Volume 67, Issue 1, 2023
Journal of Scientific Research
of
The Banaras Hindu University

Geologic control on Geomorphology-A case study from the Pindwara region of southwestern Rajasthan

Bhawna Joshi*, Harsh Bhu, and RiteshPurohit

Department of Geology, MohanlalSukhadia University, Udaipur,Rajasthan, India.
geologistbhawna1992@gmail.com*, harsh_bhu2003@yahoo.com, riteshpurohit72@gmail.com

Abstract: **The Delhi Supergroup rocksarean important tectonostratigraphic unit of the Aravalli Mountain Belt which is divided into North Delhi Terrane (NDT) and South Delhi Terrane (SDT). The area of study lies in the southwestern part of SDT, and the rocks exposed are granitic gneiss, quartzite, marble, calc-silicate, and amphibolite's which are intruded by granite, dolerite,pegmatite, quartz, and calcite veins. The granitic gneiss occurs as a basement over which younger meta-sedimentslie. Three generations of deformation are present in the area. The Pindwara region forms a sub-peneplain terrane with the granite, metavolcanic, arenaceous metasediments and calc-metasediments,outcropping as linear bands of marble in the west and a large granitic massif in contact with calcsilicate in the east.Therocks around Pindwara are metamorphosed from upper greenschist to lower amphibolite facies. Geomorphic units in the area are high rising steep slope hills, dissected hills, flat topography, linear low-lying hills, residual hills, and V-shaped valleys.The research objective is to determine the relationship between drainage patterns,geomorphic landforms,lithology, and structural pattern in the study area using geomorphological and geological analysis.The result of the study concludes that the geomorphic landforms and drainage of the area are controlled by the lithology and deformational feature.**

Index Terms: **Delhi Supergroup, South Delhi Terrane, Kumbhalgarh Group, Mesoproterozoic, Geomorphic landforms, Drainage pattern, Lithology, Structural pattern.**

I. INTRODUCTION

The Mesoproterozoic Delhi Supergroup (DSG) which unconformably overlies the AravalliSupergroup (ASG) of paleo-Proterozoic has been dated between 1800 and1000 Ma (Pandit *et al*. 2003, 2011; Singh *et al*. 2010).The Delhi Supergroup (DSG) is divided into two major terranes in terms of their variation in litho-assemblage,depositionalenvironment,geochronology,deformational pattern, and grade of metamorphism into older North Delhi Terrane (NDT) and younger South Delhi Terrane (SDT) (Crawford 1970; Chowdhury et al. 1984; Sinha-Roy 1984; Volpe and Macdougall 1990; Tobisch et al. 1994; Deb M. 2001; Pandit 2010; Singh et al. 2010; Just et al. 2011; Chatterjee et al. 2020).The South Delhi Terrane (SDT) exists as a linear belt along the western fringe of the Aravalli Mobile Belt (Heron, 1953; Sen, 1981), and comprises extensive mafic volcanism and local felsic volcanism, argillaceous-arenaceous-carbonate accumulation deposited in shallow-marine to deeper water condition (Deb, and Sarkar 1990).

The rocks of NDT are early Mesoproterozoic in age (1700-1400 Ma) whereas the rocks of SDT are late Mesoproterozoic (1200-1000 Ma) (Mahadani et al., 2013). Gupta et al., (1980) classified the rocks of SDT into two groups i.e., Lower Gogunda andUpperKumbhalgarh Group where the lower group is dominantly arenaceous, and the upper group is predominantly calcareous(Fig1). The study area consists oflithounits of Todgarh formation of the Kumbhalgarh Group.

The major trend ofrocks of the Delhi Supergroup (DSG)is NE-SW. To study the impact of lithology and deformation on the formation of geomorphic landforms and drainage pattern, an area surrounding Pindwara region (in Sirohi district) and covering parts of the Sirohi, Udaipur, and Pali districts was selected for preliminary observations for drainage patterns. The study area mostlyexperiences apartially sub-humid climate with an average annual rainfall of around 613mm mostly during months of late June to mid-September.Themonthly temperature varies from a maximum of 32.4°C to a minimum of 19.5°C(Upadhyay et al.2019).

The Pindwara region forms the southwestern part of the South Delhi Terrane (SDT). The eastern half of the area is manifested bythe sharp rising hill of granite, which is in contact with calc-

*geologistbhawna1992@gmail.com

DOI:10.37398/JSR.2023.670103

silicate, the western part consists of low-lying ridges of granite, metavolcanic and calc-metasediments with bands of marble.

Landscape and drainage patterns present in the area are the result of the local climate of the area, underlying rock structure, and slope of the land.Pindwara region consists ofsub-rounded, annular, and jagged landforms (CGWD,2013).

Granite hills are numerous in Pali and Sirohi Districts also, where the hill slopes exhibit exfoliation and cavernous weathering features (Kar, 1995).

II GEOLOGY OF THE STUDY AREA

The study area belongs to the Kumbhalgarh group of South Delhi Terrane where the eastern part of the study belongs to theTodgarh Formation and the western part shows rocks of the BasantgarhFormation (Fig. 1).

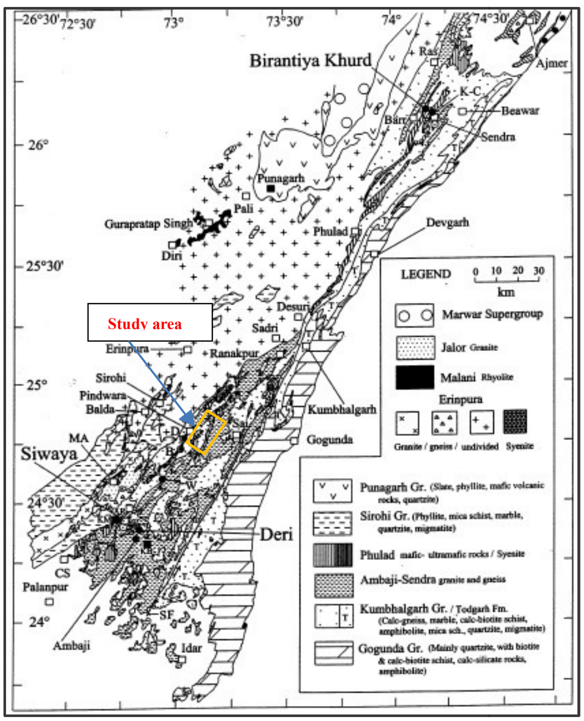

Fig. 1.Geological map of SDT (simplified from Gupta et al., 1997). AR-Abu Road; B-Basantgarh; CS-Chitrasani; D-Danva; KB-Kumbariya; K-C-Kalabar-Chitar; KM-KheraMawal; MA- Mount Abu; S-F- Sabarmati Fault; W-Watera.

