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Occurrence of *Retrocypoda almelai* Via Boada, 1959 (Decapoda: Retroplumidae) in the Eocene of Central Iran

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Abstract

The decapod crustacean *Retrocypoda almelai* Via Boada, 1959 is reported from Bartonian (middle Eocene) strata of Soh (North of Isfahan, Iran) and represents the most oriental record for the species, hitherto considered endemic and restricted to the western margin of Tethys. This finding is important to understand the paleobiogeographic distribution of retroplumid crabs, which were abundant during Late Cretaceous in America and Africa, but today their representatives are restricted to the Indopacific region.

Keywords: Crustacea, Decapoda, Retroplumidae, Eocene, Isfahan, central Iran.

Resumen

El crustáceo decápodo Retrocypoda almelai Via Boada, 1959 es reportado en estratos del Bartoniano (Eoceno medio) de la región de Soh (Norte de Isfahán, Irán), y representa el registro más oriental de la especie, considerada previamente como endémica y restringida al margen occidental del Tethys. Este hallazgo es importante para comprender la distribución paleobiogeográfica de los cangrejos retroplúmidos, que fueron abundantes durante el Cretácico Tardío en América y Africa, pero actualmente sus representantes están restringidos a la región Indopacífica.

Palabras clave: Crustacea, Decapoda, Retroplumidae, Eoceno, Isfahan, central Irán.

1. Introduction

The discovery of one specimen of *Retrocypoda almelai* Via Boada, 1959 on Bartonian (middle Eocene) strata of Soh (North of Isfahan, Iran) (Fig. 4.1), represents the most oriental record for the species, hitherto considered endemic and restricted to the western margin of Tethys. The genus *Retrocypoda* was erected by Via Boada (1959) to accommodate the sole species *R. almelai* Via Boada, 1959, based upon samples recovered in the Bartonian (middle Eocene) outcrops of Central Catalonia (NE Iberian Peninsula), but he also reported and figured the presence of *R. almelai* in Lutetian (middle Eocene) outcrops of other localities of Central Catalonia (see also Via, 1969, p. 330–331). Beschin *et al*. (1996, 2012) reported the presence of specimens of *R. almelai* in the Lutetian outcrops of the Vicenza area (northern Italy). In addition, *R. almelai* is also recorded in the Lutetian outcrops of Alicante Province (south-eastern Spain) (AO pers. obs.), and also in the Priabonian (middle Eocene) outcrops of the Central Pyrenees in Huesca Province (northern Spain), where the species migrated westward during the Bartonian transgression (Ossó *et al*., 2014). Likewise, the genus is recorded lately also in Ilerdian (early Ypresian) outcrops of Aude (south-eastern France) (AO pers. obs.). Therefore, we can observe that until now the genus *Retrocypoda* seemed

confined to the Mediterranean margin of the western Tethys during the early to late Eocene. The new Iranian specimen demonstrates that *Retrocypoda* also inhabited the oriental part of the Tethys during Eocene times.

The systematic position of *Retrocypoda almelai* has been the object of different placements and proposals of phylogenies through time. Originally, it was placed by Via (1969, 1988) and Via Boada (1959, 1980, 1982) as Retroplumidae Gill, 1894, within Ocypodoidea Rafinesque, 1815 with possible relationship with the Macrophthalminae Dana, 1851. Glaessner (1969) placed it within Palicidae Bouvier, 1898, albeit with a query. It was not until 1989 that de Saint Laurent clarified the systematics of *Retrocypoda*, and included it within the Retroplumoidea Gill, 1894, pointing out its possible relationship with *Costacopluma* Collins and Morris, 1975.

The Iranian specimen of *Retrocypoda almelai* expands eastward the distribution of this species during the Eocene and by extension the paleobiogeographical distribution of the family Retroplumoidea. The paleobiogeography of this family has been discussed formerly by many authors (for instance: Via and Cals, 1979; Via, 1980; Vega and Feldmann, 1992; McLay, 2006; Fraaije *et al*., 2006; Hyžný and Müller, 2010; Feldmann *et al*., 2014), who also hypothesized about the origins of the group and its apparent subsequent expansion eastward from both sides of the Atlantic, whether from Central America or from the west coast of Africa, where it is assumed that the group arose during the Late Cretaceous (Hyžný *et al*., 2016).

2. Geological setting

Outcrops in the Soh area include the widely distributed Paleozoic (Zahedi, 1973; Adhamian, 2003; Wendt *et al*., 2005; Ghobadipour *et al*., 2013; Bahrami *et al*., 2015) and Mesozoic deposits (Mannani and Yazdi, 2009; Yazdi *et al*., 2010), as well as the Paleocene to Oligo-Miocene deposits, the youngest marine sequences, which start with terrigenous red to white sequence of Paleocene conglomerate and sandstone, continued by Eocene fossiliferous carbonates and marls. The Sabkha deposits at the top of the Oligo-Miocene Qom Formation terminates the depositional cycle of the marine sequence.

