LATEST CRETACEOUS TO EARLIEST PALEOGENE MOLLUSCAN FAUNAS
OF NEW ZEALAND:
CHANGES IN COMPOSITION AS A CONSEQUENCE OF THE BREAK-UP OF
GONDWANA AND EXTINCTION

Jeffrey D. Stilwell

VOLUME 3

A thesis submitted for the degree of
Doctor of Philosophy
at the University of Otago, Dunedin,
New Zealand

September, 1994
Appendix B: Plates and Plate descriptions
PLATE 1

**Linucula bullensis** n. sp. (Figures 1-2, 4): 1, 2 holotype Ge 7924 (AIM), Bull Point, Kaipara, Northland, Q08/f9626 (Mh), length = 4.0 mm, x 7.8 and x 20 respectively; 4 paratype Ge 5972 (AIM), Whakapirau Creek, Kaipara, Q08/f9637 (Mh), length = 4.0 mm, x 7.8.

**Nucula s. l. teopuensis** n. sp. (Figures 3, 5, 7, 9-11): 3, 5, 7, 10-11 holotype Ge 6380 (AIM), promontory between Te Opu and Whakapirau Creeks, Kaipara, Q08/f9639 (Mh), length = 11.5 mm, x 9 (SEM), x 2.7, x 2.7, x 9 (SEM) and 17.5 (SEM) respectively; 9 paratype Ge 6379 (AIM), promontory between Te Opu and Whakapirau Creeks, Kaipara, Q08/f9639 (Mh), length = 11.0 mm, x 3.

**Nucula s. l. manuensis** n. sp. (Figures 6, 12-14): 6 paratype TM 7465 (IGNS), Manu Creek, Raukumara Peninsula, North Island, GS 1087, Z14/f8492 (Mp?), length = 10.5 mm, x 3.3; 12-13 holotype TM 7464 (IGNS), Manu Creek, GS 1087, Z14/f8492 (Mp?), length = 9.5 mm, x 4.5 and x 5.5 respectively; 14 paratype TM 7466 (IGNS), Manu Creek, GS 1087, Z14/f8492 (Mp?), length = 12.0 mm, x 3.3.

**Nucula s. l. kaiparensis** n. sp. (Figures 8, 15-16): 8, 15-16 holotype Ge 7674.1 (AIM), Te Opu, Kaipara, Northland, Q08/f9639 (Mh), length = 5.0 mm, x 10 (SEM), x 45 (SEM, sculpture) and x 19 (SEM).
PLATE 2

Leionucula suboblonga (Wilckens, 1905) (Figures 1-13): 1 Ge 7705 (AIM), Batley, Kaipara, Northland, Q08/f9636 (Mh), length = 45.5 mm, x1; 2 Ge 7690.2 (AIM), promontory between Te Opu and Whakapirau Creeks, Kaipara, Q08/f9639 (Mh), length = 17.0 mm, x 2.9; 3, 5 Ge 7686.4 (AIM) Te Opu, Kaipara, Q08/f9639 (Mh), length = 23.0 mm, x 2.5 and x 3 respectively; 4 Ge 7686.2 (AIM), Te Opu, Q08/f9639 (Mh), length = 28.0 mm, x 2.4; 6 Ge 7722 (AIM), Batley, Q08/f9636 (Mh), length = 13.0 mm, x 2.8; 7-8 L 3864 (AU), Bull Point, Kaipara, Q08/f9626 (Mh), length = 38.0 mm, x 2 and x 2.4 respectively; 9 OU 40972, Shag Point, Otago, South Island, J43/f159A (Mp-Mh), length of hinge = 19.0 mm, x 3.2; 10 OU 40956 Waianakarua River, North Otago, J42/f218 (Mp-Mh), length = 39.0 mm, x 1.3; 11 L 3865 (AU), Te Opu, Kaipara, Q08/f9639, length = 35.0 mm, x 1.8; 12-13 OU 40974, Shag Point, Otago, J43/f6544 (Mp-Mh), length = 31.0 mm, both x 2.6.
PLATE 3

*Nuculana austrodiscordia* n. sp. (Figures 1–2, 5): 1 holotype Ge 7921 (AIM), Bull Point, Kaipara, Northland, Q08/f9626 (Mh), length = 13.5 mm, x 1.9; 2 paratype Ge 7918 (AIM), Bull Point, Q08/f9626 (Mh), length = 9.0, x 3; 5 paratype Ge 5978 (AIM), Whakapirau Creek, Kaipara, Q08/f9637 (Mh), length = 9.0, x 7.

*Nuculana antichthona* n. sp. (Figures 3–4, 6–9): 3–4, 6–8 holotype Ge 6386.1 (AIM), promontory between Te Opu and Whakapirau Creeks, Kaipara, Q08/f9639 (Mh), length 8.5 mm, x 5.5, x 6, x 16 (SEM), x and x 62 (SEM); 9 paratype Ge 6395.1 (AIM), promontory between Te Opu and Whakapirau Creeks, Q09/f9639 (Mh), length = 7.5 mm, x 6.5.

*Nuculana? amuriensis* Woods, 1917 (Figure 10–11): 10 lectotype TM 2465 (IGNS; Woods, 1917, Pl. 6, Fig. 1), Haumuri Bluff, southern Marlborough, South Island, GS 6, 032/f9028 (Mp-Mh), length = 10.5 mm, x 1; 11 OU 40986, Waianakarua River, North Otago, South Island, J42/f218, x 3.9.

*Jupiteria? notolissa* n. sp. (Figure 12): 12 holotype Ge 7923 (AIM), Bull Point, Q08/f9626 (Mh), length = 9.0 mm, x 5.6.

*Saccella s. 1. sp.* (Figure 13): 13 TM 2454 (IGNS: Woods, 1917, Pl. 6, Fig. 2), Haumuri Bluff, GS 13, 032/f8025, length = 18.0 mm, x 1.

*Saccella? primaeva* n. sp. (Figures 14, 17): 14 holotype Ge 5915 (AIM), Bull Point, Q08/f9626 (Mh), length = 4.5 mm, x 12.5 (SEM); 17 paratype Ge 5916 (AIM), Bull Point, Q08/f9626 (Mh), length = 3.0 mm, x 30 (SEM).
**Jupiteria palaiozelandica** n. sp. (Figure 15): 15 holotype Ge 7683 (AIM), Te Opu, Kaipara, Q08/f9639 (Mh), length = 11.0 mm, x 12.5 (SEM).

**Portlandia? sp.** (Figure 16): 16 Ge 7915 (AIM), Bull Point, Q08/f9626 (Mh), x 3.
PLATE 4

Tindaria? veta n. sp. (Figures 1-2): 1-2 holotype Ge 7678.1 (AIM), Te Opu, Kaipara, Northland, Q08/f9639 (Mh), length = 5.0 mm, x 11 (SEM) and x 44 (SEM) respectively.

Pseudoportlandia? sp. A (Figure 3): 3 Ge 8102 (AIM), Te Opu, Q08/f9639 (Mh), length = 13.5 mm, x 2.8.

Pseudoportlandia? sp. B (Figures 4-5): 4-5 TM 7759 (IGNS), Okaihau, Bay of Islands, GS 729, P05/f104 (Mp-Mh), length = 23.0 mm, both x 2.7.

Neilo (Neiloides) cymbula (Woods, 1917) (Figures 6-13): 6-7 holotype TM 2453 (IGNS: Woods, 1917, Pl. 6, Fig. 3a-b), Saurian Beds, Middle Waipara, South Island, GS 761, M34/f7263 (Mp-Mh), both x 1; 8 OU 40941, Brighton, Otago, South Island, I45/f8510 (Mh), length = 24.5 mm, x 2.8; 9 OU 40939, Shag Point, Otago, J43/f6544 (Mp-Mh), length = 41.5 mm, x 2; 10 TM 6866 (IGNS; Crampton and Moore, 1990, Fig. 8A), Mangahouanga Stream, southern Hawke's Bay, North Island, GS 14260, V19/f184 (Mp-Mh), length = 34.0 mm, x 1.5; 11 OU 40940, Shag Point, Otago, J43/f6544 (Mp-Mh), length = 47.0 mm, x 1.5; 12-13 OU 40938, Shag Point, J43/f159 (Mp-Mh), length = 27.5 mm, x 2.8.

Australoneilo zelandica n. sp. (Figures 14-15): 14 paratype Ge 6411 (AIM), Te Opu, Q08/f9639 (Mh), length = 18.0 mm, x 2.7; 15 paratype Ge 6403 (AIM), promontory between Te Opu and Whakapirau Creeks, Q08/f9639 (Mh), length = 13.0 mm, x 2.7.
PLATE 5

*Australoneilo zelandica* n. sp. (Figures 1-6): 1 holotype L 3866 (AU), Bull Point, Kaipara, Northland, Q08/f9626 (Mh), length = 27.0 mm, x 2.8; 2 paratype TM 7467 (IGNS), Okaihou, Bay of Islands, GS 729, P05/f104 (Mp-Mh), length = 40.5 mm, x 1.9; 3 paratype Ge 6410 (IGNS), Te Opu, Kaipara, Q08/f9639 (Mh), length = 17.0 mm, x 2.8; 4 paratype L 3867 (AU), Bull Point, AU 2571, Q08/f9626 (Mh), length = 24.0 mm, x 2.8; 6 paratype L 3869 (AU), Bull Point, AU 2571, Q08/f9626 (Mh), length = 24.0 mm, x 2.8.

*Solemya suroradiata* n. sp. (Figures 7, 9-10, 12): 7, 12 holotype Ge 5977 (AIM), Whakapirau Creek, Kaipara, Q08/f9637 (Mh), length = 38.0 mm, x 2 and x 1.9 respectively; 9 paratype Ge 7654 (AIM), Whakapirau Creek, Q08/f9637 (Mh), length = 43.0 mm, x 1.5; 101 paratype Ge 7601.2 (AIM), Whakapirau Creek, Q08/f9637 (Mh), length = 33.5 mm, x 2.3.

*Cucullaea* sp. (Figures 8, 11): 8, 11 TM 2458 (IGNS; Woods, 1917, Pl. 7, Fig. 2a-c), Haumuri Bluff, southern Marlborough, South Island, GS 13, O25/f8025 (Mp-Mh), both x 1.

*Barbatia mackayi* Woods, 1917 (Figures 13-14): holotype TM 2451 (IGNS; Woods, 1917, Pl. 6, Fig. 4a-b), Haumuri Bluff, GS 13, O32/f8025 (Mp-Mh), both x 1.
PLATE 6

*Cucullaea* cf. *C. antarctica* Wilckens, 1905 (Figures 1-2, 5): 1, 5 TM 7468 (IGNS), Mangahouanga Stream, southern Hawke's Bay, North Island, GS 11359, V19/f6909 (Mp-Mh), length = 63.0 mm, both x 1.9; 2 TM 7469 (IGNS), Mangahouanga Stream, GS 11359, V19/f6909 (Mp-Mh), length of hinge = 42.0 mm, x 1.9.

*Cucullaea* (*Cucullastis*) *zealandica* (Woods, 1917) (Figures 3-4, 6-10): 3 TM 7471 (IGNS), Haumuri Bluff, southern Marlborough, South Island, GS 13, O32/f8025 (Mp-Mh), length = 36.0 mm, x 1.5; 4 TM 7470 (IGNS), Haumuri Bluff, GS 13, O32/f8025 (Mp-Mh), length = 42.0 mm, x 1.8; 76 TM 7474 (IGNS), Ruatahuna Stream, GS 14277, W18/f14A (Mp-Mh), length = 32.5 mm, x 1; 7, 10 lectotype TM 2450 (IGNS; Woods, 1917, Pl. 6, Fig. 7a-b), Haumuri Bluff, GS 13, O32/f8025 (Mp-Mh), both x 1; 8 TM 2459 (IGNS; Woods, 1917, Pl. 7, Fig. 1), Haumuri Bluff, GS 13, O32/f8025 (Mp-Mh), x 1; 9 TM 7473 (IGNS), Haumuri Bluff, GS 6158, O32/f9502 (Mp-Mh), length = 59.5 mm, x 1.3.

*Cucullaea* sp. (Figures 11-12): 11 TM 6867 (IGNS), Mangahouanga Stream, GS 11359, V19/f6909 (Mp-Mh), length = 68.0 mm, x 1.3; 12 TM 2457 (IGNS; Woods, 1917, Pl. 7, Fig. 3), Haumuri Bluff, GS 5, O32/f9027, x 1.
Austrocucullaea n. sp. cf. A. oliveroi Zinsmeister and Macellari, 1988 (Figures 1, 4): 1, 4 TM 7472 (IGNS), Mangahouanga Stream, southern Hawke's Bay, North Island, GS 11359, V19/f6909 (Mp-Mh), length = 43.0 mm, both x 2.

Indogrammatodon hectori (Woods, 1917) (Figures 2, 5): 2, 5 holotype TM 2456 (IGNS; Woods, 1917, Pl. 6, Fig. 6a-b), Boby's Creek, Middle Waipara, South Island, GS 277, M34/f7257 (Mp-Mh), length = 38.5 mm, both x 1.

Nordenskjoeldia woodsii Wilckens, 1920 (Figures 3, 7): 3, 7 holotype TM 2455 (IGNS; Woods, 1917, Pl. 6, Fig. 5a-b), McKay's Creek, Middle Waipara, GS 149, M34/f7254 (Mp-Mh), length = 57.5 mm, both x 1.

Limopsis s. s. griffini n. sp. (Figures 6, 9-10, 12): 6 holotype L 3870 (AU), Bull Point, Kaipara, Northland, AU 2574, Q08/f9626 (Mh), length = 10.0 mm, x3; 9 paratype Ge 7617 (AIM), Bull Point, Q08/f9626 (Mh), length = 6.0 mm, x 6; 10 paratype TM 7513 (IGNS), Mangahouanga Stream, GS 11359, V19/f6909 (Mp-Mh), length = 11.0 mm, x 3.3; 12 paratype Ge 7612 (AIM), Bull Point, Q08/f9626 (Mh), length = 5.0 mm, x 11 (SEM).

Glycymerita s. s. sp. (Figure 8): 8 TM 2460 (IGNS; Woods, 1917, Pl. 7, Fig. 8), Haumuri Bluff, southern Marlborough, GS 13, 032/f8025 (Mp-Mh), x 1.
Glycymerita s. s. selwynensis (Woods, 1917) (Figures 11, 13-19):
11, 15 TM 7475 (IGNS), Selwyn Rapids, GS 2157, L35/f6510 (Mp-Mh), length = 23.5 mm, x 2.3; 13-14 TM 2462 (IGNS; Woods, 1917, Pl. 7, Fig. 4a-b), Selwyn Rapids, GS 589, L35/f6008 (Mp-Mh), both x 1; 16 lectotype TM 2464 (IGNS; Woods, 1917, Pl. 7, Fig. 7), Selwyn Rapids, GS 589, L35/f6008 (Mp-Mh), both x 1; 17 TM 7476 (IGNS), Selwyn Rapids, GS 2157, L35/f6510 (Mp-Mh), length = 22.0 mm, x 2.4; 18 TM 2463 (IGNS; Woods, 1917, Pl. 7, Fig. 5), Selwyn Rapids, GS 589, L35/f6008 (Mp-Mh), x 1; 19 TM 2461 (IGNS; Woods, 1917, Pl. 7, Fig. 6), Selwyn Rapids, GS 589, L35/f6008, x 1, interior of left valve.
PLATE 8

Lycettia lanceolata (Sowerby, 1823) (Figures 1-5, 7): 1 TM 7478 (IGNS), Haumuri Bluff, southern Marlborough, South Island, GS 5, 032/f9027 (Mp-Mh), 2, 5 TM 7479 (IGNS), Haumuri Bluff, GS 5, 032/f 9027 (Mp-Mh), length = 20.0 mm, both x 2.9; 3 TM 7480 (IGNS), Haumuri Bluff, GS 9835, 032/f9530 (Mp-Mh), length = 46.5 mm, x 1.9; 4, 7 TM 2498 (IGNS; Woods, 1917, Pl. 10, Fig. 6a-b), Haumuri Bluff, GS 13, 032/f8025, both x 1.

Lycettia cf. L. foaensis Freneix, 1980 (Figure 6): 6 TM 7477 (IGNS), Mangahouanga Stream, southern Hawke's Bay, North Island, GS 11359, V19/f6909 (mp-Mh), length = 22.5 mm, x 2.7.

Septifer? eurycrenulata n. sp. (Figures 8, 10): 8 holotype OU 40942, Oyster Hill, Malvern Hills, Canterbury, South Island, L35/f67 (Mp-Mh), length = 9.5 mm, x 4; 10 paratype OU 40943, Oyster Hill, L35/f67 (Mp-Mh), length = 10.5 mm, x 3.3.

Modiolus cf. M. typicus Forbes, 1846 (Figures 9, 11-14, 16): 9, 13 TM 2497 (IGNS; Woods, 1917, Pl. 10, Fig. 4a-b), Haumuri Bluff, GS 13, 032/f8025, both x 1; 11 TM 7481 (IGNS), Mangahouanga Stream, GS 14271, V19/f182 (Mp-Mh), length = 32.5 mm, x 2.4; 12 OU 40944, Oyster Hill, Malvern Hills, L35/f67 (Mp-Mh), length = 28.5 mm, x 3; 14 TM 7483 (IGNS), Haumuri Bluff, GS 13?, 032/f8025 (Mp-Mh), length = 9.5 mm, x 5; 16 TM 7482 (IGNS), Kaiwara River, GS 9666, N33/f9811 (Mp-Mh), length = 21.0 mm, x 2.6.

Inoperna sp. aff. I. flagellifera (Forbes, 1846) (Figure 15): 15 TM 2495 (IGNS; Woods, 1917, Pl. 10, Fig. 5), Haumuri Bluff, GS 13, 032/f8025 (Mp-Mh), x 1.
Pinna sp. (Figures 1, 3): 1 TM 7484 (IGNS), Selwyn Rapids, Canterbury, South Island, GS 589, L35/f6008 (Mp-Mh), length = 66.5 mm, x 1.4; 3 TM 2535 (IGNS; Woods, 1917, Pl. 15, Fig. 1), Haumuri Bluff, southern Marlborough, South Island, GS 5, O32/f9027, x 1.

Inoceramus australis Woods, 1917 (Figures 2, 5, 8-15): 2 TM 6703 (IGNS; Crampton, 1988, Pl. 90, Fig. 13), Gisborne District, North Island, GS 8385, locality unknown, x 1; 5, 14 TM 2745 (IGNS; Woods, 1917, Pl. 12, Fig. 17a-b), Haumuri Bluff, GS 14, O32/f8026, x 0.5 (I. cf. pacificus?); 9 TM 2746 (IGNS; Woods, 1917, Pl. 12, Fig. 18), Haumuri Bluff, GS 14, O32/f8026 (Mp-Mh), x 1; 10, 13, 15 TM 2749 (IGNS; Woods, 1917, Pl. 13, Fig. 2a-c), Haumuri Bluff, GS 14, O32/f8026, all x 1; 11 TM 2747 (IGNS; Woods, 1917, Pl. 13, Fig. 19), Haumuri Bluff, GS 14, O32/f8026, x 1; 12 TM 2748 (IGNS; Woods, 1917, Pl. 13, Fig. 1), Haumuri Bluff, GS 14, O32/f8026, x 1 (I. sp. indet.).

Inoceramus sp. (Figures 4, 6-7): 4 Ge 8081.5 (AIM), Bull Point, Kaipara, Northland, Q08/f9626 (Mh), height = 15.5 mm, x 2.8; 6 Ge 8081.4 (AIM), Bull Point, Q08/f9626 (Mh), height = 21.7 mm, x 2.9; 7 Ge 8081.5 (AIM), Bull Point, Q08/f9626 (Mh), height = 21.1 mm, x 2.5.
Inoceramus pacificus Woods, 1917 (Figures 1, 5): 1 lectotype TM 2739 (IGNS; Warren and Speden, 1978, Fig. 25-1), Haumuri Bluff, southern Marlborough, South Island, GS 13, O32/f8025 (Mp-Mh), x 0.5; 5 paralectotype TM 2750 (IGNS; Woods, 1917, Pl. 14, Fig. 1), Haumuri Bluff, GS 13, O32/f8025 (Mp-Mh), x 1.

Inoceramus sp. of Woods, 1917 (Figures 3-4, 8): 3 TM 2752 (IGNS; Woods, 1917, Pl. 14, Fig. 4), Haumuri Bluff, GS 14, O32/f8026 (Mp-Mh), x 1; 4, 8 TM 2751 (IGNS; Woods, 1917, Pl. 14, Fig. 3a-b), Haumuri Bluff, GS 14, O32/f8026 (Mp-Mh), both x 1 (Tethyoceramus) madagascariensis (Heinz) (= I. nukeus Wellman), J. S. Crampton, personal commun., 1994).

Inoceramus? sp. of Crampton, 1988 (Figure 6): 6 TM 6717 (IGNS; Crampton, 1988, Pl. 90, Fig. 14), tributary of Taurangakautuku Stream, East Cape, North Island, GS 13400, Z14/f106 (Mh), distorted ligament, x 1.

Isognomon sp. (Figure 7): 7 TM 6857 (IGNS; Crampton, 1988, Pl. 1, Fig. 1), northern Hawke's Bay, North Island, GS 14251, W18/f8A (Mp-Mh), x 1.7.

Inoceramus matotorus Wellman, 1959 (Figures 2, 10): 2 TM 5381 (IGNS; Warren and Speden, 1978, Fig. 26-1), Haumuri Bluff, GS 8, O32/f8030 (Mp-Mh), x 1; 10 holotype TM 2110 (IGNS; Wellman, 1959, Pl. 10, Fig. 1), Ihungia Stream, Mata Survey District, GS 1604, Y16/f7489 (Mp-Mh), x 0.5.
Entolium membranaceum (Nilsson, 1827) (Figures 9, 11-16): 9 TM 2516 (IGNS; Woods, 1917, Pl. 11, Fig. 5), Haumuri Bluff, GS 8, O32/f9030 (Mp-Mh), x 1; 11, 13 TM 2515 (IGNS; Woods, 1917, Pl. 11, Fig. 3a-b), Haumuri Bluff, GS 8, O32/f9030 (Mp-Mh), x 5 and x 1 respectively; 12 TM 2517 (IGNS; Woods, 1917, Pl. 11, Fig. 4), Haumuri Bluff, GS 8, O32/f9030 (Mp-Mh); 14 L 3871 (AU), Bull Point, Kaipara, Northland, AU 2577, Q08/f9626 (Mh), length = 30.0 mm, x 1.8; 15 L 3876 (AU), Te Opu, Kaipara, Q08/f9639, x 4.3; 16 Ge 7652.2 (AIM), promontory between Te Opu and Whakapirau Creeks, Kaipara, Q08/f9639 (Mh), length = 31.5 mm, x 1.8.
PLATE 11

Pectinidae gen. et sp. indet. (Figure 1): 1 Ge 7602.4 (AIM), Bull Point, Kaipara, Northland, Q08/f9626 (Mh), x 2.

Aequipecten sp. (Figures 2-3): 2 TM 7566 (IGNS), Mangahouanga Stream, southern Hawke's Bay, North Island, GS 11359, V19/f6909 (Mp-Mh), length = 25.0 mm, x 1.6; 3 TM 7565 (IGNS), Mangahouanga Stream, GS 11359, V19/f6909 (Mp-Mh), length = 35.0 mm, x 1.1.

Camptonectes selwynensis (Finlay, 1927) (Figures 4-5, 7-8, 10-11, 14, 16, 19): 4 TM 7567 (IGNS) Huarau Point, southern Hawke's Bay, GS 8611, V22/f9613 (Mp-Mh), length = 8.0 mm, x 4; 5 TM 2512 (IGNS; Woods, 1917, Pl. 11, Fig. 8), Haumuri Bluff, southern Marlborough, South Island, GS 23, L35/f6017 (Mp-Mh); 7 TM 2509 (IGNS; Woods, 1917, Pl. 11, Fig. 7a-b), Selwyn River, GS 23, L35/f6017 (Mp-Mh), x 1; 11 TM 7486 (IGNS), Conway River Mouth, South Island, GS 4607, O32/f8124 (Mp-Mh), length = 11.0 mm, x 3.7; 14 TM 7485 (IGNS), Haumuri Bluff, southern Marlborough, South Island, GS 6173, O32/f9506 (Mp-Mh), length = 37.5 mm, x 1.6; 19 TM 2510 (IGNS; Woods, 1917, Pl. 12, Fig. 1), Haumuri Bluff, GS 13, O32/f8025 (Mp-Mh), x 1.

Camptonectes n. sp. (Figure 6): 6 TM 6858 (IGNS; Crampton, 1988, Pl. 1, Fig. 2), northern Hawke's Bay, GS 14251, W18/f8A (Mp-Mh), height = 8.0 mm, x 6.5.

Camptonectes n. sp.? cf. C. virgatus (Nilsson, 1827) (Figure 9): 9 OU 40945, Ocean View, Otago, South Island, I44/f280 (Mh), height = 73.0 mm, x 1.
**Mixtpecten amuriensis** (Woods, 1917) (Figures 12-13, 17-18, 21): 12 TM 2519 (Woods, 1917, Pl. 12, Fig. 2), Haumuri Bluff, GS 13, O32/f8025 (Mp-Mh), x 1; 13 TM 2523 (IGNS; Woods, 1917, Pl. 12, Fig. 6), Haumuri Bluff, GS 13, O32/f8025 (Mp-Mh), x 1; 17 TM 2521 (IGNS; Woods, 1917, Pl. 12, Fig. 4), Haumuri Bluff, GS 13, O32/f8025 (Mp-Mh), x 1; 18, 20 TM 2520 (IGNS; Woods, 1917, Pl. 12, Fig. 3a-b), Haumuri Bluff, GS 13, O32/f8025 (Mp-Mh), x 1 and x 4 respectively; 21 lectotype TM 2524 (IGNS; Woods, 1917, Pl. 12, Fig. 7), Haumuri Bluff, GS 13, O32/f8025 (Mp-Mh), x 1.

**Chlamys (Lyriochlamys) conwayensis** n. sp. (Figure 15): 15 holotype TM 7587 (IGNS), Conway River Mouth, southern Marlborough, GS 4607, O32/f8124 (Mp-Mh), length = 15.0 mm, x 3.
**PLATE 12**

_Mixtipecten amuriensis_ (Woods, 1917) (Figures 1-5, 8-10, 13, 26):
1 TM 7569 (IGNS), Haumuri Bluff, southern Marlborough, South Island, GS 13, O32/f8025 (Mp-Mh), length = 8.5 mm, x 4; 2 TM 7568 (IGNS), Haumuri Bluff, GS 13, O32/f8025 (Mp-Mh), length = 13.5 mm, x 3; 3 OU 41265, Haumuri Bluff, O32/f9529A (Mp-Mh), length = 6.5 mm, x 4.8; 4 OU 40657, Waianakarua River, North Otago, J42/f218 (Mp-Mh), length = 20.0 mm, x 1.5; 5 TM 2527 (IGNS; Woods, 1917, Pl. 12, Fig. 10), Haumuri Bluff, GS 13, O32/f8025 (Mp-Mh), x 1.5; 8 TM 2524 (IGNS; Woods, 1917, Pl. 12, Fig. 8), Haumuri Bluff, GS 13, O32/f8025 (Mp-Mh), x 8; 9 TM 2526 (IGNS; Woods, 1917, Pl. 12, Fig. 9), Haumuri Bluff, GS 6, O32/f9028 (Mp-Mh), x 1; 10 TM 2522 (IGNS; Woods, 1917, Pl. 12, Fig. 5), Haumuri Bluff, GS 13, O32/f8025 (Mp-Mh), x 1; 13 TM 7488 (IGNS), Haumuri Bluff, GS 5, O32/f9027 (Mp-Mh), length = 11.0 mm, x 4; 26 TM 2528 (IGNS; Woods, 1917, Pl. 12, Fig. 11), Haumuri Bluff, GS 13, O32/f8025 (Mp-Mh), x 8.

_Neithaea grangei_ (Murdoch, 1924) (Figures 6-7): 6 OU 40947, Barron's Hill, Brighton, Otago, South Island, c. I44/f8510 (Mh), length = 16.0 mm, x 2.8; 7 OU 40947, Barron's Hill, c. I44/f8510 (Mh), length = 11.0 mm, x 3.3.

_Anomia n. sp.?_ (Figures 11-12, 16-17): 11 TM 7489 (IGNS), Haumuri Bluff, GS 13, O32/f8025 (Mp-Mh), length = 13.5 mm, x 3; 12, 17 TM 7490 (IGNS), Haumuri Bluff, GS 9834, O32/f9529 (Mp-Mh), length = 5.0 mm, both x 9; ?16 Ge 8085 (AIM), Bull Point, Kaipara, Northland, Q08/f9626 (Mh), x 2.
Limatula sp. indet. of Fleming, 1978 (Figures 14, 20): 14 TM 7492 (IGNS), Te Hoe River, southern Hawke's Bay, North Island, GS 14260, V19/f184 (Mp-Mh), length = 5.0 mm, x 5.5; 20 TM 2533 (IGNS; Woods, 1917, Pl. 12, Fig. 15), Haumuri Bluff, GS 13, O32/f8025 (Mp-Mh), length = 5.5 mm, x 1.5.

Limea (Pseudolimea) woodsi (Suter, 1921) (Figures 15, 19, 21-22, 24-25): 15, 25 TM 2531 (IGNS; Woods, 1917, Pl. 12, Fig. 12a-b), Haumuri Bluff, GS 13, O32/f8025 (Mp-Mh), x 1.5 and x 8 respectively; 19 TM 7491 (IGNS), Mangahouanga Stream, southern Hawke's Bay, GS 11359, V19/f6909 (Mp-Mh), length = 3.5 mm, x 5.8; 21 lectotype TM 2532 (IGNS; Woods, 1917, Pl. 12, Fig. 13), Haumuri Bluff, GS 13, O32/f8025 (Mp-Mh), x 1.5; 22 TM 2530 (IGNS; Woods, 1917, Pl. 12, Fig. 14), Haumuri Bluff, GS 13, O32/f8025 (Mp-Mh), x 1.5; 24 TM 2534 (IGNS; Woods, 1917, Pl. 12, Fig. 16), Haumuri Bluff, GS 13, O32/f8025 (Mp-Mh), x 8.

Seymourtula cf. S. antarctica (Wilckens, 1910) (Figures 18, 23, 27): 18 OU 40948, Shag Point, North Otago, South Island, OU 11136, J43/f6544 (Mp-Mh), length = 11.0 mm, x 2.5; 23 OU 40971, Brighton, ?I45/f8517, length = 5.5 mm, x 4; 27 TM 5556 (IGNS; Fleming, 1978, Fig. 26), McKay's Creek, Middle Waipara, South Island, GS 149, M34/f7254, height = c. 20.0 mm, x 1.
PLATE 13

_Acesta warreni_ n. sp. (Figure 1): 1 holotype TM 7493 (IGNS), north of "Old Claverley" Stream, southern Marlborough, South Island, GS 9832, O32/f8795 (Mp-Mh), height = 190.0 mm, x 1.

_Planospirites_ sp. (Figures 2, 6): 2, 6 TM 7494 (IGNS), Koranga, North Island, GS 1401, X17/f101 (Mp-Mh), length = 11.5 mm, x 5 and x 4 respectively.

_Pseudoperina lapillicola_ (Marwick, 1926) (Figures 3-4, 7-10): 3-4 paratype TM 2507 (IGNS; Marwick, 1926, Figs. 2-3), Wairongomai River, North Island, Y15/- (not a recorded locality, I. W. Keyes, personal commun., 1994) (Mp-Mh), both x 1; 7-9 holotype TM 2506 (IGNS; Marwick, 1926, Figs. 4-6), Tuparoa Beach, GS 1922, Z15/f7498 (Mp-Mh), all x 1; 10 TM 7495 (IGNS), Whangaroa Harbour, Northland, GS 106, P04/f9494 (Mh), length = 14.0 mm, x 2.5.

_Acesta_ (Plicacesta) n. sp.? (Figure 5): 5 TM 6859 (IGNS; Crampton, 1988, Pl. 1, Fig. 3), northern Hawke's Bay, North Island, GS 14390, W18/f8A (Mp-Mh), height = 29.0 mm, x 1.8.
Plates 14

**Crassostrea** sp. (Figures 1-2, 4-6): 1 OU 40949, Oyster Hill, Malvern Hills, Canterbury, L35/f67 (Mp-Mh), length = 70.0 mm, x 0.6; 2 OU 40950, Acheron River, South Island, exact locality unknown, OU 5964, x 1; 4 TM 2503 (IGNS; Woods, 1917, Pl. 11, Fig. 1), Weka Creek, Canterbury, GS 782, M34/f7264 (Mp-Mh), x 1; 5-6 TM 2504 (IGNS; Woods, 1917, Pl. 10, Fig. 7a-b), Weka Creek, GS 782, M34/f7264, both x 1.

**Ostrea** sp. of Woods, 1917 (Figure 3): 3 TM 2505 (IGNS; Woods, 1917, Pl. 11, Fig. 2), Haumuri Bluff, southern Marlborough, South Island, GS 13, O32/f8025 (Mp-Mh), x 1.

**Pterotrigonia** s. s. **pseudocaudata** (Hector, 1886) (Figures 7-9): 7-9 lectotype TM 2474 (IGNS; Woods, 1917, Pl. 8, Fig. 2a-c), Haumuri Bluff, GS 13, O32/f8025 (Mp-Mh), all x 1.
PLATE 15

Pterotrigonia s. s. pseudocaudata (Hector, 1886) (Figures 1-8, 10): 1 TM 2478 (IGNS; Woods, 1917, Pl. 7, Fig. 9), Haumuri Bluff, southern Marlborough, South Island, GS 13, O32/f8025 (Mp-Mh), x 1; 2 TM 2476 (IGNS; Woods, 1917, Pl. 8, Fig. 5), Haumuri Bluff, GS 13, O32/f8025 (Mp-Mh), x 1; 3, 10 TM 2477 (IGNS; Woods, 1917, Pl. 8, Fig. 3a-b), Haumuri Bluff, GS 13, O32/f8025 (Mp-Mh), both x 1; 4 TM 2475 (IGNS; Woods, 1917, Pl. 8, Fig. 4), Haumuri Bluff, GS 13, O32/f8025 (Mp-Mh), x 1; 5-6 topotype TM 3353 (IGNS; Fleming, 1987, Pl. 10, Figs. 15, 18), Haumuri Bluff, GS 13, O32/f8025 (Mp-Mh), both x 1; 7 paralectotype TM 2479 (IGNS; Woods, 1917, Pl. 8, Fig. 1), Haumuri Bluff, GS 13, O32/f8025 (Mp-Mh), x 1; 8 TM 6870 (IGNS; Crampton and Moore, 1990, Fig. 8E), Hawke's Bay, North Island, GS 8206, V18/f8510 (Mp-Mh), length = 29.0 mm, x 1.4.

Pterotrigonia s. s. waitangiensis Fleming, 1987 (Figure 9): 9 holotype TM 3356 (IGNS; Fleming, 1987, Pl. 7, Fig. 19), Waitangi River, Northland, GS 1175, P5/f9499 (Mp-Mh), x 1.

Pterotrigonia (Ptilotrigonia) ultima Fleming, 1987 (Figures 11-13): 11-12 holotype TM 3357 (IGNS; Fleming, 1987, Pl. 7, Figs. 20-21), Waitangi River, GS 1175, P5/f9499 (Mp-Mh), both x 2; 13 paratype TM 5943 (IGNS; Fleming, 1987, Pl. 7, Fig. 22), Waitangi River, GS 1175, P5/f9499 (Mp-Mh), x 2.

Pacitrigonia hanetiana (d'Orbigny, 1842) woodsi Fleming, 1987 (Figures 14-15): 14 holotype TM 5930 (IGNS; Woods, 1917, Pl. 9, Fig. 6), Ostrea bed, Middle Waipara, Canterbury, South Island, GS 762, M34/f7305 (Mp-Mh), x 1; 15 paratype TM 5997 (IGNS; Fleming, 1987, Pl. 9, Fig. 6), Middle Waipara, GS 762, M34/f7305 (Mp-Mh), x 1.
PLATE 16

Pacitrigonia hanetiana (d'Orbigny, 1842) hectori Fleming, 1987 (Figures 1-10): 1 holotype TM 3360 (IGNS; Fleming, 1987, Pl. 10, Fig. 1), Haumuri Bluff, southern Marlborough, South Island, GS 13, O32/f8025 (Mp-Mh), x 1; 2, 4 TM 3611 (IGNS; Fleming, 1987, Pl. 10, Figs. 2, 7), Haumuri Bluff, no fossil record number, both x 1; 3 TM 2484 (IGNS; Woods, 1917, Pl. 9, Fig. 1), Haumuri Bluff, GS 13, O32/f8025 (Mp-Mh), x 1; 5 topotype TM 5996 (IGNS; Fleming, 1987, Pl. 10, Fig. 4), Haumuri Bluff, GS 13, O32/f8025 (Mp-Mh), x 1; 6 TM 2489 (IGNS; Woods, 1917, Pl. 8, Fig. 6), Haumuri Bluff, GS 13, O32/f8025 (Mp-Mh), x 1; 7 TM 2486 (IGNS; Woods, 1917, Pl. 9, Fig. 3), Haumuri Bluff, GS 13, O32/f8025 (Mp-Mh), x 1; 8 TM 2487 (IGNS; Woods, 1917, Pl. 9, Fig. 4), Haumuri Bluff, GS 13, O32/f8025 (Mp-Mh), x 1; 9 TM 2488 (IGNS; Woods, 1917, Pl. 9, Fig. 5), Haumuri Bluff, GS 13, O32/f8025 (Mp-Mh), x 1; 10 TM 2485 (IGNS; Woods, 1917, Pl. 9, Fig. 2), Haumuri Bluff, GS 13, O32/f8025 (Mp-Mh), x 1.

Pacitrigonia sylvesteri Marwick, 1932 (Figures 11-13): 11 TM 6869 (IGNS; Crampton and Moore, 1990, Fig. 8D), Mangahouanga Stream, southern Hawke's Bay, North Island, GS 14281, V19/f6909B (Mp-Mh), length = 77.5 mm, x 0.8; 12-13 TM 5944 (IGNS; Fleming, 1987, Pl. 9, Figs. 3-4), Acheron River, Rakaia, South Island, GS 6049, K35/f7509 (Mp-Mh), both x 1.
PLATE 17

Pacitrigonia sy1vesteri Marwick, 1932 (Figures 1, 3, 10): 1 holotype M681 (CM; Fleming, 1987, Pl. 9, Fig. 5), Conchothyra bed, Waimakiriri River Gorge, Canterbury, South Island, L35/f6013 (Mp-Mh), x 1; 3, 10 TM 5945 (IGNS; Fleming, 1987, Pl. 9, Figs. 1-2), locality uncertain, both x 1.

Iotrigonia lenseni Fleming, 1987 (Figure 2): 2 holotype TM 3350 (IGNS; Fleming, 1987, Pl. 11, Fig. 7), Towy River, near junction of Conway River, South Island, GS 6550, O31/f8539 (Mp-Mh), x 1.

Oistotrigonia ongleyi Fleming, 1987 (Figures 4-5): 4 holotype TM 3416 (IGNS; Fleming, 1987, Pl. 7, Fig. 32), Waitangi River, Northland, GS 1175, P5/f9499 (Mp-Mh), x 3; 5 paratype TM 3417 (IGNS; Fleming, 1987, Pl. 7, Fig. 33), Tuparoa Beach, Raukumara Peninsula, North Island, GS 1920, Z15/f7496 (Mp-Mh), x 2.

Oistotrigonia waiparensis (Woods, 1917) (Figures 6, 9, 12): 6 paralectotype TM 2468 (IGNS; Fleming, 1987, Pl. 7, Fig. 31), Saurian beds, Middle Waipara, South Island, GS 761, M34/f7263 (Mp-Mh), x 2; 9 TM 6872 (IGNS; Crampton and Moore, 1990, Fig. 8G), Te Hoe River, southern Hawke's Bay, GS 11359, V19/f6909 (Mp-Mh), length = 12.0 mm, x 3; 12 lectotype TM 2466 (IGNS; Fleming, 1987, Pl. 7, Fig. 27), Saurian beds, Middle Waipara, GS 761, M34/f7263 (Mp-Mh), x 3.
Oistotrigonia piripauana Fleming, 1987 (Figures 7-8, 13, 17): 7
paratype TM 3415 (IGNS; Fleming, 1987, Pl. 7, Fig. 23), Haumuri
Bluff, southern Marlborough, South Island, GS 13, O32/f8025 (Mp-
Mh), x 2; 8 paratype TM 5994 (IGNS; Fleming, 1987, Pl. 7, Fig.
24), Haumuri Bluff, GS 13, O32/f8025 (Mp-Mh), x 2; 13 holotype TM
3412 (IGNS; Fleming, 1987, Pl. 7, Fig. 25), Haumuri Bluff, GS 13,
O32/f8025 (Mp-Mh), x 2; 17 paratype TM 3414 (IGNS; Fleming, 1987,
Pl. 7, Fig. 26), Haumuri Bluff, GS 13, O32/f8025 (Mp-Mh), x 2.

Pacitrigonia n. sp.? cf. P. hanetiana hectori Fleming, 1987
(Figure 11): 11 Ge 7902 (AIM), Bull Point, Kaipara, Northland,
Q08/f9626, x 3.

Trigonia n. sp. aff. marwicki Fleming, 1987 (Figure 14): 14 TM
6860 (IGNS; Crampton, 1988, Pl. 1, Fig. 4), northern Hawke's Bay,
North Island, GS 14390, W18/f08B (Mp-Mh), length = 13.5 mm, x
3.8.

Eselaevitrigonia? n. sp.? (Figures 15, 18): 15, 18 OU 40658,
Waianakarua River, North Otago, J42/f218 (Mp-Mh), length = 29.0
mm, x 1.5.

Iotrigonia leda Fleming, 1987 (Figure 16): 16 holotype TM 3352
(IGNS; Fleming, 1987, Pl. 11, Fig. 10), Towy River, GS 7914,
031/f8543 (?Mp-Mh), x 1.
PLATE 18

Myrtea canterburiensis (Woods, 1917) (Figures 1-4, 6): 1
lectotype TM 2551 (IGNS; Woods, 1917, Pl. 16, Fig. 4), Selwyn
Rapids, Canterbury, South Island, GS 23, L35/f6017 (Mp-Mh), x 1; 2-4 TM 2552 (IGNS; Woods, 1917, Pl. 16, Fig. 5a-c), Selwyn Rapids,
GS 589, L35/f6008 (Mp-Mh), x 1, x 1 and x 4 respectively; 6 OU
40951, Selwyn Rapids, OU 10986, L35/f6510 (Mp-Mh), length = 23.0
mm, x 1.8.

Myrtea cretacea n. sp. (Figures 5, 7-8, 10-11): 5 paratype Ge
6369 (AIM), promontory between Te Opu and Whakapirau Creeks,
Kaipara, Northland, Q08/f9639 (Mh), length = 11.5 mm, x 2.5; 7-8
holotype Ge 8029 (AIM), Kaipara, Q08/f547 (Mh), length = 7.0 mm,
x 6.5 and x 8 (dorsal view: note preserved ligament) respectively; 10 paratype Ge 6374 (AIM), Te Opu, Kaipara,
Q08/f9639 (Mh), length = 11.5 mm, x 2.8; 11 paratype Ge 7935
(AIM), Whakapirau Creek, Kaipara, Q08/f9637 (Mh), length = 9.0
mm, x 2.3.

Thyasira (Conchocele) bullpointensis n. sp. (Figures 9, 12-17): 9
paratype TM 7564 (IGNS), Bull Point, Kaipara, GS 4909, Q08/f9023
(Mh), length = 48.0 mm, x 0.8; 12 paratype Ge 5954 (AIM), Bull
Point, Q08/f9626 (Mh), length = 56.0 mm, x 1; 13, 17 paratype Ge
6375 (AIM), Te Opu, Q08/f9639 (Mh), length = 11.5 mm, both x
2.6; ?14 paratype Ge 6376 (AIM), Te Opu, Q08/f9639 (Mh), length
= 7.5 mm, x 3; 15-16 holotype L 3872 (AU), Bull Point, AU 2576,
Q08/f9626 (Mh), length = 48.0 mm, both x 1.1.

