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Metavolcanics and Its Litho Structural Relationship with Assosiated Rock Types around Badi Lake, Udaipur, Rajasthan

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Abstract : ***In Indian shield, Aravalli mountain belt is in the northwestern part and uphold a well developed Proterozoic sequence which can be unearthed from approximately 2500 my to 500my. In the present study area, where different types of metasediments are present, exists basic volcanics representing the different episodes of Proterozoic volcanism. Some work has been done on various aspects of geology but detailed structural and petrographical studies on these volcanic have not been carried out in this area.***

The study of these volcanics is an excellent opening to understand and unfold the evolutionary history of Aravalli belt. In the present study area, the basic volcanic rocks are intercalated with cleaned washed quartzites and other shallow water sediments. Basically, this sequence of volcano- sedimentary unit overlies the basement of Archean age.

The present work shows that the rock sequence of the Badi lake area can be divided into broad lithological groups representing the different environmental conditions: (l) a composite suite of basic volcanics and tuffs (metamorphosed to green schists), orthoquartzites, conglomerates, brecciated ferrugenious quartzite and dolomites, (2) phyllites with minor intercalatory quartzites, (3) phyllites and schists with abundant intercalatory quartzites and minor impure dolomites.

I. INTRODUCTION

The present study investigation area is falling under Girwa tehsil in NW border of the city of Udaipur district, Rajasthan, India. It belongs to Udaipur division and located about 15 km towards west from district headquarters Udaipur on Udaipur – Badi Lake road. The rocks of the Badi Lake Group occur in between Kharpena to Madar in its south to north extension respectively, covering a distance of 30 km with the width of 3 to 5 km.

The Badi Lake Group represents a volcano-sedimentary assemblage comprising coarse to fine grained clastic sediments, syn-sedimentational basic volcanics, pyroclastic and volcaniclastic rocks overlying the Udaipur Group. The sequence of meta sedimentary-meta volcanic in the Aravalli Supergroup lies unconformably on the Banded Gneissic Complex (BGC), Heron (1953). The meta- sediments present in the BGC basement include quartzite, marbles, calc-silicate rocks, ironstone formations and mica schists. Out of all these metasediments, only quartzite and marble occur as mappable units on regional scale. Other metasediments are very thin and are highly weathered.

The stratigraphic succession of the rocks occurring in Udaipur district is given in Table1. Aravalli Supergroup has been divided into two groups- Lower Aravalli Group and Upper Aravalli Group (Roy, 1988), separated by an unconformity marked by conglomerate and red beds. Extensive residual weathering leading to the development of ferricrete, silcrete, laterite, ochreous shales and cave breccias in the topmost beds of the carbonate sequence (of the lower Aravalli Group) indicate the span of hiatus between the two groups. Gupta et al (1980, 1992, 1997) figured out the development of the volcanic belt near Badi Lake and hence named it as Badi Lake Group (Table 1).

Table 1. Stratigraphic succession showing the study area in Aravalli Supergroup by Heron (1953), Gupta et al (1997) and Roy and Jakhar (2002)

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Heron (1953)	Gupta et al (1997)			Roy and Jakhar (2002)		
Delhi System (2000-700m.y)	Delhi Supergroup			Delhi Supergroup		
"Raialo series" Aravalli System (Archean)	ARAVALLI SUPERGROUP	Jharol Group	Samlaji Formation Goram Formation	ARAVALLI SUPERGROUP		Lakhawali Formation Jharol Formation
					Upper	Kabita Dolomite
		Barilake Group	Khamnor Formation Varla Formation Sajjangarh Formation			Debari Formation
		Udaipur Group	Udaipur Sector Banswara Formation Nimach Mata Formation Balicha Formation Eklinggarh Formation Sabina Formation			Tidi Formation
					Middle	Bowa Formation = Machla Magra Formation
						Mochia Formation = Zawar Formation
		Debari Group (Babarmal Formation)				Udaipur Formation
						Jhamarkotra Formation
					Lower	Delwara Formation
Banded Gniess Complex (> 2500 m.y)	Bhilwara Supergroup			Mewar Gneiss		

A. Meta Volcanics and its Association around Badi Lake

In the north of Udaipur, Heron (1953) reported acquisition of volcanic rocks at the base of the Aravalli System, the ideal exposures being found on the east of Badi Lake (Badi Formation is considered to be equivalent to the Delwara Formation). All these volcanic rocks are supposedly metamorphosed and they show metamorphism of green schist facies.

