J. Paleont., 80(4), 2006, pp. 650–671

0022-3360/06/0080-650$03.00

NEW EARLIEST ORDOVICIAN TRILOBITE GENUS *MILLARDICURUS*: THE OLDEST KNOWN HYSTRICURID

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ABSTRACT—*Hystricurus millardensis* Hintze, 1953 has been recorded widely in Laurentia. Revision on the basis of abundant new silicified topotype material indicates that most of these records are of morphologically distinct, though related, taxa and that a plexus of related species is involved. The new genus *Millardicurus*, with *H. millardensis* as type, is proposed for this clade, which also includes two well-documented new species, *M. housensis* and *M. paramillardensis*, from the House Formation of western Utah, several named species from Greenland, and several unnamed new species from various parts of Laurentia that have in the past been referred to *M. millardensis*. *Millardicurus* is not apparently closely related to younger Skullrockian–Stairsian hystricurids from Laurentia, but may be related to poorly known coeval Siberian Platform species classified in the genus *Nyaya* Rozova, 1963. Landmark-based geometric morphometric methods comprising principal component analysis of partial warp scores and Goodall's *F* test of pairwise means indicate significant shape differences among cranidia, librigenae, and pygidia of the House Formation species of *Millardicurus*.

INTRODUCTION

THE SPECIES *Hystricurus millardensis* was established by Hintze (1953) on the basis of a single cranidium, two librigenae, and two pygidia from a horizon low in the House Formation of western Utah. The taxon has since been widely reported in Laurentia and regarded as biostratigraphically important (e.g., Texas, Winston and Nicholls, 1967; Oklahoma, Stitt, 1971, 1983; New York, Taylor and Halley, 1974; Idaho, Taylor and Landing, 1982; Newfoundland, Fortey *in* Fortey et al., 1982, and Fortey, 1983; Utah, Loch et al., 1999; Wyoming, Stitt, 2000). These subsequent reports have either not figured the species, or else have illustrated only a few specimens. In the course of a comprehensive, field-based revision of the Ibexian trilobite faunas dealt with by Ross (1951) and Hintze (1953), we have resampled the type horizon of *H. millardensis* along with nearby strata of the Barn Canyon Member of the House Formation. This has resulted in much more morphological information on the species and the discovery of two additional related species also known from rich silicified material.

The purpose of this study is to erect a new genus, *Millardicurus*, for the clade including *H. millardensis*, to describe and revise the silicified western Utah species contained in the new genus, and to assess critically the various reported occurrences of *millardensis* around the Laurentian craton. Geometric morphometric methods are used to compare shape variation in cranidia, librigenae, and pygidia of the House Formation species of *Millardicurus*.

SAMPLING

The type horizon of *Millardicurus millardensis* is Hintze's (1953) locality B-1, which lies near the base of his Section B in the southern House Range, Ibex area, western Utah (Fig. 1). We resampled this rich horizon as our B 1.1 m. The horizon is within the Barn Canyon Member (Miller et al., 2001) of the House Formation. In addition to *M. millardensis*, which occurs fairly commonly, B-1 is also the type horizon of *Symphysurina brevispicata* Hintze, 1953, which is abundant at B 1.1 m. Other species present at B 1.1 m include a common second, broad-tailed, species of *Symphysurina* Ulrich *in* Walcott, 1924 (similar to or possibly conspecific with a taxon from Oklahoma figured by Stitt [1983, pl. 6, fig. 7] as "unassigned pygidium no. 2"), a very rare third species of *Symphysurina*, a new genus and species of "dimeropygid," and a species of *Clelandia* Cossman, 1902.

There are several horizons between B 1.1 m and the base of the Burnout Canyon (middle) Member of the House Formation with obvious silicified faunas, but they are difficult to collect at Section B due to the steep cliff-face outcrop. Rich collections from this interval were obtained, however, from section Lava Dam North (our section LDN and LDNS; see Hintze, 1973; Miller et al., 2001; Adrain et al., 2003), some 2 km to the south of Section B (Fig. 1). The equivalent of the B 1.1 horizon is not silicified at LDNS, but underlying and overlying horizons at LDNS 22.5 m and LDNS 35.2–35.3 m yield well-preserved faunas with abundant *Millardicurus* n. gen. and *Symphysurina*. LDNS 22.5 is about 4 m stratigraphically below the correlative position of B 1.1 m (Fig. 2), and contains a substantially different fauna. A different species of *Millardicurus*, *M. housensis* n. sp., is abundant, a species similar to "*Euloma*" *cordilleri* Lochman, 1964 is very rare, the horizon is dominated by several species of *Symphysurina*, and no other taxa are present. *Symphysurina* is represented at Ibex by many more stratigraphically successive species than has been realized. Work is in progress on their systematics, and it is not yet clear whether any or all species of the genus are shared between LDNS 22.5 m and B 1.1 m; no species of any other taxon are shared between the horizons. Samples from LDNS 35.2–35.3 m (about 8–9 m above the correlative position of B 1.1 m) are quite rich, but contain only abundant *Symphysurina* and relatively common sclerites of a second new species of *Millardicurus*, *M. paramillardensis*, which is subtly but pervasively differentiated from the older *M. millardensis*.

SKULLROCKIAN TRILOBITE BIOSTRATIGRAPHY

Miller and Ethington *in* Miller et al., 2003 have revised and discussed the conodont biostratigraphy of the latest Cambrian and earliest Ordovician of the Ibex area. The Cambrian–Ordovician boundary occurs within the Barn Canyon Member of the House Formation, and its level is known in several sections with precision. Miller and Ethington recognized an *Iapetognathus* Zone with its base at the lowest occurrence of *I. fluctivagus* Nicoll et al., 1999 and *I. ibexensis* Nicoll et al., 1999. The global stratotype section and point (GSSP) for the lower boundary of the Ordovician System has been established as the first occurrence of *I. fluctivagus* within the Cow Head Group at Green Point, western Newfoundland, Canada. Sections in the Ibex area, however, were previously promoted as candidates for this GSSP (e.g., Miller et al., 1982).

Loch et al. (*in* Miller et al., 2003) discussed the trilobite biostratigraphy of the same interval in the Ibex area (see also Loch et al., 1999). They recognized a *Symphysurina* Zone with a tripartite subzonal division, in ascending order the *S. brevispicata*,

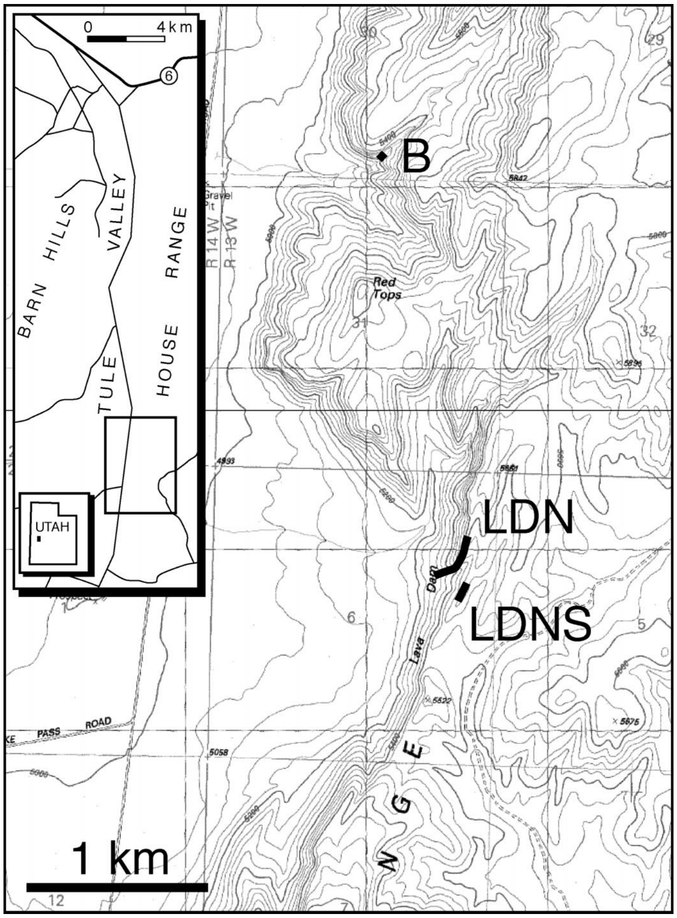

FIGURE *1*—Lines of section for Hintze's and our Section B (only the basal part of the section sampled herein is shown—Hintze's section continues up the ravine to the northeast), and our sections LDN and LDNS [the top part of our section LDN is the same line of section as Hintze's (1973) and Miller et al.'s (2001) Lava Dam North; see Adrain et al., 2003, for discussion]. Inset: position of Ibex area in Utah, and position of main detail map in the Tule Valley and southern House Range, south of US Highway 6 in Millard County.

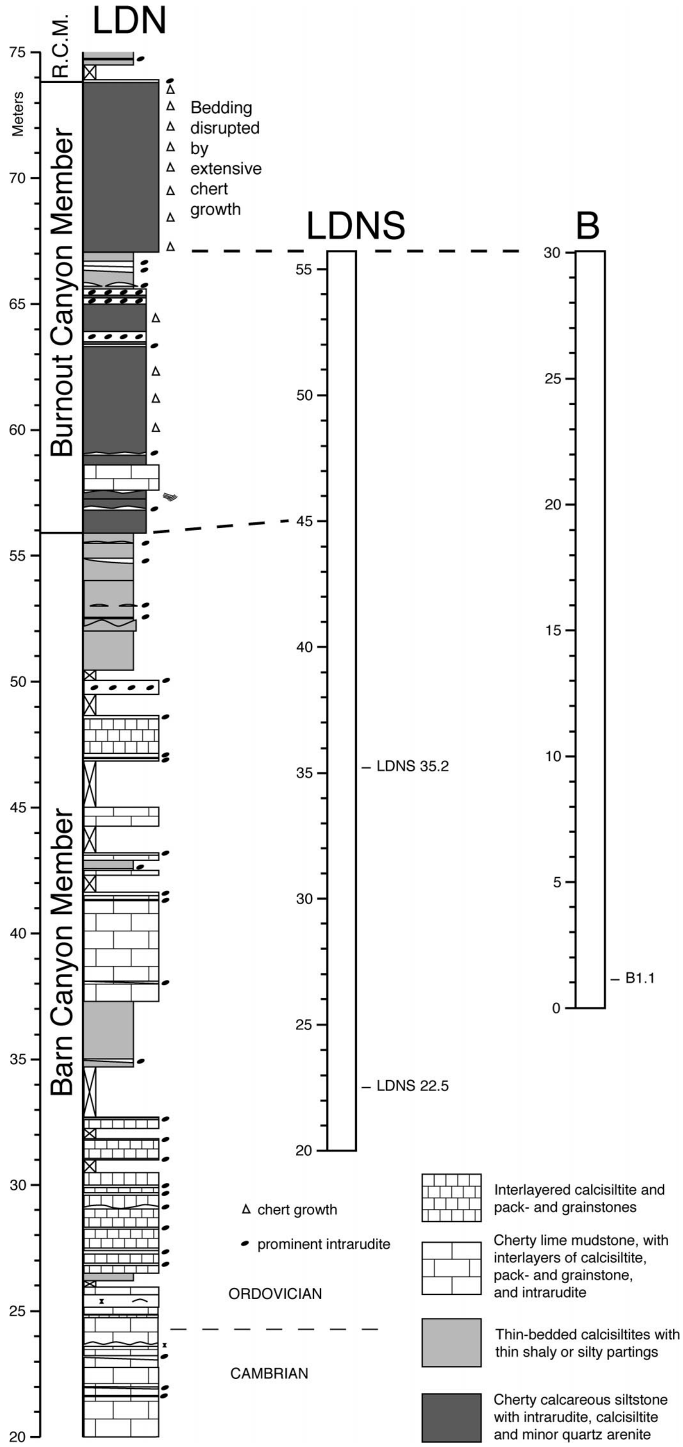

FIGURE *2*—Stratigraphic column for Section LDN, House Formation, Skullrockian Stage (see Fig. 1 for geographic position of sections). LDNS is adjacent to LDN, whereas B is about 2 km to the north. Lithological details for LDNS and B are not shown, as the succession is nearly identical to that at LDN. The base of the massive, cliff-forming Burnout Canyon Member [Hintze's (1953) ''brown marker bed''] provides an unambiguous datum. Position of the Cambrian–Ordovician boundary is based on the report by Miller et al. (2003) of the location of the base of the *Iapetognathus* Zone within a meter below a prominent brown grainstone containing the olenid trilobite *Jujuyaspis* Kobayashi, 1936.

S. bulbosa, and *S. woosteri* subzones. The Cambrian–Ordovician boundary (the base of the *Iapetognathus* Zone) correlates with the base of their *S. bulbosa* Subzone. Unfortunately, there is little published evidence to support the recognition of these trilobite subzones.

Loch et al. (*in* Miller et al., 2003) considered that the base of their *S. bulbosa* Subzone was defined by the lowest occurrence of the name-bearer. They illustrated specimens (Miller et al., 2003, pl. 1, figs. 21, 22) which they identified as *Symphysurina bulbosa* Lochman, 1964. Lochman's type material was from a well drill core from the subsurface Deadwood Formation of the Williston Basin in Montana, and consists of the rear part of a cranidium, a poorly preserved librigena, and two pygidia, one of which (Lochman, 1964, pl. 66, figs. 6, 8) is the holotype. The species will remain poorly known, as the subsurface type locality cannot be recollected. Nevertheless, *S. bulbosa* has a highly unusual pygidial morphology of a very broad axis with an expanded, bulbous termination and very small pleural areas. It is sufficiently distinct to allow critical comparison with other material attributed to the species. Stitt's (1977, pl. 5, figs. 1–6) treatment of sclerites from the Signal Mountain Limestone of Oklahoma constituted an attempt to revise the species without restudy of the types, and his conclusions served as the foundation of the *S. bulbosa* Subzone. Unfortunately, Stitt's illustrated pygidia are not conspecific with Lochman's species. The axis, though broad, does not expand posteriorly as in *S. bulbosa*, the pleural regions are much broader, and whereas the posterior pygidial margin of *S. bulbosa* is deflected and expanded around the posterior bulge of the axis, that of Stitt's specimens describes an even arc. Further, one of Stitt's (1977, pl. 5, fig. 3) illustrated librigena has a genal spine about half the length of that of *S. bulbosa* (Lochman, 1964, pl. 66, fig. 7). The difference is not ontogenetic as the specimens are almost exactly the same size, and no such intrasample variation is known in any of our rich collections of silicified *Symphysurina* from the Ibex area. Further, a second librigena assigned by Stitt (1977, pl. 5, fig. 4) is clearly not conspecific with the first (Stitt, 1977, pl. 5, fig. 3), as it has a strongly impressed lateral border furrow, an inflated lateral border, and apparently lacks a genal spine. Later, Stitt (1983) identified a second set of Oklahoma specimens, from the overlying Mackenzie Hill Limestone, as *S. bulbosa*. These are neither conspecific with the types of *S. bulbosa* nor with the older material assigned in 1977. The pygidia (Stitt, 1983, pl. 1, figs. 3, 4) have much wider pleurae than either *S. bulbosa* or the species misidentified by Stitt (1977), the axis is narrow and not inflated, and it terminates well in front of the pygidial margin. The librigena is swollen posteriorly around the base of the genal spine whereas one of the librigenae assigned earlier (Stitt, 1977, pl. 5, fig. 3) is dorsally concave in this region. As far as can be determined from published illustrations, *S. bulbosa* does not occur in Oklahoma.

