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DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH

BULLETIN 179

SEDIMENTS OF THE WESTERN SHELF, NORTH ISLAND, NEW ZEALAND

by
J. C. McDOUGALL and J. W. BRODIE
New Zealand Oceanographic Institute
Wellington

New Zealand Oceanographic Institute
Memoir No. 40

1967

Photo: Whites Aviation Ltd.

The western coastline from Pariokariwa Point (right foreground) to New Plymouth. Mount Egmont n background. Late Pleistocene marine terraces in foreground (Coastal Type V).

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PREFACE

THE western continental shelf of New Zealand has, until recently, been the least known of the marginal shallow water areas around the coastline. Over the last three years a programme of sediment sampling has been carried out on part of the western shelf of the North Island. The area is large, extending from Wanganui to Kaipara, and the results have enabled the presentation in this memoir of a preliminary analysis of the nature and distribution of the surface and subsurface sediments.

Three charts which detail sediments of the western shelf are being published separately.

The manuscript has been prepared for publication by Mrs P. M. Cullen.

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SEDIMENTS OF THE WESTERN SHELF, NORTH ISLAND, NEW ZEALAND

by

J. C. McDougall and J. W. Brodie

ABSTRACT

Sediments at the surface of the western shelf between Kaipara and Wanganui can be separated into zones in each of which one grain size is dominant. For the shelf north of Cape Egmont an Inner Very Fine Sand Zone extending out to 25 fm is succeeded by a Fine Sand Zone out to 50 fm, then by an Outer Very Fine Sand Zone to the shelf edge. South and west of Cape Egmont an extensive Mud Zone occupies most of the shelf except an inshore area, south of Cape Egmont, in which sediments possessing a coarser dominant grade are found.

The available sediment for deposition at present is mud and the coarser grades present offshore are relict from earlier sedimentary phases of late Quaternary times.

The pattern of distribution of titano-magnetite on the shelf suggests that it is not due to primary volcanic emplacement of the material.

INTRODUCTION

Sources of Data

Sediments of the western shelf of the North Island of New Zealand were sampled during two N.Z. Oceanographic Institute cruises in the M.V. *Viti* in October 1959 and May 1960 (Ironsand Cruises I and II). The area sampled extends from just south of Kaipara Heads to the mouth of the Wanganui River, and seaward to the vicinity of the 100 fm line, the position of which varies between approximately 17 and 60 miles offshore (fig. 1). In addition a supplementary series of samples was obtained in March 1963 from M.V. *Taranui*.

Sampling from M.V. *Viti* was carried out along 11 east-west lines 20 miles apart from latitude 36°40′S to 40°00′S. On each line sampling was commenced as close as practicable to the shore and successive stations were then worked at intervals of 1 mile to a distance of 5 miles offshore, at 2 mile intervals to 20 miles offshore, at 5 mile intervals to 30 miles offshore, and at 10 mile intervals to the shelf edge. Sampling was commenced no further than 2 miles offshore on most lines, the closest station to shore being half a mile out (fig. 2). The western coastline is very exposed and the circumstances of excellent weather and careful navigation greatly facilitated this sampling.

Additional samples in the Institute collections taken by HMNZS *Lachlan* and CS *Recorder* together with chart notations on Admiralty charts B.A. 1212, 2054, 2535, 2543, 3633, and N.Z. charts 46, 4423, and 4421, were utilised to extend the data on sediment distribution considered here.

Prior to the sampling on which the present investigation is based, no studies had been made of the shelf sediments in this area. However, analyses of some of the samples collected during the Ironsand Cruises have been used to examine the distribution of titaniferous ironsand over the inner portion of the western shelf (McDougall, 1961).

The survey was planned to define the grade distribution of the superficial shelf sediments and to examine in lesser detail the subsurface material by the use of short cores. Consideration of some of the factors influencing transport and deposition has been possible.

In March 1963, supplementary sampling (fig. 2) was carried out along lines intermediate between the original lines 3, 4, 5, 6, 7, and 8, giving an effective interval of 10 miles between lines of samples north of New Plymouth. Between lines 8 and 11, a series of individual samples was taken to extend the cover in this area.

In addition, material has been available as a result of earlier sampling by D. M. Garner of the N.Z. Oceanographic Institute (1959).

One of us (J. C. McD.) has been responsible for the planning and fieldwork, and the discussion of surface and subsurface sediment distributions: the

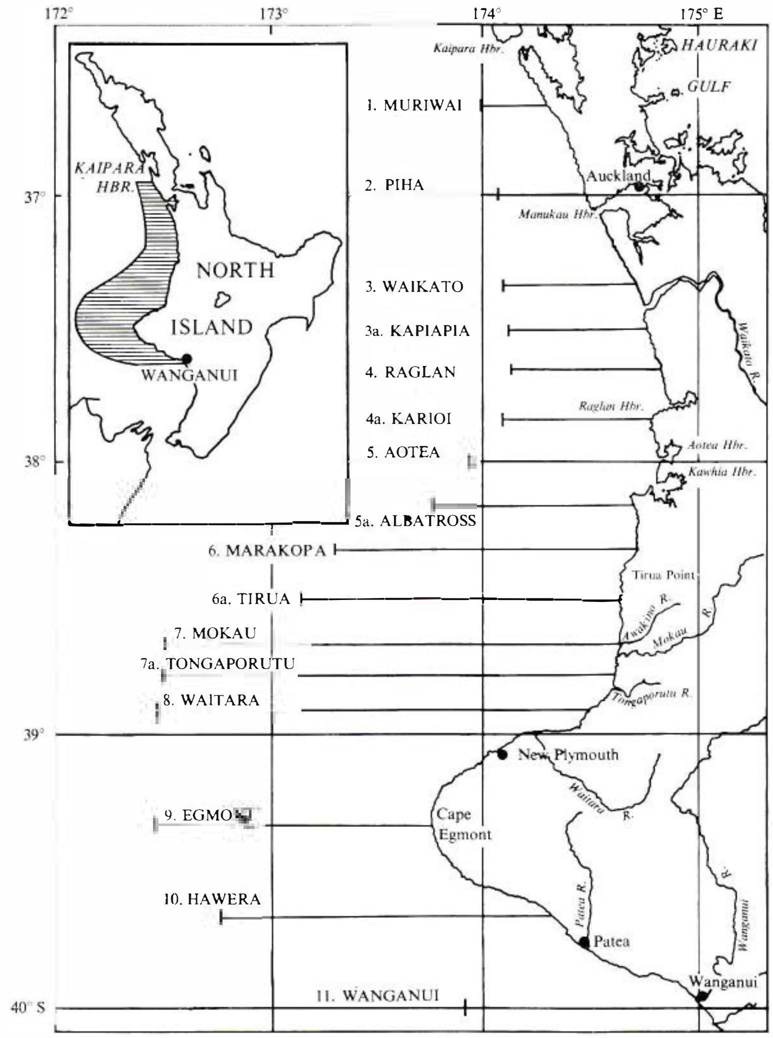

Fig. 1: Locality chart and sampling lines

other (J.W.B.) has contributed a commentary on the significance of the results in terms of late-Pleistocene and Post-Glacial chronology.

Morphology of the Area Sampled

The Continental Shelf and Slope: A general bathymetric chart is presented of the total area sampled (fig. 3). This has been compiled from chart soundings, from station depths (based on length of wire used) and from a limited number of echo soundings.

From Kaipara to Kawhia the outer limit of the shelf lies in depths between 70 and 80 fm about 30 miles offshore. The break in slope at the shelf edge is sharply defined in this northern area, but becomes less definite at 90–100 fm between Kawhia and Cape Egmont, where the shelf is 60 miles wide.

Over the area covered by lines 1–4 (fig. 1) apart from a local decrease in grade off the mouth of the Waikato River, the average inclination of the shelf is 0°17′.

Further south (lines 5–11) the shelf has a more irregular undulating surface and its width is considerably greater, the average inclination is less, being about 0°04′, except in an area just off Cape Egmont. Here the 50 fm mark is reached 6 miles offshore, and the 100 fm line 60 miles offshore.

Thus two major morphological regions exist on the western shelf between Kaipara and Egmont. Echo-sounding profiles in the northern region show that the outer portion of the shelf is steeper than the

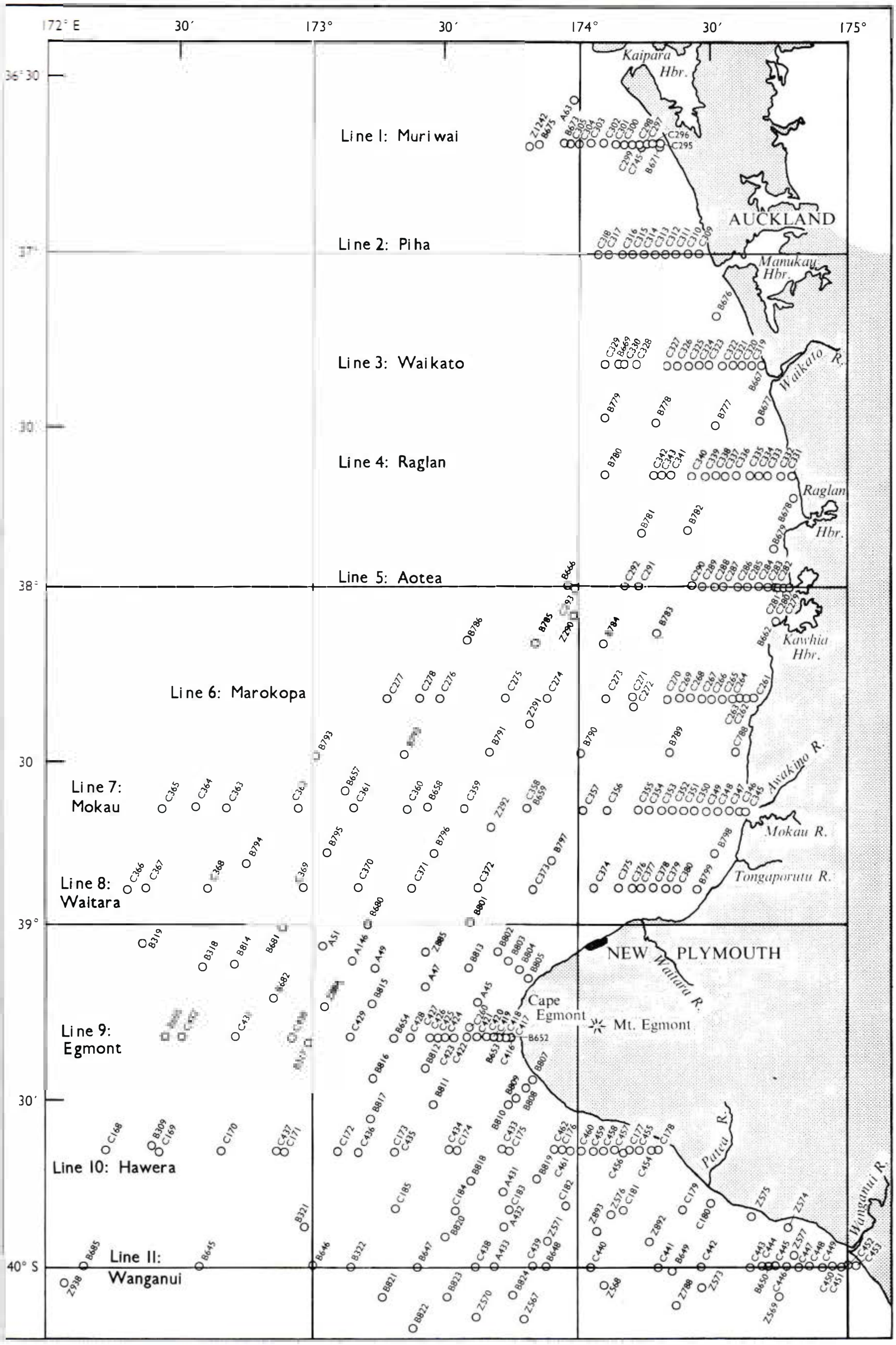

Fig. 2: Sample positions.

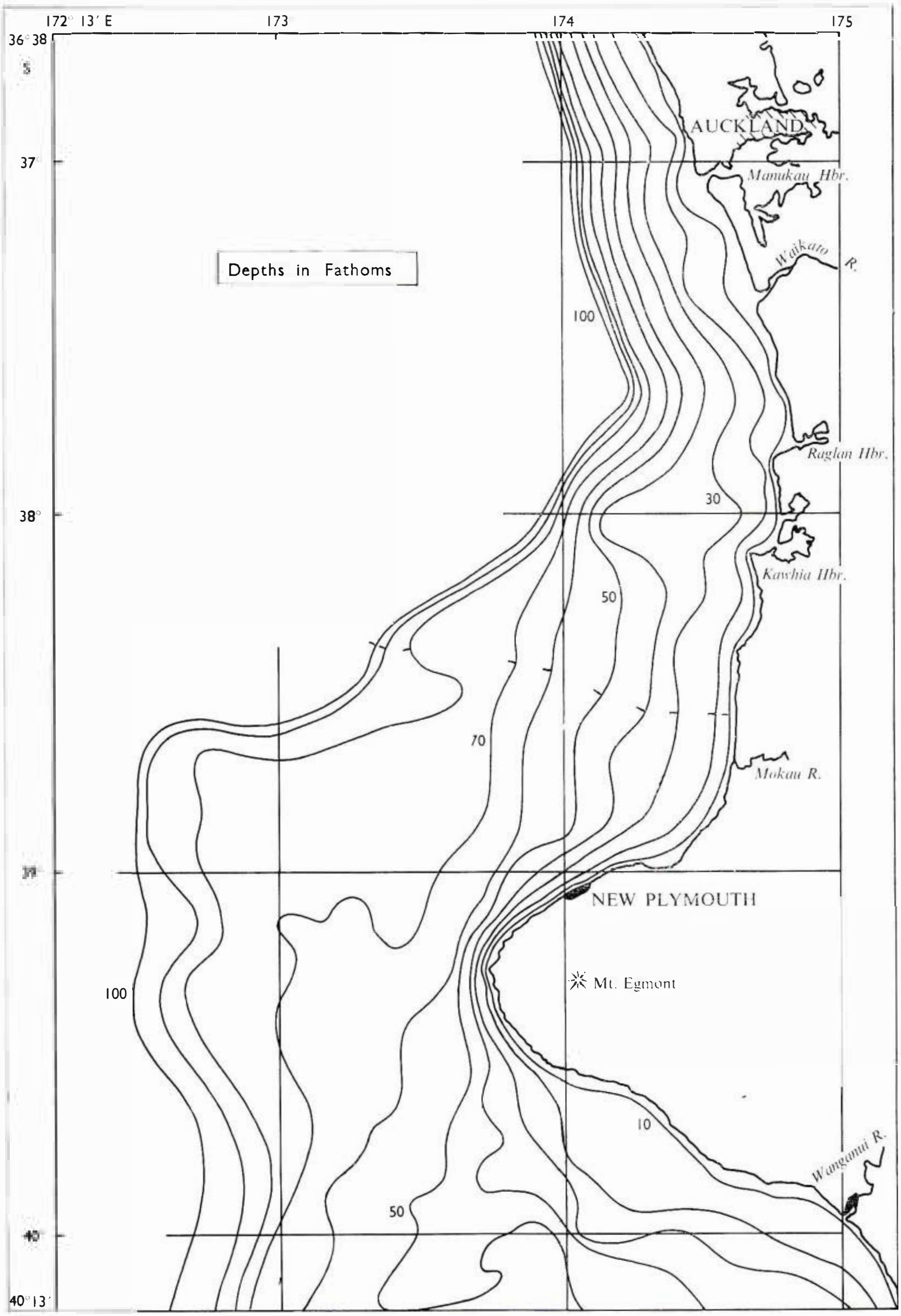

Fig. 3: Generalised bathymetric chart of the Western Shelf (contours at 10 fathom intervals).

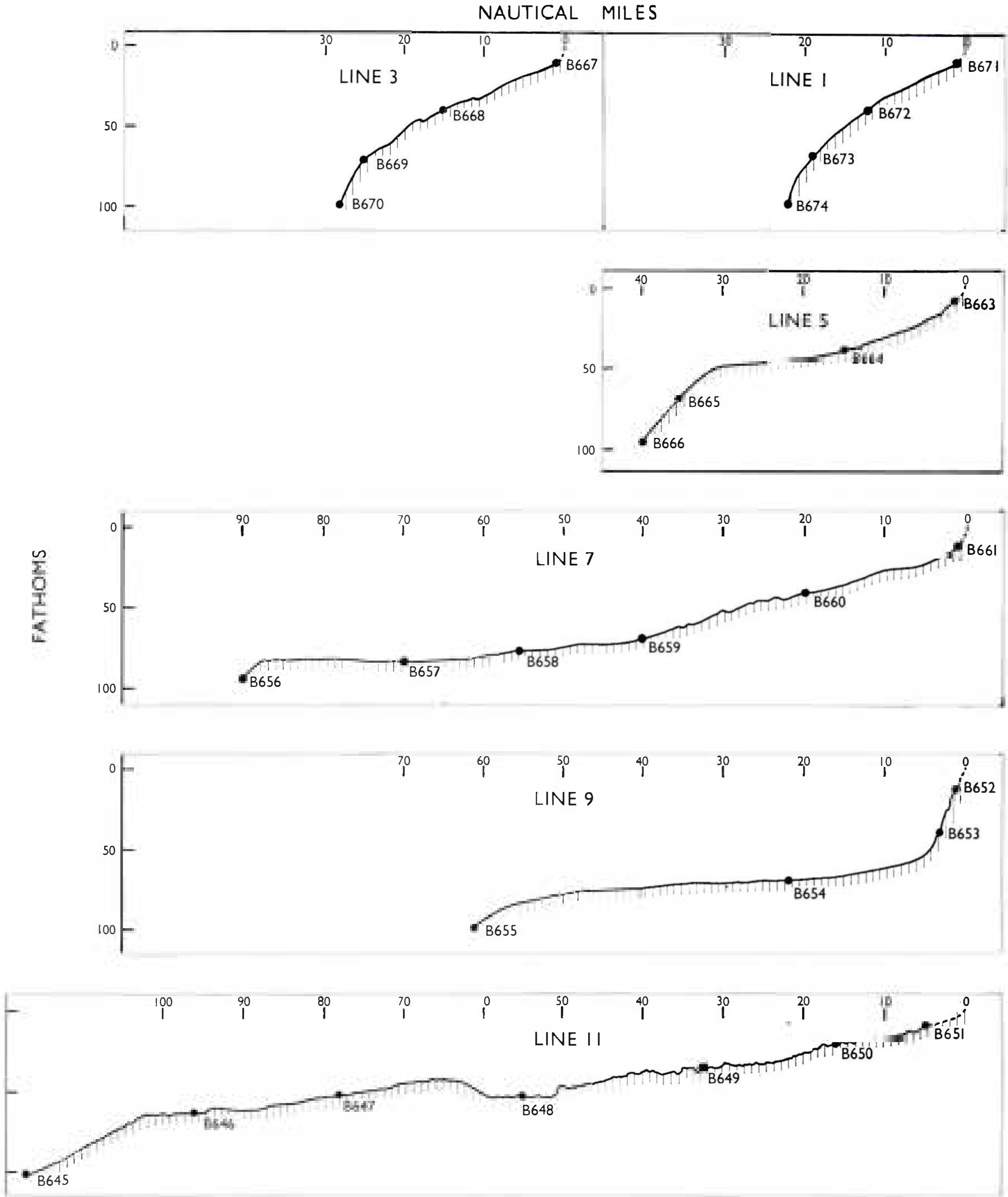

Fig. 4: Transverse profiles across the Western Shelf drawn from echo soundings: depths are in fathoms.

Photo: Whites Aviation Ltd.

PLATE 1. View north along western coastline from Muriwai to Kaipara Harbour entrance. (Coastal Type I; Type II coastline in immediate foreground, cliffs rise to 700 ft.)

inner portion. Conversely, in the southern region, the gradient is reduced seaward of the 50 fm line.

The shelf profiles along six lines, constructed from echo soundings, show these broad divisions in some detail (fig. 4).

The upper slope gradients in the central portion of the area are steep. Seaward of line 3 in latitude 37° 20′ the depth increases from 88–227 fm in a distance of 3 miles; similarly off the end of line 6, in latitude 38° 20′ in a distance of approximately 7 miles, the depth increases from 85–500 fm.

The Coastal Region: From numerous sources – photographs, maps, charts, and field observations – a broad analysis has been made of the coastal types found in the west coast region of the North Island.

The configuration of the coastline varies considerably over the section under survey, falling into eight separate categories (fig. 5: Plates 1, 2, 3).

Three major rivers, Wanganui, Mokau, and Waikato and four lesser but still substantial rivers, Tongaporutu, Awakino, Waitara, and Patea, enter the sea along this coastline. These rivers effect the major drainage of the western half of the central North Island. They traverse a wide variety of geological formations, but notably transport the products of erosion of Tertiary sedimentary rocks and of poorly consolidated Quaternary volcanics from a large part of the area.

Methods of Collection

The sampling gear used to obtain the majority of the samples consisted of:

a. N.Z.O.I. gravity corer.
b. Modified Petersen grab.
c. Medium-size Hayward orange-peel grab.

a. The gravity corer head weighs about 60 lb and to this can be added, as desired, weights of approximately 30 lb each. The average total driving weight as used during this survey was in the vicinity of 250 lb, but varied depending on the nature of the sediment being cored. A valve fitted at the top of the corer head prevents the core being washed out during recovery.

The core barrel consisted of a 3 ft length of 1½ in. diameter steampipe fitted with a plastic liner for easy removal of the core. Occasionally the nature of the sediment permitted the use of a 6 ft barrel but, as sandy sediments were encountered at many stations, the 3 ft length was usually sufficient.

The flexible-leaf core catcher was held in place at the bottom of the core barrel by the conical core cutter. The trip weight was so arranged as to allow the corer a "free fall" varying from 10–20 ft before entering the bottom sediment (Plate 4).

In the initial sampling lines 1–8 (fig. 1) the Petersen grab was used as a trip-weight: on lines 9–11 the orange-peel grab was used. The use of these large grabs as trip weights for the gravity corer minimised station time and permitted a closer cover of stations than would otherwise have been possible if the core and surface sediment samples had been secured separately. The technique likewise made possible a survey of the benthos, the grab providing a sufficient sample for a preliminary study.

b. The Petersen grab used was a standard pattern sampling 0·1 m² of the bottom, modified by the addition of lead weights on the upper portion of the jaws which had been fitted with several teeth approximately 3 in. long.

c. The modified Hayward orange-peel grab consists of four close-fitting, sharp-pointed jaws, taking a roughly hemispherical sample (of up to 1 ft³ in volume) when closed. The model used weighs approximately 100 lb, the maximum penetration being about 12 in. The grab has been modified to hang from a trip release which transfers the hauling wire attachment to a closing mechanism when the grab enters the sediment. Sheet-metal plates have been added to close over the top of the sampler when the jaws shut and cut down loss of sediment as the grab is retrieved.

