CHAPTER - VIII

GEOPHYSICAL STUDIES

CHAPTER-VIII

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The occurrence of granulite facies rocks as exhumed deep crustal segments in many of the Precambrian shield areas, leads to the inference that the large part of the lower continental crust is made up of granulite facies rocks. The minerals such as garnet, pyroxene etc. by virtue of their high density impart higher density to granulite facies rocks and suggest seismic velocities appropriate of lower crust as compared to supracrustals (Smithson and Brown, 1977). As such, the granulite facies rocks are very well reflected in the gravity maps and deep seismic reflection profiles.

VIII.1 Gravity Surveys

Systematic gravity surveys were conducted during 1976-83 by Reddy and Ramakrishna (1988) in Rajasthan-Gujarat shield. Corresponding magnetic measurements of VF also made concurrently are discussed later. The most dominant feature of the area is an elongate Bouguer gravity high of 80 m.gal extending over 300 kilometres from Singhana in Rajasthan to Limkheda in Gujarat **(Fig. 8.1)**. This has been interpreted as a horst with a narrow trough along its western margin. Besides these, a gravity high of 35 m.gal around Palanpur is also indicated suggesting another crustal block involved in vertical tectonics.

Further according to them (op cit), the residual gravity map is suggestive of the detailed topography of a denser basement (2.9 gm/cc) underlying the supracrustals (2.67 gm/cc) made up of the Precambrian metamorphites The various basement ridges and highs bear evidences of faulting and fracturing on the flanks and carry a distinct impress of tectonism. The dominant trends are NE-SW in Rajasthan and N-S in Gujarat suggesting two different orogenic episodes.

With regard to density for Bouguer correction, laboratory measurements were made for more than 150 rock samples representative of the shield and adjoining areas by Ramakrishna and Bhaskara Rao (1981). The measurements indicated overlapping densities for all the three Supergroups within the range of 2.5 to 2.7 (with majority showing 2.65 - 2.7 gm/cc)). Hence they considered it reasonable to suggest usual value of 2.67 gm/cc for the combined elevation correction. The terrain correction calculated for dozen crucial stations was found to be 1 m.gal and therefore was not applied.

