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NEW PARABLASTOIDS FROM THE WESTERN UNITED STATES

James Sprinkle[1] and Colin D. Sumrall[2]

[1]Department of Geological Sciences, Jackson School of Geosciences, University of Texas, Austin, Texas 78712-0254, USA, e-mail: echino@mail.utexas.edu; [2]Department of Earth and Planetary Sciences, University of Tennessee, Knoxville, Tennessee 37996, USA, e-mail: csumrall@utk.edu

Abstract—Two new genera and two new species of Parablastoidea are described from Early and Middle Ordovician faunas from the western United States. *Eurekablastus* n. gen. is similar in plating to *Blastoidocrinus* except that it possesses a conical pelvis with shallow basal cavity restricted to the basal circlet, one to two additional plate sets above the radials, medium to long cataspire slits, and lacks oral and ambulacral crests. *Eurekablastus ninemilensis* n. sp. from the Lower Ordovician Nimemile Shale of central Nevada and *Eurekablastus rozhnovi* n. sp. from the Lower Ordovician Wah Wah Limestone and uppermost Fillmore Formation of western Utah differ in thecal proportions, the number and distribution of interbrachial plates, the relative proportions of bibrachials and radials, and the length of the cataspire slits. *Parabolablastus* n. gen. is erected for *Blastoidocrinus?? elongatus* (Sprinkle), 1973, based on a mostly complete but crushed theca from the lower Middle Ordovician Antelope Valley Limestone of central Nevada. The plating in *Parabolablastus* may have been derived from *Eurekablastus*, but differs by having large parabolic deltoid plates, greatly enlarged bibrachials that form a complete circlet at the top of the pelvis and extend up into the vault interrays, and fewer or smaller plates in the lower pelvis. *Blastoidocrinus? rossi* Sprinkle, 1973, and *B.? nevadensis* Sprinkle, 1973, remain questionably assigned to *Blastoidocrinus* because they appear to have a high, fused, conical or cylindrical oral crest unlike the peristomial cover plates found in *Eurekablastus* and probably *Parabolablastus.*

Key words: Blastozoa, Echinodermata, systematics, Rocky Mountains, early Paleozoic

INTRODUCTION

Parablastoids are a small class of moderately advanced, brachiole-bearing, stemmed echinoderms that occur in the Early through Late Ordovician. Four genera and seven species have been described within two families in the class Parablastoidea, which has been assigned to the subphylum Blastozoa (Sprinkle, 1973). They have a rounded, biconical to bud-shaped theca (Fig. 1) with well-developed pseudo-fivefold symmetry (Sumrall and Wray, 2007) that is very similar (or a homeomorph) to true blastoids that range from the Late Ordovician (previously Middle Ordovician, Broadhead, 1984) to the late Permian. However, parablastoids (the class name means near blastoids) typically have more thecal plates, single floor plates in the ambulacra supporting each brachiole, and differently arranged, foldlike respiratory structures (cataspires in parablastoids versus hydrospires in blastoids) (Beaver et al., 1968; Fay, 1968; Sprinkle, 1973, 1976; Broadhead, 1984). Plating is most profoundly different in the thecal pelvis where several circlets of plates are present (Fig. 1; basals, B; radials, R; interradials, IR; interbrachials, Ibr; and bibrachials, Bbr), unlike true blastoids where only basals and radials are present (Fig. 1). Significantly, deltoid plates in each of these groups are nonhomologous. Deltoid plates in blastoids are homologues of oral plates in groups such as glyptocystitoids, whereas deltoids in parablastoids are differentiated thecal plates located one circlet aboral to the oral plates. Although they are classified in the same subphylum, based on these differences, parablastoids do not appear to be the sister group of blastoids (Sprinkle, 1976; Sumrall, 1997) as advocated by Breimer and Ubaghs (1974).

While studying Early and Middle Ordovician echinoderm faunas in the western United States during the past 19 years, we have extended the range of parablastoids downward into the Early Ordovician and gradually accumulated a few complete specimens of parablastoids previously known only from separate plates (see Sprinkle and Guensburg, 1997). We are publishing these new taxa at this time so they can be included in a revised *Treatise on Invertebrate Paleontology* chapter on parablastoids to accompany a major revision of the blastoids (Waters, coordinating author, in preparation). We have established the new genus *Eurekablastus* for several new Early Ordovician specimens that differ

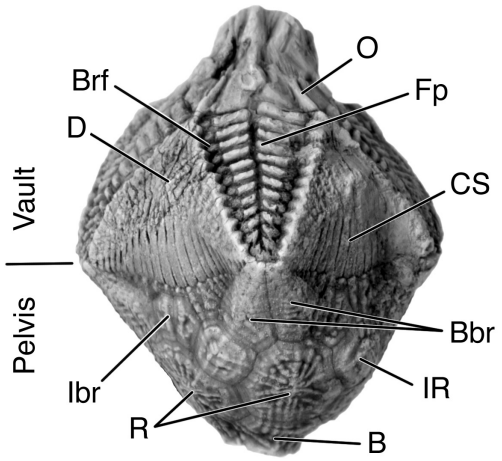

Figure 1. E-ray side view of *Eurekablastus ninemilensis* n. gen. and sp., holotype (1778TX14), showing plate designations and other morphologic features, such as vault and pelvis (left) separated by line at tips of ambulacra; *B,* basal plate forming stem cavity at base of theca; *Bbr,* bibrachial plates (paired) forming tip of ambulacrum at top of pelvis; *Brf,* brachiole facet at edge of ambulacrum; *CS,* cataspire slit through lower half of deltoid; *D,* large triangular deltoid plate making up much of vault; *Fp,* floor plate on each side of ambulacrum; *Ibr,* interbrachial plate (1 of 15–17) at top of pelvis along base of each deltoid; *IR,* interradial plate diagonally above radials; *O,* oral plate around mouth at top of vault; and *R,* medium-sized radial plate in lower pelvis. Note that very hard matrix still covers thecal summit above orals, ×3 (new).

significantly from *Blastoidocrinus* Billings, 1859. Another new genus, *Parabolablastus*, is established for very elongate deltoids that were named *Blastoidocrinus?? elongatus* Sprinkle (1973) based on a single, badly crushed, but nearly complete specimen from Nevada, and small collections of deltoids from other units in the western and southwestern United States.

PREVIOUS INVESTIGATIONS

The first triangular deltoid plates of parablastoids from the Rocky Mountains were reported by Ross (1949, 1951) and figured in Ross (1968) from the upper Garden City Formation in northeastern Utah. These and other parablastoid plate occurrences were described by Sprinkle (1971, 1973), especially from the so-called Sponge Beds and the flanking beds of a large bioherm in the middle and lower Antelope Valley Limestone in central and southern Nevada. Both of these occurrences are early Middle Ordovician (Whiterockian, Zone L or M) in age. Additional plates from the same parablastoid genera were described by Lewis (1982) from the Oil Creek Formation (also of Whiterockian age) in southern Oklahoma. Since 1989, additional specimens and plates have been discovered in the Ninemile Shale in central Nevada and from the Wah Wah Limestone and upper Fillmore Formation in western Utah, all three of late Early Ordovician (late Ibexian, Zone I–J) age, and from the Kanosh Shale in western Utah of early Middle Ordovician (Whiterockian) age (Sprinkle and Guensburg, 1997).

Parablastoids have also been described from the Early Ordovician of South Wales in the United Kingdom (Paul and Cope, 1982), from the Middle Ordovician of western Russia (Jaekel, 1918), and plates from undescribed parablastoids are probably more widely distributed in Lower to Upper Ordovician sections. Flat, radiating, holdfast molds that might belong to a parablastoid have recently been described by Cope and Donovan (2005), also from South Wales, but more likely they belong to a crinoid in this fauna.

SYSTEMATIC PALEONTOLOGY

Subphylum BLASTOZOA Sprinkle, 1973
Class PARABLASTOIDEA Hudson, 1907
Family BLASTOCYSTIDAE Jaekel, 1918
Genus EUREKABLASTUS new genus

Type species.—Eurekablastus ninemilensis n. sp.

Included species.—Eurekablastus ninemilensis n. sp., *Eurekablastus rozhnovi* n. sp.

