New genus of dimeropygid trilobites from the earliest Ordovician of Laurentia

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The new genus *Tulepyge* includes a type species, *T. tulensis* nov., from the Barn Canyon Member of the House Formation, western Utah, USA, and *T. paucituberculata* from the Broom Point Member of the Green Point Formation, western Newfoundland, Canada. Both species are earliest Ordovician in age, with occurrence immediately above the Cambrian–Ordovician boundary. Together with the hystricurid taxon *Millardicurus,* the new genus is likely to serve as an indicator fossil for the Cambrian–Ordovician boundary in Laurentia, as it is already known from different biofacies on opposite margins of the continent. *Tulepyge* is not closely comparable with contemporaneous taxa assigned to Hystricuridae but in its dorsally convex and coarsely tuberculate exoskeleton it resembles taxa which have been referred to Dimeropygidae, most of which are considerably younger in age.

Key words: Trilobita, Dimeropygidae, Hystricuridae, silicified fossils, Ordovician, Ibexian.

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Introduction

Systematics of Hystricuridae Hupé, 1953, was reviewed by Adrain et al. (2003). The genus name *Hystricurus* Raymond, 1913, had been indiscriminately applied to a broad range of Early Ordovician trilobite species. Adrain et al. (2003) restricted *Hystricurus* to a distinctive clade, which is mainly Stairsian in age, provided new diagnoses for the genus and for the subfamily Hystricurinae, and erected a new subfamily Hintzecurinae. As outlined by Adrain et al. (2003), there remain many taxa which have previously been assigned to a wastebasket concept of *Hystricurus* and which fall outside the subfamilies Hystricurinae and Hintzecurinae. The systematics of these taxa require further work.

One such taxon is *Hystricurus paucituberculatus* Fortey, 1983, which was described from conglomerate boulders of what is now the Green Point Formation, Cow Head Group, western Newfoundland (Fig. 1). This species occurs in the immediate vicinity of the Cambrian–Ordovician boundary. Fieldwork for a comprehensive revision of the shallow water faunas of the type Ibexian of western Utah and southern Idaho (Adrain et al. 2001, 2003; Adrain and Westrop 2006) has yielded a closely related species from immediately above the Cambrian–Ordovician boundary in the House Formation of the Ibex area, Utah (Fig. 2). The species share several apomorphies and are classified here in a new genus, *Tulepyge*, regarded as an early dimeropygid. The purpose of this paper is to revise *Tulepyge paucituberculata* on the basis of new material, to describe the morphology of the type species, *T. tulensis* sp. nov., which is known from well preserved silicified material, and to discuss the systematic position of the genus.

Institutional abbreviations.—SUI, Department of Geoscience, University of Iowa, Iowa City, USA; GSC, Geological Survey of Canada, Ottawa.

Localities and stratigraphy

Ibex area.—Trilobite faunas of the classic sections through the Pogonip Group of western Utah were first described by Hintze (1953), following work by Ross (1951) on coeval faunas from the Garden City Formation of southeastern Idaho and northern Utah. Although the latest Cambrian and earliest Ordovician House Formation contains the stratotype for the Laurentian Skullrockian Stage (Ross et al. 1997), its trilobite faunas had not been systematically revised in the half century between Hintze's work and that of Adrain et al. (2003). We are engaged in a comprehensive, field-based revision of the Ross/Hintze faunas. Large new collections have revealed species and genus diversity in the sections approaching an order of magnitude greater than previously recognized (Adrain and Westrop 2003). *Tulepyge tulensis* is a case in point. Despite the fact that it was sampled from the type horizon of the species *Symphysurina brevispicata* Hintze, 1953 (a zonal name bearer in the standard trilobite biostratigraphic scheme of Ross et al. 1997; Loch et al. 1999; and Miller et al.

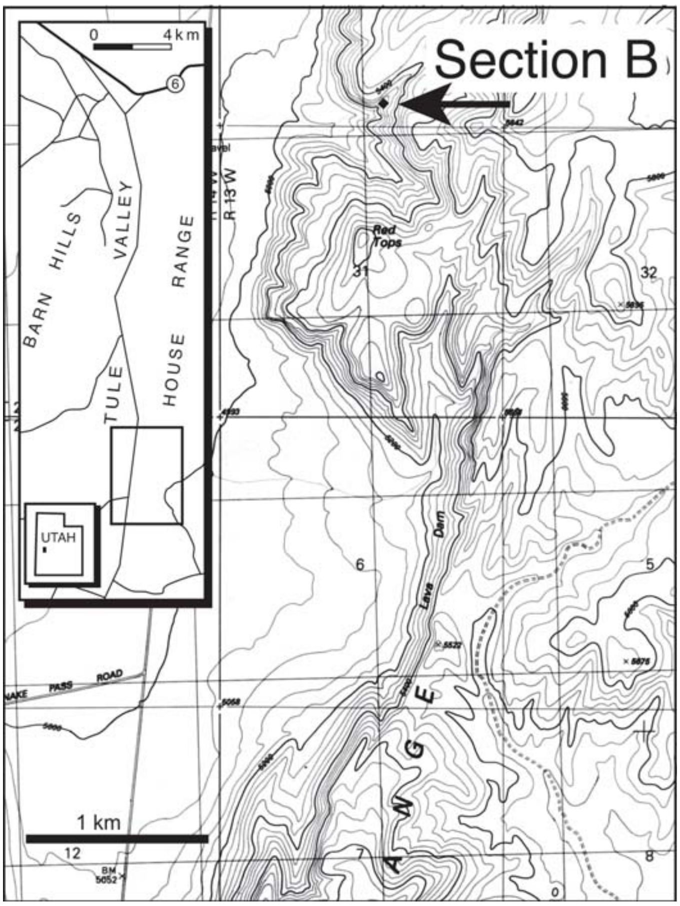


Fig. 1. Location of Section B (only the basal part of the section sampled herein is shown—Hintze's (1951, 1953) section continues up the ravine to the northeast). Inset: position of Ibex area in Utah, and position of main detail map in the Tule Valley and southern House Range, south of US Highway 6 in Millard County.

