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Woods Hole Oceanographic Institution

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1930

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TECHNICAL REPORT

Prepared under ERDA Contract ERDA 11-2440 and NOAA Office of Sea Grant Dept. of Commerce, Grant #04-4-158-8.

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Approved for Distribution: Earl E. Hays, Chairman
Department of Ocean Engineering

Abstract

This report outlines the development of an Acoustic Probe designed to resolve fine details of bottom and sub-bottom sediment layering particularly in deep water where ship sounders are usually inadequate. Penetration depths range from 12 to 72 meters and resolution approaches 15 cms.

The new instrument consists of a small but high powered short-pulse echo sounder operating at 12 kHz and designed to be lowered on 1/4 inch diameter single conductor logging cable to a maximum water depth of 6200 meters. This unit is self-contained and battery operated.

Excellent correlation has been observed between depth of sub-bottom layering as recorded by the Probe and as determined from sediment cores taken in the same location. Generally, the acoustic stratigraphy thus obtained in localized survey areas has proven sufficiently detailed to pre-determine acoustically whether an area warrants further investigation via coring or others means.

The instrument was developed jointly under NOAA Sea Grant contract #04-4-158-8 with Willard Dow and an ERDA contract (ERDA 11-2440) with Charles D. Hollister of W.H.O.I.

Development of an Acoustic Probe for Detailed Ocean Bottom and Sub-bottom Surveys

Background

Past experience has indicated that high frequency echo-sounders operating in shallow water are capable of considerable sub-bottom penetration into silty and clayey unconsolidated sediments.

In 1965 we briefly operated a high powered short pulse 12 kHz echo sounder[1] close to the bottom off Bermuda with the purpose of resolving the structure of bottom and sub-bottom sediment layering on a scale of 16-60 cms. Not only was such resolution attained, but penetration exceeded 60 meters (See Fig. I).

High resolution and substantial penetration with high frequency sound can be realized in deep water by operating the transmitter plus receiver close to the bottom, thus avoiding the significant attenuation of the high frequencies over the long two-way transmission path between surface and bottom, and concentrating the full power of the transmitted pulse over a comparatively small bottom area.

For example, if the sounder described herein was to be operated near surface where water depth was 4000 meters, approximately 4 sq. kilometers of bottom would be ensonified compared with an area of only 23 sq. meters if the gear were positioned 10 meters off bottom. Near-bottom operation thus avoids the problem of wide region "average" returns, and side echoes from local relief. Also, water-borne noise, both ship-generated and otherwise is significantly reduced at depth thus permitting detection of the first-motion phase reflectivity coefficient.

If the reflectivity of various common sediments were also known from prior measurement, and if the transmitter and receiver in the Probe were calibrated, and the receiver made amplitude linear over a wide dynamic range, it might be possible not only to contour bottom and sub-bottom layers with high resolution but eventually to predict from reflectivity their probable physical characteristics.

Accordingly, under a Sea Grant contract (Contract #22/2000.08) an experimental sounder was constructed incorporating the design features outlined above.

Specifications

The transmitter emits an extremely short (250 usec) high level pulse containing only 1-2 cycles of energy at 12 kHz, and a peak acoustic pressure approaching 120 dB/microbar, or up to 30 dB higher than conventional pingers. The A.D.P. transducer used has the broad bandwidth required to transmit this short sharp pulse. The receiver has a dynamic range of 80 dB to accomodate the wide range of amplitudes expected in bottom and sub-bottom returns, and a bandwidth of 5000 cycles in order to resolve events as short as 250 usec. The deep sounder is self-contained, battery operated, and capable of being lowered to 6200 meters in the ocean by the 1/4" diameter single conductor logging cable which is standard equipment on most of our vessels. The electrical conductor serves to relay a trigger pulse, originating at a graphic recorder keying contact, to fire the deep transmitter, and also to conduct output signals from the deep receiver back to the same recorder for display purposes. A perfectly synchronized record is thus produced on line, and all data can be recorded on magnetic tape for future analysis.

The Deep Probe was completed by the end of January 1975, (see Fig. II). The electronics are contained in three dark-gray titanium pressure cases shown mounted within the frame. Mounted just below the weight platform close to the bottom is the transducer, a 12 kHz ADP crystal unit similar to the familiar EDO type UQN-1. A single 6-foot relay rack in the ship's laboratory houses all of the gear required to operate the system except for tape recording (see Fig. III).

