CHAPTER 73

FIELD INVESTIGATION OF SEDIMENT TRANSPORT PATTERN IN A CLOSED SYSTEM

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INTRODUCTION

In order to elucidate the transport pattern of sediment in a closed system, a pocket beach was chosen and investigated from various aspects. This investigation included the following studies: (1) bathymetric survey by an echo sounder, (2) survey of submarine geology using an acoustic probe, (3) observation of nearshore current systems using floats, (4) documentation of the transport pattern of suspended sediment by aerial photographs, (5) examination of depositional environments of bottom and beach material by sieve analysis, (6) inference of long-term alongshore sediment transport pattern from the grain size properties of beach sand, and measurement of short-term trends by use of fluorescent sand, and (7) examination of long-term shoreline change using old and recent maps.

STUDY AREA

A study area was located at the bay head of Katsu'ura bay, Chiba prefecture, Japan, facing the Pacific Ocean (Fig. 1). The bay is a semicircular shape (approximately 2 km in diameter) having a south-oriented bay axis, and is bordered by coastal cliffs made of Pliocene sedimentary rocks (Fig. 2). The coastal cliff in the study area is made of Katsu'ura formation which is the alternation of sandstone and siltstone strata; these strata strike N40-50°E and dip 5-10°N. In front of the cliff a narrow sandy beach stretching 1.3 km develops. Little seasonal change of this beach has been observed. There is no major supply source of beach sand in or near the study area. The direction of wave approach is nearly normal to the beach. Tidal range at spring tide is about 1.5 m, while at neap tide is about 0.7 m.

SUBMARINE TOPOGRAPHY AND GEOLOGY

The topographical and geological surveys revealded that (1) the submarine topography consisted of portions having smooth submarine contours and irregular ones (Fig. 3), (2) the former portion was of sandy sediment, while the latter of exposed bedrock (Fig. 4), (3) from the shoreline up to a water depth of about 5 m, there was little difference between the depths of the bedrock surface and the adjacent sand bottom, while in deeper regions there existed a marked topographic break that the bedrock surface was located 2-3 m higher than the sand bottom (Fig. 5), (4) the submarine bedrock was also made of Katsu'ura formation, and (5) a veneer of sandy sediment developed spottedly on the bare bedrock.

Submarine bedrock configuration shows the existence of a large depression in the western part of the study area (Fig. 6). Figure 7 is an isopach map of sandy sediment, which was plotted on the basis of Figs. 3 and 6; the western portion constitutes a notable sedimentary region.

NEARSHORE WATER CIRCULATION PATTERN

For the measurement of nearshore current pattern, floats with current-crosses were released and traced by transits. The result showed a characteristic pattern: in the areas of exposed bedrock onshore currents developed, while in the adjacent sandy areas offshore currents occurred. This water circulation pattern is shown in Fig. 8, in which H_b = breaker height, T = wave period, U = average wind velocity obtained by the observatory located near the study area, and the letters in brackets show wind direction. Since the nearshore bedrock areas are higher than the adjacent sand areas, it is clear that the underwater topography gives rise to wave convergence in the bedrock regions and to divergence in the sandy areas; longshore currents flowing away from the zones of convergence turn seaward in the zones of divergence, forming the offshore currents.

Since the surface of exposed bedrock has changed little, submarine topography has determined the nature of wave-induced current fields: in the areas of the bedrock onshore currents dominate, while in the adjacent sandy areas the prevailing offshore currents occur.

SUSPENDED SEDIMENT TRANSPORT PATTERN

The transport pattern of suspended sediment was investigated by air-photo interpretation. Photographs were taken on Nov. 27-29, 1974 by attaching a blue-cut filter to an air-born camera in order to obtain clear underwater information (Lockwood et al., 1974). The photo scale was 1/10000. Figure 9 shows the transport patterns obtained from these photographs.

On the basis of ordinary black and white aerial photographs (scale: approx. 1/10000) taken at several different times, the locations of offshore transport of suspended sediment were depicted (Fig. 10).

Figures 9 and 10 indicate that the prevailing offshore transport occurs in the regions of sand bottom, irrespective of input wave conditions. This result reconfirms the occurrence of offshore currents in the sandy regions, and furthermore suggests the existence of onshore currents in the bedrock regions.

DEPOSITIONAL ENVIRONMENTS OF BOTTOM AND BEACH MATERIAL

On the basis of sieve analysis of submarine and backshore sand samples, the mean diameter in phi scale, $M\phi$, as a grain size parameter and its standard deviation, $\sigma\phi$, as a sorting measure were calculated. Figure 11 shows the areal distribution of $M\phi$ of 63 underwater samples; $M\phi$ in the bedrock regions is generally smaller than that in the sandy area. Namely, sediment in the former is larger than that in the latter. On the other hand, $\sigma\phi$ did not show such a distinctly zonal distribution.

