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Structural Architectures of Precambrian Metamorphites in and around Rongmil – Rongjeng Area, East Garo Hills Districts Meghalaya

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Abstract

The present work elucidates the Precambrian metamorphites in and around Rongmil-Rongjeng area in the light of their polydeformational episodes that witness four pfases of deformation showing multiple interference patterns in the ductlile to brittle fields. Field as well as microstructural study reveals that all the pre existing depositional fabrics have been affected by BD_1, the first phase of deformation under progressive metamorphic phase leading to the formation of most dominant, highly penetrative schistose and gneissose fabrics of rocks of amphibolites facies. The second phase of deformation, BD_2 forming NW-SE trending up and down facing folds of probable plane non cylindrical nature, was responsible for layer parallel shortening (buckling) of the mechanically active BS_0 and BS_1 fabrics in the NW-SE longitudinal compressive tectonics. The third phase folds, BF_3 refolded the earlier set of folds into non – plane non cylindrical nature and occur as non coaxial, open warp type gently plunging with near vertical axial plane striking NW-SE direction. BD_4, the fourth phase deformation is considered as brittle phase and represents the joints, fractures and fault structures.

Keywords: Metamorphites, Rongmil, Rongjeng, Meghalaya

1. Introduction

The Shillong plateau can be cited as a classic site of Indian Peninsular shield where Precambrian, Mesozoic and Tertiary rocks are exposed (Figure. 1). The Precambrian rocks are represented by BGG (Basement Gneissic Group) and overlying SG (Shillong Group of rocks). Quartzofeldspathic gneiss is the main component of BGG and they are often intercalated with high to medium grade basic metamorphites such as schists, amphibolites, granulites and calc-silicate rocks exposed partly in the northern part and mostly in the western part of the plateau. The SG comprises dominantly of metapelites (quartz sericite schist, garnetiferous mica schist) and quartzite along with Khasi greenstones and granite plutons listed above. The Mesozoic and Tertiary sequences girdle the south and eastern parts of the plateau. The uplift of the plateau is related to collision of the Indian and Tibetan plates during the Cenozoic period (Jhonsonand Alam 1991; Bilham and England 2001, Nandy 2001). The region is still active due to continued north to northeastward counter clockwise movement of the Indian plate against the Eurasian plate producing intense compressional tectonism (Harijan et al. 2003). Hence the structural configuration of the lithounits of the plateau is very important to understand the Tectonic history of the plateau.

