



Upper Marianian (Cambrian Series 2) trilobites from the Totanés–Noez area (Central Iberian Zone, Toledo province, Spain): systematics and intercontinental correlation

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Abstract

Marianian (Cambrian Series 2) trilobites from the area between Totanés and Noez (Central Iberian Zone) are described and their biostratigraphical significance is discussed. The trilobites come from eight localities and can be divided into two main assemblages: the first is characterised by *Serrodiscus bellimarginatus*, *Chelediscus* cf. *garzoni*, *Atops calanus*, *Pseudatops reticulatus* and indeterminate polymeroid trilobites. The second assemblage consists of *Serrodiscus bellimarginatus*, *Triangulaspis* cf. *fusca*, *Andalusiana palaciosi* n. sp., *Termierella totanesensis* n. sp. and *Acanthomicmacca* sp. Both fossil associations indicate a late Marianian age in the regional stratigraphic scheme for the Cambrian of the Iberian Peninsula, as *Serrodiscus*, *Chelediscus* and *Pseudatops* have been recorded from the upper Marianian substage, while *Triangulaspis*, *Andalusiana*, *Termierella* and *Acanthomicmacca* are indicative of the middle to upper Marianian. The taxa considered here have regional and intercontinental correlation potential. The presence of the globally distributed genus *Serrodiscus* allows correlation in the Cambrian Series 2. The first assemblage, composed of *Serrodiscus*, *Chelediscus*, *Atops* and *Pseudatops*, has been reported from the Ossa-Morena Zone, Avalonia, Laurentia, Baltica and Siberia, improving the correlation between these regions. The second assemblage of *Andalusiana*, *Termierella*, *Triangulaspis* and *Serrodiscus* is comparable to other assemblages from the Ossa-Morena Zone, the Iberian Chains and Morocco, with *Triangulaspis* also reported from Newfoundland and Siberia. In addition, the proposal of the ISCS regarding the co-occurrence of *Hebediscus*, *Calodiscus*, *Serrodiscus* and *Triangulaspis* as a potential marker for the base of the Cambrian Stage 4 may imply that the upper Marianian of Iberia could be approximately correlated with the base of this stage.

Keywords Trilobites · Biostratigraphy · Systematic palaeontology · Upper Marianian · Cambrian Stage 4 · Central Iberian Zone (Toledo, Spain)

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Resumen

Se describen por primera vez los trilobites del área de Totanés–Noez (Zona Centroibérica) y se analiza su significado bioestratigráfico. Los ejemplares se han recolectado en ocho localidades y se pueden agrupar en dos asociaciones principales: la primera está caracterizada por *Serrodiscus bellimarginatus*, *Chelediscus* cf. *garzoni*, *Atops calanus*, *Pseudatops reticulatus* y trilobites polímeros indeterminados. La segunda asociación está compuesta por *Serrodiscus bellimarginatus*, *Triangulaspis* cf. *fusca*, *Andalusiana palaciosi* n. sp., *Termierella totanesensis* n. sp. y *Acanthomicmacca* sp. Las dos asociaciones indican una edad Marianiense superior en el esquema de pisos regionales de la Península Ibérica, tal y como indican la presencia de *Serrodiscus*, *Chelediscus* y *Pseudatops*, mientras que *Triangulaspis*, *Andalusiana*, *Termierella* y *Acanthomicmacca* se registran tanto en el Marianinense medio como superior. De los taxones hallados en la región, el que presenta un mayor potencial para la correlación regional e intercontinental es el género *Serrodiscus*, que presenta una amplia distribución global, y permite establecer correlaciones dentro de la Serie 2 del Cámbrico. La primera asociación, compuesta por *Serrodiscus*, *Chelediscus*, *Atops* y *Pseudatops*, también ha sido identificada en la Zona de Ossa-Morena, Avalonia, Laurentia, Báltica y Siberia, lo que permite una buena correlación entre estas regiones. La segunda asociación, compuesta por *Andalusiana*, *Termierella*, *Triangulaspis* y *Serrodiscus*, es comparable con otras asociaciones registradas en la Zona de Ossa-Morena, las Cadenas Ibéricas y Marruecos; además, *Triangulaspis* también se ha identificado en Terranova y Siberia. Por último, la propuesta de la ISCS señalando que la coexistencia de *Hebediscus*, *Calodiscus*, *Serrodiscus* y *Triangulaspis* pudiera ser un indicador de la base del Piso 4 del Cámbrico, implicaría que el Marianiense superior podría correlacionarse *grosso modo* con la base de este Piso.

1 Introduction

Trilobites have traditionally played a role in establishing regional and intercontinental correlations of the Cambrian strata, enabling their subdivision into series and stages (Babcock et al., 2017; Peng et al., 2020). However, the highly endemic nature of trilobites from the Cambrian Series 2 has been one of the main factors preventing the International Subcommission on Cambrian Stratigraphy (ISCS) from ratifying Stages 2 to 4 (Geyer & Shergold, 2000; Palmer, 1998; Peng et al., 2020).

In the Iberian Peninsula, Sdzuy (1971) subdivided the Cambrian Series 2, in ascending order, into the Ovetian, Marianiian and Bilbilian regional stages. Liñán et al. (1993) and Liñán & Gámez-Vintaned (1993) proposed a tentative correlation chart between the lithostratigraphic units of Cambrian Series 2 in the region. Liñán (1984) subdivided the Marianiian stage into three substages (lower, middle and upper) based on distinct trilobite assemblages. Liñán et al. (1993) proposed the First Appearance Datum (FAD) of the trilobite *Delgadella*, in conjunction with the archaeocyaths zone VIII (Perejón, 1986), as markers for the lower boundary of the stage, and the Last Appearance Datum (LAD) of *Andalusiana* and *Serrodiscus* as marker for the upper boundary. In a subsequent study, Liñán et al. (1996) re-examined the validity of the aforementioned boundaries and suggested that the FAD of *Strenuella*, along with the archaeocyaths zone VIII and *Delgadella*, serve as more suitable markers for the lower boundary; the level always has been placed in the base of Archaeocyath zone VIII. In the same publication, the FAD of *Realaspis* was proposed for the base of the Bilbilian stage. Subsequent research (e.g. Gozalo et al., 2003; Liñán et al., 2002, 2004) indicated that the base of the lower

Marianian should be identified by the FAD of *Strenuella* (in conjunction with archaeocyath zones VIII and IX; Perejón, 1994), the base of the middle Marianiian by the FAD of *Strenuaeva*, and the base of the upper Marianiian by the FAD of *Serrodiscus* (see Liñán et al., 2004).

Recently, Álvaro et al. (2019) have questioned the validity of using the Marianiian Stage for correlation across the Iberian Peninsula. They argue that the various trilobite horizons suggested for the base and the top of this stage cannot be identified throughout the Cambrian exposures in the region (e.g. the suggested—but never illustrated—presence of *Andalusiana* in the Iberian Chains). However, Sepúlveda et al. (2022) figured a cephalon from the Huérmeda Fm (Iberian Chains) that bears resemblance to those of *Andalusiana cornuta* from the Ossa-Morena Zone. Additionally, we present new specimens of *Andalusiana* from the Toledo Mountains (previously reported by Liñán et al., 1993). Furthermore, Sepúlveda et al. (2021a, 2022) figured a specimen attributed to *Termierella*, a characteristic genus from the Moroccan Cambrian and the Ossa-Morena Zone, found in the Ribota Fm of the Iberian Chains, where Gámez Vintaned et al. (2023) reported *Termierella* cf. *sevillana*. This genus is figured herein for the first time from the Totanés area, where it had been reported by Liñán et al. (1993). In the same line, Collantes et al. (2022) considered the FAD of *Serrodiscus* a reliable marker for the base of the upper Marianiian in Iberia and they provided a tentative correlation chart for the Ossa-Morena and Central Iberian zones based on the stratigraphic range of this genus.

Marianian deposits are well-exposed in various regions of the Iberian Peninsula, including the Iberian Chains, the Ossa-Morena Zone and the Central Iberian Zone. Although there is a considerable number of publications dealing with

the trilobite systematics and biostratigraphy of the Marianian rocks from the Iberian Chains and the Ossa-Morena Zone (e.g. Álvaro et al., 2019; Collantes et al., 2021a, 2021b, 2022; Richter & Richter, 1940, 1941, 1948; Sdzuy, 1961, 1962; Sepúlveda et al., 2021a, 2022), studies of the Marianian deposits of the Central Iberian Zone are limited and primarily focused on tectonics and stratigraphy. However, there are multiple published works on the Marianian trilobites from the Totanés-Noez area in the Central Iberian Zone (Aparicio Yagüe & Gil Cid, 1972; Collantes et al., 2022; Gil Cid, 1981, 1986; Liñán et al., 1993; Sepúlveda et al., 2021b).

The aim of this paper is to examine the systematic and biostratigraphic significance of trilobites found in the Totanés–Noez area while evaluating their correlation potential throughout the Marianian successions of the Iberian Peninsula, as well as with other areas in the Acadobaltic province (sensu Sdzuy, 1972). The fossil assemblages analysed in this study are considered of late Marianian age, showing potential for regional correlation due to the presence of shared genera with both the Ossa-Morena Zone and the Iberian Chains. Additionally, the presence of genera with a widespread distribution—such as *Serrodiscus*—may facilitate long-range correlations with the Western Gondwana margin and other Cambrian palaeocontinents and terranes (e.g. Taconic Allochthon, Greenland, Siberia, Baltica). The co-occurrence of *Serrodiscus* and *Triangulaspis* in this area suggests a potential correlation with the *Hebediscus*–*Calodiscus*–*Serrodiscus*–*Triangulaspis* band (HCST band) of Geyer & Shergold (2000) as a potential marker for the base of the Cambrian Stage 4.

2 Geological setting

The studied area lies between the municipalities of Noez, Polán and Totanés (Toledo province), approximately 25 km to the southwest of Toledo city (Fig. 1a). The area has been referred to as the “Toledo platform” from a geomorphological standpoint (Aparicio Yagüe, 1970, 1971; Vidal Boix, 1944), and has been assigned to the foothills of the Toledo Mountains (see San José, 2003). Several inselbergs are located within the central part of this platform between the Noez and Almonacid localities.

From a geological point of view, the Toledo platform is situated in the Central Iberian Zone (CIZ), within the so-called Schist-Greywacke Complex, also named as northern CIZ (see Villaseca et al., 2014). This zone has been traditionally subdivided into three units (Aparicio Yagüe, 1970, 1971; San José, 2003) from north to south: a migmatitic and gneissic unit, a metasedimentary unit, and a granitic unit. Between the two first units, there is a mylonitic band (see Fig. 1b). The metasedimentary unit corresponds to the inselbergs, where Cambrian and Ordovician rocks with low

levels of metamorphism are exposed (Aparicio Yagüe, 1970, 1971).

However, several authors preferred the subdivision of this unit into two main divisions separated by the Toledo Shear Zone (Andonaegui, 1992; Barbero, 1995; Hernández Enrile, 1991). This shear zone separates low-grade metasediments in greenschist facies (together with the Mora late-Hercynian granitic pluton) in the hanging wall from the Toledo Anatectic Complex in the footwall (Barbero & Villaseca, 2004; Barbero et al., 2005; Barbero González, 1992), as shown by the ALCUDIA deep seismic reflection transect (see Martínez Poyatos et al., 2012). Aparicio Yagüe (1971) and Andonaegui & Villaseca (1998) showed that the Mora (also Mora-Galvez) plutonic complex is intruding into the core of an anticline composed of Cambrian and Ordovician metasediments. These metasediments are affected by low-grade regional metamorphism, to which a contact metamorphism is superimposed due to the granitic intrusion (Andonaegui, 1992).

3 Stratigraphy

There is a consensus about the lithostratigraphic subdivision of the lower Cambrian rocks in the Toledo Mountains although many outcrops are isolated or separated by faults, and varied nomenclature has been used for geographically separated areas (see Zamarreño, 1983; Liñán et al., 2002, 2004; Gozalo et al., 2003; Rodríguez-Alonso et al., 2004; Menéndez, 2014; Menéndez et al., 2019). From base to top, the succession is composed of the Pusa (San José et al., 1974), Azorejo (San José et al., 1974), Los Navalucillos (San José et al., 1974), Soleras (Zamarreño et al., 1976) and Los Cortijos fms (Weggen, 1955; Lotze, 1961; Walter, 1977).

Aparicio Yagüe (1971: 387–390) informally named the Cambrian rocks of Totanés as “serie verde” and described four sections. One section is located between the Maneco Chico hill (previously known as Cerro de la Casa) and the Pico Noez inselberg (see Fig. 2). Aparicio Yagüe & Gil Cid (1972) discovered the first trilobites from the “serie verde” in the Toledo’s inselbergs, and presented a cross section between Totanés and Pico Noez (Fig. 2, fossil site 1).

