ANTARCTICA—THE CHALLENGING CONTINENT*

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THE continent of Antarctica, which has hitherto remained least known, has been attracting the attention of scientists largely from the developed countries. Several expeditions had been undertaken in the past to know more and more about Antarctica which has often been referred to as the windiest, coldest and the stormiest of all continents in the world. Capt. Robert Falcon Scott, on reaching the South Pole on 17th January, 1912, said "Great God. This is an awful place". The development of Antarctic Science is linked with the earlier adventures and explorations. Antarctica is the 7th continent of the world, being much larger than Australia, or United States and Europe combined together. In the summer there is continuous sunlight for six months followed by continuous darkness during the winter.

Although man landed on Antarctica more than seven decades ago, his studies have largely been confined to the areas where he landed and where he built his bases of observation. This is because man in Antarctica is entirely dependent on the supplies he carries with him. This is unlike the Arctic where man can live by obtaining food from the environment and there has been a native population of Eskimos in the Arctic for centuries. The continent is almost lifeless. It has an area of 14 million square kilometres, most of which is covered with an ice sheet of 1.6 km of average thickness, varying from a maximum of 4.5 km to a minimum of 800 m. There is about 512,000 square kilometres of land mass which is free from ice. If the Antarctic ice were to melt, it would raise the world's ocean by about 60 metres.

The Indian Antarctic Program

The Department of Ocean Development decided that it would be useful from a scientific point of view to send a scientific expedition as it would add to our knowledge of factors relating to the Indian Ocean and the monsoon phenomenon. The ice sheet in Antarctica originated perhaps more than 50 million years ago and has continued since then, completely undisturbed by melt/freeze phenomena which occur, in the Himalayan glaciers. This Antarctic ice, therefore, acts as an extremely well-preserved repository of all things falling on it and buried in it such as fragments of cosmic bodies, nuclear products of cosmic rays, samples of entrapped air and minerals. Scientists from the world over have been experimenting to study and decipher these signals which undoubtedly provide records of global and cosmic changes over past millenia.

The glacial history and the past climatic changes being studied at present from the Himalayan ice samples and glaciers, etc are inextricably mixed with the effects of the spasmodic uplift (of thousands of metres) that these mountains had experienced. The Antarctica, which represents a stable situation affected only by global climate offers us a reference standard to separate the two sets of information and to refine the information about each set individually.

Studies on the mass balance of annual glaciers are at present providing us data about the current short-term climatic fluctuations in the Himalayas. Linking this to the annual changes in the sea regions of Antarctica is bound to yield important scientific insights into the global weather phenomenon, its changes and its effects on our environment. A study of the Antarctic waters, the meteorological conditions of the area and their influence on the physics, chemistry and

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biology of this area including the formation of the Antarctic bottom waters are of very great scientific and economic interest. Antarctica is crucial to global weather phenomena—the air circulation patterns, the cold phases and the sea currents. It, therefore, invites a study of its physical parameters like the radiation balance, water balance, temperature-induced phenomena, etc.

Indian science has now developed enough expertise and experience in various branches of geology, geophysics, oceanography, meteorology, astrophysics, space science and communication science to take up a detailed scientific study on the landmass of Antarctica and oceanographic studies in the surrounding seas. Keeping this in view, the Department of Ocean Development organised two scientific expeditions to the South Indian Ocean and Antarctica during 1981–82 and 1982–83.

Antarctica is attracting world-wide attention because of the tremendous biological bounty teeming in its surrounding seas and the likelihood of vast hydrocarbon and polymetallic nodule deposits on its continental shelf. The regime presently governing the activities on the continent was created by the 1959 Antarctic Treaty.

The scientific research in Antarctica can broadly be outlined as follows:

(i) Antarctica is an important location for observing the interaction of the earth's magnetic field in conjunction with charged particles from the sun.

(ii) The North and South Poles maintain the heat budget of the world in balance. The heat transported through the atmosphere and the oceans to the Poles is dissipated in space in the form of long-wave radiation.

