International Journal of Engineering Technology Science and Research
IJETSR
www.ijetsr.com
ISSN 2394 – 3386
Volume 4, Issue 7
July 2017

Polymetamorphism in the Malikhera-Mokanpura Area Of Dariba-Rajpura-Bethunmi Polymetallic Sulphide Belt Rajasthan

Dr. Samir Nawal
GSSS Jhanwar Jodhpur, Ex Research Schoolar,
Department Of Geology, JNV University Jodhpur Rajasthan

ABSTRACT

The present paper deals with the metamorphic aspect of the rocks of the Malikhera-Mokanpura area. The rocks are metamorphites in nature and are characterized by a varied key metamorphic minerals and mineral assemblages. An attempt has been made to work out the various mineral assemblages to ascertain the metamorphic facies and zones. Estimates of pressure and temperature conditions operating during the formation of metamorphic assemblages have been made. The time relationship between metamorphism and deformation has been studied and metamorphic history of the area has been described.

METAMORPHISM ASSEMBLAGE

The pelitic metasediments in the study area are characterized by the following mineral assemblages:

(i) Biotite-muscovite-sericite-chlorite-quartz.

(ii) Biotite-muscovite-sericite-almandine-quartz.

(iii) Biotite-muscovite-graphite-almandine-quartz.

(iv) Biotite-muscovite-graphite-almandine-Kyanite-quartz.

(v) Biotite-muscovite-graphite-almandine-Kyanite-Staurolite-quartz.

Impure carbonate metasediments are represented mineral assemblages

(i) Calcite-dolomite-quartz.

(ii) Calcite-tremolite-quartz.

(iii) Dolomite-calcite-tremolite-quartz.

DISTRIBUTION OF METAMORPHIC ZONES

The rocks of the Malikhera-Mokanpura area have undergone progressive regional metamorphism of the Barrovian type showing an upward increase in grade of metamorphism from chlorite to kyanite and staurolite. The metamorphic mineral assemblages of each zone has been studied petrographically.

The lowest grade of metamorphism attained by Rajpura-Dariba area is of quartz-albite-biotite sub facies schist facies. The highest is staurolite-almandine sub facies facies in the Barrovian type of metamorphism. Impact metamorphism along with dynamothermal metamorphism is certainly present in the area, but the progressive nature of metamorphism east ward indicate effect of intrusive body, beneath There is clear ‘metamorphic doming’ atleast at a side or half of the same is F exposed. Presence of such intrusive body has also evident in underground 400 level at 65° N where neo-magma has already been reported (Shrivastava, 1992). Winkler (1967) has assigned 400°C to 550°C temperature range to the green schist facies and 550°C-670°C to the amphibolite facies. 650°C is the temperature where anatexis starts. The begining of anatexis in the area is further supported by gravity survey (Reddi and Remakrishna, 1988).

International Journal of Engineering Technology Science and Research
IJETSR
www.ijetsr.com
ISSN 2394 – 3386
Volume 4, Issue 7
July 2017

Five major metamorphic zones have been recognized on the basis of specific mineral reactions.

These zones are separated by four isograded which runs almost in N-S direction Out of these three isogrades sre making typical Barriovian type metamorphism of pelitic sediments and last one separating calcareous rocks dolomitic marble from pelites. A map of the study area has been prepared (Fig. 5.1), showing various zones of metamorphism. The assemblage of silliminite zone have not been encountered.

Zone I : Quartz-Chlorite zone.

Zone II : Garnet zone (Graphite-Almandine-Muscovite-Biotite).

Zone III : Kyanite zone (Kyanite-Graphite-Almandine-Muscovite-Biotite).

Zone IV : Staurolite zone (Staurolite-Kyanite-Graphite-Almandine-Muscovite-)

Zone V : Calcite-dolomite-Tremolite-Actinolite zone.

Zone I : Quartz, chlorite zone

Chlorite in coexistence with biotite, muscovite and quartz are grouped in this zone. The rocks of this zone, are comprised of quartzite and chlorite schist (with little biotite).

