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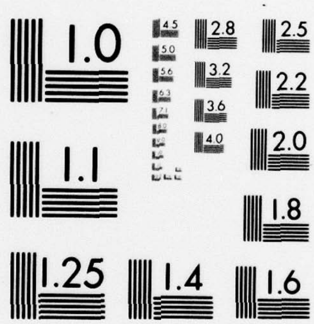
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SUMMARY OF RESEARCH ON THE ATLANTIC SHELF AND ADJOINING COASTAL AREAS CARRIED OUT AT HUDSON LABORATORIES IN 1965-1966*†‡

by

John E. Sanders

DEC 22 1966

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* Hudson Laboratories of Columbia University Informal Documentation No. 123.

† For the Committee for the Scientific Exploration of the Atlantic Shelf (SEAS), 1967 Meeting.

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This report summarizes research related to the Atlantic continental shelf being carried out at Hudson Laboratories of Columbia University, Dobbs Ferry, New York. Discussion is organized under the following headings: sampling apparatus, laboratory apparatus and techniques, lateral echo-sounding, field studies, results of laboratory studies, and computer programs.

Sampling Apparatus. Two sampling devices, a Phipps underway sampler and a modified Klovan-Imbrie box corer, were built and used extensively in nearshore areas and on the continental shelf. Two other sampling devices, a gun corer and an electric vibro-piston corer, were built and given preliminary tests. They are briefly described below.

Phipps Underway Bottom Sampler. The Phipps underway bottom sampler consists of an open pipe, 5 ft long and 3 in. i.d., balanced to tow horizontally, with a sampling bag clamped on the after end to catch the sample (Fig. 1). The main point of attachment is near the forward end, and a weak-link attachment is made at the balance point. The sampler is launched over the side and allowed to fall freely to the bottom. When the front end of the sampler strikes the bottom, a small amount of sediment enters the pipe, the weak link breaks, and the line goes slack momentarily. Retrieval begins when the slack appears. When the line is taut again the front of the device swings upward so that the sample remains in the bag at what is now the lower end.

The Phipps underway sampler is extremely useful for collecting grab samples of the bottom on the continental shelf. It has been used during lateral echo-sounding traverses on the continental shelf off Norfolk, Virginia, to bring up bottom samples for comparison with the acoustic returns from the bottom. It has recovered samples from water depths of up to 400 ft with 600 ft of half-inch manila line on a small, portable, gasoline-operated winch. Samples during lateral echo-sounding traverses have been collected at 3 knots. Other samples off New Jersey and Long Island have been collected at speeds up to 8 knots.

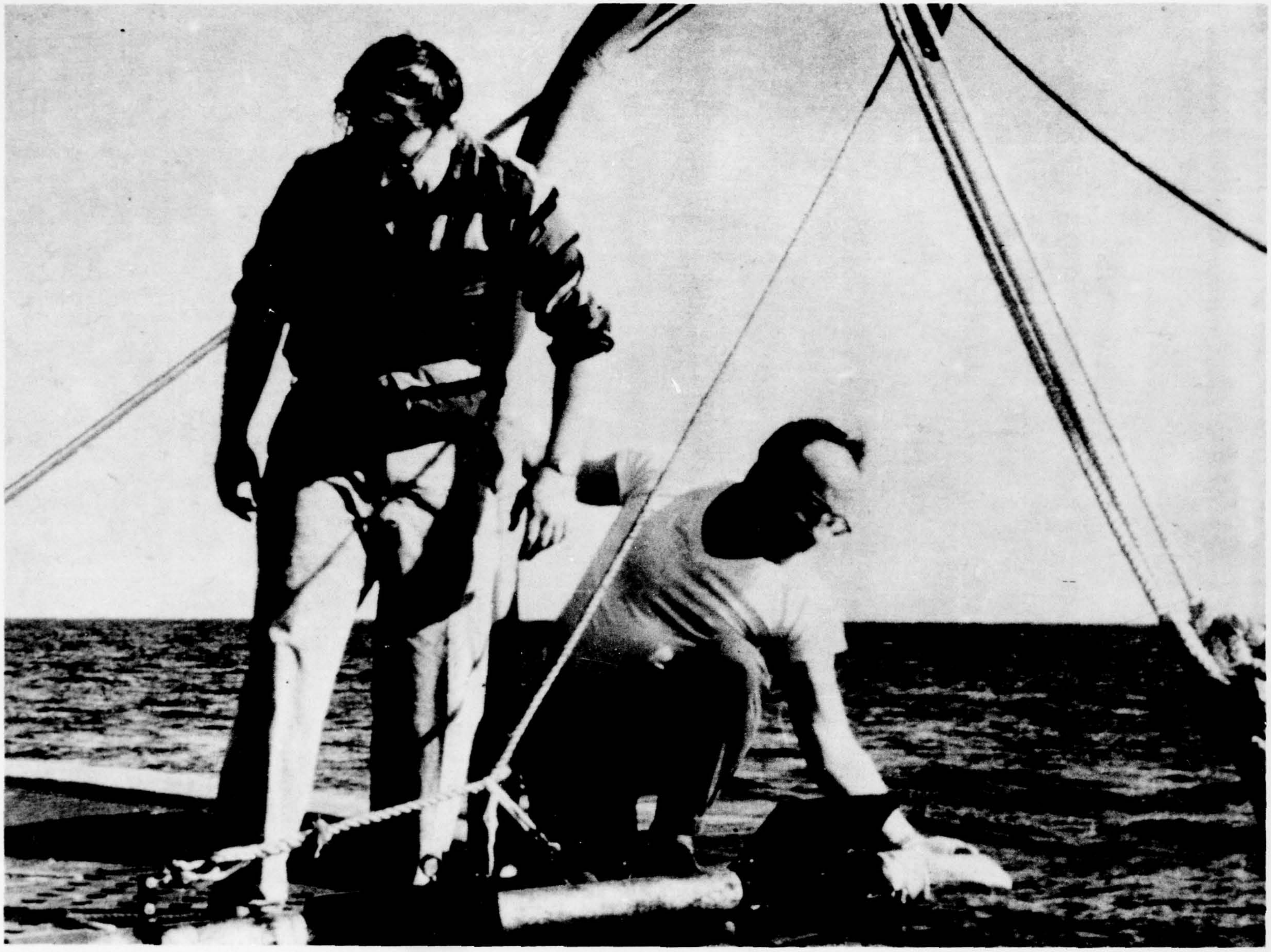


Fig. 1. Phipps underway bottom sampler ready to launch from small davit on stern of the USS Allegheny. The sampler tows in a horizontal position when rigged as shown. When it strikes bottom, however, the weak link (twine) between manila line and central balance point parts and the sampler swings to a more upright position. Sample is retrieved from filter-cloth bag (right), which contains a small plastic liner bag.

Box Corer (Hudson Laboratories Drawings No. 599-C-002 and 599-S-001). A wedge-shaped box corer modified after the Klovan-Imbrie sampler was built at Hudson Laboratories and used in North Carolina by Dr. J. A. Burger (Fig. 2), and in the Minas Basin, Nova Scotia, by Dr. G. deVries Klein. The box corer consists of three pieces: sample box, handle, and closing plate.

The sample box is 14 in. high, 1 15/16 in. wide, and 6 in. thick at the top; it is closed on top and on three sides, but is open on the fourth side. The horizontal top plate is 3/8 in. thick so that it can resist any pounding that is necessary to drive the box into the sediment. This plate bolts to the small angles that support the edges where the vertical sides join the top of the box. Large holes, approximately 3 in. in diameter, are drilled in the top plate to permit plaster of paris or other material to be poured into the sample box to stabilize the top layer of the sediment before the sample is moved. A short section of 1 1/4-in. pipe is welded to the top plate to serve as a seating collar to receive the removable handle. A 3/8-in. hole through the seating collar accommodates a bolt to keep the handle in place. The two vertical triangular sides and one inclined side consist of No. 16 gauge stainless steel plate. The inclined side makes an angle of 67° with the top plate. A stainless steel rod 3/16 in. in diameter and 14 1/8 in. long is spot-welded to each side plate along each open edge; the curved guide strips of the closing plate fit around the rods.

The handle consists of a piece of 3/4-in. pipe about 4 ft long. A 3/8-in. hole is drilled through, near one end, to accommodate the bolt that keeps the handle in place within its seating collar.

The closing plate is 15 3/4 in. long; it also consists of No. 16 gauge stainless steel plate. The closing plate is reinforced along its length by spot-welding two small stiffening angles to its face. The top of the plate is strengthened by welding on two end plates 1/4 × 1/2 × 13 1/8 in. A handle made of 3/8-in. diameter rod 5 1/8 in. long and 2 5/16 in. high is welded to the end plates. A curved guide strip is spot-welded onto each edge of the closing plate. Each guide fits around the rod on the side plate of the sample box to make a tight fit when the closing plate has been driven into place.

