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Middle Ordovician trilobites from the Castillejo Formation, Eastern Iberian Range (NE Spain): taxonomic reappraisal, biostratigraphy, and correlation

Trilobites del Ordovícico Medio de la Formación Castillejo, Cadena Ibérica Oriental (NE de España): actualización taxonómica, bioestratigrafía y correlación

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Abstract: Middle Ordovician trilobites found in 11 fossil localities from the areas of Alpartir, Aladrén, Luesma and Fombuena (Zaragoza province), and south of Calamocha (Teruel province) are studied. Most records come from the Alpartir Member of the Castillejo Formation, which is dated as Dobrotivian in age (late Darriwilian according to the global scale), with the only exception of two localities that are slightly older, from late Oretanian age (mid−late Darriwilian). In the overlying Sierra Member, three additional localities are recorded, which have estimated age ranges from late early to late Dobrotivian (latest Darriwilian, possibly reaching the Sandbian). A total of 21 different trilobite species were identified including *Uralichas hispanicus*, *Parabarrandia crassa* and "*Panderia*" *beaumonti* that are recorded for the first time in the Eastern Iberian Range. The main trilobite assemblage from the Alpartir Member belongs to the *Placoparia tournemini* Biozone, which correlates with numerous areas of southwestern Europe, and here occurs in a biofacies dominated by asaphids. The scarce data derived from the Sierra Member do not allow to distinguish biozones, although the incipient development of a trilobite biofacies adapted to sandy bottoms is recognized, which ends at the top of the *Placoparia borni* Biozone in the whole of southwestern Europe. The correlation of the trilobite assemblages with those of other formations represented in the Cantabrian, West Asturian-leonese and Central Iberian zones is also discussed, the latter probably related through the enigmatic Central Iberian Arc, a debated orocline of the Iberian Massif.

Resumen: Se analizan los trilobites del Ordovícico Medio encontrados en 11 yacimientos situados en las áreas de Alpartir, Aladrén, Luesma y Fombuena (Zaragoza), así como al sur de Calamocha (Teruel). La mayoría se localizan en el Miembro Alpartir de la Formación Castillejo, y son de edad Dobrotiviense temprano (Darriwiliense tardío de la escala global), excepto dos algo más antiguos y que datan del Oretaniense tardío (Darriwiliense medio a tardío). En el Miembro Sierra de la Formación se registran otros tres yacimientos, cuya edad estimada varía desde el final del Dobrotiviense temprano al Dobrotiviense tardío (Darriwiliense terminal, llegando posiblemente al Sandbiense). En total se identificaron 21 trilobites distintos, de los que las especies *Uralichas hispanicus*, *Parabarrandia crassa* y "*Panderia*" *beaumonti* se registran por vez primera en la Rama Aragonesa de la Cordillera Ibérica. La principal asociación de trilobites corresponde a la Biozona de *Placoparia tournemini*, correlacionable con numerosas áreas del suroeste de europa, que aquí se identifica en una biofacies dominada por asáfidos. Los datos puntuales derivados del Miembro Sierra no permiten distinguir biozonas, si bien se reconoce el desarrollo incipiente de una biofacies de trilobites adaptada a fondos arenosos, que perdura hasta el techo de la Biozona de *Placoparia borni* en el conjunto del suroeste de Europa. Se discute también la correlación de las asociaciones de trilobites estudiadas con las de otras formaciones representadas en las zonas Cantábrica, Asturoccidental-leonesa y Centroibérica, esta última como posible prolongación del Arco Centroibérico, un oroclinal debatido del Macizo Ibérico.

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INTRODUCTION

The Iberian Range or Iberian Cordillera is classically considered as the eastern prolongation of the West Asturian-Leonese Zone of the Iberian Massif (Julivert *et al.*, 1972; Martínez Catalán, 2012; Azor *et al.*, 2019). It comprises various Palaeozoic inliers, which generally constitute the core of larger alpine structures, and which are spread over the two branches in which the Cordillera is subdivided: the Western or Castilian Branch (also known as the Hesperian Ranges) and the Eastern or Aragonese Branch (also named as

Celtiberian Range or Iberian Chains). The record of Ordovician rocks with trilobites have been kown since the 18th century in the Castilian Branch (Torrubia, 1754), although it was not until the recent articles by Vizcaïno *et al*. (2004), Pereira *et al*. (2018) and Romero and Gutiérrez-Marco (2021) when they were partly studied and figured. On the other hand, in the Eastern Iberian Range the trilobite research is up to now focused on the Upper Ordovician assemblages (Kralodvorian; *ca.* upper Katian: Owens & Hammann, 1990; Hammann, 1992), while older trilobites were briefly described or illustrated in the articles of Hammann *et al*. (2008) for the Lower Ordovician; Hammann (1983) for the Middle Ordovician and Pereira *et al*. (2018) and Zamora *et al*. (2019) for the Middle–Upper Ordovician (Dobrotivian to upper Berounian; *ca.* upper Darriwilian to middle Katian) rocks from different Aragonese localities.

The Ordovician stratigraphy of the Eastern Iberian Range has been described by various authors (see Carls, 1975, among others), but the different formations were formally described in the papers by Wolf (1980), for the Lower Ordovician, and Villas (1983) for the Middle and Upper Ordovician. In the present work we analyze the trilobite record of the Castillejo Formation (Villas, 1983), a thick unit composed of shales and sandstones that overlies the ubiquitous Armorican Quartzite in the Aragonian Branch, and that crops out in both the Eastern and the Western Iberian Chains (Fig. 1).

Previous discoveries of trilobites in the Castillejo Formation began with the work of Dereims (1898), who made the first general stratigraphic division of the Palaeozoic rocks in Aragón and identified the Ordovician trilobites *Calymene tristani* Brongniart, *Illaenus* sp. and *Asaphus* sp. in ferruginous nodules included in argillaceous shales cropping out between the villages of Fombuena and Luesma, in the province of “Saragossa” (= Zaragoza in Spanish). Lotze (1929) amended the Dereims stratigraphy and specified the age of *Calymene tristani* shales in the Celtiberian Range as “Llandeilium”, by correlation with the Armorican Massif and the Montagne Noire, as well as with various areas of the Iberian Peninsula (Asturias, Almadén, Extremadura, Sierra Morena, Portugal). Many years later, Carls (1975) added new trilobite records, like *Neseuretus tristani* (Brongniart) and illaenids, identified in the lower part of the Castillejo Formation, as well as the last occurrence of *N. tristani* near the top of the same unit in the area around Fombuena.

The next trilobite records were due to Villas (1980) and are located towards the middle part of the Castillejo Formation in the Hontanar and Eras Hondas sections, west of Alpartir (Zaragoza). The author described a first horizont yielding *Eodalmantina* cf. *macrophtalma* (Brongniart), succeeded by another with *Crozonaspis* sp., *Neseuretus* sp., *Ectillaenus* sp. and several Phacopina indet.; in both cases associated with lower Dobrotivian graptolites and brachiopods.

Hammann (1983) added new records of trilobites in the Fombuena–Luesma region and within the area mapped by Kolb (1978), between Fombuena and south Cerveruela (Zaragoza province). In the type section of the Castillejo Formation, and in nodular shales located towards the upper part of the Alpartir Member (his fossil locality “Fomb I”), this author cited a lower Llandeilo assemblage containing *Neseuretus* (*N.*) *tristani* (Brongniart *in* Desmarest), *Salterocoryphe salteri* (Rouault), *Colpocoryphe rouaulti* Henry n. ssp.?, *Prionocheilus mendax* (Vaněk), *Placoparia* (*Coplacoparia*) *tournemini* Rouault and *Eodalmanitina macrophtalma* (Brongniart). Near the top of the Castillejo Formation (= upper part of the Sierra Member), a second locality (“Fomb II”) belonging to the upper Llandeilo yielded *Neseuretus* (*N.*) *henkei* Hammann, *Eohomalonotus* cf. *sdzuyi* Hammann & Henry and *Crozonaspis*? *incerta* (Deslongchamps). From the first locality, four specimens of *N.* (*N.*) *t. tristani*, *C. rouaulti* n. ssp.? and *S. salteri* were described and illustrated by Hammann (1983, pl. 5, fig. 54, pl. 12, fig. 121a–121c, pl. 23, fig. 216 and pl. 24, fig. 224; pl. 11, fig. 104a–104b; and pl. 21, fig. 204a–204b, respectively).

The general geological mapping of the Eastern Iberian Chain at a scale of 1:50,000 provided some new data on Middle Ordovician trilobites, belonging both to original finds (the citation of “*Calymene tristani*” near Alpartir made by Hernández Samaniego *et al*., 1980), as well as a transliteration of the data collected by Hammann (1983) plus several unpublished MSc and PhD dissertations carried out in this area and mentioned in their explanatory notes: Kolb (1978), Gaubatz (1981), Keller (1981), Kistner (1981) and Gutiérrez-Marco (1980, 1986). This is the case of Hernández *et al*. (1983a), who cited three horizons with trilobites in the Castillejo Formation near Fombuena: (1) a basal upper Llanvirn horizon with *Neseuretus* (*N.*) *tristani* (Brongniart), *Ectillaenus*? sp. and Dalmanitidae indet.; (2) an intermediate horizon (coincident with the Alpartir member), considered as lower Llandeilo, yielding *Placoparia* (*Coplacoparia*) *tournemini* Rouault, *Neseuretus* (*N.*) *tristani* (Brongniart), *Colpocoryphe rouaulti* Henry, *Zeliszkella* (*Z.*) *toledana* (Hammann), *Nobiliasaphus nobilis* (Barrande), *Ectillaenus* sp., *Ogygites*? sp., Asaphidae indet. And Dalmanitidae indet.; and (3) an upper horizon (coincident with the upper part of the Sierra Member) containing *Neseuretus* (*N.*) *henkei* Hammann, *Crozonaspis* sp. and *Colpocoryphe*? sp., assigned to the upper Llandeilo. Additionally, in the area south of Luesma, Lendínez González *et al.* (1989b) cited the presence of two Llandeilo trilobite assemblages: a lower one with *Placoparia tournemini* Rouault, *Neseuretus* (*N.*) *tristani tristani* (Brongniart), and *Eodalmanitina macrophtalma* (Brongniart); and an upper one with *Neseuretus* (*N.*) *henkei* Hammann and *Eohomalonotus* cf. *sdzuyi* Hammann & Henry; they were located respectively in the Alpartir and Sierra members of the Castillejo Formation. The lower assemblage was also recognized in the northern extension of the outcrops towards Aladrén, where Lendínez González *et al*. (1989a, p. 17–18) cited [sic] “*Colpocoryphe ronaulti* (Henry), *Floncekia micheli* (Tromelim), *Mucronaspis* cf. *macrophtalma* (Brogniart), *Nesenretus* (*N.*) *tristani* (Barogniart), *Nobiliasaphus* aff. *nobilis* (Barrande) and *Agygites glabala* (Salter)", an association assigned to the lower Llandeilo.

In their compilation of the Cambro-Ordovician taxa recorded in both branches of the Iberian Cordillera, Liñán *et al*. (1996) listed the occurrence of a total of fifteen different Llandeilo trilobites in the Aragonese Branch. Among them, *Crozonaspis armata* Hammann and *Placoparia* (*Coplacoparia*) *borni* Hammann are cited for the first time in the upper part of the Sierra Member; however, localities were not specified.

The most recent photographs of trilobites from the Castillejo Formation were published in two general reports on the Palaeozoic of this area. The first is a field-meeting guidebook, where Zamora *et al*. (2019, figs. 8A–8B) illustrated two specimens of *Isabelinia glabrata* (Salter) and *Eccoptochile almadenensis* Romano, recorded from an unspecified locality of the Alpartir Member. The second is a guide of regional geological itineraries, in which Villas (in Pérez García *et al*., 2021, p. 89) illustrates two specimens of *Ectillaenus* sp. and *Neseuretus* sp. from the Alpartir Member in the Alpartir area.

From this previous background, it is noticeable the clear absence of detailed works on the Middle Ordovician trilobites of the Aragonese Branch, from where only a total of four species were briefly described and eight specimens were illustrated in publications (Hammann, 1983; Zamora *et al*., 2019; Villas in Pérez García *et al*., 2021). The main aim of this work is to review all Middle Ordovician trilobite localities, both published and unpublished in academic works, essentially MSc and PhD dissertations from German and Spanish students; to accurately identify the species and to update their taxonomy; and to obtain new biostratigraphic data that can be used for correlation with other Iberian and southwestern European areas.

STRATIGRAPHY AND FOSSIL LOCALITIES

The fossil material comes from several localities in the Eastern Iberian Range (= Aragonese Branch of the Iberian Cordillera), most of them placed in the Eastern Iberian Chain, except one, located in the Western Iberian Chain (Fig. 1, inset maps A to C). All fossiliferous localities yielding Middle Ordovician trilobites are situated in the Castillejo Formation (Villas,

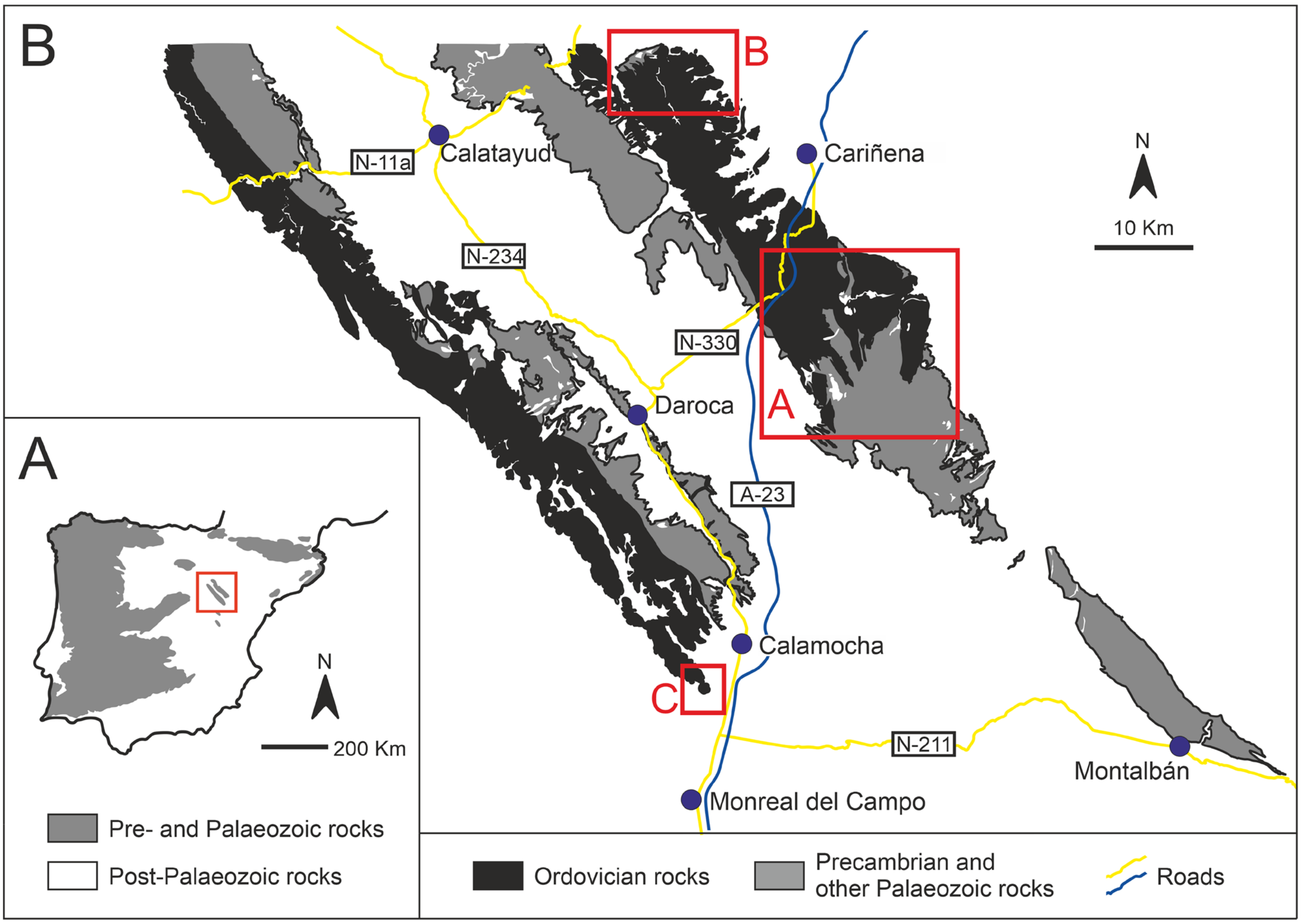

Figure 1. Sketch maps showing the position of the studied area with regard to the Variscan basement rocks of the Iberian Peninsula (**A**) and the southern part of the Eastern Iberian Range (**B**). The letters and the square areas in red correspond to the geological maps of Figure 2, where the situation of the fossil localities around Fombuena, Luesma and Aladrén (A), Alpartir (B) and Calamocha-El Poyo del Cid (C) is shown in detail.

1983 = “Lower Alternation” of Carls, 1975 and other German authors). The latter consists of up to 320 m of shales and sandstones that paraconformably overlie the ubiquitous Armorican Quartzite Formation (Lower Ordovician, essentially Floian) and contains three members, also formally defined by Villas (1983).

The lower or Marité Member (1–40 m) is composed of ferruginous sandstones and shales with up to three oolitic ironstone horizons interbedded locally. It contains upper Oretanian (*ca.* upper Darriwilian 2–lower Darriwilian 3) graptolites of the *Didymograptus murchisoni* Zone, which implies a basal sedimentary gap involving at least the entire Dapingian, as well as the lower and middle Darriwilian.

The overlying middle or Alpartir Member (110–200 m thick) is mainly composed of shales with some intercalations of sandstones and siliceous and ferruginous nodules. Graptolites of the *D. murchisoni* Zone have been found up to 25–30 m above the base of this member (Gutiérrez-Marco, 1986), being indicative of the uppermost Oretanian (*ca.* lower Dw3 of the global scale, Bergström *et al*., 2009). A scarce record of the first Middle Ordovician trilobites accompanies the graptolites in one locality (Fig. 2, loc. 5). However, trilobites become more frequent towards the middle and upper half of the Alpartir Member, both in shales and in the nodules contained in them. The associated graptolites in these levels correspond to the *Hustedograptus teretiusculus* Zone (Hammann *et al*., 1982; Gutiérrez-Marco, 1986), which here correlates with the lower Dobrotivian of the Mediterranean scale or with the upper Darriwilian 3 of the global scale (Gutiérrez-Marco *et al*., 2015, 2017). The fossil localities showing the most diverse trilobite assemblages from this part of the succession are detailed below (Fig. 2, locs. 3, 6–10).

