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MEASUREMENTS OF BACKSCATTERING FROM LARGE-SCALE PHYSIOGRAPHIC FEATURES OF THE SEA FLOOR

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ABSTRACT

Low-frequency acoustic backscattering of the sea floor has often been studied using omnidirectional measurement techniques. With directional methods, however, it is possible to process the data to obtain images of the scattered features and to estimate the scattering strength of spectific physiographic features. Such informatin is applicable to long-range acoustic mapping of the sea floor and to the study of sound-scattering phenomena of the sea floor at low frequencies. In this paper we describe scattering measurements made in the southern Tyrrhenian Sea with an explosive source and a towed-array receiver. The acoustic signals received by the array are processed by a frequency-domain beamforming procedure to estimate the directional distribution of energy for a given time increment. An assembly of these distributions as a function of time displays the geographic location of large-scale features of the sea floor that scatter sound back to the array. The scattering strengths of slopes of the Baconi seamounts over the frequency range of 200 Hz to 750 Hz are typically between -25 dB and -30 dB and are generally independent of frequency.

INTRODUCTION

Low-frequency acoustic backscattering from the sea floor has often been studied using omnidirectional measurement techniques [1-4]. Generally, an omnidirectional source and omnidirectional receiver are used (Fig. 1) and the calculation of scattering strength assumes uniform scattering in a ring-shaped area on the sea floor for a given element of travel time. It has been shown that such measurements can be contaminated by non-bottom returns having the same travel time as the scattering ring [5] or by non-uniform roughness within the scattering ring [6]. Although careful measurements using omnidirectional geometries will yield proper estimates of scattering strength, these techniques are more limited in their application than are directional methods, by which it is possible to obtain images of the scattering features and to estimate the scattering strength of specific physiographic features. Data from directional measurements are applicable to long-range acoustic mapping of the sea floor and to studying acoustic scattering phenomena of the sea floor at low frequencies. In this paper we describe such directional scattering measurements made with a hydrophone array.

EXPERIMENTAL METHODS

An omnidirectional explosive source is deployed near the hydrophone array. The sound reflected and scattered back to elements of the array are processed to form beam(s), as in Fig. 2. The scattering area is defined by the intersection of the beam and scattering ring boundaries for the particular travel time and

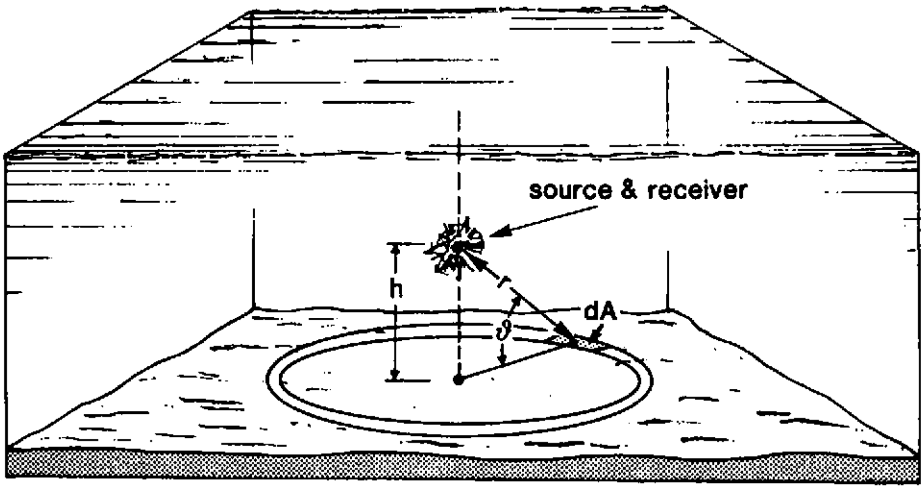

FIG. 1

OMNIDIRECTIONAL EXPERIMENTAL GEOMETRY FOR BACKSCATTERING MEASUREMENTS
For a given travel time and processing time, the scattering may occur at all elements of the scattering ring. h is the height of the source above bottom, r the range of the scattering element, dA the area of the scattering element, and ϑ the grazing angle at the bottom.