Several trial lowerings were made from R/V KNORR just north of Bermuda during a joint ONR-NSF cruise in February 1975. Bottom profiles of this area, made with the ship's 3.5 kHz echo sounder set on short pulse (0.5 Ms) show long bottom returns with featureless gray areas between, maximum penetration averaging about 55 meters (see Fig. 4A). A Deep Probe lowering (Fig. 4B) revealed that returns B_1-B_3 in the surface record were actually multiple reflectors in too close proximity to be resolved at 3.5 kHz from the surface, and that the "gray" areas contained considerable structure as well.

However, maximum penetration at 12 kHz here and in some other areas did not exceed 24 meters whereas over 30 M is required to match the penetration of the giant core. Therefore either the Probe frequency should be reduced for a better compromise between penetration and resolution, or provision made for remote switching say from 3.5 kHz to 12 kHz as required.

Ship-generated problems encountered throughout the cruise are illustrated in the figure. Flow noise from KNORR's cycloidal propulsion plagued surface records, while heavy rolling and pitching on station caused vertical excursions of the Probe support cable up to 4 meters amplitude giving the flat bottom the mountainous appearance shown in Fig. 4B. This oscillation was reduced on later cruises by moving the support point forward to a point of less motion amidships, and the remainder could be eliminated by triggered sweep graphic recording or in subsequent processing of the tape records.

Operations

The next step was to determine whether the acoustic reflectors observed could be recognized in sediment cores taken at the same site, and vice versa. Therefore, the gear was mounted on R/V KNORR for an expedition to the Rockall Trough area east of the United Kingdom where coring operations had been scheduled in August 1975.

A preliminary survey of results shows good correlation between core lithology, depth of reflectors re Deep Probe, and a plot of reflection coefficients vs depth as derived in the laboratory from core sections (see Fig. 5). Velocities used in determining these coefficients were measured on the core with a ship-board velocimeter developed by Ken Baldwin of U.N.H.[2] Velocity in sand and sandy-silt layers, such as those shown at core depths of 100-130 cms and 475-525 cms, was high compared to the adjacent clay thus producing highly reflective interfaces which probably produced the stronger returns in the Deep Probe records.

Groups of thin silt layers alternating with clay and hydrotroilite apparently produced lower peaks in the reflectivity curve and detectable acoustic returns, provided the thickness of the overall sandwich was well in excess of a wavelength at 12 kHz (see core depths 150-260 cms, 340-460 cms, 740-820 cms, and 970-1100 cms). Measurements of reflectivity derived from tape recordings of the Probe lowerings, coupled with further study of sediment material in the corresponding cores should improve our capability to relate acoustic returns to physical properties, and this work will be the subject of future reports by those involved. (See Acknowledgements)

It is of course important that Deep Probe lowerings be close to the core site, particularly in non-uniform bottom areas. The acoustic record shown in Figs. 5 and 6 was taken 28-36 meters off bottom at 56° 17.8'N, 12° 31.6'W while the corresponding core was quite close at 56° 17.9'N, 12° 36.3'W. Therefore, the correlation is better in this instance than in some others where the separation was greater.

Summary

Deep Probe is capable of producing a detailed and accurate record of sub-bottom layering to penetrational depths ranging from 12-72 meters depending on the physical properties of the sediments. Resolution is superior to that attained with conventional 12 kHz and 3.5 kHz surface echo-sounders particularly in water depths of 2500 meters or more. The Deep Probe system can be adapted to other frequency bands, and presently has a second receiving channel which can be used for broad-band operations with a calibrated hydrophone.

Future Development

In its present form the gear is quite unsuitable for towing at speeds over 1 knot. Therefore, extensive bottom surveying or regaining station if the ship drifts away is wasteful of ship time, and so far, efforts to fund a towed-fish version of the gear have been unsuccessful. However, surveying at depth remains an important objective.

An alternative which would eliminate the ship-drift problem would be to mount the instrument on the core-head so that the acoustic record could be made just prior to core release. To avoid the complexity and expense of incorporating electrical conductors into the trawl cable, the output of the deep receiver could be relayed back to the ship via a high frequency low noise acoustic link employing a F.M. modulated carrier system. This would not only provide a detailed view of sediments prior to any disturbance by coring operations, but also would furnish the accurate data required to develop interpretation of acoustic stratigraphy in terms of sediment characteristics. The F.M. system would preserve the amplitude relationship of acoustic returns regardless of carrier strength at the surface hydrophone. This configuration will be the subject of a proposal to be submitted to USA ERDA for their bottom assessment program. A similar system[3] has been used successfully in the past to relay deep hydrophone information to the surface (see A Telemetering Hydrophone by Willard Dow, Deep-Sea Research, 1960). However, even in its present form, the Probe has proved to be a very useful device for detailed in situ examination of bottom and sub-bottom structures.

