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A LATE OLIGOCENE BRACHIOPOD FAUNA FROM THE ROCKY SHORE DEPOSIT AT COSY DELL FARM, SOUTHLAND, NEW ZEALAND

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Abstract: A Late Oligocene rocky shore fauna from Cosy Dell farm, Southland, is shown to include six brachiopod genera and species and, for the first time, records the co-existence of a discinid, a craniid and a kraussinid in such a paleoecological setting in New Zealand. This study includes the first reported occurrence of *Discradisca* in New Zealand and extends the stratigraphic range of species *Megerlina miracula* Hiller, MacKinnon & Nielsen, 2008 back to the late Oligocene. In addition, this study confirms the occurrence of *M. miracula* in very shallow-water deposits.

Keywords: Brachiopod, Cosy Dell, rocky shore, Oligocene, *Discradisca*, *Novocrania*, *Magasella, Megerlina*

This study describes a modest brachiopod fauna collected from the Late Oligocene shallow-water Chatton Formation at Cosy Dell farm, Waimumu, Southland, New Zealand. The material includes representatives of five brachiopod families: Discinidae, Craniidae, Notosariidae, Terebratellidae and Kraussinidae. An incomplete specimen, damaged valves and valve fragments suggest the presence of a second genus of the Terebratellidae.

Lee et al. (2014) summarised the highly diverse, rocky shore fossil fauna from Cosy Dell, including maps and a stratigraphic column. The site has been dated at between 25.4 and 24.4 Ma using nannofossils (Conran et al. 2014) with the one-million-year age range straddling the Duntroonian–Waitakian (late Oligocene) boundary. Other fossil taxa suggest a Duntroonian age (Lee et al. 2014).

The fossil fauna includes molluscs (more than 350 species), ostracods (more than 125 species), otoliths (20 species), barnacles (9 species), brachiopods, bryozoans, echinoderms, solitary and hermatypic corals, foraminifera, nannofossils and penguin bones (Lee et al. 2014). There is also a considerable fossil flora of wood, seeds, pollen and spores. A suite of papers has been published describing the ecology and taxonomy of various taxa from Cosy Dell, including barnacles (Buckeridge et al. 2014), plants (Conran et al. 2014), ostracods (Ayress et al. 2017) and otoliths (Schwarzhans et al. 2017).

Rocky shore brachiopod faunas are known from just four other Cenozoic localities in New Zealand: Mount Luxmore, Fiordland (Duntroonian–Waitakian) (Lee et al. 1983); Bluff, Southland (Waitakian–Otaian) (Bosel & Coombs 1984); Rodney, Auckland (Otaian) (Robinson 2017a); and Whanganui, Taranaki (Late Pliocene) (Carter 1972). The range of fossil taxa found at Cosy Dell is the most diverse fossil assemblage of these rocky shore deposits by a wide margin.

MATERIAL AND METHODS

The material of this study is moderately to poorly preserved. Bulk samples of the richly fossiliferous sediments were collected from Cosy Dell by the author and other researchers, washed and sieved into fractions and the brachiopods picked under binocular microscopes. Specimens were photographed using JEOL Cambridge, Zeiss Sigma and Hitachi TM3000 SEM electron microscopes. All the brachiopod material of this study is held in the Geology Museum, University of Otago (Table 1). The Cosy Dell site is registered in the New Zealand Fossil Record File as F45/f396 (46.11182°S; 168.80015°E), administered by the Geoscience Society of New Zealand and GNS Science.

SYSTEMATIC PALEONTOLOGY

Phylum	Brachiopoda Dumeril, 1805
Subphylum	Linguliformea Williams et al., 1996a
Order	Lingulida Waagen, 1885
Family	Discinidae Gray, 1840
Genus	*Discradisca* Stenzel, 1964

Discradisca sp. Figure 1A, B, C, D.
Discinisca: —Lee et al. 2014: 200; —Robinson 2017a: 17.

Stenzel (1964) introduced two names as subgenera of the genus *Discinisca*: *Discinisca* s.s. for species with smooth dorsal valve exteriors and *Discradisca* for taxa with a ribbed ornament. Cooper (1977) raised *Discradisca* to a full genus. Radwańska & Radwańska (1984, 1986) named two new species of *Discinisca* from the Miocene and Oligocene of Europe respectively. Bitner & Cahuzac (2013) transferred these two species to *Discradisca*.