A total of 261 stations was worked, grab samples being obtained at each one and cores (12 in. or over) at 46. Only the orange-peel grab was used for the stations from M.V. *Taranui* (table 1). Where coring was difficult, either because of the nature of the sediment, or through rough weather making the gear too dangerous to handle, the corer was dispensed with and a grab sample only was taken. The grab provided a 13 oz oyster pot sample for grain-size analysis and a 4 oz sample (alcohol preserved) for microfaunal investigations: the remainder of the sample being sieved for biological material.

Ancillary sampling was carried out with a variety of equipment that included Dietz grab, cone dredge, large orange-peel grab, and some bulk sediment samples obtained in trawls were also available for examination. The mesh cone dredge used consists of a 1 ft diameter cone with a rigid tubular galvanised mesh bag 3 ft long. It is an efficient sampler for benthic organisms. A small conical canvas bag has been attached inside about half way along the length to obtain sediment samples.

Methods of Examination and Analysis

A total of 289 surface sediment samples from the area as well as 46 cores ranging from 12 in. to 36 in. in length was available in the Institute collections.

Analyses of the majority of the surface and core samples for their content of ferruginous material have been carried out. Magnetic separations were made using a separator described previously: some of these results from selected near-shore stations were reported earlier (McDougall, 1961).

Mechanical analyses of the "magnetic fractions" have also been made in similar fashion to those of the total sample. Here the grain-size proportions in the "magnetic fraction" (mainly titanomagnetite) have been utilised to prepare distribution charts.

A subsample of approximately 20 gms was set aside from each surface sample for grain-size analysis, and was treated in the following manner.

After being left overnight in a 0·03% NaOH solution to assist dispersion, the resulting slurry was stirred gently to complete the breaking up of aggregations which had resisted the action of the NaOH solution. Sandy samples presented no difficulty at this stage whereas the muddy, silty samples required prolonged stirring.

When maximum dispersion had been obtained, the sample was introduced into a nest of B.S. sieves, with mesh sizes of 8:16:30:60:120 and 240.

The sample was sieved in the wet form, using a plastic wash-bottle together with a rubber spatula moved lightly over the sieve mesh to keep the sample agitated. This was most necessary in the case of the 120 and 240 mesh muddy fractions.

For the average sample approximately 500–600 c.c. of washing water was used. The weight of –240 fraction was determined by taking a 25 c.c. pipette sample of this fraction, drying and weighing it, and then calculating the total weight of the fraction. In the case of a large amount of solid material settling out rapidly in the –240 fraction, the supernatant liquid was decanted off into a measuring cylinder, the solid residue being then dried and weighed, leaving the fine suspension to be treated by the pipette method.

The other fractions were left in the sieves and dried on a hot plate. The film of water in the wet sieve prevents some of the finer particles from passing through, so at this stage

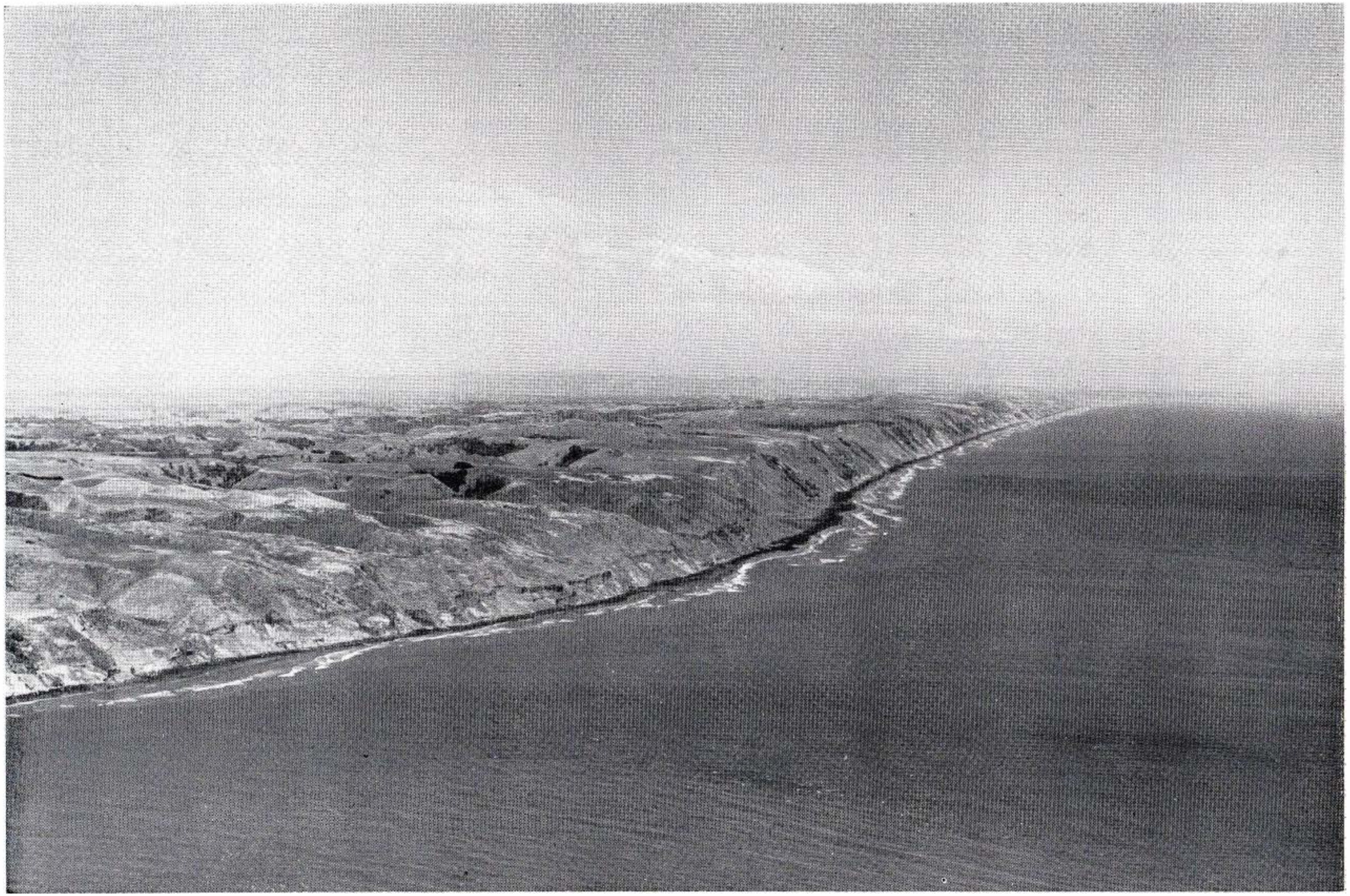

Photo: Whites Aviation Ltd.

PLATE 2. View south along western coastline from just south of Manukau Harbour entrance. (Coastal Type III.) Note ironsand beach.

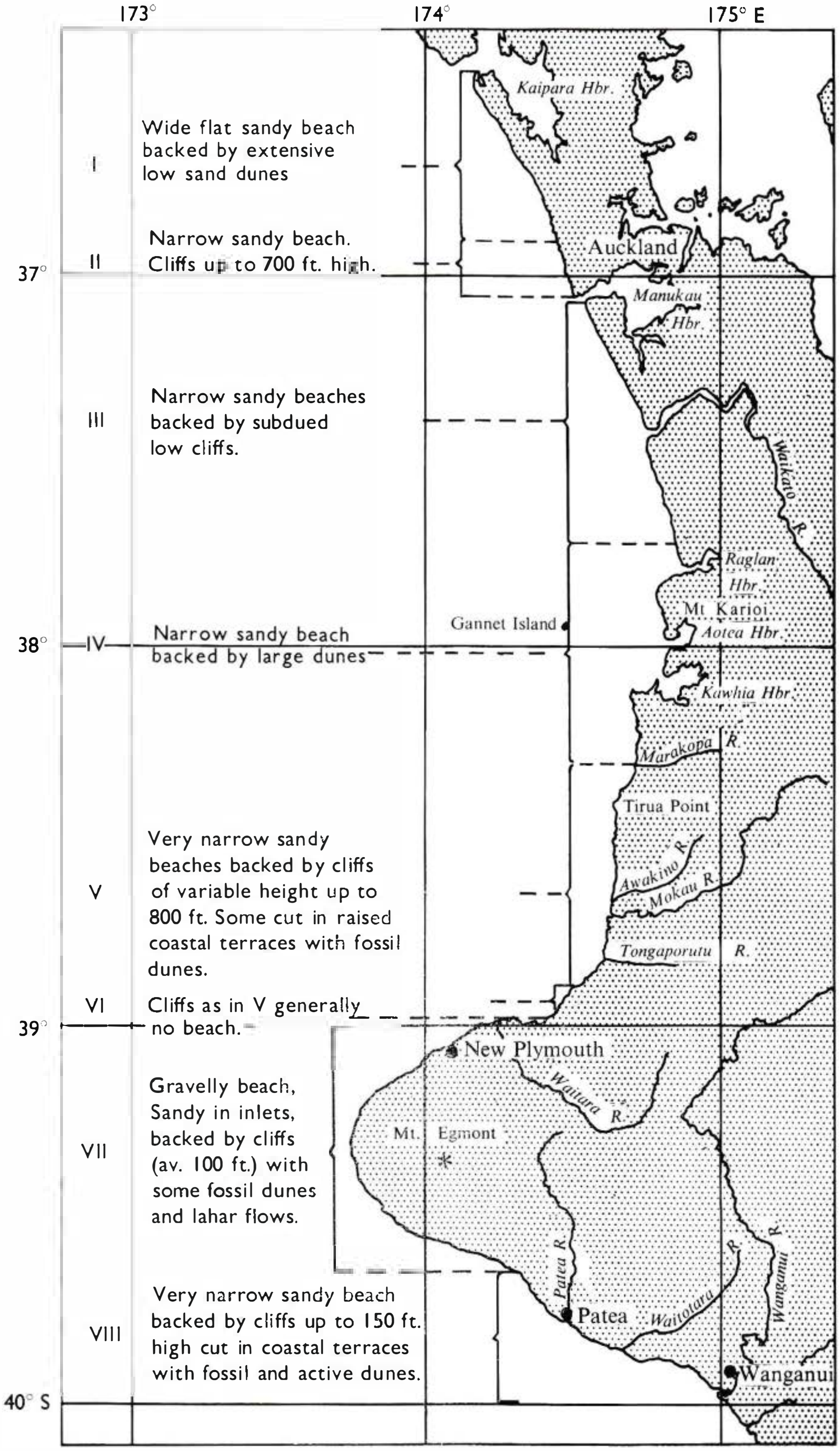

Fig. 5: Coastal types and major rivers, West Coast, North Island.

Photo: *Whites Aviation Ltd.*

PLATE 3. View north from Kawhia Harbour entrance. Mount Karioi (volcanic) in background. (Coastal Type IV.)

light tapping of the sieves completed the sieving procedure. The individual fractions were then removed and weighed. No initial weight of sample was taken, the total weight being arrived at by summation of the fractions.

The wet sieving method produces very clean, finely separated fractions and was considered the most suitable owing to the large number of muddy samples to be processed.

The laboratory technique for analysing the cores was as follows: the surrounding plastic liner was cut longitudinally by drawing the core past two fixed opposing knives; the core was then halved longitudinally, one half being kept intact for further reference.

All the cores from lines 2 and 9 were analysed (a total of 13). Subsamples 2 in. long were taken at intervals of 2 in. along the length of the half cores. These were dispersed, wet sieved and fractions weighed in the manner already described. The total weight of subsample averaged about 20 gms.

Analysis of the samples has thus taken the following forms: Complete grain-size determinations have been carried out on all the available bottom surface sediment samples out to 100 fm. In addition the percentage of titaniferous ironsand in all these samples has been determined by magnetic separation. Two of the survey lines Piha 2 and Egmont 9, situated near the northern and southern extremities of the area under consideration, were selected for investigating the vertical sediment distribution. For all cores from these lines, grain-size analysis was carried out as previously described. Visual examinations of cross sections of all the remaining cores were made and recorded on sectional diagrams.

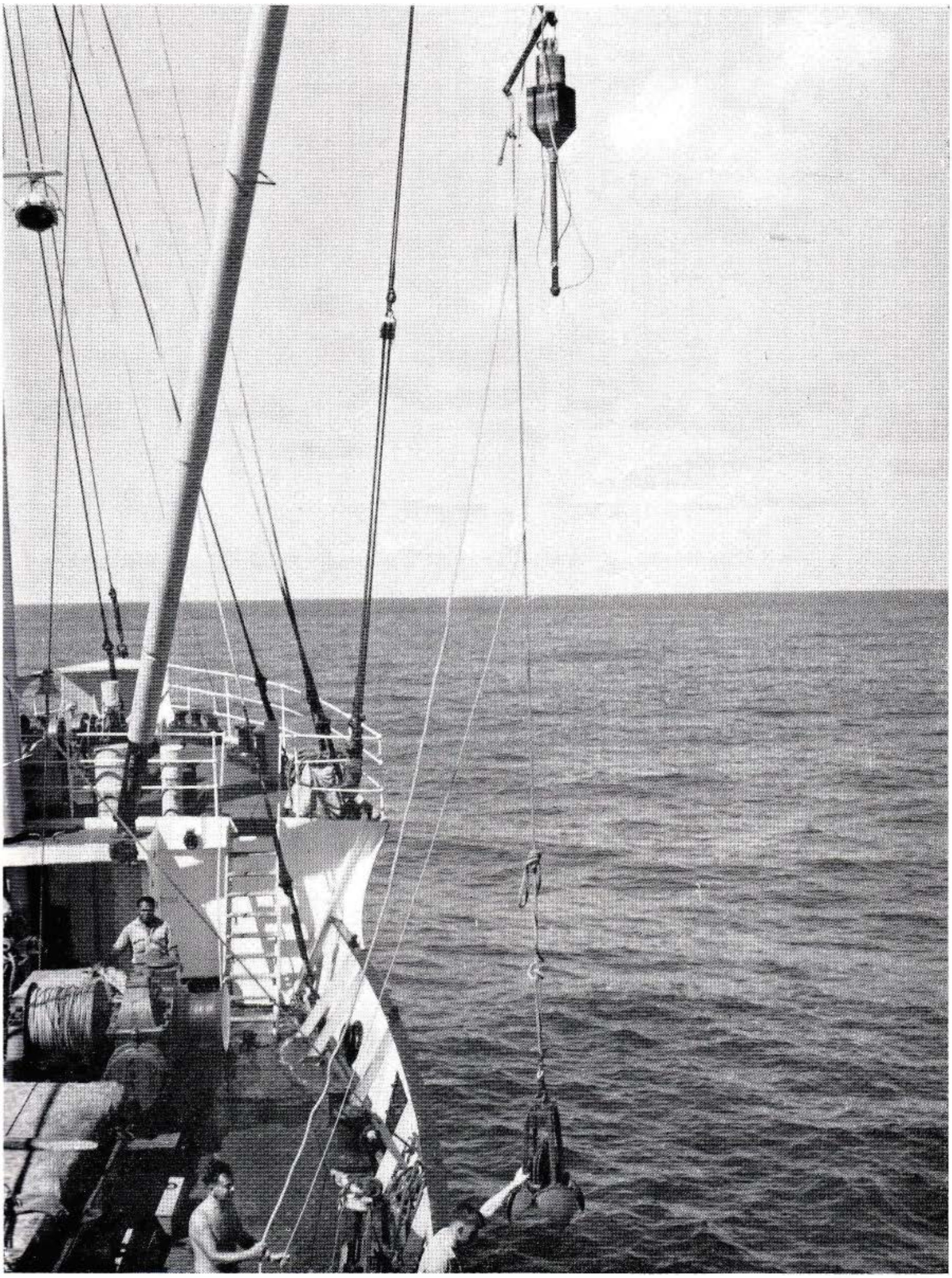

Photo: S. C Watts

PLATE 4. Corer with grab as trip weight; before lowering.

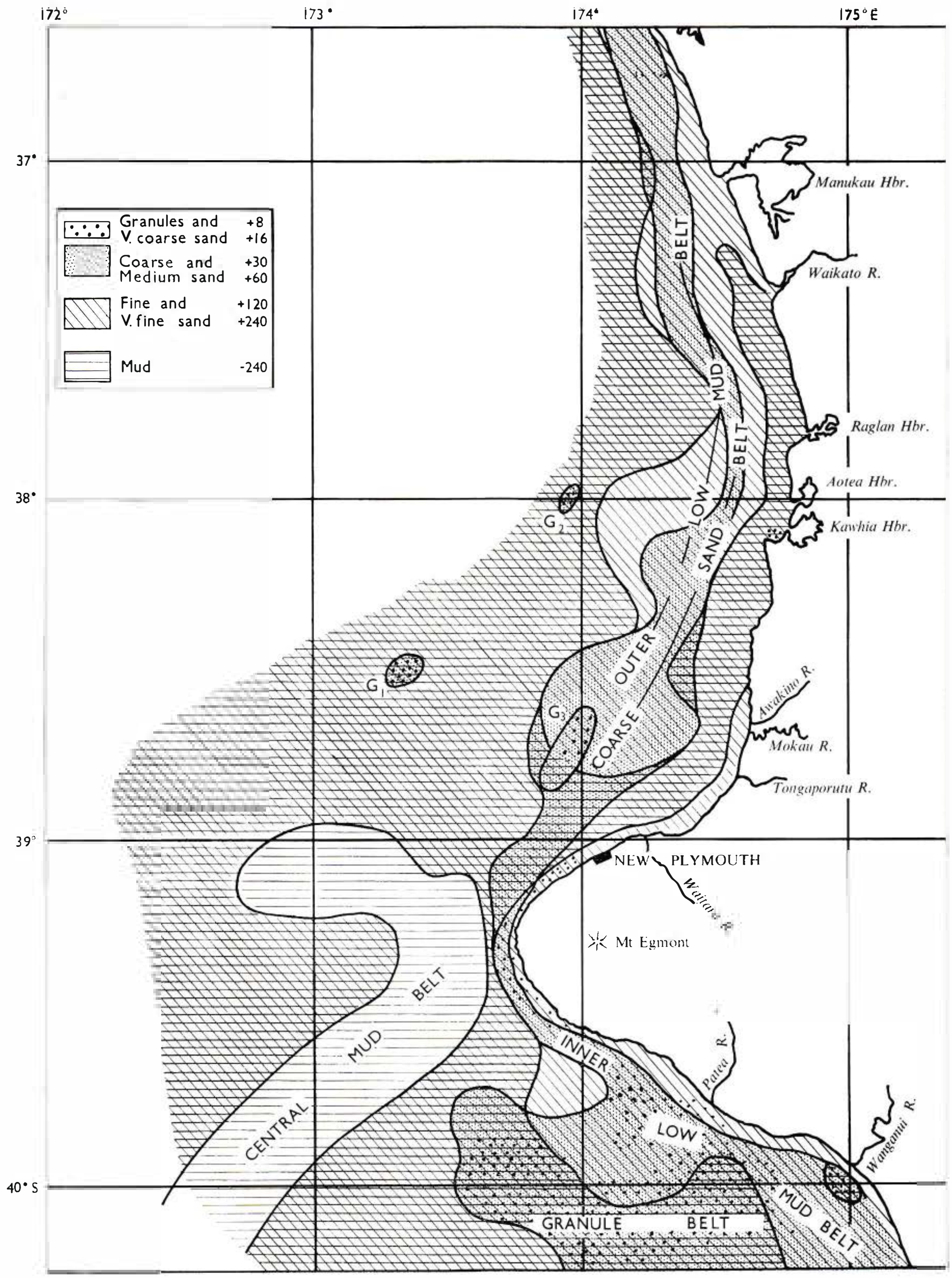

Fig. 6: Areal distribution of groups of sediment grades on Western Shelf.

System of Data Presentation

Grain-size analyses of all surface sediment samples and of selected core samples have been presented in a number of ways:

Generalised Distributions of Sediment Grades: The areal plot of distribution of groups of sediment grades shown in fig. 6 is based on the occurrence at each station of grouped sediment fractions that are 10% or more of the total sediment sample weight. For simplicity the fractions have been considered in four groups: granule gravel and very coarse sand: coarse and medium sand; fine and very fine sand; and mud.

Thus on fig. 6 coarse and medium sand that in one sample aggregated only 9% of sample weight would not be shown. In the coarsest group, between mesh 5 and 8, much of the material was shell fragments. Very few samples contained material larger than this.

Grain-size Distributions along Sampling Lines: The distribution of grain-size in surface sediments along each of the major sampling lines is shown in more detail in fig. 7. The percentage by weight of each category of grain size has been plotted against distance in miles offshore. For comparison a sketch profile of shelf contours is also given for each line.

Distribution of Dominant Grades is shown: in fig. 8a of the total surface sediment; in fig. 8b of the "magnetic fraction". The figures used have been taken from the results of mechanical analyses of the original sample (as in fig. 7) and of the "magnetic fraction" described earlier.

Only the dominant fraction has been plotted for each station.

Median Diameters: For 46 surface samples from lines 1, 7, and 11 the median diameters have been computed and their distribution along the sampling lines with respect to depth and distance offshore has been plotted (figs. 9, 10).

Subsurface Sediment Grade Distribution: Longitudinal sections of the superficial sediments along lines 2 and 9 from core analysis are shown in fig. 14. The predominant sediment grade has been plotted against core depth.

Subsurface Reflectors: A number of these are shown in cross sections of the western shelf illustrated in fig. 12. These sedimentary discontinuities were revealed by echo soundings from Traverse No. 172 by HMNZS *Lachlan;* they occur at depths of several tens of feet. (Measurements from them assume the same velocity of sound in them as in sea water.) This forms the basic data for the suggested Egmont Gulf (fig. 15).

Histograms of Grain-size Percentages in surface sediments for lines 1, 7, and 11 are shown in fig. 11. Percentage weight is plotted against sieve size, the range being +8, +16, +30, +60, +120, +240, −240 mesh.

Line 1, Muriwai: Well sorted, principally in the very fine and fine sand grades, out to 40 fm.
Line 7, Mokau: Anomalous coarse-grained sediments sampled (Sta. C 357).
Line 11, Wanganui: Predominantly poorly sorted sediments.

Also mapped were:

Quartz Sands on the Western Shelf (fig. 13a).

Area of Prominent Occurrence of Dead Shell and Shell Fragments (fig. 13b).

