CORE SAMPLES OF THE OCEAN BOTTOM

by

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If one examines a map of the world, or a globe, the most noticeable feature is the preponderance of water to land. In fact, the ocean occupies 72 percent of the surface of the earth—nearly three-quarters—and very little is known of it by comparison with our knowledge of the land. Geologists and others have studied the land and what lives on it so thoroughly that we now have reliable knowledge of its history, and the many changes that have taken place, both in the land itself and the plants and animals that lived on it, throughout many millions of years. These studies have been of great value both theoretically and practically and they are being continued with increased application. But all this time nearly three-quarters of the earth's surface has remained almost unknown and unstudied, because it lies below great depths of water. At one place the water is 6 miles deep. Here the bottom lies below us deeper in the sea than Mount Everest rises above us into the sky. Though much of what is now dry land was once below the surface of the ocean, it appears that the water covering it was never very deep. Though the sediments themselves might be many thousands of feet thick they were deposited layer on layer in shallow seas. Apparently, much of the bottom of the ocean has always been ocean bottom, and during all those millions of years that the ocean has existed there it has been accumulating the sediments dropped upon it from the waters above. These sediments, lying layer upon layer in the bottom, have become the repository of the historical record of the ocean. The record of what happened in the water above is filed away in the mud and clay and ooze below. The rocks and pebbles and sand brought by ice, the clay and mud brought by rivers and ocean currents, the skeletons of marine organisms which lived and died and evolved into various forms throughout the ages constitute this record. Some types of these organisms live only in cold water, others in warm water, some live in shallow lagoons, others in the depths of the open sea. Some prefer fresh water while others survive only in salty water. Some lived a long time ago, and others have evolved into their present forms comparatively recently. Besides these records of past life and its many changes there exist a chemical and a physical record. Oxidation and reduction and the nature of the dissolved matter in the water have all left the record of their changes in the bottom, and the natures and size of the minerals and rock fragments bear evidence of the direction and strength of former ocean currents, the movements of ice, and the depths of the ocean in the past.

Although this great historical record has long been known to exist, we have been unable to profit by it, for we could read only the topmost page. Heretofore, the samples obtained from the deep ocean bottom have been "grab samples", a mere handful of material taken from the very surface of the bottom. These samples give information of present conditions only and reveal nothing of past events.

On land the geologist can study the exposed rock strata, he can climb mountains and descend into mines, and he can study samples from test borings and deep wells. Millions of such studies have been made of the land, and a very reliable knowledge of its geologic history has been assembled, but a similar study of material lying beneath miles of water is enormously more difficult. Far out from land, in the undisturbed depths of the open ocean, the record has accumulated very slowly, so that a few feet of depth may represent a very long interval of time. Therefore if we could bring up a vertical section of several feet of this bottom, in its original undisturbed condition, we might read the history of oceanic events as the geologist deciphers the record in the rocks.

The need of such samples has been felt for many years and many devices to secure them have been tried. Recently an apparatus has been developed which has obtained such "cores" up to 10 feet in length and containing sufficient material for very comprehensive studies. (1) These cores have been brought up from ocean depths of 2,650 fathoms, which is more than 3 land-miles down.