Only partial dorsal valves (two) and dorsal valve fragments (nine) of this impunctate, chitinophosphatic

Table 1: Specimens from Cosy Dell farm examined in this study.

Genus/species	Collection number	Specimens
Discradisca sp.	OU 45776	2 partial valves and 9 fragments
Novocrania huttoni	OU 44536, OU 45309-10, OU 45368	5 dorsal valves and 100+ fragments
Notosaria antipoda	OU 45779	1 mostly complete juvenile specimen, 9 valves, 35 partial valves and fragments
Magella?	OU 47412	1 mostly complete specimen, 2 valves, 28 partial valves and fragments
Magasella sp.	OU 45775	6 partial valves and fragments
Megerlina miracula	OU 45304, 45774	1 partial specimen, 13 valves, 50+ partial valves

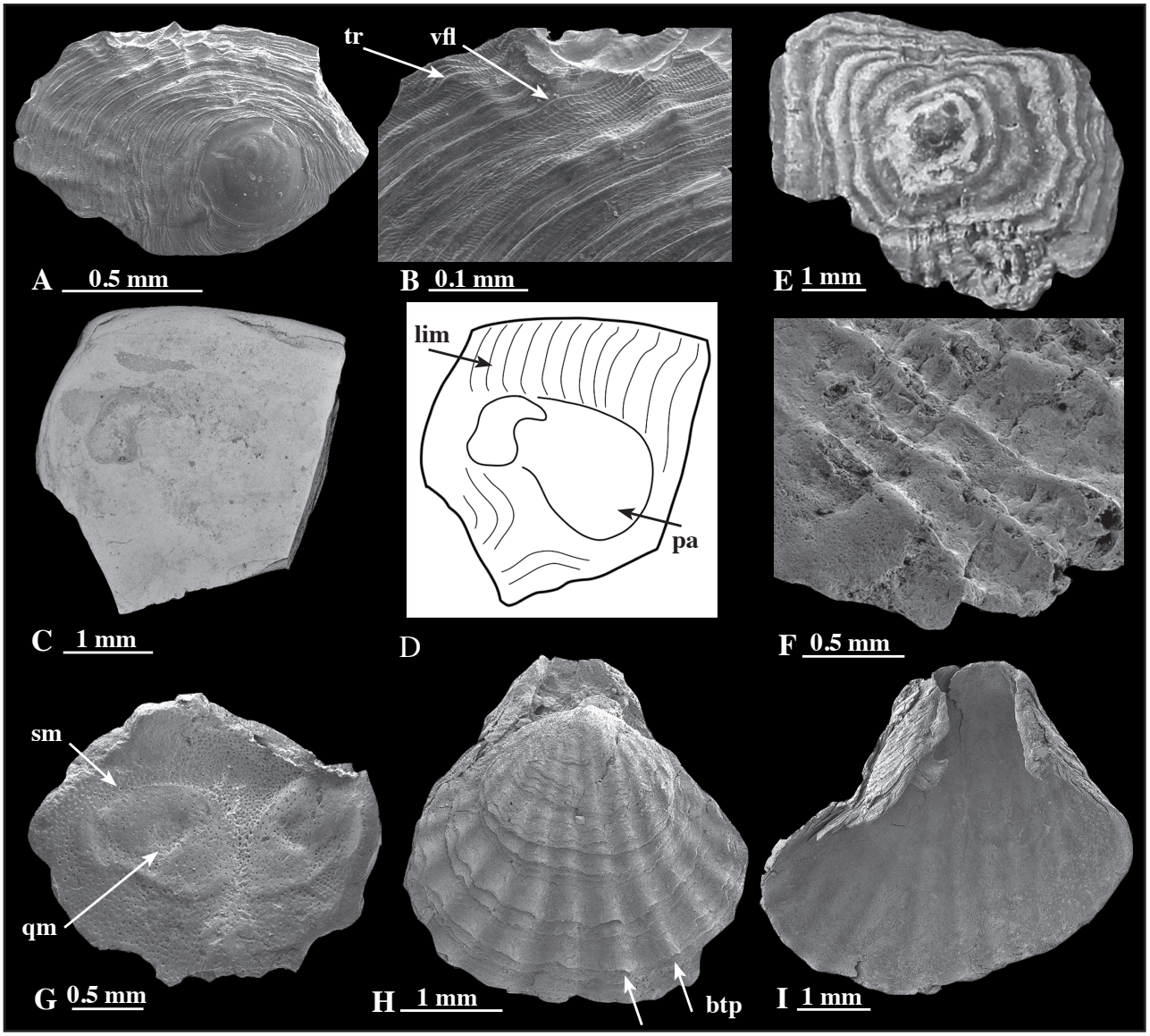

Figure 1: **A–D**. *Discradisca* sp., **A–B**. OU 45776a. **A**. Partial dorsal valve. **B**. Close-up of valve ornament. **C–D**. OU 45776b. **C**. Partial dorsal valve interior with posterior adductor muscle scar. **D**. Illustration of muscle scar and limbus. **E–G**. *Novocrania huttoni*. **E**. OU 45310a. Mostly complete (but worn) dorsal valve with concentric rings of colour and some radial ribs. **F**. OU 45310b. Partial dorsal valve with worn radial ribs. **G**. OU 45310c. Partial dorsal valve interior with anterior adductor muscle scars. **H–I**. *Notosaria antipoda*. **H**. OU 45779a. Dorsal exterior of mostly complete juvenile specimen. **I**. OU 45779b. Partial ventral valve interior. Abbreviations: btp – broken 'tent-like' projections (spines); lim – limbus; pa – posterior adductor muscle scar; qm – quick-muscle scar; sm – slow-muscle scar; tr – tuberculate ribs; vfl – very fine radial lines.

genus were found at Cosy Dell, so that placement into a species is not possible.

Description: The most complete valve includes the straight posterior margin and the smooth larval protegulum that forms the subposterior shell apex (Figure 1A). The valve is 0.1 mm thick and its estimated width (if complete) would be 2 mm. The ornament includes fine tuberculate ribs, fine concentric growth rings and a micro-ornament of very fine radial lines (Figure 1A, B). The rim of the dorsal valve is thickened and forms the smooth limbus