



FIGURE 3—Oreasterid sp., compare Figure 1.2; the rounded, unpaired terminal is at the end of the double marginal column, and a row of enlarged radial dorsals is separated from the marginals by a row of laterals, $\times 3$, loc. 86-04, hypotype, USNM 490418.

taxa apparently retreating to deeper habitats through time. Many deep-water asteroids (e.g., Pterasteridae, Brisingsida) are of delicate construction, and the contrasting sturdy arrangement of *Zoroaster* is consistent with origins in shallow, perhaps more turbulent settings.

A particularly tantalizing La Meseta fossil is the small oreasterid arm tip (Figures 2.1, 2.2, 3). Oreasterids today are found in shallow, warm-water environments, and not in the Southern Ocean, indicating a retreat from this region as temperatures declined in the Cenozoic.

The Seymour Island ophiuroid.—Only one ophiuroid species, *Ophiura hendleri*, is now known from the La Meseta Formation, although specimens are quite common. The lack of diversity seems surprising given the richness of La Meseta invertebrate faunas in general and presence of multiple ophiuroid species in many living faunas. Low apparent diversity might result in part from taphonomic changes. The taxonomy of living ophiuroids stresses plate arrangement and spine development, but recrystallization and compaction of the sandy La Meseta sediments disrupted and obscured tiny ophiuran plates. Nevertheless, all known La Meseta specimens are either clearly *O. hendleri* or so poorly preserved as to be of uncertain affinities beyond the class or family level.

Ophiura hendleri occurs as the isolated specimen or in small groups, including beneath the protective cover of molluscan shells (Figure 7.4), but most striking are the beds of ophiuroids covering areas up to an estimated 40 m² and 10 cm in thickness (Figure 7.2, 7.3, 7.6). Ophiuroid beds are more common in Paleozoic rocks (Aronson, 1987, 1991), and those of the La Meseta appear to represent local and brief reversion to Paleozoic conditions (Aronson et al., 1997). Most ophiuroids employ multiple feeding mechanisms (Warner, 1982) and *Ophiura sarsii*, living in dense populations off North Carolina at depths of 450 m, is both a suspension-feeder and a deposit-feeder (RBA, observations from the *Johnson Sea-Link* submersible, 1991–1992). *Ophiura hendleri* plausibly also was capable of a range of feeding habits.

SYSTEMATIC PALEONTOLOGY

Cladistic studies of living stelleroid genera are not currently available and therefore summary diagnoses below are traditional in structure, treating both overall form and potential unique characters. *Buterminaster elegans* Blake and Zinsmeister, 1988,

(Goniasteridae) is not discussed below, although it is a La Meseta taxon. Expanded locality data are provided in the appendix.

Class ASTEROIDEA de Blainville, 1830
Order VALVATIDA Perrier, 1884
Superorder VALVATACEA Blake, 1987
Family GONIASTERIDAE Forbes, 1841
Genus PARAGONASTER Sladen, 1889

Type species.—*Paragonaster ctenipes*, Sladen, 1889, by subsequent designation in Fisher (1919), see A. M. Clark (1993).

Summary diagnosis.—Five-armed genus of the Goniasteridae; interbrachial angles flattened to broadly rounded, arms attenuated, long, slender. Abactinal ossicles paxilliform, rows of abactinals declining in number more or less abruptly at base of arm, single row of abactinals extending from base of arm to terminal. Marginals numerous, rounded in both lateral and transverse profiles. Adambulacral furrow margin angular, furrow not tightly closed by ossicles; apical oral spine unpaired. Dorsal surface primary ossicles closely covered by granules, ventral surface ossicles with short spines; no enlarged spines or pedicellariae. (Modified from A. M. Clark and Downey, 1992).

PARAGONASTER CLARKAE new species
Figure 2.3–2.12

Diagnosis.—Species of *Paragonaster*; form robust, ossicles stout. Short spines on supermarginals; abactinal ossicles with closely appressed accessory spinelets.

Description.—Flattened, five-armed goniasterid; form dominated by stout marginals, broadly rounded interbrachial angles, sharply tapering arms. Radius estimated 90 mm in specimen of r approximately 30 mm, R/r approximately 3:1.