Finally, the upper or Sierra Member (10–150 m thick) is characterized by alternating shales and sandstones, locally grading up into thick quartzites, and showing punctually highly fossiliferous sandstone lenses with a calcareous cement. Trilobite assemblages recorded from these lenses occur in a few localities (Fig. 2, locs. 1, 4, 11). These can be assigned to the upper Dobrotivian (*ca.* uppermost Darriwilian to lowermost Sandbian of the global scale), also regarding the conodont record (Sarmiento *et al*., 1995). The top of the Castillejo Formation is capped by a new sedimentary gap equivalent to the lower Berounian (= lower Sandbian *pro parte*), being succeeded by the oolithic ironstone and fossiliferous marls of the Piedra del Tormo Member from the overlying Fombuena Formation (Villas, 1983; Zamora *et al*., 2019 with previous references; = “Upper Alternation”/”Untere Wechsellagerung” of Carls, 1975 and many other German authors).

In the Figure 2, we have detailed the position of the fossil localities included in the three areas indicated in Figure 1. The area with the largest outcrops of the Castillejo Formation, most suitable for the palaeontological study, is situated in the Eastern Iberian Chain, between the localities of Fombuena, Luesma and Aladrén–Herrera de los Navarros (Fig. 2A), situated to the south of Saragossa (Zaragoza) province. This is the reason why this area has the largest number of trilobite citations, derived both from published papers and unpublished MSc and PhD dissertations (*e.g.*, Dereims, 1898; Carls, 1962, 1975; Möhl, 1965; Kolb, 1978; Gaubatz, 1981; Keller, 1981; Kistner, 1981; Hammann *et al*., 1982; Hammann, 1983; Gutiérrez-Marco, 1986).

The review of the previous literature and unpublished data led us to study a total of eleven fossil localities with trilobites, of which eight belong to the Alpartir Member (Fig. 2, locs. 2, 3, 5–10) and three to the Sierra Member (Fig. 2, locs. 1, 4, 11). Of the eight trilobite localities reported by Kolb (1978) in the Alpartir Member, three have been restudied (his locs. F2, F3, F5), other three contained forms illustrated by the autor but little determinative (F1, F10, F11), and one of the localities has not been found (F8). We have also reviewed the unpublished trilobite localities cited by Keller (1981), Kistner (1981) and Gutiérrez-Marco (1986)–see below. However, the two localities discovered by Gaubatz (1981) south and west of Herrera de los Navarros, were not examined due to the little significance of the taxa found in a structurally complex local setting.

Next, we present the studied localities and the trilobites identified in them, following the geographical numbering of the sites established in Figure 2.

Locality 1 (Fig. 2A, point 1). It corresponds to the point F5 of Kolb (1978) which is situated 2,600 m north-northwest of the town of Fombuena, on the left bank of the Barranco de la Peña, *ca.* 350 m before its confluence with the Barranco de la Carbonera (41º 09′ 53.6″ N, 1º 12′ 26.4″ W). Stratigraphically it comprises 2–3 centimetric beds of brown sandstones with calcareous cement that are located in the highest part of the Sierra Member of the Castillejo Formation, about 6 m below the oolitic ironstone bed that defines the base of the overlying Fombuena Formation. Disarticulated and fragmentary remains of trilobites, molluscs, and brachiopods are relatively common, but are only identifiable in the decalcified parts of the rock, where they occur strongly limonitized. Among the trilobites we have recognized *Neseuretus henkei* Hammann, 1977 and *Crozonaspis armata* Hammann, 1974, but Kolb (1978) also illustrates *Crozonaspis incerta* (Deslongchamps, 1825), *Phacopidina micheli* (Tromelin, 1877) and *Eohomalonotus sdzuyi* Hammann & Henry, 1978. Analyzing the illustrations of the material, we agree on the record of these three additional species at the locality, whose identifications were also confirmed by W. Hammann (in Kolb, 1978, p. 1, 27). The locality “Fomb II” of Hammann (1983), situated near the top of the Castillejo Formation in the area of Fombuena, from where this author recorded the presence of *N. henkei*, *Eohomalonotus* cf. *sdzuyi* and *Crozonaspis incerta,* may also coincide with the present locality, given that the latter two trilobites have not been identified anywhere else in the Iberian Range.

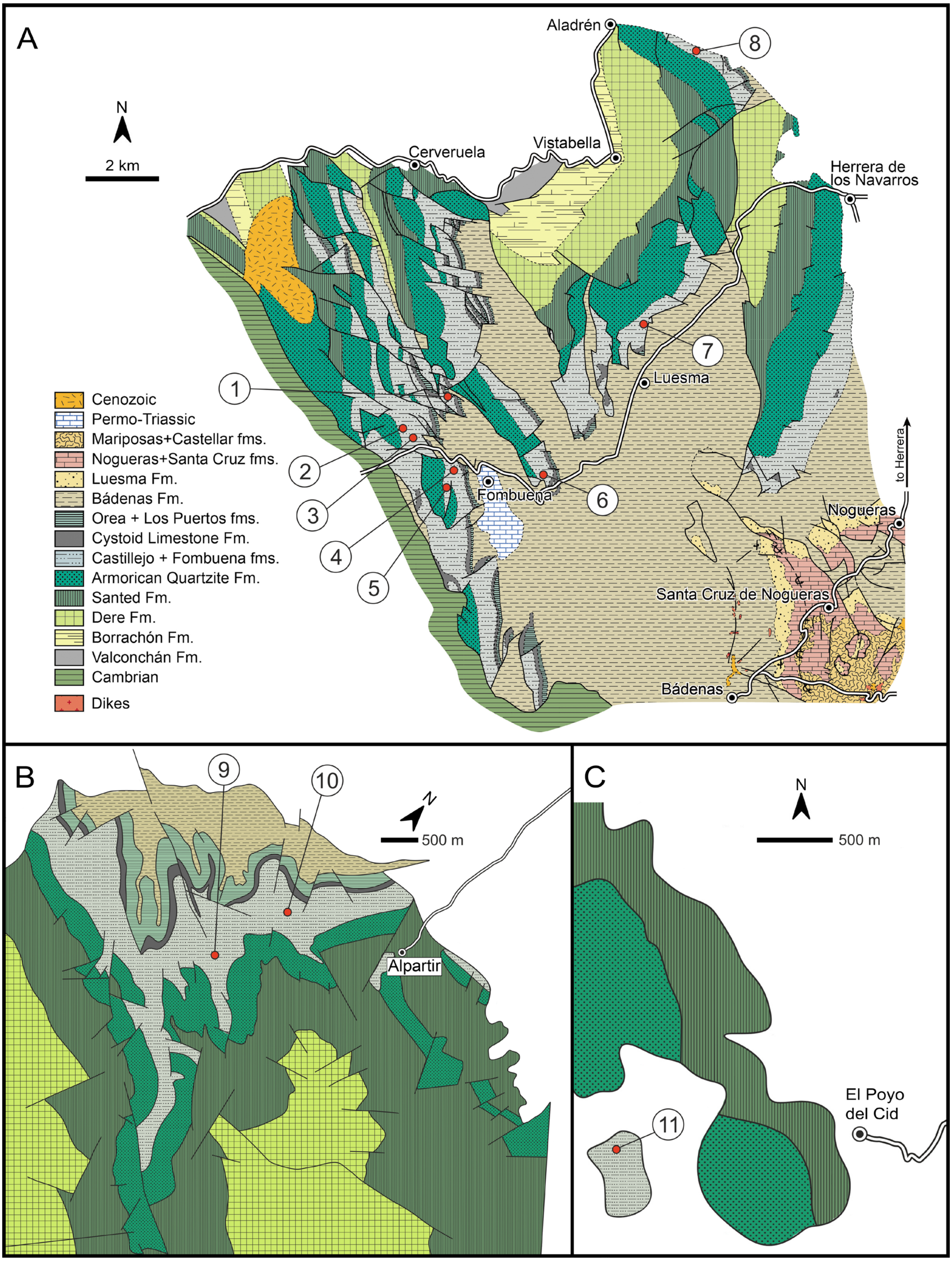

Figure 2. Geological sketch maps showing the situation of the Middle Ordovician trilobite localities in the Castillejo Formation. **A,** Palaeontological sites in the municipalities of Fombuena (1−6), Luesma (7) and Aladrén (8); **B,** idem. for localities west of Alpartir (9−10); **C,** locality west of Poyo del Cid, in the municipality of Calamocha (11). Map **A** was adapted from Zamora *et al.* (2019, fig. 2) and refers to a Palaeozoic area south of the Huerva river and east of the road CV-700 from Vistabella to Aladrén; **B** was adapted from Hernández Samaniego *et al.* (1980), and **C** from Hernández *et al.* (1983b). For a general location see the inset maps in red on Figure 1.

The trilobite assemblage was originally ascribed to the "Llandeilo" or "upper Llandeilo" and is here reassigned to the upper Dobrotivian (see below).

Locality 2 (Fig. 2A, point 2). It corresponds to the point F3 of Kolb (1978) which is situated 2,400 m northwest of Fombuena, on the left bank of a small stream that runs down the eastern slope of Cerro Pelado (41º 09′ 20.7″ N, 1º 13′ 02.6″ W). The grey argillaceous shales from the locality are scarcely fossiliferous and according to Kolb (1978, p. 26), located *ca.* 20 m above the oolitic ironstone bed at the base of the Castillejo Formation. He assigned the fossil assemblage to the "lower Llanvirn" due to the record of *Placoparia* (*P.*) *cambriensis* Hicks, 1875 (a cranidium was illustrated) and *Neseuretus* (*N.*) *tristani* (Brongniart, 1822). From this locality, we only got rare specimens of *Placoparia* cf. *tournemini* (Rouault, 1847), a younger species that leaves doubts about the older age of the site indicated by its discoverer (see discussion in the Biostratigraphy section).

Locality 3 (Fig. 2A, point 3). It corresponds to the points F2 of Kolb (1978) and FB-II of Gutiérrez-Marco (1986), situated 2,400 m northwest of Fombuena, *ca.* 150 m to the northwest of the previous locality (41º 09′ 17.7″ N, 1º 12′ 56.2″ W).

From a stratigraphical point of view, the locality comprises a narrow interval (3−5 m) of grey argillaceous shales with sparse nodules, placed towards the middle third of the Alpartir Member of the Castillejo Formation. The fossil record consists of a diverse assemblage of trilobites, sometimes represented by articulated exoskeletons, plus some brachiopods, molluscs, hyoliths and graptolites. Among the trilobites we have recognised the following taxa, all of them reported by Kolb (1978) and Gutiérrez-Marco (1986): *Neseuretus tristani* (Brongniart in Desmarest), *Placoparia tournemini* Rouault, *Nobiliasaphus* aff. *nobilis* (Barrande) and *Ectillaenus giganteus* (Burmeister); adding to the list the record of *Eodalmanitina* cf. *macrophtalma* (Brongniart) and Phacopina indet.

The assemblage was previously regarded as "lower Llandeilo" and is here assigned to the lower Dobrotivian.

Locality 4 (Fig. 2A, point 4). This locality was situated 950 m west-northwest of Fombuena, on the left bank of the Barranco de la Peña (41º 08′ 49.12″ N, 1º 12′ 11.8″ W) and corresponds to a lenticular bed of calcareous coquina, intercalated in the sandstone-dominated alternation of the higher part of the Sierra Member of the Castillejo Formation. The site was discovered by Carls (1975), who mentioned *Neseuretus tristani*, molluscs and brachiopods in this coquina found "WNW of Fombuena", and from where Kolb (1978, pl. 1, figs. 4a–4c) also illustrates a pygidium of *N. henkei*. Guided by P. Carls, one of the authors (JCG-M) ended up digging entirely the fossiliferous lens in 1980. His provisional results were published by Hernández *et al.* (1983a), citing the occurrence of *Neseuretus* (*N.*) *henkei* (Hammann), *Crozonaspis* sp. and *Colpocoryphe*? sp., together with various molluscs, brachiopods and bryozoans. Finally, Sarmiento *et al*. (1995) added some conodont data from the upper? Dobrotivian.

The revision of the trilobites from this vanished locality has been possible thanks to the original material obtained at that time by the second author, which remained largely unpublished. The final list of taxa confirms the record of *Neseuretus henkei* Hammann, adding the species *Colpocoryphe rouaulti* Henry, *Crozonaspis armata* Hammann and *Ectillaenus giganteus* (Burmeister).

Locality 5 (Fig. 2A, point 5). It corresponds to the locality FB-I of Gutiérrez-Marco (1986), which is situated 1,250 m west of Fombuena, on the right bank of a small stream that flows into the Barranco de la Peña del Tormo (41º 08′ 40″ N, 1º 12′ 25.8″ W). The fossiliferous bed is placed in the lower part of the Alpartir Member, *ca.* 25−30 m above the base of the Castillejo Formation and consists of grey and yellow argillaceous shales locally rich in graptolites and with scarce nodules. The trilobite record, mentioned by Gutiérrez-Marco (1980, 1986) and Hernández *et al*. (1983a), comprises *Neseuretus* (*N.*) *tristani* (Brongniart), Phacopina indet. and *Ectillaenus*? sp. The revision of the locality confirmed the presence of a cranidium of *N. tristani* (not figured), which was recorded inside a nodule. Associated graptolites, previously referred as "upper Llanvirn", are better indicative of the upper Oretanian.

Locality 6 (Fig. 2A, point 6). It corresponds to the locality Fomb I of Hammann (1983), LU-II of Gutiérrez-Marco (1986), and possibly also to the original locality of Dereims (1898), where this author found fossiliferous nodules with trilobites between Fombuena and Luesma villages. The fossil site is situated about 1,900 m east of Luesma, on the eastern slope of El Castillejo hill (1,147 m high, as part of the Sierra de la Pajaranca) and on the right bank of a stream that flows into the Arroyo del Val (41º 08′ 41.1″ N, 1º 10′ 30.4″ W).

The outcrop comprises 20−25 m of greenish and bluish fossiliferous shales containing some beds rich in nodules with trilobites, located in the upper part of the Alpartir Member, and ending about 30 m below the sandstone alternations that constitute the base of the Sierra Member of the Castillejo Formation. Trilobites are quite well preserved, and many specimens are complete; those that appear in the nodules retain part of its original relief, the same as some molluscs and brachiopods recorded in the assemblage. Among the trilobites we have recognised the following taxa, partly reported by Hammann (1983), Hernández *et al*. (1983a) and Gutiérrez-Marco (1986): *Neseuretus tristani* (Brongniart in Desmarest), *Salterocoryphe salteri* (Rouault), *Colpocoryphe rouaulti* Henry (= *C. rouaulti* n. ssp? of Hammann, 1983), *Prionocheilus mendax* (Vaněk, 1965), *Placoparia* cf. *tournemini* Rouault (= *P.* (*C.*) *tournemini*, *fide* Hammann, 1983), *Isabelinia glabrata* (Salter), *Nobiliasaphus* aff. *nobilis* (Barrande), *Ectillaenus giganteus* (Burmeister), *Eodalmanitina* sp. (=? *E. macrophtalma* [Brongniart], *fide* Hammann, 1983) and *Zeliszkella* sp. (*ex Z.* (*Z.*) cf. *toledana* Hammann, *fide* Hernández *et al*., 1983a); adding here to this list the first record of *Uralichas hispanicus* (Verneuil & Barrande, 1855) and *Parabarrandia crassa* (Barrande) (*ex Parabarrandia* sp., *fide* Gutiérrez-Marco, 1986).

The assemblage was previously regarded as "lower Llandeilo" and is here assigned to the upper lower Dobrotivian (see below).

Villas (1983) points out the occurrence of brachiopods in some beds of the Sierra Member of this section, which he cited as "Castillejo (South)" (= section "Fombuena 2" in Villas, 1985) and its equivalent on the other side of the valley ("Castillejo (North)" = "Fombuena 1"). We have not found identifiable trilobites in those horizons.

Locality 7 (Fig. 2A, point 7). It corresponds to the point F1 of Keller (1981) and LU-III of Gutiérrez-Marco (1986), which is located 1,400 m north of Luesma, on the right bank of a small stream that is born between the hills of 1,046 and 1,043 m of the Solanas de las Sausas, about 1,000 m before its mouth in the Herrera river (41º 10′ 46″ N, 1º 08′ 55.5″ W). The outcrop comprises grey clayey shales belonging to the middle-upper part of the Alpartir Member. Trilobites, especially complete asaphid remains, are quite frequent, having identified the following taxa: *Isabelinia glabrata* (Salter), *Nobiliasaphus* aff. *nobilis* (Barrande), *Ectillaenus giganteus* (Burmeister) and *Neseuretus tristani* (Brongniart in Desmarest).

Despite the low diversity of the assemblage and the absence of brachiopods with biostratigraphy value, the occurrence of rare graptolites (Gutiérrez-Marco, 1986) allows assigning the locality to the lower Dobrotivian.

Locality 8 (Fig. 2A, point 8). It is a locality situated in proximity and direct prolongation of the trilobite bed discovered in the Alpartir Member by Kistner (1981, locality FP 3), to the east of the town of Aladrén (province of Zaragoza), which was cited as ALA-I by Gutiérrez-Marco (1986) and also yielded brachiopods (loc. Aladrén 1 in Villas, 1985). The studied horizon is located 2,250 m east-southeast of Aladrén, on the path that leads to the intersection with the Huerva river (41º 14′ 38.6″ N, 1º 07′ 50.4″ W). In the dark brown argillaceous shales of this outcrop, which rarely include fossiliferous nodules, the trilobites are quite flattened, however a large percentage of them are complete specimens. We have identified the following taxa: *Neseuretus tristani* (Brongniart in Desmarest), *Phacopidina micheli* (Tromelin), *Isabelinia glabrata* (Salter, 1853), *Nobiliasaphus* aff. *nobilis* (Barrande), *Eccoptochile almadenensis* Romano, 1980 and "*Panderia*" *beaumonti* (Rouault, 1847). The last species occurs for the first time in the Eastern Iberian Range. Additionally, Kistner (1981, with identifications of W. Hammann) added the record of *Prionocheilus mendax* (Vaněk), *Salterocoryphe salteri* (Rouault), *Colpocoryphe* sp., *Ectillaenus* sp., *Zeliszkella* sp., *Eodalmanitina* sp. and *Placoparia* sp. Gutiérrez-Marco (1986) also cited *Colpocoryphe rouaulti* Henry, as well as a graptolite that places the assemblage in the lower Dobrotivian.

Regarding previous publications, it should be clarified that the list of trilobites provided for the Alpartir Member by Lendínez González *et al*. (1989a), is a mixture of the taxa identified in this locality and in the type section of the Castillejo Formation (Fig. 2, loc. 6). Secondly, the trilobites *E. almadenensis* and *I. glabrata* illustrated by Zamora *et al*. (2019) without provenance data, come from this locality situated east of Aladrén (donation and pers. com. of S. Zamora, June 2022).

