PETROLOGY OF THE METASEDIMENTARY ROCKS AND THE ASSOCIATED GRANITES NEAR PANSAL, DISTRICT BHILWARA

DISSERTATION SUBMITTED FOR THE DEGREE OF
MASTER OF PHILOSOPHY
IN
GEOLGY

BY
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1986
Dedicated
To
My Parents
DEPARTMENT OF GEOLOGY
ALIGARH MUSLIM UNIVERSITY

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Date: January 7, 1987

This is to certify that Mr. Shamim Ahmad Khan
has completed his research work, presented in this
thesis, under my supervision for the degree of Master
of Philosophy of the Aligarh Muslim University, Aligarh.
This work is original and has not been submitted for
any degree at this or any other University.

Syed M. Zainuddin
(SYED M. ZAINUDDIN)
ACKNOWLEDGEMENTS

As my months of hard work culminate in the submission of this work, I wish to express my gratitude to Dr. S.M. Zainuddin, my supervisor, who has been an inexhaustible source of knowledge. His enlightening guidance has greatly benefitted me. I am indebted to him.

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(SHAMIM AHMAD KHAN)
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CHAPTER - I

INTRODUCTION

The Precambrian rocks of Rajasthan forms a folded mountain chain running NE-SW from Delhi to Gulf of Cambay; the rocks are highly deformed and were effected by the four phase of deformation. On the basis of detailed Geological Survey of Rajasthan and adjoining parts between 1908-1935, the Precambrian rocks were classified into four groups, viz., the Banded Gneissic Complex (B.G.C.), the Aravalli System, the Rialo Series and Delhi System (Heron, 1953).

After the deposition and folding of rocks of Delhi System, the area was subjected to a series of igneous intrusions, which includes the Erinpura granites, Jalar-Siwana granites, Idar granites and Malani suite of volcanic and plutonic rocks. The banded and streaky granites of Central Rajasthan were grouped under Banded Gneissic Complex. This gneissic granite and associated Berach granites were considered to have been derived from same magma, they are believed to have constituted part of the premordial crust (Heron, 1936). However, later work has revealed that they are separate intrusion.

Recent survey carried by the workers of the Geological Survey of India in Southern Rajasthan and north-eastern Gujarat. The Precambrian rocks were classified into three supergroups,
viz., the Bhilwara Supergroup, the Aravalli Supergroup and the Delhi Supergroup (Gupta, et al., 1980). Each supergroup was further divided into different groups and formations.

**GEOGRAPHY OF THE AREA:**

The study area, located west of Bhilwara town (25°27' N and 74°38' E), falls within the latitudes 25°17' N to 25°30' N and longitudes 74°29' E to 74°38' E (Fig. 1). The area is accessible by rail, running from Ajmer to Udaipur, and also linked by Ajmer-Chittorgarh road. Other important connecting roads are Bhilwara-Gangapur, Bhilwara-Kotri, Bhilwara-Bagaur. An area of about 120 sq. km. was mapped. Survey of India topographic sheet number 45 K/11 on 1:50,000 scale was used as base map.

Topographical variations are most plainly referrable to the lithological difference in the constituent rocks of the area concerned. Thus, phyllite and ancient gneisses and schist, generally formed soft crumbing outcrops, scarcely rising above the ground level, while quartzite associated with phyllite and schist give rise to narrow ridges. Limestone occupies an intermediate position between these two extremes its outcrops where fairly extensive, forms steep sided ridges and plateau. Kothari river provide main drainage in the area, flowing mostly through gneisses and schist country rocks, the beds are shallow and dry during the cold and dry months of the year. The water table, however, is quite near the surface.
POSITION OF DISTRICT BHILWARA IN RAJASTHAN STATE (INDIA)

STUDY AREA (BHILWARA)

FIG. 1
Vegetation is generally poor, cactus bushes and spear grasses are common on the schist and gneisses. On the plains, the vegetation is directly dependent on the thickness of the alluvium and proximity of ground water level. When the soil cover is sufficient and the area is suitably provided with natural rock barriers or artificial embankments, the general vegetation is fairly rich and cultivation almost invariably assisted by well irrigation and canals.

PREVIOUS WORK:

Hacket (1888) mentioned the salient features of the geology of Rajasthan in his paper, 'The Geology of Aravalli Region, Central and Eastern'. The paper contains some useful information about local stratigraphy. He correlated the rocks with Aravalli and Delhi System. Gupta (1934) has carried out a detailed geological mapping of the area. He described the structure and petrology of the various rock types. He classified the rocks into three separate groups, viz., Banded Gneissic Complex, Rialo Series and Aravalli System. The basement of this metasedimentary group, according to Gupta (1934), is the Banded Gneissic Complex and the Bundelkhand granites of Rajasthan.

Heron (1953) included the whole of the metasedimentary belt within the Aravalli System. Later, Basu (1966) while describing the stratigraphy and structure of the area, grouped
the rocks into one single unit. He also reported a granitic intrusion on the western part of the area. Gupta (1969) briefly mentioned the structure and metamorphic history of the area.

Rao, et al. (1970) considered the rocks of the area to comprise a continuous geosynclinal sequence which are older than Aravalli Group and can be referred as 'Pre-Aravalli Group'. The name, 'Bhilwara Group' was suggested for these rocks as the major part of the metasedimentary belt occurring in the Bhilwara district (Rao, et al., 1970). Recently, Gupta, et al. (1980) assigned the rocks of the area into 'Pur-Banara Group' and they correlated these rocks with 'Bhilwara Supergroup' of the pre-Aravalli age or Archaean II (Table-I).

