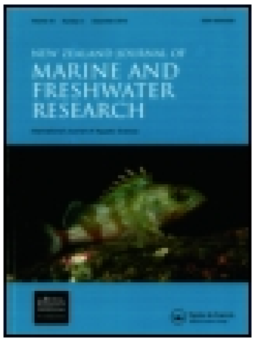

New Zealand Journal of Marine and Freshwater Research

ISSN: 0028-8330 (Print) 1175-8805 (Online) Journal homepage: http://www.tandfonline.com/loi/tnzm20

A textural analysis of Wellington Harbour sediments

Willem J. M. van der Linden

To cite this article: Willem J. M. van der Linden (1967) A textural analysis of Wellington Harbour sediments, New Zealand Journal of Marine and Freshwater Research, 1:1, 26-37, DOI: 10.1080/00288330.1967.9515189

To link to this article: http://dx.doi.org/10.1080/00288330.1967.9515189

A TEXTURAL ANALYSIS OF WELLINGTON HARBOUR SEDIMENTS

WILLEM J. M. VAN DER LINDEN

New Zealand Oceanographic Institute, Department of Scientific and Industrial Research, Wellington

(Received for publication 25 August 1966)

SUMMARY

Grain-size and carbonate analyses have been carried out on bottom sediment samples of Wellington Harbour. From grain-size parameters it was possible to establish a number of facies types and to outline sediment sources and directions of transport.

INTRODUCTION

In November 1964 a detailed benthic survey was carried out in Wellington Harbour under E. W. Dawson, and at the same time bottom samples were obtained for comparing faunal and sediment distributions. These samples and some supplementary collections form the basis of the present study.

Wellington Harbour (Port Nicholson or Te Whanganui a Tara) is a natural basin. Morphologically it may be defined as a hill-and-valley system drowned by the post-glacial rise in sea level. Bell (1910) mapped the hills and valleys as horst and graben structures of a block-faulted peneplain. Cotton (1957) advanced the theory that the Harbour basin is the product of transcurrent buckling along the Wellington Fault. Several attempts have been made, sometimes with much imagination, to trace the submarine extensions of faults of which the surface expressions stand out clearly on land (Adkin 1956; Lauder 1962; Grant-Taylor 1965).

The bottom of the Harbour basin is almost flat but slopes down gently towards a central depression trending NNE-SSW from near Somes Island towards Worser Bay. This depression might be interpreted as the surface expression of either a graben or a fault trace.

The maximum extent of the Harbour waters coincided with the Thermal Maximum, 7000–4000 B.P.; since then the Harbour coastline has been modified by a eustatic fall in sea level and by uplifts associated with earthquakes. According to Stevens (1956) the two latest substantial uplifts amounted to 4–5 ft in the sixteenth or seventeenth century and 5 ft in 1885.

The north-western coastal outline is defined by the Kaiwharawhara and Petone traces of the Wellington fault zone. The delta of the Hutt River forms the northern margin, and the headland and bay beaches the eastern margin. The southern boundary is formed by a North–South-trending ridge-and-valley system—Hataitai, Wellington Airport, Miramar Peninsula, and the Harbour entrance. Before the penultimate uplift, and the subsequent linking of Miramar Island to the mainland by a sandy isthmus (Best 1923; Stevens 1956), Evans Bay, the site of Wellington Airport, and Lyall Bay formed another connection with Cook Strait.

The bathymetry of the basin is given in the accompanying chart.* Previous work established a tidal surface current pattern, based on drift float, dye patch, and discoloured freshwater movements. A simplified generalised picture shows a clockwise flood current and an anticlockwise ebb current pattern (Brodie 1958).

SAMPLING

Most of the samples (D 276 – D 388) were collected during the N.Z. Oceanographic Institute's Wellington Harbour cruise "Benthos", 18–21 November 1964; these were taken from the Institute's vessel *Taranui*, mostly by orange peel grab. Additional samples (D 425 – D 465) were obtained with Dietz grab from nearshore waters in depths less than 6 fathoms on 5 and 6 June 1965 from the police launch *Lady Elizabeth*. Sample localities are given in the chart.