Similarly, there is no evidence that *Symphysurina bulbosa* occurs in the Ibex area. The specimens illustrated by Loch, Stitt, and Miller (*in* Miller et al., 2003, pl. 1, figs. 21, 22) are not conspecific with either *S. bulbosa* or with either of the Oklahoma taxa misidentified as *S. bulbosa* by Stitt (1977, 1983). Their pygidium differs from Lochman's types in being relatively wider (sagittal length 58% of maximum width vs. sagittal length almost the same as maximum anterior width [extrapolating for the broken left portion, Lochman, 1964, pl. 66, fig. 8]). The axis of Loch et al.'s pygidium has a narrower (37% of pygidial width at anterior, vs. 50% of pygidial width at anterior), uninflated axis which is not expanded posteriorly and which terminates well in front of the posterior margin. In addition, the pygidial margin is evenly arcuate and the pleurae are broader. Of the two Oklahoma species misassigned to *S. bulbosa* by Stitt (1977, 1983), the taxon illustrated by Loch et al. is more similar to the Mackenzie Hill Limestone species (Stitt, 1983) in its wide pygidial pleurae and uninflated axis which terminates well in front of the pygidial posterior margin.

The *Symphysurina brevispicata* Subzone is depicted by Miller et al. (2003) as occupying over 50 m of the latest Cambrian part of the Barn Canyon Member. The type horizon of the name-bearing species, however, is our B 1.1 m, which is positioned 13 m *above* the base of Loch et al.'s ''*S. bulbosa* Subzone.'' That is, the name-bearer of a Cambrian biostratigraphic unit is an Ordovician species. This would not necessarily be problematic (Loch et al. show *S. brevispicata* as having a range extending through about the lower 20 m of the ''*S. bulbosa* Subzone''), but this is an incredibly long range for a trilobite species in this interval (over 70 m). The illustrations given of a silicified cranidium, pygidium, and librigena assigned to *S. brevispicata* (Miller et al., 2003, pl. 1, figs. 8–10) are from a horizon (sample HL 490, Miller et al., 2003, table 5) approximately 16 m above the base of the ''*S. bulbosa* Subzone.'' In fact, there are no published illustrations confirming the occurrence of *S. brevispicata* within what is being called the ''*S. brevispicata* Subzone'' at Ibex.

Despite these major problems of species identification and range, the position of the Cambrian–Ordovician boundary remains identifiable on trilobite evidence. Loch et al. (*in* Miller et al., 2003, p. 53) noted that the base of the *Iapetognathus* Zone is positioned within a meter of the occurrence of the olenid trilobite *Jujuyaspis* Kobayashi, 1936 in a distinctive and regionally widespread brown grainstone bed. This bed is located at 25.0 m in the Lava Dam North measurements of Adrain et al. (2003; see Fig. 2). This horizon is approximately 31 m below the base of the Burnout Canyon Member by our measurement, and this agrees well with a value of approximately 32 m for this interval reported by Miller et al. (2003, fig. 3). All of the horizons from which species of *Millardicurus* n. gen. are reported in the current study are hence above the Cambrian–Ordovician boundary (Fig. 2), in what Miller et al. termed the ''*S. bulbosa* Subzone.'' Miller et al. (2003, fig. 8) depict ''*Hystricurus millardensis*'' as ranging through about the upper 16 m of their ''*S. brevispicata* Zone.'' The only sclerite illustrated in their work (Miller et al., 2003, pl. 1, fig. 11) is from a horizon (their HL 437) that is almost exactly at the Cambrian–Ordovician boundary. It is very similar to and could well represent *Millardicurus millardensis*, though it is from a horizon approximately 13 m downsection from the correlative position of the type horizon, but more material would be required to confirm the identity. Based on Miller et al. (2003), *Millardicurus* presumably ranges through the latest Cambrian, but no material from this interval has been illustrated.

Adrain and Westrop (2005) have argued that standards of documentation of trilobite species are generally inadequate. Difficulties similar to those discussed above for *Symphysurina* also apply to *Millardicurus*. Better knowledge of *M. millardensis* permits evaluation of the various sets of material assigned to it from elsewhere in Laurentia, and it is now clear that several distinct, unnamed species are represented (see genus discussion below). This situation exemplifies the basic problems plaguing early Paleozoic trilobite systematics: species are often based on inadequately described type material, with illustrations insufficient for detailed comparison. Inadequate information leads to fluid diagnoses and identifications based on a limited range of characters. Thus, Stitt (1977, p. 37) viewed punctate sculpture as the ''most directly distinctive feature'' of *S. bulbosa* even though, as noted above, there were clear differences in several other characters between his material from Oklahoma and Lochman's (1964) types. In many cases, identifications are not supported by illustrations if a species is judged to be sufficiently well known, so that critical evaluation of these taxonomic decisions is impossible. Stitt (2000), for example, dealt with the earliest Ordovician faunas of the Black Hills of South Dakota and the Bear Lodge Mountains of Wyoming. Treatment of these faunas are limited to a single short paper by Hu (1973), yet Stitt documented none of the taxa, explaining (Stitt, 2000, p. 361) that ''there are no new taxa, and the specimens present add nothing to the taxonomy of these well-known species and genera, which have been adequately described and illustrated in many publications.'' In fact, few of the species Stitt dealt with are known from adequate illustrations of type material and almost all subsequent treatments from other regions are at best cursory. These practices have led to the proposal of a craton-wide, ''standard'' biostratigraphic scheme for Laurentia that is founded on taxa that have often been illustrated with only a handful of sclerites. Moreover, uncritical assignment of specimens to broadly defined ''index species'' may in fact have masked the potential for higher resolution biostratigraphies of at least regional significance. We maintain that further progress in biostratigraphy will require a fresh look at its taxonomic underpinnings, and this will require an entirely new program of sampling and systematic work.

MORPHOMETRICS

The House Formation species of *Millardicurus* n. gen. are distinguished on the basis of a suite of qualitative and meristic characters as detailed in the species discussions below. In order to explore basic shape differences on a quantitative basis, landmark-based geometric morphometric analyses were employed to compare shape variation of the cranidium, librigena, and pygidium. Only the three species described or redescribed herein provide enough information for analysis. Specimens reported in the literature to date are for the most part too incomplete or too poorly illustrated for digitizing. Analyses were carried out in dorsal (cranidia and pygidia) and external (librigenae) view with specimens in standard orientations; further qualitative shape distinctions in other views (particularly sagittal) are discussed under the species below. Landmarks were digitized using the public domain program NIH Image (developed at the U.S. National Institutes of Health and available at http://rsb.info.nih.gov/nih-image/) and analyses were carried out using H. D. Sheets's free Integrated Morphometrics Package (available at http://www.canisius.edu/~sheets/morphsoft.html).

Cranidium.—Twenty-five cranidial landmarks were located (Fig. 3.1), including five on the sagittal axis and ten pairs of either side of the axis.

Cranidial sagittal landmarks:

1 – Intersection of sagittal line and posterior edge of L0.

2 – Intersection of sagittal line and posterior margin of median glabellar lobe. This margin forms a sharp transverse break in slope with the front of S0 in all *Millardicurus* cranidia.

3 – Intersection of sagittal line with anterior margin of glabella.

4 – Intersection of sagittal line with posterior margin of anterior border.

5 – Intersection of sagittal line with anterior margin of anterior border.

Cranidial paired landmarks:

6, 7 – Intersection of anterior edge of anterior border furrow with anterior section of facial suture.

8, 9 – Position of γ on facial suture.

10, 11 – Angular junction of axial and preglabellar furrow, just behind depression in preglabellar furrow.

12, 13 – Maximum point of curvature of lateral edge of palpebral lobe.

14, 15 – Maximum point of curvature of adaxial edge of palpebral furrow.

16, 17 – Maximum point of curvature of lateral edge of L2.

18, 19 – Position of ϵ on facial suture.

20, 21 – Intersection of anterior edge of posterior border furrow with posterior section of facial suture.

22, 23 – Maximum point of posterior curvature of posterior margin of distal part of posterior border.

24, 25 – Junction of posterior margin of posterior border and posterior margin of L0.

Sixteen illustrated cranidia were digitized, including seven specimens of *M. millardensis*, three of *M. housensis* n. sp., and six of *M. paramillardensis* n. sp. Landmarks were reflected across the sagittal axis, and the average value of each of the paired landmarks was used for further analysis. This permits the use of partially incomplete specimens in which each landmark is present on at least one side of the specimen. In these cases, the single value was used for further analysis. The superimposed landmark data are shown in Figure 4.1 as Bookstein coordinates, registered to a baseline between sagittal landmarks 1 and 5. The means for each species at each landmark are shown in Figure 4.2. A Procrustes GLS mean reference form was calculated using all 16 specimens. Partial warp scores were derived from thin plate spline decomposition of the data, and principal component analysis was performed on these scores. The first two principal component axes are shown in Figure 4.3, and suggest that *M. millardensis* and *M. paramillardensis* are substantially similar in overall cranidial shape, whereas *M. housensis* is distinct from them. In order to test for significant differences in cranidial shape, pairwise Goodall's *F*-tests were carried out (Table 1; see Zelditch et al., 2004, p. 218–221 for discussion of Goodall's *F*-test applied to morphometric data). This confirms the result indicated by PCA: overall cranidial shape of *M. millardensis* and *M. paramillardensis* is not significantly different, but that of *M. housensis* is significantly different from either of these species. Detailed comparison of shape is given in the species discussions below.

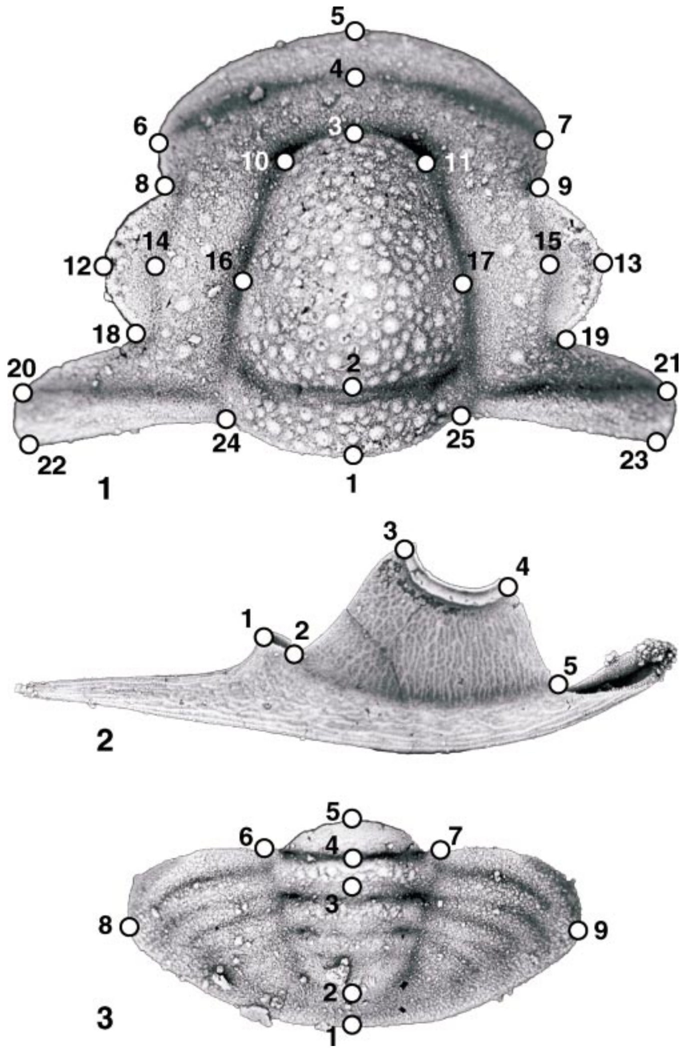

FIGURE 3—Position of landmarks digitized for morphometric analyses of *Millardicurus* n. gen. [sclerites of *M. millardensis* (Hintze, 1953) shown]. *1,* Position of 25 cranidial landmarks. *2,* Position of five librigenal landmarks. *3,* Position of nine pygidial landmarks.

Librigena.—Five librigenal landmarks were located (Fig. 3.2):

1 – Intersection of posterior facial suture with posterior margin of posterior border.

2 – Intersection of posterior facial suture with adaxial edge of lateral border furrow.

3 – Intersection of posterior facial suture with narrow furrow beneath eye socle.

4 – Intersection of anterior facial suture with narrow furrow beneath eye socle.