The quartz chlorite-biotite zone falls under the greenschist facies. the main mineral assemblages of this zone established on the basis of petrography These mineral assemblages show progressive metamorphic reactions and also retrogressive metamorphic event. The generation of chlorite and biotite are recognised under thin section. The first generations of chlorite and biotite are represented by large flakes of green and brown colour respectively, which are oriented parallel to the main foliation plane (S1). The chlorite and biotite of second generation are aligned at an angle to the foliation plane. The biotite of second generation occurs as porphyroblast across the foliation which also defines the crenulation cleavage (S2).

The appearance of biotite marks an increase in rise of P-T conditions. It is formed largely at the expanse of the chlorite and muscovite as is evidenced by patchy distribution of chlorite and porphyroblastic development of biotite **(Plate 1 Figure:1).** The possible reactions suggested are :

1. 3 muscovite + 5 chlorite → 3 Biotite + 4 Al rich chlorite + 7 quartz + H20 (Winkler, 1967)
2. Chlorite + muscovite + hematite → Biotite + H20 + 02 (Heitanen, 1967).

According to Winkler (1967), the beginning of the green schist facies is marked by the reaction involving break down of kaolinite. The equilibrium temperature of the reaction is 390°c ± 10°C at 2 kb PH2O and 405°c ± 10°C at 7 kb PH2O (Althaus, 1966). Furthermore, Winkler (1965) experimentally demonstrated that pyrophyllite, paragonite and chlorite can crystallize by heating mixtures of clay minerals and quartz to temperatures of about 400°C at PH2O = 2kb. Thus, according to him greenschist facies begins at temperature of 400°C.

Zone II : Garnet zone

This zone succeeds the chlorite-biotite-quartz zone. The first appearance of almandine in the area defines the assemblage Graphite-AlmandineBiotite-Muscovite and quartz.

Almandine is typical garnet of the garnetiferous schists resulting from regional metamorphism of argillaceous sediments, and as such it is used as a zonal mineral in regions of progressive metamorphism of these rocks **(Plate 11 Fig. A and Fig. B; Plate 12, Fig. A and Fig. B).** The almandine may be developed from the chlorite grades although, not all chlorites have an appropriate FeO/ MgQ ratio for the production of almandine. In higher grades of regional metamorphism almandine may also be produced from the breakdown of mica to give garnet and potassium feldspar and from the reaction of staurolite with quartz to give garnet and potassium feldspar and from reaction of staurolite with quartz to give garnet and Kyanite or Sillimanite (Chapman, 1952). The rise in the Mg/Fe ratio in the Adirondack garnets with increasing grade of metamorphism is believed to be the result of partitioning of Mg and Fe between the garnets and the coexisting biotites at high temperatures and pressure (Compare, however, Miyashiro, 1956) Although typically a mineral of regional metamorphism, almandine may also occur as a product of thermal or contact metamorphism. It occurs only in certain aureoles, which typically contain white mica and which lack potassium feldspar, suggesting that it is restricted to relatively wet aureoles. Yodder (1955), in the light of experimental data on the almandine stability field, suggested for these occurrences of almandine that either (a) the contact is wet and the temperature is higher than the upper stability limit of the hydrous minerals, yet lower than the breakdown temperature of garnet, or (b) the contact is dry and therefore, the garnet would be preserved at any temperature below its breakdown curve or (c) the water content of the rock is so low that the bulk composition lies in the water deficient region, and hence garnet is stable with hydrous minerals in the absence of free water at temperature below the breakdown temperatures of the hydrous minerals.

Zone III : Kyanite zone

The transition from zone II to III is observed by the appearance of kyanite **(Plate 13 to Plate 16).** The rocks of this zone are composed of Kyanite-Graphite-Almandine-Biotite-Muscovite-Quartz schist.

