Back Soils, Coastal Sands, and Marine Sediments of Nagura Bay in Comparison with Those of Kabira Bay, Ishigaki Island, Okinawa Prefecture*

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Abstract

The amounts of silt and clay in the coastal sands and the marine sediments of Nagura Bay were small as compared with Kabira Bay, which has a narrower bay mouth.

Main primary minerals of the coastal sands and the marine sediments were quartz and feldspar in both Nagura and the head of Kabira Bay. Small amounts of aragonite were in the marine sediments of Nagura Bay. Whereas, considerable amounts of calcite and aragonite were in the coastal sands and the marine sediments in the bay mouth and the bay center of Kabira Bay.

The above-mentioned differences were assumed to be due to the difference in the shape of the bays, particularly to the bay mouth features. The influence of eroded and transported backland soils to the coast and the marine bed was relatively small in Nagura Bay compared to the bay head of Kabira Bay.

Introduction

Shinagawa et al. (1980) conducted a study on the effect of back soils on the tidal zone coastal sands and the marine sediments of Kabira Bay (Fig. 1). It was shown that at the head of the bay, the main primary minerals in gravel (more 2 mm), coarse sand (2–0.2 mm) and fine sand (0.2–0.02 mm) of the coastal sands and the marine sediments were similar to those of the back soils, i. e. quartz and feldspar. The amount of silt (0.02–0.002 mm) and clay (less than 0.002 mm) of the coastal sands and the bed sediments at the bay head were greater than those at the center and the mouth of the bay. At the center and the mouth of the bay, main primary minerals of the coastal sands and the marine bed sediments were calcite and aragonite. They were not observed in the back soils. The clay mineral composition of the

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back soils and the marine sediments were similar, i. e. 7 Å mineral, illite and vermiculite. It was assumed that the clay minerals in the marine sediments were originated from the back soils, which were eroded and transported to the bay.

In the following report "Land development Works and Soil Erosion", it was shown that the agriculture, fisheries and landscapes were damaged from the above-mentioned eroded land soils from 1973 to 1980, in Okinawa Prefecture.

The objective of this study is to clarify the influence of eroded and transported backland soils on the coastal area and the marine bed of Nagura Bay in comparison with those of Kabira Bay. This will be accompolished through an identification of physical, chemical and mineralogical properties of the back soils, the coastal sands and the marine sediments.

Samples

Fig. 1. shows the sampling locations of the back soils, the coastal sands, and the marine sediments in the Nagura Bay area.

1) Soils

Table 1. gives a description of the soil samples. They were taken on the 11 th and 12 th of July, 1980. Samples 51 and 52 were regarded as representative of back soils of Nagura Bay and were classified into Red and Yellow Soils. Sample 51

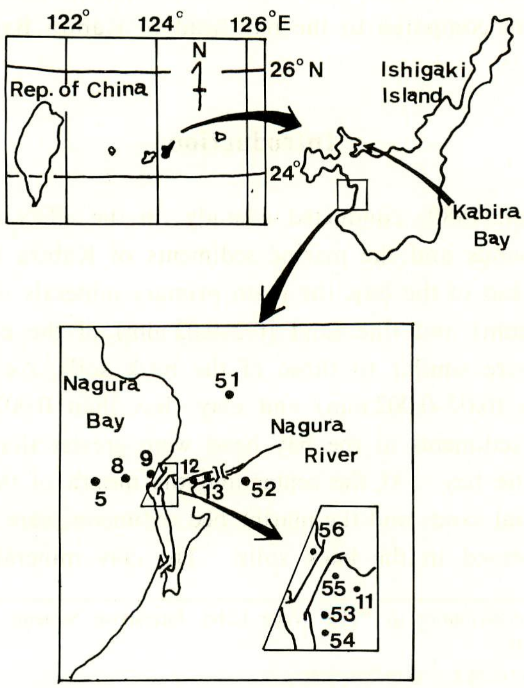

Fig. 1. Location of sampling sites.

Table 1. Description of the soil samples

Sample No.	Depth (cm)	Soil Color		Soil Great Group (Series)	Land use or Vegetation	Elevation (m)	Embankment slope	Topography
		wet	dry					
51-1	0-10	7.5 YR 3/3	7.5 YR 5/4	Red and Yellow Soils	Grazing Land	50	NW 8°	Gently Sloping Hill
51-2	10-20	7.5 YR 5/6	7.5 YR 5/4	(Arakawaatakabara Series)				
52-1	0-15	2.5 YR 3/6	2.5 YR 6/6	Red and Yellow Soils	Upland Field	15	NW 5°	Gently Sloping Hill
52-2	15-35	2.5 YR 4/8	2.5 YR 6/8	(Kawahara Series)	(pineapple)			
53	0- 8	10 YR 4/1	10 YR 7/2	Brown Lowland Soils (Yoshihara Series)	Mangrove	0		
54-1	0-0.7	10 YR 3/2	10 YR 5/2	Muck Soils (Motonagurashihara Series)	Sedge in Mangrove peat layer (0.7-12 cm)	0		
54-2	0.7-12	7.5 YR 2/1	7.5 YR 4/2					
54-3	12-20	2.5 YR 5/1	2.5 YR 7/2					

may belong to the Arakawaatakabara series, which were derived from cherty metamorphic rocks and were distributed on the undulating terraces or on the rolling to gently sloping hilly areas. Sample 52 may belong to the Kawahara series, which was largely derived from Nagura gravel layers and distributed on the undulating terraces. The height of the terraces were from 20 to 40 m. Gravel layers were not found within the first 1 m depth from the surface of the profile, although weathered and half-weathered small gravels consisting of sandstone, chert and other metamorphic rocks were sometimes present in the B horizon.