(iii) The Indian, Atlantic and Pacific Oceans meet around Antarctica as a distinct body of water which girdles the earth and is uninterrupted by any land mass.

(iv) Antarctica is a stable platform for carrying out scientific observations. It is far away from all sources of environmental contamination and thus remains an unpolluted datum point from which global changes due to pollution can be monitored.

(v) The glaciers of Antarctica comprise about 90% of the earth's ice. This continent holds about 75% of the freshwater reserve of the earth.

(vi) Antarctic ocean supports a biological community of a few species with large populations and short food chain magnifications. The important organism regulating the simple food chain in the Antarctic waters is the red shrimp-like "krill".

(vii) In the mesozoic era, the super continent of Gondwanaland had a common landmass of the five continents, Africa, Antarctica, Australia, India and South America. Later, the continents drifted apart and formed oceans in between them.

(viii) Geologists believe that rich deposits of several minerals, oil, gas, polymetallic nodules, etc could be found in the Antarctic landmass and under the surrounding seabed.

The primary objective of the First Indian Expedition to Antarctica was to initiate some of our own research programs in these fields.

FIRST INDIAN EXPEDITION

The expedition code-named 'Operation Gangotri' was undertaken on an ice-breaker M.V. POLAR CIRCLE chartered from its owner A/s. G. C. Reiber, Bergen, Norway. Twenty one scientists, technicians and naval personnel were selected, after their physical and mental examination. The team members came from seven different organisations. After the necessary formality of loading essential equipment, stores and accessories, the ship sailed from Marmagoa harbour on 6 December 1981 and covered a distance of 10 000 km. The team after a very successful cruise, landed on Antarctica on 9 January 1982. A base camp was set up at Lat. 69°, 59′, 23.12″ S Long. 11°, 56′, 26.83″ E. It was considered an important landmark in Indian

Science. The Prime Minister sent a message of greetings to the team while it was still in Antarctica. The expedition, after a stay of 10 days on the frozen continent, returned on 21 February 1982. The duration of the expedition was 77 days and the total distance covered by the ship was 21 000 km.

Summary of the Scientific work carried out during the First Expedition:

On the way to Antarctica, the Indian team made a variety of observations and collected valuable data on atmospheric temperature, pressure, windspeed, humidity, surface ozone, cloud visibility and radiation. Many of these parameters were measured at 3 or 6 hourly intervals. An unmanned weather station was set up in Antarctica to measure wind speed, wind direction, air temperature, humidity, and casing temperature. A snow-cum-rain gauge for measuring snowfall was also left behind. The weather station is solar powered and during the winter months, when there will be no sunlight, fully charged heavy-duty batteries are available to provide power to the computer which will record the data on a cassette to be recovered later. The station was named "Dakshin Gangotri", located at Lat. 70°, 45′, 12.9″S Long. 11°, 38′, 13.6″E.

Experiments on very low frequency propagation (VL), high frequency (HF) propagation and noise levels showed that radio communication in Antarctica suffers from several problems. There are radio blackouts caused by the polar cap which last from a few hours to a few days. The non-conducting ice cover makes the operation of antenna difficult. Non-directional beacon transmitters from the helicopter operations were also found difficult to set up.

Ice samples, ice cores and ice crystals were collected from the ice-shelf and studies were conducted on the melting rate of ice as well as on the radiation falling over the ice for 24-hour periods.

Magnetic studies in the ocean were carried out using a marine proton magnetometer with a towed sensor. On the whole, 20,000 line km of magnetic data were collected from the sea. In magnetic studies on land, a proton magnetometer was used for recording the total field continuously. A fluxgate magnetometer which recorded the field component continuously was used and a digital component fluxgate was used to make on the spot observations, so that the sensitivity of fluxgate could be derived and verified.

