

Magnetic basement along the Jadcharla–Vasco transect, Dharwar Craton, India

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Regional total magnetic investigations were carried out in the northern part of the Dharwar craton along the 600 km long Jadcharla–Vasco transect. From qualitative analysis various geological boundaries and tectonic features such as faults and shear zones were identified. The IGRF corrected low-pass filtered magnetic data was modelled to obtain the configuration of the magnetic basement. Three tectonic blocks bounded by deep-seated faults and corresponding to the western Dharwar block, the eastern Dharwar block and the upthrust intervening block separating the two were identified.

THE crust in peninsular India has evolved through complex geological processes that have been in operation since the Archaean times. The broad geological configuration of the Archaean to Proterozoic Dharwar craton consists of mainly three members, the peninsular gneisses, schist belts and Closepet granites, that are related to each other in complex assemblages.

However, while the Dharwar craton has been well researched geologically^{1–3}, relatively few geophysical studies have been reported. Under a national programme organized by the Geological Survey of India (GSI) with the assistance of the National Remote Sensing Agency (NRSA), systematic aeromagnetic coverage is being achieved in India by the GSI, Atomic Minerals Division (AMD) and the NRSA. More recently, various workers^{4–9} have prepared aeromagnetic maps illustrating regional features in peninsular India. Ground surveys on the other hand have been limited to regional scale surveys along the Udipi–Kavali profile and other DSS profiles.

The present work was motivated by the need to obtain a clearer perception of the subsurface structure along the Jadcharla–Vasco transect in the Dharwar craton. In view of the significant susceptibility variation¹⁰ of crustal material that is much greater than the corresponding density variation^{11,12} in the Dharwar craton, it is more than likely that the magnetic method would play a major role in the interpretation of the magnetic basement as also the major tectonic features.

Qualitative analysis of regional magnetic surveys carried out along the 600 km Jadcharla–Raichur–Gadag–Hubli–Dharwar–Vasco subtransect was attempted to identify the

various deep faults, geological contacts, shear zones, etc., with a view to understanding the broad geological configuration of the region.

Jadcharla lies 85 km southwest of Hyderabad along National Highway No. 7, and 15 km NE of Mahboobnagar town, Mahboobnagar district, Andhra Pradesh. The 600 km Jadcharla (latitude 16°41'40"N and longitude 78°08'18"E) – Vasco (latitude 15°23'40"N and longitude 73°48'55"E) transect (Figure 1) runs in an approximately E–W direction and courses through three states – Andhra Pradesh, Karnataka and Goa. Cutting across the northern part of the craton, this transect traverses almost all the geological formations occurring within the basement of peninsular gneisses that formed 3400 to 3000 million years ago (Ma)^{13–15}.

The widespread belts of subsequent schists and numerous enclaves of a wide variety of volcano-sedimentary material of the Dharwar supergroup (2900–2600 Ma) lie unconformably over the peninsular gneisses¹⁶. Of the various schist belts encountered along the transect, the Makthal, Raichur, Sindhanur and Kustagi schist belts have shown occurrences of gold. An interesting feature observed in the schist belts of the Dharwar craton is that they are generally associated with shear zones. Thus the Makthal, Raichur, Sindhanur and Tawergiri schist belts have shear zones on their western sides and the Gadag schist belt has a shear zone on its eastern side. These shear zones have considerable width and depth extents and mark the boundaries of the schist belts within which a thick series of volcanic rocks/sediments were deposited^{17–20}.

The youngest members of the geological sequence in the region are the younger granites (Closepet equivalents), exposed intermittently along the transect. Cutting through the metamorphic fabric of the older gneisses, these granites mark the end of the Dharwar cycle around 2600 Ma¹.

Total magnetic field investigations were carried out with a station interval of 1 km along the entire length of the Jadcharla–Raichur–Vasco subtransect (Figure 1) using the Model G-856 Proton Precession Magnetometer with an effective reading accuracy of 1 nT and referred to the appropriate base. The total magnetic field was corrected for the normal variation using NGRF²¹ software that incorporates the latest IGRF²². To account for the diurnal variation of the earth's magnetic field, two magnetometers were used for the survey. One was maintained at each of the bases considered in turn. The other magnetometer was taken along the traverse and the time and total magnetic field were recorded at every station and referenced to the corresponding base. A diurnal correction of less than 10 nT/hour was observed and applied to the data. The overall accuracy after reduction was 5 nT. Figure 2a shows the observed and filtered (5-point moving average) total magnetic intensities and Figure 2b, the IGRF corrected and filtered magnetic profile along the transect.

