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SURVEY OF INDIA

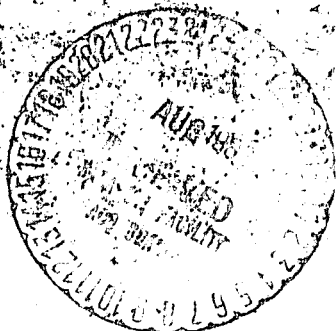
MAGSAT PROJECT



FINAL REPORT

Title of the Project : Analysis of Magsat and Surface
Data of the Indian Region

Principal Investigator : Lt.Gen.K.L.Khosla upto 30.11.1981
Major General G.C.Agarwal from 1.12.1981
Surveyor General of India.



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(To be submitted to NASA by Principal Investigator)

1. Introduction:

The project was initiated after the meeting of the National Working Group of Department of Science and Technology (DST) at New Delhi in March, 1979. A research proposal entitled 'Analysis of Magsat and Surface data of the Indian Region' under code No.M 56 with Surveyor General of India as Principal Investigator was accepted by NASA in April, 1980 and this project was jointly carried out by Survey of India (SOI), National Geophysical Research Institute (NGRI), Space Application Centre, ISRO(SAC) and Indian School of Mines(ISM) with close support from the Indian Institute of Geomagnetism, Department of Science and Technology and Oil and Natural Gas Commission. Under this agreement, Magsat data and other material was supplied by NASA, free of cost to Survey of India. Survey of India has submitted so far four periodic reports after the receipt of data.

As per the original research proposal of SOI, the following Tasks were to be performed:-

1. Use of the multilevel data at different altitudes to develop a model for variation of magnetic anomaly with altitude.
2. Development of the Regional model for the description of main geomagnetic field for the Indian sub-continent using MAGSAT and observatory data.
3. Development of Regional Mathematical Model of Secular Variations over the Indian sub-continent by using the observatory data and Magsat data.
4. Downward continuation of the anomaly field obtained from MAGSAT and its combination with the existing observatory data to produce a regional anomaly map for elucidating tectonic features of the Indian sub-continent.

Three investigator data B tapes were received under the agreement, containing the observed data at varying altitudes of the satellite and related parameters to derive the crustal anomaly field over the Indian region and adjoining areas.

2. Techniques Used:

2.1 By Survey of India:

The data tapes received from NASA contained data in binary form and it was decoded by developing a suitable software. The copies of the data tapes were supplied to co-investigators. The services of IBM 370/145 computer installed at computer centre of Oil and Natural Gas Commission, Dehra Dun, were utilised by Survey of India to decode the data. It came to the notice during scrutiny of data that observed values of Total Force (F) were missing at number of points in space.

'Z' Component was selected by Survey of India for deriving the crustal anomalies. To derive the anomaly from the observed 'Z' component, the procedures developed by Regan *etal*(1975), Maynew(1979) and Langel *etal*(1980) have been used. The difference in the procedure adopted by SOI is that the varying altitude data of the crustal anomalies has been reduced to a common elevation of 400 Kilometres(Henderson and Cordell(1971), after removing the model field, ring current and linear trend effects. In this model, the varying altitude data have been reduced to a common elevation. The x-axis has been defined in the programme, as the satellite track. The direction of 'Z' has been taken downward. The distance between two data points is 36 Kilometres and the number of harmonics were varying from 5 to 8 to achieve the best possible fit to the input data set. The entire data/over the Indian Region has been reduced to a common elevation of 400 km. No correction has been made for the varying geomagnetic inclinations. In this procedure the anomaly data obtained from geographically coincident passes were found to be matching. The 'Z' Anomaly map has been prepared from all the passes with varying K index from 0 to 33. However, it was checked that no large magnetic variation were observed at the ground observatory at Hyderabad during higher K passes. The average of the point anomaly-values falling in $2^{\circ} \times 2^{\circ}$ blocks have been calculated. The anomaly where residual exceeded 3 times the standard deviation of the mean from the initial block average was neglected. New averages for $2^{\circ} \times 2^{\circ}$ were computed and contours drawn to prepare the anomaly map on a scale of 1:6 M at contour interval of one gamma. In the final map, the average number of points per $2^{\circ} \times 2^{\circ}$ block was 9 and total number of data points were 2198, from which 648 were neglected.