Gupta (1982) carried out a detailed structural mapping of the metasediments and deciphered four successive phases of folding. Gangopadhyay (1982) described the sulphide ore mineralization in the south-western portion of the metasedimentary belt and also gave an account of the metamorphic history of the metasediments.

However, detailed petrological analysis of metasediments and associated granite gneisses (west of Meja) have not been undertaken by the earlier workers in the area. The present study based on extensive field work and detailed laboratory investigations is likely to help in understanding and interpreting the metamorphic history of the metasediments and origin of granite gneisses, whether I-type or S-type.
Table-1: Succession of Bilwara Supergroup (after Gupta et al., 1980).

<table>
<thead>
<tr>
<th>UNDIFFERENTIATED GRANITES AND BASIC ROCKS</th>
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<tbody>
<tr>
<td><strong>RAJPUR DARIBA GROUP</strong></td>
</tr>
<tr>
<td>Umar Formation (J₃)</td>
</tr>
<tr>
<td>Jhikri Formation (J₂)</td>
</tr>
<tr>
<td>Chuleshwar Formation (J₁)</td>
</tr>
<tr>
<td><strong>PUR-BANERA GROUP</strong></td>
</tr>
<tr>
<td>Samodi Formation (PB₄)</td>
</tr>
<tr>
<td>Tiranga Formation (PB₃)</td>
</tr>
<tr>
<td>Rewa Formation (PB₂)</td>
</tr>
<tr>
<td>Pur Formation (PB₁)</td>
</tr>
<tr>
<td><strong>SAWAR GROUP</strong></td>
</tr>
<tr>
<td>Morhi Formation (Sr₂)</td>
</tr>
<tr>
<td>Ghatiali Formation (Sr₁)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>GIYANGARH - ASIND ACIDIC ROCKS</th>
</tr>
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<tbody>
<tr>
<td>RAIPUR - JALAYAN MAFIC ROCKS</td>
</tr>
<tr>
<td>ULTRAMAFICS</td>
</tr>
</tbody>
</table>

| HANODLI GROUP                  |
| Kangauli Formation (H₃)        |
| Sujampura Formation (H₂)       |
| Bhadasar Formation (H₁)        |
| **MANGALWAR COMPLEX**          |
| Rajmahal Formation (M₃)        |
| Kekri Formation (M₆)           |
| Mandoki Pal Formation (M₄)     |
| Sarsarki Pal Formation (M₄)    |
| Saona Formation (M₃)           |
| Potla Formation (M₂)           |
| Lasaria Formation (M₁)         |
| **SANDMATA COMPLEX**           |
| Barach Formation (S₃)          |
| Badnor Formation (S₂)          |
| Sambhugarh Formation (S₁)      |
CHAPTER - II

GEOLOGICAL SET UP

The area under present investigation is towards west of Bhilwara extending from Pur to Banera, it is a part of the main synclinorium of Rajasthan. Gupta (1934) classified the rocks of the area into three groups, each separated by an unconformity. The quartzite, marble, and schist sequence of Pansal and Pur was correlated with the Rialo Series, whereas schist, slate and phyllites exposed towards east of Bhilwara area is considered to be equivalent of the Aravalli System. He also reported a granite ridge within Pansal synform and correlated the migmatite and granite, gneisses (west of Meja) with Banded Gneissic Complex which forms the basement of this metasedimentary belt.

Heron (1953), proposed a two fold classification for the Precambrian rocks of the area; he included whole of the metasedimentary belt within the Aravalli System and correlated the migmatite and granitised portion with Banded Gneissic Complex.

The field evidence during the course of the present investigation do not support the three fold classification, proposed by Gupta and the two fold classification of Heron though local breaks were indicated by the presence of conglomerate and grits of different stratigraphic horizons.
Conglomerate bed, 1-5 meter thick, have been reported near Pansal, Pur and Jaliya but they do not form a stratigraphic horizons. Inter-fringing and gradational relationship and structural concordence among the metasediments indicate continuous sequence, hence the conglomerates are undoubtedly of tectonic origin (Basu, 1966). Present survey also indicate that the different members are continuous; unconformity is not seen anywhere.

The western contact between mica schist and Banded Gneissic Complex is very transitional; the eastern contact is, however, mostly soil covered. Absence of unconformity between gneissic complex and metasediments or Bundelkhand granites indicate that the different members included by Heron (1953) under Aravalli and Delhi System were parts of a continuous geosynclinal sequence older than Aravalli which can be referred to as 'Pre-Aravalli Group'.

Gupta, et al. (1980) classified the metasediments into 'Pur-Banera Group' and correlated them with 'Bhilwara Supergroup' of pre-Aravalli age or Archaean II. The succession is proposed by them is as follows:

```
Archaean II
   2500 m.y. (Pur-Banera Group)

Bhilwara Supergroup
   ( Samodi Formation
     ( Tringa Formation
       ( Rewara Formation
         ( Pur Formation
```
The metasediments have been subjected to four successive phases of folding: $F_1$, $F_2$, $F_3$ and $F_4$ (Gupta, 1978). The $F_1$ folds occur in minor scale mainly in quartzite and metapellites. Folds of $F_2$ generation occur in almost all the rock types of the area in mesoscopic scale. The metasediments are regionally folded by the folds of $F_3$ generation into a number of tight antiform and synform with NNE-SSW to NE-SW trending axial traces. $F_4$ structures constitute gentle folds and warps.

