Petrography and Provenance Study of the Kabaw Formation in the Thaphanyaung-Paunggu Area, Mindon Township, Magway Region, Myanmar

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Abstract

Kabaw Formation in the study area is mainly composed of turbidite sequences of shale, mudstone, medium- to coarse-grained sandstone, gritty sandstone and conglomerate with minor tuffaceous sandstone and *Globotruncana* sp. bearing limestones. The model data of sandstone of Kabaw Formation exhibit average quartz 35%, feldspars 10%, rock fragments 25% and heavy minerals. The quartz grains are of igneous and metamorphic origin. Mineral quartz, feldspar, and rock fragments in the sandstone suggested an acidic plutonic and metamorphic provenance. Rock fragments are of sedimentary, volcanic and metamorphic rocks. The sedimentary grains include limestone, chert, sandstone and siltstone. The volcanic rock fragments are of fine grained basalts. The metamorphic rock fragments are of slates and schists. Heavy minerals include tourmaline, zircon, garnet, epidote, sphene and apatite. Hematite and calcite are the dominating cementing material with minor chlorite. The sandstone is classified as lithic graywacke. The low modal proportion of quartz and high content of rock fragments indicates low degree of mineralogical maturity of the sandstone. The poor degree of sorting, angular to sub-angular framework constituents and abundance of matrix suggested that sandstone is texturally immature. The sutured quartz grains contacts, alteration of plagioclase to clay minerals and deformed muscovite indicate diagenetic changes in the sandstone at depth under pressure. From thin section study of sandstone all samples of the Kabaw Formation of the study area fall in the fields of magmatic arc and recycled origin. The heavy minerals plot in the study area is shown that Dissected Arc and Undissected Arc. Therefore, the source area of Kabaw Formation may deposit in the Magmatic-Arc provenance and Recycle-Arc provenance. The paleocurrent direction indicates that the sediments of the study area were derived from the west, northwest and northeast of the study area. Therefore, the most probable provenances of the rock are subduction complex (Indo-Myanmar Ranges) and magmatic arc (northern part of Central Plutovolcnic Line) to a tectonic setting of Recycled orogen.

Keywords: Kabaw Formation, *Globotruncan* sp., lithic greywacke, Recycled orogeny

Introduction

Thaphanyaung-Paunggu area is located in the Mindon Township, Magway Region (Fig.1). It lies between Latitude N. 19º 19′ 30″ to N 19º 28′ 30″ and Longitude E.94º 32′ 30″ to E.94º 39′ 20″. The area is bounded by Western Ranges in the west and Central Basin in the east. Mostly, western part of the study area is an elevated upland with steep sloping hills and ridges making up closely spaced mountains, forming rugged terrain, covering with thick vegetation (Fig.2). It occupies the southern continuation of the Kabaw Valley Fault.

Cotter (1912) studied the Pegu Eocene succession in the Minbu District, near Ngape. Aung Khin and Kyaw Win (1969) reported some formal names and gave brief descriptions of some of the rock units of the Minbu Basin. Maung Maung Gyi (1983) mentioned the characters of the stratigraphic units exposed in the Mindon area. Bannert *et al*. (2011) pointed out that the obduction of Bi taung ophiolite to the surface took place during the Late Cretaceous in the NW of Mindon. The petrology of ultramafic rocks of the Nyaungyi-Kyaukpya-Kalan taung area in Mindon was done by Zaw Win Lwin and Myo Myo Chit (2015).

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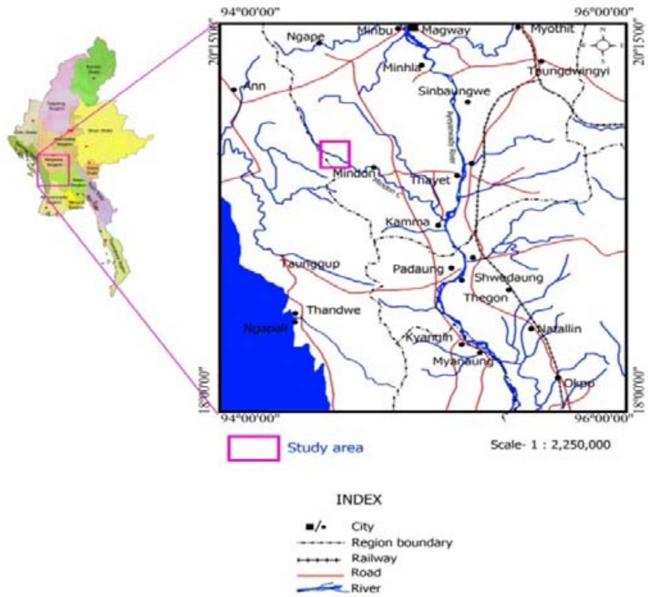