Figure 2. *Eurekablastus ninemilensis* n. gen. and sp. *1–5*, Side views of EA interray, E-ray, AB interray, plus summit and basal views of holotype (1778TX14) showing complex pelvis plating and ornament (*1–3, 5*), large deltoids with their cataspire slits (*1, 3*), raised node on upper center of deltoid (*3*), hard matrix covering orals on summit, and shallow basal cavity with four surrounding basals (*5*), ×2.5; *6–9*, side views of B-ray, CD interray, plus summit and basal views of paratype (1781TX5) showing well-preserved ambulacra with cover plates in place over side and main food grooves (*6–8*), large deltoids with cataspire slits (*6–7*), pelvis plating mostly covered by caliche (*6, 7, 9*), summit with posterior anus (*8*), large orals above deltoids, and cover plates forming low oral pyramid over central mouth (*6, 8*), ×2.5; *10*, enlargement of E-ray ambulacrum in paratype (1781TX5); note brachiole facets, single set of cover plates over side food grooves, and domed biserial set over main food groove, ×8; *11–12*, oblique inside and inside of separate paratype deltoid plate (1777TX5) showing slits at base of plate leading to thin cataspire folds that turn outward at edge of deltoid (*11*) to open between ambulacral floor plates, ×4; *13*, separate paratype deltoid plate (1781TX7) showing nearly straight sides and slightly convex lower edge, weathered cataspire slits extending approximately 40% of length, and tiny raised bumps at top of slits, ×4; *14–15*, summit and oblique CD-summit of paratype (1781TX5) showing anal opening in CD interray between deltoid and posterior oral, partly exposed orals, and large cover plates forming peristome over mouth, ×4; *16*, enlargement of E-ray ambulacrum in holotype (1778TX14); note small, elliptical, brachiole facets at edges of ambulacrum with deltoid notches alongside, raised horizontal ridges on floor plates, and deep side and main food grooves with cover plates gone (compare with *10*), ×8; *17–18*, side and oblique side view of partial paratype (1781TX6) showing large deltoids with aboral cataspire slits lining up with interbrachial plates below, elongate bibrachial plates (lower left) forming tip of ambulacrum where new floor plates and brachioles are inserted, and broken-up brachioles covering most of left ambulacrum, ×4 (new).

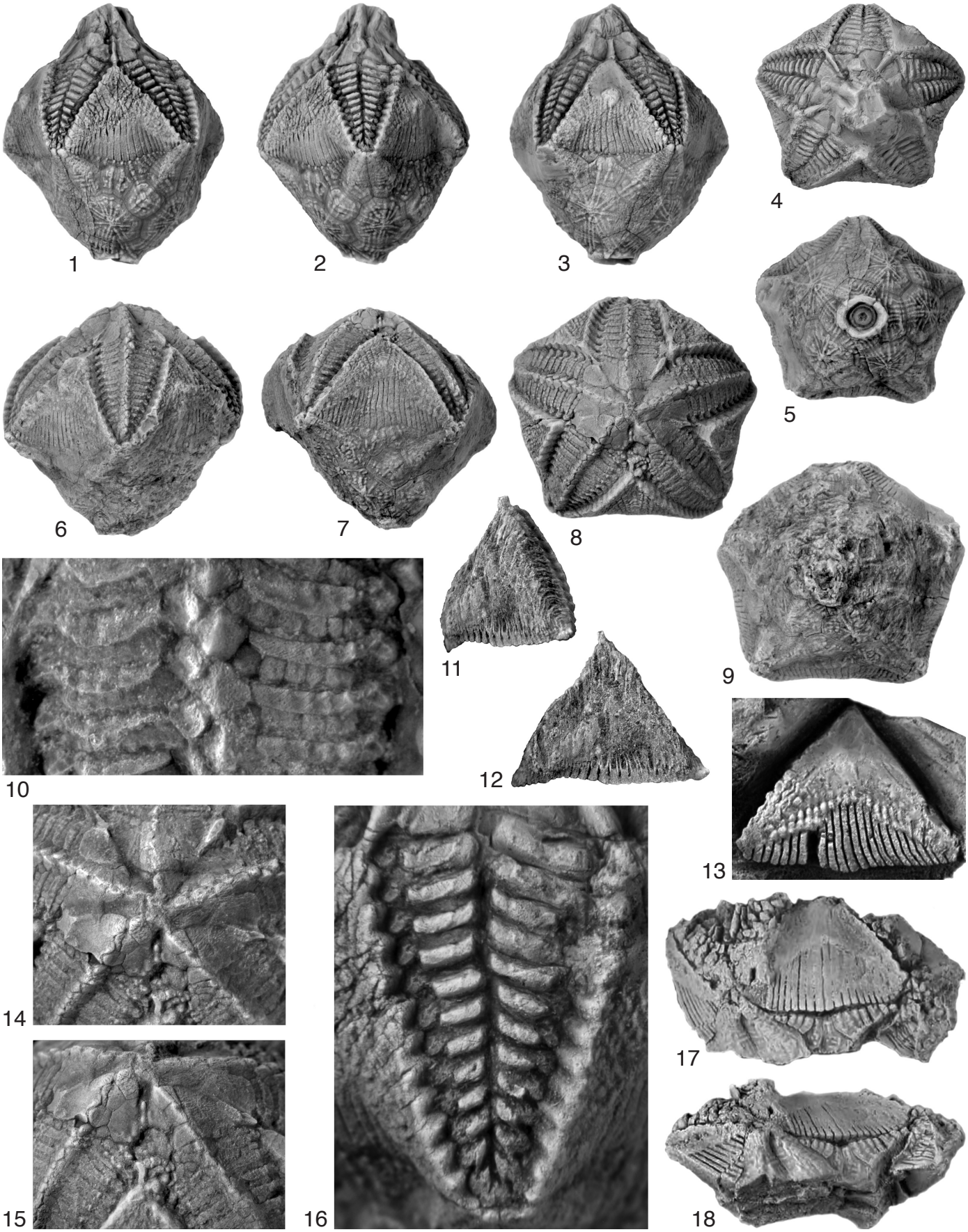

Figure 2. *For explanation, see facing page.*

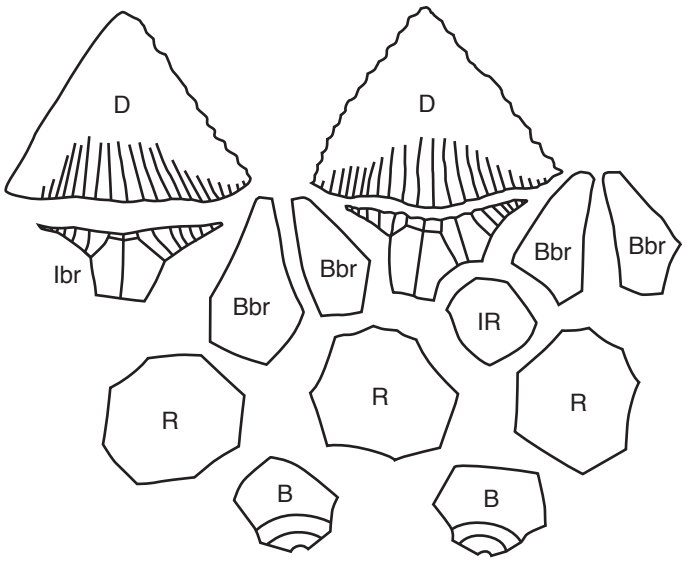

Figure 3. Side-layout plating diagram of slightly abnormal pelvis and lower vault in holotype (1778TX14) of *Eurekablastus ninemilensis* n. gen. and sp. Note that normal IR plate diagonally under A-ray is missing and mostly replaced by enlarged left bibrachial plate; *B,* basal plate; *Bbr,* bibrachial plate; *D,* deltoid plate; *Ibr,* interbrachial plate; *IR,* interradial plate; *R,* radial plate, ×3.7 (new).

Diagnosis.—Theca rounded biconical, pelvis nearly as long as vault, four visible basals forming shallow basal cavity, interradials present above and between radials in pelvis; deltoids thick with single, medium to long, cataspire slits; orals relatively large; ambulacra medium to wide, floor plates highly ridged, main food groove cover plates enlarged; oral cover plates forming very low, conical, oral covering; fused oral crest and high ambulacral crests absent.

Etymology.—The name comes both from the old mining town of Eureka, central Nevada, which was our base of operations while collecting in the Ninemile Shale at nearby Whiterock Canyon, and from the excited exclamations of the junior author in June, 1991, when he picked up the first complete specimen of a parablastoid ever found in the Rocky Mountains.

Occurrence.—Latest Early Ordovician (Ibexian), central Nevada and western Utah, United States.

Discussion.—*Eurekablastus* is characterized by thecal plating rather similar to that of *Blastoidocrinus* with large triangular deltoids, bibrachials under the ambulacral tips, and a pelvis plated with several rows of smaller plates. However, major differences include a longer pelvis, a much smaller and shallower stem cavity formed by four basals (three smaller and one slightly larger) instead of a deep stem cavity formed by hidden basals and five recurved radials, lack of strongly concave interray areas, an extra set of interradial plates above the radials, and the lack of T-shaped ambulacral crests and a cylindrical oral crest. This genus includes two new species based on newly collected complete thecae, *Eurekablastus ninemilensis*, the type species from the Ninemile Shale of central Nevada, and *Eurekablastus rozhnovi* from the Wah Wah Limestone and uppermost Fillmore Formation of western Utah. It is almost as old as *Blastoidocrinus antecedens* Paul and Cope, 1982, from the early Arenig of South Wales.

EUREKABLASTUS NINEMILENSIS
new species

Figures 1–6

Diagnosis.—Theca medium sized, slightly longer than wide, bibrachials and interradials medium sized, moderate number of interbrachials, mostly in one row, cataspire slits ~40%–50% of deltoid length, small raised node in upper center of deltoids, ambulacra moderately wide, uniserial cover plates over side food grooves versus large biserial set over main food groove, no ambulacral or fused oral crests, pelvis plates ornamented with low ridges and concentric bands.