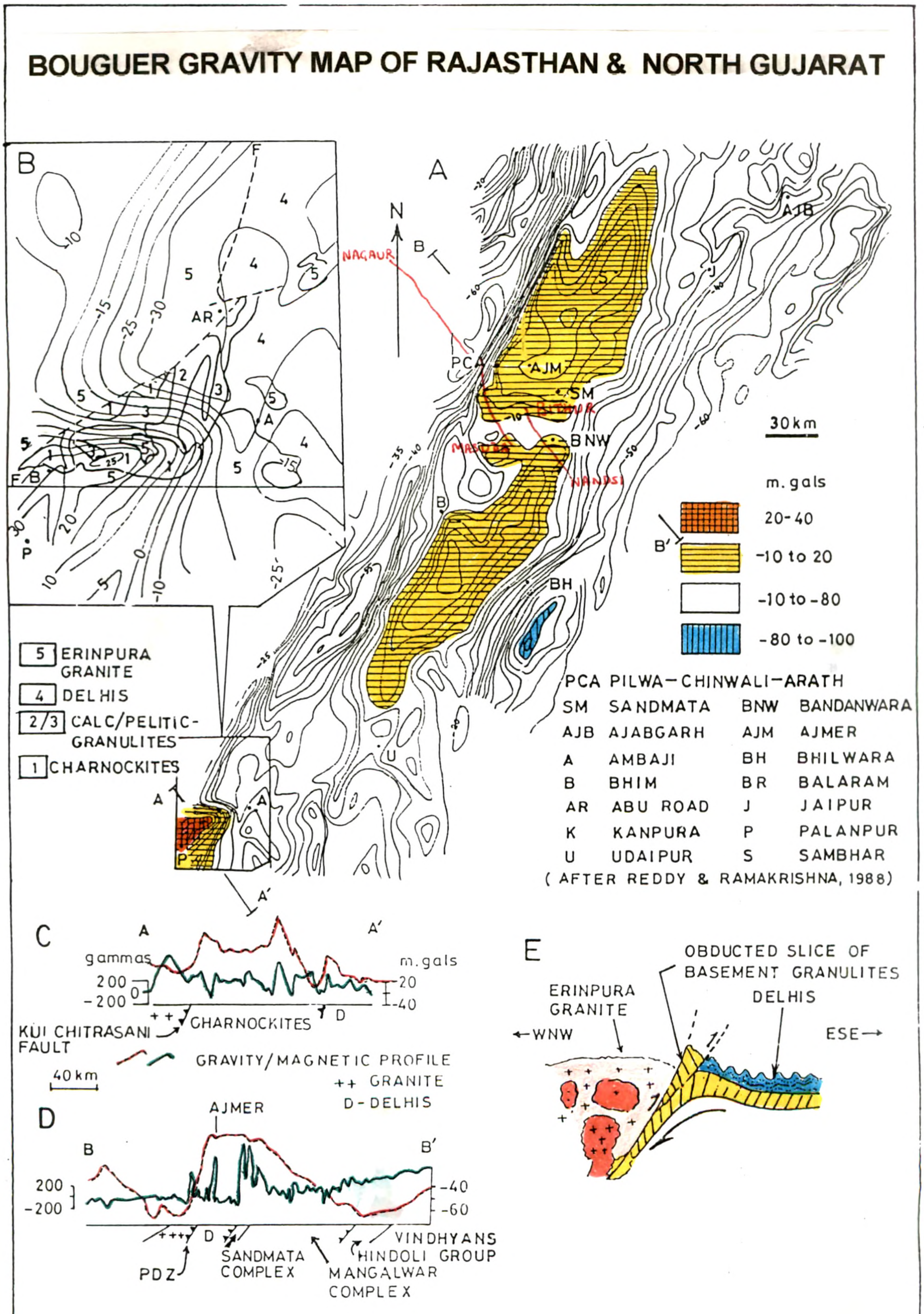
BOUGUER GRAVITY MAP OF RAJASTHAN & NORTH GUJARAT
A
B
N
NAGAUR
PCA
AJM
SM
BNW
AJB
J
BH
B
U
30 km
m. gals
20-40
-10 to 20
-10 to -80
-80 to -100
PCA PILWA-CHINWALI-ARATH
SM SANDMATA
BNW BANDANWARA
AJB AJABGARH
AJM AJMER
A AMBAJI
BH BHILWARA
B BHIM
BR BALARAM
AR ABU ROAD
J JAIPUR
K KANPURA
P PALANPUR
U UDAIPUR
S SAMBHAR
(AFTER REDDY & RAMAKRISHNA, 1988)
5 ERINPURA GRANITE
4 DELHIS
2/3 CALC/PELITIC-GRANULITES
1 CHARNOCKITES
AR
F
P
C
A
A'
gammas
m.gals
200
-200
20
-40
KUI CHITRASANI FAULT
CHARNOCKITES
D
GRAVITY/MAGNETIC PROFILE
++ GRANITE
D - DELHIS
40 km
D
AJMER
B
B'
200
-200
-40
-60
PDZ
SANDMATA COMPLEX
MANGALWAR COMPLEX
HINDOLI GROUP
VINDHYANS
E
OBDUCTED SLICE OF BASEMENT GRANULITES
ERINPURA GRANITE
DELHIS
←WNW
ESE→

FIG. 8·1

Reddy and Ramakrishna (1988) interpreted the gravity data on the basis of basic geology of Rajasthan and Gujarat given by Hacket (1881), Coulson (1933) and Heron (1953). The region comprising the Aravalli mountains and the Archaean plains to the east has been regarded as a horst by Fermor (1930). As such there is no mention of 2-pyroxene granulites and charnockitic suite of rocks in their work.

As most of the area under present study is confined to east-central part of Survey of India Sheet No. 45D (Abu Quadrangle, Gujarat and Rajasthan) it is significant to have a careful scrutiny of the Bouguer gravity map of these areas (**Fig.8.2**) The following account is after Reddy and Ramakrishna (Op cit.).

Topography The general elevation varies from less than 100 m in the SW to 300 m in the E with the exception of Abu range of hills on which the Gurusikhar peak attains a height of 1722 m.

