Petrography and Provenance of Surface Barail Sandstones, Kohima, Nagaland, India

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***Abstract*-Geological domains in North-Eastern India evolved though time after the rupture of the Gondwanaland. Collision of the Indian and the Burmese plates took place during the middle part of Cretaceous. Evolution of the Palaeogene Barail trough, Neocene Surma and Tipam Groups took place gradually. The Barail trough originated at the active margin of the Indo-Burmese plate convergence. The present study evaluates the petrographical studies of sandstone samples from Barail Group occurring in Kohima, Nagaland. It provides informations about mineralogical variations, and provenance of the area. Through the modal analysis it is clear that the sandstone samples fall mostly in the field of Quartz arenite, and point out a continental block provenance field. Framework grains are sand-sized to silt-sized particles of mainly detrital origin. The most common detrital grains are monocrystalline quartz (39.0-58.0%); polycrystalline quartz (1.8-9.6%); K-feldspar (2.7-7.2%); plagioclase (1.4-8.5%); collophane (0-3-3.1%); muscovite (0-1.5%); lithic fragments (2.1-10.4%); heavy minerals (trace). Lithic fragments are predominantly highly siliceous and finely textured. Among the main detrital framework grains, quartz constitutes. Sandstones encountered in the studied Sections have been classified as Quartz arenite, Laminated siltstone, Argillaceous Silstone and Lithic Glauconitic arenite in order of abundance.Further this study supports a humid climate during the deposition of the Barail Group of sediments.**

Keywords- Barail, Sandstone, petrography, provenance, Kohima, Nagaland

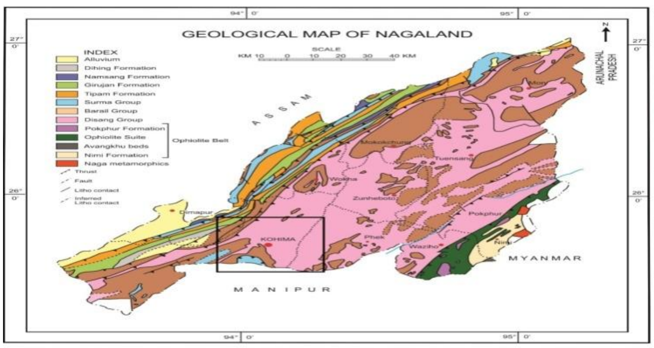
I. INTRODUCTION

The Indian and the Burmese plates collided at around Middle Cretaceous. The shelf, peripheral- and the tectonic basins came closer to one another during the Late Eocene [12]. The Barail through, Surma Valley, the Bengal Basin and the Cachar-Tripura-Mizoram Fold Belt gradually evolved in the north-eastern part of India under the influence of compressional regime through time [3], [7]. The basal part of the Barail Group has a gradational (with local tectonic) contact with the Disang Group.This gradational contact is related with a gradual change from dominantly argillaceous deep marine to a mainly arenaceous shallow marine depositional environment [9]. Geologically, there are three distinct morphotectonic units in Nagaland, the Ophiolites and related sediments in the east, Schuppen belt in the west and the Inner fold belt in the middle [13]. Except for Disang Group of rocks; all other Cenozoic lithostratigraphic units are found in the Schuppen belt in thrusted blocks, whereas presence of Disang and Barail Group of rocks with minor Surma sediments characterize the Inner fold belt which is occupied by two synclinoria, the Patkai synclinorium to the north and Kohima synclinorium to the south. The rocks of Nagaland in Kohima synclinorium occur in NE-SW trending linear belts. The study area lies in the western part of the synclinorium. A number of folds with different style and geometry characterize the area and suggest multiple episodes of deformation. In addition, there are faults traversing the study area.

II. GEOLOGY OF STUDY AREA

The study area (94°05'45" N and 25°39' 34"E) that forms a part of the Kohima synclinorium is comprised of Cretaceous to Eocene Disang Group of rocks (dominantly argillaceous), followed by the Disang- Barail Transition [14]which in turn passes gradually into the Oligocene Barail Group of rocks (dominantly arenaceous, Fig.1). The Barail sandstones of the study area are light grey to grey in colour and possess fine to medium- grained character with occasional shale intercalations. The sedimentary structures observed in these rocks include bifurcating ripples, planar cross beddings, small scale channels, pinch and swell structures and bioturbation. At places intensive bioturbation has imparted mottled character to the sandstones.

