VIII. GEOTECHNICAL PROPERTIES OF DEEP SEA SEDIMENTS FROM THE WESTERN PART OF CENTRAL PACIFIC BASIN (GH78-1 AREA)

Katsuya Tsurusaki and Keiji Handa**

Introduction

Geotechnical properties of deep sea sediments were measured on board in order to obtain basic data for both of the future manganese nodule mining technology and the geoscience. Geotechnical proterties measured on board were vane shear strength and water content of sediments.

For the subsequent laboratory geotechnical testing subcore samples were taken from each box and grab sample. The purposes of the shipboard measurement and laboratory testing are to ditermine the geotechnical properties of deep sea sediments in Central Pacific Basin and in the area concentrated with manganese nodule, trend of geotechnical disturbance caused by sampling, relationship between geotechnical properties and sediment type, and degradation of the sample due to subcoring, handling, and storage.

Procedure and equipments

Deep sea sediments were sampled by using a double spade box corer and Okean-70 grab sampler. The double spade box corer was newly developed and used as a trial. Its sampling area is 40 cm by 40 cm and sampling depth is 36 cm.

Two types of vane tester were used for measuring the vane shear strength of the sediments. One consists of motorized vane and electric torque sensor shown in Fig. VIII-1.

The other is hand held and torsional calibrated spring type vane tester. Vane size, rotation rate, and torque capacity are same for both tester. The 90 degree four blades of vane are 2 cm wide and 4 cm high and rotated at the rate of about 90°/min with 40 cm long stainless steel rod. The torque capacity is 2 kg.cm. Strength was measured at three points (i.e. 5, 10, 20 cm from the sampler wall) in the sampler to determine the disturbance caused by sampling and at 6 cm depth interval. Each measurement included original vane shear strength and remolded strength. It was done immediately after picking up of manganese nodules from the sediment surface. The maximum vane torque was converted to the shear strength through the following formula.

$$Sv = Tm / \left(\frac{\pi D^2 H}{2} + \frac{\pi D^3}{6} \right)$$

Where Sv: Vane shear strength (g/cm^2)
Tm: Maximum torque (g.cm)

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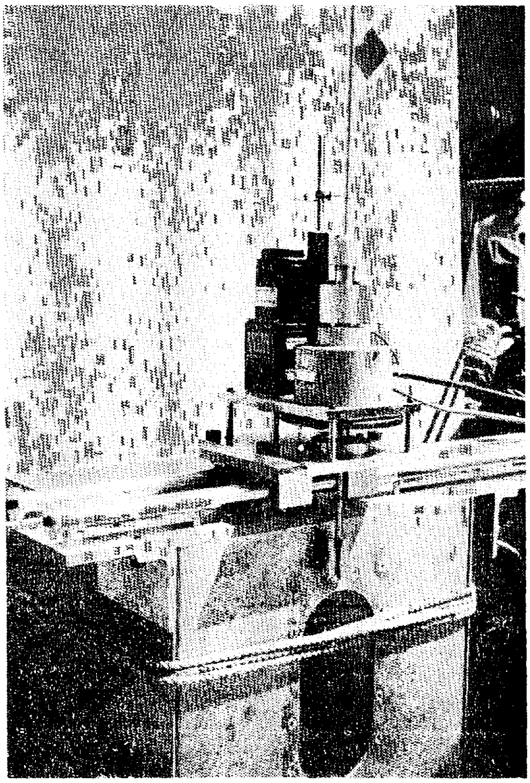


Fig. VIII-1 Electric vane tester. Motorized vane, torque sensor and slip ring are shown.

D: Vane width (cm)
H: Vane height (cm)

Two subcores were taken from each box and grab sample for water content measurement and subsequent detailed laboratory testing. A P.V.C. tube of 6 cm in diameter and a transparent acrylic resin tube of 10 cm in diameter and 40 cm long were pushed into the sediment with hand. Bigger tube was sealed with plastic inner lid, rubber stopper, and plastic tape. Some of them were stored vertically in the refrigerator and rest of them were stored in laboratory to compare the influence of the storage temperature to the geotechnical proterties. Another smaller subcore was split immediately at wet laboratory and sample cake of 2 cm thick was taken from 6 cm depth interval of split subcore.

Water content was determind from the weight of sediment sample cake before and after drying for 24 hours at 105°C. An electric load cell and recorder were used for measuring of the weight in order to neglect the influence of vibration and sway of the ship. After two minutes recording the mean value was adopted as a sample weight. 35 ppt of salinity correction was made on the calculated water content value.

Sample color was determined according to the Rock Color Chart of the Geological Society of America. It is shown in Appendix.

