Biostratigraphy of the Ribota and Huérmeda formations (Cambrian Series 2) in the Comarca del Aranda (Zaragoza province), Iberian Chains (NE Spain)

Bioestratigrafía de las formaciones Ribota y Huérmeda (Serie 2 del Cámbrico) en la Comarca del Aranda (provincia de Zaragoza), Cadenas Ibéricas (NE de España)

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Abstract: This article presents a detailed biostratigraphic analysis of the Cambrian Series 2 Ribota and Huérmeda formations of four sections of the Iberian Chains (NE Spain), and a systematic study of their trilobite faunas. We identified four major assemblages: two in the middle part of the Ribota Formation, one at the base of the Huérmeda Formation, and one at the top of the Huérmeda Formation. The studied species permit the assignment of these formations to the middle and upper Marianian and probably lower Bilbilian stages in the regional stratigraphic chart for the Iberian Peninsula, which correlates with an interval around the Cambrian Stage 3–4 boundary. The assemblages exhibit a great correlation potential with the presence of Termierella and the first figured material of Andalusianna from the Iberian Chains, two characteristic taxa of the Marianian of the Ossa-Morena Zone, having been also recorded from the Central Iberian Zone and Morocco. In addition, specimens tentatively assigned to Hebediscus are recorded for the first time from the region, a taxon with a wide geographic distribution which allows a good international correlation in the Cambrian Series 2.

Resumen: Se presenta un análisis bioestratigráfico detallado de las formaciones Ribota y Huérmeda de la Serie 2 del Cámbrico de cuatro secciones de las Cadenas Ibéricas (NE España) y un estudio sistemático de sus faunas de trilobites. Se han reconocido cuatro asociaciones principales: dos en la parte media de la Formación Ribota, una en la base de la Formación Huérmeda y otra en la parte alta de la Formación Huérmeda. Las especies estudiadas permiten asignar estas formaciones al Marianiano medio–superior y, posiblemente, a Bilbiliano inferior en la escala regional de pisos para la Península Ibérica, que se correlaciona con un intervalo alrededor del límite entre los pisos 3 y 4 del Cámbrico. Las asociaciones exhiben un gran potencial de correlación con la presencia de Termierella y el primer material figurado de Andalusianna de las Cadenas Ibéricas, dos taxones característicos del Marianiano de la zona de Ossa-Morena que también se registran en la Zona Centroibérica y en Marruecos. Además, ejemplares asignados tentativamente a Hebediscus se registran por primera vez en la región, un taxón con una amplia distribución geográfica que permite una buena correlación internacional en la Serie 2 del Cámbrico.

INTRODUCTION

Trilobites are a useful tool to establish boundaries between the different chronostratigraphic units in the Cambrian System due to their abundance and global distribution (Babcock et al., 2017; Peng et al., 2020). However, the strongly endemic character of trilobite faunas of the Cambrian Series 2 as well as other factors have prevented the ratification of this Series and Stages 2 to 4 (Palmer, 1998; Geyer & Shergold, 2000). Working toward completing the subdivision of the Cambrian System, the International Subcommission on Cambrian Stratigraphy (ISCS) encourages to establish regional biostratigraphical schemes which assist in detailed intercontinental correlations of Cambrian Series 2 successions. Recently, the upper boundary of this series was defined by the ratification of the Miaolingian Series and the Wuliuan Stage (replacing former Middle Cambrian lower strata; see Zhao et al., 2019), and its lower boundary is also under discussion (see Zhang et al., 2017; Peng et al., 2020). Nevertheless, the persistent use of the traditional informal subdivision in lower, middle, and upper Cambrian instead of the 4 series and 10 stages subdivision, adopted less than two decades ago, led Landing et al. (2021) to back up and reintroduce the subdivision of this period in three subsystems.

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The Cambrian Series 2 have been tentatively correlated to the Ovetican, Marianian and Bilbilian stages in the regional stratigraphic chart for the Iberian Peninsula (Sdzuy, 1971; Liñán et al., 1993; Shergold, 1997; Gozalo et al., 2008; Sundberg et al., 2016; Zhang et al., 2017). In this region, the Iberian Chains show one of the most complete Cambrian record ranging from the Terreneuvian to the Furongian (Liñán et al., 2002, 2004; Gozalo et al., 2008). Still, the works about the Marianian deposits (comprising the Ribota and Huérmeda formations) are preliminary, mainly focusing on stratigraphy and petrology (Schmidt-Thomé, 1973; Gámez et al., 1991; Zamora et al., 1992, 1993; Álvaro et al., 1995; Palacios & Moczydłowska, 1998; Álvaro et al., 2019), and the trilobite biostratigraphy of those formations is yet to be published.

Álvaro et al. (2019) studied the trilobite fauna of the first meters of the Huérmeda Formation in various sections of the Mesones tectonostratigraphic unit of the Iberian Chains. In this work, they argued that the Marianian stage would be invalid for correlation throughout the Iberia Peninsula, as none of the different horizons proposed for marking the base and the top of this stage would be recognizable in all regions.

Aiming to improve the knowledge of this stage in the Iberian Chains, this article offers a biostratigraphic analysis of the Ribota and Huérmeda formations for four sections, two of them belonging to the Mesones Unit (Mesones 9, M9; Minas Tierga 1, MT1), and the other two (Jarque 1, J1; Jarque 2, J2) to the Badules Unit (Fig. 1), as well as a systematic study of their trilobite faunas. The review and analysis of both the previous data as well as new findings make it possible to establish correlation levels with nearby areas, both in the Iberian Peninsula (Ossa-Morena and Central Iberia Zones) as well as with Morocco and Germany. In addition, the first record of Eodiscina in the lower Cambrian of the Iberian Chains allows new correlations with Series 2 strata in other Cambrian continents.

**GEOLOGICAL AND STRATIGRAPHIC SETTING**

The Iberian Chains are two NW-SE parallel ranges of Palaeozoic outcrops separated by the Tertiary Calatayud basin whose rocks have suffered major tectonic deformation from both Hercynian and Alpine orogenies. This area constitutes the southernmost prolongation of both the Cantabrian and West Asturian-Leonese Zones (Gozalo & Liñán, 1988; Fig. 1) in the Eastern and Western Iberian Chain respectively, where three tectonostratigraphic units (Badules, Mesones and Herrera Units) have been defined (Lotze, 1929; Carls, 1983; Gozalo & Liñán, 1988).

The lower Cambrian lithostratigraphic units of the Iberian Chains were defined by Lotze (1929, 1958, 1961), and the nomenclature for these units has been modified several times since then (see Liñán et al., 1996b, 2002, 2004, and Gozalo et al., 2008). The Ribota Formation is a carbonate unit characterized by bedded to massive dolostone with various lutite and marl intercalations. The Huérmeda Formation is a siliciclastic unit mainly composed of lutites and siltstones with minor dolostones intercalations.

