Bulletin of Pure and Applied Sciences. *Print version ISSN 0970 4639*
Vol.39F, Geology (Geological Science), No.1 *Online version ISSN 2320 3234*
January-June 2020: P.73-81 *DOI: 10.5958/2320-3234.2020.00007.4*
Original Article *Available online at www.bpasjournals.com*

Geochemistry of the Miocene Sandstones of Bhuban Formation of the Surma Group Occurring in and Around Katigorah, Cachar District of Assam, India

[1]M. Borah, [2]P.K. Das, [3]B. Bhagabaty, [4]P. Basumatary, [5]D. Das*

Author's Affiliations:
[1] Principal, Mayang Anchalik College, Rajamayang, Morigaon, Assam 782411, India;
E-mail: m.borah@yahoo.co.in
[2] Retd Professor, Department of Geological Sciences, Gauhati University, Guwahati, Assam 781014, India;
E-mail: daspradipkumar981@gmail.com
[3] Associate Professor, Department of Geological Sciences, Gauhati University, Guwahati, Assam 781014, India;
E-mail: b_bhagabaty@gauhati.ac.in
[4] Assistant Professor, Department of Geology, Dimoria College, Khetri, Kamrup, Guwahati, Assam 782403 India;
E-mail: pallabibsty03@gmail.com
[5]Assistant Geologist, Directorate of Geology and Mining, Guwahati 781019 Assam, India;
E-mail: dibakardas92@gmail.com

***Corresponding Author: M. Borah,** Principal, Mayang Anchalik College, Rajamayang, Morigaon, Assam 782411, India

E-mail: m.borah@yahoo.co.in

(**Received on 12.02.2020**, **Accepted on 29.04.2020**)

ABSTRACT

Geochemical composition (major oxides) of the Miocene Sandstones of Bhuban Formation of the Surma Group exposed in and around Katigorah, Cachar District of Assam was determined to reveal their palaeoweathering, chemical maturity, palaeoclimate, provenance and tectonic setting. Representative samples were analysed for major, minor and trace elements by method. Geochemical classifications show that the sandstones are sublithic to greywacke in composition. The positive correlation between the major elements (oxides) is observed and it suggests the influence of source rock lithology. From the study of palaeoweathering, it is seen that K-feldspar is more in Bhuban Sandstones indicating moderate intensity of chemical weathering in the source area. Regarding chemical maturity, sandstones are slightly matured. The geochemical studies reveal that the climatic condition was arid during that time. It is seen that sandstones are derived mostly from metamorphic and igneous (mostly granite) sources which are present in the adjoining areas. Under tectonic setting, sandstones are mostly of Active continental margin type and Passive margin type and the sediments were deposited in Miocene foreland basin formed due to collision orogen.

KEYWORDS: *Geochemistry, Palaeoweathering, Chemical Maturity, Palaeoclimate, Provenance, Tectonic Setting.*

INTRODUCTION

The geochemical studies are mostly concerned with differences in major and trace elements in sedimentary rocks which gives information about the source and environment of deposition sediments because the distribution of the elements in sediments are governed by various physical, chemical and biological factors. For any particular clastic sediment its geochemistry is the cumulative result of four principal factors like source rock composition in the provenance area, degree of chemical weathering experienced by the source rocks in the provenance area and during subsequent transportation, processes occurring during sediment transport and deposition, such as sorting and maturity and elements mobility during digenesis[1]. According to Fralick and Kronberg[2], the factors which control the geochemistry of a clastic sedimentary rock include: (1) composition of source terrain (2) chemical weathering (3) hydraulic sorting (4) diagenesis (5) metamorphism and (6) hydrothermal alteration.

The present study has been carried out in Katigorah in the Cachar district of Assam, India. The Miocene sandstones of Bhuban Formation belonging to the Surma Group are well exposed in the study area. It has been conducted using geochemical data of the Miocene sediments for interpreting sediment types, palaeoweathering, chemical maturity, palaeoclimate, provenance of sediments and tectonic setting of the region. The main purpose of this study is to identify the source rock character and the control of provenance and tectonic settings and source– area weathering in the study area.

