CHAPTER - II

REGIONAL GEOLOGICAL

&

TECTONIC SETTING

CHAPTER -II

REGIONAL GEOLOGICAL AND TECTONIC SETTING

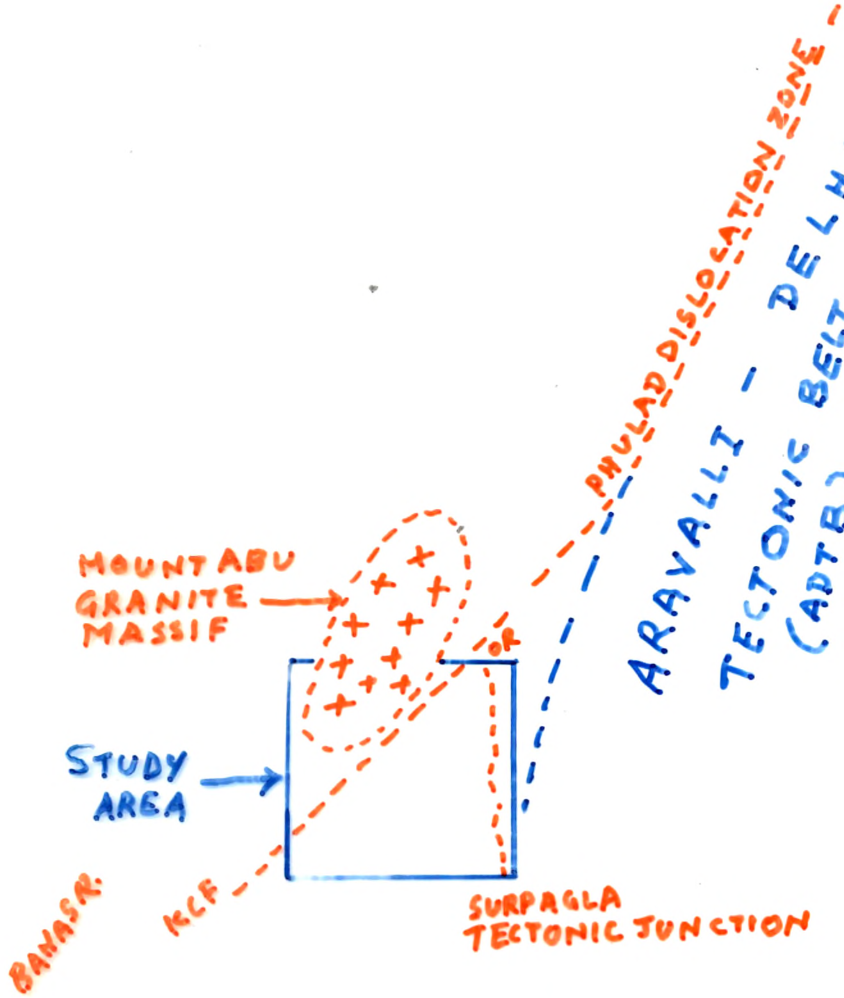
II.1 INTRODUCTION

Precambrian rocks of Rajasthan and Gujarat are classified into Bhilwara Supergroup (Banded Gneissic complex = BGC of Archaean age), Aravalli and Delhi Supergroups (Proterozoic) by Gupta et al (1992) and the granites and basic rocks intrusive into these. As seen on satellite imagery the Aravalli Delhi Tectonic Belt (ADTB) extends from Delhi to Udaipur in NE-SW direction. West of Udaipur it swerves to N-S and further south it swings towards SE **(Plate-II.1)**. The western limit of the ADTB is NNE-SSW trending Phulad lineament or Phulad Dislocation Zone (PDZ) along which Bhilwara, Aravalli and Delhi supergroup rocks are juxtaposed against granitoids to the west of PDZ. There is a wedge or triangular shaped patch of polymetamorphites, northeast of Palanpur whose trend lines and style of deformation are distinctly different from the ADTB. This wedge shaped area bounded by Kui-Chitrasani fault (KCF - the southern extension of PDZ) in the west, Or-Surpagla tectonic junction (approximately trending NNW-SSE to N-S) in the northeast and Or-Deldar fault (Patel et al, 1985) and characterised by granulite facies rocks, constitutes the study area of this research. East of Or-Surpagla tectonic junction greenschist to amphibolite facies calc-gneisses and calc-schists and associated syngenetic basemetal deposits of Delhi Supergroup (935 Ma - Deb et al, 1995) and younger granite are present. To the south thick alluvium and isolated granitoid knolls and stocks are present. Thus it is clearly evident from the satellite imagery that the granulite terrain of study area has a identity distinctly separate from the main ADTB and is located at the southwestern corner of ADTB. Southeast of the study area in erstwhile former princely state of Danta amphibolite-granulite transitional facies terrain has been investigated by Limaye (1992). This terrain also lies to the west of the main ADTB **(Plate-II.1)**. The lofty Mount Abu Batholith is situated to the northwest of the study area.

