EARLY CAMBRIAN LINGULATE BRACHIOPODS FROM GLACIAL ERRATICS OF KING GEORGE ISLAND (SOUTH SHETLAND ISLANDS), ANTARCTICA

LARS E. HOLMER, LEONID E. POPOV and RYSZARD WRONA

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Erratic boulders of Early Cambrian age, occurring within the Early Miocene glacio-marine Cape Melville Formation on King George Island (South Shetland Islands), Antarctica, have yielded lingulate brachiopods including *Eoobolus* aff. *elatus* (Pelman, 1986), *Karathele napuru* (Kruse, 1990) and *Vandalotreta djagoran* (Kruse, 1990). It is the first Early Cambrian brachiopod assemblage described from Antarctica. The fauna is closely similar to that from the late Early Cambrian (Toyonian) Wirrealpa and Aroona Creek Limestones, Flinders Ranges, South Australia. The new family Eoobolidae is proposed and the type species of *Eoobolus*, *E. triparilis* (Matthew, 1902) is re-figured. The evolution of the botsfordiids and acrothelids is discussed in the light of the new material of *Karathele napuru*, which is intermediate in morphology between *Botsfordia* and *Eothele*. The superfamily Acrotheloidea, is referred to the order Lingulida because of the similarities in muscle system, shell structure and development of pseudointerareas.

Key words: Brachiopoda, Lingulata, taxonomy, Cambrian, Antarctica, South Shetland Islands.

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INTRODUCTION

Cambrian brachiopods from Antarctica are poorly known; only five papers have been published to date (SHERGOLD *et al.* 1976; ROWELL *et al.* 1983; POPOV and SOLOVJEV 1981; POPOV 1984; HENDERSON 1992), describing Middle and Late Cambrian assemblages. The Early Cambrian brachiopods described below were first recorded by WRONA (1989) from erratic boulders of limestone within the Early Miocene glacio-marine Cape Melville Formation of King George Island, South Shetland Islands (Text-fig. 1). Earlier, BROCK and COOPER (1993) described a similar assemblage, including *Eoobolus* aff. *elatus* (PELMAN, 1986), *Karathele napuru* (KRUSE, 1990) and *Vandalotreta djagoran* (KRUSE, 1990) from the late Early Cambrian (Toyonian) Wirrealpa and Aroona Creek limestones, Flinders Ranges, South Australia.

The poorly known type species of *Eoobolus*, *E. triparilis* (MATTHEW, 1902) is re-figured to draw comparison with *Eoobolus* aff. *elatus* (PELMAN, 1986). Previously, most Early and Middle Cambrian lingulides of this type have been referred usually to "*Lingulella*" or "*Obolus*". In contrast to these genera, *Eoobolus* has a pitted larval shell, much like that of the acrotretoids, in addition to a distinctive granulated post-larval shell. Below we propose the new family Eoobolidae to include this type of lingulides.

The evolution of the botsfordiids and acrothelids is discussed in the light of the new material of *Karathele napuru*; it is possible to trace a gradual transition from botsfordiids, such as *Karathele*, to acrothelides, such as *Eothele*. The muscle system, shell structure, and pseudointerareas of the botsfordiids are very similar to those of Early Palaeozoic Obolidae (WALCOTT, 1912; POPOV, 1992), and the superfamily Acrotheloidea, is here referred to the Order Lingulida.

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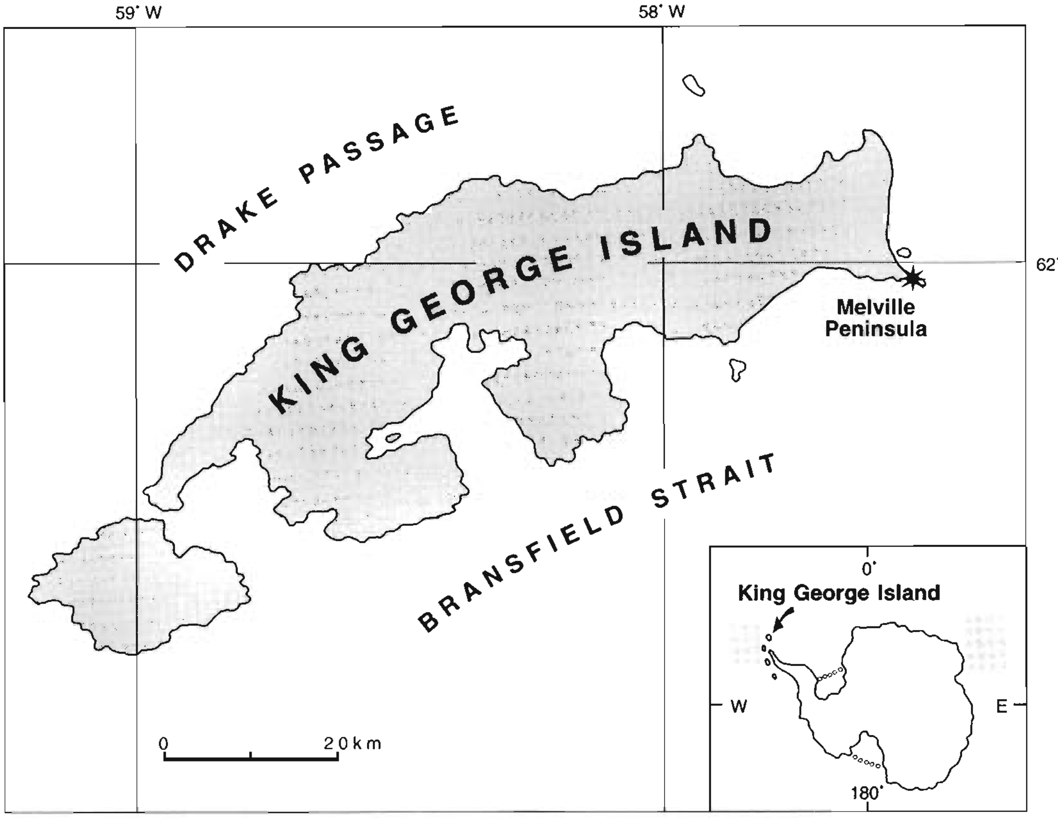

Fig. 1
Location map of King George Island (arrowed) in Antarctica, and the outcrops of glacio-marine strata (asterisked) of the Early Miocene Cape Melville Formation.

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MATERIAL

The Antarctic brachiopod material described in this paper comes from the residue of limestone erratic boulders etched with 10% acetic acid. The boulders are scattered as iceberg-rafted dropstones within the Early Miocene glacio-marine sediments of the Cape Melville Formation, exposed in the easternmost part of King George Island, South Shetland Islands (Text-fig. 1). The formation is represented by a 200 m sequence of highly fossiliferous shales with siltstone, marl and sandstone intercalations (BIRKENMAJER *et al.* 1983). The indigenous fossil assemblage of the Cape Melville Formation comprises of diatoms, chrysomonad cysts, silicoflagellates, calcareous and arenaceous foraminifera, solitary corals, polychaetes, bryozoans, gastropods, bivalves, decapods, echinoids, asteroids and fish remains (for references see

GAŹDZICKI ed. 1987). The glacial character of the sediments is evidenced by the presence of numerous, poorly rounded or sharp-edged boulders of rocks exotic for King George Island, with glacially-generated features (BIRKENMAJER *et al.* 1983; BIRKENMAJER and BUTKIEWICZ 1988; WRONA 1989). These strata also yield allochtonous Cretaceous calcareous nannoplankton (DUDZIAK 1984) and belemnites (BIRKENMAJER *et al.* 1987) dropped into the sediment from melting icebergs. The Early Miocene age of the formation, and consequently of the Melville Glaciation, was determined by biostratigraphic data (BIERNAT *et al.* 1985; GAŹDZICKI ed. 1987) as well as by radiometric dating (cf. BIRKENMAJER 1992).

The limestone erratics were collected from the erosional surface of the Melville Peninsula and are housed at the Institute of Paleobiology, Polish Academy of Sciences in Warszawa (abbreviated as AE/Me). This collection contains several hundred boulders grouped into distinct lithological types (WRONA 1989; WRONA and ZHURAVLEV 1996 this volume).

Very characteristic boulders of the light coloured calcimicrobial-archaeocyathan framestone (type 11; WRONA 1989) contain rare shells of *Eoobolus* aff. *elatus* and an abundant blue-green algae *Gordonophyton-Renalcis* and archaeocyathan assemblage of the same age as the uppermost Botoman units with *Syringocnema favus* Beds distinguished in South Australia (ZHURAVLEV and GRAVESTOCK 1994; WRONA and ZHURAVLEV 1996 this volume); they can be also correlated with facially similar beds of the Shackleton Limestone exposed in the Transantarctic Mountains (DEBRANNE and KRUSE 1986, 1987; REES *et al.* 1989; ZHURAVLEV and GRAVESTOCK 1994).

Lingulate brachiopods identified as *Eoobolus* aff. *elatus* are abundant and well preserved in black, sometimes slightly bituminous packstone and wackestone (types 12–14; WRONA 1989). These kinds of limestone erratics also contain archaeocyaths, sponge spicules, gastropods and hyoliths as well as a diverse assemblage of problematica (small shelly fossils), among them numerous sclerites of the tommotiid *Dailyatia*, which are being described separately (BENGTSON and WRONA, in preparation). This small shelly fossil assemblage can be compared with a similar fauna and sediments of the Parara Limestone (Botoman) in South Australia (BENGTSON *et al.* 1990; ZHURAVLEV and GRAVESTOCK 1994), but on the other hand it can also be correlated with an autochtonous Antarctic kennardiid assemblage recorded from the Shackleton Limestone in the Transantarctic Mountains (EVANS and ROWELL 1990; EVANS 1992).

Extremely rich and well preserved shells of larval as well as adult *Karathele napuru*, *Vandalotreta djagoran* and *Eoobolus* aff. *elatus* orginate exclusively from one erratic boulder: AE/Me52. This completely etched small boulder, size: 4 cm × 5 cm and 1 cm thick, comprised a brachiopod coquinoid limestone; it was the most fossiliferous sample studied and also contained chancelloriid and sponge spicules, gastropods, hyoliths and phosphatized trilobite carapaces. The age of this erratic can be established as late Early Cambrian (Toyonian) by the brachiopod assemblage described below, which is closely similar to the brachiopod fauna from the late Early Cambrian Wirrealpa and Aroona Creek limestones, Flinders Ranges, South Australia. Equivalent strata containing these brachiopod coquinoid limestones has not yet been discovered on the Antarctic landmass. However, the general lithological composition of the whole spectrum of erratics from the Cape Melville Formation clearly suggests that outcrops of Lower Cambrian rocks around the Weddell Sea (in particular the Argentina Range) and northern Transantarctic Mountains acted as source areas for the glacial boulders (WRONA 1987; BIRKENMAJER and BUTKIEWICZ 1988; WRONA 1989).

New material of *Eoobolus* aff. *elatus* and *Karathele napuru* from the Wirrealpa Limestone, Flinders Ranges (Ten Mile or Mount Billy Creek section within the Wilkawillina Gorge; see KRUSE (1991a) for locality data) is illustrated below for comparison with the Antarctic material. *Karathele napuru* and *Vandalotreta djagoran* were described originally by KRUSE (1990) from the early Middle Cambrian Tindall Limestone (Ordian) of the Daly Basin, Northern Territory, Australia.

