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OFF-SHORE SEDIMENTS, NORTH-WEST NELSON, SOUTH ISLAND, NEW ZEALAND

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ABSTRACT

The Kahurangi Shoals, north-west of Kahurangi Point, Nelson, and the Westland and D'Urville Currents are the major factors influencing the sediment distribution and sedimentation processes on the north-western shelf of the South Island. The sediments are derived from two major sources, one the Kahurangi Shoals, the other the high Alpine region which supplies its erosion products to sea by steep mountain streams and rivers. The Westland and D'Urville Currents not only carry the Alpine detritus to the area but also largely control the sediment distribution pattern. Immediately south and north of Farewell Spit well sorted wind-blown sands derived from the Spit have accumulated, whereas further south in Golden Bay the sediments are mainly supplied by the Aorere and Takaka Rivers. Petrologically the shelf sands are mainly a quartz–feldspar association with magnetite, ilmenite, garnet, and hornblende as major constituents in the heavy mineral assemblage. The gravels and boulders derived from the Kahurangi Shoals consist mainly of well rounded quartzites. Seismic reflection profiles give an indication of the depositional history during and since the Pleistocene and provide information on the rate of sedimentation.

INTRODUCTION

During a 10-day cruise in March–April 1965 on the m.v. *Taranui,* bottom samples were taken in Golden Bay and from the continental shelf off shore from North-West Nelson. Petrological analyses of the sediment samples were made to establish the pattern of sediment distribution and sediment transport in relation to prevailing currents and morphology.

In April 1968 this was followed by a seismic reflection survey which produced three profiles in the area. An energy of 1,000 Joule was transmitted into the water by an Edgerton Boomer. Reflections were picked up by an array of eight M.P. 1 hydrophones and after amplifying the signals they were printed on a Mufax helix recorder.

Bathymetry

The shelf in the area (Fig. 1) forms the transition between the New Zealand land mass and the Challenger Plateau, the south-eastern part of the Lord Howe Rise. The overall slope of the shelf in a north-westerly direction, into the Tasman Sea, is 0·5% down to 500 m (270 fm), the floor depth of the Challenger Plateau. From the coast down to 55 m (30 fm), however, the shelf is relatively steep with a slope of 3%. There is a break in slope midway, between 200 m and 250 m (110 fm and 140 fm), with a gradient of 1·4% separating the upper from the lower shelf. On the upper shelf Kahurangi Shoals and Paturau Bank rise some 50 m and 25 m (27 fm and 14 fm) respectively from a floor depth of approximately 60 m (33 fm).

North and north-west of Farewell Spit, the slope of the shelf is even more gentle than in the west. The slope here merges with the Cook Strait platform between the Spit and Taranaki, North Island, at 80 m (44 fm). Cook Strait platform itself is cut by a shallow depression, the North-western Trough, leading into Cook Strait Canyon to the south-east.

Golden Bay forms a shallow inlet of Cook Strait. It is separated from open sea in the north by Farewell Spit and sheltered in the south and west by the Pikikiruna, Onekaka, and Wakamarama Ranges. The area immediately south of the Spit is occupied by tidal flats over a distance of several kilometres. They are exposed at low tide and are cut by a pattern of tidal gullies.

Geology

The geology of the area as presented in Fig. 2, simplified after Grindley (1961), shows a steeply folded Paleozoic central massif consisting of predominantly metamorphic and volcanic rocks and flanked by the upper Paleozoic intrusions of the Karamea Granite in the west and the Separation Point Granite in the east. In the Wakamarama Range to the north-west these rocks are overlain by Cretaceous shallow water sediments which in turn are overlain in the coastal area by Tertiary sandstones, siltstones, and limestones. During the Quaternary alluvial deposits accumulated in the valleys of the Aorere and Takaka Rivers and tributaries and sand dunes developed on Farewell Spit.

The central area is divided into a series of blocks and nappes by a set of normal and reversed faults aligned roughly north–south. The Wakamarama Range is bounded in the south-east by a north-east–south-west fault, in line with the general structure of the Nelson and Marlborough Provinces. It seems likely that the position of the western coastline between Kahurangi Point and Cape Farewell coincides with another fault trending north-east.

The structural trend of North-West Nelson continues off shore in the Lord Howe Rise and the Nelson area is considered an emergent part of the Rise (van der Linden, 1967).

Hydrology

The surface circulation over the North-West Nelson shelf is dominated by the north flowing Westland Current. The east flowing D'Urville Current rounds Farewell Spit and flows into Cook Strait. Both currents are derived from the oceanic Tasman Current (Brodie, 1960).

SAMPLING

A total of 137 samples were taken, most of these directly from the m.v. *Taranui* in water deeper than 3 fathoms using a modified Hayward Orange Peel Grab (O.P.G.). In places, e.g., on the Kahurangi Shoals, where the O.P.G. did not produce good results successful use was made of a 6 in. pipe dredge. In near-shore waters less than 3 fathoms, off Collingwood and south and north of Farewell Spit, sampling was carried out from the ship's dinghy using a Dietz Grab. Sample localities are shown in Fig. 1.

ANALYSES

Mechanical Analysis

Samples were treated with a 10% hydrogen peroxide solution to remove organic matter and with a 6N hydrochloric acid solution to remove calcium carbonate. Samples were then washed through a Büchner funnel and sieved wet on a 0·064 mm sieve. From each sample the fraction smaller than 0·064 mm was dispersed with 0·1 mole sodium oxalate and 0·02 mole sodium carbonate and a pipette analysis was made. The fractions 0·064–0·032, 0·032–0·016, 0·016–0·008 mm, and finer than 0·008 mm were determined. The fraction coarser than 0·064 mm of each sample was dried and sieved at 0·5 phi intervals from 0·064 mm to 2·000 mm and at 1·0 phi intervals for the fractions coarser than 2·000 mm (phi $= -\log_2$ diam. (mm)).

The following statistical parameters (after Folk and Ward, 1957) were calculated by computer (Elliott 503, Applied Mathematics Division, DSIR):

Mean size $$M_z = \frac{\phi 16 + \phi 50 + \phi 84}{3}$$

Sorting (Standard Deviation) $$\sigma_i = \frac{\phi 84 - \phi 16}{4} + \frac{\phi 95 - \phi 5}{6{\cdot}6}$$

Skewness $$Sk_i = \frac{\phi 16 + \phi 84 - 2\phi 50}{2(\phi 84 - \phi 16)} + \frac{\phi 5 + \phi 95 - 2\phi 50}{2(\phi 95 - \phi 5)}$$

Kurtosis $$K_g = \frac{\phi 95 - \phi 5}{2{\cdot}44(\phi 75 - \phi 25)}$$

in which $\phi 5$, $\phi 16$, $\phi 25$, etc., are the respective percentiles in ϕ diameters taken from the cumulative size frequency distribution.

The respective parameters M_z, σ_i, Sk_i, and K_g were plotted and contoured (Figs. 3, 4, 5, and 6) to enable a classification according to average size, degree of sorting, and the asymmetry and peakedness of the size frequency distributions (after Folk and Ward, 1957).

It must be noted that in the characterisation of size frequency distributions negative or positive skewness indicates asymmetry towards the coarser or the finer fraction respectively; platykurtosis or leptokurtosis indicates respectively a poorer or better sorting in the central part of the distribution than in the tails.

Sand/silt/clay ratios have been plotted for the western and northern shelf in Fig. 7A and for Golden Bay in Fig. 7B. Dividing the "sand" corner (over 70% coarser than 0·064 mm) into three further sub-groups enabled a classification of the sediments in eight classes of which seven were present in the area. The areal distribution of these textural classes is given in Fig. 8. Size parameters of each sample are given in Table 1.

Heavy Mineral Analysis

Heavy mineral analyses were made from a number of selected samples. They are grouped in seven profiles running at approximately right angles to the coast on the western and northern shelf (*see* Fig. 1). Only the distribution of heavy minerals in the fine and medium sand fractions (0·064–0·500 mm) was estimated.

After treatment of the sample material with 10% H_2O_2 and concentrated HCl solutions the heavy minerals were concentrated using bromoform (spec. density 2·89) as a separating liquid. Minerals were identified using a polarising microscope and mechanical stage. The percentages of alterites and opaque and transparent minerals were calculated as well as the percentages of individual transparent minerals. A total of 100 transparent minerals of each sample was identified.

The results of the analyses are plotted in Table 2. The distribution of heavy minerals per profile is presented in Fig. 9. In this figure no differentiation of individual amphiboles, pyroxenes, epidotes, and phyllosilicates was made.

INTERPRETATION

The Western and Northern Shelf

Texture

Different depositional environments are defined on the basis of textural characteristics.

1. A belt of coarse clastics associated with the Kahurangi Shoals is most conspicuous on the shelf. These sediments range in size from coarse sand to boulders and can be generally defined as gravelly sand and gravel-sand mixtures. The very coarse constituents in the association, from gravel upwards, comprise mainly well rounded dark grey to black fine grained quartzites but pebbles of granite, schist, calcareous sandstone, greywacke, and quartz are also quite common.

The sediments are in general poorly sorted (σ_i = 1·00–2·00) with the exception of the area centred on the Kahurangi Shoals where they are moderately to well sorted indicating maximum current energy. Skewness values are negative to very negative denoting dominance of the coarser fraction. Kurtosis values smaller than 1·11 indicate relatively poorer sorting for the mean than for the overall distribution.

The sediments of the Kahurangi Shoal Belt have been deposited under present-day conditions, i.e., open shelf and powerful longshore currents, or under conditions not very different from those prevailing now, i.e., since the Pleistocene. Their coarseness points to a local source area, the Kahurangi Shoals, the lithology of which as testified by the abundance of quartzite pebbles and boulders is different from the composition of the coastal sandstones, mudstones, and limestones of the lower Oligocene, Landon series. The seaward dipping Landon beds overlie the quartzite conglomerate Mata series (Senonian) which in turn overlies Aorere (Ordovician) quartzites. From their lithology and position the Kahurangi Shoal rocks might thus belong to either the Mata Series or even the Aorere formation. As other evidence suggests, the shelf is separated from the coast by a fault trace which, according to the suggested Cretaceous or even Ordivician age of the Kahurangi Shoals, must have a substantial vertical throw. This fault very likely more or less follows the coastline between Kahurangi Point and Cape Farewell.

