The Study on the Ryukyu Limestone and Associated Materials

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Kiyoshi KANESHIMA,* Hatsuo TAIRA,* Akira TOKUYAMA,* Tamotsu OOMORI*

I. Introduction

The Ryukyus consist of about fifty islands extending like a chain of stepping stones from kyushu in the north, to Taiwan in the south. The annual average temperature is about 23°C and the rainfall is about 2200mm with which may be grouped into subtropical climate area of relatively high temperature and high rainfall.

The corals and the barrier of coral reef are well developped on the shore-lines arround the islands and on the islands with a full variety of carbonate materials including limestones formed on different ages. And moreover, various kinds of calcareous beech rocks are formed on the shores of the islands. These carbonates, which might have been weathered and/or transformed from the corals, can be observed at anywhere on the islands. One also observe the crystalline and hard type of carbonates in certain area of the islands which might have been altered from the metamorphic action of the limestone and/or from the other carbonate materials. From these points of views mentioned above and others, it is no exaggeration to say that the Ryukyu Islands are vast treasure-house of the field for calcium carbonate.

The chemical studies on these limestones have actively been conducted by many workers recently. Y. Kitano(1967) described, by the study on the calcium carbonate such as shells, that the remains of livings may well indicate the chemical compositions of natural water in which these livings had lived with. The minor elements, which are well concerned with the crystal form of calcium carbonate, will be of great importance in the point of knowing the life environment of these livings on their age. He insists that the studies on the calcium carbonate will greatly be helpful to understand the geochemical and geological features of prehistoric ages. He also stated that the carefull comparative studies on the calcium carbonate with new and old type will be an index for close checking of rapid human contaminations of natural water.

The investigations on various types of limestones, corals and other carbonate-associated materials such as reddish soils and manganese nodules will not only be of deep significance in the point of geological and geochemical aspects but also of being bound up with the study of the human control for the natural environment, which have been destroyed by the recent growing industrial pollutions and contaminations.

The chemical and geological investigations on the Riukiu Limestones themselves have been conducted by many workers. K. Kaneshima(1965) reported the major and minor elements in various types of the Riukiu Limestones and discussed the correlations among the chemical components. K. Konishi et. al(1972) stressed their works on the study of dolomite formation in the bulk of the limestone. They figured out the mineralogical compositions, chemical compositions of major and minor elements, and isotopic study of carbon and oxygen. It was found out from their work that the dolomite would have been formed in reductive environments with the high content of organic compounds

Received November 20, 1972

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at high temperature. A. Tokuyama et. al(1972), however, described the weathering mechanism of the Riukiu Limestone from the study of material balnce calculations on the basis of chemical species of out- and input chemical components. T. Fujinuki(1970) reported the chemical composition of the Riukiu Limestone collected from Kikai Jima island.

The present authors have worked on the carbonate materials such as dolomite, marine carbonate sediments, limestones which have partially been reported already, and other carbonate-associated samples like manganese nodules and reddish soils. These manganese nodules can often be observed in reddish soils laying on the stratum of the Riukiu Limestone. The fact which has been known from the field observations is that a layer of limestone is positively observed underneeth the reddish soil which in-holds the manganese nodules, but it does not always follow that the reddish soil will coexist with the manganese nodules and the Riukiu Limestone. This will, however, imply that the reddish soil will somewhat be associated with the limestone and will largely be concerned with the formation of manganese nodules.

The present paper will include the chemcal studies of major and minor chemical species in these carbonate materials describing how the chemical compositions, particularly minor elements, change between limestone, coral materials, and carbonate associates. Further discussions, however, will remain untouched for the other opportunities to be reported.

II. Experimental

1. The map of sampling

The locations of sampling are shown in Fig. 1 and 2.

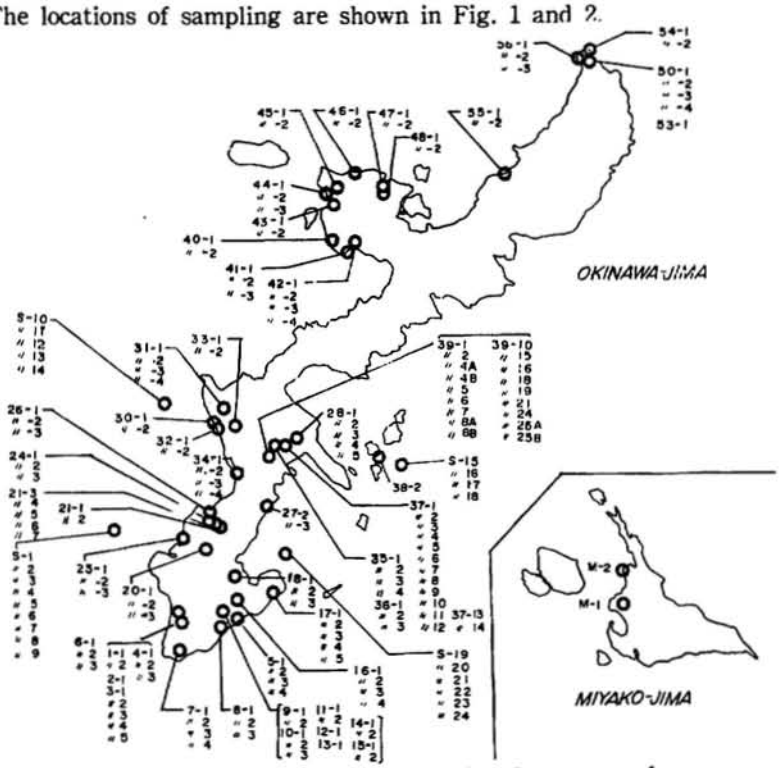

Fig 1; Sampling locations of carbonate samples.

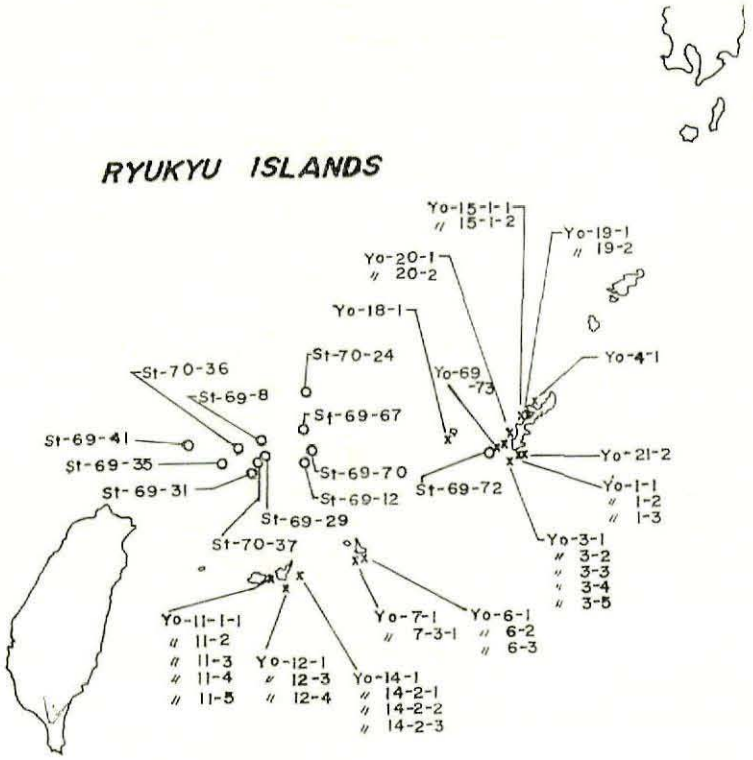

Fig 2; Sampling locations of marine sediment samples.

Table 1 Description of Limestone Samples

No.	Hardness	Geol. Classification	Date year month	Locality
1—1	H	N	1966	Kina, Itoman-cho
1—2	〃	〃	〃	〃
2—1	〃	〃	〃	Kuniyoshi, Itoman-cho
3—1	〃	〃	〃	〃
3—2	〃	〃	〃	〃
3—3	〃	〃	〃	〃
3—4	〃	〃	〃	〃
3—5	〃	〃	〃	〃
4—1	〃	〃	〃	〃
4—2	〃	〃	〃	〃
4—3	〃	〃	〃	〃
5—1	〃	M	〃	Minatogawa, Tamagusuku-son

Table 1 Continued

No.	Hardness	Geol. Classification	Date year	month	Locality
5—2	H	M	1966		Minatogawa, Tamagusuku-son
5—3	〃	〃	〃		〃
5—4	S	〃	〃		〃
6—1	〃	N	〃		Shiohirahigashibaru, Kanegusuku-son
6—2	H	〃	〃		〃
6—3	〃	〃	〃		〃
7—1	〃	〃	〃		Yamashiro-nakama-saiseki, Itoman-cho
7—2	〃	〃	〃		〃
7—3	〃	〃	〃		〃
7—4	〃	〃	〃		〃
8—1	S	Y	〃		Hanashiro, Gushichan-son
8—2	〃	〃	〃		〃
8—3	H	〃	〃		〃
9—1	S	〃	〃		Arashiro-mashidorisaiseki, Gushichan-son
9—2	〃	〃	〃		〃
10—1	〃	〃	〃		Arashiro-ooshirogumi, Gushichan-son
10—2	〃	〃	〃		〃
10—3	H	〃	〃		〃
11—1	〃	〃	〃		Arashiro-ofusogumi, Gushichan-son
11—2	S	〃	〃		〃
12—1	H	〃	〃		Arashiro-ishishinkami, Gushichan-son
13—1	S	〃	〃		Arashiro-surubi, Gushichan-son
14—1	〃	〃	〃		Arashiro-ima, Gushichan-son
14—2	〃	〃	〃		〃
15—1	〃	〃	〃		Arashiro-minamigawadaichi, Gushichan-son
15—2	〃	〃	〃		〃
16—1	H	N	〃	6	Itokazu-oozatosaiseki, Tamashiro-son
16—2	〃	〃	〃	〃	〃
16—3	〃	〃	〃	〃	〃
16—4	〃	〃	〃	〃	〃
17—1	〃	〃	〃	〃	Chinen kamikurukubara, Chinen-son
17—2	〃	〃	〃	〃	〃
17—3	S	〃	〃	〃	〃