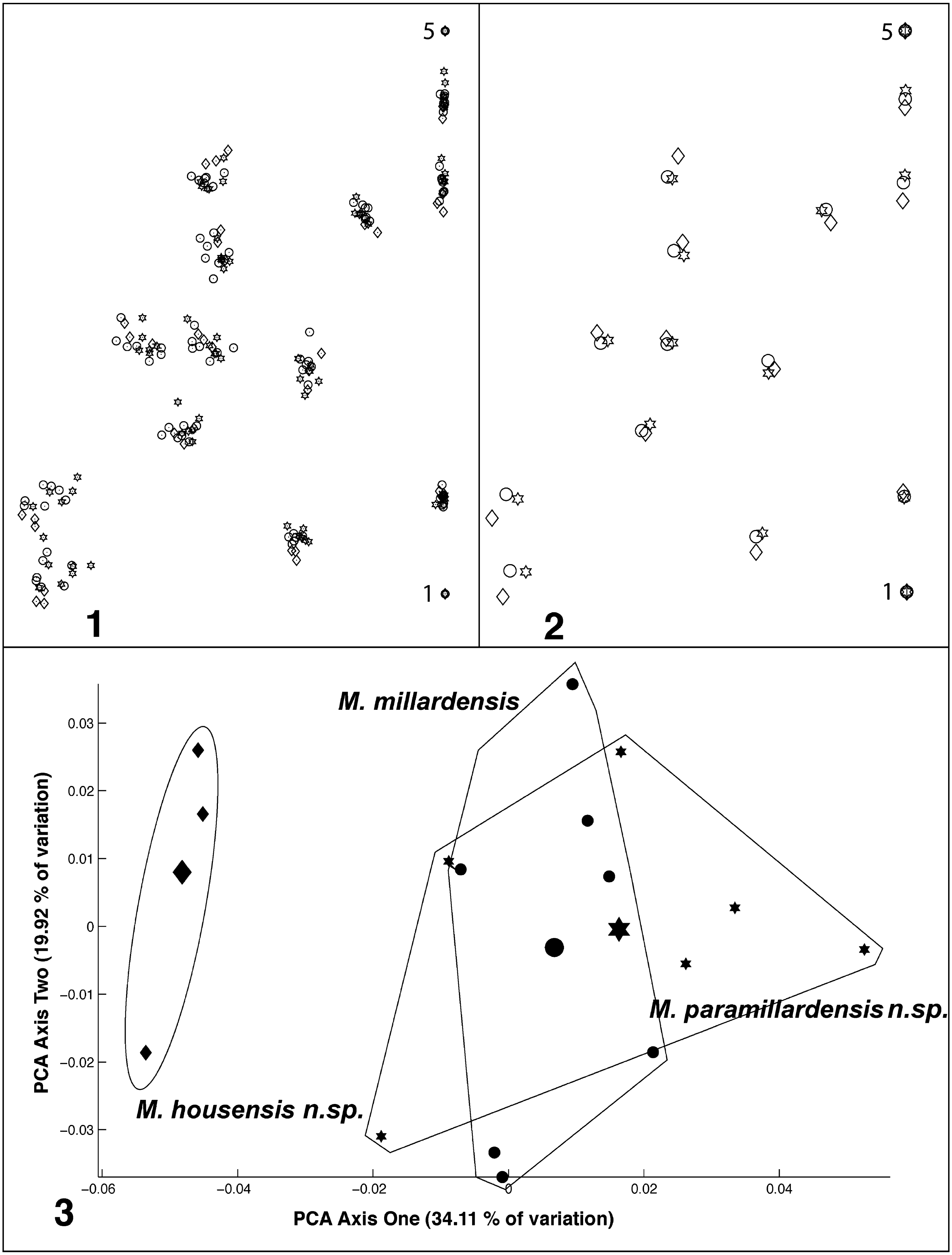
5
1
1
5
1
2
M. millardensis
M. paramillardensis n.sp.
M. housensis n.sp.
PCA Axis Two (19.92 % of variation)
PCA Axis One (34.11 % of variation)
0.03
0.02
0.01
0
−0.01
−0.02
−0.03
−0.06
−0.04
−0.02
0
0.02
0.04
3

TABLE *1*—Goodall's *F*-test for shape difference among cranidia of *M. millardensis* (*mill*), *M. paramillardensis* n. sp. (*paramill*), and *M. housensis* n. sp. (*house*). PPd = procrustes distance between pairs of mean shapes; F = value of *F*-statistic; DF = degrees of freedom.

Species	PPd	F	DF	*P*
mill vs. *paramill*	0.0295	1.37	26,286	0.11468
house vs. *mill*	0.0601	4.17	26,208	<0.000001
house vs. *paramill*	0.0680	4.56	26,182	<0.000001

5 – Intersection of anterior facial suture with adaxial edge of lateral border furrow.

Nineteen illustrated librigenae were digitized, including nine specimens of *M. millardensis*, four of *M. housensis*, and six of *M. paramillardensis*. The superimposed landmark data are shown in Figure 5.1 as Bookstein coordinates, registered to a baseline between sagittal landmarks 1 and 5 (the rear of the posterior facial sutures and the front of the lateral border furrow). The means for each species at each landmark are shown in Figure 5.2, and the first two principal components axes in Figure 5.3. PCA suggests that the librigenal shape of *M. millardensis* and *M. housensis* is similar, but that of *M. paramillardensis* is distinct. These impressions are supported by pairwise *F*-tests (Table 2), except that a null hypothesis of no shape difference between librigenae of *M. housensis* and *M. paramillardensis* just fails ($P = 0.06$) to be rejected at the $P = 0.05$ level.

Pygidium.—Nine pygidial landmarks were located (Fig. 3.3), including five on the sagittal axis and two pairs on either side of the axis:

1 – Intersection of sagittal line with posterior margin.

2 – Intersection of sagittal line with posterior edge of axis.

3 – Intersection of sagittal line with posterior edge of first axial ring.

4 – Intersection of sagittal line with posterior edge of articulating half ring.

5 – Intersection of sagittal line with anterior edge of articulating half ring.

6, 7 – intersection of anterior margin with center of axial furrow.

8, 9 – Angular maximum of curvature of margin opposite posterior pleural band of first segment.

Seventeen illustrated pygidia were digitized, including eight specimens of *M. millardensis*, three of *M. housensis*, and six of *M. paramillardensis*. Sagittal reflection was employed as for cranidia. The superimposed landmark data are shown in Figure 6.1 as Bookstein coordinates, registered to a baseline between sagittal landmarks 1 and 5 (the rear and front of the pygidial sagittal axis). The means for each species at each landmark are shown in Figure 6.2, and the first two principal component axes in Figure 6.3. PCA suggests that while there is some overlap, the mean pygidial shape of each species is distinct. This is supported by pairwise *F*-tests (Table 3), which confirm significant differences in all comparisons.

SYSTEMATIC PALEONTOLOGY

Repository.—Figured material is housed in the Paleontology Repository, Department of Geoscience, University of Iowa, Iowa City, with specimen number prefix SUI. Other specimen number prefixes listed are: MGUH, Geological Museum, Copenhagen; USNM, National Museum of Natural History, Smithsonian Institution, Washington, DC.

Terminology.—Terminology is employed as outlined by Whittington and Kelly (1997). Orientations are always used in reference to standard planes. Hence, length always refers to anteroposterior distance and width always to transverse distance; the breadth of a transverse furrow such as the cranidial anterior border furrow is its ''length,'' whereas the breadth of a furrow oriented toward an exsagittal plane, such as the cranidial axial furrow, is its ''width.''

Family HYSTRICURIDAE Hupé, 1953
Genus MILLARDICURUS new genus

Type species.—*Hystricurus millardensis* Hintze, 1953, from the House Formation of Utah.

Other species.—*Hystricurus armatus* Poulsen, 1937(=*H. sulcatus* Poulsen, 1937); *M. housensis* n. sp.; *M. paramillardensis* n. sp.; *H. longicephalus* Poulsen, 1927; ?*H. nudus* Poulsen, 1937; *M. ravni* Poulsen, 1927; the material described by Taylor (*in* Taylor and Halley, 1974) as *Hystricurus millardensis* is a new species, treated in open nomenclature below as *Millardicurus* n. sp. A; the specimen illustrated by Fortey (in Fortey et al., 1982) is probably conspecific with Taylor's species; reports of *Hystricurus millardensis* from Texas and Oklahoma by Winston and Nicholls (1967) and Stitt (1971, 1983) are discussed below.

Diagnosis.—Glabella subtrapezoidal in plan view and prominently waisted; cranidium and librigenal field with finely anastomosing and dense caecal sculpture; cranidium with subdued to coarse sculpture of moderate to large tubercles; junction of cranidial axial and preglabellar furrows marked by transverse slotlike depression; eye socle of single inflated band, circumocular suture possibly functional; rostral plate transverse and hourglass-shaped; hypostome nearly parallel-sided and subrectangular, with weak middle furrow; number of thoracic segments unknown but thoracic axial spine definitely absent; pygidium with two to four axial rings.

Etymology.—After Millard County, Utah.

Discussion.—Although superb for its time, Hintze's (1953) monograph of the Ibexian trilobite faunas of the Pogonip Group in western Utah treated many species on the basis of what is in modern terms an inadequate number of specimens. *Millardicurus millardensis* was based on one cranidium, two librigenae, and two pygidia. As discussed above, incomplete knowledge of the morphology of species has historically encouraged workers to refer material from other geographic areas to those species. Further, because the taxon is previously named, workers have cited this as a reason to provide only cursory illustration of their own material. The results are geographic species ranges and biostratigraphic correlations that are not supported by rigorous systematic work. This is the situation documented by Adrain and Westrop (2005) for the supposedly widespread and biostratigraphically significant Upper Cambrian taxa *Euptychaspis typicalis* Ulrich in Bridge, 1931 and *E. kirki* Kobayashi, 1935. Such trilobite species tend to be poorly known in their type area, and critical evaluation almost invariably demonstrates that a plexus of geographically

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FIGURE *4*—Morphometric analysis of cranidial shape in *Millardicurus* n. gen. Circles = *M. millardensis*. Stars = *M. paramillardensis* n. sp. Diamonds = *M. housensis* n. sp. *1,* Position of landmarks for all specimens following reflection across the sagittal axis, shown as Bookstein coordinates registered to a baseline between landmarks 1 and 5 (i.e., the rear and front of the cranidium). *2,* The mean values for each species at each landmark. *3,* Scores on first two principal component axes. Larger symbols represent species means. Results of pairwise statistical tests for shape difference are given in Table 1. Cranidial shape of *M. millardensis* and *M. paramillardensis* is not significantly different, but that of *M. housensis* is significantly different from either of these species.

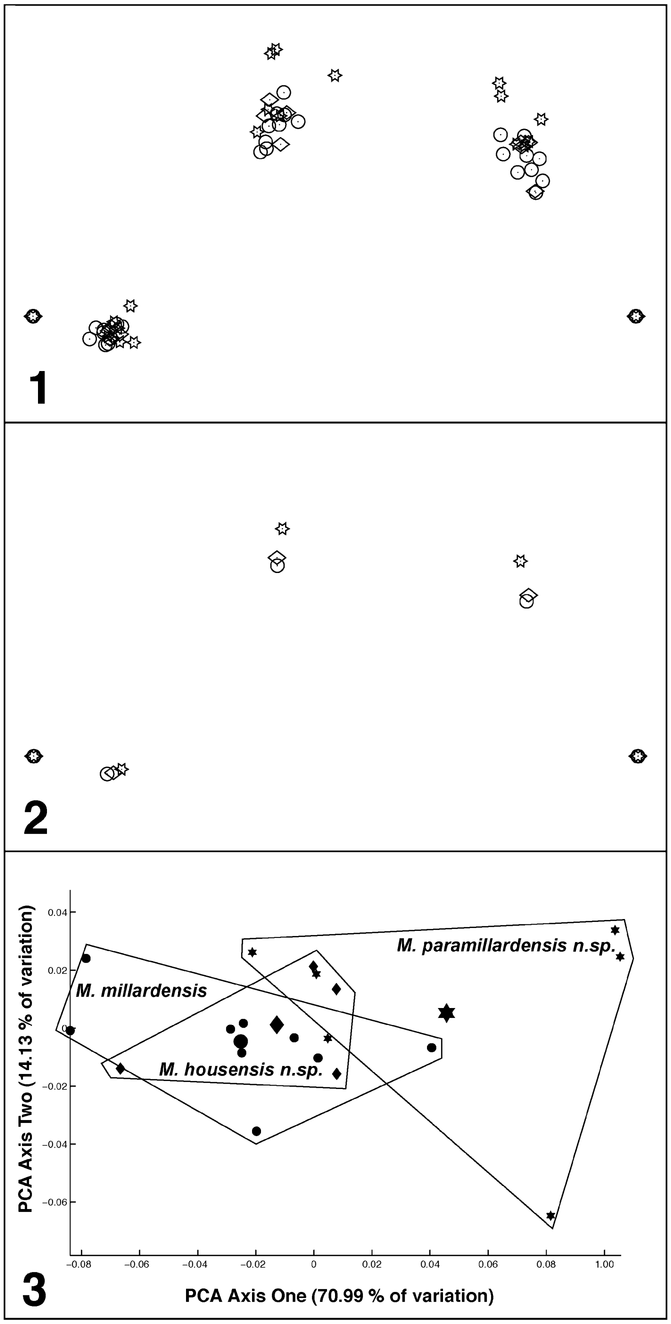

FIGURE 5—Morphometric analysis of librigenal shape in *Millardicurus*. Circles = *M. millardensis*. Stars = *M. paramillardensis* n. sp. Diamonds = *M. housensis* n. sp. *1*, Position of landmarks for all specimens, shown as Bookstein coordinates registered to a baseline between landmarks 1 and 5 (see Fig. 3.2). *2*, The mean values for each specimen at each landmark. *3*, Scores on first two principal component axes. Larger symbols represent species means. Results of pairwise statistical tests for shape difference are given in Table 2. Librigenal shape of *M. millardensis* and *M. paramillardensis* is significantly different, but other comparisons are not significantly different.

separate species is involved. This is exactly the case with *M. millardensis* and various sets of material referred to it.

Winston and Nicholls (1967, p. 76, pl. 12, figs. 14, 18) recorded *M. millardensis* in the San Saba Member of the Wilberns Formation in the Llano Uplift, Texas, but illustrated only tiny dorsal stereopairs of two cranidia. In their discussion, they noted variation in cranidial sculpture ‘‘from coarsely granulose to almost smooth.’’ No such variation exists in the large and well constrained samples documented herein, and this in itself suggests that multiple species of *Millardicurus* occur in the Wilberns Formation as they do in the House Formation. Winston and Nicholls's specimens are so poorly illustrated that they cannot be effectively compared with the well-known Utah species. They appear to be most similar to *M. millardensis* and *M. paramillardensis* in glabellar dimensions, but differ in their apparently coarser tuberculate sculpture, shorter preglabellar fields, and deeper anterior border furrows. The status of the Texas species can only be clarified with more and better material.

TABLE 2—Goodall's *F*-test for shape difference among librigena of *M. millardensis* (*mill*), *M. paramillardensis* n. sp. (*paramill*), and *M. housensis* n. sp. (*house*). PPd = procrustes distance between pairs of mean shapes; F = value of *F*-statistic; DF = degrees of freedom.

Species	PPd	F	DF	*P*
mill vs. *paramill*	0.0124	5.48	6,78	0.000897
house vs. *mill*	0.0178	0.37	6,66	0.89679
house vs. *paramill*	0.0596	2.18	6,48	0.061336

Stitt (1971, 1983) assigned material from the Signal Mountain Limestone (1971) and Mackenzie Hill Limestone (1983) of Oklahoma to *M. millardensis*. It is doubtful than any of the three cranidia illustrated by Stitt in these works are conspecific with each other. The cranidium illustrated in 1971 (pl. 8, fig. 17), inasmuch as can be seen on the tiny stereopair, is densely and finely tuberculate over much of its surface. This and the pygidium with four strong axial rings and prominently incised pleural and interpleural furrows suggest comparison with material described by Taylor (*in* Taylor and Halley, 1974) from New York State. The latter is clearly a distinct, new species, to which a cranidium figured by Fortey (*in* Fortey et al., 1982) from the Cow Head Group of western Newfoundland also appears to belong. Stitt's (1971) material is questionably assigned to this species below. The younger material (from over 30 m higher in the Oklahoma succession) assigned by Stitt (1983) comprises two cranidia from different sections. There are obvious differences in the relative size and spacing of the tuberculate sculpture, the prominence of the pits at the junction of the axial and preglabellar furrows, and the anterior width of the cranidia. The specimens are of much different size (one is nearly three times larger than the other) so the differences could conceivably be ontogenetic. No such ontogenetic variation is apparent, though, in the rich and well-constrained samples described herein from Utah. The larger of Stitt's (1983, pl. 4, fig. 2) specimens is again densely tuberculate over most of its surface. It definitely does not represent any of the Utah species. The question of its conspecificity with the smaller cranidium (Stitt, 1983, pl. 4, fig. 1) and the older cranidium from the underlying Signal Hill Limestone (Stitt, 1971) can only be resolved with more material, including librigenae and pygidia.