Description.—Only two complete thecae, a small thecal fragment, and a few additional deltoid plates are known from this taxon (Fig. 2). Theca rounded biconical, holotype ~19.4 mm long, 16.7–17.9 mm wide in different views (very slightly crushed and covered by matrix on summit), compete paratype ~18 mm long, 18.5–19.5 mm wide in different views (somewhat crushed axially), L/W ranging from 0.95–1.12 in these type specimens; maximum width at tips of ambulacra at or just below midheight, in summit view, theca pentagonal with straight to slightly concave sides; vault somewhat longer than pelvis; in holotype, vault ~11.1 mm long; pelvis ~9.0 mm long; in complete paratype vault ranging from 9.0–9.5 mm long; pelvis from 8.5–9.0 mm long, vault-to-pelvis ratio (V/P) ranging from 1.0–1.2 in these specimens; in side view, pelvis slightly convex near base, slightly concave above, vault slightly to moderately convex along ambulacra, with low pyramidal summit above.

Pelvis composed of 4 basals (B), 5 radials (R), 4–5 medium interradials (IR, 1 missing in holotype), 10 paired bibrachials (Bbr), and 10 relatively small and approximately 60–75 very small interbrachials (Ibr). Four basals, relatively small, recurved to form shallow stem cavity containing 1–2 columnals in holotype, lip of cavity slightly protruding, smooth, 3 B pentagonal, 4th hexagonal with flat top, slightly wider than others externally but forming equal segment of cavity, almost centered in E ray; 5 radials, large, all nearly same size, in complete circlet above B, 8–10 sided, all displaced slightly to right so not truly radial, heavily ornamented with multiple ridges and growth bands; 4 interradials in holotype, medium sized, pentagonal, obliquely above and alternating with R, no IR in BC interray where left B-ray Bbr especially elongate (possibly abnormal; Fig. 3); 10 paired bibrachials in 5 pairs below tips of ambulacra, each Bbr medium sized, relatively elongate, roughly pentagonal but contacting approximately 13 plates; interbrachials numerous, usually 2 relatively small plates in center, flanked by 12–15 very small plates in each interray below deltoid decreasing in size laterally, Ibr plates rectangular-pentagonal, ornamented with near-vertical ridges that line up with cataspire slits in lower deltoid.

Vault composed of 5 very large deltoids (D) separating ambulacra, and 5 or more medium-sized orals (O) around central mouth; oral and ambulacral crests apparently absent from this species.

Five deltoids, largest plates in theca, interradial, roughly triangular with slightly convex lower margin, D thick, raised over adjacent ambulacra, with raised node in center of deltoid approximately two-thirds distance up from base (Fig. 2.2–2.3), CD deltoid slightly wider than others, D bordered by approximately 13 ambulacral floor plates on each scalloped lateral margin (Fig. 4); 5 orals (perhaps more), medium sized, diamond shaped, in complete circlet around central mouth on summit, bearing vertical ridge running up center of plate, and lateral main food grooves protected by relatively large cover plates, CD oral having bottom of plate occupied by circular anal opening (Fig. 2.14–2.15); uncertain whether remainder of this plate 1 piece or divided (Fig. 5).

Ambulacra relatively long and moderately wide, slightly rounded V-shaped with sides diverging ~40°–43°, inset below edge of adjacent deltoid, separated from mouth by medium-sized OO, composed of single floor plates in biseries with most proximal floor plate on left (looking aborally), forming thecal wall with no underlying thecal plates or lancet; floor plates gradually becoming wider adorally during ontogeny, tilted 20°–10° from aboral to adoral end, each bearing a rounded brachiole facet laterally that also indents adjacent deltoid edge (implying ambulacrum and deltoid showing no relative movement during growth), floor plates having a highly raised ridge medially with small nodes surrounded by side food grooves above and below, and the main food groove (MFG) along midline; food grooves protected by small cover plates in well-preserved paratype, a single adoral set over side food grooves, a larger, domed, biserial set over wider MFG (Fig. 2.10, 4.1, 6) continuing up over sutured margins of OO to form domed peristome over central mouth, no evidence of erect ambulacral (or oral) crests present over MFG cover plates in paratype; brachiole facets small, approximately 26–27 per ambulacrum in holotype, tilted slightly outward and aboral, nearly all same size, ~0.52 mm long by 0.4 mm wide, showing central longitudinal ridge, small partial paratype preserving short, biserial, brachiole segments on one ambulacrum (Fig. 2.17), lower brachioles partly supported by concave notch in adjacent raised deltoid (Fig. 2.16, 4.2), brachioles inferred to be relatively long (because no ambulacral crests present).

Cataspires opening as single, fairly long, thin, nearly straight slits on lower D, developing into cataspire folds extending up under D, then turning outward to small exit pores along edges of adjacent ambulacra between brachiole facets; holotype having approximately 24–25 slits, slits longest in center where occupying ~40%–50% of lower deltoid length (Fig. 3), shortest at edges where new slits added during ontogeny; slits start at D-Ibr and D-Bbr sutures (implying cataspire folds attached to edges of these underlying plates) and are narrow throughout most of their length, but slits expanding slightly at adoral end, forming narrow teardrop (Fig. 2.1–2.2). Pleated folds on interior preserved on one separate deltoid; folds mostly overgrown with secondary calcite and eroded but exposed at lower and lateral edges of deltoid (Fig. 2.12); fold walls very thin (~0.02 mm), and interior of folds approximately half of spacing between folds (0.16–0.18 versus 0.30–0.32 mm).

Ornament mostly on pelvis plating, consisting of low radiating ridges to plate sides crossing concentric growth bands (Fig. 2.1–2.3, 2.5), ridges breaking up into lines of pustules on Ibr

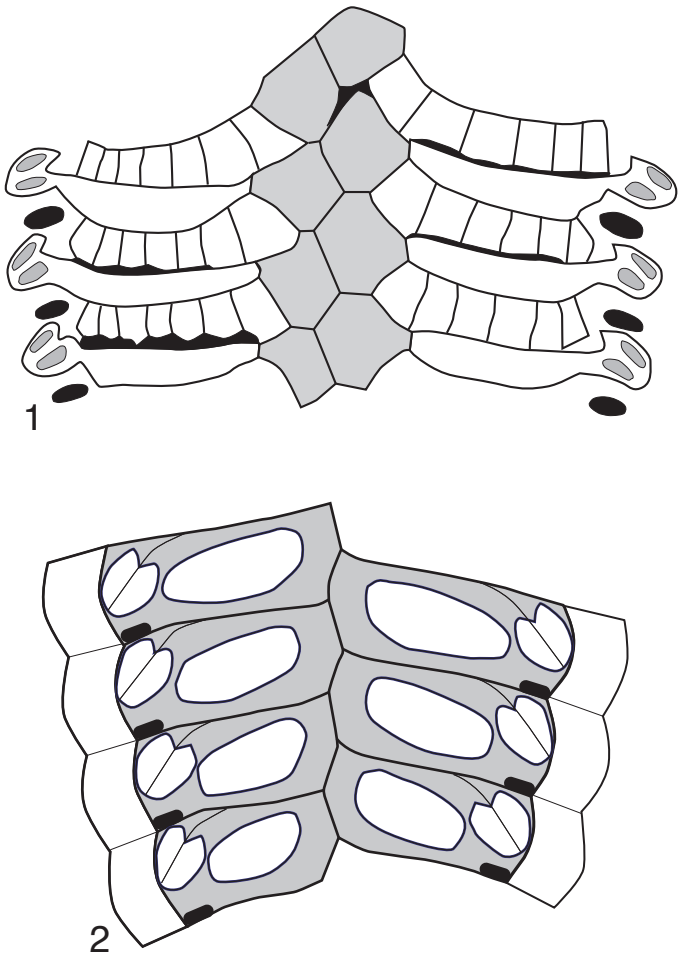

Figure 4. Details of the ambulacral plating in *Eurekablastus ninemilensis* n. gen. and sp. *1*, Proximal part of B-ambulacrum in paratype (1781TX5) with cover plates in place; main food groove cover plates (*stippled*) enlarged and biserial, whereas side food groove cover plates uniserial and attached to raised ridge (*white*) on proximal side of food groove; brachiole facets and elongate cataspire pores shown at edge of ambulacrum, ×14.5; *2*, sketch of distal part of E-ambulacrum in holotype (1778TX14) showing floor plates (*stippled*) without any cover plates preserved, elongate raised ridges (*white*) in center of floor plates, oblique and tilted brachiole facets at end of side food grooves, small cataspire pores (*elongate black dots*) between facets, and raised scalloped edge of adjacent deltoids, ×16.5 (new).

under start of cataspire slits on lower deltoids, an unornamented area; upper deltoids having fine parallel and then diverging ridges near ambulacra, and orals nearly smooth except for larger vertical ridge extending up center (Fig. 2.14).

Only 1–2 columnals from proximal stem present in shallow stem cavity (Fig. 2.5, 3), first columnal nearly circular, thin, possibly followed by second, smaller, thicker columnal with small round lumen, implying proximal stem heterotomous; length of stem and distal attachment structure unknown.

