Table 5-6-6 Chemical Composition of MORB and Chondrite

	MORB after Sun et al., 1979 (ppm)		Chondrite after Wakita et al., 1971 (ppm)
Sr	114	La	0.34
K	580	Ce	0.91
Rb	1	Pr	0.121
Ba	8	Nd	0.64
Nb	1	Sm	0.195
P	300	Eu	0.073
Zr	50	Gd	0.26
Ti	5215	Tb	0.047
Y	25	Dy	0.3
		Ho	0.08
		Er	0.2
		Tm	0.032
		Yb	0.22
		Lu	0.034

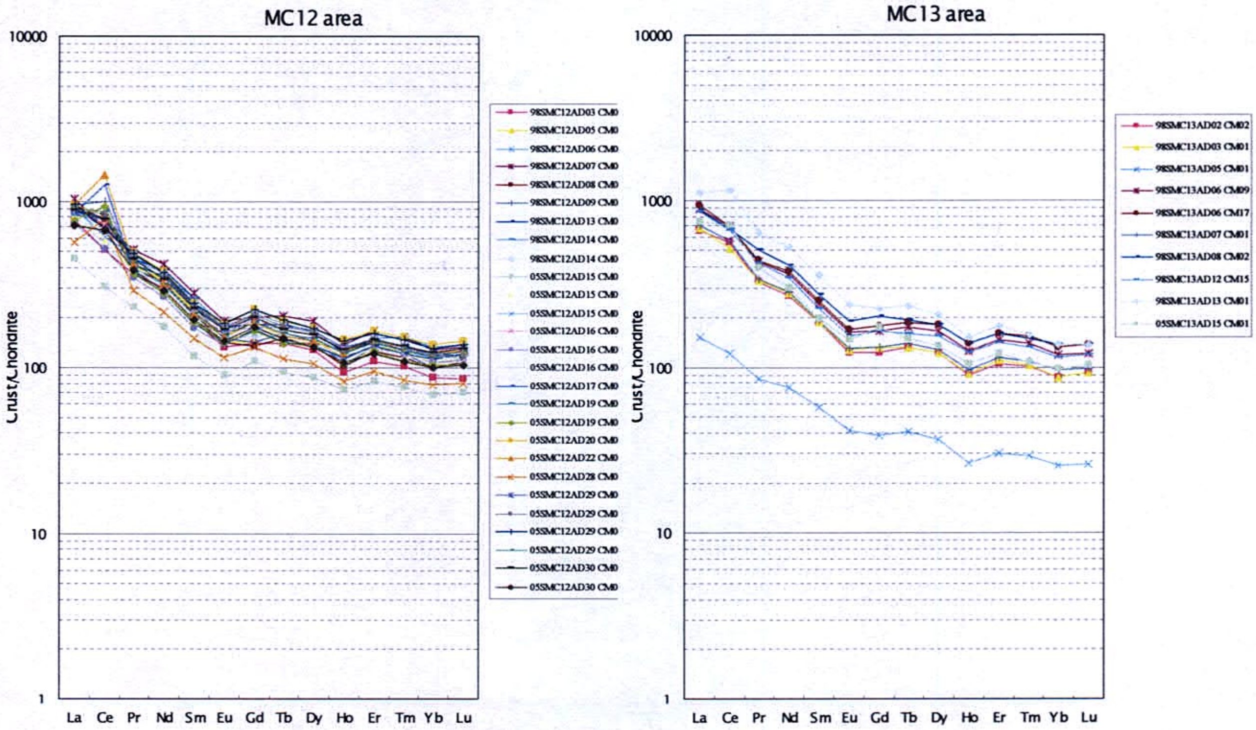


Figure 5-6-3 Chondrite Normalized Pattern of Manganese Crust

Co has high positive correlations with Ni, Mn, Pt and Ce, and has high negative correlations with Si and Al. While Ni shows high positive correlation with Co and Mn and high negative correlation with Si and Al, but no clear correlation was observed with Pt. Although Pt has high positive correlation with Co and Ce, no clear correlation was observed with other elements. Sampling depth and thickness of manganese crust show positive correlation and both of them have negative correlation with Co and Mn and positive correlation with Si and Al.

Relations of sampling depth and thickness of manganese crust versus major elements are shown on Figures 5-6-4 and 5-6-5. The three major elements (Co, Ni, Pt) tend to decrease with increase of water depth. As previously mentioned, Co and Pt shows high values approximately at 1,800m deep, and this possibly is related to the occurrences of porous manganese crust. There is also some tendency of increases of three major elements approximately at 2,400m. Similar to three major elements, Mn decrease with increase of water depth and Si, reflecting occurrences of such as clastic material and clay fillings, tends to increase with increase of water depth.

As for the relation between thickness of manganese crust and three major elements, the manganese crusts of more than 6cm thick and less than 6cm thick show different tendencies. The manganese crust of less than 6cm thick do not show clear tendency of three major elements concentration, showing both high and low concentrations. While the manganese crust of greater than 6cm thick show consistently lower concentration of Co less than 0.4%, Ni less than 0.4% and Pt less than 0.4ppm. This gives apparent negative relations between thickness and concentration of three major elements. With increase of thickness, Mn tends to decrease and Si, instead, tends to increase. This corresponds with results of manganese crust description that upper part of crust is relatively compact with less pores and lower part is generally porous texture with fillings such as clay.

Table 5-6-7 Correlation Coefficients and Non Correlation Test of MC12 Samples (major Elements, Pt, La and Ce)