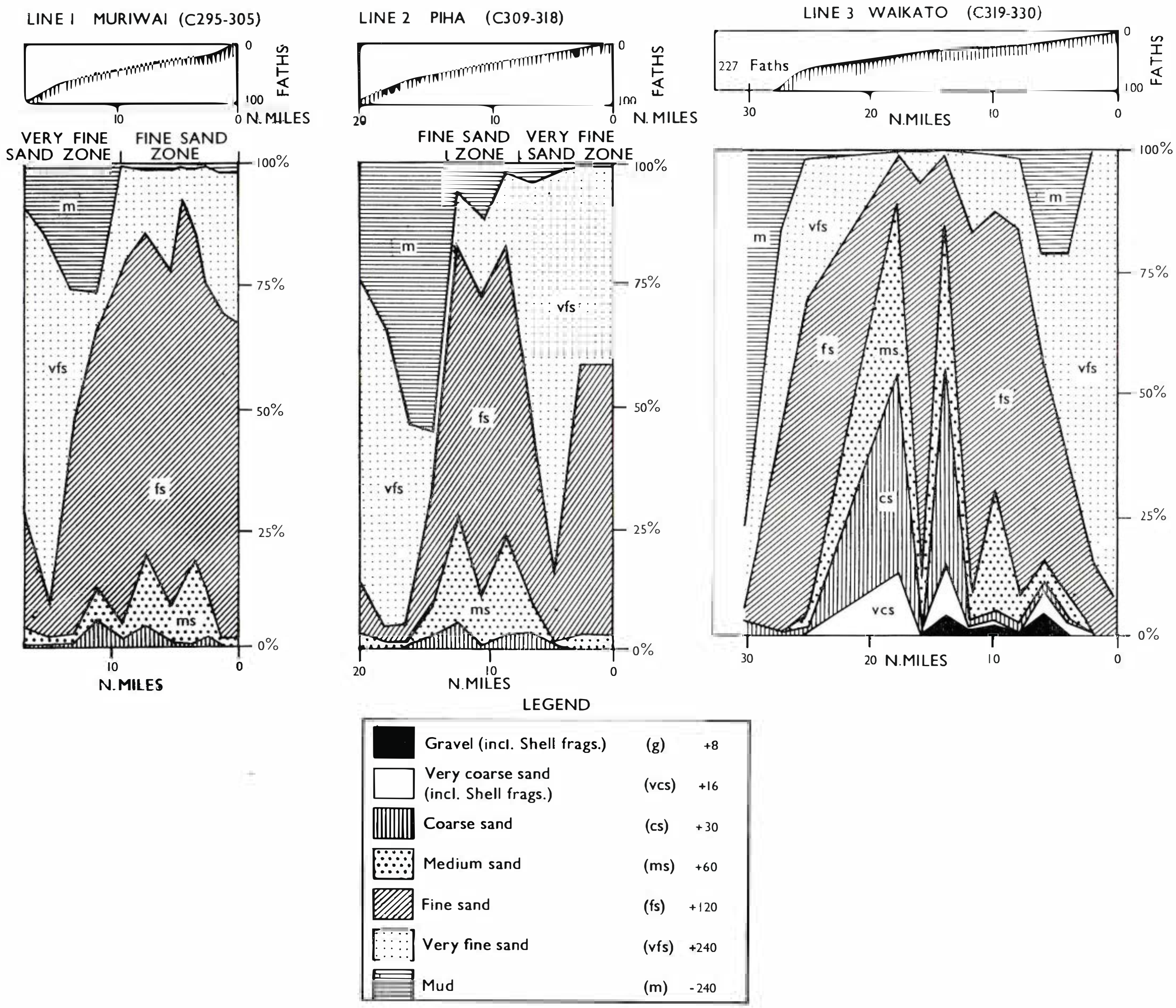

Fig. 7: Grain-size distribution along sampling lines.

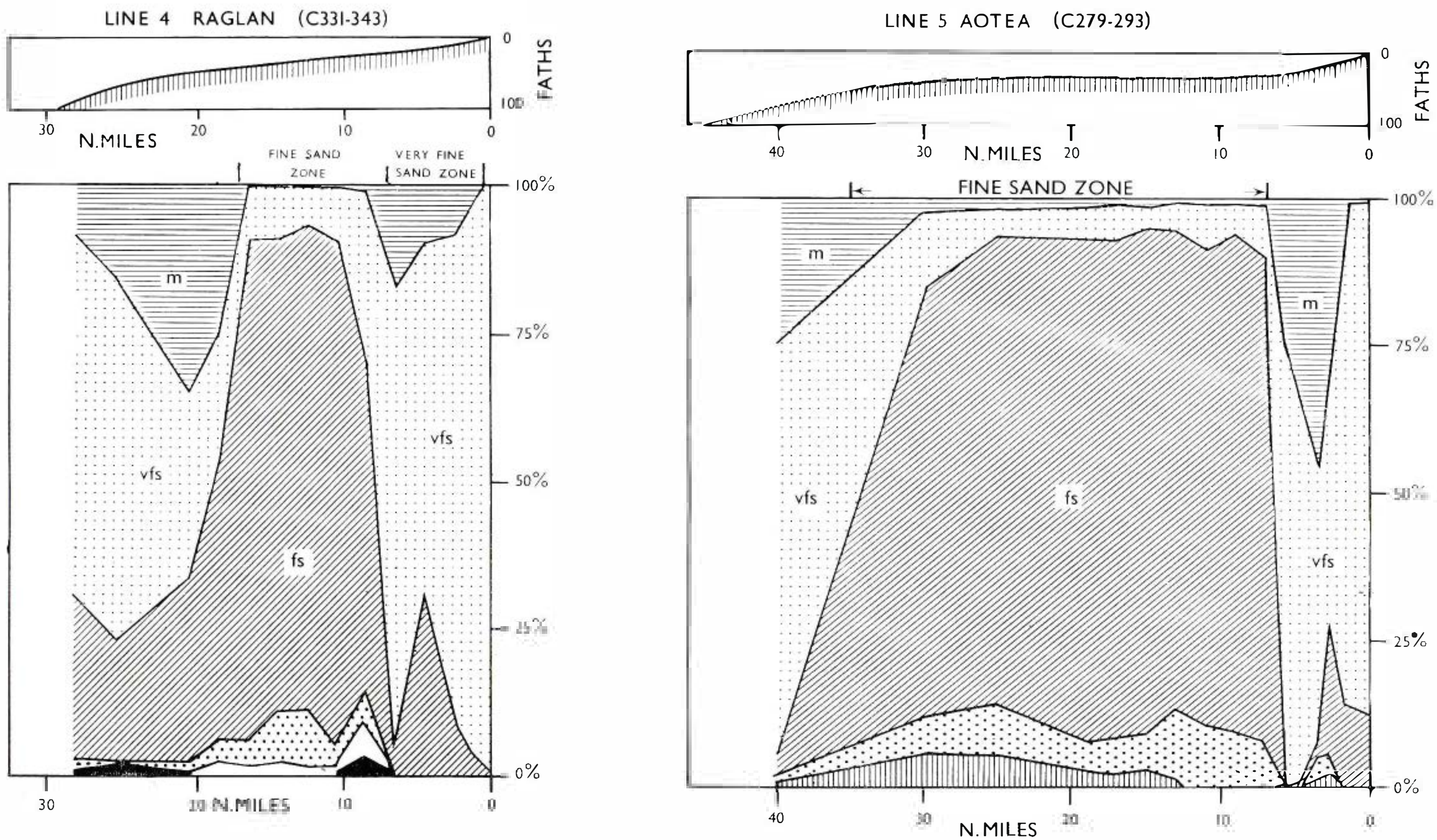

Fig 7: Grain-size distribution along sampling lines—*continued*
See p. 20 for Legend

LINE 6 MAROKOPA (C261-278)

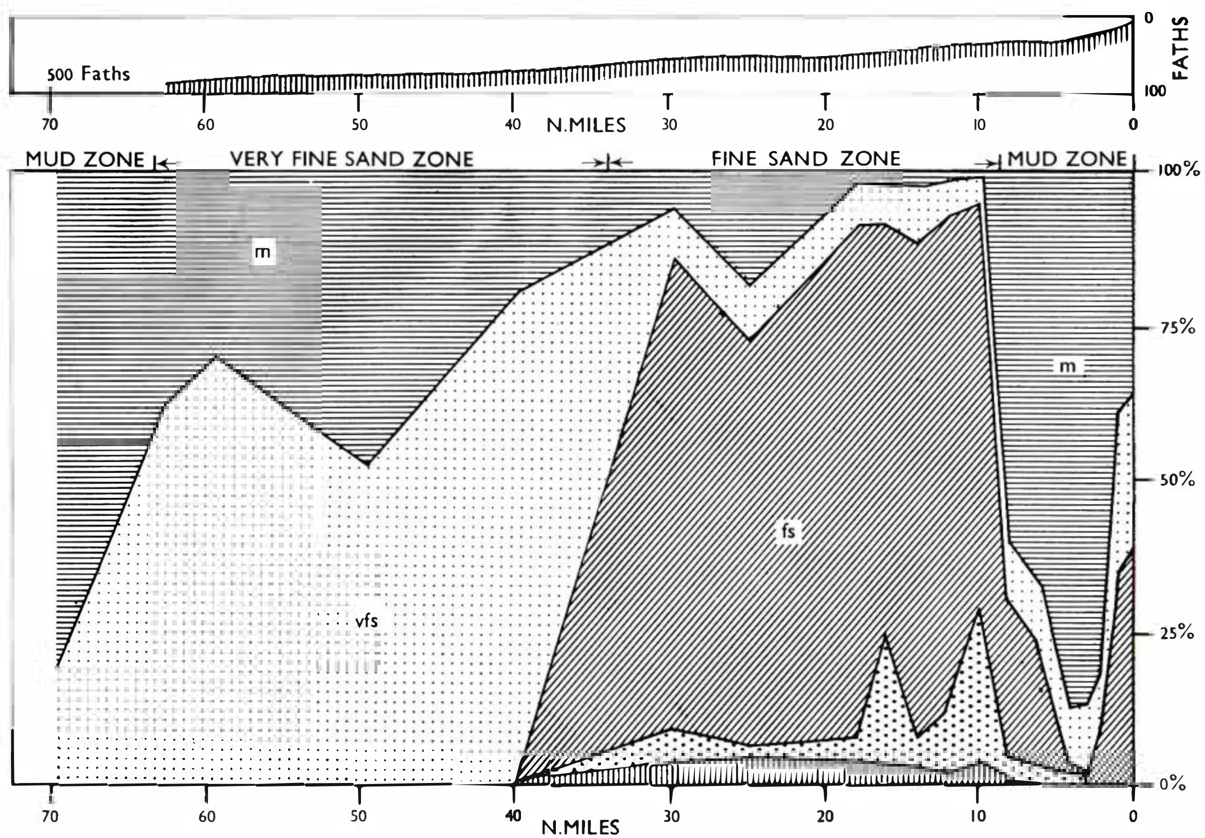

Fig. 7: Grain-size distribution along sampling lines—*continued*
See p. 20 for Legend

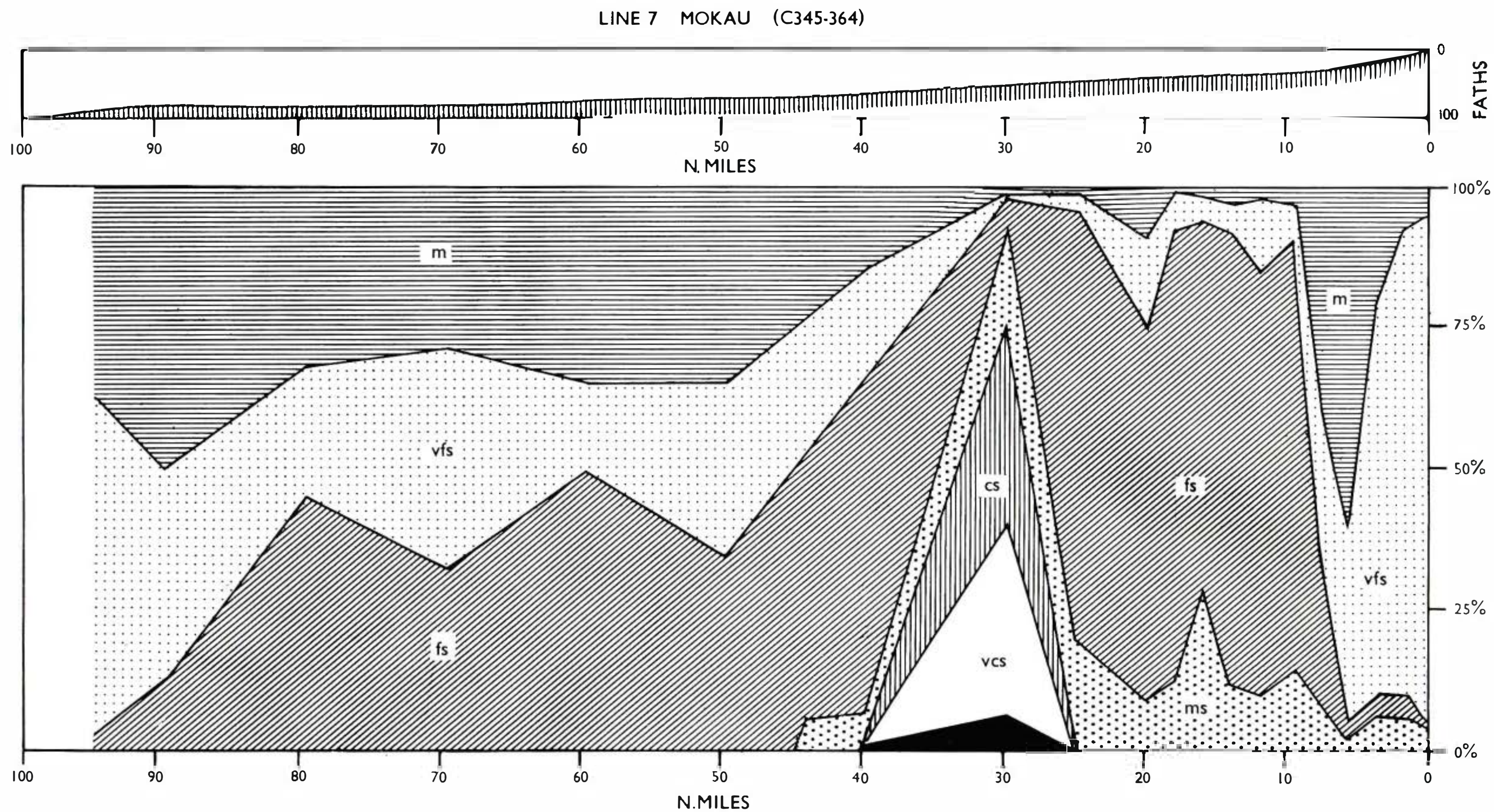

Fig. 7: Grain-size distribution along sampling lines—*continued*
See p. 20 for Legend

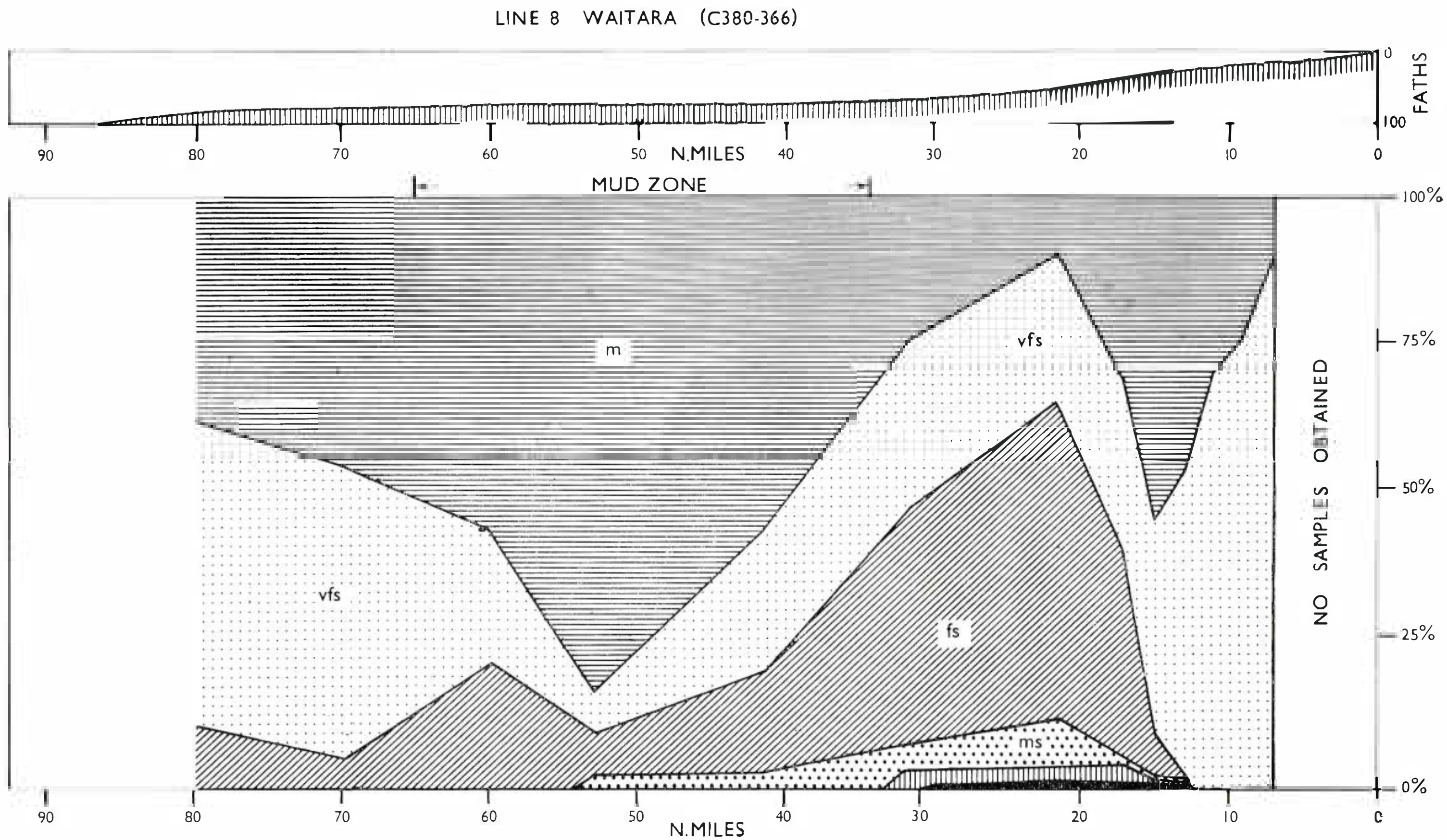

Fig. 7 : Grain-size distribution along sampling lines—*continued*
See p. 20 for Legend

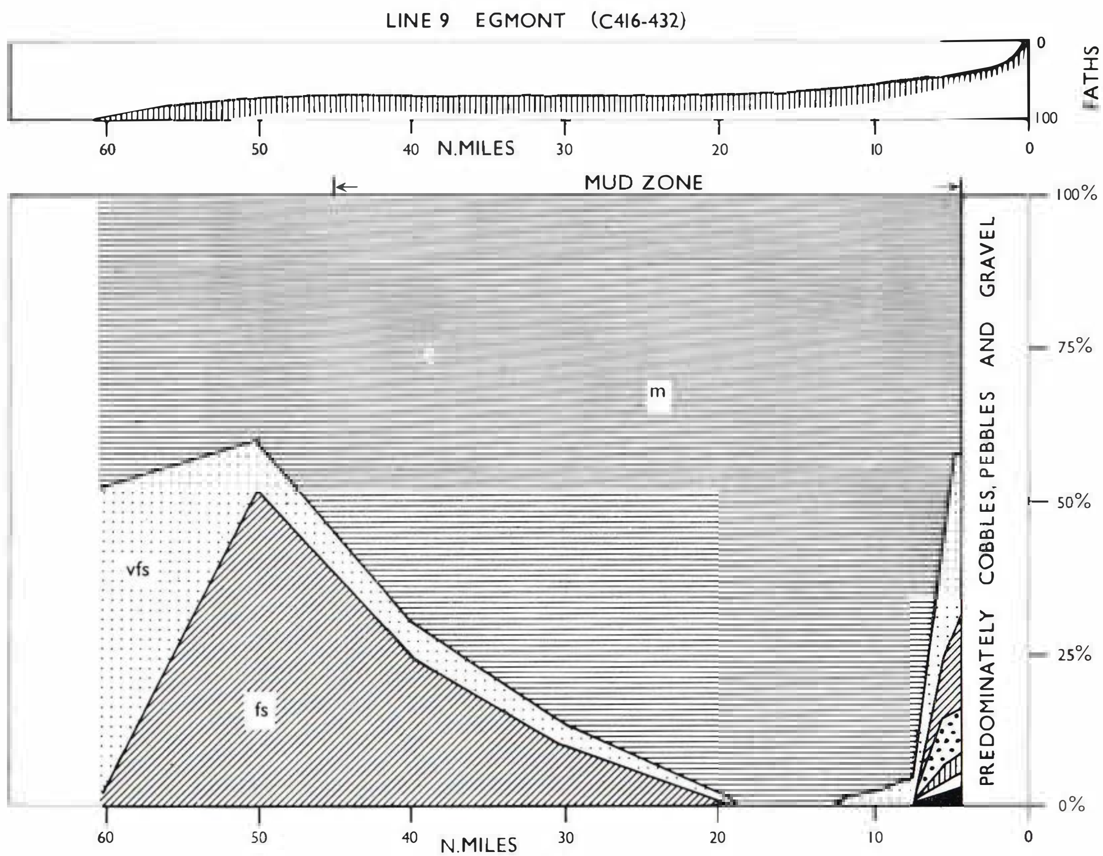

Fig. 7: Grain-size distribution along sampling lines—*continued*
See p. 20 for Legend

