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Data report on physical properties
measurements on piston cores from
Flemish Pass - Janice C. Marsters

Atlantic Geoscience Centre

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DATA REPORT ON PHYSICAL PROPERTIES MEASUREMENTS ON PISTON CORES FROM FLEMISH PASS (HUDSON CRUISES 85044, 86018, 87008)

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GEOLOGICAL SURVEY OF CANADA OPEN FILE 2421

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PREFACE

This open file report is an edited version of a contract report to the Atlantic Geoscience Centre, funded by the Offshore Geotechnics task of the Panel on Energy Research and Developement (project 6.3.2.06, Stability of Continental Slopes).

SUMMARY

This report presents data from measurements of p-wave acoustic velocity, vane shear strength, water content, bulk density, Atterberg limits and grain size from 9 piston cores (< 11m penetration) in Flemish Pass near the Gabriel C-60 and Kyle L-11 well sites. Summary downcore descriptions are also provided.

ACKNOWLEDGEMENTS

The cores were collected from CSS Hudson; I thank the Captain, officers and crew for their assistance in obtaining the cores, and the Senior Scientists of the three cruises: Keith Manchester, Russel Parrott, and David Piper. Many people assisted with physical properties measurements, either while at sea or in the AGC lab, including Harold Christian, Jorn Landva, and Kate Moran. AGC curation staff, particularly Kate Jarrett, assisted in handling cores at the AGC lab.

INTRODUCTION

Two areas of the western margin of Flemish Pass have been studied during several AGC surveys intended to define the regional surficial geological framework of Flemish Pass. Seismic reflection surveys of the Flemish Pass area indicate that the floor of the Pass is a turbidite basin. The profiles suggest that a very limited component of the sediment in the Pass is derived from Flemish Cap. The majority of sediment is supplied from slumping and from channelized turbidity current flow from the Grand Bands margin (Hudson 87008 Cruise Report, 1987).

This report presents the physical properties data from cores obtained in western Flemish Pass during three cruises - Hudson 85044, 86018, and 87008. The core sites are generally located near two valley systems, Gabriel to the north and Kyle to the south. The sites lie on the western slope of the Pass, in 500 to 1500 meters water depth. For the purposes of this report, the cores are divided into two groups: those collected near Gabriel Valley, and obtained near Kyle Valley. The studied cores are categorized in Table 1, with the length and type of core (or cores) obtained at each site. A sketch of the western slope of the Pass is shown in Figure 1, noting the location of the two valleys and the core sites. Sediment samples were taken from the cores to allow detailed studies of physical properties, facies development and biostratigraphy .

CORE PROCUREMENT AND PROCESSING

Hudson 85044

Cores from Hudson 85044 had been processed prior to the beginning of this study. The cores were collected using a standard 30-foot Benthos piston corer with a 1-tonne head. Cores were sealed and stored upright and processed within two weeks of procurement. Analysis consists primarily of vane shear strength measurements and sampling for bulk density and water content determinations.

Hudson 86018

Hudson 86018 Flemish Pass cores were obtained using a standard 30-foot Benthos piston corer with a 1-tonne head. Trigger Weight Core 15 was the only core processed during the cruise. The other cores were processed in May 1987 at AGC's core lab. A problem arose in coring and processing these cores due to a major defect in the liners in which they were collected. During the coring operations, liners frequently imploded and became jammed in the core barrels. This was attributed to the behavior of the penetrated dilatant sands and the defect in the liners. The liners of both Piston Cores 17 and 18 were severely imploded, and the cores had to be hammered out of the barrels. No physical properties testing was performed on these two cores, since the sediments were assumed to be disturbed during these procedures.

The problem with the liners was one of manufacturing control, and resulted in high hoop stresses in the liners. When Trigger Weight Core 15 was split on board, the gap made by

the router closed and overlapped behind the router bit, resulting in disturbance to the enclosed sediments. The degree of disturbance associated with this implosion was considered unacceptable for undisturbed physical properties testing. Therefore the cores were cut into 0.5 meter sections, and the enclosed sediment carefully extruded into previously split acceptable liners. The sediment was then split and processed.

A few subsamples earmarked for consolidation testing were taken prior to splitting. After splitting, cores were subsampled for determination of water content and bulk density, Atterberg limits, and grain size. Tests were also performed in the split cores for vane shear strength and compressional wave velocity.

Hudson 87008

Hudson 87008 cores were collected using the Long Core Facility, a piston coring system that obtains 11-cm diameter cores up to 30 meters long. All cores were processed on board, following the usual AGC procedures (Hudson 87008 Cruise Report). Whole round sections were measured for magnetic susceptibility, and then whole-round subsamples were taken for shorebased consolidation testing. Vane shear strength and velocity measurements were made in split cores, and subsampling was carried out for shore-based measurements of index properties and SEM fabric analysis.

Sampling and Testing Methods

Measurements of compressional-wave (p-wave) velocities were carried out using the Bedford Institute of Oceanography (BIO)/Dalhousie University Department of Oceanography's Digital Sound Velocimeter (DSV). This device measures the speed of p-waves by determining the time of transit of a signal between two rigidly fixed piezoelectric transducers embedded in the sediment core. Hudson 86018 cores were collected in 6-cm diameter liners, which do not provide enough room for measurement in the transverse (perpendicular to the core axis) direction. Hudson 87008 cores were obtained with a large-diameter corer (11-cm diameter); this large-diameter corer allowed measurement of velocity in both the longitudinal (parallel to the core axis) and transverse directions. Velocities are corrected to temperatures approximating those at the seafloor.

Vane shear tests (BS1377) were performed at 20-cm intervals in all cores, except where zones of high sand content were encountered. The AGC computer-interfaced motorized miniature vane shear device, a modification of the Wykham-Farrance device, was used. This apparatus employs a 1.27-cm vane at a rotation rate of 60° per minute. Peak and remoulded data are reported. Fall cone data was collected during 87008, and is also included.

Subsamples for water content and bulk density determinations were taken at a frequency of one every 10 cm where possible, and were processed at BIO. Those from Hudson 87008 were processed using the penta-pycnometer, resulting in more accurate bulk density results than have been obtained with the formerly used piston-syringe method. Water content is calculated as a percentage of the dry weight of the sample. A correction for the salt content, using Noorany's (1984) equations, was used in calculating the water content values.

Atterberg limit testing has been carried out on selected cores in accordance with ASTM D4318-84 (with some modifications). This data is presented in Figure 2 and Table A-2 of the Appendix. The liquid and plastic limits define the upper and lower water content range over which a soil exhibits plastic behavior. The plasticity index is the liquid limit minus the plastic limit.

Grain size tests have been performed using a standard sieve bank and settling column for the fine-grained fraction (BS 1377, 1.2). Since these tests require a large sample volume, the results shown are over the depth range indicated by the vertical heavy bars.

GABRIEL VALLEY AREA CORES

In general, the cores obtained in the Gabriel Valley area were of poor quality for physical properties study. The implosion of liners caused disturbance of Piston Core (PC) 86018-17 and PC 86018-18. Thus no physical properties sampling was performed. The PC 86018-16 attempt resulted in just a small sample in the bottom of the liner, which was bagged. PC 86018-15 was a successful core, but with some flow-in at the bottom.

Disturbance in the cores resulted in no physical properties testing in Long Core (LC) 87008-16, LC 87008-17, and LC 87008-28. In LC 87008-16, the top section of liner was imploded, and the remaining approximately 420 meters were particularly gassy with considerable disturbance. LC 87008-17 was a reverse shoe experiment, and thus the obtained sediments were unsuitable for physical properties testing. The bottom sections of LC 87008-28 were imploded, and in the core that was obtained, there was flow-in below 312 meters.

86018-15

Figure 3 shows lithology and measured physical properties for PC 86018-15. The physical properties data are also presented in Table 3. The core consists predominantly of silty sand, sand, and sandy silt. Flow-in was suspected below approximately 2.5 meters. The high sand content encountered throughout much of this core resulted in some difficulty in measuring undisturbed physical properties parameters. Most of the core was too sandy to perform vane shear measurements. Only one value of peak strength (11.9 kPa at 2.25 meters in the core) was obtained.

Velocity data are also unreliable, as drainage likely occurs during insertion of the probles. The last two measurements in the core, however, were obtained in a layer of mottled olive mud, with little or no sand, and can thus be considered with more confidence.

It was observed in PC 86018-15 (and in other cores in this study where the upper few meters were very sandy) that low water contents and high bulk densities were measured near the top of the core. While a particular water content may be the end result of many processes, it appears that anomalously low water contents occur near the tops of the sandy cores and in sand layers throughout the cores. Compaction and dewatering of the sands as a result of coring disturbance may be the cause of these values.

One grain size sample was obtained at 1.12-1.35 meters. The results are shown in Figure 3. The test results indicate a clayey sandy silt with 46% silt and almost equal amounts of clay and sand (29% and 23%, respectively).

Trigger Weight Core (TWC) 86018-15 was split and analyzed during the cruise. Figure 4 shows downcore profiles of lithology and physical properties. The data are also presented in Table 4. It is impossible to establish any correlations between the physical properties data in the trigger weight and the data in the piston core due to the small quantity of data available.

Atterberg limits samples were obtained from the intervals 0-0.18 meters, 0.73-0.79 meters, and 0.99-1.10 meters. The results are plotted on a plasticity chart in Figure 2 and are also given in Table 2, along with plasticity data from other cores. The sample obtained from 0-0.18 meters was determined to be nonplastic. The other two samples plotted at the low end of the A-line, as clayey silts of low plasticity.

86018-16

No sediment was obtained in PC 86018-16, so the trigger weight core was the only sample taken at this site, just slightly northeast of site 86018-15. Lithology and physical properties profiles are shown in Figure 5. The physical properties data is given in Table 5. The sample at 0.30 meters has a higher velocity and bulk density and lower water content than the sample at 0.45 meters and this may again indicate some compaction of the upper sediments during coring.

Both of the sample zones were described as mud with some sand. Different sand contents and the possibility of more drainage and/or disturbance at one sample site could account for the differences in the properties measured at the two depths. It is difficult to draw any conclusions with the data available.

KYLE VALLEY AREA CORES

Generally, the cores studied from the Kyle Valley area are both longer and in better condition than those obtained from the Gabriel Valley area. However, as in the Gabriel Valley area, the high sand content and problems with the liners (for 86018 cores) did cause some difficulty in the measurement of physical properties. These problems will be discussed as they pertain to each core.

85044-03

Site 85044-03 is located on the western slope of Flemish Pass, just south of Kyle Valley. Figure 6 shows the downcore lithology and physical properties profiles for PC 85044-03. The data are also presented in Table 6.

The water content and bulk density profiles show three distinct zones. From 0.26-1.05 meters, the water content increases gradually to 45%, with a corresponding decrease in bulk density (to 1.8 g/cm^3) over the same interval. This zone is described as silty mud with scattered clasts and occasional thin sequences of muddy gravel. The water content and bulk density profiles change near 1.4 mbsf. Water content drops to 25% to 30% and bulk density increases to slightly greater than 2.0 g/cm^3. At approximately 3 mbsf, another significant change in the profiles is seen. Water content increases sharply to 60% and bulk density decreases to 1.6 g/cm^3. The profiles subsequently follow fairly regular trends of slightly decreasing water content and slightly increasing bulk density with increasing depth.

Frequent grain size sampling provides a good profile in Figure 6. The grain size data indicates that the upper 3 meters of the core contain much higher sand content overall than the sediments below 3 mbsf (with the exception of a few spikes). High permeability in these sandy zones and compaction during coring may have resulted in drainage of pore fluids along the core liner and subsequent alteration of the property profiles.

Figure 7 shows the lithology and physical properties profiles for TWC 85044-03. Table 7 also contains the data. Comparisons of the profiles of the piston and trigger weight core data indicate that the surface of the piston core corresponds approximately to 0.40 meters in the trigger weight core.

85044-04

The core site was located further south of Kyle Valley near the crest of a shallow diapir-like feature detected during a SeaMarc survey. There were no physical properties measurements in the upper meter or between 3.42 and 3.80 meters due to disturbance of the sediment. The trigger weight core was lost.

The lithology and physical properties profiles are presented in Figure 8 and the data is also found in Table 8. From 1.25 meters to 1.83 meters there is a decrease in water content to a value of 37% and a corresponding increase in bulk density to a value of 1.90 g/cm^3. A sharp reversal of the expected trend then occurs in the profiles, with water content increasing to 59% and bulk density decreasing to 1.71 g/cm^3 at 2.37 meters.

The vane shear strength profiles in this zone show that the measured peak strength is very low and close to the measured remoulded strength. The lithologic description does not indicate any cause for such results. Another examination of the core and perhaps some x-rays in this zone may help to determine whether core disturbance is likely the cause, or whether the profiles indicate some sediment process (e.g. debris flow).

86018-12

Core 86018-12 is located upslope from most of the other cores in the Kyle Valley area, in just under 1000 meters water depth. The liner encasing the upper meter of sediment in the piston core was badly imploded, and thus no physical properties measurements were performed in this interval. Lithology and physical properties profiles for PC 86018-12 are shown in Figure 9, and the data are also presented in Table 9. Data for TWC 86018-12 are

presented in Figure 10 and Table 10.

The velocity profile shows good correlation with the bulk density profile and, in general, the profiles reflect the lithology. The low water content and high bulk density and velocity at 3 meters indicates the presence of a fine sand layer. A similar change in profile is seen near 4 meters. These sandy zones have likely experienced some loss of pore fluids due to drainage along the core liner caused by compaction during coring.

