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A TEXTURAL AND MINERALOGICAL STUDY OF THE
BEACH SANDS, ALONG THE SOUTHWEST
COAST OF THE NORTH ISLAND.

A thesis presented in partial fulfilment
of the requirement for the Degree of
Master of Science in Soil Science
at Massey University.

by

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ABSTRACT

A sediment survey of the beaches from Patea to Manawatu River on the southwest coast of the North Island has been undertaken. The survey objectives are to establish the beach sediment provenance, the net longshore drift and the extent of the contributing rivers to the longshore drift system. Sediments derived from the Taranaki Volcanics predominate, particularly in the northern part of the study area. However, sediment contributions from other sources (Pliocene to Pleistocene and Recent sediments, Taupo Volcanic Zone volcanics) become increasingly important in the southern part of the study area.

A gradual decrease in heavy mineral abundance indicates a net southeastward longshore drift. This is further supported by the distribution pattern of the grain size parameters and local heavy mineral distribution patterns about the river mouths within the study area.

The high abundance of heavy minerals and coarser sediment 1-3 km south of Whangaehu, Rangitikei and Turakina River mouths, suggests that the discharging river sediment is being deposited onto the beach at some distance south of the river mouths rather than immediately adjacent to them. Grain size parameters indicate that the Whangaehu and Rangitikei Rivers are contributing coarse sediment to the longshore drift system, while the Turakina River is supplying lesser amounts of, but finer and better sorted, sediment to the adjacent beaches at the river mouth.

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CHAPTER 1
INTRODUCTON.

1.1 BACKGROUND.

The Rangitikei-Wanganui Catchment Board administers the coastal region extending 85 km from the Waitotara River in the north to Himitangi Beach in the south. The Catchment Board is currently undertaking a Coastal Hazard Zone survey, which is a five year project funded by NWASCA. A survey of the beach sediments commencing in May, 1984, along the coast from Patea River in the north to Manawatu River in the south (Fig.1) was subsequently undertaken in order to determine both longshore drift directions and provenance of beach sediments.

1.2 OBJECTIVES.

This thesis has four major objectives to be determined from textural and mineralogical data,

(1) To determine the provenance of the beach sediments along the coast from Patea to Manawatu River.

(2) To verify the net longshore drift direction in the study area.

(3) To determine which rivers in the Rangitikei-Wanganui Catchment Board area (Wanganui, Whangaehu, Turakina and Rangitikei Rivers) are contributing sediment to the longshore drift system.

(4) To assess other coastal processes that have some bearing on the mineralogy and texture of the beach sands in the study area.

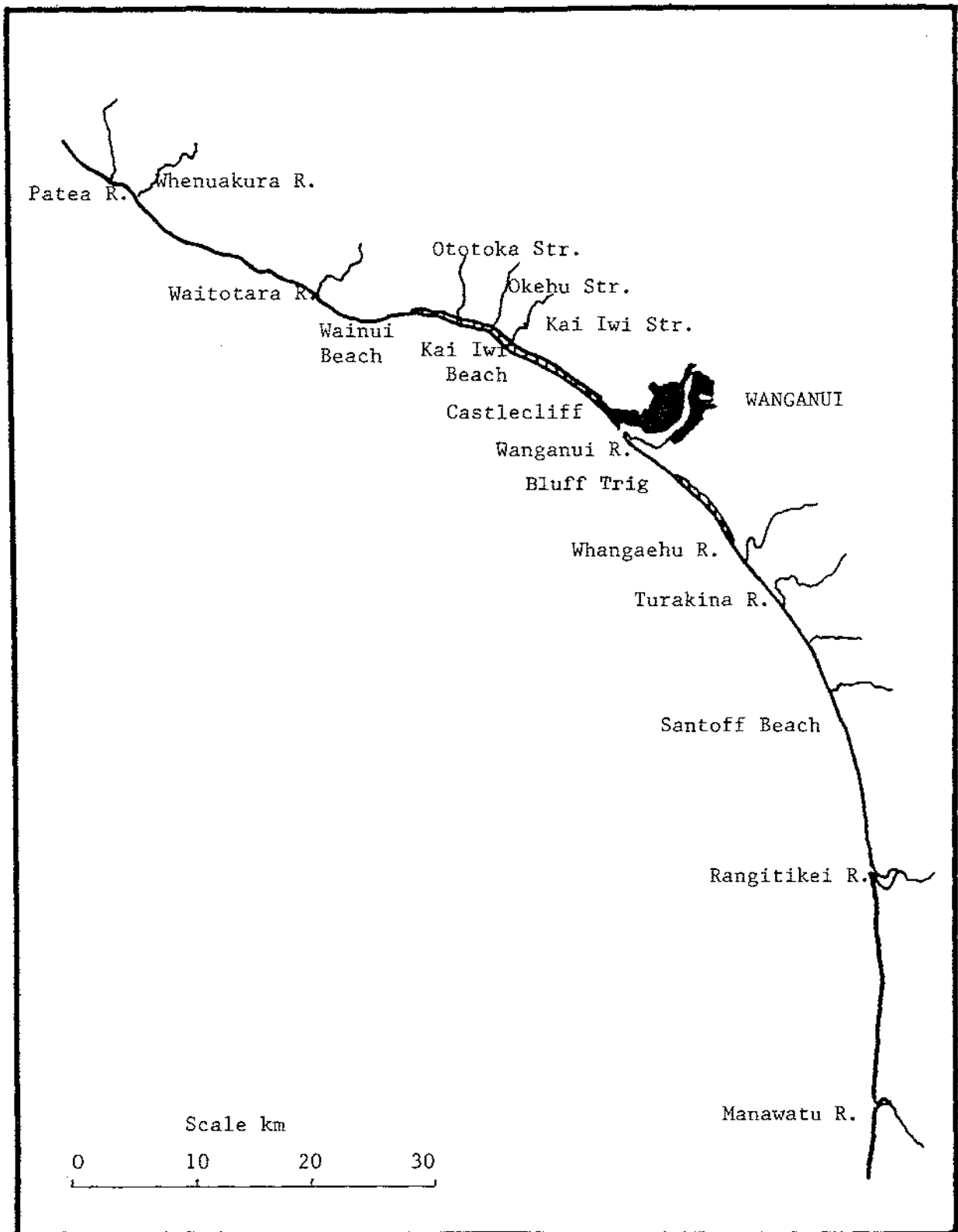


FIG. 1.

LOCATION DIAGRAM OF THE STUDY AREA

CHAPTER 2
THE TERRESTRIAL ENVIRONMENT.

2.1 INTRODUCTION.

The terrestrial environment is discussed here in terms of geological and geomorphic history, including past sedimentation and source areas for the South Wanganui Basin sediments. A summary of the coastal geomorphology and cliff exposures, the present day drainage system and meteorological conditions of the region is also provided.

In the northern part of the study area, the Pliocene to Pleistocene sediments of the South Wanganui Basin form the coastal cliffs. Pliocene and Pleistocene sediments contribute to beach sediments in the study region from the rivers and coastal erosion. The coastal geomorphology, and also rivers contributing sediment to the coast, affect the sediment distributions and processes along the coastline.

The drainage pattern is a set of northeast trending rivers draining the area covered by the South Wanganui Basin. Some of the rivers drain catchment areas from the axial greywacke ranges and Central North Island region. A summary of the areas that the respective rivers drain and possible input of sediment that rivers supply to the coast is given.

2.2 GEOLOGICAL AND GEOMORPHIC HISTORY.

The South Wanganui Basin is a broad half graben trending NNE and containing up to 4,000 m of marine Pliocene to Pleistocene sediments which developed by progressive subsidence and onlap to the south, combined with emergence and offlap in the north. Most of the basin subsidence occurred during late Pliocene to early Pleistocene time. The Wanganui Subdivision has been mapped and described in detail by Fleming (1953) and the geology of the Rangitikei region studied by Te Punga (1953). A review of the structure and evolution of the South Wanganui Basin is given by Anderton (1981). The most recent description of the New Zealand Pleistocene and late Pliocene glacio-eustatic cycles, which affected sedimentation in the study area during this time has been reported by Beu and Edwards (1984). The late Pleistocene marine terraces between Hawera and Wanganui have been mapped and correlated by Pillans (1981; 1983).

During the early to mid Pliocene, sediment supply to the South Wanganui Basin was initially from uplifted areas to the southwest but increasingly from the Tertiary rocks to the north and northeast (Anderton, 1981).

The marine late Pliocene to early Pleistocene shellbeds, sandstones, siltstones, and mudstones grade upwards into late Pleistocene to Recent paralic and terrestrial deposits including gravels, sands, volcanic ash and some lignites (Fleming, 1953; Te Punga, 1953; Beu & Edwards, 1984).

In late Pliocene to early Pleistocene time, periodically marginal

tilting pushed shorelines towards the centre of the basin, covering older sediments with littoral deposits of pebbles, shellsands and estuarine sands. Burial by marine silts and muds occurred as subsidence continued. During Castlecliffian time sedimentation was influenced by glacial-interglacial sea level fluctuations with amplitudes in the order of 100 m (Beu & Edwards, 1984). Cataclysmic rhyolitic eruptions from Central North Island also periodically flooded the basin with rhyolitic volcanoclastic sediment during Nukumaruan and Castlecliffian times, leading to the formation of pumiceous beds through the sequence (Fleming, 1953; Seward, 1976). During this time period, the emergent Tertiary rocks to the north-northwest continued to be a source of sediment, with the growing anticlines to the east, especially the Ruahine Anticline, supplying increasing amounts of greywacke derived sediment (Fleming, 1953).

The geologic history of the late Pleistocene in the Wanganui District indicates a period of physiographic development. The late Pleistocene cover-bed formations lie unconformably on marine cut benches, following a period when the early Pleistocene deposits had been gently folded, mildly faulted, and peneplained (Fleming, 1953; Pillans, 1981). These episodes of tilting and minor faulting continued through deposition of Pleistocene strata, along with fluctuations of sea-level. These late Pleistocene sediments are mainly littoral beach deposits on at least seven sea-cut benches backed by cliffs. As much as 12 m of marine sands overlying a basal conglomerate, or more rarely shell layers, are found on the wave-cut surface of individual terraces. The marine sediments are in turn overlain by peats and/or a variety of other littoral and terrestrial deposits, which may include fluvial

sediments, tephras, dune sands, loess, and laharic debris. Some of the beach deposits, which include both sand and gravel, are overlain by non-marine dune sand and lignite (Fleming, 1953).

The Taranaki Volcanics supplied much of the titanomagnetite, augite and hornblende-rich sediment that covers marine out benches as air fall tephras, beach sands, loess and dune sands. The beach and dune sands in particular have been mixed with sediments derived from both the hypersthene-andesites of Tongariro Volcanic Centre and rhyolites from the Taupo Volcanic Zone which have been transported south to the coast by major rivers in the region (Fleming, 1953).

During Recent times the geomorphic history of the study area has been dominated by both beach progradation and sand dune development, particularly in the sand country of Manawatu District. Sea levels reached their present position about 6,500 yrs ago, as shown by radiocarbon dated shells from the earliest Holocene sand dune deposits laid down at the present sea level (Gibb, 1979). Four different stages of sand dune development have been recognised in the last 20,000 years in the Manawatu Sand Country (Cowie, 1963), and are confirmed by radiocarbon dating (Fleming, 1972). The four stages are; the Koputaroa phase which occurred 20,000-10,000 years ago; the Foxton phase 4,000-2,000 years ago; the Motuiti phase 1,000-500 years ago; and Waitarere phase which commenced about 100 years ago and is still continuing.

There are three main sources of sediment for the Manawatu Sand Dunes: (1) greywacke from the axial ranges; (2) Tertiary mudstones

and sandstones flanking the greywacke axial ranges; and (3) volcanic material from both Taupo Volcanic Zone and the Taranaki Volcanics. Sediments originating from these sources are mixed and transported in the littoral zone (Hocking, 1964), which on prograding beaches acts as the source for dune building. Quartz and feldspar are the dominant minerals with titanomagnetite, augite, hypersthene and hornblende as minor constituents. These minor constituents become more abundant northwards along the coast (Hocking, 1964).

2.3 COASTAL GEOLOGY AND GEOMORPHOLOGY.

2.3.1 COASTAL GEOMORPHOLOGY.

Changes in coastal configurations are related to variations in wave energy and the supply of sediment available over a given period of time. Short term variations correlate strongly with wave energy changes (Komar, 1976), which occur during westerly and southwesterly storms approaching the southwest coast of the North Island. In this case sediment may be temporarily removed offshore during periods of high wave energy and returned to the foreshore as low, long period waves become predominant (King, 1972).

Eroding shorelines are generally composed of poorly consolidated material. Beaches are usually narrow where high tide and storm events reach the base of the cliff or toe of the foredune (Gibb, 1977a).

Accreting shorelines feature a wider backshore which acts as a sediment source for the construction of dunes. High tide rarely reaches the foredune (Gibb, 1977a).

Coastline change along the Rangitikei-Wanganui coast for approximately the last 100 years is summarised in Fig.2.1. In the vicinity of Wainui Beach retreat rates of less than 0.75 m/yr occur (Johnston, 1985). On the 25th of July, 1985, during the course of this study it was observed that recent erosion of the beach and foredunes had occurred.

The 15 to 20 km of cliffed coastline north of Castlecliff and extending to just south of Wainui Beach (Fig.2.1) has shown average cliff retreat rates of between 0.1 to 0.4 m/yr while the sandy beaches at the base of the cliffs have in places shown slight advances (Johnston, 1985).

For the 30 years prior to 1953, Fleming (1953) notes that between Wainui Beach and Ototoka Stream (Fig.2.1) on the extended beach, above the high tide mark, a low foredune had been built. Between the period from the 25th of June, 1984 and 26th of August, 1985, the beach and foredune had undergone extensive erosion. Localised beach erosion between Wainui Beach and Mowhanau was noticeable particularly where small reefs extending offshore and tidal platforms occurred at the low tide mark, exposing the underlying Nukumaruan and Castlecliffian sediments.

Further, beach progradation had been observed extending 3 km north of the Wanganui Harbour moles since their construction in 1884. Low foredunes resulting from coastal progradation due to sediment trapping on the north mole now mask the toe of the cliffs. Average rates of coastline advance have ranged from 0.5 to 2.0 m/yr since 1942

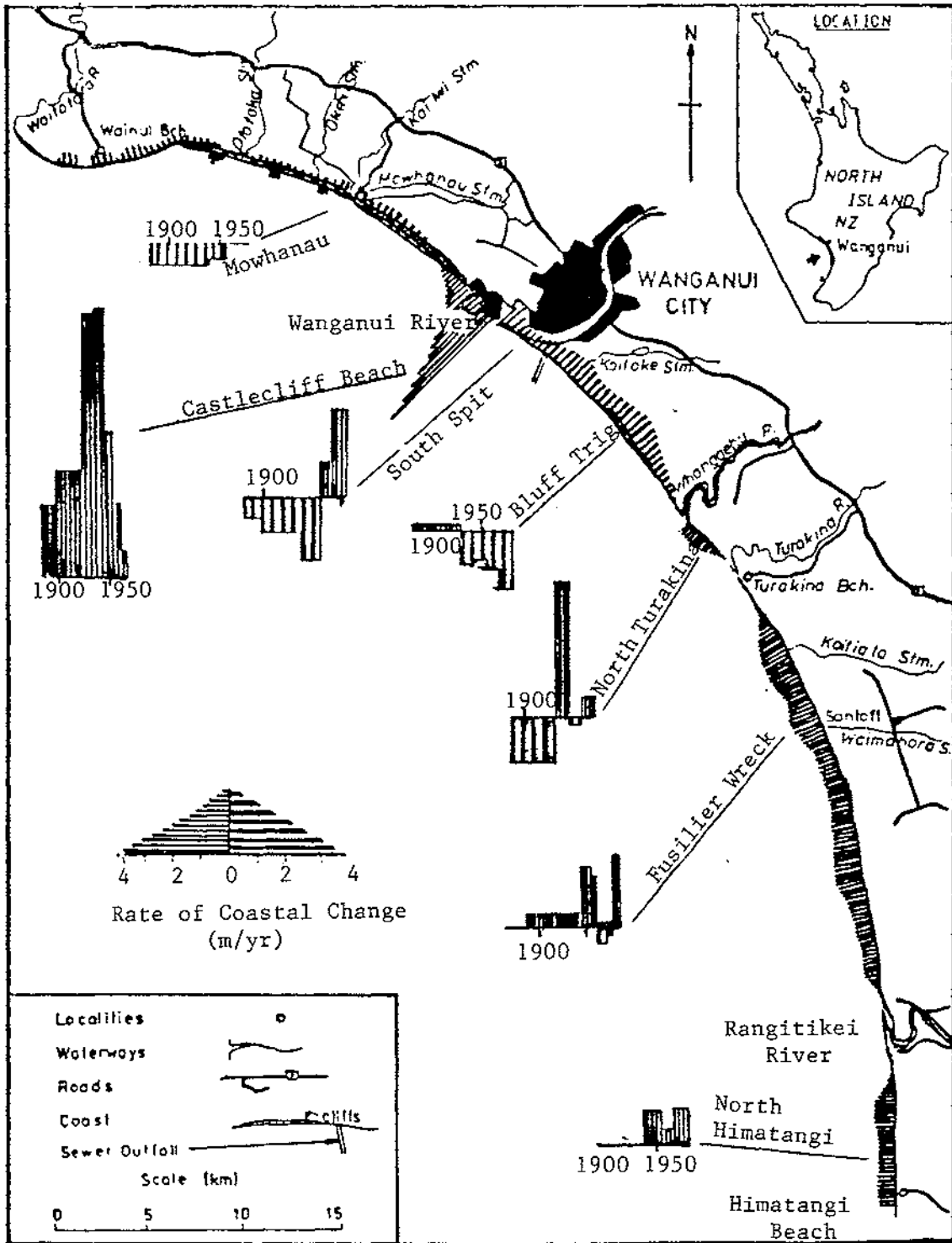


FIG.2.1.

Coastal Change (m/yr) for the Rangitikei-Wanganui Coastline, for a survey period of approximately one century prior to 1982. Histograms show the mean rate of change (m/yr) for variable time intervals within the survey period (the year 1900 and 1950 shown for convenience). (Adapted from Johnston 1985).

(Johnston, 1985). The coastline between Wanganui and Whangaehu River (Fig.2.1) has shown net shoreline advance at the South Spit since about 1960, and net erosion rates of between 0.5 to 1.0 m/yr around Bluff Trig (Johnston, 1985).

South of Whangaehu River, beach progradation occurs with advance rates between 0.5 to 2.0 m/yr (Johnston, 1985). The beaches are wider, with the backshore and sand dunes little affected by wave erosion. Active beach progradation can be observed at Santoft where the Fusiler was shipwrecked 102 years ago. The steel barque of 404 tons was wrecked during a storm in 1884, settling between low and high-water mark. Shoreline displacement measured from the wreck to Mean High Water Mark (MHWH) by Gibb (1979) indicates that the beach has prograded 100 m at a net rate of 1 m per year.

South of Turakina River, the coastline is prograding (Fig.2.1) and for about 8 km the beach morphology is characterised by berm and cusp development with a small erosional embayment occurring about 2 km north of Rangitikei River. Gravel lobes have developed to the south of Rangitikei River which shortens the foreshore width, with the remainder of the prograding coastline southwards being characterised by a wide, low angle foreshore.

2.3.2 COASTAL CLIFF EXPOSURES.

The coastal Rapanui Terrace between Patea and Whangaehu River has been cut back to form a line of cliffs 3 to 60 m high, interrupted by rivers and streams where Recent deposits have accumulated. The sea cliffs, cut in weakly consolidated Pliocene to Pleistocene sediments,

are capped by sediments of the Rapanui Formation and Holocene deposits, with a veneer of beach sands lapping up to the base of the cliffs. Locally, along the coast between Patea and Whangaehu Rivers, intertidal platforms are exposed, cut into the underlying Pliocene to Pleistocene sediments. Elsewhere the beach sand is a veneer over a cut platform, except near the mouths of rivers and streams where the channels are deeper and filled with Recent sediment.

A detailed description of the stratigraphic sequence and lithologies of the coastal outcrops is given in Fleming (1953). From the northwest of Waipipi Point to Waitotara River, the sea cliffs are cut in Upper Pliocene sandstones, siltstones, and shellbeds with resistant cemented shelly sandstones cropping out as reefs at low tide. The Upper Pliocene sediments are unconformably overlain by a thin veneer of the Rapanui Formation (Patea Dune Sands). From about 2 km north to about 2.5 km southeastwards of the Waitotara River, Patea Dune Sands are found backing the beach and unconformably overlying the older deposits.

The low coastal headland which occurs 2.5 km southeast of Waitotara River mouth and continues to Wainui Beach (Fig.2.1), is formed of detrital shell-limestone (Nukumarū Limestone) of the Nukumarū Formation, faulted against Nukumarū Brown Sand to the east, with the limestone striking seawards forming a series of reefs (Fleming, 1953).

The coastal cliffs from Wainui Beach to Castlecliff, a distance of about 15 km, are 30-50 m high, and are cut into sediments capped by deposits of the Rapanui Formation. The Lower Pleistocene stratigraphic

units from coastal exposures are summarised in Fig.2.2 and 2.3. The lithologies deposited during Nukumaruan times are shellbeds, sandstones and siltstones with rhyolitic pumice and some lignite deposits (Fig.2.2). These are unconformably overlain by finer sediments of fossiliferous sandstones, siltstones, and shellbeds deposited during Castlecliffian time (Fig.2.3) when numerous rapid sea level oscillations occurred (Beu & Edwards, 1984).

Southeast of Wanganui River mouth South Spit, a narrow tongue of sand approximately 2 km long capped by sand dunes, lies between the coast and Wanganui River which runs parallel to it. Further southeastward the coastal cliffs extend from Kaitoke Stream to about 4 km north of Whangaehu River. These cliffs, about 6 m high, comprise fossiliferous deltaic and beach gravels of the Rapanui Formation (Fleming, 1953), overlying Upper Castlecliffian Siltstone which in places crops out on the beach as tidal platforms. Further southeastward actively eroding foredunes back the beach with the underlying Castlecliffian sediments being exposed at times at the low tide-mark.

South of Whangaehu River the coastline is dominated by post-glacial sand dunes, with active beach progradation and dune building.

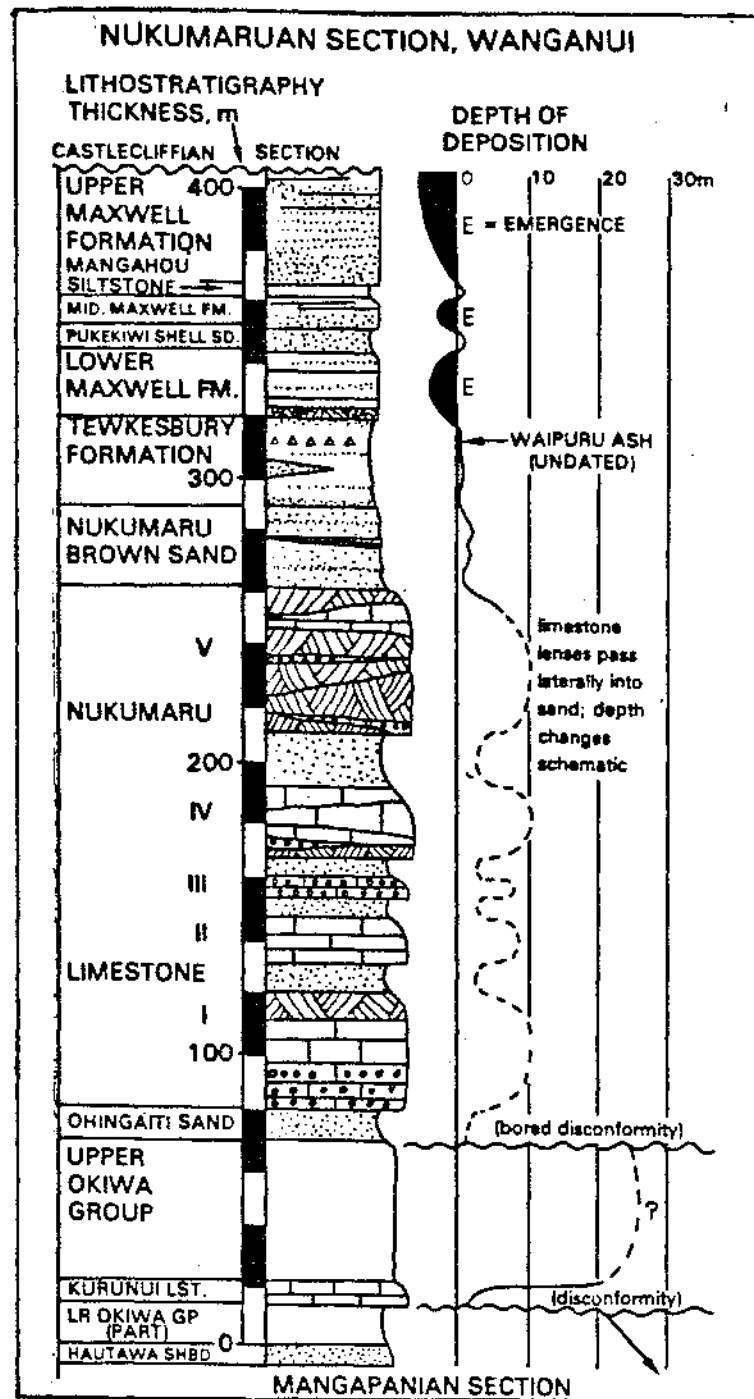


Fig. 2.2 NUKUMARUAN COASTAL SECTION, WAITOTARA TO WAINUI BEACH.

LITHOSTRATIGRAPHY, THICKNESS AND DEPTH OF DEPOSITION ARE INDICATED.

(Adapted from Beu and Edwards, 1984).

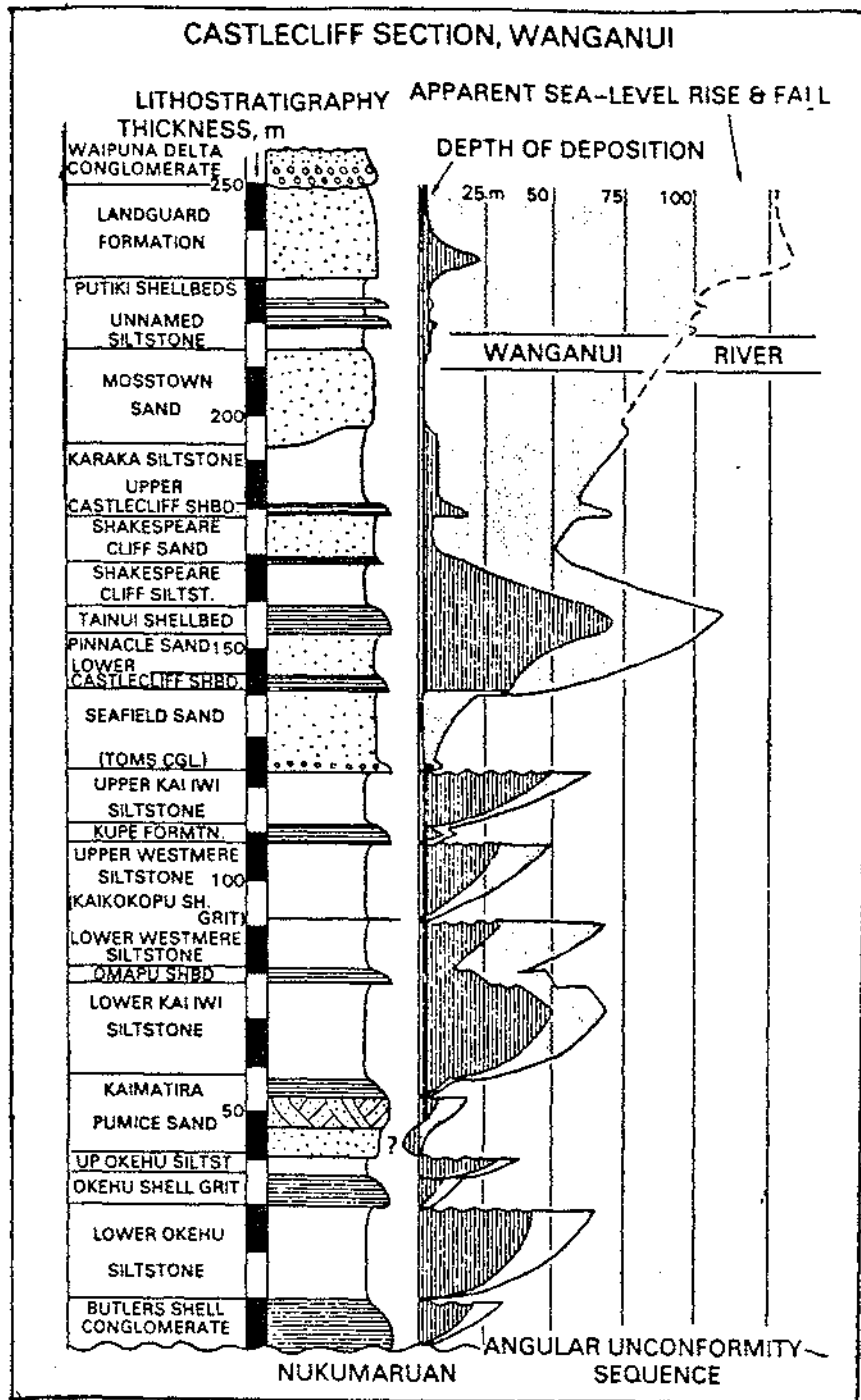


Fig. 2.3 CASTLECLIFFIAN COASTAL SECTION, WAINUI BEACH SOUTHEAST TO WANGANUI, SHOWING THE LITHOSTRATIGRAPHY AND THICKNESS, DEPTH OF DEPOSITION AND APPARENT SEA-LEVEL CHANGE.

(Adapted from Beu and Edwards, 1984).

2.4 DRAINAGE SYSTEM.

The southwest coast of the North Island is drained by a series of more or less parallel rivers which cross the landscape north-east to south-west, following the general seaward slope of the topography. In Table.1 the sediment inputs to the continental shelf are given and indicate that the Wanganui, Rangitikei and Manawatu Rivers are major sediment contributors, with the Whangaehu and Turakina Rivers contributing a smaller volume. The map in Fig.2.4 illustrates the regions that the rivers drain from and geology of the source areas.

TABLE.1.

SEDIMENT INPUTS TO THE SOUTHWEST COAST OF THE NORTH ISLAND
FROM DISCHARGING RIVERS.
ADAPTED FROM CARTER (1980)

River	Input (mt x 10 ⁶ year)	(mt = metric tonne)
Patea River	0.6	
Whenuakura River	0.1	
Waitotara River	0.3	
Wanganui River	3.0	
Whangaehu River	0.7	
Turakina River	0.3	
Rangitikei River	2.6	
Manawatu River	1.8	

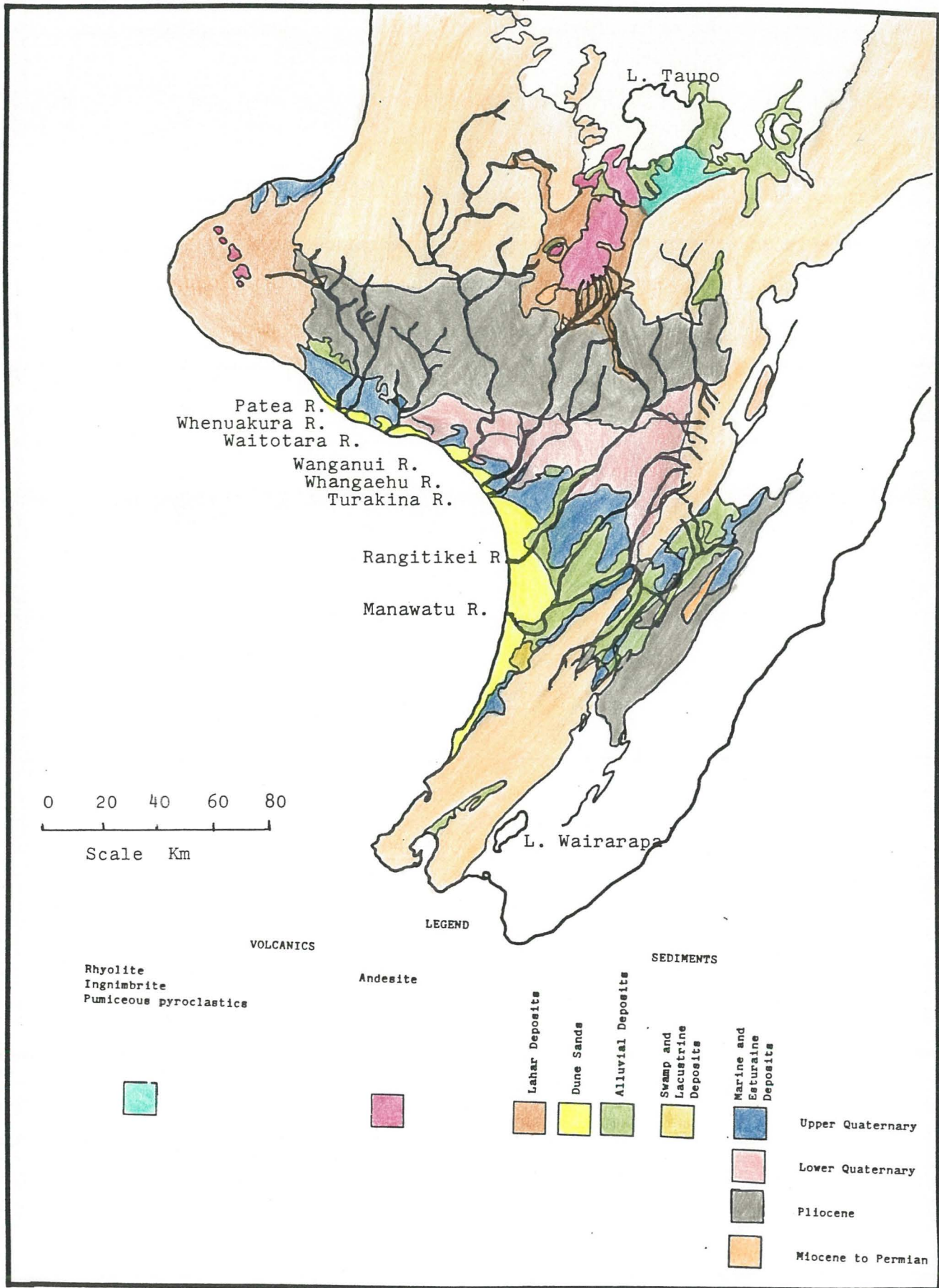


Fig. 2.4 A MAP ILLUSTRATING THE DRAINAGE PATTERN FOR THE STUDY AREA AND THE GEOLOGY OF THE SOURCE AREAS FOR BEACH SEDIMENTS.

