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Geology and Petrological Study of Metasediments Exposed Around Mordu and Khiwandi Village, Sirohi and Pali District, Rajasthan, India

Kapasya Harish[1], Sharma K. K.[2], Purohit Ritesh[2], Chauhan N. K.[3]
[1]*Department of Geology, M. L. Sukhadia University, Udaipur 313001*
[2]*Department of Geology, Government College of Sirohi, Sirohi 307001*
[3]*Department of Geology, M. L. Sukhadia University, Udaipur 313001*

Abstract: ***In the areas west of South Delhi Fold Belt (SDFB), isolated patches of metasedimentary rocks are occur in the form of a broad belt occupying the plains of Marwar lying to the southwest of Aravalli range. The metasediments of Sirohi Group are exposed in linear belt from Didwana (Nagaur District) to Palanpur (Gujarat), through Degana, Sojat, Gundoj, Nadol, Khiwandi, Mordu, Sirohi, Reodar and Mandar. The continuity of the belt is either lost under a thick soil/sand cover in the area or interrupted by the intrusive Erinpura Granite. In north of Sirohi, these metasediments occur as isolated outcrops, traceable for some distance. Further north, exposures of these rocks are quite scare, particularly beyond the Jawai river beds. These metasedimentary rocks are grouped within the Sirohi Group. One such patch of metasediments exposed to the northwest of Sumerpur. The Neoproterozoic Sirohi Group of rocks includes carbonaceous phyllite, black cherty quartzite, micaceous quartzite / schist, calc silicate rock and dolomitic marble. These rocks are intruded by granite, dolerite dyke, pegmatite and quartz vein. The granites are of two types- one is coarse porphyritic in nature and another is fine to medium grained and mainly occurring along the periphery of porphyritic granite. These granites occur generally in the form of dykes. The general strike varies from NNE-SSW to ENE-WSW with a moderate to steep dip towards south east.***

I. INTRODUCTION

The Precambrian geology in northwestern Indian shield comprises crustal developments spanning from 3300 Ma to 542 Ma. These include several orogenic activities along with magmatic episodes and constituting Aravalli Mountain Range in the region (Figure 1). Heron (1917, 1935), Coulson (1933), La Touche (1899), Blanford (1877), Gupta (1934) were some of the pioneer geologists who worked in Rajasthan prior to Indian Independence.

The Sirohi Group is the youngest of the three Precambrian orogenic metasedimentary/metavolcanic sequences in northwestern India, which along with granitoids and granite gneisses constitute the southwestern part of the Aravalli Mountain belt. The Neoproterozoic Sirohi orogeny (850 Ma) marks closure of compressional tectonic regime in the Aravalli craton. The beginning of Neoproterozoic marks one of the most dynamic periods in the history of the earth as it witnessed amalgamation of continental blocks to form the Rodinia Supercontinent at 1000 Ma and its later fragmentation at~ 750 Ma.

The Mordu-Khiwandi metasediments are part of Neoproterozoic Sirohi Group (1000-850 Ma, Sharma, 1996; Sharma, 2004, 2005, 2007, 2009). These forms isolated outcrops west of Sirnava hills in Sirohi region. It is part of the Aravalli Protocontinent which one among six protocontinents of the Indian Subcontinent. The crustal evolution and framing of the Indian Shield was primarily over by the Precambrian time and it was reframed many a time during the Post-Cambrian. The northwestern Indian shield also bears similar signatures of crustal developments spanning from 3300 Ma to 542 Ma. These include three orogenic activities (Aravalli, Delhi and Sirohi orogenies) which included many magmatic episodes. As a result of these orogenies Aravalli Mountain Range prominently came up dividing the northwestern shield from rest of the Indian subcontinent. The western part of the Aravalli Mountain Ranges mainly comprises Delhi Supergroup of rocks. These rocks are also constituents of the Sirohi region and form the basal units for the Sirohi Group of rocks.

The Mordu-Khiwandi study area lies in north of Sirohi, Rajasthan and located in the Survey of India Toposheet No. 45G/4 and 45G/3. The study area is situated in eastern and northern part of Sumerpur town. These forms linear outcrop south-west of the Aravalli Mountain Belt. The Mordu-Khwandi metasediments are part of Sirohi Group dominantly comprises shale sandstone-carbonate-carbon shale metasediments. Some of these metamorphic rocks were subjected to mylonitization and contact

metamorphism. The metasediments form outcrops in the Erinpura granitoid terrane. The metasediments are phyllite, quartzite, cacl-silicate and carbon phyllite. Sirohi region forms a significant part in the tectonic evolution of the northwestern Indian Shield.

A. Regional Geology

Geologically, the Sirohi district forms the southwestern extremity of the Delhi synclinorium. The eastern and the central part of the district is occupied by the metasediments of the Delhi Supergroup of Lower to Middle Proterozoic age. These are intruded by mafic and ultramafic rocks and granites of different ages i.e. Sendra-Ambaji Granite (840 m.y.), Erinpura Granite (735 m.y.) and Malani Igneous Suite of rocks (740 m.y. to 430 m.y.). The Delhi Supergroup is represented by the Kumbhalgarh , the Sirohi and the Sindreth Groups in decreasing order of antiquity.