In the Urda area, the “serie verde” was considered as equivalent to the entire Cambrian sequence (Pusa, Azorejo, Navalucillos, Soleras and Cortijos fms) by Martín Escorza (1976: 600–601), an equivalence subsequently followed in the memoirs of the Spanish Geological Maps (n° 686, Hernández et al., 2013a; n° 712, Rámirez et al., 2013; n° 736, Hernández et al., 2013b; n° 737, Hernández et al., 2013c) and recently by Durán Oreja et al. (2023). Furthermore, the geological maps of the study area (n° 656, Martín Parra et al., 2009; n° 657, Sánchez Carretero et al., 2009; n° 658, Martínez-Salanova et al., 2009) assigned the “serie

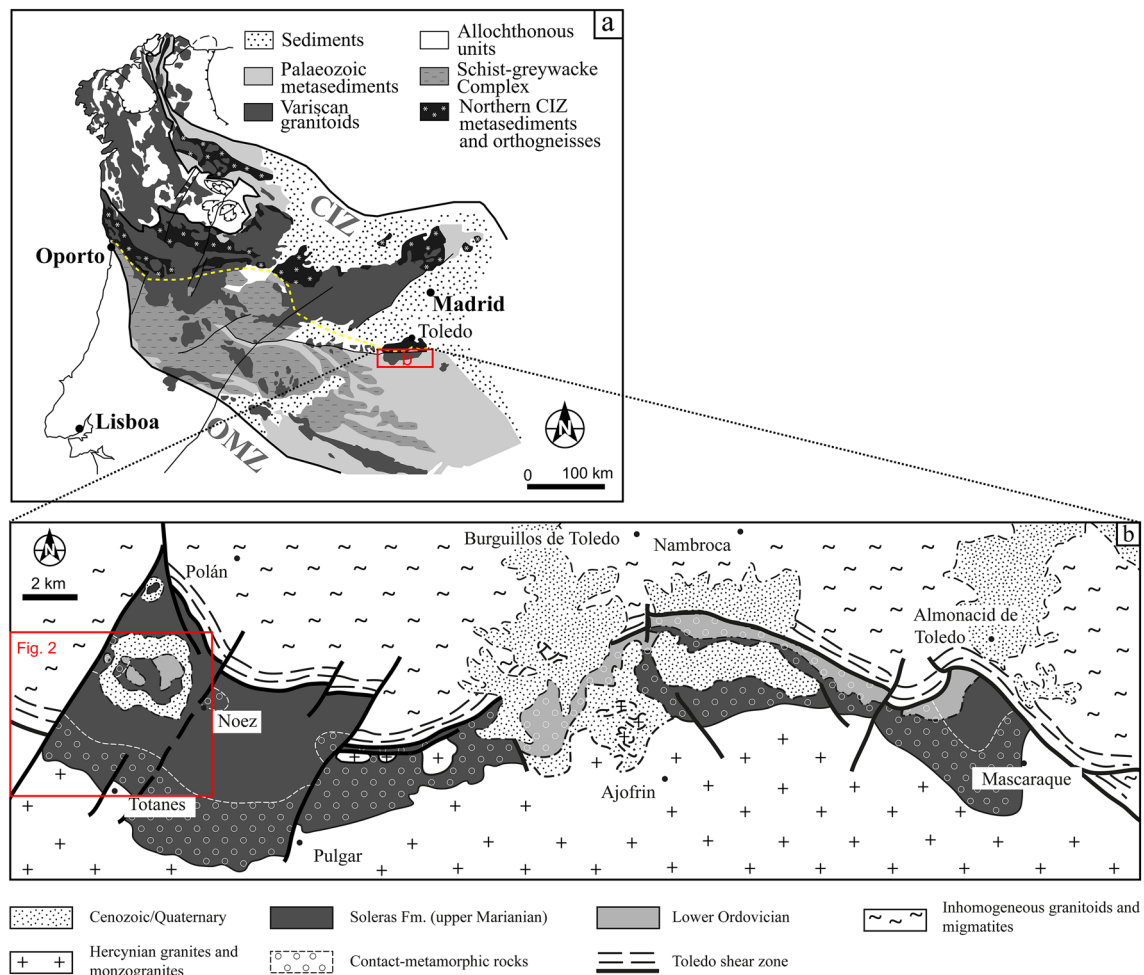


Fig. 1 **a** Sketch map of the Central Iberia Zone showing the subdivision proposed by Villaseca et al. (2014). **b** Simplified geological map of the lower Cambrian metasedimentary unit studied herein (modified

of Martín Parra et al., 2009; Martínez-Salanova et al., 2009; Sánchez Carretero et al., 2009)

verde” rocks to the Pusa Fm in this territory. However, Zamarreño (1983) unified the different local stratigraphical names used in the Toledo Mountains and proposed that the “serie verde” is equivalent to the Soleras Fm. This terminology has since been widely accepted and is followed herein.

Eight fossil sites have been found in the “serie verde” (Soleras Fm) between Totanes and Noez (Fig. 2a; appendix 1). Most of these sites yield *Serrodiscus* indicating a late Marianian age (Collantes et al., 2022; Liñán & Gámez-Vintaned, 1993; Liñán et al., 1996, 2002, 2006). After analysing the thickness of both the Soleras and Cortijos fms in the nearby areas (see the memoirs of the geological maps n° 654, Olivé et al., 1989; n° 655, Iglesias Peláez, 2009; n° 683, Moreno Serrano & Gómez Pérez, 1989; n° 685, Pérez-González et al., 1990; n° 686, Hernández et al., 2013a; n° 711, Moreno, 1981; n° 712, Ramírez et al., 2013; n° 736, Hernández et al., 2013b; n° 737, Hernández et al., 2013c), it is notable an increase in thickness and a decrease in grain

size towards the north, and the existence of lateral facies changes between the upper part of the Soleras Fm and the base of the Los Cortijos Fm (see the memoirs of the geological maps n° 711, Moreno, 1981; n° 712, Ramírez et al., 2013; n° 736, Hernández et al., 2013b; n° 737, Hernández et al., 2013c). Both the age and the lithology suggest that the “serie verde” represents the Soleras Fm, as previously noted by Zamarreño (1983), although it is thicker and probably represents a deeper sedimentary environment (see Dabrio González, 1990) than the azoic type section, which is assigned to the middle-upper Marianian based on lithostratigraphical criteria and comparison with the Endrinal Fm from Salamanca (Liñán et al., 2004).

The fossils from the different sections (Aparicio Yagüe, 1971; Aparicio Yagüe & Gil Cid, 1972; Martín Parra et al., 2009) come from three levels. The lower level (fossil sites 1 and 2) is in the lower part of the sequence and has yielded *Serrodiscus bellimarginatus*, *Chelediscus* cf. *garzoni*, *Atops*

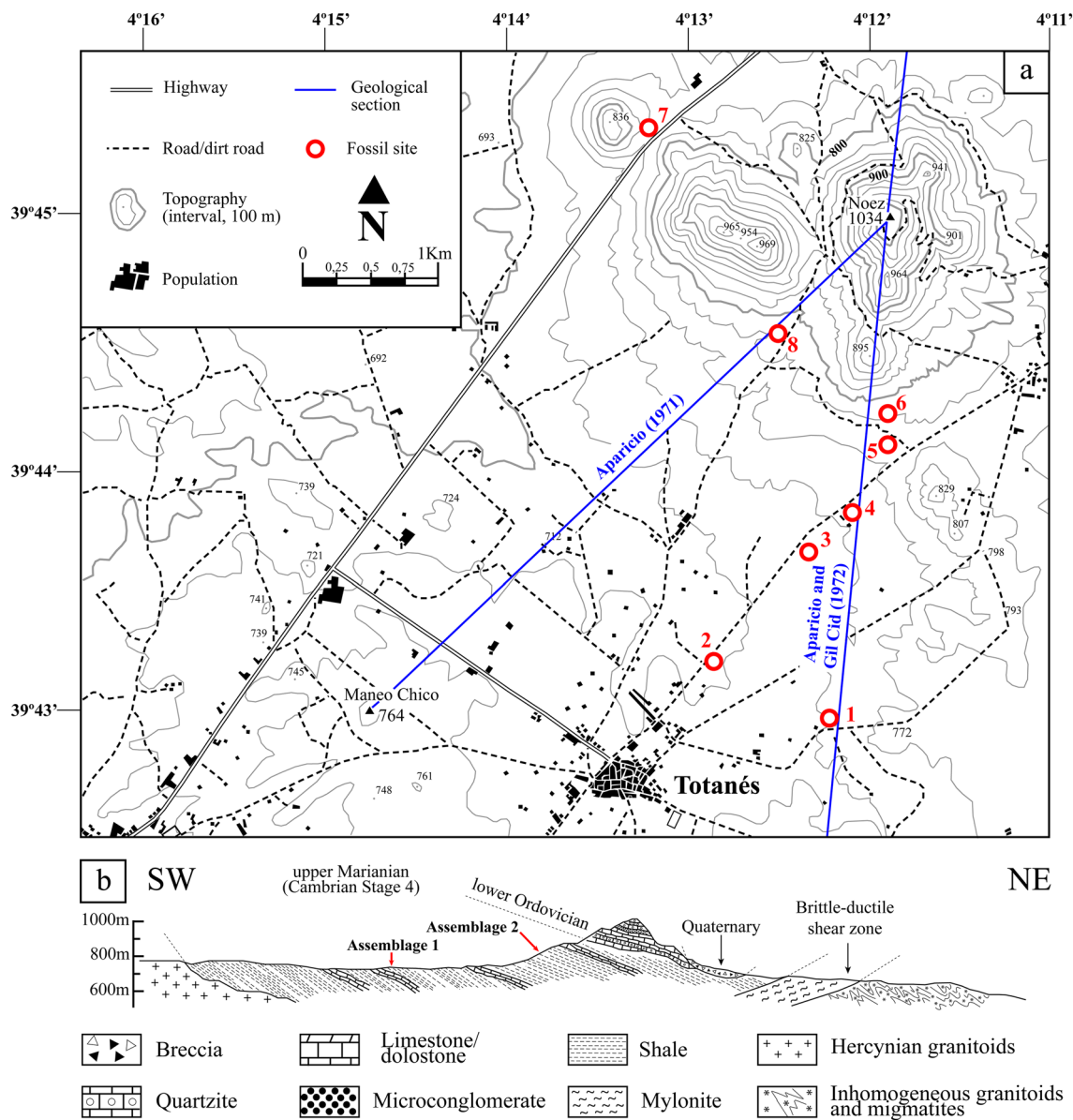


Fig. 2 **a** Topographic map of the studied region with the location of the fossil sites, Aparicio Yagüe (1971) section and Aparicio Yagüe & Gil Cid (1972) cross section. **b** Cross section between Totanés and

pico Noez from Aparicio Yagüe & Gil Cid (1972) with the stratigraphic position of the two assemblages of trilobites studied herein

calanus and *Pseudatops reticulatus* (assemblage 1 herein). The second level (fossil sites 3 and 4) is in the middle part of the sequence, and only *Serrodiscus bellimarginatus* was identified. The third level (fossil sites 5 to 8) is in the upper part of the sequence and has yielded *S. bellimarginatus*, *Acanthomicmacca* sp., *Andalusiana palaciosi* n. sp., *Termierella totanesensis* n. sp and *Triangulaspis* cf. *fusca* (assemblage 2, herein). According to Aparicio Yagüe (1971: pp. 287–388) and Aparicio Yagüe & Gil Cid (1972: Fig. 2), the second assemblage comes from the upper part of their stratigraphic level 6 (see Fig. 2b).

4 Systematic palaeontology

The material studied herein is housed in the Museo de Ciencias Naturales de la Universidad de Zaragoza, Spain, formerly the Museo Paleontológico de la Universidad de Zaragoza (under repository numbers MPZ2021/337 to MPZ2021/339, and MPZ2023/118 to MPZ2023/186) except for specimens of *Atops calanus* and *Pseudatops reticulatus*, which are housed in the Museo Paleontológico y Arqueológico Ildfonso Recio Valverde (Totanés, Toledo) under repository numbers MPT-01304 and MPT-01305.

Zoo Bank LSID: urn:lsid:zoobank.org:pub:7B04B560-0242-46E0-8FAA-2A0A0DFA718C.

Class Trilobita Walch, 1771

Order Eodiscida Kobayashi, 1939

Family Weymouthiidae Kobayashi, 1943

Serrodiscus Richter & Richter, 1941

Type species. Eodiscus (Serrodiscus) serratus Richter & Richter, 1941 (junior subjective synonym of *Microdiscus bellimarginatus* Shaler & Foerste in Shaler, 1888; see Collantes et al., 2022, p. 298).

***Serrodiscus bellimarginatus* (Shaler & Foerste in Shaler, 1888) Fig. 3a–c**

v. 1972 *Serrodiscus* sp. —Aparicio Yagüe & Gil Cid, pp. 107, 108, pl. 1, Figs. 1, 3–5.

v. 1972 *Serrodiscus* aff. *speciosus* Ford.—Aparicio Yagüe & Gil Cid, pl. 1, Fig. 2.

v. 1986 *Eodiscus (Serrodiscus) serratus*.—Gil Cid, pl. 1, Figs. 1–12.

v. 2011 *Serrodiscus speciosus* Ford, 1873.—Gil Cid et al., p. 48, pl. 3.

v. 2022 *Serrodiscus bellimarginatus* (Shaler & Foerste in Shaler, 1888) – Collantes et al. p. 300, Figs. 5–9. (with previous synonyms).

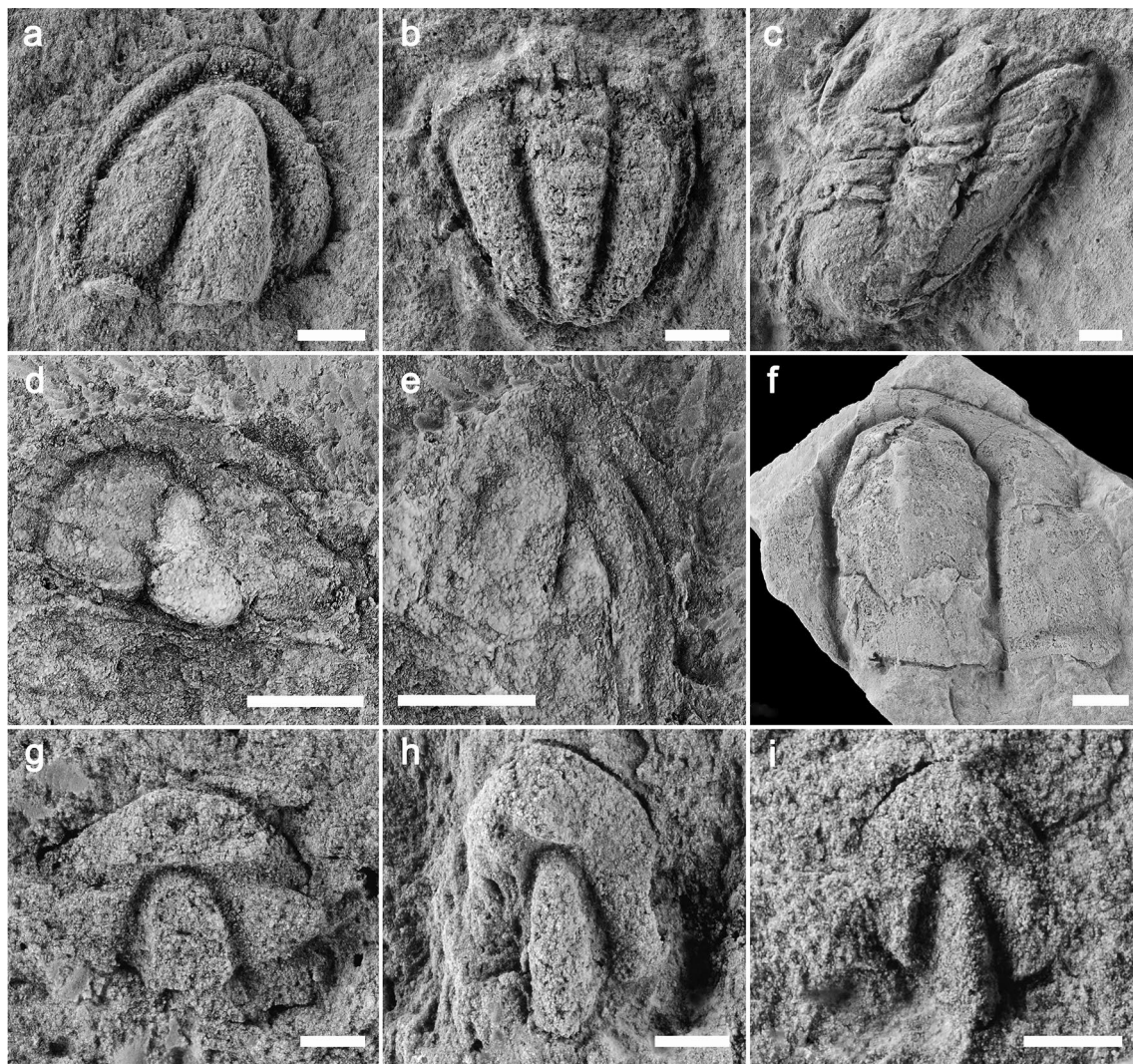


Fig. 3 a–c *Serrodiscus bellimarginatus* (Shaler and Foerste in Shaler, 1888). a Internal mould of cephalon, MPZ2021/338. b Internal mould of pygidium, MPZ2021/339. c Internal mould of complete specimen, MPZ2023/156. d, e *Chelediscus* cf. *garzoni* Collantes, Pereira, Mayoral & Gozalo, 2022b. d Internal mould of cephalon, MPZ2023/124. e Internal mould of incomplete cephalon,

MPZ2023/125. f *Acanthomicmacca* sp., internal mould of cranium, MPZ2023/118. g–i *Triangulaspis* cf. *fusca* Sdzuy, 1962. g Internal mould of cranium, MPZ2023/121. h Internal mould of cranium, MPZ2023/122. i Internal mould of cranium, MPZ2023/123. Soleras Fm, upper Marianian, Totanés, Toledo. Scale bars: 1 mm. (c–e, g–i), 2 mm (a, b), 5 mm (f)

? 2023 *Serrodiscus* (sensu lato) “*bellimarginatus*” (Shaler & Foerste, 1888)—Birch & McCobb, p. 209–211, fig. 8a–j.