/220 passes

In developing these techniques the support of the Indian Institute of Geomagnetism and Dr. B.N.P. Agarwal of ISM, were invaluable. Techniques used for other MAGSAT investigations are given in para 3.

2.2 By National Geophysical Research Institute:

For the calculation of residuals, the related techniques mentioned in para 2.1 had been followed. Following aspects were also included in the investigations.

- (i) Selection of specific profiles across major geological and tectonic boundaries over
 - (a) Indian sub-continent and
 - (b) Indian Ocean.
- (ii) Choice of ΔZ - component of MAGSAT anomalies was made due to
 - (a) the amplitude of Magsat total field anomalies being generally too small.
 - (b) incorrect assumption of induced magnetisation of crustal rocks and large latitudinal variations,
 - (c) Significant horizontal field variation but negligible variation in vertical field component in transient geomagnetic variation for night hours.

2.3 By Space Application Centre:

Anomaly contour maps were prepared for the test area defined by 16° - 26° N latitude and 70° - 82° E longitude. The data points were averaged using $0.5^{\circ} \times 0.5^{\circ}$ grid and plotted at the grid centre using VAX-11 computer at Space Application Centre. A computer programme was developed to map anomalies in contour form on line printer.

A mosaic of test area from Landsat imagery (MSS Band-7) on 1:3.369 million scale was prepared. The megalineaments were interpreted and compared with the anomaly map.

3. Accomplishments:

The final position of Magsat investigations at the formal close of the project are given below:-

- (i) Preparation of Z component anomaly map (Fig.1) of the Indian region on a suitable scale and contour interval has been accomplished by Survey of India.

NGRI made correlative studies in the latitudinal range from 36° N to 10° S through (i) seven profiles of vertical component data (ΔZ) across major geological and tectonic boundaries of the Indian sub-continent and (ii) ten profiles of ΔX , ΔY and ΔZ components over the Indian Ocean Geoid and across the coasts of southern peninsular India.

No significant difference was observed by SAC between the maps prepared by ΔZ (Z-ZMD) and ΔZ after reduction to common elevation. Thus change in field values due to altitude variations might be neglected so far as detection of anomaly is concerned. A plot of difference in altitude against difference in vector magnetic field was drawn using 33 points of intersection over India sub-continent and its environs. The scattergram was fitted by a regression line.

- (b) Alternate methodology for the determination of the regional field is under investigation by SOI. Its results will be sent to NASA as soon as the study is over. The investigation on regional model of the secular variations are also continuing although secular variation charts for D, H and Z for the period 1975-80 based on observatories data have already been prepared by SOI. In the mean while, the 'Z' values from Magsat 1980.0 model (MGST 4/81) have been computed by SOI at the corners of $2^{\circ} \times 2^{\circ}$ blocks of the region and a low order polynomial has been fitted into the magsat 1980 model values and observatory data to produce a chart at 1980.0 of 'Z' component. (Fig.2)
- (c) Magsat data has provided the observed values of magnetic elements on the land and the Oceanic areas adjoining Indian sub-continent. Also Magsat has provided the excellent data set for production of anomaly maps and observed values over the whole region for the production of isomagnetic maps of the main field over the sub-continent. These data set will be free from short wave length anomalies which usually distort the magnetic main field contours.
- (d) The study of multi-level data at different altitudes to develop a model of variation of geomagnetic anomaly with altitude is still continuing in NGRI. The results will be submitted to NASA in due course.

However, Dr. Negi and his team from NGRI have already submitted to NASA a paper, entitled 'Vertical Component Magsat Anomalies and Indian Tectonic Boundaries' from a study of 7 profiles of vertical component.

They have also submitted to NASA another paper entitled 'Magsat anomalies associated with prominent Geoidal Low of Central Indian Ocean'.

4. Significant Results:

Anomaly maps, basic tools of earth crust are now used in constructing geological models for resource assessments. A primary object of the Magsat mission was to interpret the anomalies for geological structure, composition, temperature of rock formation etc. It is also recently established that crustal anomalies of wave lengths (> 150 Km) are indicative of geologic and tectonic features of the deep crust.

