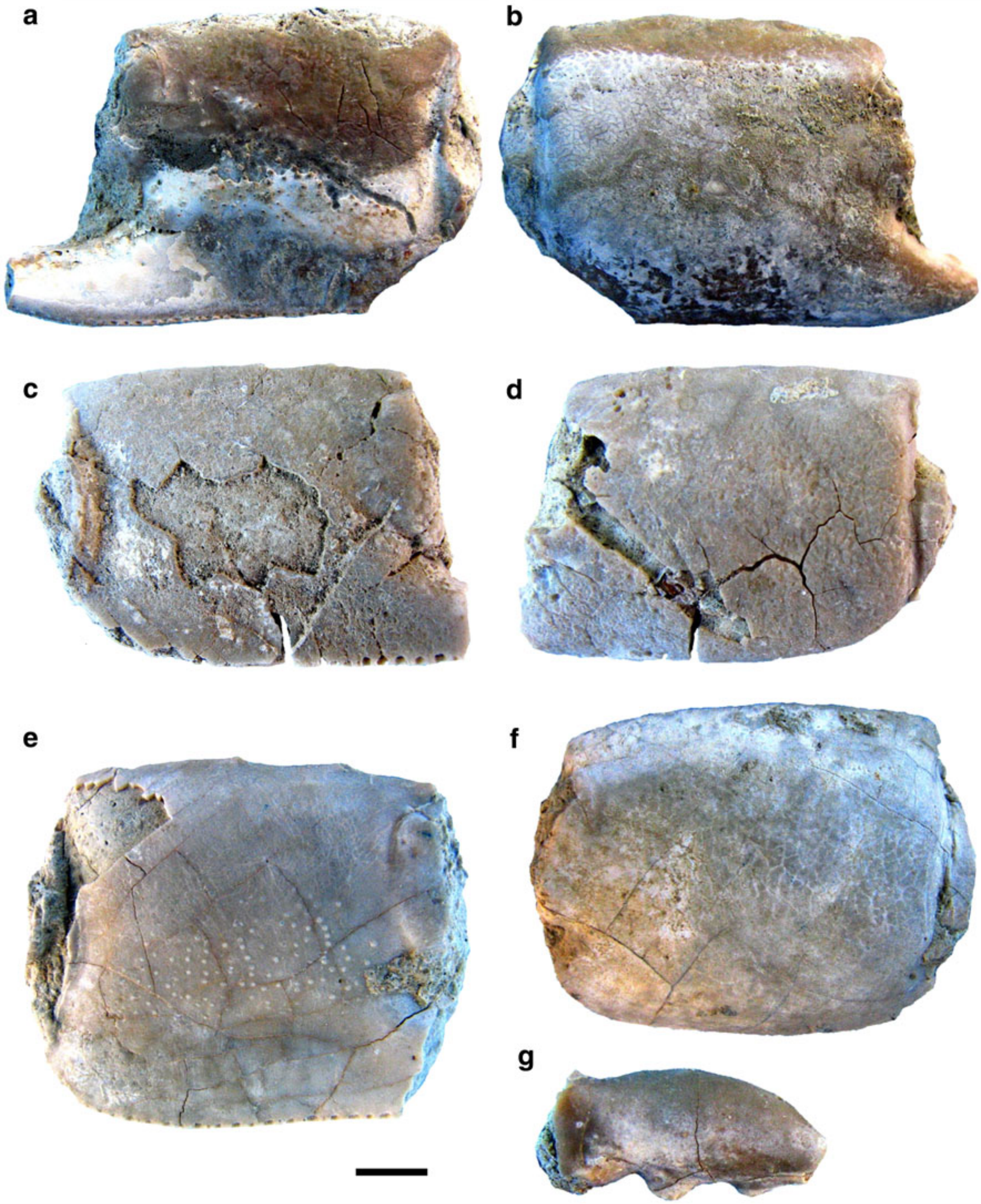

Fig. 3 *Glypturus persicus* n. sp. from the Middle-Late Miocene of Iran. Major right propodus (paratype EUIC 101826), inner lateral surface (**a**), outer lateral surface (**b**). Major left propodus (paratype EUIC 101827), inner surface (**c**), outer surface (**d**). Major left propodus (holotype EUIC 101825), inner surface (**e**), outer surface (**f**), major right dactylus (paratype EUIC 101828) (**g**). *Scale bar* 5 mm

