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SEISMIC REFRACTION ON CONTINENTAL SHELVES WITH DETECTORS ON SEA FLOOR*

BY

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Abstract

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— Seismic refraction at sea and on continental shelves requires most of all a precise positioning of the shooting and receiving stations and a good signal to noise ratio.

A new system has been developed using detectors anchored on the sea floor and radio transmission of signal for refraction work on continental shelves. This technique satisfies both requirements. The system has been tested in the western Channel in December 1971. —

Introduction

In order to set up an economical and technically valid seismic refraction field procedure for a survey in the western Channel, and in general, for the continental shelves, the principal techniques used so far were first reviewed.

A. *Two ships method*. The presence of two ships (Dobrin 1960) permits the use of sophisticated detecting equipment (hydrophone arrays, multi-channel seismic amplifier), favorable to obtain good S/N ratio. Also the positioning of both shooting and receiving stations is precise (Decca, Toran, etc.). However, the use of long hydrophone arrays in areas of heavy ship traffic is very inconvenient and chances to loose them are high. Most of all, the cost of a two-ships operation is quite high.

B. *Sonobuoys*. The replacement of the receiving ship by an expendable drifting sonobuoy is a universally used refraction technique today (Hill 1963, Ewing, Leyden, and Ewing 1969). Low-priced, very easily handled, sonobuoys are generally used simultaneously with seismic reflection yielding an unreversed refraction profile without any time loss. Results are usually mediocre, due essentially to poor S/N ratio, unforeseen changes in geological configuration (variable dip, faults, etc.) and often excessive drift of the buoy. If anchored, the S/N ratio deteriorates even more (motion of water over the hydrophone)

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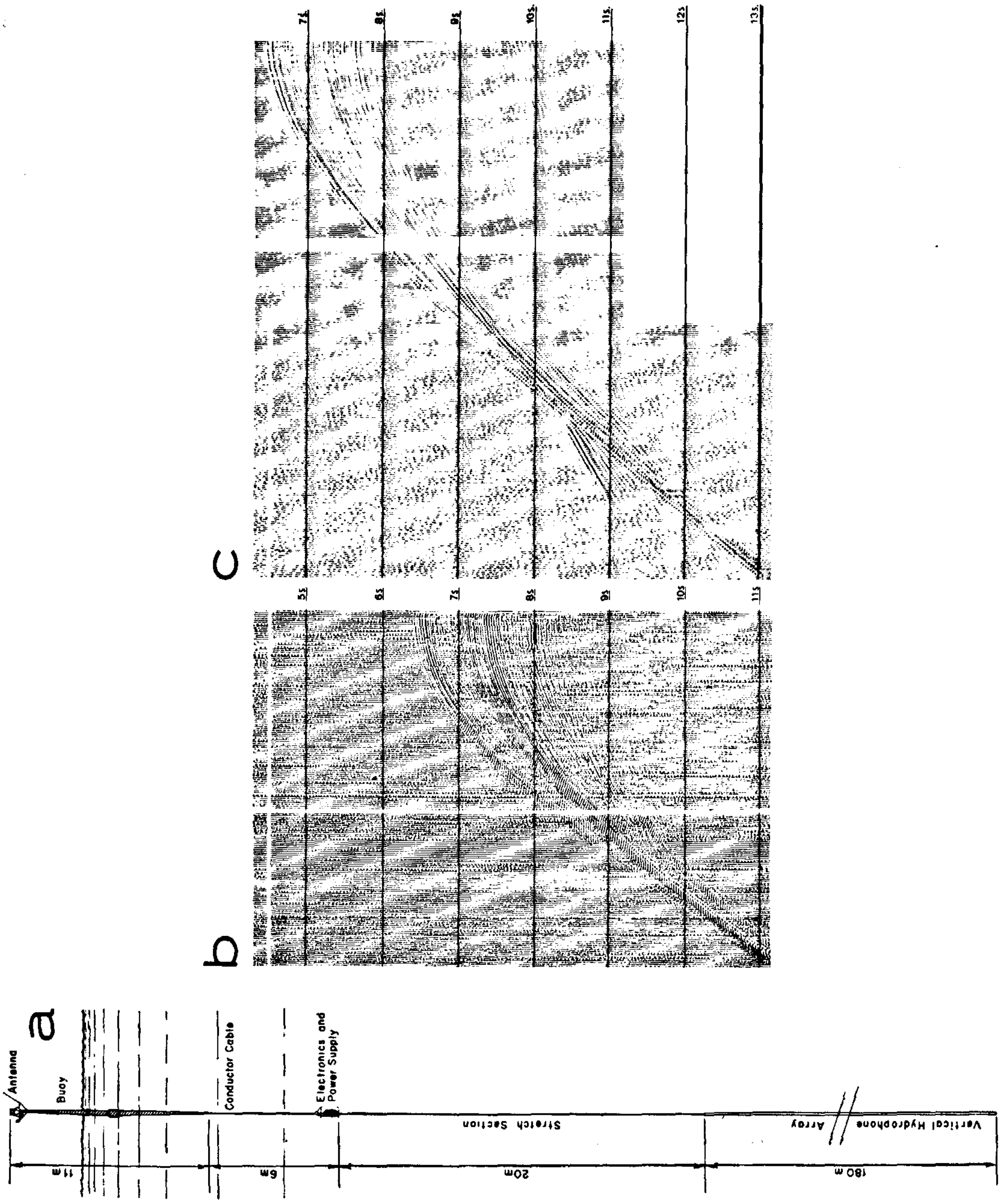