Locality 9 (Fig. 2A, point 9). It corresponds to the section "Eras Hondas" following Villas (1980, p. 84), which is located 2,800 m southwest of the town of Alpartir, in the area of Los Beltranes, between El Hontanar and Eras Hondas (41º 24′ 26″ N, 1º 24′ 30″ W). There is an outcrop of about 60 m of fossiliferous shales, belonging to the Alpartir Member in this eponymous locality, which contains abundant brachiopods and trilobites. From the study of several photographs of material from this locality, and some specimens donated by E. Villas, we have been able to confirm the presence of *Neseuretus tristani* (Brongniart in Desmarest) (ex *Neseuretus* sp.), *Ectillaenus giganteus* (ex *Ectillaenus* sp.), *Crozonaspis* sp. and other unidentified Phacopina.

The associated brachiopods identified by Villas (1980) allow assigning these beds to the lower Dobrotivian.

Locality 10 (Fig. 2A, point 10). It corresponds to the locality "Ontanat" of Villas (1980, p. 84), placed 1,700 m west of Alpartir, in the left bank of the Barranco de Hontanar (ex "Ontanat"), *ca.* 41º 25′ 3″ N, 1º 24′ 7″ W. From shales located towards the middle part of the Alpartir Member, Villas (1980, p. 84) cites the occurrence of *Eodalmanitina* cf. *macrophtalma* (Brongniart), together with lower Dobrotivian brachiopods and graptolites.

Locality 11 (Fig. 2A, point 11). It is situated in the municipality of Calamocha (northeast of the province of Teruel), *ca.* 1,400 m west of the town of El Poyo del Cid, on the promontory at the western foot of Cerro (= hill) San Esteban (*ca.* 40º 52′ 56″ N, 1º 21′ 2″ W). The locality was discovered by Scheuplein (1970, p. 41), who identified common remains of *Neseuretus tristani*, to which Gutiérrez-Marco (1986, loc. PO-I) later added some graptolites. From a stratigraphic perspective, the fossiliferous beds correspond to lumachelic sandstones placed in the sandy alternations of the Sierra Member of the Castillejo Formation. A characteristic succession is recognised below the oolitic ironstone that defines the base of the overlying Fombuena Formation, which crops out here from various mining prospecting trenchs.

The trilobite assemblage recorded from the coquinoid beds, also bearing brachiopods, molluscs and rare graptolites, includes *Neseuretus henkei* Hammann, *Colpocoryphe rouaulti* Henry, *Prionocheilus* sp., *Morgatia* sp. and a possible fragment of *Selenopeltis*? sp., correlated with the upper Dobrotivian by means of graptolites and brachiopods.

BIOSTRATIGRAPHY AND AGE

Previous biostratigraphic studies of the Castillejo Formation were carried out by Villas (1985), based on the brachiopod distribution, and Gutiérrez-Marco (1986), with graptolites. The only reported occurrence of conodonts (Sarmiento *et al*., 1995) involved a single locality and horizon and brings little valuable results.

The palaeontological record derived from the lower or Marité Member of the Castillejo Formation is limited to the graptolites of the *Didymograptus murchisoni* Zone reported in the eponymous section of this member, situated 2,600 m north-northwest of Luesma (Gutiérrez-Marco, 1980, 1986). Trilobites are absent from the yellow graptolitic shales intercalated between the ironstone beds that characterize this succession there. Elsewhere in the Iberian Range, the reduced thickness and coarse lithology of the Marité Member is unfavourable for the preservation of fossils, and it is generally reduced to a single ironstone bed at the base of the Castillejo Formation.

The shales of the Alpartir Member are fossiliferous in a number of places: in addition to the localities with trilobites here studied (Fig. 2, points 2−3, 5−10) another twelve fossil localities with brachiopods, molluscs and echinoderms are known, being distributed throughout the entire thickness of the member (*e.g.*, Möhl, 1965; Kolb, 1978; Gaubatz, 1981; Villas, 1985) or rarely forming accumulation horizons (*e.g.*, the ferruginous coquina cited near Alpartir by Villas, 1980).

The stratigraphically lowest assemblages of trilobites come from the first 20–30 m of shales above the base of the Member, in sections where the Marité Member is little developed or restricted to a thin basal oolitic ironstone bed. This is the case of locality 5 west of Fombuena, where graptolite shales of the *D. murchisoni* Zone bear scarce trilobite fragments which seem to have been transported from a shallower area: the collection includes an incomplete cranidium of *N. tristani* recorded in a nodule, plus single pygidial remains of this genus, a Phacopina indet. and an illaenid (*Ectillaenus*? sp.), the last two completely flattened and almost unrecognizable. The record of *N. tristani* indicates a late Oretanian or younger age for this horizon, a range further specified by its association with the late Oretanian graptolites. A second locality in the lower part of the Alpartir Member is situated something north (Fig. 2, point 2), in a site where Kolb (1978) cites *N. tristani* and *Placoparia cambriensis* Hicks, 1875. Based on this second species, the author suggested a "lower Llanvirn" (= early Oretanian) age, but the illustrated specimen (Kolb, 1978, pl. 1, fig. 7) is a tiny cranidium (*ca.* 5.4 mm wide) that is crushed and poorly preserved, unable to ensure specific identification by comparison with the Iberian and British occurrences of this species (among others Hammann, 1971, 1974; Romano, 1976; Rábano, 1984, 1989c; Fortey & Owens, 1987; Kennedy, 1989). New material collected by us at the locality includes a complete but flattened enrolled specimen and an isolated pygidium (non figured), both of small dimensions and which have been tentatively identified as *Placoparia* cf. *tournemini*. The absence in these beds of characteristic trilobite species of early Oretanian age (*i.e.,* the older forms *Neseuretus avus* Hammann, 1977 or *P. cambriensis*) agrees with the existence of a sedimentary gap at the base of the Castillejo Formation, which was previously suggested by the graptolite record (see above).

According to Villas (1985), the widespread fossiliferous beds located at the middle and upper part of the Alpartir Member in several sections (Aladrén, Fombuena, Luesma, Alpartir), belong to the *Heterorthina morgatensis* brachiopod Biozone (up to 20 m thick), followed through a small unfossiliferous interval by the *Aegiromena mariana*−*Crozonorthis musculosa* Biozone, which comprises the uppermost 10 m of the Alpartir Member and the 5 basal metres of the Sierra Member. This author dates these biozones as "early Llandeilo", being equivalent to the "early Dobrotivá" in the table 55 of his monograph. The record of early Dobrotivian graptolites of the *Hustedograptus teretiusculus* Zone overlaps the range of both cited brachiopod biozones, with the relative exception of their basalmost and uppermost beds, respectively, where graptolites are still unknown (Gutiérrez-Marco, 1980, 1986; Villas, 1985).

Among the trilobites from the middle and upper part of the Alpartir Member, there are six species that are distributed in both brachiopod biozones, such as *Neseuretus tristani*, *Colpocoryphe rouaulti*, *Placoparia tournemini*, *Nobiliasaphus* aff. *nobilis*, *Isabelinia glabrata*, and *Ectillaenus giganteus*. *Eodalmanitina* cf. *macrophtalma* is restricted to the *H. morgatensis* Biozone, where the first appearance of *Phacopidina micheli*, *Eccoptochile almadenensis, Prionocheilus mendax* and "*Panderia*" *beaumonti* is recorded. In the ovelying *A. mariana*−*C. musculosa* Biozone, the first regional appearance of *Salterocoryphe salteri*, *Uralichas hispanicus*, *Zeliszkella* sp. and *Parabarrandia crassa* also occur.

The record of *Placoparia tournemini* in both assemblages, despite being a relatively rare species in the studied area, allows us to refer the middle and upper part of the Alpartir Member to the homonymous trilobite biozone. Even more: the lowest identification of *P*. cf. *tournemini* at locality 2, about 20 m above the base of the Castillejo Formation, makes it possible for most, if not all, of the Alpartir Member to be integrated in the *P. tournemini* Biozone.

According to the most updated account of Gutiérrez-Marco *et al*. (2017, fig. 4), the *P. tournemini* Biozone ranges from upper Oretanian to lower Dobrotivian (*ca.* uppermost Darriwilian 2 to upper Darriwilian 3), and comprises four sub-biozones. The oldest of them (=

Eodalmanitina dest. nava sub-Biozone) is coeval with the record of the genus *Pterograptus* and is correlated with the lower part of the *Didymograptus murchisoni* graptolite Zone (upper Oretanian). As *Pterograptus* occurs in our locality 5, the sparse trilobite assemblage recorded there can be indirectly correlated with the lowest levels of the *P. tournemini* Biozone in the absence of its nominal taxon. Locality 3, with *P. tournemini*, *E*. cf. *macropthalma* and *Heterorthina morgatensis* Mélou, could be assigned to the *Zeliszkella toledana*−*Eodalmanitina macropthalma* sub-Biozone, perhaps together with its preceding fossiliferous horizon placed in the same section (locality 2 with *P*. cf. *tournemini*). The absence of Oretanian graptolites and the record of *H*. cf. *teretiusculus* at locality 3, or *Gymnograptus linnarssoni* (Moberg) at localities 6 and 8, lead us to attribute these fossil localities to the lower Dobrotivian within the above-mentioned trilobite sub-biozone -and the *H. morgatensis* brachiopod Biozone, which spans the Oretanian−Dobrotivian boundary.

The trilobite assemblage that characterises the upper part of the Alpartir Member at locality 6 is correlated with the upper part of the *P. tournemini* Biozone (= *Morgatia hupei* sub-Biozone) by the identification of *Parabarrandia crassa*, a species that has never been recorded in the Iberian Massif from beds prior to this sub-Biozone (Rábano, 1989b, 1989c). This biostratigraphic assignment also agrees with what Villas (1985) and Gutiérrez-Marco *et al*. (2017, fig. 4) concluded for the coeval *A. mariana*−*C. musculosa* brachiopod Biozone. Particularly, the identification of the dalmanellid *Howellites hammanni* Villas at the same beds reinforces their assignment to the upper lower Dobrotivian, by comparison with the Central Iberian record of this species (Reyes-Abril *et al*., 2011, fig. 1).

Finally, the trilobite assemblages recognised from the Sierra Member come from the uppermost 25 m of the Castillejo Formation in the Eastern Iberian Chain (locs. 1, 4), and from an apparently wider interval, deduced from loose stones, in an outcrop partially covered corresponding to locality 11 (Western Iberian Chain). In all cases the trilobites are accompanied by *Heterorthina kerfornei* Mélou, which defines a homonymous brachiopod biozone that extends practically the entire Sierra Member (Villas, 1985).

The synthetic list of trilobites from localities 1 and 4 includes *Neseuretus henkei*, *Colpocoryphe rouaulti*, *Eohomalonotus sdzuyi*, *Crozonaspis armata*, *C. incerta*, *Phacopidina micheli* and *Ectillaenus giganteus*. The record of *Eohomalonotus* with the above-mentioned species of *Neseuretus* and *Crozonaspis*, is exclusive of a very peculiar biofacies of the Ibero-Armorican area. This is characterised by the presence of trilobites adapted to life on sandy bottoms, in very proximal and shallow environments (Hammann & Henry, 1978; Henry, 1980a; Hammann, 1983; Rábano, 1989b). Henry (1980a) proposed assigning the corresponding beds to the so-called "*Crozonaspis incerta* biozone", which in the "Llandeilo" (= Dobrotivian) of Normandy and the Central Iberian Zone includes a diversified assemblage dominated by smooth trilobites such as *Eohomalonotus*, *Iberocoryphe* and *Kerfornella*. However, the almost total absence of homalonotids in the studied localities reveals a short development of the conditions that allowed such biofacies, replaced by a mixture of trilobites with a preference for sandy bottoms (*N. henkei, C. incerta, C. armata*), together with other trilobites, brachiopods, and molluscs typical of widespread muddy bottoms occurring in neritic environments such as, among others, *C. rouaulti* or *E. giganteus*. The lenticular coquinas from locality 4 attest to these episodes of substrate removal, transport and mixing of elements, originated from diferent places and biofacies, while the disarticulated trilobite remains recorded in consecutive sandstone strata from Locality 1 show a much lower degree of mixing. In fact, only a single pygidium of *Phacopidina micheli* can be attributed as a "foreign element" to the "*C. incerta* biozone".

From a chronostratigraphic point of view, the trilobite assemblage recorded in the upper third of the Sierra Member, within the upper part of the *H. kerfornei* brachiopod Biozone, could be tentatively assigned to the upper Dobrotivian, based solely on its stratigraphic position and the fact that it is younger than the data derived from the Alpartir Member. Although the record of *Placoparia borni* Hammann, 1971 could not be confirmed, it is known that both the trilobites *P. micheli*, *C. rouaulti* and *E. giganteus*, as well as the brachiopod *H. kerfornei*, maintained their representation until the end of the Dobrotivian (see Henry, 1980a; Rábano 1989b; Reyes-Abril *et al*., 2011, among others). The conodonts recorded in the locality 4 by Sarmiento *et al*. (1995) agree with this assignment to the upper Dobrotivian.

The biostratigraphic circumstances for locality 11 are somewhat different, since the record of the genus *Morgatia* in the *N. henkei* assemblage, reveals older horizons of the lower Dobrotivian, equivalent to the upper two sub-biozones of the *P. tournemini* Biozone, which were named after the known *Morgatia* species (Rábano, 1989b, 1989e; Gutiérrez-Marco *et al*., 2017, fig. 4). The only two examined cranidia are indeterminable due to their poor preservation and the absence of visual surfaces. In this sense, the fact that they may belong to a younger and hitherto undescribed species should not be excluded (see below). However, as the specimens have been found in a loose rock, it is more likely that they come from the basal beds of the Sierra Member, assignable in this case, to the uppermost *P. tournemini* Biozone (= *M. hupei* sub-Biozone). This would agree with a very similar case described by Villas (1985, fig. 4) for the local base of the *H. kerfornei* Biozone in his "Fombuena 1" section, also located in the first metres of the Sierra Member, and which begins in the lower Dobrotivian.

The restriction of the higher trilobites and brachiopods of the upper lower Dobrotivian to the basal part of the Sierra Member, makes it possible that the boundary with the upper Dobrotivian could be situated in the lower half of the aforementioned member. For this reason, in Figure 3 we have hypothesized that perhaps the trilobites recorded in the upper part of the Sierra Member may already correspond to the *Placoparia borni* Biozone, without this being confirmed until the future identification of its nominal species.

MATERIALS AND METHODS

The specimens studied herein are preserved as internal, external, or composite moulds occurring in argillaceous shales and siliceous nodules, affected by a variable degree of diagenetic compaction. No original calcareous material is preserved.

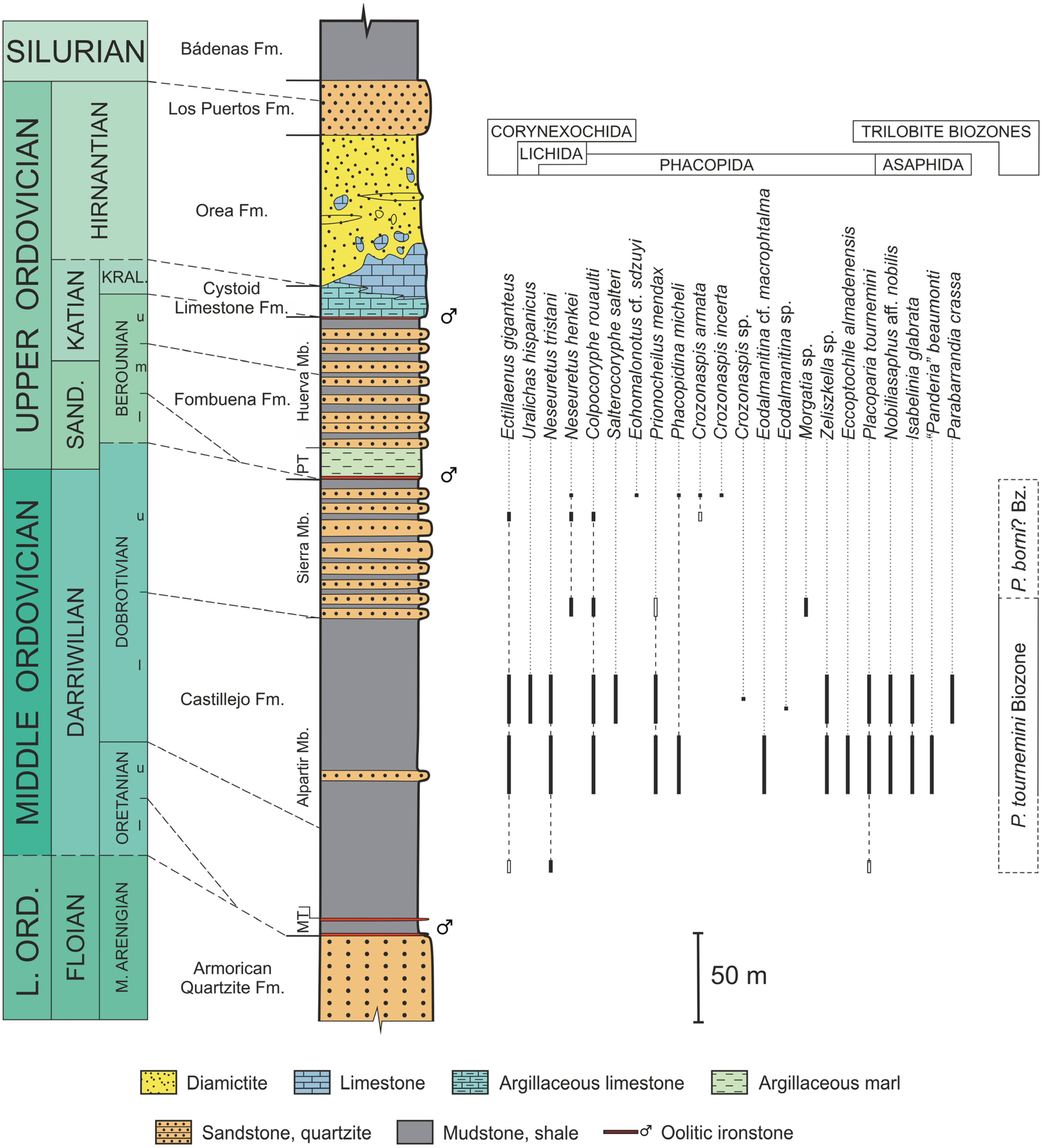

Figure 3. Schematic stratigraphical column of the Middle−Upper Ordovician formations of the Eastern Iberian Range, with the stratigraphic distribution of the studied trilobites. Abbreviations: **KRAL.,** Kralodvorian; **M,** Member; **MT,** Miembro Marité; **Sand.,** Sandbian; **PT,** Miembro Piedra del Tormo. The indentification of the *Placoparia borni* Biozone in the Sierra Member is only hypothetical.

