

# Use of Sparker Signal to Classify Seafloor Sediment

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## ABSTRACT

During the cruise 190 of *R.V. Gaveshani*, the sparker signal was recorded in the analog form on audio cassettes. This signal has been digitized and a statistical computation, viz. the normalized cross-correlation function between successive echoes, has been determined from it. The normalized cross-correlation function is used to calculate the amount of coherence between consecutive echoes. The values computed are differentiated into different groups based on the reference classification of Drapeau and King (1972) and Fader *et al.* (1977). The results obtained helped in determining the sediment type.

## INTRODUCTION

Efforts have been made over a long period of time to use acoustic signals as a rapid and efficient means of remotely classifying the seafloor sediment. With proper interpretation, acoustic techniques can provide averaged information over large swath areas.

The echo return from the bottom consists of the coherent and the incoherent component. A measure of the coherent return gives an index of the sediment roughness which can be further related to a particular sediment type.

For normal incidence, the acoustic energy returned from the oceanfloor is the sum of:

- i) the energy returned specularly from the water - sediment interface
- ii) the energy scattered from the insonified area, and
- iii) the energy returned by scatterers within a particular layer.

The proportion of the coherent and incoherent energies in the echo is determined using statistical methods. The cross-correlation function assesses the rigidity of the coherent component in the echo over small spatial translations. Fluctuation of the measurement has been minimised using ping to ping averaging.

### SIGNAL PROCESSING

An EG&G sparker was used during the cruise 190 of *R.V. Gaveshani* on line  $\phi 1$  in the region around  $15^{\circ}$  North and  $73^{\circ}$  East [8], as shown in Fig. 1. The power output used was 8 kJ for which the useful group of frequencies lies in the range 40-600 Hz. The sparker return and the trigger from the EPC recorder were stored on a dual channel analog tape recorder.

The sparker signal was post-processed in the laboratory. The signal was passed through a band pass filter (40-600 Hz) and a delay circuit [6], was then fed to a 12 bit successive approximation PC programmable A/D converter, as shown in Fig. 2. The signal was fed to a delay circuit to begin digitization at the arrival of the peak