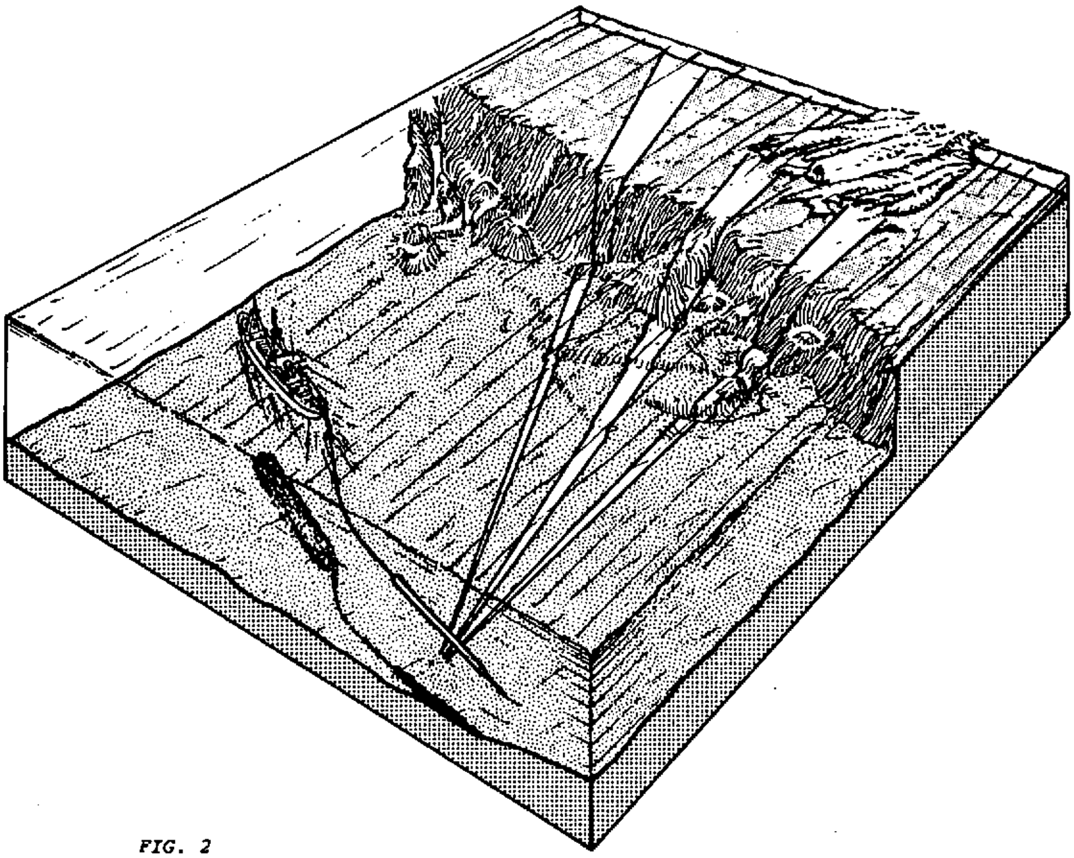

FIG. 2

EXPERIMENTAL GEOMETRY USING AN OMNIDIRECTIONAL SOUND SOURCE AND DIRECTIONAL RECEIVING BEAMS (not to scale)
For simplicity the sound source is omitted and only three beams are shown. These beams, which actually scan a vertical section of the volume, are indicated by their wedge-shaped areas on the sea floor. The complementary (ambiguity) beams are omitted, as is the near field.

processing time window, as in Fig. 3. Area coverage of the sea floor can be obtained either by an assembly of one beam of successive shots along the ship's track or by beamforming from forward to backward endfire for one shot. The first method is frequently applied at high frequencies using directional transducers to form unique broadside beams on each side ("side-scan"). The second method can be used with a low-frequency, omnidirectional source to achieve longer ranges. Problems due to right/left ambiguity of the linear array of omnidirectional hydrophones may be avoided or reduced by careful measurement geometry [7,8] or by averaging images obtained with different array headings [9,10]. In either case, area coverage of the seafloor scatterers can be obtained and the scattering level of a resolved feature may be estimated.

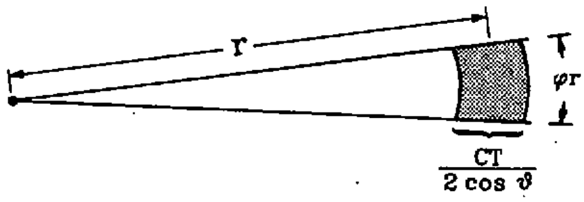

FIG. 3
SCATTERING AREA AT SMALL GRAZING ANGLES FOR A DIRECTIONAL MEASUREMENT (Approximate dimensions for simple case). C is the sound speed in water, T the processing time, φ the beamwidth (rad), ϑ the grazing angle at the bottom, and r the range.