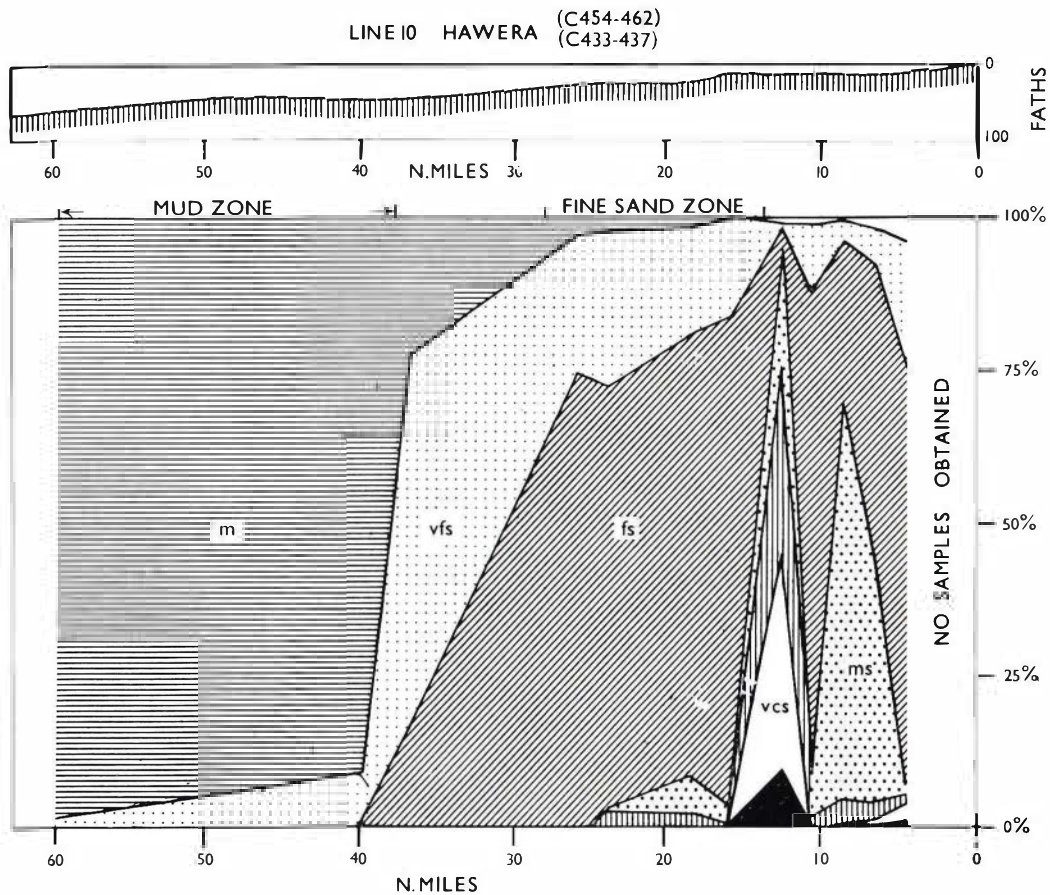

Fig. 7: Grain-size distribution along sampling lines—*continued*
See p. 20 for Legend

LINE II WANGANUI (C453-438)

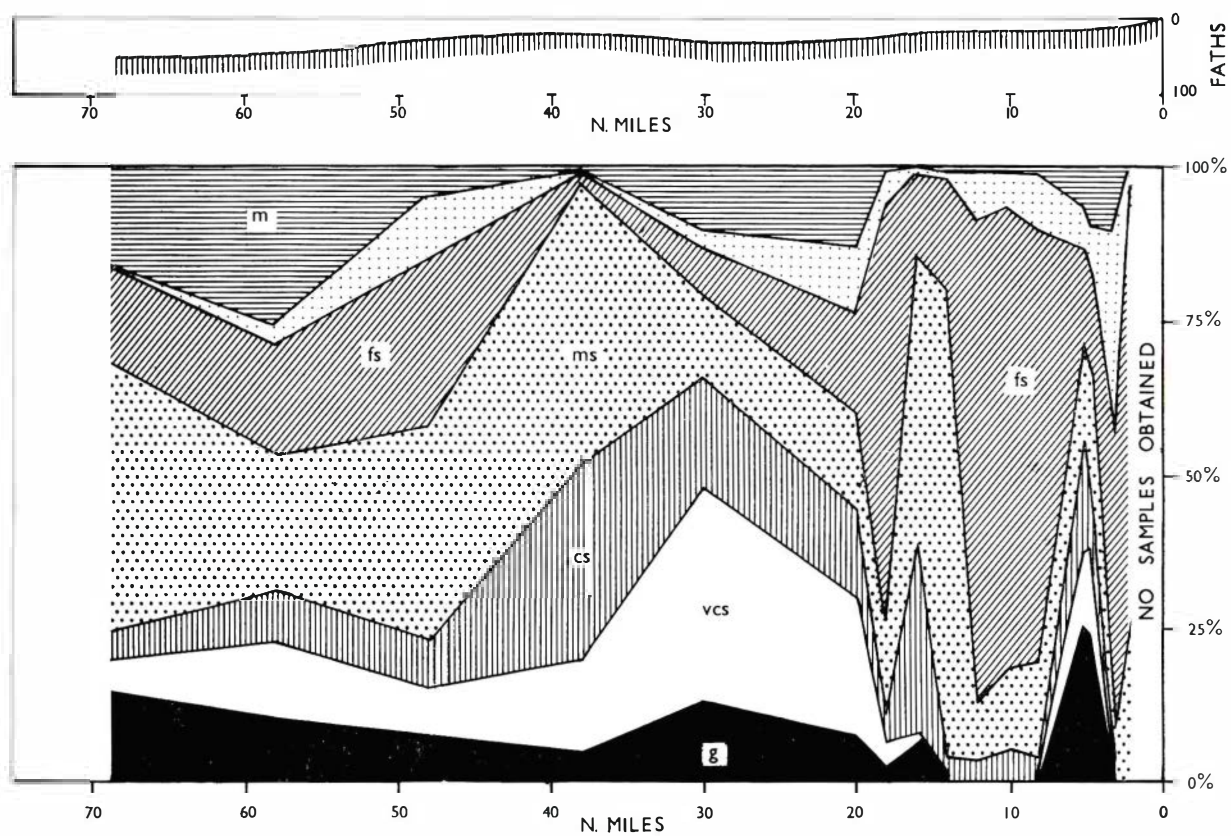

Fig. 7: Grain-size distribution along sampling lines—*continued*
See p. 20 for Legend

SURFACE SEDIMENT DISTRIBUTION

The major constituents in the sediment are mud, very fine sand and fine sand. These three together predominate over the greater part of the shelf, but particularly in the area north and west of Cape Egmont. Immediately south of Cape Egmont there is a more complex diversity of sediments.

The areal plot of sediment grades that occur in proportions of 10% and over (fig. 6) allows consideration of the major aspects of distribution. In particular it highlights the anomalous occurrences of the finer and coarser sediment grades. However, the nature of the pattern of distribution of the dominant sediments is more precisely shown in considering the variation in sediment distribution along each of the sampling lines (figs. 7, 8a).

Lines 1, 7, and 11 are here described in detail to match the additional information given on median diameters given in figs. 9 and 10.

Grain-Size Distributions Along Sampling Lines 1, 7, and 11.* (See also figs. 9, 11).

Muriwai (*line* 1): From the shoreline to 50 fm, 12 miles offshore, there is predominantly fine sand, about 12% very fine sand, very little mud, and an average of 10% of medium to very coarse sand. In the next zone offshore, the proportion of mud (20%) and very fine sand (40%) are greater; fine sand is much reduced (20%) and the medium to coarse sand grades negligible.

The percentage of mud is negligible from shore to 10 miles offshore (40 fm). Here an abrupt increase takes place to a maximum of 25%, 15 miles offshore (70 fm).

The percentage of very fine sand fluctuates between 5 and 30 out to 56 fm; coinciding with an increase in the percentage of mud, it also increases to a maximum of 75% at 15 miles offshore in 70 fm.

The percentage of fine sand rises from the nearshore figure of 66 to a maximum of 80 (4 miles off shore in 22 fm), then decreases a little to 12 miles offshore, then rapidly to a minimum of 7%, 15 miles offshore in 70 fm.

The coarser grades present (medium, coarse, and very coarse sand) broadly decrease in abundance seaward but nowhere exceed 20% of the total sediment.

The maximum of mud (at 14 miles and 75 fm) occurs slightly shoreward of the maximum of very fine sand and the minimum of fine sand.

*For similar description along all other sampling lines see Appendix.

The zone between 0 and 56 fm (0–13 miles) can be distinguished as a fine sand zone: the outer shelf can be designated a very fine sand zone.

Mokau (*line* 7): Here the zones are less clearly defined, the sediments not being as well sorted. A small very fine sand zone exists from the shore out to about 5 miles (23 fm) averaging nearly 70% very fine sand. Mud and fine sand average about 10% and 4% respectively, the coarser fractions being negligible. From 5–30 miles offshore there is a fine sand zone, with nearly 70% fine sand, 10% very fine sand, 7% mud, and 12% medium sand. The coarser fractions over this area average less than 1%. The mud fraction reaches its maximum percentage of 61, 5½ miles from shore in 23 fm.

There is a sudden change in these circumstances however about 30 miles (52 fm) offshore, where a decrease in the finer fractions occurs with very fine sand and mud becoming negligible. Fine sand also shows a marked decrease, but in this one area on line 7 the coarser fractions—coarse sand and very coarse sand—increase to 35% and 33% respectively with gravel 7%. Between 30 and 90 miles offshore (52–80 fm), the coarse fractions, medium sand, coarse sand, very coarse sand, and gravel almost disappear leaving mud, very fine sand, and fine sand with averages of 38%, 27%, and 32%.

From 90 miles offshore to the shelf edge, mud (38% at 95 miles) and very fine sand (60%) are the only two significant constituents of the sediment.

Wanganui (*line 11*): The sediments are poorly sorted over the length of this sampling line (fig. 11). Mud occurs in three separate areas with the percentage increasing from shoreline to shelf edge. The maximum percentages for these areas occur at 3, 20, and 58 miles from shore with 11%, 14%, and 25% respectively. Between them, from 8 miles to 18 miles, and at 38 miles, mud is in negligible quantities. Very fine sand follows much the same pattern with maximum percentages at 3, 20, and 47 miles from shore, the amounts being 32%, 10%, and 10%.

Fine sand reaches a maximum of 78% 12 miles offshore, fluctuates to 2% at 38 miles, then averages 20% out to the end of the line (68 miles and 46 fm). There is an average of 23% of medium sand for the whole line, reaching a maximum of 77% 14 miles offshore and a minimum of 6% 3 miles offshore.

Coarse sand, very coarse sand, and gravel follow much the same pattern, there being three areas where these coarser fractions are concentrated. At 5 miles offshore in 15 fm, coarse sand rises rapidly to 18 %, then falls away equally rapidly, rising again at 16 miles to 31 %; a slight decrease then a steady increase to a maximum percentage for the line of 32, this being reached 38 miles offshore in 23 fm then falling away gradually. Very coarse sand likewise at 4½–5 miles offshore increases from nothing to 14 %, at 16 miles shows no increase, but reaches a maximum of 35 % 30 miles offshore in 30 fm; from there gradually decreasing towards the shelf edge.

Gravel at 5 miles (15 fm) is at its maximum of 25 %. This falls away rapidly until roughly 20 miles offshore (27 fm) from which position to the end of the line the average percentage is 9.

ZONATION:

From the zonation that occurs along individual sampling lines it is possible to recognise a clear pattern of zonation of the shelf sediments as characterised by the dominant grade (fig. 8a).

The major divisions into which the surface sediments of the shelf can be classified are:

Inner Very Fine Sand.
Fine Sand.
Outer Very Fine Sand.
Mud.

In a narrow inshore zone that extends to an average depth of 25 fm sediments with a dominant percentage of very fine sand are found. This *Inner Very Fine Sand Zone* extends from Piha to Waitara.

Adjoining this zone offshore is a zone in which sediments with a dominant percentage of fine sand occur. This *Fine Sand Zone* is continuous from Muriwai to Waitara and its seaward boundary is in an average depth of 50 fm.

Further seaward is a zone of sediments with a dominant percentage of very fine sand. This *Outer Very Fine Sand Zone* extends from Muriwai to Mokau at depths from 50 fm to the shelf edge.

These zones all lie north of Cape Egmont. South of the Cape the inshore sediments are variable, but offshore is a large area of sediment in which the dominant percentage is mud. The *Mud Zone* extends south and west from depths of about 40 fm in the vicinity of Cape Egmont.

AREAL DISTRIBUTION OF INDIVIDUAL GRADE COMPONENTS

The distribution of the individual grade components has been shown by means of an areal plot (fig. 6). As has been already mentioned, all the components shown are 10 % or more of the total weight of sediment sampled.

Though this method of presentation ignores all the minor occurrences yet it is useful in two respects. The total distribution of a particular sediment grade is demonstrated whether the sediment is dominant or not: as well, the minor occurrences of less significant component grades can be assessed. In the preceding section the zones there defined are based on the sediment grade dominant in each sample. The zones are not of the same significance nor based on the same characteristics as the "belts" defined in the consideration of distribution of individual grade components that follows.

Mud: Mud is present over a large area of the shelf. From the northern extremities of the survey, just south of Kaipara Harbour, mud is present from roughly the 50 fm line to the shelf edge. This condition persists southward to an area north-west of New Plymouth where mud is present very nearly to the shoreline.

From this position there is a narrow area extending north to the Waikato River mouth in which mud is present from the shore to an average distance of 7 miles offshore (25 fm). Around Cape Egmont there is a strip from the shore to an average of 4 miles offshore in which mud is not apparent.

South of Cape Egmont mud first appears at 30 to 40 miles offshore except for a small mud area off the mouth of the Wanganui River. These distributions outline the Inner Low-Mud Belt (in the Taranaki Bight south of Egmont) and an Outer Low-Mud Belt (from Kaipara to Mokau).

The shelf area where mud is the only component present averages 15 miles in width, sweeps in from the shelf edge south-west of Egmont, extends in a north-easterly direction towards Egmont, then veers away to the west and terminates about 45 miles west of Egmont. There is an average of 98–99 % mud in this area (the Central Mud Belt).

Very Fine Sand and Fine Sand: The fine and very fine sands are present over a greater area than the mud component, and the combination is found over the entire shelf except for the area of mud just described and an area roughly 25 miles west of the Mokau River. From Cape Egmont to the Mokau River, coarse and medium sand are absent from the Inner Low-Mud Belt.

Coarse and Medium Sand: These coarser components are found in an elongated area extending from the northern to the southern limits of the survey. Between Kaipara Harbour and Cape Egmont it varies approximately in width from 4–25 miles. South of Cape Egmont, from a narrow zone 4 miles wide, it broadens to 70 miles in width in the region of Wanganui. The Coarse Sand Belt coincides approximately in the north with the Outer Low-Mud Belt around 50 fm, and in the south with the Inner Low-Mud Belt.

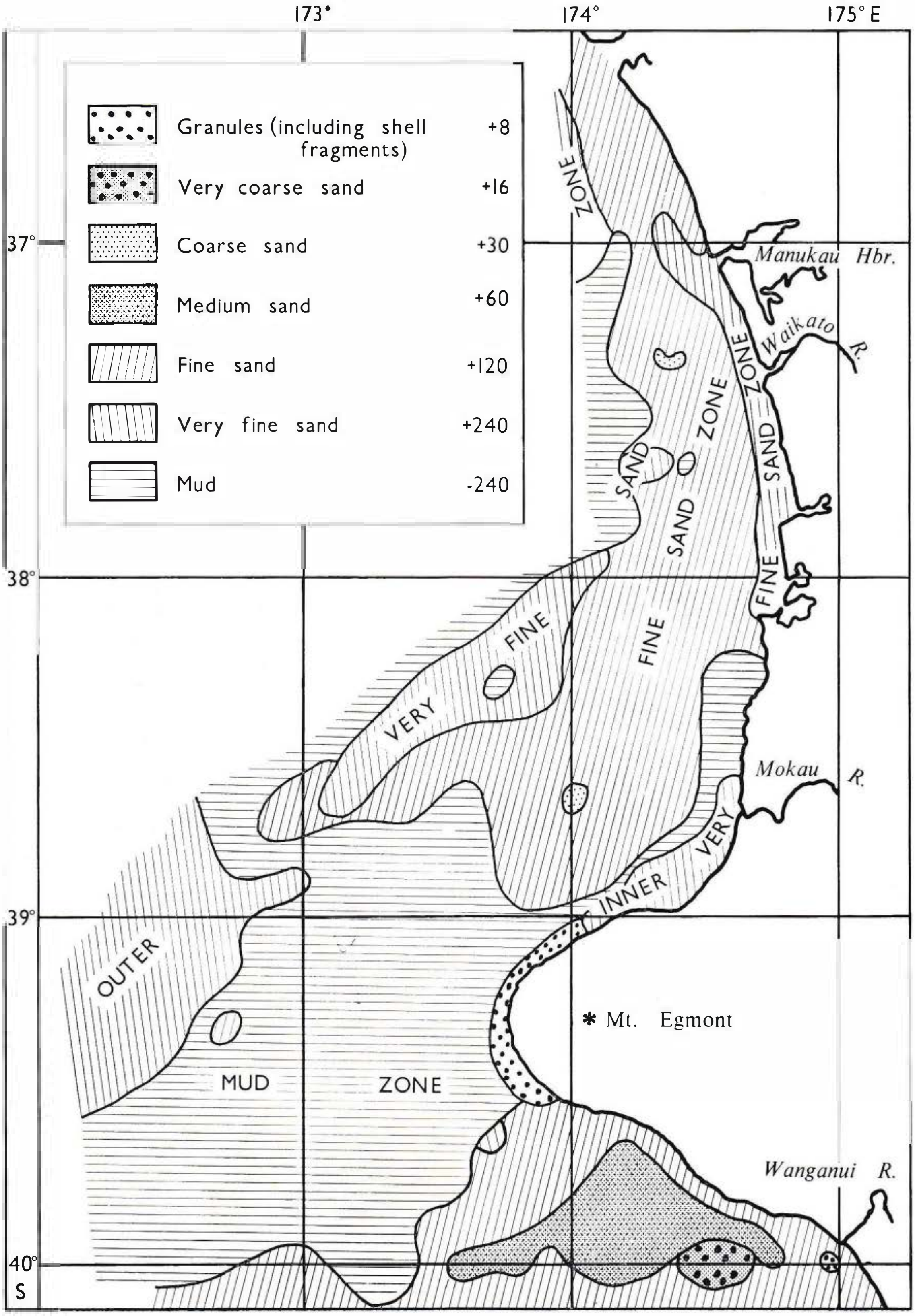

Fig. 8: (a) Distribution of dominant grades in total sediment.

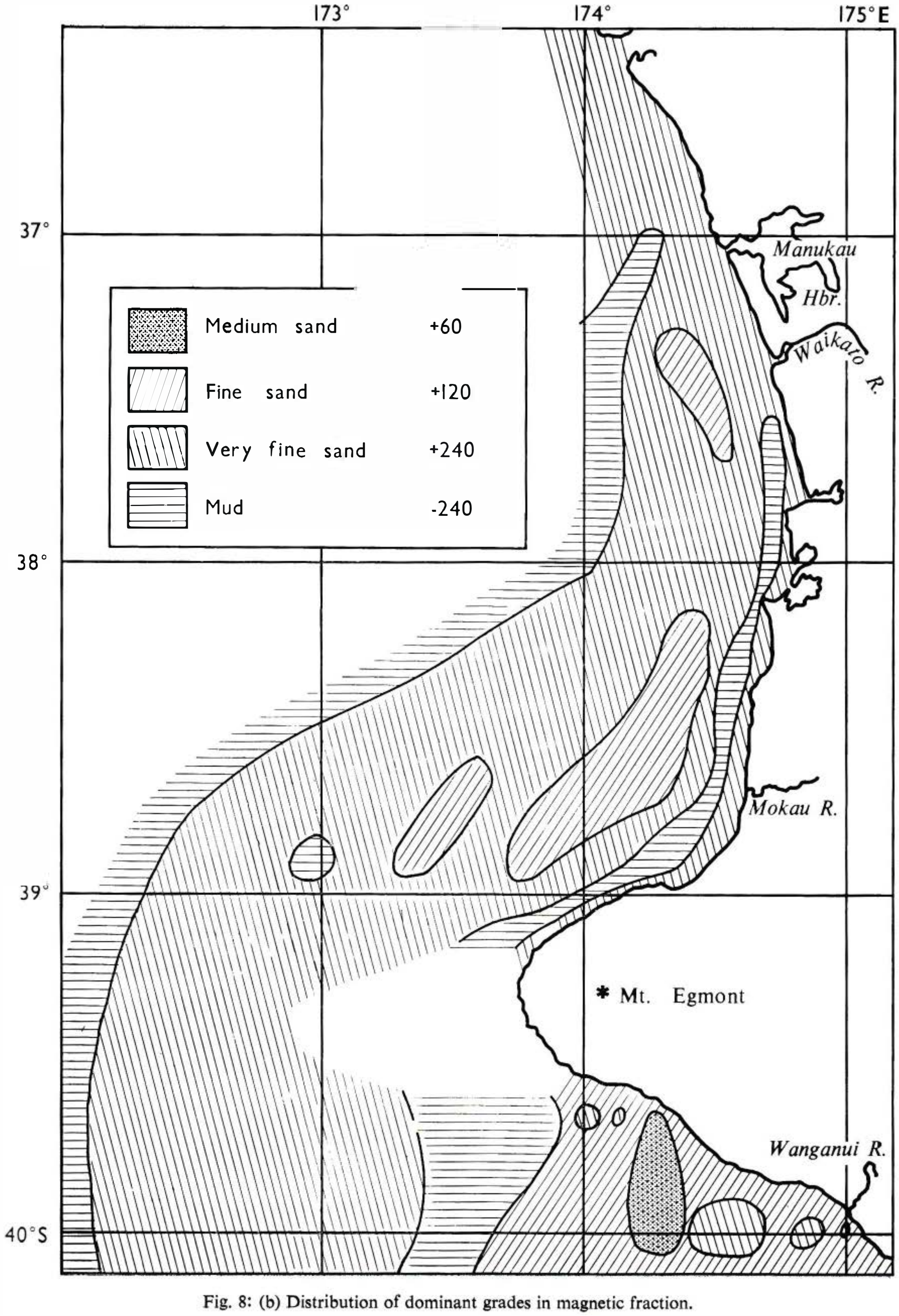

Fig. 8: (b) Distribution of dominant grades in magnetic fraction.

A variation in the composition of sand grains is evident where a distinct area of golden-grey grains extends from just south of the Manukau Harbour parallel to the coast and terminates south of the Mokau River (fig. 13a). The sand adjacent to the border of this area is principally fine grey sand, of varied composition. The sediment in the golden-grey sand areas is dominantly composed of well rounded quartz grains, some stained yellow.

A small isolated area in which reddish-brown sand occurs is situated offshore from Raglan. This has not been evident elsewhere on the shelf under survey. The sediment is similar to that in the golden-grey sand but the quartz grains are stained a deep red brown. These two areas of quartz sands lie at depths between 20 and 50 fm.

Over roughly the same area as that just described quantities of large Foraminifera are also evident in the sediment samples in sufficient amount to enable a shipboard distinction between these samples and others to be made. The area is narrow to the north and at greater depth.