Abactinal ossicles of disk paxilliform, stout, closely appressed, covered with approximately 15 closely spaced granules; granules similar over entire dorsal surface. Radial series becoming differentiated as marginal series converge at base of arm. Proximal radials slightly wider than long, then approximately square, then longer than wide; distal radials very narrow, elongate, so that marginals nearly meet at arm midline, but radial series not known to terminate on arm. Madreporite not recognized.

Marginal series robust, dominating arm margin; ossicles of two series paired, nearly flat-sided except for low ridge near ossicular edges; ossicles vertically elongate, lateral outlines nearly rectangular. Interbrachial supermarginals somewhat wider than long; medial, distal supermarginals distinctly so. Interbrachial inferomarginals distinctly higher than corresponding supermarginals, becoming equisized at base of arms; supermarginals distinctly larger than inferomarginals on most of arm. Supermarginals of disk, proximal portion of arm angular in cross section; proximal arm supermarginals with circular spine base; supermarginals of arm more rounded, surface covered by granules. Inferomarginals rounded, spines apparently lacking; inferomarginals granulated near dorsal-lateral edge, accessories grading to spinelets on ventral surface of ossicles.

Actinals in about three series, perhaps 10 ossicles present in row adjacent to adambulacral row, actinal row terminates on arm near disk. Actinals angular, accessory spinelets present. Adambulacral robust, longer than wide, longitudinal muscle depressions robust, furrow margins angular, outer face flat; armature includes short spinelets. Adambulacral of distal portion of disk and arms, robust, elongate. Ambulacral body elongate, triangular; cross-furrow articular processes vertical; four proximalmost ambulacral foreshortened. Terminal unknown. First ambulacral body rectangular, very stout; other ossicles of oral frame unknown.

Comparisons.—*Paragonaster clarkae* can be separated from

other species of *Paragonaster* based on the presence of superomarginal spines. The robust form is most like that of *P. grandis*, although it differs from this species based on the presence of closely appressed granules. Other species generally are of more delicate form, with apparently longer, more slender arms and a correlated more flattened interbrachial profile. In the other species, the lateral abactinal ossicles terminate closer to the arm base. Living *Paragonaster* is widely distributed in the world's oceans, but this is its first occurrence from the Antarctic.

Etymology.—The species is named in honor of Ailsa M. Clark.

Material.—Fragments and one nearly complete specimen from 94-3; 35 fragments were from the channel deposit at that locality, and they are poorly preserved, whereas 20 better-preserved fragments are from a thinly bedded interval at the same locality; many of the fragments probably were derived from a single specimen. Holotype, USNM 490423, paratype suite 490426, from the channel; paratypes USNM 490419–490422, 490424, paratype suite 490425 from the thinly bedded interval. Arm fragment paratype 490427, locality 86-4; four arm and disk fragments, paratype suite 490428, locality 94.3.

Genus TESSELLASTER H. L. Clark, 1941

Type species.—*Tesselaster notabilis* H. L. Clark, 1941, by original designation.

Summary diagnosis.—Five-armed genus of the Goniasteridae; interbrachial angles broadly rounded, arms triangular, attenuated. Abactinal ossicles flattened, polygonal, covered by granules, rows of abactinals declining more or less abruptly at arm base, with single row of rectangular abactinals extending to about midarm position before terminating in at least *T. notabilis*; superomarginals abut across arm axis from that point to terminal. Marginals numerous, ossicular outlines in vertical section of both series square interbrachially becoming rectangular on arms; marginals partially bare, granules inset, clustered in groups; actinals numerous, granulate. Edge of ambulacral furrow angular, furrow not tightly closed by ossicles; apical oral spine present on each mouth angle ossicle. No enlarged spines or pedicellariae. (Modified from A. M. Clark and Downey, 1992).

TESSELLASTER CLARKI new species

Figure 4.1–4.5

Diagnosis.—Species of *Tesselaster* with bulbous marginals, comparatively few marginal granules; adambulacrals foreshortened; adambulacrals, actinal ossicles both with cylindrical spines.

Description.—Flattened, five-armed goniasterid; marginals moderately large, interbrachial angles broadly rounded, arms apparently tapering sharply; arm radius unknown, disk radius approximately 15 mm in available specimens.