A thick Eocene succession is widely exposed in the studied region (Sadri, 2011; Janssen *et al*., 2013). The studied section is located near the village of Soh (70 km northwest of Isfahan) (Fig. 1) and is accessible by a 35 km unpaved road off the Isfahan – Tehran highway. The section is situated on the right side of a seasonal river valley that is observable from a distance in the plain. Coordinates for the fossil locality are: N 33º28′36″, E 51º27′6″. Structurally, the locality belongs to the Central Iran microplate, which is restricted by the NW-SE Sanandaj- Sirjan metamorphic belt to the West, and by the Great Kavir fault to the East. The studied profile (Figs. 2, 3) is about 354 meters thick. Based on field observation, sedimentological features and fossil contents, 11 lithological packages are discriminated. The details of each package are given from the top to the base:

- Alternation of light brown to grey sandstone and conglomerate with reworked clasts including *Heterastridium* spp. of late Triassic due to movements of Alpine orogeny, 33 m (package 11).
- Alternation of thin bedded sandstone with green to white marly subminors including two igneous levels (trachy-andesite and basalt), 20 m (package 10).
- Alternation of white to light brown limestone, sandy limestone, thin layers of marly limestone with abundant silicified bivalves and gastropods (*Pinna* sp., *Glycymeris* sp., *Velates* sp., *Conus* sp., *Oliva* sp., *Natica* sp.), solitary corals, condensed ostreoid layers and the *Retrocypoda almelai* specimen here reported, 68 m (package 9).
- Pink to brown trachy-andesite, 10 m (package 8).
- White to yellow green marl with sandy limestone including foraminifers, echinoids, bivalves and gastropods, 35 m (package 7).
- Alternation of dark brown to grey siliceous conglomerate and sandstone, 35 m (package 6).
- Yellow to grey medium to thick bedded sandy limestone including micro and macrofauna (*Ostrea* sp., *Natica* sp., *Velates* sp., *Cardium* sp., bivalve coquina and bryozoan remains), 30 m (package 5).
- Alternation of sandstone and marl, two green to grey tuffaceous silty horizons, and purple fossiliferous marl with abundant bivalves, 60 m (package 4).
- Green to gray loose marl including, pteropods (marine pelagic gastropods), *Helioconoides* sp. crinoids, ostracods, tiny layers of siliceous sandy limestone with foraminifera (*Nodosaria catesbi*, *Nodosaria scalaris*, *Elphidium* sp., *Marginulina* sp., *Nummulites globulus*, *Coskinolina* sp., *Spirolina cylindracea*, *Textularia* sp.), and bivalves (*Ostrea* sp., *Pinna* sp.), 30 m (package 3).
- Brown fine-grained cross-bedded marly sandstone, 15 m (package 2).
- Grey marls with thin layer of brown to yellow limestone including abundant *Rotularia* sp. (polychaete worm), charophye algae, ostracods, oysters and foraminifera (*Nodosaria catesbi*, *N. scalaris*, *Elphidium* sp., *Marginulina* sp., *Nummulites globulus*, *Coskinolina* sp.), fine sandy carbonate bed rich in crustacean remains, mainly Callianassidae at the base of the package, 18 m (package 1 – Eocene).
- Disconformity (Paleocene-Eocene boundary).
- Alternation of red to dark brown conglomerate, sandstone and siltstones including siliceous *Orbitolina* and mollusk debris, reworked from the Cretaceous due to the post Laramidian orogenetic movements, 60 m, (Paleocene).

