THE USE OF DIVING TECHNIQUES FOR IN SITU GEOACOUSTIC MEASUREMENTS ON THE SEA-FLOOR

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Standard laboratory methods exist for the analysis of the geoacoustic characteristics of sea-floor sediments. These methods are generally applied to core samples taken from the bottom and brought to the surface for analysis rather than being analyzed in situ. The results are not completely reliable because of the effects of sample disturbance and temperature and pressure changes on the analysis. Such laboratory techniques do not allow the direct determination of the response of bottom materials to seismo-acoustic waves. Therefore techniques are being developed to conduct in situ measurements using divers. One such technique consists of recording the responses of five in-line bottom-mounted, tri-axial geophone stations and hydrophones to impulse signals. The signals are generated by a spear-gun mounted on a frame that shoots into a mass of cast iron. The method and results obtained are presented.

INTRODUCTION

The knowledge of the geoacoustic properties of marine sediments has become increasingly important to all concerned with the geophysics, geology, underwater acoustics and civil engineering of the ocean floor. This knowledge has important applications to problems in ocean site investigations, hydrocarbon and mineral exploration, ocean engineering, and propagation of acoustic energy in the ocean.

Scientists and engineers are continually searching for techniques to determine the geoacoustic properties of the sea-bed. Most of the methods used to obtain data from the sea bottom (and subbottom) are indirect because the water column separates the shipboard scientist from the environment of his interest. He must use remotely-controlled equipment to obtain samples and data. Several laboratory and field methods are available to determine various sedimentary geoacoustic properties. Coring is one such method. However, coring of the sea bottom followed by shipboard (or laboratory) measurements yields results often unreliable because of sample disturbance, time lapse between sampling and measurements, and large temperature and pressure changes between the bottom and sea surface. In particular acoustic properties are highly affected by the deterioration of the chemical and mechanical bindings that occur with time because of depressurization and increased temperature between the sea bottom and ship. Also, in the laboratory, the small size of the sample does not allow direct measurements to be obtained about the response of the materials to low-frequency seismic/acoustic waves. Clearly, in situ techniques would provide the most reliable geoacoustic measurements for ocean-bottom sediments.
**THE USE OF DIVING TECHNIQUES**

Conventional surveying and sampling techniques are essential to provide large quantities of data quickly. However, only divers can obtain direct observations of and conduct operations on or near the bottom. Although diving operations are limited by depth, many measurements made by divers conducting well-controlled experiments can be extrapolated to even greater depths.

At SACLANTCEN, diving scientists have been conducting controlled experiments for several years to determine the composition, structure, and distribution of the bottom materials and to obtain undisturbed in situ measurements of their geoacoustic properties.

**VISUAL INVESTIGATION OF THE SEA-BED**

Geoacoustic studies often require the demarcation of areas covered and underlain by specific sediment types to reduce the number of variables in controlled acoustic experiments. One of the problems in demarcating such areas is to ensure that the samples taken are representative and that the sediment type profile remains relatively the same all over the area of interest. Divers have been used to visually investigate and demarcate such areas. Figure 1 shows typical areas chosen for acoustic experiments in the vicinity of La Spezia, Italy. Each area is covered by a different bottom type.

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**FIG. 1 FOUR SITE SELECTED FOR ACOUSTIC EXPERIMENTS OFF LA SPEZIA, ITALY.**
A diving scientist can usefully observe and sample the sea-floor in situ. He or she can ensure that representative and almost undisturbed cores are obtained for detailed laboratory analysis. Figure 2 shows some of the results of laboratory analysis of the samples taken by divers within the areas of Fig. 1.

IN SITU GEOACOUSTIC MEASUREMENTS OF THE SEA-BED

When seismic/acoustic waves propagate through the sediments, the dynamic properties of the sediments determine the speed, attenuation and the mode of propagation of these waves. An investigation of these characteristics can therefore provide accurate information on the physical characteristics of the sea-bed. However, when transferring cores from the bottom to the surface for later laboratory analysis even divers can degrade the reliability of geoacoustic measurements because of physical disturbance when the sampling apparatus (coring tube) penetrates the bottom and is subsequently pulled out. Therefore, in situ measurements of major geoacoustic parameters would improve the accuracy of the results of the experiments.

Diving scientists at SACLANTCEN have developed a technique to take in situ geoacoustic measurements (de Strobel, Akal, Hastrup, 1983). Five seismometer stations, each with tri-axial geophones and a hydrophone, were deployed along the measurement range that was less than 25 m, thus allowing the use of a low energy source (Fig. 3). (This also met the requirement that the source level must not exceed the elastic limit of the sediments to minimize

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**FIG. 2** LABORATORY ANALYSES OF CORES TAKEN OFF LA SPEZIA (see Fig. 1).
disturbance; high energy sources can easily exceed the elastic limit.) A hydraulic spear-gun generated the signals by shooting at a mass of cast iron anchored to the sea-bed by a heavy metal plate and energy transmission supports (Fig. 4). The gun was mounted on a frame which adjusted to different angles as appropriate to generate the various wave types, e.g., interface, Love, and P waves.
Figure 5 shows examples of the signals received (25 m from the source). For example, geophone X received the maximum energy from a transverse impulse traveling in the X direction (Fig. 5a). The corresponding hodograph (particle-motion diagram) confirms that the response is confined to the horizontal plane. The radial (Fig. 5b) and vertical (Fig. 5c) signals were much more complex; the particle motions were confined to either the radial (y) or vertical plane (z) with very small transverse (X) deflections. This behaviour is characteristic of seismic waves (Akal, Schmidt, and Curzi, 1985).

**FIG. 5** TRI-AXIAL SIGNALS RECEIVED AT A DISTANCE OF 25 m FROM THE SOURCE. Bottom traces are the corresponding hodographs (particle motion diagrams).
Figure 6 is a time-distance plot of the outputs of the geophones that sensed the X direction. Distinct wavelets travelled with a calculated speed of 90 m/s.

Details on the use of this type of information to characterize the geoacoustics of the sea-bed sediments are provided in Akal, Schmidt, and Curzi, 1985.

CONCLUSIONS

Diving scientists are using several techniques to obtain samples, to acquire data, and to measure geoacoustic and other properties of the sea-bed in situ. These results are usually more reliable than those obtained by sampling the sea bottom and analyzing the samples at sea level after a time lapse under changed environmental conditions.

SACLANTCEN's diving scientists have developed a simple spear-gun arrangement that can simulate seismic waves. The data obtained has been used in a variety of applications to determine subbottom structure as well as acoustic properties of the sea-bed.
LITERATURE CITED

Strobel, F. de, Akal, T. and Hastrup, O.F. SACLANTCEN's use of Scuba diving in oceanographic and acoustics research, SACLANTCEN SM-175. La Spezia, Italy, SACLANT ASW Research Centre, 1984.