Kyanite occurs typically as a mineral of regional metamorphism of pelitic and more rarely psammitic rocks. It has been used as a zonal mineral developing before sillimanite with increasing grade of metamorphism. Francis (1956) has shown that Staurolite (± Kyanite) pelites occur in the epidote-amphibolite facies, while staurolite free kyanite pelites are found in the amphibolite facies. Kyanite may arise also from the dehydration of paragonite with the addition of quartz and from the inversion of andalusite in areas where a regional metamorphism is superimposed on a normal thermal metamorphism (Harker, 1954). Stress of rising pressure during a fall in temperature may bring about the inversion of sillimanite to Kyanite (Hietanon, 1956). Its occurrence together with staurolite and sillimanite in a thermal aureole has been noted by Mc Call (1954) who described porphyroblastic Kyanite in a narrow zone along a granite margin where pelitic schist have been invaded by numerous granite sheets.

Zone IV : Staurolite Zone

The next higher grade of metamorphism is represented by staurolite zone. The rocks of this zone consisting of staurolite schist. The first appearance of porphyroblast of staurolite marks the beginning of staurolite zone **(Plate 17 to Plate 19).** The isograde of this zone is parallel to subparallel to the regional trend of the country rock.

Staurolite occur as porphyroblasts and are wrapped by the micaceous minerals defining the schistosity (S1). The staurolite may contains the inclusions of quartz. Staurolites are commonly twinned in cross fashion.

Staurolite is a common product of regional metamorphism and is particularly characteristic of medium grade schists derived from argillaceous sediments. In such mica schists, staurolite is associated particularly with almandine garnet, muscovite, Kyanite and quartz. Staurolite as formed also at a lower grade of regional metamorphism when converted from chloritoid. Although, staurolite bearing rocks are commonly rich in alumina, high alumina in the host rock is not essential to its formation and staurolite has been reported from metamorphosed grits and impure carbonate rocks. Staurolite and Kyanite often occur together in the progressive regional metamorphism of pelitic sediments. With increasing metamorphic grade, however, Kyanite persists beyond staurolite, and staurolite is replaced by Kyanite and almandine :

$6(OH)_2 Fe_2 Al_9 Si_4 O_{22} + 11 SiO_2 + 1\frac{1}{2} O_2 \rightarrow$

(Staurolite)

$4 Fe_3 Al_2 Si_3 O_{12} + 23 Al_2 SiO_5 + 6 H_2O$

(Almandine) (Kyanite)

This break down of staurolite and the formation from chioritoid, 19 rock containing excess silica also involve quartz, the stability field !df staurolite plus quartz defines the lower and upper limits of staurolite stability in magnetite free rocks The pressure range being considered from 4 to 8 K bar by many workers but 10 K bar in pure Mg member of staurolite with Fe solid solution Kyanite will form in such circumstances at 450°C and 4 K B pressure Andalusite would have formed if the pressure would have been further low. Staurolite indicate a pressure of 6 KB. and temperature 550°C to form as normal staurolite from pelitic sediments.

Garlick and Epstein (1967) suggested that regionally metamorphosed schist containing kyanite and staurolite appear to have crystallized at 520°C-600°C, on the basis of oxygen isotope data. This data is consistent with the staurolite + quartz stability data of Richardson (1968). According to Hoschek (1969) amphibolite facies of kyanite zone sets in at about 575°C 15°C at 2 kb H20 pressure. Staurolite and muscovite react in presence of quartz to produce kyanite or vioca-versa. The reactions suggested are:

1. Staurolite + chlorite + muscovite + quartz ↔ Kyanite + biotite + H_2O (Carmicheal, 1970)
2. Staurolite + muscovite + quartz → Kyanite + biotite + almandine + H_2O (Thompson and Norton, 1968)
3. Staurolite + muscovite + quartz → Biotite + kyanite + H_2O (Hoschek, 1969)
4. Chlorite + biotite + quartz →Almandine rich garnet + Biotite ± H_2O (Chakravarty and Sen 1967)
5. Chlorite + muscovite + quartz → Almondine garnet + biotite + H20 (Thampson and Norton, 1968)