SYSTEMATIC PALEONTOLOGY

Measurements (Tables 1–6; in millimetres if not stated otherwise) are as follows: W, L, T = width, length, height of valve; Iw, Il = width, length of dorsal pseudointerarea; Pw = width of median groove; Cw, Cl = width, length of cardinal muscle field; Vl = length of visceral area; Sl = length of dorsal median ridge. S = standard deviation, N = number of measurements, MAX = maximum value, MIN = minimum value.

The terminology of the lingulate brachiopods used here mainly follows that of ROWELL (1965); KONEVA (1986); and HOLMER (1989). The term *median tongue* was introduced by POPOV and HOLMER (1994) to denote the narrow anterior extension of the dorsal visceral field of many lingulates (Text-figs 2–3).

The illustrated and/or discussed material is deposited in the Institute of Paleobiology, Polish Academy of Sciences, Warszawa (ZPAL), South Australian Museum, Adelaide (SAM), Northern Territory Museum of Arts and Sciences, Darwin (P). United States National Museum, Washington D.C. (USNM), Swedish Museum of Natural History (RM), Stockholm, and the Royal Ontario Museum, Toronto (ROM).

Class **Lingulata** GROJANSKY *et* POPOV, 1985
Order **Lingulida** WAAGEN, 1885
Superfamily **Linguloidea** MENKE, 1828
Family **Eoobolidae** fam. nov.

Diagnosis. — Shell dorsibiconvex, somewhat inequivalved, elongate oval to subtriangular; larval shell well defined, with pitted micro-ornamentation; postlarval shell finely pustulose; ventral pseudointerarea elevated above valve floor, with deep pedicle groove and well-developed flexure lines; dorsal pseudointerarea divided, raised above valve floor; muscle system with paired umbonal muscle scars bisected by v-shaped impression of pedicle nerve; dorsal visceral field with well-developed median tongue extending to mid-length; mantle canals baculate with well-developed *vascula media*.

Genera included. — *Eoobolus* MATTHEW, 1902 (= *Clivosilingula* USHATINSKAYA, 1993); *Vassilkovia* POPOV *et* KHAZANOVITCH (in POPOV *et al.* 1989).

Discussion. — The Eoobolidae show a combination of characters, that are unique within the Linguloidea. There are no other linguloids with a finely pitted larval shell and pustulose post-larval shell. Other types of pitted micro-ornamentation are distributed widely within the superfamily, but usually involve both the larval and post-larval shell as in the Zhanatellidae, Elkaniidae, Dysoristidae, and the Paterulidae. It is possible that the eoobolids are related somehow to the Botsfordiidae, the earliest members of which are also characterised by pitted larval and pustulose post-larval shells. The detailed morphology of the larval shell of *Vassilkovia* POPOV *et* KHAZANOVITCH (in POPOV *et al.* 1989), is not known, but the pustulose post-larval shell is closely similar to that of the Eoobolidae. The family is first recorded from the Botoman (USHATINSKAYA 1993) and ranges to the Late Cambrian (POPOV *et al.* 1989).

Genus *Eoobolus* MATTHEW, 1902

1902. *Obolus (Eoobolus)* MATTHEW, p. 97.

1903. *Obolus (Eoobolus)* MATTHEW, p. 135.

1993. *Clivosilingula* USHATINSKAYA, p. 125 [Type species: *Lingulella clivosa* PELMAN, 1983; Middle Cambrian (Amgian), Siberia].

Type species: *Obolus triparilis* MATTHEW, 1902 (selected by ROWELL 1965, p. H263).

Diagnosis. — Shell dorsibiconvex, elongate suboval to elongate subtriangular; ventral valve slightly acuminate with high, orthocline pseudointerarea; pedicle groove deep, narrow, with subparallel lateral margins; dorsal pseudointerarea with broad, shallow median groove; propareas of both valves with flexure lines; ventral visceral field not extending to mid-valve; paired ventral umbonal muscle scars bisected by v-shaped impression of pedicle nerve; ventral *vascula lateralia* submarginal, straight, slightly divergent proximally; dorsal visceral area with median tongue usually bisected by median ridge and pair of submedian ridges; dorsal *vascula lateralia* marginal, arcuate; *vascula media* long, slightly divergent.

Other species included. — *Lingulella wanniecki* REDLICH, 1899; Early Cambrian, Pakistan (Salt Range). *Lingulella clivosa* PELMAN, 1983; Middle Cambrian (Amgian), Siberia. *Lingulella elata* PELMAN, 1986 (= *Clivosilingula dilatata* USHATINSKAYA, 1993); Middle Cambrian (Amgian), Siberia. *Eoobolus* aff. *elatus* (PELMAN, 1986); Early Cambrian (Toyonian), South Australia, West Antarctica (King George Island).

Discussion. — *Eoobolus* has been regarded as a junior synonym of both *Lingulella* (WALCOTT, 1912), *Obolus*, and *Ungula* (ROWELL, 1965; the figured valves probably represent *Ungula*). However, it seems that undoubted species of *Lingulella* and *Ungula* are not known earlier than from the Late Cambrian; only *Lingulella* is internally similar to *Eoobolus*, but the former has poorly developed dorsal flexure lines and pseudointerareas that are not strongly raised above the valve floor (POPOV and HOLMER 1994). *Obolus*

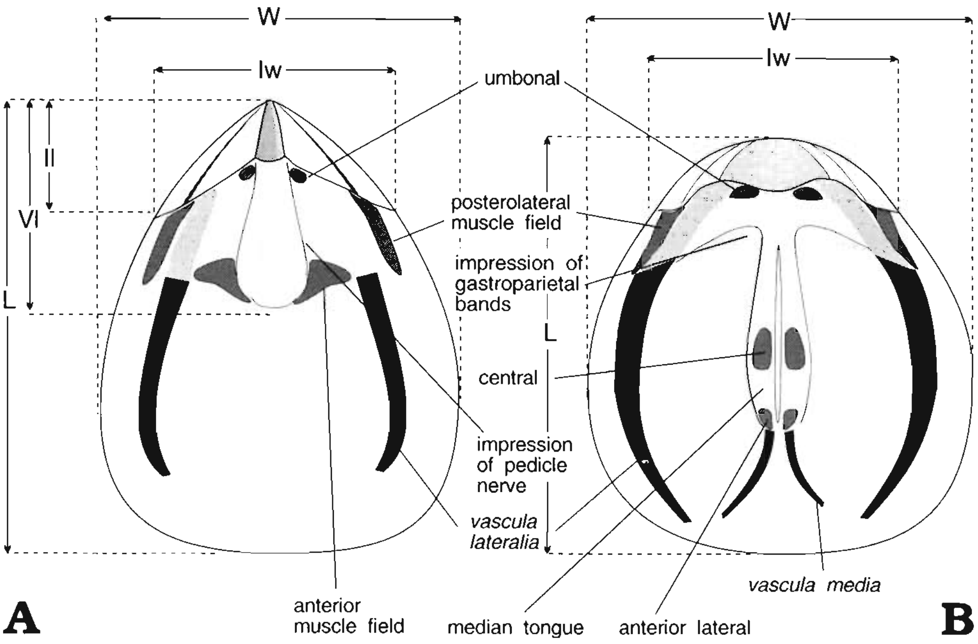

Fig. 2
Eoobolus aff. *elatus* (PELMAN, 1986), reconstruction of ventral (A) and dorsal interior (B). Location of measurements indicated: W = width, lw = width of pseudointerarea; L = length, VI = length of ventral impression of pedicle nerve, II = length of ventral pseudointerarea.

appears to be endemic to Baltoscandia and is not similar internally to *Eoobolus* (POPOV *et al.*, 1989). Moreover, our brief re-study of the type species *Eoobolus triparilis* (MATTHEW, 1902) revealed a distinctive pustulose ornamentation on the post-larval shell, of a type which is not known from any other obolid genera with the exception of *Vassilkovia* POPOV *et* KHAZANOVITCH (in POPOV *et al.*, 1989) and *Clivosilingula* USHATINSKAYA, 1993. *E. triparilis* also has a characteristic long median ridge and a pair of lateral ridges in the dorsal valve. A similar type of morphology was recorded in the type species of *Clivosilingula*, *C. clivosa* by PELMAN (1983, p. 125) and the pseudointerareas as well as most other morphological characters are closely similar; *Clivosilingula* is here regarded as a junior synonym of *Eoobolus*.

According to USHATINSKAYA (1993) *Lingulella viridis* COBBOLD, 1921, *Lingulella rotunda* PELMAN, 1977, and *Lingulella variabilis* PELMAN, 1977, may be also referred to *Clivosilingula*, but the detailed morphology of these taxa is poorly known.

Lingulella wanniecki REDLICH, 1899, from the Early Cambrian of Pakistan has a well defined median ridge and a pair of lateral ridges in the dorsal valve as well as a distinctive pustulose ornamentation (SCHINDEWOLF and SEILACHER 1955); it is referred here to *Eoobolus*.

Eoobolus triparilis (MATTHEW, 1902)
(Pl. 10: 1–9)

1902. *Obolus triparilis* MATTHEW, p. 94, pl. 1: 2a–c.
1912. *Lingulella triparilis* (MATTHEW, 1902); WALCOTT, p. 536, pl. 45: 2, 2a–f, text-fig. 44 (*cum syn.*).

Lectotype (selected here): ROM 510CM (A), dorsal valve (Pl. 2: 7).
Type horizon and locality: Middle Cambrian (Bourinot Group), Canada (Cape Breton).

Diagnosis. — Shell dorsibiconvex, slightly elongate subtriangular, with maximum width somewhat anterior to mid-length; ventral valve slightly acuminate; ventral pseudointerarea high, triangular; dorsal interior with long median ridge and pair of submedian ridges bounding narrow median tongue.

Remarks. — The micro-ornamentation of the larval shell could not be determined on any of the available specimens. The fragmentary preservation of the material at hand made it difficult obtain good measurements.

Material. — Figured. Ventral valves: USNM 51855a, 57013c. Dorsal valves: USNM 57013a, 57013d, 57013e; ROM 510CM (A), 510B, 678CB (C), 678CM (E).

Occurrence. — Type locality only.

Eoobolus aff. *elatus* (PELMAN, 1986)
(Pl. 9: 1–15; Text-fig. 2)

aff. 1986. *Lingulella elata* PELMAN, p. 138, pl. 12: 1–4.
aff. 1993. *Clivosilingula elata* (PELMAN); USHATINSKAYA, p. 133, fig. 1: 10–11.
1993. *Lingulella* sp.; BROCK and COOPER, p. 780, fig. 14: 14–15.

Material. — Figured from Antarctica. Ventral valves: ZPAL Bp.XXXIII/33S6, 33S9, 61S6. Dorsal valves: ZPAL Bp.XXXIII/50S1, 61S2. Figured from Australia. Complete juvenile shell: SAM P35112. Dorsal valves: SAM P35101, P35104, P35105, P35111. Ventral valves SAM P35102, P35103, P35109, P35110, P35114.

Measurements: See Tables 1–2.

Table 1. *Eoobolus* aff. *elatus* (PELMAN), average dimensions of ventral valves.