Geology : Kumbalgarh and Sirohi Groups of rocks of the Delhi Supergroup, Sendra Ambaji and Erinpura Granites, Malani plutonic suite around Abu (Gupta et al., 1992)

Gravity Features : The elongated low (F4) east of Sirohi represents the southwestern end of the gravity trench that extends for over 300 km. It is bounded on the west by a deep fault reflected as a band of close contours (F5) that trend NE-SW for most part and eventually swing along the periphery of the high (F6) around Palanpur. The gravity high (F7) may be considered as an extension of the Palanpur high. This high incidentally is manifested by extensive basic magmatic activity.

On the basis of the above data the author has arrived at the following observations which have a considerable relevance to the study area:

1. In the present work, the prominent high F6 has been found to be 2-pyroxene granulite (Basic charnockite suite) and is the highest gravity area in the whole of Gujarat-Rajasthan shield.
2. Granulite facies rocks between Balaram - Khapa are distinctly reflected as conspicuous gravity highs as compared to the Erinpura granite / Delhi Supergroup rocks.
3. Similarly the calc schists and calc gneisses of the Delhi Supergroup east and northeast of the granulite facies terrain are characterised by gravity low.
4. The close spaced NE-SW trending gravity contours with values falling due west separate the high gravity granulite facies rocks in the east from the Erinpura granite of low gravity in the west and mark a distinct gravity lineament.

