Mass Physical Properties of Deep-Sea Sediments in the Hawaiian Area

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by Arthur Gardner Cropper

MASS PHYSICAL PROPERTIES OF DEEP-SEA SEDIMENTS

IN THE HAWAIIAN AREA

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By

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We certify that we have read this thesis and that in our opinion it is satisfactory in scope and quality as a thesis for the degree of Master of Science in Geosciences-Geology.

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NOTATION USED IN TEXT

c — apparent cohesion (equal to shear strength in purely cohesive sediments)

C_a — area (or Kerf) ratio

C_i — inside clearance ratio

C_o — outside clearance ratio

D_e — minimum inside diameter of core nose (cutter)

D_s — minimum inside diameter of core barrel or liner

D_t — outside diameter of core barrel

D_w — maximum outside diameter of core nose (cutter)

H — penetration of corer into sediment

L_g — distance from top of core to core nose (cutter edge)

LL — liquid limit

MdΦ — median diameter in phi units

η — porosity (V_v/V)

PL — plastic limit

PI — plastic index

psi — pounds per square inch

R_g — recovery ratio

V — volume of sediment mass (wet sample)

V_d — volume of sediment mass (dried sample)

V_s — volume of solid particles of sample

V_{sh} — volume shrinkage

V_v — volume of voids in a sample (also equal to the volume of water in a saturated sample)

W_c — weight of sample container (tare)

NOTATION USED IN TEXT (cont.)

W_s	dry (105°C) weight of solid particles
W_t	weight of sample plus container
W_w	weight of water in a given sediment sample
w	water content in percentage dry (105°C) weight
wc	water content in percentage wet weight
ρ_g	grain or particle density
ρ_w	wet bulk density (wet unit weight)
ρd	dry bulk density
μ	micron (1/1000 mm.)
Φ	phi (particle diameter, $\phi = -\log_2 x$ mm)

ABSTRACT

Eighteen deep-sea cores from the Hawaiian area were investigated for mass physical properties and represent the first study of this type for the area. Methods employed were satisfactory with the exception of the porosity measurements.

Five different sediment types were found in the study area. Volcanic ash (hyaloclastite) was found underlying the brown terrigenous mud in the Hawaiian Arch area. Siliceous ooze (Ethmodiscus rex) occupied the Hawaiian Deep. Foraminiferal ooze was found within the central depression of Tuscaloosa Seamount, and turbidites were found to the north and south of the Island of Molokai.

Each sediment type showed characteristic mass physical properties. Prime controlling factors of the mass physical properties were found to be the grain-size distribution, grain shape, and sediment fabric.

Of the samples investigated 73% were silt or clayey silt. Sediments of the Hawaiian Arch area generally increase in median diameter with depth in the core. Cohesion generally increased with depth in the core due to overburden pressure.

Sediments of high deposition rates usually had porosity values in excess of 80% and wet bulk densities less than 1.45 g/cm^3, and those of normal deposition rates had less than 80% porosity and greater than 1.45 g/cm^3 wet bulk density. The top (surficial) layer of the brown terrigenous muds ranged between 80 and 84.5% in porosity. Turbidites have higher porosities than brown terrigenous muds of equivalent median diameter.

Wet bulk density (wet unit weight) was shown to be inversely related to porosity and volume shrinkage, and directly related to median diameter. Dry bulk density was found to be directly related to wet bulk density, porosity, and volume shrinkage, and inversely related to median diameter.

Volume shrinkage was found to be a function of the sediment's fabric integrity (structural non-collapsibility) rather than porosity. A high water content (porosity) does not necessarily imply a high volume shrinkage.

INTRODUCTION

Historical Background

The theory and technology employed in this investigation is based upon terrestrial soil mechanics, a discipline that began in the latter part of the 17th century but was not developed in more than an embryonic manner until the 1920's and 1930's. From that time to the present there have been many contributors, and the present theories and methods have evolved. Perhaps the greatest contributor has been Karl Terzaghi, who is commonly known as the "Father of Soil Mechanics". The fundamental modern principles and practical techniques of terrestrial soil mechanics are based on his research (Terzaghi, 1925).

Upon this foundation the study of the mass physical properties of submarine sediments has proceeded, with modifications of theories and techniques being made to accommodate sediments obtained from the submarine environment.

The first work upon mass physical properties of deep-sea sediments was published by Arrhenius (1952), who studied twenty-three deep-sea cores from the eastern Pacific Ocean. This work was performed with a Swedish cone-type penetrometer and yielded shear strength data.

Richards (1962) analyzed two cores from the northwestern end of the Hawaiian Archipelago for their mass physical properties. This is the only previous work of this type performed on cores from the Hawaiian area. No work on mass physical properties is known to have been performed on deep-sea sediments obtained within the area of this investigation.

Work in Progress in the Hawaiian Area

In addition to this investigation, J. Southworth is taking sound velocity measurements of sediments within cores taken in the Hawaiian area. Mass physical properties measurements of these cores are planned for a later date. A. Malahoff and his associates plan to analyze cores taken along both sides of The Murray Fracture Zone where it transects the Hawaiian Archipelago near French Frigate Shoals. Alpine Geophysical Associates, Inc., has performed mass physical properties work on sediments from the area north of the Island of Oahu, but their data were not available to the author at the time of writing.

Objectives of this Investigation

This research is interdisciplinary. The techniques of soil mechanics were utilized to obtain a quantitative characterization of the sediments of the study area. This study can be compared with that of Richards' (1962). Richards' paper emphasized cores from different geographic areas. This present study has been oriented towards differences in mass physical properties of sediments of differing origins. The objectives of the investigation were: (1) to obtain a knowledge of the mass physical properties of deep-sea sediments in the vicinity of the Hawaiian Islands; (2) to delineate sediment types and their provinces in the area; (3) to investigate sediment fabrics and their relationships to mass physical properties; (4) to determine the possible applications of mass physical properties to the study of submarine sedimentation and (5) to compare mass physical properties of Atlantic and Pacific core samples.

Scope of this Investigation

This investigation used a total of 19 deep-sea sediment cores from the vicinity of the Hawaiian Islands. The cores were obtained from within the geographic area bounded by 155°02'W to 157°52'W and 23°43.5'N to 18°00'N. They were collected during nine cruises aboard three oceanographic vessels. From these cores data on mass physical properties, sediment provinces, and sediment fabrics were obtained and analyzed.

The thesis subject was selected because there were no data of this type from the area of investigation and very few from any other. Another factor was a previous interest in this field.

Approach to the thesis, at the outset, was necessarily both personally and scientifically exploratory. As more data were collected, certain patterns became recognizable and new avenues of investigation became apparent. These were followed and their relationships were analyzed in this study.

Limitations

The scope of the investigation placed certain arbitrary limits on the area and types of work to be performed. Ship-time scheduling and availability of equipment placed other restrictions upon the study. Gaps in the data are due to depletion of the sample interval either by me or by other workers utilizing the same set of cores. In some instances, dessication of cores with time prohibited remeasurement at same sample intervals.

The laboratory work was accomplished under ambient temperature and humidity conditions inasmuch as the laboratory was not environmentally controlled. The oven employed was also used by others concurrently with this study, and temperatures and humidities could not be controlled at all times.

Acknowledgments

The author wishes to express his appreciation to the following individuals: graduate students Thomas Gilliard and Phillip Hubbard for help rendered at various times, and cruise participation by John Halunen, James Woodruff, John F. Campbell, Dyer Grossman and Royden Kubota. Others helping during the cruises were John Rich and Kelly Blackburn.

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Persons helping in a technical support function were Ivor Bishop, who fabricated equipment and participated in cruises, and G. Woodruff, who was helpful in many ways as superintendant of the machine shop.

Those persons outside of the University of Hawaii to whom the writer is grateful are: Dr. Richard Terry of North American-Rockwell Company for bibliographic references; Dr. Felix Fenter and James Morrow of the Ling-Temco-Vought Research Center, Honolulu, for part-time employment on related problems; Richard Bender, of the same organization, for cruise participation; and Dr. E. Hamilton, of the U. S. Naval Electronics Laboratory, San Diego, for his generosity in providing reprints and references germane to this investigation.

METHODS

Core Collection

Nineteen cores of deep-sea sediments were collected during the course of this investigation. Ten are from the flank and crest of the Hawaiian Arch. Three are from the axis of the Hawaiian Moat (Vening Meinesz, 1948). This feature is also termed the Hawaiian Deep (Dietz and Menard, 1953). Stearns (1966) states that the term Deep was renamed Trough officially in 1965. Three of the cores are from the Tuscaloosa Seamount area north of the Island of Molokai, two are from south of the islands and one is from the area northwest of Kauai.

Most cores were obtained during nine cruises between the period 1965-67 aboard the research vessels TERITU and TOWNSEND CROMWELL, and the yacht SERENA.

Seven of the Cores (MR-1 through MR-7) were obtained by Mr. Lloyd Paitson in the immediate vicinity of the proposed MOHOLE site during the reconnaissance phase of the project. These cores were donated to the Hawaii Institute of Geophysics by Brown and Root, Inc.

Upon recovery from the sea bottom, all cores were immediately capped, sealed, identified, and stored in the vertical position until transfer from the ship to the cold storage holding area at the Hawaii Institute of Geophysics. The interval between laboratory storage and initiation of work on the cores ranged from several weeks to four months.

All MOHOLE cores are identified with the prefix "MR". The remainder of the cores are coded as shown on the following page.

661003-2

First two digits = year
Middle two digits = month
Last two digits = day of month
Dash number = core number

Table I summarizes the coring equipment used during this investigation.

Table I

Description of Corers Used

Corer Type	Corer Drop Method	Core Liner Inside Dia. (inches)	Liner Length (inches)
Benthos (flap valve)	free fall	2.65	48
PVC (conical valve)	Restricted gravity*	3.20	48
Japanese (unvalved)	Restricted gravity*	2.75	48

*Restricted gravity corers are lowered on a wire line and dropped the last 100-200 meters to the bottom using the free-wheeling mode of the winch.

Navigation and Core Site Locations

The location of the cores obtained for this study are accurate to approximately ±2 nautical miles.

Navigational methods employed during the cruises were, in order of accuracy: visual bearings, ship and land radar, star fixes, Loran C, Loran A, and dead-reckoning. These methods were used either singly or in some combination depending upon the circumstances.

The relationships of the core groups and the cores to each other are shown in Figure 1. Geographic coordinates and other data are shown in Table II.

Transportation and Storage of Cores

Cores were transported by ship, airplane, and truck or some combination of the above. Some cores were exposed to the rigors of transportation for considerably longer periods of time than were others.

All cores, from acquisition to arrival at the Hawaii Institute of Geophysics, were kept sealed in the vertical position at ambient air temperature. Upon arrival, all cores were immediately rechecked for seal integrity and then placed in cold storage, at approximately 3°C, until such time that the core preparation phase of the investigation was initiated.

During the examination and data acquisition phases the cores remained out of cold storage only for the time required to perform the necessary measurements.

Core Disturbances

All cores used during the investigation were considered to be disturbed. The parameter values measured in the laboratory do not reflect the parameter values of the sediments *in situ*. This difference is due to disturbances introduced into the sediment fabric by many factors between coring and data measurement.

Core disturbances attributable to the coring and raising operations are; (1) compaction of the sediment during corer penetration, (2) peripheral drag-out of the sediment as the result of frictional resistance of

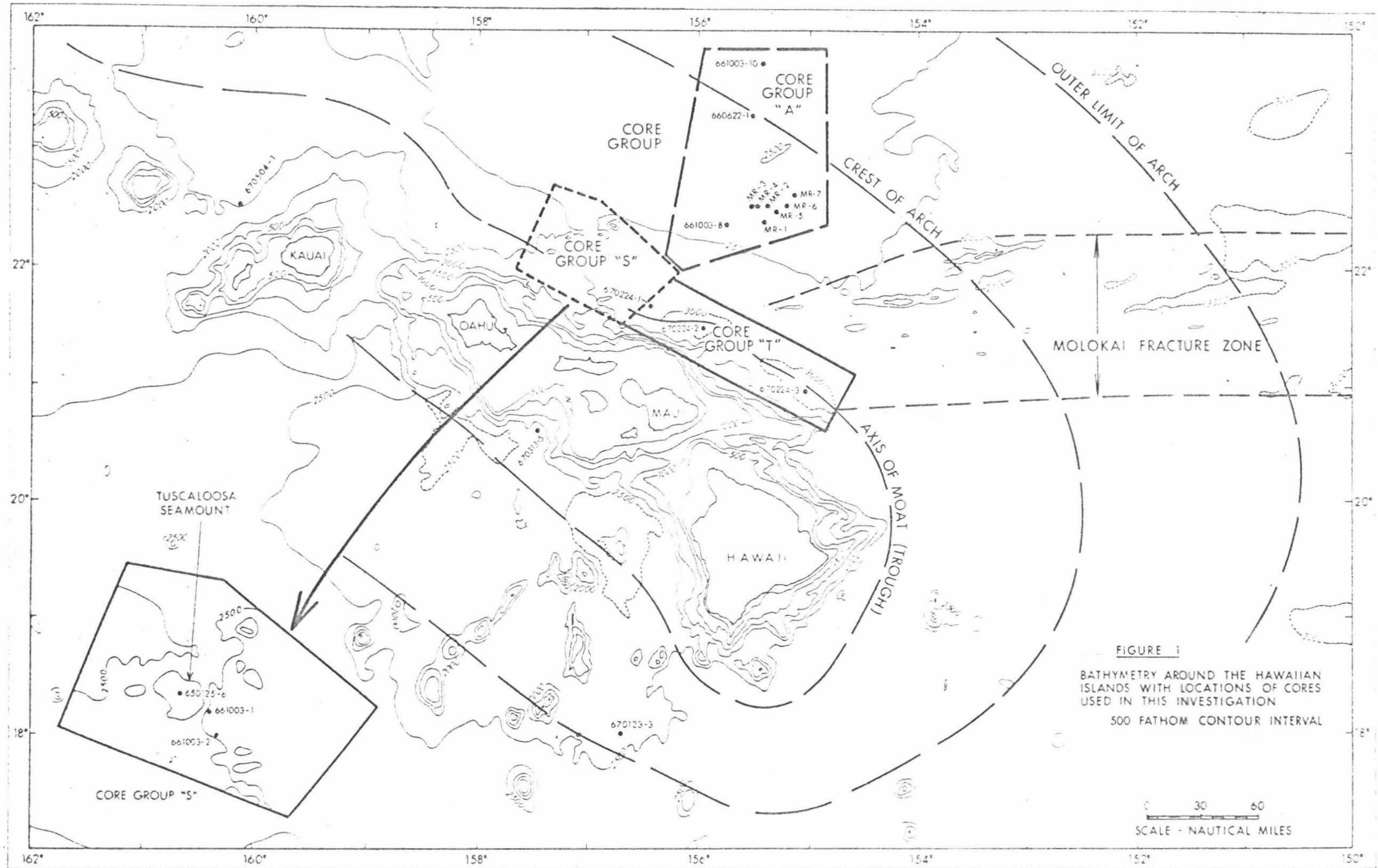


FIGURE 1

BATHYMETRY AROUND THE HAWAIIAN ISLANDS WITH LOCATIONS OF CORES USED IN THIS INVESTIGATION

500 FATHOM CONTOUR INTERVAL

TABLE II

Cores used in this Investigation

Core No.	Core Group *	Geographic Coordinates	Core Length (inches)	Water Depth (meters)		Corer Type	Collector	Ship
				Uncorr.	Corr.			
MR-1	A	22°23.0'N 155°24.0'W	44	4316	4428	Benthos	Paitson	Serena
MR-2	A	22°31.0'N 155°23.0'W	30 1/4	4261	4371	"	"	"
MR-3	A	22°31.0'N 155°31.0'W	25 5/8	4279	4390	"	"	"
MR-4	A	22°31.0'N 155°28.0'W	27 3/4	4279	4390	"	"	"
MR-5	A	22°28.0'N 155°18.0'W	33 3/4	4279	4390	"	"	"
MR-6	A	22°31.0'N 155°13.0'W	31 5/8	4234	4343	"	"	"
MR-7	A	22°35.0'N 155°09.0'W	32 1/2	4206	4313	"	"	"
660622-1	A	23°16.0'N 155°30.0'W	48	4425	4440	"	Halunen	Teritu
661003-8	A	22°21.0'N 155°43.0'W	20	~4440	~4557	"	Gilliard	"

TABLE II (cont.)

Core No.	Core Group *	Geographic Coordinates	Core Length (inches)	Water Depth (meters)		Corer Type	Collector	Ship
				Uncorr.	Corr.			
661003-10	A	23°43.5'N 155°25.0'W	36	4133	4237	Benthos	Gilliard	Teritu
670224-1	T	21°40.0'N 156°27.0'W	40 3/4	5375	5527	PVC	Cropper	"
670224-2	T	21°29.0'N 155°54.5'W	47 1/4	5700	5877	"	"	"
670224-3	T	20°55.0'N 155°02.2'W	25 1/2	5750	5930	"	"	"
661003-1	S	21°59.0'N 156°59.5'W	12	4750	4875	Benthos	"	"
661003-2	S	21°52.5'N 156°56.0'W	45	4825	4960	"	"	"
650125-6	S	22°06.0'N 157°27.0'W	Core Catcher	2909	2970	Japanese	McCoy	"
670313-5	M	20°34.5'N 157°27.0'W	21 5/8	3980	--	PVC	Gilliard	"
670123-3	M	18°00.0'N 156°41.0'W	28 3/16	4585	--	"	"	"
670504-1	M	22'30.4'N 160°06.7'W	13 7/8	4435	4552	Benthos	Rich	Cromwell

*See Fig. 1

the core material against the inner wall of the core liner, (3) sediment cascading from the top of the core into the annular space caused by the raking action of the core catcher fingers, and (4) sediment fabric (structure) alteration caused by pressure release with ascension of the core from the bottom.

A quantitative compaction measure has been defined by Hvorslev (1949) as the <u>gross recovery ratio</u> and is mathematically stated as:

$$R_g = \frac{L_g}{H} \qquad (1)$$

Corers utilized during this study did not provide a method for determining depth penetration into the sediment and thus the recovery ratio was not determined. Core shortening corrections, therefore, were not determined. Core lengths listed in Table I were those measured from the top to the bottom of the core, in the laboratory.

The gross recovery ratio and the degree of core disturbance are inversely related. The gross recovery ratio is a function of the dimensional ratios of the corer components and whether the corer was a restricted gravity or piston type. Hvorslev (1949) defines these ratios as follows:

Inside clearance ratio,

$$C_i = \frac{D_s - D_e}{D_e} \qquad (2)$$

Outside clearance ratio,

$$C_o = \frac{D_w - D_t}{D_t} \qquad (3)$$

Area (or Kerf) ratio,

$$C_a = \frac{D_w^2 - D_e^2}{D_e^2} \qquad (4)$$

These ratios were calculated for each corer type used during this study and are presented in Table III. Value relationships and limits of terms employed are shown in Table IV. From Tables III and IV it was determined that the Benthos corer obtained the least disturbed cores and the Japanese corer the most disturbed. It was not possible to determine quantitatively the degree of disturbance.

Disturbances in a core do not cease upon pullout from the bottom. A host of other disturbances are introduced between pullout and laboratory measurements. These disturbances are added to the coring disturbances. A summary of all possible types of disturbance is presented in Table V. All or any combination of these factors may apply to any one core according to its care and handling.

Core Preparation

Cores were received at the Hawaii Institute of Geophysics completely enclosed in a plastic liner, capped and sealed at both ends. It was necessary to prepare the cores in such a manner that the sediment column was visible and accessible for sampling along the entire length.

The sequence of operations described below was performed on only one core at a time. Measurements on each core were made as soon as possible after its preparation. The preparation and measurement sequences were then repeated for the next core. All cores were inspected before preparation. Only those containing a head of water above the surface of the sediment were processed for mass physical properties.

Table III

Area and Clearance Ratios, and Use-preference of Corers used in this Investigation

Corer Type	Outside Clearance Ratio, C_o, %	Inside Clearance Ratio C_i, %	Area (Kerf) Ratio C_a, %	Sum of C_o, C_i and C_a	Use Preference Order
Benthos (free fall)	3.1	6.0	54.2	61.5	1
PVC (restricted gravity)	11.8	3.2	60.3	75.3	2
Japanese (restricted gravity)	31.1	0	125.0	156.1	3

Table IV

Value Relationships and Limits of Terms Employed

Gross Recovery Ratio	Corer Efficiency, %	Degree of Core Disturbance	Sum of C_o, C_i and C_a	Use Preference
~0.5 | ~1.0	~50 | 100	highest | lowest	highest | lowest	lowest | highest

Table V

Possible Disturbances of Core Sediments

Coring Operation

- Compaction during penetration
- Peripheral drag-out during penetration
- Sediment cascading into annular spaces

Ascent to Ship

- Acceleration and deceleration due to pitch and roll
- Alteration of sediment fabric due to pressure release
- Vibration (strumming) of coring line
- Temperature changes

Transfer from Coring Line to Ship Storage

- Acceleration and deceleration due to pitch and roll
- Drainage of water before sealing
- Shock during handling
- Loss of buoyancy effect
- Temperature changes

Transport Aboard Ship

- Acceleration and deceleration due to pitch and roll
- Engine vibration
- Ambient temperature and pressure changes
- Water leakage if not properly sealed

Transfer from Ship to Other Modes of Transportation

- Acceleration and deceleration of vehicle
- Road or air shock
- Engine and road vibrations

Laboratory Storage

- Temperature changes
- Water leakage if not properly sealed
- Time compaction (settlement) of sediment

Transfer from Storage for Preparation

- Temperature changes
- Change of attitude
- Handling shocks

Table V (cont.)

Preparation of Cores for Data Acquisition
Temperature changes
Changes of attitude
Saw vibration during sectioning and splitting
Extraneous plastic debris from saw cuts
Water drainage
Desiccation
Extrusion compaction (if extrusion performed)
Data Acquisition
Temperature changes
Shift of core in liner from removal of samples
Evaporation of water
Attitude changes

Identification

Each core was inspected for presence and legibility of cruise number, core number, and attitude marks on the side of the core liner. The core length was recorded.

Tapping of Water Head

Each core was tapped of its water-head above the sediment by augering a small hole through the liner at the bottom of the water column. The water was drained into salinity bottles which were then sealed, identified and placed in cold storage until ready for water salinity determination.

Sectioning

At the outset of the study, cores were sectioned into one-foot lengths for convenience of handling and for adaptability to the laboratory vane shear tester. As the investigation continued a method was used in which transverse sectioning of the cores was unnecessary. Sectioning was accomplished with a DoAll saw with a fine-toothed blade.

After sectioning, the plastic sawdust and burrs were removed from the ends of the core.

Splitting

The core was placed in a cradle having guide surfaces for running a Skilsaw smoothly along its length. Two saw cuts were made into the liner, the depth of cut being adjusted to cut barely through the liner with minimum disturbance to the sediment. A thin steel wire was then positioned between the two saw cuts and dragged through the sediment for the length of the core, resulting in two separated core portions. The larger of the two portions was used as the working portion and the smaller was stored as the archive portion for future reference. The core splitting technique and terminology are illustrated in Figures 2 and 3.

Identification

Each portion of a sectioned or split core was identified with the appropriate core number, section number, length interval and "up" end. Archive portions were similarly marked with a felt-point pen with waterproof ink.

Sealing

It was necessary to seal the cores to prevent desiccation after sectioning and splitting, during storage, and before parameter measurements. Prior to sealing, thin plastic tubing was cut to such a length that it overhung the core liner by approximately four inches at each end. It was then pre-marked with the appropriate core identification data. The tubing was slipped over the core and both overhanging ends were twisted and secured with rubber bands. The sealing operation

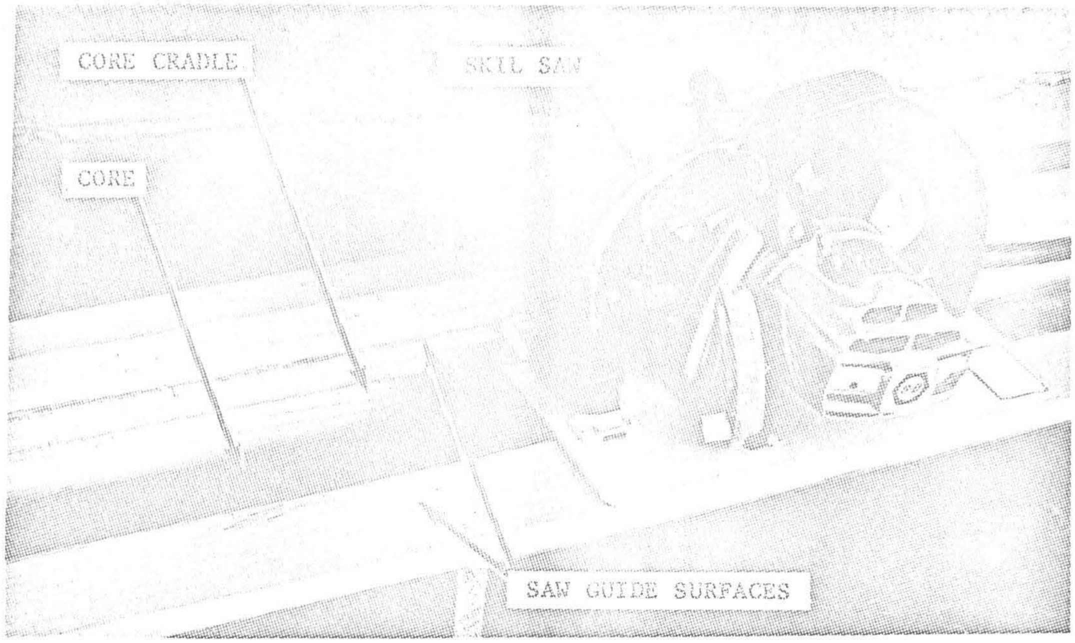


Figure 2. Method of splitting cores

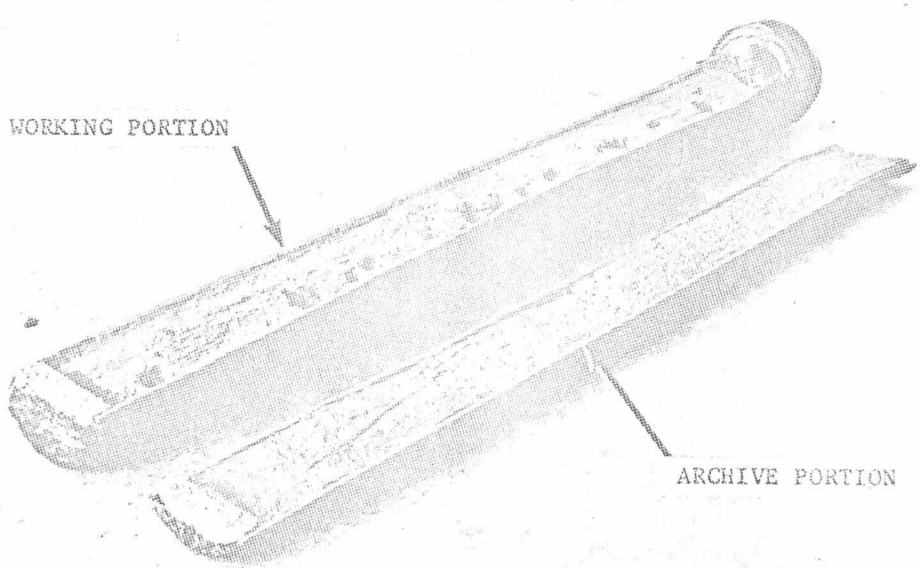


Figure 3. Core terminology

minimized the alteration of the mass physical properties of the sediment until such time that measurements were initiated.

Preparation of Cores Collected Prior to this Study

Some of the data reported were obtained from cores collected prior to this study. These cores had been extruded from their liner, sectioned and stored in unsealed plastic "bread boxes" in the cold room. They were badly desiccated. However, none of the measurements made on these cores were of parameters that vary with moisture content.

Preliminary Examination

Visual, tactile, and photographic methods were employed during the preliminary examination of the cores and prior to the parameter measurement phase of the study. The purpose of the examination was to aid in the determination of meaningful depths at which to sample the cores.

Visual

A core was laid horizontally on the work area and the plastic jacket (tubing) was carefully removed. The gross stratigraphy was recorded with obvious changes noted at the proper depth intervals. Color of the sediment in the core was compared to the Geological Society of America Color Chart (1963). The color code was then recorded for the noted intervals. Sediment types and their intervals were visually noted and recorded.

Tactile

Often differences in the consistency (firmness) of the sediments in a core were not visually detectable. By running the forefinger firmly along the length of the edge of the exposed sediment, a qualitative consistency was obtained. Changes of consistency or texture were recorded, and core-sampling depths planned accordingly. The tactile examination also aided in the selection of the proper calibrated spring for use in the laboratory vane shear tester during shear strength (cohesion) measurements.

Photographic

Polaroid photographs were made of each core before measurements were initiated. Pertinent core information was recorded on the back of each photograph.

Data Measurement

Krumbein and Sloss (1951) describe mass properties as:

> "The properties of a sediment as an aggregate, including porosity, permeability, density, color, etc."

In addition, other mass properties are sand-silt-clay ratio, median diameter, cohesion, wet bulk density, volume shrinkage, void ratio, water content, compaction and others.

The mass properties were measured by classical soil mechanics techniques, modified somewhat to accommodate soft marine sediments. Due to limitations of time and equipment, and core disturbances, all of these properties were not determined for each core. These limitations have been discussed in the introductory section.

A work flow diagram of laboratory activities and parameter determinations is shown in Figure 4. A quantitative breakdown of parameter measurements is shown in Table VI.

Cohesion

Most shear strength (cohesion) equipment and methods were designed for use on soils which are relatively dry and of which ample

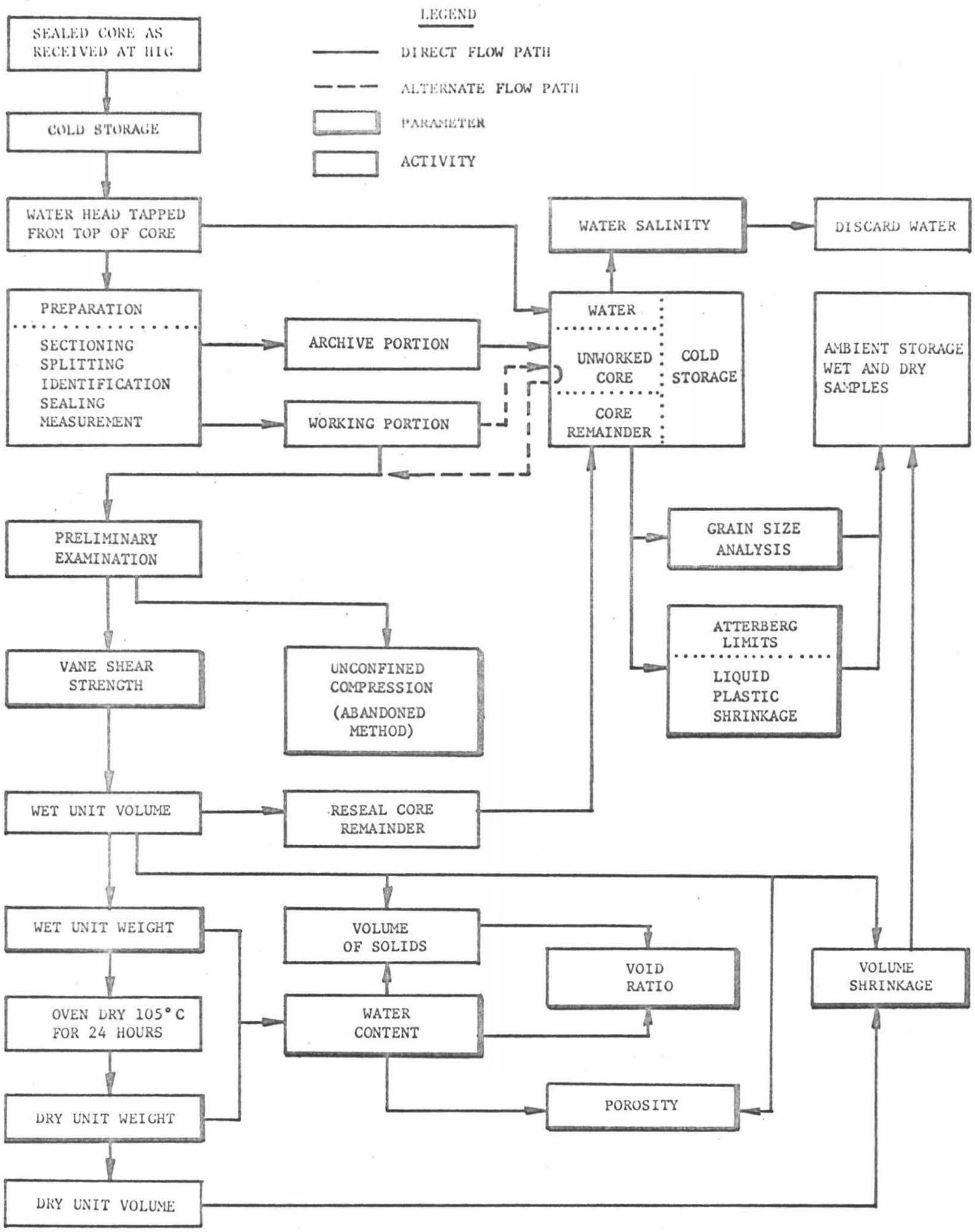


FIGURE 4. FLOW DIAGRAM OF LABORATORY ACTIVITIES AND PARAMETER DETERMINATIONS

Table VI

Number of Measurements by Core Groups and by Parameters

Parameters	Core Groups				Parameter Totals
	A*	T	S	M	
Cohesion	108	36	22	29	195
Sand-silt-clay percentage	53	19	6	17	95
Median diameter	67	23	13	18	121
Porosity	101	38	20	28	187
Wet bulk density	101	38	20	28	187
Dry bulk density	103	38	19	28	188
Volume shrinkage	105	38	20	28	199
Liquid limit	29	0	0	0	29
Plastic limit	31	0	0	0	31
Core group totals	698	230	120	176	1,224 Grand Total

*See Fig. 1

quantities are available. These methods did not lend themselves well to the study of the saturated, soft, marine sediments of this study. At the beginning of the study an attempt was made to measure shear strength by the unconfined compression method. This method was abandoned because the excess handling of the soft samples resulted in deformation with resultant data of questionable accuracy. A similar conclusion has been reached by others, as reported in A. D. Little Report No. 1281262 (Anonymous, 1962). Shear strength values were subsequently made with a laboratory vane shear tester. This method measured shear strength of the sediment while "undisturbed" in the original liner.