Material: Three articulated specimens (internal moulds: MPZ2021/337, MPZ 2023/156; internal mould and corresponding external mould: MPZ 2023/147), three cephalata (internal moulds: MPZ2021/338, MPZ 2023/151, MPZ 2023/155) and eight pygidia (internal moulds: MPZ2021/339, MPZ 2023/148, MPZ 2023/149, MPZ 2023/152–154; internal mould and corresponding external mould: MPZ2023/150; external mould: MPZ 2023/157). The material from the Gil Cid collection at the Universidad Complutense de Madrid was also examined, comprising five articulated specimens and more than 40 cephalata and pygidia.

Description: See description by Collantes et al. (2022, p. 304).

Discussion: Specimens of *Serrodiscus* from Totanés were originally assigned to *S. aff. speciosus* (see Aparicio Yagüe & Gil Cid, 1972) and *Eodiscus* (*Serrodiscus*) *serratus* (see Gil Cid, 1986). Collantes et al. (2022) grouped the species of *Serrodiscus* into three distinct groups, mainly based on morphological, stratigraphic and palaeobiogeographic data: the *bellimarginatus*, *speciosus*, and *daedalus* groups. The main morphological differences between *S. speciosus* and *S. bellimarginatus* is the presence of an occipital spine, the relief of the axial ring furrows and the presence of developed axial nodes in the latter. We therefore agree with Collantes et al. (2022) in assigning the specimens of Totanés to the *bellimarginatus* group.

Geographical and stratigraphical distribution: *Hebediscus attleboresis* Subzone (uppermost *Callavia broeggeri* Zone) to upper *Strenuella sabulosa* Zone, St. Mary’s Mb, Brigus Fm (Newfoundland and Massachusetts). Lowermost to middle “*Protolenus*” Zone, Comley Series (Warwickshire; United Kingdom). *Sectigena*, Zone Issafen Fm, middle to upper Banian Stage (Morocco). *Serrodiscus* Zone, upper Marianian, Cumbres beds (Cumbres de San Bartolomé, Cumbres de Enmedio; Huelva province, Spain), Herreñas shales (Sierra del Bujo, El Pozuelo, Minas de Cala, Arroyomolinos de León; Huelva province, Spain), La Hoya Mb, Alconera Fm (Alconera, Badajoz province); ‘Alanís (= Benalija) beds’ (Llerena; Badajoz province; and Guadalcanal and Alanís; Seville province, Spain). *Lusatiops* Mb, Charlottenhof Fm, Görlitz Synclinorium (Germany). Fossil sites 1, 2, 4, 6, 7 and 8 (Fig. 2a) in the Soleras Fm, upper Marianian (Totanés, Polán and Noez; Toledo province, Spain).

Family Calodiscidae Kobayashi, 1943

Chelediscus Rushton, 1966

Type species. *Chelediscus acifer* Rushton, 1966, Purley shales (upper Comley Series, Cambrian Stage 4), Warwickshire, United Kingdom. By original designation Rushton (1966: p. 18).

***Chelediscus cf. garzoni* Collantes, Pereira, Mayoral & Gozalo, 2023 Fig. 3d, e**

Material: Three cephalata (internal moulds: MPZ2023/124–126).

Description: Cephalon semicircular with low overall convexity, total cephalic length (sag.) about 70% of total cephalic width (tr.). Glabella subconical and convex, tapering anteriorly and distinctly elevated above the rest of the cephalon; length about 65% of total cephalic length (sag.). Anterior and posterior margins of glabella semicircular. Occipital ring short (sag.), about 7% of total glabellar length (sag.) and domed. Axial furrows narrow and deep. Genae wide (tr.) and smooth, width about 250% (anteriorly) to 120% (posteriorly) of total glabellar width (tr.). Median preglabellar furrow or preglabellar field present. Anterolateral border furrow continuous, deep and well-marked, wider than the axial furrow. Anterolateral border flat and wide (sag. and tr.), about 25% of total cephalic length (sag.) and about 12–15% of total cephalic width (tr.). Posterior border furrow deep and wide, widening laterally (sag.). Posterior border narrow (sag.).

Discussion: Collantes et al. (2023) described the species *Chelediscus garzoni* Collantes et al., 2023 from the ‘Cumbres beds’ informal unit of the Ossa-Morena Zone and emended the diagnosis of the genus to encompass the differences of the new species with other species of the genus. *C. garzoni* was erected based on various cephalic and pygidial characters, some of which cannot be recognized in the specimens studied herein due to the scarce material and poor preservation. However, specimens figured in this paper show some of the diagnostic characters of *C. garzoni* such as the smooth glabella with no transverse furrow, which differentiates this species from *Chelediscus acifer* Rushton, 1966 and *Chelediscus chathamensis* Rasetti, 1967, both characterized by a bilobated glabella. In addition, it appears that the specimen shown in Fig. 3d preserves the proximal part of the genal spines, a character lacking in *Chelediscus carus* Repina, 1972.

Geographical and stratigraphical distribution: Fossil site 1 (Fig. 2a) in the Soleras Fm, upper Marianian (Totanés; Toledo province, Spain).

Order Corynexochida Kobayashi, 1935

Family Chengkouiidae Zhu in Zhang et al., 1980

Acanthomicmacca Hupé, 1953

Type species. *Micmacca walcotti* Mathew, 1899, from the upper lower Cambrian basal Brigus Fm, southeast Newfoundland; original designation by Hupé (1953: p. 248).

Emended diagnosis: see Geyer (2016: p. 337).

***Acanthomicmacca* sp. Fig. 3f**

Material: Three cranidia (internal moulds: MPZ 2023/118–120).

Description: Cranidium subquadrate with a width/length ratio about 80%. Glabella approximately about 90% of total cephalic length (sag.), including occipital ring, and about 45% of maximum cranial width (tr.), faintly convex. Anterior margin of lobe well-rounded; lateral margins subparallel, with weakly concave sides. Lateral glabellar furrows short (tr.), developed as shallow depressions. Occipital furrow moderately deep and narrow (sag.). Subrectangular occipital ring. Axial furrows narrow and well-defined. Fixigena faintly convex posteriorly to eye ridge, with shallow palpebral furrow. Palpebral lobe about 18–20% (tr.) of glabellar width across L1; posterior tip of palpebral lobe reaches posterior border furrow. Palpebral lobes and eye ridges arc-shaped. Eye ridge narrow (sag. and exsag.) and less elevated than palpebral lobe. Preglabellar field absent. Preocular fields short (exsag.) and weakly convex. Anterior border narrow (sag.) and slightly convex. Anterior border furrow shallow, indistinct, with axial furrow in front of the glabella. Posterior border almost straight, slightly curving anteriorly in its distal section, located posterior to palpebral furrow. Posterior border furrow moderately deep, slightly curved and slightly widening towards facial suture.

Remarks: Specific identification of the three studied species is hindered due to poor preservation. Nonetheless, recognizable characters such as the lack of a preglabellar field, a narrow anterior border, and long palpebral lobe, coincide with those present in some of the oldest species assigned to *Acanthomicmacca* (*Acanthomicmacca*) by Geyer (2016: Fig. 24); specifically, *Acanthomicmacca* (*A.*) *walcotti* (Matthew, 1899), *Acanthomicmacca* (*A?*) *comleyensis* (Cobbold, 1931), *Acanthomicmacca* (*A?*) *schwarzbaehi* (Richter & Richter, 1941), *Acanthomicmacca* (*A.*) *coloi* (Hupé, 1953) and *Acanthomicmacca* (*A.*) aff. *coloi* (see Sdzuy, 1961; Sepúlveda et al., 2022).

Acanthomicmacca sp. from the Toledo Mountains differs from *A.* (*A.*) *walcotti* in a shallower anterior furrow and a less arched palpebral lobe and eye ridge, and from *A.* (*A?*) *comleyensis* in a shorter anterior border and narrower eyes ridges. Furthermore, *Acanthomicmacca* sp. differs from *A.* (*A?*) *schwarzbaehi* and *A.* (*A.*) *coloi* in a less rounded anterior margin, and in a shorter (tr.) glabella than those of *A.* (*A?*) *schwarzbaehi* and longer palpebral lobes than those of *A.* (*A.*) *coloi*. Specimens of *A.* (*A.*) aff. *coloi* have been described from the upper Marianian of the Iberian Chains (see Sdzuy, 1961; Sepúlveda et al., 2022), with a more rounded anterior margin and a narrower and more curved palpebral lobe than *Acanthomicmacca* sp. Finally, Mayoral et al. (2021) figured *Micmacca?* sp. from the Alanís beds in Cerro del Hierro (Seville province), which is morphologically close to *Acanthomicmacca* sp., but with a shorter palpebral lobe, not reaching the posterior furrow. Westrop & Landing (2000) restricted the genus *Micmacca* to the type

species, therefore the specimen can be included in the genus *Acanthomicmacca*.

Geographical and stratigraphical distribution: Fossil site 6 (Fig. 2a) in the Soleras Fm, upper Marianian (Noez; Toledo province, Spain).

Order Redlichiida Richter, 1932

Suborder Olenellina Walcott, 1890

Superfamily ‘Nevadioidea’ Hupé, 1953 (sensu Lieberman, 2001).

Family uncertain

Andalusiana Sdzuy, 1961

Type species. *Andalusiana cornuta* Sdzuy, 1961 from Guadalcanal FP. 1 (Sevilla province); by original designation Sdzuy (1961: p. 246).

Emended diagnosis. A genus of ‘Nevadioidea’ with frontal lobe rounded to slightly subtrapezoidal in outline and well-defined all around, ocular ridges separated from the frontal lobe by the axial furrows, anterior branches of the suture not noticeable, L3 expanded laterally behind anterior part of ocular lobe, L1 shorter (tr.) than both L2 and L0 and intruded by S2 and L2, 3rd thoracic segment broadened (sag.) and macropleurale, and surface covered with fine granules.

Remarks: *Andalusiana* do not follow the diagnosis for Holmiidae sensu Palmer & Repina (1993: p. 25). Thus, we herein prefer to assign *Andalusiana* to the ‘Nevadioidea’ sensu Lieberman (2001) and avoid family assignment within it.

Sdzuy (1961) erected the genus *Andalusiana* and provided a diagnosis including the presence of a protuberance on each side of the frontal lobe and above the anterior tips of the ocular ridge. This character is evident in the specimens figured by Sdzuy (1962, see pl. 19, Figs. 2, 3 and 4) and by Geyer & Palmer (1995, see figs. 6.1–6.4). A less prominent bulge is also visible in the specimen from the Iberian Chains figured in Sepúlveda et al. (2022, fig. 6E). However, the specimens assigned to *Andalusiana* from the Toledo Mountains show no trace of these bulges, which are replaced by the flat preocular area. In addition, Geyer & Palmer (1995) noted ‘the prominent lateral projections of L4 in front of the ocular lobe’ and the lack of intergenal spines in the cephalon as characteristic of the genus (p. 468). The former is present in the material studied herein (occipital lobe as L0), although it is also present in other genera, such as *Holmia* Matthew, 1890 and *Kjerulfia* Kiær, 1917. On the other hand, the L1 of *Andalusiana* is shorter (tr.) than L2 and L0 and it is incised by S2 and L2, a character not present in the aforementioned genera. Furthermore, the absence of intergenal spines is considered invalid for distinguishing the genus as Sdzuy (1962; pl. 19, Fig. 1) figured various juvenile specimens in which intergenal spines are present. In the diagnosis of the genus, Sdzuy (1961) included the presence of a granular-sculpture on the surface of the exoskeleton;

however, the specimen of Tierga figured by Sepúlveda et al., (2022; Fig. 6E) seems to show a net-like ornamentation (see Fig. 6E). Finally, the genus shows some variability regarding the shape of the frontal lobe, with a more subtrapezoidal shape in the specimen from the Iberian Chains and in various specimens from Morocco (see Fig. 6.1 in Geyer & Palmer, 1995), while the material figured by Sdzuy (1961, 1962) shows a more rounded frontal lobe. Some specimens figured herein show a more ovoid frontal lobe in shape, but in others it is more rounded or subtrapezoidal so the difference may be due to intraspecific or taphonomic variation.

Andalusiana palaciosi n. sp. Fig. 4a–n

Derivation of name: After Prof. Teodoro Palacios Medrano, for his outstanding contributions to the geology and palaeontology of the Precambrian and Cambrian of Spain and, above all, for his friendship.

Holotype: Internal and external mould of a cephalon, MPZ2023/127, Fig. 4b, c.

Type locality: Fossil site 6 in the Soleras Fm, upper Marianian (Noez; Toledo province, Spain).

Diagnosis: A species of *Andalusiana* with no protuberances in front of the anterior tip of the ocular ridge, frontal lobe inflated and wider (tr.) than the occipital lobe, no ocular furrow or barely noticeable in the anterior part of the ocular ridges, and genal spine subequal in length (sag.) to the total cephalic length or slightly longer and sagittally subdivided by a median furrow.

Material: Twelve cephalons (internal moulds: MPZ2023/128–131, MPZ 2023/138, MPZ2023/139; external moulds: MPZ2023/132–134, MPZ2023/136; internal moulds with corresponding external moulds: MPZ2023/135, MPZ2023/140), five genal spines (internal moulds: MPZ2023/137, MPZ 2023/141, MPZ2023/143, MPZ2023/144; external mould: MPZ2023/142).