Figure (1). Location map of Thaphanyaung-Paunggu area

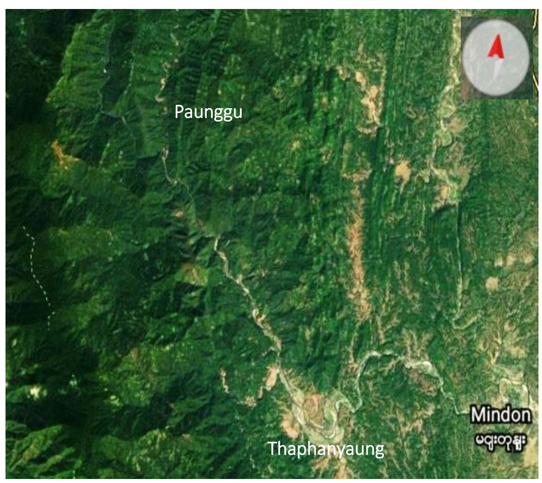

Figure (2). Satellite image showing the physiographic features of the study area

The study area is lying in the southwestern margin of the Minbu Basin and composed almost completely of Tertiary clastic sediments, Late Cretaceous turbidites and ultramafic rocks, Middle–Late Triassic flysches and low grade metamorphic rock. Five lithostratigraphic units can be classified in the study area on the basic of lithology, stratigraphic position and faunal content. In ascending order, the whole area is covered by the rocks of Kanpetlet Schists (Triassic), Thanbaya Formation (Middle –Late Triassic), Kabaw Formation (Late Cretaceous), Paunggyi Formation (Paleocene), Laungshe Formation (Eocene) and Ultramafic Igneous Rocks (post Late Cretaceous) (Fig.3).

The formation selected for research work is Kabaw Formation of Late Cretaceous age, exposed in Thaphanyaung-Paunggu area. Kabaw Formation is mainly composed of turbidite sequences of shale, mudstone, medium to – coarse grained sandstone, gritty sandstone and conglomerate with minor tuffaceous sandstone and *Globotruncana* bearing limestone mounds. The contact between the Kabaw formation and overlying Paunggyi Formation is an unconformity. Mostly the contact between the underlying Thanbaya Formation may be uncomformity due to the present of quartz pebble conglomerate band is found at the upper part of Thanbaya Formation.

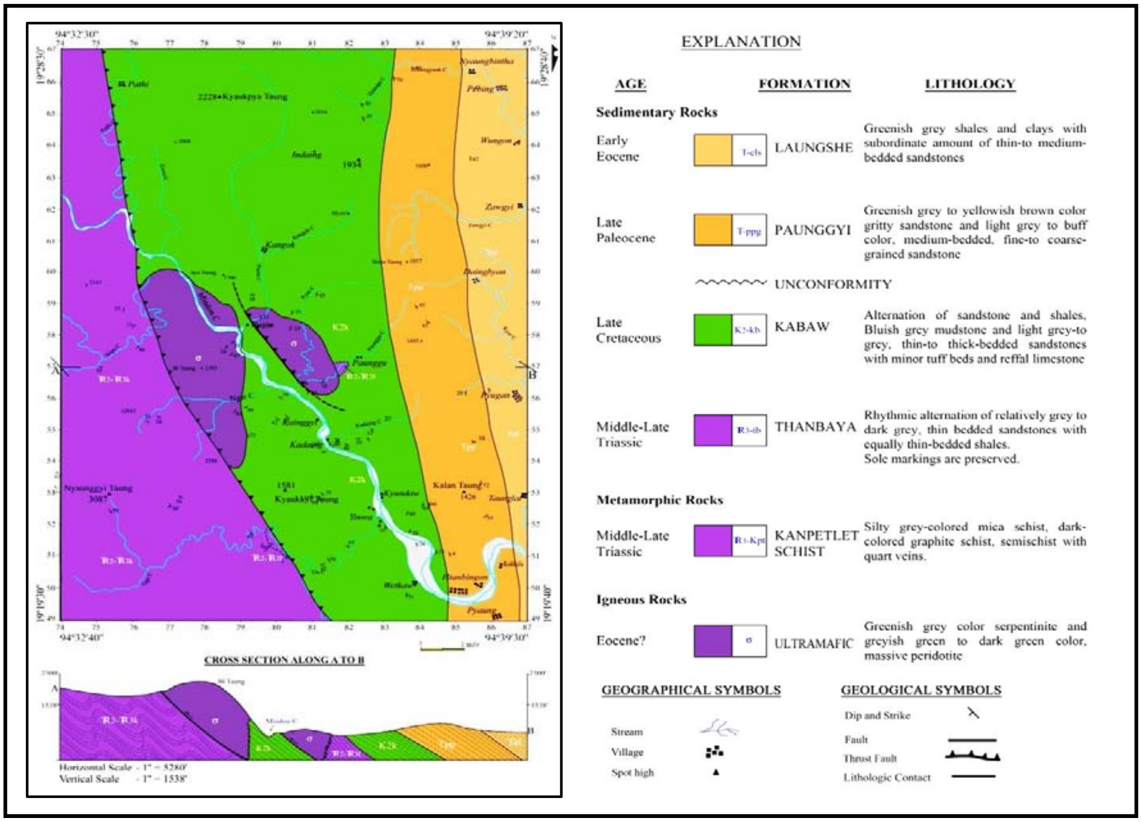

Figure (3). Geological map of the Thaphanyaung-Paunggu area
(Source: Zaw Win Lwin, 2015)

Materials and Methods

The field work was carried out in the study area to obtain geological data and collection of rock samples by using topographic sheet and instruments like Brunton compass, hammer hand lens (10x) and camera. This research study was completed in two phases, field and laboratory work. Field work consists of

1. Collection of rock samples for petrographic studies
2. Outcrop sections photography
3. Recording of geological data

Topomap sheets no.85-I/10 and 11 of were used to prepare sample location and geological map (see Fig.3) of the area. ZEISS AXIO SCOPE.A1 polarizing microscope with attached Canon camera was used for thin sections study in the petrology laboratory of the Geology Department, University of Magway. Thirteen sandstone samples of Kabaw Formation were selected for petrographic studies and preparation of thin sections. The laboratory work included cuttings of the rock samples for the preparation of thin sections. The thin sections were prepared to get maximum textural, mineralogical and diagenetic study.

