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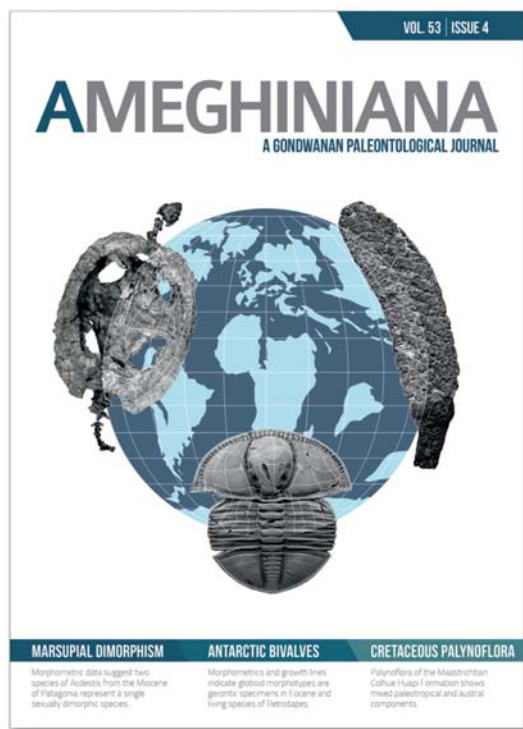


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THE "METACRYPHAEUS TUBERCULATUS GROUP" (TRILOBITA, CALMONIIDAE) FROM THE DEVONIAN OF THE PARNAÍBA BASIN, BRAZIL

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THE “*METACRYPHEAEUS TUBERCULATUS* GROUP” (TRILOBITA, CALMONIIDAE) FROM THE DEVONIAN OF THE PARNAÍBA BASIN, BRAZIL

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Abstract. Calmonioid trilobites of the “*Metacryphaeus tuberculatus* group” occur in many Devonian localities within the Malvinokaffric Realm. In the Parnaíba Basin, in northeastern Brazil, the group is represented by *Metacryphaeus tuberculatus* Kozłowski, 1923, and *M. meloi* Carvalho, Edgecombe and Lieberman, 1997, from the late Eifelian–early Givetian Pimenteira Formation in the environs of the city of Picos and the early Givetian Passagem Member (Pimenteira Formation) from the vicinities of Picos and Pimenteiras in Piauí State. Based on specimens found in the region of João Costa, southeastern Piauí State, the present study reinforces data on the occurrence of *M. tuberculatus* in the Pimenteira Formation and reports the presence of genal spines in some individuals of *M. meloi*, indicating a feature previously unknown for this species.

Key words. *Metacryphaeus tuberculatus*. *Metacryphaeus meloi*. Pimenteira Formation. Devonian. Parnaíba Basin.

Resumen. EL “GRUPO *METACRYPHEAEUS TUBERCULATUS*” (TRILOBITA, CALMONIIDAE) DEL DEVÓNICO DE LA CUENCA DEL PARNAÍBA, BRASIL. Los trilobites calmónidos del “grupo *Metacryphaeus tuberculatus*” se producen en diversas localidades del Devónico en el Dominio Malvinocáfrico. En la Cuenca del Parnaíba, en el noreste de Brasil, el grupo está representado por las especies *Metacryphaeus tuberculatus* Kozłowski, 1923, y *M. meloi* Carvalho, Edgecombe and Lieberman, 1997, la primera del Eifeliano tardío–Givetiano temprano de la Formación Pimenteira en el área de la ciudad de Picos, y la segunda del Givetiano temprano del Miembro Passagem (Formación Pimenteira), de las proximidades de las ciudades de Picos y Pimenteiras, en el Estado del Piauí. El presente estudio refuerza la presencia de *M. tuberculatus* en la Formación Pimenteira basado en especímenes encontrados en la región de la ciudad de João Costa, en el sureste del Estado de Piauí, e informa la presencia de espinas genales en algunos individuos de *M. meloi*, indicando una característica previamente desconocida para esta especie.

Palabras clave. *Metacryphaeus tuberculatus*. *Metacryphaeus meloi*. Formación Pimenteira. Devónico. Cuenca del Parnaíba.