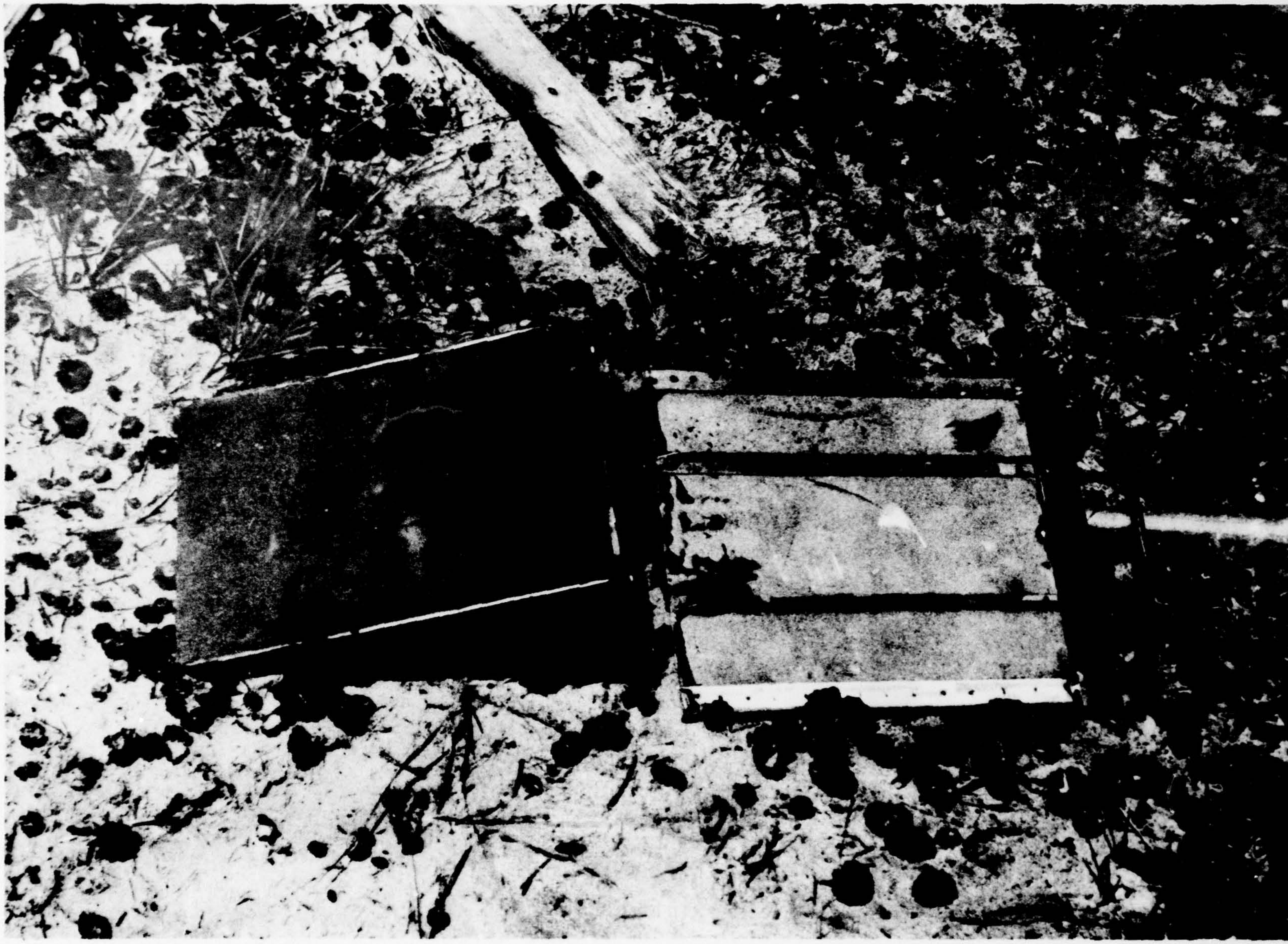


Fig. 2. Box sampler open after recovering sample on tidal flat near Oregon Inlet, North Carolina, May 1966. The face of the sediment shown was originally vertical. Note low, flat-topped ripples preserved on the *former surface* of the tidal flat. The closing plate obscures the junction between the handle and the attachment collar at the top of the box corer.

Electric Vibrator Corer. Starting with two existing vibrator motors in watertight containers, a frame was fabricated to enable counter-rotation of the motors. Approximately 800 lb was hung on springs below the motors.

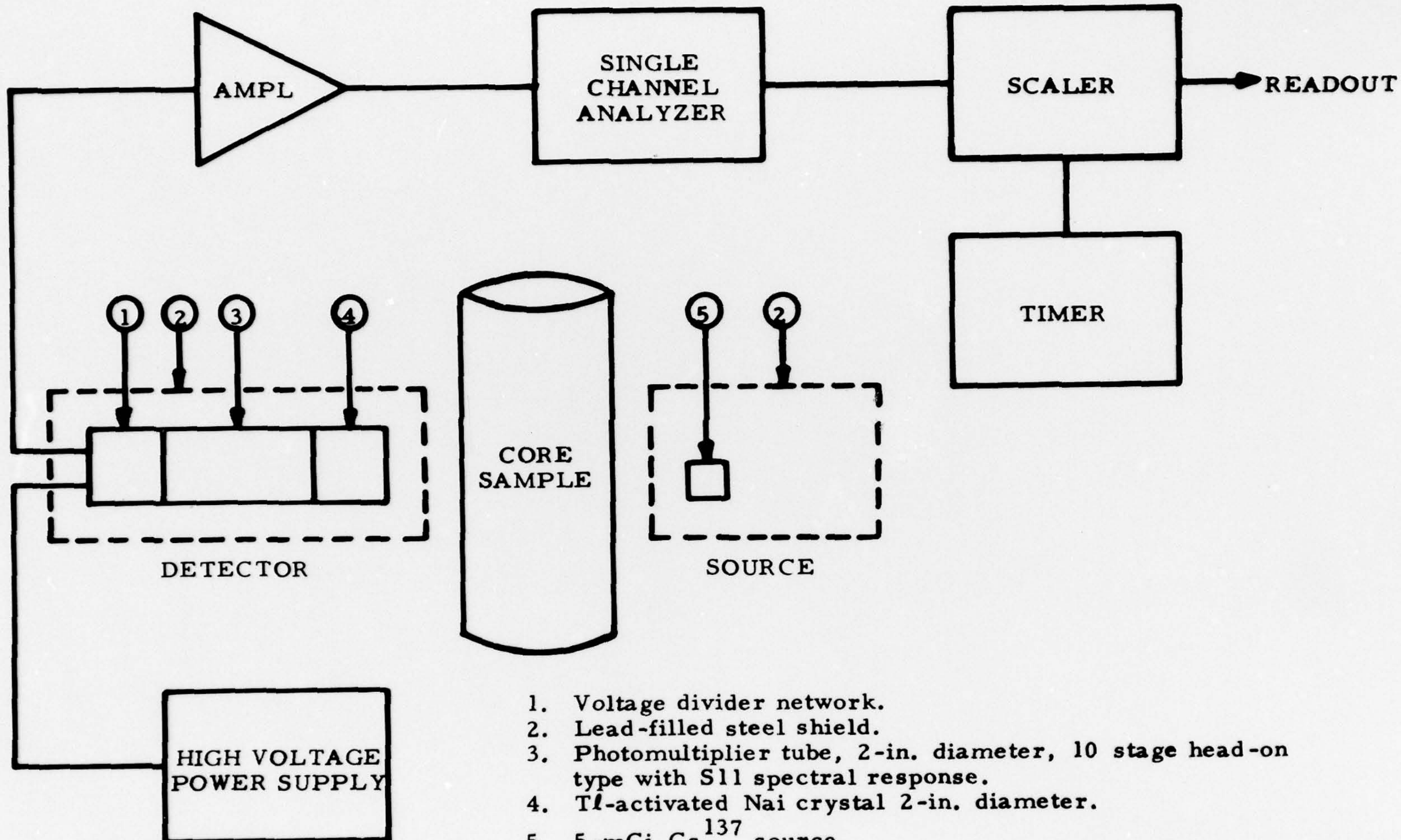
This device incorporates a "free fall" to start the coring tube in the sand, similar to the "Ewing Corer" (Lamont Geological Observatory). Then it is expected to vibrate the coring tube deeper. This corer is to be tested in November 1966.