Astarte n. sp. (Figures 18-19): 18 Ge 8615 (AIM), Hukatere
Peninsula, Northland, Q08/f9660 (Mh), length = 12.0 mm, x 3; 19
Ge 8608 (AIM), Hukatere Peninsula, Q08/f9660 (Mh), length = 15.0
mm, x 2.8.
PLATE 19

Eriphyla s. s. meridiana Woods, 1917 (Figures 1-10, 13, 16-18): 1 TM 7498 (IGNS), Haumuri Bluff, southern Marlborough, South Island, GS 13, O32/f8025 (Mp-Mh), length = 30.5 mm, x 4; 2 TM 7496 (IGNS), Haumuri Bluff, GS 13, O32/f8025 (Mp-Mh), length = 27.0 mm, x 2.1; 3-4 topotype OU 40952, Haumuri Bluff, OU 11302, O32/fc. 9529 (Mp-Mh), Length = 30.0 mm, both x 1.5; 5-6 lectotype TM 2550 (IGNS; Woods, 1917, Pl. 15, Fig. 2a-b), Haumuri Bluff, GS 2, O32/f9025, both x 1; 7-8 TM 2547 (IGNS; Woods, 1917, Pl. 15, Fig. 6a-b), Haumuri Bluff, GS 13, O32/f8025, both x 1; 9 TM 7497 (IGNS), Haumuri Bluff, GS 13, O32/f8025 (Mp-Mh), length = 30.0 mm, x 1.7; 10 TM 2545 (IGNS; Woods, 1917, Pl. 15, Fig. 5), Haumuri Bluff, GS 13, O32/f8025 (Mp-Mh), x 1; 13 TM 2549 (IGNS; Woods, 1917, Pl. 15, Fig. 3), Haumuri Bluff, GS 2, O32/f9025 (Mp-Mh), x 1; 16 TM 2546 (IGNS; Woods, 1917, Pl. 15, Fig. 7), Haumuri Bluff, GS 13, O32/f8025 (Mp-Mh), x 1; 17-18 TM 2548 (IGNS; Woods, 1917, Pl. 15, Fig. 4a-b), Haumuri Bluff, GS 13, O32/f8025 (Mp-Mh), x 3 and x 1 respectively.

?Dozyia lenticularis (Goldfuss, 1840) (Figures 11-12, 14-15, 19): 11 OU 40954, Selwyn Rapids, Canterbury, South Island, OU 10984, L35/f6510 (Mp-Mh), length = 55.5 mm, x 0.9; 12 OU 40955, Selwyn Rapids, OU 10984, L35/f6510 (Mp-Mh), length = 26.5 mm, x 2.2; 14 TM 2543 (IGNS; Woods, 1917, Pl. 15, Fig. 10), Selwyn Rapids, GS 589, L35/f6008 (Mp-Mh), x 1; 15, 19 TM 2544 (IGNS; Woods, 1917, Pl. 15, Fig. 9a-b), Selwyn Rapids, GS 589, L35/f6008 (Mp-Mh), both x 1.
PLATE 20

Anthonya elongata Woods, 1917 (Figures 1-5, 7): 1 lectotype TM 2536 (IGNS; Woods, 1917, Pl. 15, Fig. 13), Haumuri Bluff, southern Marlborough, South Island, GS 13, O32/f8025 (Mp-Mh), x 1; 2 TM 2539 (IGNS; Woods, 1917, Pl. 15, Fig. 12), Haumuri Bluff, GS 13, O32/f8025 (Mp-Mh), x 1; 3 TM 2538 (IGNS; Woods, 1917, Pl. 15, Fig. 11), Haumuri Bluff, GS 13, O32/f8025 (Mp-Mh), x 1; 4 Ge 5955 (AIM), Bull Point, Kaipara, Northland, Q08/f9626 (Mh), length = 32.0 mm, x 2; 5 TM 2537 (IGNS; Woods, 1917, Pl. 16, Fig. 1), Haumuri Bluff, GS 13, O32/f8025 (Mp-Mh), x 1; 7 TM 2541 (IGNS; Woods, 1917, Pl. 16, Fig. 3), Haumuri Bluff, GS 5, O32/f9027 (Mp-Mh), x 1.

Austrocardium acherontis Freneix and Grant-Mackie, 1978 (Figures 6, 8, 9-10, 12-13): 6, 10 OU 40957, Acheron River, Rakaia, South Island, c. K35/f1 (Mp-Mh). length = 75.5 mm, x 1.3 and x 0.9 respectively; 8 paratype L 2993 (AU; Freneix and Grant-Mackie, 1978, Fig. 6), Acheron Valley, AU 2528, K35/f1 (Mp-Mh), x 1; 9, 12 OU 40958, Acheron River, c. K35/f1 (Mp-Mh), length = 63.0 mm, x 1.5 and x 0.9 respectively; 13 paratype L 2992 (AU; Freneix and Grant-Mackie, 1978, Fig. 5), Acheron Valley, AU 2528, K35/f1 (Mp-Mh), x 1.

Cardium (Bucardium?) sp. (Figures 11, 14): 11, 14 TM 2575 (IGNS; Woods, 1917, Pl. 18, Fig. 3a-b), Haumuri Bluff, GS 13, O32/f8025, both x 1.
Austrocardium acherontis Freneix and Grant-Mackie, 1978 (Figures 1-2, 5): 1 holotype TM 5563 (IGNS; Freneix and Grant-Mackie, 1978, Fig. 1), Acheron Valley, Rakaia, South Island, GS 4885, K35/f7504 (Mp-Mh), x 1; 2 paratype TM 5564 (IGNS; Freneix and Grant-Mackie, 1978, Fig. 2), Acheron Valley, GS 4885, K35/f7504 (Mp-Mh), x 1; 5 paratype TM 5566 (IGNS; Freneix and Grant-Mackie, 1978, Fig. 4), Acheron Valley, GS 4885, K35/f7504 (Mp-Mh), x 1.

Schedocardia? waiparana Freneix and Grant-Mackie, 1978 (Figures 3-4): 3-4 holotype TM 5570 (IGNS; Freneix and Grant-Mackie, 1978, Figs. 25-26), Boby's Creek, Waipara, South Island, GS 277, N34/f6257 (Mp-Mh), both x 1.

Cardiidae? gen. et sp. indet. (Figures 6, 8): 6, 8 L 3874 (AU), Te Opu, Kaipara, AU 2553, Q08/f9639 (Mh), length = 74.0 mm, both x 1.

Granocardium (Ethmocardium) woodsi (Marwick, 1944) (Figures 7, 9-13): 7, 11 holotype TM 2573 (IGNS; Woods, 1917, Pl. 18, Fig. 5; Marwick, 1944, Pl. 36, Fig. 21), Selwyn Rapids, Canterbury. South Island, GS 589, L35/f6008 (Mp-Mh), x 2 and x 6 respectively; 9 paratype TM 2574 (IGNS; Woods, 1917, Pl. 18, Fig. 4), Selwyn Rapids, GS 589, L35/f6008 (Mp-Mh), x 1.5; 10 Ge 7897.3 (AIM), Bull Point, Kaipara, Northland, Q08/f9626 (Mh), x 5; 12 Ge 7897.1 (AIM), Bull Point, Q08/f9626, x 5.8; 13 TM 7499 (IGNS), Selwyn Rapids, GS 23, L35/f6017 (Mp-Mh), x 5.
PLATE 22

Lahillia aotearoa n. sp. (Figures 1-10): 1 paratype OU 40530, Fairfield Quarry, Dunedin, Otago, South Island, c.I44/f173 (Mh), length = 80.0 mm, x 1; 2 paratype OU 40531, Waianakarua River, North Otago, J42/f178 (Mp-Mh), length = 68.0 mm, x 1; 3, 4 TM 2568 (IGNS; Woods, 1917, Pl. 16, Fig. 8a-b), Saurian beds, Middle Waipara, South Island, GS 761, M34/f7263 (Mp-Mh), both x 1; 5 holotype TM 7500 (IGNS), Haumuri Bluff, southern Marlborough, South Island, GS 9834, O32/f9529 (Mp-Mh), length of hinge = 33.0 mm, x 3; 6, 9 paratype TM 7501 (IGNS), Haumuri Bluff, GS 9834, O32/f9529 (Mp-Mh), length of hinge = 38.5 mm, x 2.8 and x 1.5 respectively; 7 Ge 6430 (AIM), Matakohe, Kaipara, Northland, c.Q08/f567 (Mh), length = 45.5 mm, x 1.3; 8 TM 6868 (IGNS; Crampton and Moore, 1990, Fig. 8C), Te Hoe River, southern Hawke's Bay, North Island, GS 14269, V19/f185 (Mp-Mh), length = 46.0 mm, x 1.2.
PLATE 23

**Cymbophora mackayi** n. sp. (Figures 1-2): 1-2 holotype TM 7502 (IGNS), Totara Point, Whangaroa, Northland, GS 750, P04/f9497 (Mh), length = 86.0 mm, x 1.

**Raeta?** n. sp. (Figures 3, 5, 7): 3, 7 Ge 7641 (AIM), Bull Point, Kaipara, Northland, Q08/f9626 (Mh), length = 41.0 mm, both x 1.8; 5 L 3876 (AU), Bull Point, Q08/f9626 (Mh), length = 22.0 mm, x 2.8.

**Aenona** n. sp.? (Figures 4, 6, 8-9, 11-12): 4 TM 2577 (IGNS; Woods, 1917, Pl. 16, Fig. 7), Selwyn Rapids, Canterbury, South Island, GS 589, L35/f6008 (Mp-Mh), x 1; 6 TM 2578 (IGNS; Woods, 1917, Pl. 16, Fig. 6), Selwyn Rapids, GS 589, L35/f6008, x 1.1; 8 OU 40960, Selwyn Rapids, OU 10985, c. L35/f6008, x 2; 9 OU 40961, Selwyn Rapids, OU 10985, c. L35/f6008, x 2; 11 TM 7503 (IGNS), Selwyn Rapids, GS 589, L35/f6008 (Mp-Mh), length = 38.5 mm, x 2; 12 TM 7504 (IGNS), Selwyn Rapids, GS 589, L35/f6008 (Mp-Mh), length = 54.5 mm, x 1.5.

**Zenatia cretacea** (Woods, 1917) (Figure 10): 10 holotype TM 2542 (IGNS; Woods, 1917, Pl. 16, Fig. 9), Haumuri Bluff, southern Marlborough, South Island, GS 13, O32/f8025 (Mp-Mh), x 1.
PLATE 24

Garis s. l. barronshillensis n. sp. (Figures 1-5): 1-2 paratype OU 40963, Barron's Hill, Otago, South Island, OU 5443, I44/f8510 (Mh), length = 32.5 mm, x 2.7 and x 1.5 (latex) respectively; 3-4 holotype OU 40962, Barron's Hill, OU 5442, I44/f8510 (Mh), length = 35.0 mm, x 1.5 (latex) and x 2; 5 paratype OU 40964, c. I44/f8510 (Mh), length = 33.5 mm, x 2.8.

Tancredia sura n. sp. (Figures 6-8): 6 paratype TM 6873 (IGNS), Mangahouanga Stream, southern Hawke's Bay, North Island, GS 11359, V19/f6909 (Mp-Mh), length = 69.5 mm, x 1.1; 7 holotype TM 7506 (IGNS), Te Hoe River, southern Hawke's Bay, GS 14269, V19/f185 (Mp-Mh), length = 50.0 mm, x 1.6; 8 paratype TM 7507 (IGNS), Selwyn Rapids, Canterbury, South Island, GS 2157, L35/f6510 (Mp-Mh), length of hinge = 57.5 mm, x 1.8.

Aphrodina (Tikia) thomsoni (Woods, 1917) (Figures 9-10): 9-10 TM 7508 (IGNS), Selwyn Rapids, GS 2157, L35/f6510 (Mp-Mh), length = 55.0 mm, both x 1.2 (Note preserved ligament in Fig. 10).
PLATE 25

Aphrodina (Tikia) thomsoni (Woods, 1917) (Figures 1, 3-6, 8, 10-11): 1, 11 lectotype TM 2560 (IGNS; Woods, 1917, Pl. 17, Fig. 4; Marwick, 1927, Pl. 40, Fig. 55), Selwyn Rapids, Canterbury, South Island, GS 589, L35/f6008 (Mp-Mh), both x 1; 3-4 paralectotype TM 2562 (IGNS; Woods, 1917, Pl. 17, Fig. 5a-b), Selwyn Rapids, Canterbury, South Island, GS 589, L35/f6008 (Mp-Mh), both x 1; 5-6 paralectotype TM 2561 (IGNS; Woods, 1917, Pl. 17, Fig. 6; Marwick, 1927, Pl. 40, Fig. 56), Selwyn Rapids, GS 589, L35/f6008 (Mp-Mh), both x 1; 8 TM 2553 (IGNS; Woods, 1917, Pl. 17, Fig. 7), Selwyn Rapids, GS 589, L35/f6008 (Mp-Mh), x 1; 10 OU 40965, Barron's Hill, Otago, South Island, c. I45/f8510 (Mh), length = 32.0 mm, x 1.5.

Aphrodina (Tikia) wilckensi (Woods, 1917) (Figures 2, 7, 9, 12-18): 2 TM 2559 (IGNS; Woods, 1917, Pl. 15, Fig. 8), Haumuri Bluff, GS 13, 032/f8025 (Mp-Mh), x 1; 7, 9 TM 2557 (IGNS; Woods, 1917, Pl. 17, Fig. 2a-b), Haumuri Bluff, GS 13, 032/f8025 (Mp-Mh), both x 1; 12 TM 2558 (IGNS; Woods, 1917, Pl. 17, Fig. 3), Haumuri Bluff, GS 5, 032/f8027 (Mp-Mh), x 1; 13-14 lectotype TM 2554 (IGNS; Woods, 1917, Pl. 16, Fig. 10a-b), Haumuri Bluff, GS 13, 032/f8025 (Mp-Mh), both x 1; 15-16 TM 2555 (IGNS; Woods, 1917, Pl. 17, Fig. 1a-b), Haumuri Bluff, GS 13, 032/f8025 (Mp-Mh), both x 1; 17 TM 2556 (IGNS; Woods, 1917, Pl. 16, Fig. 11; Marwick, 1938, Pl. 10, Fig. 7), Haumuri Bluff, GS 13, 032/f8025 (Mp-Mh), both x 1.
PLATE 26

Aphrodina (Tikia) wilckensi (Woods, 1917) (Figures 1, 4-5): 1, 4 TM 7509 (IGNS), Haumuri Bluff, southern Marlborough, South Island, GS 9834, 032/f9529 (Mp-Mh), length = 37.5 mm, x 1.6; 5 TM 6871 (IGNS; Crampton and Moore, 1990, Fig. 8F), Te Hoe River, southern Hawke's Bay, North Island, GS 11359, V19/f6909 (Mp-Mh), length = 41.0 mm, x 1.1.

Costacallista? n. sp. (Figures 2, 8): 2 L 3875 (AU), Bull Point, Kaipara, Northland, AU 2571, Q08/f9626 (Mh), length = 13.5 mm, x 4.2; 78 TM 6874 (IGNS; Crampton and Moore, 1990, Fig. 8I), southern Hawke's Bay, GS 13801, V19/f129 (Mp-Mh), length = 41.0 mm, x 1.4.

Cyclorismina woodsi Marwick, 1927 (Figures 3, 6-7, 9-17): 3 paratype TM 2564 (IGNS), Selwyn Rapids, Canterbury, South Island, GS 589, L35/f6008 (Mp-Mh), height = 42.5 mm, x 0.9; 6-7 holotype TM 2563 (IGNS), Selwyn Rapids, GS 589, L35/f6008 (Mp-Mh), length 55.5 mm, both x 1.1; 9, 17 paratype TM 2565 (IGNS), Selwyn Rapids, GS 589, L35/f6008 (Mp-Mh), length = 48.0 mm, x 0.7 and x 1.1 respectively; 10 OU 40966, Selwyn Rapids, OU 10987, c. L35/f6008 (Mp-Mh), length = 53.0 mm, x 1.3; 11-12, 16 paratype TM 2566 (IGNS), Selwyn Rapids, GS 589, L35/f6008 (Mp-Mh), length = 40.5 mm, all x 1.3; 13-15 paratype TM 2567 (IGNS; Woods, 1917, Pl. 18, Fig. 2), Selwyn Rapids. GS 589, L35/f6008 (Mp-Mh), length = 62.0 mm, x 0.6, x 0.8 and x 1 respectively.
Surobula cf. S. nucleus (Wilckens, 1910) (Figures 1-2): 1-2 Ge 7913 (AIM), Bull Point, Kaipara, Northland, Q08/f9626 (Mh), length = 8.5 mm, x 2.8 and x 6.6 respectively.

Corbulidae gen. indet. n. sp. (Figures 3-4): 3-4 Ge 7714 (AIM), Batley, Kaipara, Q08/f9636 (Mh), x 6.

Cyrtodaria n. sp. (Figures 5-6, 8): 5 Ge 8090 (AIM), Bull Point, Q08/f9626 (Mh), length = 10.0 mm, x 3; 6 L 3873 (AU), Te Opu, Kaipara, Q08/f9639 (Mh), length = 11.5 mm, x 3; 8 Ge 6368 (AIM), promontory between Te Opu and Whakapirau Creeks, Q08/f9639 (Mh), length = 4.5 mm, x 11.5 (SEM).

Panopea clausa Wilckens, 1910 (Figures 7, 9-14): 7 TM 2582 (IGNS; Woods, 1917, Pl. 18, Fig. 7), Haumuri Bluff, southern Marlborough, South Island, GS 3, O32/f8026 (Mp-Mh), x 1; 9-10 Ge 7892 (AIM), Bull Point, Q08/f9626 (Mh), length = 59.0 mm, both x 1.3; 11-12 TM 2581 (IGNS; Woods, 1917, Pl. 18, Fig. 6a-b), Haumuri Bluff, GS 3, O32/f8026, both x 1; 13 OU 40968, Shag Point, North Otago, South Island, OU 11128, J43/f6544 (Mp-Mh), length = 47.0 mm, x 1.2; 14 OU 40967, Shag Point, OU 11128, J43/f 6544 (Mp-Mh), length = 57.5 mm, x 1.
PLATE 28

Panopea malvernensis Woods, 1917 (figures 1-3, 5): 1 lectotype TM 2585 (IGNS; Woods, 1917, Pl. 18, Fig. 9), Selwyn Rapids, Canterbury, South Island, GS 589, L35/f6008 (Mp-Mh), x 1; 2 paralectotype TM 2586 (IGNS; Woods, 1917, Pl. 19, Fig. 2), Selwyn Rapids, GS 589, L35/f6008 (Mp-Mh), x 1; 3, 5 paralectotype TM 2587 (IGNS; Woods, Pl. 19, Fig. 1a-b), Selwyn Rapids, GS 589, L35/f6008 (Mp-Mh), x 1.

Clavipholas birchhollowensis n. sp. (Figure 4): 4 holotype TM 7512 (IGNS), Birch Stream, Waipara, South Island, GS 7954, M34/f7896 (Mp-Mh), length = 33.0 mm, x 2.4.

Pholadidea (Hatasia) wiffenae Crampton, 1990 (Figures 6-9): 6-7, 9 paratype TM 6941 (IGNS; Crampton, 1990, Pl. 2, Figs. 1, 3; Pl. 3, Fig. 4), Mangahouanga Stream, northern Hawke's Bay, North Island, GS 14241, V19/f6909A (Mp-Mh), length (excluding siphonoplax) = 17.1 mm, x 4.9 (SEM), x 4.9 (SEM), and x 34.7 (SEM) respectively; 8 paratype TM 6940 (IGNS; Crampton, 1990, Pl. 3, Fig. 2), Mangahouanga Stream, GS 14241, V19/f6909A (Mp-Mh), x 22.4 (SEM of detail of callum at commissure).
Pholadidea (Hatasia) wiffenae Crampton, 1990 (Figures 1-7): 1, 4, 6 holotype TM 6942 (IGNS; Crampton, 1990, Pl. 1, Figs. 1, 3-4), Mangahouanga Stream, northern Hawke's Bay, North Island, GS 14241, V19/f6909A (Mp-Mh), length (excluding siphonoplax) = 17.6 mm, all x 5.1 (SEM); 2 paratype TM 6940 (IGNS; Crampton, 1990, Pl. 1, Fig. 5), Mangahouanga Stream, GS 14241, V19/f6909A (Mp-Mh), x 8.7 (SEM of mesoplax showing periostracal folds, anterior up); 3, 5 paratype TM 6938 (IGNS; Crampton, 1990, Pl. 2, Figs. 2, 4), Mangahouanga Stream, GS 14241, V19/f6909A (Mp-Mh), length (excluding siphonoplax) = 17.6 mm, x 5.1 (SEM, dorsal view) and x 5.1 (SEM, ventral view) respectively; 7 paratype TM 6950 (IGNS; Crampton, 1990, Pl. 3, Fig. 1), Mangahouanga Stream, GS 14241, V19/f6909A (Mp-Mh), x 10.5 (SEM of anterior aspect of prora and umbonal reflection, dorsal up).
Pholadidea (Hatasia) wiffenae Crampton, 1990 (Figure 1-4): 1 paratype TM 6951 (IGNS; Crampton, 1990, Pl. 1, Fig. 6), Mangahouanga Stream, northern Hawke's Bay, North Island, GS 14241, V19/f6909A (Mp-Mh), x 8.2 (SEM of mesoplax, anterior up); 2 holotype TM 6942 (IGNS; Crampton, 1990, Pl. 1, Fig. 2), Mangahouanga Stream, GS 14241, V19/f6909A (Mp-Mh), length (excluding siphonoplax) = 17.6 mm, x 4.6 (SEM of anterior aspect); 3 paratype TM 6950 (IGNS; Crampton, 1990, Pl. 3, Fig. 3), Mangahouanga Stream, GS 14241, V19/f6909A (Mp-Mh), x 34.7 (SEM of anterior aspect of prora and umbonal reflection, dorsal up); 4 paratype TM 6949 (IGNS; Crampton, 1990, Pl. 3, Fig. 5), Mangahouanga Stream, GS 14241, V19/f6909A (Mp-Mh), x 19.1 (SEM of apophysis and umbonal-ventral ridge, anterior to right).

Thracia haasti Woods, 1917 (Figures 5, 8-10, 13-14): 5 Ge 7677 (AIM), Te Opu, Kaipara, Northland, Q08/f9639 (Mh), length = c. 4.5 mm, x 14.5 (SEM) (juvenile?); 8-10 holotype TM 2580 (IGNS; Woods, 1917, Pl. 19, Fig. 3a-c), Haumuri Bluff, southern Marlborough, South Island, GS 13, 032/f8025 (Mp-Mh), all x 1; 13-14 TM 2579 (IGNS; Woods, 1917, Pl. 19, Fig. 4a-b), Saurian bed, Middle Waipara, South Island, GS 761, M34/f7263 (Mp-Mh), both x 1.

Cuspidaria surocretacica n. sp. (Figures 6-7): 6-7 holotype Ge 7621 (AIM), Bull Point, Kaipara, Northland, Q08/f9626 (Mh), length = 3.0 mm, both x 16.5.
Bivalvia gen. et sp. indet. (Oxytomidae n. gen.? et sp. of Crampton, 1988) (Figures 11-12): 11 TM 6862 (IGNS; Crampton, 1988, Pl. 1, Fig. 6), northern Hawke's Bay, North Island, GS 14390, W18/f8A (Mp-Mh), length = 4.0 mm, x 11; 12 TM 6864 (IGNS; Crampton, 1988, Pl. 1, Fig. 8), northern Hawke's Bay, GS 14390, W18/f8A (Mp-Mh), length = 3.4 mm, x 23.
PLATE 31

**Perotrochus maoriensis** (Wilckens, 1922) (Figures 1-4, 6): 1, 4 TM 7514 (IGNS), Haumuri Bluff, southern Marlborough, South Island, GS 2161, O32/f9035 (Mp-Mh), height = 64.5 mm, x 1 and x 0.7 respectively; 2 TM 5378 (IGNS; Warren and Speden, 1978, Fig. 25-8), Haumuri Bluff, GS 6158, O32/f9502 (Mp-Mh), x 0.67; 3 lectotype TM 2593 (IGNS; Wilckens, 1922, Pl. 1, Fig. 2), Haumuri Bluff, GS 5, O32/f9027 (Mp-Mh), x 1; 6 paralectotype TM 2594 (IGNS; Wilckens, 1922, Pl. 1, Fig. 1), Haumuri Bluff, GS 5, O32/f9027 (Mp-Mh), x 1.

**Chelotia woodsi** (Wilckens, 1922) (Figures 5, 7-8): 5, 8 lectotype TM 2592 (IGNS; Wilckens, 1922, Pl. 1, Fig. 4), Haumuri Bluff, GS 5, O32/f9027 (Mp-Mh), both x 1; 7 paralectotype TM 2591 (IGNS; Wilckens, 1922, Pl. 1, Fig. 3), Haumuri Bluff, GS 5, O32/f9027 (Mp-Mh), x 1.

**Cellana? n. sp.** (Figures 9, 12-13): 9, 12 TM 7516 (IGNS), Old Claverley Stream, southern Marlborough, South Island, GS 9832, O32/f8795 (Mp-Mh), length = 42.0 mm, both x 1.6; 13 TM 7517 (IGNS), Old Claverley Stream, GS 9832, O32/f8795 (Mp-Mh), length = 41.0 mm, x 1.5.

**Patelloidea? n. sp.** (Figures 10-11): 10-11 TM 7515 (IGNS), Te Rata Stream, North Island, GS 13375, Y16/f203 (Mp-Mh), length = 24.0 mm, x 2.5.

**Patella? amuritica** Wilckens, 1922 (Figure 14): 14 lectotype TM 2597 (IGNS; Wilckens, 1922, Pl. 1, Fig. 8), Haumuri Bluff, GS 13, O32/f8025 (Mp-Mh), x 1.
PLATE 32

Brookula (Paleobrookula) marshalli n. subgen. n. sp. (Figures 1-4): 1-4 holotype TM 7518 (IGNS), Whangaroa Harbour, Northland, exact locality unknown, height = 3.5 mm, x 11 (SEM, oblique view), x 8, x 10.5, and x 7.5 respectively.

Amberleya whangaroaensis n. sp. (Figures 5-6, 9, 11-13): 5, paratype Ge 6424 (AIM), Te Opu, Kaipara, Northland, Q08/f9639 (Mh), height = 17.5 mm, x 3.1; 6 holotype TM 7519 (IGNS), Whangaroa Harbour, c. P5/f7606 (Mh), height = 46.5 mm, x 1.5; 9 paratype Ge 7658 (AIM), Te Opu, Q08/f9639 (Mh), height = 11.5 mm, x 3; 11 paratype G 7037 (AU), Bull Point, Kaipara, AU 2577, Q08/f9626 (Mh), height = 17.5 mm, x 2.5; 12 paratype Ge 5996 (AIM), Whakapirau Creek, Kaipara, Q08/f9637 (Mh), height = 32.0 mm, x 1.5; 13 paratype G 7038 (AU), Bull Point, AU 2577, Q08/f9626 (Mh), height = 25.0 mm, x 2.

Angaria? sp. (Figures 7-8, 10): 7-8, 10 TM 2596 (IGNS; Wilckens, 1922, Pl. 1, Fig. 5a-c), Haumuri Bluff, GS 13, O32/f8025 (Mp-Mh), all x 1.

Calliomphalus s. l. hickmanae n. sp. (Figures 14-16): 14-16 holotype G 7039 (AU), Te Opu, Kaipara, AU 2553, Q08/f9639 (Mh), height = 8.5 mm, x 6.5 (SEM), x 2.7 and x 6.5 (SEM) respectively.
PLATE 33

Calliomphalus s. l. hickmanae n. sp. (Figures 1-2): 1-2 holotype G 7039 (AU), Te Opu, Kaipara, Northland, AU 2553, Q09/f9639 (Mh), height = 8.5 mm, x 21 (SEM, oblique view of part of umbilicus) and x 40 (SEM, detail of sculpture).

Trochidae gen. indet. n. sp. (figure 3): 3 TM 7522 (IGNS), southern Hawke's Bay, North Island, GS 4894, W22/f8499 (Mp-Mh), height = 12.5 mm, x 4.5.

Kaiparomphalus australinus n. gen. n. sp. (Figures 4-10, 13): 4, 10 paratype G 7041 (AU), Bull Point, Kaipara, AU 2574, Q08/f9909 (Mh), height = 3.5 mm, x 8 and x 67.5 (SEM, detail of sculpture at suture); 5-6, 9 holotype G 7040 (AU), Bull Point, AU 2574, Q08/f9909 (Mh), height = 4.5 mm, all x 7; 7 paratype Ge 7670.1 (AIM), Te Opu, Kaipara, Q08/f9639 (Mh), height = 4.5 mm, x 5.3; 8, 13 G 7042 (AU), Bull Point, AU 2574, Q08/f9909 (Mh), height = 6.5 mm, x 5.7 and x 6 respectively.

Chrystostoma selwynensis Trechmann, 1917 (Figures 11-12): 11-12 G 27427 (BMNH; Trechmann, 1917, Pl. 21, Fig. 4a-b), Selwyn River (precise locality unknown), Canterbury, South Island, L35/- (Mh), both x 3.

Calliostoma decapitatum Wilckens, 1922 (Figures 14-17): 14-15 lectotype TM 2588 (IGNS; Wilckens, 1922, Pl. 1, Fig. 6a-b), Oaro Creek, Haumuri Bluff, southern Marlborough, South Island, GS 14, O32/f8026, both x 1; 16 TM 2595 (IGNS; Wilckens, 1922, Pl. 1, Fig. 7a-b), Oaro Creek, GS 14, O32/f8026, x 1; 17 TM 7521 (IGNS), Hokianga Harbour, Northland, GS 5355, O05/f9573, height = 12.0 mm, x 5.3.
Protodolium speighti (Trechmann, 1917) (see Stilwell, 1994, Figs. 2-3) (Figures 1-19 herein): 1-2, 14 OU 40916, Selwyn Rapids, Canterbury, South Island, L35/f74 (Mp-Mh), height = 30.5 mm, all x 2.5; 3 OU 40918, Selwyn Rapids, L35/f74 (Mp-Mh), height = 14.5 mm, x 3.3; 4, 19 TM 7462 (IGNS), Selwyn Rapids, GS 589, L35/f6008 (Mp-Mh), height = 10.5 mm, x 3.3 and x 3.5 respectively; 5 TM 6878 (IGNS; Crampton and Moore, 1990, Fig. 8M), Te Hoe River, southern Hawke's Bay, North Island, GS 14260, V19/f184 (Mp-Mh), height = 41.0 mm, x 1.1; 6, 8 TM 2650 (IGNS; Wilckens, 1922, Pl. 4, Fig. 4a-b), Selwyn Rapids, GS 589, L35/f6008 (Mp-Mh), both x 2; 7 paralectotype G 27448 (BMNH; Trechmann, 1917, Pl. 19, Fig. 13), Selwyn Rapids, L35/- (Mh), x 1; 9 lectotype G 27447 (BMNH; Trechmann, 1917, Pl. 19, Fig. 12), Selwyn Rapids, L35/- (Mh), x 1; 10 paralectotype G 27450 (BMNH; Trechmann, 1917, Pl. 19, Fig. 15), Selwyn Rapids, L35/- (Mh), x 2; 11, 16 TM 2651 (IGNS; Wilckens, 1922, Pl. 4, Fig. 3), Selwyn Rapids, GS 589, L35/f6008 (Mp-Mh), both x 1; 12 OU 40917, Selwyn Rapids, L35/f74 (Mp-Mh), height = 29.5 mm, x 2.3; 13 TM 7460 (IGNS), Haumuri Bluff, southern Marlborough, South Island, GS 13, O32/f8025 (Mp-Mh), x 1.3; 15 paralectotype G 27449 (BMNH; Trechmann, 1917, Pl. 19, Fig. 14), Selwyn Rapids, L35/- (Mh), x 1; 17-18 TM 7461 (IGNS), Mangahouanga Stream, southern Hawke's Bay, GS 11359, V19/f6909 (Mp-Mh), x 2.5 and x 2.0 respectively.
PLATE 35

*Damesia?* n. sp. (Figure 1): 1 TM 7526 (IGNS), Okarahia Stream, southern Marlborough, South Island, GS 9827, O32/f8790 (Mp-Mh), height = 2.5 mm, x 8.2.

*Neritopsis (Hayamiella?)* sp. (Figures 2-3): 2 TM 7527 (IGNS), Waitangi River, Northland, GS 1175, P05/f9499 (Mp-Mh), height = 20.0 mm, x 1.8; 3 TM 2609 (IGNS; Wilckens, 1924, Pl. 54, Fig. 5), Shag Point, North Otago, South Island, GS 592, J43/f6472 (Mp-Mh), x 1.

*Zygopleuridae?* gen. indet. n. sp. (labelled "*Loxonema* n. sp." at IGNS) (Figures 4, 7, 15): 4 TM 7533 (IGNS), Te Kopi Stream, North Island, GS 9808, T27/f6005 (?Mp-Mh), x 1.3; 7 TM 7531 (IGNS), Te Kopi Stream, GS 9808, T27/f6005 (?Mp-Mh), x 1.5; 15 TM 7532 (IGNS), Te Kopi Stream, GS 9808, T27/f6005 (?Mp-Mh), x 1.4.

*Zygopleura?* *obliquestriata* (Trueman, 1924) (Figures 5-6, 8-14): 5 TM 7529 (IGNS), Mangarua Creek, Tapuwaeroa Valley, North Island, GS 2077, Z15/f6500 (?Mp-Mh), height = 30.0 mm, x 2.6; 6 TM 7530 (IGNS), Mangarua Creek, GS 2077, Z15/f6500 (?Mp-Mh), height = 21.0 mm, x 2.8; 8 TM 7528 (IGNS), Rotokautuku Creek, GS 1086, Z15/f6489 (?Mp-Mh); 9 holotype TM 2603 (IGNS; Trueman, 1924, Fig. a), Mangarua Creek, precise locality unknown, x 1.5; 10-14 paratypes TM 2598-2602, 2604-2607 (IGNS; Trueman, 1924, Figs. b-f), Mangarua Creek, precise locality unknown, x 1, x 5, x 2, x 1, and x 4 respectively.
Bathraspira zealandica n. sp. (Figures 16, 19): 16, 19 holotype TM 7536 (IGNS), Waimarama, southeastern North Island, GS 4894, W22/f8499 (?Mp-Mh), height = 11.0 mm, x 5.8 and x 5.4 respectively.

Bittiscala inaequicostata (Wilckens, 1922) (Figures 17-18, 20-21): 18 lectotype TM 2614 (IGNS; Wilckens, 1922, Pl. 2, Fig. 4), Haumuri Bluff, southern Marlborough, South Island, GS 9, O32/f9031 (Mp-Mh), x 1; 17 OU 40975, Shag Point, c.J43/f6544 (Mp-Mh), height = 12.5 mm, x 4.0; 20 TM 7534 (IGNS), Urewera National Park, GS 14263, W18/f10 (Mp-Mh), height = 15.5 mm, x 3.5; ?21 TM 7535 (IGNS), Waimarama, GS 4894, W22/f8499 (Mp-Mh), x 5.
PLATE 36

Rhabdocolpus? minutus n. sp. (Figures 1-2): 1-2 holotype G 7043 (AU), Kaiwhata Estuary, Hokianga, Northland, AU 2548, 005/f136 (?Mp-Mh), height = 6.8 mm, x 30 (SEM) and x 10.5 (SEM).

Procancellaria parkiana Wilckens, 1922 (Figures 3-5, 7-8, 12): 3 TM 7525 (IGNS), Haumuri Bluff, southern Marlborough, South Island, GS 13, O32/f8025 (Mp-Mh), height = 12.5 mm, x 3.5; 4 TM 5380 (IGNS), Haumuri Bluff, GS 13, O32/f8025 (Mp-Mh), x 2.1; 5, 8 lectotype TM 2673 (IGNS; Wilckens, 1922, Pl. 5, Fig. 2), Haumuri Bluff, GS 13, O32/f8025 (Mp-Mh), x 2.1 and x 1 respectively; 7 TM 7524 (IGNS), Haumuri Bluff, GS 13, O32/f8025 (Mp-Mh), block length = 28.5 mm, x 2.9; 12 paralectotype TM 2672 (IGNS; Wilckens, 1922, Pl. 5, Fig. 1), Haumuri Bluff, GS 13, O32/f8025 (Mp-Mh), x 2.

Costacolpus solitaria (Wilckens, 1922) (Figures 6, 9-11, 13, 16-18): 6 TM 7537 (IGNS), Hapuka River, Marlborough, South Island, GS 293, O31/f9497 (Mp-Mh), height = 4.5 mm, x 10; 9, 13 lectotype TM 2683 (IGNS; Wilckens, 1922, Pl. 5, Fig. 20; Marwick, 1966, Fig. 2), Hapuka River, GS 293, O31/f9497 (Mp-Mh), x 1 and x 8 respectively; 10 G 27430 (BMNH; Trechmann, 1917, Pl. 19, Fig. 11), Selwyn Rapids, Canterbury, South Island, L35/- (Mh), x 2.5; 11 TM 7538 (IGNS), Hapuka River, GS 293, O31/f9497 (Mp-Mh), length of slab = 32.0 mm, x 3.7; 16 paralectotype TM 7492 (IGNS; Marwick, 1966, Fig. 4), Hapuka River, GS 293, O31/f9497 (Mp-Mh), x 8; 17 paralectotype TM 7490 (IGNS; Marwick, 1966, Fig. 1), Hapuka River, GS 293, O31/f9497 (Mp-Mh), x 8; 18 paralectotype TM 7491 (IGNS; Marwick, 1966, Fig. 3), Hapuka
River, GS 293, O31/f9497 (Mp-Mh), x 8.

*Perissoptera waiparensis* (Hector, 1886) (Figures 14-15): 14 Ge 8146.4 (AIM), Te Opu, Kaipara, Northland, Q08/f9639 (Mh), height = 20.0 mm, x 3.6; 15 TM 2628 (IGNS; Wilckens, 1922, Pl. 2, Fig. 9), Haumuri Bluff, GS 9, O32/f9031 (Mp-Mh), x 1.
Perissoptera waiparaensis (Hector, 1886) (Figures 1-12): 1 G 7044 (AU), Bull Point, Kaipara, Northland, AU 9806, Q08/f9626 (Mh), height = 49.0 mm, x 2; 2 Ge 8147.7 (AIM), Te Opu, Kaipara, Q08/f9639 (Mh), height = 22.0 mm, x 2; 3 holotype TM 2626 (IGNS; Wilckens, 1922, Pl. 2, Fig. 8), Haumuri Bluff, southern Marlborough, South Island, GS 9, O32/f9030 (Mp-Mh), x 1; 4 G 7045 (AU), Te Opu, AU 2553, Q08/f9639 (Mh), height = 36.5 mm, x 2; 5, 7 TM 7539 (IGNS), Haumuri Bluff, GS 9, O32/f9030 (Mh), height = 40.5 mm, x 1.8; 6, 11 Ge 5968 (AIM), Whakapirau Creek, Kaipara, Q08/f9637 (Mh), height = 7.5 mm, x 7 (SEM) and x 20 (SEM, detail of sculpture); 78-9 TM 2632 (IGNS; Pleurotoma otagoensis Wilckens, 1922, Pl. 5, Figs. 18-19), Shag Point, North Otago, South Island, GS 592, J43/f6472 (Mp-Mh), both x 1; 10 OU 40661, Waianakarua River, North Otago, J42/f218 (Mp-Mh), height = 28.0 mm, x 1.8; 12 Ge 7655.2 (AIM), Te Opu, Q08/f9639, height = 50.5 mm, x 1.5.
Struthioptera haastiana (Wilckens, 1922) (Figures 1-8, 10-12, 17): 1 TM 7542 (IGNS), Selwyn Rapids, Canterbury, South Island, GS 589, L35/f6008 (Mp-Mh), height = 30.0 mm, x 2.6; 2 OU 40978, Shag Point, North Otago, South Island, J43/f159A (Mp-Mh), length of small block = 78.5 mm, x 1; 3 TM 7543 (IGNS), Te Hoe River, southern Hawke's Bay, North Island, GS 14260, V19/f184 (Mp-Mh), height = 29.5 mm, x 2; 4 G 27429 (BMNH; Trechmann, 1917, Pl. 19, Fig. 7), Selwyn Rapids, L35/- (Mh), x 1; 5 TM 7540 (IGNS), Selwyn Rapids, GS 589, L35/f6008 (Mp-Mh), height = 26.5 mm, x 2.7; 6 G 27428 (BMNH; Trechmann, 1917, Pl. 19, Fig. 6), Selwyn Rapids, L35/- (Mh), x 1; 7 paralectotype TM 2619 (IGNS; Wilckens, 1922, Pl. 2, Fig. 7), Selwyn Rapids, GS 589, L35/f6008 (Mp-Mh), x 1; 8 TM 7541 (IGNS), Selwyn Rapids, GS 589, L35/f6008 (Mp-Mh), height = 40.5 mm, x 1.8; 10-11 lectotype TM 2616 (IGNS; Wilckens, 1922, Pl. 2, Fig. 5a-b), Selwyn Rapids, GS 589, L35/f6008 (Mp-Mh), both x 1; 12 paralectotype TM 2617 (IGNS; Wilckens, 1922, Pl. 2, Fig. 6), McKay's Creek, Middle Waipara, GS 149, M34/f7254 (Mp-Mh), x 1; 17 TM 6877 (IGNS; Crampton and Moore, 1990, Fig. 8L), Mangahouanga Stream, southern Hawke's Bay, GS 11359, V19/f6909 (Mp-Mh), height = 31.0 mm, x 1.5.
Struthioptera novoseelandica (Wilckens, 1922) (Figures 9, 13-16, 18): 9 paralectotype TM 2621 (IGNS; Wilckens, 1922, Pl. 2, Fig. 13), Haumuri Bluff, southern Marlborough, GS 13, O32/f8025 (Mp-Mh), x 1; 13 paralectotype TM 2622 (IGNS; Wilckens, 1922, Pl. 2, Fig. 14), Haumuri Bluff, GS 13, O32/f8025 (Mp-Mh), x 1; 14 paralectotype TM 2620 (IGNS; Wilckens, 1922, Pl. 2, Fig. 12), Haumuri Bluff, GS 13, O32/f8025 (Mp-Mh), x 1; 15 paralectotype TM 2624 (IGNS; Wilckens, 1922, Pl. 2, Fig. 11), Haumuri Bluff, GS 13, O32/f8025 (Mp-Mh), x 1; 16 lectotype TM 2623 (IGNS; Wilckens, 1922, Pl. 2, Fig. 10), Haumuri Bluff, GS 13, O32/f8025 (Mp-Mh), x 1; 18 TM 7545 (IGNS), Pitt Island, Chatham Islands, GS 12152, CH/f466 (Mp-Mh), height = 19.0 mm, x 3.5.
PLATE 39

Arrhoges (Latiala) suteri (Trechmann, 1917) (Figures 1-2): 1 G 7046 (AU), Rout Point, Kaipara, Northland, AU 2564, Q08/f9669 (?Mh), height = 40.0 mm, x 2; 2 holotype G 27450 (BMNH; Trechmann, 1917, Pl. 19, Fig. 5), Selwyn Rapids, Canterbury, South Island, L35/- (Mh), x 1.5.

Conchothyra parasitica Hutton, 1877 (Figures 3-17):
3-5 OU 40980, Waimakariri River, Canterbury, L35/f6013A (Mp-Mh), height = 46.0 mm, all x 0.9; 6-8 TM 2634 (IGNS; Wilckens, 1922, Pl. 3, Fig. 2a-b, d), Selwyn Rapids, Canterbury, GS 589, L35/f6008 (Mp-Mh), all x 1; 9-10 TM 2633 (IGNS; Wilckens, 1922, Pl. 3, Fig. 1a-b), Selwyn Rapids, L35/f6008, both x 1; 11, 13 lectotype? TM 2635 (IGNS; Wilckens, 1922, Pl. 3, Fig. 3a-b), Boby's Creek, Waipara, South Island, GS 277, N34/f6257 (Mp-Mh), both x 1; 12 G 27440 (BMNH; Trechmann, 1917, Pl. 20, Fig. 4), Waimakiri River Gorge, precise locality unknown, x 1; 14 G 27441 (BMNH; Trechmann, 1917, Pl. 20, Fig. 5), Waimakiri River Gorge, precise locality unknown, x 1; 15-17 OU 40979, Waimakiri River Gorge, L35/f6013A (Mp-Mh), all x 1.
Conchothyra parasitica Hutton, 1877 (Figures 1-3): 1

TM 2636 (IGNS; Wilckens, 1922, Pl. 3, Fig. 4), Boby's Creek, Waipara, South Island, GS 277, N34/f6257 (Mp-Mh), x 1; 2-3 G 27421 (BMNH; Trechmann, 1917, Pl. 20, Fig. 3a-b (see correction in Trechmann, 1917, p. 342), Waipara Gorge, precise locality unknown, both x 1.

