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Echinoids from the Chlamys Ledge Member (Polonez Cove Formation, Oligocene) of King George Island, West Antarctica

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Abstract: New echinoid material from the Oligocene Chlamys Ledge Member (uppermost part of the Polonez Cove Formation) on King George Island, West Antarctica, includes the "regular" echinoid *Caenopedina aleksandrabitnerae* sp. n. and poorly preserved spatangoids, here tentatively identified as members of the genus *Abatus*. *Caenopedina aleksandrabitnerae* sp. n. is characterized by fully tuberculate genital plates, which sets it apart from most other species in the genus, by the uneven periproctal margin which indicates that periproctal plates were incorporated into the apical disc, and by moderately wide interambulacral plates with a height/width ratio of 1:3. Among the modern *Caenopedina* species it is closest to the Australian and New Zealand representatives, which is in contrast to previous reviews of Cenozoic Antarctic echinoid faunas that suggested limited relationship to the Australasian region. This is the first record of *Caenopedina* from Antarctica; it considerably extends its historical distribution to the south.

Key words: Antarctica, South Shetlands, Cenozoic, echinoids, *Caenopedina*, *Abatus*, new species.

Introduction

So far, relatively few records of Antarctic fossil echinoids have been published. Early reports were reviewed by Hotchkiss (1982). Since then, extinct sea urchins have been described mainly from the Maastrichtian and Eocene (Blake and Zinsmeister 1991 and McKinney *et al.* 1988; Radwańska 1996, respectively) of Seymour Island, the Upper Cretaceous of the James Ross Basin (Néraudeau *et al.* 2000) and the Lower Cretaceous of Alexander Island (Smith and Crame 2012). Echinoid material from the Polonez Cove Formation was mentioned earlier by Hotchkiss (1982) and Jesionek-Szymańska (1984). Hotchkiss (1982) briefly reported on the presence of a "regular" echinoid which possibly belonged to the

South African genus *Polyechinus*, while Jesionek-Szymańska (1984) recorded disarticulated plates and spines which she tentatively assigned to the modern Antarctic genera *Notocidaris* and *Sterechinus*.

The new material presented here differs from all material previously studied from this formation and records the presence of additional echinoid taxa. Preservation of the new specimens is rather poor – the corona of the spatangoids is completely leached, being preserved as distorted moulds within the matrix. Such can be identified only tentatively on the basis of general shape and are most similar to some of the spatangoid genera extant in the region today, *i.e.*, *Abatus* and *Tripylus*. The most important find, however, is an internal mould with adhering test fragment belonging to a "regular" echinoid. Based on ambulacral structure and tuberculation it can be attributed to the pedinid genus *Caenopedina*. The genus is predominantly known from extant species distributed in continental shelf and slope waters of tropical to sub-Antarctic regions (Anderson 2009), with most species occurring at depths in excess of 200 m. It is the sole modern representative of the order Pedinoida, which was much commoner and more diverse during Mesozoic times. The present record fills a gap in the temporal range of this genus, which is thought to have originated in the Middle Jurassic (Smith and Kroh 2011), but is poorly documented in the post-Jurassic fossil record. Its presence in Oligocene sediments of King George Island considerably extends the range of this genus southwards. Given that climatic conditions in the Oligocene were warmer than today it is not surprising that taxa limited to the sub-Antarctic at the southern end of their distribution area ranged further south in the past.

Anderson (2009) identified two different, yet unnamed, groups within the genus *Caenopedina*: forms with wide interambulacral plates and dense secondary tuberculation similar to the extinct genus *Diademopsis* and those with tall interambulacral plates and few secondary spines. The new *Caenopedina* species from King George Island falls within the former group (to date encompassing only Australia and New Zealand representatives) and is the oldest member of this group known so far. The new species also constitutes one of the rare records of an echinoid taxon in common between Australasia and West Antarctica – the absence of which has been remarked on by Hotchkiss (1982) – and indicates that the rarity of such taxa may indeed be mainly a result of our poor knowledge of fossil Antarctic echinoid faunas. In this respect, the fauna of the Chlamys Ledge Member is a good example, being more diverse than previously acknowledged. It is likely that further sampling will yield additional taxa, including new ones.