	L	W	Il	Iw	Vl	L/W	Il/L	Iw/W	Vl/L
N	27	27	26	26	17	27	26	26	17
X	2.39	1.79	0.62	1.17	1.29	135%	27%	68%	50%
S	1.117	0.882	0.264	0.513	0.545	7.46	3.1	5.9	6.1
MIN	1.04	0.60	0.28	0.52	0.64	120%	20%	58%	40%
MAX	5.28	4.28	1.40	2.56	2.36	150%	32%	79%	63%

Table 2. *Eoobolus* aff. *elatus* (PELMAN), average dimensions of dorsal valves.

	L	W	Iw	L/W	Il/L	Iw/W	Vl/L
N	20	20	17	27	26	26	17
X	2.27	1.81	1.12	135%	27%	68%	50%
S	0.860	0.700	0.464	7.46	3.1	5.9	6.1
MIN	1.06	0.84	0.52	120%	20%	58%	40%
MAX	4.32	3.48	2.40	150%	32%	79%	63%

Description. — Shell slightly dorsibiconvex, elongate suboval, on average 135% as long as wide, with maximum width somewhat anterior to mid-length. Ventral valve gently and evenly convex, slightly acuminate; ventral pseudointerarea high triangular, orthocline, on average 27% as long as wide, occupying 68% of valve width; ventral propareas slightly raised above valve floor, with well defined flexure lines; pedicle groove narrow, with steep, subparallel lateral margins. Dorsal valve gently convex; dorsal pseudointerarea moderately high, orthocline, occupying on average 66% of valve width; median groove broad, shallow, poorly defined laterally; dorsal propareas narrow with flexure lines. Larval shell small, close to circular, around 0.10–0.15 mm across, ornamented by fine circular pits, around 1 m across. Post-larval shell covered by fine, densely spaced pustules, around 5–6 m across.

Ventral visceral area somewhat thickened, extending to mid-length; ventral umbonal muscle scar paired, bisected by v-shaped impression of pedicle nerve; ventral *vascula lateralia* subperipheral, slightly arcuate. Dorsal visceral area, with narrow median tongue extending somewhat anterior to mid-valve; dorsal median ridge weakly developed; dorsal *vascula lateralia* marginal, arcuate; *vascula media* weakly impressed.

Discussion. — The specimens from Antarctica are similar to *Eoobolus elatus* (PELMAN) from the Kuonamka Formation of Siberia (USHATINSKAYA 1993, figs 1–11) in size, general outline, and in having a weakly developed dorsal median ridge, as well as in the absence of dorsal submedian ridges; the only difference appears to be that the ventral visceral area is more thickened in the Siberian specimens. However, the detailed morphology of the Siberian species is still poorly known and it cannot be compared in detail with the Antarctic material. A second species, *Eoobolus dilitatus* described by USHATINSKAYA (1993, fig. 1: 5–9) from the same horizon, differs from *Eoobolus elatus* in being transversely oval and wider, but these features are known to be very variable in lingulids and moreover, change significantly during ontogeny; thus, *E. dilitatus* may be a junior synonym of *E. elatus*.

The Antarctic material of *E.* aff. *elatus* is also closely similar to *Lingulella* sp. described by BROCK and COOPER (1993) from the Early Cambrian Wirrealpa and Ramsay limestones of the Flinders Ranges and Yorke Peninsula, South Australia. Additional material from the Wirrealpa Limestone illustrated here

(Pl. 9: 3–4, 6–8, 10, 13, 15) indicates that they may be conspecific, as the Australian specimens have an identical type of external and internal morphology.

Occurrence. — Early Cambrian (Toyonian), South Australia; King George Island erratics, Antarctica; Middle Cambrian (Amgian), Siberia.

Superfamily **Acrotheloidea** WALCOTT *et* SCHUCHERT, 1908

Diagnosis. — Shell with short, convex posterior margin; postlarval ornament of fine, evenly distributed granules or pustules; larval shell pitted, with apical spines or tubercles; ventral valve convex or low conical; ventral pseudointerarea vestigial or lacking; pedicle emerging through delthyrium or foramen posterior to apex; dorsal pseudointerarea vestigial or lacking; muscle system linguloidean-like, with paired umbonal muscle; mantle canal system of both valves baculate; *vascula media* well-developed; shell structure baculate.

Discussion. — The close relationship between the Botsfordiidae and Acrothelidae has long been recognized (ROWELL 1965). As noted by ROWELL (1965) it is probable that the botsfordiides were ancestral to the acrothelides; moreover, it now seems possible to trace an almost continuous gradual transition in morphology from *Botsfordia* (Pl. 10: 10–15; Text-fig. 3A–B) through the intermediate *Karathele*, with a deep, but unrestricted delthyrial pedicle opening and rudimentary ventral pseudointerarea (Text-fig. 3C–D) to early acrothelides, like *Eothele* (Pl. 12: 6–8) with a low, subconical ventral valve, a reduced pseudointerarea that is gradually transformed into the pedicle tube, and with an elongate, suboval pedicle foramen that is formed post-larvally (Pl. 12: 6–8).

The muscle system of botsfordiides is very similar to that of Early Palaeozoic Obolidae (WALCOTT 1912; POPOV 1992); the earliest known genera, *Botsfordia* and *Edreja* have scars that appear to match a full set of obolide muscles (Text-fig. 3A–B), whilst the number of muscles in most acrothelides was probably reduced. The scars of a linguloid type of v-shaped pedicle nerve in *Botsfordia* and *Edreja* (Text-fig. 3A) also may indicate a close relationship between the two groups.

The shell structure of botsfordiides has not yet been studied adequately, but includes baculate laminae (HOLMER 1989; POPOV and HOLMER 1994).

The earliest evolution of the group is still poorly known. Although the botsfordiides and acrothelides have some characters in common with the acrotretoids, such as a pitted larval shell and a pedicle foramen (in acrothelids), it is clear that they also exhibit many lingulid features, such as baculate shell structure. They might be related closely to the lingulid family Eoobolidae, which is also characterized by a pitted larval shell and a pustulose-granular post-larval ornamentation. WILLIAMS and ROWELL (1965) proposed that the acrothelides probably were ancestral to the discinides, but in view of the considerable differences in their ontogenies, this is unlikely (CHUANG 1971; HOLMER 1989).

Family **Botsfordiidae** SCHINDEWOLF, 1955

Diagnosis. — Shell biconvex; ventral pseudointerarea vestigial, divided by deep pedicle groove forming triangular delthyrium; dorsal pseudointerarea vestigial, divided by median groove; muscle system consisting of paired umbonal, transmedian, outside lateral, internal lateral, anterior lateral, and central muscles; *vascula lateralia* straight, submedian, divergent in both valves; larval shell with one to three apical tubercles in ventral valve and two in dorsal valve.

Genus *Karathele* KONEVA, 1986

Type species: *Karathele coronata* KONEVA, 1986.

Type horizon and locality: Middle Cambrian (*Peronopsis*? *ultimus* and *Ptychagnostus atavus* Zones), Kazakhstan (Malyi Karatau).

Diagnosis. — Shell subequibiconvex, subcircular; ventral pseudointerarea narrow triangular, procline to catacline, with vestigial propareas; pedicle groove deep, with steep lateral slopes; dorsal valve slightly sulcate; dorsal pseudointerarea vestigial, with poorly defined median groove; ventral larval shell with three tubercles and one or two pairs of dorsal tubercles; ventral visceral field small, short, only slightly thickened; dorsal visceral field small, slightly thickened; median tongue narrow, extending to mid-valve, bisected by median ridge; mantle canal system baculate; both valves with straight, submedian, divergent *vascula lateralia*; *vascula media* long, divergent.

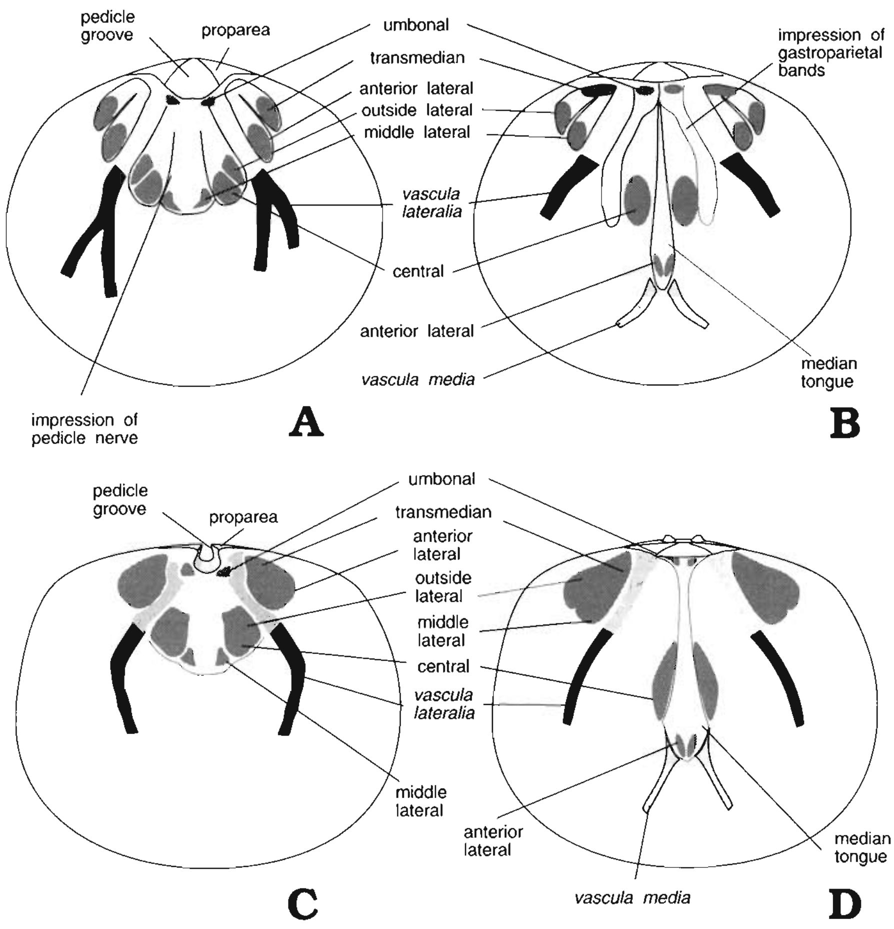

Fig. 3
Reconstruction of ventral (A) and dorsal interior (B) of a generalised Botsfordiidae and ventral (C) and dorsal interior (D) of *Karathele napuru* (KRUSE, 1990).

Other species included. — *Eothele napuru* KRUSE, 1990; Early Cambrian (Toyonian)–early Middle Cambrian, Australia, Antarctica.

Discussion. — *Karathele* was referred originally to the Acrothelidae by KONEVA (1986); however, it has an open delthyrium throughout ontogeny, with a ventral pseudointerarea and pedicle groove much like those of *Botsfordia* and *Edreja* (Text-fig. 3). *Karathele* differs from both *Botsfordia* (Pl. 10: 10–15) and *Edreja* mainly in having a procline to catacline ventral pseudointerarea with vestigial propareas, small, densely spaced post-larval pustules, one pair of ventral larval tubercles, as well as a short ventral visceral area that does not extend anteriorly to mid-valve. Externally *Karathele* is closely similar to *Eothele* (Pl. 12: 6–8), but the delthyrium in *Karathele* remains open through out ontogeny. The juvenile shells of *Eothele spurri* are similar to *Karathele* in the morphology of the larval shell, delthyrium and rudimentary pseudointerareas, but unlike *Karathele*, a regular pedicle foramen is formed in adults of *Eothele spurri* (Pl. 12: 7) and the ventral propareas are completely lost. The interior of *Eothele* is poorly known and cannot be compared directly.