With the increase in P-T condition staurolite is the earliest mineral to appear in the amphibolite facies. It is form at the expanse of muscovite and chlorite in presence of quartz. Close association of biotite and staurolite and textural appearance of biotite being replaced by staurolite is observed. Staurolite can be formed by any of the following reactions

1. Chlorite + 3 muscovite → Staurolite + 3 biotite + 7 quartz + 14 H_2O (Hoschek, 1969)
2. Chlorite + muscovite + quartz → Almandine garnet + biotite + staurolite + H_2O (Winkler, 1967)
3. Fe-rich chlorite + muscovite → Staurolite + biotite + almandine + H_2O (Hoschek, 1967)
4. Garnet + chlorite + muscovite → Staurolite + biotite + quartz + H_2O (Carmichael, 1970)

For the 1st reaction Hoschek (1969) ascertained following P-T conditions. 540°C ± 15°C at 4 kb H_2O pressure

565°C ± 15°C at 7 kb H_2O pressure

Winkler (1974) arrived at somewhat similar P-T condition for the formation of staurolite. It can be inferred that the staurolite zone in the area is formed in the temperature range between 540°C to 565°C ± 15°C at pressure varying from 4 to 7 kb.

Zone V : Calcite-Dolomite-Tremolite-Actinolite zone

The metamorphism of quartz-bearing carbonate rocks provides interesting examples of metamorphic reactions. Eskola (1922) and later Bowen (1940) made a systematic study of the sequence of reactions occurring in carbonate rocks at some given CO_2 pressure in response to rising temperature. The following minerals, well known from progressive metamorphism, are formed tremolite, forsterite, diopside, wollastonite, periclase (brucite), monticellite, akermanite, spurrite, mervinite, larnite, and others. Later, Tilley (1948) added talc as the mieral forming at even lower temperature than tremolite.

Metamorphic reactions of siliceous carbonates liberate CO_2, but since water is present in the rock before metamorphism, one cannot regard CO_2 pressure and temperature as the only factors in metamorphism petrology and mineral assemblages are shown in photomicrographs presented in Plates from 20 to 23. Besides temperature, the total fluid pressure (being the sum of the partial pressures of CO_2 and H20) and the ratio of the two partial pressures (or the mole fraction of either CO_2 or H_2O) have to be taken into account. Therefore in most reactions involving carbonates the equilibrium is (at least) bivariant. This is true even if H_2O is absent in the reaction equation, because H_2O always is a constituent of the fluid phase present in metasediments. In the supercritical state the two components H_2O and CO_2 costitute one single fluid phase; they are miscible in all proportions. The application of bivariant equilibria to natural parageneses is more complicated.

In the present case, formation of tremolite can be explained simply following reaction.

5 Dolomite + 8 Quartz + I H_2O

= I tremolite + 3 calcite + 7 CO_2

In the reactions shown in various circumstances by Winkler (1967), the reaction 4 is applicable to the area. Isobaric diagrams presented in **Fig. 5.2 and Fig. 5.3** has been prepared by Winkler (1967). In these diagrams, reaction 4 is explaining the formation of tremolite in dolomitic marble. Otherwise the dolomitic marble is showing simply recrystallizations.

International Journal of Engineering Technology Science and Research
IJETSR
www.ijetsr.com
ISSN 2394 – 3386
Volume 4, Issue 7
July 2017

In the genesis of massive marble, the thermal metamorphism of sedimentary carbonate rocks (limestone or dolomite) produces recrystallization involving single phase, in which solid crystalline grains grow in a matrix of identical composition Shrivastava and Shrivastava (1989) have proposed that in ideal conditions, grains attempt to minimize interfacial tension by producing a stable configuration of 1200 triple point junction The theory (Shrivastava and Shrivastava, op cit) further state that the histograms occur nearer to 1200 tripple point, while plotting triple point angles as abscissa with distribution frequency as ordinate, will prove the superiority as regards the subgrade. All the photomicrographs from Malikhera marble shows a great deviation from 120° triple point junction, thus are of poor quality as for as degree of crystallinity is concerned.