THE genus *Metacryphaeus* Reed, 1907, is the most typical taxon of the calmonioid trilobites, with several species occurring in Devonian deposits in many localities of South America and South Africa. In Brazil, the genus is extensively known from the Paraná Basin by way of the species *Metacryphaeus australis* Clarke, 1913. A second species, *M. rotundatus* Kozłowski, 1923, originally recorded from Bolivia, was recently added to the list of *Metacryphaeus* species in this basin (Soares *et al.*, 2008). In the Parnaíba Basin, located in northeastern Brazil, the species *M. kegei* Carvalho, Edgecombe

and Lieberman, 1997, and *M. meloi* Carvalho, Edgecombe and Lieberman, 1997, occur in the Pimenteira Formation and, additionally, rare fragments of an indeterminate species of *Metacryphaeus* were collected from the Longá Formation (Carvalho, 1995). Claims that *M. tuberculatus* Kozłowski, 1923 –formerly known from Bolivia– was also present in the Parnaíba Basin were raised by Lieberman *et al.* (1991) and Lieberman (1993), based on a specimen found in the Pimenteira Formation in the area of Picos city in eastern Piauí State. The presence of *M. tuberculatus* in the

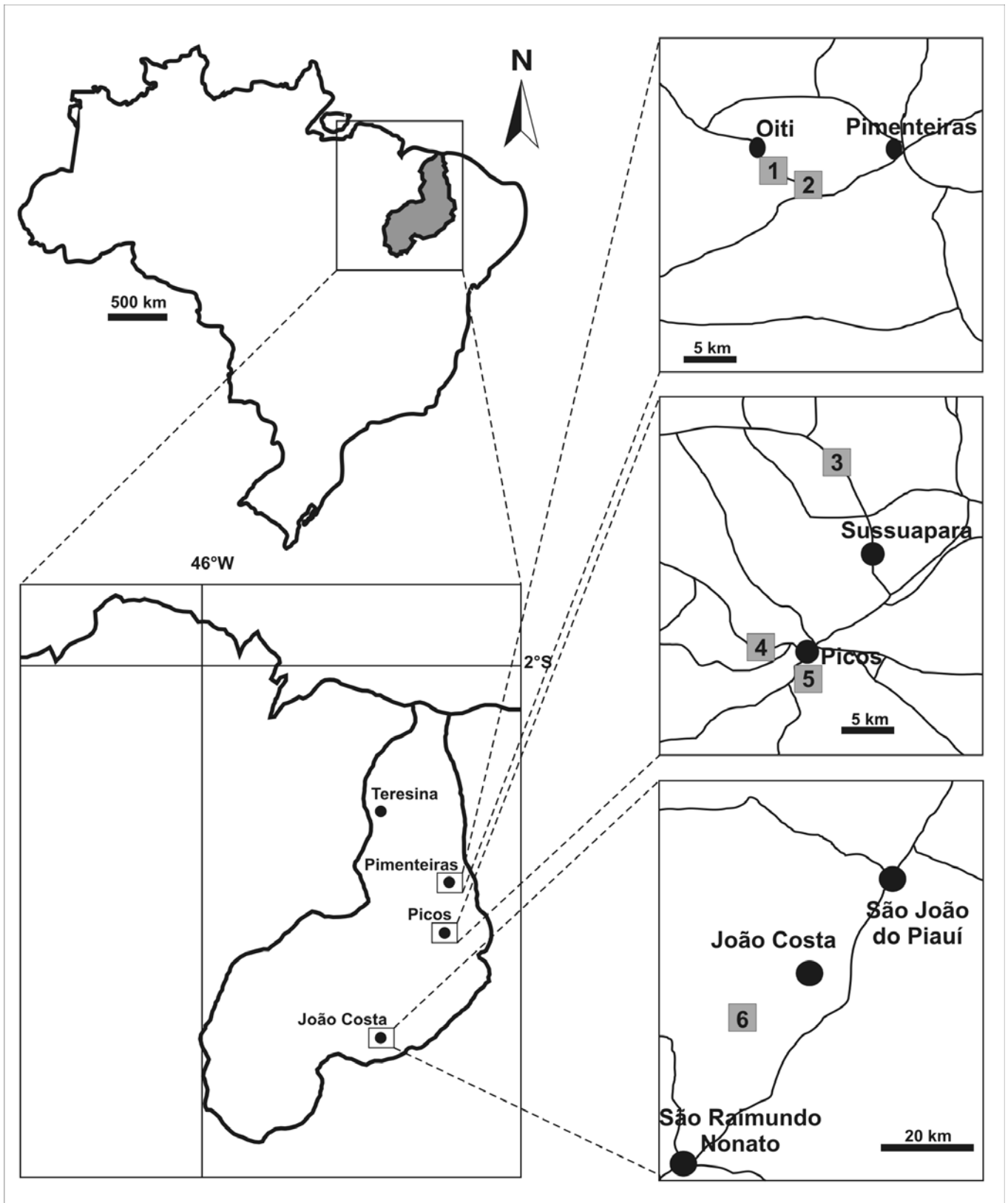


Figure 1. Areas of documented occurrences of *Metacryphaeus meloi* (1–4) and *Metacryphaeus tuberculatus* (5, 6) in Piauí State, northeastern Brazil. 1, Rio Banguê, Pimenteiras city (Ponciano *et al.*, 2012a). 2, Oiti, Pimenteiras city, 3, Barreiro Branco, Sussuapara city, 4, km 305 of BR 316 road, Picos city (Carvalho *et al.*, 1997; Ponciano *et al.*, 2012a), 5, 2 km south of Picos city (Lieberman *et al.*, 1991), 6, São João Vermelho, João Costa city (present work). Modified from Ponciano *et al.* (2012a,b).