Fig no 1: Geological map of Nagaland and Locations of the Study area



III. MATERIALS AND METHODS

Among the collected samples, Ten selected sandstone samples were studied from the different locations of Quarry section A1-A10. Thin sections were prepared by vacuum impregnation with blue- dyed resin prior to cutting and grinding to a standard 30 m thickness. An Olympus BX50F4 microscope with Coolpix 990 Nikon automatic camera attachment was used for petrographic analysis. Compositional percentages of samples were based on 300-point modal analysis. In order to differentiate major provenance categories the QFR, QmFRt and QtFRt triangular diagrams were used.

IV. PETROGRAPHY

Petrography suites of sandstone provide information about the nature of source rocks, the uplift history and evolution of orogenic belts. The main assumption behind sandstone provenance studies is that different tectonic settings contain their own rock types, which when eroded, produce sandstones with specific compositional ranges, used the frequency of different types of quartz grains to infer the type of source rocks. Thus, simple petrographic descriptions of different quartz constituents can be utilized for this purpose. In the present study compositionally, the sandstones are sublithic wackes, lithic arenites, and sublithic arenites in a modified [6] classification.

The Barail Tertiary sandstones consist predominantly of moderately indurated, and sorted, fine-grained type showing predominantly subangular sand grains. Based on point-count data (10 samples), the following framework grains are present (in vol% of the total rock): monocrystalline quartz (39.0-58.0%); polycrystalline quartz (1.8-9.6%); K-feldspar (2.7-7.2%); plagioclase (1.4-8.5%); collophane (0-3-3.1%); muscovite (0-1.5%); lithic fragments (2.1-10.4%); heavy minerals (trace). Lithic fragments are predominantly highly siliceous and finely textured. The original nature of these lithics is dominantly siltstones and mudstones. Four petrographic types are identified: Quartz arenite, laminated siltstone, Argillaceous siltstone, Lithic Glauconitic arenite. Among these Siltstone dominate the petrographic types. The identified petrographic types are described below following [6] scheme of classification of sandstones.

Table no: 1 Modal Percentages of Quartz, Feldspar and Rock fragments of Barail Sandstones and Undulose Quartz, Non Undulose Quartz, and Polycrystalline Quartz.

SI.NO	Sample No	Quartz (Mono+Poly)	Feldspar (Plag+Micro)	Rock fragments	Sl.No	Sample No	Quartz Undulose	Quartz Nonundulose	Quartz Polycrystalline
1	A1	97.321	0	2.925	1	A1	10.886	73.625	12.81
2	A2	95.68	0.125	4.216	2	A2	13.08	66.34	16.26
3	A3	96.21	0	4.645	3	A3	12.25	69.13	14.83
4	A4	96.395	0	3.295	4	A4	10.625	69.89	15.88
5	A5	95.925	0	4.298	5	A5	12.665	69	14.26
6	A6	96.354	0	3.646	6	A6	10.677	69.792	15.885
7	A7	95.642	0	4.358	7	A7	13.074	66.313	16.495
8	A8	95.257	0.593	4.15	8	A8	12.846	67.984	14.427
9	A9	96.93	0	3.07	9	A9	14.181	67.544	15.205
10	A10	97.232	0.369	2.399	10	A10	13.395	67.898	15.242

