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Petrography of the Barail Sandstones Occurring in and around Mandardisa, North Cachar Hills, Assam, India

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Abstract— Petrographic studies of the Barail Sandstone occurring in and around Mandardisa of North Cachar Hills, Assam, India have been carried out to determine the mineralogical classification, diagenesis, tectonic setting, palaeoclimate and provenance of the sediment. Quantitative mineralogical classification shows that the sandstones are mostly quartzose arenite and sub-litharenite types and are mineralogically sub matured to matured. These sandstones have shown all stages of diagenesis. Triangular plots of quartz, feldspar and rock fragment population in the sandstones show that the sediments were derived from recycled orogen provenance of a fold thrust province or a collision suture zone. From the climatic study, it is observed that the sediments suffered from subhumid to humid climatic conditions during deposition. From the provenance study, it is seen that the sediments of the sandstones were mostly derived from metamorphic and igneous source rocks transported from Eastern Himalaya and Indo-Burma ranges during Oligocene time. Few sediments were transported from Meghalaya Plateau of the neighbouring areas.

Index Terms— Sandstones, Petrography, Diagenesis, Tectonic provenance, Palaeoclimate, Mandardisa, Assam.

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1 Introduction

THE sandstone petrography is used as an important tool to determine the provenance and tectonic setting of the depositional basin of sandstones (Basu et. al, 1975; Dickinson and Suczek, 1979; Zuffa, 1980; Dickinson, 1985; Ingersoll et. al, 1995; Uddin and Lunberg, 1998; Das, 2008, Das et. at, 2008; Das and Sarma, 2009)

Petrographic studies have been carried out to find out the mineralogical and rock fragments composition etc. of the sandstones. It helps to know the character and type of sandstones, degree of diagenesis i.e. compaction, cementation, lithification and effect of pressure solution and effect of tectonic control of framework of sedimentation. The provenance and tectonoprovenance setting of sandstones can be deciphered based on their petrography (Dickinson, 1985). Petrographic studies also help in the reconstruction of the palaeoclimate as existed during the time of deposition (Suttner and Dutta, 1986).

2 Geology of the Area

The Tertiary sedimentary rocks are well exposed in and around Mandardisa of North Cachar Hills, Assam. The area is covered by the survey of India toposheet no. 83G/2 and lies between the longitude 93°05′-93°10′E and latitude 25°40′-25°45′N. (Fig.1)

The sedimentary rocks exposed in the area dominantly composed of sandstones (Fig. 2a, b) with siltstone and shale which represent the Barail Group of rocks. As the area is geologically virgin, no detail lithology of the rocks is found elsewhere. However, after field observations, the following stratigraphic succession has been made along with salient lithological characters.

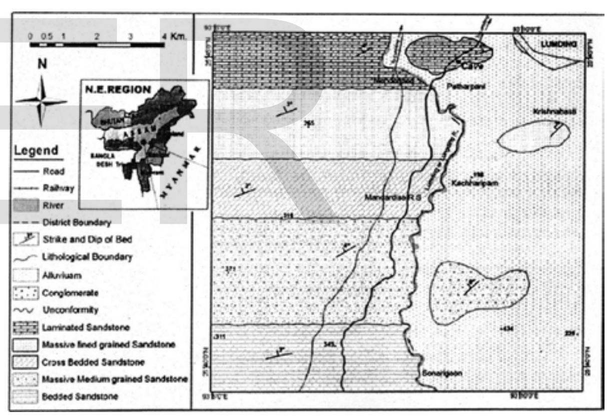

Fig.1 Geological Map of the study area (after Sen et al., 2015)

TABLE 1
Stratigraphic Succesion of the Study Area

Age	Group	Lithology
Pleistocene to Recent		Newer and older alluvium
…………………Unconformity…………		
Miocene	Surma (Bokabil)	Alternates of laminated micaceous sandstones with a conglomerate bed
………………Unconformity…………		
Oligocene	Barail	Grey, medium to fine-grained, ferruginous, massive and current bedded, occasionally laminated sandstones with siltstone and shale layers.
…..……..…….. Base is not seen……..…….		

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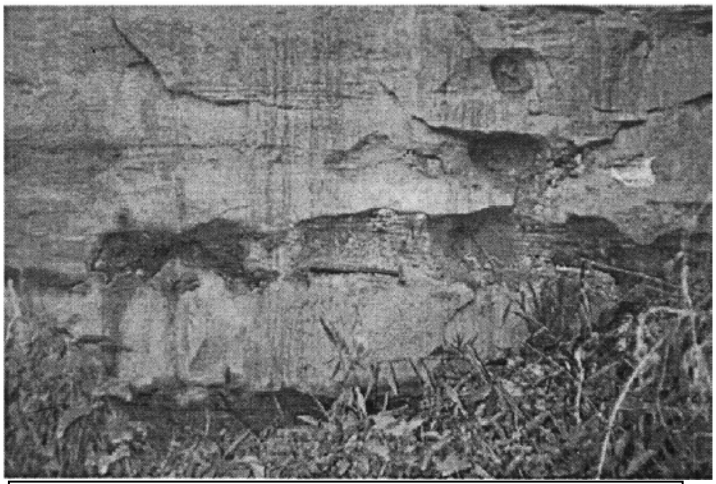

Fig.2a Field exposure of Barail Sandstone.