Samples 53 and 54 were taken from the mangroves, which are widely distributed on the estuary of Nagura River. According to Dr. TAGAWA and Dr. SUZUKI, the dominant species of the Nagura mangroves are *Bruguiera* sp., *Rhizophora* sp. and *Avecennia* sp. sample 53 may belong to Brown Lowland Soils, YOSHIHARA series. Sample 54 was taken from a sedge marsh, which was located in a small area of the Nagura mangrove forest. Sample 54-2 (sub-soil of 54-1) was a peat layer. Therefore, sample 54 may belong to Muck Soils, Motonagurashihara series. The classification and the names of soil series are based on YAMADA et al. (1973) (according to the Japanese soil classification system).

2) Coastal sands and marine sediments

Samples 55 and 56 were taken in the estury of Nagura River. Site 55 (sample 55) was in the tidal zone 5 m distant from the mangrove forest. Site 56 (sample 56) was in the river bed where the water wás constantly running. Samples 9. 11, 12, and 13 were sands from the tidal zone.

Samples 8 and 5 were marine sediments, taken 300 and 800 m distant from the coast.

Samples 5, 8, 9, 11, 12 and 13 were taken by Dr. A. INOUE, Professor of Kagoshima University (present Director of Kagoshima University Research Center for the South Pacific).

Experimental Methods

Physical, chemical, and mineralogical properties of the samples were analyzed by standard methods for soil analysis.

X-ray diffractograms of samples were obtained by Geigerflex D-3F (Cu Kα-ray).

Results and Discussions

As shown in Tables 2 and 3, clay contents of samples 51 and 52 were approximately 30-35 % and soil texture was generally LiC. Samples 51-2, 52-1 and 52-2 were highly acidic, while 51-1 was not. They exhibited a lack of humus horizon and low base saturation degree (less than 30 %). These are the main characteristics of representative Red and Yellow Soils of the Okinawa Islands (Chinzei *et al.* 1967; HAMAZAKI, 1979 a and b, KOBAYASHI and SHINAGAWA, 1966; SHINAGAWA *et al.* 1980; YAMADA *et al.* 1973). The deviation of sample 51-1 in some chemical properties, e. g. pH and Y_1 was assumed to be due to the liming.

Table 2. Particle size distribution and coefficient of permiability of soil samples (over-dry basis)

Sample No.	Gravel (%)	Fine Soil* C. S.	F. S.	Silt	Clay	Texture	Coefficient of Permeability (cm/sec)
51-1	17.9	19.5	25.9	19.7	34.9	LiC	2.1×10^{-4}
51-2	10.7	17.3	27.2	21.0	34.5	LiC	—
52-1	5.0	33.5	20.9	12.7	32.9	LiC	3.4×10^{-4}
52-2	2.0	23.6	22.2	22.7	31.5	LiC	2.1×10^{-5}
53	4.5	88.3	9.2	1.7	0.8	LCS	3.7×10^{-3}
54-1	•4.5	63.7	30.7	3.3	2.3	LCS	
54-3	4.0	86.3	10.8	1.8	1.1	LCS	

* Figures are expressed as per cent of inorganic materials (oven-dry-basis)

Table 3. Chemical properties of the soils and coastal sands (oven-dry basis)

Sample No.	Moisture (%)	Soil Acidity				Soil Organic Matter*			
		pH		Y_1 Value		Total C	Total N	Humus	C/N
		H_2O	N KCL	N KCL	N CaOAc				
51-1	5.2	6.9	6.0	0.2	3.3	2.19	0.097	3.78	22.6
51-2	5.0	5.0	4.0	12.0	22.8	1.14	0.074	1.97	15.4
52-1	5.3	5.2	4.0	11.9	14.4	0.22	0.021	0.38	10.5
52-2	6.6	5.2	4.1	16.8	14.1	0.20	0.015	0.34	13.3
53	1.2	7.8	8.0	—	—	1.09	—	1.88	—
54-1	4.9	6.8	6.7	0.2	4.7	5.14	0.210	8.86	24.2
54-2	8.4	5.6	5.4	0.4	—	10.11	0.440	17.4	23.0
54-3	0.6	7.8	8.1	—	—	0.6	0.020	1.03	30.0
55	1.1	8.2	8.4	—	—	0.39	0.037	0.67	10.5
56	0.4	8.1	8.5	—	—	0.04	—	0.07	—

* Figures are expressed as per cent of Total (oven-dry basis)

