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Preliminary Geological Investigation for Poly-metallic Deposits in Khera North Block (Thanaghazi), Alwar District, Rajasthan

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Abstract: **The rocks exposed around Thanaghazi town are part of the Thanaghazi Formation of the Delhi Supergroup. The rocks exposed in the area are carbon phyllite, cherty quartzite, tremolite bearing dolomitic marble and felsic meta-volcanics which have a general trend of NW-SE. The litho-units have suffered three phases of deformation. The cherty quartzite acts as the capping rock of Khera North block. The field characteristics of these rocks include their medium to fine grained size, dark grey colour of carbon phyllite to white to off-white colour of cherty quartzite, the occurrence of tremolite as long prismatic crystals in fine grained dolomitic marble. The surface indications of mineralization in the area are manifested by the presence of old workings, greenish colour malachite stains ($Cu_2CO_3(OH)_2$), ferruginisation and the fresh specks of sulfides. The sulfides, such as chalcopyrite, pyrrhotite, arsenopyrite occur as disseminations, stringers, streaks, veins and at places as massive zones and layers and indicate the presence of poly-metallic sulfide deposits in the area.**

Index Terms: **Alwar, Fresh sulfides, Malachite stains, Thanaghazi, Tremolite.**

I. Introduction

The Indian shield is comprised of five cratonic blocks, the Dharwar, Singbhum, Aravalli, Bastar and Bundelkhand (Naqvi and Rogers, 1987; Sharma and Mondal, 2019). The Aravalli craton forms north-western part of the Indian Shield and comprises rock units from Archean to Recent time. The basement of Aravalli craton is Bhilwara Supergroup which is overlain by lower Proterozoic supra-crustal rocks. The Proterozoic fold belt, Delhi fold belt, hosting rocks of Delhi Super Group is deposited in fluvial conditions in many fault bounded basins (Gupta et. al 1980) and extends from Gujarat in Southwest to Delhi in the Northeast. Heron (1953) had divided Delhi system into two sectors based mainly on his work in Alwar basin- an arenite facies dominated Alwar series, resting unconformably over the quartzite of Raialo series, and a pelitic carbonate dominated Ajabgarh series. The North-Delhi fold belt is divided into three sub-basins, namely Bhayana-Lalsot, the Alwar- Jaipur and the Khetri basins. The Alwar-Jaipur sub-basin has an extension from Jaipur in the South to beyond Rajasthan- Haryana border in the North and is situated between the Bhayana-Lalsot basin in the east and Khetri basin in the West. Bhayana-Lalsot and Alwar-Jaipur sub-basins are comprised of sedimentary sequences deposited in fluvial and marine environments. The Alwar Group and the Ajabgarh Group form part of Alwar sub-basin and the Ajabgarh overlies Alwar conformably in the central portion of the Alwar sub-basin and disconformably along the flanks. The Ajabgarh group is sub-divided into five formations, namely, Kushalgarh, Seriska, Thanaghazi, Bhakrol and Arauli-Mandan formation. The Khera North block forms part of Thanaghazi formation and serves as the area of a preliminary investigation for the mineralization.

II. Geological setting

The geological details of the area and adjoining parts were described by Heron (1917) who classified the rocks of Delhi System into Raialo Series, Alwar Series and Ajabgarh Series. Banerjee (1980) suggested the formational classification of Raialo group, Alwar group and Ajabgarh group. The exposed rocks in the study area belong the Delhi Supergroup, part of North Delhi Fold Belt (NDFB) and are distributed in three main sedimentary

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sub-basins. These sub-basins are namely- the Bayana-Lalsot, the Alwar and the Khetri-Ajmer-Pindwara sub-basins from east to west (Singh, 1988). The stratigraphy of the Alwar sub-basin for the Delhi Super Group is as given below (Chakrabarti et al. 2004).