An anomaly map of 'Z' component at an elevation of 400 kilometers has been produced by SOI for the first time in India covering the Indian sub-continent. The mean anomalies at $2^\circ \times 2^\circ$ block for the whole region (8° N to 36° N latitude and 62° E to 100° E longitude) varies from +21nT to -27nT. The Z anomalies are positive over the Deccan Traps and Bangla Desh and negative over the Himalayas and Ocean areas. There is a very prominent negative over Western Nepal. Two of the Zero contours are located at the northern limit of Indo-gangetic plain and the southern limit of Peninsular India.

The crustal anomalies obtained from the passes (Fig.3) have been studied by Negi *etal*(1983) and correlated with major geological and tectonic boundaries/features of the sub-continent(Fig.4). A prominent magnetic low is reflected in all the profiles centred between 19° to 23° latitude over the broad peninsular 'high'. Clear magnetic signatures are identified over super order synclises 'sharp low', Narmada-Son Rift a 'low'. The other conspicuous 'low' with sharp gradient is confined to the region between Sarda depression (29° N to 31° N) and foot-hills of Himalayas. Interesting magnetic signatures are identified over Narmada Son Rift and Godavari ~~gap~~. The magnetic responses from these geological and tectonic boundaries suggest that anomalies of wave-length of the order of 150-200 km could be resolved from MAGSAT heights.

Recent study by NGRI on 'Magsat Anomalies associated with Prominent Geoidal low of central Indian Ocean' through the profiles (Fig.5) anomalies in the X component compared well with the regional geoidal low (Fig.6). The resolution of short wave length anomalies seems to be better in the Z component and exhibits a conspicuous magnetic low over the tectonic ridges. The long wave-length features in the Y component over the eastern coast are quite different from the rest of the area. The paper highlights the geological implications of some of the above mentioned feature.

A chart of Z component for 1980.0 has been prepared for the first time by Survey of India by using Magsat model and observatory data for the Indian region. 1975.0 epoch chart was prepared by normal departmental method where as 1980.0 chart has been prepared by using the DAWSON and NEWITT method. The Magnetic Equator remains more or less at the same position as shown in geomagnetic charts of 'Z' element of epochs 1975.0 and 1980.0. The Z component values of 25000 nT almost coincides with latitude 24° line on 1975.0 chart, but it has shifted to the south by almost ½ degree on 1980.0 chart.

Studies at SAC show that the majority of magnetic highs in the study area are well corelated with the Dharwar, Aravalli, Sausar and Eastern Ghats folding area (Shield area) and with the major faults as detailed in GRI Tectonic Maps. While the magnetic lows correlate well with the late Paleozoic-Mesozoic and Tertiary-Quaternary graven, areas and boundary of Deccan Traps.

Many megalinements and tectonic features like the Gulf of Khambhat (Cambay) as interpreted from the Landsat imagery are found to be in good agreement with the anomaly map.

5. Publications:

The following papers/reports were released during the period of Magsat project in meetings/published:-

- i) Anomaly map of 'Z' component of Indian sub-continent from Magsat Data (1983) by Arur etal (submitted for IAGA meeting).
- ii) Analytical Representation of spatial and Temporal variations of the geomagnetic field in the Indian region (1983) by ARORA etal (Earth and Planetary sciences section of the Indian Academy of sciences - in press).
- iii) Vertical component Magsat Anomalies and Indian tectonic Boundaries (1983) by Negi, Agarwal, Thakur (submitted to GRL).
- iv) Magsat Anomalies Associated with prominent geoidal Low of Central Indian Ocean (1983) by Negi etal (submitted for IAGA meeting)

Copies of papers (i) to (iv) are being supplied to NASA.

6. Problems:

In the computer programmes package sent by NASA to SOI some programmes could not be run on the computer as the card images of some statements were missing. Therefore a suitable software for the reduction of data to a common elevation had to be developed based on the formulae given by Henderson and Cordell (1971). Perhaps as the 'F' scalar magnetometers did not work well during the life time of Magsat, therefore a large portion of 'F' observed values were found missing. As the Vector magnetometers worked quite nicely, they provided an excellent data for the production of anomalies maps for the geomagnetic field components. This data can be used also for the production of isomagnetic charts on the regional basis as well as on global basis

The correlative studies and geomagnetic field models could not be completed within the time schedule due to the following reasons :-

- i) Heavy time consumption in decoding of MAGSAT data
- ii) New computer programmes had to be developed as the programmes supplied by NASA for reduction of MAGSAT data were not readily usable.