Propellant Gun Corer for Hard Sand Sediment. A number of tests were made on the corer with a view to first checking safety, then efficiency of penetration, efficiency of shipboard time use and core retention, and absence of core disturbance. In all respects the results were exceptionally good. Refinements are being made with cutting heads and core catchers. Because time-consuming ship anchoring is not required, it is anticipated that a core can be taken every half hour. A patent application has been filed by T. Farrell and J. Taylor.

Laboratory Apparatus and Techniques. The core laboratory became operational during 1965-66. Three suites of cores collected in plastic liners, from Jamaica, southeastern Virginia, and the Outer Banks of North Carolina, were sawed open longitudinally, sub-sampled, and one face used to make relief peels. In addition, a gamma-ray core scanning device was completed by G. Imbimbo and P. Rooney (Rooney has since left the Laboratory); and all of Dr. Burger's cores from the Outer Banks of North Carolina were measured by gamma rays prior to being sawed open. The technical details of the gamma-ray core scanner are shown in the schematic diagram of Fig. 3. It is utilized in a manually operated densitometer which is being adapted for shipboard use. A computer program to calculate porosity from the output of the counters is discussed below, p. 24.

Dr. Burger designed and supervised construction of a camera-mounting mechanism to be used in photographing cores.

Lateral Echo-Sounding. During 1965-66 lateral echo-sounding experiments were carried out in four areas: (1) continental shelf off Norfolk, Virginia; (2) continental shelf off New Jersey (B-B' of Fig. 4); (3) Minas Basin, Nova Scotia; and (4) Gulf of Maine and continental shelf east of Long Island. The following paragraphs summarize the equipment used and some of the results obtained.



1. Voltage divider network.
2. Lead-filled steel shield.
3. Photomultiplier tube, 2-in. diameter, 10 stage head-on type with S11 spectral response.
4. Tℓ-activated Nai crystal 2-in. diameter.
5. 5-mCi Cs^{137} source.

Fig. 3. Schematic diagram of gamma-ray core scanner. Gamma rays from 5-mCi $cesium^{137}$ source pass through core sample in plastic liner tube, are received by the Tℓ-activated sodium-iodide crystal and photomultiplier tube, and are displayed on the scaler. Sample attenuates gamma rays according to the bulk density of solid and fluid phases present.

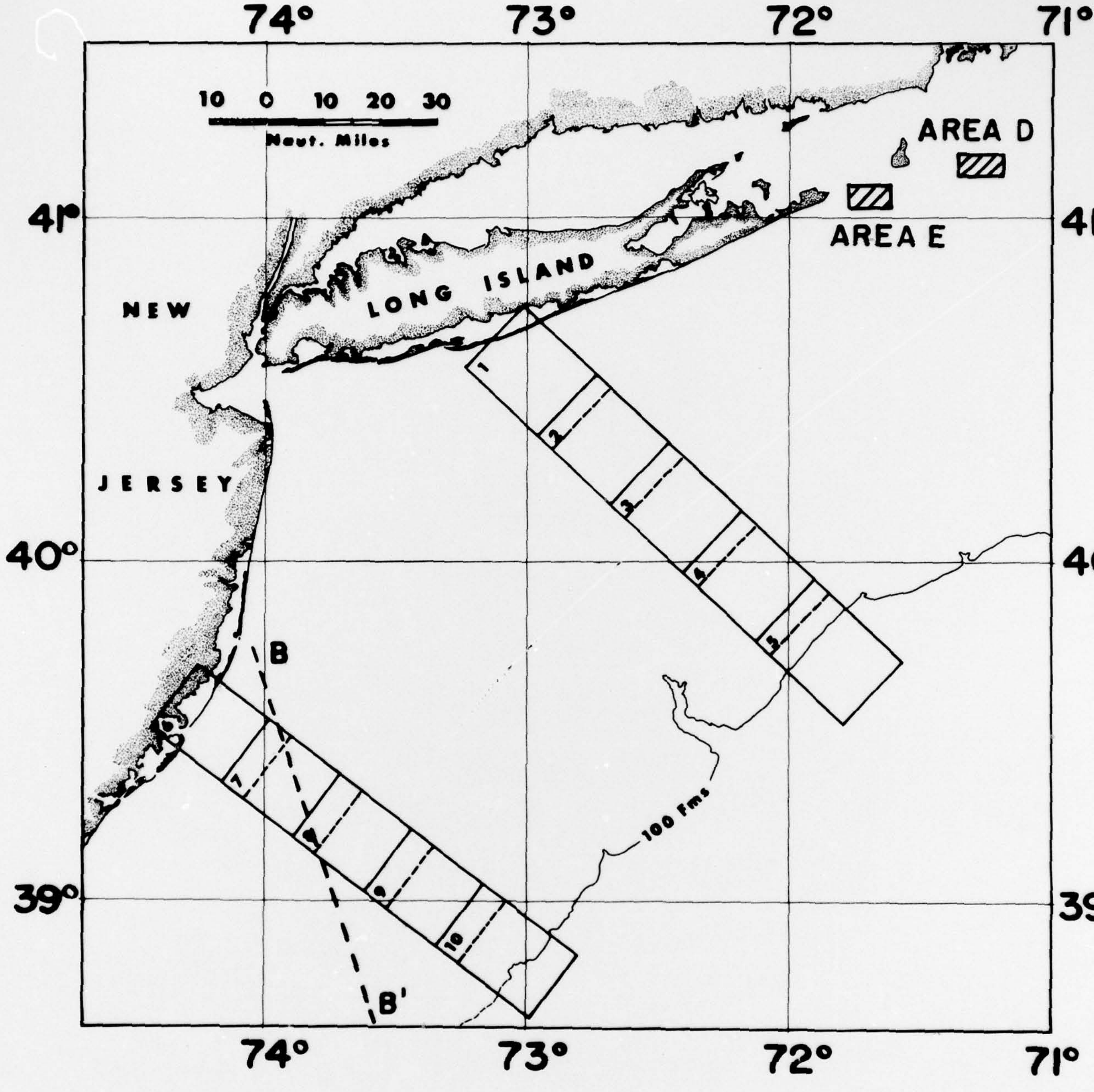


Fig. 4. Index map of Long Island and New Jersey shelf areas showing location of Dr. Friedman's traverses (numbered rectangles) and areas where lateral echo-sounding experiments were made during 1966 (dashed line and small shaded rectangles). The rectangles numbered from 1 through 10 show locations of Decca charts on a scale of 2 in. = 1 nautical mile made in 1965 at Hudson Laboratories for Dr. Friedman. Dashed line B-B' shows general traverse followed in joint operation conducted aboard USS Allegheny in May 1966, in cooperation with Bell Telephone Laboratories. Areas D and E show where lateral echo-sounder was used during a joint cruise (Gosnold 91) with Woods Hole Oceanographic Institution in September 1966.

Equipment. The equipment used is an outgrowth of the original Clay-Liang lateral echo sounder, Model CL-1.[1] A considerably modified version was built at Hudson Laboratories in 1965 by F. Cole, of the Electronic Engineering Department, and Cole's system has been used during the experiments conducted during 1965-66.

The Cole system (Fig. 5) generally follows the Clay-Liang circuits for pingers and receivers, but uses a different layout of the electronic parts in order to make the unit easier to service and trouble-shoot in the field. In addition, Cole's modifications in the Alden helix recorder part of the system permit greater flexibility of operation. In both systems the speed of rotation of the 19-in. helix is 1 rev/sec. In the Clay-Liang system a dual helix is used so that a full 1.0-sec sweep is presented simultaneously from the hydrophones on both sides. Hence, each 9.5-in. record represents a lateral range of 2400 ft. In the Cole system, cams and microswitches are used to ping the hydrophones alternately once per second, one array on the even second, and the other at the half-second mark. The returns from each hydrophone are fed alternately to the recorder for a period of 0.5 sec. The 9.5-in. record represents a range of 1200 ft on each side. Special switches have been introduced to permit the hydrophone array on either side to display a full 1.0-sec sweep across the 19-in. record, with a range of 2400 ft. In this equipment the right-hand side of the helix prints the record from the starboard hydrophone array, and the left-hand side of the helix prints that from the port hydrophone array. The same recorder can be used for continuous seismic profiling without further modification. In the Clay-Liang system the lateral exaggeration is twice that of the Cole system. The Cole system also incorporates other changes, mostly in the pinger circuit and time-variable gain controls.

In 1966, three principal changes were made in the Cole system: (1) new hydrophone arrays were built, using more sensitive PZT-4 crystals instead of the PZT-5 crystals in the Clay-Liang system; (2) parabolic lead reflectors were built by F. Cole; and (3) both channels were converted to a frequency of 30.5 kHz.

