特別寄稿

Marine Geology of Tosa Bay, Shikoku, Southwest Japan, part 3, Sedimentological Aspects[1)]

— Marine Geology of very shallow portions, part 15 —

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Ⅰ. Introduction

Tosa bay sediments are subjected to be analysed in detail during past few years by many researchers especially in regional scale. Mitusio (1985a, 1985b, 1986, 1989, 1991) described the shallow sediments in the area also with special concentration on artificial organic matters in Uranouchi bay that is in the west part of the present study area[2)-6)]. Mitusio *et al.* (1980) explained sub-bottom strata of Uranouchi bay using three core samples[7)]. Then Guruge *et al.* (1993) found several submarine buried valleys by a seismic survey that are important for route changes of paleo-Niyodo river during the latest glacial age[8)]. Guruge and Mitusio (1993) reported the outline of the bottom sediments in the studied area[1)]. Also Mitusio and Guruge (1994) mentioned the sedimentological aspects such as composition of sand grains, clay mineral, organic matters, molluscan species as well as ^{14}C dating[9)]. The study history of the other data on sediments including sub-bottom strata mentioned in the other reports by the same writers (Mitusio and Guruge, 1994)[9)].

The present paper is describing the details of the distribution and grain size parameters of the surface sediments.

Ⅱ. Materials and Methods

2 − 1 Sample Collection

Totally 65 sediment samples are collected by Ekman type and Smith-MacIntyre grab samplers, that are 19 samples from Uranouchi bay, and 20 samples from Niyodo river mouth and 26 samples from the shallow shelf of Tosa bay. The samples from Tosa bay have collected approximately 4 km intervals.

Location map is illustrated in Fig. 1 . All positioning of the sample locations were done by the Global Positioning System (GPS).

2 − 2 Grain size analysis

First all samples were described visually, and the colour was determined by the Japanese Agricultural association colour chart.

Grain size analysis was determined by standard sieving and pipette method. About 50g of dried sediments were wet sieved through 62 micron sieve to separate sand and gravel-size fraction. The remainder was disagregated by dilute Calgone solution for an over night and pipetted to determine

the silt and clay-size fraction, following Stokes settling velocity equation (Krumbein and Pettijohn, 1938)[10].