The four studied sections are located in the Comarca del Aranda (Zaragoza province, NE Spain). The J1 and J2 sections are located at the Badules Unit (Fig. 1). The J1 section extends parallel to the Aranda River at 0.5 km westwards from the town of Jarque. The upper part of Series 2 and the Miaoalignian deposits of this outcrop and their trilobite fauna have been studied extensively (i.e., Dies-Alvarez et al., 2001, 2004; Liñán et al., 2003; Dies-Alvarez, 2004; Chirivella-Martorell et al., 2003, 2009, 2017, 2020; Dies-Alvarez & Gozalo, 2006; Chirivella-Martorell, 2008). Nevertheless, the knowledge on the Marianian stage in this section is limited to the stratigraphy of the Ribota and Huérmeda formations. Moreover, an incomplete trilobite faunal list exists with the ellipsocephalidae species *Strenuea incondita* Sdzuy, 1961, *Lusatiops ribotanus* Richter & Richter, 1948 and *Kingaspis* (*Kingaspidoidea*) *velata* Sdzuy, 1961 (Liñán et al., 1996a, 2003, 2008). The to date unpublished J2 section is located at 100 m southward stretching parallel to the J1 section, and its stratigraphy and trilobite fauna is presented herein.

The Ribota Formation in the J1 section is faulted at its base, having a thickness of 84 m characterized by various packages of yellow and grey dolostone and interbedded green marly shale (Fig. 2). The two shale levels in the upper half of the formation have yielded the fauna studied herein along with the first shale levels of the Huérmeda Formation, which is characterized by a 72 m thick succession of green shale and a thick dolostone intercalation in its middle part. The Ribota Formation in the J2 section (Fig. 3) is mainly characterized by a succession of dolostones and shales of 102 m in thickness, with two packages of massive dolostone at the top. The fauna studied herein was collected from two shale levels in the upper half of the Ribota Formation. The base of the Huérmeda Formation is composed of 22 m thick shales with scarce fossils recorded from the top of level 17 and the bottom of level 18. 

The M9 and MT1 sections are located in the Mesones Unit (Fig. 1). The area of Mesones de Isuela contains various stratigraphic sections whose upper part of Cambrian Stage 4 and Miaoalignian trilobites have been studied in different works (i.e., Valenzuela et al., 1990; Gozalo et al., 1993; Gozalo & Liñán, 1996; Álvaro, 1996; Dies-Alvarez, 2004; Chirivella-Martorell, 2008; Esteve, 2013; Pates et al., 2017). The M9 section (2.5 km westwards from the town of Mesones de Isuela, Zaragoza) records the Ribota and Huérmeda formations and Álvaro et al. (2019) studied a nearby section under the name ‘Barranco del Judío’. These authors indicated the occurrence of the species *Lusatiops ribotanus*, *Strenuea incondita*, *Redlichia* (*Redlichia*) *isuelaensis* Álvaro, Esteve, Gracia &
Zamora, 2019, and the onaraspids *Onaraspis garciae* Álvaro, Esteve, Gracia & Zamora, 2019, *Luciaspis matiasi* Álvaro, Esteve, Gracia & Zamora, 2019, and *Paulaspis tiergaensis* Álvaro, Esteve, Gracia & Zamora, 2019 in the lowest meters of the Huérmeda Formation and presented a schematic stratigraphic profile of the section.

The MT1 section is situated near the Santa Rosa mine, in the vicinity of Tierga. Schmidt-Thomé (1973) published a synthetic stratigraphy of the area. Liñán et al. (2003) reported the species *Kingaspis* (*Kingaspidoides*) cf. *velata* Sdzuy, 1961 from the level 23 of the MT1 section, and Sepúlveda et al. (2021a) recorded in three levels the presence of *Kingaspis* (*Kingaspidoides*) *velata*, *Lusatiops ribotanus*, *Strenuava incondita*, *Onaraspis garciae*, *Luciaspis matiasi*, *Paulaspis tiergaensis*, *Termierella* sp. and *Redlichia?* sp.

The upper part of the Ribota Formation in the M9 section comprises 30 m of massive dolostone without trilobite remains (Fig. 4). The Huérmeda Formation is characterized by 101 m-thick succession mainly composed by shale with some interbedded dolostone levels. The first shale levels are very fossiliferous, but there are some other shale levels with scarce trilobite remains above the lowest dolostone levels in the half part of the formation, and another level with trilobites

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*Figure 1. A, Map of the Iberian Peninsula showing pre-Hercynian outcrop areas; B, Location of the studied sections in the Iberian Chains. Modified from Gozalo and Liñán (1988). 1, Jarque 1 and 2 sections; 2, Minas Tierga 1 section; 3, Mesones 9 section; SPZ, South Portuguese Zone; OMZ, Ossa-Morena Zone; CIZ, Central Iberian Zone; WALZ, West Asturian-Leonese Zone; CZ, Cantabrian Zone; SD, Demanda Mountains; CI, Iberian Chains; PY, Pyrenees; CCC, Catalan Coastal Range; BC, Betic Chain.*
lies above the quartz dyke in the lowest meters of the upper half of the formation. MT1 is a 250 m thick section (Fig. 5) comprising 150 m strata of the Ribota Formation mainly composed of dolostones and marly dolostones with an intercalation of 10 m thick shales with trilobites. The uppermost 100 m of the section belong to the Huérmeda Formation and contain the other two levels with trilobites studied herein, the former located at the base of the formation and the latter at the top of the formation above dolomitic marlstone and siltstone levels.

In addition, the works for the Geological Map 1:50.000 of Spain in the area comprising the localities discussed in this work cited the presence of the despujoliid genus Realaspis Szdzy, 1961 in the Huérmeda Formation (Ramírez et al., 1981), the first appearance datum (FAD) of which was used to define the base of the Bilbilian stage in the Iberian Peninsula (see Liñán et al., 1993, 2006).

**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.

![Figure 2. Stratigraphy and distribution of trilobites in the Jarque 1 (J1) section (modified from Liñán et al., 1996a, 2008).](image)

**ORDER EODISCINA Kobayashi, 1939**

**SUPERFAMILY EODISCOIDEA Raymond, 1913**

**FAMILY HEBEDISCIDAE Kobayashi, 1944**

**GENUS *Hebediscus* Whitehouse, 1936**

*Type-species.* *Ptychoparia attleborensis* Shaler & Foerste in Shaler, 1888 from the Briggus Formation, Massachusetts; by original designation. Cambrian Series 2; United States.

*Hebediscus?* sp.

**Figure 6A–6D**

**Material and locality.** Three cranidia and one pygidium from level 2 of the Huérmeda Formation of the M9 section.

**Description.** Cranidium subrectangular to subelliptical in outline, with a low curvature of the anterior margin. Glabella subrectangular and slightly tapering forward, with its maximum width at the occipital ring and with anterior margin evenly rounded. Glabellar furrows obsolescent. Semi-circular and narrow occipital ring extending backwards, delimited anteriorly by a shallow occipital furrow. Deep and well-marked axial furrow connected with the anterior border furrow. Anterior border furrow deep and wide (sag. and exsag.), ascending with even slope towards the anterior margin of the glabella and the ocular area, reaching its maximum depth where it coalesces with the anterior border. Anterior border narrow (sag. and exsag.), with low curvature and raised. Fixigena semi-circular and moderately convex, with its most elevated point near the eye. Narrow pre-ocular area. Weakly indicated eye ridge and short (sag.) but relatively wide (tr.) palpebral lobe. Posterior part of the fixigena low and narrow (sag.). Posterior border convex in transverse profile. Thorax unknown. Pygidium subelliptical in outline and convex, with a prominent axis. Pygidial axis subconical and tapering posteriorly, of more than 3/4 of the pygidial length and with a subevenly curved posterior margin almost connected with the pygidial border furrow. Axial ring slightly more inflated than the rest of the axis. Shallow axial furrow and well-marked pygidial border furrow. Lateral and posterior pygidial borders narrow (sag. and exsag.) and strongly elevated, forming a more-or-less uniform curvature at the exterior margin, very similar to the anterior border of the cranidium.