In the trans-Aravalli region, three major litho-tectonic associations are present. These are granites belonging to the Erinpura Igneous Suite, the meta-sedimentary rocks grouped within the Sirohi Group and the volcanics of the Malani Igneous Suite.

Table-1: Startigraphic succession of rocks present in the Sirohi region (Sharma, 2004)

Malani Magmatism	Hypabyssal intrusion	Dhanta Porphyry and dolerite Dykes
	Plutonism	Mirpur Granite (Jalore Granite)
	Volcanism and associated sedimentary units	Angor conglomerate Arkose Volcanic silicic tuff Angor Rhyolite Basalt and pyroclasts Sindreth conglomerate
Angular Unconformity		
Sirohi Group	Balda granite Carbonaceous phyllite (local) Calc-silicates and marble Mica schist	
Basement Rocks	Granitoids, granitic gneiss, and meta gabbro	

The Sirohi Group of rocks occur in a broad belt in the central part of the district and comprise mainly phyllite and mica schist and also contain migmatite, gneiss, calc-gneiss, marble, quartzite etc. The Sindreth Group comprising conglomerate, quartzite, shale, phyllite, and basic flows occur in the area between Sindreth and northeast of Pandiv. The rocks of the Sirohi and the Sindreth Groups are intruded by the Erinpura Granite and the Malani Igneous Suite of rocks. The Erinpura Granite occur intermittently and occupy large area in the west under a veneer of aeolian sand. The granites are fine to very coarse-grained, massive to foliated and are commomly grey to pink in colour. The Malani magmatism commenced with a volcanic phase marked by felsic lava flows giving rise to tuff, rhyolite with ash beds and volcanic breccias.

B. Lithology

1) *Granite:* The granite that occurs extensively in and around the Sirohi Town, is the main country rock which surrounds the linear outcrops of the Sirohi Group metasediments. The basement granite of Mordu-Khiwandi region forms isolated hillocks, tors and basement plain covered by sand-soil. Three major types of granites are identified in the area on the basis of physical appearance and hand specimen mineralogy, from the area. First type of the granite is coarse to medium grained, gray coloured and gneissic foliation present. In coarse grained varieties, feldspar megacrysts occur as large oval or tabular shaped grains measuring over 5-6 cm along length in some cases (Plate 1A). These megacrysts set in a fine- grained matrix (biotite – quartz groundmass) and commonly occur parallel to the foliation. The clasts content is about 40% of the rock (Plate 1A). This granite is seen in well sections, at Khiwandi village and southeast of Khiwandi. The second type is fine grained granite**,** mainly intruded within first type of Granite and Carbonate rock across the trend. Xenoliths of Biotite schist also found in the fine grained granite.

The third variant is pegmatatic in character, containing feldspar, quartz, mica and tourmaline (Plate 1B) and it occurs as small bodies along the interface of porphyritic granite and carbonate rock exposed in the eastern part of Khiwandi.

Petrographically, the Granite of the study area is characterized by the presence of phenocryts of the both quartz and feldspar. The other important minerals in the rock are quartz, microcline, feldspar and biotite, muscovite, iron oxide, occurs as minor constituents. K – Feldspar grains are of variable sizes, K – Feldspar exhibits crosshatched twinning which is characteristic of microcline. Orthoclase grains generally untwinned are also present. Perthitic growth is very common in which fine veinlets of albite plagioclase replaces microcline. Some grains show myrmikitisation along margins. Plagioclase feldspar grains are fine to coarse grained, and are subhedral in shape. Lamellar twinning is characteristic feature.

Quartz grains are of variable shapes and sizes. Polygonal and serrated grains are quite common.

Biotite is the mafic mineral in the granites of the study area, which occurs in considerable amount. Most of the grains are prismatic in shape, aligned parallel to the direction of the foliation. Muscovite occurs as small flakes along with biotite.

Quartz and feldspar are the two most dominant minerals in this granitic rock. Quartz constitutes about 40% of the total rock whereas K-feldspar and plagioclase feldspar together make up about 40% of the volume. Total mica is about 15%; white iron oxides and other minerals is about 5% of the total volume. In some samples, higher value of mica may be the result of sericitisation of feldspar due to shearing. The geochemical analysis of 2 samples (HK-11 and HK-12) of this rock is presented in Table 1. It shows 71 – 74 % of silica, 6.81 – 10.74 % of ferric oxide, 6.61 – 6.89 % of aluminium oxide and 5 – 6.89 % of potassium oxide.