The instrument employed was a Farnell laboratory vane shear tester (Soiltest No. C-200), modified by the addition of a constant-speed, synchronized, electric motor (G. K. Heller, Model 2T60-540, and a motor speed control unit (G. K. Heller, Model 2T60). The vane shear tester was originally operated by a hand crank. Addition of the motor and control unit allowed torque application at a constant rate and eliminated variances caused by hand-cranking.

Springs employed in the shear tester were calibrated at the factory and graphs of pressure versus deflection for each spring were furnished by the manufacturer.

The rate of torque application by the constant speed electric motor averaged 35.4 degrees per minute at the dial setting of 5 on the motor speed control unit. This rate was employed on all cores tested.

Table VII shows the torsion spring constant for each spring employed in the shear tester, and Figure 5 shows the modified shear vane tester with a core in position for testing.

Table VII

Torsion Spring Constants

Spring Number	Spring Constants ($lbs/ft^2/°$ spring deflection)
1	18.28
2	15.10
3	11.20
4	8.13
5A	4.11
5B	3.38
6A	1.25
6B	1.27

The shear testing procedure was initiated by the insertion of the shear vane into the sediment until the top of the vane was approximately three-quarters of an inch within the sediment. All testing was performed with the vane inserted normal to the split surface of the core. The angle indicator of the tester was set against the stop and the initial angle recorded. The motor was turned on, set at 5 on the speed control unit dial, and allowed to run until shear failure of the sample occurred. The final angle was then read and recorded. The difference between the initial and final angles determined the deflection angle swept before

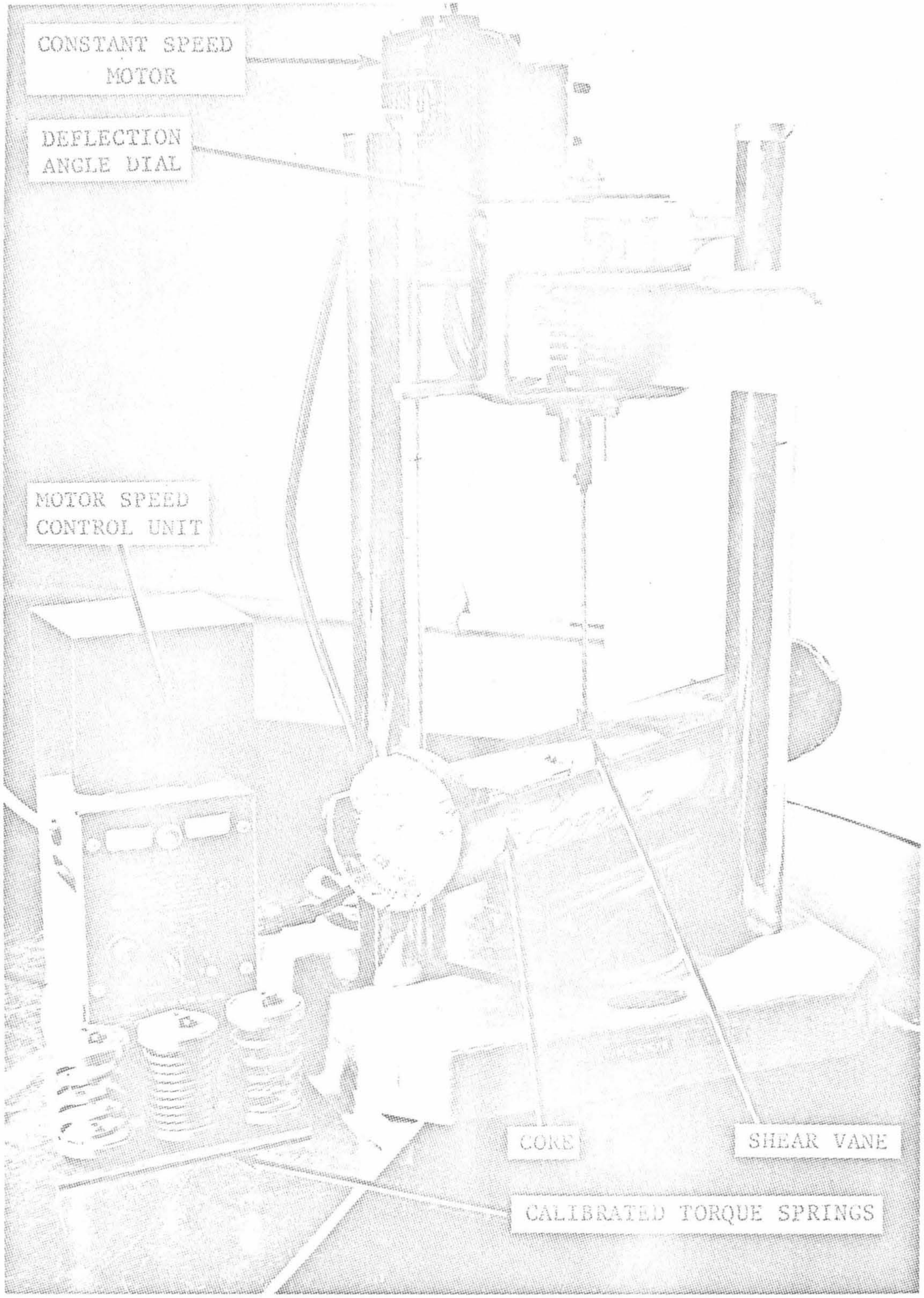


Figure 5. Modified laboratory vane shear tester and core

failure occurred. The deflection angle, in degrees, was multiplied by the appropriate spring constant (Table VII) to obtain shear strength in pounds per square foot. Values in pounds per square foot were then converted to pounds per square inch. This procedure was repeated for each selected sample depth in the core.

Water Content

Prior to obtaining water content samples it was necessary to process the sample containers. Thin-walled glass cylinders, 11/16 inch inside diameter by 7/8 inch long, were identified by scratching identifying numbers on the outside surface with a diamond-point scriber. The cylinders were weighed, and their internal volume determined by the mercury method and by mensuration. Both methods showed close agreement of values. The same group of cylinders and their associated weights and volumes were used repeatedly throughout the testing. Silicone grease (Dow-Corning DC-400) was applied as a thin film to the interior surface of each cylinder as a parting agent between the sediment and the cylinder wall. Between each sample test the cylinders were washed, dried, and relubricated.

Where possible, water content samples were taken at the same depth intervals as the shear strength tests. A sample was obtained by carefully pressing a glass cylinder into the core sediment, using a spare cylinder as a ram. The sampled sediment was allowed to rise approximately 1/8 inch above the top surface of the sample cylinder and allowed to come to equilibrium for approximately two minutes. It was then undercut and withdrawn from the core. Excess sediment, at each end, was carefully cut off and smoothed even with the cylinder ends.

This procedure was followed until all samples were obtained from one core.

Each sample was immediately weighed and the combined weight of the sediment and cylinder recorded. The samples were placed in a thermostatically controlled oven and allowed to dry for 24 hours at 105°C ±2°. Upon removal, the samples were allowed to cool for 15 minutes. Each sample was again weighed and the combined weight of the sediment and cylinder recorded. The cylinder weight was then subtracted from the combined wet, and the combined dry weights of the sample and cylinder, and the results recorded as the wet and dry weights of the sediment sample. The water content, on a dry basis, was then calculated by the following equation:

$$w = \frac{W_w}{W_s} \times 100 \qquad (5)$$

Another measure for water content is expressed as a percentage of the total wet weight. This is expressed as:

$$wc = \frac{W_w}{W_s + W_w} \times 100 \qquad (6)$$

A useful conversion from water content on a wet basis to water content on a dry basis is:

$$w = \frac{100\ wc}{100 - wc} \qquad (7)$$

Porosity

Porosity was derived from data obtained during the water content determination. Porosity is expressed in percentage by the equation:

$$\eta = \frac{V_v}{V} \times 100 \qquad (8)$$

Wet Bulk Density (also termed Wet Unit Weight or Saturated Unit Weight)

Wet bulk density was calculated from data obtained during the water content determination by the following equation:

$$\rho_w = \frac{W_t - W_c}{V} \times 100 \qquad (9)$$

Dry Bulk Density (at shrinkage limit)

The dry bulk density was calculated from the equation:

$$\rho_d = \frac{W_s}{V_d} \qquad (10)$$

The weight of the solids (W_s) was determined during the water content determination, and the dried volume (V_d) was obtained by the mercury displacement method.

Volume Shrinkage

Shrinkage represents the decrease in volume from the wet unit to the dry unit. It was determined by the following equation and is expressed in percentage:

$$V_{sh} = \frac{V - V_d}{V} \times 100 \qquad (11)$$

V was determined during the water content determination and V_d was determined by the mercury displacement method.

Atterberg Limits

The Atterberg Limits (Atterberg, 1911) are best described by G. F. Sowers (1965, p. 391) as follows:

> "The Atterberg Limits are indices of the workability or firmness of artificial mixtures of soil and water as affected by the content of water in the mexture. The limits are defined by the water contents required to produce specified degrees of consistency that are measured in the laboratory."

Dawson (1960) has shown that different operators may obtain slightly different results in the limit tests, despite test standardization. This is based upon the subjective nature of the tests, where the accuracy of the quantitative results are based largely upon subjective personal judgement rather than objective measurements.

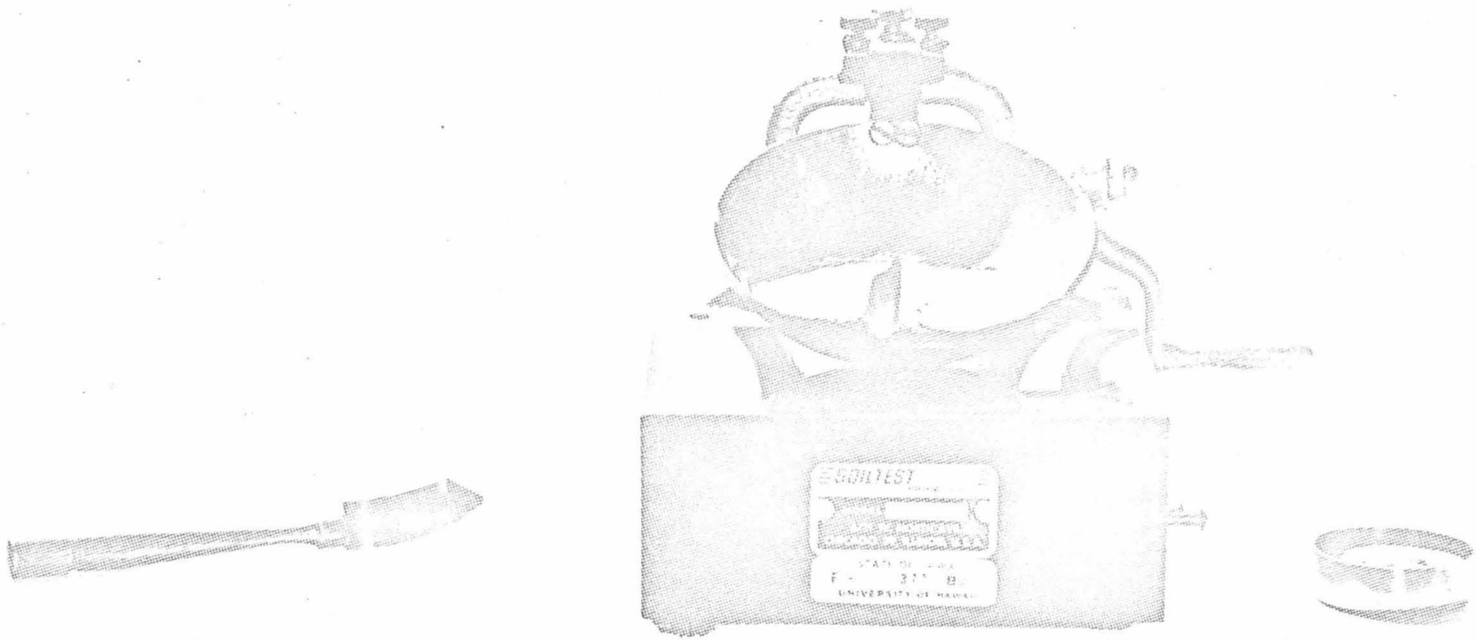
Water used for determining these limits was that overlying the core and was of approximately the same salinity as the interstitial water of the core sample. Fresh water, accidentally used for one liquid limit test, revealed that the liquid limit was very sensitive to the salinity of the interstitial water. Fresh water deflocculated the sample with resultant erroneous data. Martin (in Richards, 1961; oral communication) reports further evidence for this observation. Figure 6 shows equipment employed in acquiring Atterberg Limits data.

Procedures for determining the limits are described by Lambe (1951) and the terms are defined by the American Society for Testing Materials (1958). Atterberg Limits were determined for only cores MR-1 through MR-6, after which this procedure was discontinued.

Grain Size

Where possible, each core was sampled for size analysis from the same intervals as for cohesion and water content. The wet sample size was approximately 30 grams.

Grain size was determined by the classical sieve and pipette methods of analyses. Pipetting was performed on multiple samples on a timed sequence basis (Staff, Allan Hancock Foundation, 1958). Pipette samples were washed four times in distilled water and centrifuged each time in order to purge the sample of saline water. Carbonates were not removed.



GROOVING TOOL LIQUID LIMIT TESTER SHRINKAGE LIMIT CUP

FIGURE 6, ATTERBERG LIMITS EQUIPMENT

From the measurements of the sieve and pipette analyses, percentage weight was calculated for each phi-size. From this data a histogram and a cumulative curve were plotted for each sample. Median diameter, in phi units, was obtained from the cumulative curve for each sample.

The sediments were classified by particle size according to the nomenclature of Wentworth (1922), and the phi notation of Krumbein (1934). Selection of the Wentworth classification for use in this investigation was based upon the fact that it is the most widely used in the United States. The Wentworth classification with its equivalent grain-size units is shown in Table VIII. Size units employed by geologists and soil scientists are included in Table VIII as a reference convenience to the reader.

Table VIII

Grain-Size Scales for Sediments

GRADE SCALES

WENTWORTH (1922) after Udden (1898)	Phi $\phi = -\log_2$ (m.m.)	(m.m.)	MICRONS μ	U.S. BUREAU OF SOILS
BOULDER				
	−8	256		
COBBLE	−7	128 / 100		
	−6	64		LARGE (GRAVEL)
PEBBLE	−5	32		LARGE (GRAVEL)
PEBBLE	−4	16 / 10		LARGE (GRAVEL)
PEBBLE	−3	8		MEDIUM (GRAVEL)
	−2	4		MEDIUM (GRAVEL)
GRANULE				MEDIUM (GRAVEL)
SAND: VERY COARSE	−1	2		FINE (GRAVEL)
	0	1	1000.	COARSE (SAND)
SAND: COARSE	+1	1/2	500.	MEDIUM (SAND)
SAND: MEDIUM	+2	1/4	250.	FINE (SAND)
SAND: FINE	+3	1/8 / 1/10	125.0	FINE (SAND)
SAND: VERY FINE	+4	1/16 / 1/20	62.5	VERY FINE (SAND)
SILT: COARSE	+5	1/32	31.3	SILT
SILT: MEDIUM	+6	1/64	15.6	SILT
SILT: FINE	+7	1/128	7.8	SILT
SILT: VERY FINE	+8	1/256 / 1/200	3.9	SILT
CLAY: COARSE	+9		1.95	CLAY
CLAY: MEDIUM	+10	1/1024	0.98	CLAY
CLAY: FINE	+11		0.49	CLAY
CLAY: VERY FINE	+12	1/4096	0.24	CLAY
COLLOID				CLAY

SEDIMENT TYPES AND SOURCES

General Statement

Sediments northeast of Oahu are derived from five principal sources; (1) volcanic detritus and pyroclastics, (2) shallow water carbonate sediments, (3) planktonic organisms, (4) benthonic organisms, and (5) the continental areas, Moberly and McCoy (1966). The material from these sources is transported to the deep-sea environment by water currents, slumps, and turbidity currents (Hamilton, 1957), as well as by trophospheric wind transport (Rex and Goldberg, 1958). The sources and agencies are reflected in variations of grain-size and mass physical properties measured in this investigation.

Specifically, the sediments found in this study were siliceous ooze (principally of the diatom *Ethmosiscus rex*), calcareous ooze (foraminiferal), volcanic ash, brown muds, and turbidites.

Figure 7 shows the locations of the sediment types. The boundaries depicted are arbitrary inasmuch as the sediment types grade into each other horizontally and are not yet clearly defined for either bottom surface or subbottom sediment type provinces.

Siliceous Ooze

The Challenger Report (1887) first defined an ooze as containing 30% or more of biogenous material. The siliceous ooze of the Hawaiian Deep contains up to 70% biogenous material as reported by Belshé, Gilliard, Cropper and Grunwald (in prep., 1968). The top 8 inches of the siliceous ooze cores consisted of brown mud of a gelatinous consistency and a much lower percentage of diatom tests.

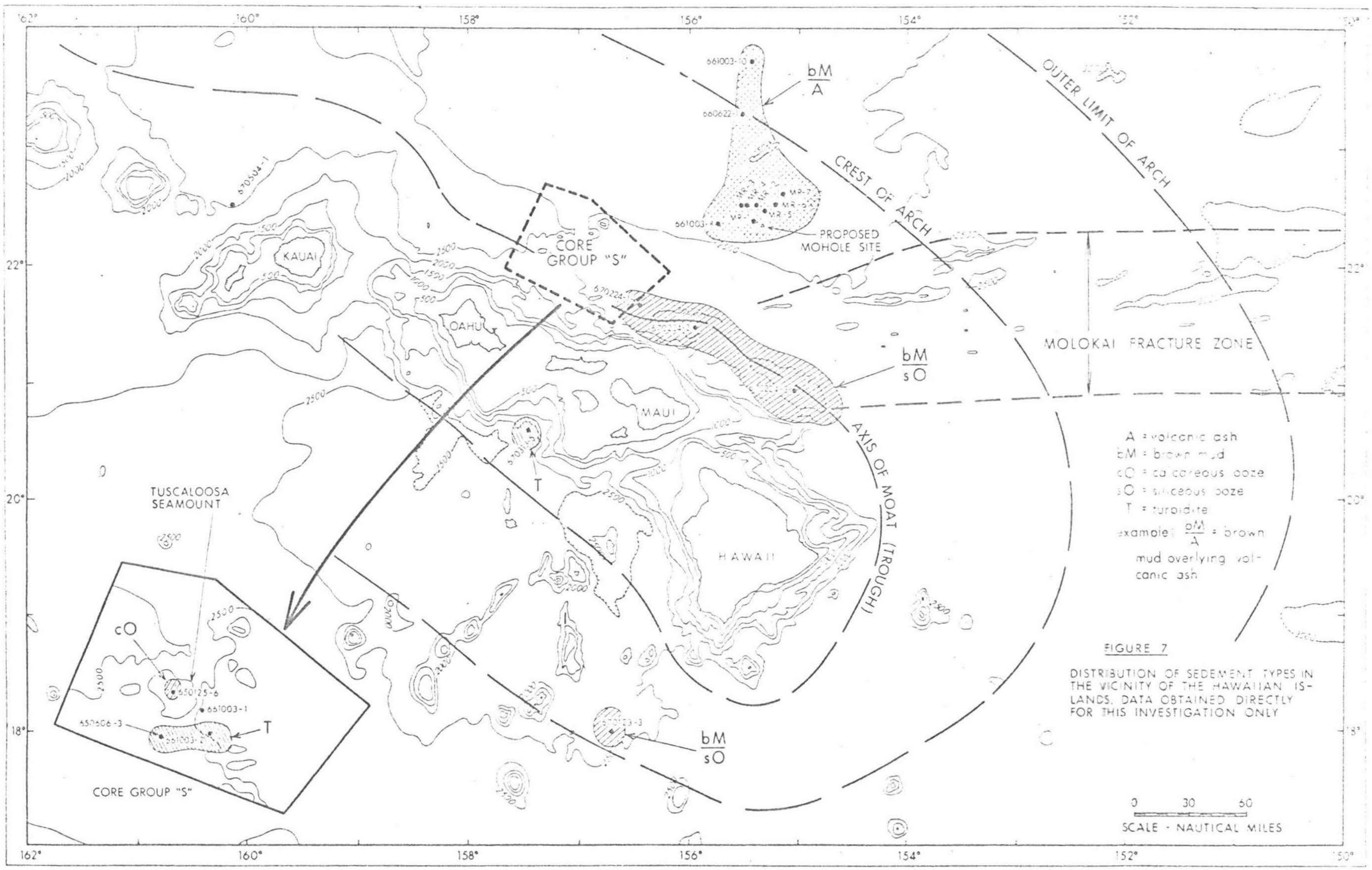


FIGURE 7

DISTRIBUTION OF SEDEMENT TYPES IN THE VICINITY OF THE HAWAIIAN ISLANDS. DATA OBTAINED DIRECTLY FOR THIS INVESTIGATION ONLY

Ethmodiscus rex (Rattray) Hendey, is the diatom found in large concentrations in the Hawaiian Deep. It was first noticed by Grunwald in 1966 in the Hawaiian area, identified by W. Reidel, and its areal extent explored and defined by the author and Gilliard in 1967. The greatest concentrations lie in the northern part of the Hawaiian Deep, adjacent to the main islands. It extends around the eastern and southern side of the Island of Hawaii and continues westward in decreasing amounts.

Hanzawa (1933) described the limits of Ethmodiscus ooze deposits as latitudes 19°08.5'N - 8°40.0'N and longitudes 136°22.6'E - 153°06.5'E. Discovery of Ethmodiscus ooze near the Hawaiian Islands extends Hanzawa's area or defines a new separate region. It is not known at this time if there is an extension of the ooze deposits along the more northerly islands of the Hawaiian Archipelago.

Because Ethmodiscus rex has seldom been found in the living state, its life history is not adequately known. It is likely that this species blooms rapidly and in enormous numbers and mass mortality is swift with consequent rapid deposition of siliceous exoskeletons. Concentration in the deeper portions of the Hawaiian Deep by bottom current winnowing is a possibility.

Taliaferro (1933) first discussed the relationship between the frequent association of siliceous (cherts) and volcanic rocks in geosynclines. Khvoroba (1968) states that diatomites were generated in a sea where a considerable amount of volcanic dust was brough from adjacent volcanic land, creating a favorable nutrient medium for diatom blooms. The relationship of siliceous and volcanic rocks also permits the assumption of the existence of submarine hotsprings yielding silica in forms useable by diatoms. Either or both of these hypotheses might explain the presence of siliceous ooze in the Hawaiian area. Concentration in another deep region (Marianas Trench) has also been reported by Haeckel (1887) during the Challenger Expedition in 1862-76 and by Wiseman and Hendey (1953) from the Challenger II in 1950-51.

Volcanic Ash

Volcanic ash (more correctly termed hyaloclastite in this case) was found in the vicinity of the proposed MOHOLE site and to the west and north. Only one layer of ash was penetrated at the MOHOLE site by five of the seven cores. The values of the mass physical properties of the bottom of the remaining two cores, when compared to those that penetrated the ash layer, showed values similar to the portion of the core immediately above the ash layer.

None of the MR cores completely penetrated the ash layer into another sediment type. The high cohesive strength of the ash layer stopped the corer.

Core 661003-10, taken to the north of the MOHOLE site penetrated two ash layers interstratified between brown muds. The cohesion of these ash layers was considerably lower than that found at the MOHOLE area. Whether one of these ash layers is the same one cored in the MOHOLE area is not known.

A microscopic examination of the ash revealed the shards to be sharp and angular. Heavy minerals, probably magnetite, were present as inclusions within the volcanic glass shards. The ash is rather friable and contains a high water content (greater than 80% porosity) which is not visually apparent until remolded. The origin is believed to be submarine volcanic inasmuch as no indications of bubble-wall shards were found which would suggest subareal origin.

The areal extent of the ash layer is not known at this time. Because of the four-foot corer length limitation, only ash layers within this depth were sampled. It is possible that the ash stratum continues and deepens as it approaches the Hawaiian Deep.

Calcareous Ooze

The core with the highest carbonate content was from the central depression of Tuscaloosa Seamount, approximately 51 nautical miles north of the western end of the Island of Molokai. The water depth was approximately 3000 meters, well above the depth of solution for carbonates in Hawaiian waters.

Predominant species are planktonic foraminifera with some benthonic species. Minor constituents are sponge spicules and radiolarian tests. The sample also contained clay and silt intermixed with the skeletal remains. Percentage of organisms in each phi-size are listed in Table VII.

Samples taken around the base of the seamount contained approximately 2% foraminifera within the brown mud. The decrease in foraminifera percentage probably is due to solution of the carbonate tests. Carbonate solution depth in the Hawaiian area is approximately 4800 meters.

Other cores in which oozes appeared were those which sampled turbidites. The ooze is predominantly planktonic foraminifera, usually occurring at the base of the turbidite and not exceeding more than 1 1/2 inches in thickness. These layers were graded and contained heavy dark minerals increasing in quantity towards the bottom of the organic basal layer. Identification of foraminifers is listed in Table IX.

Table IX

Identification of Foraminifers

From top of Tuscaloosa Seamount
Sample 650125-6
Depth, 2970 meters

Size: Mesh	Size: Phi	Identification by J. M. Resig
+16	0	Few planktonic foraminifera embedded in sediment matrix. No loose tests.
+32	1	Organisms 2/3 of sample, consist entirely of foraminfers. (P) Foraminiferal species: _Globoratalia tumida_ (1), _Globigerinoides conglobatus_ (2), _Globigerinoides sacculifer_ (3), _Orbulina universa_, _Globorotalia truncatulinoides_, _Globigerina conglomerata_, _Globigerina dutertrei_, _Sphaeroidinella dehiscens_ (B) _Planulina_ sp., _Pyrgo_ sp.
+60	2	Organisms 3/4 of sample, consist entirely of foraminifera. (P) Foraminiferal species: All of the above plus _Globigerinoides ruber_ (1), _Globigerina hexagona_, _Hastigerina aequilateralis_, _Globorotalia hirsuta_, _Globorotalia inflata_, _Candeiana nitida_, (Note, 2nd in abundance

Table IX (cont.)

Size		
Mesh	Phi	
		Globigerina conglobatus, Globigerinoides sacculifer).
		(B) Same as above plus Cassidulina sp. with alveolar ornamentation.
+115	3	Organisms 1/2 of sample, foraminifers. Many broken tests of foraminifera present.
		(P) Foraminiferal species: All of above plus (Globorotalia tumida present only in fragments) plus several unidentified species of Globigerina, Globigerina bulloides, Globigerina ruber (1)
		(B) Bulimina rostrata, Pullenia bulloides, Lagena spp., Cassidulina sp., Cassidulina subglobosa, Gyroidina sp., Epistominella sp., Fissurina spp., Pullenia sp.
+250	4	Foraminifera 2/3 of sample. Many broken tests of forams present. Radiolarians rare.
		Foraminiferal species: Immature forms of before-mentioned species plus Globigerina humilis.

Base of Tuscaloosa Seamount
Sample 750707-3
Depth, 4915 meters

+16	0	No foraminifers.

Table IX (cont.)

Size		
Mesh	Phi	
+32	1	Foraminifers present: Shell fragments approximately 2% of sample.
+60	2	Foraminifers present: Approximately 1% of sample. (P) Foraminiferal species: Globorotalia tumida, Globigerinoides sacculifer, Globigerinoides ruber (1), Globorotalia menardii, Globigerina hexagona, Globorotalia truncatulinoides, Globigerinoides conglobatus (B) Pyrgo sp., Amphistegina sp. (from shallow water), Cibicides sp., Gyroidina sp.
+115	3	Foraminifers 1 - 2% of sample (plus some sponge spicules). (P) Foraminiferal species: Above species plus Globigerina bulloides, Pulleniatina obliquiloculata, Globoratalia hirsuta, Globigerina spp. (no one species dominant). (B) Trifarina bradyi, Cibicides sp., Ehrenbergina sp., Cassidulina subglobosa, Bolivina sp., Cassidulina spp., Gyrodina sp., Siphonodosaria, Bolivina globulosa.
+250	4	Foraminifers same as above (P) Foraminiferal species: Immature specimens of beforementioned species plus Globigerina humilus (B) About equal in abundance to planktonics. Bolivina spp.

Table IX (cont.)

(1), *Cassidulina* spp., *Trifarina bradyi*, *Fursenkoina* sp.

Legend: (P) Planktonics, (B) Benthonics
Number in parenthesis indicates position in abundance.

Turbidites

One positively identified and two probable turbidites were found during the investigation. The first is located north of the Island of Molokai. A probable turbidite is located 12 1/2 miles away, and the other probable turbidite is located south of the Island of Molokai. All were located within 20 nautical miles of the steeper island submarine slopes. Information pertinent to these cores is shown in Table X.

Table X

Turbidite Core Data

Core No.	Position of Core	Water Depth (meters)	Core Length (inches)	Turbidite Thickness (inches)
661003-2	21°52.5'N 156°56.0'W	4960	45	25 1/2
650606-3	21°49.2'N 157°08.6'W	5000	32 1/4	25 5/8
670313-5	20°34.7'N 157°27.2'W	3980	21 3/8	7 1/2

The source area for the sediment of core 670313-5 is clearly the submarine canyon south of Molokai. The source area(s) for cores 650606-3 and 661003-2 are not as clearly defined. Figure 8 shows possible source

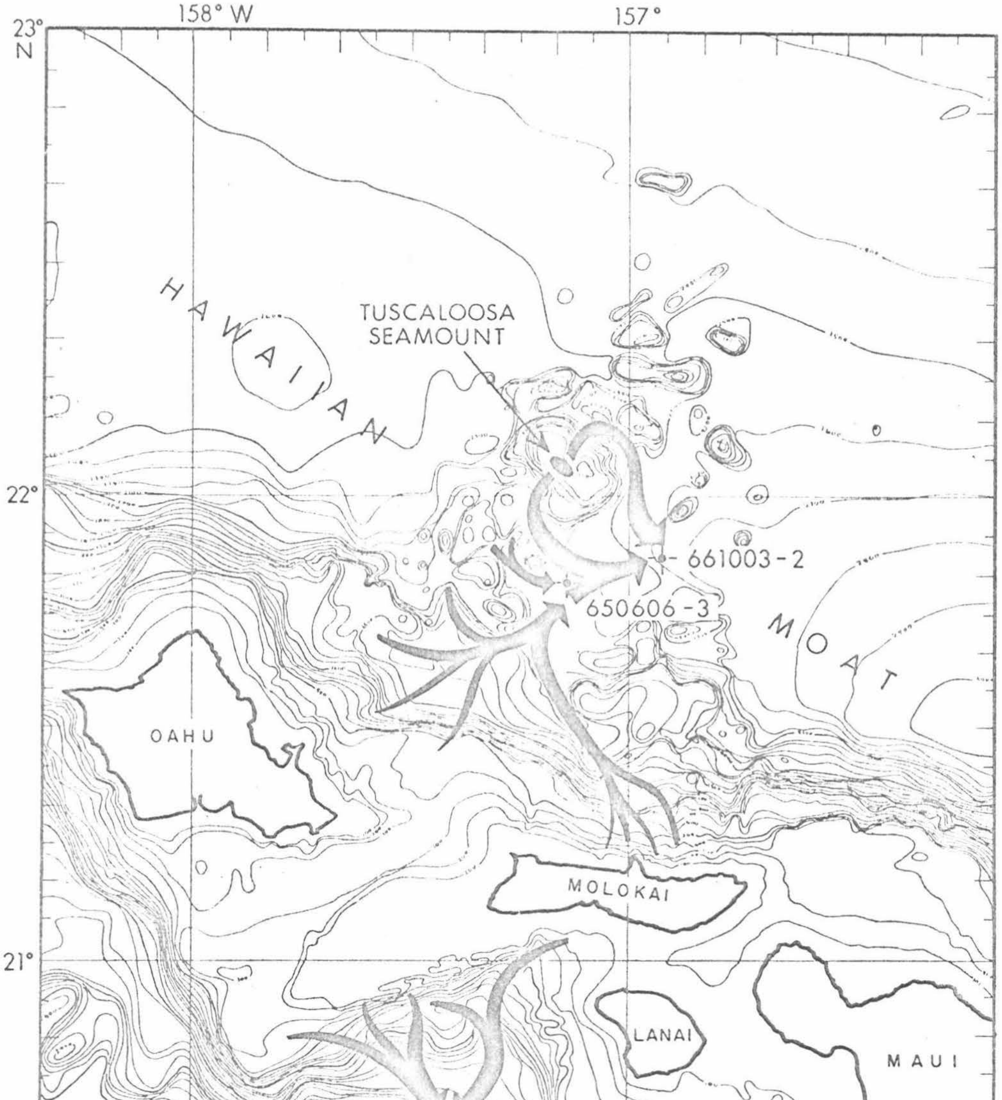


Figure 8. Possible source areas and channels to the turbidite core locations.

areas and submarine channels which could have directed the turbidity currents to the deposition sites of the cores. It is believed that the two northern turbidite cores are part of the same turbidite, inasmuch as they are only 12.5 nautical miles apart. It was not possible, however, to perform mass physical properties measurements on core 650606-3 for comparison due to its dried condition at the time of investigation. Similarities of the two cores are (1) the basal foraminiferal layers occur at about the same depth interval, the basal layer of core 650606-3 being several inches deeper, and (2) both are at a water depth where calcareous material should be sparse.

Both cores contained volcanic fragments and heavy minerals within the graded foraminiferal layers. An investigation of the dark minerals within the foraminiferal layer of core 661003-2 showed a small weight percentage increase with depth. The same core also showed grading within the brown mud of the turbidite portion. Figure 9 shows histograms of the turbidite portion of the core. Davidson and Keen's (1963) histograms of a turbidite are shown alongside for comparison.

The turbidite portion of core 661003-2 covered a normally deposited brown mud. Examination of the mass physical properties graph (Appendix B) shows an offset of the curves of most parameters at the turbidite/brown mud contact. The graph also suggests a degree of compaction of the upper portion of the brown mud by the overburden pressure of the turbidite.

