TAXONOMY AND MORPHOLOGY OF ECHINODERMATA FROM THE APTIAN OF ALEXANDER ISLAND

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ABSTRACT. The Aptian of Alexander Island includes several stratigraphically important echinoderm horizons. Two new species, *Isocrinus aptiensis* and *Ophiura paragraysonensis*, are described from an assemblage zone of crinoids, ophiuroids and rhabdocidaroid spines. (?)*Hemipedina* is associated with the lamellibranch (?)*Parallelodon* and several ophiuroids in two marker horizons, and larger subconical irregular echinoids identified as (?)*Anorthopygus* occur below the lower of these two marker horizons. The irregular echinoid (?)*Epiaster* forms two key horizons. The frequent occurrence of echinoderms in concentrations in the stratigraphical succession could indicate original gregarious communities.

THE only echinoderms previously recorded from the Antarctic Peninsula were collected from the (?)Miocene marine tuffs of the Hidden Lake area, James Ross Island, north-east Graham Land (Bibby, 1966). Between 20 and 30 moulds of stelleroids (probably ophiuroids) were found on a large slab of fine-grained sandstone, but they have not yet been identified.

In the (?)Upper Aptian sediments of the east coast of Alexander Island there are five stratigraphically important echinoderm marker horizons which have yielded many of the fossils described and figured here. At Succession Cliffs (Figs. 1 and 2, locality B), upper and lower (?)*Epiaster* biozones which are 179 and 20 ft. (54·5 and 6·1 m.) thick, respectively, have proved useful in correlating the stratigraphy of localities B and C (Figs. 2, 3 and 5). The third marker horizon, a 15 ft. (4·6 m.) thick assemblage zone* with numerous crinoids, ophiuroids and rhabdocidaroid spines, has been used to correlate Mount Ariel with localities E, F and G (Figs. 3 and 5). At Fossil Bluff, Mount Ariel and locality H (Figs. 3 and 4), upper and lower assemblage zones comprising (?)*Hemipedina* and (?)*Parallelodon* have been used for correlation between these three localities (Fig. 5). (?)*Anorthopygus* is present in beds 60 ft. (18·3 m.) below the lower assemblage zone.

The upper and lower limits of these faunal marker horizons are not always easy to define in the field, because the characteristic fossils are abundant in some beds in the sequence but relatively rare elsewhere. For example, in the lower of the two (?)*Hemipedina*/(?)*Parallelodon* assemblage zones at Fossil Bluff, (?)*Hemipedina* occurs in 100 ft. (30·5 m.) of strata, although the echinoid is most numerous in a 10 ft. (3·0 m.) bed in the middle of the sequence.

The articulate preservation of many of the ophiuroids and crinoids in the assemblage zone at locality G suggests quiet-water marine sedimentation conditions and rapid burial.

CRINOIDEA

Crinoids are poorly represented in the Cretaceous of the Southern Hemisphere. Only two species, *Isocrinus australis* Moore and *Isocrinus parvus* Howchin, have been described from the Cretaceous of Australia (Howchin, 1921) and South American Mesozoic crinoids are usually referred to as *Pentacrinus* sp. Because crinoids are few in number and often poorly preserved, it is especially interesting to discover that they are relatively abundant in the Aptian of Alexander Island where several specimens have almost complete crowns. Although much of the calcite has been removed in solution, latex casts have been made from the natural moulds. On the basis of several dozen specimens collected from a number of localities on the east coast of Alexander Island, a new species *Isocrinus aptiensis* is described.

Most of the crinoids from Alexander Island were collected from locality G (Figs. 1 and 3), where the crinoid/ophiuroid/rhabdocidaroid assemblage zone is well exposed. Large areas of bedding plane are exposed and many of the crinoids and ophiuroids are articulated. The majority of the crinoids consist of a crown and the proximal columnals of a stem. The specimens are relatively small and the average height of the crown is 35 mm. The relative proportions

* A biostratigraphic unit defined and identified by a group of associated fossils rather than by a single index fossil.

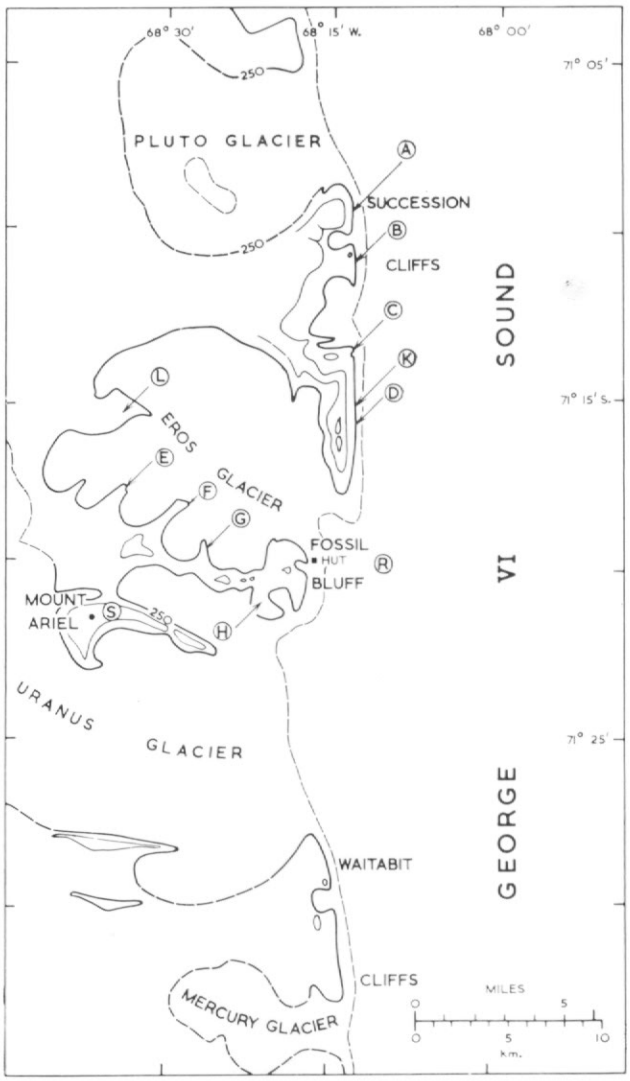

Fig. 1. Sketch map of part of the central east coast of Alexander Island, showing the localities where fossil echinoderms have been collected.

of crown to column in these small crinoids is indicated by a specimen (KG.1.959) collected by W. O. Tracy from Fossil Bluff.

Another much larger crinoid is indicated by some isotomous arms and fragmentary columns. The arms, which are at least 10 cm. in length, were collected by J. P. Smith from Fossil Bluff while the stem fragments were obtained from locality H. It is not known whether the two sizes of crinoid represent separate species.

A crinoid biozone, 50 ft. (15·2 m.) thick, containing small concentrations of stems and ossicles has been used for stratigraphic correlation between localities H and N.

The Isocrinoidae, which range from Triassic to Recent, include the fossil genera *Isocrinus*, *Cainocrinus*, *Balanocrinus* and *Austinocrinus*, and such living representatives as *Annacrinus*, *Neocrinus* and *Hypalocrinus*. In most genera the infrabasals cannot be seen and the basals,