The position of the bifurcating Kahurangi Belt (the belt of coarse clastics, indicating maximum current energy), marks the path of the Westland and D'Urville currents (Fig. 8).

2. In the classification diagram, Fig. 7A, a number of samples are grouped at the boundary of the sand triangle and the very sandy mud zone. They occur off the mouth of the Buller and Paturau Rivers, and extend in a north-easterly direction parallel to the coast (Fig. 8). The isolated area of very sandy mud just north-east of Cape Farewell, is considered to be a continuation of the Paturau River Belt which is overlain north of the Cape by sediments of the Kahurangi Belt.

The sediments derived from the Buller and Paturau Rivers belong to the finest clastics on the western shelf (M_z in general greater than 3 ϕ diameters or $<$0·125 mm; off the Paturau River even greater than 4 ϕ diameters or $<$0·064 mm; i.e., the average composition lies in the very fine sand and silt range). They are in general poorly to very poorly sorted because of mixing with coarser sediments derived from further south (cf. section 4 below) and from the Kahurangi Shoals. The skewness values are very positive, $>$0·30, indicating dominance of the finer fraction. Kurtosis values vary greatly and testify, as do the sorting coefficients, to the mixing in various proportions with coarser clastics from other sources.

3. The sediments in the area north and north-east of Farewell Spit are relatively uniform in texture. Mean diameters are roughly between 2·0 and 2·6 ϕ diameters (0·250–0·165 mm) and the size frequency distributions show log-normal curves, i.e., they are more or less symmetrical, mesokurtic to slightly leptokurtic. The standard deviations are small, 0·50 to less than 0·35, indicating a well to very well sorted association. All these size parameters point to maturity of the sediment distribution. The sediments are considered to be mainly wind-blown sands derived from the Spit where they have passed through cycles of beach and dune formation since at least the Pleistocene.

4. Outside and in between the areas occupied by sediments of the Kahurangi Belt and Buller and Paturau River Belts and the wind-blown Spit derivatives, there are zones of fine and medium sands which seem to be characteristic for the South Island's western shelf. The associations described in preceding paragraphs are anomalous as they reflect special local conditions affecting a relatively small area only.

The fine and medium sands of the western shelf are the erosion products of the Southern Alps brought to sea by numerous short and steep mountain streams and carried north by the Westland Current. Mineralogically they are a quartz-mica-feldspar association indicating their origin from granites, gneisses, and schists.

Within the area investigated it is difficult to assess their exact textural parameters as they are mixed in varying proportions with the sediments derived from local sources. This effect is reflected in the sorting coefficients indicating poor to very poor sorting. The skewness measures, all positive, indicate, however, a dominance of the finer grades even in the areas outside the Buller and Paturau River Belts.

5. Two texturally well marked zones point to the influence of breakers; one in the present coastal area, the other in a former coastal area, now off shore, related to a lower stand of sea level.

(*a*) Sorting coefficients less than 0·50 and kurtosis values between 0·90 and 1·50 mark a narrow zone of fine sands occurring in shallow water marginal to the coast. Their better sorting, especially in the central part of the distribution, is attributed to winnowing in the high energy regime of breaking and plunging waves.

(*b*) Without markedly affecting standard deviation, skewness, and kurtosis the average size of the sediments tends to increase towards the outer shelf. From approximately 130 m (70 fm) outward, the grain size increases gradually from values over 3 ϕ diameters (finer than 0·125 mm; i.e., very fine sand) to less than 2 ϕ diameters (coarser than 0·250 mm; i.e., medium sand). No detailed information is available as to what happens to the mean values further off shore. The overall sediment distribution in the area as presented in Fig. 11, however, indicates that for the central part of the New Zealand western shelf down to approximately 250 m (140 fm) sand is the dominant constituent, and that from the shelf edge outward mud prevails. This shows that the zone of medium sands as encountered in approximately 140 m (77 fm) is a relatively narrow zone only.

Although different in absolute size this situation is similar to that described by McDougall and Brodie, 1967, for the western shelf off the North Island. There, a belt of fine sand occurs in between two zones of very fine sand lying respectively closer inshore and further off shore. The explanation given for the occurrence of the northern belt of coarser clastics seems a plausible one and may apply under the same terms for the medium sand belt off Nelson, that is, that they are a relict from an earlier sedimentary phase during a lower stand of sea level in the Pleistocene. While the evidence for this is not conclusive it shows that the idea that sediment grades should decrease outward across the shelf is no longer a dogma (Shepard, 1963).

Heavy Minerals (Table 2 and Fig. 9)

The heavy mineral assemblage does not vary greatly in composition over the area investigated. The average proportions of opaques, alterites, and transparent minerals are 20%, 35%, and 45% respectively.

Judged from the magnetic susceptibilities of a number of selected samples, using the FRANTZ Isodynamic Separator, the opaque minerals consist mainly of magnetite and ilmenite.

The alterites are the heavy minerals which hide their true character as the result of various destabilising and decomposing processes. Opaque dust, inclusions, chloritic alterations, and the like made it impossible to identify the original mineral. Especially epidote, andalusite, the amphiboles, and pyroxenes seemed to be susceptible to decomposition in the assemblage and have therefore influenced the true proportions of the individual minerals.

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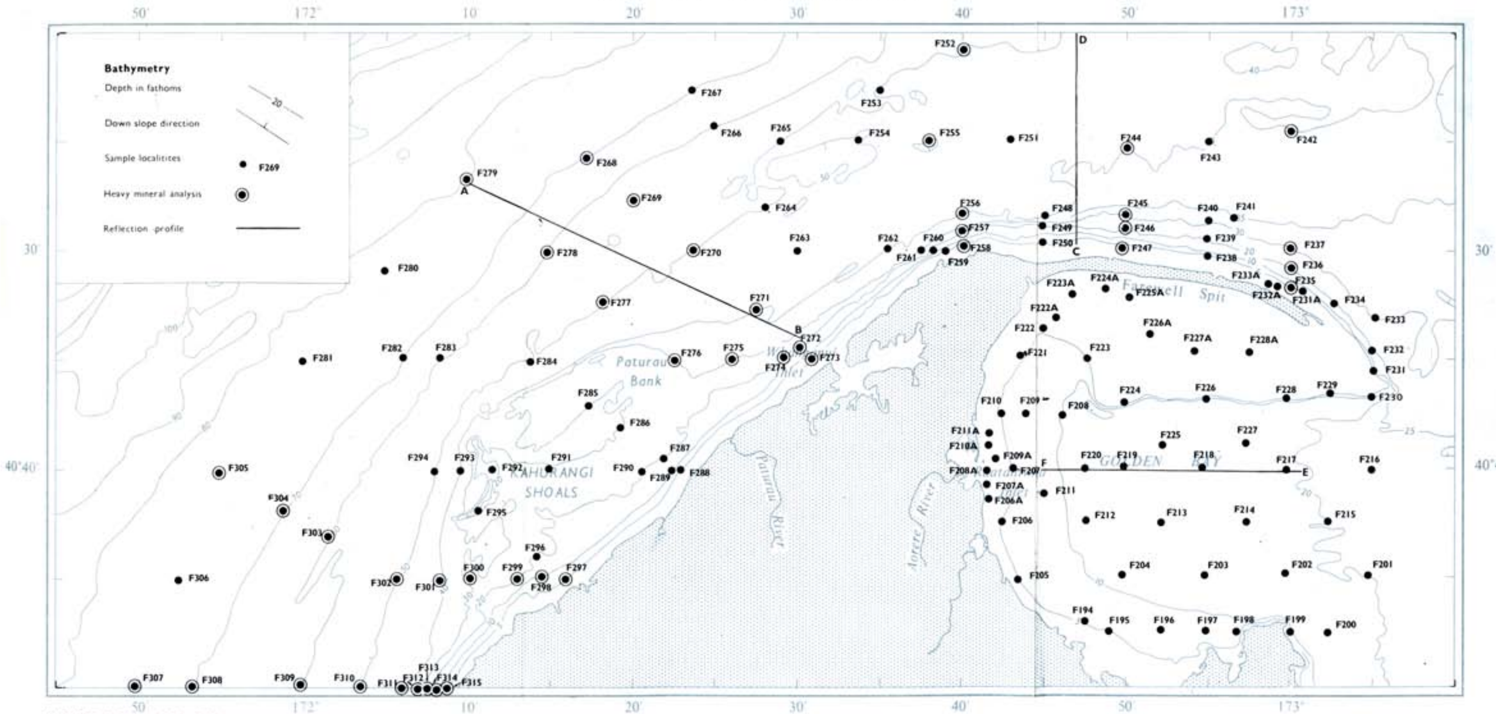
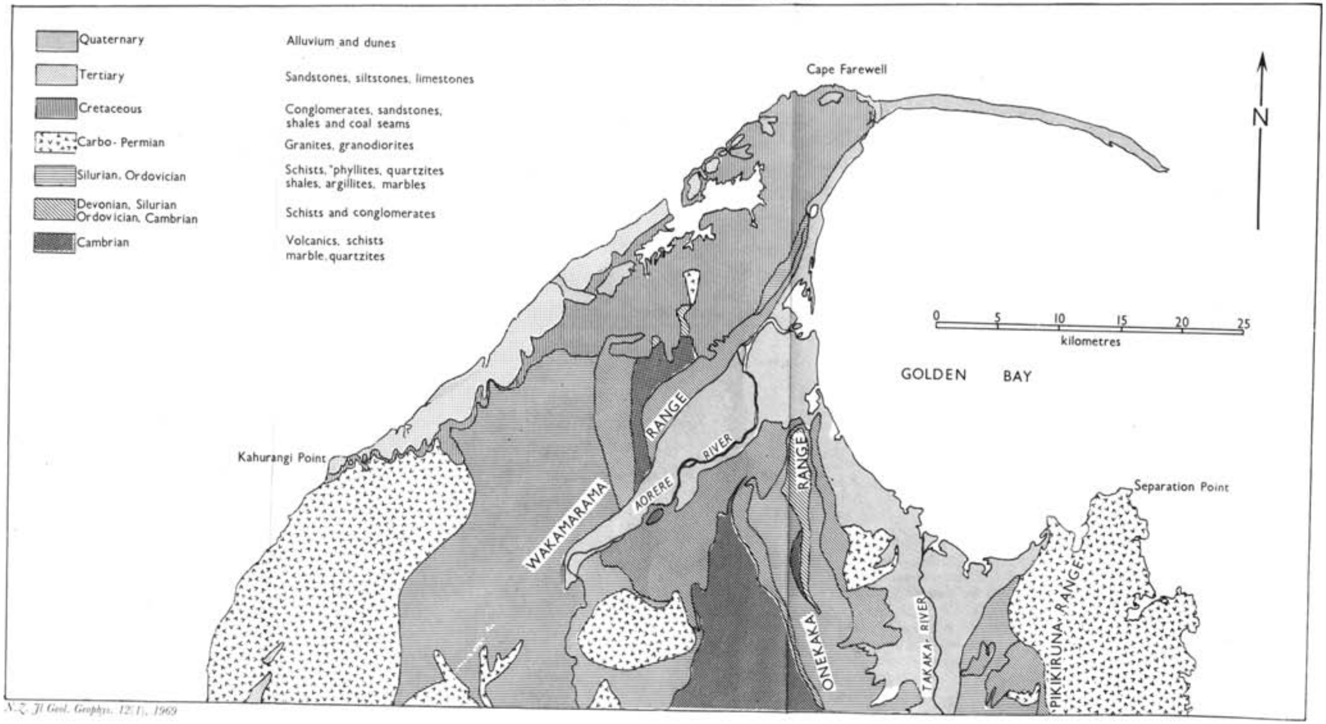


