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The first record of *Dinesus* (Trilobita, Dinesidae) in the Cambrian of the Mediterranean region

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An important problem facing inter-regional correlation in the Cambrian is the scarcity of shared taxa between different palaeogeographic domains. Currently, species of the Corynexochida are proposed as tools to define the base of Cambrian Series 3. However, few Mediterranean Corynexochida species are known. A specimen of *Dinesus truyolsi* comb. nov. from the middle Cambrian of Spain represents the first record of this genus in the Acadobaltic province. *Erbia* and *Tingyuania* are accepted as junior subjective synonyms of *Dinesus*, and we now recognize 22 species within this genus. *Dinesus* has been found previously in lower to middle Cambrian strata of Australia, Russia, Kazakhstan, North America and China providing the potential for improved global correlation for this interval.

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Key words: *Dinesus*, systematics, correlation, biostratigraphy, middle Cambrian, Mediterranean region, Acadobaltic province.

ONE of the most important problems facing inter-regional correlation in the Cambrian is the lack of shared genera and species between different palaeogeographic provinces; i.e. many of the zonal trilobite species for Cambrian Series 3 (Stage 5 and Drumian Stage) are representatives of the Ptychagnostidae, but this family has not yet been found in the Mediterranean region. Many of the trilobite species in this region are endemic. Correlation between the Mediterranean and other regions must depend on the few and rare taxa that have wide geographic distribution.

Two species currently being considered as potential guides for the base of Cambrian Series 3 are *Oryctocephalus indicus* (Reed, 1910) and *Ovatoryctocara granulata* Tchernysheva, 1962 (see Fletcher 2003, Geyer 2005, Zhao *et al.* 2008); both are within the Corynexochida, and neither is known from the Mediterranean region. Few Corynexochida specimens are known from the Mediterranean, and their diversity is very low. However, some (e.g. *Tonkinella* sp. aff. *T. breviceps*) are useful for correlation (see Gozalo *et al.* 2003). Here we report the first occurrence of the widespread genus *Dinesus* in the Mediterranean area, within the Acadobaltic province *sensu* Sdzuy (1972). Previously, *Dinesus* has been found in Australia, the Siberia Platform, Altai-Sayan Fold Belt (Russia), Alaska, Canada, Kazakhstan and China.

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Regional setting and stratigraphy

The species described here was collected in the Ateca-2 section of the Mansilla Formation (Leonian regional Stage, middle

Cambrian; Stage 5 of Cambrian Series 3) of the Badules unit in the Ateca area of the western Cadena Ibérica (asterisk, Fig. 1A, B). The Mansilla Formation (*sensu* Liñán *et al*. 1992, 2002) is 10–90 m thick and composed of alternating brown dolostones and limestones, and purple and violet shales containing trilobites, brachiopods, sponges, algae, hyoliths, monoplacophorans and ichnofossils. Trilobites have been found only in the upper part, and their assemblages belong to the *Eccaparadoxides asturianus* Zone (late Leonian Stage) and the *Badulesia tenera* Zone (early Caesaraugustan Stage; see Sdzuy *et al*. 1999).

The Ateca-2 section (Fig. 1C) is located 6 km north of Ateca village (Zaragoza province), at a site named 'La Veguilla'. The section, which includes parts of the Mansilla and Murero formations, has been studied by Álvaro Blasco (1994).

Trilobite assemblage

Based on the data presented by Chirivella Martorell (2008), the trilobite assemblage of the *Eccaparadoxides asturianus* Zone in the Mansilla Formation in the Ateca area is composed of *Eccaparadoxides asturianus* (Sdzuy, 1968), *Eccaparadoxides sdzuyi* Liñán Guijarro, 1978, *Cainatops schirmi* (Sdzuy & Liñán, 1996), *Parabailiella* sp., *Holocephalina? leve* Gozalo & Liñán, 1996, *Parasolenopleura ouangondiana* (Hartt in Dawson, 1868), *Asturiaspis inopinatus* Sdzuy, 1968, *Peronopsis acadica* (Hartt in Dawson, 1868), *Peronopsella pokrovskajae* Sdzuy, 1968 and *Dinesus truyolsi* (Liñán & Gozalo, 2001). This assemblage is recorded just below the FAD of *Badulesia tenera* (Hartt in Dawson, 1868), which marks the beginning of the Caesaraugustian Stage. Sdzuy *et al*. (1999) and Gozalo *et al*. (2003, 2007) have provided correlation charts for this interval.