Holotype theca slightly abnormal by lacking one Ir plate in BC interray where left Bbr enlarged, extending further downward,

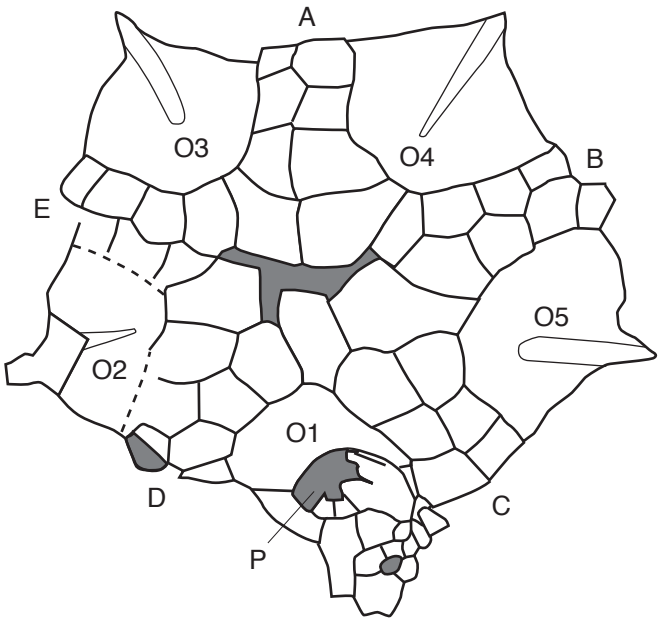

Figure 5. Summit view of complete paratype (1781TX5) of *Eurekablastus ninemilensis* n. gen. and sp. showing numbered oral plates (*O1–O5*), peristomial cover plates, and ambulacral cover plates; *A–E,* ray designations; *P,* periproct, ×8.5 (new).

and sutured with slightly displaced B radial to take up missing space (Fig. 2.3, 3).

Etymology.—Named for the Ninemile Shale in central Nevada, where both complete specimens and the separate plates were found.

Material.—Complete holotype Texas Memorial Museum (TMM) 1778TX14 collected by Sumrall in 1991; complete paratype TMM 1781TX5 collected by Sprinkle in 2002; thecal fragment paratype TMM 1781TX6 collected by Schneider in 2001, plate paratypes TMM 1777TX5, 1777TX6, 1778TX15, and 1781TX7 collected by Sprinkle between 1989–1997.

Occurrence.—All type specimens came from the upper Ninemile Shale in the *Pseudocybele nasuta* Zone (old Zone J), upper Ibexian (middle Arenig, uppermost Lower Ordovician), the holotype from ~15 m (49 ft.) above the 0 ledge at locality WR-1, the Front Section, the complete and thecal fragment paratypes from ~4.5 m (15 ft.) and 5.5 m (20 ft.) above the base of the section at locality WR-2A, the Narrows Section side gulley, and the plate paratypes from several levels in the WR-1, WR-2 (Narrows Section), and WR-2A sections, ~1.6 km (1 mi.) (WR-1) and 1.8 km (1.1 mi.) (WR-2 & 2A), respectively, up Whiterock Canyon from the terminus of the southside dirt track that enters the canyon, just off the Antelope Valley graded dirt road (Nevada Rt. 82) west of Martin Ridge, eastern Monitor Range, ~70.5 km (44 mi.) by road southwest of Eureka, Eureka County, central Nevada, western United States.

Discussion.—*Eurekablastus ninemilensis* n. sp., differs from *E. rozhnovi* by having: 1) a lower L/W ratio, 2) narrower ambulacra, 3) larger bibrachials, smaller and fewer interradials, and no extra plate series in the pelvis, 4) shorter, nearly straight, cataspire slits, and 5) a raised node in the upper center of the deltoid. It is also similar to the separate deltoids of *Blastoidocrinus*? *nevadensis* Sprinkle, 1973, from the overlying Antelope Valley Limestone, also in central Nevada, but that taxon appears to have a cylindrical oral crest that is absent in this new species, thicker deltoid plates, and shorter cataspire slits extending only one-quarter to one-third of the deltoid length.

EUREKABLASTUS ROZHNOVI new species

Figures 7–8

Diagnosis.—Theca much longer than wide, bibrachials small, interradials large and paired with extra plates, interbrachials numerous and in two rows, cataspire slits usually ~70%–80% of deltoid length, ambulacra wide, no apparent ambulacral or fused oral crests, some brachioles enlarged distally to protect smaller brachioles, thecal ornament subdued, stem apparently long with alternating larger and smaller rounded columnals.

Description.—Only one large, complete, but heavily weathered theca in a slab, one partial flattened theca, and one separate deltoid are known for this taxon. Theca rounded biconical, length much greater than width, holotype ~33 mm long, 24 mm wide (very slightly crushed), L/W approximately 1.38 (Fig. 7.3, 7.7), partial paratype smaller and lacking most of pelvis, ~17.5 mm wide (crushed flat; Fig. 7.1–7.2), maximum width just above tips of ambulacra in lower deltoids; in summit view, theca pentagonal with slightly concave sides, in side view, vault slightly longer than pelvis, vault slightly to moderately convex along ambulacra, with low pyramidal summit above, vault in holotype ~16.7 mm long, pelvis profile nearly straight, pelvis in holotype ~16.2 mm long, V/P approximately 1.03.

Pelvis in holotype apparently composed of 4 basals (B), 5 radials (R), 5 medium interradials (IR), 5 extra plates between interradials, 10 small paired bibrachials (Bbr), and approximately 140 small to very small interbrachials (Ibr) (Fig. 8.2). Four basals (2 exposed, 2 mostly hidden), medium sized, recurved to form shallow stem cavity, left basal hexagonal (flat topped), right one pentagonal; apparently 5 radials (3 visible), large, hexagonal, in complete circlet above B; 5 interradials (2 visible), large, above and alternating with R; 5 extra plates (parts of 3 visible), medium sized, alternating with IR (Fig. 8.2); 10 small paired bibrachials (parts of 2 pairs visible), radially positioned just below tips of ambulacra, roughly 5–6 sided but surrounded by 8–10 plates; 2 interbrachial groups exposed, approximately 32–34 very small Ibr in each interray below most of deltoid width lying directly below cataspire slits; in large holotype Ibr forming 2 rows with approximately 22–23 plates immediately below most of deltoid, underlain by approximately 11–12 additional plates in center of interray (Fig. 8.2), smaller paratype having only approximately 17–18 Ibr mostly in single horizontal group below center of deltoid (Fig. 8.1).

Vault in holotype composed of 5 large deltoids (D) separating wide ambulacra and overlain by 5 or more orals (OO). Five deltoids (3 visible), largest plates in theca, interradial, roughly triangular with nearly straight (holotype) or slightly convex (paratype) lower margins, D thick, raised over adjacent ambulacra, smoothly convex without raised node in upper center, right-center deltoid