Karathele napuru (KRUSE, 1990)
(Pl. 11: 1–8; Pl. 12: 1–5; Text-fig. 3C–D)

1990. *Eothele napuru* KRUSE, p. 31, pl. 12A–K, text-fig. 16.
1991b. *Eothele napuru* KRUSE, p. 178, fig. 7A–E.
1993. *Eothele napuru* KRUSE; BROCK and COOPER, p. 782, fig. 15: 1–14.

Holotype: Ventral valve SAM P85206.
Type horizon and locality: Middle Cambrian, Tindall Limestone (bore-hole NTGS 83/3), Daly Basin, Northern Territory, Australia.

Material. — Figured from Antarctica. complete shells: ZPAL Bp.XXXIII/29S8, 38S4; ventral valves: ZPAL Bp.XXXIII/53S2, 5340U, 54S3; dorsal valves: ZPAL Bp.XXXIII/29S5, 34S3, 50S2, 50S3, 53S4. Figured from Australia. Ventral valves: SAM P35100, SAM P35107, SAM P35113.

Measurements: See Tables 3–4.

Table 3. *Karathele napuru* (KRUSE), average dimensions of 5 ventral valves.

	L	W	Iw	Pw	Vl	Vw	L/W	Iw/W	Vl/L
X	1.12	1.18	0.33	0.16	0.38	0.43	97%	27%	34%
S	0.242	0.331	0.130	0.038	0.060	0.103	8.6	5.9	3.8
MIN	0.82	0.76	0.16	0.10	0.32	0.32	84%	21%	29%
MAX	1.40	1.46	1.34	0.20	0.40	0.50	108%	34%	39%

Table 4. *Karathele napuru* (KRUSE), average dimensions of 6 dorsal valves.

	L	W	Iw	Sl	L/W	Iw/W	Sl/L
X	1.41	1.59	0.38	1.86	89%	24%	60%
S	0.334	0.409	0.083	0.28	2.5	3.5	6.4
MIN	1.02	1.16	0.28	0.58	85%	20%	52%
MAX	2.14	2.14	1.22	1.22	92%	29%	69%

Diagnosis. — Pedicle groove deep, forming narrow slit in mature specimens; dorsal larval shell with two tubercles.

Description of material from Antarctica: Shell slightly ventribiconvex, subcircular, about 97% as long as wide. Ventral valve low subconical with maximum height at umbo; ventral pseudointerarea narrow triangular, procline to slightly catacline, occupying on average 27% of valve width; pedicle groove very deep, forming high triangular to semioval delthyrial opening; posterior part of delthyrium forming narrow slit in mature specimens; ventral propareas vestigial. Dorsal valve gently convex with maximum height at about umbo; dorsal pseudointerarea vestigial, occupying about 24% of valve width. Ventral larval shell with high median tubercle above delthyrium and pair of tubercles in posterolateral part. Dorsal larval shell with two high tubercles posterolaterally.

Ventral visceral area small, occupying about 34% of valve length and 38% of valve width; *vascula lateralia* of both valves submedian, straight, divergent. Dorsal interior with slightly raised visceral area occupying about 60% of valve length; dorsal median tongue bisected by long ridge.

Discussion. — *Karathele napuru* differs from the type species, *K. coronata* (KONEVA, 1986), in having only two tubercles on the dorsal larval shell, and a much deeper pedicle groove.

There are virtually no differences between our material and the material described by KRUSE (1990, 1991b). However, the maximum recorded size from the Antarctic (max L = 2.14) is much smaller than that recorded by KRUSE (1990; max L = 7.6), and the delthyrium remains open throughout ontogeny in the Antarctic specimens, whilst the larger valves described by KRUSE (1990) have a fine slit or suture. A similar type of delthyrium is also found in the larger specimens from the Wirrealpa Limestone, Flinders Ranges (Pl. 12: 4–5), but in all known specimens of *K. napuru* the delthyrial margins remain separated (even though they might "touch" one another) and do not join completely as in mature shells of *Eothele* (Pl. 12: 6–8).

Occurrence. — Early Cambrian (Toyonian)–early Middle Cambrian, Australia (Nothern Territory). King George Island erratics, Antarctica.

Order **Acrotretida** KUHN, 1949
Superfamily **Acrotretoidea** SCHUCHERT, 1893
Family **Acrotretidae** SCHUCHERT, 1893
Genus *Vandalotreta* MERGL, 1988

1988. *Vandalotreta* MERGL, p. 292.

1990. *Luhotreta* MERGL and ŠLEHOFEROVÁ, p. 95 (Type species: *L. pompeckji* MERGL *et* ŠLEHOFEROVÁ, 1990).

Type species: *Vandalotreta vafra* MERGL, 1988.

Type horizon and locality: Middle Cambrian (Amgian), High Atlas (Yagour inlier), Morocco.

Diagnosis. — Shell transversely oval to subcircular with narrow, convex posterior margin; ventral valve wide conical; ventral pseudointerarea procline to catacline, poorly defined laterally with intertrough; foramen not enclosed within larval shell; dorsal valve weakly convex; dorsal pseudointerarea short with broadly triangular median groove; apical process forming boss-like thickening anterior to internal foramen; dorsal visceral field with narrow median tongue, usually bisected by vestigial median ridge; dorsal median buttress developed.

Other species included. — *Acrotreta pompeckji* MERGL *et* ŠLEHOFEROVÁ, 1990; Middle Cambrian, Jince Formation, Central Bohemia (Czech Republic). *Hadrotreta djagoran* KRUSE, 1990; Early Cambrian (Toyonian)–early Middle Cambrian, Australia, West Antarctica. *Acrotreta limoensis* WIMAN, 1903; early Middle Cambrian(?), South Bothnian Sea (Limön), Sweden.

Discussion. — *Luhotreta* MERGL *et* ŠLEHOFEROVÁ, 1990, from the early Middle Cambrian of Bohemia differs only slightly from *Vandalotreta* in details of ornamentation and the complete absence of a dorsal median ridge; the genus is regarded here as a junior synonym. *Vandalotreta* is most similar to *Hadrotreta* ROWELL, 1966, but differs mainly in having a boss-shaped apical process that does not fill the entire apex as in *Hadrotreta*; moreover, the dorsal median ridge is vestigial to completely absent in *Vandalotreta* and the dorsal valve lacks a median sulcus. *Vandalotreta* is also somewhat similar to the ceratretide *Bozshakolia* HOLMER *et* USHATINSKAYA, 1994, in the poor development of a dorsal median ridge and having a foramen that is not enclosed within the larval shell, but differs in the lack of a ridge-like apical process enclosing the pedicle tube. The poorly known *Acrotreta limoensis* WIMAN, 1903, from early Middle Cambrian(?) glacial erratics on the Island of Limön in the South Bothnian Sea can also be referred to *Vandalotreta* (HOLMER and MERGL in preparation).

Vandalotreta djagoran (KRUSE, 1990)
(Pl. 13: 1–9; Text-fig. 4)

1990. *Hadrotreta djagoran* KRUSE, p. 29, fig. 5, pl. 11A–N.
1991b. *Hadrotreta djagoran* KRUSE, p. 178, fig. 6H–L.
1993. *Hadrotreta primaeva* (WALCOTT): BROCK and COOPER, p. 782, fig. 14: 1–13.

Holotype: Ventral valve SAM P85138.

Type horizon and locality: Middle Cambrian, Tindall Limestone (bore-hole NTGS 83/3), Daly Basin, Northern Territory, Australia.

Material. — Figured from Antarctica; complete shells: ZPAL Bp.XXXIII/29S1, 39S8, 54S6, 54S7; ventral valves: ZPAL Bp.XXXIII/54S5, 61S80, 5337U; dorsal valves: ZPAL Bp.XXXIII/5333U.

Measurements: See Tables 5–6.

Table 5. *Vandalotreta djagoran* (KRUSE), average dimensions of ventral valves.

	L	W	T	L/W	T/L
N	8	8	8	8	8
X	0.55	0.65	0.26	85%	48%
S	0.148	0.239	0.118	1.82	1.61
MIN	0.30	0.34	0.10	83%	33%
MAX	0.80	0.94	0.46	88%	80%

Table 6. *Vandalotreta djagoran* (KRUSE), average dimensions of dorsal valves.

	L	W	Il	Iw	Pl	Cl	Cw	Sl	L/W	Iw/W	Cl/L	Cw/W	Sl/L
N	5	5	4	4	4	4	4	4	5	4	4	4	4
X	0.85	0.99	0.055	0.54	0.21	0.23	0.64	0.66	86%	45%	26%	56%	60%
S	0.439	0.503	0.025	0.230	0.099	0.079	0.189	0.388	4.5	6.9	3.1	6.1	6.4
MIN	0.30	0.36	0.02	0.24	0.08	0.14	20%	0.12	81%	39%	23%	49%	52%
MAX	1.30	1.56	0.08	0.76	0.32	0.32	32%	0.98	90%	65%	30%	63%	69%

Diagnosis. — See KRUSE (1990, p. 29).

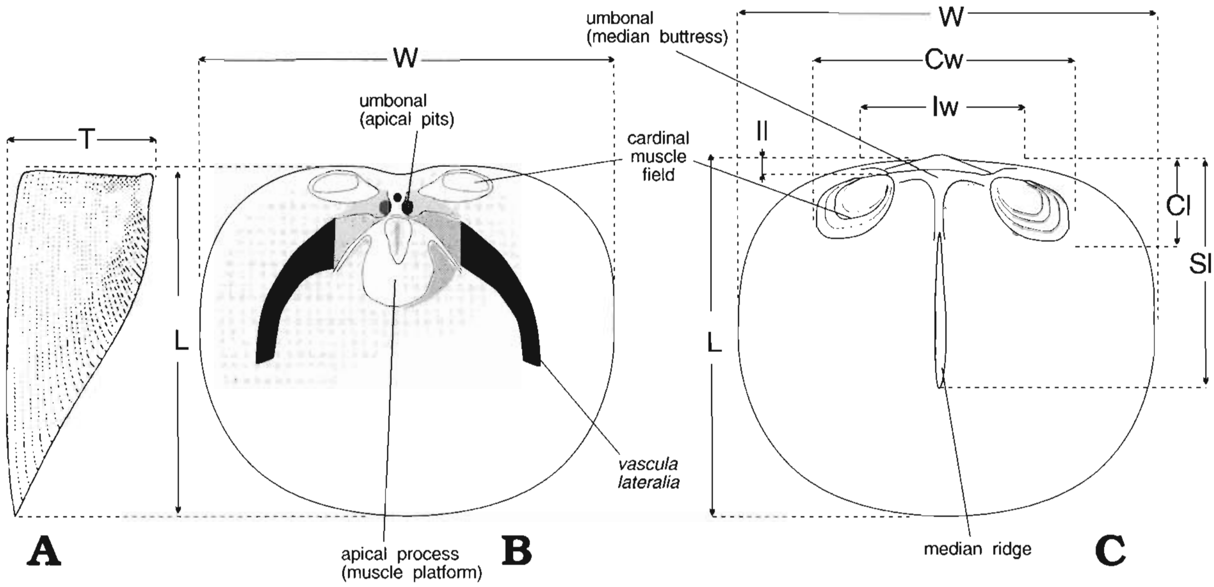

Fig. 4

Vandalotreta djagoran (KRUSE, 1990), lateral view of the ventral valve exterior (A), reconstruction of ventral (B) and dorsal interior (C). Location of measurements indicated: W — width of valve, Cw — width of cardinal muscle field, Iw — width of dorsal pseudointerarea; L — length of valve, Il — length of dorsal pseudointerarea; T — height of valve.