Emended description. Manus length exceeding height (length/height ratio $\sim$ 1.1–1.2); upper margin converging distally, proximally keeled, bearing three prominent spines pointing distally, proximalmost spine around mid-margin, keel terminating in blunt corner; lower margin sharp and keeled, in larger specimens denticulate, lined with a row of setal pits on inner lateral surface; proximal margin convex on outer face, concave on inner; distal margin weakly convex; lateral tuberculation on outer surface from base of fixed finger diagonally to lower margin and proximal lower corner; lateral tuberculation on inner surface of propodus restricted mainly to area of

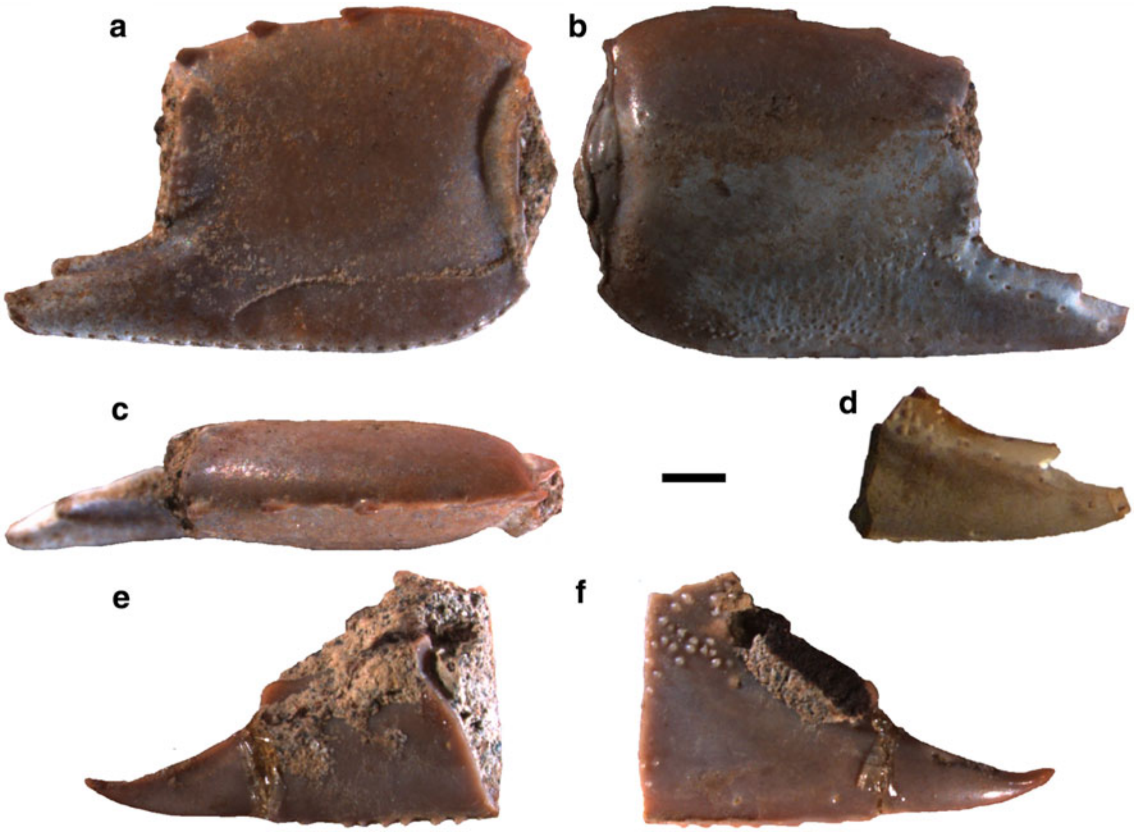

Fig. 4 *Glypturus toulai* (Rathbun, 1919) from the Upper Miocene Gatun Formation of Panama (paralectotypes). Major right propodus, inner lateral surface (**a**), outer lateral surface (**b**), view from above (**c**); broken major right fixed finger (**d**); broken major right fixed finger, inner lateral surface (**e**), outer lateral surface (**f**). All specimens are deposited under collective number NHMW 1933/0018/0160. *Scale bar* 1 mm