The close affinity of *Millardicurus* is not easy to assess. It predates the appearance of the subfamily Hintzecurinae Adrain et al., 2003, the earliest securely dated representatives of which appear at the base of the upper Skullrockian Red Canyon Member of the House Formation. There is little reason to suspect a close relationship with hintzecurines, all of which have, for example, prominent thoracic axial spines. Hystricurinae also make their first appearance within the Red Canyon Member, though they do not become common until the overlying Stairsian Stage. *Millardicurus* does share some features with the much younger Stairsian genus *Hystricurus* (revised by Adrain et al., 2003), including a waisted glabella and a lack of a thoracic axial spine. However, early species that apparently represented *Hystricurus* (personal

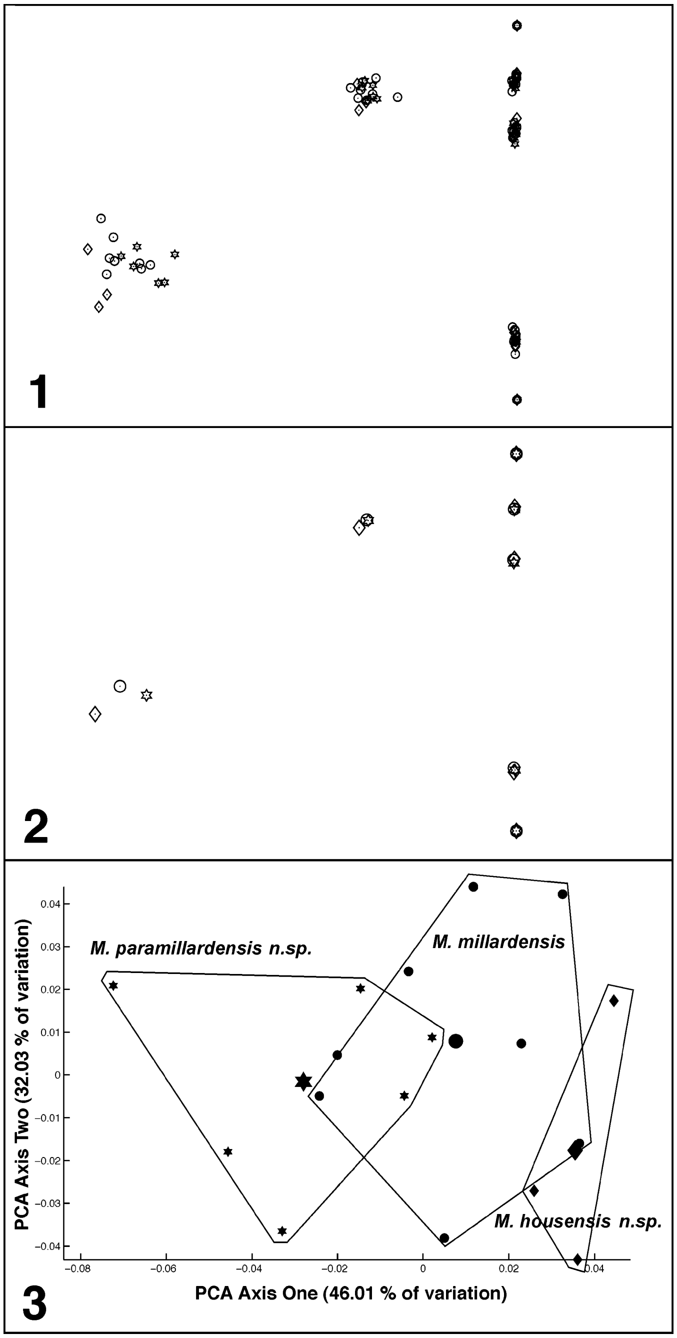

FIGURE 6—Morphometric analysis of pygidial shape in *Millardicurus* n. gen. Circles = *M. millardensis*. Stars = *M. paramillardensis* n. sp. Diamonds = *M. housensis* n. sp. *1,* Position of landmarks for all specimens, shown as Bookstein coordinates registered to a baseline between landmarks 1 and 5 (see Fig. 3.3). *2,* The mean values for each specimen at each landmark. *3,* Scores on first two principal component axes. Larger symbols represent species means. Results of pairwise statistical tests for shape difference are given in Table 3. The pygidial shapes of all three species are significantly different.

data) are extremely dorsally convex, vaulted, and densely tuberculate, and in the present state of knowledge we suspect similarity between the genera is homoplastic. That *Millardicurus* represents an aulacopleuroidean seems clear, as the paired glabellar and fixigenal tubercles characteristic of all aulacopleuroidean taxa (Adrain and Chatterton, 1993) are visible in smaller silicified cranidia.

TABLE 3—Goodall's *F*-test for shape difference among pygidia of *M. millardensis* (*mill*), *M. paramillardensis* n. sp. (*paramill*), and *M. housensis* n. sp. (*house*). PPd = procrustes distance between pairs of mean shapes; F = value of *F*-statistic; DF = degrees of freedom.

Species	PPd	F	DF	*P*
mill vs. *paramill*	0.0690	2.62	10,120	0.006585
house vs. *mill*	0.0427	2.10	10,90	0.032741
house vs. *paramill*	0.0678	5.91	10,70	0.000002

More extensive consideration of its affinity must await ongoing revision of all members of the family and the description in progress of many new species.

The type species of the Siberian genus *Nyaya* Rozova, 1963 is *N. nyaensis* Rozova, 1963, from the Il'tyk Formation, Kulyumbe River, Igar region, northern Siberia, Russia (see also Rozova, 1968, 1977; Gorovcova and Semenova, 1977). *Nyaya* takes its name from the Nya Horizon (Nyayian Horizon of Kanygin et al., 1988) of the Siberian Lower Ordovician, established by Rozova (1968) with a type section on the Kulyumbe River. Rozova (1968) regarded the Nyayian as the earliest interval of the Ordovician, and the underlying Loparian Horizon as latest Cambrian (the Loparian is shown as Ordovician by, for example, Kanygin et al., 1988, but this is apparently based on the lowest occurrence of dictyonemid graptolites). *Nyaya* has sometimes been regarded as related to a variety of genera often considered aphelaspidines (e.g., *Olentella* Ivshin, 1956; see Shergold et al., 2000, p. 611). However, the taxon is at least superficially similar to *Millardicurus*, possessing a waisted glabella, slotlike pits at the junction of the axial and preglabellar furrows, similar cranidial dimensions and similar pygidia, with 3–4 axial rings. None of the species of *Nyaya* are very well known, however (others include *Nyaya grata* Rozova, 1968, Il'tyk Formation, Kulyumbe River, and *N. orientalis* Ogienko, 1974, Ust'Kut Formation, Oka River, Siberian Platform). Librigenae, hypostomes, rostral plates, and thoraces are unknown for any species and most figured sclerites are internal molds. *Nyaya* does differ from *Millardicurus* in its much deeper and more prominent palpebral furrow, larger palpebral lobe, presence of a median keel on the glabella (at least on internal molds: Rozova, 1968, pl. 16, figs. 5, 8), and lack of obvious tuberculate sculpture. Further assessment of affinity of the taxa will require more and better information on the morphology of *Nyaya*.

Nyaya novozemelica Burskii, 1970 and *N. paichoica* Burskii, 1970 were both figured and have plate captions, but lack any mention in the text. As they were not accompanied by a diagnosis they fail to meet the requirements of Article 13.1 of the ICZN and are apparently nomina nuda. In any case, both species have very large eyes, narrow frontal areas, and a dorsally inflated preglabellar field. They may belong to *Tersella* Petrunina, 1973, but are not obviously related to species of *Nyaya*.

Nyaya sp. was reported from the upper Tremadocian Pontoon Hill Siltstone Member of the Florentine Valley Formation of Southwest Tasmania by Stait and Laurie (1980, fig. 3, app. 1). When the trilobite fauna was documented systematically by Jell and Stait (1985), however, no mention was made of the assignment to *Nyaya* and one of specimens listed by Stait and Laurie (1980, app. 1, U.T.G.D. 95983) as *Nyaya* sp. was made the holotype of *Tanybregma tasmaniensis* Jell and Stait, 1985. *Tanybregma* Jell and Stait, 1985 is a hystricurid genus unrelated to and younger than *Millardicurus* and *Nyaya*.

The visual surface is not preserved on any recovered *Millardicurus* librigena in the large silicified samples obtained from the Barn Canyon Member. Few librigenae from elsewhere have been figured, though the visual surface is also missing from the specimen illustrated by Taylor and Halley (1974, pl. 3, fig. 14) and from those of *M. armatus* illustrated by Poulsen (1937, pl. 2, figs.


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6–8). It is possible that this is a preservational artifact due to a very thin cuticle across the eye surface. However, most of the preserved edges of the eye socle (e.g., Fig. 4.1, 4.9–4.12) are not ragged as would be expected if they represented a contact with a contiguous but broken visual surface. It is possible that species of *Millardicurus* retained a functional circumocular suture.

MILLARDICURUS MILLARDENSIS (Hintze, 1953)
Figures 3, 7–9

Hystricurus millardensis HINTZE, 1953, p. 168, pl. 6, figs. 17–21.
?*Hystricurus millardensis* HINTZE; WINSTON AND NICHOLLS, 1967, p. 76, pl. 12, figs. 14, 18.
?*Hystricurus* sp.; HU, 1973, pl. 1, fig. 33.
non *Hystricurus millardensis* HINTZE; STITT, 1971, p. 46, pl. 8, figs. 17, 18 (?=*Millardicurus* n. sp. A herein).
non *Hystricurus millardensis* HINTZE; TAYLOR AND HALLEY, 1974, p. 31, pl. 3, figs. 10–16 (=*Millardicurus* n. sp. A herein).
non *Hystricurus millardensis* HINTZE; STITT, 1983, p. 25, pl. 4, figs. 1, 2 (=*Millardicurus* sp. indet.).
non *Hystricurus millardensis* HINTZE; FORTEY *IN* FORTEY ET AL., 1982, p. 108, pl. 3, fig. 10 (=*Millardicurus* n. sp. A herein).
?*Hystricurus millardensis*; STITT, 2000, pl. 360.
?*Hystricurus millardensis* HINTZE; MILLER ET AL., 2003, pl. 1, fig. 11.

Diagnosis.—Large cranidia with relatively deep and narrowly incised anterior border furrow and long preglabellar field, dense but quite subdued tuberculate sculpture, very sparse on preglabellar field and frontal area; glabella anteriorly broad; pits at junction of axial and preglabellar furrow not prominent; S1-S3 visible as distinct smooth areas; pygidium with three well-expressed axial rings and poorly defined fourth, first ring with prominent tuberculate sculpture, posterior rings increasingly effaced.

Description.—Cranidium. Cited dimensions are the range and mean of measurements made on the six nearly complete and well-preserved specimens illustrated in Figure 7.1, 7.3, 7.4, 7.9, 7.13, and 7.22. Sagittal length 64–69 (66.3)% maximum width across posterior fixigenae; width across anterior border 55–60 (56.8)% width across posterior fixigenae; width across midpoint of palpebral lobes 67–77 (72.7)% width across posterior fixigenae; anterior border with sagittal length 69–95 (84.0)% sagittal length of L0, 67–102 (91.5)% sagittal length of preglabellar field; anterior margin of anterior border describing broad and even anterior arc; anterior border tapering in length abaxially, tubelike in sagittal profile with stronger sagittal curvature anteriorly than dorsally, with sculpture of fine, raised lines continuous and subparallel with margin on anterior aspect, less continuous and more wandering in course on dorsal aspect, dorsal region with several medium and more numerous, very fine, subdued tubercles scattered among raised lines, more prominent in middle third of width in most specimens; anterior border furrow with general course describing shallower anterior arc than anterior margin, more or less evenly arcuate in some specimens (Fig. 7.3, 7.13), with very shallow ''W'' shape, bending back in front of junction of axial and preglabellar furrows and bowed forward medially, in others (Fig. 7.1, 7.22), relatively short (sag.; exsag.) and shallow, slightly deeper abaxially in most specimens; preglabellar field and frontal area quite shallowly declined, more shallow than front slope of glabella, with sculpture of very fine, generally anteroposteriorly oriented caecae and sparse scattering of subdued medium tubercles on posteriormost two-thirds of area; anterior sections of facial sutures moderately bowed laterally, maximum point of divergence just behind intersection of anterior border furrow; eye ridge variably expressed, ranging from obvious and with break in slope defining front and back edge (Fig. 7.1) to weakly expressed with break in slope only anteriorly (Fig. 7.9, 7.20, 7.22), to almost completely obscure (Fig. 7.13), apparently became more prominent in larger specimens, running forward at about a 30° angle from the transverse plane; glabella weakly inflated in sagittal profile, widest posteriorly, axial furrows convergent opposite L1, bulged slightly laterally around L2, pinched in so that that glabella is quite strongly waisted opposite S2, then strongly convergent to junction with preglabellar furrow, frontal lobe of glabella markedly narrow; junction of axial and preglabellar furrows with pair of obvious deep pits corresponding to ventral position of fossulae; preglabellar furrow with gentle anterior arc; axial and preglabellar furrows of similar short width and length, respectively, and similar depth except for pits at junction; glabella with sculpture of closely crowded medium and small tubercles, much more dense and coarse than any other part of cephalon except for L0; S1-S3 variably expressed, all obvious in largest specimens (e.g., Fig. 7.1) as smooth patches lacking tubercles and as faint furrows ventrally (Fig. 7.11), expression ranges to almost entirely obscure dorsally (e.g., Fig. 7.22); S0 long and of similar length in median three-fifths, rear of glabella sharply defined, S0 shorter and deeper abaxially behind L1, course transverse in median three-fifths, turned sharply anteriorly behind L1; L0 with sagittal length 13–16 (14.7)% that of cranidium and 23–28 (25.8)% L0 width; rear of L0 describing even posterior arc, smooth, with no posteriorly protruding tubercles; L0 longest medially, shorter behind S0 pit behind L1, with sculpture of densely scattered medium and small tubercles similar to that on glabella, no distinct median tubercle in most specimens; interocular fixigena with width 18–20 (18.7)% that of cranidium opposite midpoint of palpebral lobe, with weak dorsal inflation, background sculpture of very fine granules, subdued medium tubercles, more prominent than those on frontal area, restricted to abaxial half of fixigena; palpebral furrow relatively shallow but firmly impressed along entire course to fully isolate palpebral lobe, bowed medially around front and back edges of lobe and bowed laterally opposite midpoint of lobe, describing lateral arc less bowed than that of palpebral lateral margin; palpebral lobe with width at midpoint 8–10 (9.0)% cranidial width at same point, exsagittal length 27–35 (32.0)% sagittal length of cranidium, appears to decrease in relative length with size of specimen, elevated at about 40° from horizontal plane, mostly smooth and lacking sculpture except for sparse scattering of very fine tubercles along lateral margin in some specimens (e.g., Fig. 7.22); posterior fixigena with width 30–32 (31.3)% posterior cranidial width, short strip of fixigena behind rear of palpebral lobe, bearing a few small and subdued tubercles, tapering in length rapidly abaxially and smooth abaxial to rear of palpebral lobe; posterior border furrow similar in length and depth to lateral part of S0,

