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Petrographic studies of Barial sandstones in and around Churachandpur district, Manipur, Ne-India

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Abstract

Representative sandstone samples from Churachandpur areas have been investigated for their petrographic properties. The rocks are mostly Quartz wacke, Arkosic wacke and Lithic wacke types. The colour of the rocks ranges from light grey to dark grey depending upon the cementing materials. Cross-bedding and ripple marks are the main structures. The rocks are transverse by quartz and calcite veins. The minerals are identified by petrological microscope and their minerals percentages are counted by point counter. The heavy minerals are also identified which are used to suggest diversity of source rocks.

Keywords: Churachandpur, petrography, thin slide, Barial sandstone, modal analysis

Introduction

The petrographic study of sedimentary archives is the most effective systematic method of many keys to deciphering geological history by study mineralogical and textural properties and micro-structure of clastic sedimentary rocks in hand specimen and thin section (Garzanti E., 2019) ^[15].

Descriptive petrography and classifications of sand and sandstone can be easily studied and distinguished by using petrographic microscope which is proposed more than half a century ago are still in use (Garzanti E., 2019) ^[15]; and, most of the world oil and natural gas fields are found in sands and sandstones because of their high porosity and permeability.

Sandstones are composed of framework grains, matrix, chemically precipitated cement and pores; has been used by sedimentologist during past few decades to decipher the provenance and tectonic setting of the source area (Dickinson, 1970; Crook, 1970; Dickinson and Suczek, 1979; Pettijohn F.J. 1987) ^[8, 9, 26]. In worldwide, such studies have been widely prove and applied by many authors.

Consequently, modal analysis of the detrital framework grains of clastic sedimentary rocks has been used to infer their provenance and tectonic provenance (Dickinson, 1970; Basu *et al.*, 1975; Dickinson and Suczek, 1979; Critelli *et al.*, 2003) ^[8, 1, 9, 5].

The aim of the present investigation is to identify the mineral present, texture of the rocks and to classify the rocks in order to understand the provenances, environments and diagenesis of the rocks.

Geological Setting of the Study Area

The study area covers the road section of about 30km from Churachandpur to Tuilaphai located at latitudes 24°20'– 24°25'N and longitudes 93°35'– 93°45'E stretches along National Highway No. 2. The geological formations exposed in the study area include Disang Group, Barail Group and Alluvium (fig. 1). A simplified stratigraphic succession of the study area is given in table 1.

The Disang Group of rocks lie unconformable just above the Basement complex. The Disangs are dominated by argillaceous rocks like shales and interbedded with flaggy sandstone. Minor amount of mudstone and siltstone are present at the lower part of the column where as bedded splintery shales and interbedded siltstone and sandstone are present at the upper part of the formation. Brachiopod fossils of Eocene age are abundantly present in the Disang shale. The Disang shales are characterised splintery nature due to the present of many joints which are the results of tectonic movements.

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The Barails Group of rocks particularly the arenaceous one lies above the Disang Group with gradational contact (fig. 2). Fine to medium grained multi-storied bedded sandstones are well developed, interbedded with thin layers of shale

Brown colour sandstones contain coal streaks/carbonaceous materials. Cross-bedding and ripple marks are the prominent structures of the rocks. Wood fossils of Oligocene age can be seen in the rocks.

