

Relationships between the Tidal Zone's Coastal Sands and the Marine Sediments of Kabira Bay and their Back Soils in Ishigaki Island, Okinawa Prefecture

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Introduction

This work is carried out as one branch of the "Study on the coral reef-area ecosystem in Okinawa, its present status and environmental change" (Grant-in-Aid for Special Project Research, 1974–1977, Japanese Ministry of Education, Head investigator: Dr. M. Horigoshi, Professor of Tokyo University). The purpose of this report is to elucidate the distributions and qualities of the land soils inflowed and deposited on to the coast and marine bed of Kabira bay in Ishigaki Island, Okinawa Prefecture.

The land soils, coastal sands of tidal zone and marine sediments are successive though the respective environments are quite different. The environment of the land soils, especially, of the surface soils are oxidative, for the tidal zones, the environments are oxidative during low water and reductive during high water, namely, both conditions occur alternatively. On the contrary, the marine sediments are in a reductive condition. Few official reports have been published on the relationships among the physical, chemical and mineralogical properties of the above-mentioned three successive materials.

Ishigaki Island, Okinawa Prefecture is situated in a sub-tropical region (see Fig. 1.) and on the coast of this island, coral reefs are well developed. But recently, the ecosystem and environment of the coast and marine bed seem to have been considerably altered by men. In about 1970, when the forest-road in back land of Kabira bay was being constructed for the forest industry development,

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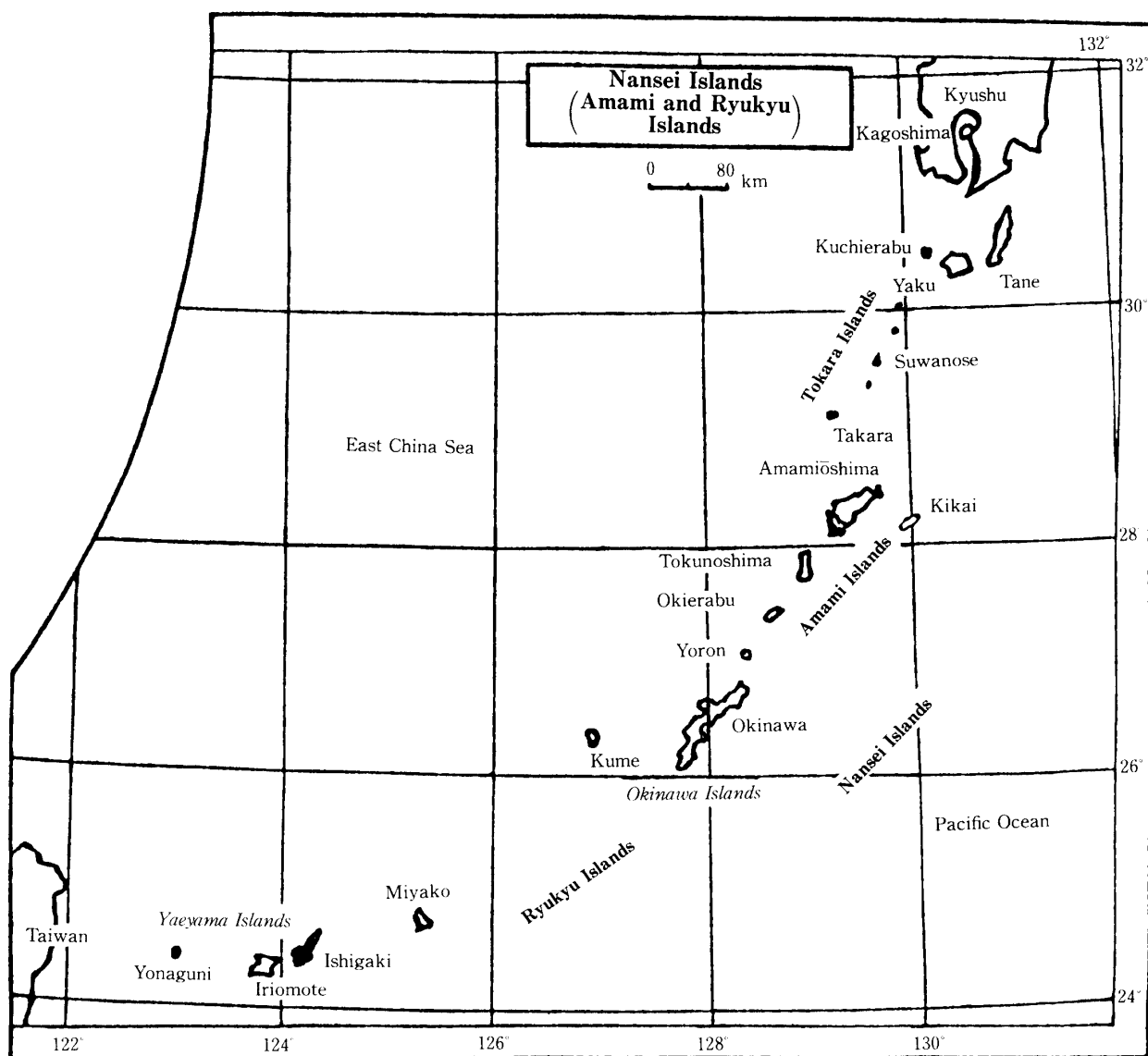


Fig. 1. Nansei Islands.

it was said that considerable amounts of back soils inflow on to the coast and the marine bed of the bay head, therefore, the marine-ecosystem changed and the fishermen stopped the forest road construction. And the Agriculture development plan in which newly developing upland fields for vegetables shall be built on the bay's east upland, goes on; soil dressing to the bay's east field is in progress. Another problem that soils and sewages are going to inflow on to the bay, subsequently the turbidity of the sea is to be increased and development of coral reef is going to be stopped, will also occur in the near future.

Accordingly, the authors would like to prepare this report as some fundamental data to be used to prevent an undesirable change of the ecosystem in the coral reef-area.

Samples

Fig. 2 showed the sampling localities of the soils, coastal sands and marine sediments.

1. Soils

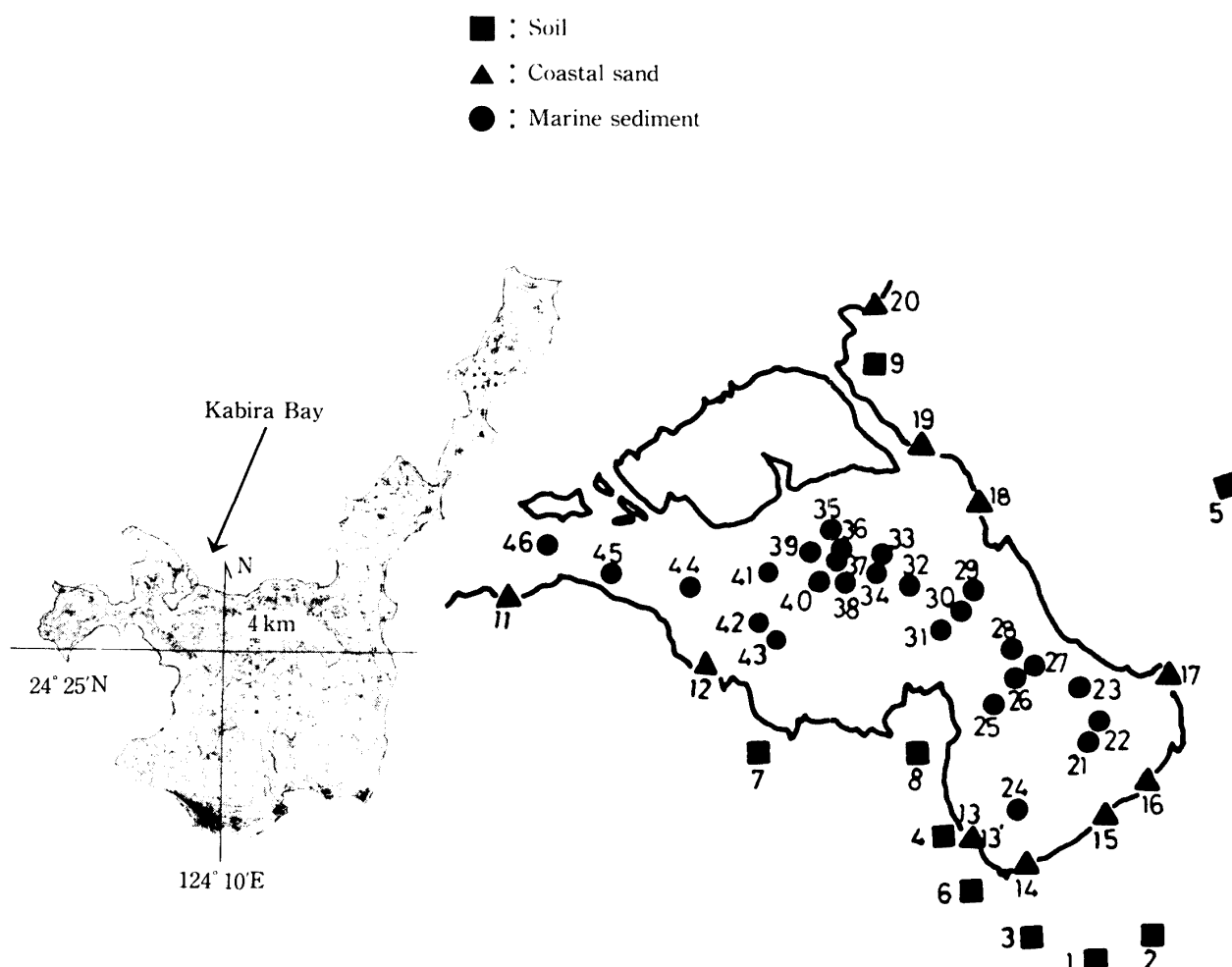


Fig. 2. Localities of the samples.

Table 1 illustrated the descriptions of the soil samples. They were taken in July, 1974 and in November, 1976.

No. 3 is the surface soil of an ill drained paddy field, No. 5 is the land soil of coastal dike and a vapor of hydrogen sulfide develops from its surface. According to Table 1, soil colors of those two samples were grayish and their drainage conditions were not good. Therefore, No. 3 and 5 may belong to the category of Gley Soils* (Sanza series "Os" by Yamada et al.⁴⁾). Gley Soils were sparsely distributed near Kabira bay.

By Yamada et al.⁴⁾, most of the back soils of Kabira bay are granitic residual soils and may belong to Red and Yellow Soils* (Kabira series "Kb"). No. 1 and 2 are residual virgin soils and seem to be typical Red and Yellow Soils. No. 6 and 9 were cultivated field soils and No. 7 and 8 were abandoned field soils, a trace of applied calcium carbonate was found in the surface of No. 6, 7, 8 and 9.

No. 4 is formed from Ryukyu limestone and was transported to the locality as soil dressing from Ishigaki Island, excepting the back land of Kabira bay, to make the vegetable field. Its value of soil color was 4 (dark red). No. 4 may belong to the Dark Red Soils** (Maeri series "M"⁴⁾).