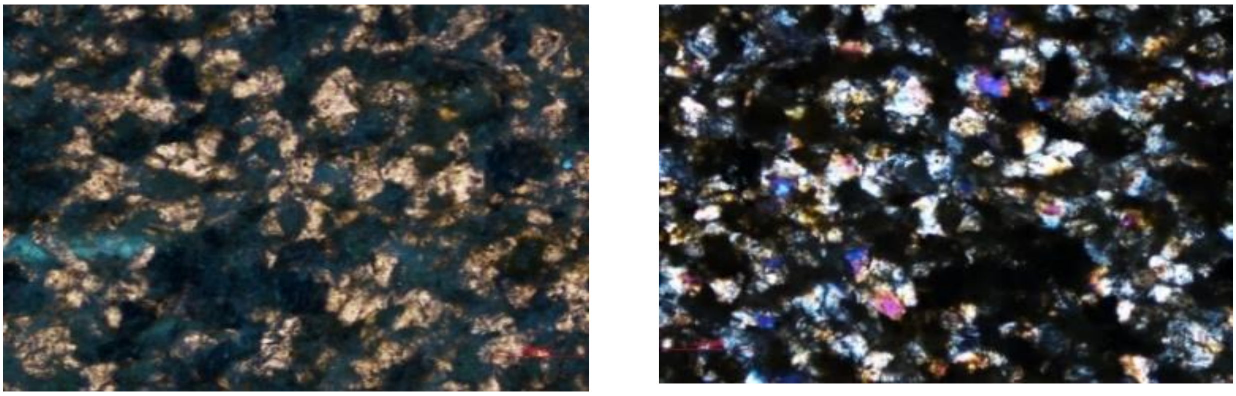


Fig no: 2 Photomicrographs showing petrographic type rich in fine-medium size sub angular quartz grains and feldspars are found.

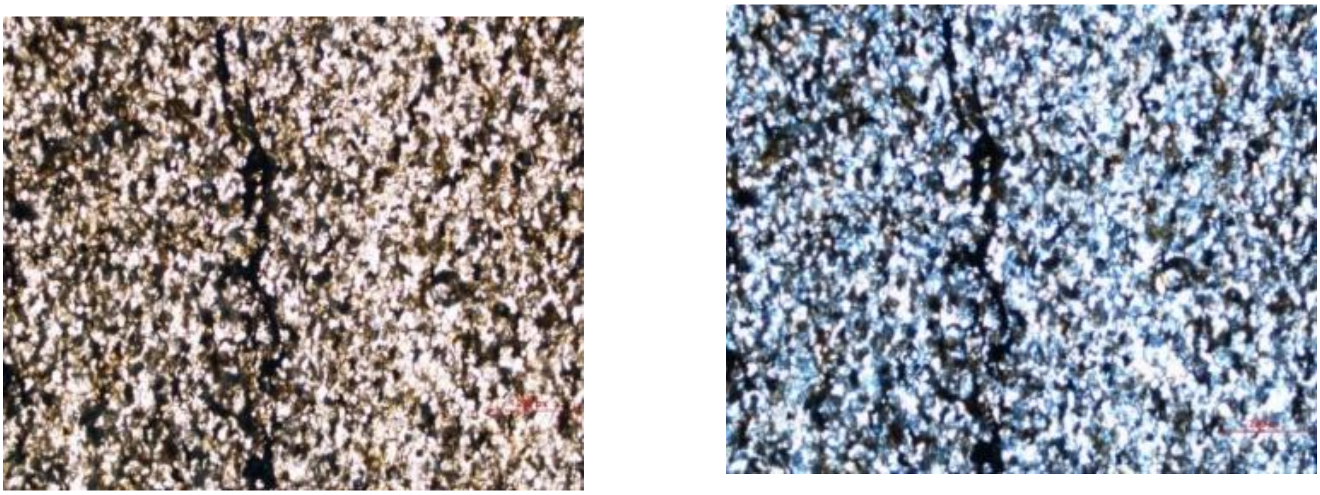


Fig no:3 Photomicrographs showing for alternate layers of coarse silt and thick clay layers and fine alternate layers of fine silt and shale layers as revealed in the petrographic type.

