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The Higher Grade Metamorphic Zonation of The Delhi Supergroup Rocks Around Bar, Pali District, Rajasthan

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Abstract: **The present paper deals with the metamorphic aspects of rocks present in Phatakhera-Megarda-Kanuja-Kotra villages of Bar region of Pali district in Rajasthan. The other important localities are Rail Magara–Bheru ki Bariya–Kashiya–Bhilan villages. The Granitic gneisses, Barotia and Sendra formations are polymorphisms in nature and are characterized by varied mineral assemblages. The isograds that separate these metamorphic zones indicate the initial appearance of index minerals in the pelitic rocks. Mineralogical compositions are one of the fundamental properties of any metamorphic rock which has direct relationship with metamorphic provinces and pressure temperature conditions. Therefore, petrographical studies are an important tool to decipher the metamorphic grades along with the metamorphic environment of different types of rocks. It also helps to know the characteristic features and tectonic conditions of rocks. Moreover, such studies also help to infer the degree and type of metamorphism which, in turn, categorize the distribution of different zones.**

Keywords: **Granitic gneisses; Barotia formations; Sendra formations; Isograds**

I. INTRODUCTION

The tectonic movements of the earth's crust and magmatic intrusions cause complex processes of metamorphism of rocks. Metamorphism means any alteration and transformation of rocks occurring under the effect of changed physico-chemical conditions after formations of rocks and following the action of endogenous forces [1]. Mainly three principal factors are responsible for these alternations, they are as follows: i) pressure i.e. the weight or burden of overlying rocks and called petrostatic pressure or directed tectonic pressure or stress, ii) high temperature and iii) chemically active and extremely mobile substances in solution and gaseous forms. Metamorphism involves partial of complete recrystallisation, changes of structure and texture and, in number of cases, of the mineral composition as well. All alterations occurred in a solid state of the substances without their passing into a liquid phase.

An attempt has been made to work out the various mineral assemblages of ascertain the metamorphic facies and zones. The estimate of pressure and a temperature conditions operating during the metamorphic assemblage has been made. The time relationship between metamorphisms and deformational episodes has been studied and described along with metamorphic history of the study area. The rocks exposed around investigated area of Raipur region of Pali district have been regionally metamorphosed and are characterized by a wide intermediate zone of biotite-staurolite-kyanite-sillimanite fringed in the southwest by biotite-garnet-staurolite and in the northeast to southeast by staurolite kyanite sillimanite zones respectively (Fig. 2). The textural relations indicate that staurolite began to form only slightly after garnet during progressive metamorphism. The pegmatite veins around Bar-Phatakhera village area and granite outcrops at Bhilan and Kotra villages are the typical evidence of contact metamorphism. In thin sections, the only effect of contact metamorphism is recorded is the frequent development of spongy garnets and staurolite in the schist occurring in proximity of the granite outcrops (Fig. 1 a). The schistosity is very well developed in the rocks of study area and the porphyroblasts of garnet and staurolite have grown between D1 and D2 phases of deformation.

II. ROCK TYPES AND SAMPLE DESCRIPTIONS

The study area is situated around Bar in the Pali district of Rajasthan (Fig. 1). Rock samples were collected from 25 sites in and around Phatakhera, Megarda, Bhilan, Rail Magara, Bheru ki Bariya, Kashiya, Kanuja, and Kotra of the Pali district, Rajasthan. The rocks in the study area predominantly exhibit a conglomeratic nature, particularly in the Bar conglomerate horizon, and are characterized by folding and metamorphism. Along the road section from Phatakhera–Megarda–Rail Magara–Bheru ki Bariya–Kashiya villages of Barotia Formation consisting of biotite, garnet and staurolite with minor kyanite bands are exposed dipping at 86° towards 140°N. All exposures have been subjected to medium to high temperature and medium pressure leading to conversion of rocks into the amphibolite facies. This metamorphism is highest (kyanite is the characteristic index mineral) in the Motisar Bera near Gunda Bera village. The

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Megarda village is comes in the northwestern side of the study area and the grade increases away from that region. The porphyroblasts of garnet and staurolite of almandine-amphibolite facies are superimposed across and earlier fabric; and have probably grown under the influence of heat arising from the thermal sills of pegmatites present near Megarda village.