Table 3. (cont) Chemical properties of the soils and coastal sands

Sample No.	Cation Exchange Capacity (me/100g)	Exchangeable Bases				Base Satu. Degree (%)	Ca. Satu. Degree (%)	Phos. Absorp. Coeffi.	Available P_2O_2 (ppm)
		Ca	Mg	K	Na				
			me/100 g	soil					
51-1	24.2	5.91	0.97	0.46	0.11	30.8	24.4	385	53.3
51-2	11.0	0.88	0.27	0.10	Tr	11.3	8.0	477	19.5
52-1	11.1	0.46	1.54	0.26	0.11	21.4	4.2	433	36.7
52-2	12.0	0.84	2.41	0.21	0.26	30.9	7.0	454	6.8
53	8.1	5.69	2.70	0.48	7.53			Tr	8.3
54-1	38.7	5.05	7.89	0.40	7.23			77	27.0
54-2	44.8	4.59	6.19	1.78	0.53			48	12.0
54-3	6.5	8.41	0.86	0.05	0.98			7.5	103
55	5.7	7.91	3.01	0.45	5.26			207	11.3
56	2.9	3.69	1.87	0.10	1.72			176	7.5

As shown in Fig. 2, the X-ray diffraction pattern of random powder specemens of sand (2-0.02 mm) and silt (0.02-0.002 mm) fractions showed that the main primary minerals of samples 51 and 52 were quatz and feldspar. It was observed that the intensity of quartz's peaks were sharper and more distinct than those of feldspar's. Whereas, under polarizing microscope observation, weathered feldspars were dominate. A small amounts of clay minerals, probably illite (10 Å) and metahalloysite (7.2 Å), were present in the silt fraction of 52-1.

Fig. 3. shows the X-ray diffractograms of deferrated and oriented specemens of clays. The dominant clay minerals of samples 51 and 52 were illite and kaolin

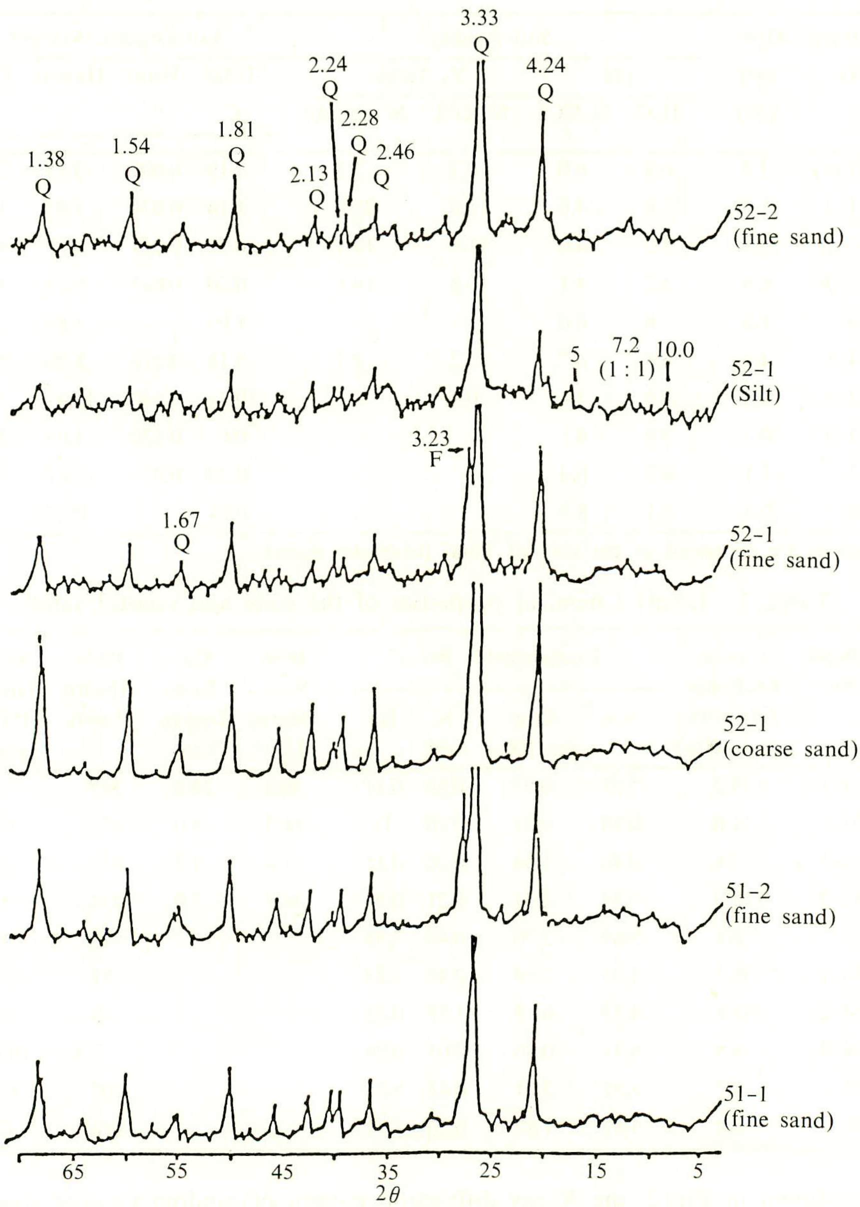

Fig. 2. Random powder X-ray diffractograms of coarse sand (2–0.2 mm), fine sand (0.2–0.02 mm) and silt (0.02–0.002 mm) fractions of the back soils (samples 51 and 52). Q ; Quartz, F : Feldspar, I : Illite.

minerals (probably metahalloysite) with small amount of vermiculite. These samples contained no montmorillonite. YAMADA *et al.* (1973) and SHINAGAWA *et al.* (1980)