Table 1 Continued

No.	Hardness	Geol. Classification	Date year	month	Locality
17—4	H	N	1966	6	Chinen kamikurukubara, Chinen-son
17—5	〃	〃	〃	〃	〃
18—1	〃	〃	〃	〃	Haebaru, Oozato-son
18—2	〃	〃	〃	〃	〃
18—3	〃	〃	〃	〃	〃
20—1	〃	〃	〃	〃	Shuri-nishimori, Naha-shi
20—2	〃	〃	〃	〃	〃
20—3	S	〃	〃	〃	〃
21—1	〃	〃	〃	〃	Urasoeyudore-shita, Urasoe-son
21—2	〃	〃	〃	〃	〃
21—3	H	〃	〃	〃	Fukuharagumi, Urasoe-son
21—4	〃	〃	〃	〃	〃
21—5	S	〃	〃	〃	〃
21—6	〃	〃	〃	〃	〃
21—7	H	〃	〃	〃	Shiromagumi, Urasoe-son
24—1	〃	〃	〃	〃	Nagasakigumi, Urasoe-son
24—2	〃	〃	〃	〃	〃
24—3	S	〃	〃	〃	〃
25—1	〃	〃	〃	〃	Ameku-kokubagumi, Naha-shi
25—2	〃	〃	〃	〃	〃
25—3	〃	〃	〃	〃	〃
26—1	〃	〃	〃	〃	Makiminatouranotakadai, Urasoe-son
26—2	H	〃	〃	〃	〃
26—3	S	〃	〃	〃	〃
27—2	〃	〃	〃	〃	Yagibarusaiseki, Nakagusuku-son
27—3	H	〃	〃	〃	〃
30—1	S	Y	〃	〃	Toya moriokasaiseki, Yomitan-son
30—2	H	〃	〃	〃	〃
31—1	S	〃	〃	〃	Zakimi nitsutasaiseki, Yomitan-son
31—2	〃	〃	〃	〃	〃
31—3	〃	〃	〃	〃	〃
32—1	〃	〃	〃	〃	Sobe-sobesaiseki, Yomitan-son
32—2	〃	〃	〃	〃	〃

Table 1 continuod

No.	Hardness	Geol. Classification	Date year	month	Locality
33—1	S	Y	1966	6	Yomitankōkōnishi, Yomitan-son
33—2	H	〃	〃	〃	〃
34—1	S	N	〃	〃	Gunbyoinminami, Chatan-son
34—2	H	〃	〃	〃	〃
34—3	〃	〃	〃	〃	〃
34—4	〃	〃	〃	〃	〃
35—1	〃	〃	〃	7	Chibana-OM saiseki, Misato-son
35—2	〃	〃	〃	〃	〃
35—3	〃	〃	〃	〃	〃
35—4	〃	〃	〃	〃	〃
36—1	〃	〃	〃	〃	Chibana-Chibanasaiseki, Misato-son
36—2	〃	〃	〃	〃	〃
36—3	〃	〃	〃	〃	〃
37—3	〃	〃	〃	〃	Akamichi-Akamichisaiseki, Misato-son
38—2	〃	〃	〃	〃	Henza-jima,Tonankaigan
40—1	〃	C	〃	〃	Shiokawa-kokusaikensetsu, Motobu-cho
40—2	〃	〃	〃	〃	〃
41—1	〃	〃	〃	〃	Buma-kokubagumi, Yabu-son
41—2	〃	〃	〃	〃	〃
41—3	〃	〃	〃	〃	〃
42—1	〃	〃	〃	〃	Awakonabaru, Yabu-son
42—2	〃	〃	〃	〃	〃
42—3	〃	〃	〃	〃	〃
42—4	〃	〃	〃	〃	〃
43—1	〃	〃	〃	〃	Toguchi-Motobu-sho, Motobu-cho
43—2	〃	〃	〃	〃	〃
44—1	S	Y	〃	〃	Urasaki, Motobu-cho
44—2	〃	〃	〃	〃	〃
44—3	〃	〃	〃	〃	〃
45—1	〃	〃	〃	〃	Kitazato, Kamimotobu-son
45—2	〃	〃	〃	〃	〃
46—1	〃	〃	〃	〃	Oyadomari, Kamimotobu-son
46—2	H	N	〃	〃	〃

Table 1 Continued

No.	Hardness	Geol. Classification	Date year	month	Locality
47—1	S	Y	1966	6	Nakijin-sho-minami, Nakijin-son
47—2	〃	〃	〃	〃	〃
48—1	〃	N	〃	〃	Hokubuseito-nishi, Nakijin-son
48—2	〃	〃	〃	〃	Nakijinsonyakusho-nishi, Nakijin-son
50—1	H	C	〃	〃	Hedo-hedosaiseki, Kunigami-son
50—2	〃	〃	〃	〃	〃
50—3	〃	〃	〃	〃	〃
50—4	〃	〃	〃	〃	〃
53—1	〃	〃	〃	〃	Hedoburaku-iriguchi, Kunigami-son
54—1	〃	〃	〃	〃	Hedomisaki, Kunigami-son
54—2	〃	〃	〃	〃	〃
55—1	〃	〃	〃	〃	Kijyoka, Oogimi-son
55—2	〃	〃	〃	〃	〃
56—1	〃	〃	〃	〃	Kitagunisho-higashi, Kunigami-son
56—2	〃	〃	〃	〃	〃
56—3	〃	〃	〃	〃	〃
M—1	S	N	〃	〃	Toriba, Hirara-shi, Miyako-jima
M—2	H	Y	〃	〃	Sunayama, Hirara-shi,Miyako-jima

H ; Hard Limestone, S ; Soft Limestone, N ; Naha Limestone,
Y ; Yontan Limestone, C ; Crystalline Limestone, M ; Machinato Limestone.

Table 2 Description of Coral Samples

No.	Hardness	Mineralogical Composition Aragonite(%)	Mg-Calcite(%)	Locality
S— 1	H	100	0	Sea bottom of Chiibishi(west side of Naha)
S— 2	〃	60	40	〃
S— 3	〃	100	0	〃
S— 4	〃	〃	〃	〃
S— 5	〃	〃	〃	〃
S— 6	〃	〃	〃	〃
S— 7	〃	99	1	〃
S— 8	〃	100	0	〃
S— 9	〃	95	5	〃
S—10	〃	99	1	Sea bottom at sea side of Yomitan-kaigan
S—11	〃	100	0	〃
S—12	〃	〃	〃	〃
S—13	〃	96	4	〃
S—14	〃	99	1	〃
S—15	〃	〃	〃	Sea bottom at Henza-kaigan(Katsuren-son)
S—16	〃	96	4	〃
S—17	〃	100	0	〃
S—18	〃	〃	〃	〃
S—19	〃	50	50	Yonabaru-kaigan, (Yonabaru-cho)
S—20	〃	97	3	〃
S—21	〃	100	0	〃
S—22	〃	99	1	〃
S—23	〃	〃	〃	〃
S—24	〃	〃		

H ; Classified as Hard type

Table 3 Desciption of Marine Sediment Samples from Senkaku Retto

No.	Date	Water Depth (m)	Mineralogical (%) Composition Mg-Calcite	Aragonite	Quartz	Location Latitude	Longitude
St.69— 8(M)	6/24/1969	141				26°09.0′N	123°44.9′E
(10M)							
(20M)							
(42M)							
(65M)							
(80M)							
(100M)							
〃.69—12(M)	6/24/1969	210	82±5	5±3	6.3	25°54.9′N	124°31.0′E
(10M)			85±5	6±3*	3.5		
(20M)			88±5	2±1	4.4		
(42M)			84±5	2±1	5.0		
(65M)							
(80M)							
(100M)							
〃.69—29(M)	6/30/1969	140	53±5	40±5*	7.36	25°56.2′N	123°48.0′E
(10M)							
(20M)							
(42M)							
(65M)							
(80M)							
(100M)							
〃.69—31(M)	7/1/1969	125				25°43.8′N	123°37.6′E
(10M)							
(20M)							
(42M)							
(65M)							
(80M)							
(100M)							
〃.69—35(M)	7/4/1969	115	65±8	20±8*	9.5	25°50.9′N	123°12.3′E
(10M)			50±8	40±8*	3.4		
(20M)			64±8	28±8*	4.5		
(42M)							
(65M)							
(80M)							
(100M)							
〃.69—41(M)	7/5/1969	110				26°09.7′N	122°33.4′E
(10M)							
(20M)							
(42M)							
(65M)							
(80M)							
(100M)							

Toble 3 continuedand

No.	Date	Water Depth (m)	Mineralogical(%) Composition Mg-Calcite	Aragonite	Quartz	Location Latitude	Longitude
〃.69—67(M)	7/7/1969	146				26°25.5′N	124°23.0′E
(10M)							
(20M)							
(42M)							
(65M)							
(80M)							
(100M)							
〃.69—70(M)	7/7/1969	175				26°03.8′N	124°35.1′E
(10M)							
(20M)							
(42M)							
(65M)							
(80M)							
(100M)							
〃.69—72(M)	7/8/1969	195	80±8	13±6	7.0	26°04.0′N	127°24.8′E
(10M)			90±9	5±3	5.5		
(20M)			90±9	5±3	5.1		
(42M)			86±9	10±5	5.2		
(65M)			85±9	8±4	6.9		
(80M)			80±8	12±6	7.8		
(100M)			77±8	11±6	11.6		
〃.69—73	7/8/1969	160				26°05.7′N	127°27.3′E
〃.70—24(M)	6/19/1970	120				27°02.0′N	124°26.3′E
(10M)							
(20M)							
(42M)							
(65M)							
(80M)							
(100M)							
〃.70—36(M)	6/20/1970	130	47±10	43±10*	6.4	26°03.3′N	123°25.6′E
(10M)			61±10	32±10*	3.8		
(20M)			69±10	30±10*	5.7		
(42M)							
(65M)							
(80M)							
(100M)							
〃.70—37(M)	6/20/1970	132				25°52.0′N	123°42.2′E
(10M)							
(20M)							
(42M)							
(65M)							
(80M)							
(100M)							