Magnetic anomalies are in general complex in nature when compared to other geophysical anomalies. This is

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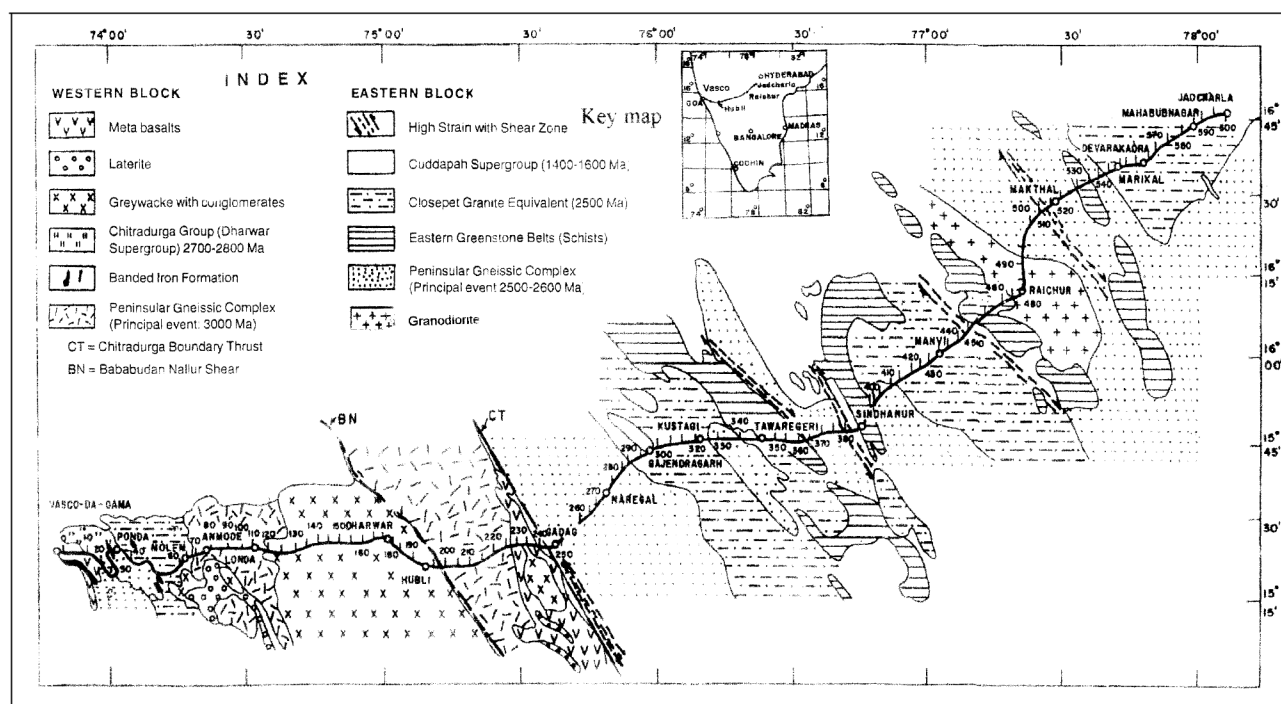


Figure 1. Geology and layout map along the Jadcharla–Vasco transect.