Systematic palaeontology

Order CORYNEXOCHIDA Kobayashi, 1935

Suborder CORYNEXOCHINA Kobayashi, 1935

Family DINESIDAE Lermontova, 1940

Dinesus Etheridge, 1896

Type species. *Dinesus ida* Etheridge, 1896, p. 56, pl. 1, figs 1–4 only.

Comments. For many years, *Dinesus* had been considered a monotypic genus containing only *D. ida* (see Palmer 1968, p. B60). However, Palmer (1968) proposed to include *Erbia granulosa* Lermontova, 1940 and the new species *D. arcticus* in *Dinesus*; he commented that the relationships between *Dinesus* and *Erbia* are very close. Subsequently, Repina & Romanenko (1978, p. 226) considered *Erbia* Lermontova, 1940 and *Paratollaspis* Kobayashi, 1943 as junior synonyms of *Dinesus*. Recently, Zhu *et al*. (2005, p. 560) also considered the Chinese genus *Tingyuania* Sun & Chang in Chang, 1937 as a junior synonym of *Dinesus*. Finally, Lin (2008, p. 58) reassessed all Chinese species previously classifed as *Erbia* and *Tingyuania* and included all of them in *Dinesus*. We also agree that *Erbia, Paratollaspis* and *Tingyuania* are junior subjective synonyms of *Dinesus*.

However, we consider that *Tingyuania granulosa* Sun & Chang in Chang, 1937 does not belong in *Dinesus*. The diagnosis proposed by Sun & Chang in Chang (1937, p. 38) for this species states: '*Tingyuania* with very broad convex frontal limb, . . .', a character that is clearly identifiable in the figures of this species by Lu *et al*. (1965, pl. 19, figs 12–13). This character makes the species quite different from others included in *Dinesus* where the preglabellar field is absent or is very short (sag.); see the emended diagnosis of *Dinesus* by Palmer (1968, p. B60).