II.2 GEOLOGICAL SETTING OF THE AREA

II.2a *Physical Features*

Physiographically, the area is divisible into three main units. These physiographic units, obviously controlled by the geological formations, extend diagonally in a NE-SW direction and are as under :-


PHULAD DISLOCATION ZONE
ARAVALLI - DELHI
TECTONIC BELT
(ADTB)
MOUNT ABU
GRANITE
MASSIF
STUDY
AREA
OR
BANAS R.
KCF
SURPAGLA
TECTONIC JUNCTION

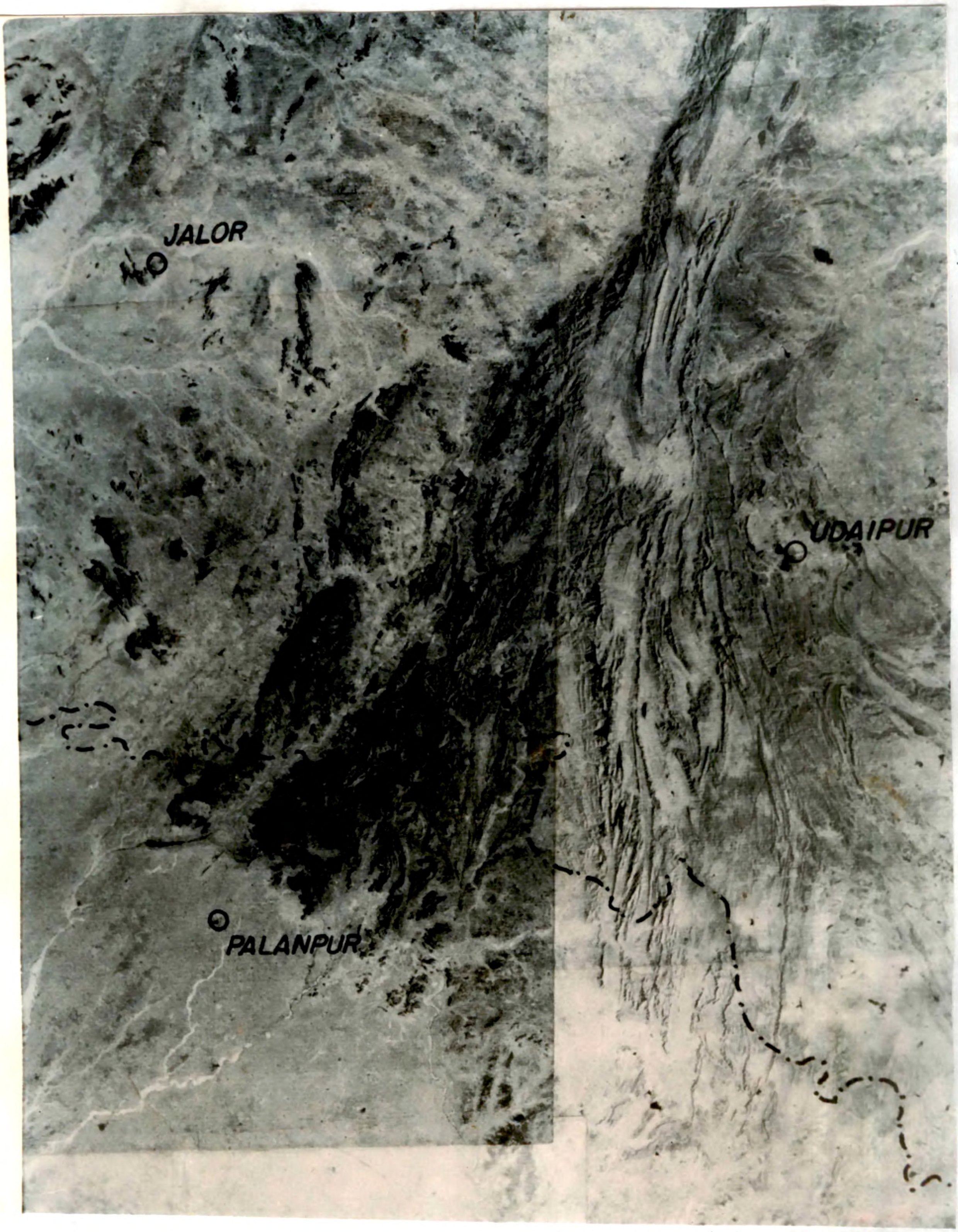


Plate-II.1 Satellite imagery of part of Precambrian terrain of Rajasthan and North Gujarat showing the ADTB, various lineaments, study area and its relationship to ADTB.

1. In the extreme NW corner of the area is a hilly terrain of altitudes varying from 500 to 1089 m above m.s.l. NE-SW ranges of hills consisting of several high peaks occupy mostly the NW, S and SE portion of the area. This hilly tract composed principally of Erinpura granite, forms large cones, tors and domes which are extremely deep and rugged, dropping to deep and narrow valleys in which there are often perennial streams cascading over rocks.

2. On proceeding southeastwards, the Erinpura granites are truncated by a major NE-SW fault - the Kui-Chitrasani fault. Along this fault, the intense secondary silicification has resulted in the development of narrow (+50 m thick) elongated ridges intermittently cropping out in the alluvium over a length of about 24 km trending in NE-SW direction, the general strike of the foliation of the country rocks. This fault dips moderately due NW. The preponderant rock of these hills is reddish or purple chert, sometimes associated with vein-quartz, and encloses fragments of phyllite, amphibolite, granite and pegmatite, which have undergone various degrees of secondary silicification. Severe crushing and faulting suffered by these rocks is evident from the slickensides and crushed surfaces. After faulting and crushing silica-bearing solutions ascended along the fault replacing in part the disrupted rocks and consolidating as chert.