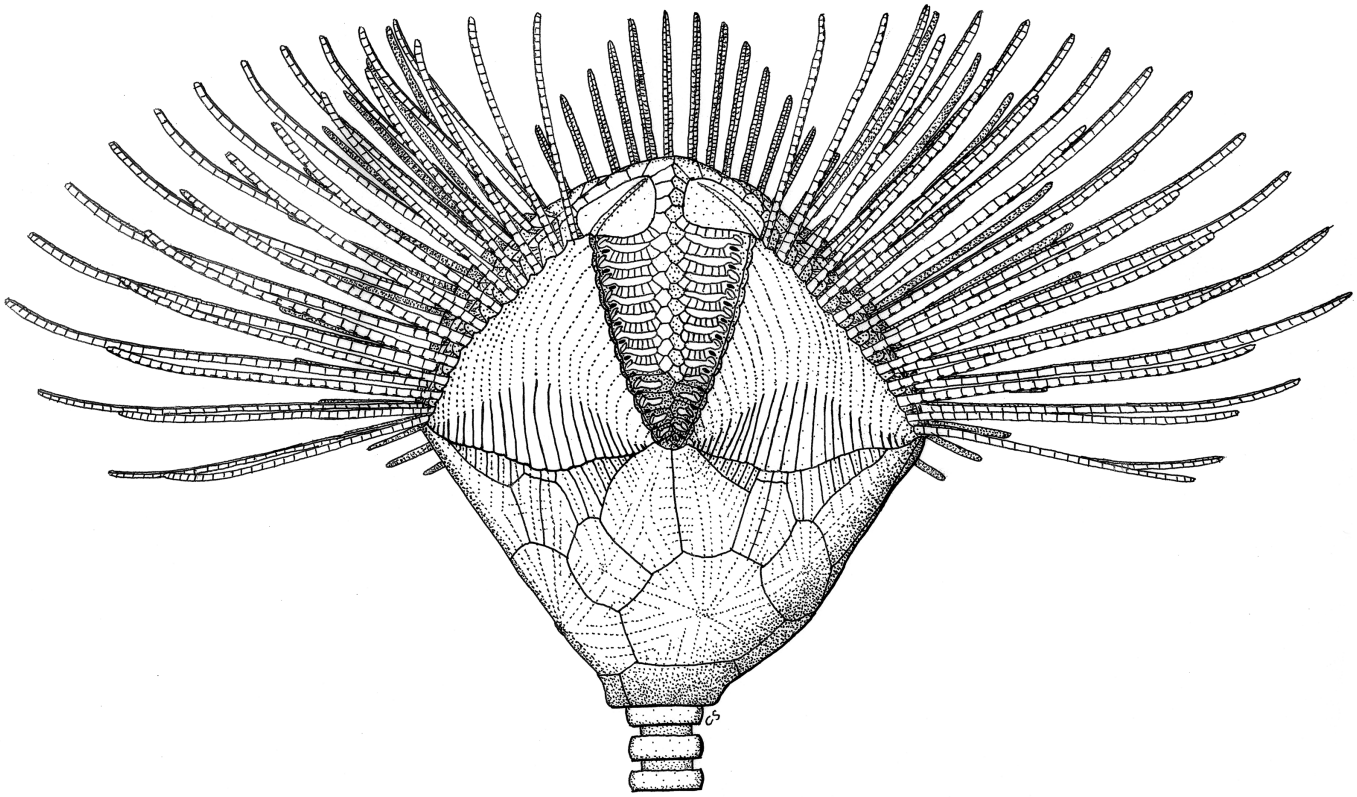

Figure 6. Thecal reconstruction of *Eurekablastus ninemilensis* n. gen. and sp. with brachioles deployed for feeding based on complete holotype and paratype. Note that generalized brachioles and aboral-most cover plates are stripped from facing ambulacrum. Short stem segment partly based on *Eurekablastus rozhnovi* n. gen. and sp. stem impression (new).

on holotype slightly wider that others (possibly CD), D having approximately 24–25 long, thin, cataspire slits extending most of D length, D bordered by approximately 13–14 ambulacral floor plates on each lateral margin; orals 5 (or more; parts of 2 visible), poorly preserved on top of weathered vault, medium sized, diamond shaped, in complete circlet above deltoids and below central mouth on summit, having traces of large cover plates on lateral edges, anal opening perhaps located in right-center oral above widest deltoid (possibly making this CD interray); peristome poorly preserved and partly covered by large clump of matrix.

Ambulacra relatively long and very wide, V-shaped, with sides diverging at ~60°, inset below edge of adjacent deltoid, separated from mouth by medium-sized OO (Fig. 7.6), composed of single floor plates in biseries forming thecal wall (no underlying thecal plates or lancet, see Fig. 7.7, left), floor plates gradually becoming wider adorally, slightly curved and tilted ~10°, each bearing a rounded brachiole facet laterally (which also indents adjacent deltoid edge, implying ambulacrum and deltoid showing no relative movement), floor plates also having a raised ridge medially with marginal side food grooves above and below, and main food groove (MFG) along midline; few cover plates poorly preserved on possible C-ray ambulacrum (Fig. 7.7, right).

Approximately 7–8 short brachiole segments preserved on small flattened paratype, these present on at least 3 ambulacra, biserially plated, cover plates very small, longest segment ~9.8 mm long, 0.8 mm wide, and 1.5 mm deep distally, several brachioles expanding distally to nearly double the facet length and width, perhaps to protect other smaller brachioles when infolded (see Sprinkle, 1973, p. 163).

Cataspires opening as single, very long, thin, slightly converging slits on D, developing into cataspire folds (see below) extending up under D, then turning outward to small exit pores along edges of adjacent ambulacra between brachiole facets; holotype having approximately 24–25 slits, slits longest in center, where they occupy ~70%–80% of deltoid length (Fig. 7.1, 7.3), shortest at edges where new slits added during ontogeny, separate deltoid plate having shorter cataspire slits extending only ~40% of deltoid length; slits start at D-Ibr and D-Bbr sutures (implying cataspire folds attached to edges of these small underlying plates), remaining narrow throughout most of their length.

Ornament mostly missing from deeply eroded holotype, subdued on flattened paratype D and Ibr with only trace of slight ridging (Fig. 7.1), also subdued on separate paratype deltoid.

Proximal stem only known from impression on slab below holotype stem cavity (Fig. 7.4); proximal stem impression ~29 mm long, 3 mm wide, with apparent alternating larger and smaller rounded columnals; another approximately 8 mm segment of medial stem with similar larger and smaller rounded columnals present, starting ~54 mm below stem facet.

Etymology.—Named for Sergei Rozhnov, Paleontological Institute, Moscow, who found the large holotype specimen during a visit to the Ibex area in the western United States in 1997.

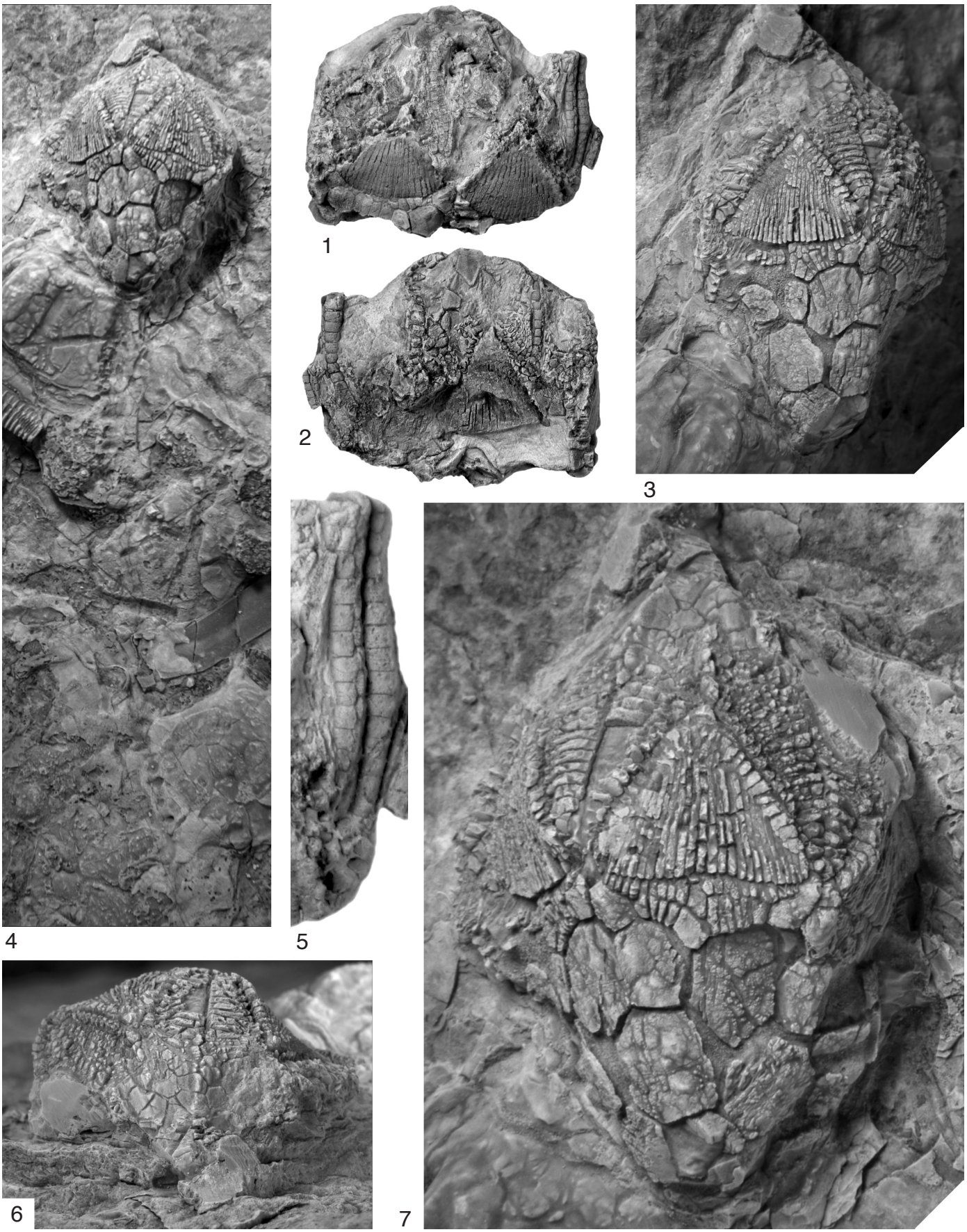

Figure 7. *For explanation, see facing page.*

Material.—Holotype TMM 1965TX12, a very large but deeply weathered theca with stem impression found by Rozhnov in 1997, paratype TMM 1964TX16, a nearly flat, weathered-out, partial theca with a few brachioles preserved, collected by Sprinkle in 1997, and separate paratype deltoid TMM 1966TX12 in a small slab collected by T. E. Guensburg in 1990.

