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Classification and provenance studies of the sandstones exposed along Durtlang road section, Aizawl, Mizoram

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Abstract

Mizoram predominantly comprises of Surma Group of rocks which also cover the whole area of the Aizawl city. Sandstones exposed along Durtlang road section in the northern part of the Aizawl city are composed mainly of quartz, mica group of minerals like biotite and muscovite, lithic fragments and feldspar group of minerals like plagioclases, microcline and orthoclase, and other minor detrital components. The classification and provenance studies of sandstones are basically done on the basis of three important major detrital minerals like quartz, feldspar and lithic fragments. On the basis of these three components, the sandstones exposed along Durtlang road section were classified into litharenite and sublitharenite. The sources of the sediments were determined to be of igneous and metamorphic terrains, probably of Himalayan orogen and the Indo-Burmese collision zones.

Key words: Durtlang road; Middle Bhuban Formation; modal analyses; provenance; sandstones.

Introduction

Now-a-days the provenance studies of sedimentary rocks received impulses through time. Mizoram is located in the southern most part of north-east India forming a part of the folded chain of the Assam-Arakan basin.[1] The entire area geologically comprises of sedimentary rocks of Tertiary age. The present knowledge on geology of Mizoram and Aizawl was due to the work done by a few geologists working under the Geological Survey of India which dates back to 1891, 1964 and 1973.[2-5] There are huge scopes for geological investigations in different areas of sedimentology, geochemistry, seismology and engineering geology. In spite of different contributions by various geologists since the last three to four decades, detailed studies on the implications of mineralogical compositions in the classification and provenance studies of sedimentary rocks found in Mizoram are rarely documented. Therefore, the present work deals with the modal mineral compositions controlled by different tectonic settings as have been studied by sedimentologists in different parts of the world.[6-10]

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The present study basically focused on these contexts for Bhuban Formation of Surma Group exposed along Durtlang road section in Aizawl located within the geographical coordinates of 92°43'30" to 92°44'42" E longitude and 23°45'18'' to 23°46'30" N latitude (Fig. 1).

Recently, provenance studies of Surma Group of rocks in Mizoram and its neighbouring country of Bangladesh were done by various workers on the basis of heavy mineral analyses, petrography and geochemistry.[11-15]

General geological settings

The entire city of Aizawl comprises of the Upper and Middle Bhuban Formations of Surma Group of rocks. These rocks comprise of alternate beds of sandstone, shale, siltstone and mudstone of various thicknesses. The rock beds strike N-S and dip towards east and west in the northern and southern parts of the city respectively. The study area in Durtlang road section specifically exposes the Middle Bhuban Formation predominated by argillaceous rocks intercalated with a lesser but sometimes massive and thick layers of sandstones. The shale beds are very brittle and easily broken into fragments while the sandstones were compact, hard and more stable relative to the shale beds.

Materials and Methods

Field work and sampling

A geological field work is carried out in the area of Durtlang road section to study various geological characteristics of lithology. During field work, eleven (D1 – D11) representative rock samples are collected from different points of the sedimentary strata for further analyses such as thin section preparation and further studies under microscope for characterization of mineralogical components.

Sample preparations and microscopy

The ten representative rock samples were cut into 20 thin slabs (two slabs for each sample) of about 0.3cm in Geological Laboratory at Pachhunga University College. These thin slabs of

Table 1. A quantitative mineralogical composition or modal analyses of sandstones of Middle Bhuban Formation of Surma Group of rock exposed along Durtlang road section.

