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THE CAINOZOIC CIDARIDAE OF AUSTRALIA.

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Plates XII–XV.

Nearly 60 years ago Professor P. M. Duncan described the first Australian Cainozoic cidaroid before the Geological Society of London. During the next 20 years Professors R. Tate and J. W. Gregory published references to our fossil cidaroids, but further descriptive work was not attempted until the present authors undertook to examine the accumulated material in the National Museum, the Tate Collection at Adelaide University Museum, the Commonwealth Palaeontological Collection, and the private collections made by the late Dr. T. S. Hall, F. A. Singleton, the Rev. Geo. Cox and the authors.

The classification of the Cidaridae is founded mainly upon living species and it is partly based on structures which are only rarely preserved in fossils. Fossil cidaroid tests are usually imperfect. On abraded tests the conjugation of ambulacral pores is obscure. The apical system is preserved only in one specimen among those examined. The spines are rarely attached to the test and pedicellariae are wanting. Therefore, in dealing with our specimens we have been guided mainly by the appearance and structure of ambulacral and interambulacral areas. Certain features used in our classification vary with the growth stage of the test : for instance, the number of coronal plates in vertical series, the number of ambulacral plates adjacent to the largest coronal plate, and sometimes the number of granules on the inner end of ambulacral plates.

In the collections before us only one test has the spines still attached ; in another specimen, the test and a spine are only slightly separated ; and in a third a group of spines was closely associated in a block of marly limestone though the test was not collected.

Where the evidence warrants it, we have suggested that cidaroid tests and generically related unattached spines found in the same layer belong to the same species. Original colour markings of spines are sometimes recognisable, especially when specimens are thinly varnished ; this is a detail of some importance, since that feature is used in classifying recent cidaroids. Some spines, as in living examples, are encrusted with growths of parasitic polyzoa.

In the following pages five genera and eight species of Tertiary Cidaridae are recognised, including 7 new species. The only cidaroid remains recorded from pre-Cainozoic strata in Australia are portion of a test of *Cidaris comptoni* (Glauert, 1923, p. 48), cidaroid spines indeterminate (Eth. fil.) from the Cretaceous of Gingin, W.A., and a fragmentary spine of *Cidaris* sp. (Whitehouse, 1925, p. 1) from the Jurassic east of Geraldton, W.A.

The geological map of Cape Otway district, Victoria, referred to in lists of localities, is Wilkinson's, published in 1865.

Class **ECHINOIDEA.**

Order **Cidaroida** Duncan.

Family **CIDARIDAE** Gray.

Genus STEREOCIDARIS Pomel 1883.

This genus has non-conjugate pores (Mortensen, 1928) ; it was founded on fossil forms. Its history begins in the Cretaceous of Europe ; it also occurs in the Eocene of Europe and possibly of America. A fossil spine described from the Miocene of Java may also belong to this genus.

Stereocidaris is found living in the Atlantic, the Indian Ocean, the Philippine seas and around Japan. It has not been recorded from the Australian region (Clark, 1925).

Stereocidaris australiae (Duncan).

Leiocidaris australiae Duncan, 1877, p. 45, pl. III, figs. 1, 2.
? *Cidaris striata* Hutton, Tate, 1894, p. 122.
Cidaris (*Stereocidaris*) *australiae* Duncan, Tate, 1898, p. 411.

Plate XII, figs. 1–6b ; plate XV, figs. 32a, 34–36c.

Duncan's original description (1877) is as follows :—"The test is greatly and suddenly depressed towards the actinosome. The ambulacra are slightly wavy, narrow, and have four vertical rows of small miliary tubercles, the inner rows having the smallest tubercles ; and the poriferous zones are sunken, the pores being conjugate, and each pair separated from its neighbours by a distinct ridge. The interambulacral tubercles are few in number, and most are very large ; the perforate mamelon is small in relation to the plain, large, conical and well-developed boss. The scrobicule is deeply sunken, elliptical, and is overhung by the scrobicular circle which slopes down to the suture, being ornamented by radiating rows of two or three very small tubercles. The median interambulacral space is sunken, and the vertical sutures of the plates are distinctly marked by a lower space, which is in a zigzag from above down-

wards. The large upper tubercles have a smaller scrobicular area than those in the middle of the test ; and the tubercles diminish rapidly in size towards the actinosome."

Observations.—Duncan stated that the pores are conjugate, but all our specimens of this species from the type locality (Castle Cove, near Cape Otway) and from Aldinga (Port Willunga) have non-conjugate pores, a character seen in *Stereocidaris*. The pores of a pair are close together, the inner round and the outer slightly oblique.

The poriferous zone is narrow. Adult specimens have 12 ambulacral plates adjacent to the largest interambulacral plate at the ambitus. The larger ambulacral plates bear numerous tubercles and granules, comprising several vertical rows. The test is small to medium. As in recent species, the non-spine-bearing abactinal coronal plates vary considerably in number in different tests ; several of the uppermost plates often have a shallow scrobicular area, tiny in proportion to the size of the plate, with a small imperforate boss. We have found no trace of crenulation in adult specimens, but one young test from Aldinga ("C")* shows partial crenulation of the primary tubercles. Interambulacra are narrow. Scrobicules are circular, except below the ambitus, where they are slightly elliptical. Tubercles composing the ring round the scrobicules are small and the ring is inconspicuous. Scrobicules are not confluent, though in the actinal region the rings merge together. They are often far more sunken than in any other Australian Cainozoic cidaroid, but this character is variable.

The median area of the interambulacrum is very narrow in young specimens, widening with age ; in the actinal region, especially in young specimens, it is very little sunken, but pits usually occur at the ends of horizontal sutures between coronal plates. The ends of sutures nearest the ambulacra sometimes form slight grooves. There are commonly six or seven coronal plates in a vertical series ; some specimens from Aldinga with six vertical rows of tubercles in the interporiferous area have up to nine plates. The deeply sunken scrobicules and, as a rule, lack of perforate mamelons on the abactinal plates, readily distinguish this species from others included in this paper.

During the last fifty years there has been much confusion in regard to this variable cidaroid. The holotype, which came from Castle Cove (Aire Coast, Wilkinson's No. 5 Section) is in London, and we have not seen it. Tate (1898, p. 411) states that he had compared Duncan's type, "which is a single inter-ambulacral plate, with complete interambulacral zones of a

*For abbreviations see p. 142.

Cidarid from Aldinga and it is matched with the largest of the tuberculated plates of the Aldinga specimens. These latter belong to *Stereocidaris* and indicate a conic test, the broad base being nearly flat, to about one-half the total length of the arc, thence roundly bent backward at about sixty degrees ; the basal half consists of four plates in each row having areolar areas, the posterior ones of which are the largest ; the four or five anterior plates in each row are without areoles or one or two may show traces of them." Duncan's figure of the type specimen (1877, pl. III, fig. 1) shows both ambulacral and interambulacral plates ; we therefore doubt that Tate saw the actual specimen.

The latter part of the above remarks by Tate concerns a fragmentary specimen (an interambulacral zone) in the Tate Collection ; this specimen was kindly lent to us for examination (Pl. XII, fig. 3). The "basal half" is the actinal portion of the test, the "posterior" plates are those near the ambitus and the "anterior" plates are those of the abactinal region. With regard to the remark by Tate that his specimen indicated a conic test, we find that the zone, when placed in a strictly vertical position, is not so emphatically indicative of a conic test as Tate stated. We think this specimen, which he definitely places under *S. australiae*, represents a large individual in which the upper portion of the test has been crushed.

A complete test of *S. australiae* from Aldinga (Tate Collection) bears Tate's ms. name "*Goniocidaris inermis*," (Pl. XII, figs. 1, 2). The test is both abactinally and actinally depressed. Each interambulacral zone has feebly scrobiculated plates abactinally, three in left vertical series and two in right. This unique specimen also exhibits the only apical system preserved in our fossil cidaroids ; all plates are present, even the anal plate, which is depressed into the underlying matrix. *Measurements :*—diameter at ambitus, 34 mm. ; height of test, 20 mm. ; width of interamb zone at ambitus, 15 mm. ; width of amb, 3.5 mm. ; diameter of apical system, 13 mm. ; diameter of peristome, 10.5 mm. ; width of coronal plate at ambitus, 9 mm.

Two fragments of tests collected by the late Dr. T. S. Hall from the type locality are here figured (Pl. XII, figs. 5, 6b). One has six coronal plates in vertical series. Abactinal interambulacral plates have a small, shallow scrobicule with a rudimentary boss, in striking contrast to the large, deeply sunken scrobicules with perforate mamelons nearer the ambitus. *Measurements :*—abactinal portion of interamb zone ; height of test, about 19 mm. ; greatest width of interamb area, 18.5 mm. ; horizontal diameter of coronal plate at ambitus, 10 mm.

No previous workers have described spines of this species. The collections under examination comprise over three thousand Australian Cainozoic cidaroid spines, the largest number brought together at one time. From these we have selected, on morphological grounds (as well as because their range and distribution are co-extensive with tests of this species), a number which we believe to belong to the above species. Some spines of

recent species of the genus figured by Mortensen (1928, Plates XIX and XXII) are almost identical in appearance with certain of the fossil spines. Our specimens may be divided into several minor groups, which, however, shade into one another.