Parnaíba Basin was subsequently questioned by Carvalho *et al.* (1997), who questioned the provenance of the specimens.

The present study provides some new information concerning the members of the "*Metacryphaeus tuberculatus* group" (Lieberman, 1993) from the Pimenteira Formation. With the discovery of specimens ascribed to this taxon from the São João Vermelho village, in João Costa city, south-eastern Piauí State, the study herein presented endorses the claims that *M. tuberculatus* is present in the Pimenteira Formation and reports the presence of genal spines in some specimens of *M. meloi*, a feature not previously known for this species.

The occurrences of *M. meloi* cover different areas of eastern Piauí State. *Metacryphaeus tuberculatus* is known only from the Picos and João Costa areas (Fig. 1).

GEOLOGICAL SETTING

The Middle Devonian to early Carboniferous interval in the Parnaíba Basin is represented by part of the Canindé Group; namely, the Pimenteira, Cabeças and Longá formations.

The Parnaíba sedimentary basin corresponds to the south-central portion of the Meio Norte sedimentary Province (Góes, 1995), also known as Parnaíba Province (Almeida *et al.*, 1977). The province is bounded to the north by the Vicente Ferrer-Urbano Santos-Guamá Arc; to the east, by the Taua fault; to the southeast, by Senador Pompeu lineament; to the west, by the Tocantins-Araguaia Basin lineament; and to the northwest, by the Tocantins Arc (Góes, 1995).

The Pimenteira Formation, dated between the late Eifelian and the early Givetian on the eastern flank of the Parnaíba Basin (Melo, 1985; Grahn *et al.*, 2006) but extending from the late Eifelian to the early Famennian in the central portion and on the western flank (Grahn *et al.*, 2006, 2008), contacts with both the underlying Itaim Formation and the overlying Cabeças Formation (Vaz *et al.*, 2007). Its lithology, representing shallow storm-dominated platform environments (Della Fávera, 1990), consists of rhythmites of fine sandstones with hummocky cross-stratification and bioturbated pelites (Vaz *et al.*, 2007; Fonseca and Ponciano, 2011). The variety of fossils therein recorded includes many invertebrates (brachiopods, bivalves, gastropods, tentaculitids, trilobites, crinoids, conularids, ostracods and

hyolithids), vertebrates (chondrichthyans and acanthodians) and plants (Kegel 1953; Melo, 1985; Fonseca and Melo, 1987; Carvalho, 1995; Caputo *et al.*, 2005). According to Melo (1988), in the range of outcrops located east of the basin, the fossiliferous horizons occur mainly at the base of sandstones with hummocky cross-stratification associated with intraclasts of clay or quartz pebbles and within ferruginous concretions located on the top of the outcrop section.

The Passagem Member corresponds to a proximal facies of the upper Pimenteira Formation cropping out on the eastern flank of the Parnaíba Basin and dated as Givetian based on its invertebrate macrofossils (Melo, 1988). It mainly consists of fine sandstones with asymptotic and hummocky cross-stratification, with subordinate siltstone interbeds. Fossils consist of invertebrates (brachiopods, bivalves, gastropods, trilobites, crinoids and tentaculitids) and plants occurring in yellowish to purplish, very micaceous fine-grained sandstones interbedded with siltstone and conglomeratic sandstones (Fonseca and Ponciano, 2011).

Initially proposed as the basal unit of the Cabeças Formation (Plummer, 1948), Beurlen (1965) observed this unit to grade laterally into facies typical of the upper Pimenteira Formation in the Picos region. Recent studies have confirmed Beurlen's (1965) statement (Breuer and Grahn, 2011; Ponciano *et al.*, 2012a).

MATERIALS AND METHODS

The studied material consists of external and internal molds preserved in sandstones and concretions. The specimens are housed at the Fundação Museu do Homem Americano (FUNDHAM), São Raimundo Nonato, Brazil; the Museu de Ciências da Terra of the Departamento Nacional de Produção Mineral (MCT-DNPM), Rio de Janeiro, Brazil; the American Museum of Natural History (AMNH) New York, USA; the Instituto de Geociências of the Universidade Federal do Rio de Janeiro (IG-UFRJ), Rio de Janeiro, Brazil; and the Museu Paraense Emílio Goeldi (MPEG), São Braz, Brasil.