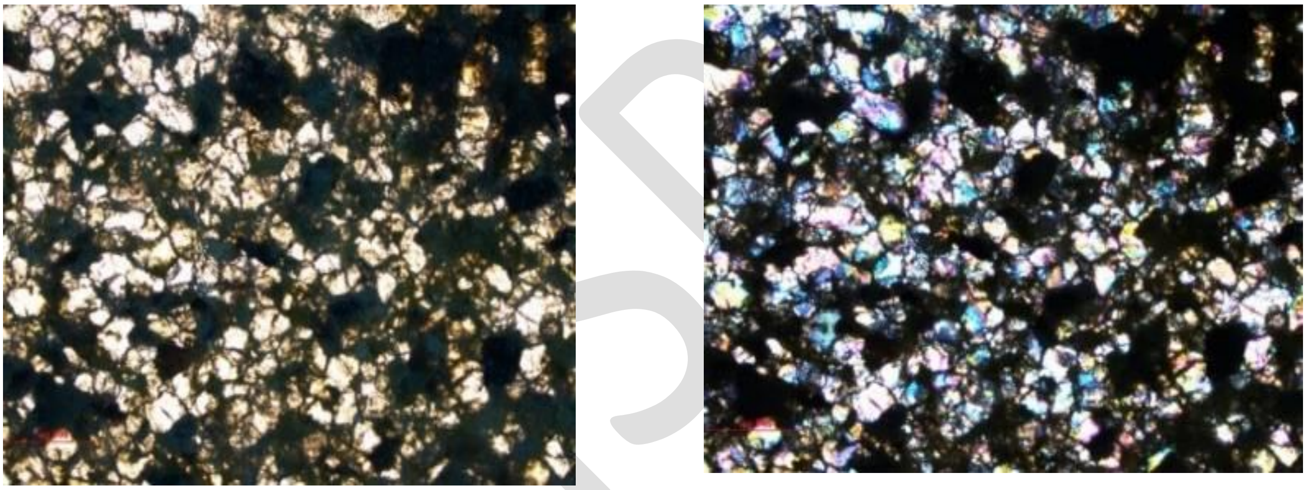


Fig no:4 Photomicrographs showing for angular silt size quartz showing tight packing, and argillaceous matrix acts as a cement.

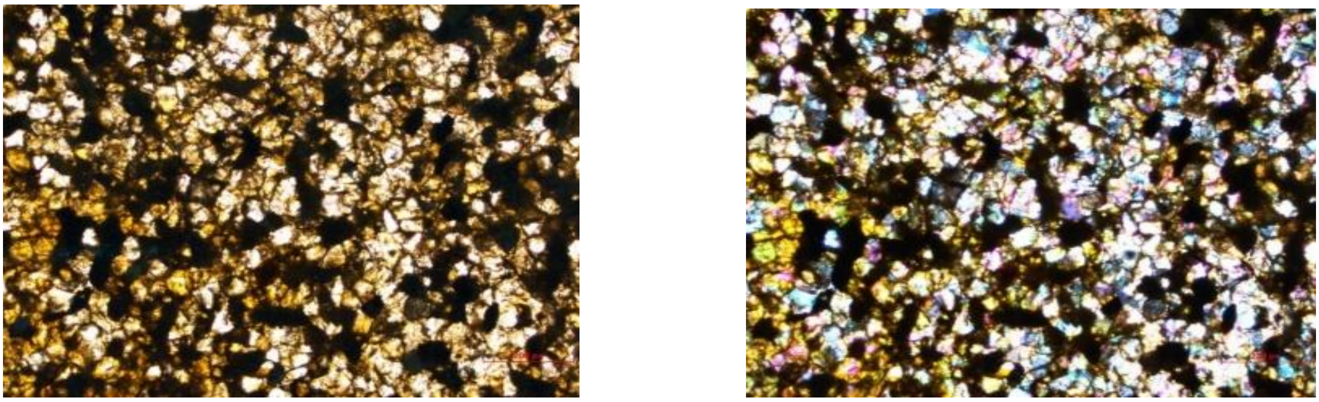


Fig no:5 Photomicrographs showing for petrographic type exhibits sub angular medium size quartz grains along with glauconite pellets cemented in argillaceous material.

A. Quartz Arenite : It is quartz rich and many of the quartz grains are medium to fine and angular shape. Feldspars are found. However there are no in situ bioclasts and most probably these reworked bioclasts were eroded and transported from the underlying Disang shale. Perhaps all those detrital feldspars have been diagenically altered to clays.

B. Laminated Siltstone: It is rhythmically deposited alternate layers of quartz rich silt layer (white colour) alternate with silty clay layers. Fine silt size quartz grains are highly angular. They are tightly packed and compacted and unfossiliferous. It also encloses few shale lithic fragments. Many silt size quartz grains are linear in shape suggesting their derivation from metamorphic source. They are found aligned parallel to flow lines during deposition. The shale fragments are some angular and some linear in shape.