around the interior margin. In the most complete specimen the posterior adductor muscle scars (0.2 mm wide) and the posterior ends of the anterior adductor muscle scars are faintly visible. One fragment includes a large (1.5 mm wide) posterior adductor muscle scar (Figure 1C, D) very close to the limbus. Margins of larger fragments are up to 1 mm thick.

Remarks: If the proportions of shell size to muscle-scar size remain constant through ontogeny, this species may have grown to at least 15 mm across. A morphologically similar, Late Oligocene, very shallow-water species, *D. steiningeri* (Radwańska & Radwańska, 1986), described from Austria, reached a maximum of 16 mm across and Recent intertidal species *D. strigata* (Broderip, 1834) also reaches a maximum of about 15 mm across (Paine 1962).

The posterior adductor muscle scar (Figure 1C, D) appears to be in two parts, a smaller, more deeply incised comma-shaped part (on the left) and a larger suboval lobe (Figure 1C, D). Radwańska & Radwańska (1984: 257–8, text-figure 2b-c) noted the presence of 'malformations' on the muscle scars of *Discradisca*.

Discradisca has a known stratigraphic range of Early Paleocene to Recent (Stenzel 1964), but has not previously been reported from New Zealand. Recent *Discradisca strigata* is known from rocky shore localities in Baja California (Paine 1962), where it lives under flat rocks both above and below the low tide zone, and Punta Patilla, Panama (La Barbera 1985) where it occurs under rocky overhangs and in crevices in the mid-intertidal zone. *D. sparselineata* (Dall, 1920) from the Seto inland sea, Japan, lives intertidally but attached to boulders buried in coarse sand (Kato 1996).

Order Craniidina Waagen, 1885
Family Craniidae Menke, 1828
Genus *Novocrania* Lee & Brunton, 2001

Novocrania huttoni (Thomson, 1916), Figure 1E, F, G
Stratigraphic range: Duntroonian (Late Oligocene) – Recent (Robinson 2018)

Five small, mostly complete dorsal valves and 100+ fragments have been collected at Cosy Dell; this is the only fossil material known of *N. huttoni* (Robinson 2018). For a complete synonymy of Recent *Novocrania huttoni* see Robinson (2017b).