articulation with dactylus in small specimens, but covering large lower part of manus in larger specimens with lower margin of tuberculated area diagonally crossing from area of articulation of dactylus toward (but not reaching) proximal lower corner; fixed finger triangular, sharply pointed, with distinct blunt tooth on occlusal margin around mid-length, tooth pointing distally. Dactylus stout, occlusal margin without evident tooth, tip hooked.

Remarks. Toula (1911) noted possible affinities with the brachyuran family Trapeziidae Miers, 1886. The affinities of the material with Callianassidae were recognised by Rathbun (1919). On the basis of the presence of three spines on the upper margin of the propodus, Todd and Collins (2005) transferred the species to *Glypturus*. They argued that *Glypturus toulai* exhibited close similarities to extant *G. acanthochirus* and pointed out that *G. toulai* might be found to be synonymous to the former in the

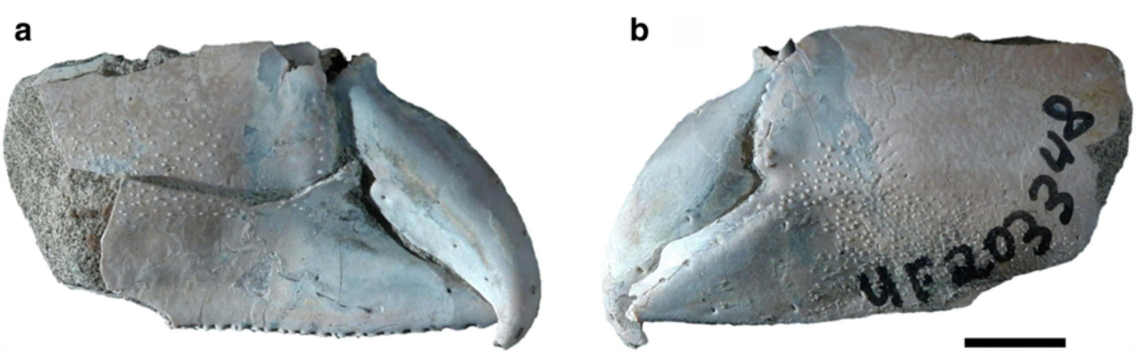

Fig. 5 *Glypturus toulai* (Rathbun, 1919) from the Upper Miocene Gatun Formation of Panama. Major left propodus (UF 203348), inner lateral surface (**a**), outer lateral surface (**b**). *Scale bar* 5 mm

