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Geochemical study of upper Bhuban sandstone in Muthi, Mizoram, India

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Abstract

Sandstones from the Upper Bhuban formation were measured for major oxides by X- Ray Fluorescence Spectrometry (XRF) in order to investigate palaeo-weathering, geochemical classification, and tectonic setting of the basin. The Muthi sandstone was found to have moderate to high content of SiO_2 ranging from 64.54 to 76.66 wt% with an average value of 71.73 wt%. The Al_2O_3% content was high ranging between 10.78 to 18.19 wt% and 14.93 wt% (average). The high value of Al_2O_3 could be due to alteration of K-feldspar. Geochemically, the sandstone could be classified as arkose, litharenite and wacke. The sandstones were depleted in CaO (0.57) and enriched in Al_2O_3, Fe_2O_3 and Na_2O. The value of chemical index alteration (CIA) in the Muthi sandstone was high 72.25 to 85.46 an average value of 79.45 indicating high intensity of chemical weathering in the source areas. The average CIA value (79.45) was above than that (50) of the upper continental crust. The geochemical parameters suggest an active continental margin for the upper Bhuban sandstones.

Key words: Geochemical classification; Muthi; palaeoweathering; tectonic setting.

Introduction

Geochemical data have been widely used as an indication of provenance of sedimentary formations, tectonic and climatic conditions in which they were deposited. Thus, the geochemical composition is a guide to the source rocks in the provenance and the tectonic setting of the depositional basin.[1]

Published literature on palaeontological aspect of Mizoram are available which mainly cover molluscan fauna along with the presence of gastropods, echinoids, crab, corals and foraminifers.[2-4] However, no systematic geochemical work has yet been carried out in the Upper Bhuban sandstone in Muthi village of Mizoram. The purpose of the present study is to identify chemical composition, palaeoweathering, geochemical classification and the tectonic setting of the basin by using major elements.

Materials and Methods

Muthi village (Lat. 23° 46'20" N: 92°45' 50" E in the Survey of India Topo Sheet No.

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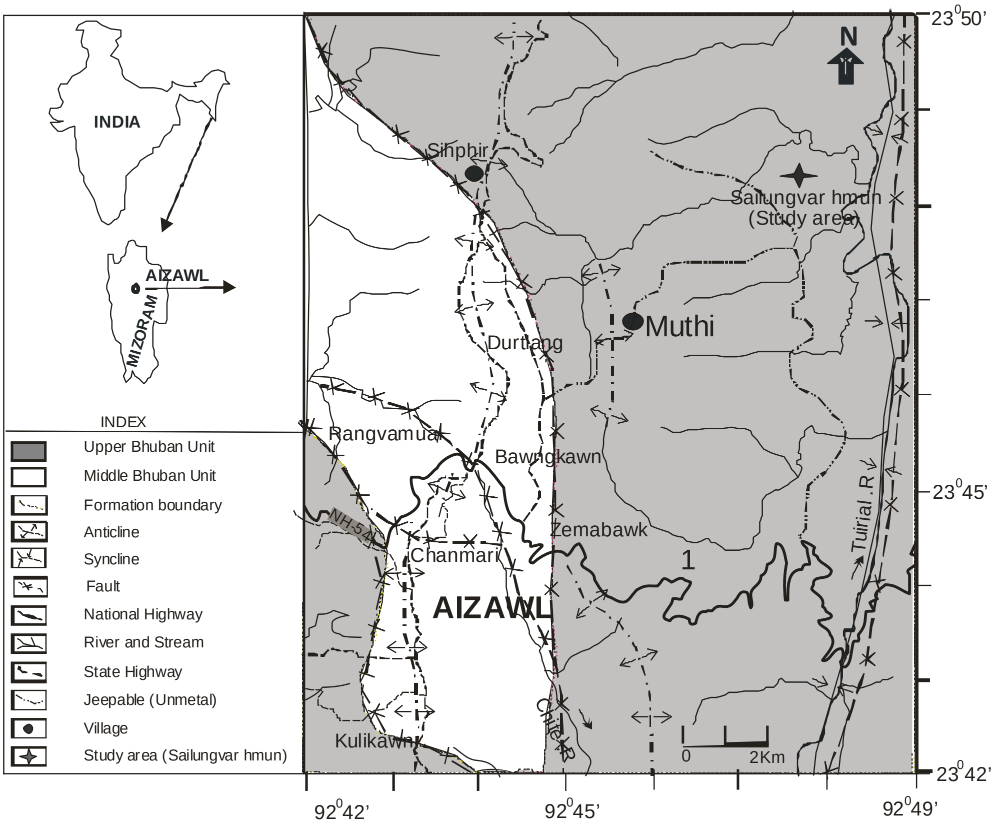

Figure 1. Location map of the study area.