Description: Cephalon semicircular, total cephalic length (sag.) about 50% of total cephalic width (tr.). Glabella subconical, higher relief than the remainder of cephalon, occupying about 75% of total cephalic length (sag.) and almost reaching anterior border. Frontal glabellar lobe inflated, about 58% of total glabellar length (sag.), ovoid in outline, expanded posteriorly extending into L3. S3 to S0 transglabellar and narrow (sag.); S2 to S0 deep abaxially and shallower medially; S3 deep and short (tr.), interrupted by axial furrow. S3, S1 and S0 strongly curved backwards adaxially; S2 almost straight. L3 to L1 convex, width (tr.) and convexity progressively decreasing backwards, lower relief than frontal lobe. L3 expanded laterally, inner and outer tips slightly backward-projected. L2 broadened (sag.) in the medium part; L1 short (sag.) medially, intruded by L2 and S1. Occipital lobe narrow (sag.) and convex, about 10% of total cephalic length (sag.) (without occipital spine), and slightly wider (tr.) than L1; lower relief than the rest

of the glabella, subtly widened axially (sag.) and slightly curved with convexity backwards. Short, pointed occipital spine, representing 12% of total cephalic length (sag.). Narrow, shallow axial furrows convergent to the posterior area, opposite the end of the ocular ridges. Interocular area slightly domed, trapezoidal, width (tr.) approximately 50% of extraocular area width at S1 level. Ocular lobe prominent, arc-shaped, located slightly closer to glabella than to lateral border and with the anterior part subdivided by a shallow and barely noticeable furrow in some specimens; exsagittal length equivalent to 40% of sagittal cephalic length. Anterior tip of ocular lobe opposite S3, posterior tip opposite SO. Inner margin of ocular lobe well defined. Ocular lobes anteriorly connected to posteriormost part of the frontal lobe but distinguished by shallow axial furrow. Extraocular area flat to subtly domed, extending from lateral sides of frontal lobe to the posteriormost area of the cephalon, sloping outwards. Lateral border furrow shallowing backwards, until lateral border gets fused with extraocular area. Anterior border subtly convex and rounded, moderately wide, occupying about 15% of cephalic length (sag.); lateral border fading into the genal area. Narrow, deep anterior border furrow, incised by the frontal lobe of the glabella, continuous with lateral border furrow. Posterior branch of suture barely noticeable in some specimens, short (sag.), extending obliquely from posteriormost part of ocular lobe to the medium part of the posterior border furrow. Posterior border furrow subtly curved (convexity backwards), shallowing at the genal area and joining with the lateral border furrow. Genal angle equivalent to intergenal angle. Posterior border narrow (sag.), about 5–8% of total cephalic length (sag.), low relief, slightly curved (convexity backwards) below the posterior tips of the ocular lobes forming a metagenal corner without spine; increasing curvature at the point of intergenal angle and merging into base of genal spine. Base of genal spine broad, about 10–12% of total cephalic width (tr.), length (sag.) of genal spine subequal to total cephalic length (sag.), or slightly longer. Spine subdivided sagittally into two subequal bands by a continuous and deep furrow. Surface covered by a very fine coarse granulation, including genal spines.

Discussion: The material assigned to *Andalusiana palaciosi* n. sp. fits well the diagnosis of the genus provided by Sdzuy (1961), except for the lack of the bulges in front of the anterior part of the ocular ridge and the lack of net-sculpture. As noted by Sdzuy (1961), the anterior branches of the suture are not noticeable, whereas the posterior ones may be slightly indicated running obliquely from the posterior part of the eye in various specimens of *Andalusiana cornuta* Sdzuy, 1961 from Seville (see pl. 3, Figs. 1–4 and 6 in Sdzuy, 1961) and Toledo (see Figs. 6b, d and g). In addition, another significant similarity between *A. palaciosi* n. sp. and the specimens of *A. cornuta* from Seville (Sdzuy,

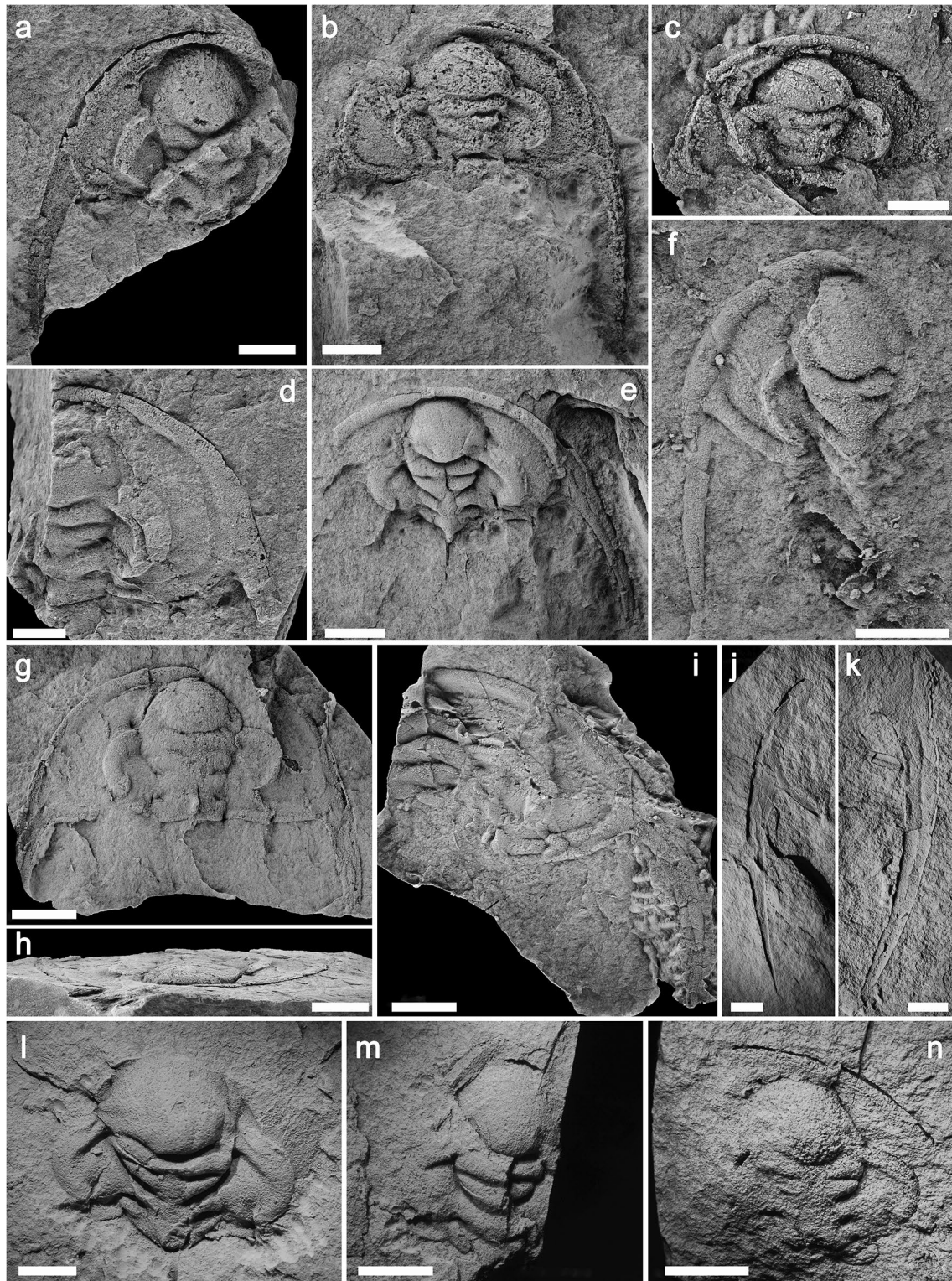


Fig. 4 *Andalusiana palaciosi* n. sp. **a** Internal mould of cephalon, MPZ2023/128. **b, c** Internal and external mould of cephalon, holotype MPZ2023/127. **d** Internal mould of cephalon, MPZ2023/129. **e** Internal mould of cephalon, MPZ2023/130. **f** External mould of cephalon, MPZ2023/132. **g, h** Internal mould of cephalon in dorsal and frontal view, MPZ2023/135. **i** External mould of cepha-

lon, MPZ2023/133. **j** Internal mould of genal spine, MPZ2023/143. **k** Internal mould of genal spine, MPZ2023/137. **l** Internal mould of cephalon, MPZ2023/131. **m** Internal mould of cephalon, MPZ2023/138. **n** Internal mould of cephalon, MPZ2023/139. Soleras Fm, upper Marianian, Totanés, Toledo. Scale bars: 5 mm (a–f, j–n), 10 mm (g–i)

1961, pl. 3, Figs. 1–7; 1962, pl. 18, Figs. 19, 20, pl. 19, 1–5) and Morocco (Geyer & Palmer, 1995, Figs. 6.1–6.8), and *Andalusiana* cf. *cornuta* from Tierga (Sepúlveda et al., 2022, Fig. 6E) is the pattern of the glabellar lobes and lateral furrows, with L3 expanded laterally behind the ocular ridge with its external tips slightly projected backwards, L1 shortened (sag.) by the backward directed S2 and narrower (tr.) than the occipital ring and L2, and a short (tr.) S3. Also, the frontal lobe of the new species is well defined and separated from the ocular ridge by the axial furrows, which is characteristic of *Andalusiana* as noted by Sdzuy (1961). On the other hand, Sdzuy (1961) characterized *A. cornuta* as having a genal spine of about $\frac{2}{3}$ of the total cephalic length (sag.) in addition to the characters mentioned in the diagnosis of the genus. However, in several specimens figured herein the length (sag.) of the spine is subequal or slightly longer than the cephalon (see Fig. 4b and e), and it bears a median furrow (Fig. 4e, i and k) which is absent in *A. cornuta*. In addition, specimens of *A. palaciosi* n. sp. from Noez differ from the specimens of *A. cornuta* in a considerably more inflated frontal lobe of the glabella wider (tr.) than the occipital ring, with axial furrows convergent to the rear and a relief decreasing to the posterior area, ocular ridges considerably wider (tr.) with no ocular furrow subdividing the eye or barely noticeable, and a longer (sag.) occipital spine. In addition to the absence of the protuberances in front of the ocular ridges, *A. palaciosi* n. sp. differs from *Andalusiana* cf. *cornuta*. from Tierga (Sepúlveda et al., 2022) in a very subtle and wide border furrow in the latter, with parallel-sided glabella with frontal lobe shorter (tr.) than the occipital lobe and non-transglabellar lateral furrows, and cephalon with net-sculpture ornamentation.

Geographical and stratigraphical distribution: Fossil site 6 (Fig. 2a) in the Soleras Fm, upper Marianian (Noez; Toledo province, Spain).

Suborder Redlichiina Richter, 1932

Superfamily Ellipsocephaloidea Matthew, 1887

Family Ellipsocephalidae Matthew, 1887

Triangulaspis Lermontova, 1940

Type species: *Ptychoparia meglitzkii* Toll, 1899; by original designation Lermontova (1940: p. 120–121).

Remarks: *Triangulaspis* Lermontova, 1940 has been assigned to Eodiscidae Raymond, 1913 (Cobbold, 1931), Pagetiidae Kobayashi, 1935 (Lermontova, 1940) and Ellipsocephalidae Matthew, 1887 (Richter & Richter, 1941). Sdzuy (1962) figured a complete specimen of *Triangulaspis fusca* Sdzuy, 1962 bearing up to seven thoracic segments and placed the genus under the Ellipsocephalidae. Whittington et al., (1997: p. 404) referred to *Triangulaspis* as “probably belongs to Ellipsocephaloidea” following Sdzuy’s (1962) finds. Therefore, we agree with Sdzuy (1962) in placing *Triangulaspis* under Ellipsocephalidae.

***Triangulaspis* cf. *fusca* Sdzuy, 1962 Fig. 3g–i**

Material: Three cranidia (internal moulds: MPZ2023/121–123).

Description: Cranidium subelliptical and highly convex; cranidial length (sag.) about 75% of cranidial width (tr.) across palpebral lobes. Glabella subconical and strongly convex, about 60% of total cranidial length (sag.) and 35% of total cranidial width (tr.), with no glabellar furrows; occipital furrow weakly indicated or absent. Axial furrows deep and well-marked. Posterior margin of glabella subtly and evenly curved; anterior margin of glabella semicircular. Fixigena highly convex, about 90% of maximum glabellar width. Palpebral lobes about 30% of total cranidial length (sag.) and strongly curved. Ocular ridges indistinct. Anterior branch of facial suture shorter than palpebral lobes and strongly diverging outwards. Posterior branch of the facial suture shorter than the anterior ones, diverging outwards. Preocular area very short (tr.), progressively widening to the sides. Anterior border subtriangular to semicircular, very long (sag.), about 35% of maximum cranidial length, highly convex. Posterior border furrow shallow, but well-marked. Posterior border short (sag.), widening outwards.

Remarks: Specimens of *Triangulaspis* figured herein agree with the diagnosis of *Triangulaspis fusca* in Sdzuy (1962), with a glabella of more than 30% of maximum cranidial width (tr.), glabellar and occipital furrows absent and length of frontal area subequal to the length of the glabella excluding the occipital ring. However, the eye ridges in the specimens of Pico Noez are barely noticeable, and the occipital spine is absent unlike in *T. fusca*, but this may be due to the poor preservation of the specimens, as the occipital spine is also absent in various specimens figured by Sdzuy (1962) (see pl. 22, Figs. 12 and 13, and pl. 23, Figs. 3, 5 and 7). Specimens from the Toledo Mountains show a semicircular posterior margin of the occipital lobe just as in the specimens from the Ossa-Morena Zone, but the latter have a more subtriangular outline when the occipital spine is preserved (see Sdzuy, 1962, pl. 23, Figs. 1, 4, and 6).

Geographical and stratigraphical distribution: Fossil site 6 (Fig. 2a) in the Soleras Fm, upper Marianian (Noez; Toledo province, Spain).

Termierella Hupé, 1953

Type-species. *Termierella latifrons* Hupé, 1953 from Zone VII of the Issafen Syncline, Anti-Atlas, Morocco, by original designation (Hupé, 1953: p. 227).

Emended diagnosis. Eyes wide (tr.) and almost bilobated by well-marked to indistinct ocular furrow, preocular area sloping to the eye and almost fused with the eye ridge, ocular ridges of the same width as the palpebral lobes or widening towards them, oblique furrows running obliquely from the anterior tips of the ocular ridge, and small portion of the intraocular area inflated next to L1.

