PETROGRAPHIC EVOLUTION OF METAGABBRO FROM SOUTH DELHI FOLD BELT

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Certificate

This is to certify that Mr. Sandipan Bhattacharya has worked under my guidance and completed his thesis entitled "Petrological evolution of meta-gabbro from parts of South Delhi Fold Belt, Rajasthan" in the Department of Geological Sciences, Jadavpur University in partial fulfilment of his Master of Science Examination in Applied Geology of Jadavpur University in 2019.

Mr. Bhattacharya has fulfilled all the prescribed requirements and this work has not been presented for any degree or diploma elsewhere.

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Abstract

In north-western Indian shield South Delhi Fold Belt (SDFB) is a northeast southwest trending, multiply folded and poly-metamorphosed rock of Proterozoic age. The western margin of the SDFB is demarcated by Phulad Shear Zone (PSZ) of mid-Proterozoic age (~810 Ma). The PSZ is characterized by north-easterly striking ductile shear zone with a well-developed mylonitic foliation and a down-dip stretching lineation. The deformation in the PSZ has developed in a transpressional regime with top-to-the-west reverse sense of movement. The present study deals with petrological evolution of a meta-gabbro that occur parallel to this shear zone.

The meta-gabbros are coarsed grained and are variably deformed. The gabbro shows strong development of dominant foliation with attitude 38/87˚E and prominent down dip lineation. Systematic study of mesoscopic structures of the meta-gabbro and the shear zone rocks demonstrate a similarity in geometry and style. This indicates that the deformation in the meta-gabbro and the shear zone is broadly synchronous.

The meta-gabbro contains clinopyroxene, plagioclase, ± orthopyroxene, amphibole with ilmenite, sphene in minor amounts. In the least altered meta-gabbro, the rock preserves prominent evidence of igneous texture. In the altered variety, the clinopyroxene grains are rimmed by amphibole grains with relict of clinopyroxene at the center. In more deformed variety the amphibole grains are completely replaced the clinopyroxene grains. Electron microprobe analysis data show the amphibole composition varies from actinolite to hornblende and edenite. Textural relation suggests actinolite formed earlier and hornblende and edenite formed later. Mylonitic gabbro comprised of amphibole minerals which exhibit well defined foliation appearance along with dynamically recrystallised plagioclase grains. Textural relations show formation of coronal sphene over ilmenite grains. Integrating the

mesoscopic and textural relation it is suggested that all the metamorphic reactions are fluid driven reactions that further facilitate the exhumation of the present suite of gabbro.

Chapter-1

Introduction:

The Aravalli mountain range is 700 km long mountain chain consisting of multiply folded and poly-metamorphosed rocks of Proterozoic age in North-Western Indian Shield. General orientation of the Fold Belt is northeast-southwest trending. The previous workers e.g. Heron (1953), Gupta (1934), Gupta and Mukherjee (1938) have reported multiple deformations and metamorphism in all the Precambrian rocks from Rajasthan and Formed a basic framework of Precambrian rocks of Rajasthan. In this study area mainly consists of calc-silicates, granite gneiss, mica-schists and some mafic rocks mainly gabbroic rocks. These gabbroic rocks show different metamorphic textures at different locations. Detailed field work and lab work is done to know proper history of metamorphic evolution of the gabbroic rock.

The present study aims to understand the metamorphism process and its spatial change of the gabbroic rocks.

Regional Geology:

Basement Rocks:

The basement rocks of Rajasthan are referred to as Banded Gneissic Complex (BGC) (Heron, 1953), where it is best exposed in the south of Mewar. These BGC essentially contains igneous rocks and multiple cycles of metasediments that form banded composite gneiss. Zircons derived from the basement gneiss yielded an age of 3.5Ga age (venkobarao et al., 1958) suggesting an Archean age for the gneisses. This has been further supported by the age of Untala granites (2.9Ga) which are intrusive within the BGC (Chaudhary et al. 1981).

The pre-Aravalli basement is made up of five sequences as follows:

1) Bimodal gneisses containing alternate bands of tonalite/granodiorite and orthoamphibolites.

2) The intrusive granite bodies within the pre-Aravalli basement are Untala and Gingla granites (2.96 Ga) and Berach Granite (2.6 Ga).

3) Two pre-Aravalli supracrustal sequences:

    a) An older greenstone like sequence consists of discontinuous bands and patches of ultramafic bodies, amphibolites, pelitic schists, calc silicate rocks, chert graphite schist and meta greywacke.

    b) A younger greenstone named as Hindoli Group consists of mafic to felsic volcanic in the lower part and metagraywacke and meta-pelites. The Hindoli Group sequence is now considered as early Proterozoic since its basement Berach Granite is dated 2.6 Ga.

The three sequences (1, 2 and 3a) are grouped together and named as Mangalwar Complex.

4) The granulite facies rocks occurs as tectonic wedges within BGC near Sandmata known as Sandmata complex and consists of garnet-sillimanite gneiss, enderbite and charnockite, two pyroxene granulite, leptynite and cordierite-garnet gneiss. The enderbite- charnockite occurs as intrusive pluton within the granulite gneiss and the emplacement of charnockite took place at 1723 Ma. (U-Pb age).