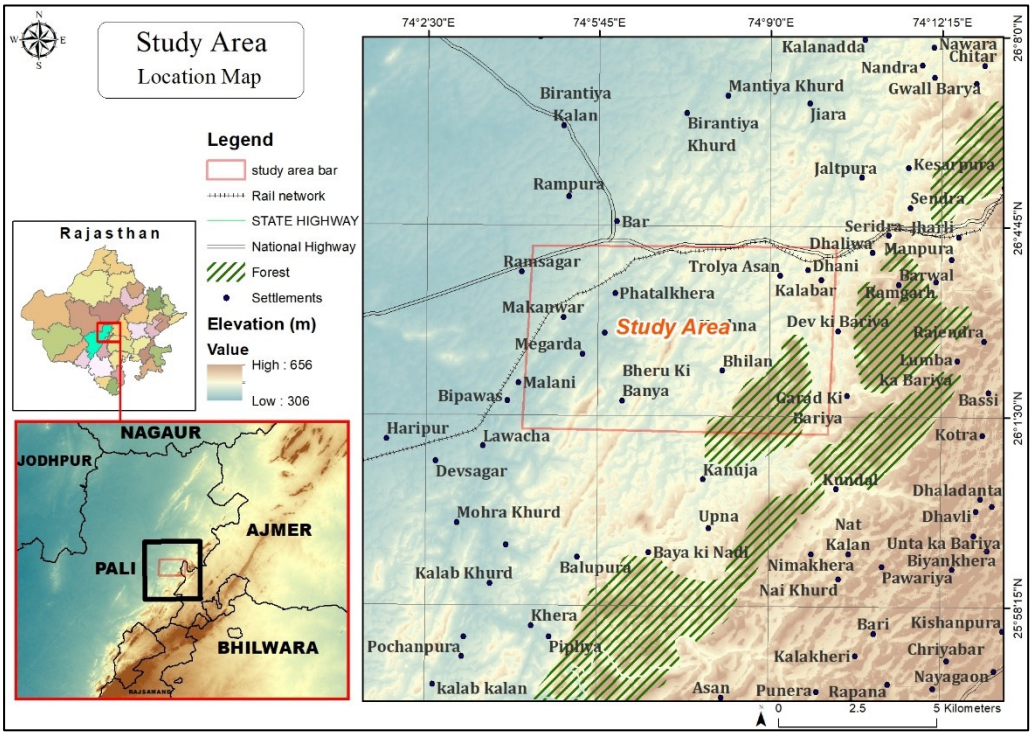

Figure 1. Location map of study area around Bar, Pali district, Rajasthan

III. OUTLINE OF GEOLOGY

The rocks of south western side of study area include scattered outcrops of granitic gneisses which are mostly concealed under thick pile of loose sand layer. The posts-tectonic dikes, sills of pegmatite and granite and quartz veins are quite common in this area. Igneous intrusive activity, especially acidic, is widespread in Bar, Birantiya, Lawacha and Haripur and its immediate vicinity. The faint impressions of granitization are also present in the form of veins and boudins at Phatakhera and at Haripur villages, however, not as well marked rock formations. These veins indicate the presence of intrusive activity in the region, as also noticed by Naha et al. (1984) [2], these veins bear tourmaline, garnet, beryl etc. Identification of xenoliths is not always possible, bur at places like Haripur, three to four xenoliths are present. The study area included three main tectonic divisions of Delhi Supergroup from southwest to northeast viz. Banded Gneiss Complex (BGC of Heron, 1953 [3]), Barotia Formation (Alwar Group) and Sendra Formation (Ajabgarh). All the three tectonic divisions are well displaced in the study area. The BGC is made up of Precambrian basement in the southwestern side and the lower most tectonic unit of the area [4]. It is separated from the overlying rock of the Barotia Formation with an unconformity [5]. The Barotia Formation consists of Bar conglomerate horizon, calc amphibolite schist, quartzite schist and calc-schist with intercalated quartzite schist. The Bar conglomerate horizon is further subdivided into various types, including quartzofeldspathic schist, Bar conglomerate schist, garnetiferous mica schist, staurolite schist, and kyanite schist. The overlying Sendra Formation constitutes the northeastern part of the study area. Dolomite (equivalent to Nandana crystalline limestone of Heron, 1953 [3]) separates the Sendra Formation from the underlying Barotia Formation conformably. The Sendra Formation is constituted of mostly gneisses with alternate bands of mica schist and foliated quartzite [6-7].