2003) and *Millardicurus millardensis* (Hintze, 1953), its presence has not previously been reported, and it does not appear in Hintze's classic monograph nor in his faunal list (Hintze 1953: 26) for the horizon.

The horizon from which *Tulepyge tulensis* was sampled is Hintze's (1953) B-1, positioned seven feet above the base of his Section B in the Barn Canyon Member, House Formation, southern House Range (Fig. 1). In our new measurements (Adrain and Westrop 2006), this horizon is Section B 1.1 m. The base of the Ordovician (FAD of the conodont *Iapetognathus fluctivagus* Nicoll, Miller, Nowlan, Repetski, and Ethington, 1999) is not exposed at Section B, but B 1.1 m correlates locally and regionally to a position within the Barn Canyon Member of about 13 m above the Cambrian–Ordovician boundary (Adrain and Westrop 2006), and within what Loch et al. (in Miller et al. 2003) term the "*Symphysurina bulbosa* Subzone" of the earliest Ordovician (see Adrain and Westrop 2006 for discussion of the criteria for recognition of this subzone). *Tulepyge tulensis* occurs at horizon B 1.1 m together with *Symphysurina brevispicata* Hintze, 1953, two additional undescribed species of *Symphysurina*, *Millardicurus millardensis* (Hintze, 1953; revised by Adrain and Westrop 2006), and an undescribed species of *Clelandia* Cossman, 1902.

Western Newfoundland.—Stratigraphy of the Cow Head Group has been comprehensively documented by James and Stevens (1986). The group ranges in age from Middle Cambrian to earliest Middle Ordovician, and contains a unique record of Laurentian shelf margin shelly faunas, preserved in boulders in a complex series of allochthonous megaconglomerates interbedded with autochthonous ribbon limestones and shales. The rich trilobite record of the group has been treated by Young and Ludvigsen (1989; Middle Cambrian), Ludvigsen et al. (1989; Sunwaptan Stage, Upper Cambrian), and Whittington (1963; early Whiterockian Stage, Middle Ordovician). Work on trilobite faunas from other parts of the succession is in progress, and the only other interval to have received detailed treatment comprises the strata surrounding the Cambrian–Ordovician boundary (Fortey et al. 1982; Fortey 1983).

Fortey's (1983) type material of *T. paucituberculata* was collected from a single boulder from the "B1" conglomerate (Fortey et al. 1982) at the Broom Point South section, Broom Point, western Newfoundland. This bed is Unit 57 of James and Stevens (1986; see Fig. 2), assigned to the Broom Point Member of the Green Point Formation. Material of *T. paucituberculata* illustrated herein is all from a second boulder, BPS 496, in the C. H. Kindle collection of the Geological Survey of Canada, which was also collected from Unit 57. This unit contains the earliest Ordovician trilobites to appear in the sequence. *Tulepyge* occurs together in Unit 57 with *Millardicurus* (Fortey 1983: table 1; Adrain and Westrop 2006) and material identified by Fortey (in Fortey et al. 1982; Fortey 1983) as *Symphysurina brevispicata*. Hence, it is likely of very similar age to horizon B 1.1 m in Utah, occupying a position immediately above the base of the Ordovician.

Significance and ecology

Although known only from two species, *Tulepyge* occurs with the genus *Millardicurus* Adrain and Westrop, 2006, in strata of almost exactly the same age on opposite margins of the Laurentian paleocontinent. Further, the species are derived from substantially different environments. The Barn Canyon Member (Miller et al. 2001) of the House Formation is composed of cherty lime mudstone, calcisiltite, occasional grain- and packstone, and minor intrclastic rudstone. The environment of deposition was a relatively high energy shallow subtidal setting, above storm wave base. The boulders containing *T. paucituberculata* from the Broom Point Member in Newfoundland are of the classic "pure white limestone" type (Lane 1972) characteristic of the shelf-margin algal buildups which typify many of the trilobite faunas of the Cow Head Group. Given the radically different geographic and environmental occurrences of the known species, it may be predicted that additional species of *Tulepyge* will be recovered in other regions