Fig.2b Field exposure of Barail Sandstone showing Current Bedding.

3 METHOD OF STUDY

Petrographic studies have been made in thin sections prepared from the hard sandstones collected from different field exposures. Different constituents were identified under the microscope and thus volumetric percentages were determined with the help of Grid method for petrographic analysis (Modal Analysis). (Table-2) The symbols of grain types like monocrystalline quartz (Qm), polycrystalline quartz (Qp), total quartz (Qt), feldspar (F) and total rock fragments (Rt) or lithic fragments (Lt) are shown in Table-3. The recalculated tabulated data from Table - 2 for classification are shown in Table - 4.

Mineralogical classification, framework composition, tectonic setting and provenance were studied by plotting modal analysis data in triangular diagrams of Folk (1980), James et. al (1986), Dickinson and Suczek (1979), Dickinson et. al. (1983), Dickinson (1985). The palaeoclimate study was made after Suttner and Dutta (1986).

TABLE 2
MODAL ANALYSIS OF SANDSTONE SAMPLES

Sample No.	Monocrystalline Quartz				Polycrystalline Quartz					Total	Feldspar	Micas
	Unit	Undulose	Vein	Qmt	Composite	Pressure	Schistose	Chert	Qpt	Qt=(Qmt+Qpt)		
1	18	18	3	33	8	2	10	4	24	57	3	3
2	13	17	-	30	10	2	16	2	30	60	3	2
3	10	6	-	16	10	3	2	5	38	54	1	5
4	16	14	1	31	5	5	16	5	31	62	1	4
5	24	20	-	34	10	1	16	6	33	67	3	7
6	17	12	-	29	12	1	18	5	36	65	4	3
7	10	6	1	17	9	3	22	3	37	54	1	5
8	12	20	3	35	10	5	16	4	45	70	2	4
9	12	10	1	23	8	2	14	4	28	51	2	4
10	29	8	1	39	10	2	12	6	30	69	1	4
11	10	19	2	31	8	3	10	5	26	57	2	3
12	18	12	-	30	9	6	20	3	38	68	3	2
13	22	8	1	31	7	1	11	1	20	51	1	12
14	28	14	-	42	8	2	15	3	28	70	1	1
15	15	18	-	33	12	3	17	2	34	67	1	2
16	12	20	1	33	10	2	16	6	34	67	2	2
17	23	9	-	32	11	4	18	5	38	70	3	4
18	27	7	1	35	9	4	14	2	29	64	61	2
19	8	29	-	37	12	3	14	1	30	67	1	1
20	20	12	-	32	10	4	20	4	38	70	2	2
21	17	19	-	36	9	3	20	3	35	71	1	1
22	12	18	-	30	11	4	24	5	44	74	3	1
23	26	11	-	37	10	3	9	2	24	61	1	1
24	11	171	1	29	9	2	17	5	33	62	1	1

TABLE 3
CLASSIFICATION AND SYMBOL OF SANDSTONE GRAIN TYPES

(Modified after Dickinson, 1985; Trop and Ridgeway, 1997)

Symbol	**Definition**
QM	Monocrystalline quartz
Qp	Polycrystalline quartz
Qt	Total quartz grains

FELDSPAR GRAINS

P	Plagioclase
K	Potassium feldspar
F	Total feldspar (P+K)

LITHIC GRAINS

Lm	Metamorphic lithic fragments
Ls	Sedimentary lithic fragments
Li	Igneous lithic fragments
Lt	Total lithic fragments

TABLE 4
RECALCULATED TABULATED DATA (5) FROM TABLE 2

Sample No.	Data for QFR Diagram			Data for Frt Diagram		
	Q	F	R	Qmt	F	Rt
1	81.4	4.2	14.4	71.7	6.5	21.8
2	81	4	15	75	6.8	18.2
3	81.8	1.5	16.7	57.1	3.5	39.4
4	82.6	1.3	16.1	70.5	2.3	27.2
5	80.7	3.6	15.7	68	6	26
6	82.2	5	12.8	67.4	9.3	23.3
7	80.5	1.5	18	56.6	3.3	40.1
8	84.4	2.5	11.1	76	4.3	19.7
9	75	2.9	22.1	57.5	5	37.5
10	82.1	1.2	16.7	72.2	1.9	25.9
11	81.5	1.3	17.2	70.4	4.5	25
12	80.5	1.5	18	63.8	6.4	29.8
13	82.7	1.1	16.1	73.8	2.4	23.8
14	8.4	3	13	76.4	1.8	21.8
15	81.6	1.4	17	78.6	2.4	19.0
16	87.5	1.3	11.2	73.3	4.4	22.3
17	89.9	1.1	9	69.6	6.5	23.9
18	86.2	1.4	12.4	70	2	28
19	78.9	1.1	20	75.5	2	22.5
20	85.6	1.4	13	72.7	4.5	22.8
21	81.3	1.8	16.9	69.2	1.9	28.9
22	86.4	2.4	11.2	71.4	7.1	21.5
23	81.8	1.8	16.4	72.5	2.0	31.8
24	80.2	3.8	16	65.9	2.3	31.8
25	77.2	2.6	20.2	50	3.1	46.9