The two low water content measurements at 0.66 meters and 0.88 meters in the piston core might be a result of the disturbance due to the imploded liner, but these values do seem to correspond with those in the trigger weight core, and thus may be real. The descriptions also do not indicate any obvious reason for the water content and bulk density values obtained at 1.18 meters, 1.38 meters, and 1.55 meters. The values in this zone are uniform at 44%, then jump to 70% at 1.88 meters. The sediment from 1.06-1.52 meters is described uniform gray mud with local mottling. This indicates that the intensity of mottling is the main difference between the two lithologies, as there is no significant grain size change. The 86018-12 core site appears to be located within the Kyle Valley proper, and the zones of higher water content may indicate zones of mass deposition of sediment by debris flows. The zones of debris flow deposition would be expected to have higher water contents since they have not dewatered in usual manner. The "mottling" described may be debris flow features. Again, another look at the core and possibly some x-rays might assist in the interpretation in this zone. More grain size tests would also be useful.

86018-13

Core 86018-13 is located slightly north of Kyle Valley in the valley floor. Figure 11 shows the downcore profiles of lithology and physical properties. The physical properties data is also given in Table 11. Figure 12 and Table 12 present the physical properties data for the trigger weight core.

The description for 86018-13 shows frequent alternations of mud (sometimes mottled), silty mud, and sandy mud, apparently reflecting different depositional modes. The physical properties profiles are extremely variable, principally due to variations in sand content. However, as seen in some of the previous cores, there is an unusual overall trend to the profiles in the upper few meters. Above 26 mbsf, the water contents increase, while the bulk densities and p-wave velocities decrease. This is again opposite to the trend expected in normally consolidating sediment sequences, and may indicate disturbance in this upper section.

Below 2.6 meters, water content generally decreases, and vane strength, bulk density and velocity increase slightly (with variations due to laminae with higher and lower sand content). No vane measurements were performed in the interval 3.7-4.5 meters in the piston core due to the high sand content. Lower water contents and higher bulk densities are measured in this zone, and these irregular values are likely the result of compaction of the sand and drainage along the liner during and after coring.

This 86018-13 core site is located further from the valley mouth than the 86018-12 site. The generally smoother profiles for 86018-13 are probably explained by its receiving more distal turbidites, i.e. no thick debris flow as experienced by 86018-12 located within the valley.

86018-14

Physical properties data for PC 86018-14 are found in Figure 13 and Table 13. The data for the trigger weight core are found in Figure 14 and Table 14. Insufficient data exists for the upper meter of the piston core to allow correlation between the piston and trigger weight cores. The piston core generally has high sand content, and thus few vane strength measurements were made.

Generally, there is little variation downcore in PC 86018-14, as compared with PC 86018-12. PC 86018-14 is located in the middle of the pass floor, much further from the valley source of debris flow sediments. The most dramatic variations in physical properties occur near the bottom of the core, where the lithology changes from sand and sandy mud throughout the upper 3.4 meters of the piston core to stiff clayey mud from 3.44 to 3.97 mbsf. This stiff mud contained scattered clasts, but no sand. This change in lithology is reflected in increasing water contents, high vane strengths, and decreasing bulk densities and p-wave velocities, and changing grain size ratios.

87008-13

The physical properties data for LC 87008-13 are presented in Figure 15 and Table 15. The profiles are fairly uneventful, except for some slight variations seen in zones where alternating beds of sand and mud occur, such as between 5-6 meters. As has been observed in previous cores, the upper few meters of sediment in LC 87008-13 show physical properties trends opposite to those expected for a normally-consolidating sequence; this is likely indicative of disturbance during coring.

The site of LC 87008-13 is located on the east side of the pass floor, and is too far from the source valley to be subject to the majority of the debris flow deposition. Instead, thinly-bedded turbidites dominate. The resulting physical properties profiles, while showing some slight irregularities, are smoother than those for cores located closer to the valley source.

87008-15

Figure 16 and Table 16 present the physical properties data for LC 87008-15. The profiles for this core are much more variable than those of LC 87008-13. There is a distinct zone of anomalous physical properties between approximately 4.2 and 5.8 meters. Water contents increase sharply to 50-60% from 20-30% and bulk densities and velocities drop. At approximately 6 mbsf, the profile again experiences a sharp change, as water contents drop and the bulk densities and velocities increase. Shear strength profiles for 87008-15 show considerable variation, and the values obtained and trends observed for peak strength by vane and fall cone methods are in reasonable agreement.

The site of LC 87008-15 is located near the mouth of the Kyle Valley, and is thus much

closer to source sediments from debris flows that move down the valley. Irregular zones of higher water content may represent underconsoidated, rapidly deposited flow sequences, although this cannot be determined without stress history evaluation.

SUMMARY

Physical properties data obtained from cores taken at nine sites in Flemish Pass have been presented. The properties measured include water content, shear strength, bulk density, compressional-wave velocity, grain size, and Atterberg limits. In general, cores obtained closer to the valley systems, which supply the pass with debris flow sediments, show significantly more variation in physical properties with depth. These variations likely reflect the rapid deposition of debris flow sequences. Cores obtained at sites closer to the east side of the pass show much less variation in physical properties. Stress history evaluation is required to confirm this interpretation.

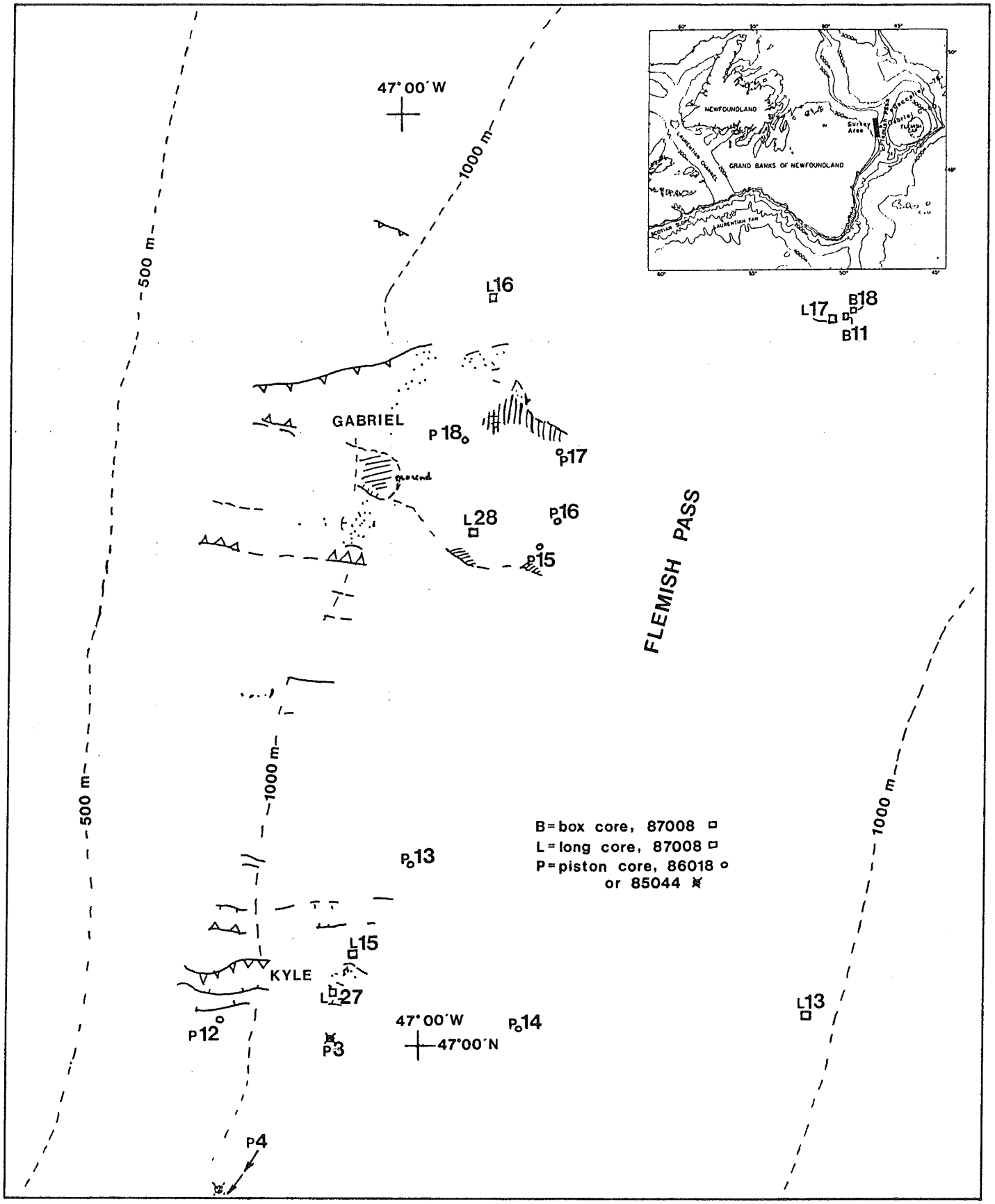

Figure 1 - Western Slope of Flemish Pass Showing Location of Kyle and Gabriel Valleys and Core Sites