Fig. 1. a) Buoy with vertical hydrophone array. b) Refraction profile with drifting sonobuoy and c) vertical hydrophone array.

and the performance of the buoy is practically null when currents exceed 1,5 knots.

To improve the S/N ratio more sophisticated detectors should be used with a consequent increase of complexity and price. For example, the buoy developed at the Centre Océanologique de Bretagne (C.O.B.) (Martinais and Clavelloux 1971) (fig. 1a) uses a 180 m long vertical array of hydrophone with a preferential direction of reception at 45° from the axis of the arrays. It is suspended under a buoy with a shock absorber to diminish the hydrodynamic noise. Each hydrophone is followed by a delay unit corresponding to the hydrophone spacing. Directivity of the array is such that in the seismic frequency spectrum (5-80 Hz) sensitivity of reception is maximum in a 45° cone and minimum in a plane orthogonal to the array. In presence of isotropic noise, the signal to noise ratio is improved by about 8 dB. Transmission of the signal is through frequency modulation (carrier 31 MHz). The gain of the buoy is telecommanded from distance. Radiophonic distance is over 100 km. Results proved the good performance of the buoy and its very favorable S/N ratio (figure 1 b and c). Unfortunately, this array cannot be used on continental shelves due to its fixed length. The minimal depth necessary is about 300-350 meters.

In conclusion, none of the techniques used so far in refraction profiling seems to be well adapted for work on continental shelves in presence of relatively high currents (2-3 knots) and heavy traffic.

Proposed Technique

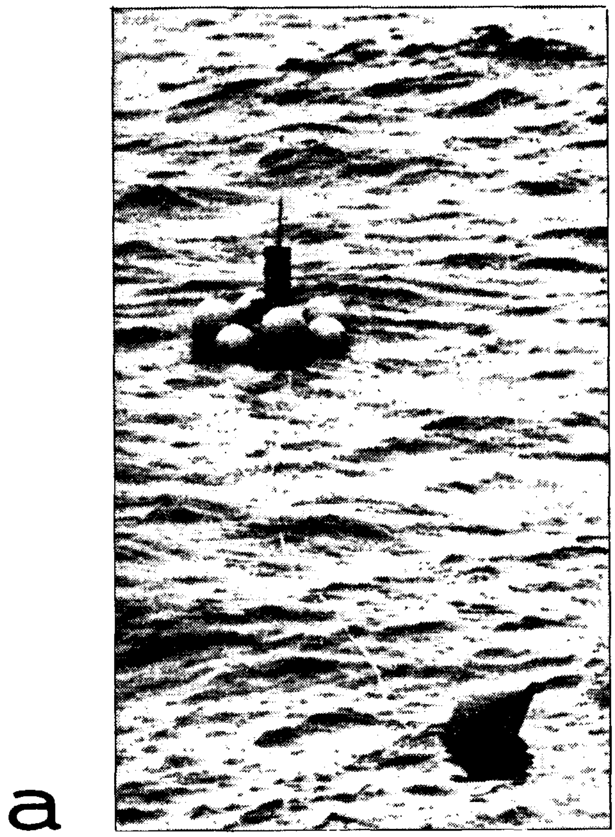
The main sources of noise on a suspended hydrophone are (in addition to the isotropic noise in water):