Here, the Banded Gneissic Complex appears at the base of the ridge quartzite. These ridge quartzites are succeeded by the meta – volcanics upward. Thin bands are also present in it of impure limestone and discontinuous quartzites with sheared granite. The broad belt of amygdular meta – volcanics nearly 3 km wide, passes upward into dull fine-grained light green chlorite-schist which Heron (1953) believed to be the product of volcanic tuffs topping the lava forming most of the remainder of the sequence of meta-volcanics. Some pelitic bands have also been recognised within these meta-volcanics (Fig 1 & 2).

Quartz vien with the invariable association of calcite and epidote are common throughout the exposures and in the amygdules. Heron considered the whole association of meta-volcanics of biotite – chlorite schist, amphibolites and hornblende schists, etc. as the original volcanic effusive but it appears certain that in this belt of rocks mapped as volcanic by Heron (1953), identified as quartzites, pelites, limestones and marly sediments which are metamorphosed. Heron was impressed by the amygdaloidal nature of

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these rocks at places and classified them as volcanic rocks. Elongation of amygdules and quartz pebbles of quartzite are in the same direction exhibits the same episode of deformation.

Two set of cleavage are usually present in the meta-volcanics (Plate 1D). Intersectional cleavages are always clear and form one of the most common lineations in these rocks. Somewhere in fresh surfaces mineral streaks of biotite and chlorite are present.

On the basis of different litho variation in associated rocks, metavolcanics in the Badi Lake area is divided into three different associations.

B. Metavolcanics with Amygdules and Tuffs

1) *Massive Amygdular Metavolcanic Association:* This association is found in the eastern side of the Badi Lake overlying the basement and extending upto Varla village, depicted by its amygdular character revealing its volcanic nature. The rock is hard and massive and of dark green colour and shows a feebly developed cleavage. At some places brownish green colour is due to the severe effect of weathering which makes it soft and friable in nature. The amygdules seen vary from 2 – 20 mm long, are filled with quartz, calcite minerals and rarely epidote deformed and elongated showing the preferred orientation in the direction of dip. They are in general fine grained and greenish black to greyish black in colour. (Plate 1A & 1B)
2) *Conglomerate– Greenschist Association:* This association is a characteristic feature of volcanic rocks which are represented by chlorite schist with amygdular and vesicular character in some greenschists revealing its volcanic percentage (lava flows and ash fall tuffs, cf. Heron, 1953; Roy and Paliwal, 1981). The belt of greenschist occupy a large area in the western side of Badi Lake along with diamictic conglomerate, occurs in isolated outcrops occupying the cores of anticlinal folds (antiformal anticline, cf. Ramsay, 1967).

Pebbles and boulders, mostly of quartzite and vien quartz, sometimes its longer axis (X) is as large as 50 cm (Plate 1C). Pebbles of comparatively smaller size (between 0.5-2cm X axis are seen in the outcrops of greenschist near Badi Lake. The schistosity in greenschist is wrapping the flattened pebbles and large clasts.

The contact between the two units in the east is sharp possibly fault controlled. A narrow band of greenschist, at places, alternates with the conglomerate – quartzite near the base of the basal formation.

C. Greenschist Associated with Quartzite and Granite

The contact between greenschist and quartzite is clearly visible in (Plate 2A & 2B) western part of the Badi Lake overlying the amygdular greenschist. An interesting feature associated with this, is the occurrence of pyrophyllite schist at the contact of granite with quartzites (Plate 1E). It precisely follows the contact between the granite and quartzites. The pyrophyllite schists have preserved all the minute details of polyphase deformation. Since pyrophyllite is restricted to a specific time surface, the granite – quartzite contact, therefore it marks the invaluable marker horizon.

1) *Quartz – Pyrophyllite – Chlorite – Sericite Association:* The proportions of mineral present in this association are not constant and vary from place to place. A fine grained rock is slightly foliated and all the constituents minerals are mixed together as they are fine grained. Chlorite is light green to dark green or light yellowish green to green in colour. There are some pockets of pyrophyllite along the contact of granites with the basal conglomerate – quartzite. It is a light green schistose rock with greasy touch, appearing crenulated and puckered in nature (Plate 1D & 1E). It contains quartz, chlorite, pyrophyllite and sericite. Pyrophyllite is white with occasional greenish shade

D. Metavolcanics in Association With Dolomites

These rocks are light green to greenish black in colour and show very strong cleavage. The cleavages are closely spaced and lineations are at steep angle. Somewhere on the cleavage surfaces, glistening flakes of black mica are seen. Somewhere, the rock is like phyllites of the Aravalli System and is indistinguishable from it.

Dolomites appear as grey or rusty brown coloured, massive bodies crisscrossed by viens of quartz. These are poorly bedded rocks comprising of 90% dolomite with minor calcite along with quartz, chlorite, talc, plagioclase and biotite. Fine thin laminated bands are frequently seen in the outcrops (Plate 1F). Sporadic occurrences of silcrete and ferricrete accompanied by laterites, in the outcrops are indicators of paleo-weathering activity (Roy and Paliwal, 1981; Roy and Jakhar, 2002). The carbonates show uniform dolomitic composition suggesting an early dolomitization.