Sample No.	Minerals				
	Quartz			Feldspar	Lithic fragments
	Qp	Qm	Qtot		
D1	48	109	157	42	63
D2	78	59	137	35	78
D3	54	134	188	15	25
D5	61	107	168	22	55
D6	60	70	130	16	76
D7	74	124	198	22	82
D8	82	114	196	32	72
D9	38	92	130	19	28
D10	65	136	201	31	48
D11	45	127	172	21	67
Total	605	1072	1677	255	594
%	36.08	63.92	66.39	10.1	23.51

Index: Qp= Polycrystalline quartz, Qm= Monocrystalline quartz, Qtot= Total quartz

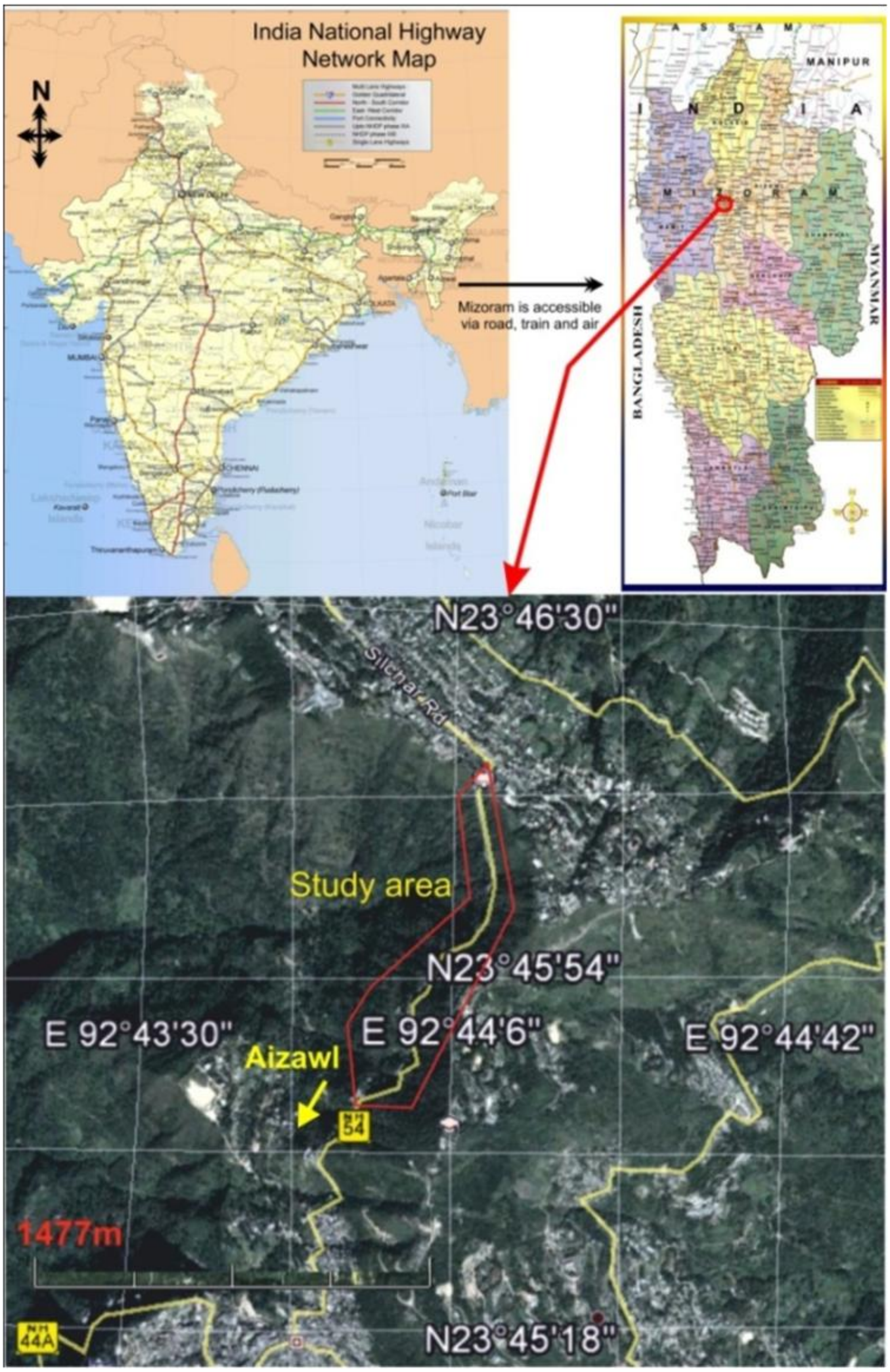


Figure 1. Location and accessibility of the study area.