C. Argillaceous Siltstone: The framework grains are assorted, but quartz rich fine grains. Few lithic fragments of shale (fine size) are seen scattered. Quartz silty grains are highly angular. Some silt size quartz grains exhibit linear shape, but angular. These linear grains align themselves parallel to flow lines. The green colour is imparted due to the presence of chlorite mica and glauconite pellets. One or two ferromagnesian heavy minerals are also observed. In certain sections the mica flakes are bent suggesting a moderate to deep burial diagenesis. This is also corroborated by the presence of penetrative quartz grains, even though they are fine grain size. Some silt rich sections point out tight packing of clasts.

D. Lithic Glauconitic Arenite: It is fine grained quartz rich rock. Several shale and siltstone lithic fragments are observed. There is a drastic reduction of argillaceous material. No feldspars could be identified. Quartz grains are subrounded to subangular. Quartz grains are both undulated and extinct types. Quartz grains reveal penetrative characteristics with adjacent grains prompting to conclude that this rock type was subjected to deep burial diagenesis. Quartz grains also reveal concaco-convex as well as long contacts. Few green colour pellets found scattered around are glauconitic types. This petrogrpahic type is unfossiliferous. It is moderately sorted and tightly packed and compacted rock. Cement is argillaceous material. Overall these petrographic types reveal a shallow upward sequence. Cement is clay rich fine material.

V. MODAL ANALYSIS AND MINERALOGICAL CLASSIFICATION

Modal composition of Barail Sandstone samples, and their plots using three members of quartz, feldspar and rock fragments following [14], [8]) and [10], has helped to classify the sandstones. Prior to plotting the necessary components, quartz, feldspar, and rock fragments were recalculated to 100%, neglecting matrix cement and other detrital minerals. 10 representative samples are selected for modal analysis. The modal composition of the Barail Sandstone of Quarry samples in Nagaland (Fig no:6). Among the framework grains, quartz is the most abundant constituent. Majority of quartz grains are subangular to sub- rounded. A few well rounded grains are also seen. Non-undulatory quartz grains dominate over undulatory quartz. Rock fragments rank second after quartz but it is very less. In the case of feldspar it is present in negligible amount (Fig no: 6-Fig no:7).

VI. FRAMEWORK COMPOSITION AND TECTANO-PROVENANCE

The mineral composition is presumed to reflect the tectonic history of the source area, and the site of deposition as conceptualized by [11], in [15].. The proportions of detrital framework grains when plotted on triangular diagrams using the three groups such as QFR, QmFRt and QtFRt provide a powerful tool in interpretations of plate interaction of the geologic past. In the triangular plot of [14] using the Barail Sandstone samples fall mostly in the in the field of Quartz arenite types and some samples show Sublithic arenite types also (Fig no: 6). Triangular plots of QFR [10], show the sandstones are Quartz arenite (Fig no:7) .Ternary diagram of [8]clearly indicate that the samples fall in Quartz Arenite types (Fig no: 8).Further other plots illustrated in clearly point out a continental block provenance field [4],(Fig no:10). QmFRT plot of [5] (Fig no:11) also corroborates a tectonic setting of continental block provenance for the Barail Sandstones.

VII. PALAEOCLIMATE

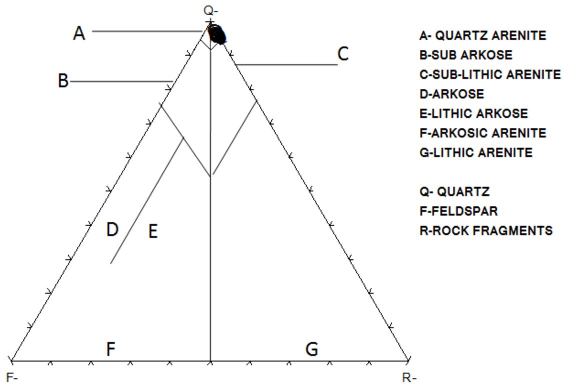
Climate affects sand composition through its influence on pedogenic process which brings about parent rock destruction, and the framework mineralogy is a reflection of it. The ratios of feldspar+ lithic fragments to polycrystalline quartz or to total quartz are sensitive indicators of climatic heritage of sand. This climatic signature is preserved in the sand when they were deposited [17].