ACKNOWLEDGEMENTS

The author would like to acknowledge the assistance of the following in the development and testing of the new equipment and in the preparation of this report:

Dr. Charles Hollister made ship time available for sea trials on three cruises aboard R/V KNORR.

Sydney Knott, Edward Laine and Hartley Hoskins of the W.H.O.I. Geology and Geophysics group provided substantial assistance with the development and calibration of the gear at W.H.O.I. and with operations at sea. They are also analyzing data from the cruises.

Armand Silva, (W.P.I.) provided the core water content data, and Ken Baldwin (U N.H.) the in-core sound velocity measurements used by Edward Laine in computing the reflectivity coefficients plotted vs depth in Fig. V.

David Mason helped to construct and test the instrument and also assisted with rigging the system aboard R/V KNORR.

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REFERENCES

1. Dow, Willard; Stillman, Steven L., Inverted Echo Sounder W.H.O.I. Ref. #63-6, Feb. 1963. ONR contract Nonr - 1367 (00) NR-261-102.

2. Baldwin, Kenneth; Shipboard Apparatus to Measure Acoustic Properties of Marine Sediments (unpublished manuscript).

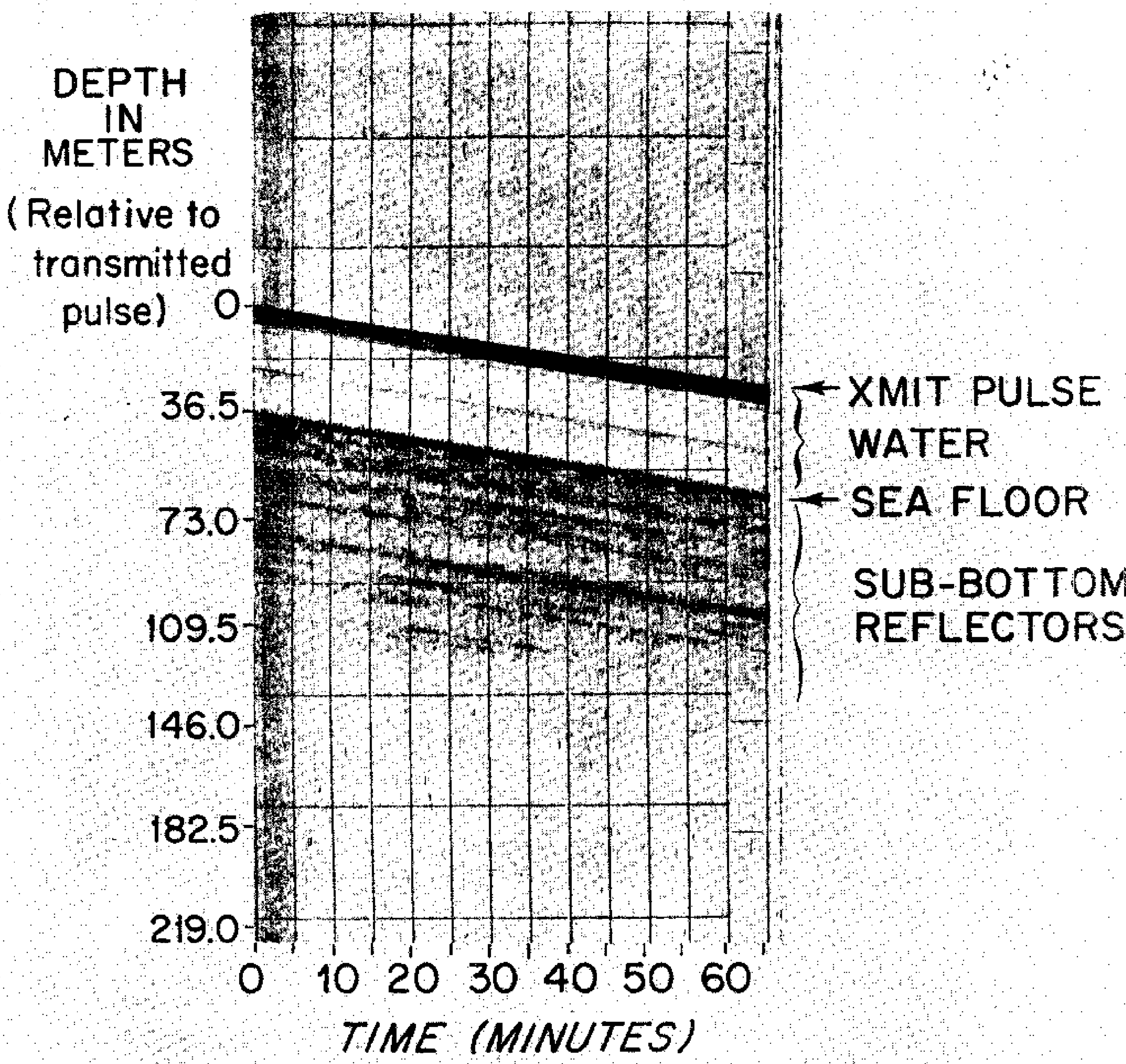
3. Dow, Willard, A Telemetering Hydrophone, Deep-Sea Research, 1960 Vol. 7, pp. 142-147.