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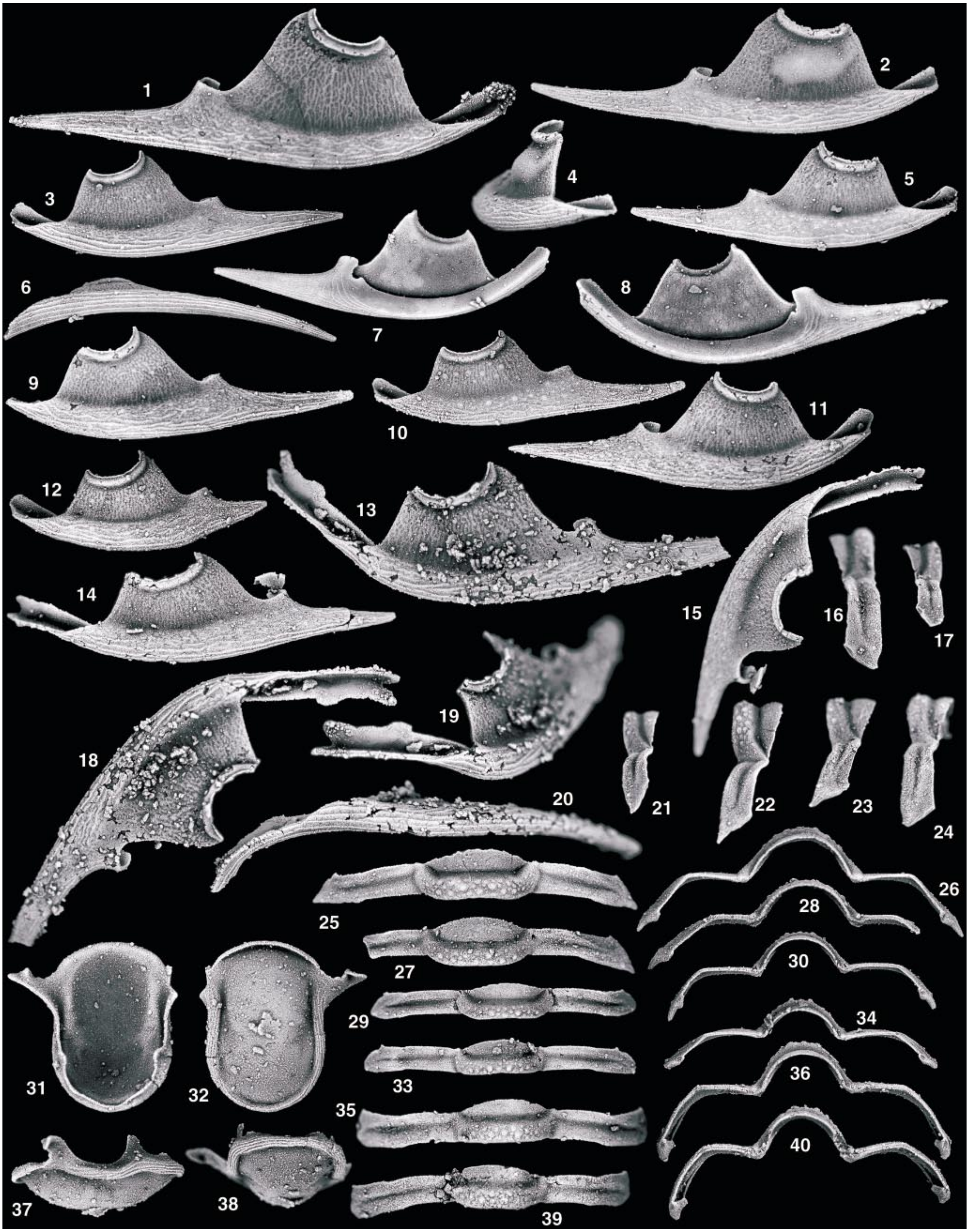
FIGURE 7—*Millardicurus millardensis* (Hintze, 1953), from the Barn Canyon Member, House Formation (lower Skullrockian), Section B 1.1 m. Magnifications are ×10 except where noted. *1, 2, 6, 11, 17*, Cranidium, SUI 100082, dorsal, left lateral, anterior, ventral, and oblique views, ×7.5. *3, 5, 8*, Cranidium, SUI 100083, dorsal, left lateral, and anterior views, ×7.5. *4, 7, 10*, Cranidium, SUI 100084, dorsal, anterior, and right lateral views, ×7.5. *9, 12, 14*, Cranidium, SUI 100085, dorsal, anterior, and right lateral views. *13, 15, 16*, Cranidium, SUI 100086, dorsal, left lateral, and anterior views. *18–20*, Cranidium, SUI 100087, anterior, right lateral, and dorsal views. *21, 22, 24*, Cranidium, SUI 100088, right lateral, dorsal, and anterior views. *23, 25, 26*, Cranidium, SUI 100089, left lateral, dorsal, and anterior views. *27–29*, Cranidium, SUI 100090, right lateral, dorsal, and anterior views.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nearly transverse, with slight posterior deflection in course at fulcrum, markedly shallowed near contact with facial suture; posterior border very short proximally, lengthening rapidly between fulcrum and distal tip, tubelike in exsagittal profile but more flattened distally, essentially smooth, with only finely granulate sculpture, tip broadly rounded at facial suture; doublure beneath L0 with very fine raised lines parallel to posterior margin; doublure absent beneath proximal part of posterior border but developed as recurved subtriangular strip lacking sculpture under distal part, anterior tip of strip does not protrude forward of posterior fixigena and is not visible in dorsal view; broadly transverse strip of doublure underlying front edge of anterior border, with sculpture of fine raised lines subparallel with margin continued from anterior aspect of anterior border, posterior margin of doublure describing broad arc parallel with anterior cranidial margin, connective sutures long and with nearly transverse course; prominent fossular pits at ventral junction of axial and preglabellar furrows.

Librigena. Cited dimensions are the range and mean of measurements made on the eight specimens illustrated in Figure 8.1–8.3, 8.5, 8.9, 8.10, 8.11, and 8.14. The specimen in Figure 8.12 was not included because its genal spine length is atypical and that in Figure 8.13 because the genal spine is broken. Maximum width achieved behind eye, 31–33 (32.1)% length; maximum width of field behind eye 47–61 (52.9)% length of field; width of field at anterior end of eye 32–44 (38.4)% its length; field 38–42 (39.9)% overall length of librigena; eye with exsagittal length 15–22 (18.6)% that of librigena, eye socle of single inflated band, of same width all along course, describing lateral arc, slightly flattened around midpoint of eye, separated from field by very narrow, incised furrow, and separated adaxially from a narrow rim (a circumocular suture?) by a second very narrow and incised furrow; field with strong caecal sculpture of raised anastomosing trunks oriented mostly in a transverse direction, single exsagittal row of subdued medium tubercles and very sparsely scattered small tubercles developed on smaller specimens (Fig. 8.3, 8.5, 8.10), almost entirely lost in larger specimens; posterior border and posterior border furrow with very limited course, posterior section of facial suture cutting border just above genal spine base; lateral border furrow fully incised only in small specimens (Fig. 8.12), in large specimens mainly a depression or break in slope between the field and border, somewhat deeper anteriorly, describing very gentle lateral arc; lateral border inflated and tubelike, width opposite midpoint of eye 21–29 (26.4)% maximum width of librigena, with sculpture of raised lines, linear and subparallel to margin laterally, more wandering and discontinuous adaxially, similar to sculpture on anterior border, subdued medium and fine tubercles developed near lateral border furrow on smaller specimens (Fig. 8.10), absent from larger specimens, width of border increasing posteriorly; lateral margin of librigena describing very gentle lateral arc opposite field, running into genal spine with only slight deflection in course at spine base, lateral aspect of spine nearly straight in external view; genal spine with length 26–37 (33.5)% that of librigena, base of similar width to posteriormost part of lateral border, tapering rapidly and evenly to sharp point, lateral border and genal spine with smooth and even curvature in ventrolateral view (Fig. 8.6), dorsal sculpture of raised subparallel lines along abaxial and adaxial aspect, more disjointed and meandering along dorsal aspect on proximal two-fifths of spine; doublure sharply turned in from border with angular change in slope (Fig. 8.8), entirely smooth and flat beneath lateral border, prominent panderian notch present in front of genal spine base (Fig. 8.7), ventral aspect of genal spine with raised lines curving up from lateral border to run around panderian notch toward small part of doublure beneath posterior border, fine raised lines subparallel to margin on ventral aspect of distal part of genal spine.

Rostral plate. Broadly hourglass-shaped (Fig. 8.15, 8.18) and transverse, connective sutures describing sharp, laterally directed ''V,'' anterior margin flush with facial suture on anterior projection of librigena, posterior part protruding posteriorly from rear of librigenal doublure, posterior margin describing shallow posterior arc.

Hypostome. Sagittal length 85% maximum width (extrapolated) across anterior wings; width across posterior lobe of middle body 70% sagittal length; anterior margin describing even and moderate anterior arc, margin turned ventrally into sharp rim, set off by incised crescentic furrow; lateral border furrow very shallow anteriorly, incised opposite anterior wing, deepest anterior to middle furrow, narrow and incised posteriorly and running without interruption into posterior border furrow, which describes even, semi-circular posterior arc subparallel to that of posterior margin; anterior wing wide, with subtriangular base lacking sculpture, prominent thornlike wing process marked ventrally by deep pit near distalmost part of wing; lateral border narrow and rimlike, narrowing posteriorly, with sculpture of three to four fine raised lines subparallel with margin, bowed slightly laterally around posterior lobe of middle body, running without interruption into posterior border; middle body with moderate ventral inflation, entirely lacking in sculpture, middle furrow impressed abaxially, running posteromedially, effaced on median two-fifths of middle body, bifurcate with very fine limb directed posteriorly on posterior lobe; doublure forming narrow vertical rim, extended dorsally into tab-shaped and unsculptured posterior wing.

Thorax. Axis broadest relative to pleurae posteriorly, occupying about 39% of width, steadily decreasing in relative width posteriorly to about 34% in posterior segments; fulcrum set approximately three-quarters distance distally in anterior segments (Fig. 8.25), just over half distance in posterior segments (Fig. 8.39); articulating half ring large and dorsally inflated; ring furrow transversely straight across most of its course, deflected anteriorly at lateral parts; rings very slightly longer (sag.) than articulating half rings, posterior margin slightly anteriorly bowed, inflated and with prominent tuberculate sculpture similar to that on glabella; axial furrow shallow and bowed around lateral margin of axial ring; pleural furrow deep and incised, running slightly posterolaterally,

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FIGURE 8—*Millardicurus millardensis* (Hintze, 1953), from the Barn Canyon Member, House Formation (lower Skullrockian), Section B 1.1 m. Magnifications are ×7.5 except where noted. *1,* Right librigena, SUI 100091, external view. *2, 4,* Right librigena, SUI 100092, external and anterior views. *3, 6, 7,* Left librigena, SUI 100093, external, ventrolateral, and internal views. *5,* Right librigena, SUI 100094, external view. *8, 11,* Right librigena, SUI 100095, internal and external views. *9,* Left librigena, SUI 100096, external view. *10,* Left librigena, SUI 100097, external view, ×10. *12,* Left librigena, SUI 100098, external view, ×10. *13, 18–20,* Left librigena and rostral plate, SUI 100099, external librigena, dorsal rostral plate, anterior, and ventrolateral views, ×10. *14, 15,* Left librigena and rostral plate, SUI 100100, external librigena and dorsal views, ×10. *16, 35, 36,* Thoracic segment, SUI 100101, left lateral, dorsal, and anterior views, ×10. *17, 29, 30,* Thoracic segment, SUI 100102, left lateral, dorsal, and anterior views. *21, 33, 34,* Thoracic segment, SUI 100103, right lateral, dorsal, and anterior views. *22, 25, 26,* Thoracic segment, SUI 100104, right lateral, dorsal, and anterior views. *23, 27, 28,* Thoracic segment, SUI 100105, right lateral, dorsal, and anterior views. *24, 39, 40,* Thoracic segment, SUI 100106, right lateral, dorsal, and anterior views, ×10. *31, 32, 37, 38,* Hypostome, SUI 100107, dorsal, ventral, left lateral, and posterior views, ×12.