(Adapted from N.Z. Geo. Sur. 1972; 1973).

Patea River headwaters rise on the eastern slopes of Mount Egmont, and the river is swelled by tributaries draining from marine Tertiary sediment (Fig.2.4). The Whenuakura River rises in the Matemateonga Ranges of central Taranaki. The Waitotara River also rises in central Taranaki, receiving its tributary, the Moumahaki, from the west. Both rivers drain from catchments comprising marine sediment of Pliocene age. Ototoka, Okehu, Kai-Iwi, and Mowhanau Streams are all important minor waterways draining the area between Waitotara and Wanganui Rivers (Fleming, 1953). These streams have headwaters formed in Pleistocene Dune Sands (Fig.2.4).

The Wanganui River, which is 300 kms long, drains a catchment of 7,300 km² comprising soft, unconsolidated sandstones and mudstones and rises west of the Central Volcanic Plateau of the North Island (Fig.2.4). It is swelled by the Ohura and Tangarakau Rivers which drain marine Tertiary sediments from inland North Taranaki, and by the Manganui-a-te-ao River draining the western slopes of Mount Ruapehu.

The Whangaehu River and its tributaries rise on the southern slopes of Ruapehu and are later joined by the Mangawhero River as a tributary. The sediment load carried by the Whangaehu River is proportionally greater than that of either the Wanganui or Turakina Rivers due to its steeper downstream gradient (Fleming, 1953).

In contrast the Turakina River, which is smaller than the Wanganui or Whangaehu Rivers, carries only a small sediment load. The catchment basin is formed in Pliocene and Pleistocene sediments which contains no volcanic material except near the coast where volcanic material has

been derived from coastal terraces (Fleming, 1953).

The Manawatu and Rangitikei Rivers traverse north-east to south-west over extensive floodplains. The floodplains are characterised by low elevation, relatively level topography and comprise sediments ranging from gravels and sands to silts and muds. Both the Rangitikei and Manawatu Rivers drain greywacke catchments with the tributaries also draining Pliocene to Pleistocene sediment areas (Fig.2.4). During flood conditions the Rangitikei River discharges gravel at the coast. The gradient of the Manawatu River over the last 48 km is about 1 m per 5 km and with the meandering nature and a sediment load of mainly sand/mud through the sand country, suggests that it is not a major supplier of foreshore material. During flood periods the discharge sediment would most likely be swept offshore (Gibbard, 1972).

2.5 METEOROLOGICAL CONDITIONS.

The study area lies within Robertson's (1959) climatic district D, characterised by the prevalence of west to northwest winds with relatively frequent gales. The annual rainfall is 900 mm to 1300 mm and is evenly distributed throughout the year, with warm summers and mild winters (Robertson, 1959). Records from the meteorological station at Wanganui Airport (0.6 km from the coast) show that the mean annual air temperature ranges from 8.7°C to 18.0°C (mean 13.6°C), and rainfall averages 906 mm/yr. The wind flow is predominantly from the northwest quadrant with the southeast quadrant being the next most common. Wind regime data on average during the year at Wanganui Airport is shown in Fig.2.5 (N.Z.Met.S.Misc.Pub.171(25)).

In the study area the weather pattern and gradient wind flow is dominated by anticyclones from the west to southwest with modifications to the wind pattern occurring due to orographic effects. A westerly or southwesterly wind entering the South Taranaki Bight is deflected southward as it is concentrated through Cook Strait, which acts as a natural funnel between the mountain chain of the North and South Islands (Garnier, 1958). Furthermore, Heath (1978) indicates that in the northwestern Cook Strait area these strong orographic effects act on predominantly northwest-directed winds associated with high atmospheric pressure disturbances, and predominantly southeast directed winds associated with low atmospheric pressure disturbances. This will be discussed further in Chapter 3, relating the wind pattern to coastal currents and the wave climate.

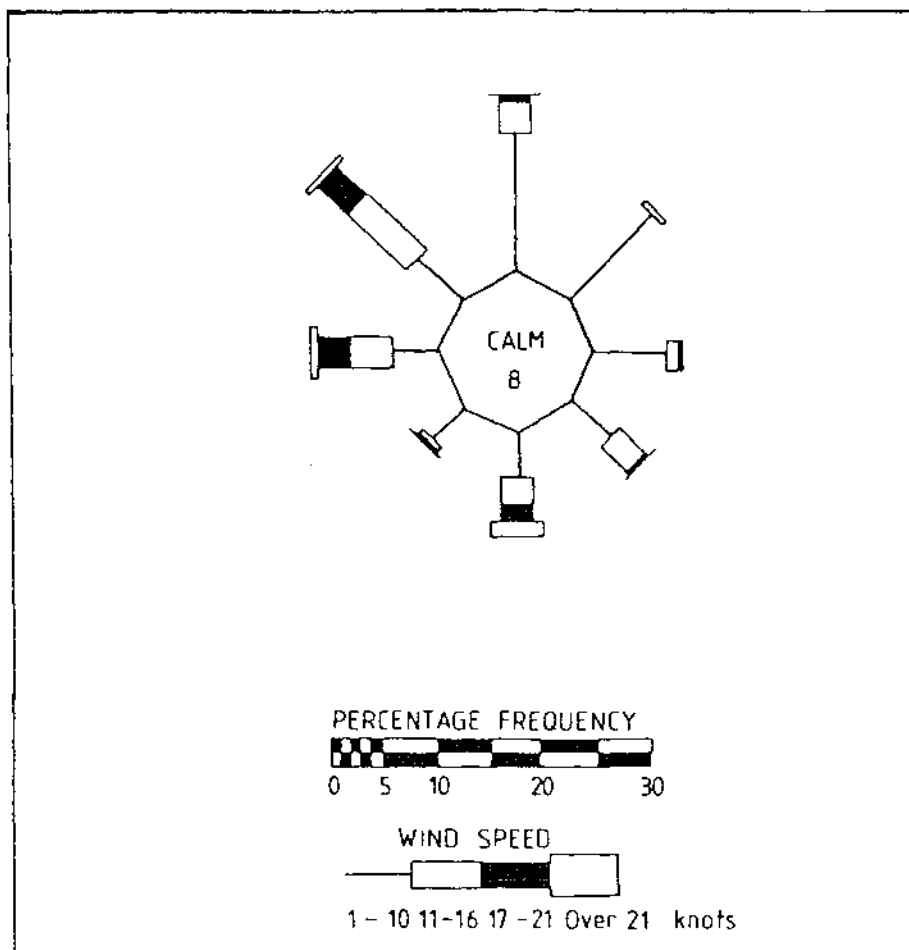


FIG.2.5.MEAN ANNUAL WIND FREQUENCY (%) OF SURFACE WIND DIRECTIONS AT WANGANUI AIRPORT, 1977 - 1981
Frequencies found from hourly observations
(from N.Z. Met. S. Misc. Pub. 171 (25))

2.6 SUMMARY.

Sedimentation in the South Wanganui Basin has been complex, with rapid changes in the rate of sedimentation, volcanic supply, diastrophic activity and climatic changes. Diastrophic movement occurred throughout the period of establishment and growth of the South Wanganui Basin. This together with climatic changes, has been responsible for the major features of the present physiography, and the coastal configuration.

Sediments varied in amount and nature according to provenance, relief of hinterland, and volcanism. Sediment sources originally were from the Tertiary rocks to the north and northeast with a granitic source to the southwest. Later, sedimentation was influenced by both the volcanic activity from Central North Island and Taranaki and greywacke derived sediment from the growing anticlines to the east.

The drainage pattern is a series of northeast trending rivers draining catchments formed in marine Pliocene to Pleistocene sediment, with part of the Whangaehu and Rangitikei River sediment bed load comprising volcanic and greywacke material.

The meteorological conditions are strongly influenced by the topographical setting of New Zealand. The surface wind pattern is strongly affected by the relief and coastal configuration, so that the southwest coast of the North Island is subjected to strong west to northwesterly winds associated with high atmospheric pressures.

CHAPTER 3
THE MARINE ENVIRONMENT.

3.1 INTRODUCTION.

The objective of this chapter is to review the literature on offshore sediments and their distribution, the coastal currents present, and wave regime developed and modified by the marine environment on the continental shelf, all of which affect the coastal processes and sediments on the beaches in the study area. The central region of the Western Continental Shelf of New Zealand, is here defined as the North West Cook Strait Shelf (Fig.3.1).

The marine environment is a complex system whereby many factors interact and influence each other, so that no one factor can be considered to operate in isolation of an other. The effects of the marine processes are examined to determine the net sediment transport direction and mechanisms for both offshore environments and along the coastline in the study area. This is important in understanding the coastal processes and in determining beach sediment distribution and supply from contributing rivers.

The wave and current energy available at any beach is strongly influenced by the coastal configuration and offshore topography. The latter determines both the direction and subsequent modification by refraction of waves approaching the coast. The dominant currents and waves examined, are influenced by meteorological conditions, which in turn further influences sediment transport and deposition. These affect the supply and redistribution of sediments to the coast and to offshore environments.

3.2 BATHYMETRIC FEATURES.

The bathymetry affects both the direction and strength of marine currents and causes modification of wave trains by refraction. The offshore topography also modifies sediment transport and deposition on the North West Cook Strait Shelf area (Lewis, 1979).

The bathymetric features for the North West Cook Strait shelf are shown in Fig.3.1. The Cook Strait Basin slopes gently towards the Cook Strait Canyons, which extend from the saddle of the Farewell-Egmont Rise, south-east to the Cook Strait Canyon. Maximum shelf depths of about 150 m occur in the Cook Strait Trough (Lewis & Eade, 1974). South of Rangitikei River mouth rapid offshore deepening occurs as the offshore gradient increases, especially in the region of the Cook Strait Canyons southwest of Kapiti Island, culminating at a depth of 390 m (Fig.3.1).

The submarine contours are sub-parallel to the present coastline except where modified by several rocky outcrops off Patea which reflect the along strike continuation of the Wanganui Basin strata. The deeper bathymetric contours are smoother suggesting that the earlier shoreline was gently curving with fewer interruptions to longshore drift than at present (Lewis, 1979).

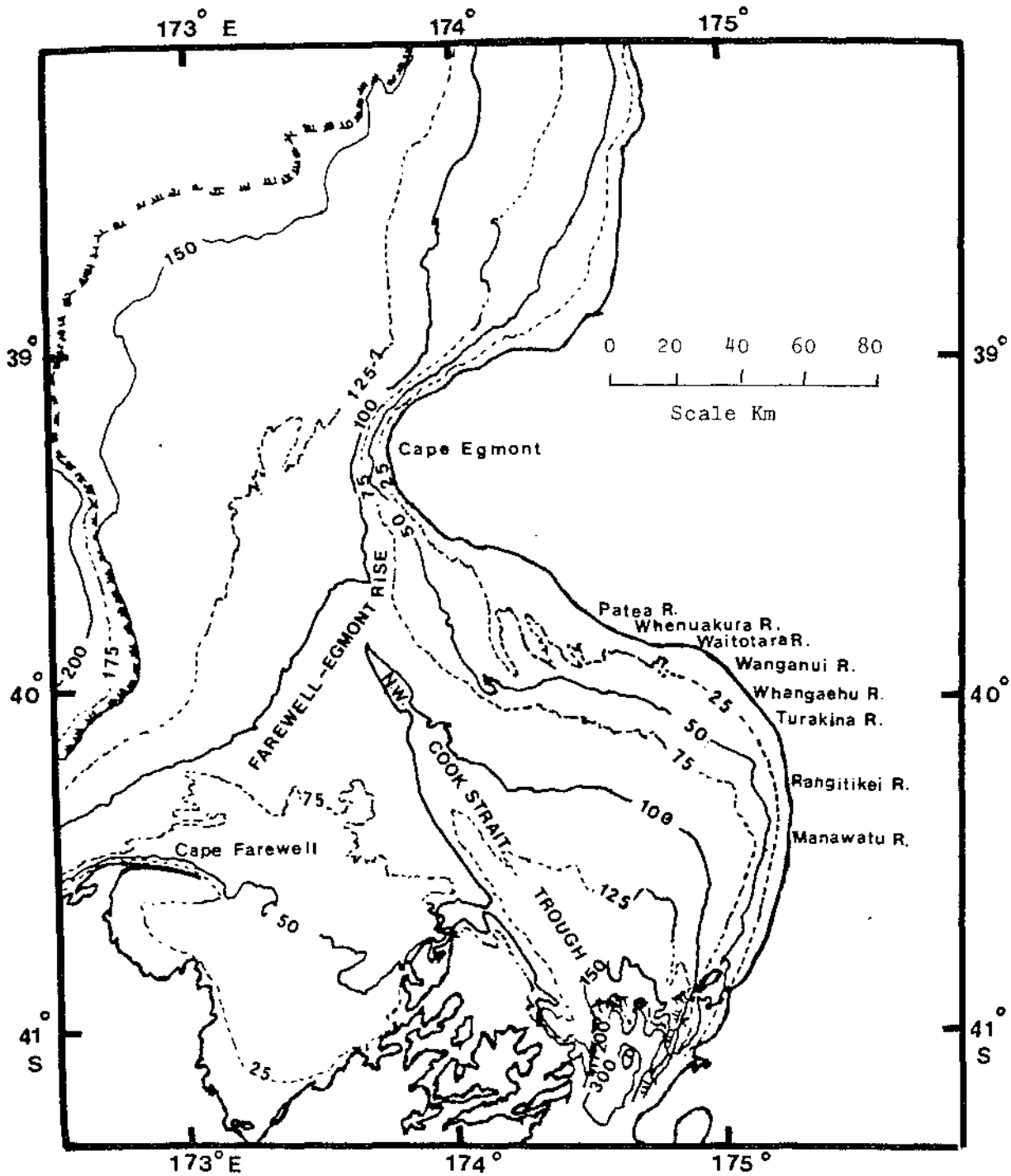


FIG. 3.1.

OFFSHORE BATHYMETRY FOR THE NORTH WEST COOK STRAIT SHELF AREA;
 ISOBATHS ARE IN METRES AND SAWTOOTH LINE REPRESENTS THE SHELF
 EDGE.

Source: N.Z.O.I. Bathymetry Charts (Brodie, 1964; 1966)

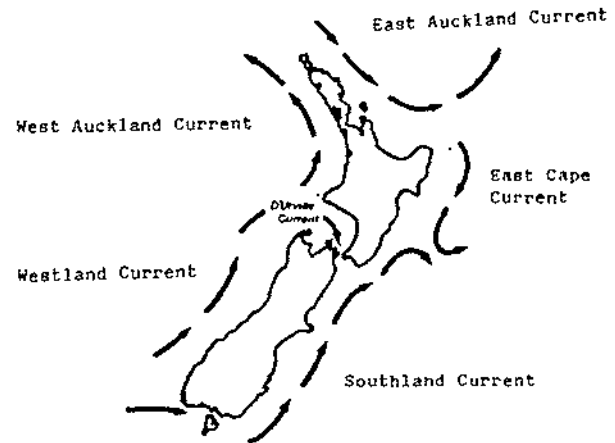
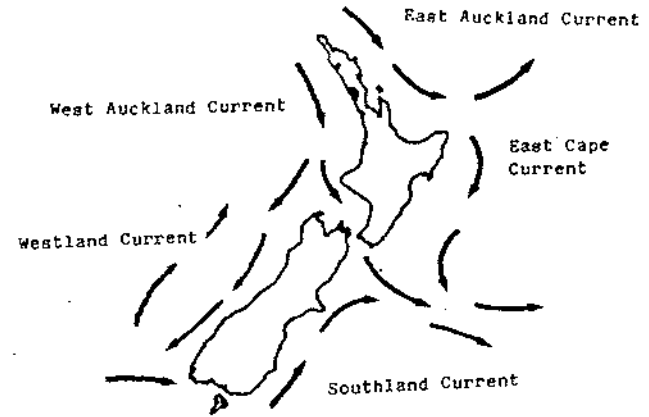
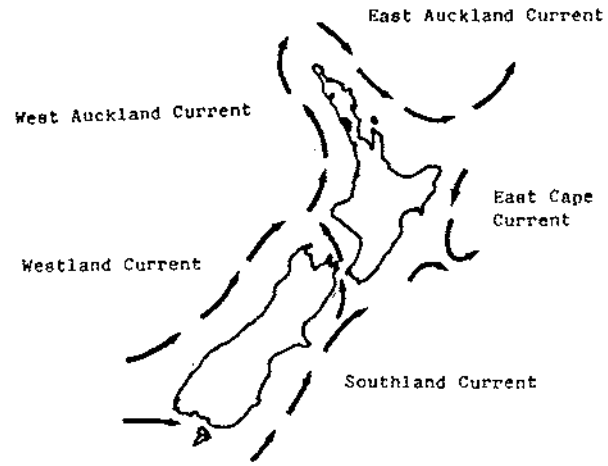
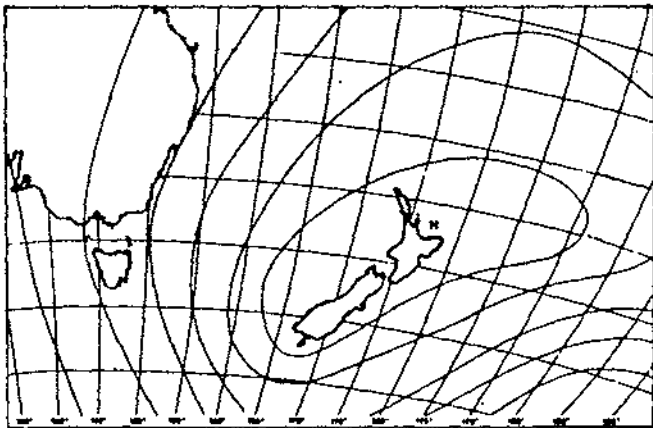
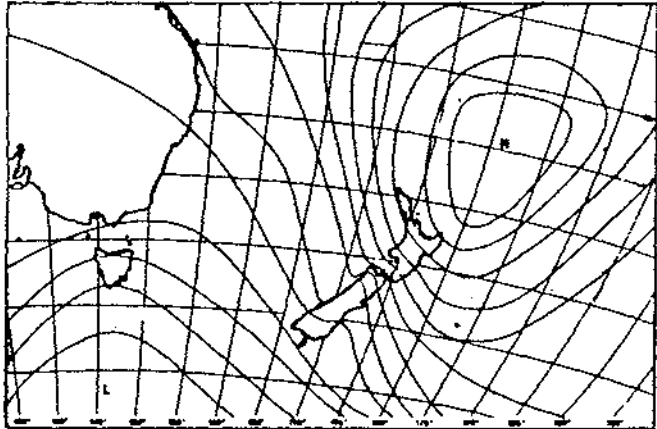
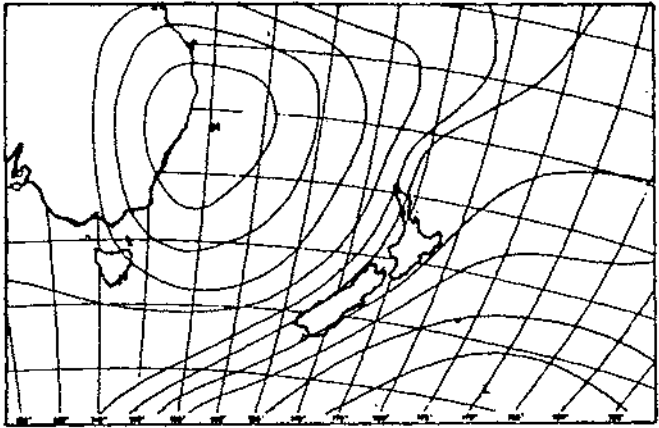
(and Carter, 1980).

3.3 CURRENTS ON THE NORTH WEST COOK STRAIT SHELF.

Coastal current drift is northward along the west coast of the South Island in what is known as the Westland Current (Brodie, 1960; Heath, 1969; Kibblewhite et al, 1982). To the north-west of Farewell Spit, the Westland Current splits, forming an offshoot called the D'Urville Current, which flows from the west into Cook Strait, the remainder of the Westland Current flows northward (Kibblewhite et al, 1982). This occurs when an anticyclone is centred over New Zealand. However, during periods of strong southerly winds when an anticyclone is centred to the west of New Zealand, the northward flowing Westland Current extends to the north of Cape Egmont. As the anticyclone moves off to the east the winds change direction and blow from the north-northwest, producing a southeasterly coastal current in the study area (Kibblewhite et al, 1982). The idealised representations of ocean surface currents that affect the study area are represented in Fig.3.2.

From analysis of sediment off North-West Nelson, van der Linden (1969) found that a bottom current system existed in this region which was similar to the surface current deduced by drift cards, that is, branching into two components north of Farewell Spit. For sediment transport a bedload of mainly fine and medium sand would require near bottom current speeds in excess of about 35-40 cm/s to initiate grain movement (van der Linden, 1969; Carter & Heath, 1975). From current meter records of current flows below the water layer subject to strongly directed wind influences, Heath (1978) and Kibblewhite et al (1982), measured a net current flow of 13 cm/s, which confirmed the existence of the D'Urville Current on the North West Cook Strait Shelf

FIG. 3.2. IDEALISED REPRESENTATION OF OCEAN SURFACE CURRENTS ON THE WESTERN SIDE OF NEW ZEALAND FOR TYPICAL METEOROLOGICAL SITUATIONS. (From Kibblewhite *et al*, 1982).



(Table.2). This also means circulation of the D'Urville Current is too weak to instigate sediment transport of very fine sand or coarser sediment (Carter & Heath, 1975).

Tidal currents on the open shelf are weak with maximum surface speeds of up to 21 cm/s except in Cook Strait (Table.2). Tidal currents alone are insufficient to move sediment.

On the North West Cook Strait Shelf, the tidal and mean flows are weak with the dominant sediment moving currents being storm induced (Table.2). Carter (1980), suggested that from net current velocities and their depth range, modern waves simply stir the seafloor sediment without inducing significant transport beyond the confines of the ironsand (titanomagnetite and/or magnetite and ilmenite) bearing zones. In storm conditions, the prevailing west and northwest winds generate wind drift currents that would transport wave suspended sediment southeastwards and southwards. In response to the onshore buildup of water, induced by the wind drift and changes of atmospheric pressure (Heath, 1978), secondary flows such as storm surge currents may be set up (Carter, 1980). During an unusually long westerly storm in 1976 documented by Tomlinson (1976), it was inferred that a southeast-trending storm surge current was generated in the South Taranaki Bight with a calculated near sea bed speed of 60 cm/s (Lewis, 1979).

In summary, the major transport currents for river detritus dumped on the offshore seabed are induced by storms. The storm induced currents result largely from west-northwest winds that would transport

TABLE.2. Summary of main water motions on the Western Shelf, Northwest of the Cook Strait, outlining their dominant direction of travel and speeds at particular depths. In the case of waves, direction of propagation and depths at which very fine sand is moved by a wave of given period (P) and height (H) are given.

x = mean threshold value (see Carter, 1980). Adapted from Carter, (1980).

Component	Locality	Data Source	Direction	Speed (cm/s)	At Depth (m)
MEAN FLOW					
Westland Current	Westland Nelson	Stanton (1976) Heath (1969)	NE	0 - 50	0
Westland Current	N.W. Cook Strait	Heath (1978)	NE	x = 3	11
D'Urville Current	N.W. Cook Strait	Heath (1969, 1974, 1978)	E to SE	1 - 13	0 - 68
TIDES					
	N.W. Cook Strait	Heath (1974)	Flood WNW Ebb ESE	x = 1.3; max. = 31	0
	Cook Strait	Heath (1974)	Flood NNE Ebb SSW	x = 9.1; max. = 350	0
		Gilmour (1960)	NW	50	73
	S. Taranaki Bight	Heath (1974)	Flood NW	x = 0.5; max. = 21	0
WIND DRIFT CURRENT					
	Western Shelf	Calculated; see Carter (1980)	N to E	29 (in gale- 14 force winds 5 17.2 m/s)	0 30 75
				41 (in storm- 27 force winds 15 24.5 m/s)	0 30 75
BAROTROPIC CURRENT					
	S. Taranaki Bight	Heath (in Lewis, 1979)	SE to S	Up to 60 in 20 yr storm	50
	N. Taranaki Bight	Heath (1978)	N	10	79
BAROCLINIC CURRENT					
	Westland	Stanton (1976)	SW	7	30
WAVES					
	Taranaki	Pickrill & Mitchell (1979)	W to SW	For P _{1/3} = 8.8s H = 1.8m, sand moved at depths < 36m. For "largest" waves P = 13 s, H = 5m and P = 11 s, H = 9.7 m Sand moved at depths < 94m.	

wave suspended sediment and other suspended sediment southeastwards and southwards.

3.4 WAVE CLIMATE.

3.4.1 GENERAL.

Between latitudes 30°S and 70°S westerly winds blow around the Southern Hemisphere virtually unimpeded by any large land mass. New Zealand lies between $34^{\circ}04'\text{S}$ and $41^{\circ}02'\text{S}$ and cuts across this westerly flow. The wave environment of New Zealand is dominated by west and southwest swell and storm waves generated in the temperate latitude belt of westerly winds. As a result, the coastline in the study area is an exposed, high energy coastline. These wave conditions are examined below in light of their influence on sediment transport.

3.4.2 SEA FETCH.

The height and period of wind generated waves is a function of the velocity and duration of wind flow and fetch, or sea distance over which the wind flows (King, 1972). The available fetch for wave approach is important in determining the type of wave and wave spectrum arriving at the coastline. This is illustrated in Fig.3.3 where the fetch lengths for various directions of wave approach are indicated. The beaches in the study area, under the prevailing southwest winds, lie in the lee of North-West Nelson, so that the maximum wave fetch is limited to about 100 km. In contrast, the beaches have unlimited fetch for westerly and northwesterly winds, with a more northwesterly fetch component for Otaki and Paekakariki beaches. (Gibbard, 1972).

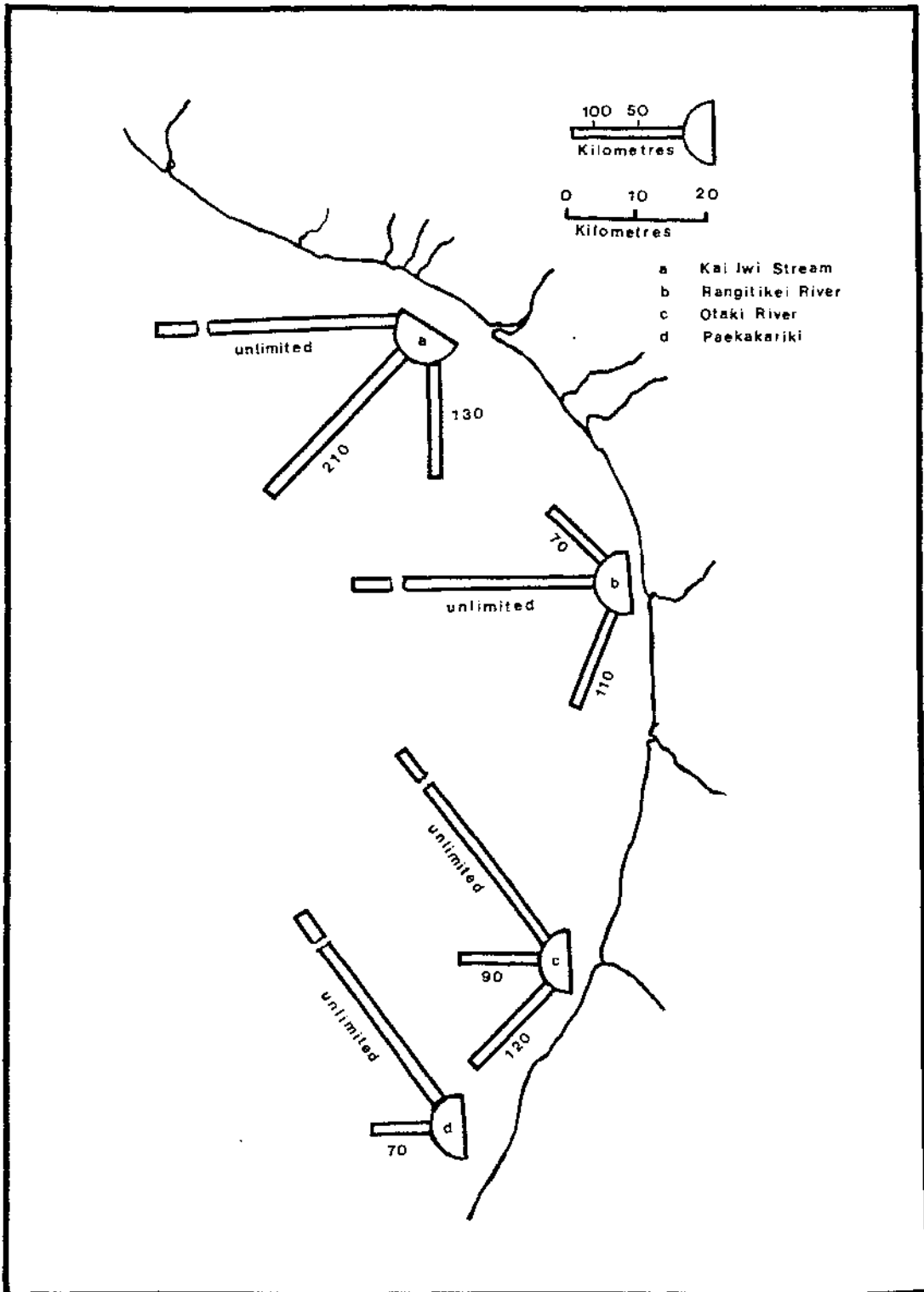


FIG. 3.3. LINEAR FETCH LENGTHS FOR VARIOUS DIRECTIONS OF WAVE APPROACH, ALONG THE SOUTHWEST COAST OF THE NORTH ISLAND (Upper Scale for fetch length, bottom scale for coastline distance). (from Gibbard, 1972).

3.4.3 WAVE PERIOD.

Wave period is affected less by wave refraction than wave height and direction. Pickrill and Mitchell (1979) reported that wave periods of 6-8 s recorded at the offshore rigs in the Maui Field, are generally shorter than those at nearby coastal stations. Kibblewhite et al (1982) recorded an average wave period of about 6-7 s at the Maui Field rigs, although a persistent swell from the southwest of average wave period 12 s is present most of the time. The largest wave period recorded exceeded 20 s. Burgess (1971) reported at Wanganui a range in wave periods from 5-18 s, with the modal class ranging from 6-9 s.

3.4.4 WAVE DIRECTION.

While swell waves may retain their characteristics for both long periods and distances at sea, upon entering shallow water, waves are subject to refraction (Munk & Traylor, 1947). Gibbard (1972), using wave refraction diagrams with wave trains of 10 seconds, shows that all wave trains undergo refraction in the study area, "the extent of which depends upon the initial degree of alignment between wave crests and offshore conditions". Refraction coefficients for the northern beaches have a maximum for waves from the southwest and southern beaches for northwesterly wave trains. Interpretation of refraction diagrams indicates that the present coastline is best adjusted to wave trains from a west-northwesterly direction, and the coastline is being altered by the present wave regime towards a new equilibrium form. The present outline may also to a large degree reflect the geological history of the area (Gibbard, 1972).

Kibblewhite et al (1982) report that in the Maui platform region

the wave climate is dominated by southwesterly swell waves and storm waves generated by westerly winds. Despite the effects of refraction, shore based observations at Wanganui by Burgess (1971), confirmed that the west to southwesterly quarter was the prevailing approach direction.

For the period 1968-1969, Burgess (1971) used Wanganui Harbour Board wave data to calculate the net longshore drift. At a depth approximately 5 m below the mean sea level the ratio between the north- to -south and south- to -north longshore wave energy components was 3:1. Wave refraction ensures that waves approach the shore at angles generally less than five degrees, and available longshore energy at Wanganui favours longshore drift from north to south, although sequences of wave trains from a southern direction do occur.

3.4.5 WAVE HEIGHTS.

The deepwater wave heights around New Zealand based on oil rig data are the most reliable, particularly since the southerly through to the westerly waves approach much of the shoreline in the study area obliquely and undergo extensive refraction (Pickrill & Mitchell, 1979).

Kibblewhite et al (1982) recorded the following wave heights and frequencies from 1977 to 1981 in the Maui platform region:

- (1) The greatest significant wave height was 10.5 m.
- (2) The highest wave was 19.5 m.
- (3) The average significant wave height was 2-3 m.
- (4) Wave heights were less than 2 m for 35.7% of the time.
- (5) Wave heights were greater than 4 m for 10.3% of the time.

On the Wanganui coastline a mean wave height of 1.2 m has been recorded (Burgess, 1971; McLean & Burgess, 1974). The coast is described by Burgess (1971) as being one of moderate to high energy, since breaker height frequently exceeds 1.2 m. Gibbard (1972) also suggests that, due to fetch considerations and the duration of generating winds, the greatest proportion of waves greater than 3 m in height will arrive from the west.

3.5 OFFSHORE SEDIMENTS.

The North West Cook Strait Shelf area is mantled by Recent, terrigenous sediment. The sediment grain size distribution pattern is shown in Fig.3.4 and illustrates that instead of a regular sequence of seaward fining followed by coarsening gradients, there is a sand (>90% sand) and muddy sand (50-90% sand) covered shelf with large patches of mud (<10% sand) and gravel. Modern sand is restricted to the inner shelf from whence it grades into either relict and palimpsest gravelly sands, as is the case off Patea (Lewis, 1979), or muddy sand, as is found off the remainder of the coast. The mud belt existing in the North West Cook Strait Shelf region (Fig.3.4) is favoured by the North-West Cook Strait Trough acting as a "sink" for mud emanating mainly from nearby Wanganui, Rangitikei, and Manawatu Rivers. Due to high tidal current velocities in the narrow part of Cook Strait no mud is deposited in Cook Strait itself as mud is winnowed out, leaving behind deposits of sand and gravel (van der Linden, 1969). The gravel apron 5 km wide around Cape Egmont contains up to boulder size clasts, derived either from lahars from Mount Egmont or by erosion of coastal lahar deposits (Carter, 1980), or both.

