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Comparison of the Aero and marine magnetic data over Peninsular India.

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Abstract

Rigorous reprocessing of the degree sheet aero magnetic maps over peninsular India up to 17^0 N acquired from the Geological Survey of India was undertaken. These degree sheet maps include surveys that have been carried out by different agencies at different epochs and altitude and have not been corrected for the main field. The data grid spacing has a crucial effect on the nature of the map prepared. In order to utilise the aeromagnetic data for studying the deep crust, we have manually redigitised the degree sheet maps at 6' interval and corrected for the main field using IGRF (International Geomagnetic Reference Field) model corresponding to the epoch and altitude of the data collection. Within the Cuddapah region the aeromagnetic data were not available with us; we have therefore merged our ground magnetic data in this region. In a similar manner the published marine magnetic anomaly data were re-digitised. To be able to prepare a composite magnetic anomaly map the aeromagnetic data were downward continued to the mean sea level. The two data sets are handled independently, as the errors in the two are of different nature. We do not merge the data sets, but just place them adjacent to each other to study the trends of the anomalies. The colour shaded aero cum marine magnetic anomaly map over Peninsula India, thus prepared brings out several features that are presented. From the analysis of the aeromagnetic data, we find that the source rocks of the aeromagnetic anomalies are the host province of Charnokites in the Southern Granulite Terrain (SGT) and the intrusives/iron ore bodies in the Dharwar belt (Harikumar et al, 2000). The marine magnetic data is also analysed in a similar manner, to be able to locate the position of the magnetic sources. We find that the SGT continues to the offshore between Madras and south of Karaikal. North of Madras the trends change in the offshore region. Results of the combined aero and marine magnetic sources are presented.

Introduction

The susceptibility variations of the crustal material is much greater than it's density variations and it therefore is very likely that the magnetic anomalies could play a very decisive role in the interpretation of the tectonic features. Very valuable set of aeromagnetic data is available over Peninsular India and could go a long way in contributing to the understanding of the complexities of the deep crust; we have acquired the degree sheet total Intensity aeromagnetic maps up to 17^0N. The mosaics of aeromagnetic maps acquired have different altitudes, epoch of survey, line spacing and line direction. As the main geomagnetic field is known to undergo secular variations and change with altitude, the preparation of an accurate magnetic field anomaly map over the peninsular region is a non-trivial task. At the same time the preparation of a good and accurate aeromagnetic anomaly map is extremely crucial for the proper identification and understanding of the magnetic sources.

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Reddy et al. (1988) have published valuable results up to 12^0 N using the collected aeromagnetic data and Bahulayen (1997) has utilised the aeromagnetic data up to 14^0 N incorporating corrections for the main geomagnetic field. All these papers have utilised the original data that are very closely spaced and these have very effectively brought out the finer structures but many of the long range co-relations have been lost in the details.

Harikumar et al (2000) have prepared an aeromagnetic map to depict the regional features of Peninsular India, after correcting for the main field at the appropriate altitude and epoch; henceforth we refer to this paper as Paper I. The map in Paper I was prepared after manually re-digitising