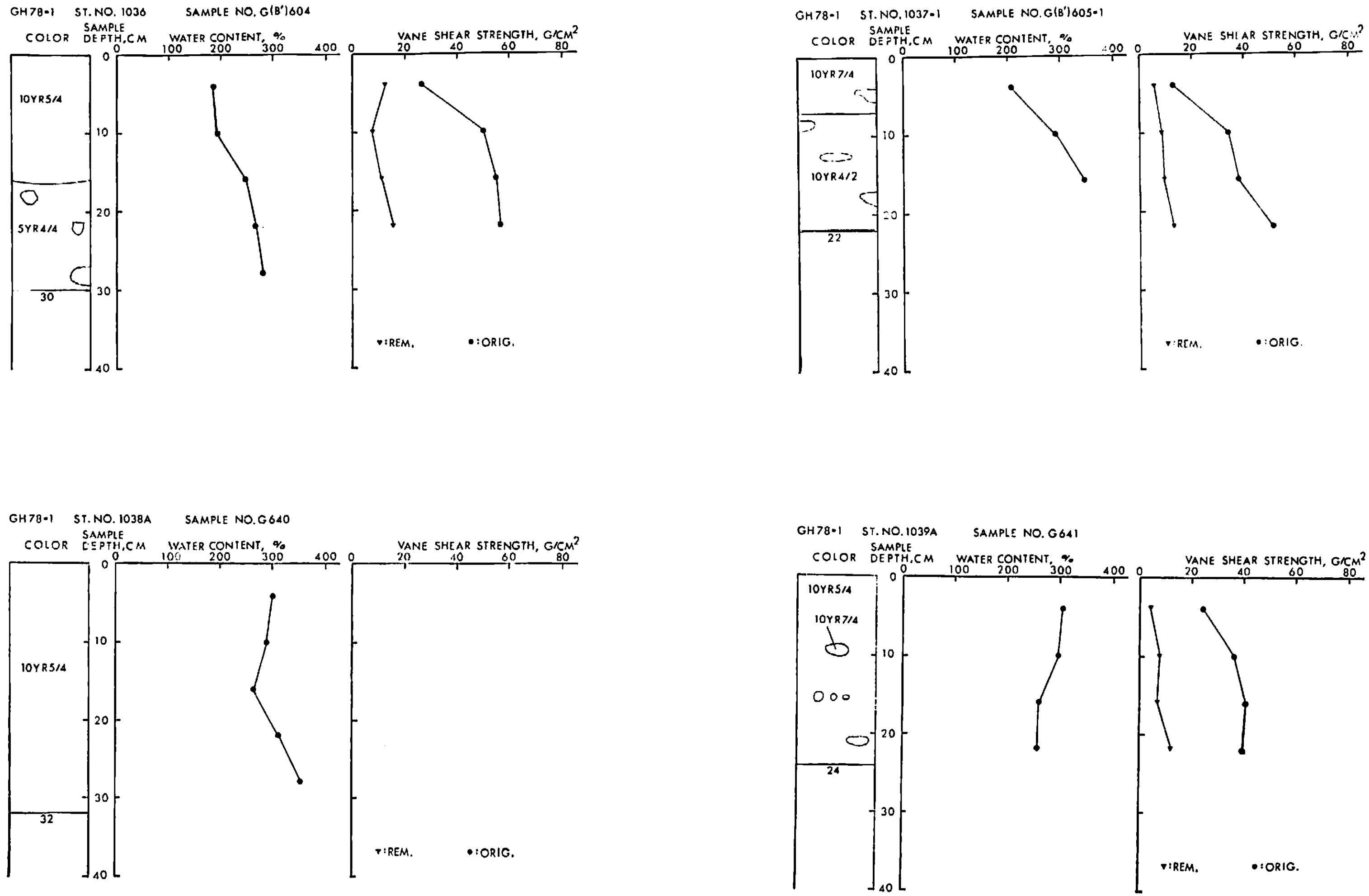
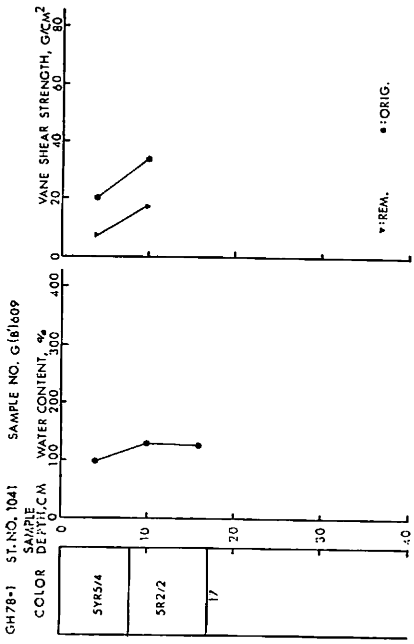


Fig. VIII-2 Vane shear strength, water content and color for each sample.


