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THE CAINOZOIC GEOLOGY OF FLINDERS ISLAND, BASS STRAIT

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with

Appendix, 2 figures, 6 tables and 2 plates

ABSTRACT

Cainozoic sediments and volcanic rocks superficially overlie the mountainous Palaeozoic basement of Flinders Island and mainly form the coastal plains.

Marine deposits include Middle Pliocene to Recent near-shore and littoral coquinoid beds, and some Quaternary beds appear related to old marine stands at about 15-18 m., 4.5-6 m. and 0.6-1.5 m. above MHWS. Quaternary dune deposits are predominantly calcareous on the west coast and predominantly siliceous on the east coast, and show varying degrees of consolidation and soil development generally related to age. A Recent beach ridge and coastal barrier system is developed and lagoonal deposits include Pleistocene limestone and Recent peat. Non-marine gravel and grit deposits (including stanniferous and sub-basaltic deposits) were sometimes reworked by later marine incursions.

Scattered volcanic rocks include tuffs, alkali olivine-basalts and olivine-nephelinites, erupted from several centres roughly aligned along a north-westerly trend. The volcanism was largely Tertiary in age and some lavas are lateritised.

The Cainozoic history was initiated by faulting, tilting and uplifting of the Flinders Island block by early Tertiary time, with subsequent volcanism. During the Cainozoic, alternations of predominantly terrestrial or marine erosion and deposition on Flinders Island were related to fluctuating sea-levels, which influenced some faunal movements.

INTRODUCTION

This paper is based on observations made during visits to Flinders Island by the authors, supplemented by a study of aerial photographs, unpublished maps and reports, museum collections, and correspondence with a number of other workers. In particular, E. D. Gill and T. A. Darragh (National Museum of Victoria) assisted with radio-carbon and molluscan determinations and other matters, D. J. Taylor and A. C. Collins (Melbourne) identified foraminiferal faunas, and G. M. Dimmock (C.S.I.R.O.) supplied data and aerial photographs related to his soil mapping; other workers are mentioned in the text and acknowledgment section.

R. C. Kershaw visited the Island for 7 days in August 1957, when he collected from The Dutchman quarry and Nelson Lagoon drain and made geomorphological observations, particularly on the dune systems. F. L. Sutherland visited the Island for 3 days in April 1964, 5 days in April 1965 and 5 days in March 1970, when he sampled volcanic rocks, collected fossil material (from Holloways quarry, drains and waterholes on the Furneaux and Wingaroo Estates, and sites around Loccota and Lughrata), visited the Ranga cave, and made other general observations. The authors also examined material previously collected from Flinders Island and held in the Queen Victoria and Tasmanian Museums. Specimens collected by the authors are held in the Queen Victoria Museum, National Museum of Victoria and Tasmanian Museum, and thin sections of volcanic rocks are catalogued in the Tasmanian Museum. Specimen numbers refer to the Queen Victoria Museum collections, unless otherwise stated.

This paper deals with the Cainozoic geology of Flinders Island and some of the interpretations are based on geomorphological data to be presented more fully elsewhere (Kershaw and Sutherland, in press).

GENERAL

Flinders Island (lat. 40°S, long. 148°E, 65 Km. long, 40 Km. wide and 1,333 sq. Km. in area) is the largest island in the Furneaux Group, stretching across Bass Strait on the Bassian Rise connecting Victoria and Tasmania (Jennings, 1959a).

The Island is a mountainous basement ridge flanked by coastal plains. The western plain is mostly narrow, but carries important dune systems around Marshall Bay and Palana. The eastern plain is wider and more extensive, with a gentle slope marked by numerous dunes and lagoons and several residual basement hills. The steep mountain slopes ensure rapid run off and deep grit beds on the flanks are evidence of the erosive forces. However the dune systems have dammed the drainage to form extensive lagoons whose soils are an important agricultural asset. The dunes are generally stabilised and extensive modern blowouts are very

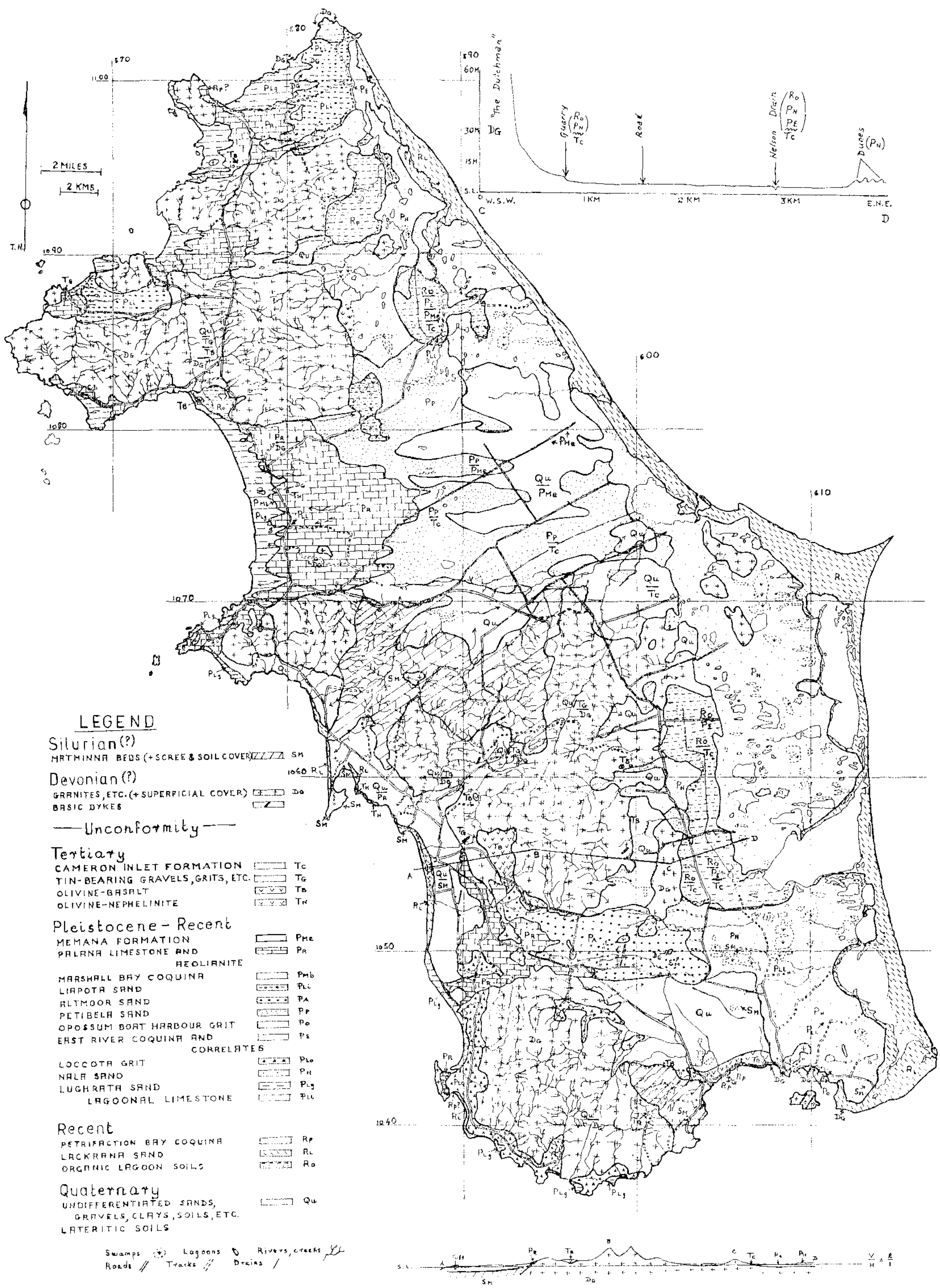

Fig. 1.—Generalised geology, Flinders Island. Modified from Dimmock (1957), based on unpublished Tasmanian Mines Department mapping by Blake (1947), Keid (1949), Everard (1950), and D. J. Jennings, field mapping by T. A. Darragh, D. M. Shanks and H. E. Wilkinson (National Museum of Victoria party, 1969), and mapping by F. L. Sutherland and R. C. Kershaw (1957-1970).

ocalised. Soils of the Island and their use are mapped ınd described by Dimmock (1957) and Pryor (1967), ınd limestone resources are discussed by Everard (in Hughes, 1957).

The geology of the Island consists of a Palaeozoic basement overlain with a superficial veneer of Cainozoic rocks (Figure 1). The basement consists of steeply folded quartzites and argillites, intruded by granite, associated with later basic doleritic dykes. The strata resemble Mathinna Beds of N.E. Tasmania (Siluro-Devonian, Spry ınd Banks, 1962). Carey (1953) postulated that these beds are folded along NNW-SSE trend, the Furneaux Anticlinorium, but most of the strikes observed on the sland by Blake (1947) and the authors were NNE-SSW o NE-SW in trend. Bores show that these beds extend ınder Cainozoic deposits around Whitemark (Hughes, 1959b). Granite forms most of the exposed basement, commonly in bold outcrops and sometimes including pegmatitic and aplitic phases (Flinders, 1814; Strzelecki, 1845; Gould, 1872; Johnston, 1879; Blake, 1935, 1947; Everard, 1950; Carey, 1953; Hughes, 1959a). It is regarded as an extension of the granite of N.E. Tasmania, ntruded after the Tabberabberan Orogeny (Spry and Banks, 1962) and dated as Late Devonian (370 m.y.; McDougall and Leggo, 1965).

Recent preliminary investigations of the granitic rocks suggests that there are at least nine petrological types (D. I. Groves, pers. comm.). The largest area is covered by porphyritic biotite (muscovite) granites and adamellites with smaller areas of non-porphyritic biotite muscovite granites and adamellites and a limited area of biotite hornblende granodiorites and biotite granodiorites. The distribution of granite types, and the outcrop and projected shape of the sedimentary sequence together with its internal structure, suggests an essentially NNE trending regional structure.

The associated basic dykes tend to follow this regional trend. Preliminary petrological examination (F.L.S.) suggests that the dykes are mainly near-saturated dolerite resembling similar dykes intruding the Palaeozoic basement on Cape Barren Island and in eastern Tasmania (analysis 71, Spry and Banks, 1962, p. 283). They are probably late Devonian or Carboniferous in age.

CAINOZOIC STRATIGRAPHY

The Cainozoic rocks include marine, littoral, estuarine, aeolian, alluvial and residual sediments, with volcanic flows and pyroclastics. They are generally undisturbed tectonically, and the probable succession is summarised in Table 1.

TERTIARY NON-MARINE BEDS

Gravels, grits, sands, clays and lignites up to at least 6 m. thick, including stanniferous deposits, rest on the Palaeozoic basement of the Island (Blake, 1935, 1947; Keid, 1949; Jack, 1966). The lower levels of these

TABLE I. PROBABLE STRATIGRAPHIC SUCCESSION, FLINDERS ISLAND.

UPPER HOLOCENE	LACKRANA SAND (modern barrier growth). Alluvium, lagoon, beach and dune bone deposits.
——?——?——	LUGHRATA SAND. PETRIFACTION BAY COQUINA (post-glacial maximum sea?)
LOWER HOLOCENE	NALA SAND (old barrier reorientation). Ranga cave bone deposits. Tektite shower (?)
——?——?——	Frontal dunes & old barrier ridges. LOCCOTA GRIT. Lagoonal limestones. Tasmanian Aboriginal migration?
UPPER PLEISTOCENE	EAST RIVER COQUINA and correlates (4.5 m. sea?; old barrier growth). ?
	MARSHALL BAY COQUINA (15 m. sea?) LIAPOTA SAND. ALTMOOR SAND. PETIBELA SAND.
——?——?——	Trousers Point aeolianite ('Helicidae Sandstone' of Johnston). OPOSSUM BOAT HARBOUR GRIT. ?
LOWER PLEISTOCENE	
——?——?——	PALANA LIMESTONE (older to younger dunes). MEMANA FORMATION (Werrikooian sea?). Stanniferous beds.
UPPER PLIOCENE	
——?——?——	CAMERON INLET FORMATION (post-Kalimnan-Maretimo sea?) ('Turritella limestone' of Johnston?).
LOWER PLIOCENE ?	
——?——?——	'Kalimnan & older marine beds' (off-shore)? Lateritic profiles?
MIOCENE TO LOWER	ALKALI OLIVINE-BASALTS. OLIVINE-NEPHELINITES. 'Miocene marine beds'?
TERTIARY	Sub-basaltic tuffs. Sub-basaltic & 'Lower - Mid-Tertiary' stanniferous beds.
——Unconformity——	
PALAEOZOIC	GRANITIC INTRUSIONS, with basic dykes (Devonian?).
BASEMENT	MATHINNA BEDS (Siluro-Devonian?).