The above studies are being continued.

7. Data quality and Delivery:

The data quality provided by the Magsat Mission was quite good. The Magsat data was received bit late as our research proposal was submitted and approved late.

8. Recommendations:

The Magsat - like programme should be repeated with gravity field measurements. It would also give a model of the secular variations for extension of Magsat mainfield model.

9. Conclusions:

Magsat provided a unique and valuable data for studying the description of main field and production of anomaly maps. It has opened a new era in geomagnetic research and allied fields.

10. Acknowledgements:

The Principal Investigator acknowledges with gratitude the data, literature and programmes received from NASA.

The close support of the Indian Space Research Organisation, the Indian Institute of Geomagnetism, the Department of Science and Technology and the Oil and Natural Gas Commission is thankfully acknowledged.

The investigations under this project have been possible due to the active participation of Scientists from NGRI (Dr.J.G.Negi, Dr.P.K.Agarwal and Dr.N.K.Thakur), SAC(Dr.Baldev Sahai, Mr.R.M.Dwivedi and Dr.S.R.Nayak), ISM (Dr.B.N.P.Agarwal) and SOI(Col.(Dr.)M.G.Arur, Mr.P.S.Bains, Mr.Jeevan Lal, Mr.T.R.Joshi and Mr.S.N.Kumar). Their valuable contribution is highly appreciated.

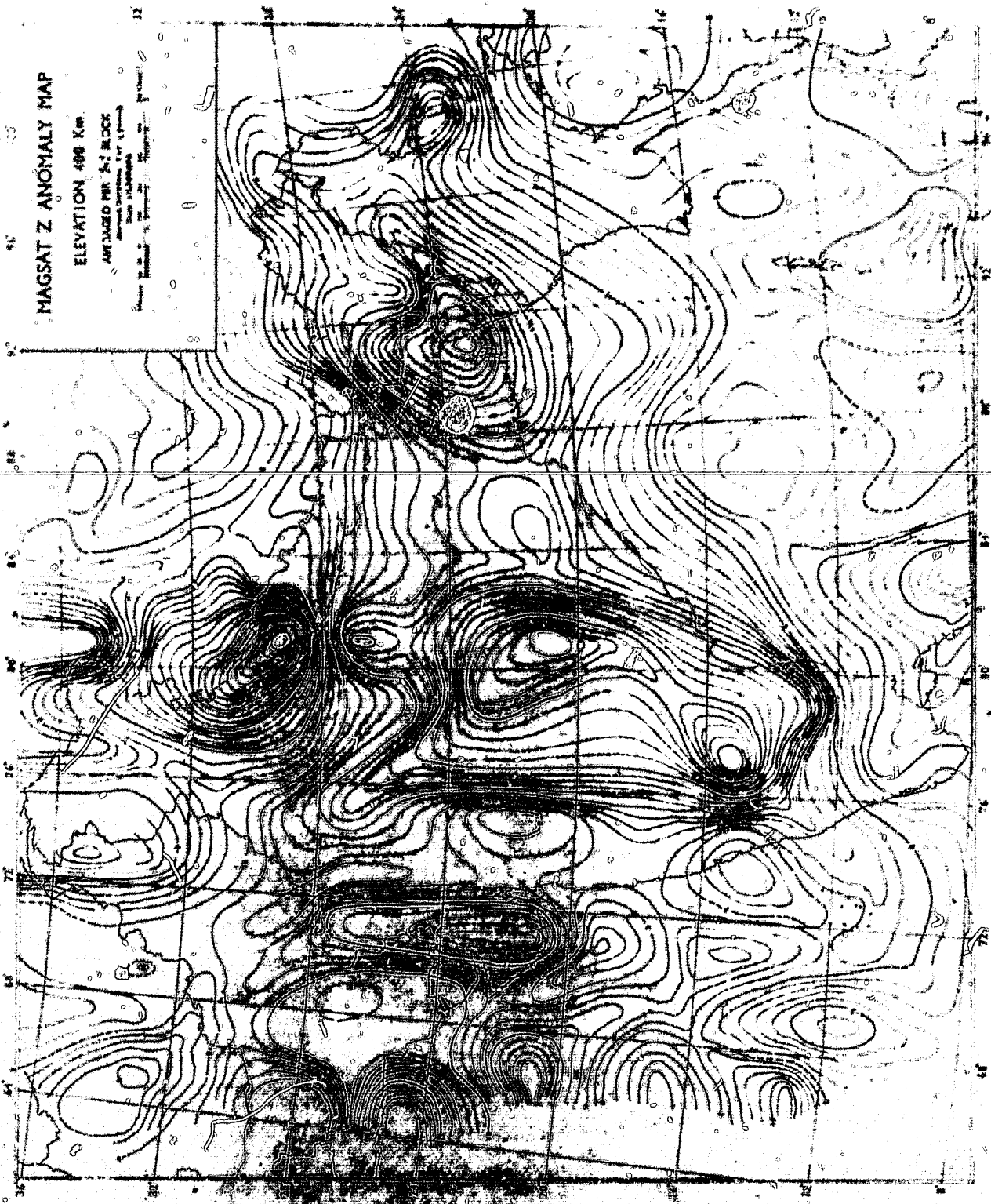
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Figure 1