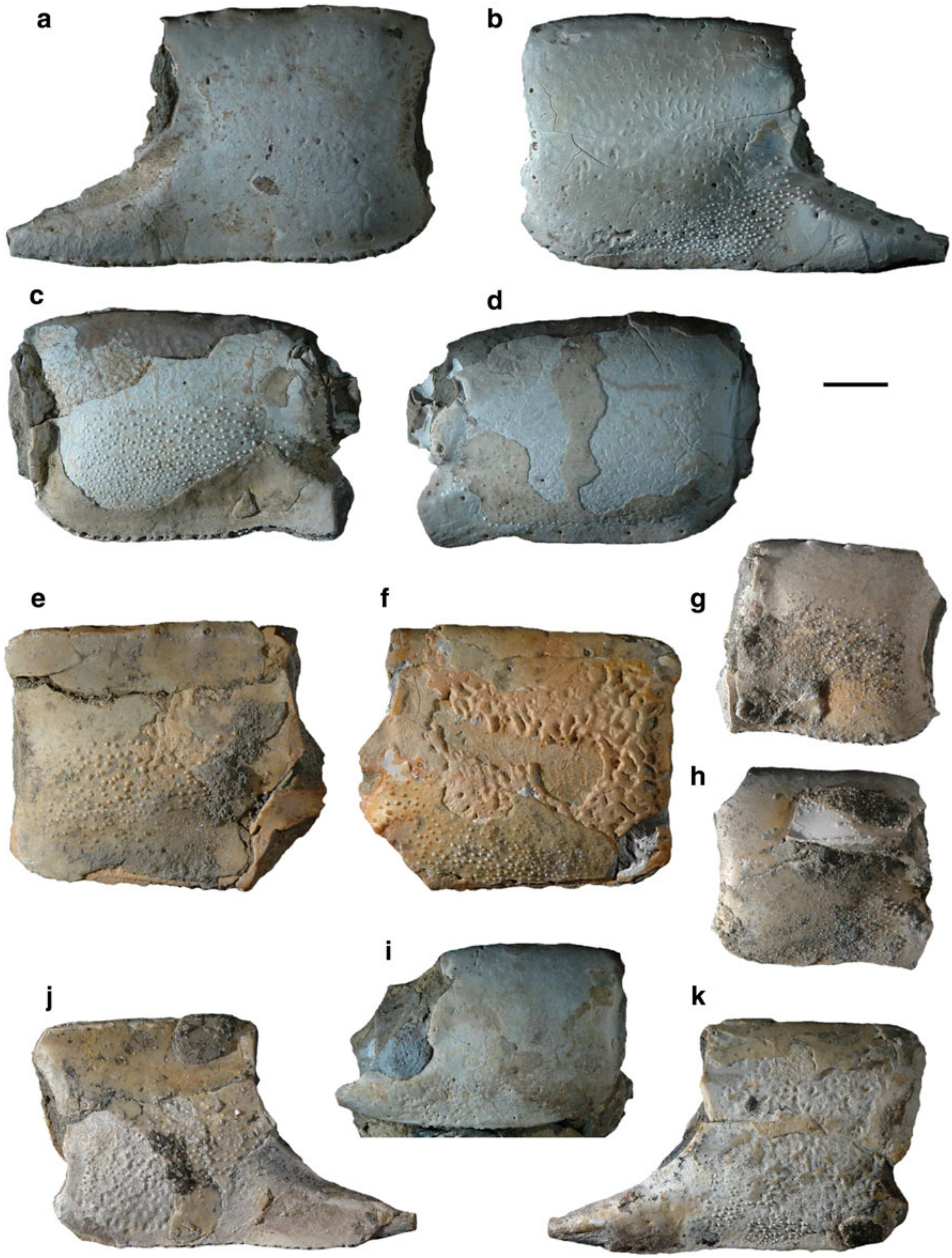

Fig. 6 *Glypturus toulai* (Rathbun, 1919) from the Lower Miocene Culebra Formation of Panama. Major right propodus (UF 233767), inner lateral surface (**a**), outer lateral surface (**b**). Major left propodus (UF 233764), inner surface (**c**), outer surface (**d**). Major left propodus (UF 233793), inner surface (**e**), outer surface (**f**). Major right propodus (UF 233794), inner surface (**g**), outer surface (**h**). Major left propodus (UF 233765). Major left propodus (UF 233792) (**i**), inner surface (**j**), outer surface (**k**). *Scale bar* 5 mm

future. The tuberculation on the outer surface of the propodus, considered of taxonomic importance (Biffar 1971; Manning 1987; Hyžný and Müller 2012), is not seen in the figure supplied by Toula (1911: pl. 15, fig. 14), but he described pustules on the lower side, apparently referring to tubercles. An illustration in Todd and Collins (2005:

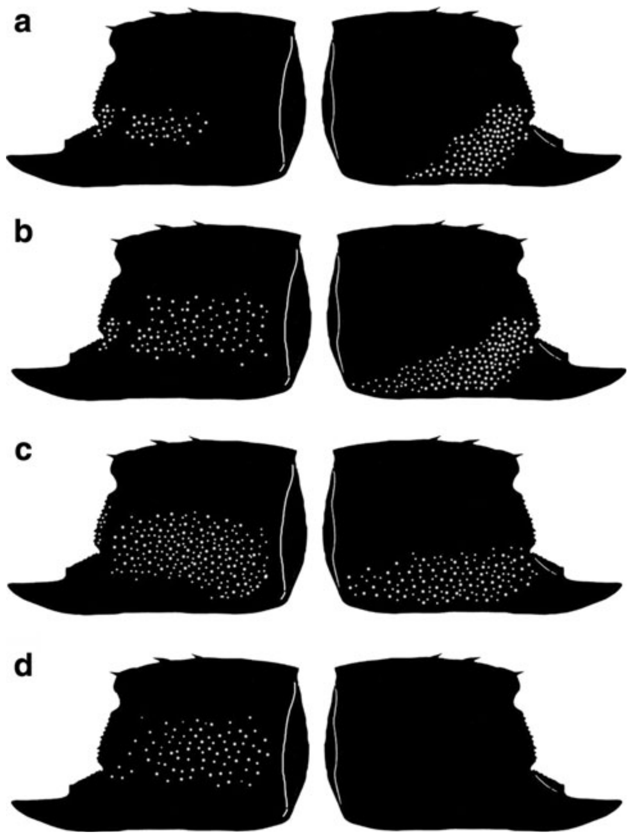

Fig. 7 Scheme of tuberculation on the major propodus of selected *Glypturus* species plotted on a standardised outline. Western Atlantic region – *G. acanthochirus* Stimpson, 1866, Pleistocene–Holocene (**a**); *G. toulai* (Rathbun, 1919), Miocene (**b**); *G. berryi* (Rathbun, 1935), Oligocene (**c**); **d** *Glypturus persicus* n. sp., Miocene of Iran. *Left column* inner lateral surface, *right column* outer lateral surface

pl. 1, fig. 1) is more informative, but lacks the lower proximalmost margin. The original material of Toula (1911), recently retraced, enables a comparison with that of Todd and Collins (2005). The nature of the outer surface tuberculation is similar in both specimens. The additional specimen from the Upper Miocene Gatun Formation of Panama and the new material from Lower Miocene Culebra Formation of Panama provide new insight for larger specimens and confirm the extent of tuberculation on the outer lateral side.

The extent of the major propodal tuberculation on the outer lateral surface is close to that of *G. berryi* (Rathbun, 1935) (Oligocene, Mississippi, USA) and *G. fraasi* (Noetling, 1885) (Eocene, Europe), but the extent of the tubercles appears more pronounced at the proximalmost part in the latter two. Interestingly, the extent of tuberculation on the outer lateral surface in *G. toulai* seems to be intermediate (Fig. 7b) between *G. berryi* (Fig. 7c) and *G. acanthochirus* (Fig. 7a) from the Late Pleistocene of Jamaica (Collins et al. 1996, 2009) and the Holocene of the Gulf of Mexico and the Caribbean (Sakai 2011), suggesting it may represent a single lineage. Future research will investigate this further.

Discussion

The presence of propodal spination is critical in assigning fossil material to *Glypturus*. Although taxonomically important characters on the genus level are present also on the major carpus and merus (Hyžný and Müller 2012), these cheliped elements are generally rarely found in the fossil record. On the other hand, isolated propodi are the most common fossil remains of ghost shrimps in general. The extent of tuberculation on propodi has been considered taxonomically important on the species level for *Glypturus* (Hyžný and Müller 2012). In this respect, it is important to note that the preservation of material may prevent the identification of the fossil material to respective species. Taphonomic processes may obliterate the tuberculation patterns, especially in smaller specimens where the tubercles are not as strongly developed as in larger individuals.