**Remarks.** The characters of the cranidium are consistent with the diagnosis provided by Jell (1997) and subsequent authors such as Westrop and Landing (2012), with a glabella having almost straight lateral margins and the occipital lobe poorly defined. In any case, both cranidium and pygidium have characters closely similar to *Hebediscus lemdadensis* Geyer, 1988. However, the imperfect preservation of the specimens from the Huérmeda Formation does not permit a confident determination.
| Fm.  | Level | m | Lithology                      | Trilobites                          | Stage | Series |
|------|-------|---|--------------------------------|-------------------------------------|-------|--------|
| Huérmeda | 18   | 100 | Chert                         | Andalusiana                        | M     | Marianian Series 2 |
|       | 17   | 75  | Chert and dolostone alternation | Lussatios steinensis                |       |        |
|       | 16   | 50  | Shale                         | Strenaeva incondita                 |       |        |
|       | 15   | 25  | Dolostone                     | Acanthomacmaca (A.) aff. coloi     |       |        |
| Ribota | 14   | 0   | Shale                         | Paulaspis matasi                    |       |        |
|       | 13   |     | Chert                         | Lucaspis tiberensis                 |       |        |
|       | 12   |     | Chert                         | Andalusiana cornuta Sdzuy, 1961     |       |        |
|       | 11   |     | Chert                         | Andalusiana cf. cornuta Sdzuy, 1961 |       |        |
|       | 10   |     | Chert                         | Andalusiana cf. cornuta Sdzuy, 1961 |       |        |
|       | 9    |     | Chert                         | Andalusiana cf. cornuta Sdzuy, 1961 |       |        |
|       | 8    |     | Chert                         | Andalusiana cf. cornuta Sdzuy, 1961 |       |        |
|       | 7    |     | Chert                         | Andalusiana cf. cornuta Sdzuy, 1961 |       |        |
| Jalon  | 6    |     | Chert                         | Andalusiana cf. cornuta Sdzuy, 1961 |       |        |
|       | 5    |     | Chert                         | Andalusiana cf. cornuta Sdzuy, 1961 |       |        |
|       | 4    |     | Chert                         | Andalusiana cf. cornuta Sdzuy, 1961 |       |        |
|       | 3    |     | Chert                         | Andalusiana cf. cornuta Sdzuy, 1961 |       |        |
|       | 1    |     | Chert                         | Andalusiana cf. cornuta Sdzuy, 1961 |       |        |

**Figure 3.** Stratigraphy and distribution of trilobites in the Jarque 2 (J2) section.

**Occurrence.** Huérmeda Formation, Iberian Chains (Spain).

**Age.** Upper Marianian (Cambrian Series 2).

**Order REDLICHIIDA Richter, 1932**

**Suborder OLENELLINA Walcott, 1890**

**Family HOLMIIDAE Hupé, 1953**

**Subfamily HOLMIINAE Hupé, 1953**

**Genus Andalusiana Sdzuy, 1961**

**Type-species.** *Andalusiana cornuta* Sdzuy, 1961 from Guadalcanal FP. 1 (Sevilla province); by original designation. Cambrian Series 2; Spain and Morocco.

*Andalusiana cf. cornuta* Sdzuy, 1961

**Material and locality.** One cephalon preserved as internal mould collected by Prof. Klaus Sdzuy (1925-2005) in level 23 of the lowermost Huérmeda Formation in the MT1 section (according to the notes presented to Eladio Liñán and field data). This specimen is currently not available (Gerd Geyer, personal communication, 2021).

**Remarks.** Sdzuy (1971) reported the presence of *Andalusiana* in the lower part of the Huérmeda Formation based on a single incomplete but well-preserved specimen from level 23 of the MT1 section, which he determined as *Andalusiana cf. cornuta* Sdzuy, 1961. This cephalon resembles specimens of *Andalusiana cornuta* Sdzuy, 1961 figured by Sdzuy (1961, 1962) from the Ossa-Morena Zone. The specimen has
subtrapezoidal frontal lobe, a protuberance in front of the eye ridges, a very fine granulation covering the surface of the cephalon, and lacks a facial suture. According to Sdzuy’s notes, differences between the specimen from the MT1 section of the Iberian Chains and the previously described material from the Ossa-Morena Zone exist in the more trapezoidal rather than subspherical outline of the frontal lobe, the shallower S2 across the glabella, and the probably broader (sag.) occipital ring. Sdzuy ascribed these differences to differences in the ontogeny since the specimens from the Ossa-Morena Zone are smaller than this specimen. However, the material of *Andalusiana cornuta* Sdzuy, 1961 from Morocco figured by Geyer and Palmer (1995) includes some specimens with a less rounded frontal lobe slightly tapering backwards just as the here described specimen found by Sdzuy.

**Occurrence.** Huérmeda Formation, Iberian Chains (Spain).

**Age.** Upper Marianian (Cambrian Series 2).

*Andalusiana?* sp.

Figure 6F

**Material and locality.** Cephalic fragment with the left genal area and genal angle preserved as external

| Fm.  | Level | m  | Lithology | Trilobites | Stage | Series |
|------|-------|----|-----------|------------|-------|--------|
| H    | 6     | 100|           |            |       |        |
| U    | 5     | 75 |           |            |       |        |
| É    | 4     | 50 |           | Dolostone  | M     | CAMBRIAN |
| R    | 3     | 25 | Siltstone |            | M     | SERIES  |
| E    | 2     | 25 | Shale     |            | M     |        |
| D    | 1     | 25 |           |            | M     |        |
| A    | 1     | 25 | Lusatops ributanus | | M     |        |
| A    | 2     | 50 | Onaraspis garciae | | M     |        |
| A    | 3     | 75 | Luciaspis mariasi | | M     |        |
| A    | 4     | 100| Strenueva incondita | | M     |        |
| A    | 5     | 125| Andalusiana? sp. | | M     |        |
| A    | 6     | 150| Hebediscus? sp. | | M     |        |
| A    | 7     | 175| Paulaspis tiergaensis | | M     |        |

Figure 4. Stratigraphy and distribution of trilobites in the Mesones 9 (M9) section.
mould in yellow-brownish shale from level 2 of the Huérméda Formation in the M9 section.

**Description.** Genal area subtriangular in outline, with flat to slightly convex librigenal field. Border furrow absent. Distinction between genal field and lateral border noted only by an increase in convexity in the latter. Lateral border narrow, with an arched lateral margin leading into the genal angle. Posterior margin at the inner part of the genal area straight, progressively bending near the genal angle. Base of the genal spine stout. Surface of the genal area covered with a very fine granulation.