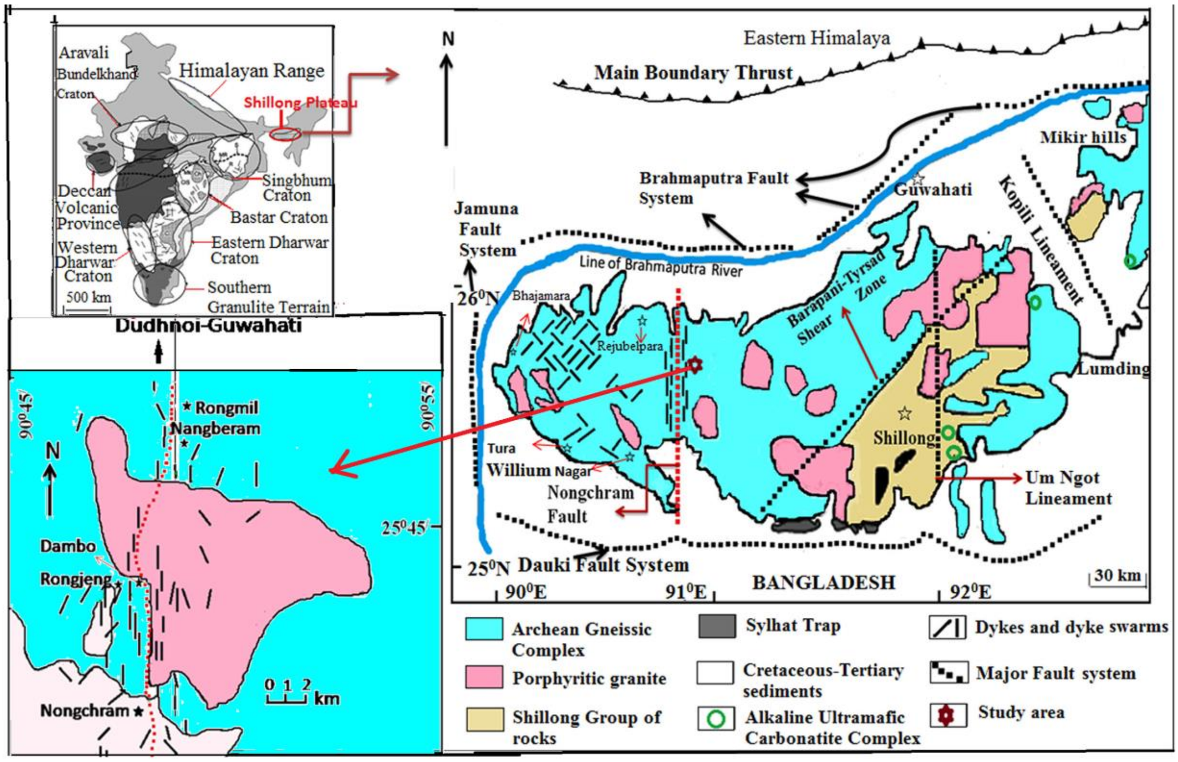


Figure. 1. Generalised geological map of Rongmil-Nangberram area and the Shillong Plateau as a whole showing different lithounits (modified after Devi 2020 and Srivastava and Sinha 2004, Rao et al. 2009). A generalised map showing different cratons of Indian shield (after French et al. 2008; Srivastava et al. 2008) is shown as inset (top left).

A number of workers have suggested a complex structural manifestation for BGG and SG showing evidences of superposed deformation and associated polymetamorphism Sarma and Dey (1997, 1998), Dey et al (1996), Maswood et al (1997), Sarma (2002) and Devi et al. (2002) from different parts of the plateau. But the Precambrian metmorphites comprising BGG of Garo Hills district is not studied in detail except a few (Barooah, B.C, 1972, 2009). The present work is the outcome of the structural studies of the Precambrian metamorphites exposed in and around Rongmil and Rongjen area of the East Garo Hills districts of Meghalaya.

2. Regional Geological Setting

The E-W trending Shillong Plateau, being tectonically separated from the rest of the Indian peninsula by the large scale Garo Rajmahal tectonic depression, represents the Precambrian cratonic block of NorthEastern Indian Region (NEIR) (Ermenco et al. 1969; Nandy 2001). The plateau is bordered by Brahmaputra lineament to the north, NE–SW trending Naga–Disang thrusted Schuppen Belt (Indo-Myanmar mobile belt, IMMB) to the east, E–W trending Dauki thrust to the south and Dhubri–Yamuna lineament to the west. Towards further ortheast the Plateau is again separated into two massifs namely Meghalaya Massif and Mikir Massif by NW–SE trending Kopili fault system (Evans 1964; Dasguptaand Nandy 1982; Acharyya et al. 1986, Figure 1). Besides the boundary faults, SP is crisscrossed by numerous lineaments in NE–SW, N–Sand E–W directions (Chattopadhyayaa andHashimi 1984). The entire lithologicalsetting of Shillong plateau is controlled by the Basement Gneissic Group (BGG) and Shillong Group of rocks deposited in the intracratonic Shillong basin. (Figure 1, Srivastava andSinha 2004; Devi and Sarma 2006, 2010; Sarma et al. 2014, 2015; Devi 2018). The Sylhet Traps, late Jurassic to Cretaceous sedimentary rocks and Tertiary sedimentary rocks are partly observed towards south, eastern and northeastern part of the plateau. Besides there are some dyke swarms being directionally parallel to the major tectonic structures.

The Precambrian metamorphites, the prime focus of the present study belong to Rongmil-Rongjeng area of East Garo Hills district towards the western part of the Plateau. Quartzofeldspathic gneiss, Migmatites, hornblende biotite schists, amphibolites, porphyritic granitoids and pink granites are the main lithologies of the BGG in the study area. The N–S trending deep seated Nongchram fault (Nambiar and Golani 1985; Nambiar 1987; Gupta and Sen1988; Golani 1991) is one of the major structural features of the area. Some mafic and alkaline dykes are observed to occur directionally parallel to this fault.