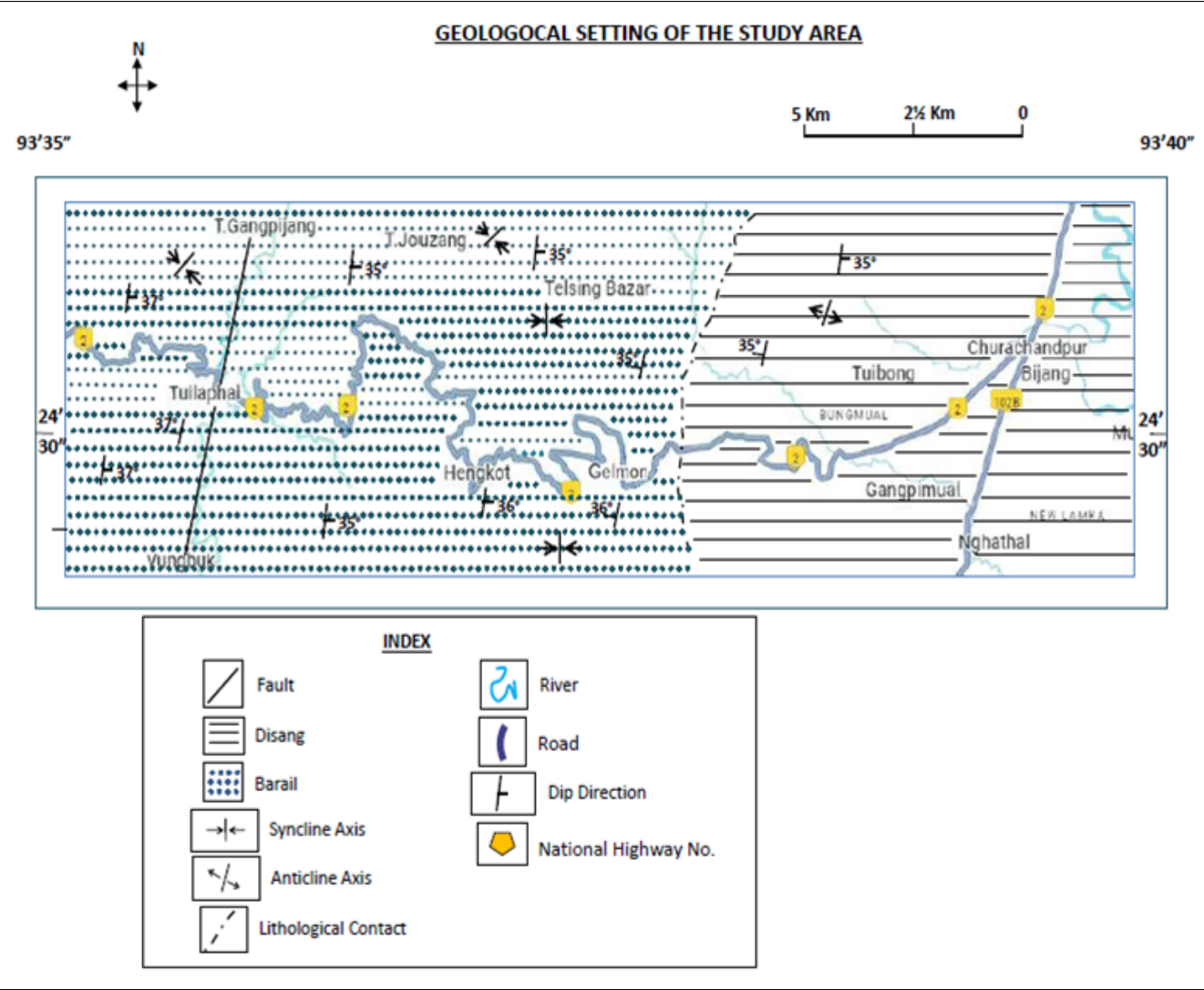


Fig 1: Pictorial representation of geological setting of the study area

The Barails rocks are unconformably overlain by a group known as alluvium. The deposits consist of dark grey to

black clay, silt and sandy deposits of fluvio-lacustrine origin.

Table 1: Stratigraphic succession of the study area

Group		Description of Rocks
Alluvium		Dark grey to black clay, silt, and sandy deposits of lacustrine origin
Stratigraphic break		
Oligocene	Barail Group	Fine medium grained multi-storied bedded sandstone alternated with shale. Brown colour sandstone often contained carbonaceous materials. Shale is thinly laminated.
Gradational contact		
Eocene	Disang Group	Dark grey splintery shale inter bedded with siltstone and fine grained sandstone. Thickness of the sandstone and siltstone are maximum at the upper part. Argillaceous dark grey shale inter-bedded with mudstone and thinly bedded the siltstone at the lower part.
Unconformity		
Basement complex		unseen

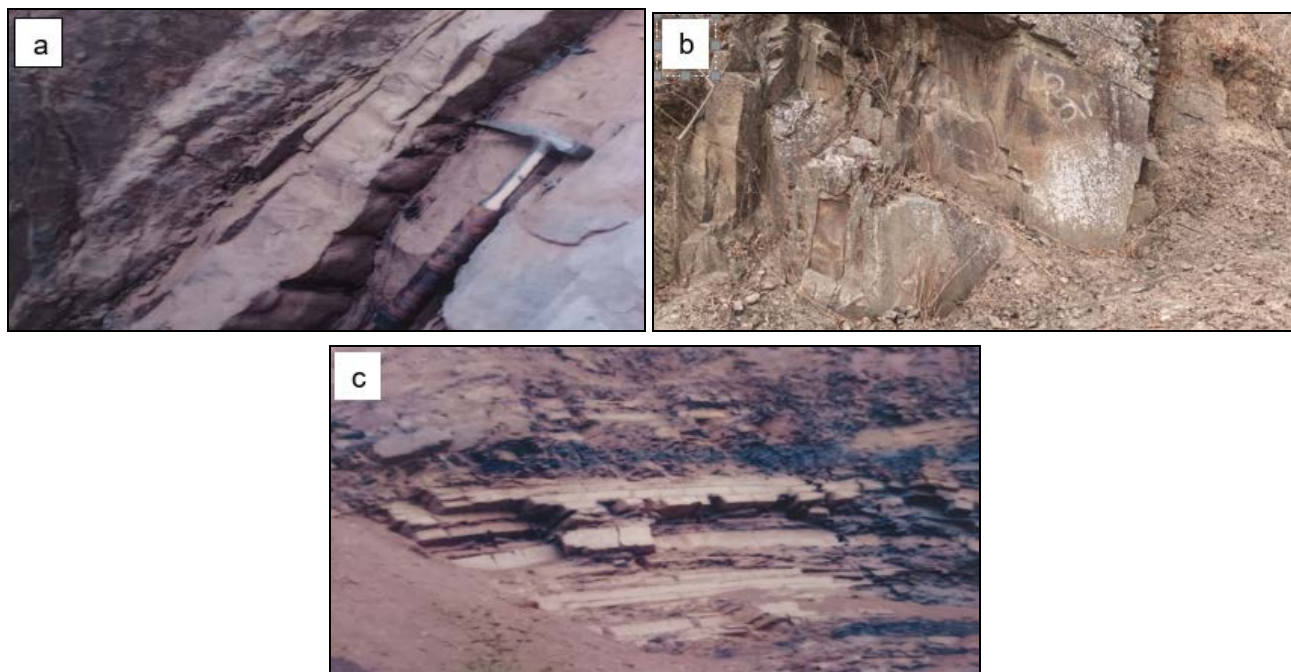


Fig 2: Photographic representation of out-crops where sample collected: (a) Gelmon (b) Henkot (c) Tuilaphai

Materials and Method

The study area is selected because of abundances and fresh exposures of Barail rocks. The area is geologically mapped on the scale of 1:50000 (fig. 1). The sample were collected from suitable areas at the sizes of 4:7 cm and kept the sample in the black polyethylene bags. About 25 rock samples were selected for petrographic investigations including classification of rocks. The rock slides were prepared at the laboratory of Earth Sciences Department, Manipur University along with the technician of the department. The slides were investigated in the laboratory of Geology Department, Imphal College and D. M. College of Science, Imphal. The rocks are classified accordingly with the slide.

