

MARINE GEOLOGY OF TOSA BAY, SHIKOKU, JAPAN, Part 2

...Bottom Sediments of Very Shallow Portions, Part 7...

Taikou MITSUSIO

Department of Geology, Faculty of Science Kochi University, Kochi, Japan

(Keywords: bottom sediments, Tosa Bay, shallow sea, marine sediments)

ABSTRACT

Bottom sediments in the northwestern part of Tosa Bay, including some very shallow parts of coastal areas of the bay, are described in this study. Bottom topography has already been described (Mitsusio, 1985a, 1985b). Sandy sediments are distributed into two major divisions, usually separated: (1) the shallow area along the coast; (2) the deeper portion of the bay floor below about 140 m depth. Muddy sediments are found generally between the two main sandy regimes.

I. INTRODUCTION

The writer has been studying the bottom sediments which are distributed in the very shallow parts of the Genkai-nada Sea, northern Kyushu, and in part 1 of this series, he described the bottom sediments near Tsuyazaki, northwest of Fukuoka City (Mitsusio, 1964; 1981). In parts 2 and 3, he clarified the characteristics of the sediment distributions off the Itoshima Peninsula, west of Fukuoka City (Mitsusio, 1965a; 1982; 1983). In part 4, the bottom sediment distribution and a companion malacological study were made (Mitsusio, 1983); while in part 5, the submarine topography was described and a submarine valley off Karatsu Bay was named, and the distribution of sediments in the valley was also clarified.

As part 6, the submarine topography in the northwestern part of Tosa Bay was examined and the continental shelf including the bay floor was named. In addition, Tsuruzu Submarine Terrace was described and named (Mitsusio, 1985a; 1985b).

In the course of the Tosa Bay study, the writer will describe the characteristics of bottom sediments in the northwestern part of Tosa Bay and subsidiary small bays along the coast of the bay (Fig. 1).

As in the previous studies concerning bottom sediments in Tosa Bay, the charts of the Japan Hydrographic Bureau (1949) first depicted the general character of the sea floor. Following the initial work, the Kochi Prefecture Fisheries Station surveyed the shallower parts of the bay in a much more detailed fashion, including the Bungo and Kii Straits during the years from 1958 to 1972. Recently, the Geological Survey of Japan surveyed the entire area in 1982 and 1983, and Okamura *et al.* (1985) discussed some aspects of the muddy sediments. Mitsusio (1985a) also showed the bottom sediment characteristics of the northwestern portion of the bay. Tamai (1985) discussed the mud

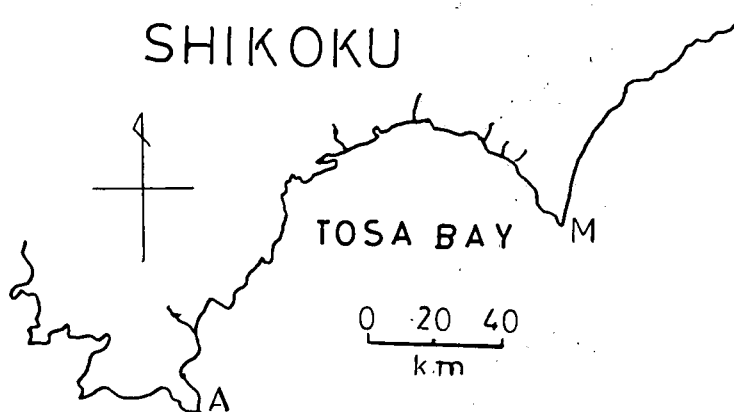


Figure 1 - Index map of Tosa Bay, south Shikoku, Japan. Symbols: A = Ashizuri Point, M=Muroto Point.

contents of the sediments, especially focusing on the benthic animal communities. Also, Ikehara and Okamura (1985) showed the entire sediment pattern.

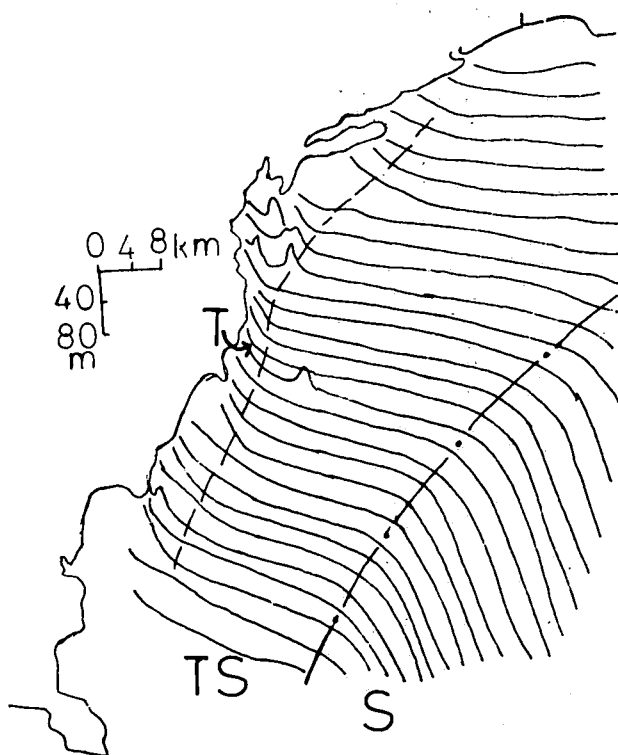


Figure 2 - Series of continuous profiles of the northwestern part of Tosa Bay (after Mitsusio, 1985a; 1985b). Symbols: T=Tsuruzu Submarine Terrace, TS = Tosa Bay Continental Shelf Plain, S = Continental Slope.