One variety from the lower beds at Aldinga, from Castle Cove and from Point Flinders near Cape Otway, is long, comparatively slender, and circular in section ; in some cases it is almost twice the horizontal diameter of the test in length. Length of longest spine, apex missing, from Aldinga, about 85 mm. ; a similar spine from near Cape Otway, apex missing, 63 mm. Shaft, which in the longer specimens flattens slightly towards apex, ornamented with closely set ridges bearing short spinose tubercles ; these tuberculate ridges usually extend close to apex, in which case the spine is generally slender and has an almost terete habit, but close to apex it broadens and terminates in a cup-shaped structure on exterior of which the vertical ridges become coarser and more salient. Interior of cup smooth or slightly radiately granulose. Between ridges, surface of shaft is very finely longitudinally striated ; the striae continue across neck, collar and ring.

A second variety is found at Castle Cove and in lower beds at Aldinga ; spines long, slender, with tuberculate or bluntly spinose ridges similar to those already mentioned and two coarser spinose ridges upon opposite sides of shaft ; in some the spinules coalesce to form an alate ridge. Terminations less cupped, palmate. Portion of shaft next apex flattened and sometimes curved. Both in character of spinose side ridges and of palmate termination, the second variety differs from spines of living forms and is more like certain spines of *Goniocidaris* and *Prionocidaris ;* but after examining a long series, we are satisfied that they belong to *Stereocidaris australiae*, as do the allied spines more typical of the genus. Their occurrence in a fossil species supports Mortensen's suggestion (1928, p. 230) that the Goniocidarids may have been derived from the *Stereocidaris*-like forms.

A link between the two groups of spines is provided by a third variety from near Cape Otway and from lower beds, Aldinga : more generally spinose and with palmate ending.

All these varieties have excessively fine vertical striae on surface of neck, collar and ring. Crenulation of outside of margin of acetabulum is rarely preserved.

A fourth variety tapers, and has prominent wing-like projections on either side near base (see Clark, 1925, p. 26). Near Cape Otway and at Aldinga (Tate and "C." Colls.) spines of this species are common ; at Aldinga some have narrow encircling colour bands ("C." Coll.).

Measurements.—Length of complete cup-ended spine from near Cape Otway (plesiotype), 26 mm. ; another spine, apex missing, 58 mm. ; diameter of widest cup, 9 mm. ; length of spine (plesiotype) from Aldinga, apex missing, 86 mm.

Localities.—Victoria—Castle Cove, Aire Coast, Wilkinson's No. 5 Section ("C." ; plesiotypes, 3 interamb zones, H., C.). Point Flinders, near Cape Otway, Aire Coast No. 1 Section of Geol. Surv. (Plesiotypes, 2 spines and 4 cupped terminals, C. ; also W. and "C."). Quarter mile northerly from Bird Rock, Torquay, in polyzoal rock (a small test ; "C."). Mitchell River (a test fragment ; D). South Australia—Aldinga, lower beds (Plesiotypes, interamb zone, D ; 10 spines, C ; 3 plesiotypes in Tate Coll. ; specimens in S., "C." and Tate Coll.). Wongulla, lower beds (a small test ; "C.").

Range.—Upper Oligocene to Miocene.

Genus PHYLLACANTHUS Brandt, 1835.

(Synonym : *Leiocidaris* Desor, 1855.)

This genus has primary spines cylindrical or terete, sometimes with a series of small serrations but never with thorns or projecting ridges. The pores are conjugate. (Clark, H.L. 1925).

Mortensen (1929) has recently listed five of the six known living species of this genus as inhabiting Australian seas ; he states that *Phyllacanthus* must be restricted to those species which have thick, smooth, cylindrical spines. Living species are littoral. Duncan (1877, p. 45) refers to the possible occurrence of *Phyllacanthus* in our strata. Spines from Miocene deposits of India and of Madagascar probably belong to this genus (Mortensen, 1929). *P. javanus* Martin occurs in the Miocene of Java (Martin, 1883–7) and Yule Island, Papua (Chapman and Crespin in Montgomery, 1929–30). Miss Currie (1930) has figured some spines from Late Tertiary beds of Kenya, East Africa.

Phyllacanthus duncani sp. nov.

Leiocidaris sp. nov., Duncan, 1887, Q.J.G.S., vol. 43, p. 412.

Plate XII, figs. 7–9 ; Plate XV, fig. 33.

Duncan's description of *Leiocidaris* sp. nov. is as follows :—

"The ambulacrum is rather undulating and narrow ; the poriferous zone is very slightly sunken ; the pores are large ; the outer one of a pair is the larger and elliptical ; the inner or adoral is round ; they are united by a groove, and about seventeen pairs are in relation to a large interradial coronal plate. Interporiferous area with a row of small, imperfect secondaries, with slightly raised scrobicules and a small boss, no mamelon, placed close to the poriferous zone, and a series of smaller secondaries nearer the median line, in a vertical row extending along the middle of the area, but not reaching much actinally or far towards the apex. The primaries of the interradia are large ; the scrobicules are distinct, nearly circular, and there is a row of small secondaries and a few granules between them and the horizontal sutures of the plates. The boss is broad at the base and conical, and the mamelon is contracted at the neck and is perforated. There is no crenulation. The margin of the scrobicular circle is sunken, and is surrounded by a row of small secondaries made up of an elongated raised scrobicule, longest transversely, and a small boss ; there are a few smaller tubercles placed beyond the circle, and fitting in between the larger, so as to complete the circle, and a few exist beyond it. Two or three rows of still smaller tubercles extend along the plates beyond the circle towards the median line, and the median area of the interradium is narrow. Numerous spines are in the collection, and the large and nearly smooth ones may be associated with this genus."

Observations.—We have named this form after the late Prof. P. M. Duncan, whose description we have quoted above, and have referred it to *Phyllacanthus,* of which *Leiocidaris* is a synonym, being guided partly by the nature of the spines.

The tests are medium to large, tall and a little depressed abactinally. The poriferous zone is distinctly sunken and pores are not close together. Ambulacral plates show two, three, or even four vertical rows of tubercles ; a fourth row occurs on a large imperfect test from Port Macdonnell which was at first thought to represent a distinct species, but its large size appears to be merely a feature of senility. At Batesford there occur coronal plates (25.5 mm. by 14 mm.) from tests which were even larger. Coronal plates in the vertical series are probably seven in number. Interambulacral zones from Bairnsdale, whence came the original specimen, and from Batesford, show that the median area at the ambitus is broad, with plate margins sloping slightly down to the suture. The scrobicular rings do not overhang the scrobicules ; the latter are nowhere confluent, though the rings merge in the actinal region. The area beyond the rings is covered with closely-packed miliaries.

J. W. Gregory (1890, p. 482) has recorded this species from Willunga, South Australia, but the fossil probably came from Port Willunga on Aldinga Bay. Unless the fragment came from the upper bed, it almost certainly represents the new species now named *Prionocidaris scoparia*.

Neither Duncan nor Tate figured cidaroid spines. Some spines from the same stratum as the tests of *Phyllacanthus duncani* are undoubtedly conspecific ; they are all fairly long, very gradually tapering, without thorns, somewhat rounded at the end, with a moderately blunt point. Minor characters divide them into two varieties which we have never found together in the same bed. There is no variation in the tests, and possibly further collecting may show that differences in the spines are due either to their range in time or to factors of environment.

In the first kind, ring is milled by fine lines which cross it vertically ; above ring shaft narrows, then widens before tapering towards apex, maximum width being sometimes greater than diameter of ring. Shaft covered with fine granules, irregularly scattered near neck, but a little above it arranged in straight lines, giving blunt apical portion a ridged or fluted appearance. Viewed under high magnification, remainder of the surface is a network of fine cells. *Localities.*—Victoria—Mitchell River at Bairnsdale (N.M., "C." and "G.C."). Swan Reach ("G.C."). Nicholson River ("C."). Curlewis, locality Ad 12 or 13, Geol. Quarter Sheet 23 SW. (N.M.). Beaumaris, washed out into the shingle ("C."). South Australia—Beach at Port Macdonnell ("H."). Aldinga, upper beds (no narrowing or swelling of spines; "C."). Upper beds near Morgan, Murray River ("C.").

Spines of second kind have no constriction above collar. Granules coarser, linearly arranged nearer neck. The network of cells visible only in exceptionally well-preserved specimens. Diameter of shaft rarely as much as that of ring ; spine tapers evenly to blunt end.

Localities.—Victoria—Batesford (N.M., "H.," "C."). Flinders (N.M., "C."). Knight's Bridge, Moorabool River, near Maude, TM 1–4 (N.M.). Kawarren ("H."). "Upper Coralline beds" at No. 3 of Wilkinson, between Castle Cove and Eagle's Nest Rock, Cape Otway district (N.M., "C."). Green Gully, Keilor (N.M.). Clifton Bank, Muddy Creek, Hamilton (2 worn spines, "H."). Tasmania—Table Cape, lower beds ("C."). Cape Barren Islands, Flinders Group, Bass Strait (Geol. Surv. Tas. Coll., Hobart).