2) *Micaceous quartzite:* Micaceous quartzite is present in Mordu-Khiwandi area in form of low ridges running in NNE-SSW to E-W direction and dipping towards SE direction (Figure 2). Quartzite is yellowish brown, generally compact but becomes schistose at places, due to presence of thin micaceous layering. With increase in the proportion of the mica, quartzite grades into quart-muscovite schist. In NW to W and NE to East region of Khiwandi, micaceous quartzite, exhibiting bedding plane (S_0) and cleavage plane (S_1) almost parallel to each other and in North of Khiwandi region possessing cleavage plane (S_1) perpendicular to bedding plane (S_0). Boudinization of quartz veins occur due to stretching and shearing at some places (Plate 1C). Vein quartz in quartzite exhibiting perfect crystallization and forming geodes in North and NE area of Khiwandi village. This quartzite is foliated with 2 to 3 sets of joint. Petrographically, this quartzite is medium to fine grained and foliated. Mainly composed of quartz and fine grained biotite and muscovite. In thin sections, quartz grains are flattened, elongated, recrystallized, showing interlocking arrangement. Sericitization occurs along grain boundaries of quartz. Biotite and muscovite shows parallel arrangement in form of foliation and schistosity (Plate 1D). Mica flakes are replaced by secondary iron. Mylonitization is observed and grains become finer due to shearing effect. It is composed of 70 % of quartz, 25 % of biotite and muscovite, and 5 % of other minerals. The geochemical analysis of 3 samples (HK-8, HK-9 and HK-10) of this rock is presented in Table 1. It shows 76.61 – 80.90 % of SiO_2, 6.43 – 8.42 % of Fe_2O_3, 3.21 – 4.81 % of Al_2O_3 and 2 – 2.98 % of K_2O.

3) *Carbonate Rocks*: In the major part of the area, calcareous facies rocks occur as intercalated layers with biotite schist. It occurs as linear bands along the ridges of Kavar Pahar and on the flanks of Kaliya Pahar. In the areas where calcareous rocks occurs in contact with the granite, they grade laterally into marble and calc silicate bands due to the thermal effect of granite on these rocks. The carbonate unit shows variation in texture and lithology (see Figure 2). Dolomite inter-bedded with numerous thin layers of greenish black coloured biotite schist has been observed, whereas the dolomite is fine to medium grained, greyish to brownish white in color. On other two moderately higher ridges linear outcrops of calc – silicate occurs in the study area. Both outcrops are running in the NNE – SSW and E – W direction. The southern outcrop is approximately 18 km in length and with a maximum width of about 500 meters. It occurs associated with porphyry granite in SE and carbonaceous phyllite in NW (Plate-1F). on the other hand the northern outcrop is thinner than the southern outcrop, approximately 16 km in length with 150 meters width. Towards west side calc – silicate is intruded by numbers of dolerite dykes (Plate-2L), fine grained granitic body and pegmatite. In central part of the Khiwandi area, ultra mafic body is also intruded in calc – silicate rock. Occurrence of calcite mineralization at the contact of granite and calc – silicate, actinolite and tremolite occurs in northern outcrop. Calc-silicate rock is fine grained, yellowish to dark brown colored and occurs as banded form. Alternate silicate minerals and leucocratic minerals layers define the banding (Plate-1E). This banding is more prominent on the weathered surface of the rock. It displays characteristic deformational structures such as folds and small scale isoclinal fold. Bedding is observed in these rocks, it is identified due to color variations and differential weathering. Late stage quartz, calcite and iron rich veins are seen cross cutting the calc silicate rocks. Petrographically, the calc – silicate rock of the research area is medium to fine grained and weakly foliated. It is mainly composed of calcite and quartz and minorly of carbonaceous matter and iron oxide. Calcite and quartz grains have interlocking arrangement. The geochemical analysis of sample (HK-4) is presented in Table 1. It shows

47.06 % of SiO_2, 10.66 % of CaO, and 10.94 % of MgO.Massive dolomite occurs as a thin unit of 10-20 meters thick outcrop between Kavar Pahar and Kaliya Magra with a northeasterly trend. This rock is a fine grained, massive and hard, light bluish to grey colored rock**.** The litho unit shows typical elephant skin weathering and gives slow effervescence when cold dilute hydrochloric acid is poured on it. Bedding planes is identified by variation in color and differential weathering. Three sets of joint also observed in this rock. Petrographically, this dolomite appears medium to fine grained and foliated. It is composed essentially of calcite; quartz, carbonand iron oxide are present as accessory minerals. In thin section, calcite grains show 3 sets of cleavage, low relief, equigranular shape and interlocking arrangement (Plate 2G). Carbonaceous matter showing black color occurs in foliation plane. Actinolite radiating needles in carbonate rock of Khiwandi area (Plate 2H). The geochemical analysis of dolomite sample (HK-5) is presented in Table 1. It shows 63.06 % of calcium oxide, 14.94 % of magnesium oxide and 9.6 % of ferric oxide.Recrystallised limestone occurs as white marble bands around the hill at Khiwandi. In these places marble occurs interbanded with calc-silicates bands. Marble found in the area is grayish to white in colour, and is medium grained. Yet no body have to mine it out. In thin section, the rock shows medium to fine grained texture. It is mainly composed of calcite, having 3 sets of cleavage and low relief. Carbonaceous and sericite occurs in minor amount. Large calcite grains with irregular boundaries show xenoblastic texture and sericite grains occur in groundmass as well as in the calcite crystals. The geochemical analysis of sample (HK-7) is presented in Table 1. It shows 64.72 % of CaO, 15.05 % of SiO_2, 8.26 % of MgO. Towards east of Khiwandi area, northern outcrop of calc – silicate rock show huge amount of iron. The geochemical analysis of this rock sample (HK-6) is presented in Table 1. It shows 52.88 % of SiO_2, 21.52 % of CaO and 13.29 % of Fe_2O_3.

