The Late Cambrian trilobite *Hamashania* from Korea

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The Late Cambrian trilobite genus *Hamashania* Kobayashi, 1942a has hitherto been poorly understood and is herein revised based on well-preserved specimens from Korea. *Platysaukia* Kobayashi, 1960 and *Goumenzia* Guo & Duan, 1978 are treated as junior synonyms of *Hamashania*. *Hamashania* comprises only two species, *H. pulchera* Kobayashi, 1942a and *Pterocephalus busiris* Walcott, 1905, and is restricted to North China and Korea. The new genus *Pacootasaukia* is proposed to accommodate the Australian species *Platysaukia jokliki* Shergold, 1991 as type species, and *Platysaukia tomichi* Shergold, 1991, which are so distinct that they cannot be included within *Hamashania*. The generic concept of *Mareda* Kobayashi, 1942b, which was often confused with *Hamashania*, is confined to the type material.

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HAMASHANIA Kobayashi, 1942a was, when erected, based on an incomplete pygidium and a fragmentary cranidium from the Late Cambrian of Liaoning, North China. Kobayashi (1942a) suggested that *Hamashania* might possibly be a member of the Saukinae, whereas Lochman-Balk in Harrington *et al.* (1959) placed it under Order and Family Uncertain, apparently owing to insufficient knowledge of its morphological features. Kobayashi (1958) assigned a fragmentary pygidium from Danyang in Korea questionably to *Hamashania* but *Hamashania* has not been documented in subsequent studies. Presumably, incomplete preservation of the type material prevented later investigators from identifying the genus with confidence. For instance, Kobayashi (1960) himself failed to recognize *Hamashania* in a collection from the Late Cambrian Hwajeol Formation of Korea, but instead erected a new genus *Platysaukia* based on a poorly-preserved cranidium. Guo & Duan (1978) assigned a cranidium to another new genus *Goumenzia*, and associated pygidia to *Mareda* Kobayashi, 1942b from Hebei and Liaoning provinces of North China; all this material, however, belongs to *Hamashania* (see below). On the other hand, two species referred to *Platysaukia* from Australia by Shergold (1991) cannot be assigned to *Platysaukia* (=*Hamashania*), because their cranidia and pygidia are profoundly different from those of *Hamashania*.

During recent investigations of the Cambrian-Ordovician Taebaek Group in the southeastern corner of the Taebaeksan Basin (Fig. 1), several fossiliferous horizons were located within the Hwajeol Formation, which yielded relatively diverse and well-preserved trilobites. The fauna comprises uppermost Cambrian trilobites, including *Quadraticephalus*, *Sinosaukia*, *Haniwa*, *Hamashania* and *Tsinania*. Of particular interest is the occurrence of well-preserved specimens assignable to *Hamashania*. More than 30 cranidia, pygidia, and free cheeks of *Hamashania* in the present collection provide a good opportunity to examine the morphological details of this hitherto poorly known genus. Accordingly, this study attempts to resolve the taxonomic problems involving *Hamashania* so as to provide better information on stratigraphic and palaeogeographic interpretation.

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Geology and fossil locality

The Cambrian-Ordovician sedimentary rocks in Korea, Joseon Supergroup, are widely exposed in the Taebaeksan Basin, which occupies the central-eastern part of the Korean peninsula (Fig. 1). The Joseon Supergroup rests unconformably on Precambrian granitic gneiss and meta-sedimentary rocks and is overlain unconformably by Permian-Carboniferous sedimentary rocks. The lower Palaeozoic sediments are shallow marine strata and are composed predominantly of carbonate with lesser amounts of sandstone and shale. In the early Palaeozoic, the Taebaeksan Basin was a shallow marine mixed siliciclastic-carbonate system with progressively greater depth to the west (Yeongwol area), as indicated by the occurrence of coarse siliciclastic sediments in the eastern margin of the Taebaeksan Basin (Chough *et al.* 2000). This siliciclastic-carbonate system persisted throughout the Cambrian, until rapid accumulation of carbonate sediments in Yeongwol area resulted in the formation of a widespread carbonate platform across the Taebaeksan Basin in the Early Ordovician. This carbonate platform seems to have been characterized by low relief with shoals, lagoons, and tidal flats that persisted into the Early and Middle Ordovician (Choi *et al.* 2001). Marine sedimentation virtually ceased over the whole Taebaeksan Basin in the Late Ordovician and most of the Taebaeksan Basin was emergent during the middle Palaeozoic until marine transgression resumed in the Late Carboniferous.