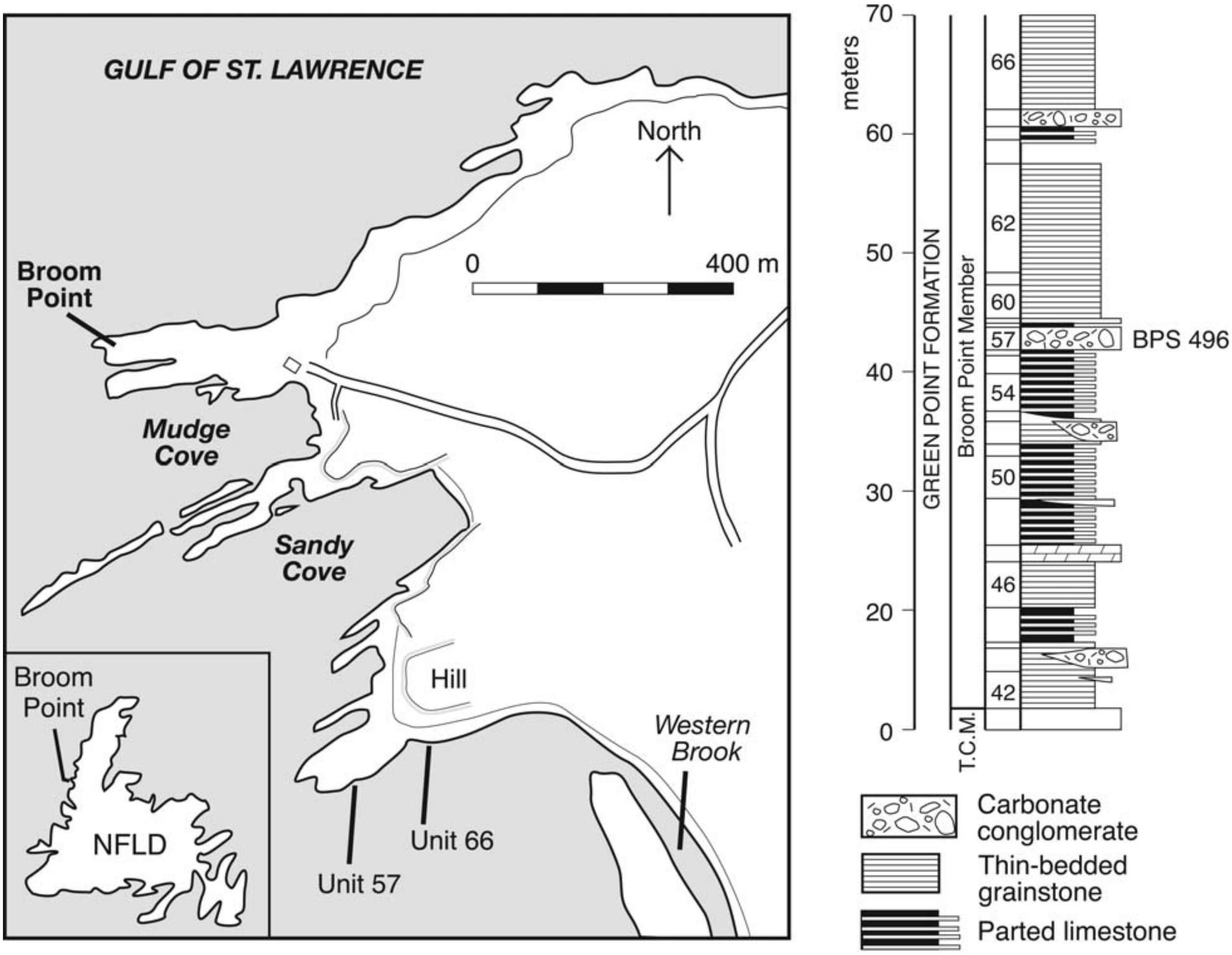


Fig. 2. Geographic and stratigraphic position of conglomerate bed in unit 57 of Broom Point South section (James and Stevens 1986), from which earliest Ordovician boulder BPS 496, containing the illustrated material of *Tulepyge paucituberculata*, was collected. NFLD = Newfoundland, Canada; T.C.M. = Tuckers Cove Member.

and environments. The close similarity in age of the known taxa, and their association with the more widely known genus *Millardicurus* Adrain and Westrop, 2006, which has a similarly narrow stratigraphic range, indicate that *Tulepyge* may serve as a potentially important trilobite indicator fossil for the position of the base of the Ordovician in Laurentia. Unlike the coeval genus *Symphysurina* Ulrich in Walcott, 1924, which is much more widely known, it has no known range through the uppermost Cambrian.

Systematic paleontology

Family Dimeropygidae Hupé, 1953

Discussion.—Classification of the Dimeropygidae is in flux (therefore we omit higher categories, as the question of which are correct is currently open), but current generic content was given Jell and Adrain (2003: 469). Generic content of the related family Hystricuridae follows Jell and Adrain (2003: 472) with the addition of *Millardicurus* Adrain and Westrop, 2006. Hystricuridae has often been considered a paraphyletic taxon which "gave rise" to (i.e., contains the sister taxa of) other elements of the order Proetida Fortey and Owens, 1975. As argued by Adrain et al. (2003), the hystricurid group contains major monophyletic units, including the taxa Hystricurinae Hupé, 1953 (*sensu* Adrain et al. 2003) and Hintzecurinae Adrain, Lee, Westrop, Chatterton, and Landing, 2003. Just as the order Proetida is itself "cryptogenetic" (Stubblefield 1959; Whittington 1981; Fortey 1997, 2001) in the context of higher trilobite phylogeny, the origins and sister group relationships of families of Proetida, including Aulacopleuridae Angelin, 1854, Brachymetopidae Prantl and Přibyl, 1951, Dimeropygidae Hupé, 1953, Rorringtoniidae Owens in Owens and Hammann, 1990, Scharyiidae Osmólska, 1957, and Telephinidae Marek, 1952, are also essentially unknown.

Unravelling the phylogenetic structure of the group is beyond the scope of this paper, although ongoing descriptive work on the Ross/Hintze faunas will add a wealth of new data to help address the problems. *Tulepyge* does not compare closely with hystricurids (to which *T. paucituberculata* was first assigned), and in fact with knowledge of *T. tulensis* it is more similar in its vaulted, tuberculate exoskeleton and librigena with a very short genal spine to younger taxa such as *Dimeropygiella* Ross, 1951, and *Ischyrotoma* Raymond, 1925 (see Adrain et al. 2001, for revisions of both), which have been considered members of Dimeropygidae. There are a great number of undescribed vaulted, tuberculate species of upper Skullrockian, Stairsian, and Tulean age in the Ibex sections. The closest comparison of *Tulepyge* is possibly with an essentially undescribed younger Skullrockian clade, sclerites of which have been reported in open nomenclature by Ross (1951: pl. 9: 25, 29, 30, pl. 14: 5, 8, 12). We have sampled multiple undescribed species of this group, all from the Red Canyon Member of the House Formation and coeval strata of the Garden City Formation. In general, cranidial dimensions and sculpture of these species are similar, especially to *T. tulensis*, and the structure of the librigena is almost identical. However, pygidia of the taxa are very different. Those of the upper Skullrockian forms (Ross 1951: pl. 9: 25, 29, 30) have a corona of sharp pleural spines, beneath which the distal part of the pleura forms a nearly vertical wall not crossed by pleural or interpleural furrows. The tails also feature only two or three segments, *versus* five in *Tulepyge*. Confident hypotheses of relationship of *Tulepyge* must await much work in progress on younger taxa, but it is tentatively interpreted as a plesiomorphic member of a group also encompassing genera such as *Dimeropygiella* and *Ischyrotoma*, and this group is tentatively assigned to Dimeropygidae.

Genus *Tulepyge* nov.

Type species: *Tulepyge tulensis* nov., from the House Formation of western Utah, USA.