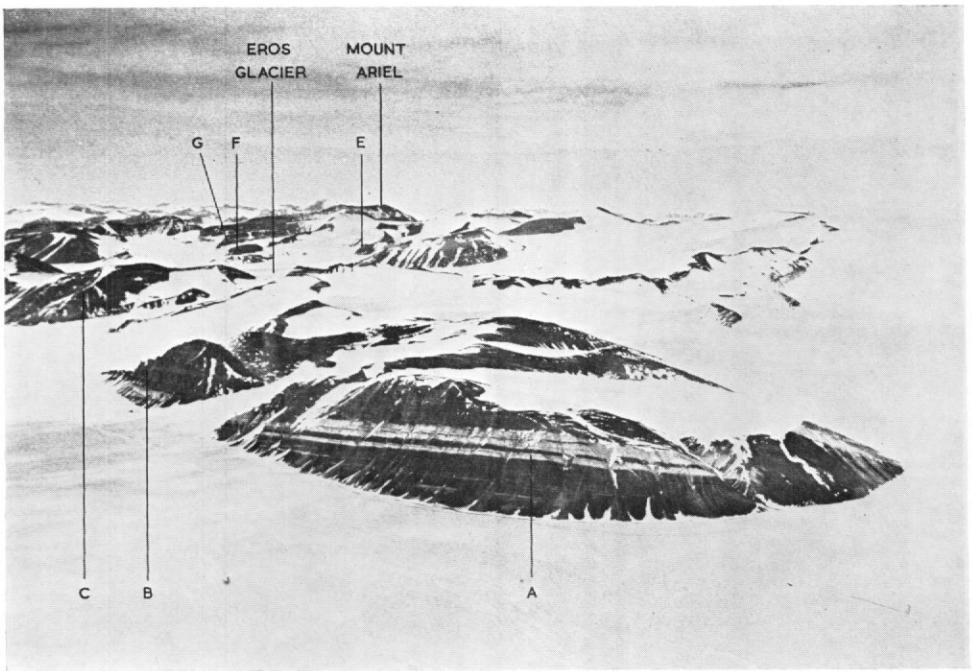

Fig. 2. An air photograph looking south-westward across the central east coast of Alexander Island from a position north-east of the northern block of Succession Cliffs (the block in the foreground). The annotation of the photograph corresponds to the localities given in Fig. 1.

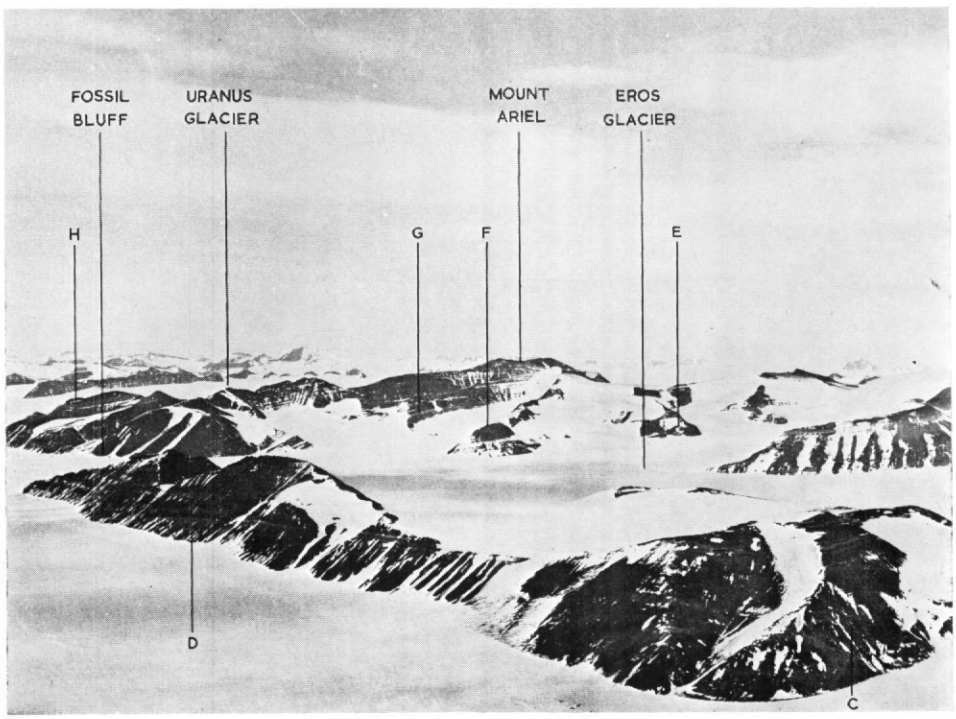

Fig. 3. An air photograph looking south-westward across the central east coast of Alexander Island from a position east of the southern block of Succession Cliffs. The annotation of the photograph corresponds to the localities given in Fig. 1.

Fig. 4. An air photograph looking westward at Fossil Bluff, Alexander Island.

which are often small, are separated externally by prominent radials which may extend to the uppermost columnals. The arms are isotomously branched and pinnulate except for the proximal brachials. The columnals are stellate, pentagonal, quinquelobate or circular in plan view and the cirri are arranged alternately or in whorls of five (Moore and Vokes, 1953, p. 122).

ORDER PENTACRINOIDEA
FAMILY ISOCRINOIDAE GISLÉN

Genus *Isocrinus* von Meyer
Type species: *Isocrinus pendulus* von Meyer
Isocrinus aptiensis sp. nov.
Figs. 6a, b, d, f

Material

The holotype (KG.5.3; Fig. 6a) was collected from the crinoid/ophiuroid/rhabdocidaroid assemblage zone at locality G. The specimen, which is preserved in a dark grey siltstone or sub-greywacke, is a natural mould consisting of an incomplete crown and the attached proximal part of a stem. The stem, which is crossed by several cirri, supports a small calyx 4 mm. wide at its distal end, and seven isotomously branched arms. The height of the crown is 27 mm. There are only a few pinnules and several of them are disjointed. The orientation of the calyx has not been determined.

The majority of the paratypes were collected from the assemblage zone at locality G, where natural moulds comprising a crown and the proximal columnals of a stem are relatively abundant (KG.5.1, 2, 4, 5, 21). The most complete crinoid (KG.1.959), which was collected by W. O. Tracy from Fossil Bluff, comprises an incomplete crown (35 mm. high) and a cirrate stem (42 mm. long). Some of the original calcite is preserved. Additional stem fragments were collected from locality H.

Diagnosis

Dorsal cup two to three times the width of the column. Secundibrachs 13 to 15 in number. Linguiform syzygial union between II Br_{3+4} and III Br_{2+3}. Re-entrants of columns accentuated by radial pores.