II. OUTLINE OF THE BOTTOM SEDIMENT DISTRIBUTION

A continuous series of bottom profiles of the northwestern part of Tosa Bay is shown in Figure 2. The continental shelf is extensively displayed in the arc of the bay and has been named "the Continental Shelf Terrace Plain of Tosa Bay" (Mitsusio, 1985b). Just adjacent to the coastline, another submarine terrace is developed and has been named "the Tsuruzu Submarine Terrace" with a gradient of less than about 1° . Continental slope in this area has an inclination of about 2° . Figure 3 shows the pattern of sand-sandy mud-mud for this same area. An obvious zonal pattern can be seen in Figure 3. Sandy sediments are distributed extensively along the coastline of the bay. The other area of sandy sediments is found below a water depth of 140 m where we encounter the shelf edge, the boundary between shelf and upper slope, indicating the position of an ancient shoreline at low sea level (Figure 11).

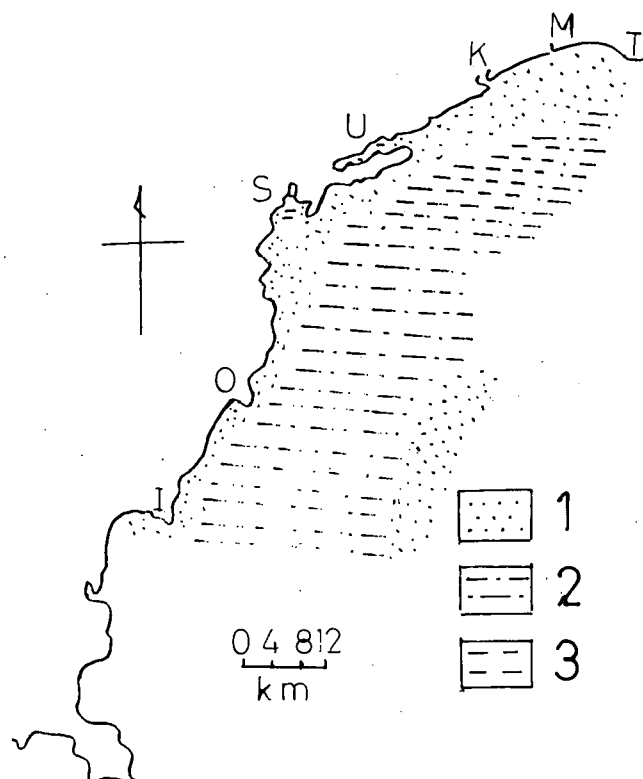


Figure 3 - Distribution of bottom sediment types in the northwestern Tosa Bay (after Mitsusio, 1985a). Symbols: 1=sand, 2=sandy mud, 3=mud. T=Tei Point, M=Monobe River, K=Urado Bay (Kochi Port), U=Urano-uchi Bay, S=Susaki Bay (including Nomi Bay), O=Okitsu-ura Bay, I=Ino-misaki Point.

Muddy sediments lie between the sandy zones, and mud is also found off Kochi Port, Urado Bay.

Wave base, or the mudline, which indicates the lower limit of wave erosion, can be found at depths of about 40 m to 60 m below present sea level. Hoshino (1958, 1985) discussed the depth of wave base around the Japanese Islands, and he noted that the depth depended on the condition of the sea.

Figure 4 is an iso-value map of mud content modified after Tamai (1985). The maximum of 80% is found to the north of Urado Bay, with a bull's-eye contour. Minimal percentages of less than 10% mud content is found near Hane Port, in the eastern part of Tosa Bay. Also, 20% mud content is found in the shallow parts near the coastline of Hane Point to Shirano-hana Point, west of Kochi City, and near the mouth of the Shimanto River and on to Ohtsusaki Point. Another area of 20% mud content also exists in the deeper part of the middle eastern portion of Tosa Bay. The 50% contour trends from about the central area to the northern region, and then turns to the west. There it extends to Shirano-hana Point. From there, it passes south along the coastline from Susaki Port to Ashizuri Point.

These mud content isopleths lie nearly parallel to the coastline from Ashizuri to Hane, in the shape of an ox-bow or wave shape.

