Magnetometrics in the Study of Sub-surface Structures of Antarctica Margin

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ABSTRACT

During the second Indian Antartica expedition in addition to monitoring time variation in the geomagnetic field components a preliminary ground based magnetic survey was conducted Magneto metric data obtained along six 10 -15 km long profiles, after correction for transient and day- day varia bility are examimed in the form of magnetic profiles and anomaly contour map . Qualitative interpretation of data suggests the presence of a north- south trending rift structure on the topographic ridge between 10- 12 E. The structure appears to be northward continuation of rift valley mapped on the continental margin of the Princes Astrid coast. The rift structure appears to terminate against a sharp discontinuity.

INTRODUCTION

The study of continental margin has received the attention of several workers in the past two decades. It is well recognised that in geological sense the coastal line is not the true boundary between continent and ocean. The rocks and structures seen on land extend under the sea and hence the real boundary between the continent and ocean must be looked for far out to sea. The average equality of free-air gravity anomalies over both oceans and continents, established in the beginning of century, suggested an isostatic balance between continents and ocean basins with either a shallower depth to Moho and /or denser crust and upper mantle beneath the ocean basins Subsequent seismic and gravity modelling have confirmed that the crust-mantle boundary rose from 30-35 km depth beneath the continent to a depth of 10 km beneath the ocean basins over a transition zone of approximately 200 km wide. In some regions, the ocean-continent boundary appears to be fairly easily defined as a sharp discontinuity while in other s there is no consensus on its position or on the width of a possible region of transitional crust situated between true oceans and true continental crust.

Magnetic anomalies have been particularly useful in locating *edge anomalies* between more highly magnetized oceanic crust and continental crust with lower magnetization (Keen, 1969, Emery *et al*, 1970, Keen and Keen, 1974) More recent analysis has suggested the value of both magnetic anomalies and two dimensional local Any isostatic gravity anomalies as the key to locating the ocean-continent boundary (Talwani and Eldholm, 1972,1973, Rabinowitz and LaBreque, 1977) On average, the magnetic anomalies associated with such edge effect exhibit an increasing trend away from continent reaching a peak over ocean-continent boundary, followed by a steady decrease and have amplitude of several hundreds of gammas. Any geophysical study ot the morphology of Moho at ocean-continent junction through its gravity and magnetic character is complicated by the presence of topographic structures on continental shelf and slope bordering the continent.

In view of the geological and economic importance, continental margins of several continents have been studied extensively. Studies of the continental margins of Australia, India, South Africa and South America, which once formed single landmass, would be informative in providing better understanding of the structural evaluation and rifting processes associated with the splitting of

Gondwana landmass. Our knowledge of continental margins, particularly of Antarctica, is still very scanty and much more needs to be known. In the past two decades, several countries have carried out geophysical surveys which are continuously filling the gaps in our knowledge about this continent.

In the first Indian expedition to Antarctica, several geophysical measurements, including marine magnetometrics, were undertaken. The magnetometer sensor towed by the ship made measurements throughout its voyage to Antarctica. The measurements during the onward and return cruises from Goa to Antarctica, revealed several magnetic anomalies which could be qualitatively associated with Mauritius island rises, Southwest Indian ridge, the Crozet plateau rises etc. A magnetic anomaly of more than 1000 gammas was also observed in association with hitherto unreported sea-mount, now named as *Indira* Mount. Within the Antarctica area (south of 60^0S), several strong magnetic anomalies were registered on the continental margin off the Dronning Maud Land. This continental margin is characterised by the three prominent North-South trending topographic highs. The eastern one at about 33-35^0E is known as the Gunner Ridge and the western one between the 0 and 5^0E has been named as the Maud Bank. Between these two ridges lies an unnamed ridge between 10-12^0E. A rift structure was mapped on this ridge. In some areas rift is marked by magnetic lows of 150-200 gammas. The eastern flank of the Gunner Ridge was marked by a broad anomaly of about 100-200 gamma and ridge itself has a broad anomaly. In addition, to the further east, a broad-magnetic anomaly of about 400-500 nT is noticed on the continental slope of Lutzov Holm bay.

The results of marine magnetometrics have clearly demonstrated the utility of magnetic anomalies in delineating the structural features of Antarctica margin. In view of the usefulness of magnetic data, the Indian Institute of Geomagnetism had planned and carried out a preliminary ground-based magnetic survey during the second Indian Scientific Expedition to Antarctica. This report presents the initial results of this survey.

SURVEY PLAN AND DATA REDUCTION

Measurements were undertaken along six North-South trending profiles running parallel to 11^0E longitude. Interprofile spacing was close to 500 m and interstation spacing was about 400 m. The locations of profiles and observation points in relation to the Base Camp of expedition ($69^0$59'03"S and $11^0$55'28"E), are shown in Fig. 1. At each of these points spot values of total field F were taken using sensitive Proton Precision Magnetometer (PPM). Base station in itself was equipped with PPM and Fluxgate magnetometers which continuously registered the time variation in total field F and in the three components (D, H and Z) of earth's magnetic field. These data

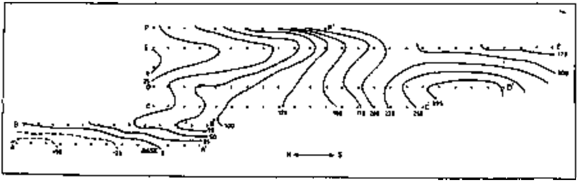

Fig. 1. Map showing the location of observation points along six North-South trending profiles across Antartica continental margin. The magnetic field values alter suitable reduction are contoured to demonstrate the influence of the sub-surface geology on magnetic measurement.

facilitated corrections to survey data in respecl of diurnal and disturbance variation as well as for day-to-day variability. Table I gives the dates and interval during which survey was conducted together with the global magnetic activity conditions, as represented by the three-hourly magnetic index Kp, prevailing at such times.