An appropriate parameter describing the signal loss of a resolved feature may be calculated from the received level, RL. For a process of totally incoherent scattering, the scattering strength S, in dB/m^2, expressed in terms of the sonar equation, is

$$S = RL - SL + 2\ TL - 10\ \log dA \quad , \qquad (1)$$

where TL is the one-way transmission loss, SL the source level, and dA the effective scattering area of the bottom in m^2. All other units are in dB re 1μPa. If the process is entirely that of specular reflection from an area of the seafloor greater than one or two Fresnel zones, a reflection loss ("bottom-loss") BL would be more appropriate:

$$BL = SL - RL - TLI \quad , \qquad (2)$$

where TLI is the transmission loss over the (two-way) image path. If the process involves a combination of scattering, reflection, and diffraction, then the estimated parameter may have errors or may be inappropriate.

MEASUREMENTS

Scattering measurements were made in the southern Tyrrhenian Sea at the location shown in Fig. 4 with an explosive SUS source (0.8 kg TNT) set at 245 m depth near a receiving array towed at 100 m depth. The measured signals at 32 hydrophones were split into 0.34 s processing segments. For each processing segment a frequency-domain beamforming procedure (Fig. 5) was performed to obtain averaged beam-power levels for beam azimuths corresponding to 128 azimuths of the central frequency of a 60 Hz band for 5 frequencies over the range of 200 to 750 Hz. Repeating the beamforming procedure for adjacent processing time segments gives a display of the geographic location of large-scale features of the sea floor that scatter sound back to the array.

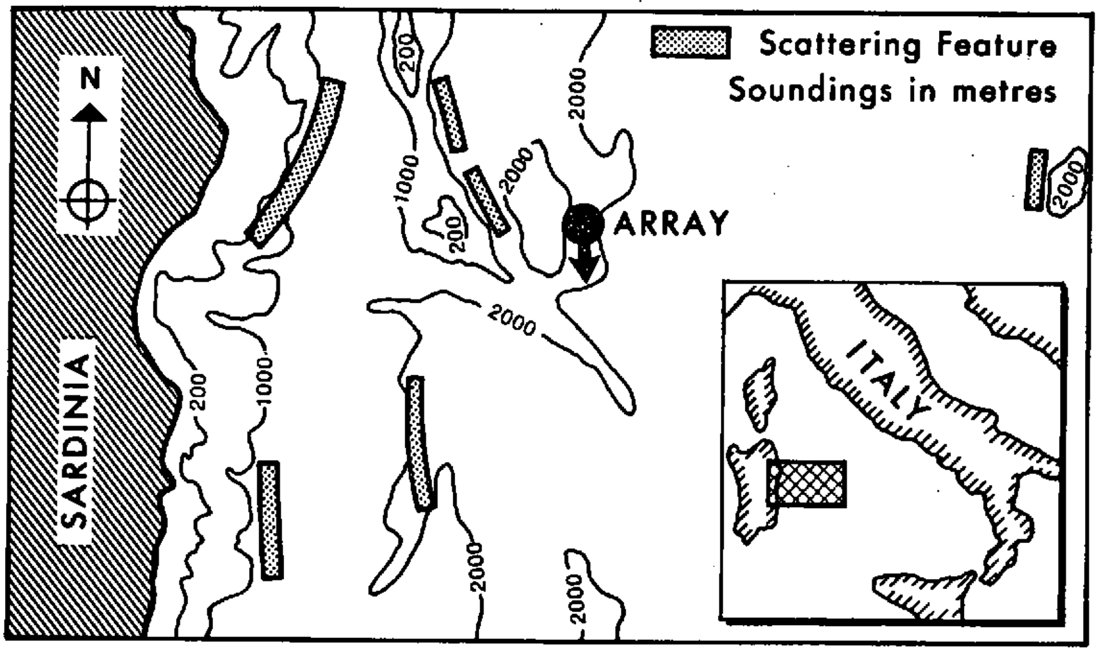

FIG. 4
LOCATION OF SCATTERING MEASUREMENT AND INTERPRETATION OF SCATTERING FEATURE LOCATIONS.