The Joseon Supergroup has been divided into the Taebaek, Yeongwol, Yongtan, Pyeongchang, and Mungyeong groups based on their geographic distribution and unique lithologic features (Kobayashi 1966, Choi 1998). Of these, the Taebaek and Yeongwol groups are regionally extensive (Fig. 1) and stratigraphically well investigated owing to prolific occurrence of trilobites and conodonts, whereas the stratigraphy of the latter three groups is not adequately understood due to complicated geologic structures and paucity of fossils.

The Taebaek Group occupies the eastern half of the Taebaeksan Basin (Fig. 1) and comprises in ascending order the Jangsan/Myeonsan, Myobong, Daegi, Sesong, Hwajeol, Dongjeom, Dumugol, Makgol, Jigunsan, and Duwibong formations (Kobayashi 1966, Choi 1998). The conventional Cambrian-Ordovician boundary was drawn at the boundary between the Hwajeol and the Dongjeom formations. The Hwajeol Formation has been subdivided into three members based on lithologic association (Cheong 1969): the lower member (up to 100 m thick) is characterized by alternations of limestone and shale beds, showing a conspicuous banded appearance; the middle member (*ca.* 20 m thick) consists mainly of sandstone with occasional intercalations of limestone beds; and the upper member (*ca.* 60 m thick) comprises alternating beds of limestone, marlstone/shale, and limestone conglomerate. Kobayashi (1935, 1966) recognized five biozones within the Hwajeol Formation: they are from oldest to youngest the *Prochuangia*, *Chuangia*, *Kaolishania*, *Dictyites*, and *Eoorthis* zones. The Dongjeom Formation (10-50 m thick) is characterized by the dominance of light to dark gray sandstone with occasional association of shale and limestone lenses; *Pseudokainella iwayai* is the only known trilobite species from the formation (Kobayashi 1953).

All of the specimens considered in this study were collected from a measured section of the Hwajeol Formation in the Taebaeksan Basin, called the Sokgaejae section (Fig. 1). The Sokgaejae section is located along a mountain trail at the elevation of approximately 1,000 m high, where a nearly complete succession of the Taebaek Group (*ca.* 1 100 m thick) is well exposed. The Hwajeol Formation in the section is about 53 m thick, consists mainly of alternations of limestone, shale, and limestone conglomerate beds, and is considered to represent the upper member of the Hwajeol Formation. Trilobites were recovered from eight stratigraphic intervals within the Hwajeol Formation and represent the two trilobite assemblages, the *Quadraticephalus* and *Mictosaukia* faunas. The *Quadraticephalus* fauna consists predominantly of the eponymous