In cross-section spines are practically round: unabraded specimens distinctly granulose, but where successive coats have peeled off, slightly different structures are revealed. Outer coat may carry coarse granules in longitudinal lines and inner coat fine granules similarly arranged. Specimens further abraded are smooth. Internal structure revealed by thin sections is characteristic of the genus *Phyllacanthus* (cf. Mortensen, 1928, p. 502, fig. 162). In one spine from Batesford ("C.") shaft is flattened near apex.

Measurements.—Holotype (imperfect test from Batesford); width of interamb area at ambitus, 27 mm.; height of test, about 42 mm. Plate in region of ambitus; diameter, 15 mm.; height, 10.5 mm.; horizontal diameter of boss, 9 mm. Paratype (imperfect test); vertical series of three uppermost abactinal interamb plates, 33 mm.; greatest width of interamb zone, 39 mm.; horizontal diameter of largest plate, 19 mm. Spines:—length of longest spine, figured as a paratype, 59 mm.; diameter of ring, 5 mm.; width near tip, 2 mm.

Localities.—Victoria—Batesford; "H.," "C." and "F.A.S."; holotype, interamb zone (M.); paratypes, abactinal portion of interamb zone (H.) and 5 spines (C.). Waurn Ponds, Geelong ("C."). Curlewis polyzoal limestone (N.M. and "C."). Bird Rock Cliffs, Torquay (N.M.). Airey's Inlet ("C."). Maude, locality WTM 1–4 on Geol. Surv. map (N.M.). Left bank of Moorabool River, Lethbridge ("C."). Flinders (N.M., "G.C.," "H.," "C."). Green Gully, Keilor (N.M.). Bairnsdale (N.M., "H." "C.," "G.C."). Nicholson River ("C."). Swan Reach ("G.C."). Swan Reach, upper and lower beds ("C.P.C."). Toorloo Creek, Lake Tyers (Ashburner Coll.). Mississippi Creek, Lakes Entrance ("C.P.C."). Rosehill Farm, Mitchell River ("C."). Kawarren ("H."). Bowker's Steps, Princetown (D.). Calder River limestones, Hordern Vale, Cape Otway district ("C."). Aire Coast, polyzoal limestone at locality Wilkinson's 3AW (W., "C."). Beaumaris (washed into shingle; "C."). Clifton Bank, Muddy Creek, Hamilton (several worn spines, record uncertain; "F.C.," "C."). Balcombe Bay, Mornington (one spine; N.M.). South Australia—Port Macdonnell (paratype, interamb zone (H.); also spines, "H." Aldinga, upper beds ("C."). First cliff north of "Brittana," 3 miles below Morgan, upper beds ("C."). Tasmania—Table Cape, upper and lower beds ("C."). Cape Barren Islands, Flinders Group, Bass Strait, in polyzoal limestone (Geol. Surv. Tas. Coll., Hobart). Western Australia—Booanya, near Balladonia (N.M., pres. Miss A. E. Baesjou).

Range.—Upper Oligocene to Lower Pliocene.

Genus PRIONOCIDARIS A. Agassiz 1863.

This Indo-Pacific genus is represented around the Australian coast by three living species, in the main littoral (Mortensen, 1929). Primary spines are often very diverse (Clark, 1925). Pores are conjugate. Mortensen states that various species, ranging from the Cretaceous of Europe and the Eocene of

Europe and of India to the Miocene of Europe, probably belong to *Prionocidaris*, though none is placed by their authors in that genus.

Prionocidaris scoparia sp. nov.

Plate XII, figs. 10, 11 ; Plate XV, figs. 28–30.

Test large, tall and slightly depressed abactinally. Ambulacrum narrow and wavy, ambulacral plates usually with two vertical rows of small miliary tubercles, making four rows present in interporiferous area ; poriferous zone slightly sunken ; pores conjugate, oval, close together. About fifteen ambulacral plates adjacent to largest interambulacral plate. Seven coronal plates. Boss broad, uncrenulated, with perforate mamelon slightly contracted at neck. Scrobicules shallow, circular towards apex, elsewhere elliptical. Scrobicular circle bounded by a ring of tubercles which does not overhang margin of scrobicule. Except in abactinal region, the rings merge together ; between scrobicules near actinosome they tend to disappear. Median area of interambulacra very narrow, even near ambitus ; only slightly depressed at suture ; covered with closely packed miliaries of unequal size. No pits or grooves in horizontal or vertical sutures.

Remarks on Tests.—The syntype from Mt. Gambier, in common with other specimens which we have seen, shows that the test is large and high ; in the syntype from Aldinga the test is nearly complete but considerably flattened by crushing in situ (Pl. IX, fig. 10). Fortunately a spine has been preserved on this test ; it lies across the apex not far from the mamelon from which it was detached. This spine corroborates our earlier determination of isolated spines of this species.

Measurements.—Syntype (interamb zone), from Knight's Railway Siding Quarry, Mt. Gambier, S.A. (Mines Dept. Vict. Coll.) :—height of test, about 64 mm. ; width of interamb area at ambitus, 38 mm. ; width of interamb plate in region of ambitus, 21 mm. ; height of plate, 12 mm. ; width of amb plate, 3.5 mm. Syntype from Aldinga, lower beds (Tate Coll.) : a nearly complete test. Present diameter of test, 75 mm. ; height, considerably reduced by crushing, 32 mm. ; diameter of apical system, about 20 mm. ; diameter of peristome, about 22 mm. ; width of amb, 8.5 mm. ; width of interamb area at ambitus, 38 mm. ; width of interamb plate in region of ambitus, 20 mm. Spine without apex lying on test 38 mm. long ; base to end of collar, 8 mm. ; diameter of ring, 6 mm. ; greatest diameter of shaft, 5 mm.

Spines long, stout, slightly tapering, usually cylindrical ; some widened and much flattened on both sides towards apex. Ring finely milled ; diameter much greater than that of shaft ; no narrowing of shaft above ring. Shaft ornamented with thorns, all long or all short, scattered or arranged linearly. Extremely fine granules cover shaft between thorns. Spines with rounded shafts have apex flared, forming depression surrounded by pointed terminals of granular ornament of spine. Flattened spines have no terminal depression ; apex composed of projections of ornament ; shaft terminates as though cut across at 45 degrees to its length. *Localities.*—Waurn Ponds, Nelson, Mount Gambier and lower beds, Aldinga.

Measurements.—Paratypes (spines), both from lower beds, Aldinga : length of thorn-bearing spine, tip imperfect, 100 mm. ; width at ring, 6 mm. , width

of shaft near tip, 4 mm. Complete spine with shorter thorns, length 87 mm.; width at ring, 9 mm.; width of shaft near tip, 4.5 mm. Fragmentary flattened spine showing terminal, lower beds, Aldinga (Tate Coll.); thickness, 3.25 mm.; minimum width, 6.5 mm.; maximum width, 9.25 mm.

Observations.—*Prionocidaris scoparia* has the narrow interambulacrum found in recent species. In young specimens the median area of the interambulacrum is very small; it becomes larger as the test grows, but even in adults it is relatively narrow. In a young test from Aldinga primary tubercles are partially crenulated. Lyman Clark states that the interambulacra in recent species are not densely clothed with miliaries.

Though fragments of tests of *P. scoparia* are difficult to distinguish from those of *Phyllacanthus duncani*, the latter species has a wider interambulacral median area, more sunken scrobicules, and pores of a pair more widely separated. So far we have not seen both species from the one horizon, though in a few cases both occur in the one locality.

Localities.—Victoria—Castle Cove, Aire Coast, Wilkinson's locality No. 5AW. Allotment 14, Parish of Wataepoolan ("C.P.C."). Waurn Ponds ("H.," "C."). Nelson ("H."). South Australia—Aldinga, lower beds; S., "C."; paratypes, 4 spines, C. and 4 fragmentary spines, S.; syntype and paratype (spine), Tate Coll. Knight's Railway Siding Quarry, Mt. Gambier ("C.," "F.C."; syntype, N.M.). Morgan, lower beds ("C.," a young specimen ?).

Range.—Upper Oligocene to Miocene.

Genus GONIOCIDARIS L. Agassiz and Desor 1846.

Living species of *Goniocidaris* are confined to Australasian seas; *G. tubaria* is mainly a littoral form, but *G. australiae* has been found down to 470 metres. The genus is well represented in our Cainozoic rocks. The main distinguishing characters are the conspicuous bare sunken areas of the ambulacrum and of the interambulacrum, and the pits in the latter. Pores are non-conjugate (Clark, 1925, and Mortensen, 1928). In other parts of the world various fossils have been referred to this genus, but the only examples which, we believe, may belong to it occur in the Miocene of India and in the Miocene and Pliocene of the Persian Gulf.

Goniocidaris prunispinosa Chapman and Cudmore.

Plate XIII, figs. 12–14.

Goniocidaris prunispinosa Chapman and Cudmore, in Chapman, 1928, p. 90.

The following description is amplified and emended from our preliminary description.