The rocks of the SDT are characterized by greenschist to amphibolite facies metamorphism and multiple stage folding (Roy et al., 1985). The rocks type exposed in the Pindwaraarea includes granite schist and gneiss, migmatite, amphibolite, granulite, calc-silicate, marble, biotite schist, and quartzite. These are seen to be traversed by pegmatite and quartz veins. The calcite marble shows gradational variation from calc schist and calc gneiss along the strike of the area. Biotite schist occupies the valleys and plainsand ismostly exposed in the Nala cuttings.

Theintrusive granite isyounger than Calc-gneiss, Calcitic marble, Biotite-schist, Amphibolite and Quartzite, and ductile deformation often marks boundaries between them.The older lithological unit are showing imprints of varying degrees of deformation.

III. METHODOLOGY

An automatic extraction technique has been used for the extraction of drainage/ stream data fromthe study area. Carto-DEM (Digital Elevation Model) downloaded from the BHUVAN portal was used for the purpose. The DEM was overlain on the LANDSAT-7 satellite imagery. The extracted basin and stream networks are projected to the regional projection (WSG 1984, UTM Zone 44N) using ArcGIS software. Rose diagrams of the structural data like bedding, foliation, and joint planes are prepared using GeoRosesoftware. Fresh representative and oriented rock samples were collected for thin section study under the microscope in the laboratory.

IV. GEOMORPHICVARIATIONS IN THE STUDY AREA

Morphologically the area is characterized by the undulating topography in the west, hilly in the north and east, pediments exposed along the hill slopes, and the flat land area in the central part. Alluvial plains lie along the west Banas and Jawai Rivers. The highest elevation in the area is 900m above mean sea Level. The main drainage river of the area isWest Banas and Jawai River.

A. Landforms

As a result of the geomorphic operations under the semi-arid condition on a diverse group of rocks, the area has acquired a rugged topography. The Digital Elevation Model depicts the three-dimensional shape of the area which reveals the sharp high rising ridges and maximum positive relief present in the eastern part of the area (Fig. 2a).Thegeomorphicfeaturespresent in the area are classified into different classes (Fig. 2b). The geomorphic variations are linear following the trends of the lithologies.Thehigh-rising topography consists of dissected hills and valleys with quartzite and calc-silicate and the low-lyingpeneplain topography is occupied by granite gneiss.

Hills are classified as Dissected in granitenear Kyari, Malera and Nislakhera village, Linearin calcsilicate, marble and quartzitenear Ajari, Basantgarh, Kotalvillage, and Isolated hills of graniticgneiss, near Kundal,Thandiberi village.

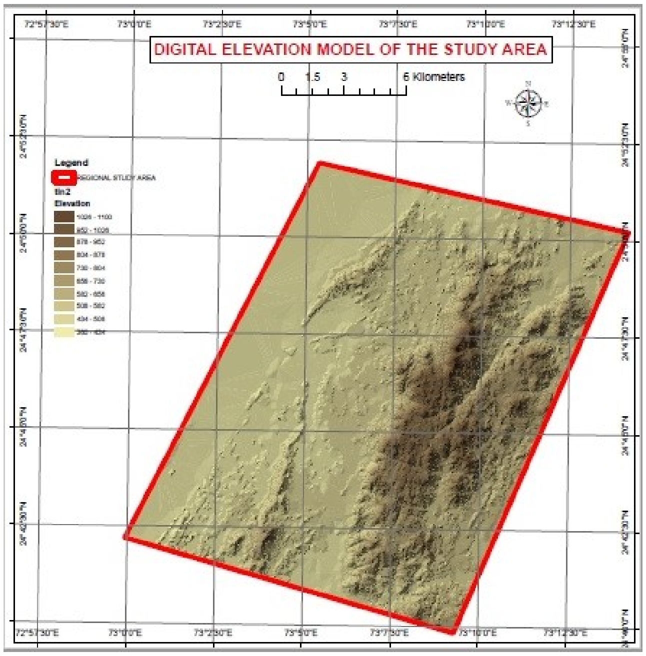

Fig. 2a. Map showing the Digital Elevation Model of the Pindwaraarea.

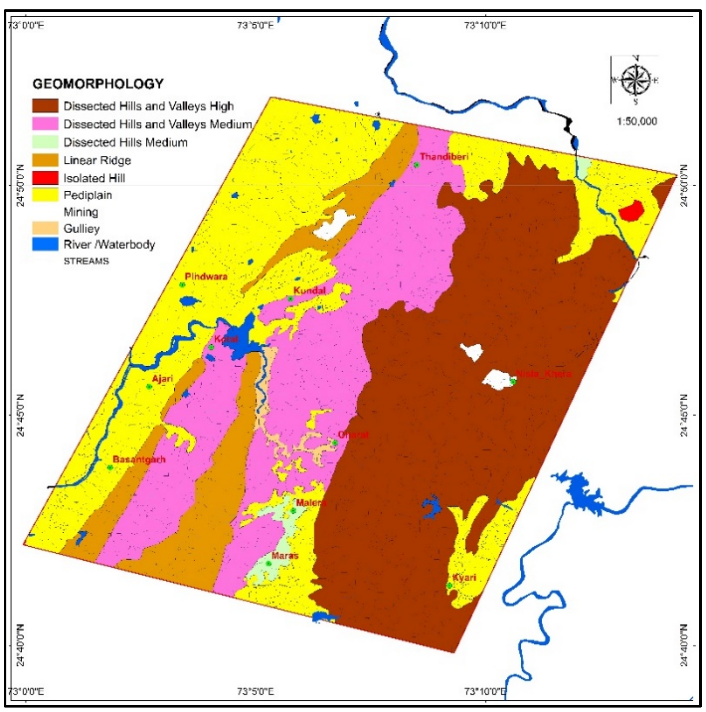

Fig. 2b. Map showing various geomorphic features in the Pindwara area.