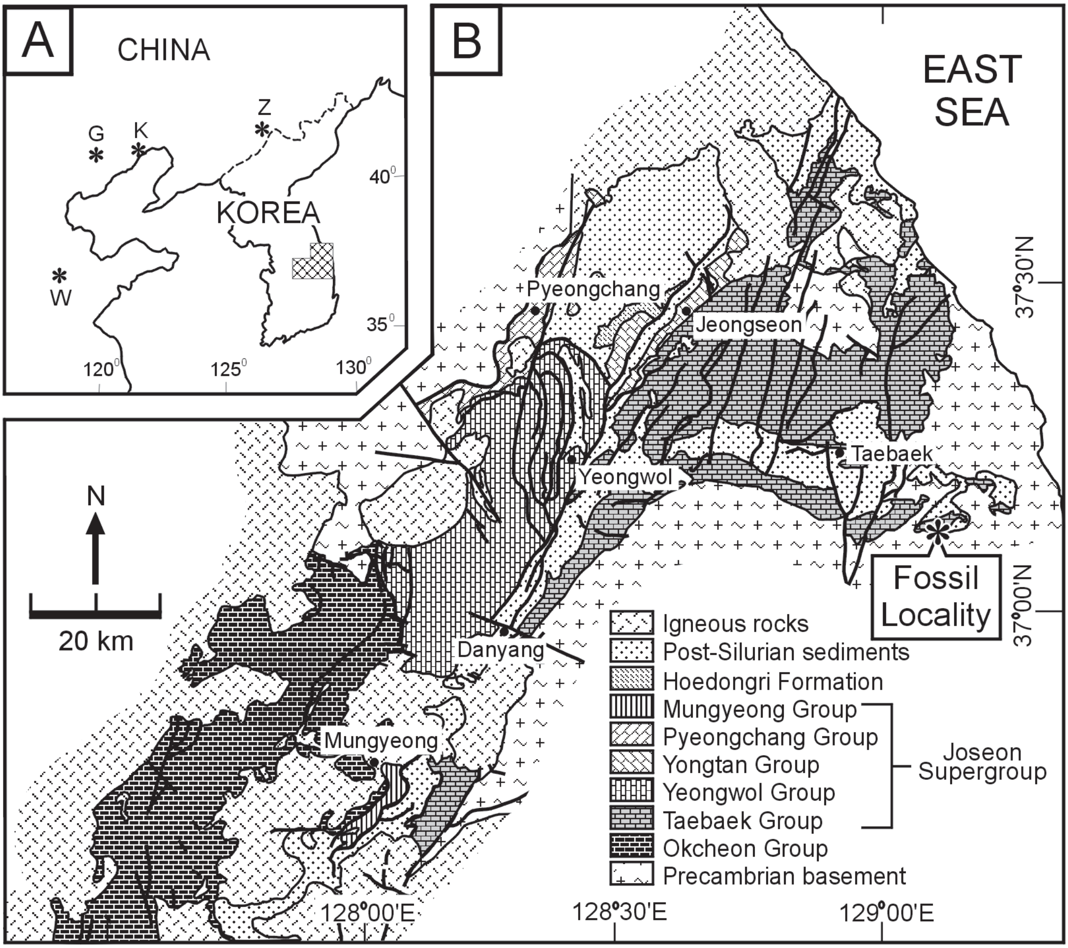

Fig. 1. Locality maps. **A**, index map showing the position of figure B (hatched box) and fossil localities of *Hamashania* in China. The asterisks with letters G, K, W, Z indicate the localities of material studied by Guo & Duan (1978), Kobayashi (1942a), Walcott (1905, 1913) and Zhu (1992), respectively. **B**, simplified geologic map of the Taebaeksan Basin showing the distribution of the lower Palaeozoic Joseon Supergroup. The fossil locality examined in this study is indicated by an asterisk (*) in the right of the figure.

genus (about 40% in abundance) along with *Sinosaukia*, *Haniwa*, *Tsinania*, *Hamashania* and agnostoids. The overlying *Mictosaukia* fauna includes *Koldinioidia*, *Mictosaukia*, *Coreanocephalus*, *Haniwa*, *Pagodia* and agnostoids. These Late Cambrian trilobite faunas are well traceable to North China. *Hamashania* is confined to the *Quadraticephalus* fauna in Korea, whereas it has been recorded from the *Tsinania-Ptychaspis* and *Changia* zones of North China (Zhang & Jell 1987).

Systematic palaeontology

The morphological terms used in this study are defined by Whittington & Kelly (1997) and descriptive terms for glabellar furrows and facial sutures follow Henningsmoen (1957). All of the specimens from the Hwajeol Formation described herein are deposited in the palaeontological collections of Seoul National University with registered SNUP numbers. The specimens with PA numbers are the original material studied by Kobayashi (1942a) and are presently stored at the University Museum of the University of Tokyo, Japan.

Order Asaphida Salter, 1864
Superfamily Dikelocephaloidea Miller, 1889
Family Dikelocephalidae Miller, 1889

Hamashania Kobayashi, 1942a

1942a *Hamashania* Kobayashi, p. 37.
1959 *Hamashania* Kobayashi: Lochman-Balk *in* Moore, p. 517.
1960 *Platysaukia* Kobayashi, p. 407.
1978 *Goumenzia* Guo & Duan, p. 450.

Type species. *Hamashania pulchera* Kobayashi, 1942a from the Late Cambrian of Liaoning, North China.