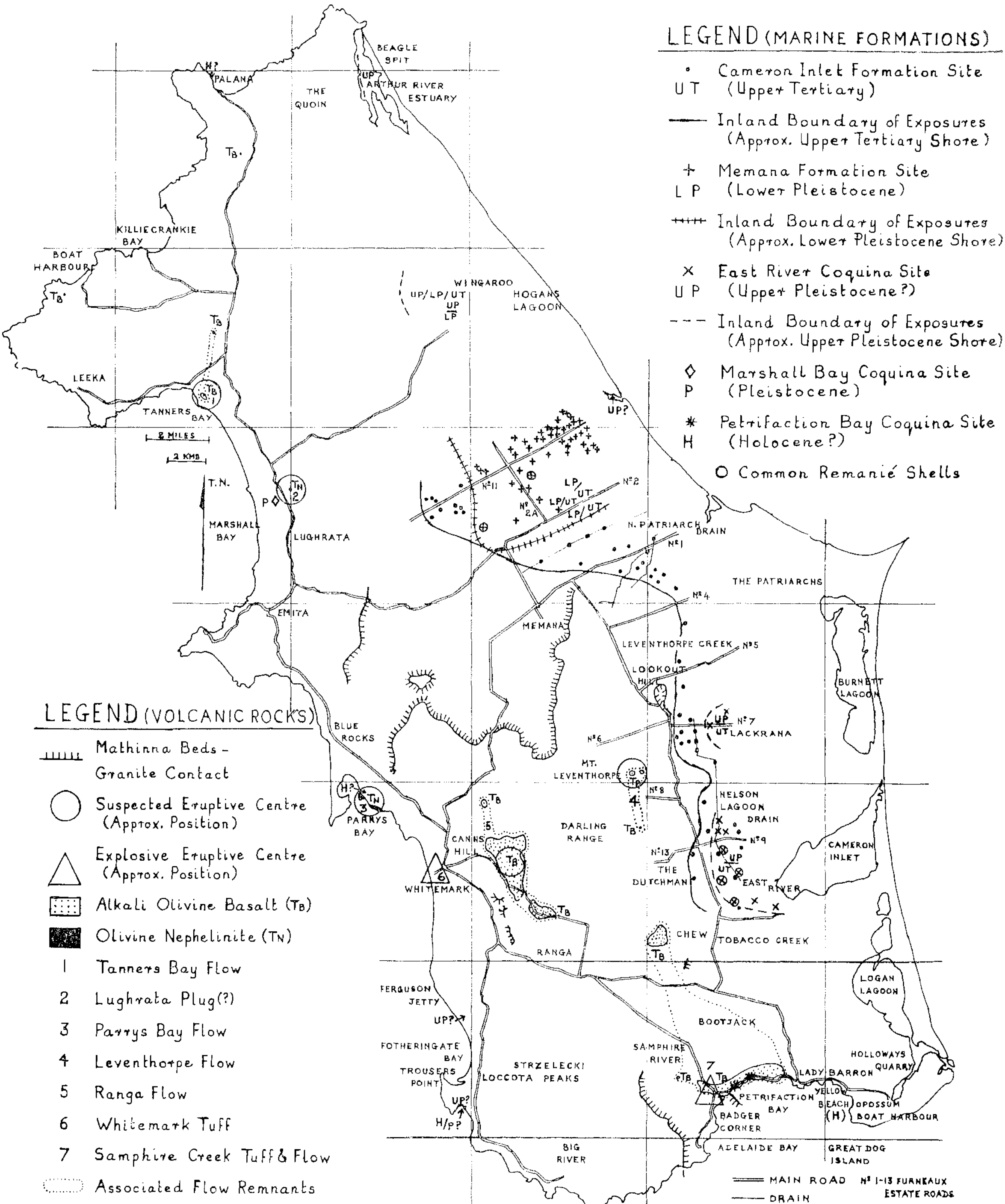

Fig. 2.—Distribution of Cainozoic volcanic features and marine formations on the Palaeozoic basement, Flinders Island. Based on field work by F. L. Sutherland, R. C. Kershaw, T. A. Darragh, D. M. Shanks and H. E. Wilkinson.

deposits may be well consolidated and probably represent Tertiary coastal drainage and pondage deposits. Similar sediments on Cape Barren Island are dated palynologically as Upper Oligocene/Lower Miocene, while post-basaltic material from 3.3 m. depth at Tanners Bay tinfield is tentatively dated as Pliocene-Pleistocene (Harris, 1965). Sub-basaltic stanniferous quartz boulder, grit and clay deposits are known at Canns Hill (Blake, loc. cit.). Some beds are pyritic and native sulphur is recorded from Tertiary sandstones on the Island (10.4%S; Tasm. Dept Mines, 1970).

TERTIARY VOLCANICS

Restricted outcrops of alkali olivine-basalts and olivine-nephelinites represent a number of small isolated eruptions. The thickest and highest exposure is 15 m. of lava N. of Ranga at 120 m. elevation, and the other exposures lie on the coastal plains. Outcrops show rough N.W. alignment with some cross trends, and some eruptions were explosive. The centres appear to be located mainly along Tertiary fault trends or near intrusive granite basement contacts (Figure 2).

Basaltic tuff containing numerous silicified logs was reported near Badger Corner (Johnston, 1879). This occurrence was not relocated, but small patches of weathered tuff (1966:34:14) were noted under basalt below high-tide level around Samphire River and 0.8 Km. E. These contain subrounded fragments of tachylytic basalt up to 0.8 mm. across and rare weathered peridotite (?) fragments. Silicified wood collected on the shore in this vicinity was one species referable to the Melaleuca (ident. A. Baker). Basaltic tuff was encountered in a bore at Whitemark Hotel, 4.5 m. below sea-level overlying limestone (Hughes, 1959b), and petrological examination (Appendix 1) suggests a possible hyaloclastite deposit.

Alkali Olivine-Basalts

(1) Adelaide Bay—Chew Tobacco Creek area.

The basalt is massive with cooling columns west along Adelaide Bay, but becomes strongly vesicular and amygdaloidal to the east and at Chew Tobacco Creek. Vesicles are coated with yellow or blue clay or sublimate and amygdales commonly contain carbonate, often forming botryoidal radiating masses weathering to limonite.

Petrologically (Appendix 1) the basalt resembles near saturated alkali olivine-basalts of Tasmania (Sutherland, 1969). It may have erupted from the explosive centre near Samphire River, probably flowing over a flat coastal plain extending to below present sea-level. It is overlain by undifferentiated Cainozoic sediments, Pleistocene Altmoor Sand and Recent Petrification Bay Coquina, and forms some lateritic soil W. of Samphire River. *See Addendum for further evidence of age.*

(2) Ranga—Whitemark area.

Massive basalt overlies a deep lead at Canns Hill here (Blake, 1935, 1947) apparently filling a N.W. trending valley. Outcrop pattern and basement topography suggest that this valley partly follows a N.W. fault line. A strong E-W lineation, probably a fault, crosses the southern part of the Darling Range and would intersect this line below the highest basalt, inferring location of the vent on such cross faulting.

Petrologically, the basalt is undersaturated alkali olivine-basalt, rich in glomeroporphyritic olivine and titan-augite and approaching a picritic type (Appendix 1; Analysis 1 Table 2). It is distinct from the Adelaide Bay flow, but its age relationships are obscure. It is overlain by Pleistocene Palana Limestone and Altmoor Sand and appears to be lateritised (Pliocene?) near Ranga.

TABLE 2. CHEMICAL ANALYSES & C.I.P.W. NORMS, FLINDERS ISLAND LAVAS.

ANALYSIS	1	2	NORM	1	2
SiO_2	43.16	41.85	Or	6.50	12.47
TiO_2	1.71	2.66	Ab	13.12	12.16
Al_2O_3	10.99	11.01	An	14.89	3.21
Fe_2O_3	4.13	4.90	Ne	5.00	14.46
FeO	8.67	8.75	Di	17.32	17.85
MnO	0.21	0.18	Ol	30.11	20.79
MgO	16.17	11.88	Mt	5.99	7.10
CaO	7.95	8.57	Il	3.25	5.05
Na_2O	2.64	4.59	Ap	1.02	6.01
K_2O	1.10	2.11	Ca	—	0.27
P_2O_5	0.43	2.75	Other	2.24	1.03
H_2O+	1.86	1.03			
H_2O-	0.38	—			
CO_2	—	0.12			
TOTAL	99.40	100.40		99.44	100.40

1. Alkali olivine-basalt (picritic phase). N. Ranga, Flinders Island; F. L. Sutherland, analyst.
2. Olivine-nephelinite (with peridotitic inclusions). N. Lughrata, Flinders Island; E. Kiss, analyst.

(3) Tanners Bay—Boat Harbour—Palana areas.
Small poor basalt exposures in north Flinders Island occur near Tanners Bay and in drill holes to the north 9 m. below late Tertiary-Pleistocene sediments (Jack, 1966; D. J. Jennings, pers. comm.), as pebbles brought to the surface by uprooted trees in dune limestone near Boat Harbour (coll. W. F. Ellis), and as float S.W. of Palana. The rocks are dense to amygdaloidal alkali olivine-basalt, sometimes carrying small peridotite xenoliths and accidental xenocrysts (Appendix 1). The question of separate extrusions or their source is uncertain from present exposures.

(4) E. Mt Leventhorpe area.
Small poorly exposed residuals of dense massive basalt here suggest localised extrusion of undersaturated alkali olivine-basalt (Appendix 1) onto the eastern coastal plain.

Olivine-Nephelinites

Outcrops of dense dark fine grained rock on Parrys Bay shore and float near Lughrata represent separate extrusions of olivine-nephelinites (Appendix 1; Analysis 2, Table 2). The Lughrata rock lies within granite basement, is found as pebbles in overlying Pleistocene Palana Limestone, and contains numerous small peridotitic xenoliths and xenocrysts in comparison to their relative rarity in the Parrys Bay rock.

Discussion

Ages of the Flinders Island volcanic rocks are not well established, but stratigraphic evidence suggests that most are pre-Pleistocene and probably Tertiary. They fall geographically between the Victorian and Tasmanian basalt provinces. They form an alkaline suite resembling the Older Volcanics of Victoria (Palaeocene-Lower Miocene; Singleton and Joyce, 1969) and the alkaline basalt associations of Tasmania (Eocene-Upper Cainozoic; Sutherland, 1969), both of which extend to opposite coasts of Bass Strait adjacent to Flinders Island.

The lavas range from strongly undersaturated alkaline rocks to mildly undersaturated basalt. Such rocks have been tentatively interpreted as products of segregation of parent alkali basalt magmas at depths of 35-75 Km. under Tasmania, with the nephelinitic associates representing products of more restricted and hydrous mantle melting at greater depths (see Sutherland, 1969). Preliminary electron microprobe analyses of the lherzolitic peridotite xenoliths in the rocks, indicate that they are inclusions of deep seated origin, possibly derived from the mantle (R. Varne, pers. comm., Appendix 1).

TERTIARY MARINE BEDS

These are exposed on the east coast and probably include 'Turritella' limestone at Heathy Valley (Johnston, 1879, 1887; Ludbrook, 1967). Johnston compared this fauna (see text, Table 3) with the Table Cape beds in N.W. Tasmania (Lower Longfordian; Quilty 1965), but considered that most species were different. It may represent the Cameron Inlet Formation of Middle-Upper Pliocene age (Darragh and Kendrick, 1970, and herein), or possibly remanié forms in the overlying Lower Pleistocene Memana Formation.

Bryozoal and cidaroidal marine limestones of Miocene age on Cape Barren Island (Crespin, 1945b) and Preservation Island (Tas. Mus. Colln. Y629; P. G. Quilty, pers. comm.) are unknown on Flinders Island, but may have been removed by erosion, or become covered. Derived foraminiferal faunas of probable Upper Miocene age in dune limestones at Ranga (described later) suggest the former presence of such marine beds around western Flinders Island. Fossil fish teeth, washed up on the east coast suggest Miocene-Pliocene marine beds off shore there. These include a right mandibular tooth of *Edaphodon sweeti* (1966:39:1; coll. H. O. Clifford, 1963; ident. T. Scott), recorded from basal Kalimnan in Victoria (Chapman and Pritchard, 1907), and a tooth of *Carcharodon megalodon* (1966:39:9; height 11.6 cm., breadth 9.8 cm.; coll. F. Henwood, 1914), recorded from Janjukian, Balcombian and Kalimnan (probably derived) in Victoria (Chapman and Pritchard, 1904).

Tertiary marine beds were apparently penetrated in Wingaroo No. 1 Bore, in shell beds between 3-24 m. depth, within alternating fine and coarse sands containing almost perfect shells (Nye, 1931). The fauna from 17-24 m. depth (Table 2) includes *Tylospira coronata, Turritella (Colpospira* sp.), *Miltha flindersiana* and *Placamen* cf *placida* (Singleton and Woods, 1934; Wilkins, 1962b; Gill, 1962; Ludbrook, 1967). Singleton and Woods considered that the faunas were very late Tertiary and the proportion of Recent species listed suggests correlation with the Cameron Inlet Formation, possibly passing up through Maretimo into Werrikooian and younger horizons above 17 m. depth. Comparison of species at different horizons in the bore (Tables 3 and 4) with the present day fauna, suggest a lagoonal shore to near-shore sandy to sandy mud shallow water facies down to 17 m. depth (Kershaw, 1958), in keeping with eastern Flinders Island today. Below 17 m. the fauna suggests a similar facies, but with reduction of exposure as found in semi-sheltered bays.

Cameron Inlet Formation (Darragh and Kendrick, 1970). This Pliocene formation was originally described by Wilkins (1962a) from The Dutchman lime quarry (grid 546N-028E, Dutchman Coquina) and from Nelson Lagoon Drain (grid 612N-040E, Cameron Inlet Marl). It is exposed in quarries, bores, drains and waterholes on the eastern coastal plain (Figure 2), lying below the Petibela, Nala, Wingaroo, Memama and Bootjack Soil Associations of Dimmock (1957), and may exceed 7.5 m. in thickness. It varies in lithology from sand, gravel, coquina to marl and the molluscan fauna (Table 3) includes *Tylospira (Singletonaria) gilli* (Marwick, 1960; Gill, 1962), *Miltha flindersiana* (Singleton and Woods, 1934; Wilkins, 1962b; Ludbrook, 1969), *Placamen* n. sp. (Gill, 1962) and *Eucrassatella deltoides* and *E. memanae* (Darragh, 1965).