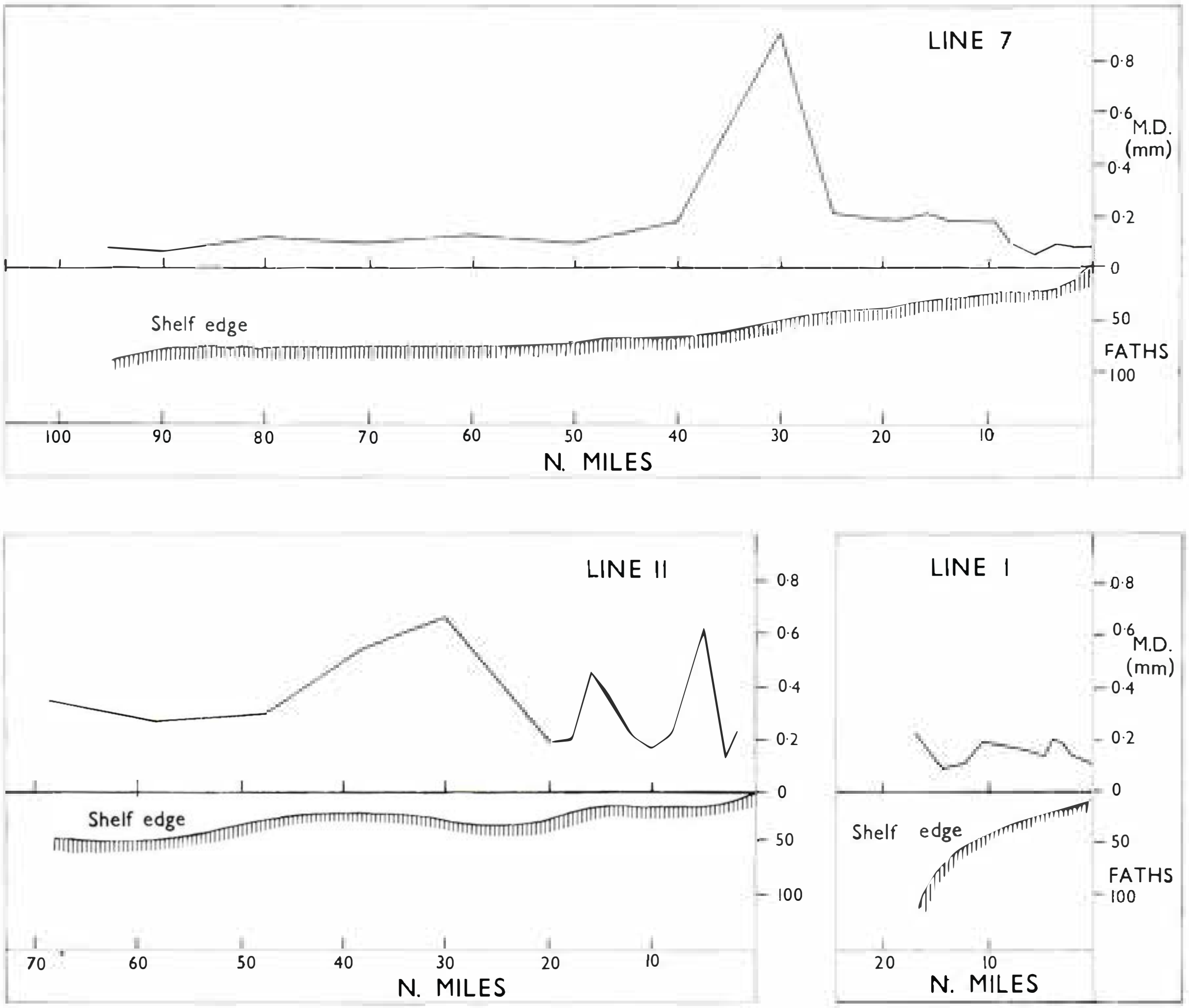

Fig. 9: Median diameters of surface sediments along three sampling lines; 1, 7, 11.

On several areas of the shelf, shells and shell fragments form a significant proportion of the sediment (fig. 13b).

Granules (*including shell fragments*): North of Egmont this component appears in three small isolated areas G1 (60 miles offshore), G2 (44), and G3 (20), (fig. 6). The outermost two areas lie at the shelf edge: G3 is in 50–60 fm. South of Egmont off the Patea coast lies the extensive Granule Belt which occupies the same area of shelf as the coarse and medium sand.

Each of the small areas shows variation in the type of sediment found. G2 contained pieces of encrusted well bored fine-grained ledge rock (B666). South-west of this is an area where numerous large shell fragments abound. G1 has sediment ranging from pebbly coarse black sand at its northern end to muddy fine sand with coarse shell fragments and numerous rounded andesite pebbles (B797) up to 3 in. long.

Close inshore around Mt. Egmont the granule grade includes rounded gravel and small blocks and boulders of volcanic rocks which have been sampled up to 5 miles offshore. Further south in this Belt the boulders tend to disappear, the surface sediment consisting dominantly of coarse shell fragments and gravel.

Median Diameters

Median diameter values for the surface sediments, obtained from lines (1, 7 and 11) show that diameters of less than 0·25 mm are predominantly at 10–40 fm and less than 25 miles offshore, though they are also found at 70–90 fm. Median diameters greater than 0·40 mm are found at depths not greater than 30 fm nor more than 40 miles off shore (fig. 10).

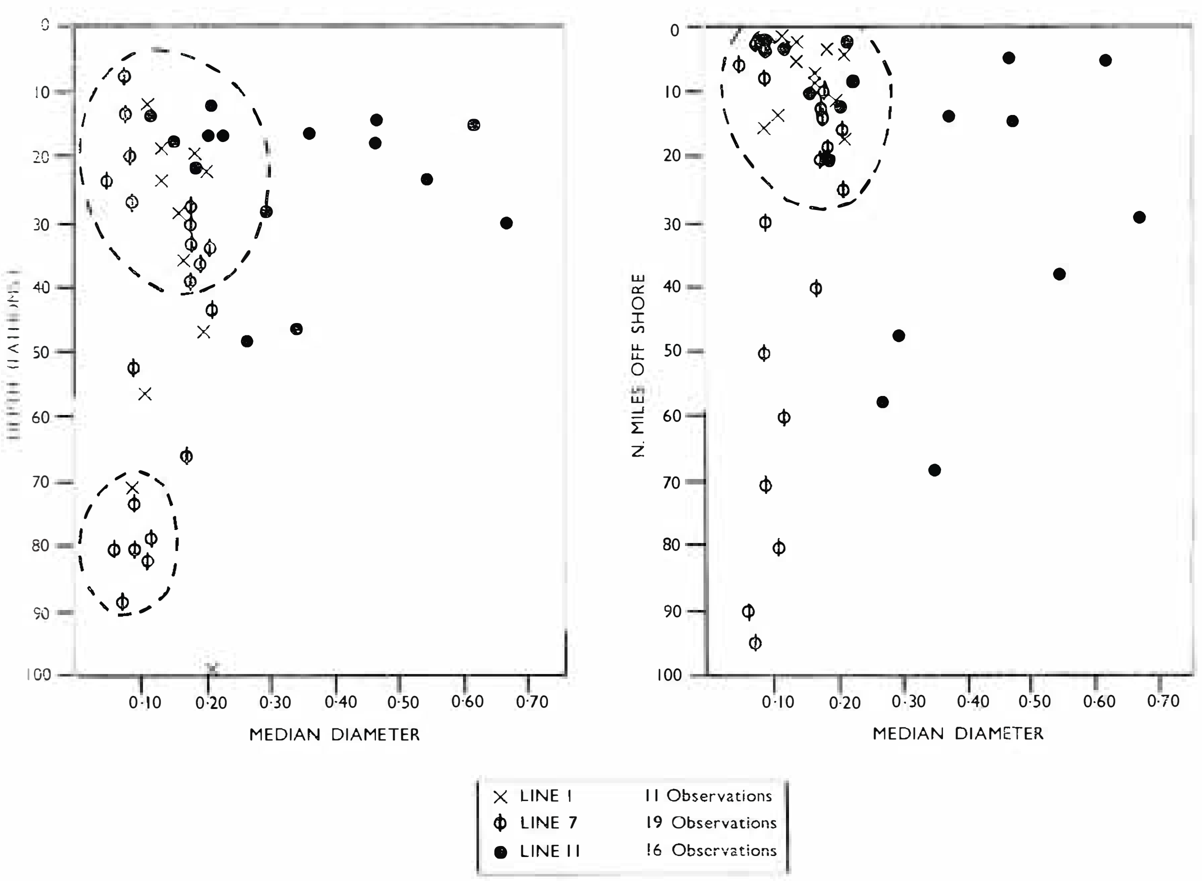

Fig. 10: Distribution of median diameters with depth and distance along lines. As line 11 is oblique to the shoreline a greater scatter of observations is present.

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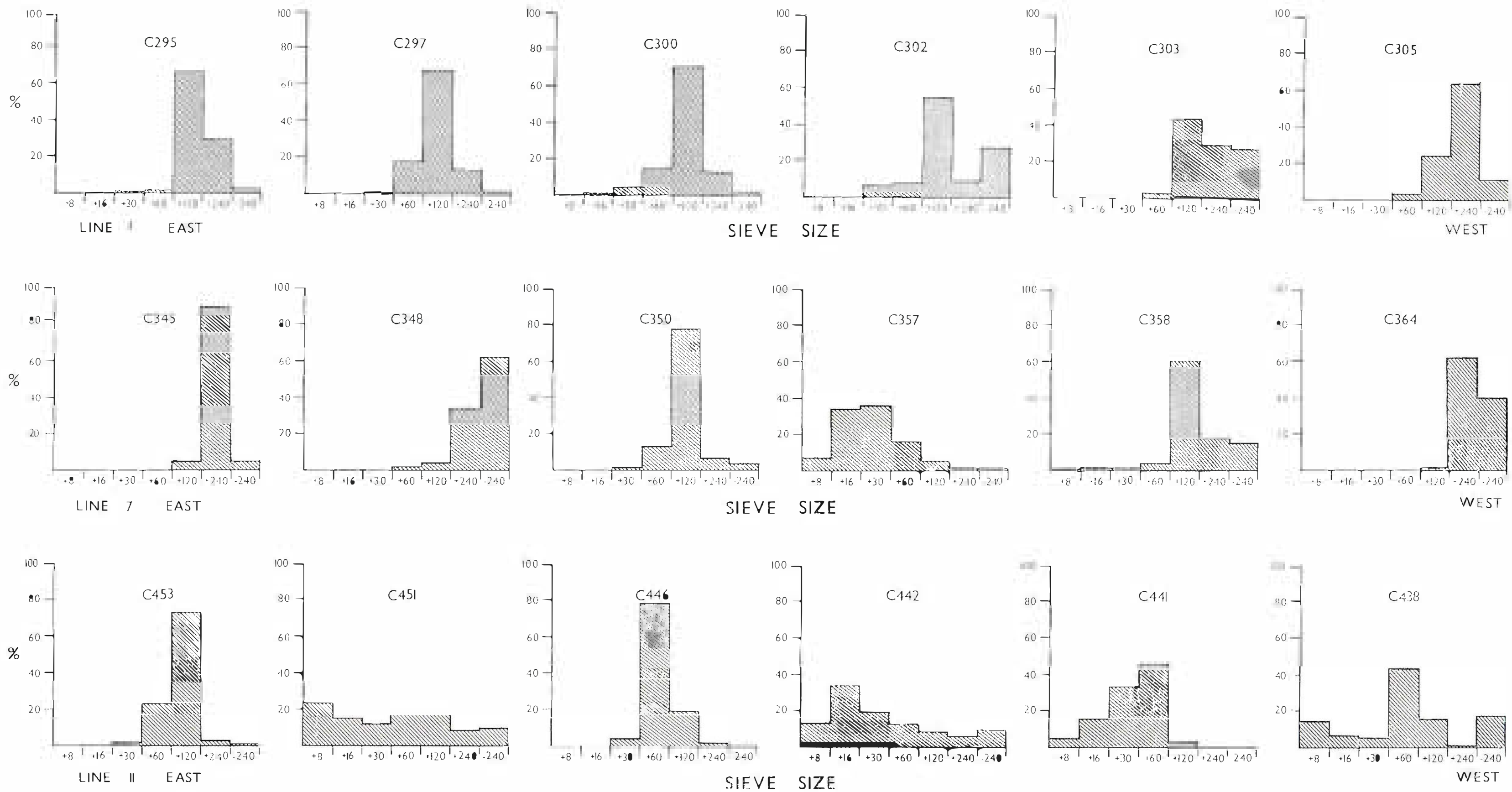


Fig. 11: Histograms of grain-size percentages for lines 1, 7, and 11, showing variations in grade and in sorting of the sediments.

Distribution of Dominant Fractions of the Total Sediment and of Titanomagnetite

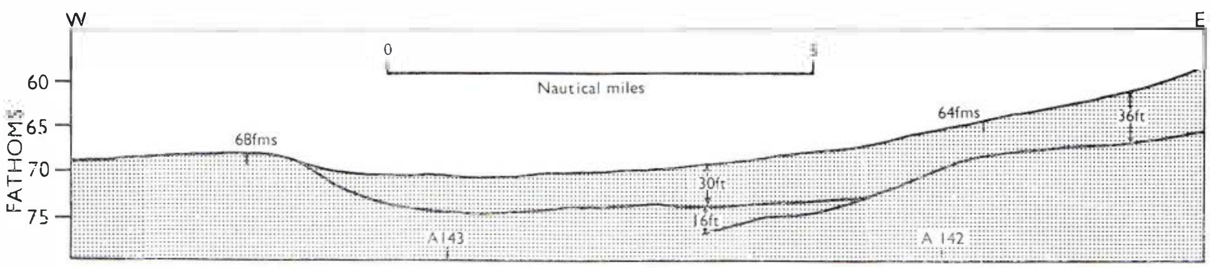
A comparison has been made between the distribution of the dominant fractions of the total sediment and the "magnetic fraction" (fig. 8).

Titanomagnetite occurs in the total sediment only in small proportions (ranging from 0·3 to 36%), however the average proportion is 2·1% (McDougall, 1961). The distribution of total sediment has been described earlier. The distribution of titanomagnetite follows a broadly similar pattern for the area north of Cape Egmont. Here the distributions of different dominant grades are aligned parallel to the shore and shelf edge as are the total sediment dominant grade zones. A narrow area of very fine sand near shore is succeeded seaward by a narrow area of mud, then by very fine sand over most of the shelf, broken by elongate patches of dominant fine sand. Near the shelf edge the titanomagnetite dominant is mud.

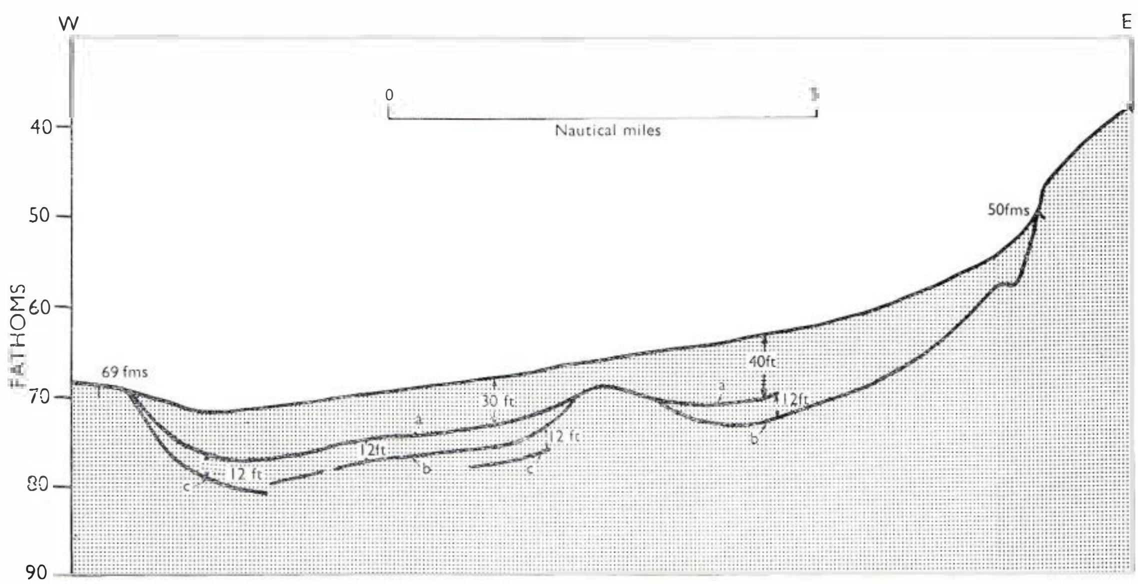
South and west of Egmont the distribution is poorly documented and the dominant grade varies from medium sand to mud. Along the Egmont sampling line the proportions of titanomagnetite in the samples were so small that insufficient material was available for mechanical analysis.

Comparison of Distribution: Where the dominant grade in titanomagnetite fractions is mud along the shelf margin the dominant grade in total sediment samples is the same except for six stations where this grade is slightly coarser or slightly finer. In the area south of Cape Egmont the total sediment is coarser, being medium and fine sand.

Fig. 12: Profiles of subsurface reflectors. Echogram along traverse shown in (a) below.



(a) Offshore from 39° 13′ S. 173° 42·5′ E bearing 284.



(b) Offshore from 39° 18·5′ S. 173° 41′ E bearing 270.

For the narrow area of titanomagnetite mud grade just offshore between Waitara and Marokopa the dominant grade is the same for the total sediment. North of this, to the Waikato River mouth the titanomagnetite mud area lies in the Inner Very Fine Sand Zone of the total sediment. Where the dominant grade of titanomagnetite is very fine sand the dominant grade of total sediment is typically fine sand, particularly for the shelf north of Cape Egmont. Conversely, however, where the dominant grade of total sediment is mud, in the offshore area south and west of Cape Egmont the dominant grade in the titanomagnetite is for the most part coarser, being mainly very fine sand.

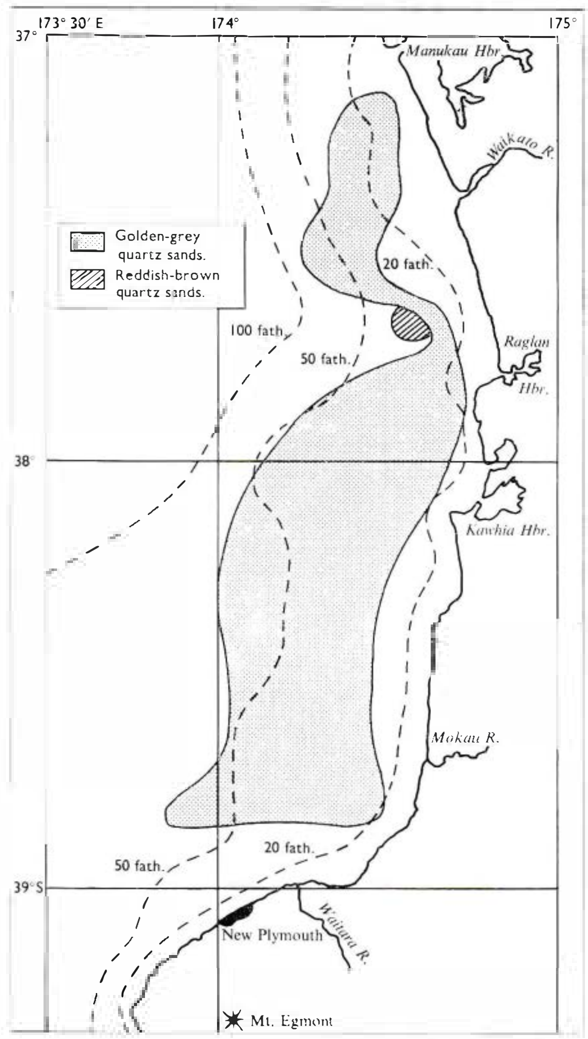


Fig. 13: (a) Areas of quartz sands on the Western Shelf.

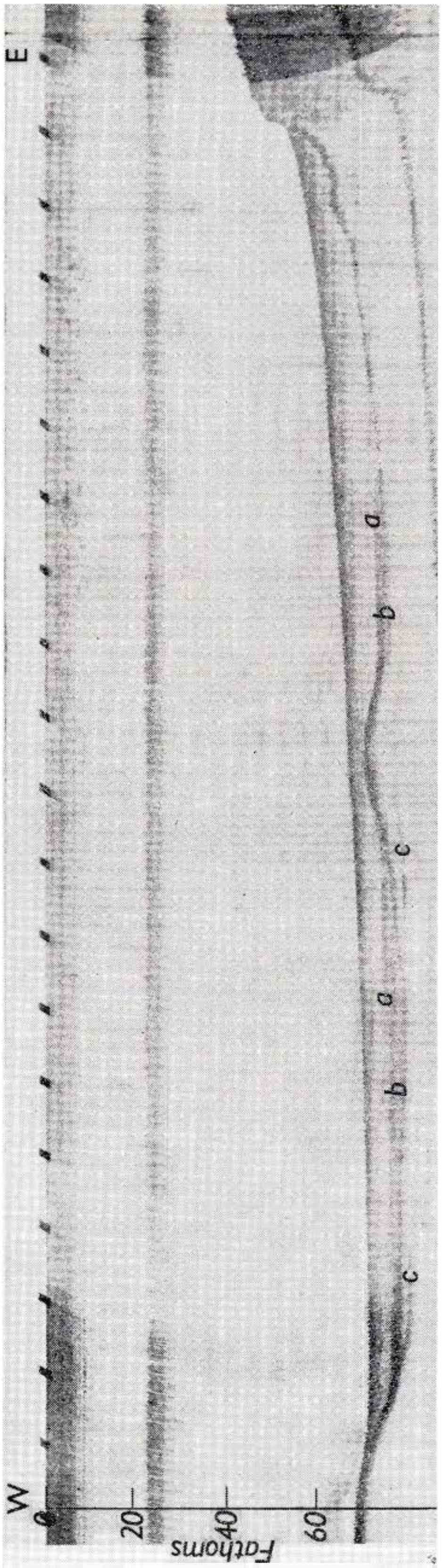


Fig 12: (c) Echogram along traverse shown in fig. 12(a).