The microscopic study of thin sections was carried out under Polarizing microscope (LEICA DM750P) for identification of constituent minerals, determination of model mineralogical composition, extent of variation in particles size, degree of roundness of the framework grains and classification of sandstone. Photographs of important features were also taken.

Petrography

Thin sections of sample were prepared, labelled and studied under petrographic microscope. The photomicrographs were taken. The detail microscopic study of sandstones and limestones of Kabaw Formation were carried out. For the petrological study of Kabaw Formation the samples were taken in areas of varied lithology such as change in color, grain size or contacts. The modal composition of sandstones of Kabaw Formation in the study area is shown in table (2).

Table (1). Modal composition of the sandstones of Kabaw Formation

Sample No. / Composition	Kb-1	Kb-2	Kb-3	Kb-4	Kb-5	Kb-6	Kb-7
	Composition in volume %						
Quartz	30	34	32	35	30	33	32
Feldspar	12	15	16	14	15	14	15
Rock Fragment	25	26	23	25	27	25	26
Mica	3	2	3	1	2	1	1
Heavy Mineral	3	1	2	1	2	1	1
Matrix	24	17	22	18	18	20	18
Cement	3	5	8	6	6	6	7
Total Volume (%)	100	100	100	100	100	100	100

The sandstones of Kabaw Formation are composed of detrital framework whose average modal abundance is 65-75 percent, 20 to 30 percent of matrix and 3 to 8 percent of cement (Fig.4). The detrital grains are packed together with the argillaceous matrix and calcite or iron oxide cement. Most of the detrital grains are subangular to subrounded, poorly to moderately sorted and fine- to coarse-grained.

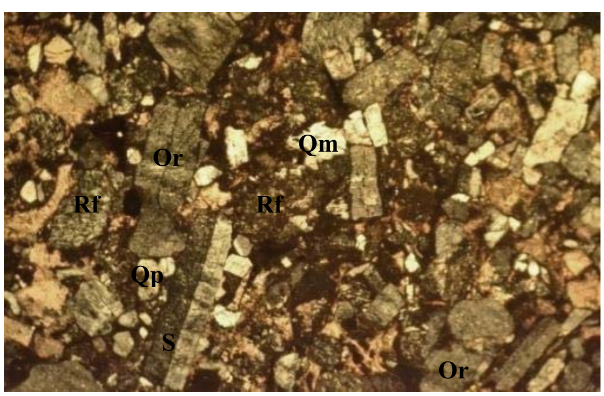

Figure (4). Modal composition of sandstone (Kb-1 to Kb-6) of Kabaw Formaiton showing monocrystalline quartz (Qm), plagiocalse (Pl),orthoclase (Or), rock fragment (Rf). Under X.N; Magnification x 4.

Detrital Fraction

The detrital grains are quartz 46–50 percent, feldspar 19–25 percent, rock fragments 32-38 percent and mica and heavy minerals as a few content. The diameter of detrital grains ranges from 0.3mm to 0.5mm.

Quartz

Quartz is the dominant grain type of detrital grains and comprising 30 to 35% percent of the total rock volume. Mostly, the quartz grains are subangular to subrounded outlines. Rarely, however, quartz grains with angular boundaries also occur. They are euhedral to subhedral with variable sized from 0.3mm to 0.5 mm. Quarts occur both as monocrystalline and polycrystalline grains. The monocrystalline variety is much more abundant than the polycrystalline. The contact between quartz grains are planner, point, sutured and concavo-convex. Tourmaline, mica and zircon inclusions (Fig.5.a) are common in quartz grains. Moreover, many of the quartz have well developed overgrowths around them (Fig.5.b). Most of the quartz grains are fresh and clean, while a few of them are dirty and display shades of pale yellow to reddish colors due to staining from ferruginous cementing material. The quartz grains display undulatory extinction due to strain induced crystallographic dislocation in lattic. Some of the quartz grains show fractures, which are filled with cement or opaque materials. In polycrystalline quartz, composite nature of the grains is clear in the view taken with cross polars. They are the characteristics of quartz from metamorphic source. Among these grains, igneous quartz grains are more abundant. Igneous derived quartz grains are displayed by straight boundaries between individual grains and no distinct crystallographic orientation.

Feldspar

The amount of feldspar grains in thin section ranges from 10-15%. Plagioclase, orthoclase and sanidine (Fig.5.c) are commonly identified in most thin sections while microcline is rarely found. The grains of orthoclase show the simple twinning and contain inclusions of tourmaline and mica. The plagioclase feldspar shows polysynthetic and combination twinnings (Fig.5.d). The banding of twin plane can be observed in a few plagioclases. There was also occurrence of zoned plagioclase (Fig.5.e). Grains of microcline are mostly fresh and show diagnostic cross-hatched twinning (Fig.5.f). Calcite cement was also filling in corroded feldspar. Alteration of feldspar into sericite and clay is observed.