**GENERAL GEOLOGY:**

The area mapped is a part of the NNE-SSW trending synformal metasedimentary belt, commonly known as 'Pur-Banera Belt'. The metasedimentary belt is bounded by Banded Gneissic Complex on the western side and by hornblende schist on the eastern side. Geology of the area mapped on 1 : 50,000 scale is shown in Figure-2.

The oldest member of the formation is hornblende schist which is exposed towards east of Pansal and Pur. The outcrops are generally isolated as the area is mostly soil covered. The rock is black in colour and highly jointed.

Mica schist overlies the hornblende schist; outcrops of mica schist are exposed north-west of Pur and extend up to Banera. The schist is well foliated; the foliation strikes NNE-SSW. Large idioblastic, porphyroblast of garnet are very conspicuous in the mica schist.
GEOLOGICAL MAP
AROUND PUR AND PANSAL WEST OF BHILWARA DISTT.: RAJASTHAN

FIG. 2

KEY:
- DYKE
- GRANITE GNEISS
- Banded Ferrigenous Quartzite
- Calc Silicate Rocks
- Light Coloured Calc Silicate
- Impure Marble
- Quartzite
- Garnetiferrous Mica Schist
- Hornblende Schist

KILOMETRES

10
The impure marble overlying the mica schist is exposed west of Pansal as narrow ridge parallel to strike; the closer is seen south-west of Pansal. The outcrops generally appears as irregular blocks due to weathering. Light grey coloured rock is exposed at the contact of impure marble; the outcrops are generally irregular and appears as discontinuous mounds. This is overlain by a highly jointed quartzite, rusty white in colour. Isolated outcrops of schist are exposed in the soil covered valley. These rocks forming a synformal structure, are repeated across the axis in order.

The mica schist is also exposed towards west of Pansal at the contact of impure marble. The quartzite forms a closer south-west of Pur and foliated towards north of Pur, having a N-S strike and steep dip.

Calc-silicate rocks dark grey in colour is exposed within the Pur synform and extend up to Dhulkhera. The ferruginous quartzite is exposed along the synformal axis within the calc-silicate bands.

The quartzite overlying calc-silicates is exposed towards south as well as north of Dedwas. A different ferruginous quartzite ridge is exposed towards north-east of Sauras, strikes NNE-SSW.

A different calc-silicate rock dark grey in colour is exposed towards north-east and south-west of Sauras, and grades into calc-schist at few places. The calc-silicate rock is overlain by quartzite.
The youngest bed of the formation is mica schist; the outcrops are seen towards south of Mandal. The contact between mica schist and granite gneiss was not observed as the area is soil covered.

Migmatite and bands of granite gneiss are exposed towards west of Meja. The outcrops rarely rises above the ground level, they form small isolated mounds.

The succession of the rocks in Pur and Pansal area as determined by Basu (1966) and also corroborated by the present investigation is as follows:

```
Pur Formation
{Pegmatite and quartz vein
{Granite
{Metabasic rock
{Garnetiferous mica schist
{Calc silicate rocks and marble
{Samodi quartzite
{Ferruginous quartzite
{Calc-silicate rocks and marble
{Pur quartzite
{Garnetiferrous mica schist
{Hornblende schist
```
CHAPTER - III

LITHOLOGY

HORNBLENDE SCHIST:

It is a highly fractured, dark coloured rock which is exposed in a 6 km wide belt in the south-eastern part of the area; the outcrops are isolated as the area is mostly soil covered. The rock mainly consist of hornblende and plagioclase, ranging in composition from oligoclase to andesine; zoning in plagioclase is occasionally observed. Uniform mineralogy and absence of carbonates indicate that it is a metabasic rock, its wide expansion further suggest volcanic origin (Basu, 1966).

GARNETIFEROUS MICA SCHIST:

The hornblende schist is overlain by mica schist which is very well exposed near Pur, west of Pansal and extends up to Banera. The rock is well foliated and strikes almost N-S with a vertical or a very steep dip.

Under the microscope, the rock shows porphyroblastic texture. The rock consist of biotite, muscovite, plagioclase, kyanite, garnet and quartz. Apatite, actinolite-tremolite and opaques are the common accessories.
Biotite and muscovite occurs as tabular crystals and has inclusions of quartz. Plagioclase, ranging in composition from oligoclase to andesine and kyanite is elongated to prismatic in shape. Staurolite appears as porphyroblast with inclusions of biotite and curiform twinning. Garnet occurs as porphyroblast, subidioblastic to idioblastic in shape. Quartz also occur in significant amount (Plates-I & II).

PUR QUARTZITE :

The quartzites are highly jointed, greyish or rusty white in colour. The rock is generally coarse grained and compact and show granoblastic texture. It was observed under the microscope that the grains are subidioblastic to idioblastic in shape. The rock consists mainly of quartz, feldspar, and mica. The quartzite, north of Pur is foliated and appears to be banded; biotite, muscovite, actinolite constitute the dark bands. Apatite, clinozoisite and opaques are the common accessories.