The Dutchman quarry (now grassed over) exposed up to 1.2 m. of white friable limestone containing numerous thick shelled mollusca (Table 3; Plate 1, fig. 1) and extended down from 6.5 m. above MHWS. Wilkins (written comm., 1958) remarked 'I don't think anyone has yet noticed the horizon of phosphatic nodules at the lime quarry. Also associated Lovenia . . . and cidaroid spines. These I found around the deepest excavation . . . The nodules represent a disconformity of some sort and are comparable to the nodule beds in Victoria, though they look only faintly phosphatic'. A chemical analysis of the coquina gave 81% $CaCO_3$ and 0.12%

TABLE 3. PLIOCENE MOLLUSCA, CAMERON INLET FORMATION, FLINDERS ISLAND

Molluscan Identifications	Dutchman Quarry	Nelson Lagoon Drain	N. Patriarch -Memana Area	Wingaroo Bore N°-1 17-24 m.
GASTROPODA				
Alocospira aff. marginata (Lamarck)			x	
Amorena undulata (Lamarck)			x	
Bankivia cf. fasciata (Menke)	x			x
Cancellaria sp.				x
Cassis (Hypocassis) fimbriata (Quoy & Gaimard)			x	
Ctenocolpus australis (Lamarck)				x
C. terehellatas (Tate)			x	
Cupidoliva nymphala (Tate)	x			
Ericusa papillosa (Swainson)		x		
Eugyrina sp.				x
Floraconus anemone (Lamarck)				x
Fusus novae hollandiae (Reeve)				x
Gazameda gunni (Reeve)				x
Leiopyrga quadricingulata Tate			x	
Phasianotrochus sp.			x	
Phos. sp.			x	
P. senticosus (Linne)	x			
Polinices conicus (Lamarck)				x
P. aff. *cunninghamensis* (Harris)			x	
Sigapatella calyptraeformis (Lamarck)				x
Terebra sp.	x			
Turbo (Subninella) sp.	x			
Turritella (Colpospira) cf. *pagodula* Tate	x			
T. (Ctenocolpus) cf. conspicabilis Tate		x		
Tylospira coronata (Tate)	x	x	x	
T. (Singletonaria) gilli Marwick	x			
Umbilia hesitata Iredale			x	
PELECYPODA				
Bassina aff. *pachyphylla* (Jonas)			x	
B. cf. *paucirugata* (Tate)			x	
Cardium sp.				x
Chlamys cf. asperrimus (Lamarck)			x	
Cucullaea praelonga Singleton	x	x*	x	
Divalucina cumingi (Adams & Angas)			x	x
Donacilla erycinaea (Lamarck)				x
Dosinia sp.				x
Eucrassatella deltoides Darragh	x	x*		
E. memanae Darragh			x	
Eumarcia sp.		x		

Table 3. Pliocene Mollusca, Cameron Inlet Formation, Flinders Island (continued)

Molluscan Identifications	Dutchman Quarry	Nelson Lagoon Drain	N. Patriarch -Memana Area	Wingaroo Bore N°-1 17-24 m.
E. cf. fumigata (Sowerby)				x
Gari aff. *kenyoniana* (Pritchard & Gatcliff)			x	
Glycymeris convexa (Tate)	x	x*	x	x
G. halli Pritchard	x		x	x
Homalina cf. *mariae* (Tenison Woods, 1875)			x	
Katelysia rhytiphora (Lamy)				x
K. peronii Lamarck				x
Miltha flindersiana (Singleton & Woods)	x	x		x
Neotrigonia cf. *margaritacea* (Lamarck)			x	
Notocallista cf. *kingi* Gray	x			
Ostrea sp.		x		x
O. cf. *angasi* Sowerby			x	
O. arenicola (Tate)	x			
O. aff. *manubriata* (Tate)	x			
Phacosoma cf. *coerulea* (Reeve)			x	
Placamen sp.	x			
Placamen cf. *placida* (Philippi)	x		x	x
Proxichione moondarae Darragh			x	
Scaeoleda crassa (Hinds)				x
Tawera sp.	x			
Tucetilla radians (Lamarck)				x

Identifications by T. A. Darragh, E. D. Gill and R. W. T. Wilkins, with Wingaroo Bore No. 1 mollusca modified from Everard (1950), and some species listed from Darragh (1965), Dorman (1966) and Darragh and Kendrick (1970). Asterisks beside Nelson Lagoon Drain material indicates shells found both in the basal marl and overlying beds, including remanié forms in the Pleistocene East River Coquina; lack of asterisk indicates shells only from the basal marl. Material includes Tasm. Mus. Colln., Z 1371-1373, 1448-1475. R. M. Johnston (1879, 1887) lists the following amended species from the Tertiary beds of Flinders Island, but their exact status is uncertain; *Cucullaea (Cucullea) corioensis, Glycymeris (Cucullea) cainozoica, Nucula tumida, Turritella* sp., *Roxania (Cylichina) woodsi* and *Diplodonta subquadrata.*

P_2O_5(Everard, in Hughes, 1957). Matrix from the top of the coquina contained *Glandulina kalimnensis* Parr (common), *Rotalina hamiltonensis* Parr, *Nonion victoriensis* Cushman, *Massilina lapidigera* (Howchin and Parr) and an assemblage of large miliolids, polymorphines and rotalids, with many small lagenids, suggesting shallow water but open sea conditions (A. C. Collins, per E. D. Gill, pers. comm.). Broken and separated bivalves in the upper part of the coquina suggest possible reworking of a shallow water, near-shore deposit. Lateral equivalents to this reworked top of the coquina are apparently exposed in waterholes 0.8 Km. N. and up to 2 Km. E. to S.E. Here, the matrix varies from a gravelly quartz grit or sand, mixed with about 20% calcareous detritus, to predominantly calcareous detritus with rounded to angular quartz grains up to 5 mm. across; it sometimes forms hard calcrete.

The type exposure in the extreme N. end of Nelson Lagoon Drain was a 0.6 m. thickness of green glauconitic shelly marl, stratified as follows (R. W. T. Wilkins, written comm.):

a) 15 cm. *Cucullaea* horizon.

b) 23 cm. *Eumarcia* horizon.

c) 23 cm. *Cucullaea* horizon, with mixed 'rolled' and 'unrolled' shells, to water level; the top of the horizon was apparently eroded and bored and may have been exposed as old beach rocks. The position of this horizon has been studied further south in the Drain Section, 0.8 Km. N. of East River (grid 550N-050E), where the succession (Plate 1, fig. 2) is:

a) 0.4 m. lagoon soils with freshwater shells on the ırface.

b) 1.4 m. sandy subsoil with grit (Nala Sand and 'possum Boat Harbour Grit?).

c) 0.3 m. shell bed with numerous Quaternary shells ıd remanié species from underlying beds (East River oquina).

d) 15 cm. shelly sandy bed.

e) 30 cm. sandy bed.

f) 7.5 cm. green glauconitic marl, containing eroded ivalves, and excavated to water level. These beds nderlying the East River Coquina are considered to present the Cameron Inlet Formation and they extend own from about 2 m. above MHWS. The glauconitic ıarl (unit f) contains a similar molluscan fauna (Table to The Dutchman coquina and may be a lateral, but eeper water facies. The upper members (units d and e) onsist of friable, greenish grey, calcareous, silty sand, ith sparse generally complete shells in unit (e) and umerous randomly orientated shells, predominantly *ucullaea*, in unit (d). The disconformable base of the verlying East River Coquina contains forams of alimnan affinities, considered to be derived from the nderlying sands, as described later.

Similar shell beds, mostly fine silty coquinoid lime-ones and sands, are exposed in excavations northwards om the type area of the Formation from Lackrana rough Memana to the North Patriarch area, where ey are disconformably overlain by the Lower Pleis-ocene Memana Formation. They may be buried under ırface sands and soils up to over 2 m. deep, sometimes ith organic or calcareous pans, and extend down from out 2-4 m. above MHWS. The western deposits inland om the North Patriarch area are largely friable co-uinoid gravels and grits, with much fragmentary shell etritus, and commonly contain worn shells. The grit ontent tends to increase to a maximum in the western-ost exposures, where the deposits appear to represent ear-shore to littoral facies. The molluscan fauna (Table includes a predominance of oyster shells in places, ıd matrix material from the type locality of *Eucrassa-lla memanae* (Darragh, 1965) showed a foraminiferal ıuna with high ratio of planktonics to benthonics, ıggesting an inner shelf deposit (D. J. Taylor, pers. omm.). Skeletal fragments of whales, mainly vertebrae, ave been recovered from excavated debris from drains round Memana. They include a skull (coll. H. O. lifford and A. Dart, 1963; Nat. Mus. Vict., Colln. 23961-2), belonging to the genus *Ziphius* (Plate 2), but ffering from any living species (J. Moore, per J. W. 'arren, pers. comm.). Rare coral includes *Plesiastraea ıanas* (Ellis & Solander) and *P. cf. versipora* (Lamarck), ent. M. R. Banks, from excavations passing into liocene beds at Lackrana and near North Patriarch rain, but the exact stratigraphic location is uncertain.

The eastward swing in distribution of the Cameron ılet Formation between Memana and Lookout Hill igure 2), is influenced by the alluvial deposits of eventhorpe Creek. Drain and dam excavations (to .5 m.) and bores (to 27 m. deep) in this area do not ıcounter the shell beds penetrated just to the east. /hether this is due to the existence of the alluvial ın as an original land barrier during the marine eposition or whether it results from later Pleistocene erosion of the marine beds is uncertain on present exposures. The small inswing in the Formation's distribution E. of Mt Leventhorpe, and its apparent absence on the southern coastal plain may correlate with basalt flows in these areas tending to act as barriers to the marine incursion.

The palaeontological evidence suggests that the Cameron Inlet Formation is Middle to Upper Pliocene in age (Darragh, 1970 and herein). Wilkins (1962a) assigned a probable post-Kalimnan, pre-Maretimo age to the molluscan fauna from The Dutchman and the lowest Nelson Lagoon Drain horizon, and stated 'The faunas . . . have a very strong Kalimnan aspect, but when the Pliocene species is ancestral to a modern one, the Flinders Island form is intermediate between the Kalimnan and living form, e.g. *Bankivia, Bassina*.' Some of the reworked upper parts and upper members of the Formation, however, may represent later deposits of the withdrawing Pliocene sea and may extend into the Maretimo in age. Palaeotemperature oxygen isotope measurements on *Ostrea* shells from The Dutchman quarry (Dorman, 1966), gave values up to 16.5°C and indicated a moderately warm Pliocene sea intermediate in temperatures between the tropical mid-Tertiary and cool Quaternary seas of Bass Strait.

CAINOZOIC LATERITES

Lateritic soils were mapped in several widely scattered localities on the Island (Dimmock, 1957) and also occur on basalt N.W. of Ranga (grid 536N-928E) and 3 Km. N.W. of Badger Corner. These consist mainly of siliceous sandy and gritty pisolitic ferricrete, and a ferruginised sandstone containing impressions of probable Pliocene marine shells was observed just west of soil site H101 of Dimmock (R. W. T. Wilkins, pers. comm.). Most of these occurrences appear to represent weak or semi-lateritisation, typical of conditions in Victoria during the later Pliocene and/or possibly in Pleistocene Interglacials (Gill, 1964). True lateritisation with development of pallid lower profiles may be present on the basalt at Ranga where Dimmock (1957) notes a clay underlying ferruginous material. Such profiles have been ascribed to at least the Lower Pliocene in Victoria (Gill, 1964).

QUATERNARY MARINE AND LITTORAL BEDS

Coquinoid deposits related to Quaternary seas occur on Flinders Island coasts to elevations of about 15 m., but generally less than 5 m., above MHWS. Well worn grit beds also occur and probably represent reworked littoral deposits.

Memana Formation

This Formation appears in the North Patriarch area (Figure 2, Plate 1, fig. 3) outcropping through, and encountered in excavations in soils of the Memana Association (Dimmock, 1957). It lies up to 5-7 m. above MHWS and is at least 4.5 m. thick. The following general succession was established at the E. end of No. 11 Road from excavation debris and communication with the property owners.

a) surface gravelly or loamy sand, up to 0.6 m. thick.

b) clay horizon, 5-30 cm. thick.

c) hard coquinoid calcrete or calcareous bands and nodules, 15-45 cm. thick.

d) gravelly and gritty shelly sands and sandstone, up to 1.5 m. thick.

TABLE 4. QUATERNARY MOLLUSCA, MARINE BEDS, FLINDERS ISLAND. (LOWER PLEISTOCENE-RECENT).