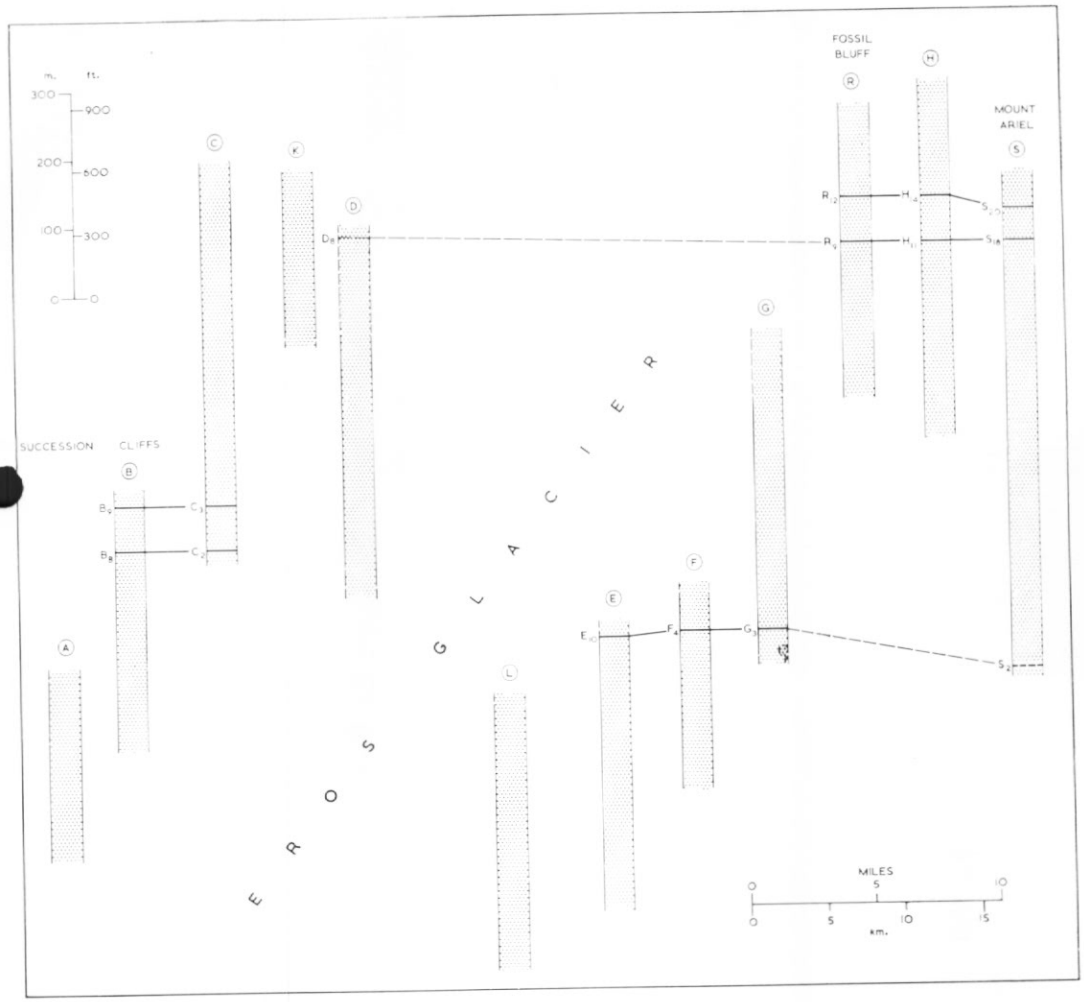

Fig. 5. Diagrammatic representation of the lateral distribution of marker horizons used in correlating the (?)Upper Aptian succession on the central east coast of Alexander Island. The marker horizons are indicated by a locality letter (Fig. 1) together with a subscript figure. For this purpose Fossil Bluff is locality R and Mount Ariel is locality S.

Description

Dorsal cup. The dorsal cup is a discoidal shell two or three times the width of the stem. In the holotype (KG.5.3) the basal plates cannot be seen but in the paratypes (KG.5.1, 4) basal plates are visible. In specimen KG.5.4 there is a small, bulbous basal plate which is surrounded on two sides by proximal extensions of the radials. This plate is rhomboidal in outline and has a relatively straight basal margin (Fig. 6b). In specimen KG.5.1 the two exposed basal plates are small and bulbous and their under surfaces are notched. The plates rest directly on the stem. The radials are rectangular in outline and laterally in contact with one another. In side view they are usually concave with slightly bulbous distal and proximal margins. The articular facet of one of the radials of specimen KG.5.4 is exposed as a fairly deep cavity.

Arms. There is a rectangular proximal *primibrach* and a pentagonal axillary to each ray. The distal facets of the axillary differ slightly in their shape and inclination but they support isotomous branches.

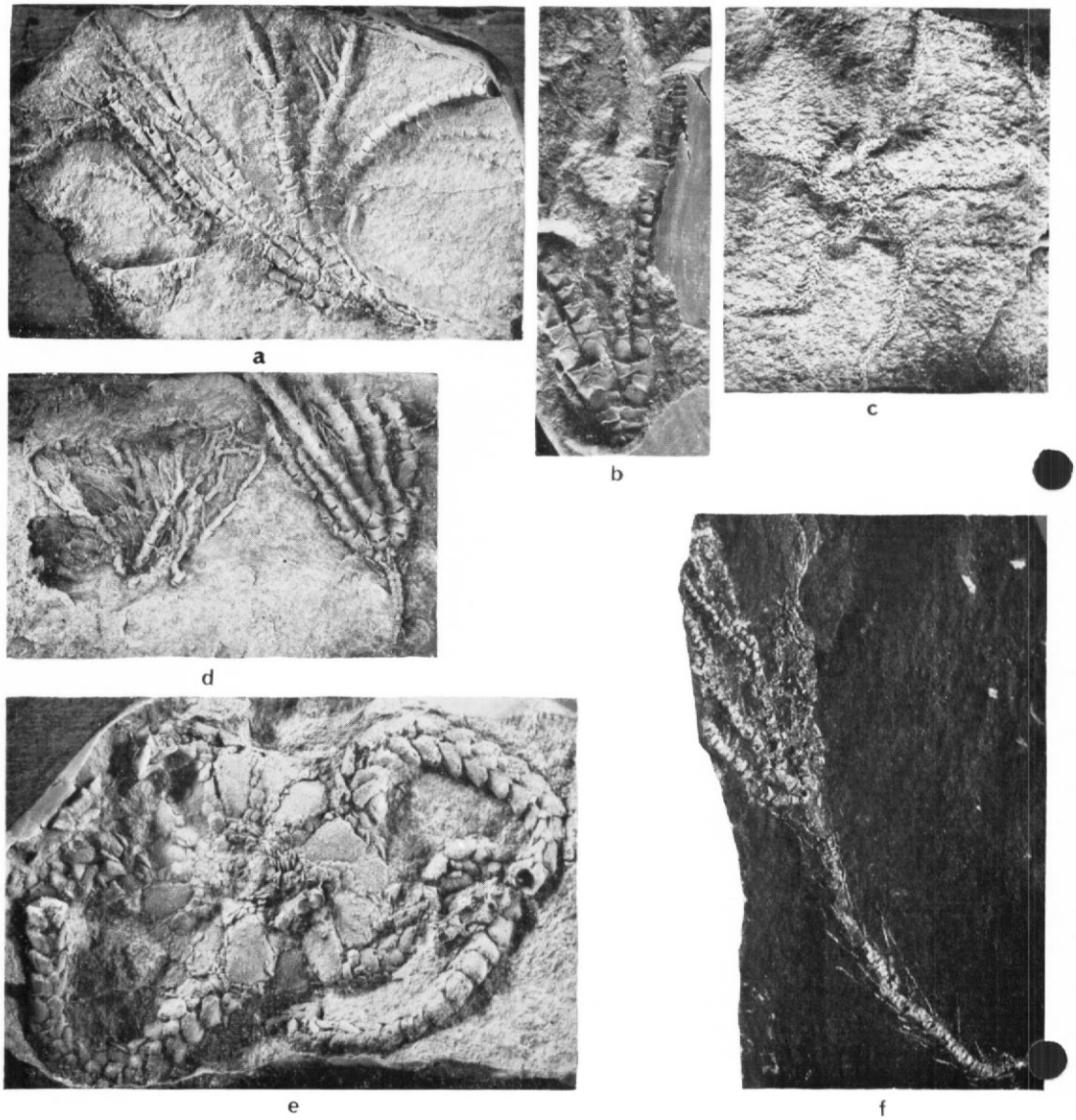

Fig. 6. a. A latex cast from the natural mould of *Isocrinus aptiensis* sp. nov. (holotype); ×2, coated. (KG.5.3)
b. A plasticine cast from the natural mould of *Isocrinus aptiensis* sp. nov. (paratype); ×1·3. (KG.5.4)
c. A latex cast from the natural ventral (oral) mould of *Ophiura paragraysonensis* sp. nov. (paratype); ×2, coated. (KG.5.20)
d. A latex cast from the natural mould of *Isocrinus aptiensis* sp. nov. (paratype); ×2, coated. (KG.5.1)
e. A latex cast from the natural dorsal (aboral) mould of *Ophiura paragraysonensis* sp. nov. (holotype); ×3·3, coated. (KG.5.15)
f. A natural specimen of *Isocrinus aptiensis* sp. nov. (paratype); ×1. (KG.1.959)

Each branch is composed of between 13 and 15 wedge-shaped *secundibrachs*. Although the outside margin of the first brachial is longer than the inside margin, the difference is not sufficiently great to compensate for the strongly inclined attitude of the underlying axillary facets, and therefore the distal articular facets of the first brachial slope towards the outside

of the ray. However, the second brachial is a larger plate and, as its outside margin is proportionately longer, the distal articular facet of the plate is inclined towards the inside of the ray.

The third brachial (which is also the largest plate) and the fourth together form a syzygial pair. The articular facet of the third secundibrach is linguiform in outline with an overlapping distal edge that partly conceals a row of radiating crenellae. The junction is clearly seen in paratypes KG.5.1 and 4 (Figs. 6d and b). No pinnules are given off by either brachial. The remaining secundibrachs, which are unequal in size, were probably joined by muscles. Many of the hollows between the brachials are striated. In side view the secundibrachs are concave inwards with slightly protruding distal margins. A number of jointed pinnules are given off from the secundibrachs, some of the pinnules lying close to the arms whereas others diverge widely. The distal facets of the second axillaries are almost equal in size and in inclination, supporting isotomous arms.