Ajabgarh Group
- Arauli Formation
- Bhakrol Formation
- Thana-Ghazi Formation
- Seriska Formation
- Kushalgarh Formation

----------Local unconformity----------

Alwar Group
- Pratapgarh Formation
- Kankwarhi Formation
- Rajgarh Formation

----------Local unconformity----------

Raialo Group
- Tehla Formation
- Serrate Quartzite Formation
- Dogeta Formation

----------Unconformity----------

The Raialo Group is divided into Dogeta, Serrate Quartzite and Tehla formations. The Dogeta formation comprises of conglomerate, sandstone, siltstone, siliceous and dolomitic limestone, the Serrate Quartzite formation of sandstone with the interlayered oligomictic conglomerate, and the Tehla formation of basic volcanics, conglomerate, sandstone, siltstone and limestone. The Alwar Group has Rajgarh Formation at the base, comprising of basal conglomerate followed upward by feldspathic quartzite and grit. It is overlain by Kankwarhi formation comprising of micaceous quartzite, mica schist and calcareous biotite quartzite. The Kankwarhi formation is overlain by Pratapgarh formation with ortho-quartzite and sericite quartzite as the main rock types. The Alwar group is overlain by Ajabgarh Group which is a combination of calcareous, argillaceous and arenaceous components along with intercalations of volcanic rocks (Mukopadhyay et al. 2019).

The relationship between the sedimentary facies and palaeoenvironment of Delhi Supergroup can be best studied by an intracratonic rift-basin model. A rise in sea level due to large scale downwarping led to the joining of all interbasin highlands and formation of a wider basin wherein the calcareous Ajabgarh group was deposited. However, the sedimentation was also frequently interrupted by basin wide subaqueous volcanism (Singh, 1988).

The rocks of the Alwar and the Ajabgarh groups have a similar type of deformational imprints. The asymmetric, doubly plunging with NE-SW striking axial planes folds are developed in these rocks, leading to the development of axial culminations and depressions. The first phase of deformation is manifested in the area in the form of isoclinal folds, second in the form of ight to open folds and third as superposition producing culminations and depressions (Ramsay, 1967).

III. Geological investigation by mapping

The reconnaissance geological studies and detailed geological mapping was carried out in some part of Khera North Block, Thanagazi, Alwar district, Rajasthan, part of the toposheet no. 54A/7 on 1:2000 scale. The geological mapping was done using the tape and compass method. In this method, first a reference point was taken and the latitude and longitude of the point was recorded with the help of GPS (Global Positioning System). After the establishment of the reference point, the first point was marked at the contact of two lithology and named as Station 1. Station 2 was marked at some distance from station 1 on the contact. The direction of Station 2 from Station 1 was recorded using the forward bearing method of brunton compass and the distance between them with the help of a measuring tape. The same method was employed for marking all the points on the contact of a particular type and also for all the lithology contacts present in the area. The structural data related to planar and linear features along with mineralization indicators (old workings, malachite stains, ferruginisation, fresh sulfide specks) were noted. The data pertaining to direction, the distance between stations were plotted on the grid sheet along with the structural data such as trends of bedding, foliation, joints, lineation and quartz veins for an overall geological map of the area (Fig. 1).