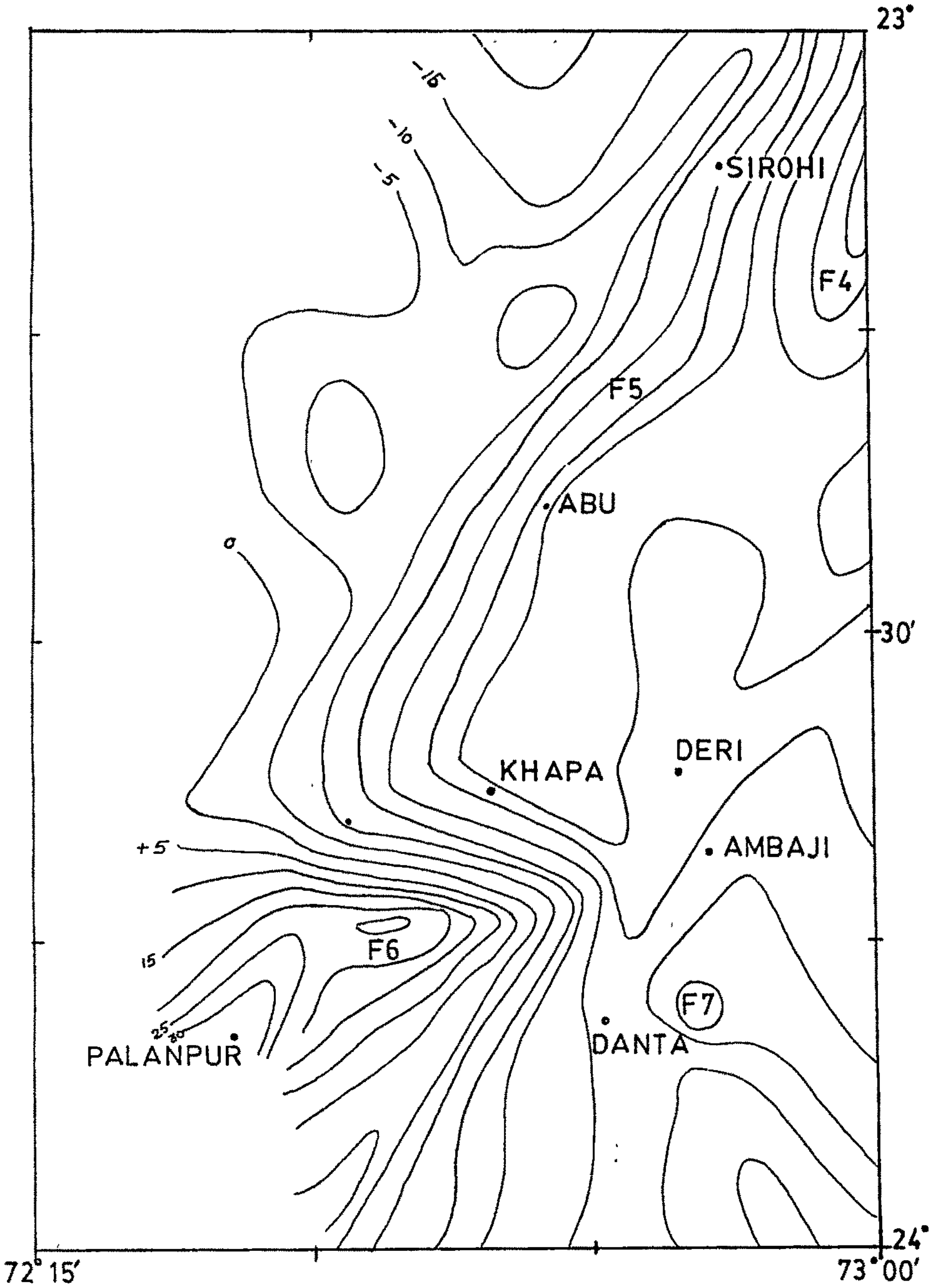

Fig.8.2 Gravity map of Abu Quadrangle (after Reddy & Ramakrishna, 1988)

5. This gravity lineament tallies with the NE-SW trending area between Kui-Chitrasani Fault and the Banas River. This gravity lineament is in fact the SW extension of the Phulad dislocation Zone (PDZ) or Phulad lineament.

VIII.2 Local geophysical data vis a vis regional geophysical data

The Bouguer gravity map of Rajasthan and north Gujarat (Reddy and Ramakrishna, 1988) shows three clearcut NNE-SSW trending elongated domains of high gravity values as under:

1. Palanpur and Virampur -Kanpura in North Gujarat while in Rajasthan they occupy the areas around
2. Bhim - Karera and 3. Ajmer - Sambhar region.

The first domain shows the high gravity values between -10 to +30 m.gals **(Fig.8.1A)** while the other two domains show a range between -10 and +10 m.gals. The higher gravity values are generally indicative of presence of the rocks either exposed or occupying near subsurface areas that contain the ferromagnesian high density minerals like olivine, pyroxene, garnet and amphibole groups. The superimposition of gravity map over geological map of Balaram - Abu Road area **(Fig. 8.1B)** broadly substantiates the previous views that :-

1. The charnockitic rocks, occupy the contours of positive (high) gravity values, the maximum being around Dabheli (between Balaram and Virampur villages).
2. The highest gravity values of (+30 m.gals) contour near Palanpur (just outside the southern limit of the present research area) probably suggest the presence of charnockitic rocks below the alluvium. This inference was confirmed from the bore hole core from a depth of 20 m from an alluvium/soil covered place near Ukarda south of study area, the sample being that of a 2-pyroxene granulite (basic charnockite).
3. The associated granulitic rocks (pelitic and calc-granulites) fall within the contours of lower gravity.
4. The zero contour of gravity probably marks the contact between charnockitic rocks and parametamorphites and follows the zero gravity contour for considerable distance.
5. The sudden swing of the -30 m.gals contour west of the Or-Surpagla tectonic junction marks the boundary between the granulitic rocks (Pre-Delhis) and the calc schists and calc gneisses (Delhis).
6. The close spacing of (0 to -30 m.gals) gravity contours and their deviation from

the positive gravity contours west of Chitrasani - Kui and Abu Road Station marks an important lineament (Kui-Chitrasani fault) along which the charnockitic and granulitic rocks of relatively high density are juxtaposed against low density Erinpura granites.

Petrographic studies amply reveal that the various charnockitic rocks contain the high density minerals like olivine, diopside, hypersthene, bronzite together with calcic-plagioclase (labradorite and bytownite) etc. and are responsible for the positive gravity contours in Balaram - Rabaran - Kanpura area. In contrast to this,

(i) the pelitic- and calc-granulites of Pre-Delhi age,

(ii) the calc schists and calc gneisses of the Delhi Supergroup and

(iii) the post-Delhi Erinpura granites, in general, are deficient in high density minerals and hence are identically reflected as gravity lows in the Bouguer Gravity map.