Holotype (test from Morgan, S.A., with spines still attached). Test small and low in proportion to width. Ambulacra very slightly wavy. Ambulacral plates level, with two vertical rows of small miliary tubercles which consist of boss and mamelon; on each plate the tubercle nearest poriferous zone is the larger; the smaller tubercle placed at 45 degrees downwards from the larger; median suture visible; margin of plate slopes slightly downwards towards suture. Poriferous zones sunken. Pores non-conjugate, circular, close together, adjoining pairs separated by a pronounced ridge. Six ambulacral plates adjacent to largest interambulacral plate. Interambulacra rather broad. Seven coronal plates; serobicules sunken, elliptical, becoming circular near apex; boss conical, uncrenulated; mamelon perforate, contracted at base. Plates against apex not divided from adjacent plates below by wide horizontal sutures or grooves. Marginal area of plates nearest poriferous zones covered with miliaries varying in size and irregularly arranged; portion sloping down to median interambulacral suture covered with scattered miliaries which diminish regularly in size towards suture. Suture a slightly zigzag line. Tubercles around scrobicule not noticeably arranged into a ring, but margin overhangs serobicule. Scrobicules not confluent; separated only by thin margin in actinal region. Median area of interambulacra broad.

Spines still attached to test slender, with basal ring finely ridged; shaft slender, cylindrical, tapering towards apex; surface ornamented with prominent, upwardly directed spinules, often arranged in longitudinal lines but in some instances irregularly scattered; in one example tip distinctly flared into cup-shaped ending.

Measurements.—Holotype; diameter of peristome, about 12 mm.; diameter of test, 29 mm.; height of test, 16 mm.; width of interamb zone, 15 mm.; width of amb, 4.5 mm.; width of coronal plate at ambitus, 8 mm.; height of plate, 4.5 mm. Attached spines: length, 21 mm.; thickest part of shaft, 2 mm.; diameter of flared tip, 4.5 mm.

Observations.—This species lacks some characters of the recent genus *Goniocidaris* and may eventually be separated from it. The median suture of the interambulacra, although occupying a depressed area, is not bare and shows no sign of pits. In the ambulacra there are no bare areas between the two rows of miliaries on either side of the suture.

Crenulated bosses, though absent from the holotype, are occasionally present on other specimens. For instance, under the microscope one interambulacral zone shows that bosses nearest the actinosome are crenulated, and those on a few of the many separated plates, probably from near the ambitus, are more plainly crenulated; half the circumference of the platform of the boss remains smooth.

Spines more slender than those of living species, but have characters typical of the genus. Chiefly long, slender, delicate with fairly distant, usually very sharp, spinules. Shaft rounded to elliptical; spinules emerge at angles ranging from vertical to acute. One variety carries coalescent thorns forming a wing on each side of spine; another clothed closely with short stout thorns; in a third thorns coalesce to form sheath at tip of spine; one side of shaft often bare of spinules; in others, short spinules are arranged in straight lines and they diminish in size towards apex. Surface finely striated in well-

preserved specimens. Many specimens from Balcombe Bay have flared, cup-shaped spinal endings; margin of cup finely striated. Some very short spines (11.5 mm.) are strongly forked with four or five terminal prongs. Some spines from Balcombe Bay ("C.") and Murgheboluc ("C.") retain traces of encircling colour bands.

Localities.—Victoria—Balcombe Bay ("C.," N.M.; paratypes, 17 spines, C.). Grice's Creek ("C."). Altona Bay Coal Shaft ("C."). Sorrento Bore (N.M., depths 995, 1034, 1310, 1340, 1376, 1490, 1580 and 1667 feet). Gellibrand ("H.," "C."). Fischer Point, Aire River ("C."). Orphanage Hill, Fyansford (N.M., "C."). Red Hill, Shelford ("H.," "C."). Murgheboluc, near Bannockburn, Geelong district ("C."). Native Hut Creek ("C."). Waurn Ponds ("C."). Ocean Grove ("C."). Left bank of Moorabool River, Lethbridge ("C."). Neumerella (F.C.). Dreir's, Mitchell River, lower bed ("C."). Forsyth's, Grange Burn (remanié fragments, "H."). Railway cutting between station and river, Dartmoor ("C."). South Australia—About 15 feet above river level, Murray River Cliffs at Morgan ("C."; holotype, C.). Four miles below Morgan, Murray River, middle bed ("C."). Murray River Cliffs from Wongulla to Mannum, lower beds ("C."). Near Millicent ("C."). Aldinga, lower beds ("C.").

Range.—Upper Oligocene to Miocene.

Goniocidaris pentaspinosa Chapman and Cudmore.

Plate XIV, figs. 18, 19.

Goniocidaris pentaspinosa Chapman and Cudmore, in Chapman, 1928, p. 91.

The following description is amplified and emended from our preliminary description:—Test small, very depressed; ambulacra wavy; interporiferous areas with two vertical rows of small miliaries on inner ends of opposing ambulacral plates; towards ambitus, two other rows of smaller tubercles inclined at 45 degrees downwards from larger tubercle on same plate; surface then sharply descends to a sunken area; this area, containing the suture, is as wide as either poriferous zone and consists of horizontal ridges leading downwards from the tubercles. Poriferous zones sunken; pores non-conjugate, circular, close together, each pair separated from next pair by a ridge. Six ambulacral plates adjacent to largest coronal plate. Coronal plates up to seven in number. Scrobicules sunken and circular, becoming elliptical near actinosome; boss conical, uncrenulated; perforate mamelon contracted at base, small in proportion to boss. Tubercles on coronal plates almost entirely confined to prominent ring, though a few are situated towards median interambulacral area; ring slightly overhangs scrobicule. Scrobicules not confluent, though rings merge in actinal region. Median interambulacral area narrow, continuous, sunken, bare, with pits at angles of coronal plates. Upper abactinal plates separated by grooves at horizontal sutures.

Slender spines found in same strata as tests polygonal in section, bearing usually from five to eight ridges, finely but distinctly serrated. Ornamentation varies from mere punctae to short spinules, the latter invariably arranged in series; towards base spinules more accentuated and salient. Ring milled. Colour bands occasionally preserved.

Observations.—*Goniocidaris pentaspinosa* is a typical member of the genus, and like *G. prunispinosa* has a wide range in

Australian Cainozoic deposits. It is distinguished from all other fossil species by the prominent evenly-composed scrobicular ring which has no miliaries visible to the naked eye outside it. The imperfect test from Wongulla now selected as a neotype is substituted for that specimen from Neumerella (Reg. No. 13754) originally figured, which proves to be *G. murrayensis*.

Measurements.—Neotype: height of test, 10 mm.; width of interamb area, 8 mm.; width of amb plate, 1.75 mm.; width of coronal plate, 4.5 mm.; height, 3.5 mm. Paratypes: length of longest spine, 34 mm.; diameter of shaft at ring, 2 mm.

Localities.—Victoria—Grice's Creek, near Frankston ("C."; paratypes, 5 spines, C.). Balcombe Bay, Mornington (N.M., "C."). Altona Bay Coal Shaft ("F.A.S.," "C."). Sorrento Bore at 1330 ft. (N.M.). Orphanage Hill, Fyansford (N.M., "C."). Murgheboluc, Sections 4A and 2B ("C."). Neumerella (F.C.). Mitchell River (D.; "F.C."). Skinner's, Mitchell River ("C."; spines with colour bands, "C.P.C."). Clifton Bank, Muddy Creek, Hamilton ("F.C.," "C."). Gellibrand ("H.," "C."). Nelson ("H."). South Australia—Wongulla, Murray River, near base of cliffs ("C."; neotype, C.). Morgan, lower beds ("C."). Four miles below Morgan ("C."). Murray River Cliffs, from Wongulla to Mannum, lower beds ("C."). Torrensdale, Holding's Old Quarry, 4 miles N.N.W. from Mt. Gambier ("C.").

Range.—Upper Oligocene to Miocene.

Goniocidaris murrayensis sp. nov.

Plate XIV, figs. 20–22.

Goniocidaris pentaspinosa Chapman and Cudmore (pars), 1928, pl. XI, figs. 74g.

Test small, round, very depressed. Apex wider than actinosome. Ambulacra broad, sinuous; poriferous zones sunken. Pores non-conjugate, circular, close together, separated by thin ridge; ambulacral plates bearing them often not horizontal. On upper part of inner end of each ambulacral plate, a tubercle with well-developed boss; separated from similar tubercle on next plate of same vertical series towards apex by small granule on margin of that plate; a second and smaller tubercle at 45 degrees downwards from the first; opposite these tubercles a third smaller than the second usually present. The third tubercle occupies part of median area of sunken interporiferous zone; the side of this area consequently has a raised zigzag appearance; interporiferous zone equal in width to a poriferous zone. Five ambulacral plates adjacent to largest coronal plate. Six coronal plates. Scrobicules slightly sunken, circular, tending to become elliptical near actinosome; boss large, conical, uncrenulated; mamelon perforate, small in comparison to boss. Scrobicular ring slightly overhangs scrobicule; composed of closely packed tubercles of uniform size; a few tubercles also closely packed outside ring, but (including in count those in ring) they are never more than two deep on plates except towards median area of interambulacra; in this area are two extensions of tubercled surface, three tubercles being in a row, linking each plate to similar extensions from each of the two nearest plates in opposite vertical series; suture faintly visible. Plates nearest apex marked off from adjacent plates below by a deep horizontal sutural groove; elsewhere in the vertical series

the rings meet, but on either side of each junction horizontal sutures are marked by a groove; groove next median interambulacral area leads into deep pit between extensions of ornament already mentioned. Scrobicules not confluent. Median area of interambulacrum narrow.