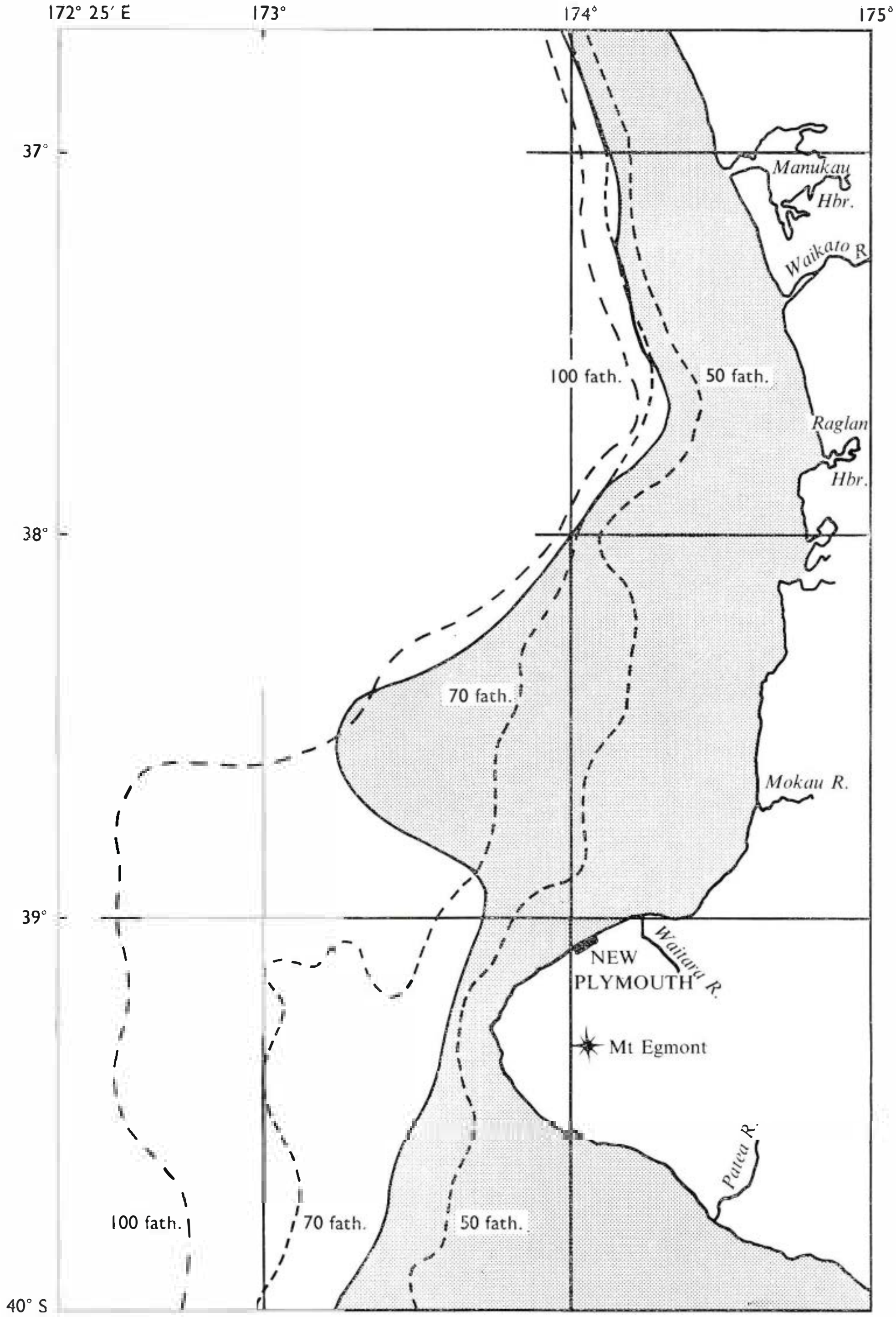


Fig. 13: (b) Area of prominent occurrence of dead shell and shell fragments.

Distribution of Sediments in Cores

The distribution of the subsurface sediments is shown by means of two sectional diagrams (fig. 14) of lines 2 (Piha) and 9 (Egmont).

Piha (Line 2): From shoreline to the shelf edge, a distance of 20 miles, 10 stations were occupied, five of which produced cores averaging 16 in. in length. The distribution of surface sediments over this distance is principally fine and very fine sand out to 50 fm. At this point mud makes itself apparent to a marked degree and continues to the shelf edge as the major constituent of the sediment.

Core C 311 (6 miles offshore in a depth of 23 fm). The top 1 in. consists of unconsolidated muddy fine sand with numerous fine shell fragments. The remainder of the core (20 in.) is evenly distributed muddy (fine – very fine) sand with an average of 28 % mud and 67 % of the fine – very fine sand component. There are fewer shell fragments in this lower section.

Core C 312 (8 miles offshore in 30 fm) is of a similar pattern but with more fine shell fragments throughout its length of 12 in. The top 3 in. consists of unconsolidated fine sand with numerous fine shell fragments, and the remaining 9 in. of the core are coarser in grade than the previous core. To a depth of 6 in. some of the shells and shell fragments are noticeably coarse.

Core C 313 (19 in. long, 10 miles offshore in 37 fm), consists of evenly distributed muddy fine sand with small shells and shell fragments, a slightly greater percentage of these being in the top 1 in. and lower 6 in.

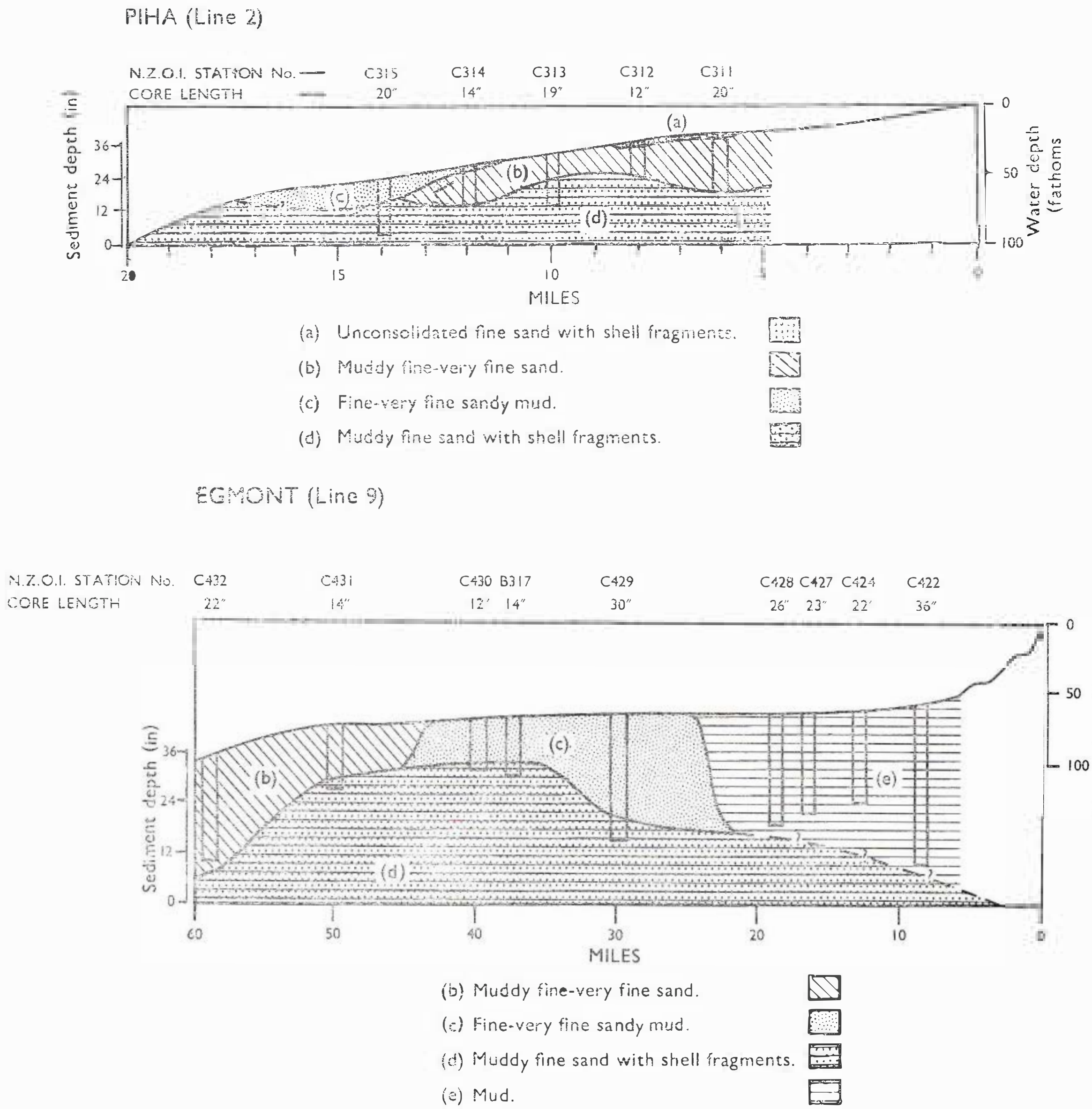


Fig. 14: Cross sections of sediment beds along two sampling lines.

Throughout the total length of the core there is an average of 60% fine sand – very fine sand and 25% mud.

Core C 314 (14 in. long, 12 miles offshore in 43 fm). The core consists of evenly distributed muddy fine sand with small shells and shell fragments. There is an average of 73% of the fine sand – very fine sand component and 20% mud.

Core C 315 (20 in. long, 14 miles offshore in 54 fm). This core is well graded, being muddier in the top 6 in. than the previous cores, and becoming coarser throughout its length. The top 2 in. is fine sandy mud with 59% mud, 35% fine sand – very fine sand and 5% of coarser material. At the bottom of the core these percentages have become 15 and 59 respectively and 26% of coarser material principally made up of shells and shell fragments.

The individual cores obtained along line 2 demonstrate in fig. 14 (a):

(1) out to 30 fm (8½ miles offshore) there is a surface unconsolidated layer of fine sand with a maximum thickness of 3 in. – layer (a);

(2) this overlies a lens of light grey muddy fine sand with numerous fine sand grade shell fragments which decrease in number progressively down the core to an average of 14 in. – layer (b);

(3) a third layer which contains fewer shell fragments but in which the sand grade has become coarser – layer (d);

(4) from 12 miles offshore in 45 fm, a muddy layer becomes apparent, overlying the previously mentioned layers. Coarse sand grade shell fragments appear in this region and increase towards the bottom of the core – layer (c).

Egmont (*Line 9*). From the shoreline to the shelf edge, a distance of 60 miles, 17 stations were occupied, eight of which produced cores averaging 23 in. in length, with the longest core being 36 in. Surface sediment distribution has been discussed earlier; between 20 and 68 fm (the Central Mud Belt) the surface sediment is principally mud: from this depth to the shelf edge the mud and very fine sand – fine sand component averages 61% and 37% respectively.

Core C 422 (9 miles offshore in 60 fm). Throughout its length of 36 in. there is a consistent average of mud 95%, and very fine sand – fine sand 4%.

Cores C 424, 427, and 428 are similar in composition to core C 422 with a slight increase in the mud percentage from 95 to 98. They were taken in 61, 62, and 66 fm being 22, 23, and 26 in. long respectively.

Core C 429 (30 miles offshore in 68 fm and 30 in. long). This core shows a different consistency from the previous cores of the line. The percentage of mud decreases from 86 at the surface to 30 at the bottom of the core. There is a marked increase in coarser material in the top 24 in. as shell fragments up to ½ in. diameter. At this stage there is 30% mud, 37% very fine sand – fine sand, 6% coarse – medium sand and 26% shell fragments of granule size. The general appearance of the core remains the same from this area to the bottom, with the numbers of very coarse shell fragments varying slightly, upsetting the percentages in a marked fashion as they vary.

Core C 430 (40 miles offshore in 71 fm, 12 in. long). In this core the upper 8–9 in. consist of sandy mud with an average of 60% mud and 37% very fine sand – fine sand. There is a gradually increasing but small percentage of fine shell fragments down the core. In the bottom 2–3 in. of the core, however, there is a marked increase in the quantity of shell fragments although there are more of the larger sizes seen in the previous core. In this section there is 33% mud, 50% very fine sand – fine sand, and 11% shell fragments of granule size.

Core C 431 (50 miles offshore in 74 fm, 14 in. long). The upper 10 in. is a very even consistency of muddy fine sand with an average of 42% mud and 56% very fine sand – fine sand. Shell fragments are not apparent in this section but are present to a small degree in the bottom part of the core. Here the mud decreases to 30% with an increase in the very fine sand – fine sand component to 65%. There is a noticeable amount of fine shell fragments which comprises the remaining 5%.

Core C 432 (60 miles offshore in 98 fm, 22 in. long). There is a very consistent appearance over the total length of this core. Percentages show a slight decrease in the mud fraction from 46 to 30, and an increase in the very fine sand – fine sand component from 52 to 70. The remaining fractions are negligible throughout.

The picture shown in fig. 14 (b) of the subsurface sediment distribution from the shore to the edge of the shelf along line 9 is of a layer of mud and muddy sand averaging 2–3 ft in thickness, overlying a layer with shell material of varying degrees of coarseness.

From the shore to about 20 miles offshore the mud layer consists of light grey mud averaging 97% mud, with no shell material at all, layer (e). Between 20 miles and the shelf edge there is a marked increase in the very fine sand – fine sand component making the pure mud into muddy fine sand, layers (c) and (b). The general tendency is for a muddier sediment at the surface becoming less muddy and more sandy down the core.

The shelly layer is apparent from 30–50 miles, layer (d). Cores inshore of this zone did not sample the shelly layer (fig. 14b).

Subsurface Reflecting Horizons

In the area immediately to the west of Cape Egmont, echo soundings have recorded a substantial subsurface feature (figs. 12a, b). Two east–west traverses 5 miles apart show a depression in the sediment surface. On the northern traverse (fig. 12a), this first shows at a depth of 60 fm and terminates 11 miles seaward in a slight rise in 68 fm. On the southern traverse (fig. 12b), the depression commences about 9 miles offshore in a depth of 50 fm and extends 11 miles seaward terminating in 69 fm.

Underlying this depression in the sediment surface (fig. 12b) are reflecting horizons, the most substantial appearing to be a continuation of the exposed sea floor surface at the east and west boundaries of the feature. This interface lies at a depth of about 50 ft below the sediment surface. Two other interfaces appear at 30–40 ft below the sediment surface.

PRESENT-DAY SEDIMENTATION

Three factors control the sediment distributions that can be seen at the present time.

(1) Nature of the sediment in specific localities under earlier régimes.

(2) Availability of present-day sediments.

(3) Present-day water turbulence and velocities.

Undoubtedly all the near shore sedimentary facies exist or persist under the direct effects of the present physical environment. Along and near the shoreline the maximum wave effects are exerted and though, as Pantin (1964) has pointed out, oceanic and tidal currents may have maxima that lie offshore, yet there is no external evidence of this in the area here considered. If decreasing turbulence because of decreasing wave effect with increasing depth be assumed, this then implies the existence of the classic seaward distribution of:

(1) Inshore mud deposited by flocculation at river mouths;

(2) Near shore zone of sands;

(3) Zone of finer sands and muds.

North of Cape Egmont

Inner Shelf: Zonation of dominant sediment grades on the shelf is clear and for the area north of Cape Egmont follows a regular pattern. The succession of dominant grades seaward – very fine sand; fine sand; very fine sand – does not follow the distribution model: the coarser of these grades dominates in an Inner Shelf Zone between 25 and 50 fm. This coarsening of grade seaward as indicated by the dominant grade is matched by the occurrence of coarse sand near the mid-shelf.

Thus on the Inner Shelf one or other of these circumstances is dominant.

(1) The distribution of water turbulence and velocity is anomalous;

(2) Pre-existing sediments have not yet been buried by present-day deposits; or

(3) Basically different sediments are being supplied to different portions of the Inner Shelf.

It is obvious that there are no critical external criteria for establishing the degree to which each of these circumstances prevails. If the current régime is markedly variable over the shelf then the velocity over the Fine Sand Zone and Coarse Sand Belt is higher than that inshore and offshore from this inner and mid-shelf area. The deposition of mud, which as suggested above is there available as a present-day sediment, would thus be prevented and the coarse sands of the Coarse Sand Belt remain in substantial proportions in the surface sediment.

In view of the heterogeneous assemblage of volcanic and sedimentary rocks forming the present hinterland of the North Island west coast, it is not easy to see that local differences in the resulting present-day sediments could be a dominant factor in controlling grain size distribution.

Mid-Shelf: The coarse sediments in the mid-shelf region north of Egmont (the quartz sands of the Coarse Sand Zone) are more probably associated with water velocities of an earlier wave zone rather than with the smaller current velocities expectable in the present depths (25–50 fm) over this area, though as suggested these may be sufficient to prevent mud deposition. This implies a former near shore (0–5 fm) environment in which the quartz sands were deposited. The zone terminates at Cape Egmont. If sea level were then at the −50 fm mark then at this Mid-Shelf time, the coastal outline would have continued southwestward toward the South Island and Cook Strait would not have been open.

Outer Shelf: The shelf deeper than 50 fm is covered with sediments in which very fine sand grade is dominant and at its outer margin by mud. The clear boundaries to the sediment zones and their association with particular depths both suggest that over all of this northern shelf these sediments are largely relict and owe their existence to sedimentary processes developed at lower stands of sea level. It is of course possible that the distribution of water velocities on the shelf is zoned, in a similar manner to the sediments, but as stated earlier there is no external evidence that this is the case.

South of Cape Egmont

On this part of the shelf sediments with mud as the dominant grade are widespread. With these grouped as the mud zone there is little other evidence of zonation. It is made clear by the occurrence of mud in depths of 40–70 fm (but beginning close inshore near Cape Egmont) that this is the normal sediment appropriate to these depths on this part of the shelf.

The supply of sediment from shoreline and rivers may well be such that the present day "normal" sediment for the whole of the shelf area other than the near shore zone may be mud. The amount deposited from place to place varies from nil to substantial enough quantities to make it the dominant grade. It is not possible to distinguish present day from relict mud if such occurs.

There are few data that help to explain the substantial difference between the shelf sediments north of Cape Egmont and in the mud zone. The area of dominant mud south and west of Cape Egmont lies mostly seaward of the 40–50 fm line. For comparable depths on the northern part of the shelf, the mud percentage is mostly low. This implies either that there is a lesser amount of mud available here for deposition, or that the water velocities are high enough to prevent substantial deposition of the mud fraction, or that the mud of the mud zone is partly relict. If a significant part of this mud is relict then the difference between the two parts of the shelf that exists now also existed in Post Shelf Edge time. In both these times the mud may in fact be derived from the sedimentary materials produced on the west coast of the South Island that are carried northward by coastal currents (Brodie, 1960) and deposited where these currents slacken over the wider extent of shelf in the western entrance to Cook Strait.

To summarise, present-day sediments are probably confined principally to the mud and very fine sand grades. Except for the near shore zone the areas with dominant grades coarser than mud are probably areas of relict sediments from earlier sedimentary environments.

PHASES OF SEDIMENTATION

The morphological divisions into which the shelf south of Cape Egmont falls can be taken as indicative of at least two major time intervals. It is reasonable to suppose that the processes of erosion and sedimentation that shaped the near-horizontal but irregularly surfaced outer shelf – stretching from the gradient discontinuity in 50–60 fm to the shelf edge – were distinct from those that followed and controlled the shaping of the inner shelf from 20 fm to the shore. Correlation with the mid-shelf (40 fm) discontinuity in gradient in the northern area considered here is probable but by no means clear.

For the southern area it is helpful to recognise two time intervals—Post Shelf Edge, and Post Mid-Shelf. The inner margin of the Cape Egmont subbottom reflectors coincides with the seaward boundaries of granule areas in the Coarse Sand Belt and of the Outer Low-Mud Belt. The area in which the reflectors lie has a possible north–south seaward boundary and lies in the Central Mud Belt. Judged by this example and the less deeply buried reflectors to the south (Echo Sounding traverse No. 422), the uppermost sediment is filling depressions in a pre-existing shelf surface that elsewhere coincides with the present upper surface of the sediments. On this basis the present-day sediment in the area off Cape Egmont is mud.

The sedimentary interfaces (fig. 12) may be major grade changes (e.g., they may be coarser sand and gravel underlying muddy sand as described by Pantin (1964)) or they may be compaction unconformities in sediments of more uniform grade composition. Under earlier conditions of high sea level, as at the present day, sediments in the mud grade could similarly have been deposited in the Cape Egmont "depression". Then compaction unconformities would have occurred if, in intervening periods of lower sea level, the upper less-compacted portions of the previously deposited sediment were stirred up by increased wave and current activity and transported elsewhere.

If sea level were radically lowered then near shore wave and current processes could bring about the deposition of coarser grades. The coarser sediments that are at the surface just landward of the eastern boundary of the "depression", and the slightly coarser grades west of this area suggest that the interfaces may be composed of similar materials.

Consideration of the relative stratigraphic positions of these horizons is complicated by two factors. One is the proximity of the depression in which they lie to the Cape Egmont volcanic complex, and its associated fault features. It is at least possible that the depressed area is the superficial indication of a small graben-like structure.

Secondly, while the depression may be a function of erosion and deposition the area may have suffered from warping and relative vertical movements. (Superficially, the surfaces could have undergone tilting with a seaward component.) However, no quantitative estimate can be made of the effects of these events if in fact they did occur. The lowest reflector is at present between 72 and 80 fm (av. 76) below sea level. The distances to areas where the present sediment surface lies at these depths are 30 miles to the south-west and only 7 miles to the north. Considering that there now exists a relief of about 12 fm between the lowest reflector and the sea floor at the seaward margin of the depression there is room for the possibility that an "Egmont Gulf" – 15 miles wide and of unknown length – may have existed in Post Shelf Edge time connected with the open sea to the north at depths the same as those on the present Outer Shelf (fig. 15).

Following the Shelf Edge time erosion, then in Post Shelf Edge time, the Egmont Gulf stratigraphy indicates:

Deposition – on surface (a) under rising and high sea level up to present sea floor.
Erosion – under lowered sea level to produce surface (a).
Deposition – under high sea level.
Erosion – under lowered sea level to produce surface (b).
Deposition – formation of surface (c) – under rising and high sea level on surface (c).

The lowering in sea level needed to achieve the erosion indicated is not clear. If near shore conditions are represented then the fluctuations would have been extreme and the low stands could have approached the sea level of Shelf Edge time.

Stands of Sea Level

The analyses so far attempted indicate a succession of low stands of sea level.

The earliest low sea level is that of Shelf Edge time when the outer shelf edge was cut. The average present depth in the area considered here is 85 fm, and sea level at the time of shelf edge formation thus stood at approximately 80 fm.

The deepest of three reflecting horizons (fig. 12) that appear at present depths between 72 and 80 fm has been correlated with the outer shelf edge. The two later horizons can be considered as representing successive sea level stands near 75 and 70 fm respectively.

In the 40 – 60 fm zone a marked change in the shelf gradient (fig. 4) combined with mid-shelf shell, pebbles and coarse sands are indicative of a near-shore environment.

The concentration of ironsand found at 15 fm over a wide area of the shelf has been ascribed to wave processes operating at a time of Late Glacial low sea level (McDougall, 1961).