B. Drainage

The southwestern (SW) part of the area is mainly drained by West Banas, DivrotNadi, and northeastern (NE) drained by Jawai.which are nourished by a few tributaries from the adjacent hillocks.The West Banas Rivermerges near Pindwaraand flows in the southwest direction from its origin and the drainage length of the West Banas in the study area is 17km.The Jawai River is the longest and largest riverthatjoinsthe Luni River, andit is the main river in the northern part. Jawai River extends for a 9 km drainage length in the study area (Fig 3a). The major drainage trend of these rivers is NNE – SSW, a direction that is parallel to the regional strike of the outcrop. In the northeastern (NE) part of the area tributaries of the Jawai River drain the area which trends in the NW-SE direction. In NW and SE parts of the area the Kalumbri dam and CheeniyaBandh store a considerable amount of water in a reservoir (Fig. 3b).

The trend of high-order streams is litho-contact controlled and runs parallel to the strike of the ridges. Low-order streams are fracture controlled and are usually perpendicular to the regional outcrop strike (Fig 4). Thus, generating different types of drainage patterns like Rectangular, Deranged, Dendritic, Trellis, and Radial. These are correlated with the lithologies in the area in (Table I) (Fig 4 and 5).

Table I. Drainage pattern in thearea

S.No	Drainage Pattern	Lithology
1.	Rectangular Pattern	High-rising carbonate and quartzite
2.	Deranged Pattern	Calc- metasediments
3.	Dendritic Pattern	Parallel ridges of carbonate
4.	Trellis Pattern	Granite, Calc-silicate
5.	Radial Pattern	Granite and Quartzite

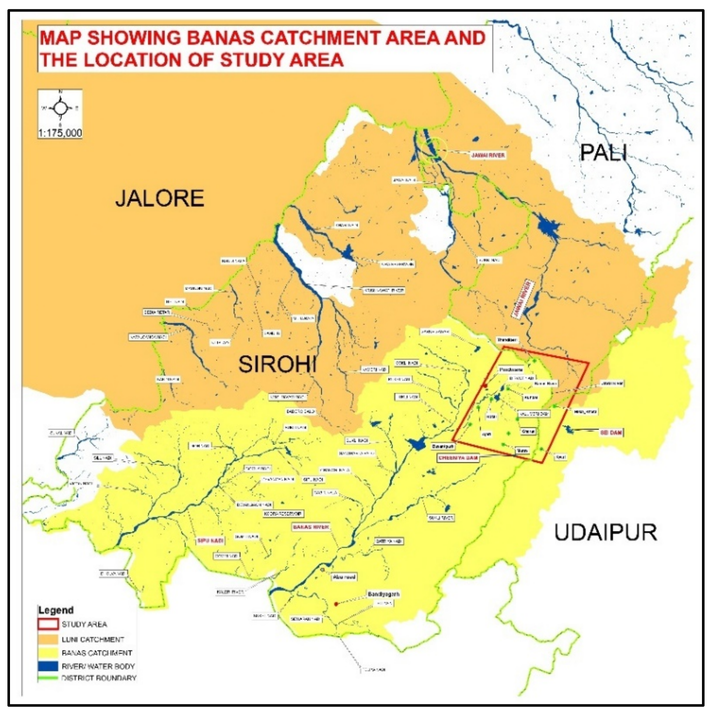

Fig. 3a. Map showing different watersheds present in the Pindwara area.