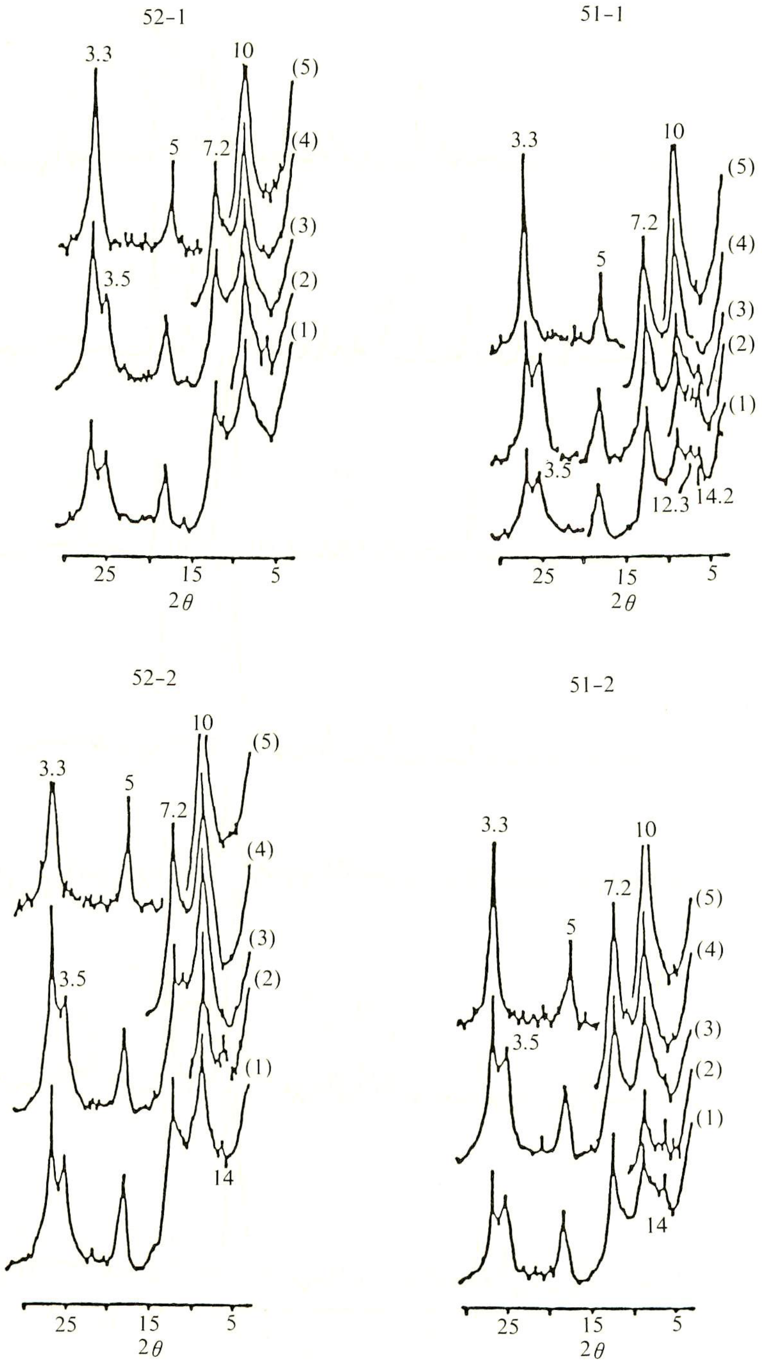

Fig. 3. Oriented X-ray diffractograms of deferrated clay (less than 2 mm) fractions of the back soils (samples 51 and 52). (1) : Mg-clay. (2) : Mg-ethylenglycol clay. (3) : K-clay. (4) : K-clay 350°C, (5) : K-clay 550°C.