GEOLOGY OF THE AREA

The outcrops of tertiary rocks are exposed in and around of Katigorah of Cachar District, Assam. The location map of the Bhuban Formation of the area is shown in map (Figure 1). Lithological characters show that these are the sandstones of Bhuban Formation belonging to Surma Group. Lithologically sandstones are medium to fine ground, bluish grey to greenish and yellowish grey in colour. Moreover, sandstones are loose and hard, massive to bedded in nature. Intercalated shales are common mostly within the fine grained sandstones. Based on lithological characters, Bhuban Formation may be divided into three divisions which are shown in following stratigraphic succession (Table 1).

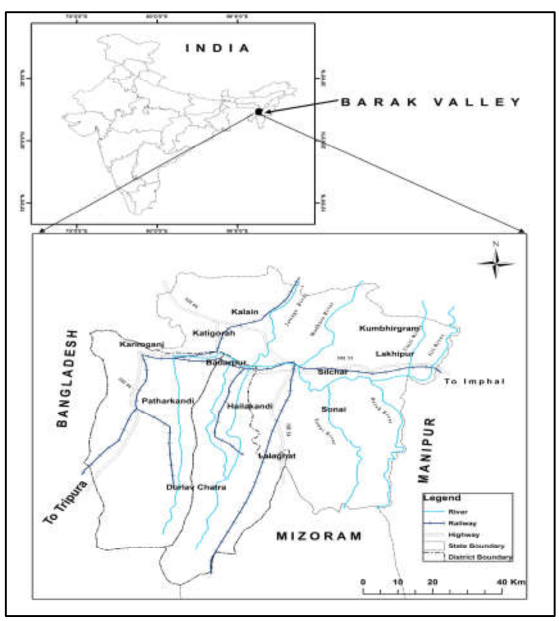

Figure 1: Location Map of the Study Area

Table 1: Stratigraphic succession (based on field observations)

Age	Group	Formation	Lithology
Miocene	Surma	Bhuban	Upper: Medium grained, grey to greenish grey, hard, bedded sandstones. Middle: Medium to fine grained, grey to yellowish in colour, massive to bedded with shale. Lower: Fine grained, hard and loose, bluish to greyish, bedded sandstones with intercalated shales.
...Unconformity...			
Oligocene	Barail	Undifferentiated	Sandstones, siltstone and shale

METHODS

Fine grained sandstone samples were collected in the field for chemical analysis. These samples were collected from Bhuban Sandstone Formation occurring in and around Katigorah, Cachar district and adjoining areas of Badarpur, Karimganj District of Assam, India. Ten representative sandstone samples were analysed in the laboratory for major and minor elements. The samples were analysed in the department of USIC, Gauhati University by XRF method. The instrument used in the analysis is PAN analytical AXIOS XRF spectrometer. The accuracy and precision of the instrument are within 1.5 percent of major elements.

RESULTS AND DISCUSSION

The geochemical analysis of sandstone samples mainly included major (oxides) and minor elements studies. Ten representative sandstone samples of Bhuban Formation were analysed for major oxides.

Major Oxides: In order to identify the source rocks and tectonic settings major oxides study of sandstones was essential. The major element chemistry gave ideas regarding the provenance type as well as weathering conditions, which were controlled by the tectonic setting of the basin. Bhatia[3] had put forward a tectonic classification based on SiO_2 content and K_2O/Na_2O. Palaeoclimate interpretation was done with the help of bulk composition by Suttner and Dutta[4]. Chemical maturity and palaeoweathering etc. were also determined with the help of major oxides. The percentage of major oxides variation of Bhuban sandstones of Katigorah area are given in (Table 2). These included SiO_2, Al_2O_2, Fe_2O_2, Na_2O, K_2O, Cao, MgO, TiO_2, Mno and P_2O_5. The variations in major element geochemistry are shown with the help of Harkar variation diagrams (Figs. 2-5). The variations were analysed in relation to SiO_2 and variations between other radicals. The Bhuban sandstones have high SiO_2 concentration of 60.52 to 76.52 wt%. Considering SiO_2 as a common factor, it was seen that Al_2O_3, Fe_2O_3, K_2O, Na_2O, MnO and MgO show positive correlation with it. It indicated dominance of free silica in the form of quartz. The correlation between alumina with oxides like K_2O and Fe_2O_3 showed a negative nature. The Al_2O_3 content was high (Av. 11.50 wt %) and it might be due to alteration of K-feldspar. It indicated an aluminous source. The correlation between Fe_20_3+MgO and Al_20_3 implied that both Fe and Mg were controlled by clay minerals and/or mica. The TiO_2 concentration was low (0.29 to 0.91 wt %) and might have come from metamorphosed argillaceous rocks or acid igneous rocks.