The existence of coarser sediment in the zones of the exposed bedrock suggests that this material would probably be produced by bedrock erosion, although its quantity would be very small due to high resistivity of the bedrock to wave erosion.

Figure 12 illustrates the alongshore variation of $M\phi$ and $\sigma\phi$ of the backshore sand samples which were taken from 24 locations shown in Fig. 3; there is larger and poorly sorted beach sand in the vicinity of location Nos. 5 and 13. Since the areas of bare bedrock in the seaward regions of these localities are larger (Fig. 4), this result suggests that the coarser material on the bedrock could be transported to the beach by the onshore currents dominating in the bedrock regions.

ALONGSHORE SEDIMENT TRANSPORT PATTERN

Considering the beach locations of Nos. 5 and 13 as supply sources of littoral drift to the whole beach, the direction of alongshore sediment transport was inferred from the variation series of $M\phi$ and $\sigma\phi$ (Sunamura and Horikawa, 1972). The result is shown by arrows in Fig. 12: westward transport dominates in the western part of the beach, while transport pattern in the eastern part is complicated.

In addition to this study of long-term trends of transport pattern, short-term phenomena were investigated by tracing different-colored fluorescent sand which was released at three different alongshore locations (Fig. 13). Figure 13 shows that the transport direction at each location varies according to wave conditions.

LONG-TERM SHORELINE CHANGE

The examination of shoreline change during the period of 87 years from 1883 to 1970 indicated that the beach had been suffering erosion at a mean annual rate of 0.1-0.4 m/year (Fig. 14). Since (1) the study area was uplifted 30 cm at the time of Great Kanto Earthquake in 1923 (Omura, 1926) and (2) it was also uplifted about 5 cm during the period from 1923 to 1965 (Fujii, 1968), it is clear that this whole beach has been eroded more severely. This means that all the material once washed away from the beach has not been returned to the beach, i.e. that the pattern of long-term sediment transport has not formed a closed loop.

INFERRED SEDIMENT TRANSPORT PATTERN

Figure 15 is an illustration of the sediment transport pattern inferred from the above various investigation results. Material resting on the exposed bedrock is transported shoreward by the onshore currents, drifted alongshore on the beach or in the surf zone, and eventually transported offshore by the offshore currents. The characteristics of submarine topography tell that the material transported offshore to the regions shallower than a water depth of 5 m has the possibility of being carried to the bedrock regions again by circulating currents; this transport pattern would probably form closed loops. On the other hand, the material once transported to deeper regions has less possibility of returning due to the existence of the marked topographic break. Therefore, the transport pattern would not be closed.

CONCLUSION

In the present study area, submarine topography greatly influences nearshore current fields and also governs the resultant sediment transport pattern.

ACKNOWLEDGMENT

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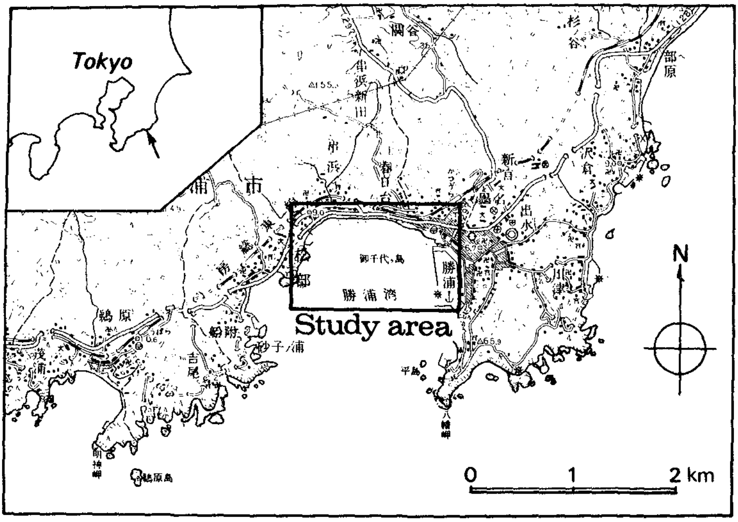

Figure 1 Study area.

