Petrochemistry of Shale and Sandstone form Legyi Formation, Nowndwin Area, Sagaing Township

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Abstract

Major, minor oxides and trace elements of shale and sandstone of clastic sedimentary rocks from Legyi Formation at Nowndwin Area, Sagaing Township analyzed data are used to discuss the petrochemical characters. Twenty samples were collected and subjected to inorganic analysis which includes major oxides, trace elements, and rare earth element. Major elements are SiO_2 TiO_2, Al_2O_3, Fe_2O_3, FeO, MnO, MgO, CaO, Na_2O, K_2O and P_2O_5. The Legyi Formation of sandstones are classified mainly arkose and litharenite according to the diagram of Herron (1986). Bhatia discrimination diagrams are used for the recovered sediments from Legyi clastic sediments to determine the tectonic setting of the study area. Roser and Korsch tectonic settings determinant diagrams are used to distinguish tectonic setting. According to (Roser and Korsch) discrimination diagrams the sandstones are fall into active continental margin. Trace elements such as, As, Sr, Zr, Pb, Cr, Cl, Rb, Ni, Y, Zn, S, Cu and Br are most suited for provinces and tectonic setting determination. Legyi Formation of sandstones show uniform k/Rb ratio that lie close a typical differentiated magmatic suite or main trend with a ratio, sediments a derivation from rocks of acidic and intermediate compositions. The immobile trace elements Zr and immobile oxide TiO_2 variation diagrams that the Legyi Formation of sandstones are derived from felsic igneous rock and intermediate igneous. Roser and Korsch discriminate function 1 and function 2 that the Legyi Formation of sandstones are fall in felsic provenance.

Keywords: active continental margin, magmatic suite, felsic provenance

Introduction

The research area is situated at the Nowndwin area, Sagaing Township, Sagaing Region in UTM 2295-12 map. It can be readily approached by motor-car from Sagaing through Monywa to Shwe Bo throughout the year. The location map of the study area is shown in figure (1).

The present area is situated at the eastern margin of Central Myanmar Tertiary Basin. This area is generally trending NNW-SSE direction. It is suddenly arise to the east from the flat plain of the western part. Topographically low hills to moderate rugged ridges and valley are common in the research area. Dipping is occurred between 40° and 45° to the west. In the S-W of the area, Upper Irrawaddy Formation and secondary calcite veins are filled in joints. The research area is actually interbedded with loose sand, silty shale, mud and hard sand. In core of the anticline hard sand occur as Legyi Formation.

In general all streams are radial and main streams are trending NNW-SSE and flowing into the Mu River in the west. Minor streams are more occurred in the northern part than the southern portion of this area and they flow from NE-SW. The great to medium dentritic drainage pattern is developed in the western part of the area and it reflects to shallow dipping strata and massive sandstone. Generally all streams are dry in the whole year but they are occurred as the temporary streams during a torrential raining period (Fig. 2).

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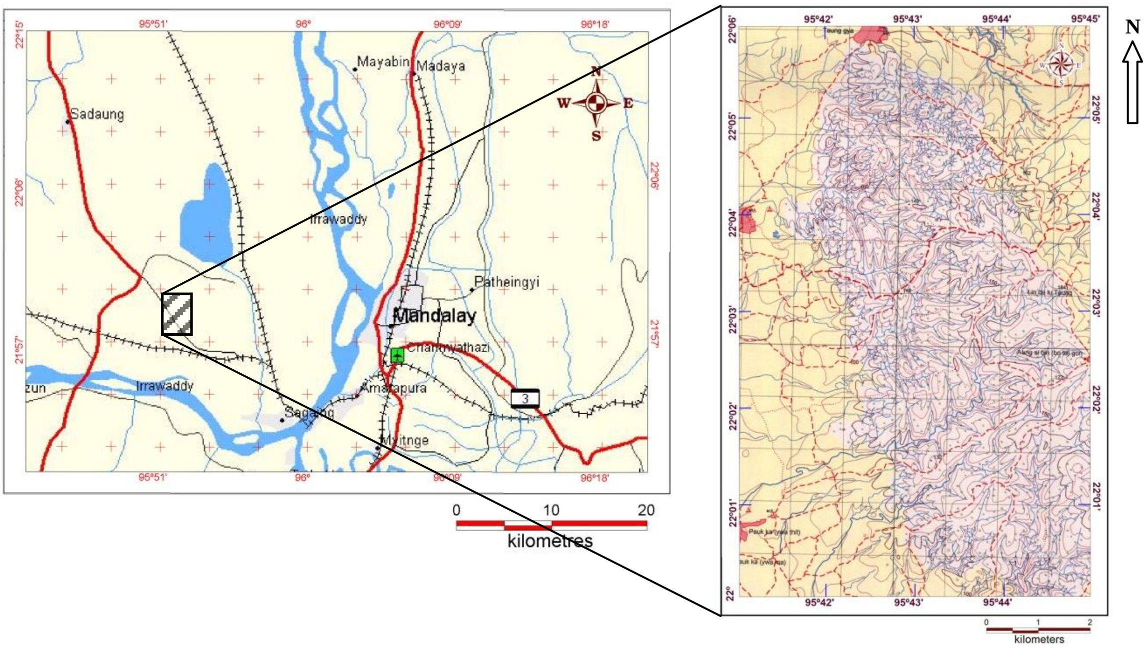