Palaeoweathering: Alteration of minerals resulting from chemical weathering mainly depended on the intensity and the duration of weathering. The feldspar degradation, which was very sensitive to chemical weathering, increased the mobility of many elements through clays. During weathering, calcium, sodium and potassium were diminished from feldspar by Nesbitt et al[5].

According to Nesbitt and Young[6] the impact of weathering on sedimentary rocks was calculated using Chemical Index of Alteration (CIA). The degree of weathering of source rocks was indicated by the CIA values and was determined by the equation –

$$CIA = [Al_2O_3 / (Al_2O_3 + CaO\ sil. + Na_2O + K_2O)] \times 100 \quad \text{........ Eq(1)'}$$

Where, CaO sil represents CaO associated with silicate phases.

The CIA gave the ratio of original/primary minerals and secondary products such as clay minerals. CIA values were nearly 50 to 100 for completely weathered rocks, considering entirely of secondary minerals. Whereas low values (i.e.50 or less) indicated unweathered source areas, high CIA value depicted intensive chemical weathering in the source area. The calculated CIA values for the Bhuban sandstones vary from nearly 65.50 to 75.70% with an average of 68.50 which indicated that sandstones were derived from the least to moderate weathered zones.

Table 2: Table showing major oxide variations (in Wt%) of the Bhuban Sandstones of the study area

Sp. No.	Lab No.	SiO_2	Al_2O_3	Fe_2O_3(T)	MnO	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	CIA
1	4084	70.29	12.30	2.68	0.013	1.01	0.51	2.87	1.60	0.29	0.03	68.25
2	4085	71.75	10.56	2.74	0.011	1.05	0.60	2.80	1.76	0.38	0.07	69.20
3	4086	76.52	11.13	3.01	0.110	1.07	0.60	2.81	1.95	0.56	0.09	72.60
4	4087	70.14	10.50	4.51	0.100	1.08	0.58	2.79	1.80	0.78	0.24	66.50
5	4088	74.92	11.00	2.99	0.090	1.08	0.61	2.70	1.68	0.91	0.06	65.30
6	4089	60.52	10.98	5.05	0.155	1.56	2.88	2.70	2.40	0.86	0.11	75.10
7	4090	63.19	11.50	5.61	0.170	1.66	2.51	3.10	2.10	0.71	0.10	74.65
8	4091	73.30	12.82	2.80	0.01	1.08	0.50	2.81	2.22	0.70	0.08	69.25
9	4092	73.78	10.51	2.81	0.011	1.04	0.50	2.78	1.70	0.33	0.03	68.10
10	4093	72.08	11.25	4.82	0.012	1.48	0.48	2.80	3.01	0.68	0.22	66.20

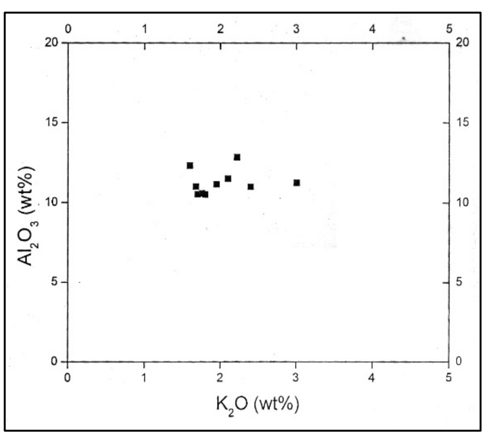

Figure 2: Scatter plot of K_2O vs. Al_2O_3 of Bhuban Sandstones (Harker Variation)

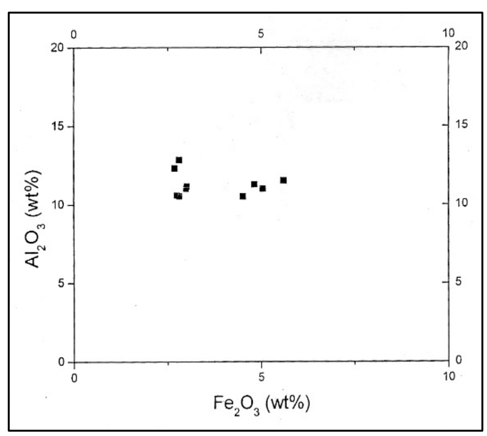

Figure 3: Scatter Plot of Fe_2O_3 vs. Al_2O_3 of Bhuban Sandstones (Harker Variation)