Thus the high density province of Balaram - Rabaran - Kanpura area represents the basement rocks containing the original basic and ultrabasic rocks over which the pelitic, psammopelitic and calcareous sediments were deposited which gave rise to the variety of charnockitic and granulitic rocks. Similar domains of positive gravity values of Bhim Karera and Ajmer - Sambhar areas of Rajasthan **(Fig. 8.1A)** could be the northeastward extension of Palanpur - Kanpura domain of North Gujarat where the high grade rocks of identical associations are already reported. The classic study on high grade charnockitic and granulite facies terrains of Rajasthan by Rode et al (1969), in Bhim Karera area and Bandanwara Bhinai area by Gyani et al (1970, 1996) in Bhim - Kankroli - Gulabpura domain and by Sharma et al (1995) in Sandmata area of Ajmer - Sambhar domain support the contention of Srikarni, Desai and Patel (1996).

The author therefore considers that the present study area (granulite facies rocks) is a southwestern extension of the Sandmata Complex, Bandanwara-Bhinai and Bhim-Karera area of the Bhilwara Supergroup of Archaean age of South-central Rajasthan.

Reddy and Ramakrishna (op cit) suggested that the NE-SW trending gravity highs which are bounded to their west by steep fault represents a horst with a complementary trench to their west supporting an earlier view of Fermor (1930). These gravity highs have been shown to be bounded by a gravity lineament which corresponds to PDZ (Srikarni, Desai and Patel, 1996). These workers have interpreted this lineament (PDZ) as representing a collision margin along which the westerly moving Indian plate collided with an ancient crustal block and subducted westwards during the Pre-Delhi orogeny. This is possibly be the same collision zone as suggested by Tewari et al (1995) and extends from Rian in Rajasthan southwestwards to Palanpur in Gujarat. All the granulite provinces of northwestern India have been demonstrated to occur east of the gravity lineament (PDZ). They also showed that the granulite facies rocks occur as tectonic wedges or slices which have been obducted from the subducting lower crustal basement oceanic plate. According to these authors the gravity anomaly is suggested to represent monoclinal flexure of the basement whose geomorphic analogue would be a hogback or cuesta like basement steeply dipping due WNW and having a gently dipping backslope which flattens out due ESE.

A detailed interpretation of the gravity, magnetic and seismic data in plate tectonic modelling is given in Chapter -IX (Upliftment History).

VIII.3 ***Magnetic Profiles***

Concomitant magnetic profiles across the regional strike (NNE-SSW) by Reddy and Ramakrishna (1988) have brought out distinct magnetic peaks corresponding to the basic / ultrabasic charnockites in the study area. The magnetic profile west of PDZ is in general flat in Rajasthan (Sinha Roy et al, 1995). In the study area too, the magnetic profile west of Banas River is flat (Fig. 8.1C). A smaller magnetic peak seen between Kui-Chitrasani fault and Banas River is probably suggestive of concealed basic charnockite body. It also suggests that the Banas River follows lineament which is parallel to the Kui - Chitrasani lineament.

VIII.4 Seismic Reflection Profile

Only one deep seismic reflection profile along the Nagaur-Jhalawar Transect is available for the NW Peninsular Indian shield (Tewari et al., 1995, Reddy et al., 1995). Although this transect is far away in Rajasthan, extrapolation of the salient observations to the study area with the help of gravity data appears to be not only relevent but significant too.

Salient features of the seismic section along different segments of Nagaur - Jhalawar transect is shown in **Fig. 8.3**.

1. Nagaur - Rian Sector : This lies mostly in the Trans-Aravalli Vindhyan (TAV) region and is about 90 km long. The strongest of the reflective bands in the western part is almost flat and may represent Moho. Most of the other reflections are discontinuous, weak and appear to be dipping due SE upto Rian. A narrow band of upper crustal updip towards SE is present in the Mora Rian part of the profile **(Fig.8.3)**. This represents a thrust plane or a listric fault merging with general trend of the reflections (Tewari et al, 1995). The surface projection of this band may coincide with the exposed Erinpura Granite or Delhis. This approximately coincides with the PDZ of Bouguer Gravity map.