Latex casts were made from critical external moulds that preserve the details of the ornamentation and other features of the external surface.

Latex casts and natural moulds were whitened with vapours of magnesium oxide for photography. Specimens were photographed using a Canon EOS 7D digital camera with Canon Macro 60 and 100 mm lens. Figures were assembled with Adobe Photoshop 2020 (the fossil plates) and made in CorelDRAW 2020 (the maps).

The material identified and illustrated herein is deposited at the Natural History Museum of the University of Zaragoza (**MPZ**), where some originals of Villas (1980) are also housed. Our collection includes specimens from some previous works that remained unpublished (Gutiérrez-Marco, 1980, 1986), as well as donations of specimens illustrated by certain authors (Zamora *et al*., 2019). Additionally, original samples from the collection of the Geological Map of Spain, stored at the "MAGNA Lithotheque" of the Geological Survey of Spain (IGME-CSIC), were consulted in its repository of Tres Cantos (Madrid).

PALAEONTOLOGICAL NOTES

The trilobites identified in this work belong to various genera and species with a wide distribution in the Ordovician of southwestern Europe (France, Spain, Portugal). They were taxonomically described in numerous modern studies carried out in the Iberian and Armorican massifs, mainly published by Henry (1965a, 1965b, 1966, 1968a, 1968b, 1970, 1980a, 1980b, 1981), Nion and Henry (1967), Henry and Nion (1970), Clarkson and Henry (1970), Hammann (1971, 1974, 1983), Henry and Clarkson (1975), Romano (1976, 1980, 1982, 1990a, 1990b, 1991), Bruton and Henry (1978), Hammann and Henry (1978), Henry and Romano (1978), Romano and Henry (1982), Hammann and Rábano (1987), Rábano (1981, 1989a, 1989b, 1989c, 1989d), Rábano and Gutiérrez-Marco (1983), Henry *et al*. (1993), Tauber and Reis (1994), Tauber *et al*. (1997), Sá *et al*. (2006), Rábano *et al*. (2010, 2018), Gendry *et al*. (2013), Gendry and Courville (2014) and Courville *et al*. (2016), among others. However, the detailed knowledge of the Middle Ordovician trilobites in the Iberian Range is far to be reached, as with the relative exception of the data presented by Hammann (1983) and Romero and Gutiérrez-Marco (2021), there is a general scarcity of data about these fossils in the Middle Ordovician formations.

In this paper we examine the main species recognized in the Eastern Iberian Range based on a review of the previous data (partly unpublished), a reduced number of existing collections and from additional material obtained in recent sampling campaigns.

Since most of the identified taxa have already been described in detail in the palaeontological literature of southwestern Europe (see above), the systematic part of this article is here replaced by some taxonomical notes on each of the recorded taxa, including the problems raised for their full identification. The order adopted by us largely follows the *Treatise on Invertebrate Paleontology* in its last edition (Fortey, 1997) with additions from Adrain (2011) and Fortey *et al*. (2022).

Corynexochid trilobites

The trilobite order Corynexochida Kobayashi, 1935 is represented by the genus *Ectillaenus* Salter, 1867 (Family Illaenidae Hawle & Corda, 1847), and the single species *Ectillaenus giganteus* (Burmeister, 1843). It is a persistent (but never abundant) element in the trilobite assemblages of the middle and upper part of the Alpartir Member from localities 3, 6, 7 and 9 (lower Dobrotivian: *P. tournemini* Biozone), although its first appearance seems to date back to the upper Oretanian in the locality 5. The studied material includes various complete specimens, both articulated (Fig. 4A and material from Villas in Pérez García *et al*., 2021), and partially disarticulated (Fig. 4B, 4G), as well as isolated cranidia, pygidia and librigenae (Fig. 4C–4F). The main morphological characters of the species, reviewed in detail by Rábano and Gutiérrez-Marco (1983), agree with our material, especially the size ratio between cephalon and pygidium, the length and shape of the axial furrows of the cephalon, the outline of the facial suture and the size and position of the eyes, the cranidial and pygidial convexity in the little deformed material from nodules, the morphology of the rostral plate and its horizontal connective sutures, the short and weakly marked pygidial rachis, and the shape and proportions of the pygidial doublure.

Ectillaenus giganteus is a common species throughout the Ibero-Armorican area (see Rábano & Gutiérrez-Marco, 1983; Rábano, 1989e; Courville *et al*., 2016, among others), and has a wide stratigraphical range that extends from the base of the lower Oretanian to the uppermost Dobrotivian (base of middle Darriwilian to lowermost Sandbian of the global scale). It was also recorded in the lower Darriwilian of Saxo-Thuringia, Germany (Budil *et al*., 2009; Fatka *et al*., in press). In the Western Iberian Range *E*. cf. *giganteus* has been identified at the top of the upper Dobrotivian *Placoparia borni* Biozone (Romero & Gutiérrez-Marco, 2021, fig. 8A–8E). The material from our locality 4 (Fig. 4F) could be placed in a comparable stratigraphical position and consists of a librigena recorded together with trilobites showing preference for sandy substrates (*N. henkei, C. incerta*). However, the morphology of this element is similar to that of *E. giganteus* and very different in outline to the librigenae of other species recorded in sandy sediments from the South-Gondwanan Dobrotivian, such as *E. benignensis* (Novák, 1918) (Rábano *et al*., 2010, and references therein). That is why we tentatively assign the studied librigena also to the Ibero-armorican species.

On the other hand, "*Panderia*" *beaumonti* (Rouault, 1847), a second species which, according to the traditional classification (partially accepted by Adrain, 2011) would be integrated into the order Corynexochida (Fig. 4H), is later treated here as belonging to a family, modernly related to the order Asaphida Salter, 1867, following the classification proposed by Fortey (1997). The close relationships of Panderiidae Bruton, 1968 with typical Nileidae Angelin, 1854 (order Asaphida), and its probably sister group Hemibarrandiidae Courtessole & Pillet, 1975 (similar glabellar muscle scars, position of the glabellar tubercle and eyes, absence of lunettes, etc.), support their clear differences with Illaenina (Pereira *et al*., 2016, 2017) (see below).

Lichid trilobites

These remarkable trilobites (order Lichida Moore, 1959) are comparatively rare regarding other trilobite groups, being represented in the characteristic Calymenacean–Dalmanitacean faunas of the southern Gondwana marine shelf. Its single representative in Dobrotivian strata from SW Europe is *Uralichas hispanicus* (Verneuil & Barrande, 1855), which reaches a wide distribution in the Iberian and Armorican massifs, where the species described from Spain has chronological priority over other Portuguese form (see Rábano 1989a, for a review and complete taxonomic description of the species). But for being a giant trilobite, which could reach up to 66 cm or more in axial length, complete and articulated specimens are virtually unknown, and the record of the species is normally limited to isolated cranidia, hypostomes and librigenae, with just a few pygidia and thoracic segments.

The material of *U. hispanicus,* recognized up to date, mainly comes from the Central Iberian Zone and is illustrated in the papers of Rábano (1989a, with previous references), Guy and Lebrun (2010) and Lomas Martín (2018). The genus was scarcely recorded in the Cantabrian Zone (Gutiérrez-Marco *et al*., 1999; Gutiérrez-Marco & Bernárdez, 2003) and is not known in the rest of the Iberian Peninsula, although it has been also described and illustrated from the French Armorican Massif (as "*U. heberti*" or "*U.* gr. *heberti*", see Lebrun *et al*., 2010a, 2010b; Courville *et al*., 2016 and references therein). Because of this, the single specimen recorded by us at locality 6 (Fig. 4I–4L) represents the first occurrence of *Uralichas* in the Iberian Range, being also one of the rare complete and articulated exoskeletons of *U. hispanicus* hitherto known. Unfortunatelly, our specimen was broken exposed on the rock surface and lost the last thoracic rings and the pygidium. Its identification as *U. hispanicus* is based on the relatively large width (tr.) of glabella across posterior part of bullar lobes, which is higher than that of the other Ibero-Armorican species *U. gutierrezi* Rábano, 1989a. The ornamentation of this second species is somewhat finer than that of the studied specimen, which agrees with *U. hispanicus* in having the cephalon and thorax covered with irregularly shaped tubercles of different sizes: large tubercles distally rounded to conical; intercalated irregularly to densely set small tubercles (Fig. 4L).

According to Rábano (1989a), *U. hispanicus* ranges from upper Oretanian to upper Dobrotivian strata (*ca.* upper Dw2–Dw3) in Ibero-Armorica. In the East Iberian Range the species was recorded towards the middle-upper part of the *P. tournemini* Biozone (lower Dobrotivian).

Odontopleurid trilobites

Trilobites belonging to the order Odontopleurida Whittington, 1959 are commonly represented in the Middle Ordovician of Southwestern Europe by the remarkable genus *Selenopeltis* Hawle & Corda, 1847, which for many years gave its name to the "Mediterranean" palaeoprovince of South Gondwana (Whittington & Hughes, 1972). In the Iberian Massif, *Selenopeltis* is recorded by 3–4 species that essentially occur in the Dobrotivian of all zones except the West Asturian-Leonese Zone (Romano, 1982; Hammann & Rábano, 1987; Rábano, 1989e; Gutiérrez-Marco *et al*., 1996, 1999; Gutiérrez-Marco & Bernárdez, 2003). In the Western Iberian Range, *Selenopeltis* is a rare genus, having been described so far in the uppermost Dobrotivian of the Aragoncillo inlier (Romero & Gutiérrez-Marco, 2021, fig. 8I–8M). Although we have not yet found any specimens attributable to the genus in the studied area, the species *Selenopeltis buchi* (Barrande, 1846) had been mentioned in the Western Iberian Range from possible Upper Ordovician strata. It was originally cited as *Acidaspis Buchi* Barrande by Hernández-Sampelayo (1942, p. 386, 388), who supossedly recorded the species from shales west of Balconchán (Zaragoza province). The outcrop almost certainly belongs to the Borrachón Formation according to the geological profile from Santed to Balconchán, illustrated by the same autor (Hernández-Sampelayo, 1942, p. 383). This makes very improbable, if not impossible, the identification of an odontopleurid trilobite in this locality. First, because the Balconchán

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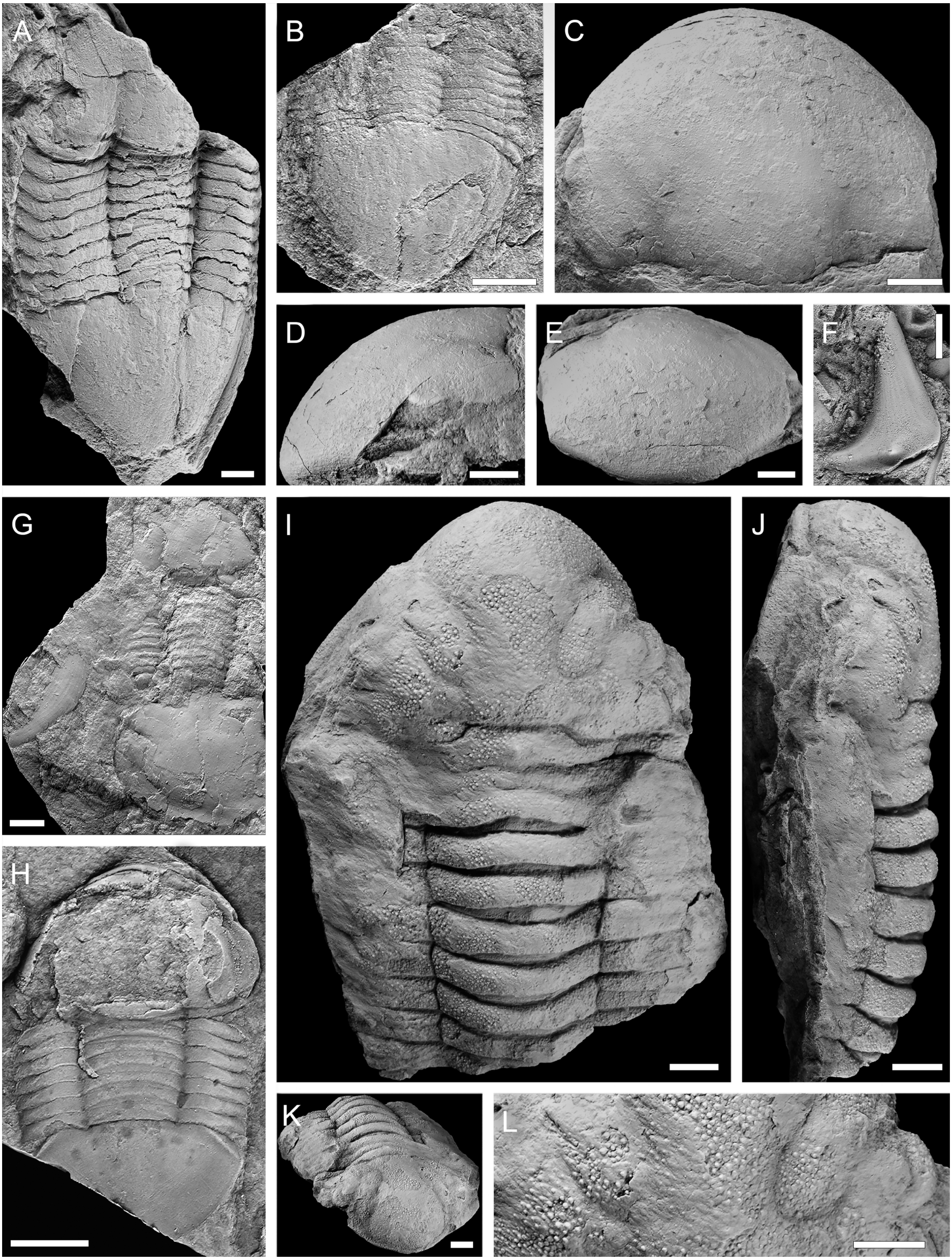
Figure 4. Illaenid (**A**–**G**), asaphid *s.l.* (**H**) and lichid (**I**–**L**) trilobites from the Castillejo Formation, collected in fossil localities 4 (**F**), 6 (**C**–**E**, **I**–**L**), 7 (**G**), 8 (**H**) and 9 (**A**–**B**). **A**–**G**, *Ectillaenus giganteus* (Burmeister, 1843); **A,** MPZ 2023/24, internal mould of a nearly complete specimen in dorsal view; **B,** MPZ 2023/25, internal mould of thorax and pygidium in dorsal view; **C**–**E,** MPZ 2023/26, internal mould of cranidium in dorsal (**C**), left lateral (**D**) and front (**E**) views; **F,** MPZ 2023/27, internal mould of librigena in ventral view; **G,** MPZ 2023/28, latex cast of complete specimen with rostral plate to the left; **H,** "*Panderia*" *beaumonti* (Rouault, 1847), MPZ 2023/29, latex cast of a nearly complete specimen in dorsal view; **I**–**L,** *Uralichas hispanicus* (Verneuil & Barrande, 1855), MPZ 2023/30, internal mould of articulated cephalon and thorax in dorsal (**I**), left lateral (**J**) and oblique-front (**K**) views, with a detail of the external ornament of the posterior part of cephalon (**L**); scale bars = 5 mm.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Formation is of Furongian to earliest Ordovician age, and therefore much older than the appearance of *S. buchi*, whose age range extends from the ?middle Darriwilian to the late Katian (Hammann & Rábano, 1987; Bruton, 2008). Second, because the mere presence of *Selenopeltis* in the Borrachón Formation is highly unlikely, since it only includes Tremadocian beds prior to the oldest record of the genus in the Floian strata of Morocco and France (Dean, 1966; Bruton, 2008). And third, because Upper Ordovician strata are very unknown in the Western Iberian Chains of the Eastern Iberian Range (Ruiz *et al*., 1991).

Phacopid trilobites: the calymenines

The trilobite order Phacopida Salter, 1864 constitutes the most abundant and diverse trilobite group recorded in Middle and Upper Ordovician strata of southwestern Europe, naming the so-called Calymenacean–Dalmanitacean trilobite fauna that characterized the high-latitude shallow-shelf seas in the southern margin of the Gondwana continent (Cocks & Fortey, 1990; Fortey & Cocks, 2003).

Both calymenines (suborder Calymenina Swinnerton, 1915) and dalmanitoids (suborder Phacopina Struve, 1959) are recorded in the Castillejo Formation, together with a third group of phacopid trilobites, the cheirurines (suborder Cheirurina Harrington & Leanza, 1957).

Calymenine trilobites are quite abundant in the Dobrotivian shale and sandstone lithofacies; this agrees with the first historical record of Ordovician trilobites in the Iberian Range (Dereims, 1898; Lotze, 1929), which were assigned to its more conspicuous representative "*Calymene*" or "*Synhomalonotus*" *tristani* (now a species of the genus *Neseuretus*: Henry, 1970; Hammann, 1983; Rábano, 1989d).

The calymenines identified in this study belong to five different genera included in three families. The first of these is the family Calymenidae Burmeister, 1843, which includes the important subfamily Reedocalymeninae Hupé, 1955 and the widespread genus *Neseuretus* Hicks, 1873. In this sense, the reedocalymenines are a biogeographically diagnostic group that were distributed across Gondwana and peri-Gondwana throughout the Ordovician (Turvey, 2005, and references therein).

Two species of *Neseuretus* were identified in the Castillejo Formation. The first is *Neseuretus tristani* (Brongniart in Desmarest, 1817), recorded from shales and nodules along the entire Alpartir Member (upper Oretanian to lower Dobrotivian) and, on the other, *N. henkei* Hammann, 1977, occurring in the sandstone facies of the lower to basal upper Dobrotivian of the Sierra Member. Both species were previously classified in the subgenus *N.* (*Neseuretus*), but it fell out of use when Hammann and Leone (1997) gave a full generic rank to the former subgenus *N.* (*Neseuretinus*) Dean, 1967.

Neseuretus tristani (Fig. 5A−5J) scarcely occurs in localities 2 and 5 from the lower part of the Castillejo Formation, in the second case associated to upper Oretanian graptolites. Higher up, the species become more common in lower Dobrotivian shales bearing fossiliferous nodules, being recorded by several cephala, pygidia, and rarely by complete specimens in localities 3, 6, 7, 8 and 9. Previously illustrated material includes a thoracopygon plus a cranidium (Kolb, 1978, pl. 1, fig. 2–3 –from his locality F11 southeast of Cerveruela), one juvenile pygidium (Keller, 1981, pl. 7, fig. 6 –from loc. 7), one cephalon + first thoracic segment (Hammann, 1983, pl. 5, fig. 54 –from loc. 6), and a prone complete specimen (Villas in Pérez García *et al*., 2021, fig/p. 89 –from loc. 9). Articulated material, in the form of prone to partially enroled specimens were obtained by us at localities 6 (Fig. 5J) and 8 (Fig. 5A–5B). The last case refers to a strongly flattened specimen that however preserves the hypostome in place.