1) *Greenschist – Carbonate – Quartzite Association:* Quartzites and greenschists are two prominent rock types belonging to study area in this association. The sequence in all starts with the quartzite, which rarely grades into conglomerates. Greenschist bands

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are either interstratified with or overlie conformably the quartzites (Plate 2B). The greenschist is a field term applied to the chlorite schists. Presence of deformed amygdules at some places of these rocks confirms their volcanic percentage.

2) *Carbonate association:* The basal sequence of conglomerate – quartzite and greenschist passes upwards into the rocks of a calcareous facies, grouped here under this association. The contact between the two is gradational in nature. The dominant rock unit of this association is dolomite, the ferrugineous dolomite, chert, argillaceous limestone and phyllites constitutes a very small portion of this association. Several pockets of talc have also been developed near the intrusive contacts, as a result of hydrothermal alteration of dolomites. Somewhere because of the extremely rapid facies variation from dolomitic limestone to orthoquartzite it is not mappable at this scale the two units separately.

II. PETROGRAPHY

The basal Aravalli volcanic are greenish to dark green coloured, fine to medium grained rocks possessing schistose structure. The green schists are amygdular in places (deep green in colour) and are highly schistose. The schistosity is well marked by preferred dimensional orientation of chlorite, actinolite and or hornblende and subordinate amounts of albite, quartz, epidote and calcite. They are composed of typical greenschist facies mineral assemblage and exhibit a low grade regional metamorphism. These volcanics show some relict minerals, vescicles or amygdules which are preserved despite of pervasive recrystallization, and show porphyritic characters.

A representative specimen from the eastern banks of Badi lake is an actinolite-albite quartz schist containing amygdules filled with brown biotite or pale grey quartz. The vesicles are elongated in the direction of foliation and are 2 – 10mm long.

These metavolcanics in thin sections comprises chlorite, actinolite, hornblende, and albite, orthoclase with grains of quartz, epidote and sphene. The orthoquartzites and conglomerates interstratified with the green schists occur as discontinuous outcrops forming narrow ridges.

Mineralogically, the greenschist comprise chlorite, quartz and feldspar with or without actinolite/hornblende as the chief constituents, whereas epidote, biotite, sericite and sphene are less commonly occurring minerals. Major opaque minerals include magnetite, hematite, pyrite and ilemenite.

Chlorite is the most dominant mineral in greenschists generally occur in the form of irregular flakes and prisms of varying dimensions, slightly elongated showing preferred orientation parallel to S1 plane. The grains are strongly pleochroic in different shades of green.

Amphiboles (actinolite/tremolite or hornblende) occurs as elongated needles or tabular laths. They are present in the form of xenoblast and porphyroblast at some places. Presence of ilemenite, rutile with hornblende, epidote and clino-zoisite suggest the retrogression of pyroxene to amphibole by uralitization. Hornblende is euhedral to subhedral, green in colour, pleochroic in nature (X- pale yellow to brown, Y- light green, Z- dark green).

Pyroxene present is commonly clino-pyroxene (aegerine-augite) with the perfect two set of cleavages. Brown augite is showing one set of cleavage, phenocryst being euhedral to subhedral in shape.

Relict plagioclases occur rarely as medium sized or coarse grains, highly weathered and altered to sericitized aggregates euhedral to subhedral in shape.

Quartz usually occurs as granular aggregates of equidimensional grains. It also occurs as small irregular inequant grains. The grains are flattened and are aligned with actinolite and chlorite. It defines schistosity in meta volcanics.

Epidote occurs more or less rounded grains, as well as elongated laths. Generally as already mentioned, it is a secondary mineral in the vesicles or in the groundmass together with chlorite.

Calcite in some rocks occurs in granular aggregates within the groundmass. Besides, there are some euhedral crystals of calcite and also some calcite viens in the greenschist following either schistosity or fracture planes.

A. Metavolcaincs with Amygdules and Tuffs

1) Under microscope, greenschist show a schistose texture (Plate 2E, 3B & E). In rare instances, volcanic flow structure has been preserved. Some greenschist show vesicles and amygdules of varying shape and size. These vesicles are invariably flattened and stretched (Plate 2C & D). The minerals filling the amygdules are calcite, coarsely crystalline epidote, quartz, feldspar and iron oxide.