Specimens larger than holotype have seven coronal plates; in more mature tests tubercles nearest interambulacral median area do not extend across suture except in actinal portion of test; on abactinal portion surface containing suture becomes more prominent as a depressed, bare area linking up pits; marginal surface next median suture is widened and is ornamented with more numerous, crowded tubercles.

Observations.—This well-preserved little test undoubtedly belongs to the genus *Goniocidaris*. It is close to *G. pentaspinosa*, but varies from it in the ladder-like character of the interambulacral median area. The sutural groove separating uppermost coronal plates from plates lying next but one to the apex is a feature of the living *G. tubaria*. The usual number of ambulacral plates adjacent to the largest coronal plate is seven. Spines have not been recognised. The interambulacral zone from Neumerella previously figured (1928, Pl. XI, fig. 74g) as *G. pentaspinosa* is now referred to *G. murrayensis*.

Measurements.—Holotype: diameter of test, 13.25 mm.; height, 6.25 mm.; diameter across apical system, 6.5 mm.; diameter across peristome, 5 mm.; width of amb, 2 mm.; width of interamb, 5 mm.; width of coronal plate at ambitus, 3 mm.; height, 2.5 mm.

Localities.—Victoria—Neumerella (N.M., Reg. No. 13754). Longford ("H."). Flinders ("C."). South Australia—Lower Murray Cliffs (Holotype, complete test, N.M.). Morgan, lower beds ("C."; paratype, N.M.). Wongulla, Murray River, lower beds ("C."). Aldinga, lower beds (S., D., "C.").

Range.—Upper Oligocene to Miocene.

Goniocidaris mortenseni sp. nov.

Plate XIV, figs. 23, 27.

Test rather small. Ambulacra broad, slightly sinuous. Poriferous zones sunken. Pores non-conjugate, oval, close together, separated by thin ridge. Margin of interporiferous zone on each ambulacral plate marked by a single large tubercle, consisting of boss and mamelon, opposite end of ridge which divides pairs of pores from one another; against inner side of tubercle two small granules form a defined edge from which horizontal, broad, rounded ridges slope sharply downwards to median suture. There is therefore a pronounced nearly vertical ridge between poriferous zone and median area of interporiferous zone. Eight ambulacral plates adjacent to largest coronal plate. Number of coronal plates unknown. Scrobicules sunken; elliptical in actinal region, nearly circular elsewhere; not confluent. Perforate mamelon small in comparison to conical, uncrenulated boss. Scrobicular ring does not overhang scrobicule; composed of large tubercles; a few smaller tubercles lie beyond it, particularly in region of interambulacral median area where ornament ends and surface of plate drops vertically to a bare, sunken area. Suture in

middle of this area only slightly zigzag. Horizontal sutures between coronal plates end against poriferous zone in small well-defined pits, but in median interambulacral area they terminate in deep, v-shaped grooves or pits. Halfway between any two of these latter grooves, opposite centre of each plate, is a much smaller depression in sunken median area.

Spines short, probably never as long as horizontal diameter of test. Many retain original purplish colour. Ring milled, collar finely striated. No narrowing of shaft near neck ; it sometimes thickens slightly above neck, then tapers to apex ; tapering often very slight. Spines covered with short thorns, irregularly arranged, inclined a little towards apex. A few spines flattened apically. Apex more or less flared, often cup-shaped ; diameter of cups never exceeds that of thickest part of shaft.

Measurements.—Holotype (test fragment) : vertical length of four coronal plates, 19.5 mm. ; height of largest plate, 5.25 mm. ; width of largest plate, 9.5 mm. ; width of amb plate, 3.5 mm. Paratypes (spines) : length of longest spine, 23 mm. ; diameter of shaft, 2.5 mm.

Observations.—*Goniocidaris mortenseni* is very close to the living *G. tubaria*, but has a less depressed test, fewer tubercles on the portion of the coronal plate next the interambulacral zone, and broader and shorter v-shaped grooves. The interporiferous area as far as the suture, not counting marginal tubercles, is more sunken, and is equal in width to the poriferous zone. The poriferous zone is more sunken, and the longitudinal ridge of tubercles marginal to it is far more pronounced. Only fragments of the test have been found. Spines and test-fragments are from the same stratum and are undoubtedly conspecific. The spines differ from those of living species in being more slender and rarely flattened ; they terminate in tiny cup-shaped flares, whereas the apex in recent spines is shaped like a nearly fully opened hand.

We have named this species after Dr. Th. Mortensen, whose magnificent Monograph on the Cidaroida has proved of the greatest help to us.

Localities.—South Australia—Aldinga, upper beds (holotype, C. ; paratypes, 6 spines from same beds, C ; also "C.")

Range.—Lower Pliocene.

Genus CHONDROCIDARIS A. Agassiz 1863.

Both living species of *Chondrocidaris* are confined to the Indo-Pacific. A possible fossil form of this genus occurs in the (?) Miocene of Madagascar. Some of the spines described as *Phyllacanthus sundaica* Martin from the Miocene of Java probably belong to the same genus. The pores are conjugate (Mortensen, 1928).

Chondrocidaris clarkii sp. nov.

Plate XIII, figs. 15–17 ; Plate XV, fig. 31.

Syntype from Morgan : an almost complete young test, actinal portion of one interamb zone alone missing ; somewhat flattened at apex, depressed abactinally, of medium size. Ambulacra wide, nearly straight ; level interporiferous areas at ambitus with six vertical rows of small miliary tubercles, two of which disappear towards actinosome and probably also towards apex. No trace of median depression, but suture visible. Poriferous zones slightly sunken. Pores conjugate, oval, close together. Ten ambulacral plates adjacent to largest coronal plate. Interambulacra broad. About eight coronal plates ; marginal area adjacent to poriferous zone flat. Boss uncrenulated ; small mamelon, contracted at neck. Scrobicules deeply sunken, not confluent ; elliptical at ambitus and towards actinosome, circular towards apex ; bounded by a ring of tubercles which slightly overhangs margin ; tubercles composing ring widely spaced, the space between any two being entirely bare and not invaded by granules placed beyond ring. Median area of interambulacra broad and flat ; no trace of median depression ; uniformly covered with small, closely packed miliaries. Median suture either invisible or very faint.

Syntype from near Overland Corner : a perfect adult test, large. Abactinal region well shown. Rows of small miliary tubercles in ambulacra similar to those of smaller syntype. Suture a fine line in almost flat median interambulacral area. Entire perignathic girdle visible. Eight coronal plates ; marginal areas adjacent to poriferous zone almost flat. Fourteen ambulacral plates opposite largest coronal plate.

Measurements.—Syntype from Morgan : diameter across peristome, 13 mm.; horizontal diameter of test, 36 mm. ; height of test, about 22 mm. ; width of interamb area at ambitus, 17.5 mm. ; width of amb, 4.25 mm. ; width of coronal plate at ambitus, 9.25 mm. ; height of plate, 5.25 mm. Syntype from below Overland Corner : horizontal diameter, 62 mm. ; height, 33 mm. ; diameter across apical system, about 21.5 mm. ; diameter across peristome, 20.5 mm. ; width of interamb area at ambitus, 30 mm. ; width of amb, 6 mm. ; width of coronal plate at ambitus, 16 mm. ; height of plate, 9 mm.

Spines resembling those of living species of *Chondrocidaris* occur in same strata as tests, and evidently belong to this species. Figured paratypes from an infilled pocket in strata at Morgan evidently came from one individual. Length of longest spine, 50 mm. Long, slender, thorny near base, longitudinally ridged towards apex. Collar finely striated ; lines crossing ring give it a milled appearance. Plane of ring not at right angles to shaft. No narrowing of shaft above collar, and little tapering. Near collar, shaft is circular in section, but it gradually flattens. More flattened side bare of ornament near collar ; for more than half length of shaft bears broad, thin thorns, outwardly directed, becoming wing-like along sides of shaft ; these thorns give place to thin ridges capped with outwardly directed points. Ridges end at blunted spinal apex. A smaller spine (30 mm.) has no ridges, but ends in winged apex with serrated edges : an identical spine was collected at Brown's Creek, Cape Otway district. Another spine (16.5 mm.) bears only fine serrated ridges which increase in height towards blunt apex. All retain traces of original purple colour.

Observations.—The principal features distinguishing the above species are the typically flattened and closely granulated plates

of the interambulacral median area ; the conjugate pores and the characteristic spines.

We have much pleasure in naming this species after Dr. H. Lyman Clark who assisted us both by his personal advice and publications.

Localities.—Victoria—Brown's Creek, Cape Otway district ("H."). South Australia—Morgan, Murray River Cliffs, about 12 feet above river level ("C." ; syntype, and paratypes—6 spines, all C.). Murray River, lower beds, eighth cliff below Overland Corner, left bank (syntype, C.). Overland Corner, Murray River, lower beds (C.). Wongulla district, Murray River, lower beds ("C.").

Range.—Upper Oligocene to Miocene.

Club-shaped Spines, *incertae sedis.*

Plate XIV, figs. 25, 26*a*, *b*.

We have failed to correlate certain cidaroid spines with any of the above species.