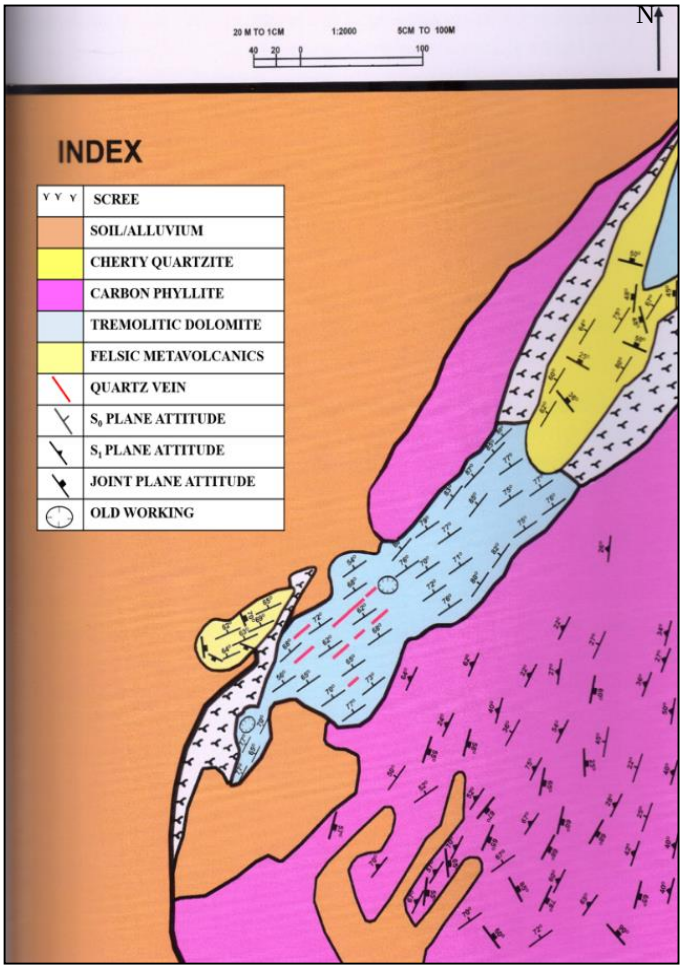

Fig. 1 Detailed geological map of Khera North block, Thanaghazi, Alwar district, Rajasthan

IV. Lithological Association

A. *Carbon phyllite*

Carbon phyllite in the area is a very fine-grained rock having fine laminations. The rock has colour ranging from dark grey to black (Fig. 2). It is found as an interlayer sequence with cherty quartzite and tuffaceous rock. The carbon phyllite in the study area is mainly exposed in E-ESE. Due to oxidation, the upper surface of carbon phyllite alters from ferrous to ferric and obtains the reddish colour observed in field. The soil produced due to weathering of carbon phyllite is greyish black.

Quartz veins are intruded in some parts of the carbon phyllite while at some places oxidization and ferruginisation is seen. Phyllite found in the area is of both types- friable and easily breakable and the hard and compact. Vesicles are also observed in the rock at places. The presence of vesicles indicates that the protolith may be volcanogenic fine ash.

Fig. 2 Carbon phyllite exposed in the eastern part of the Khera North Block

B. *Cherty quartzite*

Cherty quartzite is white to off white in colour (Fig. 3). The surface is mostly brownish red with patches of grey at certain locations. The rock is fine-grained in size and is present as an interlayered sequence in the south-western part with felsic volcanics which has malachite stains present all over the surface. It is present as capping rock of North Khera Block and is quite compact and resistant. The brownish-red colour of the rock on the surface is due to ferruginization and limonitization process.

Fig. 3 Massive and jointed cherty quartzite in eastern part of Khera North block

C. Felsic meta-volcanics

The felsic meta-volcanic rock of the study area is light to dark grey and off white in colour (Fig. 5). In the eastern part of the study area, the felsic meta-volcanics are found as an interlayer within carbon phyllite. The compaction of the rock varies from friable to compact at different locations. At places, it has huge quantity of scree materials deposited at low-angle slopes. It is foliated and have vesicles, which is not filled *i.e.* without amygdaloids. Malachite stains are generally developed prominently in north-western part of the study area as weathering product throughout the lithology.