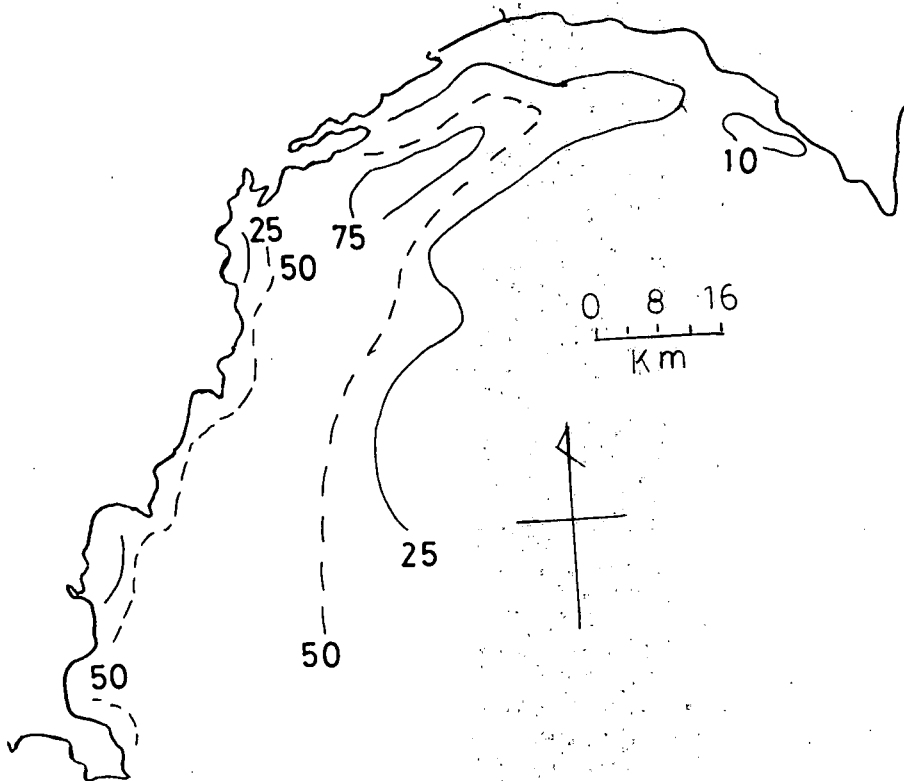


Figure 4 - Isoleths of mud content in percent (revised after Tamaki, 1985).

These trends of bottom sediment characteristics are nearly the same as those shown by the Hydrographic Bureau, Japan Maritime Safety Board (1949), and also resembles the pattern shown by Ikehara and Okamura (1985) who reported mean diameters of the bottom sediments using the Md (ϕ) classification.

The shallower parts of the Tosa Bay floor will be discussed later.

III. MINOR DISTRIBUTIONAL PATTERNS OF BOTTOM SEDIMENTS IN SMALL BAYS

A. Okitsu-ura Bay

The oceanographic and bottom sediments surveys were made by the writer in 1976 using a small boat. Grain-size analysis was done using a T-1 automatic size analyser which is a design by Taira (1973). Fourteen samples were collected using an SK type snapper and an Echmann-Berge dredge.

The size range of the analysed sediments are all coarse to fine sands. The distribution pattern is shown in Figure 5. The mode, or the peak value of the size frequency distribution, ranges from 2.0 to 2.7 ϕ , and the minimum of 2.0 ϕ is found at the north-eastern end of the bay. In contrast, the maximum modal diameter of 2.7 ϕ is about at the center of the bay. All sample values are generally between 2.3 and 2.5 ϕ , which is in the medium sand size range. All samples are well sorted.

Figure 6 illustrates the distribution of bottom sediments collected by the Kochi Prefecture Fisheries Station. According to the figure, the sediments vary from coarse to fine sands. If we compare both distributions of Figures 5 and 6, it is clear that

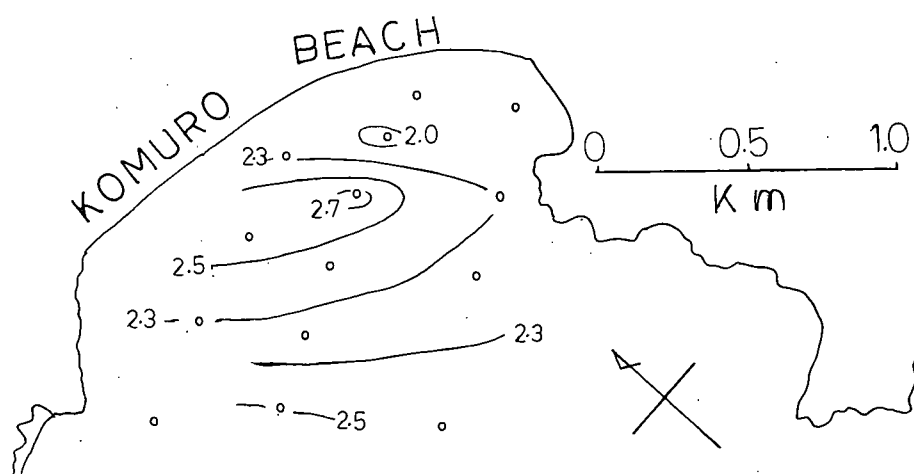


Figure 5 - Distribution of modal diameters in bottom sediments collected in Okitsu-ura Bay (ϕ scale).