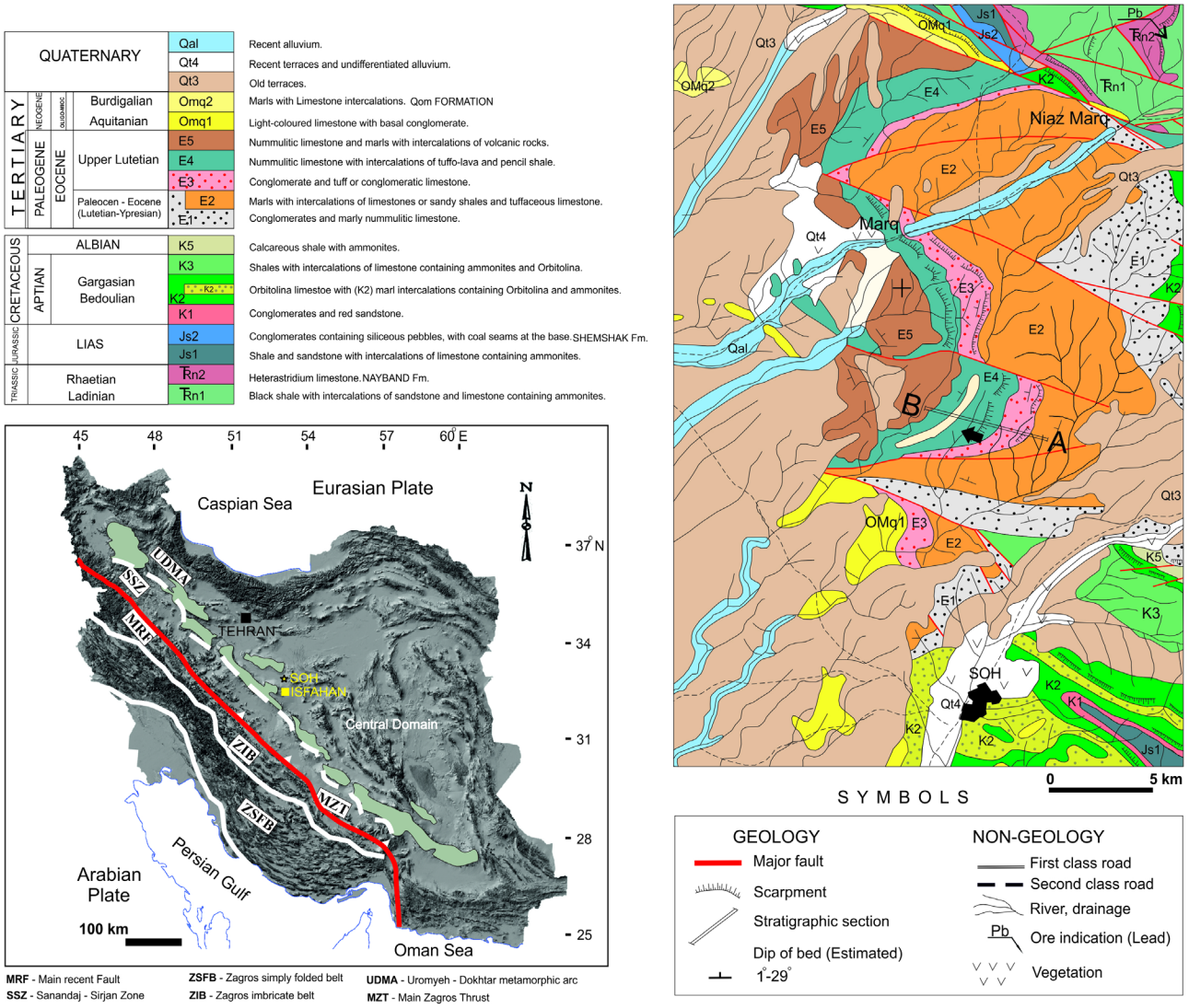

Figure 1. Location and geologic maps of study area with position of fossil locality (arrow), north of Isfahan, Iran.

3. Repository

Department of Geology, Faculty of Science, University of Isfahan, Iran: EUIC. Museo del Desierto, Saltillo, Coahuila, Mexico: MUDE. Museu de Geologia de Barcelona (Barcelona, Catalonia): MGB. Museo Civico "G. Zannato" di MontecchioMaggiore (Vicenza, Italy): MCZ.

4. Systematic Paleontology

Order Decapoda Latreille, 1802
Infraorder Brachyura Latreille, 1802
Section Eubrachyura de Saint Laurent, 1980
Subsection Heterotremata Guinot, 1977
Superfamily Retroplumoidea Gill, 1894
Family Retroplumidae Gill, 1894

Genus *Retrocypoda* Vía Boada, 1959
Type species. Retrocypoda almelai Vía Boada, 1959

Retrocypoda almelai Vía Boada, 1959
(Fig. 4)

1943 Fragmentos de crustáceos; Ríos *et al*., p. 360
1949 "especie completamente inédita"; Via, p. 171
1950 *Macrophthalmus almelae* n. sp.; Bataller, p. 224 (*nomen nudum*).
1952 *Ocypodidae* n. sp.; Via, p. 86.
1959 *Retrocypoda almelae* Vía Boada, 1959; p. 394, f. 20.
1961 *Retrocypoda almelae* Via Boada, 1959; Farrés, p. 21
1969 *Retrocypoda almelai* Via Boada, 1959; Glaessner in Moore, p. 532, f. 339.1.
1969 *Retrocypoda almelai* Vía Boada, 1959; Via, p.