84A/13) is located nearly 15 Km northeast of Aizawl city in Mizoram (Fig. 1). Mizoram geologically is a part of Tripura-Mizoram depositional basin and it has been considered as the southern extension of Surma Valley. The entire sedimentary column of the area is a repetitive succession of arenaceous and argillaceous rocks. This succession form N-E trending longitudinally plunging anticlines and synclines affected by numerous faults and thrusts. The generally N-S trending beds dip at 20° to 50° either eastward or westward. The exposed sequences comprise sandstones, siltstones, shales, mudstones with pockets of shell limestones, calcareous sandstones and intraformational conglomerates.[5-7]

The sediments in Mizoram have been grouped under the Surma Group and the Tipam Group. The Surma Group is divided into the lower Bhuban Formation and the upper Bokabil Formation. The Bhuban Formation is further subdivided into the Lower, Middle and Upper Bhuban units with conformable contacts. The Upper Bhuban unit is extensively developed in Mizoram[8]. The rock succession in the vicinity of Muthi village constitutes a part of the Upper Bhuban unit of the Bhuban Formation, Surma Group (lower to middle Miocene). This unit is represented by a repetitive succession of shales, siltsones, sandstones and their admixture in various proportions and constitutes an eastern limb of the Aizawl anticline. The siltstones are also grey to brown in colour. The sandstones represented by grey to buff facies are hard, compact, bioturbated and occasionally silty. Samples from the exposed sandstones were collected from this area.

Samples were collected from the outcrop sections. The collected samples were washed thoroughly in the distilled water to remove contamination. Ten samples were analyzed for major oxides by X Ray Fluorescence Spectrometry (XRF Philips PW 2440). The analytical work was carried out at National Geophysical Research Institute, Hyderabad.

RESULTS AND DISCUSSION

The percentage of Muthi Sandstone is given in the Table 1. The Muthi sandstones had moderate to high content of SiO_2 which varies from 64.54 to 76.66 wt% with an average value of 71.73 wt%. SiO_2 was taken as a common factor, Al_2O_3, Fe_2O_3, N_2O, K_2O, MgO, and MnO show negative correlation with it. It is suggested that the control of free silica in the form of quartz. The correlation between alumina with oxides like Fe_2O_3 and K_2O, showed negative values in nature.

The content of Al_2O_3 was high varying from 10.78 to 18.19 wt% and the average value was 14.93 wt%. The high concentration of Al_2O_3 could be due to alteration of K-feldspar. Fe_2O_3, MgO and Al_2O_3 enrichment were observed. Fe and Mg were controlled by clay minerals or micas.

The concentration of TiO_2 was low in the Muthi sandstones (0.59 to 0.9 wt %) with an average value of 0.69 wt%. It might have come from the metamorphosed argillaceous rocks or granitoid rocks. Generally, it is a characteristic of sediments that have undergone long period of consistent of sub aerial weathering. It was observed that CaO was depleted in the Muthi sandstone. In the Muthi sandstones K_2O (2.58 wt%) was slightly higher than Na_2O (0.75 wt%) and CaO (0.57 wt%); thus, it indicated the chemically mature sediments.[9]

The SiO_2/Al_2O_3 ratio of the Muthi sandstone varied from 3.55 to 7.08 and the average value was 4.80. It was observed that the Muthi sandstones fall in the quartz rich field (Fig. 2).

The bivariate plot of Al_2O_3+K_2O+Na_2O, against SiO_2 differentiates the climatic conditions under which the sediments were deposited. In the bivariate plot the Muthi sandstones fall into arid climatic condition and increasing chemical maturity in the Muthi sandstone (Fig. 3).

The data of major oxides gives useful information regarding the climatic conditions which prevailed during the depositions of sedimentary rocks. The chemically immature sandstones with low silica content indicate a less intense weathering with arid or cold climate, where as sub-mature and mature sandstones with high silica content indicates warm -humid climate. The bivariate plot of Al_2O_3+K_2O+Na_2O, against SiO_2 suggest an arid climatic condition for the Muthi sandstones (Fig. 3).

The influence of weathering on sedimentary rocks can be calculated by using Chemical Index of Alteration (CIA). The CIA value which indicates the degree of weathering of source rocks and is determined by the equation

$$CIA = [Al_2O_3 (Al_2O_3 + CaO\ sil. + Na_2O + K_2O)] \times 100$$

where CaO sil. represents association with silicate phases. The CaO content in most of the samples is low. Therefore, the total CaO content, instead of CaO sil. is used in the calculation of CIA value. The CIA is a good measure of Palaeoweathering conditions and it essentially monitors the progressive weathering of feldspar to clay minerals.[10] High CIA values indicate intensive chemical weathering in the source area. CIA in the Muthi sandstone values ranged between 72.25 and 85.46 (average 79.45) indicating high intensity of chemical weathering in the source areas (Table 1).

