# The hystricurid trilobite *Metabowmania* in the Lower Ordovician (Ibexian; Stairsian) of the Great Basin, Utah and Idaho, USA

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ADRAIN, J.M. & WESTROP, S.R., 2007:12:21. The hystricurid trilobite *Metabowmania* in the Lower Ordovician (Ibexian; Stairsian) of the Great Basin, Utah and Idaho, USA. *Memoirs of the Association of Australasian Palaeontologists 34*, 227-242. ISSN 0810-8889.

The Lower Ordovician (Stairsian; approximately lower-mid Tremadocian) trilobite genus *Metabowmania* Kobayashi, 1955, has previously been known with certainty only from the holotype cranidium of its type species. The discovery of four new species in upper Stairsian rocks of Utah and Idaho greatly increases knowledge of the taxon. *Metabowmania* is a highly distinctive and easily recognised clade, and is closely related to hystricurids such as *Hillyardina* Ross, 1951 and *Hyperbolochilus* Ross, 1951. These derived taxa and relatives are assigned to a new subfamily Hillyardininae. New species described are *Metabowmania morgani* and *M. braggi*. Two other species are apparently new, but material is inadequate for formal naming and they are reported under open nomenclature.

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Keywords: Ordovician, Laurentia, Utah, Idaho, trilobite, taxonomy, biostratigraphy.

LIKE MANY of the taxa erected by Kobayashi (1955) in his monograph of the Lower Ordovician faunas of the McKay Group of British Columbia, Canada, the monotypic Metabowmania Kobayashi, 1955 (type species: M. latilimbata Kobayashi, 1955), has been difficult to interpret. Kobayashi (1955) illustrated the taxon with small photographs of two uncoated cranidia along with a line drawing. The photographed cranidia are from separate localities and are not clearly conspecific. The holotype specimen was revised by Dean (1989, pl. 17, figs 1, 4, 11), who also considered the unique holotype of Amechilus tuberculatus Kobayashi, 1955, which is from the same locality, to be conspecific. This assignment is tentatively accepted herein, but can only be confirmed through collection of additional specimens from the type locality. Dean (1989) assigned three poorly preserved cranidia from the upper massive member of the Survey Peak Formation of Alberta to "Metabowmania sp.". This total of six specimens, all cranidia and mostly poorly preserved, is all that has been known to date of the genus.

A new program of intensive field sampling for a comprehensive revision of the Ibexian faunas described by Ross (1951, 1953) from northern Utah and southeastern Idaho and by Hintze (1953) from western Utah has yielded an order of magnitude more taxa than originally described (Adrain *et al.* 2001, 2003; Adrain & Westrop 2003, 2006a, b, 2007). Among these are four species assigned herein to *Metabowmania*. These discoveries are significant in that they transform a scarcely interpretable genus known with confidence from a single specimen into a well understood clade of five species, represented by a complete articulated specimen and knowledge of multiple silicified cranidia, librigenae and pygidia.

# LOCALITIES AND STRATIGRAPHY

General information on new Stairsian measured sections has been given by Adrain & Westrop (2007) and is briefly summarised, along with details on newly reported horizons, below.

# Fillmore Formation, Utah

Material from the Ibex area, western Utah (Figs 1-2), is all from the lower ("basal ledge-forming") member of the Fillmore Formation. It was recovered from three horizons in Hintze's (1953) Section G, which we remeasured, and two horizons near the top of our new section MME (Adrain & Westrop 2007).

Section G (Fig. 2B) 26.6 m and 27.0 m are thin (4-5 cm), trilobite-rich grainstone and bio-intraclastic rudstone beds, respectively, that lie



*Fig. 1.* Locations of measured sections. A. General location of sections in or near the southern Confusion Range, Ibex area, Millard County, western Utah (inset). Black blocks show position of detailed maps shown in B and C. SP = Skullrock Pass, where the holotype of *M. morgani* was collected. B. Position of section MME on the east slope of Middle Mountain. C. Position of section G on the southeast slope of the Confusion Range. D. General location of Section HC6 in the Bear River Range, Franklin County, southeastern Idaho (inset). E. Position of Section HC6 along ridge crest on west side of Hillyard Canyon.

directly beneath a unit of small thrombolitic microbial buildups. They are almost certainly the horizons reported by Hintze (1953) as his collection "G-3 (90')" and by Demeter (1973) as "G96" and "G97." They contain an identical, almost wholly undescribed fauna dominated by hystricurids, pliomerids and dimeropygids. The only species thus far named are *Pilekia* (?) *loella* Demeter, 1973, *Bearriverops alsacharovi* Adrain & Westrop, 2007, *B. ibexensis* Adrain & Westrop, 2007, and *Metabowmania braggi* sp. nov.

Section G 48.5 m is the horizon reported by Hintze (1953) as his collection "G-5 (140')" and by Demeter (1973) as "G175". It consists of a thin lamina of silicified trilobites within an

interval of lime mudstone and calcisiltite. The associated fauna includes *Goniophrys prima* Ross, 1951, *Hyperbolochilus marginauctum* Ross, 1951, *Hystricurus oculilunatus* Ross, 1951, "*Parahystricurus*" bispicatus Hintze, 1953, *Protopliomerops superciliosa* Ross, 1951, and a number of undescribed species. This horizon is high in Ross's (1951) "Zone F" ("Protopliomerops superciliosa Zone").