rocks were sent to Hindustan Minerals & Natural History Specimens Supply Co., Kolkata and Wadia Institute of Himalayan Geology, Dehradun. The mineralogical identifications were carried out with a trinocular Leica DM EP Petrological Microscope mounted with Nikon camera. During mineralogical modal counting, a manual grid per grid counting process was adopted by carefully maintaining the grid patterns. The mineralogical modal data obtained from microscopic identifications were used in various plotting techniques to make conclusion on the implications of mineralogy to classification and provenance studies of the investigated sandstones.

RESULTS AND DISCUSSIONS

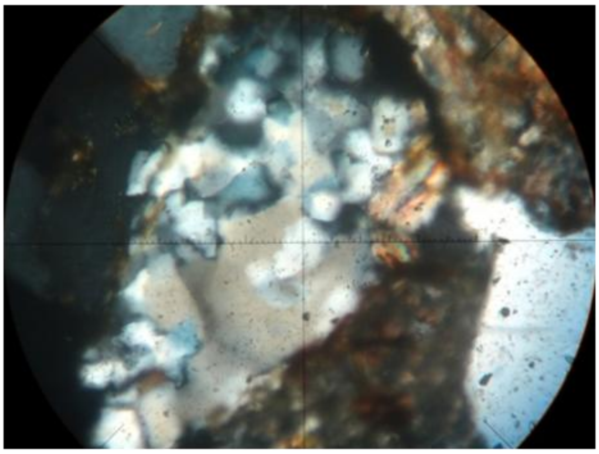
Mineralogy and modal analyses

The bulk mineralogical compositions of the sandstones are expressed as detrital and authigenic components. A quantitative mineralogical composition or modal analyses and compositional means (in %) of the sandstones for quartz, lithic fragment and feldspar are shown in Table 1. The detrital components are sand-sized particles of either monomineralic or polymineralic grains. The important detrital mineralogical components comprise of quartz, lithic fragments, feldspar and mica. Opaque detrital grains are also commonly observed in the rocks.

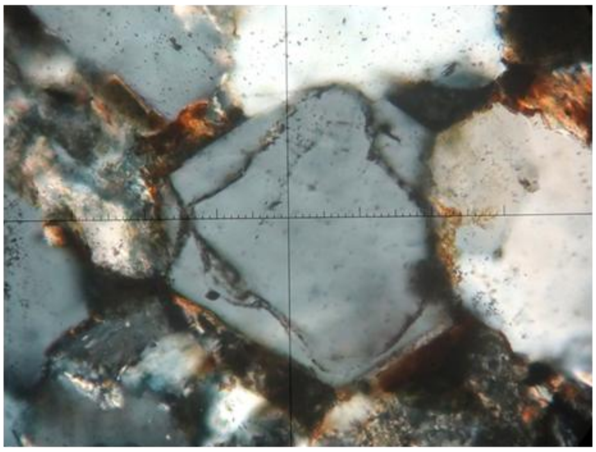
Quartz is the predominant mineral. The modal analyses indicated that quartz constitutes about 54.8 to 82.46% of the total sediments with an average of 68.63%. The contents of quartz were fairly high in all the rocks which might be indicative of acidic igneous source or metamorphic equivalents of these kinds of rocks. The quartz grains are observed in two main different forms such as monocrystalline quartz (nonundulatory or undulatory) and polycrystalline quartz. They are generally poorly sorted, angular to sub angular shape which indicated short transportation and immature sediments. The boundary of polycrystalline quartz are straight or sutured depending upon the degree of metamorphism or the pressure and temperature condition of formation during its genesis in the parent rock (Plate 1a). The thin section reveals that some detrital grains of quartz undergo secondary silica cementation during diagenesis assuming crystalline outlines due to precipitation of silica overgrowth onto the quartz grains in presence of open pore spaces (Plate 1b). In such quartz, the original grain outline is revealed by presence of small speckles of bubbles or hematite or lines of impurities.[10] The occurrence of myrmeckite formed by the intergrowth of quartz and orthoclase was also observed in the rock which indicated the source rock to be of alkali-rich plutonic igneous rock (Plate 1c).