Molluscan Identifications	Memana Formation	Marshall Bay Coquina	East River Coquina	Coquina, Arthur River Estuary	'Oyster Bed' Johnston, 1879	Wingaroo 0—4.5	Coquina, South of Trousers Pt (lagoon)	Petrifaction Bay Coquina	Coquina, South of Trousers Pt (dune)	Coquina, Yellow Beach
GASTROPODA										
Acmea scalarina Cox		x	x*			x		x		
Amblychilepas crucis (Beddome)						x				
Amorena undulata (Lamarck)	x									x
Assiminea tasmanica Tenison Woods		x								
Astele subcarinatum Swainson	x					x				
Austrocochlea sp.					x					
A. adelaidae (Philippi)					x			x		x
A. concamerata (Wood)								x	x	x
A. constricta (Lamarck)		x						x		x
Austrodrillia beraudiana (Crosse)			x							
Austroginella muscaria (Lamarck)			x*			x				
Bankivia fasciata (Menke)	x		x*			x				
Battilariella estuarina (Tate)				x						
Bedeva paivae (Crosse)	x		x*		x			x		
Bembicium auratum (Lamarck)								x		x
B. nanum (Quoy & Gaimard)									x	
Bullaria botanica (Hedley)				x						x
Cacozeliana granaria (Kiener)			x*	x			x			
Capulus violaceus Angas								x		
Chemnitzia mariae Tenison Woods			x							
Chiazacmea flammea (Quoy & Gaimard)								x		
Cingulina spina (Crosse & Fisher)			x							
Clanculus plebejus Philippi					x					
Cominella eburnea (Reeve)	x									
Cominella sp.				x						
Conicella porcellana (Tate & May)		x*								
Coxiella sp. N.M.				x						
Ctenocolpus australis (Lamarck)	x					x				
Cylichnina sp.					x					
C. iredaleana (Hedley)			x					x		

Cymatiella verrucosa (Reeve)						x				
Dentimitrella sp.			x*							
D. lincolnensis (Reeve)			x*							
D. menkeana (Reeve)										x
D. tayloriana (Reeve)			x*							
Diala lauta Adams			x	x	x					
D. pagodula Adams			x*							
Eubittium lawleyanum (Crosse)				x						x
Floraconus anemone (Lamarck)			x*							
Herpetopoma sp.			x							
Hypotrochus monachus (Crosse & Fischer)			x*							
Isoclanculus dunkeri			x*	x	x					
Kimberia sp.					x					
Lenamaria cf. *nitida* (Sowerby) N.M.			x*							
Macrazafra atkinsoni (Tenison Woods)			x							
Mesoclanclus ochroleucus (Philippi)								x		
Micrastraea aurea (Jonas)										x
Microcolus dunkeri (Jonas)										x
Munditia australis (Kiener)										x
Nassarius sp.						x[1]				
Nevia spirata (Lamarck)	x									
Niotha pyrrhus (Menke)	x		x*	x				x		x
Notocochlis sp.	x									
Notosetia sp.					x					
N. nitens (Frauenfeld)								x		
Ophicardelus sulcatus (H. & A. Adams)		x								
Parcanassa pauperata (Lamarck)						x		x		x
Pervicacia ustulata (Deshayes)	x									
Phasianella australis (Gmelin)										x
Phasianotrochus irisodontes (Quoy & Gaimard)								x	x	
Pleuroploca australasia (Perry)				x						
Plicaginella sp.	x					x				
Polinices conicus (Lamarck)										x
Proxiuber sp.	x									
Pseudamycla dermestoidea Lamarck			x*			x[1]				

TABLE 4. QUATERNARY MOLLUSCA, MARINE BEDS, FLINDERS ISLAND (LOWER PLEISTOCENE-RECENT—continued)

Molluscan Identifications	Memana Formation	Marshall Bay Coquina	East River Coquina	Coquina, Arthur River Estuary	'Oyster Bed' Johnston, 1879	Wingaroo 0.-45 m.	Coquina, South of Trousers Pt (lagoon)	Petrifaction Bay Coquina	Coquina, South of Trousers Pt (dune)	Coquina, Yellow Beach
Pyrazus sp.?						x[1]				
P. ebeninus (Bruguière)										N.S.
Salinator fragilis (Lamarck)									x	
Sigapatella calyptraeformis (Lamarck)	x					x[2]				
Sydaphera purpuraeformis (Kuster)	x									
Tavaniotha munieriana (Crosse)								x		
Turritella sp.?					x					
Zeacumantus cerithium (Quay & Gaimard)				x						
Z. diemenensis (Quoy & Gaimard)		x		x				x		x
PELECYPODA										
Anadara trapezia (Deshayes)										N.S.
Anapella cycladea (Lamarck)							x		x	
Bellucina crassilirata (Tate)			x*							
Chlamys asperrimus (Lamarck)	x		x			x[2]				
Codakia sp.						x[2]				
Cuspidaria sp.						x[2]				
Divalucina cumingi (Adams & Angas)	x									
Donacilla angusta Reeve						x				
D. cuneata (Lamarck)		x						x	x	
Electromactra antecedans Iredale		x								
Equichlamys bifrons (Lamarck)	x		x*							x
Eumarcia fumigata ? (Sowerby)						x[1]				
Fulvia tenuicostata (Lamarck)	x		x*	x		x	x			
Glycymeris sp.						x[2]				
G. flammeus (Reeve)	x									
Homalina deltoidalis (Lamarck)		x		x						
H. mariae (Tenison Woods)				x						
Hormomya erosa (Lamarck)		x		x			x	x		x
Katelysia peronii (Lamarck)		x		x				x		
K. rhytiphora (Lamy)			x*	x		x[2]	x			x
K. scalarina Lamarck										x

Kellia australis (Lamarck)		x							
Laternula creccina (Reeve)				x					
Limnopsis sp.						x			
Lutraria rhynchaena? Jonas	x								
Mactra pura Deshayes	x								
M. rufescens Lamarck						x			
Modiolus pulex (Lamarck)							x		
Myadora brevis (Sowerby)	x								
Mysella sp.				x					
Mytilus planulatus (Lamarck)	x								
Neotrigonia margaritacea (Lamarck)	x								
Notocallista disrupta (Sowerby)	x								
Notospisula trigonella (Lamarck)		x	x				x	x	
Ostrea sp.					x				
O. angasi Sowerby			x*	x		x[2]			
Phacosoma coerulea (Reeve)	x								
Placamen placida (Philippi)	x								
Pseudarcophagia victoriae (Gatcliff & Gabriel)		x		x					x
Scaeoleda crassa (Hinds)						x[2]			
Solen vaginoides (Lamarck)	x								
Soletellina biradiata (Wood)				x					
Tawera gallinula (Lamarck)						x[2]			
T. lagopus (Lamarck)	x					x			
T. striatularis (Reeve)	x					x			
Zemyria cf. *globosa* (Adams)				x					
Zenatiopsis ultima Darragh & Kendrick	x								

Identifications by R. W. T. Wilkins, R. C. Kershaw, E. H. Turner and T. A. Darragh, with listing from Nye (1931) and Darragh and Kendrick (1970). Material listed under 'Oyster Bed', Johnston, 1879, was identified by R. C. Kershaw from Johnston's Arthur River Estuary Collection (some labelled Oyster Bed), held in the Tasmanian Museum (amongst Z861-Z917). N.M. against molluscan species indicates a non-marine dweller. Asterisked species from the East River Coquina indicate shells found in the type section in Nelson Lagoon Drain. Species numbered 1 and 2 amongst the Wingaroo mollusca indicate shells found in the 0-3 m. and 3-4.5 m. depths respectively in the Wingaroo Bore (Nye, 1931). N.S. indicates shells found not *in situ*. Material includes Tasm. Mus. Coll. Z1476-1539. R. M. Johnston (1879) lists the following species (amended) exposed from the inland sand dunes and lagoons of Flinders Island, but their exact status is uncertain; *Bankivia fasciata (varians), Philine angasi? (aperta), Neotrigonia (Trigonia) margaritacea Tucetilla (Pectunculus) striatularis? (rubens), T. (P.) radians? (roseus), Salinator (Ampullarina) fragilis, Anadara (Arca) trapezia, Scaeoleda (Leda) crassa, Fulvia (Cardium) tenuicostata (tenuicostatum), Glycymeris (Cucullea) cainozoica (remanié?), Glycymeris (Pectunculus laticostatus (remanié?), Cucullaea (Cucullea) corioensis (remanié)*. Examples of the modern molluscan fauna of the Furneaux Group are listed in Johnston (1879), May (1958), Turner (1970) and the Tasmanian Museum Molluscan Register.

TABLE 5. FORAMINIFERA, QUATERNARY DEPOSITS, FLINDERS ISLAND

Formaniferal Identifications	Palana Limestone	East River Coquina	Marshall Bay Coquina, Coquina, S. of Trousers Point (dune foot)
Ammonia beccarii (Linne)	x	x	
Anomalina sp.	x		
Cibicides mediocris (?) Finlay	xR		
C. reflugens (Montfort)	x		
C. victoriensis (?) Cushman	xR		
Clavulina multicamerata Chapman	x		x
Discorbinella biconcava (Jones & Parker)	x		x
Discorbis dimidata (Jones & Parker)	x		x?
Elphidium advenum (Cushman)	x		
E. argenteum Parr	x	x	x
E. crassatum Cushman	xR		
E. crispum (Linne)	x		
E. macellum Fichtel & Moll	x	x	x
cf. Epistominella pulchra (Cushman)	x		
Globigerina bulloides d'Orbigny	x		
Globigerinoides conglobulata (Brady)		xR	
Guttulina yabei Cushman & Ozawa	x		
Miliolinella oblonga (Montagu)	x		
Nonion victoriense Cushman		xR	
Operculina victoriense Chapman & Parr	xR		
Parrellina imperatrix (Brady)	x		
Patellinella inconspicua (Brady)	x		
Polystomellina clathrate (Brady)	x		
Quinqueloculina lamarkiana d'Orbigny	x		
Rectobolivina sp.	x		
Rosalina australis (Parr)	x		x
Spiroloculina angulata Cushman	x		x
S. subimpressa Parr	x		x
Streblus beccarrii d'Orbigny	x		
Textularia sp.	x		
T. pseudogramen Chapman & Parr	x		x
Triloculina striatula Parr	x	x	x
T. trigonula Lamarck	x		

Identifications by Crespin (1945a), Ludbrook (1965) and D. J. Taylor. R. indicates probable remanié species.

e) shelly silts, soft sands and limestone, 1.5-3 m. thick.
f) hard gravelly and gritty coquinoid limestone, at 4.2-4.5 m. depth.

The basal coquinoid horizon (unit f) contains numerous worn shells, including remanié Pliocene species, associated with well preserved *Bankivia fasciata* and appears to represent a near-shore or littoral deposit. It is found at shallower depths to the south and eventually the horizon gives way laterally to the underlying Cameron Inlet Formation.

The shelly soft beds (unit e) are well exposed around No. 2A Road, between Nos 11 and 2 Roads. The molluscan fauna here (Table 4) is essentially modern, but includes rare *Zenatiopsis ultima* (Darragh and Kendrick, 1970) and some remanié Pliocene shells, and suggests a probable Lower Pleistocene (Werrikooian) age. The fauna suggests shallow off-shore bay conditions, and some *Chlamys asperrimus* shells bore growths of barnacles (cf. *Balanus variegatus,* ident. E. C. Pope).

The upper members (units d and c) contain strongly worn shells and in some places resemble littoral deposits. The succession to the N.E. thus appears to encompass deposits of transgression and following regression of the Lower Pleistocene sea into a large bay. However, the role of possible later Pleistocene transgressions (represented by deposits elsewhere on the Island) in this area is uncertain, and they may have reworked part of the upper succession. The northerly extent of the Formation is not precisely known, but it extends into the Wingaroo area amongst the shell horizons overlying the Tertiary beds at the 17 m. depth in the Wingaroo bore (Nye, 1931; T. A. Darragh, pers. comm.).

Marshall Bay Coquina

This coquinoid siliceous calcarenite is poorly exposed E. of Palana Road, N. of Lughrata (grid 760N-793E) at about 15 m. above MHWS, disconformably overlain by Lughrata Sand and apparently disconformably overlying Palana Limestone. Traces of similar shelly rock have been noted elsewhere around Lughrata (D. I. Groves, pers. comm.).

It contains up to 25% worn and broken mollusc shells, and the molluscan fauna (Table 4) suggests a beach deposit with sheltered sandy bay environment common *Hormomya erosa, Katelysia peronii),* with sand flats *(Donacilla, Notospisula)* and shallow water off-shore with sandy bottom *(Electromacta, Pseudarcophagia).* The matrix is greyish fawn, tough, compact calcrete, weathering white. It contains shell fragments, worn foraminifera and about 30% angular to rounded quartz grit in abundant calcareous cement. The foraminiferal fauna (Table 5) was reported as ' . . . similar to that living on the sea floor in Bass Strait today . . . The worn nature of the specimens suggests it is a 'displaced' fauna, but the specific content does not indicate that it is derived from Tertiary sediments' (D. J. Taylor, pers. comm.).

The rock probably represents a littoral deposit associated with a 15-18 m. level (MHWS). The fauna, degree of lithification and elevation suggest a Pleistocene Interglacial age, probably not younger than early Riss/Würm.

East River Coquina

This coquinoid sandy silt, 30-38 cm. thick, is exposed in Nelson Lagoon drain (grid 550N-050E), N. of East River between 2-3.5 m. above MHWS. It disconformably overlies the Cameron Inlet Formation and is disconformably overlain by at least 1.7 m. of sands and lagoonal soils, including Nala Sand and Opossum Boat Harbour Grit (?), (Plate 1, fig. 2).

The fauna contains numerous Quaternary shells (Table 4) and remanié species from the underlying bed (Table 3) mainly in a mixed transitional zone to 8 cm. thick. Numerous marine bivalves, sometimes packed tightly, include generally complete oysters apparently *in situ.* The formation top is well defined, but with slight reduction in shell numbers, and no marine shells occur in the overlying deposits. The fauna represents a mixed assemblage, apparently an accumulation on a bay floor, and includes species normally living on sea-weeds *(Bankivia),* near-shore or inter-tidal species *(Katelysia, Cacozelliana)* and off-shore species *(Fulvia, Equichlamys).* In most cases a sandy mud or sandy environment is indicated, but with some nearby rocks as suggested by presence of algal dwellers and *Floroconus anemone.*

The matrix is sandy silt largely composed of quartz, both clear angular and rounded frosted grains, and shell fragments, The foraminiferal fauna of a basal sample included *Nonion victoriense, Globigerinoides conglobata* and several other Kalimnan species (D. J. Taylor, pers. comm.). However, in view of remanié molluscan fauna, these are probably remanié forams from underlying Pliocene horizons.

Other sites with numerous remanié mollusca (including *E. deltoides,* Darragh, 1965) occur in water hole excavations E. of The Dutchman between Memana road and Nelson Lagoon drain, and these excavations include shark's teeth and whale vertebrae (1966:39:7; coll. F. Rhodes). Matrix from the top of such coquina contained a sparse extant foraminiferal assemblage (Table 5, D. J. Taylor, pers. comm.). The Formation extends S. of East River and N. to Lackrana (Figure 2).