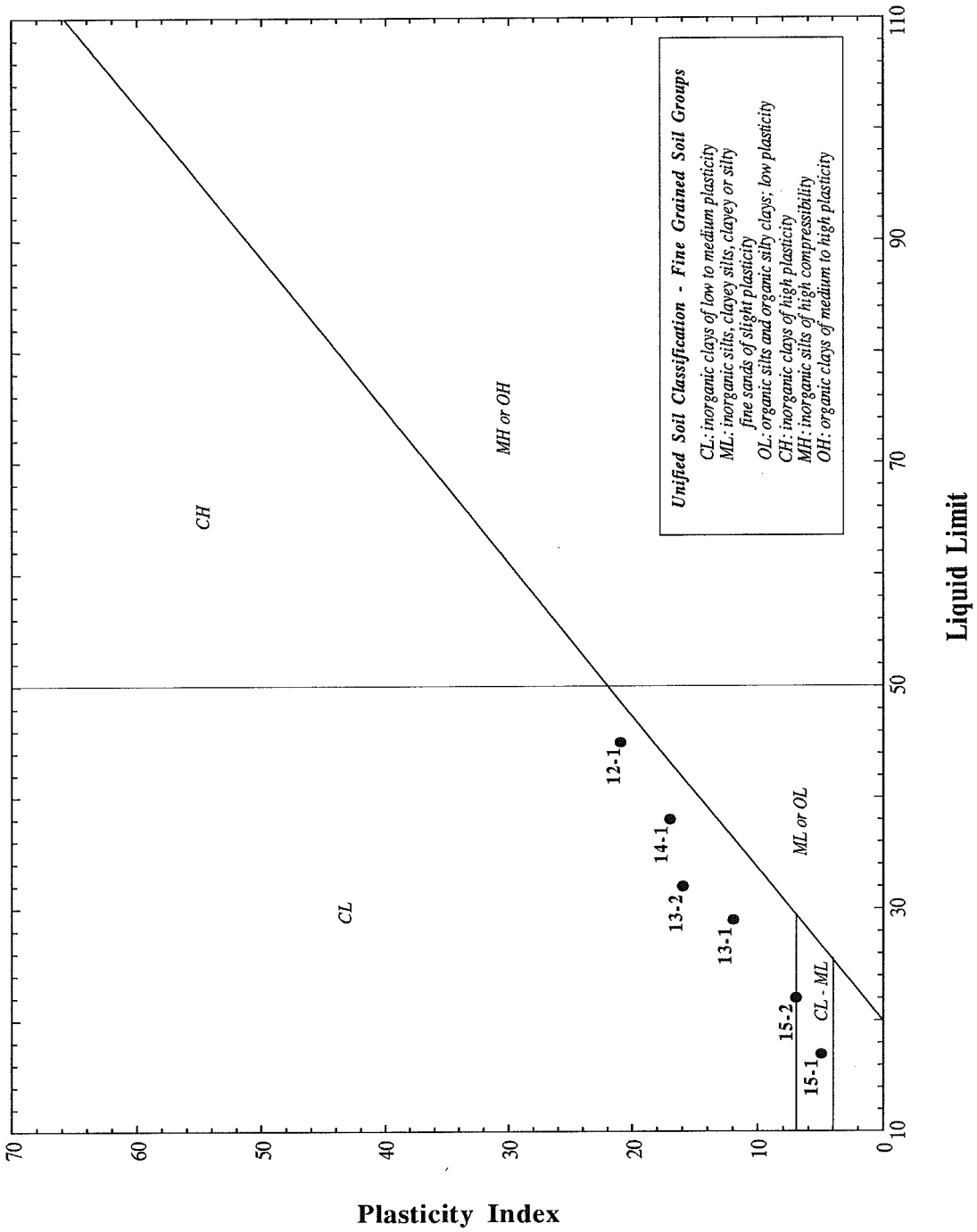

Figure 2 - Atterberg Limits Data for 86018 Cores

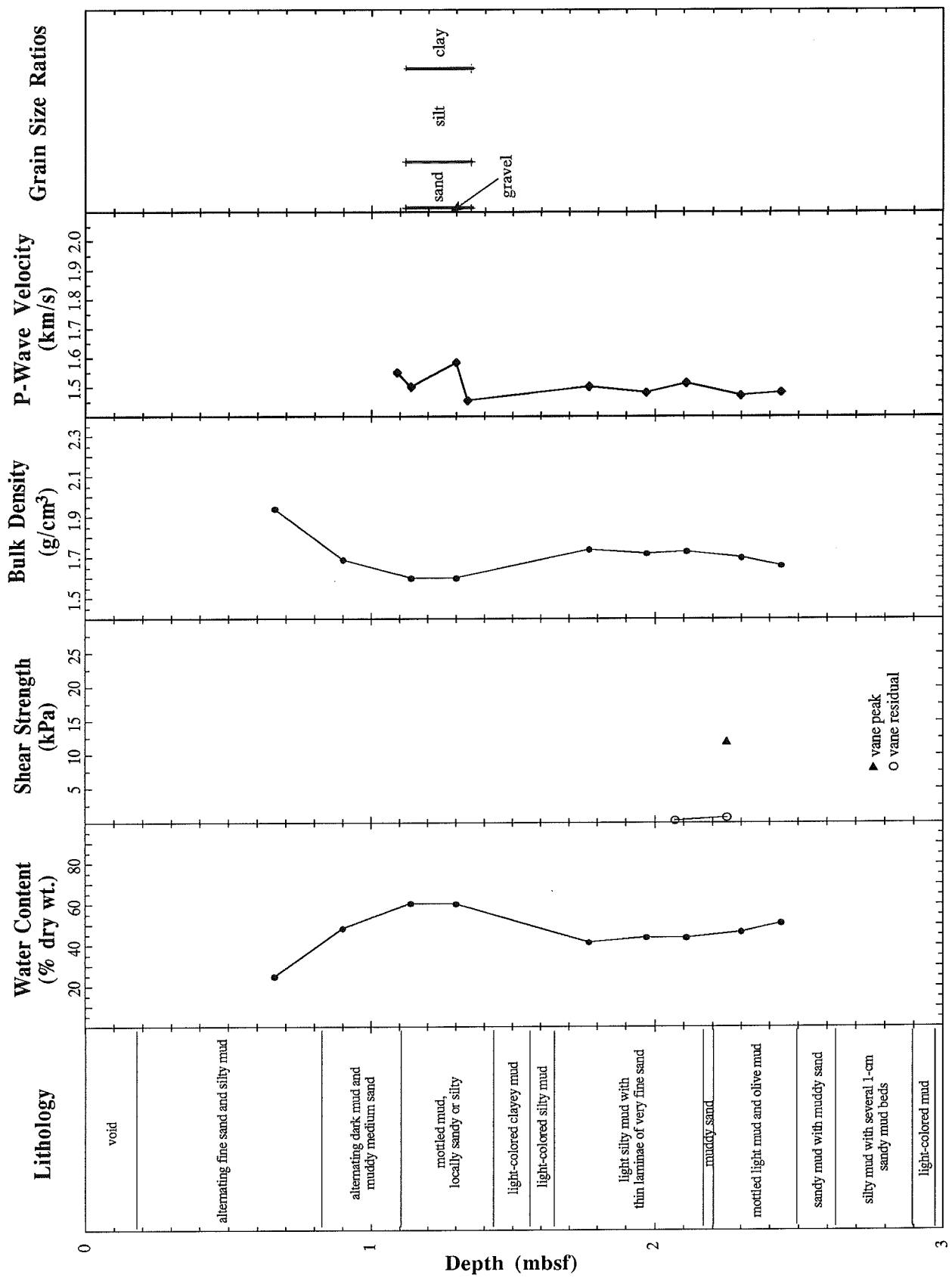

Figure 3 - Physical Properties Data for PC 86018-15

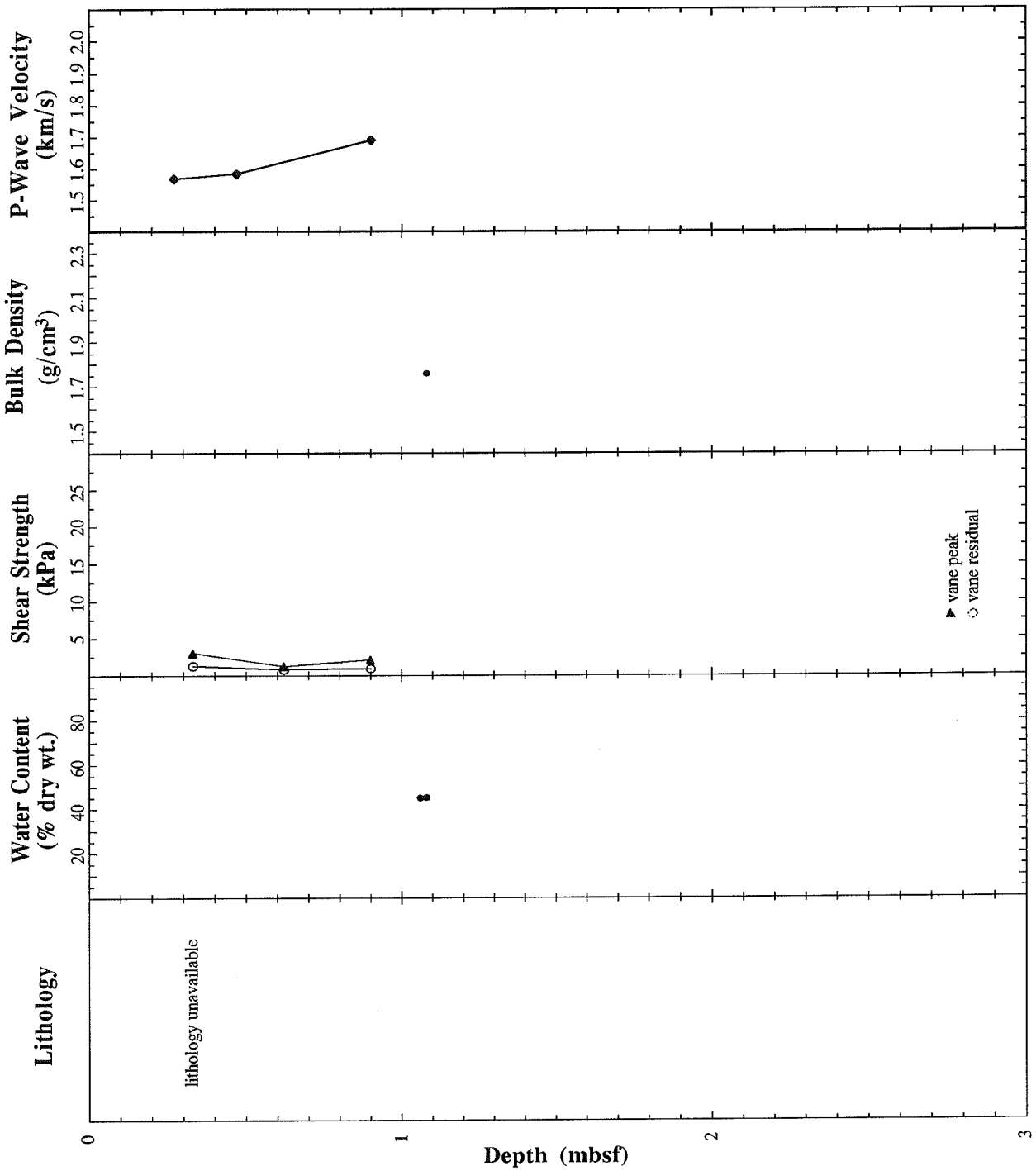

Figure 4 - Physical Properties Data for TWC 86018-15

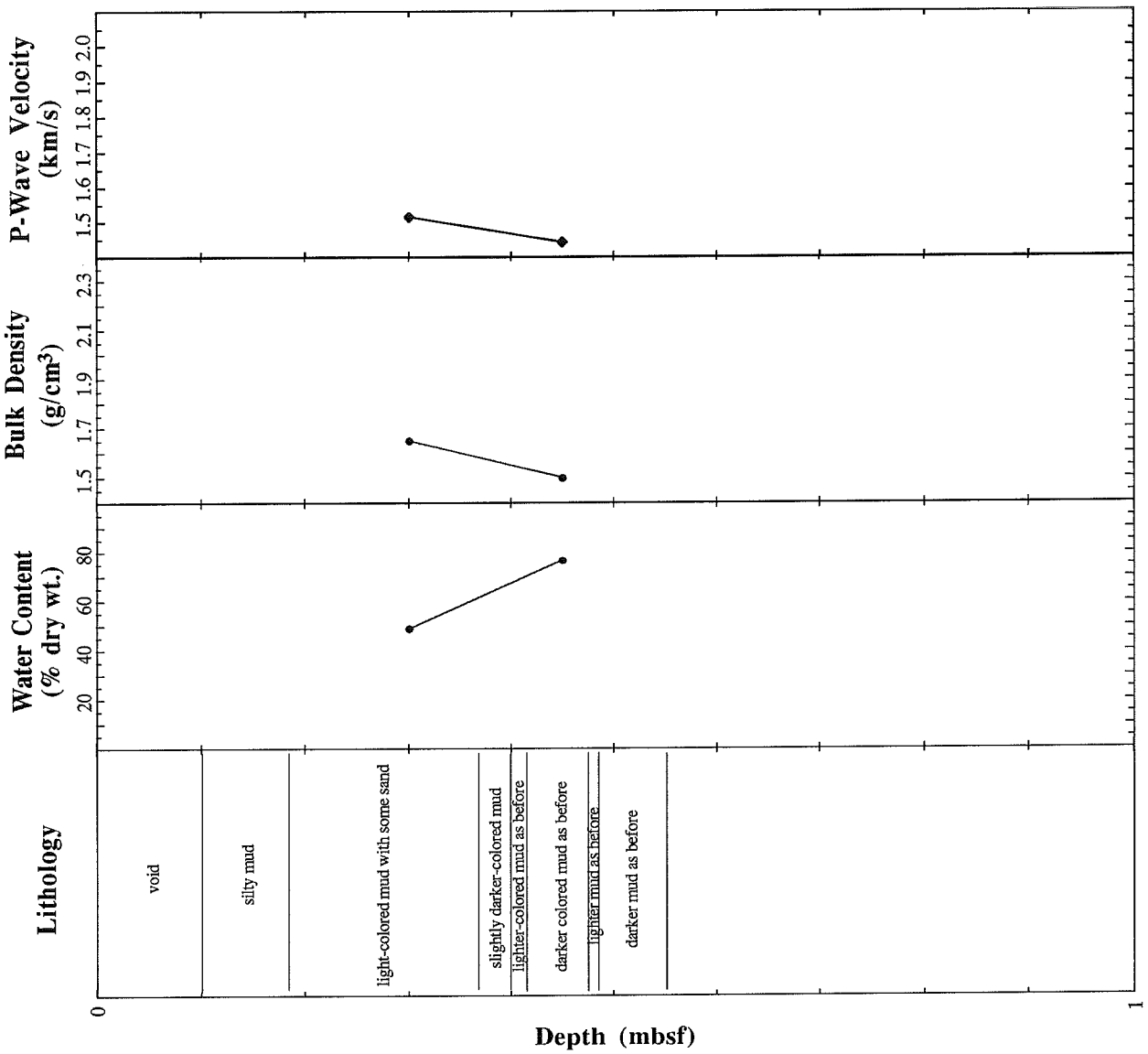

Figure 5 - Physical Properties Data for TWC 86018-16

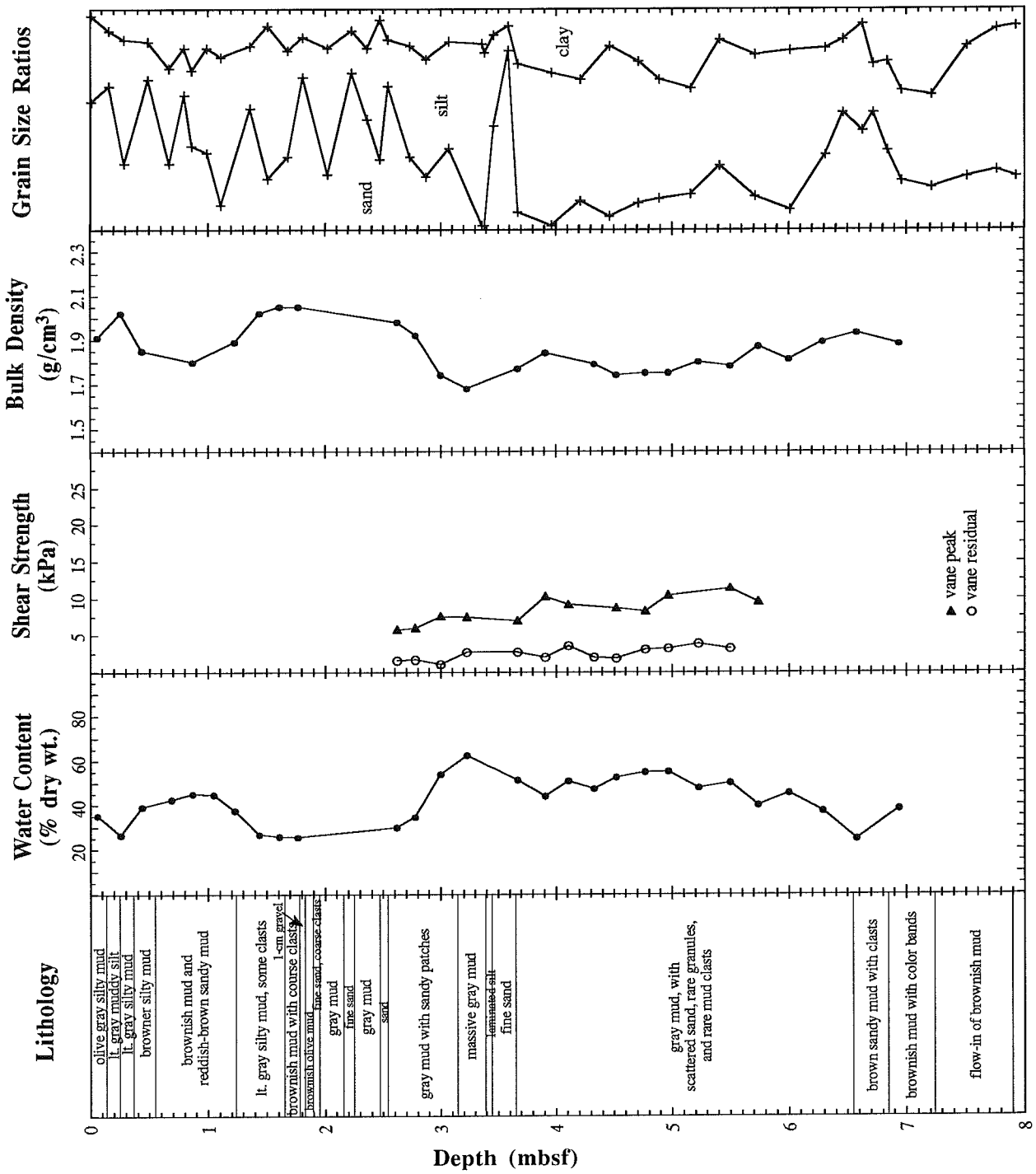

Figure 6 - Physical Properties Data for PC 85044-03

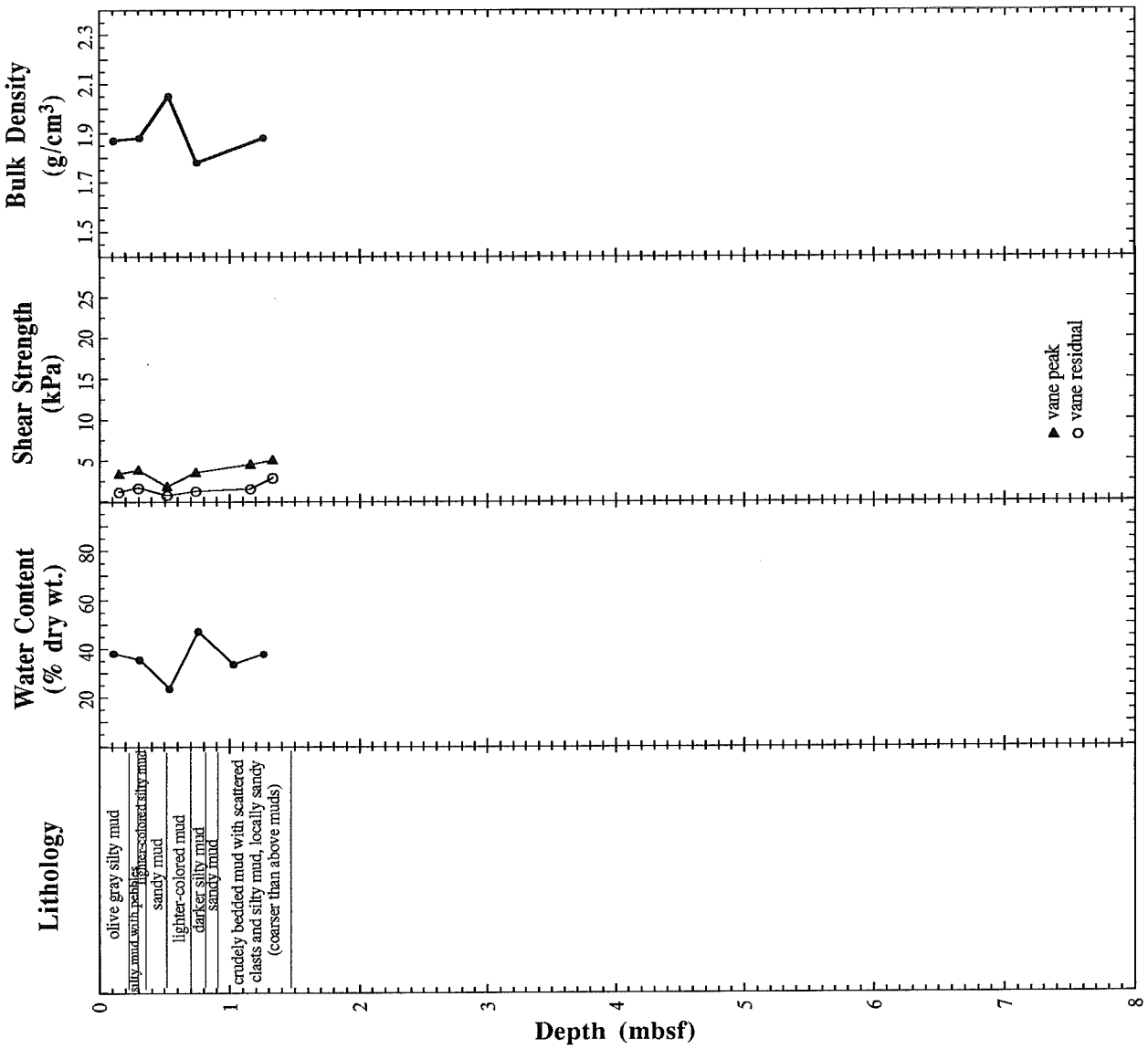

Figure 7 - Physical Properties Data for TWC 85044-03

