

First record of the Ordovician fauna in Mila-Kuh, eastern Alborz, northern Iran

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Abstract. Restudy of the Cambrian–Ordovician boundary beds, traditionally assigned to the Mila Formation Member 5 in Mila-Kuh, northern Iran, for the first time provides convincing evidence of the Early Ordovician (Tremadocian) age of the uppermost part of the Mila Formation. Two succeeding trilobite assemblages typifying the *Asaphellus inflatus*–*Dactylocephalus* and *Psilocephalina lubrica* associations have been recognized in the uppermost part of the unit. The Tremadocian trilobite fauna of Mila-Kuh shows close similarity to contemporaneous trilobite faunas of South China down to the species level, while affinity to the Tremadocian fauna of Central Iran is low. The trilobite species *Dactylocephalus levificatus* and brachiopod species *Tritoechia tenuis* from the Tremadocian of Mila-Kuh are new to science.

Key words: Trilobita, Brachiopoda, Tremadocian, biostratigraphy, biogeography.

INTRODUCTION

The position of the Cambrian–Ordovician boundary in the Alborz Region, northern Iran, was a matter of controversy for almost half a century since the publication of the pioneering paper by Stöcklin et al. (1964) where the Palaeozoic sequence of northern Iran was described for the first time. The key problem was the age of the uppermost part of the Mila Formation introduced by Stöcklin et al. (1964). The unit contains rich mid- to late Cambrian trilobite and conodont faunas, while the Ordovician trilobites were not reported in the original publication. Stöcklin et al. (1964) subdivided the Mila Formation into five informal members, which later found a broad application in the Alborz Region, although they have no defined boundaries. The Ordovician age was inferred by some researchers for the Mila Formation Member 5 (Peng et al. 1999; Bruton et al. 2004). Müller (1973) described and illustrated Cambrian (Furongian) conodonts, including *Cordylodus proavus* Müller, 1959, from the uppermost part of the Mila Formation Member 4 in the Mila-Kuh section. Kushan (1973) pointed out the occurrence of *Mictosaukia rotunda* (Kushan, 1973) and *Pagodia* sp., which he considered as proof of the Tremadocian age of the uppermost part of the Mila Formation Member 4, while elsewhere both genera occur below the presently defined position of the

Cambrian–Ordovician boundary (Jell & Adrain 2002). There are no previous reports on fossil occurrences in the Mila Formation Member 5 of the Mila-Kuh section except a brief note of Kushan (1973) on the occurrence of *Pagodia* sp.

The Mila-Kuh section was not a subject of geological and palaeontological studies for almost 40 years. For some time, the Mila Formation Member 5 has been considered as a stratigraphical equivalent of the Lashkarak Formation; though, a recent study by Ghobadi Pour et al. (2011a) gave sufficient evidence that the Lashkarak Formation, as it was originally defined by Gansser & Huber (1962), has Mid-Ordovician (Darriwilian) and younger age.

To resolve the existing uncertainty with the position of the Cambrian–Ordovician boundary and correlation of the upper part of the Mila Formation, our research team revisited the type section of the Mila Formation in Mila-Kuh in 2013.

GEOLOGICAL SETTING

The Mila-Kuh area is situated in the eastern Alborz Mountains, about 50 km west-southwest of Damghan, about 6.5 km southwest of the Tuyeh village and about 5 km northwest of the road connecting Semnan to

Damghan (Fig. 1). It is the type area for the Middle Cambrian to Lower Ordovician Mila Formation introduced by Stöcklin et al. (1964). The geographic coordinates of the studied section are 35°58'54"N, 53°48'44"E. The measured section starts from the top of the Mila Formation Member 4, exposed along the western side of an unnamed valley. Rocks dip at 50° southeast.

According to the original report by Stöcklin et al. (1964, p. 21), the Mila Formation Member 5 comprises up to 47 m grey compact quartzites in the lower part. These are succeeded by silty shales, more than 70 m thick, with brown sandstone intercalations (shown also as brown limestone on the stratigraphic column, Stöcklin et al. 1964, fig. 5) in the middle part. The Mila Formation is overlain by the Devonian Geirud Formation.

The criteria, which define the lower boundary of the Mila Formation Member 5, were not discussed in its original description, except a brief note that the lower boundary of the unit is accentuated by ‘a quartzite bed, which suggests break between Member 4 and Member 5’ (Stöcklin et al. 1964, p. 24). Therefore the lower boundary of the Mila Formation Member 5 can be placed at the top of the last bioclastic limestone bed in the Cambrian part of the Mila Formation. The succession is as follows in the ascending order (Fig. 2):

Unit M5/1 – 26.5 m of intercalating sandstones and siltstones with a few beds of quartzose sandstones with

Cruziana trace fossils and two horizons rich in nodules at 7.4–7.9 m and at 16.0–17.6 m above the base of the unit. A bed of flat-pebbled breccia is present at 17.6–17.8 m above the base of the unit. The uppermost 1.5 m contains rare trilobites *Mictosaukia* sp. (sample MK-4/8). The upper boundary of the unit is a sharp uneven surface with large ripple marks about 1 m in length.

Unit M5/2 – 10.0 m of dark to light brown and greenish-brown, fine to medium-grained quartzose sandstones with tabular, low-angle cross-lamination (about 5°) and with bidirectional cross-bedding at the top of the unit.

Unit M5/3 – 4.6 m of greenish-grey argillite with a few beds of sandstone.

Unit M5/4 – 6.1 m of sandstone. The lower interval about 1 m thick is medium- to coarse-grained, calcareous sandstones with three shell beds comprising disarticulated valves of billingsellide brachiopods and with bedding surfaces covered by *Cruziana* trace fossils in the upper part. The interval from 1.0 to 1.3 m represents a matrix-supported breccia with abundant brachiopod coquinas. The upper 4.8 m comprise fine- to medium-grained quartzose sandstone.

Unit M5/5 – more than 60 m of greenish-grey argillite and siltstone with beds of calcareous sandstone at 31.3–31.5 m and 34.7–34.9 m above the base of the

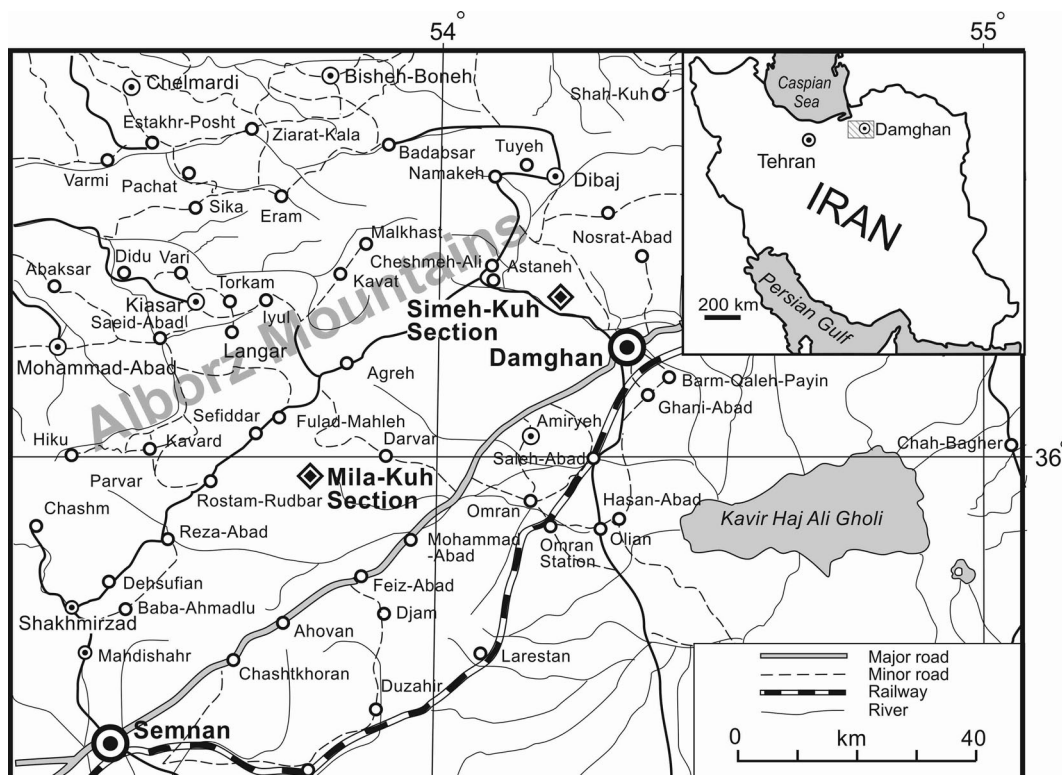


Fig. 1. Geographical map of northern Iran showing the position of the Mila-Kuh section.