Geological setting

The echinoid samples studied derive from the Chlamys Ledge Member of the Polonez Cove Formation which crops out at steep cliffs and ledges between the

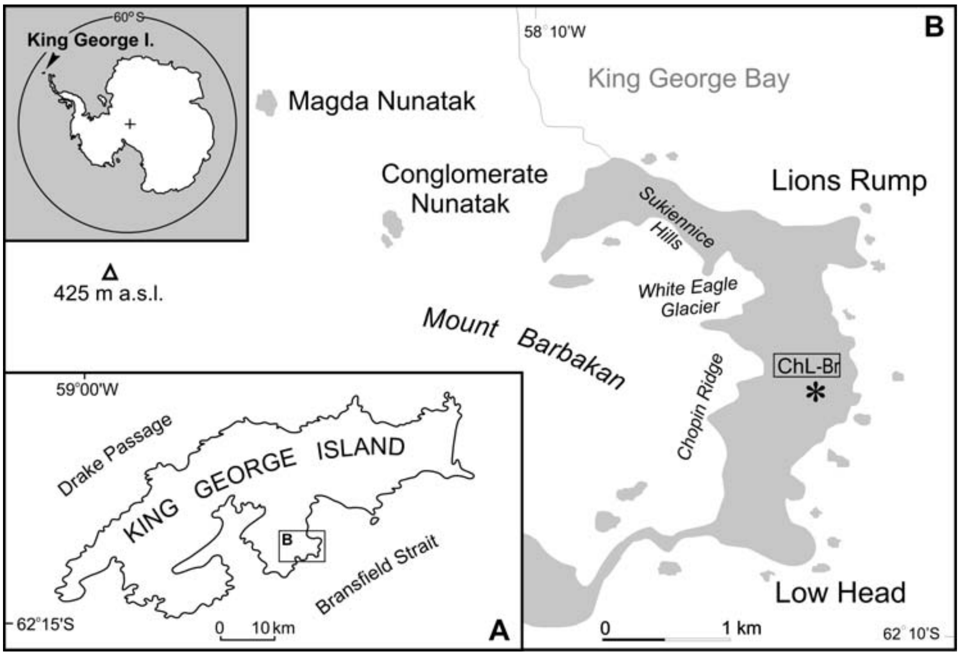

Fig. 1. Map of King George Island (inset **A**) and location of the Low Head-Lions Rump area (**B**). Asterisk indicates location of the echinoid-bearing strata of the Chlamys Ledge Member of the Polonez Cove Formation (Oligocene). Shaded areas are exposed rock (modified from Bitner *et al.* 2009).

Low Head and Lions Rump on King George Island, South Shetland Islands (Fig. 1). The formation consists of up to 60 metres of glacio-marine strata and overlies Upper Cretaceous to Eocene basalts of the Mazurek Point Formation (Birkenmajer 1980, 1982, 2001; Troedson and Smellie 2002). It is subdivided into six members: the basal Krakowiak Glacier Member (continental tillites) and five glacio-marine units (Bayview, Low Head, Siklawa, Oberek Cliff and Chlamys Ledge members) which formed during the glacial episode of the Polonez Glaciation (see Birkenmajer 1980, 1982, table 3; 1994, 2001; Porębski and Gradziński 1987; Dingle *et al.* 1997; Troedson and Smellie 2002, fig. 3; Jonkers 2003; Quaglio *et al.* 2014, fig. 3; Majewski and Gaździcki 2014, fig. 2). The Polonez Cove Formation is overlain by the mid-Oligocene dacite and andesite lavas and agglomerates of the Boy Point Formation.

The Polonez Cove Formation was originally dated as Pliocene (Barton 1965; Birkenmajer 1980, 1982; Gaździcki 1984; Gaździcki and Pugaczewska 1984), but later it was found to be Oligocene in age, based on calcareous nannoplankton (Gaździcka and Gaździcki 1985), planktonic foraminifera (Gaździcki 1989), K-Ar dating of associated volcanic rocks (Birkenmajer and Gaździcki 1986; Birkenmajer *et al.* 1991), and Sr isotope stratigraphy (Dingle *et al.* 1997; Dingle and Lavelle 1998).