3. A fairly undulating terrain with comparatively lower elevations occupies most of the central area. This terrain is mainly made up of mafic, granitic and metamorphic rocks. The strike of the hills in these particular regions swerves from NW-SE to NE-SW through NS in conformity with the strike of the constituent rock types particularly the pelitic- and calc-granulites. Low lying plains occupying scattered regions in the terrain form a flat area covered by alluvial deposits and sandy soils. Rock exposures are few in this portion, except in the stream sections.

Balaram River is the major river flowing westwards while Banas River in the NW part flows SW. Most of the streams and sometimes the main river too, dry up during summer.

II.2b *Outline of Geology*

Rajasthan and Gujarat have received much attention from geologists and a wealth of data is available on various aspects of these regions' geology. A brief account of the different workers' views have been cited in "review of previous work" in Chapter-I. Apart from these, the interested reader is referred to the works of Blanford (1869), Hacket (1881), Oldham (1893), La Touche (1902), Heron (1917, 1936, 1953), Middlemiss (1921), Auden (1931), Merh (1950, 1967), Niyogi (1952, 1960), Jhingran (1958), Ghosh and Naha (1962), Naha and Choudhari (1967), Naha and

Mukherjee (1969), Gangopadhyaya (1970), Gangopadhyaya and Sen (1971) and Mitra (1971).

The study area forms a part of the regions investigated by Heron & Ghosh (1938). Although the area is not large, yet it serves as an important link between those described in Middlemiss' (1921) Memoir on "The Geology of Idar State" to the east, Coulson's (1933) Memoir on "The Geology of Sirohi State" to the northwest, and Heron's (1935, 1936) work in Mewar to the N and NE of the present area.

The salient features of the geology of the region is the presence of various groups of rocks, mostly PreCambrian, forming a folded mountain system (Aravalli Mountain chain) running across from the north of Delhi in the NE to as far as the Gulf of Cambay in the SW. The Central part of the Aravalli ranges is occupied by a great synclinorium comprising the Delhi and Aravalli metasediments. These metasedimentaries are intruded by granites and basic rocks of more than one generation, and the overall geology is of great complexity. The major formations have been classified as under (Sharma, 1931; Sharma & Nandy, 1936) :

Malani Suite of igneous rocks)	
Delhi System)	Upper
Raialo Series)	Precambrian
Aravalli System)	Lower
Banded Gneissic Complex)	Precambrian

The Malani Group has been further subdivided a under :

Olivine-dolerite and Basalt dykes	
Oligoclase-dolerite dykes)	
)	Intrusives
Gabbro and dolerite plugs)	
Erinpura granite & Pegmatite)	
Epidiorites & Hornblende Schists)	

II.2c *Delhi System :*

The total thickness of Delhis consisting originally of sandstones, shales and limestone is probably 6000 m. This system occupies a synclinorium extending almost along the main axis of the Aravalli mountain from near Delhi in the north through Ajmer and Mewar in Rajasthan to Idar and Palanpur in the south. The exposures are much broader and full in the main part of the synclinorium in the Ajmer-Merwara and Mewar areas. Here, they consist of two major synclines separated by a tongue of pre-Aravalli gneisses. The synclines coalesce in the south and when traced southwards (into Gujarat) they are profusely intruded by granitic rocks of Erinpura age, so much so that these almost obliterate the Delhi sedimentaries. The Delhi System has been classified into a **lower Alwar Series** and an **upper Ajabgarh Series**. The succession is fully developed in Alwar, where two extra horizons namely Kushalgarh limestone and hornstone breccia intervene between Alwar and Ajabgarh Series. The Alwars are 3000 - 4000 m thick, consisting of compact quartzites, grits and conglomerates. The Kushalgarh limestone overlies the Alwars, and comprises banded dolomitic limestone. The hornstone breccia appears at some horizons only in the Kushalgarh limestone, more often near the top. The Ajabgarh Series is mainly argillaceous forming synclinal valleys, though it contains subordinate siliceous limestone, calcareous siltstone and ferruginous quartzite.

The Ajabgarh Series is divided by Heron and Ghosh (1938) as follows :

Phyllites)
Calc-gneissesandlimestones)
Calc-schists)
Phyllites and biotite schists)

Some of the members of the lowest stage have many characters of an arkose, while others are like a porphyry. This division also includes crumpled biotite schists and rusty quartzites with encrustation of malachite and chrysocolla, and has been penetrated by tourmaline pegmatites and extensively so by quartz veins with ores of iron and copper. The calc-schists form an anticline with vertical dips and pitching rapidly towards southwest. The calc-gneiss outcrops are much broken up by granite. Some of the layers of calc-gneiss have suffered silicification and resemble outcrops of quartzite. The limestones, which are developed only in some parts, weather into rectangular slabs Calc-gneisses, crystalline limestone and marble cover a large area and are seen to pass on into the other; as elsewhere, they probably represent varying degrees in purity of a calcareous sediment. The phyllites at the top are described as ordinary grey phyllites, shining and crinkly on the foliation planes, a good deal contorted and shattered where they have become garnet and staurolite bearing schists.