3. Structural Configuration and Sequences

The area has undergone multideformational episodes accompanied by polymetamorphism and reveals a variety of multi scaled planar, linear and folds structures. The greater part of the studied Precambrian complex is predominantly covered by a wide variety of quartzofeldspathic Gneiss (QFG) including grey gneiss and migmatites. Amphibolites, hornblende-biotite schist and calc silicate rocks occurring as bands and or enclaves are observed to be enclosed within the QFG (Figures.2A, B). Layers of mylonotic gneiss, augen gneiss and mylonites are restricted to certain narrow zone of high strain in QFG. Some parts of the area is mostly covered by porphyritic granite of Neoproterozoic age and they are mostly girdled by recent alluvial deposits. The gneisses are essentially quartzofeldspathic with quartz, feldspar (microcline), sodic plagioclase (An_{10}-An_{20}), biotite and rarely hornblende as essential mineral constituents. Amphibolites are medium to coarse grained and dark greenish black in colour. They are constituted dominantly by hornblende, plagioclase, quartz and subordinate amounts of biotite and garnet with epidote, sphene, zircon, apatite, and magnetite. Hornblende-biotite-schist differs from the amphibolites in lacking plagioclase. Calc silicate rocks intercalated with other metabasites are medium to coarse grained, dark brownish green in colour with lots of garnets and mafic minerals.

The generalised strike of BGG is NE-SW mostly dipping towards SE. It encloses large number of basic and acidic xenoliths, such as amphibolites, QFG, calc silicate rocks or hornblende- biotite-schist (Figs.2A, B, G, H, I). Intrusive porphyritic granite occupies about 40% of the area and is not deformed by ductile deformation. It is coarse grained and is characterized by the occurrence of large phenocryst of k-feldspar which exhibit preferred orientation (Figures. 2 C-D).

Utmost care was taken to build up the structural network of the area in spite of discontinuity of exposures either due to thick forestation or tectonic separation and/or attenuation was very common. The structural inhomogenity of the studied area can be broadly classified under four phases of deformation referred to here from oldest to youngest as D_1 to D_4. BGG is abbreviated with the prefix ‘B’ and thus deformations are listed as BD_1, BD_2 etc, folds as BF_1, BF_2, etc; foliation as BS_1, BS_2 etc and lineation as BL_1, BL_2 etc. The analysed structures developed during the various phases of deformation are as follows

3.1 Structural elements of First phase of deformation (BD_1)

The most prominent structural feature of the Precambrian complex of the area is a planar elemnt, defined by dominant banding and associated small tight folds (Barooah, 2011). The earliest recognisable planar structure BS_0 is deformed by the first generation of fold designated, as BF_1 which is tight to isoclinal in habit and has similar style and geometry. These folds are tectonically attenuated and torn out in the direction of tectonic transport and preserved as tectonic fish showing characteristic thickened hinge and thinned limbs. The regional foliation is axial planar to BF_1 fold (Figure. 2A). The BF_1 folds maintain high amplitude –wavelength ratio and the intrados curvature is normally greater than the extrados curvature. Such folds maintain intrafolial and isoclinals nature and usually marked by most competent rock units enclosed within the QFG. The sense of BF_1 varies from S-type (anticlockwise) to Z-type (clockwise) whereas at the fold hinges M and W types are observed (Figure. 2A). Such BF_1 folds with competent lithologies are floated within the ductile QFG host. The thin limbs of BF_1 show pinch and swell structures at places. Such BF_1 folds are of similar to modified similar in nature (class2 and class3 types of Ramsay, 1967) and are associated with a highly penetrative axial planar foliation (BS_1) which transect the BF_1 fold hinges at a maximum angle (50-65^0) but maintain near parallelism with the limbs of the BF_1 folds. The plunge of BF_1 folds is highly variable but confined within moderate to low angles either towards NE and /or SW. Intensive layer parallel shear couple on an initial litho setting (which is presumed to be near horizontal) leads to the development of total transposition of initial stratification (BS_0) in the form of discontinuous layers and lenses and the contemporaneous growth of the minerals resulting the dominant foliation, BS_1 (parallel to BS_0, Figure.3A-B).