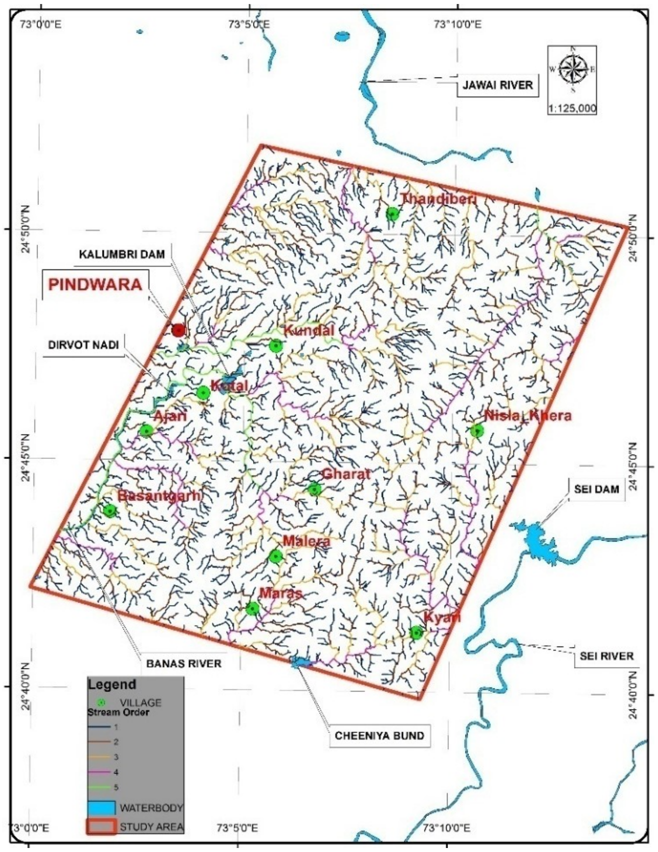

Fig. 3b. Map showing main rivers and their drainage pattern in the Pindwara area

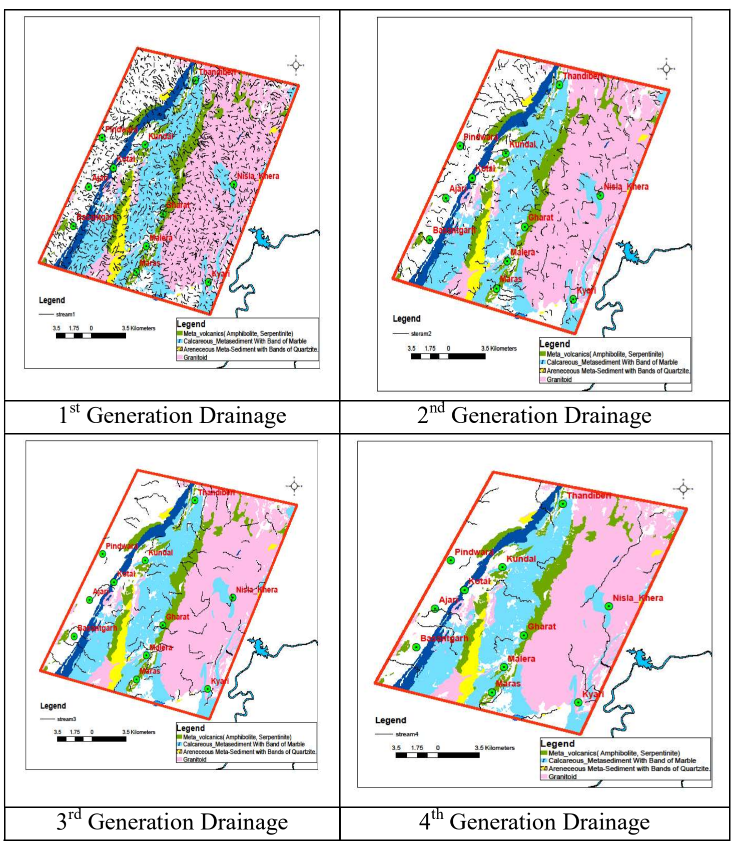

Fig 4. Different generations of drainage in the Pindwara area.

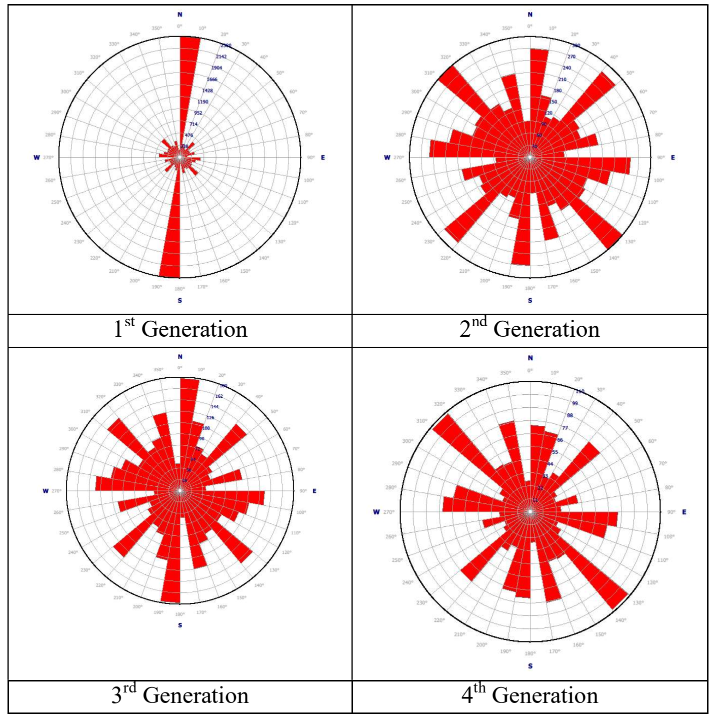

Fig. 5. Rose diagram of drainage showingfour generations of streams of the Pindwara area.

V. Lithological And Petrological Variation In The Study Area

The lithology present in the study area is Granitoid (granitic gneiss and granite), Arenaceous metasediments with bands of quartzite, calcareous metasediments with bands of marble, and metavolcanics (amphibolite,serpentinite, and chlorite schist) (Fig. 6).The thin section study has been done to understand the rheological nature of the rock type present in the area which is affected by the structural planes in the rocksfor example the granite gneisses are more susceptible for weathering compared to massive granites. The secondary structures and the microstructures present in the rocks makes them more prone for directional weathering i.e., ease in formation of drainage.

A. Granitic Gneiss

It is dark grey and is the most prominent lithology in the area. It occurs in a low-lying area in contact with calc-metasediments.The granitic gneiss is present on low-lying peneplain topography and granite occurs as a high-rising ridge. The peneplain topography is covered by a vast field of agricultural land. Insome places, massive non-foliated granite is gradually transforming to the foliated gneissic character.Granitic gneiss also occurs as a banded texturewhere alternate bands of light and dark color mineral (Fig.7a).

In thin sections, grains are elongated due to shearing, myrmekitic or wormy texture, a strain feature is formed as an intergrowth of quartz and K-feldspar crystal which are most common in granites (Fig. 7b), myrmekitic intergrowth is inferred to as metamorphic event occurring post-dating emplacement.