An evolutionary trend is observable in *Glypturus* with the most tuberculated forms dating from the Eocene (*G. fraasi*) and Oligocene (*G. berryi*) and less tuberculated forms today (e.g., *G. armatus* and *G. laurae* (de Saint Laurent *in* de Vaugelas and de Saint Laurent, 1984)). This trend is clearly seen in the possible West Atlantic lineage *G. berryi*–*G. toulai*–*G. acanthochirus*. Similarly, in the Tethyan region, the stratigraphically older *G. fraasi* is distinctly more tuberculated than the younger *G. munieri* (Brocchi, 1883) from the Miocene (Hyžný and Müller 2012). In the Indo-West Pacific region the situation is less clear as the data on *G. pugnax* (Böhm, 1922) from the Early Miocene of Indonesia are limited (Hyžný and Müller 2012 erroneously stated its age as Late Miocene). Böhm (1922) mentioned the presence of a tuberculated area on both propodal surfaces; nevertheless its extent is difficult to determine from the figures only (Böhm 1922: pl. 63, figs 22, 24, 25). *Glypturus armatus* is completely smooth and *Glypturus persicus* n. sp. from the Middle-Late Miocene of Iran is tuberculated on the inner propodal surface only.

Acknowledgments The authors are grateful to the anonymous reviewer and editor for useful comments and thank Peter C. Dworschak, Mathias Harzhauser, Oleg Mandic and Andreas Kroh (all Naturhistorisches Museum Wien, Vienna, Austria) for access to collections of extant (PCD) and fossil (MH, OM, AK) ghost shrimps. John W.M. Jagt (Natuurhistorisch Museum Maastricht, Maastricht, The Netherlands) kindly improved the English of an earlier draft of the manuscript. This work has been supported by Austrian Science Fund (FWF): Lise Meitner Program M 1544, APVV-0640-10 and APVV-0436-12 to M. H., the Jon L. and Beverly A. Thompson Endowment Fund to A.A.K., and National Science Foundation grant 0966884 (Partnerships for International Research and Education). This is University of Florida Contribution to Paleobiology 658.

References

Beschin, C., De Angeli, A., Checchi, A., & Zarantonello, G. (2005). Crostacei eocenici di Grola Presso Spagnago (Vicenza, Italia settentrionale). *Studi e Ricerche, Associazione Amici del Museo, Museo Civico 'G. Zannato', Montecchio Maggiore (Vicenza), 12*, 5–35.

Beschin, C., De Angeli, A., Checchi, A., & Zarantonello, G. (2012). Crostacei del giacimento eocenico di Grola Presson Spagnago di cornedo vicentino (Vicenza, Italia settentrionale) (Decapoda, Stomatopoda, Isopoda). *Museo di Archeologia e Scienze Naturali 'G. Zannato', Montecchio Maggiore (Vicenza)*, 104 pp.

Biffar, T. A. (1971). The genus *Callianassa* (Crustacea, Decapoda, Thalassinidea) in South Florida, with keys to the western Atlantic species. *Bulletin of Marine Science, 21*, 637–715.

Böhm, J. (1922). Crustacea. In K. Martin (Ed.), Die Fossilien aus Java. *Sammlung Geologischen Reichsmuseum Leiden Neue Folge*, (vol. 1/2, pp. 521–538).

Böhm, J. (1926). Über tertiäre Versteinerungen von den Bogenfelser Diamantfeldern. In E. Kayser (Ed.), *Die Diamantenwüste Südafrikas* (vol. 2, pp. 55–87, pl. 31–34).

Brocchi, P. (1883). Notes sur les Crustacés fossiles des terres tertiaires de la Hongrie. *Annales des Sciences Géologiques, 14*, 1–8.

Collins, J. S. H., Donovan, S. K., & Dixon, H. L. (1996). Crabs and barnacles (Crustacea: Decapoda & Cirripedia) from the late Pleistocene Port Morant Formation of southeast Jamaica. *Bulletin of the Mizunami Fossil Museum, 23*, 51–63.

Collins, J. S. H., Portell, R. W., & Donovan, S. K. (2009). Decapod crustaceans from the Neogene of the Caribbean: diversity, distribution and prospectus. *Scripta Geologica, 138*, 55–111.

Dana, J.D. (1852). Crustacea. Part I. United States Exploring Expedition, during the years 1838, 1839, 1840, 1841, 1842, under the command of Charles Wilkes, U.S.N.13, (viii + 685 pp.) Philadelphia: C. Sherman.