The systematic review of the material followed the criteria and morphological terminology used in Harrington *et al.* (1959), Eldredge and Braniša (1980), Lieberman *et al.* (1991), Lieberman (1993) and Whittington *et al.* (1997). For photographs, some samples were coated with magnesium oxide in order to highlight details (Fig. 2.2–3).

Abbreviations. *sag*, sagittally; *exsag*, exsagittally; *tr*, transversally; **L1**, first lateral glabellar lobe; **L2**, second lateral glabellar lobe; **L3**, third lateral glabellar lobe; **S0**, occipital furrow; **S1**, first lateral glabellar furrow; **S2**, second lateral glabellar furrow; **S3**, third lateral glabellar furrow.

SYSTEMATIC PALEONTOLOGY

Order PHACOPIIDA Salter, 1864

Family CALMONIIDAE Delo, 1935

Subfamily CALMONIINAE Delo, 1935

Genus *Metacryphaeus* Reed, 1907

Type species. *Metacryphaeus caffer* Salter, 1856.

Metacryphaeus tuberculatus Kozłowski, 1923

Figure 2.1–5

1923 *Cryphaeus australis* var. *tuberculatus* Kozłowski; p. 43, pl. 3, figs. 20–21.

?1923 *Cryphaeus australis* Kozłowski; p. 43, pl. 3, fig. 7.

1965 *Metacryphaeus caffer* Branišić; p. 106, pl. 21, fig. 14.

1965 *Metacryphaeus caffer* var. n. Branišić; p. 106, pl. 21, fig. 16.

1968 *Metacryphaeus tuberculatus* Wolfart; p. 102, pl. 17, fig. 17, pl. 18, fig. 1.

1991 *Metacryphaeus tuberculatus* Lieberman *et al.*; p. 825–827, fig. 1.1–6, 1.8–9, 1.11–13.

1993 *Metacryphaeus tuberculatus* Lieberman; p. 562, fig. 2.11.

Diagnosis (Lieberman, 1993 p. 562). Coarsely tuberculose prosopon, broad and triangular extension of cephalic anterior border beyond glabella; rounded frontal lobe; deep, broad, strongly divergent cephalic axial furrows.

Examined material. FUMDHAM 197602; AMNH 63283.

Geographic and stratigraphic provenance. Late Eifelian to early Givetian. Pimenteira Formation at São João Vermelho village, João Costa city, southeastern Piauí State; also from 2 km south of Picos city, eastern Piauí State, Brazil.

Description (FUMDHAM 197602). Cephalon with subtriangular outline, length (*sag*) of about 55% of the width (*tr*). Anterior margin with moderate convexity. Lateral margins slightly convex. Posterior border furrow straight and broad

(*exsag*), with the same length (*exsag*) as the occipital furrow. Narrow occipital ring (*sag*, *exsag*) medially vaulted forward. Cephalon covered by small tubercles.

L1 narrow (*exsag*), crescentic, curved backward, in contact with the axial furrows. L2 wider (*exsag*), crescent in shape and curved backward. L3 straight, broadening abaxially. Frontal lobe extended laterally, with subrhomboidal outline and length (*sag*) of about 60% of glabellar length. Axial furrows broad.