The QFR triangular [5],indicate largely a hot humid to humid climatic condition for the samples .Bivariate Log-Log plot (the ratio of polycrystalline quartz to feldspar+ rock fragments against the ratio of total quartz to feldspar+rock fragments) for interpretation of palaeoclimate from Barail Sandstone samples, [17], most of the samples sweep across the field of humid climate .(Fig no:15)

VIII. PROVENANCE

Quartz is the most dominant detrital grain in the study area. From the petrographical studies of the sandstone samples, it has been observed that the sediments were derived mostly from granitic terrain and metamorphic schist. The constituent clastic quartz grains indicate their derivation from dual sources (or provenance) (Fig no: 13). Monocrystalline quartz indicates their derivation of sediments from intrusive igneous rocks. Predominance of unit quartz and undulose quartz is indicative of low rank metamorphic, and plutonic sources of variable pressure effects [1].

Studies of intercrystalline boundaries, crystal size, shape and sorting within polycrystalline grains are potentially useful in source rock identification [2]. Composite quartz with straight boundaries on the other hand point out a plutonic igneous derivation. Qun-Qnun-Qp ternary plot of detrital quartz suggest plutonic source.



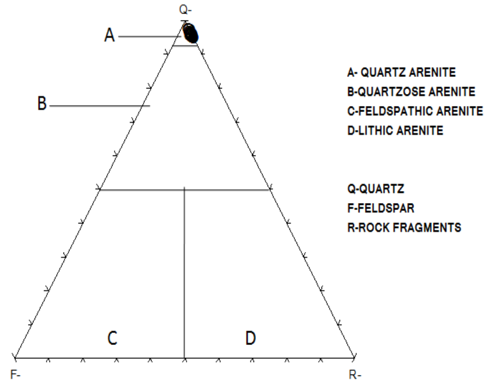
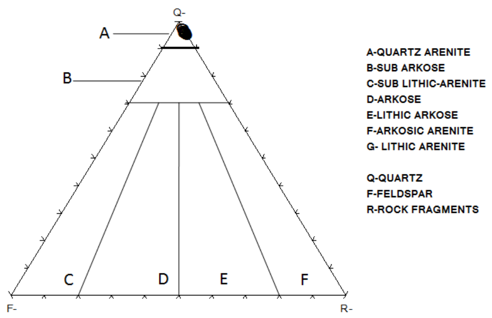


Fig no: 6,&7 Triangular plot of QFR of the Barail Sandstones(after pettijohn et al.,1972 and after James et al., 1986).

Fig no: 8 & 9 Triangular plot of QFR and QFRt of the Barail Sandstones(after Folk et al.,1980 and after Dickinson et al., 1985)



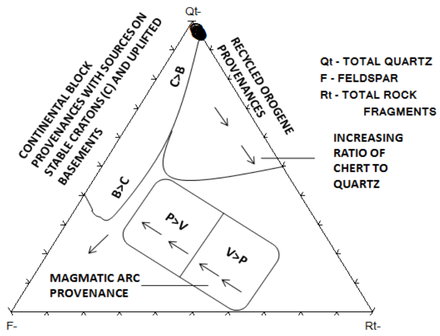
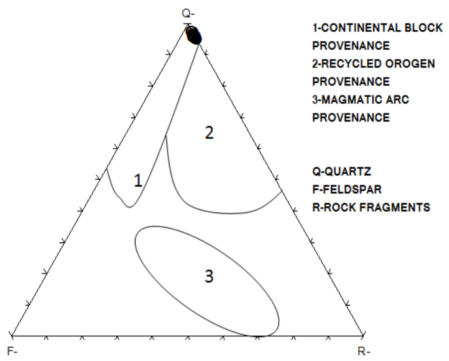


Fig no:10 & 11 Triangular plot of QFR and QFRt\ of the Barail Sandstones(after Dickinson and Suczek, (1979) and after Dickinson et al., 1983)