Material and methods

The specimens studied were collected by B. Błażejowski, A. Gaździcki and Mariusz Potocki during the austral summer of 2006/2007. The relatively rare echinoids come from the upper part of the Chlamys Ledge Member at site ChL-Br (S 62° 08.82, W 58° 07.72; ~100 m above sea level, see Fig. 1.). They are embedded in greenish-grey sandstone and mudstone beds. Other fossils found at the site include common brachiopods (Bitner *et al.* 2009), solitary corals (Gaździcki and Stolarski 1992), bivalves, benthic foraminifera (Majewski and Gaździcki 2014) and recycled stromatolites (Gaździcki 2008). The echinoid material studied is kept at the Institute of Paleobiology, Polish Academy of Sciences, Warszawa under the repository numbers ZPAL E.11/1 to E.11/3.

Abbreviations: ZPAL – Institute of Paleobiology, Polish Academy of Sciences, Warszawa, Poland; TD – test diameter; TH – test height; TL – test length; TW – test width; ∠APP – angle between anterior paired petals; ∠PPP– angle between posterior paired petals.

Systematic part

Higher-level classification follows Kroh and Smith (2010).

Class Echinoidea Leske, 1778
Subclass Euechinoidea Bronn, 1860
Order Pedinoida Mortensen, 1939
Family Pedinidae Pomel, 1883
Genus *Caenopedina* A. Agassiz, 1869
Caenopedina aleksandrabitnerae sp. n.
(Figs 2A–C, 3A–G, 4A–B)

Diagnosis. — A medium-sized species of *Caenopedina* characterized by fully tuberculate genital plates, angular periproctal margin, low corona, moderately wide interambulacral plates with a height to width ratio of 1:3 to 1:3.3 ambitally, and slit-shaped ocular pores.

Etymology. — Named in honour of Maria Aleksandra Bitner (Warszawa), esteemed colleague and specialist of Cenozoic brachiopods.

Holoype. — ZPAL E.11/1, an internal mould with test remains adhering.

Type locality. — Site ChL-Br (S 62° 08.82’, W 58° 07.72’; ~100 m above sea level), Low Head-Lions Rump cliffs area, southeastern King George Island, South Shetland Islands, West Antarctica.

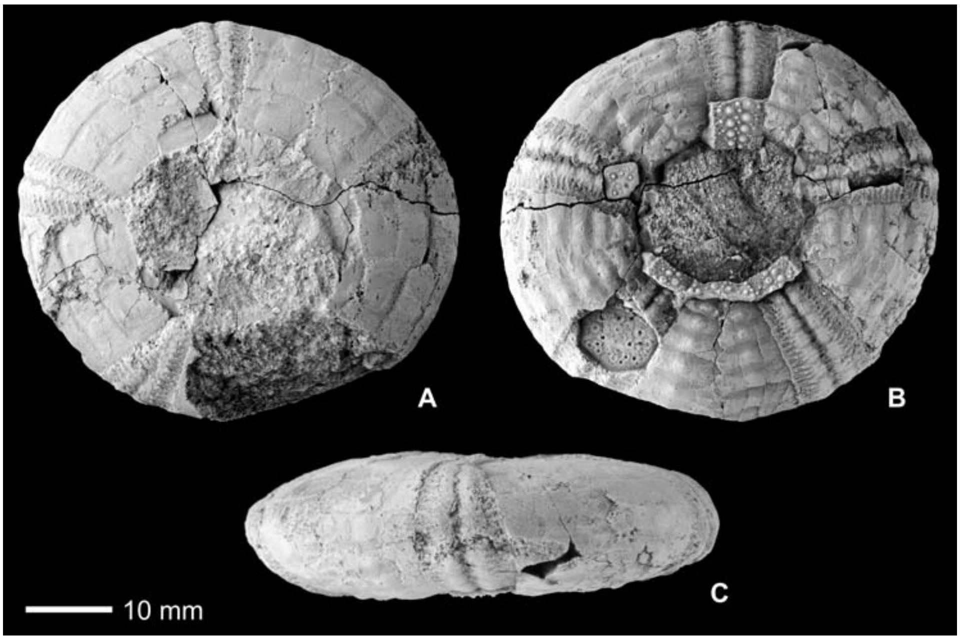

Fig. 2. *Caenopedina aleksandrabitnerae* sp. n., holotype ZPAL E.11/1; in aboral (**A**), oral (**B**), and lateral (**C**) views. Specimen whitened with ammonium chloride.