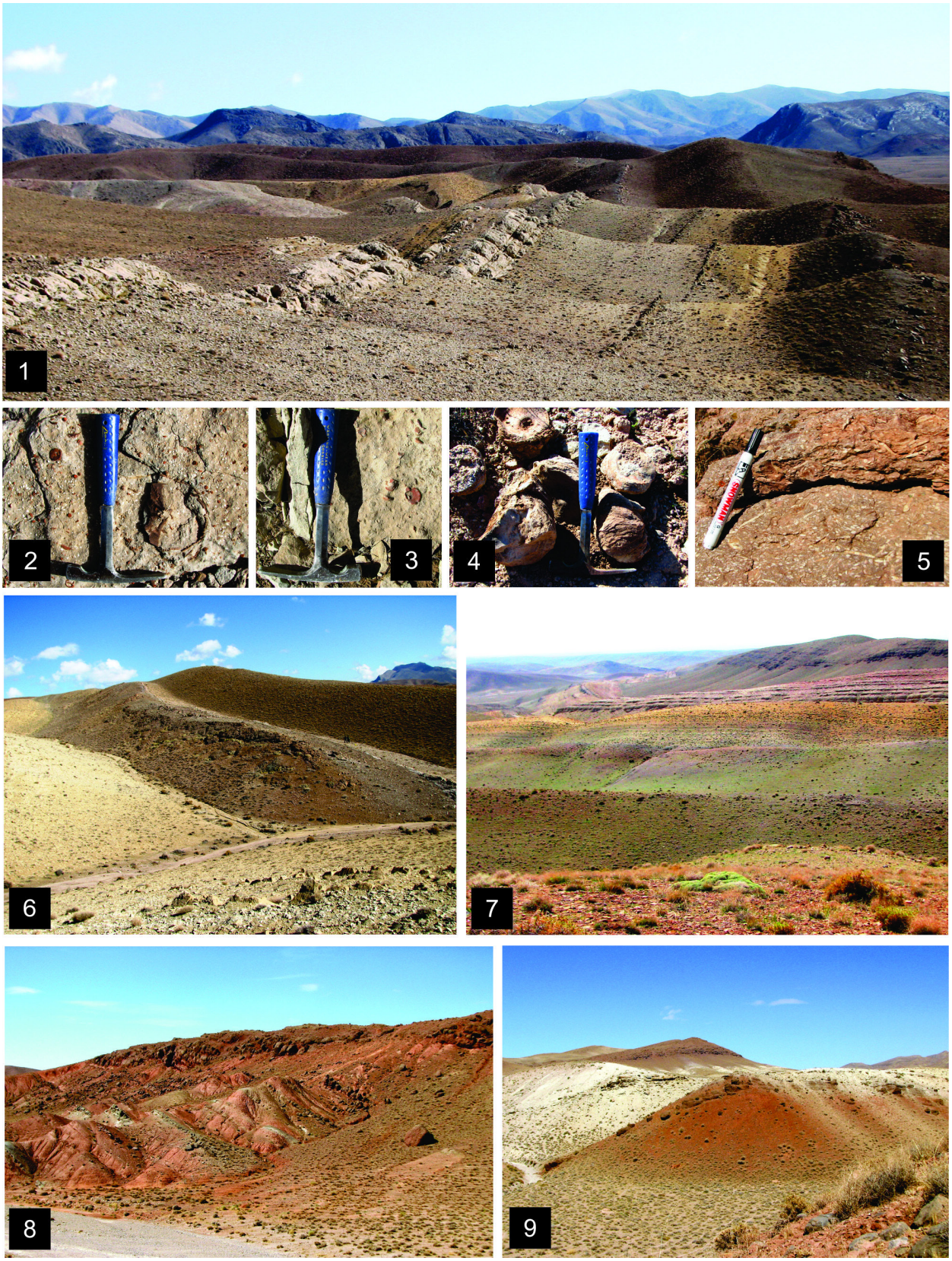

Figure 2.1, General view of the Sarakeh syncline with indication of the crustacean horizon in studied carbonate level. 2, 3, Silicified echinoids, bivalves and foraminifers found below and within the studied carbonate horizon. 4, Oyster rich level at the top of the carbonate horizon. 5, Silicified foraminifera horizon 2 m above the Oyster rich level.6, Igneous (trachy-andesite) below the carbonate level. 7, General view of the Srakeh syncline with indication of conglomerate levels at the base and top of the carbonate horizon. 7, Paleocene red clastic and continental deposits at base of studied profile. 9, Paleocene-Eocene boundary (red to white) transitional level.

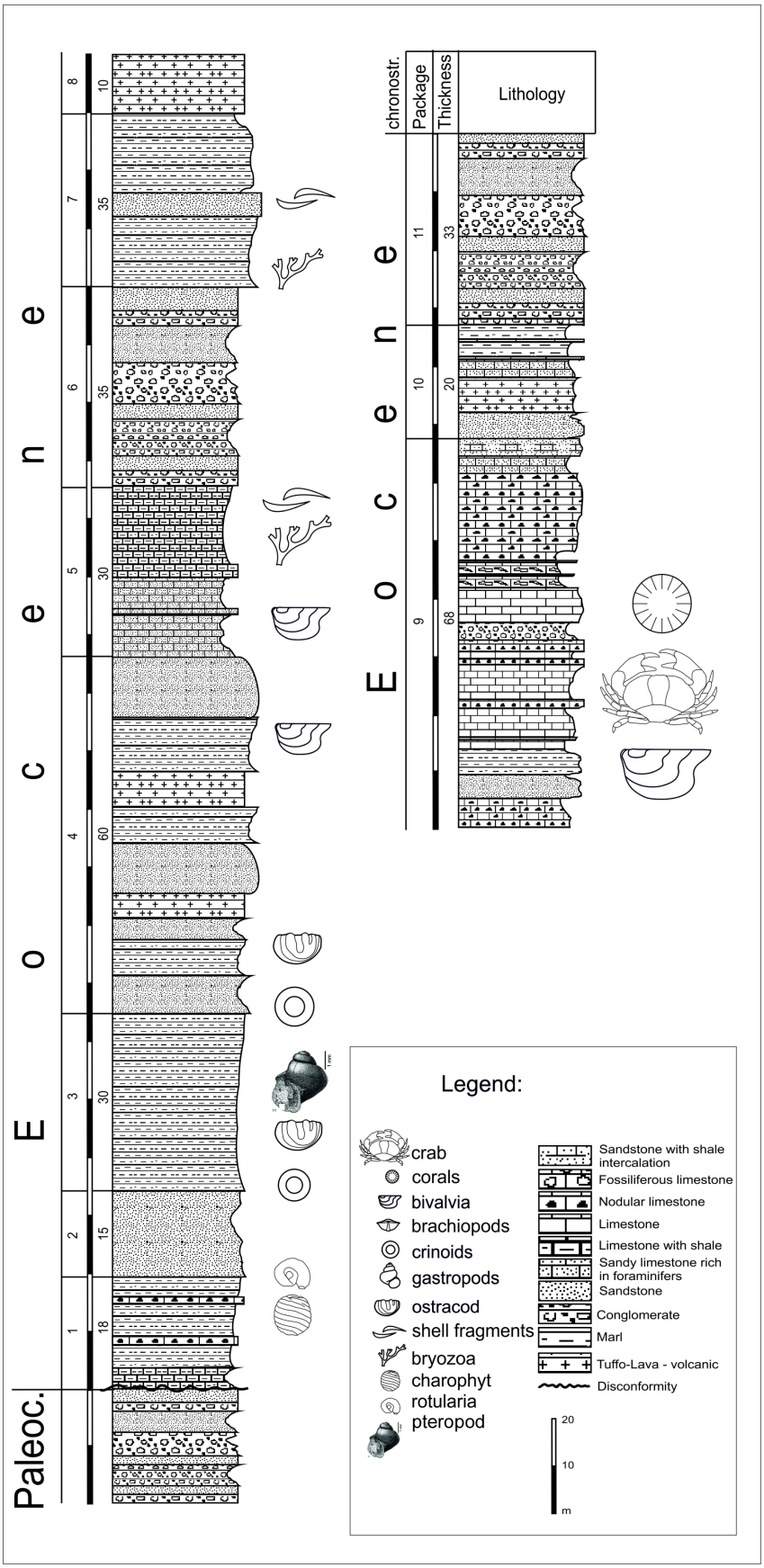

Figure 3. Stratigraphic profile of study section.