4) *Carbonaceous phyllite:* The carbonaceous phyllite present in Mordu – Khiwandi area is in the form of low ridges running in NNE – SSW to E – W direction and dipping towards SE to S direction (Figure 2). The carbonaceous phyllite is medium to fine grained, dark grayish to black colored foliated rock which soil fingers on rubbing. In Khiwandi region carbonaceous phyllite is associated with micaceous quartzite (Plate-2I) and calc – silicate rock. It is mainly composed of carbonaceous matter and siliceous matter. At some places, carbonaceous phyllite possesses yellowish color due to limonitic stains. Near Mordu and Khiwandi village, folded laminations and bedding are identifiable in carbonaceous phyllite due to color variation and differential weathering. Sub-radiating and irregular needles are present in carbonaceous phyllite. Epidote and pyrite occurs in carbonaceous phyllite, epidote occurs in cleavage plane and joint plane. Irregular and folded quartz veins are present in carbonaceous phyllite. Boudinization of quartz veins occurs due to shearing (Plate-2J). Carbonaceous phyllite three sets of joints and cross joints at right angle to each other. In thin section study, it shows medium to fine grained and foliated texture. Both carbonaceous matter and quartz occur in significant amount. Quartz grains are elongated and show equigranular texture. Carbonaceous matter occurs along the cleavage planes identifiable as black color bands. Euhedral crystals of andalusite occur in carbonaceous phyllite (Plate-2K). The geochemical analysis of 3 samples (HK-1, HK-2 and HK-3) of this rock is presented in Table 1. It shows 65.95 – 79.79 % of SiO_2, 3.67 – 8.29 % of Fe_2O_3, 4.26 – 13.02 % of Al_2O_3.

C. Dyke Rocks

There are a number of dykes, which are running in N-S and NNW-SSE direction. The dykes are almost parallel to each other.

1) *The dykes belong to three categories*

a) *Feldspar porphyry dykes :* These are light pink to grey coloured characterised by the presence of feldspars phenocrysts in fine grained ground mass. Rocks consist of plagioclase feldspar, orthoclase and quartz as essential minerals. Chlorite and calcite occur as secondary minerals. These dykes vary in thickness from 2 to 10 mts. The maximum length is approximately 250-300 meters.

b) *Quartz porphyry dyke:* It is a greenish looking fine grained rock, showing phenocrysts of quartz. The silica percentage is higher in these rocks, which gives compactness. The dyke intrudes the Carbonate rock.

c) *Dolerite dyke :* hese are of smaller dimensions as compared to the porphyry dykes. These are fine to medium grained composed of augite, hornblende, plagioclase as major constituents, occur parallel to the feldspar porphyry dykes. Biotite and opaque minerals occur as accessory minerals.

II. CONCLUSION

The granitic gneisses form the basement and the cover rocks are the metasediments of the Sirohi Group in the study area. Granitic gneisses exhibit a sharp contact with Mordu-Khiwandi metasediments. Granite forms isolated hillocks, tors and plain are covered by sand-soil. The Mordu – Khiwandi metasediments comprise dominantly of carbonates, carbonaceous phyllite and micaceous quartzite. Carbonates in the area are grading into calc-silicate rocks. The rocks of study area are characterized by shearing and

folding. Numbers of younger dykes of feldspar porphyry, quartz porphyry and dolerite are intruded in metasediments. Post tectonic quartz, pegmatite, calcite and iron veins in metasediments. Detailed geological and structural studies of these metasediments along with petrology and field relation suggest that it belongs the Sirohi Group (Sharma, 1999).

Table – 1: Geochemical analysis of Mordu – Khiwandi metasediments.

