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Research Paper

PETROGRAPHY AND HEAVY MINERAL ANALYSIS OF BARAIL SANDSTONES, ZUBZA VILLAGE, KOHIMA DISTRICT, NAGALAND INDIA

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In this paper petrographic and heavy mineral account of the Barail sandstones of Zubza village area is presented. The sandstones are dominated with Quartz arenite. Few other petrographic types are Argillaceous Siltstone, Laminated Siltstone, Micaceous Quartz Arenite and Lithic Glauconitic Arenite. The modal composition reveals that the percentage occurrences of different constituents of these Barail sandstones range as Quartz (39.85% to 64.10%, Feldspar 5.27% to 8.25%, and Rock fragments 4.53% to 14.25%). However the rich Monocrystalline quartz implies their derivation from intrusive igneous rocks. The Predominance of unit quartz and undulose quartz collectively corroborate the dual sources of low rank metamorphic, and plutonic sources of variable pressure effects. QFL triangular plot infers the derivation of the sandstones from recycled orogenic sources. QmFRt triangular plot shows that the provenance of these Barail sandstones were mainly of mixed and dissected arc types. However, few of them also show their derivation from quartz arenite recycled origin. Heavy mineral study reveals that the Barail sandstones contain both opaque and non –opaque minerals. The non-opaque minerals include Zircon, Tourmaline, Rutile, Sillimanite, Kyanite, and Staurolite. ZTR maturity indices vary from 82.059% to 96.082% with an average 88.538%. ZTR triangular diagram points out the predominance of tourmaline and zircon which further infers the derivation of the Barail Sandstones from both metamorphic and igneous sources.

Keywords: Provenance, Heavy mineral, Barail sandstones, Zubza, Kohima district, Nagaland

INTRODUCTION

Nagaland is located in the northern extension of the Arakan Yoma ranges representing orogenic upheavals in this part of the country during cretaceous and tertiary periods. In this paper a petrographic and heavy mineral study of the barail sandstones are occurring around in Zubza village, Kohima District, Nagaland. 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