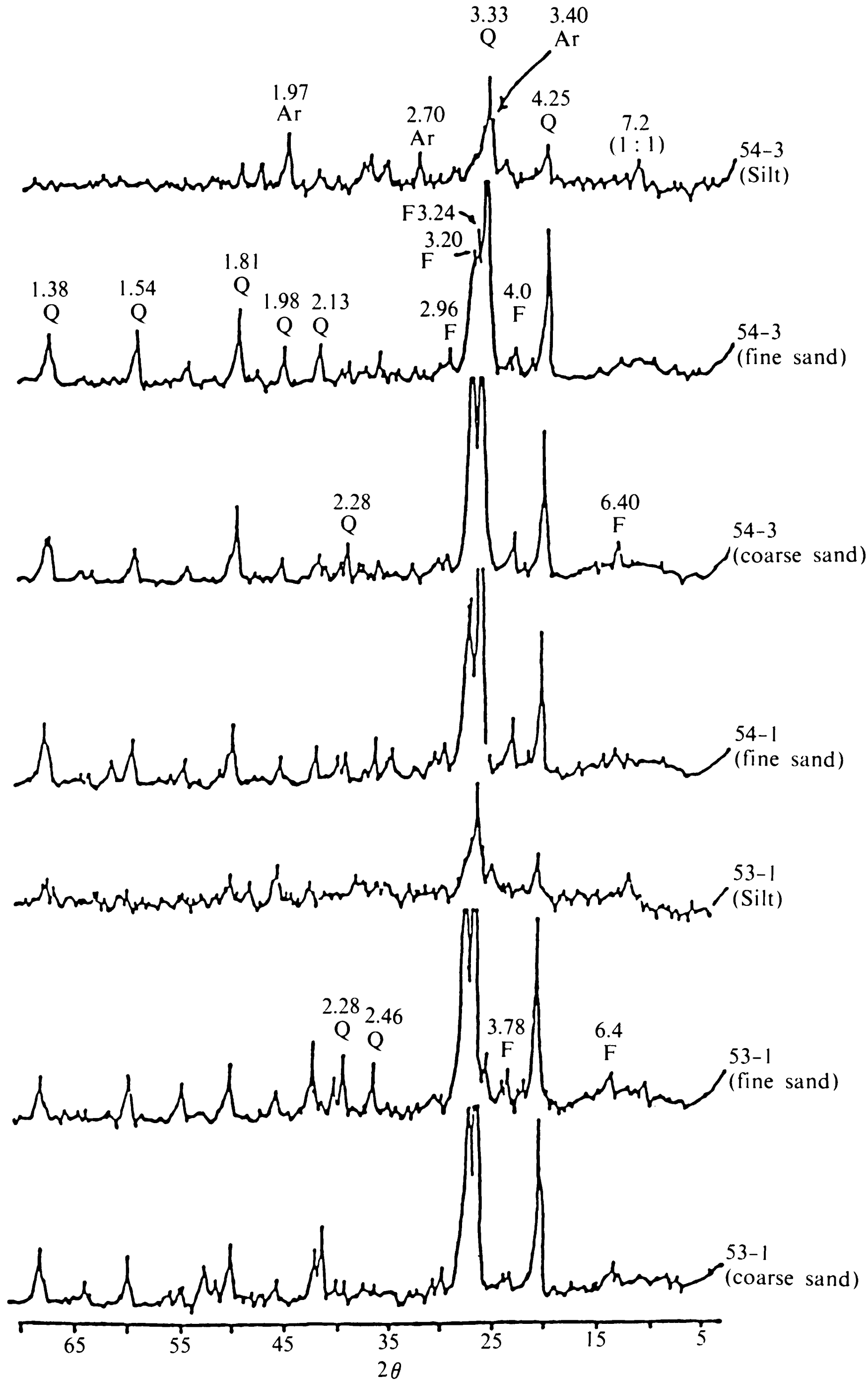

Fig. 4. Random powder X-ray diffractograms of coarse sand (2-0.2 mm), fine sand (0.2-0.02 mm) and silt (0.02-0.002 mm) fractions of the mangrove soils (samples 53 and 54).
Q : Quartz, F : Feldspar, Ar : Aragonite.

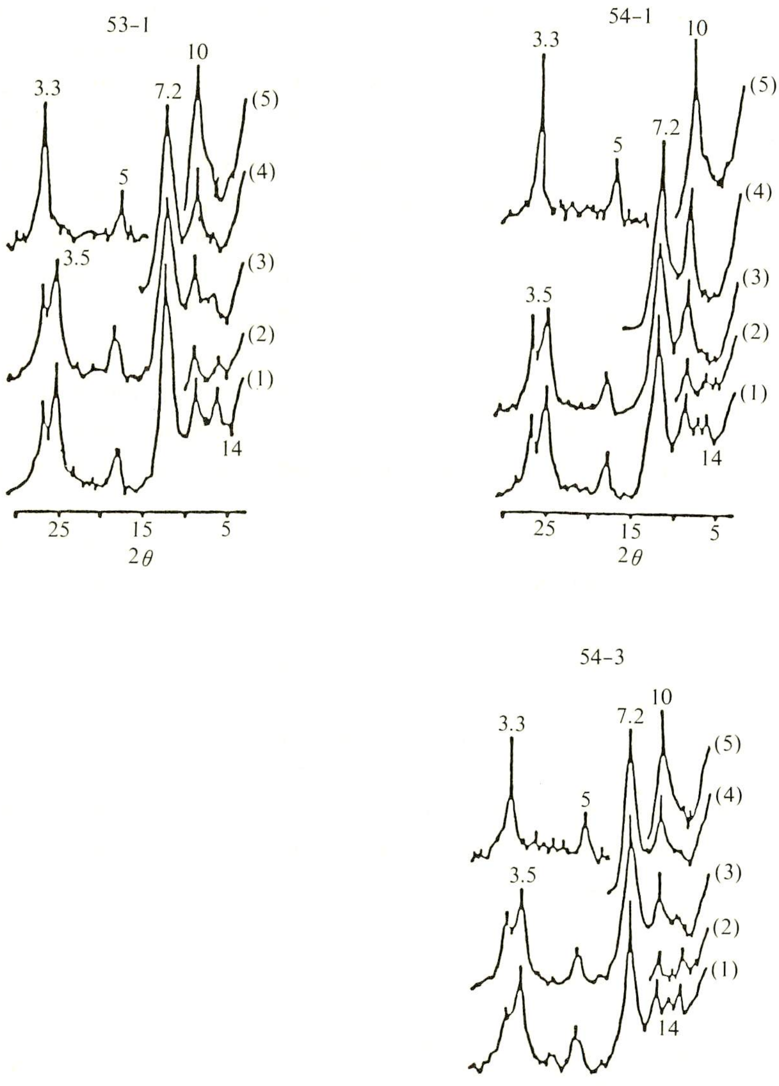

Fig. 5. Oriented X-ray diffractograms of deferrated clay (less than 0.002 mm) of the mangrove soils. (samples 53 and 54).
(1) : Mg-clay, (2) : Mg-ethylenglycol clay, (3) : K-clay,
(4) : K-clay 350°C, (5) : K-clay 550°C.

showed that the main clay minerals of Red and Yellow Soils on Ishigaki Island were 7, 10 and 14 Å minerals, and the proportion of these minerals seemed to depend on the parent materials, land use, topography, etc. The results obtained in this study were in fair agreement with the data of cited references.