Further, heterogenity of grain size ranges from fine grained to coarse grained texture even in a single photomicrograph. It shows a poor degree of recrystallisation during thermal metamorphism of the parent sedimentary rock. Apart from absence of homogenity in the degree of crystallinity, effect of deformation is also evident at Malikhera alongwith metamorphism resulted in producing linear alignment and elongation of the grains.

TIME RELATION BETWEEN METAMORPHISM AND DEFORMATION PHASES

The metamorphites of the area have suffered progressive regional netamorphism ranging from greenschist to amphibolite facies i e from hiorite to Staurolite on the basis of metamorphic textures An attempt as been made to decipher the metamorphic history and time - relationship between different phases of metamorphism and deformation Three main metamorphic episodes, named Ml, M2 and M3 have been recognised and described as below :

(i) First Phase of Metamorphism (M1)

First phase of metamorphism (M1) took place in rocks which were subjected to increase in temperature and confining pressure due to load and overburden of rocks. During this phase the main schistosity was formed. Alignment of chlorite, muscovite, biotite, quartz along the SI schistosity plane and absence of growth of garnet, staurolite and kyanite related to SI (Dl deformation) suggest that the schistosity was formed under greenschist facies. This schistosity forming metamorphism is syn-kinematic to Dl and is designated as Ml metamorphism.

(ii) Second Phase of Metamorphism (M2)

The metamorphism reached its peaks during second phase of metamorphism M2, with the crystallization of pelitic index minerals like garnet, staurolite and kyanite. Two stages are recognised under this metamorphism.

The first stage of M2 metamorphism took place during post D1 under static condition. Porphyroblasts of biotite, garnet, kyanite and staurolite grew across the S1 schistosity. The second stage of M2 metamorphism coinsided with the initiation of D2 deformation. syntectonic garnet porphyroblast syn-kinematic to D2 folds are observed. The crenulation cleavage related to D2 deformation show crenulation cleavage with the preferable aligned biotite, muscovite. These textural relationship suggests that during D2 metamorphism, only micas and garnet have grown. This phase was prograde regional metamorphism of Barrovian type.

(iii) Third Phase of Metamorphism (M3)

Garnet and biotite showing alteration to chlorite is widely distributed, suggesting a retrograde phase of metamorphism. This retrograde phase of metamorphism was resulted due to fall in temperature and pressure as a result of uplift. Retrogression is post D2 and hence this phase of metamorphism is designated as M3. It shows growing down grade with decreasing temperature involving hydration and carbonation reactions.

RELATION BETWEEN CRYSTALLIZATION AND DEFORMATION

The mutual relations between crystallization of minerals and deformation of rocks are very significant in understanding metamorphic history of the area. This has been deciphered by the study of porphyroblasts of garnet and biotite and geometric relation of Si to Se fabric. Most of these porphyroblasts show the presence of Si and Se fabric. The Si fabric is the internal S-surface of of porphyroblast, which is mainly determined by trails of quartz and magnetite inclusions. The Se fabric represents the external S-surface in the immediate vicinity of porphyrobiasts and is marked by preferred orientation of mica flakes.

International Journal of Engineering Technology Science and Research
IJETSR
www.ijetsr.com
ISSN 2394 – 3386
Volume 4, Issue 7
July 2017

The characteristic features of garnet porphyroblasts observed are given below:

1. None of the porphyroblasts exhibit sigmoidally curved Si in continuation with Se. The suggests no rotation of garnet during its crystallization at the time of Dl deformation.
2. In the garnetiferous mica schist the Se fabric defined by biotite and opaque minerals in which garnet porphyroblast shows superimposed growth suggesting post tectonic (Post schistosity Dl) crystallization.
3. In few porphyroblasts both Se and Si are sigmoidally curved and is continuous. The geometric relation of D2 fold sympethetic to folded Se and Si suggests that the garnet is syntectonic to D2.