Description of material from Antarctica: Shell ventribiconvex, transversely suboval, on average 85% as long as wide, and 43% as high as long. Ventral valve moderately convex with maximum height near umbo; pedicle foramen subcircular, situated immediately posterior to apex, not enclosed within larval shell; ventral pseudointerarea moderately high, procline to slightly catacline, divided by broad intertrough. Dorsal valve gently convex; dorsal pseudointerarea low, with broad, shallow median groove, and narrow propareas.

Ventral interior with apical process forming low boss-shaped projection with median depression anterior to foramen; internal pedicle tube short; apical pits closely spaced on either side of apical process. Dorsal median ridge thin, low, occupying about 60% of valve length, and originating directly anterior to low, triangular median buttress; dorsal cardinal muscle fields relatively small, somewhat thickened, extending anteriorly for about 26% of valve length; dorsal central muscle scars weakly impressed.

Discussion. — There are no significant differences between the specimens from Antarctica and Australia. *Vandalotreta djagoran* is closely similar to the type species, *V. vafra*, differing only in having a more transversely suboval outline, and a more well defined dorsal median ridge, as well as less well defined dorsal central muscle scars; it may prove to be a junior synonym of the type species.

Occurrence. — Early Cambrian (Toyonian)–early Middle Cambrian, Australia (Northern Territory), King George Island erratics, Antarctica.

REFERENCES

BENGTSON, S., CONWAY MORRIS, S., COOPER, B.J., JELL, P.A. and RUNNEGAR, B.N. 1990. Early Cambrian fossils from South Australia. — *Association of Australasian Palaeontologists, Memoir* **9**, 1–364.

BIERNAT, G., BIRKENMAJER, K. and POPIEL-BARCZYK, E. 1985. Tertiary brachiopods from the Moby Dick Group of King George Island (South Shetland Islands, Antarctica). — *Studia Geologica Polonica* **81**, 109–141.

BIRKENMAJER, K. 1992. Cenozoic glacial history of the South Shetland Islands and Northern Antarctic Peninsula. *In*: J. López-Martinez (ed.) *Geologia de la Antártida Occidental. Simposios T 3*, 251–260. III Congreso Geológico de España y VIII Congreso Latinoamericano de Geologia. Salamanca, España.

BIRKENMAJER, K. and BUTKIEWICZ, T. 1988. Petrography and provenance of magmatic and metamorphic erratic blocks from Lower Miocene glacio-marine deposits of King George Island (South Shetland Islands, Antarctica). — *Studia Geologica Polonica* **95**, 23–51.

BIRKENMAJER, K. GAŹDZICKI, A. and WRONA, R. 1983. Cretaceous and Tertiary fossils in glacio-marine strata at Cape Melville, Antarctica. — *Nature* **303**, 56–59.

BIRKENMAJER, K. GAŹDZICKI, A., PUGACZEWSKA, H. and WRONA, R. 1987. Recycled Cretaceous belemnites in Lower Miocene glacio-marine sediments (Cape Melville Formation) of King George Island. Antarctica. *In*: A. Gaździcki (ed.) Palaeontological Results of the Polish Antarctic Expeditions. Part I. — *Palaeontologia Polonica* **49**, 49–62.

BROCK, G.A. and COOPER, B.J. 1993. Shelly fossils from the Early Cambrian (Toyonian) Wirrealpa, Aroona Creek, and Ramsay limestones of South Australia. — *Journal of Paleontology* **67**, 758–778.

CHUANG, S.H. 1971. The morphology and paleobiology of *Trematis elliptopora* Cooper (Inarticulata, Brachiopoda). *In*: J.T. Dutro (ed.) Paleozoic perspectives: a paleontological tribute to G. Arthur Cooper. — *Smithsonian Contributions to Paleobiology* **3**, 93–100.

COBBOLD, E.S. 1921. The Cambrian horizons of Comley (Shropshire) and their Brachiopoda, Pteropoda, Gastropoda. — *Geological Society of London, Quarterly Journal* **76**, 325–386.

DEBRENNE, F. and KRUSE, P.D. 1986. Shackleton Limestone archaeocyaths. — *Alcheringa* **10**, 235–278.

DEBRENNE, F. and KRUSE, P.D. 1987. Shackleton Limestone archaeocyaths. Corrigendum. — *Alcheringa* **11**, 138.

DUDZIAK, J. 1984. Cretaceous calcareous nannoplankton from glaciomarine deposits of the Cape Melville area, King George Island (South Shetland Islands, Antarctica). — *Studia Geologica Polonica* **79**, 37–51.

EVANS, K.R. and ROWELL, A.J. 1990. Small shelly fossils from Antarctica: an Early Cambrian faunal connection with Australia. — *Journal of Palaeontology* **64**, 692–700.

EVANS, K.R. 1992. *Marocella*: Antarctic specimens of an enigmatic Cambrian animal. — *Journal of Palaeontology* **66**, 558–562.

GAŹDZICKI, A. (ed.) 1987. Palaeontological Results of the Polish Antarctic Expeditions. Part I. — *Palaeontologia Polonica* **49**, 1–168.

GORJANSKY, V.J. and POPOV, L.E. (Горянский, В.Ю., Попов, Л.Е.) 1985. Морфология, систематическое положение и происхождение беззамковых брахиопод с карбонатной раковиной. — *Палеонтологический журнал* **3 (1985)**, 3–14.

HENDERSON, R.A. 1992. Inarticulate Brachiopoda. *In*: R.A. Henderson, F. Debrenne, A.J. Rowell, and G.F. Webers (eds) Brachiopods, archeocyathids, and Pelmatozoa from the Minaret Formation of the Ellsworth Mpuntains, West Antarctica. — *Geological Society of America, Memoir* **170**, 251–255.

HOLMER, L.E. 1989. Middle Ordovician phosphatic inarticulate brachiopods from Västergötland and Dalarna, Sweden. — *Fossils and Strata* **25**, 1–172.

HOLMER, L.E. and POPOV, L.E. 1994. Revision of the type species of *Acrotreta* and related lingulate brachiopods. — *Journal of Paleontology* **68**, 433–450.

HOLMER, L.E. and USHATINSKAYA, G.T. 1994. Ceratretide brachiopods from the Early and Middle Cambrian of Sweden, Kazakhstan, and Siberia. — *GFF* **116**, 203–210.

KONEVA, S.P. (Конева, С.П.) 1986. Некоторые средне- и позднекембрийские беззамковые брахиоподы Малого Каратау (южный Казахстан). — *Труды Института геологии и геофизики Сибирского Отделения АН СССР* **669**, 201–209.

KRUSE, P.D. 1990. Cambrian palaeontology of the Daly Basin. — *Northern Territory Geological Survey, Report* **7**, 1–58.

KRUSE, P.D. 1991a. Cyanobacterial-archaeocyathan-radiocyathan bioherms in the Wirrealpa Limestone of South Australia. — *Canadian Journal of Earth Science* **28**, 610–615.

KRUSE, P.D. 1991b. Cambrian fauna of the Top Springs Limestone, Georgina Basin. — *The Beagle, Records of the Northern Territory Museum of Arts and Sciences* **8**, 169–188.

KUHN, O. 1949. *Lehrbuch der Paläozoologie*, 1–326. Schweizerbart'sche Verlagsbuchhandlung, Stuttgart.

MATTHEW, G.F. 1902. Notes on Cambrian faunas. — *Royal Society of Canada, Transactions, Ser.2, Sect.4*, 93–112.

MATTHEW, G.F . 1903. *Report on the Cambrian rocks of Cape Breton*, 1–246. Geological Survey of Canada, Ottawa.

MENKE, C. T. 1828. *Synopsis methodica molluscorum generum omnium et speciarum earum quae in Museo Kenkeano adservantur*, 1–91. Pyrmonti.

MERGL, M. 1988. Inarticulate brachiopods of early Middle Cambrian age from High Atlas, Morocco. —*Véstnik Úsredniho ústavu geologického* **63**, 291–295.

MERGL, M. and ŠLEHOFEROVÁ, P. 1990. Middle Cambrian inarticulate brachiopods from Central Bohemia. — *Sbornik geologickych věd, Paleontologie* **31**, 67–104.

PELMAN, Yu.L. (Пельман, Ю.Л.) 1977. Ранне- и среднекембрийские беззамковые брахиоподы Сибирской платформы. — *Труды Института геологии и геофизики Сибирского Отделения АН СССР* **316**, 1–168.

PELMAN, Yu.L. (Пельман, Ю.Л.) 1983. Среднекембрийские беззамковые брахиоподы реки Муны (Лена, нижнее течение). — *Труды Института геологии и геофизики Сибирского Отделения АН СССР* **541**, 115–128.

PELMAN, Yu. and PERELADOV, V.S. (Пельман, Ю.Л., Переладов, В.С.) 1986. Стратиграфия и брахиоподы нижнего-среднего кембрия р. Арга-Сала (Южное Прианабарие). — Труды Института геологии и геофизики Сибирского Отделения АН СССР **669**, 119–154.

POPOV, L.E. (Попов, Л.Е.) 1984. Описание беззамковых брахиопод. *In:* И.А., Соловьев, Л.Е, Попов, В.В. Самсонов, Новые данные о верхнекембрийской фауне гор Элсуэрт и Пенсакола (Западная Антарктида). —*Антарктика* **23**, 66–71.

POPOV, L.E. 1992. The Cambrian radiation of brachiopods. *In*: J.H. Lipps and P.W. Signor (eds) — *Origin and Early Evolution of Metazoa*, 399–423. Pergamon, New York.

POPOV, L.E. and HOLMER, L.E. 1994. Cambrian-Ordovician lingulate brachiopods from Scandinavia, Kazakhstan, and South Ural Mountains. — *Fossils and Strata* **35**, 1–156.

POPOV, L.E., KHAZANOVITCH, K.K., BOROVKO, N.G., SERGEEVA, S.P., and SOBOLEVSKAYA, R.F. (Попов, Л.Е., Хазанович, К.К., Боровко, Н.Г., Сергеева, С.П., Соболевская, Р.Ф.) 1989. Опорные разрезы и стратиграфия кембро-ордовикской фосфоритоносной оболовой толщи на северо-западе Русской платформы. — *АН СССР, Министерство Геологии СССР, Межведомственный стратиграфический комитет СССР, Труды* **18**, 1–222. Наука, Ленинград.

POPOV, L.E. and SOLOVJEV, I.A. (Попов, Л.Е., Соловьев, И.А.) 1981. Среднекембрийские беззамковые брахиоподы, ханцеллории и трилобиты Западной Антарктиды, хребты Шеклтон и Арджентина. — *Антарктика* **20**, 64–72.

REES, M.N., PRATT, B.R., and ROWELL, A.J. 1989. Early Cambrian reefs complexes, and associated lithofacies of the Shackleton Limestone, Transantarctic Mountains. — *Sedimentology* **36**, 341–361.

REDLICH, K.A. 1899. The Cambrian fauna of the eastern Salt-Range. — *Memoirs of the Geological Survey of India. Palaeontologia Indica* **1**, 1–13.