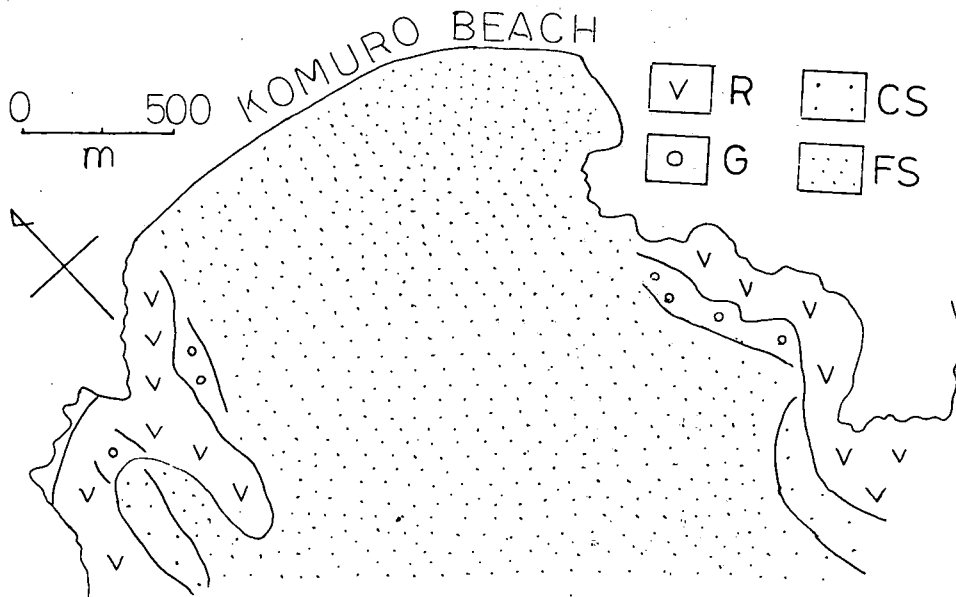


Figure 6 - Distribution of bottom sediments (revised after Kochi Prefecture Fisheries Station, 1972). Symbols: R = rock, G = gravel, CS = coarse sand, FS = fine sand.

there is only minimal difference between them. This indicates that the Fisheries Station map is still useful for our discussion and study.

The writer will now discuss the bottom sediment distribution off Kubokawa Town. This area has already been discussed with regard to the submarine topography (Mitsusio, 1985a; 1985b).

B. Area off Kubokawa Town

Figure 7 shows a continuous series of profiles off Kubokawa Town (Mitsusio, 1985b). This is a more detailed scale than that used in Figure 2, and the Continental Shelf Terrace of Tosa Bay is found at the southeastern end of Figure 7. In the area shallower than this terrace, the Kotsuruzu Submarine Terrace is developed (Mitsusio, 1985b).

Bottom sediments can be classified into five types in this area. These are rocky bottom, gravel, coarse sand, fine sand, and mud (Figure 8). All of these except the muds contain shell fragments.

Rocky bottom is found at the spurs of Shiwa-zaki Point (to the north) and Kanmuri-saki Point (to the south in Figure 8), which have been named earlier (Mitsusio, 1985b). The other area of rocky bottom is near the coastline, and also is found deeper to depths of about 20 m below sea level (Figure 8).

Coarse sand is the principal material widely distributed in this area. These always