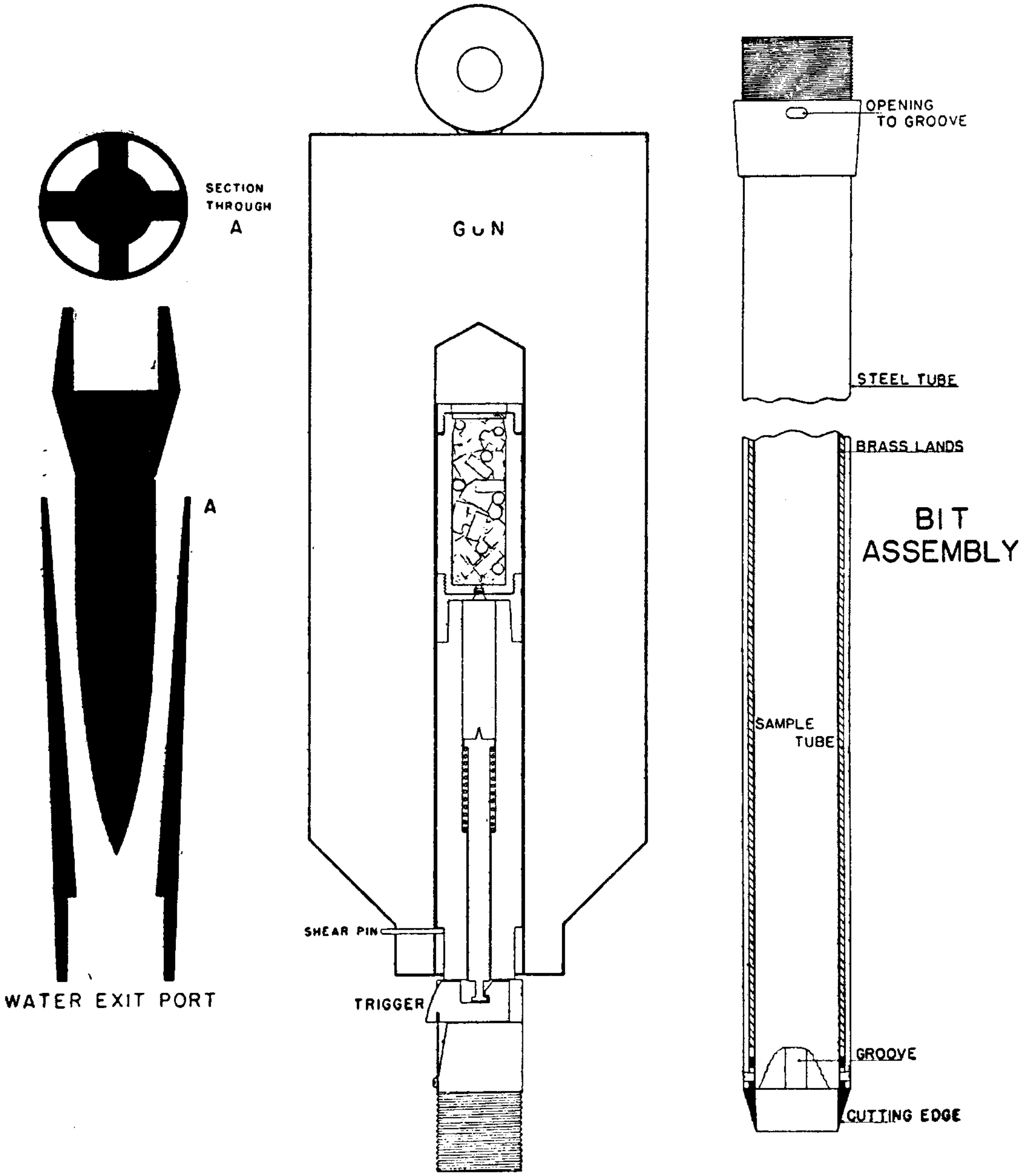

FIG. 1.
Diagram of core sounding apparatus showing parts drawn to same scale.

The apparatus is self-contained and may be attached to any existing sounding line strong enough to lift it. It functions automatically on reaching the bottom and consists essentially of a steel tube (inside which is a brass tube) which, on arriving at the bottom, is forced into the sediment by an explosion of cannon powder contained in a weight or "gun" attached to its

(1) PIGGOT, C. S., Apparatus to secure core samples from the ocean-bottom. *Bull. Geol. Soc. Amer.*, vol. 47, pp. 675-84, May 1936.

upper end. When brought to the surface the sample is held inside the brass tube, which is slipped out and labeled, and another tube put in its place ready for another sounding. The sample remains undisturbed in its brass tube until opened for examination in the laboratory.

The value of these samples, over previous ones, is that the material is available for study in the undisturbed sequence existing in the bottom, and consequently a record of succeeding events may be obtained from it. Particular strata may be traced over wide areas, and a knowledge of the succession of events in terms of time and extent may be obtained.

DETAILS OF THE APPARATUS.

The apparatus consists of five principal parts: a weight or "gun", a cartridge, a firing mechanism, a water-exit port, and a bit. These are shown diagrammatically in figure 1, and the assembled apparatus, with a 10-foot bit, in plate 1.

WEIGHT OR GUN.

The weight is made of cold rolled steel, 10 inches in diameter and 20 inches long. At its upper end is a 1-inch drop-forged eyebolt, to which is spliced a steel cable (3/8-inch diameter) 4 feet long. A self-releasing hook may be placed here if it is desired to leave the weight on the bottom. The other end of the cable is spliced to a ring of drop-forged steel, about 3 inches in diameter. This ring constitutes the upper end of the apparatus, and it is at this point that the ship's sounding cable is attached.

The lower end of the gun is tapered to within 1 inch of the muzzle, causing the gun to have a 1-inch-thick wall for that length. One inch from the muzzle are four holes, drilled radially, through which a one-eighth-inch brass shear-pin may slip easily. The bore of the gun is the only part that must be made with precision. This must be reamed straight and smooth and must furnish a snug sliding fit for the cartridge and firing-pin housing.

CARTRIDGE.

The cartridges (pl. 2) are made of stainless steel and are exactly 2 inches in diameter and about 4 3/4 inches long. They consist of three parts—a midsection, which is the powder chamber and top and bottom sections. Both ends of the midsection have small circular ridges, which cut into copper disks and assure a tight seal. The walls of the powder chamber are one-quarter inch thick, and its bottom contains a recess into which a rifle primer fits exactly. Over this is placed a copper disk, against which the bottom section screws tightly. In the center of this bottom section is a small hole, opposite the primer, through which the point of the firing-pin may strike the copper disk with sufficient force to distort it and thereby set off the primer. This primer disk, however, is thick enough to prevent distortion of the primer by the hydrostatic pressure of the water. It is also made thick enough to have sufficient strength to prevent the primer from being blown backward out of its seat at the moment of firing. Furthermore, the thickness of this primer disk is so adjusted, with respect to the shape of the firing-pin point and the strength of the firing spring, that the point will distort it enough to fire the primer but will not punch a hole through it. When functioning satisfactorily the blunt-pointed firing-pin punches a dome-shaped depression in the copper disk sufficiently deep to fire the primer, and then this dome has enough strength to support the primer in its position against the high pressure of the main explosion.

