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Gravity Survey (Helicopter Supported) between Schirmacher Oasis and Wohlthat Mountains, Dronning Maud Land, Antarctica

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Abstract

The helicopter-borne magnetic survey conducted between the Schirmacher Oasis (SO) and the Wohlthat Mountains (WM) during the Seventh Indian Antarctic Expedition (IAE) revealed a number of interesting anomaly zones in the region. To study some of these features in detail, a helicopter supported gravity survey was conducted during the Ninth IAE. Details of the logistics planning, data acquisition, processing and interpretation relating to this survey are described,

Introduction

The need to conduct gravity survey around SO and in the region between SO and WM was realized when a number of interesting features were revealed by the helicopter-borne magnetic survey done during the seventh IAE. While the nunataks between the SO and WM showed high magnetic anomalies, the SO was found to be associated with a magnetic low (Fig. 1). Also a strong magnetic high was observed just northwest of SO. In order to further study this strong magnetic anomaly of more than 600 nT associated with the SO, a gravity survey was carried out during the Ninth IAE and measurements were taken along 4 profiles in the vicinity of SO. One of these profiles was extended upto Humboldt mountains while another (fifth profile) was taken between the eastern margin of SO and the foot-hills of the Gruber massif. After the standard data reduction and processing, the observed gravity values were interpreted considering available geological and geophysical information in the region.

Selection of Profiles

As shown in Fig. 2, four profiles in the N-S direction were selected for gravity measurements in the vicinity of SO. Two of these profiles of about 30 km length lie on the ice shelf west of SO. The third profile of about 90 km length runs from the western tip of SO to the foot-hills of the Humboldt mountain. This profile coincides with the aeromagnetic profile (taken during the seventh IAE) for which detailed interpretation is provided by Mital and Verma (1989). The fourth profile of about 30 km runs in N-S direction, passing close to the 'Maitri' station. In addition, a fifth profile of about 60 km length was taken from the easternmost margin of SO to the foot-hills of Gruber massif, The initial and final coordinates of the five measured profiles are given below:

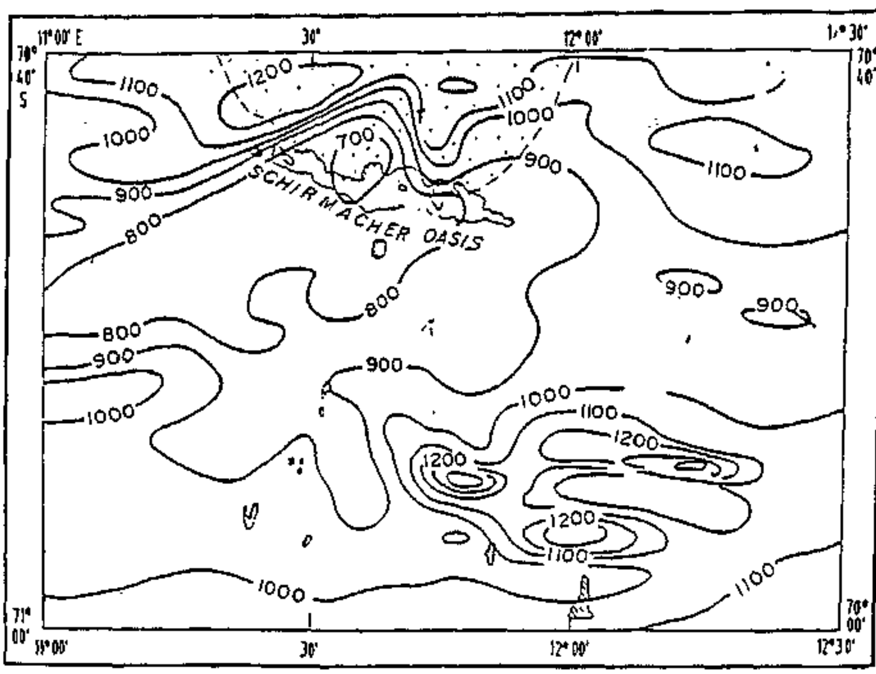

Fig. 1. Total intensity magnetic anomaly contour map around Schumacher Oasis region.