Metal Oxides	HK-1	HK-2	HK-3	HK-4	HK-5	HK-6	HK-7	HK-8	HK-9	HK-10	HK-11	HK-12
SiO_2	79.796	76.28	65.954	47.061	6.885	52.883	15.058	79.616	76.097	80.908	74.049	71
Al_2O_3	4.26	7.299	13.022	4.098	1.21	0.601	1.55	4.812	3.215	4.318	6.897	6.617
Fe_2O_3	8.292	4.225	3.678	21.713	9.672	13.292	6.662	6.435	8.424	7.028	6.818	10.743
MgO	0.469	0.269	0.382	10.94	14.943	7.65	8.261	0.877	2.197	1.113	0.327	0.797
CaO	0.637	0.862	0.241	10.669	63.069	21.529	64.726	1.741	5.34	1.288	1.36	2.039
Na_2O		0.163	0.227	0.164	0.148		0.185	0.133		0	1.13	0.777
K_2O	2.597	4.521	7.939	0.196	0.172	0.209	0.626	2.982	2.088	2.144	6.89	5.001
TiO_2	0.462	0.951	1.517	1.143	0.386	0.116	0.331	0.72	0.472	0.526	0.62	0.823
P_2O_5	0.183	0.46	0.121							0.151		0.118
MnO	0.147			0.503	0.798	0.319	0.326		0.102			0.183
SO_3	1.336	1.76	2.922	1.082	1.08	1.003	0.871	1.067	0.885	0.784	0.746	0.837
CuO												
Rb_2O		0.116	0.136								0.188	0.182
SrO					0.104	0.154	0.165					
Y_2O_3												
ZrO_2			0.119					0.157			0.186	0.113
RuO_2		0.425	0.321	0.38	0.724	0.419	0.705	0.681	0.112	0.261		
Sb_2O_3	0.204		0.157	0.103					0.331			
BaO			0.105									
Cr_2O_3	0.663	0.232	0.211	0.578	0.205	0.751		0.254	0.23	0.212	0.172	0.147
PbO	0.139	0.173										
V_2O_5	0.152	1.469	2.349									
As_2O_3		0.171										
NiO				0.842		0.577						
CeO_2												0.19

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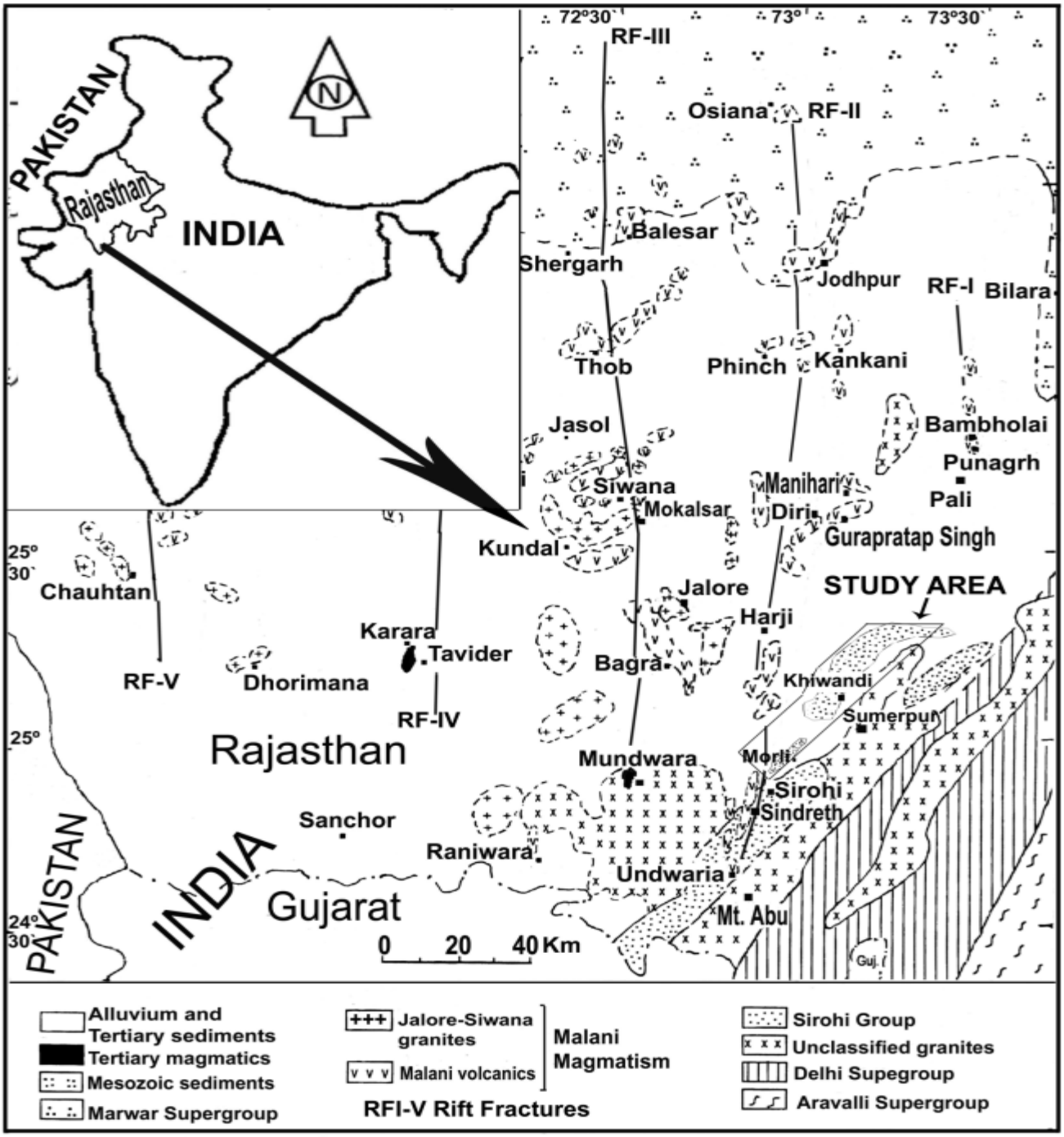