Brown Muds

The term brown mud used in this investigation refers to those brown muds of locally derived terrigenous nature as opposed to the term

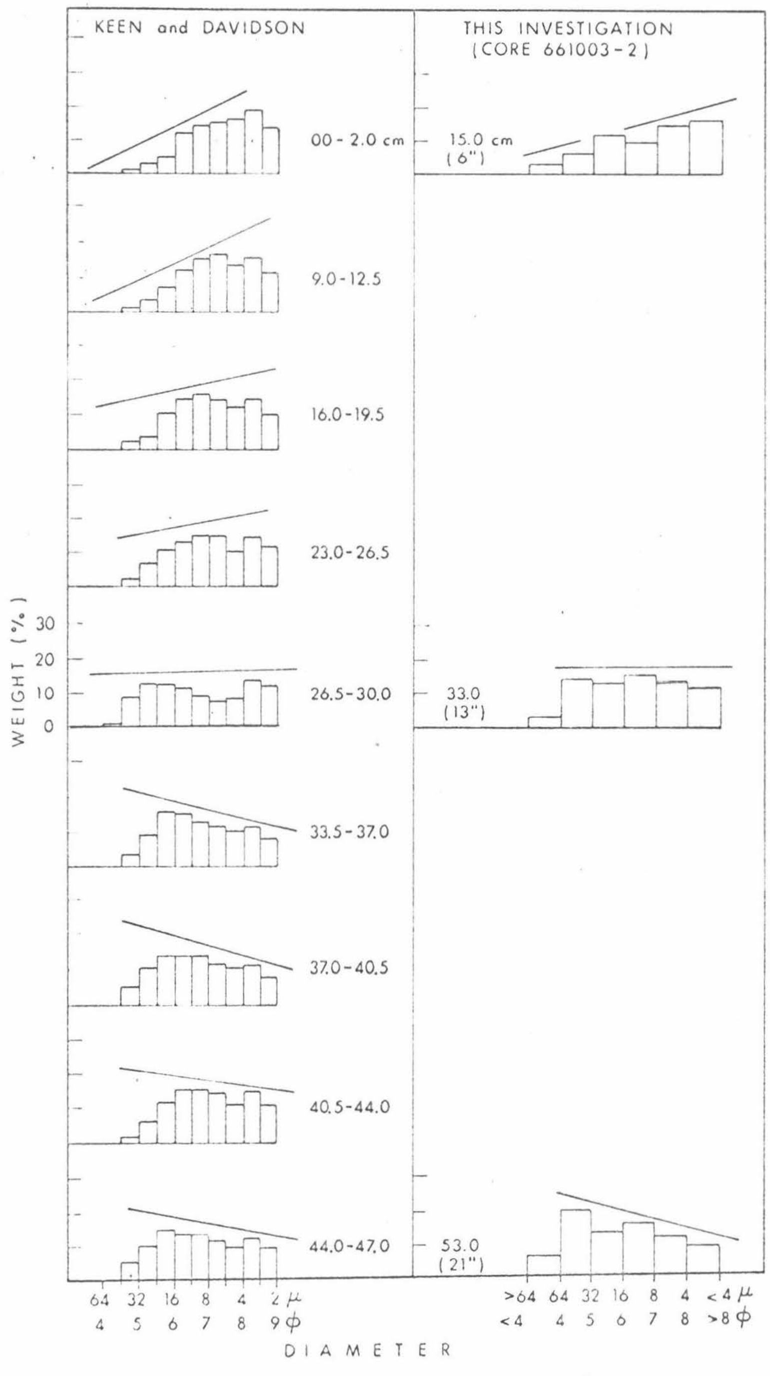


Figure 9. Comparison of Davidson and Keen's turbidite histograms with those of this investigation. Slope lines over histograms show the same trend with depth in turbidite.

"pelagic" brown muds usually of a finer median diameter and deposited far from land by currents and trophospheric winds. The author prefers to use the term brown terrigenous muds for the sediments of the investigation. They fall within Shepard's (1963) definition of terrigenous muds as having more than 30% of sand and silt of definite terrigenous origin. In essence, the brown terrigenous mud of this study is a mixture, the major contribution being locally derived and the minor derived from distant "pelagic" sources. The locally derived terrigenous muds decrease in quantity with distance from the islands as shown by Rex and Goldberg (1958). They have shown dilution of the aeolian quartz content in pelagic sediments by weathering products from the Hawaiian Islands. This dilution effect occurs to a distance of 150 nautical miles north of the islands, i.e., to the crest of the Hawaiian Arch.

With the exception of the foraminiferal ooze on the summit of Tuscaloosa Seamount, the uppermost layers of all cores are highly porous brown mud. This layer, in most cases, has a smaller median diameter than those sediments underlying it. Generally the muds increase in median diameter with depth, varying about the median curve. This suggests a transition from a colder, wetter climate with mechanical erosion dominant to a sub-tropical climate and predominantly chemical weathering, leading to finer grained sediments. It may also suggest a decrease in volcanic activity, or both factors acting concurrently.

CONTROLLING ELEMENTS OF SEDIMENT MASS PHYSICAL PROPERTIES

General Statement

Since a sediment consists of many discrete particles, its mass physical properties are dependent upon the total effect of these particles. The prime controlling factors of mass physical properties are grain-size distribution, grain shape, and the sediment fabric. These parameters, either singly or in combination, determine the values of the mass physical properties.

Grain-size Distribution

Pettijohn (1957) states that, in theory, a sediment composed entirely of spherical particles, perfectly sorted, would have the same porosity as any other similar sediment composed of either larger of smaller particles. It would also have its maximum porosity of about 48% in the most open packing arrangement and 28% in the most closed arrangement.

In fact, however, finer grained sediments have higher porosities. Porosity may be closely related with grain size distribution and grain shape which may be the primary cause for porosity difference of sediments of the same median grain size. Addition of larger or smaller particles into a sediment tend to lower porosity by filling in interstices or intragrain voids in the case of organisms. The loss in porosity is directly proportional to the amount of matrix added.

Grain Shape

Grain shape has a noticeable effect on porosity. This is most marked in the case of very flat particles. The siliceous ooze of this study is a very good example of the effect of grain shape and size upon the values of porosity. Grain shapes range from spheres to flat plates; most are intermediate between these forms. Grains may also be solid or porous. Most biogenous and pumice particles are porous, whereas most monomineralic grains are solid.

Grain shape has a great influence on the mass physical properties of sediments. It controls settling velocity, sediment fabric and perhaps contributes to the packing pattern.

Practically all mass physical properties are related to the amount of interstitial water in a sediment (Richards, 1962). Interstitial water may be divided into intragrain and intergrain water. Sediments formed only of solid grains contain only intergrain water, while those containing hollow, punctate, or "basketwork" grains contain both intergrain and intragrain water. The "hollowness" or porosity of these grains determines the quantity of water they will encompass within their shape envelope. In many cases the intragrain water may exceed the intergrain water. Figure 10 shows the highly porous and hollow nature of several types of organisms found in the area of the study.

Sediment Fabric

The pattern or arrangement in which particles are deposited to form a sediment is termed sediment fabric by geologists. In civil engineering parlance this arrangement is termed sediment structure. The term sediment fabric will be used hereafter in this study. Sediment fabric is controlled by the grain shape, rate of deposition, and the electromagnetic

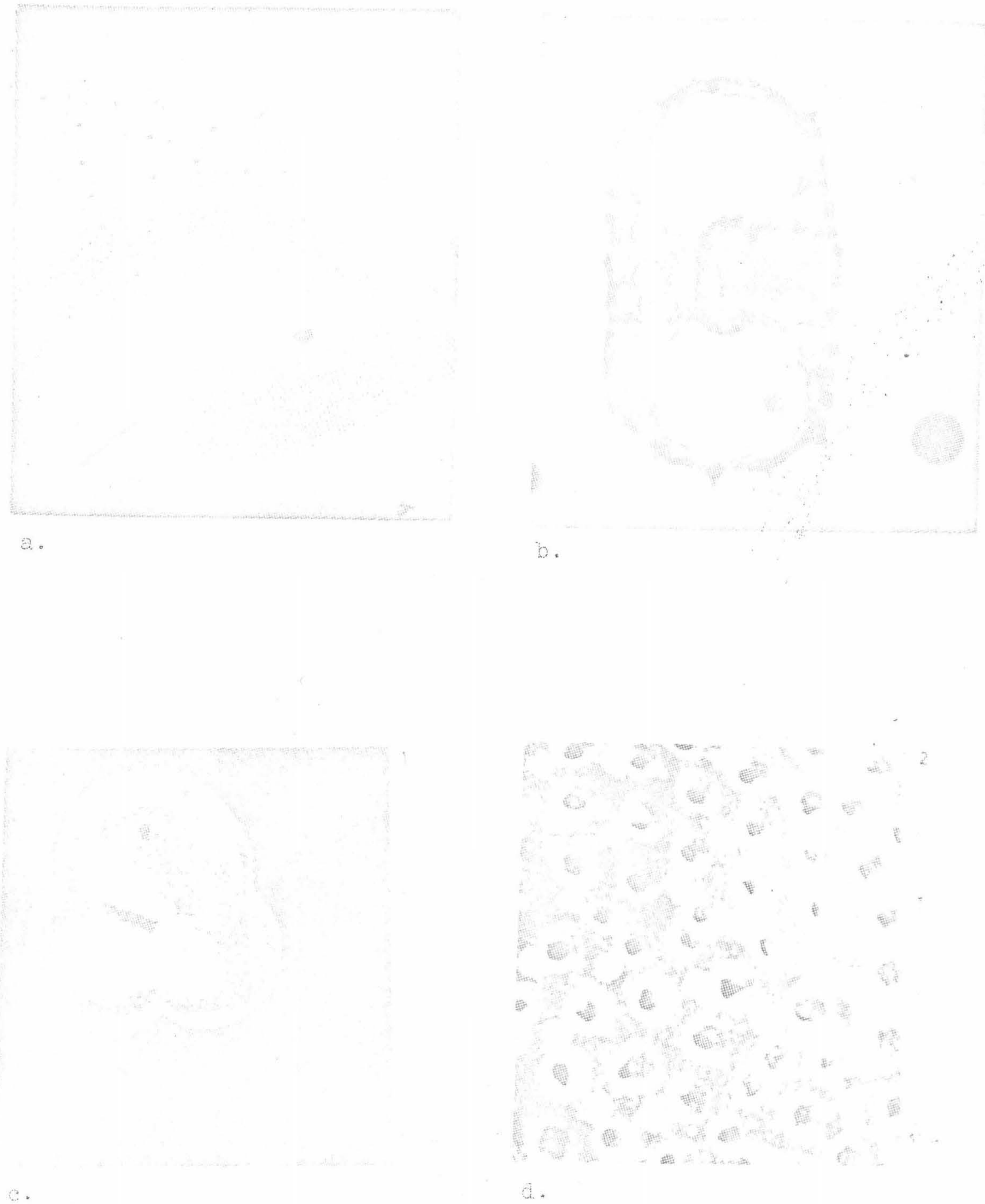


Figure 10. Organic particles showing high grain porosities: a. diatom (*Ethmodiscus rex*), b. radiolarian, c. foraminifer (*Globigerinoides ruber*), and d. porous wall structure of c.

field. The spectrum of sediment packing ranges from the most efficient rhombohedral to the most inefficient and randomly oriented one, such as the "honeycomb" and "cardhouse" fabrics. Most sediments lie between the above extremes. Sediments of bulky solid particles more closely approach the rhombohedral packing and those composed of platy particles, the "cardhouse" packing.

Sedimentation Rates

Sediments of several different deposition rates were found in the study area. Compared with the rates of deposition of brown muds and foraminiferal ooze, the turbidites, siliceous ooze and volcanic ash were deposited nearly instantaneously, on a relative basis. Arrhenius (1952) stated that a normal deposition rate for deep-sea brown clays of median diameter 10ϕ, deposited far from land, would be on the order of 1mm/1000 years. Since the study area is in the vicinity of islands, the rate of deposition should, therefore, be higher. The median diameter between 7ϕ and 8ϕ for most of the brown muds in the study area is coarser than for pelagic muds in general, and thus corroborates this assumption.

Upon deposition intergrain porosity develops. For equivalent-sized grains, slower rates of deposition create sediments of more efficient (lower porosity) packing, while rapid deposition creates sediments of less efficient packing and higher porosities. Particles coming to rest upon a sediment, without simultaneous interference by other settling particles, have time to settle into their equilibrium position. This is the case for "normal" deposition. In the case of rapid deposition, adjacent particles settling simultaneously upon the bottom encounter interference with each other in seeking their equilibrium. As a result, there is bridging and resultant higher porosities.

Core 660622-1 was selected as being the most representative of the normal depositional regime of the Hawaiian Arch area. It appears to be the core least disturbed by volcanic or biogenous deposition. It also showed the least variation in mass physical properties with depth in the core. The length of the brown mud interval in the core was 35 inches and the average median diameter was 7Φ.

MASS PHYSICAL PROPERTIES

General Statement

Mass physical properties, as previously defined, describe a sediment quantitatively. The mass physical properties of 18 deep-sea cores were measured and the results of each of the parameters were plotted versus depth in the core. Figures B1 through B18 of Appendix B show the graphed measurements of all parameters in each core and Appendix C shows the same parameters in numerical tables. A core log of visual examinations of the cores is included as Appendix A.

In addition to the individual core investigations, the sample values of the 18 cores as a group were plotted against various parameters. From this emerged much new data for sediments of the Hawaiian area.

Sand-Silt-Clay Percentages

Sand-silt-clay percentages were calculated from sieve and pipette analyses for the 18 cores. Ninety-five samples were plotted on a ternary diagram system devised by Shepard (1954). Table XI shows percentage of samples in each nomenclature area of the diagram, Figure 11. Clayey silt and silt comprise 74% of the sediments.

Sediment samples of similar origin have been outlined in Figure 11 for comparison to each other. The brown muds of area "A" contained the least percentage of sand-size particles and the siliceous oozes of area "T" the greatest.

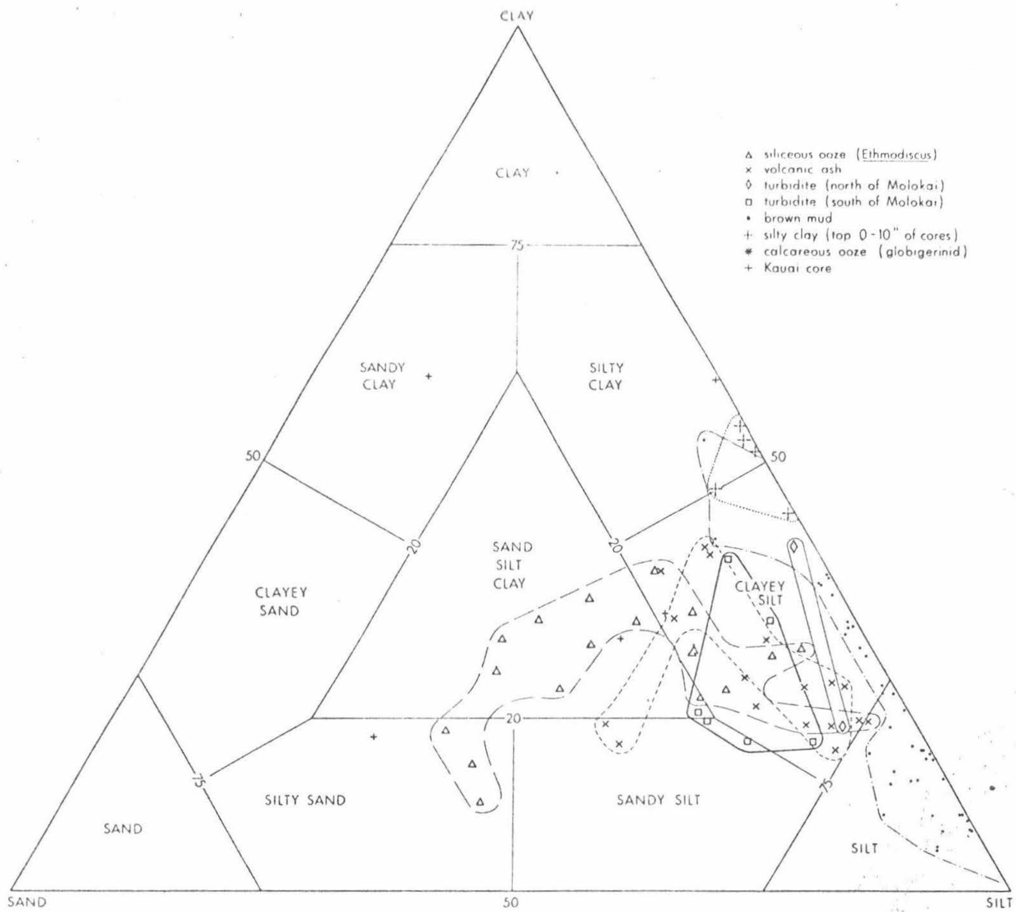


Figure 11. Classification and groupings of sediments of different sources.

Table XI

Distribution of Samples by Sediment Nomenclature

Sediment Nomenclature	Number of Samples	Percent of Samples
clay	0	0.0
silty clay	6	6.2
clayey silt	43	45.2
silt	27	28.3
sandy silt	4	4.1
silty sand	4	4.1
sand	0	0.0
clayey sand	0	0.0
sandy clay	1	1.1
sand silt clay	10	11.0

A comparison of the nomenclature areas into which Richards' (1962) Atlantic core samples and those of this investigation fell is shown in Figure 12. Richards' samples were of smaller median diameter and from sites farther removed from land than those of this study. He also found fewer sediment types. These factors are reflected in the smaller area on the graph and its position toward the clay apex of the ternary diagram, when compared to the sediments of this study.

Median Diameter

By plotting a cumulative percentage curve from the results of sieve and pipette analyses, the median diameter, in phi units, was obtained. The median diameter may be slightly in error due to the differences in the means of size separation between sieving (mechanical separation) and pipetting (gravity separation). The median diameters of the samples studied fell between 2.78Φ and 8.00Φ. The largest median diameter was measured in core 670224-2 and the smallest in core

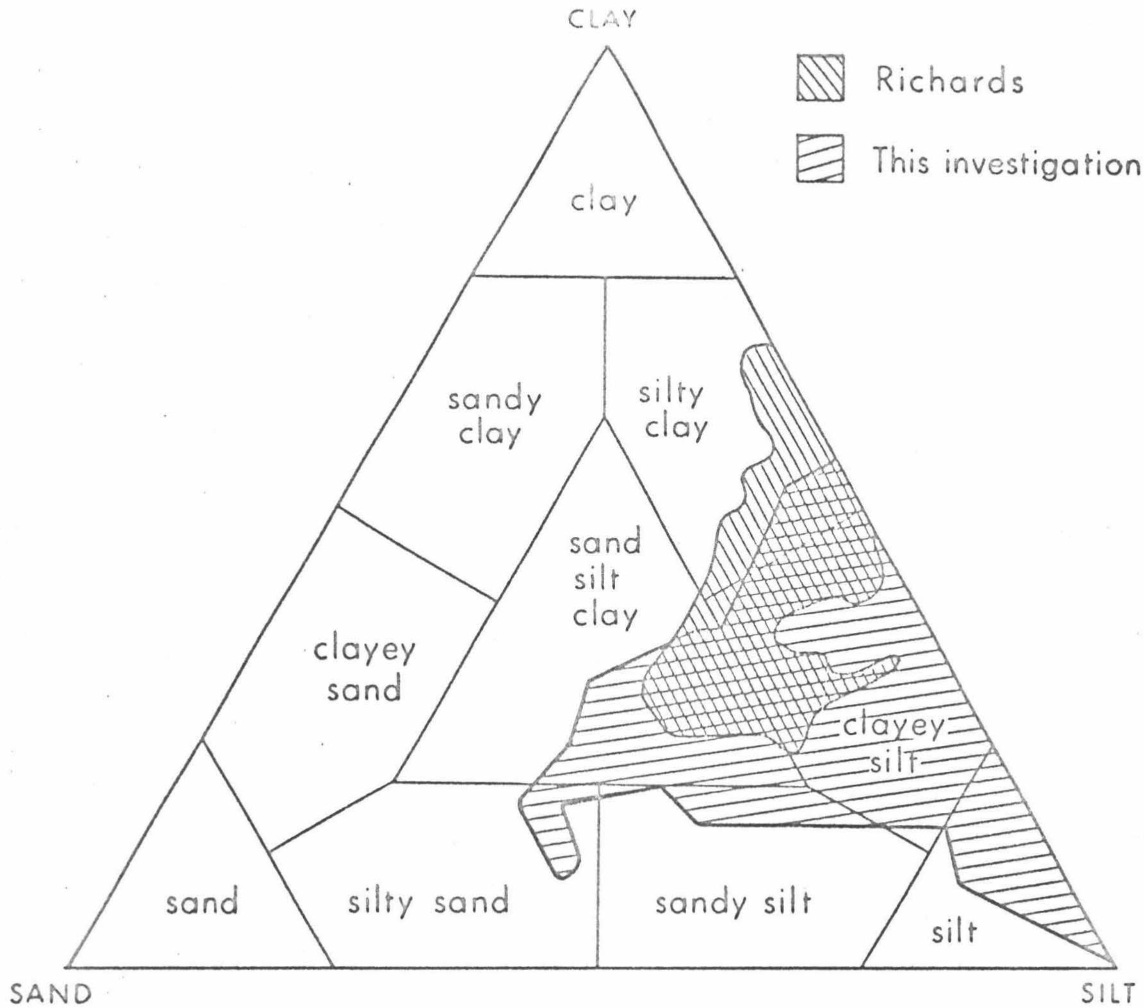


Figure 12. Sediment classification areas into which Richards' samples (1962) and those of this investigation fell.

661003-10. On the average, sediments composed of organisms have a larger median diameter than the brown muds.

Figure 13 shows plots of the median diameter versus porosity. In theory, grain size has no influence on porosity. In fact, finer grained sediments have higher porosities, however this is not a cause and effect relationship. It is believed to be due to differences in the grain shape. This is confirmed by the high porosities of the siliceous ooze (flat platy particles) plotted in Figure 13. The graph also shows that the top 0-10 inches of core samples, deposited at normal rates, are more porous than the brown muds underlying them, although both have the same average median diameter. Median diameter is not definitive enough to allow differentiation between normally and rapidly deposited sediments. Of most importance, the graph shows that normally deposited sediments picked up by turbidity currents are redeposited in a state 14% more porous than in their original form.

Keller and Bennett (1968) state that Atlantic sediments are denser, stronger and have lower porosities than those of the Pacific. Plotting median diameter versus porosity of both Richards' Atlantic data and those of this investigation, the envelopes enclosing the data of both investigations show that the sediments of this investigation, generally, have a higher porosity, for the same median diameter, than do Atlantic cores. This is probably due to more rapid deposition of the sediments in the vicinity of the Hawaiian Islands. Figure 14 shows this relationship.

Cohesion

Cohesion values of the samples were measured with depth in the core

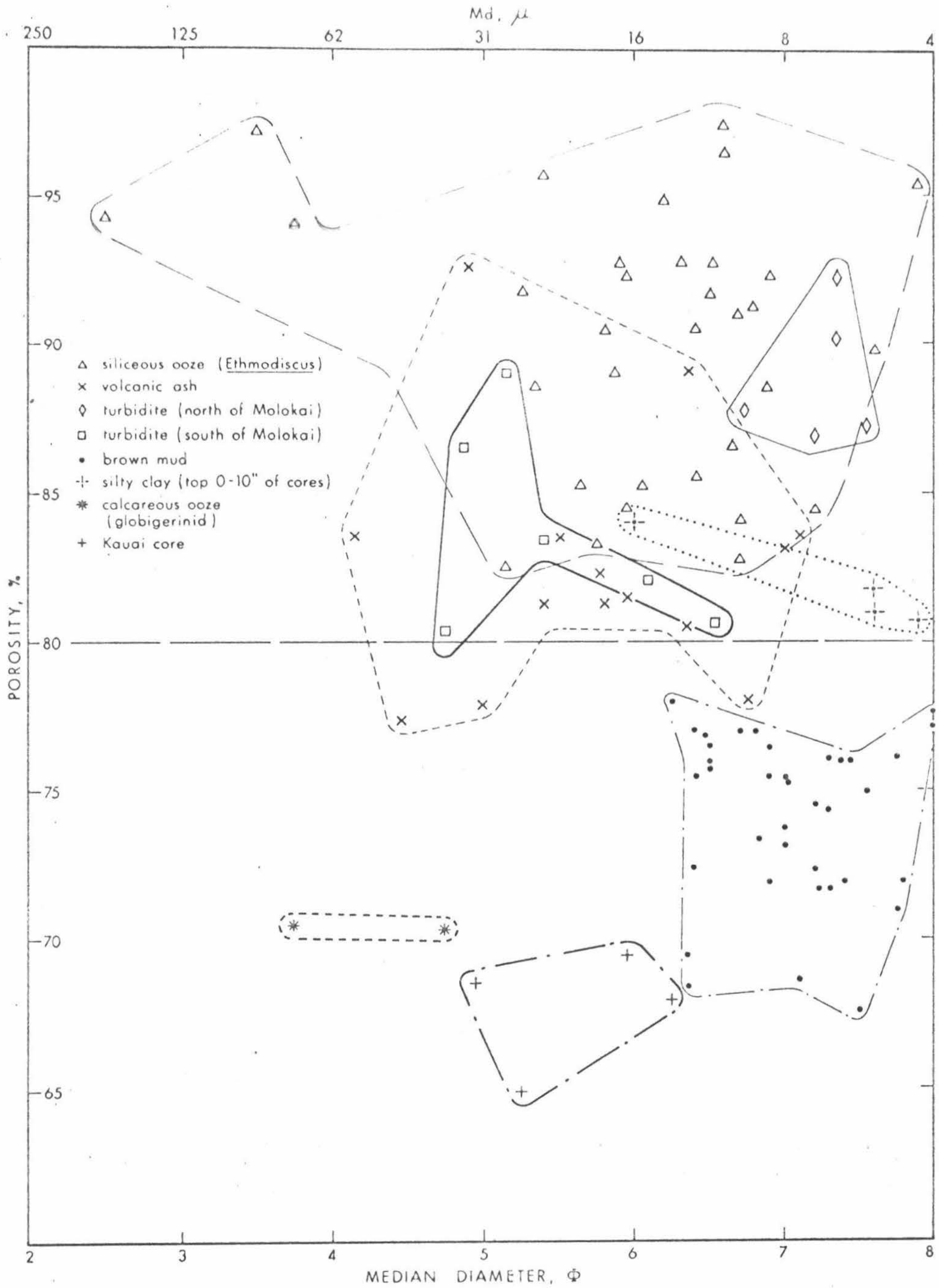


Figure 13. Median diameter plotted against porosity.

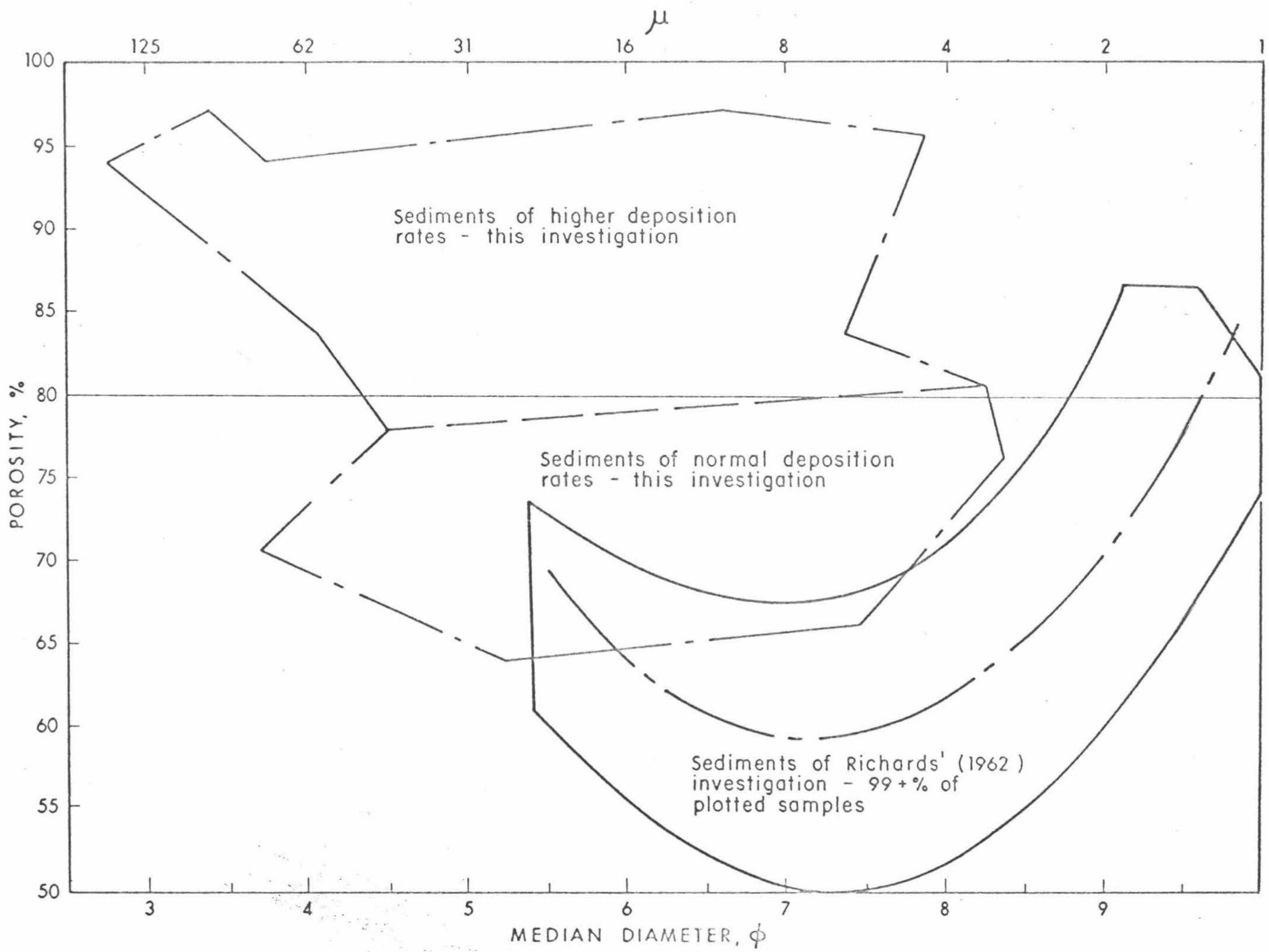


Figure 14. Comparison of Richards' (1962) porosity versus median diameter envelope with that of this investigation.

with a laboratory vane shear tester. Values ranged from a minimum of 0.035 psi at the surface of core 670224-2 to a maximum of 21.83 psi at the base of core 661003-8. The minimum value occurred at the surficial layer of a siliceous ooze core, which was of a gelatinous consistency. The maximum cohesion recorded is at the base of a volcanic ash.

Hamilton (1959) states that in general cohesion values in a core generally increase with depth due to the effect of the overburden pressure. The results of the cohesion study of this investigation corroborate Hamilton's findings. Figure 15 shows trend lines of the scatter points plotted for different types of sediments. All show an increase of cohesion with depth, although at varying rates.

Trask (1959) found that for a mud of given grain-size and water content the strength increases as the ratio of clay to silt increases. For coarser sand and silt, grain size had little effect. This was attributed to the greater surface area of the clays on which forces could act.

Through statistical analyses Goodell (1966) found that 41.60% of the variations of cohesion in siliceous ooze is accounted for by six factors. He states that in order of their relative importance as ranked in multiple regression they are: (1) depth in core, 20.88%; (2) $CaCO_3$ content, 9.0%; (3) silt content, 3.07%; (4) water content, 5.16%; (5) sand content, 1.62%; and (6) sorting, 1.87%. Goodell also stated that in calcareous ooze, core cohesion is a function of (1) depth, 63.91% and (2) the chlorite:illite ratio, 24.19%. The findings indicate that depth in core is the major factor in the increase of cohesion in a core for all sediment types. Second most important factors are; for brown

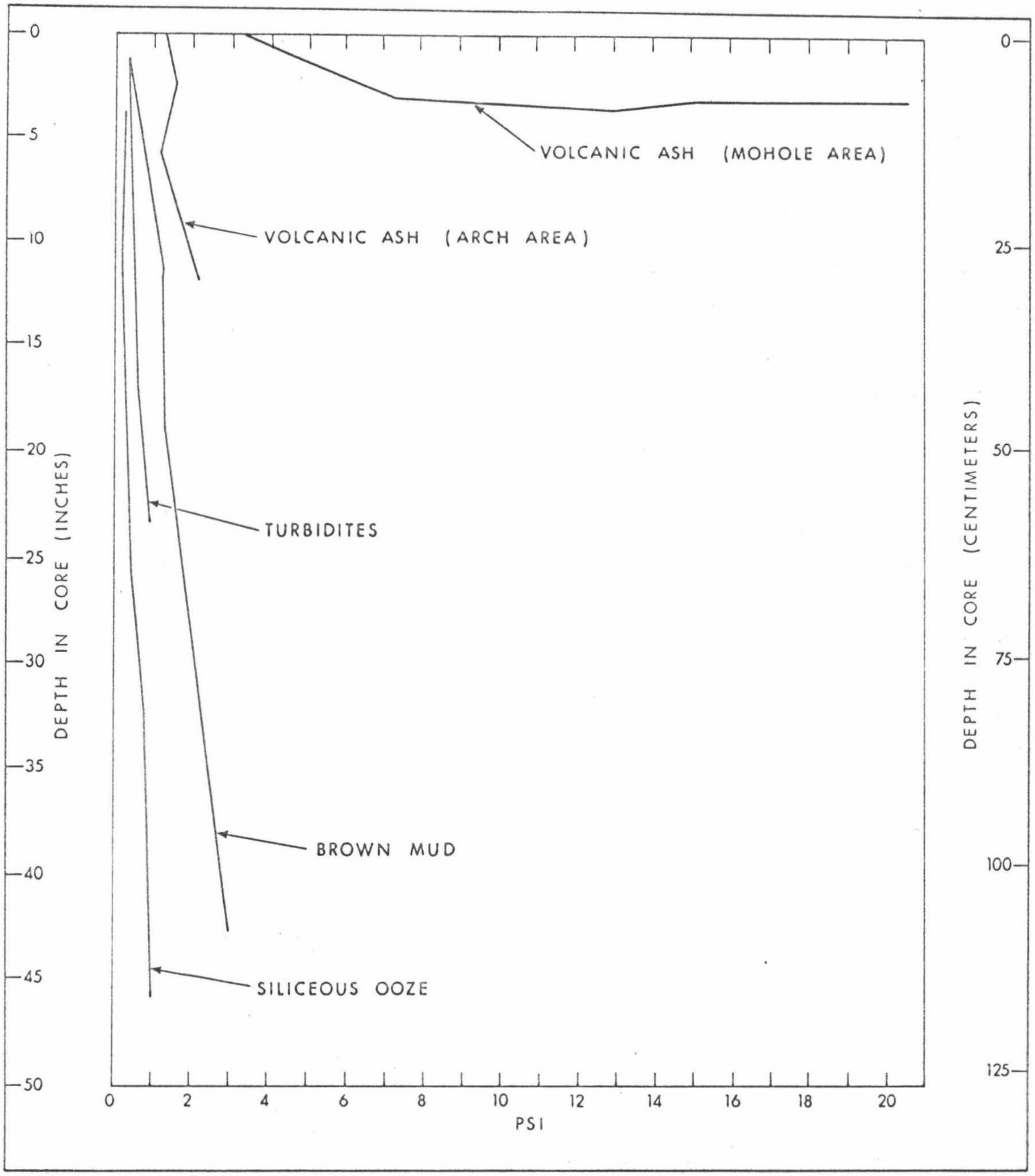


Figure 15. Cohesion versus depth in core. Plots represent trend lines of different sediment types. Tops of volcanic ash layers have been adjusted to zero depth.

muds, clay content; for siliceous ooze, carbonate content; and for calcareous ooze, the chlorite:illite ratio.