Lithic Fragments

Lithic fragments are generally considered to be one of the common constituents of sandstones; hence, their abundance in the studied samples of the sandstones of Kabaw Formation is rather high. The overall modal abundance of rock fragments is 19-27 percent. They are predominance over feldspar. Most of the rock fragments occur as sub-angular to sub-rounded grains with various sizes. They include igneous, sedimentary and metamorphic types. Most of the igneous rock fragments are volcanic fragments of basaltic composition with much plagioclase content. The volcanic fragments show porphyritic texture (Fig.6.a) and some of them are corroded by cement. In addition to volcanic fragments, plutonic fragments such as serpentinite also occur in these sandstones. Sedimentary rock fragments are composed mostly of sandstone. In these sandstones, chart fragments forming “zebraic” structure, a fibrous microquartz cavity lining can be observed frequently (Fig.6.b). They show alternately light and dark when viewed along the fiber elongation direction under cross–polarized light. They are often a pore–fill rather than replacement. They occur in deep marine strata (Scholle & Scholle, 2003). Metamorphic rock fragments are consisted of phyllite, slate and schist and gneiss. Schist fragments (Fig.6.c) can be observed easily by their schistosity and microfolds. The augen texture is clearly seen in gneiss fragments in the studied samples.

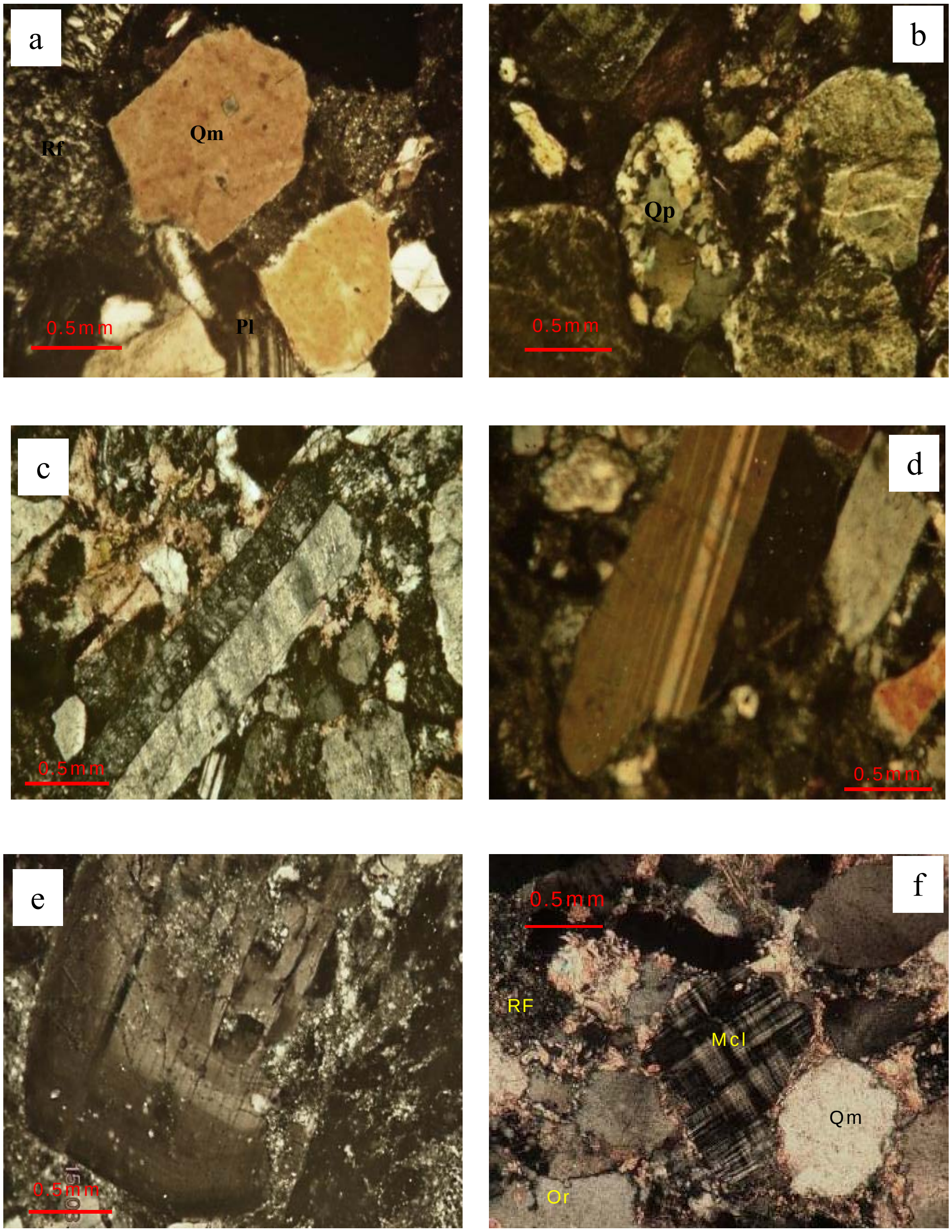

Figure (5). Photomicrograph of sandstones of Kabaw Formation (Under X.N, magnification x 10): (a) mocrystalline quartz having zircon inclusion; (b) polycrystalline quartz grains having suture boundaries. Note eolongate, lenticular, interlocking and suture crystals; (c) elongate sanidine (Sn) showing simple twinning; (d) cross–hatched twinning in microcline; (e) combination of Carlsbad and multiple twinning in plagioclase (Pl); (f) zoning and alteration in core of plagioclase.