IMPURE MARBLE :

The marble has a fairly wide distribution in the Pur-Banera belt. The rock is exposed towards west of Pansal and is found to be associated with quartzites and is repeatedly folded
Plate-I
(a) Garnet porphyroblast in Mica Schist.
(b) Kyanite porphyroblast in Mica Schist.
Plate-II  Chloritoid porphyroblast in Mica Schist.
with quartzite. Irregular joints are present. Being less resistant to weathering the outcrops occur as discontinuous blocks and fragments.

Microscopic study reveals that the grains are coarse with subidioblastic to xenoblastic shape. The rock has a granoblastic texture and is composed of calcite-dolomite with calc-silicates (anthophylite-actinolite). Gupta (1934) correlated the marble with Rialo marble and has classified it as Rialo Series.

**CALC-SILICATE ROCKS:**

Calc-silicate rocks are widely distributed in the area. These rocks are of two types; one is a dark grey variety exposed north of Pur and the other is light grey in colour, exposed within Pansal synform. Dark grey coloured rock is highly deformed and has an steep dip towards east or sometimes west. At a few places the rocks appear to be banded. The calc-silicates are granoblastic in texture; the grains are coarse with a xenoblastic to subidioblastic shape. Mineral constituents are calcite-dolomite, actinolite, diopside, hornblende, plagioclase, quartz, K-feldspar and biotite. Common accessories are apatite, sphene, chlorite and opaques.

The rocks exposed within Pansal synform is light grey in colour and is highly jointed. The outcrops appears as isolated blocks due to weathering and erosion. The rock has a NE-SW strike
with a westerly dip. The rock is coarse grained and comprises xenoblastic crystals of mainly diopside, actinolite, plagioclase (albite to oligoclase), K-feldspar and quartz. The quartz crystals are highly strained. Calcite, apatite and zircon occurs as accessories. Towards the northern part of the outcrop, diopside is absent; actinolite is depleted and K-feldspar is perthitic in nature.

The calc-silicate rock is known to have some sulphide mineralization, which is encountered in the bore hole samples. However, the rock specimens collected from the outcrops did not contain any sulphide minerals.

**FERRUGINOUS QUARTZITE**:

The outcrops northwest of Pur comprises of thick vertical beds of quartzite which extends up to east of Dhulkhera, the quartzite strikes NNE-SSW. The upper portion of the quartzite band is sometimes ferruginous.

The chain of high hills, striking NNE to SSW between Sauras and Jaipa is formed chiefly of ferruginous quartzite. The rock outcrops weather to form irregular blocks, the western slope of the ridge is calcareous.

Banding is the common feature in the iron bearing rocks, the bands vary in composition, colour, thickness and grain size. The bands ranges from a few feet thick to paper thin laminations.
The rock is medium grained and exhibit granoblastic textures. The minerals are quartz, biotite, plagioclase and amphiboles; the opaques include magnetite, haematite, goethite and limonite.

**SAMODI QUARTZITE** :

The quartzite north of Samodi forming an antiform, (south-west of Dedwas) dips at higher angles towards east. The rock is hard, compact and rusty white in colour. The rock is medium grained and exhibits granoblastic textures. The quartzite consist mainly of quartz, plagioclase and K-feldspar. Apatite occurs as accessories.

**DARK GREY CALC-SILICATE ROCK** :

The calc-silicates, west of Sauras is dark grey in colour and is well foliated. The rock consists mainly of calcite-dolomite, hornblende, diopside, plagioclase and quartz; it grades into calc-schist at few places. Hornblende and diopside also occurs as porphyroblast.

**GRANITE GNEISS** :

The area west of Meja constitute a portion of Banded Gneissic Complex. Basu (1966) reported a granite intrusion,
west of Dedwas. The area, however, is not accessible as it is submerged under Meja dam reservoir. Conformable bands of migmatite and granite gneiss are exposed west of Meja-Bagaur road. The granite gneiss is well foliated; the foliation planes strike NNE-SSW. The contact between granite gneiss and the mica schist is very gradational.

General texture of the rock is foliated, xenoblastic with the grains being medium to coarse in size, the rock sometimes show subidioblastic texture (Plate-III).

Plagioclase (An$_{10}$ to An$_{50}$) is the dominant mineral phase of the rock; it constitute 40.35% of the rock and is followed by quartz with average modal percentage of 33.97%. The plagioclase crystals are unzoned. K-feldspar is subordinate in amount; their average modal composition is 13.1%.

Quartz is the other dominant mineral phase and is characterized by wavy as well as patchy extinction. The quartz grains are generally fresh, sometime included in feldspar as small rounded crystals; vermicular intergrowth of quartz and plagioclase are commonly seen at the contact of plagioclase and microcline (Plate-IV).

K-feldspar is dominantly microcline; however, a few orthoclase crystals are also present. The microcline crystals are generally large in size, commonly having inclusions of quartz.
Plate-III (a) Granite gneiss showing xenoblastic texture.

(b) Inclusion of Apatite in Biotite.
Plate-IV (a) Vermicular intergrowth of quartz in Plagioclase.

(b) Vermicular intergrowth of quartz in Microcline.
Biotite is the major mineral phase among the accessories, its average modal percentage is 12.7%. Biotite crystals are oriented almost parallel in one direction and are generally concentrated in bands imparting a gneissic texture. The crystals are unaltered and have inclusions of euhedral apatite and zircon. Muscovite is found only in a few thin section. Zircon crystals are subhedral to rounded in shape. Generally magnetite, euhedral to subhedral in shape comprises the opaques.