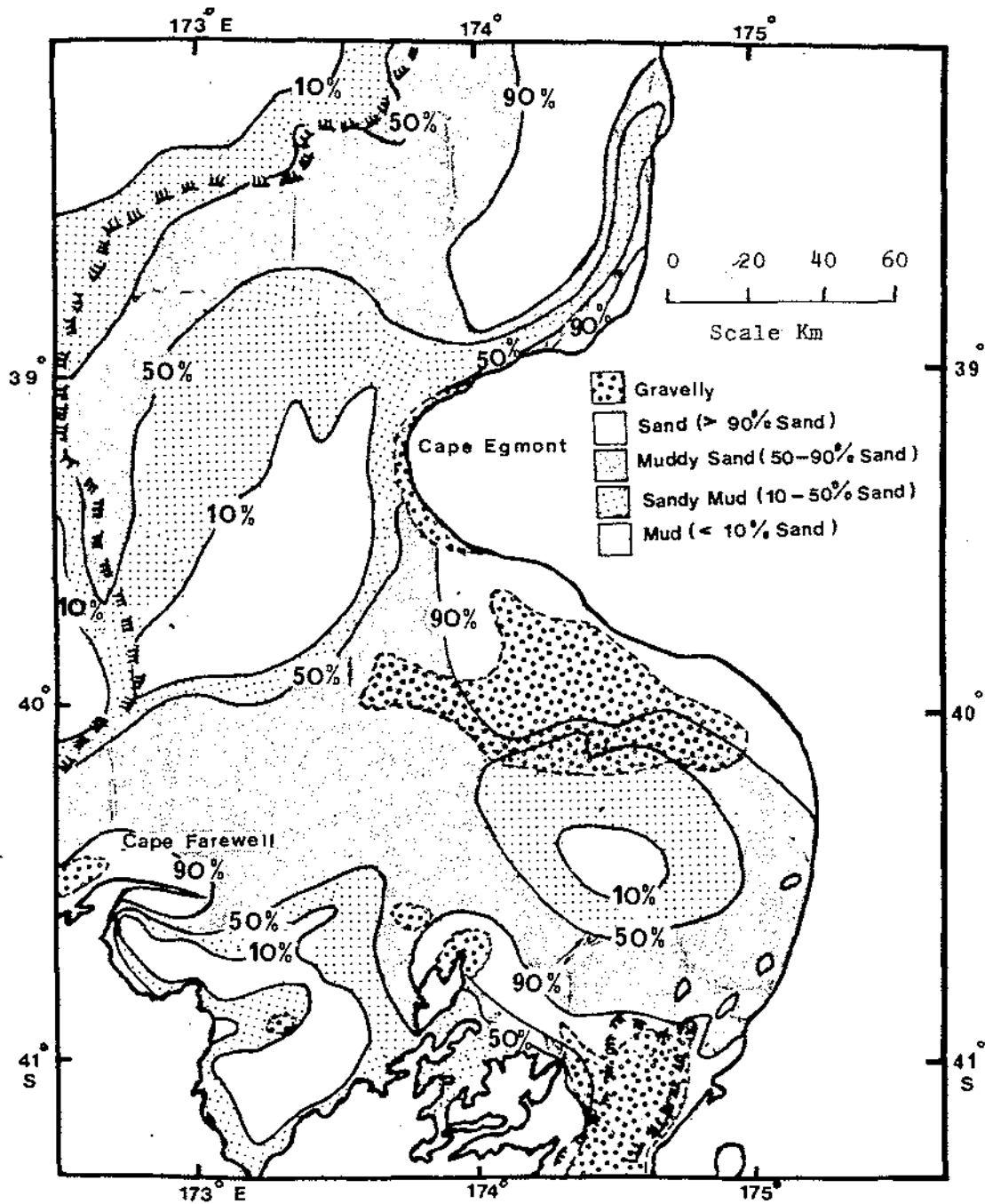


FIG. 3.4.

SEDIMENT DISTRIBUTION ON THE NORTH WEST COOK STRAIT SHELF AREA.

CONTOURS REPRESENT PERCENTAGE SAND WITH TEXTURAL TYPES CATEGORISED

AFTER FOLK (1974). (From Carter, 1980).

The distribution of ironsand (ilmenite, titanomagnetite and/or magnetite bearing sand) over the North West Cook Strait Shelf is shown in Fig.3.5. Sediments containing >5% ironsand are restricted to the inner and middle shelf, but elsewhere ironsand contents are low. The concentration off Patea reaches a maximum of 22% at depths between 20-40 m (McDougall, 1961). Ironsand contents gradually decrease to the southeast from Cape Egmont, but are locally high near Wanganui River. Further to the southeast, ironsand again decreases, presumably due to dilution by river sands (Finch, 1947).

On the inner to middle shelf off Wanganui, Lewis (1979) has mapped a series of sand ridges comprising coarse, mafic rich "blacksand" containing 2-4% ironsand. These black sand ridges formed 12,000 to 9,000 years ago as "shoreface connected shoals" (Lewis, 1979). Areas between ridges are mantled by modern sand ribbons of either medium to coarse shelly, felsic and mafic sand with up to 11% ironsand, or fine felsic sand with <2% ironsand. The black sand described by Hutton (1940) and Fleming (1946) is derived from the Taranaki Volcanics. The light coloured sand is derived mostly from Pliocene to Pleistocene marine deposits of the Wanganui Basin and from voluminous rhyolitic tephra eruptions of the Taupo Volcanic Zone. A lesser contribution is from the greywacke ranges, and the light fraction from Taranaki Volcanics (Fleming, 1946; 1953).

With storm induced currents, wave suspended sediment would be driven southeastward and southward by wind drift currents generated by the prevailing strong west and northwest winds (N.Z.Meteorological Office, 1977). From threshold values for ironsand in Table.2, and

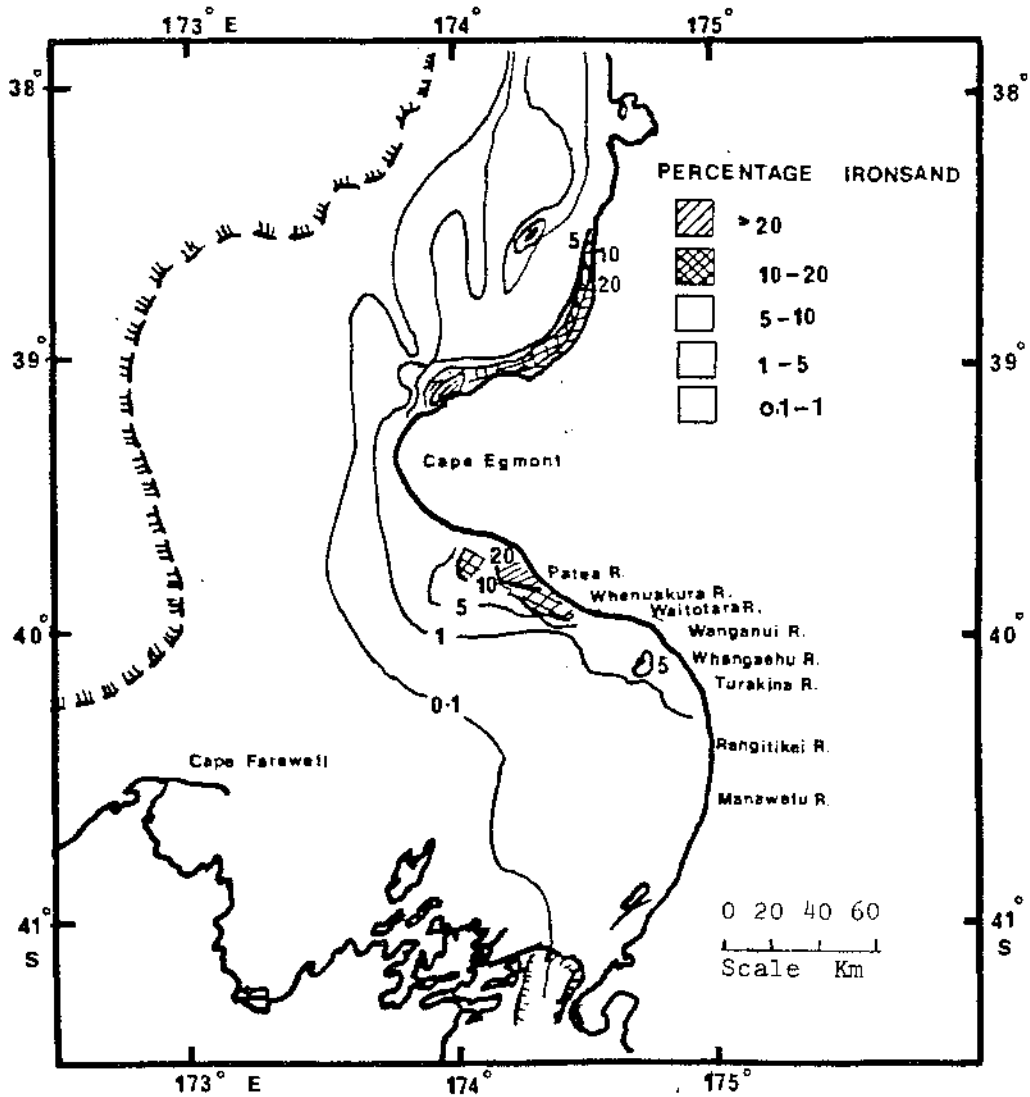


FIG. 3.5.

DISTRIBUTION OF IRONSAND IN SEDIMENTS FINER THAN 2mm DIAMETER.
 CONTOUR VALUES ARE PERCENT IRONSAND BY WEIGHT (Adapted from
 McDougall, 1961 and Carter, 1980).

conclusions from Lewis (1979) and Carter (1980), it appears unlikely that sediment at depths greater than 30 m would be mobilised except under extreme storm conditions.

Present day deposition is confined mainly to the mud and very fine sands offshore, and to the nearshore zone where present wave and wave induced currents are sufficiently strong to transport sediment discharged to the longshore drift zone.

3.6 SUMMARY.

The shallow gradient of the North West Cook Strait Shelf subjects the predominant westerly wave trains to modification by refraction over a considerable distance before reaching the coast. Waves approaching the southwest coast of the North Island are dominantly from the west to southwest quarter, with the sea fetch being limited for the southwesterly waves. For waves approaching the coast the average wave period is 6-9 s. Wave heights frequently exceed 1.2 m, with the coast described as one of moderate to high energy.

Surface drift on the west coast of the South Island is northwards with the Westland Current, which forms an easterly directed offshoot, the D'Urville Current. The D'Urville Current flows from the west into Cook Strait during westerly wind conditions particularly when an anticyclone is centred over New Zealand. While tides and waves can stir sediment on the inner and middle shelf, most of the sediment transport occurs during storm periods when wave suspended sediment is moved by a combination of tidal induced and storm induced circulation. In storm conditions, the prevailing west to northwest winds generate

drift currents that transport wave-suspended sediment southeastward and southward. Furthermore, the direction of sediment transport can be either northwards or southwards depending on the prevailing weather system.

In the study area, dominant southeastward longshore drift along the coast occurs (Burgess, 1971), with rivers discharging sediment primarily during flood conditions. The storm waves and induced currents sort the detritus at the river mouth and transport resuspended material to the middle shelf regions or further afield. The remaining sand and coarser fraction is either redistributed over the inner shelf or is fed into the longshore drift system.

CHAPTER 4

TEXTURAL CHARACTERISTICS OF THE FORESHORE ALONG THE
SOUTHWEST COAST OF THE NORTH ISLAND.

4.1 LITERATURE REVIEW.

Studies by sedimentologists have placed much emphasis on the use of grain size analyses to characterise sediment textures in specific sedimentary environments (Krummbien, 1936; Inman, 1949; Friedman, 1961; 1979; Folk, 1974; Pettijohn, 1975).

Since the work of Udden (1914) it has been recognised that sediment size characteristics approximate a log-normal distribution. In reality, however, most sediments deviate from log-normality; deviations from the Gaussian model being given various environmental interpretations (Folk & Ward, 1957; Mason & Folk, 1958; Friedman, 1961; 1979; McLaren, 1981). Other workers have differentiated log-normal subpopulations defined by distinct breaks within the complete size range of the sample (Moss, 1962; Visher, 1969; Glaister & Nelson, 1974; Middelton, 1976), with each subpopulation reflecting a specific transport mode.

Krummbien (1938) listed the environmental factors that affect a size frequency distribution, and emphasised the importance of continuous or progressive changes in distribution statistics from source to final deposition. Inman (1949) recognised that certain relationships exist between depositional environment and mean grain size, sorting, skewness and kurtosis. This formed the basis for investigation of grain size distributions in relation to depositional processes (Friedman, 1967; Visher, 1969). McLaren (1981) further suggested that the mean, sorting, and skewness of grain size frequency distributions follow trends that can be used to both identify the direction of transport, and the sedimentary processes of winnowing,

selective deposition, and total deposition.

The sediment grain size distribution in beach deposits reflects the conditions of the depositional environment, the source material, the processes operating and the energy level at which those processes are operating (Inman, 1949; Folk, 1974; McLaren, 1981; McLaren & Bolwes, 1985). For example, sandy beaches almost always comprise well sorted, matrix-free sands because there is a continuous and extensive energy expenditure on these sediments by waves. Particles are segregated according to their hydrodynamic behaviour, which is largely dependent on their size (Lowright et al, 1972) although specific gravity and shape may also be significant factors (Steidtmann, 1982; Winkelmolten, 1982). Fines are winnowed away and coarse grains are concentrated in the highest energy locale, or buried.

The mean grain size of coastal sediments is a function of both the size range of available materials and a measure of the energy imparted to the sediments. The latter in turn depends on the current velocity (longshore drift) and also partially the distance from the source area (Folk, 1974; McLaren, 1981; McLaren & Bolwes, 1985). McLaren and Bolwes (1985) further suggest that the sediment distributions are related not only to their source but also to the probability that sediment will be eroded and transported. For determination of sediment transport direction two trends are indicative: (1) finer, better sorted and more negatively skewed sediment in the direction of transport if the source sediment is eroded and the resultant transport sediment is deposited; or (2) coarser, better sorted and more positively skewed sediment, if the sediment in transport undergoes

selective deposition. Textures of beach sediments generally show a progressive decrease in grain size and improvement in sorting in the direction of transport (Folk, 1974). This is largely the result of selective sorting, whereby smaller grains outrun the larger and heavier grains in a down current direction.

Beach sands are usually well sorted, having values between 0.25-0.50 (σ_I), compared to river sands between 0.35-1.00 (σ_I) (Folk, 1974). There are some notable exceptions; beach sands formed from eroding cliffs are more poorly sorted than when detritus is continually supplied to the beach, and river sediments whose source is in well sorted ancient beach or marine sands will also be well sorted (Friedman, 1961; 1962). Coastal sand dunes tend to be slightly better sorted than associated beach sands and near shore marine sands are somewhat more poorly sorted than corresponding beach sands (Friedman, 1961; Folk, 1974).

Skewness indicates how closely the grain size distribution approaches the Normal Gaussian Probability Curve, and the more extreme the values the more non-normal the size curve. Single source sediments such as most beach sands tend to have a distribution approaching that of a normal probability curve, while sediments from multiple sources such as river sands and eroding cliffs show pronounced skewness (King, 1972; Folk, 1974). Bimodal sediments may exhibit extreme skewness values, although the pure end members of such mixtures have nearly normal curves. Sediments consisting dominantly of one end member with only a small amount of the other end member are extremely skewed, the sign of skewness depending on which end member dominates. Bimodal

sediments consisting of equal amounts of the end members may well be symmetrical (Folk, 1974).

4.2 MATERIALS AND METHODS.

4.2.1 SEDIMENT SAMPLING.

In the present study, channel sampling across the foreshore of sand beaches and point sampling from a foreshore cusp apex for gravel beaches (Fig.4.1), was adopted as a standard procedure (Gibb, 1977b). Samples were obtained from the foreshore zone, since tracer experiments have shown that this zone best represents longshore transport (King, 1972). This method of sampling was adopted for both textural and mineralogical analysis. In the present study, channel sampling was adopted to minimize the effect of localised concentrations of heavy minerals (King, 1972; Folk, 1974; Gibb, 1977b), because it has been shown that heavy mineral concentrations occurred where a ridge and runnel system had developed along the foreshore, the heavy minerals being concentrated in the runnels (Fig.4.1). Along actively eroding shorelines very high concentrations of heavy minerals occur in the backshore zone with progressive dilution across the foreshore zones (Gibb, 1977b). Accreting beaches, however show little localised variation in heavy minerals.

Samples were taken between the Manawatu and Patea Rivers on 23-25th May, 1984, with the area being resampled 5-7th September, 1984, and resampling between Wainui Beach and Kai-Iwi Beach on 26th July, 1985. Channel samples were taken at intervals along a transect from Mean Low Water Mark (MLWM) to Mean High Water Marks (MHWM) (Fig.4.1). Each channel was 2 m long, 5-10 mm deep and spaced at 10-15 m intervals

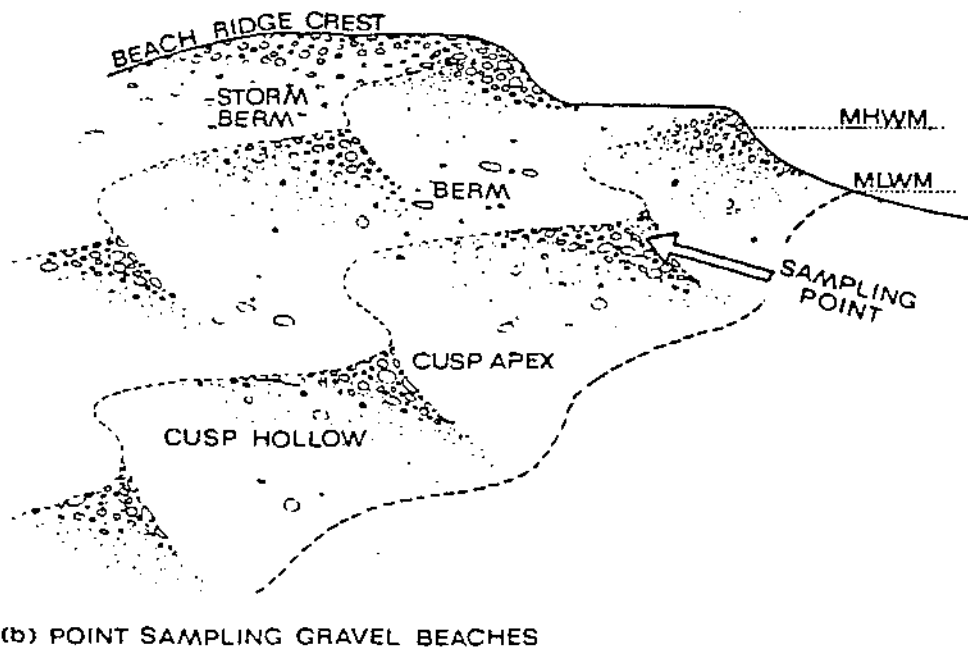
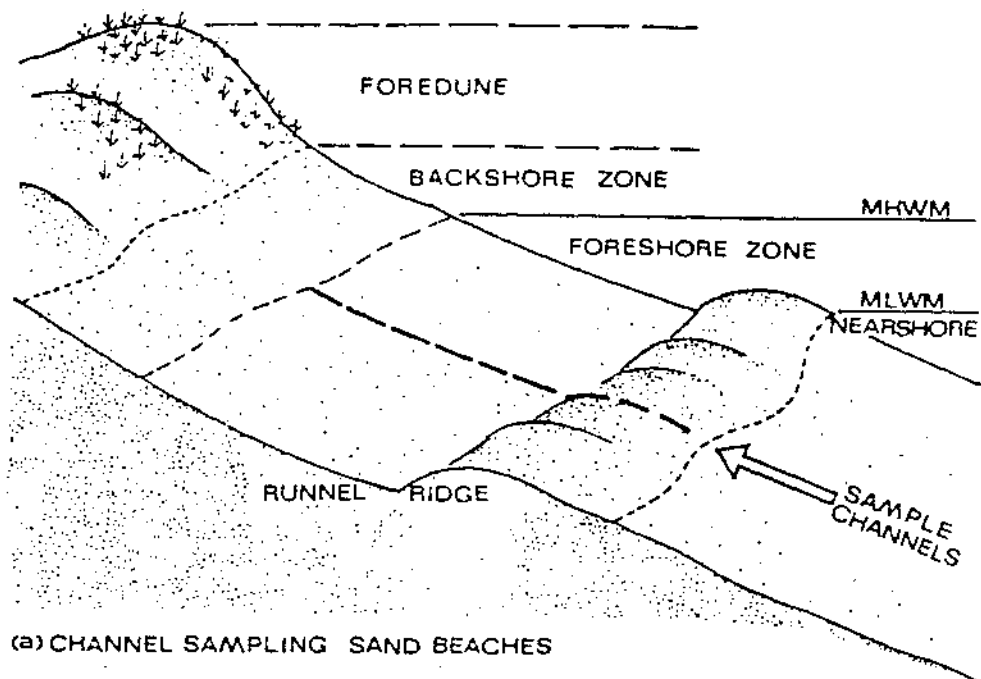


FIG.4.1. Sediment sampling of sand and gravel beaches for the investigation of longshore variations in sediment properties. Sampling procedures are described in the text. (from Gibb, 1977b).

along the transect, with the distance depending on the width of the exposed foreshore (transect length). The channel samples from each transect were combined as a bulk sample.

Samples collected for analysis totalled 64 from beaches, 8 from rivers and 7 from sand dunes and sea cliffs. Samples prefixed by S are for beach samples, SR are beach samples from repeat sampling, RS are samples from rivers discharging onto the coast, SD are sand dunes and SC are coastal cliff exposures. Sample stations are listed in Appendix B, Table.3, and are plotted with distance along the coast in Fig.4.2.

4.2.2 CARBONATE ANALYSIS.

Samples were air dried and thoroughly mixed, then split into sample sizes of 0.5 to 2.0 kg depending on the amount of gravel present, using a Jones Mechanical Sample Splitter. The split sample was weighed to 0.01 g. Carbonate was removed by treating with 1M HCl and gently heated to ensure complete carbonate dissolution. The samples were then washed in water, air dried and finally reweighed, with the percent carbonate being determined by mass difference.

$$\%CaCO_3 = \frac{\text{total wt} - \text{wt HCl treated}}{\text{total wt}} \times 100$$

The weight percent carbonate from each sample is recorded in Appendix B, Table.3.

FIG.4.2 An index for textural and mineralogical plots, to compare the location of sample stations with repeat samples, sand dunes and coastal cliff sample stations, along the southwest coast of the North Island.

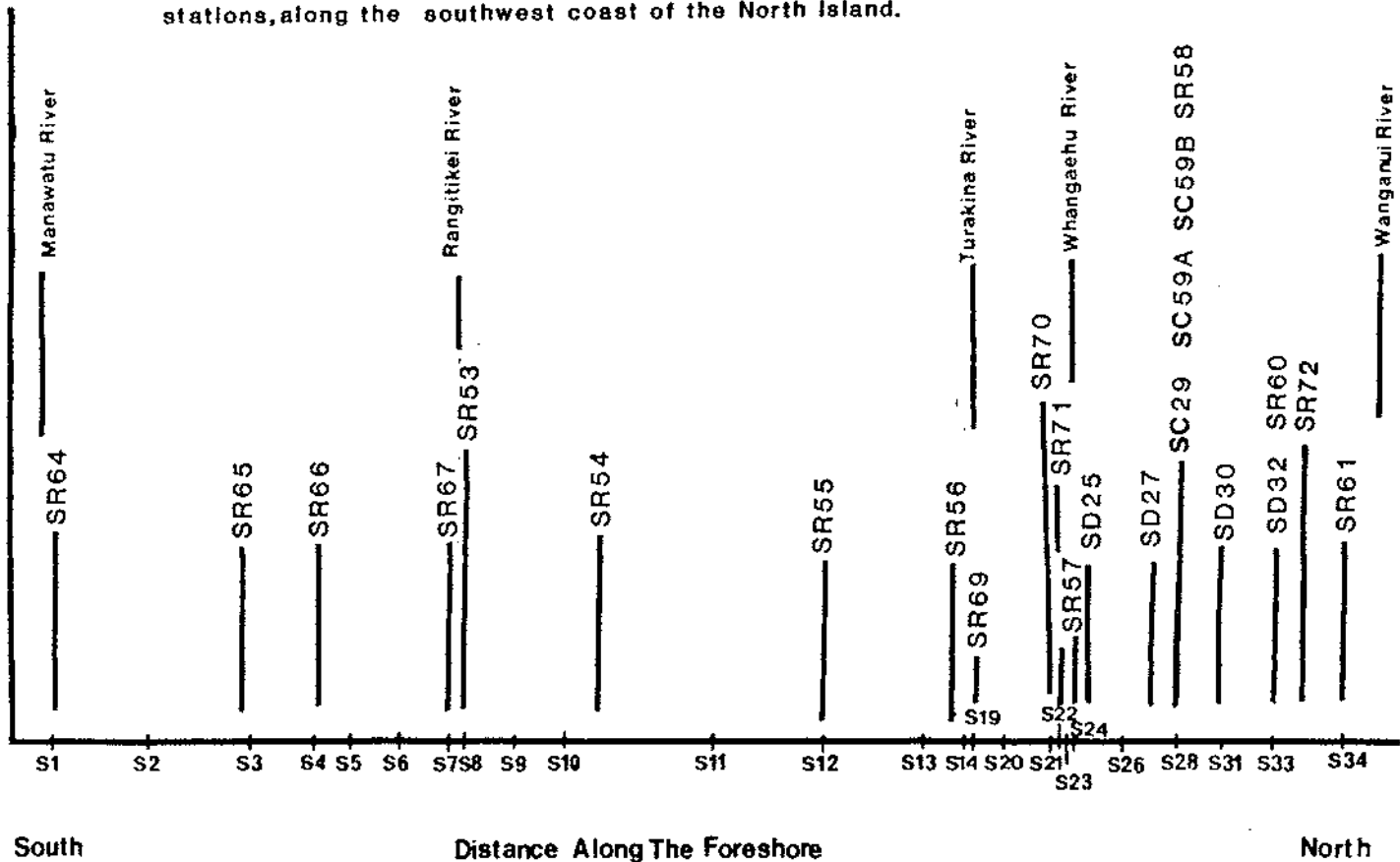
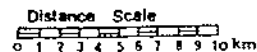
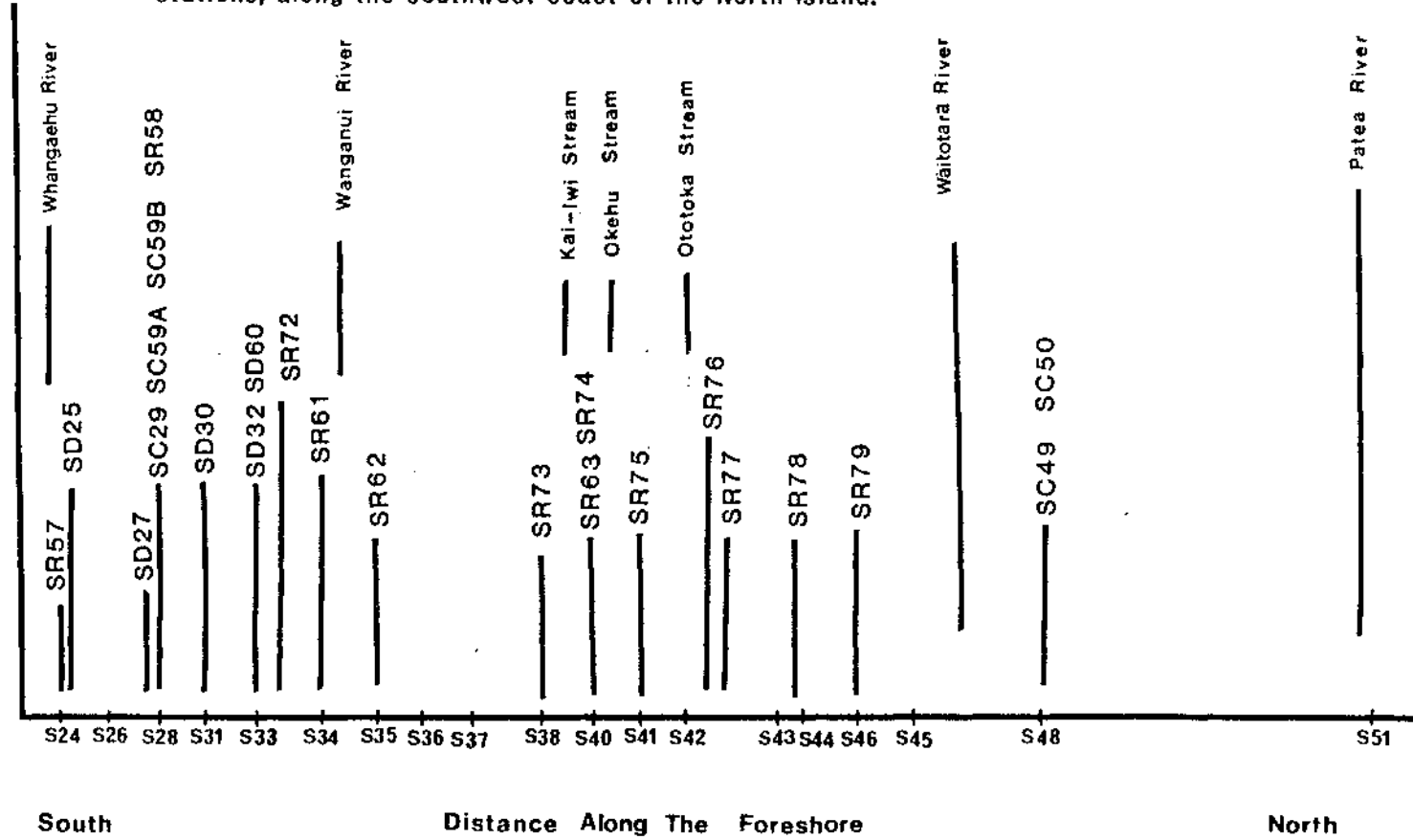
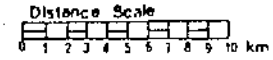


FIG. 4.2

An index for textural and mineralogical plots, to compare the location of sample stations with repeat samples, sand dunes and coastal cliff sample stations, along the southwest coast of the North Island.



4.2.3 TEXTURAL ANALYSIS.

For textural and mineralogical analysis, carbonate free samples were used. Between 100-120 g of sample was accurately weighed to 0.01 g and passed through a nest of B.S.410 Test Sieves at 0.25 ϕ intervals. An Endecotts Test Sieve Shaker was employed with a shaking time of 15 minutes.

Where gravels were present samples of 0.5-6.0 kg, depending on the size range, were sieved with additional sieves employed at 1 ϕ intervals for gravel sized material coarser than -2 ϕ .

Samples that contained greater than 5% material finer than 4.0 ϕ (0.063 mm) were analysed by sieving and pipette analysis (Folk, 1974; Lewis, 1981). Size classes of the sediments are described by the nomenclature of Wentworth (1922).

Grain size parameters employed in this analysis are those of Folk (1974), where

M_z = Graphic Mean

σ_I = Inclusive Graphic Standard Deviation

SK_I = Inclusive Graphic Skewness

Formulae for these parameters are given in Appendix A.

Grain size data was analyzed using a computer program designed by Adams (1977). Grain size parameters for the sample sites are recorded in Appendix B, Table.4.

