Late Ordovician trilobites from the Karagach Formation of the western Tarbagatai Range, Kazakhstan

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ABSTRACT: Two trilobite faunas of late Ordovician (Sandbian and Katian) age are described from the siliciclastic Karagach Formation, western Tarbagatai Range, eastern Kazakhstan. They comprise 15 families and 24 genera and include the new taxa *Agerina acutilimbata* sp. nov., *Birmanites akchiensis* sp. nov., *Dulanaspis karagachensis* sp. nov. and *Kimakaspis kovalevskyi* gen. et sp. nov. Most of the Karagach Formation yields graptolites characteristic of the *Diplograptus foliaceus* [*multidens*] Biozone, which are associated with the older trilobite fauna; the uppermost part, which is the source of the younger trilobite fauna, contains *Orthograptus quadrimucronatus* and *Dicranograptus hians* which suggest a younger age, equating with the lowermost *Ensigraptus caudatus* Biozone, and the base of the Katian Stage. Most of the trilobite genera in both faunas have a wide geographical distribution in the late Ordovician, although *Dulanaspis* and *Sinocybele* are characteristic of low latitude eastern peri-Gondwanan faunas.

KEY WORDS: Katian, nileid biofacies, peri-Gondwana, Sandbian, taxonomy

The Tarbagatai Range lies on the border between eastern Kazakhstan and Xinjiang Province, north-western China, and is an area from which little has been published on Ordovician trilobites. The first were discovered by Vasilievsky in 1912 and were subsequently described as *Remopleurides sibiricus* by Vasilievsky *in* Weber (1948); otherwise, only three Upper Ordovician taxa, *Dindymene brevicaudata* Kolobova, 1972 from the Karagach Formation (upper Sandbian), *Dionide tarbagataica* Koroleva, 1979 (precise horizon and locality unknown) and *Pliomerina rigida* Kolobova, 1972 from the upper Kulunbulak Formation (upper Katian), have been described, whilst others remain known only from lists of preliminary identifications (e.g. Nikitin 1972), which are not always reliable. Fortey & Cocks (2003) recently reported a deep-water Caradoc trilobite fauna from the vicinity of Karagach village, which was examined by Fortey amongst extensive collections made by the late M. K. Apollonov. Part of this collection, comprising six samples derived from three levels in the siliciclastic Karagach Formation (Sandbian to lower Katian; Caradoc), is the subject of this present paper. In spite of a relatively small number of specimens, the fauna is taxonomically diverse, comprising 24 genera. The Karagach Formation has yielded graptolite faunas indicative of the *foliaceus* and *clingani* biozones (Tsai 1976), discussed below.

1. Stratigraphy and age

The section of the Karagach Formation sampled by the late Mikhail Apollonov is situated about 35 km east of the town of Ayaguz, on the east side of the Ayaguz River, about 7 km north of Akchii village (Figs 1, 2). According to Nikitin (1972, p. 206, text-fig. 69), the Karagach Formation overlies a discontinuous sequence of fine siliciclastic rocks belonging to the Middle Ordovician Naiman Formation, and underlies the Upper Ordovician Zhartas Formation, which comprises andesitic volcanic rocks and tuffs with units of volcaniclastic sandstones and argillites. Tsai (1976) estimated the thickness of the Karagach Formation to be over 1200 m, and subdivided it into four informal units (see Figs 2–3) which in ascending order are: (1) limestones about 10 m thick; (2) dark grey siltstones with a few beds of fine-grained sandstones about 200 m thick; (3) alternating sandstones and siltstones about 130 m thick; (4) siltstones about 675 m thick with a few beds of sandstones and calcareous siltstones in the uppermost 30 m of the unit.

Graptolites occur sporadically in the sequence, and were described by Tsai (1976). They provide relatively good age constraints for the trilobite faunas, and have been recovered from all three fossiliferous horizons in the Karagach Formation. Those from the two lower ones (samples 201, 202, 205) are considered to be indicative of the *Diplograptus foliaceus* [*multidens*] Biozone. Sample 201 (unit 2) has yielded *Dicranograptus ramosus* (Hall, 1847), *D. nicholsoni diapason* Gurley, 1896, *Pseudoclimacograptus scharenbergi* (Lapworth, 1876), *Hustedograptus teretiusculus* (Hisinger, 1840) and *Diplograptus diminutus* (Ruedemann, 1947); samples 202 and 205 (unit 3) have yielded *Pseudoclimacograptus scharenbergi* and *Dicranograptus* sp. From the top of unit 4 of the Karagach Formation, samples 203, 203a, 203b have yielded *Orthograptus quadrimucronatus* (Hall, 1865) and *Dicranograptus hians* (Hall, 1905). These two species occur together at the base of the *Ensigraptus caudatus* Biozone at the Black Knob Ridge section, Oklahoma, the stratotype section for the base of the Katian Stage (Goldman *et al.* 2007).

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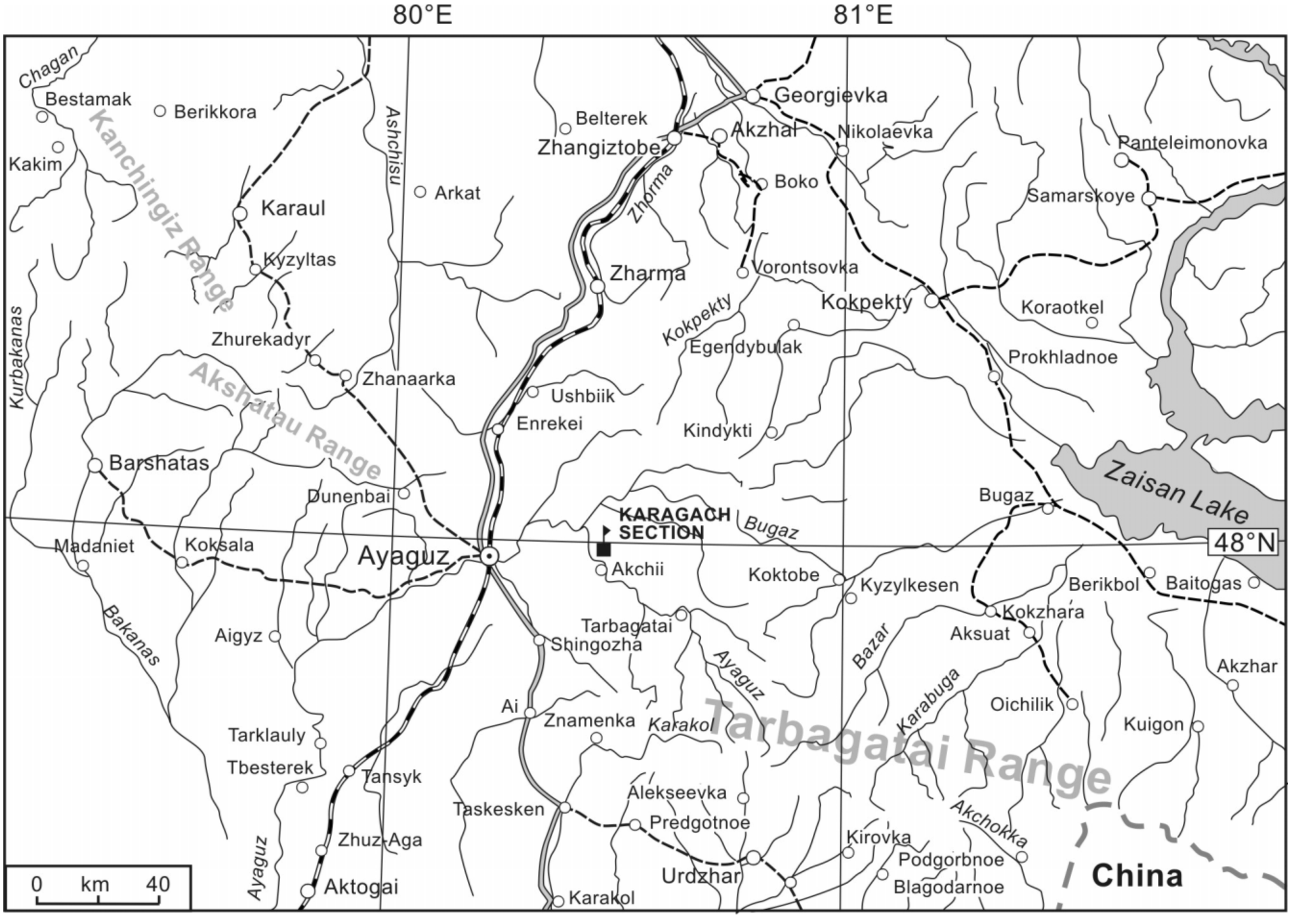

Figure 1 Part of eastern Kazakhstan, showing position of the Karagach section in the western Tarbagatai Range.

The two trilobite assemblages in the Karagach Formation occur at three levels; both are considered to be characteristic of outer shelf environments. The lower one, from units 2 (sample 201) and 3 (samples 202 and 205) includes the pelagic cyclopygids *Cyclopyge*, *Microparia* (*Heterocyclopyge*) and *Symphysops*, which co-occur with *Dindymene*, *Dionide*?, *Dulanaspis*, *Raphioampyx*?, *Shumardia* and a trinucleid (*Kimakaspis* gen. nov.). This association indicates a somewhat deeper environment from that of unit 4. However, neither association includes three-segmented raphiophorids, which are otherwise widespread in deep water environments across eastern Kazakhstanian terranes.

The upper part of unit 4 (samples 203, 203a, 203b) contains a medium diversity trilobite assemblage which includes the genera *Agerina*, *Amphilichas*, *Ceraurinella*?, *Dulanaspis*, *Illaenus*, *Nileus*, *Remopleurides*, *Stenopareia*, *Sphaerocoryphe* and *Sinocybele*, which may represent a nileid biofacies. This fauna occurs together with a brachiopod assemblage dominated by *Christiania*, in association with *Acculina*, *Glyptambonites* and *Leptaena* (*Ygdrasilomena*) among others.

2. Significance of the fauna

In their brief review of the trilobite assemblage from the Karagach Formation, Fortey & Cocks (2003) pointed out that it includes geographically widespread taxa (e.g. *Dionide*, ?*Raphioampyx*, *Shumardia*, *Eodindymene*, *Microparia* and *Cyclopyge*), and this is true mainly for the lower assemblage from the *Diplograptus foliaceus* [*multidens*] Biozone. The assemblage from the uppermost Karagach Formation contains, among other taxa, *Dulanaspis* and *Sinocybele* which, together with the occurrence of *Pliomerina* reported by Kolobova (1972) from the somewhat younger Kulunbulak Formation, is clear evidence of affinity with the mid to late Ordovician 'eastern' peri-Gondwanan *Eokosovopeltis*–*Pliomerina* fauna, distributed through central Asia, the Taurides in Turkey, Tarim, North and South China, Sibumasu and eastern Australia (Zhou & Zhou 2006, p. 387; Edgecombe & Webby 2006, p. 414). The latter authors (2006, p. 414) noted that *Sinocybele* should be regarded as an additional biogeographically sensitive indicator of this fauna.

Most of the genera recorded from the Karagach Formation also occur in other parts of Kazakhstan; in particular, they are known from the Anderken and Dulankara formations of Chu-Ili Range (Chugaeva 1958) and from the approximately contemporaneous Besharyk (=Ichkebash) Formation of the Dzhebagly Mountains (Kolova 1936). However, biofacies differentiation of late Ordovician trilobite faunas of Kazakhstan remains poorly understood, which makes further comparison difficult. There is little doubt, however, that all these faunas belong to separate early Palaeozoic terranes (Fortey & Cocks 2003, Popov *et al.* 2009) and typical Kazakhstanian genera such as *Birmanites* and *Dulanaspis* are represented in the assemblage from the Karagach Formation by local endemic species.

A small trilobite fauna described by Kolobova (1983) from the Anderken Regional Stage of Koryk and Malkeldy in the Chingiz Range contains one species (*Encrinuroides septemcostatus* Kolobova) which is probably common to the Karagach Formation, but the species of *Nileus* from that assemblage is different, and there are no other genera in common.

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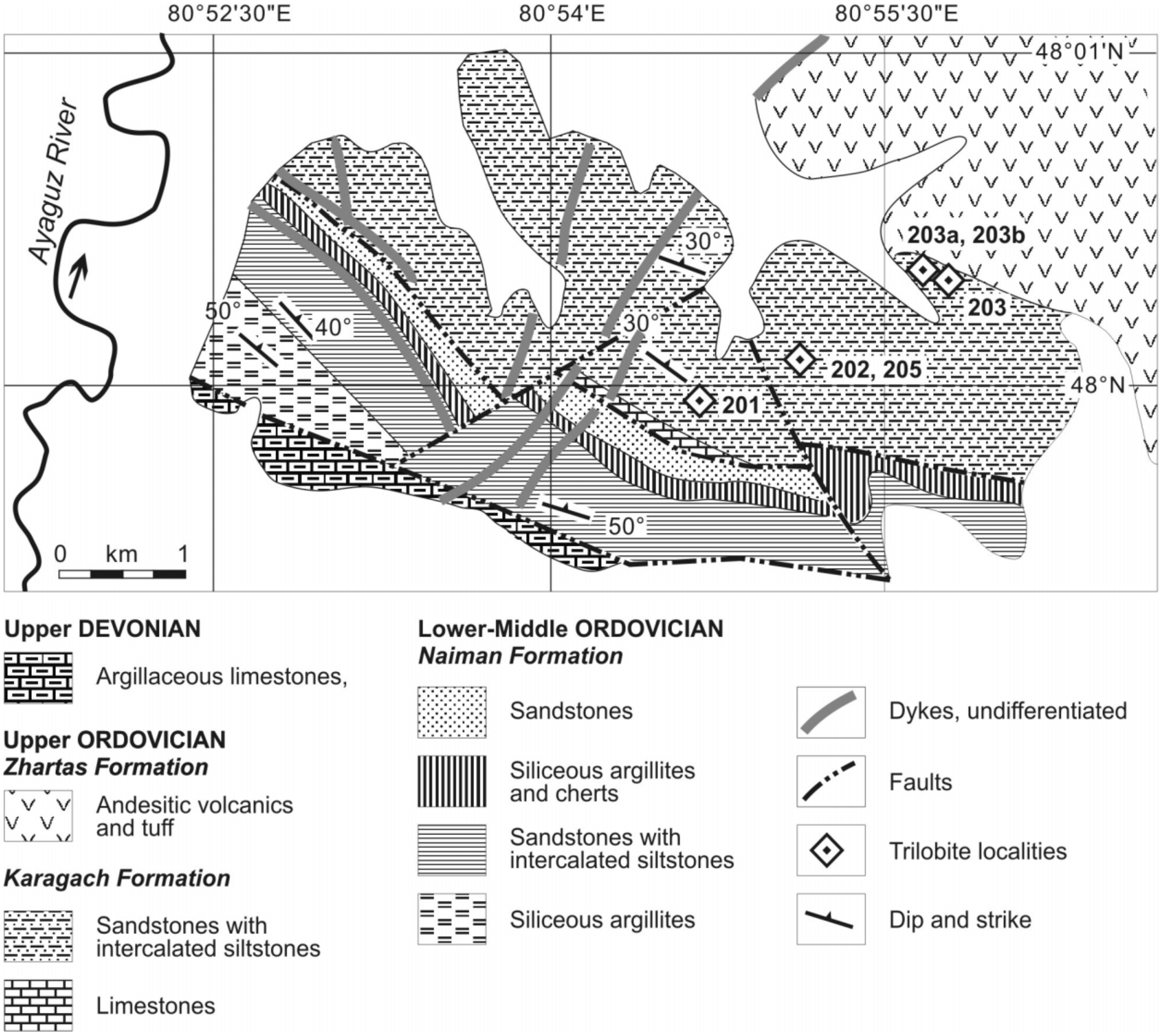

Figure 2 Schematic geological map of the area east of Ayaguz River showing distribution of the Middle to Upper Ordovician rocks and the positions of fossil localities (modified from Nikitin, 1972).

3. Systematic palaeontology

Most of the specimens are deposited in the Department of Geology, National Museum of Wales, Cardiff (NMW, Accession number 2005.32G). Some illustrated and referred type specimens are deposited in the F. N. Chernyshev Central Geological Scientific Research and Exploration Museum (CNIGR), St Petersburg. The terminology and systematic classification follows Whittington & Kelly (*in* Kaesler 1997).

Measurements are in millimetres. Abbreviations: L=length of exoskeleton, Cl, Cw=cranidial length and width; CPl, CPw=cephalic length and width; Gl, Gw=glabellar length and maximum width; GPw=posterior glabellar width; ORl=sagittal length of occipital ring; Pl, Pw=pygidial length and width; PAl, PAw=pygidial axis length and width.

Family Shumardiidae Lake, 1907
Genus *Shumardia* Billings, 1862

Type species. *Shumardia granulosa* Billings, 1862, Middle Ordovician, Darriwilian Stage, *Shumardia* Limestone, Québec, Canada.

Remarks. Following Waisfeld *et al*. (2001), *Shumardia* and *Conophrys* are considered to be separate genera, and *Shumardoella* Pek & Vaněk, 1989 is regarded as the junior subjective synonym of *Shumardia*.

Shumardia aff. *extensa* Weir, 1959
(Fig. 4a–h)

aff. 1997 *Shumardia* (*Shumardoella*) *extensa* Weir; Hammann & Leone, p. 44, pl. 4, figs 1–8.

Material. NMW 2005.32G.259, exoskeleton, internal mould (L, 5·0, Cl, 1·8, Pl, 1·9, PAl, 1·25); NMW 2005.32G.261, NMW 2005.32G.262 (Cl, 1·6, Cw, 2·6, Gw, 1·5, GPw, 1·0, ORl, 0·4), cranidia, internal moulds; NMW 2005.32G.260, pygidium with thorax, internal mould; NMW 2005.32G.264, pygidium, internal mould (Pl, 1·6, Pw, 2·4, PAl, 1·1, PAw, 1·0); all from sample 201. NMW 2005.32G.147, cephalon with thorax, internal mould (Cl, 1·9, Cw, 2·9, Gw, 1·7); NMW 2005.32G.148, pygidium, internal mould; both from sample 205.