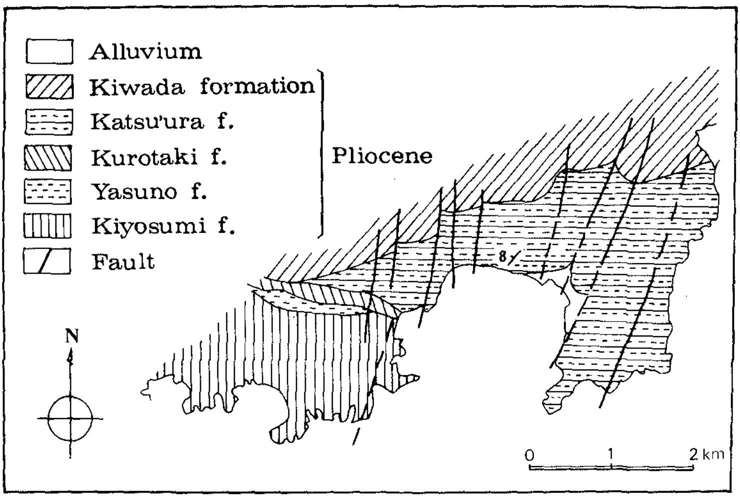

Figure 2 Geology around study area (modified after Koike, 1955; Hatai, 1958).

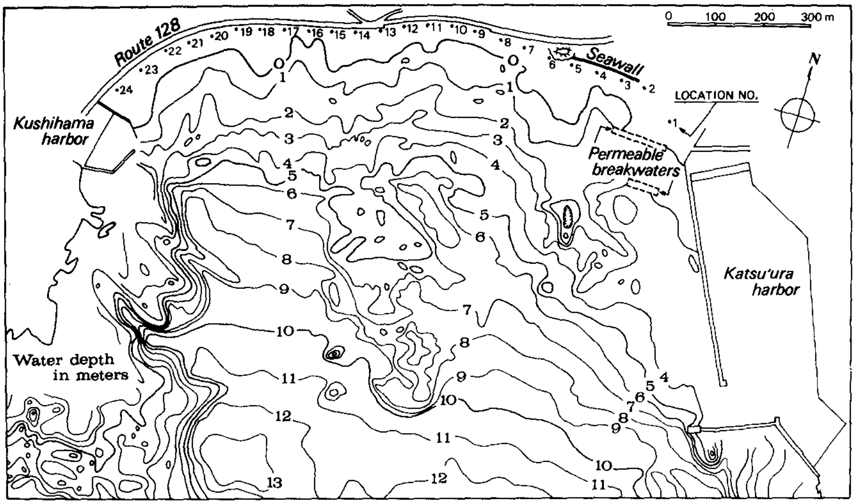

Figure 3 Submarine contour map.

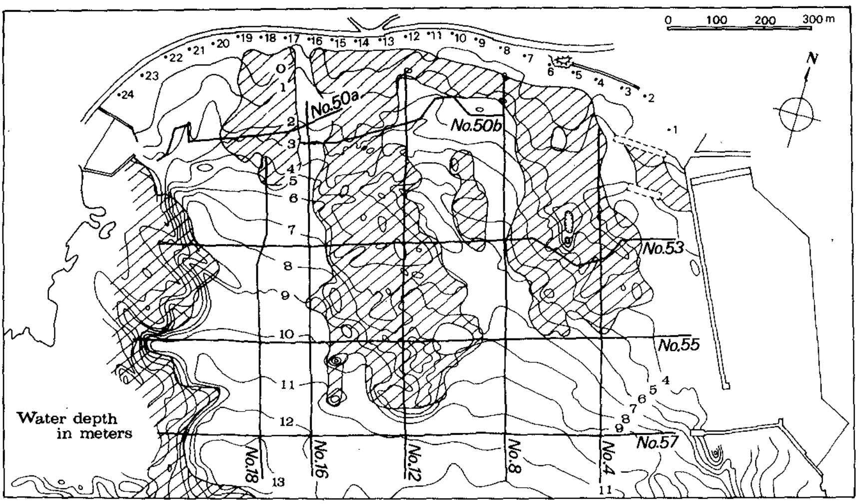

Figure 4 Area of exposed submarine bedrock: hatched portion.