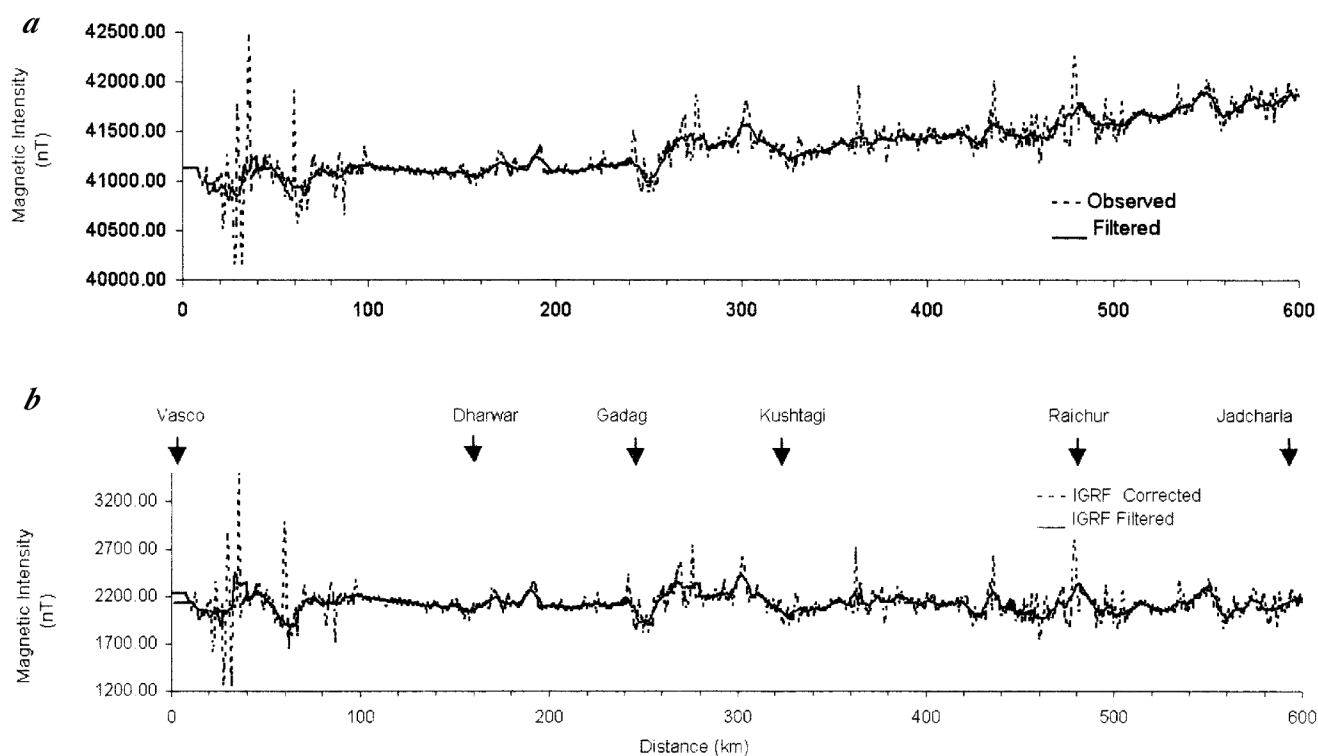


Figure 2. *a*, Observed and filtered total magnetic intensities and *b*, IGRF corrected and filtered total magnetic intensities along the Jadcharla–Vasco transect.