**Modal Analysis of Granite Gneiss:**

Grain count method of Chayes (1956) was employed to determine the relative proportion of various minerals present in granite. The modal composition of seven samples of granite is given in the Table-2.

**Table-2 : Modal Composition of Granite Gneiss**

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Mean</th>
<th>Range</th>
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<tr>
<td>Quartz</td>
<td>33.97</td>
<td>27.40 - 40.54</td>
</tr>
<tr>
<td>Plagioclase</td>
<td>40.35</td>
<td>32.71 - 48.00</td>
</tr>
<tr>
<td>K-feldspar</td>
<td>13.10</td>
<td>4.20 - 22.00</td>
</tr>
<tr>
<td>Biotite</td>
<td>12.70</td>
<td>5.00 - 20.40</td>
</tr>
<tr>
<td>Muscovite</td>
<td>0.58</td>
<td>0.00 - 0.58</td>
</tr>
<tr>
<td>Apatite</td>
<td>1.18</td>
<td>0.96 - 1.41</td>
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</tbody>
</table>
The modal values of quartz, K-feldspar and plagioclase, recalculated to 100%, were plotted on quartz, orthoclase, plagioclase triangular diagram of James and Hamilton (1966). The plots of granite-gneiss (Fig. 3) fall towards the corner, away from the K-feldspar field. The diagram, superimposed on the Strikiesen's (1973) classification diagram, shows the plots of granite in the grano-diorite field (Fig. 4).

Plagioclase Twinning in Granite Gneiss:

The nature and type of twinning in plagioclase is dependent on the physico-chemical condition of the formation of granite. As such, the frequency of the twin types can be utilized to determine the genesis of the rock. Gorai (1951), Turner (1951) and Vance (1961) found that plagioclase twinning in igneous rock differs from that in metamorphic rocks. Gorai described the genesis of plagioclase, whether derived from a liquid or of metamorphic origin, on the basis of twin types.

Twinning in plagioclase disappear due to recrystallization and intense deformation (Barth, 1969) and with increased deformation, the twin lamellae coalesce and the plagioclase appears as untwinned crystal. Vance (1961), Kohler (1949) and Turner (1951) have observed that plagioclase in metamorphic rocks are untwinned or only slightly twinned.
FIG.-3 TERNARY DIAGRAM OF QUARTZ PLAGIOCLASE POTASH FELDSPAR MODAL VALUES FOR GRANITE GNEISS.
FIG.- 4 MODAL VALUES OF GRANITE GNEISS SUPER IMPOSED ON STRECKIESEN'S CLASSIFICATION DIAGRAM 1973.
Twinning in plagioclase is generally of two types, primary and secondary. The primary twinning is developed during the growth of the crystal (Berger, 1945); it includes Carlsbad, manebech, bavaeno, complex or combination twinning. According to Burger, the primary twinning frequently grow in magmatic rocks due to rapid growth; whereas, secondary twins are the result of mechanical deformation. Gorai (1951), Vance (1961) and Flaming (1977) favoured the primary growth of poly-synthetic twinning. However, Bair (1930), Emmons and Gate (1943), Emmons and Manns (1953), Kohler (1944), Kohler and Razz (1945) believed that the poly-synthetic twinning is of secondary origin. Vance (1961) has differentiated the polysynthetic twins as secondary glide twins and primary lamellar twins.

Gorai (1951) classified the plagioclase twinning into two groups on the basis of their types and orientation. A-twins are found both in igneous and metamorphic rocks; it includes albite, pericline, and glide twinning. C-twinning such as Carlsbad, Carlsbad-albite, Baveno, Manebach and other combination twinning are developed in crystals during growth and are restricted in magmatic rocks.

Using Gorai (1951) method plagioclase twin type in granite gneiss were studied to determine the origin of rock. The rock constitute dominantly A-twins, Carlsbad twins observed in a few thin section. Bending in twin lamelle, strained crystals of plagioclase and untwinned plagioclase are also observed (Plate-V).
Plate-V (a) Displacement of Twin Lamellae in Plagioclase.

(b) Bending of Plagioclase crystal.
Plate V (a)

Plate V (b)
These features indicate the deformation and recrystallization of the rock.

Table-3 : Frequency of Plagioclase Twinning in Granite Gneiss.

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>%A</th>
<th>%C</th>
<th>% untwinned</th>
</tr>
</thead>
<tbody>
<tr>
<td>G-2</td>
<td>65</td>
<td>15</td>
<td>20</td>
</tr>
<tr>
<td>G-3</td>
<td>60</td>
<td>15</td>
<td>25</td>
</tr>
<tr>
<td>G-4</td>
<td>70</td>
<td>-</td>
<td>30</td>
</tr>
<tr>
<td>G-5</td>
<td>90</td>
<td>-</td>
<td>10</td>
</tr>
<tr>
<td>G-6</td>
<td>60</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>G-7</td>
<td>80</td>
<td>-</td>
<td>20</td>
</tr>
<tr>
<td>G-8</td>
<td>60</td>
<td>10</td>
<td>30</td>
</tr>
<tr>
<td>Average</td>
<td>69.28</td>
<td>8.59</td>
<td>22.14</td>
</tr>
</tbody>
</table>

Abundance of A-twins, in granite gneisses suggest its metasomatic origin. Structural and textural features indicate that the rock is derived from the granitization of younger mica schist. Granite intrusion, southwest of Meja has been reported by Basu (1966), this intrusion was probably responsible for the granitization of the country rocks. Field evidence such, as absence of veins and apophyses in country rock also support the metasomatic origin of the granite gneiss.
INTRUSIVES:

Basic Dyke:

A basic dyke, reported from western part of Pansal, cuts across the marble ridge; the rocks grades into metadolerites. The rock exhibit blasto-ophitic texture. Amphiboles (mainly actinolite), plagioclase (andesine to bytownite) and pyroxenes including diopside, aegirine and augite constitute the rocks. Magnetite occurs as accessory mineral.