Lithic fragments are common detrital components in the present sandstones (Plate 1d). The modal analyses show that lithic fragments constitute about 10.96% to 34.23% with an average of 22.58% of the total sediments. Since all sandstones were containing certain amounts of lithic fragments, they might have to be classified generally into lithic class of any of arkose or arenites. They show schistose as well as gneissose fabrics which are characteristics to pressure influenced metamorphisms. The lithic fragments are usually composed of fine aggregates of lensoidal or elongated, light and dark colored minerals showing differential extinctions, and are believed to be derived from schists. Less commonly, there are also lithic fragments containing coarse-grained lensoid quartz grains exhibiting wavy extinction believed to be derived from gneissic parent rocks.

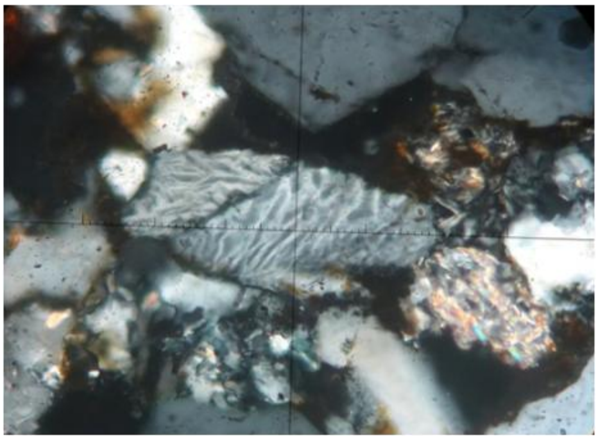
In order of abundance, feldspar is the least abundant mineral among the three important detrital minerals such as quartz, lithic fragments and feldspar. Feldspar constitutes about 6.58% to 16.03% with an average of 11.30% of the total sediments. The rocks were relatively low in these components compared to quartz and lithic fragments. Both alkali feldspar and plagioclase feldspars are found in more or less similar amount, but in some rock samples alkali feldspars like microcline and orthoclase are more common (Plate 1e,f). The presence of microcline reveals the source rock to be of low grade meta-



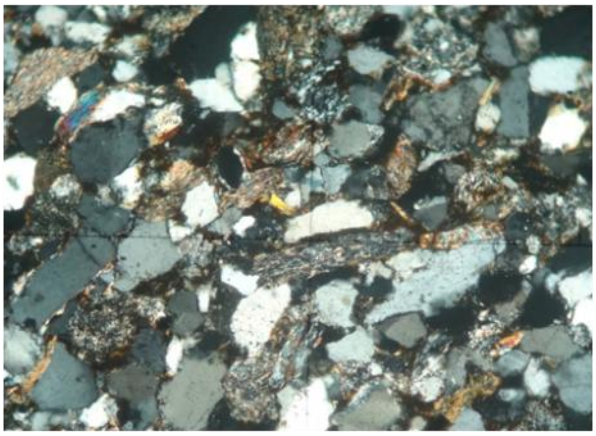
(a) Polycrystalline quartz.



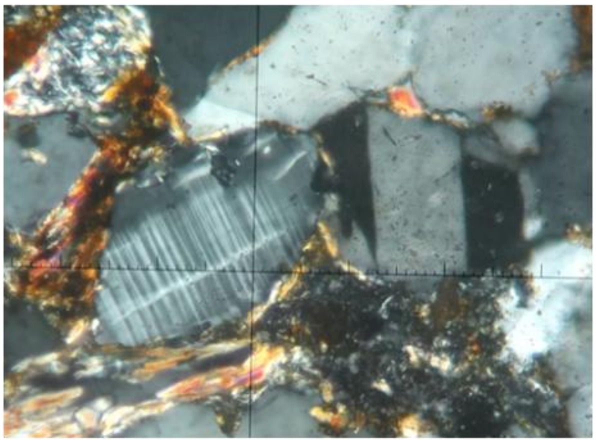
(b) Secondary growth of silica over quartz.