Forty samples of aerosol were collected during the cruise by running an indigenously fabricated sampler. These measurements will give an insight into the pollution levels in the oceanic areas between Goa and Antarctica. Rock samples were collected in Antarctica from the out-crops. Dust and debris from within the ice-layers were also collected for petrological and geochemical studies. Some significant observations were made on pack-ice, bay-ice and ice-shelf.

A continuous temperature profile in the sea up to 70 m depth was taken between Goa and Antarctica, to understand the energy transfer mechanism. Seismic profiling of the ocean-bed was carried out. A productivity survey of the Indian Ocean and the Antarctic waters was accomplished. Distribution of chlorophyll-bearing plankton was studied to assess the primary productivity of Antarctic waters. Benthic studies were carried out on the bottom sediments (sea-floor) to evaluate the qualitative and quantitative aspects of life. Hundreds of water samples were collected for the chemical analysis of dissolved oxygen, phosphorus, nitrogen, silicate, calcium, magnesium, sulphate, fluroride, bromide and iodide. Several samples of primitive vegetation such as mosses and lichens from the rock crevices were collected for further investigations.

SECOND INDIAN EXPEDITION

During the year, after the successful completion of the first expedition, the Department organised a second expedition to Antarctica. The 28-member team successfully landed on the frozen continent on 28 December 1982.

Summary of scientific work carried out during the Second Expedition

Geological mapping of an area of 4.5 square kilometres on 1:10,000 scale, within the Dakshin Gangotri range Lat. 70°, 45′, 12.9″S, Long. 11° 38′, 13.6″E was completed.

The following studies were carried out near the base camp and far inland upto Dakshin Gangotri Hills (a) snow accumulation and ablation at the shelf (b) changes in the surface micro-relief of the shelf ice (c) nature of movement along the crevasses within the shelf ice (d) experiment on artificial augmentation of ablation of the shelf-ice (e) thermal profile of the shelf ice (f) crystal studies on ice (g) snow stratigraphy and density profiling of polar and shelf ice (h) studies on iceberg flow drift and stratigraphy.

In addition, a map of the Dakshin Gangotri glacier was made marking the terminal of the ice front. Ice core samples have been collected for dating purposes.

In all, 55 balloons were launched from Antarctica which included 8 low level sondes, 6 ozone sondes, 10 omega sondes and the rest radio-sondes. Lowest temperature recorded was $-15°C$ and the highest was $+8°C$. However, the average temperature was well below zero most of the time ranging between $-5°C$ and $-10°C$. Winds had a particular pattern of fluctuations with spells of calm interspersed between spells of high winds. The intensity of high winds was increasing towards the end of the stay. There were many clear days in January but cloudy spells increased during February—both low and medium clouds were present. Excellent visibility prevailed most of the time (upto 10 km) but during the storms it was reduced to 50 m. Strong reflection of solar radiation from the snow was the most interesting feature of the radiation measurements. Spectral measurements in the UV band showed no significant attenuation of UV in the reflected solar radiation. Temperature under snow showed a steep gradient going down to -13.5 at 20 feet sharpest gradient existed between the first 10 feet under snow. Diurnal variations were negligible.

VLF propagation experiment consisted of recording the VLF/OMEGA signal phase and the amplitude. The phase measurements were carried out with respect to an atomic frequency source. The VLF experiment had also been carried out during the previous expedition and similar conclusions were drawn regarding the quiet time Solar Zenith angle dependence of the D-region electron density. With more extensive data, these conclusions were reassessed.

Riometer experiment consisted of continuous recording of the extra terrestrial cosmic noise along the local zenith on two frequencies—20 and 30 MHz. The analysis of the cosmic noise variations will yield quantitatively the nature of the lower ionospheric variations during quiet time as well as during the geomagnetically disturbed conditions. Several cosmic noise absorption events have indeed been recorded. These events correlated very well with the poor long distance HF reception (from COMCEN Bombay).

A continuous set of observations was made on the temperature at the sea surface and at a level of 40 feet of humidity at the 40 feet level, and of the wind speed and direction at the 40 feet level. A computer program has been developed to compute the various heat flux terms. It is proposed to compare the heat flux computations as outlined above with the semi-theoretical model calculations worked out earlier.