FIG. 1—Bathymetry (after Brodie, 1965)


Quaternary
Alluvium and dunes
Tertiary
Sandstones, siltstones, limestones
Cretaceous
Conglomerates, sandstones, shales and coal seams
Carbo- Permian
Granites, granodiorites
Silurian, Ordovician
Schists, phyllites, quartzites shales, argillites, marbles
Devonian, Silurian Ordovician, Cambrian
Schists and conglomerates
Cambrian
Volcanics, schists marble, quartzites
Cape Farewell
N
0 5 10 15 20 25
kilometres
GOLDEN BAY
Kahurangi Point
Separation Point
WAKAMARAMA
RANGE
AORERE RIVER
RANGE
ONEKAKA
TAKAKA RIVER
PIKIKIRUNA RANGE

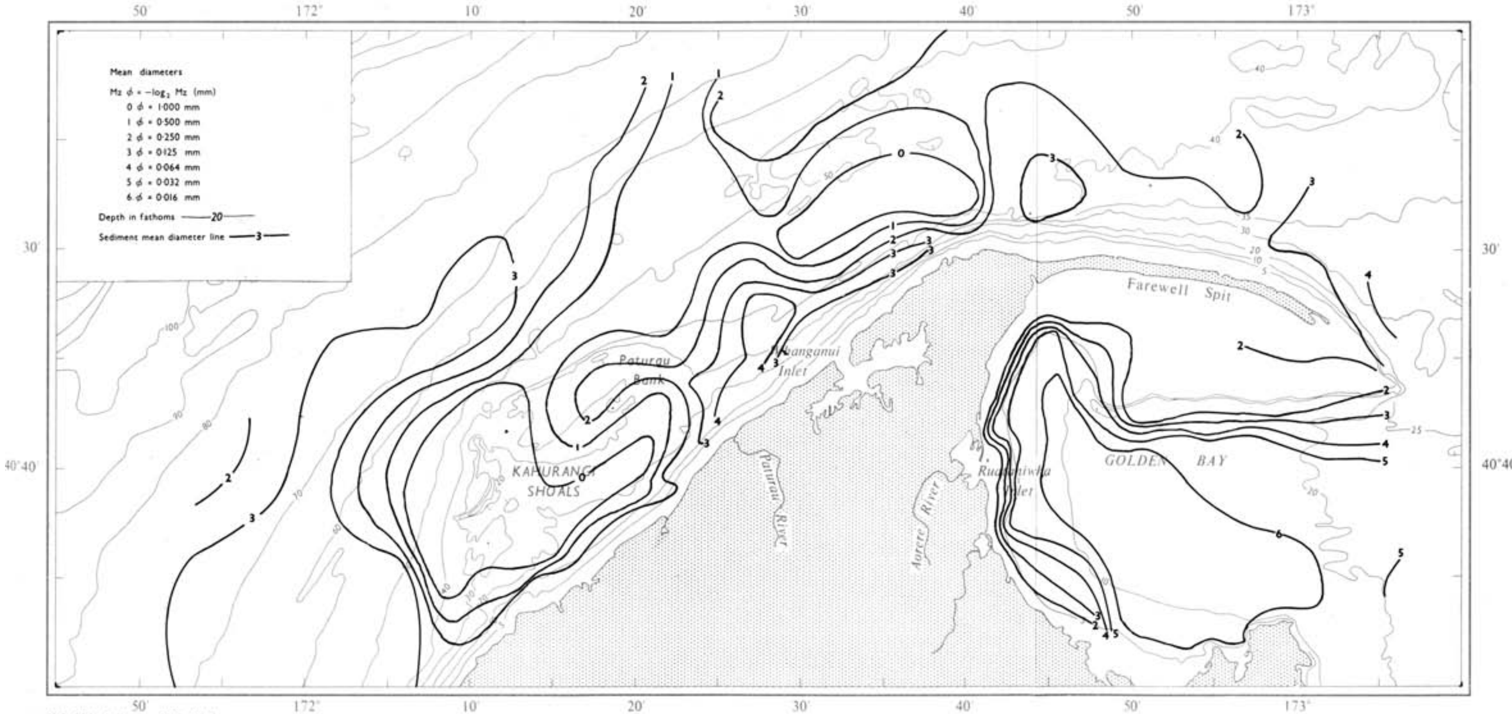


Fig. 3—Map showing mean sizes (in φ diameters) of bottom sediments.

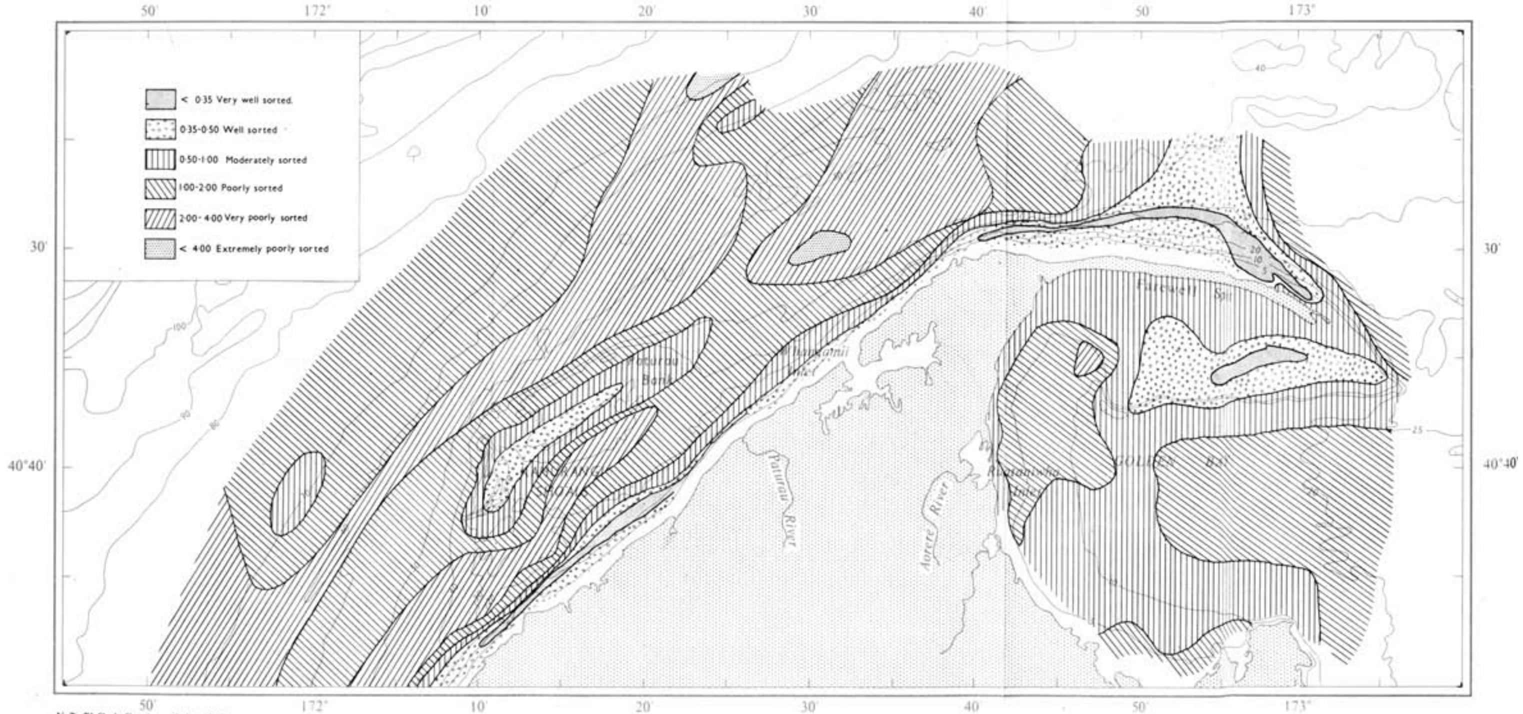


Fig. 4—Map showing standard deviations (in ϕ diameters) of the size frequency distributions.