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IV. DISTRIBUTION OF METAMORPHIC ZONES

The rocks of the Megarda-Lawacha-Dipawas-Malni region lies in the Barotia Formation and have undergone progressive regional metamorphism of the Barrovian and equivalent type showing an upward increasing metamorphic grade from biotite to kyanite. The mineral assemblage of the pelitic rocks of in and around Bar-Raipur region correspond to green schist to upper amphibolite facies of Turner (1968) [8] and Winkler (1974) [9]. The metamorphic mineral assemblages of the area are polymetamorphosed and belong to low to medium pressure zones. Five major metamorphic zones have been recognized in the increasing grade of metamorphism and they are separated by four isograds on the basis of specific mineral reactions (isoreaction grade of Winkler, 1974) [9]. The metamorphic zones and isograds from northeast to southwest (Fig. 2) (Table 1) are given below:

Table 1. The metamorphic zones

Zone- A	:Biotite zone
Zone- B	:Garnet zone
Zone- C	:Staurolite zone
Zone- D	:Kyanite zone
Zone- E	:Sillimanite zone

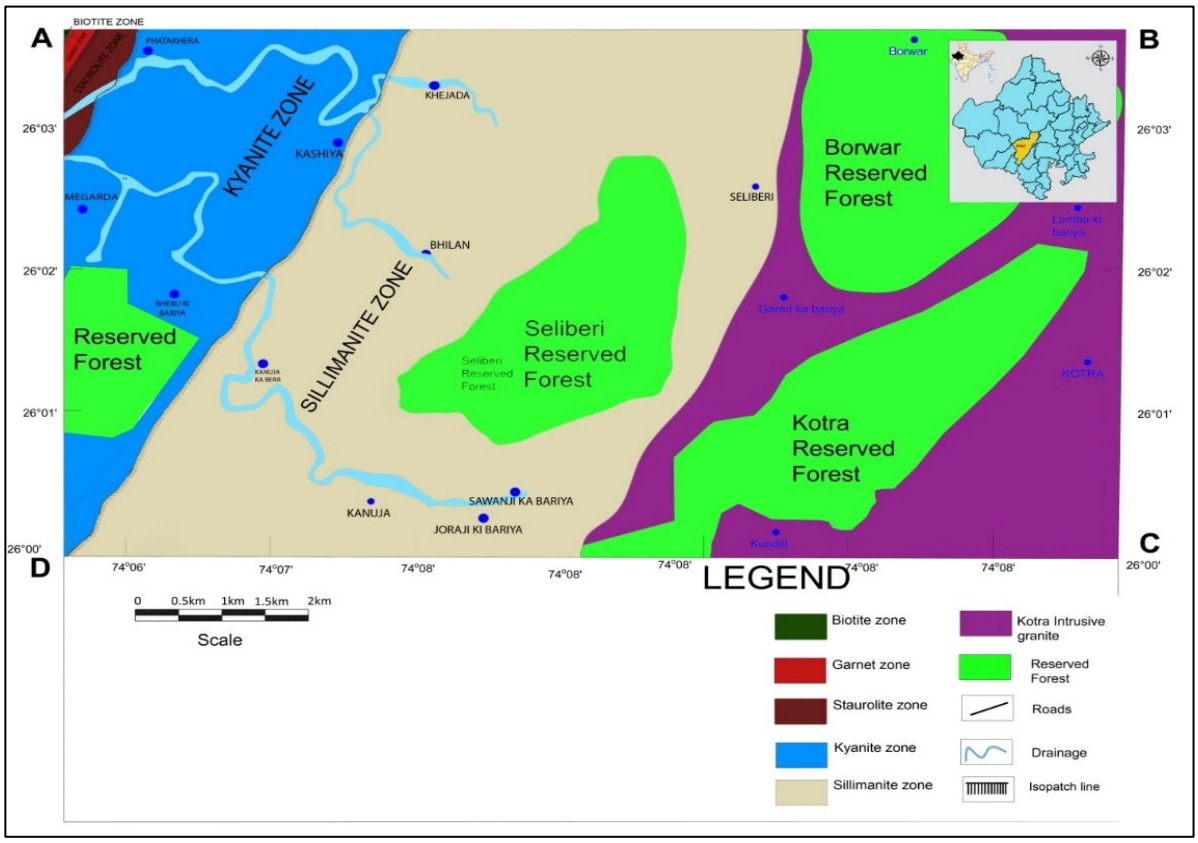

Figure 2: The metamorphic zones and isograds map of Phatakhera-Megarda-Kanuja-Kotra of Pali district (Rajasthan)

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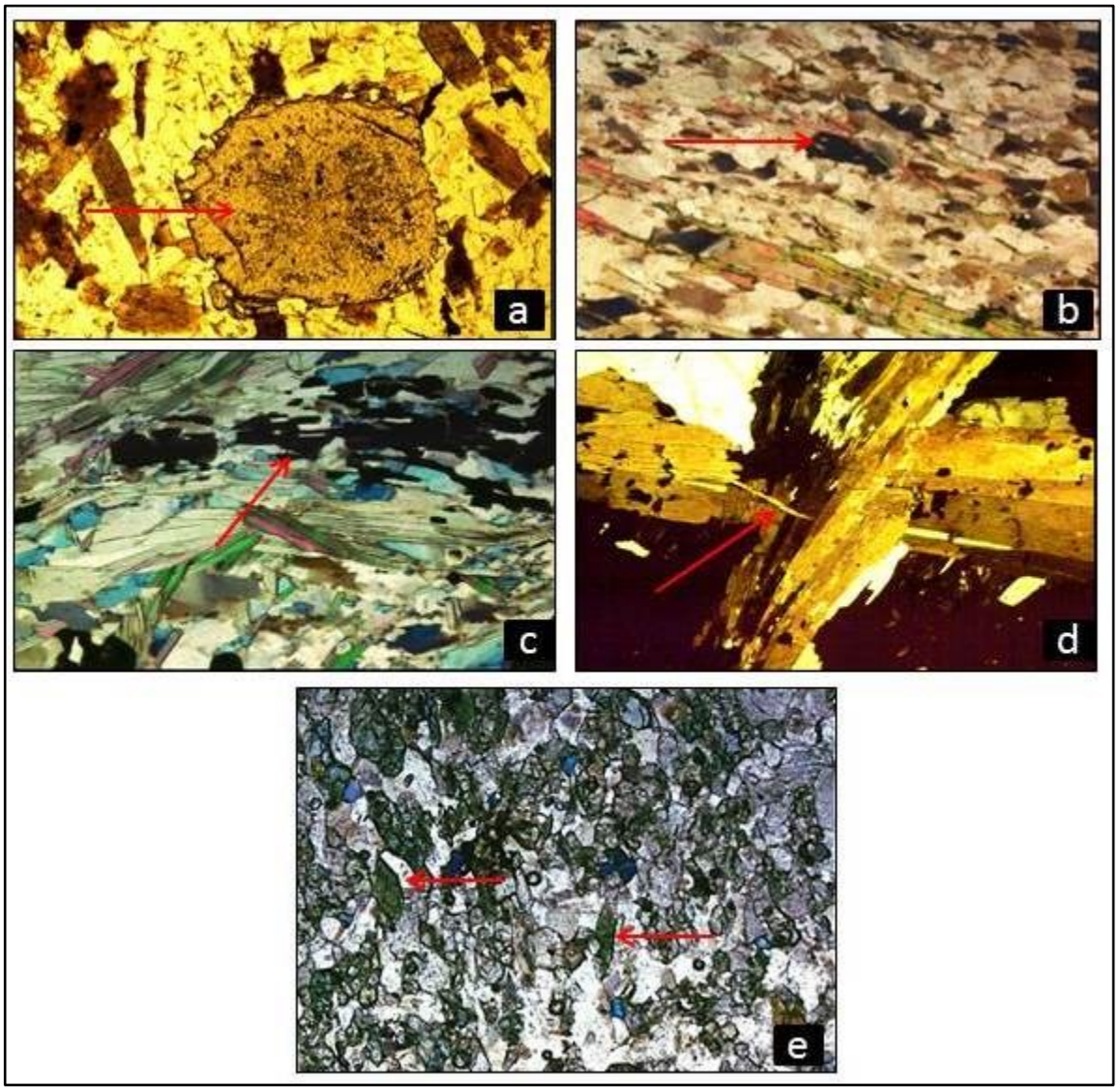