Classification for terrigenous sands based on log(Na_2O/K_2O) versus log(SiO_2 /Al_2O_3) has been propsed. Most of the Muthi sandstones fall into Arkose (Fig. 4a). Herron modified the diagram using log (Fe_2O_3/K_2O) instead of log(Na_2O/K_2O).[11] According to this

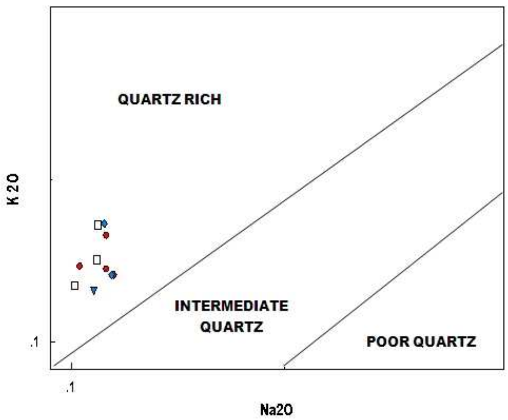

Figure 2. K_2O vs Na_2O diagram for quartz richness of the Muthi sandstone.

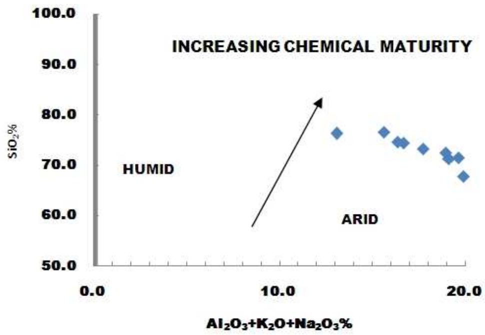

Figure 3. Diagram for chemical maturity of the Muthi sandstone and their affinity towards different climatic settings.

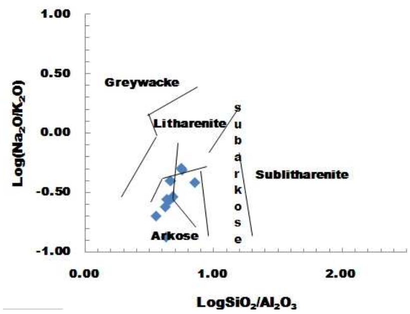

Figure 4a. Geochemical classification of Muthi sandstone $log(Na_2O/K_2O)$ vs $log(SiO_2/Al_2O_3)$.

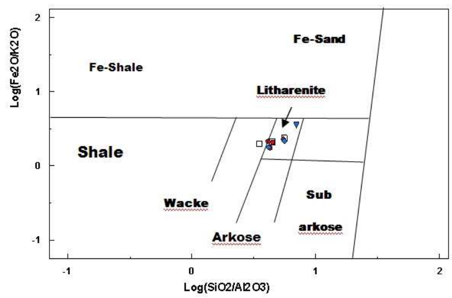

Figure 4b. Geochemical classification of Muthi sandstones after Herron (1988) $log(Fe_2O_3/K_2O)$ vs $log(SiO_2/Al_2O_3)$.

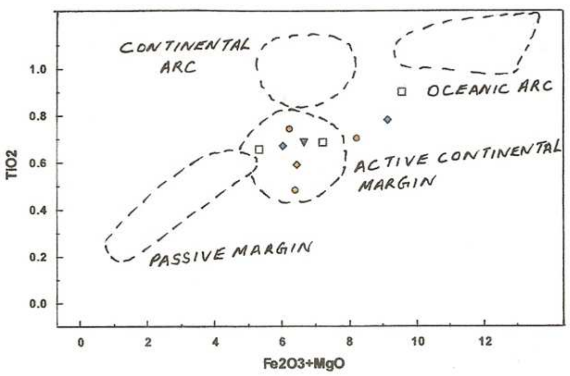

Figure 5a. Discrimination diagram for Muthi sandstone after Bhatia (1983) by using TiO_2 + ($Fe_2O_{3(Tot)}$+ MgO).

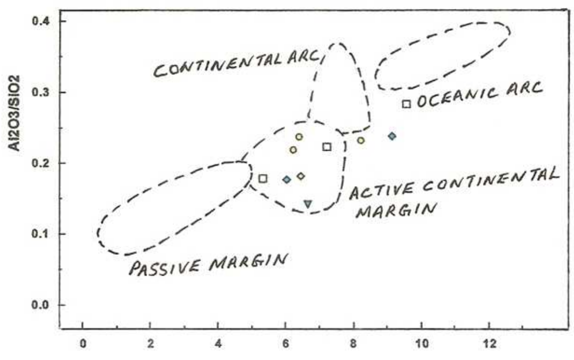

Figure 5b. Discrimination diagram for Muthi sandstone after Bhatia (1983) by using Al_2O_3/ SiO_3 vs ($Fe_2O_{3(Tot)}$+ MgO).