Section MME (Fig. 2A) 121.6 m and 121.9 m are thin (2-3 cm) bioclastic rich horizons within an interval of shale and wave-rippled calcisiltite and calcareous siltstone that includes small sponge-microbial buildups along strike. The associated fauna consists entirely of apparently



*Fig. 2.* A. Stratigraphic log through a portion of Section MME, showing position of horizons yielding *Metabowmania* sp. nov. A. B. Stratigraphic log through a portion of Section G, showing horizons yielding *M. braggi* sp. nov. and *M. morgani* sp. nov. See Fig. 1 for geographic position of sections.

new and undescribed species. These horizons fall within Ross's "Zone F," but are apparently stratigraphically lower than the G 48.5 m fauna and share no species with that assemblage.

# Garden City Formation, Idaho

Ross (1951) treated material from his "Zone F" at HC6 (Fig. 1) as an undivided fauna, reporting the interval of each species as 305-340 feet above the base of the Garden City Formation. It is now apparent that there are at least two distinct, stratigraphically successive faunas within this interval, with few or no species in common. We have made rich collections from horizons (Fig. 3) at HC6 127.5 m and 131.3 m, as well as talus blocks which appear to be weathering nearly in place at HC6 132.0 m. All contain the same fauna, characterised by abundant *Flectihystricurus flectimembrus* (Ross, 1951) and *Pyraustocranium orbatum* Ross, 1951. We have not encountered species such as *Goniophrys prima* Ross, 1951 or *Hystricurus oculilunatus* Ross, 1951. However, we have sampled faunas containing these latter species at Ibex (G 48.5 m and MME 129.9 m). There, faunas containing *Pyraustocranium* (MME 121.6-121.9 m) occur



St. Charles Fm.

*Fig. 3.* Stratigraphic log through a portion of Section HC6, showing position of horizons yielding *Metabowmania* cf. *M. latlimbata* Kobayashi. See Fig. 1 for geographic position of section.

about 8 m lower than those containing *G. prima*. Metreages and spacing of faunas have been shown to be remarkably similar between the Pogonip Group and Garden City Formation successions. Hence, Ross likely sampled his *G. prima* fauna from somewhere around HC6 135-139 m. This interval is now entirely covered and we have not located the fauna. The base of the Tulean stage lies immediately above this interval, and a well preserved fauna from HC6 142.0 m contains Tulean trilobite species.

The fauna from HC6 127.5-131.3 m is most closely comparable to that of MME 121.6-121.9 m at Ibex, in that both feature common *Flectihystricurus* along with the occurrence of *Pyraustocranium*. However, the species of these genera are clearly different in either region, and it has yet to be determined whether there are any species definitely shared between the horizons.

#### BIOSTRATIGRAPHY

As discussed by Adrain & Westrop (2007), the trilobite biostratigraphy of the Stairsian stage will require revision once description of the newly recovered faunas is more advanced. Ross's (1951) "Zone E" is essentially a single horizon. At MME, this horizon is represented by a rich fauna at MME 75.5 m. The correlative position of horizon

G 26.6-27.0 m, the type horizon of the oldest known species of *Metabowmania*, *M. braggi*, is MME 102.2 (see Adrain & Westrop 2007). Ross's "Zone F" is a narrow interval containing at least two stratigraphically separate faunas near the top of the Stairsian Stage (see above). Horizon G 48.5 m, which contains *Metabowmania morgani*, is correlative with what appears to be the lower of the main "Zone F" faunas in the Garden City Formation. Hence, *Metabowmania* occurs through roughly 30 m of upper Stairsian strata, with a first occurrence in a presently unzoned interval lying between Ross's Zones "E" and "F" and a last occurrence within Zone "F" near the top of the Stairsian Stage.

# SYSTEMATIC PALAEONTOLOGY

Figured material is housed in the Paleontology Repository, Department of Geoscience, University of Iowa, Iowa City, with specimen number prefix SUI.

Family HYSTRICURIDAE Hupé, 1953 Subfamily HILLYARDININAE subfam. nov.

Included genera. Hillyardina Ross, 1951; Hyperbolochilus Ross, 1951; Metabowmania Kobayashi, 1955; Pachycranium Ross, 1951; Tanybregma Jell & Stait, 1985.

*Diagnosis*. Cranidium with frontal area typically broad; preglabellar field usually with shallow median furrow, at least early in ontogeny; glabella relatively small and elongate; librigenal field usually broad; inner edge of genal spine and posterior border usually with fringe of small spines; librigenal lateral border usually flattened with sharp ventrolateral edge and broad, ventral sector that is distinct from narrow, inturned doublure; eye small; thorax of ten segments, long axial spine present on sixth in most but not all taxa; pygidium with rectangular spines transecting pleurae at fulcrum, spines merged or nearly merged into continuous or nearly continuous raised ridge in some taxa.