Neseuretus henkei (Fig. 6A–6H) represents the local second species of the genus, in this case it is recognized towards the top of the Castillejo Formation in sandstone-dominated lithofacies. It was first identified at locality 4 by Hammann (in Kolb, 1978, pl. 1, fig. 4a−4c, a pygidium), Hammann *et al*. (1982) and Hammann (1983). We have recognized the species through a slightly more abundant material (several cranidia, pygidia and one librigenae) coming from localities 1 (Fig. 6D−6F, 6H), 4 (Fig. 6A, 6C, 6G), and 11 (Fig. 6B). Hammann (1983) studied in great detail the representatives of the genus *Neseuretus* occurring in the Ordovician of Spain, with valid conclusions for SW Europe, which were also adopted by Rábano (1989d) and Turvey (2005). However, Gendry *et al*. (2013) slightly modify the taxonomic framework by establishing an essentially stratigraphic distinction between the subspecies *N. t. tristani* and *N. tristani* "*tardus*" Hammann, 1983, which they elevated to full species rank. Their proposal is supported by a morphometric study on a small number of specimens

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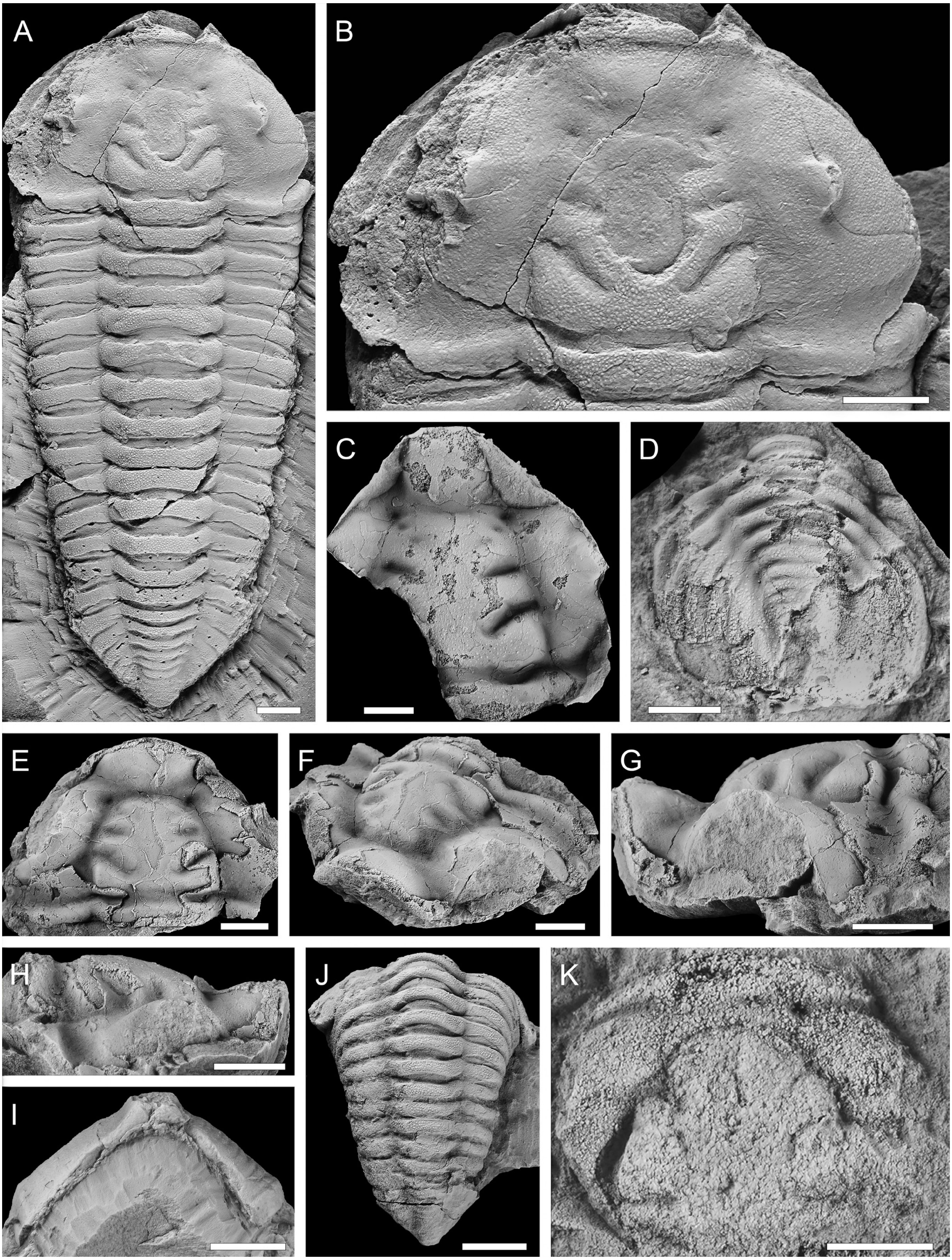
Figure 5. Calymenid trilobites (*Neseuretus*, *Prionocheilus*) from the Castillejo Formation, collected in the localities 6 (**C**–**J**), 8 (**A**–**B**) and 11 (**K**). **A**–**J**, *Neseuretus tristani* (Brongniart in Desmarest, 1817); **A,** MPZ 2023/31, flattened complete specimen in dorsal view (**A**) and detail of the cephalon with the hypostomal pits and the partly dettached glabella, showing the ventral hypostome nearly *in situ* (**B**); **C,** MPZ 2023/32, latex cast of incomplete cranidium in dorsal view showing ornamentation; **D,** MPZ 2023/33, latex cast of compressed pygidium in posterior view showing ornamentation; **E**–**G,** MPZ 2023/34, internal mould of cranidium in dorsal (**E**), left antero-lateral (**F**) and left lateral (**G**) views; **H,** MPZ 2023/35, internal mould of cranidium in right side view; **I,** MPZ 2023/36, internal mould of pygidium in ventral view; **J,** MPZ 2023/37, complete specimen, partly enrolled, in dorsal view; **K,** *Prionocheilus* sp., MPZ 2023/38, internal mould of a poorly-preserved cranidium in dorsal view; sale bars = 5 mm, except figures C and D (= 3 mm).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(less than 50 cephala and as many pygidia) preserved in nodules and interpreted as devoided of tectonic or diagenetic distortion. The study has many deficiencies for underestimating the effect of deformation, obvious even in some specimens illustrated in their figures 8 and 9 and provides a revised diagnosis of *N. t.* "*tardus*" which continues to make its distinction from *N. tristani* virtually impossible in specimens showing "standard preservation" (*sic* in their fig. 10). According to Gendry *et al*. (2013, fig. 8), *N.* "*tardus*" is represented in the lower Sandbian (*Lagenochitina ponceti* and ?*L. deunffi* chitinozoan biozones), but with a partial range overlapping *N. tristani* "suspected in Brittany" for the uppermost Darriwilian (top of the *Linochitina pissotensis* chitinozoan Biozone). Additionally, they claimed to be the first to find *N. t.* "*tardus*" in the Armorican Massif, regardless that Henry (1980a, pl. 10, fig. 6a−6b) had already found hypostomes with the characteristic thick maculae of the *tardus* morphotype at the well-known (and pre-Sandbian) site of Traveusot en Guichen (upper part of the Traveusot Formation, Martigné-Ferchaud Syncline). On the other hand, the nicely preserved material of *N. tristani* from the lower Sandbian of the Aragoncillo inlier (Romero & Gutiérrez-Marco, 2021), dated with graptolites, shows mixed characters both with *N. tristani* and *N. t.* "*tardus*". Even in the relief specimens from the nodules of our locality 6, *N. tristani* shows variations in glabellar morphology and convexity (Fig. 5C and 5E, 5G and 5H, respectively) due to a deformation difficult to quantify. These reasons led Rábano (1989d) to propose reunifying, for practical purposes, the subspecies of Hammann (1983) into a single species, pending future detailed studies with material in better conditions to clarify the status of the *tardus* morphotype, something that the paper by Gendry *et al*. (2013) fails to resolve.

In our opinion, the specimens from the fossil localities studied here have been fully identified as *N. tristani* because either they are preserved flattened (Fig. 5A−5B), or the morphology of the specimens in relief coming from nodules agree with the description of *N. t. tristani* of Hammann (1983), despite the fact that they are associated with some pygidia showing a thickened and prominent terminal piece (Fig. 5I). The latter, according to Gendry *et al*. (2013, p. 469), would fit better within the diagnosis of "*N. tardus*".

In addition to the reedocalymenine *Neseuretus*, other calymenids identified in the Castillejo Formation are the colpocoryphine genera *Colpocoryphe* Hicks, 1873 and *Salterocoryphe* Hammann, 1977 (subfamily Colpocoryphinae Hupé, 1955). The first was recognized in six different localities, through the species *Colpocoryphe rouaulti* Henry, 1970, ranging from the middle part of the Alpartir Member to the upper part of the Sierra member. The second is represented by *Salterocoryphe salteri* (Rouault, 1851), a relatively rare species not figured here, known from a few specimens coming from two localities of the Alpartir Member.

Colpocoryphe rouaulti (Fig. 6I−6N) was identified by several cephala and complete specimens in localities 1, 4, 6, 8 and 11, and was also figured from two other specimens not revised here: a cranidium from locality F1 of Kolb (1978, pl. 1, fig. 5) in the road south of Cerro Pelado (west of Fombuena), and a cephalon from locality "east of Martucha" (west-south-west of Herrera de los Navarros = HERR-II in Gutiérrez-Marco, 1986), cited and figured by Gaubatz (1981, pl. 4, fig. 29). This author indicates an additional locality for the species on the eastern bank of the Barranco Regacho, *ca.* 2 km south of Herrera de los Navarros. From locality 6, a finely preserved complete specimen of "*Colpocoryphe rouaulti*? n. ssp." was described by Hammann (1983, p. 85; text-fig. 7; pl. 12, fig. 121a–121c; pl. 23, fig. 216; pl. 24, fig. 224). The purported separation of this possible new subspecies with regard to the type material of *C. rouaulti*, coming from the Traveusot en Guichen locality in Brittain (Henry, 1970, 1980a), are based in small differences on the outline and lower convexity of the glabella, the lesser prominency of the eyes in side view, as well as on slight details relative to pygidial relief. The characteristics of the specimen described by Hammann have not been repeated in other material collected by us at the site, entirely comparable to *C. rouaulti*, so we attribute the aforementioned differences to an intraspecific variation that is common in the genus and frequently affects the pygidial morphology. This has been verified by us in the abundant material of another related *Colpocoryphe* species occurring in the Western Iberian Range (Romero & Gutiérrez-Marco, 2021).

From *Salterocoryphe salteri* (not figured) a meager material collected in localities 6 and 8 is known. Two complete specimens and a thoracopygon come from the first site, which were partly illustrated by Hammann (1983, pl. 11, fig. 104a−104b; pl. 21, fig. 204a–204b). From locality 8 derives a single specimen also identified by Hammann (in Kistner, 1981, p. 25). The illustrations

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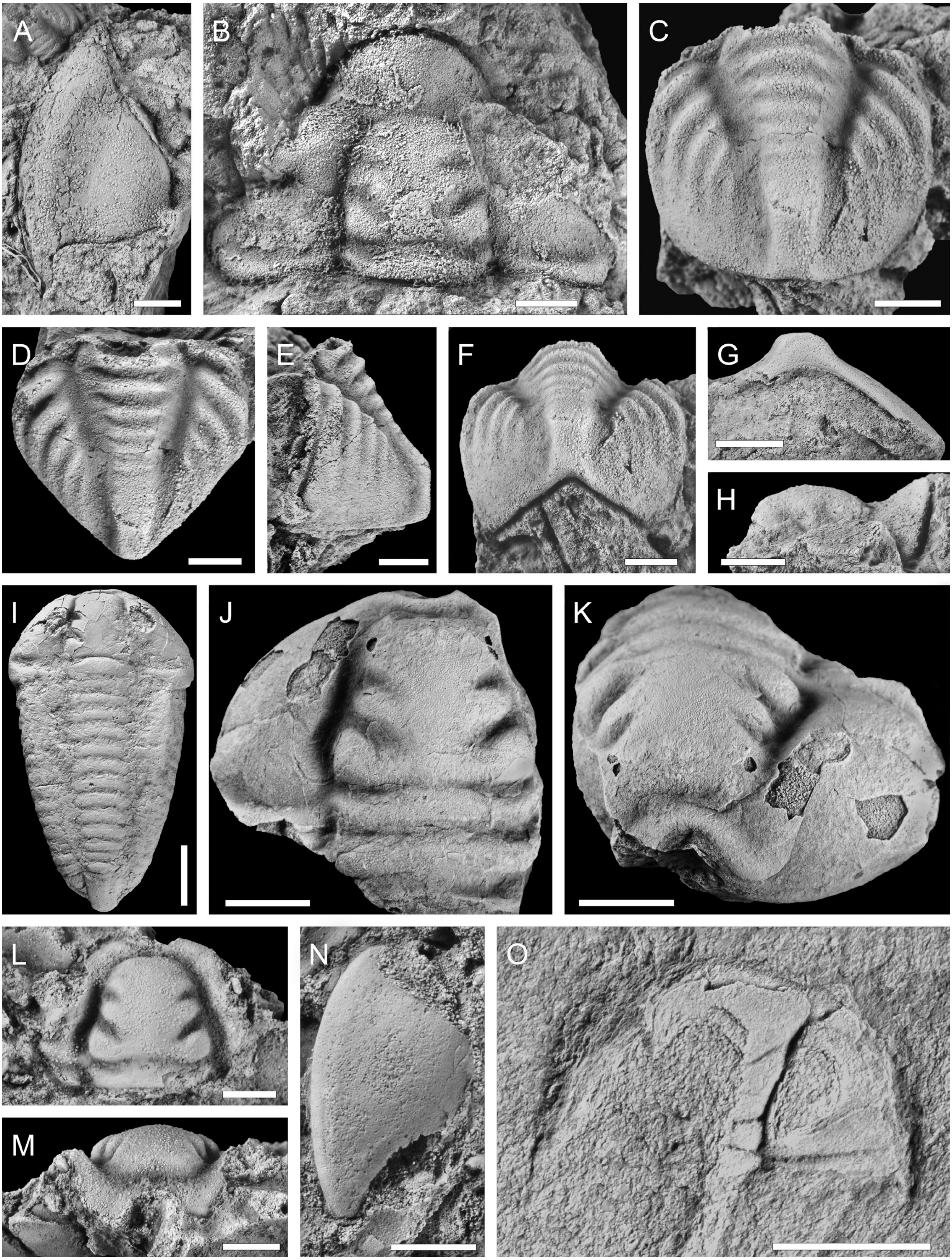
Figure 6. Calymenid (**A**–**N**) and phacopid (**O**) trilobites from the Castillejo Formation, collected in the localities 1 (**H**), 3 (**O**), 4 (**A**, **C**–**G**, **L**–**N**), 6 (**I**–**K**) and 11 (**B**). **A**–**H,** *Neseuretus henkei* Hammann, 1977; **A,** MPZ 2023/39, internal mould of left librigena; **B,** MPZ 2023/40, internal mould of cranidium in dorsal view; **C**–**F,** MPZ 2023/41, internal mould of pygidium in posterior (**C**), dorsal (**D**), right lateral (**E**) and postero-ventral (**F**) views; **G,** MPZ 2023/42, internal mould of pygidium in ventral view; **H,** MPZ 2023/43, internal mould of cranidium, right side view; **I**–**N,** *Colpocoryphe rouaulti* Henry, 1970; **I,** MPZ 2023/44, young complete specimen, composite mould; **J**–**K,** MPZ 2023/45, external mould, partly exfoliated, of incomplete cranidium with the first thoracic segment in dorsal (**J**) and oblique front (**K**) views, showing ornamentation; **L**–**M,** MPZ 2023/46, internal mould of cranidium in dorsal (**L**) and anterior (**M**) views; **N,** MPZ 2023/47, internal mould of left librigena; **O,** *Eodalmanitina* cf. *macrophtalma* (Brongniart, 1822), MPZ 2023/48, internal mould of incomplete cephalon; scale bars = 3 mm, except for figures A–B, G, I–K (= 5 mm).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published in the first paper are highly demonstrative of the occurrence of the species in the area, to which has been added by us a single complete specimen collected in locality 6.

Calymenines from the family Pharostomatidae Hupé, 1953 are represented in the Iberian Range by the genus *Prionocheilus* Rouault, 1847, a rare trilobite known after four specimens from the uppermost Dobrotivian nodules of the Aragoncillo inlier (Romero & Gutiérrez-Marco, 2021, p. 79) and by five specimens in the lower Dobrotivian beds of the Castillejo Formation (localities 6, 8 and 11). All of them could be identified as *Prionocheilus mendax* (Vaněk, 1965), except a poorly preserved cranidium recorded in sandstone from locality 11 (Fig. 5K) which remains in open nomenclature as *Prionocheilus* sp. A nice illustration of a cephalon and thorax belonging to a fragmentary complete specimen of *P. mendax* was presented by Kistner (1981, pl. 1, fig. 5) from locality 8. In locality 6, the same species was listed by Hammann (1983, fig. 4) and Gutiérrez-Marco (1986). According to Romero and Gutiérrez-Marco (2021), this widespread species occurs in the Dobrotivian over a large area including SW Europe and Bohemia, where its record extends to the Berounian (Romano, 1991, and references therein). However, it is necessary to consider that the oldest evidences of *P. mendax* go back to the Oretanian, with its first representatives in the “lower Llanvirn” (= lower Abereiddian) shales of southwestern Wales and Shropshire, Great Britain (Kennedy, 1989), followed by its record in the upper Oretanian of the Sueve Formation of the Cantabrian Zone (Gutiérrez-Marco *et al*., 1999; Gutiérrez-Marco & Bernárdez, 2003; Bernárdez *et al*., 2022). In any case, the genus *Prionocheilus* shows a wide stratigraphic range in the Eastern Iberian Range, since it was also documented in the Lower Ordovician through *P.* cf. *languedocensis* (Courtessole & Pillet, 1975) (Hammann, 1983), in the middle Berounian by *P. almelai* Hammann, 1992 [ex *P. costai* (Delgado) *sensu* Gutiérrez-Marco, 1986] and in the Kralodvorian by *Prionocheilus obtusus* (M’Coy, 1846) (Hammann, 1992).