(c) Myrmeckite (quartz –orthoclase intergrowth).



(d) Lithic Fragments of lensoid aggregates.



(e) Plagioclases (lamellar twinning).

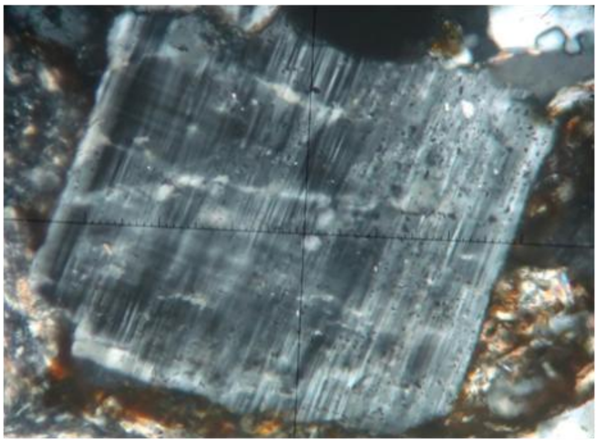
(f) Microcline (polysynthetic twinning).

Plate 1

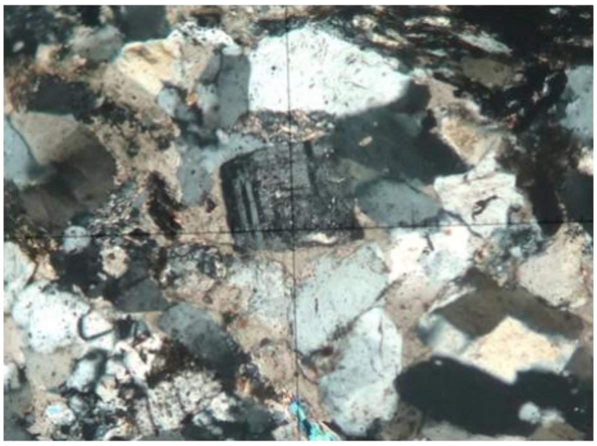
morphic terrain and alkali rich granites. Perthite is also common in the present sandstones which may indicate alkali-rich igneous as well as metamorphic provenance (Plate 2a). Antiperthite is also uncommonly observed in the rocks. There was also occurrence of zoned plagioclase indicating volcanic source (Plate 2b).[16] There are some pure fragments of feldspar grains which may indicate igneous origin, while others show high or partial alteration probably indicating metamorphic origin. The alterations of plagioclase minerals result in the formation of muscovites (Plate 2c).

Mica mineral such as muscovite and biotite are abundant in the finer sandstones. They occur as thin flakes, usually deformed lamellar structures. Muscovites are identified on the basis of colorlessness in plane polarized light, one set cleavage, high birefringence with higher order pink and blue interference color and parallel extinction. Biotites are identified by its brown color under plane polarized light and strong pleochroism. These mica minerals are usually present as deformed mineral between grains of the more competent detrital minerals like quartz and feldspars.

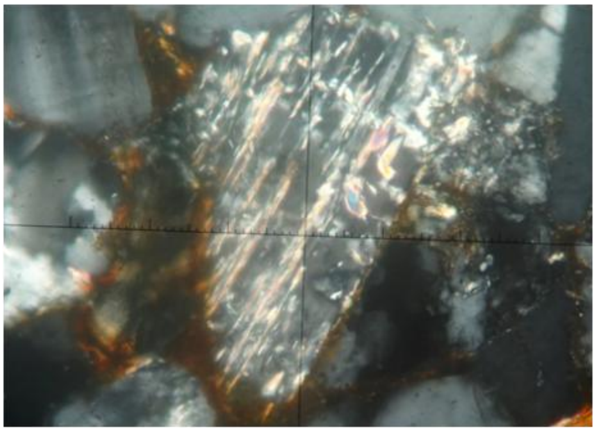
The authigenic components of the present sandstones comprise of those formed during diagenesis and lithification such as siliceous cement, iron oxides and carbonate cements. Authigenic or secondary quartz occurs as cement which is the most common cementing ma-