Other species: *Hystricurus paucituberculatus* Fortey, 1983, from the Green Point Formation of western Newfoundland, Canada.

Etymology: *Tule*, after the Tule Valley, western Utah, and the Greek noun πυγε, rump; gender is feminine.

Diagnosis.—Exoskeleton vaulted; anterior border furrow shallowed medially; librigenal field with prominent exsagittal row of large tubercles; eye socle of single band; genal spine short and thorn-like; pygidium with five axial rings, prominent large tubercle pair on first four, pleural furrows sharply declined at fulcrum but running without interruption to strong border; adaxial margin of border with scalloped shape due to contact with inflated distal part of posterior pleural bands.

Discussion.—See family discussion above.

Tulepyge tulensis sp. nov

Figs. 3, 4

Derivation of the name: After the Tule Valley.

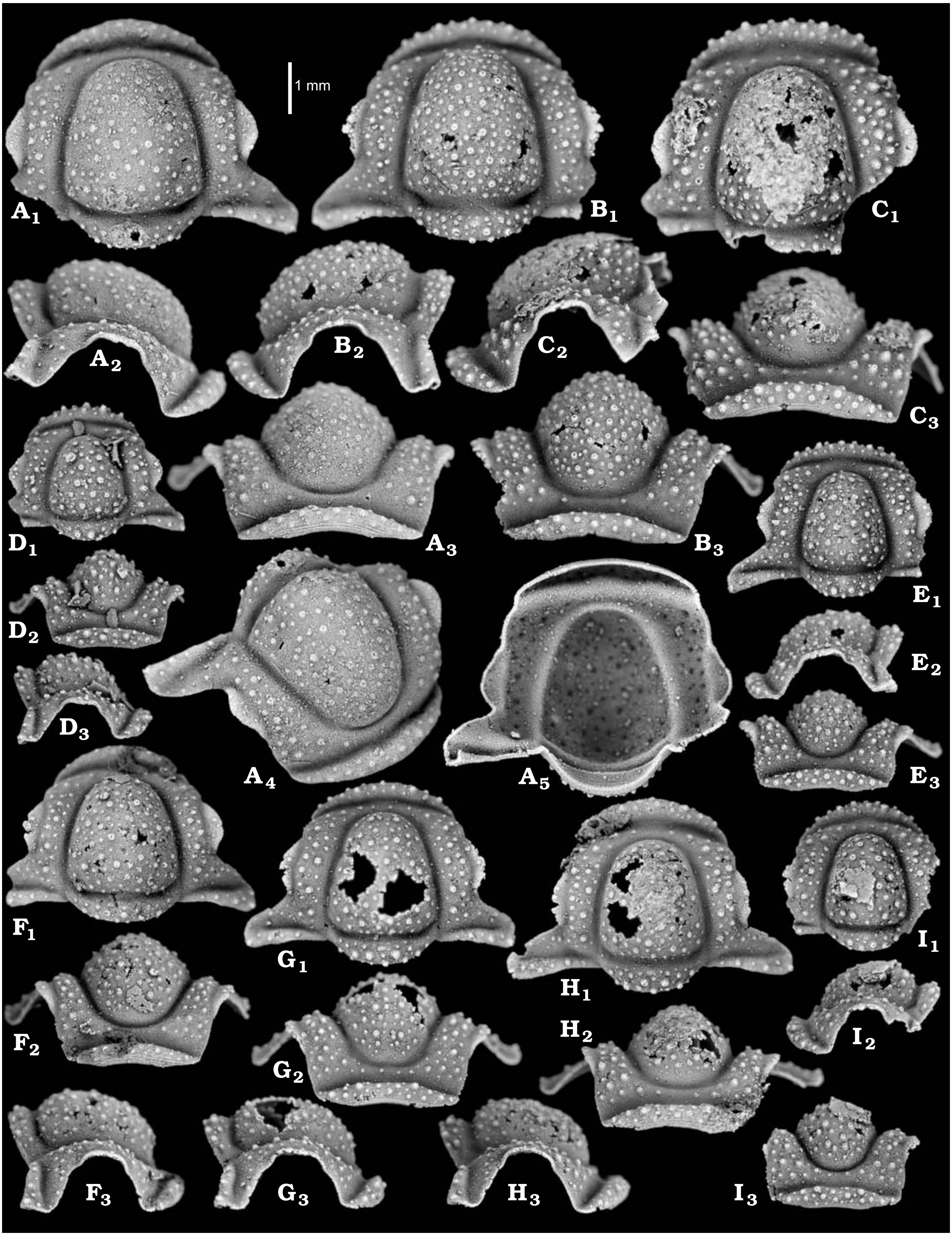
Type locality and horizon: Holotype, cranidium, SUI 100169, and paratypes SUI 100170–100195, all from Section B 1.1 m, Barn Canyon Member, House Formation (lower Skullrockian), southern House Range, Ibex area, Millard County, western Utah.

Diagnosis.—Cranidium with relatively dense tuberculate sculpture, variable from somewhat subdued to coarse and thorn-like; anterior border furrow short (exsag.) and incised; preglabellar field short; librigena with accessory tubercles in addition to single main row on field; eye socle with inflated anterior lobe; librigenal lateral border densely tuberculate, with raised lines confined to near lateral edge; pygidium long relative to width, with prominent transverse tubercle rows on posterior pleural bands and more posteriorly arcuate, though variable, posterior margin.

Description.—Cited proportions are based on measurements of the illustrated specimens. Where there is variation, the mean value is reported followed by the range in parentheses.