Figure – 1 Generalized map of west of Aravalli Mountain (After Sharma, 2005)

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Figure 2: Geological Map of Mordu – Khiwandi Area

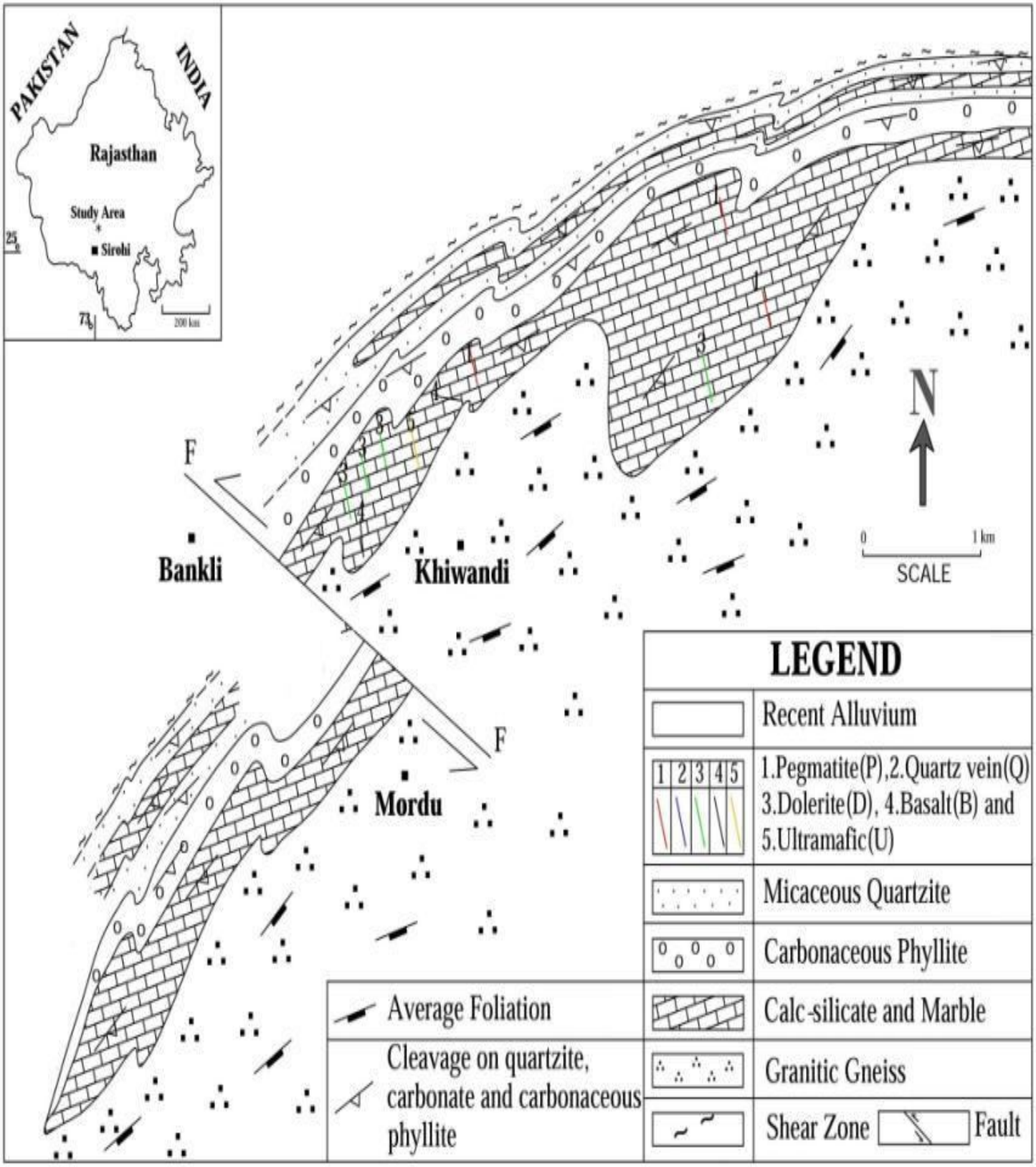

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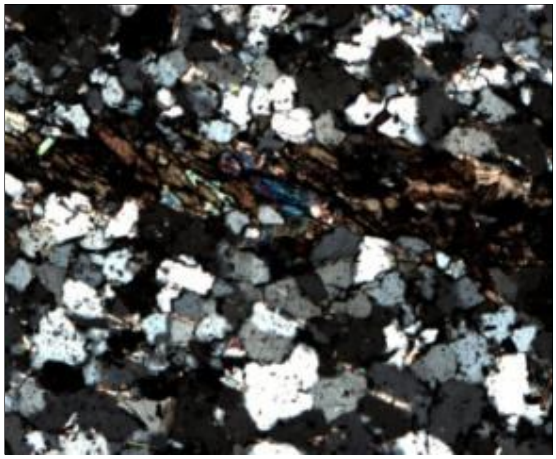
Plate – 1

A: Photograph showing large oval and tabular shaped megacryst of K-feldspar in fine matrix (Granitic rock).