Components	Water depth	Thickness	Co	Ni	Cu	Mn	Fe	Mn/Fe	Pt	Pb	Zn	Ti	Mo	V	Si	Al	Ca	Na	K	P	Ba	Sr	LOI	H2O+	H2O-	La	Ce
Water depth	-	0.4083	-0.5519	-0.3097	0.4811	-0.5420	0.3773	-0.5504	-0.3009	-0.6821	0.0646	0.1740	-0.5313	-0.4428	0.6818	0.4827	-0.6824	0.1051	0.3631	-0.5762	0.1726	-0.3902	-0.3455	-0.2116	-0.3413	-0.1556	-0.4685
Thickness	*	-	-0.3993	-0.5682	0.2042	-0.5157	0.4569	-0.4978	-0.1680	-0.6654	0.1994	0.1525	-0.3461	-0.1133	0.3921	0.3608	-0.2047	0.0959	0.0402	-0.1361	0.0039	-0.2385	-0.2650	-0.2688	-0.3046	0.0414	-0.4350
Co	**	*	-	0.6387	-0.3147	0.6742	-0.3830	0.5868	0.7638	0.6564	-0.1300	-0.1832	0.5980	0.2597	-0.7370	-0.5181	0.3063	0.2997	-0.3097	0.1939	-0.0439	0.5152	0.8956	0.4626	0.2805	0.4348	0.7136
Ni		**	**	-	-0.0567	0.6854	-0.5858	0.6686	0.2866	0.6825	-0.2014	-0.4185	0.7295	0.0264	-0.7553	-0.5986	0.2985	-0.2037	-0.3056	0.2536	0.4382	0.4248	0.6225	0.1339	0.1341	0.3311	0.4732
Cu	*				-	-0.5030	0.1459	-0.4952	0.0755	-0.1895	-0.2526	0.2555	-0.3097	-0.7027	0.1979	0.4229	-0.5611	0.3262	0.3315	-0.1116	-0.1180	-0.2618	0.0864	-0.0419	0.0589	-0.1585	0.0091
Mn	**	**	**	**	*	-	-0.6767	0.9598	0.2553	0.7148	0.0548	-0.2286	0.7927	0.5865	-0.8010	-0.8660	0.5025	-0.1884	-0.6157	0.2578	-0.1833	0.8037	0.8592	0.1262	0.5908	0.6204	0.4477
Fe		*		**		**	-	-0.8373	-0.0617	-0.4202	0.2725	0.4868	-0.6441	-0.2454	0.5636	0.4122	-0.6048	-0.3871	-0.2706	-0.4110	0.3280	-0.0089	-0.3261	0.0134	-0.2021	-0.1270	-0.1576
Mn/Fe	**	**	**	**	*	**	**	-	0.1852	0.6570	-0.0060	-0.3314	0.8003	0.5392	-0.7673	-0.7718	0.6077	-0.0800	-0.4764	0.3608	0.1212	0.7056	0.7972	0.2457	0.3487	0.4673	0.3675
Pt			**						-	0.3143	-0.1810	0.0854	0.0547	0.0298	-0.3995	-0.1967	0.0691	0.5699	-0.0359	0.0061	-0.0962	0.1778	0.6699	0.4506	0.0346	0.2665	0.7391
Pb	**	**	**	**		**	*	**		-	-0.2088	-0.1893	0.7445	0.1986	-0.8397	-0.7547	0.3953	-0.3800	-0.7338	0.3865	0.0425	0.8392	0.6372	0.1467	0.4875	0.4869	0.7777
Zn											-	0.5226	-0.1873	0.5961	0.2507	-0.1542	-0.0659	-0.6147	-0.0759	-0.1463	0.7089	-0.1703	-0.6873	-0.1406	-0.5579	0.1682	-0.3222
Ti				*			*				**	-	-0.4413	0.2765	0.3808	0.1375	-0.4261	0.0612	0.0700	-0.3443	0.2969	-0.0757	-0.1679	0.1093	-0.0406	0.0186	-0.0413
Mo	**		**	**		**	**	**		**		*	-	0.2932	-0.8589	-0.7500	0.5161	-0.4029	-0.6837	0.4589	-0.2699	0.7975	0.6771	-0.1285	0.6239	0.5790	0.3725
V	*				**	**		**			**			-	-0.2464	-0.4519	0.4297	0.0335	0.0566	0.1620	-0.3600	0.1593	0.1407	-0.1893	0.5704	0.3475	-0.0362
Si	**	*	**	**		**	**	**	*	**			**		-	0.8230	-0.5644	0.2465	0.7328	-0.4778	0.1129	-0.8400	-0.8844	-0.1339	-0.5246	-0.6297	-0.6559
Al	*		**	**		**	*	**		**			**	*	**	-	-0.4232	0.5484	0.8940	-0.2797	-0.4454	-0.9247	-0.6257	-0.1940	-0.2704	-0.7046	-0.5070
Ca	**				*	**	**	**		*		*	**	*	**	*	-	0.0927	-0.0569	0.8926	-0.3316	0.0635	0.2546	-0.0432	0.1918	0.1585	0.1127
Na									*		**					*		-	0.7170	-0.3915	-0.6487	-0.4768	0.1998	0.1125	0.0886	-0.2354	0.0888
K						**				**			**		**	**		**	-	-0.4609	-0.4248	-0.8816	-0.3575	-0.0291	-0.2050	-0.7152	-0.4997
P	**						*						*		*		**			-	0.0801	0.3963	0.1011	-0.1691	0.1587	0.1043	0.1125
Ba											**							**			-	0.0728	-0.3240	0.1055	-0.5071	-0.1047	0.0771
Sr			*			**		**		**			**		**	**			**			-	0.6087	0.0537	0.5057	0.8045	0.6462
LOI			**	**		**		**	**	**	**		**		**	**						**	-	0.1873	0.5572	0.7038	0.7155
H2O+																								-	-0.2922	-0.0412	0.4215
H2O-						**				*	*		**	*	*						*	*	*		-	0.4327	0.2436
La			*			**		*		*			**		**	**			**			**	**			-	0.4313
Ce	*	*	**	*		*			**	**					**	**			*			**	**			*	-

Non Correlation Test * :5% **:1% Red: Positive Correlation Blue : Negative Correlation