Description. Cranidium semioval, about 65% as long as wide. Glabella about 60% as wide as cranidium, with maximum width at about one quarter glabellar length from the anterior margin, comprising not more than 150% of posterior glabellar width. Axial furrows deep, shallowing near anterior margin of glabella. Preglabellar furrow weakly defined. Anterolateral glabellar lobes separated from rest of glabella by very shallow, anteromedially directed glabellar furrows fading anteriorly, their posterior margins situated at about mid-length

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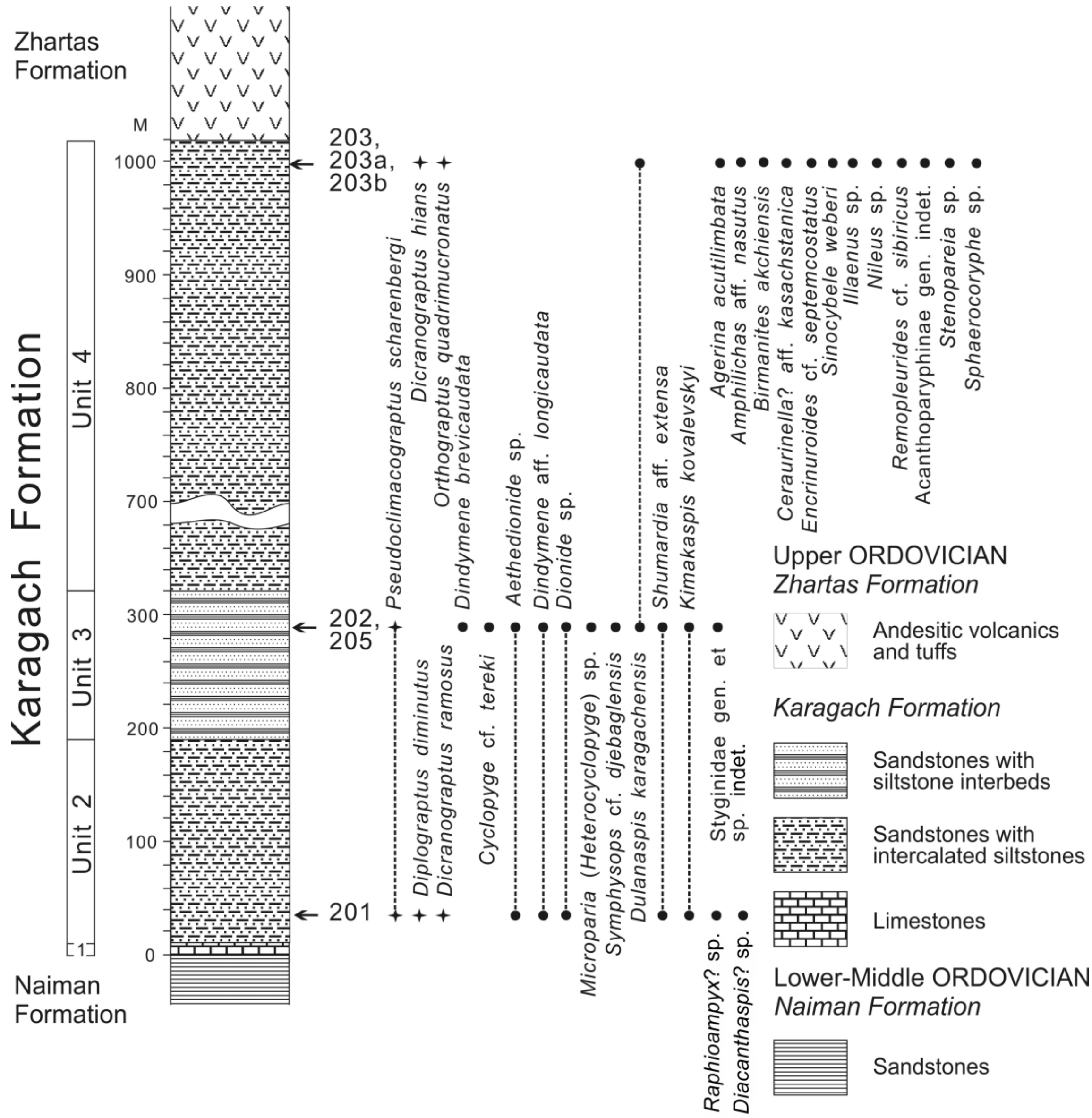

Figure 3 Stratigraphical section through the Upper Ordovician deposits on the eastern side of Ayaguz River, showing the horizons of the fossil localities (numbers as in Fig. 2) and stratigraphical ranges of trilobite and graptolite species.

of the cranidium and their width (trans.) almost equal to occipital ring length (sag.). S1 short (trans.), curved, defining small bacculae. Occipital ring occupying about 20–25% of cranidial length, with a straight, transverse posterior margin, separated from the glabella by a narrow, straight occipital furrow. Preglabellar field very short (sag.). Fixigenae subtriangular with posterior border slightly widening (exsag.) abaxially and a straight posterior margin slightly inclined posteriorly abaxially. Posterior border furrow transverse, narrow. Librigenae and hypostoma unknown.

Thorax of six segments with wide axis, about half as wide (tr.) as thoracic segments and lacking a macropleural segment.

Pygidium parabolic, about 65% as long as wide, with axis occupying up to 45% of maximum pygidial width and up to 70% of pygidial length. Axis subconical, with four axial rings separated by deep, transverse ring furrows, deepening abaxially, and a terminal piece. Axial furrows deep, converging posteriorly. Pleural fields gently convex with four pairs of pleural ribs separated by weakly defined pleural furrows, fading abaxially. Doublure wide (sag.), occupying almost one third of pygidial length.

Remarks. The morphology of *Shumardia* aff. *extensa*, including the presence of distinct bacculae, the absence of a macropleuric thoracic segment, an elongate pygidium with an axis not extending to the margin, and a curved convex posterior pygidial margin, are diagnostic for *Shumardia* (for details see Waisfeld *et al.* 2001). In their cranidial and pygidial morphology, they are almost identical to those described from Sardinia by Hammann & Leone (1997) from the Cyclopygid Bed of the Punta S'Argiola Member of the Domusnovas Formation (Katian) as *Shumardia* (*Shumardoella*) *extensa* Weir, 1959, and they may well be conspecific. However, the attribution of the specimens from Kazakhstan and Sardinia to this species is questionable, because the original description of *S. extensa* is based on a single cranidium.

Shumardia aff. *extensa* differs from the type species, *S. granulosa* Billings, 1862 revised by Whittington (1965), in having a more elongate cranidium, a larger glabella with evenly rounded anterior margin, and smaller anterolateral lobes not strongly projecting laterally, a preglabellar field lacking a median depression, and a parabolic pygidial outline with only four axial rings. *Shumardia* aff. *extensa* is similar to

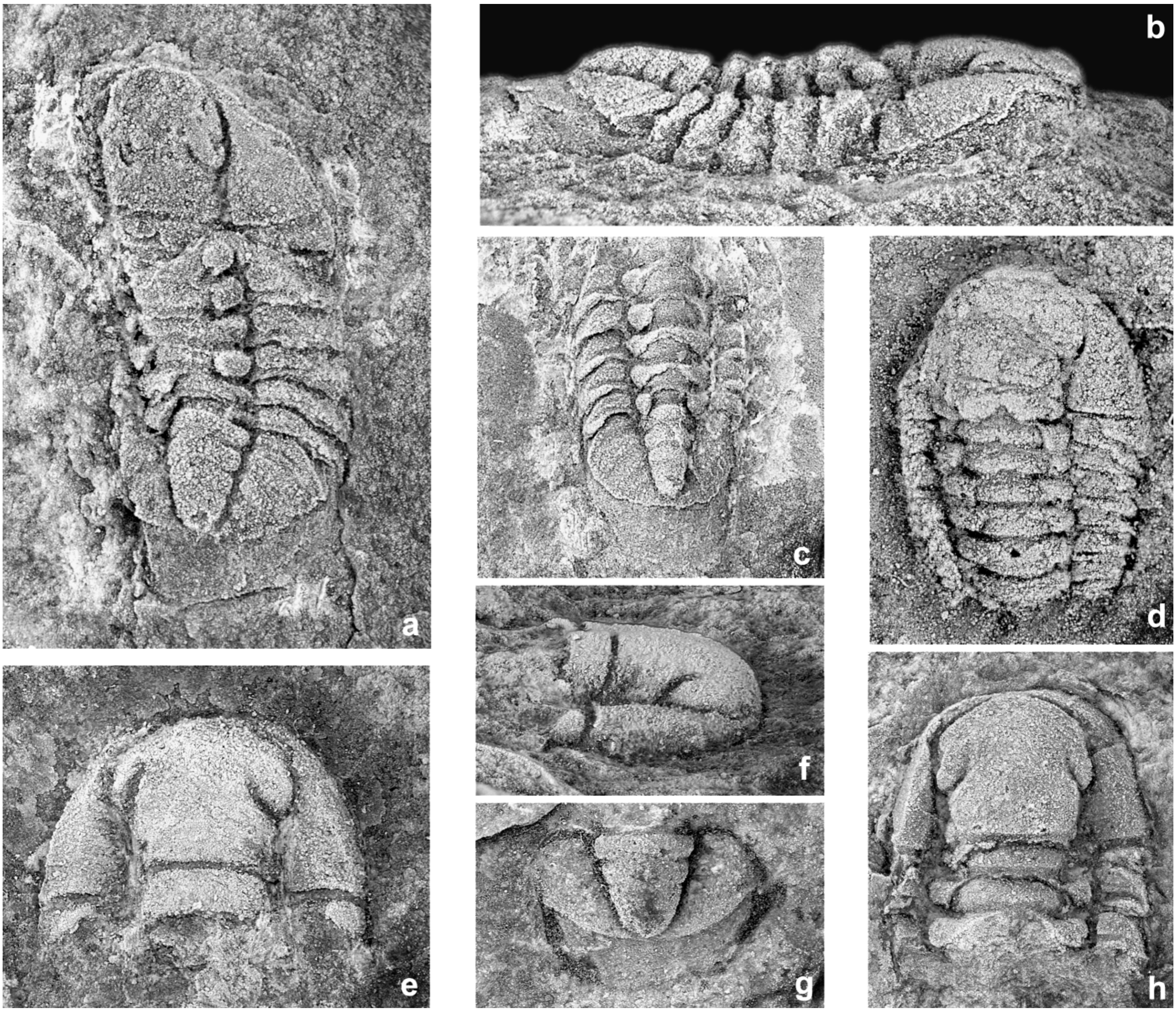

Figure 4 *Shumardia* aff. *extensa* Weir, 1959: (a–b) NMW 2005.32G.259, incomplete exoskeleton, internal mould, dorsal and lateral views, × 15, × 16, sample 201; (c) NMW 2005.32G.260, pygidium with attached thoracic segments, internal mould, × 9, sample 201; (d) NMW 2005.32G.147, cranidium with attached thorax, internal mould, × 13, sample 205; (e–f) NMW 2005.32G.261, cranidium, internal mould, dorsal and lateral views, × 22, sample 201; (g) NMW 2005.32G.148, pygidium, internal mould, × 16, sample 205; (h) NMW 2005.32G.262, cephalon with two thoracic segments, internal mould, × 15, sample 201.

S. lacrima Koroleva, 1964 from the late Sandbian/early Katian Mailisor Formation of northern Kazakhstan, but has a more elongate cranidium, a shorter (sag.) occipital ring, a distinctly wider pygidium with a shorter pygidial axis bearing only three axial rings (instead of six), and a smaller number of pygidial pleural ribs (three pairs instead of six). This species differs from *S. analoga* Koroleva, 1964, also from the Mailisor Formation, in having an evenly rounded anterior cranidial margin, a wider glabella with anterolateral glabellar lobes which terminate posteriorly at cranidial mid-length, a very short preglabellar field, fixigenae with a subtriangular (not subrectangular) outline, and a shorter pygidial axis with only three axial rings.

Shumardia aff. *extensa* differs from *S. tarimuensis* Zhang, 1981 from the Saergan Formation (upper Darriwilian to lower Sandbian) of Tarim and the Chedao Formation (lower Sandbian) of north-western China (Zhou & Dean 1986) in having a more elongate cranidium with a very narrow preglabellar field and evenly rounded anterior glabellar furrow, a significantly wider glabella with smaller anterolateral glabellar lobes, fixigenae with a subtriangular outline, and a pygidium with a suboval, not subtriangular outline.

Family Leiostegiidae Bradley, 1925
Genus *Agerina* Tjernvik, 1956

Type species. *Agerina erratica* Tjernvik, 1956; Lower Ordovician, Floian Stage, Billingen Regional Stage, Latorp Formation, Närke, Sweden.

Agerina acutilimbata sp. nov.
(Fig. 5a–c)

Derivation of name. From the pointed anterior margin of cranidium.

Holotype. NMW 2005.32G.135, articulated exoskeleton, external mould (L, 6·4, W, 3·9); sample 203a.

Paratypes. NMW 2005.32G.137, partly disarticulated exoskeleton, external mould (CPl, 2·8, CPw, 3·5, Gl, 2·1, Gw, 1·4); NMW 2005.32G.138, cranidium, internal mould (Cl, 2·4,

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Cw, 2·8, Gl, 2·1, Gw, 1·4); NMW 2005.32G.139, pygidium, external mould (Pl, 1·4, Pw, 2·0, PAl, 1·5, PAw, 0·5); sample 203.

Diagnosis. Cephalon semioval, about 80% as long as wide; elongate, parallel axial furrows with evenly rounded anterior margin confined to the anterior border furrow; three pairs of very weakly defined glabellar furrows; occipital ring transverse with a small median tubercle; convex cephalic border of equal width with short median spine; medially (exsag.) situated palpebral lobes about 25% of cephalic length; eight thoracic segments, and pygidium with conical axis about 35% of maximum pygidial width, four axial rings and very short terminal piece; pleural fields with three to four pairs of ribs; border narrow, fading posteriorly abaxially.

Description. Exoskeleton elongate suboval, about 165% as long as wide with maximum width at the posterior margin of the cephalon, and lateral margins converge gently posteriorly. Cephalon semioval, about 80% as long as wide. Cranidium about 85% as long as wide with a strongly convex, elongate subrectangular glabella. Glabellar furrows short (tr.), very weakly defined; S1 oblique, and define very small subtriangular L1; S2 situated at about glabellar mid-length; S3 opposite anterior termination of palpebral lobes. Frontal margin of glabella gently rounded, almost confined to anterior border furrow. Occipital ring strongly convex, transverse, with a small median tubercle; occipital furrow narrow, deep and transverse. Cephalic border convex, of constant width, bearing a short, subtriangular median spine, defined by a deep and narrow border furrow. Postocular fixigena short (exsag.), narrows abaxially with bluntly rounded lateral termination. Palpebral lobes semioval, maximum length (exsag.) about 25% that of cephalon (sag.), with posterior termination at about 30% cephalic length from the posterior margin. Preocular facial sutures slightly divergent anteriorly. Librigenae wide (tr.) and convex, with a short (tr.) posterior border. Genal spines present but poorly preserved.

Thorax with eight segments. Axis about 35% of thoracic width, pleurae long (exsag.) with a wide and deep pleural furrow, tapering and terminating at inner margin of facet. Outer portion of pleura bends posteroventrally, and terminates with a rounded distal extremity; prominent facet present on the anteriolateral part of pleura, about 50% of its width (tr.).

Pygidium small, transverse, semioval, about 60% as long as wide with a conical axis occupying about 35% (tr.) of the anterior margin and about 75% (sag.) of pygidial length. Axis with four rings and a small terminal piece, defined by deep axial furrows, slightly converging posteriorly. Posteriormost axial ring very short (sag.) and separated from a short terminal piece of about equal length by a very faint axial furrow. Pleural field with three to four pairs of pleural ribs, slightly curved backwards and bisected by faint interpleural furrows. Pleural furrows deep and narrow. Border narrow, fading anteromedially, separated from the pleural field by a shallow, weakly defined border furrow.

Remarks. In their revision of *Agerina*, Adrain & Fortey (1997) suggested that this generic name should be applied to taxa which have a parallel-sided glabella with effaced glabellar furrows, and a pygidial border ornamented by subparallel, raised terrace ridges, similar to the type species and to *Agerina pamphylica* Dean, 1973 from the Middle Ordovician Sobova Formation of the Taurus Mountains, southern Turkey. In its cephalic morphology, *A. acutilimbata* sp. nov. is similar to this group of species, but the short median spine on the anterior margin of the anterior cranidial border is unique for *Agerina*. *A. acutilimbata* differs from *A. pamphylica* in having very poorly defined glabellar furrows and a granulose, not pitted ornament on the cranidium and librigenae.

Family Asaphidae Burmeister, 1843
Subfamily Asaphinae Burmeister, 1843
Genus *Birmanites* Sheng, 1934

Type species. *Ogygites birmanicus* Reed, 1915; Upper Ordovician, Sandbian Stage, Hwe Mawng Beds, northern Shan States, Burma.

Species assigned. In addition to the type species, the genus includes: (1) *Birmanites hupeiensis* Yi, 1957, Middle Ordovician Miapo and Shihtzupu formations, south China; (2) *Niobe lata* Angelin, 1851, Katian Stage, Jonstorp Formation, Västergötland, Sweden (Kielan 1960) and Şort Tepe Formation, south-east Turkey (Dean & Zhou 1988); (3) *Ogygites pamiricus* Balashova, 1966, upper Darriwilian Stage, Kozynsdy Formation, eastern Pamir, Tajikistan; (4) *Opsimasaphus asiaticus* Petrunina *in* Yaskovich & Repina, 1975, Upper Ordovician olistolith, Madygen, Turkestan Range, Kyrgyzstan; (5) *Ogygites kolovae* Chugaeva, 1958, lower Katian Stage, Dulankara Formation, Chu-Ili Range, Kazakhstan; (6) *Ogygites almatiensis* Chugaeva, 1958, Sandbian Stage, Anderken Formation, Chu-Ili Range, Kazakhstan; (7) *Ogygites* sp., Abdullaev *in* Abdullaev & Khaletskaya, 1970, Upper Ordovician, Beshtor Formation, Pskem Range, Uzbekistan.

Birmanites pamiricus Balashova, 1966, from the Tremadocian Stage of eastern Pamir, Tajikistan is based on a single poorly preserved external mould of a cephalon, and its precise generic attribution cannot be made (Balashova 1966, p. 208, pl. 3, fig. 9). Therefore, this taxon is considered here as a *nomen dubium*. However, the binomen *Birmanites pamiricus* Balashova, 1966, is a senior homonym of *Ogygites pamiricus* (see Balashova 1966, p. 215) because the latter is a valid species of *Birmanites*.

Birmanites akchiensis sp. nov.
(Fig. 7a–e)

Derivation of name. From Akchii village south of the type locality.

Holotype. NMW 2005.32G.181, external mould of cranidium (Cl, 26·6, Cw, <30·3, Gl, 14·6, Gw, 16·6); sample 203b.

Paratypes. NMW 2005.32G.182, librigena, external mould, sample 203b; NMW 2005.32G.183, hypostome, internal mould, sample 203a; NMW 2005.32G.184, pygidium, external mould (Pl, 39·0, PAl, 26·7, PAw, 26·70), sample 203b; NMW 2005.32G.185, pygidium, internal mould (Pl, 40·3, PAl, 26·5, PAw, 10·8), sample 203b; NMW 2005.32G.200, pygidium, internal mould, sample 203a.