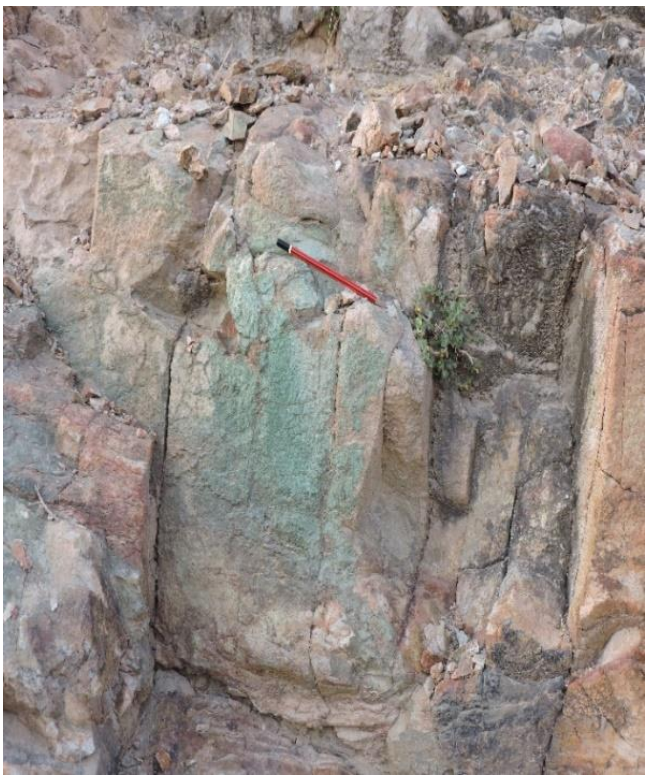

Fig. 4 Felsic meta-volcanics rock in northern part of the Khera North Block

D. Tremolite bearing dolomitic marble

The rock of the study area is buff grey in colour with tints of red (Fig. 4). The tremolite found in the rock is generally present in varying colour of white and grey. At some places, tremolite occurs as prismatic crystals and forms flower-like pattern known as Rosette structure. Quartz and calcite veins are present as intrusives in the rock. The quartz forms secondary folds within the rock due to deformation in the area. The dolomite surface is ferruginised and limonitised at some places. The presence of boudinage type structure indicates shearing in the area.

Fig. 5 Tremolite bearing dolomitic marble in western part of Khera North Block.

V. STRUCTURES

A. Primary Structure

1) Beddings

The primary structures present in the area are the bedding planes that are distinguished by the colour, grain, size and composition which is found to be well preserved in quartzite, carbon phyllite and dolomitic marble intercalated with quartzite. In general, the bedding (S_0) has a strike of NE-SW with moderate to steep westerly dips (Fig 6).

Fig. 6 Bedding (S_0) in tremolite bearing dolomitic marble in Khera North Block.

B. Secondary Structures

1) Planar structures

The area has the two distinguishing set of foliations- S_1 and S_2 (Fig. 7).The S_1 foliation strike NNE-SSW to NE-SW with moderate to steep dip towards WNW to NW. The S_2 foliation is well developed in the hinge zone of the large scale F_2 fold and is well preserved in tremolitic dolomite marble, carbon phyllite and quartzite. The S_2 strikes N-S to NNE-SSW and dips vertically or sub-vertically towards W or WNW. The S_1

and S_0 foliations are parallel except in the hinge portion of F_1 fold. A third set of foliation S_3 associated with the third generation of fold is also found in the area and has a trend of E-W.

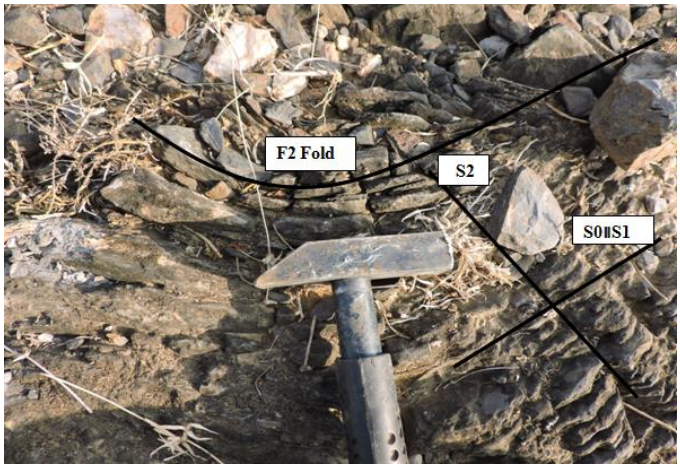

Fig. 7 Foliation S0‖S1 and S2 preserved in the carbon phyllite rock exposed in Khera North Block.