*Remarks*. New field collections include many new species and several new genera belonging to Hillyardininae, and will permit clarification of most of the existing genus concepts. Full documentation is monographic in scope and will be presented elsewhere. Monophyly of Hillyardininae is supported by the unique librigenal lateral border morphology and unique pygidial morphology. The only potential challenge to the group's monophyly lies in the origin of Aulacopleuridae. Fortey & Owens (1975) speculated that species now recognised as Hintzecurinae (see Adrain *et al.* 2003) were related to Aulacopleuridae. Boyce (1989, pp. 36-37, fig. 12), however, argued that "Otarion (Aulacopleura) may have been derived directly from Hillyardina." The basis of the reconstruction Boyce used to illustrate his comparison is actually Hyperbolochilus *marginauctum* Ross, 1951, the type species of Hyperbolochilus. Boyce (1989) considered *Hyperbolochilus* a junior subjective synonym of *Hillyardina*. New collections demonstrate that the number of thoracic segments (nine) in Boyce's reconstruction is incorrect. The sister group of Aulacopleuridae remains a key question in the higher phylogeny of the aulacopleuroideans. Evidence that it lies within Hillyardininae is scant. Most of the features listed by Boyce (1989, p. 37) are general and shared widely among aulacopleuroideans (e.g., "palpebral lobes small; palpebral furrows concave-outward"; "posterior fixigenal areas acutely triangular"; "cranidial prosopon pustulose to smooth"; "thoraxes [sic] with narrow axes, broad pleural areas"; etc. Aulacopleurids show no trace of the highly modified librigenal morphology of hillyardinines, nor of the fulcral ridge-like spines developed on the pygidium. Several hillyardinines (unpublished data) do have a thoracic axial spine developed on the sixth segment. Siluro-Devonian aulacopleurids such as Otarion Zenker, 1833 and *Cyphaspis* Burmeister, 1843 also have a spine in this position. However, work in progress on Ordovician aulacopleurids with axial spines (JMA, unpublished data) shows that the spines were usually on the seventh segment. Several clades of aulacopleurids (Aulacopleura Hawle & Corda, 1847, Maurotarion Alberti, 1969) lack thoracic axial spines. In sum, it is difficult at this point to specify any compelling synapomorphies uniting Hillyardininae and Aulacopleuridae.

Hillyardininae is known primarily from Laurentia (including the Laurentian San Juan Terrane of the Precordillera of Argentina -*Hillyardina* sp. of Vaccari *et al.* 1986), but with certainty also from Australia, in the form of *Tanybregma tasmaniensis* Jell & Stait, 1985, from the Florentine Valley Formation of Tasmania. A second Tasmanian hillyardinine species is represented by some but not all of the sclerites assigned by Jell & Stait (1985) to "*Hystricurus lewisi* (Kobayashi, 1940)."

# Metabowmania Kobayashi, 1955

*Type species. Metabowmania latilimbata* Kobayashi, 1955, from the McKay Group, British Columbia, Canada.

Other species. Metabowmania braggi sp. nov.,

Fillmore Formation, Stairsian, Utah; *M. morgani* sp. nov., Fillmore Formation, Stairsian, Utah; *Metabowmania* sp. nov. A, Fillmore Formation, Stairsian, Utah; *Metabowmania* cf. *M. latilimbata* Kobayashi, 1955, Garden City Formation, Stairsian, Idaho.

*Diagnosis*. Frontal area and librigenal field very broad; in most species with sculpture of moderate to large, irregularly shaped tubercles; glabella small, narrow, and either with much smaller and more subdued tubercles than frontal area or lacking tubercles; librigenal lateral border furrow very narrow and deeply incised; external aspect of lateral border narrow, with very sharp ventrolateral edge; most of lateral border expressed ventrally as broad, flat, pseudo-doublural sector, separated from true doublure (which is sharply upturned at acute angle to border) by distinct narrow ridge; thoracic segments (known in only one species) with pleural furrow running sharply posteriorly from anterior contact with axial furrow, set very near the posterior margin and running subparallel to margin, but slightly anteriorly for most of course, so that posterior pleural band is very short (exsag.), slightly longer abaxially; thoracic axial rings with distinct lateral nodes; pygidia short and wide, with five axial rings.

*Remarks*. Adrain (in Jell & Adrain 2003) considered *Metabowmania* a junior subjective synonym of *Hillyardina*. Newly collected topotype material of the type species of *Hillyardina*, *H. semicylindrica* Ross, 1951, shows that it lacks the synapomorphies of *Metabowmania*, which is clearly a separate clade.

*Metabowmania* is a stratigraphically late appearing component of Hillyardininae and has several atypical features. As far as is known on the basis of extensive new material, all other hillyardinines have a long thoracic axial spine, but the holotype specimen of *M. morgani* shows that such a spine is lacking in this species, and no isolated segment-bearing spines that could be associated are known to occur with the other species. The polarity of the spine character can only be assessed in the context of a wider analysis, but it is tentatively interpreted as a secondary loss (with its reduction and loss, hence potentially synapomorphic) in *Metabowmania*. The pygidial morphology of *M. braggi* is also somewhat unusual, as it superficially appears to lack the ridge-like spines, which transect the pleural bands near the fulcrum in other hillyardinines. Ventral morphology (Fig. 6I), however, shows that these spines are present, but reduced. The spines are visible dorsally (Fig. 6C), but transect only the posterior pleural band, the pleural furrow and the



*Fig. 4. Metabowmania* cf. *M. latilimbata* Kobayashi, 1955, from Section HC6 127.5-131.3 m, Garden City Formation, (Stairsian, Zone F), west side of Hillyard Canyon, Bear River Range, Franklin County, Idaho, USA. A-B, E, cranidium, SUI 102954, dorsal, left lateral, and ventral views, x12 (HC6 127.5). C, F, right librigena, SUI 102955, external and internal views, x10 (HC6 127.5). D, G, I, K, pygidium, SUI 102956, right lateral, dorsal, ventral, and posterior views, x15 (HC6 127.5). H, J, right librigena, SUI 102957, external and internal views, x6 (HC6 127.5). L-M, pygidium, SUI 102958, posterior and dorsal views, x7.5 (HC6 131.3).

posterior part of the anterior pleural band. Again, this reduced condition is tentatively interpreted as secondary within Hillyardininae. Librigenae of many taxa of Hillyardininae have a row of small spines along the adaxial aspect of the genal spine. These spines are absent from *M. morgani* (Fig. 8F), *Metabowmania* sp. nov. A (Fig. 9E), and *M.* cf. *M. latilimbata* (Fig. 4F), but they are present in *M. braggi* (Fig. 5M, P, Q, S, T). It is possible that *M. braggi*, the stratigraphically oldest species, is also the most plesiomorphic, and that reduction and loss of these spines is synapomorphic for the remaining species.