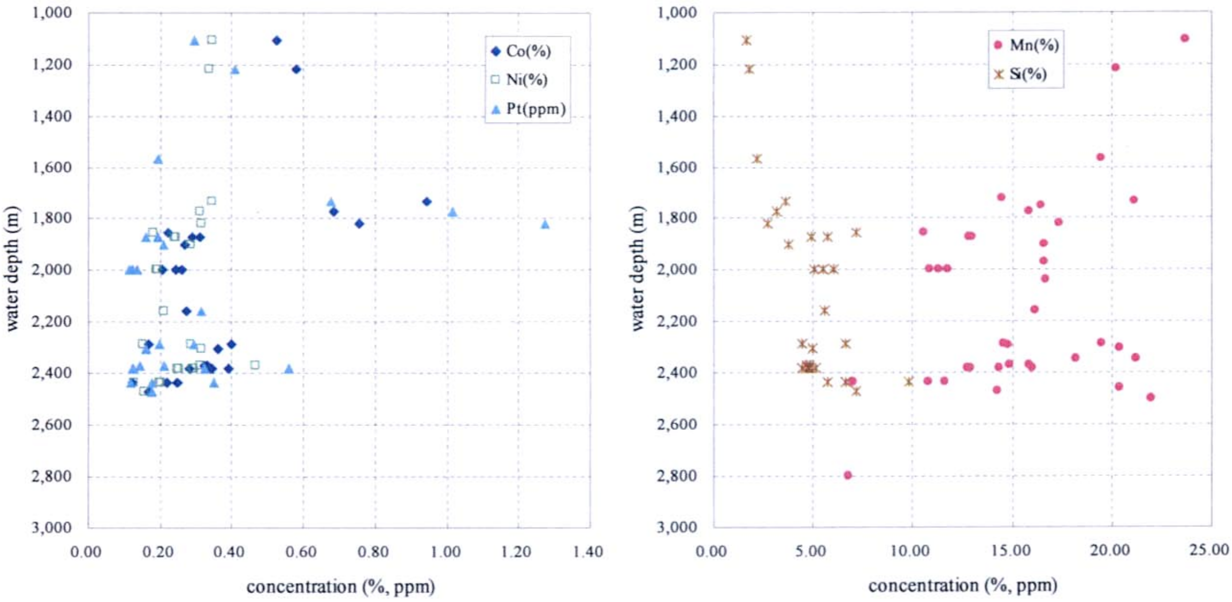


Figure 5-6-4 Relations of Water Depth and Major Elements

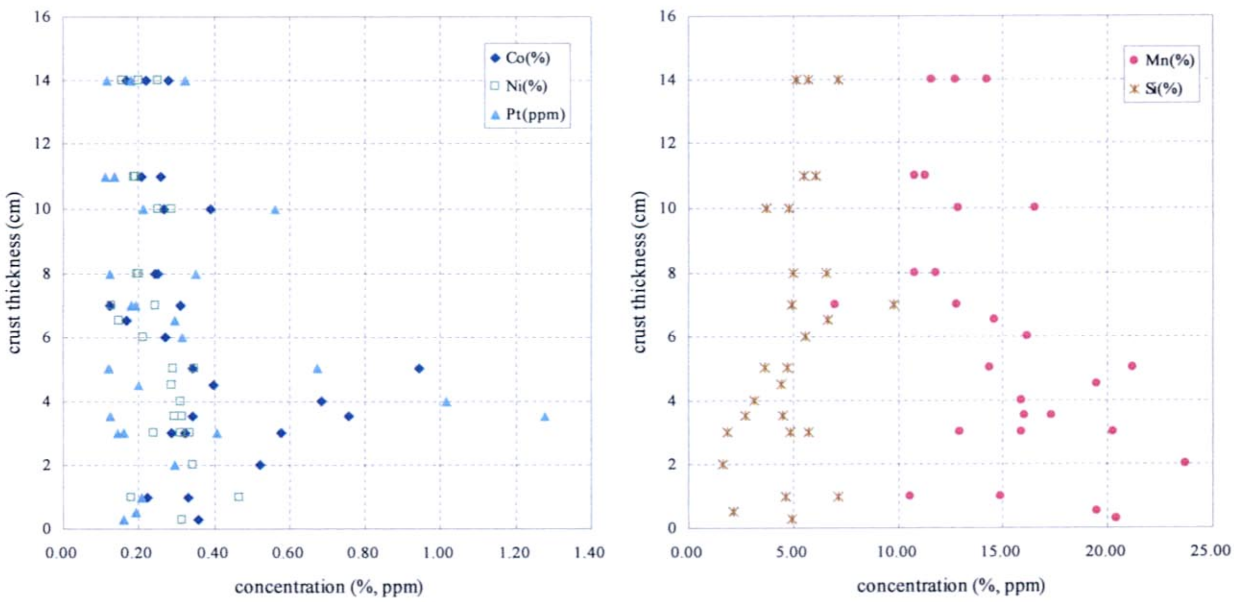


Figure 5-6-5 Relations of Thickness and Major Elements

(2) Chemical compositions of Layer Samples

For typical samples of manganese crust with clear layering structure, chemical analyses were conducted for samples taken from each layer in addition to bulk samples. Figure 5-6-6 shows chemical variations of layer samples together with columnar section of the manganese crust collected in MC12 area.

The manganese crusts of MC12 area tend to show similar layer structure regardless of water depth, consisting of upper, homogeneous and compact layer and lower slightly soft layer with columnar texture of few mm wide filled by brown clay. The upper layer is occasionally covered by or replaced by porous layer without fillings. Between upper and lower layers, additional layers with intermediate appearance between upper and lower layers showing slightly compact and columnar texture, sometimes, occur.

The chemical characteristics reflecting the layer structure are observed in chemical variation diagram of Figure 5-6-6. Co, Ni and Mn decrease from upper layer to lower layer and, on the contrary, Si increases from upper layer to lower layer. These relations correspond to the results of sample descriptions. Not like Co, Ni and Mn, Pt does not drastically decrease toward lower layers and, contrary to the appearances of samples, it commonly increases toward lower layers. As mentioned earlier, Pt seems to have a tendency to be enriched in porous layers with less fillings. Also Pt seems to be enriched in older manganese crust (e.g. Halback et al., 1989). An ambiguity still remains even in recent researches concerning the mechanism of Pt enrichment to manganese crust, and this investigation only suggests that the behavior of Pt is possibly different from those of Co and Ni.

The REE chondrite normalized patterns of layer samples show that Ce positive anomaly becomes smaller from upper layer to lower layer and the even negative Ce anomaly is observed in the lowest layer. (Figure 5-6-7). This can be possibly explained by factors such as contents of impurities in lower layer, growth speed of manganese crust and environment of generation similar to diagenetic.

5-6-6 Summaries

The manganese crust collected in MC12 and MC13 areas show slightly lower grades of Co, Ni (mostly less than 0.4%) and Pt (mostly less than 0.3ppm) compared to those of high potential area elsewhere such as Hawaii and the Marshall Islands. In the MC12 area, porous type manganese crusts collected approximately at 1,800m deep are enriched in Co and Pt.

The manganese crust in the MC12 area has common characteristics consisting of homogeneous, compact upper layer and slightly soft lower layer with columnar texture of few mm wide filled by brown clay. Corresponding to the appearance of manganese crust, Co and Ni is higher in upper layer, while Pt shows slightly different tendency of being enrich in some of the lower layer samples.