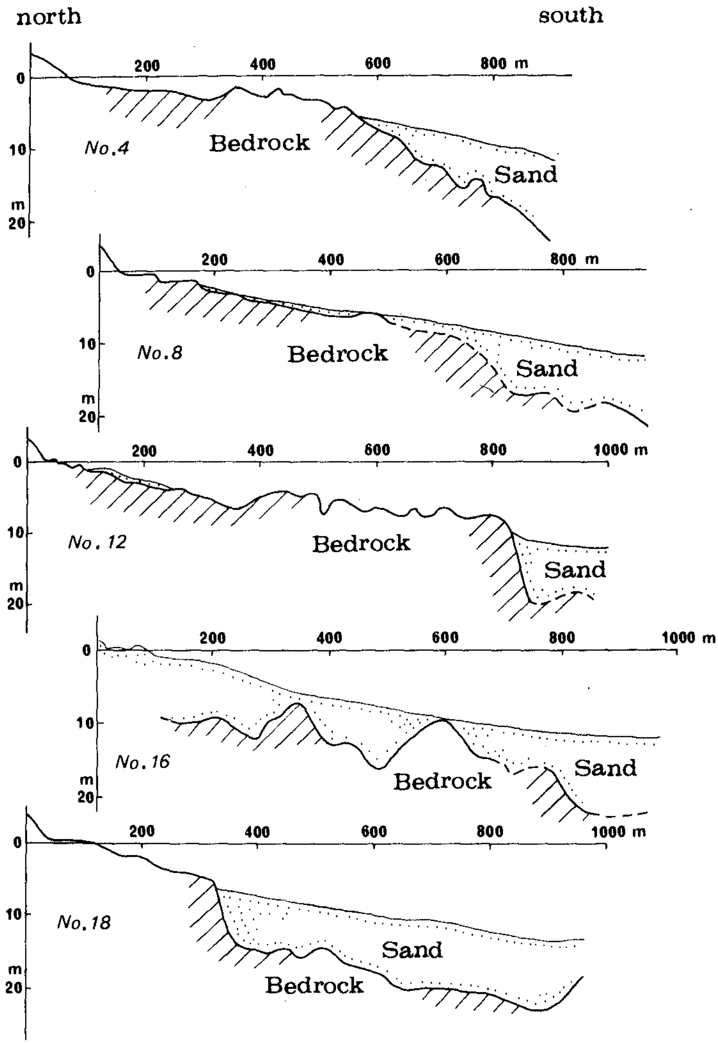

Figure 5a Geological cross sections along survey lines shown in Fig. 4.

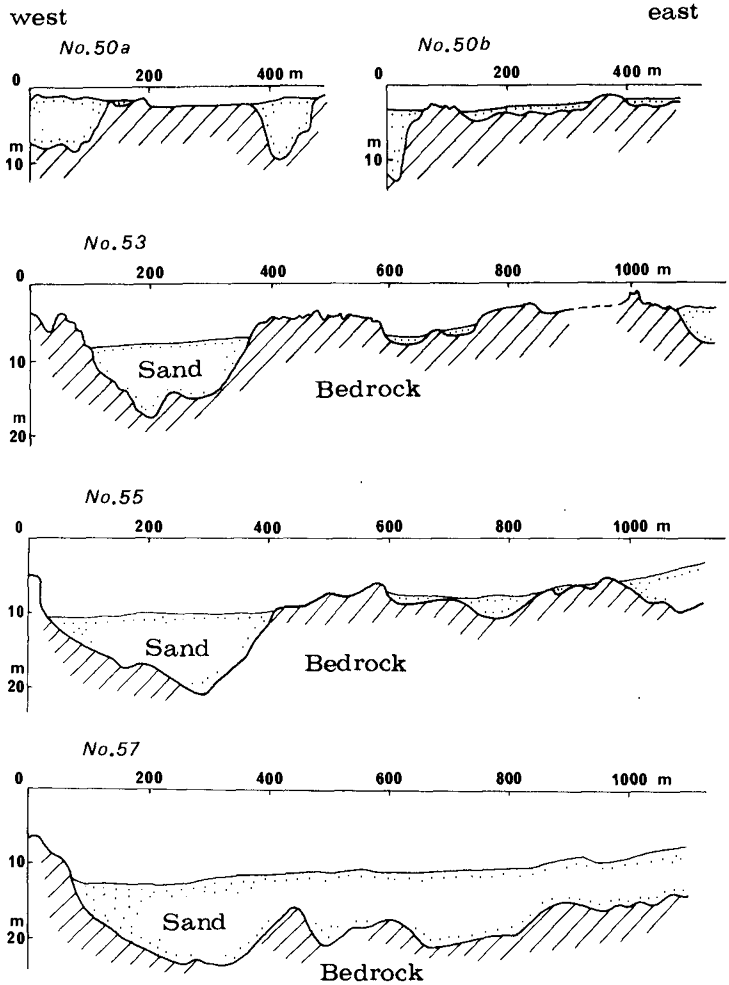

Figure 5b Geological cross sections along survey lines shown in Fig. 4.