Mica

Mica is consisted of 1-3 percent of total detrital framework. The micas are usually present as deformed mineral between grains of the more competent detrital minerals like quartz and feldspars. Muscovite is more common than biotite since it is more resistant to weathering. The scarcity of mica in the studied samples probably reflects selective sorting of detrital grains during deposition. Trace amounts of muscovite occur as flakes in the studied samples. They show bending due to deformation (Fig.6.d). In addition to muscovite, biotite also occurs. However, it mostly appears to be irregularly bifurcated due to the effect of compaction processes. Biotites are identified by its brown color under plane polarized light and strong pleochroism.

Heavy minerals

Heavy minerals comprise about 1-3 percent of the total rock volume. These grains are subangular to subrounded and range in size from 0.05mm to 0.08mm in diameter. It is coated by calcite cement. Heavy mineral grains composed of in this sandstone are hornblende, glauconite, garnet, zircon, tourmaline, rutile and other opaque minerals. Hornblende shows 2 set of cleavage at 120˚ (Fig.6.e). Some ore minerals, predominantly rutile having reddish brown to blood red color (Fig.6.f) is commonly observed. Euhedral chrome-spinel crystal is also found in this sandstone. Besides, the occurrence of a substantial amount of goethite, an ore mineral of iron, has also been noticed in one of the studied thin sections. A few of the samples also contain tiny grains of epidote. Another heavy mineral found in the studied samples is zircon. The grains of zircon are very small in size. It is rather rare and mostly occurs in the formed of inclusions in the grains of quartz and feldspar.

Matrix and Cement

In the sandstones samples, argillaceous matrix consists of 20 to 30 percent but chemical cement comprises 10 to 12 percent of the total rock volume. The matrix is a fine-grained intergrowth of sericite and chlorite together with silt-size quartz and feldspar. The detrital grains are bounded together by matrix and chemical cement. Argillaceous matrix (Fig.6.g) filling in the interstitial pore spaces are frequently observed in some slide. The matrix is apparently recrystallized by post depositional changes. Sericite and chlorite in the matrix are authigenic minerals. In some slides, cement such as calcite and iron-oxide cement corrosions are preserved due to wedged apart in some of the detrital grains. Most of the matrix of older greywackes seems to be epimatrix. They are generally marine sediments and are believed to be turbidites sands of the flysch facies (Dickinson, 1979). The interstitial pore spaces among the detrital fractions are commonly filled with clay matrix. These are form <10 percent of the total rock volume. The two foraminifera, *Boloides* sp. and *Globigerinella* sp. are embedded in the matrix and cement. Their boundaries are found as irregular and straight. The iron-oxide cement is accomplished with the calcite cement (Fig.6.h).

Nomenclature

In the sandstones of Kabaw Formation, quartz content is less than 75% and the lithic fragments predominance over the feldspar. All the grains are dispersed in a matrix greater than 15 percent. Therefore, these sandstones fall in "Lithic graywacke" according to Pettijohn's *et al*. (1987) (Fig.7).

