A spiny lobster (Decapoda, Achelata) from the Upper Cretaceous (Cenomanian–Turonian) of Gara Sbaa, southeastern Morocco

GIOVANNI PASINI & ALESSANDRO GARASSINO

Abstract
A spiny lobster, genus and species undetermined (Palinuridae Latreille, 1802) from the Upper Cretaceous (Cenomanian–Turonian) of Gara Sbaa (southeastern Morocco, NW Africa), is herein described. This is the second fossil record for a palinurid from Africa, enlarging the knowledge on the worldwide distribution of the family.

Keywords: Crustacea, Palinuridae, taxonomy, Konservat Lagerstätte, NW Africa.

1. Introduction
The studied specimen was collected from the Gara Sbaa Member sensu Martill et al. (2011) (Kem Kem region, southeastern Morocco). The Member is correlated with the basal horizon of the open shelf carbonate Akraobou Fm that includes laminated dolomitized limestones, deposited within a transgressive fluvio-lagoonal carbonate platform sequence and considered Cenomanian–Turonian (Late Cretaceous) in age. The fossiliferous layers from the Gara Sbaa yielded a rich fossil fauna (mainly fishes) that were the object of several studies (see Cavin et al. 2010; Martill et al. 2011; Murray et al. 2013).
Numerous arthropods (hymenopteran and orthopteran insects; isopods, and decapod crustaceans) have been discovered forming the bulk of the invertebrate biota (Garassino et al. 2008; Martill et al. 2011). The isopods were assigned to the sphaeromatid Unusuropode castro i Duarte & Santos, 1962 (Corbacho et al. 2018). Rare xiphosuran limulids were also reported by Garassino et al. (2008) and recently assigned to Mesolimulus tafraoutensis Lamsdell, Tashman, Pasini & Garassino, 2019 (Lamsdell et al. 2019). The decapod crustaceans have been studied by several authors (Garassino et al. 2006, 2008; Guinot et al. 2008; Garassino & Pasini 2018) (see Appendix).

The studied specimen was collected from the sublithographic, laminated limestone beds at the top of Gara Sbaa Member (Aaronson, pers. comm. 2020), interpreted to be deposited within a transgressive fluvio-lagoonal carbonate platform sequence and suggesting a possible shallow marine water environment (Murray et al. 2013).

Based upon Schweitzer et al. (2010, 2015) the Palinuridae are known to date in Africa with only one species, Linuparus africanus Glaessner, 1932 from the Late Cretaceous (Santonian) of Cameroon (Central Africa). Hence, the studied specimen represents the second report of a spiny lobster from Africa enlarging the knowledge both of the worldwide distribution of the family and of the crustacean faunal fossil assemblage from Gara Sbaa Member environment. We also provide an updated list of decapod crustaceans known to date from the Gara Sbaa Konservat Lagerstätte (see Appendix).

2. Material
One complete specimen preserved in ventral view on a laminated dolomitized limestone slab, partially covered/encrusted by iron-oxide deposits, is housed in the palaeontological collections of the Museo di Storia Naturale di Milano (MSNM).

We provide natural and UV-light photos of the specimen in order to distinguish better some morphological details of the tiny phosphatized structures.

Abbreviations: lcxp: carapace length; la: antennae length; lb: total body length (excluding antennae); P1–P5: pereiopods 1 to 5; Mxp3: third maxilliped; s1–s6: pleonal somites 1 to 5; wcxp: carapace width.

3. Systematic palaeontology

Infraorder Achelata Schlotz & Richter, 1995

Family Palinuridae Latreille, 1802

Genus and species undetermined

Figs. 1, 2

Material and measurements: One nearly complete specimen in ventral view. MSNM i29337 – lcxp: 14 mm; wcxp: 10 mm; la: 130 mm; lb: 25 mm.