The majority of BF_1 folds show large scale variations in the attitudes and have their axial planes showing moderate to low dips either towards NW or SE. This variation is apparently caused due to the effect of subsequent deformations, which control the present lithosetting of the area. The parallel orientation of platy and flaky minerals in the metabasites and QFG define the regional foliation (BS_1), while elongated grains or grain aggregates also define the foliation in the QFG at places. The mineral lineation, fold axes lineation, intersection lineation of BS_1 and BS_0, pinch and swell structures and boudin lineation are identified as BL_1, to $BD_{1.}$ BL_1 is dominantly of mineral type and they are deformed by subsequent deformations. Parallelism of some directional properties in the rocks such as parallel orientation of elongated flakes of mica mostly by biotite defines the mineral lineation in QFG. BL_1 is highly dispersive but mostly confined into the NE and SW quadrants at low to moderate plunge. In thin section study of the hinge zones of the BF_1 folds, nowhere platy and flaky minerals are bent parallel to the hinge curvature rather such minerals transect the curvature zone along the axial planar orientations.

3.2 Structural elements of Second Phase of Deformation (BD_2)

$BF_{2,}$ the folds of second generations is dominantly asymmetric but mostly upright to plan noncylindrical in nature and is characterized by long and short limbs, the longer limb being always gentle than the steep shorter limb. The plunge varies from 10 to 20^0 either due NE and /or SW and the axial planes dips towards NW at a steep to sub vertical angles. Fold morphology varies with competency of the rocks and in micaceous schists small scale crenulations are developed along the periphery of amphibolites. The intrados curvature is less than extrados curvature ($i < e$), which is more common to QFG. Such relationship is almost equal ($i = e$) in case of amphibolite layer. The F_2 folds are developed due to layer parallel shortening (LPS of Geiser, 1988) and the folded foliation(S_1) suffers from strain and developing extensional cleavage transacted at a low angle(<10^0) with respect to BS_1 foliation. Both dextral and sinistral habit of BF_2 can be seen and the BF_2 are sometimes similar in nature in incompetent rocks whereas they are concentric in competent units. The BF_2 folds are mostly non cylindrical in nature and show enechelon pattern especially in the incompetent schistose rocks. BS_2 invariably lie in the direction of axial plane foliation to F_2 folding and is non-penetrative in nature. The orientation of BF_1 and BF_2 being NE-SW is coaxial with little variation at places. In the case of close type of BF_2 folds in competent rock units, axial planar fracture cleavage is observed which is filled with quartz. In metabasites and quartzofeldspathic gneiss (QFG) strain slip cleavage or extension crenulations cleavage is identified and they are axial planar to the BF_2. BS_2 intersects BS_1 at high angle and sometime maintain coaxiality. Crenulation lineation, intersection of BS_1 with BS_2, BF_2 fold axis and orientation of vein quartz define BL_2, the lineation related to BD_2. Occasionally BL_1 and BL_2 usually plunging towards NE and/or SW show co-axial nature.