The samples that were chosen for analysis were observed to be in either a loose or moderately indurated state. The impregnation process was deemed crucial for the successful preparation of each sample. Subsequent procedures were executed following the impregnation process to facilitate the production of thin sections.

Preparation of Standard Thin Section

Rock slabs were cut with a knife, and washed with water, then acetone to remove gases. Araldite resin and Araldite hardener were mixed 1:1 and diluted with toluene to increase viscosity (30% glue, 70% toluene). After submerging the samples in it for 3 days, the solution penetrated them. The indurated samples were then heated in an oven at 40°C temperature for 2 days to increase their rigidity. One side of the impregnated slab was polished on a coarse grinding lap and a glass plate until smooth and flat. Then, this was mounted on a clean microscope slide, applying Araldite glue (resin: hardener = 1:1) on the polished surface. The sample's free face was ground on a coarse lap until light could pass through. The sample's thickness was tested regularly using a polarising microscope until it reached 0.03 mm. After adding Canada balsam to the heated rock slide, a thin cover slip was applied (Md. Mesbah Uddin Bhuiyan *et al.*, 2024) [23].

The thin section petrographic analysis involved the determination of the texture and mineral/framework element

compositions of the sandstones was done by following Okwudiri A. Anyiam *et al.*, (2017) through point counting of constituent grains. The texture and framework elements of the sandstones are indicative of the depositional environments.

Result and Discussion

Petrography

The petrographic properties of sandstones provide a basic tool for of rock classification. Combined with other parameters, it can be used to solve many intricate sedimentological problems. Composition of sandstone is influenced by the characteristics provenance, the nature of sedimentary processes within the depositional basin, and kind of dispersal path linked provenance to the depositional basin (Dickinson and Suczek, 1979) [9]. Key relations between provenance and depositional basin are governed by plate tectonics, which are ultimately controls the distribution of different type of sandstones.

For the present investigation, among 30 samples those collected from the study area, 25 representative sandstones samples were selected for detailed petrographic studies. Texturally and mineralogically, these sandstones were found to be more or less similar, hard and compact; and, composed of quartz, feldspar, rock-fragments, micas, opaque minerals, heavy minerals and matrix/cementing materials.

Quartz

Quartz is the most dominated framework component of sandstone. Both monocrystalline and polycrystalline varieties of quartz were present in the samples collected from the study area but monocrystalline variety was more abundant than the polycrystalline one. In the present samples, quartz were varies from 28.40% - 55.60%. Minimum percentage of quartz was observed in sample number HK3-A collected from the Henkot village and the maximum in sample number GML2-B from Gelmol village (table 2). Most of the quartz grains shown floating contact however, suture point, concavo-convex, long contacts were also present. These quartz grains were variable in shape and

size as sub-rounded, rounded and angular (fig. 3a). Many quartz grains were characterised by the presence of various type of inclusion like, muscovite, biotite, chlorite, feldspars, gas bubbles, fluid inclusions and heavy minerals. (fig. 4 & 5). In some of the sample, gas bubbles shown preferred orientation. Inclusion of heavy minerals viz. andalusite, haematite, Zircon, gluconite, kyanite, sphene, spinel, brookite, tourmaline, garnet, magnetite, rutile, epidote, zoisite, chloritoid, amphibolite, have also been observed in the quartz grains (fig. 4h & 4i; fig. 5).

Feldspar

Feldspar is another important framework component of sandstone. In the present samples, amount of feldspar were found varies from 1.60% - 7.00% (table 2), which includes plagioclase and orthoclase. Plagioclase was more common than orthoclase feldspars. Most of the feldspar grains were decomposed and could not be recognized on the basis of optical properties and hence considered as matrix. The plagioclase feldspars (fig. 4c) were identified by their characteristic twinning. Un-twinned orthoclase was differentiated from quartz by their turbid nature and brown colour under plane polarized light and Carlsbad twinning.

Rock Fragment

Rock fragments are also an important framework component of sandstone. In the present sample, chert (fig. 3f) and polycrystalline quartz (fig. 3e) were found as the most common type of rock fragments and ranging from 1.8% - 11.80% (table 2). These rock fragments might have been derived from igneous, metamorphic and sedimentary source.

Micas

Mica group of minerals are minor contributor to the sandstones, which rarely exceeds 2% of the terrigenous fraction and normally less than 0.5%. In the present samples, micas were found varies from 1.2% - 6.60% (table 2). Muscovite being chemically stable was observed more abundant than that of the biotite. Among the mica group of minerals muscovite (fig. 4g) was more common in most of the samples. These muscovite grains were observed as elongated, slender, and platy to flaky in nature, whereas, colourless in polarized light and show one set of prominent cleavages. Biotite were found as subhedral grains and light brown colour, highly pleochroic and show straight extinction. By partial decomposition, it was altered to chlorite. In some samples, both muscovite and biotite grains were crumple twisted around the clastic grains boundaries (Fig. 5c).