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[1] C. S. Clay and W. Liang, Lateral Echo Sounder - Model CL-1 (HL Tech. Rept. No. 114, March 12, 1964).

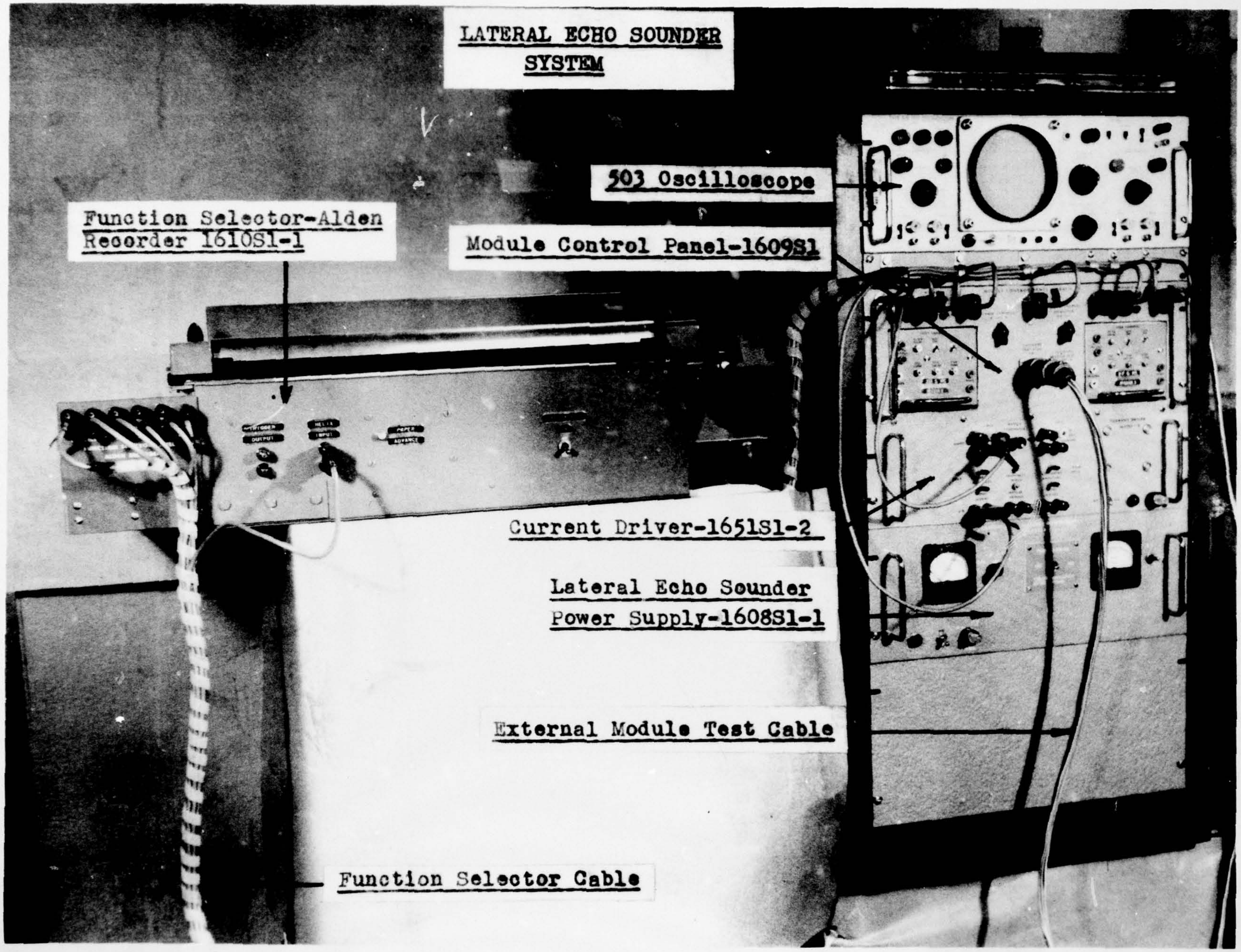

Fig. 5. Electronic components of lateral echo-sounder system built by F. Cole, Hudson Laboratories. Unit has subsequently been modified as described in text. Transducer is not shown.

Two towing vehicles ("fish") were used, the 13-ft XS-2 fish for open-sea towing, and a 6-ft experimental aluminum fish. The XS-2 fish was modified to permit the sound beam from the corner reflectors to be used at lower grazing angles and to permit the parabolic reflectors to be attached. The 6-ft aluminum fish was built in 1965 for use in the Minas Basin. It was modified in 1966 by the addition of an electric motor and mechanical system so that the angle of the parabolic lead reflectors could be changed by remote control without interrupting a traverse to bring the fish aboard and change it manually. A readout circuit was added so that the angle of the reflectors could be determined. These changes were designed and built by Mr. Cole.

In the 1965 experiments in the Minas Basin the system proved to be "noisy." Part of the noise was electronic and part of it came from the reaction between the water and the oil-filled pressure-compensating "boot" on the hydrophone array. When the hydrophone arrays were mounted with this boot on the forward end, the up-and-down motion in the water produced noise. This noise was eliminated by mounting the hydrophones with the boot on the trailing end.

These changes were made at various times during the year, so that the equipment used in each of the four experiments was not identical. In the Virginia and New Jersey shelf experiments, the PZT-5 hydrophone arrays were used with the original Clay-Liang corner lead reflectors, but the changes were made in the pinger circuits and time-variable gain controls. In the Minas Basin experiments the PZT-4 hydrophone arrays and parabolic lead reflectors were introduced. In the joint cruise with Woods Hole, the 27.0-kHz circuit was converted to 30.5 kHz.

Results. The object of the experiments using the lateral echo-sounder has been to make maps of the bottom. No such maps have yet been made owing to the difficulties with equipment and navigational control. Analysis of the data from three experiments is now in progress: (1) the New Jersey shelf project, carried out jointly with Bell Telephone Laboratories, using Decca Hifix, Decca Navigator, and Loran A; (2) the Minas Basin experiments, using transit sights from shore; and (3) the Gulf of Maine and Long Island areas surveyed jointly with Woods Hole Oceanographic Institution, using

Decca Navigator and Loran A. In each area the horizontal scale of the records will be determined from the precise location data. When this has been done, the records will be photographed with the Hudson Laboratories flow camera to eliminate the lateral exaggeration. Bottom maps will be prepared from the films made in the flow camera.

An example of the type of records made with the modified Cole system is shown in Fig. 6. The record shows a trace of the bottom contour and permits distinction of areas of bedrock ledges, gravel, sand, and mud. The bedrock areas are shown by the linear light and dark areas that are interpreted as irregular surfaces of rock that has been cut by fracture systems at right angles. One bedrock mass extends under the ship's track from a lateral range of approximately 1200 ft (at time 1315-1322 written along top of record). Other bedrock areas exist to the side of the ship's track, but do not extend under the track (time 1327-1336). The narrow bedrock ledge at left (time 1337-1339) extends for approximately 1200 ft at right angles to the ship's track, but stops approximately 300 ft from the ship's track. Its continuation toward the ship's track is in the form of a small ridge of boulders or sand.

Field Studies. Further field studies were carried out on the tidal flats of the Minas Basin during July and August 1966 by Dr. Klein (of the Department of Geology, University of Pennsylvania, a part-time member of Hudson Laboratories), and on the continental shelf off New Jersey and Long Island during July, August, and September by Dr. Gerald M. Friedman (of the Department of Geology, Rensselaer Polytechnic Institute, a part-time member of Hudson Laboratories).

Minas Basin Results. Dr. Klein and his two assistants prepared geologic maps of the approaches to Parrsboro Harbor, and Five Islands area, Nova Scotia (Fig. 7), where lateral echo-sounding traverses were carried out in 1965 and 1966. The appearance of the Parrsboro Harbour area at high tide is shown in Fig. 8. Nearly the same area at low tide is shown in Fig. 9.