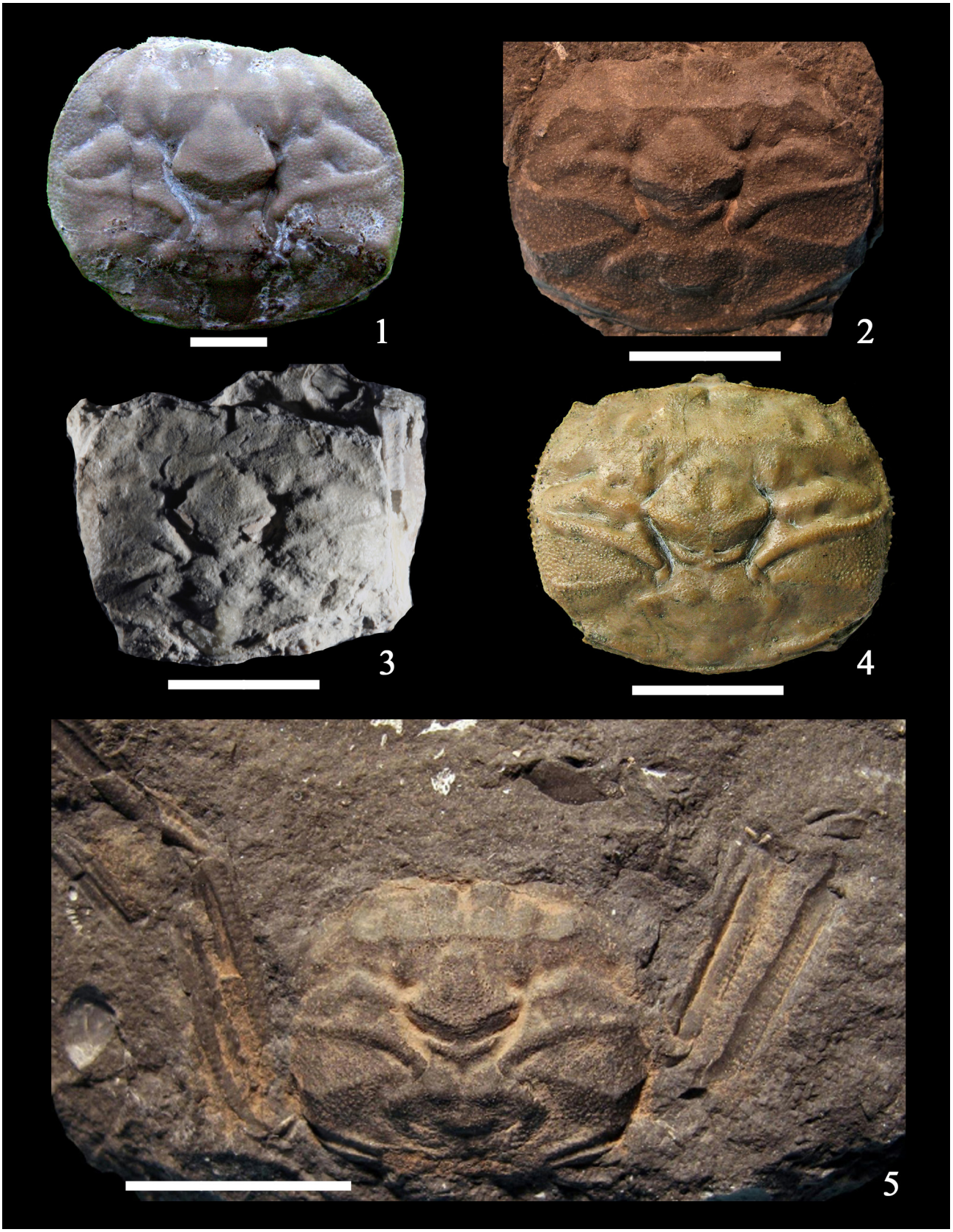

Figure 4. *Retrocypoda almelai* Via Boada, 1959.1: EUIC 2238, Bartonian (middle Eocene) of Soh (Isfahan, Iran). 2: MGB 70438, Priabonian (late Eocene) of Yebra de Basa (Huesca, Spain). 3: CPC-1840, Bartonian (middle Eocene) of La Pobla de Claramunt (Anoia, Catalonia).4: MCZ 2727, Lutetian of Grola, (Vicenza, Italy). 5: AO C-023/6, Priabonian (late Eocene) of Yebra de Basa (Huesca, Spain). Scale bar equal to 10 mm.

330, fig. 41, t. 38, f. 4, t. 39, ff. 1–5.
1980 *Retrocypoda almelai* Vía Boada, 1959; Via Boada, p. 58, t. 1, f. 5.
1982 *Retrocypoda almelai* Via Boada, 1959; Via Boada, p. 18, f. 1.
1985 *Retrocypoda almelai* Via Boada, 1959; Vela, p. 22.
1988 *Retrocypoda almelai* Via Boada, 1959; Via, p. 351, f. 343.G.
1989 *Retrocypoda almelai* Vía Boada, 1959; Solé and Vía, p. 31.
1989 *Retrocypoda almelai* Vía Boada, 1959; de Saint Laurent, p. 143-150, t. 6, ff. A-E, t. 7, ff. A-G.
1996 *Retrocypoda almelai* Vía Boada, 1959; Beschin *et al*., p. 96, fig. 5, t. 2, f. 1.
2001 *Retrocypoda almelai* Vía Boada, 1959; De Angeli and Beschin, p. 28, f. 21.3.
2006 *Retrocypoda almelai* Vía Boada, 1959; De Angeli and Garassino, p. 52.
2007 *Retrocypoda almelae* Via Boada, 1959; Feldmann and Portell, p. 91.
2010 *Retrocypoda almelai* Vía Boada, 1959; Schweitzer *et al*., p. 100.
2011 *Retrocypoda almelai* Via Boada, 1959; De Angeli *et al*., p. 41, T1.
2013 *Retrocypoda* Via Boada, 1959; Guinot *et al*., p. 140, 216.
2015 *Retrocypoda almelai* Via Boada, 1959: Jagt *et al*., p. 887, 880, f. 71–15.6, B-C.