Type stratum. — Chlamys Ledge Member, uppermost part of the Polonez Cove Formation, Oligocene.

ZooBank LSID. — urn:lsid:zoobank.org:act:10CDCE64-2FB5-4B1B-9591--175B8EBE0883

Description. — Test diameter *c*. 50 mm, test height now 15 mm (30% TD), but was slightly higher originally, probably around 40% of TD, since the material is deformed due to sediment compaction (Fig. 2). Outline circular.

Apical disc large, about 46% of TD. Apical disc plates not preserved *in situ*, but a single genital and ocular plate each were preserved inside the corona and could be extracted during preparation. Genital plates (Fig. 3E) large, with single circular gonopore positioned slightly abaxially of the centre of the plate. Plate densely covered by tubercles. Lateral and abaxial margin of the plate bevelled, underlying adjacent ocular and interambulacral plates. Axial margin irregular, which suggests that periproctal plates were incorporated into the apical disc. Ocular plate (Fig. 3F) about one quarter the size of the genital plate, with several tubercles and a slit-shaped, radially elongated ocular pore. Based on the shape of the two plates the apical disc can be inferred to have been dicyclic.

Ambulacra about half as wide as the interambulacra at the ambitus; plates relatively high, with a height:width ratio of 1:1.3 at the ambitus. Ambulacral

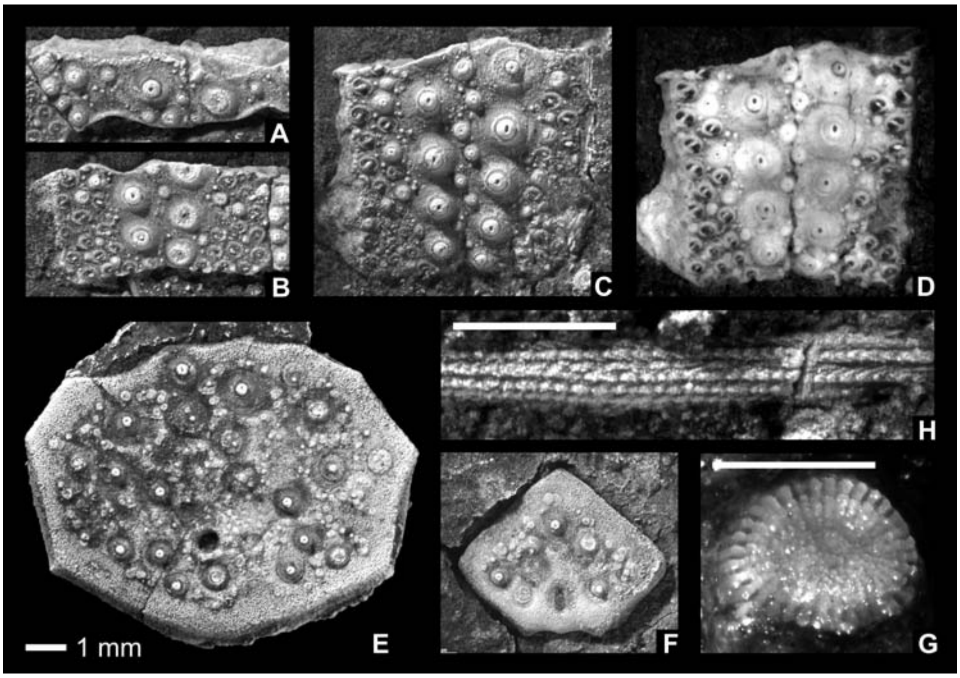

Fig. 3. *Caenopedina aleksandrabitnerae* sp. n., holotype ZPAL E.11/1. **A**. Adoral interambulacrum with shallow buccal notches. **B**–**D**. Adoral ambulacra (C and D show same area, but D is immersed in water). **E**. Genital plate. **F**. Ocular plate. **G**. Cross section of spine. **H**. Primary spine sculpture. A–C, E–F, H whitened with ammonium chloride. A to F at same magnification (1 mm scale bar), G and H more strongly magnified with separate scale bars (equalling 500 µm).