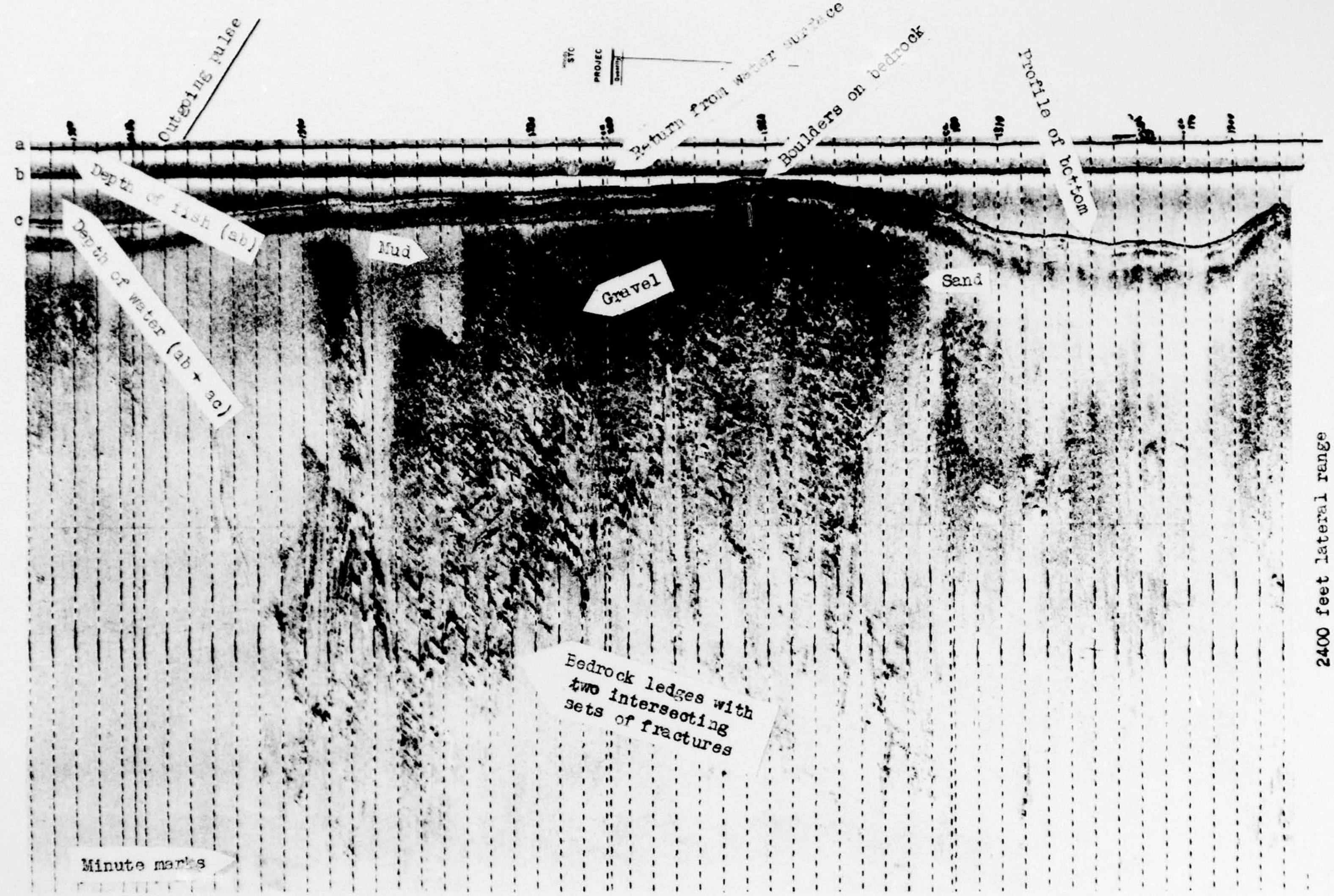

Fig. 6. Photograph of lateral echo-sounder record made with Cole system, Cashes Ledges, Gulf of Maine, September 14, 1966, during joint cruise (Gosnold 91) with Woods Hole Oceanographic Institution. Full 1-sec sweep on port side hydrophone. Starboard hydrophone not in use. Fish towed at 30 m depth. Water depth 35 to 110 m. Speed 2 knots. Corner reflector with top plate set at +5° with horizontal. Traveling south, scanning toward east. Photograph by WHOI.

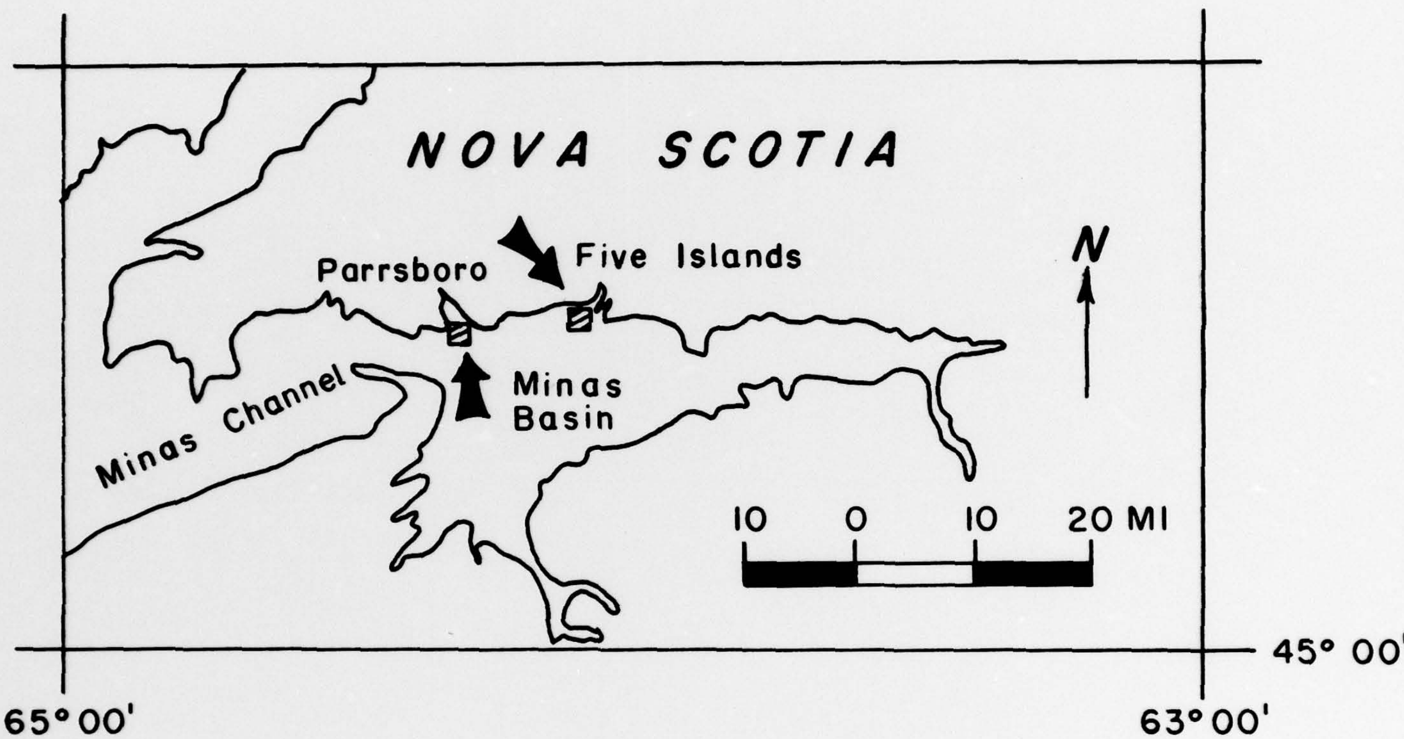

Fig. 7. Index map showing location of Parrsboro Harbour and Five Islands areas.