**Remarks.** Despite the imperfect preservation of the specimen, the morphology of the genal area is clearly different from those of the co-occurring Redlichiina Richter, 1932 as it lacks facial suture. Also, the other redlichioid trilobites studied herein present a well-marked furrow separating the genal field from the lateral border and a much shorter (tr.) genal field. The presence of *Andaluissiana* Sdzuy, 1961 in equivalent levels of the Huérméda Formation in the MT1 section suggest a tentative assignment of the specimen to this genus.

**Occurrence.** Huérméda Formation, Iberian Chains (Spain).

**Age.** Upper Marianian (Cambrian Series 2).

**Figure 7N**

**Material and locality.** One incomplete thorax with the posterior six thoracic segments attached to an incomplete pygidium; from level 23 of the MT1 section.

**Description.** Axial ring subrectangular and slightly convex, with a flat-arched posterior margin. Remnants of an axial node. Axial furrow narrow and well-marked. Pleurae flat, slightly shorter (trans.) than the axial ring, and backwards-directed specially in its distal part. Pleural furrow narrow (sag. and exsag.) and shallow, conforming two subtriangular pleural bands. Pleural spines narrow and strongly backwards-directed, increasing in length to the pygidium. Spines of the two posteriormost thoracic segments reach posteriorly beyond the posterior margin of the pygidium. Pygidium small and oval to semi-circular in outline.

**Remarks.** Despite the morphological characters of the thorax resemble that seen in *Redlichia* (Redlichia) *isuelaensis* Álvaro, Esteve, Gracia & Zamora, 2019, the specimen described herein (Fig. 7N; MPZ 2021/384) is not included in Redlichia (Redlichia) *isuelaensis* Álvaro, Esteve, Gracia & Zamora, 2019 from the equivalent strata of the Minas Tierga section. The oval shape of the pygidium and the strongly backwards-directed spines that extend beyond the posterior margin of the pygidium distinguish this specimen from those of the co-occurring onaraspids.

**Occurrence.** Huérméda Formation, Iberian Chains (Spain).

**Type-species.** *Onaraspis somniurna* Opik, 1968 from near Deep Well, Rodinga area, Northern Territory (Australia), locality Rd 10, Ordian; by original designation. Cambrian Series 2; Australia.

**Onaraspis garciae** Álvaro, Esteve, Gracia & Zamora, 2019

(?) 2017 Redlichid trilobite; Pates *et al.*, p. 755, fig. 6. vp. 2018 Neoredlichiidae gen. et sp. indet.; Sepúlveda *et al.*, p. 598–560, fig. 4H, 4I, 4K, 4L. v.* 2019 *Onaraspis garciae* n. sp.; Álvaro *et al.*, p. 12–14, fig. 6. v. 2021a *Onaraspis garciae* Álvaro *et al.*, 2019; Sepúlveda *et al.*, p. 232–233, fig. 3G, 3H.

**Material and locality.** 112 cranidia, two articulated specimens, one cephalon, one exuviae, 10 pygidia, one hypostome and 13 librigenae, preserved as internal and external moulds from levels 111, 113 and 115 of the J1 section; levels 12, 13 and 34 of the MT1 section; and levels 1, 2, 4 and 6 of the M9 section.

**Remarks.** Álvaro *et al.* (2019) erected the subfamily Onaraspinae Álvaro, Esteve, Gracia & Zamora, 2019 and introduced the species *Onaraspis garciae* Álvaro, Esteve, Gracia & Zamora, 2019, *Luciaspis matiasi* Álvaro, Esteve, Gracia & Zamora, 2019 and *Paulaspis tiergaensis* Álvaro, Esteve, Gracia & Zamora, 2019 from the lowest levels of the Huérméda Formation. They also place this subfamily under the family Saukiandidae Hupé, 1953 based on the presence of macropleurae and micropleurae and the subsequent subdivision of the thorax into prothorax and opisthothorax. However, they did not mention the proposal to include the *Onaraspis* Opik, 1968 clade into Bathynotidae Hupé, 1953 by Elicki and Geyer (2013). In addition,
Figure 5. Stratigraphy and distribution of trilobites in the Minas Tierga 1 (MT1) section (modified from Sepúlveda et al., 2021a).
Zylińska and Masiak (2007) indicated the affinities of Conomicmacca plana Matthew, 1895 with the genus Onaraspis and Geyer (2016) regarded this genus as a junior subjective synonym of Conomicmacca Hupé, 1953.

Previously, Quarch (1967) and Ramírez et al. (1981) reported the presence of Realaspis Sdzuy, 1961, a genus which is now assigned to the family Despujolsiidae Geyer, 2020, in the Huérmeda Formation of the Borobia section and in the area studied herein. Sdzuy (1961) described Realaspis strenoides Sdzuy, 1961 from the Los Cortijos Formation of the Central Iberian Zone, from strata with lower Bilbilian age. However, the distorted specimens figured in Sdzuy (1961) strongly resemble the poorly preserved material of Onaraspis garciae from the M-9 section (see Fig. 7C; MPZ 2021/385). Álvaro et al. (2019) did not consider many shared characters between the newly described onaraspids and various despujolsiids, especially with Realaspis. The cranidium and the pygidium fit well with Realaspis as characterised by Geyer (2020). Moreover, Geyer (2020) cited the presence of a macropleura on the eleventh segment of Perrector Richter & Richter, 1940, Masaira Hupé, 1953 and Despujolsia Neitner & Poctey, 1950 (see Geyer, 2020). They all have a broad (sag., exsag.) anterior border and a similar pattern of distinct characters of the cranidium. In addition, the morphology and the attachment of the hypostome in Perrector falloti Hupé, 1953 figured by Geyer (2020) recall those of Luciaspis matiasi Álvaro, Esteve, Gracia & Zamora, 2019 figured in Álvaro et al. (2019) and herein (Fig. 7K; MPZ 2021/395).

Occurrence. Huérmeda Formation, Iberian Chains (Spain).

Age. Upper Marianian (Cambrian Series 2).

Genus Luciaspis Álvaro, Esteve, Gracia & Zamora, 2019

Type-species. Luciaspis matiasi Álvaro, Esteve, Gracia & Zamora, 2019 from the base of the Huérmeda Formation of the Iberian Chains, Spain; by original designation. Cambrian Series 2; Spain.

Luciaspis matiasi Álvaro, Esteve, Gracia & Zamora, 2019

Figure 7I–7K

Material and locality. 16 cranidia preserved as internal and external moulds from level 17 of the J2 section; levels 23 and 34 of the MT1 section; and level 2 of the M9 section.

Remarks. Álvaro et al. (2019) described this species from the lower levels of the Huérmeda Formation and assigned it to the newly erected subfamily Onaraspinae. However, the morphology of the cranidium strongly resembles those of some Despujolsiidae as Perrector Richter & Richter, 1940, Marsaisa Hupé, 1953 and Despujolsia Neitner & Poctey, 1950 (see Geyer, 2020). They all have a broad (sag., exsag.) anterior border and a similar pattern of distinct characters of the cranidium. In addition, the morphology and the attachment of the hypostome in Perrector falloti Hupé, 1953 figured by Geyer (2020) recall those of Luciaspis matiasi Álvaro, Esteve, Gracia & Zamora, 2019 figured in Álvaro et al. (2019) and herein (Fig. 7K; MPZ 2021/395).