Short club-shaped spines with slightly expanded tips and ornamented with linearly arranged granules are rare except at Booanya, Western Australia, where 985 specimens were collected and presented to the National Museum by Miss A. E. Baesjou. Mortensen (1928, fig. 46) figures tests of *Prionocidaris* and *Stereocidaris* exhibiting spines which tend to become club-shaped, but evidence concerning the spines here considered does not justify correlation with species of those genera described by us, of which only *Phyllacanthus duncani* occurs at Booanya. Two long spines, bearing some resemblance to the small club-shaped spines in ornamentation have been collected with them at Waurn Ponds ("H") and near the Glenelg River ("C.P.C."). The great abundance of clubs at Booanya and the absence of identically ornamented slender spines from the collection made there suggest genera which bore club-shaped spines only, as for example in *Eucidaris*, a genus now living in Northern Australia. We hope to elucidate this problem by comparing sections of these fossil spines with other Australian forms and by additional field evidence.

Localities.—Victoria—Waurn Ponds, Geelong (C. ; "C."). Near Glenelg River, Parish of Wataepoolan ("C.P.C."). Point Addis ("C."). South Australia—Mt. Gambier ("C."). Western Australia—Booanya, near Balladonia (N.M.).

Range.—Miocene.

Smooth Spines, *incertae sedis.*

Plate XIV, fig. 24.

The spines are typically smooth and colour-banded ; towards the apex some have several very faint lines of prickles and more

rarely a spinule (0.5 mm. in length). The longest spine bears seven dull purplish-brown colour-bands (1 mm. wide) encircling the shaft at intervals of 2 mm. ; on one side of the shaft the colour is less pronounced. The shaft is slender, circular in section and tapering ; it bears fine striae which cross the ring.

Although there is a suggestion of affinity with *Goniocidaris prunispinosa*, we are unable to determine to which species these spines belong.

Measurements.—Longest spine, apex missing, Wongulla, Murray River, lower beds : length, 27 mm. ; average length about 21 mm.

Localities.—South Australia—Morgan, lower beds, and from Wongulla to Mannum, River Murray, lower beds. Aldinga, lower beds. Figured spines in (C.) ; all others in ("C.").

Range.—Upper Oligocene to Miocene.

Synopsis of Material.

In order to indicate relative abundance of different species we have made an approximate count of specimens examined by us. The amount of collected material is partly governed, of course, by the accessibility of the richer localities to collectors.

	Tests	Fragments	Spines
Stereocidaris australiae	3	99	534
Phyllacanthus duncani	—	174	615
Prionocidaris scoparia	1	22	114
Goniocidaris prunispinosa	1	26	468
G. pentaspinosa	—	10	115
G. murrayensis	1	22	—
G. mortenseni	—	26	160
Chondrocidaris clarkii	2	5	30
Smooth spines, *incertae sedis*	—	—	60
Club-shaped spines, *incertae sedis* ..	—	—	985

Key to Abbreviations of Names of Collections.

Collections in the National Museum :—

N.M.=National Museum general collection. D.=Dennant Coll. S.=Sweet Coll. M.=Mulder Coll. W.=Wilkinson Coll. (Geol. Surv. Vict.). C.=Cudmore Coll. F.C.=Chapman Coll. H.=Hall Coll.

Other collections (all distinguished by inverted commas) :—

"C."=Cudmore Coll. "C.P.C."=Commonwealth Palaeontological Coll. "F.C."=Chapman Coll. "F.A.S."=Singleton Coll.. "G.C."=Rev. G. Cox Coll. "H."=Hall Coll. (the part in Cudmore Coll.).

Synopsis of Species.

St. australiae	Ph. duncani	Pr. scoparia	Ch. clarkii
Test small to medium. Abactinally depressed, actinally greatly depressed.	Medium to large. Slightly abactinally depressed.	Large. Slightly abactinally depressed.	Rather small to large. Somewhat depressed.
Non-conjugate pores.	Conjugate.	Conjugate.	Conjugate.
12 ambulacral plates adjacent to largest coronal plate in adult specimens.	17 Plates.	15 Plates.	10 Plates.
Ambulacra narrow, slightly wavy; 4, 6, or 8 vertical rows of miliaries in interporiferous areas.	Undulating, narrow; 4, 6, or 8 rows of miliaries.	Undulating, narrow; 4, sometimes 6, rows of miliaries.	Broad, nearly straight; 6 rows of miliaries.
Scrobicules deeply sunken (variable); slightly elliptical below ambitus, otherwise circular.	Sunken, elliptical, becoming circular.	Shallow, elliptical at ambitus, circular near apex.	Sunken, elliptical, circular near apex.
Scrobicular ring overhangs; inconspicuous.	Not overhung; ring conspicuous.	Not overhung; ring conspicuous.	Slightly overhangs; ring conspicuous.
Interambulacral median area broad (narrow in young specimens); sunken.	Broad; only slightly depressed at suture.	Very narrow; only slightly depressed at suture.	Broad, flat.
Pits and grooves at horizontal sutures between coronal plates.	No pits or grooves.	No pits or grooves.	No pits or grooves.
Perforate mamelons usually absent from abactinal coronal plates; 1–5 in each iamb series.	Never more than one rudimentary non-perforate mamelon in each iamb zone.	Ditto.	Ditto.

G. prunispinosa	G. pentaspinosa	G. murrayensis	G. mortenseni
Rather small. Depressed.	Small. Very depressed.	Small. Very depressed.	Rather small. Shape unknown.
Non-conjugate pores.	Non-conjugate.	Non-conjugate.	Non-conjugate.
6 ambulacral plates adjacent to largest coronal plate in adult specimens.	6 Plates.	5 Plates.	8 Plates.
Suture in interporiferous area very slightly sunken.	Sunken.	Sunken.	Sunken.
Scrobicules sunken, elliptical, circular near apex.	Sunken, circular, elliptical near actinosome.	Slightly sunken, circular, elliptical near actinosome.	Sunken, elliptical in actinal region, nearly circular elsewhere.
No ring of tubercles around scrobicules. Margin overhangs latter. Tubercles on non-scrobicular portion of plate not numerous.	Conspicuous scrobicular ring overhangs slightly. Tubercles on plate almost entirely confined to ring.	Conspicuous scrobicular ring overhangs slightly. Tubercles outside ring crowded.	Conspicuous ring does not overhang. Few tubercles outside ring.
Interambulacral median area broad, tuberculate, not sunken. No pits at angles of plates.	Narrow, sunken, bare. Pits present.	Median area is crossed by raised ornament connecting adjacent plates; pits in between.	Bare, sunken. Pits present.
No horizontal sutural groove between two uppermost abactinal iamb plates.	Sutural groove present.	Sutural groove present.	Unknown.

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Explanation of Plates.

Plate XII.

Fig. 1. *Stereocidaris australiae* (Duncan). Actinal view of plesiotype ; Aldinga, lower beds. Tate Coll. Nat. size.

Fig. 2. *S. australiae.* Abactinal view of same specimen, showing apical system. Nat. size.

Fig. 3. *S. australiae.* Large iamb zone ; Aldinga, lower beds ; Plesiotype ; Tate Coll. Nat. size.

Fig. 4. *S. australiae.* Iamb zone with nine perforate mamelons in an iamb row ; Aldinga, lower beds ; Plesiotype (Reg. No. 13698) ; Nat. Mus., Dennant Coll. Nat. size.

Fig. 5. *S. australiae.* Abactinal portion of iamb zone ; Castle Cove ; Plesiotype (Reg. No. 13697). Nat. Mus., coll. T. S. Hall, pres. F.A.C. Nat. size.

Fig. 6*a*, *b*. *S. australiae.* *a*, actinal portion of iamb zone. Plesiotype (Reg. No. 13725) ; Nat. Mus., pres. F.A.C. *b*, iamb zone ; Plesiotype (Reg. No. 13701) ; Nat. Mus., coll. T. S. Hall, pres. F.A.C. Both from Castle Cove. Nat. size.

Fig. 7. *Phyllacanthus duncani*, sp. nov. Iamb zone; Batesford; Holotype (Reg. No. 13707); Nat. Mus., Mulder Coll. Nat. size.

Fig. 8. *P. duncani*, sp. nov. Abactinal portion of iamb zone; Batesford; Paratype (Reg. No. 13706); Nat. Mus., coll. T. S. Hall, pres. F.A.C. Nat. size.

Fig. 9. *P. duncani*, sp. nov. Large iamb zone; Port Macdonnell; Paratype (Reg. No. 13705); Nat. Mus., T. S. Hall Coll. Nat. size.

Fig. 10. *Prionocidaris scoparia*, sp. nov. Abactinal view of test, showing spine; Aldinga, lower beds; Syntype; Tate Coll. Nat. size.

Fig. 11. *P. scoparia*, sp. nov. Iamb zone; Knight's Railway Siding Quarry, near Mount Gambier; Syntype (Reg. No. 13709); Nat. Mus., pres. by the Mines Dept. of Victoria. Nat. size.

Plate XIII.

Fig. 12. *Goniocidaris prunispinosa* Chapman and Cudmore. Spines; Balcombe Bay; 16 Paratypes (Reg. No. 13715); Nat. Mus., pres. F.A.C. x 2.

Fig. 13. *G. prunispinosa*. Spine with cup-shaped apex; Balcombe Bay. Paratype (Reg. No. 13714); Nat. Mus., pres. F.A.C. Nat. size.