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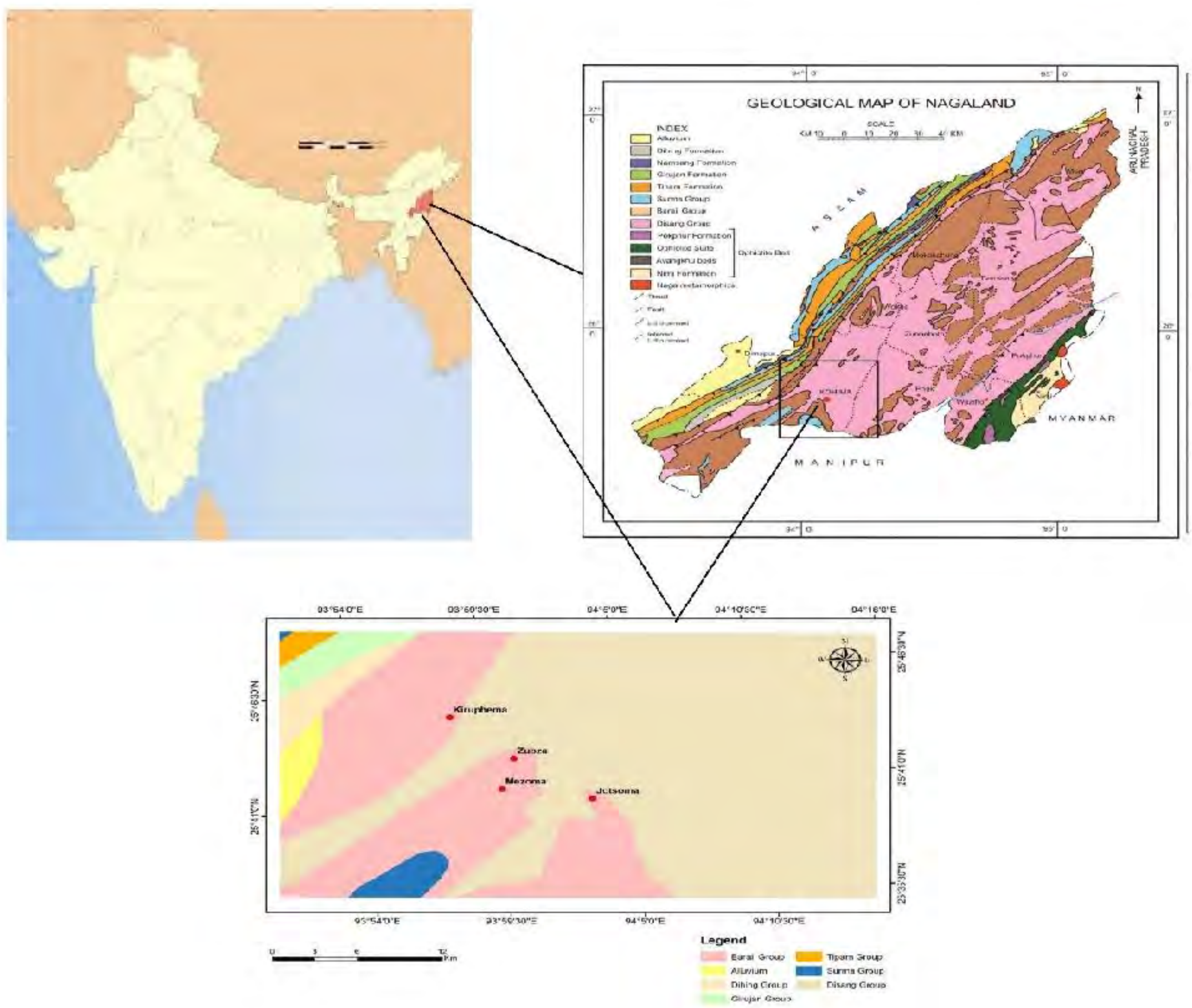
deformation. In addition there are faults traversing the study area. Hence this is the type section of the Barail group of rocks. A location map of the study area is presented in the Figure 1.

Figure 1: Location Map of Study Area



GEOLOGY OF THE STUDY AREA

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. The area selected for the present study is situated in Kohima District of Nagaland. The study area covered in the survey of India Top sheet No. 83 K/7. The exact place from where the samples collected is a stone quarry located at Zubza Village. The sedimentary rocks exposed in the area dominantly composed of sandstones with shale intercalations which represent the Barail Group of rocks.

MATERIALS AND METHODS

For petrographic study, rock thin section slides have been prepared from the Barail sandstone samples collected from the study area. Among the collected samples, Ten selected sandstone samples were studied from the Zubza locations of Quarry section. 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.

Though several methods of minerals separation are available, the heavy liquids that are commonly used for separation of heavy minerals are bromoform (sp.gr. 2.89) and Thoulet's solution (sp.gr. 3.40). For the present study, bromoform liquid was used to separate heavy minerals. Since the rock samples were hard and compact, their disintegration for heavy mineral separation was not possible and hence the method suggested by Folk (1980) has been used. Around 50 gm of samples for heavy mineral separation were crushed gently, washed properly and then subjected to alternate treatment with hydrogen peroxide, distilled water and dilute hydrochloric acid and stannous chloride, followed by boiling for about 5 to 10 minutes so as to remove the authigenic clay, carbonate and ferruginous coatings on the grains. After thorough washing and drying, the sample is sieved using the ASTM sieve mesh 120. The samples obtained from 120 mesh are used for heavy mineral separation.