Material and locality. 16 cranidia preserved as internal and external moulds from level 17 of the J2 section; levels 23 and 34 of the MT1 section; and level 2 of the M9 section.

Remarks. Sdzuy (1961) figured a cranidium (pl. 3, fig. 15) found in the area of Tierga (personal communication to Eladio Liñán and Rodolfo Gozalo, 1986) that strongly resembles those of the onaraspids from the base of the Huérmeda Formation described later in Álvaro et al. (2019). The morphology of the cranidium is probably more similar to Paulaspis tiergaensis Álvaro, Esteve, Gracia & Zamora, 2019 than to Onaraspis garciae Álvaro, Esteve, Gracia & Zamora, 2019 and Luciaspis matiasi Álvaro, Esteve, Gracia & Zamora, 2019. This specimen lacks the wide (sag. and exsag.) and inflated anterior border of Luciaspis matiasi, and both the anterior margin and the anterior branch of the facial suture are more straight than those in Onaraspis garciae. In addition, the specimen figured by Sdzuy (1961) has a more robust and wider (tr.) glabella than Onaraspis garciae.
Occurrence. Huérmeda Formation, Iberian Chains (Spain).

Age. Upper Marianian to lower Bilbilian (Cambrian Series 2).

Family ELLIPSOCEPHALIDAE Matthew, 1887
Genus Kingaspis Kobayashi, 1935

Type-species. Anomocare campbelli King, 1923 from the Nubian Sandstone of Wadi Zerka Ma’in, Jordan; by original designation. Cambrian Series 2 and Miaoilingian; Jordania, South Korea, Morocco and Spain.

Subgenus Kingaspis (Kingaspidoideas) Hupé, 1953

Type-species. Kingaspis (Kingaspidoideas) armatus Hupé 1953 [=Kingaspis (Kingaspis) brevifons Hupé, 1953], by original designation. Cambrian Series 2; Morocco.

Kingaspis (Kingaspidoideas) velata Sdzuy, 1961

Discussion. Sdzuy (1961) figured various specimens from the Huérmeda section of the Iberian Chains which were assigned to Kingaspis velatus Sdzuy, 1961. On the other hand, he determined poorly preserved material from Los Cortijos de Malagón (Central Iberian Zone) as Kingaspis cf. velatus Sdzuy, 1961. Later, Dies-Álvarez et al. (1999) reported the presence of Kingaspis campbelli King, 1923 in the Valdemiedes Formation of the Iberian Chains with a Bilbilian age. Liñán et al. (2003) reviewed the Spanish material of this genus and differentiated two morphologies interpreted as the subgenera Kingaspidoideas and Kingaspis proposed by Hupé (1953), distinguished by the presence of a preocular-preglabellar furrow in the former. They placed the former Kingaspis velatus and Kingaspis cf. velatus in the subgenus K. (Kingaspidoideas) Hupé, 1953 and Kingaspis campbelli in K. (Kingaspis) Kobayashi, 1935. Also, they figured a cranidium from level 23 of the MT1 section which was determined as Kingaspis (Kingaspidoideas) cf. velata Sdzuy, 1961, and distinguished between this species and Kingaspis (Kingaspidoideas) velata Sdzuy, 1961 by the presence of a moderately marked anterior border furrow and a more convex anterior margin in the former. The material from the J2 section studied in this work contains probably the best-preserved specimens of this subgenus found in the Iberian Chains. One of the specimens (Fig. 6G, 6I; MPZ 2021/371) differs from the other specimens assigned to Kingaspis (Kingaspidoideas) velata in a more strongly tapering glabella and by the presence of a narrow and convex edge running across the anterior part of the frontal area and the anterior branch of the facial suture. Liñán et al. (2003) stated that Kingaspis (Kingaspidoideas) cf. velata has a preglabellar field three times wider (sag.) than the border, but in the specimen discussed herein the anterior border is distinctly narrower (sag.) than the preglabellar field. Also, none of the specimens of Kingaspis (Kingaspidoideas) cf. velata figured in Sdzuy (1961) and Liñán et al. (2003) shows this edge extending to the anterior branch of the facial suture. This specimen has the same convexity of the anterior margin and the cranidium as the rest of the specimens and fits well into the variability of...
the species as dealt with in Liñán et al. (2003). More material is needed to clarify if these differences may be attributed to intraspecific or interspecific variance or to the preservation of the specimen and to resolve the affinities with Kingaspis (Kingaspidoides) cf. velata.

Occurrence. Ribota and Huérmeda formations, Iberian Chains (Spain).

Age. Middle and upper Marianian (Cambrian Series 2).

Genus Lusatiops Richter & Richter, 1941

Type-species. Protolenus lusaticus Schwarzbach, 1934 from the Lusatiops Member of the Görlitz synclinorium, Germany; by original designation. Cambrian Series 2; Germany.

Lusatiops ribotanus Richter & Richter, 1948

Figure 6K, 6L, 6P

1961 Lusatiops ribotanus Richter & Richter, 1948; Sdzyuy, p. 566–568 pl. 8, figs. 2–14 (with previous synonyms).

v. 1993 Lusatiops ribotanus Richter & Richter; Liñán et al., p. 820.

v. 1996a Lusatiops ribotanus; Liñán et al., fig. 24.

v. 1996b Lusatiops ribotanus; Liñán et al., fig. 4.

v. 2003 Lusatiops ribotanus Richter & Richter; Liñán et al., p. 11, fig. 2.

v. 2008 Lusatiops ribotanus Richter & Richter; Gozalo et al., p. 140–141, 143, fig. 1.

v. 2018 Lusatiops ribotanus Richter & Richter, 1948; Sepúlveda et al., p. 598, fig. 4E–4G.

2019 Lusatiops ribotanus Richter & Richter, 1948; Álvaro et al., p. 8–10, fig. 5.

v. 2019 Lusatiops ribotanus; Zamora et al., p. 40, fig. 23D.

v. 2021a Lusatiops ribotanus Richter & Richter, 1948; Sepúlveda et al., p. 232, fig. 3D.

Material and locality. 84 crania, one articulated dorsal exoskeleton, one cephalon, six librigenae and one exuviae preserved as internal and external moulds from levels 112, 113 and 115 of the J1 section; levels 13, 15 and 17 of the J2 section; levels 18 and 23 of the MT1 section; and levels 1, 2 and 3 of the M9 section.

Remarks. Richter and Richter (1948) described the species based on the small holotype with a preglabellar field which is wider (sag.) than the anterior border. Álvaro et al. (2019) stated that the wider preglabellar field may be useful to distinguish L. ribotanus Richter & Richter, 1948 from the type species, L. lusaticus (Schwarzbach, 1934) along with other differences. However, larger specimens figured in the publications of the Richters show an anterior border which is slightly wider (sag.) than the preglabellar field, an ontogenetic pattern than can be also seen in the material figured in Sdzyuy (1961), Álvaro et al. (2019) and herein (Fig. 7K and 7L; MPZ 2017/739 and MPZ 2021/399). Geyer and Elicki (1995) figured additional material of L. lusaticus with some variability in this character, including some specimens with the preglabellar field as wide as the anterior border. Thus, this character is not valid to distinguish these species and a more detailed study is necessary for the characterization of these two species.