Conchothyra marshalli (Trechmann, 1917) (Figures 4-25): 4-7 OU 40982, Selwyn Rapids, Canterbury, South Island, OU 10980, c.L35/f6510 (Mp-Mh), height = 20.5 mm, x 2.5, x 2.5, x 2.5 and x 2 respectively; 8-10 TM 2639 (IGNS; Wilckens, 1922, Pl. 4, Fig. 1a-c), Selwyn Rapids, GS 589, L35/f6008 (Mp-Mh), all x1; 11-13 OU 40983, Selwyn Rapids, OU 10980, c.L35/f6510 (Mp-Mh), height = 22.5 mm, x 2.4, x 2 and x 2 respectively; 14 G 27416 (BMNH; Trechmann, 1917, Pl. 19, Fig. 4), Selwyn Rapids, L35/- (Mh), x 1; 15-16 TM 2640 (IGNS; Wilckens, 1922, Pl. 4, Fig. 2a-b), both x 2; 17 G 27415 (BMNH; Trechmann, 1917, Pl. 19, Fig. 3), Selwyn Rapids, L35/- (Mh), x 1; 18 G 27414 (BMNH; Trechmann, 1917, Pl. 19, Fig. 2), Selwyn River, L35/- (Mh), x 1; 19 OU 40981, Selwyn Rapids, c.L35/f6510 (Mh), height 23.0 mm, x 2; 20 lectotype G 27413 (BMNH; Trechmann, 1917, Pl. 19, Fig. 1), Selwyn Rapids, precise locality unknown, x 1; 21 OU 40987, Selwyn River, OU 10980, c.L35/f6510 (Mp-Mh), height = 19.5 mm, x 3.5; 22, 25 TM 2638 (IGNS; Wilckens, 1922, Pl. 3, Fig. 6a-b), Selwyn Rapids, GS 589, L35/f6008 (Mp-Mh), both x 1; 23-24 TM 2637 (IGNS; Wilckens, 1922, Pl. 3, Fig. 5a-b), Selwyn Rapids, GS 589, L35/f6008 (Mp-Mh), both x 1.
**PLATE 41**

*Vanikoro*? n. sp. (Figures 1-2): 1-2 Ge 7629 (AIM), Bull Point, Kaipara, Northland, Q08/f9626 (Mh), height = 5.5 mm, both x 7.5.

*Sigapatella? solitaria* Wilckens, 1922 (Figure 3): 3 lectotype TM 2610 (IGNS; Wilckens, 1922, Pl. 1, Fig. 10), Waipara, South Island, GS 277, M34/f7257 (Mp-Mh), x 1.

*Trichotropis (Cerithioderma) waimaramaensis* n. sp. (Figures 4, 11, 18): 4 holotype TM 7546 (IGNS), Waimarama, southern Hawke's Bay, North Island, GS 2566, V22/f8492 (?Mp-Mh), height = 28.5 mm, x 2.7; 11, 18 paratype TM 7547 (IGNS), Waimarama, GS 2566, V22/f8492 (?Mp-Mh), height = 19.5 mm, both x 3.3.

*Crepidula hochstetteriana* Wilckens, 1922 (Figures 5-6): 5-6 lectotype TM 2608 (IGNS; Wilckens, 1922, Pl. 1, Fig. 9a-b), Haumuri Bluff, southern Marlborough, South Island, GS 13, 032/f8025 (M-Mh), both x 1.

*cf. Capulus? sulcatus* wilckens, 1910 (Figures 7-8): 7-8 G 7047 (AU), Bull Point, Kaipara, AU 2574, Q08/f9909 (Mh), height = 8.5 mm, x 4.
Euspira selwyniana (Wilckens, 1922) (Figures 9-10, 12-17, 19-25):
9-10 G 27422 (BMNH; Trechmann, 1917, Pl. 19, Fig. 8a-b), Selwyn Rapids, L35/- (Mh), both x 1; 12 TM 6879 (IGNS; Crampton and Moore, 1990, Fig. 8N), Te Hoe River, southern Hawke's Bay, GS 14260, V19/f184 (Mp-Mh), height = 12.0 mm, x 2.7; 13, 16 G 27423 (BMNH; Trechmann, 1917, Pl. 19, Fig. 9a-b), Selwyn Rapids, L35/- (Mh), both x 1; 14, 20 G 27424 (BMNH; Trechmann, 1917, Pl. 19, Fig. 10a-b), Selwyn Rapids, L35/- (Mh), both x 1.5; 15 OU 40984, Barron's Hill, Otago, South Island, c. I45/f8510 (Mh), height = 9.5 mm, x 4.3; 17 TM 7549 (IGNS), Te Hoe River, GS 14260, V19/f184 (Mp-Mh), height = 10.0 mm, x 5.5; 19 TM 7548 (IGNS), Te Hoe River, GS 14260, V19/f184 (Mp-Mh), height = 15.5 mm, x 3.8; 21-23 TM 2611 (IGNS; Wilckens, 1922, Pl. 2, Fig. 2a-c), Selwyn Rapids, GS 589, L35/f6008 (Mp-Mh), all x 1; 24-25 TM 2612 (IGNS; Wilckens, 1922, Pl. 2, Fig. 1a-b), Selwyn Rapids, GS 589, L35/f6008 (Mp-Mh), both x 1.
Eunaticina? omapereensis n. sp. (Figures 1, 3, 6): 1, 3 holotype TM 7550 (IGNS), Lake Omapere, North Auckland, North Island, GS 6027, P05/f9646 (Mp-Mh), height = 30.0 mm, both x 2.1; 6 paratype TM 7551 (IGNS), Lake Omapere, GS 6027, P05/f9646 (Mp-Mh), height = 29.0 mm, x 2.4.

Amauropsona? n. sp. (figures 2, 4): 2 Ge 8144 (AIM), Te Opu, Kaipara, Northland, Q08/f9639 (Mh), height = 8.0 mm, x 2.8; 4 G 7048 (AU), Te Opu, AU 2553, Q08/f9639 (Mh), height = 5.0 mm, x 6.8.

Naticidae gen. et sp. indet. (Figures 5, 7-8, 12): 5 TM 7553 (IGNS), Waimarama, southern Hawke's Bay, North Island, GS 4894, W22/f8499 (Mp-Mh), height = 11.5 mm, x 5.1; 7 TM 7552 (IGNS), Waimarama, GS 4894, W22/f8499 (Mp-Mh), Manu Creek, North Island, GS 1087, Z14/f8492 (Mp-Mh), height = 8.5 mm, x 6.6 and x 5.8 respectively.

Acirsa (Notacirsa?) pacifica (Wilckens, 1922) (Figures 9, 13): 9 TM 7556 (IGNS), Haumuri Bluff, southern Marlborough, South Island, GS 13, O32/f8025 (Mp-Mh), height = 13.0 mm, x 5; 13 lectotype TM 2615 (IGNS; Wilckens, 1922, Pl. 2, Fig. 3), Haumuri Bluff, GS 13, O32/f8025 (Mp-Mh), x 1.

Opalia cramptoni n. sp. (Figures 10-11): 10-11 holotype TM 7557 (IGNS), Waimarama, southeastern North Island, GS 2566, V22/f8492 (?Mp-Mh), height = 15.5 mm, x 4.5 and x 4 respectively.

"Cryptorhytis" vulnerata Wilckens, 1922 (Figures 14-15): 14-15 lectotype TM 2652 (IGNS; Wilckens, 1922, Pl. 4, Fig. 13a-b), Selwyn Rapids, GS 589, L35/f6008 (Mp-Mh), x 1.

Perissitys? sp. (Figures 16-17): 16-17 Ge 7651 (AIM), Te Opu, Kaipara, Q08/f9639 (Mh), height = 34.5 mm, x 1.6.
Sycostoma notiale n. sp. (Figures 1-4): holotype TM 7558 (IGNS), Kaipara Harbour, Northland, precise locality unknown, probably Bull Point, c. Q08/f9626 (Mh), height = 52.5 mm, x 1.7; 2-3 paratype G 7049 (AU), Bull Point, Kaipara, AU 2571, Q08/f9626 (Mh), height = 55.0 mm, both x 1.7; 4 paratype Ge 7891 (AIM), Bull Point, Q08/f9626 (Mh), height = 53.5 mm, x 1.5.

Pseudoperissolax? similis (Wilckens, 1922) (Figures 5-7, 12-15, 18-19): 5 paralectotype TM 2654 (IGNS; Wilckens, 1922, Pl. 4, Fig. 11), Haumuri Bluff, southern Marlborough, South Island, GS 13, O32/f8025 (Mp-Mh), x 1; 6 paralectotype TM 2657 (IGNS; Wilckens, 1922, Pl. 4, Fig. 7), Haumuri Bluff, GS 13, O32/f8025 (Mp-Mh), x 1; 7 paralectotype TM 2659 (IGNS; Wilckens, 1922, Pl. 4, Fig. 6), Haumuri Bluff, GS 13, O32/f8025 (Mp-Mh), x 1; 12 paralectotype TM 2655 (IGNS; Wilckens, 1922, Pl. 4, Fig. 10), Haumuri Bluff, GS 13, O32/f8025 (Mp-Mh), x 1; 13-14 lectotype TM 2658 (IGNS; Wilckens, 1922, Pl. 4, Fig. 8), Haumuri Bluff, GS 13, O32/f8025 (Mp-Mh), height = 9.0 mm, x 1 and x 5.3 respectively; ?15 G 7052 (AU), Bull Point, AU 2580, Q08/f9626 (Mh), height = 61.0 mm, x 1; 18-19 paralectotype TM 2656 (IGNS; Wilckens, 1922, Pl. 4, Fig. 9a-b), Haumuri Bluff, GS 13, O32/f8025 (Mp-Mh), both x 1.

Saulopsis? n. gen. n. sp. (Figures 8-10, 16): 8-9, 16 TM 2660 (IGNS; Wilckens, 1922, Pl. 4, Fig. 12a-b), Selwyn Rapids, Canterbury, South Island, GS 23, L35/f6017 (Mp-Mh), height = 28.0 mm, x 1, x 1, and x 1.8 respectively; 10 G 7050 (AU), Bush Gully, Coalgate, Canterbury, AU 484, L35/f6646 (Mp-Mh), height = 30.0
Tudicidae gen. et sp. indet. (Figures 11, 17): 11, 17 TM 7754 (IGNS), Waimarama, southern Hawke's Bay, precise locality unknown, height = 38.5 mm, x 1.3 and x 1.0 respectively.
PLATE 44

Tudiclidaceae? gen. et sp. indet. (* = ?Tudicla biangulata* of Hector, 1886) (Figure 1): 1 OU 41266, Fairfield Quarry, Otago, South Island, I44/f127 (Mh), height = c. 50.0 mm, x 1.

Tornatellaea evansi n. sp. (figures 2-5): 2-3 holotype Ge 7669 (AIM), Te Opū, Kaipara, Northland, Q08/f9639 (Mh), height = 10.0 mm, both x 3; 4 paratype Ge 8141.2 (AIM), Te Opū, Q08/f9639 (Mh), height = 7.5 mm, x 4.5; 5 paratype Ge 8141.1 (AIM), Te Opū, Q08/f9639 (Mh), height = 12.5 mm, x 1.5.

Eriptycha punamanutica Wilckens, 1922 (Figures 6-15, 18-20, 23-24): 6, 7-9, 12 lectotype TM 2674 (IGNS; Wilckens, 1922, Pl. 5, Fig. 5a-c), Haumuri Bluff, southern Marlborough, South Island, GS 13, O32/f8025 (Mp-Mh), x 6.5, x 1, x 1, x 1 and x 6.5 respectively; 10-11 Ge 8139.1 (AIM), Te Opū, Q08/f9639 (Mh), height = 7.5 mm, both x 3.3; 13 OU 40985, Fairfield Quarry, c. I44/f127, height = 11.0 mm, x 3.3; 14, 23-24 Ge 8137.1 (AIM), Te Opū, Q08/f9639 (Mh), height = 6.5 mm, x 7.5, x 25 (SEM) and x 30 (SEM) respectively; 15 TM 7559 (AIM), Waitangi River, Northland, GS 1175, P05/f9499 (Mp-Mh), height = 9.0 mm, x 6; 18 Ge 7638 (AIM), Bull Point, Kaipara, Q08/f9626 (Mh), height = 3.5 mm, x 26 (SEM); 20 G 7053 (AU), Bull Point, AU 1716, Q08/f9626 (Mh), height = 12.5 mm, x 3.

n. gen.? aff. Aplustrum selwynensis Trechmann, 1917 (Figures 16-17, 19, 21-22): 16 G 27433 (BMNH; Trechmann, 1917, Pl. 21, Fig. 2), Selwyn Rapids, L35/- (Mh) x 1; 17, 21 G 27432 (BMNH; Trechmann, 1917, Pl. 21, Fig. 3a-b), Selwyn Rapids, L35/- (Mh), x 3 and x 1.5 respectively; 19 TM 7562 (IGNS), Selwyn Rapids, GS 2157, L35/f6510 (Mp-Mh), x 2.3; 22 lectotype G 27431 (BMNH; Trechmann, 1917, Pl. 21, Fig. 1), Selwyn Rapids, L35/- (Mh), x 1.
PLATE 45

Ringicula s. s. zigzagia n. sp. (Figures 1-8): 1-3, 5-8 holotype Ge 8140.1 (AIM), Te Opu, Kaipara, Northland, Q08/f9639 (Mh), height = 7.5 mm, x 2.8, x 2.8, x 2.8, x 37 (SEM, spiral sculpture), x 185 (SEM, greatly magnified view of zigzag sculpture), x 14.5 (SEM), and x 14.5 (SEM); 4 paratype TM 7560 (IGNS), Nedler's Point, Whangaroa, Northland, GS 6959, P04/f9499 (Mh), height = 7.0 mm, x 9.

Gastropoda (Buccinidae?) gen. indet. n. sp. (Figures 9, 11): 9, 11 G 7056 (AU), Te Opu, Kaipara, AU 2553, Q08/f9639 (Mh), height = 5.5 mm, x 6.

Cylichnania thomsoniana (Wilckens, 1922) (Figures 10, 13, 16-17): 10 TM 6876 (IGNS; Crampton and Moore, 1990, Fig. 8K), Mangahouanga Stream, southern Hawke's Bay, North Island, GS 14260, V19/f184 (Mp-Mh), height = 19.0 mm, x 2.3; 13 TM 2671 (IGNS; Wilckens, 1922, Pl. 5, Fig. 6), Haumuri Bluff, southern Marlborough, South Island, GS 13, O32/f8025 (Mp-Mh), x 1; 16 Ge 7671.1 (AIM), Te Opu, Kaipara, Q08/f9639 (Mh), height = 5.5 mm, x 6.5; 17 lectotype TM 2653 (IGNS; Wilckens, 1922, Pl. 5, Fig. 7), Haumuri Bluff, GS 13, O32/f8025, x 1.

Odostomia? paleozelandica n. sp. (Figures 12, 14-15, 18): 12, 14 holotype Ge 7903 (AIM), Bull Point, Kaipara, Q08/f9626 (Mh), height = 4.5 mm, x 44 (SEM) and x 15.5 (SEM) respectively; 15, 18 paratype G 7055 (AU), Te Opu, Kaipara, AU 2553, Q08/f9639 (Mh), height = 4.5 mm, x 8.5 and x 10 respectively.
PLATE 46

*Cylichnania thomsoniana* (Wilckens, 1922) (Figures 1-3, 5-6): 1 TM 7561 (IGNS), Totara Point, Whangaroa, Northland, GS 750, P04/f9497 (?Mh), height = 18.0 mm, x 3.8; 2-3, 5-6 Ge 7628.1 (AIM), Bull Point, Kaipara, Q08/f9626 (Mh), x 47 (SEM, spiral sculpture), x 17 (SEM), x 100 (SEM, magnified view of 2), and x 17 (SEM) respectively (juvenile?).

*Dentalium (Laevidentalium) morganianum* (Wilckens, 1922) (Figures 4, 7-11, 13): 4, Ge 8617 (AIM), Hukatere Peninsula, Northland, Q08/f9660 (Mh), length = 7.5 mm, x 6.3; 7 TM 7760 (IGNS), Haumuri Bluff, southern Marlborough, South Island, GS 13, 032/f8025 (Mp-Mh), length = 57.5 mm, x 1.3; 8 TM 2675 (IGNS; Wilckens, 1922, Pl. 5, Fig. 8), Haumuri Bluff, GS 5, 032/f9027 (M-Mh), x 1; 9 lectotype TM 2677 (IGNS; Wilckens, 1922, Pl. 5, Fig. 9), Haumuri Bluff, GS 13, 032/f8025 (M-Mh), x 1; 10 TM 6875 (IGNS; Crampton and Moore, 1990, Fig. 8J), GS 11359, V19/f6909 (M-Mh), length = 29.0 mm, x 2.2; 11 M 145 (AU), Bull Point, AU 2574, Q08/f9909? (Mh), length = 13.5 mm, x 3.7; 13 M 144 (AU), Te Opu, Kaipara, AU 2553, Q08/f9639 (Mh), length = 10.0 mm, x 5.8.

*Antalis grantmackiei* n. sp. (Figure 12): 12 holotype Ge 7905 (AIM), Bull Point, Q08/f9626 (Mh), length = 13.5 mm, x 4.
PLATE 47

Leionucula palaioanaxea Stilwell, 1993 (Figures 1-5): 1 holotype OU 39604, Mitchells Rocks, Wangaloa, southeastern Otago, South Island, H46/f166A (Dwg), length = 9.5 mm, x 4; 2 paratype OU 39606, Mitchells Rocks, Wangaloa, H46/f166A (Dwg), length = 10.0 mm, x 5.5; 3 paratype OU 39640, Mitchells Rocks, Wangaloa, H46/f166A (Dwg), length = 7.5 mm, x 12 (SEM); 4-5 paratype TM 4095 (IGNS), Boulder Hill, Otago, GS 10195, I44/f8486 (Dwg), length = 3.2, both x 2.

Leionucula cf. L. palaioanaxea Stilwell, 1993 (Figure 6): 6 TM 7573 (IGNS), Dunrobin Road, North Otago, GS 3804, J41/f8675 (Dwg), length = 6.5 mm, x 4.5.

Varinucula? n. sp. (Figure 7): 7 TM 7572 (IGNS), Kaiwhata River, southern North Island, GS 6314, T27/f6728 (mid to upper Dt), length = 2.5 mm, x 21 (SEM).

Linucula austrobullata n. sp. (Figures 8-9): 8 holotype TM 7570 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), length = 3.0 mm, x 9; 9 paratype TM 7571 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), length = 3.0 mm, x 5.5.

Jupiteria maxwelli n. sp. (Figures 10-14): 10 holotype TM 7574 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), length = 6.5 mm, x 5; 11 paratype TM 7576 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), length = 4.5 mm, x 8.5; 12 paratype TM 7580 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), length = 4.0 mm, x 7; 13 paratype TM 7575 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), length = 4.5 mm, x 13 (SEM); 14 TM 7578 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), length = 4.5 mm, x 5.5.
**Jupiteria** n. sp.? (figures 15, 17-18): 15 TM 7581 (IGNS), Kaiwhata River, GS 6314, T27/f6728 (mid to upper Dt), length = 5.5 mm, x 5; 17-18 TM 7582 (IGNS), Kaiwhata River, GS 6314, T27/f6728 (Dwg), length = 6.0 mm, x 6.3.

**Ledina taioma** (Finlay and Marwick, 1937) (Figures 16, 19-20): 16 holotype TM 4103 (IGNS), Boulder Hill, I44/f8486 (Dwg), length = 13.0 mm, x 4; 19 paratype TM 4104 (IGNS; Finlay and Marwick, 1937, Pl. 1, Fig. 6--specimen subsequently too damaged for photography), Boulder Hill, I44/f8486 (Dwg), x 6; 20 OU 41160, Mitchells Rocks, Wangaloa, H46/f166A (Dwg), length = 11.5 mm, x 6.
PLATE 48

Spineilo elongata (Marshall, 1917) (Figures 1-4, 6-8): 1 OU 40999, Mitchells Rocks, Wangaloa, southeastern Otago, South Island, H46/f166B (Dwg), length = 32.0 mm, x 2.3; 2-3, 6 OU 11162, Wangaloa, H46/f9552 (Dwg), length = 23.5 mm, x 4.5, x 2.3, and x 2.3 respectively; 4 OU 41162, Mitchells Rocks, Wangaloa, H46/f116B (Dwg), length = 23.0 mm, x 2.3; 8 holotype C 75.3 (OM), Wangaloa, ?H46/f9500 (Dwg), x 2.4.

Neilo n. sp. (Figure 5): 5 TM 7583 (IGNS), Kaiwhata River, southern North Island, GS 6314, T27/f6728 (mid to upper Dt), length = 18.5 mm, x 2.5.

Cucullaea (Cucullona) inarata Finlay and Marwick, 1937 (Figures 9-12): 9-10 holotype TM 225 (AIM), Boulder Hill, Otago, I44/f8486 (Dwg), length = 68.0 mm, both x 1; 11-12 TM 225-2 (AIM), Boulder Hill, I44/f8486 (Dwg), length = 56.0 mm, both x 1.
PLATE 49

Cucullaea (Cucullona) inarata Finlay and Marwick, 1937 (Figures 1-4): 1-2 paratype TM 4123 (IGNS), Boulder Hill, Otago, South Island, GS 10195, I44/f8486 (Dwg), length = 79.5 mm, both x 1; 3-4 paratype TM 7305 (IGNS), Boulder Hill, GS 10195, I44/f8486 (Dwg), length = 71.0 mm, both x 1.

Cucullaea (Cucullona?) dunrobinensis n. sp. (Figures 5-11): 5, 8 paratype TM 7586 (IGNS), Dunrobin Road, North Otago, GS 3804, J41/f8675 (Dwg), length = 13.0 mm, both x 3.5 (juvenile); 6 TM 7588 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), length = 8.5 mm, x 5; 7 paratype TM 7587 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), length = 11.0 mm, x 3.3; 9-11 holotype TM 7585 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), length = 25.5 mm, x 1.5, x 1.5 and x 2.8 respectively.
PLATE 50

Cucullaea (Cucullastis) barbara Finlay and Marwick, 1937 (Figures 1-4): 1-2 paratype TM 224.2 (AIM), Boulder Hill, Otago, South Island, I44/f8486 (Dwg), x 1.1; 3-4 holotype TM 224 (AIM; Finlay and Marwick, 1937, Pl. 1, Fig. 16), Boulder Hill, I44/f8486 (Dwg), length = 72.5 mm, x 1.1.

Limopsis (Limopsista) microps Finlay and Marwick, 1937 (Figures 5-9): 5-6 holotype TM 4175 (IGNS), Mitchells Rocks, Wangaloa, southeastern Otago, H46/f9500 (Dwg), length = 5.0, both x 6.5; 7 OU 41163, Mitchells Rocks, Wangaloa, H46/f166 (Dwg), length = 4.3 mm, x 7; 8-9 OU 41165, Mitchells Rocks, Wangaloa, H46/f166 (Dwg), length = 4.5 mm, x 8 (SEM) and x 20 (SEM) respectively.

Glycymerita s. s. concava (Marshall, 1917) (Figures 10-12): 10 holotype C 78.3 (OM), Wangaloa, H46/f9500 (Dwg), length = 41.0 mm, x 1; 11 TM 7589 (IGNS), Dunrobin Road, North Otago, GS 3804, J41/f8675 (Dwg), length = 9.0 mm, x 4.3; 12 OU 41167, Mitchells Rocks, Wangaloa, H46/f166A (Dwg), length = 51.5 mm, x 0.9.
PLATE 51

**Glycymerita s. s. concava** (Marshall, 1917) (Figures 1-4): 1-2 TM 7458 (IGNS), Boulder Hill, Otago, South Island, GS 10195, I44/f8486 (Dwg), x 1.2; 3 TM 7590 (IGNS), Dunrobin Road, North Otago, GS 3804, J41/f8675 (Dwg), length = 30.0 mm, x 2.1; 4 paratype TM 4149 (IGNS), Wangaloa, H46/f9500 (Dwg), length = 62.5 mm, x 0.7.

**Septifer? alata** n. sp. (Figures 5-7): 5 paratype TM 7592 (IGNS), Raupo Creek, North Otago, GS 3773, J41/f8640 (Dwg), height = 6.5 mm, x 3; 6 holotype TM 7591 (IGNS), Raupo Creek, GS 3773, J41/f8640 (Dwg), height = 8.0 mm, x 3.6; 7 paratype TM 7593 (IGNS), Raupo Creek, GS 3773, J41/f8640 (Dwg), length = 13.5 mm, x 2.5.

**Electroma (Pterelectroma) intecta** (Finlay and Marwick, 1937) (Figures 8-13): 8-9 holotype TM 258 (AIM), Boulder Hill, I44/f8486 (Dwg), length = 6.0 mm, both x 6.3; 10 paratype TM 4185 (IGNS), Mitchells Rocks, Wangaloa, GS 760, H46/f9500 (Dwg), length = 4.0 mm, x 6.5; 11 OU 41170, Mitchells Rocks, Wangaloa, H46/f166A (Dwg), length = 2.5 mm, x 9; 12 OU 41171, Mitchells Rocks, Wangaloa, H46/f166A (Dwg), length = 2.5 mm, x 9; 13 OU 41168, Mitchells Rocks, Wangaloa, H46/f166A (Dwg), length = 2.0 mm, x 11.

**Isognomon s. s. wellmani** Crampton, 1988 (Figures 14-17): 14-15 holotype TM 6689 (IGNS; Crampton, 1988, Pl. 88, Figs. 1 (internal mold of left valve), 9 (latex mold of ligament area), Broken River, Canterbury, South Island, GS 14183, K34/f48 (Dwg), x 1.3 and x 0.7 respectively; 16 paratype TM 6690 (IGNS; Crampton, 1988, Pl. 88, Fig. 2), Broken River, GS 14183, K34/f48 (Dwg), x 0.7; 17 OU 40544, Broken River, c. K34/f48 (Dwg), height = 68.5 mm, x 0.8.
PLATE 52

Chlamys s. l. raupoensis n. sp. (Figures 1-2): 1 holotype TM 7594 (IGNS), Raupo Creek, North Otago, GS 3772, J41/f8639 (Dwg), length = 10.0 mm, x 2.8; 2 paratype TM 7595 (IGNS), Raupo Creek, GS 3773, J41/f8640 (Dwg), length = 8.5 mm, x 4.5.

Anomia sp. (Figure 3): 3 TM 7596 (IGNS), Kaiwhata River, southern North Island, GS 6314, T27/f6728 (mid to upper Dt), length = 17.0 mm, x 2.8.

Pycnodonte (Notostrea?) sp. (figures 4, 7): 4, 7 TM 7597 (IGNS), Boulder Hill, Otago, I44/f8486 (Dwg), length = 33.5 mm, x 1.

Ostrea n. sp.? (Figures 5-6, 8-9): 5 TM 7598 (IGNS), Raupo Creek, GS 3772, J41/f8639 (Dwg), length = 8.0 mm, x 3.3; 6 TM 7599 (IGNS), Raupo Creek, GS 3772, J41/f8639 (Dwg), length = 9.5 mm, x 3.3; 8 TM 7600 (IGNS), Raupo Creek, GS 3773, J41/f8640 (Dwg), length = 8.5 mm, x 3.3; 9 TM 7601 (IGNS), Raupo Creek, GS 3773, J41/f8640 (Dwg), length = 17.5 mm, x 2.7.

Pteromyrtea obesa Finlay and Marwick, 1937 (Figures 10-11): 10 holotype TM 646 (AIM), Boulder Hill, I44/f8486 (Dwg), length = 12.0 mm, x 3.8; 10 TM 7306 (IGNS), Boulder Hill, GS 10195, I44/f8486 (Dwg), length = 9.0 mm, x 4.

Pteromyrtea modica n. sp. (Figures 12-16): 12-13 paratype TM 7605 (IGNS), Dunrobin Road, North Otago, GS 3804, J41/f8675 (Dwg), height = 16.0 mm, both x 3; 14 TM 7606 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), height = 13.0 mm, x 5; 15 TM 7603 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), length = 18.0 mm, x 3.3; 16 holotype TM 7602 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), length = 16.5 mm, x 3.3.
Miltha agilis Finlay and Marwick, 1937 (Figures 1-5): 1 holotype TM 474 (AIM), Boulder Hill, Otago, South Island, I44/f8486 (Dwg), length = 26.0 mm, x 1.9; 2-3 paratype TM 4349 (IGNS), Boulder Hill, I44/f8486 (Dwg), length = 13.0 mm, x 3 and x 3.4 respectively; 4 OU 41172, Mitchells Rocks, Wangaloa, southeastern Otago, H46/f166A (Dwg), length = 29.0 mm, x 1.8; 5 OU 41173, Mitchells Rocks, Wangaloa, H46/f166A (Dwg), length = 34.0 mm, x 1.8.

Myrtea microlirata (Finlay and Marwick, 1937) (Figures 6-9): 6 OU 41175, Mitchells Rocks, Wangaloa, H46/166A (Dwg), length = 5.5 mm, x 5; 7 paratype TM 4356 (IGNS), Boulder Hill, GS 10195, I44/f8486 (Dwg), length of hinge = 3.5 mm, x 7; 8 OU 41174, Mitchells Rocks, Wangaloa, H46/f166A (Dwg), length = 8.5 mm, x 4.4; 9 OU 41176, Mitchells Rocks, Wangaloa, H46/f166A (Dwg), length = 7.5 mm, x 5.8.

Thyasira (Conchocele) n. sp. (figures 10-11): 10-11 TM 7610 (IGNS), Wimbledon, southern Hawke's Bay, North Island, GS 14019, U24/f281 (mid to upper Dt), length = 64.0 mm, x 1 and x 0.7 x respectively.

Thasira? sp. (figure 12): 12 TM 7609 (IGNS), Kaiwhata River, southern North Island, GS 6314, T27/f6728 (mid to upper Dt), length = 16.5 mm, x 3.

Kellia? paleocenica n. sp. (figures 13-14): 13 paratype OU 41179, Mitchells Rocks, Wangaloa, H46/f116B (Dwg), length = 7.0 mm, x 7.5; 14 holotype OU 41178, Mitchells Rocks, Wangaloa, H46/f116B (Dwg), length = 7.0 mm, x 5.9.
Purpurocardia fyfei (Finlay and Marwick, 1937) (Figures 15-17): 15-16 holotype TM 821 (AIM), Boulder Hill, I44/f8486 (Dwg), length = 50.0 mm, both x 1; 17 OU 41181, Mitchells Rocks, Wangaloa, H46/f116B (Dwg), length = 43.0 mm, x 1.1.
PLATE 54

**Purpurocardia fyfei** (Finlay and Marwick, 1937) (figures 1-7): 1, 4 paratype TM 7612 (IGNS), Boulder Hill, Otago, South Island, GS 10195, I44/f8486 (Dwg), length = 37.5 mm, x 1.2 and x 1.7 respectively; 2 OU 41180, Boulder Hill, OU 5730, c. I44/f8486 (Dwg), length = 37.0 mm, x 1.9; 3 TM 7613 (IGNS), Dunrobin Road, North Otago, GS 3804, J41/f8675 (Dwg), length = 18.0 mm, x 3; 5-6 paratype TM 7611 (IGNS), Boulder Hill, GS 10195, I44/f8486 (Dwg), length = 45.0 mm, x 1 and x 1.4 respectively; 7-8 paratype TM 4314 (IGNS), Boulder Hill, GS 10195, I44/f8486 (Dwg), length = 33.5 mm, x 1.9 and x 1.3 respectively.

**Nemocardium (Pratulum) modicum** Marwick, 1944 (figures 9-17): 9 TM 7615 (IGNS), Dunrobin Road, North Otago, GS 3804, J41/f8675 (Dwg), length = 12.0 mm, x 3.3; 10 OU 41182, Mitchells Rocks, Wangaloa, southeastern Otago, H46/f116B (Dwg), length = 9.5 mm, x 3.7; 11 TM 7616 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), length = 15.5 mm, x 2.7; 12 TM 7614 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), length = 4.5 mm, x 6.2; 13 OU 41185, Mitchells Rocks, Wangaloa, H46/f116B (Dwg), length = 10.0 mm, x 5; 14 OU 41183, Mitchells Rocks, Wangaloa, H46/f116B (Dwg), length = 7.5 mm, x 3.8; 15 OU 41184, Mitchells Rocks, Wangaloa, H46/f116B (Dwg), length = 6.5 mm, x 3.3; 16-17 holotype TM 4497 (IGNS; Marwick, 1944, Pl. 36, Figs. 17-18), Boulder Hill, GS 10195, I44/f8486 (Dwg), x 3 and magnification not specified.
Lahillia neozelanica Marshall and Murdoch, 1923 (figures 1-8): 1, 3 OU 41186, Mitchells Rocks, Wangaloa, southeastern Otago, South Island, H46/f166A (Dwg), length = 88.0 mm, both x 1; 2 lectotype TM 4505 (IGNS), Wangaloa, H46/f9500 (Dwg), length = 60.0 mm, x 1; 4 TM 7309 (IGNS), Boulder Hill, Otago, I44/f8486 (Dwg), length = 73.0 mm, x 1.4; 5, 8 TM 4508 (IGNS), Wangaloa, H46/f9500 (Dwg), length = 77.0 mm, both x 1; 6-7 TM 4509 (IGNS), Boulder Hill, GS 10195, I44/f8486 (Dwg), length = 65.5 mm, both x 1.4.
Maorimactra perialla n. sp. (Figures 1-4, 7): 1 holotype TM 7617 (IGNS), Dunrobin Road, North Otago, GS 3804, J41/f8675 (Dwg), length = 8.0 mm, x 5.5; 2 paratype TM 7618 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), length = 6.5 mm, x 6.8; 3 paratype TM 7622 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), length = 5.5 mm, x 5.8; 4 paratype TM 7619 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), length = 5.0 mm, x 3; 7 paratype TM 7621 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), length = 9.0 mm, x 3.8.

Mactra s. l. praeobtusa (Finlay and Marwick, 1937) (figures 5-6, 8): 5-6 holotype TM 4510 (IGNS), Wangaloa, H46/f9500 (Dwg), length = 35.0 mm, both x 1.5; 8 OU 41187, Mitchells Rocks, Wangaloa, H46/f148A (Dwg), length = 36.0 mm, x 1.5.

Aphrodina (Tikia) lepra n. sp. (Figures 9, 11-12): 9, 11-12 holotype OU 39556, Mitchells Rocks, Wangaloa, H46/f116B (Dwg), length = 34.0 mm, x 3, x 2 and x 2 respectively.

Gari tokomairiroensis n. sp. (Figure 10): 10 holotype TM 7623 (IGNS), Tokomairiro River Mouth, Wangaloa, GS 3815, H46/f9508 (Dwg), length = 40.5 mm, x 2.

Marwickia parthiana (Marwick, 1927) (Figures 13-17): 13 OU 41188, Measly Beach, Wangaloa, H46/f9552A (Dwg), length of hinge = 22.5 mm, x 2.5; 14, 17 holotype TM 323 (AIM), Boulder Hill, Otago, South Island, I44/f8486 (Dwg), length = 43.0 mm, both x 1.2; 15-16 paratype TM 4589 (IGNS), Boulder Hill, Otago, South Island, GS 10195, I44/f8486 (Dwg), length = 32.5 mm, x 2 and x 1.3 respectively.
PLATE 57

**Dosinia (Dosinobia) ongleyi** (Marwick, 1927) (Figures 1-5): 1-2
holotype TM 4591 (IGNS), Mitchells Rocks, Wangaloa, southeastern Otago, South Island, GS 887, H46/f9500 (Dwg), length = 16.0 mm, x 4 and x 2.9 respectively; 3 TM 7625 (IGNS), Dunrobin Road, North Otago, GS 3804, J41/f8675 (Dwg), length = 14.0 mm, x 3.4; 4 TM 7626 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), length = 13.0 mm, x 3.6; 5 TM 7624 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), length = 12.0 mm, x 3.3.

**Dosinia (Kereia?) n. sp.** (Figure 6): 6 holotype TM 4693 (IGNS), Boulder Hill, I44/f8486 (Dwg), length = 32.0 mm, x 1.

**Dosinia (Dosinobia) perplexa** (Marwick, 1927) (Figures 7-8): 7-8
holotype TM 4593 (IGNS), Wangaloa, GS 887A, H46/f9500 (Dwg), length = 21.0 mm, x 3 and x 1.9 respectively.

**Panopea n. sp.? aff. P. worthingtoni** Hutton, 1873 (figures 9-15):
9 OU 41193, Mitchells Rocks, Wangaloa, H46/f148B (Dwg), length = 46.0 mm, x 1.5; 10 TM 4777 (IGNS), Measly Beach, Wangaloa, GS 280, H46/f9500 (Dwg), length = 36.0 mm, x 1.5; 11 OU 41192, Mitchells Rocks, Wangaloa, c. H46/f116 (Dwg), length = 52.0 mm, x 1.3; 12 OU 41189, East Taieri, Otago, I44/f8516 (Dwg), length = 58.0 mm, x 1; 13-14 OU 41191, Measly Beach, c. H46/f9552 (Dwg), length = 74.0 mm, x 1; 15 OU 41190, Kakanui River, North Otago, J41/f224 (Dwg), length = 67.0 mm, x 1.
PLATE 58

Conominolia conica (Marshall, 1917) (Figures 1-3, 5, 7): 1-2
holotype C75.9 (OM), Wangaloa, southeastern Otago, c. H46/f9500
(Dwg), height = 6.5 mm, both x 6; 3, 5, 7 OU 41194, Mitchells
Rocks, Wangaloa, H46/f148A (Dwg), height = 6.5 mm, x 34 (SEM,
sculpture), x 4.5 (SEM), and x 24 (SEM, spire).

Bolma (Ormastralium) eoaustralicus n. sp. (Figures 4, 6): 4
paratype TM 7761 (IGNS), Raupo Creek, North Otago, GS 3773,
J41/f8640 (Dwg), diameter of last whorl 3.5 mm, x 8.5; 6 holotype
TM 7627 (IGNS), Raupo Creek, North Otago, GS 3773, J41/f8640
(Dwg), height = 5.0 mm, x 3.5.

Bittiscala simplex (Marshall, 1917) (figures 8-12, 14-15): 8 TM
7631 (IGNS), Boulder Hill, GS 10195, I44/f8486 (Dwg), height =
8.5 mm, x 7; 9-10 TM 103 (AIM), Boulder Hill, I44/f8486 (Dwg),
height = c. 12.0 mm, both x 9; 11 holotype C75.16 (OM), Wangaloa,
c. H46/f9500 (Dwg), height = 12.0 mm, x 3.7 (specimen
subsequently broken); 12 OU 41195, Mitchells Rocks, Wangaloa,
H46/f166A (Dwg), height = 4.5 mm, x 6; 14-15 TM 6696 (IGNS),
Boulder Hill, GS 10194, I44/f8486 (Dwg), height = 16.25 mm, both
x 3.1.

Colposigma mesalia Finlay and Marwick, 1937 (Figures 13, 16-21):
13 paratype TM 5377 (IGNS), Boulder Hill, GS 10194, I44/f8487
(Dwg), height = 3.5 mm, x 7.5; 16-17 holotype TM 5376 (IGNS),
Wangaloa, H46/f9500 (Dwg), height = 15.0 mm, both x 3.7; 18 OU
41196, Mitchells Rocks, Wangaloa, H46/f166A (Dwg), height = 15.0
mm, x 3.9; 19 OU 41197, Mitchells Rocks, Wangaloa, H46/f166A
(Dwg), height = 10.5 mm, x 6; 20 TM 7628 (IGNS), Dunrobin Road,
North Otago, GS 3804, J41/f8675 (Dwg), height = 11.0 mm, x 4.6;
21 OU 41264, Mitchells Rocks, Wangaloa, H46/f148A (Dwg), height =
7.0 mm, x 7.5.
Zeacolpus (Leptocolpus) semiconcavus (Suter, 1911) (Figures 1-7, 10-11): 1-2 TM 4433 (IGNS), Boulder Hill, Otago, South Island, GS 10194, I44/f8487 (Dwg), height = 88.0 mm, both x 1; 3 holotype TM 4475 (IGNS), Wangaloa, southeastern Otago, H46/f9500 (Dwg), height = 67.5 mm, x 0.8; 4, 11 TM 4434 (IGNS), Boulder Hill, GS 10194, I44/f8487 (Dwg), height = 65.5 mm, both x 0.9; 5 OU 41198, Mitchells Rocks, Wangaloa, H46/f166A (Dwg), height = 29.0 mm, x 2; 6 TM 7634 (IGNS), Raupo Creek, North Otago, GS 3773, J41/f8640 (Dwg), height = 15.5 mm, x 3.5; 7 OU 41199, Mitchells Rocks, Wangaloa, H46/f166B, height = 34.5 mm, x 1.8; 10 paratype TM 4476 (IGNS), Wangaloa, H46/f9500 (Dwg), height = 39.5 mm, x 1.3.

Spirocolpus globulus n. sp. (Figures 8-9, 12-14, 16): 8, paratype TM 7630 (IGNS), Dunrobin Road, North Otago, GS 3804, J41/f8675 (Dwg), height = 12.5 mm, x 3.5; 9 paratype TM 7631 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), height = 13.25 mm, x 3.5; 12 paratype TM 7633 (IGNS), Dunrobin Road, North Otago, GS 3804, J41/f8675 (Dwg), height = 7.0 mm, x 15 (SEM, sculpture); 13-14 holotype TM 7629 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), height = 21.0 mm, x 3.5 and x 3 respectively; 16 paratype TM 7632 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), height = 8.0 mm, x 5.5.

Drepanocheilus (Tulochilus) bensoni Finlay and Marwick, 1937 (Figures 15, 17-18): 15 holotype TM 253 (AIM), Boulder Hill, I44/f8486 (Dwg), height = c. 11.0 mm, x 5; 17-18 OU 41109, Mitchells Rocks, Wangaloa, H46/f166B (Dwg), height = 8.5 mm, x 6 and x 17 (protoconch and first teleoconch whorl).

n. gen.? n. sp. aff. Hemichenopus (Figure 19): 19 TM 7348 (IGNS), Boulder Hill, GS 10195, I44/f8486 (Dwg), height = 12.0 mm, x 3.2.
PLATE 60

**Struthioptera osiris** Finlay and Marwick, 1937 (Figures 1-5): 1-3 holotype TM 5745 (IGNS), Wangaloa, southeastern Otago, South Island, GS 887, H46/f9500 (Dwg), height = 75.0 mm, all x 1; 4-5 TM 7331 (IGNS), Boulder Hill, Otago, GS 10195, I44/f8486 (Dwg), height = 21.0 mm, both x 1.8.

**Conchothyra australis** (Marshall, 1916) (Figures 6-16): 6, 8 G 27420 (BMNH; Trechmann, 1917, Pl. 20, Fig. 2a-b), Wangaloa, precise locality unknown, both x 1; 7 OU 41200, Mitchells Rocks, Wangaloa, H36/f148A (Dwg), height = 35.0 mm, x 1.3; 9 paratype C16.57-3 (OM), Wangaloa, c. H46/f9500 (Dwg), height = 40.0 mm, x 1.3; 10-11 G 27407 (BMNH; Trechmann, 1917, Pl. 20, Fig. 1a-b), Wangaloa, precise locality unknown, both x 1; 12 holotype C16.57-1 (OM), Wangaloa. c. H46/f9500 (Dwg), height = 42.5 mm, x 1.3; 13 paratype C16.57-2 (OM), Wangaloa, c. H46/f9500 (Dwg), height = 45.0 mm, x 1; 14-16 TM 5746 (IGNS), Wangaloa, GS 887, H46/f9500 (Dwg), height = 42.0 mm, x 1.2, x 1.4 and x 1.2 respectively.
OU 11176, Tokomairiro River Mouth, Wangaloa, southeastern Otago, South Island, H46/f9568 (Dwg), height = 37.5 mm, x 1.6, x 2 and x 1.6 respectively; 5, 7 TM 196 (AIM), Boulder Hill, Otago, I44/f8486 (Dwg), height = 40.0 mm, both x 1.

Perissodonta mita n. sp. (Figures 4, 8, 12-13, 17): 4, 17
paratype TM 7636 (IGNS), Dunrobin Road, North Otago, GS 3804, J41/f8675 (Dwg), height = 17.0 mm, both x 2.5; 8, 12-13 holotype TM 7635 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), height = 17.5 mm, all x 3.

Perissodonta minor (Marshall, 1917) (Figures 6, 9-11, 14-16): 6, 15 holotype TM 7329 (IGNS), Wangaloa, c. H46/f9500 (Dwg), height = 15.5 mm, both x 3; 9 paratype TM 7330 (IGNS), Wangaloa, c. H46/f9500 (Dwg), height = 17.0 mm, x 3.5; 10 C (OM), Wangaloa, c. H46/f9500 (Dwg), height = 17.0 mm, x 3.5; 11 OU 41201, Mitchells Rocks, Wangaloa, H46/f116B (Dwg), height = 14.5 mm, x 4.5; 14 OU 11144, Measly Beach, Wangaloa, H46/f9552 (Dwg), height = 18.5 mm, x 2.3; 16 OU 41202, Mitchells Rocks, Wangaloa, H46/f116B (Dwg), height = 9.0 mm, x 4.
Sigapatella (Spirogalerus) lamellaria (Finlay and Marwick, 1937) (Figures 1-7): 1-2, 5 holotype TM 721 (AIM), Boulder Hill, Otago, South Island, I44/f8486 (Dwg), height = 27.0 mm, x 2.5, x 1.3 and x 1.3; 3-4 OU 5800, Boulder Hill, c. I44/f8486 (Dwg), height = 26.5 mm, x 1.7 and x 1.9 respectively; 6 OU 41203, Mitchells Rocks, Wangaloa, H46/f166A (Dwg), height = 6.0 mm, x 6.5 (juvenile?); 7 OU 41204, Mitchells Rocks, Wangaloa, H46/f166A (Dwg), height = 3.5 mm, x 7.5 (juvenile?).

Globisinum spirale (Marshall, 1917) (Figures 8-12): 8-9 OU 41205, Mitchells Rocks, Wangaloa, H46/f148A (Dwg), height = 18.5 mm, both x 3; 10-11 holotype C 75.2-1 (OM), Wangaloa, c. H46/f9500 (Dwg), height = 25.0 mm, both x 1.6; 12 C 75.2-2 (OM), Wangaloa, c. H46/f9500 (Dwg), height = 28.5 mm, x 1.8.