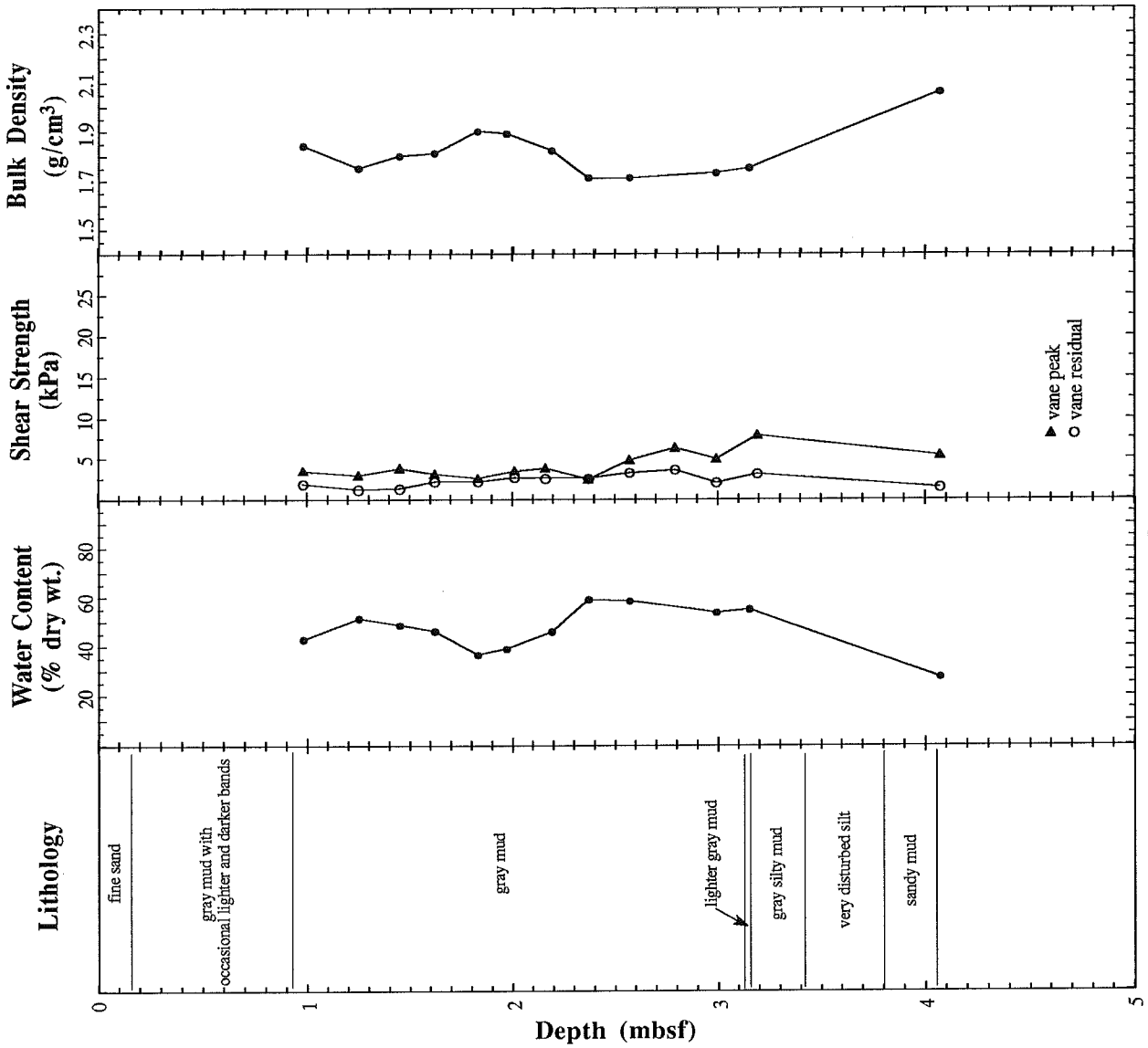

Figure 8 - Physical Properties Data for PC 85044-04

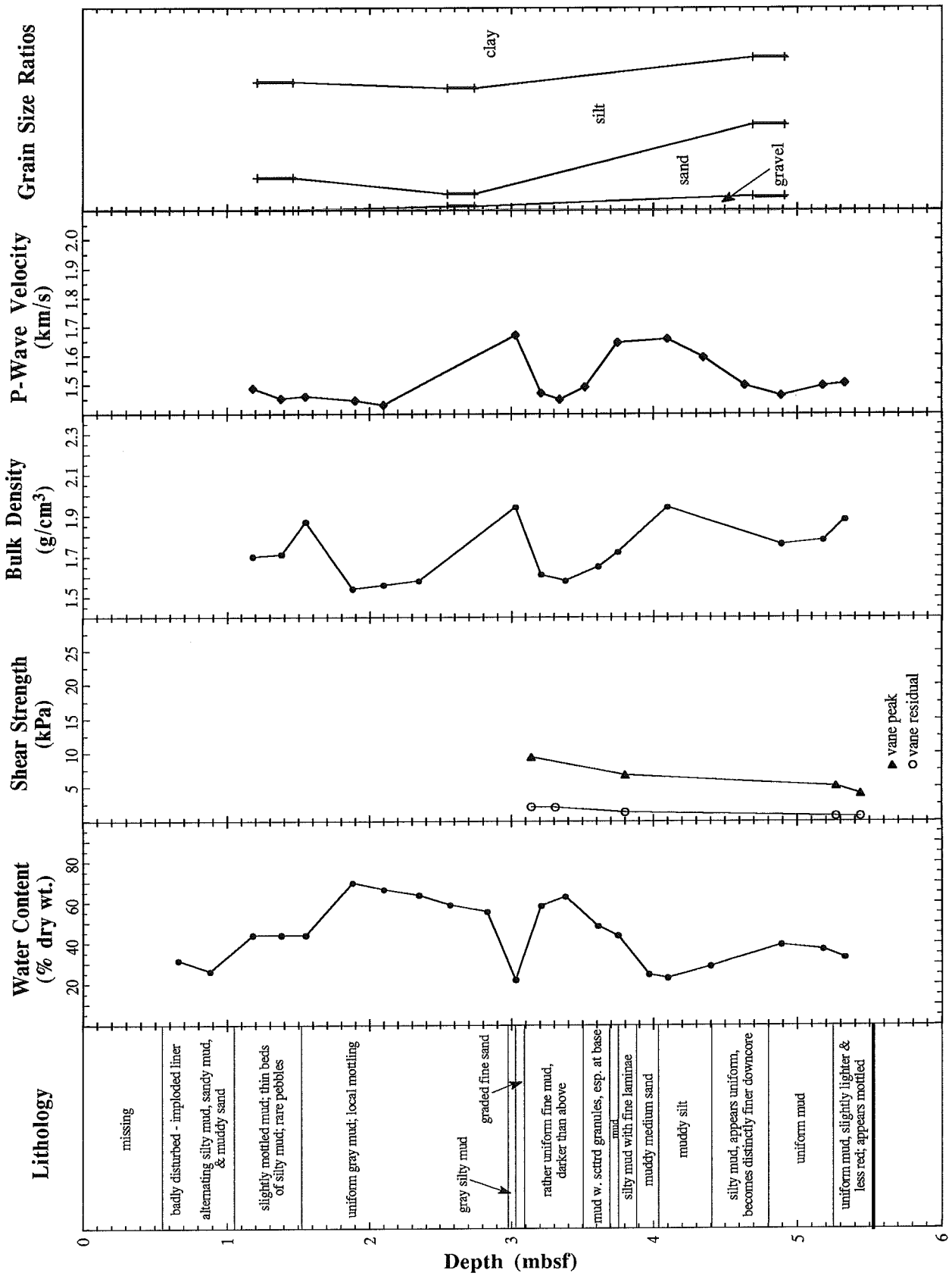

Figure 9 - Physical Properties Data for PC 86018-12

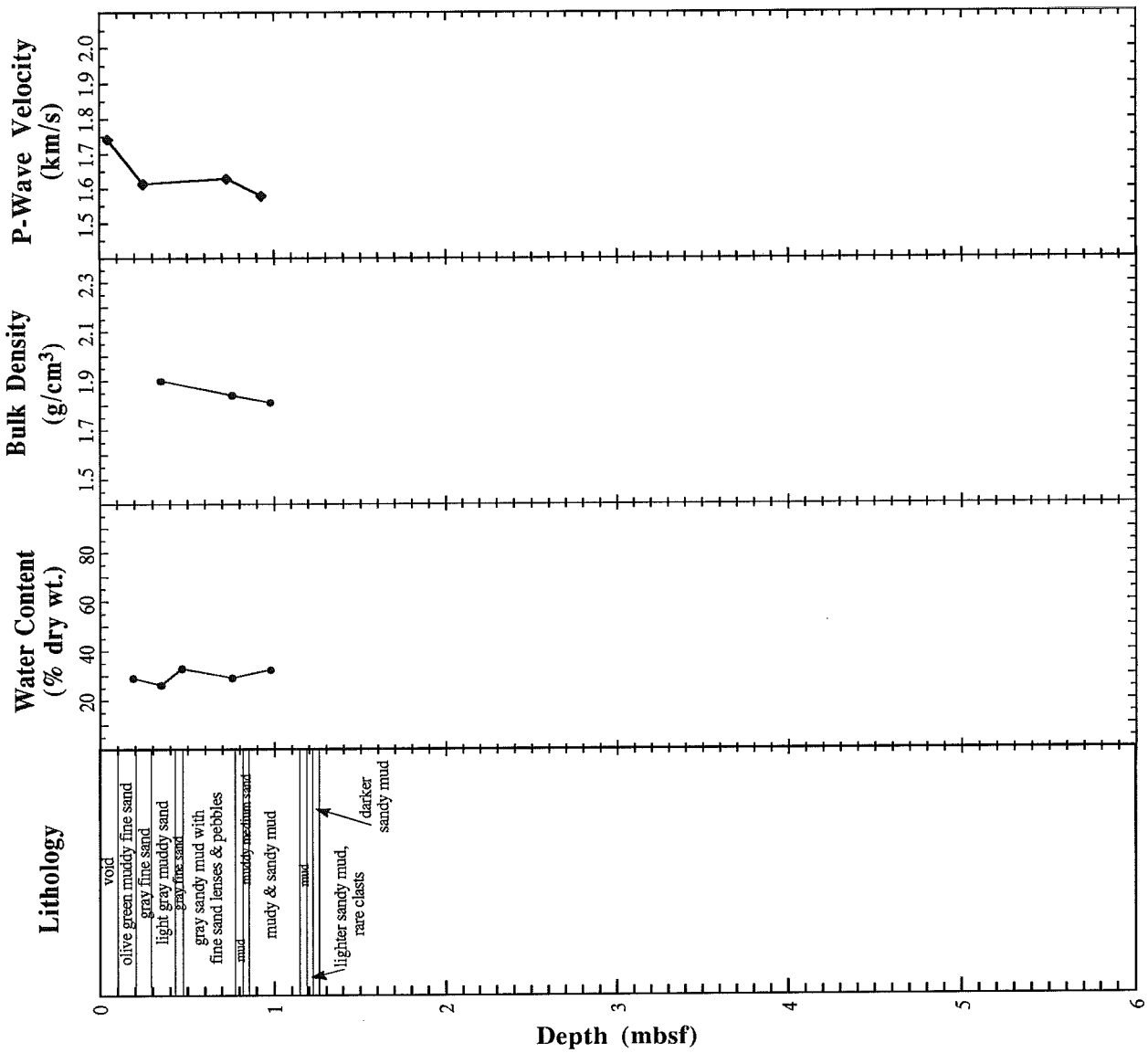

Figure 10 - Physical Properties Data for TWC 86018-12

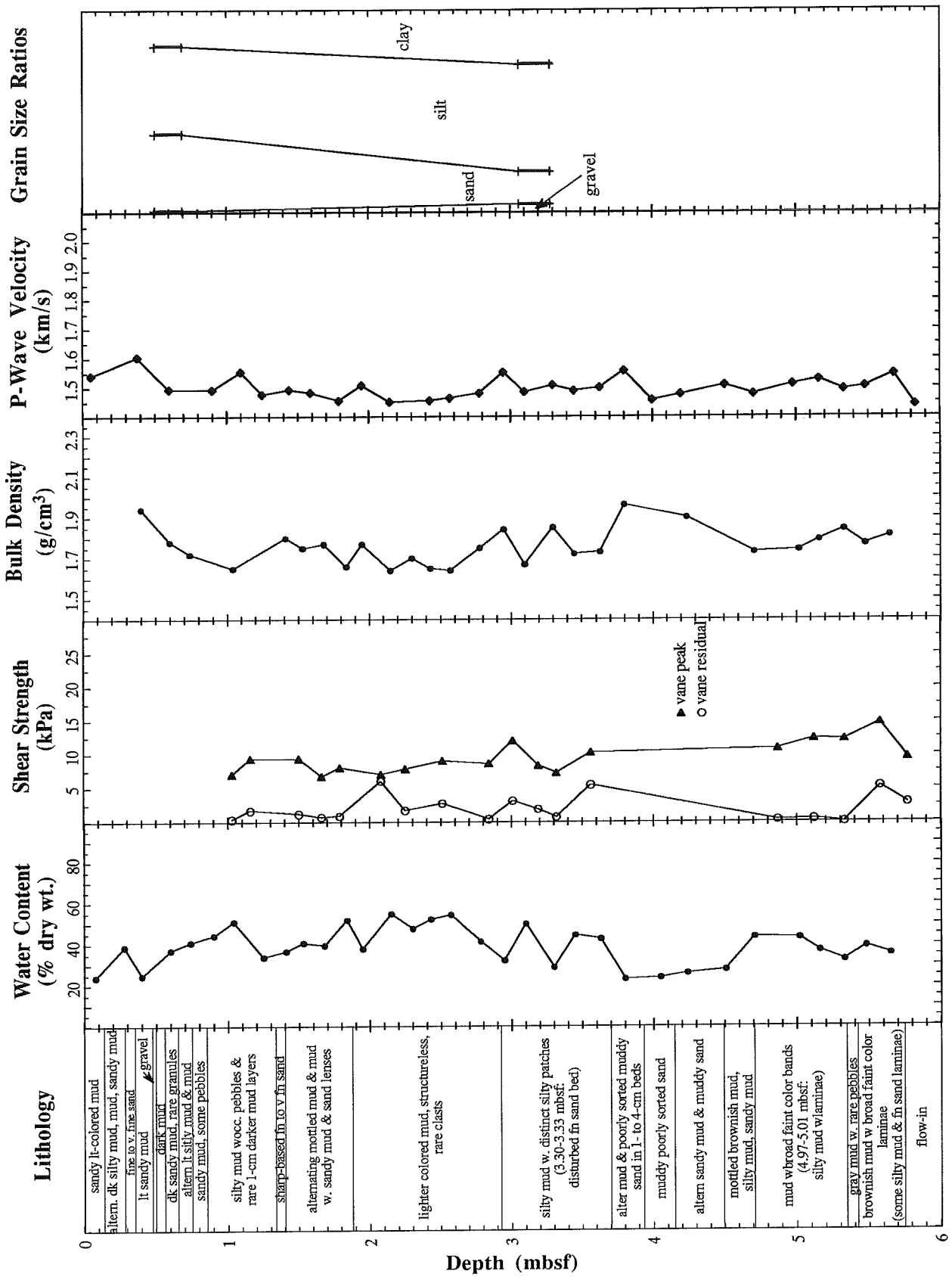

Figure 11 - Physical Properties Data for PC 86018-13

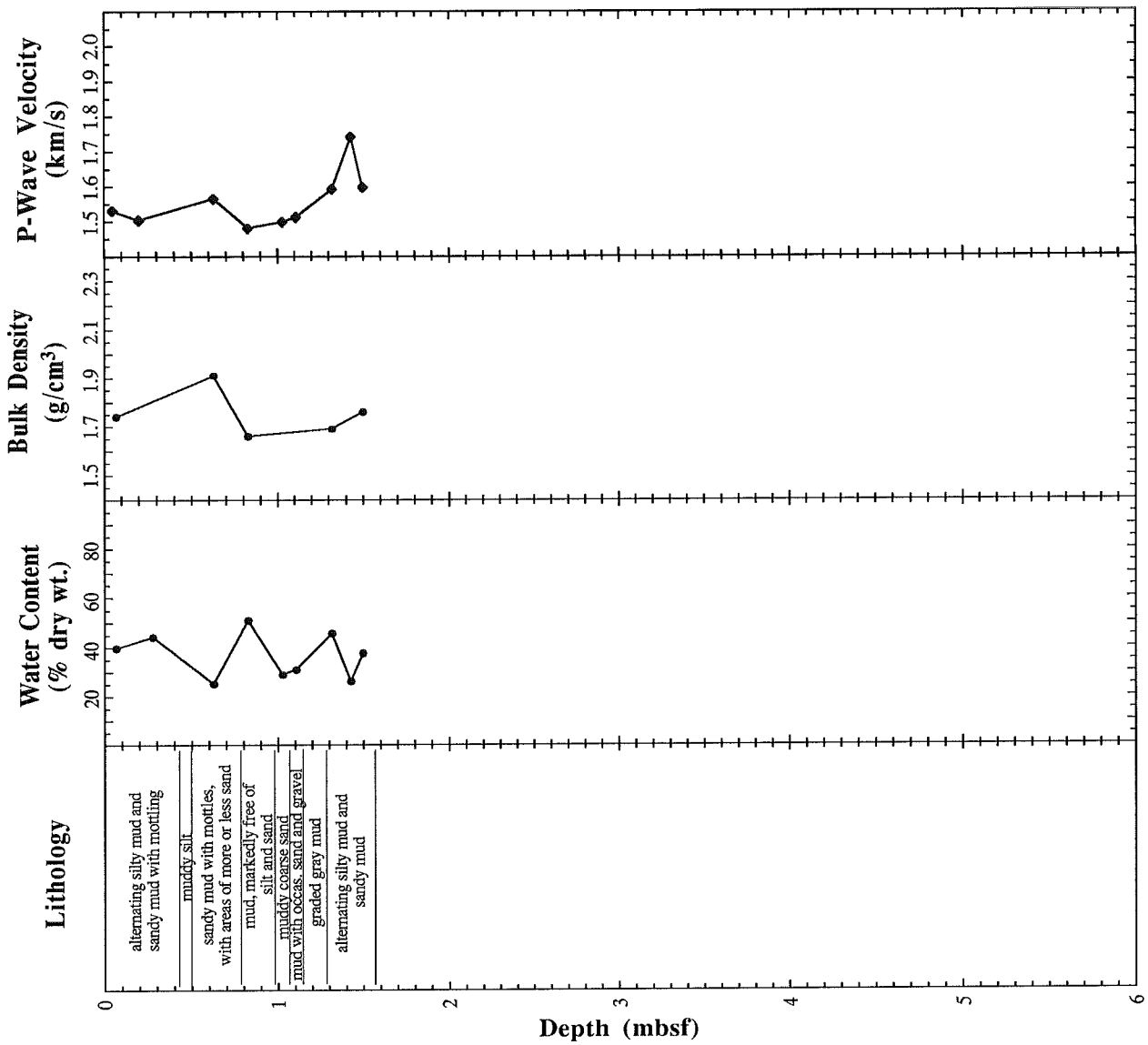

Figure 12 - Physical Properties Data for TWC 86018-13

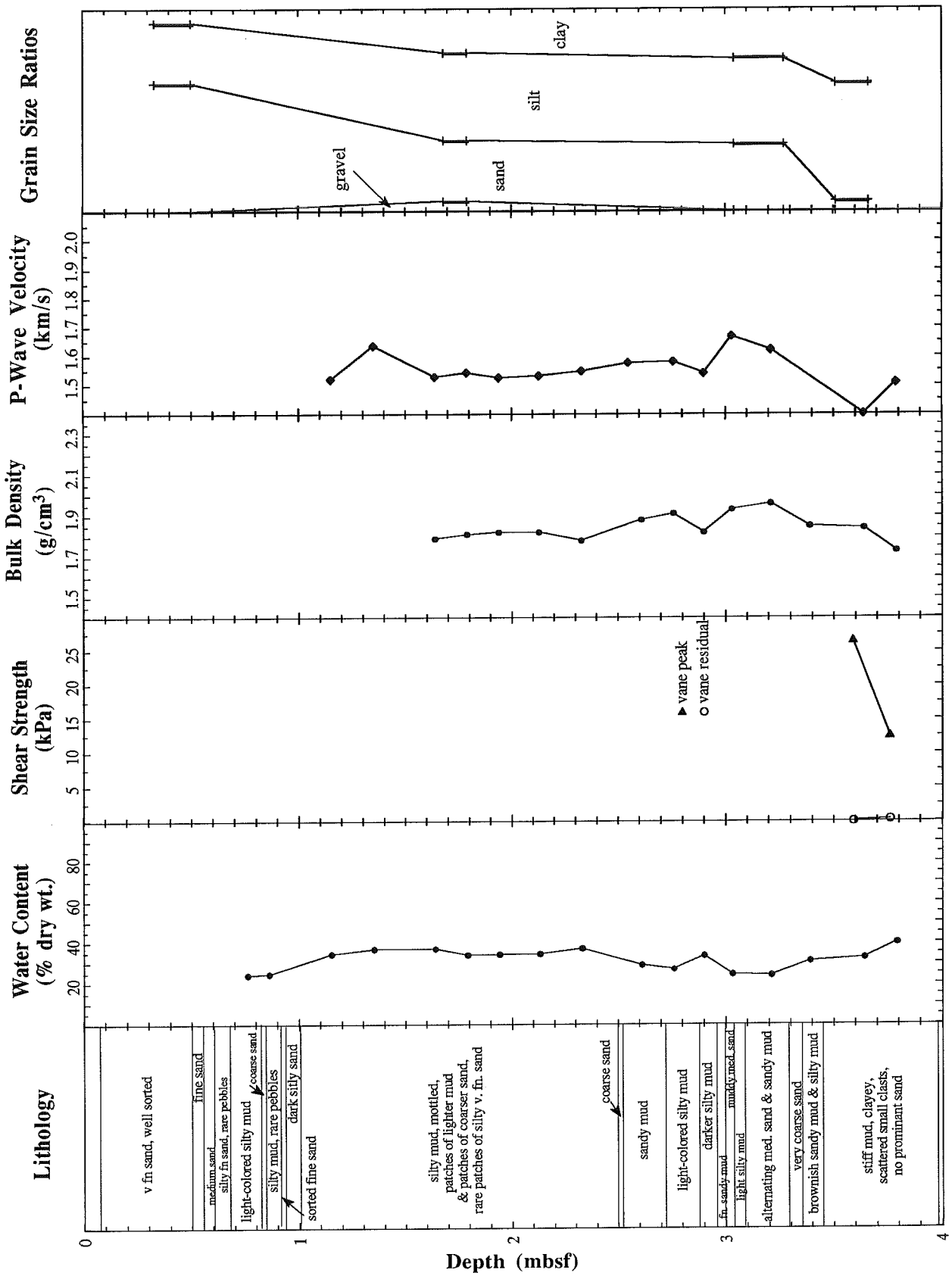