The Coquina may be an off-shore Pleistocene marine deposit, probably related to the 4.5 m. level (MHWS), correlated with the later Riss/Würm Interglacial. Precise dating awaits more detailed investigation. Erosion of underlying beds by such a sea is indicated by the remanié fauna, and similar erosion occurs off-shore at present as *Cucullaea* valves commonly wash ashore. However, the presently exposed disposition of the Formation is also compatible with possible marine flooding of an elongate coastal inlet through Cameron Inlet. Probable equivalent or near-equivalent deposits to the East River Coquina include coquinas near Loccota, Arthur River and Wingaroo.

The Loccota deposits include an exposure in an old lagoon bank, S. of Trousers Point (grid 419N-894E) with a fauna (Table 4) rich in *Fulvia tenuicostata* (1965:38:76) in a friable darkish sandy silt matrix. The deposit is up to 1.5 m. above MHWS and is interpreted as an off-shore facies *in situ* on a shallow sandy mud floor of a former Pleistocene Interglacial or Interstadial sea bay. A further coquina at similar elevation, in a drain S. of Ferguson Jetty (grid 472N-896E), contains common *Anapella cyclyadea,* suggesting deposition on sandy mud flats in sheltered to estuarine waters. The matrix here is now tough, light coloured sandy calcrete containing about 30% predominantly angular quartz grains with foraminiferal and other organic remains.

A coquina, 0.8 m. thick, is exposed in a cliff on the west shore of Arthur River estuary opposite Beagle Spit (grid 998N-838E) at 3-4 m. above MHWS. It disconformably overlies Pleistocene sand (Liapota Sand?) and is disconformably overlain by unconsolidated sand. The coquina may be related to the 'Oyster Bed' of Johnston (1879), which shows similarities in molluscan fauna (Table 4), but which was reported at a slightly higher elevation. A thick, tightly packed oyster bed was exposed in the estuary's west bank over twenty years ago, but has since largely washed away (J. Robinson, pers comm.) and this spot almost 0.7 Km. N. of the described section probably represents Johnston's site. The succession exposing the coquina is:

a) Cliff top, 5.4 m. above MHWS with shallow depression of former lagoon.

b) blackish sandy soil with limestone pieces from (c)—30 cm.

c) limestone without shells—av. 15 cm.

d) fine compact unlithified sand—1.1 m.

e) white gritty sand, densely packed with shells—15 cm.

f) white sand with reduced grit content, few shells including *Laternula* in life posture—35 cm.

g) white sand, shells densely packed—35 cm.

h) yellow and red-brown sands, lower levels covered with detritus.

The beds are exposed 50 m. horizontally and at one point horizon (d) lenses out and more than 30 cm. of limestone (c) rest on the upper shell bed of the coquina (e-g). Beds are level, but end abruptly against grey sand (Liapota Sand?). At the southern extremity this sand is sharply contrasting and contains carbonaceous and compacted grit bands 2-5 cm. thick. At the northern extremity the sand is firstly grey, then yellow and grey. Some mixing of materials is inferred across the near-vertical extremities, but with little disturbance, and it seems to represent a former stream site.

The molluscan fauna (Table 4) is appropriate to sheltered waters such as an estuary or sheltered bay. It includes species preferring mud *(Ostrea, Zeacumantus)*, sandy mud *(Laternula, Homalina, Katelysia peronii, Bullaria)*, sand *(Soletellina, Katelysia rhytiphora)* to brackish mud *(Batillariella)*. *Hormomya* lives in compacted sandy mud and grit with weeds as exists at present in Arthur River estuary, and *Fulvia tenuicostata* is an off-shore sandy bottom species. Thus, the assemblage suggests variable conditions with some species washed in, and *Niotha* and *Bedeva* preying on the fauna. *Coxiella*, an euryhaline mollusc, indicates a marked change in conditions.

Sand from horizon (e) shows (A. C. Collins, per E. D. Gill, pers. comm.): 'The floatings are almost entirely *Streblus* sp. the same form as that from Lake Pertrobe. I think, with a few rare and poorly developed *Elphidium* and a lot of coxiellid gastropods. This of course amounts to brackish water conditions, estuarine or lagoonal. I found nothing that could be taken as a purely marine form, suggesting there was little or no influx of tidal waters. The sand grains are well rounded and frosted, there were a few plates of mica, and some vegetable debris'.

Thus, the presence of *Coxiella* and brackish water micro-fauna requires interpretation and it is considered that a brackish lagoon temporarily established on the upper shell bed of a marine transgression. This transgression probably relates to the 4.5 m. level (MHWS), correlated with a later Riss/Würm Interglacial sea. Shell beds, met at depths below 6.5-7 m. above MHWS under the lagoonal soils around Wingaroo (Figure 2; Table 4; Nye, 1931) probably represent further related deposits of this sea.

Petrifaction Bay Coquina

This coquina, 5-8 cm. thick, is exposed on Petrifaction Bay shore slightly above MHWS, disconformably overlying basalt (Plate 1, fig. 6). The coquina contains about 60% shell material in loose matrix of coarse rounded to angular quartz grit, with fine silty micaceous and calcareous detritus (1966:35:6).

The shelly fauna (Table 4) is that of a sheltered bay with sandy mud or mud, grits and stones, and is the same as in the similar present local environment. The Coquina appears to be a shore-line or near-shore deposit related to a former sea-level about 0.6 m. above MHWS of probable Holocene, or possibly late Pleistocene age. Similar coquinas at equivalent elevations are known on the granite shore up to 2 m. above MHWS at Palana, below the surface at Wingaroo (Nye, 1931), in Arthur River Estuary and near Trousers Point, but it is uncertain that they are all equivalent deposits.

The Arthur River deposit is exposed 46 m. along the cliffs, N. of the 3-4 m. MHWS coquina, at 2.2 m. above MHWS as a lens 11 m. long overlain by 0.6-0.9 m. of sand to the cliff top. It contains a fauna of Recent aspect with common *Austromylitus erosus* (Lamarck) and is virtually identical to that of the present sandy shore.

The Trousers Point coquina, 5 cm. thick, is exposed at the base of a fore-dune at about 1.5 m. above MHWS, in the bay south of the point (grid 418N-893E). It contains a mixed molluscan fauna (Table 4) favouring a sandy bay with some shelter or reduction of wave action of wide sandy flats, with *Bembicium* and *Austrocochlea* apparently washed in. It includes carapace of *Philyra laevis* (Bell), the littoral smooth pebble crab (1966:38:3; ident. A. Dartnell), and the deposit appears to represent a high tide accumulation. The matrix is loose yellow-fawn foraminiferal calcareous sand with minor amounts of mica flakes and small quartz grains. The foraminiferal fauna (Table 5) is rich, beautifully preserved and identical with those in sea-floor samples taken from Bass Strait today, being very similar to that listed by Brady, 1884, from 'Challenger Station 162' off East Moncoeur Island in 73 m. of water (D. J. Taylor, pers. comm.). This suggests an assemblage more that of an inner shelf deposit with a possible depth range of 15-90 m. and this puzzling feature may be due to a later Holocene sea strand washing into Pleistocene deeper water deposits at this site.

Opossum Boat Harbour Grit

This siliceous grit, at least 8 m. thick, is exposed in Opossum Boat Harbour cliffs (grid 430N-110E, Plate 1, fig. 4) resting on granite basement and disconformably overlain by Nala Sand. It is dark brown, moderately consolidated, friable coarse grit containing well rounded to subangular quartz grains in a carbonaceous organic matrix. Further exposures of such grit occur on Cameron Inlet shore and underlie much of the area covered by Nala Sand. Teeth of the sperm whale *Physeter* were found in similar gritty sand, just above high tide level on nearby Great Dog Island (coll. J. Nield; 1966:39:12).

The degree of consolidation and development of organic matrix suggest a Pleistocene age. The Grit probably represents detrital accumulations from erosion of highland areas, possibly prior to, but with extensive marine reworking during, the Riss/Würm Interglacial and/or a Würm Interstadial.

QUATERNARY DUNE DEPOSITS

These include extensive coastal dunes on the west and east coasts with some relatively small inland deposits. Calcareous dune deposits characterise west coast series whereas siliceous dunes characterise east coast series.

Palana Limestone

This is predominantly calcified aeolian calcarenite, at least 9 m. thick in places, occurring on the western Flinders Island coast and typically exposed in the Palana, Lughrata and Ranga districts. It is variable in thickness and outcrops from below sea-level to elevations about 150 m. above. It overlies Palaeozoic basement; disconformably overlies Cainozoic sands and lavas, and disconformably underlies Lughrata Sand. On weathering it develops deep red-brown soils of the Ranga Association (Dimmock, 1957).

The limestone is generally cream to buff, with fragments of mollusc shells, bryozoans, echinoid spines, holothurian remains, algal remains (including *Lithothamnium),* poorly preserved foraminifera and quartz grains; secondary calcification is prominent and organic remains may be almost completely replaced (Crespin, 1945a; Everard in Hughes, 1957; Ludbrook, 1965). Chemical analyses (Everard, loc. cit.) generally show 60-95% $CaCO_3$, with a mean at 83%, except at Parrys Bay—Blue Rocks area where more siliceous rocks average about 70% $CaCO_3$.

Early workers considered the limestones to be marine deposits, but Dimmock (1957) considered them dune aeolianites, a view supported by the author's geomorphological studies Foraminifera in the limestones (Table 5) have been dated as upper Pliocene-Pleistocene (Crespin, 1945a), Pleistocene (Ludbrook, 1965) and 'derived from the Tertiary' (D. J. Taylor, pers. comm.). The latter forms were described from Ranga as 'poorly preserved, badly worn and fragmental foraminifera, bryozoa and mollusca. Foraminiferal determination was difficult at specific level, though several species of *Cibicides* were present *(C. victoriensis* and *C. mediocris),* at least one species of *Elphidium (E. crassatum)* and some fragments which could be assigned to *Operculina victoriensis.* From my knowledge of the Bass Basin (both marginal and offshore drilling) I am of the opinion that these faunas were derived from Middle to Upper Miocene sediments . . . one could say Balcombian to Mitchellian with a slight possibility of Kalimnan. The Ranga dune limestone is totally different to faunas which I regard as Quaternary'.

The available evidence suggests that the calcareous dunes from which the Palana Limestone developed cover a range in time. Some of the dunes, as at Ranga, possibly originated in the late Tertiary or early Pleistocene when lower sea-levels associated with glaciation would have exposed vast areas of Upper Tertiary calcareous marine beds. The limestone is cut by the 4.5 m. level (MHWS), correlated with the later Riss/Würm Interglacial sea, and this with other geomorphological considerations suggests a Lower Pleistocene, pre-Riss/Würm age for most of it.

The Palana Limestone appears to include a more siliceous younger dune member, which may represent a separate formation on very detailed mapping. This siliceous aeolian calcarenite, at least 3 m. thick, is exposed S. of Trousers Point (grid 420N-890E, Plate 1, fig. 5) overlying granite basement. It contains species of 'Helicidae' and represents the 'Helicidae' Sandstone of Johnston (1879). Johnston's term, however, appears also to partly include the more calcareous Palana Limestone. Dunes of the aeolianite outcrop from sea-level to about 30 m. above, and were mostly observed in the Loccota district.

It is coarse to fine grained, cross-bedded, fawny calcarenite. It is consolidated, but friable, generally lacks the lithification shown by much of the Palana Limestone, and contains moderate to considerable amounts of angular to rounded quartz grit, with some feldspar and rare biotite. Samples contain reworked and worn foraminiferal species similar to those listed from the Upper Quaternary (?) fauna isolated from the coquina in the foredune S. of Trousers Point (Table 5; D. J. Taylor, pers. comm.). The dunes are cut by the late Quaternary 0.6-1.5 m. level (MHWS) and also appear planed by the 4.5 m. level (MHWS), suggesting, with degree of consolidation and calcareous content, an age at least pre-late Riss/Würm.

Liapota Sand

This siliceous aeolian sand, at least 6 m. thick, is typically exposed around The Quoin and forms the chief soil type in the Liapota Association (Dimmock, 1957). It disconformably overlies Palana Limestone, is disconformably overlain by Lughrata Sand, and inundates granite hills up to 180 m. in elevation.

It is white to grey sand passing down into darker coloured strongly developed carbonaceous organic 'B' horizons, suggesting a Pleistocene age. Geomorphological evidence suggests dunes associated with old Pleistocene shore lines, at least Riss/Würm in age.

Altmoor Sand

This siliceous aeolian dune sand, at least 2.3 m. thick, is exposed at Ranga at elevations mostly 30-60 m. above sea-level, and forms the chief soil type in the Altmoor Association (Dimmock, 1957). It disconformably overlies Palana Limestone and undifferentiated Cainozoic non-marine beds. It is dark to light grey sand with organic carbonaceous horizons and is a similar deposit to Liapota Sand. The developed soil profile suggests Pleistocene age, and geomorphological evidence suggests possible association with old Pleistocene shorelines, at least Riss/Würm in age.

Petibela Sand

This siliceous gritty aeolian sand with clay, at least 2 m. thick, occurs on the east coast at elevations 5-30 m. above MHWS, and forms the chief soil type of the Petibela Association (Dimmock, 1957). It disconformably overlies Pleistocene (?) stratified sandy clay loams, clayey grits and grits, and is disconformably (?) overlain by Nala Sand. It forms marked parabolic dunes whose elevation above sea-level and presence of some organic accumulation with development of slight organic pan, suggest a late Pleistocene age, probably Riss/Würm.