Remarks: Hupé (1953) gave a diagnosis of the genus including some variability in various characters to encompass the morphologies of the subgenera *Termierella* (*Termierella*) Hupé, 1953, *Termierella* (*Jalonella*) Hupé, 1953 and *Termierella* (*Brevitermierella*) Hupé, 1953, and included the genus in the newly erected subfamily Termierellinae Hupé, 1953. He characterized *T.* (*Termierella*) as having a wide (sag.) preglabellar field almost merged with the anterior border, preocular area crossed by oblique furrows, the presence of a furrow dividing the ocular ridges and a parafrontal band in front of the glabella. On the other hand, *T.* (*Jalonella*) and *T.* (*Brevitermierella*) were characterized by having a narrow (sag.) and convex preglabellar field and the absence of a parafrontal band. In addition, oblique furrows would be absent in *T.* (*Jalonella*) as well as the ocular furrows in *T.* (*Brevitermierella*). Hupé (1953) assigned various specimens of *Lusatiops ribotanus* Richter & Richter, 1948 to *T.* (*Jalonella*) *celtiberica* and to *T.* (*Brevitermierella*) *brevifrons*, but later Sdzuy (1961) retransferred them to *L. ribotanus*. Sdzuy (1961) described the species *Termierella sevillana* Sdzuy, 1961 from the Guadalcanal locality of the Ossa-Morena Zone in Spain and considered the course of the facial suture and the prominent posterior part of the preocular area as typical characters of *Termierella*. He also re-assigned the genus to the Protoleninae arguing that some of the characters listed by Hupé (1953) could also be observed in various genera of this subfamily. Later, Geyer (1990b) considered the differences between *T.* (*Termierella*) and *T.* (*Brevitermierella*) significant enough to represent two separate genera, the latter with a narrow (sag.) preglabellar field, a longer and more strongly curved S1 and the ocular ridges widening towards the palpebral lobes.

However, the crescentic ocular ridges seem to be present in various cranidia and cephalae assigned to *T. sevillana* and other species assigned to this genus under open nomenclature by Sdzuy (1961, 1962) (see Sdzuy, 1961; pl. 10, Figs. 4–6; Sdzuy, 1962, pl. 21, Fig. 15 and pl. 22, Fig. 5), as well as in some specimens assigned to the type species *Termierella latifrons* Hupé, 1953 (see Geyer, 1990b; pl. 54, Figs. 7a and 10). Geyer (1990b) argued that this character would be typical of *Brevitermierella*, an assumption which turns to be inconsistent as it is present in both *Termierella* and *Brevitermierella*. *Termierella sandomirensis* Samsonowicz, 1962 from Poland shows an ocular ridge widening towards the glabella, and Żylińska (2013) did not mention the presence of the oblique furrows, therefore the assignment of this material to *Termierella* is doubtful. On the other hand, the length and the curvature of the S1 show a certain degree of variability between different specimens assigned to *T. latifrons* and to *T. sevillana*. However, the material from Toledo studied in this work, with a short (sag.) preglabellar field (typical of *Brevitermierella*), show a straight S1 (see Fig. 5b in this work), while this genus

was characterized by a S1 more curved than in *Termierella* (sensu Geyer, 1990b, p. 209). Hupé (1953) stated that the presence of a parafrontal band is a diagnostic character of *T.* (*Termierella*), although Geyer (1990b) included this character in the description of *Brevitermierella brevifrons* Hupé, 1953. Furthermore, the presence of an inflated portion of the preocular area almost fused with the eye, noted by Sdzuy (1961) as diagnostic of the genus, is present in the specimens of Totanés (e.g. Fig. 5a–c) and in Moroccan specimens of *Brevitermierella*, as well as the presence of an ocular furrow, which were regarded as typical of *T.* (*Termierella*) and absent in *T.* (*Brevitermierella*) in Hupé (1953). As a result, the only clearly appreciable difference between *Termierella* and *Brevitermierella* is the length (sag.) of the preglabellar field and its junction with the anterior border, which we do not consider enough to assign the different species in two separated genera. Accordingly, the genus *Brevitermierella* should be included in *Termierella* with the species *Termierella latifrons* Hupé, 1953, *Termierella brevifrons* Hupé, 1953, *Termierella sevillana* Sdzuy, 1961 and *Termierella totanesensis* n. sp.

***Termierella totanesensis* n. sp. Figs. 5a–j and 6a–o**

Derivation of name: After the municipality of Totanés (Toledo province, Spain), where part of the specimens studied in this work have been found.

Holotype: External mould of a cranidium, MPZ2023/161, Fig. 5a.

Type locality: Fossil site 8, Soleras Fm, upper Marianian (lowermost Cambrian Stage 4), Totanés, Toledo, Spain.

Diagnosis: A species of *Termierella* with short (sag.) preglabellar field, anterior border with high relief and separated from the preglabellar field and the preocular area by a well-marked furrow, anterior branch of the facial suture about 1 to 1.2 times the length of palpebral lobe (sag.) and with its intersection with the anterior border furrow lying close to the anterior margin of the frontal lobe, well-marked terrace lines in the anterior border and cranidium covered with fine granulated ornament, especially in the rear part.

Material: 21 cranidia (internal moulds: MPZ2023/158–160, MPZ2023/162, MPZ2023/163, MPZ2023/165–168, MPZ2023/182–184; internal moulds and corresponding external moulds: MPZ2023/161, MPZ2023/164; external moulds: MPZ2023/169–172, MPZ2023/175, six incomplete articulated specimens (internal moulds MPZ2023/173, MPZ2023/186), four incomplete thoraxes (internal mould: MPZ2023/174; internal moulds and corresponding external moulds: MPZ2023/176; external moulds: MPZ2023/179, MPZ2023/180) and two librigenae (internal moulds: MPZ2023/177, MPZ2023/178).

Description: Cranidium subquadrate to subtrapezoidal in shape, with low overall convexity. Total cranidial length (sag.) about 80–100% of total cranidial width (tr.) across

palpebral lobes. Glabella subconical, moderately convex, about 85% of total cranial length (including occipital ring). Frontal lobe convex and rounded. Axial glabellar furrows deep and well-marked, converging forwards. Three pairs of parallel, straight, non-transglabellar furrows directed backwards, decreasing in length and shallowing from S1 to S3, with S3 barely noticeable in some specimens. Occipital furrow deep and slightly curved to the sides, running straight in the middle. Occipital ring semioval in outline, about 20% of total glabellar length (sag.), narrowed to the sides. Fixigenae about 70% of maximum glabellar width (tr.) (including the palpebral lobes), more or less flat. Intraocular area subtrapezoidal, slightly protruding next to L1 and downsloping to the eye furrow, where it is slightly inflated next to the eye. Palpebral lobes wide (tr.) and moderately curved, about 30% of total cranial length (exsag.) and slightly elevated from the fixigena. Eye ridges almost straight and running obliquely to the axis, slightly narrower than the palpebral lobes, reaching the axial furrows slightly above the S3. Palpebral furrow is well-marked, slightly shallower than the axial furrow. Preocular area subtrapezoidal and wide (sag.), strongly convex next to the axial furrow and ocular ridge, with no clear separation with the latter. Oblique furrows short (exsag. and tr.) and shallow, running obliquely from slightly above the contact between ocular ridge and axial furrow. Short (sag.) preglabellar field, slightly depressed. Anterior branch of facial suture shorter than palpebral lobes, diverging outwards about 30° to the axis; mostly straight but curved sharply just before the anterior border furrow to meet the anterior margin. Intersection between anterior branch of suture and anterior margin slightly posterior to the most advanced part of the preocular area and preglabellar field; intersection between anterior branch of suture and anterior border furrow close to anterior part of the frontal lobe. Anterior border furrow shallow but distinct. Anterior border convex, slightly wider (sag.) laterally, longer (sag.) than preglabellar field and about 50% of preocular area; with parallel terrace lines in the anterior area, prominent on external moulds. Anterior margin slightly curved. Posterior branch of suture shorter (sag.) than anterior branch, the former diverging outwards about 45° to the axis. Posterior border furrow shallow, wider (sag.) abaxially. Posterior border convex, short (sag.), slightly wider behind the palpebral lobes. Surface covered with fine granules, except posterior part of fixigenae, posterior border, L1 and occipital ring, where the granules are coarse and differentiated. Rostral plate also with distinct terrace lines. Librigena flat, with moderately wide (tr.) border having subparallel terrace lines. Border furrows shallow. Genal spine long, sharp and slightly curved backwards.

Thorax with up to 14 segments. Axial rings slightly convex and short (sag.), slightly narrowing laterally with moderately curved anterior and posterior margins, about

120% (anteriorly) to 100% (posteriorly) of pleural width (tr.) (excluding the spines); subequal in width (tr.) until the third segment and then decreasing progressively backwards. Axial furrows shallow but distinct. Pleurae with deep, wide (sag.) pleural furrows, slightly wider (sag.) near the axial ring. Pleural furrows slightly curved near the axial ring and then running straight to the spine, subdividing pleurae in a slightly shorter (sag.) anterior part narrower (sag.) near axial ring and a wider (sag.) posterior part to the axial ring. Posterior margin of pleurae straight, subtly curved near the spine. Pleural spine short (tr.), sharp and directed slightly backwards in its distal part, about 5% the length of pleurae (tr.), and with curved posterior margin. Axial rings, pleurae and spines covered with fine granules, coarser in the rear part of the axial rings.

Remarks: *Termierella totanesensis* n. sp. differs from *T. latifrons* Hupé, 1953 and *T. seviliana* Sdzuy, 1961 in having a preglabellar field shorter (sag.) than the anterior border, which is also more inflated and covered by subparallel and distinct terrace lines and separated from the preglabellar field by a deeper anterior border furrow. This is also applicable when distinguishing *T. totanesensis* n. sp. from *Termierella* sp. Sdzuy, 1961, *Termierella* sp. A Sdzuy, 1962, *Termierella* sp. B Sdzuy, 1962 and *Termierella* sp. indet Sdzuy, 1962. Furthermore, *T. totanesensis* is distinguished from *T. seviliana* in a glabella wider (tr.) at the occipital ring than the greatest distance between the palpebral lobes and the axial furrows whereas they are subequal in length in the latter, and the absence of an occipital tubercle in the former. The new species differs from *T. latifrons* Hupé, 1952 in having a less curved anterior margin, the absence of a parafrontal band, and the presence of a granular ornamentation. *T. totanesensis* n. sp. differs from *Termierella brevifrons* Hupé, 1953 in a less curved anterior margin of the cranium and a longer anterior branch of the facial suture, which intersects with the anterior border furrow at the anterior part of the frontal lobe, whereas in *T. brevifrons* this intersection lies at the contact between the ocular ridges and the dorsal furrows of the glabella. In addition, *T. brevifrons* has a parafrontal band according to Geyer (1990b), who did not mention the presence of terrace lines on the anterior border and granules covering the surface of the cranium, whereas they are clearly evident in *T. totanesensis* n. sp.

Geographical and stratigraphical distribution: Fossil sites 6, 7 and 8 (Fig. 2a) in the Soleras Fm, upper Marianian (Totanes, Noez and Polán; Toledo province, Spain).

Order uncertain

Family Atopidae Hupé, 1954

Atops Emmons, 1844

Type species (by monotypy). *Atops trilineatus* Emmons, 1844 from the *Elliptocephala asaphoides* faunule in New York.

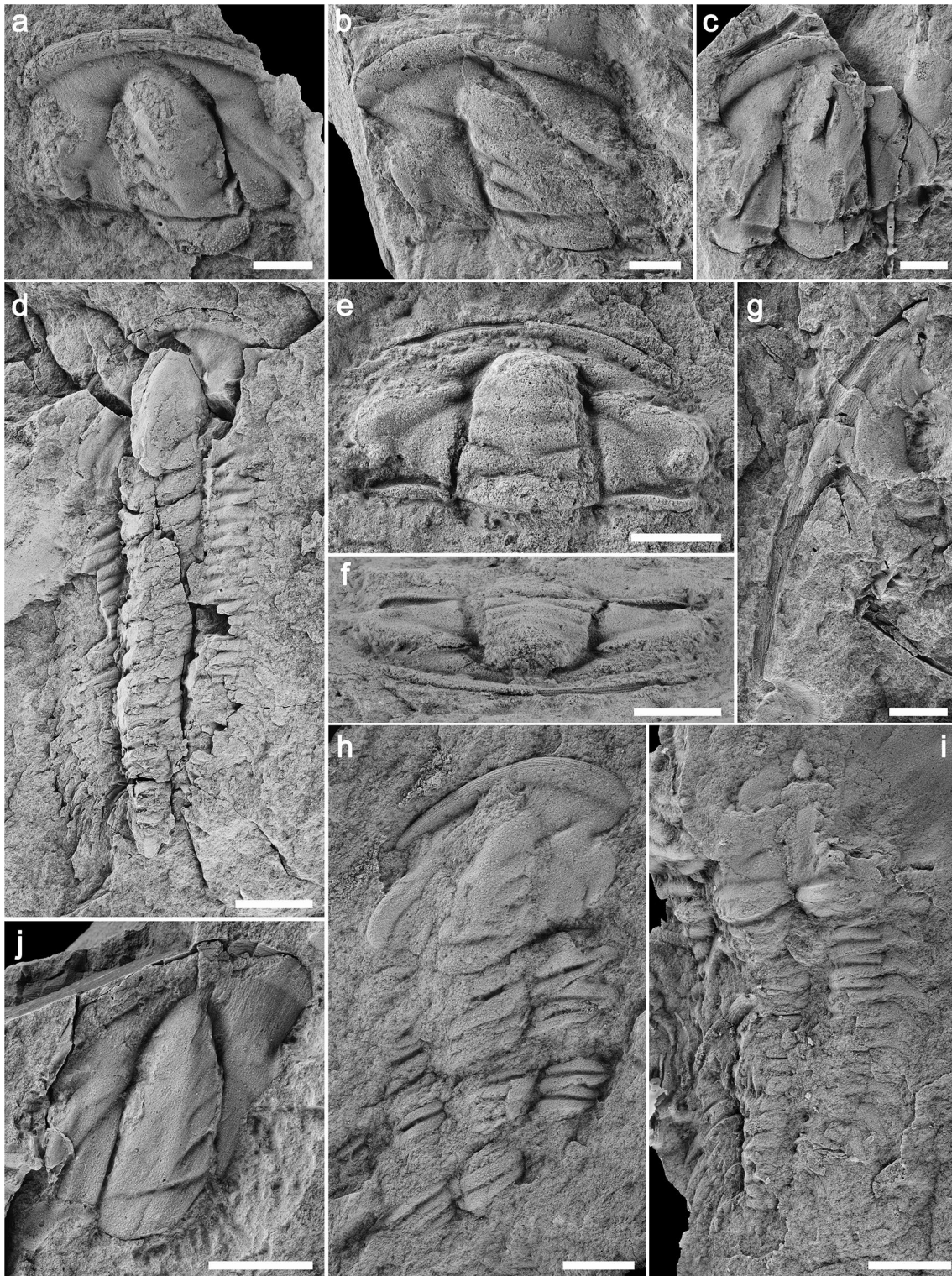


Fig. 5 *Termierella totanesensis* n. sp. **a** External mould of cranium, holotype, MPZ2023/161. **b** Internal mould of cranium, MPZ2023/165. **c** Internal mould of cranium, MPZ2023/166. **d** Internal mould of complete specimen, MPZ2023/173. **e, f** Internal mould of cranium in dorsal and frontal view, MPZ2023/158. **g**

Internal mould of librigena, MPZ2023/177. **h** External mould of cranium and thoracic segments, MPZ2023/169. **i** External mould of cranium and thorax, MPZ2023/186. **j** Internal mould of cranium, MPZ2023/162. Soleras Fm, upper Marianian, Totanés, Toledo. Scale bars: 3 mm (j), 5 mm (b, c, e–h) 1 cm (a, d, i)