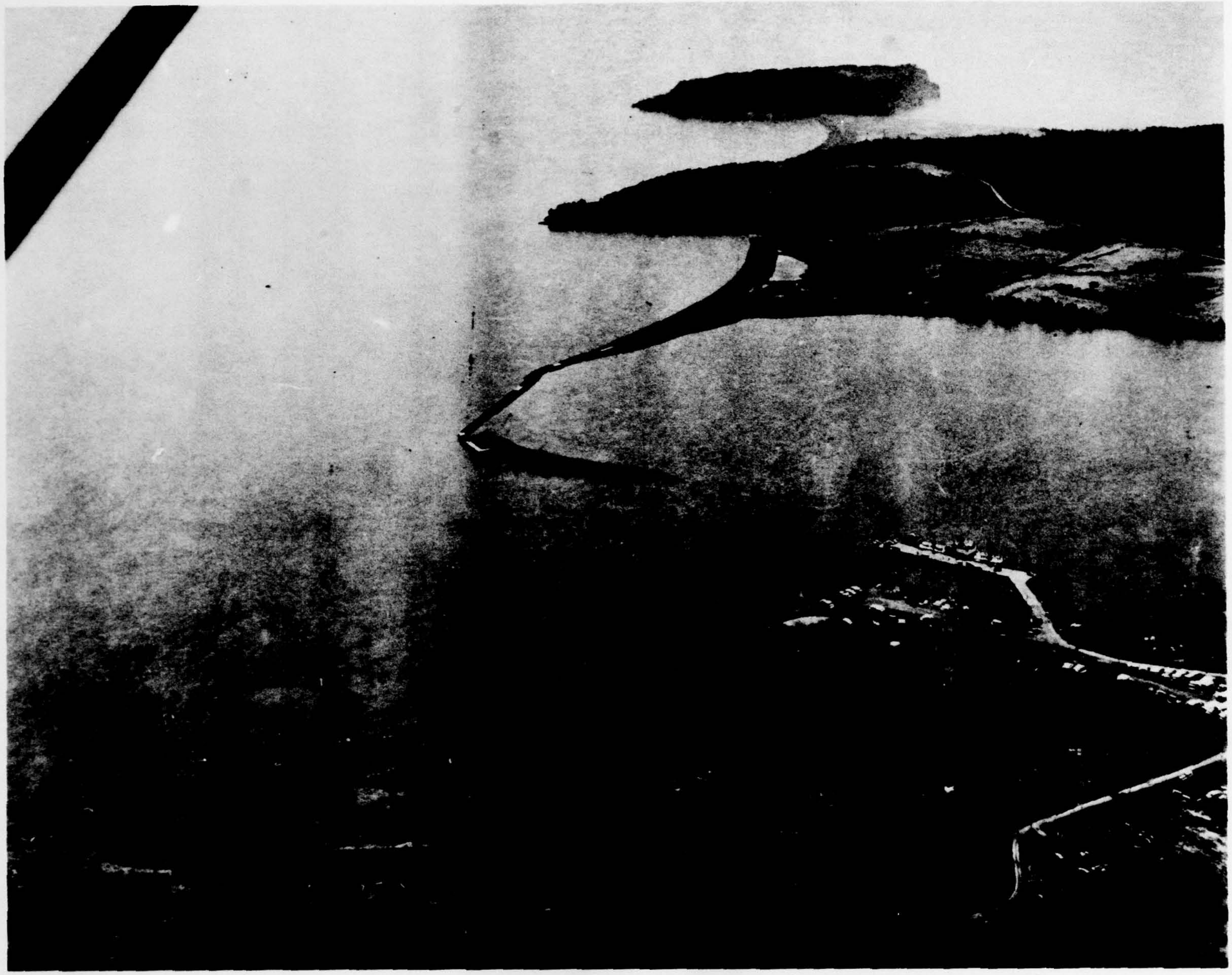

Fig. 8. Aerial view of Parrsboro Harbour, Cumberland County, Nova Scotia, at high tide, looking south-southwest. Cargo vessel Hugo Nielsen is tied up at government wharf (which is *400 ft long*) loading lumber. Crane Point is in middle distance and Partridge Island, in far distance (top, center). Compare with low-tide view, Fig. 9. Photo by S. Frank, April 1966.

Fig. 9. Aerial view of Parrsboro Harbour, Cumberland County, Nova Scotia, at low tide, looking south-southwest. Government wharf (400 ft long) is in right center and lighthouse, left center. Crane Point appears in upper left corner at lower end of dark area (wing strut of airplane) that crosses corner of photograph diagonally. Photo by Dr. Klein, July 1966.

In 1966 Dr. Klein made 200 measurements of the velocity and 230 measurements of the direction of tidal currents and studied the relationship of these to the movement of sand on the tidal flats. Studies of the sand included the digging of 20 trenches 10 to 15 ft long, 30 trenches 3 to 5 ft long, collection of 100 box cores, preparation of peels from 71 of the box-core samples, collection of 170 small samples for laboratory analysis, 25 ft of 3-in. diameter cores, and making of 30 plaster casts of the shapes of ripples and related features on the surface of the sand. Dyed sand was used to measure migration distances of the larger features (megaripples and sand waves).

New Jersey and Long Island Shelf Areas. During 1966 Dr. Friedman and his two assistants extended their surveys, so that they now have collected 358 samples from 716 miles of traverse lines off New Jersey and Long Island (Fig. 4). The new samples were collected as follows:

Dates	Ship	Area	Number of bottom samples (grab samples)
7/7/66 - 8/4/66	R/V Manning	Long Island shelf	115
		New Jersey shelf	57
8/22/66 - 9/1/66	USS Allegheny	Long Island shelf	37
		New Jersey shelf	59

Six cores were collected with the new gun corer: four off Sandy Hook, one off New Jersey, and one off Long Island. The coring program was unsuccessful because of loss of the projectile-barrel, inability to retain sand in the core barrel, and bad weather. As a result, the intended chemical measurements could not be made.

The bottom was scanned with the underwater television camera. It was mounted on a frame that could be placed on the bottom with a slack line and would remain there with camera at the proper focal distance to permit observations from the ship. Five stations were made opposite Brigantine Bay, New Jersey, at depths of 27, 50, 67, 82, and 100 ft, during extremely calm weather. In spite of the smooth water, sediment was apparently in motion on the bottom. Ripples were active at depths of 50 ft. Dead shell material was aligned in rows at 100 ft, suggesting the effects of the waves. Two stations were made on the Long Island shelf, at depths of 90 and 102 ft. No sand was observed in motion, but inactive ripples were noted at the 90-ft depth with shell material concentrated on ripple crests. The sand at a depth of 200 ft was much burrowed by organisms.

Samples collected will be processed in the laboratory to determine grain-size distribution, mineral composition, and microfaunal remains. Results of samples collected in 1965 are mentioned in a subsequent section.

Results of Laboratory Studies. Laboratory studies have commenced in the new core lab, and were also carried out at R.P.I. by Dr. Friedman, at the University of Pennsylvania by Dr. Klein, and at Beloit College by Dr. Burger.

The results at R.P.I. have concerned size-frequency distribution and microfaunal analysis of sand samples collected on trips supported by Hudson Laboratories. All samples collected in 1965 have been processed, and the grain-size data subjected to computer analysis at Hudson Laboratories. Further comment on the grain-size results will be deferred until all samples have been analyzed.

The microfaunal studies of foraminifera carried out by Joel Gevirtz on the 1965 samples indicate that three distinct faunal zones can be recognized. These zones trend parallel to the shoreline and are also related to depth of water. The fauna includes Arctic, Boreal, and Cosmopolitan forms; the Arctic forms are more common off Long Island, and the Boreal forms are more common off New Jersey. The shallowest zone consists almost entirely of two species: Elphidium incertum clavatum and Nonion pauciloculum albiumbilicatum. The next zone contains a more varied fauna. In this zone the Eggerella advena, with agglutinated tests, appears. The third zone contains a highly varied fauna including many forms that are typical of deeper water. Planktonic types occur in great abundance at the outer edge of the shelf and on the continental slope;

their abundance decreases markedly toward shore. This zonation appears in general on both New Jersey and Long Island traverses, but a marked departure occurs on the Long Island line where the bottom consists of muddy or silty sand. Further studies on the samples collected during 1966 will include live foraminifera in an attempt to relate the fauna to depth, and also to temperature and salinity data obtained through the courtesy of the Sandy Hook Marine Laboratory.

The grain-size analysis of Minas Basin tidal-flat samples collected in 1965 has been completed by Dr. Klein at the University of Pennsylvania, and the results await computer analysis at Hudson Laboratories.

Dr. Burger completed the preparation of the structure peels from the cores collected along three traverses across the Outer Banks, North Carolina (Fig. 10). Study of the stratigraphy, grain-size, and environmental significance of these cores is now in progress at Beloit College. Grain-size measurements and gamma-ray scans have been completed.

Computer Programs. Ocean-bottom geology research required five new computer programs, which were written by E. Werner, of the Analysis Department. These programs involved factor analysis, coefficients of correlation, graph-plotting, gamma-ray measurements and porosity calculations, and grain-size analysis of sediments.