Diagnosis. Dikelocephalidae with cranidium with frontal area differentiated into relatively long preglabellar field and weakly upturned anterior border; glabella trapezoidal; two pairs of lateral furrows, more or less transverse; S1 longer and more clearly incised than S2; palpebral lobes long and extending from level with occipital furrows to S4, with well-defined palpebral furrow that merges with axial furrow. Pygidium ovoid in outline, slightly indented postero-medially; pygidial axis consisting of seven rings and conical terminal piece; pleural furrows more clearly incised than interpleural furrows; pygidial doublure broad and flat, with densely covered terrace lines.

Remarks. *Hamashania* is revised on the basis of re-examination of the type material (Fig. 2), and new collections comprising more than 30 cranidia, pygidia, and free cheeks from the Hwajeol Formation, Korea. It is easily distinguished from *Mareda* Kobayashi, 1942b in having a broader pygidial axis with seven, rather than twelve, axial rings. However, poor understanding of *Hamashania* hindered identification of the genus and led later workers to assign some pygidia to *Mareda* or to erect new genera. Kobayashi (1960) established *Platysaukia* based on a single, incomplete, poorly preserved cranidium from the Hwajeol Formation (Kobayashi 1960, pl. 19, fig. 12; fig. 2A), which lacks part of the frontal area, one of the important features in differentiating dikelocephalid genera. However, its weakly bulging glabella and large palpebral lobes are among the distinctive features reminiscent of *Hamashania pulchera* (see below) and thus *Platysaukia* is synonymized with *Hamashania*. *Goumenzia* Guo & Duan, 1978, established on the basis of a cranidium from Liaoning of northeastern China, shares diagnostic morphological features with, and hence is treated a junior synonym of, *Hamashania*. Guo & Duan (1978) recovered some pygidia belonging to *Hamashania* from the same collection, but assigned them to a new species *Mareda sinuata* Guo & Duan, 1978.

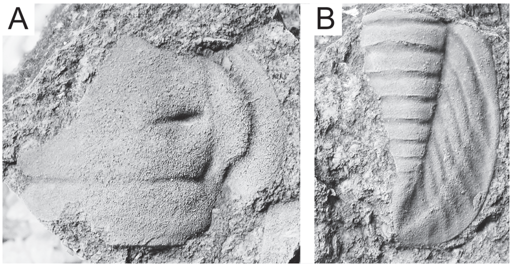

Fig. 2. The type material of *Hamashania pulchera* Kobayashi, 1942a from the Late Cambrian of Liaoning, China. **A**, incomplete cranidium, PA1859, x2.4. **B**, **holotype** pygidium, PA1860, x2.3.

Shergold (1991) established two new species from the Pacoota Sandstone of Australia, *Platysaukia jokliki* and *Platysaukia tomichi* which, however display morphological features of the Saukiidae in having a short frontal area, a clearly-incised transverse S1, and small palpebral lobes. Therefore, they cannot be accommodated with *Hamashania* or other pre-existing genera and are herein assigned to the new genus *Pacootasaukia* (see below).

Hamashania pulchera Kobayashi, 1942a (Figs 3A-G)

1942a *Hamashania pulchera* Kobayashi, p. 38, figs 1-4.
1960 *Platysaukia euryrachis* Kobayashi, p. 407, pl. 19, fig. 12, text-fig. 13b.
1960 *Mareda mukazegata* Kobayashi, p. 407, pl. 19, figs 31-32, text-fig. 14b.
1978 *Mareda sinuata* Guo & Duan, (*pars*), p. 456, pl.

2, fig. 21.
1987 *Mareda busiris* (Walcott); Zhang & Jell, *(pars)*, p. 245, pl. 121, fig. 6.

Diagnosis. A species of *Hamashania* having smooth glabella and pygidia with obsolete interpleural furrows.