*: Soil order category according to Japanese soil classification

**: Soil sub-order category

Table 1. Descriptions

No.	Parent Material	Depth (cm)	Soil classification	Soil (wet)
1-1	Granite	0-15	Red and Yellow Soils	2.5 YR 5/6
1-2		15-60		2.5 YR 6/8
2-1	Granite	0-10	"	5.0 YR 5/4
2-2		10-60		7.5 YR 6/8
2-3		60-		2.5 YR 5/8
3	Alluvial	0-20	Gley Soils	10.0 YR 4/6
4-1	Limestone	0-15	Dark Red Soils	10.0 YR 4/8
4-2	Granite	15-60	Red and Yellow Soils	7.5 YR 4/6
5	Alluvial	0-10	Gley Soils	5.0 YR 3/4
6	Granite	0-10	Red and Yellow Soils	10.0 YR 5/6
7-1	Granite	0-25	"	10.0 YR 3/4
7-2		25-40		10.0 YR 3/4
8	Granite	0-20	"	7.5 YR 4/4
9	Granite	0-20	"	10.0 YR 3/4

2. Coastal sands

Coastal sand samples whose localities are shown in Fig. 2 were taken in 1974-1976. The depths of all the samplings were 0-10 cm. No. 12's locality is the estuary of the sewage drainage basin. No. 13' is sea-shore-sand of coastal dike, its color is reddish brown (2.5 YR 4/4). Reddish brown sand such as No. 13' is distributed in a small area (about 10 m²) of the bay head.

3. Marine sediments

Marine sediments samples were taken by Dr. M. Horigoshi, Professor of Tokyo University and his collaborators in 1974. Those samples were sent to Dr. K. Konishi, Professor of Kanazawa University. The authors received the samples in February, 1975 from Dr. Konishi. The sampling localities are shown in Fig. 2.

Experimental methods

1. Physical and chemical properties

Three kinds of samples were analyzed by usual soil analysis.

2. Primary minerals

Coarse sand (2-0.2 mm) and fine sand (0.2-0.02 mm) of typical samples were separated into three fractions (spgr > 2.8, 2.8-2.7, < 2.7) by a heavy liquid. After microscopic examination, each fraction was dissolved in 0.3% HCl to dissolve calcite and aragonite. Undissolved fractions (which may be originated from land rocks) were weighed. And X-ray diffraction studies of the ground coarse and fine sand fractions (random specimens) were made by Geigerflex D-3F (CuK_α ray, 25 KV, 10 mA).

3. Clay minerals

of soil samples

color (air dry)	Land use (vegetation)	Sampling locality	Remark
10.0 YR 6/6 5.0 YR 6/8	Grass land (Mischansus)	Sakieda Ishigaki city	Upland
2.5 Y 7/2 10.0 YR 8/6 5.0 YR 6/8	Grass land	"	Top of upland
2.5 Y 6/2	Paddy field (paddy rice)	"	
2.5 YR 5/6 7.5 Y 5/4	Upland field (In 1974, new develop field was making)	Yoshihara Ishigaki city	4-1: <u>Soil Dressing</u>
5.0 YR 5/2		Kabira Ishigaki city	Land soil of coastal dike
10.0 YR 7/2	Upland field (sugar cane)	"	
7.5 YR 5/4 10.0 YR 5/2	Grass land	"	Abandoned field
7.5 YR 5/4	Grass land	"	"
10.0 YR 3/4	Upland field (sugar cane)	Nakasuji Ishigaki city	

Clay fractions (<0.002 mm) were deferrated by Mehra and Jackson's method³⁾ and oriented X-ray diffractograms of K-clay, K-clay 350°C, K-clay 550°C, Mg-clay and Mg-ethylenglycol clay were obtained by Geigerflex D-3F (Cu K_{α} ray, 25 KV, 10 mA).

4. DCB soluble R_2O_3

Dithionate-citrate-bicarbonate soluble (hereafter these soluble fractions are called DCB soluble fractions) Fe_2O_3 and Al_2O_3 were determined by atomic spectrophotometry. DCB treatment was performed by Mehra and Jackson's method³⁾.

Results and Discussion

1. Physical and chemical properties

(1) Soils

As shown in Table 1, the color of the samples was generally reddish yellow except for No. 3 and 5 (Gley Soils) and No. 4 (Dark Red Soils). The physical properties and mechanical compositions are shown in Table 2.

Percentage of soil phase were generally 42.3–59.9, but Gley Soils such as No. 3 and 5 showed low values (28.6–29.6%). Clay (<0.002 mm) contents of the samples were various, according to the parent materials, topography, land use etc. No. 4-1 which was originated from limestone contained 53.6% of clay. On the other hand, a relatively small amount of clay (6–8%) was found in the cultivated field soils (No. 6 and 9) and the abandoned field soils (No. 7 and 8). Water permeabilities of No. 3, 5 and 4-1 (Gley Soils and limestone soils) were not good, its coefficients of permeability were 10^{-5} – 10^{-6} cm/sec. For Red and Yellow Soils, as the clay percent rose from 6.5 to 30.2 (No. 7-1, No. 1-2), permeability coefficients decreased from 10^{-2} to 10^{-4} cm/sec. re-

Table 2. Physical properties and mechanical composition of soil samples

No.	Bulk density	Solid phase (%)	Coefficient of permeability (cm/sec.)	Gravel (%)	Fine soil				Texture
					Coarse sand (%)	Fine sand (%)	Silt (%)	Clay (%)	
1-1	1.2	45.2	1.8×10^{-4}	25.9	22.1	23.5	24.2	30.2	SC
1-2	1.3	44.6	3.5×10^{-4}	7.0	19.6	40.9	15.8	23.7	SCL
2-1	1.2	49.7	1.2×10^{-3}	0.3	18.5	32.3	43.1	6.1	L
2-2	1.4	53.6	1.1×10^{-3}	4.6	22.4	26.9	33.8	16.9	CL
2-3	1.3	44.8	1.4×10^{-4}	2.3	26.9	27.4	25.3	20.4	CL
3	1.0	28.6	7.3×10^{-5}	0.1	5.2	19.9	40.3	34.6	LC
4-1	1.3	42.3	2.1×10^{-5}	3.3	3.2	14.6	28.6	53.6	HC
4-2	1.3	47.4	1.2×10^{-4}	11.0	14.6	20.2	43.4	21.8	CL
5	1.1	29.9	8.6×10^{-6}	3.0	28.6	36.5	16.6	18.3	SCL
6	1.1	42.7	1.4×10^{-2}	2.1	24.8	61.2	5.8	8.2	LCS
7-1	1.3	50.1	2.2×10^{-2}	4.0	61.4	17.9	14.2	6.5	CSL
7-2	1.4	49.5	5.6×10^{-3}	0.9	52.6	22.3	19.1	6.0	CSL
8	1.4	51.8	4.3×10^{-3}	0.2	60.1	20.3	12.3	7.3	CSL
9	1.6	59.9	4.5×10^{-3}	0	72.6	9.5	6.2	11.7	CSL

spectively.

Table 3 illustrated the chemical properties of the soil samples. No. 4-1 showed a weak alkaline reaction and a high degree of base and calcium saturation, but its exchangeable base contents

Table 3. Chemical properties of

No.	Moisture (%)	Soil acidity				Soil organic matter			
		pH		$Y_{1\text{KCl}}$	$Y_{1\text{CaOAc}}$	Total carbon (%)	Total nitrogen (%)	Humus (%)	C/N
		H ₂ O	N-KCl						
1-1	3.64	5.5	5.0	0.5	1.7	0.47	0.04	0.81	11.8
1-2	2.55	5.0	4.2	2.4	2.0	0.09	0.02	0.16	4.5
2-1	3.92	5.9	5.4	0.5	2.3	1.73	0.13	2.98	13.3
2-2	1.92	5.1	4.6	4.2	2.0	0.62	0.05	1.07	12.4
2-3	3.76	4.1	4.3	4.4	3.4	0.24	0.03	0.41	8.0
3	3.41	5.6	4.7	0.6	4.5	3.53	0.30	6.09	11.8
4-1	5.21	7.8	7.0	0.1	0.3	0.44	0.03	0.70	14.7
4-2	7.68	4.7	3.8	3.8	6.5	1.45	0.11	2.50	13.2
5	0.49	7.8	7.0	0.1	5.3	1.42	0.07	2.45	20.3
6	0.46	8.2	7.2	0.1	3.6	0.52	0.03	0.90	17.3
7-1	0.65	5.1	4.2	3.2	27.1	0.73	0.04	1.26	18.3
7-2	0.77	5.0	4.1	6.1	30.9	0.75	0.04	1.29	18.8
8	0.53	5.8	4.6	0.5	19.0	0.71	0.05	1.22	14.2
9	0.65	5.9	4.9	0.1	20.9	0.84	0.06	1.45	14.0

were not so high, except for Ca. Owing to the application of calcium carbonate, No. (7-2)'s and 9's base and calcium saturation degrees were considerably higher than others. In most of Red and Yellow Soils, pH (H₂O, N-KCl) values were low and base saturation degrees were less than 45%. Clay contents of the cultivated and abandoned field soils (No. 6, 7, 8 and 9) were lower than 20% and their CEC values were lower than 13 me, therefore, their total exchangeable base contents were not so high, but base saturation degrees were calculated to be comparatively high percentage. Furthermore, in the cultivated fields, there were possibilities of the existence of various bases which were artificially applied as fertilizers. Consequently, cultivated and abandoned field soils showed a coarser texture than those of virgin soils by the stronger illimerization and a somewhat different base status both of which are due to the cultivation.

Fe²⁺ contents of Gley Soils (No. 3 and 5) were large (5.38 and 2.43 ppm). The other soils except for Gley Soils were poor in Fe²⁺.

It is evident that the data presented in Table 1 and 2 are in fair agreement with the results of Kobayashi and Shinagawa³⁾, Yamada et al.⁴⁾ and Chinzei et al.¹⁾. The authors would like to conclude that the back soils of Kabira bay are quite common ones in the sub-tropical region of Japan.