Dean (1989) assigned three cranidia from the Survey Peak Formation of Alberta to *"Metabowmania* sp.". None are well preserved. Two (Dean 1989, p. 16, figs 1-2, 5) are from the same stratigraphic horizon in the middle member of the formation and appear to be conspecific. This species is characterised by a glabella that is subtriangular in plan view, with a sculpture of prominent, closely scattered, small to medium tubercles. The glabellar shape does not resemble that of any of the species assigned in this work to Metabowmania, and it is unlikely to belong to the genus. The third cranidium (Dean 1989, pl. 16, figs 4, 6) is from the upper massive member  $\frac{16}{100}$ of the formation and is not obviously conspecific with the first two, differing in glabellar outline and a more steeply declined preglabellar field. It represents a hillyardinine and possibly a species of *Metabowmania*, but is too poorly preserved for meaningful comparison.

#### Metabowmania latilimbata Kobayashi, 1955

- 1955 *Metabowmania latilimbata*; Kobayashi, p. 458, pl. 6, fig. 13, pl. 8, fig. 9?, pl. 9, figs 7a, b.
- ?1955 Amechilus tuberculatus; Kobayashi, p. 459, pl. 6, fig. 11.
- 1989 *Metabowmania latilimbata*; Kobayashi; Dean, p. 24, pl. 17, figs 1, 3?, 4, 6?, 11.

*Material*. Holotype, cranidium, GSC 12713 (Kobayashi 1955, pl. 6, fig. 13; Dean 1989, pl. 17, figs 1, 4, 11), McKay Group, GSC locality 7977 (=locality 2 of Kobayashi 1955), "north of Brisco Trail", British Columbia, Canada.

Remarks. Kobayashi (1955, pl. 8, fig. 9) assigned a second cranidium from his Locality 12, which is in the same area as the type locality. This specimen consists of the anterior part of a cranidium. It could represent *M. latilimbata*, but the quality of preservation and illustration precludes meaningful comparison. Dean (1989) considered *Amechilus* tuberculatus Kobayashi, 1955, to be a junior subjective synonym of M. latilimbata, and reillustrated the holotypes of both species. The specimens are both from Locality 2, but differ in morphology. The holotype of A. tuberculatus is only a little smaller than that of *M. latilimbata*, yet it has a relatively narrower glabella, and a preglabellar field that is not as steeply declined as in the holotype of *M. latilimbata*. They could conceivably be conspecific, but like most of Kobayashi's material they are scarcely interpretable in the absence of well constrained modern collections from the units. As noted by Dean (1989), Kobayashi's material from Locality 2 clearly included stratigraphically mixed samples of different ages. Dean's synonymy of the taxa is tentatively accepted herein, but interpretation of *M. latilimbata* below is restricted to comparison with its holotype, which is a reasonably well preserved cranidium.

Metabowmania cf. M. latilimbata Kobayashi, 1955 (Fig. 4)

1951 Unassigned pygidia, Zone "F", locality 6 (Not described); Ross, pl. 19, figs 32, 35.

*Material*. Assigned specimens SUI 102954-102958, from Section HC6 127.5-131.3 m, Garden City Formation (Stairsian, Zone F), west side of Hillyard Canyon, Bear River Range, Franklin County, Idaho, USA.

Remarks. Sparse material from Section HC6 represents a species of Metabowmania, based on close comparison of the available cranidium with the holotype of *M. latilimbata* and librigenae featuring the unique lateral border/border furrow morphology. Unfortunately, the available cranidium (Fig. 4A-B, E) is incomplete, but it is very close in general dimensions to that of M. *latilimbata*. It appears to differ in having a slightly narrower glabella (though this is very difficult to determine given the state of preservation) and particularly in having a glabella and frontal area lacking tubercles versus bearing a scattering of small tubercles (Dean 1989, pl. 17, figs 1, 4). On this basis, different species are likely represented, although much more material is necessary to assess either taxon with confidence.

Pygidia are assigned on the basis of similar rare occurrence, general similarity in dimensions with those of *M. braggi*, and the lack of other hillyardinine species in the collections with which they could be associated. *Metabowmania* cf. M. *latilimbata* differs from *M. braggi* in its smooth versus coarsely tuberculate dorsal cranidial and librigenal sculpture, much more divergent anterior sections of the facial sutures, larger palpebral lobe, cranidial axial furrows that are anteriorly convergent versus nearly subparallel, larger eye, much shorter genal spine lacking an adaxial fringe of spines, and pygidium lacking tuberculate sculpture and with rectangular spines much more prominent, set in a more distal position, and partially (anteriorly) to nearly fully (posteriorly) merged into a semi-continuous ridge around the pygidium, overlying a vertical area above the border. Metabowmania cf. M. latilimbata is compared with *M. morgani* and *M.* sp. nov. A under discussion of those taxa below.