Globisinum suratulum n. sp. (Figures 13, 15-16, 20): 13 paratype TM 7639 (IGNS), Dunrobin Road, North Otago, GS 3804, J41/f8675 (Dwg), diameter of last whorl = 4.5 mm, x 5 (immature individual); 15-16 holotype TM 7637 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), height = 11.0 mm, both x 3; 20 paratype TM 7638 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), height = 12.5 mm, x 3.2.

Magnatica (Spelaenacca) procera Finlay and Marwick, 1937 (Figures 14, 17-19): 17-18 paratype TM 6903 (IGNS), Wangaloa, GS 1494, H46/f9500 (Dwg), height = 22.0 mm, both x 1.8; 14, 19 paratype TM 6902 (IGNS), Boulder Hill, GS 10195, I44/f8486 (Dwg), height = 18.5 mm, both x 1.9.
Magnatica (Spelaenacca) procera Finlay and Marwick, 1937 (Figures 1-2): 1-2 holotype TM 433 (AIM), Boulder Hill, Otago, South Island, I44/f8486 (Dwg), height = 27.5 mm, both x 1.8.

Magnatica (Spelaenacca) firma Finlay and Marwick, 1937 (Figures 3-7, 9, 11-12): 3, 5, 7 holotype TM 811-1 (AIM), Boulder Hill, I44/f8486 (Dwg), height = 24.0 mm, x 2.3 (oblique view, suture and growth lines), x 2.4 and x 2.4 respectively; 4, 6, 9 paratype TM 811-2 (AIM), Boulder Hill, GS 10195, I44/f8486 (Dwg), height = 20.0 mm, x 2.3, x 2.8 and x 2.8 respectively; 11-12 paratype TM 6898 (IGNS), Boulder Hill, I44/f8486 (Dwg), height = 29.0 mm, both x 1.5.

Magnatica (Spelaenacca) kakanuiensis n. sp. (Figures 8, 10, 13): 8, 10 paratype TM 7642 (IGNS), Dunrobin Road, North Otago, GS 3804, J41/f8675 (Dwg), height = 9.5 mm, x 4.5 and x 6.5 respectively; 13 paratype TM 7641 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), height = 9.5 mm, x 38 (SEM, protoconch).
Magnatica (Spelaenacca) kakanuiensis n. sp. (Figures 1, 3, 12): 1 paratype TM 7643 (IGNS), Dunrobin Road, North Otago, South Island, GS 3804, J41/f8675 (Dwg), height = 11.0 mm, x 5.5; 3, 12 holotype TM 7640 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), height = 11.5 mm, both x 3.9.

Taniella (Pristinacca) seniscula (Marwick, 1924) (Figures 2, 4-10): 2, 4 TM 7645 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), height = 3.25 mm, x 6 and x 8.5 respectively; 5-7 holotype TM 816-1 (AIM), Boulder Hill, Otago, I44/f8486 (Dwg), height = 6.0 mm, all x 3; 8-9 paratype TM 816-2 (AIM), Boulder Hill, I44/f8486 (Dwg), height = 6.25 mm, x 5.3 and x 4.8 respectively; 10 TM 7644 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), height = 5.0 mm, x 7.

Amauropsona major (Marshall, 1917) (Figures 11, 13, 16): 11 holotype C 75.12 (OM), Wangaloa, southeastern Otago, ?H46/f9500 (Dwg), height = 9.5 mm, x 5; 13, 16 OU 11151, Measly Beach, H46/f9552 (Dwg), height = 20.5 mm, x 2.4 and x 3.7 respectively.

Amauropsis teres (Marwick, 1924) Figures 14-15, 17-21): 14, 19 OU 41206, Mitchells Rocks, Wangaloa, H46/f148A (Dwg), height = 11.5 mm, both x 4.3; ?15 TM 7646 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), height = 14.0 mm, x 3.2 (Friginatica?); 17-18 holotype TM 29 (AIM), Boulder Hill, I44/f8486 (Dwg), height = 14.0 mm, x 3 and x 3.5 respectively; 20-21 TM 7646 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), height = 9.0 mm, both x 4.8 (Friginatica?).
Euspira fyfei (Marwick, 1924) (Figures 1-6, 8-10, 13, 15): 1, 3, 5 holotype TM 812 (AIM), Boulder Hill, Otago, I44/f8486 (Dwg), height = 38.0 mm, all x 1.7; 2 OU 41207, Mitchells Rocks, Wangaloa, H46/f1168 (Dwg), height = 29.5 mm, x 1.8; 4, 6, 10 TM 813 (AIM), Boulder Hill, GS 10195, I44/f8486 (Dwg), height = 18.0 mm, all x 2.5; 8, 13 TM 6919 (IGNS), Boulder Hill, I44/f8486 (Dwg), height = 15.0 mm, x 2.5 and x 1.9 respectively; 9, 15 TM 6920 (IGNS), Boulder Hill, GS 10195, I44/f8486 (Dwg), height = 9.0 mm, x 4 and x 4.7 respectively.

Polinices (Polinices) parki Finlay and Marwick, 1937 (Figures 7, 11-12, 14): 7 paratype TM 7323 (IGNS), Wangaloa, GS 1494, H46/f9500 (Dwg), height = 33.0 mm, x 1.5; 11-12 holotype TM 7321 (IGNS), Wangaloa, GS 1494, H46/f9500 (Dwg), height = 32.0 mm, x 1.4 and x 1.6 respectively; 14 paratype TM 7322 (IGNS), Wangaloa, GS 1494, H46/f9500 (Dwg), height = 30.0 mm, x 1.5.
POLINICES (POLINELLA) FINLAYI (MARWICK, 1924) (FIGURES 1-3, 7-9, 12, 14): 1-2 HoloType TM 810 (AIM), Boulder Hill, Otago, South Island, I44/f8486 (Dwg), height = 37.0 mm, bOTH x 1.4; 3, 7 TM 7648 (IGNS), Dunrobin Road, North Otago, GS 3804, J41/f8675 (Dwg), height = 28.0 mm, x 2.0 and x 2.5 respectively; 8, 12 OU 41208, Mitchells Rocks, Wangaloa, southeastern Otago, H46/f166A (Dwg), height = 39.0 mm, x 1.3 and x 1 respectively; 9, 14 OU 41209, Mitchells Rocks, Wangaloa, H46/f166A (Dwg), height = 26.0 mm, x 1.8 and x 2 respectively.

POLINICES (POLINELLA) HYPSASPEIRA N. SP. (FIGURES 4-6, 10-11): 4 Paratype TM 7651 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), height = 8.75 mm, x 5.4; 5-6, 10-11 holoType TM 7650 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), height = 10.5 mm, x 4, x 4, x 5.8 and x 4.6 respectively.

EUNATICINA? AURIFORME (MARWICK, 1924) (FIGURES 13, 15): 13, 15 holoType TM 472 (AIM), Boulder Hill, I44/f8486 (Dwg), height = 3.5 mm, both x 8.
Eunaticina nota n. sp. (Figures 1-3, 5-7): 1-3 holotype TM 7652 (IGNS), Dunrobin Road, North Otago, South Island, GS 3804, J41/f8675 (Dwg), height = 10.0 mm, both x 4.2; 5-7 TM 7653 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), height = 10.0 mm, both x 4.6.

Galeodea s. s. n. sp.? aff. G. modesta (Suter, 1917) (Figure 4): 4 TM 7654 (IGNS), Kaiwhata River, southern North Island, GS 6314, T27/f6728 (mid to upper Dt), height = 34.5 mm, x 1.8.

Taieria allani Finlay and Marwick, 1937 (Figures 8-11, 15): 8-9 paratype TM 7332 (IGNS), Boulder Hill, Otago, GS 10195, I44/f8486 (Dwg), height = 28.0 mm, both x 1.6; 10-11 holotype TM 751 (AIM), Boulder Hill, I44/f8486 (Dwg), height = 40.0 mm, x 1 and x 1.2 respectively; 15 OU 41210, Kakanui River, North Otago, J41/f216 (Dwg), height = 15.0 mm, x 3.

Priscoficus obtusa (Marshall, 1917) (Figures 12-14, 18-19): 12-13 holotype C 75.13 (OM), Wangaloa, ?H46/f9500 (Dwg), height = 24.5 mm, both x 2; 14, 18-19 TM 7344 (IGNS), Boulder Hill, GS 10195, I44/f8486 (Dwg), height = 41.5 mm, x 1.2, x 1 and x 1 respectively.

Priscoficus minuta n. sp. (Figures 16-17, 20): 16, 20 paratype TM 7656 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), height = 7.0 mm, both x 6; 17 holotype TM 7655 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), height = 6.5 mm, x 5.5.
Melanella lautoides Finlay and Marwick, 1937 (Figures 1-5): 1-2
OU 41211, Mitchells Rocks, Wangaloa, southeastern Otago, South Island, H46/f116B (Dwg), height = 5.0 mm, both x 8; 3-4 holotype TM 454 (AIM), Boulder Hill, I44/f8486 (Dwg), height = 4.5 mm, both x 8.7; 5 paratype TM 7387 (IGNS), Boulder Hill, GS 10195, I44/f8486 (Dwg), height = 3.0 mm, x 9.

Melanella? n. sp. (Figure 6): 6 TM 7657 (IGNS), Dunrobin Road, North Otago, GS 3804, J41/f8675 (Dwg), height = 4.5 mm, x 9.

Acirsa (Notacirsa) parvicostata (Marshall, 1917) (Figures 7-10): 7, 9 OU 41212, Boulder Hill, c. I44/f8486 (Dwg), height = 27.5 mm, both x 2; 8 TM 7367 (IGNS), Boulder Hill, GS 10195, I44/f8486 (Dwg), height = 24.5 mm, x 1.9; 10 holotype C 75.15 (OM), Wangaloa, H46/f9500 (Dwg), height = 20.0 mm, x 3.3.

Acirsa (Notacirsa) dieffenbachi n. sp. (Figures 11, 17-19): 11 holotype TM 7659 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), height = 17.0 mm, x 3.5; 17-18 paratype TM 7690 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), height = 16.0 mm, x 3.8 and x 4.3 respectively; 19 paratype TM 7691 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), height = 12.5 mm, x 4.

Niso putata Finlay and Marwick, 1937 (Figures 12-13): 12-13 TM 7658 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), height = 8.5 mm, x 4.5 and x 4.8 respectively.

Acirsa (Plesioacirsa) sp. (Figure 14): 14 TM 7692 (IGNS), Raupo Creek, North Otago, GS 3773, J41/f8640 (Dwg), height = 8.5 mm, x 8.
Acirsa (Plesioacirsa) otagoensis n. sp. (Figures 15-16): 15-16
holotype OU 41213, Mitchells Rocks, Wangaloa, H46/f148A (Dwg),
height = 11.5 mm, both x 4.5.

Amaea s. s. casca n. sp. (Figures 20-22): 20 paratype OU 9020,
Measly Beach, Wangaloa, H46/f9552 (Dwg), height = 17.0 mm, x 3.8;
21 paratype OU 41215, Measly Beach, Wangaloa, H46/f9552 (Dwg),
height = 16.5 mm, x 3.5; 22 holotype OU 41214, Mitchells Rocks,
Wangaloa, H46/f212 (Dwg), height = 36.0 mm, x 1.8.

Austrofusus s. s. ayressi n. sp. (figure 23): 23 holotype TM 7693
(IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), height = 11.5
mm, x 3.2.
PLATE 69

Austrofusus (Nassicola) sublurida (Marshall, 1917) (Figures 1-2):
1-2 holotype C 75.7 (OM), Wangaloa, southeastern Otago, South Island, H46/f9500 (Dwg), height = 25.0 mm, both x 2.4.

Austrofusus (Nassicola?) n. sp.? (Figure 3): 3 TM 7695 (IGNS), Kaiwhata River, southern North Island, GS 6314, T27/f6728 (mid to upper Dt), height = 17.0 mm, x 2.5.

Buccinulum adelum n. sp. (Figures 4-5, 8): 4, 5, 8 holotype OU 41216, Mitchells Rocks, Wangaloa, H46/f148B (Dwg), height = 20.5 mm, all x 2.5.

Buccinulum paleoqenicum n. sp. (Figures 6-7, 9-10, 13): 6-7 holotype TM 7696 (IGNS), Dunrobin Road, North Otago, GS 3804, J41/f8675 (Dwg), height = 9.0 mm, both x 5.9; 9 paratype TM 7698 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), height = 7.0 mm, x 4.1; 10, 13 paratype TM 7697 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), height = 15.0 mm, x 3.7.

Penion proavitus (Finlay and Marwick, 1937) (Figures 11-12, 15, 17): 11-12 holotype TM 836 (AIM), Boulder Hill, Otago, I44/f8486 (Dwg), height = 19.0 mm, both x 1.9; 15, 17 paratype TM 7361 (IGNS), Boulder Hill, GS 10195, I44/f8486 (Dwg), height = 15.0 mm, both x 3.4.

Aeneator dyskritos n. sp. (Figure 14): 14 OU 41217, Mitchells Rocks, Wangaloa, H46/f166A (Dwg), height = 15.0 mm, x 4.3.
Pseudofax ordinarius (Marshall, 1917) (Figures 16, 18-23): 16 TM 7385 (IGNS), Boulder Hill, GS 10195, I44/f8486 (Dwg), height = 5.5 mm, x 8.4; 18, 20 holotype C 75.21 (OM), Wangaloa, ?H46/f9500, height = 19.0 mm, both x 3.3; 19 C 75.14 (OM), Wangaloa, ?H46/f9500 (Dwg), height = 10.0 mm, x 4.6; 21 TM 7704 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), height = 6.0 mm, x 6; 22 TM 7703 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), height = 10.0 mm, x 4.5; 23 TM 7701 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), height = 10.5 mm, x 4.6.
PLATE 70

_Pseudofax ordinarius_ (Marshall, 1917) (Figures 1-4): 1 OU 41218, Mitchells Rocks, Wangaloa, Wangaloa, southeastern Otago, H46/f116B (Dwg), height = 7.5 mm, x 8; 2 TM 7702 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), height = 15.0 mm, x 5.5; 3 TM 7699 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), height = 15.5 mm, x 3.4; 4 TM 7384 (IGNS), Boulder Hill, Otago, GS 10195, I44/f8486 (Dwg), height = 13.5 mm, x 3.9.

_Saulopsis n. gen. zelandicus_ (Marshall, 1917) (Figures 5, 9, 12-18): 5 OU 41222, East Taieri, Otago, South Island, I44/f8516 (Dwg), height = 20.0 mm, x 2.7; 9 OU 41221, Mitchells Rocks, Wangaloa, H46/f148A (Dwg), height = 20.5 mm, x 3; 12, 14 OU 41220, Boulder Hill, I44/f196 (Dwg), height = 44.0 mm, x 1.8 and x 1.2 respectively; 13, 16, 18 neotype? TM 5743 (IGNS), Boulder Hill, GS 10195, I44/f8486 (Dwg), height = 50.0 mm, x 0.9, x 1 and x 1 respectively; 15, 17 OU 41219, Mitchells Rocks, Wangaloa, H46/f116B (Dwg), height = 39.0 mm, x 1.3 and x 1.5 respectively.

_Austrocominella imitatrix_ (Finlay and Marwick, 1937) (Figures 6-8): 6-8 holotype TM 873 (AIM), Boulder Hill, I44/f8486 (Dwg), height = c. 25.0 mm, all x 1.9.

_Austrocominella cancellaria_ (Finlay and Marwick, 1937) (Figures 10-11): 10-11 holotype TM 872 (AIM), Boulder Hill, I44/f8486 (Dwg), height = c. 32.0 mm, both x 2.5.
"Pyropsis" zinsmeisteri Stilwell, 1993 (Figures 1-3, 5-6, 8): 1, 3 holotype OU 39607, Mitchells Rocks, Wangaloa, southeastern otago, South Island, H46/f166 (Dwg), height = 21.0 mm, both x 6; 2 paratype OU 39609, Mitchells Rocks, Wangaloa, H46/f166 (Dwg), height = 20.0 mm, x 4; 5, 8 paratype OU 39608, Mitchells Rocks, Wangaloa, H46/f166 (Dwg), height = 18.5 mm, both x 4; 6 OU 39610, Mitchells Rocks, Wangaloa, H46/f166 (Dwg), height = 17.5 mm, x 4.

Tudiclana simulator Finlay and Marwick, 1937 (Figures 4, 7, 9-12): 4, 10 paratype TM 7345 (IGNS), Boulder Hill, Otago, GS 10195, I44/f8486 (Dwg), height = 19.5 mm, x 1.8 and x 2.5 respectively; 7 holotype TM 780 (AIM), Boulder Hill, I44/f8486 (Dwg), height = 22.5 mm, x 3; 9 OU 41224, Measly Beach, Wangaloa, H46/f9552 (Dwg), height = 8.0 mm, x 3 (Note repaired break reflecting predation by a probable lip-peeler); 11 paratype TM 7347 (IGNS), Boulder Hill, GS 10195, I44/f8486 (Dwg), height = 21.5 mm, x 2.6; 12 OU 41223, Measly Beach, Wangaloa, H46/f9552 (Dwg), height = 13.0 mm, x 3.3.
PLATE 72

Columbarium vulneratum (Finlay and Marwick, 1937) (Figures 1-3):
1-2 holotype TM 329 (AIM), Boulder Hill, Otago, South Island, I44/f8486 (Dwg), height = 27.0 mm, both x 2.5; 3 OU 11145, Measly Beach, Wangaloa, southeastern Otago, H46/f9552 (Dwg), height = 17.5 mm, x 3.

Columbarium n. sp.? (Figure 4): 4 TM 7705 (IGNS), Kaiwhata River, southern North Island, GS 6314, T27/f6728 (mid to upper Dt), height = 25.0 mm, x 2.

Exilia vixcostata (Finlay and Marwick, 1937) (Figures 5-8): 5-6 holotype TM 897 (AIM), Boulder Hill, I44/f8486 (Dwg), height = 25.0 mm, both x 2; 7-8 OU 9033, Measly Beach, Wangaloa, H46/f9552 (Dwg), height = 27.0 mm, both x 2.

Fyfea lirata Finlay and Marwick, 1937 (Figures 9-11): 9, 11 paratype TM 7410 (IGNS), Boulder Hill, GS 10195, I44/f8486 (Dwg), height = 11.5 mm, x 5 and x 4 respectively; 10 holotype TM 334 (AIM), Boulder Hill, I44/f8486 (Dwg), height = 11.0 mm, x 3.2.

Fyfea tuberculata Finlay and Marwick, 1937 (Figures 12-14): 12-13 holotype TM 7397 (IGNS), Wangaloa, H46/f9500 (Dwg), height = 7.0 mm, both x 5.7; 14 paratype TM 7398 (IGNS), Wangaloa, H46/f9500 (Dwg), height = 5.0 mm, x 8.6.

Microfulgur longirostris (Marshall, 1917) (Figures 15-20): 15 C 75.5 (OM), Wangaloa, ?H46/f9500 (Dwg), height = 13.25 mm, x 3.7; 16 OU 41226, Mitchells Rocks, Wangaloa, H46/f148A (Dwg), height = 7.5 mm, x 6; 17-18 TM 7374 (IGNS), Boulder Hill, GS 10195, I44/f8486 (Dwg), height = 19.0 mm, x 4.8 and x 4.4 respectively; 19 holotype C 75.10 (OM), Wangaloa, ?H46/f9500 (Dwg), height = 8.0 mm, x 7; 20 OU 9032, Measly Beach, Wangaloa, H46/f9552 (Dwg), height = 13.5 mm, x 4.5.
Microfulgur longirostris (Marshall, 1917) (Figures 1-4): 1 TM 7375 IGNS), Boulder Hill, Otago, South Island, GS 10195, I44/f8486 (Dwg), height = 15.0 mm, x 4.2; 2-4 OU 41225, Mitchells Rocks, Wangaloa, H46/f148B (Dwg), height = 21.0 mm, all x 2.5.

Volutidae? gen. indet. n. sp. (Figure 5): 5 OU 41229, East Taieri, Otago, I44/f8516 (Dwg), height = 21.5 mm, x 2.9.

Wangaluta henaconstricta n. gen. n. sp. (Figures 6, 9, 12, 15): 6, 9, 12, 15 holotype OU 41227, Mitchells Rocks, Wangaloa, H46/f166A (Dwg), height = 49.5 mm, x 3.5, x 2, x 2 and x 2 respectively.

Volutomitra n. sp. (Figures 7-8): 7-8 TM 7706 (IGNS), Raupo Creek, North Otago, GS 3773, J41/f8640 (Dwg), height = 8.5 mm, both x 6.

Uttleya? sp. (Figures 10, 13): 10, 13 TM 7247 (IGNS), Boulder Hill, GS 10195, I44/f8486 (Dwg), height = 7.0 mm, both x 6.

Wangaluta? n. gen. neozelanica (Finlay and Marwick, 1937) (Figures 11, 14): 11, 14 holotype TM 7343 (IGNS), Boulder Hill, GS 10195, I44/f8486 (Dwg), height = 44.0 mm, x 1.1 and x 1 respectively.
Alcithoe s. l. w angaloaensis n. sp. (Figures 1-2): 1-2 OU 41228, Mitchells Rocks, Wangaloa, southeastern Otago, H46/f166A (Dwg), height = 32.0 mm, x 1.5 and x 3.8 respectively.

Austrotoma indiscreta Finlay and Marwick, 1937 (Figure 3): 3
holotype TM 80 (AIM), Boulder Hill, I44/f8486 (Dwg), height = 33.0 mm, x 2.5.

Marshallaria multicincta (Marshall, 1917) (Figures 4-9): 4
holotype C 75.24 (OM), Wangaloa, ?H46/f9500 (Dwg), height = 14.0 mm, x 3.9; 5 C 75.8 (OM), Wangaloa, ?H46/f9500 (Dwg), height = 7.0 mm, x 7; 6 C 75.8-2 (OM), Wangaloa, ?H46/f9500 (Dwg), height = 6.5 mm, x 7.2; 7 OU 41230, Mitchells Rocks, Wangaloa, H46/f148B (Dwg), height = 15.0 mm, x 5.5; ?8 TM 7756 (IGNS), Boulder Hill, GS 10195, I44/f8486 (Dwg), height = 25.0 mm, x 2.1; 9 OU 41231, Mitchells Rocks, Wangaloa, H46/f166A (Dwg), height = 9.0 mm, x 7.8.

Campylacrum sanum Finlay and Marwick, 1937 (Figures 10-12, 16-18): 10 OU 41233, Mitchells Rocks, Wangaloa, H46/f116B (Dwg), height = 11.0 mm, x 4.5; 11 holotype TM 5749 (IGNS), Wangaloa, GS 887, H46/f9500 (Dwg), height = 8.0 mm, x 8; 12 paratype TM 5750 (IGNS), Wangaloa, GS 887, H46/f9500 (Dwg), height = 7.5 mm, x 6.8; 16 OU 41234, Mitchells Rocks, Wangaloa, H46/f116B (Dwg), height = 10.0 mm, x 4.5; 17 TM 132 (AIM), Boulder Hill, I44/f8486 (Dwg), height = 9.0 mm, x 5.5; 18 TM 7324 (IGNS), Boulder Hill, GS 10195, I44/f8486 (Dwg), height = 7.5 mm, x 7.3.

Amuletum s. s. mitchellsrocksensis n. sp. (Figures 13-15): 13-15
holotype OU 41232, Mitchells Rocks, Wangaloa, H46/f148A (Dwg), height = 25.5 mm, all x 2.
PLATE 75

Cosmasyrinx (Tholitoma) dolorosa (Finlay and Marwick, 1937)
(Figures 1-8): 1 OU 41235, Mitchells Rocks, Wangaloa, southeastern Otago, H46/f116B (Dwg), height c. 10.0 mm, x 17 (SEM, protoconch); 2-3 paratype TM 7328 (IGNS), Wangaloa, H46/f9500 (Dwg), height = 12.0 mm, x 5 and x 6 respectively; 4-5 TM 7707 (IGNS), Dunrobin road, North Otago, GS 3804, J41/f8675 (Dwg), height = 11.0 mm, x 5 and x 20 (SEM, protoconch); 6 OU 451237, Mitchells Rocks, Wangaloa, H46/f166A (Dwg), height = 5.0 mm, x 15 (SEM, protoconch); 7 holotype TM 7326 (IGNS), Wangaloa, H46/f9500 (Dwg), height = 14.0 mm, x 3.6; 8 OU 41235, Mitchells Rocks, Wangaloa, H46/f116 (Dwg), height = 2.5 mm, x 13.

Hesperiturris gemmiformis n. sp. (Figures 9, 14-15, 17-19): 9, 15 paratype TM 7709 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), height = 7.0 mm, both x 7; 14 holotype TM 7708 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), height = 11.0 mm, x 5; 17-18 TM 7712, Dunrobin Road, GS 3804, J41/f8675 (Dwg), height = 5.5 mm, both x 7.5; 19 paratype TM 7710 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), height = 5.5 mm, x 7.

Zemacies immatura Finlay and Marwick, 1937 (Figures 10-13): 10, 12 holotype TM 877 (AIM), Boulder Hill, I44/f8486 (Dwg), height = 24.0 mm, both x 3; 11, 13 paratype TM 7368 (IGNS), Boulder Hill, GS 10195, I44/f8486 (Dwg), height = 10.5 mm, x 4.7 and x 5.6 respectively.

Inquisitor boucheti n. sp. (Figures 16, 20-21): 16 paratype TM 7714 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), height = 12.0 mm, x 4.3; 20-21 holotype TM 7713 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), height = 13.0 mm, x 5 and x 6.3 respectively.
aff. Inquisitor n. sp. (Figure 1): 1 TM 7715 (IGNS), Dunrobin Road, North Otago, South Island, GS 3804, J41/f8675 (Dwg), height = 14.5 mm, x 6.

Eothesbia microtomoides Finlay and Marwick, 1937 (Figures 2, 9): 2, 9 holotype TM 7362 (IGNS), Wangaloa, southeastern Otago, H46/f9500 (Dwg), height = 9.0 mm, both x 5.

Tomopleura striata (Marshall, 1917) (Figures 3-8): 3-5 OU 41239, Mitchells Rocks, Wangaloa, H46/f148B (Dwg), height = 19.5 mm, x 2.7, x 3 and x 3 respectively; 6 holotype C 75.18 (OM), Wangaloa, H46/f9500 (Dwg), height = 20.0 mm, x 3.3; 7-8 OU 41240, Wangaloa, H46/f9568 (Dwg), height = 14.0 mm, both x 3.5.

Taioma tricarinata Finlay and Marwick, 1937 (Figures 10-17): 10, 11 paratype TM 7334 (IGNS), Boulder Hill, Otago, GS 10195, I44/f8486 (Dwg), height = c. 55.0 mm, both x 1.1; 11-13 OU 41241, Mitchells Rocks, Wangaloa, H46/f148A (Dwg), height = 14.5 mm, all x 4; 14 paratype TM 7342 (IGNS), Wangaloa, GS 887, H46/f9500 (Dwg), height = 19.0 mm, x 1.8; 15 paratype TM 7335 (IGNS), Boulder Hill, GS 10195, I44/f8486 (Dwg), height = 37.0 mm, x 1; 16 holotype TM 753 (AIM), Boulder Hill, I44/f8486 (Dwg), height = 32.0 mm, x 1.3.

Pristimerica dolioides Finlay and Marwick, 1937 (figures 18-21): 18-20 OU 41242, Mitchells Rocks, Wangaloa, H46/f148A (Dwg), height = 32.0 mm, all x 1.5; 21 holotype TM 7363 (IGNS), Wangaloa, H46/f9500 (Dwg), height = 31.0 mm, x 1.7.
Cancellariidae gen. indet. n. sp. (Figures 1-3): 1-2 OU 9018, Measly Beach, Wangaloa, southeastern Otago, South Island, H46/f9552 (Dwg), height = 21.5 mm, both x 2.5; 3 OU 41243, Measly Beach, Wangaloa, H46/f9552 (Dwg), height = 17.5 mm, x 3.

Antepepta nasuta Finlay and Marwick, 1937 (Figure 4): 4 holotype TM 37 (AIM), Boulder Hill, Otago, I44/f8486 (Dwg), height = 16.0 mm, x 1.4.

Coptostomella pupa Finlay and Marwick, 1937 (Figures 5-6): 5 holotype TM 202 (AIM), Boulder Hill, I44/f8486 (Dwg), height = 10.2 mm, x 6.5; 6 OU 21244, Mitchells Rocks, Wangaloa, H46/f163 (Dwg), height = 7.5 mm, x 6.

Coptostomella campbelli n. sp. (Figures 7-10): 7-10 holotype TM 7716 (IGNS), Dunrobin Road, North Otago, GS 3804, J41/f8675 (Dwg), height = 12.5 mm, x 4.3, x 4.3 and x 8.5 (SEM, spire sculpture), and x 50 (SEM, sculpture highly magnified).

Kapuatriton? n. sp. cf. K. kaitarus Beu and Maxwell, 1987 (Figure 11): 11 TM 7717 (IGNS), Kaiwhata River, southern North Island, GS 6314, T27/f6728 (mid to upper Dt), height = 13.0 mm, x 3.4.

Acteon semispiralis Marshall, 1917 (Figures 13-14, 17): 13 holotype C 75.22 (OM), Wangaloa, ?H46/f9500 (Dwg), height = 10.0 mm, x 5.6; 14, 17 OU 41245, Mitchells Rocks, Wangaloa, H46/f116B (Dwg), x 7.3 and x 25 (SEM, sculpture at suture) respectively.

Acteon wangaloa Finlay and Marwick, 1937 (Figures 12, 15-16): 12 OU 41246, Mitchells Rocks, Wangaloa, H46/f148B (Dwg), height = 10.0 mm, x 5; 15 paratype TM 7377 (IGNS), Wangaloa, H46/f9500 (Dwg), height = 10.0 mm, x 5; 16 holotype TM 7376 (IGNS), Wangaloa, H46/f9500 (Dwg), height = 9.0 mm, x 5.2.
Wangacteon grebneffi Stilwell, 1993 (Figures 1-3): 1-3 holotype OU 39611, Mitchells Rocks, Wangaloa, southeastern otago, South Island, H46/f166 (Dwg), height = 11.5 mm, x 7, x 25 (SEM, sculpture) and x 7 respectively.

Acteon austropunctatus n. sp. (Figures 4-12): 4, 7 paratype TM 7720 (IGNS), Dunrobin Road, North Otago, GS 3804, J41/f8675 (Dwg), height = 11.0 mm, both x 5.5; 5, 8 TM 7722 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), height = 7.5 mm, x 10 (SEM) and x 16 (SEM, sculpture); 6 paratype TM 7721 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), height = 6.0 mm, x 6; 9-10 holotype TM 7718 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), height = 14.5 mm, x 4.8 and x 4.3 respectively; 11-12 paratype TM 7719 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), height = 9.5 mm, x 5.5 and x 4.5 respectively.
PLATE 79

Crenilabium paleocenicum n. sp. (Figures 1-4, 6-7, 11): 1-4 paratype OU 41250, Mitchells Rocks, Wangaloa, southeastern Otago, South Island, H46/f148B (Dwg), height = 6.0 mm, x 9 (SEM), x 42 (SEM, protoconch), x 52.5 (SEM, protoconch) and x 95 (SEM, protoconch); 6 paratype OU 41249, Mitchells Rocks, Wangaloa, H46/f212 (Dwg), height = 14.0 mm, x 3.5; 7 holotype OU 41247, Mitchells Rocks, Wangaloa, H46/f148B (Dwg), height = 7.5 mm, x 6.5; 11 paratype OU 41248, Mitchells Rocks, Wangaloa, height = 7.5 mm, x 4.5.

Crenilabium darraghi n. sp. (Figures 5, 8-10, 16-17): 5 paratype TM 7724 (IGNS), Dunrobin Road, North Otago, GS 3804, J41/f8675 (Dwg), height = 11.5 mm, x 5; 8 paratype TM 7725 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), height = 12.5 mm, x 5.3; 9-10 paratype TM 7727 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), height = 6.0 mm, x 9.5 (SEM) and x 22 (SEM) respectively; 16 holotype TM 7723 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), height = 13.5 mm, x 4.3; 17 paratype TM 7726 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), height = 10.5 mm, x 5.

Kaurueon insolitus n. gen. n. sp. (Figures 12-15, 18-19): 12, 14, 18-19 paratype TM 7729 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), height = 10.0 mm, x 5, x 5, x 17.5 (SEM, abapical portion of last whorl), and x 20.5 (SEM, spire) respectively; 13, 15 holotype TM 7728 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), height = 11.5 mm, both x 4.5.
PLATE 80

Ongleya tholispira Finlay and Marwick, 1937 (Figures 1-4, 6): 1-2
OU 41251, Measly Beach, Wangaloa, southeastern Otago, H46/f9552A
(Dwg), height = 14.0 mm, both x 2.5; 3-4 holotype TM 5747
(IGNS), Wangaloa, GS 887, H46/f9500 (Dwg), height = 13.5 mm, x
3.8 and x 3.5 respectively; 6 paratype TM 5748 (IGNS), Wangaloa,
GS 887, H46/f9500 (Dwg), height = 13.5 mm, x 4.

Ongleya n. sp. cf. O. tholispira Finlay and Marwick, 1937
(Figures 7-8): 7 TM 7731 (IGNS), Kaiwhata River, southern North
Island, GS 6314, T27/f6728 (mid to upper Dt), height = 11.5 mm, x
8; 8 TM 7730 (IGNS), Kaiwhata River, GS 6314, T27/f6728 (mid to
upper Dt), height = 13.5 mm, x 3.3.

Tornatellaea morbosa Finlay and Marwick, 1937 (Figures 5, 10):
5 paratype TM 7354 (IGNS), Wangaloa, H46/f9500 (Dwg), height = 5.5
mm, x 6.5; 10 holotype TM 7353 (IGNS), Wangaloa, H46/f9500 (Dwg),
height = 7.0 mm, x 7.

Tornatellaea incompta Finlay and Marwick, 1937 (Figure 9): 9
holotype TM 768 (AIM), Boulder Hill, Otago, I44/f8486 (Dwg),
height = 6.5 mm, x 7.3.

Superstes exquisitus n. sp. (Figures 11-12, 15-17, 20): 11-12
holotype TM 7732 (IGNS), Dunrobin Road, North Otago, GS 3804,
J41/f8675 (Dwg), height = 9.5 mm, both x 3.4; 15 paratype TM 7733
(IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), height = 10.0
mm, x 4; 16-17 paratype TM 7734 (IGNS), Dunrobin Road, GS 3804,
J41/f8675 (Dwg), height = 12.0 mm, both x 2.8; 20 paratype TM
7735 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), height =
8.0 mm, x 8 (SEM, aperture).
**Tornatellaea saucia** Finlay and Marwick, 1937 (Figures 13-14): 13
OU 41252, Mitchells Rocks, Wangaloa, H46/f166B (Dwg), height = 7.0 mm, x 6; 14 TM 7355 (IGNS), Wangaloa, H46/f9500 (Dwg), height = 6.5 mm, x 7.

**Superstes dentatus** n. sp. (Figures 18-19, 21-23): 18-19, 22-23
holotype TM 7736 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), height = 4.5 mm, x 6.4, x 6.4, x 8 (SEM), and x 17 (SEM, aperture); 21 paratype TM 7737 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), height = 5.0 mm, x 5.4.
Cylichnania impar Finlay and Marwick, 1937 (Figures 1-3): 1
holotype TM 232 (AIM), Boulder Hill, Otago, South Island,
I44/f8486 (Dwg), height = 8.0 mm, x 7.5; 2-3 paratype TM 232-2
(AIM), Boulder Hill, I44/f8486 (Dwg), height = 6.5 mm, x 8.1 and
x 7.5 respectively.

Cylichnania daphneae n. sp. (Figures 4-5, 9, 13, 18): 4-5, 9, 18
holotype TM 7738 (IGNS), Dunrobin Road, North Otago, GS 3804,
J41/f8675 (Dwg), height = 5.0 mm, x 8, x 8, x 10 (SEM) and x 8
respectively; 13 paratype TM 7739 (IGNS), Dunrobin Road, GS 3804,
J41/f8675 (Dwg), height = 5.0 mm, x 8.

Priscaphander cingulatus (Marshall, 1917) (Figures 6-7, 11): 6,
11 paratype TM 7365 (IGNS), Boulder Hill, GS 10195, I44/f8486
(Dwg), height = 16.0 mm, both x 3.5; 7 holotype TM 7389 (IGNS),
Wangaloa, southeastern Otago, H46/f9500 (Dwg), height = 19.0 mm,
x 3.

Priscaphander elongatus n. sp. (Figures 8, 10, 12, 14, 16): 8, 14
holotype TM 7741 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg),
height = 16.0 mm, both x 3.3; 10, 16 paratype TM 7742 (IGNS),
Dunrobin Road, GS 3804, J41/f8675 (Dwg), height = 15.5 mm, x 3.6
and x 3.1 respectively; 12 paratype TM 7743 (IGNS), Dunrobin
Road, GS 3804, J41/f8675 (Dwg), height = 7.5 mm, x 4.9.

Wangaloa depressa n. sp. (Figures 15, 17, 19-20): 15 paratype OU
41255, Mitchells Rocks, Wangaloa, H46/f212 (Dwg), greatest
diameter = 10.5 mm, x 4; 17, 19-20 holotype OU 41254, Mitchells
Rocks, Wangaloa, H46/f116A (Dwg), greatest diameter = 13.5 mm, x
3, x 7.5 and x 4.3 respectively.
Wangaloa plana (Marshall, 1917) (Figures 1-5): 1-4 OU 41253, Mitchells Rocks, Wangaloa, southeastern Otago, South Island, H46/f166A (Dwg), greatest diameter = 13.5 mm, x 3.2, x 3.5, x 4, and x 4 respectively; 5 holotype C 75. 11 (OM), Wangaloa, ?H46/f9500 (Dwg), greatest diameter = 10.0 mm, x 5.

Eomathilda paxilla Finlay and Marwick, 1937 (Figures 6-9): 6-7 holotype TM 266 (AIM), Boulder Hill, Otago, I44/f8486 (Dwg), height = 6.5 mm, both x 7; 8 paratype TM 7755 (IGNS), Boulder Hill, GS 10194, I44/f8487 (Dwg), height = 4.0 mm, x 8; 9 paratype TM 7758 (IGNS), Boulder Hill, GS 10194, I44/f8487 (Dwg), height = 3.5 mm, x 8.

Gegania subreticuloides n. sp. (Figures 10-11, 13-17): 10 paratype TM 7749 (IGNS), Dunrobin Road, North Otago, GS 3804, J41/f8675 (Dwg), height = 3.5 mm, x 15 (SEM, protoconch and early teleoconch whorls); 11, 14 paratype TM 7748 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), height = 5.5 mm, x 6.8 and x 6 respectively; 13, 16 paratype TM 7747 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), height = 8.5 mm, x 6 and x 5 respectively; 15, 17 holotype TM 7745 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), height = 9.0 mm, x 3 and x 3.2 respectively.

Gegania hendersoni (Finlay and Marwick, 1937) (Figures 12, 18-21): 12 TM 7744 (IGNS), Boulder Hill, GS 10195, I44/f8486 (Dwg), height = 13.25 mm, x 3.3; 18-19 OU 41256, Mitchells Rocks, Wangaloa, H46/f212 (Dwg), height = 23.5 mm, both x 2.8; 20-21 holotype TM 5744 (IGNS), Wangaloa, GS 887, H46/f9500 (Dwg), height = 18.0 mm, x 2.9 and x 3.3 respectively.
PLATE 83

Odostomia n. sp.? (Figures 1-3): 1 TM 7750 (IGNS), Dunrobin Road, North Otago, South Island, GS 3804, J41/f8675 (Dwg), height = 2.5 mm, x 25 (SEM); 2-3 OU 41257, Mitchells Rocks, Wangaloa, southeastern otago, H46/f116B (Dwg), height = 5.0 mm, x 44 (SEM, sculpture) and x 5.5 respectively.

Pyramidella? n. sp. (Figure 4): 4 TM 7751 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), height = 9.5 mm, x 6.

Antalis multistricta (Finlay and Marwick, 1937) (Figures 5, 7-9): 5 TM 7752 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), length = 7.0 mm, x 7; 7 OU 41262, Mitchells Rocks, Wangaloa, H46/f166B (Dwg), length = 34.0 mm, x 2; 8 OU 41261, Mitchells Rocks, Wangaloa, H46/f148B (Dwg), length = 32.0 mm, x 1.9; 9 holotype TM 4811 (IGNS), Measly Beach, GS 760, H46/f9500 (Dwg), length = 15.0 mm, x 4.

Fissidentalium waikaroensis n. sp. (Figures 6, 14): 6 holotype OU 41259, Mitchells Rocks, Wangaloa, H46/f116B (Dwg), length = 9.0 mm, x 6.5; 14 paratype OU 41260, Mitchells Rocks, Wangaloa, H46/f148A (Dwg), length = 5.0 mm, x 7.

Gadila n. sp. (Figures 10-13): 10 OU 41263, Mitchells Rocks, Wangaloa, H46/f148B (Dwg), length = 4.5 mm, x 6; 11 TM 7753 (IGNS), Dunrobin Road, GS 3804, J41/f8675 (Dwg), length = 2.25 mm, x 10; 12 TM 4817 (IGNS), Boulder Hill, GS 10195, I44/f8486 (Dwg), length = 4.0 mm, x 7.8; 13 TM 7757 (IGNS), Boulder Hill, GS 10195, I44/f8486 (Dwg), length = 3.5 mm, x 7.7.
Eutrephoceras? sp. (Figures 1-2): 1-2 OU 40753, Mitchells Rocks, Wangaloa, southeastern Otago, South Island, H46/f166 (Dwg), body chamber fragment with counterpart below, length of fragment = 150.0 mm, maximum shell thickness = 5.5 mm, both x 1.
APPENDIX C: Publications and Papers resulting from Ph. D. research
FIRST RECORD OF THE FAMILY RINGICULIDAE
(GASTROPODA) FROM THE MIDDLE TERTIARY OF ANTARCTICA

WILLIAM J. ZINSMIEISTER AND JEFFREY D. STILWELL
Department of Earth and Atmospheric Sciences, Purdue University,
West Lafayette, Indiana 47907

ABSTRACT—A new species of the late Mesozoic-Cenozoic family Ringiculidae (Ringicula (Ringicula) cockburnensis n. sp.) is described from basal glauconitic beds of late Eocene age of Cockburn Island, Antarctica, and is the first reported occurrence of the family Ringiculidae from the continent of Antarctica. Ringicula (R.) cockburnensis n. sp. most closely resembles R. castigata from the middle Oligocene Duntooionian Stage of New Zealand and provides further support for the strong provinciality (Weddellian Province) that existed along the southern margin of the Pacific during the Late Cretaceous and early Tertiary.

INTRODUCTION

Cockburn Island is one of several islands of the James Ross Island group (Figures 1 and 2) located on the northeast tip of the Antarctic Peninsula and showing well-exposed Cretaceous and Tertiary sediments. Although Cockburn Island is situated near Seymour and James Ross Islands, sites of considerable field activity during the last decade, very little work has been done on the island since Otto Nordenskjold’s Swedish South Polar Expedition, 1901–1903 (Andersson, 1906).

Our knowledge of the geology of Cockburn Island is based almost entirely upon initial field work and collections made by Nordenskjold’s expedition (Andersson, 1906; Buckman, 1910; Wilckens, 1924). The only other scientific party to visit the island prior to 1981 was a Falkland Island Dependencies Survey (now British Antarctic Survey) sledging party led by W. N. Croft during the austral summer of 1946. After Croft’s sledging party, another brief visit was made by members of the First American Expedition to Seymour Island in March, 1981 (Zinsmeister, 1987). A third American Expedition to Seymour Island in 1987 provided the first opportunity for a detailed survey of the geology of Cockburn Island (Stilwell and Zinsmeister, 1987; Elliot and Rieske, 1987). The material described in this paper was collected at that time. Ringicula is an ancient group having a long stratigraphic range with its earliest occurrences found in the Cenomanian (Zilch, 1959–1960; Davies, 1971; Powell, 1979). The group has a cosmopolitan geographic distribution in tropical and temperate seas from the Late Cretaceous to the Recent of Europe, West and South Africa, North and South America, Asia, Indonesia, Australia, New Zealand, Formosa, and Japan. The discovery of the ringiculid fauna in Antarctica extends the distribution of the group to include all continents of the Southern Hemisphere and provides additional data concerning the biogeographic history of the shallow-marine molluscan faunas of the southern circum-Pacific.