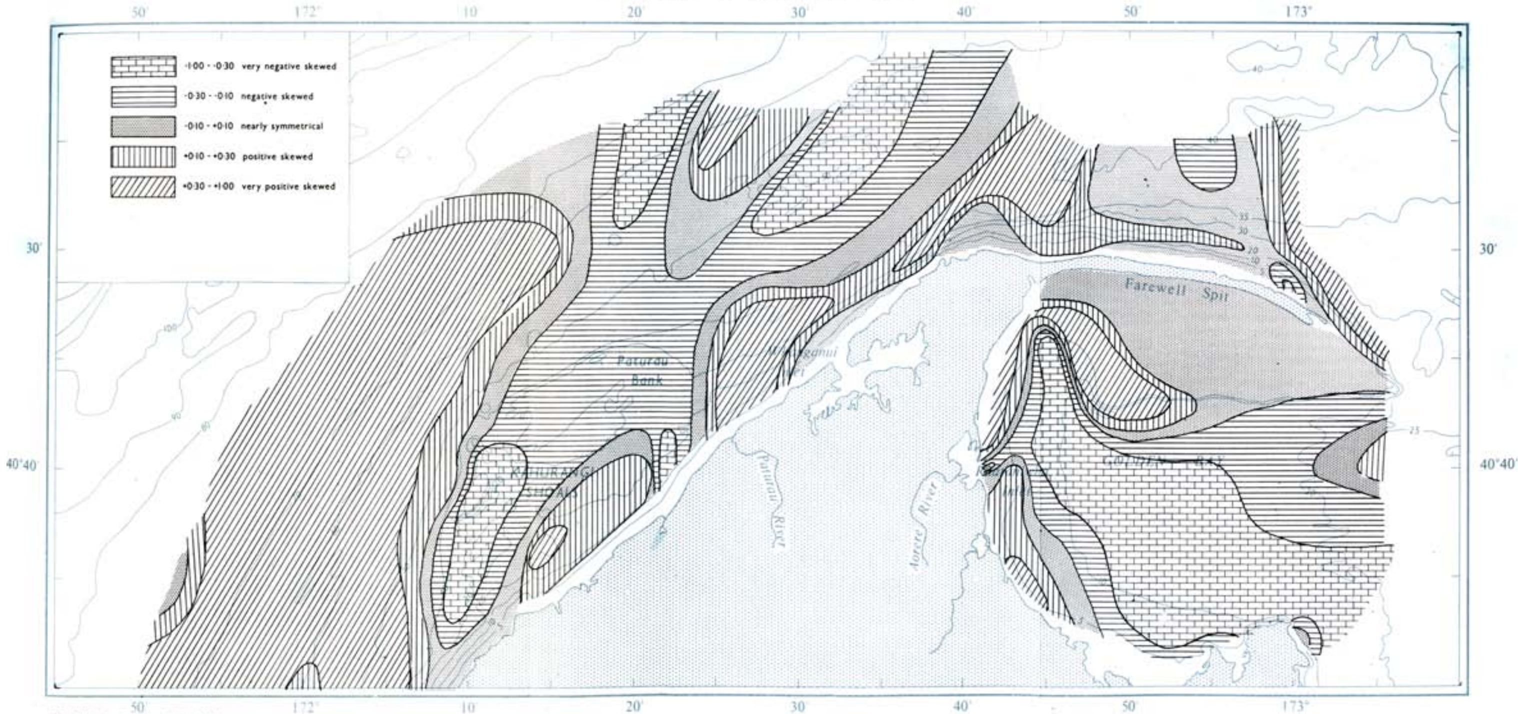


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Fig. 5—Map showing skewness measures (pure numbers) of the size frequency distributions. Negative and positive skewnesses indicate asymmetry of the frequency distributions towards the coarse and fine fractions respectively.

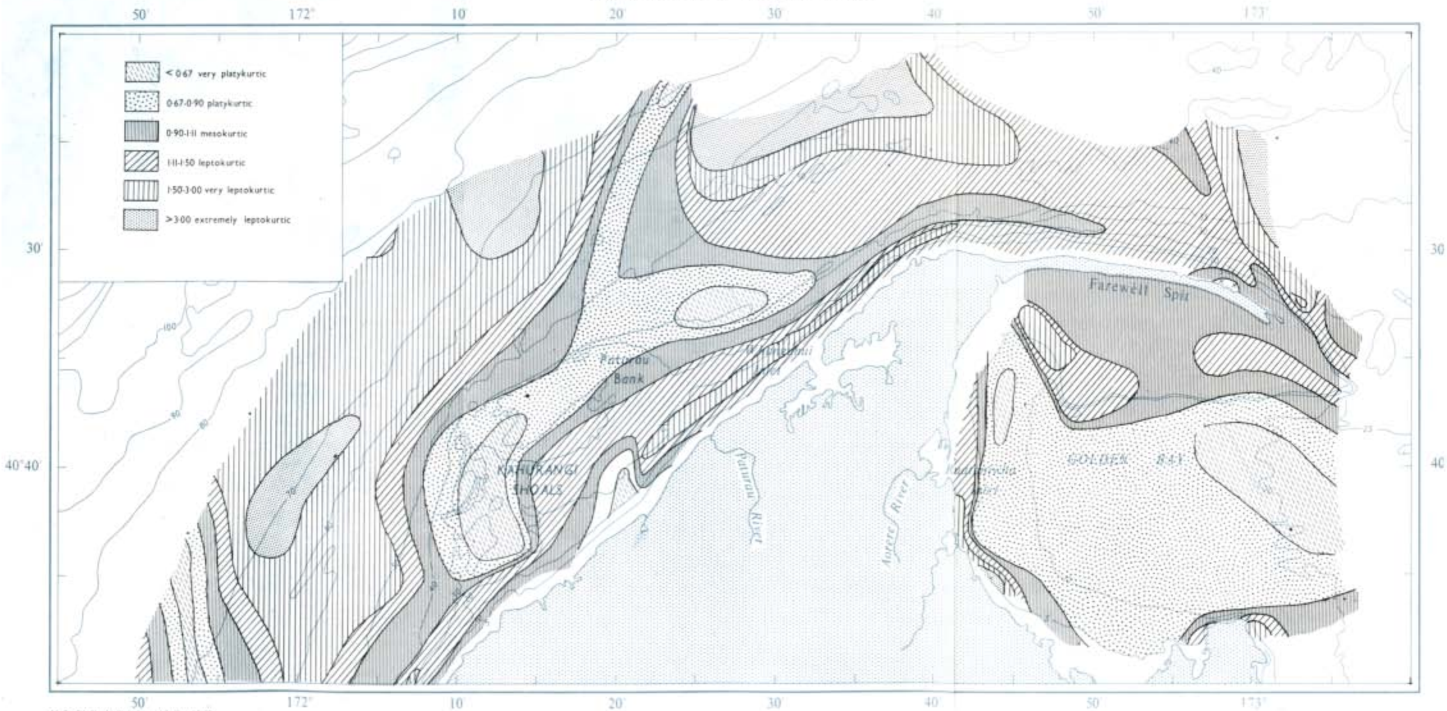

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Fig. 6—Map showing kurtosis (pure numbers) of the size frequency distributions. Platykurtosis and leptokurtosis indicate relatively poorer and better sorting respectively in the central parts of the frequency distributions than in the extremes.

TABLE 1—Textural Parameters and Classification of Shelf and Bay Sediments

Sample No.	Depth (m)	M_z	σ_i	Sk_i	K_g	Classification (based on Fig. 7)
F194	13	1·86	0·76	0·03	1·04	fine sand
F195	13	5·92	1·07	−0·13	0·78	silty pelite
F196	17	6·28	0·93	−0·34	0·82	silty pelite
F197	17	6·09	1·06	−0·29	0·81	silty pelite
F198	13	6·14	1·33	−0·54	1·19	silty pelite
F199	15	0·36	0·64	0·07	1·53	coarse sand
F200	33	5·78	1·57	−0·45	1·06	sandy pelite
F201	37	5·02	1·92	−0·36	0·86	sandy pelite
F202	31	6·24	0·98	−0·38	0·78	silty pelite
F203	26	6·24	0·97	−0·36	0·76	silty pelite
F204	22	6·35	0·90	−0·37	0·85	silty pelite
F205	9	2·32	0·95	0·34	3·24	fine sand
F206	9	4·98	1·30	0·19	0·78	sandy pelite
F206A	2	1·23	0·66	0·27	1·67	medium sand
F207	13	5·35	1·19	0·26	0·73	silt
F207A	1	1·54	0·83	−0·07	1·19	medium sand
F208	22	6·13	1·13	−0·46	0·79	silty pelite
F208A	1	0·47	0·82	−0·04	1·19	coarse sand
F209	15	5·78	1·20	−0·14	0·67	silty pelite
F209A	3	−0·07	1·21	−0·38	1·48	coarse sand
F210	11	4·81	1·29	0·30	1·15	sandy pelite
F210A	3	1·57	1·01	0·39	1·44	medium sand
F211	20	6·22	0·94	−0·29	0·74	silty pelite
F211A	2	4·35	0·98	0·34	1·38	sandy pelite
F212	24	6·19	0·97	−0·29	0·78	silty pelite
F213	30	6·14	1·04	−0·33	0·74	silty pelite
F214	35	5·98	1·15	−0·30	0·75	silty pelite
F215	40	5·72	1·29	−0·27	0·57	silty pelite
F216	42	5·08	1·50	0·16	0·69	sandy pelite
F217	38	5·58	1·36	−0·11	0·67	silty pelite
F218	35	5·91	1·23	−0·34	0·71	silty pelite
F219	31	6·36	0·93	−0·42	0·86	silty pelite
F220	26	6·21	1·05	−0·43	0·89	silty pelite
F221	12	5·27	1·35	0·13	0·72	sandy pelite
F222	15	5·89	1·41	−0·50	0·74	silty pelite
F222A	6	1·62	0·95	0·38	2·40	medium sand
F223	17	3·41	2·05	0·78	2·39	fine sand
F223A	3	1·69	0·59	0·01	0·99	medium-fine sand
F244	15	1·18	0·44	0·17	1·14	medium sand
F244A	1	1·72	0·52	0·00	0·99	medium-fine sand
F225	31	5·82	1·23	−0·27	0·68	silty pelite
F225A	1	1·67	0·55	0·00	0·99	medium-fine sand
F226	11	1·58	0·43	0·05	1·06	medium sand
F226A	1	1·74	0·43	−0·02	0·99	medium-fine sand
F227	35	5·58	1·35	−0·12	0·67	silty pelite
F227A	2	1·74	0·50	0·04	1·06	medium-fine sand

continued . . .