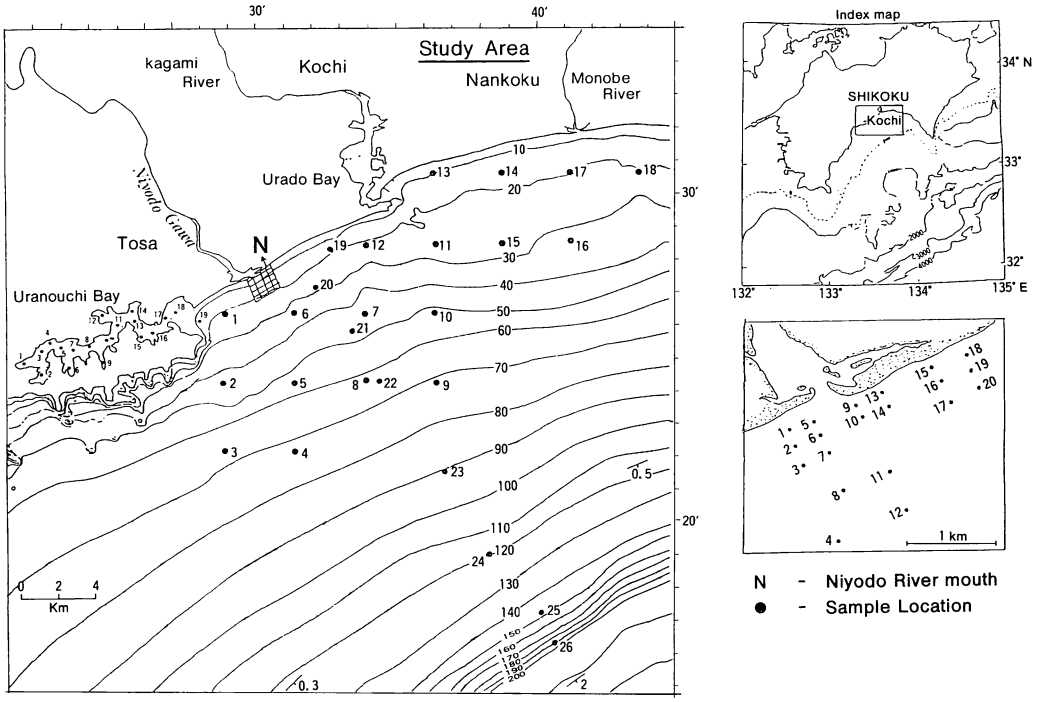

Fig. 1. Index map showing the study area in the central Tosa bay, off Kochi City.
Number ; sample location. small number ; sample location in Uranouchi bay . italic small number ; depth in meter. right upper ; total index map showing Tosa bay. right down ; sample location near the Niyodo river mouth.

The sand fraction was separated by using standard sieve set of 1 phi (ϕ) intervals. Pebble, granule, sand, silt and clay fractions theoretically should be composed of particles with diameters (Friedman, 1962)[11] over than 4,000 microns (less than $-2\ \phi$), within 4,000 to 2,000 microns (-2 to $-1\ \phi$), 2,000 to 62.5 microns (-1 to $4\ \phi$), 62.5 to 3.91 microns (4 to $8\ \phi$), and less than 3.91 microns (greater than $8\ \phi$), respectively. The sediments were classified by the method of Shepard (1954)[12].

2 — 3 Statistical parameters

The weight of each fraction is converted to percentage and further cumulative weight percent of coarse to fine fractions are calculated. According to above data following statistical parameters; mean diameter ($M\ \phi$, the average size), standard deviation ($\sigma\ \phi$, the scatter of various sizes about the average), skewness ($\alpha\ \phi$, the asymmetry about the average), and kurtosis ($\beta\ \phi$, the peakedness of the curve) that can be interpreted, respectively, and these are determined by the computor programe as Inman equations (1952)[13].

Designations of each ϕ values of above statistical parameters are described in Tab. 1.

Tab. 1 . Designations of sedimentary parameters

mean size Mϕ		sorting $\sigma\phi$		skewness $\alpha\phi$		kurtosis $\beta\phi$	
ϕ	designation	value	designation	value	designation	value	designation
-2	pebble	<0.35	very well	-1.0—-0.3	very	<0.67	very platykurtic
-1	gravel		sorted		negatively		
0	very coarse sand	0.35-0.5	well sorted		skewed	0.67-0.9	platykurtic
1	coarse sand	0.5 -0.8	moderately	-0.3—-0.1	negatively		
2	medium sand		well sorted		skewed	0.9 -1.1	mesokurtic
3	fine sand	0.8 -1.4	moderately	-0.1— 0.1	nearly		
4	very fine sand		sorted		symmetrical	1.11-1.5	leptokurtic
5	coarse silt	1.4 -2.0	poorly sorted	0.1— 0.3	positively		
6	medium silt	2.0 -2.6	very poorly		skewed	1.5 - 3.0	very leptokurtic
7	fine silt		sorted	0.3— 1.0	very		
8	very fine silt	> 2.6	extremely		positively	3.0<	extremely
9	clay		poorly sorted		skewed		leptokurtic

Ⅲ. Results and Discussion

3 — 1 Sediment Classification and Regional Trends

3 — 1 — 1 Frequency Curves

Frequency curves, that describe the grain-size distribution of whole sediment, were derived from the method of Krumbein (1934)[14]. In Uranouchi bay most samples are bimodal. Frist mode changes fine silt (7 ϕ) to very coarse sand (0 ϕ) while secondary mode changes coarse silt (5 ϕ) to fine sand (3 ϕ) from inner bay to bay mouth. It shows the tail of coarse materials are turning gradually to fine tail towards bay mouth. In Tosa bay most sediments are unimodal but some patches of bimodal sediments, that are with fine tails available. Also shelf break sediments are consisted with bimodel fine tail sediments. Niyodo river mouth sediments are shown with both bimodel and unimodel. Coarse tails of sediments in Tosa bay and Uranouchi bay are dominant with biogenic meterials such as mollluscs, coral rubbles and other carbonaceous matters, and detrital meterials of rock fragments that is in Niyodo river mouth sediments.