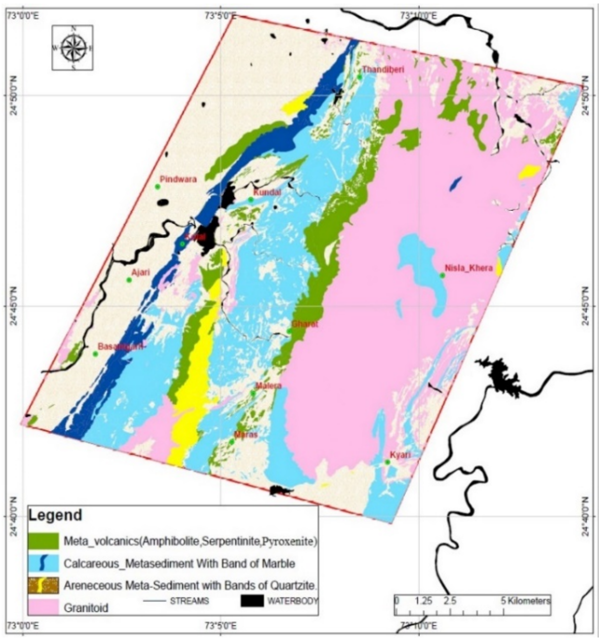

Fig. 6 Map showing the regional geology of the Pindwara area

Fig. 7 (a). Field photographs showing alternate bandsof felsic and maficminerals in Granitic Gneissnear Moras village

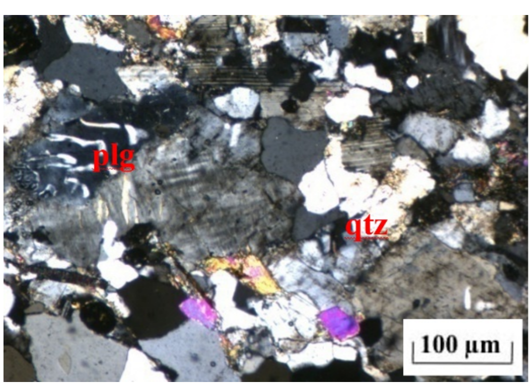

Fig.7 (b) Photomicrograph showing myrmekitic texturein Granite near NE of Moras village(Qt-Quartz, Plg-Plagioclase).

B. Quartzite

Foliated and massive quartzite are observednear villagesMoras and Malera. They are brownish grey to whitish pink to pinkish brown in color due to the variable amount of iron oxide in them. They are hard, compact, massive to bedded, and occasionally foliated or sheared, occurring as an isolated linear outcropwithin schistose meta-sediments. Joints are common in them (Fig.8a). Under thin sections, rounded to elongated grains of quartz show undulate boundaries. The mineral constituents in them are quartz and feldspar where feldspar grains show cross-hatched twinning. Polycrystalline quartz aggregates and subgrain formation are indicative of recrystallization. In foliated quartzite, quartz grains are elongated and aligned along foliation planes (Fig. 8b).

Fig. 8 (a). Field photographs show grey quartzitewith 3 sets of joints near east of Kotalvillage

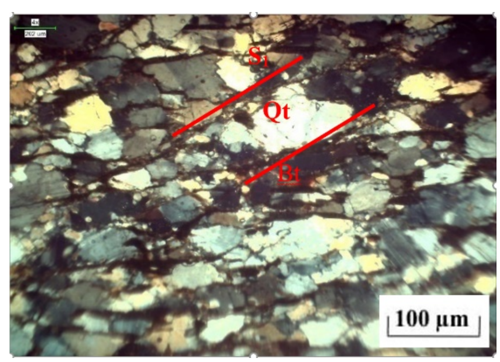

Fig.8 (b)Photomicrograph showing recrystallizedgrains of quartz and platy biotite mineral along the foliationnear east of Kotal village (Qt-Quartz Bt- Biotite, S_1-Foliation plane).

C. Calc-silicate

The calc silicatesoccur as massive, banded rock containing linear bands of marble near the Kyari,Ajari, and Basantgarh areas. It is dark to light grey to white representing calcareous and siliceous beds (Fig. 9a). Under thin sections,calcite and quartzare the main constituents of calc-silicates. Quartz grains are elongated and aligned parallel to the bedding/ foliation plane. The interlocking arrangement is between quartz and calcite, with irregular boundaries showing recrystallization(Fig.9b).

Fig. 9 (a). Field photographs show dark to light greyto off-white calcareous and siliceous beds near Kyari village

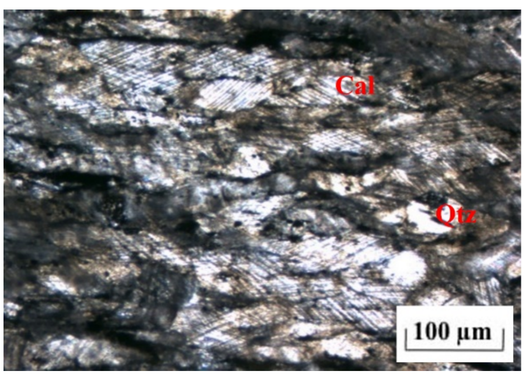

Fig. 9 (b). Photomicrograph showing the interlocking mosaic texture ofquartz and calcite; irregular grain boundaries are due to recrystallization near Kyari village. (Cal-calcite, Qtz-quartz) (under X Nicols).

D. Pyroxenite

Pyroxenite isa dark greenish to blackcoloredrock, very coarse-grained, massive,and dominated by the needle-shaped crystal of pyroxene.Theirfresh surface is dark green whereas the weathered surfaces have a pale brownish color (Fig. 10a).It occurs as massive outcrops along Ajari, Bansantgarh, and Kundalareas.Under thin section,pyroxene is the main constituent followed by plagioclase feldspar.

Larger crystals of pyroxene are present with some accessory minerals (Fig. 10b).Olivine is less than 10% in the rock.

Fig. 10 (a). Field photographs show a dark-greenish shining surface of pyroxenite near north of Kundal village

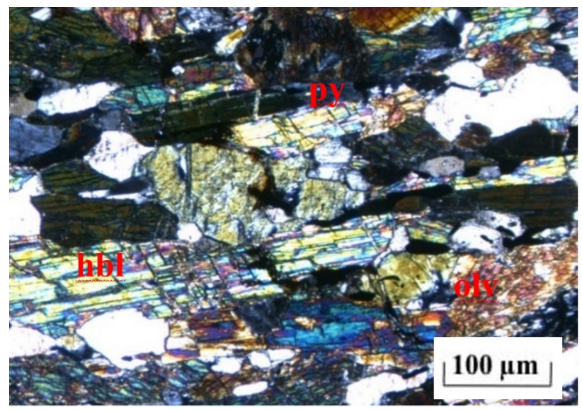

Fig. 10 (b). Photomicrograph showing laths ofpyroxene near north of kundal village. (Olv-olivine, Py-pyroxene, Hbl-Hornblende) (under X Nicols).