Figure (1). Location Map of the research area

Methods of study

The present study includes field methods and laboratory investigations and employs the three methods to achieve the objectives of the research. The three methods are (a) landsat image and aerial photographic interpretation were made before doing field trip, (b) detailed studies of outcrops and sampling applying the GPS II Plus method and (c) using the EDXRF analysis to discuss the major and trace element content.

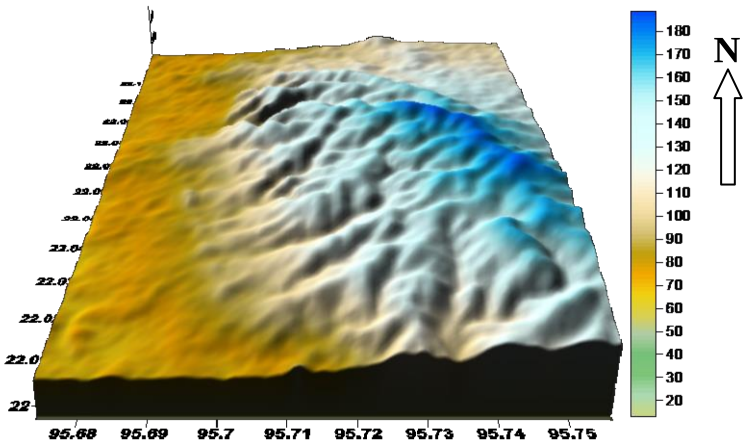

Figure (2). 3D view of the project area

Stratigraphy

In the research area, over 5000ft thick of Neogene sedimentary rocks are belonging to the Legyi Formation and Irrawaddy Formation. They are exposed in northwest plunging anticline (Myint Thein, 1981). The conglomerate band between these two formations that occur in the Tawgamaw Chaung and Thabyet Chaung shows an unconformity between them. The geological map of the study area is shown in figure (3).

The rocks exposed in the research area can be arranged as follows (after Myo Min, 1996);

Rock Sequence	Age
Alluvium ^^^^^^^^^^^^^^^^	Quaternary
Irrawaddy Formation ^^^^^^^^^^^^^^^^	Pliocene to Pleistocene
Legyi Formation	Middle Miocene