Aravalli Supergroup:

Sea (1981) divided the Aravallis into two separate belts- the bhilwara belt and the Udaipur belt. The two belts represent two separate basins and there is a small time gap between them.

The rocks of the bhilwara are metamorphosed to higher level amphibolites facies with occasional lower grade assembledge. The rocks are graphite phyllite or schists with almandine garnet, stauroloite, kyanite, marble, cal-magnesium granulite with diopside or tremolite, amphibolites, banded magnesite quartzite and quartzites. Metavolcanics of basaltic to andesite composition now represented by amphibolites and small intrusive granite bodies are present.

The Aravalli rocks of the Udaipur belt are considered as the type area of Aravalli Supergroup. The Raialo Series rocks are now included in the Aravalli Supergroup because of absence of any structural and stratigraphic break between Aravalli and the Raialo.

The Supergroup is associated with synorogenic granitic intrusions

Intrusives into Aravalli Rocks

The important intrusions are:

a) Acidic intrusion-Fine grained aplogranitic and coarse-grained porphyritic type.

b) Soda granite of Kisengarh- one large intrusion and nine small sills like intrusive within the pre-aravalli gneisses.

c) Basic intrusive-epidiorites and hornblende schist represent original sills and dykes probably belonging to several periods of intrusion,

d) Rikhabhdev ultramafic suites- bands, lenses, stringers of altered ultramafic.

Delhi Supergroup:

The Delhi Supergroup of rocks extends from Delhi in the NE through Ajmer and Mewar to north of Gujrat in the SW. According to Heron it lies with a profound unconformity over the underlying sequence BGC, Aravallis or Raialos. There is a change in litho-facies of the Delhi supergroup halfway along the Aravalli range. Therefore, the lithological classification adopted in the NE is not applicable in the SW.

According to workers there exist several contradictions to the above-mentioned classification. Like –

- Existence of continuous litho-stratigraphy from north to south of the whole mountain belt (Singh 1988)
- Older NDFB and younger SDFB have the same structural history (Naha et al. 1984)
- The whole Delhi fold belt have the metamorphic history

In the NE part the Delhi Supergroup is principally divided into the lower Alwar and the upper Ajabgarh Group. The Raialo Group was placed by Heron below the Alwar Group, although initially be included it in the lower part of Delhi Sequence. Roy 1988, Gupta et al 1992 included the Raialo Group within the Delhi Supergroup and the Kushalgarh limestone and Hornstone Breccia are included as lower formations withim the Ajabgarh Group.

Delhi Supergroup	Ajabgarh Group (3000m)	Argillaceous sequence (slate, phyllite and mica schist containing garnet staurolite and andalusite) with subordinate impure arenites and carbonates
	Hornstone Breccia Kusghalgarh limestone (450m)	Brecciated and granular quartzite with intercalated carbonaceous phyllite Dolomitic limestone with intercalated impure argillaceous marble.

	Alwar Group (300-400m thick)	Massive to current bedded quartzite with subordinate argillaceous (slate and phyllite) and impure limestone.
Raialo Group		

The SW section is divided into 5units and Heron included the lower units in the Alwar and the upper three in the Ajabgarh Group. Later, Scientists renamed the section because of lithological differences from the Alwar and Ajabgarh rocks in the NE section. The latest stratigraphic classification by GSI workers is as follows:

DELHI SUPERGROUP (SW SECTION)

Punargarh Group: Slate, Phyllite, Quartzite and metabase with pillow structure

Sirohi Group: Phyllite, mica schist was intercalated marble and quartzite bands (earlier considered aas Aravalli sequence

Kumabhalgarh Group containing Phulad ophiolite complex (earlier Ajabgarh sequences)

Gogunda Group (earlier Alwar sequence)

According to Gupta et al (1995) Delhi supergroup of rocks are bounded by Pre-Delhi gneisses and schists on either sides. Pre-Delhi having identical trend bisects Delhi Supergroup of rocks into two parts, the western or Barotiya-Sendra basin and eastern Rajgarh-Bhim basin. Delhi Supergroup is divided into 4 groups which are shown on the table above.

SUPERGROUP	**GROUP NAME**	**LITHOLOGY**

Delhi Super group	Barotiya	Western unit:-Barr mica schist & conglomerate, impure marble, subarkose& metavolcanics with associated intertrappens of meta pelite and calc-schist
		Middle unit:-Nanana marble with metavolcanics
		Eastern unit:- Thick Barr mica schist & conglomerate, impure marble, subarkose& metavolcanics
	Sendra	Interbedded
	Rajgarh	Pelitic schist band of massive quartzite and calc gneiss
	Bhim	Dungarkherapelitic schist formation
		Dungarkhera semi-pelitic schist formation
		Todgarh Calc-gneiss formation
		Todgarh impure marble formation
	Ras Marble	2 bands of marble (coarsely crystalline, grey colored) bounded either side by poorly exposed Pre-Delhi granites, gneisses and pelitic schist.