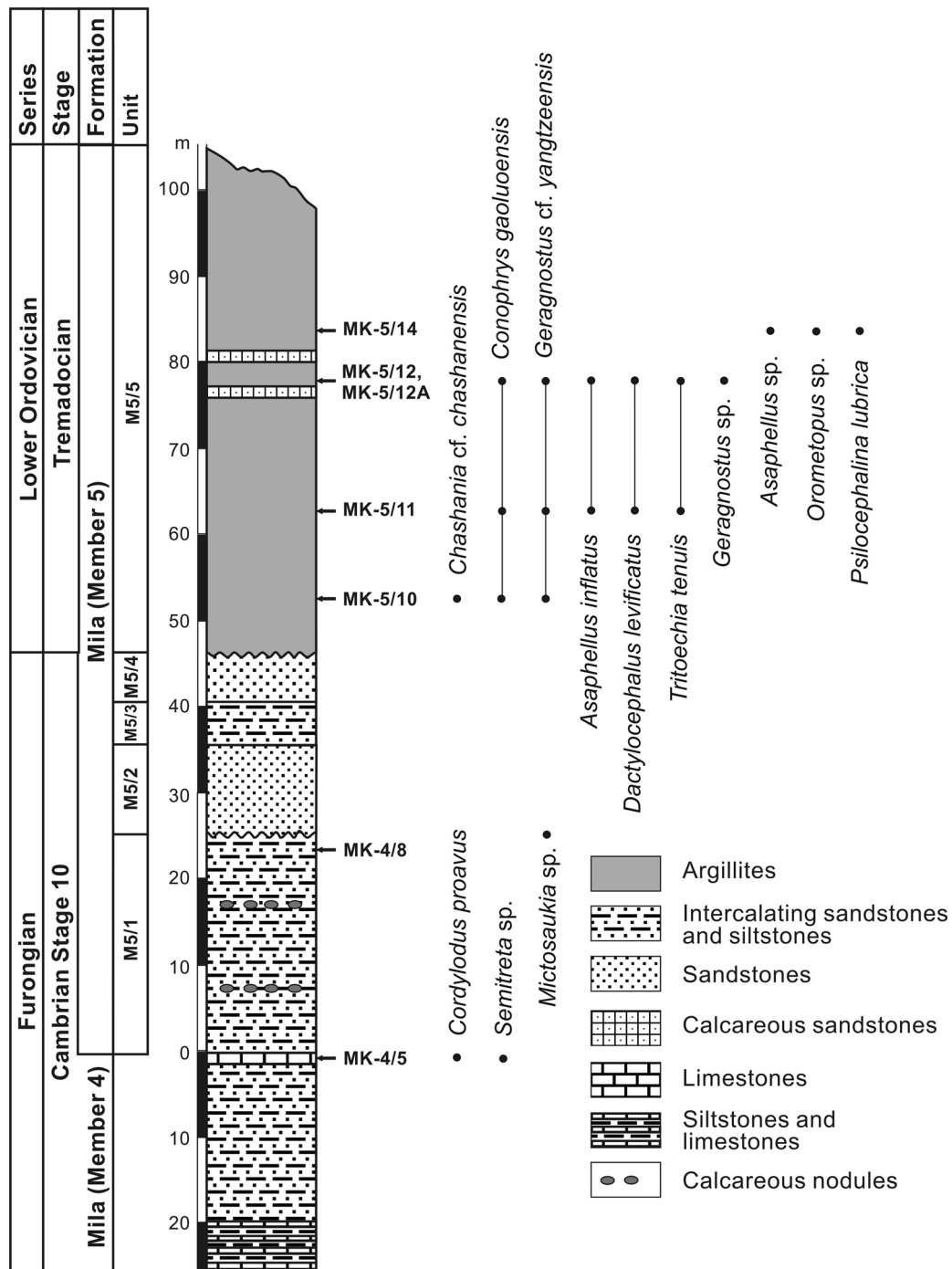


Fig. 2. Stratigraphical column of Mila Formation Member 5 in Mila-Kuh, showing the horizons of fossil localities and stratigraphical ranges of trilobite, brachiopod and conodont species.

unit. The lower boundary of the unit coincides with a sharp change from sandstones to argillites. There are four fossil horizons within the unit. The lowermost horizon (sample MK-5/10) at 5.8 m above the base of the unit contains the trilobites *Chashania* cf. *chashanensis* Lu & Sun in Zhou et al., 1977, *Geragnostus* cf.

yangtzeensis Lu, 1975 and *Conophrys gaoluensis* (Zhou in Zhou et al., 1977). The next two fossiliferous horizons (sample MK-5/11 at 16.2 m and samples MK-5/12 and MK-5/12A at 31.8–31.95 m above the base of the unit) contain the trilobites *Asaphellus inflatus* Lu, 1962, *Geragnostus* cf. *yangtzeensis*, *Conophrys*

gaoluensis and *Dactylocephalus levificatus* sp. nov. and the brachiopod *Tritoechia tenuis* sp. nov. The uppermost fossiliferous horizon at 39.5–39.6 m above the base of the unit (sample MK-5/14) yields a different trilobite assemblage, including *Psilocephalina lubrica* Hsü, 1948, *Asaphellus* sp. and *Orometopus* sp.

The last outcrops of the argillaceous unit are separated from the lowermost exposures of the Devonian Geirud Formation by 23 m of alluvial sediments. Thus the contact between the Devonian and the underlying strata was not observed.

The validity of the Mila Formation, as the lithostratigraphical unit introduced by Stöcklin et al. (1964), is questionable. Geyer et al. (2014) pointed out that formally it represents a junior homonym of the ‘Mila Formation’ introduced a year earlier by Assereto (1963). The latter by original designation includes also Devonian sediments. Therefore, pending a general revision of the early Palaeozoic lithostratigraphy of the Alborz Region, here we avoid the assignment of the Lower Ordovician sediments exposed in Mila-Kuh to any existing formal lithostratigraphical unit.

The Alborz Region is usually shown as situated within the Gondwana domain in the palaeogeographical reconstructions for the Ordovician (e.g. Torsvik & Cocks 2009). Nevertheless, faunal evidence indicates that Alborz was most probably a separate microplate located in temperate latitudes somewhere between the Gondwana margin and South China (Ghobadi Pour 2006, fig. 17; Ghobadi Pour et al. 2011a) through the early Palaeozoic.

BIOSTRATIGRAPHY AND AGE OF THE FAUNA

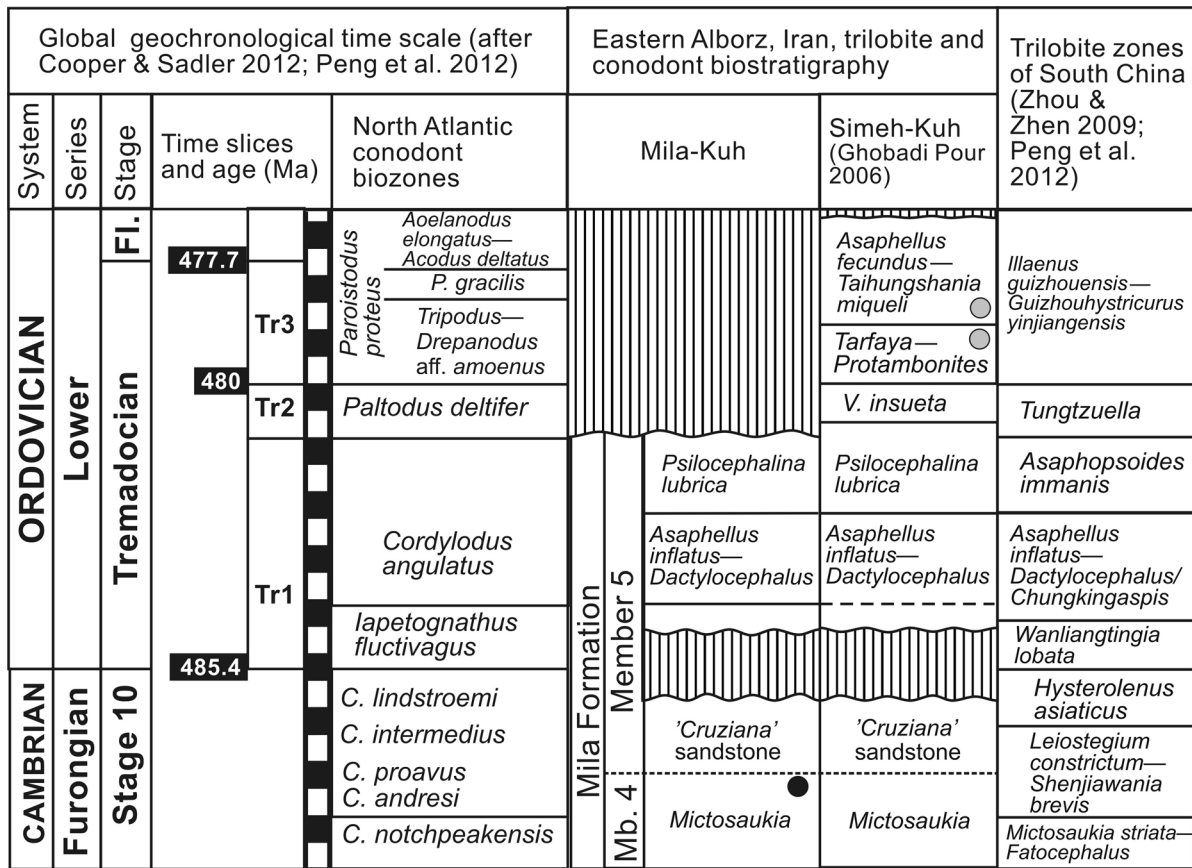
The end of the Cambrian Period in eastern Alborz was the time of a lowstand, when a unit of cross-bedded quartzose sandstones with *Cruziana* trace fossils and billingsellide brachiopod shell beds was deposited within shoal systems nearshore. The 47.2 m thick stratigraphic interval from Unit M5/1 to Unit M5/4 with confidence can be compared with the lower sandstone unit of the Mila Formation Member 5 as it was characterized by Stöcklin et al. (1964). However, it contains a characteristic Cambrian trilobite *Mictosaukia* sp. (sample MK-4/8) and brachiopod shell beds not recorded in the original description. These ‘*Cruziana*’ sandstones are widely recognized in eastern Alborz, in particular in Deh-Molla (Ghobadi Pour et al. 2011a).

The overlying argillites (Unit M5/5) have a sharp contact with sandstones. They contain three succeeding trilobite assemblages. The lowermost assemblage (samples MK-5/10) is characterized by the occurrence of the

trilobites *Chashania* cf. *chashanensis*, *Geragnostus* cf. *yangtzeensis* and *Conophrys gaoluensis*. At 10.4 m upsequence it is succeeded by a more diverse faunal assemblage, including the trilobites *Asaphellus inflatus*, *Geragnostus* cf. *yangtzeensis*, *Conophrys gaoluensis* and *Dactylocephalus levificatus* sp. nov. and the brachiopod *Tritoechia tenuis* sp. nov., which occur in samples MK-5/11, MK-5/12 and MK-5/12A in the lower part of Unit M5/5. At 39.5 m above the base of Unit M5/5 it is replaced by another trilobite assemblage with *Psilocephalina lubrica* as the dominant taxon, which occurs in association with *Asaphellus* sp. and *Orometopus* sp. The observed succession of trilobite assemblages closely resembles the succeeding *Asaphellus inflatus*–*Dactylocephalus* and *Psilocephalina lubrica* associations described by Ghobadi Pour (2006) from the Tremadocian of the Simeh-Kuh section northwest of Damghan.