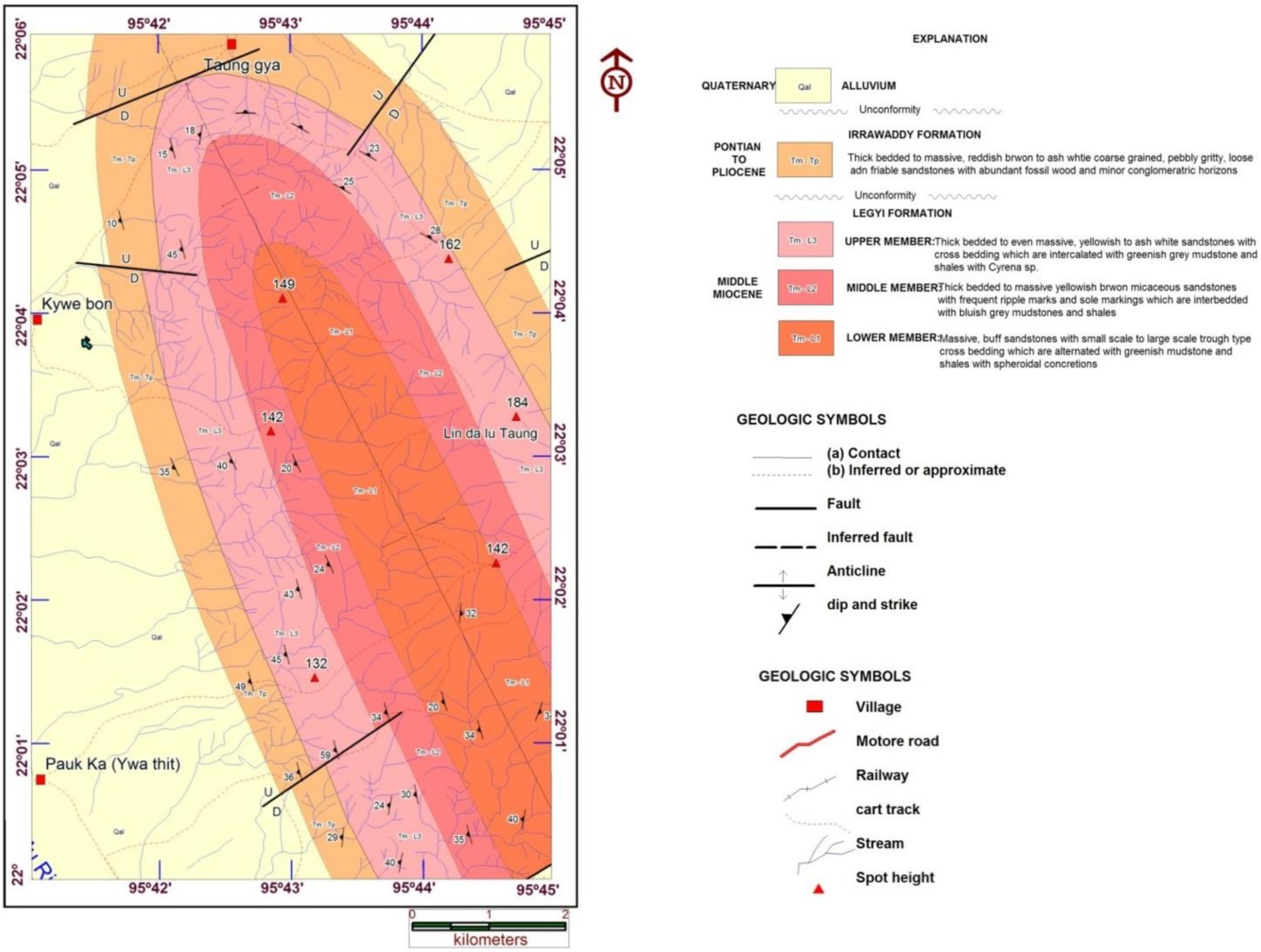

Figure (3). Geological map of the project area (Myo Min, 1996)

Legyi Formation

Legyi Formation was first named by People's Oil geologists, (P.O.I. Annual Review for 1964). It is named after Legyi village which is situated near the southern border of study area and mainly cropped out in stream section along Thabyet Chaung. This formation is occurred as ridge and valley topography because the alternation sequence of sandstone and shale.

The Lower member of Legyi Formation is mainly composed of dark grey to dark blue sandstone and clay interbedded. The sandstones are coarse-medium grained, thin bedded to massive and yellowish-grey to pale yellow. The hard sandstones are thickly bedded and dark blue green to white blue green.

The Middle member is characterized by hard sandstone interbedded with shale and clay. Sandstones are brown to yellowish brown, green to dark grey in color, well bedded to massive and medium grained in size. Disc shape concretion or concretion bands occur along the strike direction between the sand layers of fissile shale are 0.25 inch to 2 inch in thickness alternating with clay or siltstone. Yellowish loose sands are 1cm to 2cm in thickness.

In the Upper member of the Legyi Formation white sand, pale yellow and white to grey loose sandstone occur. White grained sands are thought to be formed from erosion of fine grained quartz. The lower contact with the middle member is obscure and conformable. The upper contact with the Irrawaddy Formation is clearly observed and the conglomerate bands are occurred in the stream sections.

Petrochemistry

Petrography

Sandstone is the predominant rock type in the study area. But in some places, it is not quite as abound as shale and siltstones. The sandstones are quite homogeneous being largely fine- to medium-grained, clay, quartz greywacke sandstones with varying amount of ferrogenous and silica cements. The sandstones are almost always cross bedded with trough cross-stratification.

Siltstones and shales are also well exposed in the Thabyat chaung and chaung section. Bedding is usually well developed in both the siltstone and shale. The siltstones are commonly thin-bedded or laminated, sometimes with gentle undulations or laminated, sometime with gentle undulations

Feldspar is the second most common mineral in the detrital framework, and the feldspar includes orthoclase, plagioclase and microcline. They constitute 21% 30% of the detrital framework. The sandstones are cemented by calcite, hematite or both in varying proportions. In some thin sections, hematite grains are corroded by the calcite cements.

Chemical Analysis by X-Ray Fluorescence Spectrometry

Twenty samples of shale and sandstones units from Legyi Formation, Middle Miocene age were collected, grind, pulverized and sieved with a <125µm. Bulk-rock geochemistry of major oxide, trace elements, and rare earth elements was utilized for the geochemical classification, the provenance and tectonic setting determination.