Cranidium.—Sagittal length 67 percent width across posterior fixigenae and 87 (84–90) percent width across midlength of palpebral lobes; glabella (excluding LO) with sagittal length 111 (104–117) percent maximum width across L1; entire cranidium with background sculpture of fine, densely spaced granules; anterior border short, longer sagittally than exsagittally, with strong dorsal convexity, sculpture of fairly large, closely spaced tubercles on dorsal and anterodorsal aspect and fine raised lines running subparallel to margin on anteroventral aspect; anterior border gently bowed in anterior profile, ventral margin bowed over about 50% of middle part of course, cut by transverse connective sutures on abaxial parts; anterior border furrow short (sag.; exsag.) and deep, with somewhat irregular course and depth, shallower medially in many specimens; preglabellar field short, quite steeply inclined in sagittal profile, in most larger specimens not bearing tubercles directly in front of glabella, though smaller specimens typically have two or three tiny tubercles in this area; interocular fixigena and frontal area grade into each other with increasingly steep slope in front of palpebral lobe; eye ridge not discernible dorsally, but very faintly expressed ventrally (Fig. 3A_5, especially left hand side), running from anterior edge of palpebral lobe obliquely forward toward preglabellar furrow; interocular fixigena with sculpture of moderate sized tubercles in approximately three exsagittal ranks, in many specimens with scattering of finer tubercles interspersed among them; small cranidia (Fig. 4E_1) with only a single row of three large tubercles posteriorly and smaller tubercle anteriorly; sculpture on frontal area similar to that on interocular fixigena; anterior sections of facial suture slightly anteriorly convergent in front of palpebral lobe, changing course oppo-

Fig. 3. *Tulepyge tulensis* gen. et sp. nov., from the Barn Canyon Member, House Formation (Lower Ordovician; lower Skullrockian), Section B 1.1 m, Ibex area, Millard County, western Utah. **A**. Cranidium, holotype, SUI 100169, dorsal (A_1), right lateral (A_2), anterior (A_3), oblique (A_4), and ventral (A_5) views. **B**. Cranidium, SUI 100170, dorsal (B_1), left lateral (B_2), and anterior (B_3) views. **C**. Cranidium, SUI 100171, dorsal (C_1), left lateral (C_2), and anterior (C_3) views. **D**. Cranidium, SUI 100172, dorsal (D_1), anterior (D_2), and right lateral (D_3) views. **E**. Cranidium, SUI 100173, dorsal (E_1), left lateral (E_2), and anterior (E_3) views. **F**. Cranidium, SUI 100174, dorsal (F_1), anterior (F_2), and right lateral (F_3) views. **G**. Cranidium, SUI 100175, dorsal (G_1), anterior (G_2), and right lateral (G_3) views. **H**. Cranidium, SUI 100176, dorsal (H_1), anterior (H_2), and right lateral (H_3) views. **I**. Cranidium, SUI 100177, dorsal (I_1), left lateral (I_2), and anterior (I_3) views. All ×10. →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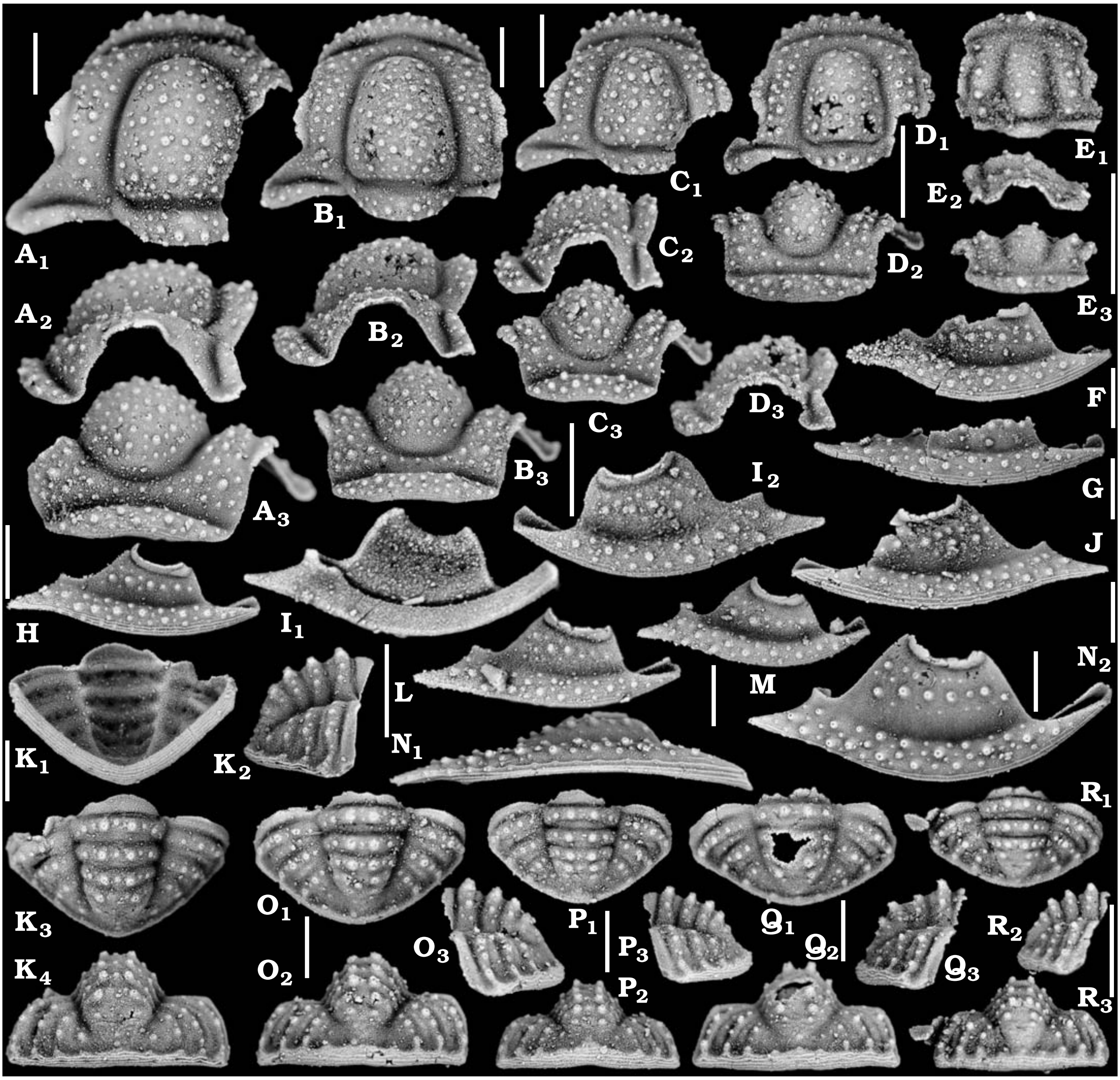