ANALYSES

MECHANICAL ANALYSIS

Samples were treated with a 10% hydrogen peroxide solution to remove organic matter and with a 6N hydrochloric acid solution to remove calcium carbonate. Samples were then washed through a Büchner funnel and sieved wet on a 0.064 mm sieve. In each sample the fraction smaller than 0.064 mm was dispersed with 0.1 mole sodium oxalate and 0.02 mole sodium carbonate and a pipette analysis was made. The fractions 0.064–0.032, 0.032–0.016, 0.016–0.008 mm, and finer than 0.008 mm were determined, and thus percentages at 1.0 phi intervals obtained (phi $= -\log_2$ diam. (mm)). The fraction coarser than 0.064 mm of each sample was dried and sieved at 0.5 phi intervals.

CARBONATE ANALYSIS

To eliminate the effect of granular variations the samples were crushed in a mortar and the fraction 0.125–0.500 mm obtained by sieving. One gram of this material was treated with 20 cc hydrochloric acid 1N for 10 minutes at 50°–60°C. Using methyl orange as an indicator the amount of superfluous hydrochloric acid was titrated with a 1N solution of sodium hydroxide.

A simple nomogram (Fig. 1) based on the analyses of pure (100%) calcium carbonate and of a blank provided a rapid method of obtaining the required percentage. An advantage of the nomogram is that the normality of the reagents is not critical, but a new nomogram must be constructed every time new reagents are used.

* Chart of Wellington Harbour sediments in pocket inside back cover.

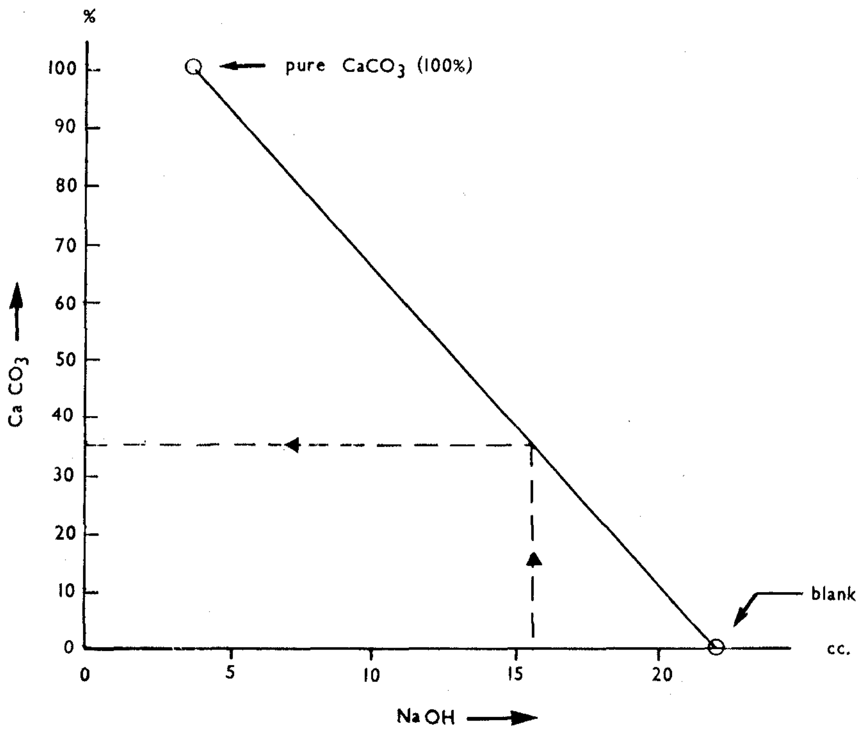

FIG. 1—Nomogram for the determination of carbonate percentages.

EVALUATION OF DATA

From the raw data of the mechanical analyses cumulative percentages were calculated and these were plotted on arithmetic probability paper. From the curves obtained, the median diameter (Md or 50 percentile) and the quartile values (Q1 and Q3, the 25 and 75 percentiles respectively; Q1 > Q3) were derived as sample statistics. These enabled sorting ($So = \sqrt{Q1/Q3}$) and skewness ($Sk = Q1.Q3/Md^2$) to be estimated.