ROBERTS, J., JELL, P.A. 1990. Early Middle Cambrian (Ordian) brachiopods of the Coonigan Formation, Western New South Wales. — *Alcheringa* **14**, 257–309.

ROWELL, A.J. 1965. Inarticulata. *In*: R.C. Moore (ed.) *Treatise on Invertebrate Palaeontology, Part H. Brachiopoda* 1(2), H260– H296. Geological Society of America and University of Kansas Press, Boulder, Colorado and Lawrence, Kansas.

ROWELL, A.J. 1966. Revision of some Cambrian and Ordovician inarticulate brachiopods. — *The University of Kansas Paleontological Contributions* **7**, 1–35.

ROWELL, A.J. 1980. Inarticulate brachiopods of the Lower and Middle Cambrian Pioche Shale of the Pioche District, Nevada. — *University of Kansas Paleontological Contributions, Paper* **98**, 1–34.

ROWELL, A.J., COOPER, R.A., JAGO, J.B., and BRADDOCK, F. 1984. Paleontology of the Lower Paleozoic of Northern Victoria Land: brachiopods with Australian and New Zealand affinities. — *Antarctic Journal of the United States* **18**, 18–20.

SCHINDEWOLF, O.H. 1955. Über einige kambrische Gattung inartikulater Brachiopoden. — *Neues Jahrbuch für Mineralogie, Geologie und Paläontologie* **1**, 1–15.

SCHINDEWOLF, O. H. and SEILACHER, A. 1955. Beiträge zur Kenntnis des Kambriums in der Salt Range (Pakistan). — *Akademie der Wissenschaften und der Literatur, Abhandlungen der mathematisch-naturwissenschaftlichen Klasse* **10**, 1–341.

SCHUCHERT, C. 1893. A classification of the Brachiopoda. —*The American Geologist* **11**, 141–167.

SHERGOLD, J.H., COOPER, R.A., MACKINNON, D.I. and YOCHELSON, E.L. 1976. Late Cambrian Brachiopoda, Mollusca, and Trilobita from Northern Victoria Land, Antarctica. — *Palaeontology* **19**, 247–291.

USHATINSKAYA, G.T. (Ушатинская, Г.Т.) 1993. Ранне- и среднекембрийские лингулиды Сибирской Платформы. —*Палеонтологический журнал* **2 (1993)**, 133–136.

VORONOVA, L.G., DROZDOVA, N.A., ESAKOVA, N.V., ZHEGALLO, E.A., ZHURAVLEV, A.Yu., ROZANOV, A.Yu., SAYUTINA, T.A. and USHATINSKAYA, G.T. (Воронова, Л.Г., Дроздова, Н.А., Есакова, Н.В., Жегалло, Е.А., Журавлев, А.Ю., Розанов, А.Ю., Саютина, Т.А., Ушатинская, Г.Т.) 1987. Ископаемые нижнего кембрия гор Маккензи (Канада). — *Труды Палеонтологического института АН СССР* **224**, 1–88.

WAAGEN, W. 1885. Salt Range fossils. I. *Productus*-limestone fossils 4 (5). — *Memoirs of the Geological Survey of India. Palaeontologia Indica* **13**, 729–770.

WALCOTT, C.D. 1912. Cambrian Brachiopoda. — *Monograph of the U.S. Geological Survey* **51**, 1–872.

WILLIAMS, A. and ROWELL, A. 1965. Morphology. *In:* R.C. Moore (ed.) *Treatise on Invertebrate Paleontology, Part H, Brachiopoda* 1(2), H57–H138. Geological Society of America and University of Kansas Press, Boulder, Colorado and Lawrence, Kansas.

WIMAN, C. 1903. Studien über das Nordbaltische Silurgebiet. I. Olenellussandstein, Obolussandstein und Ceratopygeschiefer. — *Bulletin of the Geological Institutions of the University of Uppsala* **6**, 12–76.

WRONA, R. 1987. Cambrian microfossil *Hadimopanella* Gedik from glacial erratics in West Antarctica. *In*: A. Gaździcki (ed.) Palaeontological Results of the Polish Antarctic Expeditions. Part I. — *Palaeontologia Polonica* **49**, 37–48.

WRONA, R. 1989. Cambrian limestone erratics in the Tertiary glacio-marine sediments of King George Island, West Antarctica. — *Polish Polar Research* **10**, 533–553.

WRONA, R. and ZHURAVLEV, A.Yu. 1996. Early Cambrian archaeocyaths from glacial erratics of King George Island (South Shetland Island), Antarctica. *In*: A. Gaździcki (ed.) Palaeontological Results of the Polish Antarctic Expeditions. Part II. — *Palaeontologia Polonica* **55**, 9–36.

ZHURAVLEV, A.Yu. and GRAVESTOCK, D.I. 1994. Archaeocyaths from Yorke Peninsula, South Australia and archaeocyathan Early Cambrian zonation. — *Alcheringa* **18**, 1–54.

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PLATE 9

Lingulate brachiopods from the Cambrian glacial erratics (dropstones) found in the Cape Melville Formation (Lower Miocene) at Melville Peninsula, King George Island, West Antarctica (Figs 1–2, 5, 9, 14), except for specimens of Figs 3–4, 6–8 and Figs 10, 13, 15 which are from Wirrealpa Limestone (sample no. 13, L.E. HOLMER 1993), Flinders Ranges, Australia.

Fig. 1. Ventral valve exterior, ZPAL Bp.XXXIII/33S9, erratic boulder Me66, × 15.

Fig. 2. Dorsal valve exterior, ZPAL Bp.XXXIII/61S2, erratic boulder Me52, × 5.5.

Fig. 3. Dorsal valve exterior, SAM P35111, × 12.

Fig. 4. Ventral valve exterior, SAM P35109, × 40.

Fig. 5. Ventral pseudointerarea, ZPAL Bp.XXXIII/61S6, erratic boulder Me52, × 39.

Fig. 6. Dorsal valve exterior, SAM P35101, × 18.

Fig. 7. a – ventral valve interior, SAM P35103, × 11; b – oblique posterior view of ventral valve interior and pseudointerarea, × 30.

Fig. 8. Ventral pseudointerarea, SAM P35110, × 21.5.

Fig. 9. Dorsal valve interior, ZPAL Bp.XXXIII/50S1, erratic boulder Me66, × 16.5.

Fig. 10. Dorsal valve interior, pseudointerarea, SAM P35105, × 37.5.

Fig. 11. a – ventral valve exterior, SAM P35102, × 10; b – oblique posterior view, × 50.5.

Fig. 12. Ventral valve interior, SAM P35114, × 19.5.

Fig. 13. a – dorsal valve interior, SAM P35104, × 15; b – oblique lateral view, × 30.

Fig. 14. Ventral valve exterior, ZPAL Bp.XXXIII/33S6, erratic boulder Me66; a – oblique lateral view, × 25; b – ventral view, × 22,5; c – pustulose ornamentation of post-larval shell, × 65; d – magnified fragment of the same surface as c, × 375.

Fig. 15. Complete juvenile shell, SAM P35112; a – dorsal view × 55; b – oblique lateral view, × 55; c – oblique posterior view of larval shell, × 195; d – pitted micro-ornamentation of dorsal larval shell, × 760.

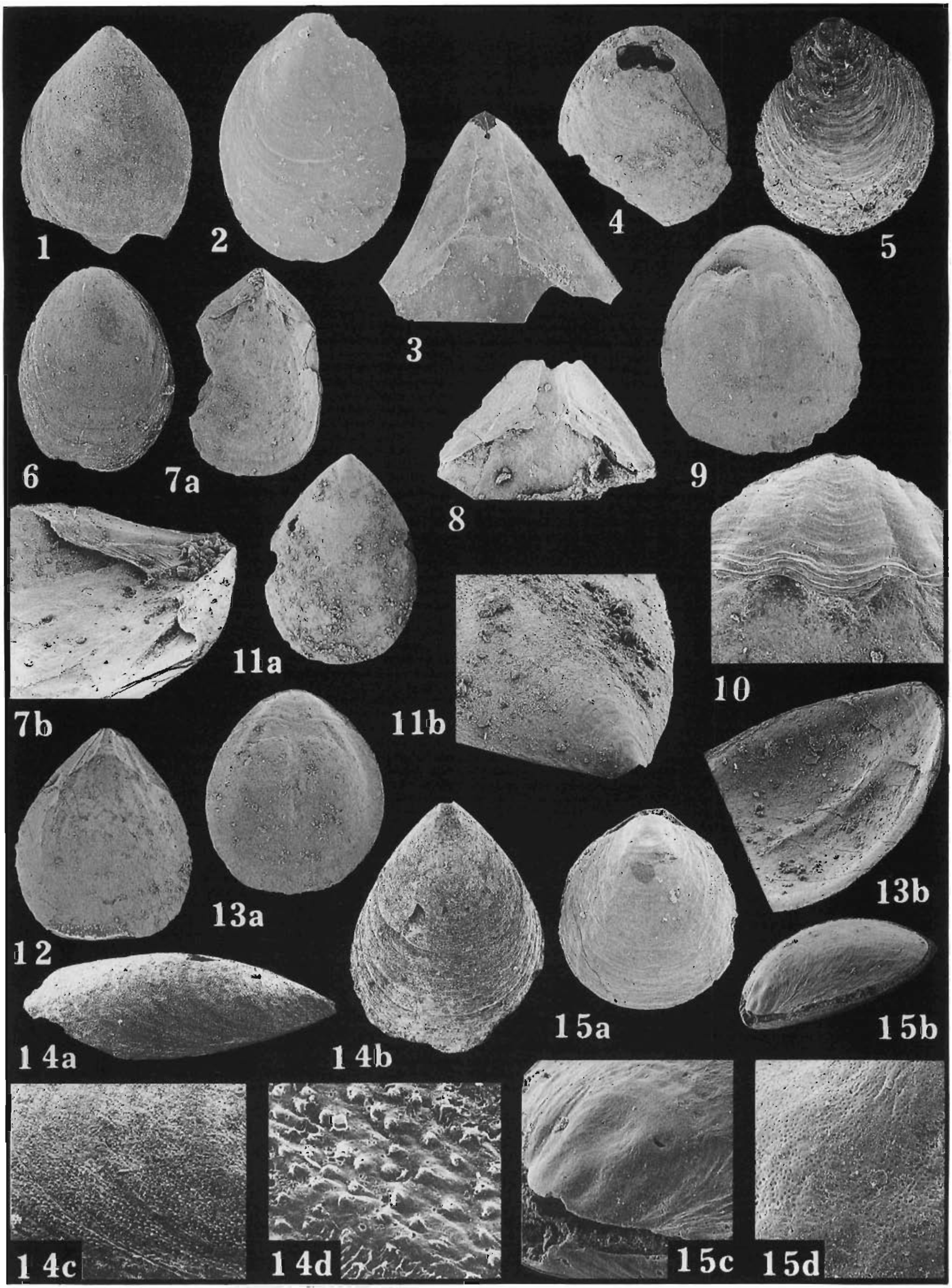

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PLATE 10

Eoobolus triparilis (MATTHEW, 1902) 42

Specimens on Figs 1–9 are from the Middle Cambrian, Cape Breton, Nova Scotia, Canada.