Quartz Veins:

The quartz veins are common in the area and have been reported from different places. A large vein is seen intruding the mica schist towards north of Pur.

Pegmatite Veins:

The younger mica schist is the main host of the pegmatite veins in the area. The pegmatite also occur in quartzites.
METAMORPHIC HISTORY:

The metasediments of the area are the product of medium to high medium grade (amphibolite facies) regional metamorphism, as is evident from the mineralogical assemblages, textural and structural features. The mineral assemblage of the different rock types is as follows:

Pelitic Assemblage:

1. Quartz-plagioclase (albite)-biotite-muscovite.
2. Quartz-plagioclase (andesine), muscovite, biotite-chloritoid-almandine-kyanite.

Quartzo-Feldspathic:

1. Quartz-plagioclase (oligoclase to andesine)-muscovite-biotite.

Basic:

1. Quartz-plagioclase (andesine)-hornblende.
Calcareous:

1. Quartz-plagioclase-microcline-actinolite-diopside.
2. Calcite-actinolite-diopside-hornblende-plagioclase quartz.

The uppermost grade of metamorphism in mica schist is indicated by the appearance of kyanite or staurolite. Chloritoid is seen in one thin section of the rock, it might have yielded staurolite in a prograde break down as suggested by Plekiaan (1913, listed in Harker, 1974) according to the following reactions:

\[ 9H_2FeAl_2SiO_7 = 2HFeAl_5Si_4O_{22} + SiO_2 + 5FeO + 8H_2O \]

(chloritoid) (staurolite)

Since staurolite has a narrow range of temperature stability, it has probably changed to kyanite and garnet in the high grade mica schist according to the reactions, suggested by Harker (1974) and Charmichael (1970).

1. 6 staurolite + 11 quartz = 23 kyanite + 4 almandine + 3H_2O
2. Chlorite + muscovite + staurolite + quartz = kyanite + biotite + H_2O

The lowermost level of metamorphism in mica schist is indicated by the assemblage biotite-quartz-plagioclase (albite). The mineral assemblages reveal that the rock is derived from
the pelitic sediments, rich in alumina, by medium grade regional metamorphism.

The quartzite of the area is derived by the metamorphism of arenaceous sediments with intercalatory shale under medium grade metamorphism. The ferruginous quartzites appear to have been derived from iron rich arenaceous sediments.

The lower limit of metamorphism of calcareous sediments is indicated by the assemblages calcite-biotite-albite-tremolite and the high grade metamorphism is represented by the mineral assemblage, diopside-hornblende plagioclase (oligoclase to andesine) and K-feldspar. Diopside and tremolite probably formed by the reaction between silica and dolomites as follows (Winkler, 1974).

1. \[5 \text{ dolomites} + 8 \text{ quartz} = 1H_2O + 1 \text{ tremolite} + 3 \text{ calcite} + 7CO_2\]
2. \[1 \text{ tremolite} + 3 \text{ calcite} + 2 \text{ quartz} = 5 \text{ diopside} + 3CO_2 + 1H_2O\]
3. \[1 \text{ tremolite} + 3 \text{ calcite} = 1 \text{ dolomite} + 4 \text{ diopside} + 1 \text{ CO}_2 + 1H_2O\]
4. \[1 \text{ dolomite} + 2 \text{ quartz} = 1 \text{ diopside} + 2CO_2\]

It is evident by the mineral assemblages that the calc-silicate rocks were derived by the metamorphism of calcareous clay under medium to high temperature condition.
The mineral assemblages plotted on AKF and ACF diagram indicate that the metasediments belongs to amphibolite facies and they attained a metamorphic grade up to kyanite zone of Barrow (Fig. 5 a, b). Retrogressive metamorphic effects are observed in the chloritization of biotite and hornblende, sericitization of K-feldspar and kyanite and perthitic intergrowth in feldspar. These features indicate the decline of temperature. Appearance of kyanite indicate that the rocks belong to medium to high pressure facies series of Miyashiro (1974).
FIG. 5(a) AMPHIBOLITE FACIES KYANITE ZONE A K F DIAGRAMS FOR ROCKS WITH EXCESS SiO$_2$ & Al$_2$O$_3$. QUARTZ & PLAGIOCLASE ARE ADDITIONAL PHASES. (b) ACF DIAGRAM FOR ROCKS WITH EXCESS SiO$_2$. 
CHAPTER - IV

GEOCHEMISTRY

The petrological study of the rock is useful for petrogenetic interpretation, but the interpretation based on petrological data may not always be reliable unless it is corroborated by the geochemical studies. Concentration of certain elements, in rocks and the ratio of various elements have been utilized not only to differentiate various rock type but have also been very useful in determining the origin of the rock types.

The major and trace element geochemistry of granite gneiss exposed towards west of Bhilwara, have not been carried out by earlier workers in the area. Geochemical study of granite gneiss is undertaken in the present study to decipher the petrogenesis of the rock.

