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NEW PYGOCEPHALOMORPH (PERACARIDA) FROM THE PERMIAN OF THE SOSIO VALLEY (SICILY, ITALY)

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ABSTRACT

Sosiocaris schrami n. gen. n. sp., is described from the Permian Sosio Limestone (Lercara Formation) of the Sosio Valley, Palermo Province, Italy. *Sosiocaris schrami* is attributed to Pygocephalomorpha *incertae sedis*. The brachyuran-like carapace morphology of *S. schrami* suggests that its overall morphology might have been convergent on that of brachyurans, an evolutionary trend that has also been observed in other pygocephalomorphs. *Sosiocaris schrami* represents the first occurrence of a pygocephalomorph from the Sosio Limestone, an assemblage of Permian-aged limestone olistoliths from which several unusual crustaceans have been described.

KEY WORDS: carcinization, Peracarida, Permian, Pygocephalomorpha, Sosio Limestone

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INTRODUCTION

General Issues

Described herein is a new pygocephalomorph peracarid, *Sosiocaris schrami* n. gen., n. sp., from the Permian Lercara Formation exposed in the Sosio Valley, Palermo Province, Italy. The new taxon is attributed to Pygocephalomorpha, but not to any previously recognized family, and is here left incerta sedis due to the incomplete nature of the material examined. The three specimens were discovered by one of the authors (AR) during research conducted in October, 2014, by the Museo Civico di Storia Naturale of Comiso and authorized by the Dipartimento Azienda Foreste Demaniali de Sicilia, into the Riserva Naturale Orientata Monti di Palazzo Adriano e Valle del Sosio (Palazzo Adriano, Palermo).

Crustacean fossils have long been known from the Permian Sosio rocks (Gemellaro, 1890; Greco, 1935; Gheyselinck, 1937; Ruggieri, 1959). Gemellaro (1890) recognized three putative decapod genera: *Palaeopemphix* Gemellaro, 1890; *Oocarcinus* Gemellaro, 1890; and *Paraprosopon* Gemellaro, 1890; however, none of those genera has been retained in Decapoda upon re-evaluation. Glaessner (1928) reassigned *Oocarcinus* and *Palaeopemphix* to Cyclida, a middle Paleozoic to Cretaceous group of maxillopodans (Schram et al., 1997; Dzik, 2008). Feldmann et al. (2004) re-evaluated *Palaeopemphix*, and retained the three species described by Gemellaro (1890), but reassigned them to Phyllocarida: Archaeostraca: Palaeopemphicida. Feldmann et al. (2004) further agreed with the assertion of Glaessner (1928) that neither *Oocarcinus*, nor *Paraprosopon* is a decapod, although it seems that *Paraprosopon* could conceivably be a glypheidean lobster and merits re-evaluation. The specimens described here bear resemblance to neither *Paraprosopon*, nor *Oocarcinus* and, as such, cannot be accommodated in either genus. *Sosiocaris schrami* represents the first documented occurrence of a pygocephalomorph peracarid from the Sosio Limestone.

Geologic Setting

Permian fossils described herein come from the extraordinarily fossiliferous Pietra di Salomone megablock southwest of Palazzo Adriano, Sosio Valley (Monti Sicani, western Sicily). All data about the geographic position, geological setting, age, and facies were given in detail by Flügel et al. (1991). The megablocks represent chunks of Permian limestone enclosed in Permian debris flow and turbidite sediments deposited in a base-of-slope position. Flügel et al. (1991) asserted that the blocks are mainly of Wordian (Murghabian) age. It is also possible, however, that some pebbles derived from reef facies are Capitanian (Midian) or even Wuchiapingian (Dzhulfian) in age. Jenny-Deshusses et al. (2000) gave a Capitanian (Midian) to Wuchiapingian (Dzhulfian) and probably even a Changhsingian (Dorashamian) age for the Pietra di Salomone megablock. Therefore, the studied specimens have a Wordian to latest Permian age.