*Aragonite+Low-Mg-Calcite

Table 4 Description of Marine Sediment Samples Collected by Yomiuri Go and Tansei Maru

No.	Date	Water Depth (m)	Mineralogical Composition (%) Mg-Calcite	Aragonite	Quartz	Location Latitude	Longitude	
Yo— 1—1	9/14/1967	210	75±8	15±8	4.8	26°03.2′N	127°44.7′E	(the offing of Minatogawa)
〃 1—2	〃	〃	81±8	4±2	7.0	〃	〃	〃
〃 1—3	〃	〃	81±8	5±2	7.0	〃	〃	〃
〃 3—1	9/17/1967	182	75±8	18±8	2.5	26°02.7′N	127°38.7′E	(the offing of Minatogawa)
〃 3—3	〃	〃	54±8	41±8	1.5	〃	〃	〃
〃 3—4	〃	200	57±8	32±8	3.1	〃	〃	〃
〃 3—5	〃	182	55±8	41±8	1.5	〃	〃	〃
〃 4—1	9/19/1967	150	68±8	16±8	12.7	26°47.0′N	128°01.0′E	(north east of Kori-Jima)
〃 6—1	10/ 5/1967	60	95±8	2±1	0.32	24°41.5 N	125°22.0′E	(south of Tomori, Miyako-jima)
〃 6—2	〃	109	95±8	2±1	0.54	〃	〃	〃
〃 6—3	〃	230	85±8	10±5	1.94	〃	〃	〃
〃 7—1	10/ 9/1967	70	88±8	10±5	0.16	24°39.8′N	125°15.2′E	(south of kurima-jima, Miyako)
〃 7—3—1	〃	240	87±8	10±5	2.4	〃	〃	〃
〃 7—3—2	〃	〃	84±8	8±5	5.4	〃	〃	〃
〃 11—1—1	10/21/1967	41	87±8	2±1	0.8	24°23.5′N	124°04.5′E	(the mouth of Nakura-bay, Ishigaki)
〃 11—2	〃	43	93±8	2±1	0.8	〃	〃	〃
〃 11—3	〃	55	74±8	22±8	0.8	〃	〃	〃
〃 11—4	〃	90	80±8	10±5	4.3	〃	〃	〃
〃 11—5	〃	〃	73±8	20±5	5.0	〃	〃	〃
〃 12—1	10/29/1967	230	90±8	2±1	4.8	24°17.9′N	124°15.7′E	(the offing of Shiraho, Ishigaki-Jima)
〃 12—3	〃	〃	89±8	6±3	2.84	〃	〃	〃
〃 12—4	〃	〃	85±8	7±3	5.14	〃	〃	〃
〃 14—1	10/30/1967	281				24°22.0′N	124°26.6′E	(the offing of Ibaruma, Ishigaki-jima)
〃 14—2—1	〃	284	89±8	5±2	3.58	〃	〃	〃
〃 14—2—2	〃	〃	87±8	5±2	4.04	〃	〃	〃
〃 14—2—3	〃	〃	82±8	10±5	4.24	〃	〃	〃
〃 15—1—1	11/ 7/1967	200	67±8	20±8	8.13	26°32.8′N	127°53.5′E	(the Nago bay, Okinawa)
〃 15—1—2	〃	〃	58±8	30±8	8.16	〃	〃	〃
〃 18—1	11/14/1967	68	20±8	70±8	0.87	26°18.2′N	126°45.0′E	(the offing of Torishima, Kume-jima)
〃 19—1	11/20/1967	104				26°32.8′N	127°55.9′E	(the Nago bay, Okinawa)
〃 19—2	〃	190				〃	〃	〃
Ta— 20—1	5/26/1966	60	78±8	17±8	1.1	26°16.6′N	127°31.1′E	(the offing of Izena Jima)
〃 20—2	〃	〃	82±8	14±5	0.75	26°16.8′N	127°30.8 E	〃
〃 21—2	5/25/1966	〃	52±8	44±8	0.50	26°53.7′N	127°54.3 E	〃
〃 22—1	5/25/1966	76	91±8	8±4	0.25	27°01.4 N	128°29.4 E	(the offing of Yoron Jima)

Table 5 Description of Manganese Nodules

No.	Mineralogical classification	Date	Locality
N—1	P	1965	Nakijin son, Nakasone
N—1—2	P	〃	〃 〃
N—2	P	〃	〃 〃
N—3	N	〃	Nakijin son Sakiyama
N—5	N	〃	Haneji son, Nakooji
K I—1	N	〃	Kin son, Kin
K I—2	N	〃	〃 〃
Y—1	N	〃	Yomitan, son, Sobe
Y—2	N	〃	〃 Ooki
Y—3	N	〃	〃 Kina
Y—4	N	〃	〃 〃
G i—1	C	〃	Ginowan shi,
G i—2	C	〃	〃
G i—3	N	〃	〃
G i—4	N	〃	〃 Ganiku
G i—5	C	〃	〃 〃
S—1	N	〃	Sashiki son, Oyakebaru
S—2	C	〃	〃 〃
S—3	C	〃	〃 〃
S—4	C	〃	〃 〃
S—5	N	〃	〃 〃
T—1	N	〃	Tamagusuku son, Hiyakuna
K—1	N	1959	Kumejima, Gushikawa son
M—1	C	1965	Miyako Jima, Irabu son
M—2	C	〃	〃 〃
M—3	N	〃	〃 Gusukube cho
M—4	C	〃	〃 〃
M—5	C	〃	〃 〃
M—6	C	〃	〃 Ueno son, Nobaru
M—7	C	〃	〃 Hirara shi, Nishibe
M—8	N	〃	〃 Hirara shi Kagamihara
M—9	N	〃	〃 Shimoji cho Sugama
M—10	C	〃	〃 Hirara shi, Shirakawa
YA—1	O	〃	Ishigaki Jima, Sakieda
YA—3	O	〃	〃 〃
YA—4	O	〃	〃 〃
YA—5	O	〃	〃 〃
MO—1—1	O	〃	Motobu cho, Yakimata
MO—1—2	O	〃	〃 〃
MO—1—3	M	〃	〃 〃
MO—1—4	O	〃	〃 〃
MO—2—1	O	〃	〃 Manna
MO—2—2	O	〃	〃 〃
N—4—1	O	〃	Nakijin son, Yonamine
N—4—2	O	〃	〃 〃

P; pyrolusite N: manganese nodule O; manganese ore C; manganese clod M: magnetite

TabIe 6 Description of Reddish Soils

No	Mn-nodule associated	Sampling Date	Locality
Aka—1	no	1971	Ishigaki Jima, Akashitabashi
Shikina	〃	1972	Naha shi, Shikina
M—Mi—4	〃	1971	Miyako Jima, Minahuku
M—No—5	〃	〃	〃 Nobarugoshi
Chi—2	〃	〃	Chinen son, Chinen
O—Oy	yes	〃	Sashiki son, Oyakebaru
O—Oy—4	〃	〃	〃 〃
O—Ku	no	〃	Itoman cho, Kuniyoshi
O—Kin	yes	〃	Kin son, Kin
O—Awa	no	〃	Nago shi, Awa
U—1	〃	〃	Urasoe shi Yudore
U—2	〃	〃	〃 〃
O—Kita	〃	〃	Motobu cho, Kitazato

2. The description of samples

The descriptions for samples are shown in Tables of 1, 2, 3, 4, 5 and 6 including hardness, date of sampling, locality, mineral composition and classification.

3. Experimental techniques for the chemical analysis

(1) Decomposition of samples

Few grams of the carbonate samples were decomposed by the following three ways; 1) 6N hydrochloric acid leaching for S_iO_2, Ca, Mg, Fe, A1 and P_2O_5 analysis, 2) hydrogen perchloric acid leaching for Mn and Cl determlnation, 3) mixed acid solution of concentrated hydrochloric and hydrogen perchloric acids for Zn, Cu, Sr and Mn analysis.

All of the reddish lateritic soils and manganese nodules (1～5g) were decomposed by the leaching of aqua regia solution.

(2) Chemical analysis for major and minor components

(a) Carbonate samples

The major components in corbonate samples were analyzed by the following conventional methods; S_iO_2 by gravimetry for residual solid phase of 6N hydrochoric acid leaching, calcium and magnesium by titration with EDTA standard solution by the use of Dotite NN and EBT as indicators, total iron by titration with EDTA standard solution and Variamine blue-B as an indicator, aluminum by titration with EDTA standard solution and Cu-PAN as an indicatior, phosphate by spectrophotometry with anmonium molybdate as a coloring agent, sulfate by gravimetry as barium sulfate, chlorine by spectrophotometry with mercuric thiocyanate, sodium by flamephotometry, and manganese

by both spectrophotmetry with persulfate and atomic absorption technique for newly weigbed samples. Other minor elements, such as Zn, Cu, Mn(in part) and Sr, were determined by atomic absorption method.

(b) Reddish soils and manganese nodules

The chemical analysis of major species, such as $Si\ O_2$, total iron, aluminum, calcium and magnesium were followed by the same techniques as described above for the analysis of the carbonate samples.