Diagnosis. Cranidium of about equal length and width, with broadly and evenly rounded anterior margin; preglabellar field smooth, with very weakly expressed longitudinal median ridge; pygidium about 70% as long as wide, with axis occupying 20% of pygidial width and 75% of maximum pygidial length, and terminating with a short postaxial ridge; axial furrows are shallow and wide, almost straight; 12 well-defined axial rings; pleural field flattened, with six pairs of pleural ribs which do not reach border.

Description. Cranidium as long as wide with maximum width at posterior margin, only slightly exceeding maximum width of preglabellar field. Anterior margin evenly curved. Surface covered by a Bertillon pattern of terrace ridges. Glabella gently convex, about 60% cranidial length (sag.) and 35% its width (tr.), with maximum width at occipital ring. Axial furrows shallow and narrow, shallowing in front of palpebral lobes. S1 transverse, deep and wide, situated opposite mid-length of palpebral lobe, distally directed backwards,

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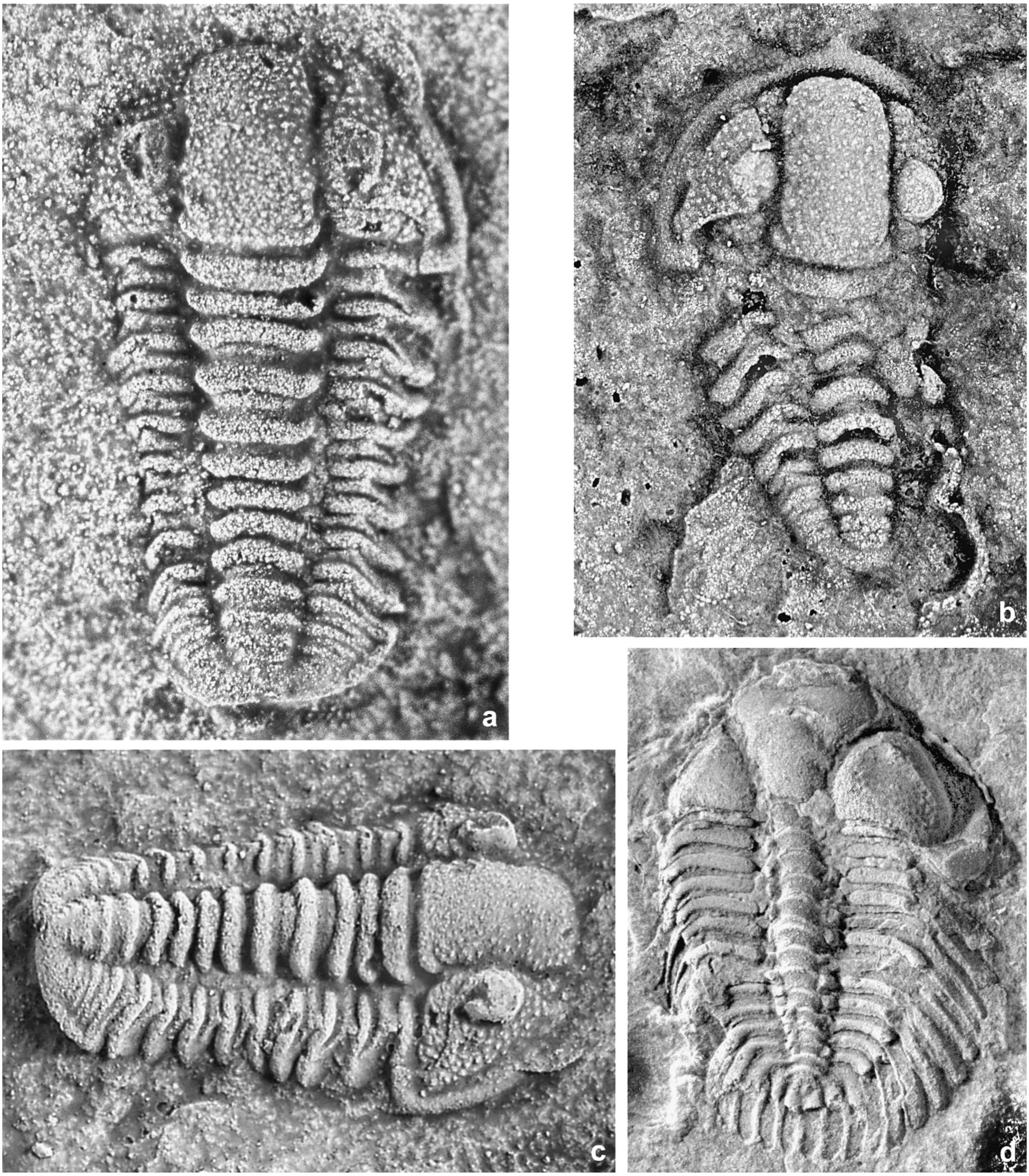

Figure 5 (a–c) *Agerina acutilimbata* sp. nov.: (a, c) NMW 2005.32G.135, holotype, articulated exoskeleton, latex cast of external mould, dorsal and oblique views, × 19, × 15, sample 203a; (b) NMW 2005.32G.137, paratype, partly disarticulated exoskeleton, latex cast of external mould, × 15, sample 203. (d) *Dindymene brevicaudata* Kolobova: NMW 2005.32G.177, articulated exoskeleton, internal mould, dorsal view, × 9, sample 201.

but not reaching occipital furrow, and partially defining subtriangular L1. S2 shallow and wide, situated opposite anterior end of palpebral lobe. Preoccipital tubercle present between first lateral glabellar lobes (L1). Occipital furrow narrow, deepens abaxially. Occipital ring slightly wider than preoccipital glabella, and about 15% glabellar length (sag.). Palpebral lobes semicircular, very large, about 20% cranidial length (exsag.) and situated towards posterior end of cranidium. Postocular fixigena wide (tr.) and very short (exsag.), with a shallow and narrow posterior furrow and relatively broad (exsag.) posterior border, widening abaxially. Preocular fixigenae very long (sag.) and wide (tr.), about 35% of cranidial length and about 90% of maximum cranidial width (tr.). Palpebral area of fixigena reaches same height as glabella; palpebral furrow shallow and wide, strongly curved (exsag.), separating a prominent palpebral rim from the rest of the palpebral area. Preocular facial sutures at first only slightly divergent, then strongly diverging before finally curving

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anteromedially. Postocular facial sutures strongly divergent to almost transverse.

Librigenae wide with broadly convex lateral margin and a broad, flat subtriangular genal spine directed backwards. Eye socle low, ridge-like, separated from rest of librigena by a very shallow furrow. Surface of librigenae covered with fine concentric terrace ridges. Doublure very wide, with subparallel terrace ridges.

Hypostome elongate, about 80% as wide as long, with a gently convex anterior margin. Anterior wings very small, curved dorsally. Anterior lobe of middle body subquadrate, slightly convex. Well-defined maculae at beginning of middle furrows, at posterolateral angles of the middle body. Middle furrows deep and wide, merge posteriorly to create transverse furrow. Posterior lobe of the middle body transverse, gently convex with an effaced posterior border furrow. Posterior border deeply cut by a large U-shaped notch; posterior fork broad-based, pointed posteriorly. Posterolateral regions elongate subtriangular, with lateral margins almost posteriorly directed. Lateral borders flattened, widening posteriorly. Border furrows deep and wide. Surface covered by fine transverse terrace ridges. Thorax unknown.

Pygidium semielliptical, about 70% as long (sag.) as wide (tr.). Axis narrow, conical, with 12 axial rings and a very small terminal piece. Axis about 20% of maximum pygidial width and about 75% of pygidial length. Axial furrows shallow and wide, almost straight, converging posteriorly. A short post-axial ridge is recognisable. Pleural field flattened with six pairs of flat pleural ribs, widening abaxially and shallowing and dying out towards border. Anteriormost three pairs curved gently backwards; three posterior pairs almost straight and run posterolaterally. Pleural furrows shallow and wide. Doublure very wide, extending to axial termination posteriorly and very close to axial furrows laterally. Surface of pygidium and doublure is covered by coarse terrace ridges, which are subparallel laterally and convex posteriorly.

Remarks. This species is most similar to *B. kolovae* (Chugaeva, 1958, p. 39, pl. 3, figs 9–16; text-fig. 6), but is easily distinguished by having an evenly rounded rather than pointed anterior cranidial margin, and a less transverse pygidium with a longer axis bearing 12 axial rings. *Birmanites akchiensis* differs from *B. almatyensis* (Chugaeva, 1958, p. 42, pl. 4, figs 1–6; text-fig. 8) in possessing a very weak median ridge bisecting the preglabellar field, in having a rounded anterior cranidial margin and a less transverse pygidium bearing a short postaxial ridge. It differs from *B. hupeiensis* Yi, 1957 in the absence of a prominent medial longitudinal ridge on the preglabellar field, in having a longer glabella, a pygidium with almost straight axial furrows and 12 well defined axial rings. Incomplete preservation of the cranidium in *B. asiaticus* (Petrunina *in* Yaskovich & Repina, 1975) makes it difficult to compare it with *B. akchiensis* in cephalic morphology, but the new species clearly differs from the former in having a pygidium with a narrow axis ending with a short post-axial ridge and bearing 12 axial rings, and in possessing a flattened pleural field with only six (instead of eight) pairs of pleural ribs. The pygidium of *B. akchiensis* shows similarities in the number of axial rings and pleural ribs to the specimens from Pamir described by Balashova (1966) as *Ogygites pamiricus*. However, it differs from the latter in having a more elongate pygidium and pleural ribs that terminate some distance from the border. More detailed comparison with *O. pamiricus* is impossible due to significant deformation of the specimens, poor illustrations and schematic description. *B. pamiricus* described by Balashova in the same paper does not appear to be conspecific with *Ogygites pamiricus* (see above).

Family Cyclopygidae Raymond, 1925
Subfamily Cyclopyginae Raymond, 1925
Genus *Cyclopyge* Hawle & Corda, 1847

Type species. *Egle rediviva* Barrande, 1846; Upper Ordovician, Sandbian Stage, Beroun Series, Vinice Formation, Beroun, Czech Republic.

Cyclopyge cf. *tereki* Koroleva, 1967
(Fig. 7j–k, m)

?1982 *Cyclopyge quadrangularis* Kielan; Koroleva, p. 117, pl. 24, figs 1–5 [*non* Kielan 1960, p. 83, pl. 9, figs 1–9]

Material. NMW 2005.32G.186, cephalon with attached thorax, internal mould (CPl, 6·5, CPw, 3·7); NMW 2005.32G.203–206, cranidia, internal moulds; NMW 2005.32G.187, pygidium with attached thorax, internal mould (Pl, 1·9, Pw, 5·3, PAl, 0·8, PAw, 5·6); NMW 2005.32G.188, pygidium with attached thorax, external mould (Pl, 1·8, Pw, 4·1, PAl, 1·0, PAw, 1·1); NMW 2005.32G.207–208, pygidia with attached thorax, external moulds; all sample 205. NMW 2005.32G.201, 202, pygidia with attached thoracic segments, internal moulds; NMW 2005.32G.209, axial shield, internal mould; all sample 201.

Description. Cranidium with subcircular outline, glabella 95% as long (sag.) as wide (trans). Shallow S1 inclined gently backwards, and lies about one third of the way forwards from posterior margin of glabella. Thorax with six segments, axis tapering gently backwards. Pygidium transverse, 40–45% as long (sag.) as wide (trans.), although these values are approximate due to some distortion. Axis with blunt termination, with one ill-defined ring. Weak first pleural furrow, otherwise pleural areas smooth. Ill-defined, broad, weakly convex border. No postaxial ridge.

Remarks. This species is similar to *Cyclopyge tereki* from the Sandbian Stage of north-east Kazakhstan (Koroleva 1967, p. 89, pl. 10, figs 15, 16; 1982, p. 115, pl. 23, figs 8–11) in having one ill-defined ring on the pygidial axis, but differs in being more transverse in outline, having a less well-defined pygidial border, and lacking a postaxial ridge. *Cyclopyge umbonata bohemica* Marek (1961, p. 22, pl. 1, figs 6–9) from the Darriwilian Dobrotivá Formation, Prague district, Czech Republic, also has only one, very ill-defined pygidial axial ring, and has a shallow border furrow, but has a proportionately longer (sag.) postaxial area. The specimens described here resemble those from the Tarbagatai Mountains described by Koroleva (1982, p. 117, pl. 24, figs 1–5) as *Cyclopyge quadrangularis* Kielan. The figures are dark and difficult to interpret, but the pygidium in her fig. 1B has a similar outline to that of the present specimens, the axis lacks well-defined rings, and a trace of a weak pygidial border can be seen on the right hand side. These Tarbagatai Mountains specimens are possibly conspecific with *C* cf. *tereki*. They are not conspecific with *C. quardangularis* (Kielan 1960, p. 83, pl. 9, figs 1–9) from the *Staurocephalus clavifrons* Zone (Katian Stage) of the Holy Cross Mountains, Poland, which differs in that the glabella is more elongated, with S1 closer together and closer to the posterior (Kielan 1960, pl. 9, figs 6, 7) and the pygidium has a more tapered axis with one ring clearly defined (Kielan 1960, pl. 9, fig. 7).

Genus *Microparia* Hawle & Corda, 1847

Type species. *Microparia speciosa* Hawle & Corda, 1847 from Upper Ordovician, Katian Stage, Králův Dvůr Formation, Králův Dvůr, Czech Republic.

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Subgenus *Heterocyclopyge* Marek, 1961

Type species. *Cyclopyge pachycephala* Hawle & Corda, 1847 from Upper Ordovician, Sandbian Stage, Vinice Formation, Trubín near Beroun, Czech Republic.

Microparia (*Heterocyclopyge*) sp.
(Fig. 7l)

Material. NMW 2005.32G.189, pygidium, internal mould (Pl, 4·6, Pw, 6·5, PAl, 2·6, PAw, 2·6), sample 205.

Remarks. The distinctive triangular pygidial axis with three well-defined rings and a triangular terminal piece finds parallels in such *M.* (*Heterocyclopyge*) species as *M.* (*H.*) *abunda* Zhou, McNamara, Yuan & Zhang, 1994 (figs 5C, D, F–I, 6A–H, 7A, C, E, H, M), from the early Sandbian Charchaq Group, Tarim and *M.* (*H.*) *shelvensis* Whittard, 1961 (pl. 24, figs 3–4; Owens 2002, pl. 3, fig. 4) from the Llanvirn Series (Darriwilian) of the Welsh Borderland and central Wales. It differs from the first in the subquadrate pygidial outline (see, e.g. Zhou *et al*. 1994, figs 5F, I; 6A, C), and from the second in having deeper, broader pleural furrows. A very similar pygidial axis also occurs in *Cyclopyge kossleri* Klouček, 1916 from the Darriwilian Šárka Formation of the Prague district (Marek 1961, pl. 1, figs 15–17) and the Llanvirn (Darriwilian) Llanfallteg Formation of Pembrokeshire, Wales (Fortey & Owens 1987, fig. 37 a–b), but the glabella of this species has deep S1, typical of *Cyclopyge*. The triangular pygidial axis in *C. kossleri* is not shared by other *Cyclopyge* species, so it should perhaps be transferred to *Microparia* (*Heterocyclopyge*) – the lack of deep S1 in species currently attributed to the latter may simply be due to effacement. The presence in *C. kossleri* of both deep S1 and a triangular pygidial axis suggests derivation of *M.* (*Heterocycolpyge*) from *Cyclopyge*.

Subfamily Pricyclopyginae Fortey & Owens, 1987
Genus *Symphysops* Raymond 1925

Type species. *Aeglina armata* Barrande, 1872, from Upper Ordovician, Katian Stage, Králův Dvůr Formation, Králův Dvůr, Czech Republic.

Symphysops cf. *djebaglensis* (Kolova, 1936)
(Fig. 7i)

cf. 1936 *Cyclopyge djebaglensis* Kolova, p. 37, pl. 2, figs 1–3.

Material. NMW 2005.32G.171, pygidium, incomplete internal mould; NMW 2005.32G.190, pygidium, external mould (Pl, 9·8, Pw, 18·5, PAl, 5·8, PAw, 5·9); sample 205.

Description. Pygidium almost semicircular in outline, about half as long as wide. Axis convex, subconical, about 60% as long as the pygidium, about as long as wide, with a well-defined first axial ring, very poorly-defined second and third rings, and a terminal piece. Pleural fields gently convex, effaced with two very weakly defined pairs of pleural ribs. Border wide, gently convex; border furrow wide and shallow.

Remarks. These pygidia show close affinity to that from the Besharyk Formation of the Dzhebagly Mountains, southern Kazakhstan described and figured by Kolova (1936, p. 37, pl. 11, fig. 3) as *Cyclopyge djebaglensis*. They differ from this specimen in apparently having much more weakly defined pleural ribs, although preservation is poor. Pygidia figured as *Cyclopyge* (?) by Weber (1932, p. 9, pl. 4, figs 52–54), also from the Dzhebagly Mountains, may be conspecific, but the material is too incomplete and the figures too small for detailed comparison.

Family Nileidae Angelin, 1854
Genus *Nileus* Dalman, 1827

Type species. *Asaphus* (*Nileus*) *armadillo* Dalman, 1827, Middle Ordovician, Darriwilian Stage, Holen Limestone Formation, *Asaphus expansus* Biozone, Östergötland, Sweden.

Nileus sp.
(Fig. 11f, h)

Material. NMW 2005.32G.193, cephalon with attached thoracic segments, external mould (CEl, 5·7, CEw, 7·0, Cw 6·6), sample 203; NMW 2005.32G.194, pygidium, internal mould (Pl, 5·9, Pw, 10·5, PAw, 5·0), sample 203a.

Description. Cephalon semioval, about 80% as long as wide, strongly convex (sag., tr.). Cranidium slightly elongate, subrectangular, strongly effaced with glabella not clearly separated from fixigenae. Palpebral lobes large, almost semicircular, occupying almost 60% of cephalic length, with anterior terminations situated just 15% from the anterior cranidial margin. Preocular facial suture very short, weakly divergent, curved adaxially at anterior cephalic margin. Postocular facial sutures divergent at an angle of 50° to axis. Postocular fixigenae small, subtriangular, poorly defined. Librigenae with genal angles narrow (tr.) and steeply inclined laterally. Visual surface of eyes vertical and smooth.

Thorax with a wide axis, about 60% of thoracic width, and very weakly defined axial furrows.

Pygidium transversely semioval, about 55% as long as wide, with a short axis, which is weakly defined anteriorly and occupies almost half of anterior pygidial width. Pygidial border wide, gently concave in cross section. Pygidial doublure wide, concave and ornamented by strong terrace lines, with U-shaped anterior margin mainly confined to axis.