plates trigeminate with P3 isopores (*sensu* Smith 1978) adorally (Fig. 3B–D). Ambulacral compounding diadematid with three equally sized platelets extending from perradial to adradial suture (Fig. 4). All but the most adapical platelets united in perradial wedge. About 18 ambulacral and 10 to 11 interambulacral plates per column. Each interambulacral plate borders two to three ambulacral plates. Adoral and ambital interambulacral plates much wider than high (between 1:2.5 and 1:3.3 height/width ratio). Plates becoming much taller towards the apical disc (Fig. 2A), with the tallest plates (1:1.5 ratio) bordering the apical disc.

Tuberculation preserved only on fragments of the peristomial margin adhering to the internal mould and on the apical plates. Bulges on the internal mould, however, reveal that each ambulacral plate and each interambulacral plate bore one large primary tubercle. Preserved tubercles perforate, noncrenulate, with slightly undercut mamelon.

Peristome about 35% of TD, with very shallow buccal notches (Fig. 3A). Girdle consisting of slender auricles, but it is unknown whether or not they meet perradially.

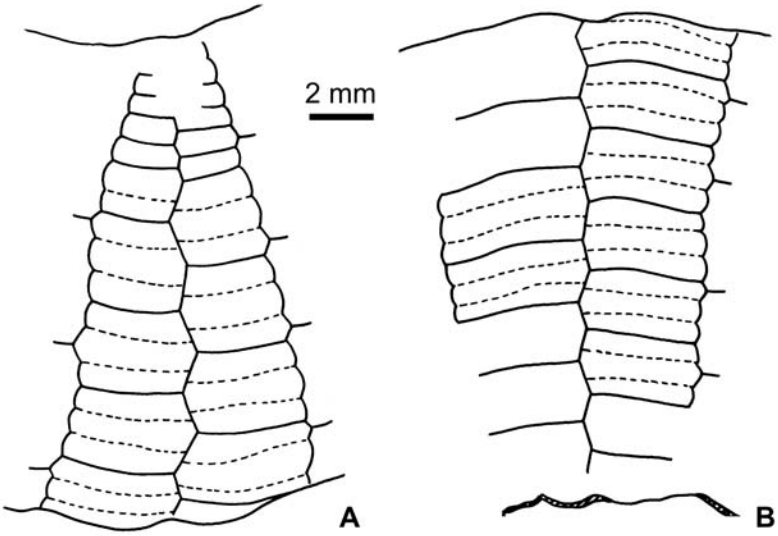

Fig. 4. *Caenopedina aleksandrabitnerae* sp. n., holotype ZPAL E.11/1; ambulacral plating showing plate compounding, in aboral (**A**) and oral (**B**) views.

Primary spines found within the matrix filling the corona longitudinally striated, with serrated ridges (Fig. 4H); solid in cross section, with medulla filled by dense, irregular meshwork (Fig. 4G). Although this cannot be demonstrated beyond all doubt these spines are considered to belong to the same specimen as the corona. Spine morphology is consistent with that known from extant members of the genus.

Discussion. — The King George Island specimen clearly belongs to the genus *Caenopedina*, based on its large perforate, noncrenulate tubercles on each plate that occupy most of the plate height at the ambitus, ambulacral plate compounding and large apical disc. In *Diademopsis*, which has similar features, the aboral ambulacral plates are not united in perradial wedges and in *Phymopedina* there are multiple subequal tubercles on ambital interambulacral plates. *Hemipedina* can be ruled out because only two of the three elements are encompassed by the primary tubercle in the ambulacral plates (Smith and Crame 2012).