STUDY AREA:

Location and Accessibility:

Kamalighat is a village located in Pali district in Rajasthan state of India (Fig- 1, 2). The area is well connected by a network of roads and railways. The NH-62 is the main lifeline for road communication to this area. The area is served by the meter-gauge network of North-Western Railways. The nearest railway station is Ajmer and Jaipur. Jodhpur and Jaipur are the only civil airports in the area. The M. Sc. Dissertation work comprises detailed study of lithology and structure of the rocks of the Delhi Supergroup near Phulad.

The location of the area is:

Coordinates:

Latitude: $25^0 33^{'}$18.6’’N

Longitude: 73051’15.1’’E

Climate:

The study area comes under tropical, warm climate zone and moreover it is in close proximity with the Thar Desert in North- West Rajasthan. As a result, the area experiences a wide diurnal fluctuation in temperature. During daytime the temperature goes upto 50^0C during summer. Even during winter, the temperature remains nearly 30^0C during daytime but at night it may fall to 10^0C. The average annual rainfall is very less, about 5-10 cm.

Physiography of the study area:

The area can be grouped into three domains namely (i) the western sandy plains, (ii) the hill ranges and (iii) the eastern plains. These divisions based on the existing relief-features and provide a basis for the study of geomorphic evolution of the terrain, which has been sculptured through number of erosional cycles represented by various surfaces. The region is characterised by mature topography with more or less flat-topped mountain ridges, escarpment and vast stretches of plains. The whole area is undulating in nature and dominated by hilly terrains.

Chapter-2

Mesoscopic study:

The general trend of Delhi Fold Belt is NE-SW. The gabbroic rock shows near about same trend (Fig- 3A, 3B). The rock type of the present study area is massive and dark in colour (Fig-3C), belongs to the Todhgorh formation. The rock is gabbroic in nature. The rock body shows some asymmetric folded pattern. The rock contains plagioclase, clinopyroxene and amphibole grains. At the limb part grains are oriented in a particular direction which is fabric defining in nature. But at the hinge part grains are haphazardly oriented. In some place’s amphibole grains are enriched and formed a lair of amphibolite. In a single rock sample strain variation also observed (Fig- 4A). At the high strain part grains are parallel to each other but at the low strain part the grains are haphazardly oriented (Fig-4B to 4C).Although the rock is massive and dark coloured, at some places it show some interlocking texture in naked eye and some where it is fine grained massive dark with no such texture which can be observed in naked eye.

Microscopic study:

For the study,gabbro from different locations have been collected in the field and thin sections are prepared. From thin sections study,rock shows different texture and mineralogy under microscope. From west to east different rock samples have been studied under microscope as thin sections different minerology and textures have been observed of those rock samples. In the photomicrograph plagioclase and clinopyroxene can be easily identified (Fig-5A). The rock shows ophitic to sub-ophitic texture mainly, but at some places intergranular texture also present which indicate that the rock is igneous in origin. The grain size is large which indicate that the rock is plutonic. Due to its composition it is classified as gabbro. At the low strain part clinopyroxene are present but at the high strain domain there is no clinopyroxene grains left, it indicates that the rock is slightly less metamorphosed at the low strain domain compared to high strain domain. At the low strain domain grains are haphazardly oriented and grain size large but at the high strain domain amphibole grains are finer and show recrystallization texture. Here the grains are oriented in a particular direction which is fabric defining. In this photo micrograph amphibole grains are present at the rimal part and the cleavage planes of clinopyroxene grains (Fig-5B, 5C). Some plagioclase laths are present in the ground mass surrounded by recrystalized fine grain plagioclase (Fig-5D). Some opaque phases also identified which are ilmenite and magnetite. These are identified under transmitted light. Sphene formed as corona around the ilmenite grains (Fig-6) but in some places, it completely engulfed the ilmenite grains.

Further three different amphiboles are identified form the EPMA data and element mapping. Firstly actinolite, which is present at the ground mass near clinopyroxene. These grains are surrounded and engulfed by hornblende grains which are present all over the thin sections. It engulfed the pyroxene grains along the rimal part and the fracture planes of clinopyroxene. Edenite grains are present near the plagioclase grains and the opaque phases. Al, Fe and Na concentrations increases form actinolite to hornblende to edenite (Fig-7A, 7B). Plagioclase laths shows slightly higher concentrations of Al, Ca than recrystalize plagioclase grains. Plagioclase does not show any specific compositional zoning. It is haphazardly oriented due to difference in compositional mobility. Plagioclase grains are more Al rich near edenite than hornblende.

Possible reactions:

Actinolite present haphazardly in between hornblende near clinopyroxene, and they are present very few amounts. It can be formed from clinopyroxene in a very early stage as hornblende engulf the actinolite along with clinopyroxene. It also indicates that hornblende formed from clinopyroxene and also from the actinolite. Hornblende grows simultaneously with edenite as there is no specific time gap in between them, it is clearly evident that they grow cumulatively and there is no engulf texture present. Hornblende grows in the cleavage plane of clinopyroxene, so clinopyroxene to hornblende can form without plagioclase.Sphene replace the ilmenite as it takes the shape of ilmenite with the sharp edge with hornblende and edenite with the presence of Ca.