Description. Carapace medium sized; subrectangular, wider than long (ratio 0,80), maximum width at midlength of carapace; sculptured, finely granulated; crossed by four more or less marked transverse ridges. Frontal margin long; front very narrow, not present; supraorbital margin long, sinuous; strong outer orbital tooth broken. Lateral margins convex; laterally stepped, inward directed anteriorly, finely spiny; anterolateral margins gently arched toward the anterior corner, posterolateral margins convex, posteriorly convergent; posterior margin long, slightly convex, rimmed. Anterior first ridge straight medially, and downward oblique laterally crossing the protogastric and hepatic regions; second ridge sinuous, with rounded edge, acute in mesogastric lobe, crossing mesogastric and epibranchial regions; third ridge acute, downward oblique, short, traverses from epi- and mesobranchial regions to branchicardiac groove; posterior fourth ridge upward oblique, short, crossing mesobranchial and cardiac regions, interrupted by branchiocardiac groove. Epigastric lobes slightly inflated; protogastric lobes slightly swollen; mesogastric lobe well marked, bounded and separated from narrow metagastric lobes by deep cervical groove; urogastric region depressed; cardiac lobe rhomboidal, slightly swollen; intestinal region depressed. Gastric pits present between meso- and metagastric lobes.

Material. One specimen, EUIC 2238.

Measurements (in mm). Length = 39.9 Width = 51.6, Fronto-orbital width = 32.3. Ratio L/W = 0.77; ratio FOW/W = 0.62.

Discussion. The Iranian specimen of *Retrocypoda almelai*, dorsally well preserved (Fig. 4.1), fits perfectly with the Iberian and Italian specimens of this species (Fig. 4.2 – 4.5), being noteworthy in its unusual larger size (51 mm width). This discovery expands the paleobiogeographic range of this species, so far considered endemic of the Western Tethys. It was recovered in a sandy limestone level attributed to the Bartonian. Accompanying fauna such as bivalves, gastropods and oyster layers, indicates a nearshore environment (Janssen *et al*., 2013).

The apparent confinement of *Retrocypoda* to the Mediterranean margin of Western Tethys might not be such, in light of this new discovery in Iran, and to attribute this apparent confinement to the lack of fossil record in other Tethyan areas. However, the fossil record shows that Europe and especially the area of the western end of Tethys (comprised between northern and eastern of Iberian Peninsula and northern Italy), comprises the highest stock of retroplumids genera during the Eocene, higher than any other geological epochs, including the present time, namely: *Gaudipluma* Artal, Van Bakel *et al*., 2013, *Loerenthopluma* Beschin *et al*., 1996, *Loerenthoplumopsa* Schweitzer *et al*., 2011 (see *Loerentheya* Beurlen in Lőrenthey and Beurlen, 1929), *Retrocypoda* Via Boada, 1959, *Retropluma* Gill, 1894 (2 species) and *Serrablopluma* Artal *et al*., 2013, which have their first occurrences mainly in the mentioned area since the early Eocene. This fact might support in part, the hypothesis of Hyžný *et al*. (2016) according to which, ancestors of these Tethyan retroplumids, would have to be found among the African lineage of *Costacopluma* Collins and Morris, 1975, for instance *C. senegalensis* (Rémy in Gorodiski and Rémy, 1959) from the Paleocene of Senegal, which is geographically and temporally closest to the aforementioned area of the Western Tethys (Hyžný *et al*., 2016, p. 153). We concur, at least regarding *Retrocypoda* which is *Costacopluma*'s closest genus, differing from it in their spiny lateral margins medially convex, carapace sculpture and by its supplementary fourth transverse ridge, instead of the three in *Costacopluma*.

Since de Saint Laurent (1989) clarified the retroplumid condition of *Retrocypoda almelai*, subsequent authors, with some exceptions, accepted this systematic placement (*e.g*. Beschin *et al*., 1996; De Angeli and Beschin, 2001; De Angeli and Garassino, 2006; Feldmann *et al*., 2006; McLay, 2006; Feldmann and Portell, 2007; Hyžný and Müller, 2010; Schweitzer *et al*., 2010; De Angeli *et al*., 2011 and Hyžný *et al*., 2016). We can add in support of the retroplumid condition of *Retrocypoda*, that besides the contrasted presence of modified and reduced sternite 8 and reduced coxa of P5 (Via, 1969, p. 335; de Saint Laurent, 1989, T7, fig. A-B), some samples preserved in matrix of *Retrocypoda almelai* from outcrops of Central Catalonia, preserved remains of the reduced subcylindrical P5 (See appendix). However, *Retrocypoda* possesses stronger and

more developed chelipeds, markedly heterochelic, mainly in males, characterised by long palms with acute upper margin, with short and stout dactily, unlike most of other retroplumid genera whose chelipeds are usually slender and thin with elongate and sharp tipped dactily (Via, 1969, p. 329; de Saint Laurent, 1989, p.113-114, f.7; McLay, 2006, p. 389). These cheliped features can be observed also in some samples of *Costacopluma nordestina* Feldmann and Martins-Neto, 1995 (cfr. Távora and Miranda, 2004, fig. 5), thus arguing in favor of the close relationship of *Retrocypoda* with *Costacopluma*.