(2) Coastal sands

Color, solid phase, mechanical composition and Fe²⁺ content of coastal sands were illustrated in Table 4. According to the physical properties, coastal sand samples seem to have been classified into three groups. Namely, a) group : No. 13, 14, 15 and 16 from the bay head, b) group : No. 11 and 12 from the west bay entrance and No. 20 from the oceanic sea shore on the east coast, and c) group : No. 18 and 19 from the east coast of bay center.

a) group : Wet color were reddish yellow (7.5 YR 5/6-7.5 YR 6/6), soil phase was about 50%, water permeability coefficients were 10⁻²-10⁻³ cm/sec. respectively, relatively poor in coarser frac-

the soil samples (oven dry basis)

Cation exchange							Phosphoric acid absorption coef.	Available P ₂ O ₅ (ppm)	Fe ²⁺ (ppm)
me/100 g					Base saturation degree (%)	Ca saturation degree (%)			
CEC	Ca	Mg	K	Na					
10.77	1.05	2.11	0.34	0.58	37.8	9.7	461	20.4	0.23
10.24	0.40	2.82	0.15	0.69	39.5	3.9	389	17.3	0.17
12.46	2.68	2.12	0.47	0.34	45.0	21.5	174	29.3	0.26
9.16	0.93	1.49	0.24	0.28	32.1	10.2	949	30.6	0.82
12.65	0.54	1.36	0.19	0.29	18.9	4.3	200	6.8	0.35
20.04	4.59	0.84	0.18	0.57	30.8	22.9	539	9.7	5.38
26.11	18.47	1.31	0.25	1.34	81.8	70.7	943	3.4	0.61
23.35	0.83	1.93	0.15	0.38	14.1	3.6	461	4.1	0.22
24.46	2.69	3.49	0.54	8.15	60.8	11.0	781	80.8	2.43
13.04	3.94	0.24	0.11	0.30	35.2	30.2	727	103.0	0.06
2.81	0.46	0.19	0.11	0.11	31.0	16.4	746	18.0	0.04
3.13	1.63	0.09	0.10	0.26	66.5	52.0	781	5.0	0.03
3.13	0.78	0.33	0.14	0.20	46.3	24.9	746	20.0	tr.
3.44	1.19	0.38	0.15	0.11	53.2	34.6	727	5.0	0.02

Table 4. Color, physical properties, mechanical composition and Fe²⁺ content of coastal sands

No.	Color		Bulk density	Solid phase (%)	Coefficient of permeability (cm/sec.)	Grav-el (%)	Fine soil					Fe ²⁺ ppm/oven-dry basis
	(wet)	(air dry)					Coarse sand (%)	Fine sand (%)	Silt (%)	Clay (%)	Texture	
11	5.0 YR 8/2	2.5 Y 8/2	1.3	44.9	2.6×10 ⁻¹	18.6	97.6	1.7	0.7	tr.	LCS	0.34
12	5.0 YR 6/8	7.5 YR 7/4	1.4	53.5	1.2×10 ⁻¹	16.2	90.5	7.1	2.4	tr.	LCS	0.10
13	7.5 YR 7/6	7.5 YR 7/4	1.3	51.3	8.9×10 ⁻²	0.8	91.7	4.7	3.1	0.6	LCS	0.12
13'	2.5 YR 4/4	2.5 YR 4/6	1.3	50.5	8.2×10 ⁻²	0.7	89.6	7.3	2.7	0.4	LCS	0.10
14	7.5 YR 6/6	7.5 YR 6/4	1.3	50.2	9.0×10 ⁻²	0	85.2	11.4	3.0	0.4	LCS	0.07
15	7.5 YR 7/6	7.5 YR 7/6	1.3	46.9	7.8×10 ⁻³	2.9	79.5	16.6	2.6	1.3	LCS	0.60
16	7.5 YR 6/6	7.5 YR 7/4	1.3	49.4	8.9×10 ⁻²	0.2	90.3	8.2	1.2	0.3	LCS	0.05
17	10.0 YR 5/6	10.0 YR 7/4	1.2	47.1	8.9×10 ⁻²	1.1	92.5	5.6	1.9	tr.	LCS	0.02
18	2.5 Y 8/2	2.5 Y 8/2	1.3	36.7	5.2×10 ⁻¹	15.7	95.8	2.7	1.5	tr.	LCS	0.48
19	2.5 Y 8/2	5.0 Y 8/2	1.1	27.6	1.3×10 ⁻¹	7.9	90.2	8.8	1.0	tr.	LCS	0.18
20	2.5 Y 8/4	5.0 Y 8/4	1.1	37.1	4.2×10 ⁻¹	42.4	98.2	1.5	0.3	tr.	LCS	0.20

tions (gravel plus coarse sand were less than 90%) and small amounts of silt and clay were contained in them, therefore, the texture of a) group was the finest among the three groups.

b) group : Color value of No. 11 and 20 was 8 (white color), this group contained large amounts of coarser fraction (gravel: 18.6–42.4%, coarse sand: 97.6–98.2%, fine sand: only 1–2%). Therefore, it is concluded that b) group's texture was coarsest and the permeability coefficients were nearly 10^{-1} cm/sec. respectively.

c) group : The physical properties of c) group were intermediate between those of a) and b), or rather closer to those of b).

Any mutual relationships among Fe²⁺ contents of the samples, their localities and textures were not perceived.

In general, most of the coastal sands situated to the south of Amami Islands are coral reef particles, their colors are white and the main primary mineral is calcite.

The reddish yellow color of Kabira bay head coastal sands and their relatively finer texture compared with those of the bay entrance and bay center are presumably based on the land soils which inflow on to the sea shore from the back land. The sampling locality of No. 12 is the estuary of the sewage drainage basin, its color values was 6, fine sand and silt contents were 7.1 and 2.4% and its texture was finer than that of No. 11. In the future, if the population of the bay west entrance will become more dense, and various components in the drain water will increase, the physical and chemical properties of the coastal sands in the drainage basin will change and bring the environmental contamination of the coast.

Red sea shore sand of the coastal dike in the bay head like No. 13' is sparsely distributed (about 10 m²). As discussed on page 125, DCB soluble R₂O₃ amount was largest, but Fe²⁺ content was smallest in all the sample sands. On the other hand, Fe²⁺ content of No. 4 (land soil of the coastal dike in the bay head) was large. It can therefore be presumed that red color of No. 13' is based on stable Fe³⁺, this Fe³⁺ is originated from Fe³⁺ in land soils which are inflow on to the coast from the end of the coastal dike and are changed into stable Fe³⁺ under an unknown special oxidative environment.

Texture of the oceanic sea shore sand on the east coast (No. 20) was coarsest the color was the

Table 5. Depth, color and Fe²⁺ content of marine sediments

No.	Depth (m)	Color		Fe ²⁺ ppm/oven dry basis
		(wet)	(air dry)	
21	9.0	2.5 Y 5/2	2.5 Y 5/2	2.20
22	9.0	2.5 Y 4/2	5.0 Y 5/2	2.20
23	14.0	5.0 Y 5/2	2.5 Y 5/2	1.78
25	12.0	5.0 Y 5/2	2.5 Y 7/2	2.24
26	13.8	7.5 Y 5/2	7.5 Y 6/2	1.90
27	14.0	5.0 Y 4/2	2.5 Y 6/2	1.66
28	14.5	5.0 Y 5/2	2.5 Y 7/2	2.08
29	10.0	5.0 Y 5/2	2.5 Y 7/2	2.54
30	16.0	5.0 Y 5/2	5.0 Y 5/2	1.76
31	15.0	5.0 Y 5/2	5.0 Y 7/2	1.82
32	14.5	5.0 Y 5/2	2.5 Y 7/2	1.76
33	10.4	2.5 Y 7/2	2.5 Y 8/2	0.96
34	14.2	5.0 Y 5/2	2.5 Y 7/2	1.90
35	12.3	5.0 Y 5/2	10.0 YR 7/2	1.54
36	15.8	5.0 Y 5/2	2.5 Y 7/2	1.72
37	15.9	5.0 Y 5/2	5.0 Y 7/2	1.72
38	15.5	2.5 Y 6/2	5.0 Y 7/2	1.78
39	15.5	10.0 Y 5/2	5.0 Y 8/2	1.82
40	10.4	5.0 Y 7/2	5.0 Y 7/2	1.50
41	12.0	5.0 Y 5/2	5.0 Y 7/2	1.64
42	12.9	2.5 Y 6/2	5.0 Y 7/2	2.18
43	14.5	5.0 Y 4/6	5.0 Y 7/2	2.08
44	10.2	5.0 Y 7/2	5.0 Y 8/2	0.98
45	3.9	2.5 Y 8/2	2.5 Y 8/2	0.68
46	3.8	2.5 Y 8/2	10.0 YR 8/2	0.64

whitest and the silt phase was virtually the smallest of all sand samples. At the site of No. 20, all finer fractions were washed away to the high sea by a strong ocean current.

(3) Marine sediments

Color and Fe²⁺ content of marine sediments are shown in Table 5 and their mechanical compositions are presented in Table 6.

In general, colors of the samples were yellowish gray, namely, color hues were 2.5 Y–10.0 Y, color values were 4–8 and color chromas were 2. During the air drying at room temperature, the marine sediments' color turned whiter and color values increased. But the degrees of color changing with air dryness were different, owing to the sampling localities. The gray color of No. 21 and 22 from the bay head was almost the same degree before and after the air drying (value: 4–5). Also No. 45 and 46 from the bay entrance were white and were not changed with the air dryness (value: 8).

No. 21 and 22 were relatively rich in Fe²⁺ but No. 45 and 46 were poor and the texture of No. 45 and 46 were coarse, their clay plus silt contents were small and their gravel plus coarse sand contents were very large (see Table 6). Accordingly, the fact that color remains unchanged during the airdrying process was attributed to the presence of a relatively large amount of stable Fe²⁺ compound in the cases of No. 21 and 22 from the bay head. But, for the bay entrance samples

Table 6. Mechanical composition of marine sediments

No.	Gravel (%)	Fine soil				Texture
		Coarse sand (%)	Fine sand (%)	Silt (%)	Clay (%)	
21	0.6	10.9	58.2	19.4	11.5	FSL
22	0.8	15.4	62.2	17.2	5.2	FSL
23	0.3	14.7	47.9	24.5	12.9	L
25	0.1	3.8	54.2	26.0	16.0	CL
26	0.1	4.2	51.4	35.8	8.6	L
27	0	2.4	41.6	34.4	21.6	CL
28	0	4.1	46.2	37.8	11.9	L
29	0.1	7.0	64.7	17.8	10.5	FSL
30	0	1.9	33.2	47.5	17.4	SCL
31	0.1	3.0	43.0	38.5	15.5	CL
32	0.1	2.8	71.8	12.5	12.9	FSL
33	0.1	69.1	28.8	1.6	0.5	LCS
34	2.1	0.7	65.0	18.8	15.5	SCL
35	1.9	60.5	28.7	6.0	4.8	LCS
36	0	6.0	54.0	25.8	14.2	L
37	0	0.6	45.2	32.5	21.7	CL
38	0	1.0	46.4	33.5	19.1	CL
39	0	1.3	56.8	27.2	14.7	L
40	7.3	28.9	64.1	4.9	2.1	LFS
41	1.1	4.7	77.3	10.0	8.0	FSL
42	1.9	11.2	65.5	14.0	9.3	FSL
43	0	4.2	57.9	21.4	16.5	CL
44	0.1	21.4	74.5	0.3	3.8	LFS
45	54.0	86.6	9.3	0.6	3.5	LCS
46	15.0	84.1	12.2	1.7	2.0	LCS

(No's. 45, 46), the reason for the nearly constant color under both wet and dry conditions was presumed to be based on their coarser texture and poor Fe^{2+} contents.

