

GLIALPI – geophysical and limnological investigations of the Antarctic lakes for palaeoclimatic inferences

Antarctic sediments dating from 30 million to 145 million years ago (a time during which the vast Antarctic ice sheet is thought to have formed and the Transantarctic mountains pushed up) have been a valuable source of information about the forces that changed the climatic conditions of the Antarctic continent¹. Additionally ice cores collected from the southern high latitudes (Antarctica) have provided records of ultra-high resolution, sub-annual scale climatic changes through the last ~800,000 yrs BP². Palaeoclimatic records from the ice-cores have also helped to infer the effect of changes in the concentration of various atmospheric gases on the global climate, as well as the asynchronicity in the climatic changes in the southern and northern hemispheres. Yet, differences have been noted in the timing and amplitude of climatic changes as archived in the ice-cores recovered from different parts of Antarctica itself³. Thus, ice-cores clearly indicate regional climatic changes in Antarctica. Such regional climatic changes have often been assigned to the different climatic conditions in southern latitudes, the moisture source for Antarctica. However, the regional climatic changes from all parts of Antarctica cannot be inferred only from the ice-cores, as certain parts are only seasonally covered with ice. Additionally, as Antarctica is the storehouse of the largest amount of freshwater locked up in the ice-sheets, global warming-induced changes in the sea-level are significantly controlled by the melting of ice-sheets in Antarctica. The ideal locations to recover archives of geologic changes in the ice-sheet extent as well as sea level, are the marginal areas of Antarctica, as such regions are affected by changes in ice-sheet extent and sea level. Unfortunately, majority of the marginal Antarctica is devoid of stable, permanent ice-cover.

Interestingly, the peripheral Antarctica has a number of lakes of various types, viz. (i) perennially exposed, (ii) seasonally covered with ice sheet, and (iii) perennially covered with ice sheet. A few of these lakes lie in close proximity of the shore-line and thus are affected during transgression and regression of the sea. Such lakes being present almost through-

out the marginal Antarctica, provide ample opportunity to reconstruct regional climatic changes, including changes in the ice-sheet extent and sea level, from different parts of Antarctica. The changes in population and distribution of environmentally sensitive organisms over the geologic past can also be inferred from the lake sediments. Though most of the lakes present in the peripheral region of the Antarctica came into existence after the last deglaciation, and thus provide the geologic history of Antarctica since the last deglaciation, a few lakes were formed much before as evident from the much older sediments recovered from these lakes^{4,5}.

A number of international science programmes have been launched with a pooling of resources and expertise to unravel the mysteries covered within the sediments of various lakes in the Antarctic region. For example, ANDRILL (ANtarctic geological DRILLing) is a multinational collaboration comprising of more than 200 scientists, students, and educators from five nations (Germany, Italy, New Zealand, the United Kingdom and the United States) to recover stratigraphic records from the Antarctic margin using Cape Roberts Project technology. The chief objective is to drill back in time to recover a history of palaeoenvironmental changes that will guide our understanding of how fast, how large, and how frequent were glacial and interglacial changes in the Antarctic region. Future scenarios of global warming require guidance and constraint from past history that will

reveal potential timing, frequency and site of future changes.

The ANDRILL programme aims to obtain high-resolution sediment cores that record major glacial events and transitional periods over the past 40 million years, determine orbital and sub-orbital glacio-climatic fluctuations that vary on 100,000, 40,000 and 20,000 year cycles, obtain a refined record of the onset and development of the East Antarctic ice sheet (EAIS) 40 million years ago, identify how the Antarctic region responded to past events of global warming, derive a detailed history of Antarctic Holocene environmental change at the end of the last glaciation and test global linkages between climate changes in the northern and southern hemispheres (<http://andrill-server.unl.edu/index.htm>).