The manganese content in manganese nodules were determined by the following method; manganese by titration with ferrous sulfate standard solution, and manganese peroxide by the back titration of standard oxalic acid with potassium permanganate standard solution.

The minor elements were analyzed by both spectrophotometric and atomic absorption methods. The copper and nickel were determined by spectrophtometry as follow; the copper by the extraction with dithzone into carbon-tetrachloride, and the nickel by the extraction of dimethyl-glyoxime complex into chloroform solvent. Other minor elements in the solution, such as Zn, Cu Ni and Sr, were analyzed directly by the introduction of the atomic absorption technique.

III. Chemical Composition of Carbonate and Associated Materials on the Ryukyu Islands

The major and minor components in limestone, coral, dolomite, marine sediments taken from Senkaku Retto off-shore and Yomiuri Go, and manganese nodules and reddish soil samples, are shown in Tables 7, 8, 9, 10, 11 and 12, respectively.

Table 7 The Major and Minor Components in Limestone Samples

No.	SiO_2 (%)	Fe_2O_3 (%)	Al_2O_3 (%)	CaO (%)	MgO (%)	P_2O_5 (%)	SO_4 (%)	Cl (%)	Na (%)	Zn* (ppm)	Cu* (ppm)	Sr* (ppm)	Mn** (ppm)
1—1	0.75	0.10	0.09	54.56	0.38	0.06	0.006	0.0034	0.013				24
1—2	0.93	0.17	0.11	54.49	0.29	0.06	0.021	0.0011	0.019				31
2—1	1.31	0.17	0.15	53.90	0.19	0.05	0.014	0.0039	0.010				26
3—1	0.73	0.12	0.07	54.24	0.17	0.04	0.005	0.0011	0.019	14.3	3.4	260	14
3—2	1.55	0.17	0.11	54.03	0.29	0.06	0.022	0.0011	0.007				13
3—3	3.35	0.57	0.28	52.34	0.36	0.14	0.019	0.0011	0.013				26
3—4	9.55	2.06	0.91	46.46	0.55	0.15	0.012	0.0026	0.010	34.1	5.2	200	52
3—5	3.34	0.47	0.33	51.72	0.39	0.07	0.024	0.0014	0.011				56
4—1	0.63	0.13	0.06	54.73	0.25	0.04	0.008	0.0009	0.006	16.5	15.4	400	34(24.3)
4—2	0.83	0.15	0.07	54.30	0.23	0.07	0.023	0.0012	0.018				24
4—3	3.48	0.46	0.27	52.27	0.53	0.11	0.023	0.0032	0.017	45.8	5.4	500	52(89.2)
5—1	0.37	0.09	0.02	54.81	0.19	0.02	0.023	0.0029	0.011				12
5—2	0.92	0.21	0.06	53.83	0.84	0.07	0.020	0.0044	0.019	31.5	4.3	500	28(44.6)
5—3	0.85	0.23	0.08	53.92	0.70	0.06	0.014	0.0011	0.013	16.5	3.0	700	24(62.8)
5—4	1.17	0.29	0.11	53.44	0.67	0.06	0.019	0.0031	0.014	14.3	3.1	460	67
6—1	3.22	0.49	0.33	51.09	0.20	0.07	0.019	0.0009	0.019	19.5	9.0	300	43(44.6)
6—2	0.37	0.07	0.04	54.77	0.45	0.04	0.016	0.0011	0.017	17.3	5.1	200	12(14.9)
3—C	3.34	0.47	0.33	51.72	0.39	0.07				20.8	7.2	350	56
7—A	0.70	0.11	0.08	54.22	0.70	0.07				18.8	7.8		47(29.7)
7—1	1.00	0.09	0.12	54.45	0.33	0.04	0.007	0.0054	0.019	16.5	8.3	500	32(31.8)
7—2	9.23	1.21	0.58	47.42	1.01	0.13	0.037	0.0011	0.019	31.7	14.0	340	15
7—3	0.70	0.11	0.08	54.22	0.07	0.07	0.020	0.0010	0.006				47
7—4	4.63	0.65	0.45	51.22	0.55	0.21	0.028	0.0027	0.018				87
8—B	0.92	0.24	0.14	54.58	0.03	0.09				23.3	9.0	200	42
8—1	3.45	0.27	0.63	52.28	0.25	0.08	0.016	0.0053	0.013				126
8—2	0.92	0.24	0.14	54.58	0.03	0.09	0.026	0.0065	0.013				42
8—3	0.57	0.12	0.07	54.73	0.25	0.06	0.017	0.0052	0.012				26
9—1	1.17	0.19	0.14	53.86	0.10	0.06	0.008	0.0066	0.019				47
9—2	0.42	0.09	0.06	54.99	0.30	0.05	0.008	0.0012	0.006				13
10—1	0.36	0.06	0.07	54.89	0.33	0.04	0.009	0.0109	0.008	15.7	3.2	250	18(25.7)
10—2	2.32	0.36	0.28	53.05	0.45	0.09	0.022	0.0021	0.013	25.2	6.4	220	39
10—3	1.19	0.21	0.11	54.03	0.29	0.07	0.017	0.0015	0.017	21.0	7.8	500	23(31.1)
11—1	2.84	0.41	0.34	52.74	0.28	0.08	0.017	0.0053	0.014				4
11—2	3.02	0.41	0.32	52.14	0.10	0.07	0.022	0.0030	0.010				34
12—1	1.16	0.16	0.18	53.48	0.41	0.11	0.012	0.0017	0.003				41

Table 7 continued

No.	SiO_2 (%)	Fe_2O_3 (%)	Al_2O_3 (%)	CaO (%)	MgO (%)	P_2O_5 (%)	SO_4 (%)	Cl (%)	Na (%)	Zn* (ppm)	Cu* (ppm)	Sr* (ppm)	Mn** (ppm)
13—1	1.68	0.18	0.19	53.36	0.53	0.08	n.d	0.0050	0.028				41
14—A	2.05	0.36	0.27	52.99	0.06	0.117				22.2	11.4	230	49(88.2)
14—1	2.05	0.36	0.27	52.99	0.06	0.12	0.044	0.0035	0.013				49
14—2	5.64	0.70	0.60	50.18	0.42	0.19	0.019	0.0018	0.010				71
15—1	0.78	0.14	0.13	54.40	0.19	0.07	0.008	0.0045	0.014				15
15—2	1.33	0.35	0.17	53.57	0.51	0.09	0.007	0.0067	0.019	16.0	8.0	130	29
16—A	0.83	0.12	0.08	54.38	0.10	0.09				17.3	7.5	600	14(17.7)
16—1	1.05	0.12	0.06	54.38	0.04	0.04	0.012	0.0018	0.006	18.1	6.2	260	17
16—2	0.75	0.14	0.07	54.53	0.81	0.06	0.016	0.0011	0.013	28.5	5.1	600	9(20.3)
16—3	1.60	0.32	0.18	53.85	0.23	0.10	0.028	0.0054	0.007	16.0	5.4	350	66
16—4	0.83	0.12	0.08	54.38	0.10	0.09	0.017	0.0029	0.018				14
17—1	0.63	0.15	0.10	54.40	0.26	0.07	0.020	0.0021	0.014				14
17—2	1.55	0.35	0.19	53.62	0.24	0.08	0.009	0.0036	0.017	17.1	3.9	310	n.d
17—3	1.54	0.78	0.23	53.45	0.53	0.08	0.010	0.0009	0.007				48
17—4	1.80	0.30	0.22	53.63	0.26	0.06	0.010	0.0214	0.014				46
17—5	0.85	0.13	0.05	52.78	0.33	0.05	0.002	0.0126	0.018				38
18—1	0.54	0.17	0.04	54.45	0.25	0.06	0.012	0.0026	0.022	17.3	9.9	500	65(77.0)
18—2	0.92	0.17	0.14	54.47	0.38	0.07	0.019	0.0019	0.006				53
18—3	0.56	0.12	0.06	54.43	0.20	0.04	0.007	0.0014	0.006				32
20—1	2.03	0.15	0.09	53.73	0.40	0.09	0.024	0.0022	0.020	16.0	3.5	300	14
20—2	0.42	0.11	0.06	54.73	0.30	0.05	0.020	0.0039	0.008	14.0	4.1	280	19
20—3	4.42	0.55	0.41	51.29	0.50	0.11	0.016	0.0112	0.028	21.1	8.0	330	65
21—1	0.38	0.40	0.14	53.76	0.16	0.08	0.017	0.0032	0.003	15.7	4.9	260	42
21—2	1.04	0.31	0.15	54.21	0.38	0.07	0.017	0.0019	0.014	17.1	5.7	300	35
21—3	0.55	0.12	0.08	54.35	0.26	0.09	0.020	0.0029	0.013	14.3	2.6	230	16
21—4	14.62	0.40	0.42	46.61	0.27	n.d	0.011	0.0121	n.d				34
21—5	16.89	0.57	0.53	44.88	0.16	0.19	0.010	0.0018	0.013	21.5	4.4	230	72
21—6	1.98	0.39	0.20	53.83	0.05	0.06	0.004	0.0016	0.004				42
21—7	0.50	0.21	0.04	54.49	0.16	0.06	0.027	0.0019	0.013				17
24—1	1.86	0.22	0.19	53.79	0.39	n.d	0.013	0.0032	n.d				39
24—2	11.78	0.60	0.48	47.50	0.33	0.14	0.004	0.0010	0.002	18.5	7.0	160	8
24—3	14.19	2.42	1.62	43.63	0.33	0.36	0.011	0.0050	0.001	45.2	9.3	200	180
25—1	9.73	0.62	0.30	48.56	0.03	0.09	0.020	0.0038	0.013	24.4	7.0	300	49
25—2	6.12	0.44	0.28	50.90	0.45	0.08	0.018	0.0032	0.019				38
25—3	9.61	0.80	0.41	47.60	0.25	0.09	0.031	0.0058	0.011				74