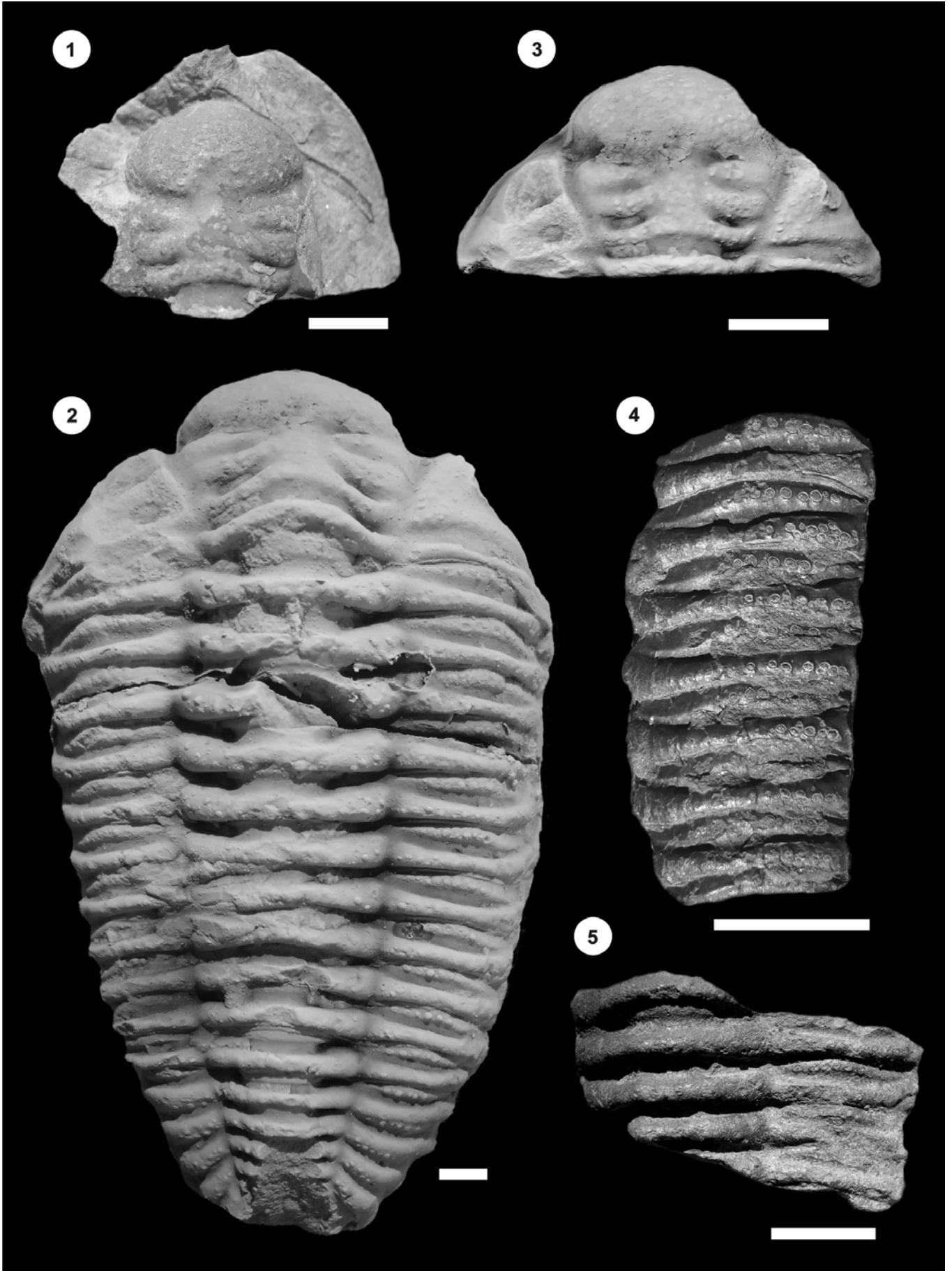
S0 wide (*sag*, *exsag*), in contact with axial furrows, bearing apodemal pits close to the limit with axial furrows. S1 crescent in shape, with apodemal pits. S2 shallow, slightly vaulted posteriorly, in contact with axial furrows. S3 broad (*exsag*), oblique and straight, in contact with axial furrows.

Thorax composed of 11 segments. Axial rings with width (*tr*) of about 40% of the maximum breadth of thoracic segments. Axial rings with width (*sag*, *exsag*) constant through their extension, with slight bulging abaxially. Pleurae with deep and broad pleural furrows. Anterior pleural band slightly elevated, bearing a row of small tubercles well delineated on the surface. Posterior pleural band wider (*exsag*) and more elevated, with a row of less conspicuous but larger tubercles on it. On the axial rings, tubercles are only observed abaxially.

Pygidium with the first axial rings arched forward; this curving decreases toward the posterior rings. Axial rings with constant width (*sag*, *exsag*) through their extension, widening abaxially. Apodemal pits present abaxially on the ring furrows. Pleural ribs narrowing adaxially. Pleural rib tips slightly vaulted forward in the first ribs; the curvature increases along the posterior ribs.

Discussion. The occurrence of *M. tuberculatus* in the Pimenteira Formation was proposed by Lieberman *et al.* (1991) and Lieberman (1993). The authors based such claim on a specimen (Fig. 2.1) recovered 2 km south of Picos city, eastern Piauí State. The specimen differs from the Bolivian

Figure 2. 1–5, *Metacryphaeus tuberculatus*. Specimens collected from 2 km south of Picos (1) and from São João Vermelho (2–5). 1, cephalon in dorsal view, AMNH 063283; 2, 3, articulated specimen with cephalon, thorax and pygidium and detail of cephalon in dorsal view, FUMDHAM 197602; 4, fragment of thoracic pleurae in dorsal view, FUMDHAM collection (no identification number); 5, thoracic segments in dorsal view, FUMDHAM collection (no identification number). Scale bars= 1 cm.