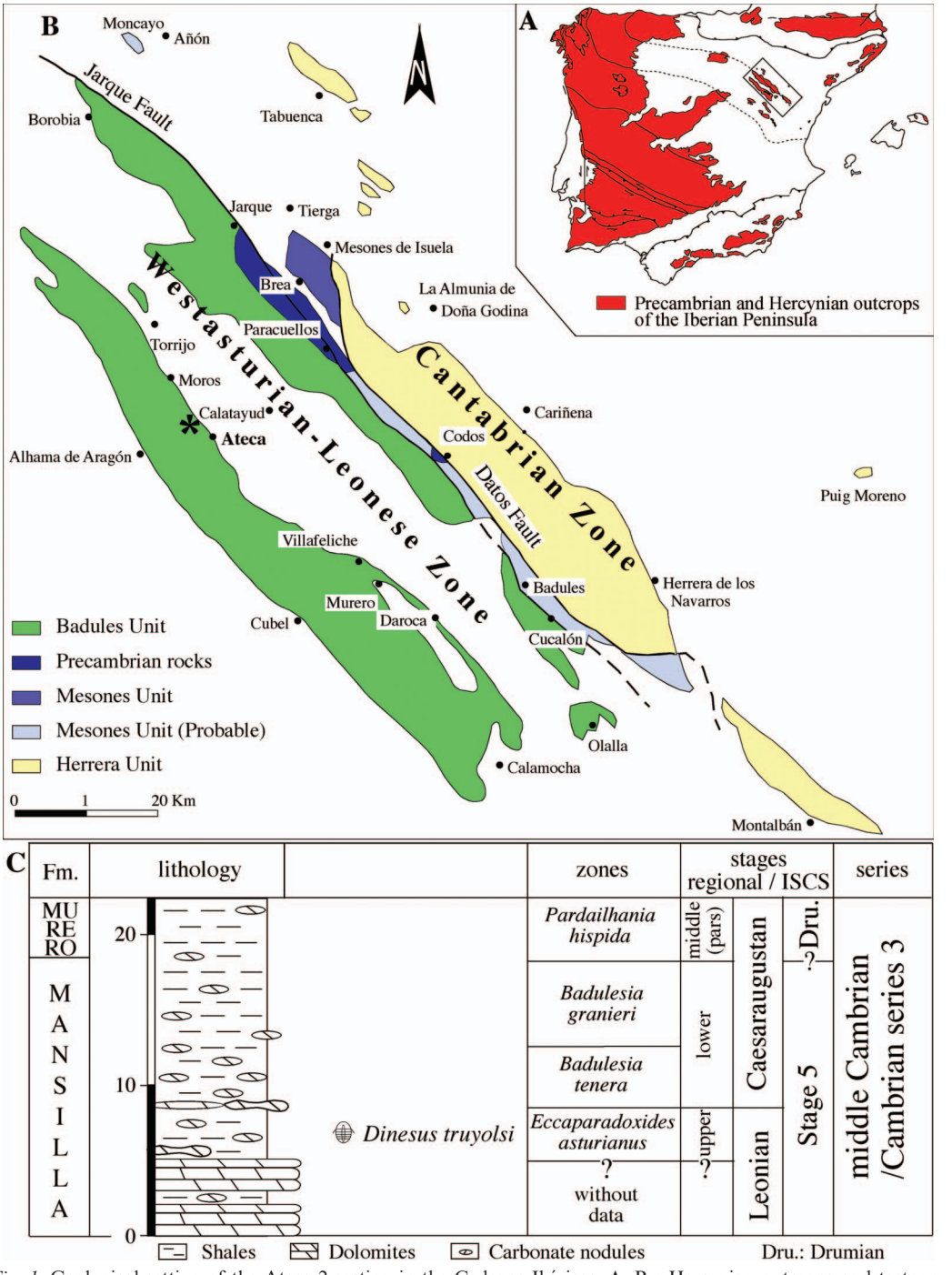

Fig. 1. Geological setting of the Ateca-2 section in the Cadenas Ibéricas. **A**, Pre-Hercynian outcrops and tectono-stratigraphic zones of the Iberian Peninsula; the Cadenas Ibéricas are framed. **B**, Pre-Hercynian outcrops and tectono-stratigraphic zones and units of the Cadenas Ibéricas; *At2 section (modified from Gozalo & Liñán 1988). **C**, Composite stratigraphic section of the Mansilla Formation in the Ateca region, modified from Álvaro Blasco (1994).