GH78-1
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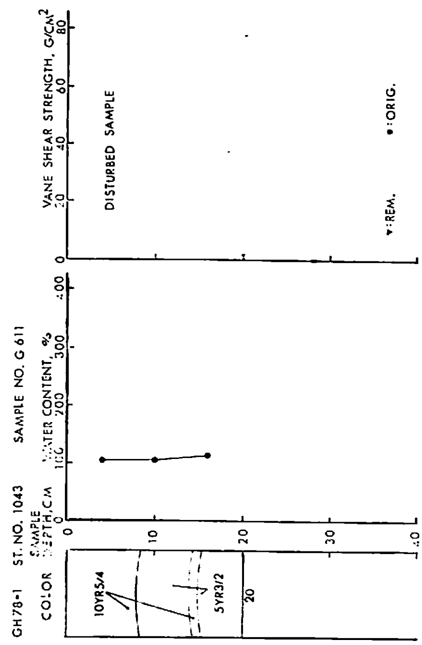
ST. NO. 1041
SAMPLE DEPTH, CM
SAMPLE NO. G(8')609
WATER CONTENT, %
VANE SHEAR STRENGTH, G/CM2
5YR5/4
5R2/2
17
▾: REM.
●: ORIG.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SAMPLE NO. G 611
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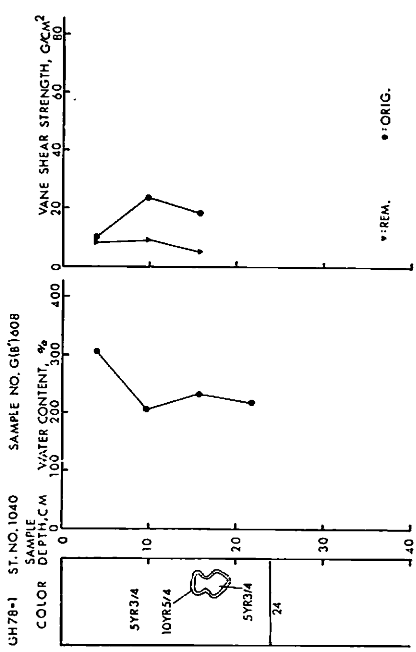
VANE SHEAR STRENGTH, G/CM2
DISTURBED SAMPLE
10YR5/4
5YR3/2
20
▾: REM.
●: ORIG.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SAMPLE NO. G(8')608
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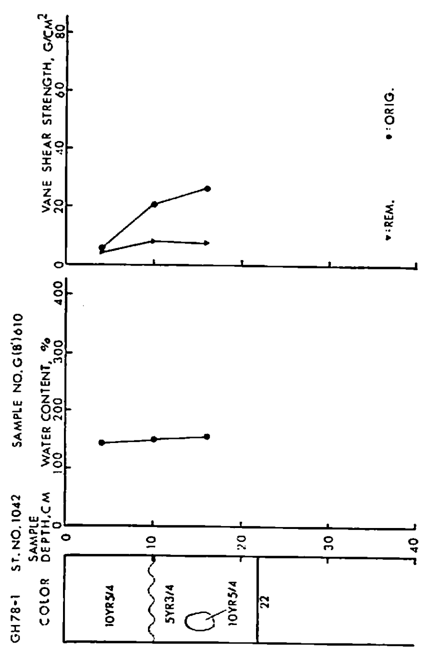
VANE SHEAR STRENGTH, G/CM2
5YR3/4
10YR5/4
5YR3/4
24
▾: REM.
●: ORIG.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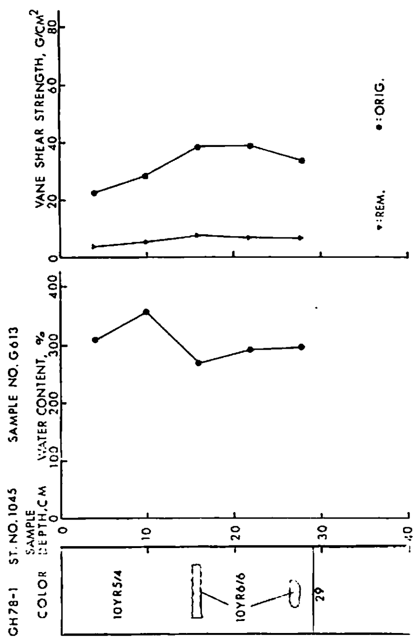
WATER CONTENT, %
VANE SHEAR STRENGTH, G/CM2
10YR5/4
5YR3/4
10YR5/4
22
▾: REM.
●: ORIG.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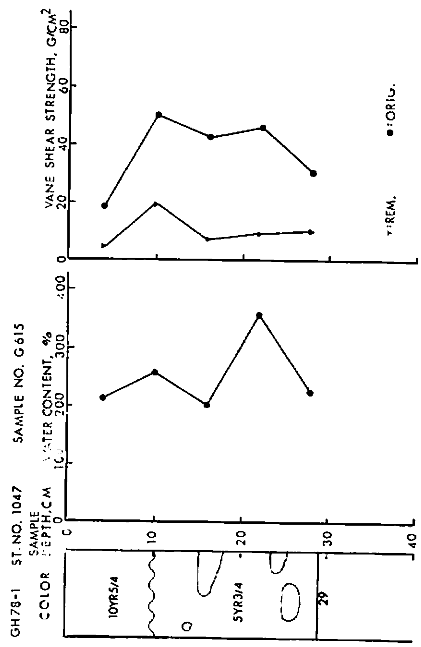
COLOR
SAMPLE DEPTH, CM
WATER CONTENT, %
VANE SHEAR STRENGTH, G/CM2
10YR5/4
10YR6/6
29
▾: REM.
●: ORIG.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COLOR
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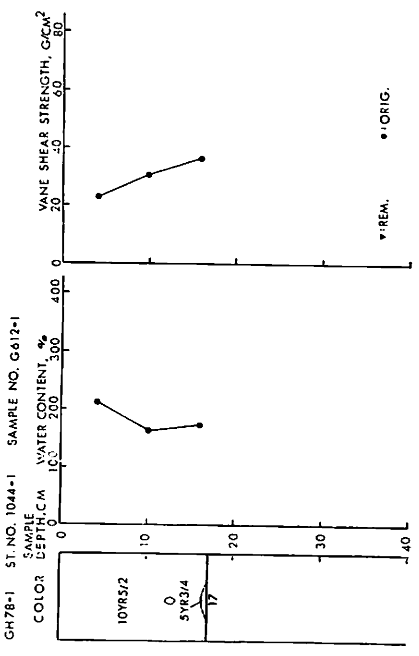
WATER CONTENT, %
VANE SHEAR STRENGTH, G/CM2
10YR5/4
5YR3/4
29
▾: REM.
●: ORIG.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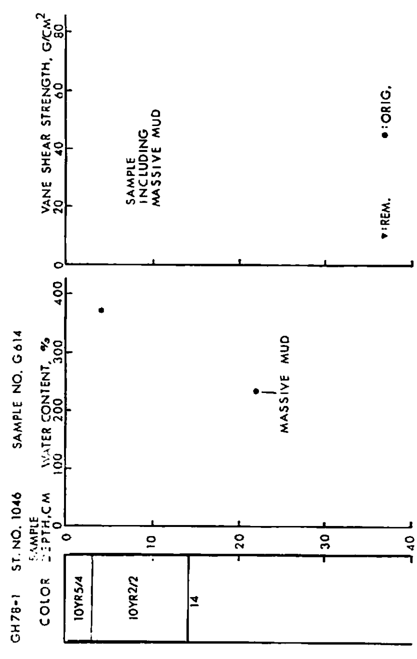
COLOR
SAMPLE DEPTH, CM
WATER CONTENT, %
VANE SHEAR STRENGTH, G/CM2
10YR5/2
5YR3/4
17
▾: REM.
●: ORIG.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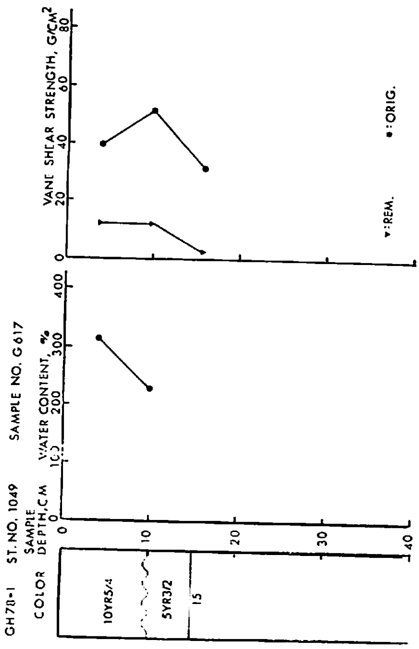
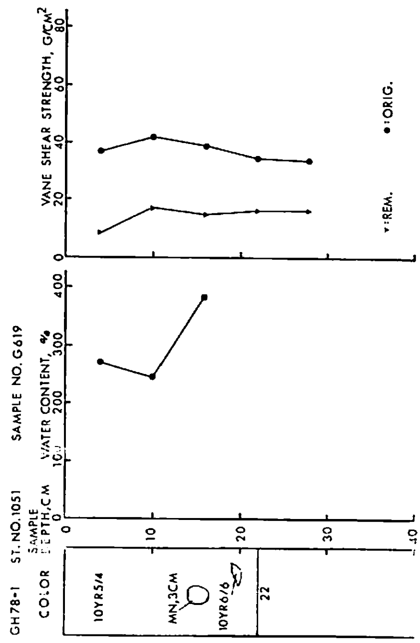
COLOR
SAMPLE DEPTH, CM
WATER CONTENT, %
VANE SHEAR STRENGTH, G/CM2
10YR5/4
10YR2/2
14
MASSIVE MUD
SAMPLE INCLUDING MASSIVE MUD
▾: REM.
●: ORIG.


