Acoustic Studies at and Around *Dakshin Gangotri* Antarctica

H.R.S. Sastry

Naval Physical and Oceanographic Laboratory, Cochin

ABSTRACT

During the Second Indian Scientific Expedition to Antarctica, a programme of studies in the fields of acoustics, seismology, physical oceanography and hydro-acoustics was successfully carried out The details of the experiments and the results are presented in this paper The seismic studies indicated the existence of a sedimentary layer below the ice shelf with characteristics similar to those of strata off the Indian Coast. Acoustic studies on ice cracks led to the determination of characteristic frequencies of the ice crack sounds. Ocean thermal structure was recorded upto 450 m by using XBT in Southern Indian Ocean Existence of sound channels in shallow depths of 10—100 metres was established in the ocean near Antarctica Sonar ranges in these sound channels were calculated The advantage of cylindrical propagation in the sound channel is offset to some extent by the higher attenuation co-efficient values at low temperature and high salinity Noise spectra of the sounds from birds, penguin and skua, are presented Finally, a few recommendations are made for the benefit of future expeditions to Antarctica

INTRODUCTION

Acoustic studies of ice cracks

The ice sheet of Antarctica develops certain cracks especially during summer time for various reasons like tidal effects near the coast, melting of ice due to sun's heat etc. Such cracks develop both in pack ice and in continental ice cap including ice shelf.

These cracks give out acoustic omissions during the initial stages of their development when they are not wide. In pack ice, these sounds omitted by the cracks are of very short duration and repeat themselves at a frequency of four to six pulses per minute. These sounds can be heard in air and are considered to be similar to those of breaking ice. It may be some sort of a surface phenomenon.

Scratching type of sounds are heard when two ice blocks — one from pack ice and the other from ice shelf-move with respect to each other. This sound resembles that of pulling a coir rope around a wooden pole and it may be due to slippage of the two ice blocks.

Glaciological studies, carried out by scientists from Geological Survey of India near these ice cracks, indicated that the two ice blocks slipped over 10° in a period of four days.

The sound was recorded using B & K hydrophone type 8100, B & K precision conditioning amplifier type 2650 and cosmic deck type CO-703 D.

Seismic studies

Seismic studies were carried out on the Antarctic ice shelf near our Base Camp using plastic explosives. The experimental site is situated very close to our Base Camp in Princess Astrid Kyst in Dronning Maud Land of Antarctica. The Base Camp is situated about 5 km interior from the edge of the ice shelf at a latitude of 69°59'S and a longitude of 11°55'E.

Traverse was laid along North-South direction covering a range of 1.925 km. The distance between any two successive geophone locations was 175m. Except for two locations of N_1 and S_1 for measurement from all other locations, the shot point location was offset from otherwise normal symmetrical as read.

Miniature digital grade geophones type HP 1-A of M/s Syn-Tex Geophysics Inc., USA were used to sense the seismic waves. They have low distortion of less than 0.1% and low profile for noise reduction. They have high out-put-to-weight ratio and operate at a frequency of 8 Hz.

The output signals from the geophones were recorded on a tape in the field. The seismic records were obtained in the laboratory using a refraction recording system consisting of Model RA-44A Geophysical Amplifier and Model R-6B Recording Oscillograph of SI E Division, M/s Geosource Inc., USA

Ocean thermal structure

Studies on ocean thermal structure were carried out using expendable bathy-thermographs (XBT) in the Southern Indian Ocean. XBT launcher and probes developed by Naval Physical and Oceanographic Laboratory, Cochin (Manufactured by M/s ECIL, Hyderabad) were used in conjunction with Plessey/Sippicon XBT Recorder, The recorder can record temperatures from $-2^{o}C$ to + 35 C and it can give a continuous record of ocean thermal structure upto 450m. The probes were released from hand held launcher. The launcher developed some mechanical trouble after sometime and no records could be obtained due to lack of proper contact on pins A, B and C. After a detailed study of this problem, it was decided that the defect could not be rectified on board the ship and, therefore, an improvised technique was adopted, via. soldering of three connecting leads on every XBT probe before launching. It worked very well and good BT records were obtained. Thus ocean thermal structure was studied over a wide area ranging from tropical waters of Indian Ocean to cold waters of Antarctica.

Hydro-acoustic studies

Sound channels: A negative sound velocity gradient followed by a positive sound velocity gradient leads to a situation where sound propagates in this "channel" with more or less cylindrical spreading. It gives longer sonar ranges compared to those under spherical spreading. The existence of sound channels can be studied from the ocean thermal structure data. Occurrence of sound channels in shallow depths can be used to advantage for long range underwater communication and detection.

Underwater acoustic propagation studies: An experiment in underwater acoustic propagation in the cold waters around Antarctica was planned to be carried out using explosives as sound sources. However, this experiment could not be carried out for the following reasons:

(a) The Captain of the ship, *Polar Circle,* refused permission to detonate any quantity of explosive charge from on board the ship though he was assured that the detonation would be at a safe distance from ship. He argued that the whole team be left behind at Antartica in case of any unforeseen accident.