Porosity

Porosity was calculated from water content and volume measurements. Porosities range from a minimum of 64.80% at a wet bulk density of 1.59 in core 670504-1 to a maximum of 98.00% at a wet bulk density of 1.26 in core 670224-3.

Figure 16 shows porosity plotted against wet bulk density of 167 samples. It shows the relationship to be linear as shown previously by Richards (1962). It also shows separation of sediments of normal and rapid deposition on both the x and y axes. Normally deposited sediments plot below the 80% porosity line and to the right of the 1.45 wet bulk density line. The exceptions were the normally deposited surficial sediments of some cores which showed an upper limit of 84.5% porosity. This limit correlates well with the findings of Arrhenius (1952) for the Pacific, 84%; Emery (1960) off southern California, 86%; Shumway (1960) the Pacific and Arctic Oceans, 86%; Trask (1953) the Gulf of Mexico, 86%; and Richards (1962) the Atlantic, 86.5%.

As a check on the accuracy of porosity and wet bulk density, the values measured were used in the equation for grain density (or specific gravity):

$$\rho g = \frac{\rho_b - \eta}{1 - \eta} \qquad (12)$$

where: ρ_g = grain density
ρ_b = wet bulk density
η = porosity

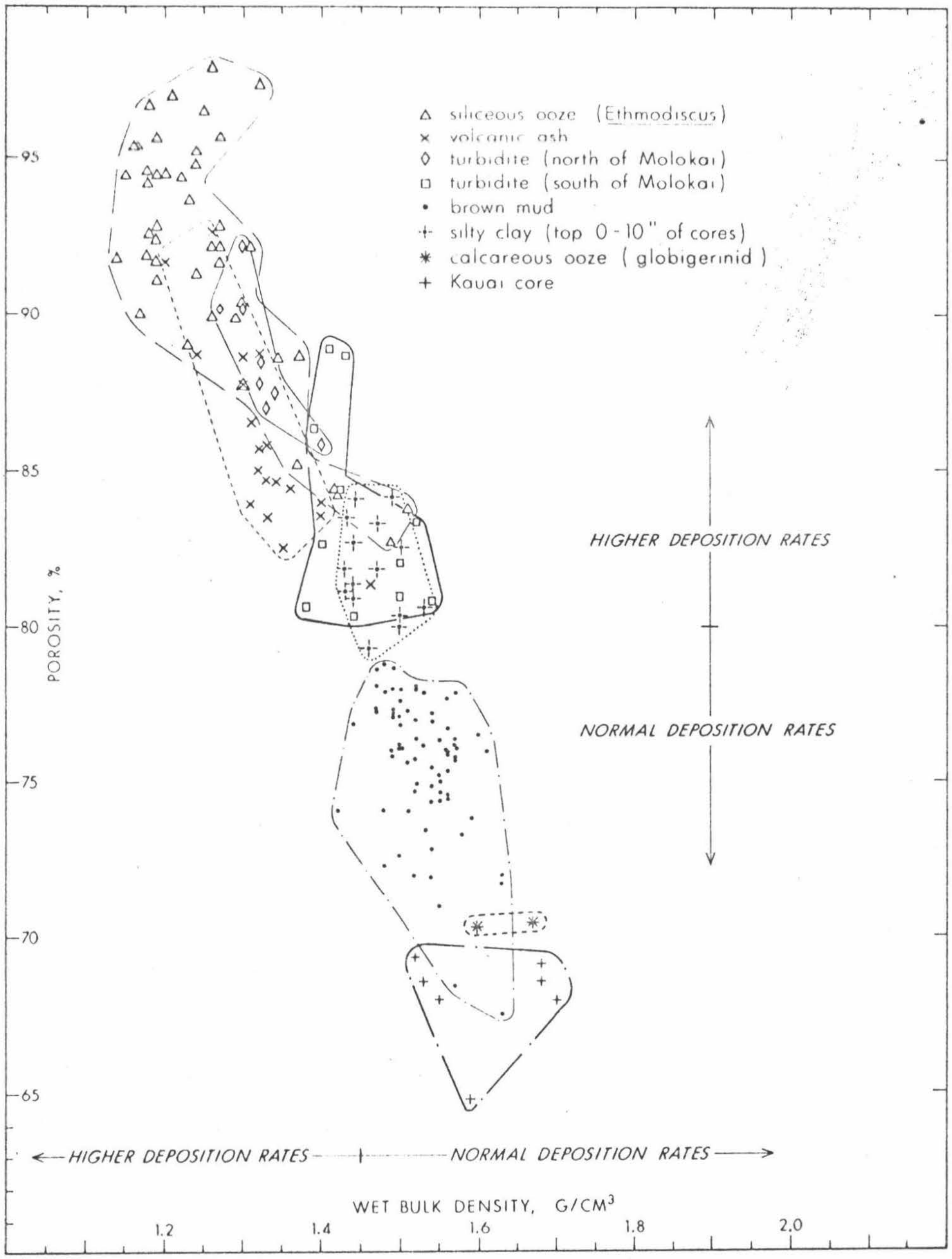


Figure 16. Wet bulk density plotted against porosity. Sediments of this investigation.

Calculation of grain densities show most values of ρ_g to be too high, which suggested that either measured porosity or wet bulk density values are too high. It was suspected that the small sample size was responsible.

In order to evaluate this assumption, an experiment was conducted utilizing sample cylinders of 17.5mm diameter (those used during the investigation) and 28mm diameter. The larger cylinder contained approximately four times the volume of the smaller. It was found that samples taken with the larger cylinder fell within reasonable limits for grain density, i.e. 2.5 - 3.0 g/cm^3, and that the porosities obtained were approximately 3 1/4% lower than samples taken with the small cylinders. Wet bulk densities remained the same or were slightly reduced in value. The 3 1/4% porosity discrepancy applies to Figures 13, 14, 16 and 18 and lowers all plotted values by this amount, however it does not affect the interrelationships or trends of the plotted points.

<u>Wet Bulk Density</u>

Wet bulk densities of the samples ranged from a minimum of 1.14 g/cm^3 at 91.80% porosity to a maximum of 1.70 g/cm^3 at 68.00% porosity. The former values were in a siliceous ooze and the latter in the Kauai core, i.e., sediments of higher grain density and larger median diameters.

Wet bulk density was found to be inversely related to porosity and volume shrinkage and directly related to median diameter. Sediment samples of less than 1.45 g/cm^3 were usually deposited rapidly, while those greater than 1.45 g/cm^3 were found to be those deposited at "normal" rates.

Dry Bulk Density

The dry bulk density range of the samples was from 0.32 g/cm^3 after 38.28% shrinkage to 1.68 g/cm^3 after 45.51% shrinkage. The former values was in siliceous ooze and the latter in brown mud.

Dry bulk density was found to be directly related to wet bulk density, porosity and volume shrinkage and inversely related to median diameter. Dry bulk density appears to be more dependent upon sediment structural integrity than upon the original porosity of the sample. Sediments forming "cardhouse" structures, e.g. Ethmodiscus ooze, are less prone to shrinkage even though they are of high porosity. This is probably due to bridging by particles during rapid deposition and to interlocking of the irregular edges of adjacent particles.

Atterberg Limits

Atterberg limits were measured for only six cores in the vicinity of the proposed MOHOLE site. The liquid limit measured ranged from 70 in the brown mud of core MR-1 to 191 in the volcanic ash of core MR-6. Plastic limit ranged from 23 in the brown mud of core MR-3 to 135 in the volcanic ash of core MR-4. The plasticity index ranged from 34 in the brown mud of core MR-1 to 108 in the volcanic ash of core MR-5.

Casagrande (1948) developed a system of classification utilizing the plasticity index (LL - PL) and the liquid limit (LL) of Atterberg (1911). Using Casagrande's system 25 samples were plotted from six cores of the MR group. The results are shown in Figure 17. Line "A" of the graph nearly separated the sediments of differing depositional environments and confirms the findings of others (Terzaghi, 1955; Trask

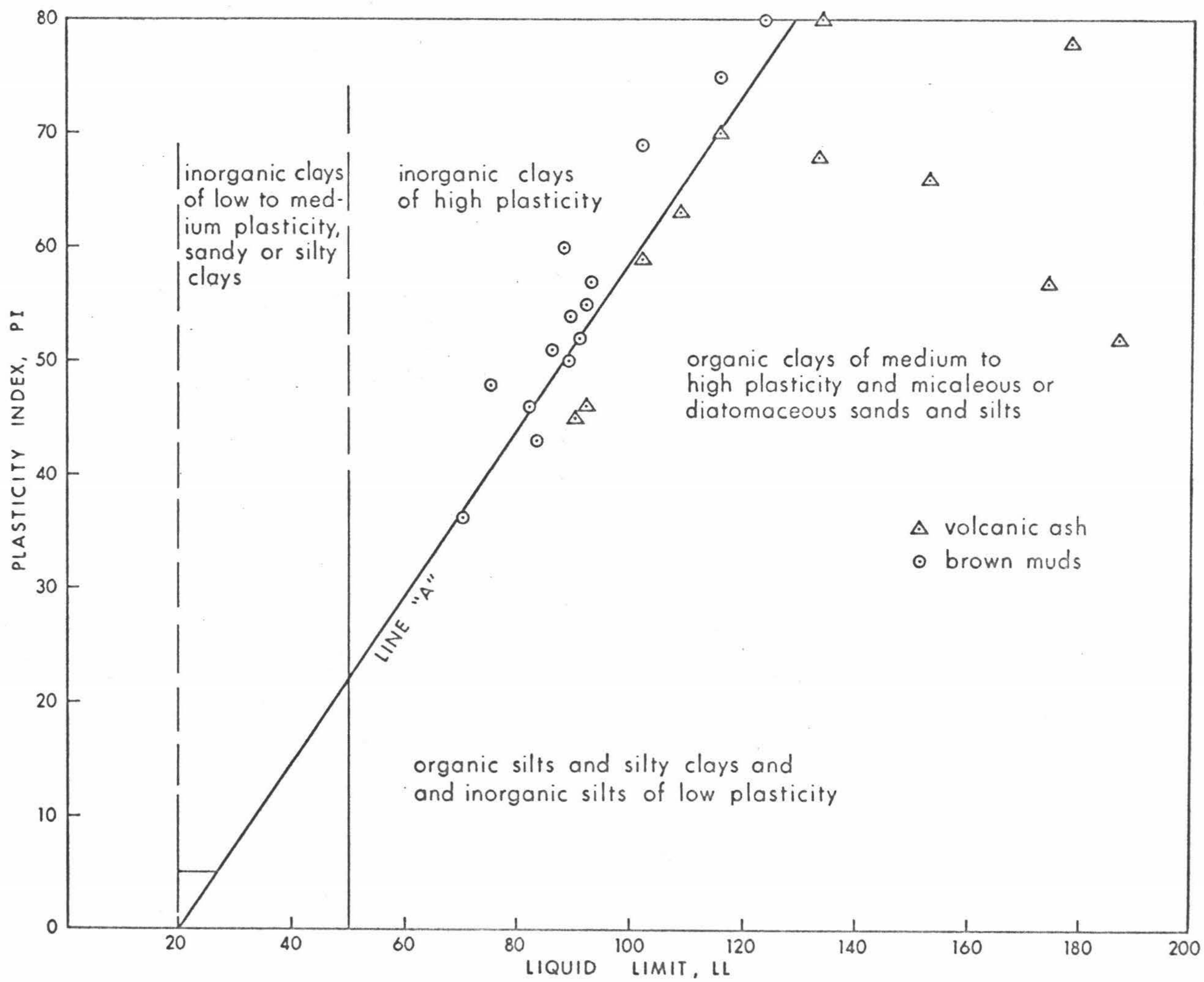


Figure 17. Plasticity index versus liquid limit of core samples from the vicinity of the proposed MOHOLE site. Axes, terminology and line A after Casagrande (1948).

and Rolston, 1950, 1959; and Richards, 1962). Those points on the graph lying to the left of the "A" line represent brown muds and those lying to the right, volcanic ash. Those lying on, or very close to, the line represent transitional mixtures.

Volume Shrinkage

Volume shrinkage values obtained from the samples ranged from a minimum of 2% at 70.5% porosity in core 661003-3 (foraminiferal ooze) to a maximum of 58.61% at 86.03% porosity in core 660622-1 (volcanic ash).

As shown in Figure 18, there is no discernible relationship between porosity and volume shrinkage that may be applied to all sediment types. The plotting of porosity versus volume shrinkage, however, appears to give better sediment type separation than other parameter plots. Figure 19 shows the upper 7 1/2 inches of a core to be visually wetter than the remainder of the core. The upper portion is the surficial brown mud layer and the remainder is siliceous ooze. The wetter-appearing upper portion, however, contains less water than does the lower portion. This is due to the difference in sediment structures, the siliceous ooze having a "cardhouse" structure. The results of shrinkage of samples from this core are shown in Figure 20. The two dried sample pellets on the left contained less water, but shrank more, than the remainder of the samples consisting of siliceous ooze. Volume shrinkage appears to be a function of the collapsibility or non-integrity of the sediment fabric.

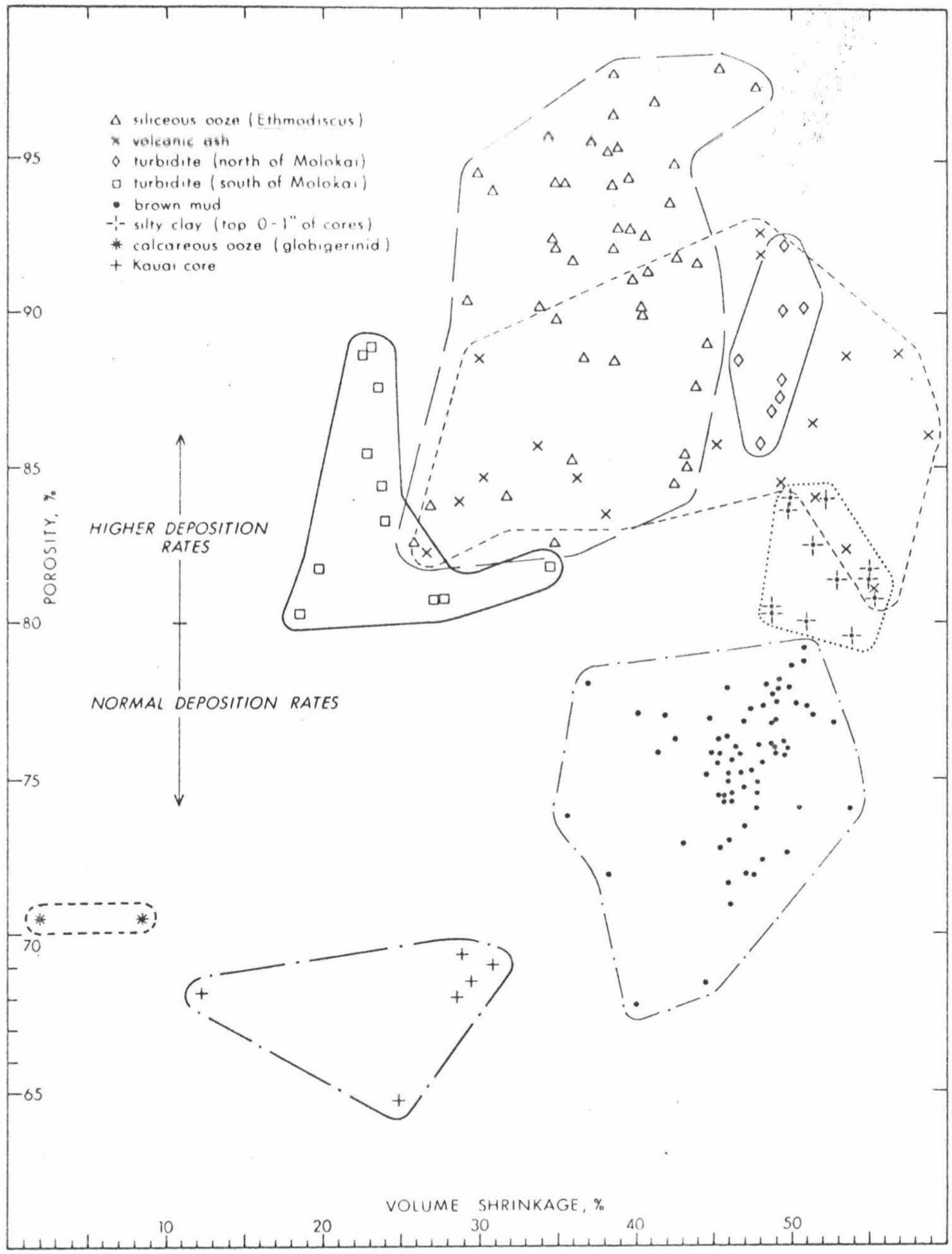


Figure 18. Porosity versus volume shrinkage of the samples. Outlined areas show groupings of sediments of different origins.

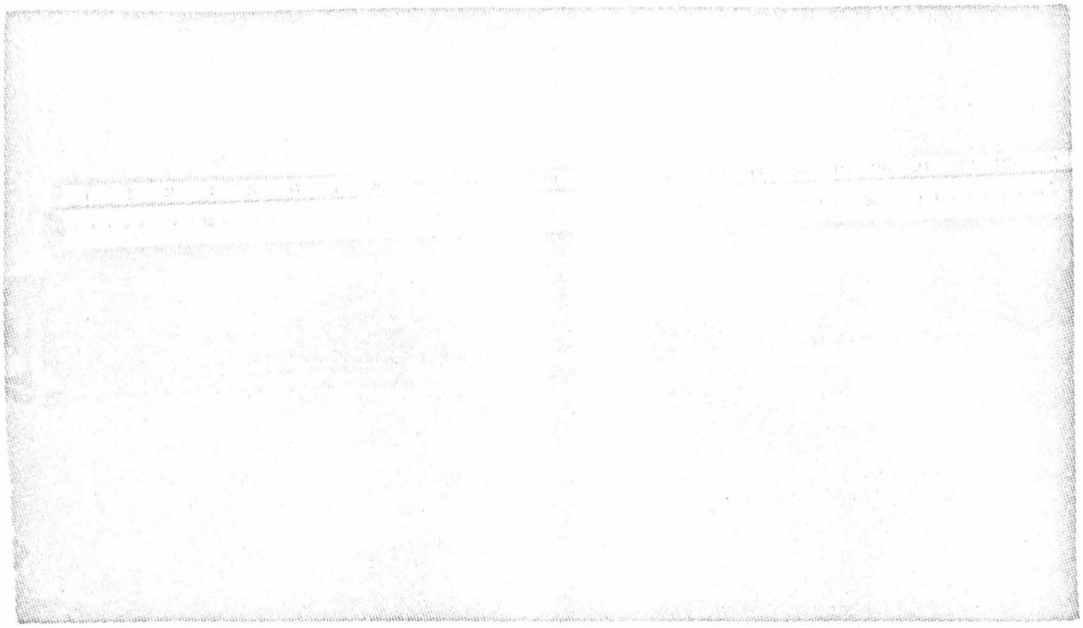


Figure 19. Freshly opened core (670224-3) showing the apparent difference in water content and consistency. The drier appearing portion at the right actually has a higher water content than the wetter appearing portion.

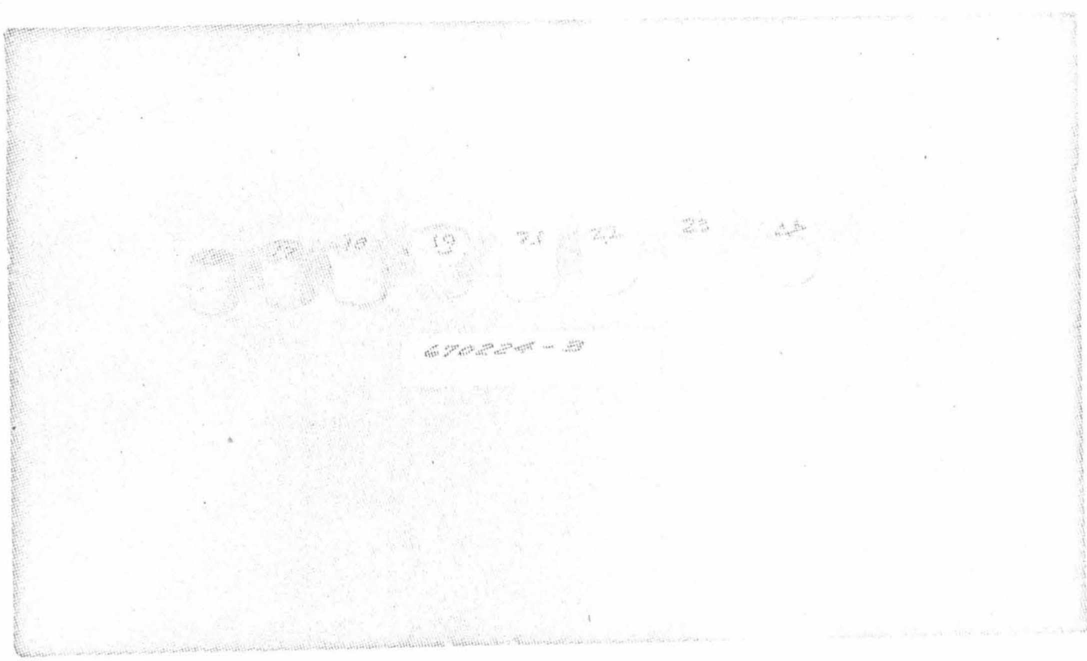


Figure 20. Relative shrinkage of dried sample pellets of above core. Two samples on left are clay and the remainder are siliceous ooze.

SUMMARY AND CONCLUSIONS

Eighteen deep-sea cores from the Hawaiian area were investigated for mass physical properties and represent the first study of this type for the area. Methods employed were satisfactory with the exception of the porosity measurements.

Summary graphs of the mass physical envelopes of four sediment types are included as Figures 21 and 22.

Five different sediment types were found in the study area. Volcanic ash (hyaloclastite) was found underlying the brown terrigenous mud of the Hawaiian Arch area. Siliceous ooze (Ethmodiscus rex) occupied the Hawaiian Deep. Calcareous ooze (foraminiferal) laid within the central depression of Tuscaloosa Seamount, and turbidites were found to the north and south of the Island of Molokai. Definite lateral boundaries of the sediment types are difficult to set because of the gradational nature of the sediment types.

Discovery of siliceous ooze of the diatom Ethmodiscus rex in the Hawaiian area defines a new separate region from that described by Hanzawa. Greatest concentrations lie in the northern part of the Hawaiian Deep, with a maximum of 70% recorded. The ooze extends around the eastern and southern side of the Island of Hawaii and continues westward in decreasing amounts. It is not known whether the siliceous ooze deposits extend along the more northerly island of the Hawaiian Archipelago.

The volcanic ash underlying the brown terrigenous muds of the MOHOLE area is of submarine origin, and is more properly termed

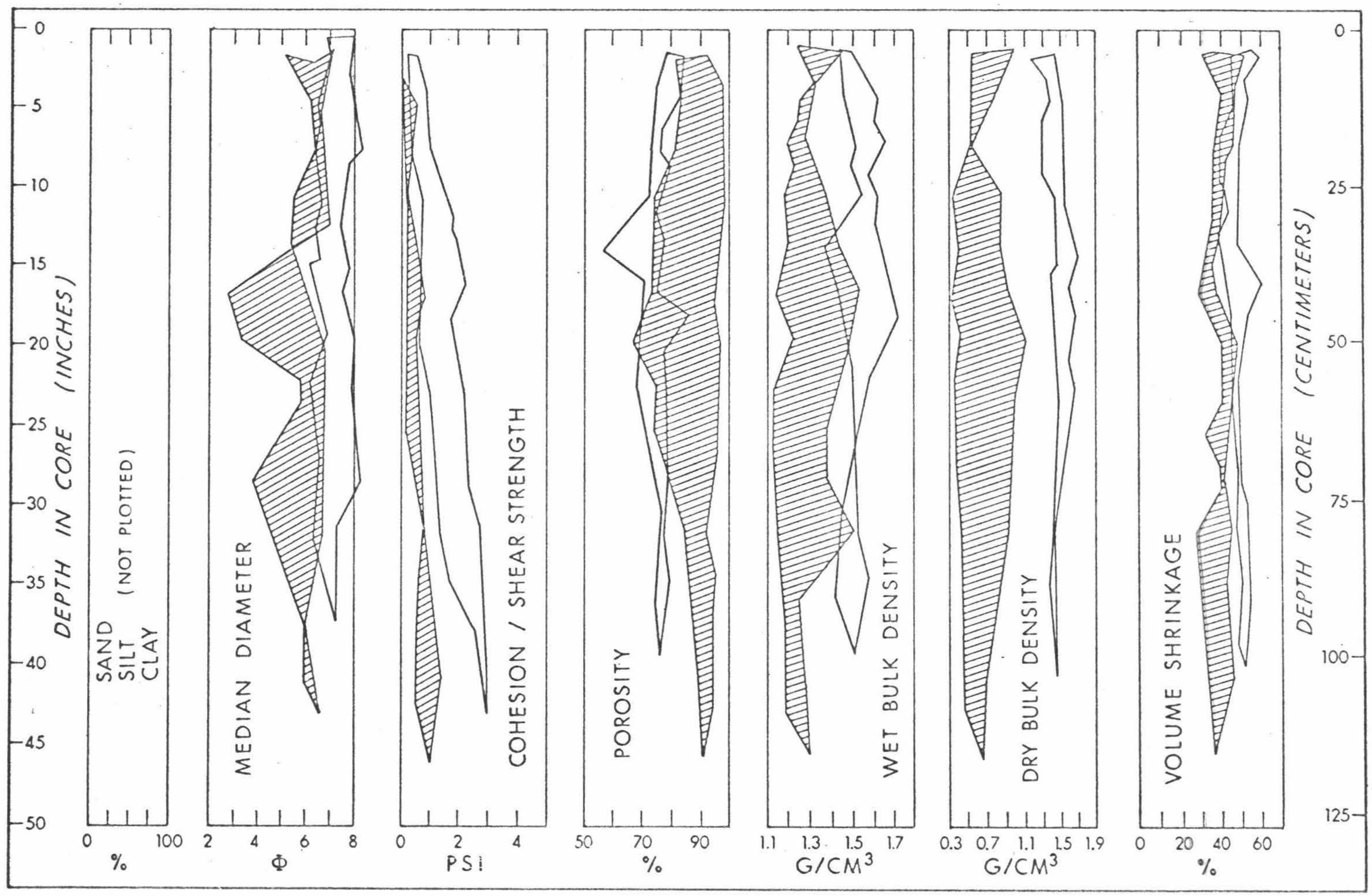


Figure 21. Summary of mass physical properties values with depth in core. All brown mud values fell within the unhatched areas and all siliceous ooze values within the hatched areas.

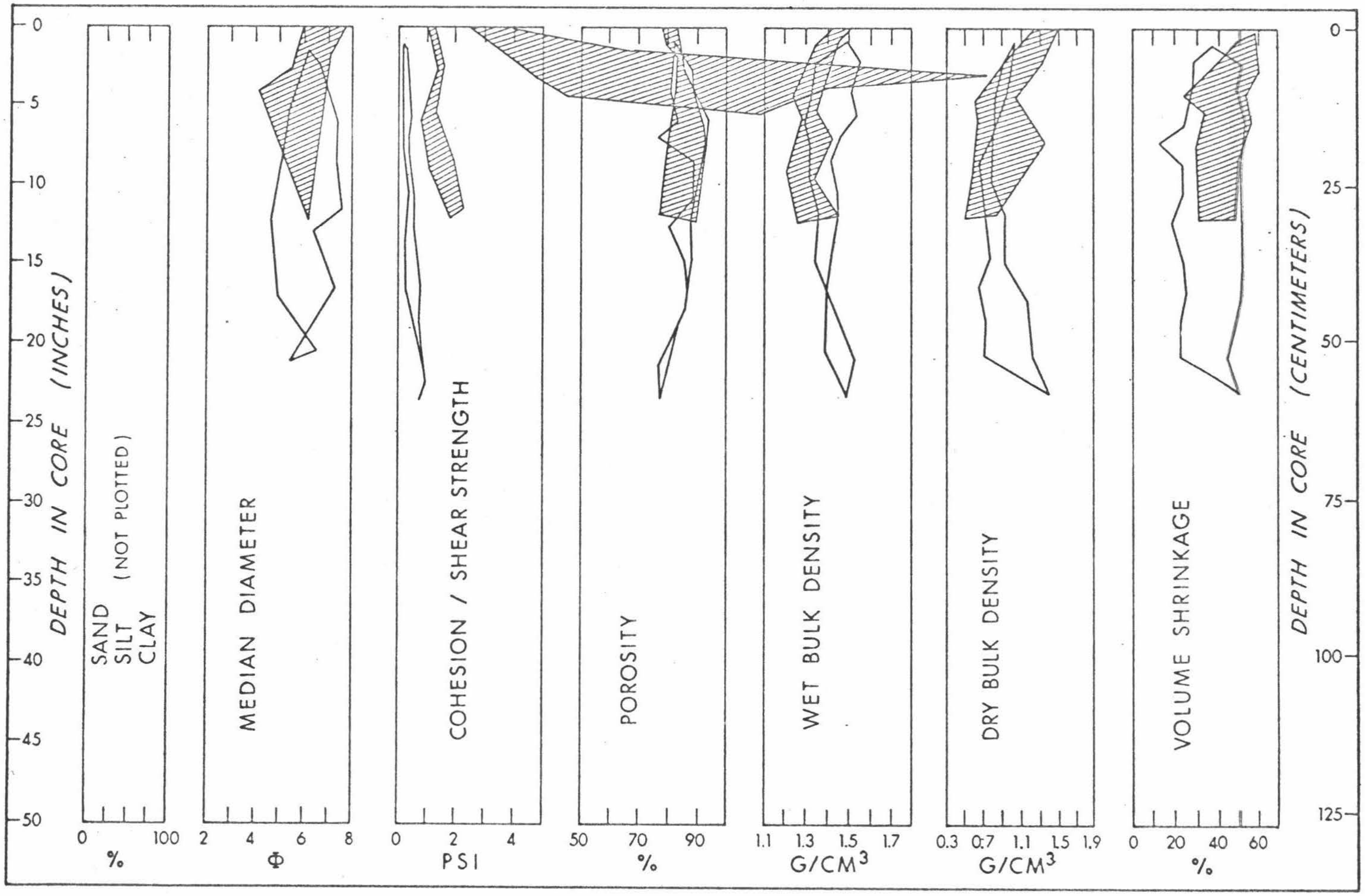


Figure 22. Summary of mass physical properties values with depth in core. All volcanic ash fell within the hatched areas and all turbidites within the unhatched areas. Tops of all volcanic ash layers have been adjusted to "0" depth in core.

hyaloclastite. No evidence of terrigenous bubble-wall shards was found. The ash layer ranged as high as 21+ psi in cohesion.

Calcareous (foraminiferal) ooze was found in the seamount core and as the basal layer in the turbidite cores. It occured at approximately 3000 meters water depth at the seamount and at approximately 4825 meter depth at the turbidite locations north of Molokai. Predominant foraminifer species are planktonic with a few benthonic species.

One positively identified and two probable turbidites were found during the study. All were located within 20 nautical miles of the steeper, island submarine slopes. The two northern turbidite cores were located 12.5 nautical miles apart and may possibly be samples of the same turbidite deposit. They cover the normal brown terrigenous mud of the area. Another probable turbidite is located south of Molokai at the base of a steep slope and aligned with the axis of a submarine canyon.

Brown terrigenous mud was the most predominant sediment of the study area. It is the locally derived island contribution to the seafloor and extends to a distance of 150 nautical miles north of the islands, i.e. the crest of the Hawaiian Arch. At this distance the island contribution dilutes the aeolian quartz content of pelagic sediments.

Each sediment type showed characteristic mass physical properties. The prime controlling factors of the values of these properties were found to be the grain-size distribution, grain shape, and sediment fabric.

Of the samples investigated 73% were silt or clayey silt. The brown terrigenous mud of the Hawaiian Arch area generally increases in median diameter with depth in the core. This suggests a transition from a colder, wetter climate with mechanical erosion dominant to a sub-tropical climate and predominantly chemical weathering, leading to finer-grained sediments. It may also suggest a decrease in volcanic activity, or both factors acting concurrently. Cohesion generally increased with depth in the core due to overburden pressure.

Sediments of high deposition rates usually had porosity values in excess of 80% and wet bulk densities less than 1.45 g/cm^3. Sediments of normal deposition rates had porosity values less than 80% and wet bulk densities greater than 1.45 g/cm^3. The top (surficial) layer of the terrigenous muds ranged between 80 and 84.5% in porosity.

Turbidites were shown to have higher porosities than brown terrigenous muds of equivalent median diameter.