Most samples belong to the mud (pelite) range (< 0.064 mm). Therefore, as the lower limit of the analysis was 0.008 mm, no 84 percentile and certainly no 95 percentile could be estimated for the majority of samples. As a result, calculations of better statistical parameters such as mean diameter, standard deviation, and skewness as defined by Inman (1952) or even better as defined by Folk and Ward (1957) could not be made. Md, $\sqrt{Q1/Q3}$, and $Q1.Q3/Md^2$ are limited as characteristic values, especially as the greater number of samples show a polymodal grain-size distribution. The parameters therefore, are only broad indicators of average size, degree of sorting, and degree of asymmetry.

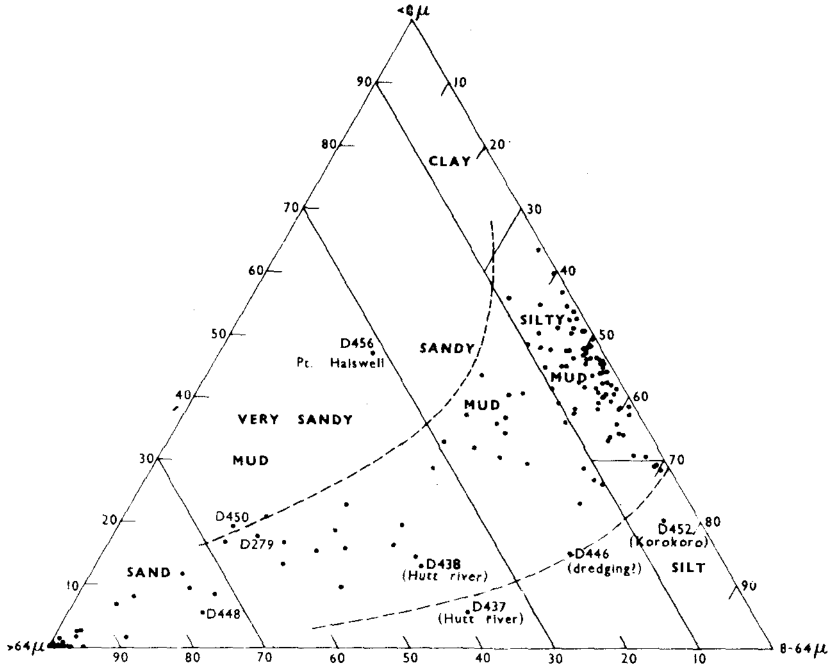

FIG. 2—Classification diagram based on sand–silt–clay ratios (modified from Bouma and Nota 1961, table p. 61). (N.B. mud ≡ pelite.)

SIZE FREQUENCY

To compensate for the limitations mentioned above, a triangular diagram was used to show the proportions of sand, silt, and clay. The diagram is based on the general classification and terminology of Bouma and Nota (1961); slight modifications have been made to the size limits (Fig. 2). Its practical value was tested on a variety of samples by comparing field nomenclature with plotted analytical results. It differs markedly from the usual sand–silt–clay diagram in that for practical purposes clay is defined as the fraction smaller than 0.008 mm, the lower limit of the mechanical analysis. Modal frequency based on this diagram gives a more realistic characterisation of the sediments than can be obtained from median diameters only. The majority of samples are within the area enclosed by dashed lines in Fig. 2. This area has a normal sediment "population", pure silt and pure sand–clay mixtures being extremely rare. For easy reference some samples are indicated with sample number and locality.

The areal distribution of sediment types based on the classification diagram is given on the chart, and the median diameter values of 0.008, 0.016, 0.032, 0.064, and 0.250 mm have been contoured.