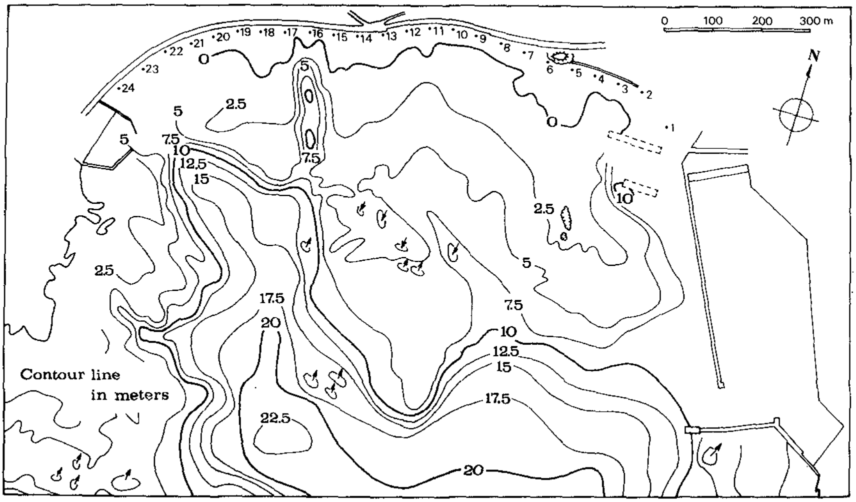

Figure 6 Submarine bedrock configuration.

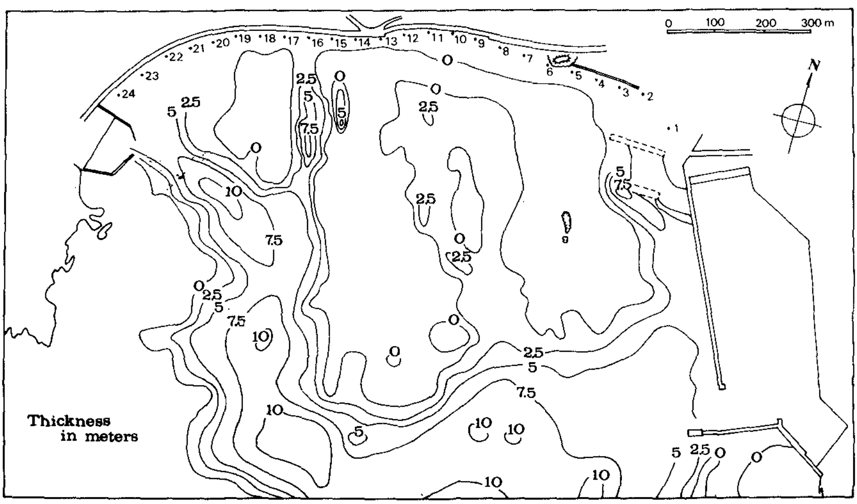

Figure 7 Isopach map of sandy sediment.

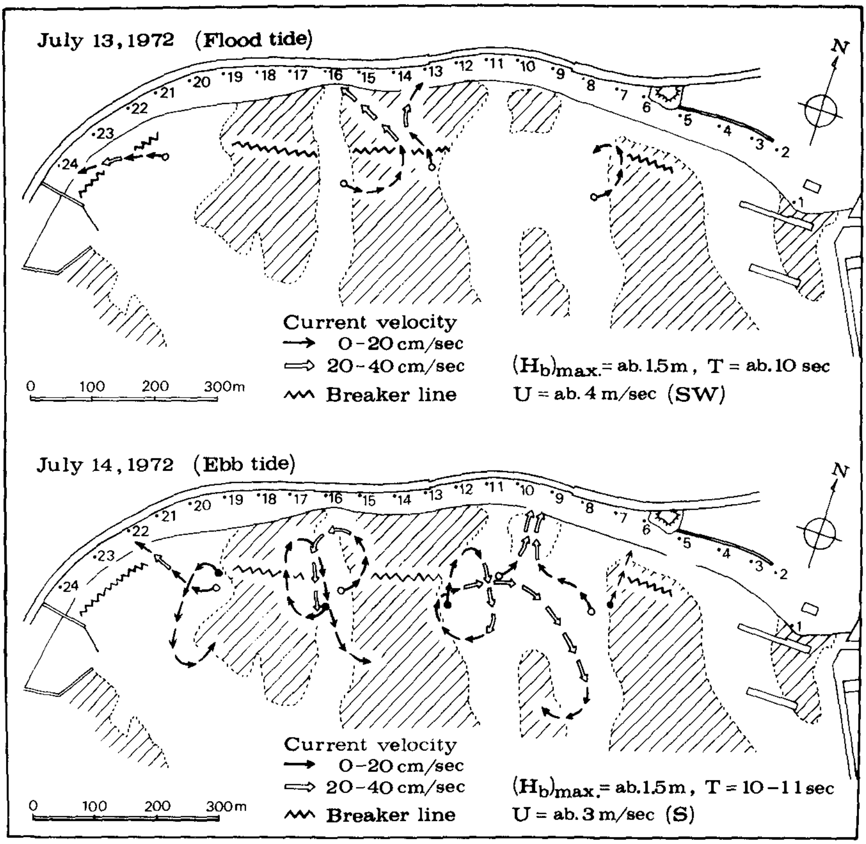

Figure 8 Water circulation pattern.