Nala Sand

This gritty unconsolidated aeolian sand, up to 1.5 m. thick, occurs on the east Flinders Island coast at about 4.5-8 m. above MHWS, and is the chief soil type of the Nala Association (Dimmock, 1957). It disconformably overlies Opossum Boat Harbour Grit, Petibela Sand and older Pleistocene deposits, and is disconformably overlain by Lackrana Sand.

The formation forms well developed parabolic dunes Its material probably derives in part from underlying grits and sands and in part from siliceous material blown inland from the shallow eastern coastal shelf, when exposed by sea-level lows during late Würm and/or possible early Holocene time.

Lughrata Sand

This unconsolidated aeolian calcareous sand, at least 3 m. thick, occurs on the west Flinders Island coast, typically around Lughrata, and forms the chief soil type of the Lughrata Association (Dimmock, (1957). It disconformably overlies Palana Limestone, Loccota Grit and Marshall Bay Coquina and is disconformably overlain by Lackrana Sand. It is dominantly small shell fragments, with some organic matter and concretionary carbonate in the lower horizons, and ranges from 27-83% $CaCO_3$ (Dimmock, loc. cit.). A whale paddle bone was recovered from the sand at Loccota (J. Nield, coll. 1940; 1966:39:13).

The formation forms well developed parabolic dunes and forms the calcareous west coast counterpart of the siliceous east coast Nala Sand dunes. The dunes are found on benches cut at about 4.5 m. above MHWS which are correlated with a late Riss/Würm Interglacial sea. They show freshness of form and immaturity of soil profile which lead Jennings (1959b) to assign a young age to similar dunes on King Island. They are probably mostly early to mid-Holocene in age. The most recent coastal foredunes of this system probably range into the Upper Holocene and hence may be equivalent in age to part of the Lackrana Sand.

Lackrana Sand

This unconsolidated siliceous aeolian littoral sand, up to 3.6 m. thick, forms a beach ridge system fringing Flinders Island coasts. It is typically developed around Lackrana, and forms the chief soil type of the Lackrana Association (Dimmock, 1957). The formation disconformably overlies Nala Sand and older deposits, forming well developed ridges on the east coast with minor occurrences on the west coast. The parent material contains 3-5% $CaCO_3$ in minute shell fragments and there is only incipient development of soil profile (Dimmock, loc. cit.).

Such ridges on N.W. Tasmania are regarded by Gill and Banks (1956) as Holocene in age and possibly associated with a Post-Glacial thermal maximum, and such levels on the Tasmanian coast (Davies, 1959) are found to have beach ridges formed continuously to the present day. The Flinders Island ridges probably had a similar history to those of Tasmania and southern Victorian coasts (Jenkin, 1968), forming mainly in the Upper Holocene. The beach ridge at Whitemark has developed, at least in part, in historic time, as witness discarded bottles and timber buried within it.

QUATERNARY LAGOONAL AND LUCUSTRINE DEPOSITS

Extensive Quaternary dune building was associated with considerable lagoonal development on both the east and west coasts. Soils on old inland lagoons, probably Pleistocene, include those of the Metta Association (Dimmock, 1957) as found S. of Lookout Hill, E. of Mt Leventhorpe and W. of The Dutchman. Recent organic lagoon soils are mapped as the Wingaroo Association (Dimmock, 1957), while Everard (1950) refers to Recent lagoonal limestone deposits.

Grey limestone with small streaks of carbonaceous matter and numerous minute gastropods occurs in a quarry on Wingaroo road, 8 Km. N. of Emita (Ludbrook, 1965). The fauna (Table 6) indicates deposition in a marginal lake or mud-flat under non-marine conditions, probably in the Pleistocene. An extensive platform of dense, tough limestone with numerous gastropods, recently exposed under sandy soil near Wingaroo gate, presumably represents a Pleistocene lagoonal deposit at a higher level than the present Wingaroo lagoon floor.

Friable and porous limestone, over 2.1 m. thick is exposed in Holloways Quarry, 3.2 Km. N.E. of Lady Barron at about 2-5 m. above MHWS. Its base is not exposed and it appears disconformably (?) overlain by Nala Sand.

A section in the N.W. part of the quarry is:

(a) 1.2 m., pale greyish limestone (1965:33:21).

(b) 0.23 cm., pale greyish limestone with numerous small dark nodules (1965:33:20).

(c) 4.6 cm., pale greyish limestone (1965:33:19).

(d) 23 cm., pale yellowish limestone (1965:33:18), quarry floor.

The unit boundaries are gradational and all units contain freshwater gastropods. The fauna (Table 6) suggests variations in conditions in that there was some water movement at times. *Lenamaria, Simlimnea* and *Glyptanisus* are found in ponds and their abundance indicates predominance in this type of environment; *Austropyrgus, Revisessor* and *Beddomena* are more appropriate to creeks and rivers. It appears that water movement was prevalent during deposition of unit (d), but nearly absent during deposition of unit (c). Still lagoonal waters, possibly with occasional water influxes were prevalent during accumulation of unit (b), allowing development of nodular bodies and water flow probably increased during formation of unit (a). Land shells *(Egilomen, Pedicamista)* are expected as these species live in vicinity of such environments and could be washed in.

Chemical analyses from different horizons in the Quarry (Everard, in Hughes, 1957) range from 55-91% $CaCO_3$. The highest $CaCO_3$ is shown by unit (d) and the lowest by a sample that includes the nodule horizon (b). The nodules appear to be carbonate and siliceous (?) material and are not noticeably phosphatic (178 p.p.m. phosphorus in nodule, cf. 87-99 p.p.m. for matrix; det. F. Brown).

TABLE 6. QUATERNARY MOLLUSCA. LAGOONAL LIMESTONES, FLINDERS ISLAND

Molluscan Identifications	Lagoonal Limestone Holloway's Quarry					Lmst. N. of Emita
	Bed d	Bed c	Bed b	Bed a	R. W. T. Wilkins Colltn.	
Assiminea tasmanica (Tenison Woods)?						x
Coxiella sp.					x	
Freshwater species						
Austropyrgus buccinoides (Quoy & Gaimard)	x	x	x		x	
Beddomena lodderae (Petterd)	x		x		x	
Glyptanisus atkinsoni (Johnston)		x	x		x	
G. meridionalis (Brazier)					x	
Lenamaria sp.			x			
L. sp. *(juveniles)*				x		
L. pyramidata (Sowerby)		x			x	
Revisessor turbinatus (Petterd)	x		x	x	x	
Simlimnea sp?						x
S. gunni (Petterd)		x				
S. neglecta (Petterd)		x				
Valvatasma tasmanica (Tenison Woods)?				x		
Land Species						
Egilomen barrenense (Petterd)			x		x	
Geminoropa sp.? (juvenile)						x
Pedicamista caesa (Legrand)					x	
Thyrasona diemenensis (Cox)?						x

Identifications by R. C. Kershaw (Holloway's Quarry) and Ludbrook, 1965 (limestone, N. of Emita).

Similar Pleistocene lagoonal deposits may be represented by soft earthy limestone N. of Lady Barron (Dimmock, 1957, p. 27), from the Five Mile Lagoon (Wingaroo) area (Everard, loc. cit.) and from 0.4 Km. E. of Franklin Village jetty, Cape Barren Island (1964:35:5; coll. R. W. T. Wilkins).

QUATERNARY ALLUVIAL DEPOSITS

These are most prominent flanking highlands of Palaeozoic basement rocks such as the Strzelecki and Darling massifs.

Loccota Grit

This siliceous grit and gritty clay, at least 1.5 m. thick is exposed around Loccota in creeks draining into Fotheringate Bay and forms the chief part of the Loccota Soil Association (Dimmock, 1957). It overlies granite basement, and in part at least, appears to disconformably (?) overlie Palana Limestone. It contains a high percentage of angular quartz grit and represents alluvial accumulations of granite detritus from Strzelecki Peaks. Part, or most, of the material was probably derived and deposited during the Würm Glacial. Where grits with cemented organic 'B' horizons occur, as at Big River (Dimmock, loc. cit.), these probably represent older deposits.

UNDIFFERENTIATED QUATERNARY DEPOSITS

These include beds of waterworn grits, gravels, sands and clays, including stanniferous and organic enriched deposits in the Whitemark-Blue Rocks, Tanners Bay-Killiecrankie, Bootjack and Memana areas (Dimmock, 1957; Jack, 1966). Pebbles and crystals of gem quality topaz and associated minerals occur in such beds at Killiecrankie (Gould, 1872; Petterd, 1911). Some deposits resemble Opossum Boat Harbour Grit and probably represent alluvial accumulations reworked by Pleistocene seas. Some angular quartz grits and clay resemble Loccota Grit, as in the Whitemark-Blue Rocks area, at the mouth of the Leventhorpe Creek and elsewhere. These are probably alluvial deposits formed in areas exposed by withdrawal of the last Pleistocene Interglacial or Interstadial sea or in areas unaffected by Pleistocene marine transgression.

Old drainage deposits include an exposure in road cuts on the Whitemark-Memana Road (grid 630N-

913E) of a boulder bed 70 m. across and at least 2.4 m. thick. This occupies an east-west trending stream profile cut into underlying Mathinna Beds. The deposit consists mainly of rounded fragments of Mathinna Beds up to 23 cm. across, but includes fragments of hornfels and quartz and in places passes into a coarse sandy matrix.

Minor areas of siliceous dune ridges occur around Bootjack, Memana and Blue Rocks, and many of the well developed profiles in Soil Associations mapped by Dimmock (1957) were developed during the Pleistocene.

Recent deposits include:

(1) alluvial deposits of the present drainage,
(2) soils developing on late Quaternary dunes and ridges,
(3) coastal barriers enclosing east coast lagoons,
(4) beach accumulations including shell beds,
(5) lagoonal peat deposits,
(6) cave and dune bone deposits,
(7) miscellaneous deposits.

The first three types of deposit will be discussed in more detail when the geomorphological aspects of the authors' studies are presented and only the others will be considered further here.

Beach Shell Accumulations

These occur at a number of shore localities and include buried deposits. At Yellow Beach, Lady Barron, digging into the sandy beach 0.3 m. below the high tide level exposes a packed shell bed 15-23 cm. below the surface and extending to at least 0.6 m. in depth. The fauna (Table 4) is identical to that of the present shore here, and pieces of wood occur amongst the shells at about 0.4 m. depth. This wood gave a radiocarbon dating of 3,970$\pm$90 years B.P., suggesting that the deposit possibly formed by a sea retreating from a Post-Glacial higher level (E. D. Gill, pers. comm.).

Lagoonal Peat Deposits

Descriptions and approximate analysis and oil determination of material from such a deposit near Badger Corner are given by Carey (1945), Blake (1947) and Nye (1969). Cane (1966), investigating alleged 'oil' occurrences in this area showed that it was plant degredation product derived from such peaty material and gave further chemical analyses. Peats associated with lagoonal soils of the Wingaroo Association on the east coast are described by Dimmock (1957, p. 31).

Cave and Dune Bone Deposits

Scattered and fragmented bones have been found in crevices and in floor deposits of a cave in Palana Limestone, W. of Ranga (grid 486N-935E). A collection (F. Henwood and L. L. Waterhouse, 1917; Scott and Lord, 1922) includes *Vombatus ursinus* (femur, fig. Scott, 1915) and *Arctocephalus tasmanicus* (proximal phalange, first digit right fore flipper, ident. R. M. Warneke, 1965:39:10) as well as bones (ident. N. A. Wakefield) of *Potorous tridactylus* (femora, 1965:39:4), *Wallabia rufogrisea* (femora and skull, 1965:39:3) and *Trichosurus vulpecula* (ulna fragments, 1965:39:5). More recent excavations and explorations in the cave yielded further marsupial bones of dasyurids, vombatids, peramelids, phalangerids, macropods and murids, as well as some lizard and bird bones (Hope, 1969). Most of the recovered species are still extant on the Island, but some are now found only on the Tasmanian mainland, and two species, *Aepyprymnus rufescens* and *Pseudomys* cf. *novaehollandiae*, no longer live in South eastern Australia. The two topmost layers of the bone deposits in the cave floor gave Carbon 14 dates of 8,110$\pm$340 and 8,200$\pm$120 years B.P. respectively, and Hope suggests that the deposit may partly represent an old lair of the Tasmanian Devil *Sarcophilus harrisi*.

A sub-fossil bone deposit was exposed in a large sand blow in Lughrata Sand at Palana and included remains of tachyglossids, dasyurids, peramelids, phalangerids, vombatids, macropods, murids, birds and lizards (Hope, 1969). Almost all the species represented in the deposit are present on Flinders Island today, but *Isodon obesulus* now exists in Bass Strait only on West Sisters Island and *Sarcophilius harrisi* is now extant only on the Tasmanian mainland. Macropod and vombatid bones were also exposed in sand blows at Killiecrankie and Trousers Point.

Miscellaneous

Emu egg shell fragments were recovered near Emita, 6.5 Km. inland at about 180 m. elevation (coll. F. Jackson, 1917; 1965:39:6). This appears to be the first record of the emu on the Furneaux group, but the distribution data of this bird makes it uncertain that the Flinders Island fragments are truly local (Hope, 1969, p. 232).

An Australite, found in an abandoned tin mine near Killiecrankie Bay (Tasm. Mus. Colln. Y132, pres. J. Dunn, 1962) is lens shaped, 12x9x5 mm. in size (S.G. 2.45) and shows numerous fine ridges radiating from the centre of one surface. This presumably belongs to the tektite shower over Australia dated stratigraphically as late Pleistocene or early Holocene, possibly between 7,380$\pm$250 and 4,830$\pm$250 years B.P. (Gill, 1965). However, recent K-Ar isotopic dating of Australites (McDougall and Lovering, 1969) indicates an age of formation possibly as old as 0.86$\pm$0.06 m.y., with atmospheric flight shortly after. This enigma between physical and stratigraphic dating still requires reconciliation.