Calcite

Calcareous material is one of the common cement in mesozoic and cenozoic sandstones (Tallman, 1994) [29]. In the present investigation, crystal of calcite could be seen varies from 0.20% - 2.00% (table 2) along in the rocks as calcareous cement and calcite vein present at sample GLM2-F which was collected from Gelmon (Fig. 4d).

Heavy Mineral

Heavy minerals identified from the present samples include zircon and tourmaline, garnet, magnetite, rutile, epidote, spinel, hematite, andalusite zoisite, sphene, etc. Most of these heavy minerals occurred as inclusion in quartz grains but some of the coarse grained heavy minerals were also

present independently in the ground mass.

Matrix

Matrix is the binding materials in the detrital sedimentary rocks. These may be associated intimately, crystallizing together in the same pore spaces or may be distributed in more or less isolated patches. Therefore, both fine grained detritus and chemically precipitated minerals were observed as cementing material in all rock samples. However, fine grained detritus were more common than the precipitated cementing materials. The matrix included detritus fine-grained quartz, weathered feldspar, ferruginous materials etc. The percentages of the matrix in the sample collected from the study area were observed varies greatly ranges from 32% - 64.60% (table 2). The sample from Gelmol area could have little matrix whereas comparing to sample collected from HK3-A that have high amount of matrix. Calcareous material was found act as cement in some samples.

Modal Analysis

Detrital framework grains of sandstone suites from different kind of basin are the function of provenance types and governed by plate tectonics. Provenance studies focuses on proportion of detrital framework grains as character and amount of interstitial cement and matrix largely a function of diagenesis (Dickinson, 1970) [18].

For comparative analysis of sandstone suites, varied framework grains must be cast in common terms that reflect key factors of sand genesis. Modal analysis is best suited method for the estimation of relative proportion of framework grains, which are used for comparative analysis of sandstone suite (Dickinson and Suczek, 1979) [9].

In case if size of the framework grains are highly variable, Gazzi-Dickinson method of point counting gives relatively better result (Dickinson 1970; Graham *et al.*, 1976; Ingersoll *et al.*, 1984; Zuffa, 1985) [8, 16, 18, 31]. The Gazzi-Dickinson method distinguishes interstitial matrix from framework grains strictly on the basis of size of framework components of the sandstones in the samples were variable and used to work out the modal composition. The results obtained from the modal analysis are shown in table 2.

For the present analysis, all model composition as volumetric proportion were recalculated into QmFLt, where, Qm stand for monocrystalline quartz; F stand for feldspar and Lt for lithic fragments. Percentage of these framework grains are shown in table 3. QmFLt plot after Dickinson and Suczek (1979) [9] indicates that majority of the present sediments were derived from continental block provenance except GLM2-F derived from recycle orogenic provenance.

Classification

There are numerous schemes for the classification of sandstones based on textural and mineralogical parameters, proposed by various workers. Most of the classification uses triangular diagram with quartz, feldspar and rock fragments as end members. The triangle is derived into various fields and rocks with a specific modal composition falling within a particular field are given a specific name.

Some of the notable workers who have contributed significantly in the classification of sandstone are Fischer (1933) [11], Krinine (1948) [20], Tallman (1949) [29], Dapples *et al.*, (1953) [7], Folk (1954) [12], Van-Andel (1958) [30], Fuchtbauer (1959) [14], Hubert (1960) [17], Fujji (1962) [13], Mc. Bride (1963) [22], Krumbein and Sloss (1966) [19],

Shutov (1967) ^[28], Boggs (1967) ^[3], and many other. Packman (1954) ^[25] and Crook (1970) ^[6] have used structure, texture and mineralogy for the classification of sandstone. Dott (1964) ^[10] scheme for the classification of sandstone modified by Pettijohn F.J. (1984) ^[26] is widely accepted one and has been adopted for the classification of present sandstones. It is simple scheme of classification and suitable for both ancient as well as modern sediments because it uses mineralogy of the framework grains and matrix both Quartz, Feldspar and rock fragments are used as end members in this triangular. On the basis of matrix percentage, sandstones is classified into three major groups such as Arenite with matrix (<15%), Wacke with matrix (15% - 75%) and Mudstone with matrix (>75%).

Since the matrix amount in the present samples ranges from 15% - 75%, it was categorised as wackes. For further subdivisions of this wackes, percentage of quartz, feldspar and rock fragment obtained from the modal analysis (table 3) was plotted in the triangular diagram (fig 6). Analysis of QmFLt diagram revealed that out of 25 samples which were selected for the modal analysis, 19 samples were categorised

in the lithic grey wacke category followed by 3 samples in arkosic wacke category and again, 3 samples in quartz wacke category (table 4) (fig. 7).

Greywacke

Wackes are the transitional group between arenites and mudrocks. Dominant with considerably high amount of quartz and a fairly large proportion of grained- matrix and are term as quartz wackes. The term arkosic wacke is used for the sandstones with the significant proportion of matrix and feldspars more than the rock fragments (Pettijohn F.J., 1984) ^[26]. Wackes containing more rock fragments than the feldspar are terms as lithic wackes.

From above finding, it may discuss that due to the presence of large proportion of matrix, wide range of grain size variation, and lack of rounding and sorting of the framework grains is the indications of textural immaturity. The presence of feldspars and rock fragment of various types may indicate mineralogical immaturity (Pettijohn F.J., 1984; Sengupta S.M., 1996) ^[26, 2].