Description: Carapace. Carapace poorly preserved, subrectangular, longer than wide, with concave posterior margin; frontal margin poorly preserved, rostrum indistinct; pterygoistomial regions with irregular coarse granulations; epistome smooth, with a median frontal triangular projection. Pleon. Pleonal somites s1–s6 subrectangular; pleurae not visible; s1–s6 decreasing posteriorly (s1 = 9 mm; s6 = 6 mm); telson poorly preserved, downturned posteriorly under the body. Thoracic...
Fig. 1. Palinuridae, genus and species undetermined, MSNM i29337. (A) General view by natural light. Scale bar equals 8.3 mm. (B) General view by UV light. Scale bar equals 12.5 mm. (C) Close-up of the cephalic appendages by UV light. Scale bar equals 5 mm. (D) Close-up of the tail fan by UV light. Scale bar equals 2.2 mm. Abbreviations: an1, an2: antennular peduncles 1 and 2; anf1, anf2: antennular flagellum 1 and 2; apl–ap3: antennal peduncles 1–3; af: antennal flagellum; Mxp3: third maxilliped; P1–P5: pereiopods 1–5; uex: uropodal exopod; ued: uropodal endopod.
smooth sternum flattened, triangular-shaped, iso-
sceles, decreasing in size distally. **Cephalic appendages.** Thick antennae, with very elongate flagellum, decreasing in size distally; strong peduncle with 3 well-developed spinose articles; antennae about 4.3 times longer than body; antennulae slender, elongate (12 mm total length), 11 times shorter than antennae; proximal elongate slender peduncle 3 times longer than the distal one, with smooth lateral margins; distal short slender pedun-
cle, with smooth lateral margins; two unequal flagellae shorter than the peduncle; outer flagellum short and wide, subtruncate; inner flagellum elongate and thin, decreasing in size distally; scaphocerite absent; Mxp3 elongate with distal triangular dac-
tylos. **Thoracic appendages.** P1–P5 well exposed, covered by granulate, coarse ornamentation; P1–P3 having same length; P1 with strong merus, carpus, and globular elongate propodus; strong triangular P1 dactylus slightly downturned, with a medial longitudinal groove; P1 twice wider in transverse section (2 mm) than P2–P3; P2–P3 elongate and more slender (1 mm) than P1, ending in a pointed triangular dactylus; P4–P5 much thinner (0.5 mm) and shorter than P2–P3, with triangular pointed dactylus and decreasing in length posteriorly; P1–P3 covered by coarse irregular granulations on merus, carpus, and propodus; P4–P5 smooth. **Pleonopal appendages.** Pleopods poorly preserved; uropodal exopod only partially exposed; petal-like exopod with a longitudinal thin medial ridge and subtruncate posterior margin; uropodal endopod poorly preserved, seems to have a thin longitudinal medial ridge.

**Discussion:** Despite the small body, we can confidently exclude that the studied specimen could represent a pre-adult or an “intermediate transitional development stage” **sensu Haug & Haug** (2016) due to the presence of a well-sclerotized hardened and developed pleon and the absence of the typical biramous elongate pleopods with plumose natatory setae on the pereio-
pods. Indeed, it’s almost impossible to recognize in fossil spiny lobsters the intermediate development stages simply based upon the size or the generic body morphologic characters only (see for example the case of “*Palinurina tenera* in Haug & Haug 2016) and when lacking an enough number of comparable specimens. Indeed, *palinurid puerulus* transitional stage (= benthic juvenile development) usually resembles the adult body plan.

Based upon Schweitzer et al. (2015) the diagnostic charac-
ters of the studied specimen fit those of the Palinuridae in having subcylindrical or semirectangular carapace; epistome in broad contact with carapace; broad, triangular sternum; very large antennae, thick antennal bases usually with spines; scaphoceri-
te absent; P1 almost always same length or only slightly longer than other pereiopods.

According to Schweitzer et al. (2015), the Palinuridae includes 15 fossil and extant genera. The best-preserved charac-
ters of the studied specimen have been compared with those of the genera having more affinities in the body structure and P1 structure and shape.

The studied specimen clearly differs from Jasus Parker, 1883 in having shorter antennae, longer antennulae, and deve-
loped pleonal somites with spiny pleurae; Justitia Holthuis, 1946 in having carapace with imbricate scales and longer P1 subchelate, not distinctly wider than others; Panulirus White, 1847 in having antennular flagellum shorter than peduncle, smooth P1 not enlarged, and spiny pleurae margin (Holthuis 1991; Schweitzer et al. 2015).