INDIAN REGION

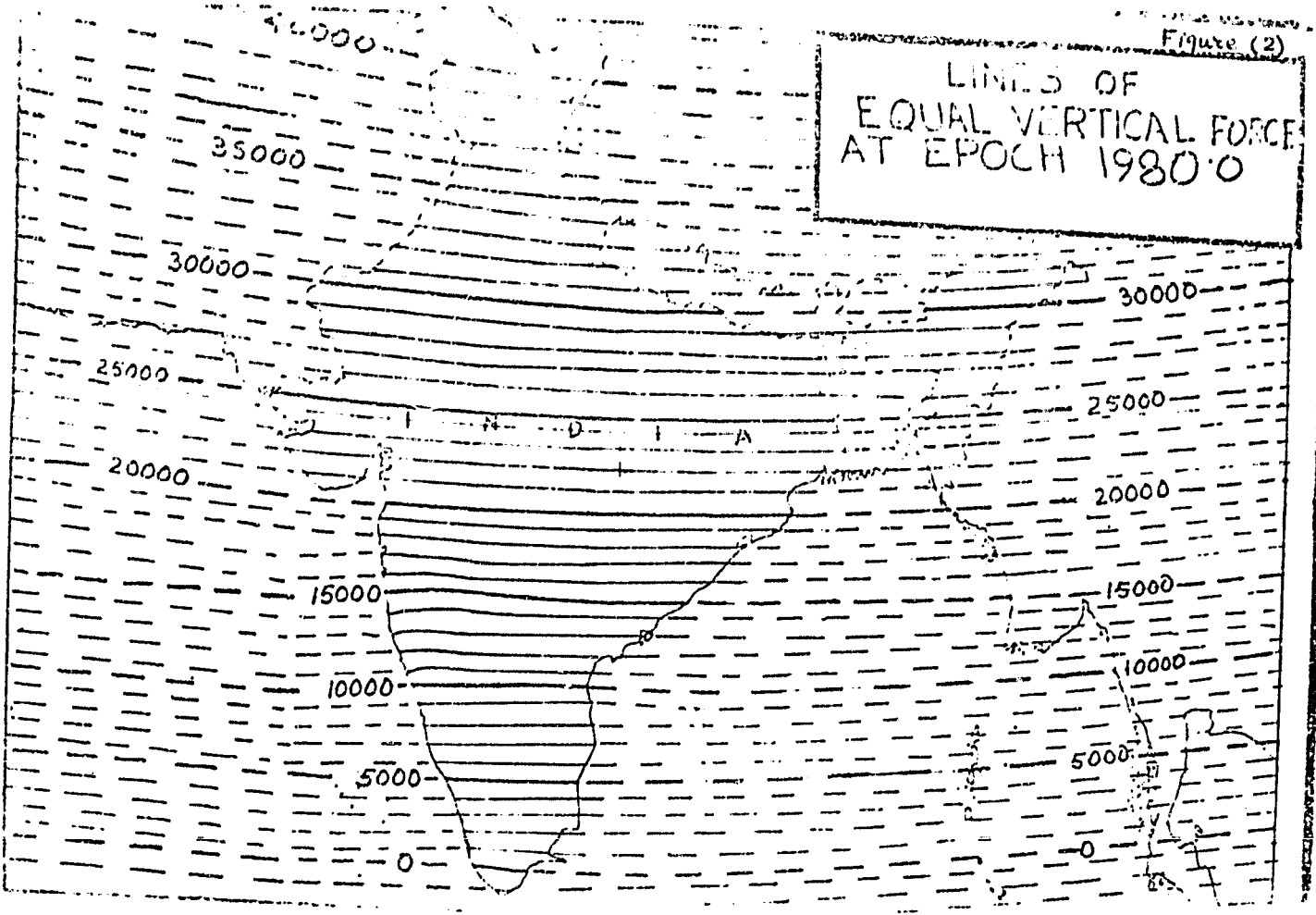


MAGSAT Z ANOMALY MAP

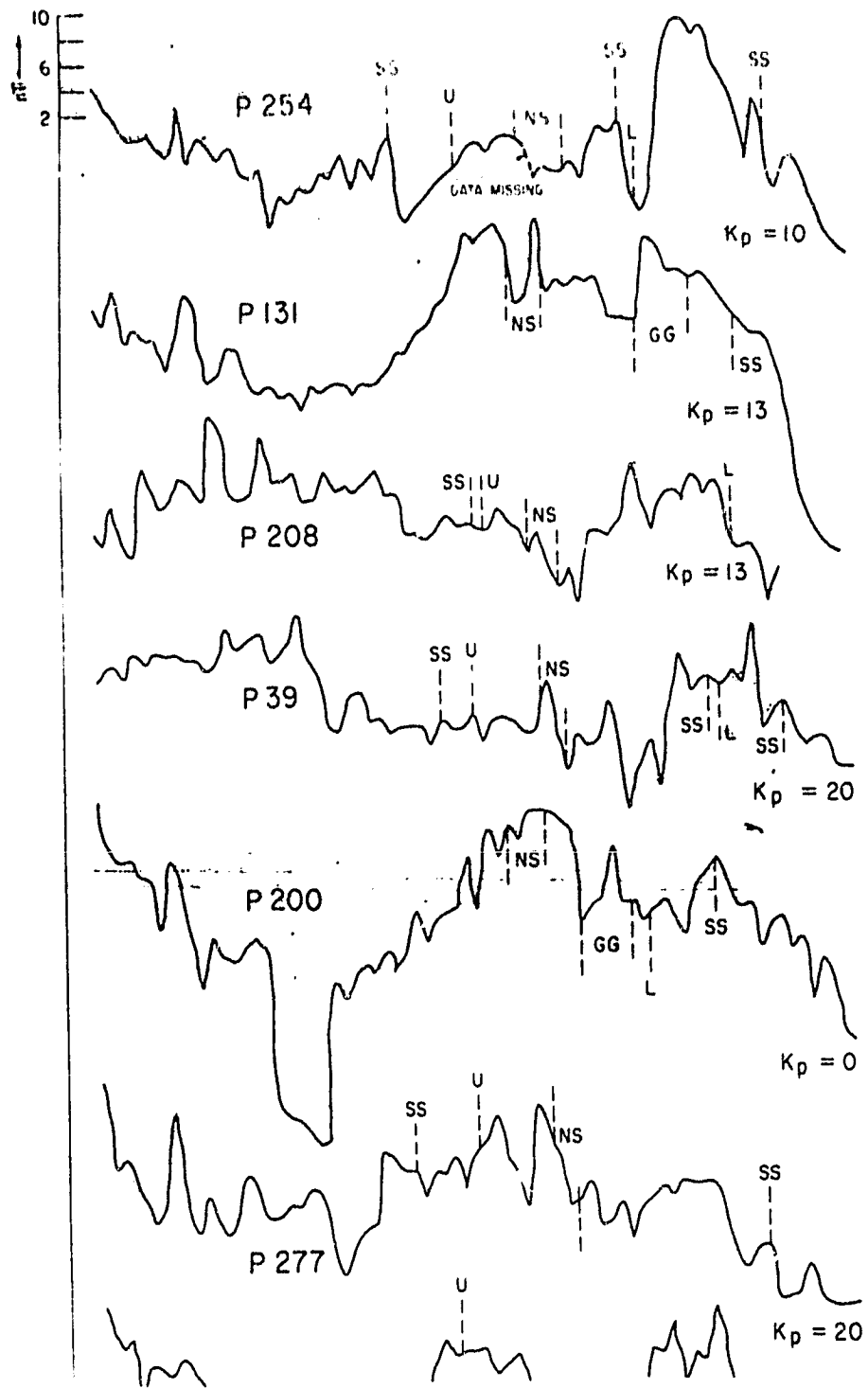
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Magnetic Intensity in Gauss