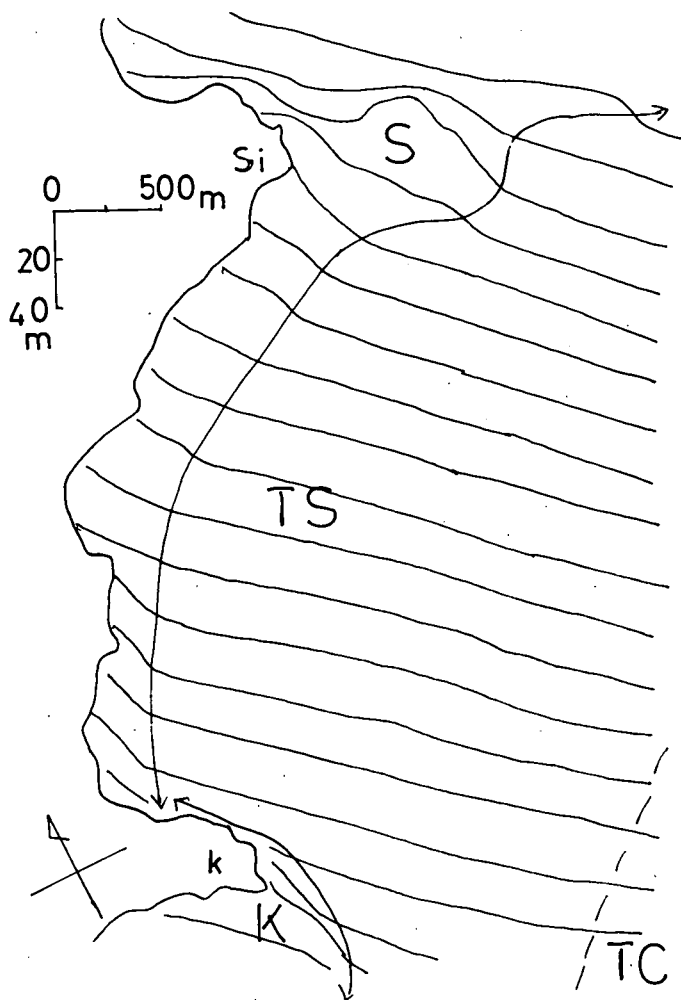


Figure 7 - Continuous profiles off Kubokawa Town, showing characteristic topography (after Mitsusio, 1985b). Symbols: T=Tsuruzu Submarine Terrace, TS=Tosa Bay Continental Shelf Terrace Plain, S=Shiwa-saki Spur, K=Kanmuri-saki Spur, si=Shiwa-saki Point, k=Kanmuri-saki Point.

include shell fragments.

Fine sand, including the rarer medium sand areas, is typically only found off Kotsuruzu at depths of from 20 m to 30 m.

Mud, with scarce shell fragments, is distributed extensively off Kubokawa Town, where the typical bottom depths are about 60 m.

This pattern indicates that the mudline exists in this bay at depths of about 60 m. Moreover, below this depth, the main shelf terrace of Tosa Bay is extensively developed. In contrast, the Tsuruzu Submarine Terrace is characterized mainly by very coarse sand, and spurs of Kanmuri-saki and Shiwa-saki are characterized by rocky floors.