2) At some places, the vesicles do not show any deformation and are spherical in shape except for that the groundmass of the rock shows a sort of pressure shadow effect. There are thin flakes of biotite present which by their parallel orientation define the

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cleavage in the rock. Quartz and plagioclase are also present. Presence of quartz particularly in the groundmass around the amygdale region, suggests its replacement origin. Arrangement of chlorite flakes are showing folding of second generation which is identified by folding of cleavage plane (Plate 2E).

B. Greenschist Associated with Quartzite and Granite

The rock is dark green coloured and shows schistose texture. The rock shows fairly well developed two set of cleavages (Plate 3B & E). Vesicles and amygdules are elongated in the direction of dip. Some igneous characteristics are shown by flow structure and amygdule structure. While clastic characters and metamorphic characters are shown by parallel arrangements of chlorite and quartz mineral (Plate 2F) in quartzites associated with it. There is an interesting feature present in this association is the occurrence of pyrophyllite schist at the contact of granite with quartzites.

1) The rock show perfect cleavage developed by the parallel orientation of biotite flakes and dimensionally elongated quartz, calcite and very subordinate plagioclase feldspar. Chlorite appears distinctly pleochroic from light green to green. Both pyrophyllite and chlorite contains some tiny yellow rutile grains and shows moderate pleochroism. It occurs as small flakes and show grey to greyish brown polarization colours. Sericite also occurs as tiny colourless flakes.

2) In a moderately foliated rock, quartz form lenticles parallel to schistosity and sericite changes to muscovite (Plate 3A). In some rocks, calcite is present which is recrystallised into patches and lenticles within chlorite mass

3) In highly foliated, lenticles of quartz are common embedded in chlorite and muscovite demarcating the prominent schistosity of the rock (Plate 3B & E).

C. Metavolcanics in Association with Dolomites

1) In the least metamorphosed dolomite, a cluster of very fine grained aggregates embedding small dolomitic spars represents micritic texture. The impact of low grade green schist metamorphism is evident from the occurrence of chlorite fibres, fine needles of penninite-chlorite and biotite. Very few grains of amphibole such as hornblende are also present. Another evidence of upper green schist facies metamorphism is the occurrence of colourless to faint green pleochroic prismatic fibrous laths of tremolite-actinolite which show incipient impact of high grade metamorphism.

2) It is a fine grained rock with a very well developed cleavage which is unaffected by any later movements. Sometimes, there are deciphered bands in which the grain size and mineralogical composition is variable. The minerals present are quartz, sericite, chlorite, calcite, magnetite and plagioclase feldspar.

3) The carbonate material is essentially in the form of vein or patches (Plate 3D). Some chlorite has recrystallised at places and the recrystallised chlorite appears to be later to the development of cleavage in the rock. Impure varieties of dolomite contain, besides dolomites and quartz, a few grains of chlorite, phlogopite, rarely tremolite, feldspar and tourmaline.

4) Feldspar grains are fresh and have irregular grain boundaries. A few feldspar grains show twinning on albite laws and range in composition between albite and oligoclase (Plate 3C). Feldspar grains show effects of deformation. Unstrained quartz grains occur in clusters, varying in size. Larger grains of quartz show undulose extinction (Plate 3C & D). In some rocks tremolite are seen embedded in the dolomitic matrix and shows sieve structure with pores filled in with dolomites.

III. CONCLUSION

In this area, the basic volcanic rocks occur as lava flows, intercalated with clean washed quartzite and other shallow water sediments. These volcano-sedimentary sequences overlie the basement complex of Archean age popularly known as Banded Gneissic Complex (BGC) and are overlain by a volcanoclastic/conglomerate one. This belt of metavolcanics coincides roughly with the boundary between the shelf and the deep-sea sedimentary facies associations of the Aravalli Supergroup.

On the eastern side of these meta-volcanics, present the high ridge quartzites and on its western side, there are thin bands of impure limestone within these meta volcanic with some quartzites (which are not mappable) which passes upwards to diamictic comglomerate (quartz pebble conglomerate) and some sheared granite.

Petrographically, the rocks display almost uniform mineral assemblage and textural relations. These are generally composed of typical greenschist facies mineral assemblages predominantly comprise serpentinites, which show extensive alteration to talc-carbonate, talc and chlorite schist rocks. These metabasic volcanic rocks show iron enrichment.

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In general the growth of metamorphic minerals has obliterated the primary minerals and textures. However, few relict minerals such as pyroxene and plagioclase and the magmatic features including vesicles and amygdules and ophitic textures are also preserved favours that these are metamorphosed, volcanogenic sediments mixed with clastic seiments.