4 PETROGRAPHY

Petrographic study of the sandstones was carried out for mineralogical composition, diagenesis, classification, and for other details. For this purpose, mineralogical constituents are grouped as (i) primary detrital constituents (ii) Lithic fragments (rock-fragments) (iii) miscellaneous detrital constituents and (iv) matrix and cement.

4.1 Primary detrital constituents:

The detrital constituents include different varieties of quartz followed by feldspar, micas. (Figs. 3, 4, 5, 6, 7, 8 & 9).

4.1.1 Quartz:

Quartz is the most abundant grain type and it is classified based on number of distinctive features like undulose extinction, strained action crystal shapes, inclusions etc. Quartz types are classified following Dotty and Hubert (1962) and Conolly (1965). Broadly the quartz grains can be grouped under two main classes - monocrystalline and polycrystalline (Conolly 1965 and Blatt, 1967). The following quartz types have been studied from sandstone samples of the area.

4.1.1.1 Monocrystalline Quartz:

Unit grains with smooth boundaries are termed monocrystalline quartz and further classified into 3-types.

Unit quartz: This type of quartz is also known as common or non-undulose quartz. Quartz grains which show uniform extinction may vary from 1^0 - 3^0 are called unit quartz. The grain boundaries are straight, sutured or corroded. The Grains are mostly angular to sub-angular, though few grains are sub-rounded to rounded.

Undulose quartz: Undulose quartz is identified by their unit boundary and extreme undulose extinction. The grains are mostly angular to sub-rounded. Grain boundaries show straight, sutured or curved nature. Undulose quartz grains are less stable than non-undulose quartz grains and tend to break into small grains (Blatt et. al, 1980)

Vein quartz: Vein quartz grams present m the sandstones show the plane of weakness in which growth of secondary quartz takes place.

4.1.1.2 Polycrystalline quartz:

Polycrystalline quartz grains which show two or more units under cross nicols but look like a single gram under polarized light are called polycrystalline quartz (Conolly, 1965).

Depending on shape, size and nature of boundary conditions, polycrystalline quartz is again subdivided as follows.

Composite quartz: Grains are identified by the presence of two or more internal quartz units. Grains show a single grain outline under polarised light while the internal units are distinctly visible under cross nicols. Contact of sub-grains are almost straight.

Schistose quartz: In schistose quartz, gram boundaries show a number of individual microcrystalline units under cross-nicols and their boundaries are smooth, irregular as well as suture. The sub-grains are mostly oriented in a particular direction.

Pressure quartz: It is identified by the presence of internal elongated units of different optical orientation which gives is a mosaic like appearance. The grains show extreme undulose extinction. The internal grain boundaries are smooth and the units show both unit and undulose extinction.

Chert: Chert is chiefly composed of microcrystalline grams with subordinate megaquartz grains and minor impurities (Folk, 1980). Chert grains differ from polycrystalline quartz by pin-point extinction and very minute and regular size of the internal units. In the thin sections of the present sandstones contain mostly of secondary chert with very few grains of detrital quartz.

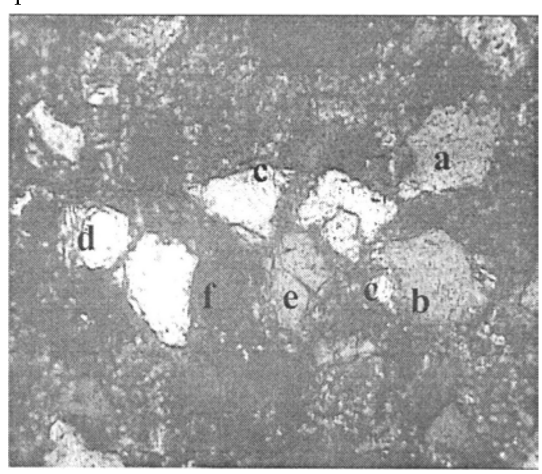

Fig. 3 : Photomicro graphs (10x) showing: a) Undulatory Quartz; b) Sericitization of K – Feldspar; c) Overgrowth of Quartz; d) Dissolution of Quartz; e) vein Quartz, and f) Rock Fragments

4.1.2 Feldspars:

ISSN 2229-5518

Feldspars rank second in dominance in the sandstones. Both k-feldspars and plagioclase are present in the sandstones. Plagioclase feldspars are few and characterized by lamellar twining. Orthoclase are mostly untwined and give a cloudy appearance.