Chemical Maturity: Chemical Maturity Index (CMI) of clastic sediments was given as SiO_2 percent and SiO_2/Al_2O_3 ratio defining chemical maturity by Pettijohn et al[7]. The sediments of Bhuban sandstones showed comparatively higher SiO_2/Al_2O_3 ratio. The plots of $Al_2O_3 + K_2O + Na_2O$ against SiO_2 in the Suttner and Dutta (1986) binary diagram (Fig. 6) suggested slightly increasing chemical maturity.

Palaeoclimate: Major elemental data puts forward useful information regarding the climatic conditions which existed during the deposition of sedimentary rocks[4]. The bivariate plots of Al_2O_3+K_2O+Na_2O against SiO_2 differentiated the climatic conditions under which the sediments were deposited. The chemically immature sandstones with low silica content indicated a less intense weathering with arid or cold climate, whereas sub-mature and mature sandstones with high silica content indicated warm-humid climate[4]. The plots of Al_2O_3+K_2O+Na_2O against SiO_2 in the Suttner and Dutta[4] binary diagram (Fig. 6) suggested arid climatic condition for Bhuban sandstones.

Provenance: Source rock composition is usually thought to be the dominant factor. However, secondary processes like weathering, diagenesis can have an adverse impact on chemical composition and therefore, one best relies on elements that generally shows lesser mobility under the geological conditions[8]. In order to decipher the provenance of the source region geochemical characters of clastic rocks were used. The geochemistry of terrigenous sand was a function of complex interplay of provenance, weathering, transportation and diagenesis. Major element geochemistry gave ideas about the provenance[9]. Condie[10] had proposed a ternary diagram of Fe_2O_3-MgO-Tio_2 for wt% of the Bhuban sandstones samples fall in the field 1 (Fig. 7) which indicated that the source rock of sandstone was probably granite and quartz monzonite. The plots following Crook[11] have suggested the sediments of the sandstones were derived from quartz rich provenance (Fig. 8). The plots in the CaO-Na_2O-K_2O ternary diagram after Le Maitre[12] showed that the provenance is granitic (Fig. 9) for Bhuban sandstones.

Tectonic Setting: The tectonic setting of sedimentary rocks was inferred from major elemental data. It mostly exhibited the nature and proportion of their detrital components and the bulk composition defineed the tectonic setting of the basin[13]. Winchester and Max[14] had successfully used elements as geochemical tectonic indicators in immature sediments. For determining the tectonic setting, discrimination plots suggested by Bhatia and Roser and Korsch were used[3,15]. Moreover, plots of Blatt et al[16] were also used for tectonic setting. For sandstones of the area the plots in the Roser and Korsch binary diagram are falling mostly in the Active Continental Margin (ACM) to Passive Margin. (Figurre 10). The ratio of Al_2O_3/SiO_2 gave an indication of the quartz enrichment in sandstones. The ratio of $Al_2O_3/(CaO+Na_2O)$ was a comparative measure of mobile to the immobile oxides. The plots of K_2O for Bhuban sandstones were close to Active Continental Margin (ACM) to Passive Margin (PM) (Figs. 11 and 12). The plot of Bhuban sandstones fall mostly in Euogeosyncline of ferromagnesium sodium sandstone (Fig. 13). Blatt et al.[16] stated that Euogeosynclinal sediments are deposited in near Continental to Passive Margin environments. Low Al_2O_3/SiO_2 ratio of sandstones was further indicative of quartz rich source deposited in a Continental Margin Setting and K_2O/Na_2O ratio and resultant overlap between passive and active continental margin settings reflected a complex provenance and history of recycling of these sediments[17].

Geochemical Classification of The Sandstones: On the basis of major elemental composition, geochemical classification of terrigenous sedimentary rocks has been proposed by many authors[7,11,16,18]. Using the indices of SiO_2/Al_2O_3 and Na_2O/K_2O ratios Pettijohn et al[7] proposed a classification for terrigenous sands based on a plot of log (Na_2O / K_2O) versus log (SiO_2 / Al_2O_3). Herron[18] modified the diagram of Pettijohn et al[7] by using log (Fe_2O_2/K_2O) instead of (Na_2O/K_2O). The plots after Pettijohn et al[7] for the collected samples fell mostly in the litharenite field to greywacke field (Fig. 14). The plots after Herron[18] fell mostly in wacke field (Fig. 15).