Table 2: Table shows the result of the Modal analysis

Sl. No	Sample	Quartzm	Feldspar	Rock Fragments	Micas	Calcite	Matrix
1	GLM1-1,2	43.95	7.00	7.30	2.75	1.50	37.50
2	GLM1-A3	37.60	6.60	6.80	3.00	0.60	45.40
3	GLM1-A4	46.20	3.20	8.20	2.70	0.90	38.80
4	GLM1-A5	36.80	5.60	7.80	1.40	1.00	47.40
5	GLM1-B	40.20	5.60	7.60	4.20	0.60	41.80
6	GLM1-C	48.00	3.00	6.20	1.40	1.00	40.40
7	GLM1-D	36.20	6.60	6.00	3.40	0.60	47.20
8	GLM1-E	35.60	6.40	8.60	2.60	1.20	45.60
9	GLM1-F	38.80	5.20	7.40	4.40	1.20	43.00
10	GLM1-H	36.00	4.20	6.00	2.00	0.40	51.40
11	GLM2-B	55.60	4.40	5.00	1.50	1.00	32.50
12	GLM2-D	31.60	1.80	3.20	4.80	0.40	58.20
13	GLM2-E	31.60	3.20	11.80	1.20	1.80	50.40
14	GLM2-F	50.40	3.60	4.30	2.50	0.20	39.00
15	GLM2-G	46.20	3.20	6.80	2.40	0.20	41.20
16	GLM2-H	34.40	3.20	6.00	2.60	1.80	52.00
17	GLM2-I	33.40	2.60	3.40	3.80	0.20	56.60
18	GLM2-K	34.40	3.40	4.60	4.40	0.60	52.60
19	GLM2-M	39.00	3.40	4.60	4.60	0.80	47.60
20	GLM2-N	37.80	4.00	5.60	3.40	1.60	47.60
21	GLM2-O	29.80	4.60	7.60	3.00	0.80	54.20
22	HK3-A	28.40	2.20	2.00	2.20	0.60	64.60
23	HK3-B	35.40	2.00	2.20	6.60	0.60	53.20
24	HK3-C	42.60	1.60	1.80	3.60	0.80	49.60
25	TL4-A	31.00	6.40	7.20	5.80	2.00	47.60

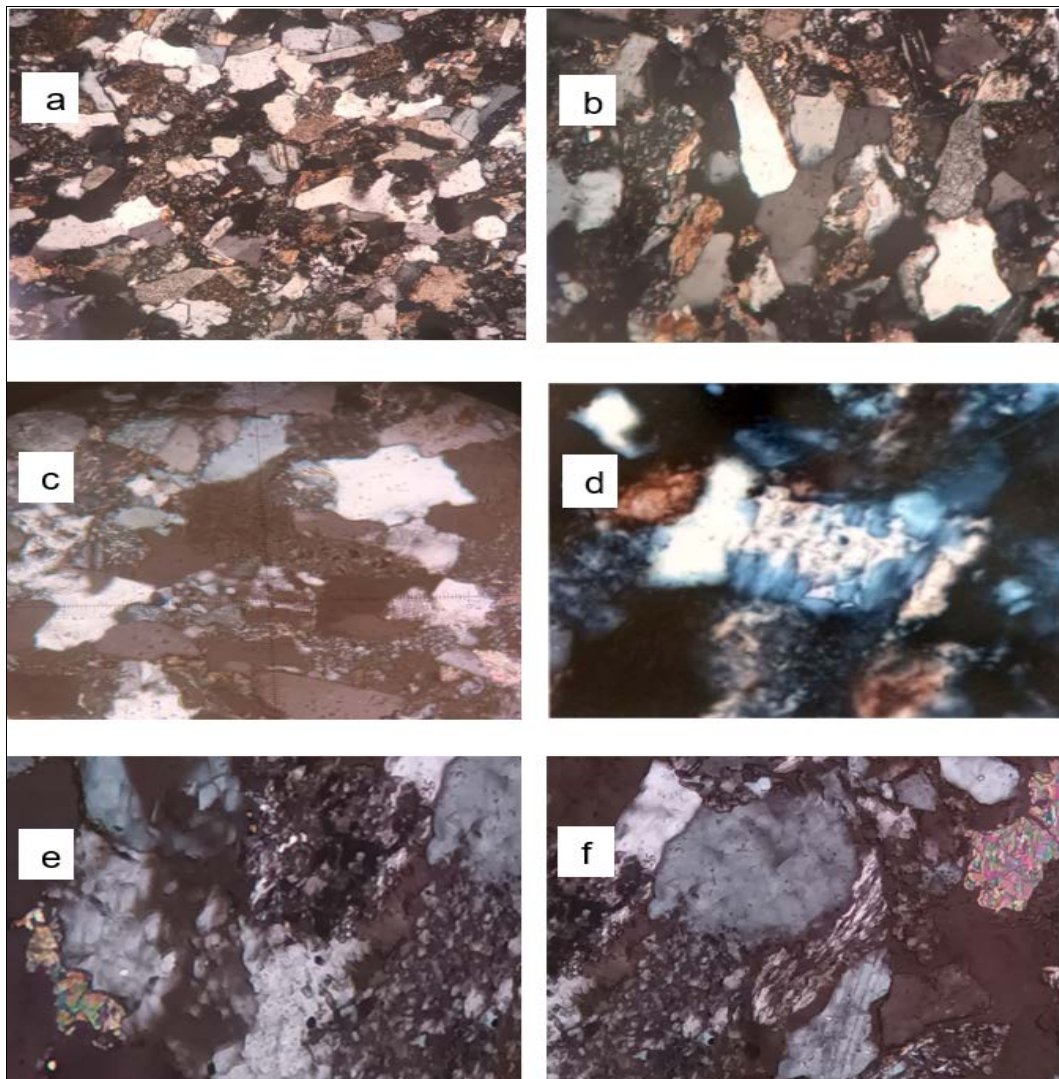
Table 3: QmFLt percentage calculated from the result of Model analysis