Figure 3: **a.** Garnet shows spongy core and massive rim which may suggests that crystallization of garnet started with a nucleation over an earlier formed outer garnet, under plane polarize lightX20**. b.** Primary biotite showing alteration to secondary biotite suggested retrograde phase of metamorphism, under cross nicol's X20. **c**. Muscovite andbiotite flakes containing linear trains of cleavage (Si) parallel and oblique to foliation traces show parallel relation to Se fabric of S1 plane, under cross nicol's X20. **d**. Majority of kyanite crystals are aligned parallel to S1 foliation, indicating their syn-D1 crystallization. A second set of kyanite crystals are growing obliquely to S1 foliation defining a shear- foliationunder cross nicol's X20. **e**. Euhedral sphene is present in sillimanite gneiss under cross nicol's x20

A. Zone–A:Biotite

Zone-A represents the lower grade of metamorphism in the study area and is initially metamorphosed in biotite zone which subsequently developed biotite, sericite quartz, plagioclase and muscovite indicating upper green schist to medium amphibolite facies conditions. All the rocks that contain biotite in coexistence with muscovite and quartz are grouped in this zone. The rocks of this zone are comprised of biotite schist, quartzite schist along with thick and thin pegmatite and granite veins ranging from 1.5cms to 2.0 meters in thickness. The biotite schist is restricted within the Barotia Formation and isograde boundary is parallel to the Barotia Formation. Isograde of Zone A are imposed towards the inner boundary of Barotia Formation.

Mineral Assemblages

The biotite zone represents the zone of lowest grade of metamorphism in the study area. All the rocks that contain biotite in coexistence with sericite, muscovite, albite, plagioclase and quartz are

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grouped in this zone. These mineral assemblages show progressive metamorphic reaction and two generations of biotite are recognized under thin section. The first generation of biotite is represent by large brown colour flakes with one set of cleavage which is oriented parallel to the main foliation plane (S1). The biotite of second generation is aligned at right angle to the foliation plane. The second-generation biotite flakes occur as porphyroblasts across the foliation plane (Fig. 3 b). The schistose rocks show more than one set of schistosity [10].

B. Zone–B:Garnet

This zone succeeds the biotite zone. The first appearance of almandine garnet appears just after Bar conglomerate formation near Makerwali village define the beginning of garnet zone. The rocks of this zone include garnetiferous mica schist and calc amphibolite schist. The zone B is wider than biotite zone and extends from Makerwali village in the northeastern side and after crossing the Rail Magra village in the northeastern side. The isograde boundary is parallel to subparallel to the trend of the regional strike.

Mineral Assemblages

Tourmaline, zircon, carbonaceous content also occurs in the mica schist. Garnet is another ubiquitous mineral occurring in the mica schist almost throughout the study area except biotite zone. It is dark maroon in colour, xenomorphic, sometimes subidioblastic and poikiloblastic (Fig. 3 a). The size of garnet grains varies from microscopic to mesoscopic. The common mesoscopic size is 1mm to 1.5mm but at the contact of pegmatite vein and schistose formation, the size become 1 cm to 0.5 cm. The garnet grains are formed at the expanse of chlorite and biotite during progressive regional metamorphism. Garnet porphyroblasts are wrapped around by schistosity defined by micas. Two type of garnet are recognized. The one which are skeletal and subhedral, contains numerous inclusions of quartz and iron oxide while the other is euhedral garnet show relatively less inclusions, well developed faces and grow over the foliation plane suggesting post tectonic nature [11].

C. Zone–C:Staurolite

Medium grade of regional metamorphism in the study area is indicated by the crystallization of porphyroblasts of staurolite and almandine which have grown during more than one metamorphic phase, thus suggesting that the rocks are polymetamorphosed.