Inside the muzzle end of the powder chamber is an annular shoulder, one-eighth inch from the muzzle. On this shoulder rests a steel disk, one-eighth inch thick, with its outer surface flush with the end of the powder chamber. Its function is to take the strain of the hydrostatic pressure and thereby prevent distortion or breaking of the rupture disk. Between the pressure disk and the rupture disk is a thin copper disk, which serves as a gasket. The rupture disk is of steel and of such thickness and strength that it will allow the pressure within the cartridge to build up to the proper working pressure before it ruptures and releases the energy to the mechanism.

POWDER CHARGE.

The explosive charge furnishes the energy required to do the necessary work. This varies with the depth and the character of the bottom. The charge consists of a primer, 1 gram of high-speed black powder, 1 gram of rifle powder, and a varying number of pellets of 155-mm howitzer powder. The 2 grams of small powder play the double role of promoting ignition and quickly building up a pressure, in which environment the large-grained powder functions explosively. If this high pressure were not provided, the latter would not burn properly.

The total available energy is regulated by counting into the cartridge a varying number of pellets of the big powder. This required energy is of three parts: (1) That which is necessary to overcome the hydrostatic pressure at a particular depth ; (2) that which is necessary to overcome the inertia of the bit and to put it into motion; and (3) that required to drive the bit into the particular material encountered. Only the second can be determined in advance ; the other two must be provided for at each sounding. The possible work that can be done is a combination of the total available energy and an intensity factor—i. e., the pressure at which the explosive gases are released. The control of this "working pressure" is accomplished by the steel rupture disk at the mouth of the cartridge. Up to the time this disk is blown out, the powder is protected from the water. These disks are relatively thin, and, therefore, capable of distortion, and at a certain depth the hydrostatic pressure might conceivably be greater than the desired "working pressure"—hence, the steel "hydrostatic pressure disk", which relieves the rupture disk of all strain and enables it to be adjusted to the requirements.

FIRING MECHANISM.

The firing mechanism is simple and rugged and can be easily removed for cleaning or replacement. It consists of a trigger, which is essentially a piece of steel, 2 inches by 1 inch by one-fourth inch, sliding in an appropriate keyway and containing a projection which catches the end of the firing pin when "cocked". A slight downward movement of the gun, on reaching the bottom, forces the trigger over and disengages the firing pin, which is pushed forward by a stiff coiled spring. The firing pin is streamlined at its forward end and is grooved longitudinally to facilitate the movement of water out of the space progressively occupied by the pin as it advances. This eliminates a cushioning of the blow by the water. The forward end of the pin contains a conical tip of appropriate size and shape to enter the hole in the base of the cartridge and explode the primer through the copper primer disk. A safety pin of hardened steel is so situated that it holds the firing pin back, in the cocked position, even when the trigger is disengaged, and even if the gun should be forced down and shear this safety pin off on the outside, that which remains would prevent an accidental discharge. As this safety pin is put in place before the cartridge is attached, a premature discharge, even under most extreme conditions, is almost impossible. After the apparatus is over the side of the ship, and just before it is lowered, this pin is withdrawn (by means of a lanyard, if desired) and the apparatus is thus "armed". Should it be necessary to return the apparatus to the deck, before firing, this pin can be inserted again before the apparatus is hoisted over the side.

WATER-EXIT PORT.

Early designs contained ample openings in the walls of the bit tube at its top, and, should the bit be forced slowly into mud, the displaced water would flow out through these. But because of the high velocity of the bit, at the time of firing, the water within it acted as a solid body and did not yield space for the mud to enter. The ideal condition would be a bit tube completely open at both ends, which would then pass through the water and mud, leaving them both stationary. But a perfectly open top is not mechanically attainable because of the necessity of keeping the violent blow of the explosion accurately centered along the axis of the bit. Furthermore, this powerful blow must be mechanically carried to the walls of the bit tube. This necessitates rugged construction between the center axis and the outer walls. After much experimentation the open-tube ideal was very closely approached, by taking advantage of aerodynamic and wind-tunnel data and modifying the best curves in accord with the greater density of the water medium. The exit port somewhat resembles a nozzle in reverse. The inner walls slope outward along an ideal curve, and the center projection is so shaped that the cross-sectional area (hence, volume) available to the water is the same at any plane normal to the axis. This is true up into that portion where the four steel webs carry the force of the blow from the center axis to the walls. Near the upper end of this part, the available volume increases slightly, and this fact, combined with the outward slope of the outside of the walls, provides a partial vacuum or cavitation—during the rapid movement through the water—which removes the back-pressure from the column of water inside the bit and provides an almost open-tube condition.

Though the bit was frequently driven deep into mud, no samples were obtained until this device was perfected.

THE BIT.