Wet bulk density (wet unit weight) was shown to be inversely related to porosity and volume shrinkage, and directly related to median diameter. Dry bulk density was found to be directly related to wet bulk density, porosity, and volume shrinkage, and inversely related to median diameter.

Volume shrinkage was found to be a function of the sediment's fabric integrity (structural non-collapsibility) rather than porosity. A high water content does not necessarily imply a high volume shrinkage.

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APPENDIX A

CORE DESCRIPTIONS

Core Descriptions from Belshé, 1968

650125-6 — 22°06'N, 157°10.9'W (top of Tuscaloosa Seamount); depth 2920 m; core catcher 530 cc; B. Light grey to brown silt mixed with medium-grained sand: 50% calcareous tests and fragments, 30% volcanic, and 20% unidentified reddish-tan grains (oxide-stained calcareous or volcanic grains).

650606-3 — 21°49.2'N, 157°08.6'W (axis of Deep near Seamount north of Molokai); depth 5000 m; core length 82 cm; no core catcher; C. (Storage box broken and core dried out; original orientation of broken fragments now questionable.) Uniform dark yellow-brown compact silt broken by two greyish-black sand zones (35 cm and 70-73 cm): 50% volcanics with trace--10%--of dark minerals and unidentifiable fragments, 40% calcareous tests and fragments. Lower lens (70-73 cm) is wedge-shaped, possibly due to core penetrating at an angle ($\sim 15°$ from vertical) or to a shearing of the sand.

MR-1 (660213-1) — 22°23'N, 155°24'W (proposed MOHOLE site); depth 4320 m; core length 115 cm; core catcher 450 cc; A, B, C. Compact, uniform yellow-brown clay with shiny plastic texture.

MR-2 (660213-2) — 22°31'N, 155°23'W (proposed MOHOLE site); depth 4260 m; core length 70 cm; core catcher 225 cc; A, B, C. Uniform yellow-brown clay with shiny plastic texture.

MR-3 (660213-3) — 22°31'N, 155°31'W (proposed MOHOLE site); depth 4280 m; core length 56 cm; core catcher 150 cc; A, B, C. Uniform yellow-brown clay; compact.

MR-4 (660213-4) — 22°31'N, 155°28'W (proposed MOHOLE site); depth 4280 m; core length 64 cm; core catcher 10 cc; A, B, C. Uniform yellow-brown clay changing into darker zone at 60 cm.

MR-5 (660213-5) — 22°28'N, 155°18'W (proposed MOHOLE site); depth 4210 m; core length 75 cm; core catcher 200 cc; A, B, C. Uniform yellow-brown clay.

MR-6 (660213-6) — 22°31'N, 155°13'W (proposed MOHOLE site); depth 4235 m; core length 66 cm; core catcher 80 cc; A, B, C. Uniform yellow-brown clay.

MR-7
(660213-7) 22°35'N, 155°09'W (proposed MOHOLE site); depth 4210 m; core length 92 cm; no core catcher; A, C. Uniform yellow-brown clay.

660622-1 23°16'N, 155°30'W (near crest of Arch, NNE of Oahu); depth 4425 m; core length 122 cm; no core catcher; A, C. Uniform yellow-brown clay with slightly lighter spots beginning at 118 cm.

661003-1 21°59'N, 156°59.5'W (SE foot of Tuscaloosa Seamount); depth 4750 m; core length 30 cm; core catcher 200 cc; A, B, C. Uniform yellow-brown fine silt; core catcher content is fine sand mixed with large fraction of coarse silt with slight trace of carbonate material.

661003-2 21°52.5'N, 156°56'W (Deep, SE of Tuscaloosa Seamount); depth 4825 m; core length 115 cm; core catcher 260 cc; A, B, C. Uniform light-brown medium silt interrupted by light-tan, medium sand zone from 50 to 62 cm, attaining maximum concentration from 56 to 58.5 cm, with scattered black grains: 70% calcareous tests and fragments, 15% volcanic glass, and 15% red and tan grains.

661003-8 22°21'N, 155°43'W (Arch, NE of Oahu); depth 4390 m; core length 39 cm; core catcher 500 cc; A, C. Uniform brown clay with small black grains (some with iron oxide stains) scattered randomly throughout; high water content gives sediment a soft, elastic, jelly-like texture.

661003-10 23°43.5'N, 155°25'W (Arch, NE of Oahu); depth 4135 m; core length 91 cm; core catcher 200 cc; A, B, C. Uniform yellow-brown clay. Dull to shiny surface with jelly-like texture; water content slightly less than that of 8B or 9J.

670123-3 18°00'N, 156°41'W (Deep, SW of Hawaii); depth 4585 m; core length 71.5 cm; core catcher 1000 cc, in two boxes; A, B, C. Uniform brown silt with high percentage of coarser black grains interrupted by narrow light-yellow band (19 cm). Dark grains have lighter concentration at 45 to 50 cm. Top 20 cm has a texture characteristic of a high water content. Water content decreases with depth, producing a compact sediment with smooth, shiny surface. Worm borings present from 40 to 65 cm with maximum concentration between 45 and 55 cm. Several located in upper parts of core but those, if present, in top 20 cm are obscured by watery, hummocky structure destroying surface features. Core catcher (a, b): greyish-brown, extremely compact, fine silt not representative of lower portions of core; no unconformable structure found to indicate a change occurred.

670224-1 21°41'N, 156°27'W (Deep, north of Maui); depth 5375 m; core length 84 cm; core catcher 625 cc; A, B, C. Top 5 cm is dark yellow-brown medium silt with black grains (volcanic); shiny, moderately compact sediment. Grades into yellow-brown clay with dull aggregate or hummocky surface texture; high water content, jelly-like, interrupted by slightly diagonal, discontinuous black layer at 11 cm. Sediment changes from lighter yellow-brown (40 cm) into more plastic, compact yellow-brown clay (60 cm).

670224-2 21°29'N, 155°54.5'W (Deep, NE of Maui); depth 5700 m; core length 98 cm; core catcher 200 cc; A, B, C. Compact, dark yellow-brown clay with dark-brown mottling (10 to 18 cm) and very distinct dark-brown band (22 to 23.5 cm). Shiny, compact, plastic texture. Sediment changes to second zone of light yellow-brown with large dark-brown patches fading out toward center of core (24 to 55 cm) and terminated at 55 cm by thin, dark yellow-brown band with yellow zone at the bottom. A third zone (55 to 75 cm) is represented by greyish-brown sediment. These two zones are light and dark-brown spotted with shiny aggregated surface and compact texture. Below 75 cm the core is a fairly uniform, yellow-brown clay.

670224-3 20°55'N, 155°02'W (Deep, east of Maui); depth 5750 m; core length 58 cm; core catcher 350 cc; B, C. Uniform yellow-brown, fine silt with shiny surface changing abruptly to dark-brown clay lens at 21 cm, fading out at 24 cm and surrounded by yellow-brown clay with high percentage of black material. This changes into olive-yellow lens (26 to 28.5 cm). Both are in the center of the core. Sediment changes from light tan-brown to grey-brown lens at 35 to 36 cm and light yellow-brown band at 49 cm. Uniformly compact, but lower section (after 21 cm) has dull, aggregated surface with moist, jelly-like texture.

670313-5 20'24.7'N, 157°27.2'W (inner flank of Deep, west of Maui and Lanai); depth 3980 m; core length 54.5 cm; core catcher 750 cc; B, C. Uniform yellow-brown, calcareous, fine silt with shiny surface and fluid texture grading into light tan-brown silt at 15 cm terminated by a foraminifera-rich (90%) wedge at 18 to 19 cm. This wedge is followed by mottled, dark yellow-brown sediment getting lighter near the bottom of the core and interrupted by a light tannish-brown layer (21 to 22 cm) and tan lens at 25 cm with sharp boundaries, especially on the edge of a dark yellow-brown zone at 19 to 21 cm. The whole core and core catcher have traces (1%) of foraminifera tests as well as in the specified areas of local concentration.

670504-1 22°30.4'N, 160°06.7'W (Deep, NW of Kauai); depth 4440 m; core length 35 cm; no core catcher; B, C. Top 4 cm dark yellow-brown, coarse silt with coarser black grains (volcanic). Shiny, jelly-like texture; high water content. Black grains more abundant from 5 to 9 cm where they terminate as a diagonal black band. Below this band a hard, crumbly, coarse silt (9 to 13 cm) changes into mottled-yellow-brown, fine silt in the deeper portion of the core; all has a very compact, dull surface.

APPENDIX B

INDIVIDUAL CORE PARAMETERS GRAPHS

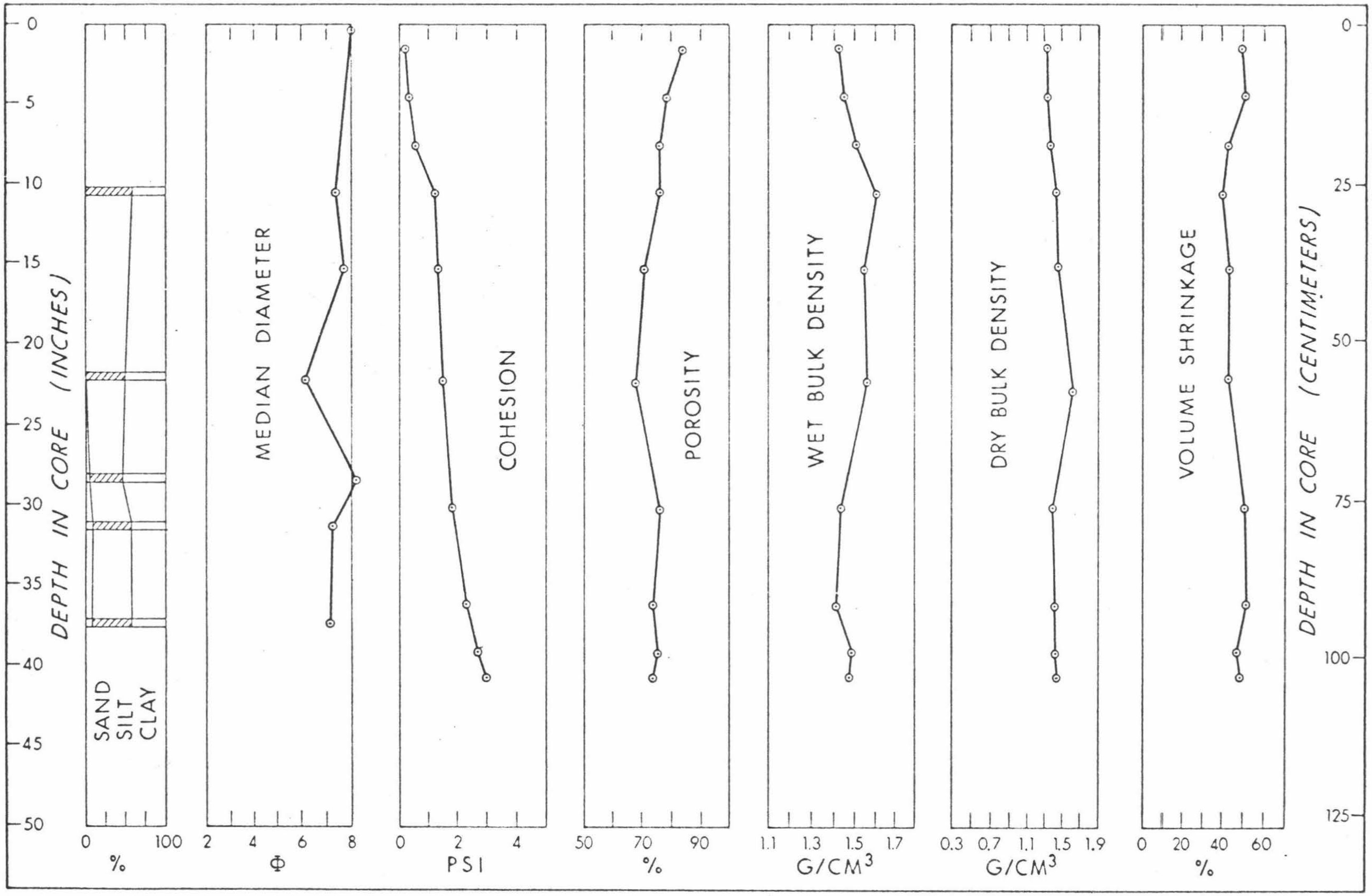

Figure B1. Mass physical properties of core MR-1 (core group A)

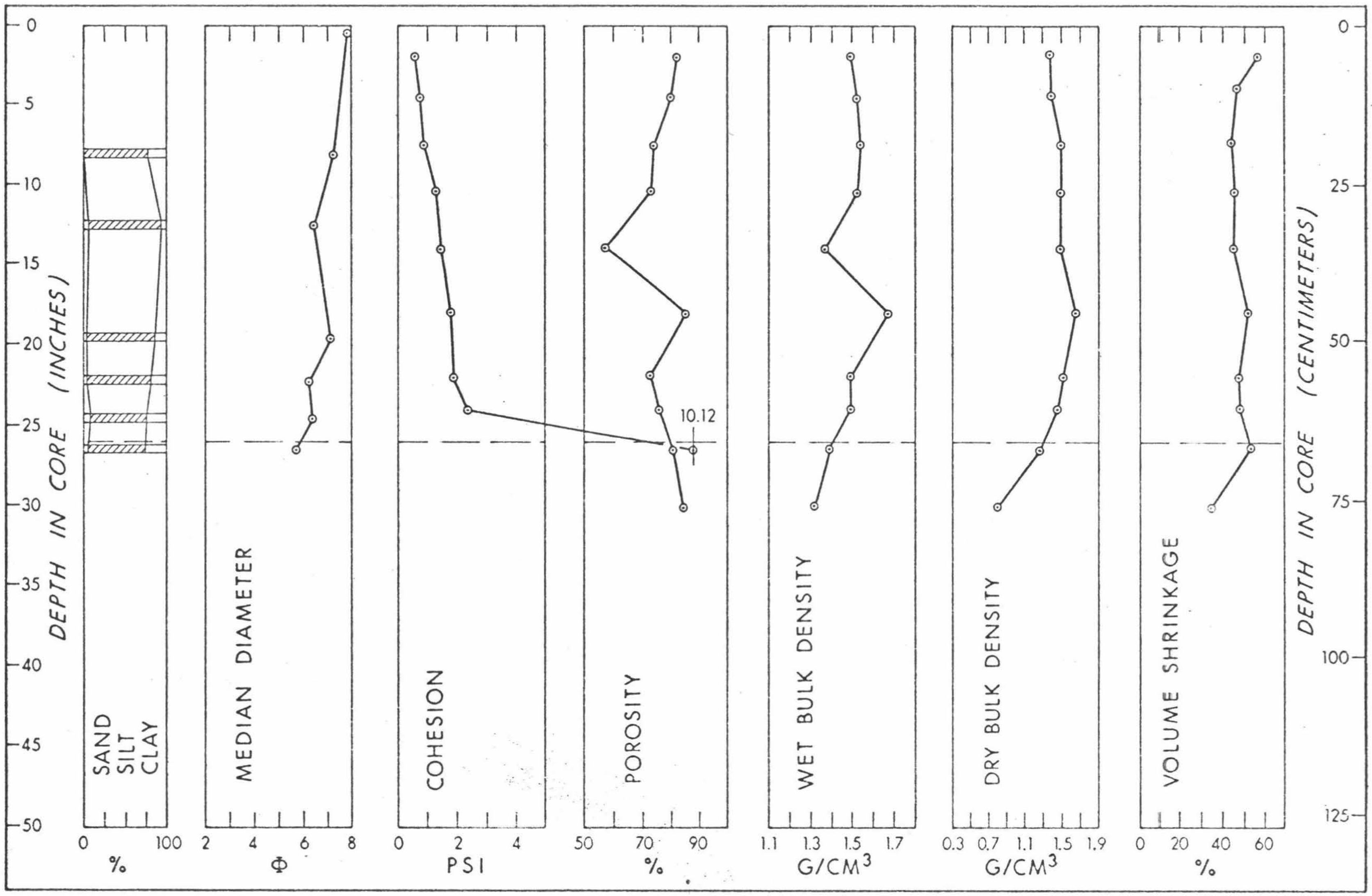

Figure B2. Mass physical properties of core MR-2 (core group A)

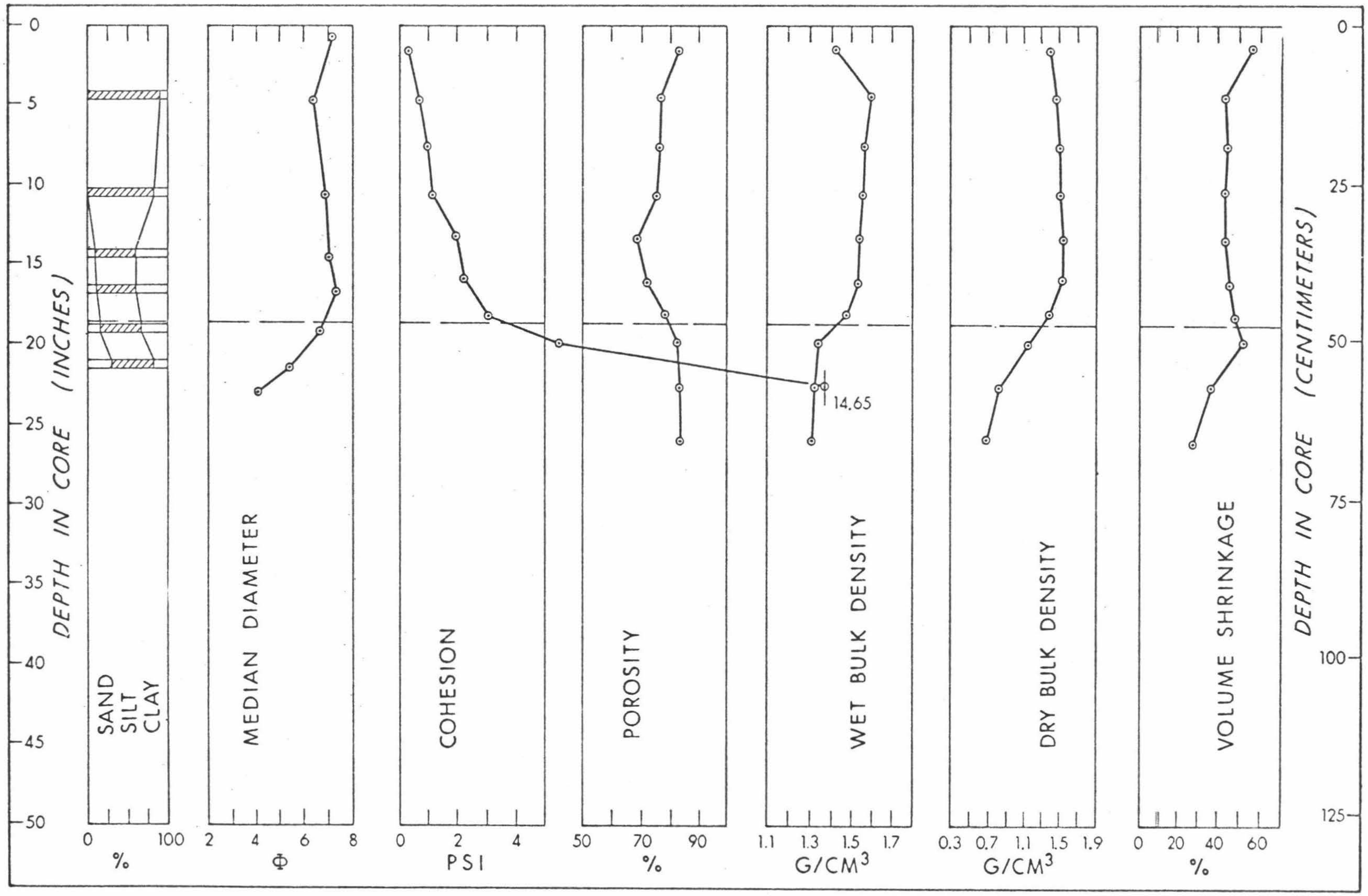

Figure B3. Mass physical properties of core MR-3 (core group A)

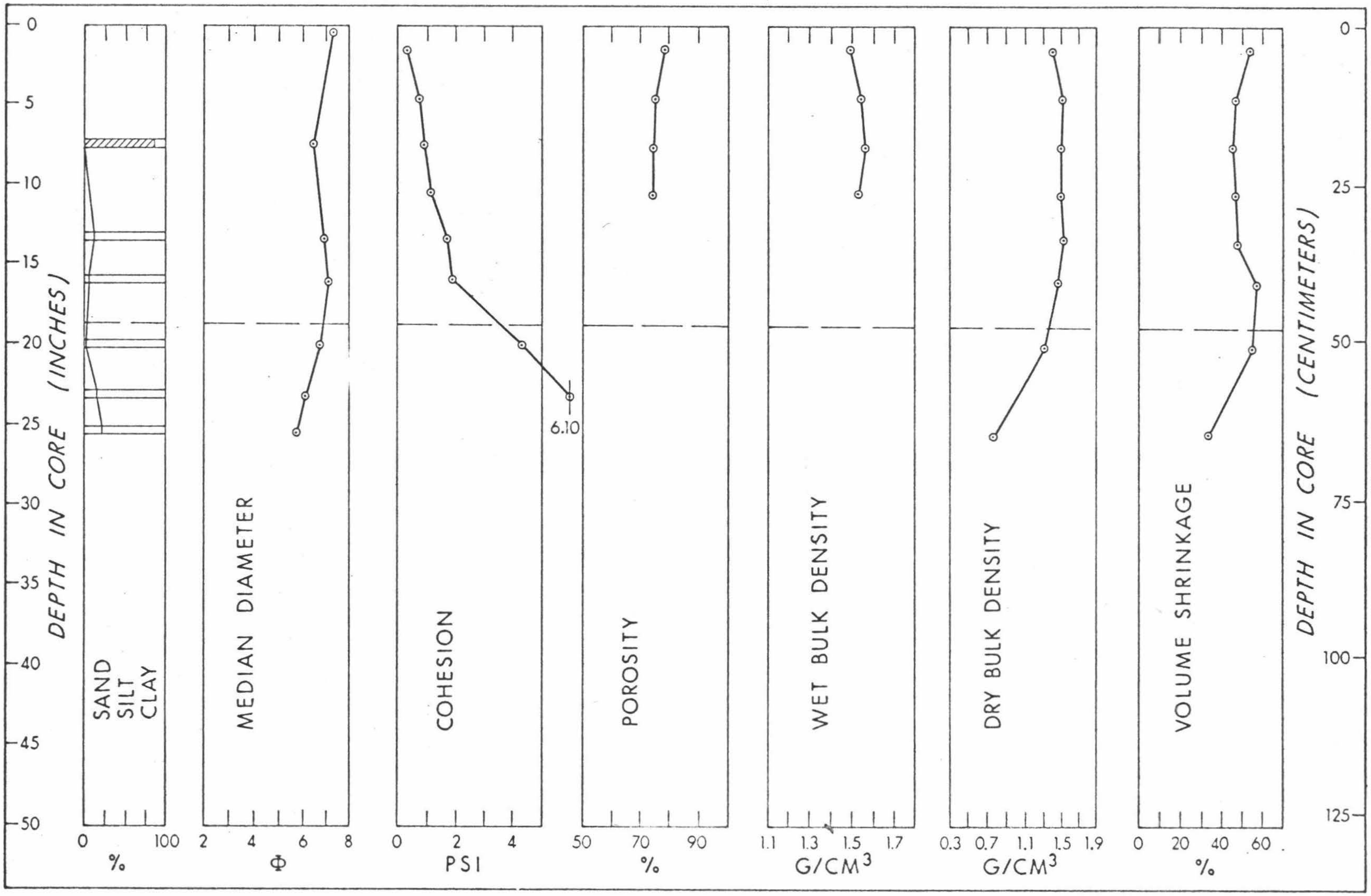

Figure B4. Mass physical properties of core MR-4 (core group A)

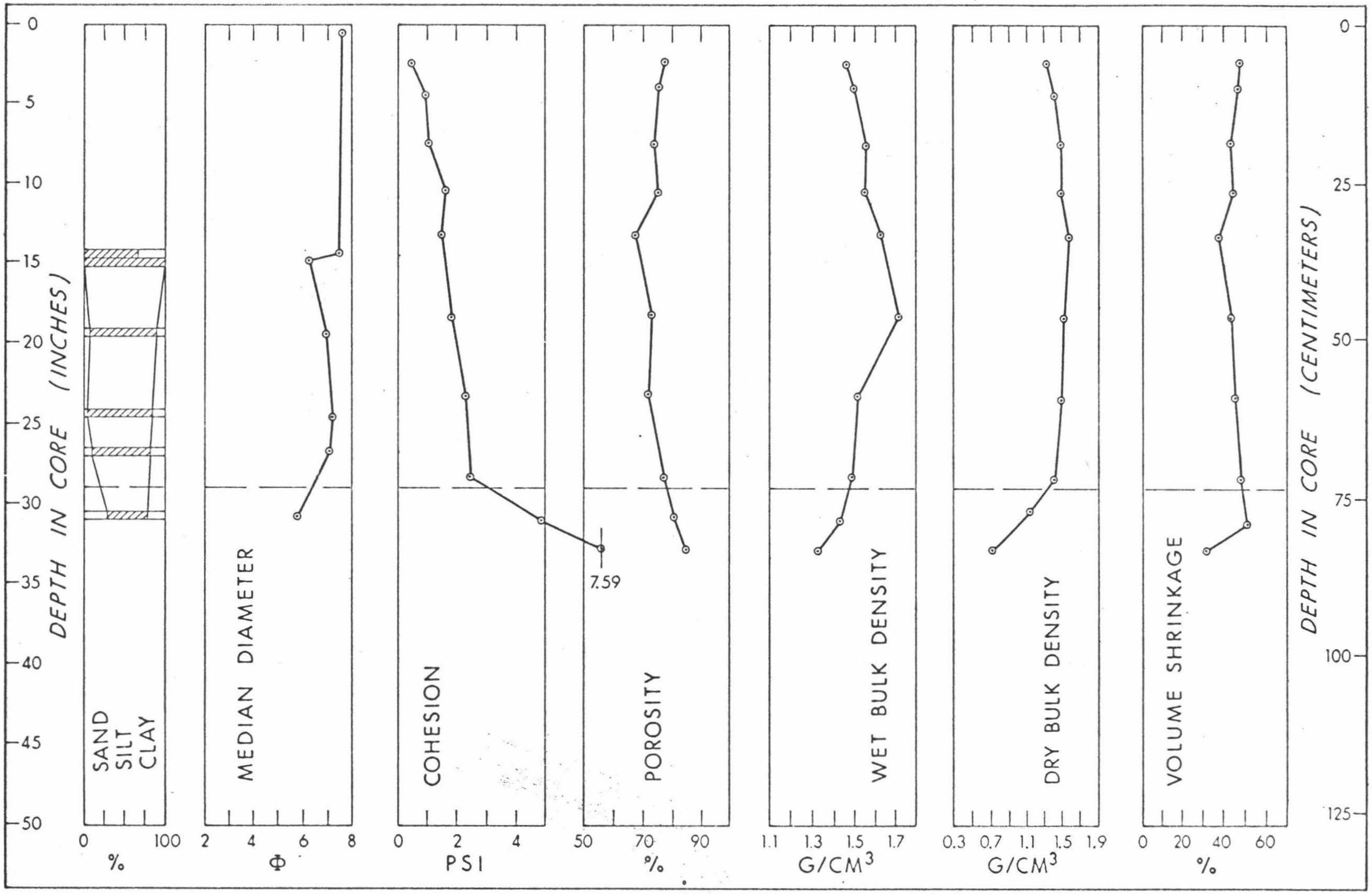

Figure B5. Mass physical properties of core MR-5 (core group A)

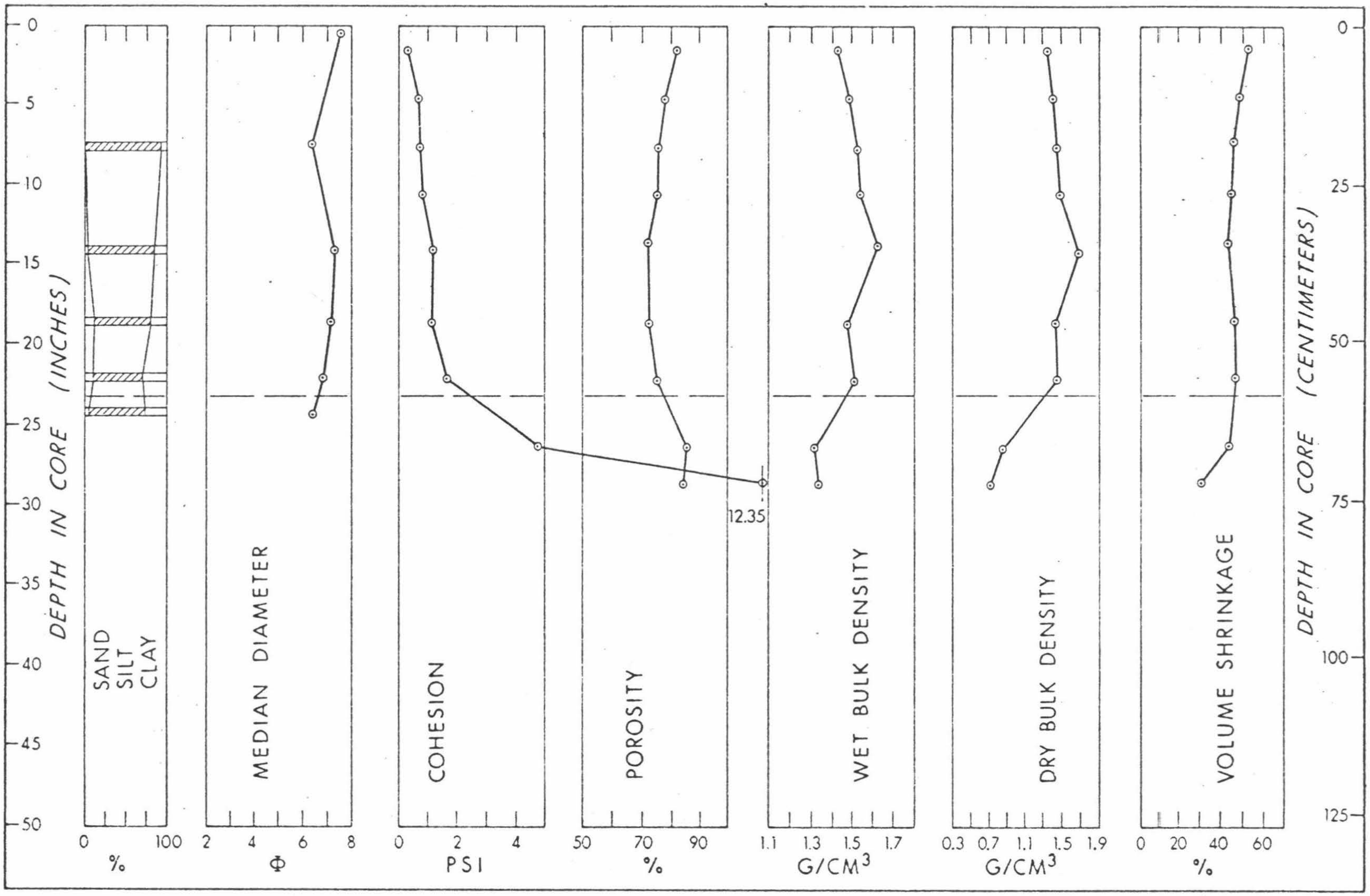

Figure B6. Mass physical properties of core MR-6 (core group A)

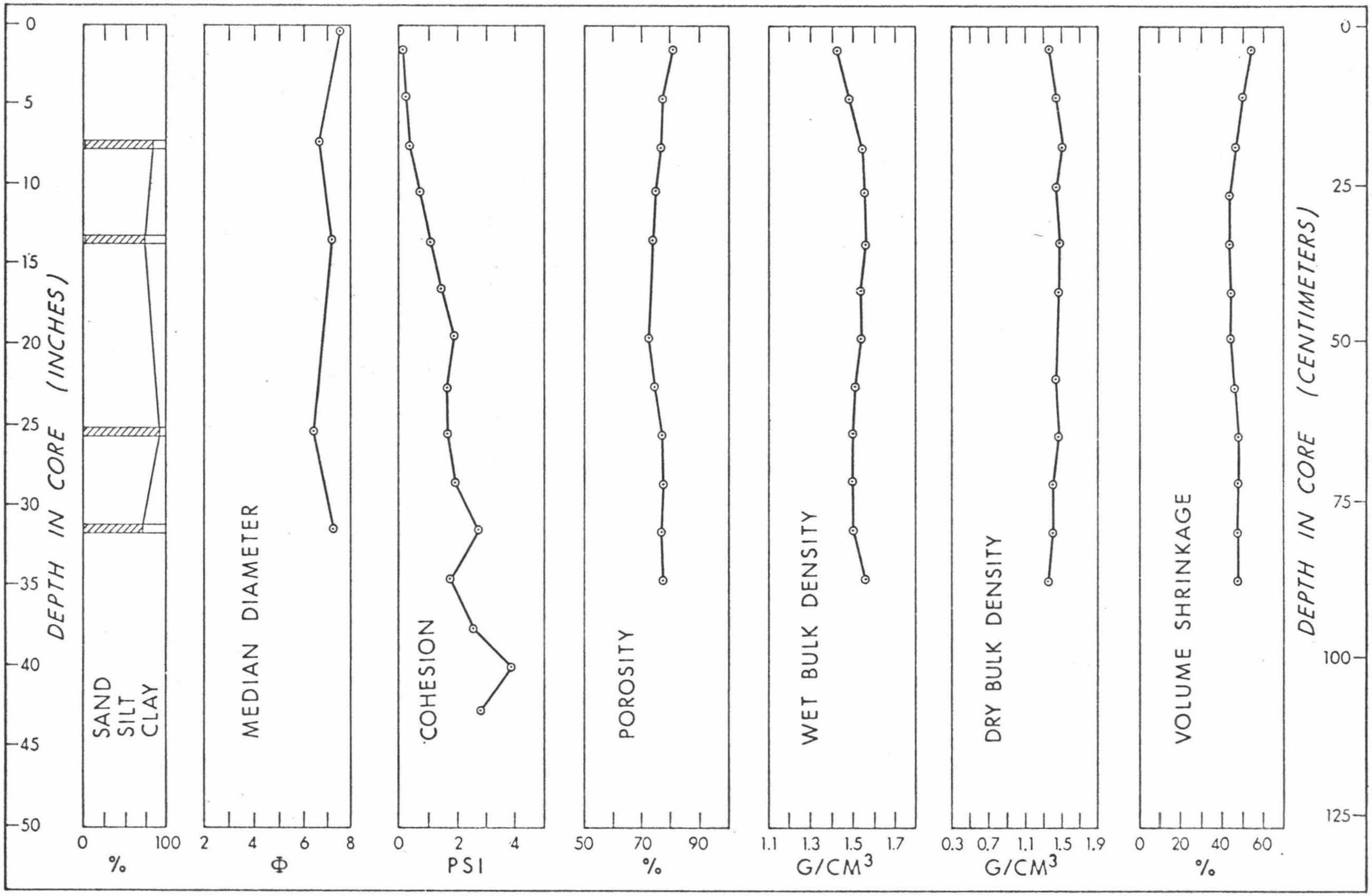

Figure B7. Mass physical properties of core MR-7 (core group A)