GH78-1 ST. NO. 1049 SAMPLE NO. G617
COLOR
SAMPLE DEPTH, CM
WATER CONTENT, %
VANE SHEAR STRENGTH, G/CM²
10YR5/4
5YR3/2
15
•: ORIG.
▾: REM.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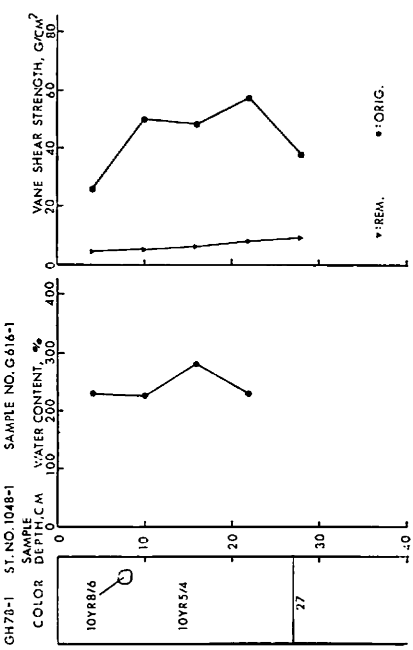
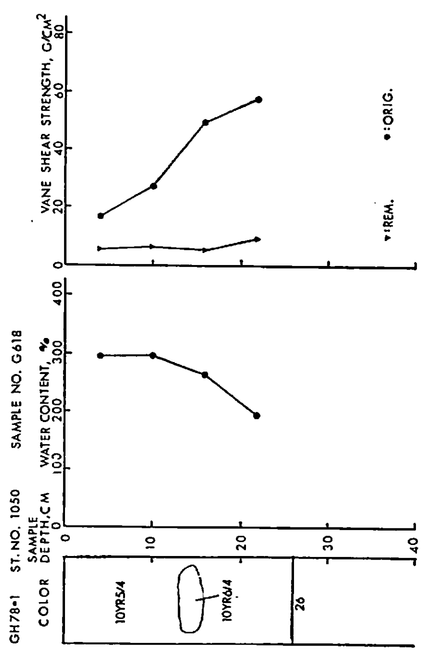
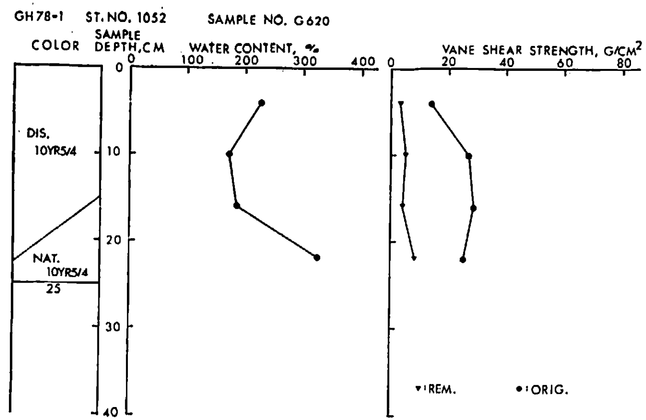
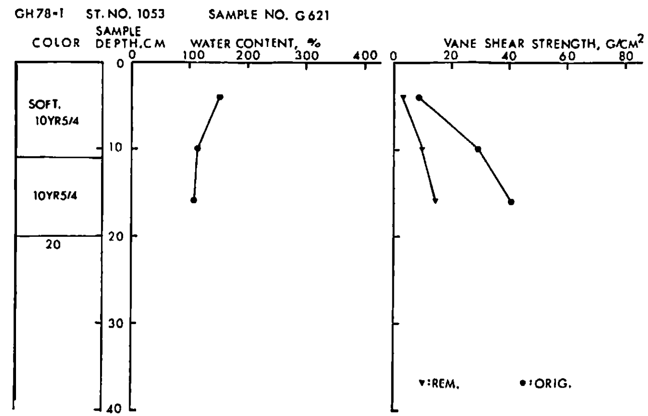
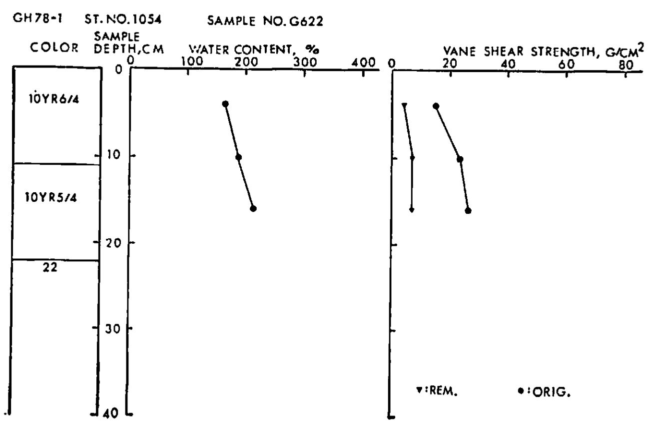
COLOR
SAMPLE DEPTH, CM
WATER CONTENT, %
VANE SHEAR STRENGTH, G/CM²
10YR5/4
MN, 3CM
10YR6/6
22
•: ORIG.
▾: REM.