Fig. 1. Dorsal internal mould, USNM 57013d, × 4.4.
Fig. 2. Dorsal internal mould, USNM 57013a, × 5.5.
Fig. 3. Dorsal internal mould, ROM 678CM (E), × 5.
Fig. 4. Dorsal valve exterior, USNM 57013e, × 5.7.
Fig. 5. Dorsal internal mould, ROM 510B, × 4.
Fig. 6. Ventral internal mould, USNM 57013c, × 4.3.
Fig. 7. Lectotype, dorsal valve, ROM 510CM (A); a – exterior, X 5.3; b – pustulose micro-ornamentation of postlarval shell, × 7.5.
Fig. 8. Dorsal internal mould, ROM 678CB (C), × 4.
Fig. 9. Ventral valve exterior, USNM 51855a, × 5.

Botsfordia caelata (HALL, 1847)

Specimens on Figs 10 and 12 are from Lower Cambrian, northcentral Siberia, River Kotuj basin, Medvezhja River, (sample no. 182/3 of A.I. GROZDILOV 1963), except for the specimens of Figs 11 and 13 which are from the Lower Cambrian, Troy (USNM loc. no. 2b), USA (New York State).

Fig. 10. Dorsal valve interior, RM Br136457; a – × 18; b – oblique anterior view, × 32.5.
Fig. 11. Oblique anterior view of ventral pseudointerarea, USNM 34617, × 21.5.
Fig. 12. Dorsal larval shell with two tubercles, RM Br136456, × 19.5.
Fig. 13. Posterior view of delthyrium and ventral pseudointerarea, USNM 36617, × 15.

Botsfordia pulchra (MATTHEW, 1889)

Specimens of Figs 14–15 are from the Lower Cambrian, Hanford Brook Formation (USNM loc. no. 308d), Catons Island, New Brunswick, Canada.

Fig. 14. Ventral valve exterior, ROM 164CM (A): a – × 4; b – oblique lateral view of umbonal area, × 8.
Fig. 15. Dorsal valve exterior, ROM 164CM (B), × 4.

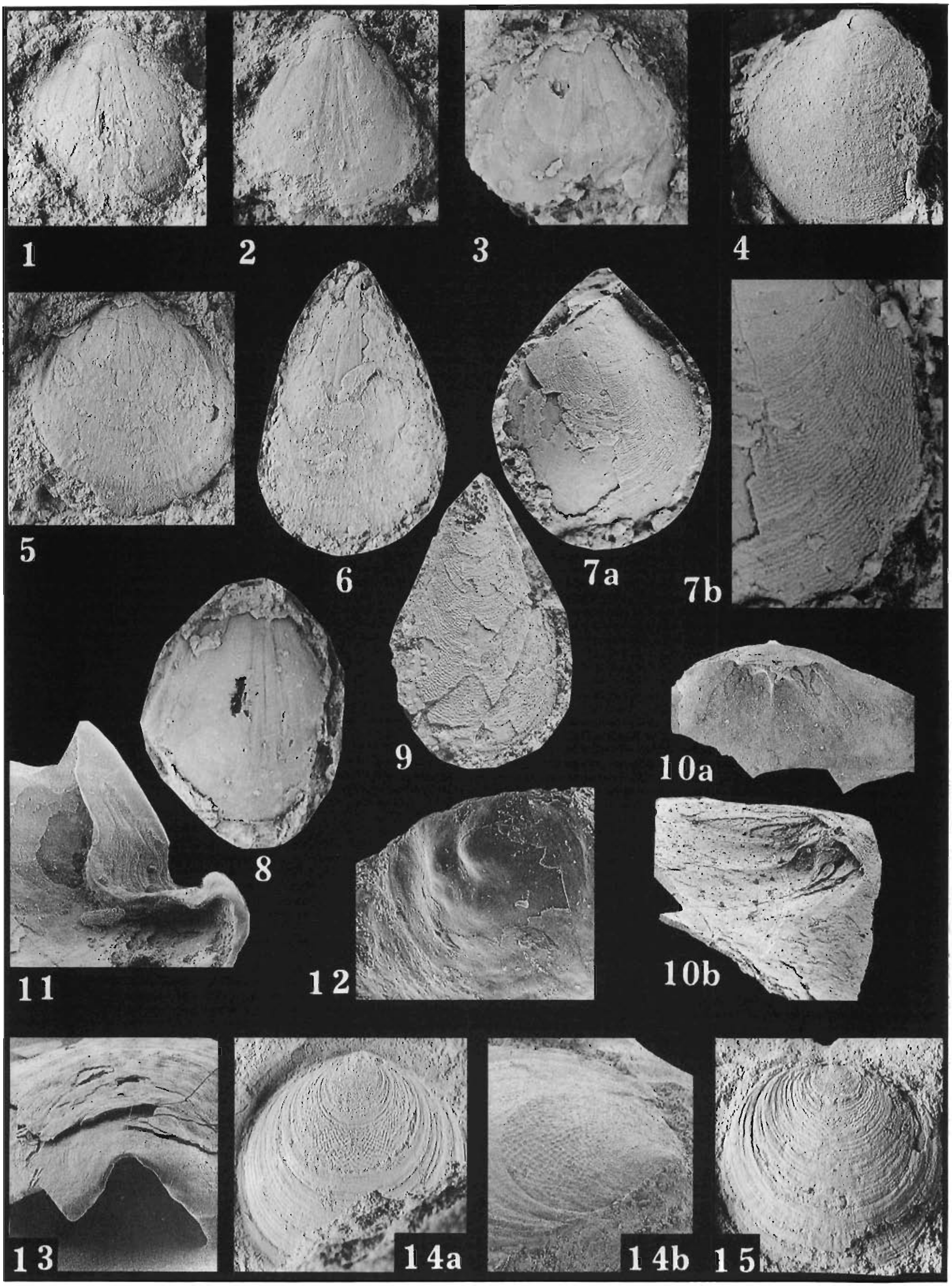

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PLATE 11

Karathele napuru (KRUSE, 1990) 45

Specimens at Figs 1–5, 7–8 are from the same Cambrian glacial erratic (dropstone) no. AE/Me52 found in the Cape Melville Formation (Lower Miocene) at Melville Peninsula, King George Island, West Antarctica; specimen of Fig. 6 is from the Wirrealpa Limestone (sample no. 13, L.E. HOLMER 1993), Flinders Ranges, Australia.

Fig. 1. Complete juvenile shell, ZPAL Bp.XXXIII/29S8; a – oblique lateral view, × 55.5; b – oblique lateral view of umbonal area, × 100; c – posterior view, × 55.5; d – ventral view, × 45; e – umbonal area, × 80.

Fig. 2. a – dorsal valve interior, ZPAL Bp.XXXIII/53S4, × 27.5; b – oblique lateral view, × 32.5; c – oblique anterior view, × 29.5.

Fig. 3. Dorsal valve interior, ZPAL Bp.XXXIII/34S3, × 30.

Fig. 4. Dorsal valve interior, ZPAL Bp.XXXIII/50S2, × 19.5.

Fig. 5. Ventral valve interior, oblique anterior view, ZPAL Bp.XXXIII/53S2, × 37.5.

Fig. 6. Umbonal area of ventral valve, SAM P35113, × 80.5.

Fig. 7. Umbonal area of dorsal valve, ZPAL Bp.XXXIII/50S3; a – oblique posterior view, × 100; b – dorsal view, × 75.5; c – pitted micro-ornamentation of larval shell, × 215.

Fig. 8. a – ventral valve interior, ZPAL Bp.XXXIII/5340U, × 10; b – detail of delthyrium, × 21.5; c – oblique lateral view of delthyrium, × 50.

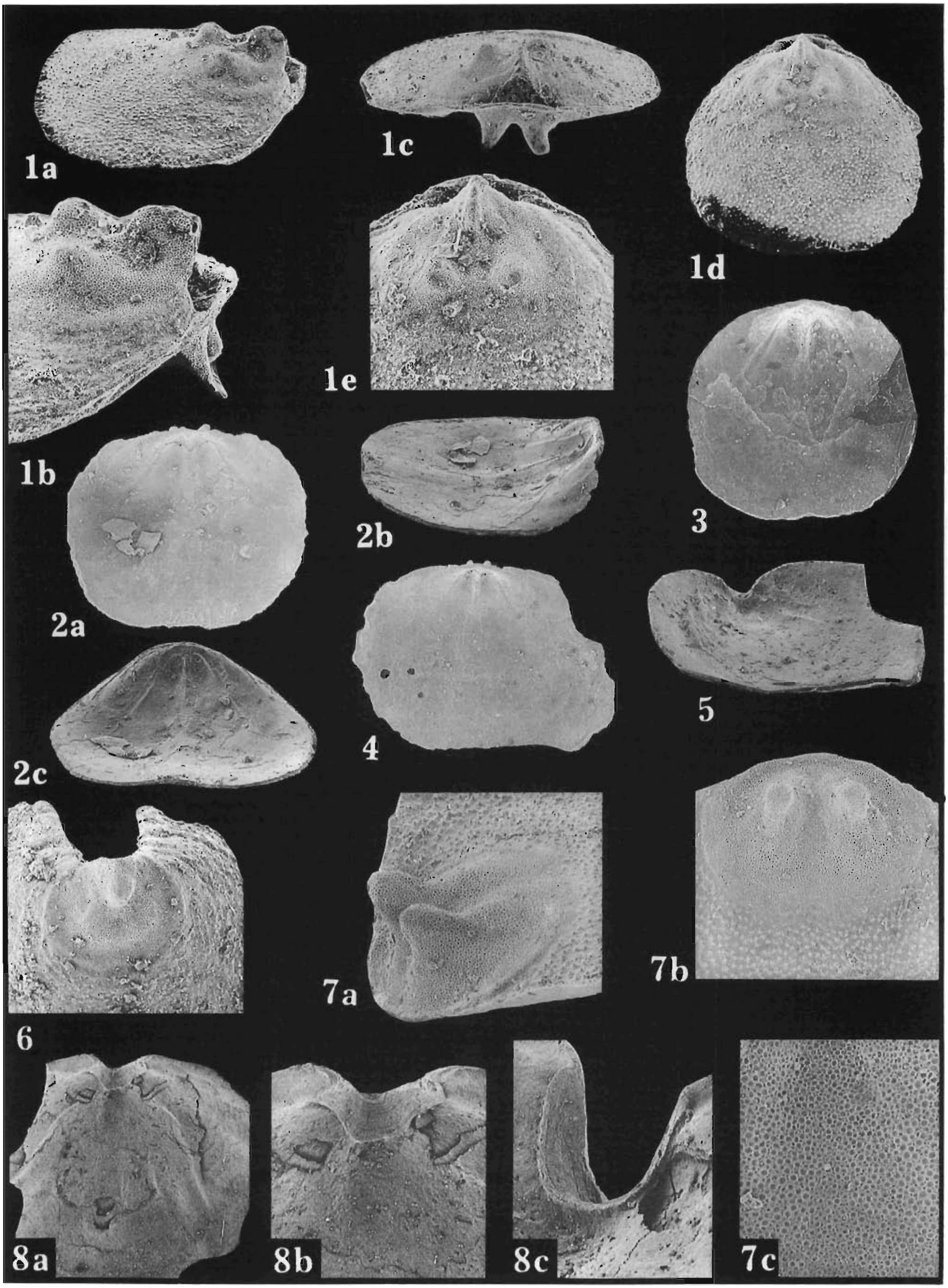

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PLATE 12

Karathele napuru (KRUSE, 1990) 45

Specimens of Figs 1–3 are from the same Lower Cambrian glacial erratic (dropstone) no. AE/Me52 found in the Cape Melville Formation (Lower Miocene) at Melville Peninsula, King George Island, West Antarctica; specimens of Figs 4 and 5 are from Wirrealpa Limestone (sample no. 13, L.E. HOLMER 1993), Flinders Ranges, Australia.