3 — 1 — 2 Distribution of Statistical Parameters

The interpolated horizontal distribution maps of mean grain size (Fig. 2), sorting (Fig. 3), skewness (Fig. 4) and kurtosis (Fig. 5) are prepared by the calculated values by Inman equations. Very shallow part of the tosa bay is coverd by fine sand. Central part of the study area that is off urado bay and the west part are consisted with zones of very fine sand and coarse silt. A patch of medium silt is located in about 2 km south of Urado bay. Mean grain size of sedimens in Uranouchi bay is gradually decreasing from very coarse sand to very fine silt from the inlet to inner bay, respectively. With in 1 km of distance from Niyodo river mouth, sudden gradual decrease of mean grain size of sediments is observed as gravel to fine sand.

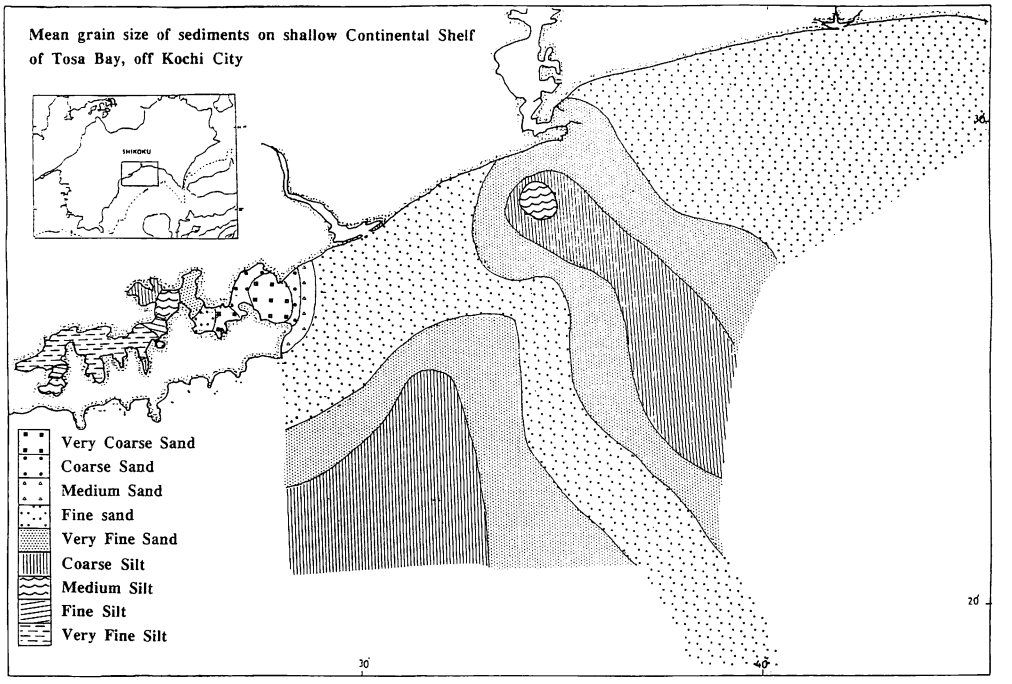

Fig. 2. Mean grain size distriubution map in the study area off Kochi city.