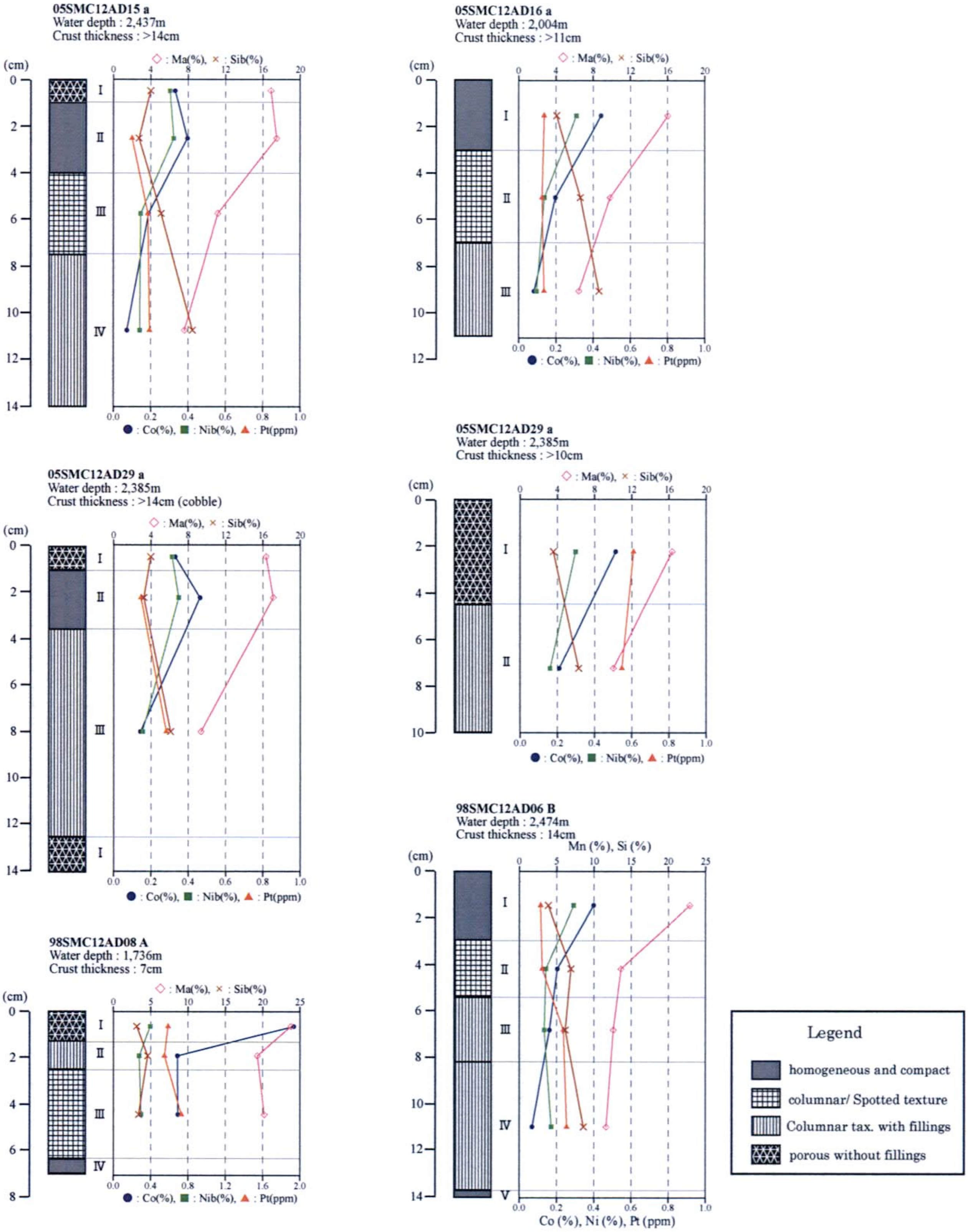


Figure 5-6-6 Layer Structure and Chemical Compositions

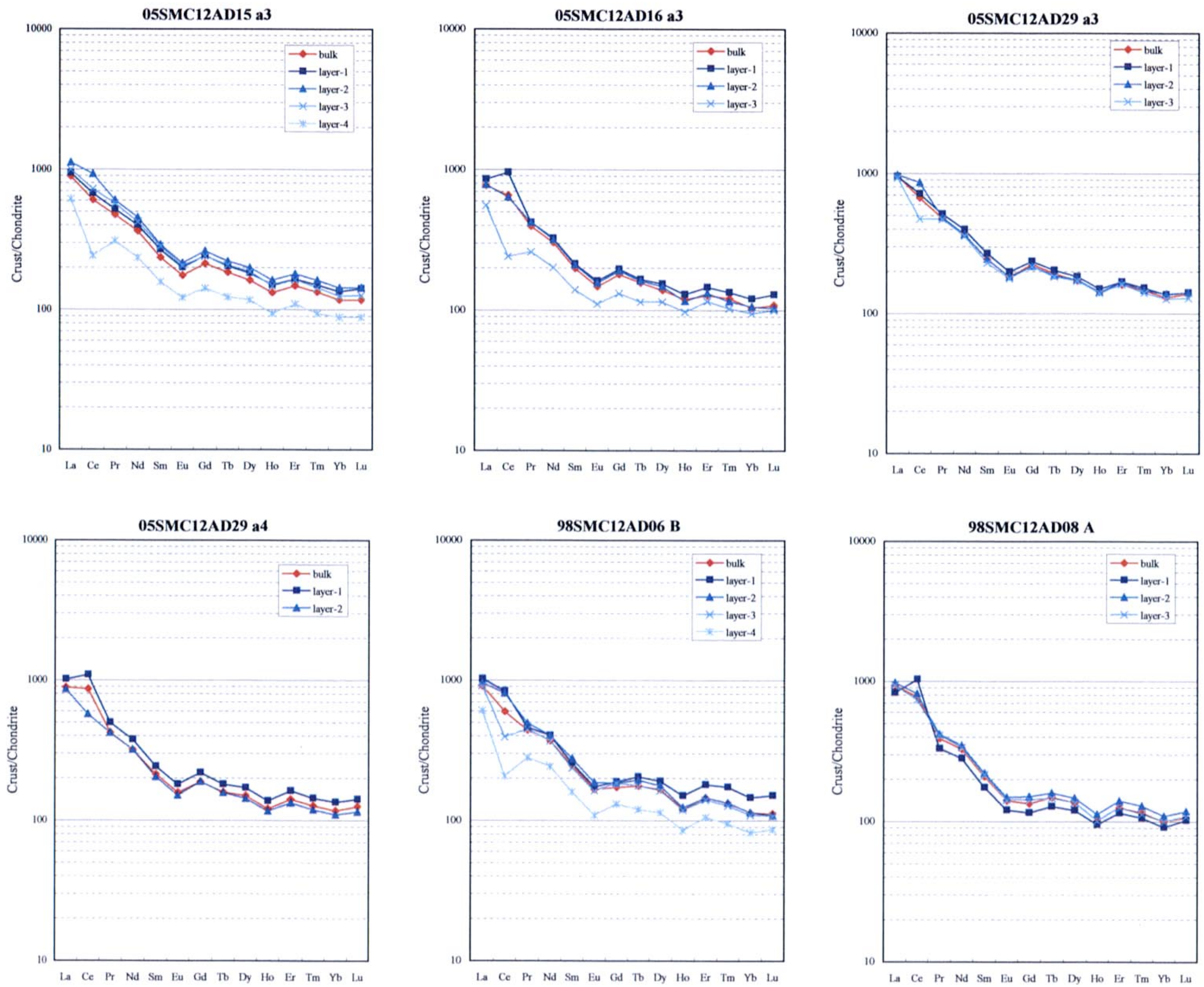


Figure 5-6-7 Chondrite Normalized Patterns of Layer Samples

Co has high positive correlations with Ni, Mn, Pt and Ce, and has high negative correlations with Si and Al. While Ni shows high positive correlation with Co and Mn and high negative correlation with Si and Al, but no clear correlation was observed with Pt. Although Pt has high positive correlation with Co and Ce, no clear correlation was observed with other elements. Sampling depth and thickness of manganese crust show positive correlation and both of them have negative correlation with Co and Mn and positive correlation with Si and Al.