Bacterial counts were taken from the shelf ice (at 5 stations) melt water (at 3 stations) and from the ice core (0, 0.5, 1, 1.5 and 2 m) taken from the ice shelf near the Indian base camp. Ice incubations were done to measure the productivity potential from the 13 samples collected from the shelf ice. Bacterial counts were taken from 5 ice samples and one core (0, 1, 2 and 3 m) was taken from the iceberg. These samples were incubated at 14°C to study the productivity potential of the samples collected from the iceberg.

Five lakes were studied for primary productivity and bacterial counts in the water along with their total suspended matter (particulate), organic carbon and ATP content of the water mass. Fifty soil samples were collected from the field sites close to the five lakes and these were immediately plated for the study of bacteria.

fungi and yeast population respectively. Bacterial counts varied from 1.2×10^4 to 1.8×10^5, fungi counts were found in the range of 10 to 2×10^2 whereas yeast counts were also equally high (500 to 9.4×10^3 counts/g of soil).

Dense patches consisting of mosses, lichens and algae were observed on rocks and on the soil. Forty samples were taken for the study of diversity, biomass, physico-chemical environment of soil supporting the life at Dakshin Gangotri.

Krill biomass was measured from 16 stations. Krills were found both North and South of 60°S. Several shoals of krill were located ranging from a few mm to mature 5 cm in length, in the cold, nutrient-rich waters of the Antarctic summer. Detailed laboratory analysis of the samples will provide data about krill biomass in the region of 67°S to 55°S of the Antarctic Ocean.

Magnetic survey (measurement of the total intensity of the earth's magnetic field) was conducted over a small part of Antarctica using proton precession magnetometer.

The diurnal variation of the earth's magnetic field was also measured at the base station during the survey period to remove the diurnal effects.

Fifty rock samples were collected from ten different sites at Dakshin Gangotri to determine their palaeomagnetism and magnetic properties.

Noises produced by the ice cracks in pack ice and those between the ice shelf and pack ice were recorded both through ice and air. The effect of the sun's radiation on the cracking sound was also studied by recording diurnal variation of these noises at intervals of every four hours.

Ocean thermal structure was studied by recording temperature profile of the ocean continuously upto 450 metres.

Existence of well-formed sound channels at shallow depth (10–100 metres) in the Antarctic Ocean was established and the variation of depth of these sound channels with latitude was studied.

The strength of the total geomagnetic field F at the Base Camp (Lat. 69°, 59′, Long. 11°, 55′) was recorded continuously using a proton magnetometer. The data were recorded every 10 seconds with a sensitivity of ± 1 gamma. The three vector components of the geomagnetic field *viz* northward, eastward and vertical (X, Y, Z) were individually recorded. The vertical component Z of the geomagnetic field was measured regularly using a direct reading digital Fluxgate Magnetometer. Spot observations of the strength of total geomagnetic field F were made at the Dakshin Gangotri Camp (Lat. 70°, 45′, Long. 11°, 38′) as well as around the ice shelf at the base camp. VHF signals at 244 MHz from the geostationary satellite FLECTSAT were also recorded.

THIRD INDIAN EXPEDITION 1983–84

The third expedition left India on 1st December 1983 and landed on Antarctica on 27 December 1983. For this expedition a large team of 83 members has been selected and the ship selected is "Finnpolaris" which is a supply-cum-ice-breaker. Besides men and material, it can take a considerable amount of cargo. The team consists of 15 scientists, and the rest of the teammates are largely drawn from the three services to give logistic support towards the establishment of a permanently-manned station. The ship has been chartered from Finland.