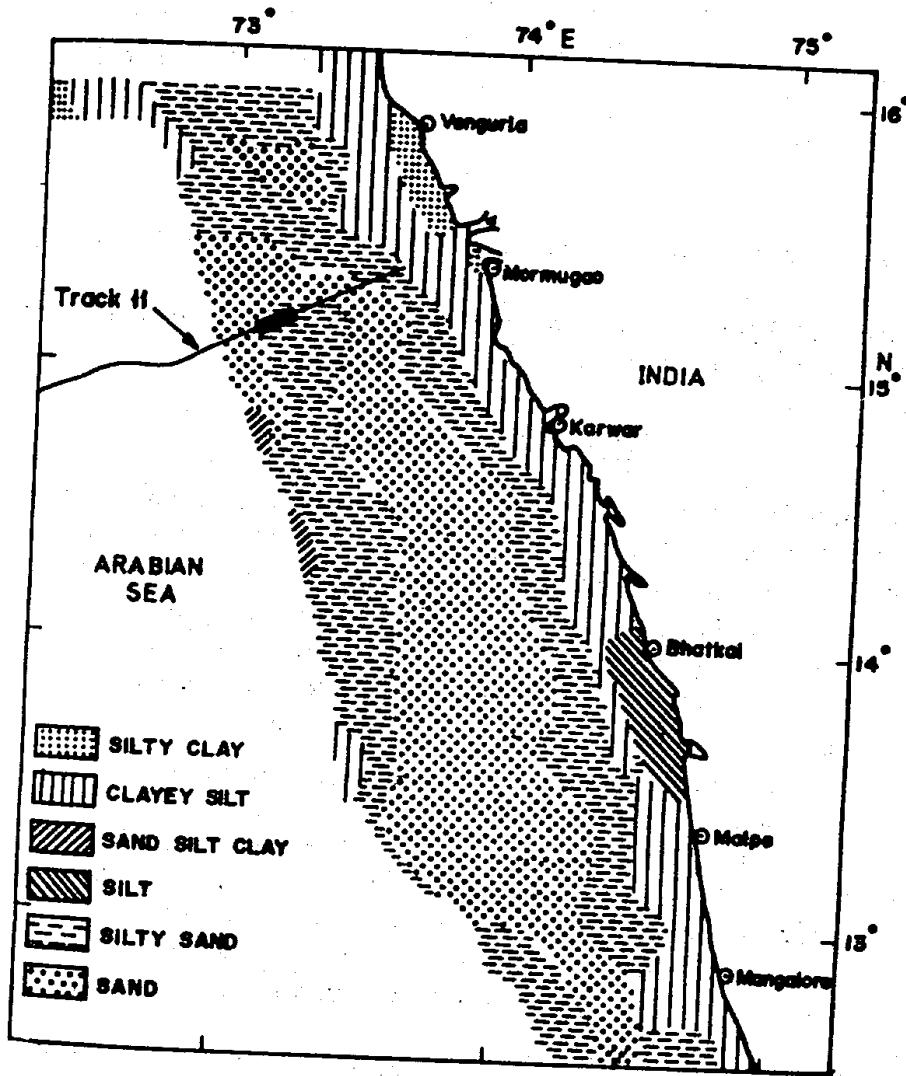


Fig. 1 — Surface sediment distribution along a part of the west coast of India with a superimposition of the track analysed

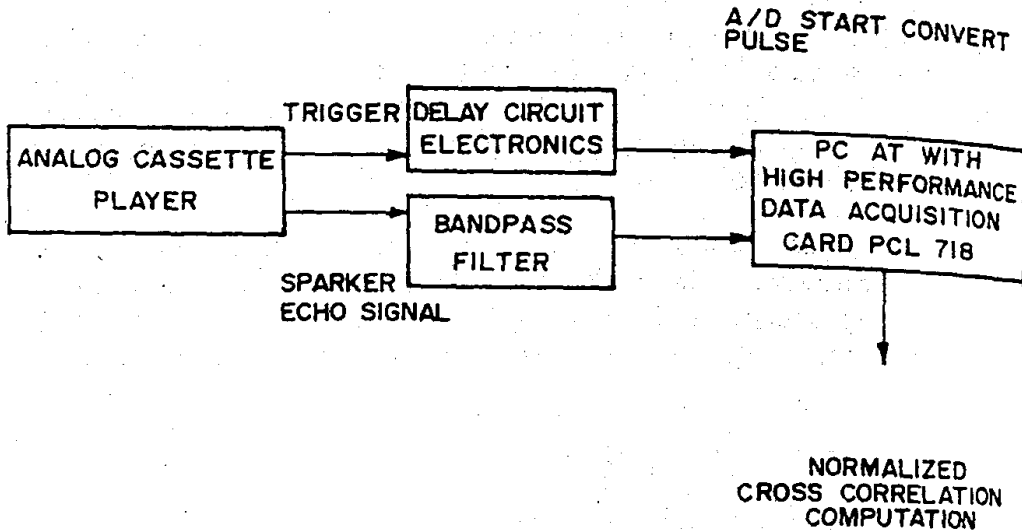


Fig. 2 — Flow diagram of the echo processor used for sparker signal processing

from the water bottom interface. Sampling frequency of 10 kHz more than satisfied the Nyquist requirement.

### STATISTICAL METHOD

A smooth bottom returns energy in a coherent fashion, while a completely rough bottom scatters the incident energy [1]. For a bottom with intermediate degrees of roughness, the echo shall contain proportions of coherent and incoherent energy. The statistical method used evaluates the proportion of coherent and incoherent energies in the bottom echo and thus a measure of the sediment roughness. The result helps to associate the sediment roughness to a particular sediment type.

The normalized cross-correlation method is based on the assumption that for spatial translation of the sound source, the coherent component changes slowly over a smooth bottom, while for a rough bottom the incoherent component varies rapidly from ping to ping. Hence, a smooth sediment would reflect a highly coherent form of energy, while the return from a rough sediment would fluctuate rapidly over a short time period. The normalized cross-correlation is used to measure the coherence between consecutive echoes.

The successive echoes can be represented as

$$\{e(t)\} = e_1(t), e_2(t), \dots \dots \dots e_n(t)$$

The normalized cross-correlation function between the  $j^{\text{th}}$  and the  $(j+1)^{\text{th}}$  echo is then defined as [4]:

$$C_{j,j+1}(\tau) = \frac{R_{j,j+1}(\tau)}{[S_j \cdot S_{j+1}]^{1/2}}$$

The numerator  $R_{j,j+1}(\tau)$  is the cross-correlation between the  $j^{\text{th}}$  and the  $(j+1)^{\text{th}}$  echo and is defined as:

$$R_{j,j+1}(\tau) = \langle e_j(t) e_{j+1}(t-\tau) \rangle$$

where  $\langle e \rangle$  represents the time average.