Profile 1: 70° 42'S, 11° 10'E to 70° 57'S, 11° 10'E with station interval of 2.8 km

Profile 2: 70° 42'S, 11° 20'E to 70° 57'S, 11° 20' E with station interval of 2.8 km

Profile 3: 70° 40'S, 11° 30'E to 7r30'S, 11°30'E with station interval of 2.8 km

Profile 4: 70° 46'S, 11°40'E to 70°57'S, 11°40'E with station interval of 2.8 km

Profile 5: 70° 47'S, 11°48'E to 71°1 l'S, 12°59'E with station interval of 2.6 km

Operational Logistics

The gravity measurements along the above mentioned profiles were taken with the support of helicopters. The average station interval varied from 2.6 to 2.8 km. After each measurement the distance to the next station was covered by helicopter. For position location, the TANS-71 Doppler Navigation system, Fitted in the *Chetak* Helicopter was used. It may be mentioned here that such a type of 'helicopter supported gravity survey' should not be confused with 'airborne gravity survey' in which the gravity measuring system itself is installed on a gyro-stabilized base inside the craft.

BOUGUER GRAVITY PROFILES (IN MILLIGALS) WITH TOPOGRAPHY IN SCHIRMACHER WOHL THAT REGION

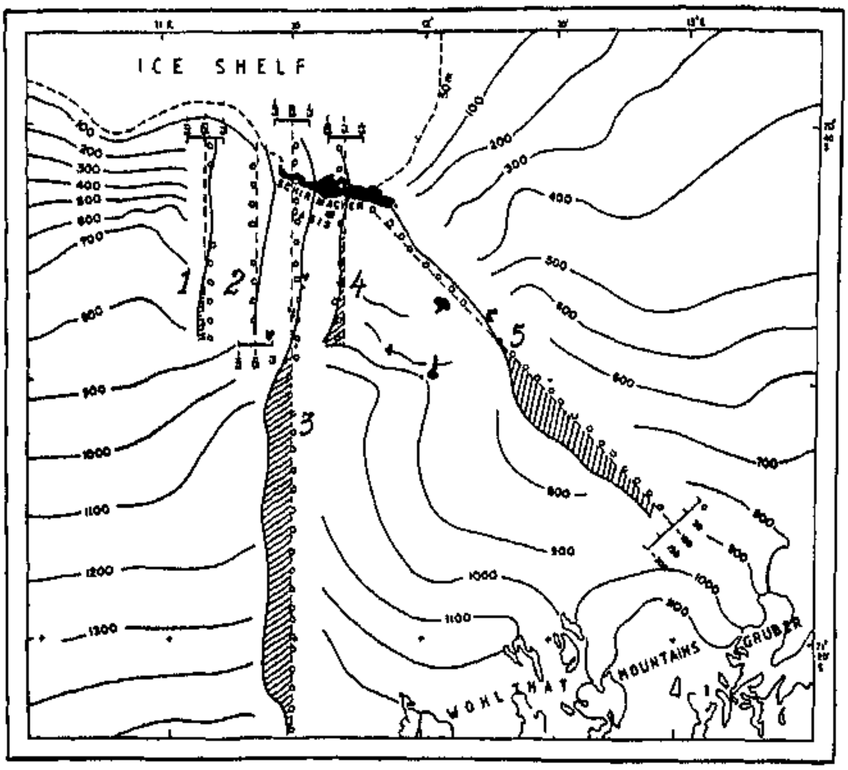

Fig. 2. Location of the five gravity profiles along with Bouguer anomaly plots

A special type of wooden tripod was fabricated to keep the base plate. This was found to be very useful in overcoming the problem of levelling variations on ice during the period required for measurements.

In Antarctic environs, strong wind conditions are a common feature. This may lead to oscillations of the beam in the gravimeter. It was found that this problem could be avoided by wrapping blankets around the gravimeter while taking readings.

Equipment Used & the Survey Procedure

The following instruments were used in the survey:

1. Lacoste Romberg gravity meter (G-954 model with electronic levelling)
2. Paulin Altimeter
3. Doppler navigation system for position location