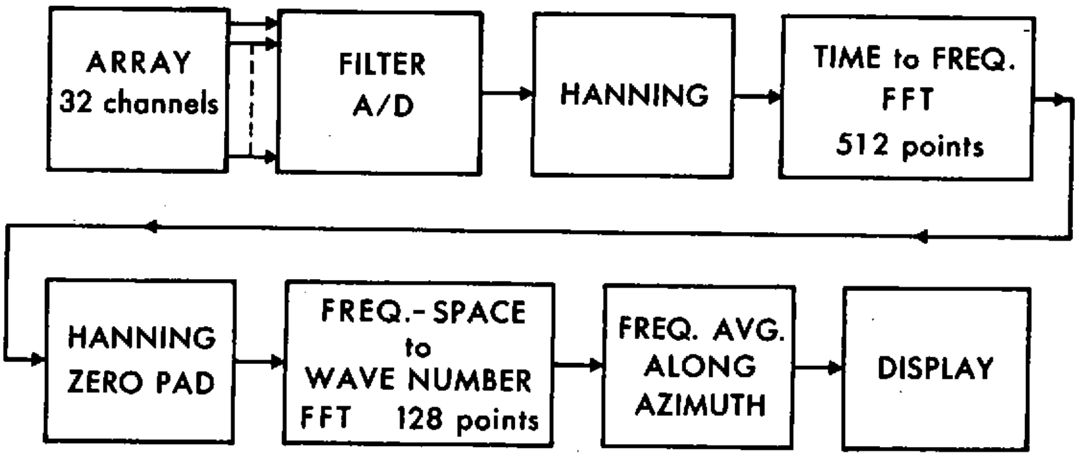

FIG. 5
ACQUISITION AND PROCESSING SYSTEM

An example of a beam-time history at 715 Hz is shown in Fig. 6. The direct arrival is followed primarily by high-grazing-angle arrivals, which are high on all beams because of side-lobe reception of the overloaded signals. Then follow arrivals primarily due to backscattering from features of the sea floor. The record also contains artifacts due to continuous arrivals unrelated to the explosive source: (a) at 0° due to common-mode noise, (b) at -90° to -60° due to towing-ship noise, and (c) at 50° to 90° due to noise from other ships. The major backscattering features are related to the coast of Sardinia and the Baconi seamount chain. An interpretation of the location of the major scattering features of the seafloor for this frequency and experimental geometry is shown in Fig. 4.