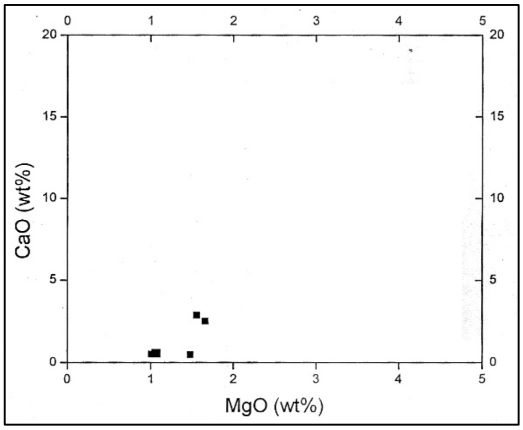

Figure 4: Scatter plot of MgO vs. CaO of Bhuban Sandstones (Harker Variation)

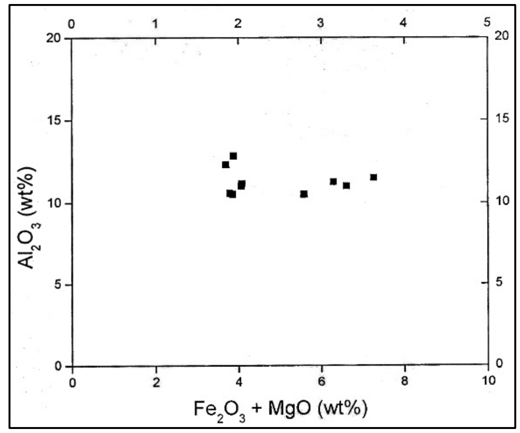

Figure 5: Scatter plot of Fe_2O_3 + MgO vs. Al_2O_3 of Bhuban Sandstones (Harker Variation)

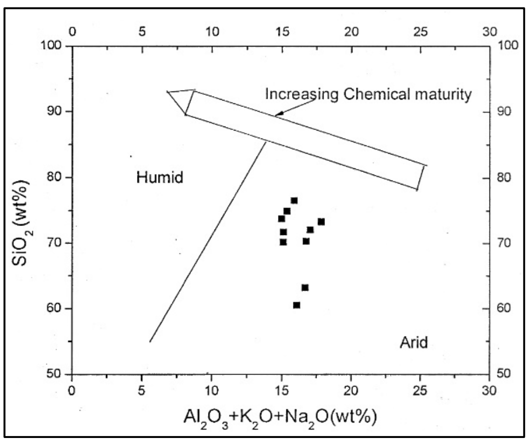

Figure 6: Scatter plot of Al_2O_3 + K_2O + Na_2O vs. SiO_2 of Bhuban Sandstones (Suttner and Dutta, 1986)

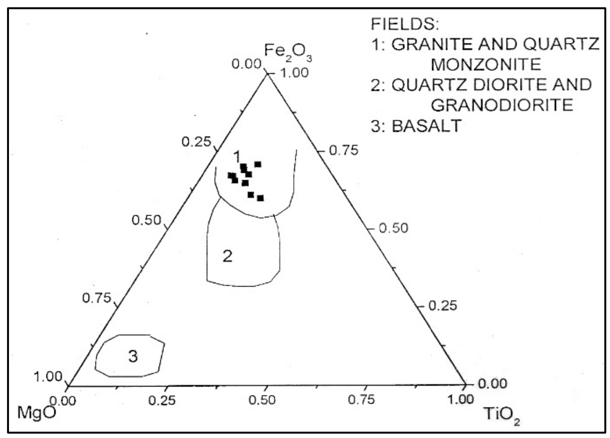

Figure 7: Fe_2O_3 – TiO_2 – MgO compositional diagram of Bhuban Sandstones (after Condie, 1967)

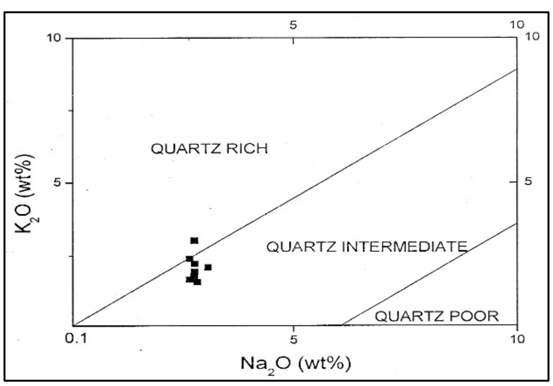

Figure 8: K_2O vs. Na_2O plot for analyses of Bhuban Sandstone (after Crook, 1974)