METHOD USED IN ANALYSIS:

After preliminary survey of the area, several traverses were taken to collect to representative sample of granite gneiss. Eight samples were selected for geochemical analysis.

Major and trace element were analysed using method recommended by Sahpiro and Brannock (1962). FeO, MgO, K₂O and Na₂O and CaO were analysed by Atomic Absorption Spectrophotometry using standard solutions.
SiO₂ and Al₂O₃ were determined in a aliquot of solution 'A' prepared by fusion of 0.1 gm of rock powder with NaOH pellets in nickle crusible, the solution was acidified with 1 : 1 HCl acid and finally transferred to one litre volume flask.

The concentration of SiO₂ and Al₂O₃ was determined by spectrophotometer using coloured ions of representative elements and measuring the absorbence on the selected wave lengths, 640 μm for SiO₂ and 475 μm for Al₂O₃.

**Distribution of Major Oxides in Granite Gneiss :**

The major oxides content of the rock is given in the Table-IV. It is evident from the table that the percentage of SiO₂ is significantly high and show narrow range concentration which varies from 65.14 to 71.88 with an average of 69%. Al₂O₃ ranges between 14.14 to 15.42% with an average of 14.61%. FeO content is 2.4 to 6.23% averaging about 4.8%. MgO is relatively low, 0.21%, the average being 0.15%. K₂O content is relatively high in the gneiss, it varies from 2.22 to 5.00% with an average of 3.54%. Na₂O is relatively low whereas, CaO values are very low 0.63 to 1.4% with an average content of 1.14%.

Only zinc and cobalt were analysed as trace elements. The average content of Zn and Co is 225 ppm and 16 ppm respectively.
<table>
<thead>
<tr>
<th>Major Oxides</th>
<th>G2</th>
<th>G3</th>
<th>G4</th>
<th>G5</th>
<th>G6</th>
<th>G7</th>
<th>G8</th>
<th>G9</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO₂</td>
<td>65.14</td>
<td>66.15</td>
<td>69.74</td>
<td>68.51</td>
<td>69.63</td>
<td>71.88</td>
<td>70.75</td>
<td>68.50</td>
</tr>
<tr>
<td>FeO (Total)</td>
<td>5.05</td>
<td>6.01</td>
<td>3.94</td>
<td>5.72</td>
<td>3.73</td>
<td>2.24</td>
<td>5.61</td>
<td>6.23</td>
</tr>
<tr>
<td>MgO</td>
<td>0.16</td>
<td>0.21</td>
<td>0.10</td>
<td>0.19</td>
<td>0.15</td>
<td>0.06</td>
<td>0.15</td>
<td>0.14</td>
</tr>
<tr>
<td>CaO</td>
<td>1.09</td>
<td>1.40</td>
<td>1.39</td>
<td>1.04</td>
<td>0.89</td>
<td>0.63</td>
<td>1.33</td>
<td>1.36</td>
</tr>
<tr>
<td>K₂O</td>
<td>3.58</td>
<td>3.13</td>
<td>2.22</td>
<td>2.93</td>
<td>3.70</td>
<td>5.00</td>
<td>4.63</td>
<td>3.17</td>
</tr>
<tr>
<td>Na₂O</td>
<td>2.66</td>
<td>2.74</td>
<td>2.14</td>
<td>2.20</td>
<td>3.28</td>
<td>2.83</td>
<td>2.91</td>
<td>1.30</td>
</tr>
</tbody>
</table>

**Trace Elements (in ppm)**

<table>
<thead>
<tr>
<th>Element</th>
<th>G2</th>
<th>G3</th>
<th>G4</th>
<th>G5</th>
<th>G6</th>
<th>G7</th>
<th>G8</th>
<th>G9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zn</td>
<td>152.10</td>
<td>321.60</td>
<td>416.70</td>
<td>126.80</td>
<td>228.90</td>
<td>130.20</td>
<td>378.90</td>
<td>288.60</td>
</tr>
<tr>
<td>Co</td>
<td>18.00</td>
<td>21.90</td>
<td>11.00</td>
<td>22.90</td>
<td>16.10</td>
<td>10.00</td>
<td>17.80</td>
<td>15.30</td>
</tr>
<tr>
<td>Al₂O₃/</td>
<td>2.04</td>
<td>2.03</td>
<td>2.45</td>
<td>2.29</td>
<td>1.91</td>
<td>1.70</td>
<td>1.63</td>
<td>2.42</td>
</tr>
<tr>
<td>(K₂O+Na₂O+CaO)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Al-Na-K</td>
<td>58.13</td>
<td>53.90</td>
<td>64.72</td>
<td>57.30</td>
<td>62.99</td>
<td>69.55</td>
<td>49.46</td>
<td>57.38</td>
</tr>
<tr>
<td>Fe + Mg</td>
<td>34.61</td>
<td>37.62</td>
<td>26.73</td>
<td>36.30</td>
<td>30.10</td>
<td>24.21</td>
<td>41.05</td>
<td>35.11</td>
</tr>
</tbody>
</table>
Classification of Granites:

Chappell and White (1974) classified the granitic rock of Kosciusko batholith (Eastern Australia) into two types, I and S-types based on origin of the rock. It has been observed that granite with molecular ratios of $\frac{Al_2O_3}{(Na_2O + K_2O + CaO)}$ greater than 1.1, that were distinguished as S-type whereas, the I-type has a ratio of less than 1.1. The S-type granites has relatively higher concentration of potassium than sodium and higher initial $^{87}Sr/^{86}Sr$ ratio.