STRATIGRAPHY

The rocks on Cockburn Island have been divided into four informal stratigraphic units: Upper Cretaceous sandy, conglomeratic silts and sandstones; well-bedded Tertiary silty, glauconitic sandstones; Quaternary basaltic flows; and terrace deposits of the “Pecten conglomerate” overlying the basalts (Andersson, 1906). The Upper Cretaceous (Campanian) unit consists of approximately 150 m of nearly horizontal, light- to medium-gray, conglomeratic silts and sandstones. These sediments are for the most part unfossiliferous, except for several horizons with poorly preserved ammonites, bivalves, gastropods, and arthropods (Stilwell and Zinsmeister, 1987). Resting unconformably on the Cretaceous on the northeast side of the island is approximately 50 m of upper Eocene sandy siltstones and glauconitic sandstones. The lower 5 m of the Eocene beds are characterized by glauconitic sands with abundant, but generally poorly preserved, marine invertebrates. The new species of Ringicula described in this paper is from this glauconitic facies. Immediately overlying the basal glauconitic sands are well-bedded flaggy, ripple-laminated, fine-grained sands and clay-rich sandstone beds. These Tertiary beds dip approximately 22° to the east. This rather steep attitude of the Tertiary strata is believed to represent initial dips associated with the burial of an irregular topographic erosional surface during the late Eocene transgressions. Similar relationships between the upper Eocene La Meseta Formation and the underlying Upper Cretaceous and lower Tertiary rocks are well developed on nearby Seymour Island (Sadler, 1988). Overlying the Cretaceous and Tertiary beds are a series of horizontal cliff-forming Quaternary basaltic flows. The thickness of these flows is in excess of 40 m, but precise measurements of the thickness are not available. On the northwest corner of the plateau is a relatively angular conical hill consisting of additional flows that escaped plantation during the last major glacial advance. Along the margin of the plateau on the east side of the island is a relatively thin Quaternary terrace deposit consisting of coarse gravelly fossiliferous marine sandstone of the “Pecten conglomerate.”

TERTIARY FAUNA FROM THE GLAUCONITIC SANDSTONE

Wilckens (1924) published a short note on Andersson’s small collection of Tertiary invertebrates from the east side of Cockburn Island. Because of the poor preservation, Wilckens described only a single species of a serpulid (Serpula (=Rotularia) (Tubulostium?) cockburnensis) from Andersson’s collection. The other 16 taxa discussed by Wilckens were given generalized generic names or an indeterminate designation. Except for a revision of the brachiopod component of the Cockburn Island fauna (Owen, 1980), there has been no further work on the Cockburn Island Tertiary fauna. The glauconitic sand at the base of the Tertiary sequence contains an abundant and relatively diverse, but poorly preserved, invertebrate fauna dominated by a diverse assemblage of brachiopods and bryozoans. A characteristic component of the fauna is a large species of hemispherical bryozaon (up to 10 cm in diameter). Unfortunately, except for the brachiopods and bryozoans, most of the fossils consist of molds and casts. The
molluscan fauna, except for a coarse-ribbed species of Chlamys and a medium-sized species of Cucullaea cf. C. raea Zinsmeister, 1984, is characterized by small gastropods. Another interesting component of the Cockburn Island fauna is the serpulid Rotularia cockburnensis (Wilckens), which is present in large numbers, though very rare in the La Meseta fauna on Seymour Island.

This small fauna from the basal glauconitic sandstone on Cockburn Island is of particular interest because a similar facies (Telm 1 of Sadler, 1988) occurs at the base of the La Meseta Formation on Seymour Island. In contrast to the low diversity of brachiopods and bryozoans of most of the La Meseta Formation, Telm 1 is characterized by a diverse brachiopod and bryozoan assemblage with molluscs representing a minor component, similar to the glauconitic facies of Cockburn Island. Stratigraphically both occur at the base of the upper Eocene beds and are thought to represent an unusual facies associated with a late Eocene transgression in the James Ross Island basin.

**SYSTEMATIC PALEONTOLOGY**

**Phylum** MOLLUSCA Linnaeus, 1758  
**Class** GASTROPODA Milne Edwards, 1848  
**Subclass** OPISTHOBRANCHIA  
**Order** CEPHALASPIDAEA P. Fischer, 1883  
**Superfamily** ACTEONACEA d'Orbigny, 1842  
**Family** RINGICULIDAE Philippi, 1853  
**Genus** RINGICULA Deshayes, 1838

*Type species.—* Auricula ringens Lamarck, 1804 (by subsequent designation, Gray, 1847), Eocene, Paris Basin.

**RINGICULA** (RINGICULA) 
**COCKBURNENSIS** n. sp.  
*Figure 3.1–3.6*

**Diagnosis.**—Shell minute, ovate to subglobose, medium-height spire, convex whorls with seven incised spiral grooves, thickened outer lip with thick parietal callus, markedly curved inner lip with two folds, siphonal canal broadly open.

**Description.**—Shell minute, relatively solid, ovate-subglobose; spire moderately elevated, approximately one-quarter total shell height, with at least three subquadrate, lightly convex whorls; sutures channelled, only slightly impressed; protoconch, conical, smooth, paucispiral; growth lines obsolete; body whorl greatly expanded, capacious, globose, convex, mostly smooth and polished except for approximately 13 flattened spiral cords separated by well-defined spirally incised lines, flattened cords becoming wider anteriorly; posterior slope of body whorl broadly convex, anterior slope moderately constricted; penultimate whorl, with seven subduded flattened spiral cords; aperture elongate, very constricted posteriorly, expanded anteriorly; posterior channel broadens slightly posterior of constriction, bordered by a thickened outer lip and parietal callus that extends well onto body whorl; siphonal canal short, open with distinct notch; col­umella covered with thick callus with two widely spaced, pro­nounced folds, posterior fold oblique, anterior fold slightly stronger, more oriented towards vertical, originating at base of columella; parietal wall with a single strong fold; inner lip with a heavy, well-margined callus that covers anteriorly the entire columella and abruptly narrows at parietal wall; inner lip distinctly curved; outer lip with a very thickened prominent varix that extends posteriorly and ends medially on penultimate whorl, outer lip also striated with growth lines; labrum only faintly denticulate within.

**Dimensions.**—Holotype, USNM 441878, height 4.0 mm (nearly complete), diameter of body whorl 3.0 mm; paratype, USNM 441879, height 2.5 mm (incomplete), diameter of body whorl 2.0 mm; paratype, USNM 441880, height 2.5 mm (nearly complete), diameter of body whorl 2.0 mm; paratype, USNM 441881, height 2.0 mm, diameter of body whorl 1.5 mm (incomplete).

**Types.**—Holotype, USNM 441878; paratypes, USNM 441879, USNM 441880, USNM 441881.

**Material.**—Nineteen specimens.

**Type locality.**—Glauconitic sand at base of Tertiary beds (Purdue University locality no. 1511) just below prominent basaltic spire at the northeast end of Cockburn Island.

**Stratigraphic range.**—Restricted to glauconitic facies at the base of the Eocene beds on Cockburn Island.


**Geographic distribution.**—Cockburn Island, Antarctic Peninsula.

**Discussion.**—Ringicula s.s. is characterized by a small, low-spired globose to subglobose shape with a sculpture of spirally incised lines or furrows (Sohl, 1964). The aperture is usually constricted posteriorly. According to Sohl (1964), the labrum or outer lip can either be smooth or denticulate. It is generally agreed (Sohl, 1964) that the earlier Cretaceous forms of the group belong to the Ringicula s.s. because of the distinctly denti­culate labrum, unlike the smooth inner surface of the labrum of the later Tertiary subgenus Ringiculella Sacco, 1892. The Ringiculella subgroup appears to be of a more recent origin with most of the Recent species belonging to this group. Many species assigned to Ringicula s.s. vary considerably and in some cases oversstep the generic limits of the group. Several authors (Murdoch and Suter, 1906; Marwick, 1929, 1931; Stephenson, 1952; Sohl, 1964) have assigned species to Ringicula s.s. that are found to be morphologically distinct with respect to parameters such
as spiral ornamentation, callous development, and aperture structure. The characteristic features of *Ringicula* s.s. are the presence of a varix-like, usually well-margined outer lip and a columella with two strong folds. The parietal wall has either a single denticle or fold.

Features of the Cockburn Island species are found to be generally consistent with the *Ringicula* s.s. group. The Antarctic species can easily be differentiated from the Paleocene to Miocene genus *Gilbertina* Morlet, 1888, group from Europe and North America by the latter having a more globose outline with a more obtuse spiral angle, an unnotched anterior siphonal canal, a labium with two internal teeth, and a prosocline growth line profile. The Cockburn Island species can be excluded from the Oligocene species, *Ringicula castigata* Marwick, 1929, of New Zealand. The Cockburn Island species approaches closely the *Ringicula* s.s. Alvarangoensis Stephenson, 1952, of the Woodbine Formation of Texas, but can be distinguished by its straighter, more thickened outer lip, strongly notched siphonal canal, and pronounced parietal fold. A similar Late Cretaceous species, *R. (R.) pulchella* Shumard, 1861, which was also figured in Sohl (1964), from the Ripley Formation of North America can be separated from the Cockburn Island species by its distinctive zig-zag spiral ornamentation. Kollmann and Peel (1983) figured an unnamed species from the Paleocene of West Greenland and referred it to the subgenus *R. (Ringiculina)*. The Greenland species is similar in outline to *R. cockburnensis* n. sp., but can be differentiated by denser spiral ornamentation, smooth labrum, and shallower siphonal notch. The Cockburn Island species most closely resembles an Oligocene species, *R. castigata* Marwick, 1929, from the Duntroonian Stage of New Zealand. *Ringicula castigata* Marwick may be separated from *R. (R.) cockburnensis* n. sp. by its more broadly convex outer lip, narrower parietal callous, and more parallel columellar folds.

In a discussion of Late Cretaceous/early Tertiary biogeography, Zinsmeister (1979, 1982) proposed the Weddellian Province for of the shallow-marine region along the southern circum-Pacific from southeastern Australia to southernmost South America. The presence of a closely allied species of *Ringicula* in the middle Tertiary of New Zealand and Antarctica and its absence in coeval deposits in South America and western and northern Australia provides another example of the provincial nature of the shelf faunas of the southern margin of the Pacific during the early Cenozoic.

**ACKNOWLEDGMENTS**

We would like to extend our thanks to D. H. Elliot and D. Reiski for making bulk sample collections from the glauconitic beds on Cockburn Island, which contained the specimens used in this paper. Access to Cockburn Island would not have been possible without helicopter support from the United States Coast Guard icebreaker *Glacier*. We would also like to thank H. Zimmermann, Earth Science Program Manager, for his enthusiastic support of our field program to the Seymour Island region. Field work and laboratory study of these fossils was supported by the Division of Polar Programs grant DPP 8416783.
as spiral ornamentation, callous development, and aperture structure. The characteristic features of *Ringicula* s.s. are the presence of a varix-like, usually well-margined outer lip and a columella with two strong folds. The parietal wall has either a single denticle or fold.

Features of the Cockburn Island species are found to be generally consistent with the *Ringicula* s.s. group. The Antarctic species can easily be differentiated from the Paleocene to Miocene genus *Gilbertina* Morlet, 1888, group from Europe and North America by the latter having a more globose outline with a more obtuse spiral angle, an unnotched anterior siphonal canal, a labium with two internal teeth, and a prosocline growth line profile. The Cockburn Island species can be excluded from the subgenus *Ringiculopsis* Chavan, 1947, from the Upper Cretaceous of Palestine by its larger size, globose outline, more flush sutures, and more constricted aperture. Although the labrum is covered by well-cemented sand grains on our specimens, a few show evidence that the labrum is finely denticulate, unlike the subgenus *Ringiculina* Montersorato, 1884. The spine in the *Ringiculina* group is short and the form more globose (Davies, 1971) as compared to *Ringicula* s.s. Although *Ringiculella* is a synonym according to Zilch (1959–1960), Sohl (1964) believed that *Ringiculella* was distinct because of the smooth inner margin of its outer lip. The evidence of a faintly denticulate labrum found in the holotype *R. (R.) cockburnensis* n. sp. supports our assignment of the new species to the older *Ringicula* s.s. Although the aperture shape and callous thickness of the new species is somewhat similar to the middle Tertiary subgenus *Ringiculospongia* Sacco, 1892, the callous of the Cockburn Island species is more flattened and more irregularly developed, and the shell profile less globose.

*Ringicula* (R.) *cockburnensis* n. sp. is very similar to shallow-water *ringiculid* taxa of North America and New Zealand. A possible close ally to the Antarctic species is the Tertiary species, *R. magellanaica* Ihering, 1907, of Argentina, but the poor state of preservation of the Argentine types prevents a detailed comparison. The Cockburn Island species approaches closely the Late Cretaceous (Cenomanian) *ringiculid* *R. (R.) arlingtonensis* Stephenson, 1952, of the Woodbine Formation of Texas, but can be distinguished by its straighter, more thickened outer lip, strongly notched siphonal canal, and pronounced parietal fold. A similar Late Cretaceous species, *R. (R.) pulchella* Shumard, 1861, which was also figured in Sohl (1964), from the Ripley Formation of North America can be separated from the Cockburn Island species by its distinctive zig-zag spiral ornamentation. Kollmann and Peel (1983) figured an unnamed species from the Paleocene of West Greenland and referred it to the subgenus *R. (Ringiculina)*. The Greenland species is similar in outline to *R. cockburnensis* n. sp., but can be differentiated by denser spiral ornamentation, smooth labrum, and shallower siphonal notch. The Cockburn Island species most closely resembles an Oligocene species, *R. castigata* Marwick, 1929, from the Duntroonian Stage of New Zealand. *Ringicula castigata* Marwick may be separated from *R. (R.) cockburnensis* n. sp. by its more broadly convex outer lip, narrower parietal callous, and more parallel columnellar folds.

In a discussion of Late Cretaceous/early Tertiary biogeography, Zinsmeister (1979, 1982) proposed the Weddellian Province for of the shallow-marine region along the southern circum-Pacific from southeastern Australia to southernmost South America. The presence of a closely allied species of *Ringicula* in the middle Tertiary of New Zealand and Antarctica and its absence in coeval deposits in South America and western and northern Australia provides another example of the provincial nature of the shelf faunas of the southern margin of the Pacific during the early Cenozoic.

ACKNOWLEDGMENTS

We would like to extend our thanks to D. H. Elliot and D. Reiski for making bulk sample collections from the glauconitic beds on Cockburn Island, which contained the specimens used in this paper. Access to Cockburn Island would not have been possible without helicopter support from the United States Coast Guard icebreaker Glacier. We would also like to thank H. Zimmermann, Earth Science Program Manager, for his enthusiastic support of our field program to the Seymour Island region. Field work and laboratory study of these fossils was supported by the Division of Polar Programs grant DPP 8416783.
Articulated crinoids from the basal Kauru Formation (Early Paleogene), Five Forks, North Otago, New Zealand

Jeffrey D. Stilwell and R. Ewan Fordyce, Department of Geology, University of Otago

Partial crinoid specimens (Phylum Echinodermata) collected recently from the Kauru Formation near Five Forks, North Otago, include articulated columnals and brachia (arms) with pinnules. Such articulated specimens are rare in New Zealand and elsewhere. Other occurrences of Cenozoic crinoids in New Zealand include abundant fragments, especially columnals, e.g. those from the Otekaikē Limestone at Waihao Forks and Pentland Hills.

The crinoids from the Kauru Formation belong to the Isocrinida, a group of benthic stalked crinoids that range from Early Triassic to Recent. A generic assignment is not possible at this time. The crinoids are present in a fossiliferous, cemented, pebbly sandstone a few millimetres above the unconformity with the Haast Schist. The associated marine fauna include abundant bryozoa, fragments of echinoids, rare brachiopods, and abundant, generally poorly preserved molluscs including Ostrea sp., Spineilo sp., Purpurocardia? sp., Pteromyrtea sp., Priscaphander sp., naticids, Acteon sp., Pseudofax. sp., Foturris sp., and Zeacolpus (Leptocolpus) sp. No foraminifera could be extracted and no palynological data are available for this part of the Kauru Formation. The age of the crinoid horizon is uncertain, but the presence of molluscs with affinities to those from the Wangaloa Formation suggests a Paleocene ("Wangaloan", Teurian) age. The stratigraphic setting is quite unusual for the preservation of articulated crinoids. The fossil assemblage is clearly a shallow marine one, and the presence of coarse pebbles in the basal (early transgressive) part of the local Cenozoic sequence further suggests a shallow water setting. That the crinoids are articulated suggests deposition below wave base and/or rapid sedimentation.

Isocrinids are today deep water crinoids and some authors suggest restriction to middle shelf or deeper environments since the mid to late Mesozoic. This report of isocrinids from the shallow water Kauru formation provides an exception to a deep water restriction for the group. The occurrence also provides a surprising example of fragile, partly articulated crinoids in a coarse-grained facies of a near-shore and possibly high energy environment.
Stratigraphy and paleontology of Campanian and Eocene sediments, Cockburn Island, Antarctic Peninsula

R. A. ASKIN\textsuperscript{1}, D. H. ELLIOT\textsuperscript{2}, J. D. STILWELL\textsuperscript{3}, and W. J. ZINSMEISTER\textsuperscript{4}

\textsuperscript{1}Department of Earth Sciences, University of California, Riverside, CA 92521 USA; \textsuperscript{2}Byrd Polar Research Center, The Ohio State University, Columbus, OH 43210 USA; \textsuperscript{3}Department of Geology, University of Otago, Box 56, Dunedin, New Zealand; \textsuperscript{4}Department of Earth and Atmospheric Sciences, Purdue University, West Lafayette, IN 47906 USA

(received July 1990; accepted January 1991)

Abstract—Approximately 150 meters of fine-grained Campanian sediments and over 100 meters of fine- to medium-grained Eocene sands underlie Pliocene basalts and conglomerates on Cockburn Island, northeastern Antarctic Peninsula. The Campanian beds are part of the "Unnamed strata" of the Marambio Group and contain invertebrate and palynomorph fossils that predate the adjacent Seymour Island López de Bertodano succession. Rich palynomorph floras suggest a middle Campanian age. Deposition was in low energy, shallow shelf environments. Invertebrate and palynomorph fossils, and lithology, all indicate correlation of the Eocene beds with the basal La Meseta Formation, members Telm 1 and lower Telm 2 of Seymour Island. The age of these beds is probably late early Eocene. The basal La Meseta sands are marginal marine to shallow shelf sediments that fill a broad valley probably incised during latest Paleocene-earliest Eocene as a result of tectonism and sea-level lowstands.

Resumen—Aproximadamente 150 m de sedimentos campanianos de grano fino y mas de 100 m de arenas eocenas finas a medianas subyacen a basaltos pliocenos y conglomerados en la Isla Cockburn, ubicada en la porcion nororiental de la Peninsula Antartica. Las capas campanianas son parte de las "Unnamed strata" del Grupo Marambio, y contienen invertebrados y palinomorfos fósiles mas antiguos que los de la sucesion de López de Bertodano de la Isla Seymour adyacente. Las ricas floras palinomorfas sugieren una edad campaniana media. La sedimentacion tuvo lugar en un ambiente de plataforma somera y tranquila. Palinomorfos e invertebrados fósiles, al igual que la litologia indican una correlacion de las capas eocenas con la porcion basal de la Formacion La Meseta, miembros Telm 1 y parte inferior de Telm 2, de la Isla Seymour. La edad de estas capas es probablemente eocena temprana tardia. Las arenas basales de La Meseta son sedimentos de plataforma somera a marinos marginales que rellenan un amplio valle, probablemente modelado durante el Paleoceno mas tardio al Eoceno mas temprano, como resultado de tectonismo y condiciones eustaticas de nivel de mar bajo.

INTRODUCTION

CRETACEOUS and Tertiary sedimentary strata and basalt flows are exposed on Cockburn Island, which lies between Seymour and James Ross Islands in the northwestern Weddell Sea near the tip of the Antarctic Peninsula (Figs. 1 and 2). Lower Cretaceous (Barremian) to Eocene sediments (Table 1) were deposited in the James Ross Basin (Elliot, 1988; Larsen Basin of McDonald et al., 1988). Lower Cretaceous rocks occur in the northwest part of the basin, adjacent to the Antarctic Peninsula. Upper Cretaceous beds crop out on James Ross and adjacent islands, and Tertiary strata are known only from Seymour and Cockburn Islands. Recent work on Seymour Island (in Feldmann and Woodburne, 1988) reported rich fossil faunas and floras, and established a stratigraphic framework for Campanian to Eocene sequences. At least two major episodes of valley cutting on the early Tertiary continental shelf separate...
Table 1. Stratigraphy of the James Ross Basin.

<table>
<thead>
<tr>
<th>Group</th>
<th>Formation</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marambio</td>
<td>Sobral</td>
<td>Paleocene</td>
</tr>
<tr>
<td></td>
<td>López de Bertodano</td>
<td>Late Campanian-early Paleocene</td>
</tr>
<tr>
<td></td>
<td>&quot;Unnamed strata&quot;</td>
<td>Campanian</td>
</tr>
<tr>
<td></td>
<td>Santa Marta</td>
<td>Santonian-Campanian</td>
</tr>
<tr>
<td>Gustav</td>
<td>Hidden Lake</td>
<td>?Coniacian-Santonian</td>
</tr>
<tr>
<td></td>
<td>Whiskey Bay</td>
<td>Albian-Coniacian</td>
</tr>
<tr>
<td></td>
<td>Kotick Point</td>
<td>Aptian-Albian</td>
</tr>
<tr>
<td></td>
<td>Lagrelius Point</td>
<td>?Barremian-Aptian</td>
</tr>
<tr>
<td></td>
<td>Nordenstjeld</td>
<td>Kimmeridgian-Tithonian</td>
</tr>
</tbody>
</table>

Eocene, and late Paleocene, from older Paleocene-Cretaceous strata on Seymour Island. Similar relations exist on Cockburn Island.

In addition, a thin package of upper Pliocene sediments (Pecten Conglomerate) is preserved on a prominent erosional bench in Pliocene basalts that overlie the older strata on Cockburn Island (Soot-Ryen, 1952; Zinsmeister and Webb, 1982; Webb and Andreasen, 1986). The Pliocene beds are not discussed here.

In this paper we summarize the lithostratigraphy, paleontology, and age interpretations of the Cretaceous and Paleogene beds on Cockburn Island, and suggest correlations with Seymour Island.
PREVIOUS WORK

Cockburn Island was first visited on January 6, 1843, during the voyage of Sir James Clark Ross around Antarctica. Ross and others landed on the island and collected a few samples, which were not described until late in the century (Prior, 1899). Their basalt, basaltic glass, and calcareous glauconitic sandstone samples could be from either outcrop or float, but the two granite samples must be glacial erratics.

The island was visited next by members of Otto Nordenskjöld’s Swedish South Polar Expedition of 1901-1903 (Nordenskjöld, 1905; reviewed by Zinsmeister, 1988). During a brief visit between November 21 and 25, 1902, they collected some “volcanic tuff” but did not recognize the presence of sedimentary strata that form most of the island. However, none of the group was a trained scientist and doubtless the volcanic cone-like form of the island (Fig. 3) and volcanic debris blanketing the slopes contributed to the oversight. J. Gunnar Andersson, who had joined Nordenskjöld on October 12, 1903, returned to the island on October 21-23 and collected fossils from the Cretaceous beds, the glauconitic sands at the base of the Tertiary sequence, and the Plio-Pleistocene Pecten Conglomerate. Buckman (1910) described the early Tertiary brachiopod fossils and Wilckens (1924) the other fossil groups.

More than 40 years passed before the next visit in 1946 by W. N. Croft of the Falklands Islands Dependencies Survey (now the British Antarctic Survey; Adie, 1958; Bibby, 1966). After establishment of the Argentine base on Seymour Island in 1969, several brief visits were made by members of the Instituto Antartico Argentino. Prior to our visit in January, 1987 (Elliot and Rieske, 1987; Stillwell and Zinsmeister, 1987), the only landing by U.S. scientists was in 1982 (Zinsmeister and Webb, 1982).

STRATIGRAPHY

In this paper we use the stratigraphic framework of Ineson et al. (1986), modified in part by Olivero et al. (1986) and summarized in Elliot (1988), in which the Marambio Group is subdivided into four units (Table 1): the Santa Marta Formation (oldest), "Unnamed strata" [part of Bibby’s (1966) Snow Hill Island Series], López de Bertodano Formation, and Sobral Formation. The López de Bertodano and Sobral Formations are currently restricted to Seymour Island, sensu Rinaldi et al. (1978). Ineson et al. (1986) used the term "Unnamed strata" for the lower part of the Marambio Group because that part of the section was poorly known and they anticipated further fieldwork would lead to additional subdivision. This is the case for the oldest Marambio Group beds from northern James Ross Island, described as the Santa Marta Formation (Olivero et al., 1986). Remaining "Unnamed strata" include predominantly fine-grained, relatively well-bedded sediments exposed at various locations on eastern and southern James Ross Island and Vega, Humps, Snow Hill, and Cockburn Islands (see Fig. 1). Pending further investigation, it is possible that some of these strata may be assigned to the López de Bertodano Formation, such as the younger (eastern) beds of northern Snow Hill Island, as suggested by Macellari (1984a), and some of the older beds may belong to the Santa Marta Formation. Pirrie et al. (in press) show that part of the Vega Island section may correlate with the López de Bertodano Formation.

The age of the "Unnamed strata" may be misinterpreted. The inadvisability of grouping all the post-Santa Marta "Unnamed strata" into the López de Bertodano Formation, as has been done by many authors, is illustrated by Pirrie and Riding’s Fig. 1 and Table 1 (1988). A latest Campanian-Maastrichtian age for all but the uppermost part of the López de Bertodano Formation — which is correct for the type locality of the López on Seymour Island — is thus incorrectly inferred for all the sedimentary outcrops on eastern and southern James Ross Island, Vega Island, Humps Island, Snow Hill Island, and Cockburn Island. As discussed below, this conclusion is invalid.

The Marambio Group is overlain by Paleogene sediments of the "Wiman," Cross Valley, and La Meseta Formations (see Fig. 2 and Table 1). These formations are, as yet, known only from Seymour Island and, in the case of La Meseta, a small exposure on Cockburn Island.

La Meseta Formation sediments crop out on northern Cockburn Island, and Cretaceous "Unnamed strata" occur on the flanks of the rest of the island. All these sediments are poorly consolidated, except for an occasional calcite-cemented bed. Both formations are overlain by Pliocene basaltic lavas of the James Ross Island Volcanic Group. Basalt talus obscures much of the underlying sedimentary packages, which are exposed in small gulleys eroding the steep (45°) slopes. This study describes beds from the south and east (Seymour) side of Cockburn Island.

The steep contact between the Cretaceous and Tertiary strata on the east side of Cockburn Island is not exposed, although in a gulley just above the shore to the north of the basalt spine, the Tertiary beds lie unconformably on the older beds. Although initially suggested as a fault contact (Elliot and Rieske, 1987), the unexposed steep eastern contact separating Cretaceous and Tertiary beds may also be erosional, as observed on Seymour Island. In Cross Valley on Seymour Island, La Meseta beds lap onto the older Cross Valley Formation with present dips, away from the contact, as high as 20° (the original depositional dip may have been over-steepened either by later slumping of soft sediment or by growth faults). The contact itself must have a dip greater than 30°. Near Cape Wiman the contact of La Meseta on older Sobral and Wiman beds is highly irregular, locally very steep and at one place is vertical. This contact also suggests valley or canyon cutting and, at least locally, significant and steep topographic relief. The
Cross Valley and lower La Meseta beds are recognized as valley fill deposits (Sadler, 1988), and it is likely that the Tertiary beds on Cockburn Island also represent sediments filling a valley incised into Cretaceous beds. The anomalously high dips of the Tertiary beds on Cockburn Island are here regarded as largely primary and the unexposed steep contact on the east side of the island as a possible unconformity, probably a buttress unconformity against a paleocanyon wall.

Cretaceous "Unnamed Strata"

The Cretaceous beds, approximately 150 meters thick, dip about 6° to the southeast, are poorly bedded to massive, medium grey (brownish weathering), and fine grained. In the measured section (Fig. 4), a lower 30-meter-thick clayey silt unit grades up into a slightly coarser-grained, more lithologically varied, fossiliferous unit about 40 meters thick. This second unit includes: silty, very fine sands with resistant sandy interbeds; indurated, calcareous clayey siltstone interbeds up to 1 meter thick in the lower part; thin silty clay interbeds; and a few horizons of calcareous concretions (up to 1.5 m diameter). The beds contain a relatively well-preserved invertebrate fauna. The upper part of the second unit is very thinly bedded, with some flaser bedding. It is overlain by approximately 50 meters of silty, very fine sands and, in places, displays very thin bedding and flaser bedding. It grades into an upper 25 meters of sandy silts.

La Meseta Formation

The Lower Tertiary beds, more poorly exposed than the Cretaceous, have a stratigraphic thickness exceeding 100 meters. A partial section of the lower part is illustrated in Fig. 5.

Glauconitic beds were observed only in the basal 22 meters of the measured section; all other examined outcrops are grossly similar to the overlying beds in that section.

The lower 22 meters of the measured section are predominantly glauconitic sands and sandstones. The loose glauconitic sands occur as beds 10-20 cm thick and contain clay-rich layers. The more lithified sandstones are each less than 1 meter thick, with widely varying glauconite content and common clay-rich stringers. These sandstone beds are weakly stratified and the upper one is flaggy.

The beds lose most of the glauconite within a few meters above the basal 22 meters, and thereafter consist of medium- to fine-grained sands alternating with muddy beds (Fig. 6). These beds continue to the overlying basalt contact. The sands, dominantly grey to greenish grey, form beds up to 20 cm thick and carry sparse concretions; clay wisps and laminae are common in the thicker beds. Cleaner, pale-colored sandstone beds have a thickness of up to 1 meter, and contain thin layers of clay and siltstone. The uppermost beds are thin, becoming finer-grained upwards, with occasional thin layers of clay. The beds are generally fine-grained, with some medium-grained layers.

Fig. 4. Stratigraphic column for the Campanian beds, section CI.
Campanian and Eocene stratigraphy and paleontology on Cockburn Island, Antarctic Peninsula

sands with lesser amounts of clay occur sporadically and have similar thicknesses. The chocolate-brown muddy beds range up to 15 cm thick. In places, the mud layers and laminae are slightly lithified and form shale-like flakes and splinters.

The lower glauconitic sandstones exhibit ripple drift cross-lamination (Fig. 7), but no other structures were observed. Sedimentary structures in the overlying thin- to medium-bedded strata are relatively uncommon. Ripple drift cross-lamination with mud drapes occurs in most thicker sands (Fig. 8) and flaser bedding is also present (Fig. 9). Load casts and flame structures are present at the base of a few beds. Small-scale penecontemporaneous faulting is evident in a few sands.

These thin-bedded strata show broad scour and fill structures that cut down several meters into underlying beds (Fig. 10). Individual beds pinch out on the flanks of the scour. Slumping of sediment in one scour has produced a recumbent fold (Fig. 11). Sediment filling scours is the same as that forming scour walls. Scours are stacked on each other (Fig. 12), which leads to widely divergent attitudes. The scour surfaces, where examined, are sharp and lack any lag deposit. The scours are interpreted as the result of slumping or mass movement of water-saturated sands and muds.

Based on lithology and fossil content, these beds bear a close resemblance to, and are interpreted as a more proximal correlative of, Members Telm 1 (in the Cross Valley area) and Telm 2 (Sadler, 1988) of the La Meseta Formation, Seymour Island.

INVERTEBRATE PALEONTOLOGY

Cretaceous Fauna

Most of the invertebrate fossils occur in calcareous, fine sandstone beds, particularly in the second unit of the "Unnamed strata," though some occur scattered throughout the rest of the section. They include the ammonites Diplomoceras lambi Spath, Gunnarites cf. antarcticus (Stuart Weller), Maarites sp., and Pseudophyllites loryi (Killian and Reboul); the serpulid Rotularia cf. fallax (Wickens); the bivalves Pinna cf. anderssoni Wickens, the oyster Pycnodonte (Phygraea) cf. vesiculosa (Sowerby), and Entolium sp., Panopea sp., Malletia sp., Lucina sp., Seymourita antarctica (Wickens); the gastropods "Cassidaria" sp., "Eunaticina" sp., and a pyramellid?; excellently preserved specimens of the lobster Hoploparia stokesi (Weller) (discussed by Feldmann and Tshudy, 1989) in small concretions; crinoid fragments; corals; an

alternating clay-rich silty sand and medium to fine grained sand with clay-rich laminae

medium to fine grained sand with clay-rich laminae

medium to fine grained sand (stone)

G glauconite

Fossils (molluscs, brachiopods, bryozoa)

Fig. 5. Stratigraphic columns for the Eocene beds, composite section 87/10. Column A represents the lower 50 meters of the exposed section. Column B was measured about 100 meters south of column A; the lithology is the same as the upper part of column A and is likely to be slightly higher stratigraphically, although the talus slopes and scour-and-fill structures make correlation of strata impossible.
irregular echinoid and spines; and fish scales. Bibby (1966) earlier reported *Gunnarites antarcticus*, *Pinna* sp., *Pecten* sp., and *Lahillia* sp. in these beds.

Although the invertebrate fauna is sparse, it is clearly distinct from the faunas of the López de Bertodano Formation on Seymour Island. The absence of any of the age-restricted latest Campanian-Maastrichtian ammonites of Seymour Island, and the presence of *Gunnarites* cf. *antarcticus*, known from Snow Hill Island, suggests that the strata on Cockburn Island are older than the Seymour Island Cretaceous beds. The only species of *Gunnarites* on Seymour Island is *G. bhavaniformis* (Kilian and Reboul), restricted to the lowermost beds (locality 1, Unit 1; Macellari, 1986). The ammonite *D. lambi* is also restricted to Campanian lower beds on Seymour Island, and occurs on Snow Hill and adjacent islands; younger specimens are now separated as *D. maximus* (Olivero and Zinsmeister, 1989). *P. loryi* ranges through the Campanian and Maastrichtian, and the presence of *Hoploparia stokesi* cannot be used for precise biostratigraphy because it is long ranging —
Fig. 10. Scour-and-fill structure in upper non-glauconitic part of La Meseta section. Thicker, cleaner, pale-colored sand beds are interspersed in alternating sands and muddy beds. The base of a scour is marked by dots. Arrow indicates location of slump fold illustrated in Fig. 11. Lower part of column B, Fig. 5.

Fig. 11. Recumbent fold formed by slumping of water-saturated, thin-bedded muddy strata, La Meseta Formation. Location indicated in Fig. 10 by arrow. Lower part of column B, Fig. 5.

Fig. 12. Stacked scour-and-fill structures, marked by white squares, in non-glauconitic strata, showing divergent attitudes of beds. Adjacent to location of column B, La Meseta Formation.
from early Campanian to earliest Paleocene. The *Rotularia* specimens are too poorly preserved for definitive species assignment but appear most similar to *R. (austrorotularia) fallax* (Wilckens) that distinguishes serpulid Zone I (Macellari, 1984a) from basal Seymour beds, Snow Hill Island, and adjacent islands. The poorly preserved bivalves and gastropods provide little information for biostratigraphic correlations.

**Tertiary Fauna**

Buckman (1910) described the early Tertiary brachiopods from Cockburn Island and Wilckens (1924) published a short note on the remainder of the early Tertiary invertebrate fauna collected during the Swedish South Polar Expedition by Andersson. Because of poor preservation of the fauna, Wilckens only named a single species of serpulid, *Serpula (Tubulostium) cockburnensis*, and used broad generic names or an indeterminate designation for 16 other taxa. No further work on the Cockburn Island fauna has been done except for a revision of the brachiopods (Owen, 1980).

The glauconitic sands at the base of the Tertiary sequence on the east side of the island contain a relatively diverse, but poorly preserved, invertebrate fauna; other La Meseta sediments on Cockburn Island are virtually unfossiliferous. Brachiopods dominate this recently collected fauna, and another characteristic component is a large species of hemispherical bryozoan (up to 10 cm in diameter). Unfortunately, most of the fossils, except for the brachiopods and bryozoans, consist of molds and casts. Furthermore, although the original shell material of the brachiopods is preserved, almost all have been crushed by compaction. The molluscan fauna is characterized by the small gastropod *Ringicula (Ringicula) cockburnensis* Zinsmeister and Stilwell (1990), along with a coarse ribbed species of *Chlamys* and medium-sized specimens of *Cucullaea cf. raea* Zinsmeister. Also notable are the relatively abundant serpulids, which are very rare in Seymour La Meseta sediments.

The small fauna from the basal glauconitic sand interval on Cockburn Island is important because a similar litho- and biofacies occurs at the base of the La Meseta Formation on Seymour Island (Telm 1; Sadler, 1988). The basal Cockburn and Seymour Telm 1 fauna in the Cross Valley area are both characterized by a diverse brachiopod and bryozoan assemblage. Molluscs represent a minor component, in contrast to invertebrate faunas from the rest of the La Meseta Formation.

| CI-24 | CI-23 | CI-22 | CI-21 | CI-20 | CI-19 | CI-18 | CI-17 | CI-16 | CI-15 | CI-14 | CI-13 | CI-12 | CI-11 | CI-10 | CI-09 | CI-08 | CI-07 | CI-06 | CI-05 | CI-04 | CI-03 | CI-02 | CI-01 |
|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 1 7 14 1 1 7 1 13 1 1 X X X | 1 24 1 X 9 X X 10 X | 2 30 1 1 1 | 2 2 X 28 1 1 8 1 8 1 | 2 X | 2 X | 2 X | 2 X | 2 X | 2 X | 2 X | 2 X | 2 X | 2 X | 2 X | 2 X | 2 X | 2 X | 2 X | 2 X | 2 X | 2 X | 2 X | 2 X |
| 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 |

Table 2. Distribution chart of palyno-
PALYNOLOGY

General

Thirty-nine (39) samples from Cockburn Island were studied for palynomorphs. These include 25 Cretaceous samples collected at 6-meter intervals in a section (CI) measured by F. C. Barbis, T. R. Kelley, and J. D. Stilwell on the south side of the island (see Figs. 2, 3, and 4), and 14 Tertiary samples (see Figs. 2, 3, and 5) collected by D. H. Elliot and D. E. Rieske from a composite section (87/10) on the northeastern side of the island.

The samples were processed using standard palynologic techniques, including mild oxidation in warm nitric acid, heavy liquid separation (with ZnCl₂), and short centrifugation. Recovered palynomorphs include marine microphytoplankton (dinoflagellate cysts, acritarchs, other algae) and transported non-marine palynomorphs (spores and pollen from land plants, rare freshwater algal remains and fungal spores).

Cretaceous Palynology

Most of the 25 Cretaceous samples yielded rich assemblages of marine and nonmarine palynomorph taxa in Campanian samples, section CI. Palynomorphs were less abundant in some sandier samples. Palynomorph preservation varies from good to fair. Spores and pollen are yellow to yellow orange and are not significantly darker in samples immediately underlying the basalt. The predominant organic matter is woody vitrinitic material. Inertinite (inert or oxidized organic matter) fluctuates in abundance, being notably the most abundant maceral type in sample CI-9A, a resistant sand and the most weathered of the sample set. Minor to rare dispersed plant cuticle occurs in some samples, including some moderately large (~500 μm) cuticle fragments.

Marine palynomorph assemblages (listed in Table 2) are dominated by *Isabelidinium cretaceum* (Cookson) Lentin and Williams and are typical of late Senonian high (to mid) latitude assemblages (e.g., Lentin and Williams, 1980). Precise correlation of dinocyst zones within the Weddellian Province of Zinsmeister (1979, 1982) is difficult, however, because of the disparity of species ranges from basin to basin — a problem noted by Dettmann and Thomson (1987), Askin (1988), and Pirrie and Riding (1988) for samples from various localities in the James Ross Basin.

Samples from Cape Lamb on Vega Island, like those from Cockburn Island, are characterized by *Isa-
belidinium cretaceum, Cribrapertidinium sp., Odontochitina porifera Cookson, cf. Canninginopsis sp., Isa-
belidinium pellucidum (Deflandre and Cookson) Lent-
tin and Williams (as I. cooksoniae), cf. Allerbidinium sp. and Operculodinium sp. This Vega assemblage
was initially interpreted (Askin, 1983) as late Cam-
panian from correlation of palynomorphs to New Zea-
land assemblages, then middle to late Campanian
(Askin, 1988) based on evidence from associated mollusc faunas (Macellari, 1984b) and foraminifera
(Huber, 1988). An older Campanian age for the Vega
palynomorph assemblage is more likely and is sup-
ported by revision of ages of correlative New Zealand Piripauan-early Haumurian stages by Edwards et al.
(1988). They placed the Piripauan-Haumurian boun-
daries in the middle of the Campanian, though noting it may be as low as Santonian.

Species of Odontochitina with I. cretaceum may be
useful biostratigraphic markers within the James Ross Basin where their presence appears to indicate a
pre-Maastrichtian age. No Odontochitina have yet
been observed in the continuous and relatively well-
dated upper Campanian to Maastrichtian section on
Seymour Island. In New Zealand, Odontochitina
survived into the early Haumurian (late Campanian;
Wilson, 1984a; Edwards et al., 1988). Likewise, in
Australia (Helby et al., 1987) and the Falkland Pla-
teau (Goodman and Millioud, p. 40 in Ludwig et al.,
1983), Odontochitina spp. are reported from Cam-
panian and older rocks. I. cretaceum ranges into the
earliest Maastrichtian in Australia (Helby et al.,
1987) and through the Campanian in New Zealand
(Wilson, 1984a; Edwards et al., 1988). It has not been
found above the Campanian on Seymour Island
(Askin, 1988). Consistent co-occurrences on Cock-
burn Island of O. porifera (to 30 m below top of
section) with common to abundant I. cretaceum are
unambiguous evidence of a pre-Maastrichtian age for
these Cretaceous sediments. Xenascus spp. are not as
well documented in the James Ross basin, but these
too have not been observed in the Maastrichtian (or
upper Campanian) on Seymour Island and typically
do not range into the Maastrichtian elsewhere.

Rare O. operculata (Wetzel) Deflandre and Cook-
son (with I. cretaceum and I. pellucidum) have now
(contrary to Askin, 1988) been found in a sample from
northern Snow Hill Island. This sample (K209), from
the cliffs close to Nordenskjöld's hut, occurs in rocks
stratigraphically below the Seymour Island López de
Bertodano beds and is palynologically more similar to
the "Naze assemblage" (Askin, 1988) from north-
eastern James Ross Island than to the Cockburn
Island flora. Cranwell (1969) also figured an O. oper-
culata specimen from the "Seymour Island area"
(most likely from Snow Hill Island; for Nordenskjöld's
Cretaceous samples, see Zinsmeister, 1988).

When compared to the samples studied by Dett-
mann and Thomson (1987), the Cockburn Island
assemblages most closely resemble their sample
D3030.3 from "back of Brandy Bay" (Santa Marta
Formation), northern James Ross Island. Similari-
ties include the presence of I. cretaceum, O. porifera,
Xenascus and Chatangiella-type (see Appendix)
dinocysts. They assigned this sample a Santonian/
Campanian age based on dinocyst and ammonite
evidence.

I. cretaceum was also found in Dettmann and
Thomson's (1987) sample D3122.3 from Cape Lamb,
Vega Island. Their assemblage lacks O. porifera but,
in addition to I. cretaceum, contains I. pellucidum,
Chatangiella cf. campbellensis (Wilson) Lentin and Williams, Palaeocystodinium granulatum (Wilson)
Lentin and Williams, and diverse angiosperm pollen,
and was assigned a Maastrichtian age.

Pirrie and Riding (1988) suggested a late Cam-
panian to early Maastrichtian age for dinocyst assem-
blages from Humps Island (see Fig.1) containing O.
porifera and I. cretaceum, with I. pellucidum, I. koro-
jonense (Cookson and Eisenack) Lentin and Williams,
and Ceratiospis diebelli (Alberti) Vozzhennikova.

It could be argued that the presence of sometimes
rare Odontochitina spp. depends on subtle facies dif-
erences. However, based on the biostratigraphically
useful series of Isabelidinium-Manumiella species on
Seymour Island (Askin, 1988), the presence of I.
cretaceum, instead of Manumiella "sp.3," strongly
argues for a Campanian rather than Maastrichtian
age for both the Vega Island sample of Dettmann and
Thomson (1987) and the Humps Island samples of
Pirrie and Riding (1988), as well as those from Cock-
burn Island. Relationships between these sequences
remain unclear, as each contains a slightly different
flora. Pirrie and Riding (1988) stated that the Humps
Island strata, based on facies analysis and con-
sideration of paleogeography, may best be interpreted
as the offshore equivalent of the Santa Marta
Formation, and not the direct age equivalent of the
basal Seymour Island strata (as suggested by their
dinocyst interpretation). The revision suggested here
for the age of the Humps Island strata (Campanian,
and older than the Seymour Island López de
Bertodano beds) supports that suggestion and is
consistent with a previous ammonite correlation sug-
gest an early-middle Campanian age for the Humps
Island beds (Howarth, 1966).