INDIA AND THE ANTARCTIC TREATY

The Antarctic Treaty was signed in Washington in 1959 and it came into effect after ratification in June 1961. The Treaty is in force for 30 years *i.e.* till June 1990. Originally, 12 countries *viz* Argentina, Chile, New Zealand, Australia, Norway, France, UK, USA, USSR, Japan, South Africa and Belgium signed the Treaty. The Antarctic Treaty was kept open to all countries who were members of the UNO. Since 1961, some other countries *viz* Brazil, Bulgaria, Czechoslovakia, Denmark, Federal Republic of Germany, Italy, Netherlands, Papua New Guinea, Peru, Poland, GDR, Romania and Uruguay have signed the Treaty. Of them Poland and Federal Republic of Germany have joined the Consultative Committee. China has also recently acceded to the Treaty. All decisions of

the Consultative Committee are through consensus. To participate in the Consultative Committee, a nation has to show evidence of substantial scientific research in Antarctica. Of the members of the Consultative Committee, 7 countries *viz* Argentina, Chile, New Zealand, Australia, Norway, France and the UK claim territory in Antarctica. The salient features of the Treaty are:

(i) Antarctica should be used for peaceful purposes only and that all military activities should be banned; (ii) Cooperation and exchange of information in scientific research should be established; (iii) Protection should be given to the vulnerable natural environment; (iv) All earlier territorial claims should be frozen and non-exploitation of resources should be encouraged.

Recently, the Treaty members have expressed interest in the resources of Antarctica. Although the Treaty does not have provisions relating to the exploitation of resources, in 1981, after consultations amongst the Treaty members, a Convention on the Conservation of Antarctic Marine Living Resources was drawn up. Under this Convention, any country having interest in exploiting the living creatures in the area would be free to join this Convention, which will not be restricted to the Treaty members alone.

The first session of the Special Consultative Meeting on Antarctic mineral resources was held in Wellington, New Zealand from 14th to 25th June, 1982. Subsequently three more meetings were held including the last one which concluded towards the end of January 1984 at Washington D.C. on Antarctic mineral resources. A regime for the exploitation of mineral resources is expected to be established in about 2 years. It is obvious that the Treaty nations have started thinking ahead and particularly to the time when the existing mandate of the Antarctic Treaty comes to an end in 1990–91. The intention seems to be to freeze the present situation thereby avoiding a scramble for resources while simultaneously confining them to a closed club. Other countries are also evincing interest in Antarctica, and perhaps in its resources. Brazil has already sent an expedition to Antarctica in 1982–83. According to reports, China and Peru may be sending expeditions to Antarctica soon. Reportedly China and Brazil sent their observers to the last Scientific Group Meeting of the Treaty. There are reports that China has been sending its scientists to the Stations of Australia, New Zealand and Chile in Antarctica. It is reliably learnt that China is preparing to send an expedition to Antarctica in the near future and is expected to set up a research base there.

Although the Antarctic Treaty was originally signed in 1959, India did not join it at that time since India's scientific interest in Antarctica has developed only in recent years.

After a careful consideration, India acceded to the Antarctic Treaty on 19 August 1983 and the Instrument of Accession was handed over to the Depository Government in Washington D.C. On September 12, 1983 at a Special Consultative Committee Meeting held in Canberra (Australia), India's nomination for a Consultative Status was considered and India was given a full Consultative Status as a 15th Member State. India's Antarctic Program was received with appreciation and in the 12th Antarctic Treaty Consultative Meeting (ACTM) held in Canberra from 13 to 27 September 1983 India participated as a full Consultative Member. In the same meeting, Brazil was also given a Consultative Status as 16th Member State.

The reasons for India's joining the Antarctic Treaty are as follows:

(i) By achieving the Consultative Status, India has a right to express her opinion on all matters related to Antarctica. (ii) India would be able to exchange scientific information with other members of the Treaty and thereby enhance its analytical capabilities. (iii) India would be able to participate in the meetings of the Consultative Committee and in doing so, will effectively project her own views as well as those of the non-aligned countries of which India is presently the Chair-person. (iv) India will be able to participate in the ongoing discussions on the Antarctic resources and ensure that any regime set up is in harmony with India's overall policies and objectives.