SORTING

Sorting coefficients (So = $\sqrt{Q1/Q3}$) have been plotted on the chart. The values 1.25, 2.00, and 3.00 have been contoured. Sorting grades have been modified after Füchtbauer (1959):

1.00–1.25 very well sorted,
1.25–2.00 moderately well sorted,
2.00–3.00 very poorly sorted,
> 3.00 extremely poorly sorted.

Intermediate grades of sorting were not distinguished, as they are confined to fairly narrow zones and sufficient data for contouring these values were lacking.

SKEWNESS

The skewness values (Sk = $Q1.Q3/Md^2$) of all samples have been grouped at 0.10 Sk intervals and combined in a frequency diagram (Fig. 3). The diagram shows a bimodal distribution of skewness values: modes are 0.60 and 1.00. The former mode indicates that there are more fine than coarse grades in the samples, the latter indicates a perfect symmetry with coarse and fine grades evenly distributed over the size interval between 25% (Q1) and 75% (Q3). Samples D 279 and D 456 have highly anomalous skewness values, 5.14 and 13.80 respectively, and were not plotted in the histogram.

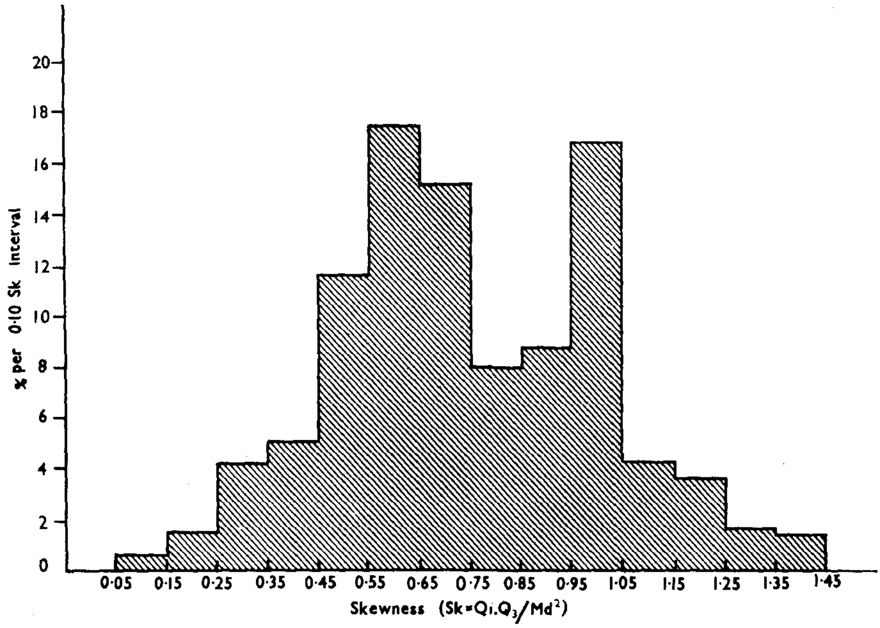

FIG. 3—Skewness frequency diagram.