B: Photograph showing pegmatite body (a variety of granite) in eastern part of Khiwandi area.

C: Photograph showing vertical early cleavage (S_1) with across sheared quartz veins in micaceous quartzite, exhibiting boudinization.



D: Photomicrograph showing parallel alignment of biotite and muscovite forming schistosity in quartzite. Note the sericitization in the middle across the photograph.

E: Bedding plane is visible by variation in colour, differential weathering and the presence of thin quartz rich layers in carbonate rock near Khiwandi area.

F: Photograph showing contact between granite (Gr) and carbonate rock (CR), in south of Khiwandi area.

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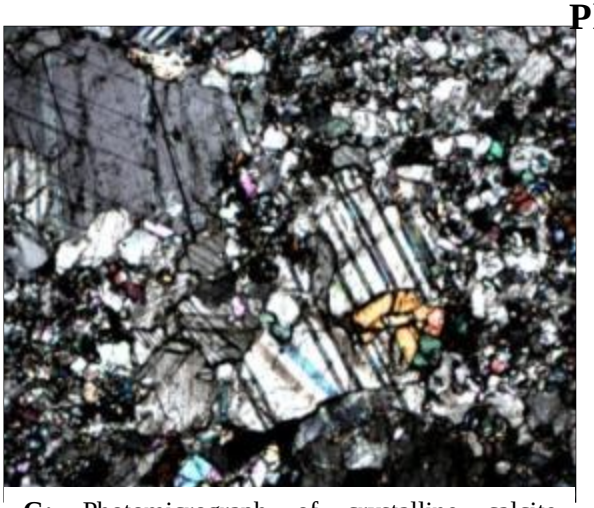
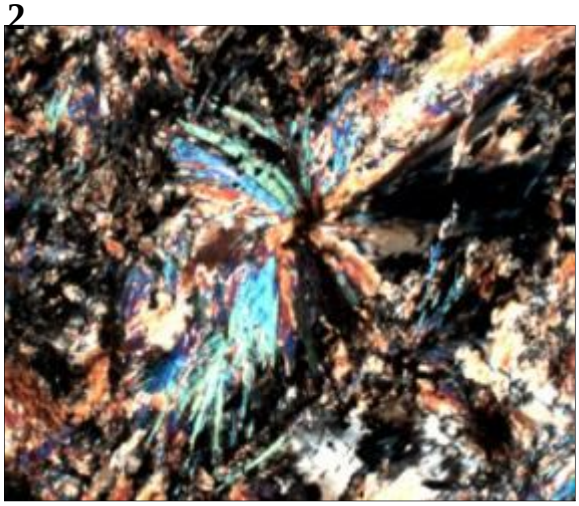
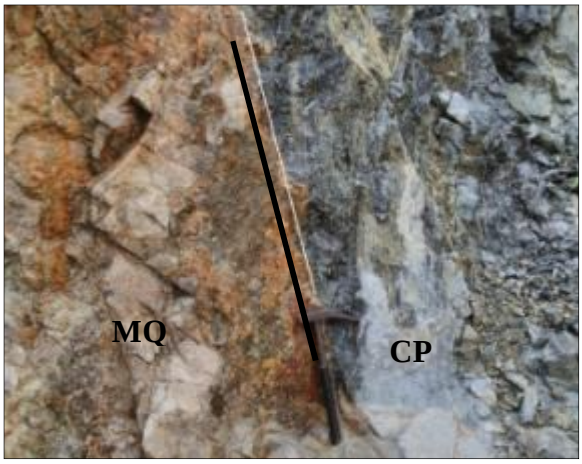
Plate – 2



G: Photomicrograph of crystalline calcite exhibiting two sets cleavage and twinkling nature (Khiwandi area).

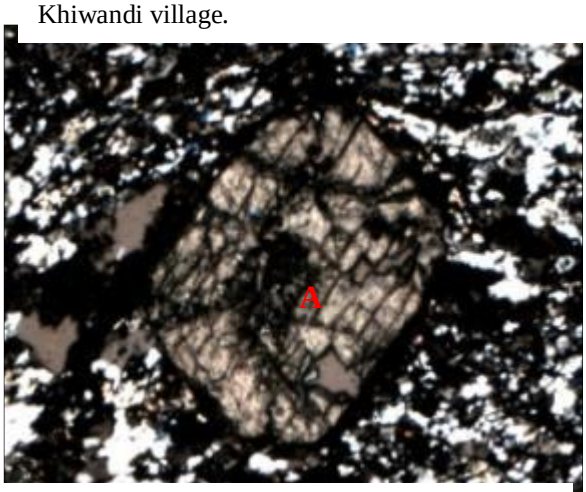


H: Photomicrograph of Actinolite radiating needles in carbonate rock of Khiwandi area.