Occurrence.—The holotype was collected from a large dipping slab just north of the ridge-top saddle on the south flank of Square Top at the top of Hintze's (1973) SQ measured section, 2 m (6.5 ft.) above the base of the Wah Wah Limestone in the *Pseudocybele nasuta* Zone (old Zone J); partial paratype theca collected ~3 m (10 ft.) above a large sponge-algal mound in the back (east) saddle of the Guen Section on the next peak, ~3 km (1.9 mi.) to the north from the same zone in the uppermost Fillmore or basal Wah Wah; plate paratype collected at the top of our SQ(Center) Section on the northwestern corner of Square Top in the same zone near the base of the Wah Wah; all three localities in the Black Hills, just east of the Tule Valley Road and south of U.S. routes 6-50 through Skull Rock Pass, in the eastern Ibex area, ~88 km (55 mi.) and 84.8 km (53 mi.), respectively, southwest of Delta, Millard County, west-central Utah, in the western United States.

Discussion.—The two relatively complete specimens of *Eurekablastus rozhnovi* are considerably different in size and show some differences that appear to be ontogenetic. The smaller specimen has one incomplete upper row of 14 interbrachial plates and 5 interbrachial plates below. The much larger holotype has an incomplete upper row of 22 interbrachial plates and a lower row of 11–12 interbrachial plates. Because larger parablastoids have more cataspire slits in the deltoid plates and the upper row of interbrachial plates are directly associated with these slits, we infer that new interbrachial plates are added ontogenetically. The higher thecal L/W ratio, the presence of 2 distinct rows of interbrachial plates, the smaller bibrachial plates, the extra set of plates beside the interradials in the pelvis, the typically longer cataspire slits in the deltoids, and the wider ambulacra in the vault all distinguish *Eurekablastus rozhnovi* from *Eurekablastus ninemilensis.*

Genus BLASTOIDOCRINUS Billings, 1859
BLASTOIDOCRINUS? ROSSI, Sprinkle, 1973

Discussion.—This species remains questionably assigned to *Blastoidocrinus* because it appears to have a high, fused, conical or cylindrical, oral crest unlike the low oral covering composed of separate cover plates (and no ambulacral crests) found in *Eurekablastus.* Pelvis plating, except for a few bibrachials, is also poorly known. Silicified plates belonging to this species are known from acid residues of beds in the uppermost Garden City Formation (lower Whiterockian) from two localities in northeastern Utah.

BLASTOIDOCRINUS? NEVADENSIS Sprinkle, 1973

Discussion.—This species also remains questionably assigned to *Blastoidocrinus* because it appears to have a fused, cylindrical, oral crest (perhaps implying the presence of ambulacral crests), unlike the low oral covering composed of large cover plates (and no ambulacral crests) in *Eurekablastus.* Pelvis plating is also unknown. Calcite and silicified plates belonging to this species are known from isolated plates on slabs and acid residues of beds from the lower and middle Antelope Valley Limestone (lower Whiterockian) at two localities in central and southwestern Nevada. *Blastoidocrinus? nevadensis* is associated with a large mud mound and a sponge biostrome at these localities, perhaps implying medium-to-high-energy conditions.

Genus PARABOLABLASTUS new genus

Type species.—*Blastoidocrinus?? elongatus* Sprinkle, 1973, by monotypy.

Diagnosis.—Theca large, apparently with highly domed vault and short, conical pelvis; deltoids parabolic with long, thick limbs diverging at 35°–55° and bordering long, relatively thin ambulacra, no ambulacral or oral crests seen, 60 or more short, zigzagged, cataspire slits along inside of elongate deltoids, numerous small interbrachials in arched row below slits, long extensions of paired bibrachials filling center of concave vault interrays along with forming large, complete, outer circlet in pelvis, possible radials smaller, forming inner circlet and possible stem cavity in center of pelvis; highly rugose or labyrinthine ornament on large deltoids and bibrachials.

Etymology.—Named for the distinctive parabolic shape of the large, elongate, deltoid plates of this domed, bud-shaped parablastoid.

Discussion.—*Parabolablastus* n. gen. is erected for parablastoids bearing unusual long-limbed parabolic deltoid plates originally described by Sprinkle (1973) as *Blastoidocrinus?? elongatus.* A single, nearly complete, although badly crushed, theca preserves enough of the salient features of the thecal plating after extensive cleaning to show that it is a distinct new genus. *Parabolablastus* differs from all other parablastoids by having elongate parabolic deltoids with numerous cataspire slits plus unusually large bibrachials that form a complete circlet at the top of the pelvis and have long extensions up into the vault interrays. Lewis (1982, pl. 11,*6–9*) had already figured unusually elongate and bent possible bibrachials that extend up into a narrow notch and have distinctive labyrinthine ornament that appear to belong to this genus and perhaps the type species. Because *Parabolablastus* has both bibrachial and apparent radial circlets in the pelvis, it probably is most closely

Figure 7. *Eurekablastus rozhnovi* n. gen. and sp. *1, 2, 5*, Front, back, and preserved brachioles of small, crushed, partial paratype (1964TX16) in slab showing three deltoids with long cataspire slits, row of interbrachial and small bibrachial plates (*1*), and enlargement of biserial brachioles attached to righthand ambulacrum in *1*, ×3, ×8; *3, 4, 6, 7*, left side view, theca and stem impression, summit view, and enlargement of front of very large holotype (1965TX12) showing heavily weathered thecal plating, large deltoids with long cataspire slits, numerous interbrachial plates bordered by small bibrachials (*7*), and ambulacra with brachiole facets, oral plates, and large oral cover plates (*6, 7*), ×2.5, ×1.5, ×2.5, and ×3.9 (new).

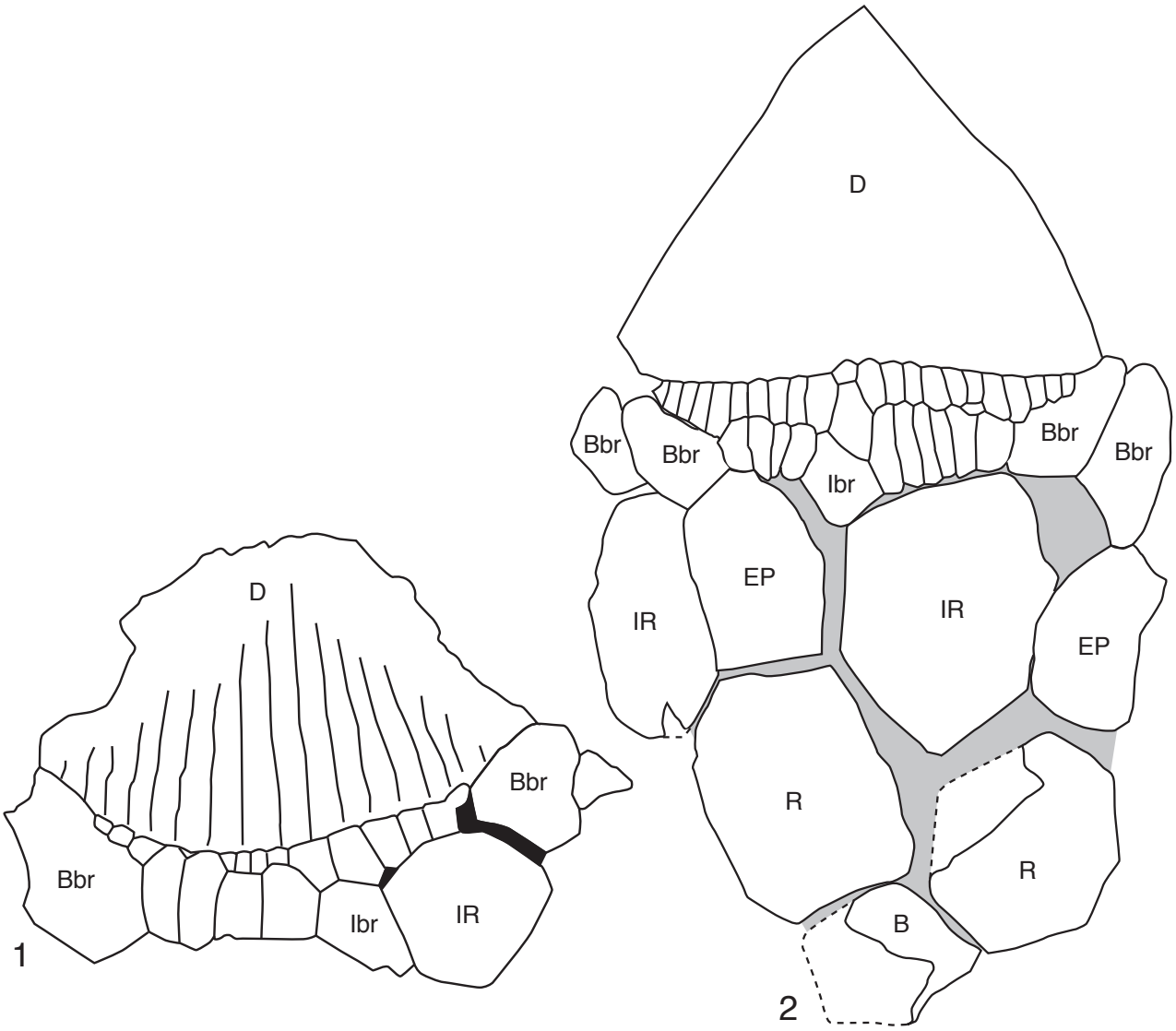

Figure 8. Side-layout plating diagrams for specimens of *Eurekablastus rozhnovi* n. gen. and sp. *1*, Deltoid plate and interbrachials of small crushed paratype (1964TX16); note the larger number of Ibr and smaller Bbr in comparison to *Eurekablastus ninemilensis* n. gen. and sp., ×8; *2*, pelvis and lower vault of somewhat disrupted very large holotype (1965TX12) showing complete circlet of large IR and intervening extra plates between circlet of R below and overlying small paired Bbr and very numerous Ibr, ×7; *B,* basal plate; *Bbr,* bibrachial plate; *D,* deltoid plate; *EP,* extra plate; *Ibr,* interbrachial plate; *IR,* interradial plate; *R,* radial plate (new).