4.1.3 Micas:

The micas include biotite, muscovite and chlorite and commonly occurs flakes. The biotite grams may be identified by their brown colour, straight extinction and pleochroism. The muscovite flakes are few and identified by their colourless appearance, elongated shape and red-green interference colour. Chlorite flakes are commonly found as altered product of biotite. Folding or kink banding of biotite grains is observed in the studied samples.

4.1.4 Lithic grains (Rock fragments):

Lithic grains are the pieces of disintegrated source rocks and are of immense importance in provenance study along with the tectonic setting of the source areas. Rock fragments found in the thin sections are of igneous, metamorphic and sedimentary rocks. Metamorphic rock fragments show preferred orientation and high interference colours under cross niclos. Igneous rock-fragment show black dotted nature under cross-nicols. Sedimentary rock-fragments show some sedimentary characters.

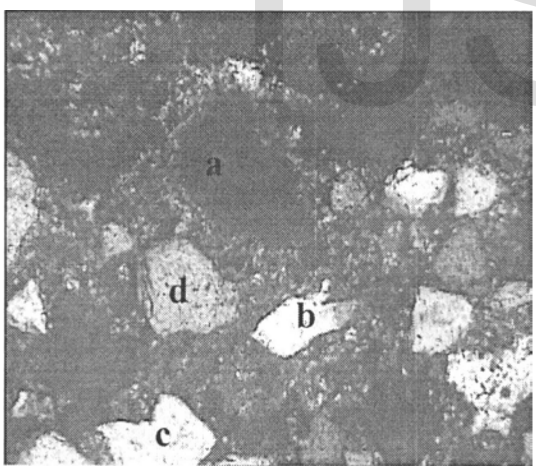

Fig. 4: Photomicro graphs (10x) showing: a) Rock Fragments; b) Overgrowth of Silica; c) Common Quartz; d) Composite Quartz

4.2 Miscellaneous detrital constituents:

These include minerals which can be divided into opaques and no-opaques. Among the opaque iron minerals are the most dominant. Zircon (colourless to pale gray), tourmaline (brown, yellow and green), epidote (colourless, pistachio green), rutile (blood red colour) are the nonopaque accessories present in the sandstones.

4.2.1 Matrix :

Matrix found in the present sandstones consists of both detrital as well as authigenic grains of argillaceous, siliceous and ferruginous materials.

4.2.2 Cement :

Cements are chemical precipitates with the intergranular spaces. In the present sandstones the cementing materials are mainly siliceous and ferruginous which occur as surrounding the grains.

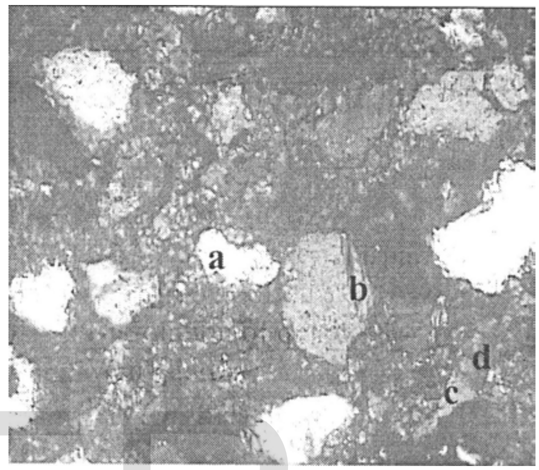

Fig. 5: Photomicro graphs (10x) showing: a) Sutured boundary in Quartz grains; b) Vein Quartz; c) Silica Cement; d) Porefilling of Secondary Chert

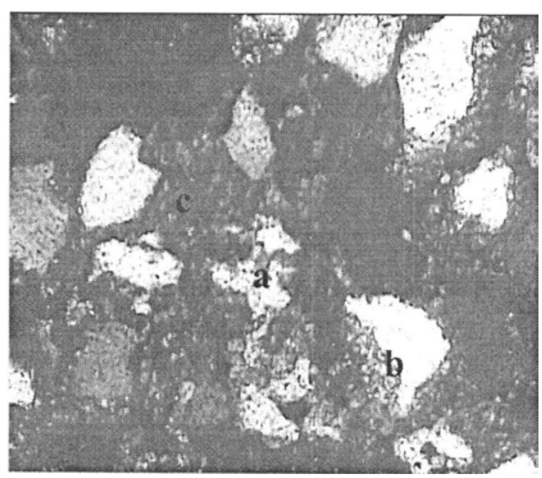

Fig. 6: Photomicro graphs (10x) showing: a) Pressure Quartz; b) Alteration of Monocrystalline Quartz to Pollycrystalline Quartz; c) Ferrogenous Cement; d) Feldspar Grains