Description: The mostly complete dorsal valves are subpentagonal to subquadrate and have concentric light and dark rings of brown or grey. The largest valve is 7 mm wide and the ornament of radial costae is partly preserved (Figure 1E). Several valve fragments have fine but worn costae 0.25 to 0.5 mm apart (Figure 1F). Some fragments are more than 1 mm thick, suggesting that this species grew to a large size; Recent *N. huttoni* may grow to 1 mm thick and 20 mm wide. Internally, the two pairs of adductor muscle scars are very large, the slow-muscle scar of the anterior adductor muscle almost completely encloses the quick-muscle dimple-shaped scar (arrowed, Figure 1G). The inner valve surface is densely punctate.

Remarks: Having very large adductor muscles to hold the dorsal valve against the cemented ventral valve suggests a life-habit in a high-energy, littoral environment. Some Recent specimens from Fiordland, New Zealand have alternating light and dark grey coloured concentric rings on the dorsal valve exterior, similar to the Cosy Dell material (Robinson 2017b). Recent *N. huttoni* has a depth range of just below low tide to ~400 in New Zealand waters (Robinson 2017b).

Class Rhynchonellata Williams et al., 1996b
Order Rhynchonellida Kuhn, 1949
Family Notosariidae, Manceñido & Owen, 2002
Genus *Notosaria* Cooper, 1959

Notosaria antipoda (Thomson, 1918), Figure 1H, I
Stratigraphic range: Duntroonian (Late Oligocene) to Otaian (Early Miocene) (Lee & Wilson 1979)

The *Notosaria* material from Cosy Dell is poorly preserved and includes one mostly complete juvenile specimen, nine complete juvenile valves and 35 partial valves and fragments, some from larger specimens. No dorsal valves with intact cardinalia have been found. Lee & Wilson