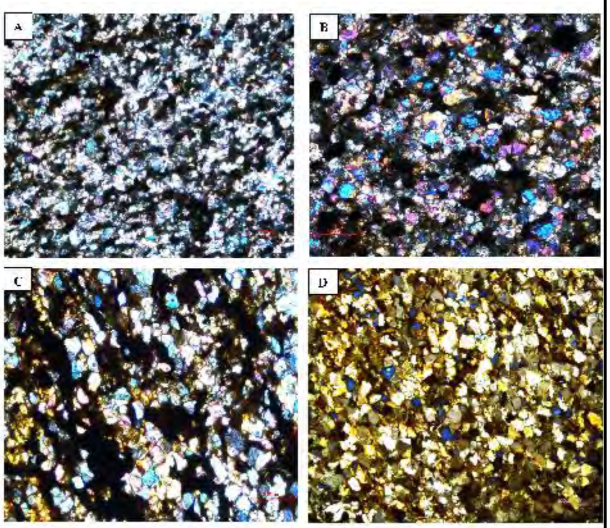
The glass stopper of the separating funnel is smeared with grease or Vaseline top to prevent leakage and fitted into the funnel. The funnel is fixed to the funnel stand and bromoform poured into the funnel through an ordinary funnel up to 2/3rd of its capacity. The sediments from which minerals have to be separated are taken on a glassy paper (to facilitate sliding) and the paper along with sediments. Gentle tapping is given to the glassy paper to allow the sediments to slide and fall into the separating funnel. A glass rod is inserted and it is stirred thoroughly, working from the bottom towards the top. The whole thing is left in the position for twenty minutes. After ten minutes, the glass rod is again inserted only half way through the bromoform, not disturbing the bottom portion while the top portion stirred gently. It is allowed to settle for another ten minutes and afterwards, the heavy crop drawn trough a funnel fitted with a filter paper into a bottle to collect the bromoform, the heavy residue left on the filter paper is washed thoroughly with ethanol from a wash bottle and the washing of bromoform is collected separately. The heavy residue is dried on a hot plate, and grains mount of it are prepared in a Canada balsam for a microscopic examination. Similarly light crops or light portion floating in bromoform can be drawn, washed with ethanol, and dried on a hot plate for preparation of grain mounts in Canada balsam for microscopic examination. To determine the relative abundance of heavy minerals in a sample, Ribbon counting method was used. Heavy mineral slides have been prepared and studied under petrological microscope. ZTR maturity index for all the samples have been calculated following Hubert (1962).According to Hubert (1962), ZTR maturity index is the percentage of combined zircon, tourmaline and rutile grains among the transparent, non-micaceous, detrital heavy minerals. In order to show the relative predominance amongst zircon, tourmaline and rutile, their individual percentages within the ZTR maturity index have been calculated and plotted in a diagram.

RESULTS AND INTERPRETATION

Petrographic Study

The prepared rock thin section slides of the Barail sandstones have been studied under petrological microscope for the classification of the Barail sandstones and to determine the tectonic setting of the source area during the time of their deposition. The results of modal analysis of these sandstones have been presented in Table 2 and Table 3. The petrographic study reveals that the Barail sandstones consist of quartz, feldspar, and rock fragments (Fig. 2). Both floating and interlocking grains are present. Interlocking grains show point contact, line contact and concavo-convex contact. Quartz is the dominant constituent in all the studied sandstones. The percentage occurrences of different constituents of Barail sandstones range as Quartz (39.85%to 64.10%, Feldspar 5.27%, Rock fragments 4.53% to 14.25% and etc. Both monocrystalline and polycrystalline varieties of quartz are present. Among the framework grains, quartz is the most abundant constituent. Majority of quartz grains are sub angular 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.

Figure 2: A) Fine Grained Barail Sandstones B) Sub Angular Medium Quartz Grains and Argillaceous Matrix C) Fine-Medium Size Sub Angular Quartz Grains Showing Development of Muscovite from Argillaceous matrix D) High Poorly Sorted Medium Grained Angular Quartz Rich Rock Forming Unbent Mica Grains as well as Few Heavy Mineral Grains



CLASSIFICATION OF THE STUDIED BARAIL SANDSTONES AFTER PETTIJOHN ET AL., 1972)

The recalculated values of quartz (Q), feldspar (F) and rock fragment (L) (Table 1) have been plotted in the QFL triangular diagram for the classification of the studied sandstones (Fig. 3). It has been observed that the sandstones under study are mostly of Quartz arenite type. However, few of them also belong to Argillaceous Siltstone, Laminated Siltstone, Micaceous Quartz Arenite and Lithic Glauconitic Arenite types.