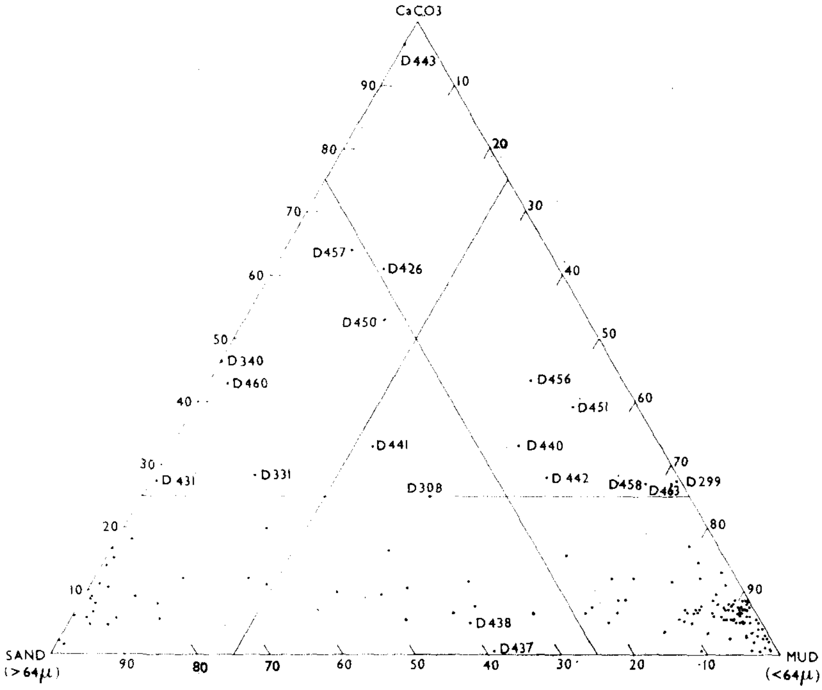

FIG. 4—Sand–mud–carbonate ratios (diagram after Füchtbauer 1959).

CALCIUM CARBONATE

Results of the carbonate analyses and mechanical analyses of the clastics coarser than 0.125 mm were combined in a triangular diagram (Fig. 4) (Füchtbauer 1959). The average value for the carbonate content of the samples with less than 80% mud is 10%, and 7% for the samples with more than 80% mud. The latter result may have been influenced considerably by the restriction of the carbonate analysis to the fraction coarser than 0.125 mm. Samples with anomalous carbonate concentrations, over 25%, have been indicated with their sample numbers for easier reference. Samples D437 and D438 from the mouth of the Hutt River with very low carbonate values, have also been indicated.

In much the same way as for the size frequency, the areal distribution of sand–mud–carbonate concentrations derived from the triangular diagram is shown in the chart. The higher concentrations of bivalves, live and dead, are also plotted from superficial examinations of the bulk samples.

INTERPRETATION

Strong to gale force winds, common in the Wellington area especially in winter, have a marked effect on the hydrology and therefore on sediment distribution, although not to the extent that movements of discoloured fresh water on the surface might suggest. Surface movements indicate the transport of suspended material, but the movement of bed load is much more restricted. It has been demonstrated that suspended material moves in a thin sheet of discoloured water over a zone of clear water (Brodie 1958). The effect of wind-induced water turbulence on the bottom sediments is restricted to the shore and very shallow waters and to the narrow Harbour entrance. During stormy periods substantial recessions of the shoreline occur at the many headland and bay beaches; subsequently equilibrium is re-established by redistribution and accretion of sediment.

Facies types denoting the different environments in Wellington Harbour can be distinguished. They are defined mainly on the basis of a combination of hydrology, sediment supply, textural, and topographical characteristics:

(1) Strong tidal currents, topography, sorting, and coarseness of sediments define the Harbour entrance facies.

(2) Topography, its influence on the current regime and texture define the Somes Island facies.

(3) Sediment supply is the decisive factor defining the Hutt, the Ngauranga, the Kaiwharawhara, and to a lesser extent the Korokoro fluvio-marine facies.

(4) Marginal facies types in micro-environments such as Evans Bay, the headland and bay beaches of the east coast and Miramar Peninsula, the Point Halswell and Point Jerningham promontories, are well defined by topographical and textural characteristics.

(5) The central harbour facies is characterised mainly by the occurrence of very poorly sorted silty pelites.

HARBOUR ENTRANCE FACIES

Both the relative coarseness and the well sorted nature of the sediments in the Harbour entrance characterise it as a winnowed deposit. In the narrowest part of the Heads, off Seatoun, sandy gravels occur (D 332); their skewness values centre on modality 1.00, thus indicating perfect symmetry. This means that silt and clay are not being deposited and any such material previously deposited is being removed. Furthermore, there is no supply of grades coarser than fine gravel. The current velocities (approx. $\frac{1}{2}$ knot at the surface) are too low to transport granule- and sand-sized particles from either Cook Strait or from the inner harbour. Under severe stormy conditions coarse material from nearby sources, such as headland and bay beaches of Miramar and the east coast, may be brought to the Harbour entrance and trapped in this bottleneck. The maximum grain size of these adjacent beaches determines the maximum grain size of the Harbour entrance sediments.