Fig. 4. *Tulepyge tulensis* gen. et sp. nov., from the Barn Canyon Member, House Formation (lower Skullrockian), Section B 1.1 m, Ibex area, Millard County, western Utah. **A**. Cranidium, SUI 100178, dorsal (A_1), left lateral (A_2), and anterior (A_3) views. **B**. Cranidium, SUI 100179, dorsal (B_1), left lateral (B_2), and anterior (B_3) views. **C**. Cranidium, SUI 100180, dorsal (C_1), left lateral (C_2), and anterior (C_3) views. **D**. Cranidium, SUI 100181, dorsal (D_1), anterior (D_2), and left lateral (D_3) views. **E**. Cranidium, SUI 100182, dorsal (E_1), right lateral (E_2), and anterior (E_3) views. **F**. Right librigena, SUI 100183, external view. **G**. Right librigena, SUI 100184, external view. **H**. Right librigena, SUI 100185, external view. **I**. Left librigena, SUI 100186, internal (I_1) and external (I_2) views. **J**. Left librigena, SUI 100187, external view. **K**. Pygidium, SUI 100188, ventral (K_1), right lateral (K_2), dorsal (K_3), and posterior (K_4) views. **L**. Right librigena, SUI 100189, external view. **M**. Right librigena, SUI 100190, external view. **N**. Right librigena, SUI 100191, ventrolateral (N_1) and external (N_2) views. **O**. Pygidium, SUI 100192, dorsal (O_1), posterior (O_2), and left lateral (O_3) views. **P**. Pygidium, SUI 100193, dorsal (P_1), posterior (P_2), and left lateral (P_3) views. **Q**. Pygidium, SUI 100194, dorsal (Q_1), posterior (Q_2), and right lateral (Q_3) views. **R**. Pygidium, SUI 100195, dorsal (R_1), right lateral (R_2), and posterior (R_3) views. All × 10, except C, H × 12, D, I, L, R × 15, and E × 20. Scale bars 1 mm.

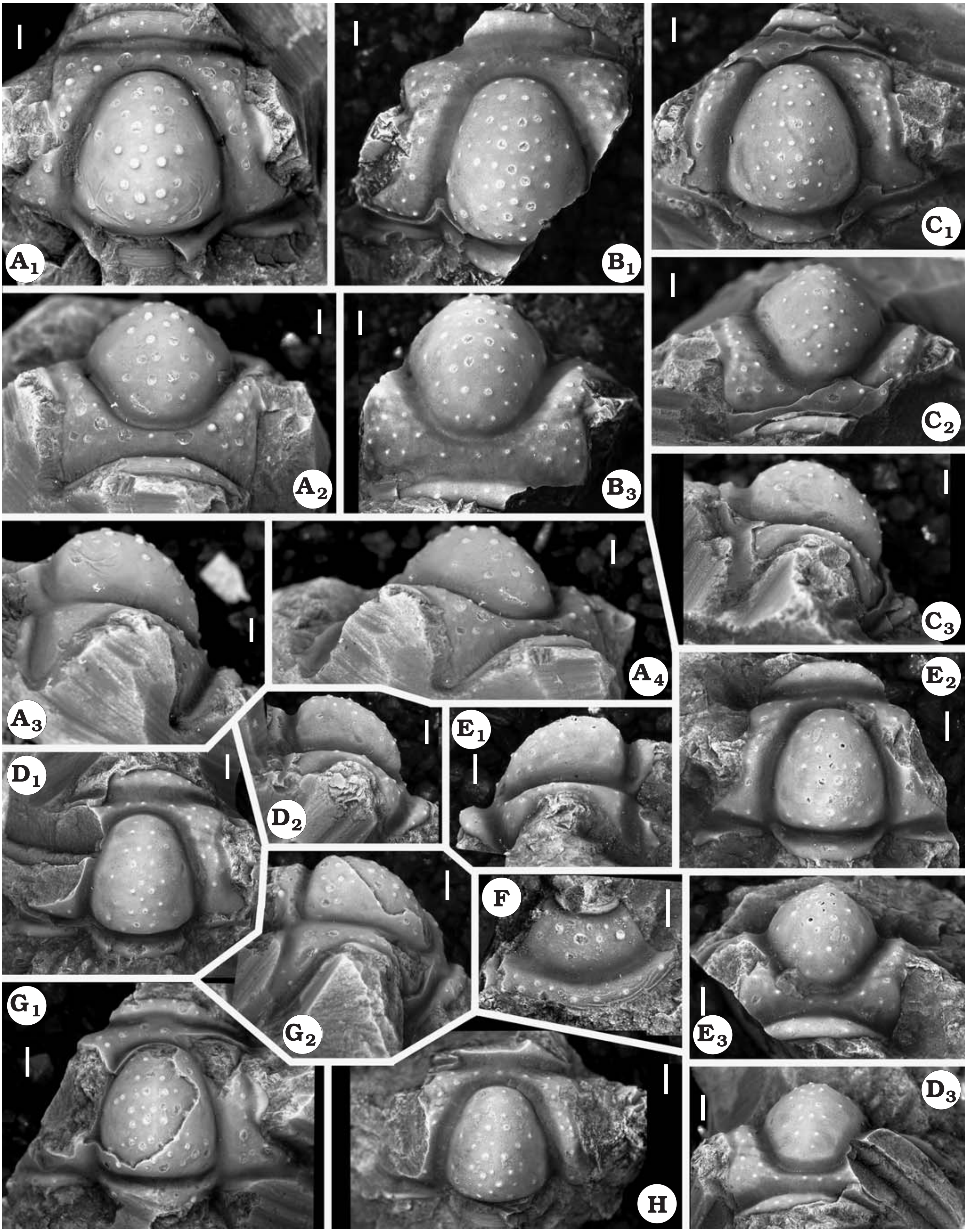
site anterior part of frontal area to become more strongly anteriorly convergent; palpebral furrow well impressed, ranging from nearly straight in some specimens (e.g., Fig. 3A_1) to laterally bowed in others (e.g., Fig. 3G_1); palpebral lobe narrow, slightly inclined from transverse plane, with two or three small tubercles which are more prominent in smaller specimens, lateral margin more strongly curved slightly posterior to midlength; posterior fixigena gradational with interocular fixigena, sculpture continued posteriorly but more subdued in that direction; posterior fixigena quite long (exsag.) behind palpebral lobe, tapering in length distally but still well expressed and bearing tubercles near tip of posterolateral projection; posterior border furrow well incised, slightly shallower than axial furrow, increasing in length (exsag.) and shallower distally; posterior border with strong dorsal convexity, very short near contact with LO, increasing in length slightly to fulcrum, then strongly distal to fulcrum; border with sculpture of single transverse row of moderate sized tubercles, typically 3–4 in total, some specimens with widely scattered interspersed smaller tubercles, particularly distally, small specimens (Fig. $4B_1$, C_1); tiny posterolaterally directed spine at distal tip of posterior border, reduced to tubercle in largest specimens (Fig. $3A_1$); doublure under LO with closely spaced raised lines on articulating surface; doublure scarcely developed elsewhere except for very short (exsag.) strip, lengthening slightly distally, beneath posterior border; no fossulae for hypostome articulation are discernible.