Relations of sampling depth and thickness of manganese crust versus major elements are shown on Figures 5-6-4 and 5-6-5. The three major elements (Co, Ni, Pt) tend to decrease with increase of water depth. As previously mentioned, Co and Pt shows high values approximately at 1,800m deep, and this possibly is related to the occurrences of porous manganese crust. There is also some tendency of increases of three major elements approximately at 2,400m. Similar to three major elements, Mn decrease with increase of water depth and Si, reflecting occurrences of such as clastic material and clay fillings, tends to increase with increase of water depth.

As for the relation between thickness of manganese crust and three major elements, the manganese crusts of more than 6cm thick and less than 6cm thick show different tendencies. The manganese crust of less than 6cm thick do not show clear tendency of three major elements concentration, showing both high and low concentrations. While the manganese crust of greater than 6cm thick show consistently lower concentration of Co less than 0.4%, Ni less than 0.4% and Pt less than 0.4ppm. This gives apparent negative relations between thickness and concentration of three major elements. With increase of thickness, Mn tends to decrease and Si, instead, tends to increase. This corresponds with results of manganese crust description that upper part of crust is relatively compact with less pores and lower part is generally porous texture with fillings such as clay.

Table 5-6-7 Correlation Coefficients and Non Correlation Test of MC12 Samples (major Elements, Pt, La and Ce)

Components	Water depth	Thickness	Co	Ni	Cu	Mn	Fe	Mn/Fe	Pt	Pb	Zn	Ti	Mo	V	Si	Al	Ca	Na	K	P	Ba	Sr	LOI	H2O+	H2O-	La	Ce
Water depth	-	0.4083	-0.5519	-0.3097	0.4811	-0.5420	0.3773	-0.5504	-0.3009	-0.6821	0.0646	0.1740	-0.5313	-0.4428	0.6818	0.4827	-0.6824	0.1051	0.3631	-0.5762	0.1726	-0.3902	-0.3455	-0.2116	-0.3413	-0.1556	-0.4685
Thickness	*	-	-0.3993	-0.5682	0.2042	-0.5157	0.4569	-0.4978	-0.1680	-0.6654	0.1994	0.1525	-0.3461	-0.1133	0.3921	0.3608	-0.2047	0.0959	0.0402	-0.1361	0.0039	-0.2385	-0.2650	-0.2688	-0.3046	0.0414	-0.4350
Co	**	*	-	0.6387	-0.3147	0.6742	-0.3830	0.5868	0.7638	0.6564	-0.1300	-0.1832	0.5980	0.2597	-0.7370	-0.5181	0.3063	0.2997	-0.3097	0.1939	-0.0439	0.5152	0.8956	0.4626	0.2805	0.4348	0.7136
Ni		**	**	-	-0.0567	0.6854	-0.5858	0.6686	0.2866	0.6825	-0.2014	-0.4185	0.7295	0.0264	-0.7553	-0.5986	0.2985	-0.2037	-0.3056	0.2536	0.4382	0.4248	0.6225	0.1339	0.1341	0.3311	0.4732
Cu	*				-	-0.5030	0.1459	-0.4952	0.0755	-0.1895	-0.2526	0.2555	-0.3097	-0.7027	0.1979	0.4229	-0.5611	0.3262	0.3315	-0.1116	-0.1180	-0.2618	0.0864	-0.0419	0.0589	-0.1585	0.0091
Mn	**	**	**	**	*	-	-0.6767	0.9598	0.2553	0.7148	0.0548	-0.2286	0.7927	0.5865	-0.8010	-0.8660	0.5025	-0.1884	-0.6157	0.2578	-0.1833	0.8037	0.8592	0.1262	0.5908	0.6204	0.4477
Fe		*		**		**	-	-0.8373	-0.0617	-0.4202	0.2725	0.4868	-0.6441	-0.2454	0.5636	0.4122	-0.6048	-0.3871	-0.2706	-0.4110	0.3280	-0.0089	-0.3261	0.0134	-0.2021	-0.1270	-0.1576
Mn/Fe	**	**	**	**	*	**	**	-	0.1852	0.6570	-0.0060	-0.3314	0.8003	0.5392	-0.7673	-0.7718	0.6077	-0.0800	-0.4764	0.3608	0.1212	0.7056	0.7972	0.2457	0.3487	0.4673	0.3675
Pt			**						-	0.3143	-0.1810	0.0854	0.0547	0.0298	-0.3995	-0.1967	0.0691	0.5699	-0.0359	0.0061	-0.0962	0.1778	0.6699	0.4506	0.0346	0.2665	0.7391
Pb	**	**	**	**		**	*	**		-	-0.2088	-0.1893	0.7445	0.1986	-0.8397	-0.7547	0.3953	-0.3800	-0.7338	0.3865	0.0425	0.8392	0.6372	0.1467	0.4875	0.4869	0.7777
Zn											-	0.5226	-0.1873	0.5961	0.2507	-0.1542	-0.0659	-0.6147	-0.0759	-0.1463	0.7089	-0.1703	-0.6873	-0.1406	-0.5579	0.1682	-0.3222
Ti				*			*				**	-	-0.4413	0.2765	0.3808	0.1375	-0.4261	0.0612	0.0700	-0.3443	0.2969	-0.0757	-0.1679	0.1093	-0.0406	0.0186	-0.0413
Mo	**		**	**		**	**	**		**		*	-	0.2932	-0.8589	-0.7500	0.5161	-0.4029	-0.6837	0.4589	-0.2699	0.7975	0.6771	-0.1285	0.6239	0.5790	0.3725
V	*				**	**		**			**			-	-0.2464	-0.4519	0.4297	0.0335	0.0566	0.1620	-0.3600	0.1593	0.1407	-0.1893	0.5704	0.3475	-0.0362
Si	**	*	**	**		**	**	**	*	**			**		-	0.8230	-0.5644	0.2465	0.7328	-0.4778	0.1129	-0.8400	-0.8844	-0.1339	-0.5246	-0.6297	-0.6559
Al	*		**	**		**	*	**		**			**	*	**	-	-0.4232	0.5484	0.8940	-0.2797	-0.4454	-0.9247	-0.6257	-0.1940	-0.2704	-0.7046	-0.5070
Ca	**				*	**	**	**		*		*	**	*	**	*	-	0.0927	-0.0569	0.8926	-0.3316	0.0635	0.2546	-0.0432	0.1918	0.1585	0.1127
Na									*		**					*		-	0.7170	-0.3915	-0.6487	-0.4768	0.1998	0.1125	0.0886	-0.2354	0.0888
K						**				**			**		**	**		**	-	-0.4609	-0.4248	-0.8816	-0.3575	-0.0291	-0.2050	-0.7152	-0.4997
P	**						*						*		*		**			-	0.0801	0.3963	0.1011	-0.1691	0.1587	0.1043	0.1125
Ba											**							**			-	0.0728	-0.3240	0.1055	-0.5071	-0.1047	0.0771
Sr			*			**		**		**			**		**	**			**			-	0.6087	0.0537	0.5057	0.8045	0.6462
LOI			**	**		**		**	**	**	**		**		**	**						**	-	0.1873	0.5572	0.7038	0.7155
H2O+																								-	-0.2922	-0.0412	0.4215
H2O-						**				*	*		**	*	*						*	*	*		-	0.4327	0.2436
La			*			**		*		*			**		**	**			**			**	**			-	0.4313
Ce	*	*	**	*		*			**	**					**	**			*			**	**			*	-