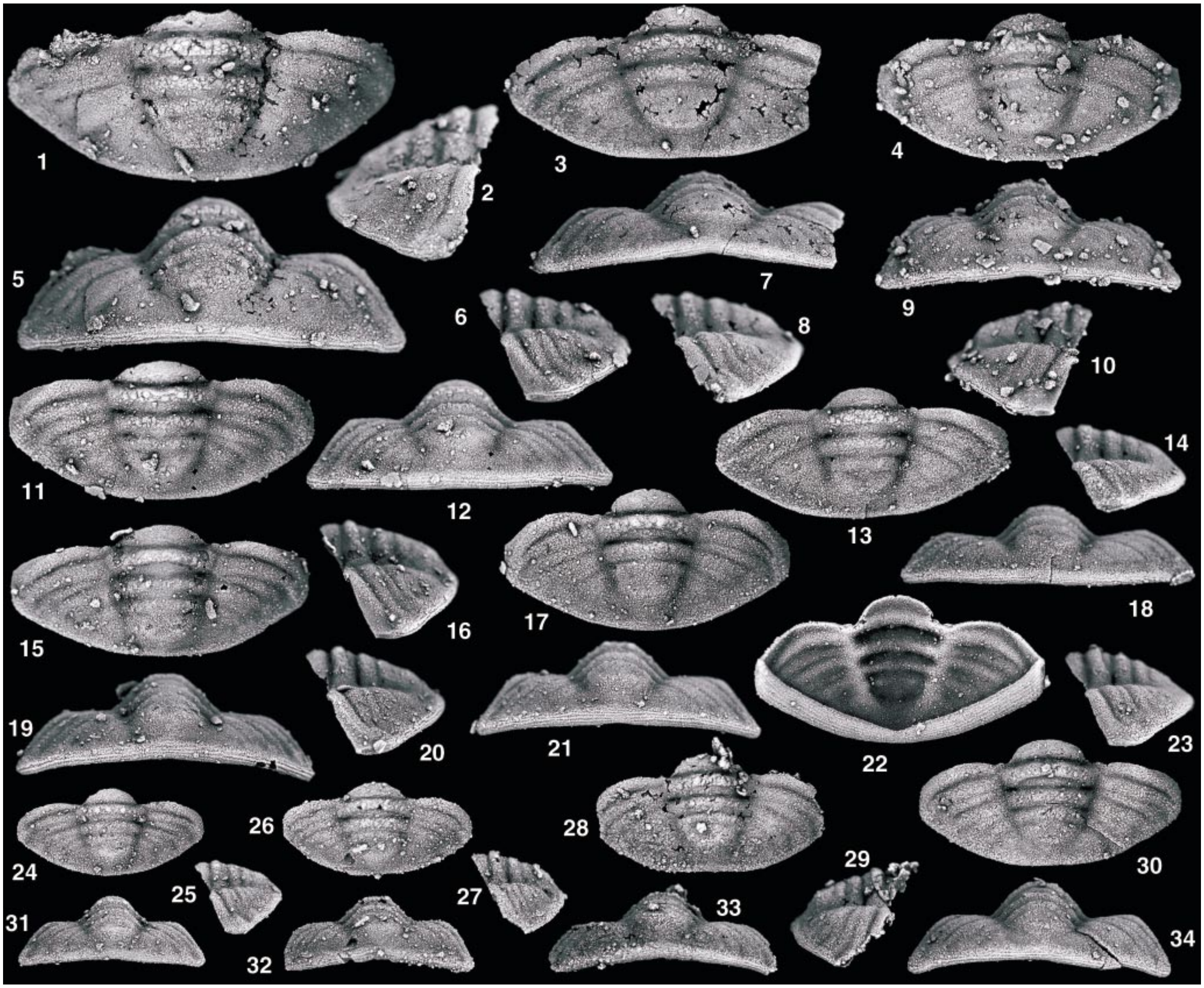


FIGURE 9—*Millardicurus millardensis* (Hintze, 1953), from the Barn Canyon Member, House Formation (lower Skullrockian), Section B 1.1 m. Magnifications are ×10. *1, 2, 5,* Pygidium, SUI 100108, dorsal, right lateral, and posterior views. *3, 7, 8,* Pygidium, SUI 100109, dorsal, posterior, and left lateral views. *4, 9, 10,* Pygidium, SUI 100110, dorsal, posterior, and right lateral views. *6, 11, 12,* Pygidium, SUI 100111, left lateral, dorsal, and posterior views. *13, 14, 18,* Pygidium, SUI 100112, dorsal, left lateral, and posterior views. *15, 16, 19,* Pygidium, SUI 100113, dorsal, left lateral, and posterior views. *17, 20–22,* Pygidium, SUI 100114, dorsal, left lateral, posterior, and ventral views. *23, 30, 34,* Pygidium, SUI 100115, left lateral, dorsal, and posterior views. *24, 25, 31,* Pygidium, SUI 100116, dorsal, left lateral, and posterior views. *26, 27, 32,* Pygidium, SUI 100117, dorsal, left lateral, and posterior views. *28, 29, 33,* Pygidium, SUI 100118, dorsal, right lateral, and posterior views.

meeting to contact axial furrow proximally; anterior and posterior pleural bands subequal in length, in some specimens with very subdued tuberculate sculpture on proximal part of either band; prominent articulating facet on distal part of anterior band, in anterior segments set off from band by distinct small ridge (Fig. 8.27); pleural furrow stops proximal to pleural tip, pleural tip with small, sharp, posteroventrally directed spine running from posterior pleural band.

Pygidium. Cited dimensions are the range and mean of measurements made on the nine specimens illustrated in Figure 9.1, 9.4, 9.11, 9.13, 9.15, 9.17, 9.24, 9.26, and 9.30. Sagittal length 38–48 (42.0)% maximum width; axis with maximum anterior width 29–34 (31.6)% pygidial width and sagittal length 82–89 (85.3)% pygidial sagittal length; articulating half ring prominent, with evenly arcuate anterior margin and transverse posterior margin, lacking sculpture; first ring furrow deep, short (sag.; exsag.) and well inscribed, of similar depth sagittally and exsagittally, with straight transverse course; axial furrows shallow but base of axis sharply delimited, becoming increasingly convergent posteriorly, meeting to define rounded rear of axis, shallowest behind axis; axis with only weak to moderate dorsal inflation, three clearly defined axial rings and very faint fourth, indistinguishable from terminal piece in some specimens; first ring with dense sculpture of small tubercles on entire dorsal aspect; second ring with sculpture reduced to medial area or nearly effaced, third ring usually lacking sculpture; second ring with distinct pseudo-articulating half ring; pseudo-articulating half ring on third ring developed faintly in some specimens (Fig. 9.11, 9.15) but absent from others

(Fig. 9.13, 9.17); second and third ring furrows much deeper abaxially at contact with axial furrow than sagittally; first two pleural furrows distinct, third very faint; first interpleural furrow distinct, second faint and third almost entirely effaced; furrows terminate at narrow, simple border, widest anteriorly, with ventrolateral sculpture of fine subparallel raised lines; pygidium with slight but distinct flex in posterior view in most specimens; posterior margin with straight oblique course opposite pleurae, rounded behind lateral extent of axis, with faint median embayment; doublure quite broad, shortest medially, inner edge with distinct ''V'' shape medially, with sculpture of very fine subparallel raised lines.

Material and occurrence.—SUI 100082–100118, all from Section B 1.1 m, Barn Canyon Member, House Formation (early Skullrockian), southern House Range, Ibex area, Millard County, western Utah.

Discussion.—*Millardicurus paramillardensis* n. sp., the species which *M. millardensis* most closely resembles, is treated below via differential description with *M. millardensis*. *Millardicurus millardensis* is compared with *M. housensis* n. sp. in discussion of the latter species below. One librigena (Fig. 8.2, 8.4) has a blisterlike growth on its field. The growth has a smooth surface, interrupting the caecal sculpture of the field, and is an evagination of the cuticle, as it is matched by a depression on the internal surface. It may represent a healed injury.

MILLARDICURUS HOUSENSIS new species
Figures 10, 11

?*Hystricurus millardensis* HINTZE; TAYLOR AND LANDING, 1982, text-fig. 4n, 4p [*non* 4o].

Diagnosis.—Glabella anteriorly narrow and strongly waisted; transverse pits at junction of axial and preglabellar furrows very prominent; in large specimens cranidial tuberculate sculpture is sparse and subdued; anterior margin of anterior border and anterior furrow more transverse than in other species; librigenal field narrow; pygidium with small, narrow axis with as few as two well-defined rings, pygidium short (sag.) relative to length.

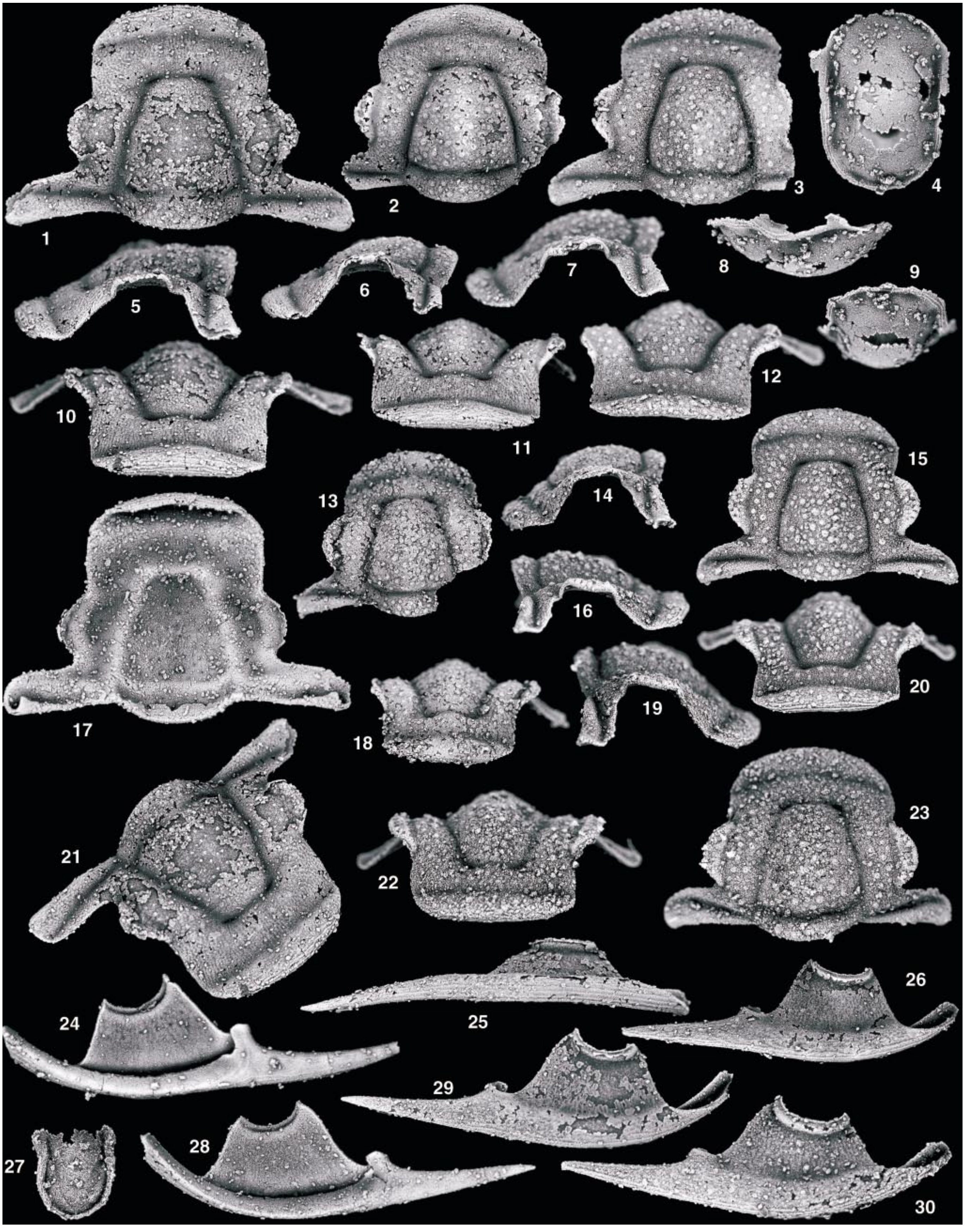
Description.—Cranidium with sagittal length 64% of maximum width across posterior fixigenae; width across maximum divergence of anterior sections of facial suture about 80% sagittal length, and width across midlength of palpebral lobes about 104% of sagittal length; glabella (including L0) with sagittal length 68% that of cranidium; main part of glabella (excluding L0) with sagittal length subequal to width across L1; dorsal sculpture of scattered and subdued moderate to fine-sized tubercles on glabellar, more faint but similar sculpture on interocular fixigena, very faint trace of similar sculpture on frontal area and preglabellar field, which have prominent finely anastomosing caecal sculpture; posterior fixigena mostly smooth and lacking dorsal sculpture; anterior margin of anterior border describing moderate anterior arc; border longest medially, shortening laterally toward connective suture, with sculpture of fairly prominent, relatively disorganized terrace lines on anterior and anterodorsal aspect, smooth posteriorly, with very gentle dorsal inflation in sagittal profile; anterior border furrow relatively shallow, with distinct shallower median part in most specimens, furrow has more incised anterior edge and more gradually shallowing posterior edge, describes arc somewhat more gentle than that of anterior margin; anterior sections of facial suture slightly anteriorly divergent in front of palpebral lobes, reaching maxima of divergence opposite about midpoint of preglabellar field, anteriorly convergent immediately behind anterior border furrow; palpebral lobe quite narrow, wider in midpart, with strong, almost ridgelike dorsal convexity, lateral margin describing subsemicircular arc, lobe held at about 30° from horizontal in anterior view; palpebral furrow prominent, evenly arcuate in some specimens (e.g., Fig. 10.2), more convex at midlength in others (Fig. 10.3), describing elongate ''W'' shape; interocular fixigena broad and with moderate dorsal inflation; axial furrows deep and incised, converging anteriorly opposite about half length of palpebral lobes to create prominently waisted glabella; preglabellar furrow slightly less prominent than axial furrows, with very gentle anterior arc; prominent transverse slotlike pits at junction of axial and preglabellar furrows; glabella with low dorsal convexity, narrow anteriorly in front of waisted part; glabellar furrows very faintly visible as slightly less sculpted areas; S0 describing very faint ''W'' shape in some specimens (Fig. 10.1, 10.3), more simply posterior arcuate in others (Fig. 10.2), similar in depth and incision to preglabellar furrow; L0 slightly shorter than anterior border, with sculpture identical to that of rear of main part of glabella; posterior fixigenal extensions running nearly transversely; posterior border furrow similar in depth and incision to axial furrow, running directly transversely; posterior border short adaxially, steadily lengthening abaxially, with fairly strong dorsal inflation in exsagittal profile, lacking sculpture; small fossular pits present ventrally beneath slotlike dorsal pits at junction of preglabellar and axial furrows.

Librigena. Field in mature specimens with width 35%–38% length, with extremely faint tuberculate sculpture mostly restricted to area beneath eye (better visible ventrally, e.g., Fig. 10.24) and more prominent fine caecal sculpture similar to that on frontal area; visual surface not preserved on any specimen and circumocular suture may have been present; socle of narrow ridge beneath eye, separated by very fine furrow from single inflated band, of similar size anteriorly and posterior, band separated from field by very shallow and narrow depression; posterior branch of facial suture longer than anterior branch; lateral border furrow generally very shallow, deepest in middle part opposite eye, shallowed posterior to anterior facial suture and particular anterior to genal angle; lateral border broad and moderately inflated, with sculpture of prominent subparallel terrace line ventrolaterally and fainter, more anastomosing lines adaxially along border furrow; faint tuberculate sculpture visible on smaller specimens (e.g., Fig. 10.30), very faint (Fig. 10.26), or completely effaced (Figs. 10.29, 11.26) in large specimens; genal spine about same length as remainder of librigena, tapering fairly rapidly and evenly posteriorly to reach a sharp point, declined slightly in ventrolateral view (Figs. 10.25, 11.22), with sculpture of terrace lines similar to that of ventrolateral part of anterior border; doublure set off from lateral border by sharp angle, lacking terrace line sculpture along field and around genal angle; terrace lines present on the underside of genal spine, but not as prominent as on dorsal aspect and entirely effaced along ventral median strip; subtrapezoidal and prominent Panderian notch present in front of and slightly adaxial to genal angle.