—motion of the buoy transmitted to the hydrophone;
—surface noise (waves);
—motion of the water over a fixed hydrophone in case of anchored buoy (currents);
—traffic noise (ships).

To overcome these difficulties, the best solution seemed to be to position the detectors, hydrophone or geophone on the bottom.

The hydrophone on the bottom should:

—eliminate the noise due to the motion of the buoy;
—reduce the surface noise;
—reduce the noise due to currents (close to the bottom in the "limit layer", the motion of water is considerable slowed down).



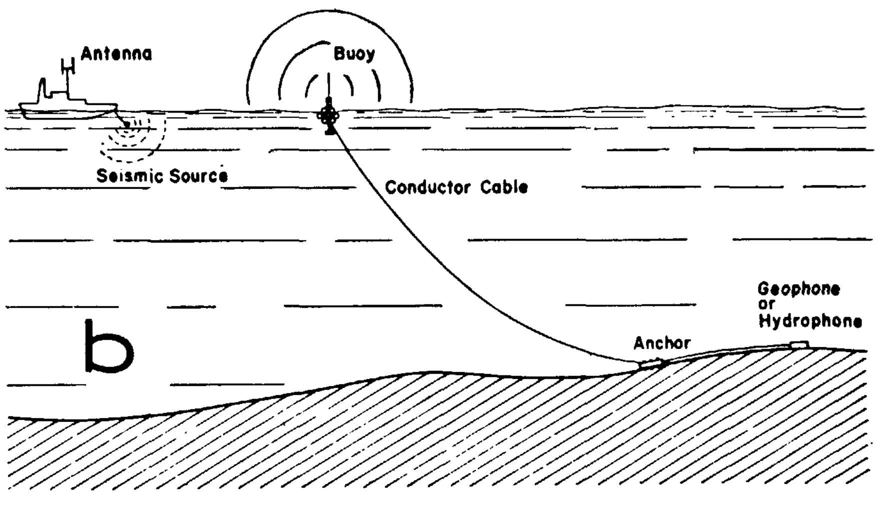


Fig. 2. a) surface float-buoy assembly. b) schematic of bottom detector.

However, it would not suppress traffic noise. The use of a geophone would solve this problem as well or the other ones.

Finally, detectors anchored on the sea-floor should eliminate the errors resulting from excessive drift of sonobuoys. On the basis of these remarks, two systems were developed, one with an hydrophone and one with a geophone (fig. 2).

The hydrophone assembly uses a EVP 10 model from Electrotechnical Labs with hydrostatic compensation and a variable gain preamplifier (up to 60 dB) with filter network. The preamplifier is powered by dry cells, insuring an autonomy of about 36 hours. The assembly is mounted on a sled. The total weight is about 25 kg (fig. 3).