Table 1: Generalized Stratigraphic Succession of Nagaland, Eastern Himalaya (Compiled After Evans, 1932 and Ranga Rao, 1983)

The Stratigraphic Succession in Nagaland

Age	Group	Formation	Member	Lithology
Quaternary to Recent (Holocene)	Alluvium	River Channel deposit	-	Sand, silt and clay
		Dhansiri Fm.		Sand, silt and clay without diagenetic.
		Dimapur/Jaluki Fm.	-	Boulder conglomerate with brownish yellow to yellowish brown sandy loam with *kankar*, sandy clay, sandstone pebbles, gravel and mottled clay with ferruginous nodules.
		Zutovi Fm.		Boulder conglomerate with brownish to reddish yellow sandy matrix and fine to medium grained brownish red sand.
Pleistocene to Pliocene	Dihing Gp.	Dihing Fm.	-	Conglomerate, grit, sandstone and clay beds.
Mio-Pliocene	Dupitila Gp.	Namsang Fm./ Dupitila Fm.	Dupitila beds	Coarse, gritty, poorly consolidated sandstone and conglomeratic coal pebbles.
Mio-Pliocene	Tipam Gp.	Girujan Fm	-	Clay, mottled sandy clay, mudstone with subordinate ferruginous sandstone.
		Tipam Fm.	-	Thick-bedded medium to coarse-grained ferruginous sandstone with interbands of siltstone and clay.
Miocene	Surma Gp.	Bokabil Fm.	-	Shale, sandy shale, siltstone, mudstone and lenticular, coarse ferruginous, sandstone.
		Bhuban Fm.	Up. Bhuban	Predominantly arenaceous sandstone with subordinate siltstone and thin shale bands, basal conglomerate, shell limestone.
			Mid. Bhuban	Predominantly argillaceous shale, silty shale with thinly bedded fine-grained micaceous sandstone.
			Low. Bhuban	Predominantly arenaceous massive, well bedded sandstone with turbidite features
Eocene to Oligocene	Barail Gp.	Renji Fm./Tikak Parbat Fm.		Massive bedded sandstone and massive coal in basal part of Tikak Parbat Fm.
		Jenam Fm. / Borgolai Fm.	-	Shale, sandy shale and carbonaceous shale with interbedded hard sandstone, thin coal seams in Borgolai Fm.
		Laisong Fm / Nagaon Fm	-	Well-bedded compact flaggy sandstone and sub-ordinate shale, thin bedded hard sandstone and inter bedded shale.
Eocene	Disang Gp.	Disang Fm.	Upper Disang	Alteration of thick sequence of grey, *khaki*, splintery shale with-foraminifers sandstone and minor siltstone beds with plant fossils, coal streaks and trace fossils.
			Lower Disang	Grey splintery shale, greywacke with rythmite, minor sandstone, slate and phyllite.
Middle Eocene	Oceanic Pelagic Sediments Gp.	Phokpur Fm. (Ophiolite Belt)	-	Polymictic conglomerate, tuffaceous greywacke, lithic felspathic arenite.
		Salumi Fm. (Ophiolite Belt)	-	Shale, siltstone with interbands of radiolarian chert.
Palaeocene – Lower Eocene		Nimi Fm. (Ophiolite Belt)	-	Limestone, marble, quartzite, phyllite.
Upper Cretaceous to Lower Eocene		Avangkhu Fm. (Ophiolite Belt)	-	Slate with minor quartzite.
	Ophiolite Suite	Mafics & Ultramafics	-	Plagiogranite
				Volcanics with flows, pillows and breccias/ agglomerates.
				Basalt, gabbro, anorthosite, etc., harzburgite, lherzolites, wehrlite, dunite and peridotite.
Proterozoic	Naga Metamorphites	Saramati Fm.	-	Quartz – muscovite – biotite schist, quartz schist, carbonaceous phyllite, quartzite.