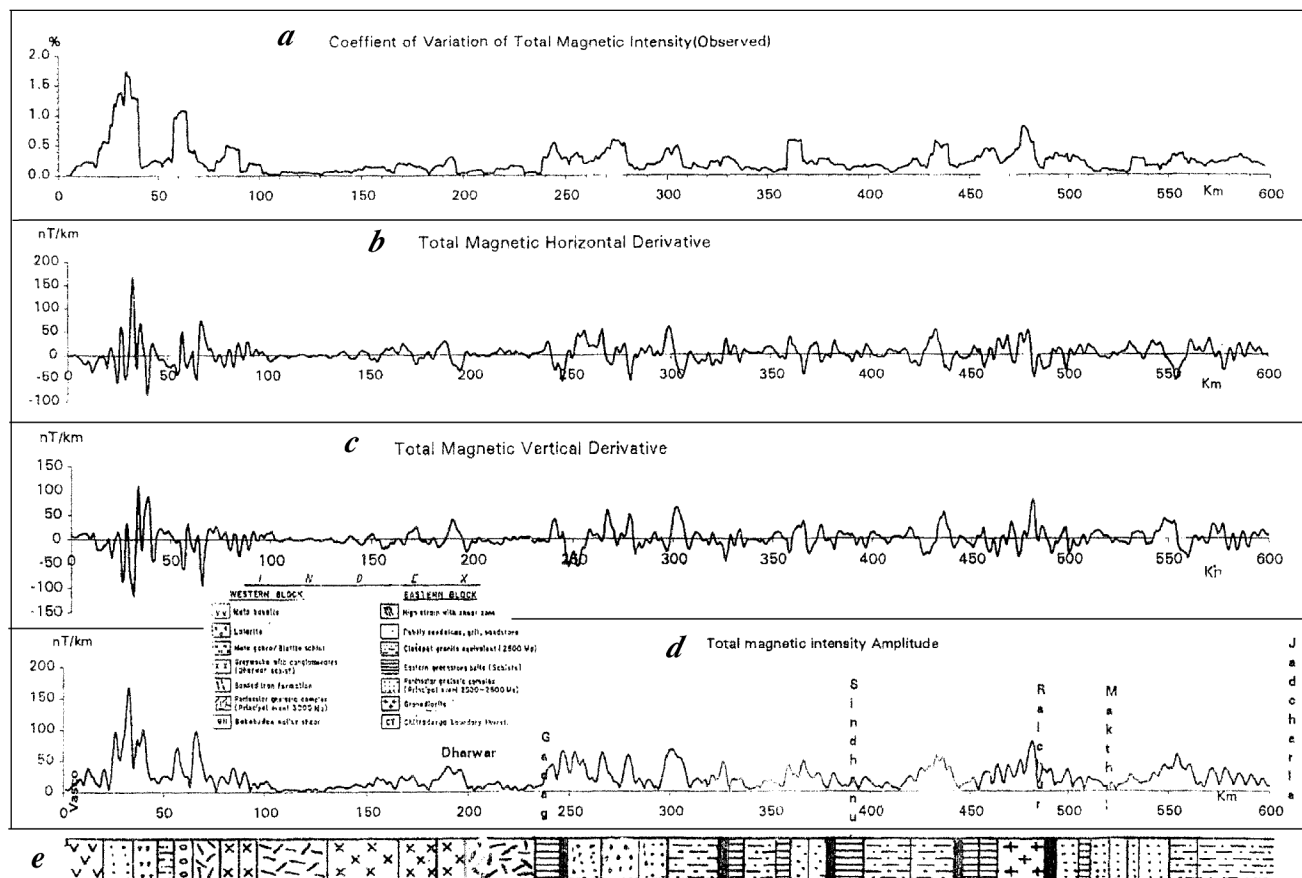


Figure 3. *a*, Coefficient of variation; *b*, First horizontal derivative; *c*, First vertical derivative; *d*, Analytical signal amplitudes of total magnetic intensities, and *e*, Inferred geological section along the Jadcharla–Vasco transect.

because magnetic susceptibility is much less uniform in nature than other physical properties. Further, magnetic signatures are determined not only by the nature of the causative but also by the inclination of the inducing field as also its bipolar nature and therefore do not necessarily overlie the causative exactly. In spite of these limitations, the method is useful for determining the basement structure.

From Figure 3 *a*, which shows the magnetic intensities along the profile, four identifiable trends can nevertheless be delineated: the western alternating high and low (stations 0 to 74), followed eastward by a broad low plateau (stations 74 to 198), a sequence of highs and lows (stations 198 to 307) and a gentle rise towards the east (stations 307 to 600).

Figure 1 indicates that the sharper features delineated are of local extent and can be attributed to variations in schists, Closepet granite equivalents (2500 Ma), younger granites (2500–2600 Ma) and peninsular gneissic complex (3000 Ma). Thus, from the amplitudes and trends of the magnetic intensity profile, it is evident that the peninsular gneisses have low but fluctuating magnetic response (40920 to 41120 nT). On the other hand, the Closepet granites

are characterized by relatively higher amplitude anomalies varying over a range of 760 nT (41160–41920 nT). The greenstone belts of the western block of the Dharwar craton exhibit perceptible magnetic signatures only when in association with BIF. These broad features are also apparent on the IGRF corrected magnetic profile for the transect.

It is worthwhile to note that magnetic properties such as the susceptibility of the lower continental crust are determined in part by the metamorphism that affects the iron compounds in rocks^{23,24}. Thus amphibolite grade rocks are not nearly as magnetic as in the corresponding granulite facies because in the granulite grade the iron bound to non-magnetic minerals in the former is released yielding nearly pure magnetite⁶. The magnetite thus released represents the most important extensive zone of increased magnetization. However, in the eclogite grade, iron again enters silicate minerals and there is a corresponding fall in magnetization levels. Thus magnetization of metamorphosed rocks varies strongly, over orders of magnitude. This in turn implies that from the relative magnetic relief (Figure 3 *a*) schists and gneisses with abundant basic intrusions can be readily delineated.