(b) Detonation of explosive charges standing on the edge of the ice shefd was not permitted by the Leader of the Expedition as it might be risky to human life.

Bio-acoustic studies: The noises of penguins and skuas were recorded on a tape and it would detailed bioacoustic studies on these two antartic birds.

RESULTS AND DISCUSSIONS

Acoustic studies of ice cracks

Typical spectrum of ice crack sounds is shown in Fig 1

Spectral analysis of the noise has indicated two different groups of frequency components The one corresponding to ice breaking covers a frequency spread of 300 to 2500 Hz The one corresponding to ice slippage, also perhaps associated with breaking, gives a second group of frequencies extending from 3000 to 5000 Hz, besides the earlier group of frequencies Some of these sounds extend in frequency even upto 10,000 Hz though with reduced amplitudes The ice crack sounds have a repetition rate of four to six pulses per minute The spectral composition is somewhat different from one sample to another In view of these facts and also because of large number of records available, computer aided studies on spectral distribution of ice crack sound energy are in progress and a separate paper will be issued in due course

The variation in spectral composition is most likely due to different ice mass that is involved in breaking at different times Also depending on the distance between the measurement position and the origin of ice breaking, there will be attenuation of high frequencies

Seismic studies

Typical seismograms obtained from the studies at Antarctica are shown in Figs 2 and 3 and the shot detector distance *vs* travel time curve is given in Fig 4

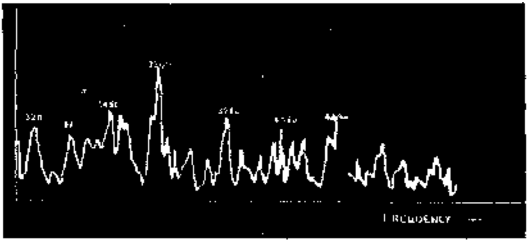

fig 1 A typical noise spectrum of IU. *L* nk

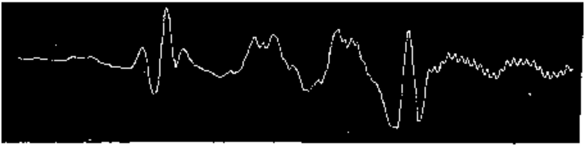

Fig 2 Seismic studies it Antarctica

As per the preliminary analysis, there are three prominent layers The first layer corresponds to a P-wave velocity of 1550 m/sec It indicates water On the ice shelf where the seismic studies are carried out, the ice has a density varying between 0 4 and 0 5 and velocity of sound within this ice is not much different from that of water Therefore, water and ice have.appeared like one layer with a thickness of 150 m

The second layer is a sedimentary layer with a P-wave velocity of 2330 m/sec This velocity suggests sandstone deposits in the sedimentary layer which has a thickness of 1500 m

The third layer is a secondary layer with a P-wave velocity of 3700 m/sec The secondary layer may contain volcanic rocks or transoceanic crust

The existence of a sedimentary layer and secondary layer below the ice shelf of Antarctica is similar to the strata off Indian Coast Whether these sedimentary and secondary layers contain fossil fuels is a problem that warrants detailed studies

Fig 3 Typical seismogram recorded at Antarctica.

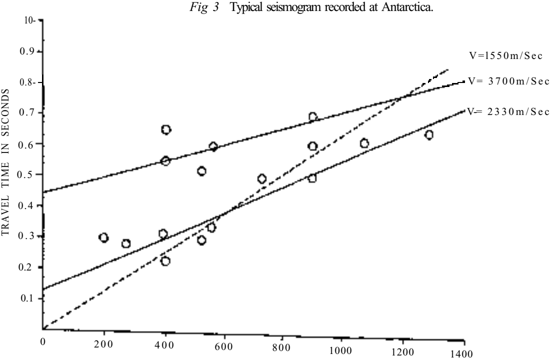

Fig.4. Travel time versus distance curve

Ocean thermal structure

The variation of thermal structure in the Indian Ocean from warm waters near the equator to cold waters around Antarctica is shown in Fig 5

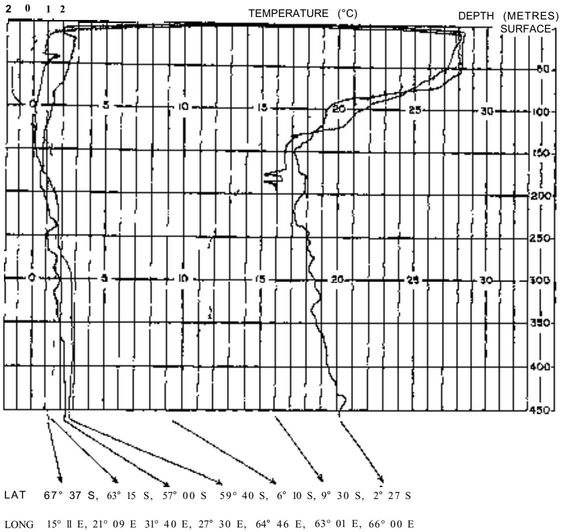

Fig 5 Comparison of the thermal structure between warm tropical waters and cold Antarctica water in Indian Ocean

It may be seen from the above figure that the isotherm that extends upto nearly 55 m at 2°S latitude practically disappears near 60 S latitude Further a steep thermocline so characteristic of warm tropical waters is not to be seen in the Southern Ocean While a deep sound channel occurs in tropical waters at an approximate depth of 1000-1500 m it has occurred almost from 10 m below the surface in the cold waters. A channel has not been formed at latitudes 57°S and 59°S But we can see a well formed sound channels at latitudes 63°S and 67°S. It clearly shows that the phenomenon of shallow sound channels occurs in the ocean south of 60°S latitude Also there is a vertical mixing of surface and deep sub zero waters and we get an almost uniform isothermal structure from 100 metres downwards.