There are at least 15 *tertibrachs*. These brachials, which are smaller than the secundibrachs, are joined syzygially at the second and third brachials (as opposed to the third and fourth secundibrachs). The articular facet of the second tertibrach is linguiform with an overlapping distal edge partially concealing a row of radiating crenellae. Several of the tertibrachs are pinnulate.

Column. Much of the information regarding the column has been obtained from paratype KG.1.959 and from more fragmentary columns collected at Fossil Bluff (KG.1.329, 330, 331) and locality H (KG.2.177, 178, 179). Two sizes of crinoid are indicated by the two sizes of column recorded. The smaller crinoids include the holotype and the paratypes collected from locality G and Fossil Bluff (KG.1.959; Fig. 6f). Much larger crinoids are indicated at Fossil Bluff by isotomous arms at least 10 cm. in length (KG.1.846), and at locality H and Fossil Bluff by columnals 9 mm. in diameter.

Although paratype KG.1.959 is incomplete, it is evident that the column of *Isocrinus aptiensis* is at least half the length of the crinoid. The column is slender (just over 1 mm. wide) and cirrate, most of the cirri lying close to the sides of the column. Since the column can be seen only in longitudinal section, its shape in cross-section is not known although it is presumed to be stellate. The number of internodals cannot be determined.

The broader columnals from Fossil Bluff and locality H are stellate in cross-section with five sharply pointed angles and five re-entrants. As only a few columnals are joined together, it is difficult to estimate the number of internodals for any given length of stem but one specimen (KG.1.330) from Fossil Bluff has seven internodals. Although these stem fragments are relatively straight-sided and of uniform width, there are perceptible differences in the thickness of the internodals and even slight differences in the profiles of their sides.

The nodals are distinguished from the internodals by five elliptical cirral sockets in the re-entrants and an almost planar distal articular surface. The sockets, which represent attachment areas for whorls of erect cirri, are at an acute angle to the long axis of the column; they are concave ellipses with a raised outer rim and an eccentric perforation. Some, if not all, of the cirral sockets are divided by a ridge into two unequal halves. The ridge, which may be bulbous at either end, falls short of the outer rim. The sockets are without radiating crenellae.

The proximal articular surface of a nodal is similar to that of an internodal with strong crenulations surrounding five petaloid ligament areas. However, the distal (lower) articular surface is nearly planar. Because the internodals vary in size, there is no clear size difference between nodals and internodals.

Five radially arranged and gently hollowed smooth-floored petaloid ligament areas characterize the articular faces of the internodals (apart from the proximal surfaces of the hypozygals). Crenellae arranged normal to these areas define the peripheries of the ligament areas, the amplitude of the crenellae decreasing towards the lumen. The lumen is small, circular and centrally located. Articular sutures radiating outwards from the lumen to meet the re-entrants define pentameres similar to those recorded in Palaeozoic crinoids (Moore and Vokes, 1953, p. 134). The fourth internodal, i.e. the first-order internodal, is the largest and the second and sixth (second order) are next in size. The four remaining internodals comprising the third order are the smallest. There are radial pores in the re-entrant angles.

Cirri. The cirri, which are arranged in whorls of five, are erect and taper evenly to a point. They are circular or elliptical in cross-section. The first cirral segment is short and tabular,

but the second is short and squarish; the other cirrals are much longer segments and they are joined by simple concave sutures.

Discussion

Two sizes of crinoid, a large and a small form, are present in the (?)Upper Aptian of the east coast of Alexander Island. The smaller crinoid species is described as *Isocrinus aptiensis*, whereas the larger one may either be conspecific with *I. aptiensis* or a separate species. The column of the larger crinoid is considered to be similar to that of *I. aptiensis* and it is described as such.

Although many of the small crinoids collected from locality G were found to be abundant on the same bedding plane, morphological differences in the shape and arrangement of the basal and radial plates suggest that the crinoids may not represent a biocoenosis. In specimen KG.5.4 a rhomboidal basal plate is sandwiched between proximal extensions of the radials, whereas in specimen KG.5.1 the basals are globular and situated below the radials (Fig. 6d). In side view the radials of some crinoids are moderately concave, whereas in others they are planar; similarly, proximal and distal margins of radials may be either bulbous or sharp.

Although the crinoids from Alexander Island share affinities with several described species, there are certain differences which have been accorded specific status. Many of the comparable crinoids are from North America.

The species *I. californicus* Clark from the Upper Triassic rocks of California is based on several isolated column fragments. Although these column fragments are very similar to those collected from Fossil Bluff and locality H on the east coast of Alexander Island, *I. californicus* and *I. aptiensis* cannot be compared satisfactorily because the holotype of *I. californicus* lacks a crown.

Specimens of *Isocrinus wyomingensis* Koch from the Sundane Formation (Upper Jurassic) of Wyoming differ from the Alexander Island crinoids in the following ways:

i. The basal plates of *I. wyomingensis* are triangular and usually protrude beyond the radials, whereas those of *I. aptiensis* are globular and rhomboidal, and either protrude beyond the radials or are located in the same plane.
ii. In side view the radials of *I. wyomingensis* are strongly convex longitudinally, whereas those of *I. aptiensis* are usually concave.
iii. The lumen of *I. wyomingensis* is pentagonal rather than circular.
iv. The nodals of *I. wyomingensis* have crenulate instead of planar distal surfaces.

In the Upper Jurassic *Isocrinus knighti* Springer the basals are within the plane of the radials and are in contact laterally; mature parts of the stem are pentagonal rather than stellate. *I. knighti* may have up to 14 internodals whereas *I. aptiensis* is believed to have seven. The lumen of *I. knighti* is small and obtusely pentagonal, and the basals are equal in height and flush with the radials.

In *Pentacrinus whitei* Clark the columnals are described as pentagonal, although illustrations suggest that they would be more accurately described as stellate. The crenellae of the petaloid ligament areas extend closer to the lumen than in *I. aptiensis* and the ligament areas themselves are more narrowly elliptical (Clark, 1893). Moore and Vokes (1953) and Koch (1962) consider that *Pentacrinus whitei* properly belongs to *Isocrinus*.

The two species from the Cretaceous of Australia, *I. australis* Moore and *I. parvus* Howchin, are incomplete and poorly preserved. *I. parvus* affords "only scant data for specific determination" (Howchin, 1921, p. 3) for both the dorsal cup and the column are unknown; *I. australis* is described in such vague terms that it also cannot be used for comparison. *I. parvus* is distinguished from *I. australis* only by virtue of its smaller size.

Two Lower Tertiary (Oligocene) crinoids, *I. oregonensis* Moore and Vokes and *I. nehalemensis* Moore and Vokes, have been described in detail (Moore and Vokes, 1953). *I. oregonensis* differs from *I. aptiensis* in the following ways:

i. Six or seven secundibrachs as opposed to 13 or 15.
ii. A straight syzygial union between II Br_{3+4} and III Br_{2+3} rather than a linguiform junction.
iii. No radial pores.

I. nehalemensis, which is more akin to *I. aptiensis* than *I. oregonensis*, differs from the Alexander Island species on the following characters:

i. In side view the radials of *I. nehalemensis* are convex whereas those of *I. aptiensis* are concave.
ii. The basals of *I. nehalemensis* occasionally project downwards as bluntly rounded spines.
iii. The column of *I. nehalemensis* is straight-sided whereas that of *I. aptiensis* is crenulate.

Ophiuroidea

Lower Cretaceous ophiuroids have been described from only three localities. A solitary articulated specimen of *Ophiura* sp. from the Old Crow area of northern Yukon Territory probably represents the earliest known Cretaceous ophiuroid, because the sediments in which it occurs are either Berriasian or Valanginian (Corgan, 1962). Two ophiuroids, *Ophiura texana* Clark and *Ophiura graysonensis* Alexander, have been described from the Cretaceous Weno Clay and Grayson Marl, respectively, of Texas. *Ophiura texana* is Lower Cretaceous in age but *Ophiura graysonensis* may be either Lower or Upper Cretaceous. *Ophiocantha fosteri* Chapman occurs in the (?)Lower Cretaceous of Queensland, Australia.