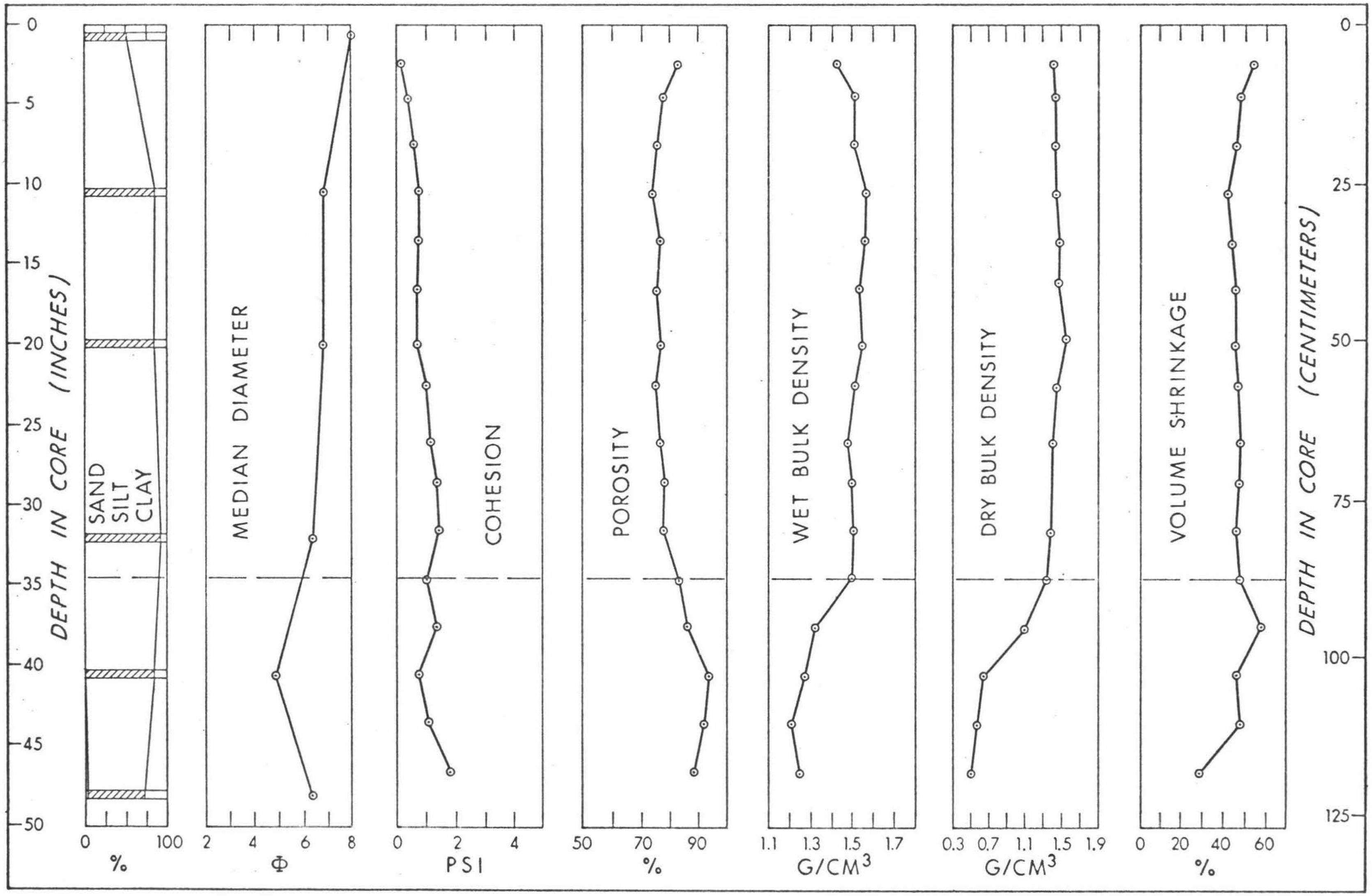

Figure B8. Mass physical properties of core 660622-1 (core group A)

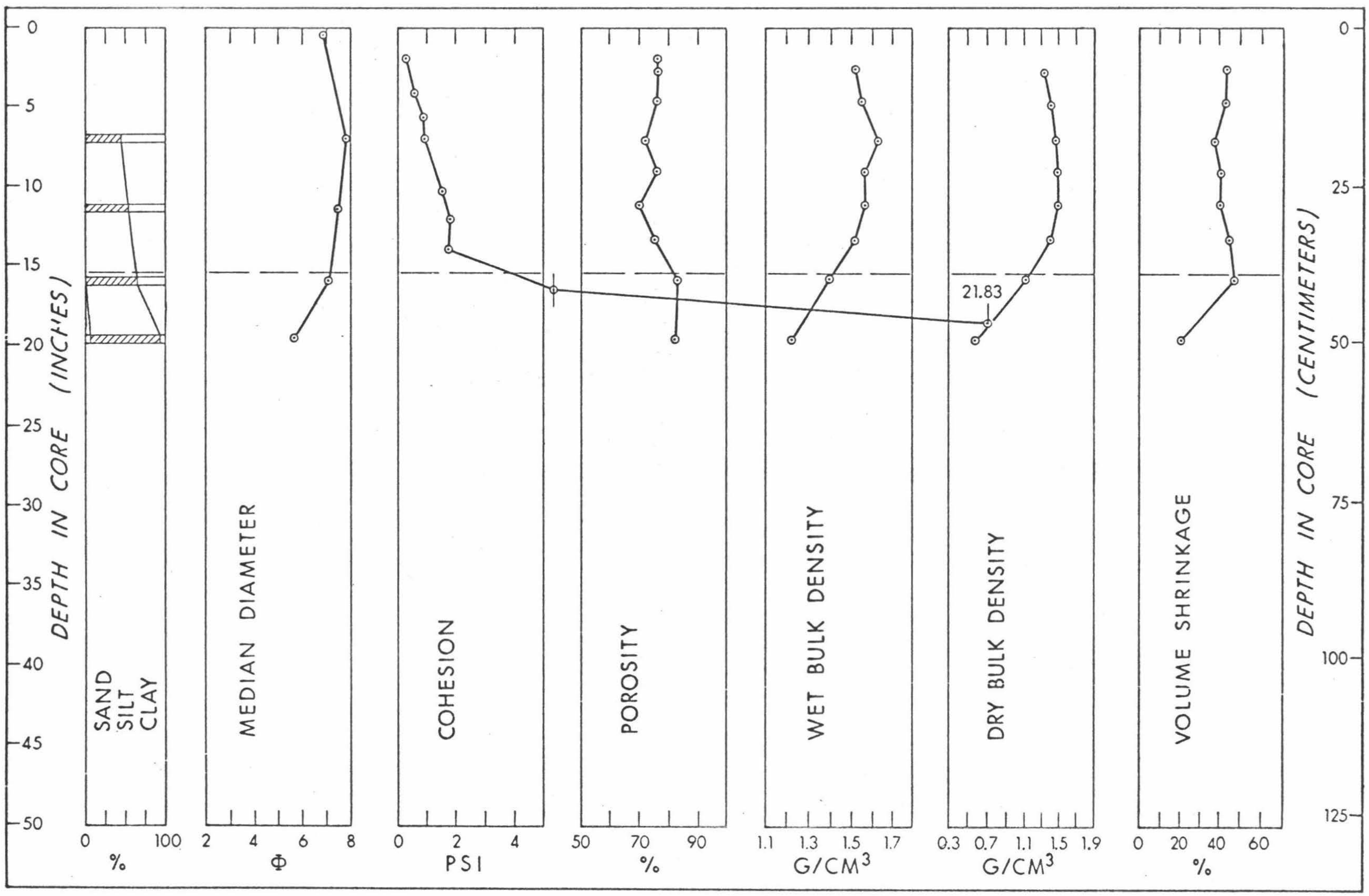

Figure B9. Mass physical properties of core 661003-8 (core group A)

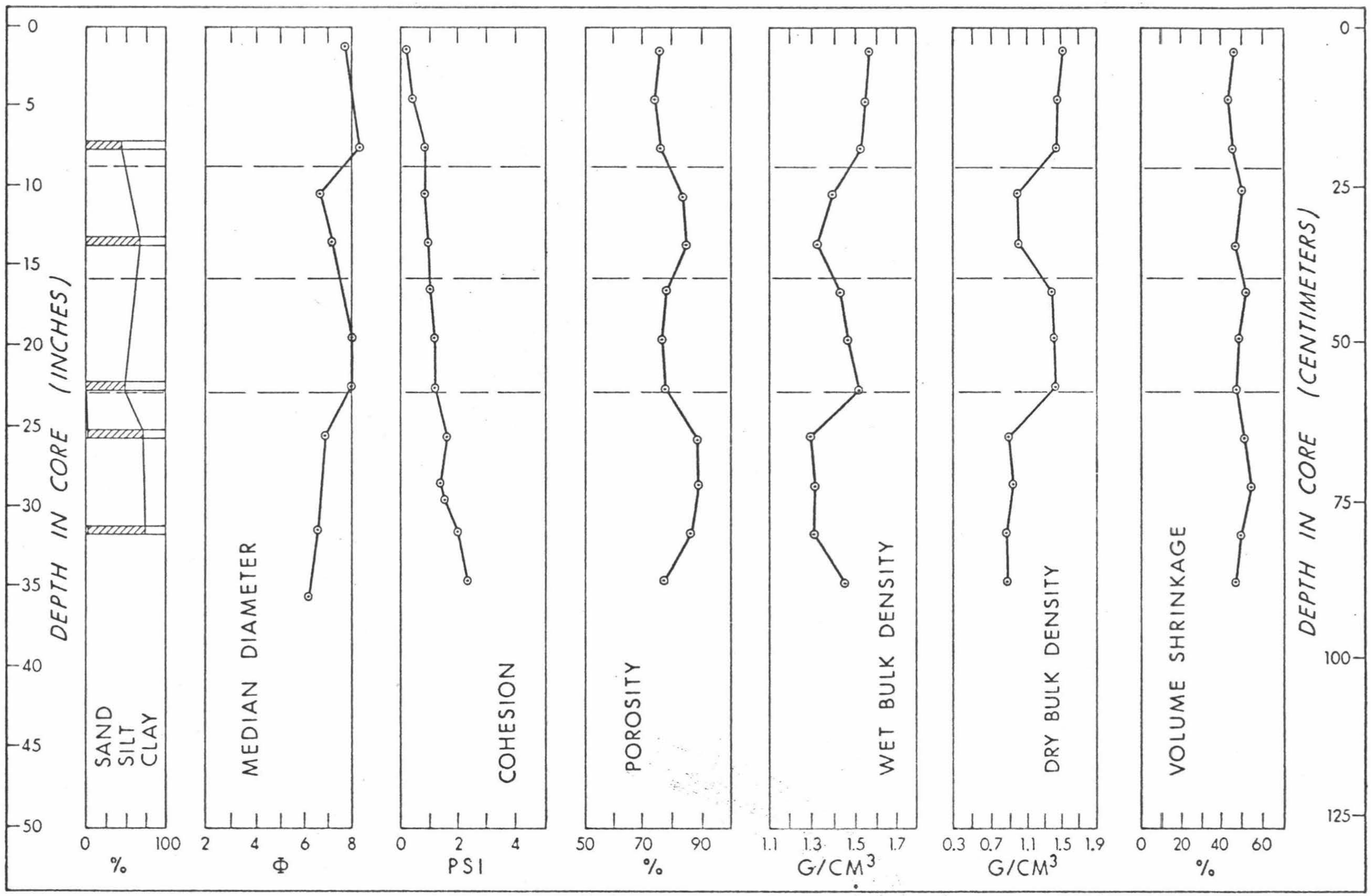

Figure B10. Mass physical properties of core 661003-10 (core group A)

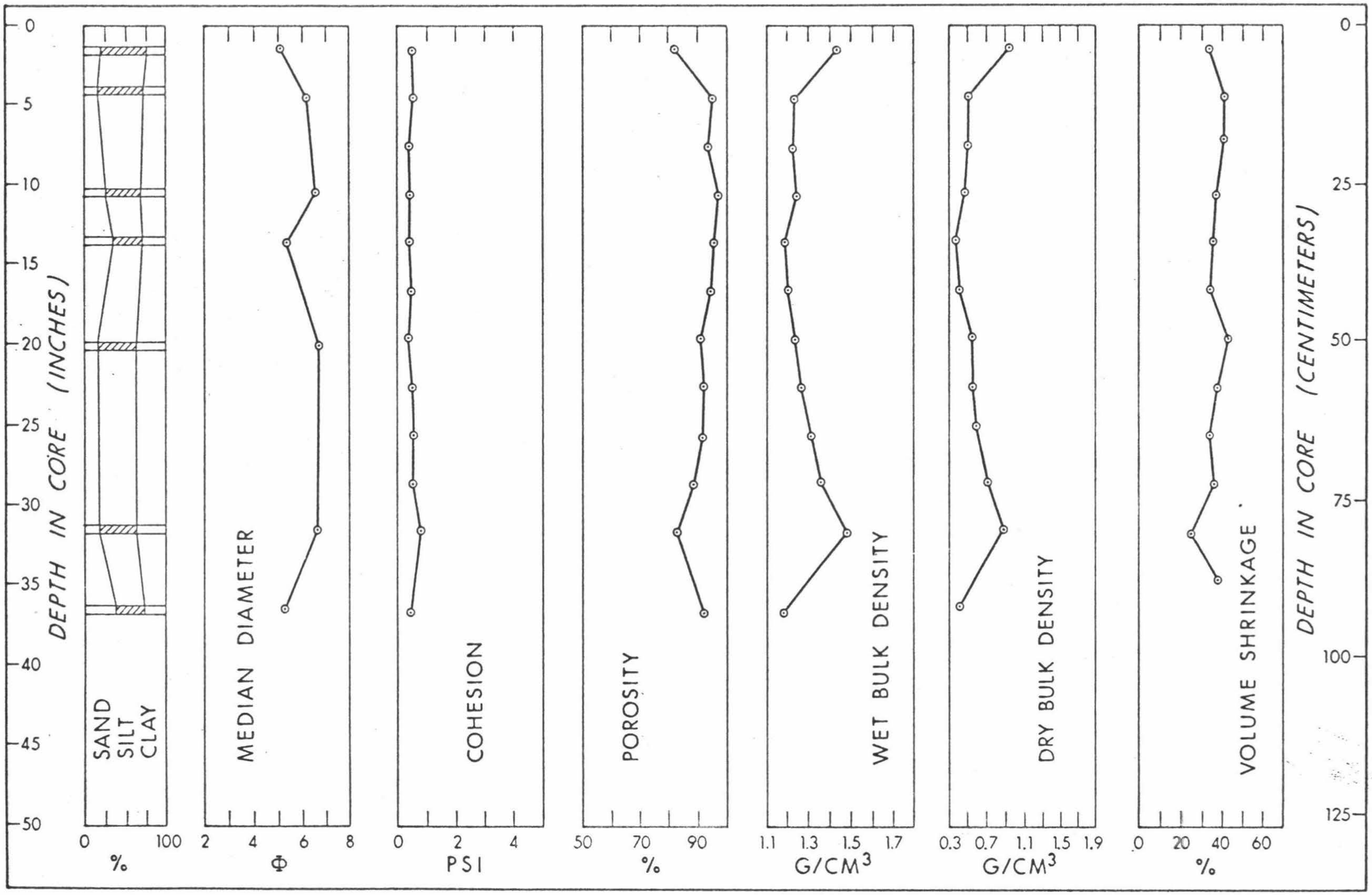

Figure B11. Mass physical properties of core 670224-1 (core group T)

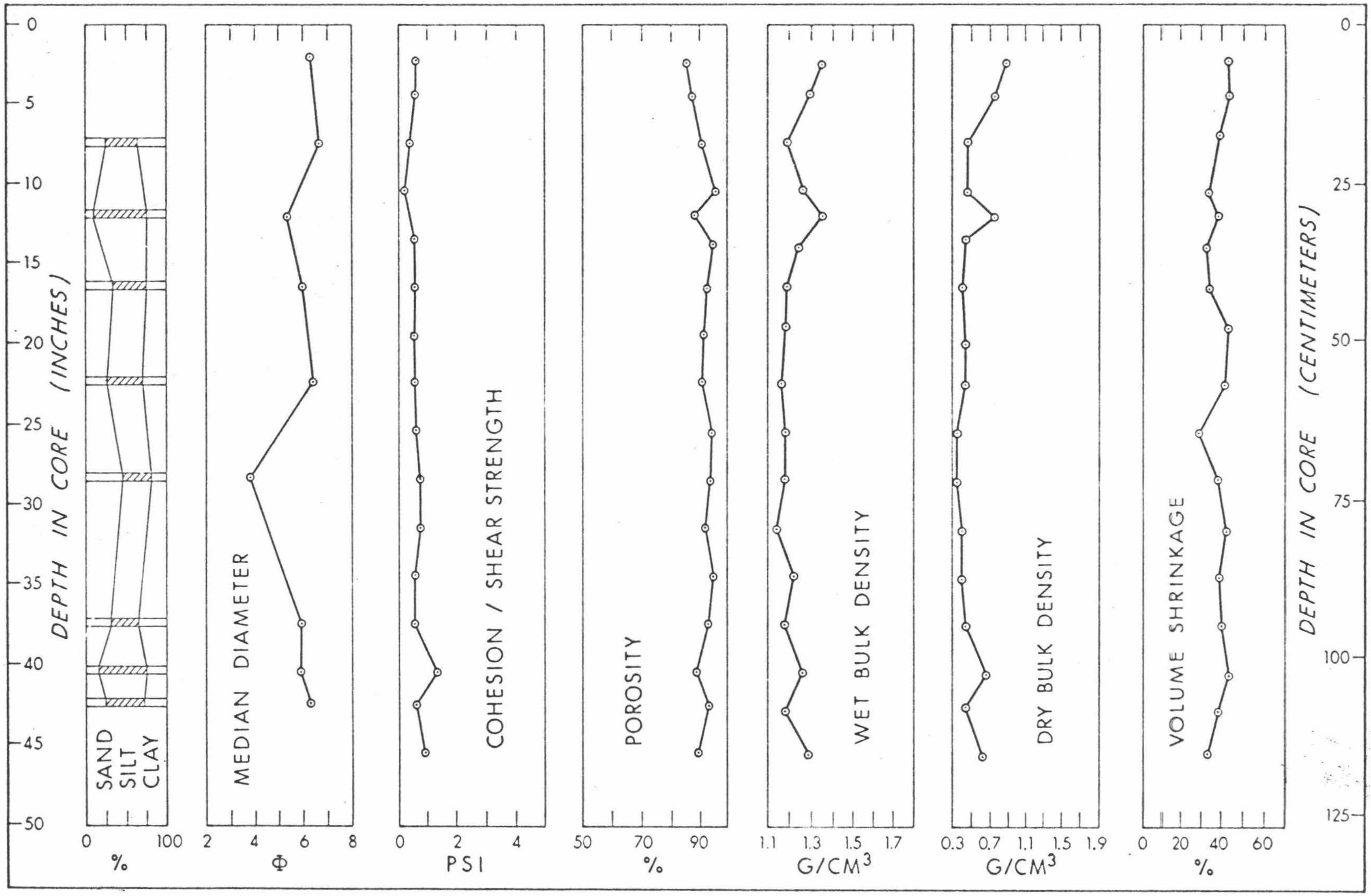

Figure B12. Mass physical properties of core 670224-2 (core group T)

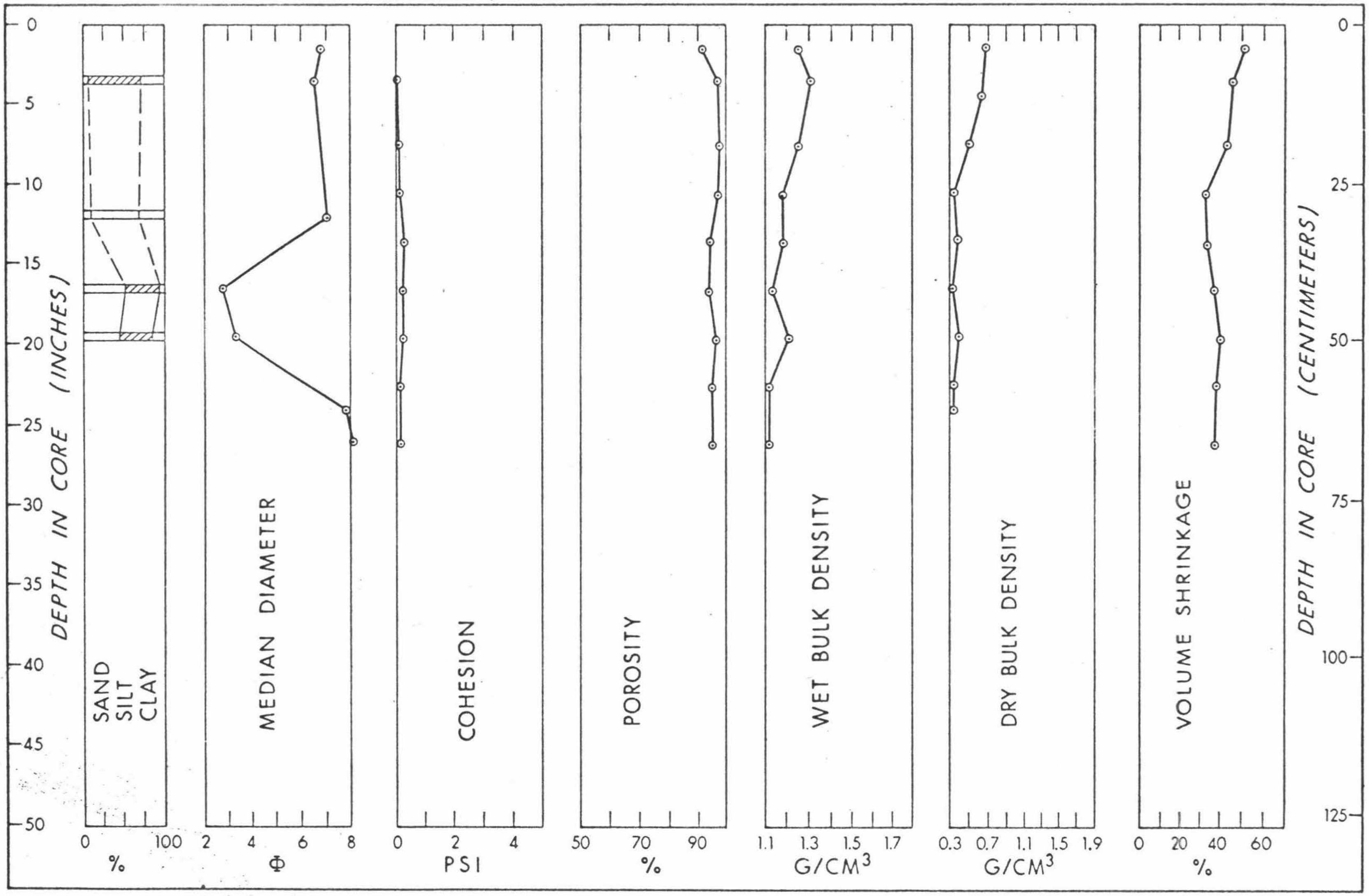

Figure B13. Mass physical properties of core 670224-3 (core group T)

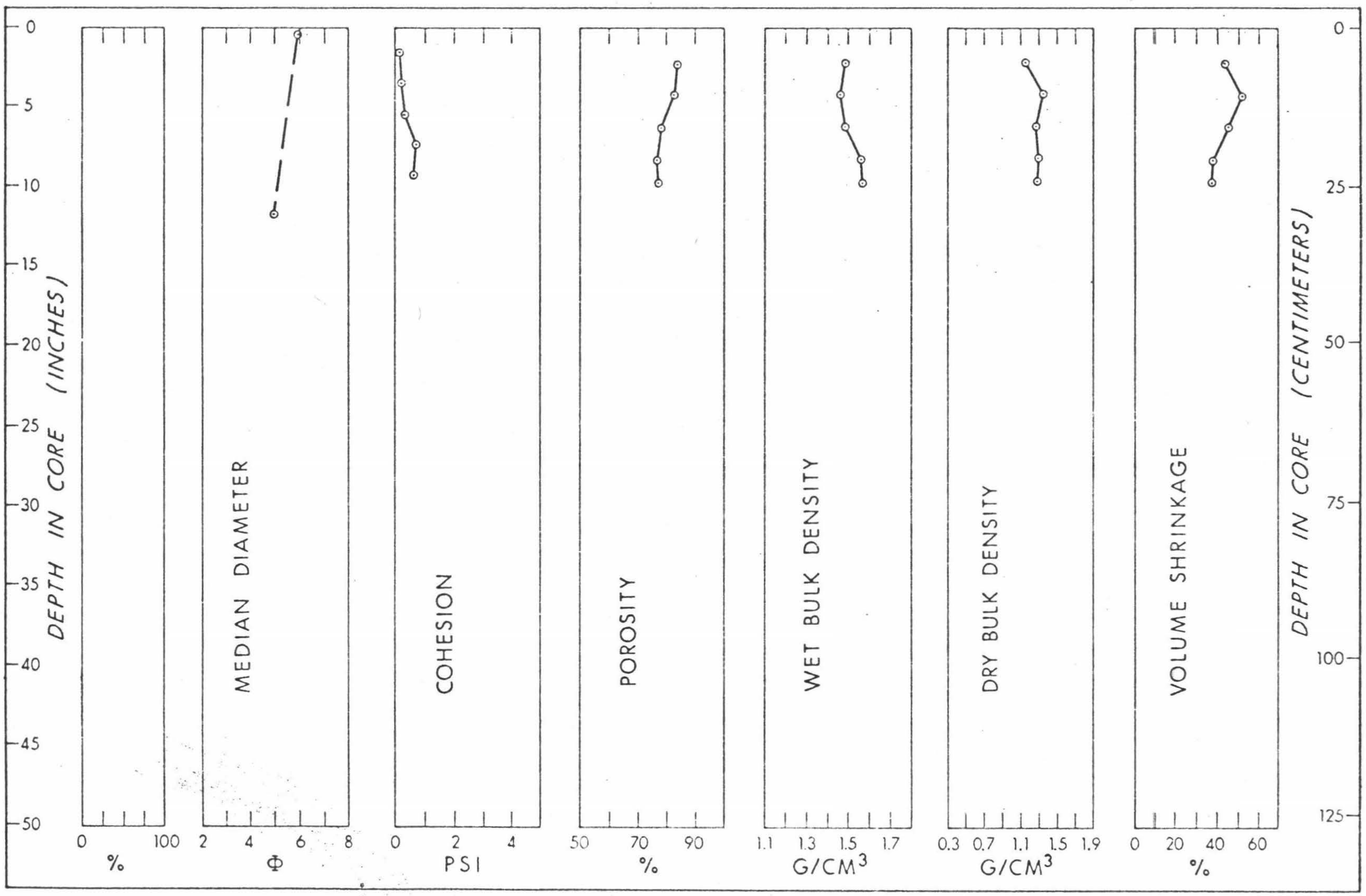

Figure B14. Mass physical properties of core 661003-1 (core group S)

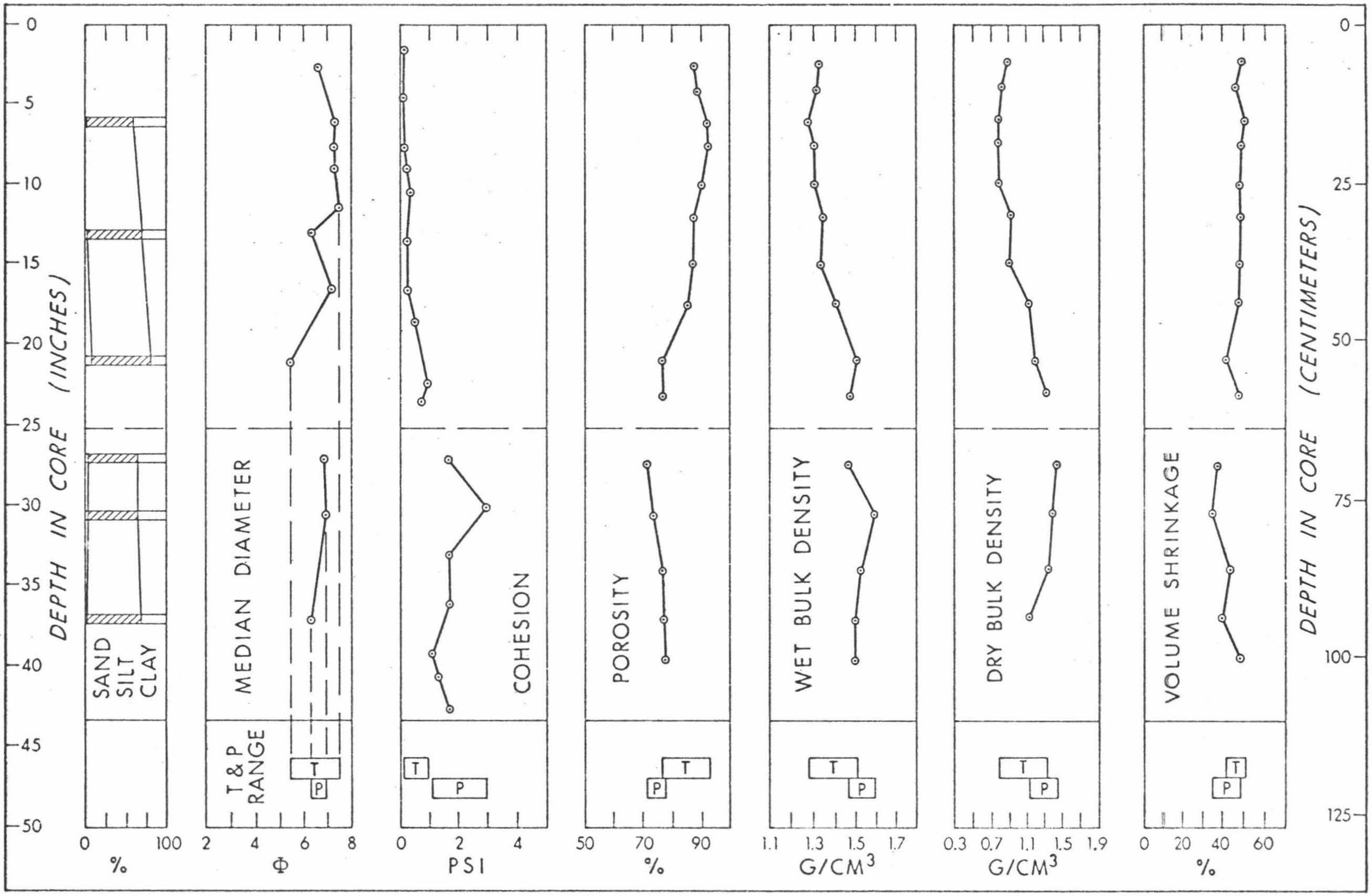

Figure B15. Mass physical properties of core 661003-2 (core group S)

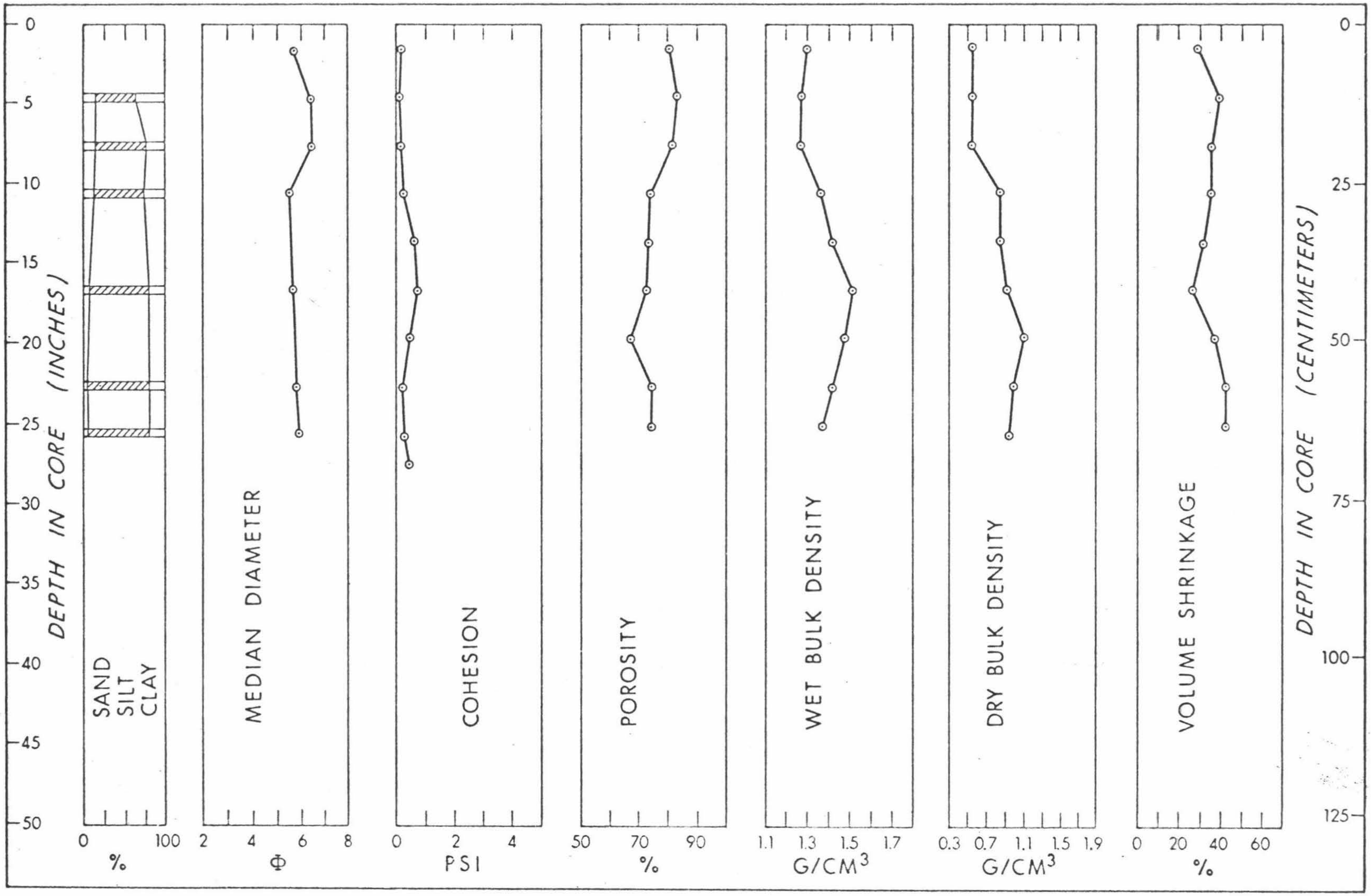

Figure B16. Mass physical properties of core 670123-3 (core group M)