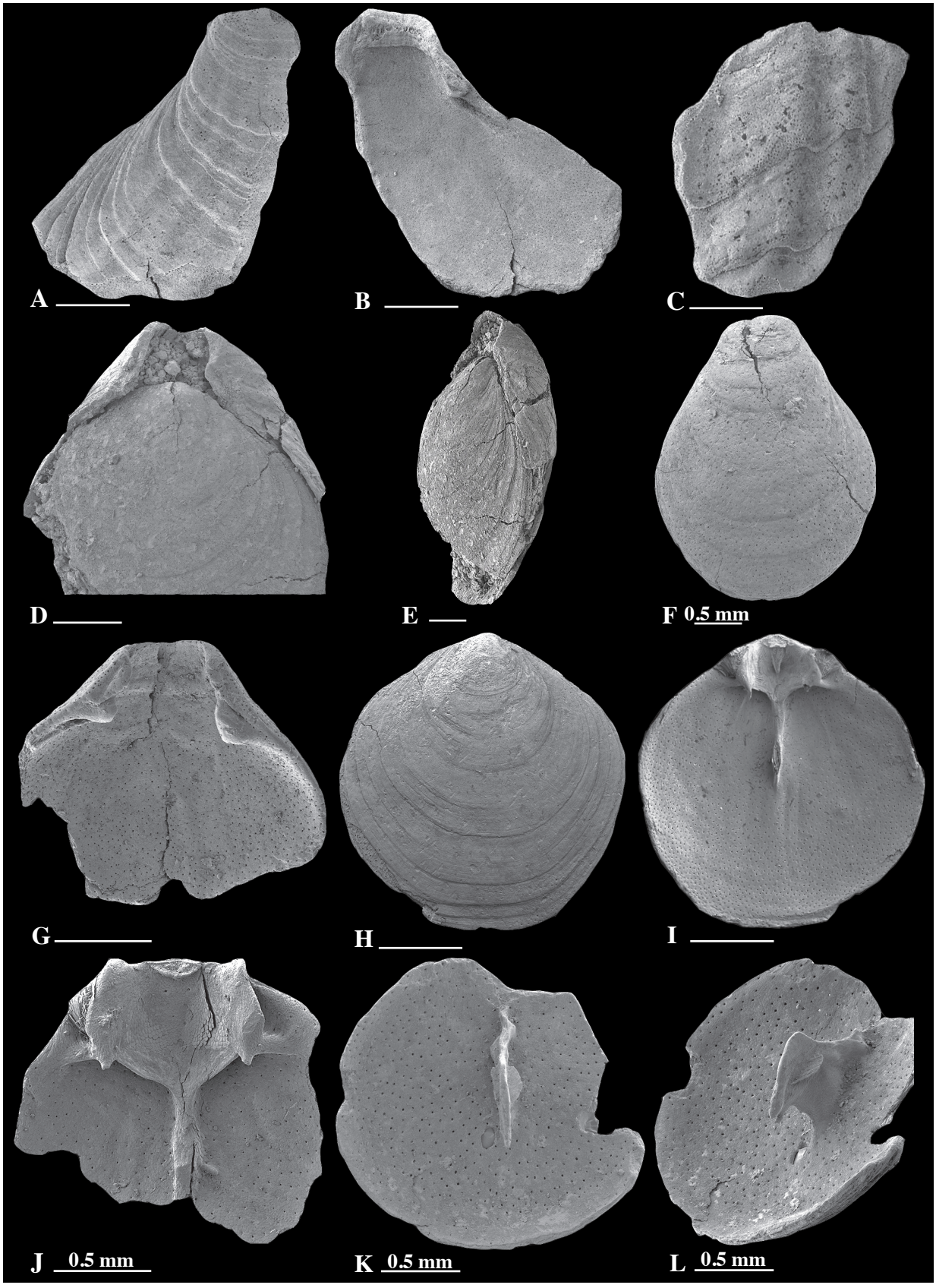

Figure 2: **A–C**. *Magasella* sp. **A–B**. OU 45775a. **A**. Exterior of ribbed partial ventral valve. **B.** Internal view with tooth, pedicle collar and punctae. **C**. OU 45775b. Partial dorsal valve with coarse ribbing. **D–L**. *Magella*? sp. **D–E**. OU 47412a. **D**. Dorsal view of mostly complete specimen. **E**. Oblique view. **F**. OU 47412b. Exterior view of ventral valve. **G**. OU 47412c. Teeth and pedicle collar of partial ventral valve. **H–I**. OU 47412d. **H**. Dorsal valve exterior. **I**. Dorsal valve interior. **J**. OU 47412e. Cardinalia of partial valve. **K–L**. OU 47412f. **K**. Interior view of partial dorsal valve with early stage septum. **L**. Oblique view. Scale bars 1 mm unless indicated otherwise.

(1979, p. 446) described the spines of *N. antipoda* as 'hardly spines in the true sense [being] short, tent-like projections which are budded off at the intersection of each costal ridge and growth line.' The broken bases of these tent-like projections can be seen in Figure 2H. For complete synonymies of *N. antipoda* see Lee & Wilson (1979) and Robinson (2017a).

Description: The most complete *N. antipoda* specimen is a juvenile 3.5 mm long (Figure 1H). Valves are laterally suboval, with strongly arched, imbricate costae that have (broken) spines at the intersection with growth lines (Figure 1H). The foramen is hypothyrid with narrow, disjunct deltidial plates, there is no pedicle collar and the teeth are small with receding dental plates (Figure 1I). The dorsal valve has a fold, weakly developed in the juvenile valves, and the ventral valve has a corresponding sulcus.

Remarks: *Notosaria* is known from the other New Zealand Cenozoic rocky shore faunas (listed above) and has occupied this habitat since the late Oligocene. *N. antipoda* occupied a range of shallow-water environments, including high-energy, littoral to sublittoral environments and calm clear waters (Lee & Wilson 1979). Living descendent *N. nigricans* ranges from intertidal (in rock pools) to 800 m but is more common at depths less than 200 m (Lee 1978).

Three other Duntroonian localities for *N. antipoda* include the shallow-water 'Fan Coral Bed' of the tuffaceous Thomas Formation, Broken River, Canterbury (Lee & Wilson 1979), the Forest Hill Limestone of Sharks Tooth Hill, Southland (Hyden 1979) and a rocky shore conglomerate at Mount Luxmore, Fiordland (Duntroonian–Waitakian, Lee et al. 1983).

Order	Terebratulida Waagen, 1883
Superfamily	Terebratelloidea Mackinnon & Lee, 2006
Family	Terebratellidae King, 1850
Genus	*Magasella* Dall, 1870

Magasella sp. Figure 2A, B, C

Six valve fragments from Cosy Dell have a radial ornament and a punctate interior surface. This material is identified as *Magasella* sp.

The genus *Magasella* has a stratigraphic range of Whaingaroan (Early Oligocene) to Recent (Dawson 1990). Fossil *Magasella* of Duntroonian age is widespread in the South Island, and has been collected from rocky shore to continental shelf strata. Duntroonian fossil localities include North Canterbury (the tuffaceous Fan Coral Bed, Hutton 1887, 1905), South Canterbury (Otekaike Limestone at Blands Bluff, Dawson 1990), North Otago (Kokoamu Greensand, Landon Creek, MacKinnon et al. 1993), Southland (Forest Hill Limestone, Hyden 1979) and Fiordland (unnamed conglomerate, Mount Luxmore, Lee et al. 1983).