That portion of the apparatus below the water-exit port has been called the "bit". Its length determines the possible length of the sample; bits of different lengths may be used as found desirable. It consists of a tube of alloy steel of 2 1/4 inches inside diameter and 1/8-inch walls. Inside it are four longitudinal lands, as in a cannon, but straight. The four grooves between these lands communicate with four openings to the outside at the top of the tube.

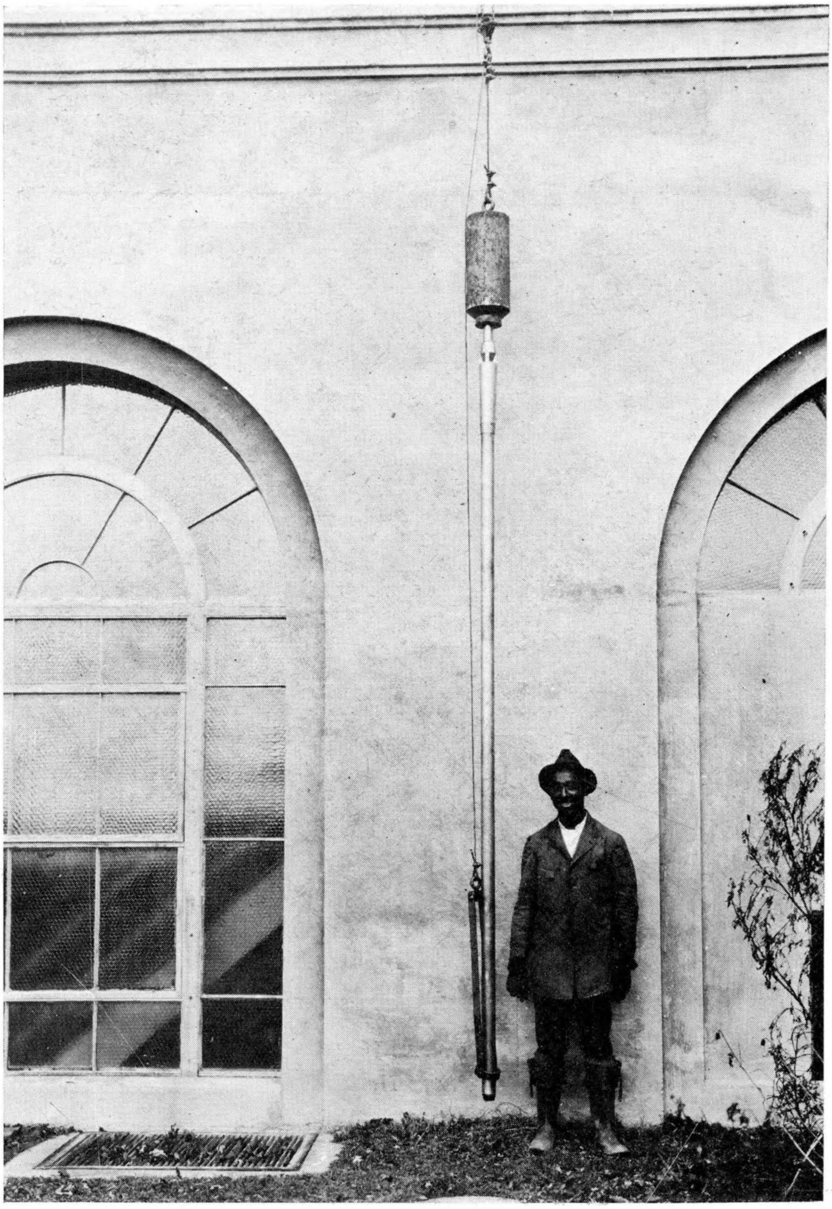

PLANCHE I

PLATE I.

ECHANTILLONS INTERNES DU FOND DE L'OCÉAN

CORE SAMPLES FROM OCEAN BOTTOM.

Poids, canon et embout.

Weight, gun and bit.