PLATE 1

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A.</td><td>
B.</td><td>C.
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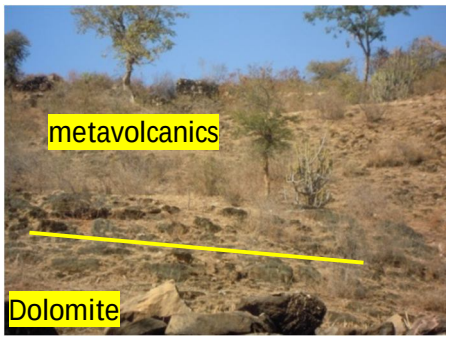
E.</td><td> 

F.</td></tr>
<tr><td colspan="3">A. Steeply dipping cleavages S1 in metavolcanics with visible vesicles and amygdules outcropping near west of Badi Lake.</td></tr>
<tr><td colspan="3">B. A close view of the chlorite schist (metavolcanics) with stretched amygdules.</td></tr>
<tr><td colspan="3">C. Local conglomertic horizon alternating with chlorite schist exposed near Badi Lake. Note the stretched pebbles.</td></tr>
<tr><td colspan="3">D. Development of crenulation cleavages (S2) on early cleavages (S1), observed in chlorite schist exposed in the north of Badi Lake.</td></tr>
<tr><td colspan="3">E. Note the younger generation kink in pyrophyllite at the contact of sheared granite and basal quartzites near village Varla.</td></tr>
<tr><td colspan="3">F. Contact between greenschist and dolomites</td></tr>
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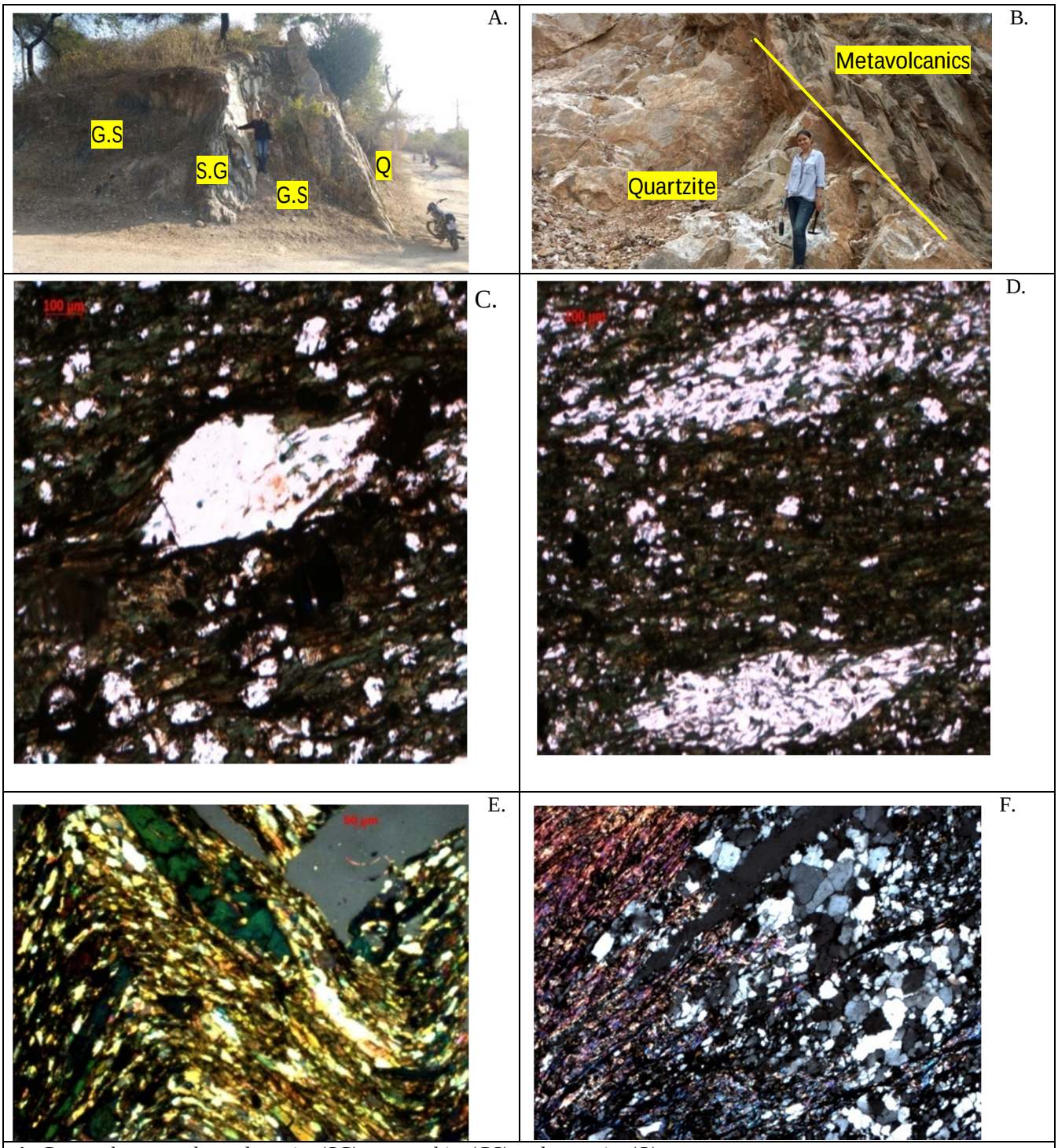
PLATE 2