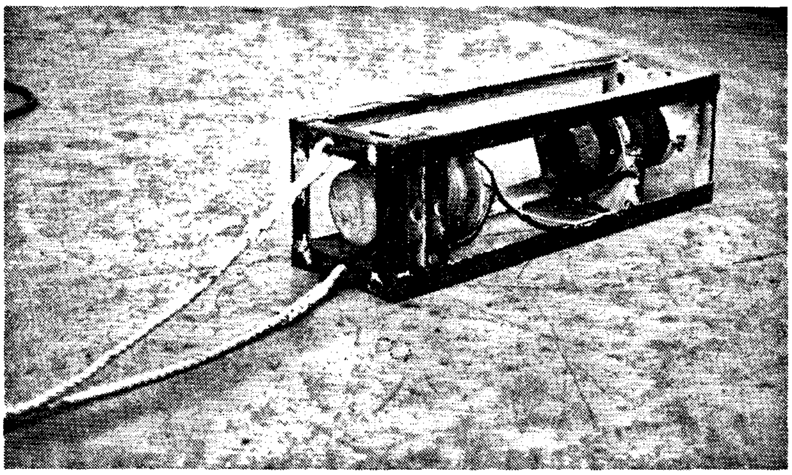


Fig. 3. Hydrophone assembly.

The geophone assembly is made of two geophones mounted in a pressure proof flat cylinder (ø 40 cm, height 15 cm, weight 40 kg) in opposite direction, so one is always in the right position when the cylinder lands on the seafloor. A mercury switch assumes the connection of the upright geophone to the amplifier and filter. Teeth (50 mm long) welded on both bases of the cylinder insure good contact with the ground. The weight/unit area is about the same as for a single geophone resting on the ground (fig. 4 a and b).

The hydrophone or geophone signals are linked to the surface buoy by a 5 mm single-conductor steel-armored cable with tensile strength of about 1.5 ton. The weight is about 10 kg/100 m. A steel container (50 $\times$ 40 $\times$ 25 cm) with grips loaded with ballast (about 110 kg) and clamped to the cable about 50 m from the detector assembly serves as an anchor for the surface buoy (fig. 5).

The surface buoy consists of a float and a modified Aquatronics SM 44 sonobuoy. This sonobuoy has replacable batteries and waterproof connectors for signal input.

The signal transmitted by the sonobuoy is received on the ship on Aquatronics STR-70 modular receiver. The signal is recorded on tape for further processing and displayed on graphic and photographic recorders.

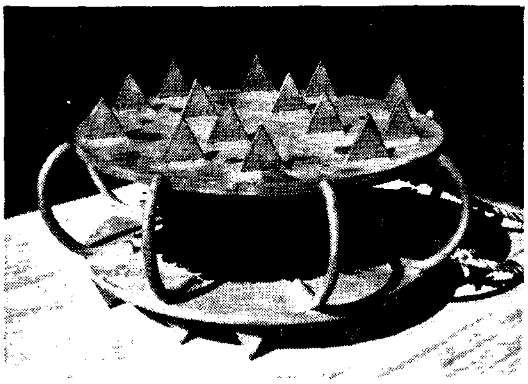


Fig. 4a.

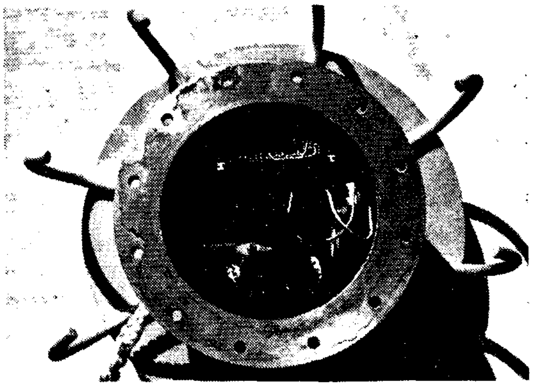


Fig. 4b.

Fig. 4. a) Geophone assembly. b) Geophone assembly open.

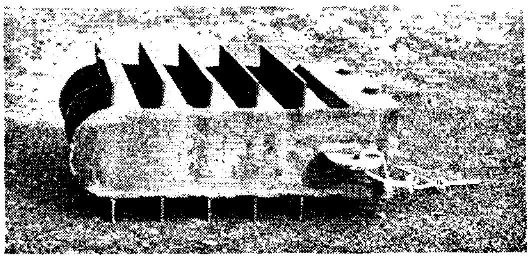


Fig. 5. Anchor.