Sandstones of the Legyi Formation have low to moderate SiO_2 contents (15.3%–64.3%), TiO_2 concentrations rage from (0.3%–1.55%), Al_2O_3 content of (9–21%) (Table 1). Generally high concentration of CaO suggests the enrichment of calcite cement in Legyi Formation. The linear relationship of TiO_2, Al_2O_3, MnO and K_2O with SiO_2 in the Legyi Formation are observed in the Harker variation diagrams (Fig. 4).

The Legyi Formation of sandstones are classified mainly arkose and litharenite according to the diagram of Herron (1986) (Fig. 5) and Pettijohn (1972) (Fig. 6). On the Na_2O-K_2O diagram, the samples of Legyi Formation in rich of quartz content fall in the intermediate and rich field (Fig. 7) (after Crook, 1974).

Table (1). The eleven major element oxides of Legyi Sandstone (in Percentage)

sample	SiO_2 %	Al_2O_3 %	TiO_2 %	Na_2O %	K_2O %	FeO %	Fe_2O_3 %	MgO %	CaO %	MnO %	p_2O_5 %	Total
1	60.8	14.5	1.55	0.344	4.07	9.6	4.8	1.47	2.31	0.187	0.224	99.555
2	38.9	11.3	0.643	0.765	1.23	4.2	2.1	1.67	38.3	0.427	0.291	99.826
3	46	19.3	0.967	13.5	2.01	4.12	2.06	0.542	2.98	0.0764	0.241	91.7964
4	61.4	19.7	1.23	1.80	3.18	5	2.4	.1.31	4.25	0.104	0.299	99.673
5	61.2	16.5	0.684	3.83	2.19	4.1	2.04	4.77	4.01	0.106	0.3	99.73
6	64.2	17.8	0.669	2.66	2.74	3.9	1.95	3.02	2.95	0.0762	0.228	99.8332
7	57.2	21.7	0.954	1.8	3.21	5.81	2.9	3.10	1.66	0.085	0.215	98.634
8	40.2	11.4	0.834	1.74	1.76	4.41	2.2	2.06	34.6	0.361	0.209	99.774
9	63	14.76	0.575	6.21	3.04	4.2	2.1	1.61	3.58	0.0706	0.215	99.3006
10	41.6	10.1	0.54	1.49	1.15	3.05	1.45	2	37.5	0.786	0.297	99.963
11	39.4	9.91	0.605	0.831	1.15	3.58	1.71	2.58	38.7	1.06	0.350	99.876
12	15.3	5.77	0.319	1.69	0.656	2.68	1.28	1.87	68.5	1.63	0.301	99.996
13	31.9	9.09	0.441	1.69	0.99	3.37	1.6	1.62	48.6	0.409	0.155	99.865
14	59.4	28.2	0.740	4.7	1.24	1.71	0.81	0.983	1.37	0.0274	0.101	99.2814
15	64.3	16.4	0.479	3.28	2.08	3.62	1.72	3.61	4.04	0.0771	0.345	99.9511

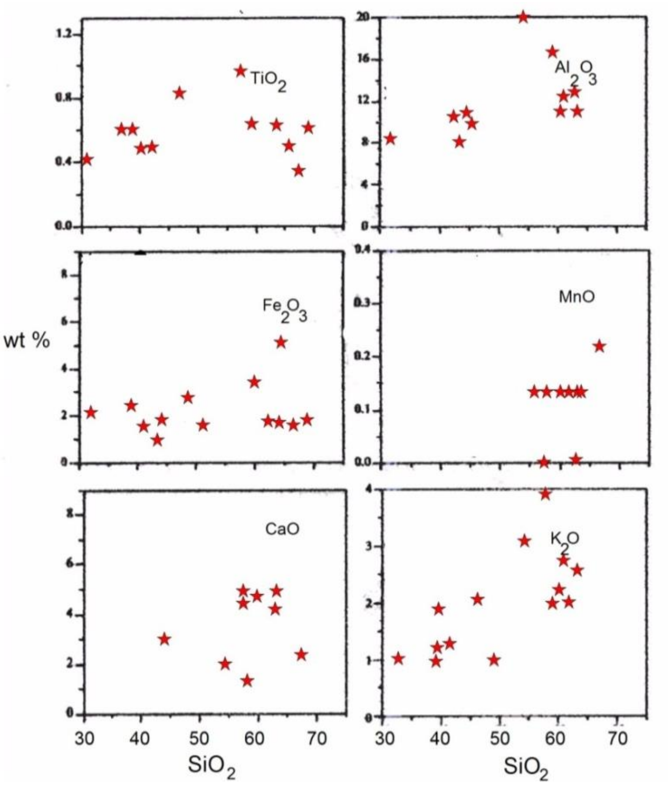

Figure (4). Harker variation diagrams for major elements in the Legyi Formation (Middle Miocene)