The *Asaphellus inflatus*–*Dactylocephalus* Association is indicative of the base of the Ordovician succession in northern Iran. In eastern Alborz *Asaphellus inflatus* invariably appears in the lower part of the shale unit, which rests with a sharp contact on cross-bedded ‘*Cruziana*’ sandstones (Fig. 3); however, associated trilobite fauna is varying in diversity and taxonomic composition. In particular, in Simeh-Kuh (Ghobadi Pour 2006) it co-occurs with *Dactylocephalus mehriae* Ghobadi Pour, 2006 and *Conophrys simehensis* Ghobadi Pour, 2006; both genera are represented in Mila-Kuh by different species. In South China the *Asaphellus inflatus*–*Dactylocephalus* Biozone is recognized as the second biostratigraphical unit for the Tremadocian (Peng 1990a; Zhou & Zhen 2009). In the Nantsinkwan Formation of western Hunan *Asaphellus inflatus* appears above the local *Monocostodus servierensis*–*Cordylodus intermedius* conodont Biozone of the uppermost Cambrian age (Peng 1990a, 1990b). Remarkably, in western Hunan it co-occurs with *Geragnostus* cf. *yangtzeensis* and *Conophrys gaoluensis*. Both taxa are also present in Mila-Kuh. *Chashania chashanensis* was previously considered as endemic to South China, where it has been documented from the lower Tremadocian (*Cordylodus angulatus* Zone equivalents) according to Zhou & Zhen (2009).

The *Psilocephalina lubrica* Association occurs in the uppermost part of the Lower Ordovician succession in Mila-Kuh. *Psilocephalina lubrica* is otherwise known from South China, in association with species of *Asaphopsis* in the *Acanthograptus*–*Tungzuella* Zone according to Zhou & Zhen (2009) and from Australia (Northern Territories), from the Tremadocian Pacoota Sandstone Formation (Shergold 1991). In the Mila-Kuh section the associated assemblage includes only an unnamed species of *Asaphellus*, which is probably a



Conodont occurrences in Iran: ● *Cordylodus proavus*; ● *Drepanodus aff. amoenus*.

Fig. 3. Summarized chrono- and lithostratigraphical chart of the uppermost Cambrian to Lower Ordovician (Tremadocian) strata of eastern Alborz showing correlation with the biostratigraphical trilobite succession of South China. North Atlantic conodont biozones are mainly after Kaljo et al. (1986), Viira (2011) and Männik & Viira (2012).

member of the local lineage and *Orometopus* sp. The former probably represents the species transitional between *Asaphellus inflatus* and *Asaphellus fecundus* Ghobadi Pour et al., 2007. In Simeh-Kuh, *Psilocephalina lubrica* appears as a common component of the more diverse trilobite assemblage, which includes *Geragnostus sidenbladhi jafari* Ghobadi Pour, 2006, *Apatokephalus* sp., *Asaphopsis elhamae* Ghobadi Pour, 2006, *Conophrys simehensis* Ghobadi Pour, 2006, *Kayseraspis ghavideli* Ghobadi Pour, 2006 and *Presbynileus? biroonii* Ghobadi Pour, 2006 (Ghobadi Pour 2006). Only *Conophrys simehensis* is a transitional taxon from the underlying deposits, whereas all other species are newcomers. The species endemic to the Alborz Region constitute a core of the assemblage, while trilobite genera *Apatokephalus*, *Asaphellus* and *Asaphopsis* are also widespread in the *Acanthograptus–Tungtzuella* Zone of South China. In Simeh-Kuh the assemblage characteristic of the *Psilocephalina lubrica* Association is replaced upsection by a low-diversity fauna including the single endemic

trilobite species *Vachikaspis insueta* Ghobadi Pour, 2006 and the brachiopod *Tarfaya jafari* Popov et al., 2009. The occurrence of conodonts characteristic of the lowermost *Tripodus–Drepanodus aff. amoenus* Subzone of the *Paroistodus proteus* Zone in the shell bed with *Tarfaya jafari* and *Protambonites hooshangi* Popov et al., 2009 above the *Vachikaspis insueta* level (Ghobadi Pour 2006; Ghobadi Pour et al. 2007) suggests that the *Psilocephalina lubrica* and *Vachikaspis insueta* levels together may correspond to the upper part of the *Cordylodus angulatus* Biozone and the *Paltodus deltifer* Biozone (Fig. 3).

The transition to the Ordovician in the Alborz Region coincided with a significant drowning event (Figs 2, 3). In the absence of conodonts and graptolites precise timing of the initial flooding of the region cannot be defined, while correlation with the *Asaphellus inflatus–Dactylocephalus* Zone of the Tremadocian succession in South China suggests that it occurred early during the *Cordylodus angulatus* Zone and was

probably synchronous with the transgressive phase of the Black Mountain Eustatic Event of Miller (1984).

Faunal replacement through the Cambrian–Ordovician transition in the Alborz Region shows high turnover rates in trilobite faunas and suggests possible extinction in the regional scale close to the Cambrian–Ordovician boundary. None of the Furongian trilobite genera documented by Kushan (1973) and Peng et al. (1999) from the Mila Formation Member 4 are present in the early Tremadocian trilobite fauna of eastern Alborz. The taxonomic composition of the *Asaphellus inflatus*–*Dactylocephalus* trilobite Association shows remarkable similarity to the contemporaneous fauna of South China down to the species level. In addition to the eponymous taxa, such species as *Chashania* cf. *chashanensis*, *Geragnostus* cf. *yangtzeensis* and *Conophrys gaoluensis* are restricted in their geographical distribution to Alborz and South China. The trilobite taxa characteristic of the *Psilocephalina lubrica* Association retain strong similarity to the South China fauna on the generic level, while most of the species are endemic to the Alborz Region. The Tremadocian trilobite fauna of Central Iran documented by Bruton et al. (2004) is of much lower diversity and has little in common with trilobite assemblages characteristic of the Tremadocian in Alborz.

SYSTEMATIC PALAEOLOGY

Brachiopods (by L. E. Popov, M. Kebria-ee Zadeh & C. Baars)

The illustrated and described material is housed in the National Museum of Wales, Cardiff (NMW). Abbreviations in tables of measurements and in the text are: Lv, Ld – sagittal ventral and dorsal valve length; W – maximum width; Iw – width of the interarea; MI, Mw – length and width of the ventral muscle field; BBw – distance between outer margins of socket ridges; Sl – length of the median ridge.

Order BILLINGSSELLIDA Schuchert, 1893
Superfamily POLYTOECHIOIDEA Öpik, 1934
Family TRITOECHIIDAE Ulrich & Cooper, 1936
Genus *Tritoechia* Ulrich & Cooper, 1936

Type species. By the original designation *Deltatreta typica* Schuchert & Cooper, 1932, Lower Ordovician, Arbuckle Group, Oklahoma, USA.

Tritoechia tenuis sp. nov.

Figure 4

Derivation of name. After Latin *tenuis*, thin, fine delicate.

Holotype. NMW2012.45G.326 (Fig. 4A–C), dorsal valve (external and internal moulds), Ld = 5.1, W = 6.25,

Iw = 5.6, BBw = 2.9, Sl = 1.05; Lower Ordovician, Tremadocian, sample MK-5/12.

Paratypes. Ventral external moulds: NMW2012.45G.335 (Fig. 4K), 360–364; ventral internal moulds: NMW2012.45G.338, 339 (Fig. 4J; Lv = 6.5, W = 8.9, Iw = 6.8, MI = 2.1, Mw = 2.0), 340, 345–349; dorsal internal moulds: NMW2012.45G.333 (Fig. 4D; Ld = 5.0, W = 6.4, Iw = 5.3, BBw = 2.1, Sl = 0.9), 341, 353–359; dorsal external moulds: NMW2012.45G.334 (Fig. 4L), 336 (Fig. 4H), 342–344, 350–352; all from sample MK-5/11. Ventral valve NMW2012.45G.323; ventral internal moulds: NMW2012.45G.327 (Fig. 4G, Lv = 7.1, W = 8.4, MI = 2.3, Mw = 2.0), 329 (Fig. 4I, Lv = 7.4, W = 7.9, MI = 2.6, Mw = 2.5), 330, 365–371, 378; ventral external moulds: NMW2012.45G.324 (Fig. 4E), 325, 332 (Fig. 4F), 337, 372–377; dorsal internal mould NMW2012.45G.331; all from sample MK-5/12. Total 36 ventral and 19 dorsal valves.

Diagnosis. Shell ventribiconvex with a very gently convex to almost planar dorsal valve, a rectimarginate anterior commissure and an apsacline ventral interarea. Radial ornament multicostellate, becoming fascicostellate distally. Ventral interior with widely divergent dental plates and a gently impressed, subtriangular ventral muscle field with the adductor scar slightly longer than diductor scars. No ventral median ridge. Dorsal interior with transverse socket ridges almost parallel to the hinge line, slit-like sockets facing posteriorly and a short dorsal median ridge about one-fifth as long as the valve.

Description. Shell ventribiconvex, slightly transverse, subpentagonal in outline, about 80–90% as long as wide with a hinge line about 90% of maximum shell width. Cardinal extremities slightly obtuse; anterior commissure rectimarginate. Ventral valve lateral profile anterior to the umbo gently convex with maximum height at the umbonal region. Ventral interarea high, triangular, planar, apsacline with a narrow, convex pseudodeltidium about twice as high as wide. Dorsal valve very gently convex to almost planar with a low, planar, anacline interarea. Chilidium broad, convex, completely covering the notothyrium. Radial ornament slightly unequally multicostellate, becoming fascicostellate in the anterior part of the shell in the largest specimens. Ribs tubular, separated by narrow interspaces, varying from 3 to 5 per 1 mm along the anterior margin; 20–22 ribs at the umbonal area and 45–65 ribs along the anterior margin of mature individuals. Concentric ornament of fine densely spaced fila.