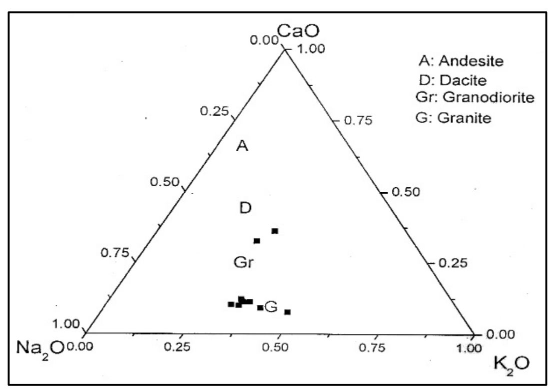

Figure 9: CaO – Na_2O – K_2O plots of Bhuban Sandstone (after Le Maitre, 1976)

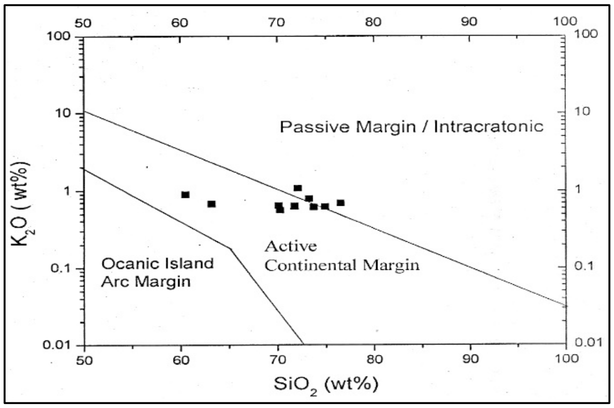

Figure 10: Scatter Plots of SiO_2 vs. K_2O of Bhuban Sandstones (after Roser and Korsch, 1986)

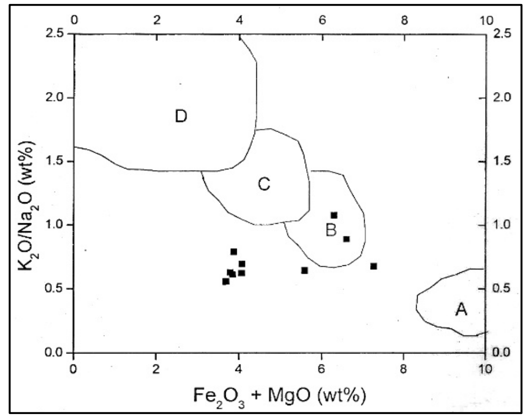

Figure 11: Scatter Plots of Fe_2O_3 + MgO vs. K_2O/Na_2O (after Bhatia, 1983). [Tectonic Fields of Oceanic Island Arc (A), Continental Island Arc (B), Active Continental Margin (C) and Passive Margin (D)]

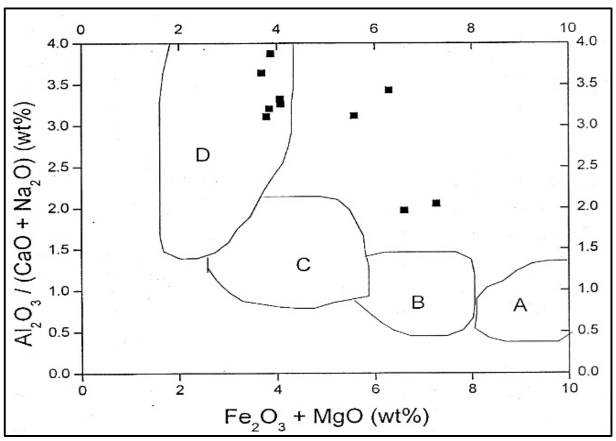

Figure 12: Scatter Plots of Fe_2O_3 + MgO vs. Al_2O_3/Na_2O of Bhuban sandstones. (after Bhatia, 1983). [Tectonic Fields of Oceanic Island Arc (A), Continental Island Arc (B), Active Continental Margin (C) and Passive Margin (D)]