LIST OF FIGURES

NOTE:

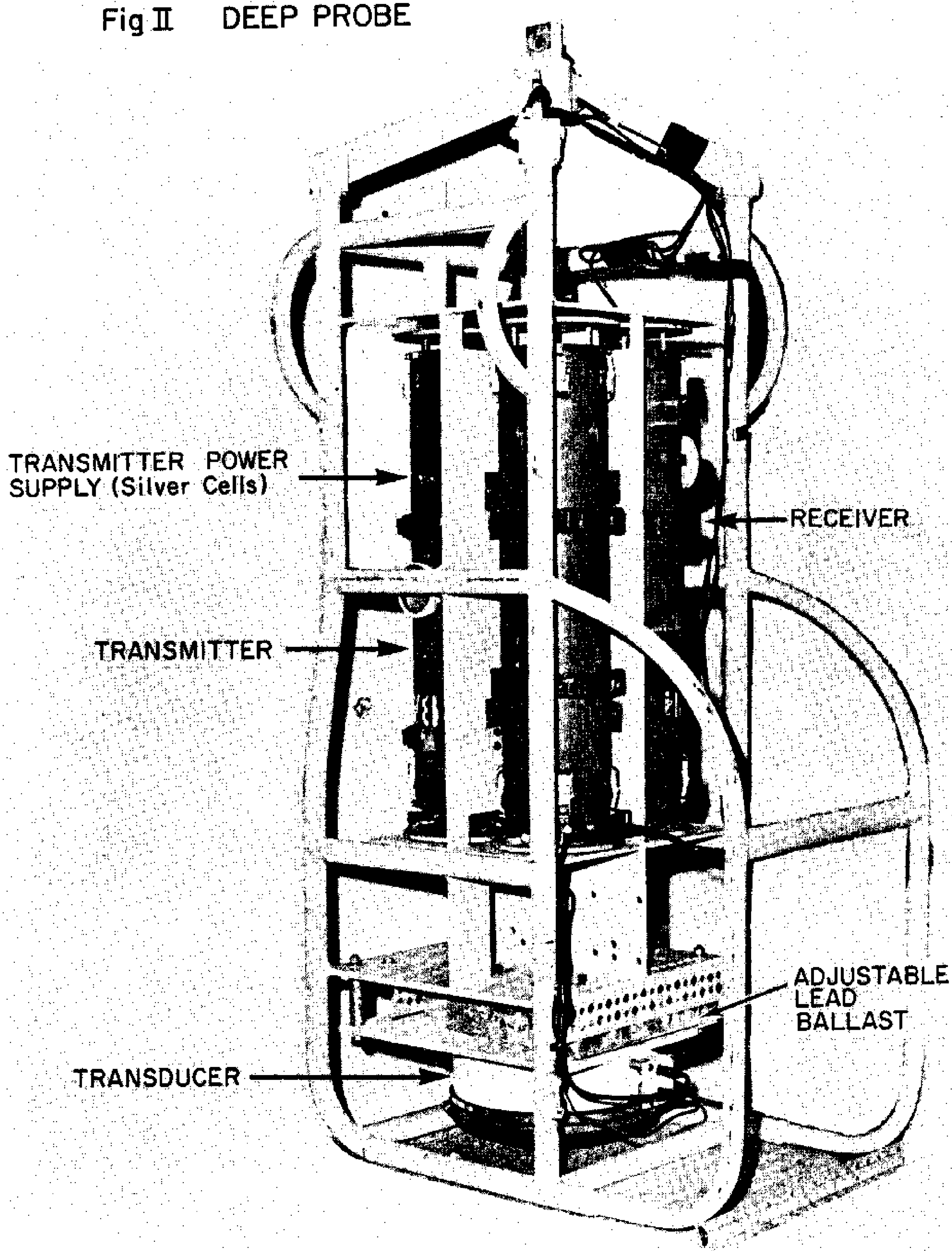
* P.G.R. = Precision Graphic Recorder

Fig. I DEEP ECHO SOUNDER PGR*
RECORD MADE NEAR BERMUDA
IN 1965



WATER DEPTH: 2690 FM
POSITION: 66°52' W
30° 30.7 N
TOW SPEED: APPROX. 1 KNOT