Factor Analysis. Factor analysis is a technique that has been widely applied in geologic problems that involve many variables. As used in geology, factor analysis begins by converting columns of data into vectorial representation, so that a cosine function can be calculated. An angle theta is calculated between the vectors that represent the columns of data. According to the theory (explained in Manson and Imbrie, Kansas Geol. Survey Computer Contributions, Spec. Dist. Pub. 13, "Fortran program for factor and vector analysis of geologic data using an IBM 7090 or 7095/1401 computer system") if the value of cosine theta is 1.0, complete similarity exists between the columns of data. If cosine theta is 0.0, complete dissimilarity exists. If cosine theta is 0.707, then a random relationship exists between the columns of data. During the study of the ocean-bottom cores supplied by NAVOCEANO,

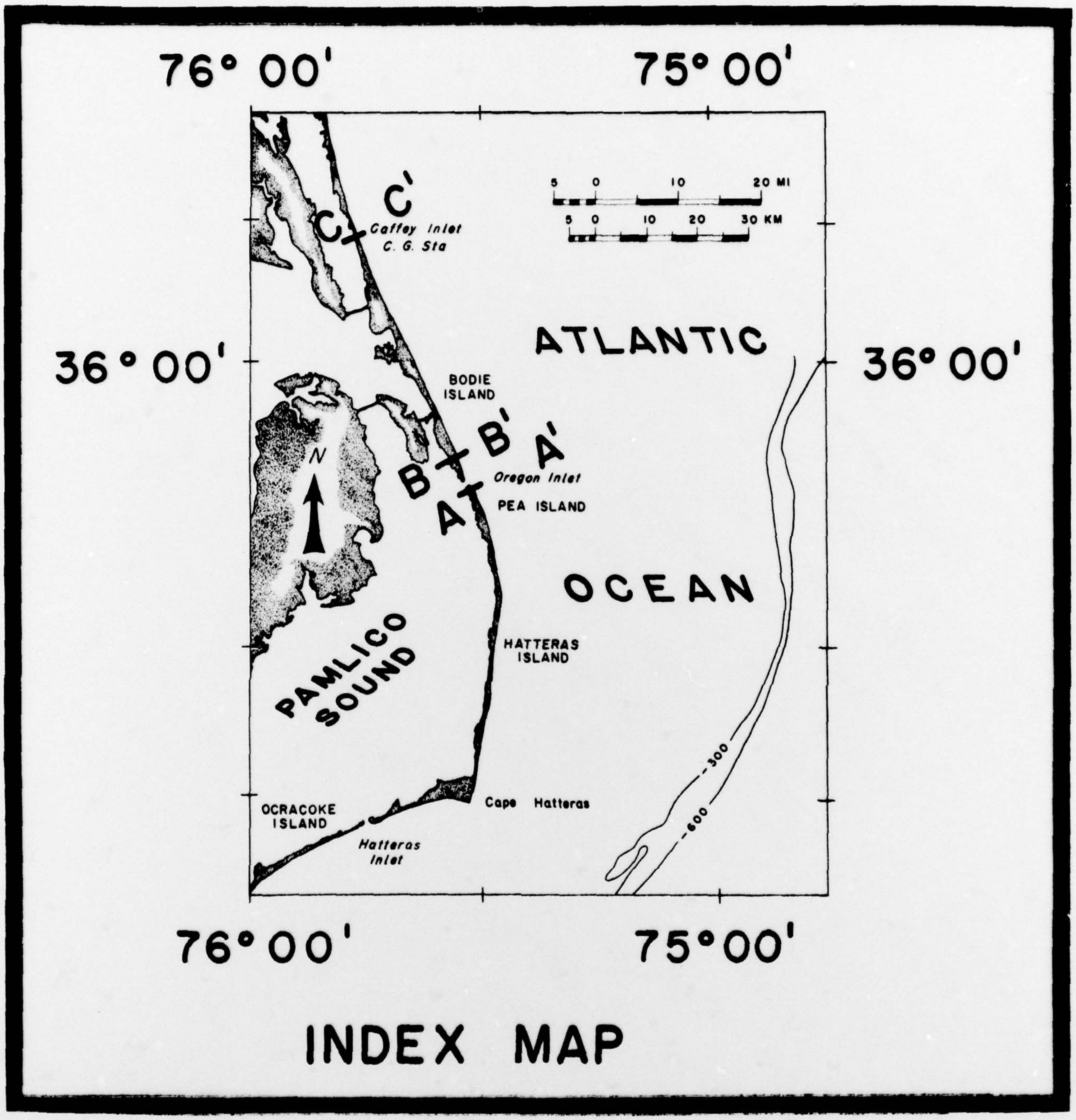

Fig. 10. Location of profiles and shallow borings, Outer Banks, North Carolina.

an attempt was made to use the factor-analysis technique. The relationships among certain properties of the cores as shown by maps did not show corresponding relationships from the calculations of cosine theta. The computer program was checked against the published results using sample numbers contained in the published reports. Finally, special pairs of raw values of various groups of inversely related numbers were used to compute cosine theta. The results are shown in Table I. Note that in each case the rows of raw value pairs sum to 1.00. A regular increase in one value is accompanied by a corresponding decrease in the other value, indicating an opposite relationship that should be expressed by a cosine theta value of 0, according to the theory. In each of the three examples used, however, a different nonzero cosine theta value was found, with high and low values of 0.85 and 0.23. The third value, 0.46, is near the theoretical random relationship. These examples raise doubt about the validity of the theory of the cosine theta technique. Because of this doubt, an alternative procedure was sought and the cosine theta technique was abandoned.

Coefficients of Correlation. The "unadjusted coefficient of correlation" taken from Ezekiel and Fox[1] was used in preference to the cosine theta technique of factor analysis in the analysis of data from cores. A correlation coefficient of +1.0 indicates a positive relationship and a coefficient of 0.0 indicates a random relationship. The same three sets of paired raw values (Table II) that produced variable nonzero cosine-theta values yielded the expected correlation coefficient of -1.0, indicating an opposite relationship.

Graph Plotting. A program was written to plot a column of data values against another column of data values as a scatter diagram, or x-y graph. The data are normalized by dividing them by the highest value of each column, so that they appear as values ranging from 0 to 1.0. The program prints out a standard x-y plot on a 5-in. square. An example is shown in Fig. 11.

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[1] M. Ezekiel and K. A. Fox, Methods of Correlation and Regression Analysis (John Wiley & Sons, New York, 1959), 3rd ed., esp. pp. 134-138.

TABLE OF RAW VALUES

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0.	1.0000
0.0500	0.9500
0.1000	0.9000
0.1500	0.8500
0.2000	0.8000
0.2500	0.7500
0.8000	0.2000
0.8500	0.1500
0.9000	0.1000
0.9500	0.0500
1.0000	0.

COSINE THETA MATRIX

1.00000	
0.23286	1.00000

TABLE OF RAW VALUES

0.7000	0.3000
0.6500	0.3500
0.6000	0.4000
0.5500	0.4500
0.5000	0.5000
0.4500	0.5500
0.4000	0.6000
0.3500	0.6500
0.3000	0.7000
0.2500	0.7500

COSINE THETA MATRIX

1.00000	
0.84692	1.00000

Table I. Cosine theta computations from pairs of number columns in which the sum is 1.00, and one increases as the other decreases.

TABLE OF RAW VALUES

0.	1.0000
0.0500	0.9500
0.1000	0.9000
0.1500	0.8500
0.2000	0.8000
0.2500	0.7500
0.3000	0.7000
0.3500	0.6500
0.4000	0.6000
0.4500	0.5500
0.5000	0.5000
0.5500	0.4500
0.6000	0.4000
0.6500	0.3500
0.7000	0.3000
0.7500	0.2500
0.8000	0.2000
0.8500	0.1500
0.9000	0.1000
0.9500	0.0500
1.0000	0.

CORRELATION COEFFICIENTS

1.00000	
-1.00000	1.00000

TABLE OF RAW VALUES

0.	1.0000
0.0500	0.9500
0.1000	0.9000
0.1500	0.8500
0.2000	0.8000
0.2500	0.7500
0.8000	0.2000
0.8500	0.1500
0.9000	0.1000
0.9500	0.0500
1.0000	0.