Mineral Assemblages

Staurolite is a stress mineral and belongs to a single mineral isograde (non-variable) with small stability range [12]. It is formed at the expense of muscovite and chlorite. With the increase in PT conditions the staurolite is the earliest one to appear and is followed by kyanite. Staurolite is the most reliable indicator of amphibolite facies [13]. Inclusions of quartz and sometimes finely micas flakes have preferred orientation and showing continuity with the fabric of schistosity.

Staurolite is also a common porphyroblastic mineral in the pelitic schist of the area and is ubiquitous in the staurolite and kyanite zones. It is pleochroic, pale yellow to colour less and either shows prismatic, hexagonal cross-section and in skeletal forms also. It is commonly grown over the mica foliation (S1) lying parallel or inclined to it with Si planar to Se. Two types of staurolite viz. skeletal and idioblastic to subidioblastic are observed. The skeletal type contains the inclusions of quartz while idioblastic to subidioblastic show less inclusions (Fig. 3 c). The textural relation indicates that the growth of staurolite initiated post-tectonic to S1 during a static phase between D1 and D2. The first appearance of staurolite thus represents slightly lower grade conditions than those at which garnet first occurs in the area.

D. Zone–D:Kyanite

Medium to High grade of regional metamorphism in the Megarda-Motisar Bera-Kashiya-Tiroliya Asan region of Bar-Raipur area is indicated by the crystallization of kyanite associated with quartz, muscovite, almandine and staurolite. These minerals are occurring in the form of bladed i.e. kyanite and porphyroblasts i.e. almandine and staurolite, which generally develop under stimulus of increasing grade of regional metamorphism observed at locality near Gunda Bera village. The stable mineralogical assemblage such as kyanite, staurolite, almandine, biotite, muscovite and albite indicates that the rocks belong to medium grade of metamorphism [13]. The rocks of this zone composed of kyanite schist intercalated with calc schist and quartzite bands (Fig. 3 d).

Mineral Assemblages

Kyanite developed from staurolite shows a rise in PT conditions with the addition of garnet. The amount of staurolite is decreases with the increase of kyanite in the kyanite-staurolite-schist. The rocks from this zone show overall coarse texture. Kyanite forms as the index mineral and is present in two forms. One of them occurs as hard, dark grey in colour, fine bladed crystals showing radiating form on mica foliation while the other type of

kyanite crystals are broad elongated plates is randomly oriented and intimately inter grown with garnet and staurolite. Microscopically fine fracture plane is present on kyanite blades (Fig. 3 d). Muscovite still persists in this zone along with biotite and staurolite [14]

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E. Zone–E:Sillimanite

Highest grade of regional metamorphism in the Bheru Ki Bariya-Kanuja-Kotra region of Bar-Raipur area is indicated by the crystallization of sillimanite associated with quartz, muscovite, biotite, staurolite and kyanite. These minerals are occurring in the form of bladed i.e. kyanite and porphyroblasts i.e. staurolite, which generally observed at locality near Gunda Bera village and most probably develop under stimulus of increasing grade of regional metamorphism observed at locality Bheru Ki Bariya, Kanuja and Kotra villages. The stable mineralogical assemblage such as sillimanite, kyanite, staurolite, biotite, muscovite, albite and quartz indicates that the rocks belong to medium grade of metamorphism [13]. The rocks of this zone represented by coarse gneisses which containing biotite, staurolite and kyanite together with potash feldspar and potash mica. In the study area sillimanite gneiss are intercalated with calc amphibolite gneiss [15].

Mineral Assemblages

Sillimanite developed from kyanite and staurolite shows a rise in PT conditions with the addition of sphene. The amount of staurolite is decreases along with the decrease of kyanite in the sillimanite gneiss. The rocks from this zone show overall coarse texture. Sillimanite forms as the index mineral and is usually occurs in the form of small size often minute and slender prismatic crystal. Some crystals are more or less bend. Microscopically sillimanite crystals are very hard and tough, dark grayish to green in colour and crystals showing parallel to sub parallel form along with transverse fracture planes are common on sillimanite gneiss (Fig. 3 e). Biotite and muscovite flakes still persist in this zone along with staurolite and kyanite blades.