The majority of the 27 ophiuroids from Alexander Island were collected from the crinoid/ophiuroid/rhabdocidaroid assemblage zone at locality G, where ophiuroids and crinoids occur together in abundance. Many of the ophiuroids are articulated. Although most of the ophiuroids have rounded discs, a few have pentagonal to sub-rounded discs. It is not known whether these two distinct disc shapes represent separate species or different views of the same ophiuroid. Much of the original calcite has been dissolved away and latex casts have been made from the natural moulds. On the basis of these 27 specimens a new species *Ophiura paragraysonensis* is described.

Order Chilophiurida
Family Ophiolepididae

Genus *Ophiura* Lamark
Type species: *Ophiura serrata* Roemer
Ophiura paragraysonensis sp. nov.
Figs. 6c, e

Material

The holotype (KG.5.15; Fig. 6e) was collected from the crinoid/ophiuroid/rhabdocidaroid assemblage zone at locality G. This specimen, which is preserved in a dark grey siltstone or sub-greywacke, is an articulated aboral mould comprising a rounded disc (11·5 mm. in diameter) and five fragmentary arms. The scalation of the disc can be clearly seen.

The majority of the paratypes were found in the same stratum. Although numbers of these are articulated, all but two (KG.5.20, 23) are poorly preserved. Specimen KG.5.20 (Fig. 6c) is an articulated oral mould with a pentagonal to sub-rounded disc. Further ophiuroids were collected from Fossil Bluff and Mount Ariel.

Diagnosis

Large lateral shields and small triangular dorsals.

Description

The holotype, representing the dorsal (aboral) side of *Ophiura paragraysonensis*, is a natural mould comprising a disc and five fragmentary arms. The disc, which is rounded in outline, is depressed centrally and along the inter-radials but the radials are arched over the fixed parts of the arms. Large pear-shaped radial shields, partly overlapped by imbricately arranged smaller plates, enclose a central area that is in some disorder. The radial shields have a rounded outer margin. A circular central plate (considered by some zoologists to be a primitive or juvenile character) is surrounded by a rosette of imbricately arranged plates (Fig. 7). Whether these plates are arranged in concentric circles about the central plate cannot be determined. In paratype KG.5.23, the "central plate" may simply occupy a medial position on the disc.

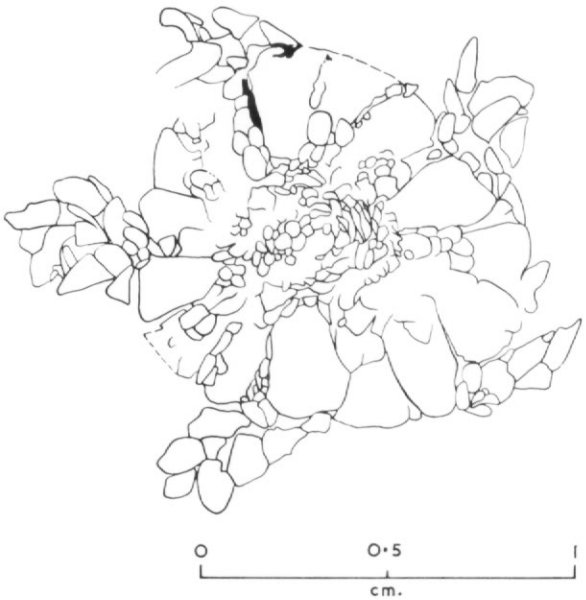

Fig. 7. A sketch showing the disc scalation of *Ophiura paragraysonensis* sp. nov. (holotype). (KG.5.15)

The inter-radial arrangement, i.e. the separation of the radial shields, may have been induced by compression and spreading of the smaller plates from the centre of the disc. The small plates are generally linguiform.

The central disc supports five sinuous and spinose fragmentary arms which are 2 mm. wide at the periphery of the disc. Unflexed, the longest arm is 24 mm. long. The arms, which are oval in cross-section, have large lateral shields joined proximally along the mid-line of the arm but they diverge distally. The dorsal arm plates are small and triangular. There are a few acicular and longitudinally fluted spines beside the arms but it is not clear how many spines project from each arm joint.

Paratype KG.5.20 is a natural mould representing the ventral (oral) view of an ophiuroid with a pentagonal to sub-rounded disc. The disc, which is 5·5 mm. broad, has a raised central area comprising a five-angled pre-oral cavity. The cavity is bounded by five inter-radial wedge-shaped jaws that constitute the mould frame, while beyond the jaws and abutting on to the lower part of the disc are the buccal shields. Small imbricately arranged plates partly cover the flattened outer margin of the disc.

Five sinuous and spinose arms composed of at least 27 joints radiate outwards from the jaws. Four adoral joints comprise the fixed parts of the arms. The ventral plates, which are evenly arched and wedge-shaped, have slightly convex distal margins and concave lateral margins; the proximal margins are obscured by the lateral shields that diverge widely. Pairs of deep and obliquely inserted puncta occupy embayments in the lateral and ventral plates, each punctum corresponding in life to a podium or tentacle. Adorally, the arm joints lengthen proportionately. No genital or bursal slits can be seen. Longitudinally fluted acicular spines with rounded and expanded bases occur alongside the lateral shields. Two spines appear to be attached to each arm joint at an acute angle.

Discussion

Numerous articulated ophiuroids, which were found crowded on the same bedding plane at locality G, may represent a biocoenosis. Two shapes of disc indicate either dimorphism, two views of the same ophiuroid or two separate species or variants.

The "primitive" disc scalation and spinosity of the ophiuroids from Alexander Island point to a close affinity with the Ophiolepididae and *Ophiura*. *Ophiura paragraysonensis* can be compared with *Ophiura texana* Clark and *Ophiura graysonensis* Alexander, but neither of the Texan species is thought to be conspecific. *O. texana* is based on three poorly preserved ventral (oral) moulds and several fragmentary arms (Berry, 1941). The disc is sub-rounded in outline. No direct comparisons can be made between *O. texana* and *O. paragraysonensis*, because there is no aboral view of *O. texana*.

O. graysonensis, which is better preserved than *O. texana*, is based on two almost complete ophiuroids (showing oral and aboral views), 12 almost complete specimens and many fragments. The species is considered to be a shallow-water form, as the Foraminifera *Globigerina* and *Textularia* were found cemented to the discs (Berry, 1941, p. 62). The scalation of the disc of *O. graysonensis* is very similar to that of the holotype of *O. paragraysonensis* (KG.5.15), for in both species the radials are pear-shaped and are arched over the fixed parts of the arms, and a rosette of imbricately arranged plates surrounds a central disc plate. However, the central disc plate of *O. graysonensis* is larger and more prominent than in *O. paragraysonensis*. Viewed orally, the disc of *O. graysonensis* is rounded, whereas in *O. paragraysonensis* the disc may be either rounded or pentagonal. In the holotype of *O. graysonensis* the oral side of the disc is assumed to be rounded.

However, the principal difference between *O. graysonensis* and *O. paragraysonensis* is in the shape and size of the dorsal arm plates. In *O. graysonensis* these plates are nearly twice as broad as they are long (Alexander, 1931, p. 152), whereas in *O. paragraysonensis* they are small and triangular. Since ophiuroid species are determined mainly on differences in the structure of the arm plates (Alexander, 1931, p. 153), the disparity in size between the respective dorsal arm plates of *O. graysonensis* and those ophiuroids from Alexander Island has been accorded specific status. However, affinities with *O. graysonensis* are implied in the choice of a prefix to the trivial name of *O. paragraysonensis*.

Regular Echinoidea

In the (?)Upper Aptian of Alexander Island "regular" echinoids characterize three stratigraphically important faunal marker horizons. Large thorn-like spines of *Rhabdocidaris* occur with numerous articulated crinoids and ophiuroids in an assemblage zone which has been used in correlating Mount Ariel with localities E, F and G. At Fossil Bluff, Mount Ariel and locality H (?)*Hemipedina* is associated with (?)*Parallelodon* in two marker horizons. Concentrations of small hemipedinid tests (between 6 and 10 mm. in diameter) in these marker horizons may represent natural living communities of sea urchins such as are known to colonize present-day sea bottoms. Although many of the tests in such concentrations are more complete than the solitary specimens, neither the periproct nor the peristome are preserved.