The chemical composition of the granites of Eastern Australia referred to be S-type by White and Chappell (1974) and is characterized by the presence of biotite with or without muscovite, cordeirite or garnet but not hornblende. Absence of metasedimentary xenoliths is also the significant feature of the S-type granite. The granites having $\frac{Al_2O_3}{(Na_2O + K_2O + CaO)}$ ratio less than 1.1, and characterized by the presence of hornblende is referred as I-type.

The most fundamental chemical difference between I and S-type granites is the ratio of K/Na; this is an important factor to differentiate the I and S-type granites (Chappell and White, 1974). During chemical weathering, Al and K are enriched relatively to Na and Ca. Since Na is removed into sea water and evaporites whereas, Ca is concentrated in limestones. As such peletic rocks have high K and Al contents relative to
Na and Ca (Turekian and Wedepohl, 1961; Kolbe and Taylor, 1966). This is reflected in the high K/Na ratios of S-type granites and their relatively low Ca contents. These features are exhibited in higher Al(Na + K + Ca) values of S-type granites.

Sediments generally contain sulphur and carbon which reduces the sediments. The granite derived from metasedimentary source have lower oxidation state as compared to igneous derived granites. Hine, et al. (1978), used the Fe$_2$O$_3$/FeO plot to separate the I-type and S-type field.

The principal mineralogical characteristics of the granites of Kosciusko batholith (Eastern Australia) are determined by the relationship Al, Na, K and Ca. This is illustrated by plotting the analysed rocks in terms of Al-(K + Na), Ca and Fe + Mg. The field of S-type and I-type is clearly demarcated in the Figure-6. The I-type plots in the plagioclase + hornblende + biotite field, whereas, the S-type is concentrated in biotite + plagioclase or biotite + plagioclase + cordierite field (Hine, et al., 1978).

The granite gneisses west of Meja having a range of SiO$_2$ content of 65.58 to 71.88%, which corresponds to the S-type granite. The plots of SiO$_2$ versus CaO, Zn and Co (Figs. 7, 8 & 9), of the granite gneiss lies towards the S-type field.

The S-type granite contains generally low Na$_2$O content as compared to I-types. The Na$_2$O-K$_2$O plots of granite gneiss reflect the higher K/Na ratios (Fig. 10), and also reflect the higher Al$_2$O$_3$/(K$_2$O + Na$_2$O + CaO) ratios. These values indicate that the rocks were derived from a metasedimentary source.
FIG. 6 Kosciusko granitoids plotted in terms of (Al-Na-K), Ca and (Fe$^{2+} +$ Mg), showing how the chemical composition determines the mineral assemblage.
The granite composition was plotted on the Al-(Na + K), Ca and Fe + Mg triangular diagrams (Fig. 11), the plots fall towards the plagioclase + biotite + Corderite field. The further corroborates the earlier information that the granite gneiss of Meja area belongs to the S-type.
FIG. 7 PLOTS OF GRANITE GNEISS ON SiO$_2$:Zn

FIG. 8 PLOTS OF GRANITE GNEISS ON SiO$_2$:CaO
FIG: 9 PLOTS OF GRANITE GNEISS ON SiO₂:CO

FIG: 10 PLOTS OF GRANITE GNEISS ON K₂O:Na₂O
FIG: 10(a) PLOTS OF GRANITE GNEISS ON $K_2O$ : $Na_2O$ DIAGRAM OF WHITE & CHAPPELL (1983).
FIG.-11 GRANITE GNEISS COMPOSITION PLOTTED IN TERMS OF Al- Na-K, Ca AND Fe+Mg
CHAPTER - V

SUMMARY AND CONCLUSION

The metasediments of Pur-Banera belt, west of Bhilwara were classified by Gupta (1934) into three groups, later classified by Heron (1953) into two groups. Field evidence, such as absence of unconformity between Banded Gneissic Complex and metasediments and Bundelkhand granites indicate a continuous sequence. Basu (1966) grouped these rocks into a single unit; the impure marble and granite within Pansal synform reported by Gupta (1934) is considered as a facies variation of calc-silicate rocks and the conglomerates being of tectonic in origin. The present investigation corroborates Basu's inference.


Mineral assemblages reveal that the rocks of the area are the products of medium to high medium grade (Amphibolite facies) regional metamorphism. They attained a metamorphic grade up to kyanite zone of Barrow (1893). The rocks correspond to medium and high pressure facies series of Miyashiro (1974).
The granite gneiss, west of Meja constitute a part of Banded Gneissic Complex. The microscopic features including the presence of polysynthetic twinning, secondary twinning and abundance of untwinned plagioclase and absence of zoned plagioclase suggest a metasomatic origin of the rock.

Displacement and bending of twin lamellae of plagioclase and fracturing of quartz and feldspar grains indicate deformation after solidification.

High $K_2O/Na_2O$ and $Al_2O_3/(K_2O + Na_2O + CaO)$ ratios, low CaO content and restricted range of $SiO_2$ percentage indicate that the rocks were derived from the sedimentary source. These features reveal that the granite gneiss of Meja area belongs to S-type as proposed by White and Chappell (1974) and were formed by the ultra-metamorphism of the metasediments.
REFERENCES


Streckeisen's, A.L. (1976) : To each plutonic rock its proper name. Earth Sciences reviews, 12, pp. 1-33.