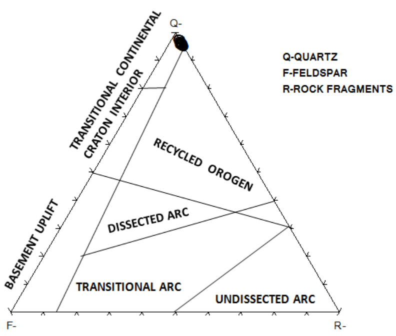
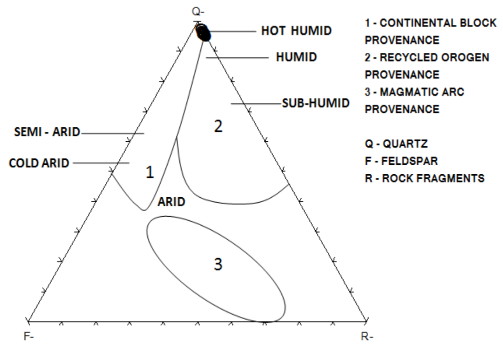
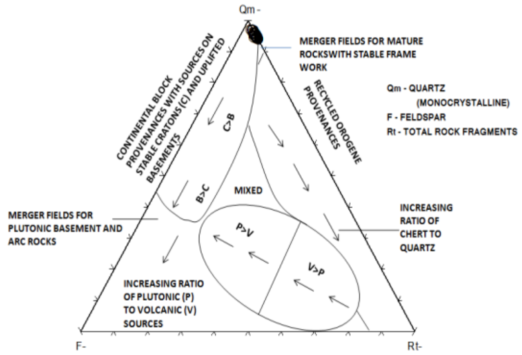


Fig no: 12 & 13 Triangular plot of QFR and QmFRt of the Barail Sandstones(after Dickinson.,1985)





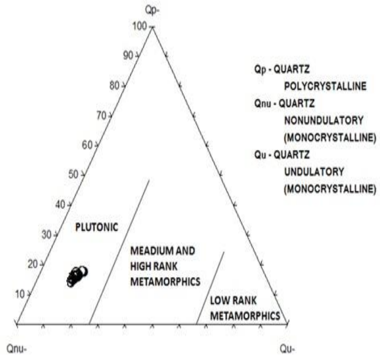


Fig no: 14 Triangular plot of detrital quartz types of the Barail Sandstone (after Basu et al., 1975).

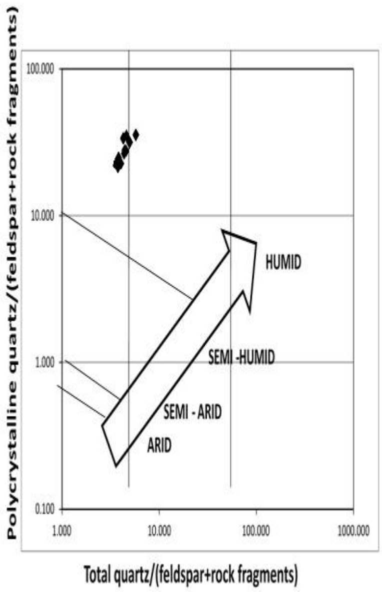


Fig no:15 Bivariate Log-Log plot of the ratio of polycrystalline quartz to feldspar+rock fragments against the ratio of total quartz to feldspar + rock fragments for interpretation of palaeoclimate from the Barail Sandstones samples (after Suttner and Dutta, 1986).

IX. RESULTS AND CONCLUSIONS

In all the Four petrographic types identified: Quartz arenite, laminated siltstone, Argillaceous siltstone, Lithic Glauconitic arenite. Among these Argillaceous Siltstone dominate in the quarry sequence. Field observations of facies distribution and petrographic identification of siltstones, lithic wacke and medium grained arenites are all correlatable. The presence bent micas, tight packing of clasts all point out a moderate to deep burial diagenesis. The reworked bioclasts of planktic foraminifera were derived from the deep water deposited underlying Disang shale facies. The ubiquitous presence of linear undulatory quartz, stretched quartz grains and certain heavy minerals collectively support that part of the sediments are sourced from metamorphic terrain besides older sedimentary (Disang siltstone and shale) and partly from igneous source provenance.

Among the framework grains, quartz is the most abundant constituent. Non-undulatory quartz grains dominate over undulatory quartz. Rock fragments rank second after quartz but it is very less. In the case of feldspar it is present in negligible amount. From the triangular plot of [15] it is clear that Barail Sandstone samples fall mostly in the in the field of Quartz arenite types and some samples show Sublithic arenite types also. Triangular plots of QFR [10] also show that the sandstones are Quartz arenite. Ternary diagram of Folk (1980) also support this. Further other plots like [4],[5] clearly point out a continental block tectonic setting.