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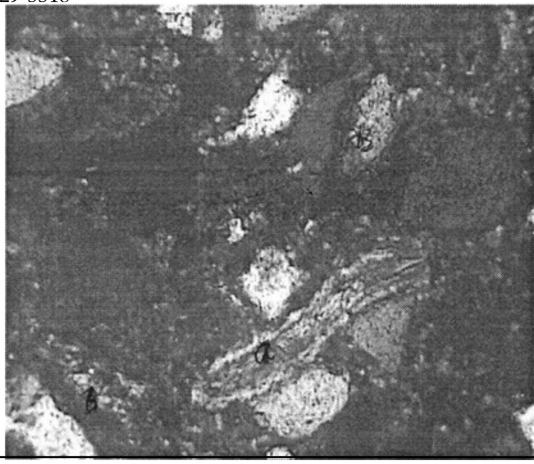

Fig. 7: Photomicro graphs (10x) showing: a) Bending of Mica Flake; b) Schistose Quartz.

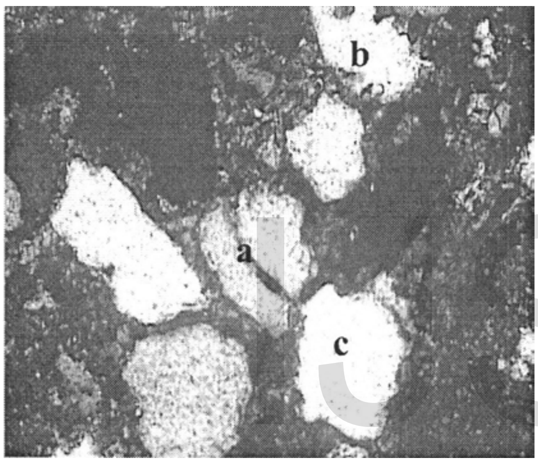

Fig. 8: Photomicro graphs (10x) showing: a) Concavo – Convex Grain boundary; b) Corroded boundary of Quartz with Inclusion; c) Alteration of K – Feldspar to Quartz

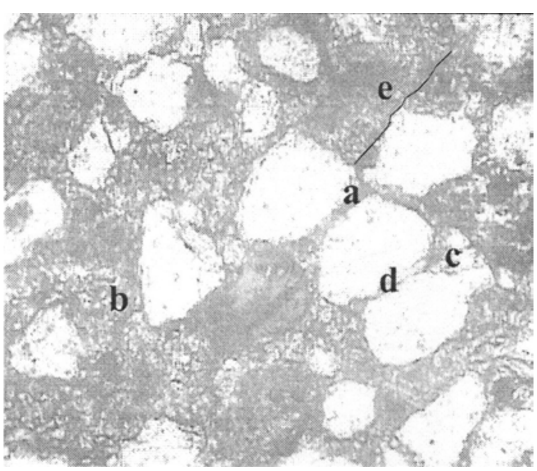

Fig. 9: Photomicro graphs (10x) showing: a) Point Contact b) Silica Clay Cement; c) Floating Quartz; d) Long Contact; e) Stylolitic Line

5 Textural and Mineralogical Maturity

Folk (1980) defined textural maturity as a degree to which sand is free of interstitial clay and is well rounded and well sorted. Accordingly the present sandstones are sub-mature in nature with <10% clay (matrix) and are moderately to poorly sorted. The grains are mostly sub-angular to sub-rounded with a few rounded grains showing textural maturity.

The ratio of quartz to feldspar and rock fragments are also used as an index of mineralogical maturity. From the observation, it is apparent that the present sandstones are mineralogically sub-matured.

6 Diagenesis

The thin section study reveals different diagenetic features that reflect varrous stages of diagenesis. The progressive diagenesis processes served as compaction and pressure solution, early cementation, authigenesis, overgrowth, dissolution, replacement and late cementation.

The basic study that deals with the subject of diagenesis are those of Siever (1979), Read and Watson (1962), Dopples (1979), Fairbridge (1983), Singer and Muller (1983); Tucker (1989) and Ahmed and Sayeed (2004). This works discuss that diagenesis embraces all those processes which begin at the moment when a sedimentary particle comes to rest and continues to a point of deep burial and orogenic buckling that cause the initiation of metamorphism or when emergence lead to exposure and the initiation of weathering and erosion. Petrographic study of compaction, grain contacts, authegenic growth of mineral grains, alteration and replacement, and cementing materials reflect the nature and extent of diagenesis suffered by the rocks and are as follows :

6.1 Compaction

Compaction during diagenesis statts as sediment-water interface and proceeds with further sedimentation over it resulting into mechanical compaction till the large scale stresses come into play during basin subsidence and basinal tectonics resulting into chemical compaction. The chemical compaction involves pressure dissolution of grains along contacts and formation of stylolitic lines (Heald, 1955). (Fig. – 9)

Mechanical compaction IS perhaps the dominate diagenetic process during the early stage of diagenesis, which results in the rearrangement of the frame work grains forming point and long contacts.