Ventral interior with delicate, transverse teeth and long, straight, widely divergent dental plates. Ventral muscle field gently impressed, subtriangular, about one-

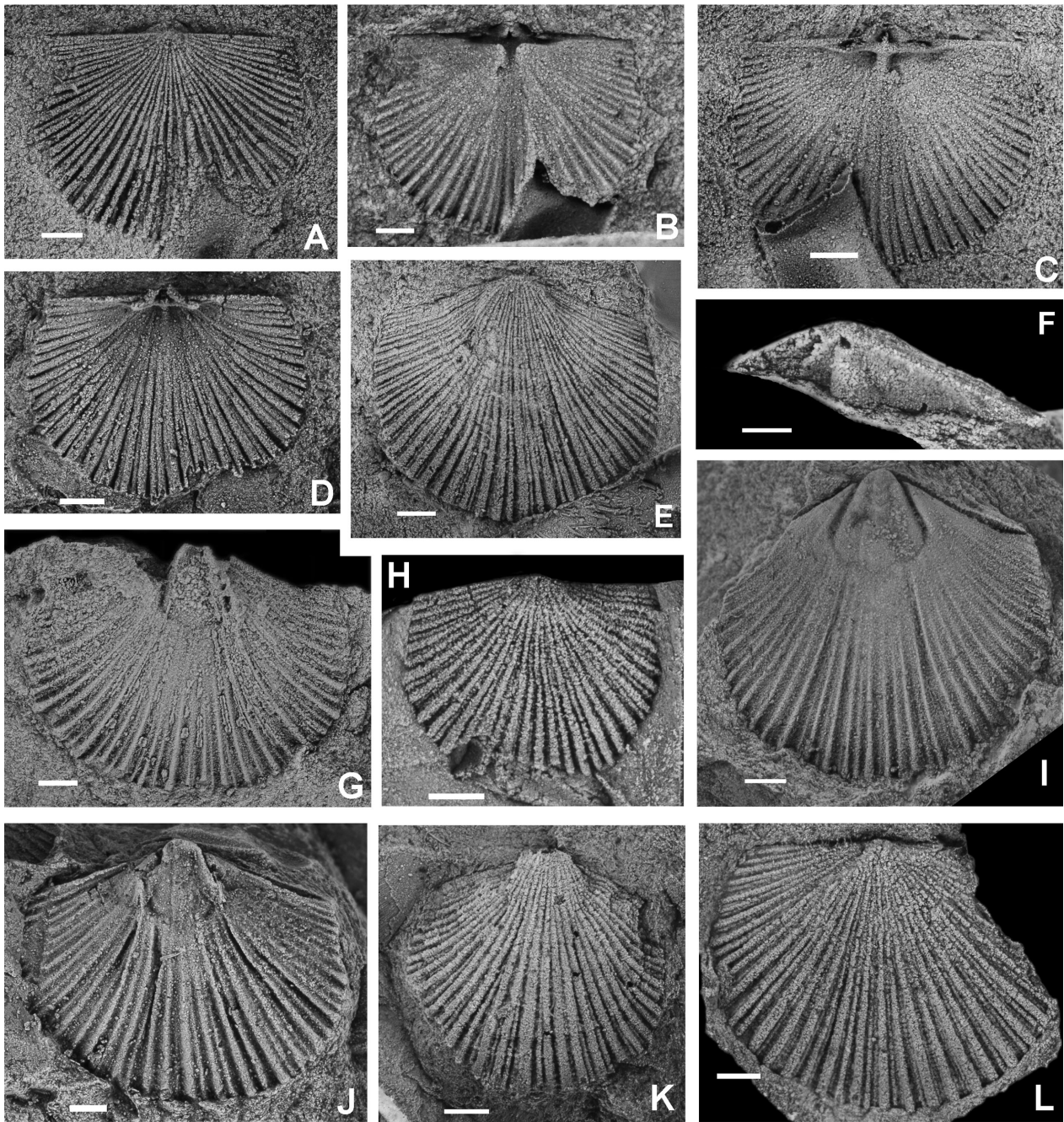


Fig. 4. *Tritoechia tenuis* sp. nov., Lower Ordovician, Tremadocian; **A–C**, NMW2012.45G.326, holotype, dorsal valve, latex cast of exterior, internal mould, latex cast of interior; **D**, NMW2012.45G.333, latex cast of dorsal interior; **E**, NMW2012.45G.324, latex cast of ventral exterior; **F**, NMW2012.45G.332, latex cast of ventral exterior, posterior view showing interarea and pseudodeltidium; **G**, NMW2012.45G.327, ventral internal mould; **H**, NMW2012.45G.336, latex cast of dorsal exterior; **I**, NMW2012.45G.329, ventral internal mould; **J**, NMW2012.45G.339, ventral internal mould; **K**, NMW2012.45G.335, latex cast of ventral exterior; **L**, NMW2012.45G.334, latex cast of dorsal exterior; **A–C, H–L**, sample MK-5/11; **D–G**, sample MK-5/12. All scale bars are 1 mm.

third as long as the valve, bordered anteriorly by the faint muscle bounding ridges. Adductor scar narrow, subtriangular, occupying one-third of the muscle field and slightly longer than gently impressed diductor scars. Dorsal valve interior with a simple, ridge-like cardinal process on a small subtriangular notothyrial platform steeply inclined posteriorly and supported anteriorly by a short median ridge about one-fifth as long as the valve. Socket ridges straight, transverse, bordering anteriorly narrow, slit-like sockets facing posteriorly. Dorsal adductor muscle scars and mantle canals in both valves undiscernible.

Remarks. *Tritoechia tenuis* sp. nov. is probably the earliest representative of the genus. Unlike most of the species referred to *Tritoechia* (e.g. Ulrich & Cooper 1938; Laurie 1980; Benedetto 1987, 2001; Popov et al. 2001; Benedetto et al. 2003) it is characterized by a very gently convex to almost planar dorsal valve lacking sulcus, a gently impressed, subtriangular ventral muscle field bounded laterally by long divergent dental plates and with an adductor scar slightly longer than diductor scars, a convex chilidium completely covering the notothyrium, transverse socket ridges almost parallel to the hinge line and a very short dorsal median ridge. Iranian species has no ventral median ridge and aditicles, which are usually considered among diagnostic features of *Tritoechia* (Rubel & Wright 2000).

Of the Tremadocian species of the genus *T. tenuis* resembles *Tritoechia lewesi* Brown, 1948 from the Tremadocian Florentine Valley Formation of Tasmania (Laurie 1980) in having a planar to gently convex dorsal valve, transverse socket ridges parallel to the hinge line and a short dorsal median ridge and in the absence of the ventral median ridge. However, it can be easily distinguished in having multicostellate radial ornament, a convex chilidium completely covering the notothyrium and a ventral adductor scar slightly longer than diductor scars.

The shells of *Tritoechia* sp. from the upper Tremadocian (*Paltodus deltifer* conodont Zone) of the Deh-Molla section in the eastern Alborz Mountains, northern Iran (Ghobadi Pour et al. 2011b), unlike *T. tenuis*, have a strongly elongate ventral muscle field, bounded laterally by long, subparallel dental plates, and a shallow dorsal median sulcus. They represent a separate, not yet formally designated species.

Trilobites (by M. Ghobadi Pour & L. E. Popov)

The illustrated and described material is housed in the National Museum of Wales, Cardiff (NMW). The terminology and systematic classification follows that of the new edition of the *Treatise on Invertebrate Palaeontology* (Whittington & Kelly in Kaesler 1997).

Class TRILOBITA Walch, 1771
 Order AGNOSTIDA Salter, 1864
 Superfamily AGNOSTOIDEA M'Coy, 1849
 Family METAGNOSTIDAE Jaekel, 1909
 Genus *Geragnostus* Howell, 1935

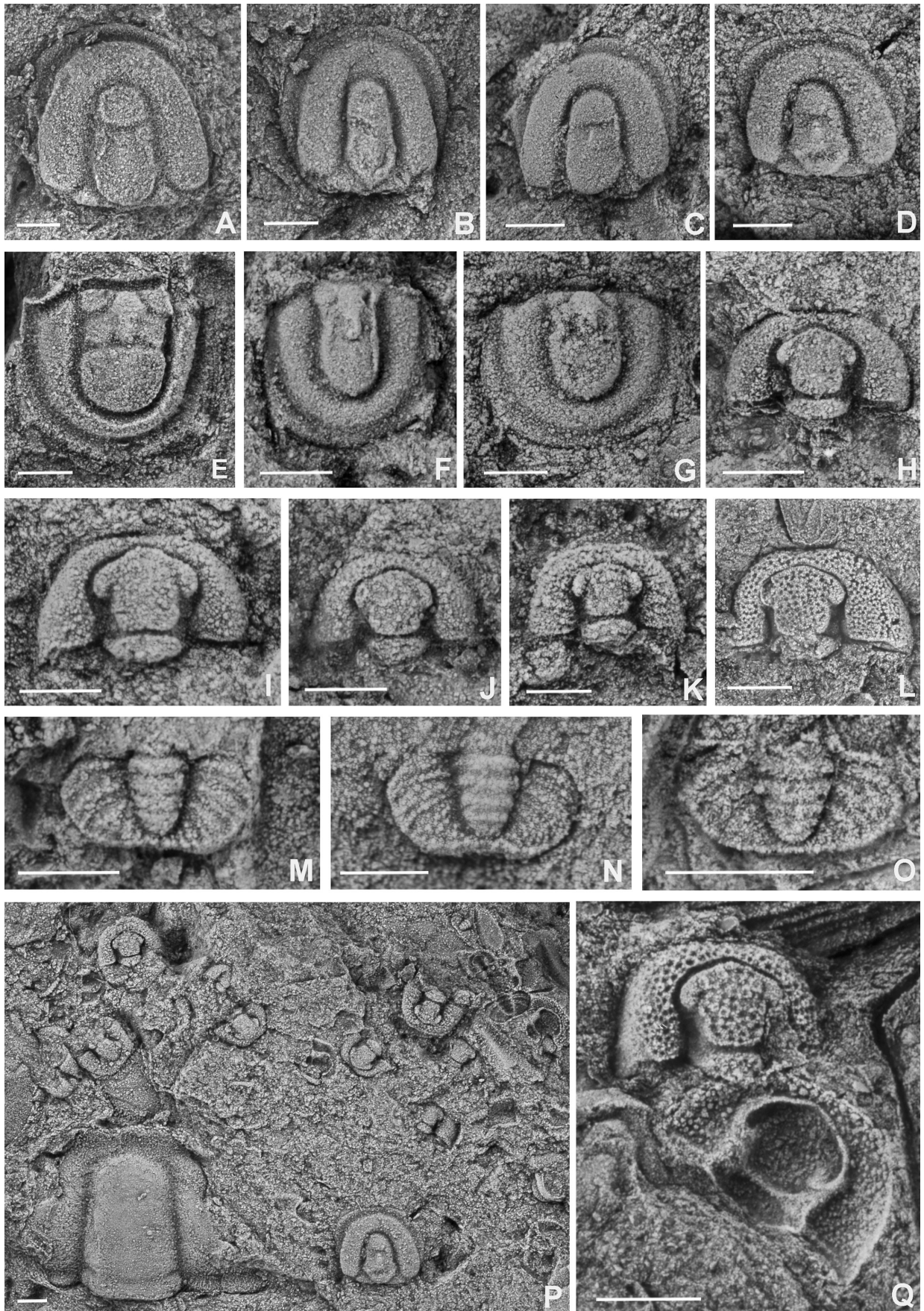
Type species. *Agnostus sidenbladhi* Linnarsson, 1869; Lower Ordovician, Tremadocian, Björkåsholmen Formation (formerly *Ceratopyge* Limestone), Västergötland, Sweden.