The QFR triangular plots [5] indicate largely hot humid to humid climatic shifts for the samples. Bivariate Log-Log plot (the ratio of polycrystalline quartz to feldspar + rock fragments against the ratio of total quartz to feldspar rock fragments) for interpretation of palaeoclimate from Barail Sandstone samples, [18] most of the samples sweep across the field of humid climate.

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REFERENCES

[1]. Basu, A., Young, S.W., Suttner,L.G.,James,W.C.,And Mack,G.W., (1975). Re – evaluation of the use of undulatory extinction and polycrystalline detrital quartz in provenance interpretation. Jour. Sed. Pet., 45, pp. 873 – 882.56 (5), pp. 157.

[2]. Blatt, H., And Christie, J. M., 1963, Undulatory extinction in quartz of igneous and metamorphic rocks and its significance in provenance studies of sedimentary rocks: Jour. Sedimentary Petrology, v.23, p. 559- 57

[3]. Dasgupta, P.K., Chakraborty, P.K. And Dutta, D. (1991). Basinward migrating submarine fan environments from the Barail Group in the North Cachar Hills, Assam-Arakan Orogen, India. *In:* A.H. Bouma and R.M. Carter (Eds.), Facies Models in Exploration and Development of Hydrocarbon and OreDeposits: VSP, Utrecht, The Netherlands, 254p

[4]. Dickinson, W.R. And Suczek, C.A. (1979). Plate tectonics and sandstone composition. Bull. Amer. Assoc. Petrol. Geologists, v.63, pp.2164-2182.

[5]. Dickinson, W.R., (1985). Interpreting relations of detrital modes of sandstone, In provenance of Arenite, G.G. Zuffa (Ed.), Redil Dovedrect, Boston, Lancaster, pp. 333-361

[6]. Dott, R.H., (1964). "Wacke, Graywacke and Matrix- What Approach to Immature Sandstone Classification?" J.Sed.Petrol., 34: 625-632.

[7]. Evans, P. (1964). Tectonic framework of Assam. Jour. Geol. Soc. India, v.5, pp.80-96.

[8]. Folk, R.L. (1980). Petrology of Sedimentary Rocks. Hamphills, Austin, Texas, 182p sandstones. Journal of Sedimentary Petrology, 32: 440–450.

[9]. Gleria Js ,Rajkumar Hs , Mehorotra Rc ,Soibam I And Rajkumar K (2005) palaeocene plant fossils of Manipur and their Palaeological Significance Palaeobotanist 4-61-77.

[10]. James , W.C., Wilmar,G.C., And Davidson, B.C., (1986). Role of quartz type and grain size in silica diagenesis of Nugget sandstone, South Central Wyoming, Jour. Sed. Pet., 56 (5), pp. 157.

[11]. Krynine (1943). The tourmaline group in sandstones. Jour. Geol.,v.54,pp-65-87.

[12]. Lindsay, J.F., Holiday D.W. And Hulbert, A.G. (1991). Sequence stratigraphy and the evolution of the Ganges-Bramhaputra delta complex; Amer. Assoc. Petrol. Geol. Bull., v.75, pp.1233-1254.

[13]. Mathur, L.P. And Evans, P. (1964). Oil in India. 22nd session, Int. Geol. Cong. New Delhi, India, 85p.

[14]. Pandey, N. And Srivastava, S.K. (1998) Preliminary report on Disang-Barail Transition, North West of Kohima,Nagaland,(abs.). Workshop on Geo-dynamics and Natural resources of North East India, Dibrugrah, p.24

[15]. Pettijohn,F.J., Potter,P.E. ,And Siever,R.,(1972). Sand and Sandstones. NewYork (Springer-Verlag), p.158.

[16]. Pettijohn, F.J. (1975). Sedimentary Rocks. Harper and Row, New York.

[17]. Suttner, L.J., Basu, A. And Mack, G.H. (1981). Climate and the origin of quartz arenites. Jour. Sed. Petrol., v.51, pp.1235-1246.

[18]. Suttner, L.J And Dutta, P.K. (1986). Alluvial sandstones composition and palaeoclimate framework mineralogy, Jour. Sed. Petrol, vol.56, pp.329-345