GH78-1 ST. NO. 1048-1 SAMPLE NO. G616-1
COLOR
SAMPLE DEPTH, CM
WATER CONTENT, %
VANE SHEAR STRENGTH, G/CM²
10YR8/6
10YR5/4
27
•: ORIG.
▾: REM.


GH78-1 ST. NO. 1050 SAMPLE NO. G618
COLOR
SAMPLE DEPTH, CM
WATER CONTENT, %
VANE SHEAR STRENGTH, G/CM²
10YR5/4
10YR6/4
26
•: ORIG.
▾: REM.


GH78-1 ST. NO. 1052 SAMPLE NO. G620
COLOR
SAMPLE DEPTH, CM
WATER CONTENT, %
VANE SHEAR STRENGTH, G/CM²
DIS. 10YR5/4
NAT. 10YR5/4
25
▾: REM.
•: ORIG.


GH78-1 ST. NO. 1053 SAMPLE NO. G621
COLOR
SAMPLE DEPTH, CM
WATER CONTENT, %
VANE SHEAR STRENGTH, G/CM²
SOFT. 10YR5/4
10YR5/4
20
▾: REM.
•: ORIG.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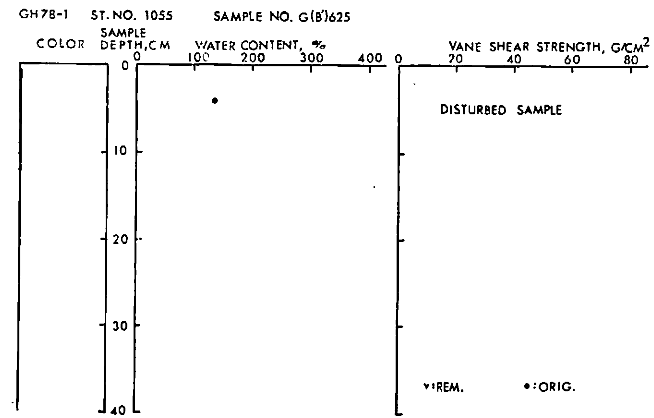
COLOR
SAMPLE DEPTH, CM
WATER CONTENT, %
VANE SHEAR STRENGTH, G/CM²
10YR6/4
10YR5/4
22
▾: REM.
•: ORIG.


GH78-1 ST. NO. 1055 SAMPLE NO. G(B')625
COLOR
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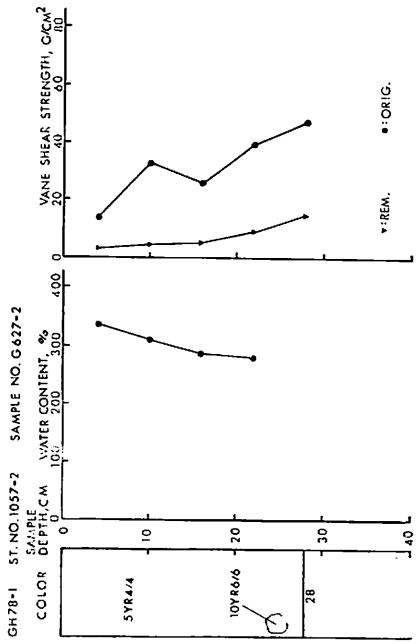
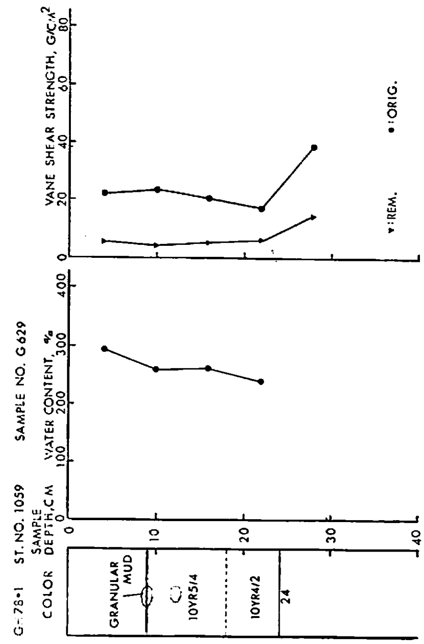
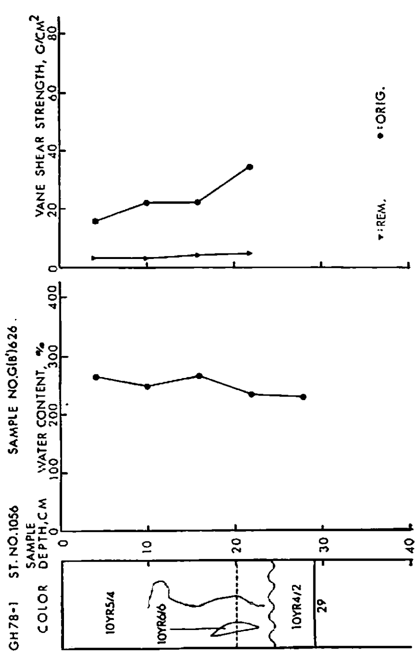
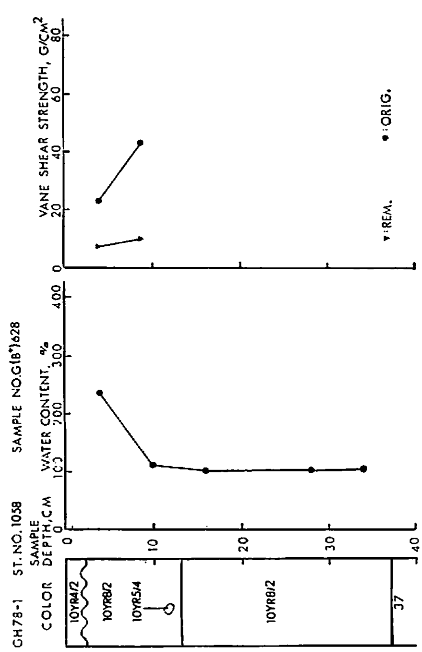
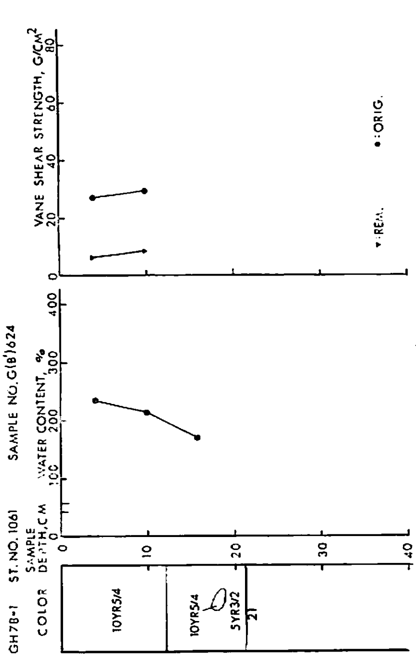
WATER CONTENT, %
VANE SHEAR STRENGTH, G/CM²
DISTURBED SAMPLE
▾: REM.
•: ORIG.