The studied specimen shows instead closer similarities with the extant and fossil genera *Palinurus* Weber, 1795 (Upper Cretaceous–Recent), *Palinurellus* von Martens, 1878 (late Eocene–Recent), and with the fossil *Palinurina* Münster, 1839 (Lower–Upper Jurassic). However, *Palinurus* has a carapace and P1–P5 ornamentation nearly smooth and notably spiny pleurae margin, whereas *Palinurellus* has a larger body, P1 shorter than the others, uniformly covered by small tubercles, and shorter antennae (Schweitzer et al. 2015).

The studied specimen shares some diagnostic characters with *Palinurina* in having antennae with strong articles; absence of scaphocerite; and P2–P5 long and slender (Schweitzer et al. 2015: 6). However, the studied specimen differs from the type species, *Palinurina longipes* Münster, 1839, in several spe-
cific characters, such as the ornamentation with coarse irregular granulations of the pterygostomian region; P4–P5 smooth, distinctly much thinner and shorter than P2–P3; P1–P3 with fine irregular granulations not ranged in rims. We consider these substantial differences (beyond the different geological age), enough to exclude the assignment of the studied specimen to *Palinurina*.

In conclusion, we prefer to leave the studied specimen in open nomenclature due to the impossibility to check the main morphological characters of the carapace. This new report is remarkable, representing the second record of a representative of a spiny lobster in Africa, enlarging our knowledge on the decapod crustacean assemblage from the Late Cretaceous Gara Sbaa fossiliferous beds.

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**References**

Cavin, L., Tong, H., Boudad, L., Meister, C., Piuz, A., Tabouelle, J., Aarab, M., Amiot, R., Buffetaut, E., Dyke, G., Hua, S., & Le Loeff, J. (2010): Vertebrate assemblages from the early Late Cretaceous of southeastern Morocco: An overview. – Journal of African Earth Sciences, 57: 391–412.

Corbacho, L., Morrison, S. & Alonso, M. (2018): First mention of Unusuropode castroi Duarte & Santos, 1962 (Crustacea: Isopoda) in the Upper Cretaceous of Gara es Sbaa Lager-
stätte, South-Eastern Morocco. – Earth Sciences, 7 (6): 289–
293. doi: 10.11648/j.earth.20180706.16

Duarte, L. & Santos, R. S. S. (1962): Fóssiles do Arenito Açu. – Anais da Academia Brasileira de Ciências, 34: 57–68.

Fabricius, J. C. (1793): Entomologia systematica emendata et aucta. Secundum classes, ordines, genera, species adjec-
tis synonymis, locis; observatiosnibus, descriptionibus. 519 pp.; Hafniae.

Garassino, A., De Angelis, A. & Pasini, G. (2008): New decap-
pod assemblage from the Upper Cretaceous (Cenomanian-
Turonian) of Gara Sbaa, southeastern Morocco. – Atti della Società italiana di Scienze naturali e del Museo civico di Storia naturale in Milano, 149 (1): 37–67.

Garassino, A. & Pasini, G. (2018): Amazighipodidae, a new family of decapod macruran astacideans from the Late Creta-
ceous (Cenomanian–Turonian) of Gara Sbaa, southeastern
Morocco. – Natural History Sciences, Atti della Società italiana di Scienze naturali e del Museo civico di Storia naturale in Milano, 5 (1): 11–18. doi: 10.4081/nhs.2018.358

Garassino, A., Pasini, G. & Duthie, D. B. (2006): Cretapnauzes berberus n. gen., n. sp. (Crustacea, Decapoda, Penaeidae) from the Late Cretaceous (Cenomanian) of southeastern Morocco. – Atti della Società italiana di Scienze naturali e del Museo civico di Storia naturale in Milano, 147 (1): 3–17.