# Metabowmania braggi sp. nov. (Figs 5-6)

Diagnosis. Cranidium with densely distributed



*Fig. 5. Metabowmania braggi* sp. nov., from Section G 26.6-27.0 m, lower member of the Fillmore Formation (upper Stairsian, unzoned interval between Zones E and F) southern Confusion Range, Ibex area, Millard County, western Utah, USA. A-B, E-F, cranidium, SUI 102936, dorsal, ventral, anterior, and left lateral views, x12 (G 26.6). C, G, I, cranidium, SUI 102937, dorsal, left lateral, and anterior views, x12 (G 27.0). D, H, cranidium, SUI 102938, dorsal and anterior views, x10 (G 27.0). J, right librigena, SUI 102945, external view, x10 (G 27.0). K-L, right librigena, SUI 102943, external and ventrolateral views, x10 (G 27.0). O, R, left librigena, SUI 102941, external, ventrolateral, and internal views, x10 (G 27.0). O, R, left librigena, SUI 102942, ventrolateral and external views, x6 (G 27.0). P, left librigena, SUI 102944, external view, x10 (G 27.0). Q, right librigena, SUI 102939, external view, x10 (G 26.6). T, left librigena, SUI 102940, external view, x10 (G 27.0).

small tubercles over glabella and large, coarse tubercles on fixigena, preglabellar field and frontal area; interocular fixigenae narrow; cranidium narrow anteriorly, anterior sections of facial sutures more nearly subparallel than congeners; librigenal field coarsely tuberculate; genal spine long, with row of small spines along adaxial edge; pygidium with five axial rings; axial rings and pleural bands coarsely tuberculate; posterior tips of posterior pleural bands extended into short,



*Fig. 6. Metabowmania braggi* sp. nov., from Section G 26.6-27.0 m, lower member of the Fillmore Formation (upper Stairsian, unzoned interval between Zones E and F) southern Confusion Range, Ibex area, Millard County, western Utah, USA. A, D, G, pygidium, SUI 102946, dorsal, posterior, and left lateral views, x10 (G 27.0). B-C, F, I, pygidium, holotype, SUI 102947, right lateral, dorsal, posterior, and ventral views, x10 (G 26.6). E, H, K, pygidium, SUI 102948, left lateral, dorsal, and posterior views, x10 (G 27.0). J, L, pygidium, SUI 102949, posterior and dorsal views, x12 (G 26.6).

curved, posteroventrally directed spines.

Description. Cranidium with sculpture of medium to large, irregularly shaped, blister-like tubercles on preglabellar field, frontal area, interocular fixigena and, as far as is known, posterior fixigena; irregular row of smaller tubercles arrayed along anterior edge of preglabellar furrow; glabella and LO with sculpture of much finer, more regularly shaped tubercles; glabella and LO occupying about half sagittal length; glabella inflated and raised prominently above palpebral lobes and fixigenae; glabella narrow, maximum width about 72% sagittal length (excluding LO), sides steeply sloping in transverse view, dorsal aspect strongly transversely curved; glabella ovate in plan view; axial furrows narrow and incised, slightly laterally bowed, curved anteriorly to run without interruption or break in course into strongly anteriorly bowed preglabellar furrow; preglabellar furrow as narrow as axial furrows but slightly shallower; interocular fixigenae dorsally flat, quite broad; palpebral furrow completely effaced, sculpture of interocular fixigena continued directly onto dorsal aspect of palpebral lobe; palpebral lobe small, sublunate, flat, surface inclined slightly anteriorly relative to that of adjacent interocular fixigena; LO short, of similar length sagittally and exsagittally, with sculpture identical to that on main part of glabella; SO not well preserved on any specimen, apparently short and deeply incised; posterior fixigena and posterior extension poorly or not preserved on available specimens; anterior sections of facial sutures anteriorly divergent in front of palpebral lobes, laterally bowed with apex of curve about three fifths distance anteriorly, turned sharply adaxially near contact with anterior border furrow; preglabellar field declined from plane of interocular fixigena at about 40°; partial anterior border furrow and anterior border preserved in only one specimen, anterior border furrow with sharp posterior edge abutting field, grading anteriorly into flat border; anterior border apparently quite long.

Librigena with long, broad field, maximum width about 45% exsagittal length, bearing tuberculate sculpture identical to that on frontal area and preglabellar field, irregular row of much smaller tubercles set along adaxial edge of lateral border furrow; posterior border furrow straight, deep, slightly more prominent than lateral border; lateral border laterally bowed, subparallel with lateral margin, adaxial edge with sharp break in slope along field, abaxial edge slightly less well defined, grading into border; contact between posterior and lateral border furrows forming relatively sharp, slightly obtuse angle to rear corner of field, giving way posteriorly to roughly subtriangular depressed region, from adaxial part of which a furrow, similar in width and depth to lateral border furrow, runs posteriorly along dorsal aspect of genal spine; lateral border with complex morphology typical of genus: dorsal aspect narrow, flat and lacking sculpture, separated from ventral aspect by sharp, prominent, blade-like lateral ridge, ventral portion facing ventrolaterally, much broader than dorsal portion, lacking sculpture abaxially, with very fine raised terrace lines adaxially; ventrolateral sector of lateral border separated from doublure by acute angle, along which a small, rim-like ridge is developed; doublure narrow and turned inward, adaxial edge lying beneath lateral border furrow; eye small, long and narrow, apparently set directly on field with no obviously developed socle or platform; genal spine very long, longer than remainder of librigena, quite broad near genal angle, tapering gradually along length, flattened in transverse section, with sharp adaxial aspect continued from blade-like ventrolateral edge in lateral border, more sub-cylindrical distally, curved gently adaxially posteriorly, furrow along dorsal aspect quite broad and shallow proximally, deepened and more linear in mid-part of spine, shallowed, faint and nearly effaced distally; abaxial edge of genal spine forming only slight angle with edge of lateral border; adaxial edge of spine forming relatively sharp, slightly obtuse angle with posterior edge of posterior border; posterior edge of posterior border and adaxial edge of genal spine along about proximal quarter of length with row of seven to eight short, cylindrical spines running posteriorly; bottom of base of genal spine with subtriangular depressed area, separated from doublure by posterior continuation of rim-like ridge marking edge of border, grading posteriorly into nearly flat ventral aspect of spine.