The Delhis are intruded by Erinpura granite and Jalor-Siwana granite as well as the Malani suite of volcanic and plutonic rocks. Similarly the mafic igneous activity is seen to have taken place before and after the formation of Erinpura granite.

The metamorphic grade is low in the north-east but increases southwestward.

II.2d *Erinpura Granite :*

The Delhi System is intruded by Erinpura granite which shows a great deal of variety (granodiorite, granite gneiss, potash granite, micro-granite including aplite veins, quartz, feldspar porphyry) in its form, size, texture and degree of foliation. It is generally a biotite-granite, and occurs in two forms - a "massive granite forming massifs and bosses and a broad and foliated "sheet complex" type. These form ideal exposures in Palanpur, Idar, Sirohi, Beawar, Jaipur and Ajmer. Mount Abu forms a large batholith of this granite. According to Coulson (1933) Erinpura granite forming the Abu massif had been intruded at the junction of Aravallis with Delhis. Thus it is probable that the Erinpura granite and its accompanying aplites and pegmatites are intrusive into both Aravalli and Delhi rocks. Roof pendants of all sizes and descriptions, and included fragments of Delhi and Aravalli rocks are common. Contact metamorphic products on large and small scale are frequent.

II.2e *Mafic Rocks :*

The various mafic and ultramafic rocks occurring in different parts of Rajasthan and N.Gujarat have been assigned to the following three main types (Coulson, 1933), Sharma & Nandy (1936), Sharma (1953), Merh (1967), Patel (1971), Raval (1971), Patel & Merh (1967).

3. Post-Erinpura granite.
2. Delhi and post-Delhi (but pre-Erinpura).
1. Aravalli and post-Aravalli.

The mafic rocks of Delhi and post-Delhi age have been described from the schists and calcic rocks of Ajabgarhs (Delhis) by Coulson (1933).In their present state they can be best described as epidiorites (gabbros and dolerites) and amphibolites, and are seen to composed of aggregates of green hornblende (uralite) and partly altered plagioclase still preserving coarse ophitic texture. Basic igneous activity was renewed more than once, before emplacement of Erinpura Granite. The rocks so produced have been affected by the folding movement and metamorphism immediately preceding the intrusion of Erinpura Granite and hence predate the granite.

Sharma & Nandy (1936) adopted a three fold classification, which corresponds more or less with Coulson's. The oldest rocks they describe as epidiorites, hornblende schists and pyroxene-granulites. In the epidiorites they mention relict ophitic texture, even after the complete transformation of the colourless or greenish non-pleochroic diopside to green hornblende, and sometimes further, to biotite and magnetite. The feldspars, oligoclase-andesine to basic andesine, are sometimes fresh, somtimes saussuritized. Some epidiorites contain but little feldspar and are composed mostly of hornblende, quartz, calcite, epidote, zoisite, chlorite and sphene. According to them pyroxene-granulites (and garnet-grnulites), although of limited occurrence, have been reported to the NE and SW of the present area. On the basis of descriptions of Sharma and Nandy (1936), Heron and Ghosh (1938) have suggested that the pyroxene granulite is an extreme modification of the epidiorites and the garnet granulite of calc-gneisses.

The study area lying in Gujarat (and belonging to the erstwhile Palanpur State) was investigated by Heron and Ghosh (1938). According to them, the mafic bodies occurring near Khapa, Kanpura to the NE and near western extremity of the area under investigation, comprise epidiorites, hornblende-schists, gabbros and dolerites of post-Erinpura age. Coulson (1933) and and Heron and Ghosh (1938) have made only a brief mention of these mafic rocks, but an E-W dyke swarm in N.Gujarat and SW Rajasthan portion attracted considerable attention from them Coulson (1933) called these dykes albitised basalts, resembling spilites in some respects, and assigned them a post-Malani age. But Heron and Ghosh (1938) considered them to be of post-Erinpura but pre-Malani age, and found that the constituent rock was more of the nature of oligoclase basalt. Patel (1971) agreed with the views of Heron and Ghosh (1938), but preferred the term "trachy-andesite" for these dyke rocks. He designated these rocks as "barkevikite trachyte" or "oligoclase andesite".

Patel (1971) considered that certain mafic rocks were definitely older than the Erinpura granites. Raval (1971) (quoted by Patel, 1971) working in the neighbouring area of Idar, to the SE of the study area, also assigned a pre-Erinpura age to the olivine bearing dolerites. Thus it is quite likely that all the olivine bearing mafic rocks of these parts of Rajasthan and N. Gujarat record one single phase of igneous activity and belong to a pre-Erinpura granite age.

Desai et al (1978) suggested that the entire terrain around Balaram, is made up of high grade metamorphic rocks of the nature of cordierite bearing and diopside bearing granulites and charnockitic rocks, which in turn have been affected by Delhi orogeny and Erinpura granite. According to them, the area typically shows two distinct cycles of metamorphism and granitisation. It was during the early metamorphic cycle, that the hypersthene bearing charnockitic rocks came into existence by processes of high grade metamorphism and granitisation under high temperature "dry" or anhydrous conditions. The late phase of changes, perhaps, connected with the Delhi upheaval and granite activity, brought about retrogression and granitisation such that the various charnockitic rocks were gradually transformed to biotite gneisses. Thus, their interpretaion of metamorphic history suggests a geological history rather different from that envisaged for some of the adjacent areas. In particular, their postulation that these rocks may be older than the Delhi System has given new dimension & direction of research in these rocks.