The color values of the other samples except for No's. 21, 22, 23, 45 and 46 increased with air dryness at room temperature. Their Fe^{2+} contents were about 1–2 ppm as shown in Table 5 (1.5–2.0 ppm's Fe^{2+} contents were intermediate values between No. 21, 22 and 45, 46). It is assumed that the air drying process changed the form of a part of iron from Fe^{2+} to Fe^{3+} and brought about the color-change of most marine sediments, from gray to a somewhat lighter gray.

The relationships between the depth of marine bed and the clay contents of the marine sediments are shown in Fig. 3. In general, the clay contents were proportional to the depth, but this proportionality can not be applied to all samples. Particle size distributions of the marine sediments are presumably dependent on many factors; namely, depth, sea bottom topography, speed and flux of the marine current, etc. This proportional relationship can be applied in the case that the surfaces of the shallow beds are more strongly affected by the marine current than the deeper bottom. By way of example, the authors would like to assume that No. 33 (depth: 10.5 m, clay content: only 1.3%) is more strongly affected by the traction than No. 29 (depth: 10 m, clay content: 17.8%).

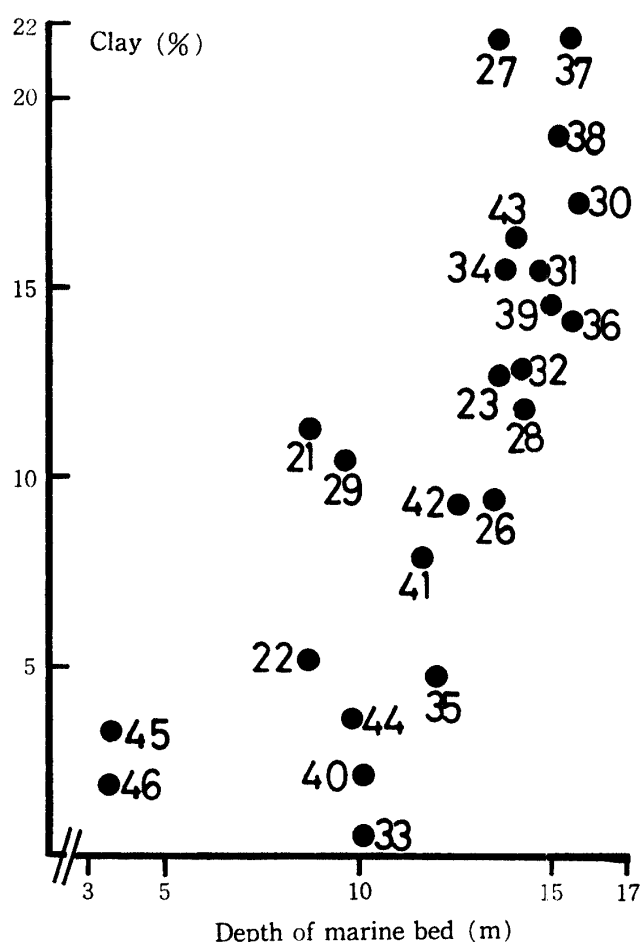


Fig. 3. Relationships between the depth of marine bed and clay (<0.002 mm) content of marine sediments.

2. Primary minerals

(1) Soils

Fig. 4 illustrated the X-ray diffraction patterns of random specimens of typical sand fractions (2–0.02 mm) of the soils.

No. 4–1 is formed from limestone and was transported as soil dressing. The X-ray spectra of No. (4–1)'s fine sand fraction showed calcite (3.04, 2.08, 1.88 Å etc.), besides quartz and feldspar. Except for No. 4–1, the main primary minerals of almost all the samples seemed to be quartz (3.33, 4.26, 1.81, 1.54 Å etc.) and feldspar (3.20, 4.04, 3.25 Å etc.) and the intensity of the quartz's peaks were sharper and more distinct than that of the feldspar's. Table 7 showed that heavy mineral (spgr>2.8)'s percentage of typical soil's sand fraction were only 1.8–2.1% and were insoluble in 0.3% HCl. Therefore, these heavy minerals were observed not to be aragonite (spgr=2.9) and were indicated to be mainly pyroxene and amphibole under polarizing microscopic observation. About the light minerals (spgr<2.8), weathered clayey feldspar was dominant though the intensity of the quartz's peaks were very strong in X-ray spectra. The above-mentioned results are in fair agreement with the data of Ryukyu Island's soils obtained by Kobayashi and Shinagawa²⁾.

(2) Coastal sands

X-ray spectra of coastal sands are shown in Fig. 5. X-ray diffraction pattern of No. 15 (from the bay head) showed the strong peaks of the quartz (3.33, 4.26, 1.82 Å etc.) and the medium peaks of the feldspar (3.20, 4.0 Å etc.) and the very weak peaks of the calcite (3.04 Å etc.), but the aragonite's

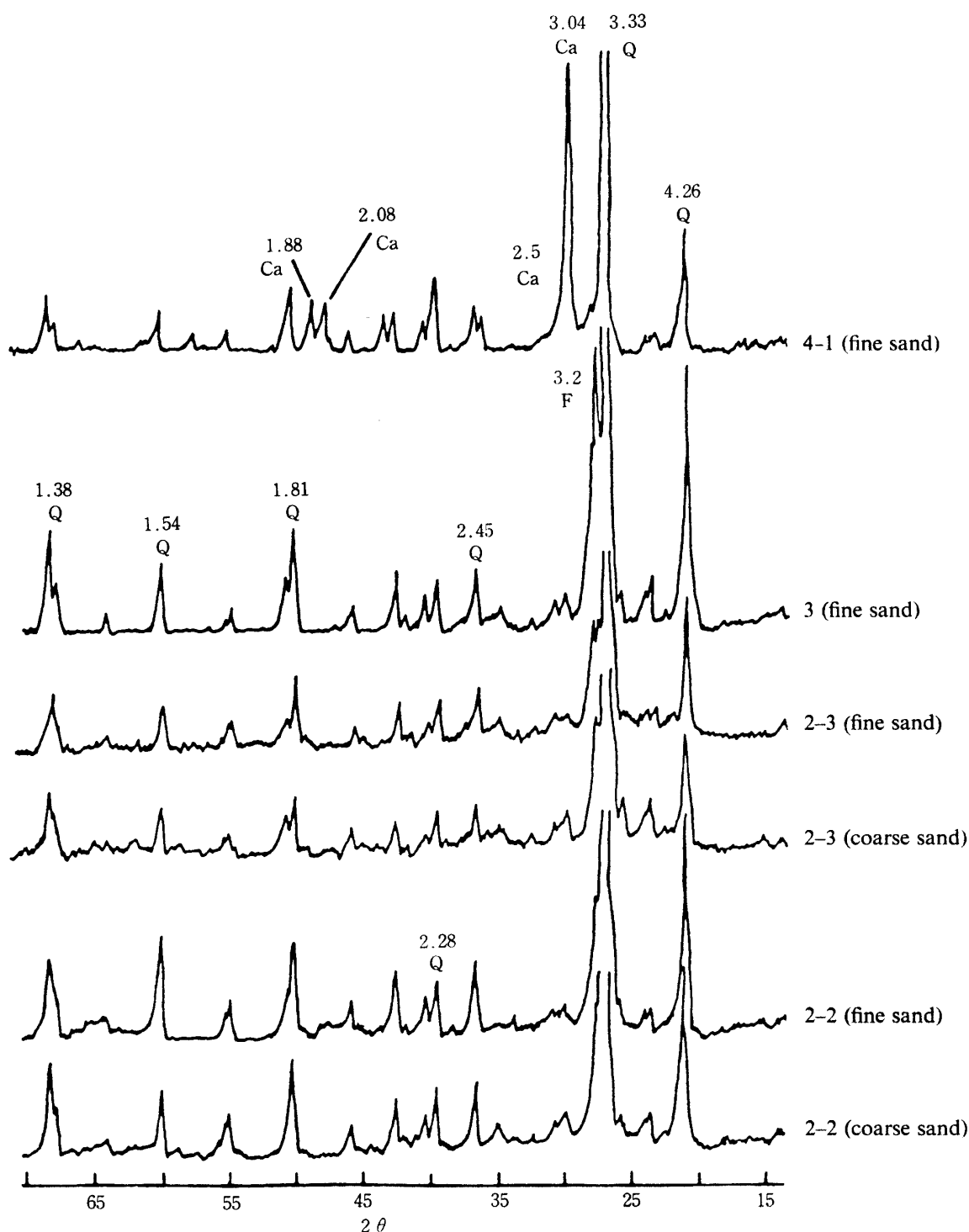


Fig. 4. Random powder X-ray diffractograms of sand fractions of the soils.

Q: Quartz, F: Feldspars, Ca: Calcite.

peaks were not appreciable. Therefore, the X-ray diffraction pattern of the bay head coastal sands showed a striking resemblance to that of the back soils (Fig. 4, No. 2-2 and 2-3). As a matter of course, the bay head coastal sands containing large amounts of shell showed the aragonite's peaks, too.

In No. 18 (from the east bay near the bay entrance) and No. 11 (from the west bay and the bay

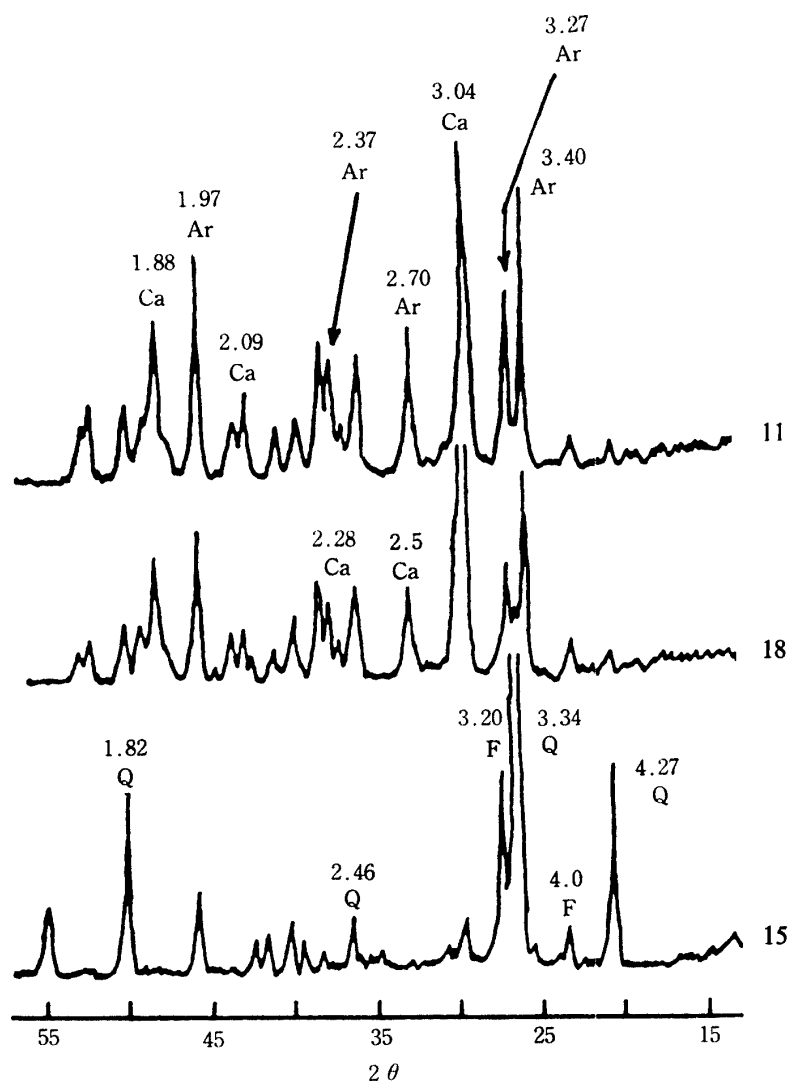


Fig. 5. Random powder X-ray diffractograms of sand fractions (2–0.02 mm) of coastal sands.