4.3 RESULTS FROM TEXTURAL ANALYSES.

4.3.1 MEAN GRAIN SIZE (M_z).

Variations in the mean grain size along the beach traverse are shown in Fig.4.3. Distances between sediment stations have been drawn to scale. In general, mean grain size decreases southeastward and superimposed on this is a southeastward decrease in grain size from a given river mouth, both of which imply a southeastward longshore drift. This is shown clearly by rivers on long open beaches, in particular the Rangitikei, Turakina, Whangaehu, Wanganui Rivers and Kai-Iwi Stream (Fig.4.3). Deviations from this general pattern are due to the following factors:

- (1) Sites some distance south of the Waitotara, Whangaehu, Turakina, and Rangitikei River mouths have coarser sediment than the sites immediately adjacent to the north and south of the river mouth (Fig.4.3). This suggests that coarser sediment from these rivers is being deposited on the beach several (1-3) km south of the river mouth rather than adjacent to it.
- (2) The beach at site S6 south of Rangitikei River is dominated by a coarse gravel lobe. Where the foreshore is reduced in width the beach sediments are gravel or gravelly sand rather than sand.
- (3) At sites S11 and S14 the beach sediment is slightly coarser than the beaches immediately to the north or south (Fig.4.3). The beach is characterised by the development of small berms and cusps, with a ridge and runnel system that results from beach accretion during quiescent periods, with the berms acting as beach sediment stores

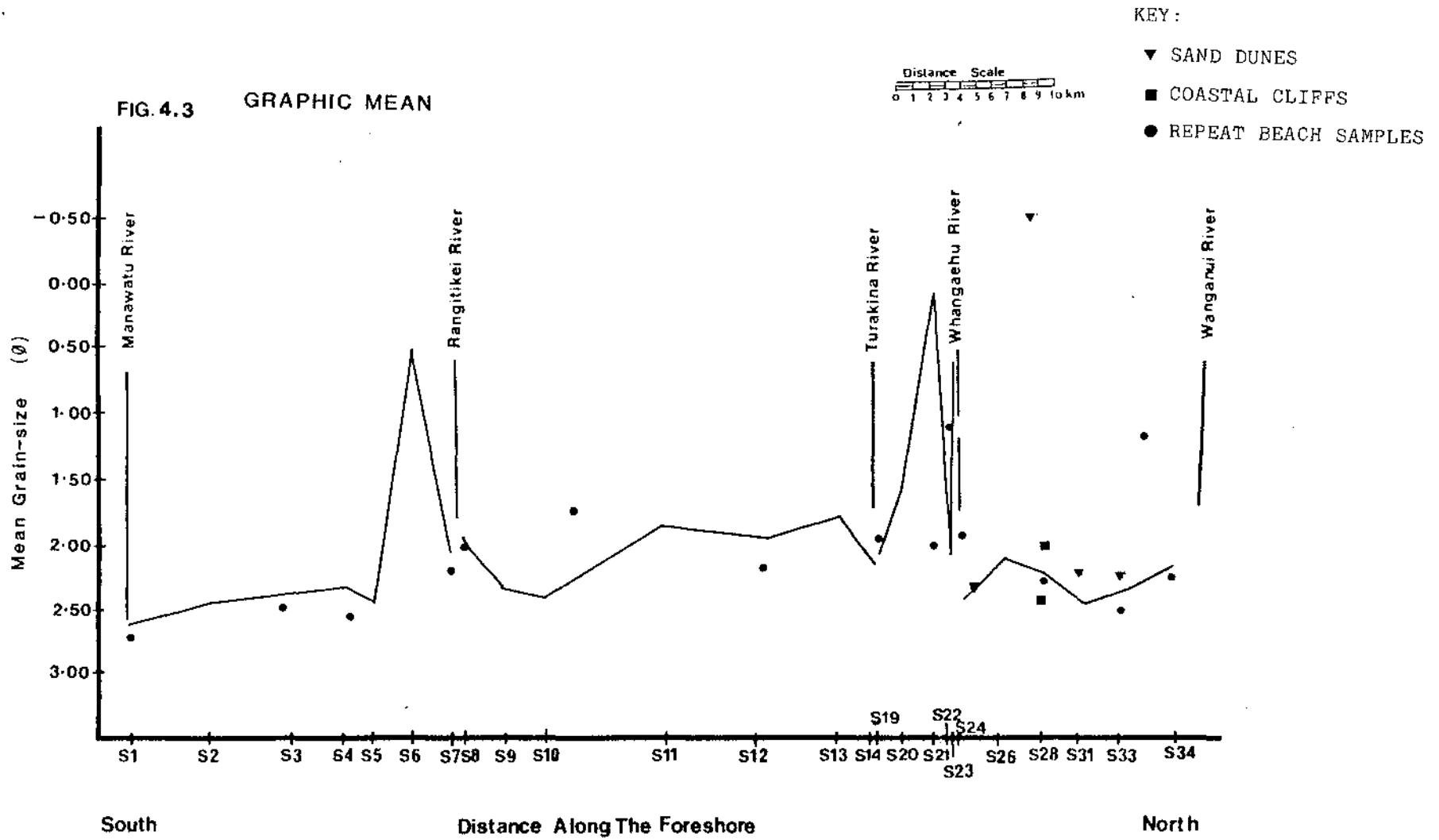
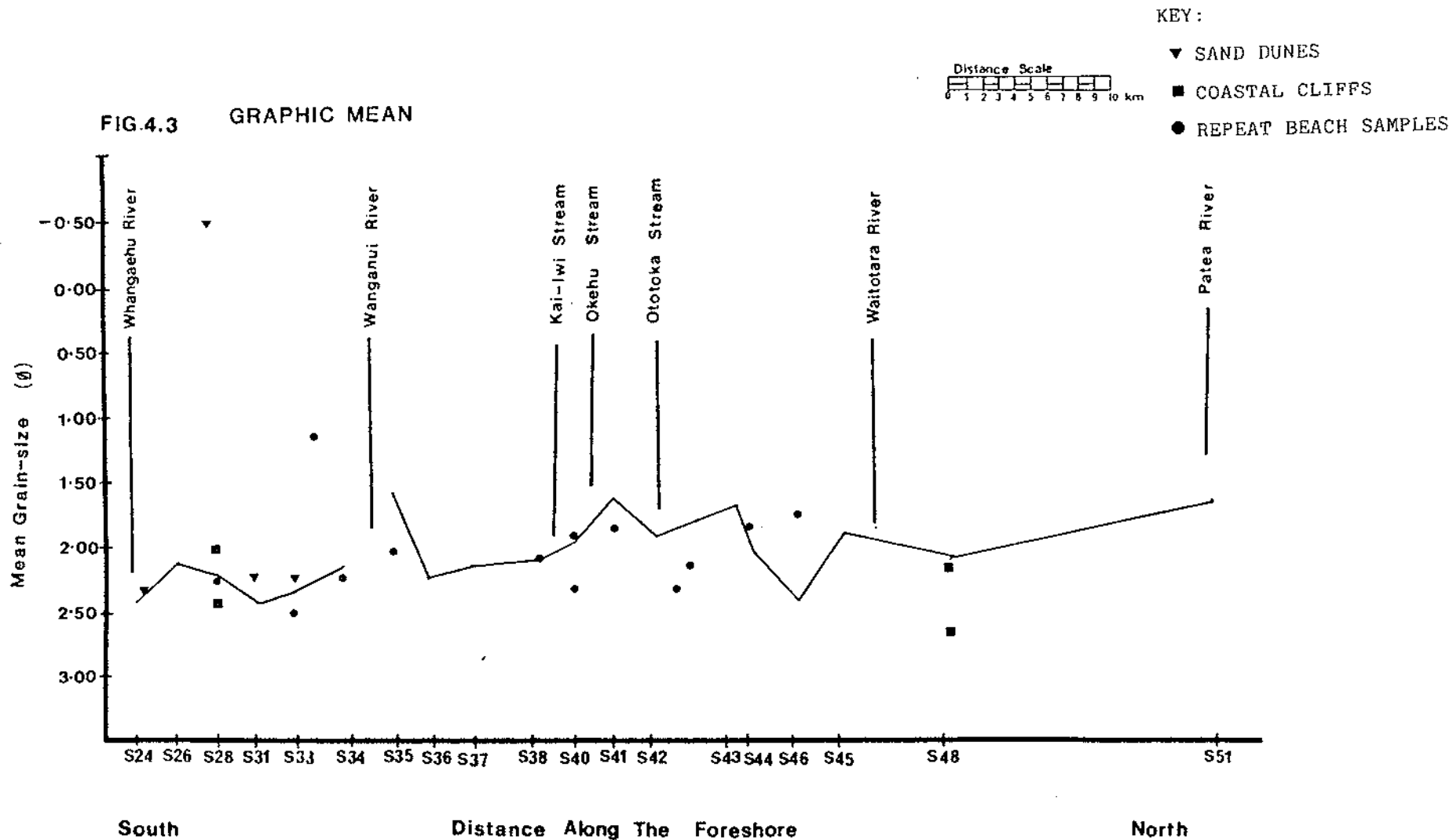


FIG.4.3 GRAPHIC MEAN



(Komar, 1976; Seymour & Aubrey, 1985). This part of the coast is typical of reflective beaches described by Short and Hesp (1982), where wave induced sand transport is at a minimum. The slight coarsening of the sand locally can be attributed to an abundance of sediment along the foreshore with a limited volume of fine sand in the surf zone supplying the foreshore.

- (4) Between Wainui Beach and Kai-Iwi Stream (S46-S40) the coastline at times has exposed local reef systems at the low tide mark that extend offshore, formed from the underlying Nukumaruan and Castlecliffian sediments. Pleistocene cliffs back the beach from sites S42 to S35 with evidence of fresh erosion particularly at Mowhanau (S38). At site S46 eroding foredunes result in an input of finer sand to the beach, thus decreasing the mean grain size of the beach sediment (Fig.4.3). Southeastwards of site S44 and S43 erosion of shell conglomerate reefs and exposed cliffs provides coarser sediment to the foreshore and to the beach sediments further southeastward. The presence of a small amount of shell conglomerate gravels is evident in the samples from site S41 and S42, resulting in a slight increase in mean grain size. Increased carbonate contents between S41 and S44 (Appendix B, Table.3) also indicates possible input from the eroding shell conglomerate reefs. However, to the south of the eroding cliffs at Mowhanau through to Castlecliff, the shoreline shows evidence that, although at times beach erosion occurs, the cliffs backing the beach have largely remained intact with little recent erosion apparent. The beach sediments are therefore reworked and show a southeastward decrease in their mean grain size (Fig.4.3). The marked increase in mean

grain size occurring at site S35 and up to 3 km north of the north mole at the Wanganui River entrance results from the longshore drift sediment being trapped by the north mole (Plate.1).

- (5) Textural variations along the coast occur due to the influence the rivers have on sediment supply. The Whangaehu River appears to be carrying considerably more coarse material than the beach sands found to the north of the river mouth, indicated by a flood deposit sampled in the Whangaehu River mouth at site S23. This deposit comprised predominantly andesitic gravel and coarse sand, deposited by the river while in flood. Gravel layers along the beach between Whangaehu River and Turakina River, comprised predominantly andesitic gravel similar to that carried by the Whangaehu River. Furthermore, the absence of abundant andesitic gravel to the north of the Whangaehu River also indicates a southeastward longshore drift. Beach deposits adjacent to the Rangitikei River mouth are coarser than those further away both to the north and south, except in the region of site S6. The presence of greywacke gravel suggests that the Rangitikei River is ejecting coarse sediment to the coast. Beaches immediately adjacent to the north and south of the Turakina River mouth, show a slight decrease in grain size which reflects the finer grained sediment being deposited at the river mouth.



Plate.1. Taken from north of Castlecliff looking south along the coast, with foredunes at the toe of the Pleistocene cliffs backing the beach north of Castlecliff (foreground). The prograded Castlecliff Beach results from longshore sediment trapping on the north mole of the Wanganui River mouth (centre). South Spit is the section of coast beyond the Wanganui River mouth, with Bluff Trig beyond in the middle distance. (Photograph supplied by Mr. R.M.S. Johnston, Rangitikei-Wanganui Catchment Board).

4.3.2 INCLUSIVE GRAPHIC STANDARD DEVIATION (σ_I) (SORTING).

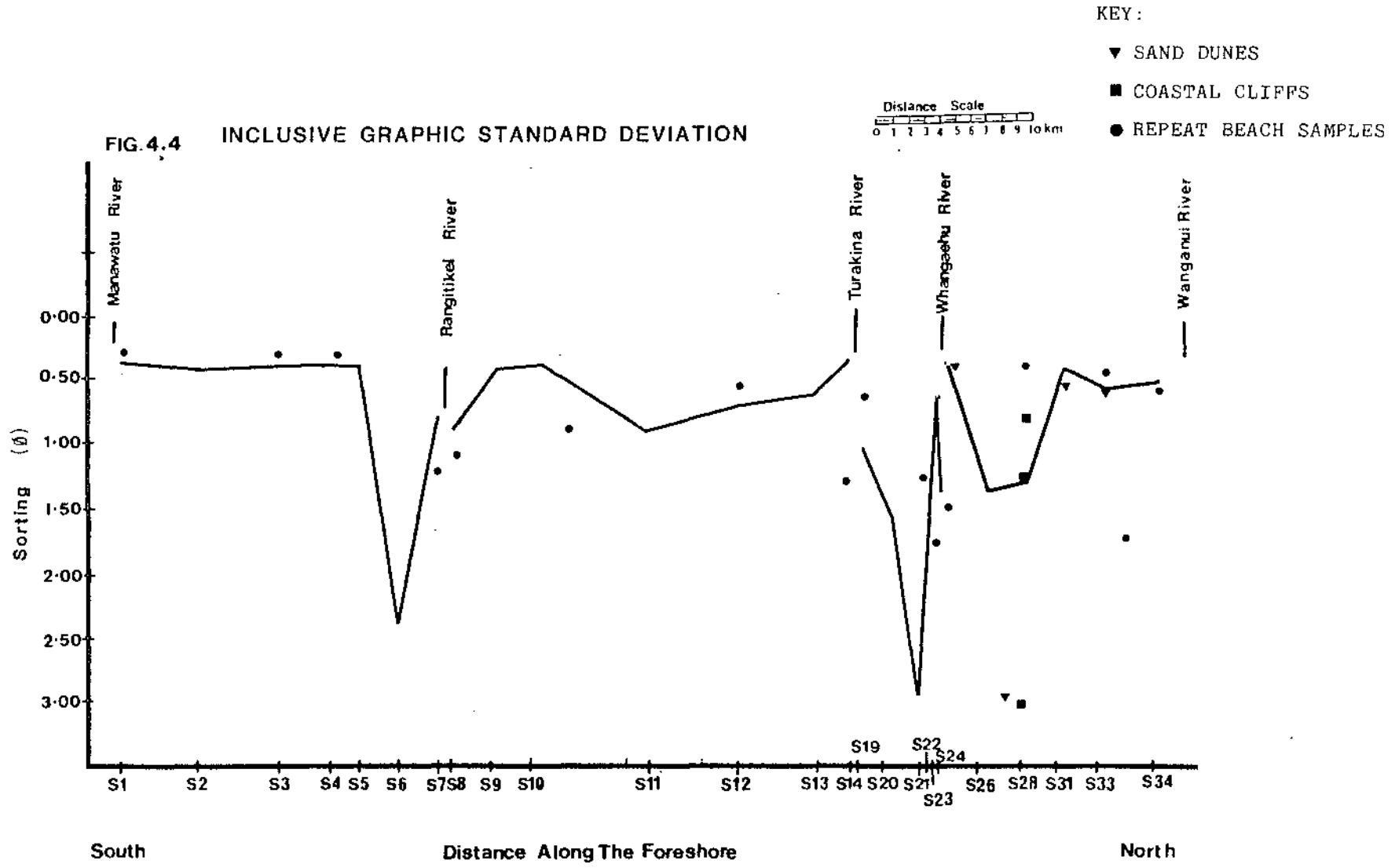
The sorting values for the sediment stations plotted in Fig.4.4 show an overall trend of increased sorting towards the southeast, supporting a net southeasterly longshore drift. In more detail the sorting values indicate local sediment sources contributing to the beach deposits.

The general trend of increase in sorting of the beach deposits in a southeastward direction along the coast appears to be distorted by the following:

- (1) The decrease in sorting immediately south of Waitotara (S45), Whangaehu (S21), and Rangitikei Rivers (S6) is consistent with changes in mean grain size and skewness that indicate that the rivers are injecting sediment into a southeastward longshore drift, with the sediment being deposited on the beach several (1-3) km south of the rivers (Fig.4.4).
- (2) The change from well sorted to poorly sorted beaches in the Kai-Iwi Beach (S37-S43) and Bluff Trig (S24-S28) areas (Fig.4.4) is attributed to the input of small quantities of gravel found in the beach sediments from the eroding coastline. The poor sorting of the beach sediments at Kai-Iwi Beach is due to the presence of shellrock fragments from the eroding shell conglomerate reefs and coarser material from the eroding cliffs. Therefore, the intermixing of sediment from longshore drift with the coarser eroded material has resulted in a decrease in sorting of the beach sands. In the Bluff Trig area it has been observed that extensive

erosion has occurred (Gibb, 1979; Johnston, 1985; Plate.2). The decrease in sorting is attributed to the eroding Pleistocene cliffs (samples SC29; SC59A and SC59B) and sand dune SD27 (sand dune with extensive gravel layers present at the base) contributing gravels to the beach foreshore. The gravels present on the beach consist of andesite, mudstone and some greywacke and are of similar composition and grain size to those from the eroding Pleistocene cliffs.

- (3) The beach sediments adjacent to Turakina River show increases in sorting, with progressive decrease further away from the river mouth. Mean grain size, sorting and skewness values taken together indicate that the Turakina River is depositing finer and better sorted material at the river mouth than is found on the surrounding beaches.



- KEY :
- ▼ SAND DUNES
 - COASTAL CLIFFS
 - REPEAT BEACH SAMPLES

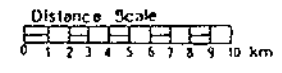


FIG.4.4 INCLUSIVE GRAPHIC STANDARD DEVIATION

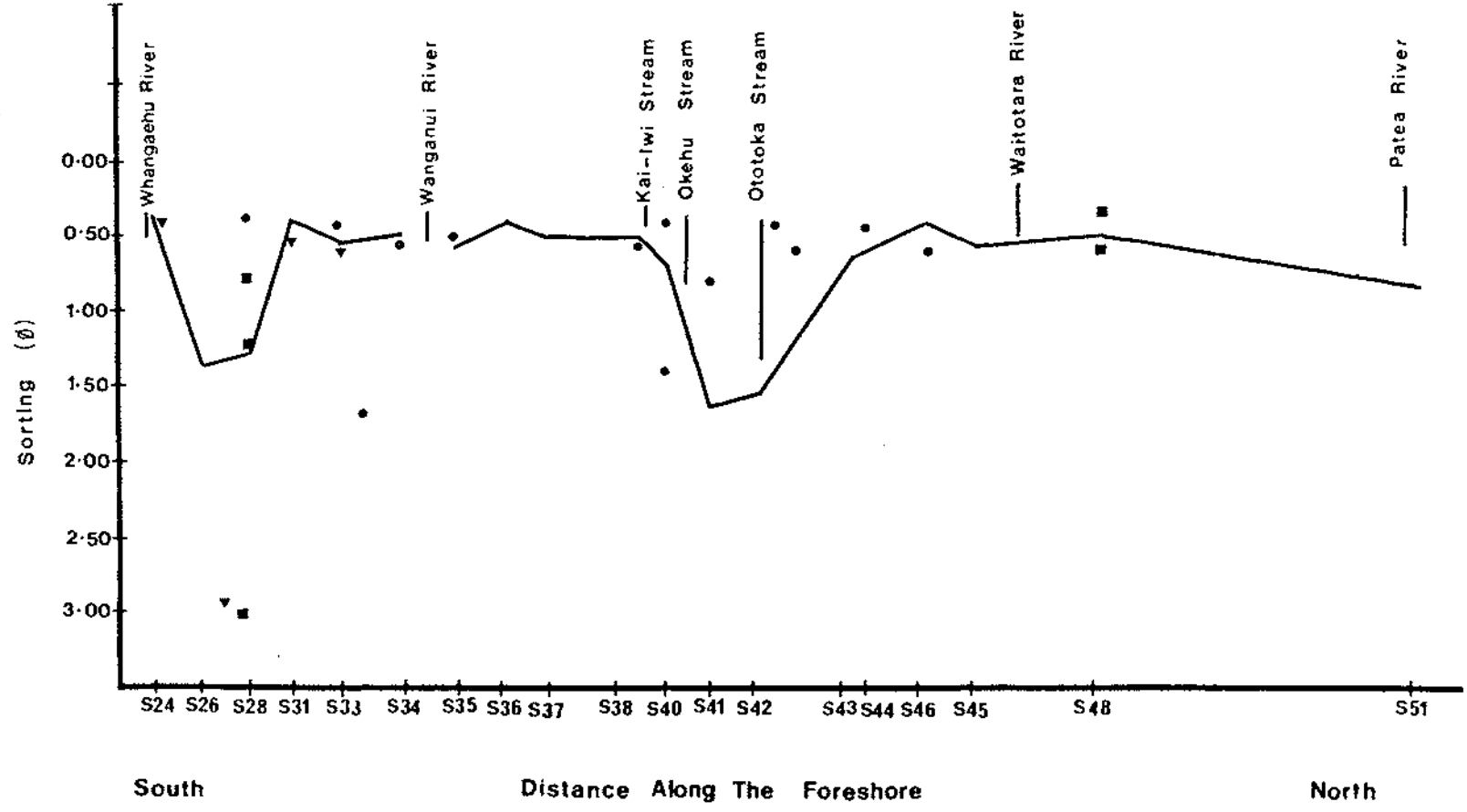




Plate.2. Looking southwards along Bluff Trig Beach. Cliffs of Pleistocene sediments back the beach with soft mudstone exposed at the mid tide mark to the right of the figure. (Photograph taken February, 1985).

4.3.3 INCLUSIVE GRAPHIC SKEWNESS (SK_I).

The skewness values are more variable along the coast and lie mainly in the range +0.10 - -0.30, with some samples being strongly coarse skewed (-0.30 - -1.00). Deviations with negative skewness indicates an overabundance of coarse sediment (compared to the normal distribution curve) and occurs in samples from Kai-Iwi Beach (S40-S42), Bluff Trig (S26, S28), and south of Whangaehu (S19-S22), Turakina (S11, S12), and Rangitikei Rivers (S6, S7) (Fig.4.5). The strongly coarse-skewed samples along Kai-Iwi Beach and Bluff Trig supports grain size and sorting evidence that small amounts of coarse sediment is supplied to the beaches from the eroding coastline. The beach sands from Kai-Iwi Beach to Wanganui River become more positively skewed indicating a southeastward direction of sediment transport.

Southeastward of Whangaehu and Rangitikei Rivers, the strongly coarse skewed beach sands (Fig.4.5) indicate that gravel is being deposited some distance (1-3 km) down the coastline. This is consistent with a southeastward longshore drift, with fining, better sorting and more positively skewed beach sands further southeastwards along the foreshore. The Whangaehu River is contributing coarse and poorly sorted andesitic gravel, while the Rangitikei River is supplying greywacke gravels with a greater proportion of sand to the southeastward longshore drift.

The coarse skewed nature of the sediments at sites S11 and S12, southeast from the Turakina River mouth, is due to a gravel component mixed with sand in the berms and cusps which have formed during a quiescent period.

FIG.4.5 INCLUSIVE GRAPHIC SKEWNESS

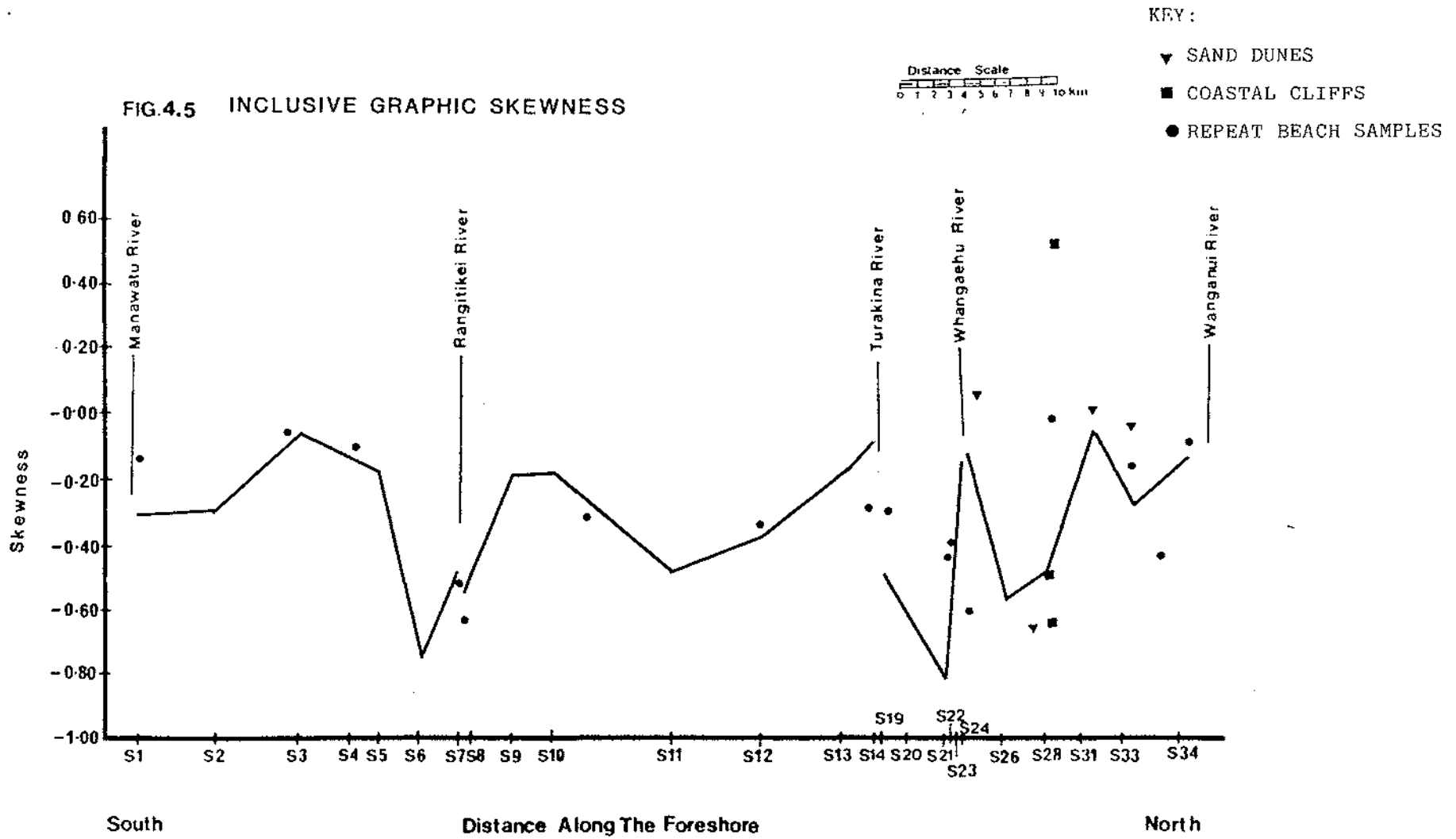
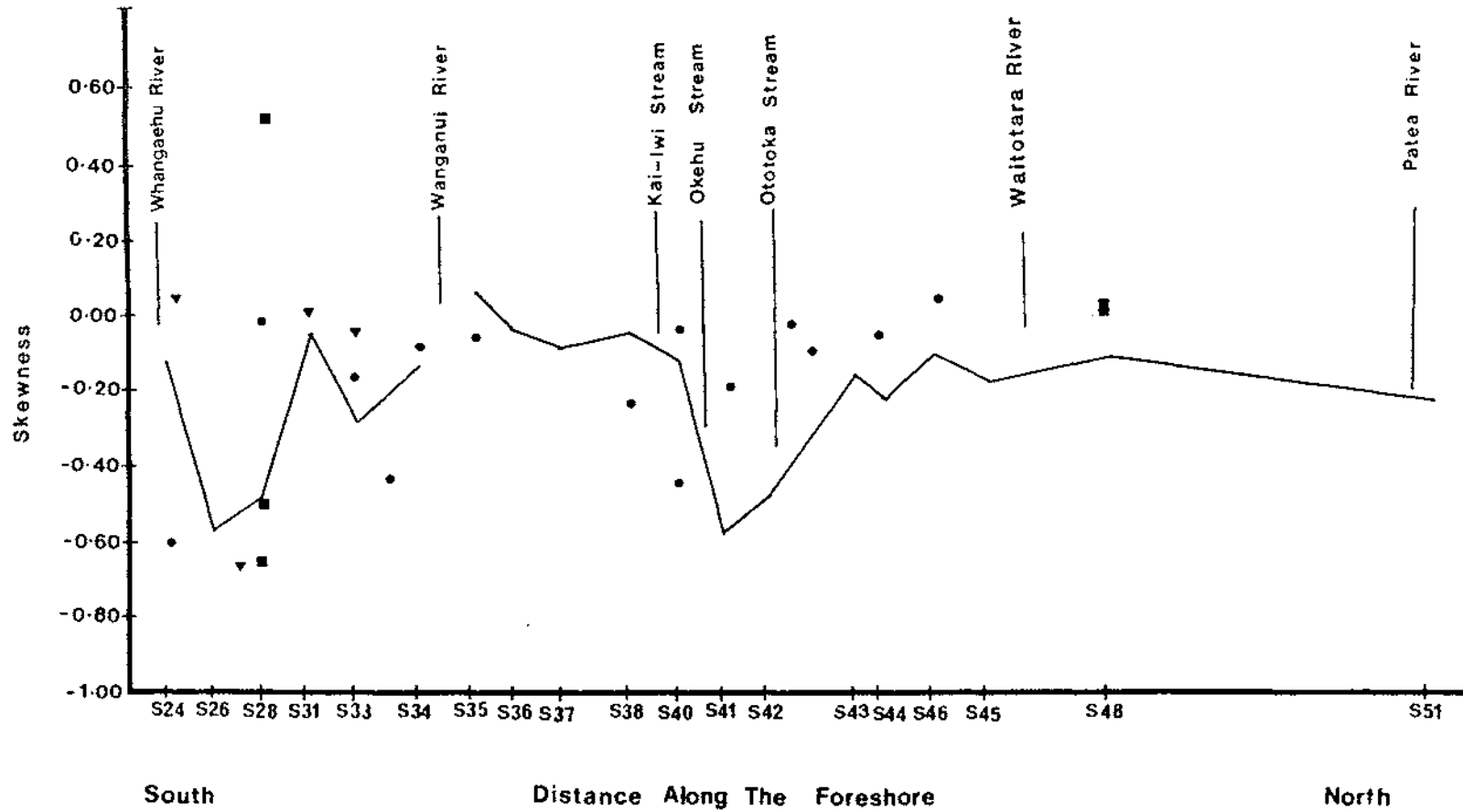
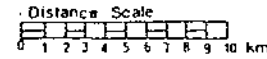


FIG.4.5 INCLUSIVE GRAPHIC SKEWNESS

- KEY:
- ▼ SAND DUNES
 - COASTAL CLIFFS
 - REPEAT BEACH SAMPLES



4.3.4 TEXTURAL PARAMETERS FROM GRAVEL FREE SEDIMENTS.

Grain size parameters were calculated, on a gravel free basis in order to remove the effect of local gravel inputs on overall changes in sediment distribution along the coast. For the samples containing gravel, the grain size statistics were recalculated to exclude sediment coarser than 1ϕ . Although this involved the recalculating of data for slightly more than one half of the original samples, the quantities of gravel in most were small and the new statistics differed very little from the original values. The gravel free grain size statistics are presented in Appendix B, Table.4, while the recalculated graphic mean, inclusive graphic standard deviation, and inclusive graphic skewness values are plotted in Figs.4.6, 4.7, and 4.8. A comparison of the recalculated grain size statistics with those of the original statistics shows that the most significant differences occur for site S6 and for the sites between Whangaehu to Turakina Rivers (S19-S23) which is indicated by the changes in the mean grain size, sorting and skewness with the removal of gravel. At sites S6 and S21 changes in grain size statistics are due to the bimodality of the sediment, with gravel and sand fractions present.

With the removal of gravel the recalculated values between Turakina and Whangaehu Rivers (S19-S23) indicate that the beach sands are better sorted and less coarsely skewed than the original sediments statistics. The Whangaehu River sediment is bimodal with gravel and sand fractions, which is being deposited onto the adjacent beaches. At site S23, the recalculated grain size parameters indicate that coarse and poorly sorted gravel occurs, with large quantities of moderate sorted coarse sand. Southeastwards the sand fraction appears to be

derived from the Whangaehu River, along with a gravel component. Around the Turakina River mouth, the recalculated values indicate a smaller contribution of finer and better sorted sediment onto the adjacent beaches derived from the Turakina River.

At Bluff Trig (S28, S26) and between Okehu and Ototoka Streams (S41, S42), the change from being poorly sorted and negative skewed to better sorted and more positive skewed sediment is the result of elimination of a small quantity of gravel from moderate to well sorted beach sands. Although absolute amounts of gravel are small, sorting and skewness values are sensitive to the influence of small contributions of gravel. The gravels are likely to be derived from the eroding cliffs or the exposed rocks at the low tide mark in the vicinity of the sample stations.