The characteristic features of biotite porphyroblasts observed are discussed below:

1. The biotite flakes containing linear trains of. quartz (Si) parallel or oblique to foliation traces show parallel relation to Se fabric or Si plane. These grains show undulose patchy extinction. This concordant relationship of Si and Se fabric represents syntectonic biotite porphyroblasts with respect to Di deformation.
2. Undulose extinction is also exhibited by biotite flakes indicating effect of D2 deformation. Such, flakes are developed along S2 schistosity. The same figure also exhibits micas bent in the hinges of fold (F2) and polygonal arcs of mica.

Relation between crystallization of some other minerals and deformation is explained below:

1. Majority of muscovite and biotite flakes are aligned parallel to Si foliation, indicating their syn - Di crystallization. A second set of muscovite and biotite flakes grow obliquely to Si foliation defining a shear-foliation later to Si as well as post - Di. **(Plate 13, Fig. B).**
2. Quartz phenocryst shows pull-apart texture dividing into three sub grains. The gaps between the pull-apart grains are filled with newly grown fine grained quartz and quartz porphyroblast showing plucking texture. This textural relationship suggests that quartz phenocrysts is pretectonic and its stretching (extension) parallel to foliation is syn-D1 deformation.
3. Minute flakes of chlorite and sericite are aligned parallel S1 foliation suggesting their syntectonic (D1) generation **(Plate 7 Fig. A and Fig. B).**
4. Thin quartz, dolomite and calcite ribbons are aligned parallel to foliation (S1) **(Plate 2 Fig. A; Plate 20 Fig. B; Plate 21 Fig. B and Plate 22 Fig. B)**

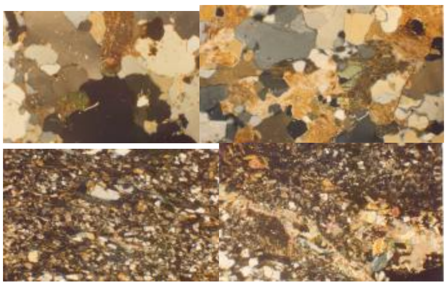

FIGURE:1

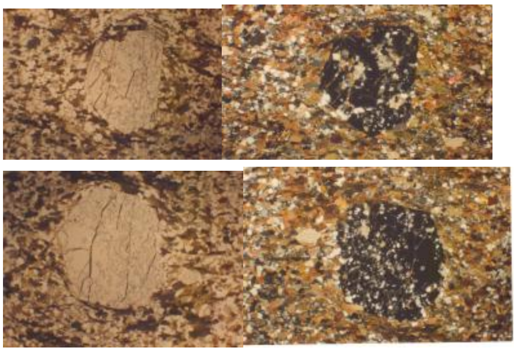

FIGURE:2

International Journal of Engineering Technology Science and Research
IJETSR
www.ijetsr.com
ISSN 2394 – 3386
Volume 4, Issue 7
July 2017