The mechanical composition of sediments IS witnessed by bending of detrital mica flakes, (Fig. -7a) fracturing of ductile grains of feldspar and rock fragments, and flowing of unstable grains around the resistant constituents like quartz, in which the mica and rock fragments are more informative of compaction and deformation. Flowing of unstable grains signify their plastic deformation in the present rock. Bending of biotite flakes suggests tectonic disturbances of the sediments, which is the evidence of moderate compaction whereas the flowing of unstable clasts between the stable grains in the sediments bear the witness of severe compaction due to pressure effect.

Fracturing of quartz grains indicate the effect of tec-

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tonic activity during post depositional period. Penetration of feldspar grains and replacement of plagioclase by polycrystalline quartz are the effects of mechanical and chemical compaction due to pressure effect.

Fracturing of quartz grams indicate the effect of tectonic activity during post depositional period. Penetration of feldspar grains and replacement of plagioclase by polycrystalline quartz are the effects of mechanical and chemical compaction which have been observed in the thin section of the sandstone samples of the studied area.

6.2 Grain Contacts

In the sandstones four types of grain contacts were identified viz., floating, point, long and concavo-convex. The grain to grain contact, grain to overgrowth and overgrowth to overgrowth contacts are observed in the studied samples. (Fig. -9a, d)

The compaction brings the grams into closure contact along long concavo-convex boundaries. Under more usual conditions, the point contacts of the sandstones suggests early burial stage of diagenesis that on increase of overburden load under deep burial stage come into closure contact along long concavo-convex grain boundaries (Blatt, 1980). Taylor (1964) attributes this change to the intrastratal solution and precipitation effect. The study reveals that the sandstones with more concavo-convex and sutured grain contacts are indicative of moderate pressure solution. Blatt et. al, (1980) explained that at greater depth of burial or during phases of marked tectonism the buried loaded sand might have a much higher proportion of long, concavo convex and sutured grain contacts. redoxomorphic stage is mainly represented by the development of the point contacts between quartz-grains; whereas locomorphic stage is evidenced by long and concavo-convex contact together with the precipitation of secondary chert. (Fig – 5d)

6.3 Alteration and Replacement:

In the sandstones four types of grain contacts were identified viz., floating, point, long and concavo-convex. The grain to grain contact, grain to overgrowth and overgrowth to overgrowth contacts are observed in the studied samples. (Fig. -9a, d)

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6.3 Cementation:

Three types of cements identified in the present sandstones are silica, iron-oxide and calcite. (Fig.5c, Fig.9b, Fig.6c) The silica cement occurs in the form of quartz overgrowth around detrital grain boundaries. Quartz overgrowth was formed from pressure solution of quartz (Heald, 1955; Dopples, 1967; Morries et. al, 1979).

In the studied samples quartz overgrowths are mainly developed on monocrystalline quartz when compared to polycrystalline quartz grains. Amongst monocrystalline quartz the overgrowth is more common around undulose grains as compared to non-undulose grains. In some grains overgrowth is well developed or moderately developed or moderately developed.

The source of silica cement may be the descending meteoric water saturated with silica or pressure solution of detrital quartz and other silicates at grain contacts. The replacement of calcite by silica is a function of pH of pore water (Blatt et. al, 1980). It is prescribed that, replacement of silica cement may have resulted in retention of original intergranular porosity. Authigenic quartz overgrowth on detrital quartz grains has partially filled up the intergranular spaces.

The iron cement is present as void filling in the studied sandstones. Iron oxide cement occurs mostly in the form of coating around detrital quartz grains. In many instances, the clastic grains have lost their grain morphology. The iron oxide cement has also replaced calcite cement. The precipitation of iron-oxide might be from iron saturated solution. Simson (1985) considered iron formation as primarily hydrothermal in origin. Weathering and leaching during uplift has resulted in the disintegration of unstable ferrornagnesiam minerals releasing iron oxide, which subsequently formed iron-oxide coating around the detrital grams. The precipitation of iron-oxide makes the sandstones more indurated in which the chemical etching and corrosion of grain boundaries are pronounced. Brownish red colouration in some thin sections may be explained as remobilisation and redistribution of early-formed ferromagnesian minerals, which is an indication of early burial reaction. The early burial redxomorphic stage establishes the final colouration of the sandstones (Dapples, 1962). The ironcoated clayey cement brings the separation among frame work grains, which may be explained by the fact that the early born diagenetic clay was later found with a younger iron-oxide cement during which the corrosion of grain boundary was an important effect.