TABLE 1—*continued*

Sample No.	Depth (m)	M_z	σ_i	Sk_i	K_g	Classification (based on Fig. 7)
F228	9	1·51	0·53	−0·10	0·84	medium sand
F228A	3	2·00	0·29	0·02	1·44	fine sand
F229	15	1·70	0·68	−0·10	0·96	fine-medium sand
F230	13	1·96	0·54	−0·17	1·20	fine sand
F231	18	2·03	0·44	−0·01	1·00	fine sand
F231A	5	2·33	0·35	−0·06	0·92	fine sand
F232	45	3·58	1·73	0·68	1·23	fine sand
F232A	1	2·14	0·57	−0·49	1·01	fine sand
F233	55	4·03	1·77	0·66	1·06	very sandy pelite
F233A	6	2·29	0·34	−0·06	0·78	fine sand
F234	31	3·00	0·99	0·37	1·96	fine sand
F235	9	2·43	0·34	−0·12	1·38	fine sand
F236	29	2·84	0·46	0·01	1·06	fine sand
F237	60	3·09	1·19	0·76	2·96	fine sand
F238	9	2·41	0·35	−0·12	1·33	fine sand
F239	38	2·57	0·36	0·12	1·42	fine sand
F240	57	2·48	0·34	0·01	1·49	fine sand
F241	66	2·00	0·42	0·01	1·15	fine sand
F242	79	2·43	1·04	0·44	3·42	fine sand
F243	75	1·82	0·39	−0·19	1·03	fine sand
F244	77	1·73	0·57	−0·03	1·31	fine-medium sand
F245	57	2·44	0·35	−0·06	1·40	fine sand
F246	31	2·65	0·36	0·17	1·01	fine sand
F247	11	2·63	0·45	−0·02	1·47	fine sand
F248	73	3·61	1·94	0·56	0·91	very sandy pelite
F249	31	2·55	0·31	0·12	1·41	fine sand
F250	13	2·63	0·41	0·24	1·46	fine sand
F251	84	2·15	1·57	0·54	2·37	medium sand
F252	91	1·72	3·72	−0·27	1·28	gravelly sand (fine)
F253	97	1·77	2·23	−0·38	3·94	gravelly sand (fine)
F254	93	0·26	2·27	−0·58	1·59	gravelly sand (medium)
F255	90	0·71	2·21	−0·19	1·63	gravelly sand (medium)
F256	77	−0·26	3·01	−0·01	0·97	gravelly sand
F257	37	1·89	0·46	0·09	1·64	fine sand
F258	13	2·51	0·35	0·03	1·40	fine sand
F259	13	2·39	0·37	−0·09	1·26	fine sand
F260	42	2·44	0·60	0·20	1·78	fine sand
F261	60	3·04	1·38	0·59	1·84	fine sand
F262	77	2·25	3·52	0·01	1·11	gravelly sand
F263	82	0·77	4·12	−0·12	1·26	gravel-sand
F264	97	1·13	1·15	−0·49	1·21	medium-fine sand
F265	101	2·63	1·20	0·28	3·54	fine sand
F266	124	2·71	0·92	0·48	3·18	fine sand
F267	135	0·07	5·09	−0·64	0·62	gravelly sand
F268	135	2·80	1·35	0·02	2·69	fine sand
F269	110	0·47	3·44	−0·42	0·72	gravelly sand (fine)
F270	99	0·78	2·82	−0·09	1·03	gravelly sand

TABLE 1—*continued*

Sample No.	Depth (m)	M_z	σ_i	Sk_i	K_g	Classification (based on Fig. 7)
F271	77	4·28	1·85	0·59	0·54	very sandy pelite
F272	38	2·68	0·55	0·33	1·63	fine sand
F273	11	2·45	0·37	−0·07	1·49	fine sand
F274	42	2·92	0·86	0·43	2·40	fine sand
F275	59	3·86	1·88	0·74	1·18	fine sand
F276	53	1·53	0·65	−0·12	0·97	medium-fine sand
F277	93	0·33	3·36	−0·21	0·88	gravelly sand (fine)
F278	121	2·79	1·01	0·36	2·98	fine sand
F279	152	2·79	1·41	−0·07	3·20	fine sand
F280	146	2·17	1·44	0·43	1·42	medium-fine sand
F281	141	2·72	1·54	0·52	1·95	fine sand
F282	132	3·88	1·45	0·73	2·39	fine sand
F283	110	3·29	1·49	0·60	2·61	fine sand
F284	90	0·58	3·10	−0·22	0·94	gravelly sand (fine)
F285	55	2·26	0·36	−0·12	0·83	fine sand
F286	57	0·74	2·37	−0·10	1·30	gravelly sand
F287	42	1·35	1·44	−0·43	2·23	fine-medium sand
F288	15	2·00	0·16	0·00	0·74	fine sand
F289	27	2·73	0·42	0·03	1·08	fine sand
F290	42	0·29	0·76	0·20	0·65	gravel-sand
F291	59	0·24	2·15	−0·17	1·22	gravelly sand
F292	38	......	......	......	......	2 pebbles
F293	82	−1·05	1·35	−0·10	0·83	gravel-sand
F294	93	−1·36	1·07	0·15	0·88	gravel-sand
F295	24	......	......	......	......	no sample (gravel?)
F296	37	−1·66	2·28	0·33	0·67	gravel-sand
F297	13	2·65	0·40	0·06	1·03	fine sand
F298	24	2·63	0·33	0·16	1·06	fine sand
F299	40	0·44	1·64	0·04	1·17	gravelly sand (coarse)
F300	53	0·07	3·36	−0·32	0·80	gravelly sand
F301	77	−1·88	3·02	−0·37	1·10	sandy gravel
F302	93	3·63	1·60	0·64	2·64	fine sand
F303	110	3·61	2·04	0·47	1·82	fine sand
F304	124	3·16	0·86	0·50	3·29	fine sand
F305	143	1·88	1·78	0·42	2·02	medium-fine sand
F306	146	3·05	3·37	−0·06	0·63	gravelly-sandy pelite
F307	137	2·44	2·26	0·54	1·43	medium sand
F308	132	3·30	2·59	0·45	0·57	very sandy pelite
F309	112	3·36	1·79	0·27	1·72	fine sand
F310	97	3·69	2·14	0·38	1·08	fine sand
F311	77	3·76	1·98	0·45	1·09	very sandy pelite
F312	53	2·63	0·45	0·23	1·53	fine sand
F313	37	2·52	0·39	0·01	1·46	fine sand
F314	18	2·98	0·40	−0·02	1·17	fine sand
F315	11	2·41	0·42	−0·03	1·08	fine sand

TABLE 2—Heavy Mineral Association off North-West Nelson

Sample number	Opaque	Alterite	Transparent	Ubiquitous			Amphibole Group						Pyroxene Group						
				Garnet	Zircon	Tourmaline	Hornblende	Basaltine	Glaucophane	Tremolite-Actinolite	Riebeckite	Σ Amphibole	Augite	Diopside	Aegirine-Augite	Spodumene	Hypersthene	Enstatite	Σ Pyroxene
F235	8·3	66·4	25·3	25	..	1	10	23	2	4	1	40	3	..	4	5	2	1	15
F236	13·1	44·7	42·2	19	..	..	14	24	..	..	..	39	1	1	1	..	..	..	3
F237	6·3	60·5	33·2	24	..	..	23	37	..	..	..	60	2	..	..	..	..	1	3
F242	15·6	21·9	62·5	54	..	2	12	6	..	..	..	18	2	..	..	2	3	..	7
F244	11·9	8·7	79·4	76	3	..	2	6	..	1	..	9	2	..	1	..	..	1	4
F245	17·7	47·6	34·7	33	1	2	14	31	..	..	..	45	1	2	1	..	..	..	4
F246	9·6	46·9	43·5	50	..	..	22	14	..	1	..	37	..	..	..	..	2	..	2
F247	20·0	54·0	26·0	53	..	..	7	24	..	..	..	31	2	..	..	..	..	..	2
F252	33·5	10·6	55·9	60	4	1	5	4	..	..	..	9	3	1	2	..	..	..	6
F255	13·3	20·0	66·7	76	4	..	4	2	..	1	..	7	..	1	2	1	2	..	6
F256	20·1	27·0	52·9	61	1	..	6	9	..	1	..	16	..	..	1	..	1	..	2
F257	9·5	54·0	36·5	47	..	2	9	24	..	1	..	34	1	..	2	..	..	..	3
F258	13·9	51·4	34·7	39	1	..	18	32	..	..	..	50	3	..	..	..	..	..	3
F268	25·0	20·7	54·3	58	1	1	4	6	4	..	..	14	..	2	..	3	..	..	6
F269	16·2	33·0	50·8	49	1	1	7	13	1	2	..	23	..	3	..	2	..	1	6
F270	28·9	15·6	55·5	74	2	1	2	3	..	..	..	5	..	1	..	..	..	..	1
F271	34·6	19·4	46·0	48	5	..	3	4	7	..	..	14	1	..	..	1	3	..	5
F272	5·7	62·4	31·9	14	1	..	10	29	1	3	..	43	5	2	1	2	3	1	14
F273	9·4	62·2	28·4	36	..	1	18	15	..	3	..	36	2	..	4	..	..	1	7
F273	9·4	62·2	28·4	36	..	1	18	15	..	3	..	36	2	..	4	..	..	1	7
F274	5·6	61·4	33·0	10	1	1	15	15	2	1	..	33	1	1	2	1	2	2	10
F275	41·1	18·6	40·3	53	3	..	6	10	..	1	..	17	2	2	1	..	1	..	6
F276	21·1	27·3	51·6	48	1	..	7	12	1	4	1	25	2	1	..	..	2	..	5
F277	35·3	10·3	54·4	59	4	1	3	10	..	3	1	17	1	..	3	1	..	..	5
F278	15·3	30·1	54·6	42	1	1	9	21	1	2	1	34	..	2	..	1	..	..	3
F279	12·8	26·2	61·0	27	..	1	16	5	..	..	..	21	..	..	..	..	1	..	1
F297	21·7	40·8	37·5	46	..	..	3	18	..	1	..	22	1	1	4	2	2	..	10
F298	8·4	62·5	29·1	26	..	1	5	28	..	4	2	39	..	1	3	1	3	1	9
F299	18·7	36·9	44·4	52	1	..	6	15	..	..	..	21	2	..	..	..	1	..	3
F300	10·0	44·5	45·5	61	1	..	4	12	..	1	..	17	2	4	2	..	1	1	10
F301	8·5	30·9	60·6	55	2	..	4	12	..	3	1	20	1	1	1	1	1	..	5
F302	25·8	21·6	52·6	70	3	..	4	5	..	3	1	13	..	1	1	1	2	..	5
F303	24·1	22·5	53·4	58	1	1	8	11	..	2	..	21	1	..	..	2	..	..	3
F304	12·8	37·9	49·3	52	2	2	5	12	..	1	2	20	1	..	2	1	1	..	5
F305	14·1	18·8	67·1	67	3	..	4	9	..	3	..	16	2	1	..	..	1	2	6
F307	29·0	26·3	44·7	45	..	..	20	19	..	..	..	39	..	..	1	..	1	..	2
F308	30·7	22·7	46·6	62	6	2	5	11	..	2	..	18	1	1	..	..	1	..	3
F309	52·8	4·3	42·9	58	22	..	7	2	..	..	..	9	4	..	..	..	..	..	4
F310	49·2	14·2	36·6	67	8	2	9	4	..	1	..	14	2	..	..	..	1	..	3
F311	28·0	27·6	44·4	38	2	1	20	9	1	2	..	32	..	..	..	..	..	1	1
F312	14·0	58·2	28·0	20	..	..	23	30	..	2	..	55	3	2	1	..	2	..	8
F313	13·2	60·3	26·5	20	1	..	16	35	..	..	..	51	3	2	1	..	2	..	8
F314	35·1	23·5	41·4	80	1	..	6	4	..	..	..	10	..	..	..	..	..	..	..
F315	12·2	50·9	36·9	47	1	..	24	3	2	3	..	32	..	..	..	..	..	..	..