Caenopedina species can be distinguished from each other by a combination of features of corona, spines and pedicellariae (Anderson 2009). Fortunately, the material studied preserves plates of the apical disc, which are particularly informative, because in most *Caenopedina* species genital plate tubercles are restricted to specific areas of these plates (see below). In *Caenopedina aleksandrabitnerae* sp. n., in contrast, genital plates are fully tuberculated. In addition, the periproctal margin of the new species is not smooth, as in all previously described *Caenopedina* species, but notched which shows that periproctal plates were incorporated into the apical disc (as in some phymosomatids and many cidaroids). In addition, ocular pores of the new species are slit shaped, not circular, as in other known species.

Caenopedina aleksandrabitnerae sp. n. is closest to *C. alanbakeri* Rowe, 1989, an extant species from the Tasman Sea, but in addition to the features outlined above, it can be differentiated from that species by its wider than tall genital plates (almost equal-sided in *C. alanbakeri*), lower test (TH is 63% TD in *C. alanbakeri*), lower number of interambulacral plates per column (19 in a 40-mm TD specimen of *C. alanbakeri*), less wide ambital interambulacral plates and more densely tuberculated distal half of the genital plates.

Caenopedina porphyrogigas Anderson, 2009, from New Zealand and the southern Tasman Rise, differs by its much wider interambulacral plates with a height:width ratio of 1:4 to 1:5.5 at the ambitus, higher number of plates per interambulacral column (27–28) and higher corona (height is 43–77% TD).

All other extant *Caenopedina* species differ by their higher interambulacral plates with height:width ratios of 1:2 or less, and by partially tuberculated genital plates. In *C. cubensis* A. Agassiz, 1869, *C. indica* (de Meijere, 1903), *C. diomedeae* Mortensen, 1939, *C. novaezealandiae* Pawson, 1964, *C. otagoensis* McKnight, 1968, *C. pulchella* (A. Agassiz *et* H.L. Clark, 1907), and *C. superba* H.L. Clark, 1925, the tubercles are restricted to the periproctal margin of the genital plates. In *C. annulata* Mortensen, 1940 they are arranged in two distinct belts, one along the inner and the other one along the outer edge of the genital plates. In *C. hawaiiensis* H.L. Clark, 1912 they too are largely restricted to the adapical part of the genital plates, although not so exclusively as in the previous species. Their distribution still is very different from the arrangement observed in *C. aleksandrabitnerae* sp. n. In *C. mirabilis* (Döderlein, 1885) genital plate tuberculation is similar, but slightly less dense than in *C. aleksandrabitnerae* sp. n.

Caenopedina capensis H.L. Clark, 1923, from South Africa, and *C. depressa* Koehler, 1927, from the Maldives, are based on small, juvenile or subadult specimens, which makes comparison with the much larger fossil *C. aleksandrabitnerae* sp. n. difficult. Again, they appear to have much taller interambulacral plates ambitally.

Stereopedina ameghinoi de Loriol, 1902, from the Miocene of Patagonia, is one of the few fossil forms now attributed to *Caenopedina* (Smith and Kroh 2011). While it is poorly known and in need of redescription it clearly differs from *C. aleksandrabitnerae* sp. n. by its small apical disc, which is less than one third of the coronal diameter.

Jurassic species of *Hemipedina* (some of which may need to be reassigned to *Caenopedina* according to Smith and Kroh 2011) differ by their larger peristome with more pronounced buccal notches and taller interambulacral plates.

Male specimens of most *Caenopedina* species (except *C. porphyrogigas*) have slit-like genital pores which lie directly on the plate margin or may even continue into the interambulacra. In contrast, the genital pores of *C. aleksandrabitnerae* sp. n. are circular and located well within the plate, slightly off centre, which could be taken as evidence that either the King George Island specimen was a female or that this new species did not show sexual dimorphism.

Occurrence. — King George Island, Polonez Cove Formation, Chlamys Ledge Member (Oligocene).