Physical and chemical properties of the mangrove soils (53 and 54) were distinctly different from Red and Yellow Soils (51 and 52). Coarser texture (LCS)

(Table 2), weak alkalin reaction and high degree of base saturation were the characteristic differences. Also, the primary mineral composition was somewhat different from that of Red and Yellow Soils (Fig. 4). Aragonite was present in the fine sand and silt fractions of samples 53 and 54, though the clay mineral composition was the nearly the same as that of back soils (Fig. 5). Sample site 54 was located in a sedge marsh of mangrove forest. Exchangeable Mg content of samples 54-1 and 54-2 was clearly greater than that of the coastal sand samples 55 and 56. The pedogenetic reasons for the development of sedge marsh and peat layer in the mangrove forest seems to be low temperature and low base concentration of ground water.

The particle size distribution of coastal sands and marine sediments are shown in Table 4. It was obvious that the content of finer fractions (silt and clay) of coastal sands and marine sediments decreased from the upstream to the down stream bed.

As shown in Fig. 6 and 7, the main primary minerals of the coastal sands were the same as those of the back soils ; i. e. quartz and feldspar. Aragonite was detected in samples 5 and 8, 800 m and 300 m from the seashore, respectively (Fig. 7). Apparently with the increased distance from the seashore, the amount of minerals formed in the marine, e. g. calcite from the coral reaf, aragonite from the shell, seem to increase gradually. Clay mineral composition of the coastal sands and the marine sediments were the same as that of back soils (Fig. 8 and 9). Therefore, each clay mineral in the coastal sands and marine sediments was assumed to originate from the eroded and the transported back soils. This assumption obtained in Nagura Bay is the same as Kabira Bay.

Table 4. Particle size distribution of coastal sands and marine sediments

Sample No.	Gravel (%)	Fine Soil*				Texture
		C. S.	F. S.	Silt	Clay	
13	26.3	83.8	6.4	5.4	4.4	LCS
12 (0-10 cm)	5.2	84.9	13.2	0.9	1.0	LCS
(10-25 cm)	14.9	93.3	4.7	1.2	0.8	LCS
11	4.7	85.5	12.9	0.7	0.9	LCS
55	1.8	83.0	13.7	1.7	1.6	LCS
56	10.3	99.7	0.3	Tr	Tr	LCS
9	5.6	97.7	1.8	0.3	0.2	LCS
8	7.2	88.3	9.7	1.0	1.0	LCS
5	1.3	96.6	2.9	0.3	0.2	LCS

* Figures are expressed as percent of inorganic materials (oven-dry basis).

Fig. 6. Random powder X-ray diffractograms of coarse sand (2-0.2 mm), fine sand (0.2-0.02 mm) and silt (0.02-0.002 mm) fractions of the tidal zone's coastal sands (samples 55 and 56).
Q : Quartz, F : Feldspar.