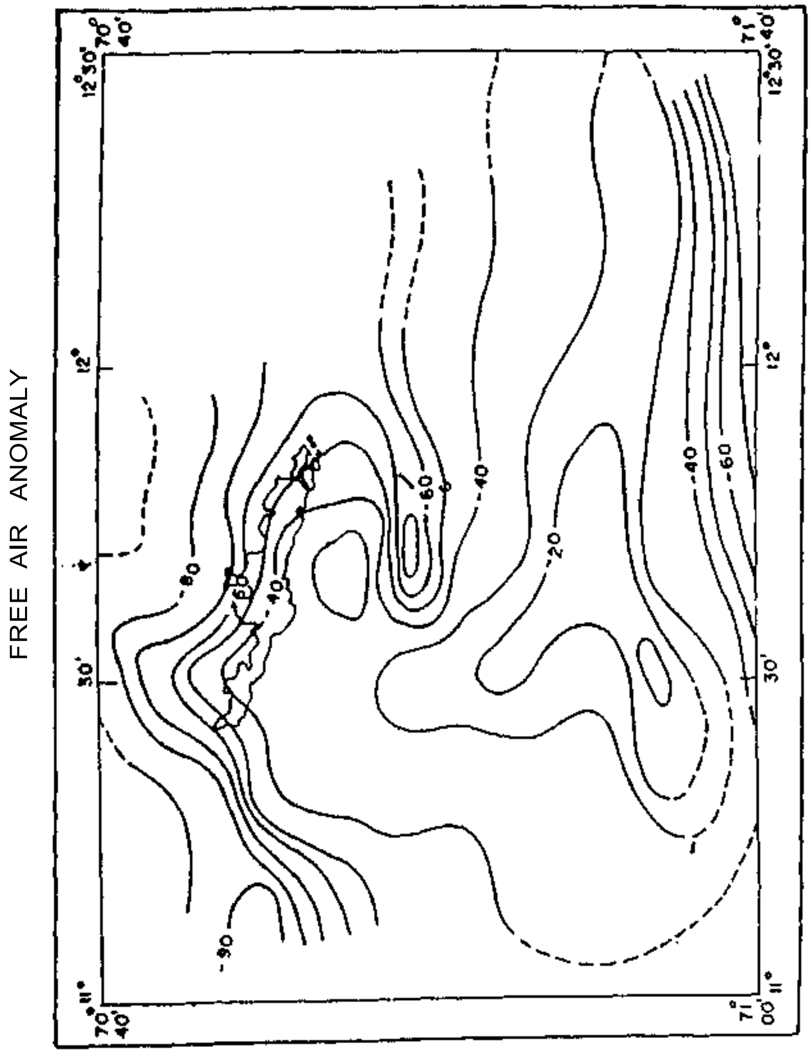

Fig. 3. Free air anomaly contour map around Schirmacher Oasis region.