FIG. 4.6 GRAVEL FREE GRAPHIC MEAN

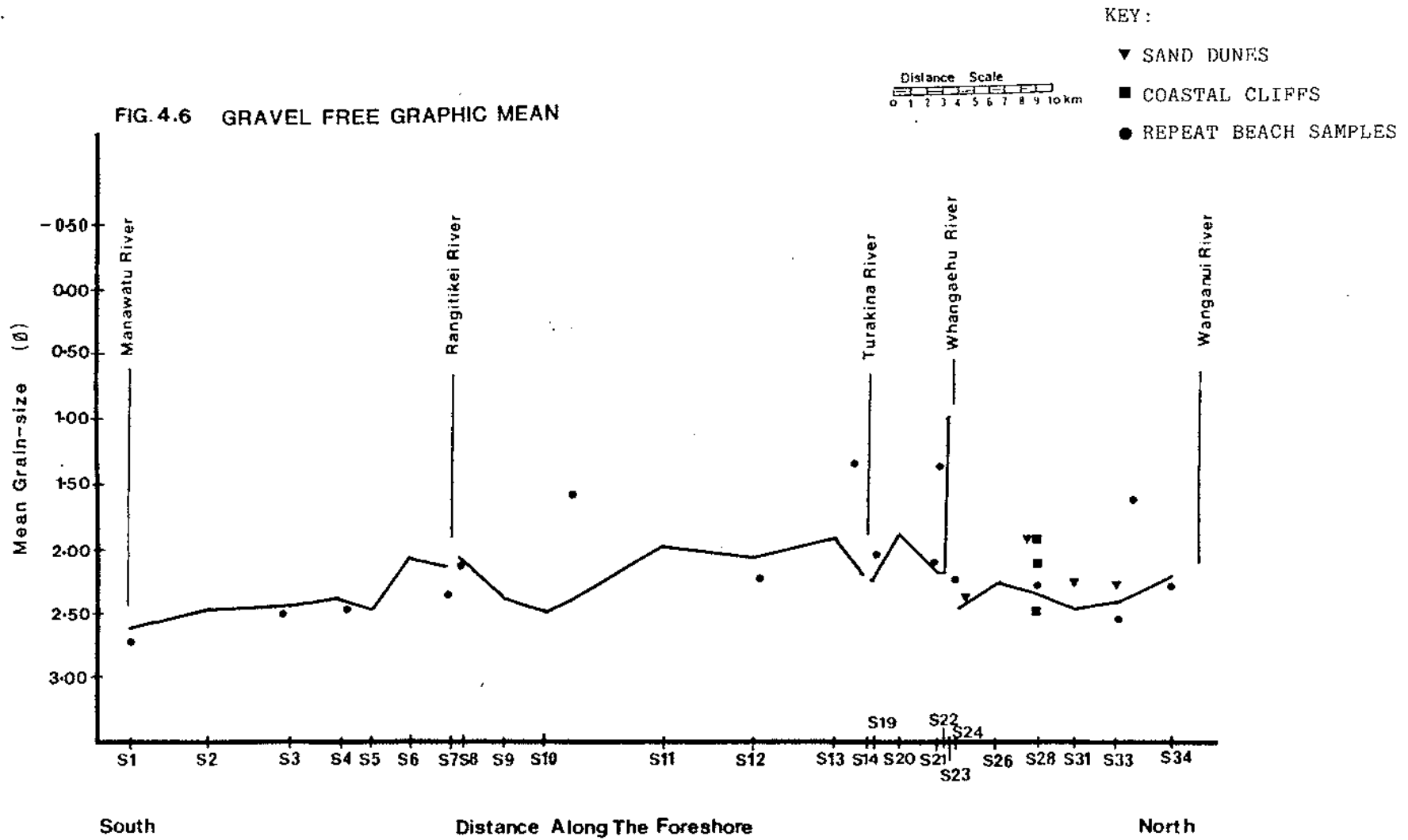
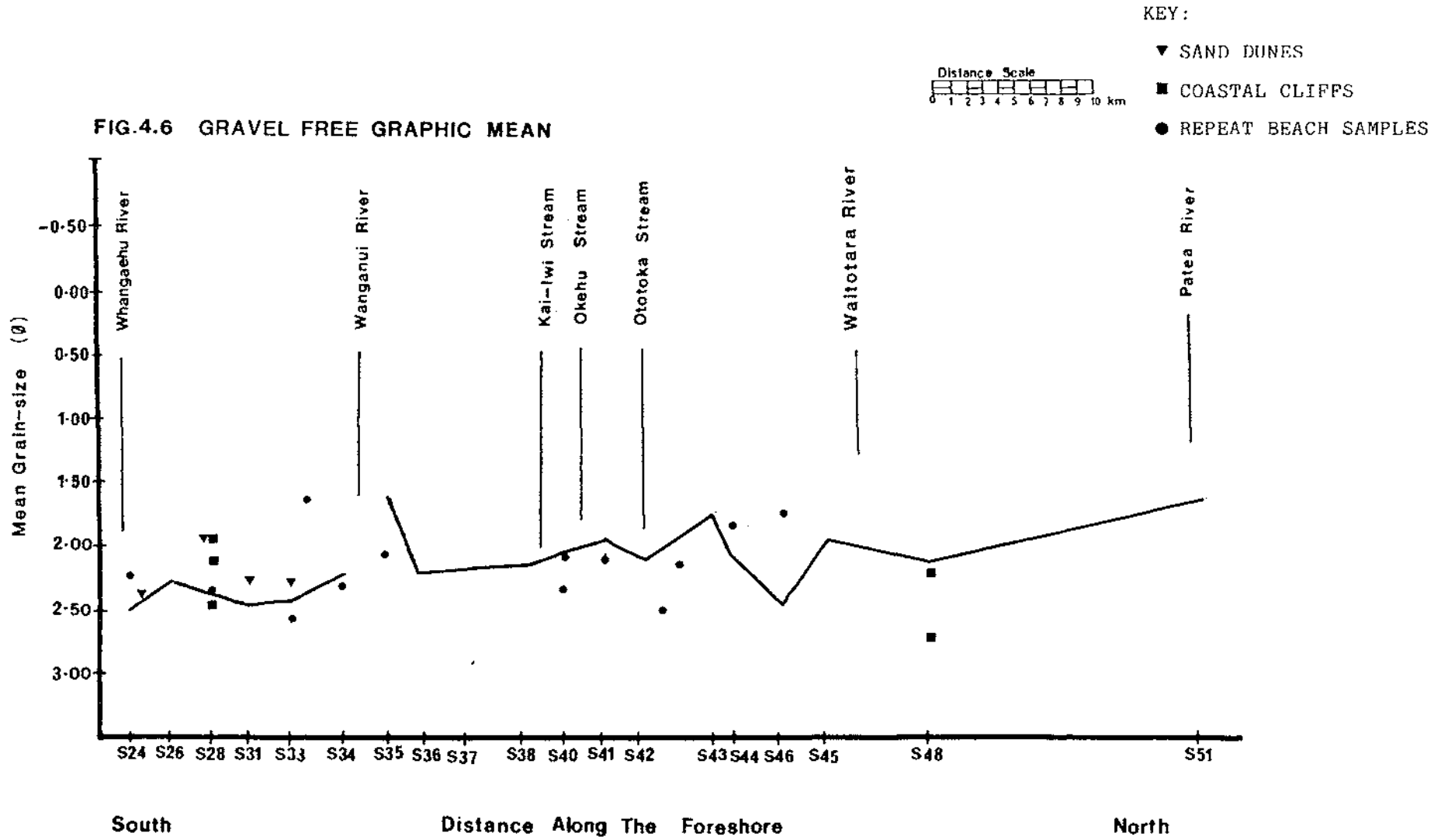


FIG.4.6 GRAVEL FREE GRAPHIC MEAN



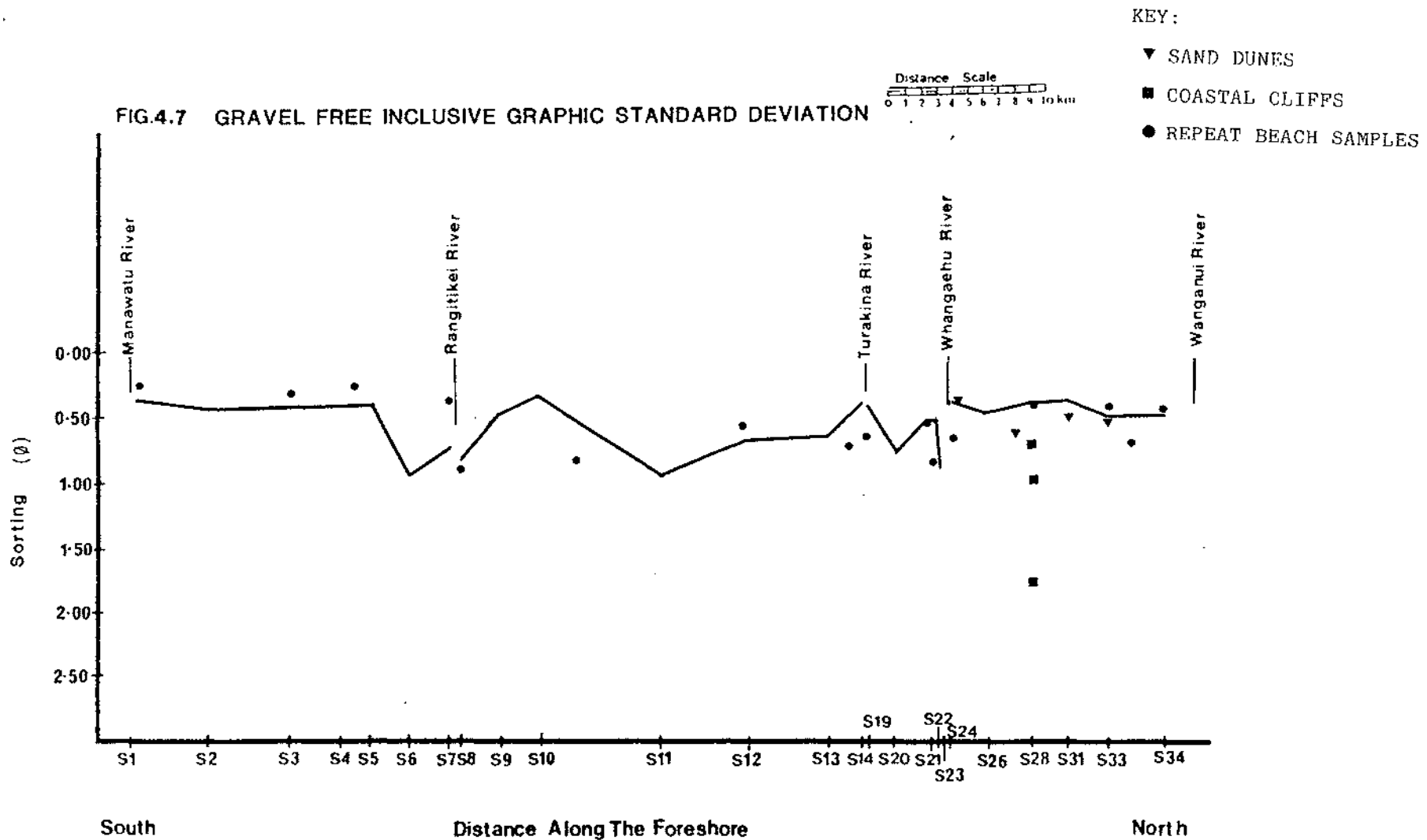


FIG.4.7 GRAVEL FREE INCLUSIVE GRAPHIC STANDARD DEVIATION

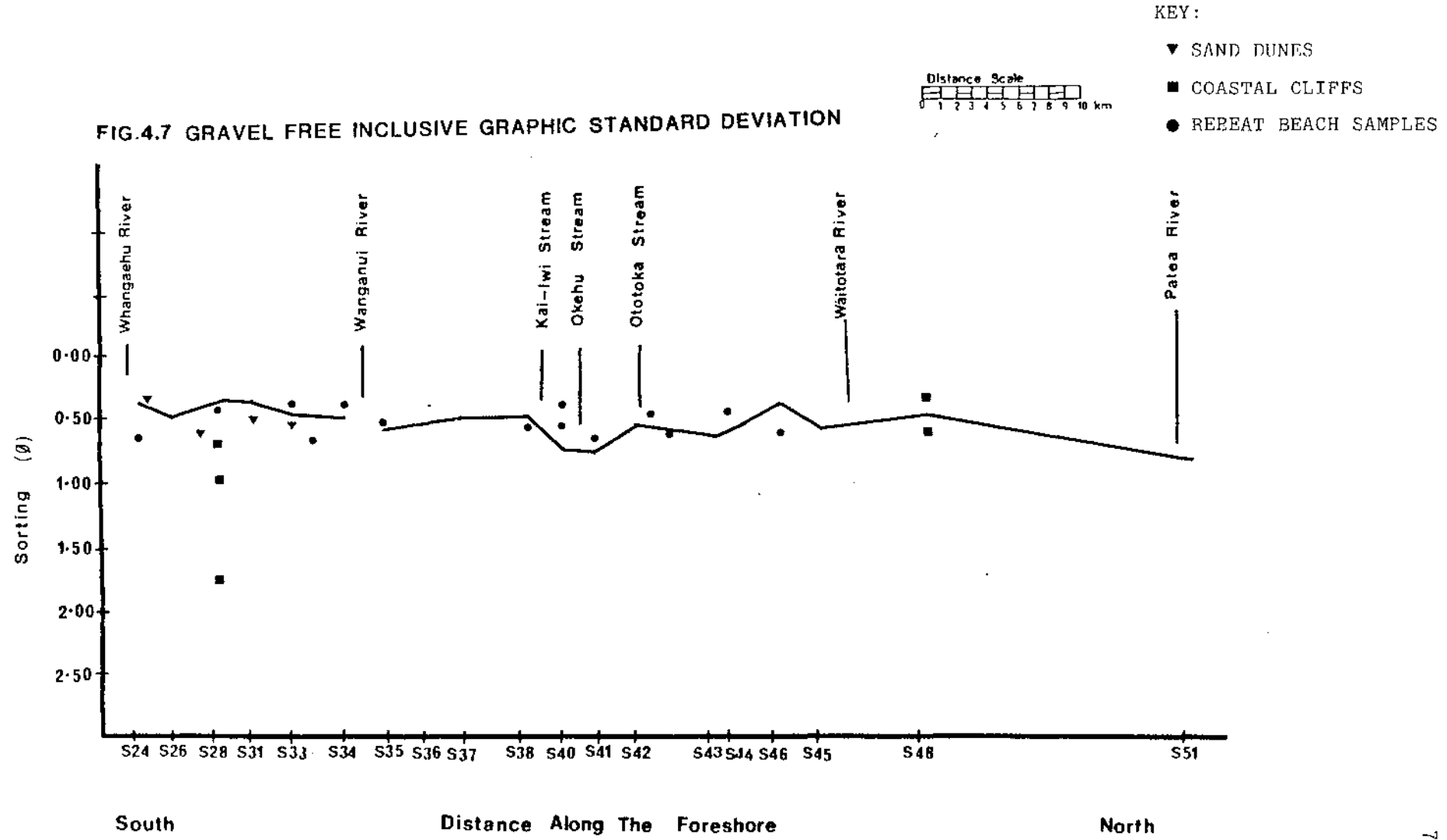


FIG 4.8 GRAVEL FREE INCLUSIVE GRAPHIC SKEWNESS

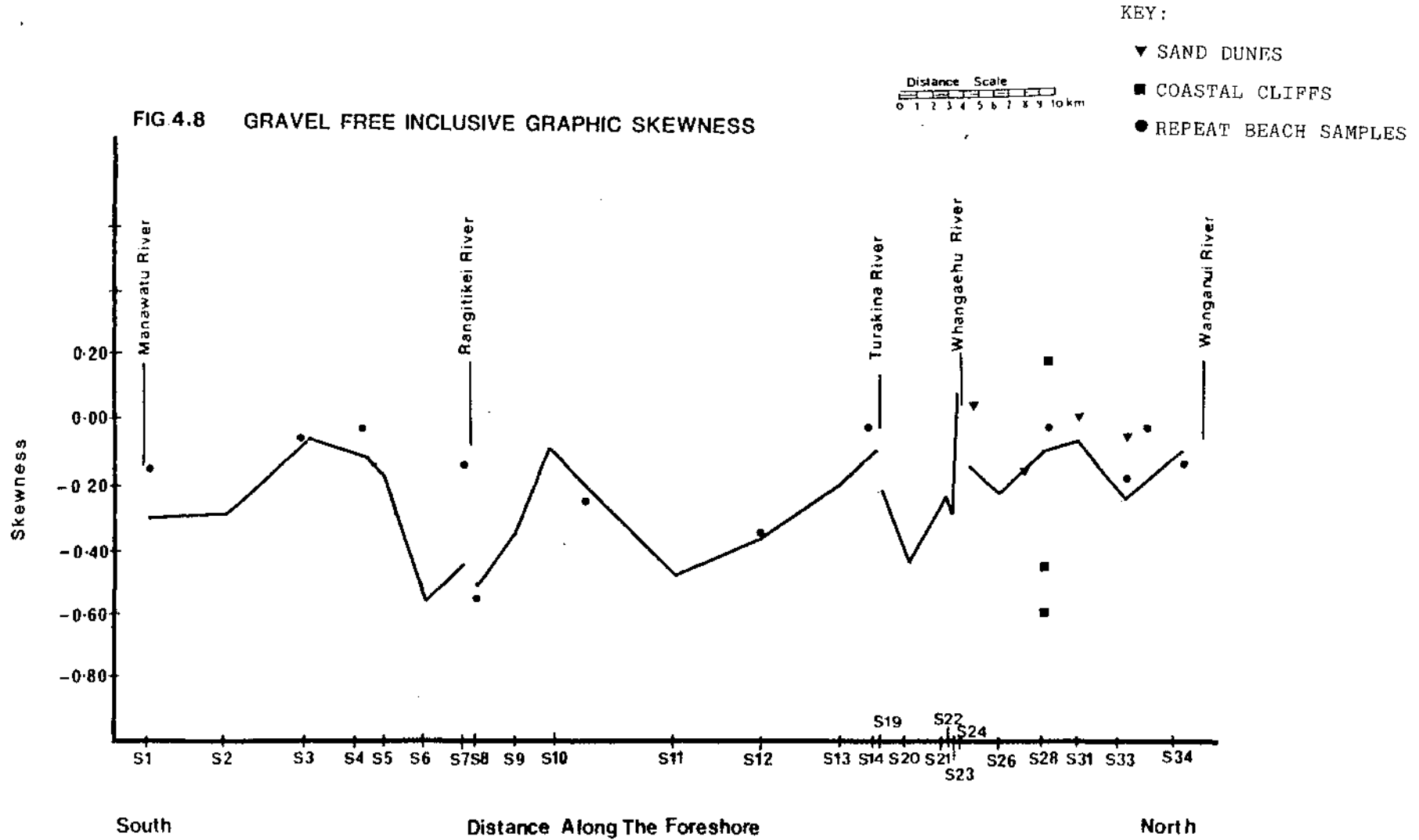
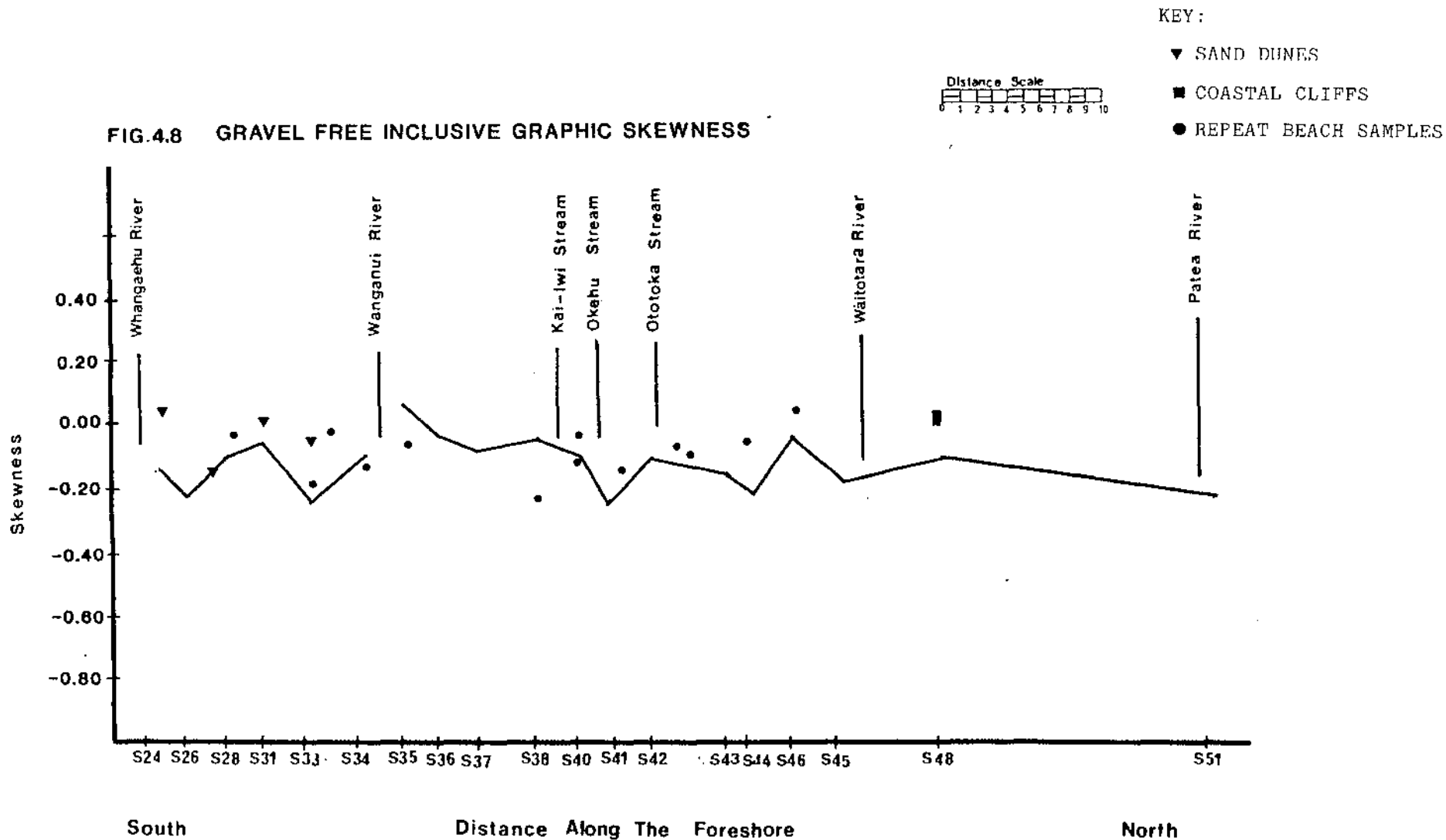


FIG.4.8 GRAVEL FREE INCLUSIVE GRAPHIC SKEWNESS



CHAPTER 5

MINERALOGICAL CHARACTERISTICS OF THE BEACH SANDS ALONG
THE SOUTHWEST COAST OF THE NORTH ISLAND.

5.1 LITERATURE REVIEW.

The heavy mineral assemblage, or a unique heavy mineral, is often indicative of provenance. It is therefore possible to characterise a particular river or source area for beach sediments from unique heavy mineral assemblages. There are numerous previous studies using mineral compositions of beach sands as aids in distinguishing the net longshore drift and source areas (Combellick & Osborne, 1977; Healy, 1978; Gibb, 1977b; 1977c; 1979; Luepke, 1980; Clark & Osborne, 1982; Hamill & Ballance, 1985).

Hydraulic behaviour of minerals is important in the determination of net longshore drift directions and the composition of source areas. In studies of hydraulic equivalence relationships of light and heavy minerals it has been recognised that heavy minerals, because of their higher specific gravity, are transported with coarser grains of other common minerals such as quartz, feldspar and rock fragments (Rubey, 1933; Rittenhouse, 1943; Swift et al, 1971; Lowright et al, 1972; Slingerland, 1977; Lewis, 1981; Steidtmann, 1982; Winkelmoen, 1982). Hydraulic behaviour also varies amongst heavy minerals, again due to specific gravity differences, so that differential transport may lead to changes in heavy mineral ratios in the direction of sediment transport. Additionally, differences in hydraulic behaviour of minerals with differing specific gravity may lead to local fractionation of light and heavy minerals across a beach profile as a result of wave action. Therefore, the effects of localised sorting have to be considered when determining longshore drift directions. Heavy minerals may also occur in a restricted size range within a source rock so that the resulting distribution is in part determined by

the source material as well as transport processes. Slingerland (1977) suggests that the deviations from ideal hydraulic behaviour are functions of grain surface roughness as well as the distance from source. Steidtmann (1982) extends this further by suggesting that the specific style of grain motion and bed configuration are important considerations in characterising hydraulic equivalence of grains for determining their deposition.

5.2 MATERIALS AND METHODS.

5.2.1 HEAVY MINERAL SEPARATION.

The samples used for mineralogical analysis were the same as those collected for textural analysis (refer to section 4.2). Samples used for mineralogical purposes are also carbonate free.

Heavy minerals are arbitrarily designated in this study as minerals with a specific gravity greater than 2.85 (specific gravity of bromoform). Where such minerals are present they can be important indicators of the geological history and sediment provenance. Many heavy minerals of interest as provenance indicators can also be separated by magnetic techniques. Unfortunately, inclusions, bubbles, polycrystallinity, grain coatings, the effects of weathering, and differences inherent between species of the same mineral commonly result in imperfect separations; i.e. no single technique will result in perfect separation of minerals (Lewis, 1981). This occurs such as in the separation of olivine in which isomorphous substitution occurs between an iron rich and magnesium rich end member.

For the present study magnetic separations as described by Gibb (1977b) was carried out, using a Frantz Isodynamic Magnetic Separator. This method was considered suitable, giving fast and efficient separations which could be standardised for heavy mineral separations with losses of less than 0.5% of sand from each sample.

In this study, heavy mineral separations were made from 10 g of sand in the 2-4 ϕ (0.063-0.250 mm) size fraction using a Frantz Isodynamic Magnetic Separator and conditions specified by Gibb (1977b).

Opaque minerals were first removed with a hand magnet, with the remaining fraction being passed twice through the Frantz Isodynamic Magnetic Separator at settings of 0.2 and 1.2 Amps. A forward slope of 25° and side slope of 15° was used for each separation with the magnetic and non-magnetic fractions being weighed to 0.01 g after separation. For this study heavy minerals are defined as those with magnetic susceptibilities less than 1.2 Amp and light minerals with magnetic susceptibilities greater than 1.2 Amp.

Heavy mineral percentages were calculated for each station and listed in Appendix B, Table.3 (Magnetic weight %).

5.2.2 GRAIN COUNTS.

For grain counts, heavy and light minerals from the 2-4 fraction were mounted in an epoxy resin (epo-tek 301), prepared as thin sections ground to 30 μm thickness, and identified using a petrological microscope. Between 400-500 grains were counted on each slide by transversing the slide using a Zeiss Mechanical Transversing Stage, and identifying all the grains on the microscope grid until the required number of grains had been counted. The relative percentages of heavy and light minerals were then calculated for each station and recorded in Appendix B, Table.5 and Table.6.

5.3 SEDIMENT SOURCE AREAS.

The source areas for the beach sediments on the southwest coast of the North Island, are;

(1) Sediments from the Taranaki Volcanics, rich in ferromagnesian minerals, are derived largely from poorly unconsolidated, andesitic lahar deposits of late Quaternary age that crop out on coastal cliffs and stream banks around the volcanic cones of Taranaki. Gow (1968) has described the mineralogy of the Mount Egmont andesites as being predominantly augite-hornblende andesites. In order of abundance the phenocryst mineralogy of the andesites is plagioclase feldspar ($An_{65}-An_{35}$), diopsidic augite, green-brown hornblende, titanomagnetite, oxyhornblende and smaller amounts of olivine and very rare hypersthene (Gow, 1968).

(2) The Taupo Volcanic Zone source comprises mostly andesitic volcanics from the Tongariro Volcanic Centre and rhyolite tephras. The Tongariro Volcanic Centre andesites have been described in detail by Clark (1960) and Cole (1978). The most voluminous andesite lava types are labradorite-pyroxene andesites, with smaller amounts of olivine andesite, pyroxene andesite and hornblende andesite. The phenocryst mineralogy is dominated by plagioclase feldspar ($An_{68}-An_{48}$), orthopyroxene, clinopyroxene (augite) and ubiquitous fine grained opaque minerals with lesser amounts of hornblende, olivine and rare apatite. In a review of the mineralogy of the acidic volcanic rocks of Taupo Volcanic Zone, Ewart (1966) described the phenocryst mineralogy as plagioclase feldspar, quartz, hypersthene, augite, magnetite, hornblende and

biotite with sanidine occurring only in ignimbrites.

(3) The marine Pliocene to Pleistocene sediments are quartz and feldspar rich, and are cut by the eroding coastal cliffs in the Wanganui Subdivision (Fleming, 1953). Further material is also contributed by rivers draining catchments formed in the Pliocene to Pleistocene sediments in the Wanganui Basin. Rivers draining catchments in the greywacke ranges also supply quartzofeldspathic rich sediment.

(4) Offshore sediments are derived ultimately from either the Taranaki Volcanics or from river sediments deposited offshore. The mineralogy for offshore sediments and their possible contribution has been discussed in Section 3.5.

A Taranaki Volcanic provenance for the beach sediments at Patea and Fitzroy was suggested from detailed study of relative mineral abundances (Hutton, 1940; 1945). A similar study of the beach sediments between Wanganui and Whangaehu River mouths showed that the concentration of heavy minerals at Wanganui was considerably less than at Fitzroy and Patea (Finch, 1947). Further, the marked drop in opaque mineral content to the south of the Wanganui River mouth is associated with an increased abundance of quartz, feldspar, hypersthene, and pumice. A decrease in opaque mineral content from Wainui Beach south to Castlecliff, near the north mole at the Wanganui River mouth was also noted by Fleming (1946; 1953). Both Finch (1947) and Fleming (1946; 1953), attribute the decrease in opaque minerals partly to the increasing distance from inferred source, indicating a dominant

southeastward longshore drift, and partly to dilution by Pliocene to Pleistocene marine sediments and Taupo Volcanic Zone volcanics derived from the Wanganui Basin.

Gow (1967), concluded that the present day beach deposits in the Hawera region are derived substantially from the erosion of the Rapanui Formation, which in turn comprises largely Taranaki Volcanics. Local concentrations of opaque minerals also occur, and results from topographic effects interacting with water and wind sorting along the coast (Ross, 1963). More recent textural and mineralogical analysis by Burgess (1969; 1971) and Gibb (1977b; 1977c; 1979) confirmed the earlier postulate (Finch, 1947) of a southeastward longshore drift.

5.4 SAND MINERALOGY IDENTIFICATION.

The mineralogy of sands examined in this study is fairly consistent with the most abundant constituents present being clinopyroxene, opaque minerals, green-brown hornblende, oxyhornblende, plagioclase feldspar, quartz and lithics. Also present in trace amounts in some samples, are garnet, epidote, muscovite, biotite, volcanic glass and microcline, with rare zircon, glauconite, olivine and orthoclase. The mineral assemblage is similar to ironsand mineralogy described at Patea and Fitzroy by Hutton (1940; 1945), for the Wanganui-Whangaehu ironsands (Finch, 1947), the beach and dune sediments around Hawera (Gow, 1967) and the general study of the heavy minerals of the southwest coast of the North Island (Gibb, 1977b; 1977c). Minerals recorded in previous studies but not noted in the present investigation were apatite, which is soluble in HCl and thus removed during carbonate diossolution, blue hornblende, monazite, sphene and tourmaline.

OPAQUE MINERALS.

Opaque minerals observed in this study comprise predominantly titanomagnetite with some ilmenite (Hutton, 1940; 1945; Fleming, 1946; Finch, 1947; Gow, 1967; 1968). High concentrations of opaque minerals are restricted to the north of Wanganui River and around the river mouths, usually being concentrated in the finer fractions. Subhedral grains are restricted to the coarser sand sizes with the well-rounded grains being more common in fine screenings. The opaque grains present are distinctly blue-black in reflected light. Opaque mineral inclusions occur frequently in augite, with less frequent occurrences in hypersthene and hornblende. Rock fragments or mineral

fragments also commonly occur around the exterior of some opaque grains.

CLINOPYROXENE.

The dominant ferromagnesian mineral present in beach and dunes sands is diopsidic augite. The remainder of the clinopyroxene present is a Ca-poor augite from Taupo Volcanic Zone volcanics. All grains are well to sub-rounded and subhedral to euhedral, with most having abundant opaque mineral inclusions, and less frequently euhedral prismatic inclusions of plagioclase and apatite. Diopsidic augite is readily identified by its pale-green colour and, in some grains, the occasional occurrence of faint yellowish brown-green pleochroism. Twinning on (100) occurs in a few grains.

HYPERSTHENE.

Hypersthene is consistently present, although only in minor amounts to the north of Wanganui, and becomes abundant in the dune and beach sands south of Wanganui River. Most hypersthene grains are prismatic euhedral and show less rounding than that of augite. Hypersthene is typically pleochroic, from pale-green to pale honey-brown. Inclusions are common, particularly of opaque minerals, and colourless euhedral inclusions.

GREEN-BROWN HORNBLLENDE.

Green-brown hornblende is the dominant amphibole present, occurring predominantly in the coarser fractions. This variety occurs commonly as elongated grains with rounded ends or as sub-rounded grains. Well developed cleavage is evident. Inclusions are less

common than in augite with opaque mineral inclusions being the most common present. It is also characterised by intense pleochroism.

OXYHORNBLLENDE.

Oxyhornblende is much rarer than the green-brown variety, and is common to both the coarse and fine fractions. Oxyhornblende is distinctive due to its brown to red-brown colour and strong pleochroism. Most oxyhornblende grains observed are prismatic, and are only slightly rounded. Some grains have a elongate prismatic shape. Inclusions occur only rarely.

EPIDOTE.

Epidote is a rare constituent, occurring as subangular to sub-rounded grains. Epidote is distinguished as colourless to faintly coloured yellow-green pleochroic grains.

GARNET.

The garnet present occurred in a wide range of grain sizes, and was fairly common at a number of sites in the study area, being more frequent north of Wanganui. Garnet occurs mostly as sub-rounded to well-rounded grains, with a few occurring as fragments. The garnet observed was mostly as colourless to faintly pink isotropic grains with high relief.

OLIVINE.

Olivine is very rare, but when present occurs as well-rounded grains in the coarser grain sizes, typically as colourless fractured grains. Inclusions are rare, but when present are small, being either

opaque or clear euhedral inclusions.

PLAGIOCLASE FELDSPAR.

The plagioclase feldspar present in beach and dune sands exhibits a wide range of composition. Both normal and oscillatory zoning were observed. Extinction angles indicate a predominant andesine to labradorite composition. In some grains colourless prismatic and rod shaped inclusions were observed, while others had opaque mineral inclusions. Rare pyroxene inclusions were observed. Grains are usually not well-rounded, but show a range from angular to rounded grains. Plagioclase grains were often observed to have a partially altered surface coating of weathering products.

ALKALI FELDSPAR.

Microcline was rare but occurs in the coarse sand in many samples. Distinctive cross hatch twinning was observed. Surface alteration is evident. In a few samples, very rare grains of orthoclase were observed in the coarser fractions. Surface alteration was evident.

QUARTZ.

Quartz occurs in all grain sizes, being rare only in size fractions high in opaque minerals. Most grains are angular to sub-rounded. In some samples polycrystalline quartz grains were observed. Quartz occurs as colourless grains, distinguished by low relief, a uniaxial +ve character, a lack of colour, cleavage and visible twinning. In some grains surface staining was observed.

MICAS.

Muscovite and biotite are rare in all samples with biotite being the least abundant. Muscovite occurs as low relief platy grains, while biotite is observed as a greenish-brown platy mineral.

ZIRCON.

Zircon occurs as a minor constituent in some dune and beach sands. Most zircons have pyramidal terminations with the grain shape varying from prismatic euhedral to rounded. Observed zircons are typically colourless with a few being pink or yellow in colour. Inclusions are rare, but some colourless prismatic inclusions were noted with opaque mineral inclusions being more predominant.

GLAUCONITE.

The occurrence of glauconite grains was very rare with only a few rounded grains being observed, as green fine-grained aggregates, probably derived from the Pliocene and Pliestocene sediments.

GLASS.

Glass was observed as irregular brown grains, with a few grains being colourless.

COMPOSITES.

Composite grains are composed of either different fragments of various minerals present or of many grains of the same mineral. The occurrence of composite grains were more frequent in the coarser grades. Two different types of lithics could be identified; volcanic lithics, which are composite grains of phenocrysts in a feldspar

microlite and glass matrix and a fine grained aggregate lithic of sedimentary origin. These are best observed under reflected light.

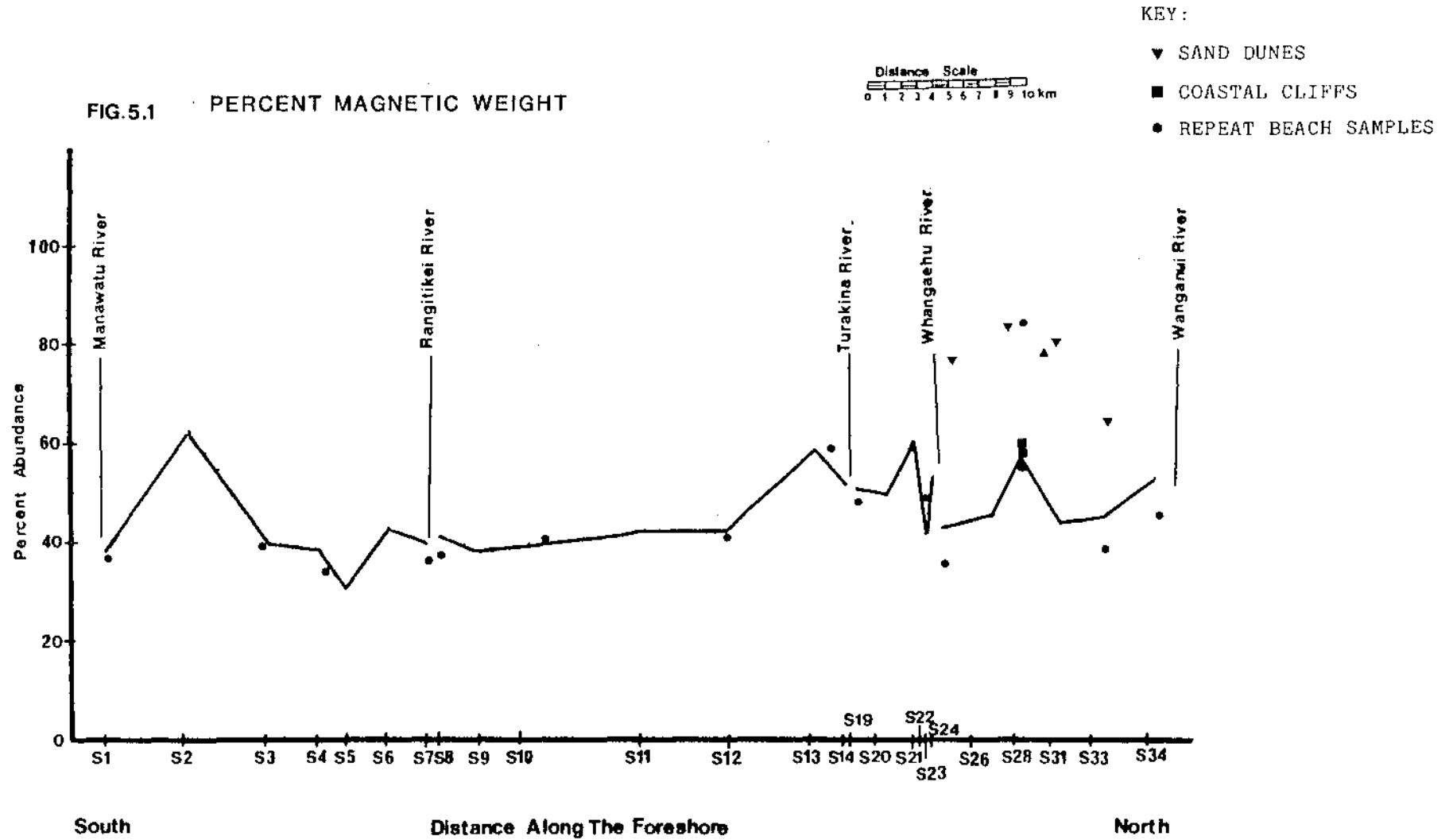
5.5 MINERALOGICAL TRENDS.