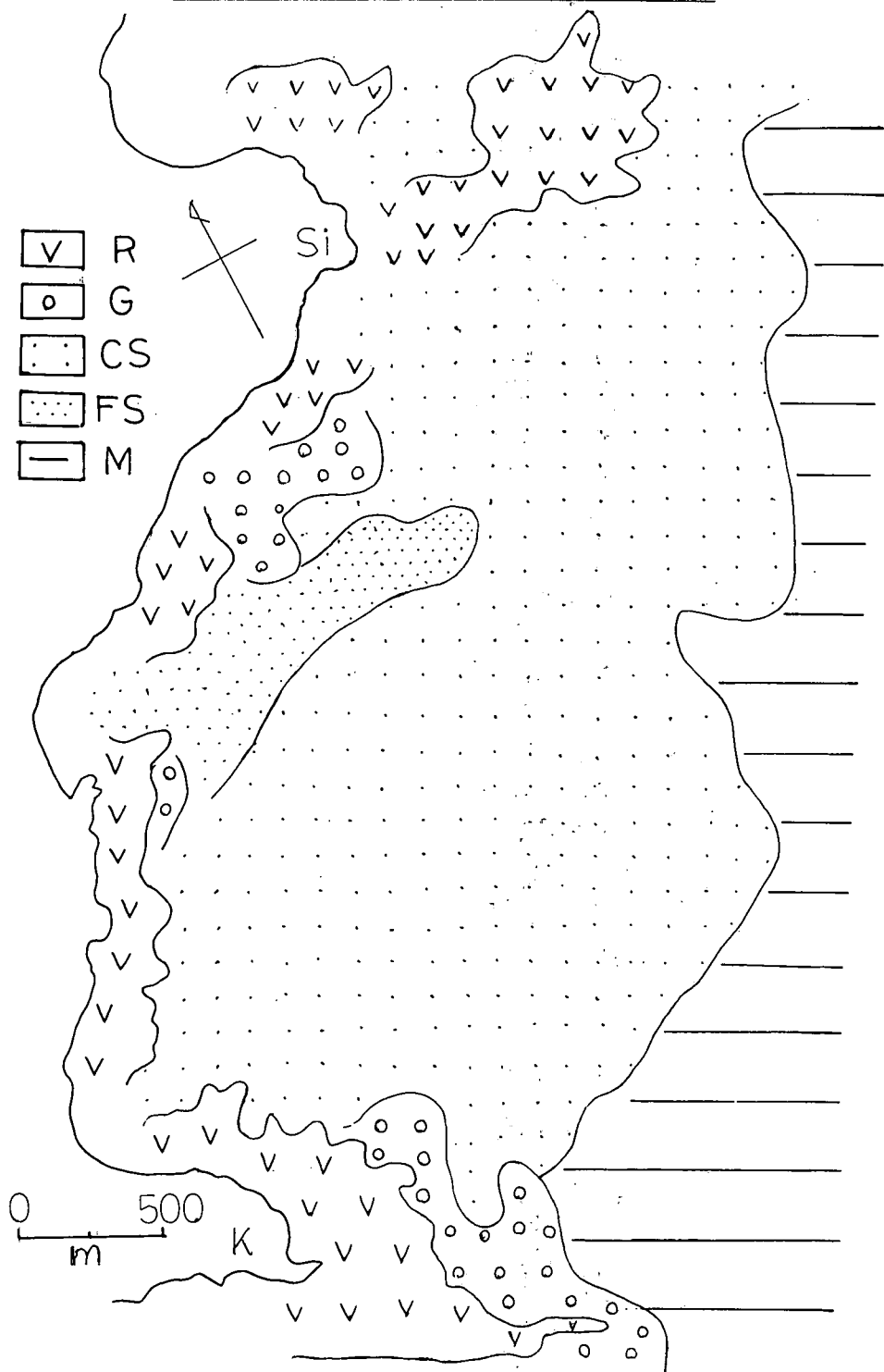


Figure 8 - Distribution of bottom sediments off Kubokawa (revised after Kochi Prefecture Fisheries Station, 1972). Symbols: R = rock, G = gravel, CS = coarse sand, FS = fine sand, M = mud, si = Shiwa-saki Point, k = Kanmuri-saki Point.

C. Susaki Bay

Susaki Bay was surveyed by Kawasaki and the writer in 1966, with the members of the Susaki High School Science Club.

Figure 9 has been revised after Kawasaki (1969), and includes Nomi Bay which is

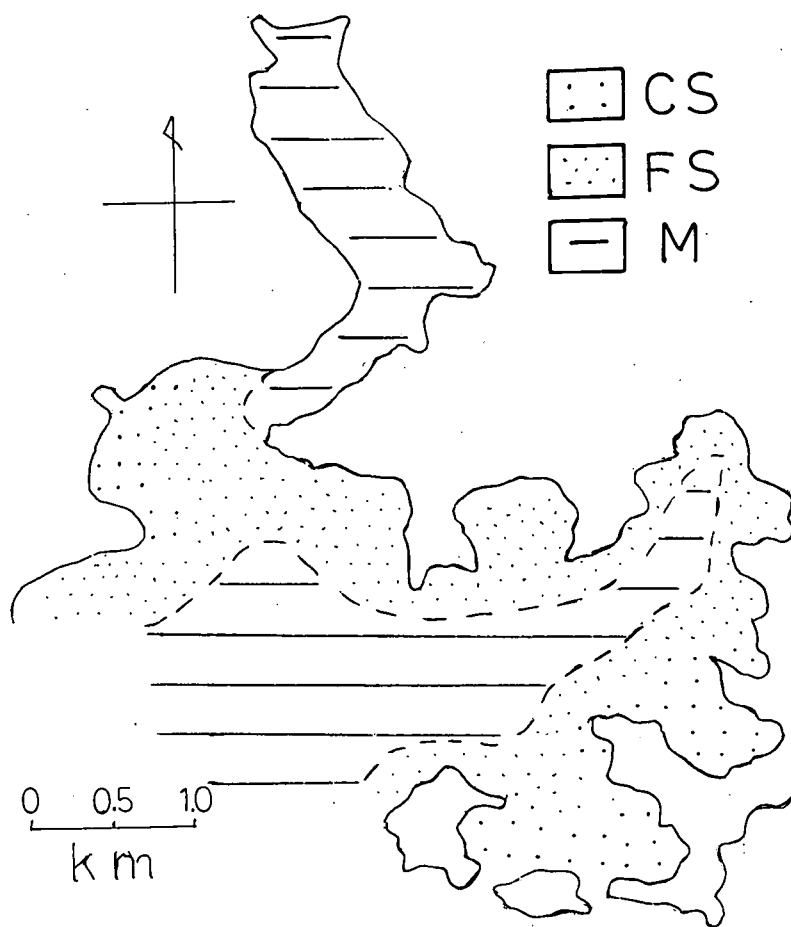


Figure 9 - Distribution of bottom sediments in Susaki Bay (including Nomi Bay), revised after Kawasaki (1969). Symbols: C=coarse sand, FS=fine sand, M=mud.

located at the bay-mouth of Susaki Bay.

Muddy sediments are the common sediment type over much of Susaki Bay. In contrast, sandy sediments with modal diameters of 2 to 4 phi are found in the parts of Nomi Bay shallower than 20 m. However, muddy sediments of about 4 to 7 phi modal diameter are found in the deepest part of Nomi Bay. Sandy sediments typically are found at the mouth of the Shinjo River which flows into the bay-mouth area of Susaki Bay.

D. Urano-uchi Bay

The general distribution of bottom sediment types in this bay were shown by Mitsusio (1979), and the most important areas where sandy sediments give way to muds, was also