Description: The largest fragment includes part of the foramen with a sessile pedicle collar and a worn tooth on the interior (Figure 2A, B). A second fragment appears to be part of the right edge of the sulcus on the dorsal valve (Figure 2C). The exterior of the fragments has an ornament of rounded costae about 0.5 mm wide (Figure 2A, C).

Remarks: Recent *Magasella* species are known from 10–330 m (Robinson et al. 2016).

Genus *Magella* Thomson, 1915

Magella? sp. Figure 2D, E, F, G, H, I, J, K, L

The material includes a single, mostly complete specimen and 30 small, damaged valves and partial valves with a smooth exterior. The cardinalia place this material in the Terebratellidae, but the smooth exterior surface suggests that these are not juveniles of the costate *Magasella* sp. in Figure 3A, C. In the Recent species *M. sanguinea*, juvenile shells are costate at 2–3 mm in length.

Based on the age of the material, the smooth shell and the submesothyrid foramen, this material might be juvenile *Waiparia* or '*Pachymagas*'. However, no material that might represent adult specimens of those genera was collected; for example, fragments of medium- to large-sized smooth valves, umbos with conjunct deltidial plates or swollen cardinalia. Also, these two genera are found in limestones, sandstones and greensands (Fryer 1999, MacKinnon et al. 1993), rock types originally deposited in continental-shelf habitats, rather than a very shallow, rocky shore.

The size of the material, the smooth valve and the canoe-shaped cardinal process suggest the small genus *Magella*. Known from shallow-shelf limestones and tuffs in the late Eocene (Kaiatan) to earliest Oligocene (early Whaingaroan) in North Otago (pers. obs.) and from shallow-shelf calcareous tuffs in the Pliocene in the Chatham Islands (Allan 1932), this genus has not been reported from strata of the intervening period (Oligocene – Miocene). The most taxonomically distinctive feature of *Magella* is the haptoid to incipiently trabecular loop (MacKinnon & Lee 2006). As none of the material is sufficiently well preserved to retain the loop, the assignment to this genus is tentative.

Description: There is a single, mostly complete specimen, 7 mm in length (Figure 2D, E). The specimen and valves

have a smooth exterior with concentric growth lines the only ornament (Figure 2D, E, F, H). Complete ventral valves are elongate-oval (Figure 2F). The deltidial plates are narrow and widely disjunct, the foramen is submesothyrid and the beak ridges are sharp (Figure 2D, E, G). The teeth are small and the pedicle collar is sessile (Figure 2G). On the dorsal valve the socket ridges are slim, the sockets are triangular and smooth, the crura extend from the socket ridges, the cardinal process is canoe-shaped and may or may not have an anteriorly pointing neck. The inner hinge plates slope medially and meet at the low septum, forming a septalium (Figure 2I, J). The septum reaches mid-valve, is low posteriorly but rises anteriorly. The best-preserved loop is at the juvenile axial stage; the loop shows only the first buds of the anterior part of the descending loop branches (Figure 2K, L).

Remarks: Jones (1970, table 1) listed material from the early Miocene of Northland as cf *Waltonia* (Davidson, 1850), now *Calloria* (Sowerby, 1846). *Magella* and *Calloria* are externally very similar and authors have suggested that *Magella* may be the ancestor of *Calloria* (Thomson 1908, Allan 1932, Allan 1949). Hiller (2011, figure 8A, B, C, D, E, F) and Robinson (2017a, figure 5P, Q, R) included figures of early Miocene specimens from Northland, identified as Terebratellidae indet, that are similar to the Cosy Dell material.

Fossil brachiopod material from the Antarctic Peninsula of Eocene and Pliocene age has also been identified as *Magella* (Owen 1980, Bitner 1996). The presence of *Magella* in New Zealand waters during the Cenozoic may have been sporadic or it may have adopted a very shallow-water habit that is rarely preserved in the fossil record.