Remarks. This species has a strongly transverse, effaced pygidium with a broad, concave border which resembles that of *Nileus transversis* Koroleva, 1982, which is also known from the Sandbian, Anderken Regional Stage of the south-western Chingiz Range in Kazakhstan. However, the cranidial characters of the latter are unknown, so further comparison is not possible. Another species from the Upper Ordovician of the south-western Chingiz Range is *N. kasachstanicus* Koroleva, 1982. *Nileus* sp. can be readily distinguished from it in having almost completely effaced cranidial axial furrows, large palpebral lobes that occupy more than half of the cephalic length, and facial sutures with very short preocular branches.

Family Remopleurididae Hawle & Corda, 1847
Genus *Remopleurides* Portlock, 1843

Type species. *Remopleurides colbii* Portlock, 1843, Upper Ordovician Katian Stage, (Ashgill Series), Killey Bridge Formation, Desertcreat, Co. Tyrone, Northern Ireland (see Whittington, 1950, for revision of species).

Remopleurides cf. *sibiricus* Vasilievsky *in* Weber, 1948
(Fig. 7f–h)

?1948 *Remopleurides sibiricus* Vasilievsky (ms.) *in* Weber; p. 20, pl. 3, fig. 7.

1982 *Remopleurides* cf. *sibiricus* Weber, Koroleva, p. 72, pl. 10, fig. 4.

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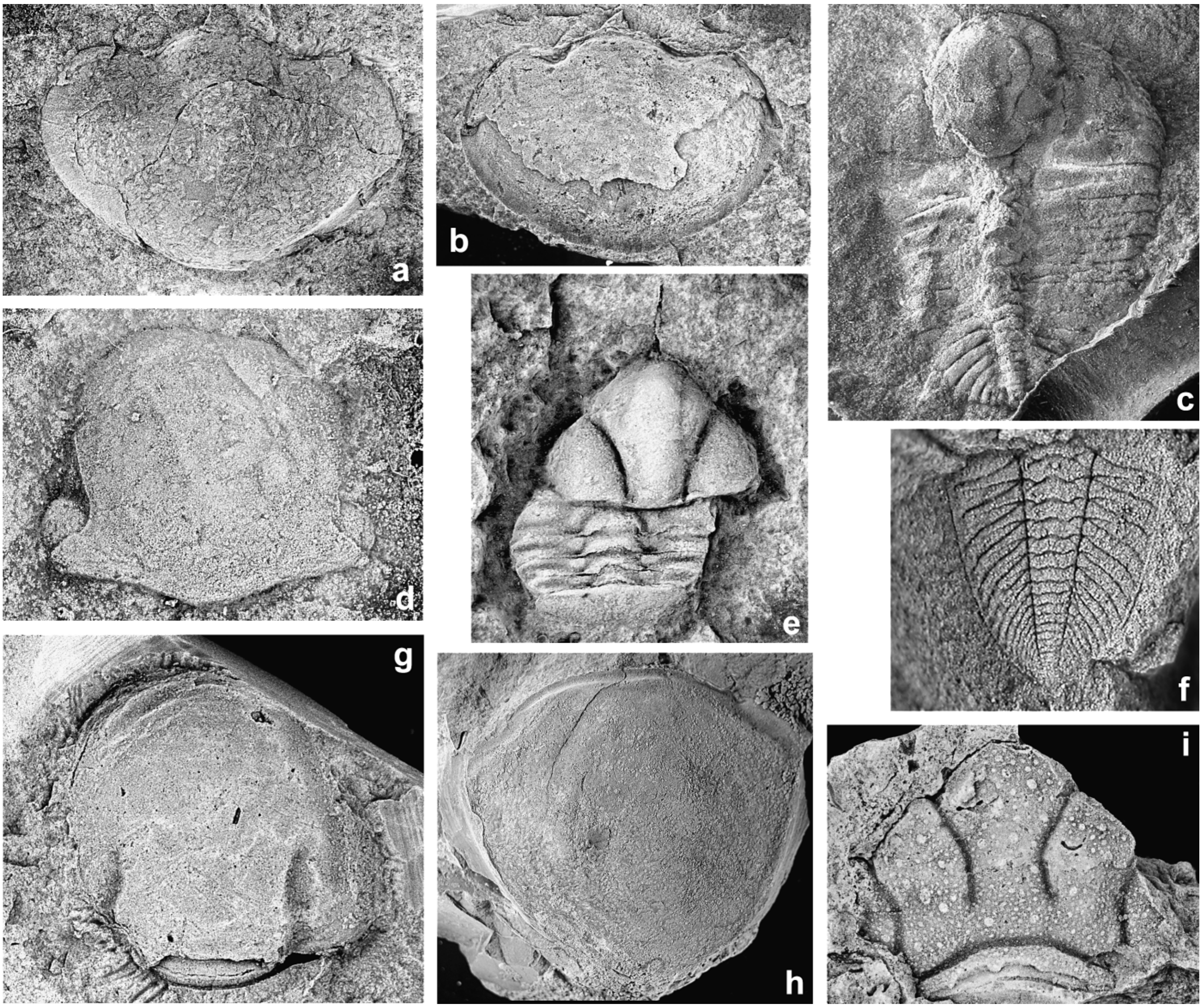

Figure 6 (a–b, d) *Illaenus* sp.: (a) NMW 2005.32G.142, pygidium, internal mould, dorsal view, × 1·8, sample 203a; (b) NMW 2005.32G.141, pygidium, internal mould, dorsal view, × 1·8, sample 203a; (d) NMW 2005.32G.140, cranidium, external mould, dorsal view, × 5·5, sample 203. (c) *Dionide* sp. NMW 2005.32G.265, disarranged articulated specimen, latex cast of external mould, × 5, sample 201. (e) *Raphioampyx*? sp.: NMW 2005.32G.162, disarticulated exoskeleton, dorsal view, × 6, sample 201. (f) *Aethedionide* sp., NMW 2005.32G.191, pygidium, internal mould, dorsal view, × 7·5, sample 205. (g–h) *Stenopareia* sp.: (g) NMW 2005.32G.145, cranidium, internal mould, dorsal view, × 1; (h) NMW 2005.32G.144, pygidium, internal mould, dorsal view, × 3·5; both sample 203a. (i) *Amphilichas* aff. *nasutus* Webby, 1974: NMW 2005.32G.192, incomplete cranidium, internal mould, dorsal view, × 3, sample 203b.

Material. NMW 2005.32G.179, external mould of cranidium; NMW 2005.32G.136, 178, 198–199, pygidia with attached thoracic segments, internal and external moulds; samples 203, 203a.

Remarks. The cranidium has a gently convex, strongly effaced glabella with a relatively short, declined anterior tongue and ornamented by very fine, transverse terrace ridges; a short (sag.) transverse occipital ring tapering distally; and a palpebral rim maintaining almost constant width along its entire length (exsag.). Pygidia attached to up to nine thoracic segments, mostly exfoliated, and the position of a thoracic median spine cannot be determined. The cranidial features suggest attribution to *Remopleurides sibiricus*. The description of this species given in Weber (1948) is based on a manuscript by Vasilievsky, who collected the specimens from an unidentified, presumably Upper Ordovician unit in the Ayaguz river basin in 1912. According to Weber (1948, p. 100), this material had been lost by 1940, and a holotype was not assigned in the original description of the species. The locality data given by Weber (1948) are very general, but specimens described in the present paper may be topotypic, or may have originated in close proximity to the type locality. The specimens described by Koroleva (1982) are probably conspecific with those from the Karagach Formation, and are therefore included in the synonymy list. *Remopleurides sibiricus* requires revision, but the available material is inadequate to discuss its affinities.

Family Illaenidae Hawle and Corda, 1847
Genus *Illaenus* Dalman, 1827

Type species. *Entomostracites crassicauda* Wahlenberg, 1818; Middle Ordovician, Darriwilian Stage, Dalby Limestone Formation (basal part – see Jaanusson 1963, pp. 35–36), Fjäcka, Dalarna, Sweden.

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Illaenus sp.
(Fig. 6a, b, d)

Material. NMW 2005.32G.140, external mould of cranidium, sample 203; NMW 2005.32G.141–143, pygidia, internal moulds, sample 203a.

Remarks. A number of species attributed to *Illaenus* and often described in open nomenclature can be found in publications by Weber (1948), Lisogor (1965) and Koroleva (1965). Due to poor illustrations and only brief descriptions, their precise taxonomic discrimination is difficult, and they require revision. The unnamed species from the Karagach Formation is distinctive among them in having a strongly effaced cranidium with posteriorly placed palpebral lobes, and a strongly convex pygidium with a relatively long, conical axis occupying about one third of its length. Among the late Ordovician species of the genus from Kazakhstan, the cranidium of *Illaenus* sp. is most similar to the specimen described by Weber (1948) as *Illaenus* sp. 17 from the Upper? Ordovician of Karatas, east of Astana (53°30′N, 72°30′E), in possessing a subquadrate outline, a strongly curved lateral profile and indistinguishable axial furrows. The pygidia of *Illaenus* sp. show similarity in outline and in their relatively long subconical axis to *I. renhuaensis* Yin *in* Yin & Lee, 1978 (revised by Zhou *et al*. 1984) from the Shihtzupu Formation of Guizhou Province, South China.

Genus *Stenopareia* Holm *in* Schmidt, 1886

Type species. *Illaenus linnarssoni* Holm, 1882, Upper Ordovician, Katian Stage, Boda Limestone Formation, Dalarna, Sweden.

Stenopareia sp.
(Fig. 6g, h)

Material. NMW 2005.32G.145, cranidium, internal mould (Pl, 47·6, Pw, 56); NMW 2005.32G.146, cranidium, internal mould (Cl, 10·6, Cw, 13·3); NMW 2005.32G.144, pygidium, internal mould (Pl, 20·5, Pw, 21·1); all sample 203a.

Description. Cranidium moderately convex (sag., tr.), about 80% as long as wide with evenly rounded anterior margin. Glabella gently convex (tr.) with shallow, subparallel axial furrows that become obsolete at cranidial mid-length. Palpebral lobe long (sag.), gently convex abaxially with anterior margin situated slightly posterior to cranidial mid-length. Prominent lunette present adjacent to axial furrow. Posterior section of fixigena very small, subtriangular. Other cranidial features are not sufficiently preserved for description.

Pygidium moderately convex, semielliptical, about 85–95% as long as wide. Axis exceeding half of anterior pygidial width, well defined by shallow, broad axial furrows in the anterior third of pygidial length in the smaller specimen, but becoming almost effaced in the larger specimen (Fig. 6h). Pygidial doublure dorsally concave, narrow, maintaining equal width posteriorly and laterally, ornamented by fine, subparallel terrace ridges.

Remarks. In its pygidial morphology, this unnamed species resembles, and may be conspecific with, the specimens described by Apollonov (1974) as *Stenopareia* sp. 2 from the Zharky Beds (Katian) of north-eastern central Kazakhstan. In common with them, it has a relatively elongate pygidium with length exceeding 80% of pygidial width, and a narrow pygidial doublure maintaining constant width along the entire pygidial margin. It differs from *S. pulchrum* Apollonov, 1974, which occurs at the same locality, in possessing relatively large, posteriorly placed palpebral lobes, and a pygidial axis that is well defined by axial furrows on the anterior third of the pygidial length in juvenile specimens. As Apollonov (1974) described neither the pygidial doublure morphology, nor illustrated the pygidium of *S. pulchrum*, further comparison with this species is not possible.

Stenopareia sp. differs from the specimens described as *S.* aff. *bowmanni* (Salter, 1848) by Zhou & Dean (1986) from the Chedao Formation (Sandbian) of eastern Gansu Province of northwest China, in having significantly larger palpebral lobes, and a more elongated pygidium with narrow doublure that maintains constant width posteriorly and laterally.

Family Styginidae Vogdes, 1890
Genus *Dulanaspis* Chugaeva, 1956

Type species. *Dulanaspis levis* Chugaeva, 1956; Upper Ordovician, Katian Stage, Dulankara Formation, Chu-Ili Range, Kazakhstan.

Dulanaspis karagachensis sp. nov.
(Fig. 8a–d)

Derivation of name. From the Karagach Formation.

Holotype. NMW 2005.32G.150, incomplete cephalon, internal mould (Cl, 10·3, Cw, 11·0, Gl, 7·1, Gw, 6·4); sample 205.

Paratypes. NMW 2005.32G.153, pygidium with attached thoracic segments, internal mould, sample 203a; NMW 2005.32G.152, pygidium, internal mould (Pl, 9·3, Pw, 14·5, PAl, 2·4; PAw, 3·2), sample 203a; NMW 2005.32G.151, pygidium, internal mould, sample 203b; NMW 2005.32G.154, pygidium, internal mould, sample 203a; NMW 2005.32G.155, pygidium, internal mould, sample 203b.

Diagnosis. Glabella slightly elongate, with maximum width at anterior margin; cranidial axial furrows strongly divergent anteriorly; very narrow cephalic border; large semicircular eye; very weakly defined posterior cephalic border; pygidium transverse, semioval, with axis completely lacking segmentation; long, well-defined postaxial ridge.

Description. Cephalon strongly transverse, semioval. Cranidium about equal length and width, with maximum width at mid-length of palpebral lobe. Glabella pestle-shaped, gently convex, about 110% as long (sag.) as wide (tr.) with maximum width at evenly curved anterior margin, extends as far as weak anterior border furrow. A very small, weakly defined L1 is present at the base of the preoccipital glabella. Axial furrows deep and narrow, almost parallel as far as point opposite mid-length (exsag.) of palpebral lobe, then diverging anteriorly. Occipital ring narrow, transverse, separated from the glabella by a shallow, weakly defined occipital furrow. Cephalic border very narrow (exsag.) with a weakly defined, shallow border furrow. Palpebral lobes semicircular, posteriorly placed with anterior margins situated slightly posterior of cephalic mid-length. Posterior border almost effaced. Postocular fixigenae narrow (tr.) and short (exsag.). Preocular facial sutures diverge immediately in front of palpebral lobes, and run more or less parallel to axial furrow. Postocular facial sutures very short, divergent posteriorly. Librigenae gently convex, subtriangular, with posterior margins strongly curved posteriorly abaxially and with acute genal angles.

Thorax with narrow, convex axis defined by deep and narrow axial furrows. Parts of eight segments are preserved (Fig. 8d); pleurae curve gently backwards, and terminate in blunt points.

Pygidium moderately and evenly convex, semioval, about 65% as long as wide. Axis subconical, short, moderately convex, effaced, about 30% of pygidial length (sag.) and about 25–30% of maximum pygidial width. Axial furrows wide and

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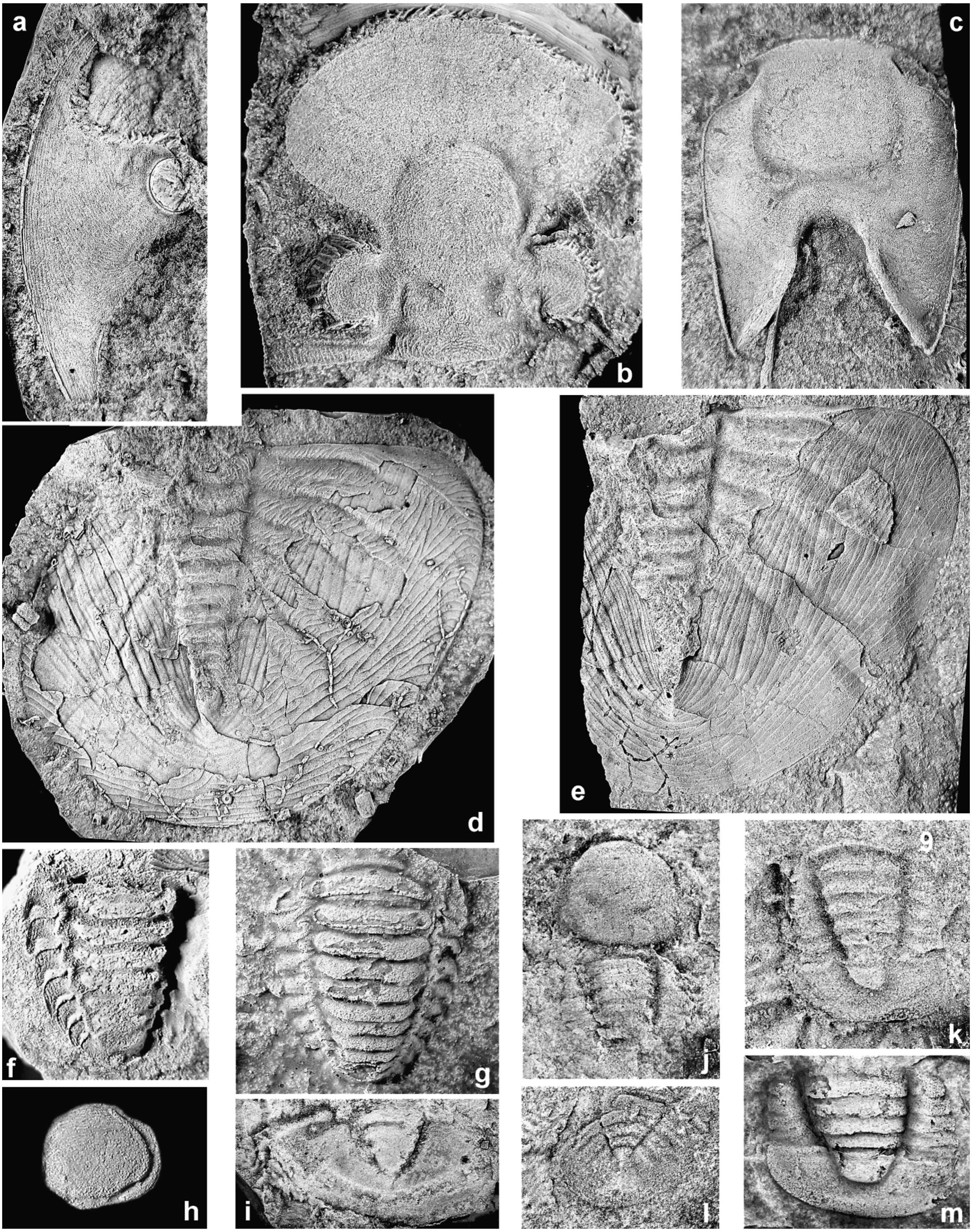

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shallow, strongly converging posteriorly. A fine, narrow postaxial ridge is present. Pleural fields evenly convex, smooth. Border wide, gently concave, separated from the pleural fields by a very shallow, weakly defined border furrow. Doublure gently concave dorsally, with fine, parallel terrace ridges. A pair of large, oblique, elongate suboval muscle scars is present, situated posterolaterally of posterior termination of pygidial axis.