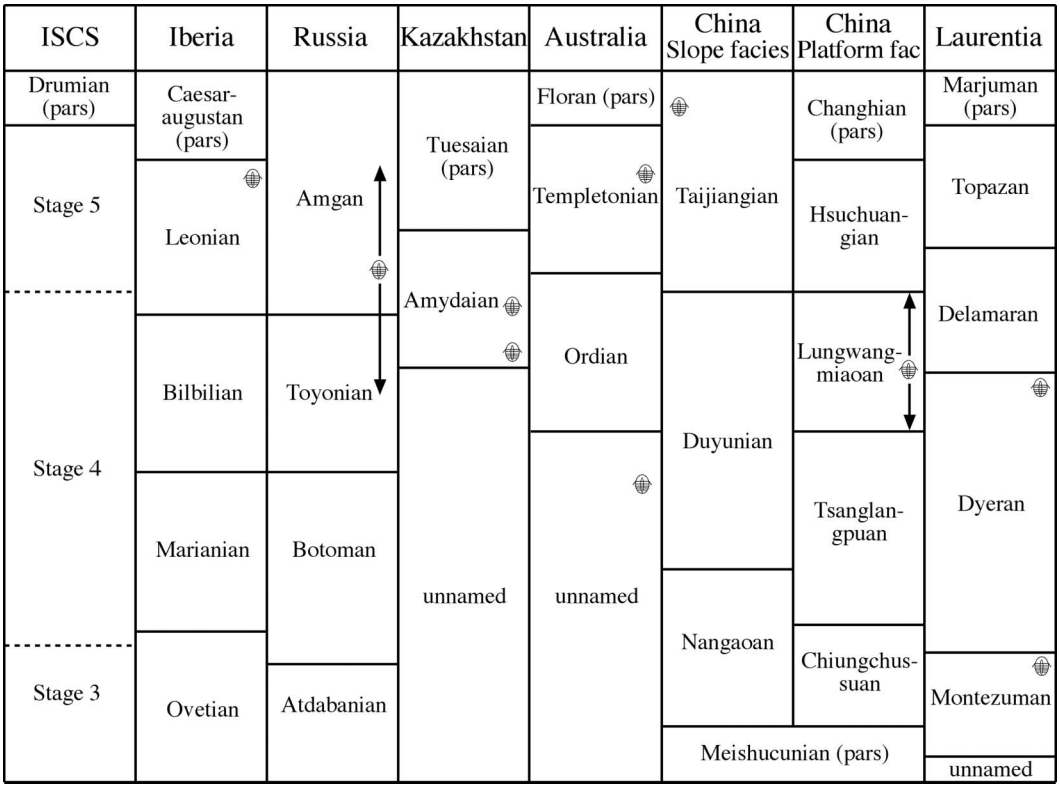

Fig. 2. Correlation chart showing the stratigraphic occurrences of *Dinesus*. The chart is based on Sdzuy *et al.* (1999), Geyer & Shergold (2000), Shergold & Geyer (2003), Babcock *et al.* (2005, 2007), Laurie (2006), Gozalo *et al.* (2007), Liñán *et al.* (2008) and Zhou & Zhen (2008). The scheme for Laurentia reflects the latest modifications by Sundberg & McCollum (2003) and Sundberg (2005).

Species included. *Dinesus ida* Etheridge, 1896; *Cyphasis sibirica* Schmidt, 1886 [type species of *Erbia* Lermontova, 1940, and type species of *Paratollaspis* Kobayashi, 1943]; *Tingyuania typica* Sun & Chang in Chang, 1937 [type species of *Tingyuania* Sun & Chang in Chang, 1937]; *Erbia granulosa* Lermontova, 1940; *Dinesus kirghizensis* Lermontova, 1951; *Erbia granulosa astricta* Suvorova, 1960; *Erbia inflata* Romanenko in Egorova *et al.*, 1960; *Erbia mirabilis* Tomashpolskoya in Egorova *et al.*, 1960; *Erbia arida* Romanenko in Romanenko & Romanenko, 1962; *Dinesus katunica* Romanenko in Romanenko & Romanenko, 1962; *Dinesus arcticus* Palmer, 1968; *Erbia dinesiformis* Tomashpolskoya in Tchernysheva, 1971; *Dinesus* sp. 1 of Fritz (1973); *Dinesus* aff. *granulosus* (Lermontova, 1940) *sensu* Öpik (1975); *Tingyuania granulata* Qiu, 1980; *Tingyuania bura* Qiu, 1980; *Tingyuania ocellata* Qiu, 1980; *Erbia spinellosa* Zhou in Zhou *et al.*, 1982; *Tingyuania latelimbata* Qiu in Qiu *et al.*, 1983 [=*Tingyuania longispina* Lin in Qiu *et al.*, 1983]; *Tingyuania tongshanensis* Lin in Qiu *et al.*, 1983; *Aragotus truyolsi* Liñán & Gozalo, 2001; *Dinesus* cf. *bura* (Qiu, 1980) *sensu* Zhu *et al.* (2005).

Stratigraphic and geographic distribution. *Dinesus* has been recorded widely (Fig. 2): *Pararaia janae* Zone (lower Cambrian) and Ordian–early Templetonian Stage (middle

Cambrian) of Australia (Brock *et al*. 2000, Paterson 2005); *Lermontovia grandis* Zone to *Kounamkites* Zone (upper lower Cambrian and lower middle Cambrian) of the Siberian Platform and Altay-Sayan Fold Belt (Russia), generally as *Erbia* (see Tchernysheva 1971, Savitsky *et al*. 1972, Repina & Romanenko 1978, Egorova *et al*. 1976, Astashkin *et al*. 1991, 1995, Repina *et al*. 1999, Pegel 2000, Varlamov *et al*. 2008, Shabanov *et al*. 2008); Lungwangmioan Stage (upper lower Cambrian) of China (see Lin 2008) and, probably, Taijiangian Stage (middle Cambrian) of China (see Peng 2008); Montezuman and Dyeran stages (lower Cambrian) of Alaska and Canada (Palmer 1968, Fritz 1973); and lower Cambrian of Kazakhstan (Ivshin 1978, Repina *et al*. 1999). The specimen described herein is the first record of the genus from Spain (Mediterranean subprovince) in the Acadobaltic province (*sensu* Sdzuy 1972). It occurs within the *Eccaparadoxides asturianus* Zone (lower middle Cambrian).