The area is suitable for the accumulation of shell and coarse shell fragments (samples D 331, D 426, and D 431). This is partly due to the growth of specimens in the area, but some of the shell fragments may have been transported in hydrodynamic equilibrium with clastic granules and fine pebbles during storms.

SOMES ISLAND FACIES

Erosion of the island results in the accumulation of coarse clastics at the base of the steep greywacke cliffs. This coarse material forms an apron around the island, elongated in a WNW–ESE direction. The eastern part of the apron joins a sandy pelite salient which forms an anomalous zone of slightly coarser sediments east and south of Somes Island.

The island acts as a breakwater for both north and south flowing currents, and is therefore a sediment trap for the silt and clay derived from the Harbour entrance and from the Hutt River.

The mixing of coarse and fine clastics results in a poorly sorted polymodal sediment. Sorting coefficients reach the maximum of 7.7 for sample D 324. Apart from samples D 442 and D 443, where the coarser clastics are dominant, the skewness values for the area indicate a strong asymmetric tendency towards the finer fraction.

The immediate vicinity of Somes Island seems to favour the growth of a rich bottom fauna; brachiopods, lamellibranchs, gastropods, and echinoderms (ophiuroidea and echinoidea) are abundant. This is reflected in the high carbonate content of the sediment: D 440, 33%; D441, 33%; D442, 28%. Sample D443 is almost entirely shell grit and clastic components comprise only 1.5%.

NORTH-WESTERN FLUVIO-MARINE FACIES

The north-western boundary of Wellington Harbour is a steeply cliffed coast marking the Wellington fault zone. The coast is open to the full force of high breakers generated by southerly winds; this causes active erosion, the effect of which is shown by the presence of a zone of coarse clastics at the base of the cliff face. (The very coarse material forming narrow beaches of shingle and pebble is not shown in the chart.)

Off the mouth of the Kaiwharawhara, Ngauranga, and Korokoro Streams the zone of coarse clastics is covered by silty pelites supplied by the streams. Once in the Harbour these muds spread north and south and mix with the cliff debris to form very poorly sorted sands and sandy pelites. The occurrence of very pure silts off the Kaiwharawhara and Korokoro Streams (samples D 276, D 280, D 461, and D 452) points to a supply of material well sorted by these rivers.

The area immediately north of the mouth of the Ngauranga Stream is another spot favourable for the growth of invertebrates. This again is revealed in the high carbonate percentages (D 450, 53%; D 299, 27.5%; and D 451, 39%). The occurrence is probably associated with both the grain-size distribution and the supply of offal from the Ngauranga Meatworks through Ngauranga Stream.

HUTT RIVER DELTA

The major source of sediment for Wellington Harbour is the Hutt River. The bed load of the river in its lower regime consists of poorly sorted sandy pelite and part of this material is deposited in a zone