Non Correlation Test * :5% **:1%   Red: Positive Correlation   Blue : Negative Correlation

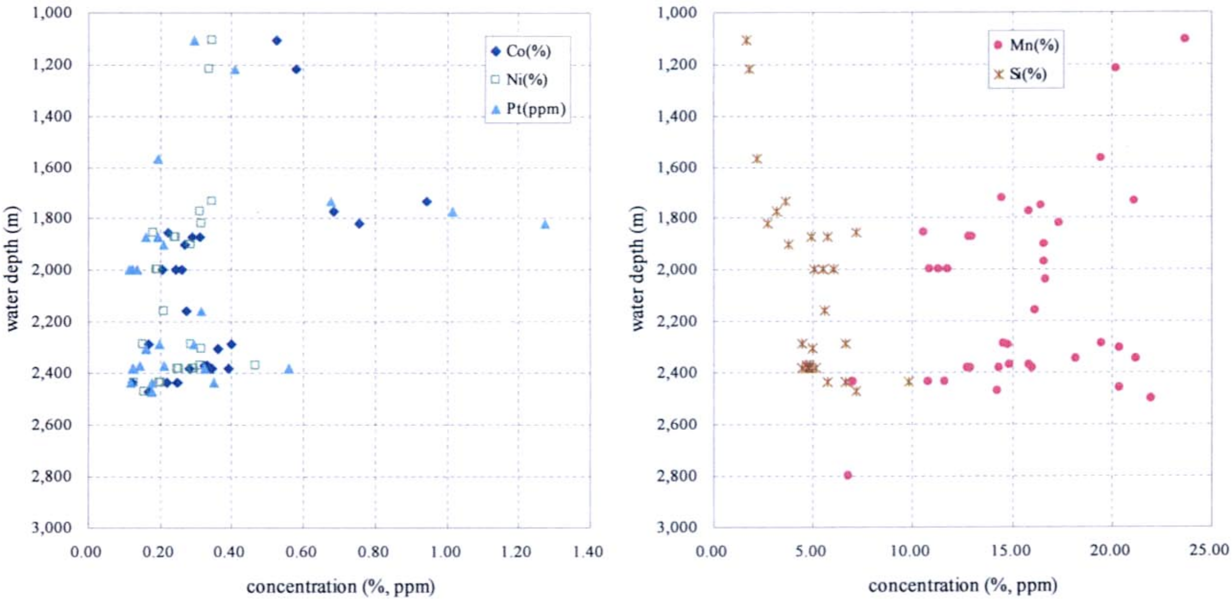


Figure 5-6-4 Relations of Water Depth and Major Elements

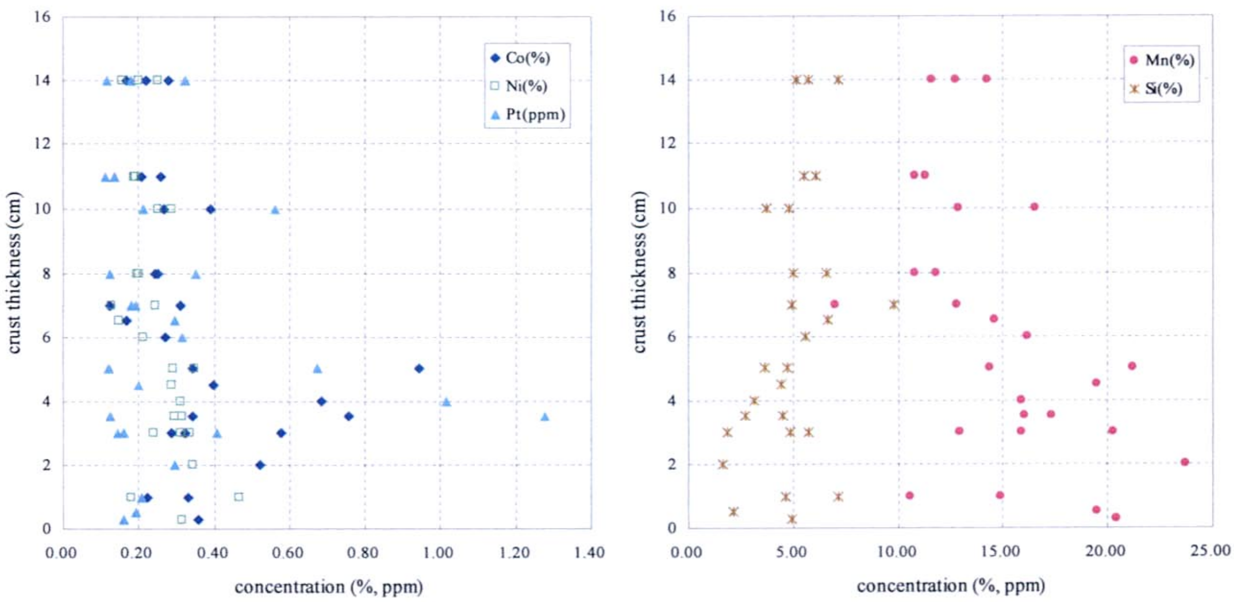


Figure 5-6-5 Relations of Thickness and Major Elements

5-7 Identifications of Microfossils and Large Fossils of Carbonate Rocks

5-7-1 Samples

The fossil identification of consolidated carbonated rocks collected from the MC12 and MC13 areas were conducted. As shown in Table 5-7-1, microfossils (planktonic foraminifera and calcareous nannoplankton) studies for eight samples and large fossil studies of five samples were conducted.