Fig II   DEEP PROBE



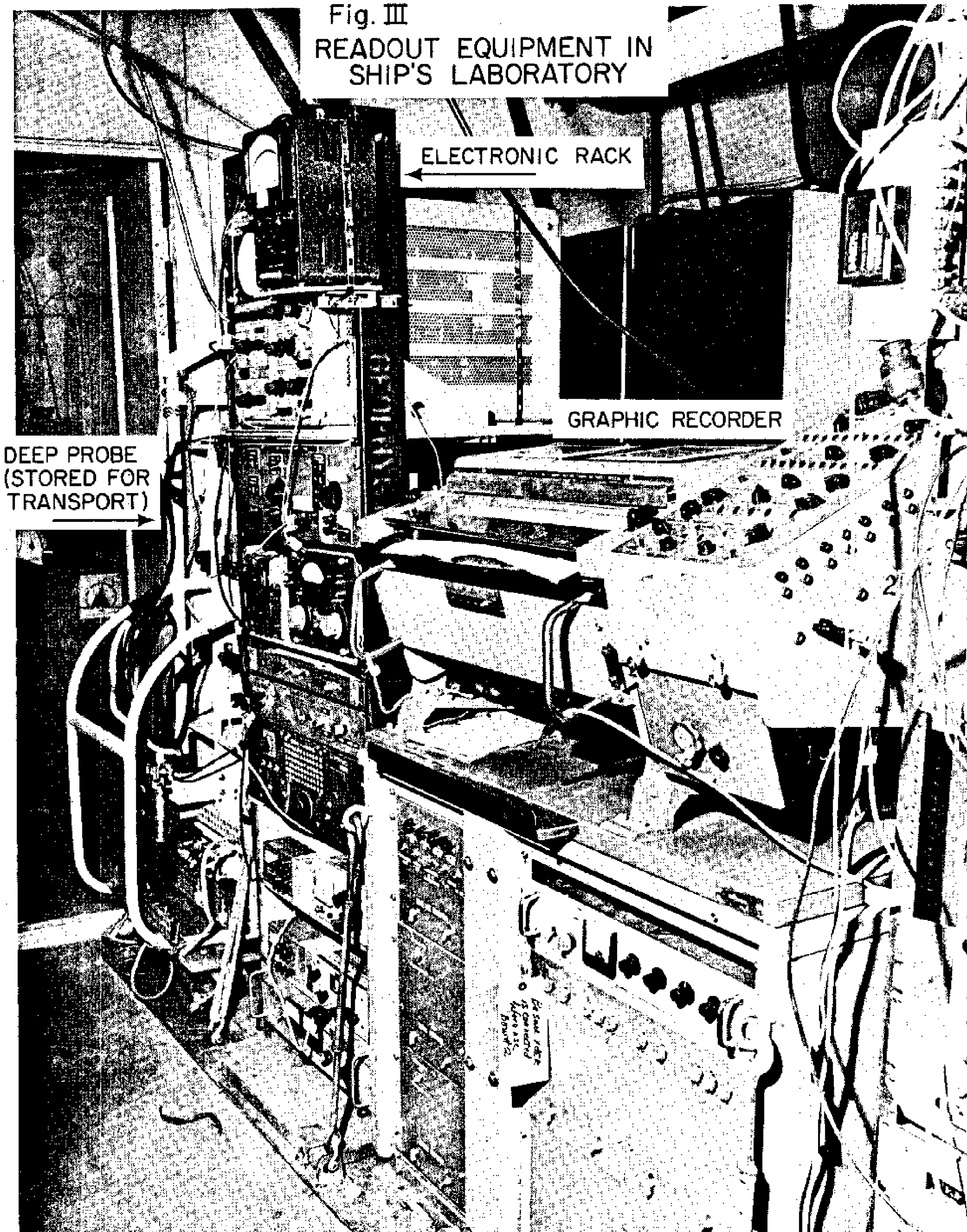


Fig. III
READOUT EQUIPMENT IN
SHIP'S LABORATORY

Fig. IV SURFACE AND DEEP ECHO SOUNDING RECORDS TAKEN IN SAME LOCATION (33°37'N, 57°40'W)
(DEPTH OF WATER = 4460 METERS)