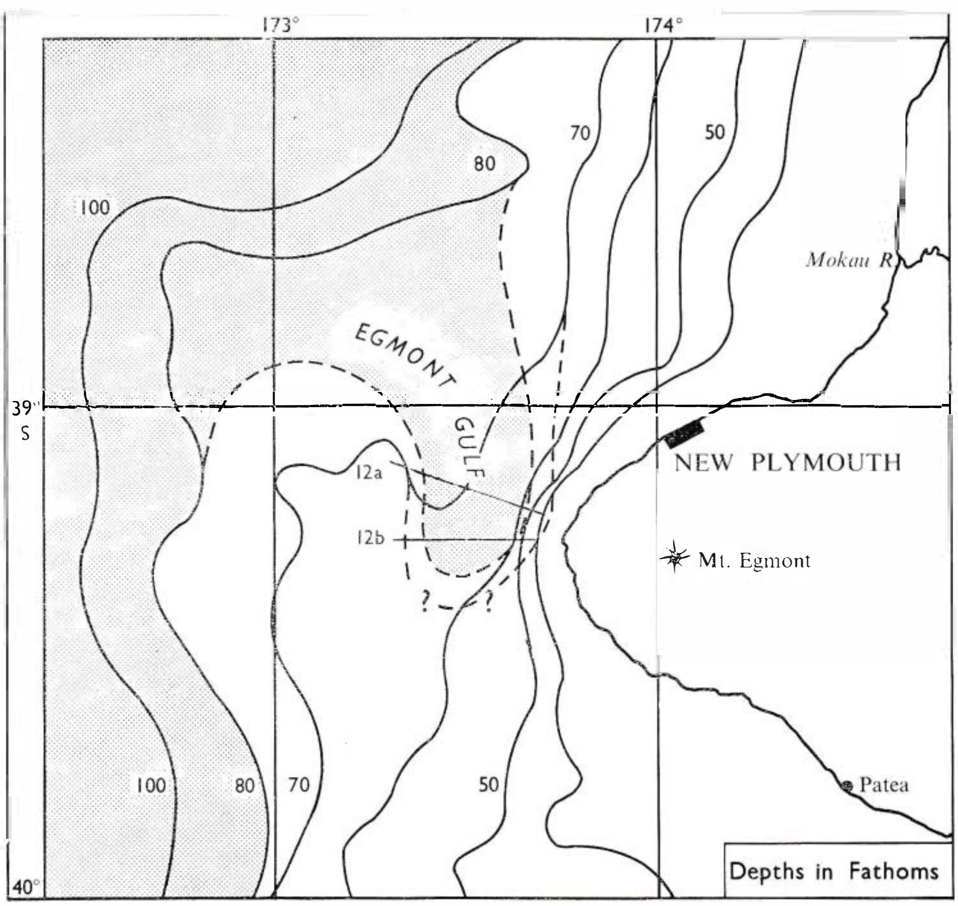


Fig. 15: A tentative reconstruction of the Shelf-Edge-time shoreline, showing the location of Egmont Gulf. (Echo-sounding traverses of figs. 12a and 12b shown west of Egmont.)

Relative Chronology

From an examination of the shelf morphology associated with glacial features off the south-western coast of the South Island Bruun *et al.*, (1958) were able to postulate that the shelf edge there was cut at a period of low sea level later than Penultimate Glaciation time and earlier than the second stadial of the last Glaciation.

It is reasonable to assume that a similar time of origin can be ascribed to the Western Shelf in general, for the shelf edge is broadly continuous. A time of origin at an early (perhaps the first) low stand of sea level in the Last Glaciation is thus indicated. Shelf Edge time can be equated with early last Glaciation time. In this (first stadial) period the shoreline was deeply indented by the Egmont Gulf.

The −75 and −70 fm surfaces preserved in the fill of the Egmont Gulf must be relatively closely associated with it in time and can be ascribed to subsequent low stands of sea level in early sub-stages of the Last Glaciation.

The near shore deposits of the present mid-shelf at −40 to −60 fm may be correlated with a late maximum (perhaps of the last substage) of the Last Glaciation.

In present depths of 15 fm the ironsand concentrations have been interpreted as beach deposits of "Late Glacial" age. Their position in shallower depths than the present mid-shelf coarse sediments suggests a time of formation at a late still-stand of sea level in the last glacial substage (table 2).

This chronology then places all the shelf events in and subsequent to the Last Glaciation. The data do not lend themselves to recognition of relatively high (interstadial) levels that might have been located at or near present sea level. Similarly evidence of the low stands of sea level that occurred in the Penultimate Glaciation would, on the hypothesis accepted here, have been destroyed during shelf formation.

Because of the width of the shelf off the Wanganui coast it cannot be clearly shown that the probable Last Interglacial high sea level Rapanui terraces described by Fleming (1953) from this area have no relation to the outer shelf. However, where the shelf is narrow as in Fiordland, then the morphological discontinuity between Last Glaciation and earlier features is clearly apparent.

Table 2. Shelf Chronology

		Age	Sea Level (Depth below present sea level in fathoms)	Feature
LAST GLACIATION	Post Mid-Shelf	"Late Glacial" Last Stadial of Last Glaciation	15–20	Beach concentration of Ironsand. Boundary between Inner Very Fine Sand Zone and Fine Sand Zone.
		Last Interstadial	High sea level	
	Post Shelf Edge	Penultimate Stadial of Last Glaciation	40–60	Discontinuity in shelf gradient Mid-Shelf coarse sands, Mid-Shelf shell and pebbles. (Stations C 357 and B 797.) Boundary between Outer Very Fine Sand Zone and Fine Sand Zone.
		Penultimate Interstadial ..	High sea level	
		?	?	?
		?Third Stadial*	70?	Reflector Horizon a.
		? Second Interstadial* ..	High sea level	
		? Second Stadial	75?	Reflector Horizon b.
		? First Interstadial*	High sea level	
		First Stadial of Last Glaciation ..	80	Shelf edge. Reflector Horizon c. ..
LAST INTERGLACIAL			High sea level	

*or fluctuations within the First Stadial.

VOLCANIC COMPONENTS OF SHELF SEDIMENTS

The volcanic constituents of the present shelf sediments have been transported there by a number of mechanisms.

Ash: First of these is the direct fall of fine volcanic ash over wide areas from the adjacent eruptive centres of Mt. Egmont and the Auckland peninsula volcanoes. Some lesser contributions can have arisen directly from the central North Island volcanoes (Grange and Taylor 1932, Fleming 1953).

The central area of the North Island that drains to the west has provided a large area from which subaerial andesitic and rhyolitic ashes and pumice have been eroded by rivers and transported to the sea.

Pre-Recent concentrations of heavy mineral constituents of earlier volcanics have been available for reworking either on the shelf or as subaerial dunes.

Lahar: Around Mt. Egmont, lahar deposits form the coastal cliffs in many places. These are recognisable in the adjacent near shore marine sediments as concentrations of large boulders and pebbles of andesite.

Hornblende crystals and fragments are common constituents of the near shore coarse sediments in the area near and south of Cape Egmont. At one station, (C 181) in 14 fm 20 miles west of Patea, crystals up to 3 mm long were abundant. These may derive from near shore weathering and working of the coarse components of lahar deposits.

Ironsands: Magnetite forms 2–5% of the ash deposited in the late Egmont ash deposits of the Wanganui-Taranaki region (Fleming, 1953). This ash covers superficial deposits that include earlier andesitic and rhyolitic ash showers.

Grange and Taylor (1932) have mapped the two Egmont andesitic ash showers that they recognise, extending along the coastline from about 10 miles south of Tirua Point to Wanganui. North of this area they have recognised an older ash from Mt. Egmont, the mainly andesitic Mairoa shower extending north almost to Raglan.

The magnetite from these and earlier showers can thus have been directly emplaced in the marine sediments. On the other hand the presence of magnetite distributed in fairly uniform proportions down the length of a 20 in. core (C 311) argues for an extended history of the magnetite as a marine sediment.

If primary subaerial emplacement controlled the distribution of volcanic components (as these are indicated by the magnetite) then some symmetric relation to the origin in Mt. Egmont could be expected. No such relation is indicated either in the distribution of grade of magnetite or of its proportion in the total sediment. The area in which the coarsest magnetite particles are dominant is just south of Mt. Egmont. In the mid-shelf area west of Cape Egmont, where the total sediment dominant is mud, the magnetite dominant grade is very fine sand. Other than this discrepancy and within limits imposed by available primary grain sizes the distribution of dominant grade is similar for both total sediment and magnetite, though the magnetite tends to be a little finer. Though the anomalous occurrences of very fine sand grade magnetite as a dominant in the Mud Zone could be taken as an indication of at least partial primary emplacement of volcanic materials, yet the magnetite is accompanied by small percentages of non-volcanic fragments in the very fine sand grades.

The weight of information supports the suggestion that the present magnetite distribution has been effected as a marine sedimentary process. Some of the magnetite has undoubtedly been concentrated in near-beach processes at late stands of sea level, and has been rederived from these concentrations (either from high sea level dunes or new submerged beaches and dunes).

ORIGIN AND METHODS OF EMPLACEMENT OF SHELF SEDIMENTS

Origin of Sediments: There are three types of sources that provide present day marine sedimentary material on the sea floor.

(1) The first group of these comprises the contemporary sources of primary particles either of alluvium, products of beach wearing or of shore erosion and volcanic ash.

(2) The second is that composed of unconsolidated or poorly consolidated marine sediments emplaced in an earlier phase of marine deposition. Some of these are the deposits that in the Flandrian rise of sea level were formed and then reworked as the sea transgressed over them, and are only in part able to be recognised as such.

(3) The third category comprises the mainly coarser materials of near shore deposits that were formed in earlier low-level stands of the sea that, because the present-day processes are unable to remove or cover them, exist as relict sediments out of phase with their environment at the present surface of the sea floor.

Methods of Emplacement: The near shore occurrence of mud at river mouths is ascribed to flocculation of river-borne fine sedimentary particles on entering salt water. Other than this circumstance, the shelf deposits – if all were contemporary – should reflect simply the tendency of the heaviest particles to fall out of suspension earlier than the fine, together with the superimposed effect of water turbulence and velocity variations. It is notable, as exemplified by the present data, that while the variations in water movement cannot readily be mapped, yet the variability of sediment grade distribution seems more than can reasonably be ascribed to this cause. If the water movement pattern were to be directly correlated with anomalous sediment distribution, then a remarkably steady pattern of distribution of water movement variations is implied.

The role of relict and reworked sediments in forming the shelf sediment grade distribution pattern is considerable and in cases such as that studied here is only little inferior to that of the present-day primary sediments.

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Table 1: Station List

GD Dietz grab. DC cone dredge. GHO medium orange-peel grab. GLO large orange-peel grab.
DCM.B mesh cone dredge with bag. Cg gravity corer. TAS small Agassiz trawl. TAL large Agassiz trawl.
GP Petersen grab. W Worzel sampler.

Station No.		Line	Date	Position Lat. S	Position Long. E	Distance* (Nautical miles)	Depth (fathoms)	Gear	Core Length (in.)	Sediment
A	45		15/2/55	39° 15′	173° 38′	6	63	GD		Mud
A	47		"	39° 11′	173° 26′	18	73	"		"
A	49		"	39° 08′	173° 14′	31	73	"		"
A	51		"	39° 04′	173° 02′	47	77	"		"
A	146		14/5/55	39° 07′	173° 09′	35	75	"		"
A	431		2/10/58	39° 47·5′	173° 46′	37	42	DC	24	Muddy fine sand.
A	432		"	39° 53′	173° 43′	46	57	"		Shelly muddy sand.
A	433		"	40° 00′	173° 40′	64	60	"		"
B	309	HAWERA	24/10/60	39° 39′	172° 24′	90	134	GHO + Cg	32	Mud.
B	317	EGMONT	26/10/60	39° 21′	172° 59′	37	83	"	15	Muddy very fine sand.
B	318	"	"	39° 07·5′	172° 35′	60	94	"		"
B	319	"	"	39° 03·5′	172° 21·5′	78	351	"	42	Very fine sandy mud.
B	321	"	27/10/60	39° 53′	172° 58′	82	82	"	16	Mud.
B	322	WANGANUI	"	40° 00′	173° 08′	89	68	"	26	Very fine sandy mud.
B	645	"	22/10/62	40° 00′	172° 34′	117	103	DCM.B		Mud.
B	646	"	"	40° 00′	173° 00′	96	64	TAL		Very fine sandy mud.
B	647	"	"	40° 00′	173° 23·5′	78	53	DCM.B		Fine sandy mud.
B	648	"	"	40° 00′	173° 52′	55	53	TAL		Predominant polyzoan and shell fragments with sandy mud.
B	649	"	"	40° 01′	174° 20·5′	33	37	DCM.B		"
B	650	"	"	40° 00′	174° 43′	16	23	"		Coarse shelly sand.
B	652	EGMONT	23/10/62	39° 20′	173° 44·5′	1	14	"		Encrusted boulders.
B	653	"	"	39° 20′	173° 42′	3	43	"		Encrusted boulders, shell fragments, fine sand.
B	654	"	"	39° 20′·5	173° 18′	22	70	"		Fine sandy mud.
B	655	"	"	39° 20′	172° 27′	61	105	"		Very fine sandy mud.
B	657	MOKAU	24/10/62	38° 37′	173° 07′	71	85	"		Muddy fine sand.
B	658	"	"	38° 39′	173° 25′	57	78	TAL		"
B	659	"	"	38° 39·5′	173° 47·5′	40	68	DCM.B		"
B	662	"	25/10/62	38° 06′	174° 44·7′	2	8	"		Pebbly shelly fine sand.
B	666	AOTEA	"	38° 00′	173° 58·2′	40	93	TAL		Encrusted bored rock.
B	667	WAIKATO	"	37° 20′	174° 40′	2	9	DCM.B		Fine sand.
B	669	"	"	37° 20′	174° 09′	26	71	TAL		Muddy fine sand.
B	671	MURIWAI	26/10/62	36° 40′	174° 17′	1	11	DCM.B		Fine sand.
B	673	"	"	36° 40′	173° 56·5′	18	68	TAL		Muddy fine sand.
B	675	"	"	36° 40′	173° 50′	23	210–154	"		Fine sandy mud.
B	676	"	26/10/62	37° 11′	174° 30·5′	5	19	GLO		Fine sand.
B	677	KAPIAPIA	"	37° 30′	174° 40′	4·5	21	"		"
B	678	"	"	37° 43·5′	174° 48′	2·5	17	"		"
B	679	KARIOI	"	37° 53′	174° 45·5′	2	21	"		"
B	680	"	27/10/62	39° 00′	173° 12·5′	45	73	DCM.B		Mud.
B	681	"	"	39° 01′	172° 53′	60	73	"		"
B	682	"	"	39° 13′	172° 50·5′	43	74	"		Fine sandy mud.
B	685	WANGANUI	28/10/62	40° 00′	172° 08′	135	167	TAL		Mud.
B	777	KAPIAPIA	15/3/63	37° 31′	174° 30′	13	34	GHO		Fine sand.
B	778	"	"	37° 30′	174° 17′	23	63	"		Muddy fine sand.

B	779	KAPIAPIA	15/3/63	37° 30′	174° 05′	33	324	"	Sandy mud.
B	780	RAGLAN	"	37° 40′	174° 05′	36	258	"	"
B	781	KARIOI	"	37° 50′	174° 13·5′	26	63	"	Fine sandy mud.
B	782	"	"	37° 50′	174° 23·5′	18	49	"	Muddy fine sand.
B	783	ALBATROSS	"	38° 07·5′	174° 17′	20	47	"	Shelly fine sand.
B	784	"	"	38° 10′	174° 05′	30	59	"	Muddy shelly fine sand.
B	785	"	"	38° 10′	173° 50′	42	81	"	"
B	786	"	"	38° 09′	173° 35′	53	533	"	Mud.
B	788	TIRUA	16/3/63	38° 30′	174° 35′	3	22	"	Shelly fine sandy mud.
B	789	"	"	38° 30′	174° 20′	15	42	"	Shelly muddy fine sand.
B	790	"	"	38° 30′	174° 00′	30	55	DC	"
B	791	"	"	38° 30′	173° 39·5′	46	82	"	Muddy fine sand.
B	792	"	"	38° 30′	173° 20′	61	89	"	"
B	793	"	"	38° 30′	173° 00′	77	352	"	Very fine sandy mud.
B	794	TONGAPORUTU	"	38° 50′	172° 45′	86	82	GHO	"
B	795	"	17/3/63	38° 48′	173° 03′	73	75	"	Fine sandy mud.
B	796	"	"	38° 48′	173° 27′	54	73	"	"
B	797	"	"	38° 49′	173° 54′	32	58	"	Muddy shelly fine sand.
B	798	"	"	38° 48′	174° 30′	5	17	"	Muddy fine sand.
B	799	WAITARA	"	38° 54′	174° 26′	3	15	"	Fine sand.
B	801	"	18/3/63	39° 00′	173° 35′	27	67	"	Fine sandy mud.
B	802	"	"	39° 05·4′	173° 42′	14	64	"	"
B	803	"	"	39° 07′	173° 44·3′	10	60	"	"
B	804	"	"	39° 08·4′	173° 46·1′	5·5	44	"	Fine sandy mud.
B	805	"	"	39° 10′	173° 48·2′	2	16	"	Shelly gravel.
B	807	"	"	39° 27′	173° 49·5′	1·5	11	"	Encrusted cobbles.
B	808	"	"	39° 29·5′	173° 48′	4·5	30	"	Gravel.
B	809	"	"	39° 31′	173° 46′	7	43	"	Muddy fine sand.
B	810	"	"	39° 32′	173° 44′	10	51	"	Fine sandy mud.
B	811	"	"	39° 32′	173° 27′	23	62	"	Mud.
B	812	"	"	39° 26′	173° 25′	19	62	DC	"
B	813	"	"	39° 07·5′	173° 34·5′	15	62	GHO	"
B	814	"	19/3/63	39° 07′	172° 42′	58	98	"	Muddy fine sand.
B	815	"	"	39° 14′	173° 13′	25	70	"	Fine sandy mud.
B	816	"	"	39° 27′	173° 13′	29	69	"	"
B	817	"	"	39° 34′	173° 13′	38	68	"	Mud.
B	818	"	"	39° 45′	173° 35′	40	52	"	Fine sandy mud.
B	819	"	"	39° 45′	173° 50′	28	42	"	Fine sand.
B	820	"	"	39° 55′	173° 30′	67	50	"	Muddy fine sand.
B	821	"	"	40° 03·5′	173° 17′	85	57	DC	Very fine sandy mud.
B	822	"	20/3/63	40° 08′	173° 25′	82	48	"	Muddy fine sand.
B	823	"	"	40° 02·5′	173° 33′	72	47	"	"
B	824	"	"	40° 02·5′	173° 48′	60	53	"	Muddy shelly sand.
C	168	HAWERA	3/9/59	39° 40′	172° 13′	99	155	TAS	Mud.
C	169	"	"	39° 40′	172° 25′	88	128	"	"
C	170	"	4/9/59	39° 40′	172° 39′	79	109	"	"
C	171	"	"	39° 40′	172° 52·5′	69	89	"	"
C	172	"	"	39° 40′	173° 05′	59	76	"	"
C	173	"	"	39° 40′	173° 18′	48	65	"	"
C	174	"	"	39° 40′	173° 32′	38	58	"	Fine sandy mud.
C	175	"	"	39° 40′	173° 44′	29	46	"	"
C	176	"	5/9/59	39° 40′	173° 57′	19	22	DC	Shell fragments bryozoa pebbles.
C	177	"	"	39° 40′	174° 10′	9	13	"	Fine sand.

* Due West from Coastline.