Occurrence. Ribota and Huérmeda formations, Iberian Chains (Spain).

Age. Middle and upper Marianian (Cambrian Series 2).

Genus Termierella Hupé 1953

Type-species. Termierella latifrons Hupé 1953 from the lower Cambrian of Issafene, morrocan Anti-Atlas; by original designation. Cambrian Series 2; Morocco.

Termierella sp.

Figure 6Q

v 2021a Termierella sp.; Sepúlveda et al., p. 231–232, fig. 3C.

Material and locality. One cranium preserved as internal mould, from level 18 of the Ribota Formation in the MT1 section.

Figure 7. A–H, Onaraspis garciae Álvaro, Esteve, Gracia & Zamora, 2019. A, cranium, latex cast of external mould, MPZ 2020/36, from level 23 of the MT1 section; B, internal mould of a cranium, MPZ 2021/389, from level 113 of the J1 section; C, internal mould of a cranium, MPZ 2021/385, from level 1 of the M9 section; D, articulated cephalon, thorax and pygidium, latex cast of an external mould, MPZ 2017/763, from level 23 of the MT1 section; E, cephalon articulated to thorax, latex cast of an external mould, MPZ 2021/386, from level 6 of the M9 section; F, internal mould of a thorax and pygidium, MPZ 2021/397, from level 23 of the MT1 section; G, latex cast of an external mould of a juvenile cranium, MPZ 2021/398, from level 23 of the MT1 section; H, internal mould of a pygidium, MPZ 2021/390, from level 1 of the M9 section; I–K, Luciaspis matiasi Álvaro, Esteve, Gracia & Zamora, 2019; I, internal mould of a cranium, MPZ 2017/759, from level 23 of the MT1 section. J, internal mould of a juvenile cranium, MPZ 2017/779, from level 23 of the MT1 section; K, internal mould of hypostome and rostrum, MPZ 2021/395, from level 23 of the MT1 section; L–M, Paulaspis tertiaeas Álvaro, Esteve, Gracia & Zamora, 2019. L, internal mould of a cranium, MPZ 2021/377, from level 17 of the J2 section; M, internal mould of a cranium, MPZ 2021/391, from level 2 of the M9 section; N, Redlichia? sp., internal mould of a thorax and pygidium, MPZ 2021/384, from level 23 of the MT1 section; O, Acanthomicmacca (Acanthomicmacca) aff. coloi Hupé, 1953, internal mould of a cranium, MPZ 2021/375, from level 17 of the J2 section; scale bars = 1 cm (D, E); 5 mm (A–C, F, I–O); 2 mm (G, H).
Description. Cranidium subquadrato to subtrapezoidal in outline of 15 mm long, with a low curvature of the anterior margin. Glabella elongated and slightly tapering anteriorly of 4/5 of the cranidium length, with rounded anterior margin. Three pairs of non-transglabellar furrows deep and well-marked, slightly backwards-directed with its inner tip more backwards-directed. Occipital furrow with subequal depth to glabellar furrows and small occipital ring reaching about 20% of the glabellar length, posterior margin with a low curvature. Axial furrows well-marked, slightly shallower than the glabellar furrows. Eye ridge oblique to axis and progressively increasing in convexity to the palpebral lobe. Palpebral lobe wide (tr.), with its posterior tip more backwards-directed than the anterior part, divided by a shallow but well-marked furrow. Anterior border short (sag. and exsag.) and convex with constant length in its entirety. Anterior border furrow shallow but well-marked and slightly convex. Preocular area three times longer (sag.) than the anterior border. Preglabellar field convex and slightly longer (sag.) than the anterior border. Two oblique, deep and well-marked furrows diverging anterolaterally from the medium part of the frontal lobe. Anterior branch of the facial suture subequal in length (sag.) and convex to meet the anterior margin. Posterior branch short and backwards-directed. Surface covered with fine granulation.

Remarks. Despite the imperfect preservation of the specimen (Fig. 7Q; MPZ 2020/32), the morphology of the cranidium exhibits some features which suggest an assignment to Termierella Hupé 1953. The presence of a medium eye furrow, a wide ocular ring and two oblique furrows diverging from the anterior glabellar lobe, the slightly convex preglabellar field and the curved anterior margin of the glabella are present in Termierella latifrons Hupé, 1953 and Termierella sevillana Sdzuy, 1961. The great similarity of the specimen with Lusatiops ribotanus Richter & Richter, 1948 does not include the presence of the ocular and oblique furrows in the latter. In addition, L. ribotanus has smaller (tr.) palpebral lobes and a more pointed anterior margin of the glabella connected to a flatter preglabellar field.

Occurrence. Ribota Formation, Iberian Chains (Spain).

Age. Middle Marianian (Cambrian Series 2).

Genus Strenuaeva Richter & Richter 1940

Type-species. Arionellus primaevus Brøgger, 1878, from the Lower Cambrian Holmia Shale (Zone of Holmia kjærlul) at Teumten, Ringsaker, Norway (sensu Ahlberg & Bergström, 1978); by original designation. Cambrian Series 2; Norway and Poland.

Strenuaeva incondita Sdzuy, 1961

Figure 6M–6O, 6R

v.* 1961 Strenuaeva incondita n. sp.; Sdzuy, p. 300–301, pl. 12, fig. 6–14, text-fig. 21 (with previous synonymies).

v. 1991 Strenuaeva incondita Sdzuy, 1961; Gámez et al., p. 262, 270, fig. 2.

v. 1993 Strenuaeva incondita Sdzuy, 1961; Liñán et al., p. 820.

v. 1998 Strenuaeva incondita Sdzuy, 1961; Palacios & Moczydlowska, p. 67, 72, 73, figs. 2, 4.

v. 2003 Strenuaeva incondita Sdzuy, 1961; Liñán et al., p. 11, fig. 2.

v. 2008 Strenuaeva incondita Sdzuy, 1961; Gozalo et al., p. 140–141, 143, pl. 1, fig. 3.

v. 2018 Strenuaeva incondita Sdzuy, 1961; Sepúlveda et al., p. 597, fig. 4B–4D.

2019 Strenuaeva incondita; Álvaro et al., fig. 3.

v. 2019 Strenuaeva incondita; Zamora et al., p. 40, fig. 23E.

v. 2021a Strenuaeva incondita Sdzuy, 1961; Sepúlveda et al., p. 232, fig. 3B.

Material and locality. 29 cranidia preserved as internal and external moulds from levels 111, 113 and 115 of the J1 section; levels 13 and 17 of the J2 section; level 23 of the MT1 section; and levels 1 and 2 of the M9 section.