Librigena.—Field with minimum width 64 percent (59–71) maximum width at posterior edge of eye, minimum width 30 percent (25–36) of length; field with very fine background sculpture of caecal pits, with exsagittal row of 5–6 prominent tubercles set nearer to eye than to lateral border furrow, with small number of much smaller tubercles scattered irregularly above, below, and among main row; eye socle of single narrow band along posterior three quarters, expanded into distinct inflated lobe anteriorly, set off from field by narrow but strongly incised furrow; visual surface not preserved on any specimen, but eye large and long, occupying about two thirds length (exsag.) of field; lateral border furrow narrow and deep anteriorly, with shallower gradation toward field but sharp break of slope toward border, shallower posteriorly and almost or completely shallowed in front of base of genal spine; posterior border furrow not evident, almost entirely restricted to cranidium; lateral border furrow and librigenal lateral margin bowed moderately (Fig. 4H, J) or more commonly quite strongly (Fig. $4I_2$, J_2) laterally; lateral border with sculpture of prominent tubercles of same size as largest on field, arranged somewhat haphazardly but with suggestion of one or two exsagittal rows, with smaller tubercles fairly densely interspersed, and raised lines with completely linear expression developed subparallel with lateral margin on very edge of external aspect and ventrolateral aspect of border; anterior projection long; connective suture with shallow "V" shape, indicating rostral plate may have been hourglass-shaped; genal spine short and thorn-like, tapering rapidly to sharp point, with tuberculate and raised line sculpture of lateral border continued to point; doublure broad, turned sharply inward to form edge at contact with lateral border, lacking obvious raised line sculpture, with shallow Panderian notch posteriorly near posterior section of facial suture.

Rostral plate, hypostome, and thorax unknown.

Pygidium.—Sagittal length 53 percent (50–57) of maximum width; axis with sagittal length 95 percent (87–99) maximum anterior width and 84 (78–90) percent sagittal length of pygidium, anterior width of axis 42 (41–44) percent maximum width of pygidium; pygidium strongly vaulted in both sagittal and transverse (posterior) profile; posterior margin more or less chevron-shaped in dorsal view, nearly flat in transverse profile, with only subtle posteromedian flexure in some specimens (e.g., Fig $4P_2$); axis dorsally inflated, with four well defined axial rings and very faint fifth not well differentiated from terminal piece but marked by small fifth pair of paired axial tubercles in most specimens; rings very slightly longer sagittally than exsagittally, with sculpture of large pair of tubercles, smaller median tubercle (variably present) and two or three smaller lateral tubercles on either side; crescentic articulating half ring similar in sagittal length to first ring; ring furrow short and deeply incised; second and third ring furrows progressively less well incised but transversely complete, third expressed mostly laterally, fourth very weakly expressed; prominent pseudoarticulating half rings present on second and third segments, merged and indistinct posteriorly; axial furrows sharply posteriorly convergent opposite first ring, more weakly posteriorly convergent opposite rings 2–5, shallowed posteriorly to only very weakly circumscribe rear of axis, which is mostly marked by break in slope, axial furrow deflected in course around lateral inflations of rings; pleural furrow distinct on first three segments, fourth very weakly expressed, of same length proximally and distally, shallow near axial furrow, contact with axial furrow weakly defined, much deeper across fulcrum and distally; anterior pleural band of approximately same length (exsag.) as posterior band, both bands of same length proximally and distally, and bands of first, second, and third segments of similar length; anterior pleural band lacking sculpture, posterior band with transverse row of moderate tubercles, slightly smaller than those on axial rings, and interspersed smaller tubercles; interpleural furrows weakly expressed, but first three discernible, progressively weaker posteriorly; pleural region proximal to fulcrum horizontal or slightly downsloping, region distal to fulcrum sharply downturned; pleural bands terminate in strongly inflated axis; anterior bands simply terminate against edge of border, posterior bands developed into sharp ridge and distal tip, merging with border to give inner edge of border scalloped appearance; border rim-like, with prominent sculpture of subparallel raised lines, mostly contiguous across entire width of border; doublure narrow, describing shallow "V" shape in ventral views, with raised line sculpture similar to that on pygidial border.

Discussion.—*Tulepyge tulensis* is distinguished from *T. paucituberculata* in its dorsal cranidial sculpture of relatively smaller but densely packed tubercles, more anteriorly inflated *versus* narrow glabella, shorter preglabellar field and frontal area, less transversely arched anterior border (in anterior view), slightly broader interocular fixigena, narrower librigena field with more accessory tubercles in addition to prominent main exsagittal row, relatively slightly shorter genal spine, denser tuberculate sculpture on the librigenal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lateral border, raised lines restricted to lateralmost aspect of external surface of librigenal lateral border *versus* distributed over about half of external area of border, raised lines contiguous *versus* somewhat irregular and noncontiguous (Fig. 5F), and longer pygidium with broader pleural areas and more rounded, *versus* strongly "V" shaped posterior margin in dorsal view.