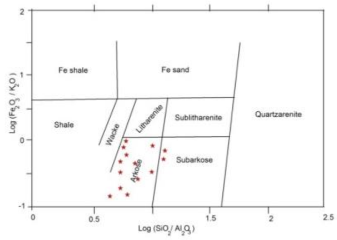

Figure (5). Chemical classification of samples from the Legyi Formation (after Herron, 1996)

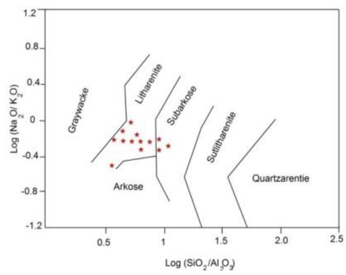

Figure (6). Chemical classification of samples from the Legyi Formation (after Pettijohn, 1972)

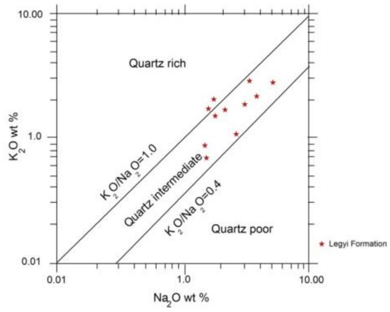

Figure (7). Analysis of sandstone according to their richness of quartz intermediate in the Legyi Formation (after Crook, 1974)

Tectonic Setting of Legyi Formation Based on Major Oxide

Knowledge of the tectonic setting of a basin is important for the exploration of petroleum and other resources as well as for paleogeography. Some authors have described the usefulness of major element geochemistry of sedimentary rocks to infer tectonic setting based on discrimination diagrams.

Bhatia proposed major element geochemical criteria to discriminate plate tectonic settings of sedimentary basin from identified well-defined sandstone suites. He compiled the average chemical composition of medium- to fine grained sandstones (e.g arkose, greywacke, lithic arenites, and quartz arenite) modern sands from various regions of the world and used these average values to propose discrimination diagrams.

Bhatia used these diagrams to infer the tectonic settings of five Paleozoic sandstone suites of eastern Australia. Bhatia considered the tectonic setting of sandstones that he studied and generally concluded that sedimentary basins may be assigned to the following tectonic settings based on the major oxides.

(1) Oceanic arc: fore arc or back arc basins, adjacent to volcanic arcs developed on oceanic or thin continental crust.

(2) Continental island arc: inter arc, fore arc, or back arc basins adjacent to a volcanic arc developed on a thick continental crust or thin continental margins.

(3) Active continental margin: Andean type basin developed on or adjacent to thick continental margin and strike-slip basins also developed in this environment.

(4) Passive continental margin: rifted continental margins developed on thick continental crust on the edges of continents and sedimentary basins on the trailing edge of continent.

These diagrams are used for the recovered sediments from Legyi clastic sediments to determine the tectonic setting of the study area.

Bhatia proposed a discrimination diagram based on a bivariate plot of first and second discrimination functions of major element analysis. The sandstones were chosen to represent the four different tectonic settings. The discrimination diagram is used to classify the suites of various samples into different tectonic setting. The discriminant functions are as follows:

Discriminant function 1: $-0.0447SiO_2 - 0.972TiO_2 + 0.008Al_2O_3 - 0.267Fe_2O_3 + 0.208FeO - 3.082MnO + 0.140MgO + 0.195CaO + 0.719Na_2O - 0.32K_2O + 7.510P_2O_5 + 0.303$;

Discriminant function 2: $-0.421SiO_2 + 1.998TiO_2 - 0.526Al_2O_3 - 0.551Fe_2O_3 - 1.610FeO + 2.72MnO + 0.881MgO - 0.907CaO - 0.177Na_2O - 1.84K_2O + 7.244\ P_2O_5 + 43.57$;

The discriminant plot is shown in figure (8). In this diagram, most of the Legyi sandstones are fall active continental margin. In the discrimination function 1 and function 2, 8 samples cannot fixed in this graph.

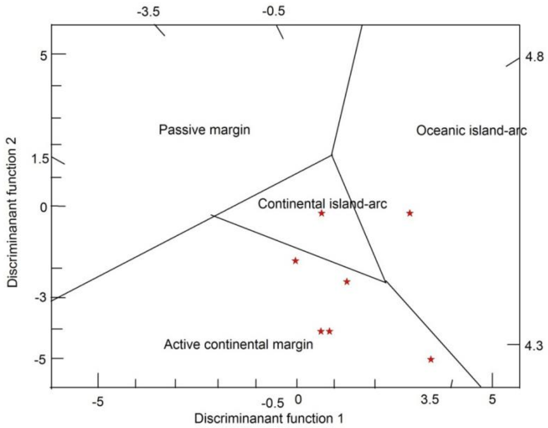

Figure (8). The discriminant function diagram for sandstones (after Bhatia, 1983) showing fields for sandstones from passive continental margins, oceanic island-arcs, continental island-arcs and active continental margin.