Epidote Group		Phyllo silicates							Sediment characteristics		
Epidote s.s.	Σ Epidote	Chlorite group	Biotite	Σ Phyllosilicates	Kyanite	Andalusite	Titanite	Rest	Dominant Grades	M_z	σ_i
7	7	2	..	2	4	2	1	3	fine sand ..	2·43	0·34
21	21	1	2	3	2	5	..	7	fine sand ..	2·84	0·46
1	1	1	..	1	7	1	3	..	fine sand ..	3·09	1·19
12	12	..	..	..	2	3	..	2	fine sand ..	2·43	0·35
6	6	..	..	..	..	..	1	1	fine-medium sand	1·73	0·57
6	7	..	..	..	3	..	3	2	fine sand ..	2·44	0·35
6	7	..	..	..	1	..	2	1	fine sand ..	2·65	0·36
9	9	..	..	..	..	..	5	..	fine sand ..	2·63	0·45
9	9	..	..	..	1	7	..	3	gravelly sand ..	1·72	3·72
3	3	1	1	2	..	..	..	2	gravelly sand ..	0·71	2·21
9	10	..	..	..	..	5	..	5	gravelly sand	—0·26	3·01
5	5	1	..	1	2	..	6	..	fine sand ..	1·89	0·46
4	4	..	..	..	..	..	3	..	fine sand ..	2·51	0·35
10	12	1	..	1	3	2	1	1	fine sand ..	2·80	1·35
10	10	2	1	3	1	2	2	2	gravelly sand ..	0·47	3·44
10	10	..	..	..	3	1	..	3	gravelly sand ..	0·78	2·82
7	8	1	..	1	6	6	..	7	silt-sand ..	4·28	1·85
8	8	6	1	7	2	10	..	1	fine sand ..	2·68	0·55
5	5	..	..	..	4	4	2	5	fine sand ..	2·45	0·37
5	5	..	..	..	4	4	2	5	fine sand ..	2·45	0·37
7	7	13	11	25	11	1	..	1	fine sand ..	2·92	0·86
7	7	1	..	1	3	1	..	8	silty sand ..	3·86	1·88
13	13	..	..	..	..	2	..	6	medium-fine sand	1·53	0·65
5	7	..	..	..	2	..	1	4	gravelly sand ..	0·33	3·36
10	10	..	..	..	4	2	..	3	fine sand ..	2·79	1·01
20	21	1	..	1	8	10	..	10	fine sand ..	2·79	1·41
8	9	..	..	..	7	2	1	3	fine sand ..	2·65	0·40
15	15	1	..	1	3	2	..	4	fine sand ..	2·63	0·33
9	9	3	..	3	2	3	1	5	coarse sand ..	0·44	1·64
7	7	..	..	..	1	..	..	3	gravel-boulders..	0·07	3·36
5	8	..	..	..	3	1	..	6	gravel-boulders..	1·88	3·02
3	4	..	..	..	2	1	..	2	fine sand ..	3·63	1·60
10	10	..	..	..	..	1	2	3	fine sand ..	3·61	2·04
8	9	..	1	1	2	1	2	3	fine sand ..	3·16	0·86
3	3	..	..	..	1	2	2	..	medium sand ..	1·88	1·78
4	4	2	..	2	..	..	5	1	medium sand ..	2·44	2·26
5	5	..	..	..	..	..	3	1	medium sand ..	3·30	2·59
3	3	1	..	1	..	..	3	..	fine sand ..	3·36	1·79
5	5	..	..	..	..	..	1	..	fine sand ..	3·69	2·14
24	24	1	..	1	1	..	..	..	fine sand ..	3·76	1·98
4	4	1	..	1	5	1	5	1	fine sand ..	2·63	0·45
5	9	3	..	3	2	1	3	2	fine sand ..	2·52	0·39
6	6	..	..	..	1	..	2	..	fine sand ..	2·98	0·40
18	20	..	..	..	..	..	..	..	fine sand ..	2·41	0·42

The transparent group has garnet and amphibole as main constituents averaging respectively 48% and 26% with basaltine (basaltic hornblende) dominant over normal hornblende. Their totals per sample range from 43% to 90% with an average of 74%. Epidote (including zoisite) and pyroxenes, mainly augite and diopside, are present as minor constituents averaging 9% and 5% respectively. Wherever zircon, andalusite, and mica form a fair proportion of the total assemblage they have also been included in Fig. 9. The heavy mineral assemblage over the western and northern shelf off Nelson can thus be characterised as a magnetite-ilmenite-garnet-hornblende association.

From the mineralogical composition it can be concluded that the sediments are derived from igneous and metamorphic series which is not surprising considering the geology of the South Island. Because of the presence of basaltine augite and diopside it seems that the source area must contain a fair amount of subsilicic igneous rocks such as, for instance, gabbro, basalt, olivine-gabbro, and peridotite.

As for the regional distribution of the heavy minerals there are only a few instances where correlation with the textural anomalies is evident.

The Buller River Belt has a relatively high proportion of zircon and magnetite. The high percentage of zircon (F309, 22%) may, however, significantly be the result of granular variation rather than be caused by an overall difference in mineralogical composition.

Samples F274 and F272 contain both more biotite and chloritic matter than found in the other samples, and this may be accounted for by their position off Whanganui Inlet.

The most obvious correlation with texture occurs in the breaker zone. In this zone of very fine well sorted sands the percentages of opaque and transparent minerals are markedly low and consequently the alterite content is high. In the transparent group the amphiboles are dominant over garnet. As the hornblendes are relatively lighter but larger than the garnets the plausible explanation for the correlation seems to be selective granular variation in the zone of higher energy.

In conclusion it can be said that the average low variance in composition of the heavy minerals in the medium and fine sand fraction in the area indicates that the sediments derived from local sources produce petrological anomalies only where they contribute to the very fine or very coarse clastics. They have no marked influence on the composition and distribution of the fine and medium sands.

Golden Bay

In the classification diagram, Fig. 7B, the bay sediments group together in four distinct areas each of which has its own textural characteristics.

(1) The shallow area immediately south of Farewell Spit which partly dries during low tide is occupied by fine and medium sands. As in the case of the area north of the Spit these are mainly wind-blown sands derived from the Spit. The aeolian sands in the bay are on average coarser and cover a much wider area than those accumulated north of the Spit because northerly winds prevail and because, once deposited, these sands are better sheltered in the bay than in Cook Strait.

Log-normal size frequency curves and moderate to very good sorting coefficients once again point to a mature sediment association. The very high sorting grades in the area below the low-water mark show the influence of breaking waves which have lost their impetus nearer the Spit where less well sorted sands occur. Between the low-water mark and approximately 5 m (2·7 fm) the sands are partly mixed with coarser sediments derived from the Aorere River (cf. (2) below) as testified by relatively poorer sorting, positive skewness, and leptokurtosis.

(2) Off the Aorere River a zone of medium sands occurs grading into almost pure silts. It appears from the sorting, skewness, and kurtosis patterns off the river mouth that the coarser detritus is picked up by a clockwise rotating current which takes the sediment north, sweeps it over the flat south of the Spit and takes it out into Tasman Bay and Cook Strait. The finer grades are carried in suspension some distance and settle down in central Golden Bay where they mix with Takaka River suspension material.

(3) No samples were taken immediately off the Takaka River. It appears, however, from the skewness and kurtosis values that the bed load, the coarser river detritus, is transported north-westward following the coastline and that the finer suspension settles in the centre of the bay.

The central Golden Bay sediments are thus a mixture of Takaka and Aorere River suspension materials and form a moderately to poorly sorted association of silty muds which links in the east with a similar association derived from Tasman Bay. Under the influence of the D'Urville Current this zone of silty muds extends eastward over central Cook Strait (Fig. 11).

(4) In the south and west of Golden Bay near the coast, poorly sorted, positively skewed, and very leptokurtic sandy muds occur. They are the result of a mixing of coastal erosion products and detritus of the Takaka and Aorere Rivers carried by a clockwise rotating current.