The single record of the calymenacean family Homalonotidae Chapman, 1890 is placed near the top of the Castillejo Formation at locality 1. From there it comes the internal mould of a cranidium preserved in sandstone and illustrated by Kolb (1978, pl. 1, fig. 1). It was assigned to *Eohomalonotus* cf. *sdzuyi* Hammann & Henry, 1978, one of the most widespread representatives of the genus *Eohomalonotus* Reed, 1918, which integrates the shallowest trilobite biofacies of the Ordovician of Ibero-Armorica and North Africa (Hammann & Henry, 1978; Henry, 1980a; Hammann, 1983; Rábano, 1989b, 1989d; Henry & Destombes, 1991).

Subsequent regional syntheses by Hammann *et al*. (1982, p. 30) and Liñán *et al*. (1996, fig. 10) cite the record of *E. sdzuyi* in the Castillejo Formation based on the specimen discovered by Kolb (1978). However, neither Hammann (1983) nor the authors of this work have managed to find new material of the species, whose identification is accredited solely by the quality of the photograph provided by the German author, in a MSc Dissertation that remains unpublished.

Phacopid trilobites: the phacopines

The trilobite suborder Phacopina Struve, 1959 is represented in the study area by at least seven different species of the superfamilies Acastacea Delo, 1935 (Acastacea *s.l. sensu* Edgecombe, 1993) and Dalmanitoidea Vodges, 1890 (family Dalmanitidae Vodges, 1890). The first includes two widespread genera such as *Phacopidina* Bancroft, 1949 and *Kloucekia* Delo, 1935, both very poorly represented in our material and with some problems in their diagnostic characterization (Pereira, 2017).

Phacopidina micheli (Tromelin, 1877) is known from few specimens derived from locality 8 in the Alpartir Member, including a well-preserved cephalon in a nodule (Fig. 7J–7N). Among other characters, it shows a wide glabella slightly expanded forwards, limited by sinuous axial furrows, but without a frontal lobe protruding laterally. The S2 are short, transversely arched and faintly marked; S3 are rectilinear and do not reach the axial furrows. The eyes are large and extend beyond the S1. Additionally, Kolb (1978, pl. 1, fig. 8) illustrated a pygidium of the same species, also cited by Hammann *et al*. (1982), coming from locality 1 in the highest part of the Castillejo Formation. This represents a relatively high horizon for the species, although in any case comparable to its occurrence in the Arangoncillo inlier of the Western Iberian Range (Romero & Gutiérrez-Marco, 2021).

The second identified acastacean is *Kloucekia drevermanni* Hammann, 1972, represented by a single cephalon from locality F8 of Kolb (1978, pl. 1, fig. 6), who also provided the only unpublished illustration of the specimen. We agree with the identification of the

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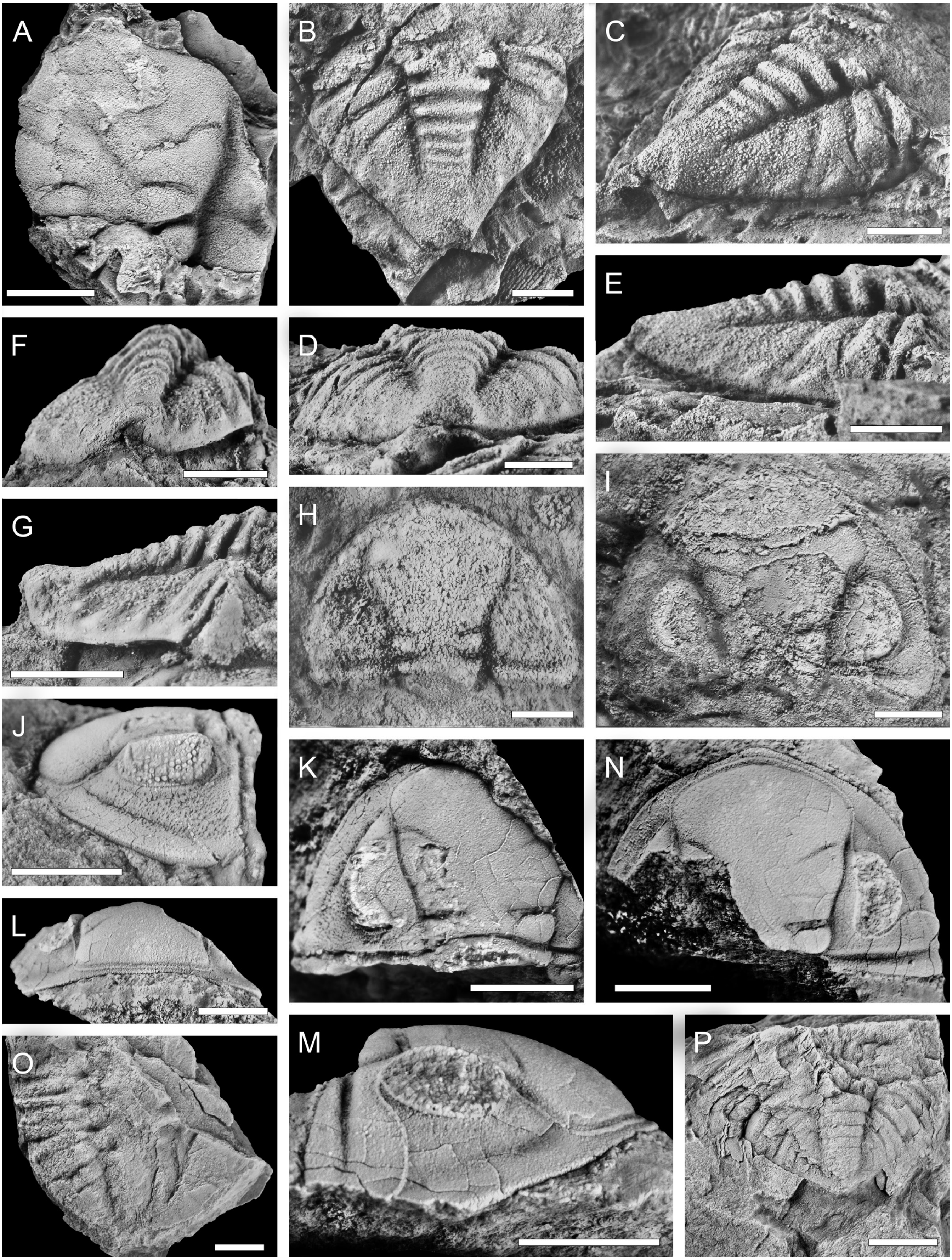
Figure 7. Phacopid trilobites from the Castillejo Formation, collected in the localities 1 (**B**–**E**), 3 (**O**), 4 (**A**, **F**–**G**), 6 (**P**), 8 (**J**–**N**) and 11 (**H**–**I**). **A**–**G,** *Crozonaspis armata* Hammann, 1972; **A,** MPZ 2023/49, internal mould of incomplete cranidium in dorsal view; **B**–**E,** MPZ 2023/50, internal mould of pygidium in dorsal (**B**), oblique lateral (**C**), posterior (**D**) and left side (**E**) views; **F**–**G,** MPZ 2023/51, internal mould of a deformed pygidium in posterior (**F**) and left lateral (**G**) views; **H**–**I,** *Morgatia* sp.; **H,** MPZ 2023/52, internal mould of poorly-preserved cephalon in dorsal view; **I,** MPZ 2023/53, internal mould of cephalon in dorsal view; **J**–**N,** *Phacopidina micheli* (Tromelin, 1877), cephalon MPZ 2023/54; latex cast of the external mould in left lateral (**J**) and dorsal (**K**) views; internal mould of same in front (**L**), right lateral (**M**) and dorsal (**N**) views; **O,** MPZ 2023/55, Phacopina indet., internal mould of thorax + pygidium; **P,** MPZ 2023/56, *Zeliszkella* sp., internal mould of thorax + pygidium –showing doublure–, in dorsal view; scale bars = 5 mm, except figures H–O (= 3 mm).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species made by Hammann (in Kolb, 1978, p. 26), which, however, is problematic since *K. drevermanni* was commonly considered as a lower Oretanian form (Rábano, 1989e). The equivalent rocks are unknown in the study area since they coincide with a stratigraphic gap at the base of the Castillejo Formation. Kolb (1978, p. 111) placed his locality F8 in shales "at the boundary Llanvirn–Llandeilo" and equivalent to the Alpartir Member. But in a correlatable stratigraphic position he also mentioned the locality F9, which provided the lower Dobrotivian graptolite *Gymnograptus linnarssoni* (Moberg, 1896), which could be more consistent with the stratigraphic position of the preceding locality.

In any case, the imprecise dating of the type material of "*Kloucekia drevermanni glabra*" Hammann, 1972 (a young synonym of *K. drevermanni sensu stricto* according to Rábano, 1989e, p. 1000), would also make possible for the species to extend punctually to upper Oretanian or Dobrotivian strata, given the derivation of the type series of *K. d.* "*glabra*" from the original material of Born (1918), which shows a proven mixture of the different horizons mentioned above (Gutiérrez-Marco, 1986; Rábano, 1989e).

Phacopine trilobites of the family Dalmanitidae (superfamily Dalmanitoidea) are represented in our material by a few specimens of four genera belonging to three subfamilies. All of them consist of poorly preserved internal moulds of cephala and pygidia, generally difficult to identify at specific level.

First, we have the genus *Crozonaspis* Henry, 1968b, from the subfamily Dalmanitinae Reed, 1905, which was identified in the upper part of the Sierra Member by the species *Crozonaspis armata* Hammann, 1972 and *C.* cf. *incerta* (Deslongchamps, 1825), co-occurring at the locality 1. The first was illustrated by Kolb (1978, pl. 1, fig. 10) through a pygidial fragment, but our reinvestigation of the locality provided a better preserved, almost complete pygidium (Fig. 7B–7E). *C. armata* was also recorded in locality 4, where it was cited with some doubts by Hammann *et al*. (1982), although the new material (Fig. 7A, 7F–7G) allows recognizing the diagnostic characters of the species (see Hammann, 1974; Rábano, 1989c).

The identification of *C. incerta* in locality 1 is based on a single cephalic fragment of reduced dimensions, which was illustrated by Kolb (1978, pl. 1, fig. 9) and also mentioned by Hammann (1983, loc. Fomb II). Despite being a unique specimen, its small size, its reduced eye and the virtually imperceptible S2 and S3 on the internal mould, differ from the co-occurring *C. armata* and support the identification made by Hammann (in Kolb, 1978, p. 27).

A third species of *Crozonaspis*, coming from older beds in the Alpartir Member, was cited in open nomenclature by Villas (1980) at locality 9. This *Crozonaspis* sp. corresponds to a different Dobrotivian species, either from the groups of *C. morenensis* Hammann, 1972 or *C. struvei* Henry, 1968b, which are the only ones represented in the shale facies of the Dobrotivian, in contrast to *C. incerta* or *C. armata*, which are species typical of sandy facies.

Another dalmanitine genus is *Morgatia* Hammann, 1972, which was solely recorded in locality 11, from sandstones belonging to the lower part of the Sierra Member. The material consists of two poorly preserved cephala showing the laterally expanded frontal glabellar lobe, rounded genal angles and large eyes, adjacent to the posterior cephalic furrow (Fig. 7H–7I). According to Rábano (1989c), the stratigraphic range of the genus extends from the upper Oretanian to the top of the lower Dobrotivian, where it nominates the *Morgatia hupei* sub-Biozone in the upper part of the *P. tournemini* Biozone. Although its occurrence at locality 11 could coincide with such sub-Biozone, the specimens are too poorly preserved to be assigned to *M. hupei* (Nion & Henry, 1967), and we prefer to identify them as *Morgatia* sp.

Phacopine dalmanitoids of the subfamily Mucronaspidinae Holloway, 1981 are represented in our material by a few specimens of the genus *Eodalmanitina* Henry, 1966, which, at most, allow to be identified in open nomenclature. Fragmentary specimens of *E.* cf. *macrophtalma* (Brongniart, 1822) have been mentioned from locality 10 (Villas, 1980) and also occur in locality 3, from which comes a single cephalon illustrated here in Figure 6O. Two additional localities in the Alpartir Member recording the genus are point 8, where Kistner (1981) cites *Eodalmanitina* sp., and locality 6, where Hammann (1983 = Fomb I) mentions *E. macropthalma*. However, the last identification possibly corresponds to *E. destombesi* (Henry, 1966), due to the occurrence of the brachiopod *Heterorthina kerfornei* Mélou, 1975 in the assemblage, which is typical of higher beds in the Dobrotivian sucession (Villas, 1985). To review the specific assignment of *Eodalmanitina* in locality 6 it is necessary to find new material in a better preservation state: in the meantime, the material of Hammann (1983) should be cited as *Eodalmanitina* sp.

Finally, the dalmanitid subfamily Zeliszkellinae Delo, 1935 is represented in the studied area by *Zeliszkella* sp., recorded at the localities 6 and 8 within lower Dobrotivian beds of the Alpartir Member. In the first fossil locality, Hernández *et al*. (1983a) identified as *Z.* (*Z.*) cf. *toledana* (Hammann, 1971) an incomplete and poorly preserved material. From the same site, we only added a thorax + pygidium with doublure (Fig. 7P), showing backward-curving posterior pleural ends and a triangular-shaped pygidium. However, the exfoliation of the doublure hinders to know the number of ribs on the flanks and, therefore, the specimen is identified here as *Zeliszkella* sp. An additional occurrence of *Zeliszkella* sp. comes from locality 8 (Kistner, 1981, p. 25). It should be noted that after the review by Jell and Adrain (2003), all the attributions to the subgenus *Z.* (*Zeliszkella*), that commonly were adopted for Ibero-Armorican Middle Ordovician species, ceased when the last of the remaining subgenera included in *Zeliszkella* adquired a full-generic rank.

Phacopid trilobites: the cheirurines

Phacopid trilobites of the Suborder Cheirurina Harrington & Leanza, 1957 are represented by two genera belonging to different families: Cheiruridae Hawle & Corda, 1847 and Pliomeridae Raymond, 1913. Both are relatively rare and are restricted to a few localities, although one of them is of appreciable biostratigraphic interest.

The first representative of the group is limited to a single complete individual of the genus *Eccoptochile* Hawle & Corda, 1847 (Fig. 8A), which comes from locality 8. It is quite flattened, which prevents appreciating the convexity of cephalon, although other observable characters allow assigning it to the species *E. almadenensis* Romano, 1980. In particular, we highlight the presence of a relatively narrow frontal area (sag.) and a pygidium with three pairs of thick, acuminated pleural spines, among the various characters which, according to Romano (1980) and Rábano (1989d) allow to differenciate this species from *E. mariana* (Verneuil & Barrande, 1855). Pereira (2017, p. 427–429) extensively discussed the posible synonymy between *E. almadenensis* and *E. mariana*, already indicated by Hammann and Leone (2007), interpreting their morphologic differences as of probable taphonomic origin. In view of this, she proposes two posible solutions: either consider both species as valid, but with *E. mariana* being restricted to its holotype, or investigate the variability induced by taphonomic compaction and tectonic deformation in those localities where the two species seem to co-occur, to try to demonstrate a supposed nomenclatural priority of *E. mariana* over *E. almadenensis*.

In our opinion, the record of an additional undeformed material similar to the holotype of *E. mariana* confirms the validity of this species, recognizable by a wider anterior border present in specimens with full relief which, when complete, associate a pygidium with three pairs of swollen pleural spines with a thick rounded end. This is proven in specimens from the Armorican Massif (Courville *et al*., 2016, fig. 10.1–10.2), as well as in unpublished material (JCG-M. coll.) from upper Dobrotivian strata near the Fresneda reservoir, in the southern Central Iberian Zone. By contrast, *E. almadenensis* have a narrow frontal area, and the pygidial spines show a lanceolate outline (Fig. 8B), especially in the earlier forms from the lower Dobrotivian.

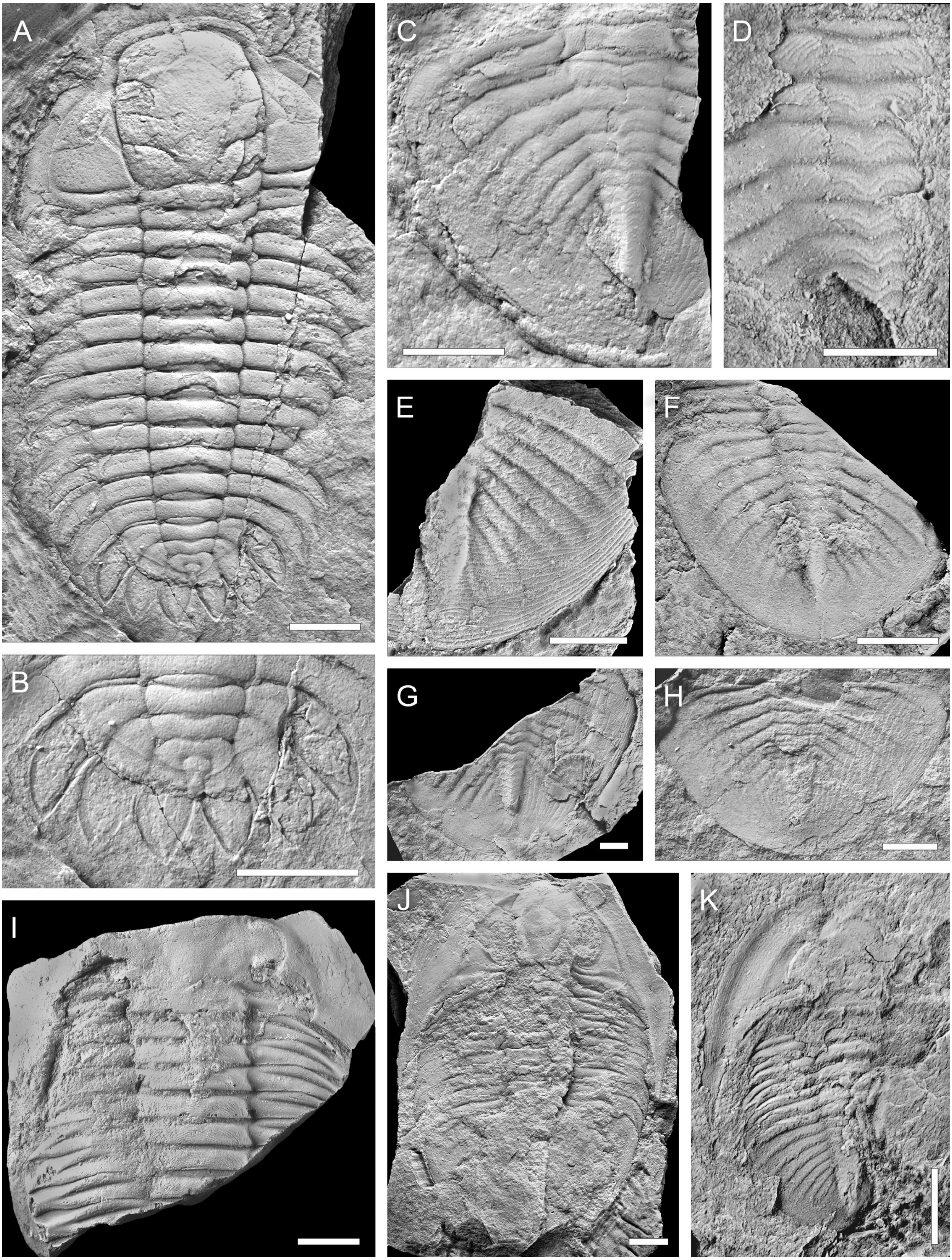
The second cheirurine trilobite identified in the study area is the pliomerid genus *Placoparia* Hawle & Corda, 1847, recorded from four localities in the Alpartir Member (2, 3, 6 and 8) through an incomplete and poorly preserved material that is not illustrated here. Gutiérrez-Marco *et al*. (2022) demonstrated that the either non-preservational or monophyletic character of the current subgenera of *Placoparia* were doubtful, so the only species recognized in our study is adscribed to *Placoparia tournemini* (Rouault, 1847). Kolb (1978, pl. 1, fig. 7) illustrates from locality 3 an external mould of a cranidium which was identified by W. Hammann as *Placoparia cambriensis* Hicks, 1875, an older late Arenigian to early Oretanian species. However, as it was indicated in the biostratigraphic section (see above), the preserved characters on this single tiny cranidium are unable to ensure specific identification. New material collected by us at the locality have been tentatively identified as *Placoparia* cf. *tournemini*.