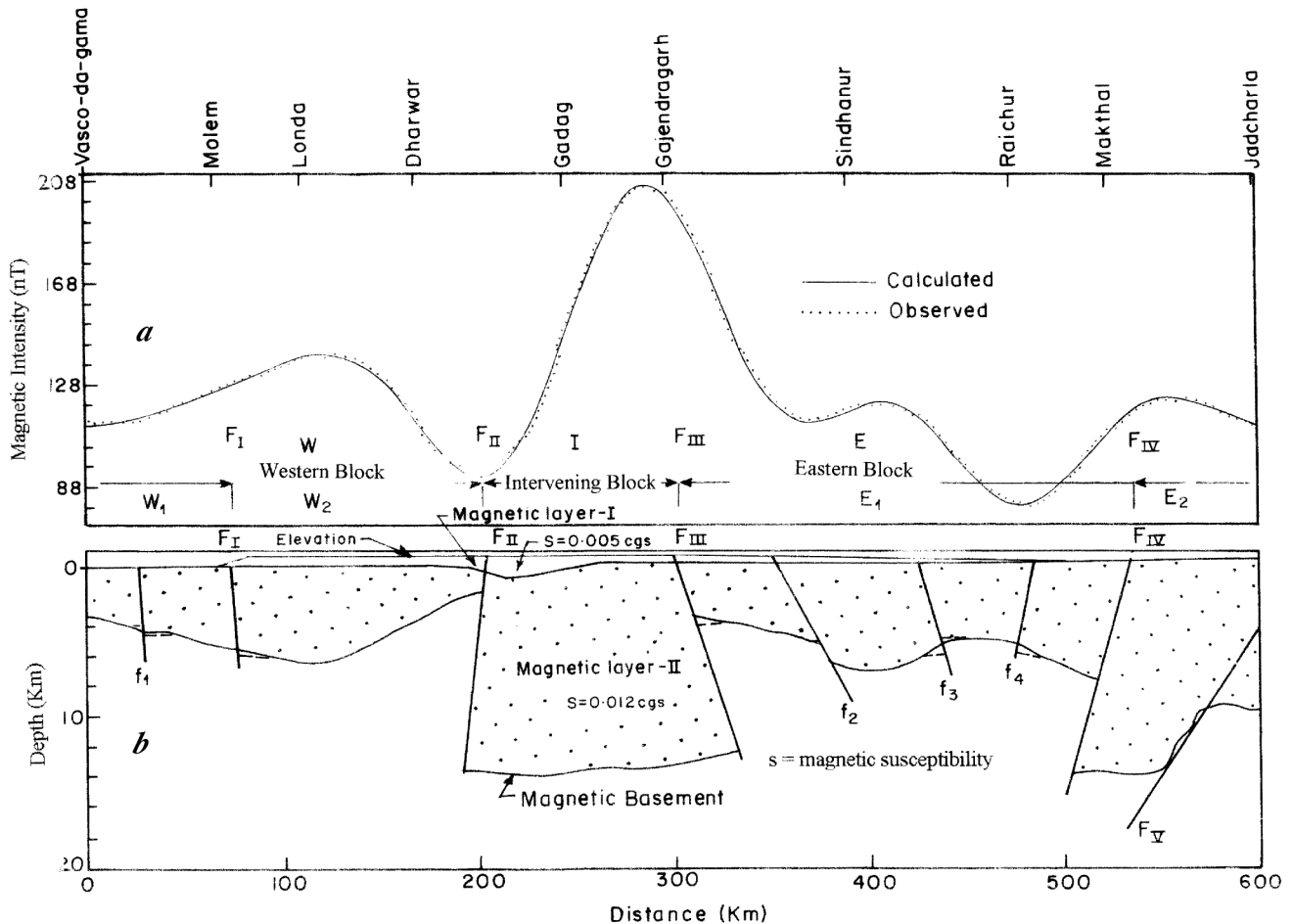


Figure 4. *a*, Low-pass filtered magnetic intensities and *b*, Magnetic basement along the Jadcharla–Vasco transect in the Dharwar Craton.

As the magnetic profile is particularly susceptible to noise interference, the coefficient of variation, a statistical parameter that reduces random noise²⁵ was computed. Figure 3 *a* shows the coefficient of variation of total magnetic intensity.