Q = Quartz, Ca: Calcite, Ar: Aragonite, F: Feldspar.

entrance), the main primary minerals were calcite (3.04, 2.29, 2.09, 1.91 Å etc.) and aragonite (3.40, 1.98, 3.27, 2.70, 2.37, 2.48, 1.88 Å etc.) and the peaks of quartz and feldspar were very weak.

According to Table 7, almost all sand fraction of No. 11 were soluble in 0.3% HCl. No. 18 contained 7–14% of 0.3% HCl insoluble fraction, but concerning the bay head sands (No. 15), 0.3% HCl insoluble fractions were dominant.

By polarizing microscopic observation, the heavier sand fractions (spgr > 2.7) of No. 11 and 18 were ascertained to be calcite and aragonite with weathered porous structures. On the other hand, the main minerals of No. 15 were weathered feldspar and quartz similar to those of the soils.

Therefore, it is assumed that the primary minerals of the bay head coastal sands were originated from land soils, in other words, they are soil influx from the back land. On the contrary, coastal sands of the bay center and the bay entrance are surely coral reef sands developed in the sea.

(3) Marine sediments

According to Fig. 6, the quartz's and feldspar's peaks of the bay head samples (No. 21) were very strong but those of calcite and aragonite were very weak. The peaks of the latter

Table 7. Fractionation of sands (2–0.02 mm) and HCl treatment

No.	Fraction size	>2.8 on frac. (%)		2.8–2.7 on frac. (%)		<2.7 on frac. (%)	
			after 0.3% HCl		after 0.3% HCl		after 0.3% HCl
Soils							
2–2	coarse*	2.1	2.1	1.5	1.5	96.4	96.4
	fine**	1.9	1.9	1.2	1.2	96.9	77.5
2–3	coarse*	2.8	2.8	0.8	0.8	96.4	96.4
	fine**	1.8	1.8	1.7	1.6	96.5	96.5
Coastal sands							
11	coarse*	24.2	0	27.6	0	48.2	0
	fine**	64.8	0	16.3	0	18.9	5.7
15	coarse*	1.5	0	2.5	2.5	96.0	96.0
	fine**	1.2	0.1	0.6	0.2	98.2	98.2
18	coarse*	8.3	0	25.3	0	66.4	6.7
	fine**	9.1	0	20.8	0	70.1	14.0
Marine sediments							
22	coarse*	6.6	0	15.7	0	77.7	38.9
	fine**	27.4	0	17.3	6.9	55.3	49.8
30	coarse*	0.6	0	0.6	0	98.8	0
	fine**	48.4	0	10.2	0	41.4	20.7
44	coarse*	13.7	0	31.2	0	55.1	0
	fine**	24.2	0	27.6	0	48.2	9.6

* coarse (2–0.2 mm)

** fine (0.2–0.02 mm)

two minerals became relatively strong and those of the former two minerals became weak in the bay center (No. 31 and 37). X-ray spectra of the bay entrance sample (No. 44) showed strong peaks of calcite, medium peaks of aragonite and very weak peaks of quartz and feldspar.

Fig. 7 illustrated the comparison between gravel (>2 mm) plus coarse sand (2–0.2 mm) and fine sand fraction (0.2–0.02 mm) of the same samples. Two samples, namely, No. 23 (from the bay head) and No. 33 (from the bay center) showed that the peaks of quartz (3.33, 4.27 Å etc.) and feldspar (3.20, 4.0 Å etc.) were stronger in finer sand fraction. On the contrary, in the coarser fraction, relatively stronger peaks of calcite and aragonite were indicated. Consequently, it is presumed that the amounts of primary minerals originated from land soils were larger in finer sand fraction, but primary minerals formed in the sea were larger in coarser fraction. Furthermore, data presented in Table 7 have revealed that the amounts of 0.3% HCl insoluble materials decreased in the following order, No. 22 (bay head)⇒No. 30 (bay center)⇒No. 44 (bay entrance). This order was essentially the same as obtained in the coastal sands. And in each sample, finer fraction

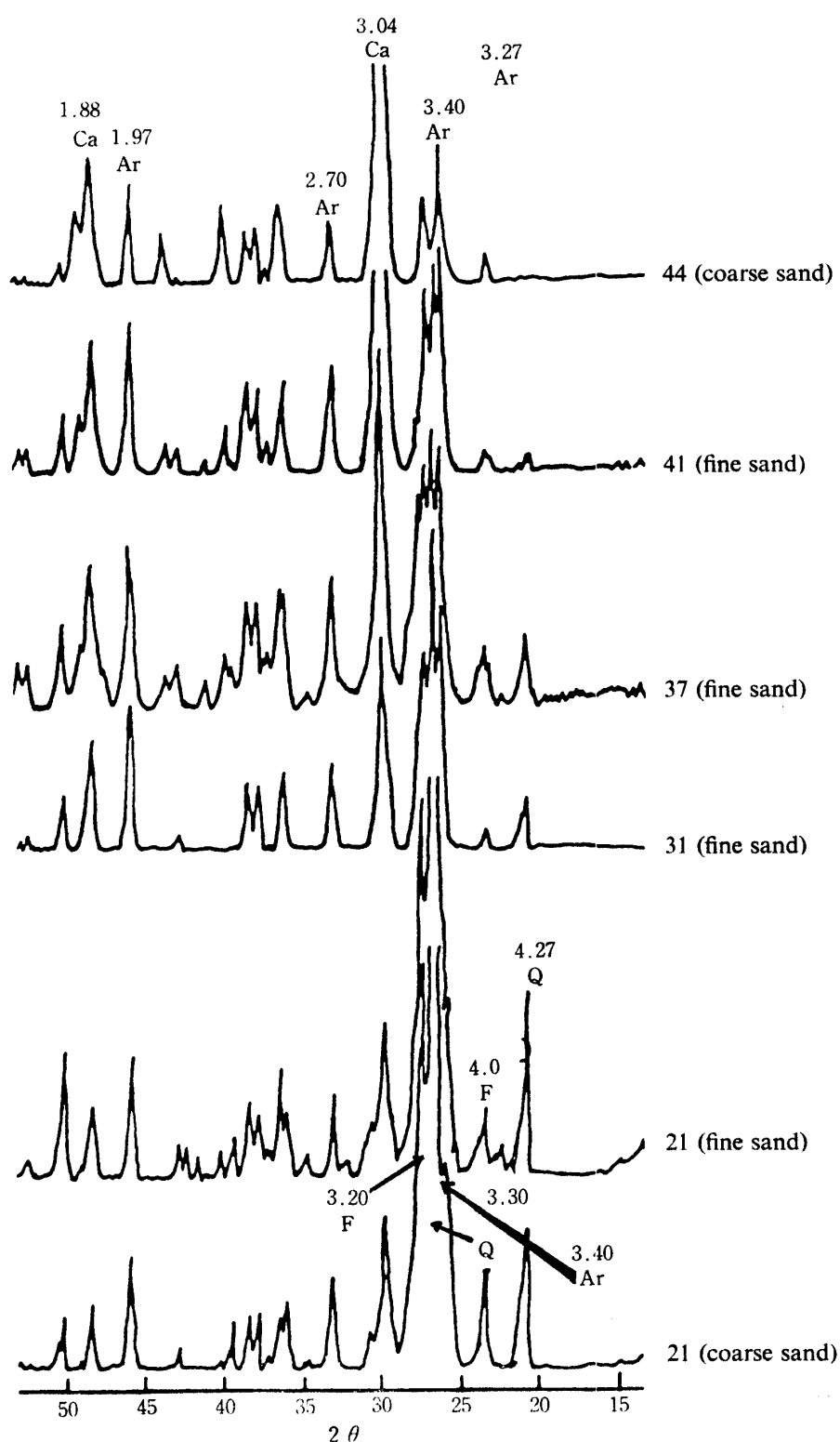


Fig. 6. Random powder X-ray diffractograms of sand fractions of marine sediments.

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

contained much more HCl insoluble materials. Those results obtained by HCl treatment seemed to be in fair agreement with the results of X-ray studies, the same as the coastal sands.

(4) Discussion

At the bay head, primary mineral composition of the coastal sands was nearly the same as the