Table 7 contiuned

No.	SiO_2 (%)	Fe_2O_3 (%)	Al_2O_3 (%)	CaO (%)	MgO (%)	P_2O_5 (%)	SO_4 (%)	Cl (%)	Na (%)	Zn* (ppm)	Cu* (ppm)	Sr* (ppm)	Mn** (ppm)
26—1	6.00	0.70	0.46	49.90	0.31	n.d	0.181	0.0893	0.095				82
26—2	1.45	0.29	0.13	54.14	0.25	0.03	0.027	0.0098	0.010	18.1	3.4	200	49
26—3	4.01	0.64	0.39	51.40	0.09	0.10	0.032	0.0210	0.019				48
27—2	1.66	0.36	0.22	54.17	0.15	0.08	0.007	0.0015	0.010				51
27—3	3.05	0.30	0.14	52.38	0.01	0.06	0.011	0.0015	0.013				46
30—1	1.38	0.17	0.12	54.17	0.25	0.08	0.016	0.0033	0.007	14.8	7.7		32
30—2	0.53	0.07	0.03	54.24	0.49	0.05	0.009	0.0005	0.008				3
31—1	0.39	0.01	0.06	55.00	0.19	0.05	0.004	0.0027	0.010	23.3	11.4		26(35.3)
31—2	0.27	0.05	0.05	54.81	0.06	0.04	0.012	0.0056	0.014				26
31—3	0.39	0.07	0.05	54.91	0.10	0.07	0.009	0.0017	0.014				19
32—1	1.45	0.18	0.13	53.81	0.40	0.08	0.023	0.0300	0.004				172
32—2	4.36	0.26	0.30	51.90	0.10	0.15	0.016	0.0094	0.019	23.1	14.2	600	159(164.6)
33—1	3.57	0.21	0.23	52.28	0.24	0.13	0.016	0.0052	0.013	14.8	8.8	350	59
33—2	0.77	0.07	0.06	54.58	0.32	0.07	0.018	0.0012	0.007	24.7	11.1	280	159
34—1	14.13	1.35	0.64	45.16	0.39	0.10	0.017	0.0024	0.011	25.7	7.2	200	56
34—2	3.53	0.41	0.13	52.76	0.04	0.06	0.019	0.0045	0.006	18.8	7.4	190	36(57.3)
34—3	27.29	0.90	0.39	38.75	0.25	0.08	0.015	0.0013	0.003				26
34—4	6.28	1.27	0.22	50.36	0.13	0.09	0.022	0.0091	0.019				88
35—1	3.33	0.27	0.11	52.49	0.55	0.06	0.013	0.0021	0.013				45
35—2	12.56	0.44	0.27	46.29	1.20	0.04	n.d	0.0040	0.013				50
35—3	5.48	0.21	0.09	51.17	0.56	0.04	0.007	0.0026	0.010				36
35—4	18.55	0.80	0.26	43.45	0.06	0.05	0.015	0.0016	0.005				214
36—1	3.14	0.30	0.18	51.99	0.65	0.03	0.014	0.0041	0.006				64
36—2	4.64	0.19	0.14	51.76	0.44	0.04	0.022	0.0052	0.006	14.2	3.4	460	57
36—3	5.15	0.24	0.15	51.45	0.32	0.03	0.009	0.0017	0.013	18.8	5.1	500	135(145.5)
37—3	4.48	0.22	0.08	51.96	0.50	0.05	0.009	0.0012	0.006	14.9	4.6	120	39
38—2	1.33	0.20	0.08	53.94	0.06	0.06	0.031	0.0496	0.045				19
40—1	0.38	0.03	0.02	54.81	0.13	0.01	0.009	0.0007	0.004	13.5	1.8	310	8
40—2	0.39	0.04	0.03	54.62	0.31	0.01	0.001	0.0008	0.017				8
41—1	0.27	0.03	0.02	54.67	0.24	0.01	0.011	0.0003	0.010	18.8	3.9	360	10(16.2)
41—2	0.24	0.04	0.01	55.15	0.33	0.01	0.009	0.0007	0.010				5
41—3	0.27	0.05	0.02	55.08	0.28	0.01	0.005	0.0010	0.006	15.5	2.3	500	10
42—1	0.35	0.03	0.02	54.96	0.10	0.01	0.008	0.0009	0.006	16.5	3.4	400	7
42—2	3.09	0.45	0.23	52.52	0.03	0.05	0.030	0.0014	0.007				43
42—3	0.19	0.03	0.02	55.24	0.20	0.01	0.010	0.0006	0.011				8

Table 7 Continued.

No.	SiO_2 (%)	Fe_2O_3 (%)	Al_2O_3 (%)	CaO (%)	MgO (%)	P_2O_5 (%)	SO_4 (%)	Cl (%)	Na (%)	Zn* (ppm)	Cu* (ppm)	Sr* (ppm)	Mn** (ppm)
42—4	0.21	0.04	0.02	55.05	0.17	0.01	0.019	0.0002	0.011	26.7	7.0	280	28
43—1	0.14	0.02	0.01	54.86	0.03	0.04	0.007	0.0013	0.007				13
43—2	0.28	0.03	0.03	54.86	0.06	0.04	0.006	0.0007	0.005	22.5	4.6	520	40(41.2)
44—1	1.38	0.17	0.14	53.58	0.35	0.05	0.023	0.0052	0.018				43
44—2	5.52	1.11	0.87	49.53	0.28	0.11	0.020	0.0069	0.013	24.1	7.3	460	49
44—3	2.16	0.23	0.19	53.52	0.30	0.05	0.025	0.0013	0.005				33
45—1	14.31	1.46	0.74	44.74	0.81	0.09	0.001	0.0028	0.001	27.2	8.0	260	155
45—2	5.87	0.98	0.52	50.24	0.63	0.07	0.018	0.0380	0.038	24.1	13.9	260	32
46—1	1.61	0.23	0.09	53.52	0.24	0.06	0.006	0.0026	0.006	15.2	11.5	180	87
46—2	0.72	0.08	0.06	53.68	0.63	0.05	0.120	0.0950	0.050				29
47—1	1.74	0.22	0.18	53.67	0.02	0.07	0.012	0.0644	0.021				54
47—2	3.30	0.53	0.29	52.43	0.06	0.07	0.011	0.0571	0.007				85
48—1	24.12	0.66	0.41	39.68	0.31	0.09	0.038	0.0300	0.013	51.4	23.5	110	80
48—2	8.04	0.75	0.37	49.18	0.17	0.11	0.016	0.0012	0.011	23.1	8.1	250	81
50—A	0.15	0.04	0.02	55.05	0.24	0.03				20.8	5.7		(35.4)
50—1	0.02	0.07	0.02	55.19	0.43	n.d	0.015	0.0009	0.006	33.8	9.3	180	48(47.8)
50—2	2.21	0.28	0.29	53.44	0.03	0.03	0.015	0.0031	0.014				27
50—3	4.18	0.59	0.83	51.49	0.01	0.04	0.002	0.0072	0.011				43
50—4	0.15	0.04	0.02	55.05	0.24	0.03	0.010	0.0008	0.006				20
53—1	10.33	0.08	0.07	48.56	0.34	0.03	0.013	0.0009	0.005				48
54—1	6.28	0.43	0.35	50.61	0.27	0.05	0.025	0.0140	0.017				80
54—2	0.15	0.06	0.01	54.49	0.87	0.06	0.018	0.0014	0.008	20.8	7.6	490	17
55—1	0.33	0.04	0.02	54.86	0.04	0.05	0.007	0.0009	0.006	17.5	1.8	230	32
55—2	0.12	0.06	0.00	55.47	0.11	0.04	0.006	0.0082	0.003	17.5	3.3	200	38
56—1	0.25	0.03	0.02	55.10	0.03	0.04	0.006	0.0017	0.006				29
56—2	0.16	0.03	0.03	55.00	0.17	0.12	0.007	0.0008	0.010	22.5	3.9	310	23(27.9)
56—3	0.17	0.03	0.02	54.67	0.68	0.04	0.005	0.0031	0.006				22
M—1	1.00	0.23	0.12	53.95	0.28	0.09	0.017	0.0574	0.032	18.1	16.4	320	30
M—2	0.39	0.09	0.06	51.09	0.17	0.05	n.d	n.d	n.d	14.5	14.7	4540	37