Order Aulodonta
Suborder Pedinina
Family Pedinidae Gregory

Genus (?)*Hemipedina* Wright
Type species: *Hemipedina* (*Pedina*) *etheridgei* Wright
Figs. 8b, c, d

Material

Several dozen natural moulds were collected from two (?)*Hemipedina*/(?)*Parallelodon* assemblage zones at Fossil Bluff, Mount Ariel, and localities H and D. The description of these hemipedinid echinoids is based primarily on latex casts made from specimens KG.3.127 and 19.10 (Figs. 8b and c).

Description

Although many of the tests are small (between 8 and 13 mm. in diameter and 5–9 mm. high), a few (KG.19.10) are of moderate size (20 mm. in diameter). Side views indicate that the un-

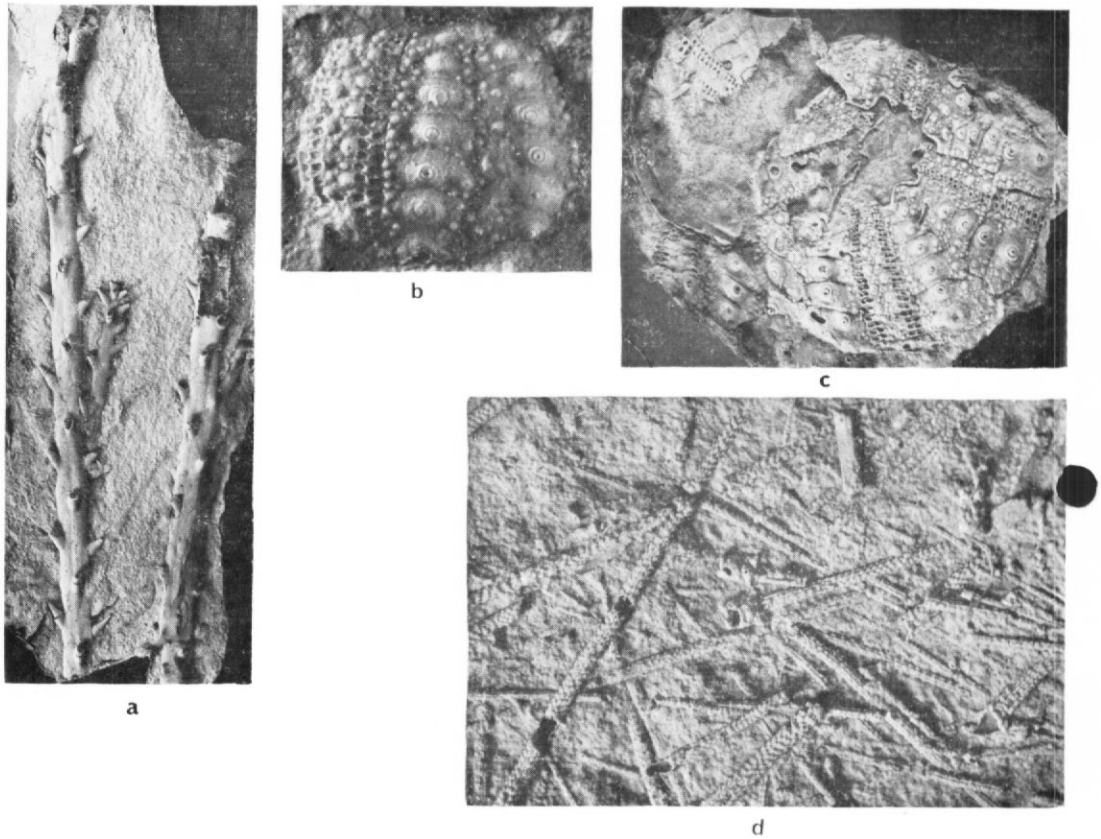

Fig. 8. a. A latex cast from the natural mould of spines of *Rhabdocidaris* sp.; ×1·3, coated. (KG.13.2)
b. A plasticine cast from the natural mould of (?)*Hemipedina*; ×4·7. (KG.3.127)
c. A latex cast from the natural mould of (?)*Hemipedina*; ×2, coated. (KG.19.10)
d. A latex cast from the natural mould of spines of (?)*Hemipedina*; ×5·3, coated. (KG.1.960)

damaged test was hemispherical. The ambulacra, which are straight and approximately half as wide as the interambulacra, have three or occasionally four plates to every one interambulacral plate. The ambulacral plates appear to be of the diademoid type (Fig. 8c). Pore pairs are unigeminal and pores in a pore pair are separated by an oblique wall. Pore pairs on either side of an ambulacrum are arranged slightly oblique to the central ambulacral suture. The interporiferous areas are tuberculate, the primaries of the ambulacra being about half the size of those on the interambulacra (Figs. 8b and c). Where there are three ambulacral plates to every one interambulacral, the primary tubercle occupies a position midway between the lower and middle ambulacral plates.

The interambulacra are cidaroid with a large and centrally placed perforate and non-crenulate tubercle to each plate. As the large areoles are nearly confluent, secondary tubercles are restricted to the median and adradial areas of the interambulacra, and there are therefore few complete scrobicular rings. Crushing has resulted in the imbrication of several of the interambulacral plates.

The spines, many of which are proportionately long (14 mm.) compared with the size of the test, are acicular and without collars. They are longitudinally ribbed with rows of non-verticillate barbs along the edge of the rib (Fig. 8d). In thin section the majority of the spines are ovate or elongate in outline with crenulate margins. Many are composed of calcite but others may have a quartz core surrounded by three distinct layers of calcite.

Discussion

Mortensen (1940) has used the terms unigeminate, bigeminate, etc. to denote the arrangement of the ambulacral plates, i.e. the number of ambulacral plates for every one interambulacral plate, whereas here the same terms are used to describe the arrangement of the pore pairs.

Because all the available specimens are poorly preserved, some difficulty has been experienced in identifying these echinoids although a close affinity to *Hemipedina* is shown by:

i. The unigeminal arrangement of the pore pairs.
ii. The small size of the primary ambulacral tubercles.
iii. The large size, central position, and perforate and non-crenulate condition of the interambulacral tubercles.
iv. The macro-structure of the spines.

The range of *Hemipedina* in Europe is from the Lias (Charmouthian) to the Cretaceous (Cenomanian).

ORDER CIDAROIDEA
FAMILY CIDARIDAE GRAY
SUBFAMILY STEREOCIDARINAE LAMBERT
GROUP RHABDOCIDARINA

Genus *Rhabdocidaris* Desor
Type species: *Rhabdocidaris* (*Cidaris*) *orbignyana* Agassiz
Rhabdocidaris sp.
Fig. 8a

Material

Large thorn-like spines resembling those of *Rhabdocidaris* Desor and *Prionocidaris* Agassiz are numerous in the crinoid/ophiuroid/rhabdocidaroid assemblage zone exposed at Mount Ariel and localities E, F and G. Two spines found at locality G were 130 and 72 mm. long, respectively. Many of the specimens are preserved as natural moulds from which latex casts have been made.

Description

These large thorny spines represent the appendages of disproportionately small echinoid tests. They are rarely attached, but at locality G a small globular test 12 mm. in diameter bears spines 72 mm. long. In a specimen from Mount Ariel the oral surface of a rhabdocidaroid echinoid is preserved in a dark grey siltstone or sub-greywacke (KG.3.1). An Aristotle's lantern comprising several finely and longitudinally striated pyramids is preserved but the peristome is absent. Three ambulacra are visible but each is poorly defined and neither the plate arrangement nor the arrangement of the pore pairs can be seen. The interambulacral plates are represented by large perforate and crenulate tubercles, and dense secondary and miliary tubercles. The areoles are confluent. Margins with adjacent ambulacra are sinuate.