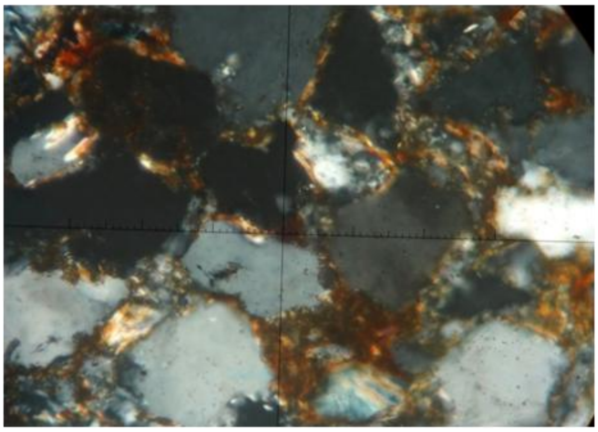
(a) Perthite (microcline-albite intergrowth).



(b) Zoned plagioclase in carbonate cement.



(c) Alteration of plagioclase to muscovite.



(d) Iron oxide cementation.

Plate 2

terial in the studied rock. It occurs as overgrowth on detrital quartz grains or filling pore spaces of other detrital minerals (Plate 1b). The authigenic iron oxide cementation is quite commonly observed which are derived by oxidation of iron-bearing minerals like biotite in pore waters (Plate 2d).[10] The iron oxide cements occur as pore-filling as well as grain replacement mode due to post-depositional reaction. It is identified by its reddish-brown to black colored appearance; high relief under plane polarized light and crossed nicols. Mostly, those of the reddish-brown sandstones were showing this characteristic cementing material. The carbonate cement was also observed as less common cementing material (Plate 2b). These cements are filling pore spaces among detrital grains with mosaic of fine crystals. However, their cementation was observed in a very patchy manner which might reflect initially patchy carbonate precipitation, or it might be due to subsequent partial removal of more or less evenly distributed cement owing to dissolution during burial or outcrop exposure.

Classification of the sandstones

The major detrital framework components, especially quartz (Q), feldspar (F) and lithic fragments (L) have been recalculated to 100% (Table 2) for ternary QFL diagram for the purpose of classification the rocks.[17] According to QFL classification scheme, the studied sandstones are plotted in litharenite to sublitharenite (Fig. 2). Based on this classification, the reddish-brown sandstones fall under the class of litharenite while those of grey to bluish sandstones fall under the class of sublitharenite.

Provenance determination

The character of sedimentary provenance, the nature of sedimentary processes within the depositional basin and the kind of dispersal paths that link provenance to basin, influence the sandstone composition.[6] The modes of detrital framework of sandstone assemblages provide information about the composition and tectonic

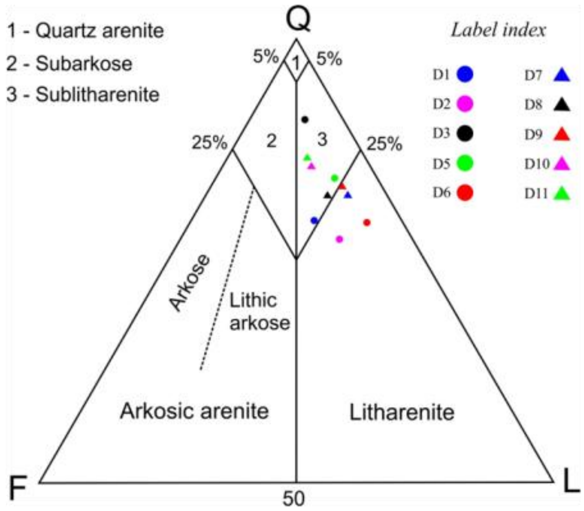


Figure 2. QFL triangular diagram for the classification of sandstone samples of Middle Bhuban Formation of Surma Group.[23]

setting of the provenance as well as the basin of deposition.[7] The provenances of the sandstones are determined on the basis of petrographic modal analyses and the QmFL and QFL tectonic discrimination diagrams for provenance determination.[6,7]