De Grave, S., Pentcheff, D.N., Ahyong, S.T., Chan, T.-Y., Crandall, K.A., Dworschak, P.C., Felder, D.L., Feldmann, R.M., Fransen, C.H.J.M., Goulding, L.Y.D., Lemaitre, R., Low, M.E.Y., Martin, J.W., Ng, P.K.L., Schweitzer, C.E., Tan, S.H., Tshudy, D., & Wetzer, R. (2009). A classification of living and fossil genera of decapod crustaceans. *The Raffles Bulletin of Zoology, Supplement, 21*, 1–109.

de Saint Laurent, M. (1979). Sur la classification et la phylogénie des Thalassinides: définitions de la superfamille des Axioidea, de la sous-famille des Thomassiniinae et de deux genres nouveaux (Crustacea Decapoda). *Comptes Rendus de l'Académie des Sciences, Paris, série D, 288*, 1395–1397.

de Vaugelas, J., & de Saint Laurent, M. (1984). Premières données sur l'écologie de *Callichirus laurae* de Saint Laurent sp. nov. (Crustacé décapode Callianassidae): son action bioturbatrice sur les formations sédimentaires du golfe d'Aqaba (Mer Rouge). *Comptes Rendus des Séances de l'Académie des Sciences, Paris, Série 3, Sciences de la Vie, 298(6)*, 147–152.

Glaessner, M.F. (1969). Decapoda. In R.C. Moore (Ed.), *Treatise on invertebrate paleontology, Part R. Arthropoda 4 (2)* (R399–R533). Boulder: Geological Society of America.

Heidari, A., Feldmann, R. M., & Moussavi-Harami, R. (2012). Miocene decapods crustacean from the Guri Member of the Mishan Formation, Bandar-Abbas, Southern Iran. *Bulletin of the Mizunami Fossil Museum, 38*, 1–7.

Hyžný, M. (2012). *Calliaxina chalmasii* (Brocchi, 1883) comb. nov. (Decapoda: Axiidea: Callianassidae: Eucalliacinae), a ghost shrimp from the Middle Miocene of Europe, with reappraisal of the fossil record of Eucalliacinae. *Zootaxa, 3492*, 49–64.

Hyžný, M., & Hudáčková, N. (2012). Redescription of two ghost shrimps (Decapoda: Axiidea: Callianassidae) from the Middle Miocene of the Central Paratethys: systematics, intraspecific variation, and in situ preservation. *Zootaxa, 3210*, 1–25.

Hyžný, M., & Karasawa, H. (2012). How to distinguish *Neocallichirus*, *Sergio*, *Podocallichirus* and *Grynaminna* (Decapoda: Callianassidae: Callichirinae) from each other in the fossil record? *Bulletin of the Mizunami Fossil Museum, 38*, 55–64.

Hyžný, M., & Müller, P. M. (2010). The first fossil record of the genus *Callichirus* (Decapoda, Axiidea, Callianassidae) from the middle Miocene of Hungary, with description of a new species. *Bulletin of the Mizunami Fossil Museum, 36*, 37–43.

Hyžný, M., & Müller, P. M. (2012). The fossil record of *Glypturus* Stimpson, 1866 (Crustacea, Decapoda, Axiidea, Callianassidae) revisited, with notes on palaeoecology and palaeobiogeography. *Palaeontology, 55*, 967–993.

Hyžný, M., & Muñiz, F. (2012). *Podocallichirus laepaensis*, a new ghost shrimp (Crustacea, Decapoda, Callianassidae) from the Late Miocene of Southwest Spain. *Journal of Paleontology, 86*, 616–625.

Hyžný, M., & Schlögl, J. (2011). An Early Miocene deep-water decapod crustacean faunule from the Vienna Basin (Western Carpathians, Slovakia). *Palaeontology, 54*, 323–349.

James, G. A., & Wynd, J. G. (1965). Stratigraphic nomenclature of Iranian Oil Consortium Agreement Area. *American Association of Petroleum Geologists Bulletin, 49*, 2182–2245.

Kashfi, M. S. (1982). Guri Limestone, a new hydrocarbon reservoir in south Iran. *Journal of Petroleum Geology, 5*, 161–171.