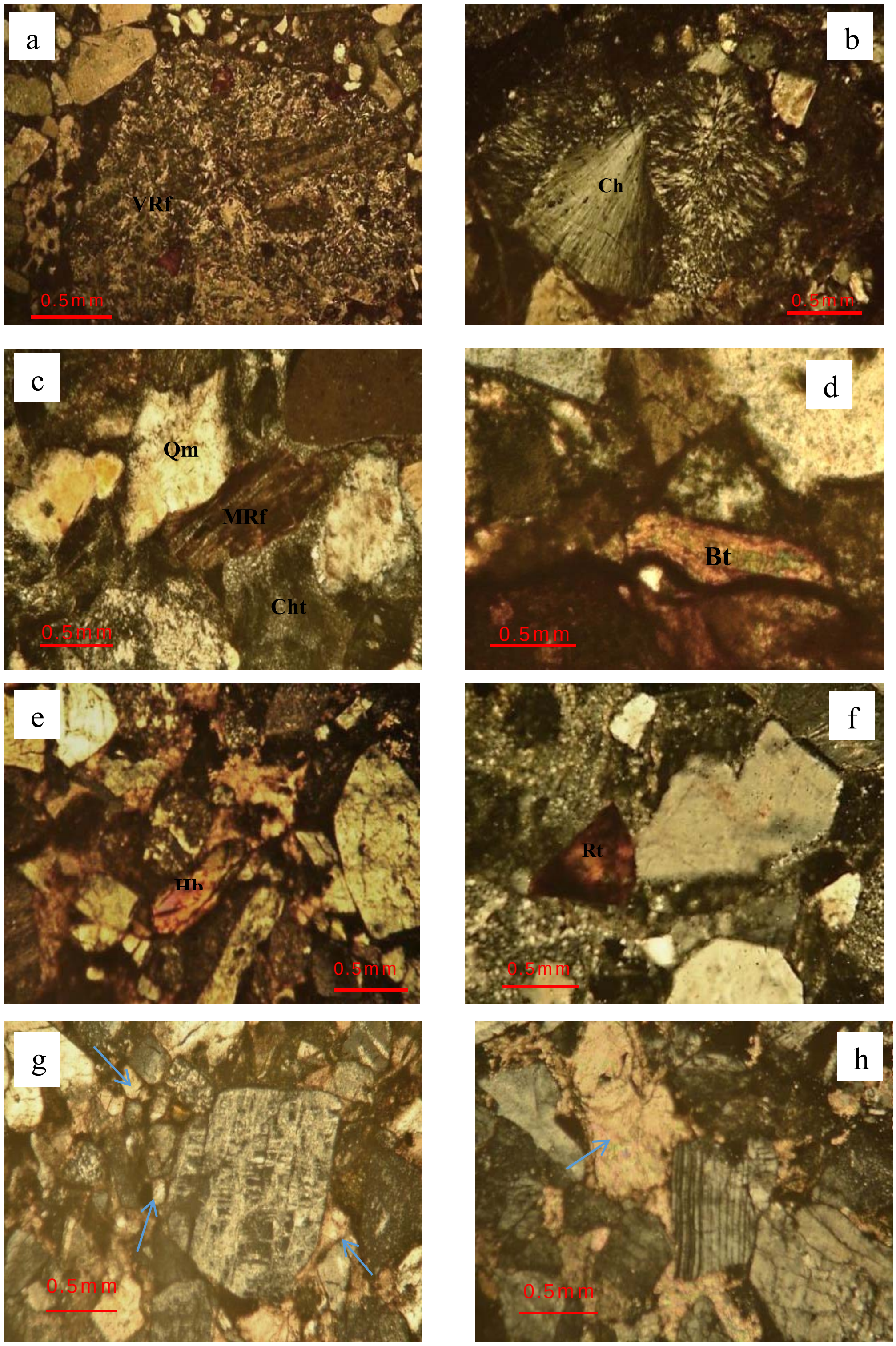

Figure (6). Photomicrograph of sandstones of Kabaw Formation (Under X.N, magnification x 10): (a) porphyritic texture of volcanic rock fragments (VRf); (b) chert fragment (Cht) forming "Zebraic" structure; (c) schist clast with foliation; (d) bending in biotite; (e) hornblende giving 2 set of cleavage at 120˚; (f) reddish rutile grain; (g) argillaceous matrix (arrows) between larger grains; (h) poikilotopic or lustre mottling of calcite cement between grains.

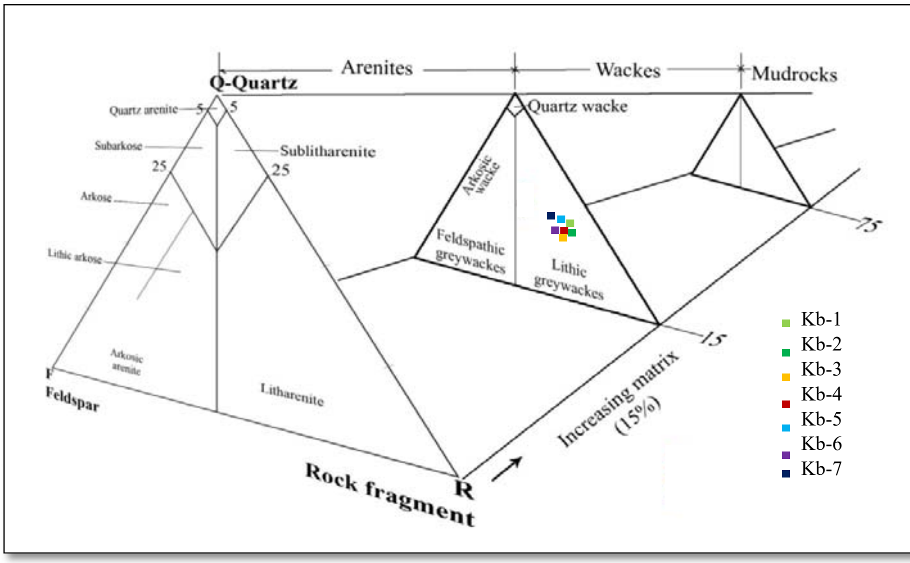

Figure (7). Classification of sandstones from the study area. After Pettijohn *et al.* (1987).

Discussion

Determination of Provenance from Modal Composition

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. The modes of detrital framework of sandstone assemblages provide information about the composition and tectonic setting of the provenance as well as the basin of deposition.

The provenances of the sandstones are determined on the basis of petrographic modal analyses of light minerals.