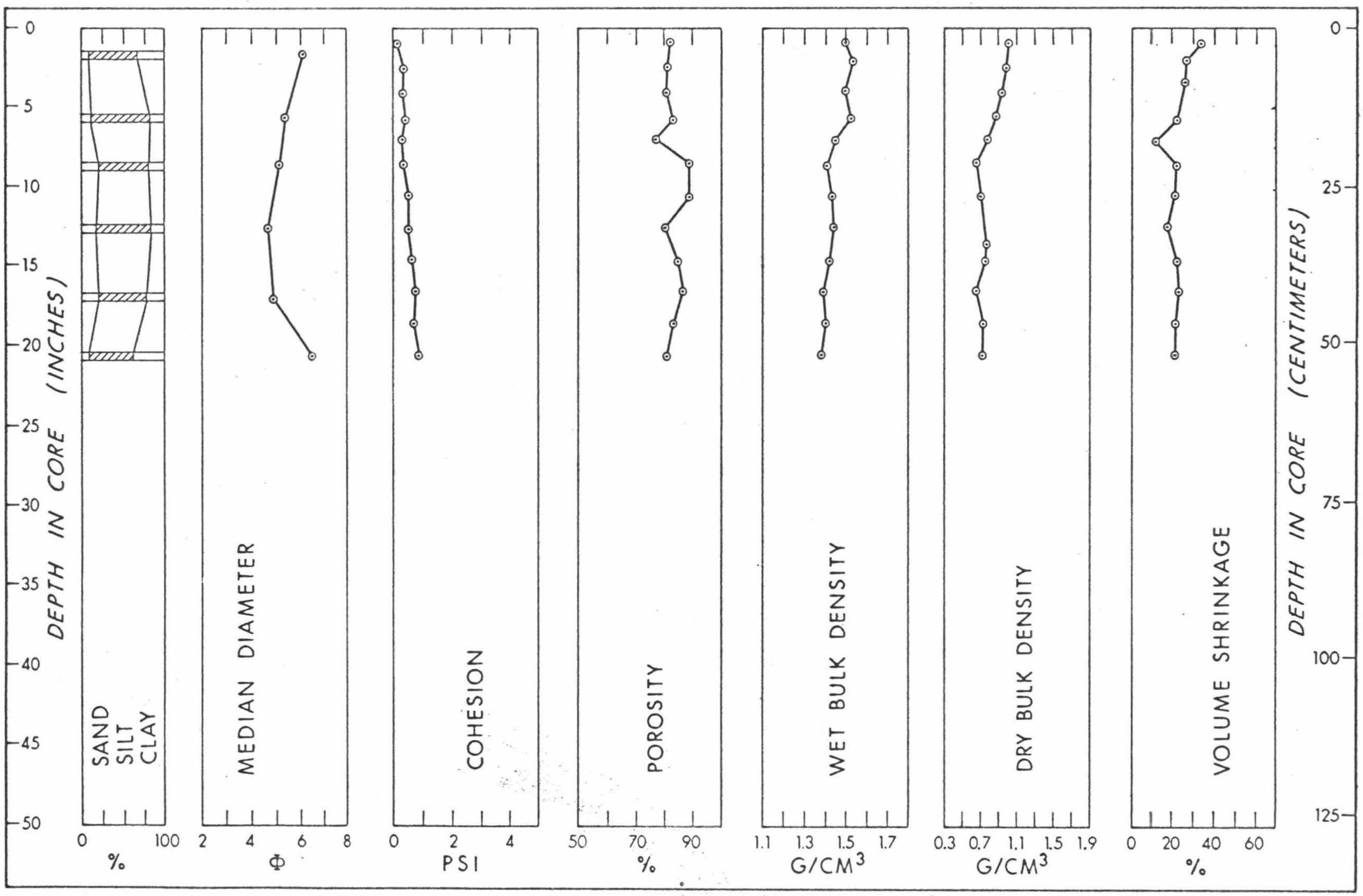

Figure B17. Mass physical properties of core 670313-5 (core group M)

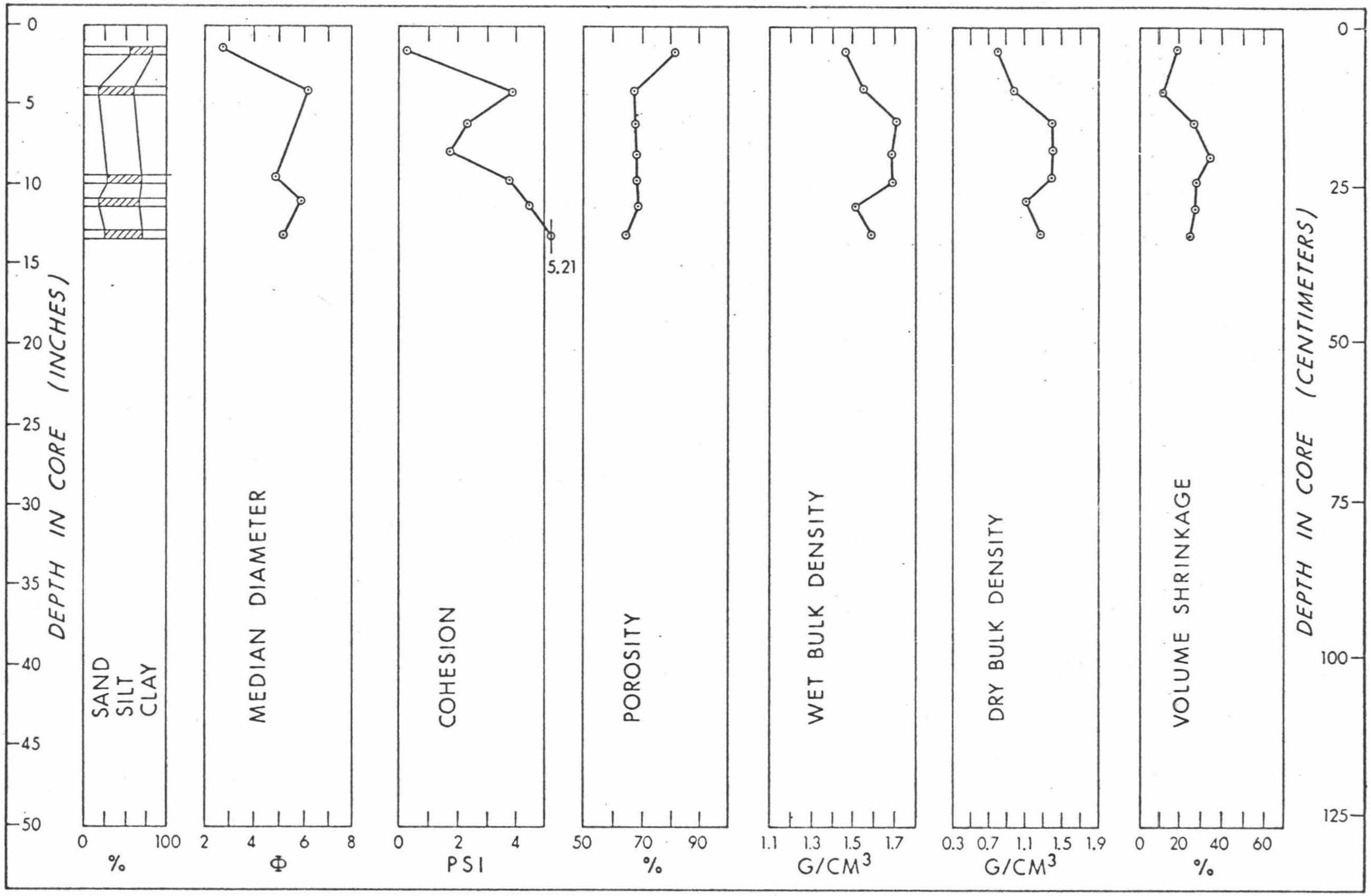

Figure B18. Mass physical properties of core 670504-1 (core group M)

APPENDIX C

INDIVIDUAL CORE PARAMETERS TABLES

AREA: A　　CORE: MR-1　　SONIC DEPTH: 4613 m.　　CORER: Benthos

CORE LENGTH: 44 in.　　CORER DIAMETER: 2.65 in. I.D.

DEPTH IN CORE, in.	0.50	1.50	4.50	7.50	10.50	15.25	22.00	23.25	28.25	30.00
SATURATION, %	~100	~100	~100	~100	~100	~100	~100	~100	~100	~100
SAND, % <4 Φ, (>62μ)	-	-	-	-	0.2	-	0.7	6.5	-	-
SILT, % >4 Φ<8 Φ, (62-4μ)	-	-	-	-	62.8	-	90.3	46.5	-	-
CLAY, % >8 Φ, (<4 μ)	-	-	-	-	37.0	-	9.0	47.0	-	-
SEDIMENT CLASSIFICATION Shepard (1954)	-	-	-	-	CSi	-	Si	SiC	-	-
MEDIAN DIAMETER, Φ	8.05				7.44	7.75	6.37	-	8.25	-
COHESION, psi	-	0.17	0.29	0.51	1.20	1.41	1.49	-	-	1.84
WATER CONTENT, % (dry)	-	1.39	119	101	90	84	77	-	-	114
WET BULK DENSITY, g/cm³	-	1.44	1.46	1.51	1.61	1.55	1.57	-	-	1.44
DRY BULK DENSITY, g/cm³	-	1.33	1.34	1.39	1.45	1.48	1.62?	-	-	1.41
VOLUME SHRINKAGE, %	-	51.21	50.28	45.52	41.43	45.80	44.39	-	-	52.21
POROSITY, %	-	84.07	79.29	75.93	75.96	71.00	68.50	-	-	76.90
PLASTIC LIMIT	-	-	-	-	-	34	36	-	-	37
LIQUID LIMIT	-	-	-	-	-	70	82	-	-	92

Sediment Classification: Sa = sand or sandy, Si = silt or silty, C = clay or clayey
(?) after value = questionable value

AREA: A CORE: MR-1 (cont.) SONIC DEPTH: ____________ m. CORER: ____________

CORE LENGTH: __________ in. CORER DIAMETER: ____________ in. I.D.

DEPTH IN CORE, in.	31.25	36.00	37.25	39.00	40.50					
SATURATION, %	~100	~100	~100	~100	~100					
SAND, % <4 Φ, (>62μ)	-	-	10.0	-	-					
SILT, % >4 Φ<8 Φ, (62-4μ)	-	-	49.5	-	-					
CLAY, % >8 Φ, (<4 μ)	-	-	40.5	-	-					
SEDIMENT CLASSIFICATION Shepard (1954)	-	-	SiC	-	-					
MEDIAN DIAMETER, Φ	7.37	-	7.25	-	-					
COHESION, psi	-	2.36	-	2.72	3.00					
WATER CONTENT, % (dry)	-	110	-	103	101					
WET BULK DENSITY, g/cm^3	-	1.42	-	1.49	1.48					
DRY BULK DENSITY, g/cm^3	-	1.44	-	1.45	1.49					
VOLUME SHRINKAGE, %	-	53.26	-	49.14	50.00					
POROSITY, %	-	74.10	-	75.80	74.10					
PLASTIC LIMIT	-	35	-	-	-					
LIQUID LIMIT	-	89	-	-	-					

Sediment Classification: Sa = sand or sandy, Si = silt or silty, C = clay or clayey
(?) after value = questionable value

AREA: A CORE: MR-2 SONIC DEPTH: 4261 m. CORER: Benthos

CORE LENGTH: 30.25 in. CORER DIAMETER: 2.65 in. I.D.

DEPTH IN CORE, in.	0.50	2.00	4.50	7.50	8.00	10.50	12.50	14.00	18.00	19.50
SATURATION, %	~100	~100	~100	~100	~100	~100	~100	~100	~100	~100
SAND, % <4 Φ, (>62μ)	-	-	-	-	0.1	-	5.0	-	-	3.0
SILT, % >4 Φ<8 Φ, (62-4μ)	-	-	-	-	78.9	-	90.0	-	-	84.0
CLAY, % >8 Φ, (<4 μ)	-	-	-	-	21.0	-	5.0	-	-	13.0
SEDIMENT CLASSIFICATION Shepard (1954)	-	-	-	-	Si	-	Si	-	-	Si
MEDIAN DIAMETER, Φ	7.84	-	-	-	7.28	-	-	6.50	7.20	-
COHESION, psi	-	0.54	0.72	0.86	-	1.25	-	1.42	1.75	-
WATER CONTENT, % (dry)	-	121	115	91	-	92	-	70.6	104.2	-
WET BULK DENSITY, g/cm^3	-	1.50	1.53	1.55	-	1.53	-	1.38?	1.68	-
DRY BULK DENSITY, g/cm^3	-	1.38	1.40	1.50	-	1.50	-	1.50?	1.65	-
VOLUME SHRINKAGE, %	-	50.81	48.24	45.74	-	46.78	-	46.31	50.29	-
POROSITY, %	-	82.47	80.54	74.36	-	73.49	-	56.90?	85.6	-
PLASTIC LIMIT	-	-	-	-	-	-	-	28	35	-
LIQUID LIMIT	-	-	-	-	-	-	-	88	86	-

Sediment Classification: Sa = sand or sandy, Si = silt or silty, C = clay or clayey
(?) after value = questionable value

AREA: A CORE: MR-2 (cont.) SONIC DEPTH: ________ m. CORER: ________

CORE LENGTH: ________ in. CORER DIAMETER: ________ in. I.D.

DEPTH IN CORE, in.	22.00	24.00	26.50	~30.00						
SATURATION, %	~100	~100	~100	~100						
SAND, % < 4 ϕ, (> 62μ)	3.0	9.0	5.0	-						
SILT, % > 4 ϕ < 8 ϕ, (62-4μ)	78.0	67.0	71.0	-						
CLAY, % > 8 ϕ, (< 4 μ)	19.0	24.0	24.0	-						
SEDIMENT CLASSIFICATION Shepard (1954)	Si	CSi	CSi	-						
MEDIAN DIAMETER, ϕ	6.40	6.50	5.80	-						
COHESION, psi	1.87	2.38	10.12	-						
WATER CONTENT, % (dry)	94.3	103	140	228						
WET BULK DENSITY, g/cm^3	1.50	1.50	1.40	1.33						
DRY BULK DENSITY, g/cm^3	1.52	1.47	1.28	0.74						
VOLUME SHRINKAGE, %	49.04	49.39	54.57	36.12						
POROSITY, %	72.7	76.1	81.4	84.8						
PLASTIC LIMIT	36	33	54	90						
LIQUID LIMIT	93	102	134	180						

Sediment Classification: Sa = sand or sandy, Si = silt or silty, C = clay or clayey
(?) after value = questionable value

AREA: A CORE: MR-3 SONIC DEPTH: 4279 m. CORER: Benthos

CORE LENGTH: 25.62 in. CORER DIAMETER: 2.65 in. I.D.

DEPTH IN CORE, in.	0.50	1.50	4.50	7.50	10.50	13.25	14.25	15.75	16.50	18.00
SATURATION, %	~100	~100	~100	~100	~100	~100	~100	~100	~100	~100
SAND, % <4 Φ, (>62μ)	-	-	0.3	-	0.2	-	-	-	11.0?	-
SILT, % >4 Φ<8 Φ, (62-4μ)	-	-	90.7	-	83.8	-	-	-	49.0?	-
CLAY, % >8 Φ, (<4 μ)	-	-	9.0	-	16.0	-	-	-	40.0?	-
SEDIMENT CLASSIFICATION Shepard (1954)	-	-	Si	-	Si	-	-	-	CSi	-
MEDIAN DIAMETER, Φ	7.20	-	6.50	-	6.98	-	7.12	-	7.37	-
COHESION, psi	-	0.28	0.66	0.94	1.12	1.98	-	2.26	-	3.03
WATER CONTENT, % (dry)	-	122	96	94	92	80.6	-	88.3	-	112
WET BULK DENSITY, g/cm^3	-	1.43	1.60	1.57	1.56	1.54	-	1.54	-	1.48
DRY BULK DENSITY, g/cm^3	-	1.40	1.47	1.49	1.50	1.54	-	1.54	-	1.38
VOLUME SHRINKAGE, %	-	50.78	45.58	46.09	45.65	44.86	-	46.76	-	49.56
POROSITY, %	-	83.52	76.53	76.07	75.17	68.70	-	72.2	-	77.9
PLASTIC LIMIT	-	-	-	-	-	-	-	46	-	46
LIQUID LIMIT	-	-	-	-	-	-	-	92	-	109

Sediment Classification: Sa = sand or sandy, Si = silt or silty, C = clay or clayey
(?) after value = questionable value

AREA: A   CORE: MR-3 (cont.)   SONIC DEPTH: ________ m.   CORER: ________

CORE LENGTH: ________ in.   CORER DIAMETER: ________ in. I.D.

DEPTH IN CORE, in.	19.00	19.75	21.25	22.50	22.75	25.75				
SATURATION, %	~100	~100	~100	~100	~100	-				
SAND, % <4 Φ, (>62μ)	17.5?	-	31.0?	-	-	-				
SILT, % >4 Φ<8 Φ, (62-4μ)	50.5?	-	52.0?	-	-	-				
CLAY, % >8 Φ, (<4 μ)	32.0?	-	17.0?	-	-	-				
SEDIMENT CLASSIFICATION Shepard (1954)	CSi	-	SaSi	-	-	-				
MEDIAN DIAMETER, Φ	6.75	-	5.50	-	4.12	-				
COHESION, psi	-	5.61	-	14.65	-	-				
WATER CONTENT, % (dry)	-	156	-	168	-	177				
WET BULK DENSITY, g/cm^3	-	1.35	-	1.33	-	1.31				
DRY BULK DENSITY, g/cm^3	-	1.13	-	0.80	-	0.67				
VOLUME SHRINKAGE, %	-	53.33	-	37.75	-	28.92				
POROSITY, %	-	82.5	-	83.5	-	83.9				
PLASTIC LIMIT	-	87	-	100	-	117				
LIQUID LIMIT	-	153	-	178	-	174?				

Sediment Classification: Sa = sand or sandy, Si = silt or silty, C = clay or clayey
(?) after value = questionable value

AREA: A CORE: MR-4 SONIC DEPTH: 4279 m. CORER: Benthos

CORE LENGTH: 27.75 in. CORER DIAMETER: 2.65 in. I.D.

DEPTH IN CORE, in.	0.50	1.50	4.50	7.50	10.50	13.25	16.00	20.00	23.25	25.50
SATURATION, %	~100	~100	~100	~100	~100	~100	~100	~100	~100	~100
SAND, % <4 Φ, (>62μ)	-	-	-	0.4	-	-	-	-	-	-
SILT, % >4 Φ<8 Φ, (62-4μ)	-	-	-	86.6	-	-	-	-	-	-
CLAY, % >8 Φ, (<4 μ)	-	-	-	13.0	-	-	-	-	-	-
SEDIMENT CLASSIFICATION Shepard (1954)	-	-	-	Si	-	-	-	-	-	-
MEDIAN DIAMETER, Φ	7.40	-	-	6.51	-	7.00	7.20	6.80	6.20	5.80
COHESION, psi	-	0.37	0.74	0.89	1.08	1.70	1.91	> 4.36	6.10	-
WATER CONTENT, % (dry)	-	114	96	100	96	-	-	-	-	-
WET BULK DENSITY, g/cm^3	-	1.50	1.55	1.57	1.54	-	-	-	-	-
DRY BULK DENSITY, g/cm^3	-	1.41	1.51	1.50	1.49	1.52	1.46	1.31	-	0.77
VOLUME SHRINKAGE, %	-	50.50	48.04	45.98	47.24	48.77	50.81	56.18	-	34.50
POROSITY, %	-	80.02	76.17	75.69	75.44	-	-	-	-	-
PLASTIC LIMIT	-	-	-	-	-	48	45	65	135	160
LIQUID LIMIT	-	-	-	-	-	-	90	133	187	168

Sediment Classification: Sa = sand or sandy, Si = silt or silty, C = clay or clayey.
(?) after value = questionable value

AREA: A CORE: MR-5 SONIC DEPTH: 4279 m. CORER: Benthos

CORE LENGTH: 33.75 in. CORER DIAMETER: 2.65 in. I.D.

DEPTH IN CORE, in.	0.50	2.50	4.50	7.50	10.50	13.25	14.62	15.00	18.25	19.62
SATURATION, %	~100	~100	~100	~100	~100	~100	~100	~100	~100	~100
SAND, % <4 ϕ, (>62µ)	-	-	-	-	-	-	1.0	0.5	-	8.0
SILT, % >4 ϕ<8 ϕ, (62-4µ)	-	-	-	-	-	-	68.0	97.7	-	82.5
CLAY, % >8 ϕ, (<4 µ)	-	-	-	-	-	-	31.0	1.8	-	9.5
SEDIMENT CLASSIFICATION Shepard (1954)	-	-	-	-	-	-	CSi	Si	-	Si
MEDIAN DIAMETER, Φ	7.63	-	-	-	-	-	7.50	6.29	-	7.00
COHESION, psi	-	0.46	0.95	1.06	1.68	1.53	-	-	1.90	-
WATER CONTENT, % (dry)	-	116	103	91	95	70.7	-	-	87.1	-
WET BULK DENSITY, g/cm^3	-	1.47	1.50	1.56	1.56	1.63	-	-	1.72	-
DRY BULK DENSITY, g/cm^3	-	1.34	1.43	1.49	1.49	1.58	-	-	1.54	-
VOLUME SHRINKAGE, %	-	49.41	48.44	45.26	46.37	39.71	-	-	45.54	-
POROSITY, %	-	78.66	76.07	74.47	75.86	67.70	-	-	73.10	-
PLASTIC LIMIT	-	-	-	-	-	27	-	-	37	-
LIQUID LIMIT	-	-	-	-	-	75	-	-	-	-

Sediment Classification: Sa = sand or sandy, Si = silt or silty, C = clay or clayey
(?) after value = questionable value

AREA: A CORE: MR-5 (cont.) SONIC DEPTH: ______ m. CORER: ______

CORE LENGTH: ______ in. CORER DIAMETER: ______ in. I.D.

DEPTH IN CORE, in.	23.25	24.62	26.75	28.25	30.38	30.87	32.75			
SATURATION, %	~100	~100	~100	~100	~100	~100	~100			
SAND, % <4 Φ, (>62μ)	-	6.0	9.5	-	-	31.0	-			
SILT, % >4 Φ<8 Φ, (62-4μ)	-	81.5	74.0	-	-	49.5	-			
CLAY, % >8 Φ, (<4 μ)	-	12.5	16.5	-	-	19.5	-			
SEDIMENT CLASSIFICATION Shepard (1954)	-	Si	CSi	-	-	SaSi	-			
MEDIAN DIAMETER, Φ	-	7.25	7.12	-	-	5.87	-			
COHESION, psi	2.30	-	-	2.52	4.93	-	7.59			
WATER CONTENT, % (dry)	90.7	-	-	108.1	146.5	-	181.0			
WET BULK DENSITY, g/cm^3	1.52	-	-	1.49	1.44	-	1.33			
DRY BULK DENSITY, g/cm^3	1.50	-	-	1.43	1.17	-	0.71			
VOLUME SHRINKAGE, %	46.91	-	-	49.93	52.65	-	33.60			
POROSITY, %	72.00	-	-	77.40	81.30	-	85.7			
PLASTIC LIMIT	39	-	-	41	48	-	163			
LIQUID LIMIT	91	-	-	116	156	-	182			

Sediment Classification: Sa = sand or sandy, Si = silt or silty, C = clay or clayey
(?) after value = questionable value

AREA: A CORE: MR-6 SONIC DEPTH: 4234 m. CORER: Benthos

CORE LENGTH: 31.62 in. CORER DIAMETER: 2.65 in. I.D.

DEPTH IN CORE, in.	0.50	1.50	4.50	7.50	10.50	14.00	18.50	22.00	24.38	26.25
SATURATION, %	~100	~100	~100	~100	~100	~100	~100	~100	~100	~100
SAND, % <4 Φ, (>62μ)	-	-	-	0.5	-	5.0?	11.0?	10.0?	6.0?	-
SILT, % >4 Φ<8 Φ, (62-4μ)	-	-	-	92.3	-	81.0?	69.5?	60.5?	69.5?	-
CLAY, % >8 Φ, (<4 μ)	-	-	-	7.2	-	14.0?	19.5?	29.5?	24.5?	-
SEDIMENT CLASSIFICATION Shepard (1954)	-	-	-	Si	-	Si	CSi	CSi	CSi	-
MEDIAN DIAMETER, Φ	7.58	-	-	6.38	-	7.30	7.20	6.90	6.50	-
COHESION, psi	-	0.32	0.63	0.72	0.80	1.16	1.07	1.61	-	4.77
WATER CONTENT, % (dry)	-	131	112	97	94	78.5	95.4	100	-	185
WET BULK DENSITY, g/cm^3	-	1.43	1.49	1.53	1.55	1.63	1.48	1.51	-	1.32
DRY BULK DENSITY, g/cm^3	-	1.37	1.42	1.47	1.49	1.68	1.45	1.45	-	0.84
VOLUME SHRINKAGE, %	-	54.63	50.25	47.31	46.27	45.51	47.84	47.87	-	45.17
POROSITY, %	-	81.85	78.69	75.29	75.18	71.80	72.40	75.60	-	85.70
PLASTIC LIMIT	-	-	-	-	-	40	39	43	67	-
LIQUID LIMIT	-	-	-	-	-	83	89	102	-	191

Sediment Classification: Sa = sand or sandy, Si = silt or silty, C = clay or clayey
(?) after value = questionable value

AREA: A CORE: MR-6 (cont.) SONIC DEPTH: ________ m. CORER: ________

CORE LENGTH: ________ in. CORER DIAMETER: ________ in. I.D.

DEPTH IN CORE, in.	28.50									
SATURATION, %	~100									
SAND, % <4 Φ, (>62μ)	-									
SILT, % >4 Φ<8 Φ, (62-4μ)	-									
CLAY, % >8 Φ, (<4 μ)	-									
SEDIMENT CLASSIFICATION Shepard (1954)	-									
MEDIAN DIAMETER, Φ	-									
COHESION, psi	>12.35									
WATER CONTENT, % (dry)	171									
WET BULK DENSITY, g/cm^3	1.34									
DRY BULK DENSITY, g/cm^3	0.71									
VOLUME SHRINKAGE, %	30.20									
POROSITY, %	84.7									
PLASTIC LIMIT	172									
LIQUID LIMIT	174									

Sediment Classification: Sa = sand or sandy, Si = silt or silty, C = clay or clayey
(?) after value = questionable value

AREA: A CORE: MR-7 SONIC DEPTH: 4206 m. CORER: Benthos

CORE LENGTH: 43.50 in. CORER DIAMETER: 2.65 in. I.D.

DEPTH IN CORE, in.	0.50	1.50	4.50	7.50	10.50	13.50	16.50	19.50	22.50	25.50
SATURATION, %	~100	~100	~100	~100	~100	~100	~100	~100	~100	~100
SAND, % <4 Φ, (>62μ)	-	-	-	0.9	-	0.3	-	-	-	0.3
SILT, % >4 Φ<8 Φ, (62-4μ)	-	-	-	82.8	-	76.4	-	-	-	92.5
CLAY, % >8 Φ, (<4 μ)	-	-	-	16.3	-	23.3	-	-	-	7.2
SEDIMENT CLASSIFICATION Shepard (1954)	-	-	-	Si	-	Si	-	-	-	Si
MEDIAN DIAMETER, Φ	7.60	-	-	6.69	-	7.20	-	-	-	6.47
COHESION, psi	-	0.09	0.23	0.31	0.68	1.03	1.40	1.89	1.62	1.69
WATER CONTENT, % (dry)	-	131	107	99	94	91	92	89	97	106
WET BULK DENSITY, g/cm^3	-	1.43	1.49	1.54	1.55	1.56	1.54	1.54	1.51	1.50
DRY BULK DENSITY, g/cm^3	-	1.38	1.46	1.51	1.46	1.49	1.48	1.48	1.46	1.48
VOLUME SHRINKAGE, %	-	55.47	50.98	48.58	45.40	45.07	45.51	45.00	47.26	48.62
POROSITY, %	-	81.09	77.25	76.97	75.01	74.56	74.30	72.87	74.13	76.81
PLASTIC LIMIT	-	-	-	-	-	-	-	-	-	-
LIQUID LIMIT	-	-	-	-	-	-	-	-	-	-

Sediment Classification: Sa = sand or sandy, Si = silt or silty, C = clay or clayey
(?) after value = questionable value

AREA: A CORE: MR-7 (cont.) SONIC DEPTH: ______ m. CORER: ______

CORE LENGTH: ______ in. CORER DIAMETER: ______ in. I.D.

DEPTH IN CORE, in.	28.50	31.50	34.50	37.50	40.00	42.50				
SATURATION, %	~100	~100	~100	~100	-	-				
SAND, % <4 Φ, (>62μ)	-	0.7	-	-	-	-				
SILT, % >4 Φ<8 Φ, (62-4μ)	-	71.6	-	-	-	-				
CLAY, % >8 Φ, (<4 μ)	-	27.7	-	-	-	-				
SEDIMENT CLASSIFICATION Shepard (1954)	-	CSi	-	-	-	-				
MEDIAN DIAMETER, Φ	-	7.32	-	-	-	-				
COHESION, psi	1.92	2.65	1.69	2.48	3.78	2.88				
WATER CONTENT, % (dry)	106	103	109	-	-	-				
WET BULK DENSITY, g/cm^3	1.50	1.50	1.56	-	-	-				
DRY BULK DENSITY, g/cm^3	1.42	1.42	1.38	-	-	-				
VOLUME SHRINKAGE, %	48.59	48.15	48.34	-	-	-				
POROSITY, %	77.65	76.14	77.76	-	-	-				
PLASTIC LIMIT	-	-	-	-	-	-				
LIQUID LIMIT	-	-	-	-	-	-				

Sediment Classification: Sa = sand or sandy, Si = silt or silty, C = clay or clayey
(?) after value = questionable value

AREA: A CORE: 660622-1 SONIC DEPTH: 4425 m. CORER: Benthos

CORE LENGTH: 48.00 in. CORER DIAMETER: 2.65 in. I.D.

DEPTH IN CORE, in.	0.50	2.50	4.50	7.50	10.50	13.50	16.50	19.50	22.50	26.00
SATURATION, %	~100	~100	~100	~100	~100	~100	~100	~100	~100	~100
SAND, % <4 Φ, (>62μ)	0.3	-	-	-	0.1	-	-	0.3	-	-
SILT, % >4 Φ<8 Φ, (62-4μ)	48.5	-	-	-	84.6	-	-	82.4	-	-
CLAY, % >8 Φ, (<4 μ)	51.2	-	-	-	15.3	-	-	17.3	-	-
SEDIMENT CLASSIFICATION Shepard (1954)	SiC	-	-	-	Si	-	-	Si	-	-
MEDIAN DIAMETER, Φ	8.05	-	-	-	6.82	-	-	6.80	-	-
COHESION, psi	-	0.11	0.31	0.53	0.69	0.69	0.66	0.66	0.97	1.08
WATER CONTENT, % (dry)	-	126	106	97	87	93	95	92	89	104
WET BULK DENSITY, g/cm^3	-	1.44	1.52	1.52	1.58	1.57	1.54	1.56	1.52	1.49
DRY BULK DENSITY, g/cm^3	-	1.42	1.44	1.46	1.47	1.49	1.48	1.54	1.47	1.41
VOLUME SHRINKAGE, %	-	54.98	48.73	47.28	42.45	44.96	46.64	46.76	47.37	48.64
POROSITY, %	-	80.86	78.09	74.99	73.41	75.63	74.90	76.92	74.62	76.00
PLASTIC LIMIT	-	-	-	-	-	-	-	-	-	-
LIQUID LIMIT	-	-	-	-	-	-	-	-	-	-

Sediment Classification: Sa = sand or sandy, Si = silt or silty, C = clay or clayey
(?) after value = questionable value

AREA: A CORE: 660622-1 (cont.) SONIC DEPTH: ________ m. CORER: ________

CORE LENGTH: ________ in. CORER DIAMETER: ________ in. I.D.

DEPTH IN CORE, in.	28.50	31.50	34.50	37.50	40.50	43.50	46.50	48.00		
SATURATION, %	~100	~100	~100	~100	~100	~100	~100	~100		
SAND, % <4 Φ, (>62μ)	-	-	0.1	-	0.7	-	-	1.7		
SILT, % >4 Φ<8 Φ, (62-4μ)	-	-	91.5	-	83.9	-	-	81.4		
CLAY, % >8 Φ, (<4 μ)	-	-	8.4	-	15.4	-	-	16.9		
SEDIMENT CLASSIFICATION Shepard (1954)	-	-	Si	-	Si	-	-	Si		
MEDIAN DIAMETER, Φ	-	-	6.34	-	4.82	-	-	6.37		
COHESION, psi	1.28	1.37	1.00	1.34	0.69	1.03	1.83	-		
WATER CONTENT, % (dry)	106	105	115	188	281	327	-	251		
WET BULK DENSITY, g/cm^3	1.50	1.51	1.50	1.32	1.26	1.20	-	1.24		
DRY BULK DENSITY, g/cm^3	1.41	1.39	1.34	1.10	0.63	0.54	0.49	-		
VOLUME SHRINKAGE, %	47.99	47.07	48.22	58.61	47.65	48.11	-	29.90		
POROSITY, %	77.97	77.33	80.30	86.03	92.67	91.74	-	88.62		
PLASTIC LIMIT	-	-	-	-	-	-	-	-		
LIQUID LIMIT	-	-	-	-	-	-	-	-		

Sediment Classification: Sa = sand or sandy, Si = silt or silty, C = clay or clayey
(?) after value = questionable value

AREA: S CORE: 661003-1 SONIC DEPTH: 4750 m. CORER: Benthos

CORE LENGTH: 12.00 in. CORER DIAMETER: 2.65 in. I.D.