Calcite cement in the present sandstones mostly occurs as microcrystalline calcite and sparry calcite. According to Buyukutku (2005), calcite cement is common in the Oligocene and Mio-Pliocene sandstones due to biogenic action

Calcite cement may precipitate from water without the dissolution of other carbonate minerals. The calcite formed during deep burial by dissolution and reprecipitation represents redistributed carbonate which was burried with sandstones

Calcite cement has partly replaced by the detrital grams. The boundaries of replaced detrital grains are markedly etched and corroded by adjoining calcite cement. Calcite cement has replaced k-feldspar, plagioclase, quartz and rock fragments. Calcite commonly fill the dissolution voids in detrital grains. Precipitation of micrite probably took place at shallow depth. Later during burial, micrite was replaced by sparry calcite in meteric hydrothermal regime along the interface of the zone of saturation.

7 Modal Analysis and Mineralogical Classification

Systematic study and genetic interpretation of sandstones cannot be done without a proper classification (Pettijhon, 1975; Folk, 1980). It is mainly governed by mineralogical composition. In the present study, classification of the sandstone samples done following Folk (1980) and James et. al (1986). Prior to plotting, the necessary minerals (quartz, feldspar, rock fragment) were recalculated to 100% neglecting matrix, cement and other detrital minerals. The classification shows that the present sandstones belong to the Sub-Litharenite and Quartzose arenite types. (Fig. 10 & 11).

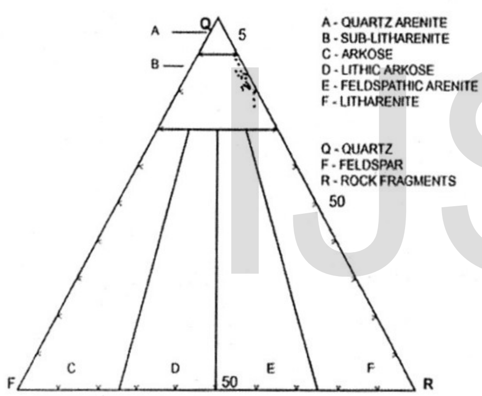

Fig.10 QFR plot of Barail Sandstone (after Folk, 1980)

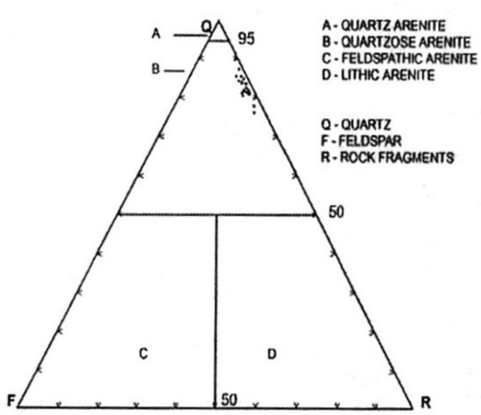

Fig.11 QFR plot of Barail Sandstone (after James et al., 1986)

8 Famework Composition and Tectono Provinces

The mineral composition is presumed to reflect the tectonic history of the source area and the site of deposition and idea presumed specially by Krynine in 1943. (Pettijhon, 1975).

The composition of the sandstone and its implications on the tectonic setting of a depositional basin, much works have been done. Noteable works amongst them are the works of Young (1976), Dickinson and Suczek (1979), Mack (1984), Dickinson (1985), and Trop and Ridgway (1997). Dickinson and Suczek (1979) opined that the key relationship between provenance and basins are governed by plate tectonics which ultimately controls the distribution of different type of sandstones.

The present analysis is based following Dickinson and Suczek (1979), Dickinson et. al (1983) and Dickinson (1985). The proportion of detrital framework grains when plotted on triangular diagrams following the above mentioned settings and, provide a powerful tool in interpretation of plate interaction in the geologic past. Basically three groups have been discriminated in triangular diagrams for the present case. These are QFR, QmtFRt and QmFRt. Triangular plots of QFR of Dickinson and Suczek (1979) (Fig.- 12) and QmtFRt of Dickinson et. al (1983) (Fig.-13) show that Barail sediments were derived from Recycled Orogen Provenance.

Low feldspars, more metamorphic rock-fragments and polycrystalline quartz grains indicate that the sediments were derived from a orogenic regions. (Dickinson, 1985; Graham et. al, 1993 and Boggs, 1995).

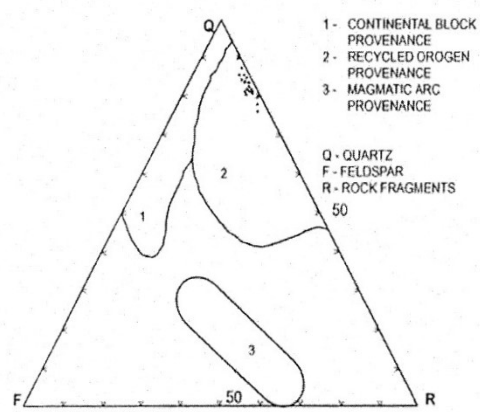

Fig.12 QFR plot of Barail Sandstone (after Dickinson and Suczek, 1979)