Family Kraussinidae Dall, 1870
Genus *Megerlina* King, 1850

Megerlina miracula Hiller, MacKinnon & Nielsen, 2008, Figure 3A, B, C, D, E, F, G, H, I
Stratigraphic range: Duntroonian (Late Oligocene) – Otaian (Early Miocene)

Megerlina miracula Hiller et al. 2008: 379, 384–385, figs 5g–j, table 2; — Hiller 2011: 75, 83–84, figs 7G–I, table 1
Argyrotheca sp. Lee et al. 2014: fig 7L
Megerlia sp. Robinson 2017a: p. 17

Although the material of this species from Cosy Dell is described for the first time herein, a figured specimen from Cosy Dell was incorrectly named as *Argyrotheca* in Lee et al. (2014, figure 7L) and all specimens were incorrectly referred to as *Megerlia* in Robinson (2017a). There is a gap of approximately five million years between the Cosy Dell material and the *M. miracula* specimens from Northland, New Zealand (Hiller 2011). Whether these morphologically very similar materials represent a single biological species or are part of a lineage or complex of closely related species is impossible to say. All of these materials are included under a single species name, with the understanding that they might be part of a species lineage or complex.

Description: The material includes one partial specimen (Figure 3A), 13 single valves and 50+ valve fragments. The valves are small: the largest partial ventral valve was 6 mm long but most were 3–4 mm long. The ventral valves are subpentagonal to drop-shaped; the dorsal valves are subquadrate to suboval (Figure 3B, C, D, E, F, G). The valves are generally wider than long with the greatest width at midvalve. The shell surface has an ornament of wide, rounded costae that may increase by bifurcation or intercalation (Figure 3B). The valves are densely punctate and punctae are visible on both internal and external valve surfaces (Figure 3B, C, D, E).

The foramen is large with very small, widely disjunct, triangular deltidial plates and an excavate pedicle collar. The teeth are small and lack dental plates. A few submarginal tubercles may occur at the anterior edge of the ventral valve's inner surface (Figure 3D, E). The dorsal valve interior has large socket ridges, the hinge plates and median ridge form a notothyrial platform. The median ridge extends to midvalve where it narrows, increases in height and begins to bifurcate (Figure 3F, G, H, I). The full development of the brachidium is not preserved. In large dorsal valves the submarginal tubercles may occur in double, triple or (faintly) quadruple rows at the anterior margin (Figure 3G, H).

Adductor muscle scars are visible on some dorsal valves, on either side of the median ridge (Figure 3G, H) but are fainter on the ventral valve, on either side of a myophragm (Figure 3D, E). Diductor muscles attach dorsally to the roughened valve edge that acts as a cardinal process (Cooper 1981). The dorsal pedicle adjustor muscle scars may be visible on the hinge plates (Figure 3G, H, Richardson 1979).

Remarks: Fossil *Megerlina* is known from the Miocene of Tasmania and New Zealand (Hiller et al. 2008); the late Oligocene Cosy Dell material is the oldest known for this genus. Hiller (2011) described specimens of *M. miracula* from four early Miocene (Otaian) localities in Northland. Three localities included invertebrate faunas that suggested shallow shelf to very shallow water. The fourth locality appeared to contain a mixture of biotopes from different depths. The Cosy Dell material also suggests

that *M. miracula* lived at very shallow depths. Hiller et al. (2008: 385) noted that *M. miracula* 'bears close similarity' to the Recent Australian species *M. lamarkiana*; this species has been collected at low tide beneath boulders in Victoria (Richardson 1979) and has a depth range of 0–~250 m (Hiller et al. 2008). Recent species of *Megerlina* are predominantly shallow water with three known from intertidal habitats (Hiller et al. 2008).

PALEOECOLOGY

Conran et al. (2014: 11) suggested the Chatton Formation at Cosy Dell was deposited in very shallow water and 'most likely tidal', based on palynology slides. The barnacle, fish and mollusc taxa from Cosy Dell suggest very shallow, rocky shore environments (Lee et al. 2014; Schwarzhans 2017). Four brachiopod genera identified from Cosy Dell (*Discradisca*, *Novocrania*, *Notosaria*, *Megerlina*) have extant species that may be found either intertidally or subtidally.