DEPTH IN CORE, in.	0.50	1.50	2.38	3.50	4.25	5.50	6.25	7.25	8.25	9.25
SATURATION, %	~100	~100	~100	~100	~100	~100	~100	~100	~100	~100
SAND, % $<4\ \phi$, ($>62\mu$)	-	-	-	-	-	-	-	-	-	-
SILT, % $>4\ \phi<8\ \phi$, ($62-4\mu$)	-	-	-	-	-	-	-	-	-	-
CLAY, % $>8\ \phi$, ($<4\ \mu$)	-	-	-	-	-	-	-	-	-	-
SEDIMENT CLASSIFICATION Shepard (1954)	-	-	-	-	-	-	-	-	-	-
MEDIAN DIAMETER, Φ	6.00		-	-	-	-	-	-	-	-
COHESION, psi	-	0.09	-	0.21	-	0.27	-	0.71	-	0.60
WATER CONTENT, % (dry)	-	-	129	-	130	-	113	-	96	-
WET BULK DENSITY, g/cm^3	-	-	1.49	-	1.47	-	1.48	-	1.56	-
DRY BULK DENSITY, g/cm^3	-	-	1.16	-	1.36	-	1.28	-	1.30	-
VOLUME SHRINKAGE, %	-	-	44.27	-	52.02	-	45.52	-	38.78	-
POROSITY, %	-	-	84.08	-	83.25	-	78.75	-	76.72	-
PLASTIC LIMIT	-	-	-	-	-	-	-	-	-	-
LIQUID LIMIT	-	-	-	-	-	-	-	-	-	-

Sediment Classification: Sa = sand or sandy, Si = silt or silty, C = clay or clayey
(?) after value = questionable value

AREA: S CORE: 661003-1 (cont.) SONIC DEPTH: ______ m. CORER: ______

CORE LENGTH: ______ in. CORER DIAMETER: ______ in. I.D.

DEPTH IN CORE, in.	9.75	11.75								
SATURATION, %	~100	~100								
SAND, % <4 Φ, (>62μ)	-	-								
SILT, % >4 Φ<8 Φ, (62-4μ)	-	-								
CLAY, % >8 Φ, (<4 μ)	-	-								
SEDIMENT CLASSIFICATION Shepard (1954)	-	-								
MEDIAN DIAMETER, Φ	-	5.00								
COHESION, psi	-	-								
WATER CONTENT, % (dry)	97	-								
WET BULK DENSITY, g/cm^3	1.57	-								
DRY BULK DENSITY, g/cm^3	1.29	-								
VOLUME SHRINKAGE, %	37.70	-								
POROSITY, %	77.88	-								
PLASTIC LIMIT	-	-								
LIQUID LIMIT	-	-								

Sediment Classification: Sa = sand or sandy, Si = silt or silty, C = clay or clayey
(?) after value = questionable value

C17

AREA: S CORE: 661003-2 SONIC DEPTH: 4825 m. CORER: Benthos

CORE LENGTH: 45 in. CORER DIAMETER: 2.65 in. I.D.

DEPTH IN CORE, in.	1.50	2.50	4.00	4.50	6.00	7.50	9.00	10.00	10.50	11.50
SATURATION, %	~100	~100	~100	~100	~100	~100	~100	~100	~100	~100
SAND, % <4 Φ, (>62μ)	-	-	-	-	1.9	-	-	-	-	-
SILT, % >4 Φ<8 Φ, (62-4μ)	-	-	-	-	57.9	-	-	-	-	-
CLAY, % >8 Φ, (<4 μ)	-	-	-	-	40.2	-	-	-	-	-
SEDIMENT CLASSIFICATION Shepard (1954)	-	-	-	-	CSi	-	-	-	-	-
MEDIAN DIAMETER, Φ	-	6.73	-	-	7.35	7.35	7.35	-	-	7.55
COHESION, psi	0.09	-	-	0.08	-	0.08	0.19	-	0.30	-
WATER CONTENT, % (dry)	-	197	207	-	244	247	-	227	-	-
WET BULK DENSITY, g/cm^3	-	1.32	1.32	-	1.27	1.30	-	1.30	-	-
DRY BULK DENSITY, g/cm^3	-	0.88	0.80	-	0.75	0.74	-	0.76	-	-
VOLUME SHRINKAGE, %	-	49.03	46.41	-	50.60	49.18	-	49.19	-	-
POROSITY, %	-	87.77	88.51	-	90.20	92.31	-	90.18	-	-
PLASTIC LIMIT	-	-	-	-	-	-	-	-	-	-
LIQUID LIMIT	-	-	-	-	-	-	-	-	-	-

Sediment Classification: Sa = sand or sandy, Si = silt or silty, C = clay or clayey
(?) after value = questionable value

AREA: S CORE: 661003-2 (cont.) SONIC DEPTH: ______ m. CORER: ______

CORE LENGTH: ______ in. CORER DIAMETER: ______ in. I.D.

DEPTH IN CORE, in.	12.00	13.00	13.50	15.00	16.50	17.50	18.50	21.00	22.25	23.00
SATURATION, %	~100	~100	~100	~100	~100	~100	~100	~100	~100	~100
SAND, % <4 Φ, (>62μ)	-	1.8	-	-	-	-	-	7.4	-	-
SILT, % >4 Φ<8 Φ, (62-4μ)	-	68.1	-	-	-	-	-	73.3	-	-
CLAY, % >8 Φ, (<4 μ)	-	30.1	-	-	-	-	-	19.3	-	-
SEDIMENT CLASSIFICATION Shepard (1954)	-	CSi	-	-	-	-	-	CSi	-	-
MEDIAN DIAMETER, Φ	-	6.40	-	-	7.20	-	-	5.46	-	-
COHESION, psi	-	-	0.25	-	0.26	-	0.49	-	0.96	-
WATER CONTENT, % (dry)	189	-	-	186	-	159	-	106	-	112
WET BULK DENSITY, g/cm^3	1.34	-	-	1.33	-	1.40	-	1.50	-	1.47
DRY BULK DENSITY, g/cm^3	0.91	-	-	0.89	-	1.04	-	1.25	-	1.32
VOLUME SHRINKAGE, %	49.05	-	-	48.18	-	47.98	-	41.69	-	47.57
POROSITY, %	87.35	-	-	86.94	-	85.84	-	77.11	-	77.35
PLASTIC LIMIT	-	-	-	-	-	-	-	-	-	-
LIQUID LIMIT	-	-	-	-	-	-	-	-	-	-

Sediment Classification: Sa = sand or sandy, Si = silt or silty, C = clay or clayey
(?) after value = questionable value

AREA: S CORE: 661003-2 (cont.) SONIC DEPTH: ______ m. CORER: ______

CORE LENGTH: ______ in. CORER DIAMETER: ______ in. I.D.

DEPTH IN CORE, in.	23.50	27.00	27.50	30.00	30.50	33.00	34.00	36.00	37.00	39.00
SATURATION, %	~100	~100	~100	~100	~100	~100	~100	~100	~100	~100
SAND, % <4 Φ, (>62μ)	-	1.5	-	-	1.4	-	-	-	0.9	-
SILT, % >4 Φ<8 Φ, (62-4μ)	-	62.6	-	-	62.7	-	-	-	67.4	-
CLAY, % >8 Φ, (<4 μ)	-	35.9	-	-	35.9	-	-	-	31.7	-
SEDIMENT CLASSIFICATION Shepard (1954)	-	CSi	-	-	CSi	-	-	-	CSi	-
MEDIAN DIAMETER, Φ	-	6.87	-	-	6.98	-	-	-	6.38	-
COHESION, psi	0.68	1.69	-	2.94	-	1.74	-	1.69	-	1.13
WATER CONTENT, % (dry)	-	-	98	-	87	-	103	-	108	-
WET BULK DENSITY, g/cm^3	-	-	1.46	-	1.59	-	1.52	-	1.49	-
DRY BULK DENSITY, g/cm^3	-	-	1.47	-	1.31	-	1.34	-	1.19	-
VOLUME SHRINKAGE, %	-	-	37.90	-	35.10	-	44.15	-	39.98	-
POROSITY, %	-	-	71.90	-	73.86	-	76.96	-	77.08	-
PLASTIC LIMIT	-	-	-	-	-	-	-	-	-	-
LIQUID LIMIT	-	-	-	-	-	-	-	-	-	-

Sediment Classification: Sa = sand or sandy, Si = silt or silty, C = clay or clayey
(?) after value = questionable value

AREA: S CORE: 661003-2 (cont.) SONIC DEPTH: ______ m. CORER: ______

CORE LENGTH: ______ in. CORER DIAMETER: ______ in. I.D.

DEPTH IN CORE, in.	39.50	40.50	42.50	45.00						
SATURATION, %	~100	~100	~100	~100						
SAND, % <4 Φ, (>62μ)	-	-	-	-						
SILT, % >4 Φ<8 Φ, (62-4μ)	-	-	-	-						
CLAY, % >8 Φ, (<4 μ)	-	-	-	-						
SEDIMENT CLASSIFICATION Shepard (1954)	-	-	-	-						
MEDIAN DIAMETER, Φ	-	-	-	6.85						
COHESION, psi	-	1.36	1.74	-						
WATER CONTENT, % (dry)	113	-	-	-						
WET BULK DENSITY, g/cm^3	1.49	-	-	-						
DRY BULK DENSITY, g/cm^3	1.33	-	-	-						
VOLUME SHRINKAGE, %	48.24	-	-	-						
POROSITY, %	77.79	-	-	-						
PLASTIC LIMIT	-	-	-	-						
LIQUID LIMIT	-	-	-	-						

Sediment Classification: Sa = sand or sandy, Si = silt or silty, C = clay or clayey
(?) after value = questionable value

AREA: A CORE: 661003-8 SONIC DEPTH: 4440 m. CORER: Benthos

CORE LENGTH: 20.00 in. CORER DIAMETER: 2.65 in. I.D.

DEPTH IN CORE, in.	0.50	2.00	2.75	4.13	4.75	6.25	7.00	8.25	9.00	10.25
SATURATION, %	~100	~100	~100	~100	~100	~100	~100	~100	~100	~100
SAND, % <4 Φ, (>62μ)	-	-	-	-	-	-	0.8	-	-	-
SILT, % >4 Φ<8 Φ, (62-4μ)	-	-	-	-	-	-	46.6	-	-	-
CLAY, % >8 Φ, (<4 μ)	-	-	-	-	-	-	52.6	-	-	-
SEDIMENT CLASSIFICATION Shepard (1954)	-	-	-	-	-	-	SiC	-	-	-
MEDIAN DIAMETER, Φ	6.90	-	-	-	-	-	7.82	-	-	-
COHESION, psi	-	0.25	-	0.53	-	0.84	-	0.89	-	1.52
WATER CONTENT, % (dry)	-	-	100	-	95	-	79	-	94	-
WET BULK DENSITY, g/cm^3	-	-	1.52	-	1.56	-	1.63	-	1.57	-
DRY BULK DENSITY, g/cm^3	-	-	1.36	-	1.44	-	1.48	-	1.49	-
VOLUME SHRINKAGE, %	-	-	45.06	-	44.67	-	38.88	-	42.04	-
POROSITY, %	-	-	76.37	-	75.96	-	72.08	-	76.34	-
PLASTIC LIMIT	-	-	-	-	-	-	-	-	-	-
LIQUID LIMIT	-	-	-	-	-	-	-	-	-	-

Sediment Classification: Sa = sand or sandy, Si = silt or silty, C = clay or clayey
(?) after value = questionable value

AREA: A CORE: 661003-8 (cont.) SONIC DEPTH: ____ m. CORER: ____

CORE LENGTH: ____ in. CORER DIAMETER: ____ in. I.D.

DEPTH IN CORE, in.	11.13	12.00	13.25	14.00	15.75	16.50	18.50	19.50		
SATURATION, %	~100	~100	~100	~100	~100	~100	~100	~100		
SAND, % <4 Φ, (>62μ)	0.8	-	-	-	0.9	-	-	4.7		
SILT, % >4 Φ<8 Φ, (62-4μ)	55.3	-	-	-	64.6	-	-	90.0		
CLAY, % >8 Φ, (<4 μ)	43.9	-	-	-	34.5	-	-	5.3		
SEDIMENT CLASSIFICATION Shepard (1954)	CSi	-	-	-	CSi	-	-	Si		
MEDIAN DIAMETER, Φ	7.55	-	-	-	7.10	-	-	5.74		
COHESION, psi	-	1.80	-	1.75	-	5.30	>21.83	-		
WATER CONTENT, % (dry)	92	-	99	-	150	-	-	194		
WET BULK DENSITY, g/cm^3	1.57	-	1.52	-	1.40	-	-	1.24		
DRY BULK DENSITY, g/cm^3	1.50	-	1.41	-	1.10	-	-	0.58		
VOLUME SHRINKAGE, %	44.15	-	46.04	-	49.20	-	-	26.20		
POROSITY, %	75.01	-	75.68	-	83.61	-	-	82.33		
PLASTIC LIMIT	-	-	-	-	-	-	-	-		
LIQUID LIMIT	-	-	-	-	-	-	-	-		

Sediment Classification: Sa = sand or sandy, Si = silt or silty, C = clay or clayey
(?) after value = questionable value

AREA: A CORE: 661003-10 SONIC DEPTH: 4133 m. CORER: Benthos

CORE LENGTH: 36.00 in. CORER DIAMETER: 2.65 in. I.D.

DEPTH IN CORE, in.	1.50	4.50	7.50	10.50	13.50	16.50	19.50	22.50	25.50	28.50
SATURATION, %	~100	~100	~100	~100	~100	~100	~100	~100	~100	~100
SAND, % <4 Φ, (>62μ)	-	-	0.6	-	0.7	-	-	0.5	1.1	-
SILT, % >4 Φ<8 Φ, (62-4μ)	-	-	45.4	-	68.3	-	-	49.3	70.3	-
CLAY, % >8 Φ, (<4 μ)	-	-	54.0	-	31.0	-	-	50.2	28.6	-
SEDIMENT CLASSIFICATION Shepard (1954)	-	-	SiC	-	CSi	-	-	SiC	CSi	-
MEDIAN DIAMETER, Φ	7.75	-	8.30?	6.70	7.19	-	8.00	8.00	6.88	-
COHESION, psi	0.16	0.36	0.76	0.77	0.92	0.90	1.13	1.15	1.62	1.36
WATER CONTENT, % (dry)	98	91	99	149	164	125	108	106	212	214
WET BULK DENSITY, g/cm³	1.57	1.55	1.53	1.40	1.36	1.43	1.47	1.52	1.30	1.32
DRY BULK DENSITY, g/cm³	1.52	1.47	1.46	0.99	1.01	1.39	1.43	1.44	0.89	0.96
VOLUME SHRINKAGE, %	49.03	45.44	47.44	51.84	49.40	53.46	50.43	48.73	53.10	56.63
POROSITY, %	76.20	74.60	76.20	84.00	84.40	79.60	77.30	78.00	88.60	88.70
PLASTIC LIMIT	-	-	-	-	-	-	-	-	-	-
LIQUID LIMIT	-	-	-	-	-	-	-	-	-	-

Sediment Classification: Sa = sand or sandy, Si = silt or silty, C = clay or clayey
(?) after value = questionable value

AREA: A CORE: 661003-10(cont.) SONIC DEPTH: ______ m. CORER: ______

CORE LENGTH: ______ in. CORER DIAMETER: ______ in. I.D.

DEPTH IN CORE, in.	29.50	31.50	34.50	36.50						
SATURATION, %	~100	~100	~100	~100						
SAND, % <4 Φ, (>62μ)	-	1.1	-	-						
SILT, % >4 Φ<8 Φ, (62-4μ)	-	74.8	-	-						
CLAY, % >8 Φ, (<4 μ)	-	24.1	-	-						
SEDIMENT CLASSIFICATION Shepard (1954)	-	CSi	-	-						
MEDIAN DIAMETER, Φ	-	6.63	-	6.25						
COHESION, psi	1.46	1.97	2.34	-						
WATER CONTENT, % (dry)	-	195	119	-						
WET BULK DENSITY, g/cm^3	-	1.31	1.45	-						
DRY BULK DENSITY, g/cm^3	-	0.88	0.88	-						
VOLUME SHRINKAGE, %	-	50.98	48.02	-						
POROSITY, %	-	86.50	77.90	-						
PLASTIC LIMIT	-	-	-	-						
LIQUID LIMIT	-	-	-	-						

Sediment Classification: Sa = sand or sandy, Si = silt or silty, C = clay or clayey
(?) after value = questionable value

AREA: T CORE: 670224-1 SONIC DEPTH: 5375 m. CORER: PVC

CORE LENGTH: 40.75 in. CORER DIAMETER: 3.20 in. I.D.

DEPTH IN CORE, in.	1.50	4.50	7.50	10.50	13.50	16.50	19.50	22.50	25.50	28.50
SATURATION, %	~100	~100	~100	~100	~100	~100	~100	~100	~100	~100
SAND, % <4 Φ, (>62μ)	20.3	18.1	-	22.0	36.5	-	17.4	-	-	-
SILT, % >4 Φ<8 Φ, (62-4μ)	57.3	53.8	-	46.6	34.0	-	45.4	-	-	-
CLAY, % >8 Φ, (<4 μ)	22.4	28.1	-	31.4	29.5	-	37.2	-	-	-
SEDIMENT CLASSIFICATION Shepard (1954)	Sa SiC	CSi	-	Sa SiC	Sa SiC	-	CSi	-	-	-
MEDIAN DIAMETER, Φ	5.14	6.20	-	6.60	5.40	-	6.78	-	-	-
COHESION, psi	0.44	0.43	0.36	0.35	0.38	0.43	0.38	0.46	0.54	0.51
WATER CONTENT, % (dry)	134	324	322	340	282	365	274	276	240	193
WET BULK DENSITY, g/cm^3	1.44	1.24	1.23	1.25	1.19	1.20	1.24	1.27	1.31	1.37
DRY BULK DENSITY, g/cm^3	0.95	0.51	0.50	0.47	0.37	0.40	0.56	0.56	0.59	0.73
VOLUME SHRINKAGE, %	34.75	42.35	42.00	38.57	37.10	35.21	40.43	38.60	34.88	36.75
POROSITY, %	82.70	94.80	93.60	96.60	95.70	94.30	91.30	92.20	92.20	88.60
PLASTIC LIMIT	-	-	-	-	-	-	-	-	-	-
LIQUID LIMIT	-	-	-	-	-	-	-	-	-	-

Sediment Classification: Sa = sand or sandy, Si = silt or silty, C = clay or clayey
(?) after value = questionable value

AREA: T   CORE: 670224-1 (cont.) SONIC DEPTH: ______ m.   CORER: ______

CORE LENGTH: ______ in.   CORER DIAMETER: ______ in. I.D.

DEPTH IN CORE, in.	31.50	34.50	36.50							
SATURATION, %	~100	~100	~100							
SAND, % <4 Φ, (>62μ)	15.6	-	39.0							
SILT, % >4 Φ<8 Φ, (62-4μ)	51.7	-	35.4							
CLAY, % >8 Φ, (<4 μ)	32.7	-	25.6							
SEDIMENT CLASSIFICATION Shepard (1954)	CSi	-	Sa SiC							
MEDIAN DIAMETER, Φ	6.67	-	5.24							
COHESION, psi	0.71	-	0.42							
WATER CONTENT, % (dry)	125	-	3.53							
WET BULK DENSITY, g/cm^3	1.49	-	1.18							
DRY BULK DENSITY, g/cm^3	0.88	-	0.42							
VOLUME SHRINKAGE, %	25.59	38.91	-							
POROSITY, %	82.70	-	91.90							
PLASTIC LIMIT	-	-	-							
LIQUID LIMIT	-	-	-							

Sediment Classification: Sa = sand or sandy, Si = silt or silty, C = clay or clayey
(?) after value = questionable value

AREA: T CORE: 670224-2 SONIC DEPTH: 5700 m. CORER: PVC

CORE LENGTH: 47.25 in. CORER DIAMETER: 3.20 in. I.D.

DEPTH IN CORE, in.	2.50	4.50	7.50	10.50	12.00	13.50	16.50	19.50	22.50	25.50
SATURATION, %	~100	~100	~100	~100	~100	~100	~100	~100	~100	~100
SAND, % <4 Φ, (>62μ)	-	-	25.5	-	10.3	-	33.4	-	27.9	-
SILT, % >4 Φ<8 Φ, (62-4μ)	-	-	40.5	-	62.0	-	42.9	-	43.3	-
CLAY, % >8 Φ, (<4 μ)	-	-	34.5	-	27.7	-	23.7	-	28.8	-
SEDIMENT CLASSIFICATION Shepard (1954)	-	-	Sa SiC	-	CSi	-	Sa SiC	-	Sa SiC	-
MEDIAN DIAMETER, Φ	6.40	-	6.67	-	5.32	-	5.95	-	6.39	-
COHESION, psi	0.55	0.51	0.38	0.17	-	0.56	0.56	0.51	0.51	0.56
WATER CONTENT, % (dry)	170	206	330	333	189	335	349	333	347	396
WET BULK DENSITY, g/cm³	1.35	1.30	1.19	1.27	1.35	1.24	1.19	1.19	1.17	1.18
DRY BULK DENSITY, g/cm³	0.89	0.76	0.46	0.44	0.76	0.43	0.41	0.43	0.43	0.34
VOLUME SHRINKAGE, %	43.08	43.70	39.86	34.29	38.49	33.87	34.60	43.78	40.16	29.84
POROSITY, %	85.50	87.70	91.10	95.80	88.40	95.20	92.40	91.70	90.30	94.60
PLASTIC LIMIT	-	-	-	-	-	-	-	-	-	-
LIQUID LIMIT	-	-	-	-	-	-	-	-	-	-

Sediment Classification: Sa = sand or sandy, Si = silt or silty, C = clay or clayey
(?) after value = questionable value

AREA: T CORE: 670224-2 (cont.) SONIC DEPTH: ______ m. CORER: ______

CORE LENGTH: ______ in. CORER DIAMETER: ______ in. I.D.

DEPTH IN CORE, in.	28.50	31.50	34.50	37.50	40.50	42.50	45.50			
SATURATION, %	~100	~100	~100	~100	~100	~100	~100			
SAND, % <4 Φ, (>62μ)	47.5	-	-	31.6	16.9	25.6	-			
SILT, % >4 Φ<8 Φ, (62-4μ)	34.1	-	-	36.7	59.6	53.9	-			
CLAY, % >8 Φ, (<4 μ)	18.4	-	-	31.7	23.5	28.3	-			
SEDIMENT CLASSIFICATION Shepard (1954)	SiSa	-	-	SaSa C	CSi	CSi	-			
MEDIAN DIAMETER, Φ	3.77	-	-	5.94	5.88	6.29	-			
COHESION, psi	0.68	0.72	0.55	0.52	1.39	0.63	0.92			
WATER CONTENT, % (dry)	387	283	376	365	238	355	218			
WET BULK DENSITY, g/cm^3	1.18	1.14	1.22	1.18	1.26	1.19	1.29			
DRY BULK DENSITY, g/cm^3	0.35	0.40	0.42	0.43	0.67	0.43	0.62			
VOLUME SHRINKAGE, %	30.92	42.38	39.53	40.40	44.31	39.40	34.80			
POROSITY, %	94.10	91.80	94.40	92.60	89.10	92.80	89.80			
PLASTIC LIMIT	-	-	-	-	-	-	-			
LIQUID LIMIT	-	-	-	-	-	-	-			

Sediment Classification: Sa = sand or sandy, Si = silt or silty, C = clay or clayey.
(?) after value = questionable value

AREA: T CORE: 670224-3 SONIC DEPTH: 5750 m. CORER: PVC

CORE LENGTH: 25.50 in. CORER DIAMETER: 3.20 in. I.D.

DEPTH IN CORE, in.	1.50	4.50	7.50	10.50	12.00	13.50	16.50	19.50	22.50	24.00
SATURATION, %	~100	~100	~100	~100	~100	~100	~100	~100	~100	~100
SAND, % <4 Φ, (>62μ)	-	6.9	-	-	-	-	53.1	46.6	-	-
SILT, % >4 Φ<8 Φ, (62-4μ)	-	64.5	-	-	-	-	41.6	38.7	-	-
CLAY, % >8 Φ, (<4 μ)	-	28.6	-	-	-	-	5.3	14.7	-	-
SEDIMENT CLASSIFICATION Shepard (1954)	-	CSi	-	-	-	-	SiSa	SiSa	-	-
MEDIAN DIAMETER, Φ	6.90	6.59	-	-	7.10	-	2.78	3.39	-	7.90
COHESION, psi	-	.035	.052	.104	-	.286	.208	.243	.148	.165
WATER CONTENT, % (dry)	285	300	359	462	-	383	478	413	473	469
WET BULK DENSITY, g/cm^3	1.26	1.31	1.26	1.18	-	1.19	1.14	1.21	1.16	1.16
DRY BULK DENSITY, g/cm^3	0.67	0.62	0.50	0.34	-	0.38	0.32	0.40	0.34	0.33
VOLUME SHRINKAGE, %	51.09	47.45	45.21	38.48	-	34.96	38.28	41.15	38.98	38.10
POROSITY, %	92.20	97.50	98.00	96.80	-	94.30	94.30	97.10	95.40	95.40
PLASTIC LIMIT	-	-	-	-	-	-	-	-	-	-
LIQUID LIMIT	-	-	-	-	-	-	-	-	-	-

Sediment Classification: Sa = sand or sandy, Si = silt or silty, C = clay or clayey
(?) after value = questionable value

AREA: T CORE: 670224-3 (cont.) SONIC DEPTH: ____________ m. CORER: ____________

CORE LENGTH: ____________ in. CORER DIAMETER: ____________ in. I.D.

DEPTH IN CORE, in.	26.00									
SATURATION, %	~100									
SAND, % $<4\ \phi$, ($>62\mu$)	-									
SILT, % $>4\ \phi<8\ \phi$, ($62-4\mu$)	-									
CLAY, % $>8\ \phi$, ($<4\ \mu$)	-									
SEDIMENT CLASSIFICATION Shepard (1954)	-									
MEDIAN DIAMETER, ϕ	8.10									
COHESION, psi	-									
WATER CONTENT, % (dry)	-									
WET BULK DENSITY, g/cm^3	-									
DRY BULK DENSITY, g/cm^3	-									
VOLUME SHRINKAGE, %	-									
POROSITY, %	-									
PLASTIC LIMIT	-									
LIQUID LIMIT	-									

Sediment Classification: Sa = sand or sandy, Si = silt or silty, C = clay or clayey
(?) after value = questionable value

AREA: M CORE: 670504-1 SONIC DEPTH: 4435 m. CORER: Benthos

CORE LENGTH: 13.88 in. CORER DIAMETER: 2.65 in. I.D.

DEPTH IN CORE, in.	1.50	4.00	6.00	7.75	9.50	11.00	13.00			
SATURATION, %	~100	~100	~100	~100	~100	~100	~100			
SAND, % <4 Φ, (>62μ)	54.9	18.9	-	-	28.9	18.7	24.5			
SILT, % >4 Φ<8 Φ, (62-4μ)	27.3	40.3	-	-	40.7	49.1	45.9			
CLAY, % >8 Φ, (<4 μ)	17.8	40.8	-	-	30.4	32.2	29.6			
SEDIMENT CLASSIFICATION Shepard (1954)	SiSa	Si Cl	-	-	Sa SiC	CSi	Sa SiC			
MEDIAN DIAMETER, Φ	2.75	6.25	-	-	4.95	5.94	5.26			
COHESION, psi	0.29	3.94	2.28	1.78	3.80	4.44	5.21			
WATER CONTENT, % (dry)	125	78	67	70	69	88	69			
WET BULK DENSITY, g/cm3	1.47	1.55	1.70	1.68	1.68	1.52	1.59			
DRY BULK DENSITY, g/cm3	0.81	0.99	1.42	1.42	1.40	1.12	1.29			
VOLUME SHRINKAGE, %	19.80	12.35	28.17	30.48	29.10	28.71	26.88			
POROSITY, %	81.80	68.00	68.00	69.20	68.60	69.40	64.80			
PLASTIC LIMIT	-	-	-	-	-	-	-			
LIQUID LIMIT	-	-	-	-	-	-	-			

Sediment Classification: Sa = sand or sandy, Si = silt or silty, C = clay or clayey.
(?) after value = questionable value

AREA: M CORE: 670313-5 SONIC DEPTH: 3980 m. CORER: PVC

CORE LENGTH: 21.62 in. CORER DIAMETER: 3.20 in. I.D.

DEPTH IN CORE, in.	1.50	2.50	4.00	5.50	7.00	8.50	10.50	12.50	14.50	16.50
SATURATION, %	~100	~100	~100	~100	~100	~100	~100	~100	~100	~100
SAND, % <4 Φ, (>62μ)	8.3	-	-	11.2	-	20.8	-	17.9	-	21.2
SILT, % >4 Φ<8 Φ, (62-4μ)	59.8	-	-	71.3	-	59.4	-	64.6	-	58.0
CLAY, % >8 Φ, (<4 μ)	31.9	-	-	17.5	-	19.8	-	17.5	-	20.8
SEDIMENT CLASSIFICATION Shepard (1954)	CSi	-	-	CSi	-	SaSi	-	SaSi	-	Sa SiC
MEDIAN DIAMETER, Φ	6.08	-	-	5.40	-	5.15	-	4.76	-	4.87
COHESION, psi	0.12	0.39	0.38	0.42	0.31	0.35	0.47	0.50	0.59	0.69
WATER CONTENT, % (dry)	120	111	117	122	112	171	161	126	147	165
WET BULK DENSITY, g/cm^3	1.50	1.54	1.50	1.52	1.45	1.41	1.43	1.44	1.42	1.39
DRY BULK DENSITY, g/cm^3	1.03	1.00	0.94	0.89	0.79	0.67	0.71	0.78	0.75	0.67
VOLUME SHRINKAGE, %	34.15	27.45	26.97	23.67	12.90	22.97	22.28	18.52	23.64	24.30
POROSITY, %	82.00	80.80	80.90	83.40	77.10	88.90	88.70	80.30	84.40	86.40
PLASTIC LIMIT	-	-	-	-	-	-	-	-	-	-
LIQUID LIMIT	-	-	-	-	-	-	-	-	-	-

Sediment Classification: Sa = sand or sandy, Si = silt or silty, C = clay or clayey
(?) after value = questionable value

AREA: M CORE: 670313-5 (cont) SONIC DEPTH: ____ m. CORER: ____

CORE LENGTH: ____ in. CORER DIAMETER: ____ in. I.D.

DEPTH IN CORE, in.	18.50	20.50								
SATURATION, %	~100	~100								
SAND, % <4 Φ, (>62μ)	-	9.3								
SILT, % >4 Φ<8 Φ, (62-4μ)	-	52.1								
CLAY, % >8 Φ, (<4 μ)	-	38.6								
SEDIMENT CLASSIFICATION Shepard (1954)	-	CSi								
MEDIAN DIAMETER, Φ	-	6.53								
COHESION, psi	0.64	0.86								
WATER CONTENT, % (dry)	162	147								
WET BULK DENSITY, g/cm^3	1.40	1.38								
DRY BULK DENSITY, g/cm^3	0.75	0.74								
VOLUME SHRINKAGE, %	23.34	22.73								
POROSITY, %	82.70	80.60								
PLASTIC LIMIT	-	-								
LIQUID LIMIT	-	-								

Sediment Classification: Sa = sand or sandy, Si = silt or silty, C = clay or clayey
(?) after value = questionable value

AREA: M CORE: 670123-3 SONIC DEPTH: 4585 m. CORER: PVC

CORE LENGTH: 28.18 in. CORER DIAMETER: 3.20 in. I.D.

DEPTH IN CORE, in.	1.50	4.50	7.50	10.50	13.50	16.50	19.50	22.50	25.50	27.25
SATURATION, %	~100	~100	~100	~100	~100	~100	~100	~100	~100	~100
SAND, % <4 Φ, (>62μ)	-	17.1	15.1	14.4	-	8.7	-	4.7	5.4	-
SILT, % >4 Φ<8 Φ, (62-4μ)	-	45.5	63.4	60.6	-	72.2	-	75.5	74.7	-
CLAY, % >8 Φ, (<4 μ)	-	37.4	21.5	25.0	-	19.1	-	19.8	19.9	-
SEDIMENT CLASSIFICATION Shepard (1954)	-	CSi	CSi	CSi	-	CSi	-	Si	CSi	-
MEDIAN DIAMETER, Φ	5.80	6.47	6.47	5.63	-	5.78	-	5.96	6.05	-
COHESION, psi	0.14	0.12	0.20	0.23	0.66	0.86	0.50	0.24	0.28	0.43
WATER CONTENT, % (dry)	228	269	260	157	146	177	111	148	158	-
WET BULK DENSITY, g/cm^3	1.30	1.27	1.27	1.37	1.42	1.51	1.47	1.42	1.38	-
DRY BULK DENSITY, g/cm^3	0.56	0.56	0.55	0.84	0.84	0.92	1.11	0.99	0.95	-
VOLUME SHRINKAGE, %	29.07	38.91	35.96	35.75	31.63	26.81	36.81	42.27	42.88	-
POROSITY, %	90.40	92.80	91.70	85.20	84.20	83.80	78.10	84.40	85.30	-
PLASTIC LIMIT	-	-	-	-	-	-	-	-	-	-
LIQUID LIMIT	-	-	-	-	-	-	-	-	-	-

Sediment Classification: Sa = sand or sandy, Si = silt or silty, C = clay or clayey
(?) after value = questionable value