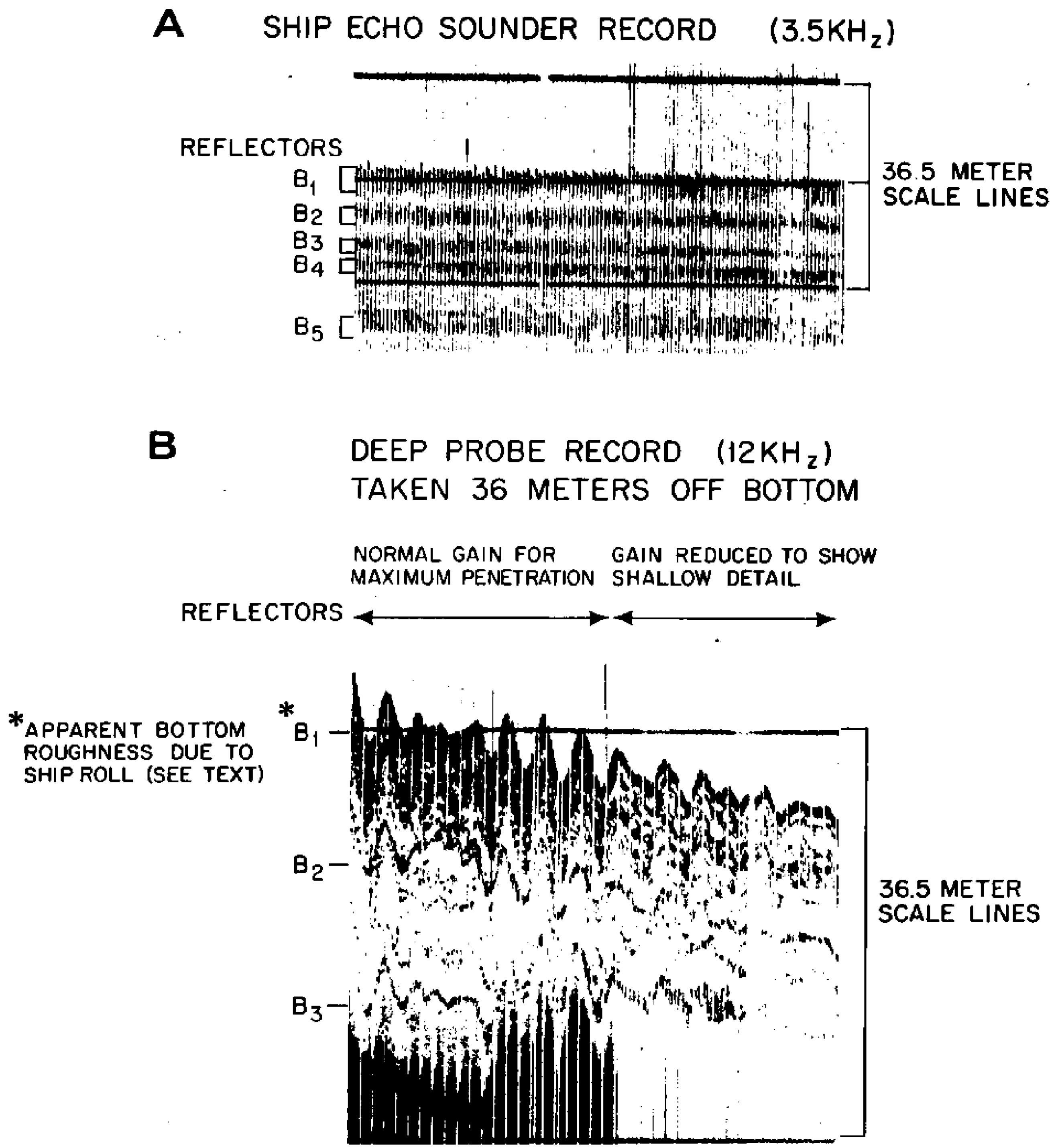


Fig. V ACOUSTIC RECORDS VS CORE ANALYSIS