The fossil studies were conducted by following scientists.

Hand specimen and microscopic descriptions: Dr. Y. Iryuu, Graduate Studies of Science,
Large fossil studies Tohoku University
Calcareous nannoplankton studies : Dr. T. Sato, Faculty of Technology, Akita University
Planktonic foraminifera studies : Dr. M. Oda, Graduate Studies of Science. Toohoku University

Table 5-7-1 Samples for Fossil Studies (carbonate rocks)

Ser. No.	Sea Mt.	Sample No.	Depth of Bottom Touch (m)	Piece No. of Sample	Micro Fossils	Large Fossils	Lithology
1	MC12	05SMC12AD15	2,437	c3	FR01	–	Mn crust
2		05SMC12AD18	1,368	c3	–	FRC01	Reef limestone
3		05SMC12AD20	1,562	a1	FR01	FRC01	Pelagic limestone
4				c1	–	FRC02	Reef limestone
5		05SMC12AD25	2,221	c1	FR01	FRC01	Calcareous conglomerate
6		05SMC12AD29	2,385	a1	FR01	–	Calcareous conglomerate
7				c2, c3	FR02	FRC01	Reef limestone
8				c4	FR03	–	Calcareous conglomerate
9	MC13	05SMC13AD15	1,724	a1	FR01	–	Siltstone
10					FR02	–	Limestone

5-7-2 Descriptions of Hand Specimen

The carbonate rocks were described using the classification of Embry and Klovan (1972), revised version of Dunham (1962) (Figure 5-7-1).

<table>
<tr><td colspan="6">allochthonous limestones original components not organically bound during deposition</td><td colspan="3">autochthonous limestones original components organically bound during deposition</td></tr>
<tr><td colspan="4">less than 10% >2mm component</td><td colspan="2">greater than 10% >2mm components</td><td rowspan="5">by organisms which act as baffles</td><td rowspan="5">by organisms which encrust and bind</td><td rowspan="5">by organisms which build a rigid frame work</td></tr>
<tr><td colspan="3">contains lime mud (less than 30micron m)</td><td>no lime mud</td><td rowspan="4">matrix (lime mud) supported</td><td rowspan="4">less than 2mm component supported</td></tr>
<tr><td colspan="2">calcareous mud supported</td><td colspan="2" rowspan="3">grain supported</td></tr>
<tr><td colspan="2">grain size: 30micro m to 2mm</td></tr>
<tr><td>less than 10% grain</td><td>greater than 10% grain</td></tr>
<tr><td rowspan="2">lime mudstone</td><td rowspan="2">wackestone</td><td rowspan="2">packstone</td><td rowspan="2">grainstone</td><td rowspan="2">floatstone</td><td rowspan="2">rudstone</td><td colspan="3">boundstone</td></tr>
<tr><td>bafflestone</td><td>bindstone</td><td>framestone</td></tr>
</table>

After Dunham (1962), revised by Embry and Klovan (1972)

Figure 5-7-1 Classification of Limestone

Hand specimen descriptions of ten samples used for identification of fossils are given below.

05SMC12AD15 FR01

The sample is a mixture of Mn oxides and pale yellowish gray to pale reddish brown clay. It is not clear whether Mn oxides permeated into the clay or the clay occurred filling interstices of Mn oxides. The different degree of consolidation between two clays, the pale reddish brown clay being more consolidated than pale yellowish brown clay, suggests different stage of formation for these clays. By naked eye and hand lens, no fossils other than planktonic foraminifera were found in clay.

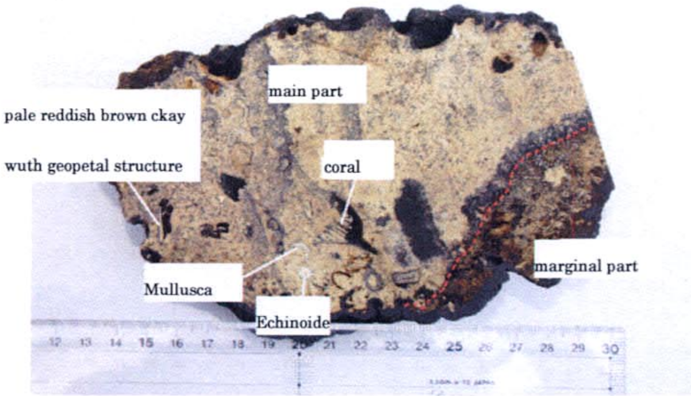
05SMC12AD18 FRC01

It is massive, white to whitish gray bioclastic grainstone and no sedimentary structure was observed. Bioclasts such as benthic foraminifera, planktonic foraminifera, framework (partly leached and forming mold) of reef coral (*Stylophora* sp.), coralline algae and *Halimeda* (?) were observed. Sparite occurs in interstices between grains. Molds occur on the surface and they are coated by thin film of Mn oxides.

05SMC12AD20 FR01/FRC01

As shown in the photograph below, this sample consists of two parts: main and marginal parts.

Main part: It is consolidated, massive, pale yellowish brown bioclastic packstone and no sedimentary structure is observed. It partly shows similar appearance to rudstone with abundant bioclasts of more than 2mm across. The bioclasts such as planktonic foraminifera, framework of coral, Mollusca, Echinoidea are observed. The bioclasts are



partly leached forming molds, which are partly filled by consolidated pale reddish brown clay and unconsolidated pale grayish brown clay, occasionally showing geopedal structure. Mn oxides permeate inside the rock and the surface of it is coated by Mn oxides of less than 1mm thick.

Marginal Part: It is pale yellowish gray to pale reddish brown bioclastic packstone. A clear boundary with permeation of Mn oxides is observed between the main and the marginal parts. The marginal part is porous, leached more intensely than the main part and abundant molds of planktonic foraminifera are observed.

05SMC12AD20 FRC02

Coral framestone or coral rudstone. Thin platy reef coral (*Porites* ?) is observed. The matrix is bioclastic packstone with bioclasts such as *Halimeda.* The sample partly include pores, possibly mold after leaching of bioclasts, of up to 2cm long. Pale reddish brown and gray unconsolidated sediments with planktonic foraminifera are attached in some of the pores and on the surface of rock. Mn oxides coating is observed on the surface of the rock.