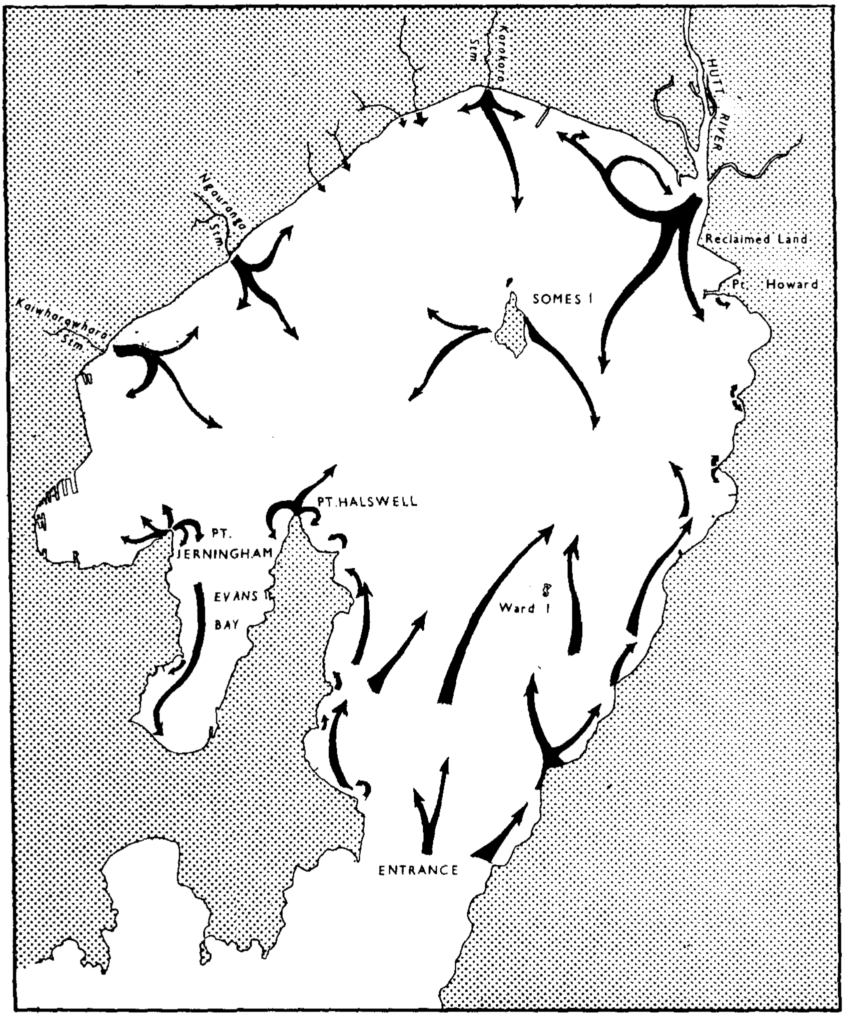

FIG. 5—Supply and transport directions of sediment in Wellington Harbour.

several hundred yards wide bordering the Petone foreshore. A small spit and some sand flats in the river mouth indicate longshore drift in an easterly direction. Another part of the bed load is carried in a southerly direction following the eastern shore line. There is some evidence of the transport of Hutt River sediments in the direction of Somes Island as indicated by the shape of the 0.008 and 0.016 mm median diameter contours off the river mouth (*see* chart). The amount of Hutt River sediment transported and deposited is not clear, as the sandy pelites are covered by a veneer of silty pelite of unknown thickness. In recent years part of the delta north of Point Howard has been reclaimed.

Observations of discoloured freshwater movements, especially after periods of heavy rain (cf. Brodie 1958), show that part of the sediment of the Hutt River is supplied to the Harbour in suspension. No measurements of the amounts falling out of these suspension clouds in the Harbour have been made, but observations show that a significant part of the thin discoloured layer can be carried out through the Heads. It is therefore suggested that suspended material derived from the Hutt River makes only a minor contribution of fine particles to the Harbour sediments.

Marginal Environments

In July 1965 storm-generated waves at Seatoun caused a strong recession of the beach profile. Most of the headland and bay beaches bordering Port Nicholson in the east and in the south are subject to the same process.

Horizontal beach profiles are, in general, suspended between two fixed points—the adjacent headlands—and the shore line will adjust itself by accretion or erosion to a smooth curve between such points. The 1855 uplift created a new marginal topography for the area to which the present beach lines are not yet adjusted. The full power of wave attack is concentrated on the many headlands that project into the sea; erosion products accumulate on the bay-beaches on either side of the promontories and this results in a gradual straightening of the coastline. For instance, in Evans Bay (*see* chart) the isobaths show that an incipient sill links Point Jerningham and Point Halswell, and as rectification of the coastline continues the bay will eventually be cut off. Considering the present depths of water between these points, however, both bar formation and natural shoaling from the head of the bay will be very slow.

The erosion products accumulating immediately off the headlands are poorly sorted, angular, and coarse, whereas the beach deposits have passed through successive erosion and deposition cycles in the breaker zone and consist of well rounded and well sorted pebbles and shingle.