Liñán *et al*. (1996, fig. 10) note the occurrence of *Placoparia borni* Hammann, 1971 in the uppermost beds of the Castillejo Formation, dated as latest Llandeilo age. However, *Placoparia* has not been recognized in this stratigraphic position in any of the studied sections, and there is no reference to the species or to the locality in any of the articles cited by Liñán *et al*. (1996) as the source of data for the Aragonese Branch.

Asaphid trilobites

The trilobite order Asaphida Salter, 1864 is represented in the study area by four species belonging to two superfamilies and three families. The most abundant and widespread taxa correspond to two species of typical asaphids (superfamily Asaphoidea Burmeister, 1843; family Asaphidae Burmeister, 1843), belonging to the subfamily Birmanitinae Kobayashi, 1960 (= Nobiliasaphinae Balashova, 1971, according to Fortey *et al*., 2022). These are *Nobiliasaphus* aff. *nobilis* (Barrande, 1846) and *Isabelinia glabrata* (Salter, 1853), which usually are recorded as articulated and sometimes complete specimens (Figs. 8C–8K, 9A–9K). The two species occur associated in localities 6, 7 and 8 of the lower Dobrotivian *P. tournemini* Biozone. However, in locality 3 *N.* aff. *nobilis* was recorded alone, and was also figured by Kolb (1978, pl. 2, figs. 13–14 –two articulated cephalothorax). From locality 7, another unpublished illustration was presented by Keller (1981, pl. 7, fig. 9 –pygidium). As regards *I. glabrata*, some material of the species was illustrated by Kistner (1981, pl. 1, fig. 4 –complete specimen from locality 3), Keller (1981, pl. 7, figs. 7 and 10 –pygidia from locality 7), and Zamora *et al*. (2019, fig. 8A – complete specimen from locality 7). Gaubatz (1981, pl. 4, fig. 28) added a putative pygidium of *I. glabrata* from the locality HERR-II of Gutiérrez-Marco (1986), but the pygidial rachis is narrower and longer than that of the species, and its higher number of pleural ribs leads us to tentatively identify it as *Nobiliasaphus* sp.

The material assigned to the genus *Nobiliasaphus* Přibyl & Vaněk, 1965, from localities 3, 6, 7 and 8, is identical to the specimens described as *N. nobilis* (Barrande, 1846) from upper Oretanian and Dobrotivian strata of the Central Iberian Zone (Rábano, 1989c; Guy & Lebrun, 2010). The species was also recorded from rocks of the same interval in the Cantabrian and West Asturian-Leonese zones (Gutiérrez-Marco *et al*., 1999; Gutiérrez-Marco & Bernárdez, 2003), as well as in the Armorican Massif (Lebrun *et al*., 2010b –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but see Courville *et al*., 2016). However, the affinities of these widespread Middle Ordovician records in comparison with the much younger Bohemian species, was questioned by Hammann and Leone (1997). They appreciate clear differences in terms of size (being the Ibero-Armorican form much smaller) and, above all, in the segmentation and ornamentation of the pygidium. Specifically, these authors point out a slightly lower number of axial rings and pleural ribs in the Spanish specimens illustrated by Rábano (1989c), as well as "a much weaker middle ridge and a higher number of finer anterolateral wrinkles" in the median backwards kink of the axial rings (Hammann & Leone, 1997, p. 53), being also different from other Middle Ordovician species such as *N. pamiricus* (Balashova, 1966), *N. repulsus* (Přibyl & Vaněk, 1968), *N. pulverigenus* Kříž & Pek, 1972, *N.*? *powysensis* Hughes, 1979 or *N. hammanni* Rábano, 1989c. Additionally, all these species are much older than the type material of *N. nobilis* occurring in the upper middle Berounian (*ca.* lower Katian) of Bohemia, and also show differences with apparently similar records of the species from Berounian strata occurring in Iberia, Sardinia and Turkey (Hammann & Leone, 1997, and references therein). Differences in age with the Bohemian species were considered important by Courville *et al*. (2016) in casting doubt on the affiliation of Middle Ordovician records from Britain to *N. nobilis*, but the deformed material illustrated in the same paper prevents any type of precise morphological consideration. In our opinion, it seems clear that the abundant material assigned to *N. nobilis* in the Middle Ordovician of Ibero-Armorica differs, at least in several pygidial characters such as the number of axial rings and pleural ribs, and a weaker ornamentation, from the species defined in the middle Berounian of Bohemia. That is why we have identified our specimens in open nomenclature. The revision of the Ibero-Armorican species is postponed, however, to the ongoing study of a large collection of well preserved Central Iberian material, in order to avoid introducing errors related to preservational characters, as it happened with some of the claimed differences shown by *N. repulsus* regarding *N. nobilis* (see, for instance, Kříž & Pek, 1974).

The type species of the genus *Isabelinia* Rábano, 1989c, *I. glabrata* (Salter, 1853), was recorded in the localities 6, 7 and 8 (Figs. 9A–9I, 9K), as well as in the Alpartir Member of the section that culminates in the fossil locality 1 (Fig. 9J). It is a species that reaches a wide distribution in the Dobrotivian of Ibero-Armorica, but seems to be present in older (Oretanian) rocks from Saxo-Thuringia (Heuse *et al*., 2010, fig. 6.2; Fatka *et al*., in press) and the Moroccan Anti-Atlas (JCG-M, unpublished data). The material from the Eastern Iberian Range agrees in all its characters with the specimens described in the Central Iberian Zone (Rábano, 1989c, with earlier references; Guy & Lebrun, 2010), as well as those illustrated in the Cantabrian and West Asturian-Leonese zones (Gutiérrez-Marco *et al*., 1996, 1999; Gutiérrez-Marco & Bernárdez, 2003; Bernárdez *et al*., 2022), the Western Iberian Range (Romero & Gutiérrez-Marco, 2021), and the Armorican Massif (Lebrun *et al*., 2010a, 2010b; Courville *et al*., 2016, with earlier references).

Superfamily Cyclopygoidea Raymond, 1925 is represented in our collection by two taxa which are included in the families Nileidae Angelin, 1854 and Panderiidae Bruton, 1968, although it has been discussed whether the latter would be included in the order Asaphida or Corynexochida (see above).

The first occurrence of the nileid trilobite genus *Parabarrandia* Prantl & Přibyl, 1949 in the Iberian Range was mentioned by Gutiérrez-Marco (1986), and later reproduced by Liñán *et al*. (1996, fig. 10). To this initial record of a poorly-preserved specimen of *Parabarrandia* sp., we add here two complete specimens (Fig. 10), which allow full identification of the species *P. crassa* (Barrande, 1872).

Parabarrandia is an extremely rare trilobite in the Middle Ordovician of France, Spain, and Portugal, recorded by less than forty specimens combined from public and private collections. Until now, all its occurrences were restricted to Dobrotivian strata of the Iberian Massif (Central Iberian and Cantabrian zones: Rábano, 1989c with earlier references; Lomas Martín, 2018; Guy & Lebrun, 2010) and the Central-Armorican domain (Gendry in Courville et al., 2016, with earlier references). All known complete specimens from Ibero-Armorica have been related to the Czech Dobrotivian species *P. crassa*, which is the only representative in the genus that has genal spines. The same applies to the material from the Iberian Range consisting of a prone specimen, preserving one of the genal spines

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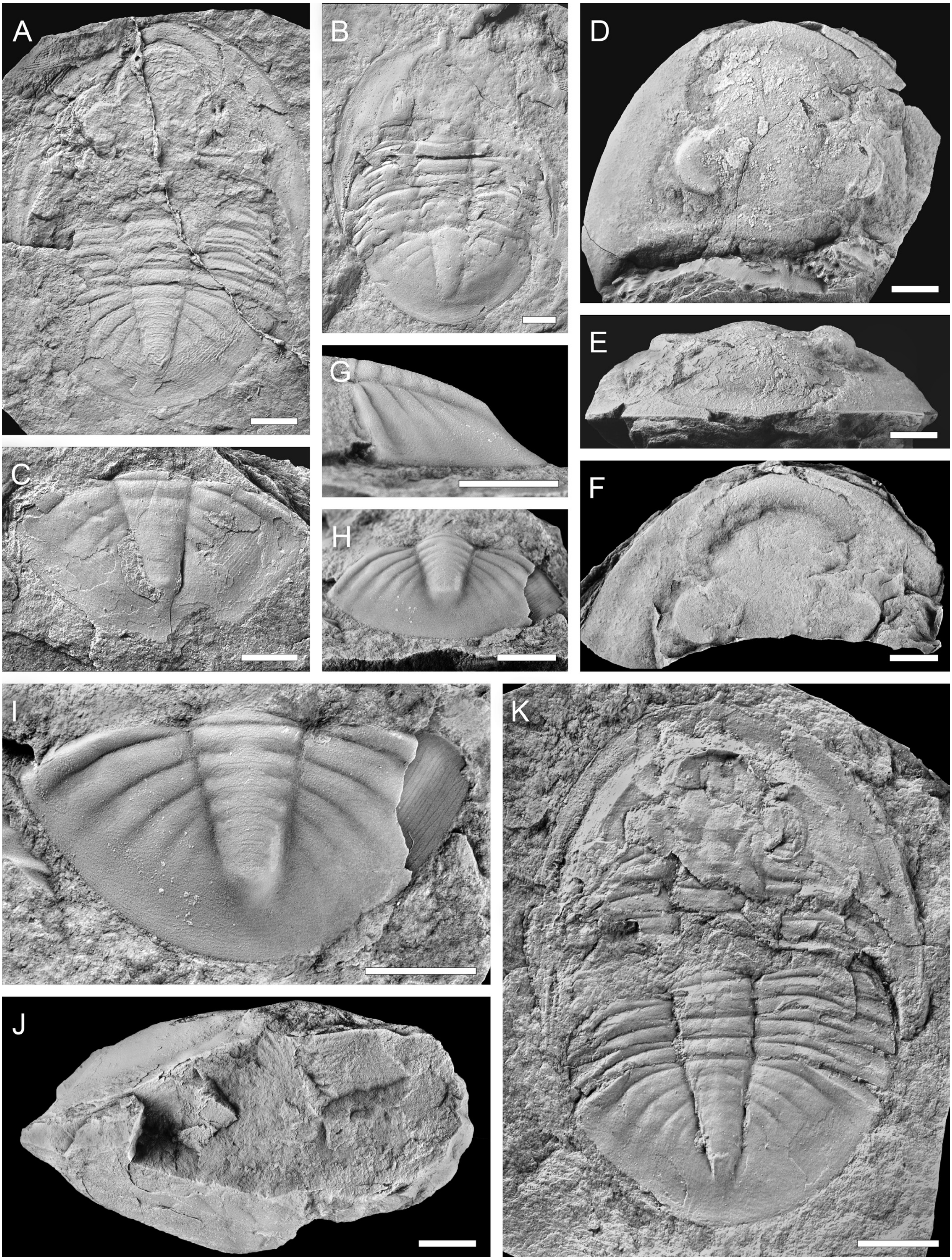
Figure 8. Cheirurine (**A**–**B**) and asaphid (**C**–**K**) trilobites from the Castillejo Formation, collected in the fossil localities 3 (**C**–**D**, **G**, **K**), 6 (**E**, **I**), 7 (**F**, **J**), 8 (**A**–**B**), and 9 (**H**). **A**–**B,** *Eccoptochile almadenensis* (Romano, 1980), MPZ 2023/57, complete specimen in dorsal view (**A**) with detail of pygidium (**B**), previously illustrated by Zamora *et al*. (2019, fig. 8B); **C**–**K,** *Nobiliasaphus* aff. *nobilis* (Barrande, 1846) *s.l.*; **C,** MPZ 2023/58, latex cast of incomplete pygidium with the last thoracic segment; **D,** MPZ 2023/59, pygidial fragment with detail of the chevron-like medial backward deflections of the ring furrows of the pygidial axis; **E,** MPZ 2023/60, latex cast of pygidium showing details of the external ornamentation; **F,** MPZ 2023/61, internal mould of incomplete pygidium in dorsal view; **G,** MPZ 2023/62, latex cast of incomplete, compressed pygidium, ornamentation of lower lamella being recognizable; **H,** MPZ 2023/63, compressed pygidium, ornamentation of the lower lamella traced through; **I,** MPZ 2023/64, incomplete cephalon + thorax showing ornamentation on rachis; **J,** MPZ 2023/65, latex cast of complete specimen; **K,** MPZ 2023/66, internal mould of a young complete specimen; scale bars = 5 mm, except figure I (= 10 mm).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(Fig. 10A), and another enrolled exoskeleton showing a complete unrolled spiral enrollment (in terminology of Bergström, 1973). Both specimens come from locality 6 in the upper part of the Alpartir Member, which provided previous indications of a first poorly-preserved specimen (Gutiérrez-Marco, 1986, p. 80). This means that we can consider *Parabarrandia* as relatively "abundant" in this locality and horizon, being the second place in abundance after the CC-I locality at the Fresneda reservoir in the southern Central Iberian Zone, with about ten specimens recorded after 35 years of intensive collecting, which were partly illustrated by Rábano (1989c) and Lomas Martín (2018). Also, for comparative purposes, Guy and Lebrun (2010, p. 49) mention the discovery of only three complete specimens of *P. crassa*, after 30 years of exploitation, in just a single of the rich Dobrotivian trilobite localities from the Valongo Formation of northern Portugal.

In addition to the genal spines, *P. crassa* can be recognized (in undeformed specimens) by its broad and moderately parabolic glabella, the slightly convex, arcuated rostral plate and a smooth, almost semicircular pygidium shorter (sag.) than the cephalon. The anterior edge of the cephalon shows a peripheral groove that Rábano (1989c) interpreted as a coaptative structure for the enrollment, but, which in the first known enrolled specimen of the species does not serve for this purpose. On the one hand, it can be seen (Fig. 10F–10G) that the posterior edge of the pygidium fits with the posterior margin of the rostral plate and, on the other, the own convexity of the rostral plate and the low number of thoracic segments (8) would make a telescoping coiling of the thorax unfeasible for the pygidium to reach the cephalic groove.

From a chronostratigraphic point of view, *Parabarrandia crassa* is recorded from Dobrotivian strata in Bohemia and southwestern Europe, but its first occurrence seems to be in the upper Oretanian rocks (Taddrist Formation) of the central Moroccan Anti-Atlas (Battou locality: Rábano *et al*., 2014, p. 367; Lebrun, 2018, p. 118).

To finish with this brief taxonomic report, trilobites of the family Panderiidae are relatively rare in the Middle Ordovician of Ibero-Armorica, where the single species "*Panderia*" *beaumonti* (Rouault, 1847) have been described and illustrated from a number of Dobrotivian to middle Berounian localities of the Armorican Massif (Courville *et al*., 2016 with earlier references), the Central Iberian Zone (Rábano, 1989e and references therein; Guy & Lebrun, 2010; Pereira *et al*., 2014; Lomas Martín, 2018) and a few places in the Aragoncillo Inlier of the Western Iberian Range (Romero & Gutiérrez-Marco, 2021). "*Panderia*" *beaumonti* is also represented by a single specimen in our collection (Fig. 4H), to which can be added the one cited by Kistner (1981, p. 25) that comes from the same lower Dobrotivian locality and horizon (No. 8). It is the only place in the Eastern Iberian Range where the species has been identified so far. The studied specimen (Fig. 4H) looks like an illaenimorph trilobite but is slightly micropygus, has eight thoracic segments with a broad rachis –the first of which practically hidden below the cephalon–, and a cephalon with a broad axis and large semilunate eyes very close to the axial furrows, being identifiable as the above mentioned panderiid. A more complete description of the species has been provided by Rábano (1989e), Pereira *et al*. (2014) and Pereira (2017). In the two cited papers, as well in all the Armorican references, "*P.*" *beaumonti* is considered as a giant representative of the essentially Baltic genus *Panderia* Volborth, 1863 (see Henry, 1989), but Pereira *et al*. (2016) reassigned the species to a new genus allied to Hemibarrandiidae Courtessole & Pillet, 1975, which are a low-diversity group of effaced trilobites restricted to the high-latitude South Gondwana region. To this regard, Pereira (2017) considers "*P.*" *beaumonti* as the type species of her new genus "*Armoricania*", a provisional *nomen nudum* which cannot be used until the taxonomic relief becomes effective with its publication under the rules of the International Code of Zoological Nomenclature.