The discriminant functions are as follows:

Discriminant function 1: -0.0447SiO_2 – 0.972TiO_2 + 0.008Al_2O_3 – 0.267Fe_2O_3 + 0.208FeO – 3.082MnO + 0.140MgO + 0.195CaO + 0.719Na_2O – 0.32K_2O + 7.510P_2O_5 + 0.303;

Discriminant function 2: -0.421SiO_2 + 1.998TiO_2 + 0.526Al_2O_3 – 0.551Fe_2O_3 - 1.610FeO + 2.72MnO + 0.881MgO – 0.907CaO - 0.177Na_2O + 1.84K_2O + 7.244 P_2O_5 + 43.57;

Modern sandstones from oceanic and continental arcs and active and passive continental margins have variable composition, especially in their $Fe_2O_{3(t)}$+MgO, TiO_2, Fe_2O_3 + MgO, Al_2O_3 / SiO_2, K_2O / Na_2O, and Al_2O_3 /(CaO +Na_2O) contents. Bhatia used this chemical variability to discriminate between different tectonic settings on a series of bivariate plots. Figure (9), shows the discrimination diagrams of sandstones based upon a bivariate plot of TiO_2 versus ($Fe_2O_{3(t)}$ + MgO). The fields are oceanic island arc, continental island arc, active continental margin, and passive margins. According to Bhatia bivariate plot, most of the Legyi sandstones are fall in active continental margin, but oceanic arc and continental arc are only one.

Roser and Korsch tectonic settings determinant diagrams are as follows: the three tectonic settings, passive continental margin (PM), active continental margin (ACM), and oceanic island arc (OIA) are recognized on the K_2O / Na_2O – SiO_2 discrimination diagrams of Roser and Korsch for sandstone mudstone suites as shown in figure (10). According to (Roser and Korsch) discrimination diagrams the sandstones are fall into active continental margin, only three samples are in oceanic island arc.

In discrimination diagram (A) the Legyi sandstones are fall in active continental margin and only each one sample in oceanic arc and continental margin. In diagram (B), most of the samples show active continental margin and only one are fall in oceanic arc and continental arc in (Fig. 11) after Bhatia, 1983), based upon (a) a bivariate plot of TiO_2 Vs ($Fe_2O_{3(t)}$ +MgO) and (b) a bivariate plot of Al_2O_3/SiO_2 vs ($Fe_2O_{3(t)}$ +MgO).

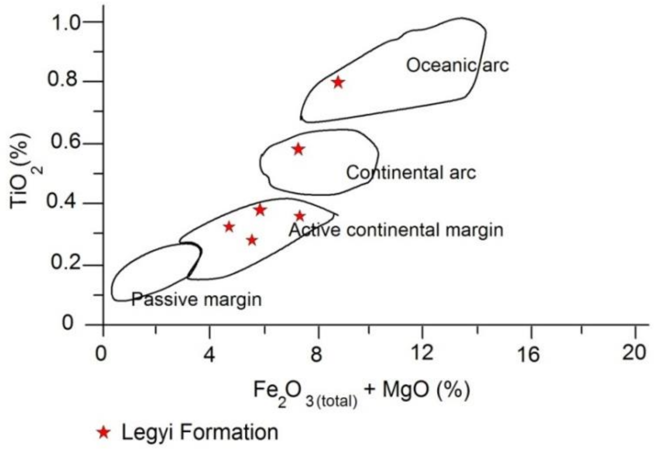

Figure (9). Bivariate plot of TiO2 versus ($Fe_2O_{3(t)}$ + MgO) diagrams for sandstones. The fields are oceanic island arc, continental island arc, active continental margin and passive margins.

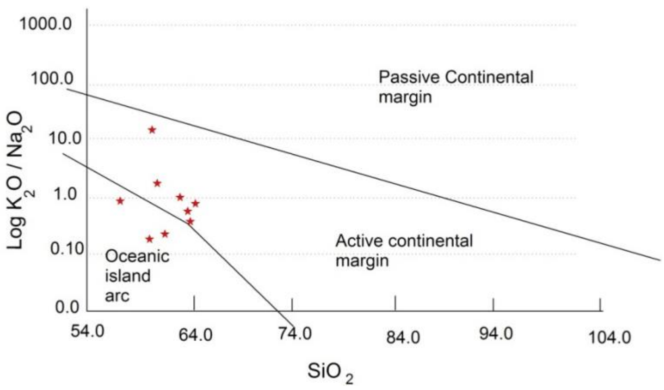

Figure (10). The plot of Log K_2O/Na_2O-SiO_2 discriminanation diagram of Roser and Korsch for sandstone mudstone suites showing the different tectonic settings.