M. tuberculatus only in presenting longer (exsag) lateral glabellar lobes L3 and eyes closer to the genal margin (Lieberman *et al.*, 1991). Carvalho (1995, 1999) and Carvalho *et al.* (1997) questioned the origin of the specimen alleging that the concretion where it is preserved differs from what is known for the Pimenteira Formation. The comparison of this sample with concretions containing fossils of the homalonotid *Burmeisteria notica* (Clarke, 1913) from the Pimenteira Formation from Picos city, housed at the Instituto de Geociências of the Universidade de São Paulo (IG-USP), São Paulo, Brazil (GP-1E 3/543, GP-1E 4971, GP-1E 5016), reveals similarities in color and overall aspect. Such correspondence indicates that the *M. tuberculatus* sample of Lieberman *et al.* (1991) from the Pimenteira Formation might belong to this unit.

Additionally, the analysis of samples from the Pimenteira Formation in the area of João Costa, southeastern Piauí State (Fig. 2.2–5), suggests they may belong to *M. tuberculatus*. Such claim is based on the fact that the samples exhibit some characteristics typical of *M. tuberculatus*; most notably, the prosopon of coarse tubercles and the broad and strongly divergent cephalic axial furrows. These specimens from the southeastern Piauí State reinforce previous reports on this species in the Parnaíba Basin (Lieberman *et al.*, 1991; Lieberman, 1993).

Metacryphaeus meloi Carvalho, Edgecombe and Lieberman, 1997
Figure 3.1–5

- 1968 *Metacryphaeus australis* Castro; p. 485, pl. 3, figs. 2–5.
1987 *Metacryphaeus cf. australis* Caldas *et al.*; p. 539, photography 1–3.
1994 *Metacryphaeus meloi* Carvalho *et al.*; p. 119 (*nomen nudum*).
1997 *Metacryphaeus meloi* Carvalho *et al.*; p. 6–9, fig. 3A–G.
?2013 *Metacryphaeus cf. australis* Leme *et al.*; p. 19, fig. 3G.

Emended diagnosis. Cephalon subtriangular, with short anterior median process; glabella densely covered with small,

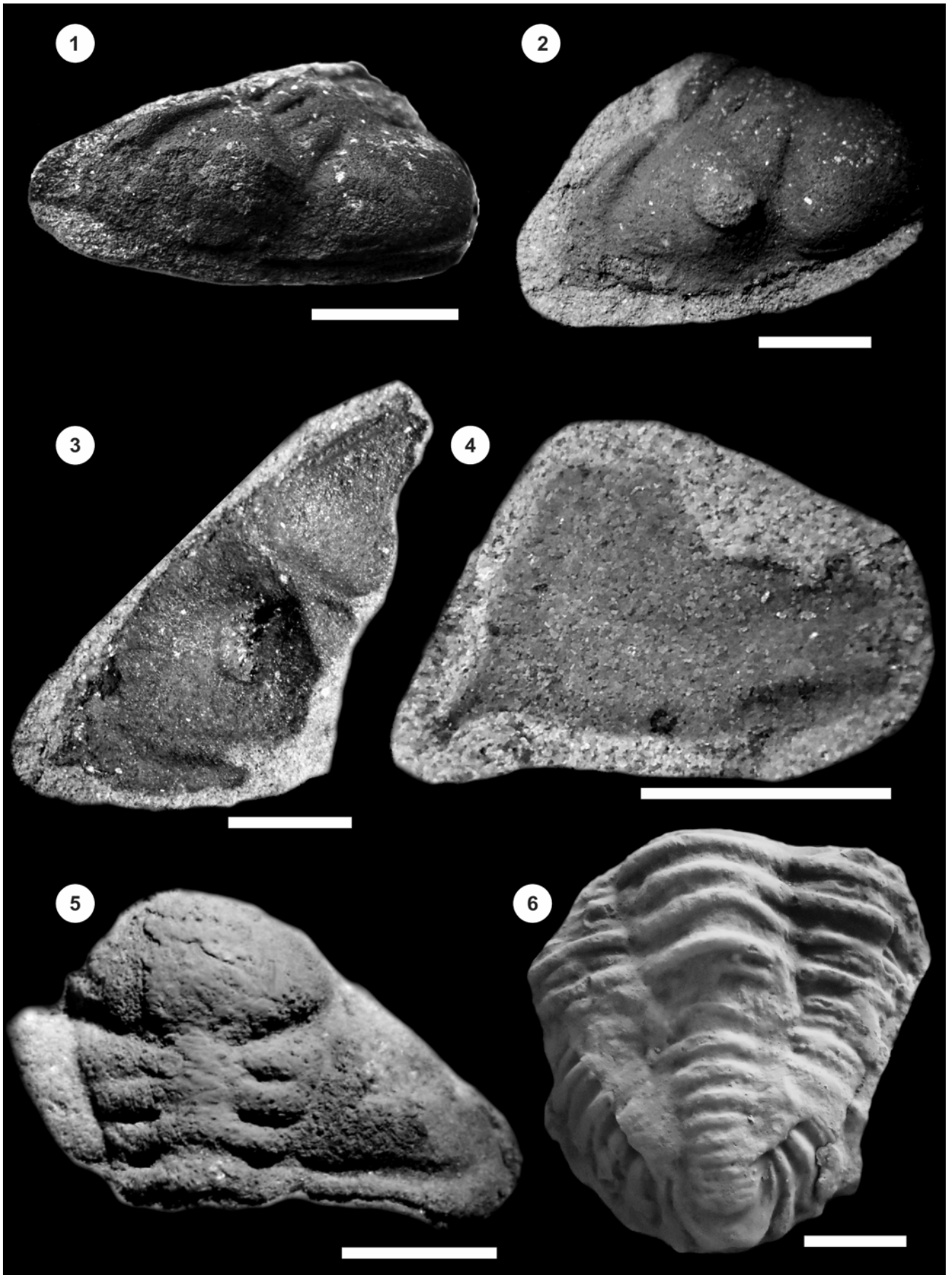
relatively subdued tubercles; genal angles bearing a triangular spine, not parallel to the lateral border, standing outward from the gena; eyes distinctly separated from axial furrows, moderately oblique (exsag). Pygidial pleurae terminate as blunt spines; axial rings convex forward medially.
Examined material. MCT-DNPM (5009, 5012, 6153, 6155); FUMDHAM 169046; AMNH 63283; MPEG (1270-I, 1271-I, 1273-I, 1275–1302-I); IG-UFRJ (37–39-Tr, 41–48-Tr, 55–58-Tr).