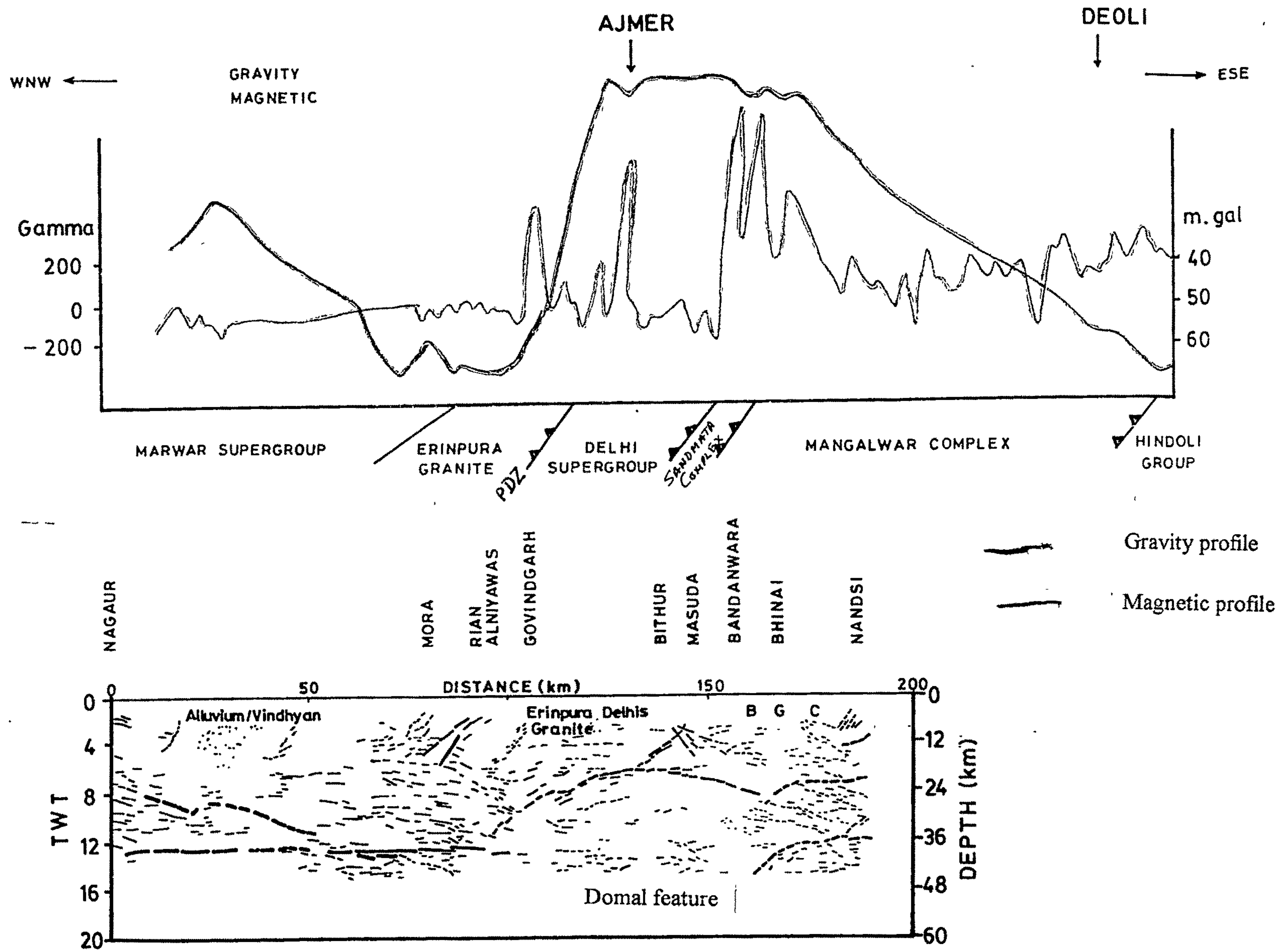

Fig. 8.3 Correlation of Gravity, Magnetic (A) & Seismic reflection profiles(B) along Nagaur - Jhalawar transect. (Modified from Tewari et al, 1995, Sinha Roy et al, 1995)

2. Alniyawas - Masuda Sector : This lies entirely over "Delhi Supergroup" rocks. The general SE down dips of the reflections continue almost upto Govindgarh Between Govindgarh and Masuda, the reflectivity of the crust decreases and only one band of discontinuous reflections with updip towards SE is a prominent feature. Very weak and discontinuous lower crustal reflections are also noticed. **(Fig.8.3)**.

