

# Nodulebottom Backscattering Study Using Multibeam Echosounder

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## Abstract

A study is carried out to observe the angular dependence of backscattering strength at nodule area where grab sample and photographic data is available. Theoretical study along with the experimentally observed data shows that the backscattering patterns are same for the same area though the levels are different.

## Introduction

Sonar profiling of the seafloor is a routine method for various applications such as geological properties, and resource evaluation for polymetallic nodules [1, 2]. The use of multibeam sounding system is a current day technique for mapping of the seabed, because of its sidelobe suppressed multinarrow main beams and wide coverages [3]. Furthermore, the multibeam system can also be a potential system for backscattering application for bottom characterization. In order to estimate the abundance and size of the nodules lying on the ocean floor, scattering of sound signal from a nodule bottom must be studied.

An experiment was performed operating multibeam sounder system (Hydrosweep System) at nodule bearing area. The ground truth of the sea floor, where the experiment is conducted, is known in the form of grab sample and underwater photographic data [4, 5]. The experimentally collected backscattered information is then compared with a theoretical study, to determine the exact backscattering signal level for the nodule area.

## Nodule Bottom Scattering Experiment

The multibeam sounder system installed on 'ORV Sagarkanya' is known as 'Hydrosweep System', manufactured by 'Krupp Atlas Elektronik GmbH, Germany'. A detail description is available in publication by Raju [6]. In the Hydrosweep system (operating frequency is 15.5 kHz), backscattered signals are collected using an additional terminal (WY-80) interfaced to the 'depth tracking module'. The backscattering amplitudes for different angles are obtained based on the reflected preformed beam number through the terminal. The received 72 channel signals across the transducers are preamplified, attenuation corrected and thereafter beams are formed at the output of the beamforming network. The preformed beams are then used for the depth determination at bottom tracking unit using necessary windowing and centre of mass calculations. In our study we have used beams near the centre beam which is upto 20°.

An extensive oceanographic survey has been carried out in the Central Indian Ocean Basin for the exploration of Polymetallic nodules, and grab samples along with photographic data are collected and interpreted [7]. The average nodule diameter and number density of the nodule of the area (the present experimental is being between latitude 10° 00'S and longitude 75° 25'E) is calculated to be 3.4 cm. and 92 (nodule/m<sup>2</sup>) respectively. The calculated abundance from grab sample is 3.2 Kg/m<sup>2</sup>.

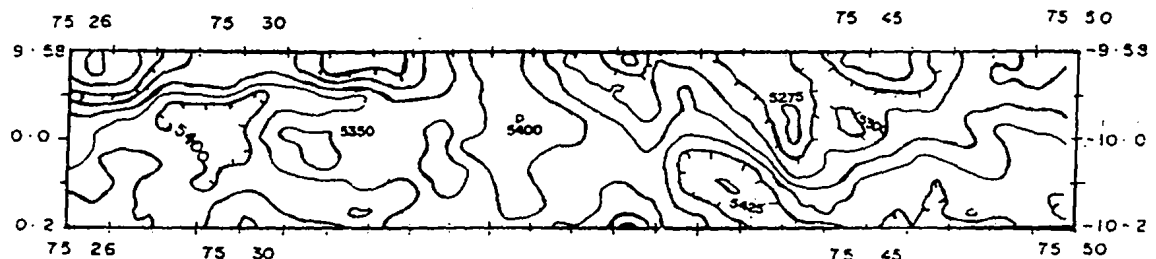
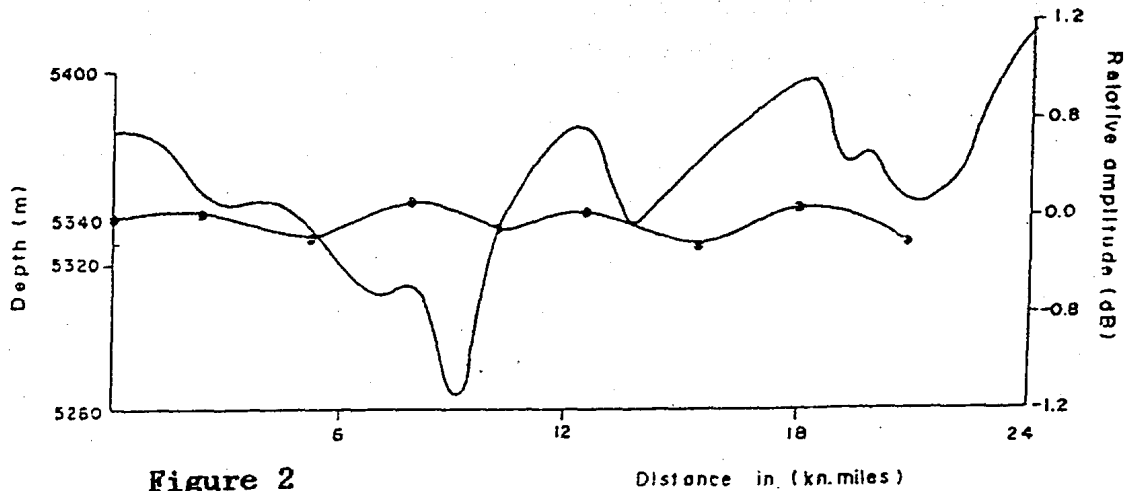