SUMMARY AND CAINOZOIC HISTORY

TERTIARY

Uplift

Vertical faulting and tilting in the late Mesozoic or Palaeocene epeiorogeny of Tasmania and Bass Strait (Spry and Banks, 1962; Jennings, 1959a; Richards and Hopkins, 1969) presumably elevated the Flinders Island Palaeozoic basement highlands. The topography suggests S.W. facing fault scarp blocks, downtilted to the N.E., and the main movements were probably along N.W. to N.W.N. trends with N.E. to E. cross-faulting and associated jointing. The prominent N.W. trend in joint patterns in the granite basement (Hughes, 1959a; aerial photograph inspection) probably belongs here as most of the late-stage basic dykes of the granite basement trend N.E.

Erosion

The Lower Tertiary history of Flinders Island is scantily recorded. It was probably one of terrestrial and coastal erosion of the uplifted fault blocks, with accumulation of detritus and organic matter around their flanks as non-marine and/or estuarine alluvial deposits. Such deposits are preserved under basalt E. of Whitemark, and on Cape Barren Island are dated as Upper Oligocene/Lower Miocene.

Volcanism

Volcanism, possibly commencing in the Lower or Mid-Tertiary, appears related to the Tertiary fracturing and the basement structure, with rough alignment of centres from Badger Corner, Ranga, Whitemark, Mt Leventhorpe, Parrys Bay and Lughrata to Tanners Bay-Palana areas. Olivine-nephelinites erupted in the central part of the Island and alkali olivine-basalts to the north and south, sometimes bringing up peridotite and country rock fragments. A tuff-shower at Samphire River overwhelmed swampy melaleuca vegetation there producing silicified logs, and tuff at Whitemark may have exploded from aqueous eruption.

Marine Deposition

Marine transgression on Flinders Island probably took place during early Miocene time, in accord with such deposits on Tasmania, Victoria and Cape Barren Island (Ludbrook, 1967; Richards and Hopkins, 1969), with the record removed or obscured by later erosion or deposition. Regression of the Miocene high sea in Upper Miocene-Lower Pliocene time, from evidence from Gippsland Basin and Bass Strait shores (Bowler, 1963; Bock and Glenie, 1965; Taylor, 1966; Sutherland and Corbett, 1967), presumably affected Flinders Island and accords with fossils washing ashore from inferred off-shore Kalimnan beds and with derived Upper Miocene-Lower Pliocene foraminifera in the aeolian Palana Limestone.

Later Pliocene marine transgression on Flinders Island is indicated by the post-Kalimnan Cameron Inlet Formation at elevations above present sea-level. These suggest a shore line fringing the eastern and northern flanks of the Darling Range and extending north through Wingaroo. Withdrawal of this sea by late Tertiary time is indicated by erosion and deposition of Pliocene remanié shells in overlying transgressive Lower Pleistocene marine deposits of the Memana Formation.

QUATERNARY

Climatic changes related to the Pleistocene Glacial had important effects on Flinders Island. Conditions became favourable for extensive dune building, and sea-level fluctuations left their imprint through variations in marine and terrestrial erosion and deposition giving stranded shorelines, dune movements and lagoonal developments.

Dune Building

Dune building on the west coast was predominantly calcareous. Vast areas of Tertiary calcarenites and marls were probably exposed on withdrawal of the initial Glacial sea, providing an abundant calcareous source. Siliceous sediment may have been largely removed from the area by predominantly east flowing currents in Bass Strait (typical of present winter flow, Vaux and Olsen, 1961), and siliceous dunes only formed in localised areas where rivers acted as siliceous sources. In contrast, dune building on the east coast was predominantly siliceous. A contributing source of siliceous sediments appears to have been the straits bounding the Island acting in similar fashion to rivers, and predominant long term drifts operating along the Tasmanian coast also tend to concentrate siliceous sediment on the N.E. corner of Tasmania (Davies, 1965). This sediment, with material eroded from Flinders Island over long periods, was probably transported by the easterly currents to deposit on the eastern coastal shelf as an abundant siliceous source.

The dune building was apparently a repeating pattern of formation of coastal dunes during relative still-stands in sea-level fluctuations, parabolic re-orientations of dunes during stormy periods, and erosion and drowning of dunes by marine transgressions during Interglacials and Interstadials. Orientations in the parabolic dune systems reflect the influence of the prevailing westerly winds, which have obviously operated over much of the Quaternary and would be particularly severe as the westerly wind belts moved northwards during Glacials. East-west orientations predominate on the west facing parabolic dune series of the west coast and inland, and also occur in east coast dune series, which however show more marked E.N.E./S.W.S. and N.W.N./S.E.S. orientations.

The older dune series of the Island became increasingly consolidated with time and developed mature soil profiles (Dimmock, 1957). Calcareous dunes, as now forming Palana Limestone, became subject to secondary cementation with formation of calcareous 'B' soil horizons. Leaching of top parts of dunes probably gave 'A' horizons of siliceous residue which possibly blew off exposing the underlying limestone and may have contributed in part to sand ridge deposits such as Liapota Sand and Altmoor Sand. Cave development was probably initiated fairly early in the consolidation of the calcareous dunes, with some development of linear caves occupied by streams. Rapid erosion by the streams resulted in sink holes, gorges and stranded caves as found west of Ranga (older than 8,000 years B.P.).

Consolidated dunes with lower calcareous content (west coast, e.g. Trousers Point aeolianite) and typically siliceous content (east coast, e.g. Petibela Sand) developed during the Upper Pleistocene. Unconsolidated parabolic dunes (e.g. Lughrata Sand and Nala Sand dunes) probably originated as beach ridges or foredunes developing continuously from the Würm Glacial. The parabolic movements were probably initiated during stormy conditions in the Würm, continuing into the Post-Glacial period, and truncation of the parabolic ridges took place with establishment of a Post-Glacial shore line. A coastal beach ridge system (Lackrana Sand) developed, continuing through to the present and punctuated in places with minor parabolic movements. The evidence of the barrier at Arthur River, at least, suggests a still-stand or a relative slowing down of the Post-Glacial sea-rise, before a rapid rise to a 0.6-1.5 m. (MHWS) level flooding the barrier, possibly about the Post-Glacial Thermal Maximum (Gill, 1955).

Lagoon Formation

Extensive lagoon development, particularly on the east coast, has been associated with dune formation on the Island, following impounding of drainage by coastal barriers and by parabolic movements. Traces of old lagoons formed during the Pleistocene and early Holocene are found in inland areas and freshwater limestones were deposited in some of these.

During the early Holocene, probably in a period of increased rainfall, small lagoons impounded by parabolic dunes increased in size and coalesced to form extensive lagoonal areas of Nelson Lagoon type. Further lagoons formed meanwhile in swales of parabolic dunes. Many of these became reduced in size, probably during a period of reduced rainfall, and lunettes developed. With the building of the present beach ridge coastal barrier, apparently following establishment of the Post-Glacial sea, extensive coastal lagoons and inlets have formed. Encroachment of the lunette at Hogans Lagoon onto the oldest beach ridges suggests that lunette formation and the associated climatic period were probably later than the Post-Glacial sea-rise.

Marine Fluctuations

Sea-level fluctuations associated mainly with Pleistocene Glacial fluctuations have left traces of old shore lines on Flinders Island. Erosional and/or depositional features have been observed associated with old shore lines at 57-72 m., 27-33 m., 15-18 m., 4.5-6 m. and 0.6-1.5 m. above MHWS. Erosional features are represented by benches cut in granite, dune limestones and other sediments, in places forming extensive coastal flats, and in the case of the 0.6-1.5 m. level by truncation of parabolic dune series. Depositional features include the Memana Formation (a shallow water marine horizon occupying a Lower Pleistocene embayment in the North Patriarch area), Marshall Bay Coquina (probably a beach deposit associated with the 15 m. level), East River Coquina (bay floor and sea-channel deposits, some with remanié material derived from underlying horizons by penecontemporaneous erosion, probably related to the 4.5 m. level) and Petrification Bay Coquina (a shallow bay deposit associated with the 0.6 m. level). Angular grits and associated sediments (e.g. Loccota Grit) probably represent detrital accumulations resulting from heightened erosion associated with marine withdrawals, as in the Würm. Well worn grits (e.g. Opossum Boat Harbour Grit) probably represent extensive reworking of such deposits during marine advances, as in the Riss/Würm Interglacial.

The 0.6-1.5 m. level includes a Post-Glacial level and possibly some late Pleistocene levels, as dated elsewhere (Gill, 1970). Dating at Lady Barron beach suggests that the sea was near this level at least 4,000 years ago. The 4.5 m. and 15 m. levels can probably be assigned to the Riss/Würm, but higher levels are probably pre-Riss/Würm and the 57-72 m. level may even represent the Mid-Miocene high sea. Many aspects of dune building and evidence of sea-level fluctuations from the Upper Cainozoic on Flinders Island parallel developmental histories of the Bass Strait region on King Island (Jennings, 1959b), the Tasmanian north coast (Edwards, 1941; Sutherland, 1971; Gill, 1970) and the Victorian coast (Jennings, and Mabutt, 1967; Jenkin, 1968).

Faunal Fluctuations

Sea-level and associated climatic fluctuations on Flinders Island during the Cainozoic would influence terrestrial faunal movements and at times isolate populations. The Island undoubtedly formed part of land bridges that connected Tasmania and the Australian mainland during Pleistocene Glacial marine withdrawals, when sea-level along Australian shores may have fallen 135 m. and possibly as much as 180-210 m. in depth (Packham, *et. al.* 1969; Gill, 1970; Jongsma, 1970).

Summaries of references to the known present fauna of the Island are given by Green (1969) and Hope (1969) and presumably endemic species are known from the Ranga cave (Green, 1963; Richards, 1967, 1970). Sub-fossil remains of *Aepyprymnus rufescens, Pseudomys* cf. *novaehollandiae, Sarcophilus harrisi* and the emu (?) represent animals no longer living on the Island, and Hope (1969) discusses possible migration and isolation patterns of some vertebrate distributions across Bass Strait.

Of interest here is the Tasmanian Aborigine, an isolated race when discovered by Europeans and occupants of Tasmania at least 9,000 years ago. Mainland Australian excavations yield similar stone implements in lower levels to Tasmanian types, suggesting a mainland origin for the race and use of the Furneaux chain as a land bridge, probably between 16,000 and 11,000 years ago (Jones, 1968). Some possible evidence of prehistoric Aboriginal occupation of Flinders Island is very meagre (W. F. Ellis, pers. comm.). Rare Aboriginal artefacts from Cape Barren Island include some flaked stone atypical of the Island and possibly transported by visitor (Rhys Jones and R. A. Littlewood, colln.). However, coastal Aboriginal camps on the old Furneaux landbridge would be now submerged under Bass Strait (Jones, 1968).

At present, the Flinders Island area experiences occasional earth tremors, being one of the seismically strongest regions of the generally quiet Tasmanian block. A swarm of tremors in N.E. Tasmania in 1883-1886 probably originated from off-shore epicentres (Shortt, 1885, 1886; Biggs, 1886). Epicentres plotted since 1929 (magnitude, m4.0-5.7) fall across the middle of the Island and may be related to cross-structures on a westerly striking seismic zone extending through the Island across Bass Strait from Longitude 156° to 144° (Doyle, Everingham and Sutton, 1968).

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APPENDIX I

Petrological Descriptions, Flinders Island Cainozoic Volcanic Rocks

T.S. numbers refer to catalogued thin sections in the Tasmanian Museum collection.

Samphire River—Adelaide Bay—Chew Tobacco Creek (T.S. 1338, 1342, 1344, 1482).

Corroded glomeroporphyritic olivine (10-15%, 3 mm. max., $2V_z \sim 93\text{-}97° \pm 3°$) is set in an intergranular groundmass of plagioclase laths (35-45%, 1.4 mm. max., mostly <0.5 mm., zoned from about Ab 44-50), pale pinkish augite (30-35%, 0.4 mm. max., av. 0.1 mm.) olivine (5%) and opaque iron oxide (5%, titano-magnetite or ilmenite), minor apatite and interstitial zoned sodic plagioclase. In dense samples the olivine is largely unaltered, iron oxides tend to form squarish grains, and interstitial patches of carbonate (up to 10%) and serpentinitic material may be prominent. In more amygdaloidal varieties olivine is rimmed by green opal or is largely altered to serpentine, 'bowlingite' and carbonate, iron oxide tends to form elongate blades, and amygdaloidal fillings include calcite, ferroan carbonate, clay, opal and chalcedony. Rare accidental quartz and quartz aggregate inclusions show thin reaction coronas of clinopyroxene needles.

N. Ranga-E. Whitemark (T.S. 1139, 1141; Analysis 1, Table 2).

Glomerophenocrysts of corroded olivine (10-15%, 1.4 mm. max., $2V_z \sim 95\text{-}100°$) and euhedral oscillatory-zoned titaniferous augite (5-10%, 1.5 mm. max., $2V_z \sim 62\text{-}48° \pm 2°$) are held in subophitic to intergranular and poikilitic groundmass of plagioclase laths (20-30%, 0.9 mm. max., zoned from about Ab 44-50), titaniferous augite (20-30%, mostly 0.05-2 mm.), sporadic iron oxide (to 0.7 mm.), apatite and rare olivine, with interstitial zoned sodic plagioclase (to 15%), minor colourless glass dusted with iron oxide and amygdaloidal carbonate.

Whitemark (Palagonite Tuff; Petrological Records, Tasm. Mines Ser. No. 58-23).

'Dark coloured rock composed of black porous fragments cemented together by carbonate of lime.