2) Folds

The area records the presence of three phases of folding. The F_1 folds (Fig. 8) are confined to the felsic meta-volcanics and dolomitic marble. The F_2 folds have axial planes (Fig. 9) with a trend of NNE-SSW and are vertical to steep dipping in nature towards WNW. F_2 folds have a plunge of moderate to steep angle towards SSW. The most characteristic feature of the deformation in the area is the formation of domes and basins. F_3 folds are rare with ESE to EW trends and having steeply dipping axial planes.

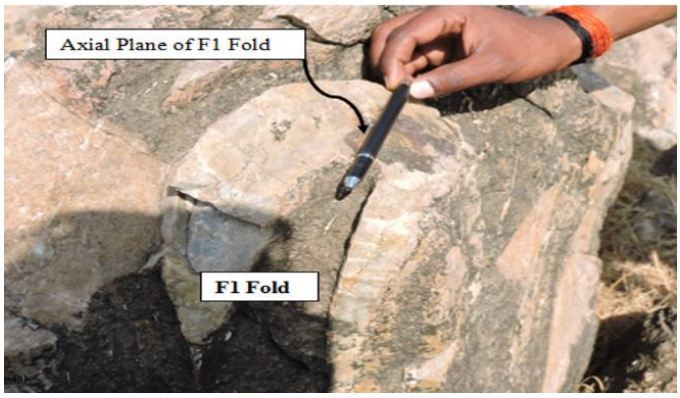

Fig 8 Isoclinal fold of first generation present in quartz vein of dolomitic marble exposed in Khera North Block.

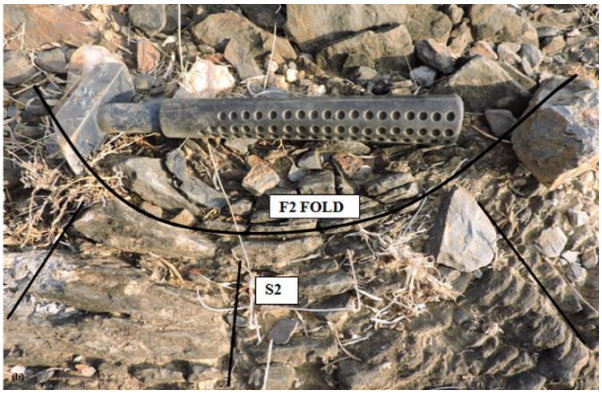

Fig. 9 Open fold of second generation with axial plane S2 present in carbon phyllite rock exposed in Khera North Block

3) Faults

Small scale faults are seen in the area as small scale displacement in quartz veins present in the tremolite bearing dolomitic marble in the NE part of the old working-2, which has a nearly E-W trend and dips at a high to moderate angle towards south.

4) Joints

The area records the presence of three sets of joints (Fig. 10) which are found to be best developed in tremolite bearing dolomitic marble and carbon phyllite. The cherty quartzite has only two sets of joints developed in it (Fig.11). The one set of joint, of the area, is parallel to the bedding while the others are found to be oblique to it. The bedding joint, appears to be the most common joint and is parallel to the regional attitude of the bedding and has moderate dips while the other two sets occur at right angles to it, and have either very steep dip or are vertical in nature. The oblique joints have trends of NW-SE and ENE-WSW directions.