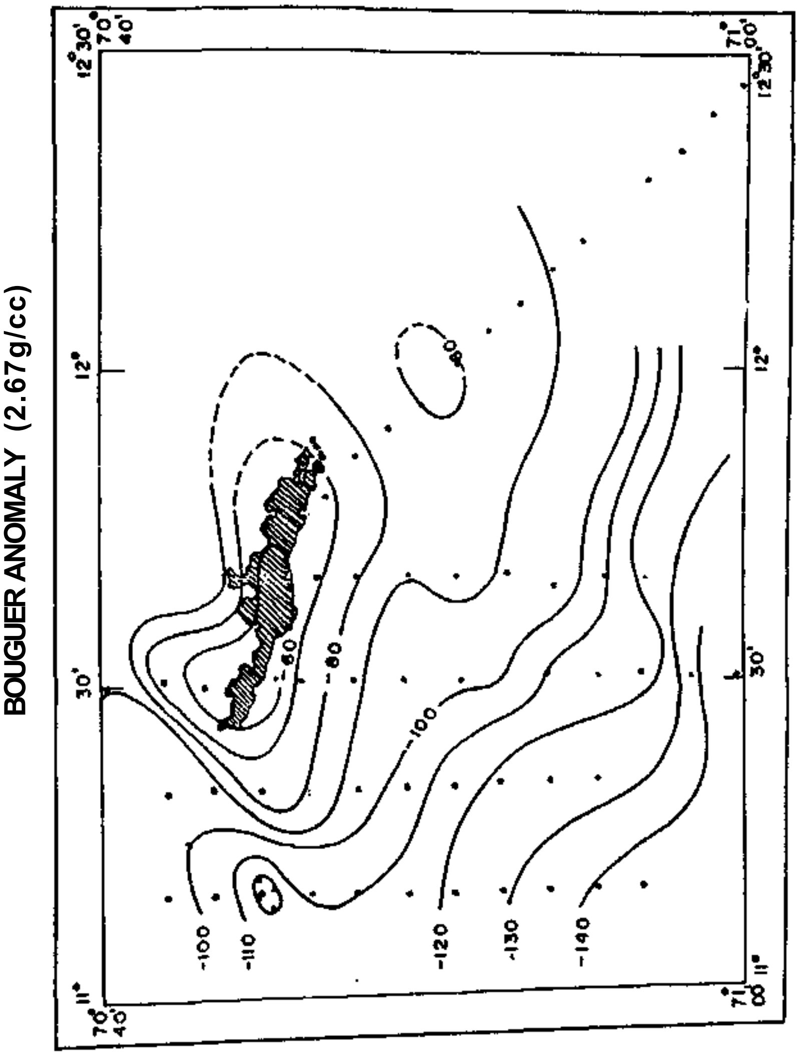

Fig. 4. Bouguer anomaly contour map around Schirmacher Oasis region.

Gravimeter

For gravity measurements LACOSTE ROMBERG (MODEL-G) gravimeter was used. This meter has a worldwide range without resetting. This instrument has an accuracy of 0.01 milligal. This instrument is thermostatized at 51 degrees C so that external temperature has little effect on the measurement. Necessary precautions were taken to overcome the problems such as levelling the instrument on the ice when the winds are relatively high and the consumption of excess power in sub zero temperature conditions. The instrument has electronic levelling facility and capacitance beam position indicator.

Poulin Altimeter

This is a standard equipment to measure the altitude at a given location. It is based on the principle of a barometer and translates atmospheric pressure variations due to changing height (in the absence of any noisy condition like blizzard etc.) into altitude values. The instrument is also sensitive to temperature variations.

The altitude values obtained by the Paulin altimeter were cross- checked with those displayed by the altimeter fitted in the *Chetak* helicopter. Though the absolute values obtained by these two systems differed, the trend displayed by them was found to be parallel, indicating a general agreement.

Doppler Navigation System

A TANS-71 Decca Racal Doppler Navigation system was used for position location. This system was fitted on board *'Chetak'* helicopter. The Doppler beams were transmitted to the earth through a dome that was fitted in the belly of the helicopter. Position of a point is displayed digitally in terms of degrees and minutes with two decimal points. A detailed description of the Doppler Navigation system is provided by Mital and Verma (1989).

Survey Procedure

At each station position location, altitude and temperature were recorded. Because of the non-availability of a gravity base near Maitri station, the Gravity base at Goa was taken into consideration for reduction of the data. A reference station was established in the Scientist's hut at Maitri Station. To apply the drift corrections, gravity measurements were repeated at every two hours at the reference station. Same procedure was adopted in the case of altimeter also. The accuracy of the altimeter in the worst case may be ± 10 m. For the survey, the helicopter took-off and landed at the same spot and the displayed positions in the beginning and at the end of the survey were noted. In general, a drift in the observed values was observed. This drift was linearly distributed while reducing the data.

Helicopter Support

The task could be completed because of the excellent support provided by *'ChetaK* helicopters flown by the Indian Navy. The equipment and the scientists were transported from station to station in this helicopter. To determine the position locations accurately, the helicopter was required to land frequently in difficult areas. Thirty three flying hours of helicopter time were utilized to complete the survey.

Results

The processing of the gravity data collected along the 5 profiles was done at the computer center, NGRI, Hyderabad. The resulting free air anomaly map is shown in Fig. 3, while the Bouguer anomaly contour map for the density value 2.67 g/cc is shown in Fig.4. The reduced Bouguer anomaly profile are drawn in Fig. 2.

A comparison of the Bouguer anomaly contour map (Fig 4) with the total magnetic intensity contour map (Fig. 1) reveals that the region northwest of SO is associated with very sharp gravity and magnetic gradients. The SO itself is associated with a low magnetic and