Geragnostus cf. *yangtzeensis* Lu, 1975
 Figure 5A–F

1990a *Geragnostus* cf. *yangtzeensis* Lu, 1975; Peng, p. 12, pl. 1, figs 1–8.

Material. Sample MK-5/10, five cephalae NMW 2012.45G.429–433, three pygidia NMW2012.45G.434–436; sample MK-5/11, three cephalae NMW2012.45G.307 (Fig. 5B), 308 (Fig. 5C), 311.1 (Fig. 5D), six pygidia

Fig. 5. A–F, *Geragnostus* cf. *yangtzeensis* Lu, 1975, Lower Ordovician, Tremadocian; A, NMW2012.45G.182, internal mould of cephalon, sample MK-5/12; B, NMW2012.45G.307, internal mould of cephalon, sample MK-5/11; C, NMW2012.45G.308, internal mould of cephalon, sample MK-5/11; D, NMW2012.45G.311.1, internal mould of cephalon, sample MK-5/11; E, NMW2012.45G.306.1, internal mould of pygidium, sample MK-5/11; F, NMW2012.45G.305.2, internal mould of pygidium, sample MK-5/11. **G,** *Geragnostus* sp., Lower Ordovician, Tremadocian; NMW2012.45G.309, internal mould of pygidium, sample MK-5/12A. **H–O, Q,** *Conophrys gaoluensis* (Zhou in Zhou et al., 1977), Lower Ordovician, Tremadocian; H, NMW2012.45G.314, internal mould of cranidium, sample MK-5/11; I, NMW2012.45G.304, internal mould of cranidium, sample MK-5/11; J, NMW2012.45G.313, internal mould of cranidium, sample MK-5/12; K, NMW2012.45G.311.4, internal mould of cranidium, sample MK-5/11; L, NMW2012.45G.321.1, latex cast of cranidium, sample MK-5/11; M, NMW2012.45G.317.1, internal mould of pygidium, sample MK-5/11; N, NMW2012.45G.175.1, internal mould of pygidium, sample MK-5/11; O, NMW2012.45G.303.7, internal mould of pygidium, sample MK-5/11; Q, NMW2012.45G.312.1, 312.2, internal mould and external mould of cranidia, sample MK-5/11. **P,** bedding surface with several specimens of *Conophrys gaoluensis* (Zhou in Zhou et al., 1977), NMW2012.45G.311.3–11; internal mould of cephalon of *Geragnostus* cf. *yangtzeensis* Lu, 1975, NMW2012.45G.311.1; and internal mould of cranidium of *Dactylocephalus levificatus* sp. nov., NMW2012.45G.311.2, sample MK-5/11. All scale bars are 1 mm.



NMW2012.45G.305.2 (Fig. 5F), 306.1 (Fig. 5E), 153.6, 168.2, 175.4, 321.3; sample MK-5/12, one cephalon NMW2012.45G.182 (Fig. 5A), one incomplete pygidium NMW2012.45G.301.

Remarks. These agonostid trilobites are closely similar to the specimens described and illustrated by Peng (1990a) as *Geragnostus* cf. *yangtzeensis* Lu, 1975 from the Tremadocian Nantsinkwan Formation of northwestern Hunan, South China, in all aspects of the cephalic morphology including: (1) shape and proportions of the cephalon, which has a maximum width at about one-third cephalic length from the posterior margin; (2) a gently tapering forward to almost parallel-sided glabella with a faint transverse glabellar furrow situated just anterior to the elongate, suboval glabellar node; (3) broadly triangular basal lobes connected to each other by the low and narrow transverse band (Fig. 5A, B); (4) a cephalic border equally wide anterior to the cephalic mid-length. Peng (1990a) considered the cephalic morphology of his specimens to completely match the holotype of *Geragnostus yangtzeensis*, but mentioned some pygidial differences such as a tapered axis and a less rounded and somewhat longer posterior segment, so he left his specimens in open nomenclature. This pygidial morphology is also characteristic of most of the specimens from samples MK-5/10 to MK-5/12 of the Mila-Kuh section (Fig. 5F, G). Until a revision of the types, here Peng's (1990a) species assignment is followed, while species attribution of the Iranian specimens is considered as provisional.

Geragnostus sp.
Figure 5G

Material. Sample MK-5/12A, one internal mould of pygidium NMW2012.45G.309 (Fig. 5G), one external mould of pygidium NMW2012.45G.310.

Description. Pygidium strongly convex, subquadrate, about 90% as long as wide. Pygidial axis strongly convex, almost parallel-sided, slightly constricted at the posterior furrow, broadly rounded posteriorly, about three-fourths as long and slightly less than half pygidium width. M1 separated from M2 by a distinct furrow slightly inclined anteriorly, then strongly curved forward adaxially. M2 with a strong median tubercle extended slightly backwards above the transverse furrow bounding its posterior margin. M3 almost half as long as the pygidial axis, delineated anteriorly by the strong transverse furrow. Pleural fields smooth, gradually becoming narrower behind the axis. Border delineated by the distinct border furrow, with maximum width along the posterolateral pygidial margins, at the level of a pair of small, oblique spines.

Remarks. The specimen shows strong similarity in pygidial morphology to *Geragnostus crassus* Tjernvik, 1956, from the Lower Ordovician, Tremadocian of Baltoscandia, as revised by Ahlberg (1992); however, it lacks a small median tubercle at the posterior part of M3, probably due to imperfect preservation. In the absence of data on cranial morphology precise taxonomic discrimination of the specimen remains doubtful.

Order PTYCHOPARIIDA Swinnerton, 1915
Suborder PTYCHOPARIINA Swinnerton, 1915
Superfamily PTYCHOPARIOIDEA Matthew, 1887
Family SHUMARDIIDAE Lake, 1907
Genus *Conophrys* Callaway, 1877

Type species. *Conophrys salopiensis* Callaway, 1877; Lower Ordovician, Tremadocian, England and Wales.

Conophrys gaoluensis (Zhou in Zhou et al., 1977)
Figure 5H–Q

1977 *Shumardia gaoluensis* Zhou; Zhou et al., p. 148, pl. 46, fig. 7.

1990a *Shumardia (Conophrys) gaoluensis* Zhou; Peng, p. 14, pl. 2, figs 1–15, text-fig. 6.

Material. Sample MK-5/11, 55 cranidia including NMW2012.45G.153.2–5, 156.2–4, 303.2–6, 304 (Fig. 5I), 305.3, 4, 306.3, 4, 311.3, 4 (Fig. 5K), 311.5–7, 311.11, 12, 312.1, 2 (Fig. 5Q), 314 (Fig. 5H), 315.1, 2, 316, 317.2–9, 321.1 (Fig. 5L), 321.2, 3, 437–454, nine external moulds of cranidia NMW2012.45G.455–463, ten pygidia NMW2012.45G.175.1 (Fig. 5N), 303.7 (Fig. 5O), 303.8, 306.2, 311.8–10, 317.1 (Fig. 5M), 464, 465; sample MK-5/12, five cranidia NMW2012.45G.203.2, 302, 313 (Fig. 5J), 379, 380.

Description. Cranidium semioval, about three-fifths as long as wide, covered by shallow pits slightly varying in size. Glabella (excluding the occipital ring) about 60–65% as long and about 45–50% as wide as the cranidium, bordered laterally by deep axial furrows. Preglabellar furrow curved forward, deep and narrow, slightly pointed medially. Anterolateral glabellar lobes teardrop-shaped, terminated posteriorly near cranial mid-length. Longitudinal glabellar furrows slightly inclined anteriorly adaxially, strongly impressed posteriorly, gradually fading anteriorly, terminated at short distance from the preglabellar furrow. L1 and L2 small, button-shaped, usually poorly preserved on the internal moulds. Preoccipital furrow deep, transverse. Occipital ring about 90–95% of maximum glabellar width and slightly more than one-fifth of cranial length. Occipital node not observed. Preglabellar field narrow (sag.), very gently convex. Fixigenae gently convex, strongly sloping down

near the outer margins. Posterior margin of fixigenae slightly transverse, curved backwards distally. Posterior border very narrow (exsag.), separated from fixigenae by a shallow, transverse border furrow terminated at some distance from the posterolateral cranial margins.