Determination of Provenance from Modal Composition

The undulatory monocrystalline quartz grains are indicative of metamorphic and igneous source rocks.[18,19] The non-undulatory monocrystalline quartz grains are indicative of fine-grained schists, phyllites and slates, volcanic, hypabyssal igneous rocks and preexisting sedimentary rocks in the provenance.[19] The presence of ten or more crystal units of polycrystalline quartz are excellent indicators of metamorphic sources.[20] These are very commonly observed in the sandstones under investigation. The polycrystalline quartz present in the rock preserved good characteristic of gneissose and schistose features that are proof of the source rocks being derived from gneisses and schists. Feldspar is generally unstable but it is important in provenance study. Microcline or orthoclase, perthitic feldspars are indicative of slow cooling

Table 2. The detrital compositional means of sandstones (in %) of the Middle Bhuban Formation of Surma Group of rock. Quantitative modes are recalculated from the data of thin section.

Sample No	QFL (in %)			QmFL (in %)		
	Q	F	L	Qm	F	L
D1	59.92	16.03	24.05	41.60	16.03	42.37
D2	54.8	14	31.2	23.6	14	62.4
D3	82.46	6.58	10.96	58.77	6.58	34.65
D5	68.57	8.98	22.45	43.67	8.98	47.35
D6	58.56	7.21	34.23	31.53	7.21	61.26
D7	65.56	7.29	27.15	41.06	7.28	51.66
D8	65.33	10.67	24	38	10.67	51.33
D9	73.45	10.73	15.82	51.98	10.73	37.29
D10	71.79	11.07	17.14	48.57	11.07	40.36
D11	66.15	8.07	25.77	48.85	8.07	43.08

Index: Q= Quartz, F= Feldspar, L= Lithic fragment, Qm= Monocrystalline quartz

and hence characteristics of the plutonic sources or it might be derived from low-grade of metamorphism rather they were found in less proportion relative to other detrital components. However, the percentage of alkali feldspar is very less in the rocks which might therefore indicated that the plutonic source is rather supposed to be having a very little contribution to the sediments. Plagioclase is of volcanic or hypabyssal origin, also of plutonic and even deeper condition. Mica is generally derived from schist and gneisses, from plutonic igneous rocks and from volcanic sources.[17] The abundance of muscovite and biotite in the rock thin sections clearly indicate the source rock that must be of micaceous in nature, possibly of mafic igneous rocks or mica schists of high grade metamorphism. The occasional presence of altered feldspar minerals in the sandstones indicate metamorphic provenance. However, there are some of the plagioclase minerals which are very well preserved without any alteration and deformation, and occurring as subhedral crystal in the rock. This could indicate an igneous source rock with slow cooling of the parent magma. The conclusion made on the present study is also in good agreement with the studies of Bhuban sandstones and Tipam sandstones investigated by earlier workers in other parts of Mizoram.[13,15]

Determination of Provenance from Tectonic Discrimination diagram

The petrographic modal analyses allow plotting of two types of triangular discrimination diagrams for provenance determinations, viz., QFL and QmFL diagrams.[6,7] There are different author who proposed recalculation of modal composition as volumetric proportions of the grains in the determination of sedimentary provenance, which was also shown in Table 2 for the present investigation.[7,16,21-25]

In QmFL diagram shown in Figure 3, the samples were concentrated in the areas of quartzose recycled and the transitional recycled field. The compositional ranges between those samples falling in the quartzose recycled to transitional recycled are gradational. The samples which are predominantly rich in quartz and poor in lithic fragments are plotted in the quartzose recycled field and they are supposed to be derived from cratonic source regions, while those that are rich in polycrystalline quartz are graded into the transitional recycled field. These rocks are relatively very high in composition of quartz compared to feldspar and lithic fragments. The compositions of lithic fragments relative to feldspar are moderately high because in the QmFL plotting, polycrystalline quartz is included with the lithic fragments.[26] The recy-