Fig. 14. *G. prunispinosa*. Ambital view of test, showing attached spines. Murray River Cliffs, Morgan, lower beds; Holotype (Reg. No. 13174); Nat. Mus., pres. F.A.C. Nat. size.

Fig. 15. *Chondrocidaris clarkii*, sp. nov. Ambital view of test; Murray River Cliffs, Morgan, lower beds; Syntype (Reg. No. 13175); Nat. Mus., pres. F.A.C. Nat. size.

Fig. 16. *C. clarkii*, sp. nov. Ambital view of the other syntype; Murray River Cliffs below Overland Corner, lower beds; Reg. No. 13159; Nat. Mus., pres. F.A.C. Nat. size.

Fig. 17. *C. clarkii*, sp. nov. Abactinal view of the same test, showing part of the perignathic girdle. Nat. size.

Plate XIV.

Fig. 18. *Goniocidaris pentaspinosa* Chapman and Cudmore. Iamb zone. Wongulla, Murray River, lower beds; Neotype (Reg. No. 13717); Nat. Mus., pres. F.A.C. ×2.

Fig. 19. *G. pentaspinosa*. Spines; Grice's Creek; 5 Paratypes (Reg. No. 13718); Nat. Mus., pres. F.A.C. ×2.

Fig. 20. *G. murrayensis*, sp. nov. Iamb zone; Morgan, lower beds; Paratype (Reg. No. 13719); Nat. Mus., pres. A. King. ×2.

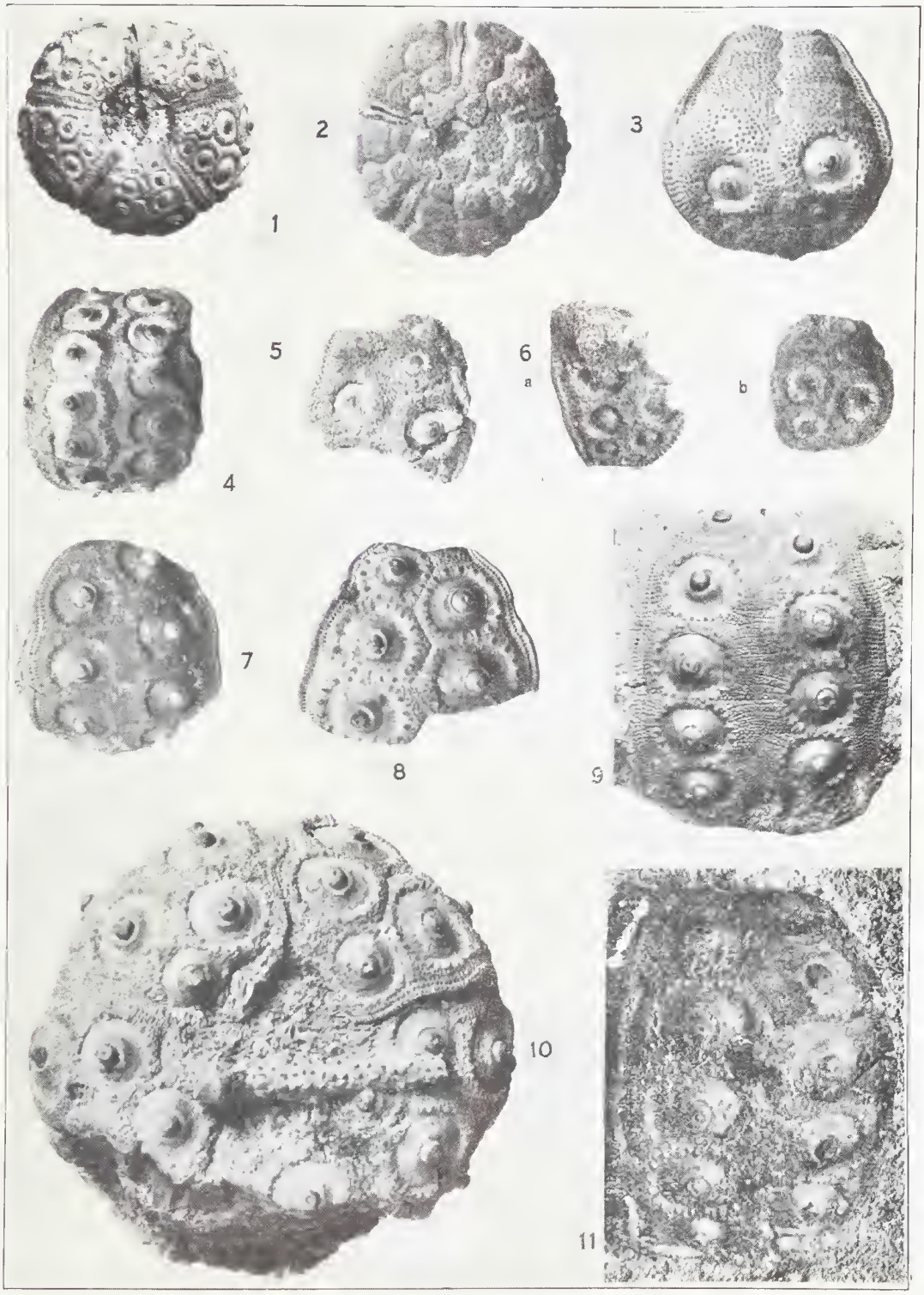
Fig. 21. *G. murrayensis*, sp. nov. Actinal view of Holotype; Lower Murray River Cliffs; Reg. No. 4674; Nat. Mus., coll. C. R. Thatcher. ×2.

Fig. 22. *G. murrayensis*, sp. nov. Ambital view of holotype. ×2.

Fig. 23. *G. mortenseni*, sp. nov. Test fragment; Aldinga, upper beds; Holotype (Reg. No. 13720); Nat. Mus., pres. F.A.C. ×2.

Fig. 24. 3 Smooth Spines, *incertae sedis*, showing colour bands; Wongulla, Murray River, lower beds; Reg. No. 13722; Nat. Mus., pres. F.A.C. ×2.

Fig. 25. 3 Club-shaped Spines, *incertae sedis*; Booanya, Western Australia; Reg. No. 13723; Nat. Mus., pres. Miss A. E. Baesjou. ×2.



Cainozoic Cidaroids

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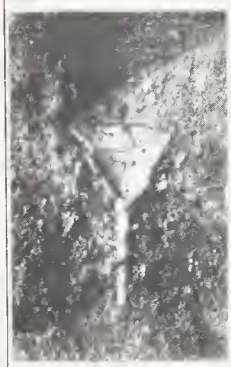

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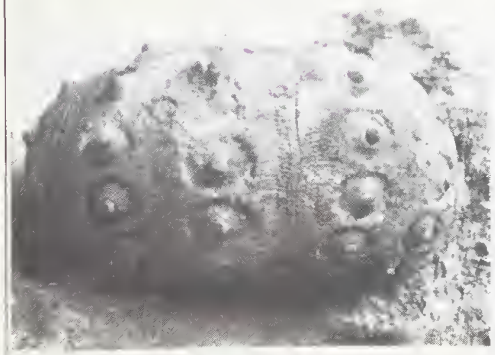

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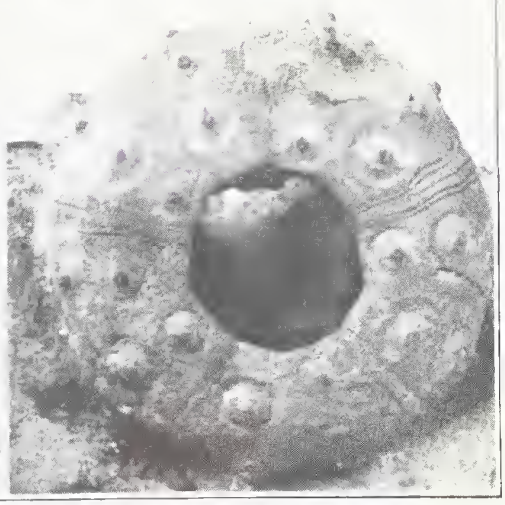