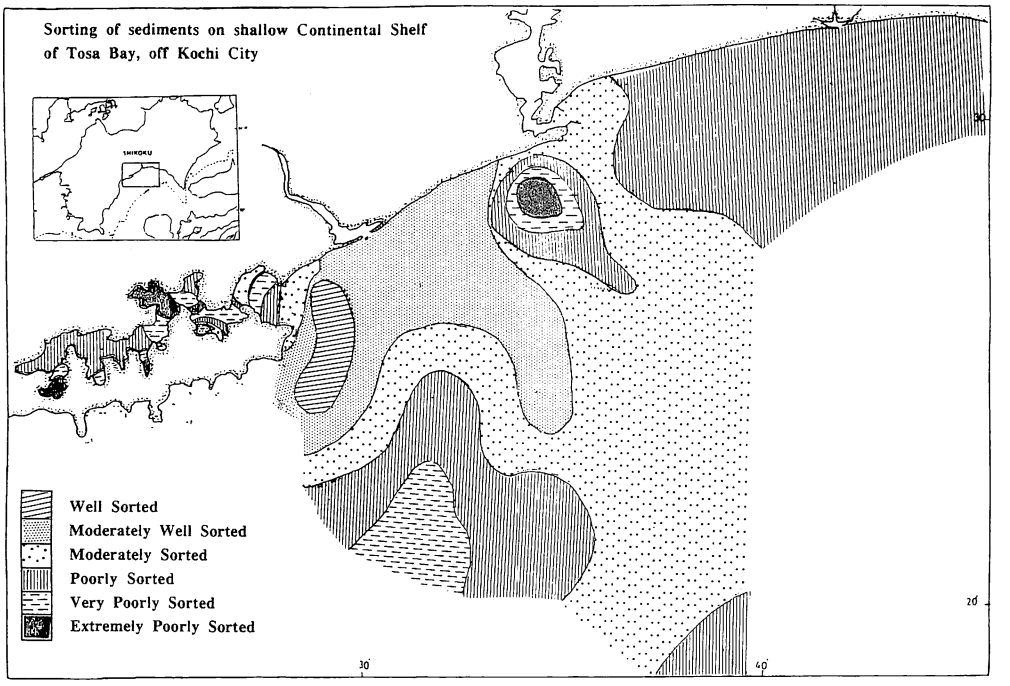

Fig. 3. Sorting of the sediments in the study area off Kochi city.

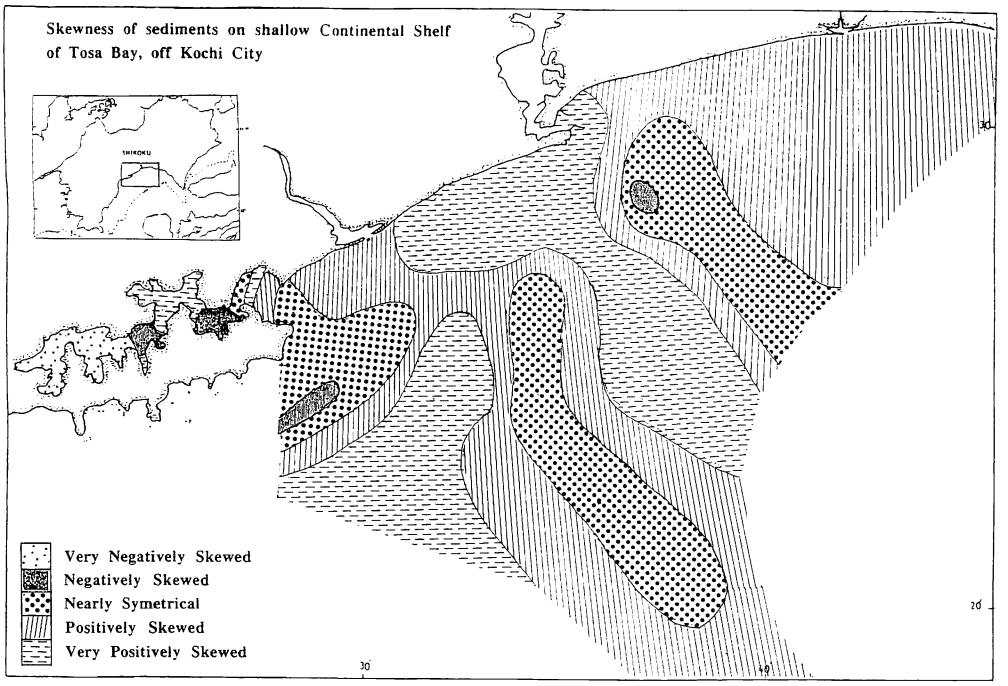

Fig. 4. Skewness of the sediments in the study area off Kochi city.