Attached to the test are several thorn-like spines which taper from a finely ribbed neck to a shaft studded with prickles. The largest of the spines, which is 1·2 mm. wide, is elliptical in cross-section with numbers of stout, upwardly inclined and oppositely arranged prickles.

Rhabdocidaroid spines are most numerous at localities F and G, where the crinoid/ophiuroid/rhabdocidaroid assemblage zone is well exposed. One large spine that appears to be branched (KG.13.2; Fig. 8a) probably represents the angular coincidence of two unrelated spines. At locality F the largest spine is 3 mm. wide and at least 62 mm. long. The prickles are usually broken off at the joints and the shafts are finely and longitudinally striated.

In thin section these spines, which are usually elliptical in cross-section, have an outer cortex, an intermediate septate layer and a structureless core. The periphery is entire where the cortex is intact, but where the cortex has been partly removed or is absent the periphery is strongly crenulate. Although the cortex is usually dense, septa extending from the middle layer occasionally cross it. The middle layer, which is the thickest of the three, is crossed by radiating septa. The septa are joined by dissepiments but they are not grouped. There is no core or axis as such but an indeterminate area that follows approximately the long axis of the

elliptical section. Random sections taken across several of these rhabdocidaroid spines indicate that the prickles are outside the cortex and are therefore structurally distinct from the shaft. The prickles are composed of solid calcite.

Discussion

The entire echinoid had a small globular test with an armature of disproportionately long thorn-like spines. *Prioncidaris*, a living genus with a similar armature, uses its long spines as walking stilts and the points of the thorns are often worn (Mortensen, 1928, p. 440). The thorn-like spines together with some fragmentary tests are referred to *Rhabdocidaris*, which ranges from the Jurassic to the Eocene (Mortensen, 1928).

Irregular Echinoidea

The irregular echinoid (?)*Epiaster* is an important constituent in the upper and lower faunal marker horizons which have been used in correlating the stratigraphy between localities B and C (Fig. 5). The upper and lower horizons are 179 and 20 ft. (54·5 and 6·1 m.) thick, respectively. This echinoid is always crushed and poorly preserved, but in the upper marker horizon at locality C (?)*Epiaster* is comparatively abundant and much of the present material was collected from this locality.

Order Spatangoida Agassiz
Suborder Amphisternata Mortensen
Family Toxasteridae Lambert

Genus (?)*Epiaster* d'Orbigny
Figs. 9a, b, d, f

Material

Eight dorso-ventrally flattened internal moulds from localities B and C. The description is based on three specimens (KG.17.1, 6, 26; Figs. 9b, a, d) from locality C.

Description

The test is small (18–36 mm. in diameter), cordiform and feebly to moderately elevated, and paired ambulacra are petaloid. The frontal notch is only slightly embayed. The apical system, which is represented by four genital pores and four regular hexagonal plates, appears to be eccentric and posterior.

The paired posterior ambulacra, which are straight and very much shorter than the anterior ambulacra, are strongly petaloid. The pores are oblong and non-conjugate; in specimen KG.17.1 there are at least 11 pore pairs (Fig. 9b). Margins with adjacent interambulacra are feebly sinuate, while the petals themselves are divided by an even more sinuate central suture. Pore pairs are arranged slightly obliquely to a central ambulacral suture.

The paired anterior ambulacra are longer than those of the bivium and in specimen KG.17.6 there are at least 31 pore pairs (Fig. 9a). The ambulacra are divided by a sinuate suture which may be either central or eccentric in position. When the suture is eccentric, the ambulacra are divided into large and small parts composed respectively of large and small ambulacral plates (Fig. 10). In the anterior ambulacra of specimens KG.17.6 and 26 there are two types of pore pairs, an inner anterior series of small, elongate or sub-rounded pores and an outer posterior series of larger elongate pores. When the ambulacral suture is eccentric, the larger posterior pore pairs are situated in the larger ambulacral plates (Fig. 10). Towards the ambitus there is an overall increase in size of the pore pairs, and individual pores in a pore pair are separated by a shallow symmetrical ridge (Fig. 9f).

Ambulacrum III is slightly wider and more straight-sided than the other petals. The interporiferous area is broader and the pores closest to the central suture are rounded or even comma-shaped (Figs. 9d and 10). Anteriorly, these comma-shaped pores are usually offset, although in specimen KG.17.6 they become more elongated (Fig. 9a). Central sutures are sinuate.

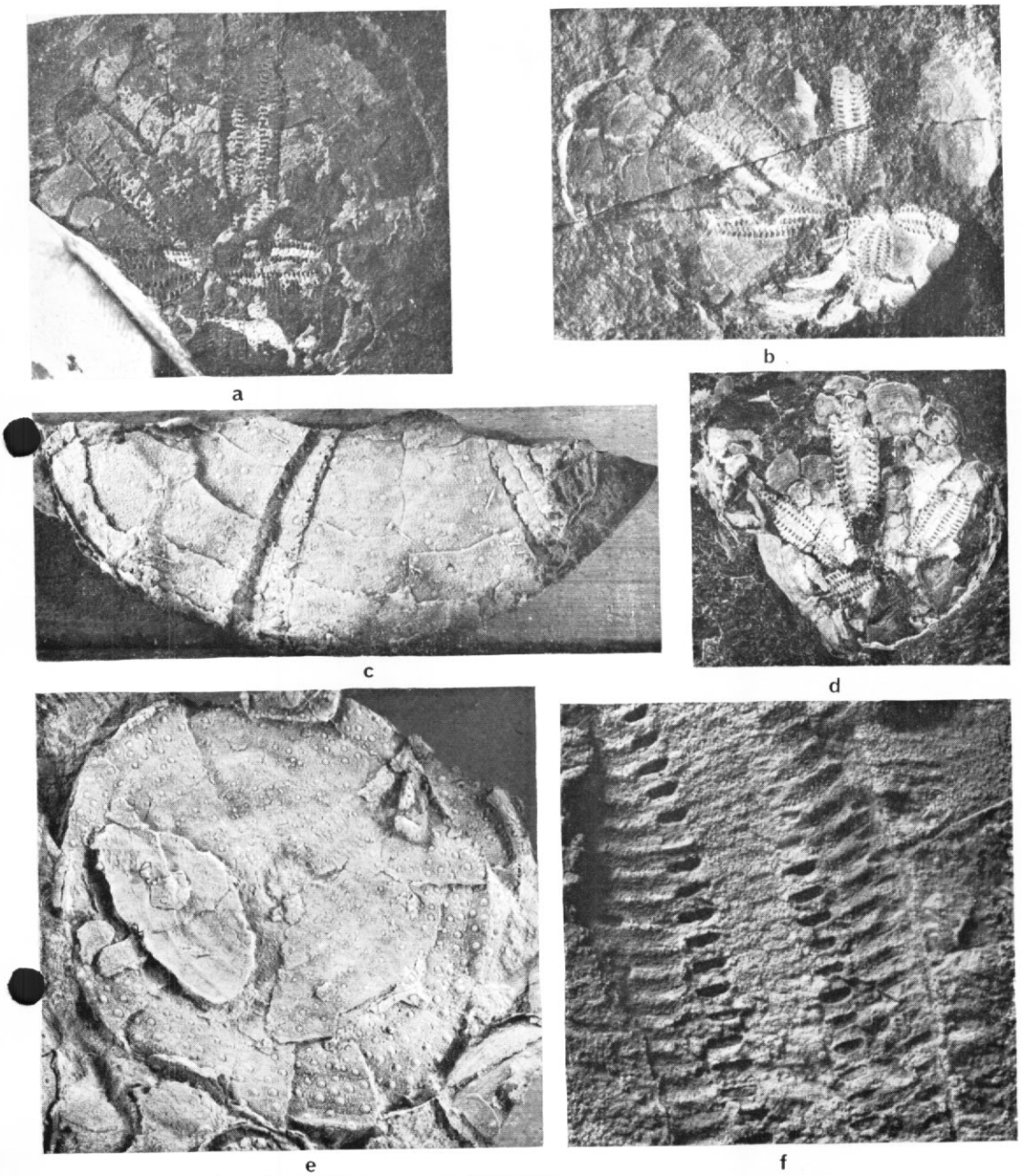

Fig. 9. a. A natural mould of (?)*Epiaster*; ×2. (KG.17.6)
b. A natural mould of (?)*Epiaster*; ×2·7. (KG.17.1)
c. A latex cast from the natural mould of (?)*Anorthopygus*; ×2, coated. (KG.3.115)
d. A natural mould of (?)*Epiaster*; ×2·7. (KG.17.26)
e. A latex cast from the natural mould of (?)*Anorthopygus*; ×1·7, coated. (KG.2.127)
f. A latex cast from the natural mould of part of ambulacrum II of (?)*Epiaster* (Fig. 9a); ×8·7, coated. (KG.17.6)