A perusal of the geological map (**Fig. 2.1**) of the study area shows the distribution of the various lithological types encountered which are as follows :

II.3 ROCK TYPES :

On the basis of field and petrographic studies,the following lithotypes of granulite facies rocks have been identified.

II.3a *Charnockitic suite of rocks*

These include the granulite facies rocks with igneous precursors. Among these the different lithotypes with the following mineral assemblages have been identified.

(a) Ultrabasic Type (Olivine - calcic-plagioclase - diopside - hypersthene - bronzite - phlogopite - calcite),
(b) Basic Type (Calcic-plagioclase - hypersthene - hornblende - phlogopite),
(c) Olivine Norites (Calcic-plagioclase - olivine - diopside - hypersthene - bronzite),
(d) Intermediate Type (Plagioclase - antiperthite - quartz - hypersthene - hornblende - biotite),
(e) Acid Type (Charnockites) (Quartz - perthite - oligoclase - hypersthene - hornblende - biotite)

II.3b *Norites and metanorites*

The rocks of the charnockitic suite and norites are closely associated in the field. They are the dominant rocks and occupy a major portion of the study area. The charnockitic terrain occupies mostly the southern part of the study area and is characterised by subdued topography - mostly mounds and small hills. Good exposures are seen along the river beds, stream sections. The best sections are seen in quarries (**Plate-II.2A & B**). Elsewhere they are concealed beneath a thin veneer of soil. Generally, the charnockitic rocks are massive in appearance but at places banding vertical to steeply dipping (**Plate-II.3A**) is seen due to variation in grain size and due to thin layers of foreign material. At few localities, these banded layers show different types of folds (**Plate-II.3B**). In field it is rather difficult to demarcate the various types and only thin sections reveal the variations shown by these rocks. In a general way, these are fine to medium grained granulitic to gneissic rocks with a characteristic greasy, greyish green appearance and look quite fresh on newly broken surface. In a few cases, even the coarser grained acid types have been noticed. The dominant amongst these granulites is the 2-pyroxene granulite (basic charnockite) which has much larger spatial distribution than other types of charnockites. Most of it is concealed beneath a thin veneer of alluvium as is evident from the bore-well cores. The ultramafic variety which

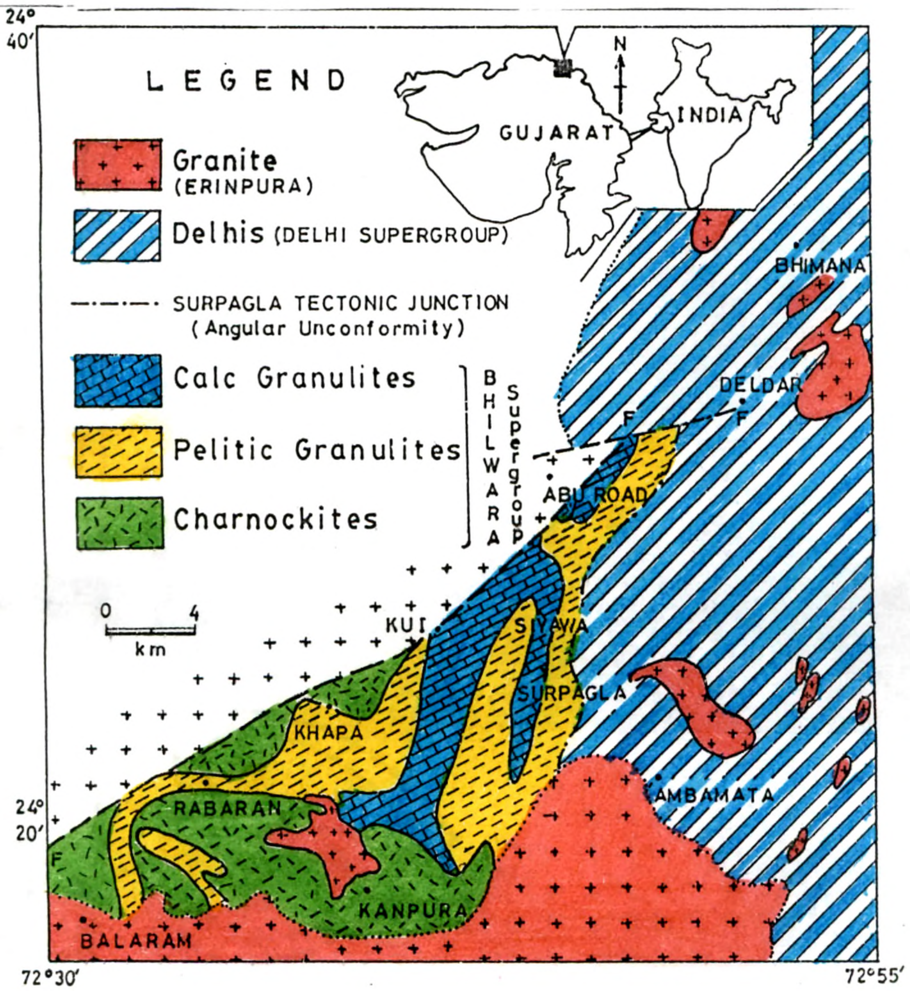


Fig. 2.1 Geological Map of Balaram - Abu Road Area, North Gujarat & SW Rajasthan (Modified from Desai & Patel, 1992)

Plate-II.2A. Exposures of charnockitic rocks in Balaram River.