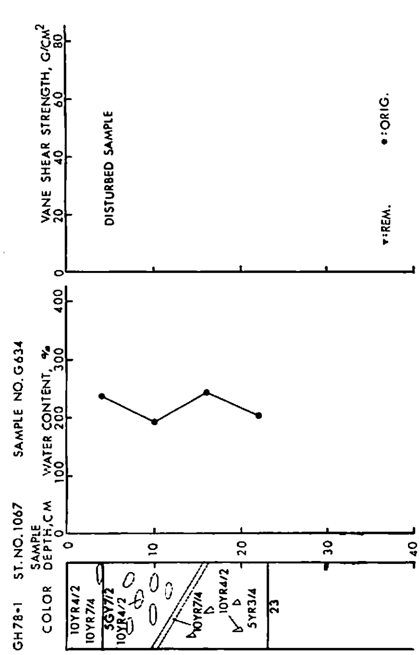

GH78-1 ST.NO.1057-2 SAMPLE NO. G627-2
COLOR
SAMPLE DEPTH, CM
WATER CONTENT, %
VANE SHEAR STRENGTH, G/CM²
5YR4/4
10YR6/6
28
▼: REM.
●: ORIG.


ST. NO. 1059 SAMPLE NO. G629
COLOR
SAMPLE DEPTH, CM
WATER CONTENT, %
VANE SHEAR STRENGTH, G/CM²
GRANULAR MUD
10YR5/4
10YR4/2
24
▼: REM.
●: ORIG.


GH78-1 ST.NO.1056 SAMPLE NO.G(8')626
COLOR
SAMPLE DEPTH, CM
WATER CONTENT, %
VANE SHEAR STRENGTH, G/CM²
10YR5/4
10YR6/6
10YR4/2
29
▼: REM.
●: ORIG.


GH78-1 ST.NO.1058 SAMPLE NO.G(8')628
COLOR
SAMPLE DEPTH, CM
WATER CONTENT, %
VANE SHEAR STRENGTH, G/CM²
10YR4/2
10YR8/2
10YR5/4
10YR8/2
37
▼: REM.
●: ORIG.