A. Contact between sheared granite (SG), greenschist (GS) and quartzite (Q).

B. Contact between quartzite and greenschist (metavolcanics).

C. Vesicle observed in metavolcanics is of eye shaped which is deformed/ elongated along the foliation plane depicting its shearing effect.

D. Rhomboidal amygdules filled with secondary quartz, exhibiting two sets of deformation.

E. Crenulated early cleavage in metavolcanics. Note the syn to post (S2) kinematic biotite developed at the limb of fold.

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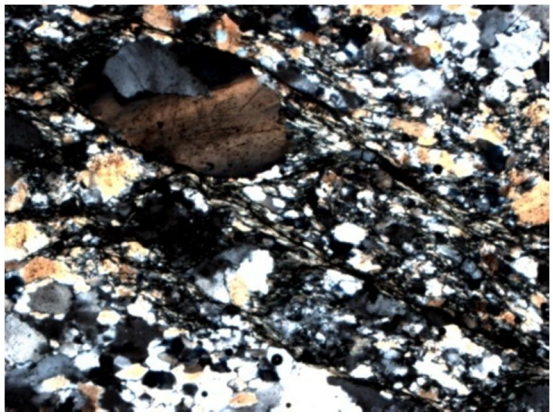
F. Sheared quartzite with fine to coarse grained quartz with the development of micaceous mineral along cleavage.

PLATE 3

A.



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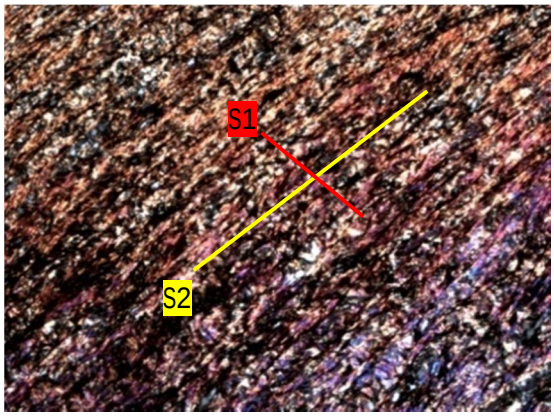

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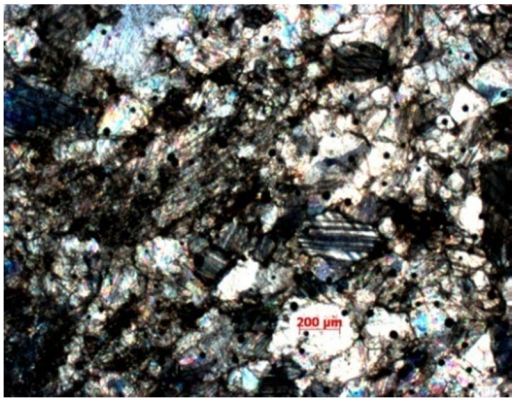

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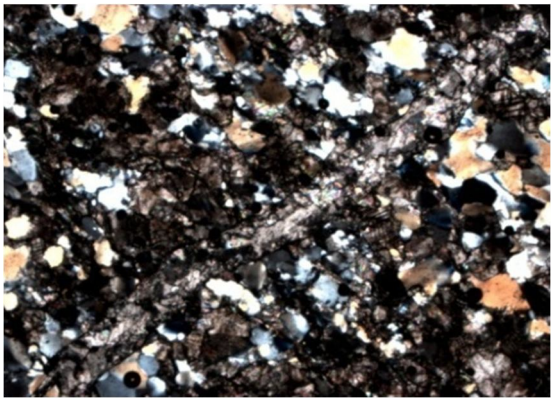

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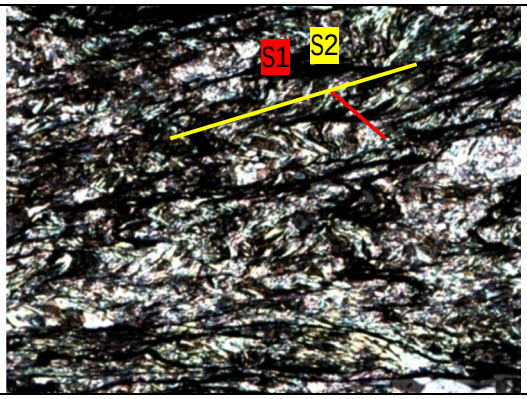

A. Sheared quartzite with fine to coarse grained quartz showing undulose extinction, exhibiting some shearing effect with the development of micaceous mineral along cleavage.