Chapter-3

Conclusion:

The above-mentioned reactions are present in the local scale. All the reactions take places due to mobility of different ions in different zones. At the low strain part metamorphism is less than the high strain part. So, we can surely say that all the metamorphism and metasomatism are fluid driven. At the high strain part, as the rock is highly deformed fluid can easily flow through it and metamorphism takes place rigorously but al the low strain part fluid percolation is less, so metamorphism slightly less. As a result, few clinopyroxene present as remnant mineral. At different location fluid play different role. At some places it completely reacted with clinopyroxene and formed amphibole, some where it completely altered ilmenite and formed sphene. Plagioclase and amphibole show recrystallization texture where it is highly deformed and fluid can easily flow through it. All the reactions take place in this study area is due to different type of fluid driven.

References:

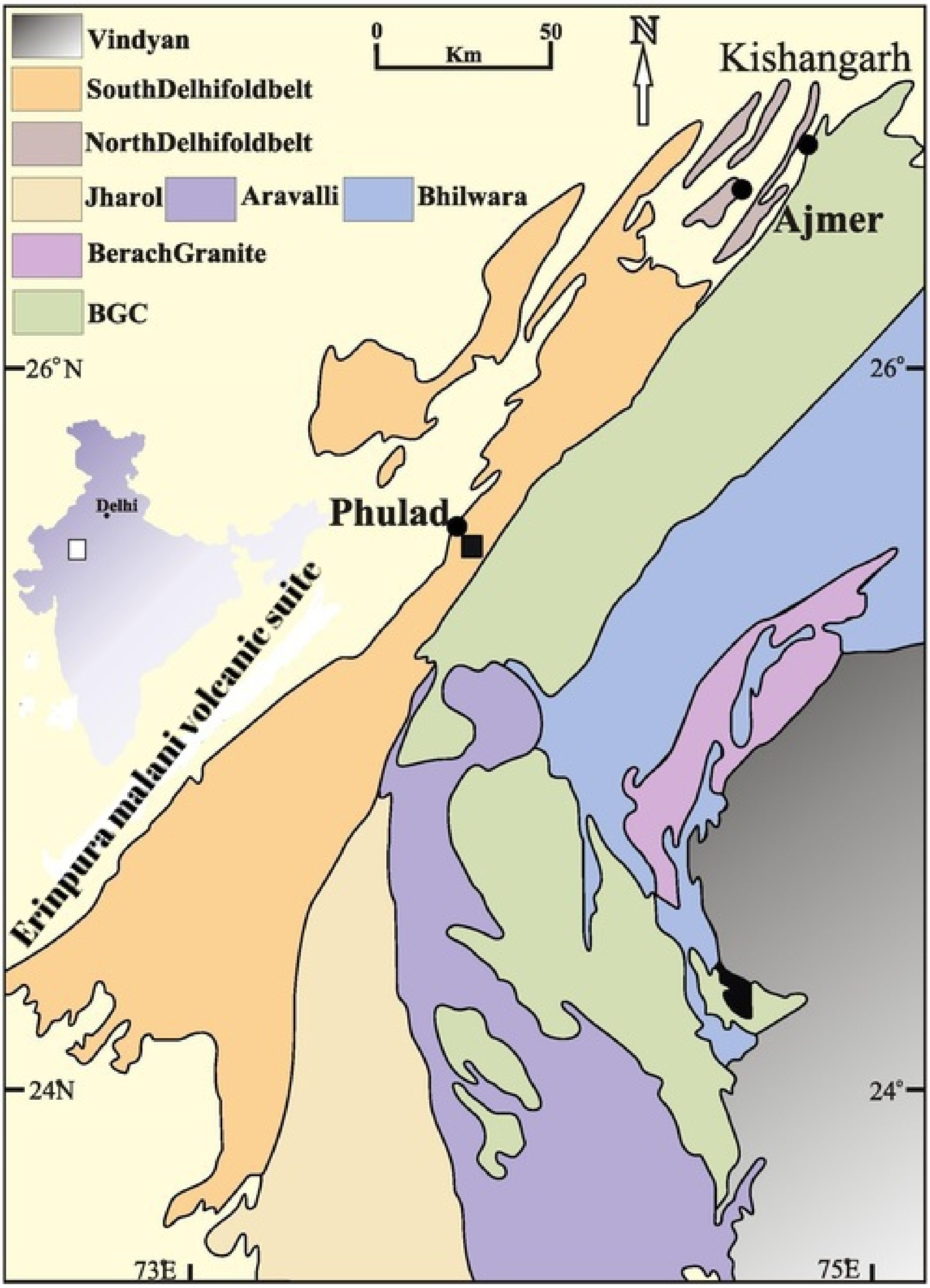

Fig 1: Simplified geological map of parts of Delhi-Aravalli Fold Belt, modified after Heron, 1953 and Gupta at all., 1980. Present study area marked by the square box