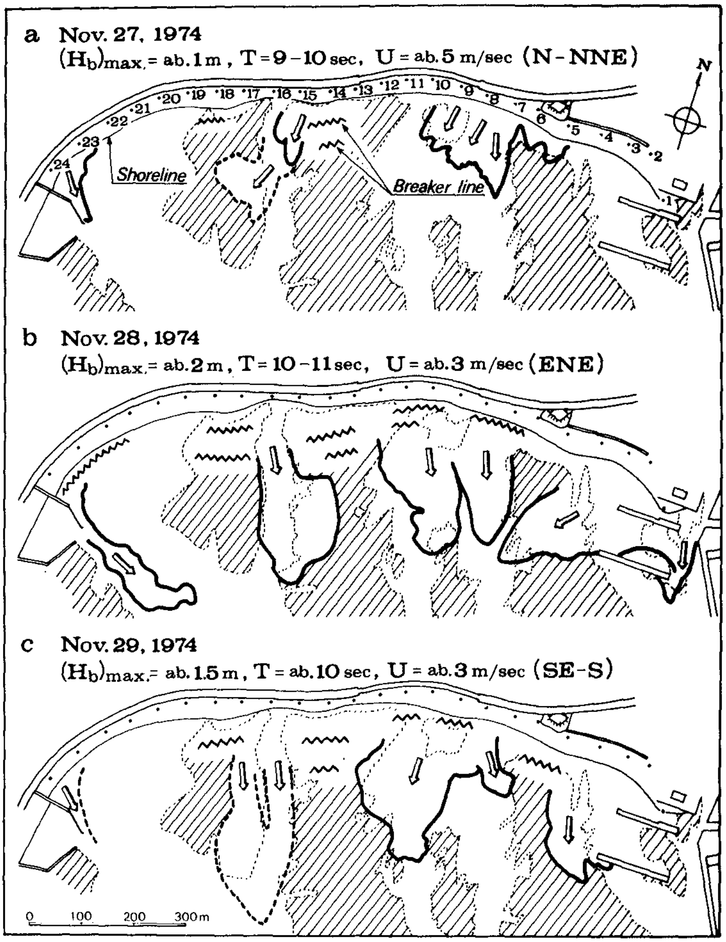

Figure 9 Suspended sediment transport pattern.

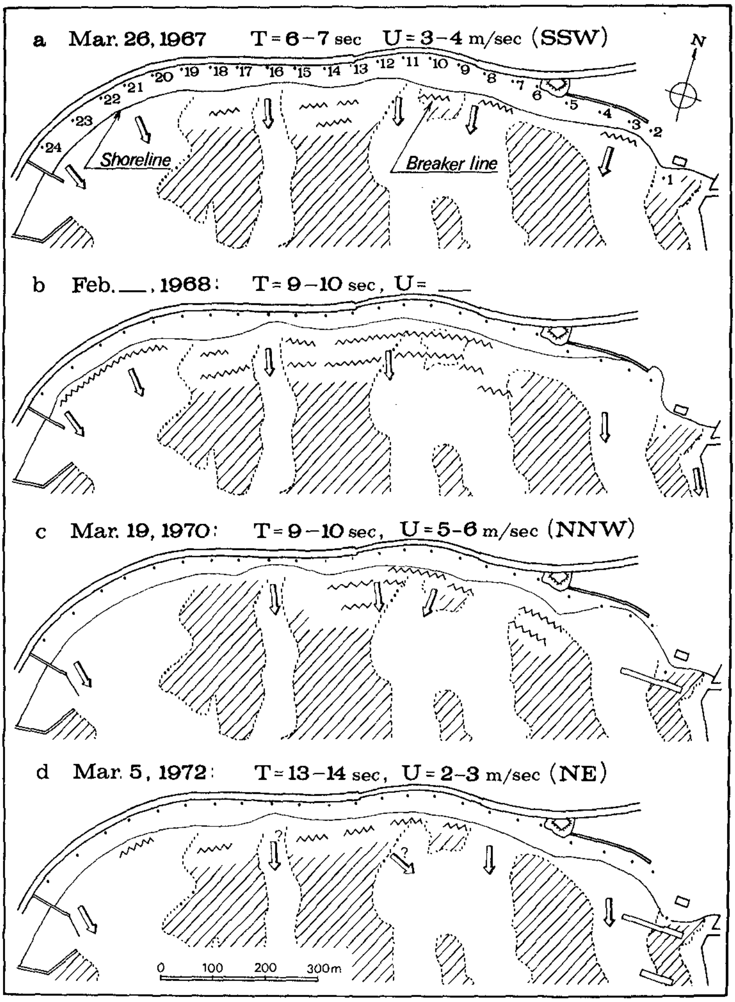

Figure 10a Locations of offshore transport of suspended sediment.