Extant and Miocene-Pleistocene retroplumids prefer deep water with muddy or muddy sand bottoms, in contrast to the Paleogene fossil record (de Saint Laurent, 1989; Collins *et al*., 2003; De Angeli *et al.*, 2011; Baldanza *et al*., 2013; Găsparič and Hyžný, 2014). *Retrocypoda* dwelt in muddy sandy or sandy bottoms, in shallower waters from inner to outer continental platform. Occurrences of *Retrocypoda* during Ypresian to Bartonian indicates a nearshore environment, whereas the Priabonian ocurrences are on muddy soft bottom of an offshore environment (see Abad, 2001; Beschin *et al*., 2012; Ossó *et al*., 2014 and herein).

5. Discussion and conclusions

Extant members of Retroplumidae, *Retropluma* and *Bathypluma* are reported only in Indo-West Pacific waters. The Iranian *Retrocypoda almelai* documents the presence of the family in the Middle East during the Eocene (Fig. 5), as does *Costacopluma* cf. *concava* Collins and Morris, 1975, recorded in the uppermost Maastrichtian of northern India (Gaetani *et al*., 1983) and *Retropluma laurentae* Collins *et al*., 2003 in the Miocene of Indonesia. Therefore, albeit being represented by very scarce taxa, Retroplumidae is documented in the Middle and Eastern Tethys during the Late Cretaceous and Cenozoic. This means either that Retroplumidae inhabited simultaneously from the Atlantic coast of America to the coast of Africa and the eastern Tethys, though the fossil record is scarce in those eastern areas, or rather, that the eastward migratory trend, widely discussed by the majority of works above mentioned, was real (Fig. 6). Given the abundant retroplumid stock of Atlantic, represented by *Costacopluma* in the Late Cretaceous and the varied Cenozoic retroplumid stock of the West Tethys, the second hypothesis seems more plausible for the time being. It is noteworthy that unlike other retroplumid genera, which generated different species through time, *Retrocypoda* remains monotypic during the whole Eocene.

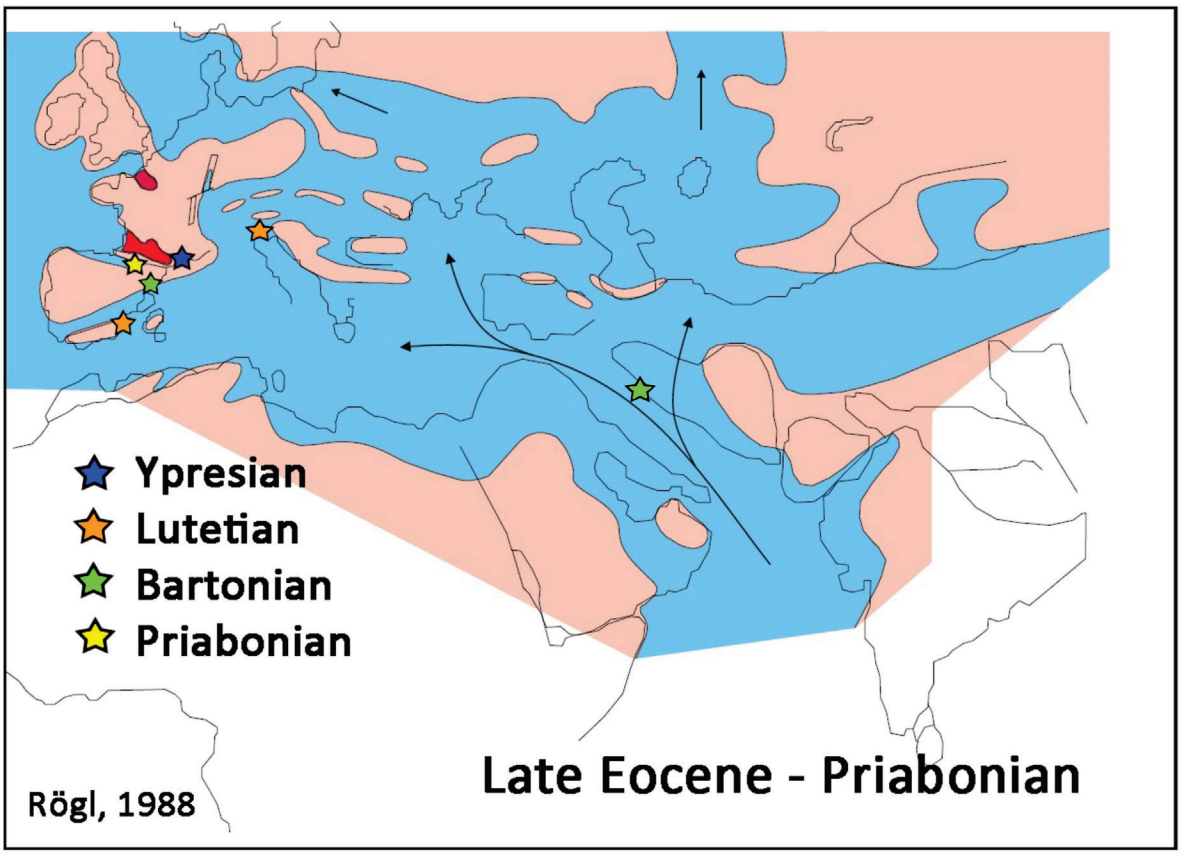

Figure 5. Approximate distribution of *Retrocypoda* during the Eocene (modified from Rögl, 1998).