3.3 Structural elements of Third Phase Deformation (BD_3)

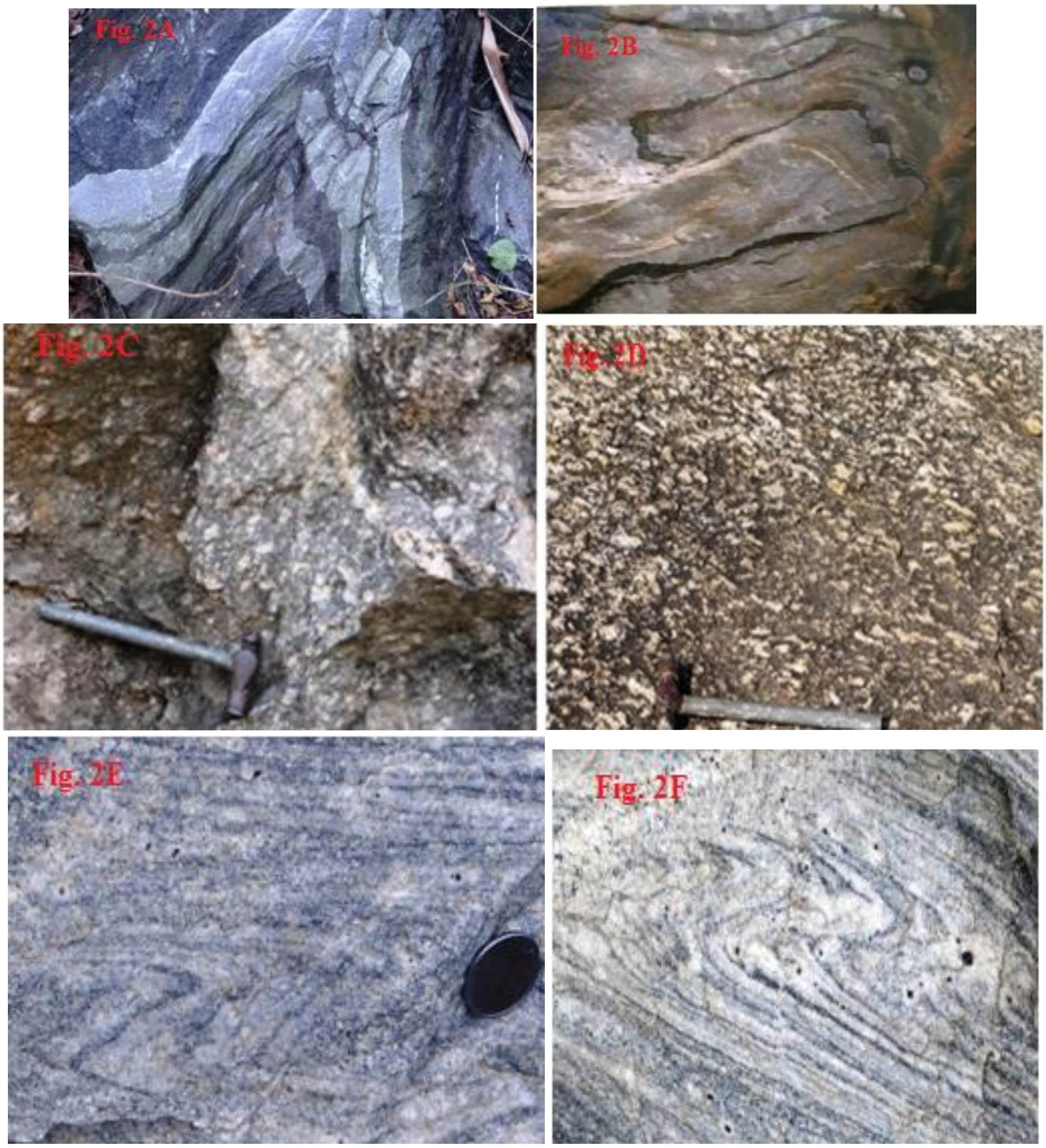
BF_3, the third generation folds deform all the earlier structures and are open and warp type in nature. The superposition between BF_1 and BF_3 and BF_2 and BF_3 results type 3 and type 1 interference patterns respectively. There is a notable asymmetric habit of BF_3 and they exhibit fold axes trending NW-SE and the axial plane dips towards SW at a moderate angle. Axial surfaces of BF_2 are often curved which is a diagnostic tool to suggest superposition of BF_3 folding (Figure. 2F). As a result of interference of BF_2 and BF_3 dome and basin interference pattern (Type I of Ramsay, 1967) are observed occasionally on handspecimen scale. BS_3 is axial planar to BF_3, non pervasive and trends NW-SE. BS_3 transects BS_2 at very high angle but BS_2 makes low angle with BS_1. BS_3 dips invariably towards SW at moderate angle. In incompetent rock crenulation cleavage is marked by orientation of pre existing flaky minerals while fracture cleavage is observed in the competent rocks. Fracture cleavage being parallel to the axial plane of BF_3 folds are considered post BF_3 or synchronous to BF_3. Some quartz veins and minor pegmatites are observed to follow the fracture cleavages. They are supposed to be connected with the emplacement of granite in the area. Crenulation lineation (BL_3), which corresponds to that of BF_3 fold axes, shows northwest and/or southeasterly plunge, at a moderate to low angle. BL_3 is superposed over earlier lineation. Plots of the above lineation (BL_2 and BL_3) are shown Fig. 3D and BL_2 plots show maxima in NE and SW quadrants and BL_3 in NW and SE quadrants.