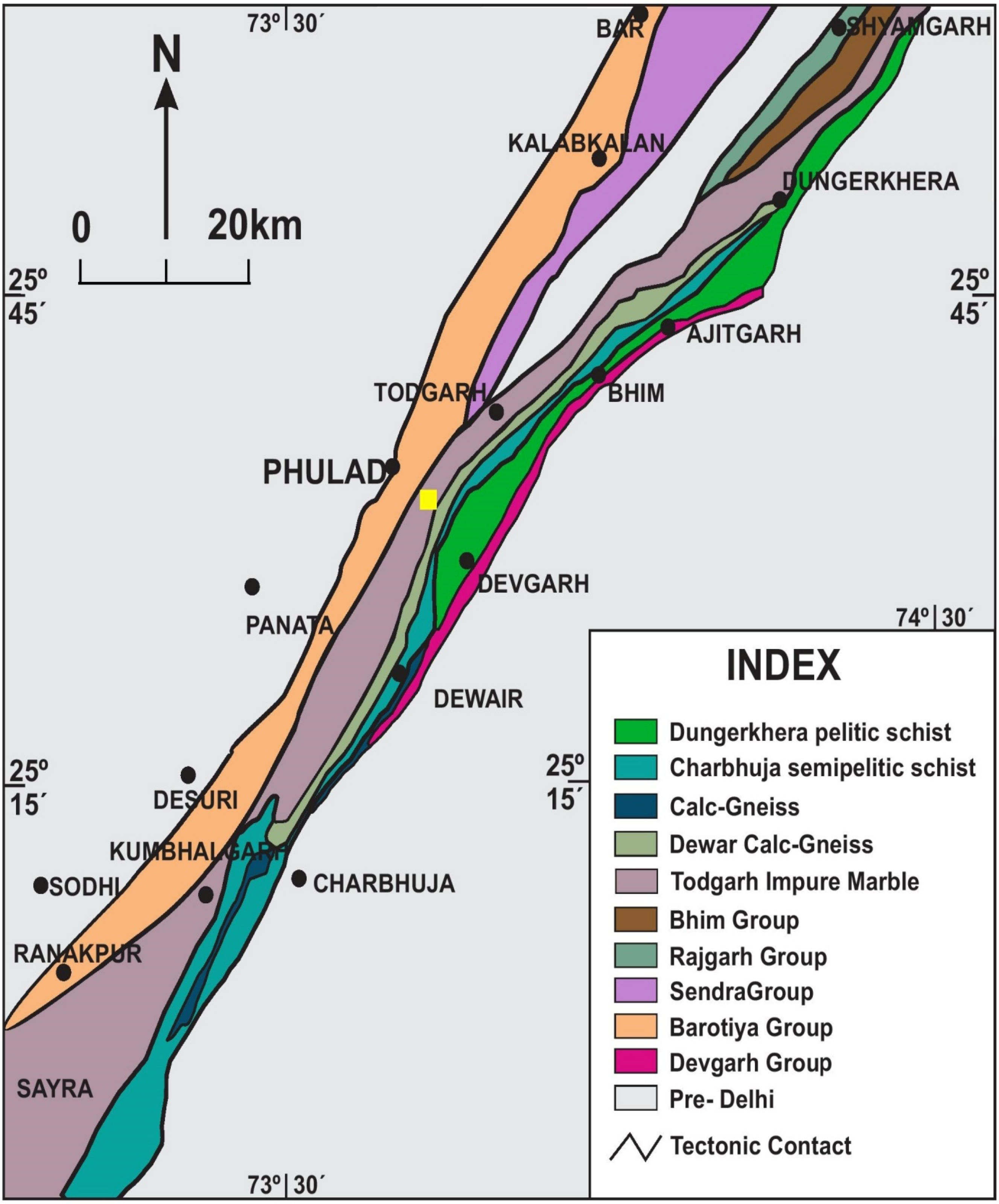

Fig 1.2: Lithological map of parts of Delhi Fold Belt, modified after Gupta et al., 1995. present study area is marked by square box (yellow coloured).

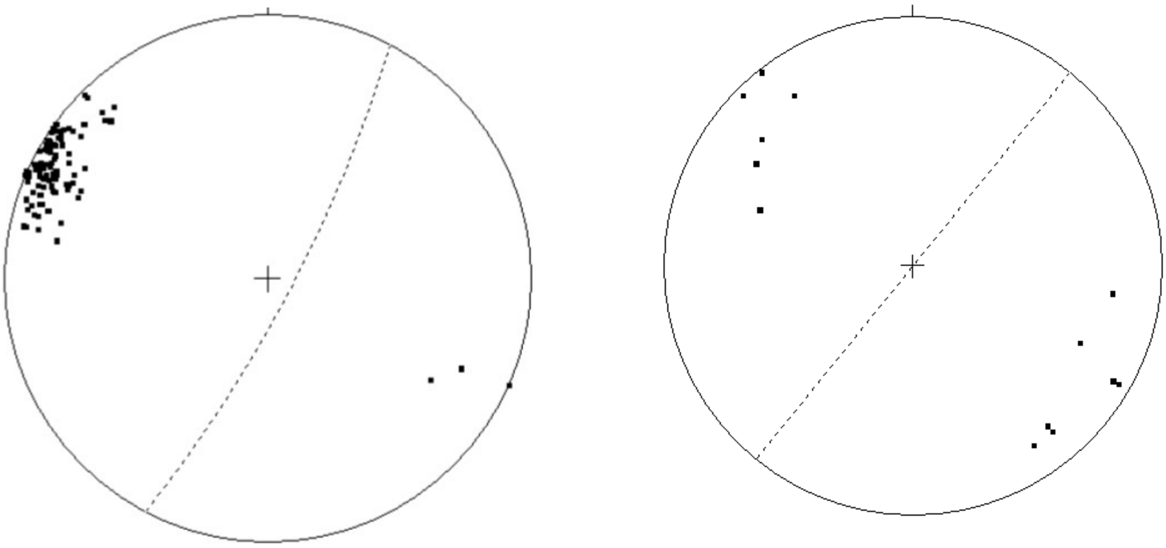

Fig: (A) Stereoplot of delhi fold belt. (B) Stereoplot of Gabbroic rock body

Fig : Field photograph of gabbroic rock.