Fig. 1. a – complete juvenile shell, ZPAL Bp.XXXIII/38S4, dorsal view, × 60.5; b – lateral view, × 65.5; c – posterior view, × 90.5; d – oblique lateral view at ventral valve, × 75.

Fig. 2. Pitted microornament of larval shell, ZPAL Bp.XXXIII/29S5, × 1360.

Fig. 3. a – ventral valve exterior, ZPAL Bp.XXXIII/54S3, X 11; b – umbonal area, ventral view, × 40; c – posterior view, × 40.

Fig. 4. Umbonal area of ventral valve, SAM P35107; a – posterior view, × 40; b – oblique lateral view, × 32.5.

Fig. 5. Ventral valve, pedicle opening, SAM P35100; × 50.5.

Eothele spurri (WALCOTT, 1908)

Specimens of Figs 6–8 are from the Lower Cambrian (*Bonnia–Olenellus* Zone), Pioche Shell (Combined Metals Member), north of Highway 93, west of Oak Spring Summit (locality no. 70-f-24; ROWELL 1980), Nevada (Lincoln County), USA.

Fig. 6. a – dorsal valve exterior, USNM 459703c, × 19.5; b – umbonal area, × 90.5.

Fig. 7. Ventral valve, USNM 459703a; a – lateral view, × 32.5; b – posterior view, × 11; c – oblique posterior view showing pedicle foramen, × 30; d – lateral view of umbonal area, × 32.5; e – larval shell and pedicle foramen, × 75.5.

Fig. 8. Dorsal valve interior, oblique anterior view, USNM 459703b; × 40.

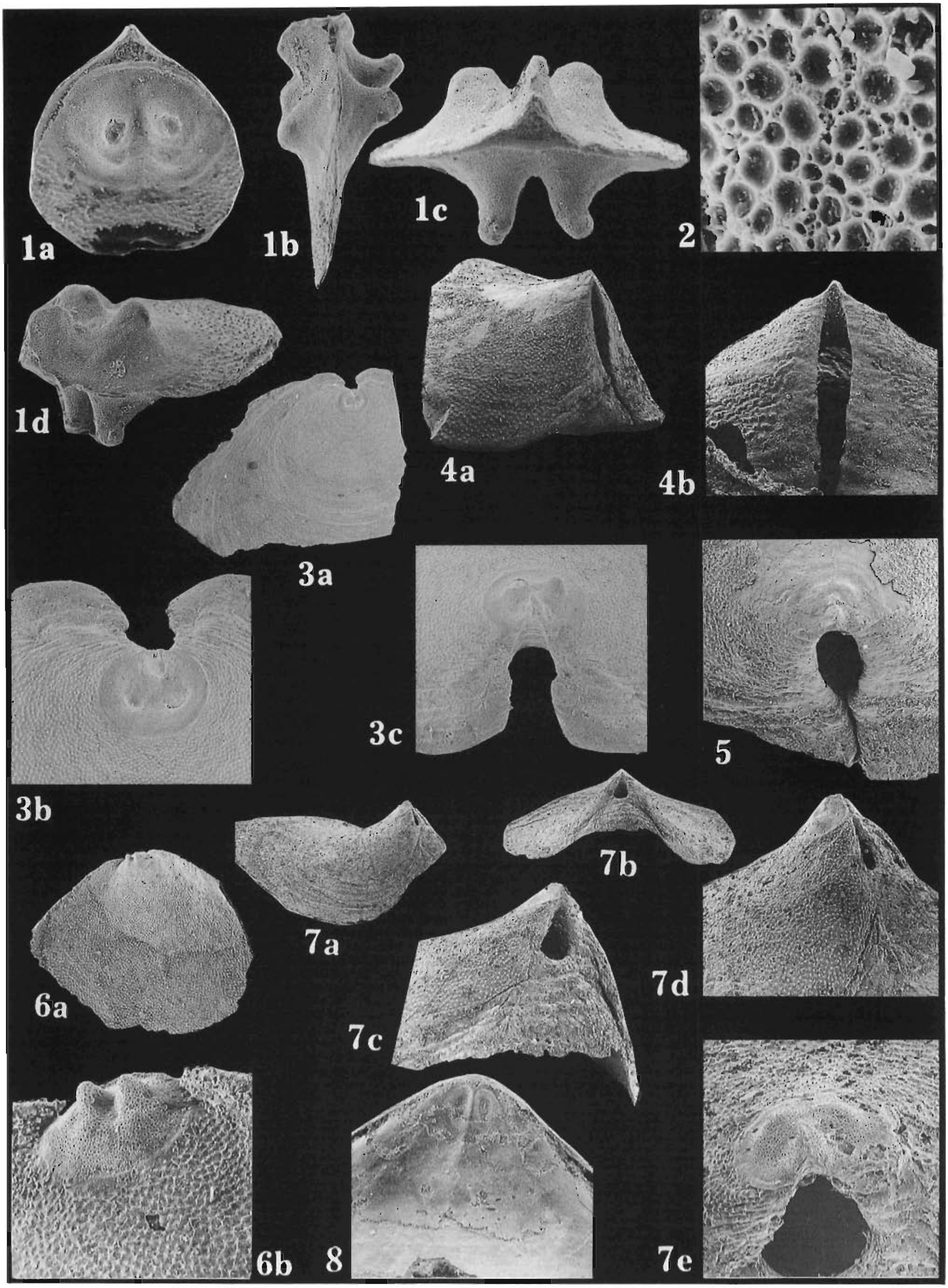

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PLATE 13

Vandalotreta djagoran (KRUSE, 1990) 47

All specimens are from the same Cambrian glacial erratic (dropstone) no. AE/Me52 found in the Cape Melville Formation (Lower Miocene) at Melville Peninsula, King George Island, West Antarctica (Figs 1–9).

Fig. 1. Complete shell, ZPAL Bp.XXXIII/54S6; a – dorsal valve exterior, × 60; b – posterior view, × 80; c – oblique lateral view, × 80; d – oblique posterior view, × 150.

Fig. 2. Ventral valve exterior, ZPAL Bp.XXXIII/54S5, × 32.5.

Fig. 3. Complete shell, ventral valve, posterior view, ZPAL Bp.XXXIII/39S8, × 90.

Fig. 4. Complete shell, oblique lateral view, ZPAL Bp.XXXIII/54S7, × 13.5.

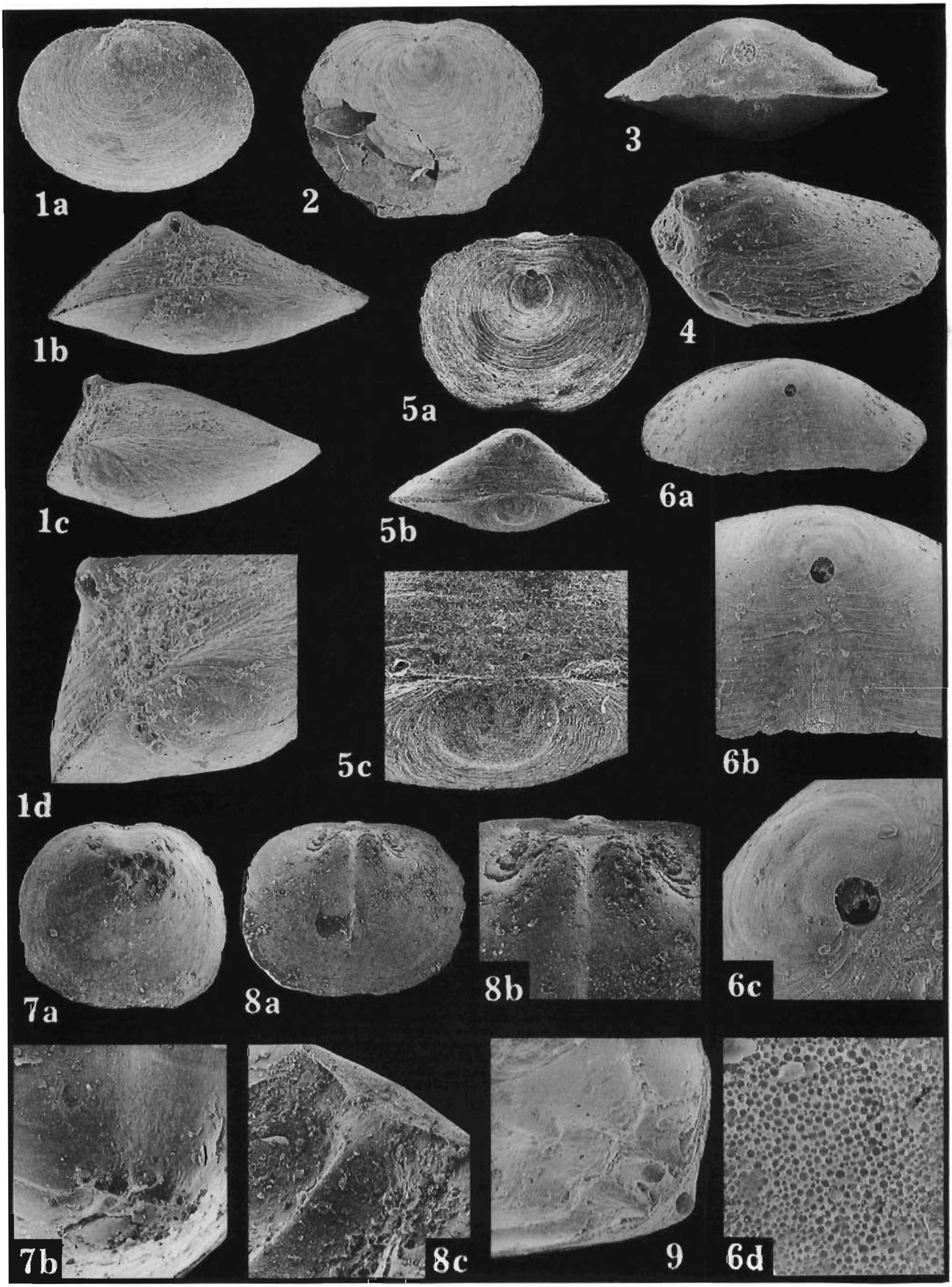
Fig. 5. a – complete shell, ventral valve exterior, ZPAL Bp.XXXIII/29S1, × 40; b – posterior view of complete shell, × 37.5; c – posterior view of commissure and dorsal larval shell, × 110.

Fig. 6. Ventral valve, ZPAL Bp.XXXIII/54S5; a – oblique posterior view, × 40; b – posterior view, × 80.5; c – posterior view of ventral larval shell and pedicle foramen, × 150; d – pitted micro-ornamentation of larval shell, posterior view, × 1010.

Fig. 7. Ventral valve, ZPAL Bp.XXXIII/5337U; a – interior, X 40; b – apical process, × 60.

Fig. 8. Dorsal valve, ZPAL Bp.XXXIII/5333U; a – interior, X 23.5; b – interior, × 50.5; c – pseudointerarea and median buttress, × 100.

Fig. 9. Ventral valve interior, ZPAL Bp.XXXIII/61S8, × 75.



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