Garassino, A. & Schweiger, G. (2006): The Upper Jurassic Solnhofen decapod crustacean fauna: review of the types from old descriptions. Part I. Infracorders Astarteida, Thalassinidea, and Palinura. – Memorie della Società italiana di Scienze naturali e del Museo civico di Storia naturale di Milano, 34 (1): 3–44.

Glæssner, M. (1932): Neue Krebsreste aus der Kreide. – Jahr

Haug, J. T. & Haug, C. (2016): "Intermetamorphic" developmental stages in 150 million-year-old achelatan lobsters – The case of the species tenera Oppel, 1862. – Arthropod Structure & Development, 45: 108–121. doi: 10.1016/j.asd.2015.10.001

Haworth, A. H. (1825): A new binary arrangement of the Nectopodidae, Nephropsidae, Scyllaridae and Palinuridae. The Decapoda Macrura of the Lower Cretaceous of Lebanon. – Journal of Paleontology, 78 (1): 3–17.

Holthuis, L. B. (1946): The Stenopodidae, Nephropsidae, Scyllaridae and Palinuridae. The Decapoda Macrura of the Snellius Expedition I. Biological Results of the Snellius Expedition XIV. – Temminckia, 7: 1–178.

Holthuis, L. B. (1991): FAO species catalogue. 13. Marine lobsters of the world. 276 pp.; Rome (Food and Agriculture Organization of the United Nations).

Lamsdell, J. C., Tashman J. N., Pasini, G. & Garassino, A. (2019): A new limulid (Chelicerata, Xiphosurida) from the Late Cretaceous (Cenomanian–Turonian) of Gara Sbaa, southeastern Morocco (Crustacea, Decapoda, Brachyura). – Atti della Società italiana di Scienze naturali e del Museo civico di Storia naturale in Milano, 149 (1): 25–36.

Larghi, C. (2004): Brachyuran decapod crustacea from the Upper Cretaceous of Lebanon. – Journal of Paleontology, 78 (3): 528–541.

Latreille, P. A. (1802–1803): Histoire naturelle, générale et particulière, des Crustacés et des Insectes, vol. 3: 468 pp.; Paris (F. Dufart).

MacLeay, W. S. (1838): Illustrations of the Annulosa of South Africa: Being a Portion of the Objects of Natural History Chiefly Collected During an Expedition Into the Interior of South Africa Under the Direction of Andrew Smith in the Years 1834, 1835, and 1836: Fitted Out by “The Cape of Good Hope Association for Exploring Central Africa”. 75 pp. London (Smith Elder).

Martens, E. V. (1878): Einige Crustaceen und Mollusken. – Sitzungsberichte der Gesellschaft Naturforschender Freunde zu Berlin, 1878: 131–135.

Martill, D. M., Ibrahim, N., Brito, P. M., Baider, L., Zhour, S., Loveridge, R., Naish, D. & Hing, R. (2011): A new Plattenkalk Konservat Lagerstätte in the Upper Cretaceous of Gara Sbaa, south-eastern Morocco. – Cretaceous Research, 32 (4): 433–446. doi: 10.1016/j.cretes.2011.01.005

Münster, G. Graf zu (1839): Abbildung und Beschreibung der fossilen langschwänzigen Krebse in den Kalkschiefern von Bayern. – Beiträge zur Petrefaktenkunde, 2: 1–88.

Murray, A. M., Wilson, M. V. H., Gibb, S. & Chatterton, B. D. E. (2013): Additions to the Late Cretaceous (Cenomanian/Turonian) actinopterygian fauna from the Agoult locality, Akarabou Formation, Morocco, and comments on the palaeoenvironment. – In: Arratia, G., Schultze, H.-P. & Wilson, M. V. H. (eds.): Mesozoic Fishes 5 – Global Diversity and Evolution, p. 525–548; München (Pfeil).

Parker, T. J. (1883): On the structure of the head in Palinurus with special reference to the classification of the genus. – Nature, 29: 189–190.

Rafinesque, C. S. (1815): Analyse de la nature, ou tableau de l’univers et des corps organisée. 224 pp.; Palermo (Barrovacchia).