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Figure (4)

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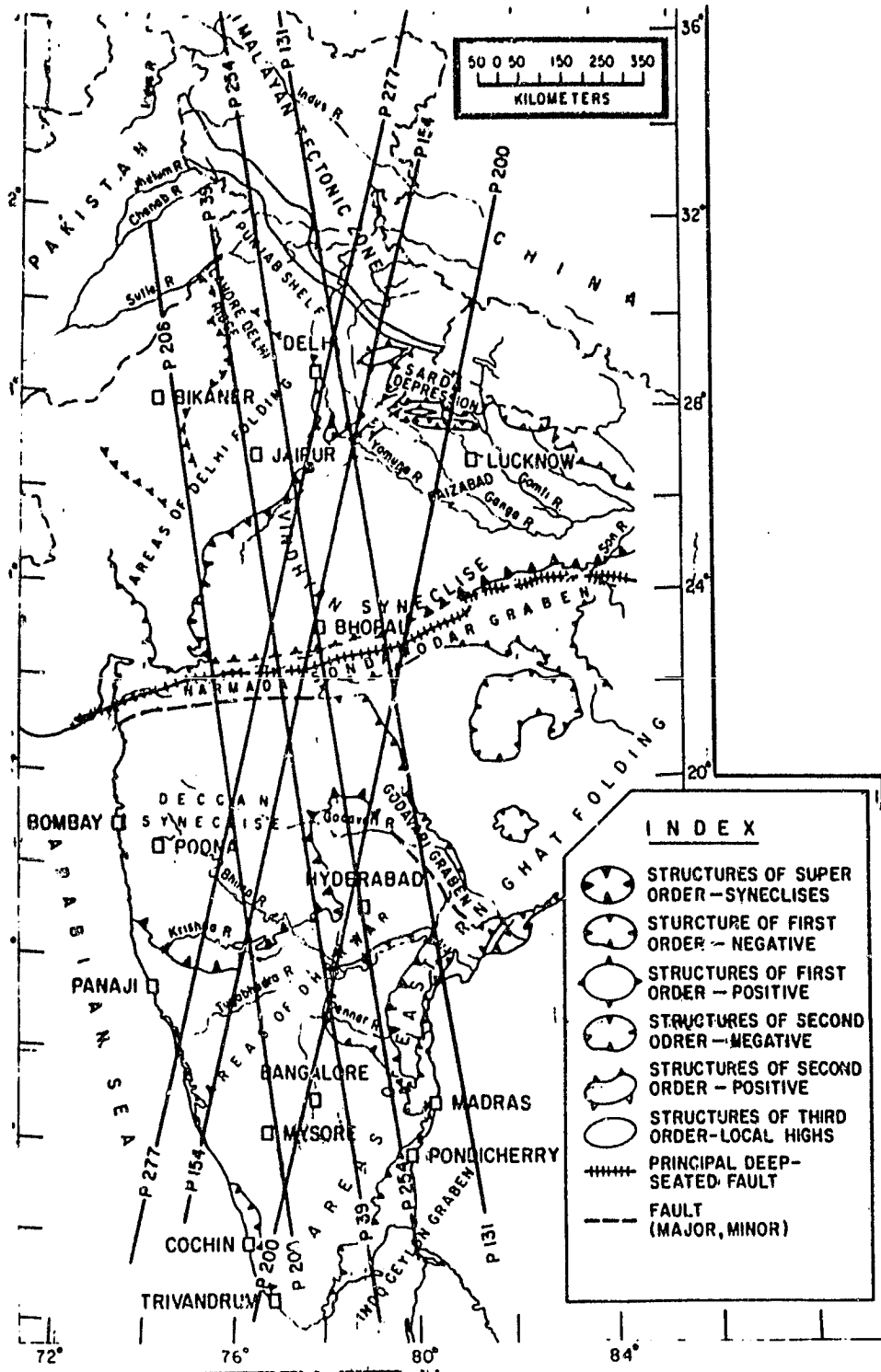


Figure (5).