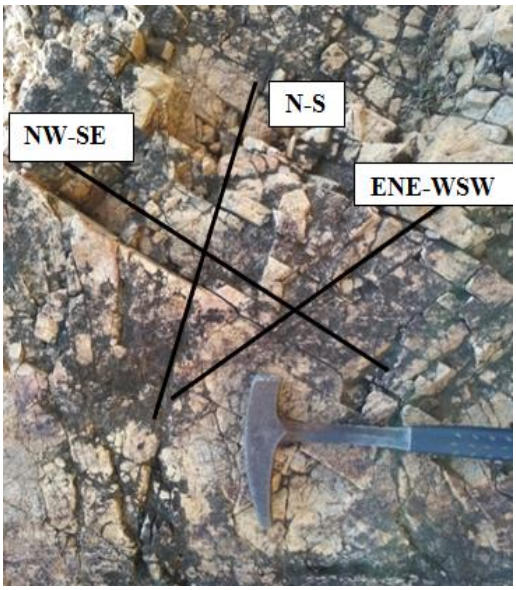

Fig. 10 Three set of joints present in meta-volcanic tuff of Khera North Block.

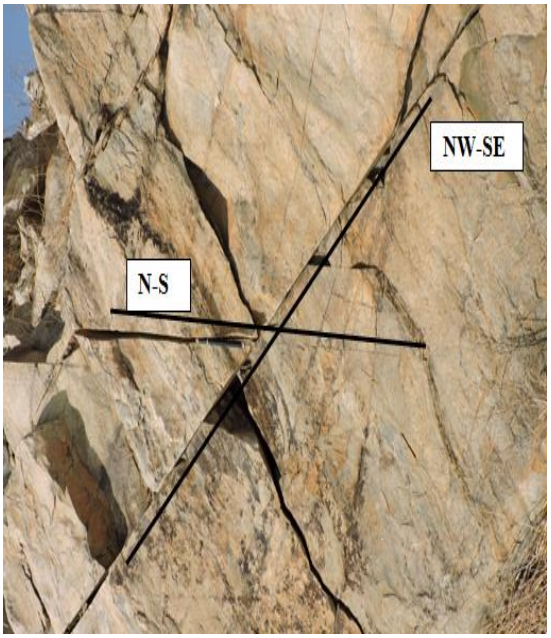

Fig. 11 Two set of joints present in quartzite of Khera North Block.

5) Shear zone

The shearing activity in the area is manifested by the presence of brecciation, rotation of stretched and boudinaged quartz veins, grain rotation, fragmentation and silicification. The shear zone found in the area is located in the eastern and western part of the tremolite bearing dolomitic marble which has a trend of NE-SW and dips at a moderately steep angle towards NW.

VI. MINERALIZATION

A. Surface indications of mineralisation

The mineralization in the area is embodied by the presence of old workings, malachite stains, fresh specks of sulphides like-chalcopyrite showing greenish yellow, arsenopyrite showing silvery white and pyrrhotite showing bronze red colours which serve as surface indications (Fig. 12). The hydrothermal alteration in the area is manifested in the form of quartz and carbonate veins having malachite stains in the mineralized zones.

The tremolite bearing dolomitic marble unit has two old workings present in it. The first old working has a trend of almost 030°-210° having 15 m length and 3 m width. The malachite stains along with ferruginisation are present all around the wall of this old working. The old working-2 occurs at a distance of 200 m from old working-1 in the direction 050º from North. The trend of the old working is 080º-260°. There is the presence of grey quartz vein in this old working which serves as path indicator of gold.

Fig. 12 Surface indication of mineralisation in the form of (a-b) old working in tremolite bearing dolomitic marble (c) Malachite staining in tuff (d) Malachite staining in quartz vein (e-f) Malachite staining in dolomite marble (g-i) Malachite staining in tuff (j-k)Malachite staining in cherty quartzite band (l)Ferruginisation.

B. Geobotanical indicators

There are certain plant species which are found to be associated with a particular type of mineral deposit of a particular environment. The plants' species like *Polycarpea spirostytis*, *Viola calimnaria*, *Amorpha canescens* serve as indicators of copper, zinc, lead respectively. The aromatic plant *Hyptis suaveolens* is a locally developed species associated with Malanjkhand copper deposit. The *Angustifolia sp*. is the local plant indicator species found associated with mineral deposits of Khera North block.