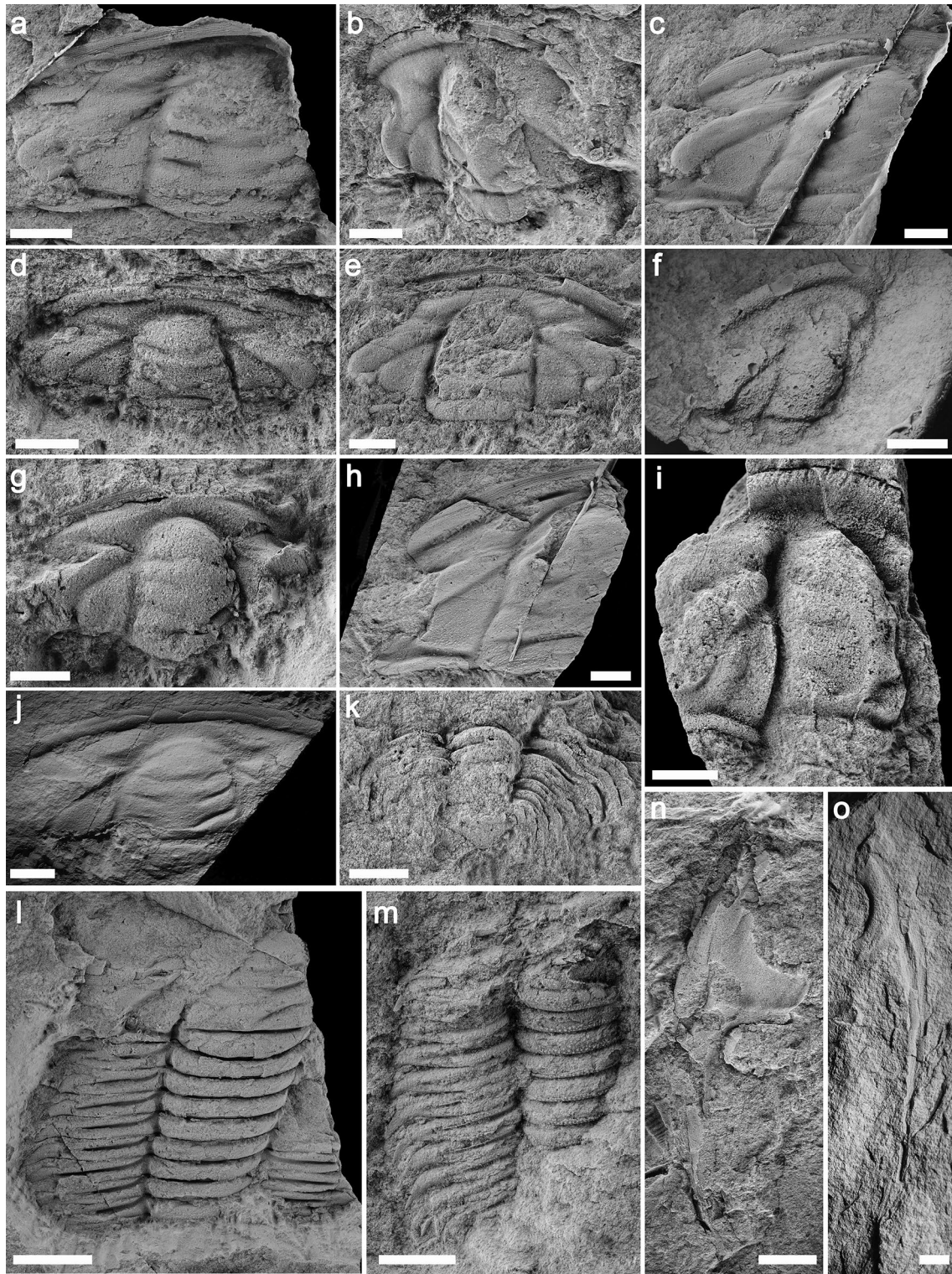


Fig. 6 *Termierella totanesensis* n. sp. **a** External mould of cranidium, MPZ2023/172. **b** Internal mould of cranidium, MPZ2023/167. **c** External mould of cranidium, MPZ2023/171. **d** Internal mould of cranidium, MPZ2023/182. **e** Internal mould of cranidium, MPZ2023/168. **f** External mould of cranidium, MPZ2023/170. **g** Internal mould of cranidium, MPZ2023/183. **h** Internal mould of cranidium, MPZ2023/159. **i** Internal mould of cranidium,

MPZ2023/184. **j** Internal mould of cranidium, MPZ2023/163. **k** Internal mould of pygidium and thoracic segments, MPZ2023/185. **l** Internal mould of thorax and part of the cranidium, MPZ2023/174. **m** External mould of thorax, MPZ2023/180. **n** Internal mould of librigena, MPZ2023/181. **o** Internal mould of librigena, MPZ2023/178. Soleras Fm, upper Marianian, Totanés, Toledo. Scale bars: 3 mm (d–g, i, k), 5 mm (a–c, h, j, m–o), 10 mm (l)

Remarks: Richter & Richter (1941) and Sdzuy (1962) figured one incomplete cranium and two fragmentary specimens assigned to *Atops? calanus* Richter & Richter, 1941. Later, Orlowski (1985) pointed out that this material may not belong to *Atops* Emmons, 1844 based on the concave anterior border, the short and tapering glabella and the straight eye ridges contradicting the diagnosis of the genus in Poulsen (1959). This was followed by Jell et al. (1992), who provided a new diagnosis of *Atops*. However, Collantes et al. (2021a) figured new and better-preserved material of *Atops calanus* and included the species in this genus, with which we agree. These specimens match the diagnosis of the genus by Jell et al. (1992) with the glabella reaching the anterior border furrow but not trespassing on it, eye ridge curved laterally and the slightly convex anterior border.

***Atops calanus* Richter & Richter, 1941 Fig. 7a**

v. 1941 *Atops? calanus*—Richter & Richter, p. 55, pl. 3, Fig. 41, pl. 4, fig. 63.

v. 1958 *Atops? calanus*—Lotze, p. 743.

v. 1961 *Atops? calanus*—Lotze, p. 164.

v. 1961 *Atops? calanus*—Sdzuy, p. 230.

v. 1962 *Atops? calanus*—Sdzuy, p. 212, pl. 23, Figs. 14, ?15 and 16.

v. 2018 *Atops* sp. cf. *calanus*—Collantes et al., p. 567, Fig. 4.7.

v. 2021a *Atops calanus* Richter & Richter, 1941—Collantes et al., p. 3, fig. 2, text- Fig. 3.

Material: One incomplete articulated specimen (MPT-01304).

Description: Cranium subtrapezoidal, total cranial length (sag.) about 50% of total cranial width (tr.). Subrectangular glabella, slightly wider (tr.) posteriorly, length (sag.) about 85% of total cranial length (sag.), including occipital lobe. Three pairs of non-transglabellar furrows, all equal in length and slightly curved backwards adaxially. Slightly curved anterior margin of the glabella. Axial furrows narrow, deeper than glabellar furrows. Occipital furrow straight and as deep as the glabellar furrows. Occipital lobe short (sag.), length (sag.) about 10% of glabellar length. Fixigena wide (tr.) and smooth, width (tr.) about 125% of total glabellar width (tr.). Ocular ridge short (tr.), running from the median part of the frontal lobe to the lateral margin; slightly curved towards the front at its median part. Preocular area short (sag.), slightly turned upward towards the anterior border. Preglabellar furrow deep and distinct, deeper than the border furrow in front of the preocular area. Anterior border narrow (sag.), slightly intruded by the glabella. Anterior branch of suture short. Posterior branch of suture much longer than the anterior one, running obliquely towards the posterior part of the cranium and cutting the fixigena near the end of the lateral margin. Posterior border short (sag. and exsag.).

Thorax consists of up to 21 segments with almost transverse orientation. Axial rings subrectangular, short (sag.) and slightly convex, progressively decreasing in width (tr.) backwards; almost subequal in length (tr.) to the pleurae anteriorly and posteriorly (excluding pleural spines), and of almost 80% of the length (tr.) of pleurae at the medium part of the thorax. An axial node is present near posterior margin. Axial furrow shallow but distinct. Pleurae short (sag.) and slightly widening (tr.) until the 8th segment and then narrowing towards the pygidium. Pleural furrow with transverse orientation and wide (sag.), about 70% of the length of the segment (sag.) and deeper than pleural bands. Distal ends of pleurae projected into short and sharp pleural spines. Pleural spines of about 15% the length of the pleurae and directed backwards, especially in their distal part. Surface covered with very fine granules. Pygidium unknown.

Discussion: Despite the imperfect preservation of the cranium, it shows various diagnostic characters of *A. calanus* as described by Collantes et al. (2021a), with a moderately inflated preglabellar area laterally and the opisthoparian facial suture close to the lateral margin of the cephalon. The narrow ocular ridges also resemble those of the species, running and curving laterally. As in one specimen figured in Collantes et al. (2021a: figs. 2.1–2.3), the glabella of the specimen from Totanés intrudes the preglabellar field reaching the anterior border. This was considered by these authors to be the result of tectonic deformation, a condition which also affects the specimen described herein. The specimen discussed here also has a subrectangular rather than subconical glabella, with a straighter anterior margin of the frontal lobe (see holotype in Richter & Richter, 1941: pl. 3, fig. 41; Sdzuy, 1962: pl. 23, fig. 14; Collantes et al., 2021a: figs. 2.1–2.2). However, Collantes et al. (2021a; fig. 2.5) also figured one poorly preserved specimen with a more subrectangular glabella as in the specimen from Totanés, thus this difference may be attributed to taphonomical variability.

In this paper, we figure the first known articulated specimen of the species. Howell & Stubblefield (1950) figured the thorax of one complete specimen of the type species *Atops trilineatus* Emmons, 1844, which is very similar to the one in *A. calanus*. The thorax of the Totanés specimen differs from that of *A. trilineatus* in having a narrower (sag.) axial ring and slightly longer pleural spines. Jell et al. (1992) depicted various thoraces from *Atops rupertensis* Jell et al., 1992 from Australia which also resemble that of the specimen discussed in this paper, primarily with respect to the relative lengths of the axial rings and the pleural region. The axial rings in both *A. calanus* and *A. rupertensis* are narrower than the axial ring of *A. trilineatus*. On the other hand, the pleural spines of the Australian specimens are significantly longer than those of *A. calanus*. The pleural furrow of *A. calanus* seems to be almost straight in its entirety, but in *A. trilineatus* and *A. rupertensis* it turns slightly backwards

in its distal part. Unlike *A. rupertensis*, *A. trilineatus* and *A. calanus* lack macropleural spines.

Geographical and stratigraphical distribution: Herreñas shale, lowermost middle Marianian (Arroyomolinos de León; Huelva province, Spain). Upper part of ‘Cumbres beds’, upper Marianian (Cumbres de San Bartolomé; Huelva province, Spain). Fossil site 1 (Fig. 2a) in the Soleras Fm, upper Marianian (Totanés; Toledo province, Spain).

Pseudatops Lake, 1940

Type species: *Conocoryphe reticulata* Walcott, 1890, by original designation (Lake, 1940, p. 291).

***Pseudatops reticulatus* (Walcott, 1890) Fig. 7b**

1890 *Conocoryphe reticulata*—Walcott, p. 649, pl. 95, fig. 6a.

1936 *Atops reticulatus* var. *comleyensis*—Cobbold, p. 231, pl. 15, fig. 1a–e.

1940 *Pseudatops reticulatus*—Lake, p. 291, pl. 2, figs. 1–3.

1950 *Pseudatops reticulatus*—Howell & Stubblefield, pl. 2, figs. 1, 2.

2001 *Pseudatops reticulatus*—Cotton, pl. 2, figs. 1–3.

2006 *Pseudatops reticulatus*—Fletcher, pl. 27, fig. 21.

v. 2018 *Pseudatops* n. sp.—Collantes et al. p. 567, fig. 4.8.

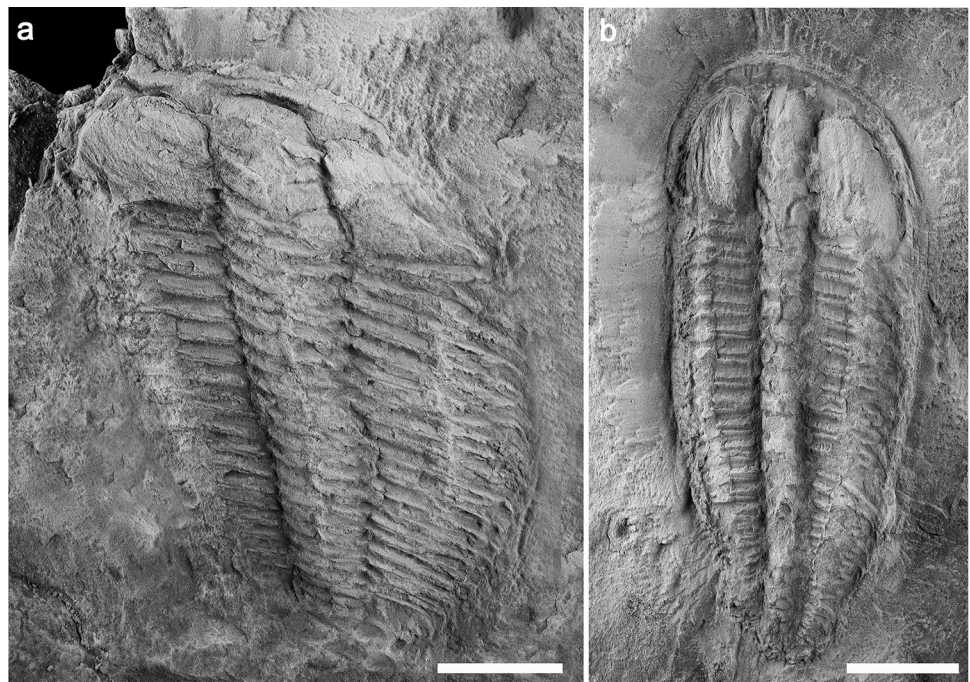
v. 2021a *Pseudatops reticulatus* (Walcott, 1890b)—Collantes et al. p. 5, fig. 4, text- Fig. 5.

Material: One incomplete articulated specimen (MPT-01305).

Description: Cranidium subtrapezoidal, total cranial length (sag.) about 45% of total cranial width (tr.). Subrectangular glabella, slightly narrowing (tr.) towards the front, about 85% of total cranial length (sag.) including occipital lobe, and reaching the anterior border. Frontal lobe with semicircular anterior margin. Three pairs of shallow, short (tr.), non-transglabellar furrows, curved slightly backwards adaxially; S3 barely noticeable. Occipital furrow deep laterally and curved backwards medially. Occipital lobe short (sag.) with gently curved posterior margin. Axial furrows deep until reaching the ocular ridges, then shallower. Ocular ridge short (sag.), strongly curved from posterior part of frontal lobe to the lateral border. Interocular area wide (sag. and tr.) and convex, about 140–110% of glabellar width at SO and S3 respectively. Subtriangular and doomed preocular area in each side of the frontal lobe. Anterior border furrow shallow, intruded by the glabella. Anterior border relatively short (sag.) and more or less flat, slightly longer in front the ocular ridges and about 15% of total cranial length (sag.) (including occipital lobe); anterior part slightly upturned. Facial suture close to the lateral margin, not cutting the gena. Lateral border continuous and narrow (tr.), about 35% of genal width (tr.) at SO. Posterior border furrow shallow and wide (sag.). Posterior border short (sag.), slightly wider (sag.) near the genal corner. Surface covered by reticulated ornamentation.