Rostral plate, hypostome and thorax unknown.

Pygidium very wide, sagittal length excluding articulating half-ring 30-35% maximum width; axis narrow, about 28% of pygidial width anteriorly; five axial rings; articulating half ring large, with transverse elliptical shape; first ring furrow long, moderately deep and posteriorly bowed in middle two thirds, interrupted by anteriorly produced lateral lobe abaxially, forming deep pit adaxial to lateral lobe alongside contact with anterior pleural band; first ring with flattened middle two thirds in transverse profile, this part bowed slightly posteriorly in dorsal view, with sculpture of three to five large, irregular tubercles plus a scattering of much smaller, faint tubercles; ring short sagittally, longer exsagittally; adaxial region subtrapezoidal in dorsal view, with three or four medium-sized tubercles, lateral edge inclined obliquely to general course of curve described by axial margin; pseudo-articulating half ring of second segment large; morphology of second and third rings reduced versions of first; fourth and fifth rings much shorter (sag., exsag.), reduced to more transverse bands with only slightly posterior bow; pleural and axial furrows with complex morphology: pleural furrow deep, quite long, in some cases with slightly irregular course deviating around large tubercles developed on pleural bands, running anteriorly near axis, contacting axis at extreme anterior corner of axial ring, protruding axially across front end of trapezoidal abaxial part of ring, meeting deep lateral pit at edge of ring furrow; axial furrow set obliquely around ring, interrupted posteriorly by anterior pleural band of next segment; axial furrow hence discontinuous, stepped in separate, obliquely inclined segments posteriorly; anterior and posterior pleural bands subequal in length over most of width, posterior band longer adaxially where pleural furrow is bowed anteriorly; both bands with sculpture of large irregularly shaped tubercles, larger than those on axial rings, and smaller interspersed tubercles; posterior band more inflated than anterior band, developed into subcylindrical ridge, which is narrowed and turned anteriorly near fulcrum; interpleural furrows shorter and deeper than pleural furrows, with regular, posteriorly bowed course; posterior pleural band running across pygidial border, turned ventrally and adaxially into small, laterally curved spine; pygidium with smooth, slightly inflated border between spines; four segments with clear expression on pleurae, bands and furrows associated with tiny fifth axial ring nearly obsolete behind axis and spines not developed; rear of axis transverse, clearly set off from posterior medial region by posterior joining of axial furrows; doublure not fully preserved on available specimens: thick band underlying border preserved, but faintly preserved much thinner region medially indicates there was probably a more extensive, very thin doublure laterally as well.

*Material*. Holotype, pygidium, SUI 102947, and paratypes SUI 102936-102946, 102948, 102949, from the lower member of the Fillmore Formation,

Section G 26.6-27.0 m (upper Stairsian, unzoned interval between Zones E and F), Ibex area, Millard County, western Utah, USA.

## Etymology. After Billy Bragg.

*Remarks. Metabowmania braggi* is known from generally fragmentary material. However, it is a very distinctive species and though none are complete, multiple specimens of cranidia, librigenae and pygidia are available. It is possible to diagnose adequately and name the species. *Metabowmania braggi* was compared with *M.* cf. *M. latilimbata* above, and is compared with *M. morgani* and *Metabowmania* sp. nov. A in discussion of those species below.

#### Metabowmania morgani sp. nov. (Figs 7-8)

*Diagnosis*. Glabella narrow, elongate, and with smooth sculpture; fixigenae, preglabellar field, and frontal area with medium-sized, moderately densely distributed but subdued tubercles; interocular fixigenae broad; palpebral lobe very small; anterior sections of facial sutures strongly anteriorly divergent; librigenal field about as wide as long, with similar tuberculate sculpture as frontal area; librigenal lateral border with dorsal region reduced to thin strip; genal spine short and sub-cylindrical in section, lacking adaxial spine row; pygidium with either four or five axial rings, tuberculate sculpture on rings and pleural bands low and very subdued relative to that on thoracic segments.