VI. STRUCTURAL FEATURES PRESENT IN THE STUDY AREA

A. Bedding

The bedding is the most prominent structural feature present in the area. The beds are indifferent shades of grey and light brown,and range in thickness from 1to 2cmand are seen in quartzite and carbonates.

The bedding plane is recognized as S_0 for meta-sedimentary rocks and generallytrends inthe NE-SW direction. The penetrative bedding parallel cleavage (S_0llS_1) is also the dominating structural feature in the area(Fig. 11), except at the hinge zone where $S_0$is perpendicular to S_1. The orientation of S_0 plane in the rose diagram is NE-SW direction (Fig 12). The dip of the bedding plane is 20^0-30^0.

Fig. 11 Field photograph showing thick and thin beds on the marble near Ajarivillage. (S_0- Bedding plane).

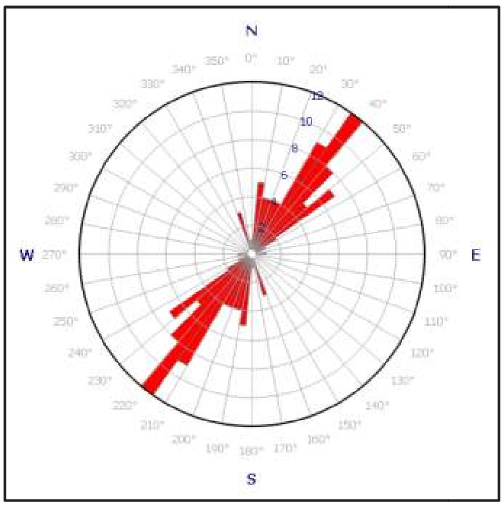

Fig. 12. Rose diagram of bedding plane showing dominant orientation in NE-SW direction.

B. Foliation

The term Foliation has been used for the nature of fissility, weak planes along which rock split. It is a dominant planar feature in gneiss, schists, and mafics in the area. It is formed by recrystallization and parallel realignment of mineral grain during metamorphism. A general trend of foliation is inthe NE-SWdirection, also seen in the rose diagram (Fig. 13). Foliation (S_1) is observed parallel to bedding(S_0) i.e. (S_0//S_1).

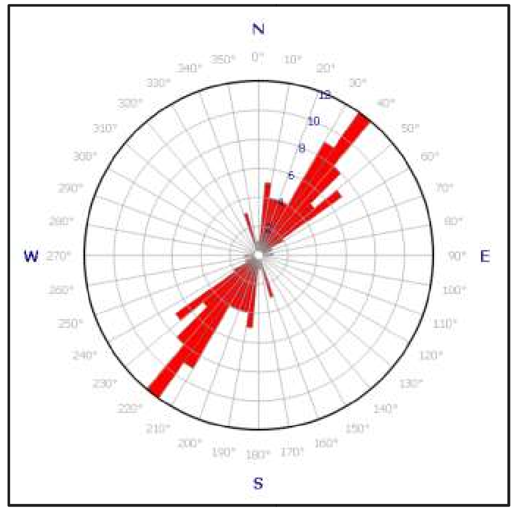

Fig. 13. Rose diagram of foliation plane showing dominant orientation in NE-SW direction

C. Joints

Irregularly spaced planar features resulting from brittle deformation of rock are termed Joints. Two sets of prominent joints are seen in quartzite. One set is parallel to beds and the others are at angles to it(Fig. 14). Rose diagram of the joint planes are showing different orientations whereJ_1 are NE-SW (Fig. 15a), and J_2 are NW-SE (Fig.15b).Penetrative joints are result into the formation of dissected hills and valley type of landforms.General attitude of J_1(50^0-60^0/40^0-50^0 -SE), J_2 (110^0-120^0/55^0-65^0 -SW) in the area.

Fig. 14. Fieldphotograph showing two sets of joints planein quartzite (J_1-NE-SW trending, J_2- NW-SE trending), near Moras village

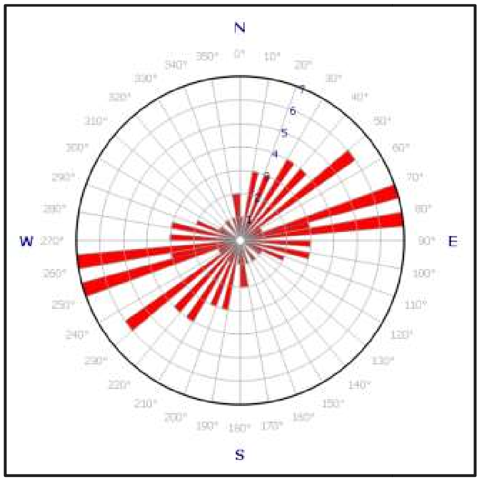

Fig. 15a. Rose diagram of Joint plane (J_1) showing dominantorientation in NE-SW direction.

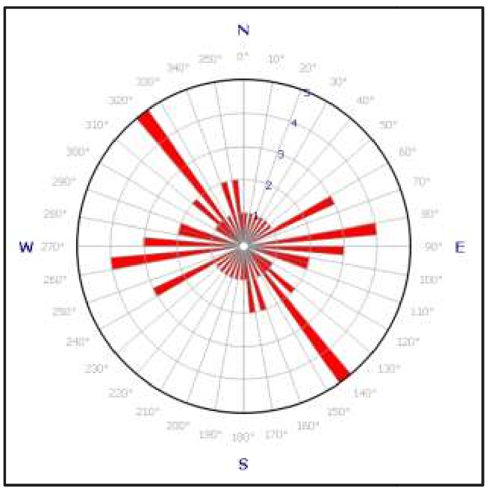

Fig. 15b. Rose diagram of the joint plane (J_2) showingdominant orientation in NW-SE direction.