PROVENANCE AND TECTONIC SETTING

Recalculated values of different quartz types (Table 1) have been plotted in the Triangular Diagram (after Basu *et al*., 1975), which indicates that the constituents of the sandstones under study were derived from middle, upper, as well as low rank metamorphic sources (Figure 6).

From the QFR triangular plot, it is inferred that the Barail sandstones were derived from recycled orogenic sources (Figure 4). Percentages of monocrystalline quartz (Qm), feldspar (F) and total polycrystalline Rock fragments (Rt) of the Barail sandstones are given in Table 1. QmFRt triangular plot shows that the provenance of these Barail sandstones were mainly of mixed and

Table 2: Modal Percentage of Quartz, Feldspar, Rock Fragments of Barail Sandstone

Sl. No	Sample No	Quartz Undulose	Quartz Nonundulose	Quartz Polycrystalline
1	B11	11.860	69.070	14.884
2	B14	11.170	68.972	15.780
3	B22	10.677	69.792	15.885
4	B24	13.527	67.979	15.753
5	B26	12.248	69.128	14.765
6	B29	13.074	66.313	16.254
7	B32	12.813	65.685	16.495
8	B35	10.886	73.616	12.731
9	B38	13.395	67.898	15.242
10	B39	10.096	74.679	12.340

Table 3: Modal Percentage of Quartz Undulose, Quartz Nonundulose and Polycrystalline Quartz of Barail Sandstone

Sl. No	Sample No	Quartz (Mono+Poly)	Feldspar (Plag+Micro)	Rock fragments (Quartzite+Chert)
1	B11	95.814	0.465	3.721
2	B14	95.922	0.177	3.901
3	B22	96.354	0.000	3.646
4	B24	97.260	0.171	2.568
5	B26	96.141	0.336	3.523
6	B29	95.642	0.000	4.358
7	B32	94.993	0.147	4.86
8	B35	97.232	0.369	2.399
9	B38	96.536	0.231	3.233
10	B39	97.115	0.000	2.885

Figure 3: Triangular Plot of QFR of Barail Sandstone (After Pettijohn et al., 1972)

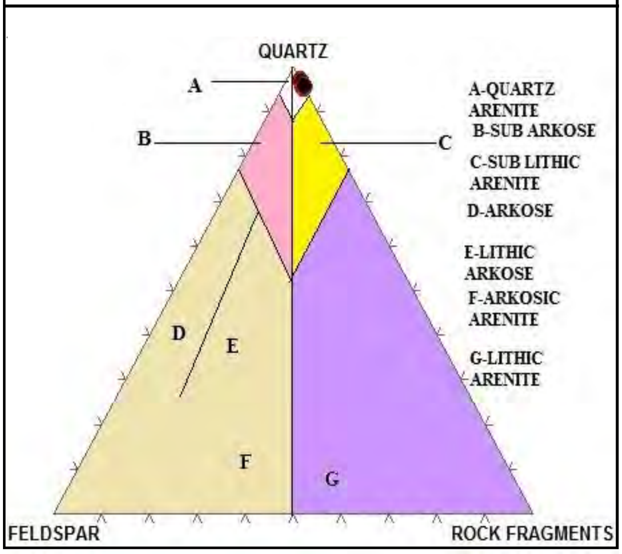


Figure 4: QFL and QmFRt, Triangular Plot of Barail Sandstone (After Dickinson et al., 1983)