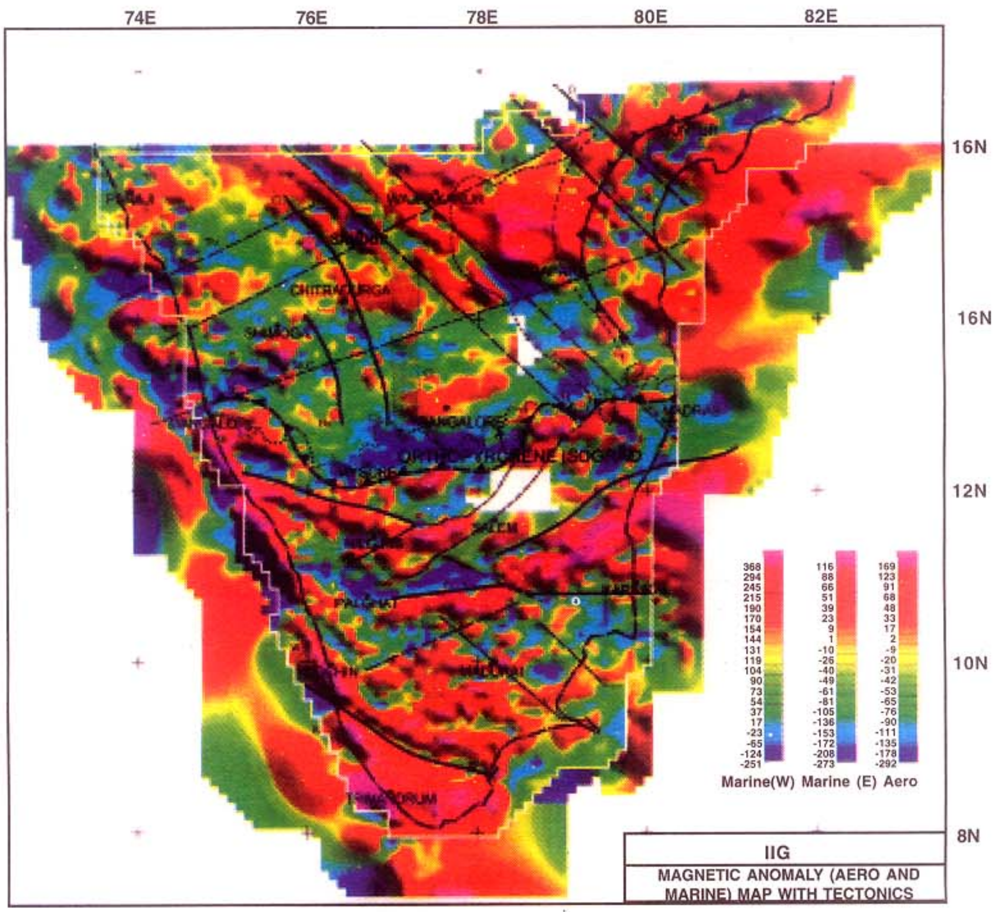

Fig. 1. Crustal Aeromagnetic anomaly map over Peninsular India after corrections, reduced to the mean sea level and the marine magnetic anomalies. Superposed on this is the interpreted tectonic elements from the aero magnetic map. The major lineaments are: Tu: Tungabhadra, K-K: Kolhapur Kurnool; Wk: Wajrakarur; M-C: Mangalore-Cuddapah; Bn: Bababudan; Ch: Chitradurga; Sa: Sandur; Cu: Cuddapah; Bh: Bhima; D: Dindi; M: Moyar; B: Bhavani; Pa-Ca: Palghat Cauvery; P: Palar; Ak: Achankovil: V: Vaigai; W: West coast fault; Cl: Closepet granite.

the degree sheet aeromagnetic maps at 6 minutes interval. This map very well brings out the regional structures as seen from 7000ft. It is our endeavour in the present paper to compare the aeromagnetic anomaly map with the marine magnetic anomalies to check the continuity of the aeromagnetic map into the off shore region and identify and isolate the sources and understand the cause of the magnetic anomalies.

Magnetic Anomaly Map

The procedure for obtaining an accurate anomaly map as detailed in paper I is briefly outlined below. Aeromagnetic surveys over the peninsular shield were conducted from 1980 to 1989 at different altitudes. It thus becomes inevitable to reduce the data to a common barometric altitude to obtain an overall idea of the magnetic response of the geological terrain in general. The catalogue published by Geological Survey of India (1995) includes details about the aeromagnetic data. There however exists a data gap, as degree sheets were not available over the Cuddapah basin. We have incorporated ground magnetic data over this basin, collected at 10km interval by Indian Institute of Geomagnetism (IIG) to fill this gap in the aeromagnetic data. Rajaram et. al (2000) noted that most of the long wavelength features at aeromagnetic height, re-digitised at 6' interval, are also evident on ground data collected at 10km interval. The data over Salem in Tamil Nadu are not available due to lack of Defence clearance.

Only contoured maps were available from GSI. In order to apply any corrections to the observed data and for any kind of analysis, it is necessary to have digital data. These degree maps had therefore, to be re digitised. The data grid spacing has a crucial effect on the nature of the map prepared. The available magnetic total intensity maps were re-digitised manually at 6 minutes interval. The main core field was represented by harmonics up to degree and order 10. The observed aeromagnetic data for each block was corrected using the appropriate IGRF models; thus we had to use the IGRF models 1980 and 1985, with the model being interpolated to the appropriate date and the altitude of observation.

The IGRF removed data in the different blocks are at different elevations. The data sets when continued to the same elevations over adjacent areas are found to mismatch along the area boundaries and they were merged, for the present study, after continuing the aeromagnetic anomalies downward to the mean sea level (Geosoft, 1999). The colour-shaded image of the aeromagnetic map thus prepared is presented in Fig. I. The warm red colours represent highs and the cool blue colours represent lows.