Thorax narrow (tr.) with up to 19 segments. Axial rings subrectangular, with a more semicircular posterior margin in the anterior segments and more straight in the posterior ones, short (sag.) and narrow (tr.), slightly convex, decreasing in width (tr.) progressively; about 90–100% (anteriorly

Fig. 7 **a** *Atops calanus* Richter & Richter, 1941, internal mould of articulated specimen, MPT-01304. **b** *Pseudatops reticulatus* (Walcott, 1890), internal mould of complete specimen, MPT-01305. Soleras Fm, upper Marianian, Totanés, Toledo. Scale bars: 10 mm (a, b)



and posteriorly) of the length of pleurae (excluding pleural spines). Axial tubercle may be present in the rear part of axial rings. Axial furrows relatively deep. Pleurae subrectangular with straight anterior and posterior margins; wide (sag.) and flat pleural furrows with transverse orientation occupying about 50% of the length (sag.) of the segment. Pleural furrows slightly less convex than the narrow (sag.) pleural bands. Distal ends of pleurae projected into short and sharp pleural spines directed backwards. Pleural spines about 40% of the length (tr.) of pleurae, invaded by pleural furrows. Surface of thorax covered by reticulated ornamentation including the pleural spines.

Discussion: The characters of the specimen studied herein are consistent with the emended diagnosis of *Pseudatops* Lake, 1940 provided by Collantes et al. (2021a), with the flat anterior border intruded by the glabella and the absence of a preglabellar area. Despite the poor preservation of the specimen, vestiges of the reticulated ornamentation can be recognized all along the cranidium. In addition, the specimen from Totanés shows all the diagnostic characters of the emended diagnosis of *Pseudatops reticulatus* (Walcott, 1890) in Collantes et al. (2021a). The cephalon is semicircular or trapezoidal, while in *Pseudatops viola* (Woodward, 1888) it is more semiovalate. In addition, the facial suture of the specimen does not cut the gena. This new specimen differs from previously figured specimens in a narrower (tr.) and more convex glabella and fixigenae, a condition probably caused by tectonic distortion as it is clearly laterally compressed. The anterior border also seems to be longer (sag.) in front of the glabella than in other specimens, and wider (tr.) laterally. Recently, Birch and McCobb (2023) suggested the monospecificity of *Pseudatops* based on newly collected specimens of *P. viola* from Gwynedd (North Wales). They figured various librigenae and offered a reconstruction of the species with the suture not crossing the lateral furrow as in *P. reticulatus* and regarded the other differences between the species of *Pseudatops* as caused by tectonic deformation.

Howell & Stubblefield (1950) figured one complete specimen and another incomplete articulated specimen of *P. viola*, but the specimen of *P. reticulatus* from Totanés is the first figured articulated and almost complete specimen of this species. The thoraxes of the two species are very similar in their general proportions, with axial rings subequal in width (tr.) until the 7th–8th segment and then slightly narrowing, and subequal or slightly narrower (tr.) than pleurae. As in *P. viola*, the axial ring probably bears an axial tubercle, although it is only weakly indicated in the 7th thoracic segment due to the poor preservation of the specimen. The reticulated ornamentation that characterizes the cephalon of *P. reticulatus* is also present in the thorax as in *P. viola*. Both species show the anterior segments with a more subsemicircular posterior margin until the 5th or 6th segment

and a straighter posterior margin from then, but in *P. viola* the anterior segments appear to be more curved. In addition, the distal end of the posterior margin of pleurae deflects backwards in *P. viola*, while the ones of *P. reticulatus* are transverse. The wide (tr.) pleural furrows of *P. reticulatus* are clear and differentiated from the more convex pleural bands, but in *P. viola* the pleurae are more uniform. Birch & McCobb (2023) figured various incomplete articulated specimens of *P. viola*, but in their reconstruction of the species the posterior margin of the pleurae is transverse, which does not match the morphology of the specimens figured by Howell & Stubblefield (1950; pl.1, figs. 1, 2). However, the specimen figured in this paper is poorly preserved and the monospecificity of the genus remains possible.

Considering the morphologies of *P. viola* and *P. reticulatus*, the thorax of *Pseudatops* differs from the one of *Atops* Emmons, 1844 in longer (sag.) axial rings and pleurae, the more semicircular axial rings, and the presence of a reticulated ornamentation. On the other hand, the length of pleural spines, the number of thoracic segments and the presence of a macropleural segment appears to be more interspecific rather than intergeneric characters, with the different species of *Atops* and *Pseudatops* showing certain variability.

Geographical and stratigraphical distribution: *Elliptcephala asaphoides* Zone, Taconic Allochthon. *Hebediscus attleborensis* Subzone, *Callavia broeggeri* Biozone, Avalonia. Upper part of ‘Cumbres beds’, upper Marianian (Cumbres de San Bartolomé, Huelva province; Spain). Herrerías shale, middle-upper Marianian (Arroyomolinos de León; Huelva Province, Spain). Fossil site 1 (Fig. 2a) in the Soleras Fm, upper Marianian (Totanés; Toledo province, Spain).

5 Biostratigraphy and correlation

The outcrops studied in this work have yielded eight fossiliferous sites which could be grouped in two main assemblages: the first assemblage is found in the lower part of the Soleras Fm in the Totanés–Noez area, and is composed of *Serrodiscus bellimarginatus*, *Chelediscus* cf. *garzoni*, *Atops calanus* and *Pseudatops reticulatus*. The second assemblage comes from the upper part of the Soleras Fm and is characterized by *S. bellimarginatus*, *Acanthomicmacca* sp., *Andalusiana palaciosi* n. sp., *Triangulaspis* cf. *fusca*, and *Termierella totanesensis* n. sp. The presence of *S. bellimarginatus* indicates a late Marianian age in the regional stratigraphic chart for the Iberian Peninsula (Collantes et al., 2022; Liñán, 1984; Liñán et al., 1993, 1996). The FAD of this genus was proposed by Liñán et al. (1993, 1996) as the marker for the base of this substage, a suggestion which was reinforced by Collantes et al. (2022) after studying numerous fossil sites of the Ossa-Morena Zone and the Totanés-Noez section.

In the Western Gondwana paleocontinent, *S. bellimaginatus* occurs in numerous localities in the Ossa-Morena Zone, as in the upper part of the Cumbres beds from Cumbres de San Bartolomé and Cumbres de Enmedio localities (Huelva province, Spain), the upper part of the Herrerías Shale from Sierra del Bujo, El Pozuelo, Minas de Cala and Arroyomolinos de León localities (Huelva province), in La Hoya Mb (Alconera Fm) from Alconera (Badajoz province, Spain), in the ‘Benalija beds’ of Llerena (Badajoz province, Spain), and in the ‘Alanís beds’ (= Benalija beds) of Alanís and Guadalcanal (Seville province, Spain) (see Collantes et al., 2022). This species has also been reported from the *Lusatiops* Mb of the Charlottenhoff Fm in the Görlitz Synclinorium (Germany) (Geyer & Elicki, 1995), in levels equivalent to the lower part of Cambrian Stage 4; and from the Issafen Fm, below the *Antatlasia guttapliviae* to upper *Sectigena* zones, upper Banian in Morocco (Geyer, 1988, 2005). In Avalonia, this species is present in the *Hebediscus atleborensis* Subzone (uppermost *Callavia broeggeri* Zone) to the middle *Strenuella sabulosa* Zone of the St. Mary’s Mb in the Brigus Fm of Newfoundland (Fletcher, 2006; Fletcher & Theokritoff, 2008; Westrop & Landing, 2012), as well as in the lowermost to middle *Protolenus* Zone in the Comley Series of Warwickshire (United Kingdom) (Rushton, 1966). The genus *Serrodiscus* is also present in Laurentia, in the lower *Arcuolenellus arcuatus* Zone (Webster, 2011) and in the *Nevadella* Zone of the MacKenzie Mountains of NW Canada (Fritz, 1973), the *Elliptocephala asaphoides* to *Acimetopus bilobatus* zones of the Taconic Allocthon (Rasetti, 1967), the upper part of the Buen Fm and the Aftenstjernesø Fm of Greenland (Blaker & Peel, 1997), and the Slaklidalen Limestone Fm in Spitzbergen Island of Svalbard, Norway (Major & Winsnes, 1955). In Baltica, *Serrodiscus* was reported from the *Protolenus–Issafienella* Zone (= *Ellipsostrenua spinosa* Zone, sensu Cederström et al., 2022) in the Holy Cross Mountains (Żylińska, 2013; Żylińska & Szczepanik, 2009). In Russia, this genus is present in the Siberian Platform (Astashkin et al., 1991; Datsenko et al., 1968), in the ‘*Menneraspis* beds’ and in the *Kooteniella–Edelsteinaspis* Zone of the Altay-Sayan Foldbelt (Astashkin et al., 1995; Korovnikov et al., 2013; Pokrovskaya, 1959), and in the *Tologoja subquadrata–Margodiscus rackovskii–Sajanaspis* Zone in Mongolia (Korobov, 1980). In Australia, *Serrodiscus daedalus* has been found in the *Pararaia janeae* Zone in South Australia and western New South Wales (Öpik, 1975; Jell in Bengtson et al., 1990; Laurie in Brock et al., 2000; Betts et al., 2017). Finally, this genus has been reported from the lower Shuangyingshan Fm in northwestern Gansu Province (Zhou in Zhou et al., 1982; Lin in Zhou & Zhen, 2008; Bergström et al., 2014).

Chelediscus garzoni has been reported from the uppermost part of the ‘Cumbres beds’ of the Cumbres block in Cumbres de San Bartolomé (Huelva province, Spain)

(Collantes et al., 2023). The genus *Chelediscus* occurs in Avalonia in the Purley Shales of the upper Comley Series, Warwickshire (Rushton, 1966), and in the Brigus Fm of Newfoundland (Fletcher, 2003). *Chelediscus* has been reported also from Siberia in the Shumny Fm of Shukharikha section, Russia (Repina, 1972), the Taconic Allocthon in the *Leptochilodiscus punctulatus* beds of East Chatham, New York (Rasetti, 1967), and from the Torneträsk Fm of Sweden (Axheimer et al., 2007), belonging to Baltica.

Acanthomicmacca is another taxon with a wide distribution. In Spain, it is present in the lower part of the Huérmada Fm of the Iberian Chains in Zaragoza (Sdzuy, 1961; Sepúlveda et al., 2022). In Western Gondwana, this genus has been reported also from levels tentatively assigned to the lower part of the Cambrian Stage 4 in the *Sectigena* Zone of the Amouslek section in Morocco (Geyer, 2016; Hupé, 1953), and in the *Lusatiops* Mb of the Görlitz synclinorium in Germany (Geyer & Elicki, 1995; Richter & Richter, 1941). In Morocco and Germany, *Acanthomicmacca* has been collected from respectively the *Morocconus notabilis* and the *Kingaspidoidea frankenwaldensis* zones (Geyer, 2016; Hupé, 1953). Furthermore, *Acanthomicmacca* occurs at various localities of Avalonia, for instance in the Brigus Fm of Manuels Brook and in the upper part of the *Callavia broeggeri* Zone in the Redland Cove section of Newfoundland (Fletcher, 2006; Matthew, 1899), and in the *Callavia* Zone of the Comley quarry in Shropshire (Cobbold, 1910, 1931). Various species of *Acanthomicmacca* are present in the Xidashan, Yingzuiyan, Huanglianba, Bianmachong and Shipai fms in various regions of China and dated as of Cambrian Series 2 in age (see Geyer, 2016). In addition, this genus was reported from the Altai-Sayan area of Turkestan (Repina et al., 1975), in strata assigned to the Wuliuan.

Andalusiana is a genus whose distribution is restricted to Spain and Morocco. *Andalusiana cornuta* is present in the middle Marianian of the ‘Alanís beds’ in Guadalcanal, Seville (Sdzuy, 1961, 1962). In addition, *Andalusiana* cf. *cornuta* was reported from the lower part of the Huérmada Fm (upper Marianian) of the Iberian Chains in Tierga (Zaragoza province, Spain) (Sepúlveda et al., 2022). *A. cornuta* is known also from the *Sectigena* Zone of the Issafen and Asrir fms in the Tadakoust section, Issafen syncline, and Jbel Taïssa section in the Banian of Morocco (Geyer & Palmer, 1995; Geyer et al., 1995). The new species *A. palaciosi* n. sp. is recorded in the Fossil site 6 in the Soleras Fm (herein).

Richter and Richter (1941) figured *Triangulaspis* in the lowermost middle Marianian of the ‘Herrerías shale’ in Cala, Arroyomolinos del León and Sierra del Bujo (Huelva, Spain). Sdzuy (1962) also reported this genus from the ‘Alanís beds’ of Guadalcanal (Seville, Spain), dated as middle Marianian, and Collantes et al. (2018) figured

various specimens from the ‘Cumbres beds’ of Cumbres de San Bartolomé (Huelva). Furthermore, *Triangulaspis* was reported by Liñán & Perejón (1981) from the upper part of La Hoya Mb (Alconera Fm) in Alconera (Badajoz, Spain). In Morocco, this genus is known from the *Sectigena* Zone of the Ida ou Drif/Jbel Tasousekht and Amousslek sections (Geyer et al., 1995; Geyer, 1988, 1990b, 2005; Hupé, 1953) of the Banian Stage. In addition, it occurs in the *Callavia* Zone of the Brigus Fm of Newfoundland, Avalonia (Fletcher, 1972, 2003; Hutchinson, 1962; Westrop & Landing, 2012). In Russia, *Triangulaspis* is present in the *Judomia–Uktaspis* (*Prouktaspis*) Zone (upper Atdabanian) through the *Bergeroniellus micmacciformis–Erbiella* and *Bergeroniellus gurarii* zones (Botoman) of the Siberian Platform (Astashkin et al., 1991, 1995; Geyer, 2005; Korovnikov & Novozhilova, 2012; Korovnikov et al., 2016; Lazarenko, 1957; Lermontova, 1940; Repina, 1972; Repina et al., 1964; Varlamov et al., 2008).