For finer resolution of lateral discontinuities in the upper crust, possibly associated with steeply dipping faults and igneous intrusions in crystallines, horizontal (Figure 3 *b*) and vertical (Figure 3 *c*) gradient profiles²⁶ and analytic signal amplitudes (Figure 3 *d*) of the magnetic signal are useful, from which the geological section can be inferred.

From the close spatial relationship and the nature of boundaries interpreted qualitatively from the total magnetic intensities, as well as the coefficient of variation of the latter, a total of 31 faults/geologic contacts and boundaries and five shear zones were identified (Figure 3 *e*).

In the present study the structure of the magnetic basement in the Dharwar craton has been analysed. The NGRF corrected magnetic data was filtered using a low pass filter. This filter retained the large wavelengths or low wave-number components (cut off wavelength of 0.005 cycles/second) of the signal, which correspond to

deep-seated sources and features of large areal extent, suppressing the short wavelength components corresponding to shallow features (Figure 4 *a*). Thus analysis of the low pass filtered signal is useful for understanding regional geological features²⁷.

Some of the many ways to get quantitative estimates of depth to basement from inversion are the local spectra method²⁸, Werner deconvolution²⁹ and analytical signal method³⁰. These methods suffer from various drawbacks in that they cannot accurately map the undulations in the basement as they give only average depths. Therefore, in the present study, forward modelling/inversion was performed using GM-SYS software³¹. The computational basis of this software is based on the methods of Talwani *et al.*³² and Talwani and Heirtzler³³ and makes use of the algorithms described in Won and Bevis³⁴. The software assumes a two-dimensional flat earth model and uses the USGS SAKI³⁵ implementation of the Marquardt inversion algorithm³⁶ to linearize and invert the data. After specifying the major parameters such as depth of interest for the survey, length of the profile, sampling interval, number of stations and units of physical property measured, a sub-surface model is interactively initiated and visually modi-

fied in terms of a layered earth using known geology as a control.

The Dharwars are essentially free from magnetic signatures except for the known iron ore deposits/intrusions⁶. Thus though there are instances of banded iron formation west of Gadag, the significant influence on the anomaly is contributed by exposures of the low susceptibility sediments. Therefore, for the present study low average magnetic susceptibilities of 0.005 and 0.012 cgs units (obtained from the Indian Institute of Geomagnetism, Mumbai) were assumed for the near surface layer (Magnetic Layer I) and the layer above the magnetic basement (Magnetic Layer II) respectively. The basement was visually modified (Figure 4b) for best fit between the observed and computed anomalies. The error in fit for the closest approximation was 1.3%.

Undulations in the modelled basement at depth along the transect correspond to sharp changes in the underlying geology, i.e. either to geological contacts or faults. Geologic contacts can be identified mainly from the near surface while faults characterize both the near as well as the deeper configuration. Since, as mentioned above, the low-pass filtered magnetic profile that selectively retains information corresponding to the deeper features was analysed, the undulations in the inferred basement have been attributed to faults: running west to east along the profile, five deep-seated faults FI, FII, FIII, FIV and FV are identified. While the east-dipping FI occurs east of Molem (at station 74) and separates the Upper Dharwar sediments from the younger granites in the region, FII (at station 198) has a westward dip and corresponds to the Bababudan Nallur shear⁹. FIII (station 307) is again marked by an eastward dip and runs along the western margin of the Closepet batholith, while FIV (station 530) lies east of the Closepet batholith, encompassing the Makthal schist. Fault FV strikes the surface 26 km east of Jadcharla and falls outside the transect.

From the above, along the transect three broad tectonic regions are identified. The westernmost block (Western Dharwar Block **W**) extends from the western end of the transect to station 198. This block is bounded on the east by the Bababudan–Nallur shear (Fault FII). The tectonic region bounded by FII on the west and FIII on the east (from station 198 to station 307) constitutes the Intervening block **I**. The region to the east of FIII (station 307) corresponds to the Eastern Dharwar Block **E**. This tectonic classification is supported by gravity studies³⁷ as well.

Further, while **W** is further subdivided into **W1** and **W2** by Fault FI (station 74), the eastern Dharwar block **E** is subdivided into **E1** and **E2** by Fault FIV (station 530). Within the broad tectonic classification of the Dharwar craton into **W**, **I** and **E** characterized by deep-seated faults, four other faults extending down to the magnetic basement, f1, f2, f3 and f4 occurring at station numbers 31, 350, 424, and 498 respectively, are perceived. On sur-

face, while f1, f2 and f4 correspond to the contacts between banded iron formation and younger granite, younger granite and schist and granodiorite and peninsular gneiss respectively, f3 is a fault within the younger granite occurrence.