* and ( ) ; by atomic absorption, ** ; by spectrophotometry

Table 8 The Major and Minor Components in Coral Samples

No.	SiO_2 (%)	Fe_2O_3 (%)	Al_2O_3 (%)	CaO (%)	MgO (%)	P_2O_5 (%)	SO_4 (%)	Cl (%)	Na (%)	Zn* (ppm)	Cu* (ppm)	Sr* (ppm)	Mn** (ppm)
S— 1	n.d	n.d	n.d	n.d	n.d	n.d	0.560	0.0632	0.345	24.5	27.5	8600	9.6(8.8)
S— 2	n.d	n.d	n.d	50.44	2.31	0.082	0.450	0.0117	0.200	31.5	16	5100	62 (89.2)
S— 3	0.013	0.010	0.058	51.51	0.02	0.0057	0.555	0.0245	0.374	26.3	13.1	8400	4 (12.2)
S— 4	0.020	0.003	0.026	53.97	0.11	0.0097	0.532	0.0283	0.391	20.3	12.6	8500	7 (6.8)
S— 5	0.045	0.004	0.054	53.24	0.24	0.0091	0.588	0.0404	0.440	19.5	8.0	7600	4 (8.1)
S— 6	0.025	0.003	0.021	53.87	0.02	0.0102	0.585	0.0271	0.372	19.5	4.9	8600	6 (8.8)
S— 7	0.070	0.001	0.018	53.98	0.02	0.0078	0.568	0.0433	0.400	19.8	5.9	7800	2 (8.1)
S— 8	0.031	0.005	0.057	53.76	0.04	0.0057	0.565	0.0406	0.370	20.6	12.6	8000	4 (9.5)
S— 9	0.069	0.002	0.027	53.31	0.25	0.0226	0.665	0.0670	0.377	22.5	5.4	8100	4 (6.8)
S—10	0.052	0.004	0.077	53.46	0.09	0.0158	0.575	0.0361	0.312	16.2	9.8	8300	6 (10.8)
S—11	0.032	0.003	0.021	53.33	0.03	0.0051	0.542	0.0265	0.316	15.8	5.0	7800	4 (6.8)
S—12	0.095	0.006	0.048	54.00	0.16	0.0233	0.535	0.0384	0.292	16.5	5.2	8400	9 (10.8)
S—13	0.159	0.009	0.073	53.08	0.39	0.0163	0.598	0.0292	0.313	18.8	7.6	8200	6 (12.8)
S—14	0.152	0.004	0.056	53.82	0.02	0.0124	0.568	0.0478	0.310	16.5	3.8	8300	5 (10.1)
S—15	0.075	0.005	0.036	53.49	0.13	0.0078	0.610	0.0695	0.390	25.5	6.6	8300	5 (8.1)
S—16	0.091	0.005	0.040	53.52	0.10	0.0214	0.528	0.0223	0.312	25.5	7.6	8300	4 (7.4)
S—17	0.668	0.002	0.056	53.35	0.06	0.0112	0.628	0.0373	0.313	27.3	6.6	8700	3 (7.4)
S—18	0.065	0.003	0.063	53.75	0.16	0.0160	0.880	0.0358	0.371	25.8	7.1	8300	10 (8.1)
S—19	0.946	0.011	0.188	51.02	2.40	0.0934	0.592	0.0130	0.204	23.9	5.0	5200	19 (21.1)
S—20	0.262	0.001	0.040	53.51	0.16	0.0220	0.528	0.0213	0.299	17.3	4.4	8200	3 (9.5)
S—21	0.117	0.001	0.043	54.13	0.04	0.0184	0.620	0.0800	0.378	18.8	5.7	8300	4 (7.4)
S—22	0.070	0.003	0.050	53.68	0.10	0.0126	0.585	0.0273	0.372	20.3	6.0	8500	6 (6.8)
S—23	0.048	0.001	0.035	53.93	0.06	0.0030	0.432	0.0550	0.308	15.8	6.8	7700	1 (8.1)
S—24	n.d	n.d	n.d	49.87	2.49	0.0305	0.500	0.0171	0.194	22.5	12.0	3800	120 (138.5)

* and ( ); by atomic absorption ** ; by spectrophotometry

Table 9 The Major and Minor Componenents in Dolomite Samples

No.	SiO_2 (%)	Fe_2O_3 (%)	Al_2O_3 (%)	CaO (%)	MgO (%)	P_2O_5 (%)	SO_4 (%)	Cl (%)	$K_2Cr_2O_7$ Consumption (mg/g)	Zn* (ppm)	Cu* (ppm)	Sr* (ppm)	Mn** (ppm)
Dark-colored Part													
37— 2	2.49	0.24	0.10	41.81	9.77	0.039	0.246	0.0083	18.0	17.5	5.7	1250	(31.0)
37— 4	3.20	0.31	0.15	45.22	6.75	0.101	0.332	0.0250	14.8	14.2	11.5	2800	27
37— 5	4.79	0.26	0.22	46.13	5.16	0.014	0.164	0.0126	13.0	14.9	5.7		43
37— 6	2.83	0.23	0.13	39.59	11.88	0.056	0.233	0.0160	16.0	17.0	7.3	1030	25
37— 7	2.60	0.39	0.13	40.76	10.88	0.093	0.218	0.0186	16.0	33.2	7.6	1160	27
37— 8	8.09	0.49	0.44	36.69	11.82	0.041	0.278	0.0088	19.8	19.1	11.6	950	58
37— 9	7.91	0.45	0.44	39.01	9.68	0.036	0.257	0.0080	21.1	14.9	7.6	1320	52
37—11	7.22	0.43	0.35	40.27	9.11	0.091	0.281	0.0108	18.0	17.6	7.3	1820	44
37—12	8.32	0.47	0.42	40.49	8.05	0.050	0.402	0.0146	24.6	17.0	8.0	1420	60
37—14	2.87	0.34	0.06	35.48	15.49	0.039	0.215	0.0086	14.8	14.2	7.3		24
39— 1	20.12	1.06	0.59	32.74	8.95	0.032	0.732	0.0136	44.0	21.0	8.4	970	90
39— 4B	16.00	0.94	0.56	35.90	8.58	0.032	0.526	0.0124	50.8	21.0	10.4	1760	82
39— 5	19.05	0.91	0.52	30.19	11.92	0.027	0.526	0.0100	42.5	21.8	5.8	530	96(105.8)
39— 6	16.10	1.19	0.68	34.83	12.25	0.053	0.816	0.0120	60.5	18.3	6.1	760	107
39— 8B	17.23	0.92	0.42	34.13	9.05	0.050	0.782	0.0112	65.5	45.0	21.8	610	94(98.5)
39—15	21.46	1.00	0.57	35.76	5.41	0.061	0.743	0.0146	59.0	19.0	4.8	1390	133
39—18	22.47	1.11	0.63	31.12	8.98	0.026	0.515	0.0084	59.0	27.8	12.2	710	94(97.0)
39—19	19.40	1.00	0.74	31.63	9.98	0.029	0.602	0.0106	47.4	22.5	10.4	1150	92(94.1)
39—21	15.14	1.26	0.67	32.88	11.08	0.049	0.936	0.0118	72.0	18.3	10.3	710	85
39—24	18.84	1.31	0.77	32.69	9.32	0.049	0.907	0.0114	73.6	24.0		890	108
39—25B	19.49	1.27	0.96	32.56	8.98	0.044	0.787	0.0114	65.5	21.9	9.0	540	143(119.0)
28— 1	20.84	0.78	0.36	32.79	9.15	0.032	0.381	0.0086	36.0	28.5	16.0	1350	50(54.4)
28— 4	13.33	0.59	0.48	36.59	8.08	0.046	0.512	0.0094	39.2	18.0	11.5	1250	52(57.3)
Light-colored Part													
37— 1	3.38	0.21	0.09	41.45	9.98	0.041	0.012	0.0046	1.6	11.5	1.6	530	(34.1)
37—10	8.24	0.47	0.24	41.40	7.65	0.046	0.108	0.0086	3.3	18.8	6.4	1160	56(58.8)
37—13	3.46	0.33	0.12	46.67	5.34	0.051	0.226	0.0160	6.5	19.5	13.0	2720	30(31.6)
39— 2	15.65	1.10	0.57	37.34	6.88	0.050	0.057	0.0020	1.6	28.5	10.4	400	111(112.4)
39— 4A	16.69	0.87	0.50	38.64	6.21	0.043	0.116	0.0074	3.3	25.5	9.9	460	78(86.7)
39— 7	18.08	1.23	0.68	32.97	9.72	0.049	0.054	0.0054	3.3	20.4	7.6	430	105
39— 8A	18.47	1.34	0.96	31.67	9.95	0.053	0.046	0.0050	6.5	28.5	13.7	430	118(130.8)
39—10	14.95	0.95	0.47	39.87	5.49	0.062	0.059	0.0052	3.3	21.0	8.8	810	116
39—16	11.46	0.67	0.49	39.62	7.25	0.035	0.097	0.0060	6.5	20.4	5.7	1190	100
39—25A	20.24	1.10	0.91	33.62	7.95	0.039	0.057	0.0020	8.2	21.3	9.0	1210	108(102.4)
28— 2	24.31	0.68	0.83	36.74	3.97	0.038	0.038	0.0018	0.8				51
28— 3	18.13	0.86	0.57	38.92	4.74	0.030	0.017	0.0010	0.3	22.5	18.6	330	64(73.5)
28— 5	16.81	0.61	0.89	30.56	12.59	0.033	0.023	0.0022	1.7	23.3	9.3	570	67

No. 28 ; Gushikawa-shi. Maibara
No. 37 ; Misato-son. Akamichi
No. 39 ; Gushikawa-shi. Kozo Saiseki

* and ( ); by atomic absorption, ** ; by spectrophotometry

Table 10 The Major and Minor Components in Marine Sediment Samples from Senkaku Retto