Seismic Reflection Profiles (Fig. 10)

The position of the profiles is indicated in Fig. 1. In the text the travelling times of sound in water and sediment have been converted into depths below sea level and below bottom respectively, assuming the sound velocity in water to be 1·5 km/sec and in sediment to be 1·65 km/sec.

Thanks to favourable weather and sea conditions at the time when recordings were made, profile AB on the western shelf produced the best results in terms of penetration and resolution. The arrival of the first bottom multiple sets the penetration limit of the profile. Below this no first arrivals are discernible. Consequently, greatest penetration is found in deepest water and approximately 35 m (19 fm) marks the minimum operational depth of the equipment used.

Over most of the shelf down to a water depth of 120 m (66 fm) a sequence of parallel-bedded sediments occurs overlying a sequence of inclined-bedded sediments. The width of the parallel-bedded sequence increases outward, from 9 m in a water depth of 35 m (19 fm), to 18 m in a water depth of 120 m (66 fm). Some horizontal bedding is apparent, however, down to a depth of 28 m below the bottom in a water depth of approximately 80 m (44 fm). It appears from the character of the boundary between parallel- and inclined-bedded sediments that this represents an old peneplain formed during the Pleistocene while this part of today's shelf was above sea level.

Over a distance of approximately 3 km, in water depths from 120 m (66 fm) to 125 m (68 fm), the horizontal series disappears and sub-bottom folded strata reach the surface. On the western flank of these structures a strong reflection appears which cuts the underlying strata discordantly and marks an ancient surface. This surface, judged from its characteristics, might well represent a Pleistocene sea bed from the coast downward to a depth of 100 m below the present sea bottom at the end of the profile. This would imply that the present 125 m (69 fm) contour marks the Pleistocene shore line for this area. (It does not necessarily imply that since the Pleistocene sea level has risen 125 m, as diastrophic movements very likely have influenced the elevation with respect to sea level considerably.)

Below the Pleistocene surface, gently folded strata occur which, near the coast, have the same seaward dip as the Pareora and Landon series on land (Grindley, 1961). This suggests that these Oligocene series continue off shore. The implications of a fault-controlled coastline and a possible pre-Tertiary age for the Kahurangi Shoals, however, make it difficult to define the age of the off-shore folded strata with certainty.

Folding becomes more intense further off shore to culminate in two anticlinal structures of which the western one is broken by a number of normal faults and reaches the surface near the inferred Pleistocene shore line. On the eastern and western flanks respectively of this anticlinorium the strata dip gently coast- and sea-ward. The maximum apparent dip in the anticlinorium is 15°.

Half way between the present and Pleistocene shore line below the horizontal Holocene strata some channelling seems apparent, very likely representing the scour and fill action of Pleistocene streams.

Profile CD shows basically a parallel-bedded series down to a depth of 95 m below bottom at the end of the profile. Only near the Spit a wedge-shaped apron of sediments overlies parallel-bedded sediments underneath, and the top of the latter most likely indicates the Spit foundation, a Pleistocene peneplain. At the foot of the Spit apron over a distance of approximately 4 km gently undulating surface topography suggests the presence of a series of off-shore bars. They form a relatively thin veneer of sands of varying thickness with a maximum of 20 m at the crests of the bars.

Beyond this zone the Holocene sediments are parallel bedded and vary in thickness between 17 and 26 m over the length of the profile.

There are no sub-bottom reflectors in the profile indicating further changes in the depositional history on this part of the shelf.

Profile EF (not presented in Fig. 10) in Golden Bay shows a fairly monotonous sequence of parallel-bedded sediments. The resolution of individual layers is hampered greatly by the arrival of first and higher order multiples. Small discontinuities in the bedding are apparent but they do not justify speculation on long or short term changes in the depositional history of the bay.

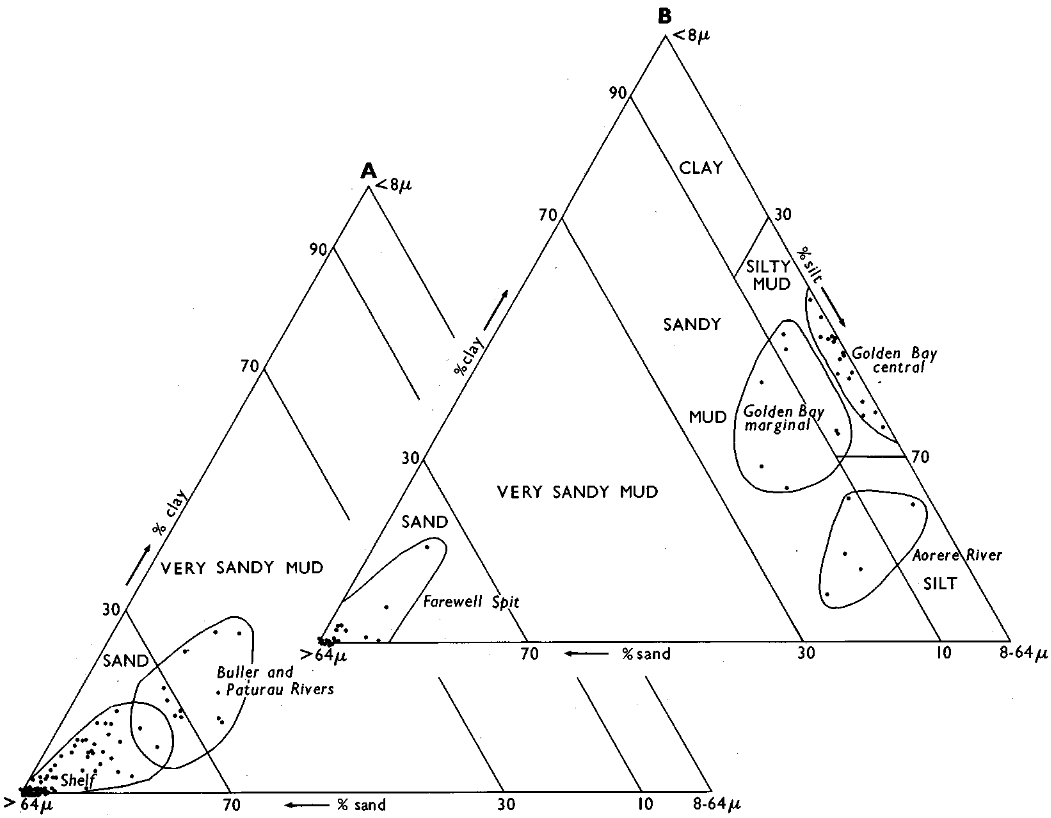

FIG. 7—Classification diagrams of sediments based on sand-silt-clay ratios. A—The western and northern shelf. B—Golden Bay.

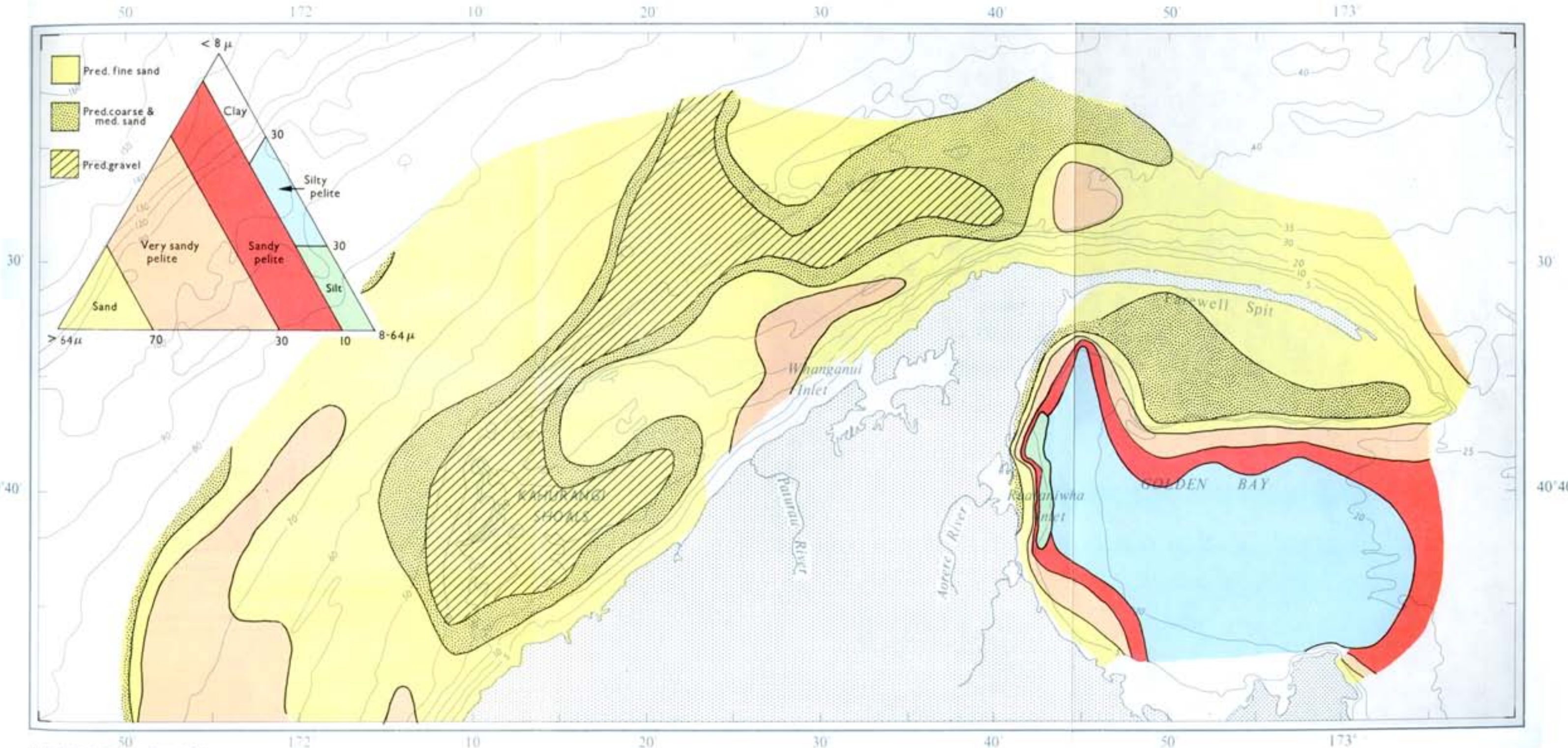

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Fig. 8—Sediment classes off North-West Nelson.