Plate-II.2B. Quarry sections in Charnockites near Balaram.

Plate -II.3A Vertical banding in charnockites in section at Chikanvas Quarry

Plate-II.3B. Banded layers in charnockites showing rootless folds near Balaram possesses distinct layering and banding has restricted occurrences around Kanpura - Dhanpur and Ajapur villages. The knotty appearance on the surface is due to large olivine crystals with a corona/rim of pyroxene - often vermicular. The banding is sub-vertical in Ajapur area whereas in Kanpura area these bands in general dip 30° due south. The morphological expression of the differential resistance of the bands is seen as ridges and grooves **(Plate-II.4A)**. There are a number of nodular features which are most conspicuous at the contact of the bands. Rhythmic banding (cryptic layering) of light coloured plagioclase rich and darker mafic rich portions is clearly seen in the freshly broken surfaces of individual bands. The intermediate and acid charnockite sensu stricto (i.e. hypersthene granite) varieties occur as patches **(Plate-II.4B)** within the above mentioned 2-pyroxene granulites. Therefore the precursors of the charnockite rocks are surmised to have constituted the basement over which pelitic and calcareous sediments were deposited and the whole sequence was later on subjected to granulite facies metamorphism.

Norites are typically igneous rocks and occur in close association with basic charnockites. It is rather difficult to distinguish norite from basic charnockite in the field, though at places norites show knots and nodules specially on weathered surfaces **(Plate-II.5B, II.6A)**. The knots and nodules are much fine grained, which are composed of the same minerals as those of the matrix rock and could possibly repesent highly recrystallised and thoroughly assimilated foreign inclusions. They are completely devoid of layering or foliation.

Norites and metanorites occur in the unaltered cores of comparatively thick dikes and sills or intrusive bodies, most of which have been transformed into pyroxene granulites. Norites also occur as intrusive bodies in the quartzo-feldspathic gneisses, granitic gneisses and granites also.

The junction between charnockites and pelitic & calc-granulites is often mylonitised, there is no evidence of a reacted contact between the two.

Separating the charnockitic basement from the overlying pelitic and calc-granulites, is a conspicuous mylonite - the best exposures of which are seen in the nala west of Kansara. The rock is a dark grey to pitch black in colour, very fine grained with ovoid patches of reddish pink coloured material **(Plate-II.6B)**. The black extremely fine grained material is glass which resulted from the pulverisation during shearing. The dark pink spots and patches are of garnet, feldspar and quartz. The texture is typical of mylonite. The mineralogical composition of the mylonites are identical to those of other rocks in the area. Mylonite formation is thus,a synmetamorphic event and is related to uplift of the area during obduction.

Plate-II.4A Alternating ridges and furrows in ultrabasic granulites near Kanpura.

Plate-II.4B. Irregular patches of acid and intermediate charnockite in basic variety near Balaram.

Plate-II.5A Charnockite quarry north of Virampur

Plate-II.5B Knotty appearance on the surface of basic charnockites & meta-norites (Near Ajapur Wanka)

Plate-II.6A. Nodular appearance of metanorites near Mota Ajapur

Plate-II.6B. Mylonite -extremely fine grained black rock with ovoid patches of pink feldspar near Kansara

II.3c *Granulites*

These include the granulite facies rocks with sedimentary parentage viz. pelitic granulites and calc granulites.

A. Pelitic Granulites

(Cordierite - garnet - hypersthene - sillimanite - biotite - potash feldspar - plagioclase - quartz - pinite - spinel - sapphirine).

B. Calc Granulites

(Diopside - plagioclase - scapolite - calcite - sphene - wollastonite - tremolite - grossularite - apatite).

II.3c *Pelitic Granulites*

The pelitic granulites are represented by garnetiferous granulite gneiss and are marked by coarse light and dark metamorphic banding. The dark grey (bluish) bands are mostly of cordierite studded with reddish brown garnets. The leucocratic bands are rich in quartzo-feldspathic material. These are seen as mesoscopic tight, isoclinal reclined folds. The size of the garnet is larger in the fold closures and much smaller in the limbs. Unlike the charnockitic rocks, these are very hard to break and on account of their resistance to weathering, they stand out as ridges. One of the prominant hill - the Divani Hill is composed of these rocks **(Plate-II.7B, II.8A)**.