Geographic and stratigraphic provenance. Early Givetian of Passagem Member, Pimenteira Formation in the vicinities of Oiti village, Pimenteirias city, eastern Piauí State (type locality of the Passagem Member); also at km 305 of BR 316 road, close to Picos city and near Barreiro Branco village, Sussuapara city, eastern Piauí State; and possibly from the late Eifelian–early Givetian of Pimenteira Formation in São João Vermelho village, João Costa city, southeastern Piauí State, Brazil.

Discussion. *Metacryphaeus meloi* is included in the “*Metacryphaeus tuberculatus* group” (Lieberman, 1993) based on the presence of exoskeletal tuberculation, a triangular anterior median process extending beyond the glabella, a rounded glabellar frontal lobe and the anterior edge of the eyes displaced from the axial furrow (Carvalho *et al.*, 1997). *Metacryphaeus meloi* shares most of its characteristics with *M. tuberculatus*, its closest relative. Nevertheless, *M. meloi* is differentiated by its less inflated frontal glabellar lobe, its narrower cephalic axial furrows, its less conspicuous tubercles on the cephalon and its less defined lateral glabellar lobes (Carvalho *et al.*, 1997). Carvalho *et al.* (1997) also drew attention to the pygidial axial rings vaulted forward medially in *M. meloi*. Yet, this feature is also present in a pygidium illustrated in Braniša (1965, pl. 21, fig. 14) and attributed to *M. tuberculatus* by Lieberman (1993, p. 562).

The presence of genal spines in some specimens, including a paratype housed at the Instituto de Geociências of the Universidade Federal do Rio de Janeiro (IG-UFRJ) (Fig.

Figure 3. 1–5, *Metacryphaeus meloi*; specimens collected from km 305 of BR 316 road in Picos (1–4) and from Barreiro Branco (5); 1, cephalon in oblique view, IG-UFRJ 48-Tr; 2, cephalon in lateral view, MPEG 1271-I; 3, cephalon fragment in ventral view, MPEG 1271-I (external mold of 3.2); 4, gena fragment in ventral view, MPEG 1271-I; 5, cephalon in dorsal view, MPEG 1297-I. 6, *Metacryphaeus cf. meloi*; specimen collected from São João Vermelho; thoracopygidium in dorsal view, FUMDHAM 169046. Scale bars= 1 cm.



3.1–4), adds a previously undescribed feature to the diagnosis of *M. meloi*. The genal spine, which stands outward from the gena and not parallel to the lateral border, is triangular.

The morphology of the genal spine is quite similar to that illustrated in *M. caffer* Salter, 1856 by Cooper (1982, fig. 61).

Carvalho *et al.* (1997) observed variations in the convexity of the frontal lobe (sag) and in the depth of the posterior median impression (PMI) incision and then attributed these features to intraspecific variation. The wider genae in two specimens, with length of glabella/width of cephalon ratios of about 42% and 48% (Fig. 3.5), is herein suggested to be an additional intraspecific variation of *M. meloi*. These values differ from the 55% ratio observed by Carvalho *et al.* (1997).