Similarly, the SHALDRILL (SHALlow DRILLing) programme aims to install a network of 5–7 m deep permafrost monitoring boreholes (shaldril.html). This network is complementary to the boreholes of 25 m to be installed in the framework of the project Permamodel/Permadrill, and also to the active layer monitoring sites (CALM-S). The dynamic sediment history preserved within the drift deposits along with the preservation of a diverse foraminifera assemblage makes the Vega Drift an attractive target for palaeoenvironmental studies, as planned for the first SHALDRILL initiative⁶.

In view of the availability of archives of Antarctic climatic conditions in the lake sediments, efforts have been made to collate regional climatic and sea-level

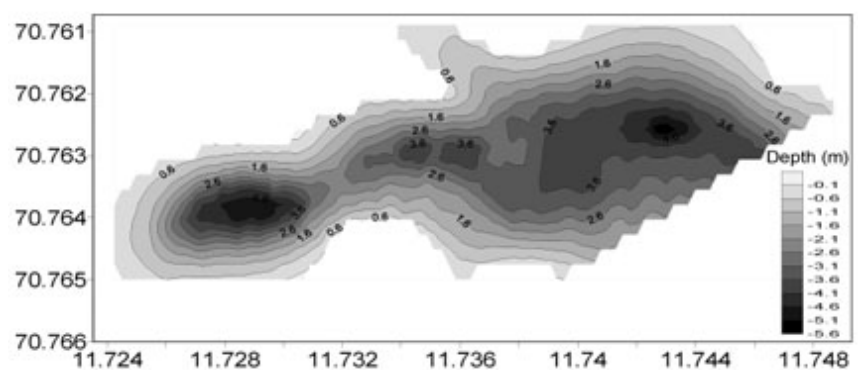


Figure 1. Bathymetric map of Lake Priyadarshini using Stratabox.