Using the New Zealand dinocyst zonation of
Wilson (1984a), the Cockburn Island assemblage
correlates with part (upper) of the Odontochitina
porifera Zone, from the association of O. porifera, I.
cretaceum, Allerbidinium acutulum (Wilson) Lentin
and Williams, and Leberidocysta chlamydata (Cook-
sen and Eisenack) Stover and Eivitt. Palynomorphs of
the O. porifera Zone occur in Piripauan-lower Hau-
murian rocks (Santonian to approximately Cam-
panian/Maastrichtian boundary; Edwards et al.,
1988). Other species of stratigraphic interest include
Vozzhennikovia cf. spinulosa Wilson and Baticaca-
sphaera sp.1. V. spinulosa occurs in upper Piripauan-
Haumurian rocks (Campanian-Maastrichtian; Wil-
son, 1984a,b) and "Leiosphaeridia" ovata (cf. Baticaca-
sphaera sp.1) was described from the Haumurian
(Maastrichtian) of Campbell Island and Campbell
The Cockburn Island assemblages are clearly equivalent to part of the Santonian to Maastrichtian Isabelidinium Superzone of the Australian dinocyst zonation of Helby et al. (1987), but considerable disparity of species ranges between these areas prevents precise correlation with either the I. cretaceum Zone (Santonian), Nelsoniella aceras Zone (late Santonian—early Campanian), Xenikoon australis Zone (early Campanian), or lower part (middle Campanian) of the I. korajonense Zone.

Despite problems with disparity of ranges, the marine palynomorphs suggest that the Cretaceous "Unnamed strata" of Cockburn Island are of Campanian age, probably middle Campanian, although possibly as old as early Campanian. They are older than zone 1 (Askin, 1988) of Seymour Island.

Nonmarine palynomorphs of the Cretaceous beds are always dominated by the conifer pollen Phyllocladidites mawsonii Cookson (see Table 2). Other conifer pollen, angiosperm Nothofagidites (southern beech) pollen, and fern spores Laeavigatosporites spp. are relatively common. The assemblage is correlated to the Phyllocladidites mawsonii (PM) Assemblage of South Island, New Zealand (Raine 1984), and probably to Zone PM2 (lower/middle Campanian to Maastrichtian).

Despite problems with disparity of ranges, the marine palynomorphs suggest that the Cretaceous "Unnamed strata" of Cockburn Island are of Campanian age, probably middle Campanian, although possibly as old as early Campanian. They are older than zone 1 (Askin, 1988) of Seymour Island.

Nonmarine palynomorphs of the Cretaceous beds are always dominated by the conifer pollen Phyllocladidites mawsonii Cookson (see Table 2). Other conifer pollen, angiosperm Nothofagidites (southern beech) pollen, and fern spores Laeavigatosporites spp. are relatively common. The assemblage is correlated to the Phyllocladidites mawsonii (PM) Assemblage of South Island, New Zealand (Raine 1984), and probably to Zone PM2 (lower/middle Campanian to Maastrichtian). Tubulifloridites lilliei (Couper) Farabee and Canright, which defines the base of Zone PM2, occurs rarely on Cockburn Island. The presence of other species such as Gambierina rudata Stover and Cranwellipollis palisadus (Couper) Martin and Harris supports a PM2 correlation. In Australia, G. rudata appears in the upper part (lower Campanian) of the Nothofagidites senectus Zone; it ranges through the "Tricolporites" lilliei Zone (base equivalent to the base I. korajonense dinocyst Zone; Helby et al. 1987), while T. lilliei and C. palisadus appear at the base of the T. lilliei Zone. Specimens similar to the Cockburn Grapnelispora sp. occur in Campanian-Maastrichtian rocks in New Zealand and Australia (see Askin, 1990).

In general, first appearances of spore and pollen species are not good biostratigraphic markers in the Weddellian Province, owing to their often long dispersal time (e.g., Dettmann, 1986; Askin, 1989).

**Tertiary Palynology**

Palynomorphs are relatively common in 3 (87/10-8, 14, 1) of the 14 Tertiary samples examined, and are sparse to rare (as is total organic matter) in the other 11 samples — which is not unexpected in these sandy samples. Palynomorphs are yellow in color and preservation is generally fair to poor. The preserved plant tissue (vitrinite and cuticle) and palynomorphs (particularly the nonmarine forms) are frequently corroded, sometimes severely, as a result of biodegradation and/or oxidation (the latter during transport and deposition, or outcrop weathering). Inertinite is relatively common to abundant. Some palynomorphs are broken or abraded. As noted above, shelly fossils in these beds are also poorly preserved. Except for Nothofagidites pollen, small-sized land-derived palynomorphs are lacking in some sandy samples. A possible explanation is that fine sedimentary particles (including palynomorphs) were removed during transport, and Nothofagidites grains were subsequently blown in. Nothofagus trees are wind-pollinating and can produce copious amounts of pollen. Wind-carried podocarpaceous conifer pollen is also relatively abundant.

Both marine and nonmarine palynomorph assemblages in these Tertiary samples are of low diversity. For the land-derived spores and pollen, this may be due to poor preservation and selective removal during transport. Poor preservation may only partly affect the marine assemblages because chorate dinocysts with complex delicate processes are among the better-preserved palynomorphs. The absolute scarcity of palynomorphs is another contributing factor for low diversity.

Marine and nonmarine palynomorph taxa identified in the 14 Tertiary samples are listed in Table 3. Only presence/absence is indicated for all but two (87/10-8, -1) because, unlike the Cretaceous samples, palynomorphs are often unidentifiable and too sparse in most samples for meaningful counts.

The marine palynomorph assemblages throughout the Tertiary section are characterized by two species of chorate dinocysts: the large flamboyant Areospaeridium sp. cf. A. diktyoplokus (Klumpf) Eaton, and the small Enigmadinium cylindrifloriferum Wrenn and Hart. The peridinioid dinocysts Deflandrea spp., including D. antarctica Wilson, are relatively common in some samples, as are some poorly preserved indeterminate forms. The nonmarine component includes Nothofagidites spp., podocarpaceous conifer pollen, and few other taxa (Table 3).

These Tertiary samples closely resemble those from the lower part (members Telm 1 and 2) of the La Meseta Formation on Seymour Island [Wrenn and Hart, 1988 (3 samples in section 17); Askin, 1988 ("zone 7"); and unpublished data] in their abundance of A. sp. cf. A. diktyoplokus, E. cylindrifloriferum, and Nothofagidites spp., and their poor representation of most other marine and nonmarine taxa. Wrenn (1982; Wrenn and Hart, 1988) assigned a late early Eocene age to the lower part of the La Meseta Formation that he studied (the basal 250 m was then unknown, and he examined samples from the overlying beds ("Interval A" which included section 17)). It is likely that the underlying La Meseta beds on Seymour Island and their correlatives on Cockburn Island are late early Eocene (or older), based in part on the presence of A. sp. cf. A. diktyoplokus. A. diktyoplokus first appears in the late early Eocene elsewhere (e.g., Williams and Bujak, 1985); however, a slightly older age for the southern form is possible because Haskell and Wilson (1975) found it in the Paleocene of the South Tasman Rise, and possible fragments occur in the Paleocene Cross Valley Formation and uppermost Sobral Formation on Seymour Island (Askin, unpublished data).

Diatom evidence (Harwood, 1988) indicates a late early Eocene age for part of the lower La Meseta
Table 3. Distribution chart of palynomorph taxa in Eocene samples, section 87/10.

<table>
<thead>
<tr>
<th></th>
<th>MARINE</th>
<th>NONMARINE</th>
<th>Fungi</th>
<th>RECONSTRUCTED FLORA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Desmophyllum aromaticum</td>
<td>Desmophyllum punctatum</td>
<td></td>
<td></td>
</tr>
<tr>
<td>87/10-5</td>
<td>X...X...X...X...X...X...X...X</td>
<td>X...X...X...X...X...X...X...X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>87/10-4</td>
<td>X...X...X...X...X...X...X...X</td>
<td>X...X...X...X...X...X...X...X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>87/10-3</td>
<td>X...X...X...X...X...X...X...X</td>
<td>X...X...X...X...X...X...X...X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>87/10-2</td>
<td>X...X...X...X...X...X...X...X</td>
<td>X...X...X...X...X...X...X...X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>87/10-1</td>
<td>X...X...X...X...X...X...X...X</td>
<td>X...X...X...X...X...X...X...X</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Counts of 200 specimens were possible in only two samples, 87/10-8 and -1. Occurrences of palynomorph taxa in other samples are denoted by an "X," and for sparse assemblages where counts were not made a heavy "X" indicates that the specified taxon is relatively abundant (from visual estimation).
Formation on Seymour Island. Harwood's material was one sample (S13-19) from a small, shelly outlier of the La Meseta Formation overlying the top of the Cross Valley Formation. Therefore, the precise stratigraphic position of his La Meseta sample is unknown, although it is stratigraphically higher than the basal La Meseta beds.

PALEOENVIRONMENTS

Cretaceous

The fine-grained Campanian strata on Cockburn Island were deposited in a low energy, shallow shelf environment. The bivalve fauna includes infaunal and epifaunal suspension feeders that suggest quiet conditions, as in younger Seymour Island López de Bertodano sediments (Macellari, 1988). Palynomorph assemblages have high relative abundances of terrestrially derived palynomorphs and plant debris including, in some intervals, common and large fragments of plant cuticle; this and the composition of the dinocyst floras, indicate shallow marine, nearshore conditions. Peridinioid dinocysts (particularly I. cretaceum group) are abundant, and the gonyaulaccean ratio (of Harland, 1973) is relatively low (mean 2.5, up to 5.5 in Cl-17), an indicator of nearshore environments. Dinocyst diversity is low (below 25 species/sample), and relative dominance (Goodman, 1979) is moderate to high, also indicating nearshore conditions. There is no significant variation in palynomorph parameters, nor a clear relationship with lithologic units, although minor variations (suggesting fluctuating conditions in distance to shoreline, water depth, local microenvironments, salinity, etc.) are evident.

Tertiary

For the Eocene Cockburn Island strata, the low diversity-high dominance dinocyst assemblages are compatible with shallow, inshore conditions (e.g., Goodman, 1979) — i.e., low salinity or estuarine/brackish. Low (<2) gonyaulaccean ratios are also typical of such an environment. This is consistent with previous interpretations for the correlative Seymour Island basal La Meseta beds. For example, Zullo et al. (1988) found Solidobalanus (in Telm 2, loc. 1), which are associated with subtidal and inner shelf faunal assemblages in moderate- to high-energy environments and exhibit preservation typical of burial of living specimens. Sadler (1988) notes that the Seymour basal sediments (Telm 1) are marginal facies including shallow, subtidal to possibly intertidal faunal elements, and that Telm 2 is prograding valley fill. A similar depositional environment existed for the Tertiary beds on Cockburn Island. It is possible that the basal glauconitic sands represent transgressive system tract deposits (Van Wagoner et al., 1988; Loutit et al., 1988), overlain by a prograding highstand complex filling the wide Cockburn-Seymour paleovalley.

While the long, complex processes of A. cf. dityoploks are typically associated with more "open marine" conditions, it is possible that the presumed added buoyancy provided by these processes were adaptations for a hypopycnal system where lower density river water flows out over sea-water.

The presence of Beaufreidites elegansiformis Cookson (sample 87/10-1, three specimens observed), although not age diagnostic, is important for its paleoclimatic implications. A humid, mild and equable climate was inferred for latest Maastrichtian Seymour Island samples containing this and other presumed "warmth-loving" (frost-sensitive) species (Askin, 1989). Aside from this single indication of mild climate in the upper part of the section, the rest of the terrestrial palynoflora is more typical of cool temperate beech (mainly fusca type) and conifer-dominated rainforest. On the South Shetland Islands to the north, the discontinuous Upper Cretaceous (Coniacian) through Miocene sequences (e.g. Birkenmajer and Zastawniak, 1989) have yielded evidence of cold phases during the Tertiary, including an early Eocene "Krakow Glaciation" based on glacimarine sediments overlain by basaltic lavas dated as 49.4 ± 5 Ma (Birkenmajer et al., 1988). This cold phase was correlated with the pre-La Meseta Formation hiatus and erosional event, but it would have to be followed by rapid and substantial warming to presumed mild, frost-free conditions suitable for B. elegansiformis. Glaciation in the early Eocene is also not easily reconcilable with other evidence (e.g., Shackleton and Kennett, 1975; Stott et al., 1990) that indicates this was a time of maximum warmth for the Cenozoic.

GEOLOGIC HISTORY

In Late Cretaceous time, during deposition of the lower to middle Marambio Group, siliciclastic sediments derived from the Antarctic Peninsula cor­dillera filled the James Ross Basin. The "Unnamed strata," deposited after (and contemporaneous with?) the Santonian-Campanian Santa Marta Formation of James Ross Island and before the late Campanian to Maastrichtian (and Danian) López de Bertodano Formation of Seymour Island, are exposed in several localities, including Cockburn Island.

The Campanian "Unnamed strata" on Cockburn Island dip at about 6° to the southeast, implying a trend conformable with beds on Snow Hill and Seymour Islands which dip at about 10° to the southeast. The Cockburn beds appear to form an older part of the Seymour Island homoclinal Marambio Group succession. Tilting of these beds occurred in post-Sobral time, and probably post-Cross Valley time — that is, latest Paleocene to earliest Eocene. Tilting and uplift may have brought the beds above sea level, although deposition was marine by the start of La Meseta time. The broad depositional trough of the La Meseta Formation, which was eroded down several hundred
meters into Sobral and uppermost López de Bertodano beds on Seymour Island, had steep and irregular margins where more resistant beds formed the valley (canyon?) wall. Cockburn Island, to the northwest, represents a more proximal part of that trough where even greater cutting into Cretaceous beds may have occurred. Downcutting to form incised valleys is commonly associated with low sea level stands brought about by regional uplift or eustatic fall in sea level. The large pre-La Meseta erosional episode was apparently caused in part by tectonism, and in part by regional uplift or eustatic fall in sea level.

112 R. A. ASKIN, D. H. ELLIOT, J. D. STILWELL, and W. J. ZINSMEISTER

CONCLUSIONS

1. The Cockburn Island Cretaceous beds are intermediate in stratigraphic position between the Santa Marta Formation (Santonian-Campanian) of northern James Ross Island and the López de Bertodano Formation (late Campanian, Maasstrichtian, and Danian) of Seymour Island. These Cockburn Island beds are included in the “Unnamed strata” of the Marambio Group.

2. The Cockburn Island Cretaceous beds are Campanian, probably middle Campanian, but possibly as old as early Campanian. Correlation and age assignment are based mainly on dinoflagellate cysts, and in part on marine invertebrates.

3. Relationships of Campanian Cockburn Island “Unnamed strata” and “Unnamed strata” elsewhere in the James Ross Basin (on Ula Point, The Naze, Hamilton Point, Humphs Island, Vega Island) remain uncertain and await further mapping and biostratigraphic study.

4. It is recommended that, until stratigraphic relationships are firmly established, none of these outcrops of “Unnamed strata” should be assigned to the López de Bertodano Formation as defined and dated for Seymour Island.

5. The Cockburn Island Campanian beds were deposited in low energy, shallow shelf environments.

6. The Lower Tertiary beds on Cockburn Island are correlated with members Telm 1 and lower Telm 2 of the La Meseta Formation of Seymour Island, based on lithologic and paleontologic similarities.

7. An late early Eocene age is suggested for these basal La Meseta Formation beds, based mainly on previous dinoflagellate cyst and diatom evidence.

8. The basal La Meseta sediments on Cockburn and Seymour Islands were deposited in a broad trough or valley eroded several hundred meters into Cretaceous and Paleocene sediments. This incised trough was probably cut in the latest Paleocene to earliest Eocene, during tilting and uplift of the Peninsula, accompanied by sea-level lowstands. The valley fill sediments are marginal marine to shallow shelf deposits.

Acknowledgements—We appreciate valuable reviews of this manuscript by Stephen R. Jacobson (Chevron Oil Field Research Co.), Peter M. Sadler (University of California, Riverside), and Graeme J. Wilson (DSIR Geology and Geophysics, New Zealand), as well as discussion on the dinocysts by Warren S. Drugg (Chevron Oil Field Research Co.). James B. Riding (British Geological Survey) kindly provided an unpublished manuscript (Pirrie, Crane and Riding, in press) and discussion. We thank Fred C. Barbia, Tim R. Kelley, and David E. Rieske for assistance with field work, Marnie Crock for palynological preparations, Linda Jankov for photographic assistance (palynology), and John Nagy for drafting. Tables 2 and 3 use Checklist II (F. Jay Phillips) software. Support for field work was provided by U.S. National Science Foundation Grants DPP 83-14186 (Askin), DPP 85-19080 (Elliott), DPP 84-16783 (Zinsmeister), and subsequent laboratory work was supported by DPP 87-16464 (Askin).

APPENDIX

Notes on Selected Dinoflagellate Cyst Species

1. The dinocyst species included in Table 2, *Cribroperidinium sp*., *Cyclopsiella sp.*, cf. *Canninginopsis sp.*, "Dinocyst N.Gen.X," *Operculodinium sp.*, and *Phelodinium sp.*, are the same as those illustrated in Askin (1988).

2. The "Isabelidinium cretaceum" group in Table 2 includes typical *I. cretaceum* and more robust, rectangular forms illustrated by Dettmann and Thomson (1987) as *I. sp. cf. I. bakeri* and by Askin (1988) as *I. sp. cf. I. cretaceum*.

3. The Cretaceous samples include members of a complex of peridinid dinocysts (e.g., Fig. 131) with variously developed pentapartite paracingulum, deltaform to thetaform intercalary archepyle, absence of large epicystal shoulders, and...
faintly to distinctly sculptured (granulate to finely spinulate) periphragm. Dettmann and Thomson (1987) illustrated similar forms as Chata ngiella cf. campbellensis (from D3122.3) and C. serratula (D3030.3). Askin (1988) assigned them to "cf. Alterbidinium sp.,” noting that there is a continuous morphologic gradation to acingulate forms then assigned to I. cooksoniae, which are now referred to I. pellucidum. Most of this complex falls into the broadly defined and extremely variable species Isabelidinium greenense Marshall recently described (Marshall, 1990) from the Campanian of the Gippsland Basin, southeastern Australia.

4. Batiacasphaera sp.1 (Fig. 13a) may be conspecific with Leiosphaeridia ovoata Wilson from Campbell Island (Wilson, 1967) and southeast Campbell Plateau, DSDP Site 275 (Wilson, 1975). The Cockburn form, however, has a thick foveolate outer wall, which sometimes has a granulate surface texture, and a thin inner wall is occasionally discernible. The thick spongy wall of less well-preserved specimens can appear "densely granulate, verrucate or reticulate" as described for L. ovoata type material by Wilson (1967). The apical archeopyle margin of the Cockburn specimens is sometimes angular rather than circular, with a sulcal notch.

5. Cf. Microdinium/Druggidinium sp. has discernible paratabulation of Pr,4',4a,6" on the epicyst only of some specimens (Fig. 13m,n). The apical archeopyle involves apicals and anterior intercalaries, and the operculum is free, though it is often adherent. The hypocyst is considerably larger than the epicyst. The sculpture is finely rugulate.

6. Vozezhnikovia sp. cf. V. spinulosa Wilson differs slightly from the type material from New Zealand (Wilson, 1984b) in its smaller, granulate sculptural elements (up to 1 μm high), larger size (110 μm) and less pronounced apical horn.

7. Following Goodman and Ford (1983), the designation Areosphaeridium sp. cf. A. diktyoplokus is used for these southern forms with ragged incomplete margins on the process terminations. The entire margin typical of northern A. diktyoplokus was not observed on any of the well-preserved Cockburn Island specimens.

REFERENCES


Soot-Ryen, T., 1952. Latercula elliptica (King and Broderip 1831) from the Pecten-conglomerate, Cockburn Island. Arkiv für Zoologie 4, 163-164.


Wilson, G. J., 1984a. New Zealand Late Jurassic to Eocene dinoflagellate biostratigraphy — Summary. Newsletters on Stratigraphy 13, 104-117.


The composition of Piripauan (Late Campanian) to Runangan (Eocene) shelf faunas of New Zealand is intimately associated with its probable separation from the East Antarctic–Australian sector of Gondwana and development of open oceanic conditions by about Early Campanian time (ca. 80–85 Ma). The relatively complete record of fossil molluscs in New Zealand affords a qualitative and quantitative analysis of the changes in composition across the Cretaceous–Tertiary boundary and provides important clues into the biogeographic history of the Gondwana Realm. This paper reviews the Late Campanian to Eocene fossil record of shallow-water faunas in light of new data, traces the changes of New Zealand biogeographic elements in the molluscan fauna (i.e. endemic, palaeoaustral, Indo-Pacific/Tethyan, cosmopolitan) through time, and quantitatively assesses similarity between the bivalve and gastropod faunas of New Zealand, Australia, Antarctica and South America to test the Weddellian Faunal Province hypothesis. This work represents the first attempt at using the entire Late Cretaceous to Early Palaeogene Austral molluscan fauna for quantifying faunal relationships between the Gondwana “fragments”.

Trends in New Zealand fossil bivalve–gastropod molluscs are:
- Piripauan Stage (Late Campanian): 43 families, 57 genera, 70 species;
- Haumurian Stage (Maastrichtian): 53 families, 67 genera, 100 species;
- “Wangaloan”–Teurian Stage (Early Palaeocene): 49 families, 96 genera, 144 species;
- Late Teurian–Waipawan–Mangaorapan stages (Late Palaeocene to Early Eocene): 39 families, 45 genera, 51 species;
- Heretaungan–Porangan–Bortonian stages (Middle Eocene): 74 families, 140 genera, 193 species;
- Kaiatan to Runangan stages (Late Eocene): 67 families, 132 genera, 160 species.

A modest decrease in the number of families during the Early Palaeocene reflects increasing endemism, whereas a decrease in genera and species diversity during the Late Palaeocene to Early Eocene may reflect poor knowledge of these faunas. Generic diversity increases over 200% by the Middle Eocene. A total of 370 genera is known from Late Campanian to Eocene time in New Zealand.

During the Late Campanian to Maastrichtian the endemic element in the New Zealand molluscan fauna barely exceeded 10% of known genera. Species-level endemism was marked, however, with only three local species known outside New Zealand, including New Caledonia, during the Late Campanian and fewer than five species during the Maastrichtian. The palaeoaustral component was about 20% during Late Campanian–Maastrichtian time and little changed until the Palaeocene. Cosmopolitan and Tethyan/Indo-Pacific elements were strong at this time, 30% and 45–50%, respectively. By the early Palaeocene, molluscan composition had altered dramatically, presumably due to separation of the Gondwana “fragments” and later isolation of “greater New Zealand”. Endemism at genus-level rose to 33% during the Early Palaeocene and was higher at this time that at any other during the Palaeocene and the palaeoaustral element rose to 64%, whereas cosmopolitan and Indo-Pacific/Tethyan elements decreased markedly to almost 15% and 20%, respectively. By the Palaeocene, all New Zealand species were endemic. During the Late Palaeocene–Early Eocene, the endemic element decreased to 20% and coupled with the palaeoaustral component remained moderately strong through the Eocene, whereas the cosmopolitan element was still weak at 18%. The influx of warm Indo-Pacific/Tethyan elements before the Late Palaeocene–Early Eocene resulted in an increase to 44%.

Data matrices of similarity coefficients were compiled using 605 bivalve and gastropod genus–group taxa from the Gondwana shelf faunas of Late Campanian to Eocene age. New Zealand faunas increasingly differ from other compared Gondwana “fragments” eastward across the Weddellian Province during the Late Campanian to Maastrichtian. New Zealand faunal ties with the eastern sector of the Weddellian Province were severed by the Palaeocene. The eastern sector of Gondwana saw an increase in generic level endemism during the Palaeocene, which indicates that the Weddellian Province had lost its identity. Before the Late Eocene the western sector of the Weddellian Province had also lost its identity. By the Eocene, molluscan faunas of each separated Gondwana fragment showed high endemism, reflecting increasing geographic and genetic isolation along the southern circum-Pacific.

The long-awaited monograph by Dr. Phillip A. Maxwell on the rich Eocene molluscan fauna of the McCulloch's Bridge area has finally come to fruition after research spanning two-and-a-half decades and a long publishing delay. This monumental work marks one of Maxwell's most significant contributions to paleontology and will interest workers in New Zealand and abroad. Rarely do fossil faunas receive such thorough comprehensive treatment in terms of taxonomy and paleoecology, as in the present scholarly work. This monograph presents significant new data on the composition of southern hemisphere Eocene molluscan faunas which will no doubt excite molluscan systematists and historical biogeographers. 250 species of bivalve, gastropod and scaphopod molluscs are described including ten new gastropod genera and 89 new species (8 bivalves, 64 gastropods and 7 scaphopods).

The history of previous geological and paleontological investigations in the Waihao district and locality details are included in the introduction. A map showing main Cenozoic molluscan localities of North Otago and South Canterbury makes up Figure 1. Surprisingly, the Waihao River was omitted from the map. Acronyms depicting general ages for each of these localities may have been useful, bearing in mind the long Cenozoic time span. Also, Paleocene localities were excluded from the locality map, as were north arrows from Figures 1 and 2.

The stratigraphy and age section reviews appropriately the applicability of the name "Waihao Greensand" and describes in detail the McCulloch's Bridge section. "Waihao Greensand" is found to be more desirable by frequency of usage in the literature than the Waihao Formation, which by the strict use of priority would exclude the former. Table 1 depicts a useful overview of the stratigraphic succession and lithologic nomenclature for the pre-Quaternary sequence in the lower Waihao Valley. Perhaps epochs could have been included in Table 1 with ages for workers unfamiliar with New Zealand stages. A useful table of macrofossils other than molluscs is presented in Table 2. A comprehensive checklist of all molluscs known from the Waihao Greensand and Ashley Mudstone and their associated stratigraphic occurrences makes up Table 3.

A family by family discussion is presented as a prelude to paleo-environmental interpretations and to enable comparison of the McCulloch's Bridge area fauna with the entire New Zealand Cenozoic fauna. Some minor comments seem appropriate here. For interest, since the monograph went to press, new work has established that the geologic range of *Ennucula* (or *Leioniucula,* depending on preference) actually extends into the latest Cretaceous in New Zealand. The tentative range of "Wangaloan" (Paleocene) to Recent given by Maxwell for this group appears unequivocal. Finlay and Marwick (1937) believed that their "Wangaloan" species was more closely related to *Ennucula* than to *Nucula* s. s., an identification with which Fleming (1966) concurred; however, I prefer to use the older name *Leioniucula.* In the Nuculidae discussion, *Sacella semiteres* (Hutton, 1877) from the Tahu Member is reported to be the oldest member of the group in New Zealand, whereas *Saccola* was recorded in the Cretaceous of Northland over 30 years ago by Marwick and Fleming in Wellman (1959). This earlier identification is supported here with recent work. The ranges of *Jupiteria* (Nuculidae) and *Limopsia* (Limopsidae) seem also to extend into the Cretaceous (Marwick and Fleming in Wellman, 1959) for interest, inferred to be mid to outer shelf taxa. It is exciting to see, in the New Zealand fauna, species of e.g. *Parathyasira, Leioniucula, Xymene* and *Zearacia,* to name a few, related closely to those from roughly coeval deposits in Antarctica. The type species of *Tenuiacteon, T. pertenuis,* is actually a Late Paleocene species from the Greggs Landing Mafu Member of the Tuscahoma Sand, not Eocene as suggested by the author here and by Beu and Maxwell (1993). As a minor sidenote, the correct spelling of this genus is "Tenuiacteon," not "Tenuiacton" as consistently spelled in the monograph. The total of 189 genus-group taxa reported in this monograph comprises 176 taxa from the Tahu Member and 66 from the Kapua Tuff. A summary dividing these taxa into various categories based on their stratigraphic ranges is presented on pp. 33-35.

Quantitative assessment of similarities of Tahu Member and Kapua Tuff molluscan faunules with other Arnold Series faunules is performed by the use of the Jaccard Similarity Coefficient (JSC). The value of JSC has come under scrutiny recently (see review of various coefficients by Smith, 1989) and has been shown to be empirically unreliable. Simpson and Dice coefficients have been deemed more empirically significant than JSC, although ISC and others are still in common use by various workers (including in the past this reviewer). In any event, the use of at least two coefficients, preferably three, seems best for meaningful comparisons. The significance of coefficient values in Table 5 should have been stated in the text. As might generally be expected genus-level similarity was found to be stronger than at species-level when the Tahu Member and Kapua Tuff faunules were compared with other Arnold Series faunules. General comparison of other coeval southern hemisphere molluscan faunas may have been desirable, but was not included in the study.

Maxwell excels in using molluscs as paleoecological tools. The section on paleoecology reveals his vast knowledge and expertise and in a global view of the discipline could be championed as a major contribution in molluscan paleoecology. His previous important monograph on Miocene molluscs from the Stillwater Mudstone (1988, NZGS Paleontological Bulletin 55) was of similar quality and scholarship. The merits and potential of using taxonomic structure analysis initially developed by Hickman (1974, 1984) is indicated by Maxwell's application of this method for deducing paleo-bathymetry. Certain anomalous taxonomic structures are also discussed and plausible explanations presented.

With respect to sea temperatures during the Mid to Late Eocene, there is unfortunately little published information on possible temperature changes across the Bortonian-Kaiatan
boundary, so only general trends could be inferred in this monograph. However, some work on
general temperatures around the southern hemisphere during this time interval has been
carried out, and should probably have been acknowledged for comparison (e.g. Shackleton
and Kennett, 1975; Mercer, 1978; Zinsmeister, 1982; Kennett, 1983; Fauna of Australia,
Volume 1a, 1987; Adams et al., 1990; Kennett and Barker, 1990; McGowan, 1990).

The systematic paleontology section is a valuable source of information on the distribution of feeding
types. Under suspension feeders (p. 50) "apporhaid" should be spelled "apporhaid" for this
family-level group of gastropods. Limitations of the study are appropriately discussed, and
a summary of results is included.

The systematic paleontology section of the monograph is thorough and
up-to-date. Species descriptions are very detailed and accurate. Allocation of species to genera is well done.
Unfortunately, many eumorphologies for new genus-level and species-level names have been left
out. Where appropriate, various species are left in open nomenclature. However, a few newly
named species are assigned questionably to genera (e.g. **Causiocorcula** (? anecps n. sp.))
whereas other new species assigned firmly to genera or subgenera (e.g. **Veronicoida**
(Spinosipella) n. sp.) are still left in open nomenclature. Only a few comments on the
systematic paleontology section are afforded here:

--In this monograph and Beu and Maxwell (1990), it is stated that **Eucrassatella australis**
(Hutton, 1873) is the oldest known species of the genus, but a closely related species, **E. wilckensi**
(Medina and Rinaldi, 1978) (re-described by Zinsmeister, 1984) from the lower
Tertiary La Meseta Formation, Seymour Island, Antarctic Peninsula, is also of Early?-Middle to Late Eocene age. No mention was made of this species which, like **E. australis**,
also has ventral crenulations; this feature is considered in the monograph to be anomalous
for the genus. A further problem is the proper generic location of **E. australis** and **E. wilckensi**.

Both groups have resillifiers that do not extend to the ventral margin of the hinge plate, and
differ from typical **Eucrassatella** in which the resillifer reaches the ventral margin. These features seem more like **Crassatella**. Perhaps further reassessment of these taxa is
necessary.

--**Polinella**, widely regarded as a subgenus of **Polinices**, is elevated to genus-level status in
the monograph. Maxwell’s justification for this revision implies that similarities between
**Polinella** and **Polinices** could be due to convergence; indeed, homeomorphy in shell
characters in the Naticidae is known to be widespread. A further explanation by the author
for this revision is that to assign **Polinella** as a subgenus of **Polinices** "implies a far more
precise knowledge of the phylogeny of the family than is warranted" (p. 102). Conversely
in my opinion, based on morphological grounds **P. Polinella** does appear closely related to **Polinices** s. s. **Polinella** could be retained in **Polinices** since no explicit morphological evidence for homeomorphy is presented to justify any change. An "absence of evidence"
approach cannot be advocated here to separate the two taxa as distinctive at the genus
level.

--The generic location of **Lunaria? elegans** (Suter, 1917) is indeed problematic, as
discussed by the author. **Lunaria** and **Euspira** are closely related, if not perhaps congeneric,
depending on weight given to minor differences to inner lip and shell outline of these
variable groups.

--Based on evidence presented in the monograph the erection of the striking, if not tiny
(hence, the name) **Luscal** (Eptoniidae) as a new, endemic group seems warranted,
notwithstanding the acknowledged plethora of genus-group names in the family.

--The synonymising of **Zelxia Finlay with Exilia Conrad** is justified as is **Tahasynnix**
Powell with **Cochlespira Conrad**.

--An excellent job is made with the diverse **Turridae** and Maxwell should be commended
for his thorough investigation of this difficult group. Also, interesting species of spiratellid and
cavallinid gastropods, along with numerous scaphopods are described.

A compilation of new taxa (species- and genus-group), new synonomies and new
combinations is presented in summary. The list of references is extensive with full titles
given and the monograph is thoroughly indexed.

Thirty superb drawings by Ron Brazier (Figures 6, 7, 9) and 438 excellent photographs
(including SEM photomicrographs) illustrate the various Eocene Mollusca from the
McCulloch's Bridge area. Plate composition is well-balanced, although a few taxa are split
up in figures and plates. Where possible more than one specimen of each species is figured.
In an inadvertent error on Plate 1, **Conus brachyrychyla** in the text and plate description
as Figures "h,"j should be labelled as "h,g" to avoid confusion with **Saccella** n. sp.(?) which
should be labelled as "i" n. sp. "j", and **Pseudoportlandia tahua** should be labelled "k","m" not "Lm" in text and plate descriptions. **Conus** (s. 1) **pseudoarmoricus** in the text is labelled as **Conus pseudoarmoricus** on Plate 20
figure caption. On Plate 29, **Spiratella sculpitii** n. sp. should be labelled "e-gj" not "e-g,i" which
would then alleviate the unlikely event of confusion of this species with **Enalina emersoni** n. sp.

The monograph will have an important impact on Paleogene molluscan paleontology and will
prove both a scientifically and aesthetically valuable addition to the libraries of molluscan
workers, students and those who like myself have a fascination with shells and their many
uses as geological tools. Taxonomic research is the root of paleontology and hence, it is quite
reassuring to see that Government research agencies are still publishing academic monographs
of this kind and caliber. My short review here underscores the monumental effort involved
and importance of this work to the molluscan scientific community and at a moderate price
NZ$70.00 (includes GST and surface mail) and US$70.00 (includes airmail postage) should
prove its worth within a short period of use.

Jeffrey D. Stilwell
Department of Geology
University of Otago, P. O. Box 56
Dunedin

REFERENCES (excluding authors of species names)


Cretaceous/Tertiary geology and macropaleontology of the Waianakarua District, North Otago, New Zealand

J.C. Aitchison**, J.D. Campbell* and J.D. Stilwell*

Cretaceous/Tertiary transgressive sediments are well-exposed in the lower Waianakarua River area of North Otago. Facies of the wholly terrestrial Taratu Formation deposited on a weathered Haast Schist surface are the products of a braided river system. The Taratu Formation is succeeded by the Herbert Formation which is dominated by facies interpreted as marine tempestites. Deeper marine sediments are seen in the overlying Katiki Formation and Otepopo Greensand. Pleistocene fluvioglacial gravels lie above an angular unconformity with Cretaceous/Tertiary sedimentary rocks. Eight new fossil localities are described, three from the Herbert Formation, five from the Katiki Formation. These extend the known distribution of fossiliferous Upper Cretaceous marine strata northwards from Shag Point. Fossils include bivalves, *Lahillia aff. L. neozelanica* Marshall and Murdoch, *Leionucula cf. L. suboblonga* (Wilckens), *Cucullaea (Cucullastis) zealandica* Woods, *Eriphyla meridiana* Woods, *Nelio cymbula* (Woods) and *Pactirigonia hanetiana* (d’Orbigny); gastropods, *Eriptycha punamutica* Wilckens, *?Protodolium speighti* (Trechmann), *Perissoptera waiparaisensis* (Hector), and *?Costacolpus solitaria* (Wilckens); and the locally abundant belemnite, *Dimitobelus (Dimitobelus?)* sp.

Keywords: Waianakarua District, North Otago, New Zealand, Cretaceous, Tertiary, geology, macropaleontology, Taratu Formation, Haast Schist, Herbert Formation, Katiki Formation, Otepopo Greensand, new fossil localities.

INTRODUCTION

During the course of an undergraduate mapping project at the Geology Department, University of Otago, a detailed examination was made in 1980 (by J. C. A.) of the homoclinal transgressive sequence of Cretaceous/Tertiary sediments in the Waianakarua district, North Otago. These sediments rest on an eroded surface of Haast Schist and are well-exposed in the North and South branches of the Waianakarua River and in the catchment of Kakaho Creek. Pleistocene fluvioglacial gravels overlie the sediments. Previous workers have made detailed studies of glauconites within the sediments (Hutton and Seelye, 1941) and of the igneous rocks to the east of the area (Benson, 1941, 1943; Coombs et al., 1986), but the sediments have been treated in only regional terms (Brown, 1938; Mutch, 1963).

Results of our study bridge a gap between areas to the north (e.g. Gage, 1957) and south (various authors including Douglas, 1970) for which detailed stratigraphic work has been published. We present a description of a sequence of terrestrial sediments and shallow marine tempestites and details of eight fossil localities. Geological maps of North Otago (McKay, 1887; D. A. Brown, MS, drawn in 1943, held at the University of Otago; and Mutch, 1963) show meridional bands of outcrop of marine rocks extending through the lower reaches of the Waianakarua River. Discovery of fossils confirms suspected continuity and their description...
establishes the Piripauan-Haumurian age (upper Campanian-Maastrichtian) of the Herbert and Katiki formations in this region.

**STRATIGRAPHY**

*Taratu Formation* is characterised by highly quartzose fluvial strata including pebble conglomerates, sandstones, siltstones and carbonaceous mudstone. Various names have been used to refer to these sediments, which are exposed extensively throughout east Otago, e.g. Taratu Conglomerate (Ongley, 1924); Taratu Series (Ongley, 1939); Taratu Formation (Benson, 1959; Harrington, 1959); Papakaio Coal Measures (Gage, 1957). Aitchison et al. (1983) proposed a rationalisation on the basis of lithological similarity, and adopted the senior synonym Taratu Formation (Ongley, 1924).

Seven lithofacies are recognized in the Waianakarua District. Lithofacies are described following the fluvial lithofacies subdivisions of Miall (1977, 1978).

*Facies Gm* consists of massive or crudely bedded conglomerate. These conglomerates are clast supported and may be imbricated. Beds are 1–2 m thick and generally have erosive bases with some clay or silt drapes on upper surfaces. Clasts are typically pebble size, and dominated by quartz. Minor intraformational, impersistent, thin lenticles of clay, siltstone or angle of repose cross-bedded sandstones are present.

*Facies Gp* consists of planar, cross-bedded, pebble sized quartz conglomerates. It is often transitional with lithofacies Gm. Imbrication can be recognized in some outcrops and forsets up to 2 m high.

*Facies Gt* consists of trough cross-bedded pebble size quartz conglomerate. Troughs are up to 50 cm deep and 2–4 m in width. Individual beds have erosional bases overlain by a slightly coarser-grained lag deposit.

*Facies St* consists of trough cross-bedded units (averaging 10 cm thick) of medium- to coarse-grained quartz sandstone. Some units are isolated, solitary scoops eroded into underlying planar cross-bedded sandstones (theta cross-stratification of Allen, 1963) and others exist as cosets of mutually cross-cutting troughs (festoon or pi cross-stratification of Allen, 1963).

*Facies Sp* consists of angle of repose planar cross-bedded medium sandstones (alpha type of Allen, 1963). Beds have sharp, flat bases and often have slightly scoured upper surfaces.

*Facies Sh* consists of massive or horizontally bedded (1–2 m thick) fine-grained quartz sandstones.

*Facies C* consists of coal and carbonaceous mudstone. Coal (up to 2 m thick) is exposed at three localities in the North Branch of the Waianakarua River. At other localities thin carbonaceous beds of mud grade are rarely seen above Sh beds.

The Taratu Formation can be subdivided into five textural facies (after Folk et al., 1970): 1) sandy gravel; 2) gravelly sand; 3) silt; 4) mud; and 5) slightly gravelly sand. Textural facies are poorly sorted with the exception of moderately well-sorted slightly gravelly sand. Sandy gravel is dominant.

The Taratu Formation is characterised by an abundance of clasts of vein quartz which suggests derivation from a Haast Schist source. Sparse, platey shaped, weathered schist pebbles are also present. Heavy minerals include abundant zircon along with lesser amounts of apatite, epidote, garnet, hornblende, magnetite, tourmaline and minor gold.

The Taratu Formation lies with angular unconformity on a deeply leached erosional surface developed on Haast Schist. The Taratu Formation is gradational with overlying Herbert Formation sandstones. In some localities Wanganui Series gravels overlie the Taratu Formation with angular unconformity.

The age of the Taratu Formation strata in this area is Mata Series, Piripauan-Haumurian Stages (uppermost Cretaceous).

*Herbert Formation*

Brown (1938) introduced the name Herbert Formation for quartz grit and sandstone overlying the Taratu Formation. Marine fossils are present at Razorback Road, J42/F175, 176 (Fig. 1).
Fig. 1 - Locality and geologic sketch map of the Waianakarua River area.
Within the Waianakarua area, the Herbert Formation consists of fine- to medium-grained sandstones with interbedded thin layers of quartz conglomerate. Subdivision can be made into two lithofacies associations. The lower Herbert Formation is dominated by a lithofacies association consisting of rhythmic interbeds of two lithotypes.

**Lithotype H1** consists of very coarse sandstone and small (1 cm) pebbles. Individual units (averaging 30 cm thick) have planar erosional bases and undulatory wave tops. Trough cross bedding is sometimes developed.

**Lithotype H2** consists of laminated, fine-grained, well sorted quartz sandstones up to 30 cm thick. Sandstones are positively graded and are increasingly bioturbated upsection. Bioturbation is in the form of brown, limonite cemented, vertical to subvertical burrows. Upper portions of individual beds are occasionally ripple cross bedded with south dipping foresets. Higher sections of the Herbert Formation are characterised by a regularly interbedded (2 m thick) alternation of a further two lithologies.

**Lithotype H3** consists of up to 10 cm thick lenses of well rounded, well sorted quartz pebbles. Lenses are laterally discontinuous and appear to be randomly orientated. Some units exhibit erosional bases and low angle cross-stratification. Other units appear to drape underlying hummocky surfaces. Lithotype H3 is repeated at approximately 2 m intervals throughout upper portions of the Herbert Formation.

**Lithotype H4** consists of fine-grained quartzose sandstones. Basal portions are slightly bioturbated and dominated by low angle hummocky cross-stratification (HCS) (R.G. Walker pers. comm. to J.C.A.). Upper portions of this lithotype are massive or plane parallel, laminated with an increasingly rich organic (plant) content upsection. Infrequent burrowed carbonaceous lenses and more common limonite cemented subvertical burrows (about 1 cm diameter) are seen at the tops of bedding units.

Marine fossils are present in local concentrations within the sandstone. Preservation is poor; shells are decalcified and heavy limonitic deposition has obscured detail on external moulds. As well as fragments of ribbed bivalves (loc. J42/1177) and a shark vertebra (loc. J42/1176), there are poorly preserved gastropods and trace fossils at locality J42/1175.

The Herbert Formation overlies Taratau Formation conformably and is transitional with the overlying Katiki Formation. The upper boundary is drawn below the first appearance of septarian concretions. In some localities the upper contact is an angular unconformity with Wanganui Series gravels.

**Katiki Formation**

The Katiki Formation (McKay, 1887; Brown and Hamilton in Fleming, 1959) consists of light grey (weathering to yellow) concretionary, fine-grained quartzose sandstone. Minor glauconite, sparse schist and wood fragments also are present. The sandstones of the Katiki Formation are moderately well-sorted and have a silty matrix. Intensive bioturbation has disrupted many bedding features. Sparserly fossiliferous, calcareous septarian concretions are concentrated along parallel bedding horizons.

The Katiki Formation is transitional to the Herbert Formation, the lower contact being defined below the first appearance of concretions. The upper contact with the Otepopo Greensand is also transitional. The Katiki Formation is overlain with angular unconformity by Wanganui Series gravels in some areas.

Concretions in the North Branch of the Waianakura River (Fig. 2) contain abundant carbonaceous material which may be associated with marine shells. Reasonably complete specimens of *Lahillia* aff. *L. neocelanica* Marshall and Murdoch and abundant belemnite guards are present in one concretion (loc. J42/1178) which also contains *Leionuclea* cf. *L. suboblonga* (Wilckens), *Cuculilea* (*Cucullastis*) *zealandica* Woods, *Neilo cymbula* (Woods), and *Eriptycha punamutica* Wilckens. Belemnites are also present in concretions in the North Branch of Waianakura River; here (loc. J42/1082) they are associated with *Pacitrigonia hanetiana* (d'Orbigny), *Lahillia* aff. *L. neocelanica* Marshall and Murdoch, *Neilo cymbula* (Woods), *Cuculilea* (*Cucullastis*) *zealandica* Woods, *Aphrodina* (*Tikia*) *wilckensi* (Woods), *Protodolium speighti* (Trechmann), and *Costacolpus solitaria* (Wilckens).
Recent fieldwork in the North Branch has resulted in the discovery (by J.D.S. and J.D.C. in early 1992) of the first calcified fossils in the Waianakarua River area. At this locality (J42/l218) bivalves are both disarticulated and articulated, and orientation appears to be random. Gastropods are sparse. Most fossils are entire and include taxa not known from other collected localities including: "Nuculana" amuriensis (Woods), Mixtepecten cf. M. amuriensis (Woods), "Eselaevitrigonia" n. sp., carditid gen. et sp. indet., Panopea clausa Wilckens, Perissoptera waiparaensis (Hector), Pyrops? sp., and a dicotyledenous leaf. Fossils present in the South Branch of the Waianakarua River include Neilo cymbula (Woods), Pacitrigonia hanetiana (d'Orbigny), Aphrodina (Tikia) wilckensi (Woods), Eritycha punamutica Wilckens, and Dimitobelus (Dimitobelus?) sp.