Results

The performance of the systems has been tested in December 1971, in the western Channel. The weather varied from calm with long period waves of 2-3 m amplitude during the first week to very agitated (30-35 knots wind and

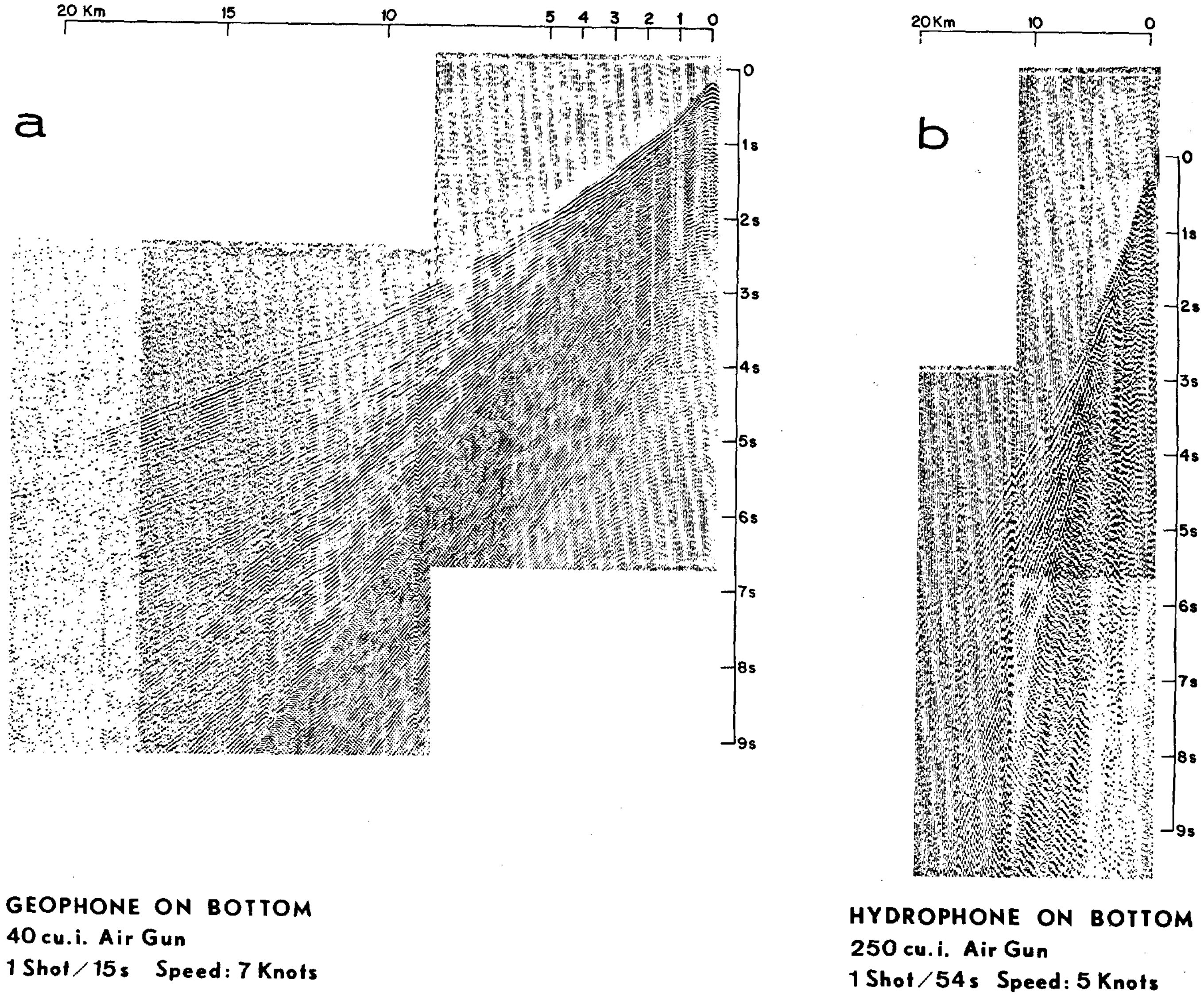


Fig. 6. a) Refraction profile with geophone (Air gun 40 cu. inch (0.655l), speed 7 knots, one shot every 15 sec). b) Refraction profile with hydrophone (Air gun 250 cu. inch (4.1l), speed 5 knots, one shot every 54 sec).