Data emerging from study of well constrained, large, and well preserved silicified samples of Upper Cambrian and Lower Ordovician species (Adrain et al. 2001, 2003; Adrain and Westrop 2004, 2005, 2006) indicate that ranges of intraspecific variation are much less than those often invoked in the systematic trilobite literature. In this context, it is important to note that *Tulepyge tulensis* displays genuine variation that is quite striking, especially in the degree of development of dorsal cranidial tuberculate sculpture. This ranges from fairly subdued in the holotype specimen (Fig. 3A), with the tubercles on the anterior border scarcely interrupting the arc of the anterior margin, through more coarsely tuberculate examples (Fig. 3B) with background tuberculation on the glabella increased and the anterior margin of the anterior border clearly interrupted by forwardly projecting tubercles, to extreme examples (Fig. 3C) in which the larger tubercles are extended into very short conical spines and the anterior margin is rendered highly irregular by the spines. Variation in tubercle/spine expression is common ontogenetically in densely tuberculate trilobites, with the typical trajectory from more coarsely tuberculate to progressively less coarse with larger size. This can be observed to a degree within *T. tulensis*, as small cranidia (Fig. 4B–D) are uniformly strongly tuberculate and only larger cranidia (Fig. 3A, F, H) have subdued sculpture. However, the cranidia illustrated in Fig. 3A–C are of nearly identical large size and the variation in large holaspid sculpture is real. As reflected by the ratios reported in the above description, librigenae vary quite widely in their dimensions, mostly obviously in the width of the field. Pygidia vary in their relative sagittal length, and in the shape in dorsal view of the posterior margin, ranging from more arcuate (Fig. $4O_1$) to more "V" shaped (Fig. $4K_3$), though none approaches the strong "V" shape of the only known pygidium of *T. paucituberculata* (Fortey 1983: pl. 23: 5).

Tulepyge paucituberculata (Fortey, 1983)

Fig. 5.

1982 *Hystricurus* sp.; Kindle 1982: pl. 1.5: 22.

1982 *Hystricurus* sp. nov.; Fortey in Fortey et al. 1982: 108, pl. 3: 14, 17.

1982 *Pseudohystricurus* sp. aff. *P. rotundus* Ross; Fortey in Fortey et al. 1982: 113, pl. 3: 12, 15.

1983 *Hystricurus paucituberculatus* Fortey 1983: 185, pl. 23: 1–7.

Material and occurrence.—In addition to type material listed by Fortey (1983: 185), figured material including GSC 69590 (Kindle 1982: pl. 1.5: 22; Fig. 5A herein), and GSC 30023–30029 (Fig. 5), all from boulder BPS 496, Broom Point Member, Green Point Formation, Broom Point South section, Broom Point, western Newfoundland, Canada; collected by C.H. Kindle.

Discussion.—When Fortey (1983) described the species he based it on four illustrated specimens all from a single boulder in the conglomerate Unit 57 of James and Stevens (1986) at Broom Point South. He also assigned two cranidia which he had illustrated previously (in Fortey et al. 1982: pl. 3: 14, 17). One (ROM 39623; pl. 3: 14) was from a different boulder in Unit 57 at Broom Point South, and the other (ROM 39627; pl. 3: 17) from a boulder in the same bed at Broom Point North. From this latter boulder he also (Fortey et al. 1982: pl. 3: 12, 15) figured a cranidium assigned to "*Pseudohystricurus* sp. aff. *P. rotundus* Ross." Fortey recognized (1983: 186) that the cranidia thus assigned to *paucituberculata* implied a wide range of variation in the expression of cranidial tuberculate sculpture. In the absence of other information, such a range would be worrisome in specimens derived from different source boulders. As discussed above, however, a similar range of variation is present in the same feature in the sample of *T. tulensis*, all of which is from a single tightly constrained *in situ* horizon. The amount of variation in the Newfoundland species is confirmed by additional material from a single boulder, BPS 496, illustrated in Fig. 5, in which sculpture ranges from subdued (Fig. $5D_1$) to coarse (Fig. $5A_1$). Given this range of variation, the cranidium assigned by Fortey (1982: pl. 3: 12, 15) to "*Pseudohystricurus*" seems also to represent *T. paucituberculata*, to which it is reassigned herein. Fortey (1983) assigned a cranidium illustrated by Kindle (1982: pl. 1.5: 22) with question to *paucituberculata*. This specimen is refigured herein (Fig. 5A). It, too, falls clearly within the range of sculptural variation confirmed by multiple specimens from the same boulder illustrated in Fig. 5, and doubt about its assignment is removed.

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← Fig. 5. *Tulepyge paucituberculata* (Fortey, 1983), from the Lower Ordovician of the Broom Point Member, Green Point Formation, Cow Head Group, conglomerate boulder BPS 496, Broom Point South section, western Newfoundland. **A**. Cranidium, GSC 69590, dorsal (A_1), anterior (A_2), right lateral (A_3), and oblique (A_4) views (original of Kindle, 1982: pl. 1.5: 22). **B**. Cranidium, GSC 30023, dorsal (B_1) and anterior (B_2) views. **C**. Cranidium, GSC 30024, dorsal (C_1), anterior (C_2), and right lateral (C_3) views. **D**. Cranidium, GSC 30025, dorsal (D_1), right lateral (D_2), and anterior (D_3) views. **E**. Cranidium, GSC 30026, left lateral (E_1), dorsal (E_2), and anterior (E_3) views. **F**. Right librigena, GSC 30027, external view. **G**. Cranidium, GSC 30028, dorsal (G_1) and slightly oblique right lateral (G_2) views. **H**. Cranidium, GSC 30029, dorsal view. A–D × 5, E, G, H × 6, F × 7.5. Scale bars 1 mm.

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