Figure 9. *Parabolablastus elongatus* (Sprinkle). *1–5*, Smoked and immersed summit views, smoked partial side view of EA interray, and smoked and immersed basal views of plesiotype (1766TX75) from Ikes Canyon showing crushed and eroded theca excavated from slab, long deltoid margins and long, relatively thin ambulacra (*2*), concave interrays with deltoid limbs underlain by row of interbrachials and bibrachial extensions (*3*), large paired bibrachials on pelvis surrounding smaller central possible radials (*4–5*), traces of rugose or labyrinthine ornament on larger plates (*1*, *3*), and parasitic borings surrounded by swellings mostly on deltoids (*1–2*), ×2; *6*, *8*, external and oblique edge views of paratype deltoid (MCZ 611) from Ikes Canyon showing coarse pustular ornament and adoral cataspire pores along ambulacrum, ×2 and ×2.4; *7*, *11*, oblique edge and external views of silicified holotype deltoid (MCZ 610) from Meiklejohn Peak showing parabolic shape and numerous cataspire slits, ×2.6; *9*, enlargement of smoked partial summit and BC interray of plesiotype (1766TX75) with possible anal opening (lower left) below possible crest over mouth (left), ambulacral floor plates and brachiole facets (right), and BC deltoid tip with several parasitic borings (right), ×4; *10*, greatly enlarged, oblique, immersed, E-side view of EA deltoid limb in plesiotype (1766TX75) showing slightly zigzagged, oblique slits above single row of interbrachials, ×8 (figures 9.6–9.8 and 9.11 adapted from Sprinkle, 1973; all other views are new).

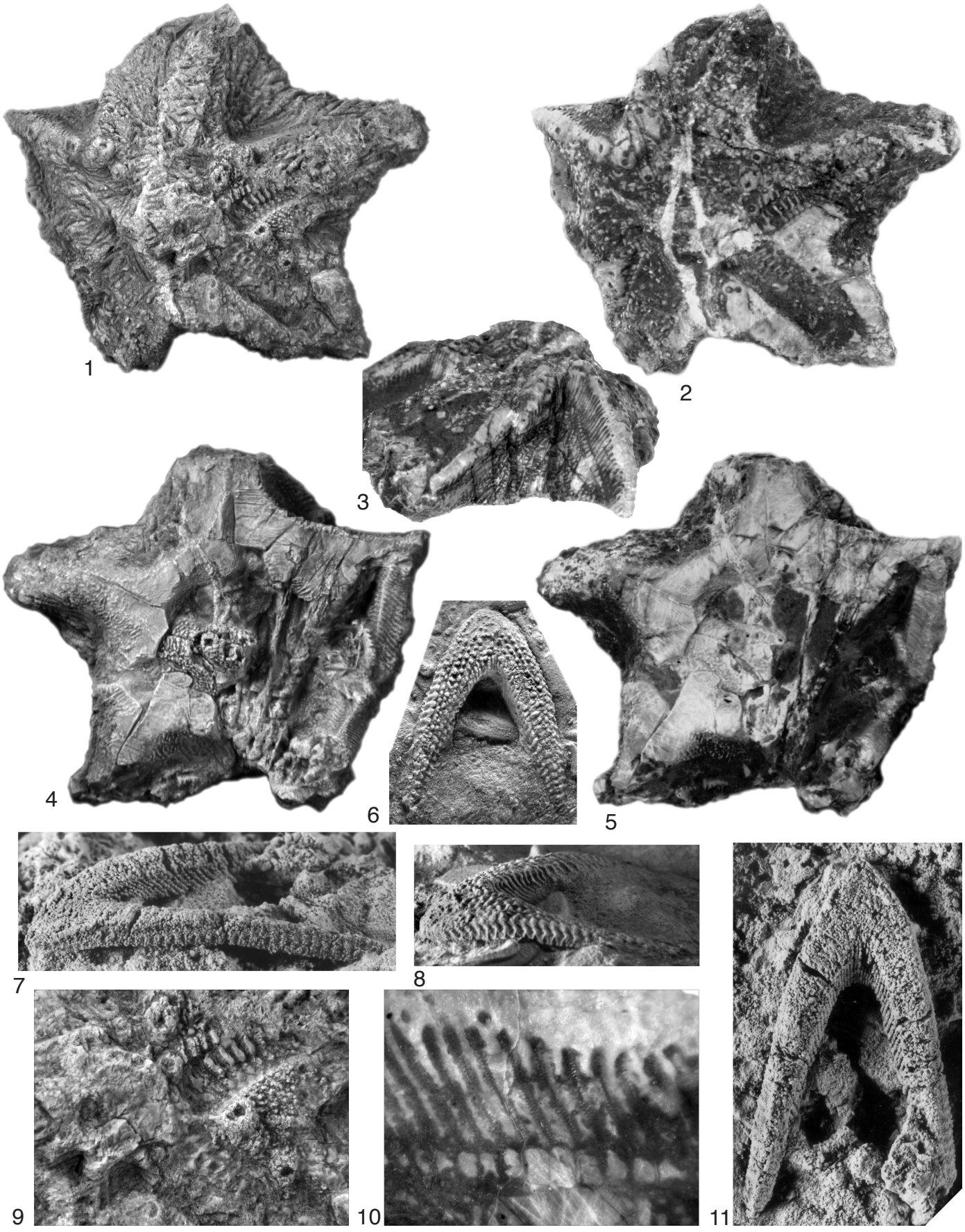

Figure 9. *For explanation, see facing page.*

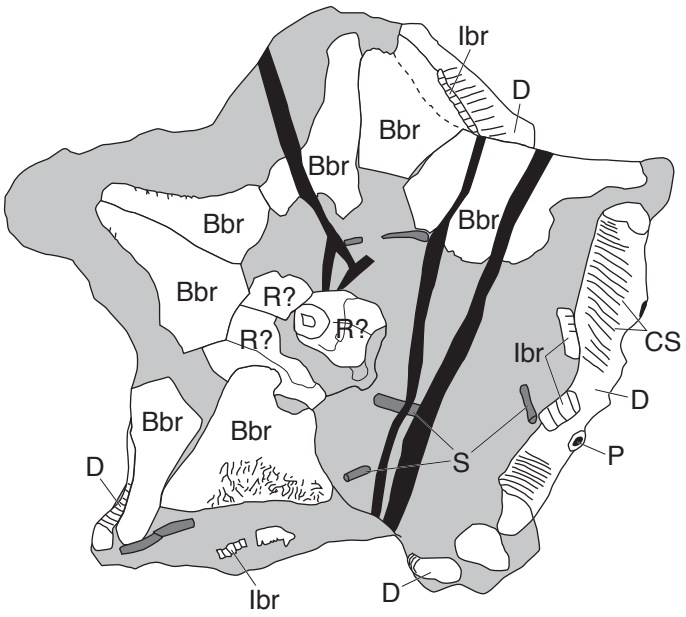

Figure 10. Pelvis plating diagram for complete but badly eroded and crushed plesiotype (1766TX75) of *Parabolablastus elongatus* (Sprinkle) showing very large paired bibrachial plates (*Bbr*) in complete circlet, possible radial plates (*R*) below them, few scattered interbrachial plates (*Ibr*), and lower edges of deltoid plates (*D*) in places showing cataspire slits (*CS*), a few *Tremichnus* pits (*P*), scattered sponge spicules (*S*), and calcite and quartz veins (*black lines*), ×2.5 (new).

related to *Blastoidocrinus* Billings and *Eurekablastus* n. gen., which also have these circlets in the pelvis but accompanied by several other types of plates. *Parabolablastus* does not appear to have a deep basal cavity as in *Blastoidocrinus*, nor a medium-sized, exposed, basal circlet as in *Eurekablastus*, but this area of the theca is very poorly preserved in the single known, crushed theca. *Parabolablastus* appears quite different from *Meristoschisma* Sprinkle, 1973, and *Blastocystis* Jaekel, 1918, which appear to have a circlet of large possible radial plates making up most of the pelvis along with typical triangular deltoids.

PARABOLABLASTUS ELONGATUS (Sprinkle), 1973

Figures 9–10

Blastoidocrinus? sp. 2 Sprinkle, 1971, p. D90, fig. 1,*15*, fig. 2, columns *B–C*.