Rostral plate unknown.

Hypostome. Maximum width excluding anterior wings about 74% sagittal length; anterior margin describing strong anterior arc and slightly upturned into small rim; lateral borders slightly posteriorly convergent, narrow, and nearly straight, ventrally inflated with sculpture of prominent subparallel terrace lines; anterior wings poorly preserved on available specimens but evidently subtrapezoidal; lateral border furrow deeper anteriorly, shallow posteriorly, narrow; lateral border runs into posterior border without interruption but with constriction in breadth, and lateral border furrow runs directly into posterior border furrow; posterior margin with strong posterior convexity; middle furrow faintly defined only near lateral border furrow, declined posteriorly at about 60°; middle body ventrally inflated and entirely lacking sculpture.

Thorax. Axis occupying about 35% of overall width anteriorly (e.g., Fig. 11.5) and about 30% on posterior segments (Fig. 11.13); articulating half ring large, only slightly shorter (sag.) than axial ring;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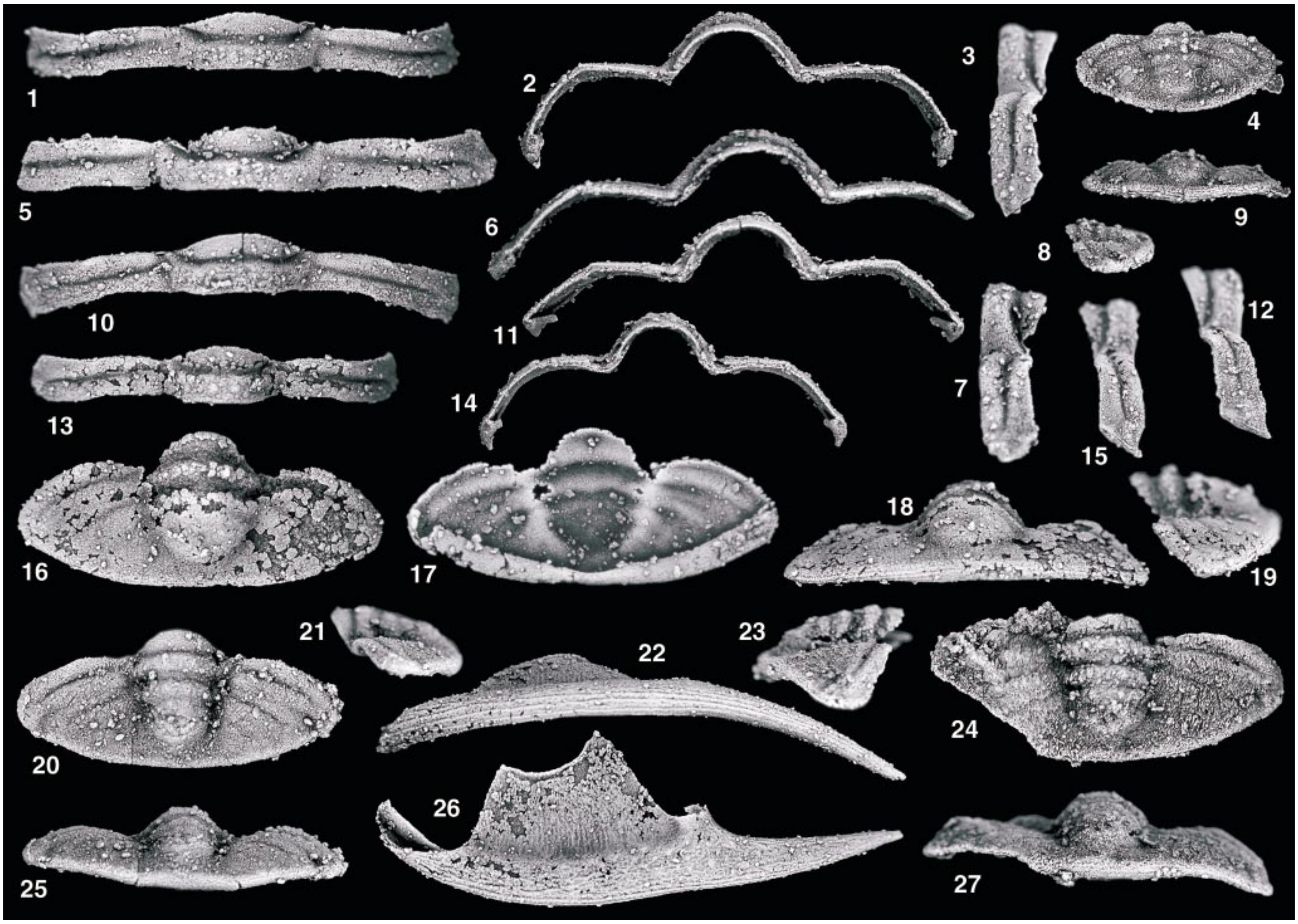

FIGURE 11—*Millardicurus housensis* n. gen. and sp., from the Barn Canyon Member, House Formation (lower Skullrockian), Section LDNS 22.5 m. Magnifications are ×10 except where noted. *1–3,* Thoracic segment, SUI 100131, dorsal, anterior, and right lateral views. *4, 8, 9,* Pygidium, SUI 100132, dorsal, left lateral, and posterior views. *5–7,* Thoracic segment, SUI 100133, dorsal, anterior, and right lateral views. *10–12,* Thoracic segment, SUI 100134, dorsal, anterior, and left lateral views. *13–15,* Thoracic segment, SUI 100135, dorsal, anterior, and left lateral views. *16–19,* Pygidium, SUI 100136, dorsal, ventral, posterior, and left lateral views. *20, 21, 25,* Pygidium, SUI 100137, dorsal, left lateral, and posterior views. *22, 26,* Left librigena, SUI 100138, ventrolateral and external views, ×6. *23, 24, 27,* Pygidium, SUI 100139, right lateral, dorsal, and posterior views.

ring furrow describing very slight ''W'' shape in some specimens (Fig. 11.10), more transverse medially in others (Fig. 11.1, 11.5), deep and incised, of similar length and depth medially and laterally; axial ring flexed slightly anteriorly, with sculpture of subdued and scattered moderate-sized tubercles; axial furrow very shallow; position of fulcrum on pleura varies according to position of segment in thorax, about two-thirds distance abaxially on more anterior segments, less than half distance on more posterior segments; pleural furrow well incised, slightly longer (exsag.) on adaxial part of pleura, terminating adaxial to pleural tip, running slightly obliquely posteriorly adaxial to fulcrum, more nearly transverse abaxial to fulcrum; anterior and posterior pleural bands subequal in length, flat-topped and lacking sculpture; articulating facet on anterior pleural band narrow and not clearly differentiated on most specimens; pleural tip triangular, with small posterolaterally directed spine in most specimens (Fig. 11.12, 11.15).

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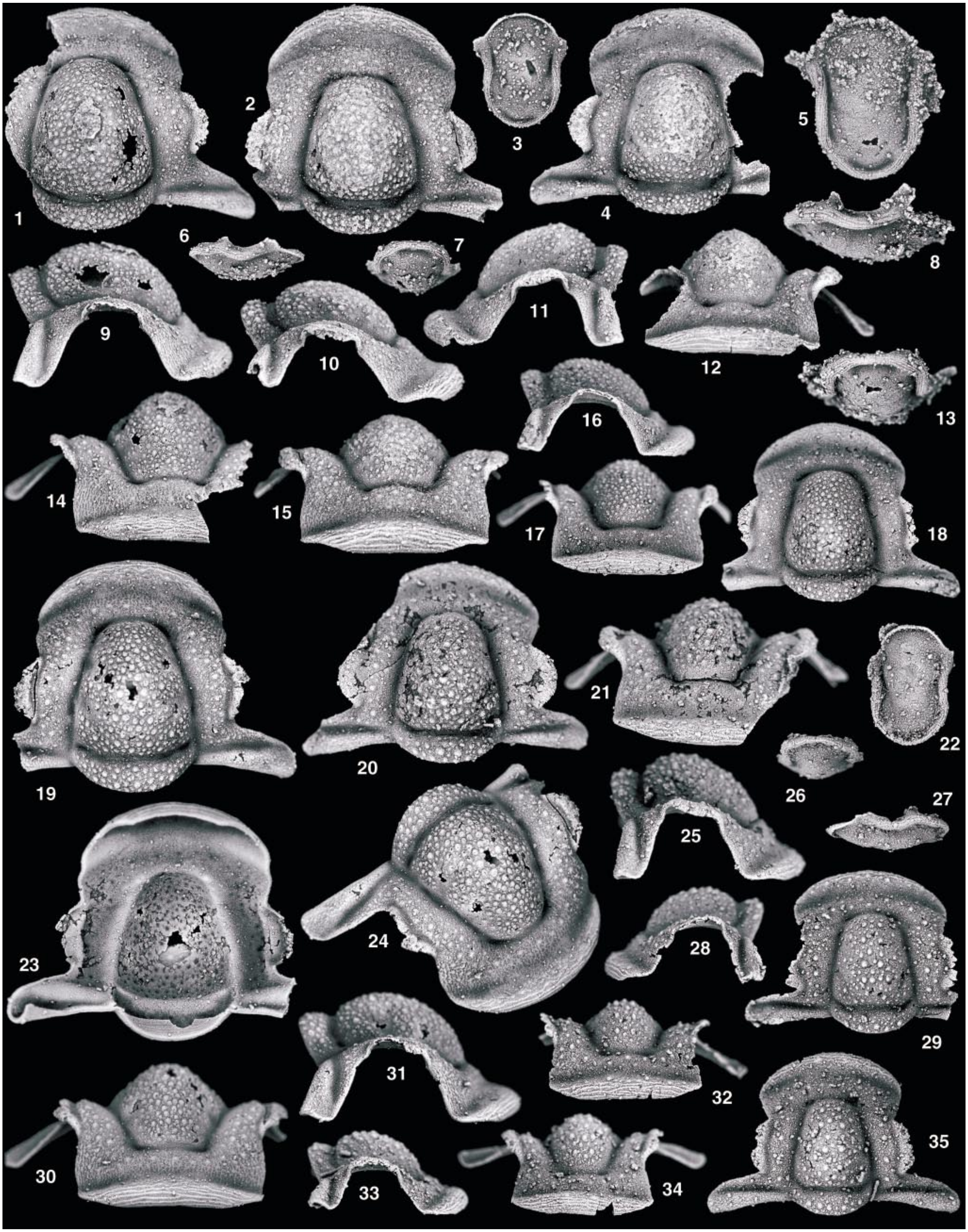
FIGURE 10—*Millardicurus housensis* n. gen. and sp., from the Barn Canyon Member, House Formation (lower Skullrockian), Section LDNS 22.5 m. Magnifications ×10, except where noted. *1, 5, 10, 17, 21,* Cranidium, holotype, SUI 100119, dorsal, left lateral, anterior, ventral, and oblique views, ×7.5. *2, 6, 11,* Cranidium, SUI 100120, dorsal, left lateral, and anterior views, ×7.5. *3, 7, 12,* Cranidium, SUI 100121, dorsal, left lateral, and anterior views. *4, 8, 9,* Hypostome, SUI 100122, ventral, right lateral, and posterior views. *13, 14, 18,* Cranidium, SUI 100123, dorsal, left lateral, and anterior views, ×7.5. *15, 16, 20,* Cranidium, SUI 100124, dorsal, right lateral, and anterior views. *19, 22, 23,* Cranidium, SUI 100125, right lateral, anterior, and dorsal views. *24,* Right librigena, SUI 100126, internal view. *25, 28, 29,* Right librigena, SUI 100127, ventrolateral, internal, and external views, ×7.5. *26,* Right librigena, SUI 100128, external view, ×7.5. *27,* Hypostome, SUI 100129, ventral view. *30,* Right librigena, SUI 100130, external view.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Pygidium. Sagittal length (excluding articulating half ring) about 36% maximum width; axis with maximum width anteriorly 26%–30% maximum pygidial width; two axial rings clearly defined, third defined posteriorly in some specimens (Fig. 11.4, 11.24) but obscure in others (Fig. 11.16, 11.20), rings with sculpture of faint tubercles, paired in some specimens (Fig. 11.4, 11.24); first ring furrow well impressed with small pseudo-articulating half ring, posterior furrows less well expressed, but second and third defined in some specimens; axis with relatively little dorsal inflation; axial furrows shallow, meeting posteriorly to fully circumscribe axis; first and second pleural furrows incised, first slightly deeper, third present but very faint, furrows terminated adaxial to border; first interpleural furrow discernible but faint, second nearly obscure and no posterior furrows visible; anterior and posterior pleural bands subequal in length, flat, and lacking sculpture; posterior margin of pygidium describing very gentle posterior arc, with very slight median flexure in some specimens (e.g., Fig. 11.16); narrow rimlike border with fine subparallel terrace lines and weak inflation; doublure much narrower medially, progressively more broad laterally, with sculpture of faint subparallel terrace lines.

Etymology.—After the House Range.

Types and occurrence.—Holotype, cranidium, SUI 100119, and paratypes SUI 100120–100139, all from Section LDNS 22.5 m, Barn Canyon Member, House Formation (early Skullrockian), southern House Range, Ibex area, Millard County, western Utah.

Discussion.—*Millardicurus housensis* differs from *M. millardensis* in its more strongly anteriorly narrowed glabella, more prominent transverse pits at the junction of the axial and preglabellar furrows, much sparser and more subdued glabellar tuberculate sculpture in large specimens, anterior sections of the facial suture that are nearly subparallel versus prominently anteriorly divergent, anterior border furrow that is more transversely straight, anterior margin of the anterior border than is less anteriorly bowed, cranidium with much less dorsal convexity in sagittal profile, including glabella with less dorsal inflation, pygidium with only two versus three well defined rings in large specimens, much smaller axis, greater width relative to sagittal length, and axial rings essentially lacking sculpture versus prominent tubercles on first ring. Most of these contrasts also differentiate *M. housensis* from *M. paramillardensis* n. sp.

The material described by Taylor and Landing (1982, text-fig. 4n, 4p) from the Garden City Formation at Franklin Basin (section FB7 of Adrain et al., 2003), Bear River Range, southern Idaho, possibly represents *M. housensis*, as the cranidium shares the anteriorly very narrow glabella and prominent slotlike pits at the junctions of the axial and preglabellar furrows. The pygidium figured by Taylor and Landing (1982, text-fig. 4o), however, is unlike any confidently associated with other occurrences of *Millardicurus* n. gen. in its extreme length relative to its width. If correctly associated, Taylor and Landing's material definitely represents a new species on this basis. While the association of the pygidium seems questionable, we have sampled no specimens like it either in western Utah or southern Idaho and can suggest no other obvious attribution for it if indeed it is incorrect.