Figure 13 - Physical Properties Data for PC 86018-14

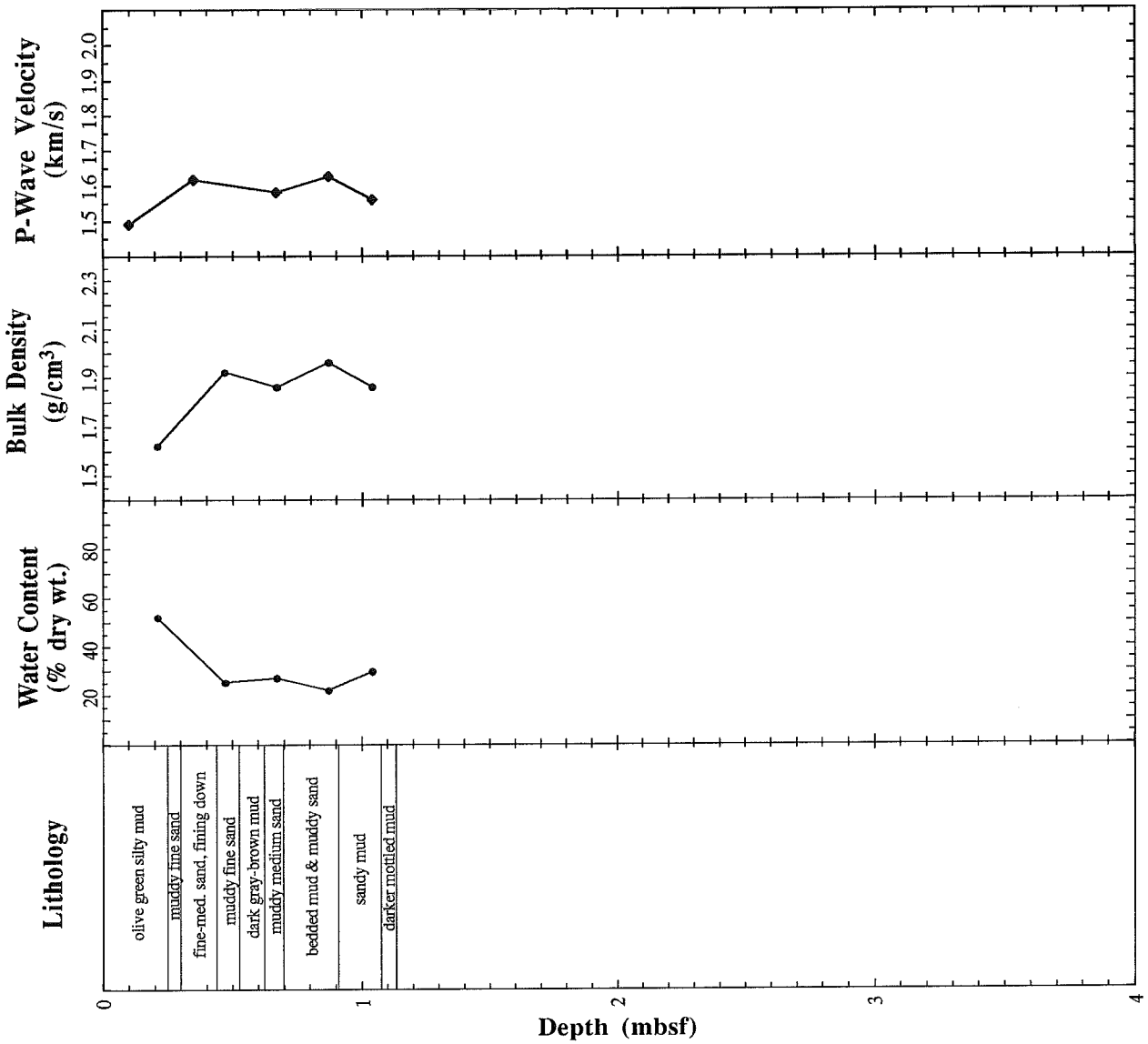

Figure 14 - Physical Properties Data for TWC 86018-14

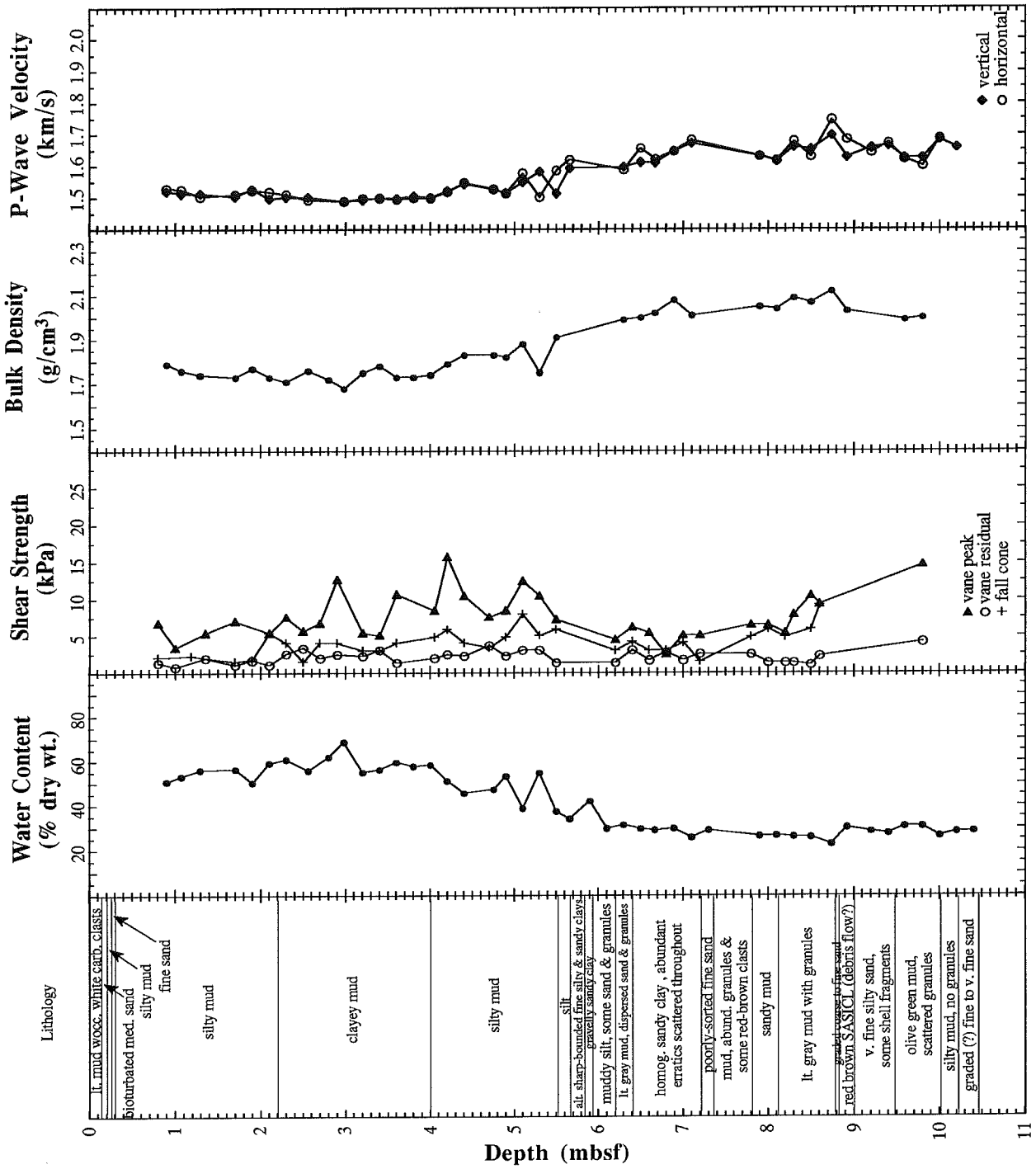

Figure 15 - Physical Properties Data for LCF 87008-13

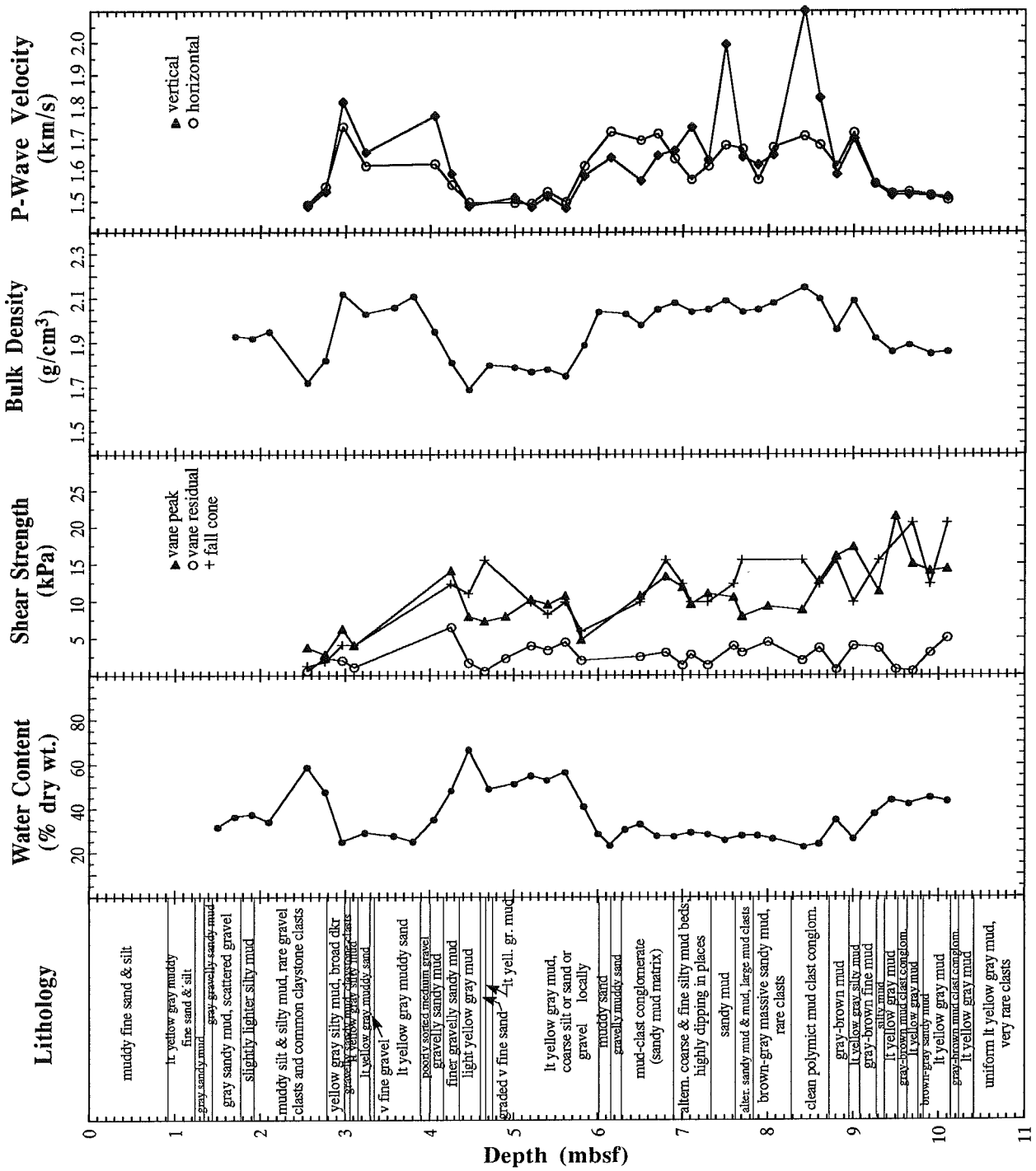

Figure 16 - Physical Properties Data for LCF 87008-015

TABLE 1 - Cores Analyzed in Study

Region	Hudson Cruise #	Site #	Water Depth (m)	Type of Core	Length of Core (m)
Gabriel	86018	15	1116	piston trigger	7.07 1.15
		16	1100	trigger	0.55
Kyle	85044	03	112	piston trigger	7.88 1.47
		04	1100	piston	4.92
	86018	12	993	piston trigger	5.52 1.26
		13	1161	piston trigger	6.41 1.57
		14	1170	piston trigger	3.96 1.13
	87008	13	1080	long core	10.46
		15	1071	long core	11.22

TABLE 2 - Atterberg Limits Data for 86018 Cores

Sample	Core	Depth Interval (mbsf)	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)
12-1	PC12	2.44-2.48	45	24	21
13-1	PC13	1.44-1.59	29	17	12
13-2	PC13	5.04-5.28	32	16	116
14-1	PC14	3.66-3.82	38	21	17
15-1	TWC15	0-0.18		non-plastic	
15-2	TWC15	0.73-0.79	17	12	5
15-3	TWC15	0.99-1.10	22	15	7