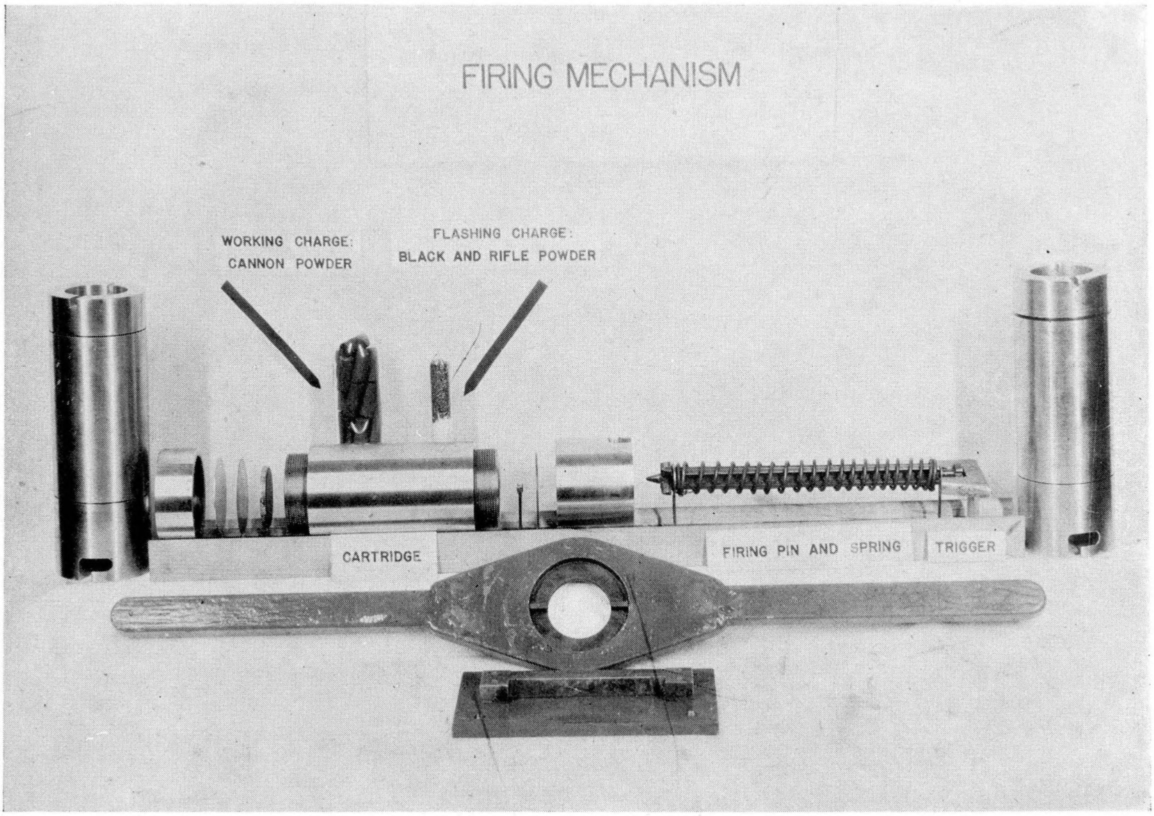

PLANCHE II

PLATE II.

ÉCHANTILLONS INTERNES DU FOND DE L'OCÉAN

CORES SAMPLES FROM OCEAN BOTTOM.

Détails du mécanisme de mise de feu.

Details of the Firing Mechanism.

Their function is to permit water to get down to the bottom of the bit and to fill the cavity in the mud created by the withdrawal of the bit—i. e., to "break the suction". The brass sample tube slips inside the lands and fits snugly against them; this causes the grooves to form longitudinal channels from the top to the bottom of the bit.

The bottom edge of the bit is provided with a cutting edge of hardened tool steel, which fits loosely between the sample tube and the steel tube and is prevented from falling off by two small screws. However, it has a play of three-sixteenths inch—i. e., may hang that far below the end of the steel tube—but when pressed up it fits snugly against the end of this tube. It therefore acts as a valve, which prevents mud from entering the grooves while the bit is being driven into the bottom, but opens and permits water to flow out of the grooves while the bit is being withdrawn from the mud.

After a "shot", the brass sample tube is withdrawn, with the mud core inside it, and a new one is inserted. It is cut off at the top of the mud, corked at both ends, and these corks securely taped. They are labeled in a manner to indicate the top and the bottom of the core and may then be shipped and kept without alteration until opened for examination in the laboratory. This is done by cutting the tube longitudinally in two diametrically opposite places and then inserting two sheets of tin in one slot and pressing them across to the opposite wall. The tube may then be opened hinge-fashion and the tin strips removed without distorting the sample. This produces two equal parts to each sample, each part lying in its own brass trough, and reveals the structure of the core. This procedure provides an undisturbed half for control or future reference; the other is used for investigation. Furthermore, the undisturbed half provides a depth scale, from the surface downward, which is of considerable value. It has been found convenient to split the half to be examined, either in half again or into quarters. This is done with each fragment individually, using a thin-bladed hacksaw or its equivalent. The fragments may always be returned to their proper place in the brass trough.

SOUNDING PROCEDURE.

The procedure on shipboard was to fasten securely to the deck, at a convenient place, a strong board. This was made straight and flat by suitable wedges, and to it were fastened prepared chocks to hold the gun, and also several chocks to hold the bit. These are so made that, when the assembled apparatus is laid in them, the bit and cartridge are lined up with the center of the bore of the gun. If such guides are not provided, the small clearance between the gun barrel and the cartridge assembly makes it exceedingly difficult to push the latter into the gun.

The apparatus is assembled in the chocks, the firing mechanism cocked, and the safety pin inserted. A cartridge is loaded in accord with the anticipated need. If it is the first sounding in a new locality, it is advisable to provide rather less than the anticipated required energy. Subsequent loads may be increased as circumstances warrant. When all is ready, the cartridge is fastened in place and the gun "loaded", by sliding the bit toward the gun, and the shear pin is put in place. The apparatus is then hoisted over the side. A man picks up the bit at the cutting edge, and, as soon as the gun clears the rail, he drops his end over the side into the water. The apparatus is immediately lowered until only the gun is out of the water; this prevents swinging against the ship's side. Finally, the safety pin is pulled out and the apparatus is lowered to the bottom. With shallow soundings the explosion can be heard and felt on the ship, and with deeper ones it can also be picked up by a microphone or the ship's sonic sounder. Where these failed to give any indication, the cable was paid out until more than the anticipated depth was out, and then the apparatus was hauled to the surface again. If it has fired, the gun and bit will be hanging separately at the end of their respective cables, the bit supported in the stirrup. If they are not so separated, and it is desired to bring the apparatus aboard, the safety pin must be inserted at the earliest possible moment while the apparatus is hanging clear of the ship. Once this pin is in place the apparatus may be brought aboard with safety.