The belemnites are long, mostly slender forms comparable to both Dimitobelus (Dimitobelus) lindsayi (Hector) and specimens at Katiki Beach previously referred to Dimitobelus hectori Stevens, 1965. Some specimens appear more like $D. (D.)$ lindsayi than $D. (D.)$ hectori. Due to poor preservation, only a general assignment of Dimitobelus (Dimitobelus?) sp. can be made at this time for these belemnites in the Wainakarua River area. As a sidenote the subgenus Dimitocamax was erected recently by Doyle and Zinsmeister (1988) for a group including $D. hectori$, the designated type species of $D. (Dimitocamax)$, and an Antarctic species $D. (D.)$ seymourensis. It should be noted also that ammonites are conspicuously absent from the eight fossil localities.

Otepopo Greensand

The Otepopo Greensand consists of glauconitic medium- to fine-grained sandstones. The formation was proposed by Brown (1938) and is the senior synonym of Otepopo Greensand (Brown, 1959b) and Waianakarua Greensand (Mutch, 1968). The sandstones are composed of conspicuous glauconite with a characteristic green colour and a significant matrix (up to 30%). Minor detrital schist grains and rare shell fragments are present. Bedding features are largely destroyed by intensive bioturbation. Irregularly spaced, limonite cemented, bedding
parallel concretions are seen in some places as well as concretionary, phosphatised burrows perpendicular to bedding.

The Otepopo Greensand grades into the Katiki Formation, with the lower boundary arbitrarily drawn at a point where glauconite content is greater than 30%. The Katiki Formation is overlain unconformably by successive Tertiary strata which are not seen in the area of detailed study. An angular unconformity with Wanganui Series is observed in some localities. No determined fossils are recorded from Otepopo Greensand and the age falls in the range Upper Cretaceous to lower Tertiary.

DEPOSITIONAL HISTORY

During the late Mesozoic, large braided river systems were developed over an area of subdued relief in east Otago. Major storms and associated highly ephemeral discharge of detritus in these systems resulted in the development of aggradational gravel bar deposits. Evidence of both linguoid and longitudinal bars is seen. Local inactive areas of the large braidplain were characterised by swampy backwaters where coal subsequently developed. Deposition of the Taratu Formation was concentrated in areas of localised subsidence and other areas of high relief were free of deposition.

Gradual marine transgression resulted in the encroachment of marine conditions, and braided river deposition was succeeded by shoreface deposition of the Herbert Formation. Sedimentation continued to be dominated by the effects of large storms to give tempestites. Storm wave orbital base action on shallow marine sands resulted in the development of hummocky bottom topography. Gravel swept offshore by storm surges drapes some of these hummocks. Similar bedding features are described by Miocene sandstones in the western USA (Leithold and Bourgeois, 1984) and have been seen by one of us (J.C.A.) in the Lower Cretaceous Yuasa Formation beds on Kii Peninsula, Japan. Deposition during inter-storm periods is represented by finer-grained sandstone and carbonaceous material.

The effect of storm-wave orbital base action on bottom sediment decreased with increasing water depth associated with continuing marine transgression, and was negligible during Katiki Formation deposition. Anomalous schist cobbles may be dropstones which may have fallen from the roots of floating trees. A slow sedimentation rate can be inferred from the highly bioturbated nature of these sediments which are sparsely fossiliferous.

The Otepopo Greensand was deposited in a shallow marine, nearshore environment below storm weather wave base. The high glauconite content suggests a slow sedimentation rate in an area with a low terrestrial sediment input.

Following tilting of Cenozoic cover and basement Wanganui Series, fluvio-glacial deposits developed concurrently with Pleistocene glaciations. Initial fluvial erosion was followed by deposition of aggradational gravels on glacier outwash braidplains, which were developed extensively over the eastern South Island.

FOSSIL LOCALITIES

The fossil specimens collected from eight localities during the course of this study have been deposited in the University of Otago Geology Museum. The fossils listed in this paper have

Fig. 3 – a, Dimitobelus (Dimitobelus?) sp., J42/8082, OU 40538, 3.25×; b, Cucullaea (Cucullastis) zealandica Woods, 1917, right valve, partially distorted, J42/178, OU 40532, 2.5×; c, Cucullaea (Cucullastis) zealandica Woods, 1917, right valve, juvenile, J42/178, OU 40533, 2.5×; d, Nello cymbula (Woods, 1917), right valve, J42/178, OU 40535, 2.25×; e, ?Protodolium speighti (Trechmann, 1917), abapertural view, J42/8082, OU 40537, 2.5×; f and h, Eriptycha punanensis Wickens, 1922, f, abapertural view exhibiting part of outer lip and spiral sculpture, J42/178, OU 40534, 3×, h, apertural view exhibiting inductura, 3×; g and i, Lahillia aff. L. neozelanica Marshall and Murdoch, 1923, g, dorsal view of articulated specimen, J42/178, OU 40531, 1×, i, right valve, nearly complete, 1×; j, Aphrodina (Tikia) wilckensi (Woods, 1917), left valve, posterior margin incomplete, J42/8082, OU 40536, 2.25×.
been identified by J.D. Stilwell, and figured specimens have been assigned unique, OU
catalogue numbers (Figs. 3, 4). All fossils were coated with ammonium chloride before
photography. Abbreviations used are: OU = Otago University, NZMS = New Zealand Map
Series, Mp = Piripauan Stage, Mh = Haumurian Stage (Upper Cretaceous), and f = locality
registered in the New Zealand Fossil Record File.

Descriptions of fossil localities and lists are as follows:

**Locality 1**: J42/f082.
Grid reference NZMS 260, 1984, J42/358486. Collected by J.C. Aitchison and J.D. Campbell
17/05/1980. True left bank of North Branch of Waianakarua River in a river cut platform
which has since been washed away by floods. Fine-grained, concretionary quartz sandstone
of Katiki Formation. Inferred age: Mp-Mh. Fossils include:
- *Neilo cymbula* (Woods, 1917)
- *Solemya*? sp.
- *Cucullaea (Cucullastis) zealandica* Woods, 1917
- *Indogrammatodon hectori* (Woods, 1917)
- *Glycymerita*? sp.
- *Pacitrigonia hanetiana* (d'Orbigny, 1842)
- *Aphrodina (Tikia) wilckensi* (Woods, 1917)
- *Costacolpus solitaria* (Wilckens, 1922)
- *Protodolium speighti* (Trechmann, 1917)
- *Dimitobelus (Dimitobelus?)* sp.

**Locality 2**: J42/f127.
Grid reference NZMS 260, 1975, J42/359469. Collected by J.C. Aitchison and J.D. Campbell
07/10/1980. Concretions exposed on true left bank of South Branch of Waianakarua River,
1 km above State Highway 1 bridge. Concretionary sandstone of Katiki Formation about 20
m above top of Herbert Formation and 30 m below base of Waianakarua Greensand. Inferred
age: Mp-Mh. Fossils include:
- *Neilo cymbula* (Woods, 1917)
- *Pacitrigonia hanetiana* (d'Orbigny, 1842) subsp. indet.
- *Aphrodina (Tikia) wilckensi* (Woods, 1917)
- *Eriptycha punamutica* Wilckens, 1922
- *Dimitobelus (Dimitobelus?)* sp.

**Locality 3**: J42/f175.
Grid reference NZMS 260, 1984, J42/340410. Collected by J.C. Aitchison and J.D. Campbell
Limonitic, quartzose sandstone of Herbert Formation, ? 10 m above top of Taratu Formation
and more than 10 m below base of Katiki Formation. Inferred age: Mp-Mh. Fossils include:
- Gastropoda sp. indet.
- trace fossils

**Locality 4**: J42/f176.
Grid reference NZMS 260, 1984, J42/335431. Collected by J.C. Aitchison and J.D. Campbell
16/09/1986. East Trig K near large bluff. Massive quartz sandstone with gravel lenses of
Herbert Formation 10 m+ above top of Taratu Formation and >10 m below base of Katiki
Formation. Inferred age: Mp-Mh. Fossils include:
- shark vertebra
Locality 5: J42/f177.
Grid reference NZMS 260, 1984, J42/323402. Collected by J.C. Aitchison 16/09/1986, Outcrop at top of peak (512 m) along Razorback Road. Limonitic quartzose sandstone and gravel of Herbert Formation >10 m above top of Taratu Formation and <10 m below base of Katiki Formation. Inferred age: Mp-Mh. Fossils include: Bivalvia fragment sp. indet.
Locality 6: J42/178.
Grid reference NZMS 260, 1984, J42/358484. Collected by J.C. Aitchison and J.D. Campbell 17/1/1987, North Branch of Waianakarua River, E/W reach downstream of wide corner. Katiki Formation. Inferred age: Mp-Mh. Fossils include:
Leionucula cf. L. suboblonga (Wilckens, 1905)
Neilo cymbula (Woods, 1917)
Cucullaea (Cucullastis) zealandica Woods, 1917
Lahillia aff. L. neozelanica Marshall and Murdoch, 1923
Eriptycha punamutica Wilckens, 1922
Dimitobelus (Dimitobelus?) sp.

Locality 7: J42/215.
Grid reference NZMS 260, 1984, J42/35654850. Collected by J.D. Stilwell 08/12/1990. Concretionary sandstone boulder (float) along southwestern side of North Branch of Waianakarua River about 150 m downstream of J42/f082. Generally poorly preserved and distorted fossils in concretionary sandstone of Katiki Formation. Inferred age: Mp-Mh. Fossils include:
Neilo cymbula (Woods, 1917)
Cucullaea (Cucullastis) zealandica Woods, 1917
Eriphyla meridiana Woods, 1917
Eriptycha punamutica Wilckens, 1922
Dimitobelus (Dimitobelus?) sp.

Locality 8: J42/218.
Grid reference NZMS 260, 1984, J42/359484. Collected by J.D. Stilwell and J.D. Campbell 29/01/1992. In situ fossiliferous sandstone concretion in river bed approximately 1 km southeast of New Zealand Forestry Service Headquarters and 50 m to the west-northwest of large bend in the North Branch of the Waianakarua River. Bivalves are both articulated and disarticulated and orientation is apparently random. Gastropods are sparse. Most fossils are entire and calcareous. Katiki Formation. Inferred age: Mp-Mh. Fossils include:
Leionucula cf. L. suboblonga (Wilckens, 1905)
?Nuculana" amuriensis (Woods, 1917)
Neilo cymbula (Woods, 1917)
Cucullaea (Cucullastis) zealandica Woods, 1917
Mixtipecten cf. M. amuriensis (Woods, 1917)
"Eselaevitrigonia" n. sp.?
Pacitrigonia hanetiana (d'Orbigny, 1842)
Lahillia aff. L. neozelanica Marshall and Murdoch, 1923
Eriphyla meridiana Woods, 1917
carditid? gen. et sp. indet.
Aphrodina (Tikia) sp.
Panopea clausa Wilckens, 1910
Perissopiera waiparaensis (Hector, 1886)
Pyropsis? sp.
?Costacolpus solitaria (Wilckens, 1922)
Eriptycha punamutica Wilckens, 1922
Dimitobelus (Dimitobelus?) sp.
dicotyledenous leaf

ACKNOWLEDGMENTS
We gratefully acknowledge the assistance of Brian Allingham who discovered new
Herbert Formation fossil localities and who accompanied J.C.A. and J.D.C. in the field. NZFS Herbert Office kindly gave information about the original location of the fossil shark vertebrae and Donald MacFarlan assisted with initial Katiki Formation fossil identification. Don Weston of University of Otago is thanked for his help in photographing specimens. We appreciate the helpful comments of an anonymous reviewer.

REFERENCES


Journal of the Royal Society of New Zealand, Volume 23, 1993


Orbigny, A.D. d', 1842. Voyage dans l’Amérique Meridionale...exécuté pendant...1826–33 par A. D’Orbigny, etc. Paléontologie, Tome 3 (4), Paris.


Received 1 July 1992; accepted 21 September 1992
NEW EARLY PALEOCENE MOLLUSCA FROM THE WANGALOA FORMATION OF SOUTH ISLAND, NEW ZEALAND

JEFFREY D. STILWELL
Department of Geology, University of Otago, Box 56, Dunedin, New Zealand

ABSTRACT—New Mollusca from the shallow marine, highly fossiliferous Wangaloa Formation of southeastern Otago, South Island, New Zealand, are described. This paper reports three new species and one new genus: *Leionucula palaioanaxea* n. sp. of the Nuculidae, *Pyropsis zinsmeisteri* n. sp. of the Tudiclidae, and *Wangacteon grebneffi* n. gen. and sp. of the Acteonidae. These taxa represent new records in New Zealand of apparently endemic taxa. The molluscan fauna of the Wangaloa Formation is important in the understanding of Paleogene biogeography of the Southern Hemisphere and changes in faunal composition of the Cretaceous–Tertiary Gondwana Realm. Genus- and species-level endemism in the “Wangaloan” fauna is marked and is probably a reflection of “greater New Zealand”’s geographic and genetic isolation during the Paleocene. Although deposits containing early Paleogene Mollusca are generally rare in the Southern Hemisphere, comparisons of known Gondwana molluscan taxa and those of similar age in the Northern Hemisphere indicate that the Mollusca of the Wangaloa Formation have Early Paleocene affinities. Microfossil evidence, in addition, supports an Early Paleocene age for the fauna. However, an uppermost Cretaceous age is indicated for the basal part of the Wangaloa Formation stratigraphically below the shell beds, but the K-T boundary has yet to be located.

INTRODUCTION

THE CENOZOIC rocks of New Zealand contain an exceptionally rich marine molluscan fauna. The early New Zealand geologist J. Hector, who made a small collection of molluscs near Wangaloa (see Figures 1, 2) in 1869, little realized that these Mollusca would represent an important part of what we know about the early Paleogene molluscan composition of the Southern Hemisphere. These fossils were collected from what is now known as the Wangaloa Formation, a highly fossiliferous quartz sandstone and conglomerate sequence which is exposed north of the Clutha River (previously called “Molyneux”) along the coast between Mitchell’s Rocks (New Zealand Map Series 1 imperial (S180) and New Zealand Map Series 260 metric (H46) scale topographic maps; also known as Mitchell Point, Mitchell’s Point, or Mitchell’s Rocks) and Measly Beach near Wangaloa, southeastern Otago. The formation is also exposed at Boulder Hill approximately 14 km northwest of Dunedin (Figure 1). Lindqvist (1986) in his study of teredinid-bored Araucariaceae logs, ichnofauna, and sedimentary features present near Mitchell’s Rocks concluded shoreface or storm deposition near fair-weather wave base for the Wangaloa Formation sediments. A quieter environment of deposition along the inner or mid-shelf is suggested for fossiliferous sediments at Boulder Hill (Beu and Maxwell, 1990). Although Marshall (1916, 1917) was the first to describe these fossils in any detail, the most comprehensive review to date of the “Wangaloan” fauna was in a classic monograph by
Finlay and Marwick (1937). Little work has been done since Finlay and Marwick's monograph other than a list of Mollusca from localities other than Finlay and Marwick (1937) that was provided by C. A. Fleming (Fleming in Harrington, 1958) and a recent review of representative Early Paleocene Mollusca of New Zealand (Beu and Maxwell, 1990). Because of the great advances in molluscan systematics over the last 50 years, the Late Cretaceous to early Paleogene molluscan faunas of New Zealand need extensive revision. This paper is the result of recent studies on the "Wangaloan" molluscan fauna and provides important insight, not only for our knowledge of early Paleogene molluscs of New Zealand, but also for our understanding of late Mesozoic–early Cenozoic biogeographic distributions of the Gondwana Realm.

AGE OF THE WANGALOA FORMATION MOLLUSCA

Age assignments of the Wangaloa Mollusca have been quite varied in the literature—as young as "upper Tertiary" (Hector, 1872) or "Upper Miocene" (Hutton, 1875) to as old as Late Cretaceous (Finlay and Marwick, 1937, 1940). Finlay and Marwick's assignment of a Danian age was considered latest Cretaceous, not earliest Tertiary as it is today. The "Wangaloan" molluscan fauna contains bivalve and gastropod genera in common with the Late Cretaceous fauna of New Zealand, but contains no Mollusca typical of the Cretaceous such as inoceramid bivalves, belemnites, or ammonites. Trigoniid bivalves, more common in Mesozoic rocks, are present in Tertiary rocks in Australia, but all trigoniids in New Zealand are Late Cretaceous or older.

The miospore Tricolpites lilliei Couper, characteristic of zone PM2, Haumurian Stage (Upper Cretaceous) in New Zealand (J. I. Raine in Edwards et al., 1988), has been recorded from the base of the Wangaloa Formation (H46/f112) as a common species along with Tricolpites pachyexinus Couper, Quadratopus brossus Stover, Camarozonospirites ohaiensis (Couper), and others, which are all restricted Cretaceous taxa (D. C. Mildenhall and G. J. Wilson, personal commun. in Lindqvist and Douglas, 1987). This sample was taken approximately 10 m below the shell beds present at Mitchells Rocks where the new species described from this paper were collected. Dinoflagellates are rare in the Wangaloa Formation, but no restricted Cretaceous taxa were recorded in sample H46/f112, suggesting an age close...
to the Cretaceous–Tertiary boundary. A sediment sample from the Mitchells Rocks facies (H46/f183) contains a very sparse palynoflora with mainly terrestrial derived palynomorphs with rare dinoflagellates. The presence of *Halarugacioides harristi*, however, in the sample is indicative of a Late Teurian (Late Paleocene) age (D. T. Pocknall, personal commun.), but a sample (H46/f181) from the “Trig C” facies approximately 35 m stratigraphically above sample H46/f183 contains a palynoflora of mid to late Teurian age. Most samples processed unfortunately were not age diagnostic. Webb (1973a) assigned an Early Paleocene age for foraminifera species found in sediments (“Trig C” facies) overlying the molluscan shell beds of Mitchells Rocks. The Wangaloa Stream estuary area, earlier, Harrington’s (1958) extensive review of the Wangaloa Formation stated that the “Trig C” facies overlying the “Mitchell Point” facies at Wangaloa contains a microfauna with some latest Cretaceous affinities, but a Paleocene to Early Eocene age was preferred. Beu and Maxwell (1990) also advocated an Early Paleocene age for the molluscan fauna of the Wangaloa Formation. Based on microfossil evidence, excluding the depauperate foraminiferal and dinoflagellate assemblages, the basal Wangaloa Formation sediments were assigned a firm Haunian (Late Cretaceous) age (D. C. Mildenhall and G. Wilson, personal commun. in Lindqvist and Douglas, 1987). The preservation of the dominant, Cretaceous palynoflora indicates that there is no evidence for reworking into early Tertiary (D. A. Mildenhall, personal commun.). The possibilities remain then that the Cretaceous–Tertiary boundary with respect to macro- versus microfossil last occurrences does not coincide at Wangaloa or more likely that the K–T boundary lies within the formation below the molluscan horizons. More data and detailed sampling are needed. While Finlay and Marwick supported the use of the Wangaloan Stage, Hornbrook and Harrington (1957) and Webb (1973a, 1973b) suggested that the Wangaloa Stage be regarded as equivalent to part of the New Zealand Teurian Stage. Beu and Maxwell (1990) used “Wangaloan” not as a formal stage, but only as a convenient term for the distinctive, shallow marine molluscan faunas of the early Tertiary of New Zealand and also because its relationship to the long Teurian stage is still unclear. “Wangaloan” is used herein in agreement with Beu and Maxwell (1990).

The molluscan fauna from the Wangaloa Formation is here considered endemic on the specific level, although a few taxa from the Middle Paleocene Pebble Point Formation of Australia may be conspecific. Approximately 33 percent of genus-group taxa from the Wangaloa Formation are considered endemic. It is therefore difficult to compare the “Wangaloan” fauna with other Austral faunas of similar age. Indeed, few molluscan faunas of early Paleogene age are known from the Southern Hemisphere. The mollusca from the Sobral Formation of Seymour Island, Antarctic Peninsula, are probably Early Paleocene in age, but except for some described bivalves (Zinsmeister and Macellari, 1988) and undescribed gastropods the fauna is not particularly diverse. Mollusca from the Paleocene of South America also are not well known. Darragh (1985) discussed Middle and Late Paleocene molluscan faunas from Australia, but no Early Paleocene Mollusca are known. Marwick (1928) and Campbell et al. (1988) showed that a relatively diverse Late Paleocene molluscan fauna exists in the Chatham Islands, but no Early Paleocene Mollusca are known there. The tectid gastropod *Pyropis zinsmeisteri* n. sp. described from this paper is very similar to known *Pyropis* species from the Paleocene of North America. Another example of a species from the Wangaloa Formation is morphologically similar to an Early Paleocene *Leionucula* species from Antarctica. In general, the faunal ties on the generic level between Mollusca of the Wangaloa Formation and the Middle Paleocene Pebble Point Formation of southeastern Australia are quite strong, indicating marine links between New Zealand and southeastern Australia during the Paleocene. If reworking is discounted, the presence of apparent Late Cretaceous microfossil taxa at Wangaloa would indicate that the age of the mollusca there is indeed close to the Cretaceous–Tertiary boundary. An Early Paleocene age is inferred herein for the Mollusca of the Wangaloa Formation.

**SYSTEMATIC PALEONTOLOGY**

The new Mollusca described in this paper are known only from the Wangaloa Formation of New Zealand. Holotypes and paratypes are housed at the Geology Museum, University of Otago, unless stated otherwise. Abbreviations used are: OU, Otago University; NZGS, New Zealand Geological Survey; NZMS, New Zealand Map Series; and TM, Type Mollusca.

Phylum MOLLUSCA, 1758

Class BIVALVIA Linnaeus, 1758

Subclass PALEOTAXODONTA Korobkov, 1954

Order NUCULOIDA Dall, 1889

Superfamily NUCULACEA Gray, 1824

Family NUCULIDAE Gray, 1824

Subfamily NUCULINAE Maxwell, 1988

Genus LEIONUCULA Quenstedt, 1930

*Leionucula Quenstedt*, 1930, p. 110, 112.

Type.—*Nucula albensis* d’Orbigny, 1844 (by original designation).


**Discussion.**—The cosmopolitan nuculid bivalve *Leionucula* Quenstedt, 1930, is characterized by having a smooth shell, an oblique resilifer, and a smooth, inner ventral, shell margin. *Leionucula* has been regarded in the past as a senior subjective synonym of several genera, including *Lissanucula* Woodring, 1973 (replacement name for *Nuculopsis* Woodring, 1925) and *Ennucula* Iredale, 1931 (e.g., Thiele, 1934; Macpherson and Gabriel, 1962; Keen, 1969; Abbott, 1974). The morphologic features stated above for *Leionucula* are consistent with *Ennucula*. Most New Zealand and Australian workers retain *Ennucula* as a distinct genus separate from *Leionucula* (Allan, 1959; Cotton, 1961; Powell, 1979; Maxwell, 1988; Beu and Maxwell, 1990). Powell (1979, p. 357) recognized the need for a critical examination of the above listed taxa before “upsetting an obviously close Australian–New Zealand relationship” by synonymizing *Ennucula* with *Leionucula* as many previous North American and European workers have done. Maxwell (1988, p. 89) remarked that the type species of *Ennucula* (E. obliqua) from the Recent of Australia is “not unlike the type species of *Leionucula* Quenstedt, 1930, *L. albensis* (d’Orbigny, 1844) (Early Cretaceous, France) in shape and lack of definite sculpture, but differs in having a much less strongly impressed escutcheon and a less well defined anterior area.” These morphologic differences may well reflect early and more recent interspecific variation of *Leionucula*. The type specimens *(Lot number 5984)* of *Leionucula albensis* (d’Orbigny, 1844) were studied by the author recently at the Muséum National d’Histoire Naturelle in Paris. The holotype is articulated but incomplete so no view of the hinge was possible. Another example of *L. albensis* (Number 5984c) was too poorly preserved for study. Two of d’Orbigny’s type specimens of *L. albensis* are presumed lost. Schenck (1934) in an extensive review of the *Nuculidae* remarked that the escutcheon of *L. albensis* is slightly depressed and in an added footnote (p. 34) stated that Prof. Quenstedt made available to him a specimen of *L. albensis* (after his paper went into press).
which has an arched row of about 25 anterior teeth, a straight posterior series of about 10 teeth, and a chondrophore which is oblique. These features are consistent with *Ennucula* Iredale, although it is agreed that the description is far from detailed for accurate comparison of other nuculids. Without having seen a hinge earlier, Schenck (1934) discussed that *Leionucula* indeed may be closely related to *Ennucula*. Although the hinge of the believed rare species *L. albensis* has not been figured (Maxwell, 1988), it is my opinion that the separation of *Ennucula* from *Leionucula* is questionable. The morphologic features found to be most variable within the generally conservative *Leionucula* group, excluding shell size, are the escutcheon (impressed or only slightly) and size and degree of downward projection of the oblique chondrophore. The morphologic variation between New Zealand species assigned to *Ennucula* Iredale is believed to be within the limits of generic variability of *Leionucula*. *Leionucula* is a cosmopolitan group that ranges from Cretaceous to Recent. In New Zealand the range is at least latest Cretaceous to Recent. An undescribed nuculid, *Nucula* sp., is known from the Haumurian Upper Cretaceous Conway Siltstone, Haumuri Bluff District, South Marlborough (Warren and Speden, 1977), but it is not known whether this species is referable to *Ennucula*. The presence of *Leionucula* in the Late Cretaceous of New Zealand has recently come to light from studies by the author. The genus is now known from Shag Point and Waianakarua River in the South Island and also from Northland. The range of the group in Australia has been reported to be Late Eocene to Recent by Darragh (1985), but *Leionucula* may extend into the Late Paleocene—Early Eocene.

**Leionucula palaioanaxea** n. sp.

*Figure 3.1–3.4*

*Nucula* n. sp. Finlay and Marwick, 1937, p. 16, Pl. 1, figs. 9, 10. *Ennucula* n. sp. Fleming, 1966, p. 102, Pl. 2, figs. 32, 33; Keyes, 1972, p. 11.

**Diagnosis.**—Shell obliquely subovate to subtrigonal; umbo located less than one-quarter the length of shell from posterior margin; anterior part of hinge with twice as many hinge teeth compared to posterior part; chondrophore anteriorly oriented at 46°.

**Original description.**—“Shell small, suboval, somewhat compressed. Umbo about posterior fifth. Posterior truncated. Lunate not defined; escutcheon drawn out into a slight wing. Surface apparently smooth. Hinge with 12 anterior and about 5 posterior teeth, the anterior ones increasing considerably in strength with distance from the umbo” (Finlay and Marwick, 1937, p. 16).

**Supplementary description.**—Shell moderately large for the family, thin, slightly to moderately inflated, obliquely subovate to subtrigonal; umbo prominent, strongly opisthogyrate, located slightly less than one-quarter of length of shell from posterior margin; umbral ridge slightly developed; anterodorsal margin slightly concave near beak, more anteriorly produced to a broadly convex, blunt wing that terminates about one-eighth of length of shell from anterior margin; posterodorsal margin short, concave near beak, obliquely truncated more posteriorly; both anterior and posterior margins narrowly rounded; ventral margin smooth, moderately rounded; surface of shell smooth with punct-
tuated, slightly raised, commarginal growth pauses and extreme-
ly faint radial striactions; hinge plate relatively narrow, posterior
half of hinge with approximately 5–7 subchevron-shaped teeth
and anterior half of hinge with 12–14 subchevron-shaped teeth,
becoming stronger and more peg-like anteriorly; hinge teeth
small under beak, progressively increasing in size anteriorly and
posteriorly; chondrophore moderately large, elongate subtri-
gei
palaioanaxea
small under beak, progressively increasing in size anteriorly and
of 46°; posterior adductor scar elongate subcircular; anterior
adductor scar elongate subpyriform; pallial line integripalliate;
grid reference
the earliest record in the New Zealand Tertiary. In New Zealand,
ticular shell bed of a sandstone that overlies quartz gravels and
sands on the north flank of the hill and outcrops some
46°15'27
ft.
260,
200
4095:
28
272, Ross

Dimensions. — Holotype, OU 39604, left valve length 9.5 mm,
height 7.5 mm; paratype, OU 39605, left valve length 7.0 mm,
height 5.5 mm; paratype, OU 39606, right valve length 10.0
mm, height 8.5 mm; paratype, OU 39640, right valve length
7.5 mm incomplete, height 7.0 mm; paratype, TM 4095: NZGS
10195, left valve length 3.2 mm, height 2.9 mm.
Types. — Holotype, OU 39604; paratype, OU 39605; para-
type, OU 39606; paratype, OU 39640; paratype, TM 4095:
NZGS 10195.
Type locality. — Mitchells Rocks, Wangaloa, South Otago (lat.
46°15'27.6"S, long. 169°57'57.6"E), southernmost part of cliffs
along sandy beach about 200 m north from ladder accessed
cove.
Locality. — Mitchells Rocks, Wangaloa, South Otago (NZMS
260, H46f/166a, 768337); Boulder Hill, Dunedin, Otago, “len-
ticillar shell bed of a sandstone that overlies quartz gravels and
sands on the north flank of the hill and outcrops some 270 ft.
above the track” (Finlay and Marwick, 1937, p. 5): approximate
grid reference NZMS 260, 144/055876; approximate lat.
45°47'13"S, long. 170°21'48.5"E.
Material. — Fifteen specimens.
Discussion. — The presence of *Leionucula palaioanaxea* n. sp.
in the earliest Paleocene of New Zealand marks one of the
earliest records of the genus in the Southern Hemisphere and
the earliest record in the New Zealand Tertiary. In New Zealand,
species of *Leionucula* have a rather scattered temporal distribu-
tion throughout the Cenozoic: “Wangaloan” (Paleocene), *L.
palaioanaxea* n. sp.; Kaian (Late Eocene) L. n. sp.; Kaian (Late
Eocene) L. n. sp.; Kaian (Late Eocene) L. n. sp. (Saul,
1986); and Recent, *L. strangi* (A. Adams, 1856) and
*L. strangiformis* (Dell, 1956). The type species of *Leio-
nucula* (L. albemis d’Orbigny) is quite similar to *L. palaioanaxea*
n. sp. in outline and sculpture, but the former can be distin-
guished from the latter in having a less well developed anterior
“wing,” a more posteriorumbo, and apparently more distinct
commarginal sculpture. *Leionucula palaioanaxea* n. sp. can be
separated from the Miocene species *L. grangei* (Marwick, 1926)
by the former having an anterodorsal, blunt “wing” and a more
elongate and subovate outline. The Miocene species is more
subtrigonal. The “Wangaloan” species has an outline and chon-
drophore very similar to *L. strangeiformis* (Dell, 1956) from the
Recent of the Chatham Islands, but the Paleocene species is
much larger and more oblique in outline with a more arcuate
hinge. *Leionucula nova* Wilckens, 1911, from the Middle?-Up-
er Eocene La Meseta Formation of Seymour Island, Antarctic
Peninsula, is similar in size of shell, general outline, and hinge
structure to *L. palaioanaxea* n. sp., but the Antarctic species
lacks the anterodorsal “wing” and has several more anterior
and posterior hinge teeth. *Leionucula palmeri* Zinsmeister, 1984,
also from the La Meseta Formation, can be easily separated from
the “Wangaloan” species by being much smaller with a
subtrigonal outline. *Leionucula palaioanaxea* n. sp. closely re-
sembles *L. hunickeni* Zinsmeister and Macellari, 1988, from the
Lower Paleocene Sobral Formation of Seymour Island, but the
Antartic species is more inflated with a less defined anterodor-
sal wing. *Leionucula?* sp., previously referred to *Ennucula* aff.
E. grayi (d’Orbigny, 1846), is known from the Miocene of Sites
270 and 272, Ross Sea, DSDP Leg 28 (Dell and Fleming, 1975),
but the specimens are too incomplete for positive identification
and comparison. A very large (30.6 mm) specimen of Oligocene
*Leionucula* aff. *L. grayi* (d’Orbigny) was reported by Beu and
Dell (1989) from the Antarctic CIROS-1 drillhole. However, a
partly crushed nuculid specimen 28.0 mm in length (housed at
the University of Otago Geology Museum, OU 39641) from the
Pliocene of the Marine Plain, Vestfold Hills, Princess Elizabeth
Land, Antarctica, can be assigned with reasonable confidence
to *Leionucula* and is much larger with more pronounced com-
mmarginal sculpture when compared to the new Paleocene
species of New Zealand. The Antarctic species from the Ross Sea, DSDP
Leg 28, and Vestfold Hills are probably conspecific.
Etymology. — Species named from the Greek “palaio” (=anci-
ent, old) for its early record in the New Zealand Tertiary and
Greek “anaxeo” (=new smooth, polish) for its shining, polished
surface in well-preserved specimens.
Class GASTROPODA Cuvier, 1797
Order NEOGASTROPODA Wenz, 1938
Superfamily MURICACEA Rahnkes, 1815
Family TUDICIDAE Cossmann, 1901, 
emend. Finlay and Marwick, 1937
Discussion. — Gastropod genera within the Tudicidae have long
been discussed in the literature (Finlay and Marwick, 1937;
Abbott, 1959; Sohl, 1964; Davies, 1971; Zinsmeister, 1983;
Rosenberg and Pett, 1987; Poponoe and Saul, 1987; Saul, 1988;
Beu and Maxwell, 1990; Stilwell and Zinsmeister, 1992), but
the familial position of genera assigned to the Tudicidae is still
disputed and as yet unresolved. A complete review of the Tudi-
cidae is beyond the scope of this paper, but a short discussion
is appropriate. The Tudicidae encompasses seven genera
*Pyropis Conrad, Tudicula Röding, Pseudoperissolax Clark, Na-
pitus Stephenson, Tudiculana Finlay and Marwick, Perissolax
Gabb, and Rapopsis Saul*) that share such morphologic features
as fusiform or pyriform to rapiform shape, a rounded aperture,
a moderate to long anterior canal, a weak to strong columellar
fold at the base of the columella, a short to moderately elevated
spire, and whorls with angulations ornamented by nodes, axially
extending or not, or tubes (Saul, 1988). Some genera (i.e.,
*Tudicula Röding, Pyropis Conrad*) have been previously as-
signed to the Vasicidae (see Vaught, 1989), which have multiple,
columnar plait (i.e., *Tudivasisum*), quite different from Tudi-
cidae, which has one or none (Saul, 1988). Rosenberg and Pett
(1987) regarded *Tudivasisum pro Tudicula H. and A. Adams and
Tudicula as members of the Turbinellidae Vasicinae, but by the
criteria of Saul (1988) they cannot be included in the same
family. Ponder and Warén (1988) did not recognize Tudicidae
as a distinct family, but placed the group as a subfamily Tudici-
linae (=Pyropidae) within the Turbinellidae, superfamily Mur-
ciodea. Tudicidae probably includes Pyropidae and is not
closely related to Turbinellidae or Vasicinae (L. Saul, personal
commun.). Vaught (1989) assigned the above genera to the Vasi-
cidae. In accordance with Saul, Tudicidae is retained as a valid
taxon and the genera listed above are included within this fam-
ily. The Tudicidae in the Southern Hemisphere are represented in
Upper Cretaceous to lower Tertiary rocks of New Zealand
(Wilckens, 1922; Finlay and Marwick, 1937; Warren and Spe-
den, 1977) and South America (Wilckens, 1907; Malumian
et al., 1978), lower Tertiary (Middle?-Upper Eocene to lowermost
Oligocene?) of the Antarctic Peninsula (Zinsmeister, 1982; Stil-
well, 1988; Stilwell and Zinsmeister, 1992), and middle Tertiary
(Middle–Upper Miocene) of Australia (Darragh, 1985).
**Genus Pyropsis Conrad, 1860**


**Type.** *Tudicula (Pyropsis) perlata* Conrad, 1860 (by monotypy).

**Discussion.** The presence of *Pyropsis* Conrad in the Early Paleocene of New Zealand extends the Tethyan taxon to the Tertiary Austral realm. Morphologic features typical to *Pyropsis* include a pyriform to rapiform outline, a relatively short spine, a capacious body whorl with swollen shoulders, ornamentation of strong spiral sculpture with nodes, tubercles or spines, an abrupt basal contraction, a relatively long anterior siphonal canal, and a broad weak to strong swelling at the base of the col umella (Saul, 1988).

Although *Tudicula adriatica*, a paucispecifid tudi­cdid, is closely related to *Pyropsis*, the former can be separated in having a macroticarinate body whorl, a more impressed suture, a higher spine, and an apparently less oblique, anterior canal. *Tudicula adriatica* lacks, in addition, a subsutural welt so prominent in *Pyropsis*. *Pyropsis* is also closely related to *Tudicula* (Wenz, 1943; Abbott, 1959; Sohl, 1964; Saul, 1988). The new New Zealand species from the Wangaloa Formation has moderately strong spiral sculpture, but otherwise appears quite typical, morphologically, of *Pyropsis*.

**Pyropsis zinsmeisteri** n. sp.

**Figure 4.1-4.6**

**Diagnosis.** Shell small- to medium-sized; spire with at least three straight-sided to slightly concave whorls; suture complex; body whorl biaugulate; shell ornamented with two distinct rows of well-spaced, projecting nodes and numerous, closely spaced spiral ribs; aperture subhomboid; siphonal canal moderately long, slightly twisted anteriorly.

**Description.** Shell relatively small- to medium-sized for genus, moderately solid, pyriform; spire low, with at least three straight-sided to slightly concave whorls; spire angle 104°; protoconch very small, conical; suture complex with ill-defined, blunt, axially extending tubercles, bounded anteriorly by narrow, waved zone on extreme posterior part of body whorl that essentially wraps around anterior nodulation of penultimate whorl, on swollen, predominantly spirally sculptured, posterior angulation; growth lines orthocline, stronger on penultimate whorl; body whorl capacious, biaugulate; posterior and anterior angulations spaced, subequal; posterior one stronger with approximately 16 nodes that are equal in strength to posterior nodes; posterior slope of body whorl strongly concave, anterior slope concave, rapidly contracting to anterior siphonal neck; sculpture on body whorl of approximately 40 subequally and closely spaced, spiral ribs that bunch together slightly at posterior and anterior angulations; penultimate whorl sculptured with seven narrow, spaced spiral ribs; aperture elongate, subhomboid; siphonal canal moderately long, tapering, slightly twisted anteriorly at base of col umella; basal fasciole poorly developed; inner lip with moderately thick indumentia, thickest medially in parietal region; posterior sinus well-developed at inner–outer lip junction.

**Dimensions.** Holotype, OU 39607, height 21.0 mm, diameter of body whorl 15.0 mm; paratype, OU 39608, height 18.5 mm incomplete, diameter of body whorl 19.0 mm; paratype, OU 39609, height 20.0 mm siphonal canal incomplete, diameter of body whorl 18.5 mm; paratype, OU 39610, height 17.5 mm incomplete, diameter of body whorl 16.5 mm.

**Types.** Holotype, OU 39607; paratype, OU 39608; paratype, OU 39609; paratype, OU 39610.

**Type locality.** Mitchells Rocks, Wangaloa, South Otago (lat. 46°15'27.6"S, long. 169°57'57.6"E), southern part of cliffs along sandy beach about 250 m north of Mitchells Rocks along coast from ladder accessed cove, NZMS 260, H46/1166 and H46/1665, 76753340.

**Material.** Six specimens.

**Discussion.** *Pyropsis zinsmeisteri* n. sp. has a strong morp­holologic similarity to Paleocene tucidicids of the West Coast of North America. *Pyropsis fantozzii* Saul, 1988, from the early E­langian (Paleocene) of the Lower Santa Susana Formation of the Simi Hills, Ventura County, California, is distinguished from *Pyropsis zinsmeisteri* n. sp. in having stronger spiral sculpture, more axially extending tubercles, and a more capacious body whorl. *Pyropsis striata* (Stanton, 1896) from the Thanetian (Late Paleocene) of California has stronger spiral sculpture and larger, more axially extending tubercles, but closely approaches *Pyropsis zinsmeisteri* n. sp. morphologically. *Pyropsis zinsmeisteri* n. sp. is also quite similar to the type species of *Pyropsis* (P. perlata Conrad, 1860), but the New Zealand species has a biangulate profile, higher spire and sculpture of moderately strong axial nodes and more numerous spiral ribs. *Pyropsis zinsmeisteri* n. sp. has a low spire and general outline, more like "Heterotermum" (= *Pyropsis?) zelandica* Marshall, 1917, from the Wangaloa Forma­tion, but can be distinguished from the former by being smaller in size and having two distinct rows of nodes on the body whorl, unlike *P.? zelandica*, which has one set of axially extending nodes. *Pyropsis zinsmeisteri* n. sp. is also concave about the periphery, whereas *P.? zelandica* has a posterior angulation that is distinctly stronger and has a stronger axial component to its nodes, which are more closely spaced than those of *Pyropsis zinsmeisteri* n. sp. Juvenile specimens of *Pyropsis? zelandica* Marshall were also compared with the type specimens of *Pyropsis zinsmeisteri* n. sp., roughly of equal size. Consistent morphologic differences remain and there appears to be no gradation in sculpture between *P.? zelandica* and *Pyropsis zinsmeisteri* n. sp. Detailed study indicates that these two species under discussion are not closely related, although phylogenetic relationships are still unclear. *Pyropsis zinsmeisteri* n. sp. seems more closely related to North American species than to *P.? zelandica*. The generic placement of *P.? zelandica* is problematic and is not discussed here; the species may represent a new genus, but further study is required. *Pyropsis zinsmeisteri* n. sp. is quite distinct and should be separated from *P.? zelandica*. *Perissitys steward* (Zinsmeister, 1983) is superficially similar to the New Zealand species, but has a much steeper posterior slope on the body whorl and a more inflated subsutural wall. *Tudicula sim­ulator* Finlay and Marwick, 1937, from the Wangaloa Forma­tion can be separated from *Pyropsis zinsmeisteri* n. sp. in having a higher spine, a multiaugulate body whorl, and nearly straight anterior canal. *Tudicula alta* (Wickens, 1922) from the Late Cretaceous of New Zealand is similar to *P. zinsmeisteri* n. sp. in having a biangular whorl profile, but the Cretaceous species has a higher spine with more inflated early whorls.

**Etymology.** Species named in honor of Dr. W. J. Zinsmeister, Purdue University, for his work on Cretaceous–Tertiary Mollusca of the Southern Hemisphere.

**Class OPSTHOBRANCHIA Milne Edwards, 1848**

**Order CEPHALASPIDA Fischer, 1883**

**Family ACTEONIDAE d'Orbigny, 1842**

**Subclass OPSTHOBRANCHIA Milne Edwards, 1848**

**Order CEPHALASPIDA Fischer, 1883**

**Superfamily ACTEONOIDEA d'Orbigny, 1842**

**Family ACTEONIDAE d'Orbigny, 1842**

**Genus Wangaeceon n. gen.**

**Type.** *Wangaeceon grebneffi* n. sp.

**Diagnosis.** Shell elongate-conic; spire high; ornamentation of sparse, basal, punctate, spiral lines; columnella with a single, weak fold.
Discussion.—Wangacteon n. gen. is a monotypic genus within the Acteonidae with no apparent close relative, extinct or extant. The new New Zealand genus is most similar to Tenuiactaeon, which was erected by Aldrich (1921) for a group of acteonids resembling Acteon, but with shells that are more slender. The type species of the genus, T. pertenuis from the Greggs Landing Marl Member of the Tuscahoma Sand of the Wilcox Group (Upper Paleocene, Sabine Stage, corresponding in part to the
Thanetian Stage) of Alabama, has a partially emersed spire, a deep suture, a columella with one strong fold, and sculpture of numerous, incised, spiral lines. Specimens of *Tenuiactaeon pertenuis* are very rare as perhaps only two are known, the holotype and a topotype, and all known fresh outcrops of the Greggs Landing Marl are drowned beneath a reservoir (A. K. Rindsberg, personal commun.). Although *Wangacteon* n. gen. is superficially similar to the type species of *Tenuiactaeon*, the New Zealand genus is clearly distinct from the paucispecific *Tenuiactaeon* group in having only a few basal, punctate lines, and a feeble colomellar fold unlike *Tenuiactaeon* or any other acteonid group. Tertiary fossil species of New Zealand assigned to *Tenuiactaeon* are in a state of flux, and may represent a distinct group from typical *Tenuiactaeon*. *Wangacteon grebneffi* n. gen. and sp. is also reminiscent of the Recent western Pacific type species of *Leucotina A. Adams, 1860*, *L. niphonensis*, but the new New Zealand genus has only a few basal, punctate spiral lines and is much larger with a taller spire. *Wangacteon* n. gen. is not known from rocks younger than Paleocene. The presence of yet another endemic taxon in the New Zealand “Wangaloan” molluscan fauna, *Wangacteon grebneffi* n. gen. and sp. can be regarded as a reflection of New Zealand’s geographic and genetic isolation during the Early Paleocene.