1. The undulatory monocrystalline quartz grains are indicative of metamorphic and igneous source rocks.
2. 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.
3. The presence of polycrystalline quartz grains are excellent indicators of metamorphic sources. These are very commonly observed in the sandstones under investigation.
4. Feldspar is generally unstable but it is important in provenance study.
5. Microcline or orthoclase, perthitic feldspars are indicative of slow cooling and hence characteristics of the plutonic sources or it might be derived from low-grade metamorphic provenance.
6. Plagioclase is of volcanic or hypabyssal origin, also of plutonic and even deeper condition. There was also occurrence of zoned plagioclase indicating volcanic source.
7. The occasional presence of altered feldspar in the sandstones indicate metamorphic province.
8. Very well preserved subhedral plagioclase without any alteration and deformation indicate an igneous source rock with slow cooling of the parent magma.
9. The abundance of volcanic rock fragments indicates volcanic source rocks and sedimentary and metamorphic rock fragments are also present.

Determination of Provenance from Tectonic Discrimination diagram

The petrographic modal analyses allow plotting of triangular discrimination diagram for provenance determinations, viz., QFL diagrams. 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.

Table (2). Detrital composition means of sandstones (in vol%) of the Kabaw Formation of the study area.

Quantitative modes are recalculated from the data of thin section.

Sample No. / Essential framework (vol%)	**Kb-1**	**Kb-2**	**Kb-3**	**Kb-4**	**Kb-5**	**Kb-6**	**Kb-7**
Quartz	41	46	36.8	50.7	38.5	44.7	50
Feldspar	23	23	26.4	20.3	23	25.9	18.8
Lithic Fragments	36	31	36.8	29	38.5	29.4	31.2

Dickison et al. (1985 in Lalnunmawia *et al*., 2014) classified the provenances into three groups:

1. Continental blocks, for which the sources are on shields and platforms or faulted basement blocks.
2. Magmatic arc, for which sources are deformed and uplifted strata sequences in subduction zones, collision orogens, or foreland fold-thrust belts.
3. Recycled orogen, for which sources are deformed and uplifted strata sequences in subduction zones, collision orogens, or foreland fold-thrust belts.

In the QFL diagram shown in figure (8), the plots demonstrated that most of 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. Only two samples are fall in the magmatic arc. Many recycled orogens were formed by subduction or collision of terrains that were once separate continental blocks.

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 subduction zones of Indo-Myanmar Ranges 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.

It is concluded that the studied sandstone of the Kabaw Formation of the area can be classified into lithic greywacke. 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 subduction complex (Indo-Myanmar Ranges) and magmatic arc and subduction complex provenance (northern part of Central Plutovolcnic Line) to a tectonic setting of Recycled orogen.

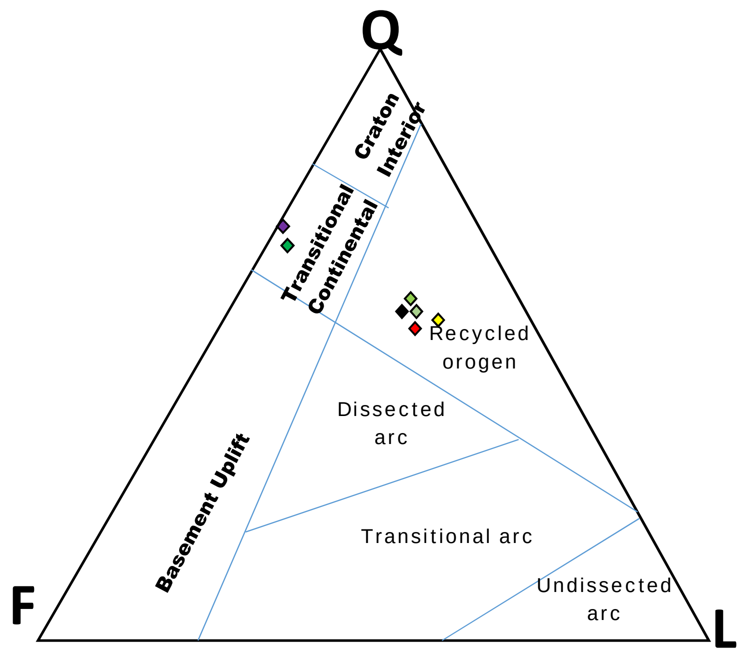

Figure (8). QFL ternary diagram showing selected sandstone samples derived from different types of provenance (after Dickinson *et al.,* 1985).

Discussion for Provenance Study

Sandstone compositions are influenced by 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. The key relations between provenance and basin are governed by plate tectonics, which thus ultimately controls the distribution of different type of sandstones (Dickinson & Suczek, 1979 in Maung Maung, 1994).

Source Rock

Provenance studies are come out from the evidence of light minerals fraction (quartz, feldspar and rock fragments) and heavy minerals analysis. On the basis of thin section studies of sandstone of Kabaw Formation of the study area, the detrital grains were derived from wide varieties of source rocks ranging from acidic to mafic and alkali-rich igneous rocks, volcanic rocks, schists and gneisses. The abundance of volcanic rock fragments indicates most of the sediments were derived from the volcanic source rock. The others plutonic, sedimentary and metamorphic rock fragments are also common.

From heavy minerals determination, it can be noted that the abundance of topaz and the presence zircon, tourmaline, rutile, biotite and muscovite indicate that the source rock may be granitic and pegmatitic rocks. Augite, hypersthenes, olivine, brown green hornblende, enstatite, and opaque (magnetite and chromite) may be derived from basic and ultrabasic igneous rock (Htet Hnaung Khant, 2015).