Blastoidocrinus?? elongatus Sprinkle, 1973, p. 154–155, pl. 37,*19–23*.

Blastoidocrinus(?) sp., cf. *B.?? elongatus* Sprinkle, 1973. Lewis, 1982, p. 254, 275–276, pl. 11,*1–9*; Oil Creek Formation, southern Oklahoma, United States.

Blastoidocrinus? sp. B, Sprinkle and Guensburg, 1997, p. 50, pl. 1, chart C; Kanosh Shale, western Utah, United States.

Diagnosis.—Same as for genus.

Description.—One crushed, eroded, and poorly preserved theca and several isolated deltoid plates, including original holotype and paratype, are known for this taxon; theca domed with convex vault and apparent slightly conical pelvis; star shaped in summit view with elongate radii and deeply concave interradii; complete crushed theca ~42 mm wide, vault height now ~16 mm, but many deltoids tilted, distorted, or broken, original pelvis height unknown but now ~6 mm (Fig. 9.1–9.5).

Pelvis only part originally exposed but poorly known because of crushing and deep weathering; 10 very large paired bibrachials (Bbr) positioned perradially beneath ambulacral tips, forming complete circlet and most of apparent flat base of pelvis plus apparently extending up into vault, no interbrachials (Ibr) seen between or above Bbr in pelvis (but see below), Bbr lower sutures indicate one or more distal circlets of smaller plates, probably radials (possibly interradials), but these plates silicified, crushed into thecal interior, and poorly exposed in center of pelvis (Fig. 10); no basals observed and unknown whether deep basal cavity present.

Crushed specimen had deeply buried vault composed of 5 very large parabolic deltoids (D) separating ambulacra, numerous small interbrachials (Ibr) and apparent upward extensions of the bibrachials from the pelvis within the deltoid limbs, and possibly 5 oral plates (O) around mouth; no oral or ambulacral crests seen. Five deltoids, largest plates in theca, interradial, parabolic, with long, strongly developed limbs ~22.5 mm long and 22 mm wide; cataspire slits numerous, short, along entire inside of parabolic deltoid, inclined toward summit, and diagonal to limb; in best-preserved interray of crushed specimen (Fig. 9.3, 9.10), 33 slits preserved on one deltoid limb, 31+ slits on other limb, for total of 64+ slits spaced ~0.33 mm apart, each slit 2 mm long, ~0.05 mm wide with sawtooth margins in basin 0.2 mm wide (Fig. 9.10), deltoids raised ~0.5 mm above adjacent ambulacra. Separate holotype and paratype deltoids (Fig. 9.6–9.8, 9.11) up to 23 mm long, having limbs that curve inward slightly and diverge at between 35°–45° and having up to 70 short cataspire slits and notches for ambulacral floor plates, indicating approximately 35 floor plates along each adjacent ambulacrum. Ibr in crushed specimen poorly constrained, in best-preserved interray, one row of small rectangular Ibr ~0.7 mm high, positioned directly below most of interior margin of deltoid and aligned with cataspire slits (Fig. 9.10), rest of lower vault apparently filled by recurved upper edges of two adjacent bibrachials from pelvis with slightly offset near-vertical suture between Bbr and labyrinthine ornament near deltoid tips, apparently no additional rows of small or vertically elongate Ibr present below single row, even in center of interray (Fig. 9.3). Orals poorly exposed above deltoids, diamond shaped, keeled, articulated to proximal tip of deltoid, forming interradial edge of peristomal opening; ambulacral cover plates becoming larger up to poorly exposed peristome, but no conical or cylindrical oral crest visible.

Ambulacra at least 19 mm long, straight, and relatively narrow, 4.2 mm wide near top of deltoid in crushed specimen, inset below edge of adjacent deltoid, separated from mouth by medium-sized OO, composed of single floor plates in biseries forming thecal wall (no underlying thecal plates or lancet); floor plates transversely

elongate, 0.75 mm high, ~1.95 mm wide, with side food groove along suture between adjacent plates ~0.25 mm wide; each floor plate bearing transversely elongate ridge, 0.25 mm high separating adjacent side food grooves; brachiole facets positioned along edge of ambulacrum facing slightly proximally, 0.6 mm long, 0.3 mm wide, brachioles unknown except for facet size; cataspire pores small, abradial and slightly below brachiole facets, 0.2 mm long, 0.1 mm wide; main food groove slightly disrupted but also ~0.25 mm wide, cover plates possibly biserial in one place, no crests observed on ambulacra or on peristome (Fig. 9.9).

Ornament on unweathered parts of crushed specimen (deltoids, bibrachials, perhaps radials): coarse pustules and wavy labyrinthine ridges, similar to that originally described on unsilicified paratype deltoid MCZ 611 from same locality (see Sprinkle, 1973).

Stem morphology, length, and likely distal attachment holdfast unknown in this species.

Material and Occurrence.—Holotype deltoid MCZ 610 from the lower Antelope Valley Formation at locality MJ-1, the west-side flank beds beside the large bioherm on the front of Meiklejohn Peak, 11.2 km (7 mi.) east of Beatty, Nye County, southwestern Nevada, western United States; paratype deltoid MCZ 611 from the middle Antelope Valley Formation Sponge Beds at locality IK-3, north side of Ikes Canyon ~0.8 km (0.5 mi.) west of the canyon mouth, central Toquima Range, ~112 km (70 mi.) southwest of Eureka, Nye County, central Nevada, western USA; complete plesiotype specimen TMM 1766T75 from IK-3 (see above); additional plesiotype deltoids TMM 1766TX76 from IK-3 (see above); TMM 1806TX2-7 from near base of Kanosh Shale at Section J, just south of Fossil Mountain, western Ibex area, ~102.4 km (64 mi.) southwest of Delta, Millard County, western Utah, western United States; and TMM 1408TX22-28 from middle Oil Creek Formation, locality I-35S, east-side roadcut of Interstate 35 on south side of Arbuckle Mountains, ~22.4 km (14 mi.) north of Ardmore, Carter County, southern Oklahoma, southwestern United States (Lewis, 1982).

Discussion.—This description of *Parabolablastus elongatus* (Sprinkle) 1973 is primarily based on a large, crushed, badly weathered, partly buried, plesiotype specimen TMM 1766TX75 infested in life with parasitic borings and later cut by calcite and quartz veins. Although collected in 2001 by Sprinkle, the exposed pelvis of this specimen was so badly weathered that it was not even recognized as the first partly complete theca of this taxon until preliminary excavation in 2007 uncovered one of the long, thin, deltoid limbs. Sumrall then spent many hours cleaning matrix off the deeply buried vault of the theca, which had critical information. Approximately two-thirds of the badly crushed vault was eventually uncovered, including portions of the proximal ambulacra and parts of all five deltoids, along with some excellent details of the cataspire slits, plating, and ornament in one interray. Unfortunately, the pelvis was already deeply weathered and partly silicified, so little additional information was recovered from this area by further cleaning.

The biggest surprise produced by this crushed specimen is that the bibrachials and interbrachials are differently arranged in *Parabolablastus* than in any other parablastoid genus. The bibrachials are very large, arranged in a complete circlet occupying nearly two-thirds of the pelvis, and recurved so they extend up into the concave interradial parts of the vault. Lewis (1982, pl. 11,*6–9*) had already figured recurved and elongate bibrachials with this distinctive shape. The interbrachials, which are between the paired bibrachials at the top of the pelvis in other parablastoids, have also been carried up into the vault to form a single elongate row along most of the inside edge of the arc-shaped deltoid. We originally thought the number of rows of interbrachials would be greatly increased to fill this area, but it turned out that only a single row of interbrachials is present in its normal position just below the cataspire slits on the deltoid, and the rest of the area is filled by the expanded bibrachials, which have also been carried up into the vault as the deltoids were arched. Because the vault-pelvis boundary is usually designated as a line through the tips of the ambulacra, the bibrachial occurrence in both the pelvis and vault of this unusual parablastoid is similar to the occurrence of elongate radials in both the pelvis and vault of bud-shaped blastoids (Beaver et al., 1968).

This specimen has an extensive infestation of borings belonging to *Tremichnus* sp. Brett (1985). These parasites produce small-to-medium-sized pits on the thecal surface surrounded by raised reaction rims. *Tremichnus* pits are most common on the upper surface, primarily on the deltoid plates, but are also found on the interbrachials, ambulacral floor plates, and orals (Fig. 9.2, 9.9). Although sponges from the Ikes Canyon locality are often infested with similar parasitic borings, no other echinoderms from this section have been noted with similar parasites, although similar infestations were described in nearly coeval rhipidocystids from northwestern Russia (Rozhnov, 1989).

Similar deltoid plates collected from the Kanosh Shale of western Utah and from the Oil Creek Formation in southern Oklahoma (both of early Whiterockian age) may also belong to *Parabolablastus elongatus* (as indicated above) or may represent additional new species of *Parabolablastus*. Unfortunately, no complete specimens of these possible new species have been found. Ronald D. Lewis (Auburn University) is currently revising the Oil Creek echinoderm fauna that he originally described in his Ph.D. dissertation (Lewis, 1982).

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