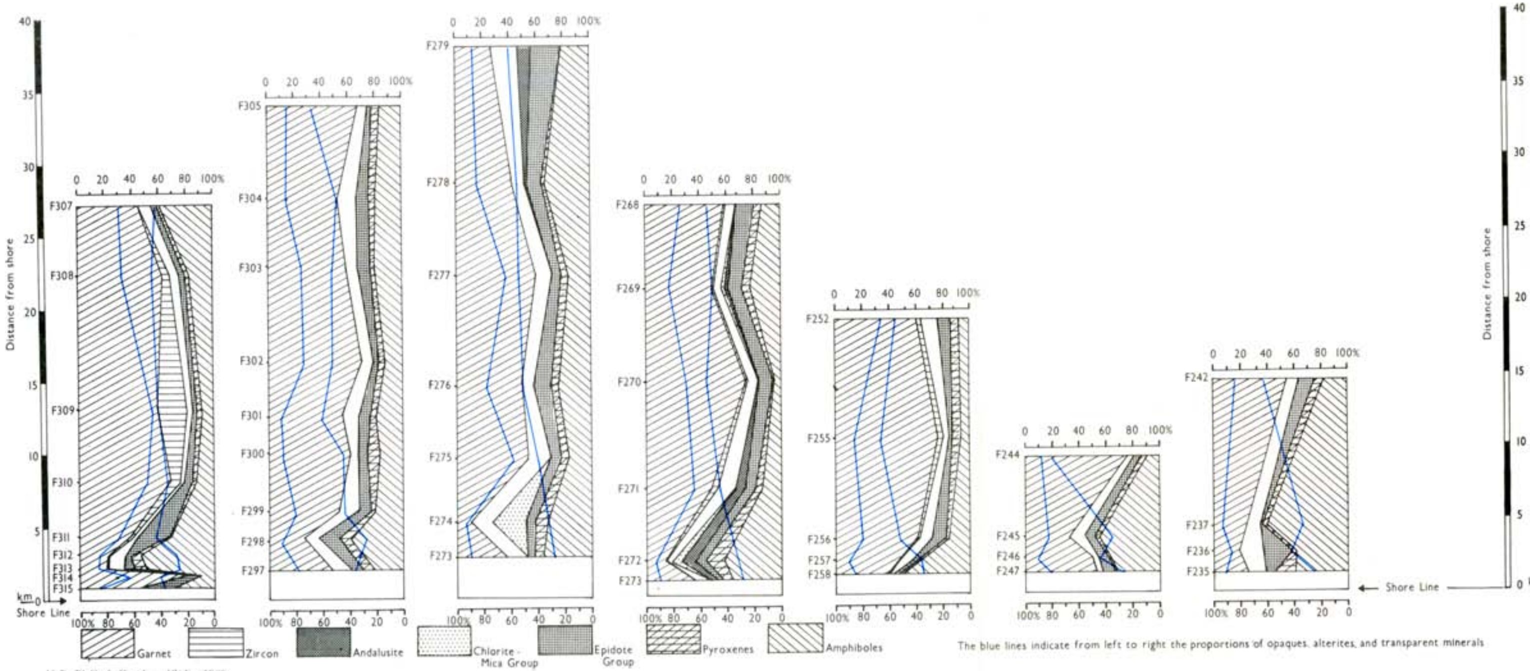

Fig. 9—Heavy mineral distribution of shelf sediments.

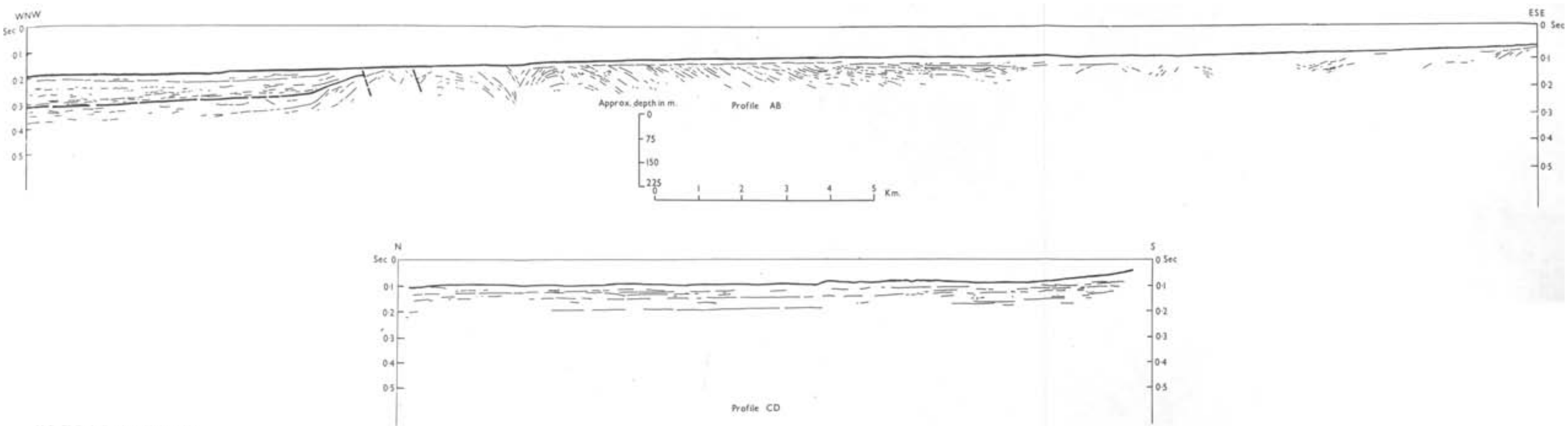

FIG. 10—Seismic reflection profiles. For position of profiles see Fig. 1.


MUD
MEDIUM AND FINE SAND
GRANULES AND COARSE SAND
COBBLES AND PEBBLES
DEPTH IN METRES
172°
173°
174°
175°
38°
39°
40°
41°
1500
1250
1000
750
500
250
100
NORTH ISLAND
North – West Nelson
SOUTH ISLAND

Sediment Transport and Rates of Sedimentation

The Westland and D'Urville Currents are the dominant water circulation patterns off the Nelson Province. Annually the Westland Current carries several million tons of detritus derived from the Southern Alps. The rate of sedimentation on the western shelf can be calculated as follows:

A conservative estimate indicates that approximately 5,000,000 cu yd of sediment passes northward annually over the shelf off Cape Foulwind (Furkert, 1947). To this amount must be added the products from coastal erosion and the sediment carried to sea by the Buller River and by the many other smaller rivers and creeks between Cape Foulwind and Cape Farewell.

From the present study and also from the sediment distributions on the shelf west of New Zealand (Fig. 11), it appears that this total of some 6–7,000,000 cu yd is swept mainly into Cook Strait. Part of it may be carried northward, however, to be deposited at the shelf edge in water depths of approximately 250 m (140 fm). According to Furkert (1947) some 4,500,000 cu yd is added annually to Farewell Spit. If one assumes that the rest is evenly distributed over the western shelf and Cook Strait then the rate of sedimentation in this area can be estimated to amount to 10–20 cm at the most per 1,000 yr. Judged from the reflection profiles this figure seems to be too low by a factor of at least 5, as in the last 19,000 yr (Shepard, 1963) some 10–20 m of sediments appear to have accumulated over the western shelf off Nelson down to at least 150 m (82 fm).

This means that either Furkert's estimates are far too low, that the Buller, Paturau, and other rivers supply several tens of millions of tons of detritus to the shelf or that the depositional area is much more restricted than anticipated.

Future seismic reflection studies in the Cook Strait area may provide substantial information to enable a more accurate estimate of rates of deposition. However, it seems clear from the present study that for the western shelf of the South Island, rates of sedimentation are high compared with those over other shelf areas.

As for the transport directions of sediment, drift card observations confirm the existence of longshore drift over the shelf and a clockwise current rotation in Golden Bay (Heath, 1969).

Sediments on the Western Shelf, Central New Zealand

To show the relationship of the sediment distribution off North-West Nelson with the sediment distribution over the western shelf off central New Zealand Fig. 11 was prepared. This figure is a compilation of dominant sediment size parameters taken from a number of sediment charts which are based on data from a variety of sources and of a varying degree of reliability (McDougall and Gibb, in press, a, b, c; van der Linden and Gibb, in press, a, b). The discrepancies in notation of this figure with the notation of Fig. 8 are a matter of detail only.

Down to approximately 250 m (140 fm), the upper edge of the continental slope, the shelf is occupied mainly by fine and very fine sands with the exception of a central mud zone west of Cape Egmont and another mud zone in Cook Strait. The occurrence of the fine sediments in the central mud zone may reflect relative low water velocities in this particular area. However, they may also be partly relict sediments deposited in a former "Egmont Gulf" (McDougall and Brodie, 1967).

The Cook Strait muds have been derived from suspension material from both the Nelson area and from North Island rivers discharging into the South Taranaki Bight. They have been deposited under present-day conditions. Because of high tidal current velocities in the narrow part of Cook Strait no muds are deposited in this area and the sands and gravels here are winnowed deposits.

Towards the outer shelf, a belt of sand occurs which most likely reflects sedimentation processes during a lower stand of sea level. The sudden break in slope, however, may give rise to considerable water turbulence which perhaps in combination with a north-flowing branch of the Westland Current may suffice to remove all previously deposited silt and mud. On the continental slope and in deeper water pelagic sedimentation becomes dominant and here foraminiferal oozes occur.

The belt of coarse clastics north-west of Taranaki is most certainly associated with the occurrence of submarine volcanics in line with and belonging to the same suite as the Egmont Quaternary volcanics.

In central South Taranaki Bight and in small pockets off the Marlborough and Wellington coasts, circumstances have been favourable for the development of shell beds giving rise to local very high carbonate concentrates in the sediment.

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