Sdzuy (1961, 1962) reported the presence of *Termierella* in the ‘Alanís beds’ (middle Marianian) of Guadalcanal (Seville, Spain). Liñán & Perejón (1981) also reported this genus from the upper Marianian of the La Hoya Mb (Alconera Fm, Alconera, Badajoz, Spain). In the Iberian Chains, *Termierella* was reported by Sepúlveda et al., (2021a, 2022) from the middle part of the Ribota Fm (middle Marianian) in Tierga (Zaragoza, Spain). Also, *Termierella* has been found in the Borobia 1 section (see Gámez Vintaned et al., 2023), from levels where Palacios & Moczydlowska (1998) found acritarchs of the *Skiagia ciliosa–Heliosphaeridium dissimilare* Zone (now *Skiagia ciliosa* Zone sensu Palacios et al., 2021). *Termierella* was reported from the *Sectigena* Zone to the *Hupeolenus* Zone in the Issafen and Asrir fms in the Issafen syncline of Morocco (Geyer et al., 1995; Geyer, 1990b; Hupé, 1953), dated as Banian in age.

The species *Atops calanus* was described by Richter & Richter (1941) in the horizon cbM2/cbM3 of the ‘Herrerías’ shale in Arroyomolinos de León (Huelva province, Spain), and assigned to the lowermost middle Marianian. Later, Collantes et al. (2021a) reported this species from the upper part of ‘Cumbres beds’ and the ‘Herrerías shale’ of Cumbres de San Bartolomé, Huelva, dated as upper Marianian. *Atops* is a genus with a wide distribution, but only *Atops koroboyi* in the Sanashtykgol Horizon of the Altai-Sayan Fold Belt in Siberia (Repina et al., 1999), and *Atops* cf. *calanus* in the *Sectigena* Zone of Morocco (Geyer, 2005) have a similar stratigraphic position. In the Cambrian Stage 3, *Atops* occurs in the *Elliptocephala asaphoides* Zone of the Taconic Allocthon (Lochman, 1956; Rasetti, 1967); in Baltica in the middle *Holmia–Schmidtellus* Biozone of the Holy Cross Mountains, Poland (Orlowski, 1985; Żylinska, 2013); in the *Pararaia janeae* Biozone of Australia (Jago et al., 2006; Jell et al., 1992); and in the upper Botomian of the Tuva Republic, Siberia (Korobov, 1973). In addition, *Atops* sp.

indet. and *Atops?* sp. indet. were reported from *Bonnia–Olenellus* Biozone of Newfoundland (Cotton, 2001) and in the *Cephalopyge* Biozone of the Purley Shales (Rushton, 1966), respectively, both in Avalonia.

Pseudatops reticulatus was found in the upper part of the ‘Cumbres beds’ in Cumbres de San Bartolomé and in the ‘Herrerías shale’ of Arroyomolinos de León, both located in the Huelva province in Spain and dated as late Marianian in age (Collantes et al., 2021a). In the Taconic Allocthon, this species was reported from the *Elliptocephala asaphoides* Zone in New York (Basset et al., 1976; Lochman, 1956), whereas in Avalonia it was found in the *Callavia broeggeri* Zone of Newfoundland (Fletcher, 2006) and in the Comley Limestones in Shropshire, United Kingdom (Cobbold, 1931, 1936). *Pseudatops* also occurs in the *Strenuella sabulosa* Biozone of North Wales and Shropshire (Basset et al., 1976; Birch & McCobb, 2023; Howell & Stubbsfield, 1950), in the *Antatlasia guttapliviae* Biozone of Morocco (Sundberg et al., 2016), and in the *Callavia–Olenellus–Holmia* Biozone in the Tuva Republic (Korobov, 1973).

Assemblage 1, which is composed of *S. bellimarginatus*, *C. cf. garzoni*, *A. calanus* and *P. reticulatus*, is also present in the upper levels of the ‘Cumbres beds’ and ‘Herrerías shale’ informal units of the Cumbres and Herrerías blocks respectively in the Ossa-Morena Zone, assigned to the upper Marianian (Collantes et al., 2021a, 2022, 2023). Furthermore, there are assemblages in the Ossa-Morena Zone that are similar to assemblage 2 of the Soleras Fm, such as in the Alconera Fm (upper Marianian), with *Serrodiscus*, *Triangulaspis* and *Termierella* (Liñán & Perejón, 1981), and in the ‘Benalija beds’ (uppermost middle Marianian) with *Andalusiana*, *Triangulapis* and *Termierella* (Sdzuy, 1961, 1962). In addition, *Termierella* is also present in the middle part of the Ribota Fm (Gámez Vintaned et al., 2023; Sepúlveda et al., 2021a, 2022), and *Andalusiana* and *Acanthomicmacca* are present at the base of the Huérmeda Fm of the Iberian Chains, dated as late Marianian in age (Sepúlveda et al., 2022). A tentative correlation chart of the Marianian in the Central Iberian Zone, the Ossa-Morena Zone and the Iberian Chains is provided here in Fig. 8. The occurrence of *S. bellimarginatus*, *C. cf. garzoni*, *Triangulaspis*, *A. calanus* and *P. reticulatus* in the upper part of the ‘Cumbres beds’ and the ‘Herrerías shale’ of the Ossa-Morena Zone as well as in the Soleras Fm of the Central Iberian Zone provides a strong correlation between the upper Marianian of these areas. In the Ossa-Morena Zone, this correlation also extends to the Alconera Fm, which records *Serrodiscus*, *Triangulaspis* and *Termierella*. On the other hand, the presence of *Andalusiana* and *Acanthomicmacca* in both the upper part of the Soleras Fm and the lower part of the Huérmeda Fm may provide a good correlation in the upper Marianian of the Central Iberian Zone and the Iberian Chains. In addition, the presence of *Hebediscus*, *Andalusiana*, *Strenuaeva* and *Termierella* in

the Ribota and Huérmeda Fms of the Iberian Chains (Sdzuy, 1961; Sepúlveda et al., 2021b, 2022) could reinforce the correlation between this region and the Ossa-Morena Zone, where these genera have been cited in the middle and upper Marianian (Liñán, 1984; Sdzuy, 1961, 1962).

The genera and species studied in this work have been cited in different horizons with an age equivalent to the lowermost Cambrian Stage 4 in the Mediterranean Subprovince (Sdzuy, 1972; Sdzuy et al., 1999). Assemblage 2 with *Serrodiscus*, *Triangulaspis* and *Termierella* is found in the upper part of the *Sectigena* Zone of the Banian of the Moroccan Anti-Atlas (Geyer, 1990b; Geyer et al., 1995, see Fig. 8). This biozone also records *Andalusiana cornuta* (see Geyer & Palmer, 1995), *Atops* cf. *calanus* (see Geyer, 2005), *Acanthomicmacca* (*Acanthomicmacca*) *coloi* and *Acanthomicmacca* (*Acanthomicmacca*) sp. C (Geyer, 2016). As in the outcrops studied herein, *Andalusiana* occurs above the FAD of *Serrodiscus* in the middle part of the *Sectigena* Zone (see Geyer & Palmer, 1995; Fig. 1). *Serrodiscus* has been also reported from the *Lusatiops* Mb of Germany (see Fig. 8), where it is associated with *Acanthomicmacca* (*Acanthomicmacca*?) *schwarzbaehi* (see Geyer, 2016).

In Avalonia and the Taconic Allochthon (Laurentia), *Serrodiscus* is associated with the *Pseudatops reticulatus* in the *Callavia broeggeri* Zone and in the middle part of the *Elliptocephala asaphoides* Zone respectively (Fletcher, 2006; Lochman, 1956). The former biozone has also yielded *Acanthomicmacca* (*A.*) *walcotti* (see Fletcher, 2006) and *Acanthomicmacca* (*Acanthomicmacca*?) *comleyensis* (see Cobbold, 1910, 1931). Furthermore, the *Callavia* Zone in the lower part of the Brigus Fm in Newfoundland (Western Avalonia) records the presence of *S. bellimarginatus*, *Triangulaspis vigilans*, *P. reticulatus* and *Acanthomicmacca* (*Acanthomicmacca*) sp. E (Fletcher, 1972; Geyer, 2016). Thus, the similarities of the taxa of the Central Iberian Zone studied in this work, plus the previously reported genera of the Ossa-Morena Zone, with those of Avalonia seems to confirm strong faunal links between these regions in the Cambrian Series 2 as pointed by other authors (e.g., Álvaro et al., 2013; Collantes et al., 2022; Sdzuy, 1972).

The *Hebediscus*–*Calodiscus*–*Serrodiscus*–*Triangulaspis* band (HCST band), proposed as a potential candidate to establish the lower boundary of the Cambrian Stage 4 (Geyer, 2005; Geyer & Shergold, 2000), would be correlatable with the upper Marianian in the Soleras Fm of the Central Iberian Zone, as well as in the Ossa-Morena Zone and the Iberian Chains.

6 Conclusions

Our study of the Cambrian Series 2 fossil sites of the Totanés–Noez area (Central Iberian Zone, Toledo province, Spain) has shown the presence of two trilobite assemblages. The first assemblage consists of *Serrodiscus bellimarginatus*, *Chelediscus* cf. *garzoni*, *Atops calanus* and *Pseudatops reticulatus*, whereas the second assemblage is composed of *S. bellimarginatus*, *Triangulaspis* cf. *fusca*, *Andalusiana palaciosi* n. sp., *Termierella totanesensis* n. sp. and *Acanthomicmacca* sp. These species are indicative of a late Marianian age in the regional stratigraphic chart of the Iberian Peninsula, and the upper Marianian can be correlated with the lowermost Cambrian Stage 4.

The assemblages facilitate correlation of the Soleras Fm of the Central Iberian Zone with other lower Cambrian successions in the Iberian Peninsula. The assemblage with *S. bellimarginatus*, *C. garzoni*, *Triangulaspis* and *P. reticulatus* is found in the ‘Cumbres beds’ and ‘Herrerías shale’ units in the Cumbres and Herrerías blocks of the Ossa-Morena Zone, whereas *Serrodiscus*, *Triangulaspis* and *Termierella* are present in the Alconera Fm, all of them dated as late Marianian in age. The presence of *Andalusiana*, *Triangulaspis* and *Termierella* is also shared with the ‘Benalija beds’ of this zone, and suggestive of the middle Marianian. Outcrops studied herein also show a good correlation with the Iberian Chains, with *Acanthomicmacca* and *Andalusiana* reported from the Huérmeda Fm as well.

Intercontinentally, various of the identified species reinforce some previously noted faunistic connections between several Cambrian domains and the Iberian Peninsula. In Western Gondwana, taxa reviewed herein permits a good correlation with the *Sectigena* Zone of the Moroccan Anti-Atlas and with the *Lusatiops* Mb of the Görlitz synclinorium in Germany, with *Serrodiscus*, *Triangulaspis*, *Andalusiana cornuta*, *Termierella* and *Atops* in the former region, and *Serrodiscus* and *Acanthomicmacca* in the latter. *Serrodiscus* and *P. reticulatus* are also present in the *Elliptocephala asaphoides* Zone of the Taconic Allochthon of Laurentia, as well as in the *Callavia broeggeri* Zone of Avalonia, with *Triangulaspis* and *Acanthomicmacca* also in the latter.

The presence of both *Serrodiscus* and *Triangulaspis* in the Soleras Fm allow for a correlation with the ‘HSCT’ band, proposed as a potential candidate for the lower boundary of the yet undefined Cambrian Stage 4.

ISCS	Iberia			Morocco		Anti-Atlas	OMZ	OMZ	CIZ	Iberian Chains	Doberlug
	Trilobites	Acritarch		Trilobites		Amouslek	Cumbres	Alconera	composite	composite	
Cambrian Series 2	Stage 4	Lower	<i>Protolenus dimarginatus</i>	<i>H. notatum</i>	Tis.	<i>Hupeolenus</i>	Rincón beds	Las Vegas Mb (La Lapa Fm)	Los Cortijos Fm	Daroca Fm	Charlottenhof Fm
		Bilbilian	<i>Realaspis</i> FAD			Ass. 2					
	Stage 3	Upper	<i>Serrodiscus</i> FAD	<i>Skiagia ciliosa</i>	Banian	<i>Sectigena</i>	Issafen Fm	Cumbres beds	La Hoya Mb (Alconera Fm)	Soleras Fm	
		Marianian	<i>Andalusiana</i> FAD							Ass. 1	
	Middle	<i>Strenuaeva</i> FAD			<i>Antatlasia guttapluyiae</i>				Ribota Fm		

Fig. 8 Tentative correlation chart of the middle Marianian to lower Bilbilian (Cambrian Series 2) in some selected sections of the Mediterranean subprovince (sensu Sdzuy, 1972, and Sdzuy et al., 1999). Chrono- and biostratigraphic units after the International Subcommission on Cambrian Stratigraphy (Peng et al., 2020), Morocco (Geyer & Landing, 2004; Geyer et al., 1995; Geyer, 1990a) and Iberia (Liñán et al., 2002; acritarch zones sensu Palacios et al., 2021). Amouslek section (Geyer et al., 1995; Hupé, 1953). Cumbres section (Collan-

tes et al., 2021a, 2022). Alconera section (Liñán & Perejón, 1981; Palacios et al., 2021). Totanés and Los Cortijos composite section (Weggen, 1955; Lotze, 1961; herein). Iberian Chains composite section (Gámez et al., 1991; Palacios & Moczydlowska, 1998; Sepúlveda et al., 2022). Doberlug (Elicki, 1997; Geyer & Elicki, 1995). Ass. 1 Assemblage 1; Ass. 2 Assemblage 2; R *Realaspis*; P *Protolenus* (*Hupeolenus*)

Appendix 1 Geographic location of the fossil sites of Fig. 2

- 39° 42' 49" N–4° 20' 02" W (Totanés, Toledo province). First fossil locality discovered and published in the region (Aparicio Yagüe & Gil Cid, 1972).
- 39° 43' 07" N–4° 13' 02" W (Totanés, Toledo province). Site PN₁/1.
- 39° 43' 44" N–4° 12' 19" W (Totanés, Toledo province). Site PN₁/2.
- 39° 43' 53" N–4° 12' 06" W (Totanés, Toledo province). Site PN₁/3.
- 39° 44' 01" N–4° 12' 06" W (Noez, Toledo province). Site PN₁/4.
- 39° 44' 03" N–4° 12' 06" W (Noez, Toledo province). Site PN₁/5. This fossil site was cited by Liñán et al. (1993).
- 39° 45' 17" N–4° 13' 18" W (Polán, Toledo province). Site PN₂. This fossil site is located at the road CM-401, km. 22.5. On older maps this site corresponds to the 23.750 km in accordance with the label of Walter's kept in the MCNZ Sdzuy collection. Dabrio González (1990) carried out a sedimentological study ("3.1.- Las pizarras cámbricas del km. 23,750 la carretera de Polán a Gálvez").
- 39° 44' 28" N–4° 12' 36" W (Noez, Toledo province). This trilobite site was discovered by Mr. Moises Ludeña and Mr. David Rueda. Dabrio González (1990) carried out a sedimentological study ("3.2.- Las pizarras y carbonatos del Cámbrico al sureste del Puerto de la Jarosa").

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Declarations

Conflict of interest The authors declare that they have no conflict of interest.

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