Samouelle, G. (1819): The entomologist’s useful compendium, or An introduction to the knowledge of British insects: comprising the best means of obtaining and preserving them, and a description of the apparatus generally used; together with the genera of Linné, and the modern method of arranging the classes Crustacea, Myriapoda, Spiders and Insects, from their affinities and structure, according to the views of Dr. Leach, etc.; London (T. Boys).

Scholtz, G. & Richter, S. (1995): Phylogenetic systematics of the extantian Decapoda (Crustacea, Malacostraca). – Zoological Journal of the Linnean Society, 113: 289–328.

Schweitzer, C. E., Feldmann, R. M., Karasawa, H. & Garassino, A. (2010): Systematic list of fossil decapod crustacean species. – Crustaceana Monographs, 10: 1–222. doi: 10.1163/156853710X128368

Schweitzer, C. E., Feldmann, R. M., Karasawa, H. & Garassino, A. (2015): Part R, Revised, Volume 1, Chapter 8H: Systematic Descriptions: Infracorder Achelata. – Treatise Online, 67: 1–17.

Weber, F. (1795): Nomenclator entomologicus secundum Entomologiam Systematicum ill. Fabricii adjectis speciebus recens detectis et varietatibus. 171 pp.; Chilonii & Hamburgi (C. E. Bohn).

White, A. (1847): List of the specimens of Crustacea in the collection of the British Museum. 143 pp.; London (The British Museum).

Zittel, K. A. v. (1885): Handbuch der Paleontologie, 1 (2) (Decapoda), p. 679–721; München & Leipzig (Oldenbourg).

Addresses of the authors

GIOVANNI PASINI, Via Alessandro Volta 16, 22070 Appiano Gentile (Como), Italy; e-mail: giovannialdopasini@gmail.com
ALESSANDRO GARASSINO (corresponding author), Department of Earth and Biological Sciences, Loma Linda University, Loma Linda, California 92350, USA; e-mail: alegarassino@gmail.com

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Appendix

Updated general list including the decapod crustaceans reported to date from the Cenomanian–Turonian (Upper Cretaceous) of Gara Sbaa Konservat Lagerstätte (after Garassino et al. 2006, 2008, 2014; Guinot et al. 2008; Garassino & Pasini 2018; and this study).

Family Penaeidae Rafinesque, 1815
Genus *Cretapenaeus* Garassino, Pasini & Dutheil, 2006
*Cretapenaeus berberus* Garassino, Pasini & Dutheil, 2006

Family Palinuridae Latreille, 1802
Genus and species undetermined (this paper)

Family Amaziphopsidae Garassino & Pasini, 2018
Genus *Amaziphopsis* Garassino & Pasini, 2018
*Amaziphopsis cretacica* Garassino & Pasini, 2018

Family Glypheidae Zittel 1885
Genus *Glyphea* v. Meyer, 1835
*Glyphea garasbaaensis* Garassino, De Angeli & Pasini, 2008

Family Galatheidae Samouelle, 1819
Genus *Galathea* Fabricius, 1793
*Galathea sahariana* Garassino, De Angeli & Pasini, 2008
Genus *Cretagalathea* Garassino, De Angeli & Pasini, 2008
*Cretagalathea exigua* Garassino, De Angeli & Pasini, 2008

Family Porcellanidae Haworth, 1825
Genus *Muelleristhes* Garassino, De Angeli & Pasini, 2014
*Muelleristhes africanus* (Garassino, De Angeli & Pasini, 2008)

Family uncertain
Genus *Corazzatocarcinus* Larghi, 2004
*Corazzatocarcinus* cf. *C. hadjoulae* Larghi, 2004

Family Dorippidae MacLeay, 1838
Genus *Telamonocarcinus* Larghi, 2004
*Telamonocarcinus* cf. *T. gambalatus* Larghi, 2004
Family Marocarcinidae Guinot, De Angel & Garassino, 2008

Genus *Marocarcinus* Guinot, De Angel & Garassino, 2008

*Marocarcinus pasinii* Guinot, De Angel & Garassino, 2008