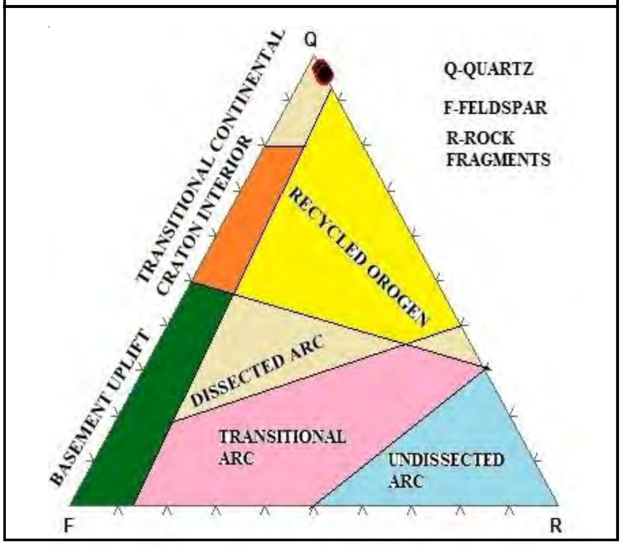
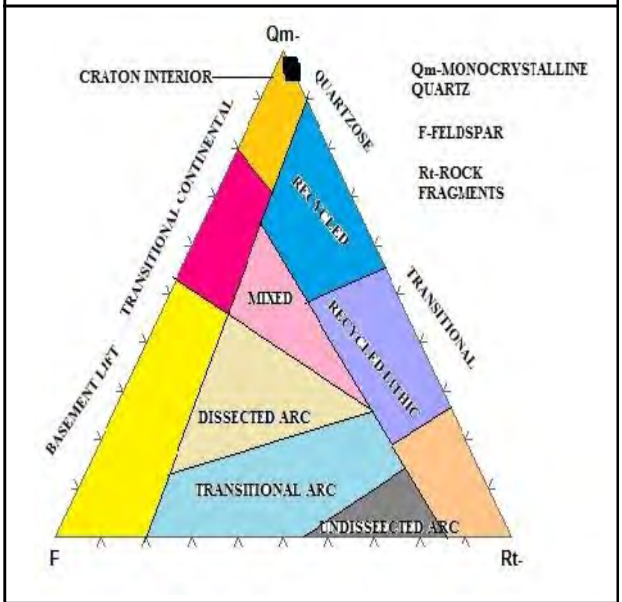
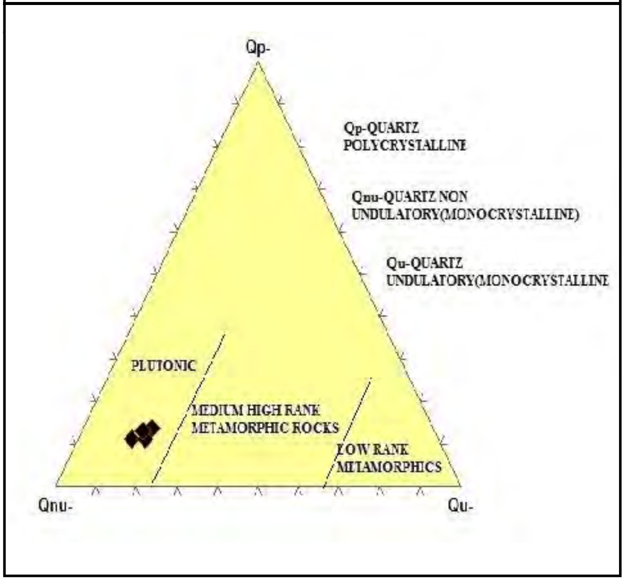


Figure 5: QFL and QmFRt, Triangular Plot of Barail Sandstone (After Dickinson et al., 1983)



dissected arc types. However, few of them also show their derivation from quartz arenite recycled origin (Figure 5). 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). 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 (Basu *et al*., 1975). Studies of intercrystalline boundaries, crystal size, shape and sorting within polycrystalline grains are potentially useful in source rock identification (Blatt and Christie, 1963). Composite quartz with straight boundaries on the other hand point out a plutonic igneous derivation.

Figure 6: Triangular Plot of Detrital Quartz Types of the Barail Sandstone (After Basu et al., 1975)



Qun-Qnun-Qp ternary plot of detrital quartz suggest plutonic source (Figure 6).

HEAVY MINERAL ANALYSIS

The heavy mineral study reveals that the Barail sandstones under study contain both opaque and non-opaque minerals. The non-opaque minerals include Zircon, Tourmaline, Rutile, Sillimanite, Kyanite, Staurolite and opaque.