In the first instance, data along each of the six profiles is corrected for diurnal and disturbance variations. A correction factor equivalent to the difference of base station's F reading corresponding to the times, first when observation at survey point was made, and second the reference time to which all observations are reduced, were worked out and subtracted from the respective survey points reading. The reference time for each profile was taken to be the time at which first observation on that profile was made. The variation of F along each profile after above correction shown in Fig. 2. As the measurements along each profile are taken on different days, a further correction corresponding to day-to-day variability was also applied to the data with the aid of base station observations. To this end, simple departure of base station's F reading, at the reference lime of individual profile, from the value corresponding to the quiet interval of survey period is taken as measure of day-to-day variability. After applying suitable corrections to each observation point, the residual field values at all points defined as departures from the base station value are used to form an anomaly map. The resulting contour map is given in Fig. 1

RESULTS AND DISCUSSION

The most salient feature of the magnetic profile shown in Fig. 2, is that the field increases steadily from north to south, *i.e.*, as one moves landward from ocean side. In two profiles, *viz.*, DD' and EE', a clear maximum is reached and then field decreases smoothly. This symmetric nature of profile is suggestive of the presence of a sharp discontinuity or a block of rocks with contrasting magnetic susceptibility. If this boundary was to be interpreted as ocean-continent boundary, one would place the boundary on the landward side of the base station rather than on the ocean side. As the base camp is hardly 50-60 km from the exposed continental rocks, it seems unlikely that ocean-continent boundary would be located so near to continent unless the transitional zone is abnormally narrow along this region of continental margin. The magnitude of the anomaly near the peak also

TABLE I

Dates and interval of magnetic measurement along six profiles together with three-hourly magnetic activity index K_v covering the duration of suivey.

S. No	Profile	Date	Time Interval in UT	Kp	Index
1.	AA'	11 Ian '83	15^h13^m-19^h34^m	3-,	20
2	BB'	8 Feb '83	14 44 -16 08	2+,	20
3.	CC'	8 Feb '83	17 OS -18 07	20,	10
4.	DD'	10 Feb '83	16 35 -17 57	2+,	2+
5.	EE'	16 Feb '83	14 37 -16 26	4+,	4+
6.	FF'	16 Feb '83	17 05 -17 56	4+,	4+

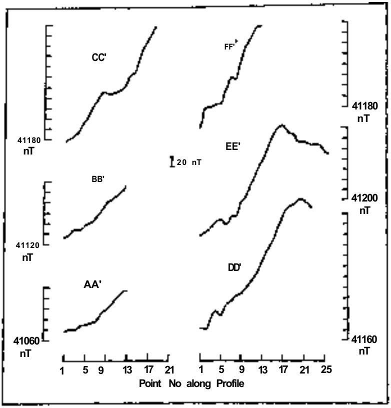

Fig 2 Geomagnetic field variations along six profiles after correction in respect of diurnal and disturbance variation

being small, does not permit the interpretation in terms of the morphology of Moho. The other most probable cause to account such anomalies may be related with the topography of the top of the magnetic rocks under the ice-shelf.

The conspicuous feature of the anomaly map presented in Fig 1 is the presence of magnetic low between profiles DD and FF'. The axis of this low runs approximately in the North-South direction along the profile EE'. It is worthy to note that a seismic record and echograms of the 10-12° E ridge obtained in first expedition had shown prominent NNE-SSW scarps with a relative height of 100-400 m and a rift valley with depth down to even 500-1000 m and apparent width of 2-5 km. It, thus, appears that magnetic low noticed on the anomaly map may be indicative of the continuation of rift valley under the ice-shelf atleast for another 10 km from base stations in the southerly direction. The magnitude of the anomaly suggests that anomaly may be related with the sediments infilling the rift valley. The spatial extent of the magnetic low can be traced right upto a station where a peak value on the profile DD and EE is registered. This sudden disappearance of low warrants that the path of valley is blocked by a sharp vertical front. Such a vertical discontinuity by virtue of representing a boundary of contrasting magnetization would also be able to account for a peak over this junction noticed in profile DD and EE'.

CONCLUSION

The qualitative analysis of preliminary magnetic data collected during second Indian expedition clearly suggests that magnetic data can be successfully employed for delineating structural feature of Antarctica continental margin Quantum of the present data is however not enough to enable quantitative interpretation. It is hoped, future expeditions to Antarctica would provide opportunities for extensive surveys and would make it possible to map several structures of importance.

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REFERENCES

Emery K O E Ochvpi J D Phillips C O Bowin ET Bonce and S T Knott (1970) Continental rise off eastern North America *Bull Am Assoc Pet Geol* 54 44 108

Keen M J (1969) Magnetic anomalies of the eastern seaboard of the United States a possible edge effect *Nature* 22 72-74

Keen C F and Keen (1974) The continental margins of Eastern Canada and Baffin Bay. In *The Geology of Continental Margins* C A Burk and C L Drake (Editors) Springer New York N Y 381 389

Rabmowitz P D and LaBreque (1977) The isostatic gravity anomaly Key to the evolution of the ocean continent boundary at passive continental margins *Earth planet Sci Lett* 35 145-150

Talwani M and O Eldholm (1972) Continental margin off Norway a geophysical study *Geol Soc Am Bull* 83(12) 3575 3606

Talwani M and O Eldholm (1973) Boundary between continental and oceanic crust at the margin of rifted contients *Nature* 241 325 330