Description. Cranidium with anterior sections of facial sutures widely anteriorly divergent, frontal area very broad; preglabellar field, frontal area, interocular fixigena, and posterior fixigena with dorsal sculpture of fairly sparsely distributed, medium to large-sized, subdued, blister-like tubercles; anterior border and anterior border furrow poorly known, border apparently long (Fig. 7, anterolateral corner); preglabellar field very long, apparently steeply declined from glabella; glabella long and narrow, maximum width about 55% sagittal length excluding LO; glabella elliptical in plan view, tapering anteriorly, fairly sharply rounded anteriorly, widest about three quarters distance posteriorly, narrower near base across L1, low and only weakly dorsally inflated, lacking sculpture; L1 narrow, not independently inflated, separated from main glabellar lobe by sharply oblique S1, which is deep near contact with axial furrow, completely shallowed posteromedially, not in contact with SO; axial furrow broad and deep, running without interruption into narrow (tr.) preglabellar furrow;

SO deep, shorter (sag., exsag.) than axial furrow is wide (tr.), curved evenly posteriorly; LO longer sagittally than exsagittally, with short transverse dorsal ridge laterally and shelf-like dorsal flat area medially, lateral ridge turned to run exsagittally, cutting across adaxial end of posterior border furrow at lateral edge of LO; LO lower than main glabellar lobe in sagittal profile, dorsally arcuate, with apex of curvature at about two thirds distance posteriorly; interocular fixigena broad, with only slight dorsal convexity; palpebral lobe small and subsemicircular, with a tiny pit in middle of dorsal area; posterior fixigena forming long lateral posterior projection; posterior section of facial suture sinuous, bowed posteriorly behind palpebral lobe, curved gently anteriorly at about two thirds distance distally, curved slightly posteriorly over most distal third of projection; fairly long strip of fixigena maintained in front of posterior border furrow along most of width of projection; posterior border lacking dorsal tuberculate sculpture, longer (exsag.) distally than proximally, with sharp, transverse dorsal ridge proximally, matching that on LO, shallowing out distally to fulcrum, posterior border ending distally in spine-like posterolateral extension.

Librigena with field about as broad as long, sculpture of moderately large but subdued tubercles identical to that on frontal area, tubercles aligned on subtle raised transverse (caecal?) ridges in some specimens (Fig. 8C); eye long, low, and small relative to size of field; lateral border furrow very narrow, expressed as score-like incision; dorsal aspect of lateral border reduced to thin ridge, broader anteriorly; posterior border with more normal, inflated and sub-cylindrical morphology, posterior border furrow broader than lateral border furrow; lateral and posterior border furrows meeting to clearly circumscribe rear corner of field in some specimens (Fig. 8C, I), effaced posteriorly so that field grades into base of genal spine in others (Fig. 8G-H); genal spine relatively short, subcylindrical in section, lacking sculpture, forming acute angle at base with posterior border and distinct but shallow, obtuse angle with lateral border, tapering evenly to sharp point (Fig. 7), with slight lateral curvature; ventral sector of lateral border broad, ventrally inflated, with sculpture of fine, closely spaced terrace lines, ventral sector of borders forming broad shelf under base of genal spine; doublure narrow and turned sharply inward, forming acute angle with ventral sector of border (Fig. 8F).

Rostral plate and hypostome unknown.

Thorax of ten segments; segments 1-4 longest (exsag.) and equally long, posterior segments becoming incrementally shorter; axial lobe very narrow, occupying about 18% overall thoracic



*Fig. 7. Metabowmania morgani* sp. nov., holotype, dorsal exoskeleton, SUI 102747, dorsal view, x3, from the lower member of the Fillmore Formation (upper Stairsian, Zone F), float block along road cut of U.S. Highway 6 through Skull Rock Pass, Ibex area, Millard County, western Utah, USA.

width; axial ring long, lacking dorsal sculpture, of similar length sagittally and exsagittally; lateral aspect of ring with prominent lateral node developed, not well set off from main part of ring by slightly oblique furrow, deeper anteriorly, node swollen, elliptical, slightly laterally protruding anteriorly, tapered posteriorly and less swollen; axial furrow set slightly obliquely, wider and shallow anteriorly and posteriorly, pinched at mid-length of segment by encroaching adaxial end of posterior pleural band; pleural furrow with unusual course, contacting axial furrow near anterior edge of segment, set strongly obliquely in proximal region, running posterolaterally to nearly contact posterior edge of segment, running very slightly anterolaterally for most



*Fig. 8. Metabowmania morgani* sp. nov. Specimens from the lower member of the Fillmore Formation (upper Stairsian, Zone F), Section G 48.5 m, southern Confusion Range, and Section MME 121.6 m, Middle Mountain, both Ibex area, Millard County, western Utah, USA. A-B, D-E, cranidium, SUI 102931, ventral, anterior, left lateral, and dorsal views, x7.5 (G 48.5). C, left librigena, SUI 102934, external view, x7.5 (G 48.5). F-G, left librigena, SUI 102933, internal and external views, x7.5 (G 48.5). H, left librigena, SUI 102935, external view, x7.5 (G 48.5). I, right librigena, SUI 102932, external view, x15 (MME 121.6).

of width of pleurae, so that very short posterior pleural band is progressively longer (exsag.) distally, running more strongly anterolaterally distally to contact with posterior edge of segment; anterior band hence much longer over most of pleura than posterior band, pinched and short proximally, long and with sculpture of single prominent transverse row of moderate to large sized subdued tubercles distally; posterior band with proximal triangular region bearing one or two small subdued tubercles, reduced to thin strip over most of width of pleura, longer distally, with one large subdued tubercle and one or two faint small tubercles on expanded most distal part; pleural tips (preserved only on upper right part of thorax of Fig. 7) subquadrate, apparently with faint longitudinal furrow set parallel to lateral margin, posterior corner of tip developed into sharp, posterolaterally directed angle.