$S = \langle e_j^2(t) \rangle$  is the energy in the echo  $e_j(t)$

where  $e_i$  represents the  $i^{\text{th}}$  echo. An individual echo was digitized to get 300 samples using a 30 ms window beginning from the peak due to the water-bottom interface. Hence, samples from the  $i^{\text{th}}$  echo could be represented as

$$e_{i1}, e_{i2}, \dots, e_{i300}$$

Thus,

$$C_{1,2}(\tau) = \frac{e_{11} e_{21} + e_{12} e_{22} + \dots + e_{1300} e_{2300}}{[(e_{11}^2 + e_{12}^2 + \dots + e_{1300}^2) (e_{21}^2 + e_{22}^2 + \dots + e_{2300}^2)]^{1/2}}$$

$C_{1,2}$  is the normalized cross-correlation between the first and the second echo. Similarly, the cross-correlation coefficients for successive echoes were determined for 245 transmissions over a track distance of approximately 2.2 km. This track is highlighted by the dark line in Fig. 1.

The following threshold values for the classification of sediments have been taken from the reference classification of Drapeau and King [2] and Fader *et al.* [3]:

- i) Silt:  $0.725 < C < 1.0$
- ii) Sand, gravel:  $0.625 < C < 0.725$
- iii) Clay:  $0.575 < C < 0.625$

The results of the analysis are given in Table 1.

Table 1 — Results of the Analysis

No. of echoes analyzed	$0.3 < C < 0.525$	$0.525 < C < 0.625$	$0.625 < C < 0.725$	$0.725 < C < 1.0$
245	6	8	51	180

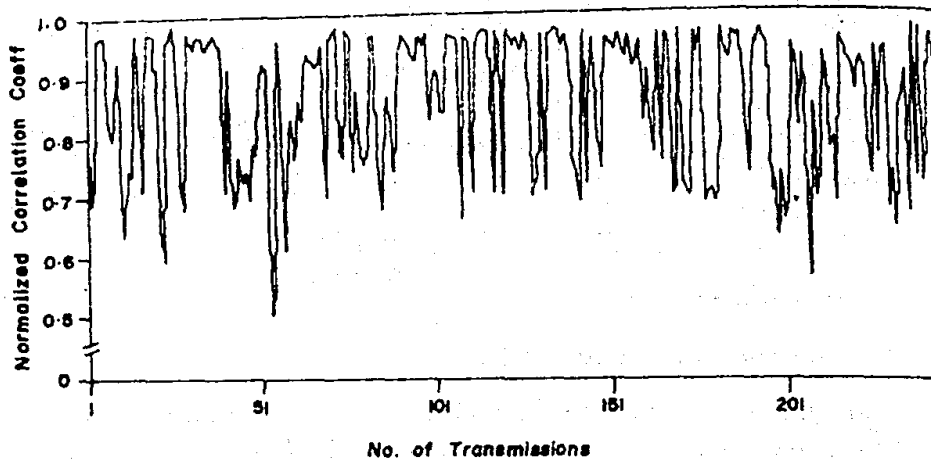


Fig. 3 — Plot of the normalized cross-correlation coefficient for successive transmissions

The value of the normalized cross-correlation coefficient obtained (Fig. 3) lies between 0.625 and 0.725, which corresponds to silt when compared with the reference classification table. The correlation coefficient obtained from the silt is of a higher value, since silt is a smooth stratified sediment and reflects strongly in a coherent manner. The ground truth is obtained from the map in Fig. 1 [5] showing detailed sediment distribution in the western continental shelf of India, which indicates sandy silt and is in closeness with the results of the analysis. A small database has been used to get the above results. A different method of analysis involving determination of the probability density function of the peak has also been employed earlier in the case of the sparker data in a different area [7]. The results of both these methods conform to the ground truth.

### CONCLUSION

A statistical method has been used to assess the coherence between successive echoes. The method is based on the assumption that sediments which are smooth in nature have a larger coherent component and thus the value of the normalized cross-correlation coefficient would be higher for such sediments. The results of the analysis of the sparker signal over a short track closely match with the ground truth results. A more detailed processing to correlate the results of analysis with ground truth over a larger track distance will form part of the future work.

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