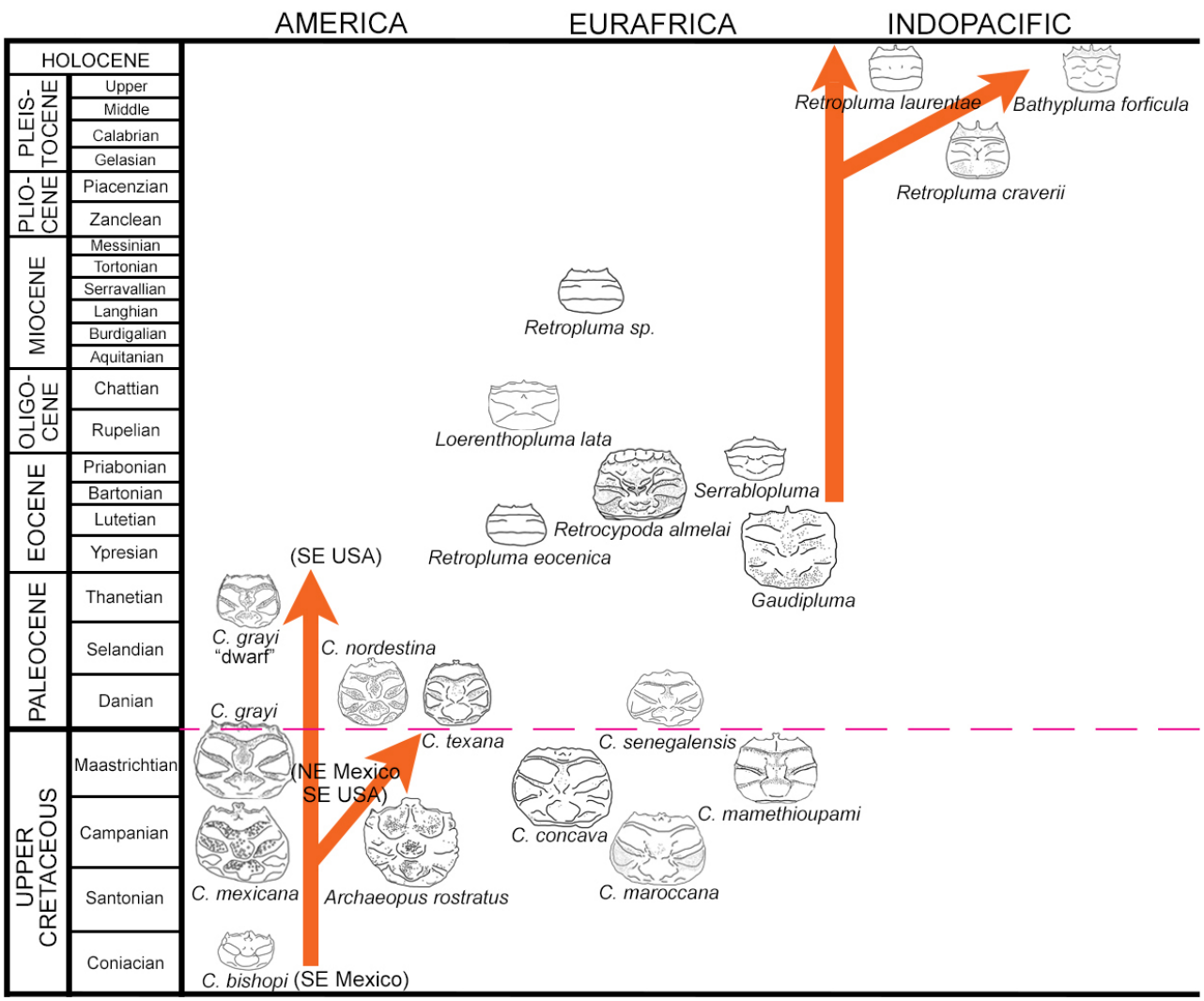

Figure 6. Paleobiogeographic distribution of Retroplumidae since Late Cretaceous (modified from Via, 1969).

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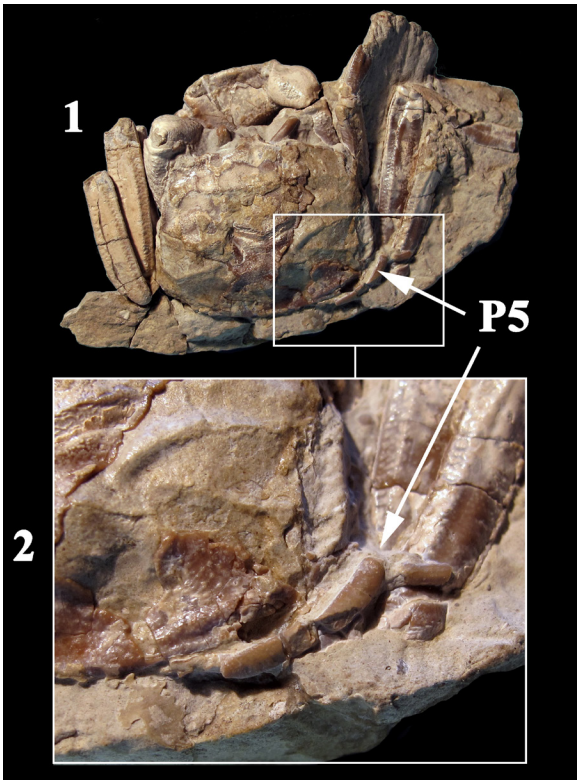

Appendix. *Retrocypoda almelai* Via Boada, 1959. AO C-023/4., Bartonian (middle Eocene) of La Pobla de Claramunt (Anoia, Catalonia). 1: Dorsal view; 2: close-up showing the reduced P5. Abreviations: P5 = fifth pereiopod. Scale bar equal to 10 mm.