B. Closely spaced crenulation cleavage in chlorite schist.

C. Gritty Dolomite having sub rounded to angular detrital grains of quarts, orthoclase, microcline and minor albite which are cemented by a matrix of crystalline 'dolomite. Feldspars are in most cases fresh. The grains of quartz and feldspar range in size of a mm constitute 55% of the rock.

D. Gritty dolomite traverse by calcite viens along the fracture planes. Under microscope it is showing 50% of carbonate grains and 30% of quartz showing undulose extintion. Feldspar also occurs which is mostly orthoclase and microcline. There is a complete absence of argillaceous matter in the matrix.

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E. Chlorite schist with quartz, muscovite, biotite and chlorite which together form a fine grain schistose fabric. It exhibits S1 and S2.

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FIG: 1 Simplified geological map of Aravalli Supergroup in the type area (After Roy et al. 1988) showing distribution of various lithological units.

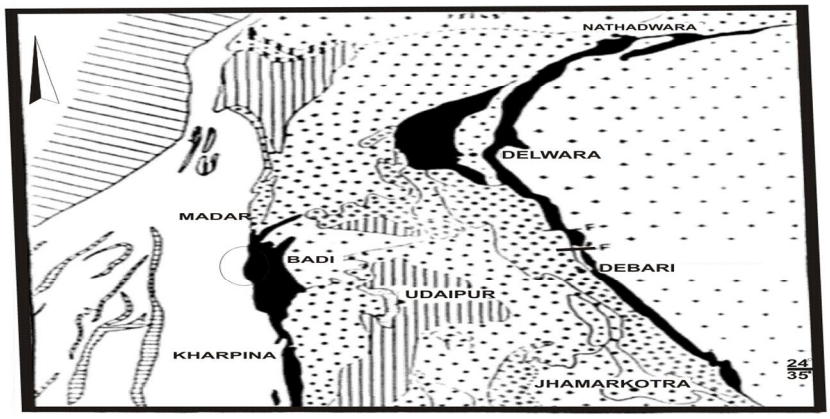

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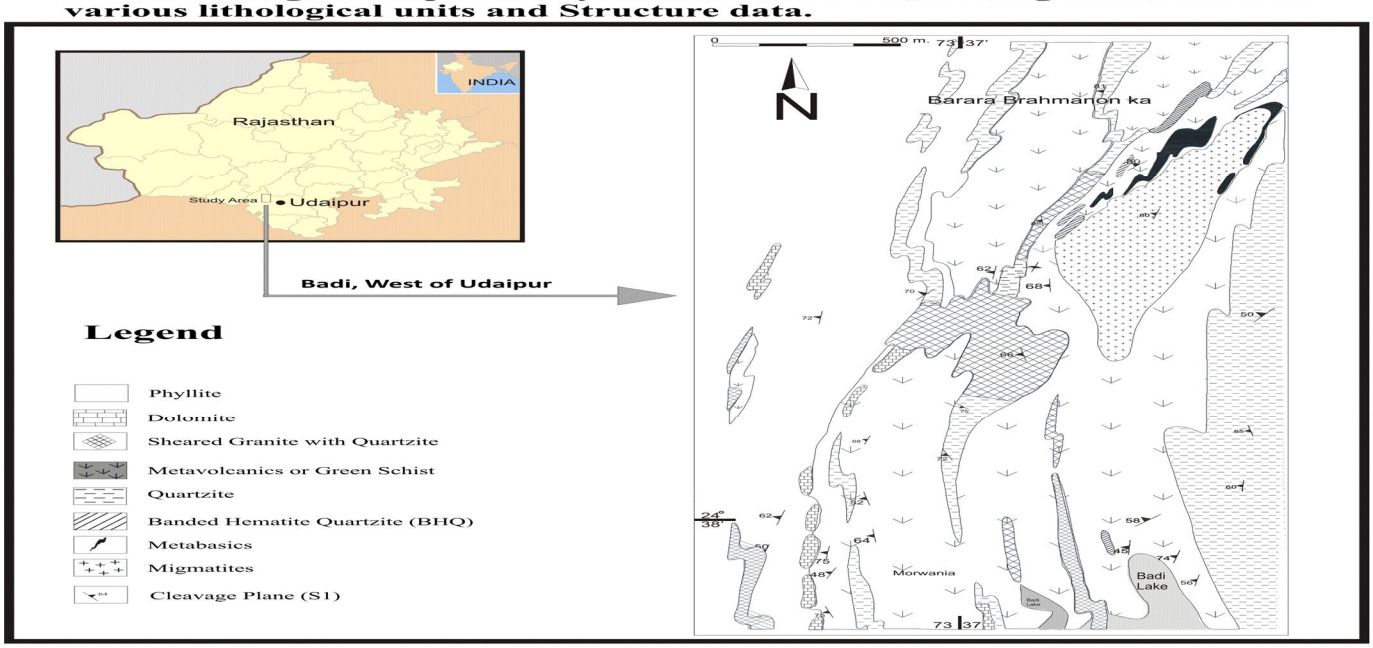
FIG: 2 Geological map of Study Area around Badi,showing distribution of various lithological units and Structure data.