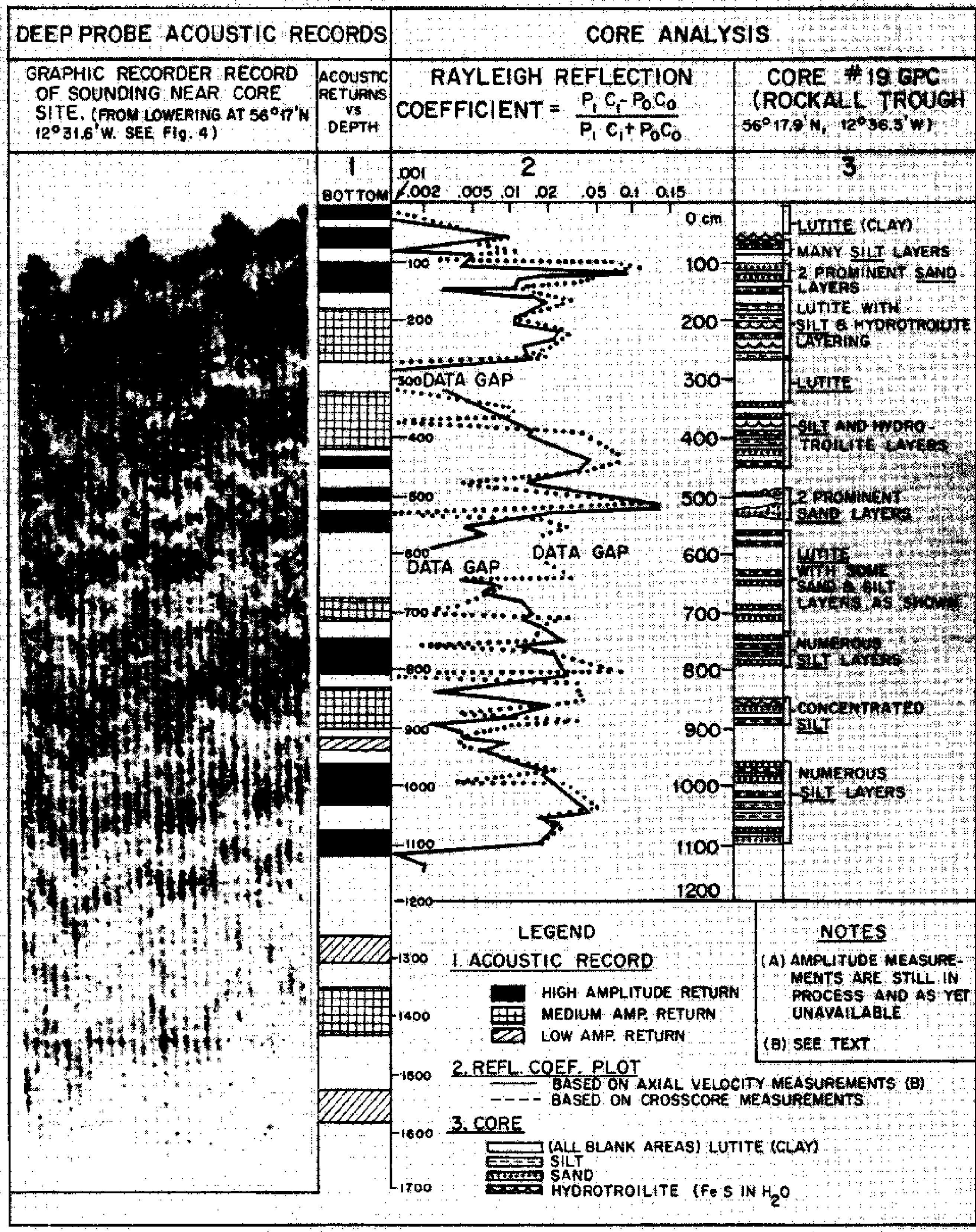


Fig. VI

TYPICAL P.G.R. RECORD OF DEEP PROBE LOWERING IN ROCKALL TRENCH AREA.