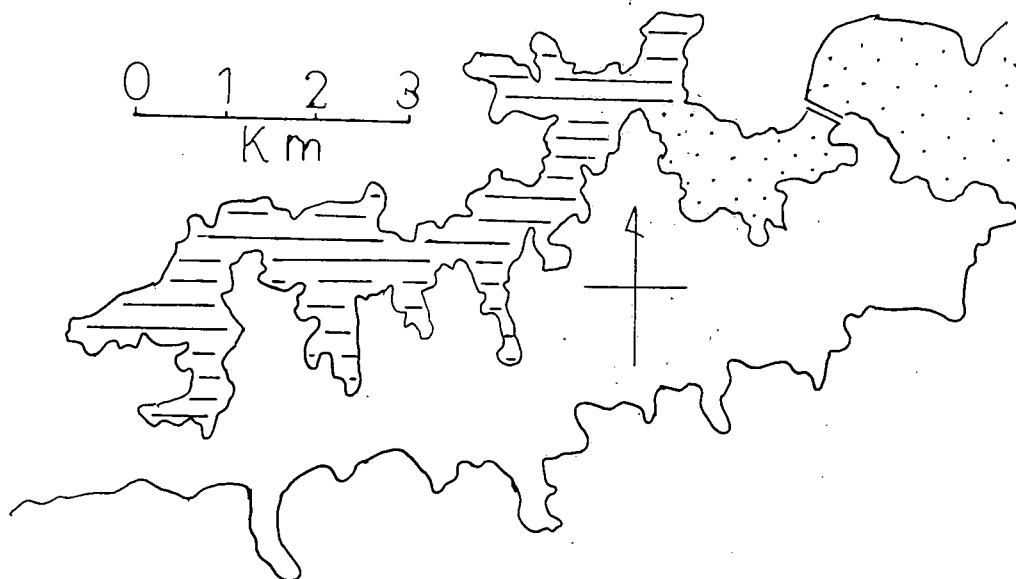


Figure 10 - Distribution of bottom sediments in Urano-uchi Bay (after Mitsusio, 1979). Symbols: Dots=sandy sediments, ---=muds.

examined in detail by Mitsusio *et al.* (1980).

Figure 10 shows the outline of the bottom sediment distribution. The sandy sediments form about one-third of the bay floor from the bay-mouth to the west. Thus the transitional zone is nearly at the line connecting Ohsaki and Tsuru-saki Points.

Muddy sediments are widely distributed in the inner part of this bay, occupying about two-thirds of the total bay floor. These muds derive from the bay-mouth area, from data from the palynological studies by Handa and Mitsusio (1978), and Nakamura *et al.* (1972), and because there are no significant rivers which bring sediment into this bay.

IV. CONCLUDING REMARKS

Examining the distribution of the bottom sediments in the northwestern part of Tosa Bay at large scale, we see that sandy sediments are distributed in the shallower waters on the Tsuruzu Submarine Terrace (Mitsusio, 1985a), and another sandy area is found on bay floors below depths of 140 m which correspond to the Wisconsin lowered sea level (Würmian glacial age) (Figure 11). In contrast, muddy sediments are found between

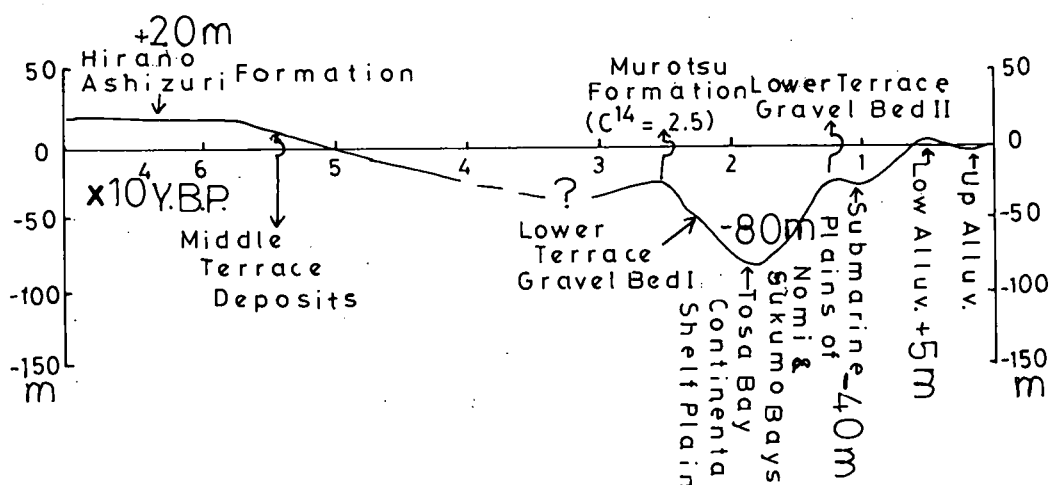


Figure 11 - Sea level curve showing position versus time of various bottom depths. Note that the time of formation of the Tosa Bay Continental Shelf Plain is about 20,000 yrs Before Present.

these two main sandy zones where water depths are about 40 m or deeper, and which indicates the position of the mudline or wave base for this area.

At smaller scales, the distribution of bottom sediments in some smaller bays in the large Tosa Bay have been examined. In closed bays such as Urano-uchi and Susaki, the degree of embayment has been defined as more than 1.0 by Mitsusio (1966), and muds occupy these floors. In contrast, open bays such as Nomi and Okitsu-ura, in which the degree of embayment is less than 1.0, the floors are dominated by sandy sediments.

These differences reflect the direct action of waves and tidal currents on the topography.