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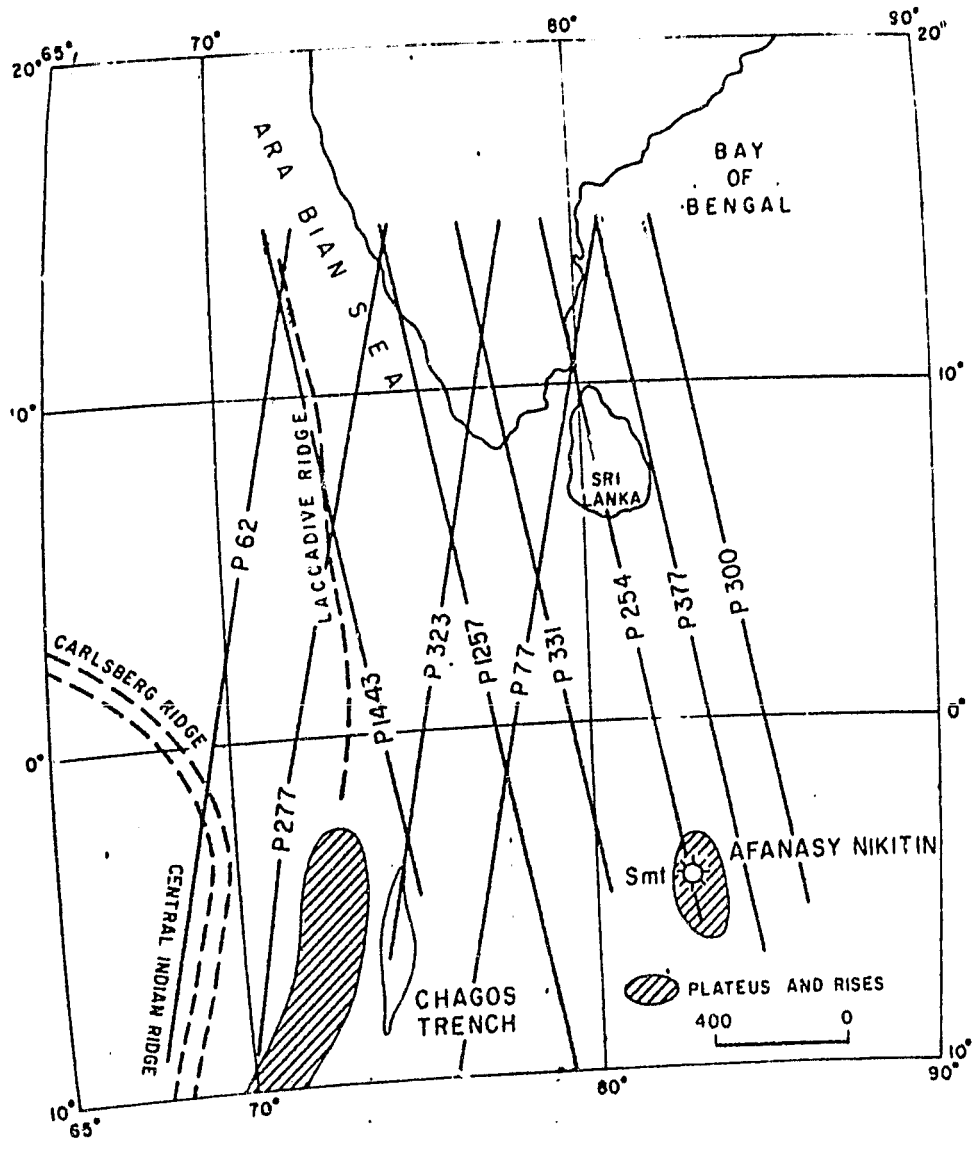


Figure (6).

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