If the apparatus has fired, the gun is hoisted up until the bit can be gotten over the side; this is laid in its proper chocks, and the gun then lowered to its chocks.

Sixteen soundings were made at sea in August 1935, yielding the 14 cores shown in plate 3, figure 1. One failure was due to a defective primer, and once the core pulled out. The 14 cores vary in length from 4 feet to nearly 9 feet and are solid throughout. The depths of these soundings varied from 200 fathoms to 1,250 fathoms.

The 11 cores shown in plate 3, figure 2, were obtained during May 1936, between the Grand Banks of Newfoundland and the edge of the continental shelf west of Ireland. Seven of them are from depths greater than 2,000 fathoms and all the remainder but one from more than

1,000 fathoms. The one exception is from the top of the Faraday Hills at 700 fathoms. The greatest depth was 2,650 fathoms. The very short core contains several inches of rock.

Plate 4 shows these cores split open ready for study, arranged, as taken, from west to east across the North Atlantic, and plate 5 a more detailed view of some of them showing the stratification and change of character of the material.

The cracks are due to drying. This can be prevented by keeping the cores in a saturated atmosphere, but since the dried segments leave marks on the brass troughs which establish their positions from the surface this is not usually done.

DISCUSSION.

These samples are of interest to many investigators. The marine biologists and micropaleontologists will find in them the remains of marine organisms which lived ages ago in the waters above. These organisms will change in character, from level to level of the core, reflecting their evolutionary development and the changes of type brought about by changes in the temperature of the water. Thus it may be possible to state that throughout a certain period in the past the water was much colder, or warmer, in that portion of the ocean. Or they may show that it was shallower—a mere lagoon, or deeper. The sedimentologist by a study of the minerals and the size of the particles of rock will be able to trace the changes of direction and possible force of ocean currents throughout past ages. The character of the sand and pebbles will indicate the presence of ice or the proximity of land where only ocean exists today. No one of these bits of evidence will be conclusive in itself, but many taken together may build up a strong corroborative presumption of a certain condition.

Some chemical and mineral constituents are of great significance, as for instance the fluorine and chlorine and other acid or basic radicals; also the metals such as manganese and iron, which are often found in great concentrations, or those which are found in extremely small concentrations, such as copper, tin, gold, selenium, or radium. The radium is of particular interest and significance because its concentration in ocean-bottom sediments has recently been found to be, in general, much greater than in either igneous or sedimentary rocks on land, and this difference is as yet not completely explained. The concentration is greatest in those portions of the ocean bottom more remote from land and lying at the greater depths. The material at the bottom of the deeper parts of the ocean generally consists of so-called red clay, and this material appears to contain much more radium than any rocks yet examined on land. If these sediments are of considerable depth, and if this radium concentration is the same throughout, these deeps constitute local concentrations of radioactive material possessing enormous stores of energy. Since we have found no sedimentary rocks with radium concentrations remotely approaching those existing in these sediments it might be inferred that the many changes of level of various parts of the earth's surface have nowhere brought up an ocean deep. It may be that the deeper portions of the ocean are permanent features of the earth, or else it may be inferred that this high radioactivity is but a transitory thing, representing the activity of radium only, unassociated with its long-lived parent substance uranium. If this be so, the nature and cause of its separation and concentration from sea water would be a most important study. Furthermore, a study of the radioactive substances and their disintegration products in these cores holds a promise of a determination of the time intervals represented by the various strata, or the age of the sediment as a whole. This in itself is of the utmost geophysical and oceanographic significance.

The only record of the history of the existing ocean lies buried in its bottom. Whether this record will be easy or difficult to decipher, voluminous or meager, remains to be ascertained, but whatever its nature it is now accessible to us through the medium of these core samples.