Remarks. This species differs from others (e.g. *D. anderkensis* Chugaeva, 1958; *D. costata* Chugaeva, 1958 and *D. levis* Chugaeva, 1956) from Kazakhstan in having a narrow (tr.) postocular fixigena, a very narrow cephalic border, and a more transverse pygidium with a semioval, not parabolic outline. It also differs from *D. costata* in the completely effaced pygidial axis and pleural fields without any traces of segmentation, and unlike *D. anderkensis* and *D. levis*, it has a long, well defined postaxial ridge.

Styginidae gen. et sp. indet.
(Fig. 8g)

Material. NMW 2005.32G.156, pygidium with parts of four thoracic segments and an associated librigena, internal mould (Pl, 13·5, Pw, 21·1, PAl, 8·0, PAw, 4·0); sample 205.

Description. Pygidium gently convex, slightly transverse, suboval in outline and about 65% as long as wide. Axis narrow, about 60% length (sag.) of pygidium and occupying about 10% of the anterior pygidial width, with six well-defined rings and a seventh, poorly-defined, posterior ring. Terminal piece occupying posterior third of axis, with bluntly rounded posterior margin. Ring furrows narrow (exsag.), well defined on flanks of axis and almost obsolete sagittally. Axial furrows deep and narrow, very slightly converging posteriorly. Pleural fields weakly convex with six pairs of flat axial ribs, which widen distally and are separated by narrow, deep pleural furrows which extend to margin. Border very weakly defined, relatively narrow, weakly concave. Pygidial surface finely granulose.

Remarks. This specimen is clearly a moult, but without an associated cephalon, its generic affiliation is uncertain. The pygidium resembles those from the Anderken Formation (Sandbian) of the Chu-Ili Range assigned to *Bronteopsis* (?) *extraordinaria* by Chugaeva (1958, p. 107, pl. 11, figs 12–14) in having a narrow, elongate axis occupying about two thirds of pygidial length, six pairs of weakly convex, almost flat pleural ribs widening distally, and a finely granulose ornament. It differs in having ring furrows that are almost obsolete sagittally, and a narrower axis occupying only 10% of the maximum width, and with axial furrows only slightly convergent posteriorly.

In describing *Bronteopsis* (?) *extraordinaria*, Chugaeva (1958, p. 107, pl. 11, figs 10, 11) associated a cephalon of a blind form with the pygidium discussed above, and later Přibyl & Vaněk (1971) made this the type species of their genus *Chugaevia*. The fixigena of the Karagach specimen has a wide doublure, the base of a genal spine and a poorly preserved eye surface, and assuming that the cephalon and pygidium were correctly associated by Chugaeva (1958) it cannot be attributed to *Chugaevia*.

Kolova (1936, p. 34, pl. 1, fig. 14) described and figured a pygidium broadly similar to ours from the Ordovician of Kara Sai, Dzhebagly Mountains, as *Bronteus* aff. *andersoni* Nicholson & Etheridge, 1879. It is immediately distinguished in having a much shorter (sag.), more tapering axis with more (seven) pairs of ribs which appear to be more convex in cross section.

Family Trinucleidae Hawle & Corda, 1847
Subfamily Trinucleinae Hawle & Corda, 1847
Genus *Kimakaspis* gen. nov.

Derivation of name. From Kimak, the ancient Turkish tribe who inhabited the area between Irtysh River and Tarbagatai Range.

Type and only species. *Kimakaspis kovalevskyi* gen. et sp. nov. Upper Ordovician, Sandbian Stage, Karagach Formation, sample 201, east side of Ayaguz river west of Karagach village, Tarbagatai Range, Kazakhstan.

Diagnosis. Fringe with pits on upper lamella dominantly radially arranged in relatively narrow, deep sulci, containing pits E_{1-2} and I_{1-2}. I pits interior of I_2 in radial alignment with sulci frontally, randomly distributed and out of radial alignment laterally and posterolaterally. Fringe with E_1 complete; E_2 developed abaxially very close to E_1, diverging from it posterolaterally until maximum curve of fringe, then converging to it posteriorly. I_1 and I_3 complete; I_2 very close to I_3 frontally, with median two I_2/I_3 pit pairs merging; I_2 increasing in distance from I_3 laterally, but cannot be traced anterolaterally due to irregular arrangement of I pits between I_1 and I_3. Apart from I_1 and I_3, I pits irregularly arranged. Around four irregular arcs between I_1 and I_3 at anterolateral corners, up to eight posterolaterally. Lateral eye ridges and tubercles absent. Pygidium with five axial rings plus terminal piece.

Remarks. In possessing two arcs of E pits, which lie very close together, *Kimakaspis* is similar to *Bergamia* Whittard, 1955 and *Tretaspis* M'Coy, 1849. On the lower lamella of *Bergamia*, the I pits are arranged in a strong, regular, radial pattern, which only becomes slightly irregular in the genal angle of the fringe. In contrast, the lower lamella of *Kimakaspis* has regular, radially arranged I pits only frontally; abaxially, the irregular distribution of I pits makes it impossible to trace radial rows of pits in a straight line from I_1 to I_3. The pygidia of the two taxa are similarly short (*Bergamia* has up to six axial rings) and wide, but the axis of *Bergamia*

Figure 7 (a–e) *Birmanites akchiensis* sp. nov.: (a) NMW 2005.32G.182, paratype, left librigena, latex cast of external mould, dorsal view, × 1·5, sample 203b; (b) NMW 2005.32G.181, holotype cranidium, latex cast of external mould, dorsal view, × 2·5, sample 203b; (c) NMW 2005.32G.183, paratype, hypostome, latex cast of external mould, ventral view, × 3·5, sample 203a; (d) NMW 2005.32G.184, paratype, incomplete pygidium, latex cast of external mould, dorsal view, × 1·75, sample 203b; (e) NMW 2005.32G.185, paratype, incomplete pygidium, internal mould, dorsal view, × 1·75, sample 203b. (f–h) *Remopleurides* cf. *sibiricus* Vasilievsky *in* Weber, 1948: (f) NMW 2005.32G.178, pygidium with attached thoracic segments, internal mould, dorsal view, × 4·75, sample 203; (g) NMW 2005.32G.136, pygidium with attached thoracic segments, latex cast of external mould, dorsal view, × 5·75, sample 203; (h) NMW 2005.32G.179, incomplete cranidium, latex cast of external mould, dorsal view, × 5, sample 203. (i) *Symphysops* cf. *djebaglensis* (Kolova, 1936): NMW 2005.32G.190, pygidium, latex cast of external mould, dorsal view, × 3·5, sample 205. (j–k, m) *Cyclopyge* cf. *tereki* Koroleva, 1967: (j) NMW 2005.32G.186, cranidium and incomplete thorax, internal mould, × 6; (k) NMW 2005.32G.187, pygidium and thorax, internal mould, dorsal view, × 5·5; (m) NMW 2005.32G.188, pygidium and thorax, latex cast of external mould, × 9. All sample 205. (l) *Microparia* (*Heterocyclopyge*) sp., NMW 2005.32G.189, pygidium, internal mould, dorsal view, × 4, sample 205.

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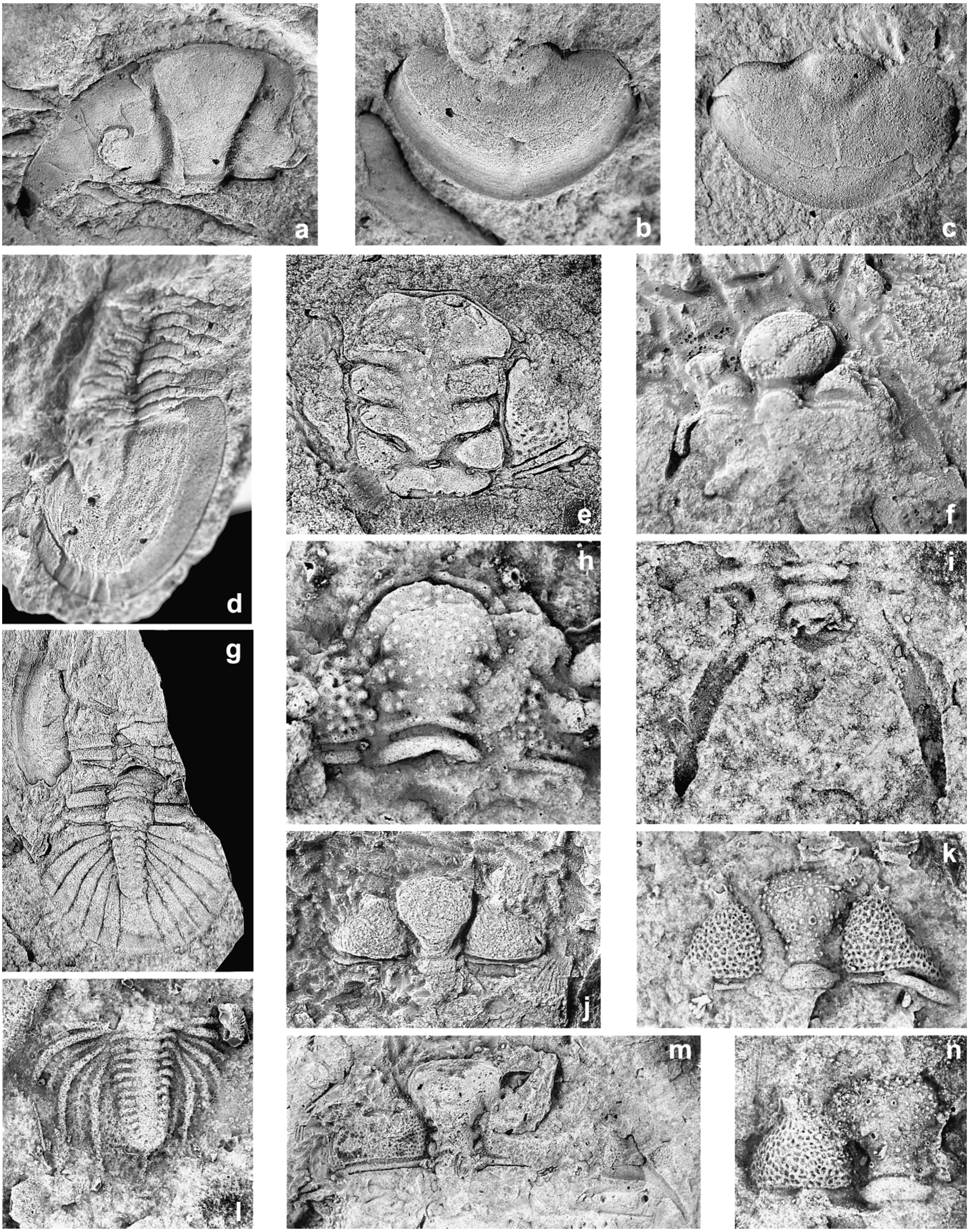

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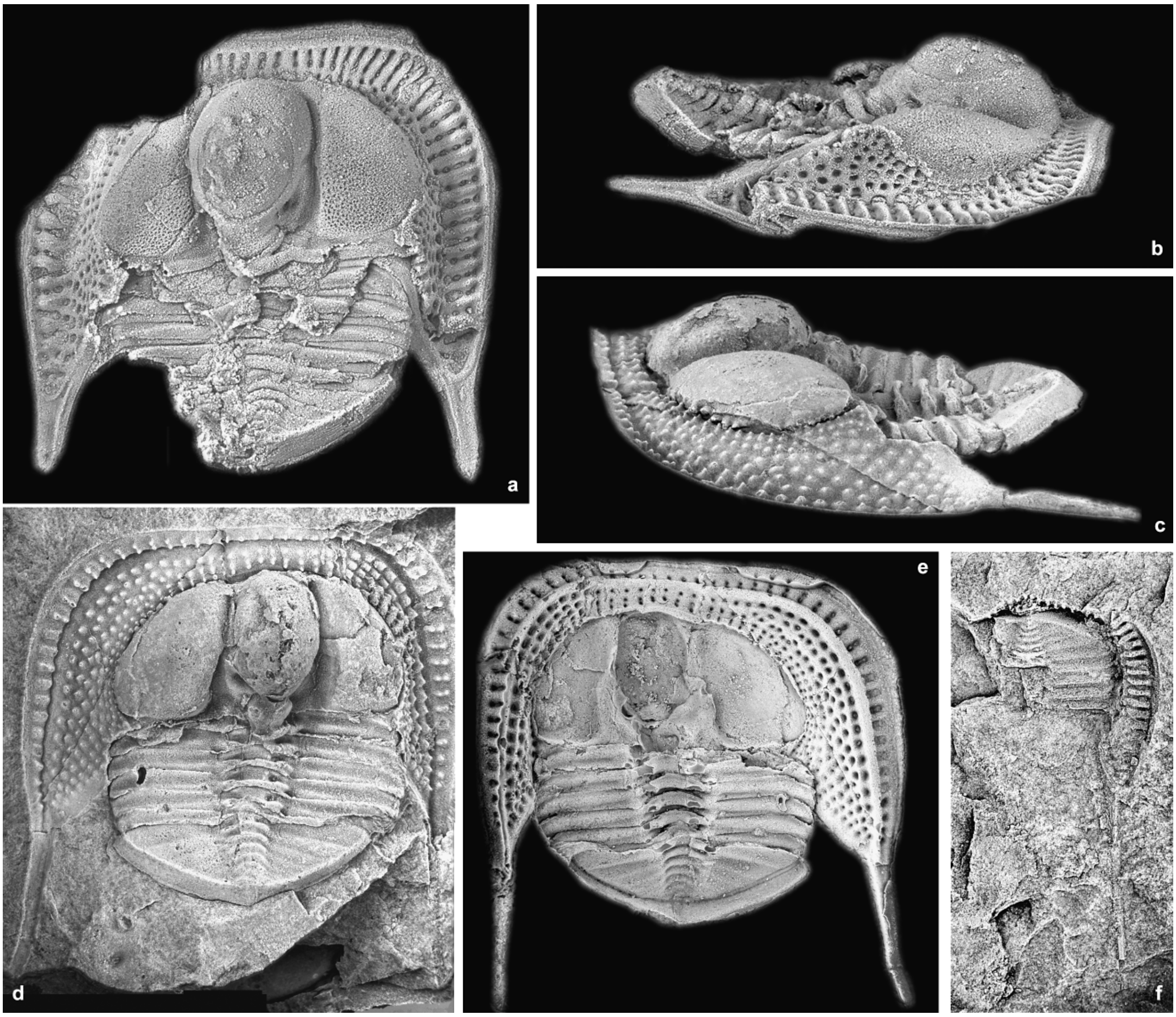

Figure 9 *Kimakaspis kovalevskyi* gen. et sp. nov.: (a–b) NMW 2005.32G.241, paratype, articulated exoskeleton, latex cast, dorsal and lateral views, × 4·5; (c–d) NMW 2005.32G.240, holotype, articulated exoskeleton, internal mould, lateral and dorsal views, × 4; (e) latex cast of previous, ventral view, × 3; all from sample 201; (f) NMW 2005.32G.242, paratype, incomplete enrolled exoskeleton, internal mould, (× 3·75) sample 205.

continues onto the posterior border, while in *Kimakaspis* the axis ends at the posterior margin.

Tretaspis has pits E_{1-2} and I_1 in radial sulci on the upper lamella, with pits I_2–I_n outside the sulci but in alignment with them (Hughes *et al*. 1975), while *Kimakaspis* has pits E_{1-2} and I_{1-2} in radial sulci, and the I pits inside this are only aligned with the sulci anteriorly, becoming more irregularly distributed laterally. *Tretaspis* also possesses lateral eye ridges and tubercles, both of which are absent from *Kimakaspis*.

Although most species of the Katian/Ashgill genus *Nankinolithus* Lu, 1954, have just one arc of E pits, some have at least a partial E_2 arc. *N. yanhaoi* Zhou & Hughes, 1989, has an arc of small E_2 pits, although this is present only anteriorly (11–12 pits per half fringe), whereas *Kimakapsis* has only E_1 anterior of the glabella, with E_2 appearing close to E_1 just abaxial of the axial furrows, and pits in both arcs are of equal size. *N. granulatus* (Wahlenberg, 1818) also differs in having E_2 anteriorly, although in this species E_2 continues posteriorly

Figure 8 (a–d) *Dulanaspis karagachensis* sp. nov.: (a) NMW 2005.32G.150, holotype, incomplete cephalon, internal mould, dorsal view, × 3, sample 205; (b) NMW 2005.32G.152, paratype, pygidium, internal mould, dorsal view, × 3, sample 203a; (c) NMW 2005.32G.151, paratype, pygidium, internal mould, dorsal view, × 3·25, sample 203b; (d) NMW 2005.32G.153, paratype, pygidium with attached thoracic segments, internal mould, dorsal view, × 4, sample 203a. (e) *Ceraurinella*? aff. *kasachstasnica* (Chugaeva, 1958), NMW 2005.32G.157, cranidium, internal mould, dorsal view, × 2·75, sample 203a. (f, i) *Sphaerocoryphe* sp.: (f) NMW 2005.32G.160, cranidium, external mould, dorsal view, × 5, sample 203a; (i) NMW 2005.32G.161, pygidium, internal mould, dorsal view, × 6, sample 203b. (g) Styginidae gen. et sp. indet.: NMW 2005.32G.156, pygidium with parts of four thoracic segments, and associated librigena, latex cast of external mould, × 5, sample 205. (h) *Encrinuroides* cf. *septemcostatus* Kolobova, 1983: NMW 2005.32G.163, cranidium, latex cast of external mould, dorsal view, × 5, sample 203b. (j–n) *Sinocybele weberi* (Kolova, 1936): (j) NMW 2005.32G.165, cranidium, internal mould, dorsal view, × 5·25, sample 203a; (k) NMW 2005.32G.166, cranidium, latex cast of external mould, dorsal view, × 5·5, sample 203; (l) NMW 2005.32G.168, pygidium, latex cast of external mould, dorsal view, × 5, sample 203b; (m) NMW 2005.32G.169, cranidium, internal mould, dorsal view, × 2·75, sample 203a; (n) NMW 2005.32G.167, cranidium, latex cast of external mould, dorsal view, × 5·5, sample 203.

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rather than being restricted to the anterior of the fringe. *N. granulatus* also differs from *Kimakaspis* in having a wider fringe with more I arcs anteriorly (at least four in the former, only three in the latter) and along the posterior margin (up to 11, rather than 8). Zhou & Hughes (1989) note that the few *Nankinolithus* species with partial E_2 arcs are middle Ashgill (Katian) in age, whereas older members of the genus (early Ashgill) have just E_1.