CORRELATION COEFFICIENTS

1.00000	
-1.00000	1.00000

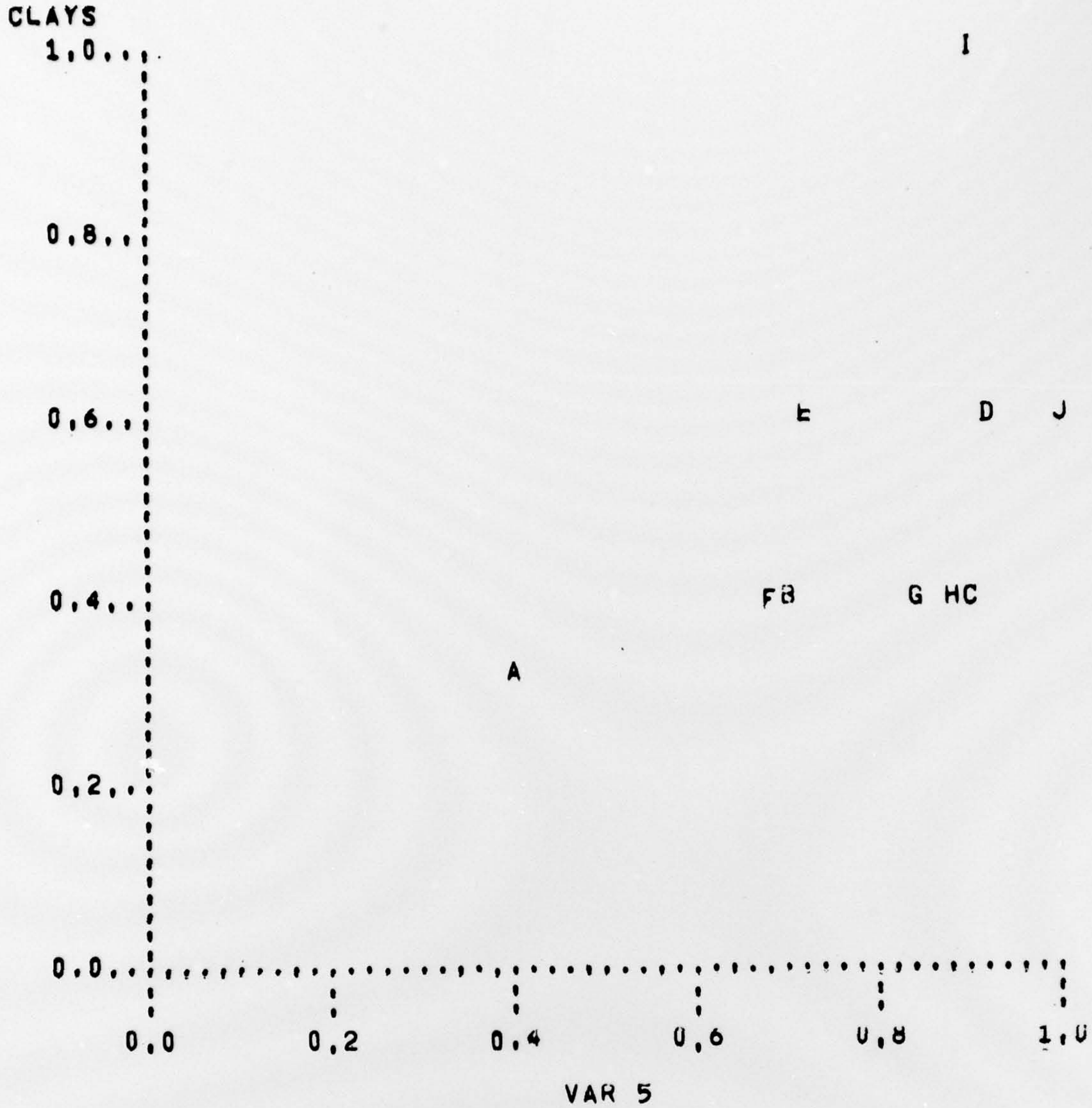
TABLE OF RAW VALUES

0.7000	0.3000
0.6500	0.3500
0.6000	0.4000
0.5500	0.4500
0.5000	0.5000
0.4500	0.5500
0.4000	0.6000
0.3500	0.6500
0.3000	0.7000
0.2500	0.7500

CORRELATION COEFFICIENTS

1.00000	
-1.00000	1.00000

Table II. Computations of correlation coefficients for same columns of numbers used for cosine theta calculations in Table I. Note that the correlation coefficient is -1.0 for each of the pairs.



CORE 28 IS A
CORE 30 IS B
CORE 42 IS C
CORE 49 IS D
CORE 34 IS E
CORE 35 IS F
CORE 39 IS G
CORE 40 IS H
CORE 43 IS I
CORE 52 IS J

Fig. 11. Example of machine x-y plot.

Gamma-Ray Measurements and Porosity Calculations. The gamma-ray and the porosity program processes the readout from the counters of the gamma-ray core-scanner and calculates porosity in percent. An example of the calculation is shown in Table III. Figure 12 shows a plot of the porosity versus depth in the core for core C-4, from Dr. Burger's Outer Banks collection.

Grain-Size Analysis of Sediments. The fifth type of program computes standard statistical moment measures from grain-size data measured on sediment samples. Two different programs have been devised. One, by John Seney, followed a previous usage of Dr. Friedman. The other, by E. Werner, follows a slightly different statistical calculation, as explained in Griffin.[1] So far the results of these two programs do not agree and an effort is being made to find out the reason for the disagreement.

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[1] J. I. Griffin, Statistics, Methods and Applications (Holt, Rinehart, and Winston, New York, 1962).

INITIAL INTENSITY IS 440991   DIAMETER OF SAMPLE IS 6,60 CM   MU = 0,074 SQ CM PER GM

GRAIN DENSITY IS 2,670 GM PER CU CM   FLUID DENSITY IS 0,   GM PER CU CM

SAMPLE NUMBER	INTENSITY	POROSITY
C 04010	190858	35,776
C 04030	201682	40,006
C 04050	189384	35,182
C 04070	167859	25,929
C 04090	167721	25,866
C 04110	167012	25,542
C 04130	165350	24,775
C 04150	159441	21,984
C 04170	160587	22,533
C 04185	159878	22,194
C 04210	192345	36,371
C 04230	170787	27,256
C 04250	163437	23,882
C 04270	172997	28,242
C 04290	168566	26,252
C 04310	166039	25,093
C 05010	202919	40,475
C 05030	205349	41,388
C 05050	206236	41,719
C 05070	212566	44,037
C 05090	200631	39,606
C 05105	215200	44,982
C 05130	204932	41,232
C 05150	189902	35,391
C 05170	189418	35,196
C 05190	193047	36,651
C 05210	187785	34,532

Table III. Example of printout from computer using program for calculating porosity (in per cent) from number of counts recorded on gamma-ray core-scanning device.

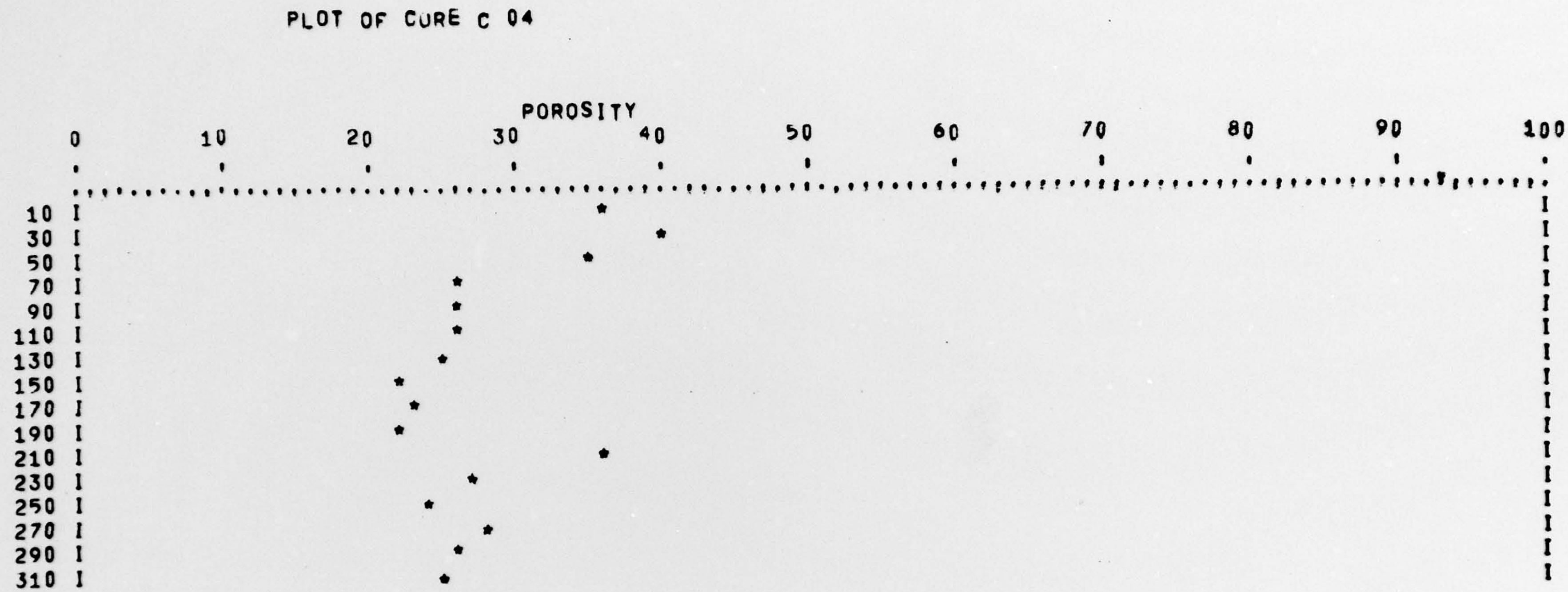

Fig. 12. Plot of computed porosity (per cent) versus depth in core (cm) for core C-4, Outer Banks, North Carolina (Dr. Burger collection). The plot was made by the Hudson Laboratories computer from input data in the form of counts from the gamma-ray core-scanner. Program by E. Werner, Analysis Department.