Hydroacoustic studies - Sound channels

A typical bathythermograph (BT) record from the cold Antarctic waters at 67 37 S latitude and 15 11 E longitude is shown in Fig 6

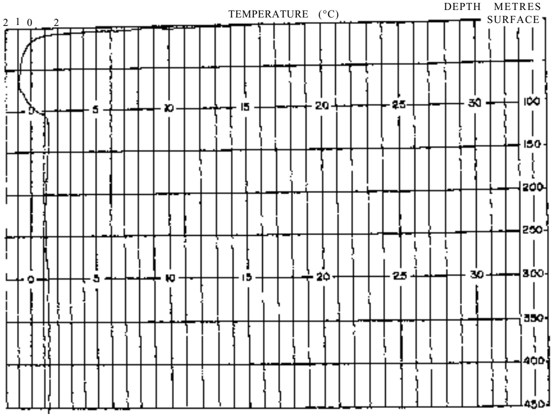

Fig.6. Ocean thermal structure at Lat. 67˚ 37" S and Long. 15˚ 11 E at 2200 hrs. on 26 Dec; 1982.

A well formed sound channel can be observed from the above BT at a very shallow depth starting from 10 m and extending upto 110 m with its apex around 50 m

The sonar ranges in these shallow sound channels can be computed if sound attenuation coefficient for these waters is correctly known Underwater acoustic propagation experiments planned to be carried out to obtain attenuation coefficient values could not be carried out due to safety reasons as explained earlier

The sound absorption coefficient in seawater increases with decrease in temperature and increase in salinity. Further in polar regions the sound propagation has one peculiarity of being similar to a band pass filter While the best propagation occurs in Arctic region in a frequency band of 15 to 30 Hz approximately both higher and lower frequencies are rapidly attenuated, the former by reflection losses from the ice cover and the latter by the fact that very low frequencies are not effectively trapped in the channel

For Arctic Ocean a sound absorption coefficient value of 11 db/kiloyard to 10 kHz was reported in literature (JASA 35 1963) For cylindrical propagation in a sound channel sonar range can be calculated from the formula

TL = 10 log R + R + 60

If the absorption co-efficient values known for Arctic region are assumed to be valid for Antarctic region also If FOM = 2 TL = 168 db (APSOH) and = 11 db at 10 kHz

R = 12 kyds

If FOM = 2 TL = 180 db (VDS 195) and = 1 1 db at 10 kHz

R = 16 kyds

It can be seen from the above computation that the advantage of cylindrical propagation is offset in polar regions by higher attenuation coefficient at lower temperature and higher salinity It is therefore imperative that one should work at much lower frequency, to achieve long range detection in freezing waters in the Southern Ocean around Antarctica

If shallow sound channels were not to exist, the detection range for a sonar of 168 db Figure of Merit (FOM) will be only 65 kyds at 10 10 kHz taking spherical spreading into account against 12 kyds in a sound channel where cylindrical spreading is considered

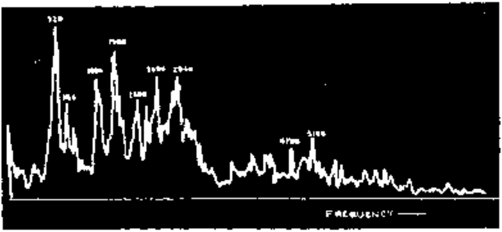

Fig 7 A typical noise spectrum of Skua

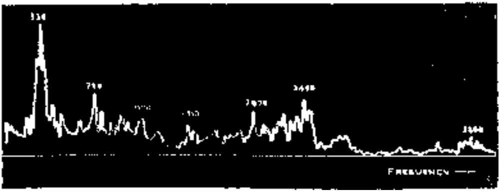

Fig 8 A typical noise spectrum of Penguin

Bio-acoustic studies

The noises of penguin and skua were analysed and it was found that skua has higher frequency components of noise compared to that of penguins Typical noise spectra of these birds are given in Figs 7 and 8

The penguin noise has peaks from 300 to 1200 Hz with a very prominent single frequency around 330 Hz It has a cluster of frequencies in its noise spread between 2000 and 2500 Hz

The skua noise has five prominent frequencies around 900, 1600, 1900, 2600 and 2900 Hz. Also high frequency components, though of smaller amplitude, extend upto 6000 Hz in contrast to 3000 Hz in case of penguin