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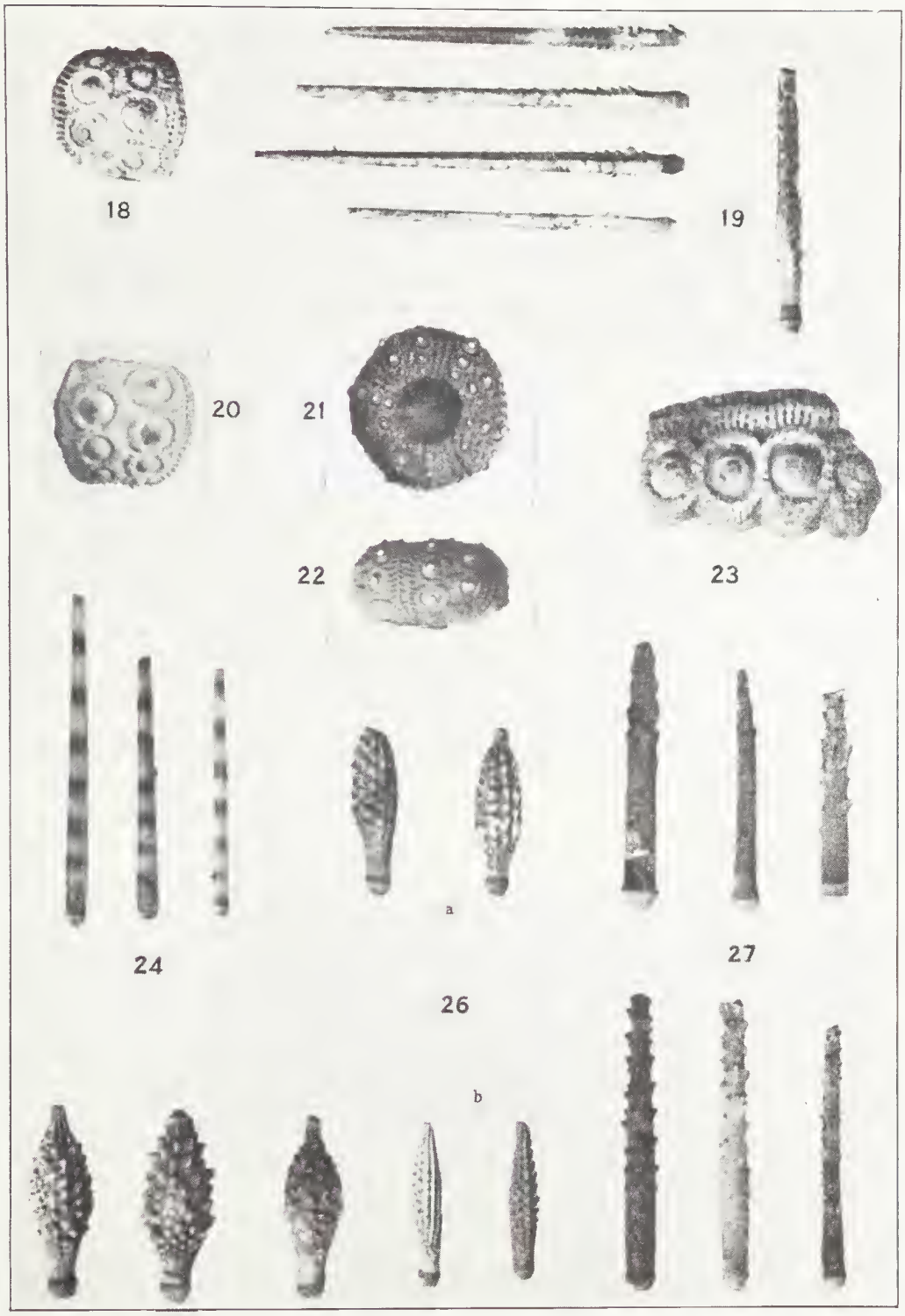

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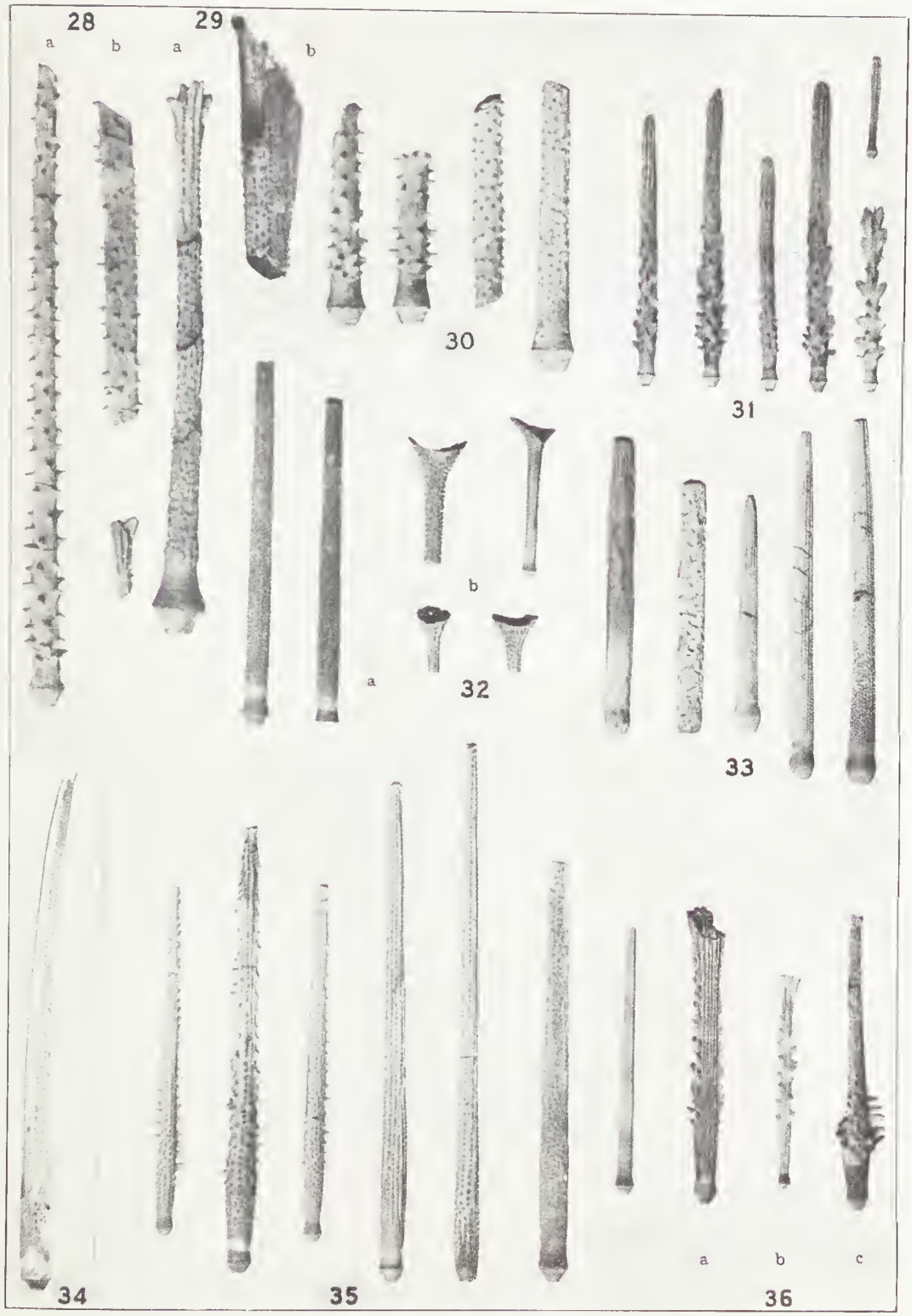

Cainozoic Cidaroids

Fig. 26*a*, b. 4 Club-shaped Spines, *incertae sedis;* Waurn Ponds; Reg. No. 13724; Nat. Mus., pres. F.A.C. ×2.

Fig. 27. *Goniocidaris mortenseni*, sp. nov. Spines; Aldinga, upper beds; 6 Paratypes (Reg. No. 13721); Nat. Mus., pres. F.A.C. ×2.

Plate XV.

Fig. 28*a–c*. *Prionocidaris scoparia*, sp. nov. *a*, thorn-bearing spine, tip imperfect; *b*, thorn-bearing spine with flattened shaft; *c*, a spine tip. All from Aldinga, lower beds; 3 Paratypes (Reg. No. 13710); Nat. Mus., pres. F.A.C. Nat. size.

Fig. 29*a*, *b*. *P. scoparia*, sp. nov. *a*, complete spine with shorter thorns, showing tip; Reg. No. 13711; Nat. Mus., pres. F.A.C. *b*, fragmentary flattened spine with similar ornament, showing tip; Tate Coll.; Paratypes. Both from Aldinga, lower beds. Nat. size.

Fig. 30. *P. scoparia*, sp. nov. Fragmentary spines to show ornament; Aldinga, lower beds; 4 Paratypes (Reg. No. 13712); Nat. Mus., Sweet Coll. Nat. size.

Fig. 31. *Chondrocidaris clarkii*, sp. nov. Spines; Morgan, lower beds; 6 Paratypes (Reg. No. 13713); Nat. Mus., pres. F.A.C. Nat. size.

Fig. 32*a*, *b*. *Stereocidaris australiae* (Duncan). *a*, Spines, tips missing; 2 Plesiotypes (Reg. No. 13699). *b*, cup-shaped spine tips; 4 Plesiotypes (Reg. No. 13700). All from Point Flinders, near Cape Otway; Nat. Mus., pres. F.A.C. Nat. size.

Fig. 33. *Phyllacanthus duncani*, sp. nov. Spines, two showing peeling of outer ornament; Batesford; 5 Paratypes (Reg. No. 13708); Nat. Mus., pres. F.A.C. Nat. size.

Fig. 34. *Stereocidaris australiae*. Curved spine; Aldinga, lower beds; Plesiotype; Tate Coll. Nat. size.

Fig. 35. *S. australiae*. Spines, one showing colour bands; Aldinga, lower beds; 7 Plesiotypes (Reg. No. 13702); Nat. Mus., pres. F.A.C. Nat. size.

Fig. 36*a–c*. *S. australiae*. *a* and *b*, spines; 2 Plesiotypes (Reg. No. 13703). *c*, spine, with wing-like projections near the neck; Plesiotype (Reg. No. 13704). All from Aldinga, lower beds; Nat. Mus., pres. F.A.C. Nat. size.