TABLE 3. Physical Properties Data for 86018-PC15

Depth (mbsf)	P-wave Velocity (m/s)	Bulk Density (g/cc)	Water Content (% dry wt.)	Salinity (ppt)	Peak Vane Strength (kPa)	Remould. Vane Strength (kPa)	sand (%)	silt (%)	clay (%)
0.66	****	1.94	24.7	34	****	****	**	**	**
0.90	****	1.69	48.3	34	****	****	**	**	**
1.09	1549	****	****	**	****	****	**	**	**
1.12-1.35	****	****	****	**	****	****	23	46	29
1.14	1501	1.60	60.4	34	****	****	**	**	**
1.30	1584	1.60	60.2	34	****	****	**	**	**
1.34	1454	****	****	**	****	****	**	**	**
1.77	1501	1.74	41.4	34	****	****	**	**	**
1.97	1481	1.72	43.7	34	****	****	**	**	**
2.07	****	****	****	**	****	0.3	**	**	**
2.11	1513	1.73	43.6	34	****	****	**	**	**
2.25	****	****	****	**	11.9	0.7	**	**	**
2.30	1471	1.70	46.5	34	****	****	**	**	**
2.44	1482	1.66	50.8	34	****	****	**	**	**

TABLE 4. Physical Properties Data for 86018-TWC15

Depth (mbsf)	P-Wave Velocity (m/s)	Bulk Density (g/cc)	Water Content (% dry wt)	Peak Vane Strength (kPa)	Remould. Vane Strength (kPa)
0.27	1567	****	****	****	****
0.33	****	****	****	3.0	1.3
0.47	1583	****	****	****	****
0.62	****	****	****	1.2	0.8
0.90	1690	****	****	2.1	0.9
1.06	****	****	45.0	****	****
1.08	****	1.76	45.3	****	****

TABLE 5. Physical Properties Data for 86018-TWC16

Depth (mbsf)	P-Wave Velocity (m/s)	Bulk Density (g/cc)	Water Content (% dry wt)	Salinity (ppt)
0.30	1514	1.65	48.8	35
0.45	1442	1.50	76.6	35

TABLE 6. Physical Properties for 85044-PC03

Depth (mbsf)	Content (% dry wt.)	Bulk Density (g/cc)	Peak Vane Strength (kPa)	Rem. Vane Strength (kPa)	Sand (%)	Silt (%)	Clay (%)
0.01	****	****	****	****	58	39	3
0.06	35.4	1.91	****	****	**	**	**
0.16	****	****	****	****	65	25	10
0.26	26.7	2.02	****	****	**	**	**
0.29	****	****	****	****	30	56	14
0.44	39.4	1.85	****	****	**	**	**
0.49	****	****	****	****	68	17	14
0.67	****	****	****	****	30	43	27
0.69	42.6	****	****	****	**	**	**
0.80	****	****	****	****	61	21	18
0.86	****	****	****	****	38	34	28
0.87	45.2	1.80	****	****	**	**	**
0.99	****	****	****	****	35	47	18
1.05	44.8	****	****	****	**	**	**
1.11	****	****	****	****	11	67	22
1.23	37.6	1.89	****	****	**	**	**
1.36	****	****	****	****	55	28	17
1.44	26.8	2.02	****	****	**	**	**
1.51	****	****	****	****	23	69	8
1.61	25.9	2.05	****	****	**	**	**
1.68	****	****	****	****	33	48	19
1.77	25.6	2.05	****	****	**	**	**
1.81	****	****	****	****	69	18	13
2.02	****	****	****	****	25	57	18
2.23	****	****	****	****	71	19	9
2.36	****	****	****	****	50	32	18
2.47	****	****	****	****	32	63	6
2.54	****	****	****	****	65	21	14
2.62	30.0	1.98	5.8	1.6	**	**	**

TABLE 6. Physical Properties for 85044-PC03 (continued)

Depth (mbsf)	Water Content (% dry wt.)	Bulk Density (g/cc)	Peak Vane Strength (kPa)	Rem. Vane Strength (kPa)	Sand (%)	Silt (%)	Clay (%)
2.73	****	****	****	****	33	50	17
2.78	34.7	1.92	6.0	1.7	**	**	**
2.87	****	****	****	****	24	53	23
3.00	54.0	1.74	7.6	1.1	**	**	**
3.07	****	****	****	****	37	48	14
3.23	62.6	1.68	7.5	2.7	**	**	**
3.36	****	****	****	****	2	82	16
3.38	****	****	****	****	2	78	20
3.46	****	****	****	****	47	41	12
3.59	****	****	****	****	81	11	7
3.67	51.5	1.77	7.0	2.7	8	67	25
3.91	44.2	1.84	10.3	2.0	**	**	**
3.96	****	****	****	****	2	69	28
4.11	51.0	****	9.2	3.6	**	**	**
4.21	****	****	****	****	13	55	32
4.33	47.4	1.79	39.5	2.0	**	**	**
4.46	****	****	****	****	6	77	17
4.52	52.7	1.74	8.7	1.9	**	**	**
4.71	****	****	****	****	12	64	25
4.77	55.1	1.75	8.3	3.1	**	**	**
4.89	****	****	****	****	14	54	32
4.97	55.3	1.75	10.4	3.2	**	**	**
5.16	****	****	****	****	16	48	37
5.23	47.8	1.80	36.0	3.9	**	**	**
5.41	****	****	****	****	29	57	14
5.50	50.3	1.78	11.4	3.2	**	**	**
5.71	****	****	****	****	15	64	21
5.74	40.0	1.87	9.6	****	**	**	**
6.00	45.5	1.81	****	****	**	**	**
6.01	****	****	****	****	9	72	19
6.29	37.4	1.89	****	****	**	**	**
6.31	****	****	****	****	34	48	18
6.46	****	****	****	****	53	33	15
6.58	24.8	1.93	****	****	**	**	**
6.63	****	****	****	****	45	48	7
6.72	****	****	****	****	53	22	25
6.84	****	****	****	****	36	40	24
6.94	38.4	1.88	****	****	**	**	**
6.96	****	****	****	****	22	41	37
7.21	****	****	****	****	19	42	39
7.51	****	****	****	****	24	59	17
7.76	****	****	****	****	27	64	9
7.93	****	****	****	****	24	68	7

TABLE 7. Physical Properties for 85044-TWC03

Depth (mbsf)	Water Content (% dry wt)	Bulk Density (g/cc)	Peak Vane Strength (kPa)	Rem. Vane Strength (kPa)
0.11	38.4	1.87	****	****
0.15	****	****	3.4	1.2
0.31	35.7	1.88	3.9	1.7
0.53	23.8	2.05	1.9	0.8
0.75	47.4	1.78	3.6	1.3
1.03	33.8	****	****	****
1.16	****	****	4.6	1.6
1.26	38.0	1.88	****	****
1.33	****	****	5.1	2.9

TABLE 8. Physical Properties for 85044-PC04

Depth (mbsf)	Water Content (% dry wt)	Bulk Density (g/cc)	Peak Vane Strength (kPa)	Rem. Vane Strength (kPa)
0.98	42.9	1.84	3.47	1.87
1.25	51.5	1.75	2.95	1.21
1.45	48.6	1.80	3.75	1.34
1.62	46.2	1.81	3.08	2.14
1.83	36.6	1.90	2.54	2.15
1.97	38.9	1.88	****	****
2.01	****	****	3.48	2.68
2.16	****	****	3.75	2.54
2.19	46.1	1.82	****	****
2.37	59.1	1.71	2.41	2.54
2.57	58.5	1.71	4.83	3.21
2.79	****	****	6.29	3.61
2.99	53.7	1.73	4.96	2.01
3.15	55.1	1.75	****	****
3.19	****	****	7.89	3.08
4.07	27.5	2.06	5.36	1.47

TABLE 9. Physical Properties Data for 86018-PC12

Depth (mbsf)	P-Wave Velocity (m/s)	Bulk Density (g/cc)	Water Content (% dry wt)	Salinity (ppt)	Peak Vane Strength (kPa)	Rem.Vane Strength (kPa)	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
0.66	****	****	31.6	35	****	****	**	**	**	**
0.88	****	****	26.4	36	****	****	**	**	**	**
1.18	1487	1.70	44.2	36	****	****	**	**	**	**
1.21-1.46	****	****	****	**	****	****	0	16	47	37
1.38	1453	1.71	44.2	35	****	****	**	**	**	**
1.55	1456	1.87	44.0	35	****	****	**	**	**	**
1.88	****	1.54	69.9	34	****	****	**	**	**	**
1.90	1450	****	****	**	****	****	**	**	**	**
2.10	1430	1.56	66.6	35	****	****	**	**	**	**
2.35	1339	1.58	63.8	35	****	****	**	**	**	**
2.57	****	****	58.9	34	****	****	**	**	**	**
2.55-2.74	****	****	****	**	****	****	2	6	52	40
2.83	****	****	55.6	35	****	****	**	**	**	**
3.03	1665	1.94	22.2	35	****	****	**	**	**	**
3.14	****	****	****	**	9.4	2.1	**	**	**	**
3.21	1476	1.61	58.5	35	****	****	**	**	**	**
3.31	****	****	****	**	****	2.0	**	**	**	**
3.34	1455	****	****	**	****	****	**	**	**	**
3.38	****	1.58	63.0	35	****	****	**	**	**	**
3.52	1494	****	****	**	****	****	**	**	**	**
3.61	****	1.65	48.5	35	****	****	**	**	**	**
3.64	****	****	****	**	****	0.5	**	**	**	**
3.75	1649	1.72	43.8	35	****	****	**	**	**	**
3.80	****	****	****	**	6.7	1.3	**	**	**	**
3.97	****	****	24.8	35	****	****	**	**	**	**
4.10	1656	1.94	23.2	35	****	****	**	**	**	**
4.35	1594	****	****	**	****	****	**	**	**	**
4.40	****	****	28.8	35	****	****	**	**	**	**
4.64	1495	****	****	**	****	****	**	**	**	**
4.69-4.91	****	****	****	**	****	****	7	35	33	25
4.89	1461	1.76	39.3	35	****	****	**	**	**	**
5.15	1495	****	****	**	****	****	**	**	**	**
5.18	1495	1.78	37.0	35	****	****	**	**	**	**
5.27	****	****	****	**	5.1	0.7	**	**	**	**
5.33	1503	1.88	33.0	35	****	****	**	**	**	**
5.44	****	****	****	**	4.0	0.7	**	**	**	**

TABLE 10. Physical Properties Data for 86018-TWC12

Depth (mbsf)	P-Wave Velocity (m/s)	Bulk Density (g/cc)	Water Content (% dry wt)	Salinity (ppt)
0.05	1742	****	****	**
0.19	****	****	29.0	35
0.25	1613	****	****	**
0.35	****	1.90	26.2	35
0.47	****	****	32.9	35
0.73	1627	****	****	**
0.76	****	1.84	29.0	35
0.93	1578	****	****	**
0.98	****	1.81	32.3	35

TABLE 11. Physical Properties Data for 86018-PC13

Depth (mbsf)	P-Wave Velocity (m/s)	Bulk Density (g/cc)	Water Content (% dry wt)	Salinity (ppt)	Peak Vane Strength (kPa)	Rem. Vane Strength (kPa)	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
0.06	1540	****	****	**	****	****	**	**	**	**
0.08	****	****	24.4	35	****	****	**	**	**	**
0.28	****	****	39.2	35	****	****	**	**	**	**
0.38	1604	****	****	**	****	****	**	**	**	**
0.40	****	1.94	25.0	35	****	****	**	**	**	**
0.50-0.69	1494	1.78	37.5	35	****	****	1	38	43	18
0.74	****	1.72	41.2	35	****	****	**	**	**	**
0.90	1492	****	44.5	35	****	****	**	**	**	**
1.03	****	****	****	**	7.0	0.4	**	**	**	**
1.04	****	1.65	51.2	35	****	****	**	**	**	**
1.10	1553	****	****	**	****	****	**	**	**	**
1.16	****	****	****	**	9.4	1.7	**	**	**	**
1.25	1476	****	34.2	35	****	****	**	**	**	**
1.41	****	1.80	36.9	35	****	****	**	**	**	**
1.44	1492	****	****	**	****	****	**	**	**	**
1.50	****	****	****	**	9.4	1.2	**	**	**	**
1.53	****	1.75	41.0	35	****	****	**	**	**	**
1.59	1482	****	****	**	****	****	**	**	**	**
1.66	****	****	****	**	6.7	0.7	**	**	**	**
1.68	****	1.77	39.8	35	****	****	**	**	**	**
1.79	1454	****	****	**	8.0	0.9	**	**	**	**
1.84	****	1.66	52.1	35	****	****	**	**	**	**
1.95	1507	1.77	38.2	35	****	****	**	**	**	**
2.08	****	****	****	**	7.0	6.0	**	**	**	**
2.15	1450	1.64	55.0	35	****	****	**	**	**	**
2.25	****	****	****	**	7.8	1.7	**	**	**	**
2.30	****	1.70	47.8	35	****	****	**	**	**	**
2.43	1454	1.65	52.5	35	****	****	**	**	**	**
2.51	****	****	****	**	9.0	2.7	**	**	**	**
2.57	1463	1.64	54.6	35	****	****	**	**	**	**
2.78	1479	1.75	41.6	34	****	****	**	**	**	**
2.84	****	****	****	**	8.6	0.4	**	**	**	**
2.95	1551	1.84	32.5	34	****	****	**	**	**	**
3.01	****	****	****	**	12.0	3.1	**	**	**	**
3.10	1484	1.67	50.2	35	****	****	**	**	**	**
3.06-3.28	****	****	****	**	****	****	4	16	53	27
3.19	****	****	****	**	8.3	1.9	**	**	**	**
3.30	1507	1.85	28.9	35	****	****	**	**	**	**
3.32	****	****	****	**	7.2	0.7	**	**	**	**
3.45	1488	1.72	44.7	35	****	****	**	**	**	**
3.56	****	****	****	**	10.2	5.4	**	**	**	**
3.63	1499	1.73	42.9	35	****	****	**	**	**	**

TABLE 11. Physical Properties Data for 86018-PC13 (continued)