From the disposition of faults, it is evident that **E2** and **I** are relatively upthrust. It is seen that these upthrust zones are associated with deeper occurrence of magnetic basement. The average depth to magnetic basement for **W1** and **W2** are 5.09 and 5.12 km respectively, while the average depth for **W** as a whole is 5.11 km. However, most marked is the configuration of the magnetic basement in the middle of the transect, from station 198 to station 307 (**I**), where the maximum depth to magnetic basement of 13.54 km is observed centered on station 280. The corresponding figure for **E1** that is characterized by an undulating magnetic basement is 6 km, while for the upthrust **E2**, it is 12.14 km.

When we look at the geology along the transect (Figure 1), it is evident that in **W** apart from the deep-seated fault east of Molem, there are ten discontinuities that correspond to the contacts between meta-basalts, laterites, meta-gabbro, graywacke/conglomerate (Dharwar schists) and the peninsular gneisses. This block is thus broadly characterized by a number of well-developed low-grade granite greenstone belts with their iron and manganese ores that are bound on their eastern side by the Bababudan–Nallur Shear (FII).

The intervening block **I** consists of two faulted contacts and a shear zone (associated with the Chitradurga thrust) and has a geology of younger granites (210–225), Gadag schists (225–245) and two intrusive bodies separated by the host peninsular gneisses (248–307). As already mentioned, this block is bounded on the east by the Closepet batholith.

In **E1** and **E2**, apart from the deep-seated fault near Makthal there are 14 faults/contacts and four schist belts/shear zones. These blocks thus consist of a general geology of younger gneiss of granitic and granodioritic composition, within which are enclosed a number of narrow linear bands of auriferous schist belts. Just as in the western Dharwar block, in the region around Makthal (station 530) over which local highs (corresponding to schists and intrusives) are observed, there is an interesting feature that suggests a shallow occurrence of granite/gneiss basement indicating a complex tectonic picture with a possibility of occurrence of crustal/sub-crustal upliftment. From magnetic gradients (Figure 3), wherein highs are associated with Closepet granites, the same were delineated easily.

These results are significant because they suggest an alternate tectonic model for the Dharwar craton. In particular, there have been conflicting opinions on the location and nature of boundary between the western and eastern Dharwars. It has variously been considered as the Closepet granite batholith¹, shear zone west of the Closepet out-

crop^{3,38,39}, and as an upthrust zone along the Chitradurga Boundary thrust fault^{9,40}. More recently, Reddy *et al.*⁴¹ reevaluated the craton with seismic wave velocities and suggested that the boundary between the eastern and western Dharwar cratons could be further west of the Closepet granite, along the eastern margin of the Chitradurga schist belt. It is worthwhile to note that, Srinivasan and Sreenivas⁴² suggested that the region between the western margin of the Chitradurga thrust and the eastern margin of the Bababudan–Shimoga belt could be of an elongated domal/intrusive nature. From the results of our analysis we believe that the extent of this domal structure (I)⁴³ is wider, stretching on its eastern side up to the western margin of the Closepet batholith. Since I seems to be upthrust, a structure that can only be explained by upwarping and consequent faulting at contacts arising possibly due to a domical/intrusive structure, it is proposed that this block, rather than any linear feature, marks the boundary between the eastern and western Dharwar cratons. This then implies that both the Gadag schist as also the Chitradurga thrust fault, believed to be members of the western Dharwars, now fall in the intervening block.

Thus from quantitative analysis of regional total magnetic field investigations carried out along the Jadcharla–Vasco transect that cuts across the northern part of the Dharwar craton, the magnetic basement was obtained. Three major tectonic blocks, the western Dharwar block, the eastern Dharwar block and the upthrust intervening block separating the two, were delineated. A further classification of the western and eastern Dharwar blocks into two subblocks each, displaced relative to each other was made. The upthrust blocks were found to be associated with deeper magnetic basement. In particular, the upthrust intervening block separating the eastern and western Dharwar cratons was found to be associated with maximum depth of occurrence of magnetic basement of 13.54 km. Further, from qualitative analysis, the geological differentiation – various faults contacts, geological boundaries and shear zones – within these blocks was detailed.

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