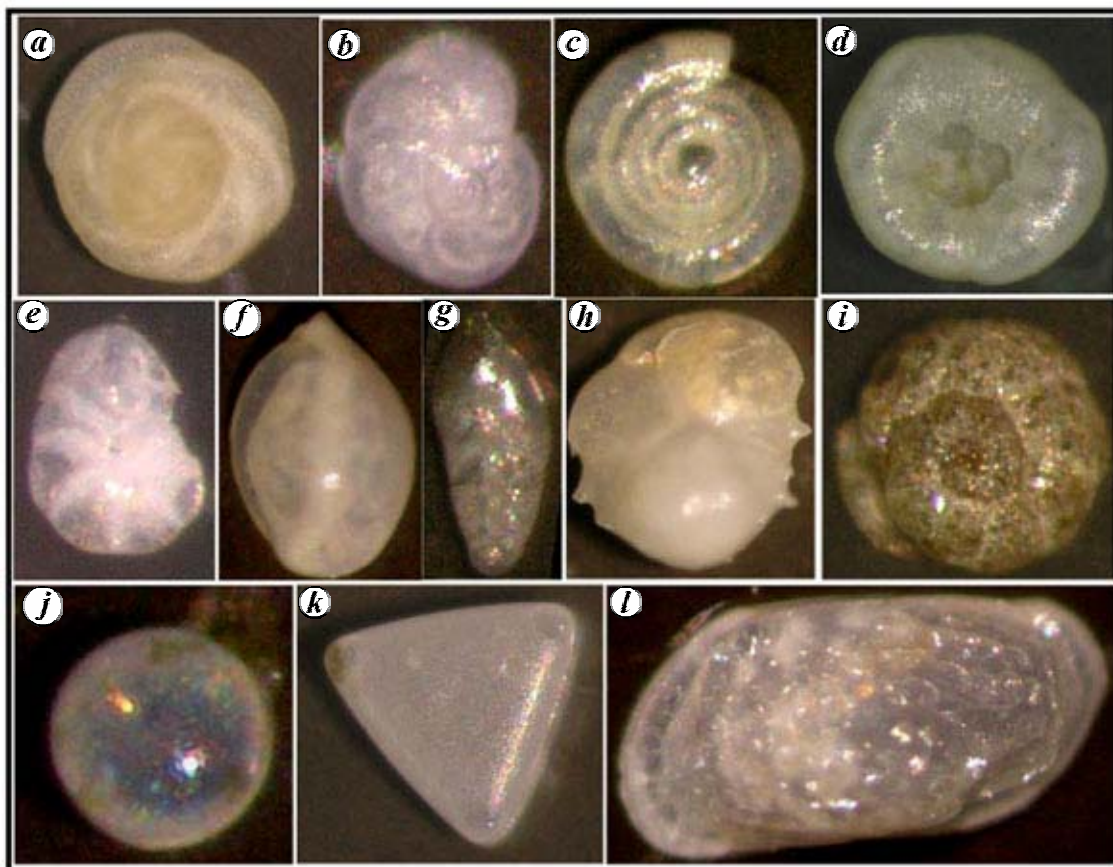


Figure 2. Microfossils recovered from a short core collected from the East Antarctic region. *a-i*, Foraminiferal species. *j, k*, Diatoms species. *l*, Ostracod species.

changes over the geologic past from these sediments.

Nevertheless, the available literature reveals that limited efforts have been made to infer palaeolimnological conditions of the Antarctic lakes, probably due to want of suitable sediment cores from these lakes. In order to fill this gap, efforts have to be made by the participating nations to launch their scientific programmes to explore various lakes spread all over the icy continent.

Accordingly, a comprehensive multi-institutional project, Geophysical and Limnological Investigations of the Antarctic Lakes for Palaeoclimatic Inferences (GLIALPI), coordinated by National Centre for Antarctic and Ocean Research (NCAOR), Goa, India, has recently been launched to generate regional palaeoclimatic history from different Antarctic lakes. GLIALPI aims to unravel the mysteries of the sediments of Antarctic lakes, which are either perennially exposed or seasonally covered with ice sheet and get exposed during summer. Lakes perennially

covered with ice sheet are investigated by ANDRILL and other international coring programmes. Developing coring technology for Antarctic lakes is another objective of this programme.

The project is a joint effort by NCAOR, Antarctic Division of the Geological Survey of India (GSI), Centre for Cellular and Molecular Biology (CCMB), Indian Institute of Geomagnetism (IIG), Birbal Sahni Institute of Palaeobotany (BSIP), Delhi University (DU) and Anna University (AU). While NCAOR as the nodal and coordinating agency provides the scientific and logistic support for overall execution of the project besides undertaking micropalaeontological investigations on Antarctic lakes, GSI helps in the collection of sediment cores as well as in generating geochemical characteristics of the sediments. CCMB explores the diverse life forms using cellular and molecular analysis techniques. Logging of the magnetic susceptibility of the sediments has been undertaken by IIG, whereas BSIP has been entrusted with

the responsibility to carry out palynological studies. A part of the foraminiferal studies will be carried out at DU in close association with NCAOR, and the geochronological aspects will be covered by AU.

Both water and sediment samples have been collected on the sidelines of the routine annual Indian Antarctic expeditions. The biological and physico-chemical characteristics have been recorded from different lakes. As the knowledge of bathymetry and sediment thickness is required in order to collect the sub-surface sediments, efforts have been made to carry out detailed bathymetric survey using hydro-box. Further preparations are underway to carry out geophysical surveys of the lakes using sub-bottom profiler. A few short cores have already been collected from different lakes and multi-proxy studies have been initiated to infer palaeoclimatic information. Towards implementing this ambitious long-term programme, a detailed bathymetric map (Figure 1) has been prepared for

Lake Priyadarshini in the vicinity of the permanent Indian station, 'Maitri'. The map is a major advance over earlier maps prepared on the basis of manual survey. Earlier palaeoclimatic studies on lake sediments by Bera⁷, based on pollen analysis in a core collected from lake Priyadarshini, showed climatic changes over the past ~8000 yrs BP. In a recent study of the subsurface sediments collected from another lake (lat. 68°37'25.40"S and long. 77°58'15.20"E) in the Vestfold Hills region of Antarctica have been examined for foraminiferal content (both agglutinated and calcareous types of foraminiferal tests) along with arcellaceans, diatoms and ostracods (Figure 2) to assess the potential presence and application of foraminiferal proxies for reconstructing the geologic history of marginal Antarctic lakes.