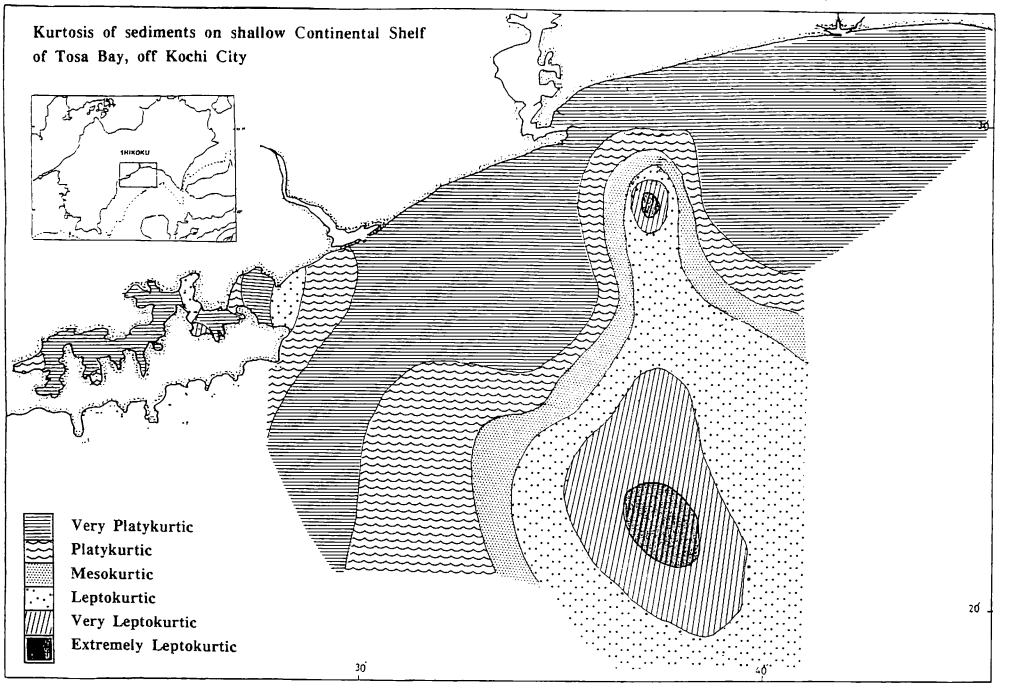

Fig. 5. Kurtosis of the sediments in the study area off Kochi city.

Sorting of the shelf sediments, a patch of well sorted sediments exists at the out side of Uranouchi bay. It becomes very poorly sorted to the south (80m of depth) and off Monobe river shelf area sediments are poorly sorted. Central part of the shelf is covered by the moderately sorted sediments. A patch of extremely poorly sorted sediments is located in about 2 km south of Urado bay. Uranouchi bay sediments are varying with poorly sorted to extremely poorly sorted. About 1km of distance from Niyodo river mouth to open sea is covered with moderately well sorted to moderately sorted sediments.

Skewness of the shelf area sediments is almost positively and very positively skewed with some patches of nearly symmetrical. Sediments of Uranouchi bay show waved pattern of skewness from inner bay to bay inlet as very positively skewed to positively skewed, respectively. Within 1 km of distance from Niyodo river mouth, almost nearly symmetrical sediments are existed.

Kurtosis of the sediments, very shallow part of the shelf is very platykurtic and its changing leptokurtic toward deep shelf in the central part. Two patches of extremely leptokurtic sediments are located in the center area. Sediments of Uranouchi bay and within 1 km of distance from Niyodo river mouth are mainly composed with very platykurtic and leptokurtic sediments.