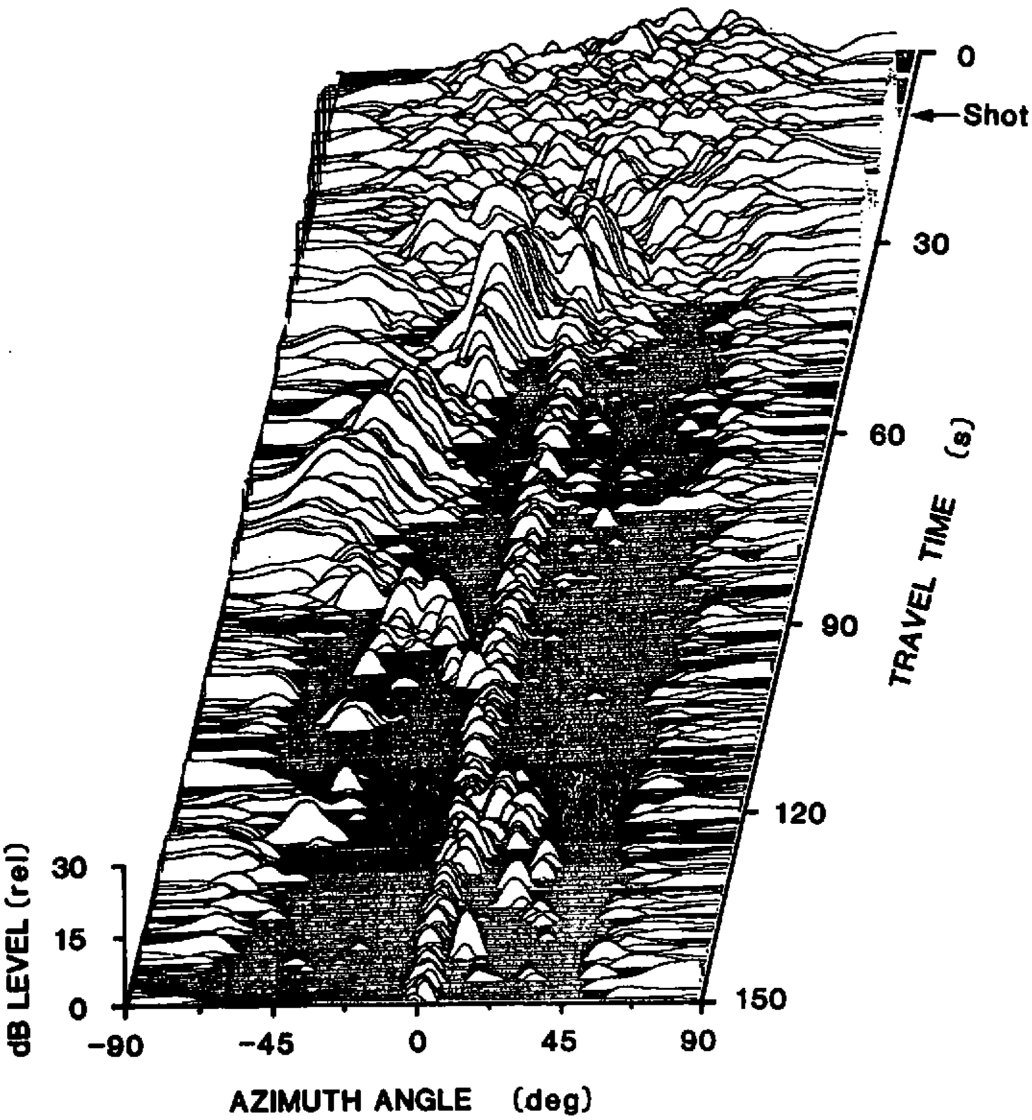

FIG. 6
BEAM-TIME HISTORY AS A FUNCTION OF AZIMUTH
AT 715 Hz and with 60 Hz BANDWIDTH

Scattering strengths for slopes of the Baconi seamount chain were calculated using Eq. (1) and are shown in Fig. 7 as a function of frequency. Also shown are other scattering-strength data determined from directional measurements at low frequencies in the southern Tyrrhenian Sea [6] and the Arctic Ocean [11]. The frequency dependence of the scattering strengths of these data does not appear strong. This is in agreement with most measurements of scattering from the seafloor at frequencies of 2 kHz to 100 kHz [12]. More data are required to establish this relationship at low frequencies. However, at this point these limited data certainly do not suggest the very strong frequency dependence (about 1.6 power dependence, or 4.8 dB per octave) found in some of the 13 to 290 kHz data of McKinney and Anderson [13].

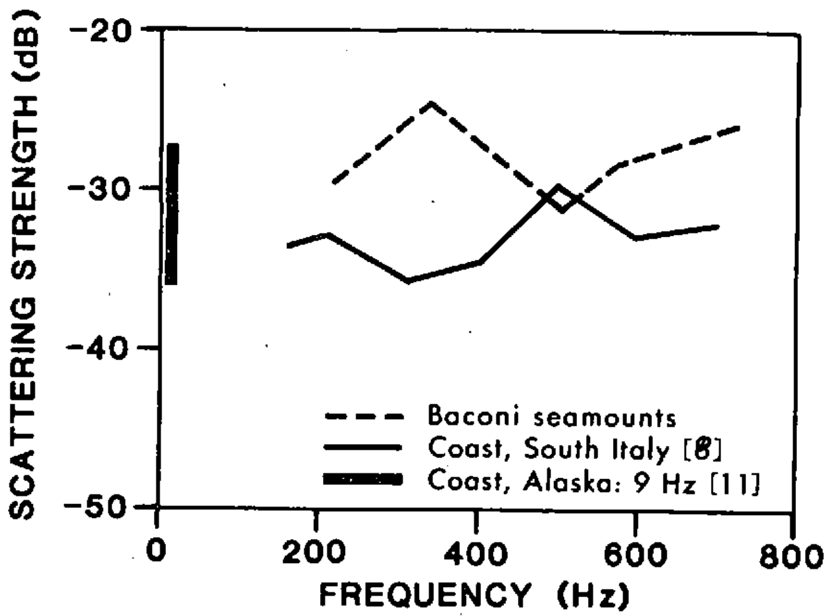

FIG. 7
SCATTERING STRENGTH MEASUREMENTS

CONCLUSION

Directional measurements of backscattering were made with an omnidirectional explosive source and a linear towed receiving array. The hydrophone signals received from scattering from the sea floor are processed to form beams from forward to backward endfire. The data are displayed as images of the scattering features of the sea floor at low frequencies. The scattering strengths of features in the area of the experiment do not exhibit a strong frequency dependence. However, more data are required before establishing the frequency dependence of low-frequency scattering from the various sea floor types. Also there is a need for additional experiments in which the transmission loss, a major factor in the calculation of scattering strengths for long-range measurements, is actually measured at the time of the scattering experiment rather than calculated later.

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