Garnet sillimanite, staurolite, serpentine and hornblende are common constituents of low to high grade metamorphic rock. Moreover, some rounded grains and the abundance of gypsum indicate recycled sedimentary rock (Fig.9) (Htet Hnaung Khant, 2015).

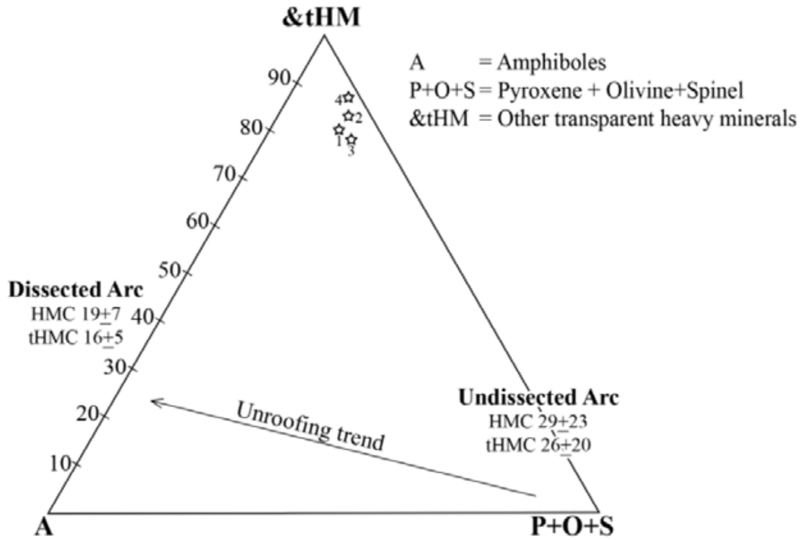

Figure (9). Heavy mineral assemblages of Kabaw Formation plotted for primary provenance (Garzanti, 2002 in Htet Hnaung Khant, 2015)

Source Area

From thin section study of sandstone all samples of the Kabaw Formation of the study area fall in the fields of magmatic arc and recycled origin of Dickinson′s QFL triangle (1979). Magmatic arc include the continental and island arcs associated with subduction and these area of volcanic, plutonic and metamorphic rocks. Recycled origins are uplifted and deformed supracrustal rocks which form mountain belts and volcanic and metasediments. The low modal proportion of quartz and high content of rock fragments indicates low degree of mineralogical maturity of the sandstone. The poor degree of sorting, angular to sub-angular framework constituents and abundance of matrix suggested that sandstone is texturally immature. The sutured quartz grains contacts, alteration of plagioclase to clay minerals and deformed muscovite indicate diagenetic changes in the sandstone at depth under pressure.

The heavy plot in the study area is shown that Dissected Arc and Undissected Arc. Therefore, the source area of Kabaw Formation may deposit in the Magmatic-Arc provenance and Recycle-Arc provenance.

The paleocurrent direction measured from ripple marks, cross beddings, sole markings and pebble imbrication in conglomerate beds indicates that the sediments of the study area were derived from the west, northwest and northeast of the study area (Soe Myat Htun, 2017).

From the above mention factors, it can be concluded that most of the sediments in the present area were probably derived from recycled origin including foreland uplift or subduction complex, and northern part of Central Igneous Line and Mixed Magmatic Arc.

Conclusion

The conclusion drawn on the basis of field and petrographical studies is as follows:

1. The study area is present in Mindon area which lies on the Eastern margin of Western Ranges and western margin of Central Lowland. Late Cretaceous Kabaw Formation is exposed in the study area. The lower contact of Kabaw Formation is unconformable with Thanbaya Formation and is also faulted with upper ophiolite suite. This fault is Kabaw Fault which is a thrust fault.
2. On the basis of mineralogical composition the sandstone of Kabaw Formation is classified as lithic greywacke. The sandstone is minerologically immature as it contains low proportion of quartz and very high abundance of rock fragments and matrix. Monocrystalline quartz is more abundant than the polycrystalline quartz while non- undulose quartz is more common than the undulose quartz grains. The angular to sub angular quartz grains indicates short distance of transportation from the source. Plagioclase feldspar albite is found in these sandstones. Alteration of feldspar grains into sericite is commonly recognized.
3. Lithic fragments of igneous, sedimentary and volcanics are abundant in the rock. The sedimentary rocks fragments are of sandstone, siltstone, chert and limestone. The metamorphic rock fragments, slates and schist are common while clasts of basalt were recognized in volcanic fragments.
4. Cementing material is dominantly of calcite and hematite while in some samples chlorite is also reported as cement. Accessory minerals tourmaline, zircon, garnet, muscovite, epidote, sphene and apatite were found in the sandstone. Presence of calcite cement shows diagenetic changes. Alteration of biotite into muscovite and chlorite mark the early stage of diagenesis. In few samples sutured and concavo convex contacts of grains also indicate diagenetic changes.

6\. The modal mineralogical data plotted on provenance discrimination diagram indicate the provenance is recycled orogeny. The low percentage of quartz and abundance of rock fragments and matrix indicates its transitional depositional environment.

7\. Shales are argillaceous in Kabaw Formation. Bands of green and red shales are dominant in Kabaw formation. Green color of shales is due to high percentage of chlorite present in them while presence of red color is due to hematite abundance in it.

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