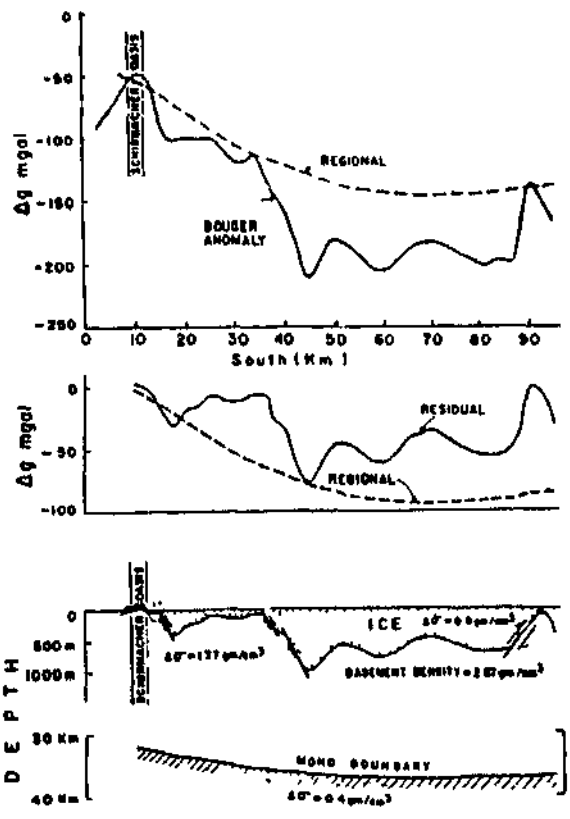

Fig. 5. Results of the gravity survey along the profile from Schirmacher Oasis to Humboldt mountains

a high gravity anomaly. While the gravity high over the exposed SO is quite understandable, the associated magnetic low poses an intriguing problem. A possible explanation could be that below the SO, there could be a granitic intrusive of recent, origin and the heat emanating from this intrusive has resulted in the demagnetisation of the adjacent rocks. While this possibility needs further verification through heat flow measurements in the SO region, the following alternative explanation also seems to be acceptable.

While interpreting the aeromagnetic anomalies, using gross 2-D special analysis in the SO-WM region, Mital and Verma (1989) reported a very deep basement below the glacier just south of the SO. A relatively large value of the ice thickness was obtained due to the magnetic low associated with SO. However, when this magnetic low (of 700 nT) and the magnetic high (of 1200 nT) are interpreted as due to a deep fault or an intrusive body, the magnetic low over the SO could be explained merely as a reflection of this fault or intrusive body. If a correction for this strong magnetic anomaly is applied in the aeromagnetic interpretation, the basement depth just south of SO is found to be at much shallower depths.

As the altimeter readings gave variations of the order of ± 10-15 m, the gravity data can be used only for a general interpretation of gross first order features. Despite this limitation, however, the longest profile (No. 3) from the SO to the Humboldt mountains has been interpreted to calculate the glacial thickness and the moho depth along the profile. The results are shown in Fig.5. First of all the regional field (Fig. 5a) was separated to obtain the residual anomaly profile (Fig. 5b). This profile was then interpreted to calculate the glacial thickness by assuming the density of the ice $\rho = 0.9$ gm/cc and that of the basement as 2.67 gm/cc, yielding a density contrast $\Delta\rho = 1.77$ gm/cc. The interpreted glacial thicknesses along the profile are shown in Fig. 5c. It may be seen that the basement depth just south of the SO (upto 25-30 km) is very shallow. The region also shows a number of faults as shown in the figure. Towards further south the glacial thickness increases to slightly more than 1 km and then gradually reduces towards the foothills of the Humboldt mountains. The observation that the region from the SO to about 35 km south of it consists of shallow ice thickness (50 to 500 m) is further supported by the occurrence of a number of nunataks in the region. The region further south consists of higher glacial thickness and no nunatak occurs in this region. This region appears to be a part of a graben like structure (flanked by faults) with a general E-W direction.

It is worth mentioning here that the glacial thickness obtained in the graben region by the interpretation of aeromagnetic data (Mital and Verma, 1989) is almost identical to that obtained by the gravity data after applying the correction for gravity data. After applying the correction for the magnetic anomaly caused by the fault (or intrusive body) N-W of the SO, the reinterpreted glacial thicknesses from the magnetic data also yield shallower glacial thicknesses in the range of 0 to 500 m in the region just south of the SO.

The Moho thickness, based on the interpretation of the regional gravity anomaly, was found to vary frotn about 38 km below the Humboldt mountains to about 32 km below the SO (Fig. 5d). This reflects the normal behaviour of crustal thickness with gradual reduction from continental margin (below the WM) towards the oceanic crust.

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Reference

Mital, G.S. and Verma, S.K. (1989): Helicopter borne magnetic survey between Schirmacher Oasis and the Wohlthat mountains, Dronning Maud Land, Antarctica. N.G.R.I. Scientific Report, submitted to Deptt. of Ocean Development, New Delhi.