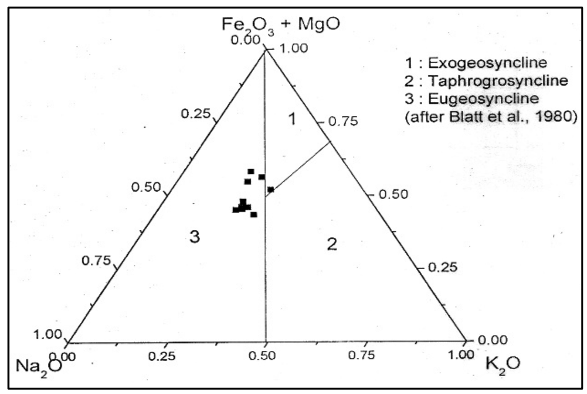

Figure 13: (Fe_2O_3+MgO) - K_2O – Na_2O plots of Bhuban Sandstones (after Blatt et al., 1980)

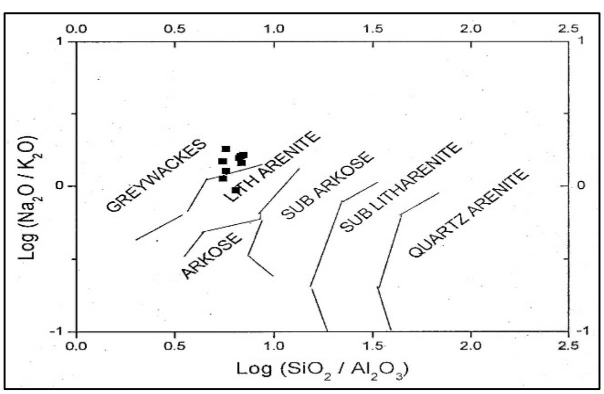

Figure 14: Geochemical classification for Bhuban Sandstones (after Pettijhon et al., 1972)

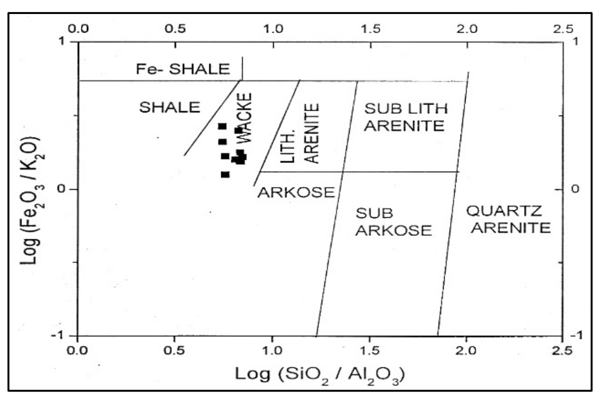

Figure 15: Geochemical classification for Bhuban Sandstones (after Herron, 1988)

CONCLUSION

From the above geochemical studies of major and minor elements of Bhuban sandstones of Surma Group the following conclusions can be made:

- The positive correlation between the major elements (oxides) is observed and it suggests the influence of source rock lithology particularly granitoid and metamorphosed argillaceous source rocks.
- From the study of palaeoweathering, it is seen that K-feldspar is more in Bhuban sandstones. Hence CIA values of Bhuban sandstones are high indicating moderate intensity of chemical weathering in the source area.
- Regarding chemical maturity, sandstones are slightly matured.
- The geochemical study suggests arid climatic condition.
- From the geochemical studies, it is seen that the sandstones were derived mostly from metamorphic and igneous (mostly granite) sources which are present in the adjoin areas.
- Under tectonic setting, sandstones are of Active Continental Margin type to Passive Margin type and were derived mostly from uplifted areas which were characteristics of igneous metamorphic and recycled sediments deposited in Miocene foreland basin formed due to collision orogen.
- The sandstones are classified as litharenite to wacke from geochemical classification.

ACKNOWLEDGEMENT

The authors are grateful to the Department of USIC, Gauhati University for analyzing the samples. The authors are also thankful to the Department of Geological Sciences, Gauhati University for their permission to use the departmental laboratory.