3 − 2 Sedimentary Facies

Totally 7 sedimentary facies are observed in the study area according to Shepard classification. Sand facies and silty sand facies in the zonal center are two facies in the shelf area. All 7 facies are abundant in Uranouchi bay as sandy gravel in the inlet and sandy silty clay in inner-most bay. This is correlated with mean grain size decreasing towards inner bay.

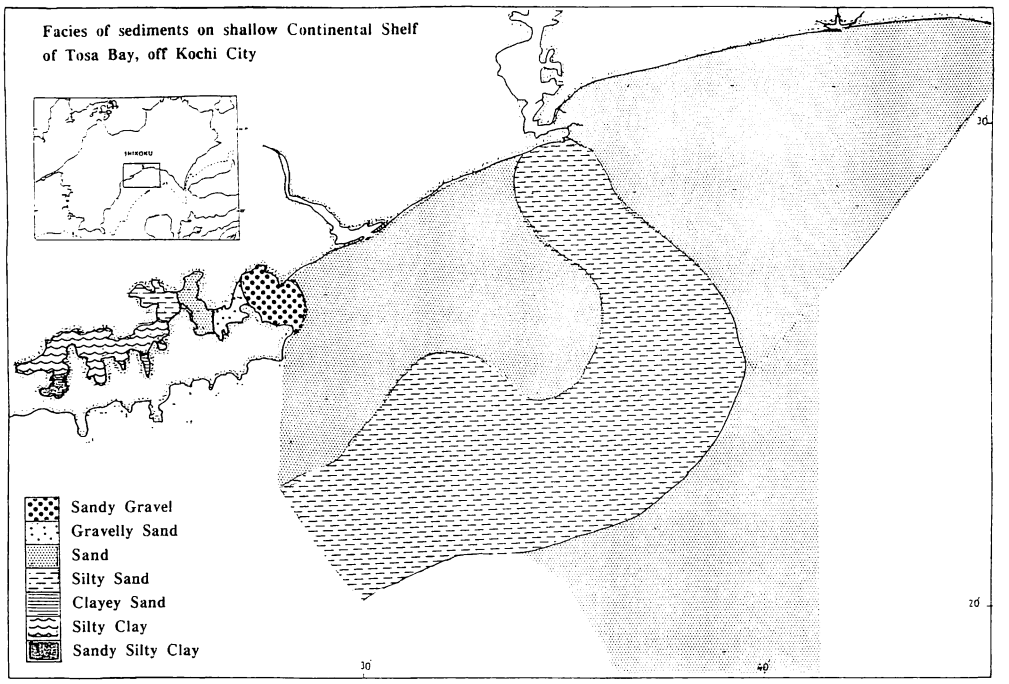

Fig. 6. Sediment facies in the study area off Kochi city.

Interrelationship of statistical parameters are shown in Figures of 7 and 8, that are useful to determine the tentative limits of above parameters for each facies.