Although *Kimakaspis* is older than known species of *Nankinolithus* that possess E_2, it is more similar to this genus than to *Bergamia* and *Tretaspis*, in the irregularity of some I arcs laterally (i.e. not all pits are aligned into concentric arcs) and because the I arcs are only distributed in a regular radial pattern anteriorly. However, where E_2 is developed in *Nankinolithus*, its distribution is different to that of *Kimakaspis*; the E_2 pits are developed anteriorly and are generally smaller than those of E_1, whereas E_2 develops abaxially in *Kimakaspis*, from pits of similar size to E_1 that are initially twinned with them. It may be that the development of E_2 in both taxa is entirely homologous, although the strong similarities in the pattern of the I arcs suggests a genuine relationship between them, and *Kimakaspis* may represent the ancestral stock from which *Nankinolithus* evolved.

A similar irregular arrangement of pits in the I arcs is seen in *Declivolithus* Přibyl & Vaněk, 1967, from the Bohdalec Formation (Katian) of the Czech Republic and similar horizons in Morocco, although this genus has a much broader 'harpiform' (Hughes *et al.* 1975) fringe and has only one E arc. The type material of *Jianxilithus latimarginis* Zhang & Zhou in Lu *et al.*, 1976, the single species assigned to this late Sandbian–early Katian genus from China is incompletely preserved, but Zhou & Hughes (1989) note that the "fringe is reminiscent of *Declivolithus*", in having only E_1 and randomly distributed inner I arcs. However, *Jianxilithus* lacks a well-defined pseudofrontal glabellar lobe, so additional material is required to clarify its relationship to *Declivolithus* and other genera. In addition to lacking E_2, *Jianxilithus* differs from *Kimakaspis* in the shape of the glabella and in possessing eye ridges.

Kimakaspis kovalevskyi gen. et sp. nov.
(Figs 9, 10, 11e, g, 13i)

Derivation of name. After the late O. P. Kovalevsky, in appreciation of his contribution to the study of the Ordovician geology and palaeontology of the Tarbagatai Range.

Holotype. NMW 2005.32G.240, articulated exoskeleton, internal mould (L, 6·4, W, 3·9), sample 201.

Paratypes. NMW 2005.32G.216, 241, 252, disarticulated exoskeletons internal and external moulds; NMW 2005.32G.254, incomplete exoskeleton; NMW 2005.32G.216, cephalon, external mould; NMW 2005.32G.272, external mould of damaged articulated exoskeleton; NMW 2005.32G.248–251, 253 incomplete cephala, internal moulds; NMW 2005.32G.247, pygidium with attached thoracic segments, internal mould; all sample 201. NMW 2005.32G.242, incomplete enrolled exoskeleton; NMW 2005.32G.243–245, fragments of fringe; sample 205.

Diagnosis. As for genus.

Description. Cephalon sub-semicircular in outline, although one large specimen (Fig. 9a) has angular anterolateral corners. Fine reticulate sculpture covering glabella and genal lobes. Glabella has maximum width (tr.) at around midlength (sag.) of pseudofrontal lobe, equal to approximately 60% of its length (sag.). Axial furrows tapering gently anteriorly; relatively deep and narrow (tr.) anteriorly, rapidly widening posterior of 3p. Pseudofrontal lobe of glabella prominent, inflated, suboval, overhangs fringe slightly; separated from posterior of glabella by wide (sag.), relatively shallow, transverse furrow 3p faintly impressed on sides of pseudofrontal lobe, just posterior of mid-lobe length (sag.). 2p furrows are deep, elongate, oval pits at posterior of pseudofrontal lobe; 1p furrow pits and occipital pits define corners of gently convex occiput, which is separated from occipital ring by shallow furrow. Occipital ring narrow (sag.), convex, tapers gently abaxially. No occipital spine. Area adaxial of 1p, 2p and 3p furrows swollen to form a composite lateral glabellar lobe, delimited adaxially by axial furrow. Posterior cephalic border narrow (exsag.), convex, separated from genal lobes by relatively deep, narrow furrow. Eye tubercles and ridges absent.

Fringe with $E_{1–2}$, and $I_{1–3}$, with numerous additional I pits laterally. No F pits present. Of E pits, only E_1 is present medially, comprising around seven pits in front of glabella. Just abaxial of axial furrows, E_2 developed very close to E_1, diverging from E_1 posterolaterally until maximum anterolateral curve of fringe; then E_1 and E_2 converge posteriorly, merging so that just a single pit is present at the posterior limit of E arcs. Girder strong and clearly expressed, of consistent width along the length of the fringe. I_1 and I_3 complete; I_2 very close to I_3 frontally, with median two I_2/I_3 pit pairs merging; I_2 diverging from I_3 laterally, but cannot be confidently traced anterolaterally due to irregular arrangement of I pits between I_1 and I_3. Abaxially, I_3 splits to form two concentric arcs of pits, running very close to each other, but gradually diverging posteriorly; the I arc outside I_3 does not cut it off. Another concentric arc of pits runs outside this arc, but it stops and does not continue along the front of the fringe. Inside I_1 laterally, there is a roughly concentric arc of pits that may represent a continuation of I_2, but some of the pits are out of alignment so that it is not a perfectly regular arc. At the anterolateral corners of the fringe, there are four arcs between I_1 and I_3, but although roughly concentric, these are not arranged in perfectly regular curves and increasing numbers of additional pits become introduced to the middle part of the fringe posteriorly, producing up to eight arcs of I pits posterolaterally. Pits on upper lamella dominantly radially arranged in relatively narrow, deep sulci (27–30 per half fringe), containing pits $E_{1–2}$ and $I_{1–2}$. I pits interior of I_2 in radial alignment with sulci frontally, but randomly distributed and out of alignment laterally and posterolaterally. In one specimen, two pairs of anterolateral sulci are interspersed with deep single pits next to the border, producing Y-shaped inter-radial ridges. Genal spines long, extending beyond pygidium.

Thorax of six segments; distal-most ends of pleurae deflected downwards; deep apodemal pits, continuous with shallow pleural furrows directed obliquely backwards; deep articulating pits in axial furrows; prominent articulating half ring on segments 2–6 (Fig. 9d, e), but specimens do not show whether this is developed on anterior-most segment.

Pygidium subtriangular, transverse, length (sag.) one-quarter to one-third maximum width (tr.). Axis gently convex; maximum width one-quarter maximum pygidium width; tapers gently to posterior margin, but does not continue onto vertical, relatively wide posterior margin. Axis defined by wide, shallow axial furrows. Axis with five rings plus terminal piece, and up to four interpleural furrows.

Remarks. The presence of two Y-shaped inter-radial ridges on the fringe of one specimen of *K. kovalevskyi* is reminiscent of *Stapeleyella* Whittard, 1955. However, the latter has this distinctive ridge pattern consistently developed all around the fringe, and the isolated occurrence of these ridges in a single specimen of *K. kovalevskyi* is thought to reflect a deformity in fringe growth, an occurrence that Hughes (1971) recognised as not uncommon in *Trinucleus fimbriatus*.

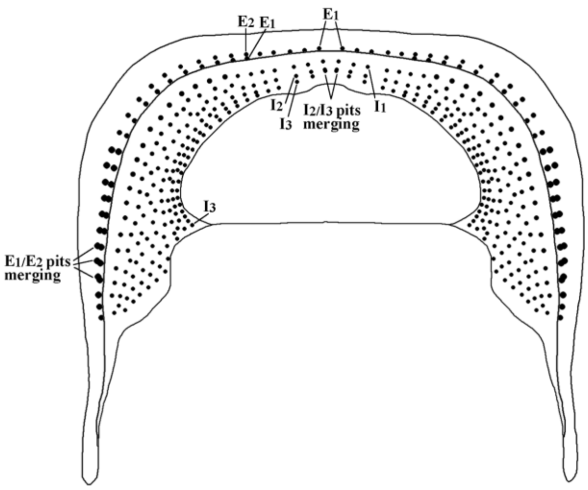

Figure 10 *Kimakaspis kovalevskyi* gen. et sp. nov. Schematic drawing showing arrangement of pits on the fringe.

Family Dionididae Gürich, 1907
Genus *Dionide* Barrande, 1847

Type species. *Dione formosa* Barrande, 1846, Upper Ordovician, Sandbian Stage, Vinice Formation, Trubín, Czech Republic.

Dionide sp.
(Fig. 6c)

Material. NMW 2005.32G.271, cephalon with attached thoracic segments, internal mould; NMW 2005.32G.265, articulated specimen, comprising incomplete cranidium, thorax and pygidium, external mould (L, 10·4, Cl, 4·2, Cw, 6·9, Pl, 3·8, Pw, 6·6), sample 201.

Remarks. The only late Ordovician species of the genus described from the Tarbagatai Range is *Dionide tarbagataica* Koroleva, 1979, from an unidentified locality and unit. It is based on a single cephalon, and the pygidium is unknown.

The articulated specimen has a slightly transverse pygidium with ten axial rings plus terminal piece. This is narrower (tr.) and has a narrower axis than other known species from Kazakhstan (e.g. *D. ammophila* Koroleva, 1979; *D. altaica* Koroleva, 1979, *D. plana* Koroleva, 1979 and *D. kasachstanica* Chugaeva, 1958). The Karagach cranidium differs from most of these, and also from *D. tarbagataica*, in having much narrower (tr.), longer (sag.) fixigenae with more evenly curved antero-lateral margins that reach a much more anterior position relative to the glabella, forming a virtually continuous arc with its anterior margin. *D. altaica* has similar fixigenae, but its glabella is subrounded and of roughly equal length and width, whilst that of *Dionide* sp. is suboval, with its width (tr.) around four-fifths of its length (sag.).

Genus *Aethedionide* Zhou & Ju *in* Qiu *et al.*, 1983

Type species. *Aethedionide fusiformis* Zhou & Ju *in* Qiu *et al.*, 1983; Upper Ordovician, late Katian Stage, Huangnehkang Formation, western Zhejiang Province, South China.

Aethedionide sp.
(Fig. 6f)

Material. NMW 2005.32G.191, pygidium, internal mould (Pl, 4·7, Pw, 4·8, PAw 1·4); sample 205.

Remarks. This pygidium is subtriangular and of almost equal length and width, with an axis bearing 18 axial rings plus terminal piece, and a pleural field with 16 pairs of ribs. It is similar to that of *Aethedionide fusiformis* Zhou & Ju *in* Qiu *et al.*, 1983 in its narrow axis and large number of axial rings and pleural ribs, but differs in being more elongate, and in lacking distinct median tubercles on the axis.

Family Raphiophoridae Angelin, 1854
Genus *Raphioampyx* Baldis & Baldis, 1995

Type species. *Raphioampyx argentinus* Baldis & Baldis, 1995, from Sandbian Stage, Las Aguaditas Formation, San Juan, Argentina.

Raphioampyx? sp.
(Fig. 6e)

Material. NMW 2005.32G.162, disarticulated exoskeleton, comprising cranidium, four thoracic segments and pygidium; sample 201.

Remarks. The triangular cranidium with short (tr.) fixigenae, short anterior spine and smooth, gently convex, rhomboidal glabella, is consistent with assignment to *Raphioampyx*, as are the deep, concave axial furrows. However, the single specimen at hand is assigned only tentatively to *Raphioampyx* because the posterior border and occipital ring are not preserved, so it is impossible to determine whether these are fused to form a continuous structure, a character that is considered diagnostic of the genus (Baldis & Baldis 1995; Turvey 2007). Four thoracic segments are preserved, and because the specimen is disarticulated behind the cranidium, it is possible that the full complement is five, which is typical for *Raphioampyx*.

Turvey (2007) described *R. sinankylosus* from the lower Darriwilian of northern Hunan, south China, and suggested that *Lonchodomas jiantsaokouensis* Lu, 1975, from the Caradoc (Sandbian–Katian) of south China and Thailand (Fortey 1997), *L. nanus* Zhou, *in* Zhou *et al.*, 1982 (see Zhou & Dean 1986), from the Sandbian of Gansu and Ningxia, northwest China and *Ampyx reedi* Yin, 1937, from the Darriwilian of western Yunnan, south China, also belong to *Raphioampyx*. The Kazakhstanian specimen is too incomplete for detailed comparison, although *L. nanus* clearly differs from it in having much wider (tr.) fixigenae.

Family Cheiruridae Hawle and Corda, 1847
Subfamily Cheirurinae Hawle and Corda, 1847
Genus *Ceraurinella* Cooper, 1953

Type species. *Ceraurinella typa* Cooper, 1953, Upper Ordovician, Sandbian Stage, Edinburg Formation, Virginia, USA.

Ceraurinella? aff. *kasachstanica* (Chugaeva, 1958)
(Fig. 8e)

Material. NMW 2005.32G.157, cranidium, internal mould (Gl, 12·4. Gw, 11·9); NMW 2005.32G.158, 159, incomplete internal moulds of cranidia; sample 203a.

Description. Glabella subrectangular, about 113% as long as wide (excluding occipital ring), with maximum width across mid part of the anterior lobe; gently convex in sagittal profile and moderately convex across the anterior lobe. Anterior margin of glabella with a small median indentation. Three pairs of deep, narrow glabellar furrows; S1 directed slightly backward as far as one third of glabellar width then curved strongly backwards to merge with the occipital furrow. S2 and

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S3 of equal length (tr.), almost parallel, inclined slightly backwards. L2 slightly shorter (tr.) than L1 and L3. Axial furrows deep and narrow, slightly concave opposite L2 and L3, bearing deep anterior pits opposite to S3. Occipital ring wide medially, tapered abaxially with a small median tubercle and almost transverse posterior margin. Occipital furrow deep, convex anteriorly and widening medially. Anterior cranidial border narrow, convex, almost transverse medially. Fixigenae incompletely preserved. Glabella tuberculate, fixigenae with coarse pits.

Remarks. These specimens are assigned provisionally to *Ceraurinella* mainly because of similarity in cranidial morphology, including a subparallel-sided glabella, S1 strongly curved backwards and merged with the occipital furrow, subparallel S2 and S3 of about equal size. They differ, however, from the type species, *C. typa*, in having longer (tr.), slightly posteriorly inclined S2 and S3, the outline of the anterior glabellar margin, and the almost transverse median part of the anterior cranidial margin. They broadly resemble the cranidium described by Chugaeva, 1958 (p. 83, pl. 9, fig. 8) as *Cheirurus* [possibly= *Ceraurinella*?] *kasachstanicus* from the Duklankara Formation (lower Katian) of the Chu-Ili Range, but are distinguished from it in having S2 and S3 slightly posteriorly inclined adaxially and a narrower (tr.) frontal lobe of the glabella with a far more prominent median indentation on its anterior margin. Another similar species is '*Ceraurus*' *exornatus* Lisogor (1965, p. 176, pl. 2, figs 1, 2) from the Angrensor Formation (Katian) of north-eastern central Kazakhstan, but unlike *Ceraurinella*? *kasachstanica*, it has a wider (tr.) frontal lobe with an evenly rounded, convex anterior margin, S3 slightly inclined anteriorly, S1 strongly shallowing abaxially.

Subfamily Deiphoninae Raymond, 1913
Genus *Sphaerocoryphe* Angelin, 1854

Type species. *Sphaerocoryphe dentata* Angelin, 1854, Upper Ordovician, Katian Stage, Upper Jonstorp Formation, Västergötland, Sweden.

Sphaerocoryphe sp.
(Fig. 8f, i)

Material. NMW 2005.32G.160, cranidium, external mould (Cl, 3·5, Cw, 6·9, Gl, 2·4, Gw, 3·1); sample 203a; NMW 2005.32G.161, pygidium, internal mould (Pl, 3·3, Pw, 5·2, PAw, 2·8); sample 203b.

Description. Cranidium transverse, about half as long (sag.) as wide (tr.), with glabella dominated by a large, almost spherical anterior lobe, which overhangs anterior cranidial margin and occupies about 70% of cranidial length (sag.). L1 very small, tubercle-like, S1 merging with occipital furrow adaxially of L1 to form a wide (sag., exsag.), depressed strip, which separates a convex occipital ring from frontal lobe. Axial furrows deep and narrow, strongly divergent anteriorly. Fixigenae strongly convex, palpebral lobes small, situated slightly anterior to base of frontal lobe. Posterior border transverse, ridge-like, separated from fixigenae by a deep and wide border furrow. Genal spines relatively short and slender, bending strongly posteriorly.

Librigenae, hypostome and thorax unknown.

Pygidium transverse, subtrapezoidal in outline, about 65% as long as wide (excluding spines). Sagittal length around 40% of exsagittal length. Axis subconical, strongly convex with two narrow (sag.), convex axial rings and with bluntly rounded terminal piece occupying posterior half of the axis. Pleural field weakly convex with two pairs of broad, indistinct pleural ribs terminated with pygidial spines. Anterior pair of spines almost transverse, exceeding in length half of pygidial width; posterior pair of spines broad and robust, about twice as long as pygidium, diverging posterolaterally for anterior half of their length, then curving evenly backwards. Span (tr.) of anterior pair of spines slightly longer than that of posterior pair of spines. Short, straight lateral margin between anterior and posterior spines.

Remarks. Although there have been previous reports of *Sphaerocoryphe* in Kazakhstan (e.g. Nikitin 1972), the specimens from the Karagach Formation are the first representatives of the genus formally described. Tripp *et al.* (1997) summarised the characters of the thirty or so known species of *Sphaerocoryphe*, noting that establishing relationships within the genus is difficult, due to different combinations of characters occurring in different species. Unfortunately, one of the most useful discriminating characters that they identified, the presence or absence of one or two pairs of profixigenal spines, cannot be applied to the Karagach species because they are not preserved on the single available cranidium. Another useful character is the length (sag.) of the anterior lobe of the glabella, expressed as a percentage of the sagittal length of the cranidium (Tripp *et al.* 1997). The value for *Sphaerocoryphe* sp. is 70%, and it falls into a group of species for which the range is 65–75%. Another distinctive character that it possesses is the presence of robust, almost transverse anterior pygidial spines. Four other species of *Sphaerocoryphe* share this combination of glabellar and pygidial morphology: *S dentata* Angelin, 1854, *S. pemphis* Lane, 1971, *S. punctata* (Angelin, 1854) and *S. murphyi* Owen *et al*., 1986.