II.3d *Calc Granulites*

The calc-granulites are easily distinguished from the pelitic granulites due to their light colour - mostly dirty white to buff colour. Development of calc-silicate minerals such as diopside, tremolite, wollastonite etc. in this unit has resulted in many irregularities in foliation planes. Outcrops of calc-granulites, as compared to the pelitic granulites, are fewer - possibly because of the dense vegetation which these bands support. They trend parallel to the adjacent pelitic granulites and are conformable with latter. The weathered surface of these bands is often very dark and could be mistaken from a distance to be a basic rock. Unlike the basic rocks, these calc granulite bands constitute prominent topographic highs **(Plate-II.8B)**. Smoky coloured patches are of scapolite, dark greenish grey minerals are clinopyroxene, pinkish grains or pits around the clinopyroxene or associated them are of garnet (Andradite), whitish, plagioclase and calcite.

II.3e *Granites*

There are no large granitic bodies in the study area but small bodies occur over the entire terrain. These are small circular outcrops paticularly south of the area which

Plate-II.7A. General look of the ultra basic country.

Plate-II.7B. Divani hill range.

Plate -II.8A The Divani Peak.

Plate-II.8B. Geomorphic expression of calc granulites. Weathered black surface and resistance to weathering. Dark bands are diopside rich near Bhaisasingh rise to some of the highest points in the region. In addition to coarse grained varieties, various granitic gneisses are also present. Nearly all of them contain biotite, hornblende, quartz and feldspar. They range from almost unfoliated to well banded rocks associated with almost all the previously mentioned rock types.

In the area, these rocks show much variation in the landscape of the terrain occupied by them, and topography reflects the original diversity of the granitic rocks. These form a series of numerous lofty peaks attaining high elevations. In the southwestern extremity, these rocks disappearbelow the alluvial plain. In the field, they show intrusive relationship with the older rocks. An excellent summary of these observations has been given by Sharma & Purkayastha (1935), Heron and Ghosh (1938) and Patel (1971)..

The wedge shaped granulite facies terrain is separated by two tectonic discontinuities or ductile shear zones viz. (i) the NE-SW trending, northwesterly dipping Kui-Chitrasani Fault (KCF) in the west that separates the granulite facies terrain from the Erinpura granite in the NW and (ii) approximately N-S to NW-SE trending Or-Surpagla tectonic junction that separates the polymetamorphites of the study area from the amphibolite facies rocks of the Delhi Supergroup occurring in the east and northeast. These rocks in turn are intruded by basic and acid igneous rocks of Post-Delhi age. The generalised stratigraphy of the area as worked out by the author is given in Table-II.1.

Table - II.1

Lithounits	Stratigraphic position	Deformation Igneous event	Metamorphic Event
Granitic Rocks (Erinpura Granite)	(Post-Delhi)	I4	M4
Calc-schists and calc-gneisses and associated meta-volcanics and syngenetic basemetal mineralisation	DELHI SUPERGROUP (Middle to Upper Proterozoic)	F3 & F4 I3	M3
Tectonic junction (Ductile Shear Zone)		Decompression	M2
Calc Granulites Pelitic Granulites Mylonites Charnockitic Rocks (with igneous precursors))	BHILWARA SUPERGROUP (Archaean ?)	F1 & F2	M1 I1

A detailed petrographic description of the above lithotypes, along with their mineral phases and chemistry of the individual mineral phases, is given in chapters-III through Chapter-V.

II.4 STRUCTURE

The author could not collect detailed stuctural data due to their paucity and thick vegetational cover in the study area. On the basis of available data and study of aerial photographs and satellite imagery, at least four phases of deformation have been established. Primary sedimentary structures have been obliterated in these rocks due to high grade metamorphism. However, some of the metasedimentaries have faint trace of bedding but the pelites, with the increase in biotite content, show gneissic foliation. The contact between pelitic and calc granulites perhaps is the true S_0 the original sedimentary bedding. The strike of the foliation in the metasedimentaries generally fluctuates from NNW-SSE to NNE-SSW though NS strikes are also not uncommon. The dip amounts are variable and the foliation mostly either dips steeply or vertical. Gentler dips as low as 45° due NE or SW are also recorded. The banding or layering observed in the charnockitic rocks is concordant with that of metasedimentaries.

1. F1 Folds are rootless eyed folds in charnockitic rocks. Development of a pervasive foliation (S1) was associated with this phase of deformation. More often, these are isoclinal folds **(Plate-II.9A & B)**. These are rarely preserved e.g. in the Balaram quarry etc.

2. F2 phase of deformation resulted in the Isoclinal reclined folding of S1 - the earlier foliation of F1. The F2 fold hinges show metamorphic segregation of quartzo-feldspathic material (in pelitic rocks) which occupies the fold closures **(Plate-II.10 A,B & II.11A)**. Garnet size is largest in the hinge and diminishes towards the limbs of the folds **(Plate-II.11B)**. Presence of quartzo-feldspathic bands associated with these folds suggests partial melt formation event and further possibly to peak metamorphic conditions. These are best seen in Divani hills.

3. F3 folding episode is conformable to regional trend of ADTB i.e. NNE-SSW and is attributed to Delhi orogeny. It corresponds to DF1 episode (Gupta et al, 1992). The F3 deformation was the most intense. Apart from the WNW-ESE stresses responsible for this deformation, there was a shear component along the NNE-SSW i.e. along the axial trace which resulted in several tight sigmoid bends on regional scale.