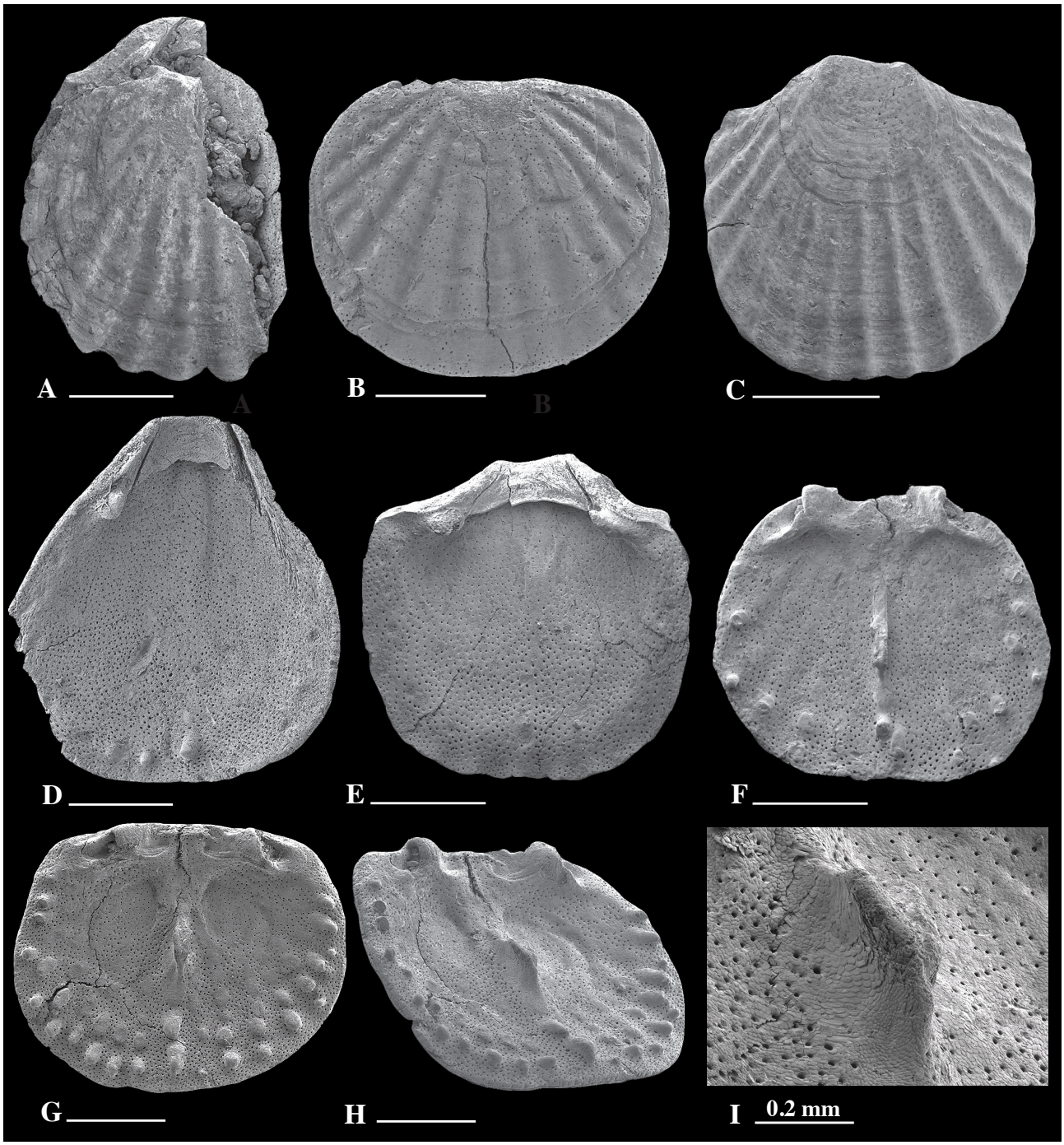

Figure 3: *Megerlina miracula*. **A**. OU 45304. Partial specimen. **B**. OU 45774a. Dorsal valve exterior. **C**. OU 45774b. Ventral valve exterior. **D**. OU 45774c. Ventral valve interior. **E**. OU 45774d. Ventral valve interior. **F**. OU 45774e. Dorsal valve interior. **G-I**. OU 45774f. **G**. Dorsal valve interior. **H**. Interior oblique view. **I**. Close-up of brachidium. Scale bars 1 mm unless indicated otherwise.

The fossil flora from Cosy Dell suggests the presence of a subtropical, lowland coastal forest nearby (Conran et al. 2014). Lee et al. (2014, figure 10) included a reconstructed paleogeographical map showing the Cosy Dell locality at the edge of a shallow inland sea between two landmasses.

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Conflict of interest

The author declares no conflicts of interest.

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