No.	SiO_2 (%)	$Fe_2O_3 + Al_2O_3$ (%)	CaO (%)	MgO (%)	P_2O_5 (%)	SO_4 (%)	Zn* (ppm)	Cu* (ppm)	Sr* (ppm)	Mn* (ppm)
St. 69— 8(M)	7.78	1.84	47.14	1.63						
(10M)	9.35	2.36	45.41	1.89						
(20M)	21.06	3.18	38.24	2.01						
(42M)	25.25	4.31	34.48	2.50						
(65M)	50.30	5.73	20.52	1.93						
(80M)	81.26	4.61	5.14	1.79						
(100M)	82.22	4.85	4.66	1.32						
〃. 69—12(M)	6.30	2.64	43.86	3.85	0.043	0.51	40.2	31	2060	1957.0
(10M)	3.46	1.92	46.08	3.59	0.031	0.65	35.8	24	2240	1357.1
(20M)	4.38	2.39	45.47	3.73						
(42M)	5.08	3.78	43.44	3.73	0.037	0.56	46.4	33	1740	1614.2
(65M)	9.20	3.98	42.36	3.47						
(80M)	19.28	4.94	36.64	3.15						
(100M)	58.81	5.14	16.17	2.14						
〃. 69—29(M)	3.52	1.34	49.26	1.89	0.023	0.53	14.8	15	2320	209.3
(10M)	4.42	1.98	46.91	3.76	0.033	0.63	33.4	34	2200	1300.0
(20M)	7.97	4.05	41.29	5.10						
(42M)	42.65	6.08	22.49	4.17						
(65M)	71.65	6.06	8.31	2.87						
(80M)	74.11	5.68	7.32	2.91						
(100M)	68.89	5.43	10.68	2.87						
〃. 69—31(M)	4.84	0.75	46.08	3.69						
(10M)	2.72	0.57	47.19	2.61						
(20M)	4.24	0.74	46.64	3.57						
(42M)	26.66	1.13	35.39	2.71						
(65M)	31.81	1.48	32.87	2.06						
(80M)	24.08	1.48	34.42	3.71						
(100M)	19.90	1.82	36.74	4.16						
〃. 69—35(M)	9.46	1.40	45.25	2.50	0.030	0.32	31.3	58	1800	1428.5
(10M)	3.40	0.98	49.41	1.80	0.017	0.36	24.2	60	2200	1557.1
(20M)	4.49	0.97	48.11	2.34	0.019	0.34	30.4	94	1870	1214.2
(42M)	70.59	4.75	9.72	2.06						
(65M)	87.40	5.02	1.39	1.48						
(80M)	87.39	4.96	1.25	1.70						
(100M)	82.35	5.14	3.94	1.86						

Table 10 Continueel

No.	SiO_2 (%)	$Fe_2O_3 + Al_2O_3$ (%)	CaO (%)	MgO (%)	P_2O_5 (%)	SO_4 (%)	Zn* (ppn)	Cu* (ppm)	Sr* (ppm)	Mn* (ppm)
St. 69—41(M)	8.45	1.64	46.36	1.40						
(10M)	8.84	2.56	44.22	2.24						
(20M)	13.41	4.38	39.95	3.01						
(42M)	40.88	5.34	30.09	2.53						
(65M)	76.26	4.37	7.11	1.92						
(80M)	86.15	4.43	2.00	1.96						
(100M)	69.83	4.49	10.88	1.66						
〃. 69—67(M)	8.68	1.63	45.58	1.60						
(10M)	8.30	2.40	44.92	2.04						
(20M)	11.48	5.36	40.39	2.89						
(42M)	72.66	7.51	6.52	2.00						
(65M)	83.70	7.79	1.53	2.00						
(80M)	81.54	7.53	2.28	2.20						
(100M)	74.69	6.49	7.22	1.80						
〃. 69—70(M)	5.14	1.54	47.22	2.78						
(10M)	3.83	1.70	46.99	3.19						
(20M)	4.65	1.94	46.79	3.33						
(42M)	4.42	1.91	46.63	3.49						
(65M)	18.96	3.12	39.85	5.08						
(80M)	25.20	3.25	31.79	5.08						
(100M)	52.75	2.87	16.67	5.89						
〃. 69—72(M)	3.27	1.09	47.73	3.37	0.029	0.65	25.4	4	2530	54.2
(10M)	2.92	0.86	47.48	4.29	0.026	0.53	18.9	5	2160	41.4
(20M)	2.10	0.91	47.99	4.06	0.032	0.60	22.8	6	2070	55.0
(42M)	3.02	0.63	47.62	4.33	0.028	0.56	21.9	6	2300	48.9
(65M)	4.68	0.58	47.19	3.90	0.031	0.63	23.9	7	2200	48.2
(80M)	5.39	0.59	46.97	3.66	0.025	0.56	22.8	7	2360	47.4
(100M)	8.73	0.71	45.19	3.35	0.025	0.57	35.4	16	2800	61.0
〃. 69—73	3.70	1.11	45.89	4.59	0.032					
St. 70—24(M)	5.78	1.81	48.30	0.90						
(10M)	6.49	2.54	45.61	2.12						
(20M)	12.04	4.35	39.56	3.13						
(42M)	53.87	4.53	18.79	2.02						
(65M)	83.77	4.37	4.08	1.30						
(80M)	80.55	4.80	4.44	2.10						
(100M)	58.25	5.26	15.41	2.10						

Table 10 Continued

No.	SiO_2 (%)	$Fe_2O_3 + Al_2O_3$ (%)	CaO (%)	MgO (%)	P_2O_5 (%)	SO_4 (%)	Zn* (ppm)	Cu* (ppm)	Sr* (ppm)	Mn* (ppm)
St. 70—36(M)	6.43	1.39	46.80	2.08	0.044	0.43	29.6	29	1940	1614.2
(10M)	3.81	1.07	48.30	2.53	0.032	0.53	25.4	27	2060	1242.8
(20M)	5.74	1.56	45.86	3.39						
(42M)	52.78	5.15	18.13	3.13						
(65M)	78.62	6.58	4.72	2.00						
(80M)	80.97	6.60	2.44	2.81						
(100M)	80.12	5.25	4.50	2.02						
〃. 70—37(M)	7.65	1.78	44.97	2.79						
(10M)	4.94	1.57	46.36	3.19						
(20M)	6.21	1.83	45.11	3.69						
(42M)	38.71	4.12	26.23	3.29						
(65M)	68.83	6.23	9.66	2.55						
(80M)	67.40	5.53	10.74	2.65						
(100M)	64.84	3.69	13.24	2.06						

M : Mesh ＊ ; by atomic absorption

Table 11 The Major and Minor Components in Marine Sediment Samples Collected by Yomiuri Go and Tansei Maru

No.	SiO_2 (%)	Fe_2O_3 (%)	Al_2O_3 (%)	CaO (%)	MgO (%)	P_2O_5 (%)	SO_4 (%)	Zn* (ppm)	Cu* (ppm)	Sr* (ppm)	Mn* (ppm)
YO— 1— 1	4.78	0.59	0.96	45.54	4.11	0.117	0.61	36.7	123	1720	66.3
〃 1— 2	7.01	2.76	1.07	42.02	4.75	0.291	0.55	36.4	15	1500	985.7
〃 1— 3	6.99	2.38	0.82	42.51	4.81	0.249					
〃 3— 1	2.52	0.13	0.43	47.06	4.03	0.093	0.63	26.3	71	2180	64.0
〃 3— 3	1.53	0.16	0.33	49.73	2.84	0.082	0.54	35.2	93	3760	55.0
〃 3— 4	3.11	0.41	0.73	45.75	3.23	0.109					
〃 3— 5	1.54	0.20	0.29	49.95	2.87	0.083		30.5	11.5	2500	127.7
〃 4— 1	12.69	0.51	0.52	41.87	4.38	0.103		60.0	92.0	1800	82.4
〃 6— 1	0.32	0.04	0.05	48.04	5.14	0.076	0.64	34.0	13	2060	29.4
〃 6— 2	0.54	0.08	0.11	47.64	5.17	0.077					
〃 6— 3	1.94	0.22	0.28	48.28	4.44	0.109		26.3	9.9	2500	80.4
〃 7— 1	0.16	0.07	0.03	48.60	4.52	0.075	0.56	36.7	18	2400	19.2
〃 7— 3— 1	2.40	0.21	0.33	47.76	4.54	0.101					
〃 7— 3— 2	5.36	0.81	0.53	45.36	4.59	0.136	0.48	23.9	13	1470	91.9
〃 11— 1— 1	0.80	0.02	0.08	47.73	4.69	0.008		30.0	9.6	2800	31.1
〃 11— 2	0.88	0.04	0.64	47.32	4.72	0.088		23.3	12.6	2800	31.8
〃 11— 3	0.82	0.19	0.18	48.81	3.87	0.116	0.52	20.4	21	3040	51.5
〃 11— 4	4.38	1.29	0.65	45.08	4.52	0.164					
〃 11— 5	5.00	0.78	0.52	45.08	4.08	0.171	0.57	22.8	11	2280	128.1
〃 12— 1	4.84	0.54	0.36	45.87	4.75	0.143					
〃 12— 3	2.87	0.38	0.46	47.38	4.66	0.111	0.52	32.8	79	1680	70.8
〃 12— 4	5.14	0.67	0.46	45.84	4.62	0.133	0.51	23.7	31	1600	197.0
〃 14— 1	10.33	13.85	1.52			0.271					
〃 14— 2— 1	3.58	0.53	0.51	48.70	3.16	0.172	0.40	23.9	12	1200	194.4
〃 14— 2— 2	4.04	0.19	0.39	47.20	3.59	0.112					
〃 14— 2— 3	4.24	0.57	0.54	47.73	3.35	0.141	0.34	45.8	85	1440	258.8
〃 15— 1— 1	8.13	0.89	0.67	43.41	3.87	0.129	0.62	29.6	25	2860	78.5
〃 15— 1— 2	8.16	1.01	0.56	43.40	3.45	0.130					
〃 18— 1	0.87	0.12	0.17	50.20	1.09	0.039	0.68	92.8	234	6300	21.4
〃 19— 1	63.68	0.83	0.77	15.27	1.92	0.052					
〃 19— 2	64.62	1.54	0.93	14.63	2.06	0.084					
TA 20— 1	1.10	0.15	0.14	48.03	4.14	0.081		26.3	24.6	3100	23.6
〃 20— 2	0.75	0.12	0.14	48.43	4.28	0.069	0.64	21.9	73	3000	22.6
〃 21— 2	0.50	0.08	0.02	50.29	2.73	0.051		23.3	41.8	4500	29.1
〃 22— 1	0.25	0.07	0.05	49.32	4.59	0.086	0.63	18.0	14	2530	19.6