REFERENCES

1. Sawyer, E.W. 1986. The influence of soruce rock type, chemical weathering and sorting from the Quetico meta sedimentary belt, Superior Province, Canada. Chem, Geol. vol. 55, pp. 77-95, DOI: https://doi.org/10.1016/0009-2541(86)90129-4.
2. Fralick, P.W. and Kronberg, B.I. 1997. Geochemical discrimination of clastic sedimentary rock sources. Sed. Geol. Vol. 113, pp. 111-124, DOI: 10.1016/S0037-0738(97)00049-3.
3. Bhatia, M.R. 1983. Plate tectonics and geochemical composition of sandstones. Jour. Geol., vol. 91, pp. 611-627., DOI: https://doi.org/10.1086/628815.
4. Suttner, L.J. and Dutta, P.K. 1986. Alluvial sandstone composition and palaeoclimate Framework mineralogy. Jour. Sed. Petrol., vol. 56, pp. 329-345, DOI: https://doi.org/10.1306/212F8909-2B24-1107-8648000102C1865D.
5. Nesbitt, H.W., Markovics, G. and Price, R.C. 1980. Chemical processes affecting alkalies and alkaline earths during continental weathering. Geochim. Cosmochim. Acta. V. 44, pp. 1659-1666, DOI: 10.1016/0016-7037(80)90218-5.
6. Nesbitt, H.W. and Young, G.M. 1982. Early Proterzoic climates and plate motions inferred from element chemistry of lutities. Nature, v. 299, pp. 715-717, DOI: 10.1038/299715a0.
7. Pettijohn, F.J., Potter, P.E. and Siever, R. 1972. Sand and Sandstone. Springer Verlag, New York, 618p, DOI: 10.1017/S0016756800045945.
8. Cullers, R.L. Basu, A. and Suttner, L.J. 1988. Geochemical signature of provenance in sand-size materials in soils and stream sediments near the Tobacco Root batholits, Montana, USA. Chem. Geol. vol. 70, pp. 335-348, DOI: https://doi.org/10.1016/0009-2541(88)90123-4.
9. Condie, K.C. 1993. Chemical composition and evaluation of upper continental curst: Contrasting results from surface samples and shales. Chem. Geol., vol. 104, pp. 1-37, DOI: https://doi.org/10.1016/0009-2541(93)90140-E.
10. Condie, K.C. 1967. Geochemistry of Early Precambrian Greywacke from Wyoming. Geochim, Cosmochim, Acta, vol. 321, pp. 2136-2147, DOI: https://doi.org/10.1016/0016-7037(67)90057-9.

11. Crook, K.A.W. 1974. Litho genesis and tectonic: the significance of compositional variations in flysch arenties graywackes. In: R.H. Dott and R.H. Shaver (Eds.), Modern and ancient geosynclinals sedimentation. Soc. Econ, Paleontol. Mineral, Spec. Pub., vol. 19, pp. 304-310.
12. Le Maitre. R.W. 1976. The chemical variability of some common igneous rocks, Jour. Petrol. Vol. 17, pp. 589-637, DOI: 10.1093/petrology/17.4.589.
13. Siever, R. 1979. Plate tectonic control on digenesis. Jour. Geol. Vol.87, pp. 127-155, https://www.jstor.org/stable/30060249.
14. Winchester, J.A. and Max, M.D. 1989. Tectonic setting discrimination of clastic sequence: an example from the late Proterozoic Erris group: NW Ireland. Precamb. Res. Vol. 45, pp. 191-201, DOI: https://doi.org/10.1016/0301/-9268(89)90039-9.
15. Roser, B.P. and Korsch, R.J. 1986. Determination of tectonic setting of sandstone mudstone suits using SiO_2 content and K_2O/Na_2O ratio. Jour. Geol. V. 94, pp. 635-650, DOI: https://www.jstor.org/stable/30078330.
16. Blatt, H., Middleton, G.V. and Murray, R.C. 1980. Origin of Sedimentary Rocks. 2nd ed., Prenrice-Hall, New Jersy, 634p, DOI: https://doi.org/10.1002/esp.3290060115.
17. Phillips, E 1991. The lithostratigraphy, sedimentology and tectonic setting of Monian Supergroup, Western Anglesey, North Wales. Jour. Geol. Soc. London, Vol. 148 pp. 1079-1090, DOI: 10.1144/gsjgs.148.6.1079.
18. Herron, M.M. 1988. Geochemical classification of terrigenous sands and shales from core or log date. Jour. Sediment Petrol., vol. 58, pp. 820-829, DOI: 10.1306/212F8E77-2B24-11D7-8648000102CI865D.