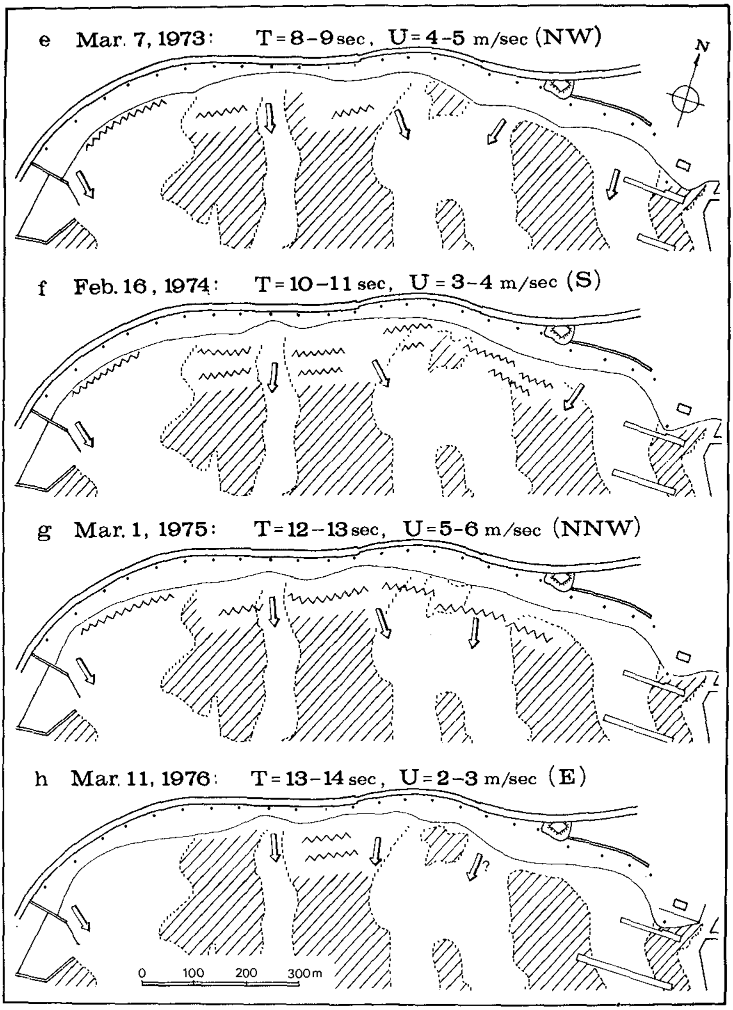

Figure 10b Locations of offshore transport of suspended sediment.

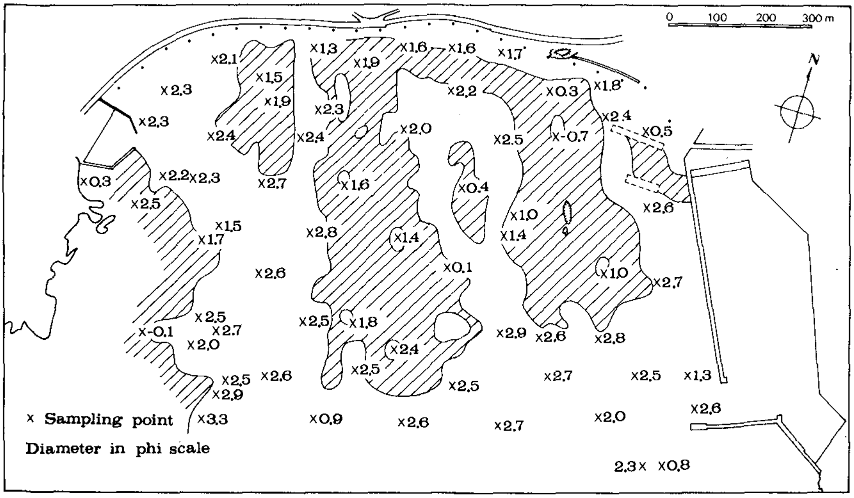

Figure 11 Mean diameter of bottom material.

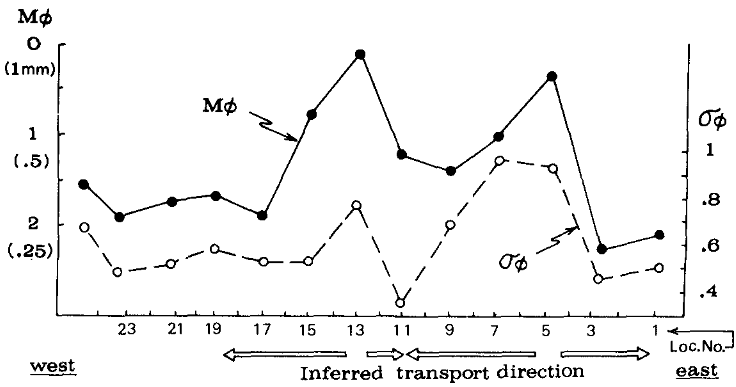

Figure 12 Mean diameter and standard deviation of beach sand, and inferred transport direction.