Figure 7: Heavy Mineral in Barail Sandstones

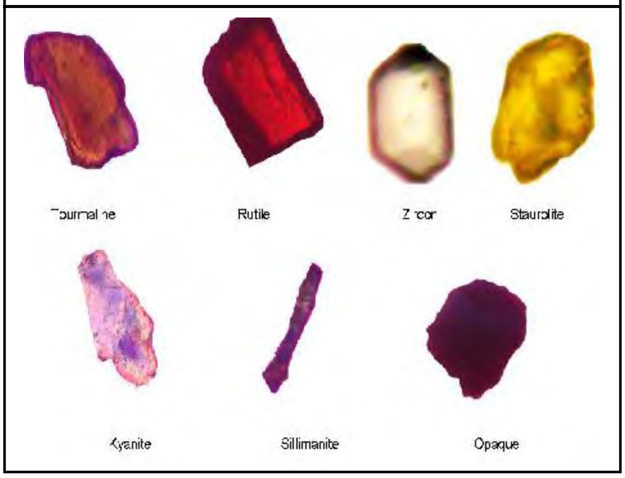
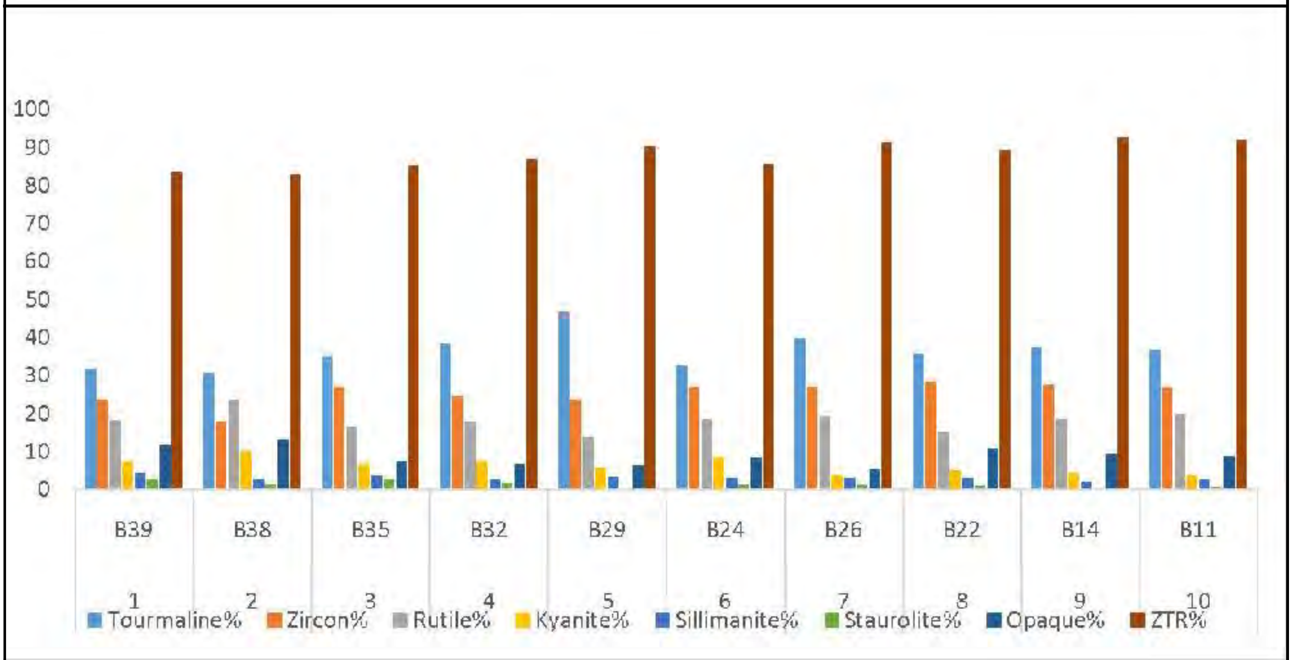