The "Sosio Limestone" is world famous for its well-preserved and very rich invertebrate fauna. Overall, more than 300 species of invertebrates have been described from the Pietra di Salomone megablock; the "Sosio Limestone" comprises multiple blocks, of which the Pietra di Salamone megablock is one. More than 520 species have been

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described from the Sosio Limestone. This fauna comprises foraminifera, sponges, corals, bryozoans, brachiopods, gastropods, pelecypods, ammonoid and nautiloid cephalopods, trilobites, ostracodes, and other crustaceans, as wells as crinoids, blastoids, and fossils of uncertain taxonomic assignment (see Flügel et al., 1991 for references). Like the rocks containing the material of *Palaeopemphix*, the specimens described here occur in a fine-grained calcareous fossiliferous matrix with vuggy solution pits infilled with secondary crystalline calcite (Feldmann et al., 2004).

SYSTEMATICS

The following abbreviations indicate the repository in which studied specimens are held: Museo Civico di Storia Naturale (MSNC), Comune di Comiso, Sicily, Italy.

Class Malacostraca Latreille, 1802
Superorder Peracarida Calman, 1904
Order Pygocephalomorpha Beurlen, 1930

Remarks.—Pygocephalomorphs are a relatively common component of Carboniferous-Permian freshwater and marine crustacean assemblages. Pygocephalomorphs, although rather variable in carapace form, consistently exhibit a relatively axially shortened carapace (although usually longer than wide); a relatively prominent gastric region, defined laterally by a cervical groove; anterolateral carapace margins defined by an acute spine or process; and at least moderately well-developed branchiostegites (Brooks, 1962; Schram, 1974a; Kensley, 1975; Briggs and Clarkson, 1985). Only carapace characters are discussed here because we have only carapaces available for study, although it merits mention that many pygocephalomorph specimens preserve oöstegites and male genital cones, and the telson is characterized by a pair of lateral lobes and a distinct terminal lobe (Schram, 1986; Irham et al., 2010).

The specimens here described are generally consistent with the above combination of characters, with the exception that the carapace is wider than long (Fig. 1A-D). We do not consider the carapace length-width ratio to be problematic in attributing the Sosio specimens to Pygocephalomorpha because the length to width ratio is quite variable among pygocephalomorph families (Brooks, 1962; Schram, 1974a; Kensley, 1975; Briggs and Clarkson, 1985).

Family *incertae sedis*

Remarks.—Pygocephalomorph peracarids are often attributed to one of the three classical families: Tealliocaridae Brooks, 1962; Pygocephalidae Brooks, 1962; or Notocarididae Brooks, 1962 (Brooks, 1962, 1969; Schram, 1974a; Hotton et al., 2002). Although rarely acknowledged, Schram (1978) erected Jerometichenoriidae Schram, 1978, a monotypic family, to accommodate *Jerometichenoria grandis* Schram, 1978, from the Lower Permian near Naryan-Mar, Nenets Autonomous Okrug, Russia. Taylor et al. (1998) erected Tylocarididae Taylor, Yan-Bin, and Schram, 1998, to accommodate *Fujianocaris* Taylor, Yan-Bin, and Schram, 1998; *Tylocaris* Taylor, Yan-Bin, and Schram, 1998, from the Early Permian of Fujian Province, and Late Permian of Hunan Province, China (Schram, 1978; Taylor et al., 1998); and *Pseudogalathea* Peach, 1883.

The specimens described here differ from species included in Tealliocaridae, as described by Brooks (1962) and Briggs and Clarkson (1985) in lacking prominent longitudinal carinae in the branchial region being more axially shortened than would be common in that family, and exhibiting very prominent anterolateral and mesolateral spines on the frontal carapace margin (Fig. 1). Our specimens differ from genera included in Pygocephalidae, as described and figured by Schram (1974a), in exhibiting much more prominent anterolateral and mesolateral frontal spines, lacking gastric spines, lacking a prominent rostrum (although this may be an artifact of preservation), and being more axially shortened than is typical of that family (Fig. 1). Although consistent with species included in Notocarididae in being strongly axially shortened, the specimens described herein lack a well-developed medial keel, and exhibit extremely prominent anterolateral and mesolateral frontal spines (Fig. 1). Genera included in that family are not characterized by those features (Clarke, 1920; Broom, 1931; Kensley, 1975; Hotton et al., 2002). The Sosio specimens also differ from species included in Tylocarididae, as described by Taylor et al. (1998), in exhibiting prominent mesolateral frontal spines, lacking a strongly invaginated medial frontal margin, exhibiting a depressed frontal region, and lacking spines on the posterolateral angle of the carapace (Fig. 1).