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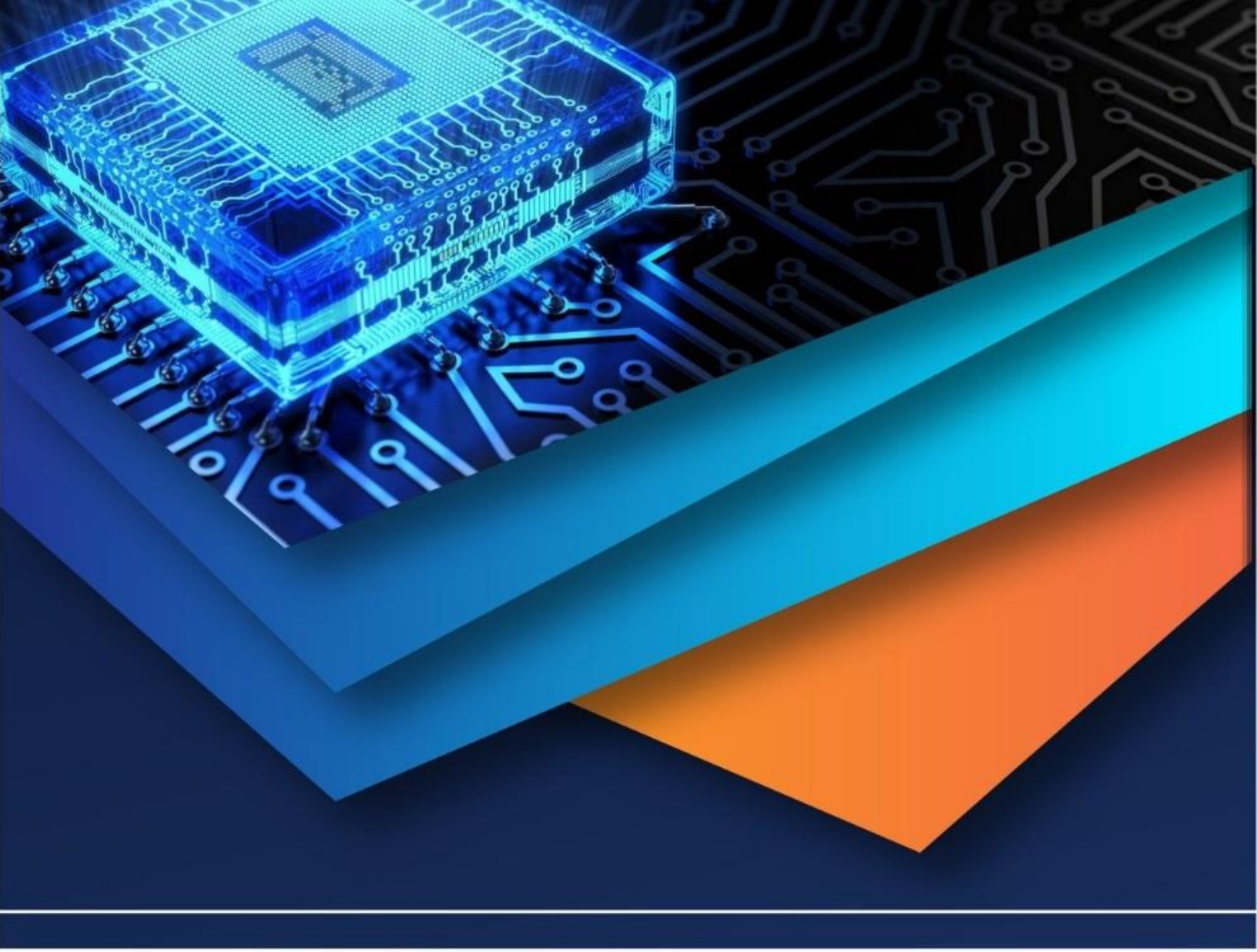

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