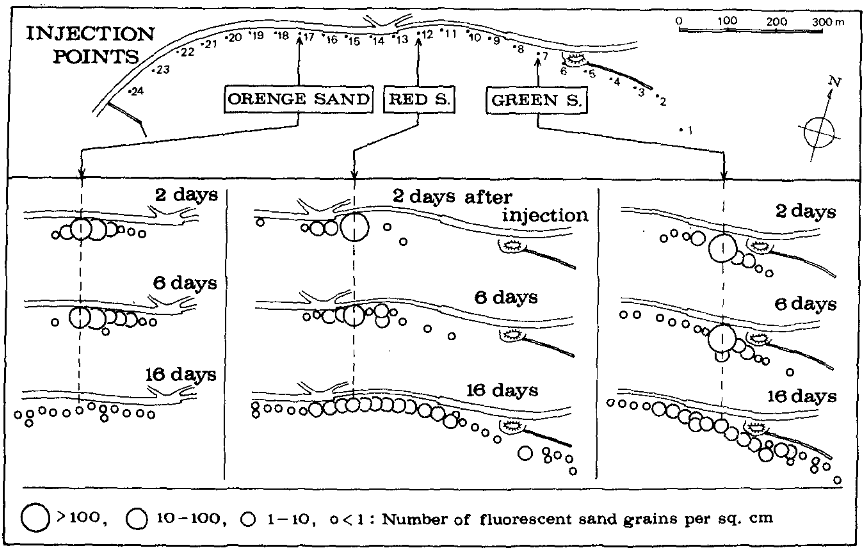

Figure 13 Dispersion of fluorescent sand.

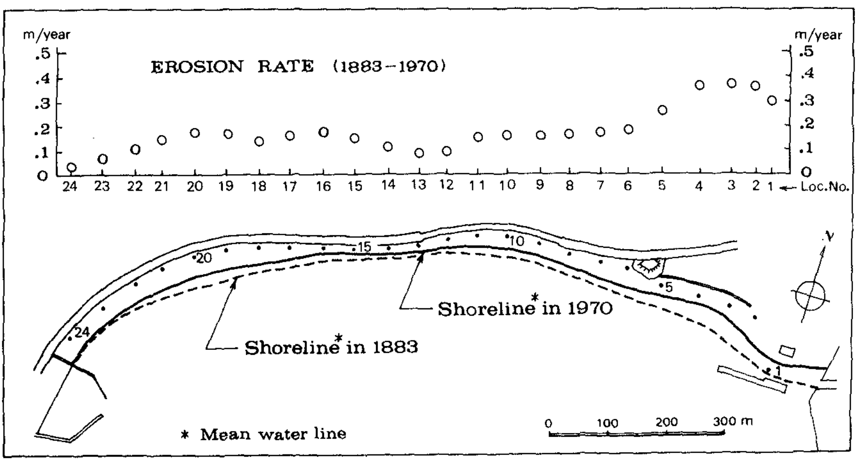

Figure 14 Long-term shoreline change.

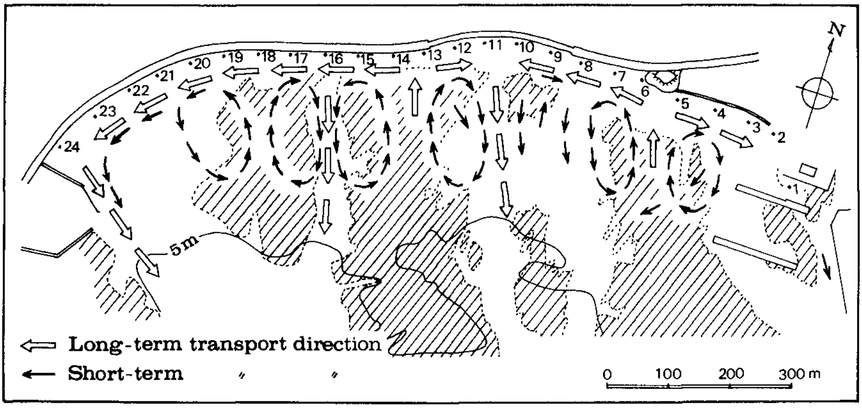

Figure 15 Inferred sediment transport pattern.