Pygidium subtrapezoidal, slightly more than half as long as wide with the posterior border slightly curved forward. Pygidial axis strongly convex, gradually tapering backwards, rounded posteriorly, with five axial rings, and a very small terminal piece, about 80–85% as long and two-thirds as wide as the pygidium, bordered by deep axial furrows. Pleurae with four, rarely five pleural ribs evenly curved backwards distally. Pleural and interpleural furrows shallow.

Remarks. *Conophrys gaoluoensis* is a well-defined taxon. Its affinities have been revealed from the phylogenetic analysis of more than forty species of Shumardiidae performed by Waisfeld et al. (2001) and also discussed in detail by Peng (1990a). The specimens from Mila-Kuh show close similarity to the specimens of *C. gaoluoensis* from the Nantsinkwan Formation of Hunan in South China re-described by Peng (1990a) and considered here as conspecific. The minor differences include more uniformly pitted ornament of the cephalon, a shorter preglabellar field and five axial rings instead of six in the specimens from South China. These differences may be referred to geographical variations within distant populations of the same species.

Two other species of *Conophrys* have been reported from the Tremadocian of Iran, including *Conophrys simehensis* (Ghobadi Pour, 2006), which also occurs in Alborz, and *Conophrys* cf. *pentagonalis* (Lu, 1975) briefly described and illustrated in Bruton et al. (2004), from the Shirgesht Formation of the Derenjal Mountains in eastern Central Iran.

Conophrys gaoluoensis can be easily distinguished from *C. simehensis* (Ghobadi Pour, 2006) by its pitted ornament covering all the surface of the cranium, larger and more prominent anterolateral glabellar lobes and a deep preglabellar furrow not fading medially.

Conophrys gaoluoensis and *C. pentagonalis* are closely similar in cranial morphology. The only difference is the less prominent posterior cranial border distinct only proximally in *C. gaoluoensis*. Surface ornamentation is unknown either in topotypes of *C. pentagonalis* or in the specimens of *Conophrys* cf. *pentagonalis* from the Derenjam Mountains, while the presence of L1 and position of the occipital node are not evident from the existing descriptions and illustrations of the specimens. The main differences between these two taxa are in pygidial morphology. Unlike *C. gaoluoensis*, *C. pentagonalis* has a concave (not transverse) median portion of the posterior pygidial

margin and a broad, strongly tapering posteriorly pygidial axis more than two-fifths as wide as maximum pygidial width.

Order PHACOPIDA Salter, 1864

Suborder CHEIRURINA Harrington & Leanza, 1957

Superfamily CHEIRUROIDEA Hawle & Corda, 1847

Family PILEKIIDAE Sdzuy, 1955

Subfamily PILEKIINAE Sdzuy, 1955

Genus *Chashania* Lu & Sun in Zhou et al., 1977

Type species. By the original designation *Chashania chashanensis* Lu & Sun in Zhou et al., 1977, Lower Ordovician, Tremadocian, Nantsinkwan Formation, Hubei, China.

Chashania cf. *chashanensis* Lu & Sun in Zhou et al., 1977

Figure 6N

Material. Sample MK-5/10, external mould of cranium NMW2012.45G.385 (Fig. 6N).

Remarks. This species was recently recovered from the lowermost Tremadocian (*Asaphellus inflatus*–*Dactylocephalus* Association) of the Deh-Molla section (Ghobadi Pour, manuscript in preparation). A single incomplete cranium from Mila-Kuh closely resembles *Chashania chashanensis* in all aspects of the cranial morphology; however, it shows a slightly pointed cranial anterior margin, a short anterior cranial border and anteriorly situated palpebral lobes which are not preserved in the types.

Order ASAPHIDA Salter, 1864

Superfamily ASAPHOIDEA Burmeister, 1843

Family ASAPHIDAE Burmeister, 1843

Subfamily ISOTELINAE Angelin, 1854

Genus *Asaphellus* Callaway, 1877

Type species. *Asaphus homfrayi* Salter, 1866; Lower Ordovician, upper Tremadocian, North Wales.

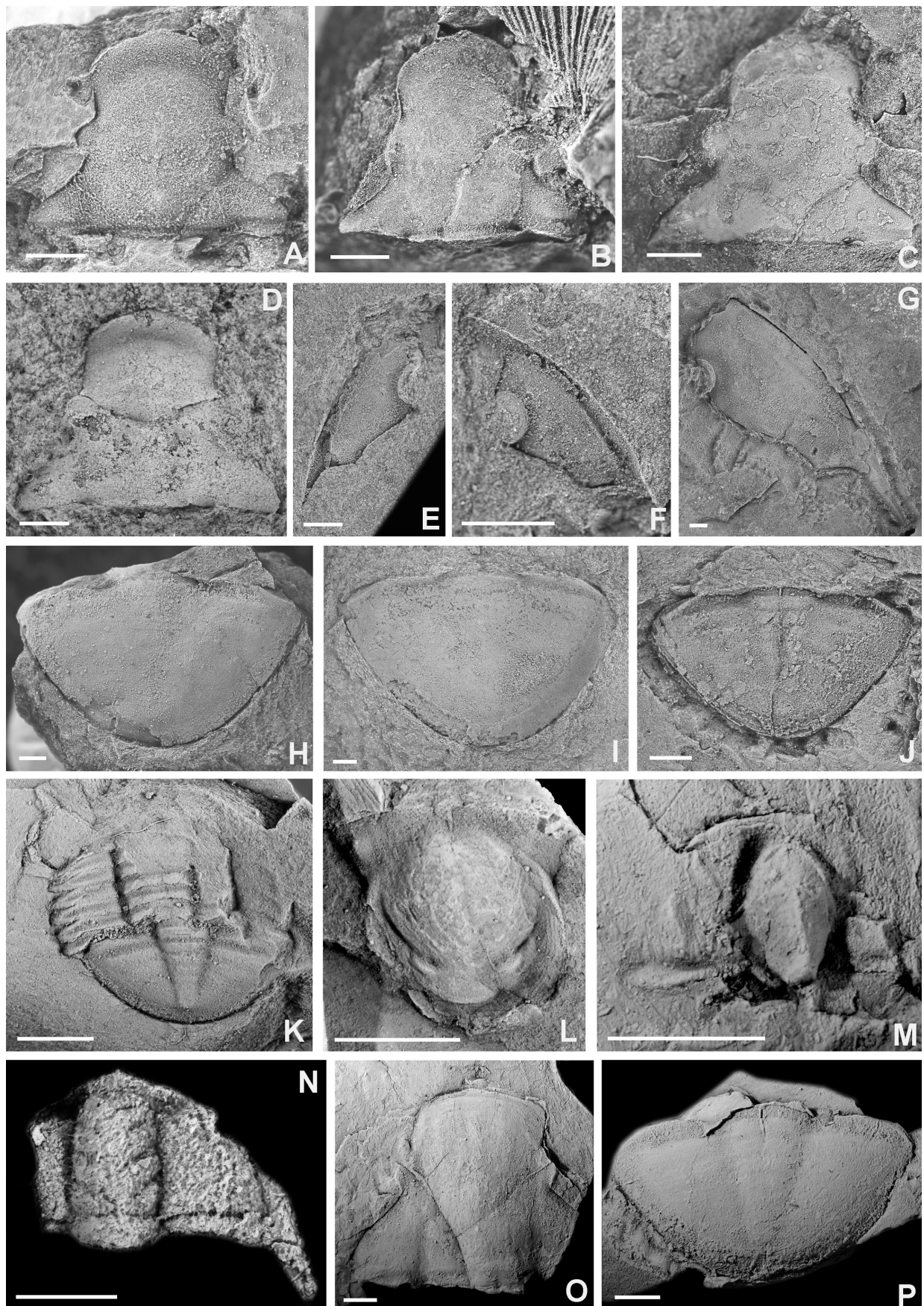
Asaphellus inflatus Lu, 1962

Figure 6A–J

1962 *Asaphellus inflatus* Lu; Wang, p. 43, figs 2–4.

2006 *Asaphellus inflatus* Lu; Ghobadi Pour, p. 102, figs 6.1–7, 9, 12 (for full synonymy).

Material. Sample MK-5/11, five crania NMW2012.45G.151 (Fig. 6C), 152 (Fig. 6B), 175.3, 303.1, 466, two librigenae NMW2012.45G.153.1 (Fig. 6F), 156.1, five pygidia NMW2012.45G.154, 155 (Fig. 6H), 201, 202, 468, two external moulds of pygidia NMW2012.45G.322, 467; sample MK-5/12,



four cranidia NMW2012.45G.157.1 (Fig. 6A), 158b, 212, 213, 11 pygidia NMW2012.45G.157.2 (Fig. 6J), 159, 203.1, 204–211, one librigena NMW2012.45G.158.1 (Fig. 6E); sample MK-5/12A, one external mould of cranidium NMW2012.45G.318 (Fig. 6D), two incomplete cranidia NMW2012.45G.217, 218, five pygidia NMW2012.45G.160 (Fig. 6I), 161, 214–216, three librigenae NMW2012.45G.162 (Fig. 6G), 219, 220.

Remarks. The occurrence of *Asaphellus inflatus* in the lower Tremadocian of the eastern Alborz Mountains was first documented by Ghobadi Pour (2006). Unlike the types of *A. inflatus* described and illustrated by Lu (1962), which were preserved in limestone and retained their original convexity, Iranian specimens of this species occur in shales and are generally flattened and slightly distorted. Nevertheless, in cranidial and pygidial morphology specimens from Mila-Kuh are well within the range of variations of the *A. inflatus* specimens described and illustrated by Lu (1975) and Peng (1990a), which were also derived from shales.

Asaphellus sp.
Figure 6K, L

Material. Sample MK-5/14, one hypostome NMW2012.45G.382 (Fig. 6L), internal mould of pygidium with thoracic segments NMW2012.45G.381 (Fig. 6K), four internal moulds of pygidia NMW2012.45G.383, 392–394, five external moulds of pygidia NMW2012.45G.388–392.