Description. Cranidium subrectangular in outline. Glabella trapezoidal, two-thirds of cranidial length, slightly tapering forwards, weakly bulging posteriorly, convex, down-sloping anteriorly and abaxially; S0 simple, transverse, clearly incised; S1 slit-like, directed oblique backwards; S2, S3, and S4 faint; occipital ring transversely rectangular, wider than glabella. Preglabellar furrow and axial furrows shallow and narrow, but clearly incised. Preglabellar field inversely trapezoidal in outline, *ca*. one-third of glabellar length, down-sloping anteriorly in the posterior two-thirds of the field and then upturned to anterior border. Anterior border convex, defined by faint border furrow, very short, medially acuminate. Palpebral area flat, semi-elliptical, *ca*. one-half of glabellar length, located at glabellar mid-length; twice longer than wide; palpebral furrow shallow, clearly incised, merging anteriorly and posteriorly with axial furrow; palpebral lobe large, bean-shaped, moderately convex, as wide as or slightly narrower than palpebral area, attached to glabella, corresponding in length to posterior four-fifths of glabella. Anterior branch of facial suture weakly divergent, straight; posterior branch of suture nearly transverse to strongly divergent. Librigena with broad and flat genal field and convex lateral border; genal field ornamented with subparallel to anastomosing ridges and grooves; lateral border elevated moderately, ornamented with subparallel ridges and grooves, separated from librigenal field by abrupt change in convexity, and prolonged into a long spine. Posterior border poorly defined.

Pygidium subquadrate in outline, longer than wide, with shallow posteromedian notch. Axis tapering backwards, width at third axial ring about one third of pygidial width, strongly convex, with well-defined articulating half ring, seven axial rings, and conical terminal piece. Axial furrow shallow and narrow. Pleural region with seven pleurae, flat to weakly convex, down-sloping peripherally; interpleural furrows obsolete; pleural furrows narrow but clearly incised, directed backwards, and nearly reaching to posterior margin. Border faint. Doublure broad, ornamented by closely spaced anastomosing terrace lines, maximum breadth *ca*. one-fifth to one-sixth of pygidial length at postero-lateral corners, narrowing anteriorly.

Remarks. *Hamashania pulchera* is differentiated from *H. busiris* (Walcott, 1905) in having smooth prosopon and obsolete interpleural furrows.

Platysaukia euryrachis Kobayashi, 1960, based on a single incomplete cranidium from the Hwajeol Formation of Taebaek, is considered a junior synonym of *H. pulchera* (see generic remarks). The associated pygidia assigned to *Mareda mukazegata* (Kobayashi, 1960, p. 407, pl. 19, figs 31-32) are also better accommodated within *H. pulchera*, based on the interpretation that they, though incomplete, possess obsolete interpleural furrows. The type material of *Mareda mukazegata* from North China (Sun 1935, pl. 4, figs 19-20) is very distinctive in having a longitudinally elongated pygidium with a narrow axis and twelve axial rings.

One of the pygidia attributed to *Mareda sinuata* Guo & Duan, 1978 (pl. 2, fig. 21) and one pygidium of *Mareda busiris* (Walcott, 1905) illustrated by Zhang & Jell (1987, pl. 121, fig. 6) share morphological features with *Hamashania* in having smooth prosopon and obsolete interpleural furrows, and thus are transferred to *H. pulchera*.

Occurrence. *Quadraticephalus* fauna of the Hwajeol Formation, Taebaeksan Basin, Korea; Late Cambrian of Liaoning, Hebei and Shandong provinces, North China.

Hamashania sp. cf. **H. busiris** (Walcott, 1905) (Figs 3H-J)

1905 *Pterocephalus busiris* Walcott, p. 68.
1913 *Pterocephalus busiris* Walcott; Walcott, p. 146, pl. 14. fig. 4.
non 1935 *Pterocephalus busiris* Walcott; Sun, p. 66, pl.