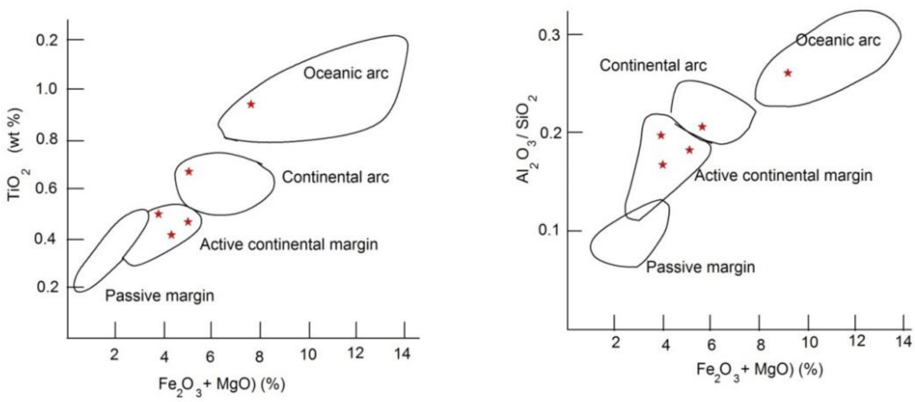

Figure (11). Discrimination diagrams for sandstones (after Bhatia, 1983), based upon (a) bivariate plot of TiO_2 vs ($Fe_2O_{3(t)}$ + MgO) and (b) a Bivariate plot of Al_2O_3/SiO_2 vs ($Fe_2O_{3(total)}$ + MgO. The fields are oceanic island arc, continental island arc, active continental margin and passive margin.

Trace elements

Trace elements such as As, Sr, Zr, Pb, Cr, Rb, Ni, Y, Zn, S, Cu and Br are most suited for provinces and tectonic setting determination because of their relatively low mobility during sedimentary processes and their low residence time in sea water (Holland, 1978). These elements are transported quantitatively into clastic sedimentary rocks during weathering and transportation, reflecting the signature of the parent materials (Bhatia and Crook, 1986).

Legyi Formation of sandstones shows uniform K/Rb ratio that lies close a typical differentiated magmatic suite or main trend with a ratio of 230 (Shaw, 1968) (Fig. 12). This characteristic reveals chemically coherent nature of the sediments and derivation from rocks of acidic and intermediate compositions.

According to the immobile trace elements Zr and immobile oxide TiO_2 variation diagrams (Hayashi et. al., 1997 in Sitaula, 2009) (Fig. 13), Legyi Formation of sandstones are derived from felsic igneous rock and intermediate igneous. The trace element of Zr and Rb are collected from Legyi sandstones are shown in table (2).

Provenance or source rock determination using major oxide, discrimination diagram proposed by Roser and Korsch distinguish the sources of the sediments into four provenance zones; **mafic, intermediate, felsic** and **quartzose** sedimentary provenance. The formula for the raw oxides used in (Fig. 13). In the Legyi Formation of sediments data are describe by calculating from (Roser and Krosch, 1988) discrimination function.

In the discrimination function (1) and (2) of (Roser and Korsch, 1988), the Legyi Formation of sediments fall in felsic igneous provenance and intermediate igneous provenance (fig. 14).

discriminant function 1 = $30.638TiO_2/Al_2O_3 - 12.541 - Fe_2O_{3(t)} / Al_2O_3 + 7.329\, MgO/Al_2O_3 + 12.03\, Na_2O/Al_2O_3 + 35.402 K_2O/Al_2O_3 - 6.382$

discriminate function 2 = $56.500\, TiO_2/Al_2O_3 - 10.879\, FeO_3(total)/Al_2O_3 + 30.875\, MgO/Al_2O_3 - 5.404\, Na_2O/Al_2O_3 + 11.112\, K_2O/Al_2O_3 - 3.89$