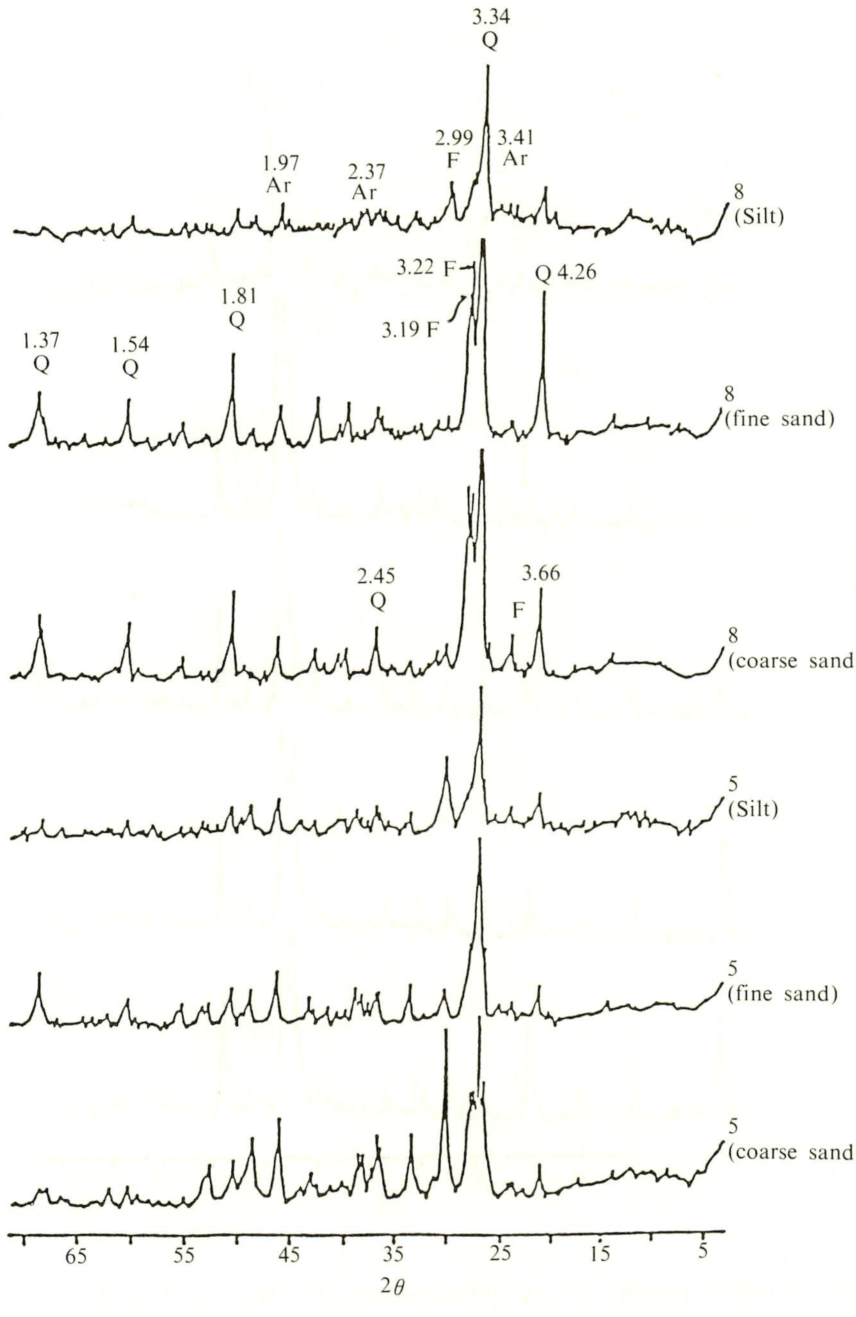

Fig. 7. Random powder X-ray diffractograms of coarse sand (2-0.2 mm), fine sand (0.2-0.02 mm) and silt (0.02-0.002 mm) fractions of the marine sediments (samples 8 and 5).

Q: Quartz, F: Feldspar, Ar: Aragonite.