Table 1. Concentration of major oxides (in Wt%) and Chemical Index Alteration (CIA) value in the Muthi sandstone.

Oxides	**MK-R-1**	**MK-R-2**	**MK-R-3**	**MK-R-4**	**MK-R-5**	**MK-R-6**	**MK-R-7**	**MK-R-8**	**MK-R-11**	**MK-R-14**
SiO_2	**76.66**	**64.54**	71.32	72.49	71.55	67.88	74.51	67.27	74.72	76.33
TiO_2	0.65	0.9	0.68	0.74	0.48	0.7	0.59	0.78	0.67	0.68
Al_2O_3	13.65	18.19	15.81	15.71	16.93	15.65	13.44	16.03	13.15	10.78
Fe_2O_3	4.27	7.28	5.47	4.72	5.02	5.69	4.94	6.43	4.59	5.74
CaO	0.38	0.38	0.39	0.41	0.18	1.76	0.37	0.63	0.57	0.65
MgO	1.08	2.29	1.77	1.54	1.39	2.54	1.5	2.73	1.46	0.91
MnO	0.02	0.05	0.06	0.04	0.06	0.19	0.03	0.06	0.05	0.79
Na_2O	0.18	0.74	0.71	0.92	0.32	0.93	1.09	0.89	1.05	0.64
K_2O	1.81	3.68	2.61	2.3	2.38	3.32	2.15	3.72	2.14	1.66
P_2O_5	0.08	0.13	0.12	0.08	0.08	0.11	0.12	0.11	0.11	0.14
Sum	98.77	98.19	98.94	98.95	98.39	98.76	98.75	98.63	98.51	98.32
SiO_2/Al_2O_3	5.62	3.55	4.51	4.61	4.23	4.34	5.54	4.20	5.68	7.08
CIA	**85.21**	**79.12**	**80.99**	**80.99**	**85.46**	**72.25**	**78.82**	**75.36**	**77.76**	**78.51**

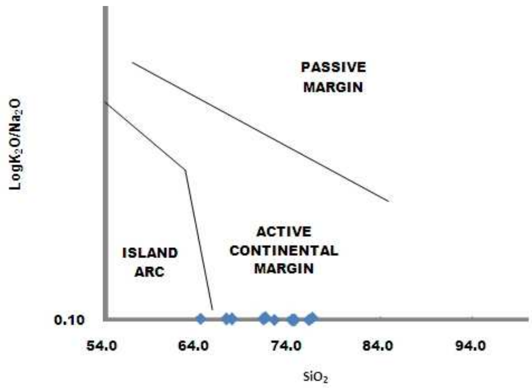

Figure 5c. The log (K_2O/Na_2O) vs Si_2O discrimination for the Muthi sandstone showing passive margin, an active continental margin and island arc.

classification the Muthi sandstones fall into wacke and litharenite (Fig. 4b).

Tectonic setting

Bhatia established a discrimination diagram using TiO_2 vs ($Fe_2O_{3(Tot)}$+MgO) and Al_2O_3/SiO_2 vs ($Fe_2O_{3(Tot)}$+MgO).[12] This includes oceanic island arc, continental island arc, active continental margin and passive margin. Most of the Muthi sandstone falls in the field of active continental margin. The diagram is depicted in (Fig 5a & b).

Discrimination of tectonic settings on the basis of the major elemental data was also proposed by Roser and Korsch[13,14] to determine the tectonic setting of terrigenous sedimentary rocks. SiO_2 and K_2O/Na_2O increase from volcanic arc to active continental margin to passive margin settings. The upper Bhuban sandstone fall in the general area of active continental margin (Fig. 5c) (but there is a scatter on plot across the two fields' active continental margin and island arc).

CONCLUSION

The Muthi sandstone of Upper Bhuban formation have moderate to high SiO_2 contents. They are depleted in CaO and enriched in Al_2O_3 and MgO. SiO_2/Al_2O_3 ratio indicated that these sandstones increase in maturity. This interpretation is supported by bivariate plot of Al_2O_3+K_2O+Na_2O, against SiO_2 (Fig. 3). The high average values of CIA reveal intense chemical weathering and possibly points to an arid climate in the source area. Geochemically, these sandstones are classified as wacke, arkose and litharenite. Tectonic discrimination diagrams suggest an active continental margin. This study reveals that the geochemical signature of Upper Bhuban sediments can be used for deciphering the lithological composition, source-area weathering, and tectonic setting of the basin. These geochemical parameters can also be used for source-basin modeling in future.

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