5.5.1 TOTAL HEAVY MINERAL CONTENT.

The total heavy mineral content present at each sample station is shown in Appendix B, Table. 3. It is evident from the data and Fig.5.1 that the heavy mineral abundance decreases southeastward along the coast from about 95% at Patea to about 35% at the Manawatu River. This is consistent with dilution and transport as distance increases away from the presumed source of much of the heavy mineral assemblage, the Taranaki Volcanics (Fig.5.1).

Considerable local variations in heavy mineral content is evident, for example at Kai-Iwi and Wainui Beach, with a notable decrease in the total heavy mineral content to the south of the Wanganui River (Fig.5.1). These variations are discussed in detail in the following sections.

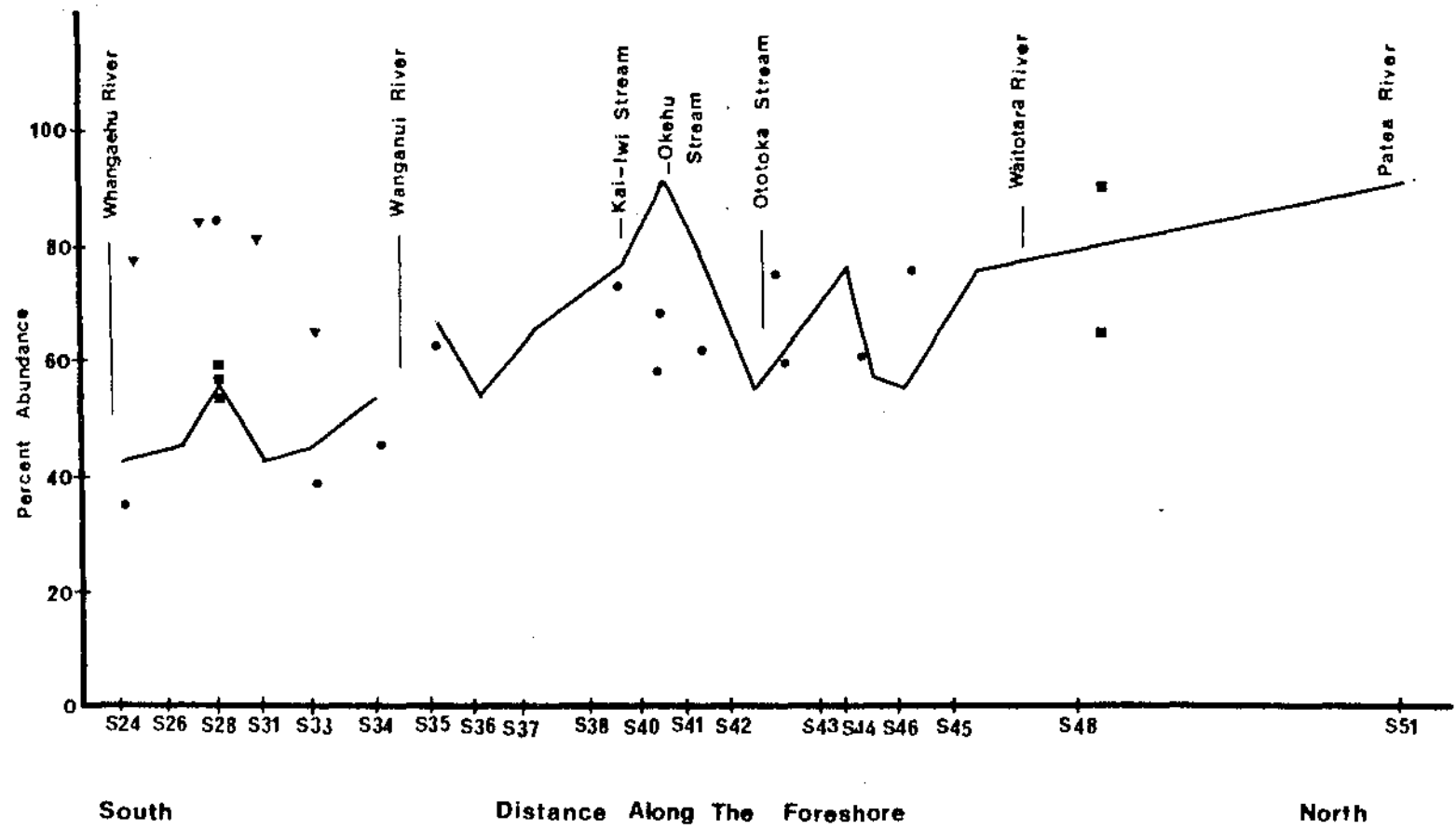
FIG. 5.1 PERCENT MAGNETIC WEIGHT



- KEY:
- ▼ SAND DUNES
 - COASTAL CLIFFS
 - REPEAT BEACH SAMPLES



FIG. 5.1 PERCENT MAGNETIC WEIGHT

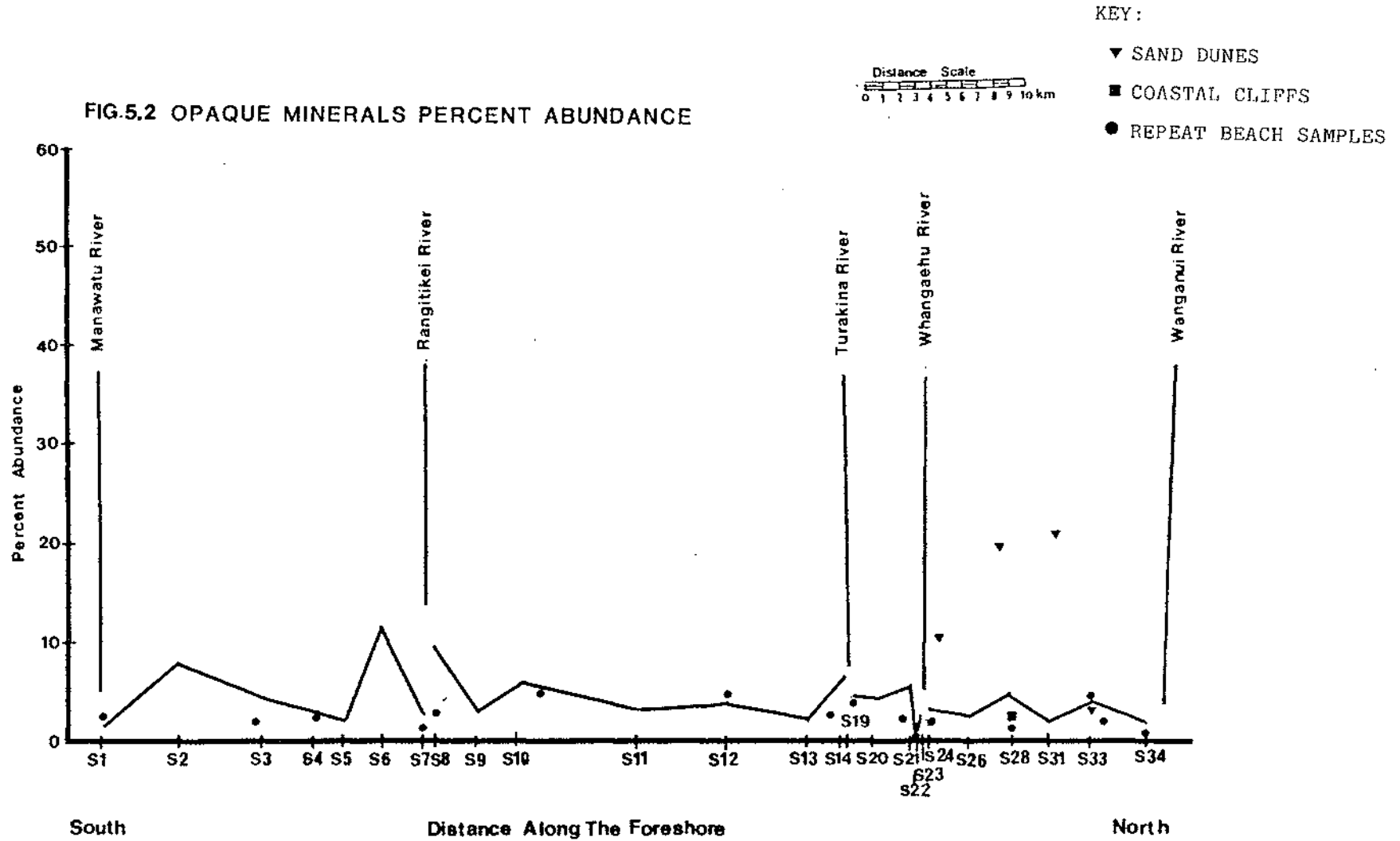


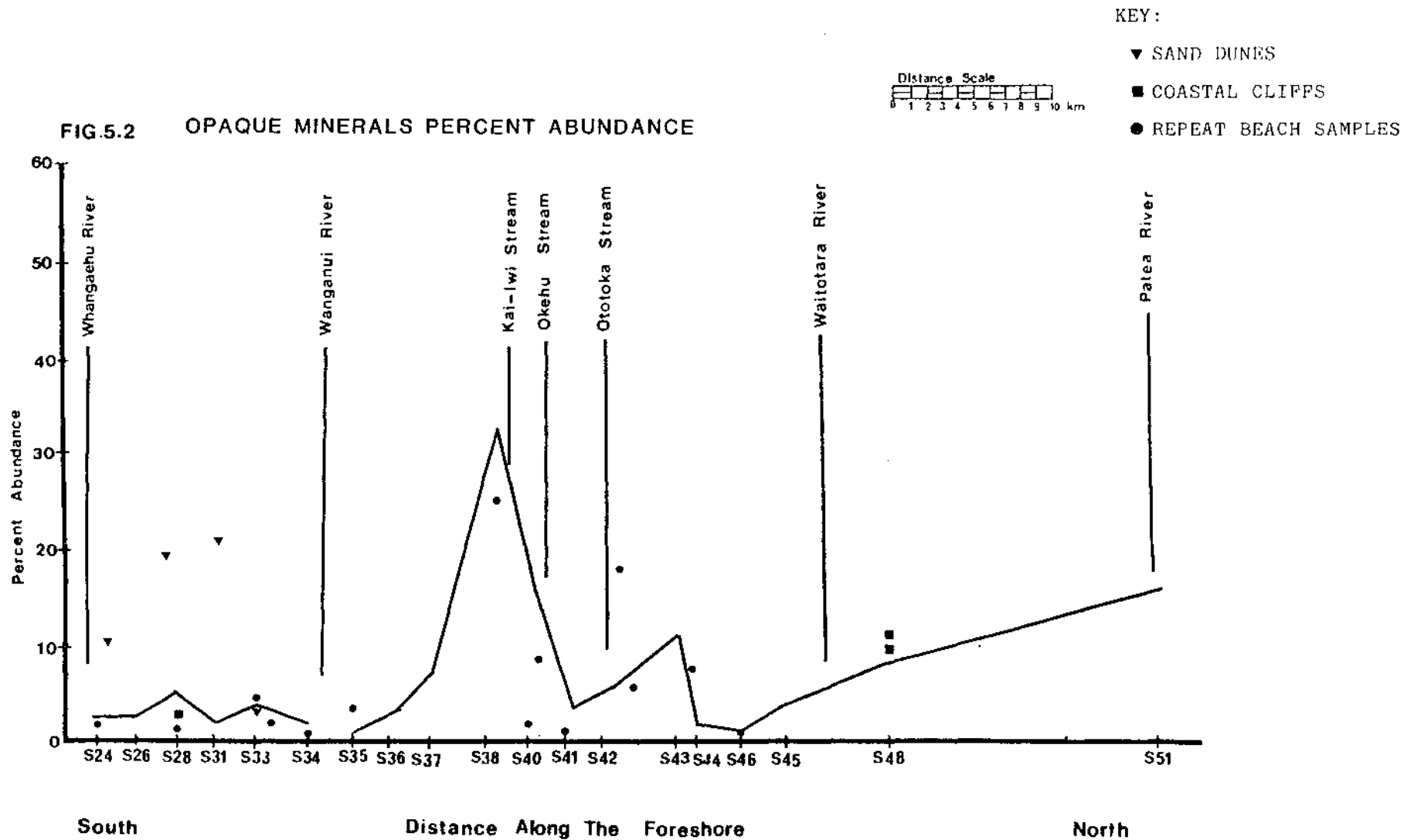
5.5.2 OPAQUE MINERALS.

The opaque mineral content of the beach sediments show considerable variation, but there is a general trend of decreasing concentration southeastward along the foreshore (Fig.5.2). High concentrations (>10%) occur predominantly north of Wanganui River (Fig.5.2), with a local concentration around the Rangitikei River (S6, S8) and small increases around the Turakina and Whangaehu River mouths. It appears evident that the main source of opaque minerals in the beach sediments is from the Taranaki andesites with minor amounts being contributed from the Taupo Volcanic Zone volcanics and greywacke catchments respectively (Hutton, 1945; Kear, 1965; Gibb, 1977c).

The land contours, such as cliff backed beaches and river mouths influence opaque mineral variations due to selective sorting along the coastline (Ross, 1963). The anomalous high abundance in opaque mineral concentration that occurs at Wainui Beach can best be explained by the eroding reef system offshore which interrupts the longshore flow of sand (Lewis, 1979). At Kai-Iwi Beach the beach is backed by coastal cliffs and to the south the beach is directly backed by eroding cliffs. The high abundance peak at Mowhanau (S38) results from a combination of factors (Fig.5.2). The abutting headland and cliffs southwards are being actively eroded by waves lapping at the base of the cliffs at high tide (Plate.3). Opaque minerals tend to become concentrated as a result of the winnowing action of waves which remove the lighter minerals from the beach faces during erosional events. This very high concentration of opaque minerals around S38, indicates that this sector of the coast was in an eroding state at the time of sampling.

FIG.5.2 OPAQUE MINERALS PERCENT ABUNDANCE







(Plate.3). Looking south along Kai-Iwi Beach with Mowhanau in the centre, showing Kai-Iwi (nearer) and Mowhanau Streams with eroding Castlecliffian cliffs south of Mowhanau. The cliffs of Nukumaruan age immediately to the north of Kai-Iwi Stream are partly protected by a small foredune built up at the toe of the cliff. The photograph was taken at low tide.

The increase in opaque minerals at site S2 is possibly due to input from the Manawatu River. To the north of Rangitikei River mouth at sites S9 and S10 a small erosional embayment which was observed at the time of sampling, appears to have produced a slight increase in opaque mineral content at S10 (Fig.5.2). The grain size parameters of the beach sediments at this site are consistent with the observed beach erosion.

5.5.3 HYPERSTHENE.

Hypersthene is present in small amounts in beach sediments to the north of Wanganui River but is abundant south of the Wanganui River. The main source area for hypersthene is likely to be from the Taupo Volcanic Zone, particularly the hypersthene andesites from the Tongariro Volcanic Centre (Clark, 1960; Cole, 1978) and voluminous Taupo Volcanic Zone rhyolites (Ewart, 1966). In contrast, the Taranaki Volcanics are known to be hypersthene poor (Gow, 1968).

The highest concentration of hypersthene occurs about and south of Whangaehu River. This river has its headwaters on the slopes of Mount Ruapehu, a hypersthene-bearing andesite stratovolcano in the Tongariro Volcanic Centre (Clark, 1960). Similarly, contributions of hypersthene-bearing sediment are shown from the Turakina and Rangitikei Rivers (Fig.5.3). Hypersthene is abundant about and south of these river mouths, rather than distributed northwards (Fig.5.3). To the south of Whangaehu River, hypersthene andesite gravels are abundant and are presumably supplied to the coast by Whangaehu River, draining from the Tongariro Volcanic Centre. Gibb (1979), traced hypersthene andesite gravels south from Whangaehu River for a distance of 100 km to

FIG.5.3 HYPERSTHENE PERCENT ABUNDANCE

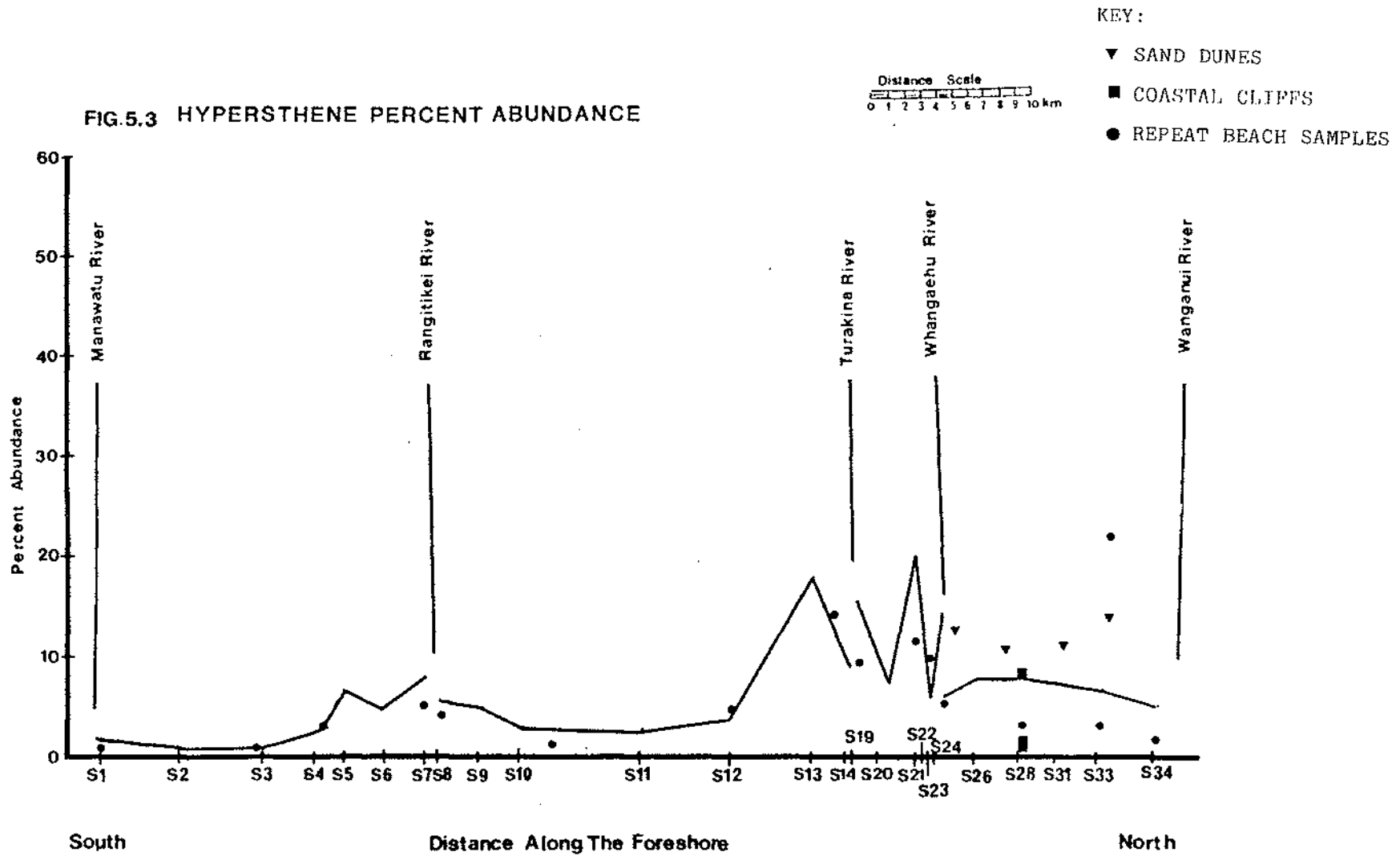
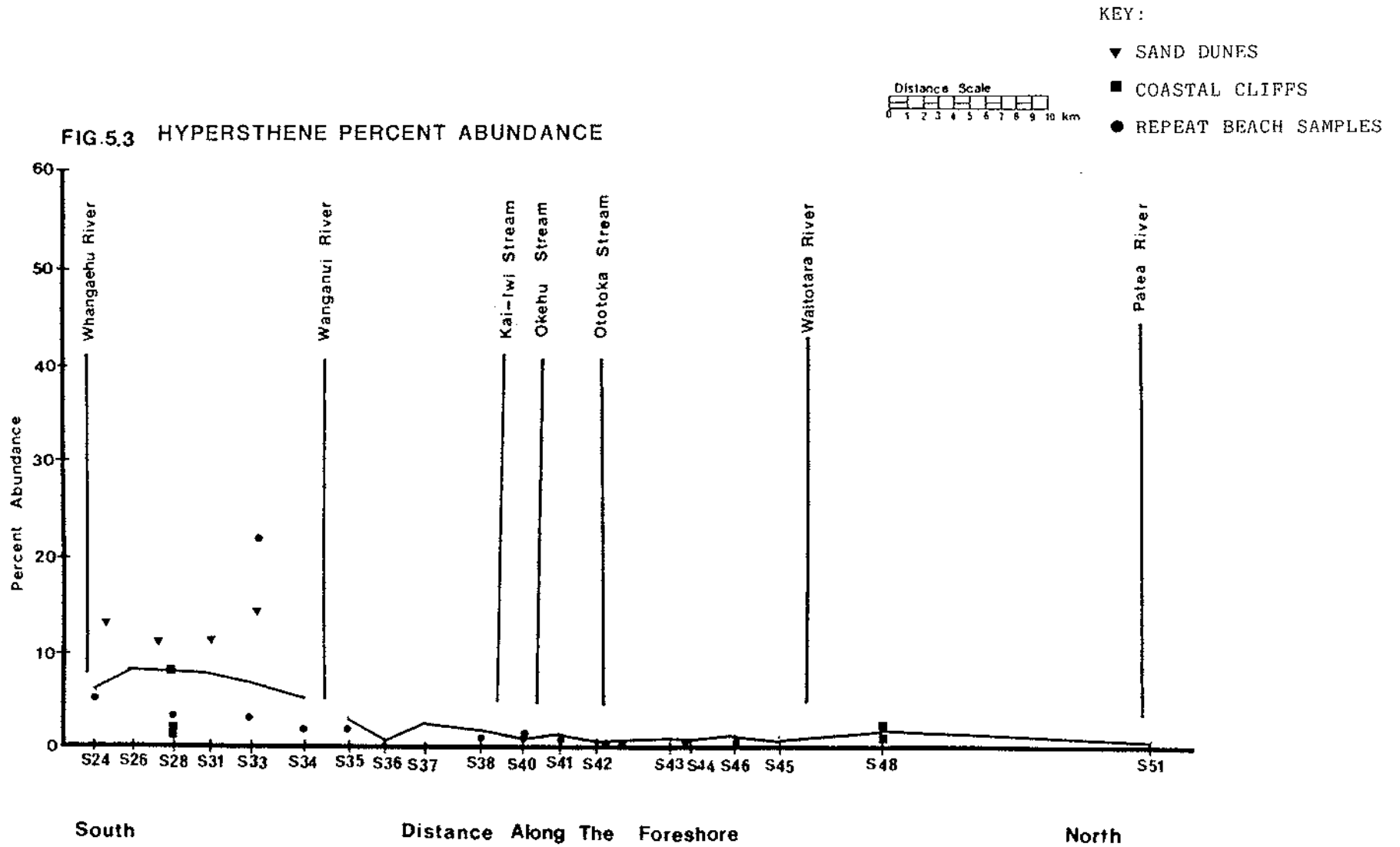


FIG. 5.3 HYPERSTHENE PERCENT ABUNDANCE



Raumati Beach. This is consistent with a southeastward longshore drift, resulting in the gradual decrease in hypersthene concentration along the shoreline.

In the Bluff Trig area southeast of Wanganui the beach showed visible evidence of erosion. Comparison of the beach sands with the dune sands (Fig.5.3) suggest that the high contents of rounded hypersthene grains in the beach sands are derived from the eroding foredunes. The comparison in roundness of other heavy minerals in beach and dune sands also suggests that part of the beach sediment is derived from the eroding foredunes at Bluff Trig. Thus, hypersthene in the beach sands is derived from longshore drift of sediment from Wanganui River intermixed with sediment derived from the eroding foredunes.

5.5.4 CLINOPYROXENE.

The dominant clinopyroxene present is diopsidic augite derived from Taranaki Volcanics and Volcaniclastics (Hutton, 1940; 1945; Gow, 1967; 1968; Gibb, 1977c) and the abundance of clinopyroxene to the north of Wanganui River indicates a Taranaki Volcanic source for at least part of the beach sediments. A Ca-poor augite is also a component of the beach sands and is derived from the Taupo Volcanic Zone andesites (Clark, 1960) and rhyolites (Ewart, 1966). Local increases in clinopyroxene abundances are similar to hypersthene variations about and south of the Wanganui, Turakina, Whangaehu and Rangitikei Rivers (Fig.5.4) and is therefore probably of Taupo Volcanic Zone origin. Marked changes in clinopyroxene concentrations are similar to the changes in opaque mineral contents at Wainui and Kai-Iwi

FIG.5.4 CLINOPYROXENE PERCENT ABUNDANCE

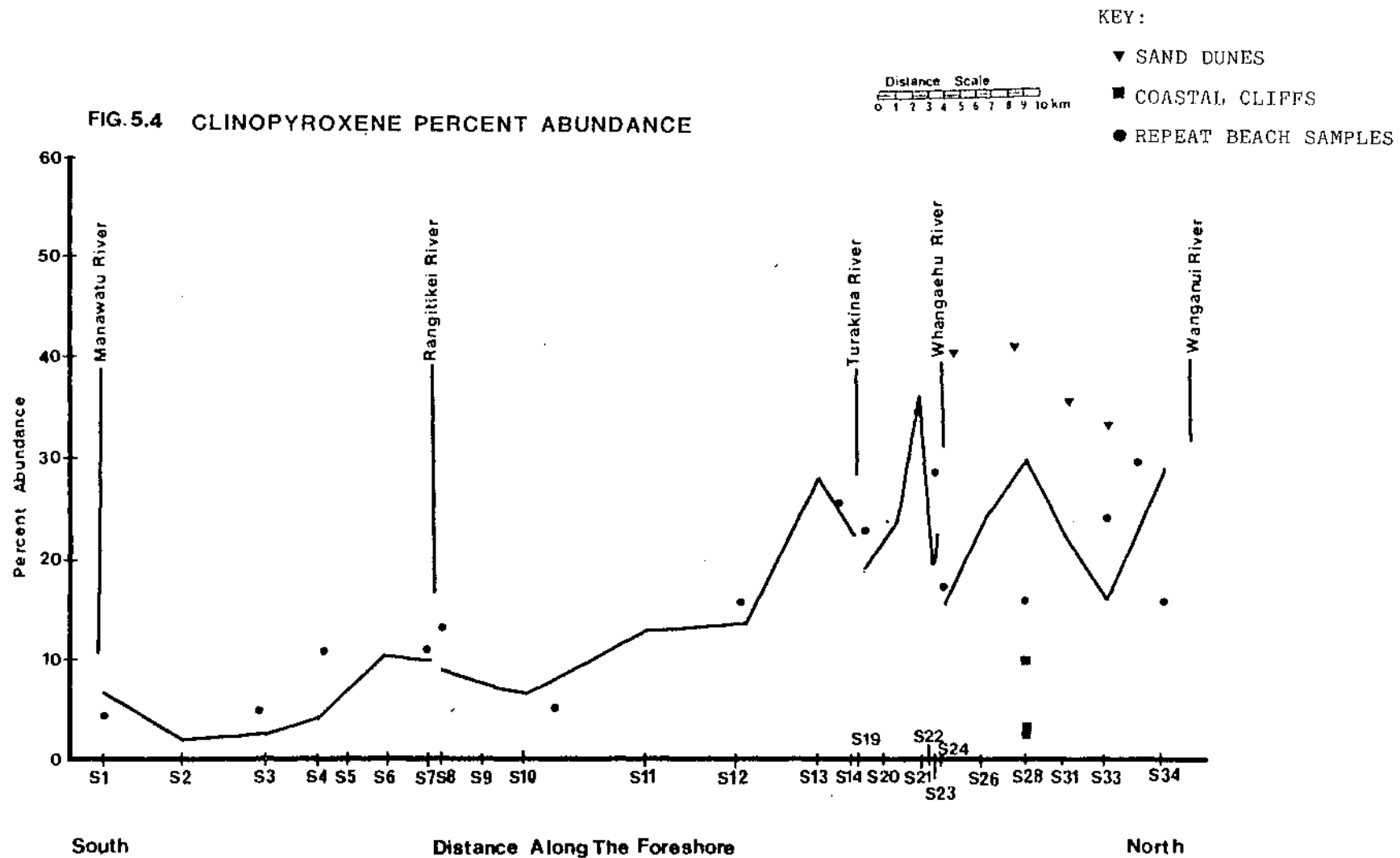
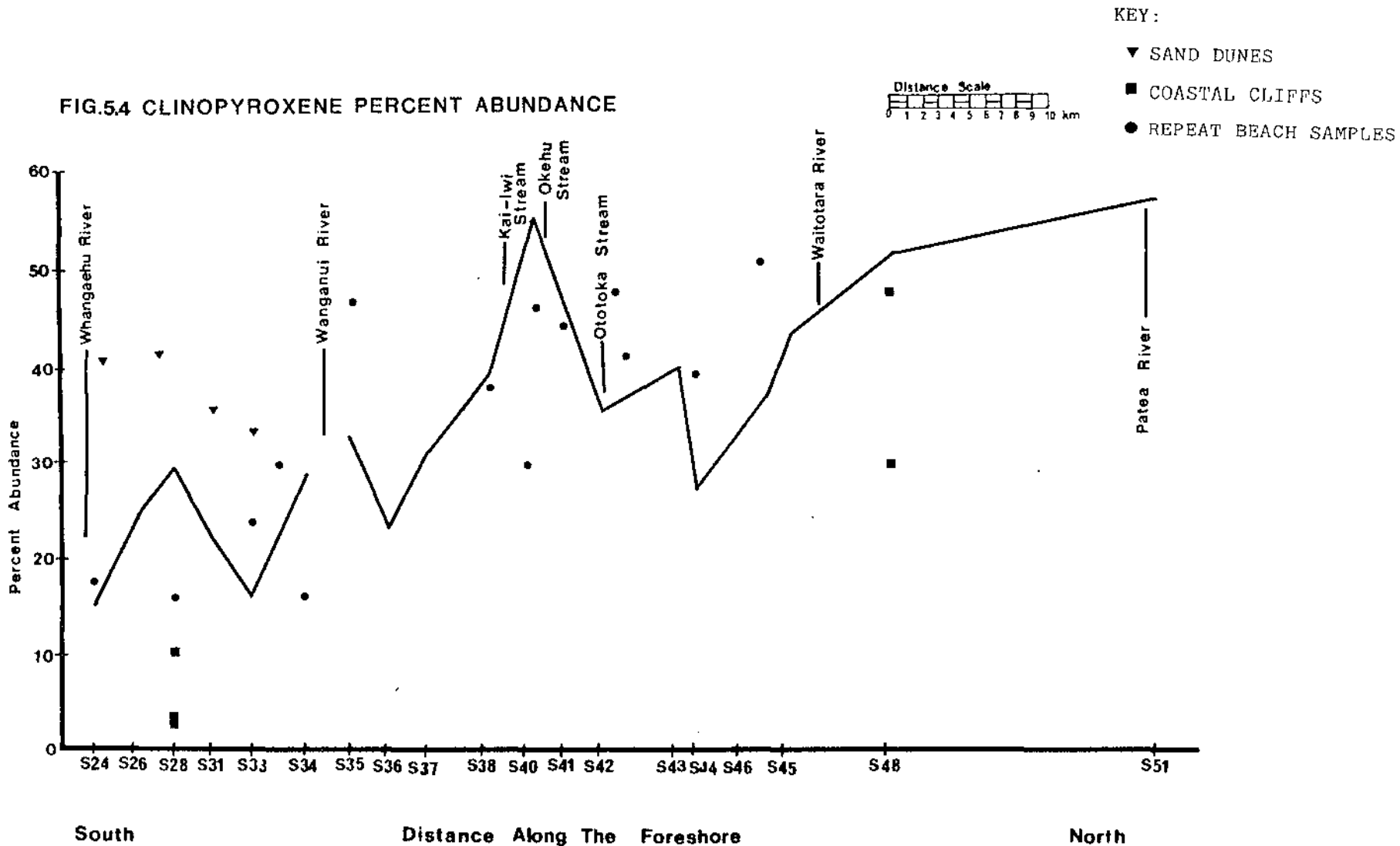


FIG.54 CLINOPYROXENE PERCENT ABUNDANCE



Beaches indicating a similar relationship to a Taranaki source.

Clinopyroxene distributions therefore confirm the general Southeastward longshore drift direction in the study region, as there is both an overall southeastward decrease, and an apparent southeastward dispersal of clinopyroxene from the river mouths (Fig.5.4).

5.5.5 AMPHIBOLE

The predominant amphibole recorded was green-brown hornblende, with some green and red (oxyhornblende) varieties. The green-brown and green hornblende are common to both the Taranaki Volcanics and Taupo Volcanic Zone, but oxyhornblende is thought to be derived almost solely from the Taranaki Volcanics (Ewart, 1966; Gow, 1968). Amphibole plotted in Fig.5.5 is of the green-brown and green hornblende varieties. Abundances (>10%) of green and green-brown hornblende are restricted to north of the Turakina River (Fig.5.5). The amphibole abundance gradually decreases southeastwards away from the possible source areas of Taranaki Volcanics and Taupo Volcanic Zone. Amphibole abundances increase around the Waitotara, Wanganui, Turakina, and Rangitikei Rivers indicating that all appear to be contributing some amphibole to the beach sediments (Fig.5.5). Decreasing amphibole abundances south from Taranaki and the distributions south of the contributing rivers also confirm a dominant southeastward longshore drift.