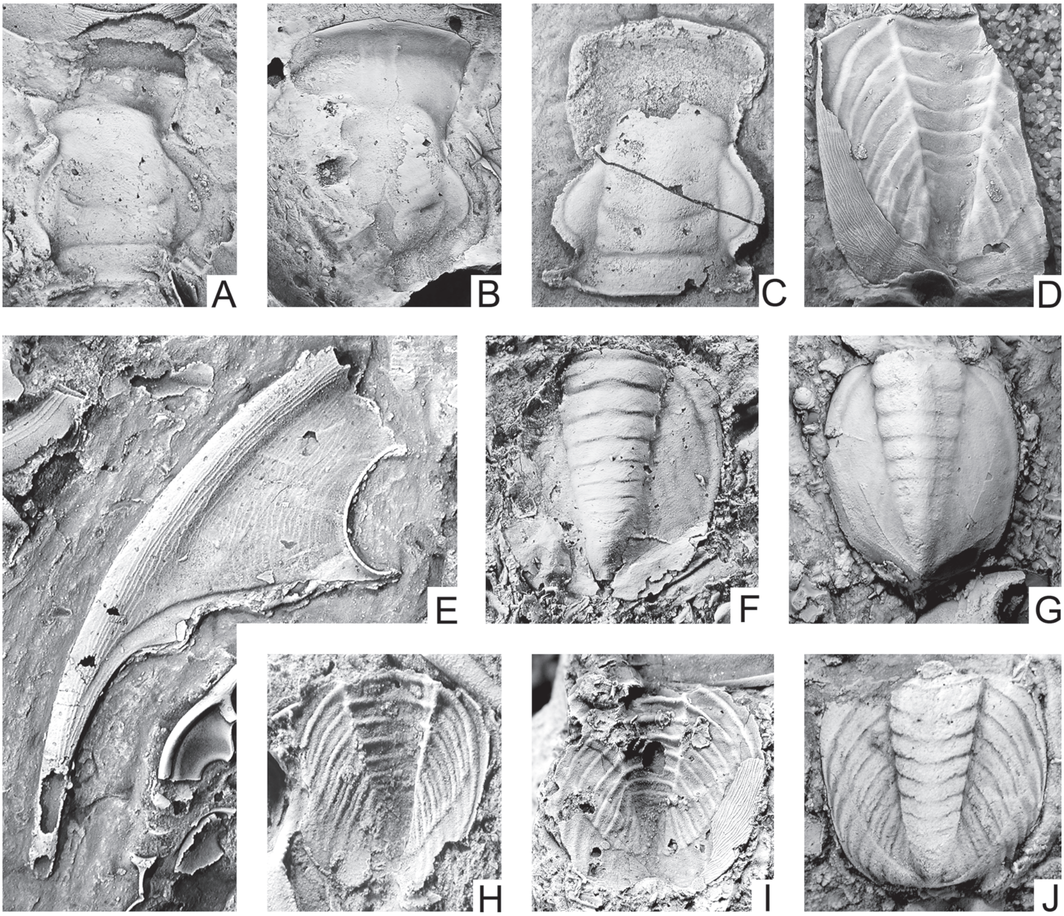

Fig. 3A-J. Hamashania pulchera Kobayashi, 1942a and *Hamashania* sp. cf. *H. busiris* (Walcott, 1905) from the Hwajeol Formation (Late Cambrian), Korea. **A-G**, *Hamashania pulchera* Kobayashi, 1942a. **A**, nearly complete cranidium, but lacking the anterior portion of preglabellar area, SNUP4005, x3.7. **B**, incomplete cranidium showing well differentiated anterior border and preglabellar field, SNUP4006, x2.0. **C**, nearly complete cranidium, SNUP4004, x2.2. **D**, ventral view of pygidium, showing closely spaced terrace lines on doublure, SNUP4007, x1.7. **E**, free cheek ornamented with subparallel to anastomosing ridges and grooves, SNUP4008, ×3.1. **F**, dorsal view of pygidium, SNUP4009, ×2.8. **G**, latex cast of pygidium, SNUP4010, x2.2. **H-J**, *Hamashania* sp. cf. *H. busiris* (Walcott, 1905). **H**, ventral view of pygidium, SNUP4011, x5.6. **I**, ventral view of pygidium, SNUP4012, x2.4. **J**, latex cast of pygidium, SNUP4013, x5.5.

4, figs 19-20. [=*Mareda mukazegata* Kobayashi, 1942b].

1965 (?) *Pterocephalia* (?) *busiris* (Walcott); Lu *et al*., p. 171, pl. 28, figs 16-17.

1978 *Goumenzia latilimbata* Guo & Duan, p. 450, pl. 2, fig. 20.

1978 *Mareda sinuata* Guo & Duan, (*pars*), p. 456, pl. 2, figs 22-23.

1987 *Mareda busiris* (Walcott); Zhang & Jell, (*pars*), p. 245, pl. 121, fig. 5.

1992 *Mareda* sp.; Zhu, p. 369, pl. 119, fig. 14.