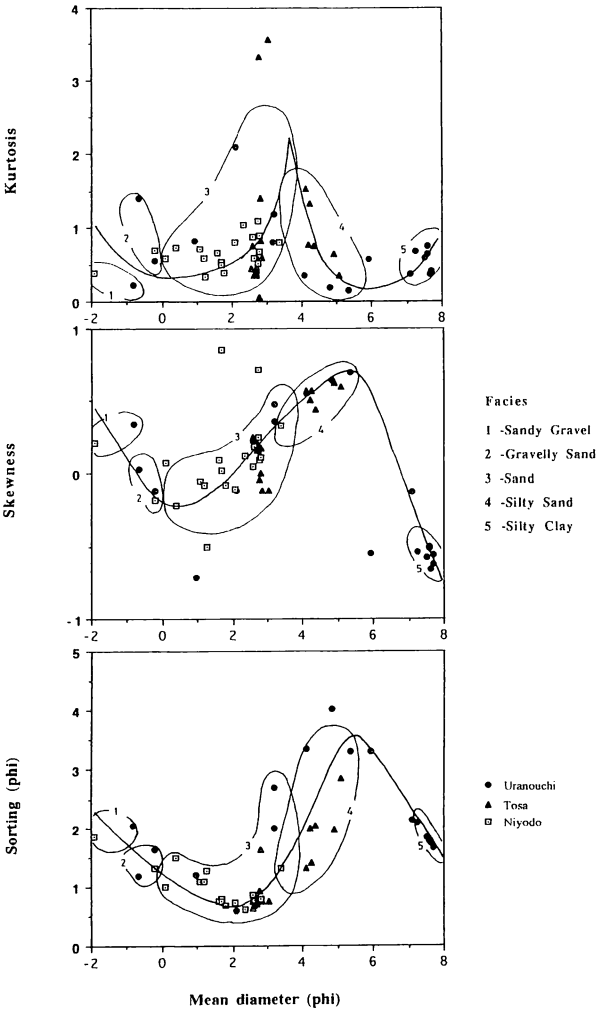

Fig. 7 . Relationship between statistical parameters- 1 .

Sorting vs mean diameter diagram shows sandy gravel to sand facies when mean diameter decreases quality of sorting (standerd deviation becomes better), and its pattern is sinusoidal. Most sorted sediments are found from the Niyodo river mouth reflecting high energy environment in the river mouth.

Skewness vs mean diameter diagram shows trend of sinusoidal curve. Sandy gravel facies is positively skewed and silty clay facies is very negatively skewed. This realizes consistence of fine tail of the sandy gravel facies and coarse tail of the silty clay facies. Mainly fine tail is composed with detrital very fine sand or silt, and materials of coarse tail is composed by biogenic shell or carbonaceous matters.

Kurtosis vs mean diameter diagram shows wavy trend, and sand and silty sand facies are leptokurtic, and sandy gravel and silty clay facies are platykurtic. Generally, Tosa bay sediments are shown leptokurtic than Niyodo river mouth and Uranouchi by sediments.

Other scatter plot diagrams of sorting and kurtosis vs skewness, and kurtosis vs sorting show complex patterns, however, first two diagrams have trend to be a circular. So that the three-dimensional plot of mean, sorting and skewness may be halical (Lewis, 1976 ; Fork and Ward, 1985)[15)16)].

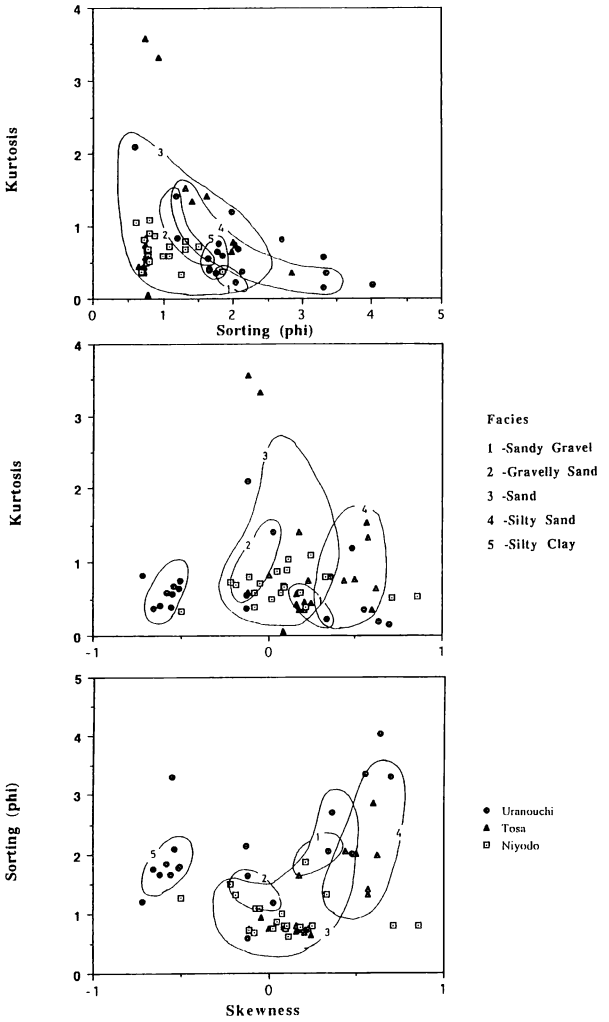

Fig. 8. Relationship between statistical parameters-2.