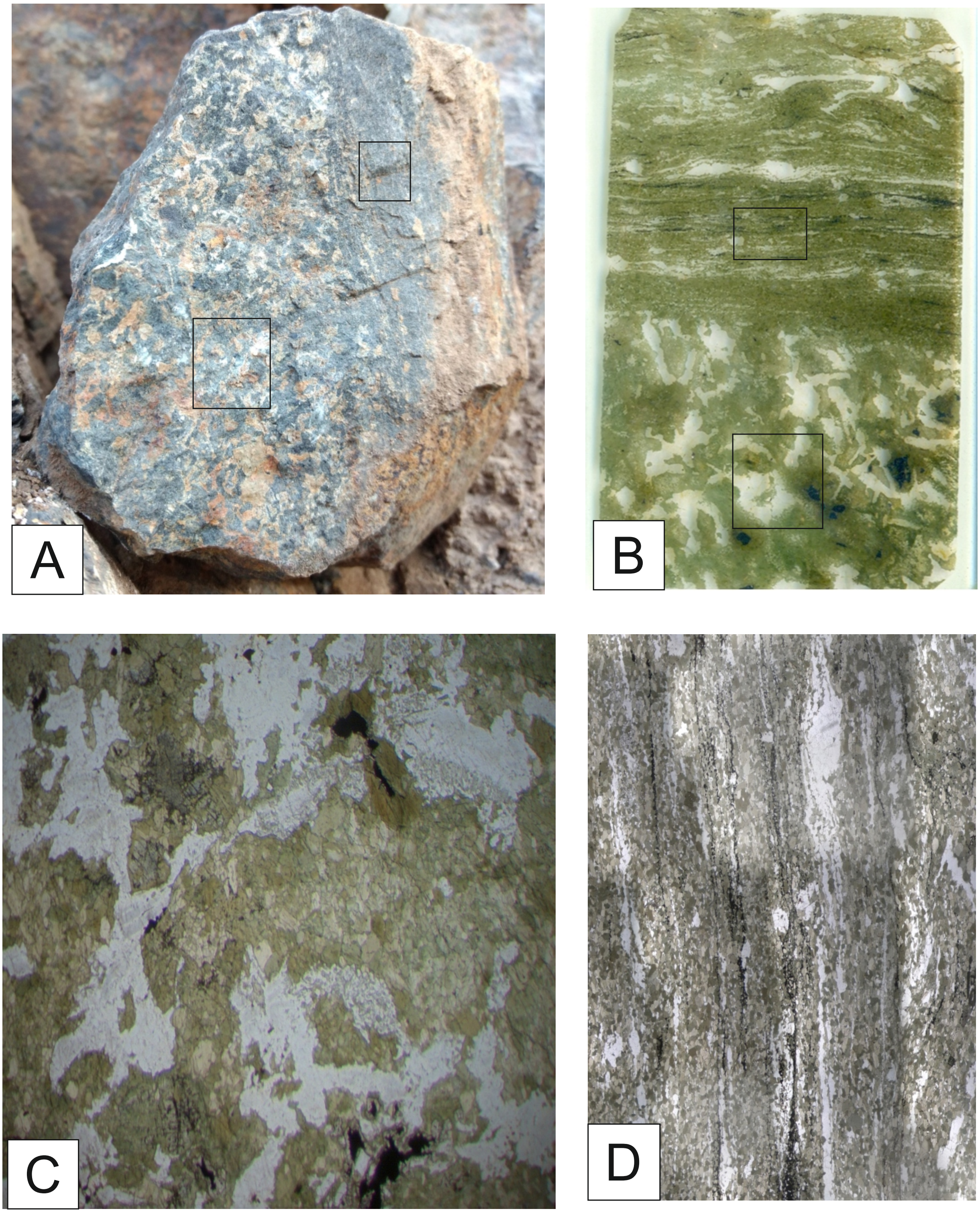

Fig :(A) Single rock sample showing strain variation in field photograph.(B) Thin section of the rock, (C) Photomicrograph of low strain domain under plane polarized light, (D) Photomicrograph of high strain domain.