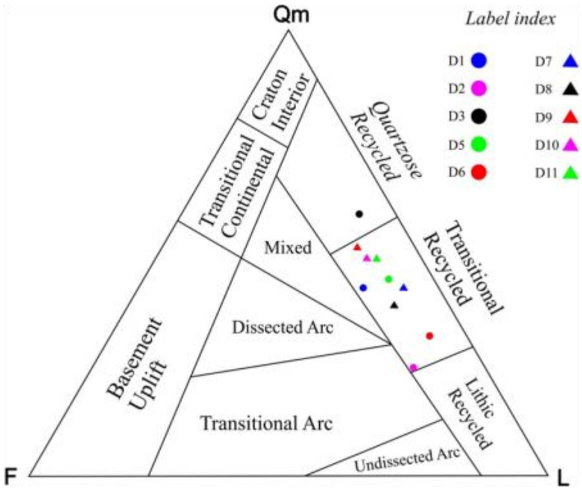


Figure 3. QmFL tectonic discrimination diagram for provenance interpretation of sandstone samples of the study area along Durtlang road section.[9]

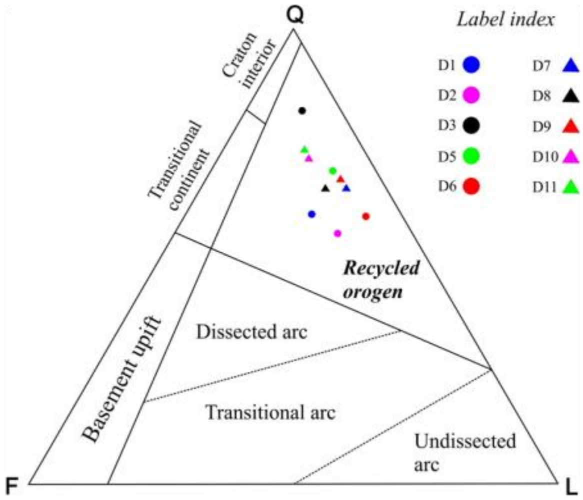


Figure 4. QFL tectonic discrimination diagram for provenance interpretation of sandstone samples of the study area along Durtlang road section.[10]

cling of these sediments typically involves deformation and uplift of miogeosynclinal successions.[7] This conclusion is in good agreement with the studies on Miocene Surma Group of Bengal Basin and on Neogene sandstones of Bengal Basin, Bangladesh suggesting the Himalayan orogen and collision zones as the most probable source of these sandstones.[12,14]

In the QFL diagram shown in Fig. 4, the plots demonstrated that all the samples cluster on the discrimination area of recycled orogeny which are the source orogens created by upfolding or upfaulting of sedimentary or metasedimentary terrains, allowing detritus from these rocks to be recycled to associated basin. Many recycled orogens were formed by collision of terrains that were once separate continental blocks.[10] Since the present sedimentary rocks were composed of materials supposed to be derived from igneous and metamorphic terrains, they might have originated from the provenance of Collision orogen of the Himalayan orogeny and collision tectonic settings characterized by geological settings of nappes and thrust sheets of sedimentary and metasedimentary rocks, along with subordinate amounts of plutonic or volcanic rocks, or even ophiolitic mélanges.[27,28] This was also very matching with the present structures observed in the Himalayan and Indo-Burmese collision settings.

Now, we may come to the conclusion that the studied sandstone of the area can be classified into litharenite and sublitharenite. The sediments of the sandstones are derived from wide varieties of source rocks ranging from acidic to mafic and alkali-rich igneous rocks, volcanic rocks, schists and gneisses. The most probable provenances of the rock are eastern Himalayas or Indo-Burmese collision zones belonging to a tectonic setting of Recycled orogen.

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