Central Harbour Facies

Sediments of the Harbour floor, with the exception of the areas dealt with in foregoing paragraphs, show fairly uniform textural characteristics. They all belong to the silty pelite grade with medium diameters roughly between 0.008 and 0.016 mm. The sorting is very poor to extremely poor as a result of the mixing of material of various grades and origin. There is a gradual transition into the Harbour entrance facies through a zone of sandy and very sandy pelites.

Three isolated patches with median diameters smaller than 0.008 mm indicate areas of low bottom-current velocities. The one south of Somes Island coincides with the deepest part of the Harbour. Skewness values indicate an asymmetric tendency towards the fine grades. The carbonate percentages show an even more uniform distribution with the exception of sample D 463, which shows an anomalous high concentration. This anomaly does not appear to be related to textural characteristics, and may reflect a concentration of faunal remains.

CONCLUSIONS

A number of facies types based on broad textural characteristics can be distinguished in Wellington Harbour. The overall picture shows a fairly uniform sediment distribution covering a smooth flat bottom. The sediments consist mainly of poorly sorted silty pelites with an average carbonate content of 10%. Coarser sediments are restricted to the Harbour entrance and nearshore areas; the Harbour entrance sediments are characterised by perfect sorting and almost symmetrical modal frequency.

Deductions from textural analysis of the sediments have been used in constructing Fig. 5 to indicate the supply and transport of sediments. Some areas apparently favour the development of a relatively rich testacean bottom fauna (*see* chart), e.g., bivalves are most abundant amongst the coarser clastics such as those off Somes Island, immediately north of the Ngauranga Stream, off Point Halswell, in southern Evans Bay, and at the Heads. These occurrences are probably not related to grain-size distribution only, but may be substantially favoured by other ecological factors, such as the presence of offal of the Ngauranga Meatworks and the existence of higher current velocities at the Heads bringing in food from Cook Strait.

ACKNOWLEDGMENTS

The author wishes to thank especially the Wellington Harbour Police, who made the launch *Lady Elizabeth* available for the collection of samples in shallow areas. He also wishes to thank members of the N.Z. Oceanographic Institute for their help in the collection and analyses of the material; Dr G. R. Stevens, N.Z. Geological Survey, for critical comment on the manuscript; and Mr C. T. T. Webb and Mr K. Little for draughting services.

REFERENCES

ADKIN, G. L. 1956: The Seatoun Fault, Miramar Peninsula, Wellington. *Trans. R. Soc. N.Z. 84:* 273–7.

BELL, J. M. 1910: The physiography of Wellington Harbour. *Trans. N.Z. Inst. 42:* 534–40.

BEST, E. 1923: Miramar Island and its history. *Trans. N.Z. Inst. 54:* 779–91.

BOUMA, A. H. and NOTA, D. J. G. 1961: Detailed graphic logs of sedimentary formations. *Rep. Int. Geol, Congr. 21:* 52–74.

BRODIE, J. W. 1958: A note on tidal circulation in Port Nicholson, New Zealand. *N.Z. Jl Geol. Geophys. 1 (4):* 684–702.

COTTON, C. A. 1957: Tectonic features in a coastal setting at Wellington. *Trans. R. Soc. N.Z. 84:* 761–90.

FOLK, R. L. and WARD, W. C. 1957: Brazos River bar: A study in the significance of grain size parameters. *J. sedim. Petrol. 27(1):* 3–26.

FÜCHTBAUER, H. 1959: Zur Nomenklatur der Sedimentgesteine. *Erdöl Kohle 12:* 605–13.

GRANT-TAYLOR, T. L. 1965: "Geology of Wellington. A Tour Guide." N.Z. Geol. Surv. Handbook.

INMAN, D. L. 1952: Measures for describing the size distribution of sediments. *J. sedim. Petrol. 22:* 125–45.

LAUDER, W. R. 1962. Port Nicholson and the "plough" mechanism in transcurrent faulting. *N.Z. Jl Geol. Geophys. 5(1):* 189–91.

STEVENS, G. R. 1956: Earth movements in the Wellington area. *N.Z. Geogr. 12(2):* 189–94.