Table 4: Heavy Minerals Percentages of Barail Sandstone

S.No	Sample no.	Tourmaline%	Zircon%	Rutile%	Kyanite%	Sillimanite%	Staurolite%	Opaque%	ZTR%
1	B39	31.959	23.711	18.213	7.216	4.467	2.749	11.684	83.658
2	B38	30.882	17.647	23.529	10.294	2.941	1.471	13.235	83.051
3	B35	34.928	27.273	16.746	6.699	3.828	2.871	7.656	85.492
4	B32	38.350	24.757	17.961	7.282	2.913	1.942	6.796	86.979
5	B29	46.721	23.770	13.934	5.738	3.279	0.000	6.557	90.351
6	B24	32.727	26.818	18.636	8.636	3.182	1.364	8.636	85.572
7	B26	39.939	27.134	19.207	3.963	3.049	1.220	5.488	91.290
8	B22	35.789	28.421	15.263	5.263	3.158	1.053	11.053	89.349
9	B14	37.544	27.719	18.596	4.561	2.105	0.000	9.474	92.636
10	B11	36.782	27.011	19.828	4.023	2.586	0.862	8.908	91.798

Figure 8: Percentages of the Different Hminerals Present in the Studied Barail Sandstones and ZTR Percentage



Photomicrographs of a number of observed non-opaque heavy minerals have been presented in Figure 7. The percentages of the heavy minerals present in the studied Barail sandstones have been presented in Table 3 and shown graphically in Figure 8. ZTR maturity index varies from

82.059% to 96.082% with an average 88.538%. (Table 3).They fall mainly in the C1 and A1 tier of the ZTR triangular diagram indicating the predominance of tourmaline and zircon which infers the derivation of the Barail Sandstones from both metamorphic and igneous sources .The low values of zircon, tourmaline and rutile (ZTR)% indicate that the sediments are mineralogically immature. Presence of kyanite, staurolite, sillimanite, brown tourmaline their derivation from acid igneous and crystalline metamorphic rocks. Igneous source is also indicated by the presence of prismatic and angular zircon grains and high percentage of opaque minerals. Subhedral and rounded zircon grains indicate their derivation from reworked sedimentary sources.

DISCUSSIONS AND CONCLUSION

The study reveals that studied Barail sandstones are mostly of Quartz arenite type of Dott, 1964 (in Pettijohn, 1984). However, few of them also belong Argillaceous Siltstone, Laminated Siltstone, Micaceous Quartz Arenite and Lithic Glauconitic Arenite types.

The presence of concavo-convex and sutured grain contacts indicates that the Barail sandstones had undergone mechanical compaction due to the pressure of the overlying strata. The same is also indicated by the bended mica flakes and bending and displacement of twin lamallae in a few plagioclase grains. However, the compaction was not much intensive during lithification of the sediment as is indicated by the presence of a number of floating framework grains.

Triangular diagram of Basu et al. (1975) has shown that the constituents of the sandstones under study were derived from middle, upper, as well as low rank metamorphic and plutonic sources. Moreover, the presence of two varieties of polycrystalline quartz viz. one with polycrystalline grains composed of five or more crystals with straight to slightly curved intercrystalline boundaries and the other with polycrystalline grains composed of more than five elongate crystals, exhibiting irregular to crenulated intercrystalline boundaries suggest an origin for the Barail sandstones from plutonic igneous and metamorphic source rocks respectively (Folk, 1974; Blatt *et al.* 1980, Asiedu *et al.,* 2000).

Presence of kyanite, staurolite, sillimanite, brown tourmaline and rutile indicates the derivation of the sandstones from high rank metamorphic source. Presence of rutile indicates their derivation from acid igneous and crystalline metamorphic rocks. Igneous source is also indicated by the presence of prismatic and angular zircon grains and high percentage of opaque minerals.

QFL triangular plot of Dickinson et al. (1983) indicates that the Barail sandstones were derived from recycled orogenic sources. QmFRt triangular plot shows that the provenance of these Barail sandstones were mainly of mixed and dissected arc types. However, few of them also show their derivation from quartz arenite recycled origin.

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