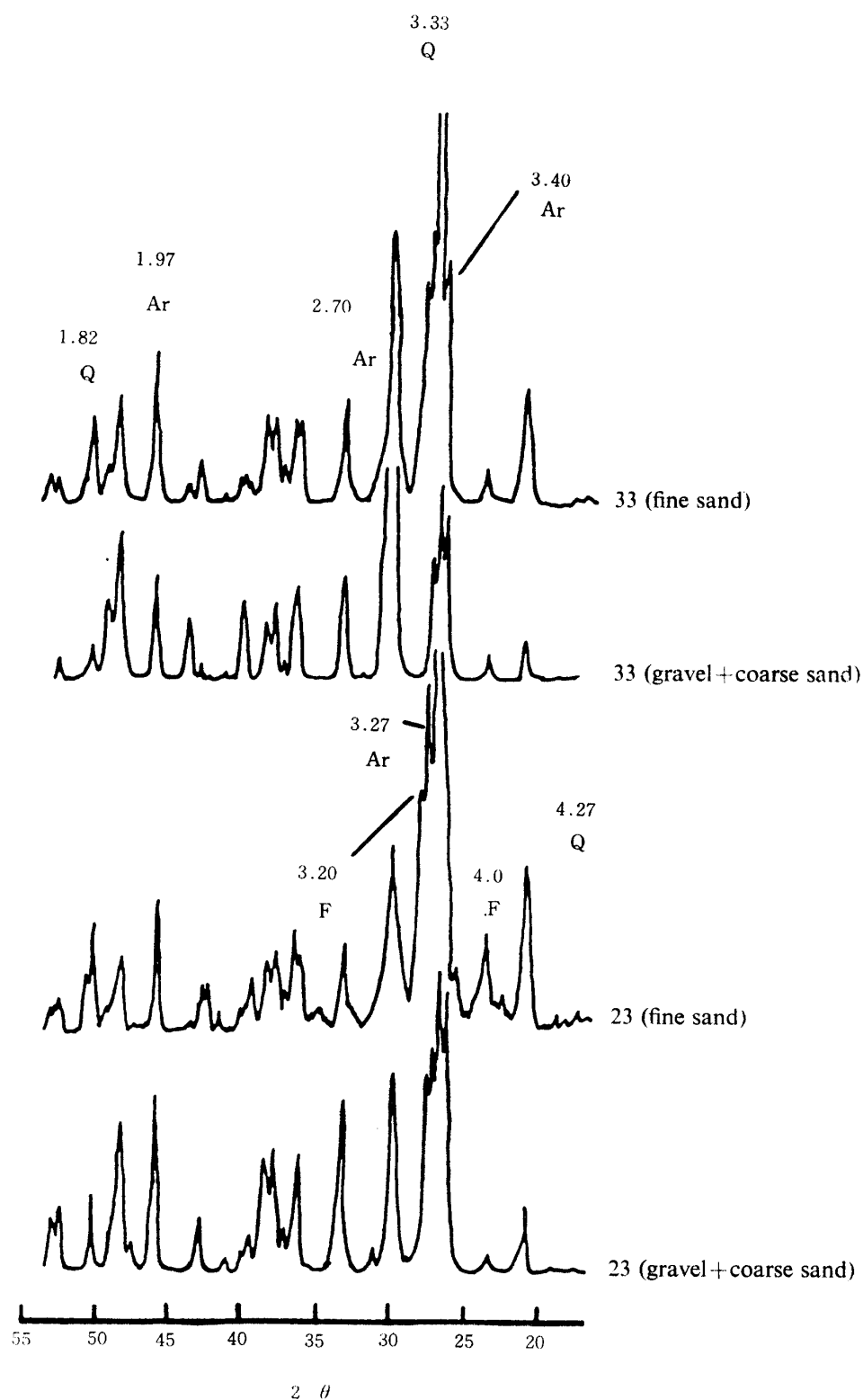


Fig. 7. Random powder X-ray diffractograms of sand fractions of marine sediments.

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

back soils. Although the sand fractions of the marine sediments contained 50–60% of HCl soluble minerals, the mineralogical composition of the residue after HCl treatment was similar to those of the back soils and coastal sands. Amount of silt (0.02–0.002 mm) plus clay (<0.002 mm) of the

coastal sands was only 0–3% (see Table 4). Consequently, nearly all coastal sands and half of marine sediments could be regarded as soil influx from the back land.

At the bay center and bay entrance, the primary mineral composition of the coastal sands and marine sediments were quite different from those of the soils. Their main minerals were calcite and aragonite and weathered ones which are formed in the sea.

Bay head \Rightarrow bay center \Rightarrow bay entrance, according to this order, feldspar, quartz etc. originated from soil minerals decreased, and calcite and aragonite increased, in other words, the amounts of land soil influx decreased.

At the same place, the finer fractions of the marine sediments contained much more land origin minerals than coarser fractions.

3. Clay minerals

(1) Soils

According to the oriented X-ray diffractograms of deferrated clays of soils as showing in Fig. 8, typical residual red and yellow virgin soils (No. 2–2 and 2–3) seemed to contain mainly 7 Å minerals (maybe kaolin), a small amount of 10 Å mineral (perhaps illite) and an appreciable amount of 14 Å mineral (maybe vermiculite) and gibbsite. As Mg-ethlenglycol clay of all samples did not show 17's peak, it is concluded that clay fraction (<0.002 mm) contained no montmorillonite minerals.

For no. 3 (paddy field, Gley Soils), the peak of 7 Å's mineral was dominant and that of 10 Å was considerably weaker and 14 Å's mineral content was very low. In No. 4–1 (formed from limestone, Dark Red Soils), 7 Å's peak was dominant but 14 Å and 10 Å minerals were not appreciable. No. (4–2)' was taken from the location 4–2 10 metre apart, and its relative intensity of 7, 10 and 14 Å was considerably different from 4–2.

Main clay minerals of the soils were 7, 10 and 14 Å minerals but the proportion of these three minerals seemed to have changed largely owing to land use, parent materials, topography, etc.

The above-mentioned results are in fair agreement with the data of Kobayashi and Shinagawa²⁾ and Yamada et al⁴⁾.

As clay fractions were scarcely contained in the coastal sands, the identification of the clay minerals in them was not carried out.

(2) Marine sediments

As indicated in Fig. 9 the main clay minerals of the marine sediments were similar to those of the soils, namely, 7, 10 and 14 Å minerals, and montmorillonite was not found. The proportion of the above-mentioned three minerals was liable to variation. The bay head samples (No. 21 and 22) seemed to contain relatively larger amounts of 7 Å mineral than the bay center (No. 30 and 37) and the bay entrance (No. 45) samples. But the variation in proportion of three minerals was small, in comparison with the land soils. By macroscopic comparison, though the sampling localities, the depth of sea and the topography of the marine bed were different, the proportion of each mineral seemed to be nearly the same. Consequently, in Kabira bay, the clay mineral composition of marine sediments' clay fraction (<0.002 mm) was presumed to be homogenous.

The environmental conditions of the soils and marine sediments are quite different, the former is oxidative, and under the former's meteorological condition (annual rainfall: about 2200 mm, average temperature: about 23.4°C) the leaching of various bases occur, the latter is reductive and is in an over saturation status of various kinds of cations and anions. The main primary minerals of the bay center and the bay entrance marine sediments obviously differed from those of soils, namely, calcite and aragonite. It seems to be impossible that considerable amounts of 7 Å minerals, illite

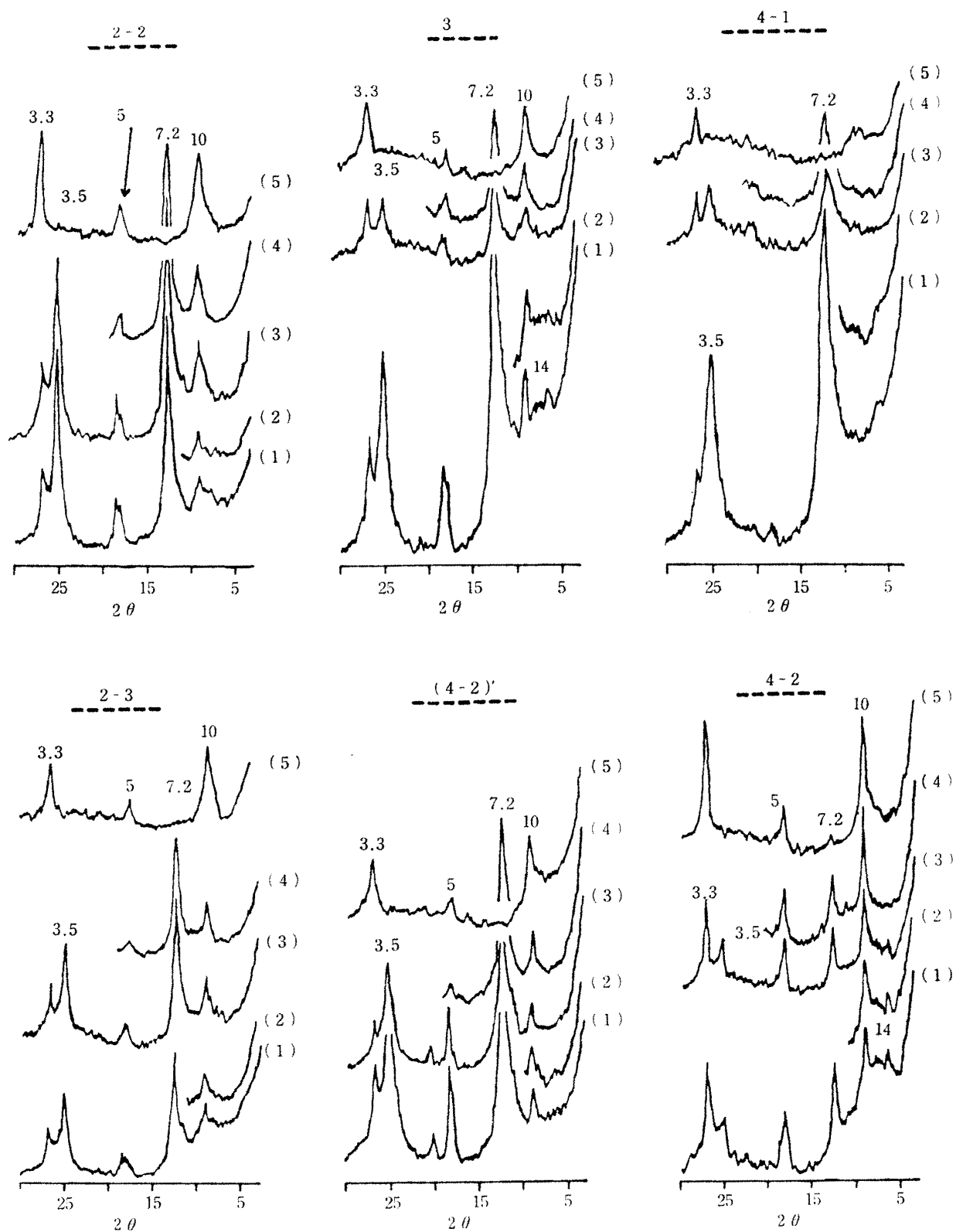


Fig. 8. Oriented X-ray diffractograms of deferrated clays ($<2\mu$) of the sample soils.

(1): Mg-clay, (2): Mg-Ethylenglycol clay, (3): K-clay, (4): K-clay, 350°C, (5): K-clay, 550°C.