Diagnosis. A species of *Hamashania* with granulate prosopon on axial portion of glabella and pygidial axis, and well-defined interpleural furrows.

Remarks. In the present collection, *Hamashania pulchera* is associated with a few pygidia of *Hamashania* with clearly incised interpleural furrows, one of the diagnostic features of *H. busiris*. However, they are seen in ventral view of the shield only and hence the granulate sculpture on the axis, if any, cannot be confirmed. In addition, they are generally smaller than most of the specimens assigned to *H. pulchera*, suggesting that they may represent early holaspides of the latter species. Thus, the specimens with well-incised interpleural furrows are provisionally assigned to *H. busiris*.

Pterocephalus busiris Walcott, 1905 was established based on a fragmentary pygidium from Shandong Province, China and was later transferred to *Mareda* by Zhang & Jell (1987). The type specimen, though incomplete, clearly demonstrates the granulate prosopon on the pygidial axis and well-defined interpleural furrows. The pygidia of *P. busiris* documented by Sun (1935) does not certainly belong to the species in having narrower axis and more axial rings and, on this basis, Kobayashi (1942b) erected the new taxon, *Mareda mukazegata*.

Guo & Duan (1978) established a new genus and species *Goumenzia latilimbata*, based on a nearly complete cranidium from Liaoning Province, North China, which only differs from the cranidia of *Hamashania pulchera* in the occurrence of fine granules on the glabella. In addition, associated pygidia assigned to *Mareda sinuata* (Guo & Duan, 1978, pl. 2, figs 22-23 only) also have granulate prosopon as well as clearly-incised interpleural furrows and hence cannot be distinguished from the type specimen of *H. busiris*. Thus, it is concluded that both the cranidium of *Goumenzia latilimbata* and the two pygidia of *Mareda sinuata* from Liaoning in fact represent a single species, *H. busiris*. A pygidium assigned to *Mareda* sp. from Jilin Province by Zhu (1992) can be assigned to *H. busiris* based on its well-defined interpleural furrows.

Occurrence. *Quadraticephalus* fauna of the Hwajeol Formation (Late Cambrian), Taebaeksan Basin, Korea.

Family SAUKIIDAE Ulrich & Resser, 1930

Pacootasaukia gen. nov.

Type species. *Platysaukia jokliki* Shergold, 1991 from the Late Cambrian Pacoota Sandstone, Amadeus Basin, Australia.

Diagnosis. Saukiid genus with broad rectangular glabella; S1 joined sagittally; broad gently convex preglabellar area not differentiated into border and preglabellar field; palpebral lobes located away from axial furrows. Pygidium subcircular to fusiform, with four to seven axial rings, well-defined pleural furrows, faintly incised interpleural furrows.

Etymology. Derived from the Pacoota Sandstone, Amadeus Basin, Australia, from which the type material was collected.

Remarks. *Platysaukia* is herein treated as a junior synonym of *Hamashania* (see above). Therefore, species assigned previously to *Platysaukia* should be transferred to *Hamashania*. However, as already stated, the Australian material referred to *Platysaukia* by Shergold (1991) cannot be accommodated within *Hamashania* or other saukiid genera. Accordingly, a new genus *Pacootasaukia* is here proposed to accommodate the two Australian saukiid species, *Platysaukia jokliki* Shergold, 1991 and *Platysaukia tomichi* Shergold, 1991. The two species have been well described and illustrated by Shergold (1991), to which little can be added.

Family Uncertain

Mareda Kobayashi, 1942b

1942b *Mareda* Kobayashi, p. 297.

Type species. *Mareda mukazegata* Kobayashi, 1942b from the Licheng Formation (Late Cambrian), Shanxi Province, North China.

Remarks. *Mareda* was erected on the basis of two pygidia originally described as *Pterocephalus busiris* by Sun (1935). Some pygidia were assigned to *Mareda* from North China (Guo & Duan 1978, Zhu 1992) and Korea (Kobayashi 1960), but all of them, except the type material, belong to *Hamashania* as already clarified above. *Mareda* is easily distinguished from *Hamashania* in having a longitudinally elliptical pygidium with narrower axis and more axial rings. Thus the type material of *Mareda* *mukazegata* (Sun, 1935, p. 66, pl. 4, figs 19-20) remains the only representatives of the genus.

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