In Fig. 1 the aeromagnetic anomalies downward continued to the mean sea level are plotted side by side with the marine magnetic data. These data have also been re-digitised from published literature, K.S. R. Murthy et al (1987) and Ahmed (1998) at 6 minutes interval and re-contoured for each block belonging to different data set, that were later merged. No attempt is made to merge the marine data with the aeromagnetic data set. Thus the figure has distinct scales to represent the aero and marine magnetic data sets independently. A shift in the baseline is expected as the two sets were corrected separately (the marine data have already been corrected at the source). The interpreted tectonic map of the aeromagnetic anomalies, from Paper I, is superposed on this map to check the continuity.

The aeromagnetic anomalies continue smoothly into the marine region in the Bay of Bengal; thus the Southern Granulite Terrain (SGT) structure appears to extend into the offshore. The Ariyalur high extends in an easterly direction quite far into the offshore together with the Karaikal high depicting a circular localised low in between the two. Off the coast of Madras there is a distinct low. However, just to the north of this, the trends undergo a dramatic change showing a high in the NE-SW direction. In the west, the aeromagnetic anomalies end abruptly at the West coast fault, whose distinct evidence is visible on the marine data as well. The West coast fault is a series of faults practically hugging the coast line but dissected by cross faults: the Panjim shear, the Tungabhadra lineament, the Mangalore- Cuddapah (M-C) lineament, the Moyar-Bhavani shear, the Palghat Cauvery shear (extension) and the Achankovil shear. The strike of the West coast fault is NNW-SSE and extends further south of the tip of the Peninsula. The Khondalite belt at the Southern tip of the Peninsula also has its extension into the offshore.

Analytical Signal

Analytical signal is a practical alternative to reduction to the pole and aids in the delineation of the source body in the aeromagnetic data at low latitudes. The absolute value of the analytic signal is defined as the square root of the squared sum of the vertical and the two horizontal derivatives of the magnetic field. This signal exhibits maxima over magnetisation contrasts, independent of the ambient magnetic field and source magnetization directions. Locations of these maxima thus determine the outlines of magnetic sources (Roest et.al, 1992, Mac Leod et al, 2000). The analytical signal of the total magnetic field reduces the magnetic data to anomalies whose maxima mark the edges of the magnetised bodies. At low latitudes, an extensive source body will have stronger analytical signal at their north and south edges. Figure II depicts the analytical signal of the aeromagnetic anomalies downward continued to the mean sea level and plotted side by side with the analytical signal of the marine magnetic anomalies. A striking feature of the combined analytical signal map is that at 13^0 N parallel, the trends of the maxima align itself along the E-W direction parallel to the orthopyroxene isograd. In fact we can map the orthopyroxene isograd from this map and it appears that the orthopyroxene isograd extends into the offshore in an east-west direction. As noted in Paper I, we find that the Dharwars are devoid of much magnetization contrasts except for the iron ore deposits of Sandur, Goa, Kudremukh and the intrusives in Cuddapah. Even in the offshore region in the Bay of Bengal, North of Madras is practically devoid of magnetic sources except that there is an isolated high at around 15^0 N, 82^0 E which may be associated with intrusives/Mantle Plumes. In fact, the M-C lineament constrains the highs in the marine region to remain to its south. Thus the Mangalore-Cuddapah (M-C) lineament goes from Mangalore via Cuddapah right across the marine region and this may have major implications. There also appears to be a lineament going from the marine area across the peninsular edge at the South of Karaikal up to Mangalore via Salem. The Eastern Ghats are characterised by a zone of maxima in an arcuate shape with convexity towards west. Quite surprisingly the signatures of the Closepet granites show up clearly in this map as a series of intrusives, though it is not quite evident directly in the aeromagnetic anomaly