Sphaerocoryphe sp. most closely resembles *S. thomsoni* Reed, 1906, from the South Threave Formation, Drummuck Subgroup (Ashgill) at Thraive Glen, Girvan, Ayrshire, which Kielan-Jaworowska *et al*. (1991) and Tripp *et al*. (1997) regard as a junior subjective synonym of the type species, *S. dentata* Angelin, 1854, and this synonymy is accepted in the present paper. The cranidia of *S. dentata* and *Sphaerocoryphe* sp. share convex cheeks, a narrow, transverse, ridge-like posterior border, a wide, deep posterior border furrow and a wide (sag.), shallow strip separating L1 and the occipital ring from the inflated frontal lobe of the glabella. Although the genal spines in *S. dentata* curve strongly posteriorly, those of *Sphaerocoryphe* sp. curve back at a sharper, more acute angle. The posterior border furrow in *S. dentata* fades out abaxially, resulting in a 'bridge' in the genal angle between the border and fixigenal field (Tripp *et al*. 1997); in contrast, the posterior border furrow continues without interruption around the genal angle into the lateral border furrow in *Sphaerocoryphe* sp. The pygidium of *S. dentata* differs in having four axial rings plus a small terminal piece as opposed to only three axial segments in total in *Sphaerocoryphe* sp. The pygidial spines are of similar size and arrangement in both species, although the anterior pair in *S. dentata* is relatively straight for half of their length (tran.) and then curve back posteriorly, while those of *Sphaerocoryphe* sp. are apparently straight and almost transverse for their entire length.

The cephalon of *S. pemphis* Lane, 1971, from the Balclatchie Formation (Sandbian) at Dow Hill, near Girvan, differs from that of *Sphaerocoryphe* sp. in having a posterior border that widens (sag.) towards the genal angle, as opposed to being transverse and uniformly narrow. The pygidium of *S. pemphis* is also different, having four axial rings plus a terminal piece, instead of three axial segments in *Sphaerocoryphe* sp. The former also has a deep anterior interpleural furrow behind the first axial ring, and there is no gap between the broad bases of the anterior and posterior pairs of pleural spines, whereas the interpleural furrows in *Sphaerocoryphe* sp. are very weak, and

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there are short, straight lateral margins separating the two pairs of spines on each side of the pygidium.

Sphaerocoryphe punctata (Angelin, 1854), from the Katian of Sweden, differs from *Sphaerocoryphe* sp. in having a narrow, shallow posterior border furrow, which fades out abaxially, while the latter has a broad, prominent posterior border furrow that is continuous with the lateral furrows. *S. punctata* also has a strong axial furrow alongside the occipital ring, while that of *Sphaerocoryphe* sp. is relatively weak.

Sphaerocoryphe murphyi Owen *et al*., 1986, from the Raheen Formation (late Caradoc) of County Waterford, Republic of Ireland, has fixigenae that are more weakly swollen than those of *Sphaerocoryphe* sp. as well as having a narrower posterior border furrow, and genal spines that are straight and divergent, as opposed to curving strongly posteriorly in the latter. The palpebral lobes are also positioned farther forward in *S. murphyi*. The pygidium of *S. murphyi* has posterior spines that are more robust and more strongly divergent than those of the Karagach species, resulting in a longer span (tran.) between the tips of the posterior spines than between the anterior, almost horizontally directed, pair. In contrast, the anterior pair of pygidial spines in *Sphaerocoryphe* sp. extends more transversely and has a span slightly greater than that of the posterior pair of spines. Further specimens of *Sphaerocoryphe* sp. are needed in which the profixigenal spines are preserved in order to establish in more detail its relationship to other known species.

Subfamily Acanthoparyphinae Whittington & Evitt, 1954

Acanthoparyphinae gen. indet.
(Fig. 12e)

Material. NMW 2005.32G.149, incomplete cranidium, external mould; sample 203b.

Remarks. The posterior part of this cranidium is missing. Part of the left hand L1 is preserved, and is defined by a deep S1, of which the adaxial end is deflected backwards. Weak, subparallel S2 and S3 are directed backwards at a similar angle to S1, and define elongate (trans.) L2 and L3. These characters are consistent with those of Acanthoparyphinae, but generic assignment is not possible on the basis of this specimen.

Family Encrinuridae Angelin, 1854
Subfamily Encrinurinae Angelin, 1854
Genus *Encrinuroides* Reed, 1931

Type species. *Cybele sexcostata* Salter, 1848; Upper Ordovician, Ashgill Series (Katian Stage), Sholeshook Limestone Formation, Pembrokeshire, Wales. Neotype selected and redescribed by Whittington (1950).

Encrinuroides cf. *septemcostatus* Kolobova, 1983
(Fig. 8h)

Material. NMW 2005.32G.163, incomplete cranidium, external mould (Cl, 6·8, Gl, 5·1, Gw, 4·9); NMW 2005.32G.164, incomplete cranidium, external mould; sample 203b.

Description. Glabella moderately convex with maximum width slightly anterior of S3. Anterior margin almost semicircular. Glabellar base narrow, slightly exceeding 60% of maximum glabellar width. Three pairs of transverse glabellar furrows, deep abaxially, rapidly shallowing adaxially. L1 narrow, ridge-like, less than half as long as L2 (exsag.); L3 and L2 about equal length (exsag.). Frontal lobe almost semicircular, with a narrow, shallow longitudinal median furrow on its anterior part. Small pit possibly present in preglabellar furrow.

Axial furrows deep and narrow, strongly divergent anteriorly. Glabella ornamented with numerous fine, irregularly distributed tubercles, with a single transverse row at L1 and a single median tubercle opposite S1. Tubercles numerous on L2 and L3, arranged in two irregular rows on each. Occipital furrow deep and wide (sag.), slightly convex anteriorly. Occipital ring strongly convex (sag., exsag.), smooth, slightly wider than base of preoccipital glabella. Fixigenae wide (tr.), subtriangular, moderately convex, ornamented with irregular, coarse tubercles and pits. Anterior cranidial border narrow, with four pairs of strong tubercles and two pairs of fine tubercles between them. Palpebral lobes high, raised, smooth, with their anterior ends situated opposite the middle part of L2 and the posterior ends opposite S1. Posterior cranidial border narrow (exsag.), ridge-like, turning gently backwards abaxially, separated from fixigenae by deep and narrow (exsag.) border furrow.

Remarks. These cranidia closely resemble those of *Encrinuroides septemcostatus* Kolobova (1983, p. 255, pl. 1, figs 9, 12) from the Anderken Regional Stage (Sandbian) of the Chingiz Range in the shape of the glabella, characteristics of the glabellar furrows and the ornament of numerous fine tubercles covering the glabella and fixigenae, and in having the anterior cephalic border visible in dorsal view. Without an associated pygidium, they cannot confidently be assigned to *E. septemcostatus*. Both the present cranidia, and those of *E. septemcostatus* are immediately distinguished from that of *E. sexcostatus* (Salter) (see Whittington 1950, p. 535, pl. 68, figs 7–10) in having a less expanded frontal glabellar lobe which does not overhang the anterior cephalic margin.

Subfamily Cybelinae Holliday, 1942
Genus *Sinocybele* Sheng, 1974

Type species. *Sinocybele baoshanensis* Sheng, 1974, Middle Ordovician, Darriwilian, Pupiao Formation, western Yunnan, China.

Remarks. Chen & Zhou (2002, p. 223), Zhou & Zhou (2006, p. 393) and Edgecombe & Webby (2006, p. 414) have shown that *Sinocybele* is a senior subjective synonym of *Koksorenus* Koroleva (type species *K. kazakhstansensis* Koroleva, 1992). The present authors accept the arguments of these authors and use *Sinocybele* herein.

Sinocybele weberi (Kolova, 1936)
(Figs 8j–n, 11a, d)

1936 *Cybele weberi* Kolova, p. 35, pl. 1, figs 15, 16.
1948 *Cybele weberi* Kolova; Weber, p. 64, pl. 10, figs 23, 24.

Lectotype (here selected). CNIGR 60/4263 (Fig. 11d) dorsal exoskeleton, internal mould; paralectotype: CNIGR 61/4263, incomplete pygidium, external mould. Both from lower Katian Stage, Besharyk Formation, Dzhebagly Mountains.

Material. NMW 2005.32G.165, cranidium, internal mould; sample 203a; NMW 2005.32G.166, cranidium, external mould (Cl, >4·5, Cw, 9·1, Gl, 2,5, Gw, 2·5), sample 203; NMW 2005.32G.167, cranidium, external mould (Cl, >3·6, Cw, 6·4, Gl, 2,9, Gw, 3·2), sample 203; NMW 2005.32G.169, cranidium, internal mould, sample 203a; NMW 2005.32G.168, pygidium, external mould (Pl, >6·7, Pw, >8·8, PAl, 4·5, PAw, 2,3); sample 203b; NMW 2005.32G.196, pygidium, external mould; sample 203; NMW 2005.32G.197, pygidium, internal mould; sample 203; NMW 2005.32G.171, pygidium, external mould, locality as for lectotype.

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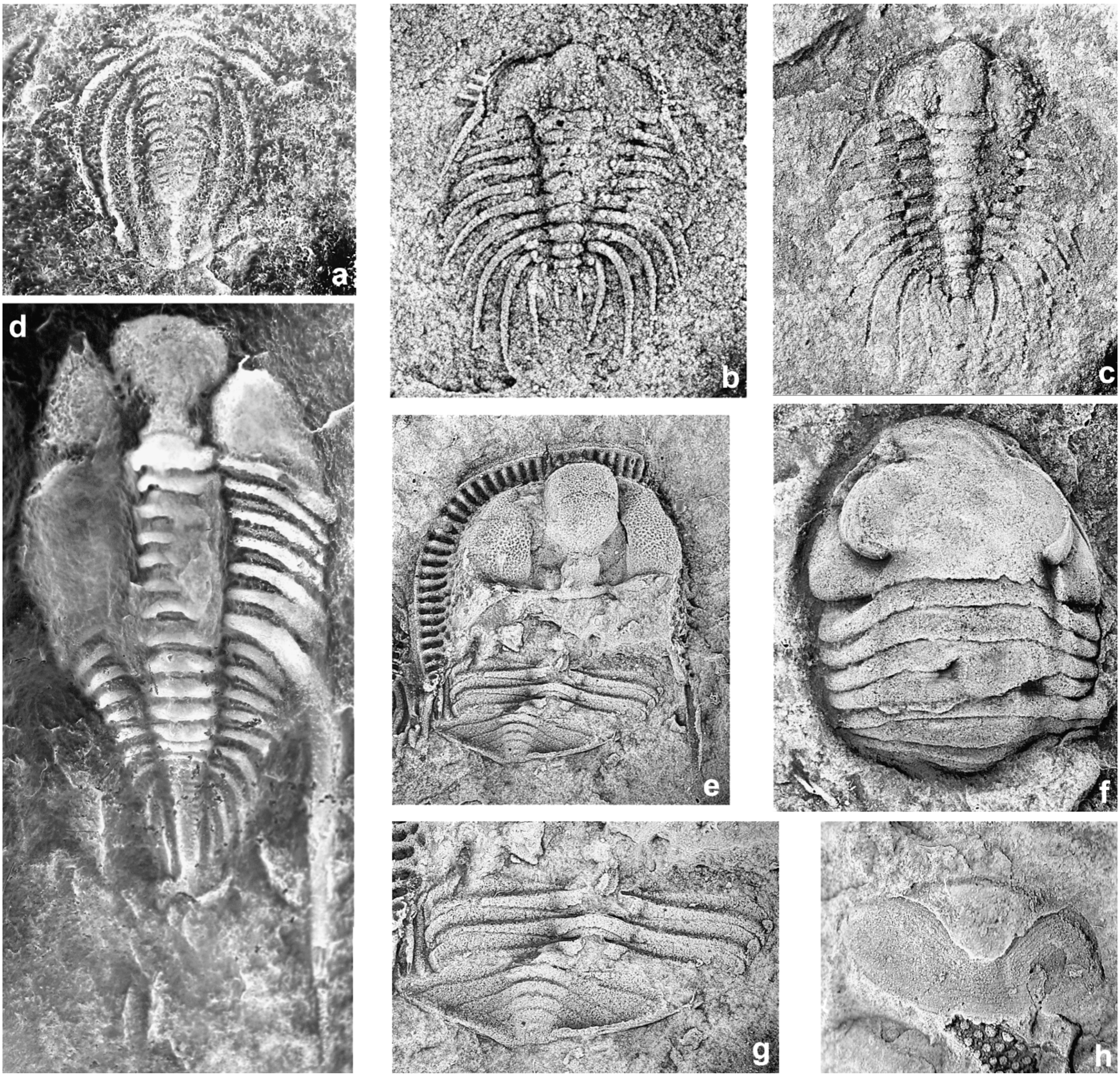

Figure 11 (a, d) *Sinocybele weberi* Kolova, 1936: (a) CNIGR 61/4263, paralectotype, incomplete pygidium, latex cast of external mould, × 9·5; (d) CNIGR 60/4263, lectotype, incomplete dorsal exoskeleton, latex cast of external mould, × 6·75. Both from Besharyk Formation (lower Katian), Dzhebagly Mountains. (b–c) *Diacanthaspis*? sp.: NMW 2005.32G.267a–b, dorsal exoskeleton, latex cast of external mould, and internal mould, × 15, sample 201. (e, g) *Kimakaspis kovalevskyi* gen. et sp. nov. NMW 2005.32G.216, paratype, disarticulated exoskeleton: (e) dorsal view, × 5; (g) pygidium and thoracic segments, detail, × 8·5, sample 201. (f, h) *Nileus* sp.: (f) NMW 2005.32G.193, cephalon with attached thoracic segments, latex cast of external mould, dorsal view, × 6·5, sample 203; (h) NMW 2005.32G.194, pygidium, internal mould, dorsal view, × 4, sample 203a.

Description. Cranidium almost semicircular, about twice as wide as long. Glabella strongly forwardly expanded, with inflated frontal lobe, slightly overhanging anterior margin of cranidium. S1 strongly curved backwards, separating small, elongate suboval L1; S2 and S3 small, pit-like. S4 visible on some internal moulds (Fig. 8m). Glabellar base about 40% of maximum glabellar width (tr). Axial furrows deep and wide, subparallel between S3 and occipital furrow, then straight, broadly divergent anteriorly. Glabellar surface ornamented with irregular tubercles, with sparse larger ones interspersed with numerous small ones. Occipital furrow narrow (sag.), convex anteriorly, pit-like abaxially. Occipital ring strongly convex (sag., tr.), strongly tapered abaxially with a posteriorly placed median tubercle. Fixigenae wide (tr.), subtriangular, convex, with narrow genal spines directed posterolaterally; ornamented by deep, polygonal pits and sparse coarse tubercles. Eye stalks anteriorly directed, with bases situated on anterior part of fixigena, located approximately opposite the widest part of glabella. Border furrow deep and narrow (sag.). Posterior border narrow (sag.), transverse proximally, curving posteriorly opposite the base of palpebral lobes and then widening abaxially. Librigenae unknown.

Thorax with 12 segments, sixth segment macropleural, bearing long spines directed backwards far beyond posterior end of pygidium.

Pygidium subtriangular in outline with a narrow, strongly convex axis occupying about 25% of maximum pygidial width and bearing 14 axial rings and a short terminal piece. Anterior

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axial rings complete; ring furrows on posterior part of axis almost obsolete medially. Axial furrows narrow, well defined. A narrow postaxial ridge is present between terminal piece and posterior pygidial margin. Pleural fields with three pairs of ribs, separated by wide, shallow pleural and interpleural furrows, in which shallow pits are present (Fig. 11a, d). Anterior pleural bands narrow, depressed; posterior pleural bands and far more prominent, convex, upstanding and extend distally into what appear to be short spines. Pleural ribs become progressively less backwardly curved so that third pair runs more or less exsagittally.

Remarks. Kolova's (1936, pl. 1, figs 15, 16) and Weber's (1948) photographs of the exoskeleton and a pygidium of *Cybele weberi* were strongly retouched, and details of the outline and characteristics of the pleural ribs of the pygidium can hardly be seen. Restudy of the type specimens, re-illustrated here as Figure 11a and d, shows that they have the morphology described above. Because there is no significant difference in cranidial and pygidial morphology (genal spines are not preserved in the types) between specimens from the Dzhebagly Mountains and those from the Tarbagatai Range, they are considered conspecific. Between them they show morphological features characteristic of *Sinocybele*, including the macropleural sixth thoracic segment and three well developed pairs of pygidial pleural ribs (e.g. Edgecombe & Webby 2006, p. 414).

Koksorenus kazakhstanensis Koroleva (1992, fig. 1 a, б, г, в) from the Karamolinsk Formation (Sandbian), Stepnyak district, north central Kazakhstan, is similar to *S. weberi*, but the illustrations are unsatisfactory. Detailed comparison is not possible without reference to the original specimens, and an attempt by one of us (LEP) to examine them (registered under the accession number IGNA 1101) during a visit to the Geological Museum of the Institute of Geological Sciences, Almaty in 2006 was unsuccessful, because they were not deposited in the museum, and their present whereabouts is unknown. The holotype (Koroleva 1992, fig. 1 a, б) has the glabella much more forwardly expanded than that of *S. weberi*, as does the crandium from Inner Mongolia attributed to *Sinocybele kazakhstanensis* by Zhou & Zhou (2006, fig. 4N), and this suggests that different species are represented. *Sinocybele gaoluoensis* (Zhou *in* Zhou *et al*., 1977, p. 260, pl. 79, figs 1a–b, 2) from the Katian Linxiang Formation of western Hubei, China is similar to *S. weberi*, but has a more inflated anterior glabellar lobe, longer, narrower posterior part of the glabella, longer genal spines and apparently longer, broader pygidial spines.

'*Cybele*' *psemica* (Abdullaev *in* Abdullaev & Khaletskaya, 1970) from the Beshtor Formation (late Sandbian/early Katian) of the Pskem Range, Uzbekistan was attributed to *Sinocybele* by Zhou & Zhou (2006, p. 386) and by Edgecombe & Webby (2006, p. 414). It has a similar glabella to that of *S. kazakhstanensis* but the holotype cranidium (Abdulleav in Abdullaev & Khaletskaya 1970, pl. 4, figs 7, 8 – incorrectly numbered in plate caption: cf. text, p. 45) has a long, backwardly oblique ocular ridge, and the pygidium has deep, narrow pleural and interpleural furrows. These morphological features indicate that this species should not be assigned to *Sinocybele*.

Subfamily Dindymeninae Henningsmoen *in* Moore, 1959

Genus *Dindymene* Hawle & Corda, 1847

Type species. *Dindymene friderciaugusti* Hawle & Corda, 1847; Upper Ordovician, Katian Stage, Králův Dvůr Formation, Czech Republic.

Dindymene brevicaudata Kolobova, 1972

(Figs 5d, 12a–d, f–g)

1972 *Dindymene brevicaudata* Kolobova; p. 244, pl. 55, figs 13, 14.

Holotype. CNIGR Museum 9/9559, Sandbian Stage, Karagach Formation, east side of Ayaguz River about 7 km north of Akchii village, Tarbagatai Range, Kazakhstan.