C. Ore Minerals

The ore minerals observed in the area are found to be associated with all the lithologies. The principal ore minerals occurring in Khera North block are chalcopyrite, pyrrhotite and arsenopyrite which are found to occur in the form of dissemination, streaks, stringers due to remobilization, massive zones and layers (Fig. 13).

Fig. 13 Core Sample of different rock type from variable depths (a-c) showing Chalcopyrite (greenish yellow) and Pyrrhotite (bronze red) mineralization in the form of veins, stringers and foliation parallel (d) Chalcopyrite mineralization (greenish yellow) in massive from (e) Arsenopyrite (silvery white) and Chalcopyrite (greenish yellow) in Dissemination form (f) Arsenopyrite mineralization in dissemination.

Chalcopyrite is the main ore mineral along with arsenopyrite, pyrrhotite and pyrite in the area. The abundance in decreasing order of minerals is chalcopyrite, arsenopyrite, pyrrhotite which has been established by the core sample and the polished sections.

1) Chalcopyrite

Chalcopyrite mineralization in the area is mainly associated with siliceous rocks and occurs in the form of disseminations, stringers, veins along structurally weaker fracture planes. Chalcopyrite in the area is the dominant ore mineral and the presence indicates copper mineralization. Under the microscope, the grains appear golden-yellow in colour, have irregular and anhedral appearance and vary in size (Fig. 14).

2) Pyrrhotite

It is the second most abundant phase after chalcopyrite in the area. It is present as veins intruded along the structurally weaker planes in the tremolite bearing dolomitic marble, as stringers along the fracture planes in tremolite bearing dolomitic marble, in the form of fine and coarse disseminations in all the lithologies, and in carbon phyllite as massive zones and layers parallel to the bedding and foliation plane. Under the microscope, the grains appear light brown in colour and have irregular, anhedral appearance associated with chalcopyrite and arsenopyrite (Fig 14).

3) Arsenopyrite

Arsenopyrite is third abundant phase found in the area. It is particularly associated with siliceous rock-unit such as felsic meta-volcanic tuffs and dolomitic marble. Arsenopyrite occurs in the form of disseminations, veins and stringers. They occur particularly as fine grained disseminations in dolomitic marble and felsic volcanic and as coarse grained veins in dolomitic marble. Under the microscope, the grains appear white in colour having blue interference and have regular mineral boundaries with euhedral appearance. The arsenopyrite is known as the path finder mineral for gold and its presence is indicative of gold in the area (Fig. 14).

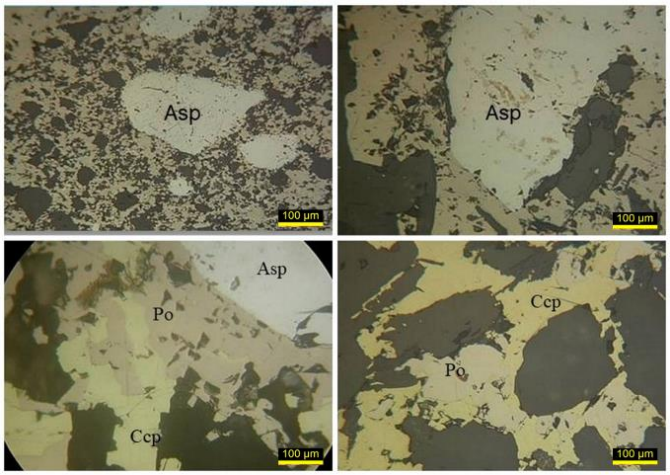

Fig. 14 Ore Microscopic images of Arsenopyrite (Asp), Chalcopyrite (Ccp) and Pyrrhotite (Po).