Gibb (1979), used oxyhornblende derived from the Taranaki Volcanics, as a mineral tracer for the net longshore drift of sediment

FIG.5.5 AMPHIBOLE PERCENT ABUNDANCE

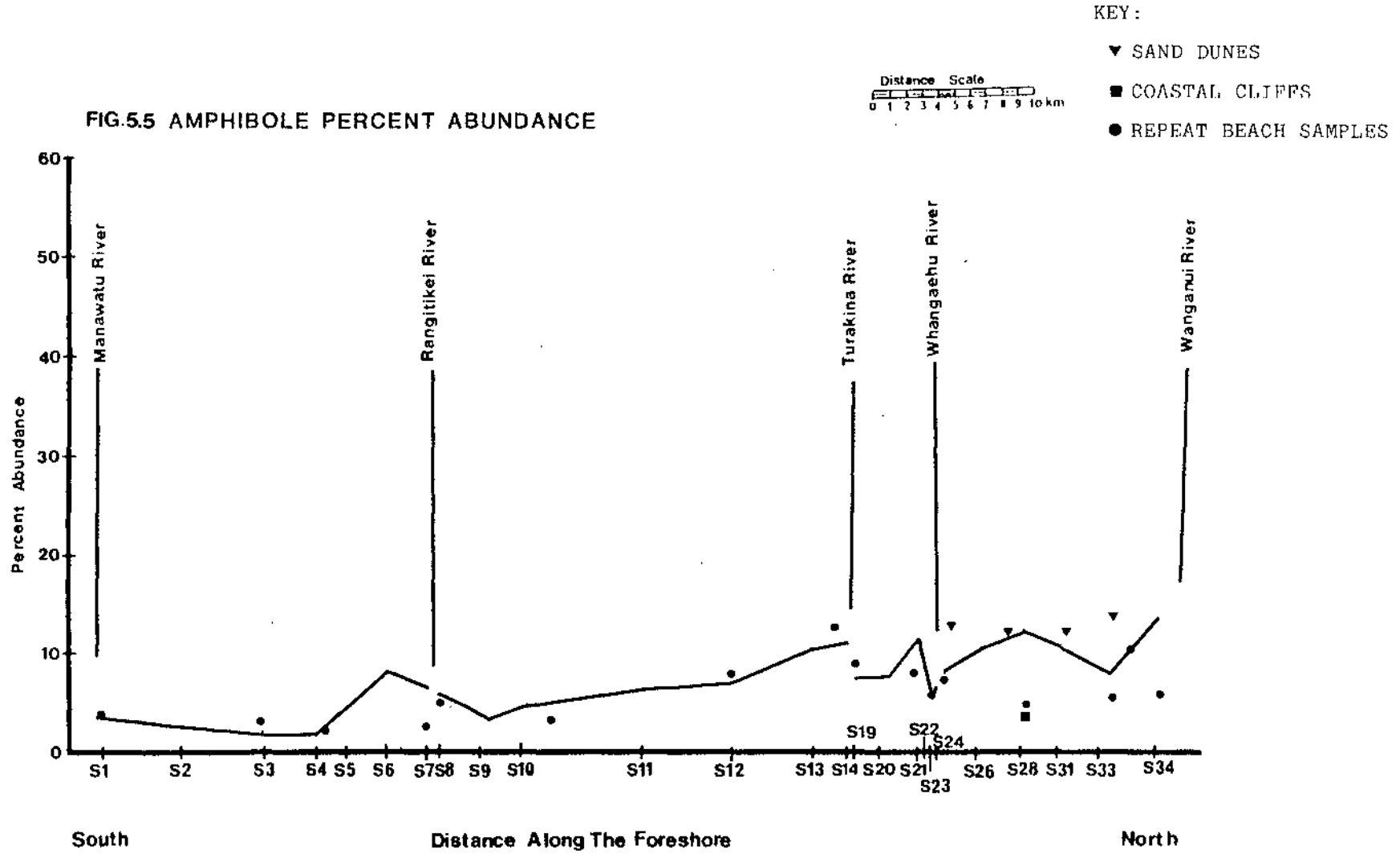
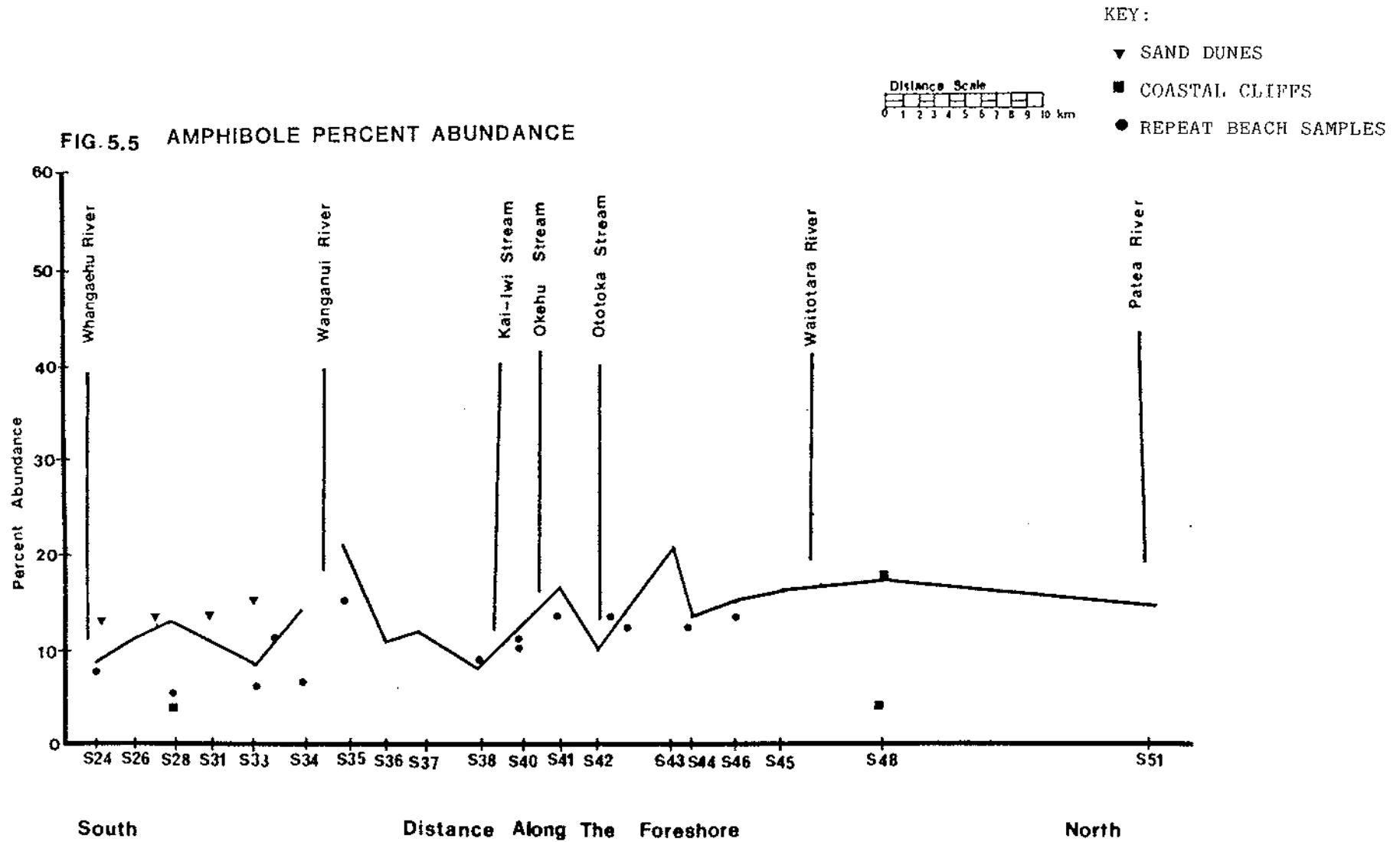


FIG. 5.5 AMPHIBOLE PERCENT ABUNDANCE



from Cape Egmont southeastward to Paraparaumu a distance of about 265 km. Although oxyhornblende apparently decreases in abundance from north to south with distance from source, the decrease is only from about 3.0% to 1.0% (Appendix B, Table.5), and the statistical error at this level is 2% (Fig.5.6). The apparent variation in oxyhornblende distribution therefore could not be used as a statistically valid indication of local longshore distribution trends in this study.

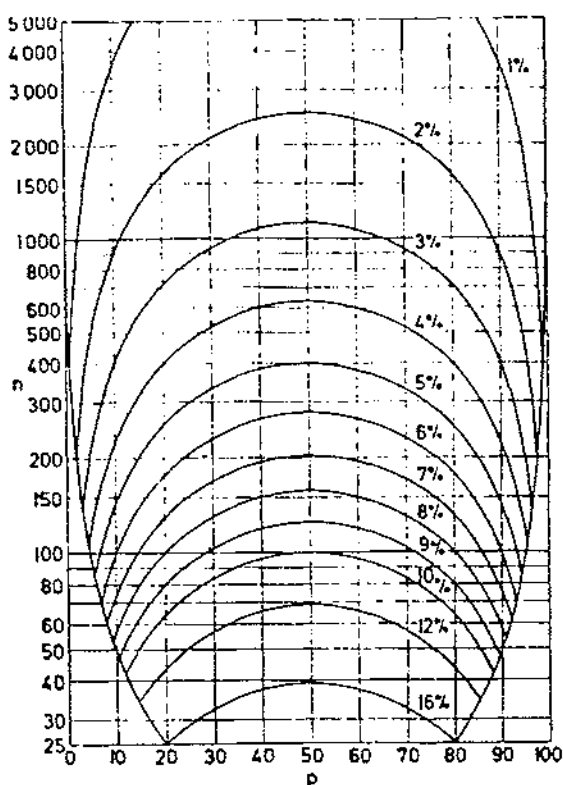


Fig. 5.6 Ninety-five percent confidence limits for mineral proportions, where n is total number of grains counted and p is the estimated proportion of a particular mineral. Curved contours in percent give confidence limits. Example: n is 400, p is 20 percent and the confidence limit is 4 percent, therefore repeated sampling at ninety-five percent confidence limits will lie within 16 and 24 percent (modified from van der Plas and Tobi, 1965, Fig. 1).

5.5.6 LIGHT MINERALS.

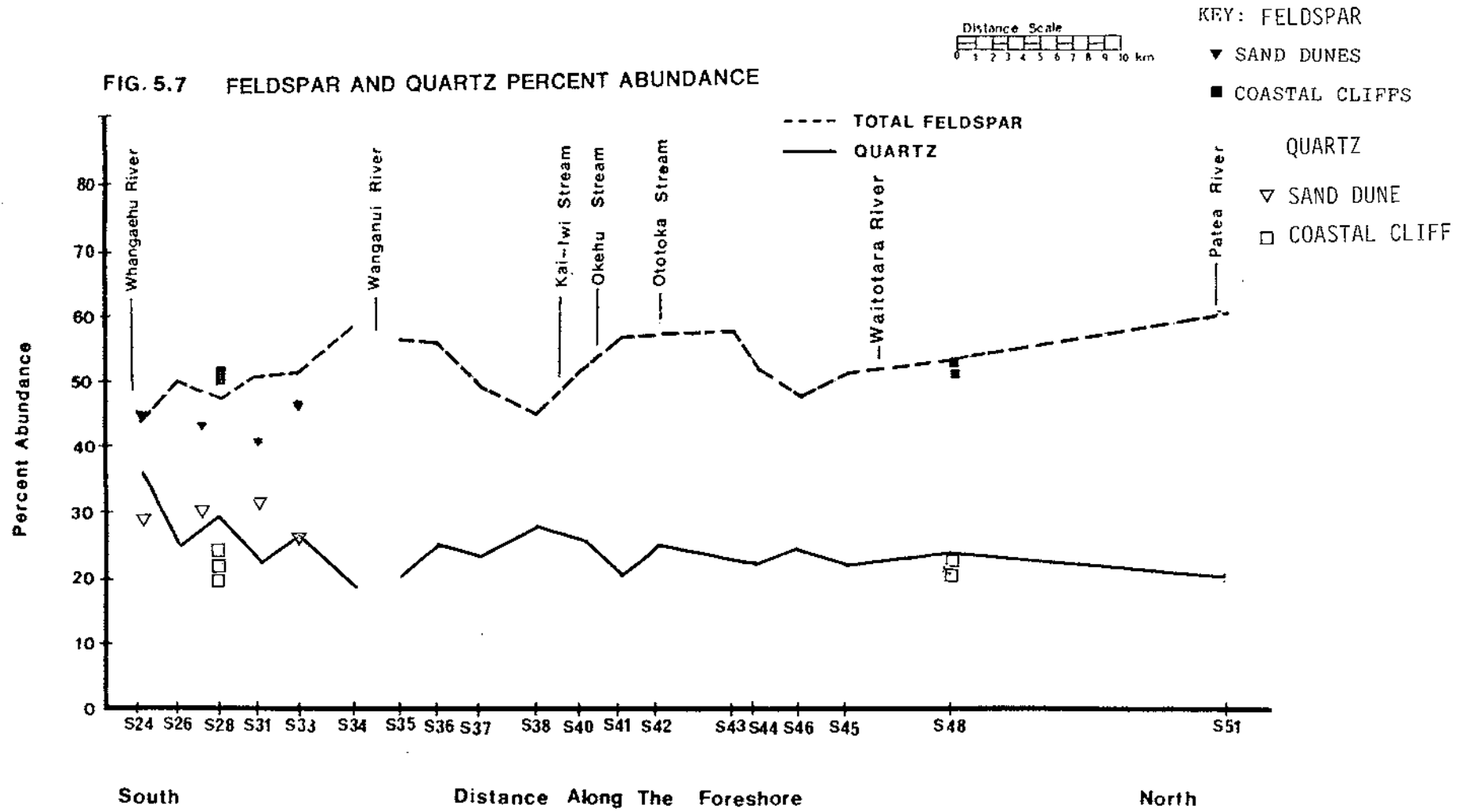
5.5.6.1 QUARTZ AND FELDSPAR.

The content of the light mineral fraction is predominantly plagioclase feldspar, quartz and lithics with minor amounts of alkali feldspar and volcanic glass. The light mineral percentages are recorded in Appendix B, Table.6. Quartz and total feldspar values are plotted in Fig.5.7.

The major trends apparent are:

- (1) Feldspar abundance decreases gradually southeastwards, with a marked decrease southeast of Wanganui River (S34-S14). Feldspar is being contributed to the longshore drift system by Wanganui and Whangaehu Rivers, as is reflected by the increase in feldspar content in the beach sediments around the river mouths (Fig.5.7). Southeastward longshore drift is implied from the decreasing feldspar content along the foreshore.
- (2) Quartz contents show a marked increase in abundance southeast of Wanganui River (Fig.5.7). Contribution of quartz from the Whangaehu, Turakina, Rangitikei and Wanganui Rivers to the longshore drift system is reflected by an increased abundance in the beach sediments.

FIG. 5.7 FELDSPAR AND QUARTZ PERCENT ABUNDANCE

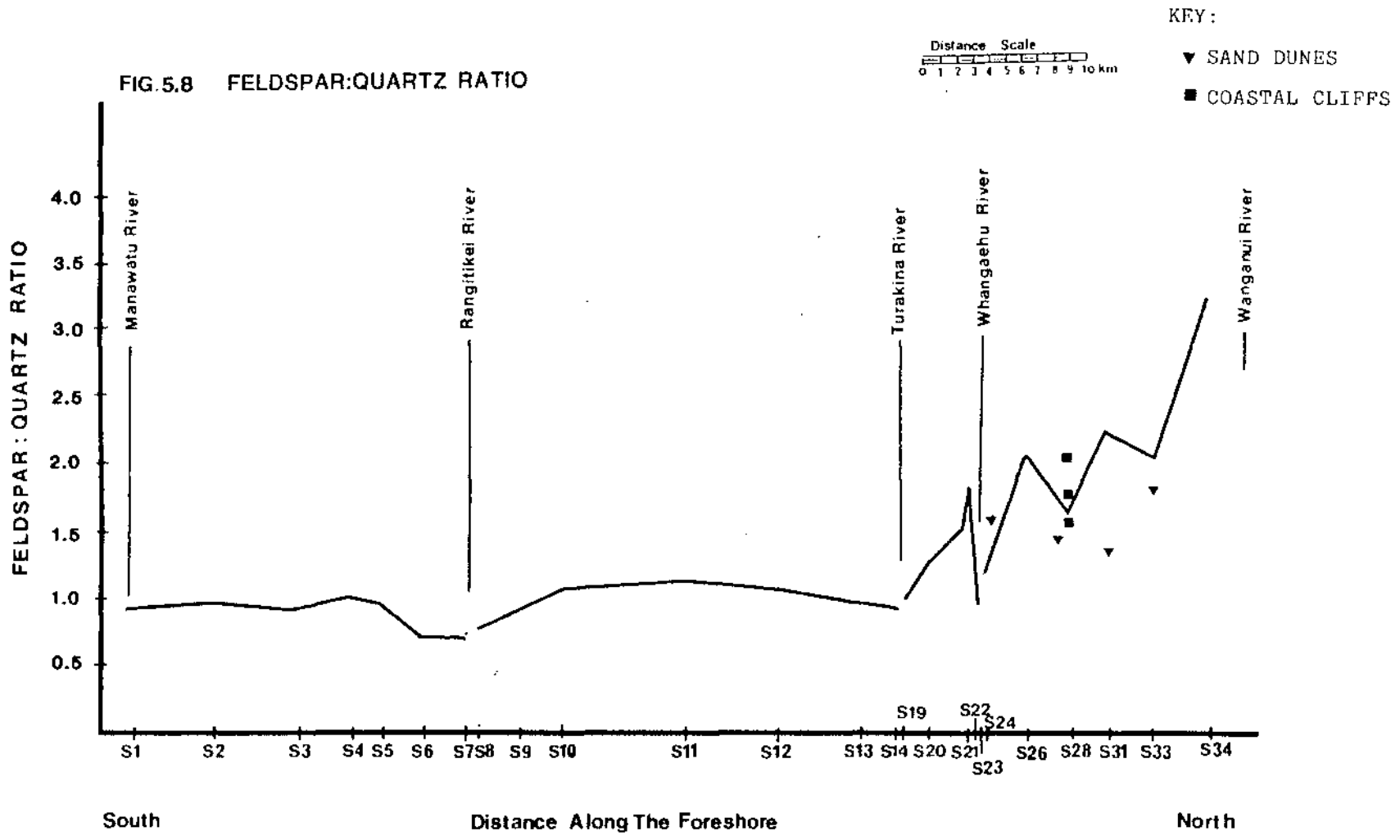


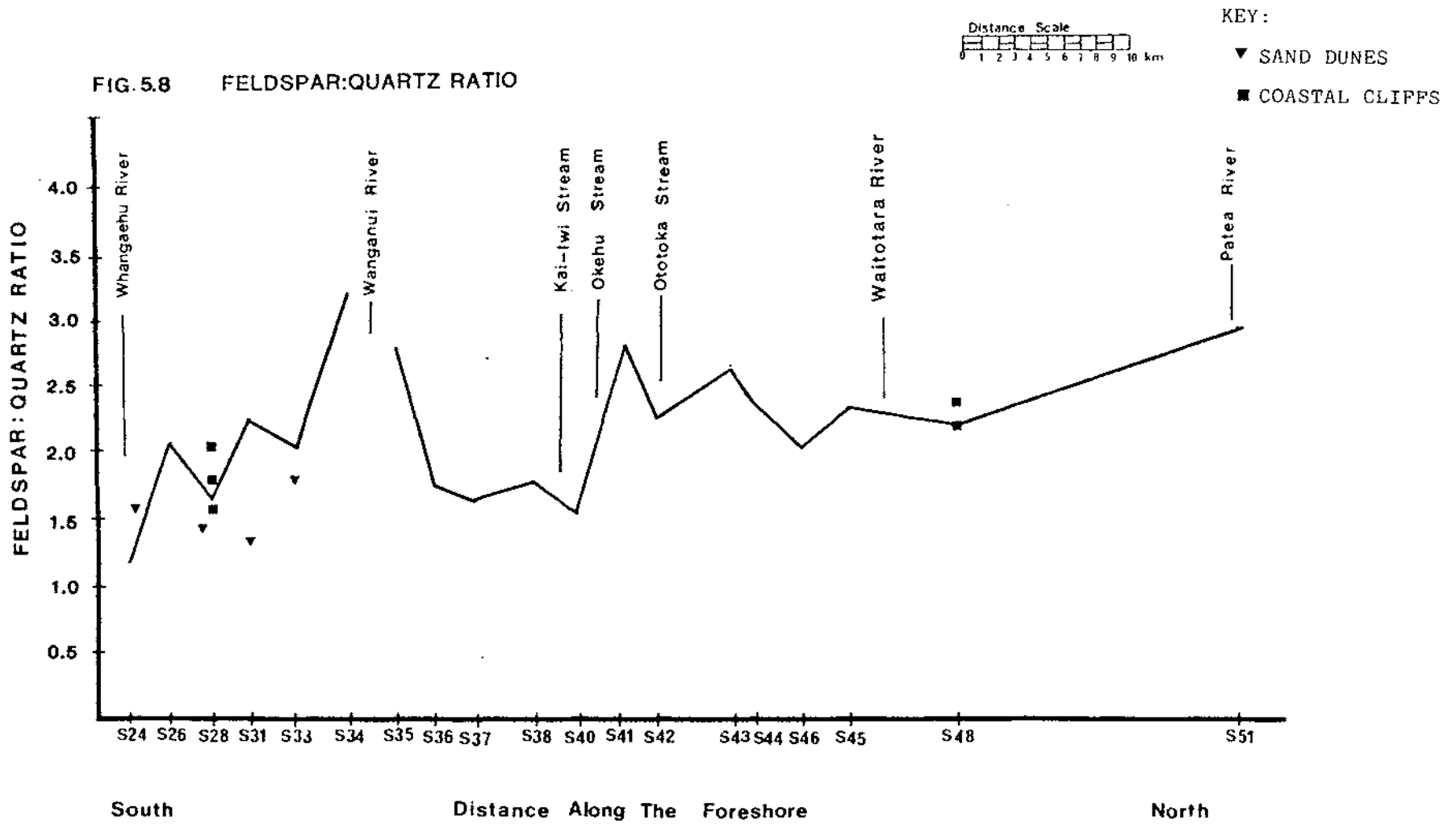
5.5.6.2 FELDSPAR:QUARTZ RATIO.

The ratios of certain light minerals, especially feldspar to quartz, can be diagnostic (Schofield, 1970; Healy, 1978). Quartz is more resistant to abrasion than feldspar (Pettijohn, 1975) and hence longshore reduction of the feldspar:quartz ratio can be indicative of the direction of net longshore drift of sediment. Also variations in the feldspar:quartz ratios where there is input from multiple sources may also be useful in identifying net longshore drift and source areas. The feldspar:quartz ratios are recorded in Appendix B, Table.6 and is plotted in Fig.5.8.

The major trends apparent are:

- (1) The feldspar:quartz ratio decreases southeastward from 2:1 north of Wanganui River to 1:1 south of Whangaehu River which implies longshore drift in this direction (Fig.5.8).
- (2) The locally high feldspar:quartz ratio from Kai-Iwi to Wainui Beach (S40-S44) (Fig.5.8), has resulted from eroding reefs and cliffs cut in the Pleistocene sediments supplying the foreshore with material.
- (3) The decrease in feldspar:quartz ratio effected by the Turakina, Rangitikei, and to a lesser extent the Whangaehu River sediment (Fig.5.8), reflects the difference in sediment composition of rivers contributing to the longshore drift in the south compared to rivers in the north of the study area.





CHAPTER 6
DISCUSSION.

DISCUSSION.

The beaches of the southwest North Island are characterised by sand size material transported in a southeastward longshore drift. The present study showed that sediment from both rivers and locally eroding coastline contribute to the longshore drift system. The sediment transport is interrupted in places by reefs, headlands and the north mole at the Wanganui River mouth.

In the present study, the abundance of the heavy mineral magnetic fraction was observed to progressively decrease from about 95% to 30% southeastward, from Patea River to Manawatu River. Furthermore, the high concentrations of augite, amphibole, opaque minerals and feldspar in the black ironsand decreases gradually from the presumed Taranaki Volcanic source along the foreshore in a southeastward direction. The decrease in abundance of heavy minerals with southeastward longshore drift from Cape Egmont is consistent with earlier reports by Finch (1947), Oliver (1948), Fleming (1953), and Gibb (1977b; 1977c; 1979), suggesting that the major contributor of heavy minerals to the beach sediments is the Taranaki Volcanics. South of Wanganui, a decrease in heavy mineral contents is due to dilution by sediment from rivers contributing quartz, feldspar, hypersthene and lithics and also increased distance from source.

The localised increase in the heavy mineral fraction around the river mouths along the coast, indicates input of sediment derived and transported by the rivers draining from the Taupo Volcanic Zone volcanics and to a minor extent the greywacke ranges. Abundant hypersthene is restricted to areas south of Wanganui River and is

brought down to the coast by rivers which have their headwaters in the Taupo Volcanic Zone.

The sources of the heavy minerals for the beaches along the southwest coast of the North Island are, in order of decreasing contribution, the Taranaki Volcanics, Taupo Volcanic Zone, greywacke ranges and from the Wanganui Basin sedimentary rocks respectively.

Two principal factors affect a heavy mineral population; the source material availability and progressive sorting (Lowright et al, 1972). Topographical features along the coast from Patea to Wanganui have considerable effect on the sorting, and Ross (1963), has shown that opaque mineral concentrations are in part due to the coastline topography. Increase in opaque mineral concentrations is associated with eroding coastline where light minerals are winnowed out by the sorting action of the waves.

The coastline to the north of Wanganui is irregular, and is studded with offshore reefs as are present off Wainui Beach which at times become exposed at the low tide mark. At Bluff Trig intermittent exposure of Castlecliffian bed rock at the low tide mark indicates beach erosion.

Detailed studies of sediment transport around headlands have led to the conclusion that sediment transport is prevented or diminished by the headland (Rice et al, 1976; Luepke, 1980) even though longshore drift may occur. Interference with the net longshore sediment transport occurs due to the more resistant lithology of the reefs and

the abutting headlands such as at Wainui Beach. Lewis (1979), reports that the rocky reefs and headlands west of Wanganui, themselves eroding, are a minor interruption to the longshore flow of sand. In the vicinity of Wainui and at Kai-Iwi Beach an abundance of opaques, augite and minor increases in abundance of amphibole occurs. It is suggested that this concentration is associated with eroding, or at best unstable, sectors of shoreline. At Kai-Iwi Beach, the beach sediments are characterised by an abundance of heavy minerals that are coarser and more poorly sorted due to the occurrence of active coastal erosion. The sea cliffs south of Mowhanau (Plate.3) are being actively eroded by wave attack and the erosive state of the area is indicated by the high abundance of opaque minerals (Fig.5.2).

At Castlecliff there has been active beach accretion which has been measured by Gibb (1979) and Johnston (1985). The beach accretion is due to trapping of sediment transported by southeastward longshore drift on the north mole at the Wanganui River mouth (Plate.1). Longshore drift movement of sediment, together with transport seaward of the breaker zone in a southeastward direction along Castlecliff Beach by waves approaching from the northwest was recognised by Burgess (1969). However, when waves approach from the south, sediment movement is northwards. By-passing of sediment around the north mole under northwest wave approach associated with ebb tide and normal river flow conditions was also postulated by Burgess (1969). This situation produces fluid velocities conducive to transporting river material accumulated near the moles either to the north or south of the river mouth entrance. The opaque mineral concentration at Castlecliff has decreased significantly due to increasing distance from source. The

coarsening of the beach sediment at Castlecliff and increase in abundance of augite, amphibole, feldspar and lithics up to 3 km north of Wanganui River suggest that the fine grained sediment is being removed. The beach sediments are also characterised by being more poorly sorted and more positively skewed when compared with beach sediments to the north. This indicates that Wanganui River is contributing material to Castlecliff Beach, probably during periods of southwesterly storms.

At South Spit a small contribution of finer and better sorted material from Wanganui River may occur at times (Burgess, 1971). The quartz and feldspar contents, and heavy mineral increase at South Spit, indicates that some sediment is being transported to South Spit from Wanganui River. This is also consistent with conclusions of Burgess (1969), that sediment at South Spit is derived from both Wanganui River and from longshore drift sediment by-passing the moles at the river mouth. Johnston (1985) has reported beach accretion at the South Spit since the early 1960's which may in part be due to the resumption of by-passing of sediment around the north mole at times, in addition to sediment derived from the Wanganui River.

At Bluff Trig, substantial erosion of the coastal sand dunes and exposed Pleistocene sediment (Gibb, 1979; Johnston, 1985) (Plate.2) has resulted from both the reduced supply of sand from north of the Wanganui River moles and insufficient river sediment being deposited on the beach immediately south of the river mouth. The sand dunes have high concentrations of rounded heavy minerals due to wind transportation and sorting prior to deposition. The beach sands in the

vicinity of the eroding sand dunes also have high concentrations of rounded heavy minerals, indicating derivation from the dunes.

Grain-size parameter variations and heavy mineral abundances immediately south of Rangitikei, Whangaehu and Turakina Rivers indicate that coarse and poorly sorted sediment high in heavy mineral content is being contributed to the southeast longshore drift and is deposited several (1-3) km south of the river mouth rather than adjacent to it. The Whangaehu and Rangitikei Rivers are major contributors of coarse sediment to the longshore drift system. In contrast to grain size parameters of sediments on the adjacent beaches, the Turakina River appears to be depositing finer and better sorted material around the river mouth. The decreases in heavy mineral contents, together with the textural parameter distribution southeastward of the contributing rivers, indicate a net southeastward longshore drift. This pattern is evident near the Whangaehu, Rangitikei, Turakina and Waitotara River mouths. Furthermore, the increase in abundance of hypersthene only to the south of Wanganui River, also indicates southeastward longshore drift. The presence of hypersthene andesite gravels southeastward of Whangaehu River, and greywacke gravels transported primarily by the Rangitikei River with distribution southeastwards along the coast further indicates a southeast longshore drift.

Textural and mineralogical data for the beach sediments, show that black, opaque mineral rich sand derived from Taranaki Volcanics is carried southeastward by longshore drift. The mineralogical character changes as the most dense minerals are left near source, light minerals are swept offshore and lithic grains disintegrate (Gibb, 1979). Thus,

by the time the black sand reaches Wanganui, it is of predominantly augite mineralogy with sub-dominant green-brown hornblende, andesitic lithic fragments and only a few percent opaque minerals. The light sand derived from Pliocene to Pleistocene marine sediments within the Wanganui Basin is transported down the rivers and some finds its way on to the beach where it dilutes the black sand with feldspar, quartz, hypersthene, and lithics. However, sediment supply to the coast from contributing rivers occurs mostly during spate flow conditions, when much of it may by-pass the breaker zone to be dumped on to the inner continental shelf. River sediment deposited off the mouth of large rivers is sorted by storm waves and strong currents into its constituent mud and sand fractions, with the mud being deposited further offshore near the centre of Cook Strait Basin (Lewis & Eade, 1974), whereas the sand fraction remains on the inner shelf (Lewis, 1979).

The sorted river sediment deposited off the river mouth remains close to the coast, where at some distance (1-3 km) south, coarser and more poorly sorted sediment with a higher heavy mineral content is deposited onto the shore. A little escapes seawards from the breaker zone and helps to build out a smooth shoreface that slopes seawards to a depth of about 15 m (Lewis, 1979). The bulk of the sand either helps prograde the beaches southeast of the Wanganui river or is blown inland to form parabolic, and self dunes (Fleming, 1953). However, the light sands, as in the case of the Wanganui River sediment, escapes seaward off the shoreface onto the continental shelf (McLean & Burgess, 1971; Lewis, 1979).

CHAPTER 7
CONCLUSIONS.

CONCLUSIONS.

(1) PROVENANCE.

The high abundances of clinopyroxene, opaque minerals, green and green-brown hornblende with associated oxyhornblende, in beach sediments north of the Wanganui River indicate that the dominant sediment source is the Taranaki Volcanics. The abundance of particularly hypersthene but also clinopyroxene, green and green-brown hornblende in the vicinity of the Whangaehu, Turakina and Rangitikei Rivers indicate that sediment contributions occur from Taupo Volcanic Zone volcanics (rhyolites and Taupo Volcanic Zone andesites) and from the sedimentary rocks in the Wanganui Basin and greywacke ranges. These contributions become more important in the southern part of the study area.

(2) LONGSHORE DRIFT.

The gradual decrease southeastwards in heavy mineral abundances along the coast in the study area indicates a net southeastward longshore drift. This is further supported by the distribution patterns of the grain size parameters and the heavy mineral abundances immediately south of the mouths of contributing rivers indicating a net southeastward drift.

(3) RIVER CONTRIBUTIONS.

The mineralogical abundance peaks of hypersthene, augite, green and green-brown hornblende in the vicinity of the Whangaehu, Turakina and Rangitikei Rivers clearly shows that they are contributing andesitic sediment. The quartz and feldspar content variations in beach sediments indicate that the Wanganui, Turakina, Rangitikei and

Whangaehu Rivers are contributing both Pliocene and Pleistocene sediments from the Wanganui Basin and material from the greywacke ranges. The grain size parameters also indicate that the Rangitikei and Whangaehu Rivers are ejecting coarse river sediment to the longshore drift system, with the Turakina River supplying less, but finer and better sorted material to the adjacent beaches at the river mouth.

The higher concentration of heavy minerals and the presence of coarser sediment 1-3 km south of the Whangaehu, Rangitikei and Turakina Rivers, rather than near to the river mouth, suggest that discharged river sediment is finding its way back to the beach at this distance southeastward of the river mouth rather than adjacent to it.

(4) COASTAL FEATURES.

Prograding coastline in the study area occurs largely to the south of Whangaehu River and locally at Castlecliff Beach. The prograding shoreline results from abundant supply of sediment to the foreshore, or as at Castlecliff, from sediment trapping by the north mole of the Wanganui River mouth. The coastline southeast of Turakina River for about 8 km is characterised by the periodic development of small berms, cusps and a ridge and runnel system resulting from an abundance of sediment. To the southeast of Rangitikei River the presence of gravel lobes indicates further an abundant supply of coarse sediment to the beach with the remainder of the coast southeastward is typical of dissipative beaches (Short & Hesp, 1982) having a wide, low angle foreshore with an abundant supply of sand size material.

Coastal erosion occurs in regions where a deficit of sediment supplying the longshore drift system occurs. This is evident in the Bluff Trig area where the coastal cliffs which are eroding, and also the headland at Mowhanau. High abundances of opaque minerals are an indicator of the erosive state of the coastline at Mowhanau. Some difficulty arises in interpreting the sediment supply and mineral abundances at Wanganui River and Bluff Trig, also observed by other authors. The processes that operate around the Wanganui River mouth are complex and are dependent on the conditions that exist at the time. At Bluff Trig active erosion by wave attack occurs and intermittently tidal platforms of the underlying Castlecliffian bed rock are exposed. Tidal platforms become exposed at low tide also to the north between Patea and Kai-Iwi Beach.