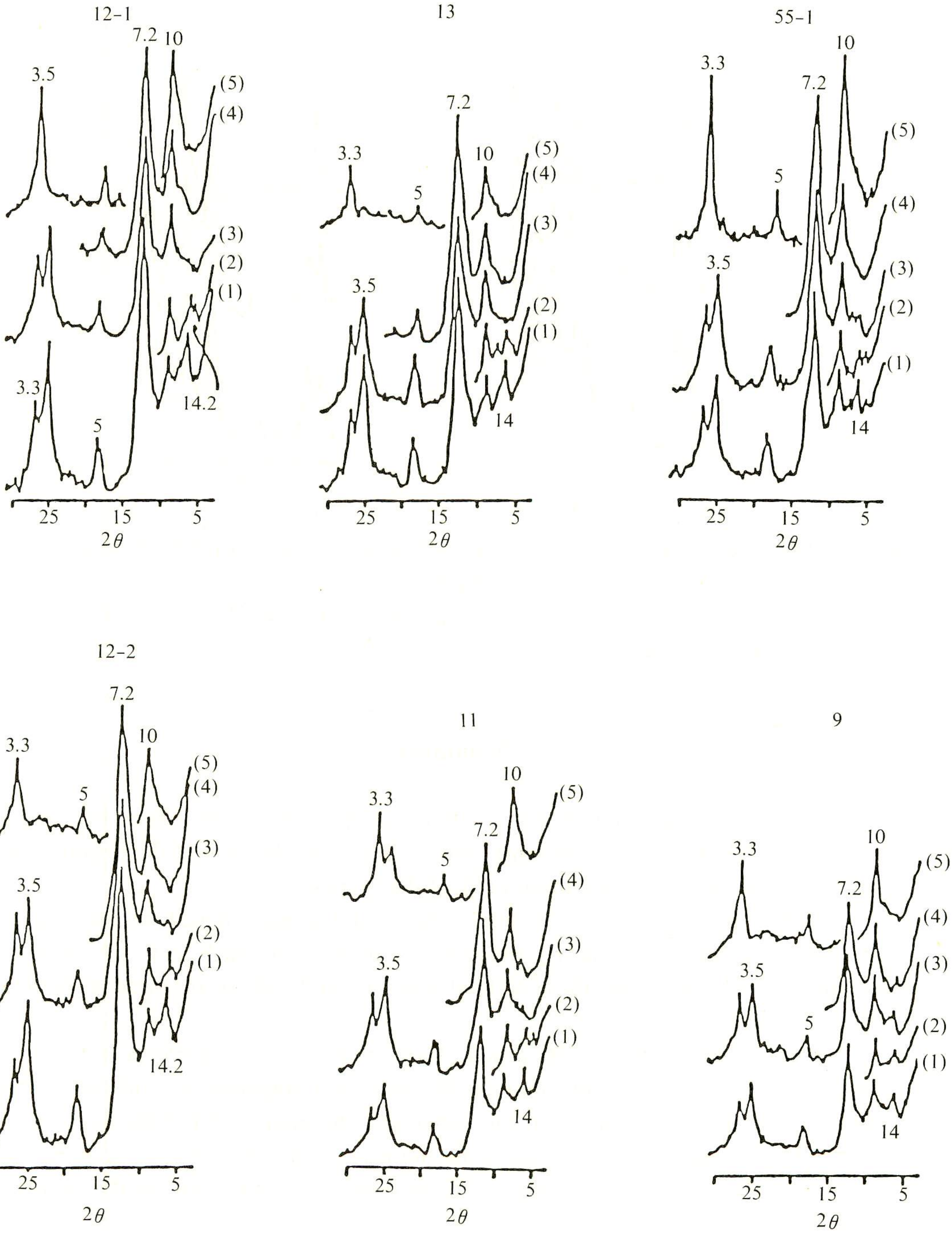

Fig. 8. Oriented X-ray diffractograms of deferrated clay (less than 0.002 mm) of the tidal zone's coastal sands (samples 55, 13, 12, 11 and 9).
(1) : Mg-clay, (2) : Mg-ethylenglycolclay, (3) : K-clay, (4) : K-clay 350°C, (5) : K-clay 550°C.

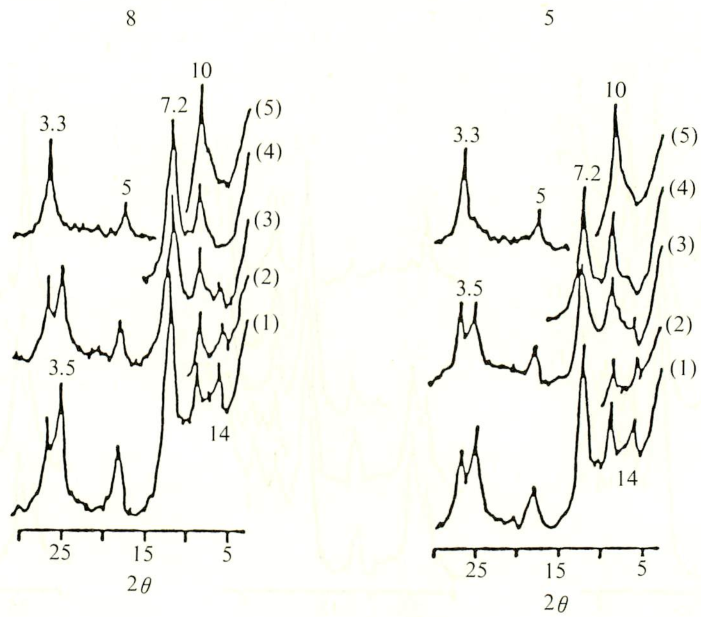

Fig. 9. Oriented X-ray diffractograms of deferrated clay (less than 0.002 mm) of the marine sediments (samples 5 and 8).
(1) : Mg-clay, (2) : Mg-ethylenglycol clay, (3) : K-clay, (4) : clay 350°C, (5) : K-clay 550°C.

Summary

1) The main back soil of Nagura Bay was Red and Yellow Soils (according to Japanese soil classification system), and its physical, chemical and mineralogical properties were identical with those of published reports.

2) Main primary minerals of tidal zone coastal sands, situated on the elongation of Nagura River were nearly the same as those of the back soils. And, these minerals were identical with those of tidal zone coastal sands in the head of Kabira Bay.

In the marine sediments, 300 m and 500 m from the shore, some aragonite was detected. Whereas, considerable amounts of calcite and aragonite were in the coastal sands and the marine sediments in the center and the mouth of Kabira Bay.

3) The amount of finer fractions (silt and clay) in the coastal sands and marine sediments of Nagura Bay was very small as compared with those in the head of Kabira Bay.

The clay mineral composition of the back soils, coastal sands and marine sediments of Nagura Bay was nearly the same. This was in fair agreement with that of Kabira Bay.

4) The above-mentioned distinct differences between Nagura Bay and Kabira Bay were assumed to be due to the diffrences in the shapes of the bays, particulary

to the bay mouth features. The influence of transported land soils to the coast and the marine bed was assumed to be relatively small in Nagura Bay as compared with the head of Kabira Bay.

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References

CHINZEI, T., OYA, J., KOJA, J., DONAHUE, R. L. and SHICKLUNA, J. C. 1967. Soils and land use in Ryūkyū Islands. Hoshi Printing Co., Nawa Okinawa. pp 187. (in English and Japanese)

HAMAZAKI, T. 1979a. Parent materials and soils of Nansei-shotō in Japan. Pedologist. 23 : 43-57. (in Japanese)

HAMAZAKI, T. 1979b. Natural environment and soil distribution of Nansei-shotō in Japan. Pedologist. 23 : 88-96. (in Japanese).

KOBAYASHI, T. and SHINAGAWA, A. 1966. Studies on the soils of Nansei Islands in the subtropical region of Japan, 1 : Soils of Ryūkyū Islands. Bull. Fac. Agr. Kagoshima Univ. 16 : 11-55. (in Japanese with English summary).

SHINAGAWA, A., HIGASHI, T. and KONDO, N. 1980. Relationships between the tidal zone's coastal sands and the marine sediments of Kabira Bay and their back soils in Ishigaki Island, Okinawa Prefecture. Mem. Fac. Agr. Kagoshima Univ. 16 : 103-128.

YAMADA, Y., MOTOYAMA, S., MATSUSAKA, Y. and KATO, Y. 1973. Soils of Ishigaki, Miyako and Yonaguni Islands. Bull. National Inst. Agr. Science (Japan) Series B. 24 : 266-355. (in Japanese with English summary).

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