Latreille, P.A. (1802). *Histoire naturelle, générale et particulière des crustacés et des insectes*. Tome 3. Dufart, Paris, 467 pp.

Lőrenthey, E. (1897). Adatok Magyarország harmadkorú rák-faunájához. *Mathematikai és Természettodományi Értesito, 15*, 149–169.

Lőrenthey, E. (1898). Beiträge zur Decapodenfauna der ungarischen Tertiärs. *Természetrajzi Füzetek, 21*, 1–133.

Lőrenthey, E., & Beurlen, K. (1929). Die fossilen Dekapoden der Länder der Ungarischen Krone. *Geologica Hungarica, Series Palaeontologica, 3*, 1–421.

Manning, R. B. (1987). Notes on western Atlantic Callianassidae (Crustacea: Decapoda: Thalassinidea). *Proceedings of the Biological Society of Washington, 100*, 386–401.

Manning, R. B., & Felder, D. L. (1991). Revision of the American Callianassidae (Crustacea: Decapoda: Thalassinidea). *Proceedings of the Biological Society of Washington, 104*, 764–792.

Miers, E.J. (1886). Report on the Brachyura collected by H.M.S. Challenger during the years 1873–1876. In J. Murray, (Ed.) *Zoology. Report on the Scientific Results of the Voyage of H.M.S. Challenger During the Years 1873–76 Under the Command of Captain George S. Nares, R.N., F.R.S. and the Late Captain Frank Tourle Thomson, R.N. Wyville Thomson, C. and J. Murray* (series eds.). (vol. 17, pp. 1–362, Plates 1–29). Edinburgh: Neill and Company.

Milne, Edwards A. (1870). Révision du genre *Callianassa* (Leach) et description de plusieurs espèces nouvelles de ce groupe fausant partie de la collection du muséum. *Nouvelle Archives du Muséum d'Histoire Naturelle, Paris, 6*, 75–101.

Noetling, F. (1885). Über Crustaceen aus dem Tertiär Ägyptens. *Sitzungsberichte der Königlich Preussischen Akademie der Wissenschaften zu Berlin, 26*, 487–500.

Rathbun, M.J. (1919). West Indian Tertiary decapod crustaceans. In T.W. Vaughan, (Ed.), Contributions to the geology and paleontology of the West Indies, (vol. 291, pp. 159–184) Washington: Carnegie Institution of Washington Publication.

Rathbun, M.J. (1935). Fossil Crustacea of the Atlantic and Gulf Coastal Plain. *Geological Society of America Special Papers*, *2*, viii + 1–160.

Sakai, K. (2005). Callianassoidea of the world (Decapoda: Thalassinidea). *Crustaceana Monographs, 4*, 1–286.

Sakai, K. (2011). Axioidea of the world and a reconsideration of the Callianassoidea (Decapoda, Thalassinidea, Callianassida). *Crustaceana Monographs, 13*, 1–520.

Schweitzer, C. E., & Feldmann, R. M. (2002). New Eocene decapods (Thalassinidea and Brachyura) from southern California. *Journal of Crustacean Biology, 22*, 938–967.

Stimpson, W. (1866). Descriptions of new genera and species of Macrurous Crustacea from the coasts of North America. *Proceedings of the Chicago Academy of Sciences, 1*, 46–48.

Todd, A. J., & Collins, J. S. H. (2005). Neogene and Quaternary crabs (Crustacea, Decapoda) collected from Costa Rica and Panama by members of the Panama Paleontology Project. *Bulletin of the Mizunami Fossil Museum, 32*, 53–85.

Toula, F. (1911). Die jungtertiäre Fauna von Gatun am Panamakanal. *Jahrbuch der kaiserlich-königlichen Geologischen Reichanstalt Wien, 61*, 487–530.

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

Vía Boada, L. (1959). Decápodos fósiles del Eoceno español. *Boletín del Instituto Geológico y Minero de España, 70*, 331–402.

Vía Boada, L. (1969). Crustacéos Decápodos del Eoceno español. *Pirineos, 91–94*, 1–479.