APPENDICES

APPENDIX A.GRAIN SIZE PARAMETERS EMPLOYED.

Grain size parameters employed in this analysis are those of Folk (1974), where

M_z = Graphic Mean

σ_I = Inclusive Graphic Standard Deviation

SK_I = Inclusive Graphic Skewness

Graphic mean (M_z) is a measure of mean grain size and is measured in phi units, where

$$M_z = \frac{(\phi_{16} + \phi_{50} + \phi_{84})}{3}$$

Inclusive graphic standard deviation (σ_I) is a measure of sorting which incorporates 90% of the size distribution. σ_I is a measure in phi units, where

$$\sigma_I = \frac{\phi_{84} - \phi_{16}}{4} + \frac{\phi_{94} - \phi_5}{6.6}$$

Verbal limits for sediment sorting are (Folk, 1974):

< 0.35	very well sorted
0.35-0.50	well sorted
0.50-0.71	moderately well sorted
0.71-1.00	moderately sorted
1.00-2.00	poorly sorted
2.00-3.00	very poorly sorted
>4.00	extremely poorly sorted

Inclusive graphic skewness (SK_I) is a measure of how closely the grain-size distribution approaches the normal Gaussian probability curve, where

$$SK_I = \frac{\phi_{16} + \phi_{84} - 2\phi_{50}}{2(\phi_{84} - \phi_{16})} + \frac{\phi_5 + \phi_{95} - 2\phi_{50}}{2(\phi_{95} - \phi_5)}$$

The inclusive graphic skewness also includes 90% of the distribution curve, so that the "tails" of the distribution are included as well. Furthermore it is geometrically independent of the sorting of the samples (Folk, 1974). Since SK_I is a ratio, it is expressed as a pure number. Positive skewness values represent fine skewed sediments and negative values represent coarse skewed sediment.

The following verbal limits for skewness are (Folk, 1974):

SK_I	+1.00 to +0.30	strongly skewed
	+0.30 to +0.10	fine skewed
	+0.10 to -0.10	near symmetrical
	-0.10 to -0.30	coarse skewed
	-0.30 to -1.00	strongly coarse skewed

APPENDIX B.

TEXTURAL AND MINERALOGICAL DATA FOR THE BEACH SEDIMENTS,

SAND DUNES, COASTAL CLIFFS AND RIVERS, ALONG THE

SOUTHWEST COAST OF THE NORTH ISLAND, NEW ZEALAND.

Table 3.

SEDIMENT STATIONS AND DATA

Beach Samples - Manawatu River to Patea River

Station	Collection Date	N.Z.M.S.1 Grid Reference	Cumulative Distance km	Carbonate (Wt %)	Magnetic (Wt %)
S1	23/5/84	N148/736210	0	3.8	37.5
S2	"	N148/739253	4.8	4.2	60.7
S3	"	N148/746313	10.0	3.8	39.2
S4	"	N148/748347	13.3	3.8	37.7
S5	"	N148/747366	15.0	3.3	30.2
S6	"	N148/747392	17.5	5.1	42.1
S7	"	N148/744419	20.0	4.0	39.9
S8	"	N148/744437	20.7	4.2	41.1
S9	"	N148/739464	23.2	3.6	40.5
S10	"	N143/732507	25.7	3.2	38.2
S11	"	N143/719579	33.2	6.2	39.6
S12	"	N143/703617	37.9	3.8	41.6
S13	"	N143/681660	42.9	2.5	58.8
S14	"	N143/668682	45.1	2.6	51.1
S19	24/5/84	N143/661690	45.3	2.6	49.9
S20	"	N143/650706	47.3	3.7	48.3
S21	"	N143/639718	49.3	2.3	60.8
S22	"	N143/630726	50.3	4.8	40.8
S23	"	N143/628730	50.5	3.6	51.2
S24	"	N143/624735	50.7	2.8	42.2
SD25	"	N143/620742	51.2	1.4	76.3
S26	"	N143/619758	53.2	1.1	44.3
SD27	"	N143/599771	54.7	2.8	84.2
S28	"	N143/591780	55.7	2.9	55.3
SC29	"	N143/591780	55.7	1.7	54.3
SD30	"	N143/575800	58.2	1.6	80.1
S31	"	N143/575800	58.2	3.7	42.4
SD32	"	N143/556819	60.7	2.4	63.9
S33	"	N143/556819	60.7	3.7	44.9
SR72	31/5/84	N137/545828	62.4	1.7	60.7

Table 3. (continued)

Station	Collection Date	N.Z.M.S.1 Grid Reference	Cumulative Distance km	Carbonate (Wt %)	Magnetic (Wt %)
S34	24/5/84	N137/530840	64.2	3.0	52.1
S35	"	N137/507860	67.0	8.0	66.2
S36	"	N137/490881	69.5	4.2	52.9
S37	"	N137/477893	72.0	4.3	65.8
S38	"	N137/447913	76.0	2.8	75.7
S40	25/5/84	N137/425925	78.4	4.5	87.1
S41	"	N137/400935	80.9	6.0	77.8
S42	"	N137/374943	83.5	4.5	55.3
S43	"	N137/323949	88.3	8.2	78.8
S44	"	N137/312944	89.6	6.7	58.0
S46	"	N137/280940	92.5	3.3	55.8
S45	"	N137/251951	95.4	5.3	76.2
S48	"	N137/188983	101.9	3.5	81.4
SC49	"	N137/188983	101.9	0.9	66.0
SC50	"	N137/188983	101.9	-	91.2
S51	"	N136/049054	119.7	5.0	94.5

Table 3. (continued)

RIVER SAMPLES - MANAWATU RIVER TO PATEA RIVER

Station	Collection Date	N.Z.M.S.I. Grid Reference		Carbonate (Wt %)	Magnetic (Wt %)
RS52	25/5/84	N129/057145	Patea River	-	39.3
RS47	25/5/84	N137/274013	Waitotara River	-	31.9
RS39	24/5/84	N138/612021	Wanganui River	-	38.1
RS17	23/5/84	N143/727742	Whangaehu River	-	74.1
RS15	23/5/84	N143/728745	Turakina River	-	25.8
RS16	23/5/84	N143/728745	Turakina River	-	28.5
RS18	23/5/84	N143/949635	Rangitikei River	-	36.9
RS68	15/7/84	N149/142358	Manawatu River	-	36.2

REPEAT BEACH SAMPLES - MANAWATU RIVER TO PATEA RIVER

Station	Collection Date	N.Z.M.S.1 Grid Reference	Carbonate (Wt %)	Magnetic (Wt %)
SR64	6/9/84	N148/736210	2.7	38.2
SR65	"	N148/744303	2.3	38.7
SR66	"	N148/748348	2.2	34.7
SR67	"	N148/744422	2.5	36.0
SR53	5/9/84	N148/744437	4.8	37.4
SR54	"	N143/732507	5.4	39.6
SR55	"	N143/703617	3.1	40.6
SR56	7/9/84	N143/721677	3.6	58.7
SR69	"	N143/661690	3.5	48.1
SR70	"	N143/639718	2.5	60.6
SR71	"	N143/630726	3.5	48.3
SR57	5/9/84	N143/624735	3.9	34.6
SR58	"	N143/591780	3.4	82.2
SC59A	"	N143/591780	6.3	58.8
SC59B	"	N143/591780	1.2	55.6
SR60	"	N138/556819	3.8	38.1
SR61	"	N137/532842	3.7	44.2
SR62	"	N137/507860	8.0	62.1
SR63	"	N137/425925	4.2	57.9
SR73	26/7/85	N137/447913	3.0	71.0
SR74	"	N137/425925	4.5	65.4
SR75	"	N137/400935	2.0	62.5
SR76	"	N137/374949	5.6	73.1
SR77	"	N137/360948	2.3	59.7
SR78	"	N137/316944	4.3	60.4
SR79	"	N137/280940	5.7	74.1

Table.4 Grain-Size Parameters.BEACH SAMPLES BETWEEN PATEA RIVER AND MANAWATU RIVER.FOLK GRAPHIC MEASURES.

SAMPLE STATION	MEAN	STD.DEV	SKEWNESS	KURTOSIS
S1	2.60	0.39	-0.31	0.98
S2	2.45	0.45	-0.29	1.10
S3	2.40	0.42	-0.06	1.05
S4	2.34	0.44	-0.13	1.00
S5	2.43	0.41	-0.18	1.11
S6	0.53	2.41	-0.75	0.76
S7	2.06	0.80	-0.49	1.82
S8	1.99	0.90	-0.54	1.73
S9	2.35	0.44	-0.22	1.39
S10	2.43	0.40	-0.19	1.22
S11	1.90	0.88	-0.49	0.85
S12	2.00	0.68	-0.38	1.08
S13	1.85	0.65	-0.21	0.93
S14	2.22	0.45	-0.10	1.07
S19	2.19	1.03	-0.49	3.10
S20	1.62	1.56	-0.63	2.08
S21	0.12	2.97	-0.82	2.00
S22	2.17	0.64	-0.34	1.49
S23	0.63	1.39	-0.18	1.40
S24	2.43	0.42	-0.13	1.08
S26	2.13	1.39	-0.58	3.80
S28	2.23	1.32	-0.49	4.38
S31	2.44	0.42	-0.07	0.99
S33	2.36	0.56	-0.29	1.13
S34	2.19	0.52	-0.14	1.07
S35	1.61	0.60	0.06	0.88
S36	2.29	0.45	-0.05	0.98
S37	2.19	0.53	-0.09	1.02
S38	2.13	0.54	-0.05	1.04
S40	1.98	0.72	-0.13	1.11
S41	1.74	1.72	-0.57	2.48
S42	1.95	1.57	-0.50	3.48
S43	1.71	0.66	-0.17	1.17
S44	2.05	0.57	-0.23	1.19
S46	2.41	0.42	-0.12	1.10
S45	1.93	0.59	-0.19	1.03
S48	2.10	0.52	-0.12	1.12
S51	1.63	0.79	-0.23	1.06

Table.4. (continued)

SAND DUNE AND COASTAL CLIFF SAMPLES.FOLK GRAPHIC MEASURES.

<u>SAMPLE STATION</u>	<u>MEAN</u>	<u>STD.DEV</u>	<u>SKEWNESS</u>	<u>KURTOSIS</u>
SD25	2.35	0.42	0.04	1.01
SD27	-0.46	2.96	-0.67	0.52
SC29	2.45	0.82	-0.51	2.00
SD30	2.24	0.55	0.00	1.04
SD32	2.27	0.58	-0.05	1.08
SC49	2.66	0.34	0.02	1.06
SC50	2.18	0.60	0.02	1.06
SC59A	-2.08	3.03	0.51	0.72
SC59B	2.01	1.26	-0.66	1.22

RIVER SAMPLES.FOLK GRAPHIC MEASURES.

<u>SAMPLE STATION</u>	<u>MEAN</u>	<u>STD.DEV</u>	<u>SKEWNESS</u>	<u>KURTOSIS</u>
PATEA RIVER				
RS52	3.13	0.53	0.29	1.32
WAITOTARA RIVER				
RS47	2.85	0.50	0.25	1.47
WANGANUI RIVER				
RS39	3.18	0.76	0.33	1.24
WHANGAEHU RIVER				
RS17	-2.14	2.36	0.51	0.63
TURAKINA RIVER				
RS15	-3.54	1.11	0.19	1.46
RS16	3.18	0.8	0.48	1.26
RANGITIKEI RIVER				
RS18	-3.58	2.15	0.63	1.72
MANAWATU RIVER				
RS68	-4.98	1.80	0.56	1.73

Table.4. (continued)

REPEAT SAMPLES BETWEEN PATEA RIVER AND MANAWATU RIVER.FOLK GRAPHIC MEASURES.

SAMPLE STATION	MEAN	STD.DEV	SKEWNESS	KURTOSIS
SR53	2.04	1.05	-0.63	1.77
SR54	1.78	0.86	-0.32	0.79
SR55	2.27	0.56	-0.36	1.55
SR56	1.25	1.32	-0.30	2.24
SR57	1.98	1.53	-0.62	2.69
SR58	2.27	0.42	-0.03	0.95
SR60	2.52	0.45	-0.18	1.10
SR61	2.28	0.52	-0.10	0.96
SR62	2.09	0.53	-0.17	1.17
SR63	1.96	1.47	-0.45	2.67
SR64	2.73	0.28	-0.16	1.03
SR65	2.50	0.34	-0.06	0.92
SR66	2.57	0.33	-0.11	1.04
SR67	2.33	1.24	-0.52	4.84
SR69	2.01	0.66	-0.31	1.14
SR70	2.04	1.28	-0.46	3.61
SR71	1.15	1.73	-0.41	2.05
SR72	1.15	1.71	-0.45	2.03
SR73	2.22	0.65	-0.23	1.05
SR74	2.56	0.38	-0.04	1.03
SR75	2.14	0.80	-0.21	1.00
SR76	2.54	0.42	-0.01	1.10
SR77	2.33	0.62	-0.14	1.04
SR78	2.09	0.43	-0.06	1.18
SR79	1.82	0.62	0.03	0.83

Table.4. (continued)

GRAVEL FREE SEDIMENT; SEDIMENT COARSER THAN -1ϕ REMOVED.FOLK GRAPHIC MEASURES.

SAMPLE STATION	MEAN	STD.DEV	SKEWNESS	KURTOSIS
S4	2.35	0.44	-0.13	0.99
S5	2.43	0.40	-0.17	1.08
S6	2.01	0.90	-0.56	1.65
S7	2.10	0.74	-0.45	1.77
S8	2.03	0.85	-0.51	1.71
S9	2.36	0.48	-0.35	1.76
S10	2.45	0.34	-0.10	1.04
S11	1.91	0.86	-0.49	0.85
S12	2.00	0.68	-0.37	1.08

RS15	1.16	1.34	0.10	0.73
RS17	1.08	0.82	-0.14	1.28
RS18	2.71	1.37	0.18	1.67
S19	2.26	0.48	-0.22	1.18
S20	1.86	0.78	-0.41	1.02
S21	2.21	0.57	-0.24	1.39
S22	2.20	0.57	-0.28	1.35
S23	0.92	0.95	0.10	0.96
S26	2.29	0.50	-0.21	1.20
SD27	1.84	0.67	-0.16	1.13
S28	2.32	0.42	-0.08	1.01
SC29	2.49	0.75	-0.47	1.91
S31	2.45	0.41	-0.06	0.97
S33	2.39	0.51	-0.24	1.03
S40	2.01	0.67	-0.08	1.04
S41	1.93	0.80	-0.29	1.01
S42	2.11	0.56	-0.10	0.93
S43	1.71	0.65	-0.16	1.14
S44	2.06	0.56	-0.22	0.18
S45	1.93	0.59	-0.18	1.03
S46	2.44	0.37	-0.04	0.96
S51	1.65	0.77	-0.22	1.05
SR53	2.17	0.91	-0.58	1.89
SR54	1.62	0.78	-0.24	0.76
SR55	2.27	0.56	-0.36	1.54
SR56	1.41	0.73	0.03	1.07
SR57	2.26	0.59	-0.29	1.07
SC59A	1.85	1.91	0.20	1.17
SC59B	2.17	1.08	-0.61	1.33
SR62	2.10	0.52	-0.15	1.14
SR63	2.10	0.63	-0.10	0.88
SR66	2.44	0.26	-0.02	1.14
SR67	2.33	0.38	-0.13	1.09
RS68	2.88	1.78	0.46	1.86
SR69	2.01	0.65	-0.30	1.13
SR70	2.12	0.52	-0.10	1.08
SR71	1.39	0.87	-0.11	0.84
SR72	1.63	0.80	-0.01	0.98
SR73	2.22	0.65	-0.23	1.05
SR75	2.18	0.75	-0.17	0.97
SR76	2.54	0.42	-0.11	1.09

Table 5.

MINERAL PERCENTAGES FROM GRAIN COUNTS IN 2-4 PHI MAGNETIC FRACTION.
BEACHES FROM, MANAWATU RIVER TO PATEA RIVER

Sediment Station	Opauques	Clinopyroxene	Green hornblende	Red hornblende	Hypersthene	Biotite	Muscovite	Epidote	Garnet	Volcanic glass	Feldspar	Quartz	Lithics	Unknown	Grains counted
S1	1.4	6.6	3.7	0.5	1.4	0.2	0.5	0.5	0.7	0.2	9.4	0.2	74.2	1.1	438
S2	7.6	2.0	2.4	1.2	1.0	0.5	-	0.2	0.7	0.2	15.4	2.9	64.5	1.2	409
S3	4.2	2.2	2.0	1.0	0.5	0.5	0.5	0.2	0.7	-	16.6	2.0	68.0	1.7	409
S4	2.7	4.4	1.9	1.2	2.4	-	0.7	0.2	0.5	-	14.8	1.5	68.7	1.2	412
S5	2.0	7.0	3.8	0.9	6.3	-	1.1	0.2	-	-	10.1	1.1	65.5	1.4	443
S6	8.5	10.2	7.7	1.0	4.8	-	0.7	0.2	0.5	-	9.2	2.9	53.6	0.7	411
S7	2.7	10.0	6.3	1.9	8.0	-	0.2	-	-	0.2	10.6	2.4	56.9	0.7	423
S8	8.9	8.9	5.9	1.7	5.4	-	0.5	-	0.2	0.2	12.8	1.2	54.8	1.0	405
S9	2.9	7.5	3.4	1.7	5.1	-	0.2	-	0.2	-	14.1	2.9	60.4	1.5	412
S10	5.8	6.6	4.6	1.7	2.4	0.2	1.0	0.2	-	-	17.7	1.2	57.0	1.5	412
S11	3.2	13.1	6.1	2.4	2.7	-	-	-	0.5	-	8.8	0.7	61.1	1.5	411
S12	3.9	13.6	6.8	0.5	3.9	-	1.2	0.2	0.5	-	10.9	0.2	57.2	1.0	411
S13	1.9	28.2	10.4	1.7	18.0	0.2	-	-	0.2	-	9.1	1.5	28.9	1.2	412
S14	6.1	22.1	10.9	1.9	9.7	-	0.5	-	0.5	0.2	5.6	0.5	40.4	1.5	411
S19	4.3	18.6	7.4	1.4	15.8	-	0.2	-	-	-	8.0	1.7	41.7	0.7	419
S20	4.1	23.4	7.7	1.7	7.6	-	0.2	-	-	-	10.4	1.0	43.0	1.0	414
S21	5.3	35.9	11.8	1.8	20.0	0.2	-	-	-	-	4.8	0.5	18.8	0.9	434
S22	1.2	19.2	6.2	1.9	5.5	0.2	-	-	-	-	20.1	0.2	43.6	0.7	417
S23	2.0	22.0	6.7	1.0	14.2	-	-	-	0.2	-	15.4	0.2	36.9	1.4	432
S24	2.5	15.0	8.3	1.7	5.7	0.2	0.5	-	-	-	11.0	-	53.6	1.5	408
S26	2.2	24.1	10.9	2.0	8.0	-	0.2	-	0.5	-	12.2	-	40.7	1.2	403
S28	4.7	29.2	12.9	1.7	7.8	-	-	-	-	-	8.7	-	33.6	1.4	423
S31	1.6	21.7	10.7	2.3	7.2	-	-	-	-	-	17.3	1.2	37.9	-	428
S33	3.9	15.6	8.3	1.8	6.3	-	1.3	0.2	0.2	-	16.0	1.5	43.5	1.1	457
SR72	1.5	29.2	10.9	1.3	21.8	0.4	0.2	-	-	-	5.5	0.4	27.7	0.9	458
S34	1.7	27.6	14.2	2.5	4.7	-	0.5	-	0.2	-	9.2	0.2	37.8	1.2	402
S35	0.6	32.1	21.0	3.1	2.7	-	-	-	0.2	-	12.2	-	26.4	1.7	484
S36	2.7	22.8	10.3	2.5	0.5	0.2	-	-	-	-	11.3	0.5	47.8	1.5	408
S37	7.4	30.8	11.3	2.3	2.1	0.2	0.2	-	0.2	-	13.6	0.2	31.0	0.5	432
S38	32.3	38.5	7.8	1.4	1.6	0.2	-	0.2	-	-	2.3	0.2	15.4	0.2	514
S40	15.7	54.6	11.8	1.2	0.7	-	0.2	-	-	-	4.3	-	10.9	0.5	414
S41	3.1	47.9	16.0	2.9	1.2	0.2	0.5	-	0.2	-	6.7	0.5	19.5	1.4	420
S42	5.2	35.0	9.7	2.3	0.6	-	0.2	-	-	-	9.1	1.0	36.2	0.6	483
S43	10.8	39.6	20.1	1.8	0.7	-	0.7	-	-	-	7.6	0.2	17.6	0.9	437
S44	1.7	26.7	13.1	2.6	0.5	-	0.2	-	-	-	11.7	0.2	42.4	1.0	420
S46	0.7	33.3	14.9	1.7	1.0	-	0.2	-	-	0.2	9.6	-	37.4	1.0	417
S45	3.4	43.2	16.0	2.7	0.7	-	-	-	-	-	7.8	0.2	53.1	1.2	412
S48	7.5	51.4	17.0	1.7	1.4	-	-	-	-	-	6.4	0.2	12.7	1.7	424
S51	15.3	57.4	14.4	2.5	0.2	0.2	-	-	-	-	3.0	-	6.3	0.7	432

Table 5 (continued)

MINERAL PERCENTAGES FROM GRAIN COUNTS IN 2-4 PHI MAGNETIC
FRACTION. SAND DUNES (SD) AND COASTAL CLIFF (SC) EXPOSURES

Sediment Station	Opagues	Clinopyroxene	Green hornblende	Red hornblende	Hypersthene	Biotite	Muscovite	Epidote	Garnet	Volcanic glass	Feldspars	Quartz	Lithics	Unknown	Grains counted
SD25	10.3	40.2	13.2	1.8	12.6	-	-	0.2	-	-	3.9	-	17.4	0.5	438
SD27	19.9	41.0	12.6	0.5	10.8	0.2	0.2	-	-	-	4.4	0.5	9.6	0.2	427
SC29	1.9	2.7	3.9	1.0	1.0	0.2	0.2	0.5	0.5	0.5	16.1	-	68.6	1.9	411
SD30	20.9	35.3	12.7	1.6	11.1	0.5	-	-	-	0.2	4.9	0.2	12.0	0.5	425
SD32	3.8	33.0	14.5	1.7	14.3	0.2	-	-	-	-	8.6	-	22.6	1.4	421
SC49	10.5	29.4	3.6	1.7	1.9	0.5	0.2	-	0.2	0.2	24.6	1.5	24.6	1.0	477
SC50	8.8	47.3	17.2	1.7	0.5	0.5	-	-	-	-	11.7	0.2	11.0	1.2	419
SC59A	2.3	9.5	6.6	1.2	7.7	0.8	1.3	0.4	-	-	8.4	3.0	55.1	0.8	483
SC59B	4.4	2.6	5.4	0.7	0.2	0.7	0.2	0.2	0.5	-	11.0	1.9	70.8	1.4	428

Table 5 (continued)

MINERAL PERCENTAGES FROM GRAIN COUNTS IN 2-4 PHI MAGNETIC FRACTION
SOUTHWEST COAST, NORTH ISLAND RIVERS

	Opagues	Clinopyroxene	Green hornblende	Red hornblende	Hypersthene	Biotite	Muscovite	Epidote	Garnet	Volcanic glass	Feldspar	Quartz	Lithics	Unknown	Grains counted
RS52 (Patea)	3.4	5.0	2.7	0.7	-	0.5	0.7	0.2	0.5	-	4.0	1.2	80.1	0.9	438
RS47 (Waitotara)	4.5	6.9	2.4	-	0.5	0.5	0.2	0.2	0.7	-	7.1	2.1	73.2	1.0	423
RS39 (Wanganui)	1.6	6.2	3.7	0.5	2.3	0.2	0.2	0.2	0.5	0.2	8.5	1.8	72.7	1.3	433
RS17 (Whangaehu)	5.5	10.7	2.4	0.7	42.0	-	-	-	0.2	-	5.3	1.2	31.0	0.7	419
RS15 (Turakina Gravels)	6.5	1.2	2.4	0.2	5.8	-	0.5	0.2	0.5	0.5	4.3	1.4	74.8	1.2	416
RS16 (Turakina Fines)	3.6	4.1	2.2	0.7	2.4	-	0.2	-	0.5	0.2	3.1	0.5	81.6	1.2	413
RS18 (Rangitikei)	3.7	2.7	1.5	1.1	3.2	-	0.5	-	0.7	-	6.0	2.0	78.2	1.5	403
RS68 (Manawatu)	3.3	6.6	2.6	0.7	3.5	0.2	-	0.2	0.5	-	3.1	2.1	75.2	1.7	419

Table 5 (continued)

REPEAT BEACH SAMPLES - MANAWATU RIVER TO PATEA RIVER

Sediment Station	Opauques	Clinopyroxene	Green hornblende	Red hornblende	Hypersthene	Biotite	Muscovite	Epidote	Garnet	Volcanic glass	Feldspar	Quartz	Lithics	Unknown	Grains counted
SR64	1.9	4.3	3.8	1.2	0.9	0.2	0.7	0.5	0.7	0.2	9.5	0.7	74.5	0.9	422
SR65	2.4	5.0	3.3	0.7	0.5	-	0.7	-	0.2	-	9.3	1.0	75.8	1.0	421
SR66	1.9	10.6	1.9	0.6	2.8	-	0.7	0.2	0.7	0.2	16.1	0.9	63.4	1.2	416
SR67	1.2	10.5	2.4	1.9	5.4	-	0.7	-	0.2	-	10.2	0.5	65.7	1.2	411
SR53	2.9	12.8	5.3	0.2	3.9	0.5	0.7	-	1.0	-	8.7	1.4	62.3	0.5	414
SR54	3.1	5.2	3.1	1.2	0.9	-	0.7	-	0.7	-	8.1	0.7	75.4	0.9	422
SR55	4.3	15.5	7.7	0.7	4.9	0.2	1.0	-	1.0	0.2	8.0	0.7	54.1	1.7	414
SR56	2.2	25.2	12.6	1.5	14.0	-	0.7	0.2	0.2	-	8.5	0.5	33.4	1.0	413
SR69	3.4	22.4	9.0	1.4	9.0	0.2	0.2	-	0.2	-	8.6	0.2	44.2	1.2	420
SR70	2.1	34.7	8.1	1.6	11.2	-	0.7	-	0.2	-	7.7	0.2	32.5	1.0	429
SR71	0.9	28.2	6.6	1.5	9.9	0.2	-	-	0.2	-	12.2	1.2	38.2	0.9	425
SR57	1.9	17.0	7.5	1.0	5.1	0.2	-	-	-	-	16.1	1.7	48.4	1.0	411
SR58	1.6	16.8	4.8	2.8	2.8	0.2	0.9	-	0.5	-	9.4	0.9	59.0	0.7	434
SR60	3.9	23.5	5.8	1.0	2.7	0.5	-	-	-	-	19.1	1.0	41.9	0.7	413
SR61	0.7	15.6	6.2	1.4	1.4	-	-	0.2	-	0.2	11.3	1.9	59.5	1.4	417
SR62	3.2	46.3	14.9	1.0	1.7	-	-	0.2	0.2	-	9.0	0.7	21.5	1.2	410
SR63	8.0	29.6	9.6	1.2	0.7	0.2	0.2	-	0.2	-	14.4	1.0	34.4	0.7	425
SR73	25.3	36.7	8.3	1.1	0.5	-	-	-	-	-	9.2	-	11.6	0.7	447
SR74	3.0	45.7	10.6	1.9	0.7	0.2	-	-	-	-	21.7	-	15.7	0.5	423
SR75	1.8	42.4	13.0	2.3	0.5	-	0.2	-	0.5	-	18.0	0.2	20.4	0.7	430
SR76	16.7	46.6	13.0	1.0	0.2	-	-	-	-	-	9.7	0.5	11.6	0.7	427
SR77	5.3	40.9	11.9	2.2	0.2	-	-	-	0.2	-	17.9	-	21.2	0.2	427
SR78	1.5	38.6	12.0	1.7	0.2	-	-	0.2	0.2	-	25.4	0.2	19.5	0.5	424
SR79	2.3	50.3	13.1	1.3	0.5	-	0.2	-	-	0.2	16.2	-	15.5	0.5	418

Table 6

MINERAL PERCENTAGES FROM GRAIN COUNT IN 2-4 PHI
NON MAGNETIC FRACTION. BEACHES FROM, MANAWATU RIVER
TO PATEA RIVER

Sample Station	Quartz	Plagioclase Feldspar	Alkali Feldspar	Total Feldspar	Glass	Total Lithics	Others	Total Grains	Feldspar: Quartz Ratio
S1	43.2	40.8	0.5	41.3	-	14.8	0.7	404	0.96
S2	42.3	41.2	0.2	41.4	0.5	14.8	1.0	402	0.98
S3	40.2	38.0	0.2	38.2	0.2	20.7	0.7	409	0.95
S4	40.7	41.2	0.5	41.7	-	17.7	0.5	407	1.04
S5	41.1	39.7	0.7	40.4	0.2	17.8	0.5	403	0.98
S6	45.7	32.8	1.0	33.8	0.7	19.3	0.5	406	0.74
S7	47.2	33.1	0.2	33.3	0.7	18.6	0.2	404	0.71
S8	46.3	35.1	0.5	35.6	0.2	17.4	0.5	408	0.77
S9	43.7	39.4	0.2	39.6	0.5	15.7	0.5	402	0.91
S10	37.5	38.8	0.7	39.5	0.2	22.3	0.5	401	1.05
S11	36.6	41.0	0.2	41.2	0.2	21.6	0.2	403	1.13
S12	40.0	41.5	0.5	42.0	0.5	17.0	0.5	404	1.05
S13	37.8	36.4	-	36.4	0.7	25.1	-	407	0.96
S14	41.0	36.0	0.7	36.7	0.7	21.3	0.2	400	0.90
S19	39.2	38.9	0.5	39.4	0.2	20.7	0.5	403	1.01
S20	37.3	47.2	0.5	47.7	-	13.9	1.0	401	1.28
S21	32.1	47.2	0.7	47.9	-	19.8	0.5	405	1.49
S22	28.7	51.2	1.0	52.0	0.2	17.8	1.2	404	1.81
S23	43.6	40.6	0.2	40.8	-	14.0	1.2	406	0.94
S24	37.3	43.7	1.4	45.1	-	16.8	0.7	404	1.17
S26	25.3	51.0	1.0	52.0	-	22.3	0.5	408	2.06
S28	29.3	48.3	0.5	48.8	-	21.8	0.3	400	1.66
S31	23.2	51.6	-	51.6	-	24.9	0.2	401	2.22
S33	26.6	52.5	0.7	53.2	-	20.2	-	406	2.00
SR72	23.2	54.0	0.5	54.5	-	21.6	0.7	408	2.35
S34	18.6	59.0	1.3	60.3	0.5	20.4	0.2	402	3.24
S35	20.8	57.8	0.5	58.3	-	20.8	0.3	400	2.80
S36	25.6	47.8	2.0	57.8	0.2	24.0	0.2	403	2.26
S37	23.7	50.1	0.7	50.8	1.0	24.7	-	431	2.14
S38	28.5	48.5	0.7	49.2	0.2	18.3	0.7	404	1.73
S40	26.3	52.8	1.0	53.8	0.2	19.4	0.7	415	2.05
S41	20.8	58.1	0.5	58.6	0.2	19.6	0.7	403	2.82
S42	26.1	59.1	-	59.1	0.2	14.5	-	401	2.26
S43	22.9	59.3	0.2	59.5	-	17.2	0.5	402	2.60
S44	22.7	53.1	1.1	54.2	-	22.7	-	400	2.34
S46	24.5	49.0	0.2	49.2	-	26.3	-	400	2.01
S45	22.9	52.7	0.7	53.4	1.0	22.1	0.5	402	2.33
S48	24.9	55.3	-	55.3	-	19.5	0.2	405	2.22
S51	21.3	62.5	-	62.5	-	13.9	1.2	403	2.93

Table 6 (continued)

 MINERAL PERCENTAGES FROM GRAIN COUNTS IN 2-4 PHI NON MAGNETIC FRACTION.
 SOUTHWEST COAST, NORTH ISLAND RIVERS

	Quartz	Plagioclase Feldspar	Alkali Feldspar	Total Feldspar	Glass	Total Lithics	Other	Grains Counted	Feldspar: Quartz Ratio
RS52 (Patea River)	26.8	54.0	0.2	54.2	-	18.0	1.0	401	2.02
RS47 (Waitotara River)	25.3	56.3	-	56.3	-	17.9	0.5	402	2.23
RS34 (Wanganui River)	31.3	46.2	0.7	46.7	0.7	20.3	0.5	411	1.49
RS17 (Whangaehu River)	33.1	48.2	0.2	48.4	0.5	17.0	1.0	404	1.46
RS15 (Turakina River Gravels)	40.2	39.4	0.2	34.6	-	19.5	0.7	403	0.99
RS16 (Turakina River Fines)	38.2	41.0	0.5	41.5	-	19.1	1.2	409	1.09
RS18 (Rangitikei River)	44.0	39.1	0.2	39.2	0.5	16.1	0.2	405	0.89
RS68 (Manawatu)	38.9	42.0	0.2	42.2	-	17.7	1.2	406	1.08

Table 6 (continued)

 MINERAL PERCENTAGES FROM GRAIN COUNTS IN 2-4 PHI NON MAGNETIC FRACTION
 SAND DUNES (SD) AND COASTAL CLIFF EXPOSURES (SC)

Sediment Station	Quartz	Plagioclase Feldspar	Alkali Feldspar	Total Feldspar	Glass	Total Lithic	Other	Grains Counted	Feldspar: Quartz Ratio
SD25	29.3	44.6	2.0	46.6	1.3	21.6	1.0	403	1.59
SD27	30.0	42.5	0.7	43.2	0.2	26.1	0.5	407	1.44
SC29	25.8	51.6	1.2	52.8	0.5	20.4	0.2	403	2.05
SD30	32.4	42.4	0.2	42.6	0.2	23.8	1.0	408	1.31
SD32	26.7	45.9	0.2	46.1	-	26.7	0.5	405	1.72
SC49	24.1	53.1	-	53.1	-	22.1	0.7	409	2.20
SC50	23.0	54.7	-	54.7	-	20.5	1.5	404	2.38
SC59A	26.7	50.2	0.7	50.9	-	21.4	1.0	409	1.90
SC59B	24.5	52.2	0.5	52.7	-	22.1	0.7	405	2.15

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