05SMC12AD25 FR01/FRC01

Whitish gray to pale brown, weakly consolidated calcareous conglomerate with volcanic rocks and limestone rubbles. The volcanic rubbles are andesite, while the limestone rubbles with planktonic foraminifera are strongly altered and details are unknown. Both of the andesite and limestone rubbles are pebble size and have irregular shape. The matrix is pale brown limestone and permeation of Mn oxides is observed. The surface of the rock is coated by Mn oxides and gray, unconsolidated clay rich in foraminifera is attached on the Mn oxides coating.

05SMC12AD29 FR01

Pale brownish gray to dark brownish gray, weakly consolidated coarse sandstone. No fossil was observed by naked eye and hand lens. Mn oxides occur on the top and bottom of sandstone, and reddish brown clay with fragments of Mn oxides and pale brown calcareous clay occur along cracks and surface of Mn oxides.

05SMC12AD29 FR02/FR01

Sample c2 is a fragment of coral with Mn oxides coating. Sample c3 is a fragment of sclerosponge covered by coralline algae on surface. It is milky white and coated by thin film of Mn oxides.

05SMC12AD29 FR03

Well consolidated, pale brown bioclastic packstone. It is massive and no sedimentary structure is observed. Many white spots are observed through hand lens, but it is not clear whether they are bioclasts. Irregular shaped pores, possibly caused by bioerosion, are observed and they are partly filled by pale yellow sediments. Surface of the rock is covered by Mn oxides coating and Mn oxides, also, occur inside of the rock.

05SMC13AD15 FR01

Well consolidated, dark brown, fine sandstone. It is massive and no sedimentary structure is observed. Pores of unknown origin occur and they are partly filled by consolidated milky white mud sediments or reddish brown clay. Mn oxides occur on the surface and inside of the rock. Gray, unconsolidated clay with planktonic foraminifera is attached on the Mn oxides coated surface.

05SMC13AD15 FR02

Consolidated, grayish white to pale yellowish brown bioclastic wackestone. It is massive and no sedimentary structure is observed. Molds after leaching of Mollusca are observed and yellowish brown pores caused by bioturbation occur filled by mud sediments with planktonic foraminifera. The surface of the rock is coated by Mn oxides and Mn oxides are, also, observed inside of the rock.

5-7-3 Microscopic Observation of Thin Secretions

The micrographs of limestone are given on Plate V and the microscopic descriptions of limestone are given below.

05SMC12AD15 FR01

It is assumed to be originally calcareous mud with planktonic foraminifera but now it has been changed to a mixture of cay and Mn oxides and nature of the original rock is obscured. Further, another calcareous mud with planktonic foraminifera of the later stage is filling the cracks of the original rock and Mn oxides. At least four precipitation stages of filling cavities by sediments are observed in the rock, and some of the sediments include clods of sediments of the earlier stage. Among the calcareous sediments filling the cavities, the sediments with pale yellowish brown color partly has less planktonic foraminifera and less carbonates compared with others.

05SMC12AD20 FRC01

Main part: Foraminiferal pack-/wackestone. It is massive without sedimentary structure and has abundant planktonic foraminifera. Bioclastic packstone fills the cavities of bioturbation, and the cavities of unknown origin are filled by calcareous mud with foraminifera.

Marginal part: Bioclastic packstone. It is massive without sedimentary structure. The bioclasts such as Bivalvia and Ostracoda are observed, however, many molds after leaching of bioclasts are observed and the rock is porous. The boundary between the main and marginal parts is not clear having been filled by Mn oxides, however, it is presumed to be a clear contact.

There are two possibilities of the formation of the main and the marginal parts. One is that the marginal part is one of inclusions of the main part as pebbles of conglomerate. The other is that the marginal part was first formed on land, then after erosion the main part precipitated filling the cavities. Only from this sample it is impossible to determine which is true. In either case, after the formation of the main and marginal parts the limestone was uplifted and once exposed on land, then cavities were formed by erosion and leaching. The cavities were, later, filled by foraminiferal packstone.

05SMC12AD25 FR01/FRC01

Limestone with pebbles of volcanic rocks and limestone. It is massive and no sedimentary structure is observed. The volcanic pebbles are andesite and vesicles are filled by foraminiferal pack-/wackestone with planktonic foraminifera. The limestone pebbles include bioclasts such as coralline and Echinoidea, and the original lithology is unknown because of strong alteration. These pebbles were covered by pale brown film of possibly either phosphorite or Mn oxides. The matrix of the limestone consists of two different types of materials. One is pyroclastics (tuffaceous silt) with planktonic foraminifera, and plagioclase and hornblende are observed. The other is foraminiferal pack-/wackestone with planktonic foraminifera and fragments of Mn oxides are included. The cavities formed by bioturbation are filled by foraminiferal packstone. The matrix is composed of a mixture of two materials, and the latter seems to be formed later than the former.

05SMC12AD19 FR01

Pyroclastic rocks (coarse sandstone) permeated by Mn oxides. Planktonic foraminifera was the only bioclasts observed in the sample, and plagioclase, hornblende and fragments of volcanic rocks are included. In interstices of grains mud sediments, partly calcareous, occur. Non-calcareous part shows darker color than calcareous part and both of them occur irregularly intermingled each other. The cavities of unknown origin are observed filled by Mn oxides.

05SMC12AD29 FR02/FRC01

A thin section was prepared for c3.

Sclerosponge. The surface is covered by tubewarm (Annelida or Mollusca), algae of Peyssonneliaceae, Bryozoa, foraminifera and coralline algae. The interstices of these fossils are filled by micrite and benthic (miliolinid foraminifera) and planktonic foraminifera are identified. Occurrence of palnktonic foraminifera suggests continental shelf environment for precipitation of this limestone.

05SMC12AD29 FR03

Foraminiferal pack-/wackestone. It is massive and sedimentary structure is not observed. Benthic foraminifera were observed and plagioclase rarely occurs. The cavities formed by bioturbation are filled by mud sediments with acicular plagioclase and benthic foraminifera.

05SMC13AD15 FR01

Fine sandstone with pyroclastic materials. It is massive and sedimentary structure is not observed. The sandstone, consisting of plagioclase, hornblende, fragments of Mn oxides, glass and alteration minerals, is arenite. The cavities of unknown origin are filled by foraminifera and pellets of mud with Mn oxides, and they show geopetal structure. Unidentified mineral with sward shape crystal occurs in interstices of grains and top of cavity fillings. Mn oxides partly occur inside of sandstone.