Abactinal area rather abruptly reduced to single radial series on arms (most of arms missing in available specimens, therefore persistence of radials uncertain); radials angular, varied in shape, closely spaced, tabulate, subcircular, domed; disk radials somewhat enlarged; abactinals generally uniform, diminishing in size toward radial interbrachial area, although some smaller ossicles present especially near midarm area; ossicles covered by granules. Madreporite small, near disk center.

Marginals robust, dominating arm margin; ossicles of two series paired, nearly flatsided, weakly cuneate on disk becoming rectangular on proximal portion of arm. Lateral ossicular outlines nearly rectangular; marginals of both series somewhat wider than long more distally on arm; outer faces domed, cross sectional profile rounded, margins bordered by granules, with few granules impressed onto otherwise bare surface; enlarged spines lacking. Actinals robust, in three or four rows, closely

spaced, appearing somewhat irregular in form, bearing short, columnar spinelets.

Adambulacrals foreshortened, apparently more or less upright in furrow, closely spaced, with two? short, stout, columnar spines. Oral frame ossicles probably fairly small; mouth ambulacral ossicles smaller than immediately adjacent adambulacrals; other ossicles of oral frame unknown.

Comparisons.—Many genera of the Goniasteridae, including *Tesselaster*, share a suite of distinctive characters including overall outline with a flattened dorsal surface; tabular, closely spaced abactinal ossicles, and robust, blocklike marginal ossicles. Arms are comparatively slender in many genera of the Goniasteridae, but in most (e.g., *Pseudarchaster*), several rows of abactinals extend most of the length of the arm. Among those with abactinals extending to the tip, *Ogmaster*, *Stellaster* and *Anthenoides* have a more or less thickened dermal layer and reduced granules; the tissue would not be preserved in the fossil, but the presence of abactinal and intermarginal granules demonstrates the absence of these tissues in life. *Rosaster*, *Nymphaster*, *Paragonaster*, and *Tesselaster* all possess narrow arms. In both *Rosaster* and *Nymphaster*, only radials extend from the disk onto the arms; in both, granules cover the superomarginals, and abactinals are more nearly paxillate in *Nymphaster*. Abactinals other than radials also terminate at the base of the arms in *Lithosoma*, as well as in a number of other genera in which abactinals are typically quite flat. In these genera, granules surround the ossicular edges but they are not present on dorsal surfaces.

In the living *Tesselaster notabilis*, many rows of abactinals terminate near the base of the arm, and a single series of radials extends to the midarm position. The series becomes disjunct before terminating. Unfortunately, only proximal portions of the arms are known from both available fossil specimens, but the thickened, tabular abactinal form, becoming rectangular in arm radials, is an important similarity between the fossils and *T. notabilis*; in addition, abactinals in both species are covered by closely spaced granules. Marginals in both are approximately square in outline, with granules along the ossicular edges and impressed into the surface in patches.

Tesselaster notabilis and *T. clarki* are readily distinguishable in that the adambulacrals are foreshortened in *T. clarki*, and they bear robust cylindrical furrow spines; similar spines are found on the actinals. In *T. notabilis*, adambulacrals are elongate, and adambulacral furrow spines are flattened and somewhat delicate. Subambulacral and actinal accessory ossicles are granules rather than true spines. Marginals are comparatively bulbous in *T. clarki*, and inferomarginal granules are more sparsely developed. In spite of these differences, the strong similarities of form, abactinal, and marginal development justifies inclusion of the new species in *Tesselaster*.

Etymology.—The species is named in honor of Hubert L. Clark.

Material.—Two incomplete specimens, both from 86-5. Holotype, USNM 490429, R approximately 13 mm; the ventral surface of the specimen is somewhat obscured by sediment. Paratype, USNM 490430, R approximately 17 mm; the specimen is largely wind-abraded, obscuring surface details but exposing ossicular arrangements and proportions.

Family OREASTERIDAE Fisher, 1911

genus and species unknown

Figures 2.1, 2.2, 3

Description.—Curled arm tip approximately 22 mm in length, 12 mm in breadth at proximal end; tip bulbous, arm bottom flattened, tip cross section approximately triangular. Dorsal surface of tip arched, abactinal radial series enlarged, ossicles