Jerometichenoria grandis is characterized by a prominent, broad, flattened anterolateral spine; a smaller, but still very prominent mesolateral spine on the frontal carapace margin; a markedly depressed frontal carapace margin; a strongly developed gastric region; a weakly developed rostrum with a corresponding axial keel; prominent, keel-like gastric spines; and well-developed branchiostegites (Schram, 1978, Fig. 1a, b). Although the specimens described here do not conform perfectly to Jerometichenoriidae, as diagnosed by Schram (1978), we believe that they are more similar to *J. grandis*, the only species included in that family than species included in Pygocephalidae, Tealliocaridae, or Notocarididae. However, the similarity is not great enough to confidently place the Sosio specimens in Jerometichenoriidae.

The Sosio pygocephalomorph specimens available for study are poorly preserved internal molds, and it remains to have more and better specimens to test their placement in a known pygocephalomorph family. For example, the apparently weak or absent rostrum could be a preservational artifact. The alternative of erecting yet another monotypic family based upon this material is not realistic.

Sosiocaris n. gen.
Fig. 1A-E

Type species.—*Sosiocaris schrami* by original designation and monotypy.

Diagnosis.—As for species.

Etymology.—The generic name alludes to the Sosio Valley, Palermo Province, Italy, the region from which the specimens were collected. The name is derived from Sosio, in reference to the Sosio Valley, and the Latin *caris*, crab.