Dinesus truyolsi (Liñán & Gozalo, 2001) comb. nov. (Fig. 3)

2001 *Aragotus truyolsi*; Liñán & Gozalo, pp. 273–274, fig. 2f.

Material. Internal mould of cranidium preserved in light beige dolomitic marl. The specimen is housed in the Museo Paleontológico de la Universidad de Zaragoza-Gobierno de Aragón, Spain, number MPZ 97/418.

Description. Cranidium subquadrate. Glabella well defined at sides by deep subparallel axial furrows, moderately convex transversely and longitudinally; front evenly and strongly rounded, reaching nearly to border (Fig. 3). Occipital furrow is badly preserved. Occipital ring moderately wide on axial line, distinctly narrower at distal ends. Axial furrows branched forward adjacent to anterior end of glabella; inner branches outline anterior end of glabella, and are tangential to border furrow on axial line; outer branches moderately divergent forward across inner part of brim to border furrow outlining lateral parts of medium triangular lobes. Frontal area very short, sagittal length less than 10% of sagittal length of glabella, exclusive of occipital ring. Anterior margin slightly concave. Border of nearly constant width and slightly convex. Area between border and anterior end of glabella on axial line concave. Fixed cheek gently convex, horizontal; width about one-half basal glabellar width. Ocular ridge short and narrow. Palpebral lobe of medium size and moderately convex, situated opposite middle third of glabella; length slightly less than sagittal length of glabella exclusive of occipital ring; palpebral furrow well marked. Posterior border furrow deep. Posterior border has distinct angulation on line directly behind palpebral lobe, directed slightly forward lateral to this angulation. External parts of all convex surfaces including palpebral lobes covered with closely spaced coarse granules.

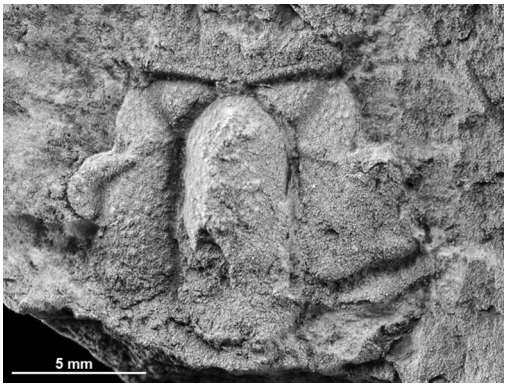

Fig. 3. Dinesus truyolsi (Liñán & Gozalo, 2001) new combination. Holotype, MPZ 97/418, cranidium from Ateca 2 section (Spain).

Comments. Liñán & Gozalo (2001) included this species in *Aragotus* Liñán & Gozalo, 2001. After publication, A. Palmer suggested to the authors that the cranidium

morphology was characteristic of *Dinesus*. In accordance with Palmer's (1968) diagnosis of *Dinesus*, the presence of a hemicylindrical glabella and a preglabellar area that disappears in the axial region and is delimited from the preocular fields by two wide, deep, oblique furrows allows us to include the Spanish material in this genus, and we propose the new combination *Dinesus truyolsi*.

The Ateca specimen resembles the type species *Dinesus ida* Etheridge, Jr, 1896, figured by Whitehouse (1939), although the Australian species has narrow palpebral lobes and fine tubercular ornamentation. Also, the stratigraphic distribution of both species is similar; *Dinesus ida* has been found in the *Xystridura templetonensis* Zone, which has been correlated with the Leonian Stage (Sdzuy *et al*. 1999, Gozalo *et al*. 2007).

Most *Dinesus* species have coarse tubercular ornamentation (Palmer 1968, Repina & Romanenko 1978) as does *Dinesus truyolsi*, but the latter has a slightly concave anterior margin whereas the other species have straight or convex margins. Some specimens of *Dinesus sibirica* figured by Egorova *et al*. (1976, pl. 22, figs 21, 25) have straight or slightly concave anterior margins, but this species always has a preglabellar area that is wider than the anterior border.

Stratigraphic distribution. The specimen was collected in the lower part of the Ateca 2 section, *Eccaparadoxides asturianus* Zone (upper Leonian Stage).

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