3-4 m waves) at the end of the cruise. Currents averaged 1,5 knots. Water depth ranged from 130-150 meters.

Seismic sources were a 40 cubic inch (0.655 l) Bolt airgun (model 1900 B) and a 250 cubic inch (4.1 l) "Sodera" (Société pour le Développement de la Recherche Appliquée, 83-Toulon, France) airgun prototype built to work at high pressures (250-300 bars). This however could not be tested at pressures higher than 190 bars due to limited pressure capability. Launching of the system took from 15 to 20 minutes, recuperation from 30 to 40 minutes. For night operation, buoys were equipped with flash lights. Profiles were run at 5-7 knots. Navigation

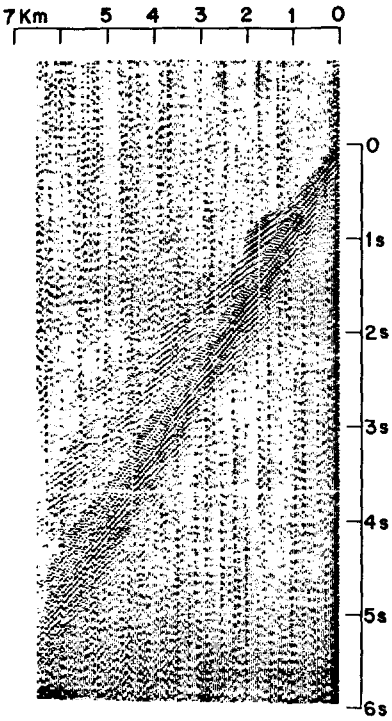


Fig. 7. Refraction profile with drifting sonobuoy.
40 cu.i. Airgun 1 shot/15 sec. speed: 7 knots.

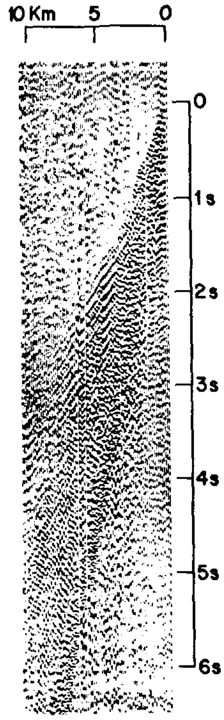


Fig. 8. Refraction profile with bottom hydrophone (sea state 7).
250 cu.i. Airgun 1 shot/54 sec. speed: 5 knots.

was interpolated from satellite, Toran, and Decca fixes. The systems have been compared in identical meteorological and geological conditions.

The first comparative profiles obtained from a bottom hydrophone and geophone (fig. 6) are almost identical. The geophone yields better definition of first arrivals. The noise is also somewhat lower.

A profile run with a drifting as well an anchored sonobuoy (Aquatronics SM 44 B) in the same geological and meteorological conditions as for figure 6 is shown on fig. 7. The drifting sonobuoy has a S/N ratio much below the bottom detector system. Results obtained with the anchored buoy are useless, the seismic signal is completely hidden by noise.

As weather deteriorated advantages of the two systems became even greater. Figure 8 shows profile obtained with hydrophone by sea state 7 and 30-35 knots wind. The noise level is almost as good as in calm weather. The profile was interrupted after waves tore off the antenna of the sonobuoy. The buoy assembly is quite rugged. It resisted an almost direct hit by a tanker.

In summary, therefore, first results with seismic detectors on sea-floor proved to be very promising. Equipment will be improved and operation procedure refined for an extensive exploratory cruise planned for the fall of 1972 in the western Channel.

Conclusion

The refraction system using seismic detectors on sea floor developed for work on the continental shelf with low energy sources has proven quite satisfactory. Its advantages over the sonobuoy have been clearly demonstrated: it improved signal to noise ratio, good positioning, low price of operation, and bad weather capability.

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