Sl. No.	Qm	F	Lt
1	80.00	10.00	10.00
2	78.00	10.00	12.00
3	81.00	05.00	14.00
4	75.00	08.00	17.00
5	74.00	10.00	16.00
6	88.00	04.00	08.00
7	77.00	12.00	11.00
8	73.00	11.00	16.00
9	79.50	06.50	14.00
10	77.00	09.50	13.50
11	93.00	03.00	04.00
12	86.00	05.00	09.00
13	59.00	02.00	39.00
14	86.00	06.00	08.00
15	84.00	06.00	10.00

16	85.00	03.00	12.00
17	87.00	07.00	06.00
18	88.00	03.00	09.00
19	87.00	05.00	08.00
20	87.00	02.00	11.00
21	75.00	09.00	16.00
22	93.00	04.00	03.00
23	89.00	05.00	03.00
24	93.00	03.00	04.00
25	87.00	07.00	06.00

Table 4: Table shows the classification of sandstones of the study area

Sl. No.	Sample No.	Types of Sample	Percentage
1	GLM2-B, HK3-A, HK3-C	Quartz Wacke	12%
2	GLM1-D, GLM2-I, TL4-A	Arkosic Wacke	12%
3	GLM1-A1, GLM1-A3, GLM1-A4, GLM1-A5, GLM1-B, GLM1-C, GLM1-E, GLM1-F, GLM1-H, GLM2-B, GLM2-D, GLM2-E, GLM2-F, GLM2-G, GLM2-H, GLM2-K, GLM2-L, GLM2-M, GLM2-N, GLM2-O, HK3-B	Lithic wacke	76%

**Fig 3:** Photographic representation of thin slide; (a) Subangular to angular quartz grains, (b) Elongated quartz grain, (c) Quartz grain showing wavy extinction (d) Interaction between quartz and calcite, (e) Polycrystalline quartz grains, (f) Chert grains.

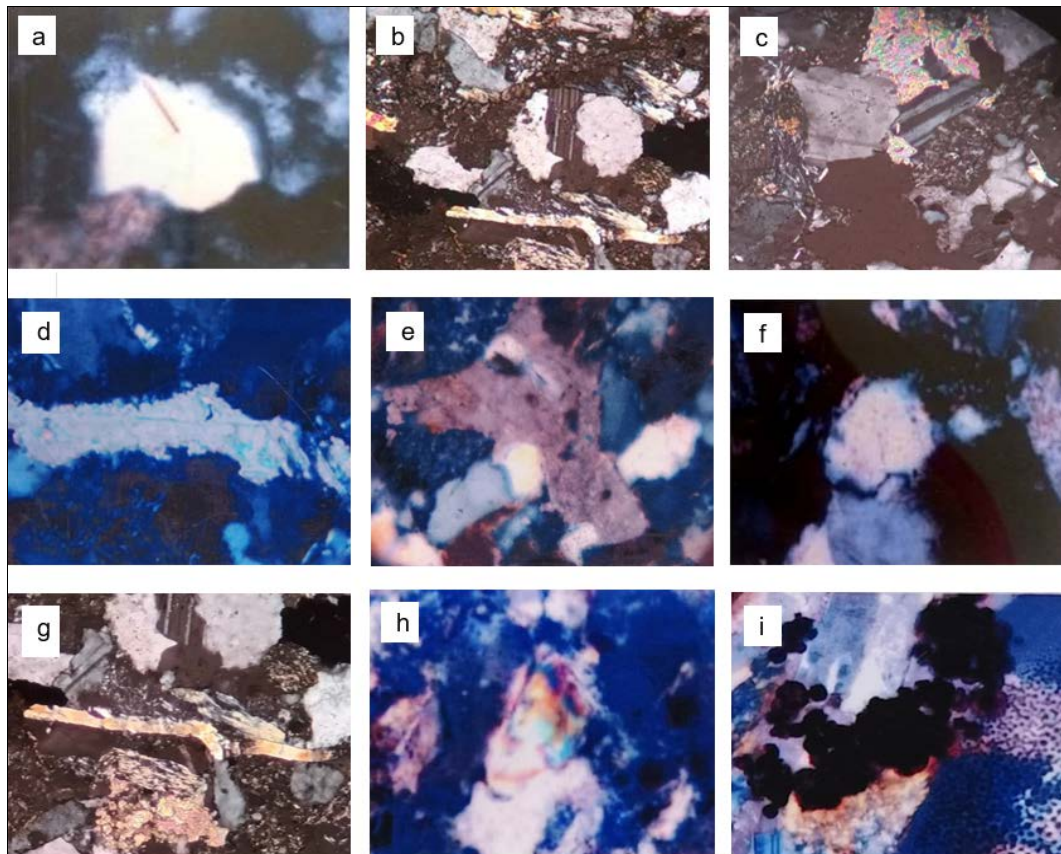


Fig 4: Photographic representation of thin slide; (a)-Muscovite inclusion in quartz grain, (b) Microcline, (c) Plagioclase, (d) Calcite vein, (e) Calcite in matrix, (f) Scattered Bubble in Quartz grain, (g) Muscovite, (h) Andalusite grain, (h) Haematite grains.