4. F4 : Broad open folds (on regional scale and macroscopic scale). The trend of the axial trace is NW- SE, the fold axis plunges due SE. It correspond to DF2

Plate-II.9 A & B. Field photographs showing isoclinal folds in pelitic granulite. The S1 foliation of F1 folds is isoclinally folded. Attenuation of limbs of the folds is clearly seen (Divani hill)

Plate-II.10 A, B

Field photograph showing development of quartz-feldspathic melt and its accumulation is conspicuous along the hinges and their vicinity (Khara)

Plate-II.11 A. Field photographs showing development of quartzo-feldspathic melt and its accumulation is conspicuous along the hinges and their vicinity.

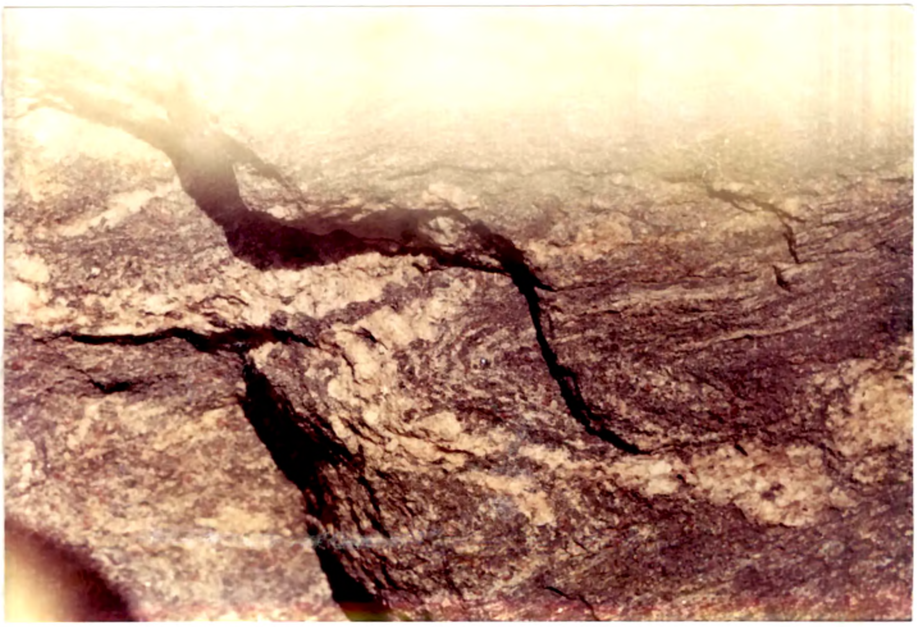


Plate -II.11B Field photograph showing development of garnets in the hinge portions imparts these rocks a reddish look (Khara) episode (Gupta et al, 1992). A regional F4 fold closure in the study area is located east of Khapa. It is easily picked up in the satelite imagery as well (Plate-II.1).

Apart from these folds of tectonic origin, irregular deformation in calc granulites gives a deceptive appearance of complicated non-cylindrical folds which the author considers to be due to differential expansion of calc silicate minerals during metamorphism (particularly thermal). Their localised nature and confinement only to calcareous lithology is confirmed by the absence of similar deformations in the adjacent pelitic bands with which calc-granulite bands are conformable.

Apart from these folds, the area has also been affected by several faults and shears :

1. The Kui-Chitrasani fault (KCF) which trends NNE-SSW is a major fault running from NE to SW across the area along the western margin of granulite facies terrain. It is roughly aligned parallel to the Banas river. Along this tectonic junction the granulite facies polymetamorphic terrain of the study area has been brought into juxtaposition with the Erinpura granite and the southern extension of the Sirohi Group rocks. The block to the southeastern side of this fault is an upthrown one. The amount of throw is merely a matter of speculation. However, it must be a feature of deep seated origin as it is seen as a prominant geophysical lineament. As will be shown later (Chapter-VIII) it is a tectonic discontinuity along which the high grade rocks were uplifted due to obduction.

2. Or-Surpagla tectonic junction along which the amphibolite facies rocks of Delhi Supergroup (situated to the northeast of the study area) abut against the granulite facies rocks of the study area, it trends approximately in NNW-SSE, NW-SE to NS direction. It constitutes another lineament marking the eastern boundary of the granulite terrain of the study area. It appears to have been involved in DF2 fold event & thus is pre-Delhi.

3. Or-Deldar fault with its WSW-ENE trend marks the northern limit of the granulite facies terrain. It must be the youngest fault as it is seen to cut both KCF as well as Or-Surpagla tectonic junction.

Regional structure : The regional structure is controlled dominantly by F3 and F4 deformations. F3 deformation is reponsible for the NNE-SSW trend of the Aravalli Mountain chain at whose SW extremity the study area is situated. Naha et al (1967), Patel & Merh (1967) and Patel (1971) also suggested that NNE-SSW trending upright folds were produced by Delhi deformation.

The pelitic and calc-silicate lithounits have sinuous outcrop pattern which defines a set of open folds on NW-SE axial trace The wave length of these folds is of the order of several kilometres and their enveloping surface defines the ENE tectonic trend already mentioned. In the southwest of the area, the banding in the charnockitic rocks is approximately parallel to the axial plane of a fold outlined by the cordierite bearing pelitic gneisses No such folds are observed in the area east of Or-Surpagla junction