D. Fault

Faults are displacements of blocks and the zonebetween the blocks along which significant displacement has occurred is known as the fault plane. Small-scale micro-faults are observed near Kyari villagewithin the calcsilicate rock (Fig 16).

Fig. 16 Field photograph showing reverse fault inthe calc-silicate rocknear north of Kyari village.

A. Shear Zone

A thick shear zone is observed locally in the western part of the study area.The shearing is along the NE-SW direction. Shear zone are the sites for intense weatheringwhich result into hills and valley type of landforms. The shear zone is marked by the ductile deformation within amphibolite, carbonate, and granite. The ductile shear features are represented byboudins near Thandiberi. (Fig 17), rotation of porphyroblasts (Fig 18) and mylonitized zones (Fig 19).

Fig. 17 Field photograph showing boudins of granitein calc-silicate rock near Thandiberi village

Fig. 18. Fieldphotograph showing dextral rotation of porphyroblastsin calc-silicate rock near South of Thandiberi village.

Fig. 19Field photograph showing mylonitic foliationdeveloped in sheared amphibolite near Gharat village.

F. Fold

Three generations of folds (DF_1, DF_2, and DF_3) differing from each other in style and orientation are preserved. The first generation DF_1 fold is tight to isoclinal, mostly recumbent/reclined fold with NE-SW trending hinge line (Fig20) resulting in bedding (S_0) parallel to foliation (S_1).The second-generation DF_2 foldsare asymmetrical open upright folds with NNE-SSW trending hinge lines with sub-horizontal to gently plunging fold axisand are easily observed in almost all the litho-unit (Fig21). The third generation (DF_3) fold exists as an upright sharp-hinged fold(Chevron fold) with NW-SE trending axial plane(Fig22).

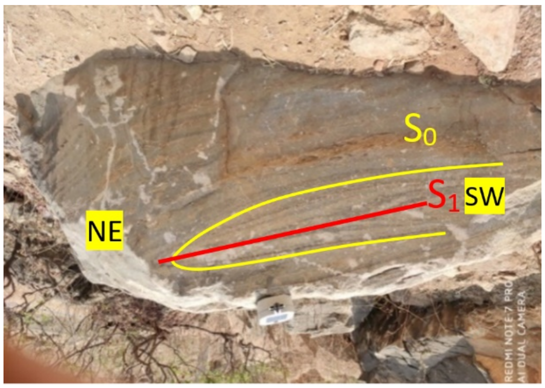

Fig. 20. Fieldphotograph showing isoclinal fold (DF_1) generation in Calcsilicate rock nearnorth of Kundal village.

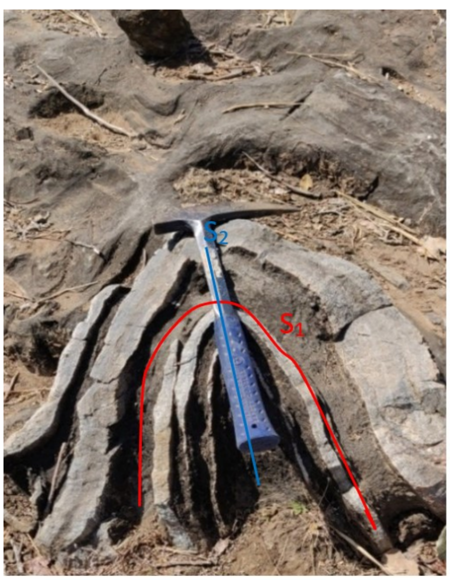

Fig. 21. Field photograph showing upright fold (DF_2) generation in calc-silicate rock near north of Kyari village.

Fig. 22 Field photograph showing sharp hinged fold(Chevron fold) (DF_3) generation in calc-silicate near Malera village

VI DISCUSSION ANDCONCLUSIONS

The Pindwara area situated in the SDFB (South Delhi Fold Belt) comprising of granite gneiss and metasediments represented by quartzites,calc-silicates, and meta-volcanic rocks as pyroxenitesand amphibolite's have a general trend of NE-SW. These rocks have also undergone three episodes of deformation resulting in three generations of folding with their major axial traces trending in NE-SW, NNE-SSW, and NW-SE directions respectively (Biswal et al. 2022). Apart from the axial traces, jointsassociated with them are also present depending on the rheology of the rocks. The shear zones have developed in the calc-silicates. These structural trends have controlled the drainage.

Different types of geomorphic landformslike hills, hill slopes,valleys,and drainage patternshave developed in the region depending on the variability of rocks and the deformational features associated with them. The peneplained areas are the calcareous metasediments and mafic rocks which are easily susceptible to weathering. The massive granites are forming hills. Structural slopes are formedwhere the inner bedrock structure, such as bedding, or foliation plane is directly projected into the relief surface (Montgomery, 1997) and are forming slopes parallel to these features. The Parallel drainage patterns are formed along the bedding/ bedding joints or foliations plane. The Radial to Trellis drainage patternshas developed in granites and calc-silicates while the dendritic pattern is developed in parallel ridges of carbonates. The jointed quartzites have rectangular patterns of drainage. A comparative analysis was performed to understand the spatial relations of the linear elements in the area. The drainage in the area is not only lithologically controlled but is also structurally inspiredwhich means that the drainage depends upon the rock type as well as the deformation pattern present in the area. The 5th and 4th order streams are parallel to the dominant foliation direction in the granitoids. The J_1 and J_2 joints are the conjugate sets and have controlled the 3rd and 4th generation drainage in quartzites and carbonates.

ACKNOWLEDGMENTS

The author thanks the Head, Department of Geology, Faculty of Earth Science, MohanlalSukhadia University, Udaipur for providing a lab facility to conduct this work.