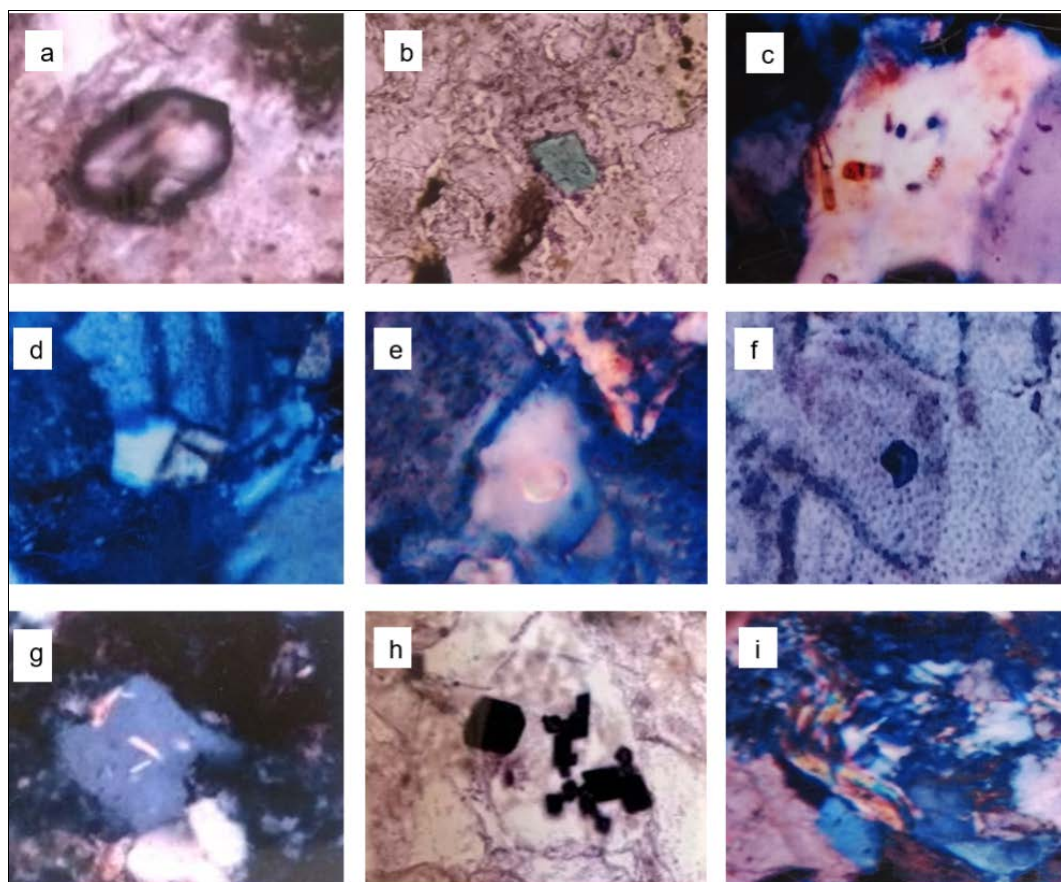


Fig 5: Photographic representation of thin slide; (a) Zircon inclusion in quartz grain, (b) Gluconite grains, (c) Kyanite inclusion in quartz grain, (d) Sphene grain, (e) Spinel inclusion in quartz grain, (f) Brokite inclusion in quartz grain, (g) Tourmaline inclusion in quartz grain, (h) Garnet inclusion in quartz grain, (i) Chlorite grains showing crenulated around the framework grain.

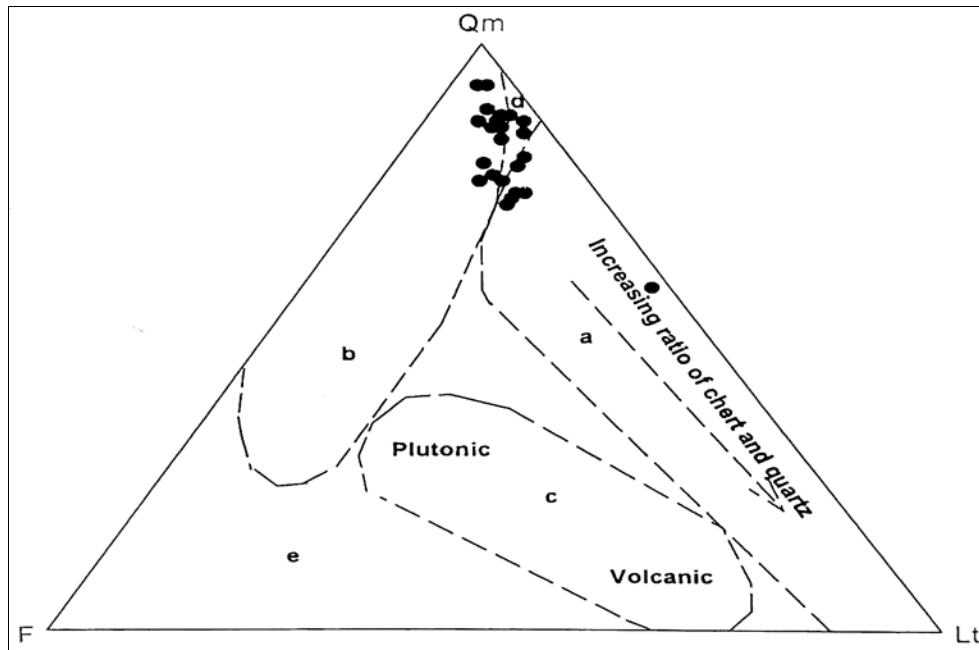


Fig 6: QmFLt diagram after Dickinson and Suczek (1979) ^[9]; a) Recycle Orogenic provenance, b) Continental Bolck Provenance, c) Magmatic arc provenance, d) Merger of fields for mature Rocks with stable Frameworks, e) Merger of fields for plutonic basement and Arc Roofs.