Figure 1

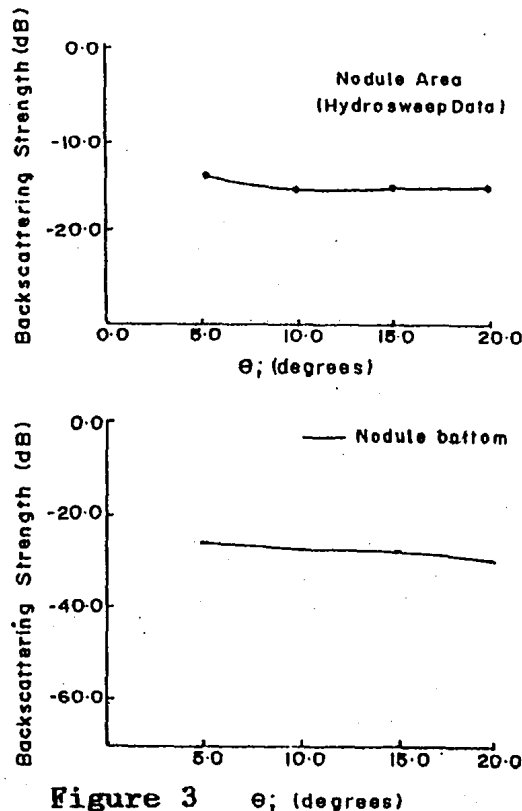
CONTOUR INTERVAL 25 mt.

Using Hydrosweep system, a bathymetry map of the experimental area is presented in Fig. 1. The map reveals that the undulations in bottom topography is low and the average depth is 5400m. A plot is drawn between centre beam depth, relative amplitude for centre beam data with distance in nautical miles as in Fig. 2. The mean amplitude is found to be varying between +0.6 dB to -2.1 dB which is averaged over six transmissions. The maximum variation of centre depth is found to be 140m and changes in centre beam backscattered signals at different points is found to be less in the entire track. Though it is difficult to conclude about the presence of nodules, but a dependence of amplitude level with the depth is obtained.



**Figure 2**

In order to observe the angular dependence of backscattering strength in the nodule area, the present experiment is extended for the incidence angles of  $5^\circ$ ,  $10^\circ$ ,  $15^\circ$  and  $20^\circ$ . The backscattered data at different angles are averaged for six transmissions, which is normalized with respect to the peak values at normal incidence angle. A clipping of the peak amplitude is frequently encountered for normal incidence angle and sometimes which is used as an information for same transmission. Unchanged backscattered level i.e., -13 dB (Fig. 3) from  $5^\circ$  to  $20^\circ$  angles at nodule area confirms the fact that the backscattering strength is angular independent which is supported by Zhitkovskii [8] and Brekhovskikh et.al [9]. The backscattered levels of the present study is not accurate though the patterns are similar with the results shown by above workers. The cause of the inaccurate values of the backscattered levels may be due to the lowly resolved analog/digital output at bottom tracking unit.



**Figure 3**

## Theoretical study

In order to know the theoretical backscattered pattern at nodule area where experiment is carried out, we have developed an expression to compute the backscattered strength of nodules. The magnitude of the scattered signal is given by [10]

$$|p_n| = \left| \left( \pi \rho_n R_0 / ka \right) \left\{ 1 / [1 + j \beta / kr] \right\} \right| P / 2r$$

where  $\rho_n$  is the number density, 'a' is the root mean square radius of the nodule which is 1.7 cm.  $\rho_n$  is 92, the values of  $\rho_n$  and 'a' are computed based upon the grab sampled data where experiment is carried out. P is the transmitted power and assumed to be unity. r is slant range for different incidence angle. The term ' $\beta$ ' is a measure of the half power beam width

$R_0$  is known as a scattering amplitude for a single nodule of elastic sphere and is expressed as

$$R_0 = 2 |f| a$$

The modulus of scattering function (f) for single elastic sphere with  $ka \ll 1$  given as [11]

$$|f| = a(ka)^2 \left\{ \frac{E - [1 / (1 - 4 / 3 H^3)] + \cos \Theta}{3E} \cdot \frac{G-1}{2G+1} \right\}$$

The term E is expressed as

$$E = G c_l^2 / c_o$$

and  $c_l$  is longitudinal sound velocity of the nodule and  $c_o$  is the sound velocity of the surrounding medium. For our case,  $c_l$  is 2123 m/s for nodules at Silicious clay region of Indian Ocean [12]. Because in our experimental area where nodules are lying on Silicious clay bottom  $c_o$  is 1500 m/s, the velocity of liquid layers, known as acoustically transparent layer [13]. The ratio term G is written as

$$G = \rho_n / \rho_o$$

' $\rho_n$ ' is the density of the nodule 1.98 gm/cc and ' $\rho_o$ ' density of surrounding medium i.e., transparent layer (1.0 gm/c.c.). The term 'H' is given as

$$H = c_t / c_l$$

$c_t$  is transverse sound velocity of nodule. The values of  $c_t$  of Indian Ocean nodule at Silicious clay region is 1083m/s [13]. Fig. 3 shows that the theoretically computed backscattered strength at nodule area for different incidence angles. The computed backscattered values are found to be independent of angle of incidence and average backscattered sound level is -26 dB. The backscattering pattern observed in experimental area is similar with the above study though the level is different.

## Conclusions

The study of backscattering strength for centre beam depth data for multibeam sounder reveals that the amplitude information is sensitive to the depth profile. From present study, the experimental backscattered data and theoretical study at nodule area ensures that the backscattering strength is independent of incident angle.

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