According to above data, following limits of each sedimentological parameter of dominant sediment facies in the study area have been determined as is shown in Tab. 2.

Tab. 2 . Sedimentary facies of the sediments in Tosa bay and Uranouchi bay.

Facies	Mode (ϕ)	Sorting($\sigma\ \phi$)	Skewness($\alpha\ \phi$)	Kurtosis($\beta\ \phi$)
Sandy Gravel	-2.0— -0.5	1.6—2.4	0.2 — 0.45	0.1 — 0.55
Gravelly Sand	-1.0— 0.0	1.0—1.8	-0.25— 0.2	0.5 — 1.5
Sand	1.0— 4.0	0.5—3.0	-0.4 — 0.6	0.1 — 2.7
Silty Sand	3.2— 5.8	1.0—3.75	-0.3 — 0.15	0.1 — 1.75
Silty Clay	7.2— 8.0	1.5—2.4	-0.71— -0.45	0.25— 1.0

3 — 3 Composition Analysis

Percentages of detrital matters from steeply decreasing from 20m to 45m of water depth in the coarse sand fraction. Also in the medium sand-size fraction, detritus matters are sharply decreasing up to 60m of depth and from there to deeper part are contained more than 80% of biogenic matters. Plant or organic matters are abundant in the depth of 65m and 90m of coarse sand fraction.

Biogenic species diversity on the shelf, in coarse sand fraction, gastropoda and pelecypoda are dominant in shallow shelf of 30m to 45m in depth. Distribution of total foraminifera that is predominant species are apparently same in this fraction. Medium size fraction of midshelf area is consisted with more than 50% of foraminifera. Biogenic constituents of fine sand fraction is less than 30% of total, concentrated in mid shelf, except 45m at depth. Detailed composition analysis are described by the writers in their other paper (Mitusio and Guruge, 1994)[9].

Ⅳ. Concluding remarks

Detrital, biogenic and relicts sediments are observed in the study area. In the shelf break, from 120m to 190m, sediments must be relicts of ancient semi-consolidated. Near shore moderately well sorted sands and well-sorted sands off Uranouchi bay mouth and sandy gravel sediments in Uranouchi bay reflect high energy wave actions. Characteristics of recent sediment facies and statistical parameters on the shelf are almost controled by the residual counter-clockwise currents (Miyata *et al.*, 1985)[17]. Pebble beach in the left side of Urado bay mouth is a good example as those bring by the above current system from the Monobe river sediment. The fine silt and clay size grains are depositing innermost part of bay shows weak tidal wave effects to the area.

Main facies and their general characteristics according to their statistical parameters are as follows.

Sandy Gravel : With 2.5mm mean grain size, very poorly to poorly sorted, positively skewed and very platykurtic sediments. Distributed in the Niyodo river mouth and outer Uranouchi inlet area.

Gravelly Sand : With 1.5mm mean grain size, very poorly to moderately sorted, near symmetrical to negatively skewed and irregular kurtosis sediments. Distributed in the inner Uranouchi inlet area.

Sand : With 0.177mm mean grain size, very poorly to moderately well sorted, irregular skewness and irregular kurtosis sediments. Distributed mainly at the areas of Niyodo river mouth, Tosa bay and Uranouchi bay.

Silty Sand : With 0.044mm mean grain size, poorly sorted, irregular skewness (Tosa bay sediments are very positively skewed) and irregular kurtosis sediments. Distributed mainly at the areas of Niyodo river mouth, Tosa bay and Uranouchi bay.

Silty Clay : With 0.005mm mean grain size, poorly sorted, very negatively skewed and very platykurtic sediments. Distributed only in the inner Uranouchi bay area.

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