Specimen FUMDHAM 169046 (Fig. 3.6) from the Pimenteiras Formation at João Costa is hereby tentatively ascribed to *M. meloi* based on the shape of the terminal lappet, the posterior pleural rib tips curved backwards and the absence of tubercles. This finding may indicate a new occurrence for this taxon which is currently known from the eastern area of Piauí State in the region of Picos city and the villages of Oiti and Barreiro Branco. However, additional better preserved specimens are required to confirm this occurrence.

METACRYPHEAEUS TUBERCULATUS FROM PIMENTEIRAS FORMATION

The presence of *Metacryphaeus tuberculatus* in the late Eifelian–early Givetian Pimenteiras Formation of the Parnaíba Basin claimed by Lieberman *et al.* (1991) and Lieberman (1993) is substantiated by the discovery of samples herein attributed to this species from São João Vermelho village, in João Costa city, southeastern Piauí State. These samples include an articulated specimen (FUMDHAM 197602, Fig. 2.2–3) presenting tubercles on the exoskeleton and broad, well divergent axial furrows.

The Parnaíba Basin yields the greatest diversity of *Metacryphaeus* species among Brazilian basins and most of such diversity was recovered from the Pimenteiras Formation. In addition to *M. tuberculatus* and *M. meloi*, this unit also includes *M. kegei* from the region of Pimenteiras (Kegel, 1953; Carvalho *et al.*, 1997) and Picos (Ponciano *et*

al., 2012b) cities, eastern Piauí State. Both *M. kegei* and *M. meloi* are exclusive of the Parnaíba Basin. Besides these Pimenteiras Formation occurrences, rare samples attributed to *Metacryphaeus* sp. were found at the base of the Longá Formation, of Famennian age (Carvalho, 1995).

In an inventory of the paleontologically important sites of the Pimenteiras Formation in the Piauí State, Ponciano *et al.* (2012b) included São João Vermelho among the most relevant areas for paleontological studies. The presence of *M. tuberculatus* in this locality increases its importance for future field work. Furthermore, the confirmation of the fact that *M. meloi* is present in deposits of São João Vermelho would indicate a new occurrence for this species therefore suggesting overlapping geographic ranges of *M. meloi* and *M. tuberculatus*. Also, it would record a different preservation mode for *M. meloi* marked by concretions in finer sediments. In contrast, molds preserved in sandier sediments are typical of the Passagem Member.

The occurrence of *Metacryphaeus tuberculatus* in the Parnaíba Basin suggests a connection between this basin and Bolivia, where the taxon is present in Early to Middle Devonian strata (Wolfart, 1968; Lieberman, 1993). This connection may not have happened prior to the Eifelian for chitinozoans typical of the Paraná Basin, the most likely seaway between Bolivia and Parnaíba, were not present in the latter locality during the Early Devonian (Lange, 1967).

THE “METACRYPHEAEUS TUBERCULATUS GROUP”

Members of the “*Metacryphaeus tuberculatus* group” (Lieberman, 1993) include *Metacryphaeus tuberculatus* from Bolivia and the Parnaíba Basin, *M. meloi* from the Parnaíba Basin, *M. australis* from the Paraná Basin, *M. allardyceae* Clarke, 1913, from West Falkland Island and *M. caffer* from South Africa and, possibly, the Falkland Islands (Carvalho, 2006). All the representatives of this group were extant contemporaneously except for *M. allardyceae*, which appeared and vanished before the other *tuberculatus* occurrences (Lieberman, 1993). These species exhibit great similarities with each other and only differ in subtle aspects (Cooper, 1982; Edgecombe, 1994). Criteria usually used to differentiate the species of this group are the position of the eyes relative to the axial furrows, the shape and extension of pygidial marginal lappets (Lieberman *et al.*, 1991; Edgecombe,

1994) and the size of the eyes, which is measured by means of the Large Eye Index (Lieberman *et al.*, 1991). In this concern, *M. australis* from the Paraná Basin is readily differentiated from *M. tuberculatus* by its larger eyes immediately adjacent to the axial furrows and its longer and blade-like pygidial lappets (Lieberman *et al.*, 1991). In contrast, there have been some controversies regarding the differentiation between *M. tuberculatus*, *M. caffer* and *M. allardyceae*. Based on the great similarity between the cephalon, Cooper (1982) considered that *M. tuberculatus* and *M. caffer* are probably conspecific. Lieberman *et al.* (1991) kept *M. tuberculatus* and *M. caffer* as separate taxa yet admitted that differences between them are slight. Edgecombe (1994) noted that *M. allardyceae* is very similar to *M. tuberculatus* and that the only aspect in which they differ is in the more triangular antero-median process in *M. allardyceae*.

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