Remarks. The different species of Strenuaeva Richter & Richter, 1940 of the Iberian Peninsula are in need of a carefully revision. The specimens attributable to Strenuaeva from the Iberian Chains indicate a great variation and suggest the existence of different species. The classical form characterized by an anterior margin with a low to moderate curvature and a strongly inflated frontal area (Fig. 6M–6O; MPZ 2021/379) are relatively distinct from other co-occurring specimens that also fit into the diagnosis of the genus provided by Ahlberg and Bergström (1978). On the other hand, the specimen shown in Figure 6R (MPZ 2021/380) has a deep and well-marked dorsal furrow and a well-defined glabella tapering towards the front. The anterior margin of the glabella is poorly defined and the preglabellar field, a semicircular anterior margin, a wider (tr.) glabella with a broader frontal lobe and deeper and well-marked glabellar furrows. Later,
Geyer (2016) referred to *S. incondita* Sdzuy, 1961 as *Issafienella incondita*, although no explanation was given. However, according to the differences between *Strenuacea* and *Issafienella* pointed by Geyer (1990), at least some of the specimens of the Iberian Chains would be more closely related to the former than to the later. The preglabellar field of the specimen in Figure 6R is raised in the medium part as in *Strenuacea*, while the specimens of *Issafienella* figured in Geyer (1990) (pl. 12, figs. 1–8) show a depressed preglabellar field clearly separated from the frontal lobe. Nevertheless, the two forms assigned herein to *S. incondita* (Fig. 6M–6O, 6R) have a subconical glabella tapering anteriorly in contrast to the species of *Issafienella*, with a more subrectangular glabella in outline. The specimens figured herein and in Sdzuy (1961) (pl. 12, figs. 6–14) have shallow glabellar furrows, while those of *Issafienella* are deeper and well-marked. In the present state of knowledge, we assign the specimens of the Iberian Chains with differing morphologies all to *S. incondita* Sdzuy, 1961.

**Occurrence.** Ribota and Huérmeda formations, Iberian Chains (Spain).

**Age.** Middle and upper Marianian (Cambrian Series 2).

Order CORYNEXOCHIDA Kobayashi, 1935
Family CHENGKOUIDAE Zhu in Zhang et al., 1980
Genus *Acanthomicmacca* Hupé, 1953

**Type-species.** *Micmacca walcottii* Matthew, 1899 from the Cambrian of Newfoundland, Canada; by original designation. Cambrian Series 2; Canada.

*Acanthomicmacca* (*Acanthomicmacca*) aff. *coloii* Hupé, 1953

**Figure 7O.**

1961 *Micmacca* aff. *coloii* Hupé 1953; Sdzuy, p. 305–306, pl. 15, figs. 15, 16, text-fig. 17 (with previous synonyms).
1993 *Micmacca* aff. *coloii*; Liñán et al., p. 820.
2008 *Micmacca* aff. *coloii*; Gozalo et al., p. 140, 143.
2008 *Micmacca* aff. *coloii*; Liñán et al., p. 12, 15.
2016 *Acanthomicmacca* (*Acanthomicmacca*) sp. D; Geyer, p. 368.

**Material and locality.** Single incomplete cranidium from level 17 of the Huérmeda Formation in the J2 section.

**Remarks.** The specimen figured herein (Fig. 7O; MPZ 2021/375) only differs from the material described by Sdzuy (1961) in a narrower (tr.) glabella and possibly in a longer (sag.) frontal area. However, these differences may be a result of the considerable deformation of the specimen. Geyer (2016) revised the ‘*Micmacca’* group and assigned the material of this genus from the Iberian Chains to *Acanthomicmacca* (*Acanthomicmacca*) sp. D. Sdzuy (1961) and Geyer (2016) noted some differences from *Acanthomicmacca* (*Acanthomicmacca*) *coloii* Hupé 1953 which are present in the single specimen studied herein, such as the poorly defined anterior border, the more curved anterior margin of the frontal lobe and the more oblique to axis eye ridges. However, the material from the Iberian Chains appears to be more closely related to *A.* (*A.*) *coloii* rather than to the other species of the genus. These two species have an anterior border with low convexity, a shallow to indistinct anterior border furrow and a relatively narrow (tr.) palpebral lobes and eye ridges with similar length. Therefore, we suggest to maintain the original assignment of this species as the scarce number of samples difficult the study of the affinities of *A.* (*A.*) aff. *coloii* with other members of the genus.

**Occurrence.** Huérmeda Formation, Iberian Chains (Spain).

**Age.** Upper Marianian (Cambrian Series 2).

**BIOSTRATIGRAPHY**

The study of the Ribota and the Huérmeda formations in the four sections discussed herein led to the recognition of four distinguishable trilobite assemblages. The lower assemblage is found at the middle part of the Ribota Formation and is primarily composed of the ellipsocephalid trilobites *Kingaspis* (*Kingaspidoides*) *velata*, *Lusatiops ribotanus*, and *Strenuacea incondita*. These species make up 95–100% of the sample collected from the fissiliferous levels at the middle part of the Ribota Formation in the MT1, J1 and J2 sections, suggesting a Marianian age according to the regional stratigraphic units for the Iberian Peninsula (Liñán et al., 1993; Gozalo et al., 2008). The first assemblage also includes *Termierella* sp., a genus characteristic for the middle–upper Marianian in the Ossa-Morena Zone (Liñán et al., 1993, 1997; Álvaro et al., 1998), reported herein for the first time from the Iberian Chains. The second assemblage is found in the shale level above and is composed of *Kingaspis* (*Kingaspidoides*) *velata*, *Lusatiops ribotanus* and *Strenuacea incondita*. In addition, these two assemblages record the presence of *Onaraspis garciae* in the MT1 and J1 sections. This species also occurs in the middle part of the Huérmeda Formation in the M9 section and at the top of this formation in MT1 (see Sepúlveda et al., 2021a) suggesting a significantly wider stratigraphic range than previously known.

The third assemblage is found at the base of the Huérmeda Formation. This assemblage is composed mainly of the three onaraspid species *Onaraspis garciae*, *Luciaspis matiasi* and *Paulaspis tiergaensis*, which make up the 70–80% of the collection in all four studied sections. These species occur jointly with the ellipsocephalids of the Ribota Formation except for *Termierella*, and with a significant amount of other taxa including *Redlichia*? sp., the holmiids *Andalusiana*.
cf. *cornuta*, *Andalusiana* sp., the chengkoui *Acanthomicmacca* (*Acanthomicmacca*) aff. *coloi*, the eodiscoid *Hebediscus* sp., and also *Redlichia* (*Redlichia*) *isuelaensis* recorded by Álvaro *et al.* (2019) from this level and *Kingaspis* (*Kingaspisidoides*) cf. *velata* (Liñán *et al.*, 2003). The upper assemblage has been only recognized in the MT1 section and is composed of *Onaraspis garciae* and *Paulaspis tiergaensis*. The position of this assemblage at the top of the Huérmeda Formation suggests a lower Bilbilian age as equivalent strata of the nearby Borobia section with *Protolenus* (*Hupeolenus*) *termierelloides* are indicative for this age (Palacios & Moczydłowska, 1998).