Depth (mbsf)	P-Wave Velocity (m/s)	Bulk Density (g/cc)	Water Content (% dry wt)	Salinity (ppt)	Peak Vane Strength (kPa)	Rem. Vane Strength (kPa)	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
3.80	1556	1.96	23.4	35	****	****	**	**	**	**
4.00	1455	****	****	**	****	****	**	**	**	**
4.05	****	****	24.0	35	****	****	**	**	**	**
4.20	1475	****	****	**	****	****	**	**	**	**
4.24	****	1.90	26.2	35	****	****	**	**	**	**
4.51	1506	****	27.9	35	****	****	**	**	**	**
4.71	1476	1.73	43.7	34	****	****	**	**	**	**
4.87	****	****	****	**	10.8	0.3	**	**	**	**
4.98	1510	****	****	**	****	****	**	**	**	**
5.02	****	1.74	43.4	34	****	****	**	**	**	**
5.12	****	****	****	**	12.3	0.4	**	**	**	**
5.16	1526	1.79	37.2	35	****	****	**	**	**	**
5.33	1492	1.84	32.6	35	12.2	0.0	**	**	**	**
5.48	1502	1.77	39.3	35	****	****	**	**	**	**
5.58	****	****	****	**	14.7	5.2	**	**	**	**
5.65	****	1.81	35.6	35	****	****	**	**	**	**
5.68	1544	****	****	**	****	****	**	**	**	**
5.77	****	****	****	**	9.5	2.8	**	**	**	**
5.83	1438	****	****	**	****	****	**	**	**	**

TABLE 12. Physical Properties Data for 86018-TWC13

Depth (mbsf)	P-Wave Velocity (m/s)	Bulk Density (g/cc)	Water Content (% dry wt)	Salinity (ppt)
0.05	1530	****	****	**
0.07	****	1.74	39.8	35
0.20	1503	****	****	**
0.28	****	****	44.4	35
0.44	1469	1.64	35.5	**
0.63	1564	1.91	25.3	35
0.83	1479	1.66	51.0	35
1.03	1498	****	28.9	35
1.11	1511	****	31.1	35
1.32	1592	1.69	45.8	35
1.43	1741	****	26.2	34
1.50	1597	1.76	37.6	34

TABLE 13. Physical Properties Data for 86018-PC14

Depth (mbsf)	P-Wave Velocity (m/s)	Bulk Density (g/cc)	Water Content (% dry wt)	Salinity (ppt)	Peak Vane Strength (kPa)	Rem. Vane Strength (kPa)	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
0.33-0.50	****	****	****	**	****	****	0	63	30	7
0.76	****	****	24.4	35	****	****	**	**	**	**
0.86	****	****	24.7	35	****	****	**	**	**	**
1.15	1519	****	34.5	35	****	****	**	**	**	**
1.35	1634	****	36.9	35	****	****	**	**	**	**
1.64	1527	1.79	37.1	35	****	****	**	**	**	**
1.68-1.79	****	****	****	**	****	****	5	30	43	22
1.79	1542	1.81	34.1	35	****	****	**	**	**	**
1.94	1525	1.82	34.3	35	****	****	**	**	**	**
2.13	1531	1.82	34.6	35	****	****	**	**	**	**
2.33	1547	1.78	37.2	35	****	****	**	**	**	**
2.55	1575	****	****	**	****	****	**	**	**	**
2.61	****	1.88	29.0	35	****	****	**	**	**	**
2.76	1579	1.91	27.1	35	****	****	**	**	**	**
2.90	1539	1.82	33.6	35	****	****	**	**	**	**
3.03	1667	1.93	24.5	35	****	****	**	**	**	**
3.04-3.27	****	****	****	**	****	****	0	33	42	25
3.18	1620	****	****	**	****	****	**	**	**	**
3.21	****	1.96	24.0	35	****	****	**	**	**	**
3.39	****	1.85	31.0	35	****	****	**	**	**	**
3.51-3.66	****	****	****	**	26.5	0.0	0	5	58	37
3.64	1399	1.84	32.7	35	****	****	**	**	**	**
3.76	****	****	****	**	12.5	0.3	**	**	**	**
3.79	1506	1.73	40.0	35	****	****	**	**	**	**

TABLE 14. Physical Properties Data for 86018-TWC14

Depth (mbsf)	P-Wave Velocity (m/s)	Bulk Density (g/cc)	Water Content (% dry wt)	Salinity (ppt)
0.10	1490	****	****	**
0.21	****	1.62	52.3	34
0.35	1616	****	****	**
0.47	****	1.92	25.4	34
0.67	1580	1.86	27.2	34
0.87	1625	1.96	22.0	34
1.04	1559	1.86	29.8	34

TABLE 15. Physical Properties Data for 87008-LC13

Depth (mbsf)	Longit. P-Wave Velocity (m/s)	Horiz. P-Wave Velocity (m/s)	Bulk Density (g/cc)	Salinity (ppt)	Water Content (% dry wt)	Peak Vane Strength (kPa)	Rem. Vane Strength (kPa)	Fall Cone Strength (kPa)
0.80	****	****	****	**	****	6.8	1.4	2.1
0.90	1519	1527	1.79	34	50.9	****	****	****
1.00	****	****	****	**	****	3.4	0.8	****
1.07	1511	1524	1.76	34	53.4	****	****	****
1.19	****	****	****	**	****	****	****	2.3
1.29	1512	1501	1.74	32	56.2	****	****	****
1.35	****	****	****	**	****	5.4	2.0	****
1.70	1502	1508	1.73	34	56.6	7.1	1.1	1.5
1.90	1526	1522	1.77	34	50.5	****	1.7	1.8
2.10	1495	1516	1.73	34	59.3	5.4	1.1	5.4
2.30	1500	1509	1.71	34	60.9	7.6	2.6	4.1
2.50	****	****	****	**	****	5.7	3.4	1.5
2.56	1500	1491	1.76	34	56.1	****	****	****
2.70	****	****	****	**	****	6.8	2.0	4.1
2.80	****	****	1.72	34	62.1	****	****	****
2.90	****	****	****	**	****	12.7	2.5	4.1
2.98	1487	1487	1.68	34	68.8	****	****	****
3.20	1491	1496	1.75	34	55.2	5.4	2.3	3.0
3.40	1498	1497	1.78	34	56.4	5.1	3.1	3.0
3.60	1496	1493	1.73	34	59.7	10.7	1.4	4.1
3.80	1504	1499	1.73	34	57.9	****	****	****
4.00	1499	1497	1.74	34	58.5	****	****	****
4.05	****	****	****	**	****	8.5	2.0	4.9
4.20	1520	1516	1.79	34	51.3	15.8	2.5	5.9
4.40	1541	1545	1.83	34	45.6	10.5	2.3	4.1
4.70	****	****	****	**	****	7.6	3.7	3.4
4.75	1525	1526	1.83	34	47.3	****	****	****
4.90	1513	1511	1.82	34	53.4	8.5	2.3	4.9
5.10	1547	1575	1.88	33	38.8	12.5	3.1	8.0
5.30	1580	1500	1.75	34	54.9	10.5	3.1	5.1
5.50	1511	1584	1.91	34	37.5	7.3	1.4	5.9
5.66	1591	1617	****	34	34.2	****	****	****
5.90	****	****	****	33	42.0	****	****	****
6.10	****	****	****	33	29.8	****	****	****
6.20	****	****	****	**	****	4.5	1.4	3.0
6.30	1595	1586	1.99	33	31.4	****	****	****
6.40	****	****	****	**	****	6.2	3.1	4.2
6.50	1610	1654	2.00	33	29.7	****	****	****
6.60	****	****	****	**	****	5.4	1.7	3.0
6.67	1608	1619	2.02	33	29.1	****	****	****
6.80	****	****	****	**	****	2.5	2.8	3.0
6.89	1645	1644	2.08	33	29.8	****	****	****

TABLE 15. Physical Properties Data for 87008-LC13 (continued)

Depth (mbsf)	Longit. P-Wave Velocity (m/s)	Horiz. P-Wave Velocity (m/s)	Bulk Density (g/cc)	Salinity (ppt)	Water Content (% dry wt)	Peak Vane Strength (kPa)	Rem. Vane Strength (kPa)	Fall Cone Strength (kPa)
7.00	****	****	****	**	****	5.1	1.7	4.1
7.10	1670	1680	2.01	33	25.7	****	****	****
7.20	****	****	****	**	****	5.1	2.6	1.5
7.30	****	****	****	33	29.1	****	****	****
7.80	****	****	****	**	****	6.5	2.5	4.9
7.90	1630	1629	2.05	32	26.5	****	****	****
8.00	****	****	****	**	****	6.5	1.4	5.9
8.10	1613	1615	2.04	32	26.7	****	****	****
8.20	****	****	****	**	****	5.4	1.4	4.9
8.30	1658	1677	2.09	32	26.3	7.9	1.4	****
8.50	1652	1627	2.07	32	26.0	10.5	1.1	5.9
8.60	****	****	****	**	****	9.4	2.3	9.2
8.74	1695	1745	2.12	32	22.8	****	****	****
8.92	1626	1683	2.03	32	30.3	****	****	****
9.20	1657	1641	****	35	28.5	****	****	****
9.40	1663	1671	****	33	27.7	****	****	****
9.59	1624	1620	1.99	32	30.7	****	****	****
9.80	1624	1599	2.00	32	30.7	14.7	4.2	****
10.00	1682	1685	****	32	26.5	****	****	****
10.20	1657	****	****	32	28.4	****	****	****
10.40	****	****	****	35	28.6	****	****	****

TABLE 16. Physical Properties Data for 87008-LC15

Depth (mbsf)	Longit. P-Wave Velocity (m/s)	Horiz. P-Wave Velocity (m/s)	Bulk Density (g/cc)	Salinity (ppt)	Water Content (% dry wt)	Peak Vane Strength (kPa)	Rem. Vane Strength (kPa)	Fall Cone Strength (kPa)
1.50	****	****	****	**	31.7	****	****	****
1.70	****	****	1.93	34	36.4	****	****	****
1.90	****	****	1.92	34	37.5	****	****	****
2.10	****	****	1.95	34	34.2	****	****	****
2.55	1482	1488	1.72	34	58.8	3.7	0.6	1.2
2.76	1529	1545	1.82	34	47.7	2.8	2.3	1.8
2.96	1813	1736	2.12	34	24.9	6.2	2.0	4.1
3.10	****	****	****	**	****	4.0	1.1	4.1
3.23	1655	1612	2.03	34	29.2	****	****	****
3.57	****	****	2.06	34	27.6	****	****	****
3.80	****	****	2.11	34	25.0	****	****	****
4.05	1770	1618	1.95	34	35.1	****	****	****
4.25	1587	1552	1.81	34	48.3	14.1	6.5	12.3
4.46	1483	1495	1.69	34	66.7	7.9	1.7	11.0
4.65	****	****	****	**	****	7.3	0.6	15.5
4.70	****	****	1.80	33	49.1	****	****	****
4.90	****	****	****	**	****	7.9	2.3	****
4.96	****	****	****	**	****	****	****	****
5.00	1510	1493	1.79	34	51.4	****	****	****
5.20	1480	1493	1.77	34	55.1	10.2	4.0	9.9
5.39	1515	1529	1.78	34	53.0	****	****	****
5.40	****	****	****	**	****	9.6	3.4	8.2
5.61	1477	1497	1.75	34	56.6	10.7	4.5	9.9
5.80	****	****	****	**	****	4.8	2.0	5.9
5.83	1579	1612	1.89	34	41.1	****	****	****
6.00	****	****	2.04	35	28.5	****	****	****
6.14	1638	1720	****	33	23.3	****	****	****
6.32	****	****	2.03	34	30.5	****	****	****
6.50	1564	1693	1.98	34	32.9	10.7	2.5	9.9
6.70	1645	1713	2.05	34	27.5	****	****	****
6.80	****	****	****	**	****	13.3	3.1	15.5
6.90	1661	1635	2.08	34	27.3	****	****	****
7.00	****	****	****	**	****	11.9	1.4	12.3
7.10	1734	1568	2.04	36	29.1	9.6	2.8	9.9
7.30	1631	1612	2.05	35	28.3	11.0	1.4	9.9
7.50	1994	1678	2.09	34	25.6	****	****	****
7.60	****	****	****	**	****	10.5	4.0	12.3
7.70	1640	1666	2.04	33	27.7	7.9	3.1	15.5
7.88	1616	1568	2.05	34	27.7	****	****	****
7.91	****	****	****	**	****	****	****	****
8.00	****	****	****	**	****	9.3	4.5	****
8.06	1647	1671	2.08	34	26.3	****	****	****
8.10	****	****	****	**	****	****	****	****

TABLE 16. Physical Properties Data for 87008-LC15 (continued)

Depth (mbsf)	Longit. P-Wave Velocity (m/s)	Horiz. P-Wave Velocity (m/s)	Bulk Density (g/cc)	Salinity (ppt)	Water Content (% dry wt)	Peak Vane Strength (kPa)	Rem. Vane Strength (kPa)	Fall Cone Strength (kPa)
8.40	****	****	****	**	****	8.8	2.0	15.5
8.42	2101	1706	2.15	34	22.5	****	****	****
8.60	1826	1679	2.10	34	23.8	12.7	3.7	12.3
8.80	1585	1611	1.96	33	34.8	16.1	0.8	15.5
9.00	1699	1717	2.09	33	26.3	17.3	4.0	9.9
9.25	1553	1555	1.92	33	37.6	****	****	****
9.30	****	****	****	**	****	11.3	3.7	15.5
9.45	1517	1524	1.86	34	43.8	****	****	****
9.50	****	****	****	**	****	21.5	0.8	****
9.65	1520	1529	1.89	34	42.1	****	****	****
9.70	****	****	****	**	****	15.0	0.6	20.6
9.90	1516	1517	1.85	33	45.0	14.1	3.1	12.3
10.10	1512	1503	1.86	34	43.4	14.4	5.1	20.6