Material. NMW 2005.32G.176 (L, 7·2, W 7·3, Cl, 2·6, Cw, 7·3, Gw, 2·1) NMW 2005.32G.177, NMW 2005.32G.210 (L, 7·2, W 7·3, Cl, 2·6, Cw, 7·3, Gw, 2·1), and NMW 2005.32G.211, articulated exoskeletons, internal moulds; NMW 2005.32G.217, cephalon with attached thorax, external mould; NMW 2005.32G.215, pygidium, external mould; NMW 2005.32G.245, pygidium, internal mould; all sample 201. NMW 2005.32G.173, pygidium, external mould (Pl, 3·8, Pw, 4·2, PAl, 2·7, PAw, 1·9); sample 205.

Description. Exoskeleton slightly elongate suboval, with maximum width at posterior cephalic margin. Cephalon almost semicircular, about 50–55% as long as wide. Preoccipital glabella strongly convex (sag., tr.), expanding anteriorly, with strongly convex anterior margin, bordered laterally by narrow and deep axial furrows converging towards occipital furrow. Base of a median glabellar spine situated at about 25% of preoccipital glabellar length from the deep, transverse occipital furrow. Occipital ring narrow with a convex posterior margin. Fixigenae strongly convex, declined outwards. Posterior border furrow deep, transverse; posterior border narrow (sag.), convex. Genal spines small, directed posterolaterally. Cephalon ornamented by coarse, widely spaced tubercles, also visible on internal moulds.

Thorax of ten segments; deep and wide axial furrows converging posteriorly, and narrow, convex axis occupying about 20% of thoracic width. Inner portion of pleurae transverse, subparallel, subdivided into flat anterior bands and more prominent posterior bands. Outer portion of pleurae directed posteroventrally at fulcrum, produced into wide and flat pleural spines and terminating with rounded distal extremities. Anterior segments are less curved and directed posterolaterally; posterior segments curved more strongly backwards, to lie parallel to pygidial pleurae.

Pygidium slightly transverse, about 90% as long as wide (including spines). A subconical axis occupies about 45% of maximum pygidial width, and has six or seven axial rings. First three axial rings are separated by deep and wide (sag.) ring furrows, connected to posteriorly directed pleural ribs. Remaining posterior axial rings fused together to form a subtriangular structure with very fine ring furrows, which do not merge with axial furrows. Terminal piece very small, subtriangular, pointed posteriorly. Axial furrows almost straight, converging posteriorly. Pleural field with three pairs of strong pleural ribs, terminating in three pairs of short, blunt pygidial spines and separated by wide, deep interpleural furrows. Two anterior pairs of pleural ribs posterolaterlly directed distally, and then bent strongly posteriorly abaxially. Third pair of pleural ribs posteriorly directed, with inner margins confined to axial furrows.

Remarks. Our specimens are topotypes, and are identical to the type specimens of *D. brevicaudata* in almost all details, but Kolobova's (1972, pp. 244–245) description includes two apparent points of difference. Firstly, she noted the presence of short, posterolaterally directed librigenal spines, which are not present on our specimens. We are unable to confirm their presence by examination of her figures (1972, pl. 55, figs 12, 13), and it is possible that the material was misinterpreted. Secondly, our specimens have six or seven pygidial axial rings,

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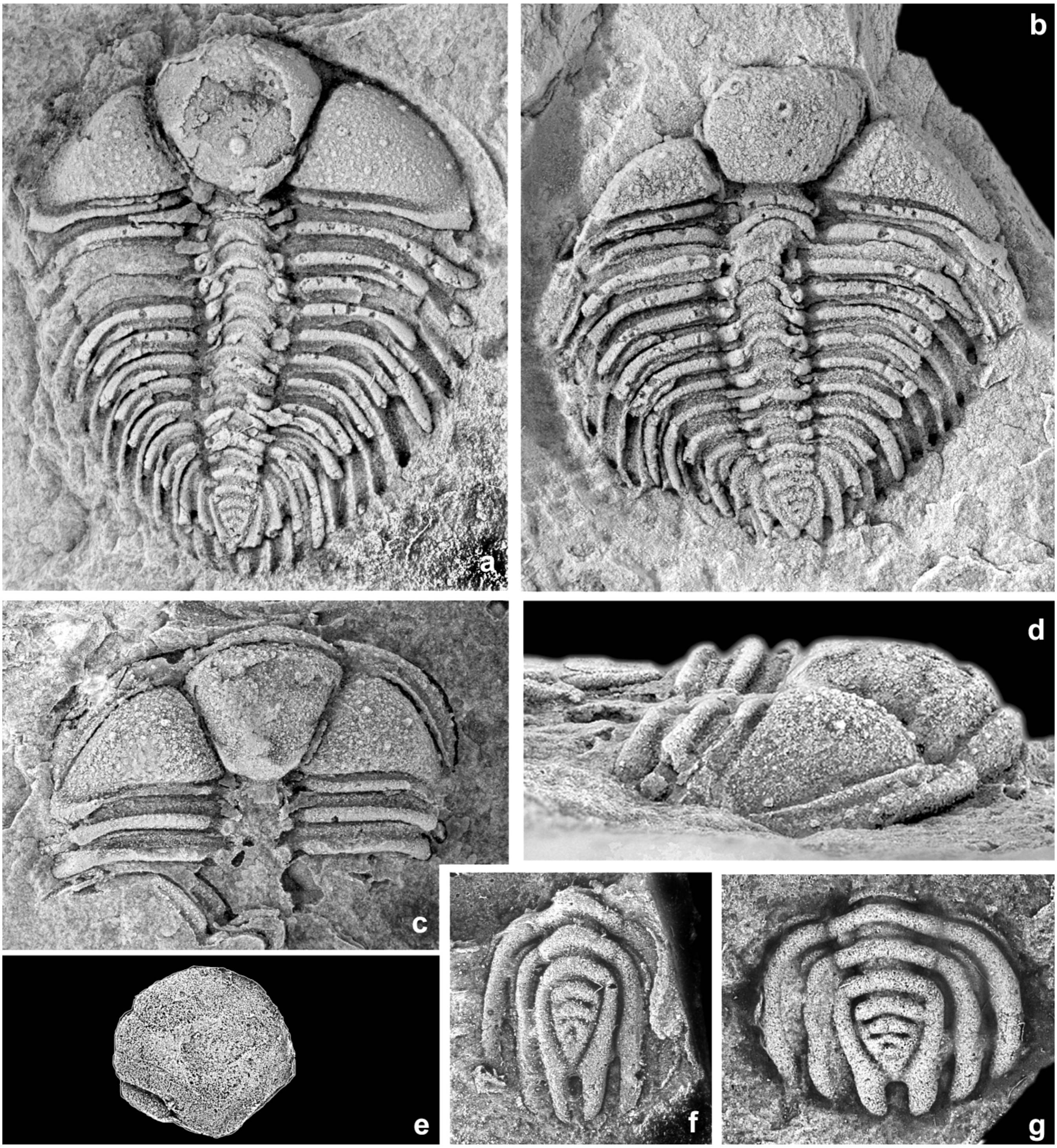

Figure 12 (a–d, f–g) *Dindymene brevicaudata* Kolobova, 1972: (a) NMW 2005.32G.210, articulated exoskeleton, internal mould, dorsal view × 8·5, sample 201; (b) NMW 2005.32G.211, articulated exoskeleton, internal mould, dorsal view × 8·5, sample 201; (c–d) NMW 2005.32G.217, cephalon with attached thoracic segments, internal mould, dorsal and lateral views, × 9·5 and × 14, sample 201; (f) NMW 2005.32G.215, pygidium, latex cast of external mould (probably belongs to the same individual as c–d), dorsal view, × 12, sample 201; (g) NMW 2005.32G.173, pygidium, latex cast of external mould, dorsal view, × 11, sample 205. (e) Acanthoparyphinae gen. indet.: NMW 2005.32G.149, incomplete cranidium, latex cast of external mould, dorsal view, × 4, sample 203b.

but Kolobova (1972, p. 245) stated that three or four are present in *D. brevicaudata*. The holotype (Kolobova 1972, pl. 55, fig. 13) has a well-preserved thorax comprising ten segments, behind which the pygidium is slightly displaced. On the latter, although the illustration is small, at least five pygidial axial rings can be discriminated, and it seems that these were miscounted in the original description. We have, therefore, no reason to exclude our material from *D. brevicaudata*.

Dindymene(?) *araneosa* Lisogor (1965, p. 181, pl. 2, fig. 7) from the Akzhar Formation (Sandbian, *foliaceus* Biozone) of south eastern central Kazakhstan, known from a single pygidium does not belong to *Dindymene*. It is a cybeline, and probably belongs to *Lyrapyge* (Fortey 1980, p. 100).

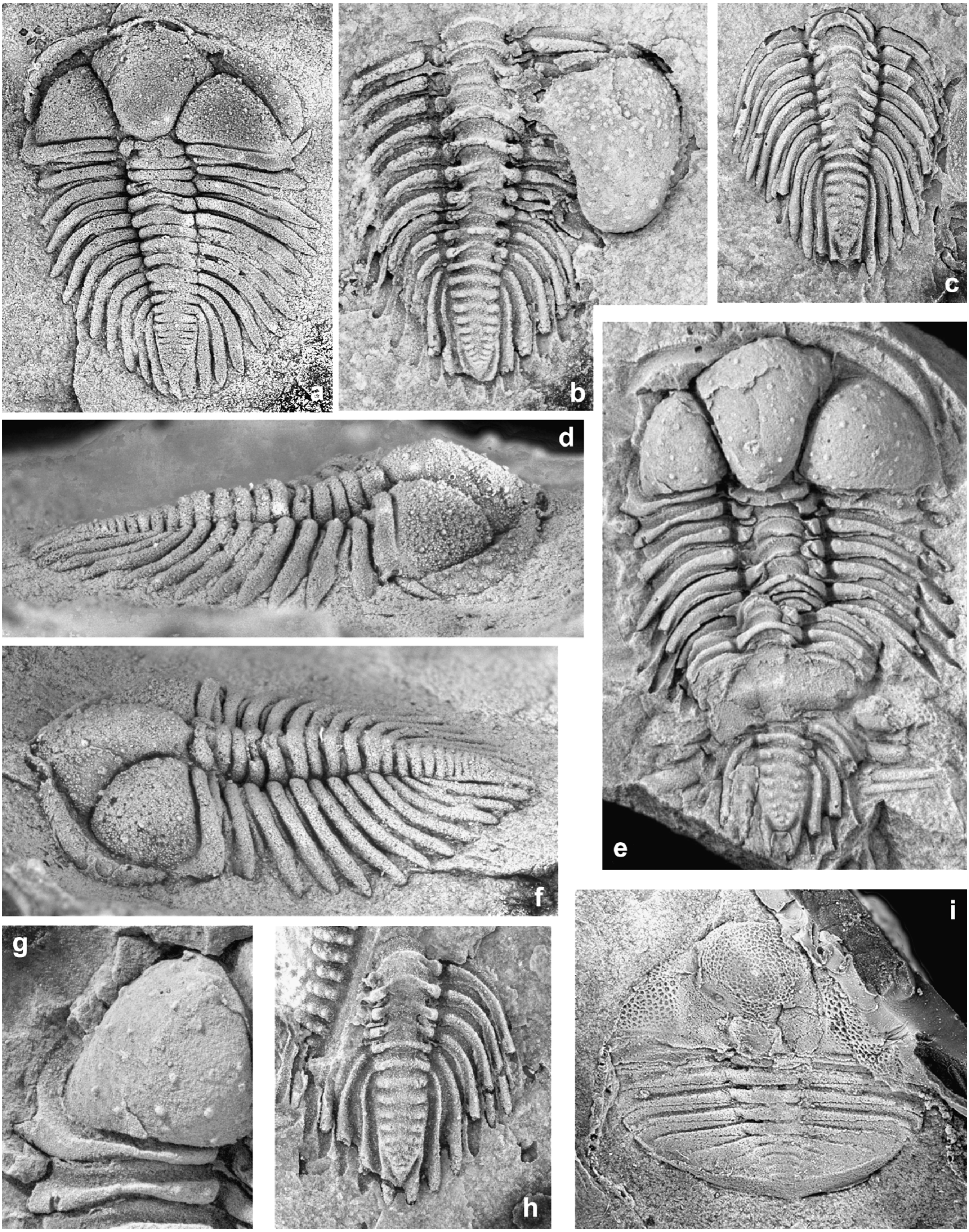

Figure 13 (a–h) *Dindymene* aff. *longicaudata* Kielan, 1960: (a, d, f) NMW 2005.32G.213, articulated exoskeleton, latex cast of external mould, (a) dorsal view, × 10; (d) lateral view, × 11·5, (f) lateral oblique view, × 11·5, sample 201; (b) NMW 2005.32G.212, thorax and pygidium, internal mould, × 9, sample 201; (c) NMW 2005.32G.214, thorax and pygidium, internal mould, dorsal view, × 5·5, sample 201; (e, g) NMW 2005.32G.180, (e) exoskeleton with pygidium disarticulated, internal mould, dorsal view, × 6·5; (g) fixigena of same specimen: detail of coarsely tuberculate ornament and transverse genal spine, × 12, sample 201; (h) NMW 2005.32G.255, pygidium with attached thoracic segments, internal mould, × 8·5, sample 201. (i) *Kimakaspis kovalevskyi* gen. et sp. nov.; NMW 2005.32G.272, paratype, latex cast of external mould of damaged articulated specimen, dorsal view, × 5·5, sample 201.

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Dindymene aff. *longicaudata* Kielan, 1960
(Fig. 13a–h)

Material. NMW 2005.32G.180 (Cl, 5·0, Cw, 10·7, Gw, 4·2, Pl, 3·6, Pw, 4·8, Aw, 1·6), dorsal exoskeleton, internal mould; NMW 2005.32G.213, dorsal exoskeleton, external mould (L, 7·8, W 5·5, Cl, 2·7, Cw, 6·0, Gw, 2·6, Pl, 2·0, Pw, 2·2, Aw, 1·0); NMW 2005.32G.218–224, dorsal exoskeleton, external moulds; NMW 2005.32G.212, 214, 256, pygidium and attached thoracic segments, external and internal moulds.; NMW 2005.32G.255, pygidium with attached thoracic segments, internal mould; all from sample 201. NMW 2005.32G.172, pygidium, external mould; sample 205.

Remarks. In addition to *Dindymene brevicaudata* Kolobova, sample 201 contains articulated exoskeletons of *Dindymene* with almost identical cephalic characters, but very different pygidial morphology. This is characterised by a long, narrow axis with 9 to 12 rings. Only two anterior axial rings are complete and separated by deep, transverse furrows, whereas succeeding axial rings merge axially and are separated by transverse furrows that almost fade medially, adaxially, and deepen towards the axial furrows. The pleural field bears three pairs of pleural ribs, but only the two anterior pairs are connected to pleural ribs, with the second pair of pleural ribs running almost parallel to the axial furrows. The third pair of pleural ribs is very short and not connected to any axial ring, and is terminated by a pair of short spines.

This distinct pygidial morphology matches in many details that of *Dindymene longicaudata* Kielan, 1960 (e.g. pl. 30, fig. 2) from the upper Katian (Ashgill) *Staurocephalus clavifrons* Biozone of the Holy Cross Mountains, Poland. The only difference is in the clear separation of the third pair of the pleural ribs from the axis. The cephalic morphology also resembles that of *D. longicaudata*, although the tubercles on the glabella appear to be a little larger and sparser (but note that we have only internal moulds available), and the short genal spines are slightly larger and broader based.

There are a number of external moulds of isolated cranidia of *Dindymene* in samples 201 (NMW 2005.32G.225–239, 257, 258), and 205 (NMW 2005.32G.174, 175), but because of the almost identical cranidial morphology of *D. brevicaudata* and *D.* aff. *longicaudata*, both of which occur in these samples, we are unable decide to which of these they belong.

Family Lichidae Hawle & Corda, 1847
Genus *Amphilichas* Raymond, 1905

Type species. *Platymetopus lineatus* Angelin, 1854, Upper Ordovician, Katian Stage, Boda Limestone Formation, Dalarna, Sweden.

Amphilichas aff. *nasutus* Webby, 1974
(Fig. 6i)

Material. NMW 2005.32G.192, incomplete cranidium, internal mould; sample 203b.

Remarks. This cranidium has an anterior median glabellar lobe which expands strongly forwards, bounded by deep longitudinal furrows, which converge gently anteriorly until cranidial mid-length, then curve strongly and diverge anteriorly adaxially. The surface is ornamented with sparse coarse and numerous fine tubercles, strongly resembling that of *Amphilichas nasutus* Webby, 1974 (pl. 34, figs 3–8) from the Upper Ordovician, lower Eastonian of New South Wales, but the latter has a greater preponderance of large tubercles. The cranidium from the Karagach Formation also resembles those described by Chugaeva (1958) as *Amphilichas karakanensis* var. *disjunctus* from the Upper Ordovician, Sandbian, Anderken Formation of the Chu-Ili Range, but differs in having a median glabellar lobe which is strongly expanded anteriorly, an unevenly curved anterior margin, and coarse, more strongly differentiated, tuberculate ornament.

Family Odontopleuridae Burmeister, 1843
Subfamily Odontopleurinae Burmeister, 1843
Genus *Diacanthaspis* Whittington, 1941

Type species. *Diacanthaspis cooperi* Whittington, 1941, Upper Ordovician, Martinsburg Formation, Virginia, USA.

Diacanthaspis? sp.
(Fig. 11b, c)

Material. NMW 2005.32G.267a–b, 268, 269, 270. Three articulated specimens (counterpart internal and external moulds, one internal mould, one external mould), one incomplete cranidium, all sample 201.

Description. Glabella tapers forwards, median lobe parallel-sided, rounded anteriorly, delineated by wide and shallow axial furrows. Glabella lateral lobes poorly defined but two can be discriminated; occipital ring transverse, wider (tr.) than median glabellar lobe. Occipital furrow narrow, well-defined. Librigena with narrow border defined by shallow border furrow; up to ten stout lateral marginal spines, decreasing progressively in length anteriorly. Genal spine slender, tapering gently, directed posterolaterally. Cranidium apparently granulose, but too poorly preserved to distinguish size range of granules. Palpebral lobe and eye not preserved.

Thorax with nine segments, posterior band of each pleura extends into a long spine. Spines become progressively longer and more strongly curved backwards towards posterior. Pair of prominent tubercles on each axial ring and two to three on each posterior band of pleurae.

Pygidium of two(?) segments, the first with a well-defined axial ring bearing two stout tubercles. First pair of pleurae with a stout tubercle, and extend laterally into major spines, which are directed posteriorly and are slightly shorter than about half the width (tr.) of posteriormost thoracic spines. Terminal pygidial segment less well-defined, tuberculate and bearing one to two pairs of short, slender, posteriorly-directed spines.

Remarks. These specimens are very small holaspides (sagittal length 2·8–3·9 mm). Confident generic assignment is not possible because of the poor preservation of the cranidia and pygidia, but such morphological features as can be seen suggest that they belong probably to *Diacanthaspis*.

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