Pygidium known only from partially preserved example in articulated holotype; pygidium broad, but not as short as in other congeners; axis very narrow relative to pygidial width; at least four axial rings, lacking dorsal sculpture; axis tapering rapidly posteriorly, describing narrow triangle in plan view; axial furrows deeper and more linear than those of thorax; pleural bands and pleural furrows of pygidial segments with morphology similar to those of thorax, except bands somewhat more subequal in length and furrow with somewhat more directly transverse course; sculpture on bands of faint tubercles, less well expressed than those on thorax.

*Material*. Holotype, dorsal exoskeleton, SUI 102747, from the lower member of the Fillmore Formation (upper Stairsian, Zone F), float block along road cut of U.S. Highway 6 through Skull Rock Pass, Ibex area, Millard County, western Utah. Assigned specimens SUI 102931-102935, from the lower member of the Fillmore Formation, sections G 48.5 m and MME 121.6 m (Stairsian, Zone F), Ibex area, Millard County, western Utah.

*Etymology*. After Sterling Morgan of Sumas, Washington, who discovered and donated for study, the holotype specimen.

*Remarks. Metabowmania morgani* is important in that it is the only member of the genus known from an articulated dorsal exoskeleton. This specimen (Fig. 7) was found in a float block along a road cut through the Fillmore Formation at Skull Rock Pass. However, sparse but undoubtedly conspecific silicified material has been recovered from section G 48.5 m (Fig. 8), just over 20 km to the south, and the stratigraphic position of the species is not in doubt. *Metabowmania morgani* has ten thoracic segments, and this number is also present in articulated material of *Hyperbolochilus marginauctum* Ross, 1951, and an unnamed genus of Hillyardininae in our collections. Boyce (1989) reported the segment count in his species



*Fig. 9. Metabowmania* sp. nov. A, from Section MME 121.6-121.9 m, lower member of the Fillmore Formation (upper Stairsian, Zone F) Middle Mountain, Ibex area, Millard County, western Utah, USA. A, H, J, cranidium, SUI 102950, dorsal, anterior, and right lateral views, x7.5 (MME 121.6). B-D, cranidium, SUI 102951, dorsal, anterior, and right lateral views, x15 (MME 121.6). E, right librigena, SUI 102952, external view, x7.5 (MME 121.6). F-G, I, cranidium, SUI 102953, dorsal, right lateral, and anterior views, x15 (MME 121.9).

*"Hillyardina" levis* as nine, but the number of segments present in the single incompletely preserved articulated specimen (Boyce 1989, pl. 6, fig. 6) is ambiguous.

Metabowmania morgani is most similar to M. braggi. The species have coarsely tuberculate dorsal sculpture on most surfaces, though that of M. morgani is more subdued. They differ in the absence of glabellar sculpture in M. morgani, its smaller palpebral lobes, less dorsally inflated glabella, more anteriorly divergent anterior sections of the facial sutures, much shorter genal spines lacking an adaxial fringe of small spines, narrower dorsal sector of the librigenal lateral border, and apparently somewhat longer pygidium (insofar as it is known in M. morgani).

*Metabowmania morgani* shares an unsculptured glabella with both *M*. cf. *M. latilimbata* and *M.* sp. nov. A. It differs from the former in its otherwise coarse dorsal tuberculate sculpture on most surfaces and much smaller palpebral lobe. Librigenae of the species are comparable in shape and dimensions, but the field of that

of *M. morgani* is tuberculate and the genal spine apparently shorter (though no complete examples are known). The disposition (or even presence) of the rectangular pygidial spines is unknown based on the incomplete example in the articulated holotype of *M. morgani*, but the pygidium has faint tubercle rows on the anterior and posterior pleural bands, versus completely lacking sculpture in *M.* cf. *M. latilimbata*.

*Metabowmania morgani* differs from *M*. sp. nov. A in its narrower cranidium, narrower interocular fixigenae, smaller and more semicircular palpebral lobes, relatively large and well expressed versus small and faint tubercles on the frontal area, tuberculate versus apparently unsculptured librigenal field, and genal spine with a much narrower base.

# Metabowmania sp. nov. A (Fig. 9)

*Material*. Assigned specimens SUI 102950-102953, from Section MME 121.6-121.9 m, Fillmore Formation (Stairsian, Zone F), Middle Mountain, Ibex area, Millard County, western Utah, USA.

Remarks. Sparse material from MME 121.6-121.9 m represents a new species of Metabowmania, but is inadequate for formal naming. Metabowmania sp. nov. A was compared with *M. morgani* above. It resembles the holotype of *M. latilimbata* in the possession of very small and subdued tubercles on the frontal area and preglabellar field, but differs in lacking tubercles on the considerably narrower glabella. It differs from M. cf. M. latilimbata in the possession of a more elongate, narrower glabella, wider interocular fixigenae, much smaller palpebral lobes, small tubercles on the frontal area, and a genal spine with a broader base. It is not closely similar to *M. braggi*, as indicated by lacking the coarse tuberculate sculpture, inflated glabella, narrow cranidium and long genal spine of that species.

#### ACKNOWLEDGEMENTS

Research was supported by NSF grants EAR 9973065 and EAR 0308685. T. S. Adrain is thanked for assistance with SUI specimen numbers and curation. We are extremely grateful to David W. Morgan and his family of Sumas, Washington, for donating the holotype specimen of *Metabowmania morgani* for study. D. Schultz, B. Beck and C. Monson provided assistance in the field. Reviews by B. D. E. Chatterton and Zhou Zhiyi helped to improve the manuscript.

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