Remarks. A few pygidia of *Asaphellus* from the *Psilocephalina lubrica* Association differ from those of *Asaphellus inflatus* in having a more transverse outline of the pygidium, which is almost half as long as wide, more strongly impressed axial pygidial furrows and a more distinct pygidial border. The associated hypostome has a subtriangular outline, an almost transverse anterior margin very gently curved distally, a rounded posterior margin and an elongate, suboval middle body. The anterior lobe of the middle body is large, subcircular, separated from the crescentic posterior lobe by the

discontinuous middle furrow completely fading in the mid-part. Maculae are well defined, situated at the anterolateral parts of the posterior body immediately behind the middle furrow. Anterior wings are large and subtriangular. This hypostome shows close similarity to the hypostome of *A. inflatus* (Peng 1990a, pl. 6, figs 8, 12), but slightly differs in having a more transverse anterior hypostomal margin and a weaker median furrow. In the absence of data on cephalic morphology, species discrimination of these specimens remains uncertain.

Superfamily CYCLOPYGOIDEA Linnarsson, 1869
Family NILEIDAE Angelin, 1854
Genus *Psilocephalina* Hsü, 1948

Type species. *Psilocephalina lubrica* Hsü, 1948; Lower Ordovician, upper Tremadocian, Fenshiang Formation, South China.

Psilocephalina lubrica Hsü, 1948
Figure 6O, P

- 1948 *Psilocephalina lubrica* Hsü, p. 24, pl. 7, figs 8–15, pl. 8, figs 1–14.
1975 *Psilocephalina lubrica* Hsü; Lu, p. 337, pl. 16, figs 4–24, pl. 17, figs 1, 2.
1977 *Psilocephalina lubrica* Hsü; Zhou et al., p. 222, pl. 66, figs 7, 8.
1977 *Psilocephalina lubrica* mut. *transversa* Hsü; Zhou et al., p. 222, pl. 66, fig. 9.
1991 *Psilocephalina* sp. cf. *P. lubrica* Hsu; Shergold, p. 39, pl. 8, figs 1–20.
2006 *Psilocephalina lubrica* Hsü; Ghobadi Pour, p. 106, figs 5.14, 5.16, 5.18–21, 10, 13.1–3, 13.6–12, 13.15.

Material. Sample MK-5/14, six internal moulds of cranidia NMW2012.45G.386 (Fig. 6O), 396–400, two external moulds of cranidia NMW2012.45G.401, 402, one attached cranidium and librigena NMW2012.45G.403, three librigenae NMW2012.45G.404–406, 15 internal moulds of pygidia NMW2012.45G.387 (Fig. 6P),

Fig. 6. Lower Ordovician, Tremadocian; **A–J**, *Asaphellus inflatus* Lu, 1962, Lower Ordovician, Tremadocian; **A**, NMW2012.45G.157.1, cranidium, sample MK-5/12; **B**, NMW2012.45G.152, cranidium, sample MK-5/11; **C**, NMW2012.45G.151, cranidium, sample MK-5/11; **D**, NMW2012.45G.318, cranidium, sample MK-5/12A; **E**, NMW2012.45G.158.1, internal mould of librigena, sample MK-5/12; **F**, NMW2012.45G.153.1, internal mould of librigena, sample MK-5/11; **G**, NMW2012.45G.162, librigena, sample MK-5/12A; **H**, NMW2012.45G.155, pygidium, sample MK-5/11; **I**, NMW2012.45G.160, pygidium, sample MK-5/12A; **J**, NMW2012.45G.157.2, internal mould of pygidium, sample MK-5/12. **K, L**, *Asaphellus* sp., Lower Ordovician, Tremadocian; **K**, NMW2012.45G.381, internal mould of pygidium and part of thorax, sample MK-5/14; **L**, NMW2012.45G.382, internal mould of hypostome, sample MK-5/14. **M**, *Orometopus* sp., Lower Ordovician, Tremadocian NMW2012.45G.384, internal mould of cranidium, sample MK-5/14. **N**, *Chashania* cf. *chashanensis* Lu & Sun in Zhou et al., 1977, NMW2012.45G.385, latex cast of cranidium, sample MK-5/10. **O, P**, *Psilocephalina lubrica* Hsü, 1948, Lower Ordovician, Tremadocian, sample MK-5/14; **O**, NMW2012.45G.386, cranidium; **P**, NMW2012.45G.387, pygidium. All scale bars are 2 mm.

408–421, three external moulds of pygidia NMW2012.45G.422–424.

Remarks. Iranian specimens of *Psilocephalina lubrica* were illustrated and described in detail by Ghobadi Pour (2006). This species is the most common in the uppermost part of the Mila Formation Member 5 of the Mila-Kuh section. Specimens of *Psilocephalina* sp. cf. *P. lubrica* described and illustrated by Shergold (1991) from the Pacoota Sandstone Formation of the Amadeus basin in Central Australia are almost identical to the Iranian specimens both in cranial and pygidial morphology except a slightly more anterior position of the glabellar node and they are considered here as conspecific.

Superfamily TRINUCLEOIDEA Hawle & Corda, 1847
Family OROMETOPIDAE Hupé, 1955
Genus *Orometopus* Brøgger, 1896

Type species. *Holometopus? elatifrons* Angelin, 1854 from the Bjökåsholmen Formation, upper Tremadocian of Sweden.

Orometopus sp.
Figure 6M

Material. Sample MK-5/14, two internal moulds of cranidia NMW2012.45G.384 (Fig. 6M), 395.

Description. Cranidium about three-fifths as wide as long with maximum width along the posterior margin. Glabella semiovoid, about four-fifths as long as the cranidium and with maximum width (tr.) about three-fifths of glabellar length, evenly sloping down anteriorly, subcarinate posterior to the glabellar median tubercle and terminating posteriorly with a spine. Occipital ring narrow (sag.). Preglabellar field (sag.) short, evenly convex (tr.). Palpebral lobes small, semicircular about one-fifth of sagittal cranial length. Posterior border narrow (exsag.), transverse, separated from fixigenae by a broad border furrow. Anterior cranial margin evenly rounded; posterior margin transverse. Anterior branches

of the facial suture slightly divergent, merging with the anterior cranial margin at the level of the glabellar front. Posterior branches of the facial suture transverse, curved outwards immediately behind the palpebral lobes.

Librigenae, hypostome, pygidium and thorax are unknown.

Remarks. The anterior cranial border, eye ridges and surface ornament have not been observed, probably because of insufficient preservation of the specimen, while an ovoid shape of the glabella and the presence of the backward-projecting glabellar spine suggest the closest affinity to the type species *Orometopus elatifrons* as revised by Ebbestad (1999). Iranian specimens differ in having a more transverse anterior cranial margin, and a wider (exsag.) preglabellar field.

Superfamily ANOMALOCAROIDEA Poulsen, 1927
Family DIKELOKEPHALINIDAE Kobayashi, 1936
Genus *Dactylocephalus* Hsü, 1948

Type species. *Dactylocephalus dactyloides* Hsü, 1948; Lower Ordovician, Tremadocian, I-Chang Formation, Hubei, South China.

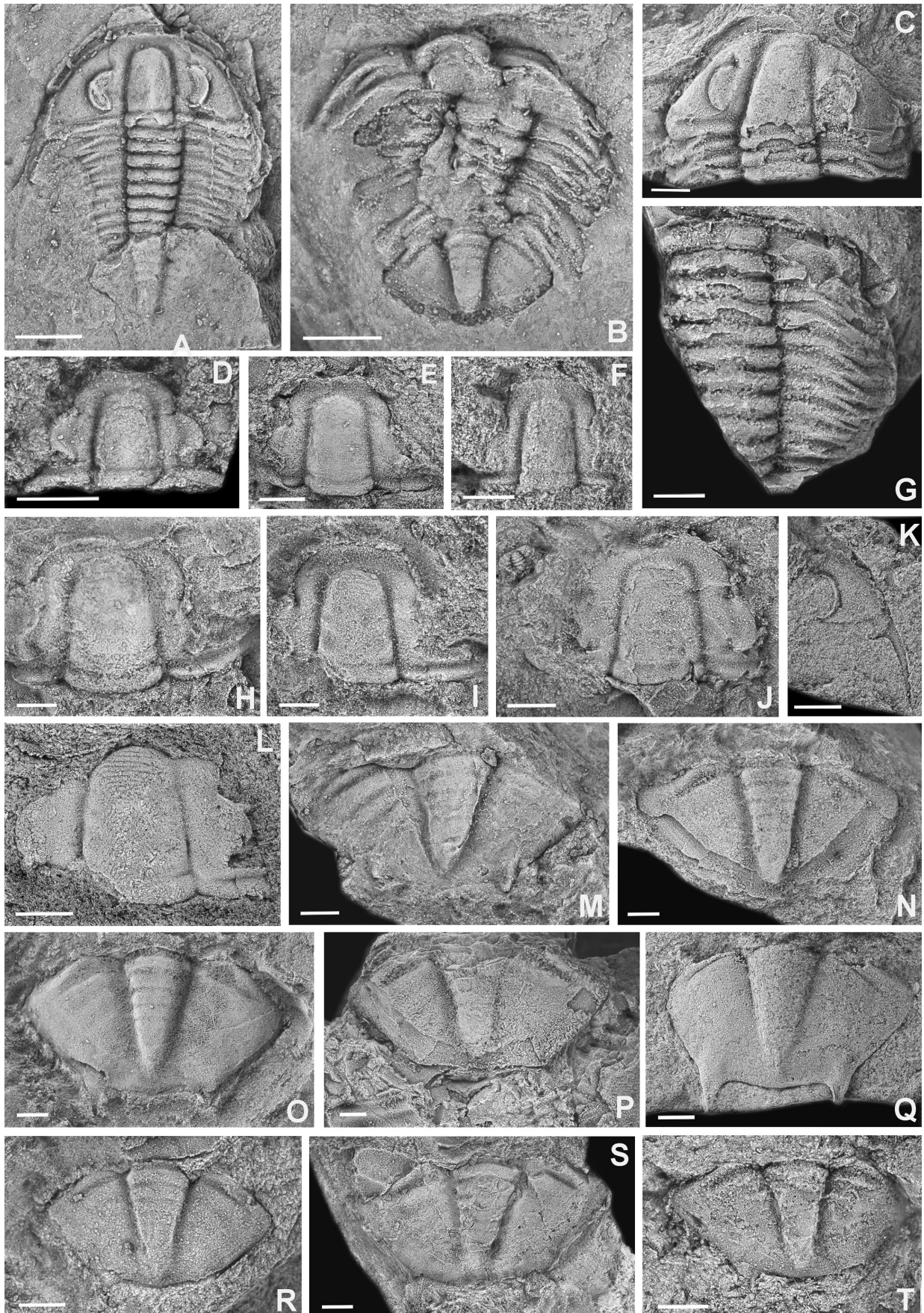
Dactylocephalus levificatus sp. nov.
Figure 7

Derivation of name. After Latin *levificatus*, smooth.