These assemblages provide a great regional and international potential for correlation despite of a marked endemism of the species studied herein (see Fig. 8). Thus, there are no species which occur in both the Iberian Chains and other regions of the Iberian Peninsula. Álvaro *et al.* (2019) stated that *Strenuaeva incondita* is present in the Ossa-Morena Zone, but there is no published evidence of this to date. Also, Gil Cid and Jago (1989) reported *Lusatiops* cf. *ribotanus* from the Los Cortijos de Malagón section of the Central Iberian Zone, but the highly distorted material does not allow a confident identification to the species, and their occurrence in lower Bilbilian strata of the Los Cortijos Formation suggests a closer relationship with *Protolenus*, a characteristic taxon of the Bilbilian of the Iberian Chains (Dies-Álvarez *et al.*, 2001; Gozalo *et al.*, 2008). This condition also applies for *Kingaspis* (*Kingaspisidoides*) cf. *velata*, which was reported by Sdzuy (1961) and Liñán *et al.* (2003) from the Los Cortijos Formation based on poorly preserved specimens with a similar lower Bilbilian age as *Kingaspis* (*Kingaspis*) *campbelli* King, 1923 from the Valdemiedes Formation of the Iberian Chains (Liñán *et al.*, 2003).

Accordingly, the trilobite with the highest significance for correlation between the Iberian Chains and the Ossa-Morena Zone is probably *Andalusiana cornuta*,

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**Table:**

| ISCS | MOROCCO | IBERIA | IBERIAN CHAINS (this work) |
|------|---------|--------|---------------------------|
| **CAMBRIAN SERIES 2** | **CAMBRIAN STAGE 4** | **LOWER BILBILIAN** | **4th Assemblage** |
| BANIAN | Hupeolenus | Protolenus *dimarginatus* | |
| | Sectigena | Realaspis | FAD |
| **CAMBRIAN STAGE 3** | **MIDDLE MARIANIAN** | **UPPER MARIANIAN** | **3rd Assemblage** |
| BANIAN | Antallasia guttapluviae | Serrodiscus | FAD |
| | | Andalusiana | 2nd Assemblage |
| | | Strenuaeva + Triangulaspis | 1st Assemblage |

**Figure 8.** Biochronology of the middle Marianian to lower Bilbilian interval in the Iberian Peninsula and Morocco (modified from Liñán *et al.*, 2002, 2006; Geyer & Landing, 2004; Sundberg, *et al.*, 2016) and the location of the four trilobite assemblages identified in this work.
as suggested by the specimen from the MT1 section which strongly resembles the specimens from the Ossa-Morena Zone (Sdzyu, 1961, 1962) and from Morocco (Geyer & Palmer, 1995). At genus level, Andalusiana occurs along with Termierella in the middle and upper Marianian Stage in the Ossa-Morena Zone (see Liñán et al., 1993, 1997), the Central Iberian Zone (Liñán et al., 1993; Sepúlveda et al., 2021b) and the Sectigena Zone in the Moroccan Anti-Atlas (Geyer & Palmer, 1995; Sundberg et al., 2016). Hebediscus has been also collected from the Ossa-Morena Zone (Liñán, 1984), where Strenuaeva has a wide range from the middle to the upper Marianian. The presence of these genera in the Iberian Chains reinforces the correlation between the middle and upper Marianian of the Ossa-Morena and Central Iberian Zones and the Iberian Chains. Moreover, Lusatiops is recorded in the Lower Cambrian of Saxony (Germany) where it occurs along with Acanthomicmacca and Serrodiscus silesius (see Geyer & Ellicki, 1995).

Liñán et al. (1993) selected the LAD of olenellids and Serrodiscus in the Ossa-Morena Zone to mark the top of the Marianian stage. Although more research is needed, the presence of Andalusiana in the Iberian Chains reported herein and in the Central Iberian Zone (Liñán et al., 1993; Sepúlveda et al., 2021b), along with the presence of other shared taxa, could allow the recognition of the top of the Marianian stage in these three regions. Finally, one of the discussed horizons for defining the base of the Cambrian Stage 4 is the assemblage of the eodiscoid trilobites Hebediscus, Calodiscus, Serrodiscus and Triangulaspis, referred as the “HCST band” (Geyer & Shergold, 2000; Geyer, 2005). Another suggested possibility for the definition of this GSSP is the FAD of Redlichia (Peng & Babcock, 2011; Peng et al., 2020). The presence of Redlichia and specimens tentatively assigned to Hebediscus in the Iberian Chains could allow a roughly correlation with the levels discussed to establish the base of the Cambrian Stage 4. However, more research is needed to confirm the presence of Hebediscus in the area and to establish the complete biostratigraphy of the Ribota and Huérmeda formations of the Iberian Chains.

**CONCLUSIONS**

A careful study of four sections in the Iberian Chains allows to establish a detailed range chart of the trilobites recorded in the Ribota and the lower part of the Huérmeda formations (middle–upper Marianian; probably uppermost Stage 3 to lower Stage 4 of Cambrian). Four significant trilobite associations have been recognized. The lowest assemblage is distributed in the middle part of the Ribota Formation and is composed of Lusatiops ribotanus, Kingaspis (Kingaspidoidea) velata, Strenuaeva incondita, Termierella sp. and Onaraspis garciae. A second assemblage occurs slightly higher in the Ribota Formation. It includes Lusatiops ribotanus, Kingaspis (Kingaspidoidea) velata, Strenuaeva incondita and Onaraspis garciae. A third assemblage is found in the lowermost strata of the Huérmeda Formation and includes Lusatiops ribotanus, Kingaspis (Kingaspidoidea) velata, Kingaspis (Kingaspidoidea) cf. velata, Strenuaeva incondita, Onaraspis garciae, Luciaspis matiasi, Paulaspis tiergaensis, Redlichia (Redlichia) isuelaensis, Redlichia sp., Andalusiana cf. cornuta, Andalusiana sp., Hebediscus sp. and Acanthomicmacca (Acanthomicmacca) aff. coloi. The highest assemblage is found in the uppermost part of the Huérmeda Formation and consists of Onaraspis garciae and Paulaspis tiergaensis.

These assemblages clearly indicate that the strata of the Ribota and Huérmeda formations belong into the middle–upper Marianian and probably lowermost Bilbilian, which thus is (in part) equivalent to the Stages 3 and 4 of the Cambrian Series 2. Our first figured report of Andalusiana from the Iberian Chains, in addition with the presence of Termierella in the region and the presence of other shared taxa as Strenuaeva and Hebediscus, could allow a relatively precise correlation with coeval strata of the Ossa-Morena Zone. The presence of Andalusiana and Termierella also provides the base for relatively precise correlations with the strata of the Central Iberian Zone and the Atlas ranges of Morocco. The presence of Hebediscus? (reported herein for the first time) together with Redlichia in the Iberian Chains could allow a roughly correlation of the lower boundary of the Cambrian Stage 4 in this region according to two of the levels discussed by the International Subcommission on Cambrian Stratigraphy.

**Supplementary Information.** The article has no additional data.

**Authors contributions.** All authors collaborated in the field work and preparation of the trilobite specimens. AS, EL and RG studied and discussed the trilobites classification. AS and RG prepared the figures. AS coordinated the work and preparation of the trilobite specimens. AS, EL and RG prepared the figures. AS, EL and RG prepared the figures. AS, EL and RG prepared the figures. AS, EL and RG prepared the figures. AS, EL and RG prepared the figures.

**Competing Interest.** We hereby declare that we have no competing interests.

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