3. Bithur Nandsi sector: It overla4ps the previous sector though offset by 15 km towards NE from Masuda **(Fig.8.1)**. It covers Delhi Supergroup and continues to adjacent BGC. The reflectivity is poor over most of this sector upto Bhinai. There is one identifiable discontinuous band of reflections near Bithur dipping due SE. SE updip is seen in Bithur-Bagsuri section. The mid and lower crustal reflectivity between Bhinai and Nandsi is quite high. Some of the reflections down dip towards SE while others updip due SE - representing a complicated reflection pattern

Summaiy of Seismic Result

1. In the TAV, the lower crustal reflectivity is generally high in Nagaur-Rian sector of the Nagaur-Jhalawar transect while upper crust is almost transparent or non-reflective.

2. Moho appears as a moderate, discontinuous subhorizontal reflection band in the SE part.

3. While most reflections show gentle SE dips, Moho remains unaffected and appears to cut the SE dipping lower crustal reflections.

4. Near Rian, a moderately strong reflector is seen to branch out from Moho in the SE part. This may represent a doubling of Moho or an upper mantle reflection which merges with Moho.

5. The strong narrow band of reflections starting upwards appears to be a thrust plane culminating in surface exposures of Delhis.

6. Further SE, the upper crust is transparent and reflectivity of lower crust is poor. It represents Delhis and part of the BGC. Cross cutting of the SE and NW dips is evident near Govindgarh. One band of discontinuous reflections in a domal shape is seen. Moho reflection is not clear in this region.

VIII.5 Conclusions :

1. Thus the relatively flat strong Moho reflection and dipping lower crustal reflections which appear to cross Moho in TAV region possibly indicate a young re-equilibrated Moho.

2. The reflective lower crust near the contact of TAV and the Delhi Supergroup indicates an ancient collision zone. The apparent cutting of the Moho by lower crustal reflections and the double Moho in parts of this region appear to be indicating a collision zone.

3. The SE updipping upper crustal reflector near Rian probably indicates a listric fault/thrust plane merging with crustal reflections.

4. Between Govindgarh and Bhinai a lower crustal domal feature is present which extends northeastwards into Sandmata Complex and southwestwards into Bhim - Karea and Balaram-Kanpura.

5. Indications of a collision zone like structure with reappearance of Moho and lower crustal reflections are also visible near Bhinai. The wedge shaped seismic reflector as indicated in this part is generally seen in shortened environment (compressional).

6. The domal feature in the middle/lower crust in the entire transect is probably responsible for the high Bouguer anomaly of ~80 m.gal and high heat flow values of 62 mWm-2 (Gupta, 1993).

VIII.6 Correlation of gravity , magnetic and seismic data :

On the basis of foregoing discussions, an attempt has been made by the author to extrapolate the seismic interpretations of Nagaur - Jhalawar transect (NJT) to the study area with the help of gravity data and summarised in Fig.8.3, and Table-VIII.1 :

Table-VIII.1

Profile	Gravity	Magnetic	Seismic
TAV (Western Part)	Rather flat	Flat	Flat Moho
(west of Kui-Chitrasani Fault)	Rather flat	-	
PDZ (near Rian)	Steep westerly gradient		SE updipping reflectivity of Upper crust represents a thrust plane
(Kui-ChitrasaniFault)	-do-		-
Erinpura-Delhi of eastern part of Delhi	High	Irregular	Domal feature of mid-lower crust
Sandmata Complex, Bandanwara-Bhinai, Bhim-Karera	V. High	High	
Balaram-Kanpura	V. High	V. High	_

Thus with the analogy in the gravity and magnetic profiles of Nagaur-Jhalawar transect (NJT) the interpretations of the seismic refelctivity data can be extrapolated to the study area and following conclusions may be drawn:

1. Kui-Chitrasani Fault (KCF) plane is similar to the one east of Rian in the NJT.
2. The granulite facies terrain southeast of KCF represents the domal feature of middle-lower crustal feature of NJT which is an Archaean basement.
3. The ancient collision zone near the contact of TAV and Delhis of NJT can be similarly extrapolated to the study area.
4. The mid-lower crustal BGC in NJT is not as much uplifted as the same in the Balaram - Abu Road area. Therefore the basement (granulite) of the study area does not show cover of Delhis while the Delhis of the NJT area are still seen to overlie the BGCs due to insufficient upliftment and exhumation.
5. KCF - PDZ therefore represents an ancient collision zone under compressional regime.