GH78-1 ST. NO. 1061 SAMPLE NO. G(B')1624
COLOR
SAMPLE DEPTH, CM
WATER CONTENT, %
VANE SHEAR STRENGTH, G/CM²
10YR5/4
10YR5/4
5YR3/2
21
▾: REM.
●: ORIG.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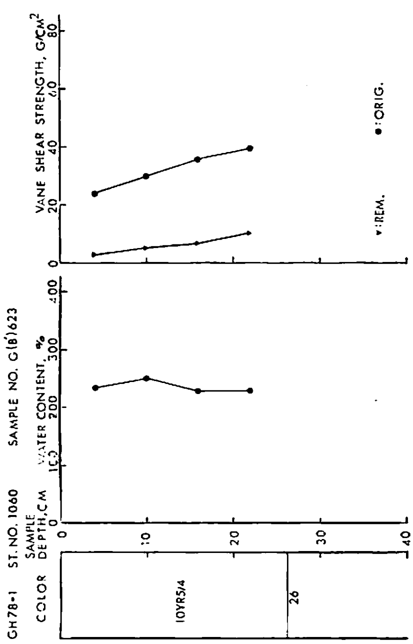
COLOR
SAMPLE DEPTH, CM
WATER CONTENT, %
VANE SHEAR STRENGTH, G/CM²
DISTURBED SAMPLE
10YR4/2
10YR7/4
5GY7/2
10YR4/2
10YR7/4
10YR4/2
5YR3/4
23
▾: REM.
●: ORIG.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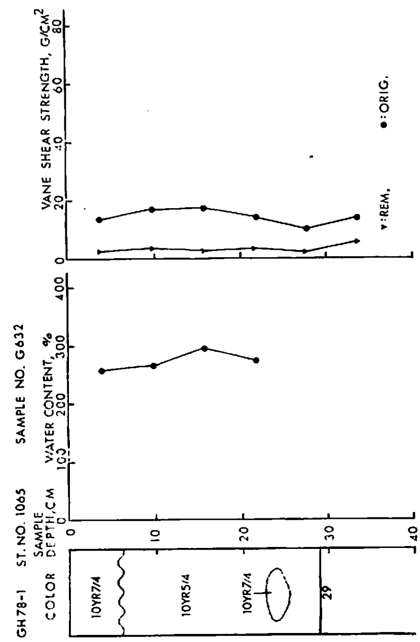
WATER CONTENT, %
VANE SHEAR STRENGTH, G/CM²
10YR5/4
26
▾: REM.
●: ORIG.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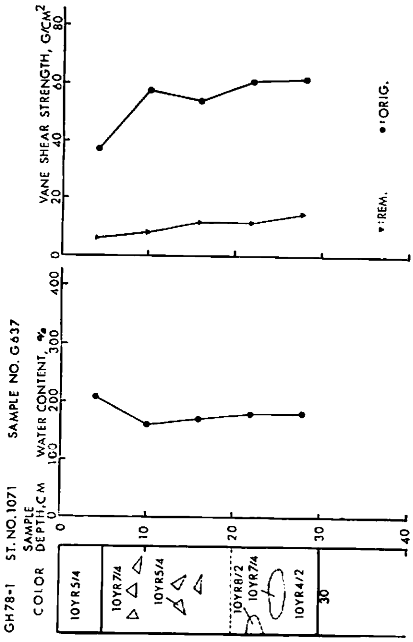
COLOR
SAMPLE DEPTH, CM
WATER CONTENT, %
VANE SHEAR STRENGTH, G/CM²
10YR7/4
10YR5/4
10YR7/4
29
▾: REM.
●: ORIG.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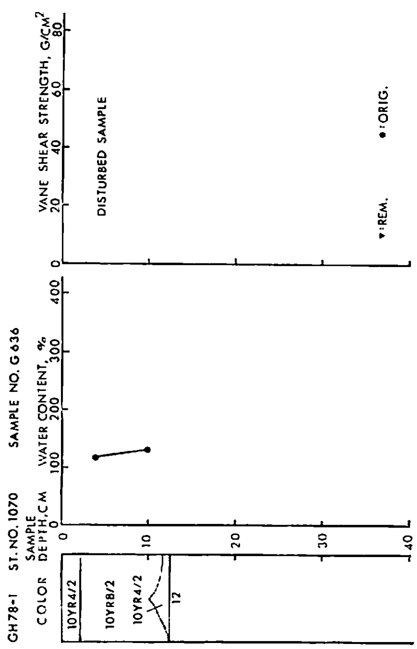
SAMPLE DEPTH, CM
WATER CONTENT, %
VANE SHEAR STRENGTH, G/CM²
10YR5/4
10YR7/4
10YR5/4
10YR8/2
10YR7/4
10YR4/2
30
▾: REM.
●: ORIG.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SAMPLE DEPTH, CM
WATER CONTENT, %
VANE SHEAR STRENGTH, G/CM²
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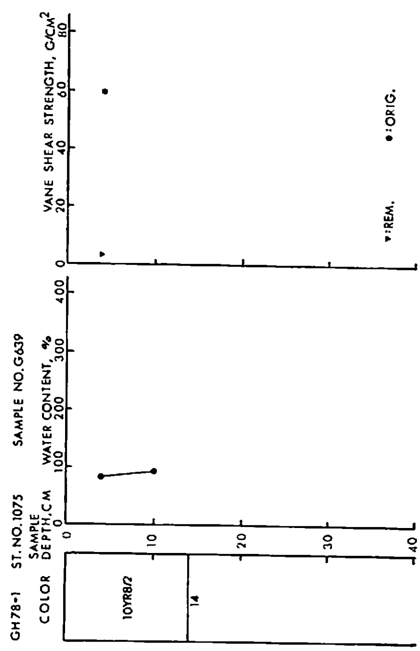
10YR8/2
10YR4/2
12
DISTURBED SAMPLE
▾: REM.
●: ORIG.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WATER CONTENT, %
VANE SHEAR STRENGTH, G/CM²
10YR8/2
14
▾: REM.
●: ORIG.

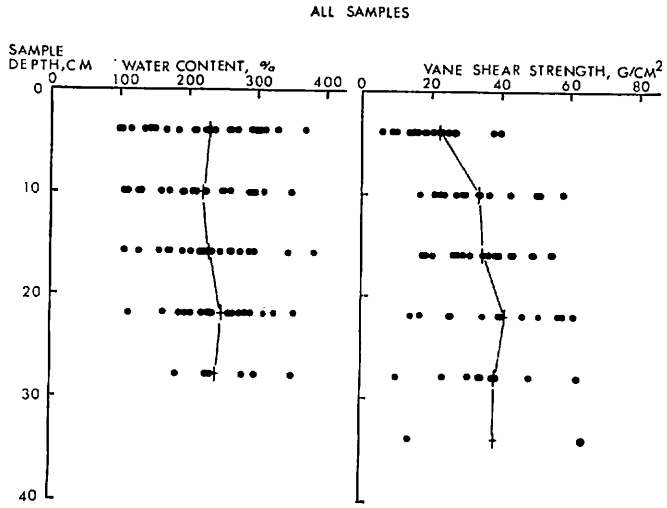

Fig. VIII-3 Statistical result of vane shear strength and water content for all samples.