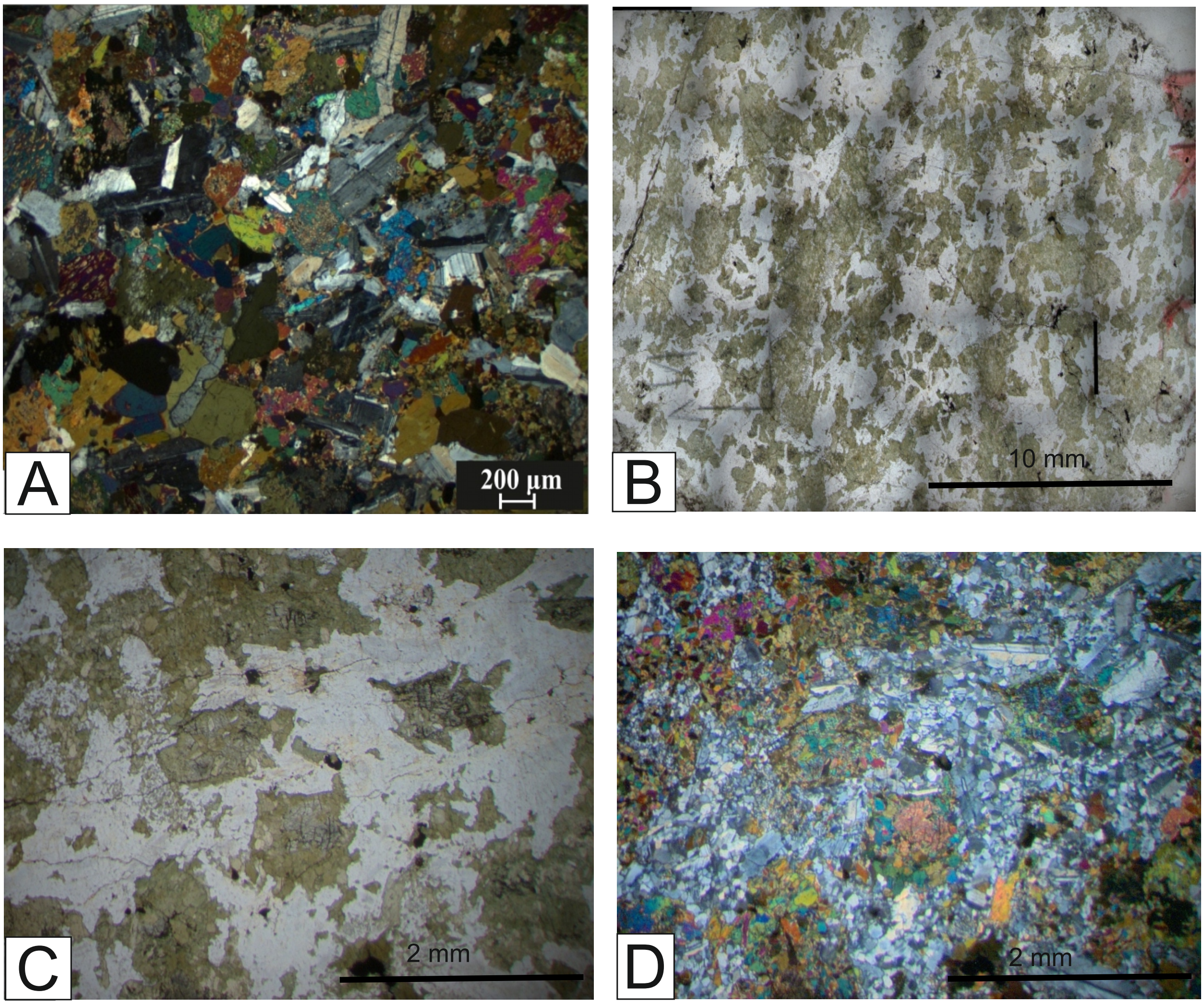

Fig : (A) Photomicrograph showing igneous texture under cross polarized light, (B) Photomicrograph of gabbroic rock sample under plane polarized light, (C)Photomicrograph showing contact relationship between clinopyroxene,amphibole and plagiclase.(D)Plagiclase lath and recrystallize plagioclase grain under cross polarized light