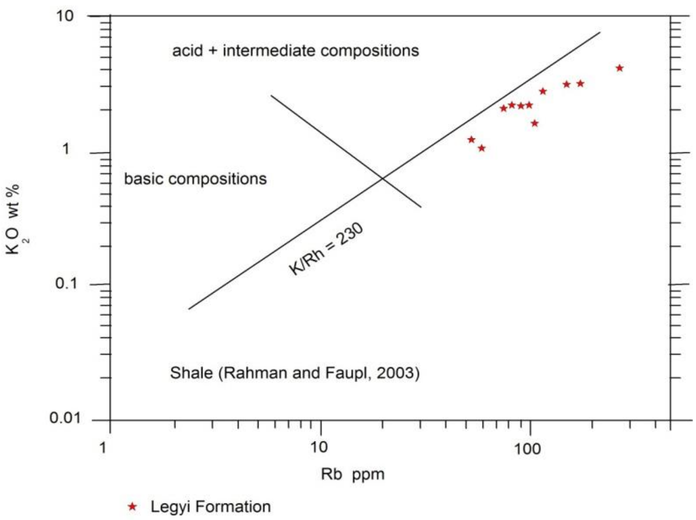

Figure (12). Distribution of K and Rb in the Legyi sediments relative to a K/Rb ratio of 230 (= main trend of Shaw, 1968)

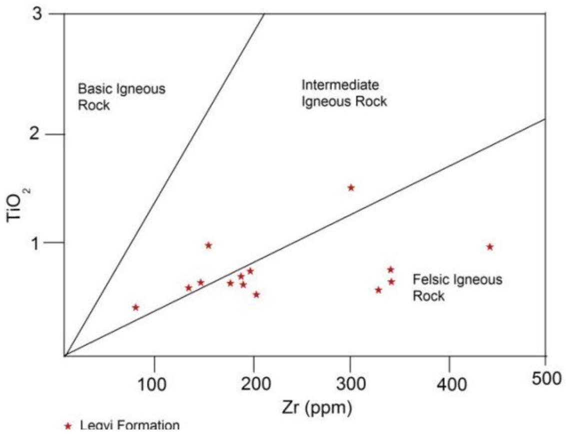

Figure (13). Plot of Legyi sandstones of TiO_2-Zr diagram (Hayashi et. al., 1997 in Sitaula, 2009)

Table (2) The data are collected from Legyi sandstones by using XRF

Sample	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Zr (ppm)	322	196	458	674	198	174	166	135	190	348	334		78	348	202
Rb (ppm)	303	73	84	97	96	141	195	116	163					55	109

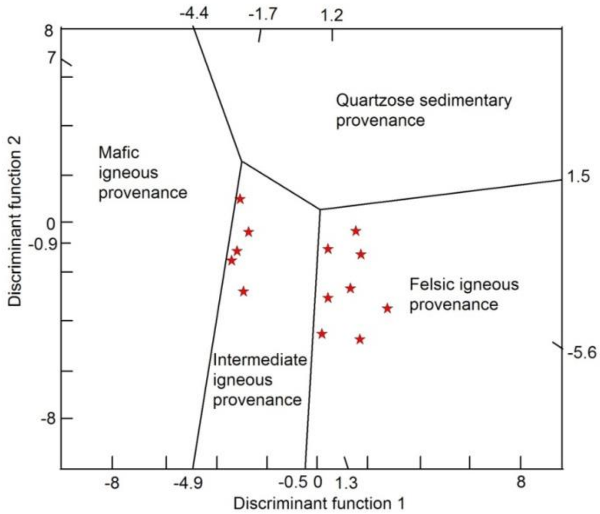

Figure (14) Discriminant function diagrams for the provenance signatures of sandstone-mudstone suite using major element ratios (after Roser and Korsch, 1988). Field for dominantly mafic, intermediate and felsic igneous provenances are shown with the field for a quartzose sedimentary provenance.

discriminant function 1= $30.638TiO_2/Al_2O_3-12.541\ Fe_2O_{3(t)}/Al_2O_3+7.329\ MgO/Al_2O_3 +12.03\ Na_2O/Al_2O_3+35.402K_2O/Al_2O_3-6.382$

discriminant function 2 = $56.500\ TiO_2/Al_2O_3-10.879\ FeO_3(total)/Al_2O_3+30.875\ MgO/Al_2O_3\ -5.404\ Na_2O/Al_2O_3+11.112\ K_2O/Al_2O_3-3.89$

Conclusion

The research area is mainly composed of clastic sedimentary rock. Based on the major elements are SiO_2 TiO_2, Al_2O_3, Fe_2O_3, FeO, MnO, MgO, CaO, Na_2O, K_2O and P_2O_5, the Legyi Formation of sandstones are classified mainly arkose and litharenite. According the discrimination diagram for major oxides, the probable provenance of the Legyi clastics sediment was mainly of active continental margin. The sandstones of Leygyi Formation are derived from the felsic and intermediate igneous sources as the diagrams of immobile trace element of Zr and oxides of TiO_2 variation diagrams. Discriminate function of (1) and (2) shows the felsic provenance of the Legyi Formation.

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