REFERENCES

[1] E. A. Kuznetsov, “Petrografila magmatic heskikh i metamorphic hes kikhporod: petrography of Magmatic and Metamorphic Rocks,” Moscow Univ. Moscow, MGU Publishers, pp. 411, 1956.

[2] K. Naha, D. K. Mokhopadhyaya, R. Mohanty, S. K. Mitra, T. K. Biswal, “Significance of contrast in the early stages of the structural history of the Delhi and the pre-Delhi groups in the Proterozoic of Rajasthan, western India,” Tectonophysics, vol. 105, pp. 193-206, 1984.

[3] A. M. Heron, “Geology of Central Rajputana,” Memo. Geological Survey of India, vol. 79, pp. 1-389, 1953.

[4] A. B. Roy, “Tectonic and stratigraphic frame work of the early Precambraian rocks of Rajasthan and Northern Gujarat,” Geol. Min. Meta. Soc. India. Bull., vol. 53, pp. 100-114, 1985.

[5] P. K. Gangopadhyay, A. Lahiri, “Barr conglomerate: its recognition and significance in stratigraphy of Delhi Super Group in Central Rajasthan,” Jour. Geol. Soc., India, vol. 24, pp. 562-570, 1983.

[6] B. Tripathi and G. Singh, “Lithostratigraphy of Bar-Mohra Khurd- Raira Khurd area of Pali district, Rajasthan and their relationship with the soil and vegetation,” Indian Forester, vol. 141, no. 12, pp. 1257-1268, 2015.

V. CONCLUSIONS

In the investigated area various litho units are exposed in a northeast-southwest direction from Phatakhera to Kotra for a distance of over 18 km. The study area is constituted by the low to upper medium grade metamorphic rocks. These metamorphites structurally overlie the Banded Gneissic Complex which is not exposed in study area. All the lithostratigraphy units of the study area are metamorphosed but the rock belongs to Phatakhera to Kotra show and upward increase in grade of metamorphism from biotite to sillimanite. The spatial distribution of the index minerals in pelitic schists of the Barotia and Sendra formations shows Barrovian type of metamorphism. The first appearance of index minerals, viz., biotite, garnet, staurolite, kyanite and sillimanite marked the different isograde in the investigated area. Five metamorphic zones have been delineated from northwest to southeast: i) Biotite zone, ii) Garnet zone, iii) Staurolite zone iv) Kyanite zone and v) Sillimanite zone.

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[7] H. Prakash, “Evaluation of soil layers around Bar Pali district Rajasthan, Journal of soils and crops, vol. 33 no. 1, pp. 168-173, 2023.

[8] F. J. Turner, “Petrogenesis of metamorphic rocks,” Mc-Graw Hill Book Co., New York, pp. 403, 1968.

[9] H. G. F. Winkler, “Petrogenesis of Metamorphic rocks,” (Revised Edition), Springer-Verlag, New York, pp. 320, 1974.

[10] W.A. Deer, R. A. Howie, J. Zussman, “Rock-forming minerals,” five volumes Longman London, pp. 69, 1962.

[11] A. Hirschberg, H. G. F. Winkler, “StabilitatsbeziehungenZwischenchlorit, cordierit, und Almandinbei der Metamouphose,” (Beitr. Mineral. Petrologie) Contrib. Mineral. Petrol, VOL. 18 NO. 1, pp. 17-42, 1968.

[12] M. P. Atherton, “The chemical significance of isograde. Controls of Metamorphism,” Oliver and Boyd London Geol. Jour. Sp. Is. No. 1, pp. 169-202, 1965.

[13] H. G. F. Winkler, “Petrogenesis of Metamorphic rocks,” Springer Verlag, New York, Berlin, pp. 220, 1965.

[14] G. Hoschek, “Stability of staurolite and chloritoid and their significance in metamorphism of pelitic rocks,” Contrib. Mineral Petrol., vol. 22, pp. 208-232, 1969.

[15] M. Georgieva, Z. Cherneva, K. Kolcheva, S. Sarov, I. Gerdjikov, E. Voinova., “P-T metamorphic path of sillimanite-bearing schists in an extensional shear zone, Central Rhodopes, Bulgaria,” Bulgarian Academy of Sciences, pp. 95-106, 2002.