TABLE 1—*continued*

Station No.		Line	Date	Position Lat. S	Position Long. E	Distance* (Nautical miles)	Depth (fathoms)	Gear	Core Length (in.)	Sediment
C	178	HAWERA	5/9/59	39° 40′	174° 17′	3	11	DC		Fine sand.
C	179	"	"	39° 50′	174° 23′	11	13	"		Coarse shelly sand.
C	180	"	"	39° 49′	174° 29′	3	14	"		Fine sand over coarse shelly sand.
C	181	"	"	39° 50′	174° 10′	21	12	"		Shelly fine sand.
C	182	"	"	39° 50′	173° 57′	31	30	"		Fine sand.
C	183	"	"	39° 50′	173° 44′	41	52	"		Muddy fine sand.
C	184	"	6/9/59	39° 50′	173° 31′	51	52	TAS		Fine sandy mud.
C	185	"	"	39° 50′	173° 18′	61	63	"		Very fine sandy mud.
C	260	EGMONT	21/10/59	39° 18′	173° 35′	8	55	GD		Mud.
C	261	MAROKOPA	22/10/59	38° 20′	174° 38·5′	3	20	GP + Cg		Fine sandy mud.
C	262	"	"	38° 19·7′	174° 37′	4	25	"	9	Mud.
C	263	"	"	38° 20′	174° 35·7′	5	27	"		Very fine sandy mud.
C	264	"	"	38° 19·5′	174° 34·8′	7	28	"	5½	"
C	265	"	"	38° 20′	174° 32·1′	9	27	"	18	Fine sandy mud.
C	266	"	"	38° 20′	174° 29·8′	11	27	"		"
C	267	"	"	38° 20′	174° 27·3′	13	29	"		Fine sand.
C	268	"	"	38° 19·7′	174° 25·1′	14	31	"		"
C	269	"	"	38° 20′	174° 22·3′	16	38	"	6	"
C	270	"	"	38° 19·8′	174° 20′	18	43	"		"
C	271	"	"	38° 20′	174° 17·3′	20	50	"		"
C	272	"	"	38° 20·3′	174° 11·8′	24	50	"	8	Muddy fine sand.
C	273	"	"	38° 20·3′	174° 05·2′	29	53	"		Fine sand.
C	274	"	"	38° 23′	173° 53′	39	67	"		Muddy very fine sand.
C	275	"	"	38° 20′	173° 43·5′	47	75	"	8	Very fine sandy mud.
C	276	"	"	38° 20′	173° 28·5′	59	80	"		Muddy very fine sand.
C	277	"	"	38° 20′	173° 16′	69	489	"		Very fine sandy mud.
C	278	"	"	38° 20′	173° 24′	62	85	"		Muddy very fine sand.
C	279	AOTEA	23/10/59	38° 00′	174° 47·8′	1·5	10	"		Very fine sand.
C	280	"	"	38° 00′	174° 46·8′	2	17	"		Muddy sand.
C	281	"	"	38° 00′	174° 45·4′	3	19	"		Very fine sandy mud.
C	282	"	"	38° 00′	174° 44′	4·5	20	"		Muddy very fine sand.
C	283	"	"	38° 00′	174° 42·8′	5·5	22	"		"
C	284	"	"	38° 00′	174° 40·2′	7	28	"		Fine sand.
C	285	"	"	38° 00′	174° 37·8′	9	32	"		"
C	286	"	"	38° 00′	174° 35·1′	11	30	"		"
C	287	"	"	38° 00′	174° 32·5′	13	37	"		Shelly fine sand.
C	288	"	"	38° 00′	174° 30·3′	15	33	"		"
C	289	"	"	38° 00′	174° 27·2′	17	31	"		"
C	290	"	"	38° 00′	174° 25′	19	33	"	4½	"
C	291	"	"	38° 01′	174° 13′	28	37	"		"
C	292	"	"	38° 00′	174° 10·5′	30	38	"		Shelly fine sand.
C	293	"	"	38° 00′	173° 57·5′	40	42	"		Muddy very fine sand.
C	295	MURIWAI	24/10/59	36° 39·8′	174° 17·5′	1	12	"		Fine sand.
C	296	"	"	36° 40′	174° 16·2′	2	16	"	10	"
C	297	"	"	36° 40′	174° 15′	3	17	"		"
C	298	"	"	36° 40′	174° 13·6′	4	20	"	13	"
C	299	"	"	36° 40′	174° 12·4′	5	23	"		"
C	300	"	"	36° 40′	174° 09·8′	7	28	"		"
C	301	"	"	36° 39·8′	174° 08′	9	35	"		"

C	302	MURIWAI	24/10/59	36° 40′	174° 05′	11	45	GP + Cg	30	Muddy fine sand.
C	303	”	”	36° 40′	174° 02′	13	56	”	22	”
C	304	”	”	36° 40′	173° 59·8′	15	70	”		Muddy very fine sand.
C	305	”	”	36° 40′	173° 57·5′	17	106	”		”
C	309	PIHA	25/10/59	37° 00′	174° 26·2′	2	12	”		Fine sand.
C	310	”	”	37° 00′	174° 23·8′	4	19	”		Very fine sand.
C	311	”	”	37° 00′	174° 21·2′	6	23	”	20	”
C	312	”	”	37° 00′	174° 18·8′	8	29	”	12	Fine sand.
C	313	”	”	37° 00′	174° 16·3′	10	37	”	19	Muddy fine sand.
C	314	”	”	37° 00′	174° 14·0′	12	43	”	14	”
C	315	”	”	37° 00′	174° 11·4′	14	53	”	20	Fine sandy mud.
C	316	”	”	37° 00′	174° 09′	16	61	”		Very fine sandy mud.
C	317	”	”	37° 00′	174° 06′	18	74	”		Muddy very fine sand.
C	318	”	”	37° 00′	174° 04′	20	98	”		”
C	319	WAIKATO	”	37° 19·6′	174° 38·5′	3	5	”		Very fine sand.
C	320	”	”	37° 19·6′	174° 36·5′	5	6	”		Muddy very fine sand.
C	321	”	”	37° 20′	174° 34′	7	11	”	16	Shelly muddy sand.
C	322	”	”	37° 20′	174° 31·6′	9	15	”	26	Fine sand.
C	323	”	”	37° 20·2′	174° 29·4′	11	18	”		”
C	324	”	”	37° 20′	174° 26·7′	13	18	”		”
C	325	”	”	37° 20′	174° 24·2′	15	30	”		Shelly coarse sand.
C	326	”	”	37° 20′	174° 21·7′	17	38	”		Fine sand.
C	327	”	”	37° 20′	174° 19·3′	19	43	”	10	Shelly coarse sand.
C	328	”	”	37° 20′	174° 11·8′	25	65	”	7	Fine sand.
C	329	”	”	37° 20′	174° 05·5′	30	227	”	12	Mud.
C	330	”	”	37° 20′	174° 09·2′	27	88	”		Muddy fine sand.
C	331	RAGLAN	26/10/59	37° 40′	174° 47·3′	2	14	”		Very fine sand.
C	332	”	”	37° 40′	174° 44·5′	4	20	”		Muddy very fine sand.
C	333	”	”	37° 40′	174° 42′	6	22	”		”
C	334	”	”	37° 40′	174° 39·5′	8	27	”	5	Shelly fine sand.
C	335	”	”	37° 40′	174° 37′	10	30	”		Shelly fine sand.
C	336	”	”	37° 40′	174° 34·9′	12	34	”		”
C	337	”	”	37° 40′	174° 32·3′	14	35	”		”
C	338	”	”	37° 40′	174° 29·8′	16	40	”		”
C	339	”	”	37° 40′	174° 27·2′	18	46	”		Muddy shelly fine sand.
C	340	”	”	37° 40′	174° 24·8′	20	53	”	12	Muddy fine sand.
C	341	”	”	37° 40′	174° 19·8′	24	67	”	8	Muddy very fine sand.
C	342	”	”	37° 40′	174° 16·4′	27	85	”		”
C	343	”	”	37° 40′	174° 18′	25·5	77	”		Muddy fine sand.
C	345	MOKAU	27/10/59	38° 40′	174° 37·5′	0·5	7	”		Very fine sand.
C	346	”	”	38° 40′	174° 36·2′	1·5	13	”		”
C	347	”	”	38° 40′	174° 33·6′	3·5	19	”		Muddy very fine sand.
C	348	”	”	38° 40′	174° 31′	5·5	23	”		Very fine sandy mud.
C	349	”	”	38° 40′	174° 28·4′	7·5	26	”		Muddy sand.
C	350	”	”	38° 40′	174° 25·9′	9·5	27	”		Fine sand.
C	351	”	”	38° 40′	174° 23·3′	12	30	”	3	”
C	352	”	”	38° 40′	174° 20·8′	14	33	”		”
C	353	”	”	38° 40′	174° 18·3′	16	34	”		”
C	354	”	”	38° 40′	174° 15·5′	18	36	”		”
C	355	”	”	38° 40′	174° 13′	20	39	”	9	Fine sand.
C	356	”	”	38° 40′	174° 06·6′	25	43	”		”
C	357	”	”	38° 40′	174° 00·2′	30	52	”	6	Gravelly coarse sand.
C	358	”	”	38° 40′	173° 47·5′	40	66	”	12	Muddy sand.
C	359	”	”	38° 40′	173° 34·4′	50	73	”		”
C	360	”	”	38° 40′	173° 20·5′	61	78	”		”

* Due West from Coastline.

TABLE 1—*continued*

Station No.	Line	Date	Position Lat. S	Position Long. E	Distance* (Nautical miles)	Depth (fathoms)	Gear	Core Length (in.)	Sediment
C 361	MOKAU	27/10/59	38° 40′	173° 08·5′	70	80	GP + Cg		Muddy sand.
C 362	"	"	38° 40′	172° 56′	80	82	"	3	"
C 363	"	"	38° 40′	172° 40′	93	80	"		Sandy mud.
C 364	"	"	38° 40′	172° 34′	98	88	"		Muddy sand.
C 365	"	"	38° 40′	172° 26′	104	241	"	15	Sandy mud.
C 366	WAITARA	28/10/59	38° 54′	172° 18′	102·5	126	"		Muddy fine sand.
C 367	"	"	38° 54′	172° 22′	99·5	137	"		"
C 368	"	"	38° 54′	172° 36′	88·5	82	"		Muddy very fine sand.
C 369	"	"	38° 54′	172° 58′	71·5	78	"	12	"
C 370	"	"	38° 54′	173° 10′	62·5	74	"	12	Sandy mud.
C 371	"	"	38° 54′	173° 21·5′	53·5	74	"	18	"
C 372	"	"	38° 54′	173° 36·5′	42	72	"	25	"
C 373	"	"	38° 54′	173° 49′	32·5	67	"	14	Muddy sand.
C 374	"	"	38° 54′	174° 02·5′	22	51	"		"
C 375	"	"	38° 54′	174° 08·5′	17	39	"		"
C 376	"	"	38° 54′	174° 11′	15	37	"	12	Sandy mud.
C 377	"	"	38° 54′	174° 14′	13	27	"		Muddy very fine sand.
C 378	"	"	38° 54′	174° 16·5′	11	22	"		"
C 379	"	"	38° 54′	174° 19′	9	22	"		"
C 380	"	"	38° 54′	174° 21·5′	7	20	"		"
C 416	EGMONT	6/5/60	39° 20′	173° 44·5′	1	20	GHO + Cg		Encrusted rock.
C 417	"	"	39° 20′	173° 43·2′	2	22	"		Rocks, mud.
C 418	"	"	39° 20′	173° 42′	3	36	"		Encrusted rock.
C 419	"	"	39° 20′	173° 41′	4	41	"		Coarse gravel.
C 420	"	"	39° 20′	173° 39′	5	42	"		Sandy mud.
C 421	"	"	39° 20′	173° 37′	7	59	"	12	Mud.
C 422	"	"	39° 20′	173° 34·5′	9	55	"	36	"
C 423	"	"	39° 20′	173° 32′	11	59	"	22	"
C 424	"	"	39° 20′	173° 29·5′	13	61	"	22	"
C 425	"	"	39° 20′	173° 28′	14	62	"	24	"
C 426	"	"	39° 20′	173° 26·5′	15	65	"	24	"
C 427	"	"	39° 20′	173° 26·5′	15	62	"	23	"
C 428	"	"	39° 20′	173° 21·5′	19	66	"	26	"
C 429	"	"	39° 20′	173° 08′	30	68	"	30	Sandy mud.
C 430	"	"	39° 20′	172° 55′	40	71	"	12	"
C 431	"	"	39° 20′	172° 42′	50	74	"	14	Muddy sand.
C 432	"	"	39° 20′	172° 29′	60	98	"	22	Muddy very fine sand.
C 433	HAWERA	7/5/60	39° 40′	173° 43·5′	29	37	"	19	Muddy sand.
C 434	"	"	39° 40′	173° 30·5′	39	56	"	26	Mud.
C 435	"	"	39° 40′	173° 18′	49	57	"	30	"
C 436	"	"	39° 40′	173° 10′	55	64	"	24	"
C 437	"	"	39° 40′	172° 51′	68	72	"	20	"
C 438	WANGANUI	"	40° 00′	173° 36·5′	67	46	"	15	Muddy coarse shelly sand.
C 439	"	"	40° 00′	173° 49′	57	48	"	17	Coarse shelly sandy mud.
C 440	"	"	40° 00′	174° 02′	47	28	"		Coarse shelly sand.
C 441	"	"	40° 00′	174° 17·5′	35	23	"		Gravelly sand.
C 442	"	"	40° 00′	174° 27·5′	27	30	"		Muddy sandy shelly gravel.
C 443	"	"	40° 00′	174° 38′	19	27	"		"

C	444	WANGANUI	8/5/60	40° 00′	174° 40·8′	17	21	GHO+Cg	Shelly fine sand.
C	445	"	"	40° 00′	174° 43·5′	15	17	"	Shelly medium sand.
C	446	"	"	40° 00′	174° 46′	13	16	"	Medium sand.
C	447	"	"	40′ 00°	174° 49′	11	16	"	Fine sand.
C	448	"	"	40° 00′	174° 51·4′	9	17	"	"
C	449	"	"	40° 00′	174° 54′	7	16	"	"
C	450	"	"	40° 00′	174° 57′	5	15	"	Muddy sandy gravel.
C	451	"	"	40° 00′	174° 58′	4·5	14	"	"
C	452	"	"	40° 00′	175° 00′	3	12	"	Muddy sand.
C	453	"	"	40° 00′	175° 01′	2	12	"	Fine sand.
C	454	HAWERA	"	39° 40′	174° 15·8′	4·5	13	"	Shelly fine sand.
C	455	"	"	39° 40′	174° 13′	6·5	14	"	Fine sand.
C	456	"	"	39° 40′	174° 10·5′	8·5	14	"	Medium sand.
C	457	"	"	39° 40′	174° 08′	10·5	12	"	Fine sand.
C	458	"	"	39° 40′	174° 05·2′	12·5	13	"	Coarse sandy gravel.
C	459	"	"	39° 40′	174° 02·6′	14·5	16	"	Fine sand.
C	460	"	"	39° 40′	174° 00′	16·5	18	"	"
C	461	"	"	39° 40′	173° 57·2′	18·5	24	GHO	Fine sand.
C	462	"	"	39° 40′	173° 54·5′	20·5	26	"	"
C	745	"	16/2/62	36° 40′	174° 13·6′	4	18	Cg	"
Z	290		–/51	38° 43′	173° 40′	45	78	W	Muddy fine sand.
Z	291		–/51	38° 25′	173° 49′	39	72	"	Muddy very fine sand.
Z	292		–/51	38° 05′	173° 59′	38·5	76	"	"
Z	567		29/11/59	40° 09·2′	173° 47·5′	65	53	"	Muddy fine sand.
Z	568		"	40° 03·2′	174° 06·1′	47	43	"	Muddy coarse sand.
Z	569		30/11/59	40° 04·8′	174° 45·2′	17	29	"	Coarse shelly sand.
Z	570		1/12/59	40° 09·5′	173° 36·2′	73	45	"	Muddy fine sand.
Z	571		1/12/59	39° 56′	173° 53′	50	48	"	Muddy coarse shelly sand.
Z	573		13/12/59	40° 03·5′	174° 28′	30	60	"	"
Z	574		10/1/60	39° 53′	174° 47·5′	5	6	"	Fine sand.
Z	575		12/1/60	39° 51′	174° 38·6′	2	7	"	"
Z	576		15/1/60	39° 50·5′	174° 7·5′	25	20	"	"
Z	577		17/12/59	39° 58′	174° 48·5′	10	20	"	Muddy fine sand.
Z	788		13/6/50	40° 07′	174° 22′	36	47	"	Gravelly sandy mud.
Z	884		25/10/50	39° 15′	173° 02′	35	75	"	Sandy mud.
Z	885		27/7/51	39° 05′	173° 25′	28	78	"	"
Z	892		12/6/50	39° 56′	174° 16′	32	18	"	Fine sand.
Z	893		12/6/50	39° 53·5′	174° 04′	40	32	"	"
Z	938		7/4/59	40° 02·9′	172° 03′	142	158	"	Muddy fine sand.
Z	1242	MURIWAI	–/5/62	36° 40·6′	173° 48·3′	25	296		Mud.

* Due West from Coastline.

APPENDIX

GRAIN-SIZE DISTRIBUTION ALONG SAMPLING LINES 2–6 AND 8–10

(See fig. 7).

Piha (line 2): A very fine sand zone extends from the shoreline to 20 fm, 7 miles offshore. Here, the very fine sand fraction reaches a maximum of 80% with the average percentage of fine sand and very fine sand being 50. The mud and coarse grades in this zone are negligible.

From 20 fm to approximately 50 fm a fine sand zone is apparent with a maximum of 63% fine sand. Very fine sand and medium and coarse sand average about 15%, mud is once again negligible.

From the 50 fm mark to the shelf edge the mud and very fine sand fractions both increase to approximately 50%, each with the fine sand and coarser fractions almost absent.

The amount of mud in the zones from shore to 50 fm ranges from 0–11%. At this point there is an abrupt increase to 55% at 54 fm. From 50–100 fm (a mud zone) there is a steady decrease to 25%.

The maximum percentage of coarse sand is 5% at 40 fm.

Waikato (line 3): There is no specific zonation along this line where the sediments are poorly sorted. The percentage of coarser fractions (medium sand, coarse sand, very coarse sand and gravel) shows a marked increase from the shore to about 17 miles offshore (44 fm) at which point they rapidly decrease, remaining negligible to the shelf edge.

Apart from an area in 5–10 fm, where the percentage of mud reaches 20, this component is negligible until 90 fm is reached where the percentage abruptly increases reaching 45 at 100 fm.

The proportion of very fine sand is 85% near the shore but, from an area between 3 and 13 miles offshore (6–30 fm), it ranges from 45 to 12% then becomes almost negligible further seawards where the coarser fractions have reached a maximum. The proportion then steadily increases as the coarser fractions decrease seaward.

Very coarse sand increases by irregular stages to a maximum of 12% at 17 miles (44 fm) and then disappears altogether.

Coarse shell fragments only appear between 7 and 40 fm with an average percentage of about 4.

Raglan (line 4): Two prominent zones occur in the region out to about 18 miles (46 fm). These consist of a very fine sand zone extending from the shore to 7 miles (25 fm) offshore with an average of 70% very fine sand, 15% fine sand and 10% mud, and a fine sand zone extending from 7–17 miles (25–45 fm) offshore. Here the fine sand averages 80% with the very fine sand being 8%. Apart from a similar amount of medium sand, the other constituents are negligible.

The third and final zone on this line consists principally of fine sand, very fine sand and mud in roughly equal proportions at 20 miles (53 fm) distance from shore, but, from that point as far as the shelf at nearly 30 miles, the mud fraction decreases steadily to about 8% with the very fine sand fraction increasing to 60%.

The mud fraction is concentrated in two areas; from the shoreline to about 7 miles (25 fm) offshore, and between 18 miles (46 fm) offshore and the shelf edge. Between these two areas there is virtually no mud at all. The maximum percentages are at 6 miles (22 fm) 17%, and at 20 miles (53 fm) 36%.

Coarse sand, very coarse sand, and gravel appear in the area 8 miles offshore to the extent of 2 or 3% each, but apart from this occurrences are negligible.

Aotea (line 5): A distinct fine sand zone extends from 25–40 fm offshore. Fine sand remains fairly constant at 80–85% with very fine sand averaging 5% and mud about 1%. Medium sand varies between 3 and 9% with coarse sand, very coarse sand and gravel all being below 2%.

Between the shore and this fine sand zone there is a predominance of very fine sand with an average of 65%. This is interspersed with mud and fine sand at irregular intervals, the mud having an average percentage of 25 and the fine sand 7. Other constituents are present only in minor quantities.

From the outer edge of the fine sand zone to the shelf edge there is an increase in very fine sand (reaching 70%) also an increase in mud (reaching 26%). The fine sand, medium sand, and the coarser fractions become almost negligible at the 100 fm line.

The mud fraction becomes apparent 2 miles from shore and rapidly increases to 47% 3½ miles from shore in 19 fm. There is an equally rapid decrease, and by roughly 6 miles (25 fm) out, the quantity is negligible. This remains constant out to 30 miles offshore in 40 fm where the percentage rises from 2–26 in 10 miles.

The coarser fractions show a slight increase between 6 and 30 miles but none of them individually reach more than 7% and percentages become minimal near the shelf edge.

Marokopa (line 6): Four zones occur, in which the dominant sediment of the nearest inshore and the furthest offshore is mud, with fine sand and very fine sand zones lying between.

The near shore mud zone extends out to about 9 miles (28 fm) and averages about 70% mud, 12% very fine sand, 13% fine sand and negligible amounts of the coarse fractions.

A fine sand zone, from 9–35 miles offshore in 60 fm, contains an average of 4% mud, 7% very fine sand, 75% fine sand, 10% medium sand, and about 1% or less of the coarser fractions. From 35–65 miles offshore (85 fm) is a very fine sand zone with an average of 65% very fine sand, 32% mud, and a very small amount of fine sand.

A second mud zone lies from 65 miles (85 fm) offshore to the shelf edge at nearly 70 miles and averages 60% mud and 36% very fine sand.

The percentage of mud increases from 39% at the shoreline to a maximum of 88%, 4 miles offshore. This rapidly decreases, almost to zero, 10 miles offshore, and remains as a small quantity (about 2%) until about 20 miles offshore when the percentage begins to increase, steadily reaching 80 at the shelf edge.

Individual coarser fractions are in the order of 1% or less along the whole line.

Waitara (line 8): Only one well defined zone exists – the mudzone between about 35 and 65 miles offshore (70–76 fm) where the mud averages 66%, very fine sand 17%, fine sand 14% and a negligible quantity of the coarser fractions. Between the shoreline and 13 miles out (27 fm) mud and very fine sand are the predominant fractions averaging 28% and 70% respectively. Between 13 and 35 miles offshore, mud, very fine sand and fine sand are all present in varying degrees but of similar average percentages – 30, 29, and 33. Medium sand increases slightly to 8% at 21½ miles and then decreases slowly, becoming non-existent 60 miles offshore. The coarser fractions are negligible for the whole line. From 35 miles to the shelf edge, mud, very fine sand and fine sand are predominant, but the average percentages vary from those earlier in the line, mud being predominant with an average of 56%, then very fine sand with 30% and fine sand with 11%.

Mud is present throughout the line reaching two peaks of maximum percentages of 55 and 84 at 15 miles and 53 miles offshore (37 and 74 fm). Between these positions the lowest percentages are 10 at 21½ miles offshore and 11 at 7 miles. Navigational hazards prevented sampling closer inshore.

The coarser fractions (coarse sand to gravel) are negligible in all the samples from this line.

Egmont (line 9): Apart from a coarse near shore area, the sediment sampled is predominantly mud. This is the only line in the survey on which cobbles and boulders were sampled, these being found from the shore to 5 miles from the shoreline below Mt. Egmont.

Coarse sand, very coarse sand, and gravel appear to the order of 1 or 2%, but disappear beyond 5 miles offshore.

A mud zone can readily be defined between 5 and 45 miles offshore, (42–72 fm) with mud averaging 90%, very fine sand 5%, and fine sand 2%. Any coarser fractions are non-existent beyond 33 miles. From 45 miles offshore to the shelf edge is a composite zone containing mud, very fine sand, and fine sand in the following proportions: 45%, 28%, and 26% respectively. As the fine sand percentage increases the very fine sand percentage decreases.

The mud fraction between 10 and 20 miles offshore remains constant at 99% of the total sediment, falling gradually to a minimum percentage of 41 at 40 miles offshore in 74 fm. A steady increase then takes place out to the shelf edge.

Hawera (line 10): The two major zones in this area are a fine sand zone between 13 and 20 miles offshore and a mud zone from 30 miles to the shelf edge. The fine sand zone contains an average of 73% fine sand, 20% very fine sand and negligible quantities of other fractions.

The mud zone contains 94% mud and 5% very fine sand. The area from the shoreline to 13 miles offshore (14 fm) shows two peaks where coarse fractions predominate. These occur at 8½ miles (14½ fm) where there is 65% medium sand and 26% fine sand. They are isolated occurrences with low percentages of medium sand on either side. At 12½ miles (13 fm), there is a concentration of gravel, very coarse sand, coarse sand, and medium sand showing percentages of 9, 35, 30, and 19 respectively. Once again these percentages are isolated, rising and falling away rapidly on either side.

Between 20 and 30 miles offshore (26–37 fm) mud, very fine sand and fine sand are the main constituents with an average of 45% very fine sand and fine sand, and 10% mud.

There is only a small percentage of mud, roughly 2 or 3%, between the shoreline and 26 miles offshore, from where it increases rapidly out to 40 miles where there is 91%. At 60 miles offshore there is 99% of mud.

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