Holotype. NMW2012.45G.158.3 (Fig. 7O), internal mould of pygidium, Lower Ordovician, Tremadocian, sample MK-5/12.

Material. Sample MK-5/11, eight cranidia NMW 2012.45G.165.1 (Fig. 7J), 167, 305.1 (Fig. 7D), 311.2 (Fig. 7E), 469–473, seven pygidia NMW2012.45G.164.1 (Fig. 7P), 165.2, 168.1 (Fig. 7T), 305.1, 175.2, 474, 475; sample MK-5/12, one incomplete exoskeleton NMW2012.45G.169 (Fig. 7A), one cephalon and attached part thorax NMW2012.45G.172 (Fig. 7C), one incomplete thorax and attached pygidium NMW2012.45G.170

Fig. 7. *Dactylocephalus levificatus* sp. nov., Lower Ordovician, Tremadocian; **A**, NMW2012.45G.169, incomplete exoskeleton, sample MK-5/12; **B**, NMW2012.45G.170, incomplete thorax and attached pygidium, sample MK-5/12; **C**, NMW2012.45G.172, cephalon and attached part thorax, sample MK-5/12; **D**, NMW2012.45G.305.1, internal mould of cranidium, sample MK-5/11; **E**, NMW2012.45G.311.2, internal mould of cranidium, sample MK-5/11; **F**, NMW2012.45G.178, internal mould of cranidium, sample MK-5/12A; **G**, NMW2012.45G.173, incomplete thorax, sample MK-5/12; **H**, NMW2012.45G.176, cranidium, sample MK-5/12A; **I**, NMW2012.45G.177, cranidium, sample MK-5/12A; **J**, NMW2012.45G.165.1, cranidium, sample MK-5/11; **K**, NMW2012.45G.163, librigena, sample MK-5/12A; **L**, NMW2012.45G.319, latex cast of cranidium, sample MK-5/12A; **M**, NMW2012.45G.181, internal mould of pygidium, sample MK-5/12A; **N**, NMW2012.45G.180, internal mould of pygidium, sample MK-5/12A; **O**, NMW2012.45G.158.3, holotype, internal mould of pygidium, sample MK-5/12; **P**, NMW2012.45G.164.1, internal mould of pygidium, sample MK-5/11; **Q**, NMW2012.45G.320, latex cast of pygidium, sample MK-5/12A; **R**, NMW2012.45G.174, internal mould of pygidium, sample MK-5/12; **S**, NMW2012.45G.171, internal mould of pygidium, sample MK-5/12; **T**, NMW2012.45G.168.1, internal mould of pygidium, sample MK-5/11. All scale bars are 2 mm.



(Fig. 7B), one incomplete thorax NMW2012.45G.173 (Fig. 7G), six cranidia NMW2012.45G.192–197, two pygidia NMW2012.45G.171 (Fig. 7S), 174 (Fig. 7R), two external moulds of pygidia NMW2012.45G.199, 200, one librigena NMW2012.45G.163 (Fig. 7K); sample MK-5/12A, seven cranidia NMW2012.45G.176 (Fig. 7H), 177 (Fig. 7I), 178 (Fig. 7F), 183–186, five external moulds of cranidia NMW2012.45G.319 (Fig. 7L), 187–190, one cranidium and librigena NMW2012.45G.179, two internal moulds of pygidia NMW2012.45G.180 (Fig. 7N), 181 (Fig. 7M), two external moulds of pygidia NMW2012.45G.320 (Fig. 7Q), 191.

Diagnosis. Small size for the genus. Glabella effaced, ornamented with faint terrace ridges; two pairs of indistinct glabellar furrows can be seen only in larger specimens. Preglabellar field short (sag.), divided from the narrow (sag.) anterior border by the broad shallow border furrow. Pygidium transverse, trapezoidal in outline, with five faint axial rings and up to three weakly defined pleural ribs. Pygidial marginal spines short, stout; posterior margin between them gently convex, weakly tipped medially.

Description. Cephalon semioval, about half as long as wide (without genal spines). Cranidium transverse, sagittal length about 60–70% of posterior width. Glabella elongate, subrectangular, about three-quarters of sagittal cranidial length, almost parallel-sided, or very gently tapering anteriorly, with evenly convex anterior margin, bounded by narrow, deep axial and preglabellar furrows. Two pairs of indistinct glabellar furrows can be seen only in larger specimens (Fig. 7I). Occipital ring transverse, parallel-sided, as wide (tr.) as maximum glabella width. Occipital furrow narrow, transverse, slightly deepening abaxially. Preglabellar field short (sag.), gently convex in sagittal profile, with a narrow (sag.) anterior border and a broad shallow border furrow. Palpebral lobes large, semicircular, occupying about two-fifths of sagittal cephalic length. Palpebral furrows shallow, crescentic. Anterior branches of the facial suture slightly divergent proximally, then gradually curved inward at the level of the glabellar anterior margin to merge within the cephalic border. Posterior branches of the facial suture become almost transverse immediately posterior of the palpebral lobe termination, then turn backwards to cross the posterior border at short distance from the posterolateral cephalic margin. Surface ornament of quite widely spaced terrace lines (Fig. 7L), arranged transversely on the anterior part of the glabella and obliquely on the fixigena.

Librigenae wide, with narrow border delineated by the shallow border furrow. Genal spines long, evenly curved backwards. Hypostome unknown.

Thorax probably incomplete, with up to 11 segments preserved. Axis about one-quarter of thoracic width, bordered by narrow axial furrows. Pleural furrows shallow, wide, transverse. Pleural terminations pointed, slightly curved backwards. Facets prominent, moderately inclined forwards.

Pygidium subtrapezoidal, about three-fifths as long as wide with maximum width along the anterior margin. Axis conical, occupying about 30% of cranidial width, terminated at short distance from the posterior pygidial margin. Axial furrows deep and narrow, fading rapidly near the posterior axial termination (Fig. 7Q). Up to five faint axial rings gradually fading posteriorly visible on the internal moulds. Pleural fields gently sloping outwards, with up to three weakly defined pairs of pleural ribs more clearly expressed on the internal moulds. A pair of short, stout marginal spines with triangular bases located at the posterolateral corners of the pygidium. Posterior margin between spines gently convex, slightly tipped medially. Doublure wide (tr., sag.), ornamented by faint concentric terrace ridges.

Remarks. The new species differs from the type species *Dactylocephalus dactyloides* Hsü, 1948 in having a cranidium with the effaced glabella lacking segmentation, a shorter preglabellar field (sag.), an effaced, transverse pygidium trapezoidal in outline with axial and pleural ribs expressed mainly on the ventral side of the sclerite, and a gently convex posterior margin between marginal pygidial spines.

Dactylocephalus levificatus sp. nov. differs from *Dactylocephalus mehriae* Ghobadi Pour, 2006, which is the only other species documented from the Tremadocian of Alborz, in having significantly smaller sizes, a cranidium with a narrow (tr.) preglabellar field, a glabella almost lacking segmentation, significantly larger palpebral lobes, a transverse pygidium with weakly defined axial rings and pleural ribs, expressed mainly on its ventral side, an axis terminated in the proximity of the posterior pygidial margin and short, stout pygidial marginal spines with a gently convex posterior margin between them.

Dactylocephalus levificatus sp. nov. can be discriminated from *Dactylocephalus latus* Peng, 1990a from the upper part of the Nantsinkwan Formation (Tremadocian) of Hunan, South China and *Dactylocephalus* cf. *latus* Peng, described by Bruton et al. (2004) from the Shirgesht Formation of the Derenjaj Mountains, Central Iran, in having a more transverse anterior margin of the cranidium, a shorter (sag.) preglabellar field, a more transverse pygidium, a narrow axis, more widely spaced and shorter pygidial spines, a relatively straight posterior margin between the spines and up to three weakly defined pleural ribs instead of 4–5 in *D. latus*.

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Ordoviitsiumi fauna esmaleid Põhja-Iraanis (Mila-Kuh, idapoolne Alborz)

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Põhja-Iraani Kambriumi ja Ordoviitsiumi piirikihtide, mida traditsiooniliselt on käsitletud kui Mila kihistu 5. kihistikku, uus uurimine Mila-Kuhis tõi esmakordselt esile veenvad tõendid kihistu ülaosa vanuse kohta. Kihistikus leitud kaks järjestikust trilobiitide kooslust (*Asaphellus inflatus*–*Dactylocephalus* ja *Psilocephalina lubrica*) viitavad kihtide kuulumisele Vara-Ordoviitsiumi (Tremadoci). Mila-Kuhis leitud trilobiitide fauna on väga sarnane (isegi liigilisel tasemel) Lõuna-Hiina trilobiitidele, samal ajal kui sarnasus Kesk-Iraani Tremadoci analoogidega on vähene. Kaks kirjeldatud fossiililiiki (trilobiit *Dactylocephalus levificatus* ja brahhiopood *Tritoechia tenuis*) on teadusele uued.