Irregularia Latreille, 1825
Order Spatangoida L. Agassiz, 1840
Suborder Paleopneustina Markov and Solovjev, 2001
Family Schizasteridae Lambert, 1905
?Genus *Abatus* Troschel, 1851
Abatus? sp.
(Fig. 5)

Material. — Remains of at least three specimens preserved as internal moulds/casts within matrix (ZPAL E.11/2); 1 partial internal mould (ZPAL E.11/3).

Dimensions (in mm):

Specimen no.	TL	TW	TH	∠APP	∠PPP
ZPAL E.11/2a	*c.* 47	*c.* 46	>10	125	90
ZPAL E.11/2b	*c.* 44	–	–	–	–
ZPAL E.11/2c	–	> 42	–	125	90
ZPAL E.11/3	–	*c.* 48	*c.* 15	115	–

Description. — Test of medium size, not quite reaching 50 mm TL in the largest specimen available. Outline rounded, with shallow frontal notch. Test length and width subequal. Maximum width apparently anterior of centre. Highest point centrally, located on adapical interambulacra which form distinct crests between the sunken petals. In profile test depressed, with tumid margins – depressed aspect probably not related to original shape, but to post-depositional compaction within the sediment.

Apical disc central; of unknown structure.

Paired ambulacra petaloid adapically. Petals straight, distinctly sunken and closed distally; extending about 60 to 65% of the corresponding test radius; widest at their midpoint. Anterior paired petals diverging at 115 to 125°, posterior ones at about 90°. Respiratory pore pairs poorly preserved, but appear to have been conjugate isopores. Ambulacrum III less deeply sunken. Any other details obliterated. Interambulacra form high crests between the paired petals around the apical disc.

Peristome, periproct, plating structure, tuberculation and fascioles not visible.

Discussion. — The specimens studied are too poorly preserved to be identified confidently at species or genus level. Based on overall shape and the form of the petals, however, an attribution to the genus *Abatus* seems likely. This genus is one of the most abundant Antarctic spatangoids today, the first members having been recorded from the Eocene (McKinney *et al.* 1988). The Eocene species from Seymour Island, *A. kieri* McKinney, McNamara and Wiedman, 1988, however, differs

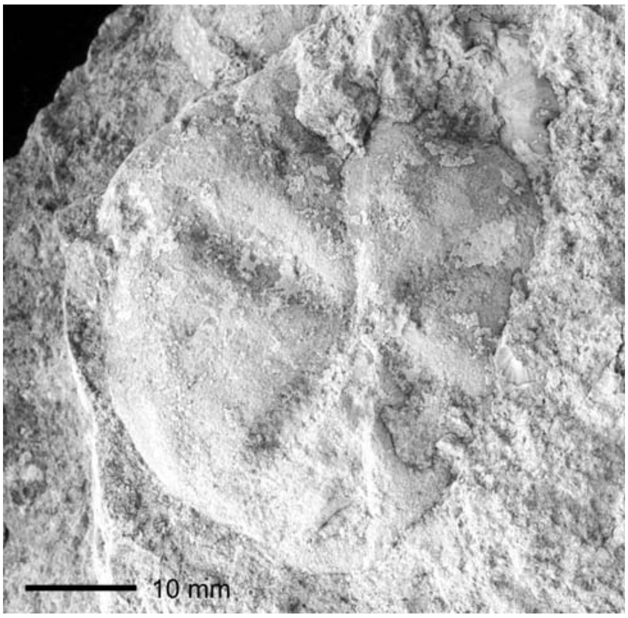

Fig. 5. *Abatus*? sp., specimen ZPAL E.11/2a, in aboral view. Specimen whitened with ammonium chloride.

by its less strongly diverging and longer petals and by its deeper frontal groove. An attribution to the genus *Tripylus* would be another possibility – since the two differ mainly by the development of the latero-anal fasciole neither option can be ruled out. Other modern Antarctic spatangoid genera (David *et al.* 2005), in contrast, can be excluded. *Amphipneustes* lacks a frontal notch; the same is true for *Brachysternaster*, *Delopatagus* and *Genicopatagus* which, in addition, have almost flush petals. *Brisaster* and *Tripylaster* have longer petals and a deeper frontal notch.

Occurrence. — King George Island, Polonez Cove Formation, Chlamys Ledge Member (Oligocene).

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