CONCLUSION

The primary geoscientific investigation has been carried out in the Khera North block for the rock types and the mineralization in the area. The study led to the establishment of four main litho-units, that is, carbon phyllite, cherty quartzite, tremolite bearing dolomitic marble and felsic volcanics belonging to Thanaghazi formation of Ajabgarh group of Delhi Supergroup. The presence of a number of old workings in the area and the lithologies bearing dominant malachite stains is indicative of mineralization. The mineralization in the area is evidenced by surface expressions and bore-hole derived cores. The occurrence of fresh specks of sulfides like chalcopyrite, pyrrhotite, arsenopyrite, in the decreasing order of abundance, hosted in the form of disseminations, stringers, streaks and veins in all the litho-units of the area and in the form of massive zones and layers in carbon phyllite is indicative of poly-metallic sulfide deposits in the area.

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REFERENCES

Banerjee, A.K. (1980). Geology and mineral resources of Alwar district, Rajasthan. *Memoir of Geological. Survey of India*, 110.

Billings, M. P. (1972). *Structural Geology*. New Delhi: PHI Learning Private Limited.

Chakrabarti, C., Pyne, T.K., Gupta, P., Basu Mallick, S. and Guha, D. (2004). Manual of the Geology of India. *Geological Survey of India, Special Publication*, 77(IV).

Geology and Mineral Resources of Rajasthan (2001), Geological survey of India. Miscellaneous Publication, 30, 12.

Gupta, S.N., Arora, Y.K., Mathur, R.K., Iqballuddin, Prasad, B., Sahai, T.N., and Sharma S.B. (1980). Lithostratigraphic map of the Aravalli region, Scale 1:100000, *Geological Survey of India*, Calcutta.

Heron, A. M. (1917). The geology of northeastern Rajputana and adjacent districts. *Memoir of Geological Survey of India*, 45, 1-128.

Heron, A.M. (1953). The geology of central Rajputana. *Memoir of Geological Survey of India*, 79, 1-389.

Marjoribanks, R. (1997). *Geological methods in mineral exploration and mining*. London: Springer.

Mukhopadhyay, S., Kumar, V. and Sangwan, M (2019). Sediment Hosted Stratiform Copper (SSC) Mineralization in Bhudoli-Basari Area, North Delhi Fold Belt, Mesoproterozoic Delhi Supergroup, Rajasthan. *Geological society of India*, 93, 663-674.

Naqvi, S.M. and Rogers, J.J.W. (1987). *Precambrian Geology of India*: Oxford University Press.

Pracejus, B. (2008). *The ore mineral under the microscope: An optical guide*. Oxford: Elsevier.

Ramakrishnan, M. and Vaidyanadhan, R. (2008). *Geology of India, Volume I. Geological Society of India*.

Ramsay, J. G. (1967*). Folding and fracturing of rocks.* International series in the earth and planetary sciences. Mc Graw Hill Book Company.

Robb, Laurence (2005). *Introduction to Ore Forming Processes.* Australia: Blackwell Publishing Company.

Sharma, R.S. and Mondal, M.E.A. (2019). Evolution of the Indian Shield: a new approach. In: Mondal, M.E.A. (Ed.), *Geological Evolution of the Precambrian Indian Shield*: Springer.

Singh S. P. (1988). Sedimentation pattern of the Proterozoic Delhi Supergroup, northeastern Rajasthan, India and their tectonic implication. *Sedimentary Geology*, 58, 79-94.

Singh, S. and Ravindra, R. (1975). Sedimentary structures and Paleocurrents analyses in Delhi group of rock from north eastern parts of Rajasthan. *Abstract in Symposium on Recent Advances in Geology of Rajasthan*. Udaipur.

Singh, S.P. (1984a). Evolution of the Proterozoic Alwar sub-basin, north-eastern Rajasthan. *Indian Journal of Earth Science, CEISM Seminar*, 113-124.

Singh, S.P. (1984b). Fluvial sedimentation of the Proterozoic Alwar Group in the Lalgarh graben, Northwestern India. *Sedimentary Geology*, 39, 95-119.

Singh, S.P. (1988). Stratigraphy and sedimentation pattern in the Proterozoic Delhi Supergroup, north-western India. In: A.B. ROY (Ed.) Precambrians of Aravalli Mountain, Rajasthan, India. *Memoir of Geological Society of India*, 7, 193-200.

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