CORRELATION

Trilobites and other benthic groups are rare fossils in the lower part of the Alpartir Member, being absent in the Marité Member. The widespread development of graptolite facies in this part of the succession, even with mesopelagic forms like *Pterograptus*, suggests that the predominance of relatively deep environments did not bring favourable conditions for the development of the *Neseuretus* fauna. The early record of *Placoparia* cf. *tournemini* in beds correlated here with the lower part of the *Didymograptus murchisoni* graptolite Biozone, is approximately equivalent to the earlier occurrence of this species in the Cantabrian and West Asturian-leonese zones (Gutiérrez-Marco *et al*., 1996, 1999; Gutiérrez-Marco & Bernárdez, 2003; Bernárdez *et al*., 2022). The Aragonian locality 5 is thus, close to the record of

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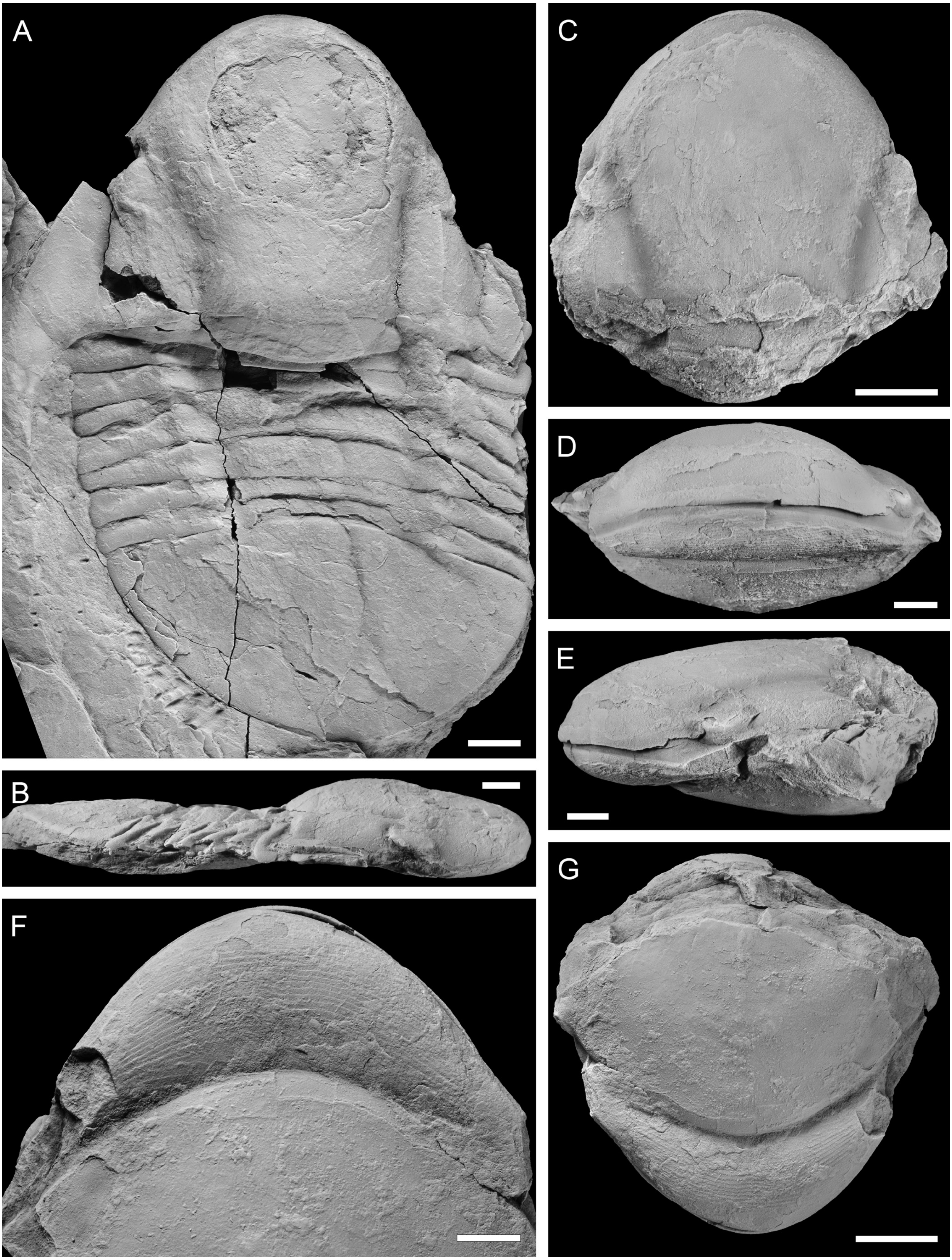
Figure 9. *Isabelinia glabrata* (Salter, 1853), an asaphid trilobite collected in the fossil localities 6 (**D**–**I**), 7 (**C**, **K**) and 8 (**A**–**B**) of the the Castillejo Formation; specimen **J** comes from the Alpartir member west of locality 1; **A,** MPZ 2023/67, latex cast of the external mould of complete specimen, showing pygidial ornamentation; **B,** MPZ 2023/68, internal mould of complete specimen previously illustrated by Zamora *et al.* (2019, fig. 8A); **C,** MPZ 2023/69, internal mould of pygidium in dorsal view; **D**–**F,** MPZ 2023/70, natural siliceous cast of cephalon in dorsal (**D**) and front (**E**) views, and latex cast of same (**F**); **G**–**I,** MPZ 2023/71, external mould of pygidium with the doublure partially exposed in left lateral (**G**), oblique-posterior (**H**) and dorsal (**I**) views; **J,** MPZ 2023/72, enrolled specimen in left lateral view, cephalon up; **K,** MPZ 2023/73, latex cast of the external mould of complete specimen; scale bars = 5 mm.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P. tournemini in the Vega de Espinareda synclinorium of the West Asturian-leonese Zone, where this trilobite occurs associated with *N. tristani*, *D. murchisoni* and *Pterograptus* (Gutiérrez-Marco *et al*., 1999). This contrasts with the Central Iberian Zone, where the base of the *P. tournemini* Biozone is clearly younger and coincides with the beginning of the lower Dobrotivian (Gutiérrez-Marco *et al*., 1984; Rábano, 1989b).

Higher up in the succession, the trilobite assemblage of the *P. tournemini* Biozone recorded from the middle and upper part of the Alpartir Member is entirely correlatable with the classical development of the lower and middle? part of this biozone in the entire Ibero-Armorican area. And more precisely, with the range of the *Zeliszkella toledana-Eodalmanitina macrophtalma*, plus the *Morgatia primitiva* sub-biozones, being only recorded here *E.* cf. *macropthalma* among these naming taxa. This interval can be parallelized as a whole with the *Heterorthina morgatensis* brachiopod Biozone (Villas, 1985), in the reviewed sense by Reyes-Abril *et al*. (2011). Their frequent association with the graptolites *Gymnograptus linnarssoni* or *Hustedograptus teretiusculus* is also a key to assign these beds to the lower Dobrotivian. However, there are several facts to be considered when we correlate the development of the lower to ?middle *P. tournemini* Biozone in the Eastern Iberian Range, by comparison to the Central Iberian Zone and the Armorican Massif.

The main difference is the relative low diversity and abundance of the trilobite, mollusc, and brachiopod assemblages in the studied area. Among the trilobites, some relevant groups reached a marginal importance, such as the meager representation of cheirurines and phacopines (less than 25 specimens in total, adding those collected in seven localities). And also, the calymenines, practically only recorded by a significant material in the localities 6, 8 and 9. In the localities 3, 6, 7 and 8, only the asaphids maintain some relevance. This scarcity of trilobites in the lower Dobrotivian localities may be explained by the persistence of desfavourable environmental conditions for the regional development of the “Dalmanitacean–Calymenacean” fauna typical of the Gondwanan shelf (Cocks & Fortey, 1990), notably the inshore *Neseuretus* fauna (Fortey & Owens, 1987). The record of mesopelagic graptolites at the beginning of the sedimentation of the Alpartir Member correlates with places in the Navia-Alto Sil domain of the West Asturian-Leonese Zone (Gutiérrez-Marco *et al*., 2002). Even though this increase in depth could have been a limiting factor for the development of the *Neseuretus* fauna, other trilobite communities, common in deeper environments, such as nileids, raphiophorids and cyclopygids, did not abruptly develop here. The influence of a greater depth is perhaps only materialized by the higher frequency of asaphids and notably by the earlier occurrence and relative abundance of the nileid *Parabarrandia*. This genus was considered a mesopelagic trilobite by Fortey (1985) and is more abundant here than at any other fossil locality from the Dobrotivian of southwestern Europe (see above). A second nileid trilobite, “*Panderia*” *beaumonti*, is recorded from the locality 8 earlier than its common range in Ibero-Armorica, which extends from the upper lower Dobrotivian (*Morgatia hupei* trilobite sub-Biozone) to middle Berounian beds.

Unlike the Tristani Beds of Central Iberia, a great part of the 110–200 m of shales forming the Alpartir Member are almost completely devoid of fossils, trace fossils or even the simplest sign of bioturbation. This implies that, similarly to the thick succession (*ca.* 1,000 m) of the Luarca shale accumulated in the subsiding trough of the Navia-Alto Sil, it is probable that here, in its prolongation to the Eastern Iberian Range, the relative higher depths were combined with a phenomenon of stratification of seawater, with the lower layer fluctuating between anoxic to disaerobic during long intervals of time. This occurs in a palaeogeographic setting far from upwelling currents or other factors favouring the organic productivity in the surface or in intermediate layers of the water column.

Temporal alteration of this scenario by climatic disturbance or tectonic activity could induce discrete episodes of aireation of the seabed, leading to the development of incipient epibenthic communities of trilobites and brachiopods, with numerically common asaphids.

The overlying sandy alternances of the Sierra Member (up to 150 m thick) show a scarce trilobite record, generally restricted to transported elements occurring in sandstone lenses with a calcareous cement. All of them belong to the *Heterorthina kerfornei* brachiopod Biozone of Villas (1985), equivalent to the *H. kerfornei*–*Aegiromena mariana* Biozone of the Central Iberian Zone (Reyes-Abril *et al*., 2011), which range from the uppermost lower to upper Dobrotivian.

Of the three localities with trilobites studied in the Sierra Member, the oldest (No. 11, west of El Poyo del Cid) is located in its lower part and bears, among others, poorly preserved specimens of *Morgatia* sp. As it has already been said, the stratigraphic range of this genus extends from the upper Oretanian to the top of the lower Dobrotivian, where it nominates the *Morgatia hupei* sub-Biozone in the upper part of the *P. tournemini* Biozone. However, its occurrence here could correspond to an

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Figure 10. *Parabarrandia crassa* (Barrande, 1872) a nileid trilobite from the Castillejo Formation recorded in locality 6; **A**–**B,** MPZ 2023/74, internal mould of nearly complete specimen in dorsal (**A**) and right lateral (**B**) views; **C**–**G,** MPZ 2023/75, internal mould of an enrolled specimen in dorsal view showing the cephalon (**A**), anterior (**B**) and left lateral (**C**) views of the same, and its reverse side (**D**) showing the pygidium and the rostral plate, with additional detail of the latter (**G**); scale bars = 5 mm, except for figure C (= 10 mm).

unknown species from SW Europe occurring in more modern horizons, since the same locality has provided (on various loose stones) *Oepikograptus bekkeri* (Öpik, 1927) (= *Glyptograptus raineri* of Gutiérrez-Marco, 1986, a *nomen nudum*), a graptolite indicative of the lower Sandbian *Nemagraptus gracilis* graptolite Zone. This possible late record of *Morgatia*, if confirmed, could be equated with its purported occurrence in the Izegguirene Formation of the Moroccan Anti-Atlas (Gutiérrez-Marco *et al*., 2003 and references therein).

The two remaining localities (1 and 4 in Fig. 1A) are situated in the upper third of the Sierra Member and yield a very particular association of trilobites adapted to life on sandy bottoms, which includes the species *Crozonaspis incerta*, *C. armata*, *Neseuretus henkei*, plus a rare specimen of *Eohomalonotus* cf. *sdzuyi*. These four taxa usually belong to the "homalonotid biofacies" developed in shallower and more proximal environments in the peri-Gondwanan platform of SW Europe (Hammann & Henry, 1978; Hammann, 1983; Rábano, 1989b; Henry, 1989) and North Africa (Henry & Destombes, 1991). Henry (1980a) adscribes the assemblage to the "*Crozonaspis incerta* Biozone", lacking precise biochronological equivalence due to its primary dependence on sedimentary facies. However, our locality 4 has been assigned to the upper Dobrotivian by means of conodonts (Sarmiento *et al*., 1995), and this coincides with the first discovery of graptolites (*Oepikograptus bekkeri*) in the "*C. incerta* Biozone" south of Almadén, Ciudad Real (JCG-M, unpublished data).

In the Eastern Iberian Range, trilobites from Dobrotivian strata were identified in a number of inliers (Herranz Araújo *et al*., 2003), with the noteworthy record of a diversified assemblage of the *P. borni* Biozone near the top of the Villar del Salz Formation (Romero & Gutiérrez-Marco, 2021) as well as a single homalonotid occurrence (genus *Eohomalonotus*) in the San Marcos Formation.

The present biostratigraphic scheme based on trilobites follows the one used in the Iberian Peninsula and locally in the Armorican Massif (Gutiérrez-Marco *et al*., 2002, 2017 and previous references), being correlatable with the Bohemo-Iberian regional chronostratigraphic scale (Gutiérrez-Marco *et al*., 2015, 2017). However, Courville (2016) has recently proposed the replacement of Henry's (1980a) biostratigraphic scheme, by a series of "faunal" (= trilobite) assemblages (numbered from 1 to 7) recognized in the French Armorican Massif, which would be directly correlated with the global Ordovician scale by means of the chitinozoan biozones for "North" Gondwana (Paris, 1990, 2016). This approach involves hypothethical – and changing! – correlations between the chitinozoan regional biozonation and the global stages and stage slices of Bergström *et al*. (2009), as well as the problematic dating of some biozones with a significant trilobite record, as for instance, the *Linochitina pissotensis* Zone, already indicated by Gutiérrez-Marco *et al*. (2017, p. 286). According to the trilobite assemblages of Courville (2016), the trilobite record from the Alpartir Member could be equivalent in range to its "Faunes" 2 to 4, but its definінition particularities are excessively local with reference to certain Central Armorican sites, and that prevents their detailed comparison with the trilobite associations studied by us. This new Armorican classification also obviates the main conclusions on trilobite biochronology reached by Henry and Clarkson (1975) and Henry (1980a), which were proven to be valid for the entire southwestern Europe, and serve as an important basis for the present trilobite biozonation.

From a stratigraphic point of view, we have already said that the Castillejo Formation begins with a stratigraphic gap, at least equivalent to the early Oretanian, recognized in its basal contact with the Armorican Quartzite. This gap is quite similar to the one detected in part of the Cantabrian Zone, where the Middle Ordovician shales were essentially deposited during the late Oretanian and Dobrotivian, allowing the direct comparison between the Alpartir Member and the Sueve Formation in chronostratigraphic terms. This could agree with the partial correlation of the Palaeozoic of the Eastern Iberian Range with that of the Cantabrian Zone, as suggested by Gozalo and Liñán (1988) for the outcrops of the Herrera Unit, which include our fossiliferous sections 1 to 10, located to the east of the Jarque Fault and the Datos Thrust (= Nigüella-Monforte Thrust according to Casas *et al*., 2016). This proposal is based on the relevance of these Variscan tectonic structures and on the supposed correlation of the Paracuellos and Narcea Precambrian antiforms that, together with the Nalón Thrust associated with the latter, serve as a separation between the Cantabrian and West Asturian-leonese zones.

However, both section 11 and the Berrueco-I locality of Gutiérrez-Marco (1986), theoretically located in the prolongation of the West Asturian-leonese Zone following the model of Gozalo and Liñán (1988), show a stratigraphic development of the Castillejo Formation entirely comparable to that of the Herrera Unit, despite being located in the Western Iberian Chain. Another puzzling point is the record of the mesopelagic graptolites at locality 5 west of Fombuena, which is only correlated with the Alto Sil domain of the West Asturian-leonese Zone instead of the Cantabrian Zone. But if the correlation with the West Asturian-leonese Zone is accepted, then the problem is that the higher fossiliferous horizons known in the Luarca Formation *s. s.* do not postdate the lowermost Dobrotivian, while the Castillejo Formation mainly comprises Dobrotivian strata.

In view of these discrepancies, it seems interesting to try another tentative correlation, exploring the link that the Palaeozoic basement of the Iberian Range can offer with the southern Central Iberian Zone through the so-called Central Iberian Arch (Martínez Catalán, 2012). This structure would be part of an S-shaped Iberian Variscan orocline and its existence has been previously suspected by some authors (*i.e.,* Llopis Lladó, 1966; Martínez Catalán *et al*., 2015, and references therein). The link between the Iberian Range and the Central Iberian Zone through the isoclinal curvature model proposed by the Central Iberian Arch, as envisaged by Shaw *et al*. (2012), would imply the direct physical continuity of the Ordovician platform between both regions. However, given the distance between them, it is easy to conceive the possible existence of lateral variations of environmental, sedimentary, and biogeographic type, which broadened or limited the correlation between different trilobite assemblages along the same shelf during pre-Variscan times. The situation of the Iberian Range itself, halfway between the axial traces of the Cantabrian and Central Iberian oroclines (Weil *et al*., 2012; Martínez Catalán *et al*., 2021 –but see Pastor-Galán *et al*., 2020 and Casas *et al*., 2022), allow to understand the palaeogeographic relations and the similarities and differences among each of the aforementioned regions.

CONCLUSIONS

A preliminary palaeontological and biostratigraphic study of Middle Ordovician trilobite localities from the Castillejo Formation of the Eastern –or Aragonian-Iberian Range is presented. Most of the fossil sites studied here are located in the Herrera Unit (Eastern Iberian Chain) and belong to the late Oretanian–early Dobrotivian *Placoparia tournemini* Biozone (*ca.* late Darriwilian of the global scale).

A total of 21 different trilobite species were identified. Their detailed description will be the subject for a subsequent paper. The most taxonomically diverse group, but generally with poor individual representation, are the Phacopid trilobites, which include 6 calymenine, 7 phacopine and 2 different cheirurine species. Corynexochids and Lichids are each represented by a single species, and Asaphid trilobites include two common species in several localities, plus two others (*Parabarrandia crassa* and "*Panderia*" *beaumonti*) that are cited for the first time in the Eastern Iberian Range. In the upper part of the Castillejo Formation, the incipient development of a trilobite biofacies adapted to sandy bottoms is recorded, represented by the species *Crozonaspis incerta*, *C. armata*, *Neseuretus henkei* and *Eohomalonotus* cf. *szuyi*.

Finally, the biostratigraphic and palaeobiogeographic framework of the trilobite assemblages is discussed by correlation with Ordovician successions of the Cantabrian and West Asturian-leonese zones, considered in all divisions of the Iberian Massif as situated in structural prolongation with the Iberian Range. But for the first time we have pointed out the possibility of establishing a correlation with southern sectors of the Central Iberian Zone, through the still hypothetical Central Iberian orocline, due to the inconsistencies revealed regarding the prolongation of the structural zones of the northwestern part of the Iberian Massif.

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