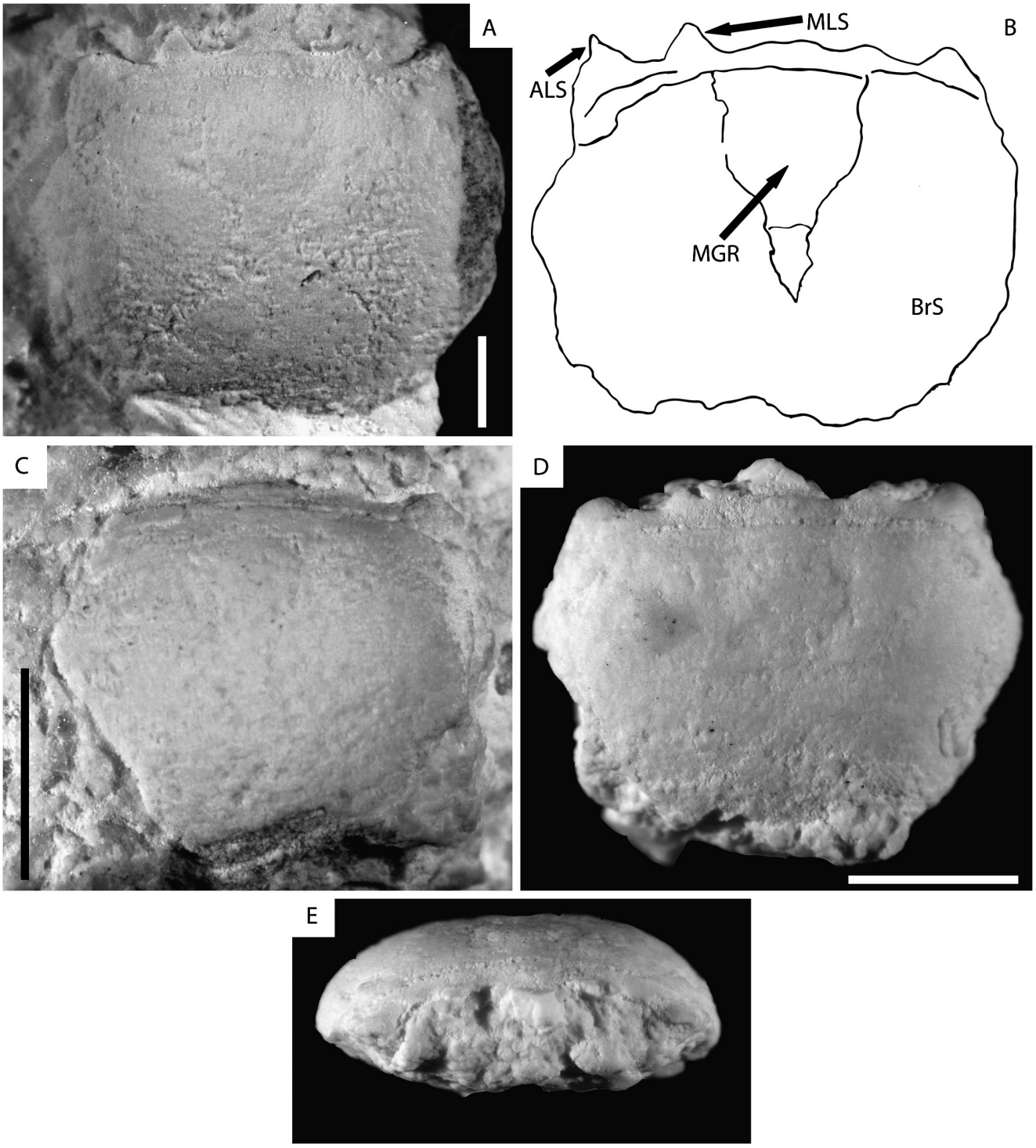

Fig. 1. *Sosiocaris schrami* new genus, new species. A, holotype MSNC 4493; B, explanatory line drawing of A; C, paratype MSNC 4494; D, paratype MSNC 4495, dorsal view; E, frontal view. ALS, anterolateral spine; MLS, mesolateral spine; MGR, mesogastric region; BrS, branchiostegite. Scale = 3 mm.

Sosiocaris schrami n. sp.
Fig. 1A-E

Diagnosis.—Pygocephalomorph with axially shortened carapace. Rostrum weak or absent. Anterolateral and mesolateral frontal spines distinct. Frontal region depressed. Lacking medial and gastric carinae. Lacking carinate ornamentation in branchial region. Lateral carapace margins smooth. Mesogastric region well developed. Hepatic region and branchiostegites moderately developed.

Description.—Carapace axially shortened, slightly wider than long (5.0-6.8 mm axial length excluding frontal spines, 6.0-8.8 mm maximum width). Broadly and weakly pyri-

form in outline. Broadening slightly from wide frontal margin, reaching maximum width at approximately 1/4 of axial length posterior to frontal margin, and tapering gradually to slightly rounded posterior margin, approximately 3/4 maximum width. Frontal margin slightly depressed, with strong spine on anterolateral corners, and mesolateral frontal spines approximately 1/3 the length of anterolateral spines. Frontal region demarcated by prominent line, slightly posterior to the frontal margin. Rostrum weak. Mesogastric region prominent, demarcated by a groove remaining constant in width and occupying slightly less than 1/3 the width of the dorsal carapace for approximately 1/2 of its axial length. Groove demarcating mesogastric region tapering abruptly at the approximate mid-point of the dorsal carapace to a blunt posteriorly directed termination. Branchiostegites moderately vaulted, not defined by a medial groove or ridge. Pleon and appendages not preserved.

Etymology.—The species name is in honor of Dr. Frederick Schram, whose contributions to Paleozoic crustacean biology are innumerable.

Types.—Holotype MSNC 4493, paratypes MSNC 4494, 4495.

Remarks.—The three specimens attributed to *S. schrami* are preserved as molds of the interior of the dorsal carapace in white, friable, micritic limestone (Fig. 1A-E). The sediment that comprises the specimens appears to lack the crystalline vuggy infills characteristic of the surrounding matrix. Resulting from the moldic preservation of the specimens, carapace groove patterns and regionalization of the dorsal carapace are probably more weakly expressed than they would be if the specimens included preserved cuticle. As such, we hypothesize that if the carinate ornamentation typical of *J. grandis*, and of the tealliocarids, were present on *S. schrami* during life, it would have been reflected in the dorsal morphology of the specimens here described.

DISCUSSION

Phylogenetic Analysis

Preliminary phylogenetic analyses of the Sosio specimens were attempted by coding the specimens into the character matrix of Taylor et al. (1998), which included fossil and extant mysids, lophogastrids, and pygocephalomorphs, and running the analyses in PAUP* 4.0 beta (Table 1). Analyses were conducted using all taxa from the character matrix of Taylor et al. (1998) and a hypothetical ancestor as the outgroup; only the pygocephalomorph species from the Taylor et al. (1998) matrix with a hypothetical ancestor as the outgroup; and only the pygocephalomorphs from the Taylor et al. (1998) matrix with *Lophogaster intermedius* as the out-group, and with *L. intermedius* and *Mysis flexuosa* as out-groups. Because the resultant topologies were poorly resolved and inconsistent, we deceided no trees from the preliminary analyses need be included here. Despite this, the Sosio specimens nearly always resolved in a clade with the other taxa generally included in Pygocephalomorpha, although their position within Pygocephalomorpha was not consistent between analyses. This, at the very least, suggests to us that Pygocephalomorpha *incertae sedis* is an appropriate assignment for the Sosio specimens pending discovery of new specimens, and a much needed restudy of taxa included in Pygocephalomorpha.