ACKNOWLEDGEMENTS

The writer would like to express his sincere thanks to Prof. D. S. Gorsline of the Department of Geological Sciences, University of Southern California, who read this paper, and Messers M. Okamura and H. Yasuda of the Marine Geology Institution (MAGI), Department of Geology, Kochi University, for their discussions and assistance. Special thanks are also due to Messers A. Taira and A. Hosomi for their aid in sample analysis. Messers K. Kawasaki and K. Tamai, and the staffs of the Kochi Prefecture Fisheries Station are gratefully acknowledged for offering their valuable data.

REFERENCES CITED

- Handa, K. and T. Mitsusio (1977): Sedimentological palynology, Part 2, Urano-uchi Bay. *Rep. Usa mar. biol. Inst.* 24, nos.1/2, 7-11 (in Japanese with English abstract)
 Hoshino, M. (1958): On the bottom sediments around the Japanese Islands. *Mem. Geol.*

- Colab. no. 7*, 4lp. (in Japanese with English abstract)
- (1985): *Marine geology*. Tokai Univ. Press, 373p. (in Japanese)
- Ikehara, K. and I. Okamura (1985): *Geology, Tosa Bay. Oceanographical review, Chap. 18, Tosa Bay*. 723—731 (in Japanese)
- Japan Maritime Safety Board (1949): Chart of the bottom sediment distribution.
- Kawasaki, K. (1969): *Geology of Susaki City. History of Susaki City*, 13—51 (in Japanese)
- Kochi Prefecture Fisheries Station (1972): Basic map on the fisheries ground. 39p.
- Mitsusio, H. (1964): Bottom sediments near the Tomioka Peninsula, Amakusa, Kumamoto Prefecture. *Sci. Rep. Fac. Sci. Kyushu Univ. Ser. Geology*, 6, no.3, 167—187 (in Japanese with English abstract)
- (1965a): Bottom sediments off the Itoshima Peninsula, west of Fukuoka City. *ibid*, 8, no.1, 63—72 (in Japanese with English abstract)
- (1965b): Bottom sediments off Tsuyazaki, northeast of Fukuoka City. *ibid*, 8, no.2, 101—124 (in Japanese with English abstract)
- (1967): Bottom sediments in bays of north Kyushu. *Mem. Fac. Sci. Kyushu Univ. Ser. D, Geology*, 19, no.1, 7—34
- (1979): Fundamental study on the development of a fishery field in shallow sea-area, historical development of the formation of Urano-uchi Bay. *Rep. of studies on the developments of marine biological resources in the sea areas off the south coast of Shikoku* 1—7 (in Japanese)
- Shibata, T. and Y. Yasuda (1980): Bottom sediments at the central part of Urano-uchi bay, Kochi Prefecture. *Rep. Usa mar. biol. Inst.* 2, 59—71 (in Japanese with English abstract)
- (1981): Bottom sediments of very shallow portions, Part 1, north of Tsuyazaki, northeast of Fukuoka City. *Res. Rep. Kochi Univ.* 30, no.6, 121—133 (in Japanese with English abstract)
- (1982): Bottom sediments of very shallow portions, Part 2, Bottom sediments and molluscan shells off Keya, west of Fukuoka City. *Rep. Usa mar. biol. Inst.* 4, 62—85 (in Japanese with English abstract)
- (1983): Bottom sediments of very shallow portions, Part 3, off Nogita. *Mem. Fac. Sci. Kochi Univ.* 4, 1—12
- (1983): Bottom sediments of very shallow portions, Part 4, Bottom sediments and shell remains at the bay-mouth area of Hakata Bay. *Rep. Usa mar. biol. Inst.*, 5, 85—99. (in Japanese with English abstract)
- (1984): Bottom sediments of very shallow portions, Part 5, off the Karatsu submarine valley. *Res. Rep. Kochi Univ.* 32, 302—320. (in Japanese with English abstract)
- Mitsusio, Taikou (1985a): To observe sea-floors, Topics of Marine Geology, *Text book of Pub. Lec. Kochi Univ.*, 47—69. (in Japanese)
- (1985b): Marine geology of Tosa Bay, Part 1, Bottom sediments of very shallow portions, Part 6. *Usa mar. biol. Inst.* 7, 73—85, (in Japanese with English abstract)
- Nakamura, J. Kuroda, T. and Mitsusio, T. (1972): Sedimentological palynology, Part 1, Subsurface sediments from the western sea-area of Kyushu and Shikoku. *Bull. Geol. Surv. Japan*, 25, 209—221 (in Japanese with English abstract)
- Okamura, O., Arita, M., et al. (1985): Fine grained sediment dispersal on the tracer of calcareous nannoplankton. *Jour. Sed. Soc. Japan*, nos.22/23, 50—53 (in Japanese)
- Tamai, K. (1985): Benthonic facies, in Tosa Bay. *Oceanographic review, Chap. 18, Tosa Bay*. 742—744 (in Japanese)
- Taira, A. (1973): A new method for the recognition of sedimentary environments using photo-electric settling tube and stepwise discriminate analysis on sediments. *Geol. Soc. Am. Abs. with Programs*, 5, 833—834

(Manuscript received: September 3, 1985)

(Published: October 18, 1985)