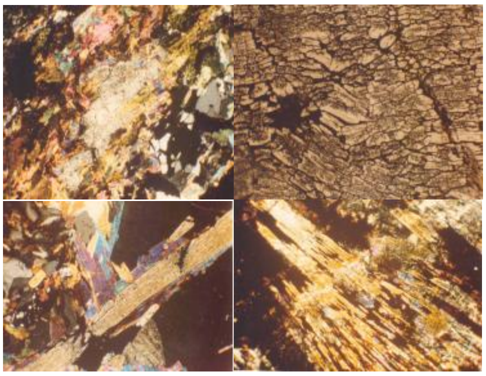

FIGURE:3

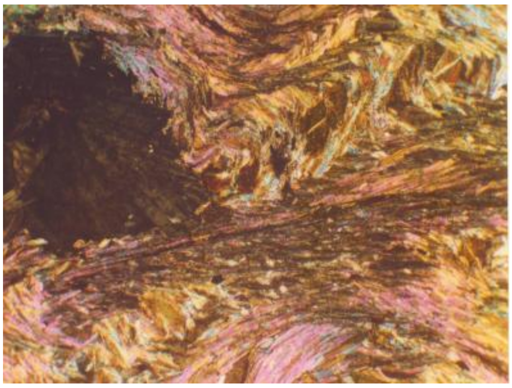

FIGURE:4

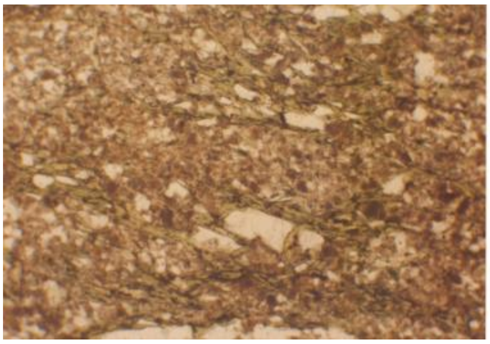

FIGURE:5

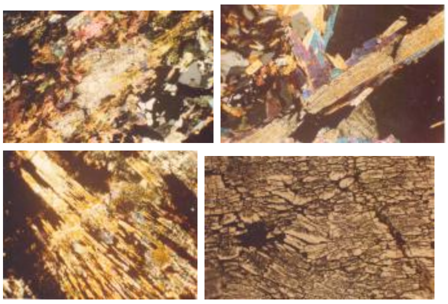

FIGURE:6

REFERENCES

- Aithaus, E., 1967. Contr Mineral. Petrol. Vol. 16 PP. 29-44.
- Bowen, N.L., 1940. J. Geol. Vol. 48 pp. 225-274.
- Chakraborty, K.R. and Sen, 8K., 1967. Contr Mineral. Petrol. Vol. 16 pp. 210-232
- Champman, C.A., 1952. Structure and Petrology of the Sunapee quadrangle, New Hampshire. Bull. Geol. Soc. Amer Vol. 63. P. 381 -391
- Eskola, R, 1922. J. Geol. 30 : 265-294.
- Francis, G.H., 1956. Facies boundaries in Pelites at the middle grades of regional metamorphism. Geol. Mag. Vol. 93, P 353.
- Garlick, G.D. and Epstein, S., 1967. Oxygen-isotope relations in co-existing minerals of regionally. Metamorphosed rocks Geochim. Cosmochim. Acta. 31, P. 181-214.
- Harker, R.K., 1954. Further data on the Petrology of the Pelitic hornfelses often earn Chuineag-lnchbae region, Ross-Shire with special reference to the status of almandine. Geol. Mag., Vol. 91. P 445.
- Hietanon, A., 1956. Kyanite, Andalusite and Sillimanite in the schist in Boehls Butle quadrangle. Idaho. Amer Mm. Vol. 41. pp. 1-20.
- Hoschek, G., 1967. Contr Mineral. Petrol. Vol. 14 pp. 123-162.
- Hoschek, G., 1969. Contr. Mineral. Petrol. Vol. 22 pp. 208-232.
- Mc Call, G.J.H., 1954. 'The Dalradian geology of the creeslough area. Co. Donegal'. Quart. Journ. Geol. Soc., Vol. 110, R 153.
- Miyashiro, A., 1956. 'Data on garnet biotite equalibria in some metamorphic rocks of the Ryoke zone'. Journ. Geol. Soc., Japan. Vol. 62. P 700.