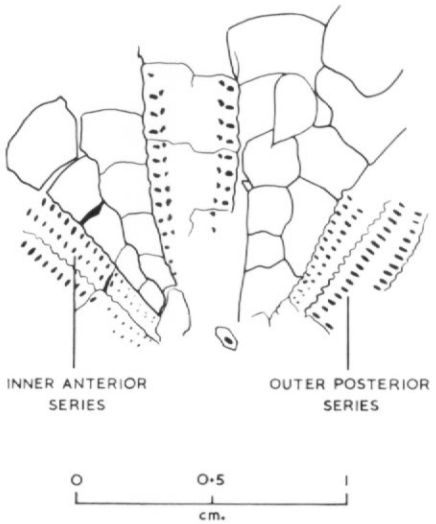

Fig. 10. A sketch showing the pore-pair arrangement in (?)*Epiaster*. (KG.17.26)

The apical system is represented by four genital plates surrounding four large pores. The system is probably ethmophract. Several detached and acicular spines, which were probably longitudinally ribbed, occur beside the tests.

Discussion

These echinoids are difficult to identify satisfactorily due to the absence of important taxonomic characters, but the following data indicate that they are spatangoids rather than clypeastroids:

i. Specialization of ambulacrum III.
ii. Simple ambulacral plates.
iii. Cordiform outline of the test.
iv. Non-conjugate rather than conjugate pores.
v. An (?)Upper Aptian age for the sediments. The Clypeastroida range from Upper Cretaceous to Recent.

Neither the periproct, peristome nor oral surface are preserved. The apical system, which is posterior and composed of four genital plates and four genital pores, is considered to be ethmophract. As all the specimens are internal moulds, there are no fascioles, although these may have been present on the test.

All the spatangoids are referred to the Toxasteridae on the following characters:

i. The posterior petals are much smaller than the anterior ones.
ii. Pore pairs comprising the outer posterior series are usually transversely elongate, whereas those of the inner anterior series are smaller, rounded or less elongate.
iii. In *Epiaster* and *Miotoxaster*, two genera closely comparable with the spatangoids from Alexander Island, the pores of ambulacrum III are small, round and comma-shaped.
iv. The absence of fascioles.

The two genera most closely related to the spatangoids of Alexander Island are *Toxaster* and *Epiaster* but there are certain significant differences. Although the apical system of *Toxaster* is posterior, the pore pairs of ambulacrum III are not differentiated and the paired petals are usually open distally. In *Epiaster* the pore pairs of ambulacrum III are rounded or comma-shaped and the posterior petals are usually shorter than the anterior ones, but the apical system is central.

The spatangoids from Alexander Island therefore share some of the characters of *Toxaster* and some of those of *Epiaster*. However, recent work on intraspecific variation in the scutellid *Dendraster* suggests that the position of the apical system may be closely related to the environment. Open-bay forms of *Dendraster* have much less eccentric apical systems than open-coast forms, which for protective reasons need to burrow deeper into the bottom sediments and therefore require a more pronounced anterior half in order to respire (Raup, 1956). The spatangoids of Alexander Island may therefore represent an open-coast form of *Epiaster*, which ranges from the Aptian to the Senonian (Mortensen, 1950, p. 344).

The large size of specimen KG.17.6 and a difference in the shape of the pore pairs of ambulacrum III compared with those of specimens KG.17.1 and 26 may indicate a variant or even a separate species.

Order Holectypoida
Suborder Holectypina
Family Holectypidae Lambert

Genus (?)*Anorthopygus* Cotteau
Figs. 9c, e

Material

Nine specimens collected from Fossil Bluff, Mount Ariel and locality H. Two of the echinoids were found *in situ* 60 ft. (18·3 m.) below the lower (?)*Hemipedina*/(?)*Parallelodon* marker horizon but the other seven were not *in situ*. The more complete tests are crushed, usually dorso-ventrally. They are approximately 40 mm. in diameter.

Description

When whole, the test was probably thin and sub-conical or sub-hemispherical with a concave upper surface and a flattened or slightly concave lower surface. Compression has resulted in the imbrication of many of the plates. In specimen KG.1.852, the ambulacra, which are non-petaloid and about one-third the width of the interambulacra, taper towards the apical disc. The plates are primarily arranged with one pore pair to every ambulacral plate and there are four or possibly five ambulacral plates to every interambulacral plate (KG.3.115; Fig. 9c). A large and a small pore comprise a pore pair, the outer (larger) pore lying above the inner pore. The pores are separated by a narrow wall. In specimen KG.1.852 the mouth is circular and central. Primary interambulacral tubercles are perforate and crenulate (KG.2.127; Fig. 9e).

Discussion

The plate arrangement and tuberculation of these echinoids indicate that they are irregular forms. The ambulacra are non-petaloid. They are referred to the Holectypoida and, because the primary interambulacral tubercles are not arranged in a series of vertical lines, they share an affinity with *Anorthopygus*, a genus which has been recorded from the Albian and Cenomanian of Texas and the Mediterranean countries.

Acknowledgements

I wish to thank Professor F. W. Shotton, Head of the Department of Geology, University of Birmingham, for providing laboratory facilities, and Dr. I. Strachan and Dr. R. J. Adie of the same Department for considerable helpful discussion and criticism. Thanks are also due to members of the Fossil Bluff station for their assistance in the field, and to Mr. L. W. Vaughan for preparing most of the plates. Specimens loaned by J. P. Smith and W. O. Tracy are gratefully acknowledged.

MS. received 11 May 1965

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APPENDIX

Locality (see Fig. 1)	*Specimen Number*	*Identification*
C	KG.17.1	(?)*Epiaster*
	KG.17.6	(?)*Epiaster*
	KG.17.26	(?)*Epiaster*
D	KG.19.10	(?)*Hemipedina*
F	KG.13.2	*Rhabdocidaris* sp.
G	KG.5.1	*Isocrinus aptiensis* sp. nov. (paratype)
	KG.5.2	*Isocrinus aptiensis* sp. nov. (paratype)
	KG.5.3	*Isocrinus aptiensis* sp. nov. (holotype)
	KG.5.4	*Isocrinus aptiensis* sp. nov. (paratype)
	KG.5.5	*Isocrinus aptiensis* sp. nov. (paratype)
	KG.5.15	*Ophiura paragraysonensis* sp. nov. (holotype)
	KG.5.20	*Ophiura paragraysonensis* sp. nov. (paratype)
	KG.5.21	*Isocrinus aptiensis* sp. nov. (paratype)
	KG.5.23	*Ophiura paragraysonensis* sp. nov. (paratype)
Fossil Bluff	KG.1.329	*Isocrinus aptiensis* sp. nov. (paratype)
	KG.1.330	*Isocrinus aptiensis* sp. nov. (paratype)
	KG.1.331	*Isocrinus aptiensis* sp. nov. (paratype)
	KG.1.846	Large isotomous arms of crinoid
	KG.1.852	(?)*Anorthopygus*
	KG.1.959	*Isocrinus aptiensis* sp. nov. (paratype)
H	KG.2.127	(?)*Anorthopygus*
	KG.2.177	Fragmentary crinoid column
	KG.2.178	Fragmentary crinoid column
	KG.2.179	Fragmentary crinoid column
Mount Ariel	KG.3.1	*Rhabdocidaris* sp.
	KG.3.115	(?)*Anorthopygus*
	KG.3.127	(?)*Hemipedina*