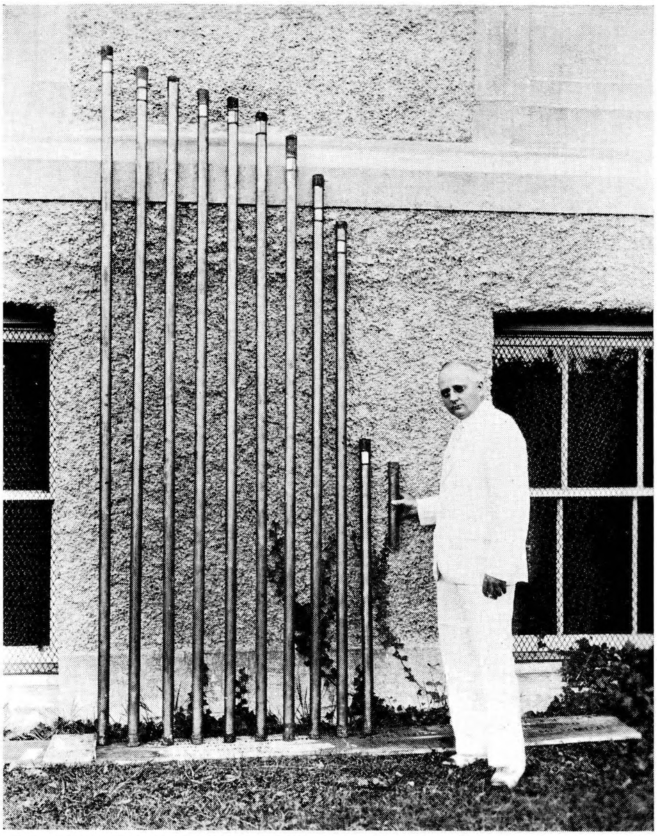

PLANCHE III

PLATE III

FIG. 2

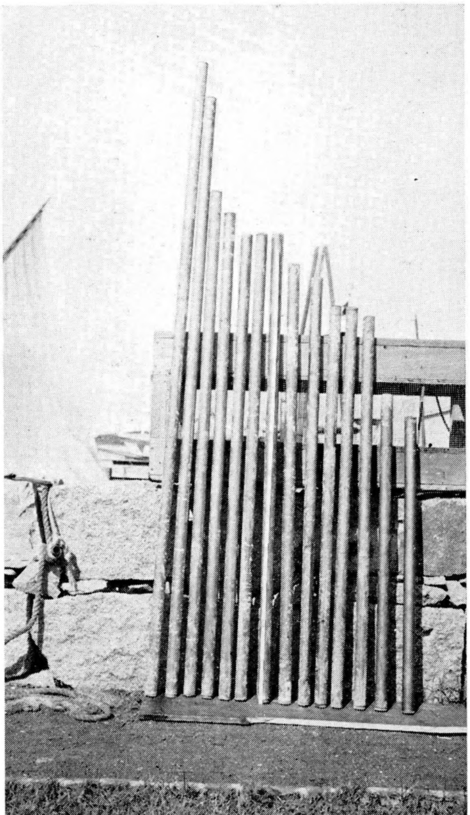

FIG. 1

ECHANTILLONS INTERNES DU FOND DE L'OCÉAN

CORE SAMPLFS FROM OCEAN BOTTOM.

Tubes d'échantillons

Tubes for cores.