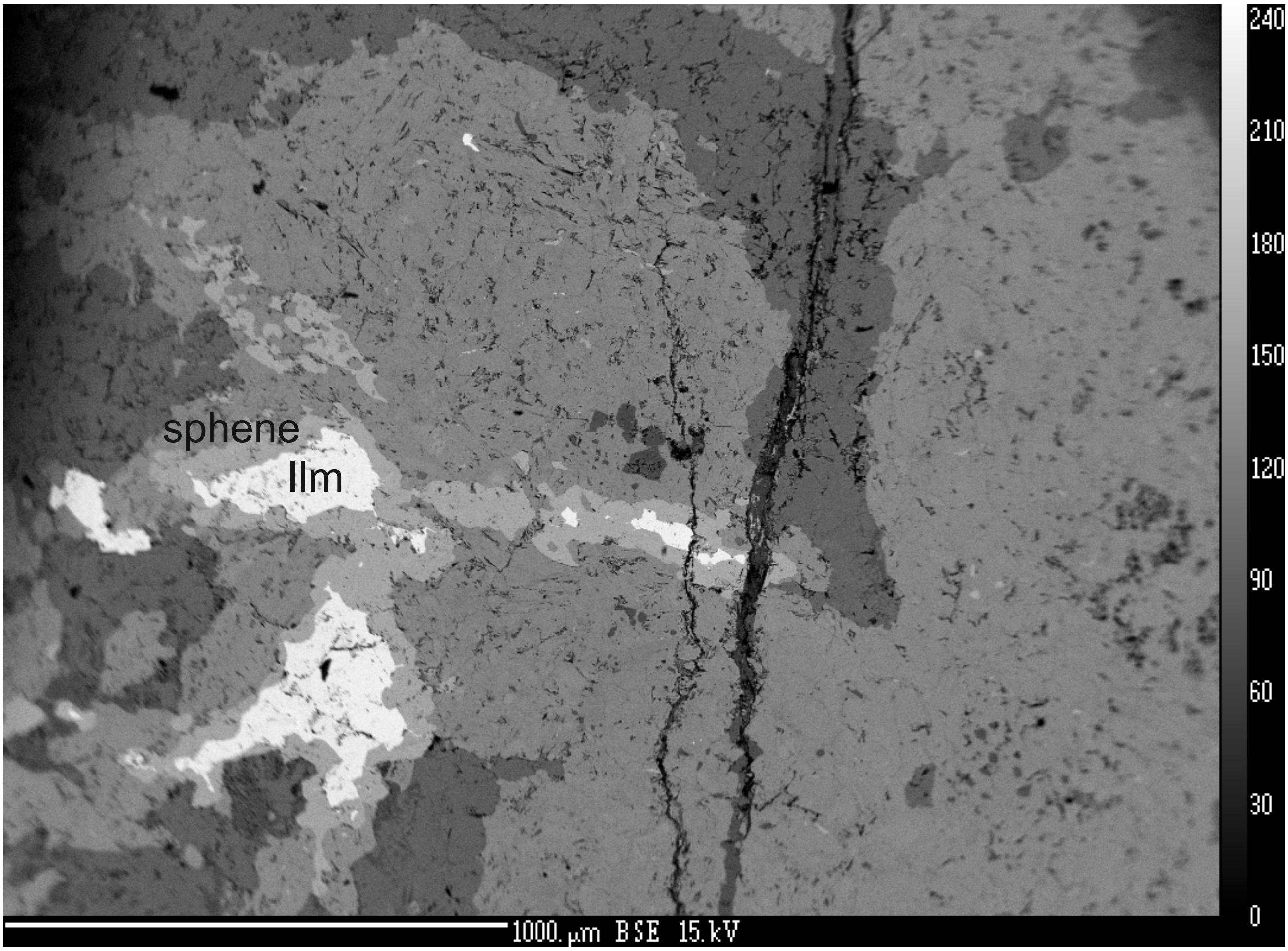

Fig : BSE image shows coronal texture of sphene around ilmenite grains

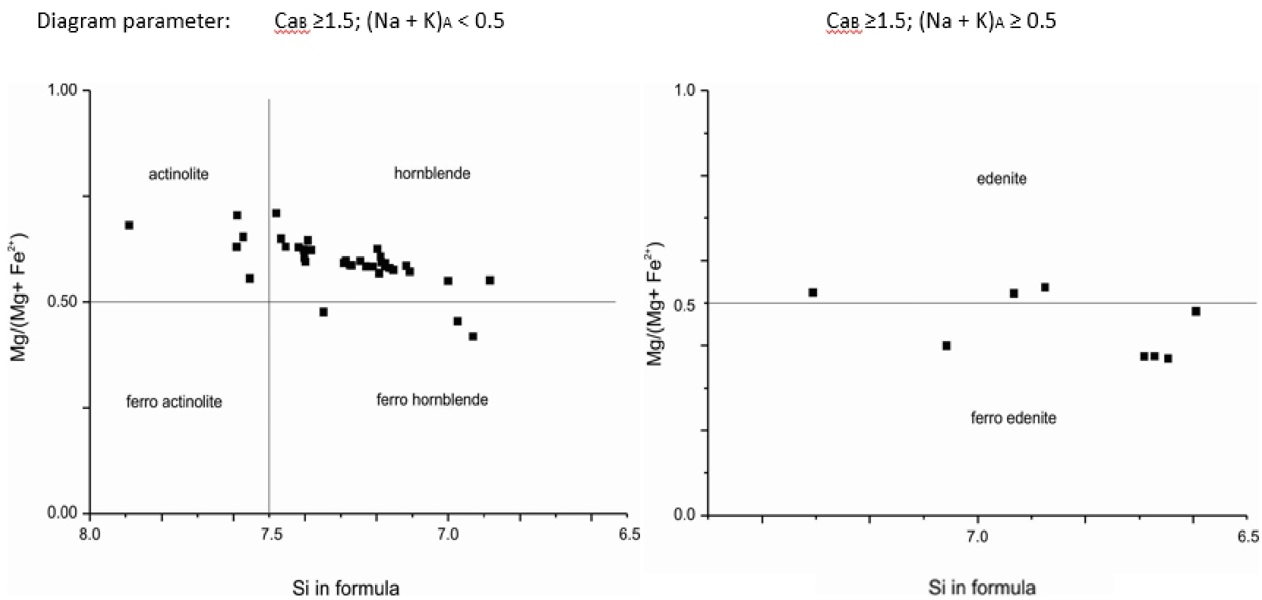

Fig :Classification of Amphibole of gabbroic rock of the study area using classification scheme of amphibole after Leake et al., References:

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