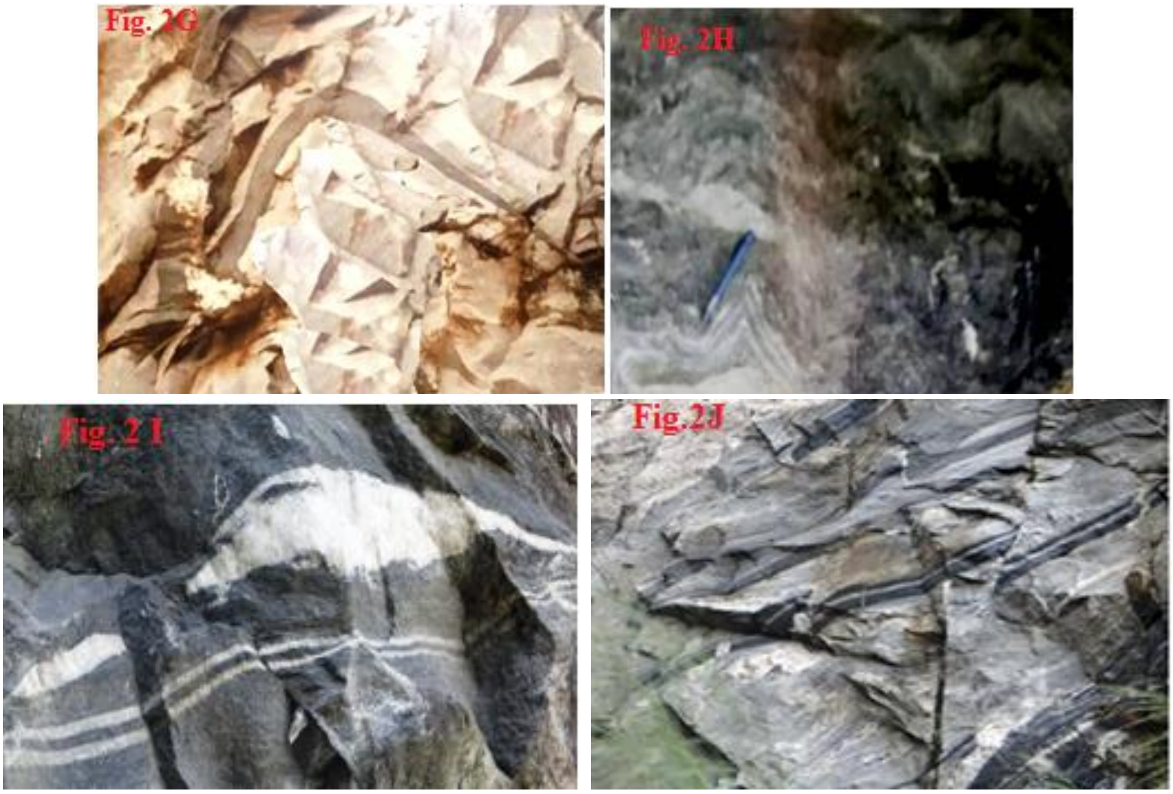
3.4 Structural elements of Fourth phase of Deformation (BD4)

The fourth phase of deformations such as joints, minor faults and kink and fault bend folds are of the latest phase of deformation. Most of the minor faults having NE-SW trending fault planes with dextral geometry are of contraction type (Figure.2J). Minor shear fracture as well as longitudinal joints, conjugate shear joints, transeverse joints are common. Along the separation zone of folded boudins ternding shear planes minor pegmatitic materials were emplaced at a high angle to the regional foliation.

4. Summary and conclusion

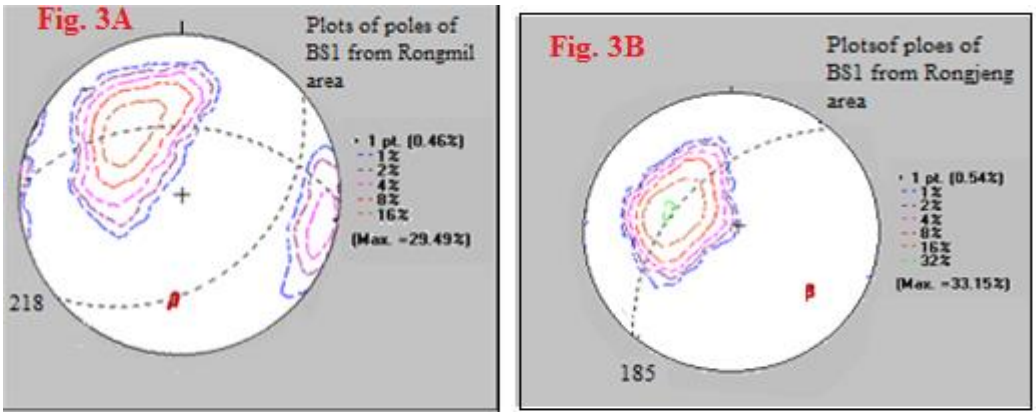
The present structural configuration of the Precambrian metamorphites of the area is largely the results of multi deformational events. Based on field relationships of the BGG in terms of cross cutting of the associated penetrative and non penetrative planar fabrics as well as fold interference, ploydeformational episodes associated with metamorphism can be delineated. BD_1 deformation leading to the development of rootless and tight isoclinals folds (BF_1) floated on the ductile matrix was supposed to be accompanied by regional dynamothermal metamorphism of under amphibolites facies condition. The dominant foliation BS_1 is axial planar to BF_1 fold and the contemporaneous lineation BL_1, is essentially parallel to the BF_1 fold axis. Boudins, pinch and swell structures might have developed at a late stage of BF_1 folding. BD_2 metamorphic event indicate retrograde phase of greenschist facies. BS_1 has been transposed by BS_2 along strain zones making an angle less than 10^0. The earlier fabrics have been deformed by **BD_3** and as a result open and warp type BF_3 folds are developed throughout the area and was followed by the emplacement of porphyritic granite. Evidences of greenschist facies metamorphism are recorded by chloritization of hornblende, biotite and garnet and they are contemporaneous to the BF_2 and BF_3 folding episodes. **BD_4,** the fourth phase deformation representing the joints, fractures and fault structures is considered as the manifestation of brittle deformation. Kink folds and fault bend folds were also developed during **BD_4**. The minor faults developed during this deformation are mostly of dextral reverse type or sinistral normal type.