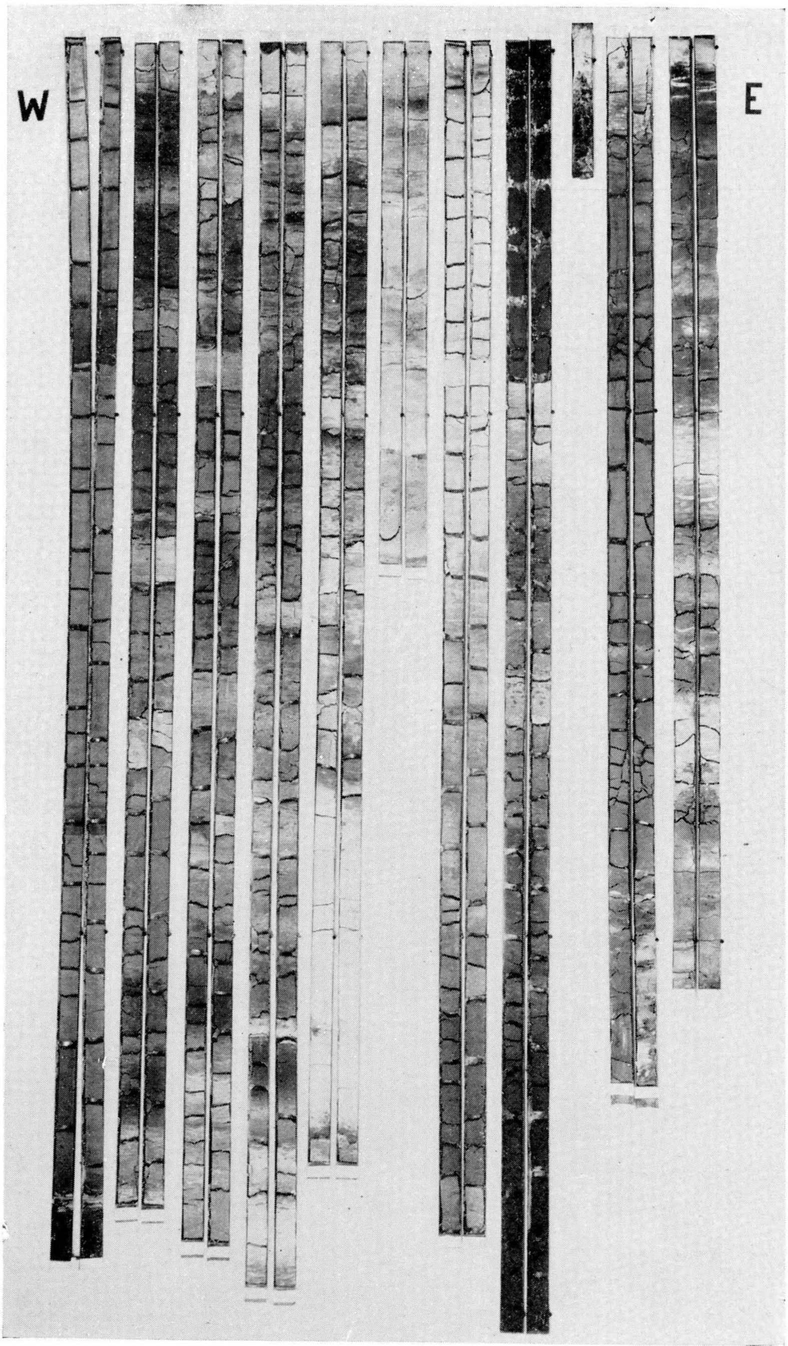

PLANCHE IV

PLATE IV.

ÉCHANTILLONS INTERNES DU FOND DE L'OCÉAN

CORES SAMPLES FROM OCEAN BOTTOM.

Echantillons prélevés dans l'Océan Atlantique Nord classés d'Ouest en Est.

Samples from North Atlantic Ocean arranged in order from West to East.

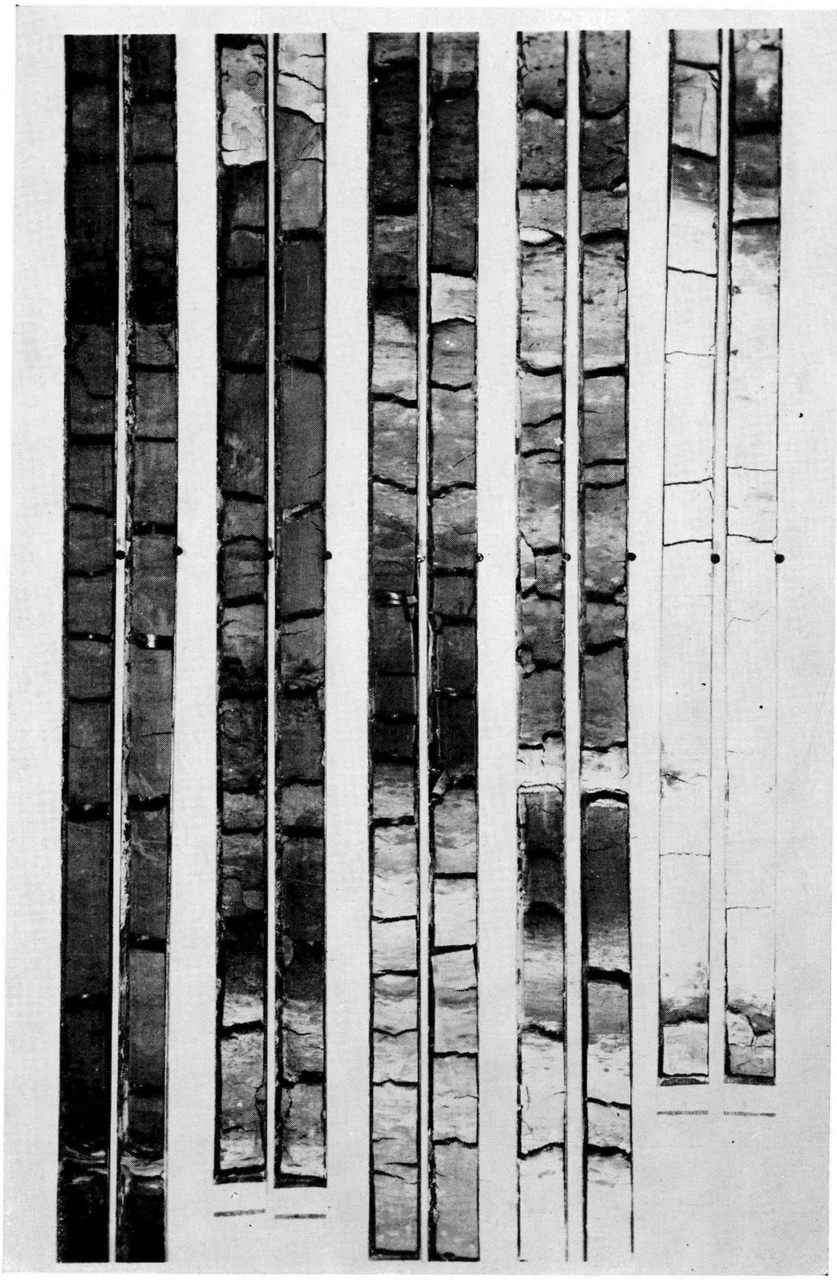

Planche V

Plate V.

Echantillons Internes du fond de l'Océan

Cores Samples from Ocean bottom.

Agrandissement d'une position de la Planche IV

Enlarged view of part of Piate IV.