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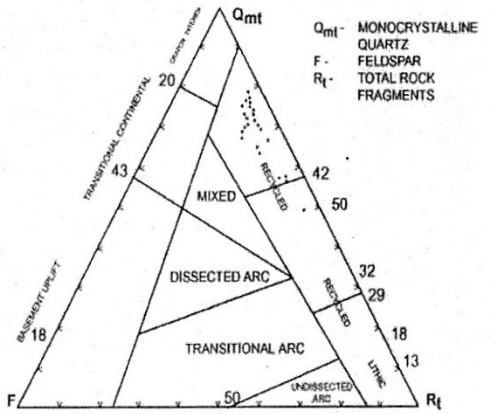

Fig.13 $Q_{mt}FR_t$ plot of Barail Sandstone (after Dickinson et al., 1983)

9 Palaeoclimate

Young et. al (1975) and Basu (1985) have demonstrated that the ratios of feldspar and Lithic fragments to polycrystalline quartz or to total quartz are sensitive indicator of climatic heritage of sand. This . climatic signature is present in the present sandstones. In the present study following Suttner and Dutta (1986), plot has been made in QFR diagram and plotted points are found in the subhumid to humid zone. (Fig.-14) This indicates the more pronounced weathering on the feldspar grains present in the sandstones.

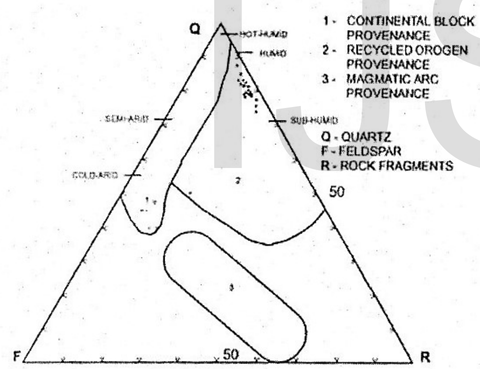

Fig.14 Plaeoclimate plot of Barail Sandstone (after Suttner and Dutta, 1986)

10 Provenance

Petrographic study is an important tool to decipher the provenance and environment of deposition of sediments. Quartz is the most dominant detrital gram in the sandstones. From the petrographic studies of the sandstones, it has been observed that the sediments were derived both from the igneous and metamorphic sources. The constituents clastic quartz grains indicate their dual sources (provenances). Monocrystalline quartz indicates their derivation of sediments from intrusive igneous rocks (Conolly, 1965). Predominance of unit and undulose quartz is indicative of plutonic and low rank metamorphic sources with variable pressure effects (Basu et. al, 1975). The presence of composite polycrystalline quartz type indicates the grains were derived from a plutonic igneous source (Young, 1976), whereas the polycrystalline quartz grains with more crystal units indicate metamorphic provenance (Blatt, 1967; Blatt et. al, 1980). Presence of detrital chert and sedimentary rock fragments indicate sedimentary source of few sediments.

Studies of intercrystalline boundaries, crystal shapes, size and sorting within polycrystalline grains are potentially useful in source rock identification (Blatt and Christie, 1963). Elongated nature of polycrystalline grains and suturing of grain boundaries between polycrystalline quartz suggest metamorphic derivation of sediments of these sandstones (Blatt et. al, 1980). Composite quartz with straight boundaries in their microcrystalline units indicate plutonic igneous derivation (Blatt, 1967). The present sandstones show effect of pressure on some grains before and after deposition. The presence of detrital micaflakes and metamorphic rock fragments suggests that the sediments were derived from mica bearing granites and gneisses, and from micaschist (Pettijhon, 1975).

Therefore, the sediments were derived from metamorphic, igneous and sedimentary source rocks transported mostly from Eastern Himalaya and IndoBurma Ranges during Oligocene time (Uddin and Lundberg, 1998). Few sediments were derived from the Meghalaya Plateau as well as neighbouring regions.

From the above characters, it can be inferred that these sandstones have close similarities with Barail sandstones of neighbouring areas (Singha and Das, 1999; Das et. al, 2008).

11 Conclusion

Petrographically, the sandstones are mainly of quartzose arenite to sub-litharenite types. The sandstones have undergone through all stages of diagenesis viz. redoxomorphic, locomorphic and phyllomorphic stages. Triangular plots of QFR, QmtFRt and QtFRt shows that the sediments were derived from recycled orogen provenance. Presence of low feldspar grains, more metamorphic rock fragments and polycrystalline quartz grains indicate that the sediments were derived from a fold thrust province or a collision suture zone. The climate plots concentrate mainly in the sub-humid to humid zone. Moreover, it can be said that the sediment composition was extensively modified during weathering under warm and humid climate at the source area and by weathering under warm and humid climate at the source area by weathering during transportation and sedimentation. The sediments of the sandstones were derived from metamorphic and igneous source with subordinate sedimentary source rocks transported mostly from Eastern Himalaya and Indo-Burma Ranges. Few sediments were derived from the Meghalaya Plateau and neighbouring areas. The sandstones occurring in and around Mandardisa have close similarities with Barail sandstones of neighbouring areas.

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