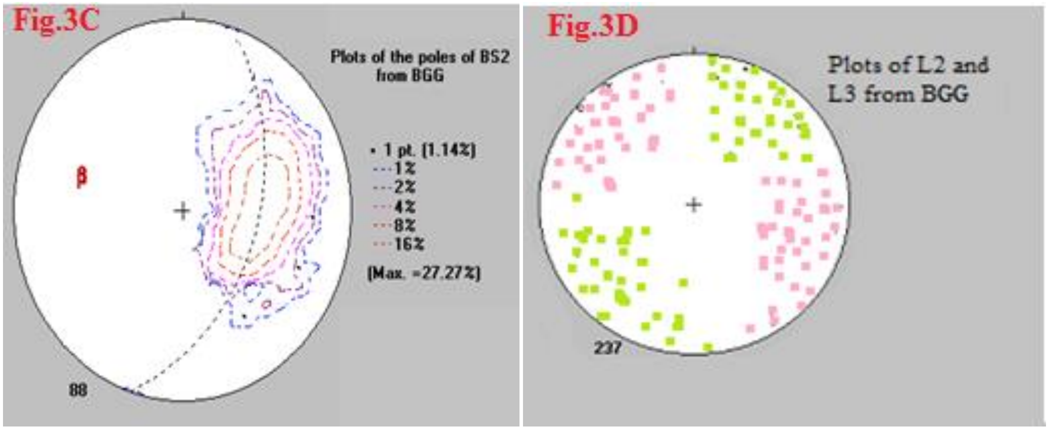




Figs. 2A-H: 2A. Folded dark and white layers in Quartzofeldspathic Gneiss (QFG), Location: Damra, 2B. Folded (M & W types) layers of metabasite enclosed within QFG, Location: Nangberram, 2C. Porphyritic granite, location: Rongmil village, 2D. Porphyritic granite showing the flow habit of feldspar phenocrysts, Location: Rongmil village. 2E. Z-type of folds in QFG, Location: Nangberram. 2F. Axial plane of tight F_2 folds is deformed by another deformation forming F_3 fold of open warp type, These F_2 folds can be differentiated from F_1 folds with the help of S_1 which is folded, Location: Rongmil.. 2G. F_2 fold of upright nature is marked by layer of amphibolites, Location: Nangberram. 2H. Symmetric angular folding marked by quartz vein. Locality; Rongjeng.

2I. Tectonically attenuated and boudinised quartz vein in metabasite forming lenses, Location:Rongmil. 2J. Outcrop scale reverse fault displayed by layers of metabasites.





Figs. 3A-D. Stereoplots of planar and linear structures in BGG. BL_2 plots show maxima in NE and SW quadrants and BL_3 in NW and SE quadrants.

The geometrical relationship observed between BF_1 and BF_2 folds suggest that the Layer Parallel Shear (LPS) were developed following NW-SE compression stress that induced a stage of strain partitioning. The LPS components of contraction deformation resulting up and down facing folds on mesoscopic scales control the present lithosettings of the area.

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