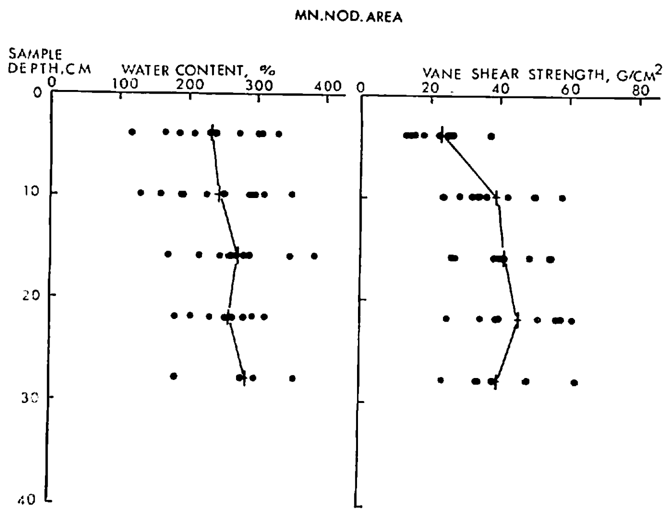

Fig. VIII-4 Statistical result of vane shear strength and water content for manganese nodule area's samples.

Preliminary results

Deep sea sediment was sampled from 22 stations by using Okean-70 grab sampler and from 9 stations by using double spade box corer. Half of the Okean samples and most of the box samples were disturbed slightly at the surface and the rest of them were relatively disturbed.

Vane shear strength was measured on 27 samples. Eight of them were sampled by using double spade box corer, 18 of them were by Okean-70 grab sampler, and one of them was by shutter type box corer which was used twice as a trial. Electrical vane tester was applied on five samples.

Vane shear strength measured at the point of 20 cm from the sampler wall was adopted as a strength of the sediment.

The results of the strength versus sediment depth for each sample are shown in Fig. VIII-2 and statistical results are shown in Fig. VIII-3 and Table VIII-1. Examination of the strength versus test depth shows that increases in strength with depth occur in the upper 10 cm of sediment: below this depth, the mean strength increases very slightly or remains constant throughout the rest of test depth. The average strength was 22.5 g/cm^2 at depth of 4 cm, 34.4 g/cm^2 at 10 cm, and 38.5 g/cm^2 for the below part.

Water content was measured on 31 sediment samples and on several manganese nodules sampled from sta. 1036 A and 1072. The water content of manganese nodule ranged 41.6% to 37.3% and the average was 39.0% of dry weight.

The results of the water content versus sediment depth for each sediment sample are shown in Fig. VIII-2 and statistical results are shown in Fig. VIII-3 and Table VIII-1. Examination of the water content versus sediment depth shows that the water content remains approximately constant throughout tested depth of the sediment in this surveyed area. This shows different tendency from

Table VIII-1 Vane shear strength and water content for all samples

Sample depth	Vane shear strength (g/cm^2) N	Max.	Min.	Mean	St. Dev.	Water content (%) N	Max.	Min.	Mean	St. Dev.
4cm	25	52.5	5.9	22.5	10.5	25	329	99	229	67.1
10	24	58.0	17.1	34.4	11.2	25	351	104	220	66.7
16	23	57.0	17.4	35.1	11.8	24	383	99	229	70.5
22	17	61.0	14.3	41.4	15.0	16	355	105	249	60.3
28	10	62.1	10.2	38.2	16.1	7	353	100	238	82.5

Table VIII-2 Vane shear strength and water content for manganese nodule area

Sample depth	Vane shear strength (g/cm^2) N	Max.	Min.	Mean	St. Dev.	Water content (%) N	Max.	Min.	Mean	St. Dev.
4cm	10	37.5	13.2	23.6	8.8	11	329	115	239	68.9
10	10	58.0	23.9	39.1	10.9	11	351	130	244	69.9
16	10	55.0	25.9	41.1	9.8	10	383	171	272	60.1
22	9	61.0	25.2	45.2	12.2	7	310	181	259	43.2
28	6	62.1	23.9	40.0	13.3	4	353	181	277	71.6

it of the sediment sampled from previous reported surveyed area. The average water content was 229% of dry weight at depth of 4 cm and 231% for all depth.

The statistical results of vane shear strength and water content for the sediment sampled from manganese nodule concentrated area are shown in Fig. VIII-4 and Table VIII-2.

According to the comparison of the statistical results for all samples and manganese nodule area's samples, it is considered that the average vane shear strength for manganese nodule area is slightly higher than that for all samples throughout the tested sample depth and water content shows the same tendency.

For subsequent laboratory geotechnical testing on land, 26 subcores were taken and 16 of them were stored in refrigerator (about 5°C) on board.

More detailed discussion will be presented later with the laboratory test results.

References

HANDA, K. (1979) Physical properties of bottom sediments relevant to manganese nodule mining. *In* T. MORITANI (*ed.*), *Geol. Surv. Japan Cruise Rept.*, no. 12, p. 152–154.

TSURUSAKI, K., HIROTA, T. (1977) Some physical properties of the bottom sediments. *In* A. MIZUNO and T. MORITANI (*eds.*), *Geol. Surv. Japan Cruise Rept.*, no. 8, p. 125–130.

————, HANDA, K. (1978) Studies on the investigation techniques and instruments for deep sea floor mineral resources——Hakurei-maru research cruise GH78-1——*Mining and Safety*, vol. 24, no. 11, p. 587–602. (in Japanese, English abstract)

APPENDIX

5YR	2/2	Dusky brown	10YR	2/2	Dusky yellowish brown
	3/2	Grayish brown		4/2	Dark yellowish brown
	3/4	Moderate brown		5/2	Moderate yellowish brown
	4/4	Moderate brown		5/4	Moderate yellowish brown
	5/4	Light brown		6/4	Moderate yellowish brown
				6/6	Dark yellowish orange
5GY	7/2	Grayish yellow green		7/4	Grayish orange
				8/2	Very pale orange
				8/6	Pale yellowish orange

(Rock Color Chart, The Geological Society of America)