**Etymology.**—New genus named for its presence in Lower Paleocene rocks near Wangaloa and its relationship to Acteonidae.

**WANGACTEON GREBNEFFI** n. gen. and sp.

**Figure 5.1–5.3**

**Diagnosis.**—Same as for genus.

**Description.**—Shell moderately large, thin, smooth, elongate-conic; spire moderately high with at least six, well-rounded, convex whorls; whorl inflation constant; spire angle 33°; suture impressed; growth lines very faint, opisthocline; last whorl slightly to moderately inflated, well rounded, mostly smooth with four near microscopic spiral lines on anterior portion of whorl, the extreme anterior spiral spaced away from posterior ones which are evenly spaced with respect to each other; spiral lines with numerous, subequally spaced punctae; last whorl contracting moderately anteriorly; penultimate and posterior whorls mostly smooth with two, anterior, well-spaced, spiral lines with numerous punctae, the anterior spiral line just above suture; earliest whorls with three or more spiral lines with punctae; col­umella with a thin, parietal glaze; aperture elongate with a single, posterior, weak fold on columella.

**Dimensions.**—Holotype, OU 39611, height of shell 11.5 mm, diameter of body whorl 5.0 mm.

**Type.**—Holotype, OU 39611.

**Type locality.**—Mitchells Rocks, Wangaloa, South Otago (lat. 46°15′27.6″S, long. 169°57′57.6″E), southern part of cliffs along sandy beach about 250 m north from ladder accessed cove, NZMS 260, H46/f166, 76753340.

**Material.**—One well-preserved specimen.

**Discussion.**—*Wangacteon grebneffi* n. gen. and sp. from the Wangaloa Formation greatly differs from other previously assigned Tertiary New Zealand acteonid species in having a stout form with sparse, basal, punctate, spiral lines and a moderately high spire. An undescribed species tentatively assigned to *Tenuiactaeon* from the Paleocene Kauru Formation near Five Forks, North Otago, New Zealand, is similar to the type species, *T. pertenuis*, in being very high spired, but differs from *Wangactaeon grebneffi* n. gen. and sp. in being much higher spired with numerous, evenly spaced, punctate, spiral cords unlike the newly described genus and species from Wangaloa. *Acteon semispiralvs* Marshall, 1917, and *Acteon wangaloa* Finlay and Marwick, 1937, both from the Wangaloa Formation, are separated from *W. grebneffi* n. gen. and sp. in having much lower spires with numerous spiral cords.

**Etymology.**—Species named in honor of A. Grebneff, research assistant and preparator, Department of Geology, University of Otago, for collecting the holotype.
ACKNOWLEDGMENTS

A great thank you is owed to W. J. Zinsmeister, Purdue University, for his support of my research. A. Grebneff, University of Otago, graciously donated specimens for this study. M. A. Ayress and D. V. Keyes, New Zealand Geological Survey, provided valuable palynological data. J. L. Lindqvist, New Zealand Geological Survey, is thanked for collecting some microfossil samples at Wangaloa for palynological analysis. While I was in Paris, S. Freneix, Museum National d'Histoire Naturelle, gave me invaluable help and access to Ornigyn's collection. Many thanks are owed to R. E. Fordyce, University of Otago, for her comments on Pytopsis and Tucidicidae. A. K. Rindsberg, Geological Survey of Alabama, and J. P. Lamb, Red Mountain Museum, Alabama, provided me with current stratigraphic data and informative photos of the holotype of Ten­niaclavataeoni pertenuis. I greatly benefitted from discussions with P. A. Maxwell, formerly of the New Zealand Geological Survey. A great thank you is owed to W. J. Zinsmeister, Purdue University, West Lafayette, Indiana, for providing me with invaluable Antarctic research experience, necessary for work on Cretaceous-Tertiary Mollusca of the Southern Hemisphere, and for his support of my work in New Zealand. A. G. Beu, New Zealand Geological Survey, Lower Hutt, and W. J. Zinsmeister, Purdue University, critically reviewed the manuscript and offered valuable suggestions. M. E. Hutchinson, Dunedin, New Zealand, gave continued encouragement throughout this study. Funding for this research was provided by a New Zealand University Grants Committee Post-Graduate Fellowship and a grant to R. E. Fordyce, University of Otago.

REFERENCES


—. 1928. The Tertiary Mollusca of the Chatham Islands including a generic revision of the New Zealand Pectinidae. Transactions of the New Zealand Institute, 58:432-506.

ACCEPTED 24 APRIL 1992
NEW INSIGHTS INTO CHANGES IN FAUNAL COMPOSITION OF GONDWANA REALM MOLLUSCA ACROSS THE CRETACEOUS-TERTIARY BOUNDARY: THE NEW ZEALAND FAUNA

Jeffrey D. STILWELL
Department of Geology, University of Otago,
PO Box 56, Dunedin, New Zealand

New data from latest Cretaceous to Early Paleogene Mollusca of New Zealand, Chatham Islands, New Caledonia, Australia and Antarctica continue to expand our understanding of the paleobiogeographic history of the southern hemisphere biota and how these taxa relate to other Gondwana Realm groups. New studies on faunas from various regions around the rim of the southern circum-Pacific (e.g. Northland, New Zealand; East Antarctica) provide a window into latest Cretaceous to early Paleogene Austral life of these areas.

Ongoing research on the rich and relatively diverse Mollusca of New Zealand indicates that faunal ties between New Zealand and other western sector Gondwana "fragments" (e.g. New Caledonia, Chatham Islands) were marked during Campanian to Maestrichtian time, compared to the eastern sector of Antarctic Peninsula and southern South America. Amongst New Caledonian bivalves, 25 latest Cretaceous genera/subgenera out of a total of 36 (c. 70%) are common between New Caledonia and New Zealand. For the Campanian to Maestrichtian in New Zealand, about 79 genus- and subgenus-group bivalve taxa have been recorded and 33 genus- and subgenus-group gastropod taxa have been recognised. Of these taxa, 10 out of the total of 112 (c. 9%) are endemic to New Zealand. Although similarities between New Zealand and Chatham Islands during the latest Cretaceous are not as strong as that between New Zealand and New Caledonia, data support close ties between these regions. Facies biases may in part account for differences between mainland New Zealand and Chatham Islands latest Cretaceous faunas. The little information available on gastropods corroborates the bivalve data.

Of New Zealand bivalve genera, 12 out of 79 (c. 15%) crossed the K-T boundary; in contrast, about 10 gastropod genera of 33 (c. 30%) are present in Lower Paleocene rocks. Molluscs which persisted across the K-T boundary include bivalve taxa Leionucula, Jupiteria, Cucullaea (Cucullastis), Glycymerita, Isognomon, Anomia, Myrtea, Lahillia, Aphrodina (Tikia) and Panopea; and gastropods Bittiscala, Struthioptera, Conchothyra, Amiapropsona, Euspira, Acirsa (Notacirsa), Tornatellaea and Cylichnania. One scaphopod, Antalis, crossed the K-T boundary. Many of the above taxa disappear from the New Zealand fossil record after the Paleocene. In all, 23 mollusc genera of 114 (c. 20%) survived the K-T transition, although a few taxa show up later in the Tertiary ("Lazarus Effect"). No New Zealand Maestrichtian species is known to have survived into the Danian. In New Zealand composite stratigraphic sections suggest the presence of a gap in the record between Maestrichtian to Danian macrofossil assemblages. This hiatus could be substantial in which case the seemingly abrupt appearance of many new genus- and species-level taxa in the Danian of New Zealand may be more apparent than real.

New data from Early to Middle Paleocene molluscs of New Zealand and southeastern Australia indicate that strong faunal ties existed between these areas. By Paleocene time the Weddellian Biotic Province, which may have extended from eastern Australia to southern South America, had probably been reduced to a small region along the newly opened Tasman Sea.
The paleoaustral genus **Protodolium** Wilckens, 1922, was an important element in the gastropod fauna of the western sector of the Gondwana Realm during Campanian to Maastrichtian time (Late Cretaceous). Previously thought to be endemic to New Zealand, **Protodolium** is now recognised in inferred Campanian rocks of New Caledonia for the first time, and also in uppermost Cretaceous rocks of Chatham Islands, Southwest Pacific. As a result of renewed interest in **Protodolium** which has not been studied in any detail for 70 years, a new species has come to light, **Protodolium pittensis**, described here from the Kahuitara Tuff, Pitt Island, Chatham Islands. Long believed to be a member of Tonnidae (Tonnacea), **Protodolium** is now reallocated to Neritopsidae (Neritacea). **Protodolium** species, previously thought to be carnivores, were probably epifaunal herbivores in the littoral to sublittoral zone shallower than mid shelf.

Keywords: **Protodolium**, Mollusca, Gastropoda, fossil, new species, Neritopsidae, paleoaustral, Late Cretaceous, Campanian, Maastrichtian, New Zealand, Chatham Islands, New Caledonia, Gondwana

INTRODUCTION

The hitherto monotypic endemic gastropod genus **Protodolium**, erected by O. Wilckens in 1922 in his “The Upper Cretaceous gastropods of New Zealand”, has received little attention in the last 70 years. A revision and review of this Late Cretaceous genus is needed in light of new data from throughout New Zealand, and the recent recognition of the presence of **Protodolium** in the Chatham Islands and New Caledonia (Fig. 1).

**Protodolium** is considered to be a relatively short-lived (Campanian to Maastrichtian) paleoaustral taxon of moderately restricted geographic distribution, which as far as is known failed to survive the end Cretaceous extinction event. The term “paleoaustral”, as coined by Fleming (1963), refers to those taxa that have fossil records ranging back into the Tertiary or Mesozoic and also those groups with inferred poor dispersal capabilities whose present or known fossil distribution reflect past land connections of the southern continents.

Proper familial placement of **Protodolium** is in need of reassessment because of the previous misconception of this taxon’s close affinity to Tonnidae (Order Mesogastropoda [ordinal name Neotaenioglossa now preferred], Superfamily Tonnacea). Rather, as discussed below, **Protodolium** is best removed from Tonnidae and placed in Neritopsidae (Order Mesogastropoda [ordinal name Neritimorpha now preferred], Superfamily Neritacea). This paper reports for the first time the presence of **Protodolium** in Campanian Upper Cretaceous marine deposits of New Caledonia, and describes a new species, **Protodolium pittensis**, from Pitt Island, Chatham Islands, New Zealand. Notes on the inferred paleoautecology of **Protodolium** are presented.

The Late Cretaceous gastropod faunas of New Caledonia and Chatham Islands are poorly known (so also are the Chatham Islands bivalves) compared with the bivalve and gastropod
Faunas of New Zealand. Approximately 150 species of bivalves, gastropods and scaphopods have been recorded from mainland New Zealand (J. D. S., unpublished data). To date only one species of gastropod, Pyrgulifera glypta Avias and Rey, 1958, has been reported from New Caledonia, whereas 44 species of Campanian bivalves have been recognised and described by Freneix (1958, 1960, 1980). Only four species of gastropods have been recognised (undescribed) in the Late Cretaceous fauna of the Chatham Islands as opposed to 24 bivalve species; only two of these gastropod species are identifiable at genus-level with any confidence (Campbell et al., in press, Table 4.3). The paucity of information available on New Caledonian and Chatham Islands Cretaceous gastropods has prompted me to write this paper for two main reasons: (1) to narrow the obvious imbalance in our knowledge of these gastropod faunas; and (2) more importantly to increase our data base on Late Cretaceous New Caledonian and Chatham Islands molluscan faunas, to enable comparisons between them and coeval Gondwanic faunas around the rim of the southern circum-Pacific.

A current interest behind this study involves a test of Zinsmeister’s (1979) Weddellian Biotic Province hypothesis. A preliminary test of this idea, with respect to a shallow-water region extending from southeastern Australia to southern South America, was described by Stilwell (1991). Here data matrices were compiled for coeval Campanian to Eocene molluscan shelf faunas (605 genus-group taxa) of New Zealand, Australia, Antarctica and southern South America. Similarities between the faunas were assessed by the use of simple binary
similarity coefficients. Although the faunal similarities of Late Cretaceous New Caledonian and Chatham Islands Mollusca were not compared directly in that study with the above Gondwana “fragments”, there appear to have been quite strong links between the bivalves then living among the western sector of the Weddellian Province, including New Zealand, Chatham Islands and New Caledonia (J. D. S., unpublished data). More data are needed to sharpen the definitions of southern hemisphere faunal provinces during the Late Cretaceous to early Tertiary. Furthermore, additional work is needed to document the changes in composition of the Late Cretaceous to early Tertiary molluscan faunas which followed the final break-up of Gondwana and the concomitant dispersion of the southern continental “fragments”. Accomplishing these tasks should allow us more clearly to understand the biogeographic history and evolution of invertebrate faunas around the southern circum-Pacific.

SYSTEMATIC PALEONTOLOGY

Specimens used in this study are housed in the Auckland University Geology Department (AU), Institute of Geological and Nuclear Sciences, Lower Hutt (IGNS), and Geology Department, University of Otago (OU). Figured and type specimens are given unique catalogue numbers. Additional acronyms include: TM (Type Mollusca) for specimens housed at the Institute of Geological and Nuclear Sciences, Lower Hutt; NZMS (New Zealand Map Series); NC (New Caledonia); GS (Geological Survey Macrofossil Collection, now Institute of Geological and Nuclear Sciences); G (BMNH, Natural History Museum, London, type or specimen number).

Phylum MOLLUSCA Linné, 1758
Class GASTROPODA Cuvier, 1797
Subclass PROSOBRANCHIA Milne-Edwards, 1848
Order NERITIMORPHA Golikov and Starobogatov, 1975
Superfamily NERITACEA Rafinesque, 1815
Family NERITOPSIDAE Gray, 1847
Genus Protodolium Wilckens, 1922


Type species (by original designation) Neritopsis? speighti Trechmann, 1917.

Synonym Pseudodolium Wilckens, 1922: 5 (= nomen nudum).

Diagnosis Shell medium- to large-sized, moderately thick and solid, subglobose; spire low, moderately obtuse, of at least three flat-sided to gently convex whorls; mean spire angle ranging from about 73°–112°; protoconch obtusely conical to slightly domed of two smooth whorls; growth lines orthocline; last whorl moderately to greatly inflated, convex, sculpture variable, predominantly spiral of strong, raised, flattened, wide cords separated by deep furrows and weak to moderately collabral strong growth lines; some specimens with axial sculpture and blunt tubercles; penultimate whorl with two or three spiral cords; umbilicus very shallow; columella concave adapically; abapical portion of inner lip slightly reflected; inductura moderately thick, narrow, thinning to a variably broad to narrow glaze in parietal region; aperture holostomatous, broadly ovate to subovate.

Biogeographic element Paleoaustral, as interpreted here.

Discussion Wilckens (1922: 18) erected the New Zealand Late Cretaceous endemic monotypic genus Protodolium for Neritopsis? speighti Trechmann, 1917. Wilckens noted that P. speighti has similarities in shell outline and sculpture to species of the Recent and Tertiary genus Dolium Lamarck, 1801 (= Tonna Brünich, 1772) and thus interpreted Protodolium as being an early representative of the family Doliiidae (= Tonnidae). Earlier, Trechmann (1917: 300) stated that Neritopsis? speighti is more likely to be related to Neritopsis Grateloup, 1832,
than to such genera as Cinulia, Dolium, Pyrula, and Fossarus because the "moderate thickness of the shell and increasing thickness of the adult lip and sharpness of the aperture point to Neritopsis...". Wilckens (1922: 19) disputed Trechmann's earlier conclusion as to the relationships with Neritopsis by concluding that "Neritopsis is characterized by the broad angular emargination of its inner lip, not present in P. speighti". Wilckens wrongly thought that the absence of a "channel" (=siphonal canal) in Protodolium is a primitive character and that in this Cretaceous genus "...the channel of Dolium has not yet developed" (p. 19). Tonna species are siphonostomatous, with a strong fasciole and thin shell, quite unlike Protodolium, which is holostomatous without a fasciole and has a solid shell of moderate thickness. Wilckens, in my opinion, placed too much weight on inferred homeomorphic characters in the orders Neritimorpha and Neotaenioglossa among others such as shell outline, sculpture and growth lines (which are common to several groups, including Tonna), and too little on the absence of a siphonal canal in Protodolium. Ironically, Wilckens' use of "Pseudodolium" (p. 5, here considered a nomen nudum; most likely a name used in earlier drafts of Wilckens' paper that remained unchanged after the formal naming of Protodolium) would have been more appropriate than Protodolium, since the latter implies a phylogenetic relationship with Dolium (=Tonna).

Wenz (1941: 1076) reviewed the diagnostic features of Protodolium and tentatively placed the genus in Tonnidae without discussion. As a sidenote, Wenz stated that Protodolium is present in Maastrichtian rocks of North America and Java?, though these records are unsubstantiated. Protodolium escaped the attention of Kase and Maeda (1980) and Kase (1984) in their extensive discussions on Neritopsis-like gastropods. Apparently, Protodolium has received little or no taxonomic attention since Wenz (1941).

The overall morphology of Protodolium is here taken to indicate a relationship to the Mid Jurassic to Recent genus Neritopsis s.s. Features common to Protodolium and Neritopsis include a globose to subglobose outline reflecting a capacious, convex last adult whorl; a moderately thick shell; a low, obtuse spire of few whorls; abaxial orthocline to adaxial prosocline growth lines towards the inner lip; variable spiral and axial sculpture, consisting in most species of predominantly spiral cords, some taxa with collabral ribs; a shallowly umbilicate to nonumbilicate shell; a thickened, narrow, inner lip; a holostomatous aperture; and an unarmoured to slightly armoured labrum. The type species of Protodolium, P. speighti, differs from the type species of Neritopsis, N. moniliformis Grateloup, 1832 (Grateloup, 1832: 125–131, Fig 1–3; see Wenz, 1938: 412, fig. 999), from the Miocene of Europe and the Recent Indo-Pacific species N. radula (Linné, 1758) (Wenz, 1938: 412, fig. 1001; Cox in Knight et al., 1960: 1278–1279, fig. 182–7–9; Cernohorsky, 1972: 52–53, pl. 11, fig. 11; Dance, 1989: 97, fig. 6), in having a larger shell; a slightly less inflated last whorl and hence a broadly convex outer lip; a slightly higher spire; well-spaced, very strong, flattened, thick spiral cords mostly without rounded nodules or pustules; a subsuturally swollen, thickened posteriormost (adapical) spiral rib giving a somewhat angular, subsutural profile; a smooth, concave columella without a blunt tooth; a seemingly more reflected abapical portion of the inner lip; an obsolete umbilicus; and an elongate subovate to sublenticular depression in the central part of the inner lip surface and sculpture of granulated, spiral cords or reticulation, significantly different from typical Protodolium. Neritoptyx Oppenheim, 1892 (type species Nerita goldfussii Keferstein in Goldfuss, 1844 (see Cox in Knight et al., 1960: 1279, fig. 182–3), a Late Cretaceous European subgenus of Neritopsis, is differentiated from Protodolium in having a prominent, parietal tubercle, absent in Protodolium. Protodolium...
is tentatively separated from *Neritopsis* s.s., *N. (Hayamiella)* and *N. (Neritoptyx)* at genus-level due to the above-stated differences in sculpture, inner lip and aperture shape, but future work may show that a subgenus-level separation is more appropriate. Although it is usually easy to differentiate between *Neritopsis* s.s. and *N. (Hayamiella)* species, morphologically intermediate forms exist (Kase, 1984: 83), so further study is needed to assess phylogenetic relationships between these taxa. Any similarity between *Protodolium* and siphonostomatous *Tonna* is superficial.

The paleoautecology of *Protodolium speighti* (Trechmann, 1917) has received little attention in the literature. It has been interpreted as an epifaunal carnivore (Warren and Speden, 1978: 50, tab. 5; Crampton and Moore, 1990: 347), evidently because of the perceived relationship with carnivorous *Tonna*. Marine neritacean gastropods are predominantly herbivorous and are generally intertidal (Cernohorsky, 1972: 48), so *Protodolium* may have had the same habits. However, although rocky shores are the main environment for neritacean gastropods, they have been observed living on sand as far as 300 m away from the nearest rock, indicating a preadaptation to a burrowing lifestyle (Fischer, 1966: 52). Also, dead shells of *Neritopsis atlantica* have been recovered from the sandy bottom off the coast of Cuba at 10–15 m depth (Sarasua, 1973: 5). Most records of *Protodolium* have been collected from sandstone deposited at interpreted tidal to subtidal depths (most likely shallower than mid shelf), suggesting that some Cretaceous neritopsids lived at greater depths than most living neritaceans. The moderately thick, solid shell of *Protodolium* species suggests that the foot was probably quite muscular. The functional significance of the very slight depression along the abapical-most part of the inner lip (more obvious in *N. speighti* (sic.), Wilckens, 1922: 18, error.) is uncertain, but may be the attachment site of the operculum (P. A. Maxwell, pers. comm.) or alternatively reflect the presence of a small inhalant siphon.

*Protodolium speighti* (Trechmann, 1917)  
Figures 2a-h, 3a-j  
*Neritopsis (?) speighti* Trechmann, 1917: 300–301, pl. 19, figs. 12–15;  
*Neritopsis speighti* (sic.), Wilckens, 1922: 18, error.  
*Protodolium speighti* (Trechmann), Wilckens, 1922: 18–20, pl. 4, figs. 3a-b, 4a-b, 5; Wilckens, 1924: 541; Wenz, 1941: 1076, fig. 3065; Fleming in Robinson, 1958: 18; Marwick and Fleming in Wellman, 1959: 139; Fleming in Wellman, 1959: 142; Fleming in Wilson, 1963: 25; Warren and Speden, 1978: 50, tab. 5; Crampton and Moore, 1990: 347; Stilwell in Aitchison et al., 1993: 50, fig. 3e.

**Supplementary description** Shell medium-sized, moderately thick, solid, subglobose; spire low, only 20% of total height of shell, moderately obtuse, compressed, paucispiral, of three, almost flat-sided to weakly convex whorls; whorl inflation rate high after apical whorls, highest between penultimate and last adult whorls; mean spire angle approximately 112°; protoconch obtusely conical to slightly domed, paucispiral, of two smooth whorls; suture slightly impressed; growth lines orthocline, very shallow sinus abapically; last whorl capacious, well-inflated, moderately convex, whorl profile of adapical portion of last whorl to periphery somewhat flat; basal constriction mostly constant; last whorl sculpture predominantly spiral, of 12–15, very strong, raised, spaced, flattened spiral cords, separated by 1.0–1.5 mm wide, deep interspaces or furrows, crossed perpendicularly by orthocline growth lines abaxially, more curved adaxially towards inner lip; spiral cords 1.5 mm wide on average (adult shells); few shells with broad axial sculpture, more subdued than spiral sculpture; adapical spiral rib on last whorl subsuturally thickened, inflated, 3.5 mm wide; first spiral furrow appears well abapical of adapical portion of sutural ramp; penultimate whorl with only two, strong, spiral cords; umbilicus very shallow; umbilicus with narrow furrow extending to abapical part of inner lip, paralleling abaxial margin of inner lip; abapical portion of inner lip slightly reflected; abapical portion of columella broadly concave; inductura moderately thick, narrow; parietal region with variable (size and shape), moderately broad to narrow glaze; aperture broadly ovate, holostomatous; labrum smooth.
Fig. 2 – The first illustrations of *Protodolium speighti* by Trechmann (1917) and Wilckens (1922): a, lectotype G 27447 (BMNH), Trechmann, 1917 (pl. 19, fig. 12), apertural view, 1x; b, paralecotype G 27450 (BMNH), Trechmann, 1917 (pl. 19, fig. 15), juvenile, abapertural view, 2x; c, d, TM 2551 (IGNS), Wilckens, 1922 (pl. 4, fig. 3), abapertural and lateral views respectively, 1x; e, paralecotype G 27448 (BMNH), Trechmann, 1917 (pl. 19, fig. 13), juvenile, abapertural view, 1x; f, paralecotype G 27449, Trechmann, 1917 (pl. 19, fig. 14), abapertural view, 1x; g, h, TM 2550 (IGNS), Wilckens, 1922 (pl. 4, fig. 4), juvenile, abapertural and apertural views respectively, 2x. Acronyms used: BMNH (= British Museum of Natural History) and IGNS (= Institute of Geological and Nuclear Sciences).

**Dimensions** OU 40916 height 30.5 mm, diameter of last whorl 27.5 mm; OU 40917 height 29.5 mm, diameter of last whorl 30.0 mm; OU 40918 height 14.5 mm, diameter of last whorl 12.0 mm; TM 7460 (IGNS) (from GS 13) height 32.0 mm, diameter of last whorl 30.0 mm; TM 7461 (IGNS) (from GS 11359) height 18.5 mm, diameter of last whorl 18.0 mm; TM 7462 (IGNS) (from GS 589) height 10.5 mm nearly complete, diameter of last whorl 11.0 mm.

**Types, figured and museum specimens** Lectotype G 27447 (BMNH; Trechmann, 1917, pl. 19, fig. 12) (designated herein); paralecotypes G 27448–27450 (BMNH; Trechmann, 1917, pl. 19, figs. 13–15 respectively); paralecotype G 27451 (BMNH; not figured); TM 2646 (IGNS; Wilckens, 1924: 541); TM 2647 (IGNS; Wilckens, 1924: 541); TM 2648 (IGNS; Wilckens, 1924: 541).

Fig. 3 – *Protodolium speighti* (Trechmann, 1917), a, b, c, OU 40916 (OU), L35/f74, abapertural, apertural and apical views respectively, 2.5x; d, TM 7460 (IGNS), O32/f8025, abapertural view, 1.3x; e, OU 40918 (OU), L35/f74, abapertural view, 3.25x; f, h, TM 7462 (IGNS), L35/f6008, abapertural and apical views respectively, 3.25x and 3.5x; g, OU 40917 (OU), L35/f74, apertural view, 2.3x; i, j, TM 7461 (IGNS), V19/f6909, apertural and abapertural views respectively, 2.5x and 2x. Acronyms used: OU (= Otago University) and IGNS (Institute of Geological and Nuclear Sciences).
Stilwell – Paleoaustral Late Cretaceous gastropod Protodolium
Wilckens, 1924: 541); TM 2549 (IGNS; Wilckens, 1922, pl. 4, fig. 5); TM 2550 (IGNS; Wilckens, 1922, pl. 4, fig. 4; Wenz, 1941, fig. 3065); TM 2551 (IGNS; Wilckens, 1922, pl. 4, fig. 3); OU 40537 (OU; Stilwell in Aitchison et al., 1993, fig. 3e).

Figured specimens herein G 27447, G 27448, G 27449, G 27450, OU 40916, OU 40917, OU 40918, TM 7460, TM 7461, TM 7462.

Type locality Selwyn Rapids, Malvern Hills, mid Canterbury, South Island, New Zealand, exact locality not given by Trechmann (1917), most likely near L35/f6017 or L35/f6008.

Material Fourteen specimens and other fragments.

Localities See Appendix for details; ?eastern slope of Barron’s Hill, Otago, South Island, I44/f8519; Fairfield Quarry, Otago, near I44/f173; near junction of Taieri Beach and Taieri River Mouth Roads, Otago, I45/f8517; Shag Point, Otago, J43/f6472, J43/f159; ?North Branch of Waianakarua River, Otago, J42/f082; Selwyn River, Malvern Hills, mid Canterbury, South Island, L35/f6017, L35/f6008; Selwyn Rapids, L35/f74; Middle Waipara, Canterbury, M34/f763; South Branch of Waipara River, Canterbury, M34/f7658; Haumuri Bluff, southern Marlborough, South Island, O32/f9542; west wing of Haumuri Bluff, O32/f8025; Okarahia Stream, southern Marlborough, O32/f8790; Waitangi River, Northland, P05/f9499; Gittos Point, Northland, Q09/f9502; Waiu River, central North Island, Vl8/f8500; south bank of Mangahouanga Stream, Hawke’s Bay, North Island, V19/f182A; Mangahouanga Stream, V19/f6909; east bank of Te Hoe River, Hawke’s Bay, V19/f184, V19/f185; west bank of Te Hoe River, V19/f186, V19/f195; main branch of Waikokopu Stream, Hawke’s Bay, W18/f026.

Stratigraphic range Okarahia Sandstone (note stratigraphic position of P. speighti in column of Warren and Speden, 1978: 46, fig. 27) (Piripauan Stage, upper Campanian, Upper Cretaceous); Selwyn Rapids Beds (= Conway Formation?), Brighton Formation, unspecified formation of “Northland Allochthon” (Haumurian Stage, Maastrichtian, uppermost Cretaceous); Chaplin Sandstone of Robinson (1958, unpublished name), Katiki Formation, Maungitaniwha Sandstone (Upper Cretaceous).

Discussion. Trechmann (1917: 301) reported the presence of Neritopsis? speighti at only one locality in New Zealand: Selwyn Rapids, in the Malvern Hills, Canterbury. Later, Wilckens (1922: 18) reported Protodolium speighti from four localities at “Amuri” (= Haumuri) Bluff in southern Marlborough; Selwyn Rapids in Canterbury; and middle Waipara. Fleming in Robinson (1958: 18) reported P. speighti as present in the southernmost extent of Upper Cretaceous, macrofossiliferous marine rocks (Chaplin Sandstone, unpublished name) of the Taieri River Mouth area, East Otago. Marwick and Fleming in Wellman (1959: 139) recorded this species, in addition, from Shag Point and Barron’s Hill, Otago. Warren and Speden (1978: 46, fig. 27) recorded the stratigraphic range of P. speighti in the Haumuri Bluff area as the lower part of the Okarahia Sandstone to possibly the lowest part of the Conway Siltstone, Speden in Wiffen (1980: 527) identified Protodolium sp. (probably P. speighti) from Campanian-Maastrichtian rocks of Mangahouanga Stream, western Hawke’s Bay, associated with Moanaaurus mangahouangaes. More recently, Crampton and Moore (1990: 347) reported P. speighti from several localities in the Te Hoe River area, western Hawke’s Bay, extending for certain the geographic range of the species to include North Island. Protodolium speighti is also present in the Katiki Formation of the Waianakarua River area, North Otago (Stilwell in Aitchison et al., 1993) and the Fairfield Greensand Member of the Brighton Formation at Fairfield Quarry, Otago (this work). In summary, P. speighti has been identified from approximately 20 localities in North and South Islands, the metric grid references of which are listed in the Appendix.

A supposed operculum of “Velates sp. cf. Neritopsis speighti” was noted (unpublished) in the information given for locality X17/f7674 (GS 8405) (headwaters of Ron Stream, Raukumara Peninsula, eastern North Island) originally determined by J. Marwick and re-
examined by I. Speden in 1970. This supposed operculum is most likely a fracture mark which has been misconstrued as an operculum or possibly the operculum has been lost (I. W. Keyes and A. G. Beu, pers. comm., 1992). As far as I know, no Protodolium specimens have been recovered with operculae present. As neritopside taxa have thick operculae, it would indeed be possible to find a specimen of P. speighti with an operculum preserved.

**Protodolium cf. P. speighti** (Trechmann, 1917)  
Figure 4d-e


cf. Protodolium speighti (Trechmann), Wilckens, 1922: 18–20, pl. 4, figs. 3a-b, 4a-b, 5; Wilckens, 1924: 541; Wenz, 1941: 1076, fig. 3065; Marwick and Fleming in Wellman, 1959: 139; Fleming in Wellman, 1959: 142; Warren and Speden, 1978: 50, tab. 5; Crampton and Moore, 1990: 347; Stilwell in Aitchison et al., 1993, fig. 3e.

**Dimensions** G 7036 (from AU 7268) height 13.5 mm incomplete, diameter of last whorl 21.5 mm.

**Figured specimen** G 7036 (from AU 7268).

Stratigraphic range Charbon Formation (Campanian, Upper Cretaceous), New Caledonia.

Discussion Specimen G 7036 from the Charbon Formation agrees well with Protodolium, and is most likely conspecific with the widespread New Zealand species, P. speighti (Trechmann, 1917). The only noticeable difference between the New Caledonian specimen and numerous specimens of P. speighti available to me is that the New Caledonian form has more crowded spiral costae on the last whorl and stronger axial sculpture on the spire whorls compared with New Zealand P. speighti; otherwise, the morphological similarity is striking. Whether or not this slight disparity is truly of interspecific importance is not known at present, as the only example is incomplete. More specimens are needed to more assess the taxonomic status of this New Caledonian form.

Protodolium pittensis n. sp. Figure 4a-c

Protodolium sp., Campbell et al., in press, tab. 4.3.

Diagnosis Small- to medium-sized Protodolium with low to moderately high spire, about 36% of total shell height; spire angle about 73°; last whorl moderately inflated, ornamented with eight, thick, broadly rounded spiral cords; axial sculpture ill defined, of very blunt collabrally aligned tubercles; penultimate whorl slightly inflated with three spiral ribs; inductura thin; inner part of labrum slightly undulating.

Description Shell small- to medium-sized, moderately thick, solid, subglobose; spire low to moderately high, approximately 36% of total height of shell, slightly obtuse, slightly compressed, paucispiral, of at least three more or less flat-sided to very gently convex whorls; whorl inflation rate moderately high after apical whorls, highest between penultimate and last adult whorls; mean spire angle about 73°; protoconch only partially preserved, obusely conical(?), paucispiral, of at least two whorls; suture slightly impressed; growth lines orthocline(?), indistinct; last adult whorl moderately capacious, inflated, gently convex, whorl profile of adapical portion of last whorl to periphery also gently convex; last adult whorl sculpture predominantly spiral of 8, very strong, thick, raised, widely spaced, broadly rounded spiral cords (slightly less than 1.5 mm wide on average), separated by 0.5 mm wide, deep interspaces or furrows, crossed by obscure, subprosocline, gently curved growth lines; adaxially towards inner lip, growth lines incising spiral cords creating very blunt tubercles; axial sculpture more subdued than spiral sculpture; extreme adapical spiral rib on last whorl subsuturally thickened, inflated, 2.5 mm wide; first spiral furrow appears abapical of adapical portion of sutural ramp; penultimate whorl slightly inflated, sculptured similarly as in last whorl by three, strong, spiral cords and collabrally aligned, very blunt tubercles; umbilicus very shallow; inner lip with equally thin inductura, extending from abapical part to parietal region; abapical portion of inner lip slightly reflected, creating shallow depression; columella abapically concave to adapically straight; aperture subovate to sublenticular, holostomatous; inner part of labrum slightly undulating, reflecting alternating, external spiral cords and furrows.

Dimensions Holotype TM 7463 (IGNS) height 23.5 mm, diameter of last whorl 18.5 mm.

Type Holotype TM 7463 (IGNS).

Type locality Shore platform on west side of Flowerpot Wharf to small bay 400 m further west, northern Pitt Island, Chatham Islands, New Zealand, CH/f466.

Material Holotype.

Stratigraphic range Kahuitara Tuff (Haumurian Stage, Maastrichtian, uppermost Cretaceous).

Geographic distribution Pitt Island, Chatham Islands.

Discussion The morphological disparity between Protodolium pittensis n. sp. and P. speighti (Trechmann, 1917) is well outside the expected/observed limits of intraspecific variability of
Stilwell – Paleoaustral Late Cretaceous gastropod Protodolium

P. speighti, per numerous specimens available to me of New Zealand P. speighti. Protodolium pittensis n. sp. is distinguished from P. speighti (Trechmann, 1917) in having a smaller shell; a higher, less obtuse, more inflated spire; a less inflated last whorl with fewer more strongly thickened, spiral cords; and a more inflated penultimate whorl with an additional spiral cord (three cords in total) compared to P. speighti. Both P. speighti and P. pittensis n. sp. have equally narrow inducturas. Protodolium speighti has a more globose shell and a lower, obtuse spire with a more capacious last whorl and more spiral cords.

Etymology New species named after the type locality on Pitt Island, Chatham Islands, New Zealand, Southwest Pacific.

ACKNOWLEDGMENTS

This paper was funded by a New Zealand University Grants Committee Postgraduate Scholarship and Paleontological Society/ Margaret C. Wray Trust grant to J. D. S. I would like to thank the following people for their comments on the manuscript and assistance throughout the course of this investigation: R. E. Fordyce, A. Greneff and D. V. Weston, University of Otago, Dunedin, New Zealand; I. W. Keyes, H. J. Campbell and A. G. Beu, Institute of Geological and Nuclear Sciences Limited, Lower Hutt, New Zealand; J. A. Grant-Mackie, University of Auckland, Auckland, New Zealand; P. A. Maxwell, Waimate; J. Cooper, British Museum of Natural History, London, U. K.; P. Naurizot, Bureau de Recherches Geologiques et Minieres, Orleans, France. B. A. Marshall, Museum of New Zealand, Wellington, New Zealand, and an anonymous reviewer provided valuable comments and suggestions.

REFERENCES


APPENDIX: LOCALITY DETAILS OF PROTODOLIUM FROM NEW ZEALAND AND CHATHAM ISLANDS

The collections cited here begin historically with Sir Julius von Haast who was apparently the first to collect a specimen of Protodolium speighti from the Selwyn River, Malvern Hills, Canterbury, South Island, in 1872. Grid references of given localities are metricated. Localities are represented by map sheet (New Zealand Map Series 260)/fossil record number, e.g. L35/f6017. Inferred stages are Mp (Piripauan Stage, upper Campanian, Upper Cretaceous) and Mh (Haumurian Stage, Maastrichtian, uppermost Cretaceous). Institute of Geological and Nuclear Sciences (= IGNS).

Protodolium speighti (Trechmann, 1917): New Zealand

144/8510
Collection Number: GS 6552 (IGNS).
Collectors and Date: P. A. Waters and D. S. Coombs. April 2, 1955.
Locality: Lower part of tree-clad escarpment, east slopes of Barron's Hill, East Otago, South Island.
Lithostratigraphic Name: Brighton Formation.
Inferred Stage: Mh.

144/I73
Locality: Face on east side of Fairfield Quarry, Otago, South Island.
Lithostratigraphic Name: Brighton Formation.
Inferred Stage: Mh.

145/8517
Collection Number: GS 6762 (IGNS).
Locality: East facing bluff on ridge west of stream flowing into swamp. 0.375 miles north-northwest of junction of Taieri Beach and Taieri River Mouth Roads, East Otago, South Island.
Lithostratigraphic Name: Chaplin Sandstone of Robinson (1958, unpublished).
Inferred Stages: Mp-Mh.

J42/82
Collection: Held at Department of Geology, University of Otago.
Locality: True left bank of North Branch of Waianakarua River in a river cut platform which has since been washed away by floods, North Otago, South Island.
Lithostratigraphic Name: Katiki Formation.
Inferred Stages: Mp-Mh.

J43/159
Collection: Held at Department of Geology, University of Otago.
Collectors and Date: A. Grebneff, J. D. Stilwell, C. M. Jones and S. Munro. August 4, 1989.
Locality: Shag Point, North Otago, South Island. Wavcut platform c. 150–200 m east of access-stairs (old plesiosaur site) and fork in road.
Lithostratigraphic Name: Katiki Formation.
Inferred Stages: Mp-Mh.

J43/6472
Collection Number: GS 592 (IGNS).
Collector and Date: A. McKay. 1886.
Locality: Shag Point, Otago Beach, at coal mine and rear of McIntosh's, Otago, South Island.
Lithostratigraphic Name: Katiki Formation.
Inferred Stage: Mh.

L35/74
Collection: Held at Department of Geology, University of Otago.
Collectors and Date: J. D. Campbell and B. R. Patterson. 1960s.
Locality: Selwyn Rapids, exact locality unknown, Malvern Hills, mid Canterbury, South Island.
Lithostratigraphic Name: Selwyn Rapids Beds (= Conway Formation?).
Inferred Stage: Mh.
L35/6008
Collection Number: GS 589 (IGNS).
Collector and Date: A. McKay. 1886.
Locality: Selwyn River, left bank below rapids, Malvern Hills, mid Canterbury, South Island.
Lithostratigraphic Name: Selwyn Rapids Beds (= Conway Formation?).
Inferred Stage: Mh.
L35/6017
Collection Number: GS 23 (IGNS).
Collector and Date: J. von Haast. 1872.
Locality: Selwyn River, Malvern Hills, mid Canterbury, South Island.
Lithostratigraphic Name: Selwyn Rapids Beds (= Conway Formation?).
Inferred Stage: Mh.
M34/7263
Collection Number: GS 761 (IGNS).
Collector and Date: A. McKay. 1891.
Locality: Middle Waipara, Ashley county, South Canterbury, South Island.
Lithostratigraphic Name: ?Conway Formation.
Inferred Stage: Mh.
M34/7658
Collection Number: GS 6165 (IGNS).
Collectors and Date: H. W. Wellman and B. W. Collins. February 1, 1954.
Locality: South Branch of Waipara River, west of Doctor’s Gorge, South Canterbury, South Island.
Lithostratigraphic Name: ?Conway Formation.
Inferred Stages: Mp-Mh.
O32/8025
Collection Number: GS 13 (IGNS).
Collector and Date: A. McKay. 1873.
Locality: Amuri Group, west wing of Amuri (= Haumuri) Bluff, Kaikoura County, South Marlborough, South Island, collected between 1873–1876.
Lithostratigraphic Name: Probably Okarahia Sandstone.
Inferred Stage: Mp.
O32/8790
Collection Number: GS 98276 (IGNS).
Locality: Okarahia Stream, south side, 0.5 miles from coast. Small cutting in landrover track from Claverley nearly at bottom of slope, South Marlborough, South Island.
Lithostratigraphic Name: Okarahia Sandstone.
Inferred Stage: Mp.
O32/9542
Collection Number: GS 10393 (IGNS).
Locality: Boulders on beach, Haumuri Bluff, southeast of Black Grit Reef.
Lithostratigraphic Name: Conway Formation.
Inferred Stage: Mh.
P05/9499
Collection Number: GS 1175 (IGNS).
Collector and Date: T. G. Fitzgerald. 1923.
Locality: Conglomerate in Waitangi River, 10 chains above junction with Waikuku Stream, Northland.
Lithostratigraphic Name: Unknown.
Inferred Stage: Mh.
Q09/19502
Collection Number: GS 4662 (IGNS).
Locality: Gittos Point, at end of Orauwharo Point, outcrop exposed between tides 115 chains at 320 from Trig B, Otameta, Northland.
Lithostratigraphic Name: Otamatea Beds.
Inferred Stages: Mp-Mh.
V18/B500
Collection Number: GS 8281 (IGNS).
Locality: Waiau River, approximately two miles upstream from Mangaenuihou River, North Island.
Grid reference from BP Oil Company Map.
Lithostratigraphic Name: Unknown.
Inferred Stages: Mp-Mh.
V19/I182A
Collection Number: GS 14407 (IGNS).
Locality: South bank of Mangahouanga Stream, approximately 100 m upstream of north-flowing tributary and c. 300 m downstream of prominent horse-shoe bend in Mangahouanga Stream, western Hawke’s Bay, North Island.
Lithostratigraphic Name: Maungataniwha Sandstone.
Inferred Stages: Mp-Mh.
V19/I184
Collection Number: GS 14269 (IGNS).
Locality: East bank of Te Hoe River, about 100 m downstream from true left tributary and about 1.8 km downstream from Mangahouanga Stream mouth.
Lithostratigraphic Name: Maungataniwha Sandstone.
Inferred Stage: Mh?
V19/I185
Collection Number: GS 14269 (IGNS).
Locality: East bank of Te Hoe River, about 1.3 km downstream of mouth of Mangahouanga Stream, western Hawke’s Bay, North Island.
Lithostratigraphic Name: Maungataniwha Sandstone.
Inferred Stages: Mp-Mh.
V19/I186
Collection Number: GS 14268 (IGNS).
Locality: West bank of Te Hoe River, c. 1.5 km downstream of Mangahouanga Stream.
Lithostratigraphic Name: Maungataniwha Sandstone
Inferred Stages: Mp-Mh.
V19/I195
Collection Number: GS 14385 (IGNS).
Locality: West bank of Te Hoe River, c. 1.5 km downstream of Mangahouanga Stream Mouth, and directly opposite mouth of west-flowing tributary (waterfall), western Hawke’s Bay, North Island.
Lithostratigraphic Name: Maungataniwha Sandstone.
Inferred Stages: Mp-Mh.

**V19/F6909**
Collection Number: GS 11359 (IGNS).
Collectors and Date: J. Wiffen and W. Moisley. March 12, 1973.
Locality: Stream boulders from bed of Mangahouanga Stream, tributary of Te Hoe River, western Hawke's Bay, North Island.

**W18/F26**
Collection Number: 14391 (IGNS).
Locality: Float in upper reaches of main branch of Waikokopu Stream (tributary of Waihoroihika Stream) upstream of mouth of south-flowing tributary south of Whakatakaa Hut. Grid reference ranges from 5787 7090 to 5720 7105.

**Protodolium pittensis** n. sp.: Pitt Island, Chatham Islands.

**CH/F466**
Collection Number: GS 12152 (IGNS).
Locality: Brown, tuffaceous sandstone in cliffs and shore platform from west side of Flowerpot Wharf to small bay 400 m further west, northern Pitt Island, Chatham Islands, New Zealand, Southwest Pacific.

Lithostratigraphic Name: Kahuitara Tuff.
Inferred Stage: Mh.