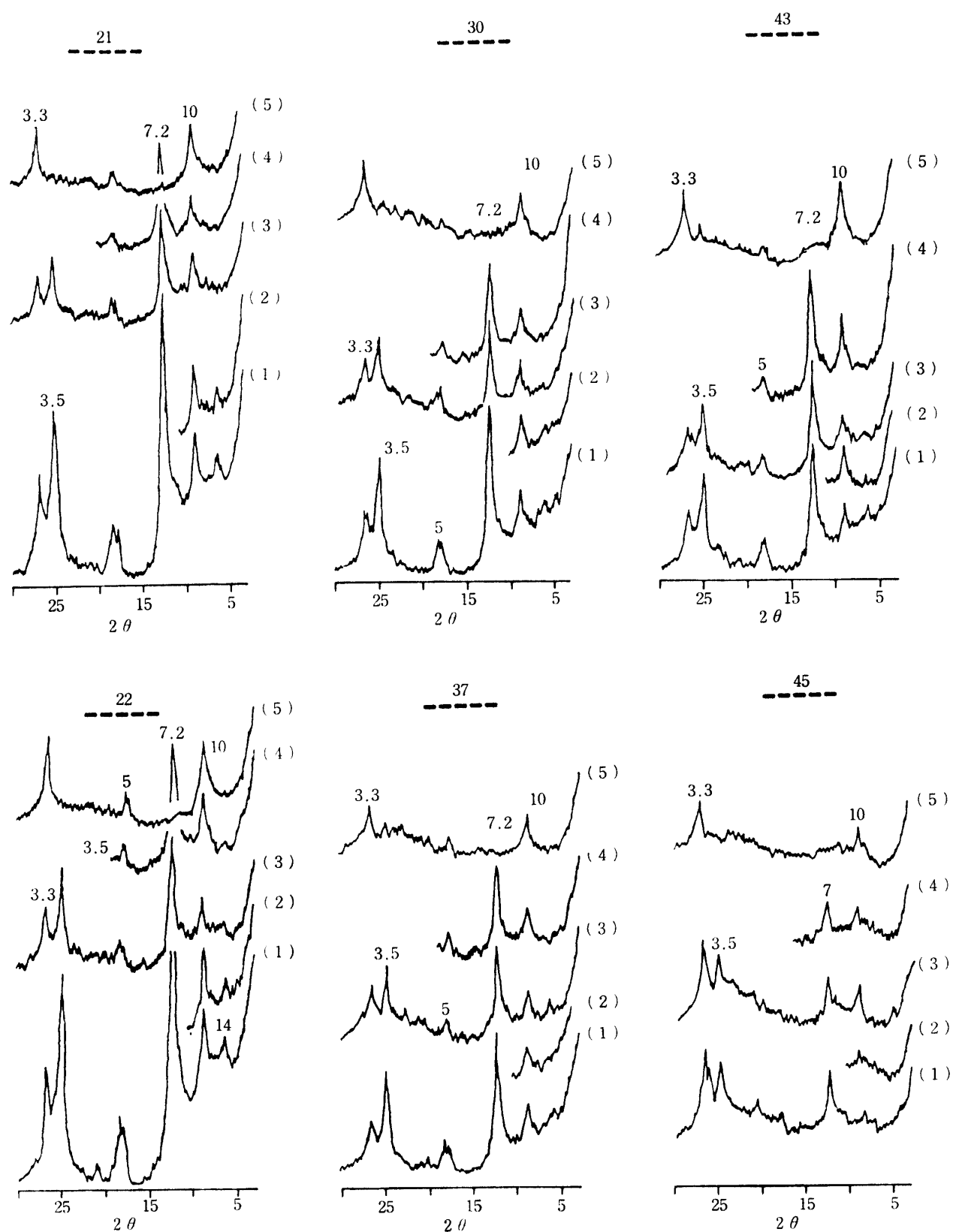


Fig. 9. Oriented X-ray diffractograms of deferrated clays ($<2\mu$) of marine sediments.

(1): Mg-clay, (2): Mg-Ethylenglycol clay, (3): K-clay, (4): K-clay, 350°C, (5): K-clay, 550°C.

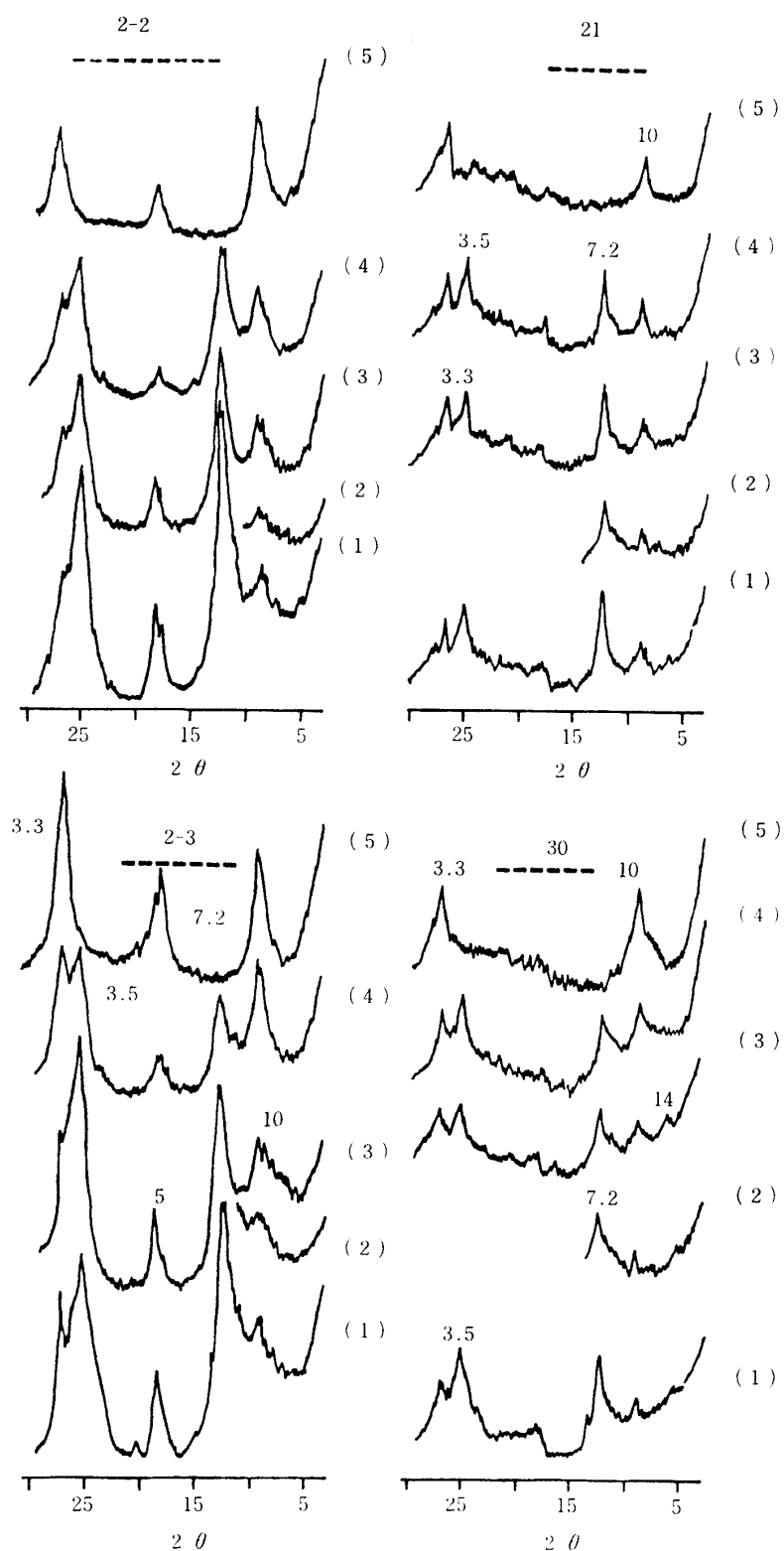


Fig. 10. Oriented X-ray diffractograms of deferrated fine clays ($<0.2\mu$) of the soils and marine sediments.

(1): Mg-clay, (2): Mg-Ethylenglycol clay, (3): K-clay (4): K-clay, 350°C, (5): K-clay, 550°C.

and vermiculite are originated from calcite and aragonite. Therefore, the authors would like to regard that marine sediments' clay minerals are originated from the land soils' clay minerals, in other words, they are influx of the land soil fractions.

The homogeneity of the clay mineral composition of the marine sediments may perhaps be due to the stirring effect of the marine current traction.

The possibility that the clay minerals of the marine sediments were originated from the marine bed's silicate minerals which may be existing under the coral reef nedes to be considered.

(3) Fine clay of soils and marine sediments

Reports that fine clay (<0.0002 mm) of granitic soils and of polder soils contained montmorillonite minerals were often published. Some soil scientist proposed the hypothesis that various silicate minerals in marine beds vary to montmorillonite. The authors tried to elucidate whether the above-mentioned results and hypothesis on the montmorillonite formation may be applied to the samples of this report. Fig. 10 showed the oriented X-ray diffractograms of deferrated fine clays of typical residual granitic soils (No. 2-2 and 2-3) and of marine sediments (No. 21 and 30). 14 \AA 's peak did not expand to 17 \AA after ethylenglycol treatment. According to these results, the conclusion that montmorillonite minerals did not exist in the soils and in the marine sediments near and in Kabira bay, could be reached.

4. DCB soluble R_2O_3

DCB soluble (see in p. 107) Al_2O_3 , Fe_2O_3 and R_2O_3 contents are shown in Table 8 (soils), 9 (coastal sands) and 10 (marine sediments). Fig. 10 illustrated the relationships between DCB soluble R_2O_3 content on clay and clay content of soils and marine sediments.

(1) Soils

DCB soluble R_2O_3 contents were 0.5–19% on soil and 5–35% on clay. Under a humid subtropical climate as Ishigaki Island, the weathering of the parent rocks are assumed to have pro-

Table 8. DCB soluble R_2O_3 content of soils (oven dry basis)

No.	Fe_2O_3		Al_2O_3		R_2O_3	
	on soil (%)	on clay (%)	on soil (%)	on clay (%)	on soil (%)	on clay (%)
1-1	3.7	12.3	3.1	10.3	6.8	22.6
1-2	2.1	8.9	1.6	6.8	3.7	15.7
2-1	0.3	4.9	0.2	3.3	0.5	8.2
2-2	0.6	3.6	0.2	1.2	0.8	4.8
2-3	1.2	5.9	0.4	2.0	1.6	7.9
3	4.6	13.3	4.1	11.8	8.7	25.1
4-1	12.1	22.6	6.8	12.7	18.9	35.3
4-2	2.4	10.9	1.6	7.3	4.0	18.2
5	1.3	7.1	0.4	2.2	1.7	9.3
6	0.7	8.5	0.2	2.4	0.9	10.9
7-1	0.7	10.8	0.5	7.7	1.2	18.5
7-2	1.0	16.7	0.5	8.3	1.5	25.0
8	0.5	6.8	0.3	4.1	0.8	10.9
9	0.5	4.3	0.3	2.6	0.8	6.9

ceeded in the following order, (a) disintegration and decomposition of primary silicate minerals of the rocks, (b) formation of secondary silicate minerals and (c) disintegration and decomposition of secondary silicate minerals and formation of sesquioxide minerals, or (a) \Rightarrow (c). DCB soluble R_2O_3 are regarded as the precursor of sesquioxide minerals and are presumed to be presenting mainly in the clay fractions. The authors have one working hypothesis that the clay contents of soils are directly proportional to DCB soluble R_2O_3 percent on clay content. According to Fig. 11, sample soils could be classified into two groups from the viewpoint of DCB soluble R_2O_3 . Concerning a) group (No. 4-1, 3, 1-1, 4-2, 2-3, 5 and 2-2), the above-mentioned proportional relationships between clay contents and DCB soluble R_2O_3 percent on clay held, namely, the working hypothesis could apply. On the contrary, No. 7-2, 7-1, 8, 6 and 9 seemed to be belonging to another b) group. Though clay contents of b) group were nearly the same (7.5–6%), DCB soluble R_2O_3 on clay amounts were various (25–10%).