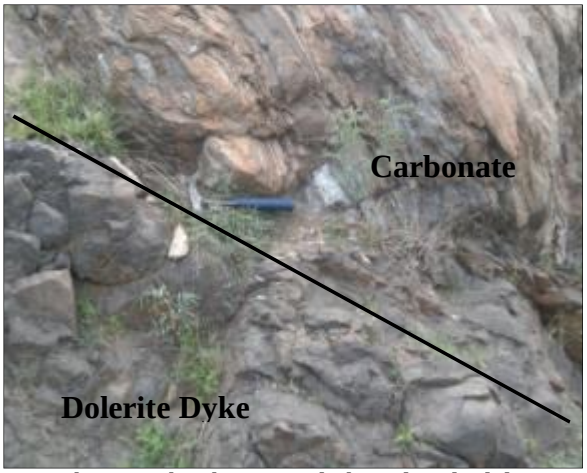


I: Field photograph exhibiting the contact between carbonaceous phyllite (CP) and micaceous quartzite (MQ), observed near Khiwandi village.

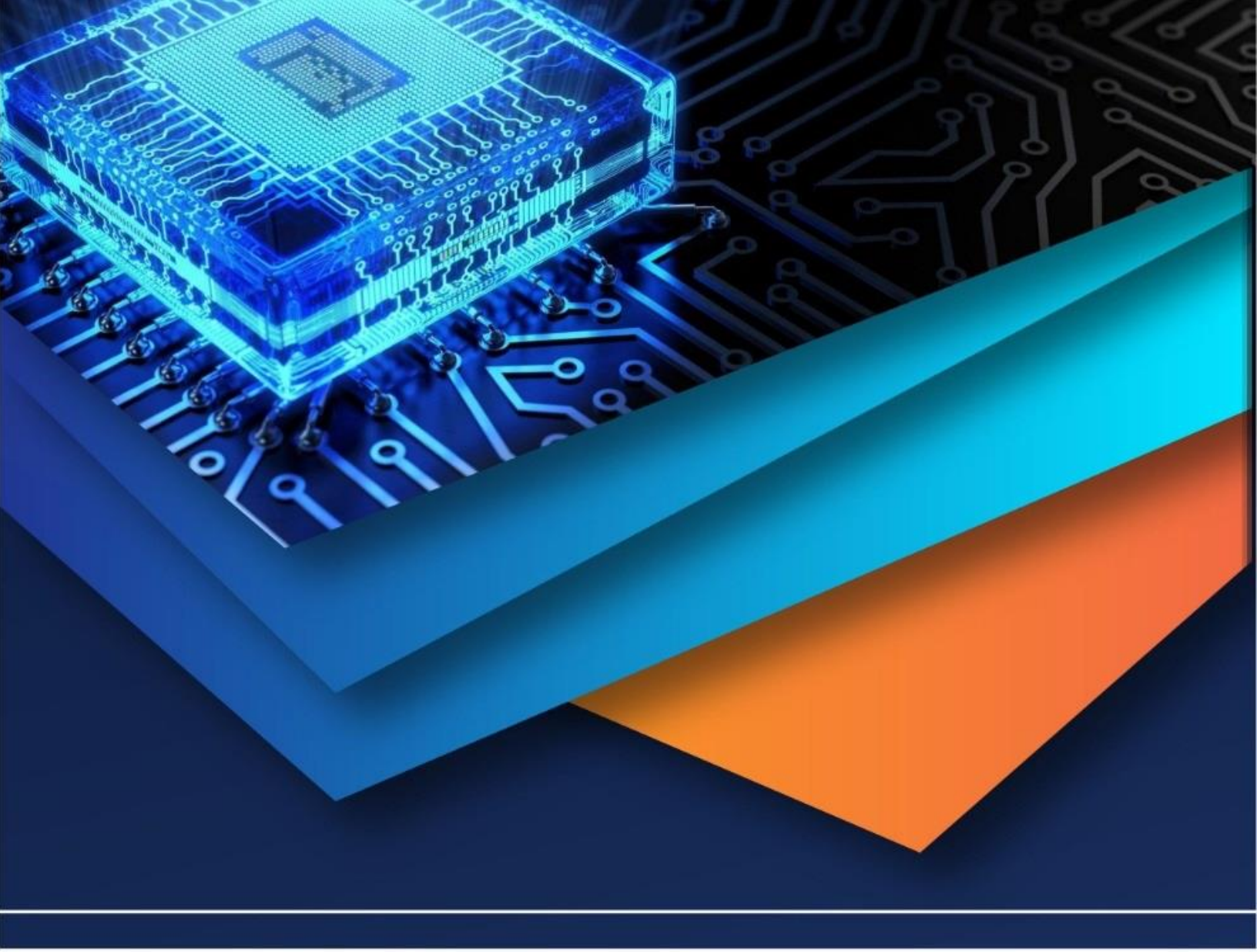
J: Boudins of quartz in carbonaceous phyllite, formed due to shearing, observed near Mordu village.



K: Photomicrograph showing euhedral crystal of Andalusite (A) in fine grained carbonaceous phyllite.



L: Photograph showing dark colored dolerite dyke, intruded in Carbonate rock, observed near Khiwandi Village.



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