* ; by atomic absorption

Table 12 The Major and Minor Components of Manganese Nodule-associated Samples

No.	SiO_2 (%)	Fe_2O_3 (%)	Al_2O_3 (%)	CaO (%)	MgO (%)	Mn (%)	MnO_2 (%)	Cu* (ppm)	Ni* (ppm)	Zn* (ppm)	Sr* (ppm)
					manganese nodule						
N—1	2.02	1.84	0.29	0.96	0.34	57.80	90.39	590	50	360	441
N—1—2	10.49	6.41	1.70	4.09	3.03	35.38	52.98	440	820	446	4461
N—2	5.34	3.03	1.34	4.07	0.20	47.88	75.21	1140	180	417	1471
N—3	36.27	15.34	2.00	0.25	0.34	13.40	19.87	120	80	155	96
N—5	29.07	17.45	11.06	0.40	0.37	14.17	20.73	140	170	205	160
KI—1	25.25	16.55	10.41	0.23	0.29	16.99	24.80	120	150	162	127
KI—2	28.19	16.70	9.98	0.85	0.63	15.60	22.95	110	150	—	—
Y—1	28.13	15.71	4.49	1.10	0.41	15.91	23.37	120	150	196	547
Y—2	29.84	13.55	7.12	1.23	0.51	15.50	23.31	140	130	234	486
Y—3	29.96	18.88	6.18	0.43	0.30	14.61	21.47	90	90	162	96
Y—4	28.89	15.15	6.78	1.00	0.44	15.32	22.82	140	130	218	405
Gi—1	68.65	9.53	7.63	0.25	0.21	2.00	2.09	20	30	80	405
Gi—2	46.36	23.56	8.72	0.32	0.23	3.28	3.90	30	50	120	268
Gi—3	23.20	18.24	10.01	0.45	0.24	12.92	19.69	100	90	152	139
Gi—4	27.85	16.95	11.02	0.14	0.19	13.20	10.63	70	90	156	86
Gi—5	47.55	9.01	12.91	0.29	0.32	7.56	11.67	50	60	162	643
S—1	26.66	21.69	10.00	0.21	0.28	12.34	19.32	90	90	154	35
S—2	49.60	8.92	12.35	0.15	0.34	7.48	11.16	50	10	151	81
S—3	50.93	10.80	16.03	0.22	0.52	1.47	2.18	50	80	200	119
S—4	29.91	11.95	15.25	0.41	0.47	14.01	21.13	60	120	161	106
S—5	24.40	22.28	9.42	0.26	0.21	13.18	19.84	80	100	163	71
T—1	30.58	17.45	10.45	0.55	0.40	13.46	20.35	100	140	186	400
K—1	30.71	17.93	7.86	0.69	0.61	14.73	21.73	190	220	457	592
M—1	47.08	22.31	5.31	0.12	0.16	5.99	9.04	30	30	146	69
M—2	47.62	15.42	5.89	0.26	0.36	8.64	12.77	50	50	133	124
M—3	34.17	24.75	8.66	0.08	0.18	7.85	11.62	100	50	—	—
M—4	32.88	27.18	7.89	0.40	0.19	7.67	11.36	80	60	161	106
M—5	41.82	18.15	8.67	0.32	0.15	6.92	10.72	40	40	139	208
M—6	34.86	21.68	8.23	0.61	0.29	9.12	13.22	70	60	188	228
M—7	61.48	10.62	6.53	0.04	0.12	3.24	4.70	30	30	159	134
M—8	36.62	14.60	8.64	0.70	0.23	11.66	17.55	100	50	179	324

Table 12 continued

No.	SiO_2 (%)	Fe_2O_3 (%)	Al_2O_3 (%)	CaO (%)	MgO (%)	Mn (%)	MnO_2 (%)	Cu* (ppm)	Ni* (ppm)	Zn* (ppm)	Sr* (ppm)
M— 9	34.44	8.66	15.34	0.38	0.18	11.88	18.28	60	50	197	236
M—10	57.91	9.68	7.49	0.06	0.15	5.01	6.68	30	30	149	230
YA—1	73.47	7.85	4.71	0.15	0.20	3.87	5.66	50	100	118	41
YA—3	62.90	15.87	5.12	0.11	0.23	3.85	5.67	90	90	154	35
YA—4	18.70	5.95	1.18	1.02	0.49	37.36	57.08	20	50	118	1506
YA—5	76.83	6.55	0.98	2.27	0.47	2.97	2.91	10	80	72	458
MO—1—1	48.14	44.54	0.13	0.04	0.05	4.40	2.49	10	60	—	—
MO—1—2	69.61	19.76	0.34	0.08	0.06	6.15	7.41	10	30	19	276
MO—1—3	2.39	71.71	0.54	0.13	0.04	13.95	18.18	90	110	—	—
MO—1—4	15.64	22.14	2.26	0.02	0.96	28.74	40.87	130	350	183	476
MO—2—1	27.74	59.61	0.46	0.10	0.14	7.27	4.84	10	200	114	116
MO—2—2	54.23	43.06	0.27	0.02	0.07	1.86	1.61	10	160	—	—
N—4—1	4.65	3.21	1.84	0.01	0.57	52.43	75.87	60	330	426	577
N—4—2	68.26	4.10	8.83	0.10	0.53	4.64	6.78	60	530	—	—
					Reddish soil						
Aka—1	—	4.57	10.21	0.184	0.232	—	0.068	26	49	99	—
Shikina	—	17.56	14.61	0.419	0.537	—	0.196	25	68	157	—
M—Mi—4	—	10.10	17.27	0.290	0.356	—	0.334	72	129	148	—
M—No—5	—	9.55	20.61	0.270	0.380	—	0.043	65	115	154	—
Chi—2	—	9.83	18.87	0.462	0.281	—	0.078	71	107	216	—
O—Oy—1	—	11.17	16.71	0.091	0.116	—	0.065	58	83	176	—
O—Ku—8	—	9.42	19.94	0.450	0.430	—	0.107	50	100	204	—
O—Kin—3	—	8.78	14.58	0.043	0.156	—	0.387	59	67	143	—
O—Kin—3′	—	7.33	13.15	0.063	0.178	—	0.242	50	62	134	—
O—Oy—4	—	8.21	15.90	0.031	0.278	—	0.512	59	77	163	—
O—Awa—3	—	9.44	13.09	0.832	0.308	—	0.058	52	100	174	—
U—1	—	8.19	17.69	0.145	0.184	—	0.042	44	75	129	—
O—U—2	—	7.46	19.18	0.209	0.219	—	0.308	36	124	192	—
O—Kita—5	—	9.33	19.91	0.185	0.295	—	0.069	59	118	181	—
O—Kita—6	—	8.54	17.35	0.166	0.499	—	0.089	56	97	161	—

* ; by atomic absorption

IV. Geochemiccal Subjects to be Discussed on the basis of the Chemical Compositions of Carbonate Materials, Reddish Soils and Manganese Nodules on the Ryukyu Islands

1. Material balance of chemical components

The behavior of major and minor elements in sedimentary environments will be discussed in detail. It is very much emenable to this end that the Riukiu Limestones formed on different ages are obtained on the Ryukyu Islands. Some aspects of behaviors for SiO_2, Al_2O_3, Fe_2O_3, P_2O_5, MgO, $CaCO_3$, Mn, Na, Cl and SO_4 have already been discussed by A. Tokuyama et. al (1972). The further consideration on the geochemical behaviors of these species, including minor elements such as Sr, Zn and Cu in particular, will be of great importance to understand the geochemical balance of the chemical elements which has been described by Y. Kitano(1967).

2. Sedimentary environment and weathering process of the limestone

On the basis of results obtained above, it is the aims to discuss the mechanism of formation of the limestone with the estimation of total amount and chemical composition of starting materials for the limestone, amount which has been dissolved eversince, chlonology of the limestone, chemical composition of waters in contact with limestone, and restoration to the original sedimentary environment.

3. Evolution of reddish soils and manganese nodules

On the study of the manganese nodules, the following subjects should be noted : 1) the mechanism of formation, 2) geochemical changes in compositions between limestone, redish soils and manganese nodules, 3) comparative study on non-carbonate and carbonate dependent reddish soils, 4) comparison with the maganese nodules formed in sea bottom, 5) the minor elements and their partition study, 6) the measurement of the rate of accretion by radiochemical techniques, 7) and others such as geological considerations. It will be helpful for the understanding of the mechanism of formation of the manganese nodules, to apply the partition studies reported by R. Chester et. al (1967).

It is, however, a quetion how the reddish soils have been formed on the Ryukyu Islands - carbonate area. The following two probable explanations will be possible. One thing, the reddish soils would have been formed from calcareous sand, corals, and other carbonates as starting materials, and the carbonate materials will gradually change to form the Riukiu Limestone in digenitic processes. The reddish soils will then be a remains of limestone in the weathering process. The other possible explanation will be the deposit at the sea bottom, such as red-clays, then happened the upheaval of the island. Some implications on this matter will be given from the radiochemical studies of manganese nodules with the estimation on their origin of the nuclei either ocean or land made.

The manganese nodules and the manganese clod(manganese poor), which coexist with reddish soil, will be an attractive materials to be investigated from the geochemical point of views. It will be said that the study on these carbonate-associated materials

will be suggestive for the understanding of the weathering processes of the Riukiu Limestone.

The subjects pointed out above have continuously been studied in this laboratoratory and will be in paper elsewhere.

V. Acknowledgements

The authors would like to thank professor Y. Kitano at Water Reserch Laboratory, Faculty of Science, Nagoya University, for the useful suggestion and advices given to throughout this work, and also for reading the manuscript. The authors acknowledge sediment samples from Tokai Daigaku-maru II, Tokai University; Yomiuri Go, The Yomiuri Press; and Tansei-maru, Tokyo University. This work has partially been financed by The Asahi Press under the contract of Asahi Science Award of 1971.

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