The presence of foraminifera indicates marine influence in a few lakes. Additional efforts are underway to document temporal changes in the sediment grain size, pigments, diatoms, magnetic susceptibility of the sediments, etc. Once available, such multi-proxy data will be used to infer the past climatic and sea-level history. Deployment of improvised sediment traps is also envisaged for round-the-year monitoring of the bio-

logical and physico-chemical characteristics of the lakes.

GLIALPI is largely funded by the Ministry of Earth Sciences, Government of India, and undertaken to utilize the lake sediments to infer the Antarctic climatic history. However, unavailability of specialized coring device that can be operated under the extremely harsh conditions in Antarctica, has hampered the collection of long cores. Therefore global efforts similar to the Ocean Drilling Program and Deep-Sea Drilling Project, and continuation of programmes like ANDRILL and SHALDRILL are required to be implemented to collect long cores from different lakes in Antarctica, in order to generate regional climatic and sea-level change history. True to the spirit of the Antarctic treaty, GLIALPI is expected to emerge as a multi-institutional and multi-disciplinary collaborative programme and will support international programmes like ANDRILL and SHALDRILL.

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N. KHARE^{1,*}
R. SARASWAT²
R. RAVINDRA³

¹Ministry of Earth Sciences,
Mahasagar Bhawan,
Block # 12, CGO Complex,
Lodhi Road,
New Delhi 110 003, India

²Centre for Advanced Studies in Geology,
Department of Geology,
University of Delhi,
Delhi 110 007, India

³National Centre for Antarctic and
Ocean Research,
Headland Sada, Vasco-da-Gama,
Goa 403 804, India

*For correspondence.

e-mail: nkhare45@gmail.com

Coda Q_c attenuation in Indo-Myanmar region, Manipur, Northeast India

The elastic structure of the lithosphere is found to be inhomogeneous from various kinds of recent geological and seismological observations. The appearance of S -coda wave following direct S -phase in seismograms is an apparent evidence for the existence of such an inhomogeneity. The scattering and attenuation of high-frequency seismic waves are important to physically characterize the earth medium.

Seismic attenuation is usually considered to be a combination of two mechanisms, scattering loss and intrinsic absorption. Scattering redistributes wave energy within the medium. Conversely, intrinsic absorption refers to the conversion of vibration energy into heat. Wu¹ introduced the concept of seismic albedo B_0 as the ratio of scattering loss to total attenuation. There are several papers^{2–5}

which discuss mechanisms for intrinsic absorption that lead to frequency-independent Q_p^{-1} and Q_s^{-1} . Scattering loss to heterogeneities distributed in the earth causes a decrease in amplitude with travel distance⁶.

Recorded waveforms show a large variation in amplitude near the direct S arrival; the variation decreases as lapse time increases. S -coda waves have a common envelope shape at most stations near the epicentre after about twice the S -wave travel time⁷. The decay of these waves with time, in a seismogram, provides the average attenuation characteristics of the medium instead of the property of a single path connecting from a source to the station. The properties of the coda can be analysed by applying a statistical method requiring a small

number of parameters. Aki⁸, and Aki and Chouet⁹, pioneers in this field, proposed the backscattering model to use the coda waves of local earthquakes for estimation of quality factors (Q_c) in a region.

Q_c estimated using single backscattering model is strongly frequency-dependent. Frequency-dependent Q_c estimated for local earthquakes recorded at two broadband seismological observatories in Manipur valley is reported here. This has shed light on the attenuation characteristics of the subducted lithosphere at shallower depth (<70 km).

The digital data from seven earthquakes recorded by two stations equipped with digital broadband (BB) systems were analysed for the estimation of Q_c . The digital seismograms were recorded by the Guralp CMG40T Broadband Seismo-