Evolutionary Implications

The dorsal carapace morphology and frontal carapace region of *S. schrami* are rather convergent to that of eubrachyurans (higher true crabs), to such an extent that Jones et al. (2015) interpreted *S. schrami* to be the first Paleozoic eubrachyuran. Carcinization, or convergent evolution of crab-like morphology, is a well-known phenomenon in decapods, with crab-like morphology having evolved (apparently) independently in brachyurans, lithodids, aeglids, pagurids, hippids, porcellanids, and galatheids to varying degrees (McLaughlin and Lemaitre, 1997; Feldmann and Schweitzer, 2010). Carcinized morphology represents a plexus of characters allowing brachyurans and some anomurans to move laterally, utilize cryptic habitats, and carry the chelipeds in a frontal position (Feldmann and Schweitzer, 2010). Note that there is no evidence for hypertrophied chelipeds in pygocephalomorphs.

Carcinization has also been recognized in pygocephalomorphs. The most pronounced carcinized morphology seems to be present in the notocarid and "pygaspid" pygocephalomorphs, which exhibit a markedly axially shortened carapace, with or without an anteroventrally reflexed pleon (Brooks, 1962; Kensley, 1975; Pinto and Adami-Rodrigues, 1996; Piñeiro et al., 2012). An anteroventrally reflexed pleon has also been recognized in species of *Pygocephalus* Huxley, 1857 and in species of *Anthrapalaemon* Salter, 1861. Whether or not the pleon was consistently reflexed, and the systematic implications of pleonal flexure are not entirely clear. This reflects a desperate need for an overall revision of the pygocephalomorphs based on detained restudy of the type material (Pinto and Adami-Rodrigues, 1996; Piñeiro et al., 2012; Pinto and Würdig, 2014).

Evidence of brachyuran-like behavior in pygocephalomorphs has also been interpreted from trace fossils. Schram (1974b) recognized a trace attributed to *Notocaris tapscotti*, from the Late Permian Dwyka Shale, Karoo Basin, South Africa, to represent sideways walking, a distinctly brachyuran behavior, or even that of spiny lobsters. Melchor and Cardonatto (2014) recently described trackways and associated resting traces from the Late Carboniferous Agua Escondida Formation of Argentina, some of which appear to represent sideways walking (Melchor and Cardonatto, 2014, Fig. 7A-D; 8A, B). These trackways were considered to probably

Table 1. Character states for *Sosiocaris schrami*, using the characters of Taylor et al. (1998).

0	5	10	15	20	25	30	33
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correspond to behavior of a pygocephalomorph similar to *Notocaris* spp. (Melchor and Cardonatto, 2014). As such, at least some evidence exists that carcinized morphology in pygocephalomorphs could have corresponded to brachyuran-like behavior.

It appears that carcinization was a relatively common evolutionary trend in the pygocephalomorphs, and *S. schrami* seems to follow this trend, although the pleon is not preserved. We suggest, pending much needed advances in pygocephalomorph paleobiology, that some pygocephalomorphs might have exhibited life habits similar to those of some brachyurans, although many pygocephalomorphs, such as some pygocephalids and tealliocarids, apparently occupied freshwater or brackish environments (Schram, 1981; Hotton et al., 2002; Piñeiro et al., 2012).

Conclusions

Sosiocaris schrami represents the first record of the pygocephalomorph peracarids from the Permian Sosio Limestone of Sicily. The overall brachyuran-like carapace morphology of *S. schrami*, as well as the brachyuran-like carapace form and reflexed pleon of notocarids, and at least some pygocephalids, suggests that carcinization, or convergent evolution of brachyuran-like morphology, was a relatively common trend in pygocephalomorphs, and, thus, not restricted to the decapods. We suggest that carcinized pygocephalomorphs could have exhibited life habits similar to those of brachyurans.

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