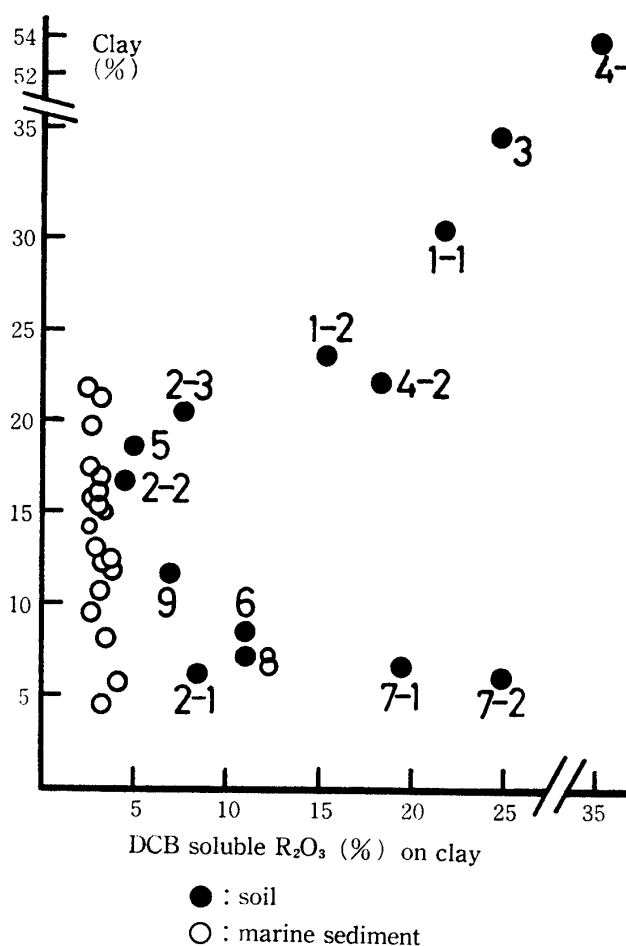


Fig. 11. Relationships between the DCB soluble R_2O_3 ($Fe_2O_3 + Al_2O_3$) and clay ($<2\mu$) content.

It is difficult to clarify the weathering and soil forming process of b) group by the data presented in this work. No. 2-1 is virgin surface soil of hill, No. 7 and 8 are abandoned fields of upland. From the authors' observations of the soil profile and topography, the weathering and the soil forming stages of b) group were nearly the same as a) group, but the illimerization degree of b) group seemed to be stronger than that of b) group. At the present working stage, the authors assumed that the characteristics of b) group in Fig. 11 related to the illimerization degree which was

accelerated by cultivation.

(2) Coastal sands

According to Table 9, No. 11 (from the bay west entrance), No. 19 (bay east entrance) and No. 20 (from the oceanic sea shore on the east coast) scarcely contained DCB soluble R_2O_3 (0.03–0.1 % on sand), percentages of the other samples were from 0.3 to 0.5.

Table 9. DCB soluble R_2O_3 content of coastal sands (oven dry basis)

No.	Fe_2O_3	Al_2O_3	R_2O_3
11	0.03	tr.	0.03
12	0.3	0.1	0.4
13	0.4	0.1	0.5
13'	0.4	0.1	0.5
14	0.3	0.1	0.4
15	0.2	0.2	0.4
16	0.2	0.1	0.3
17	0.2	0.1	0.3
18	0.1	tr.	0.1
19	0.05	0.07	0.1
20	0.03	0.02	0.05

As silt plus clay percent (see Table 4) rose, DCB soluble R_2O_3 seemed to increase. A relatively high percentage (0.3–0.5 %) of the bay head samples are possibly due to land soil influx, in other words, the presence of relatively large amounts of DCB soluble R_2O_3 is regarded as one piece of evidence that soils of the back land inflowed on to the bay head coast.

No. 12's high content of DCB soluble R_2O_3 (0.4 %) was presumably based on the sewage drain water because the locality of this sample is the estuary of the drainage basin. DCB soluble R_2O_3 content of the red sea shore sand of the coastal dike in the bay head such as No. 13' was largest. But as previously discussed, it was ambiguous as to whether DCB soluble R_2O_3 was closely related to the red color of the sand.

(3) Marine sediments

As for the marine sediments, DCB soluble R_2O_3 percent on the clay was definitely differed, due to the sampling localities. The contents of No. 21, 22 and 23 (from the bay head) were over 4 %, No. 25–39 (from the bay center) were approximately 3 percent and No. 41–46 (near the bay entrance) were less than three percent. From the stand-point of the above-mentioned weathering process of land rocks, DCB soluble R_2O_3 is regarded as weathering products of rocks. Consequently, the differences of DCB soluble R_2O_3 are possibly based on the differences in the land soil influx amounts. According to Table 10, it is assumed that the amounts of inflowed soils from the back land to the marine bed are in the following order, bay head > bay center > bay entrance.

Except for No. 44, 45 and 46, DCB soluble R_2O_3 percent on clay were from 2.8 to 4.3. The contents of the soils were 7–35 %. Fig. 11 illustrated the differences between the soils and marine sediments. Compared with the land soils, DCB soluble R_2O_3 on clay of marine sediments were regarded as nearly the same percentage for almost all samples from the stand-point of macroscopic observation. Therefore, soil clays whose DCB soluble R_2O_3 contents are various, inflowed on to the marine bed and were stirred and transported to the other places by marine current traction. Consequently, DCB soluble R_2O_3 on clay content became homogenous and were uniform through

Table 10. DCB soluble R_2O_3 content of marine sediments (oven dry basis)

No.	Fe_2O_3 (%)		Al_2O_3 (%)		R_2O_3 (%)	
	on sediment	on clay	on sediment	on clay	on sediment	on clay
21	0.3	2.6	0.2	1.7	0.5	4.3
22	0.15	2.9	0.06	1.2	0.2	4.1
23	0.35	2.7	0.15	1.2	0.5	3.9
25	0.35	2.2	0.1	0.8	0.43	3.0
27	0.6	2.8	0.1	0.5	0.7	3.3
28	0.3	2.5	0.06	0.5	0.35	3.0
29	0.2	1.9	0.1	1.0	0.3	2.9
30	0.4	2.3	0.1	0.6	0.5	2.9
31	0.4	3.6	0.1	0.6	0.5	3.2
32	0.3	2.3	0.1	0.8	0.4	3.1
34	0.4	2.6	0.1	0.6	0.5	3.2
35	0.1	2.0	0.04	0.8	0.14	2.8
36	0.3	2.1	0.1	0.7	0.4	2.8
37	0.4	1.8	0.15	0.7	0.55	2.5
38	0.4	2.1	0.16	0.8	0.56	2.9
39	0.3	2.0	0.1	0.7	0.4	2.7
41	0.2	2.5	0.04	0.5	0.3	3.0
42	0.2	2.2	0.06	0.6	0.3	2.8
43	0.4	2.4	0.2	1.2	0.6	3.6
44		tr.				tr.
45		tr.				tr.
46		tr.				tr.

all of the marine beds of Kabira bay.

Summary

To clarify the distributions and the qualities of inflowed and deposited back land soils in the tidal zone and the marine bed of Kabira bay in Ishigaki Island, the physical, chemical and mineralogical characteristics of the back soils, tidal zone's coastal sands and marine sediments were investigated.

1. Physical and chemical properties

Soils; The main back soils were Red and Yellow Soils formed from granite, their soil color was reddish yellow and their base saturation degree was low. Gley Soils and Dark Red Soils were sparsely distributed.

Coastal sands; Color and texture of the bay head coastal sands were redder and finer than those of the bay center and the bay entrance.

Marine sediments; The bay head samples were of a grayish brown color and contained much larger amounts of Fe^{2+} . Texture of ones from the bay entrance was coarsest and their color was whitest. Clay contents of the marine sediments were generally proportional to the depth of the marine bed.

2. Primary minerals

Soils; The main primary minerals were quartz and weathered feldspar.

Coastal sands and marine sediments; The primary mineral compositions of the bay head were similar to those of the soils, but in the bay center and the bay entrance, the main primary minerals were calcite and aragonite. And the finer fractions of the bay center and bay entrance contained more quartz and feldspar than the coarser fractions.

3. Clay minerals

Soils; The main clay mineral was 7 Å mineral and smaller amounts of illite and vermiculite were accompanied, but the proportions of these three minerals were largely changed owing to land use, parent materials, topography etc.

Marine sediments; Their clay minerals were similar to those of the soils, compared with the soils, though the sampling localities, depth of the marine bed were different, the proportion of the three minerals seemed to be nearly the same, judging from macroscopic comparisons.

Montmorillonite minerals did not exist in the soils and marine sediments.

4. DCB soluble R_2O_3

Soils; DCB soluble R_2O_3 contents on clay seemed to have increased proportionally as the clay enriched. But in the soils whose illimeriaztion degrees were high (especially abandoned fields and cultivated fields), DCB soluble R_2O_3 percentage on clay and the clay contents were not proportional.

Coastal sands; The bay head samples contained larger amounts of DCB soluble R_2O_3 than those of the bay center and the bay entrance.

Marine sediments; DCB soluble R_2O_3 contents on clay decreased in the following order, bay head > bay center > bay entrance. But compared with the soils, DCB soluble R_2O_3 on clay were regarded as nearly the same in almost all the samples.

5. Distributions of inflowed land soils

According to the above-mentioned 1., 2., 3. and 4., especially reddish color, finer texture, relatively larger amounts of quartz and feldspar etc., it was concluded that the amounts of inflowed land soils to the coast and the marine bed increased in the following order, bay entrance < bay center < bay head.

6. Finer fraction's homogeneity of marine sediments

In the marine bed of Kabira bay, clays (<0.002 mm) were presumed to have originated from the land soils and clay fractions whose DCB soluble R_2O_3 contents were various, were stirred and transported to the other places of the marine bed by marine current traction, therefore, the clay mineral composition and DCB soluble R_2O_3 on clay came to be nearly homogeneous.

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References

- 1) Chinzei, T., Oya, K., Koja, J., Donahue, R. L. and Shickluna, J. C.: Soils and land use in the Ryukyu Islands, p. 94–129, Hoshi Printing Co., Naha, Okinawa (1967)
- 2) Kobayashi, T. and Shinagawa, A.: Studies on the soils of Nansei Islands in the sub-tropical region of Japan. 1) Soils of Ryukyu Islands. Bull. Fac. Agr. Kagoshima Univ., No. 16, 11–55 (1966)
- 3) Mehra, O. P. and Jackson, M. L.: Iron oxide removal from soils and clays by a dithionate-citrate system buffered with sodium bicarbonate. Clays Clay Min., 7, 317–327 (1960)
- 4) Yamada, Y., Motoyama, S., Matsusaka, Y. and Kato, Y.: Soils of Ishigaki, Miyako and Yonaguni Island. Bull. National Inst. Agr. Science (Japan) Series B, No. 24, 266–365 (1973)