MILLARDICURUS PARAMILLARDENSIS new species
Figures 12, 13

Diagnosis.—Very similar to *M. millardensis*, but differentiated in the following ways: anterior border and border furrow with highly distinct morphology in similarly sized large specimens, *M. paramillardensis* with much shorter preglabellar field, long and shallow anterior border furrow that is longer sagittally than exsagittally, and shorter anterior border; glabellar, interocular fixigena, frontal area, and preglabellar field with sculpture of more densely crowded tubercles, largest tubercles smaller than in *M. millardensis* but many more small tubercles; cranidium with stronger dorsal convexity in sagittal profile, preglabellar field and anterior border much more steeply declined in front of glabella, librigenal field wider, pygidial axis posteriorly broader and more subquadrate, pygidium narrower relative to sagittal length, tuberculate sculpture on first pygidial axial ring more subdued.

Etymology.—*Para*, against, and the species name *millardensis*.

Types and occurrence.—Holotype, cranidium, SUI 100140, and paratypes SUI 100141, 100143, 100145–100166, 100168, from Section LDNS 35.2 m, and assigned specimens SUI 100142, 100144, 100167, from Section LDNS 35.3 m, Barn Canyon Member, House Formation (early Skullrockian), southern House Range, Ibex area, Millard County, western Utah.

Discussion.—*Millardicurus paramillardensis* is closely similar to *M. millardensis*, and extended written description is redundant. The species are subtly but pervasively distinguished and there is no question that separate species are represented—variation in the many features which discriminate them is disjunct and non-overlapping. All such differences are noted in the differential diagnosis above.

MILLARDICURUS RAVNI (Poulsen, 1927)

Hystricurus ravni POULSEN, 1927, p. 283, pl. 18, figs. 5–10; ROSS, 1951, p. 40; HINTZE, 1953, p. 168; FORTEY AND PEEL, 1989, p. 11.

Diagnosis.—Cranidium with strong tuberculate sculpture and long glabella; librigena with tubercles on both lateral border and librigenal field, genal spine short; pygidium with four prominent axial rings and apparently strong border.

Material and occurrence.—Lectotype, selected here, cranidium, MGUH 2343 (Poulsen, 1927, pl. 18, fig. 6), and paratypes MGUH 2342 (Poulsen, 1927, pl. 18, fig. 5), 2344 (Poulsen, 1927, pl. 18, fig. 7), 2345 (Poulsen, 1927, pl. 18, fig. 8), 2346 (Poulsen, 1927, pl. 18, fig. 9), and 2347 (Poulsen, 1927, pl. 18, fig. 10), from the Cass Fjord Formation, Cape Clay, Washington Land, northwestern Greenland.

Discussion.—Poulsen's (1927) illustrations are quite heavily retouched, so it is not clear whether the pygidial border is as strong as it is depicted. Poulsen (1927, pl. 18, fig. 5) figured an articulated specimen, the only one known for any species of *Millardicurus* n. gen. Again, this figure is retouched to an extent that it cannot be trusted. We have seen an unretouched photograph of this specimen, and the cephalic border furrow, genal spines, eye, pleural furrows, boundaries between thoracic segments, boundary between pygidium and thorax, and pygidial morphology are all

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FIGURE *12*—*Millardicurus paramillardensis* n. gen. and sp., from the Barn Canyon Member, House Formation (lower Skullrockian), Section LDNS 35.2 m (except where noted). *1, 9, 14,* Cranidium, holotype, SUI 100140, dorsal, right lateral, and anterior views, ×6. *2, 10, 15,* Cranidium, SUI 100141, dorsal, right lateral, and anterior views, ×7.5. *3, 6, 7,* Hypostome, SUI 100142, ventral, right lateral, and posterior views, ×10 (LDNS 35.3 m). *4, 11, 12,* Cranidium, SUI 100143, dorsal, left lateral, and anterior views, ×7.5. *5, 8, 13,* Hypostome, SUI 100144, ventral, right lateral, and posterior views, ×10 (LDNS 35.3 m). *16–18,* Cranidium, SUI 100145, right lateral, anterior, and dorsal views, ×7.5. *19, 23, 24, 30, 31,* Cranidium, SUI 100146, dorsal, ventral, oblique, anterior, and right lateral views, ×7.5. *20, 21, 25,* Cranidium, SUI 100147, dorsal, anterior, and right lateral views, ×10. *22, 26, 27,* Hypostome, SUI 100148, ventral, posterior, and left lateral views, ×10. *28, 29, 32,* Cranidium, SUI 100149, left lateral, dorsal, and anterior views, ×10. *33–35,* Cranidium, SUI 100150, right lateral, anterior, and dorsal views, ×10.

FIGURE 13—*Millardicurus paramillardensis* n. gen. and sp., from the Barn Canyon Member, House Formation (lower Skullrockian), Section LDNS 35.2 m (except where noted). Magnifications ×7.5, except where noted. *1–3,* Thoracic segment, SUI 100151, dorsal, anterior, and right lateral views, ×10. *4–6,* Thoracic segment, SUI 100152, dorsal, anterior, and right lateral views, ×10. *7–9,* Thoracic segment, SUI 100153, dorsal, anterior, and right lateral views, ×10. *10–12,* Thoracic segment, SUI 100154, dorsal, anterior, and right lateral views, ×10. *13–15,* Thoracic segment, SUI 100155, dorsal, anterior, and left lateral views. *16, 20,* Left librigena, SUI 100156, external and ventrolateral views. *17,* Right librigena, SUI 100157, external view. *18, 19,* Left librigena, SUI 100158, external and internal views, ×6. *21,* Right librigena, SUI 100159, external view. *22,*

almost indiscernible. The specimen is a very heavily weathered and poorly preserved internal mold.

MILLARDICURUS LONGICEPHALUS (Poulsen, 1927)

Hystricurus longicephalus POULSEN, 1927, p. 284, pl. 18, fig. 11; ROSS, 1951, p. 40.

Diagnosis.—Preglabellar field extremely long.

Material and occurrence.—Holotype (by monotypy), MGUH 2348, from the Cass Fjord Formation, Cape Clay, Washington Land, northwestern Greenland.

Discussion.—As it is based on a single incomplete cranidium, this species is essentially a nomen dubium. Nevertheless, the specimen does appear to represent *Millardicurus* n. gen., indicated by the waisted, tuberculate glabella, and pits at the junction of the axial and preglabellar furrows, and it does seem unique in its extremely long preglabellar field.

MILLARDICURUS ARMATUS (Poulsen, 1937)

Hystricurus armatus POULSEN, 1937, p. 31, pl. 2, figs. 3–9; ROSS, 1951, p. 40; HINTZE, 1953, p. 168.
Hystricurus sulcatus POULSEN, 1937, p. 33, pl. 2, figs. 1, 2; ROSS, 1951, p. 40.
Symphysurina elegans POULSEN, 1937 [*partim*], pl. 2, fig. 19 [*only*].

Diagnosis.—Glabella strongly waisted and narrow anteriorly; cranidium with dorsal sculpture of closely crowded moderately coarse tubercles on all areas; occipital spine present; cranidium with strong sagittal convexity; librigenal field broad, with prominent raised caecal sculpture and scattered coarse tubercles; pygidium apparently with relatively narrow pleurae.

Material and occurrence.—Holotype, cranidium, MGUH 3641, and figured specimens MGUH 3640 (Poulsen, 1937, pl. 2, fig. 3), 3642 (Poulsen, 1937, pl. 2, fig. 6), 3643 (Poulsen, 1937, pl. 2, fig. 7), 3644 (Poulsen, 1937, pl. 2, fig. 8), and 3645 (Poulsen, 1937, pl. 2, fig. 9), from the Cass Fjord Formation, Cape Clay, Washington Land, northwestern Greenland. The holotype of *Hystricurus sulcatus* is MGUH 3638 (Poulsen, 1937, pl. 2, fig. 1), and the other figured specimen (Poulsen, 1937, pl. 2, fig. 2) is MGUH 3639. Both are from the same locality as the holotype of *H. armatus*.

Discussion.—Poulsen (1937, p. 34) distinguished *M. sulcatus* from *M. armatus* in its ''having a wider glabella, straight frontal furrow [i.e., anterior border furrow], and a surface ornamentation consisting of larger, more closely set tubercles.'' There does seem to be a difference in glabellar width between the respective holotypes (Poulsen, 1937, pl. 2, fig. 1 vs. fig. 4), but not between the other cranidia assigned to either species (Poulsen, 1937, pl. 2, fig. 2 vs. fig. 3). If there is a difference in the size and density of the tuberculate sculpture, it is slight and not reflected on all of the specimens, and no difference in the shape of the anterior border furrow that could not be a result of preservation and photographic orientation is apparent. All of the cranidia are from the same locality and there seems little grounds on present evidence to suppose that two disjunctly varying species are represented. Hence, we consider *sulcatus* to be a junior subjective synonym of *armatus*.

Poulsen (1937, pl. 2, figs. 15, 19) assigned two hypostomes from the type locality to his new *Symphysurina elegans*. One of these (Poulsen, 1937, pl. 2, fig. 15) is probably correct, but the other (pl. 2, fig. 19) is elongate and quite narrow. It is similar to the hypostome of *Millardicurus housensis* n. sp. (see Fig. 12.22) and probably belongs to *Millardicurus armatus*.

Millardicurus armatus is distinguished from all other species in the possession of a fairly stout occipital spine. It also has the tallest, most sagittally convex cranidia of any species, morphology which is matched by the broadest librigenal field in the genus.

MILLARDICURUS? NUDUS (Poulsen, 1937)

Hystricurus nudus POULSEN, 1937, p. 34, pl. 2, fig. 10; ROSS, 1951, p. 40.
Paraplethopeltis? *nuda* (POULSEN); HINTZE, 1953, p. 202.
Paraplethopeltis nudus [sic] (POULSEN); BOYCE, 1989, p. 43.

Diagnosis.—Cranidium dorsally smooth, lacking tuberculate sculpture.

Material and occurrence.—Holotype, MGUH 3640, from the Cass Fjord Formation, Cape Clay, Washington Land, northwestern Greenland.

Discussion.—Similar to *M. longicephalus*, as it is based on a single cranidium this species is arguably a nomen dubium pending new collections. Because it lacks tuberculate sculpture, it has been compared with species of *Paraplethopeltis* Bridge and Cloud, 1947, and assigned to that genus with question by Hintze (1953) and directly by Boyce (1989). However, apart from lack of sculpture the specimen displays a waisted glabella and general dimensions consistent with *Millardicurus* n. gen. Winston and Nicholls (1967, p. 76) claimed that some specimens they referred to *M. millardensis* from the Wilberns Formation of Texas lacked tuberculate sculpture, but they did not illustrate any examples.

MILLARDICURUS new species A

?*Hystricurus millardensis* HINTZE; STITT, 1971, p. 46, pl. 8, figs. 17, 18.
Hystricurus millardensis HINTZE, 1953; TAYLOR *IN* TAYLOR AND HALLEY, 1974, p. 31, pl. 3, figs. 10–16.
Hystricurus millardensis HINTZE, 1953; FORTEY *IN* FORTEY ET AL., 1982, p. 108, pl. 3, fig. 10.

Material and occurrence.—Specimens figured by Taylor (*in* Taylor and Halley, 1974), USNM 186613–186616, from the Little Falls Formation (see Landing et al., 2003), locality H-2, Warner Hill, Washington County, eastern New York State. Fortey's (*in* Fortey et al., 1982) single specimen is from the Shallow Bay Formation, Boulder 1 in *Symphysurina* conglomerate (Bed 56 of James and Stevens, 1986), Broom Point South section, western Newfoundland, Canada.

Discussion.—A species illustrated with good photographs of two cranidia, a librigena, and a pygidium assigned to *M. millardensis* by Taylor (*in* Taylor and Halley, 1974) is clearly new, but more material would be required to treat it fully and it is recognized in open nomenclature. The species is distinct in its extremely fine and dense tubercles on almost all dorsal cephalic surfaces, including the anterior border, the adaxial part of the librigenal lateral border, and the librigenal field. It has a short preglabellar field that is dorsally inflated in sagittal profile, and very inflated and convex cranidial anterior and librigenal lateral borders. The

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Right librigena, SUI 100160, external view, ×6. *23,* Right librigena, SUI 100161, external view, ×6. *24–28,* Pygidium, SUI 100162, dorsal, ventral, anteroventral, right lateral, and posterior views. *29, 30, 38,* Pygidium, SUI 100163, dorsal, right lateral, and posterior views. *31, 32, 35,* Pygidium, SUI 100164, dorsal, right lateral, and posterior views. *33, 34, 41,* Pygidium, SUI 100165, right lateral, dorsal, and posterior views. *36, 37, 42,* Pygidium, SUI 100166, dorsal, right lateral, and posterior views. *39, 43, 44,* Pygidium, SUI 100167, right lateral, dorsal, and posterior views. (LDNS 35.3 m). *40, 45, 46,* Pygidium, SUI 100168, posterior, left lateral, and dorsal views, ×10.

pygidium has four prominent axial rings, has narrow pleurae, very deep and well-incised pleural and interpleural furrows, and an unusually prominent border. It is perhaps most similar to *M. armatus*, with which it shares dense cephalic tuberculation and a narrow pygidium with strongly incised furrows and a well-expressed border. It differs from *M. armatus* in lacking a median occipital spine, having slightly finer cephalic tubercles, and in having a much narrower librigenal field. A cranidium from the Cow Head Group of western Newfoundland illustrated by Fortey (*in* Fortey et al., 1982, pl. 3, fig. 10) is very similar to those from the Little Falls Formation and is tentatively considered conspecific. The only apparent differences are possibly more coarse tubercles and prominently incised S2 on the Newfoundland specimen. As discussed above under the genus, two specimens figured by Stitt (1971, pl. 8, figs. 17, 18) from the Signal Mountain Limestone of Oklahoma appear to represent a species closely similar to or possibly conspecific with Taylor's New York taxon. Stitt's specimens are questionably assigned here, but more specimens and much better illustrations of the Oklahoma occurrence are needed to properly assess affinity.

ACKNOWLEDGMENTS

We gratefully acknowledge support from NSF grants EAR 9973065 and EAR 0308685. T. S. Adrain is thanked for assistance with SUI specimen numbers and curation. M. Elmgaard provided information on MGUH numbers for Poulsen's specimens. D.-C. Lee showed us a photograph of Poulsen's articulated specimen of *M. ravni*. D. Schultz, B. Beck, and C. Monson provided assistance in the field. N. C. Hughes and B. S. Lieberman provided helpful reviews of the manuscript.

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ACCEPTED 9 MAY 2005