REFERENCES

Biswal T K, Pradhan R M, Sharma N K, et al. (2022) A review on deformation structures of different terranes in the Precambrian Aravalli-Delhi Mobile Belt (ADMB), NW India: Tectonicimplications and global correlation. Earth-Science Reviews. 230, 104037.

Central Groundwater Board (C.G.W.B.), (2013) Ministry of Water Resources, Groundwater Scenario, Sirohi District, Rajasthan.

Chatterjee S M, Sarkar A K, Roy A and Manna A (2020) Mid-Neoproterozoic tectonics of northwestern India: Evidence of stitching pluton along 810 Ma Phulad Shear Zone; Tectonics 39 e2019TC005902.

Chowdhury A K, Gopalan K and Sastry A (1984) Present statusof the geochronology of Precambrian rocks of Rajasthan; Tectonophysics. 10 131–140.

Crawford A R (1970) Continental drift and un-continental thinking; Econ. Geol. 65(1) 11–16.

Deb M. (2001) Metallogeny in the Aravalli–Delhi orogenic belt northwestern India; Geol. Surv. India Spec. Publ. 55 333–350.

Deb, M., Sarkar, S.C. (1990) Proterozoic Tectonic Evolution and Metallogenesis in the Aravalli- Delhi Orogenic Complex, Northwestern India. Precambrian Research 46, 115- 137.Deb M. (2001) Metallogeny in the Aravalli–Delhi orogenic belt northwestern India; Geol. Surv. India Spec. Publ. 55 333–350.

Gupta SN, Arora YK, Mathur RK, Iqballuddin, Prasad B, Sahai TN, and Sharma SB. (1997). The Precambrian Geology of the Aravalli Region, Southern Rajasthan, and NortheasternGujarat, India (with geological map, scale 1:250 000), Memoir of the Geological Survey of India, 123: 1-262.

Gupta SN, Arora YK, Mathur RK, Iqbuluddin, Prasad B, Sahai TN, and Sharma SB. (1980). Lithostratigraphic map of Aravalli region, southern Rajasthan, and northern Gujrat.Geological Surveyof India. Calcutta.

Heron AM. (1953). Geology of central Rajasthan. Mem.Geol. Surv. Ind., 79: 1-339.

Just J, Schulz B, de Wall H, Jourdan F and Pandit M. K. (2011) Monazite CHIME/EPMA dating of Erinpuragranitoid deformation: Implications for Neoproterozoic tectono-thermal evolution of NW India; Gondwana Res. 19(2) 402–412.

Kar, A. (1995) Geomorphology of arid western India. Memoirs, Geological Society of India 32: 168-190.

Mahadani T, Sunderlingam K, and Biswal T K (2013) Neoproterozoic–Pan-African orogen in the Indian peninsula and its tectonic significance in the eastern Gondwana assembly: An example from south Delhi terrane, Southern Granulite terrane and Eastern Ghat Mobile Belt; In Geospectrum (eds.) Mukhopadhyay S, Ray D and Kundu A, ACB Publications, Kolkata, pp. 334–35Montgomery, C.W. (1997), Fundamentals of geology. Wm. C. Brown Publishers, Dubuque, 412 pp.

Pandit, M.K., Carter, L.M., Ashwal, L.D., TurckeR, R.D. andTorsvik, T.H. (2003) Age, petrogenesis and significance of 1 Ga. granitoid and related rocks from the Sendra area AravalliCraton, NW India. Jour. Asian Earth Sci., v.22, pp.363-3

Pandit M. K. (2010) Neoproterozoictectonomagmatic evolution of the NW Indian craton: Implications for palaeogeographic reconstruction; In: International Applied Geological Congress, Islamic Azad University, Iran, pp. 1355–1360.

Pandit M K, de Wall H, Daxberger H, Just J, Bestmann M, and Sharma K K(2011)MaBc rocks from Erinpura gneiss terrane in the Sirohi region: Possible ocean-Coor remnants in the foreland of the Delhi Fold Belt, NW India; J. Earth Syst. Sci. 120 627–641

Roy AB and Das AR. (1985) A study of the relation movements, metamorphism, and granite emplacement in the middle-Proterozoic Delhi Supergroup of Rajasthan. Jour GeolSoc India, 26; 726-733.

Sen S. (1981). Proterozoic paleotectonics in the evolution of crust and location and location of metalliferous deposit, Rajasthan. Quart. Jour. Geol. Min. Meta. Soc. India, 53: 162-185

Sinha-Roy S (1984) Precambrian crustal interaction in Rajasthan, NW India; In: Proceeding of Seminar on Crustal Evolution of Indian Shield and its Bearing on Metallogeny, pp. 84–91.

Singh Y K, De Waele B, Karmakar S, Sarkar S and Biswal T K (2010) Tectonic setting of the Balaram–Kui–Surpagla–Kengoragranulites of the South Delhi Terrane of the Aravalli Mobile Belt, NW India, and its implication on correlation with the East African Orogen in the Gondwana assembly; Precamb. Res. 183(4) 669–688.

Tobisch O T, Collerson K D, Bhattacharyya T and Mukhopadhyay D (1994) Structural relationships andSr–Ndisotope systematics of polymetamorphic granitic gneisses and granitic rocks from central Rajasthan, India: Implications for the evolution of the Aravalli craton. Precambrian. Res. 65(1–4) 319–339.

Upadhyay H, Mittal H.K, Singh M, and Hirapara J.G. (2019) Application of SWAT Model for Estimation of Runoff in Pindwara Watershed and Assessment of its Feasibility;International Journal of Current Microbiology and Applied Sciences ISSN: 2319-7706 Volume 8 (6) 3056-3065.

Volpe A M, and Macdougall J D (1990) Geochemistry and isotopic characteristics of mafic (PhuladOphiolite) and related rocks in the Delhi Supergroup, Rajasthan, India: Implications for rifting in the Proterozoic; Precamb. Res. 48(1–2) 167–191.