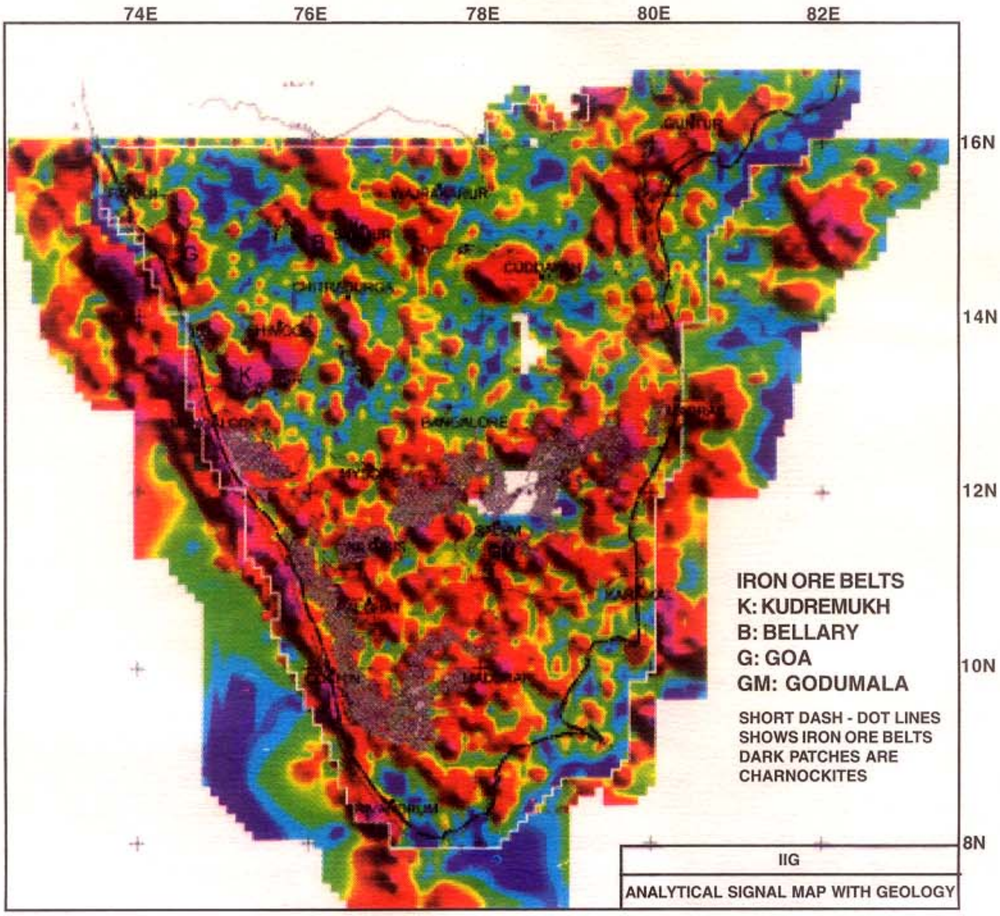

Fig. 2. Analytical signal of aeromagnetic anomaly over peninsular India (at mean sea level) and the analytical signal of the marine magnetic anomalies. Superposed on this are the mapped Charnokite regions of the SGT.

map. From the essentially EW trend in the transition zone, the trends turn to an essentially NW-SE direction below the Pa-Ca shear system. The zone between Moyar Bhavani faults and the Achankovil shear zone is characterized by many maxima, which again extend into the offshore. Plots of the known Charnokites taken from GSI (1993) are superposed on figure 2 and they match very well with the highs in the analytical signal map. We find that the Charnokites extend in an EW direction at Madras into the offshore and go south to a little beyond Karaikal. The extension of the Ariyalur high appears to be associated with Charnokites. Also all the iron belts mapped in the mineralogical map of project Vasundhara (1994) falls on the highs of fig2. Quite surprisingly no signatures of the Khondalite belts are evident in this picture though they show clear highs in the aeromagnetic anomaly map extending south in the offshore. The West Coast fault is seen as a system of faults, intesected by various cross faults. A very important aspect of Fig. 2 is that the analytical signal peaks within the Dharwar region are of the type that represent intrusives/localised iron ore bodies while south of the orthpyroxene isograd there are several peaks representing extensive sources signifying that the host province is magnetic. A very intriguing result is the fact that south of the Achankovil shear zone the analytical signal does not show any sources though we see a magnetic high in the aeromagnetic map related to the Khondalites; it maybe noted that there exists low gradients over the Khondalites in the aeromagnetic map. This implies that the source rock of the magnetic signatures in the SGT are the charnokites while in the Dharwar greenstone belt they are mainly due to the intrusives/iron ore bodies.

Conclusions

The Marine magnetic anomalies match reasonably well with the aeromagnetic anomalies continued to the mean sea level with some of the cross features cutting right across both. From the analytical signal map we infer that the sources of the aeromagnetic anomalies in the Dharwar region are mainly associated with iron ore/ intrusives; also in the marine region to the North of Madras, there is only one main magnetic source probably related to some mantle plume or intrusives. In the SGT the magnetic sources are the charnockites, which extend into the offshore between Madras and the region to the south of Karaikal. The iron ore deposits of Kudremukh, Goa, Sandur, Bellary and Salem are clearly visible in the map. The West coast fault is dissected by a series of cross faults.

Metamorphism appears to leave its imprint on the magnetic anomalies. We therefore believe that the magnetic anomalies can play a very crucial and decisive role in the understanding of the tectonics of the region. A comparison with the magnetic data from Antarctica and Australia should help to build up a tectonic model based on plate theory.

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