International Journal of Engineering Technology Science and Research
IJETSR
www.ijetsr.com
ISSN 2394 – 3386
Volume 4, Issue 7
July 2017

- Reddi, A.G.B. and Rama Krishna, T.S., 1988. 'Sub surface structure of the shield area of Rajasthan-Gujrat as inferred from Gravity'. In Mem. No. 7, (Ed. A.B. Roy). Geol. Soc. Ind., PP. 279-284
- Richardson, SW., 1968. J. Petrol. Vol. 9 pp. 467-488.
- Shrivastava, K.L. and Shrivastava, A., 1989. 'The bearing of triple point angles to assess quality of Massive marbles A case study of Rajnagar Marble' in the Symp. On Mining and processing of dimension stones. March 14-15, 1989, Jodhpur.
- Shrivastava, K.L., 1992. 'Ore Petrographic geophysical and geochemical investigation of sedimentary and metamorphosed pyrites from two sulphide deposits of India and its bearing to the ore genesis. Ph.D. Thesis (unpublished), J.N.V. University, Jodhpur (India).
- Shrivastava, K L, Nawal, S Gaur, V and Chaudhary, N, 2001 "A Petrological Assessment of dolomitic marble from Malikhera, Dariba-Rajpura-Bethunmi polymetallic suiphide belt, Bhilwara Supergroup, Rajasthan". Proceeding of National Seminar on Smal Scale Mining 5-6 March 2001. Vol. of proceedings. pp. 12-17
- Thompson, J.B. and Norton, S.A., 1968. Palaeozoic regional metamorphism in New England and adjacent areas. Ru E-An Zen et. al. eds. Studies of Appalachian Geology. Interscience Publisher (John Wiley & Sons), New York
- Tilley, C.E., 1948. Mineral Mag. 28, pp. 272-276
- Tripathi, B., 1991. 'Structural and Metamorphic history and Tectonic framework of the Salkhala Group in Ramban-Doda areaof Kashmir Himalaya'.Ph.D. Thesis (unpublished), H.N.B. Garhwal University (India.)
- Winkler, H.G.F, 1967. Petrogenesis of Metamorphic Rocks. 3rd edit. Springer-Verlag, New York - Berlin.
- Yodder, H.S., 1955. 'Role of Waler in Metamorphism'. Geol. Soc. Amer. Special Paper 62, pp. 521.

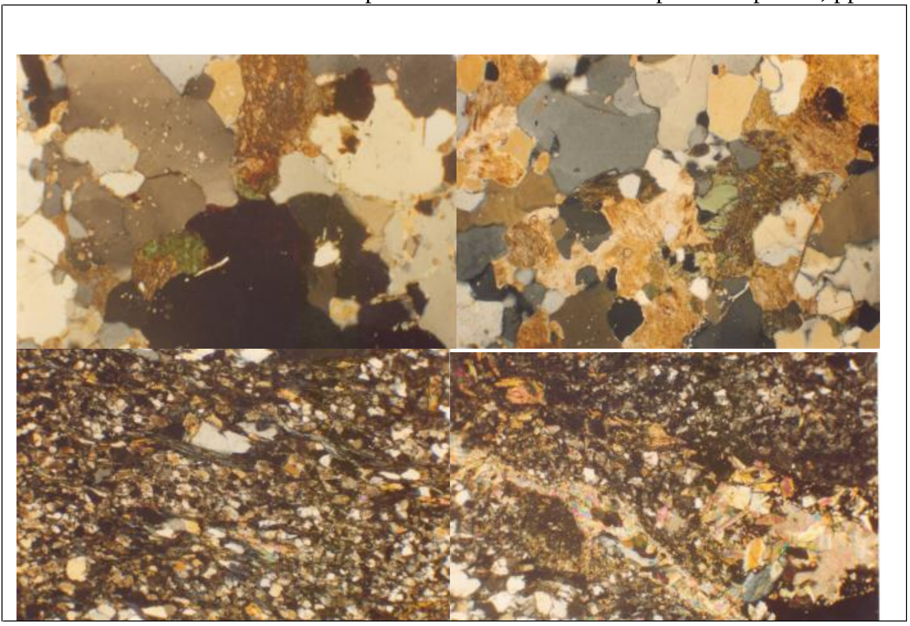

FIGURE : 1