In thin sections the black fragments appear as a brown glass and a green zeolite. The glass contains many pores some of which are filled with zeolite spherulites and others with calcite. Some fragments consist entirely of masses of zeolite spherulites. The refractive index of the glass varies, being in some parts lower than Canada balsam, in others, higher. Plagioclase and olivine occur as relic minerals from the original glass'.

E. Leventhorpe (T.S. 1483-1484)

Corroded olivine phenocrysts and grains (15-20%, 2.5 mm. max., $2V_z \sim 93\text{-}100°$) are dispersed in an intergranular to poikilitic groundmass of plagioclase laths (35-40%, 0.8 mm. max., zoned from about Ab 44-50), colourless augite (30%, 0.4 mm. max.), sporadic iron oxide (to 0.5 mm.), minor serpentinite and chlorite, small apatite needles, and interstitial and amygdaloidal zeolite (5-10%, mainly phillipsite?).

Tanners Bay-Boat Harbour-Palana (T.S. 1142, 1296-1298, 1341, 1343).

Glomeroporphyritic corroded olivine (5-20%, 3 mm. max., $2V_z \sim 90\text{-}98°$) is contained in an intergranular to pilotaxitic groundmass of plagioclase laths (35-50%, 0.4 mm. max., zoned from about Ab 44-50), pinkish augite (20%, 0.3 mm. max.,), squarish iron oxide grains (5-10%, 0.2 mm. max.,), granular olivine, apatite needles and interstitial zoned sodic plagioclase. Amygdales may contain greenish to yellowish colloform opal, radiating calcite or ferroan carbonate. Some rocks contain rare microphenocrysts of titaniferous augite (1 mm. max., sometimes with corroded riddled cores) and aggregates of prismatic clinopyroxene, sometimes in reaction coronas around fused or partially fused quartz and rare feldspar xenocrysts.

Parrys Bay (T.S. 1300, 1340, 1485-1488).

Corroded olivine phenocrysts and rarer xenocrysts (10-20%, 3 mm. max., $2V_z \sim 88\text{-}100°$) grade into a groundmass of titanaugite (30-50%, 0.6 mm. max.), squarish to irregular iron oxide grains (7%, mostly <0.2 mm.) and coarse to needle-like apatite prisms (3%, 0.6 mm. max.), with a poikilitic or hyalopilitic mesotasis (10-30%) containing variable proportions of idiomorphic to allotriomorphic potassic nepheline (0.6 mm. max.), colourless to brownish glass, some alkali feldspar, and interstitial and amygdaloidal zeolites, including stilbite, natrolite and analcime.

N. Lughrata (T.S. 1301, 1345, 1592, Analysis 2, Table 2).

Corroded olivine phenocrysts and peridotitic xenocrysts and xenoliths form 35% of the rock, in a fine grained groundmass of augite (mostly <0.2 mm.), granular olivine, squarish iron oxide grains and apatite needles in a feldspathoidal base (20%) containing potassic nepheline, colourless glass and zeolites (including analcime and natrolite) in patches up to 0.3 mm. across.

The peridotitic xenoliths (mostly <2 cm.) consist predominantly of olivine, associated withh orthopyroxene, clinopyroxene and spinel in allotriomorphic consertal to granular inclusion textures. Xenocrysts (mostly <4 mm.) derived from these xenoliths are commonly distinguished by exsolution, resorption and strain phenomena and by reaction coronas and overgrowths of the host groundmass minerals. Magnesian olivine ($2V_z \sim$ 88-97°; MgO 46.6, FeO 11.1) may show strain polarisation and translation lamellae; aluminous enstatite ($2V_z \sim 76\text{-}84°$; SiO_2 53.4, MgO 33.7, 'FeO' 5.8, Al_2O_3 5.0) may show lamellar or granular exsolution of clinopyroxene, spongy resorption or symplectic resorption intergrowths, and overgrowths of augite or coronas of olivine and iron oxide; sodic aluminous endiopside ($2V_z \sim 70\text{-}66°$; SiO_2 51.7, CaO 19.3, MgO 16.5, Al_2O_3 7.7, 'FeO' 3.0, Na_2O 2.2) may show corrosion riddling and overgrowths of zoned groundmass augite ($2V_z \sim$ 53-41°; SiO_2 49.8, CaO 23.3, MgO 14.3, 'FeO' 7.4, Al_2O_3 4.9, TiO_2 1.7) becoming coloured and titaniferous towards the rims; and olive to reddish brown chrome (?) spinel (Al_2O_3 54.3, MgO 21.1, 'FeO' 10.3) may show opaque reaction rims of chrome (?) iron oxide (preliminary electron microprobe analyses, oxide percentages, per R. Varne).

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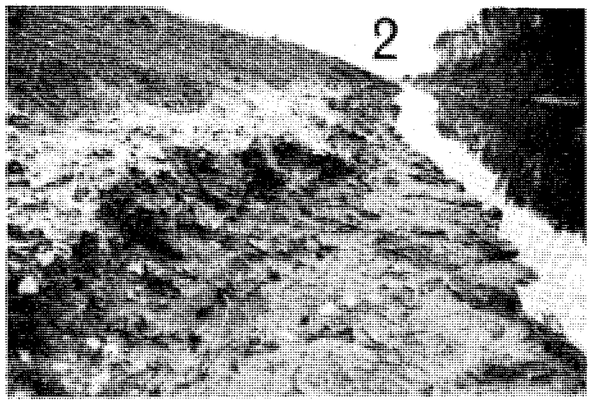
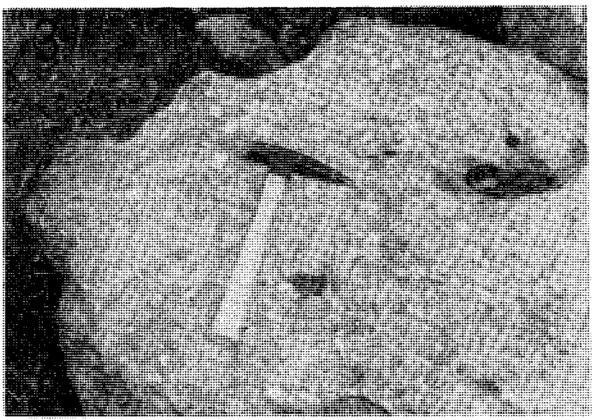
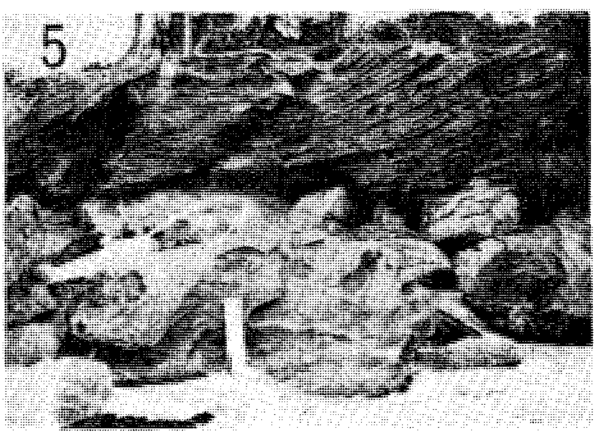
ADDENDUM

Silicified plant material recently recovered from low tide level at Petrifaction Bay (Tasm. Mus. Colln. Z1591, pers. Mrs A. W. McPhie and Mr R. Hewer) contains cones, twigs and needles, probably of casuarina (Dr J. A. Townrow, pers. comm.). It is presumably sub-basaltic in origin which suggests an age probably not exceeding early Pliocene for the basalt there. If the supposition is held that the basalt blocked the post-Kalimnan/pre-Maretimo marine transgression then this would imply a Lower Pliocene (Kalimnan) age for this eruption.







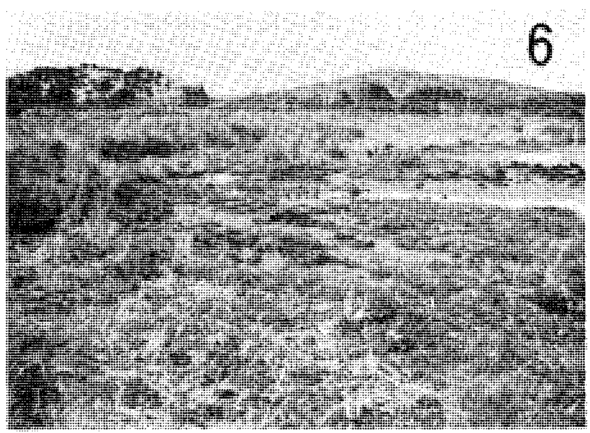


PLATE 1.

Fig. 1.—Pliocene coquinoid limestone (Cameron Inlet Formation), exposed in quarry, foot of The Dutchman (type locality of Wilkins 1962 Dutchman Coquina), looking North, 1957 photograph.

Fig. 2.—Nelson Lagoon Drain section, ½ mile N. of East River, looking north, 1957 photograph. Pliocene shelly marl (base of drain) and shelly sands of the Cameron Inlet Formation are disconformably overlain by Upper Pleistocene (?) East River Coquina containing numerous remanié *Cucullaea* at its base.

Fig. 3—Lower Pleistocene (?) coquinoid calcrete (Memana Formation), from outcrop E. end N° 11 Road, Furneaux Estate.

Fig. 4.—Cliff of Opossum Boat Harbour Grit (Upper Pleistocene?), type locality. Note erosion at cliff base, just above HWM and also at higher level below cliff top.

Fig. 5.—Aeolianite (younger Palana Limestone member), S. of Trousers Point, looking north. The aeolianite shows marked aeolian bedding, rests on granite and its upper surface is coincident with the 4.5 m. level above MHWS.

Fig. 6.—Type locality of Petrification Bay Coquina (Holocene?), which forms the terrace level just above high tide mark, looking north-east. Note basalt boulders on shore.

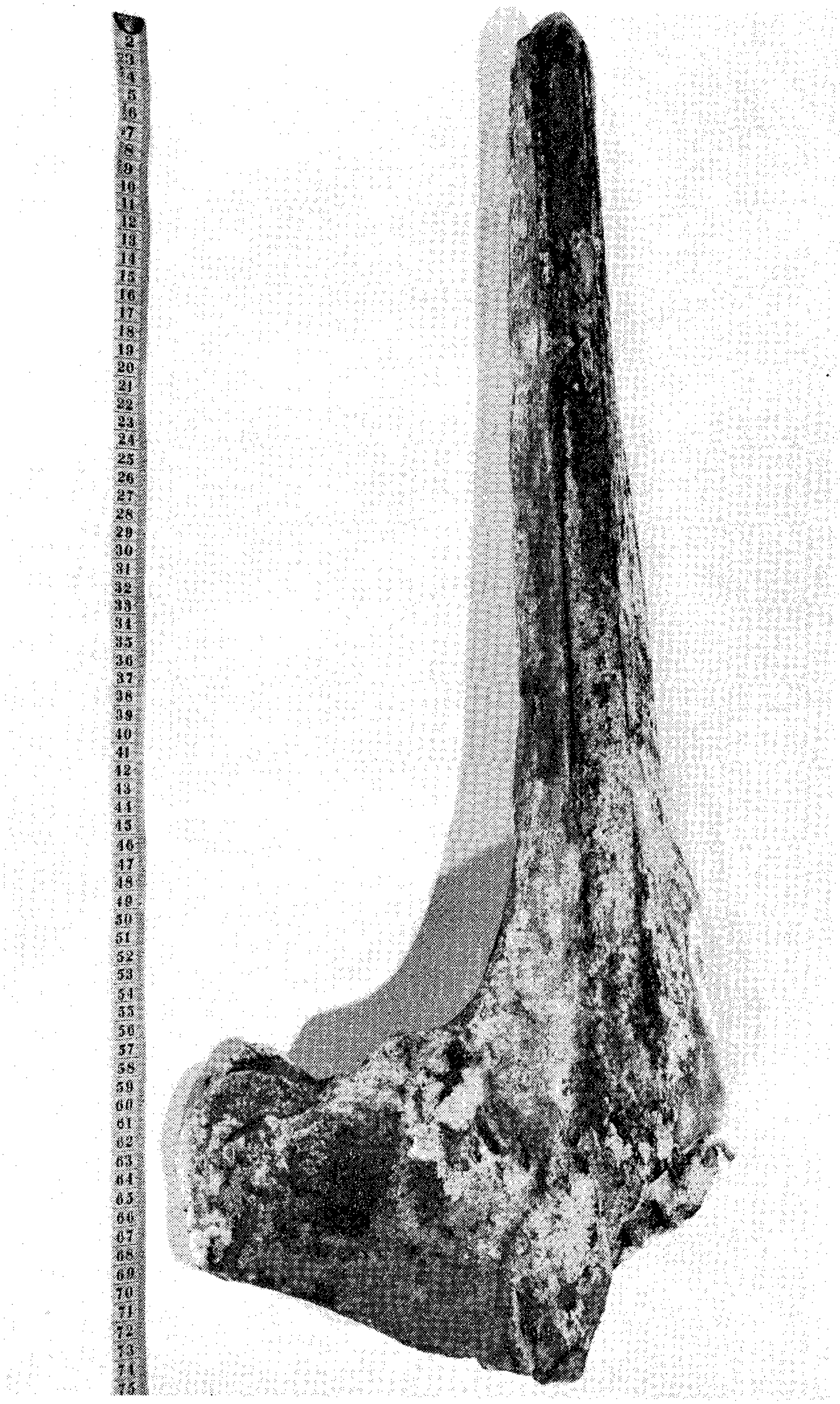


Plate 2.—Dorsal view, skull of new Pliocene whale, *Ziphius* sp., drain excavation, Memana Flinders Island (Photograph, per J. W. Warren). The scale is graduated in cms.