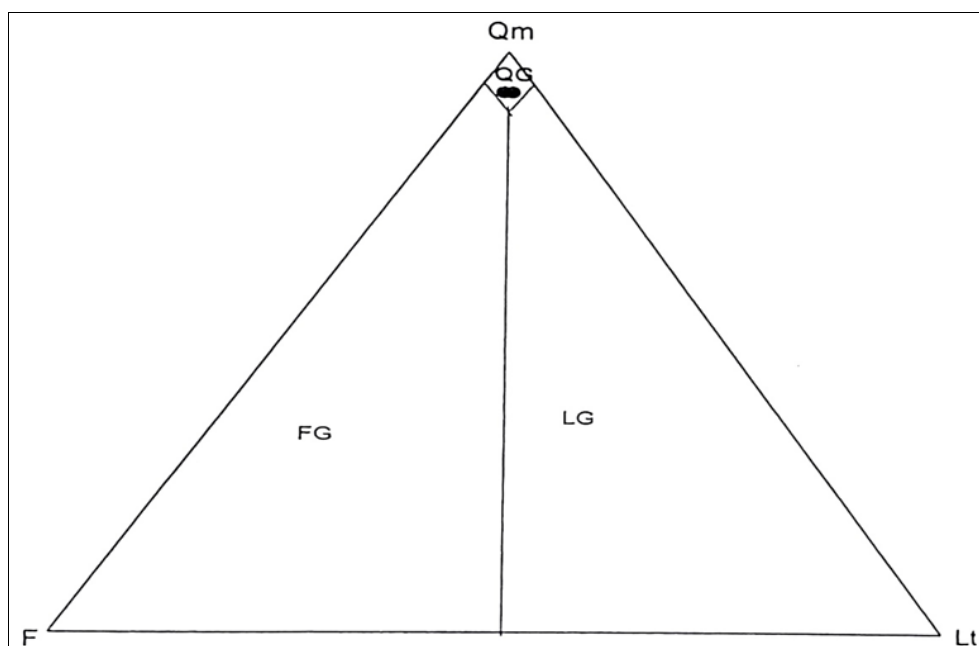


Fig 7: Ternary diagramme of showing classification of Wackes after Dott (1964); QG - Quarz Grey Wacke; FG - Feidspar Grey Wacke; LG - Lithic Grey Wacke.

Conclusions

Present study with the petrographic analysis of Barail sandstone exposed in and around Gelmol, Henkot, and Tuilaphai villages of Churachandpur Distric, Manipur. Geologically, the study area is cover with the Western hills of Manipur forming integral part of the Indo-Myanmar Ranges. Present hill ranges of the study area have resulted from the north-eastward drift of Indian continent and its collision with the Shan-Tenasserim block of Asian landmass by early mid-Eocene.

The study area belongs to one of the youngest mountain chain of the world which is tectonically very active. Geological formations exposed in the area belong to the Disang and Barial Groups and the recent Alluviums. Disang Groups of rocks are exposed in and around Gelmol

village and represented by highly weathered shales, siltstone and very fine- grain sandstones. Barail group of rocks are exposed around Gelmol, Henkot, Tuilaphai villages. It is consist of rhythmic intercalation of shale, siltstone, and sandstones.

For the present study, only Barail sandstones have been taken into account. These sandstones are fine to medium-grain, thinly to thickly bedded. At place these sandstone are massive characterised by the presence of symmetrical ripple marks and cross-bedding. Vertical lithofacies variations and presence ripple marks suggest that these sandstones are deposited in shallow environment under fluctuating energy conditions.

Petrographically, Barail sandstones are consist of quartz, feldspar, rock-fragments, micas, calcite, opaque minerals,

heavy minerals and matrix/cementing materials. Quartz is the most dominant mineral and constitutes 28.5% - 55.6% of the framework grains. Both monocrystalline and polycrystalline varieties of quartz are present, however; monocrystalline variety is more than the polycrystalline one. Most of the quartz grains floating contact however, suture, point, concavo-convex, long contact are also present suggesting variable degree of diagenesis. Some quartz grains are highly elongated and show wavy extinction suggesting metamorphic source. Fine grain minerals like muscovite, boitite, chlorite, feldspars, gas bubbles and different types of heavy minerals are present as inclusion in the quartz grains. These gas bubbles and quartz grains are arranged randomly as well as in the straight lines. In some quartz grains presence of liquid inclusions suggest their igneous origin. Samples containing large amount of decomposed feldspars and calcareous matrix show the effect of itching over the quartz grains.

Feldspar group of mineral is represented by plagioclase, microcline, and orthoclase together contributes 1 - 5.8% of the framework constituent. Most of the feldspars have been decomposed beyond the limit of recognition on the basis of their optical properties and hence consider as matrix. High amount of feldspars in some samples suggests tectonically active source area, short distance of transport and also shows igneous origin. Lithic fragments include both polycrystalline and microcrystalline quartz which contributes 1- 20.8% to the framework components suggesting metamorphic and sedimentary source.

Among the mica group of minerals, muscovite is more common however; few grains of biotite have also been observed. In the present samples mica ranges from 1 - 4.8%. Presence of muscovite supports metamorphic sources.

Conflict of Interest

Authors are declared that there is no conflict of interest.

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