

## GEOCHEMISTRY, DEPOSITIONAL AND TECTONIC SETTING OF THE BARAIL GROUP OF THE INDO-MYANMAR RANGES

**Salam Ranjeeta Devi**

Department of Earth Sciences, Manipur University, Imphal-795003, India

Email: [ranjeeta\\_27@rediffmail.com](mailto:ranjeeta_27@rediffmail.com)

### Abstract

The present paper deals with the study of the depositional environment and tectonic setting during the sedimentation of the Barail Group of rocks of the Indo-Myanmar Ranges (IMR). The Barail Group (Oligocene) consist of sandstone intercalated with shale and siltstone. Geochemical study suggests low to high degree of chemical weathering. ICV vs. CIA,  $Al_2O_3$  vs.  $TiO_2$  diagrams indicate that the sediments were derived from the multiple source rocks dominantly of mafic composition. Arid to semi-arid/semi-humid climate prevailed during the deposition of the Barail Group sediments. Sedimentation occurred in a tectonic setting of overlap of passive to active continental margin under marine environment.

**Keywords:** Geochemistry, Deposition, Tectonic setting, Barail Group, Indo-Myanmar Ranges, Marine environment.

### Introduction

Geochemical studies have shown a close relationship between chemical composition of the sedimentary rocks and their provenance. Tectonism has a primary control on sedimentary rock composition (Blatt et al., 1980). Geochemical indices are most frequently used in the interpretation of depositional environment (Roaldest, 1970). Geochemistry has been widely used as an important tool to interpret chemical weathering, source rock composition, climate condition as well as tectonic during of the sediments deposition in a basin. Geochemical analysis of the sediments provides clues for provenance interpretations for sediments of all grain sizes (Bhatia, 1983; Taylor and McLennan, 1985; Armstrong-Altrin et al., 2017; Chaudhuri et al., 2020). Geochemical studies are also suitable for the interpretation of provenance of shales (Wronkiewicz and Condie, 1987; Garver and Scott, 1995; Fedo et al., 1995). Discriminant plots based on mixtures of the oxides of Ti, Al, Fe, Mg, Ca, Na and K are useful for distinguishing different provinces (Roser and Korsch, 1988; Saha et al., 2018). Being immobile, titanium oxides and alumina are particularly useful for provenance interpretations (Hayashi et al., 1997). Different binary and ternary plots of major element oxide provide significant information about palaeoweathering, palaeoclimate, nature of source rocks, tectonic setting and depositional basin (Potter et al. 2005; Suttner and Dutta, 1986; McLennan et al. 1980; Schieber 1992; Roser and Korsch, 1986; Roaldest, 1978). The Barail Group of rocks are well exposed in most part of the Indo-Myanmar Ranges (IMR). However, geochemical studies on the Barail Group of rock have remained confined to small areas with meagre data available on geochemistry of these rocks. Systematic geochemical analysis of these rocks

from different parts of the IMR can help in understanding the degree of chemical weathering, recycling and nature of source rocks, climatic variability and reconstruction of the depositional environment, and tectonic setting during their sedimentation. This paper deals with the comparison of geochemical data of the Barail Group of rocks from different areas of Assam (North Cachar Hills, Sen et al., 2015), Nagaland (Naga Hills, Srivastava, 2013), Manipur (Manipur Hills, Devi et al., 2017), Shillong Plateau (Mandal, 2009) and the Sylhet basin (Hossain and Roser, 2006) of the IMR, to work out the source rock composition, change in source area, degree of weathering, climatic changes, and to reconstruct depositional environment and tectonic setting.

### Geological Setting

The Indo-Myanmar Ranges have been evolved as an accretionary prism due to subduction of the Indian plate beneath the Myanmar plate (Soibam, 1998). The IMR consist of Naga- Hills, Manipur Hills, Mizo-Chin Hills and Arakan Yoma Hills (Fig. 1). It comprises of ophiolites and associated Late Cretaceous sediments, the Disang Group of Eocene consisting of thick sequences of dark grey to black splintery shales with intercalation of siltstones and fine to medium-grained sandstones. The Disang-Barail transition strata comprises of siltstone, sandstone and shale. The contact between the sediments of Disangs and Barails, runs more or less parallel to the western margin of the Imphal valley and continues northerly towards Kohima in Naga Hills and further south along the eastern border of Mizoram Hills of the Indo-Myanmar ranges. The contact is usually gradational with some local tectonic contacts marked by a high angle reverse fault (Soibam, 1998) and in some places by conglomeratic horizon.

This gradational contact is related with a gradual change from dominantly argillaceous marine to a mainly arenaceous shallow marine depositional environment. The shale of the Upper Disang transition with Lower Barail shows relatively increasing intercalations of thin siltstone beds and fine sandstones

which are thinly to moderately thick bedded and massive in nature. Silty shale is again a very important component of the Disang-Barail transition and is found associated with many plant (leaves, barks, fruits, etc.) impressions which sometimes are weakly to moderately carbonized (Guleria et al. 2005). The Barail Group of

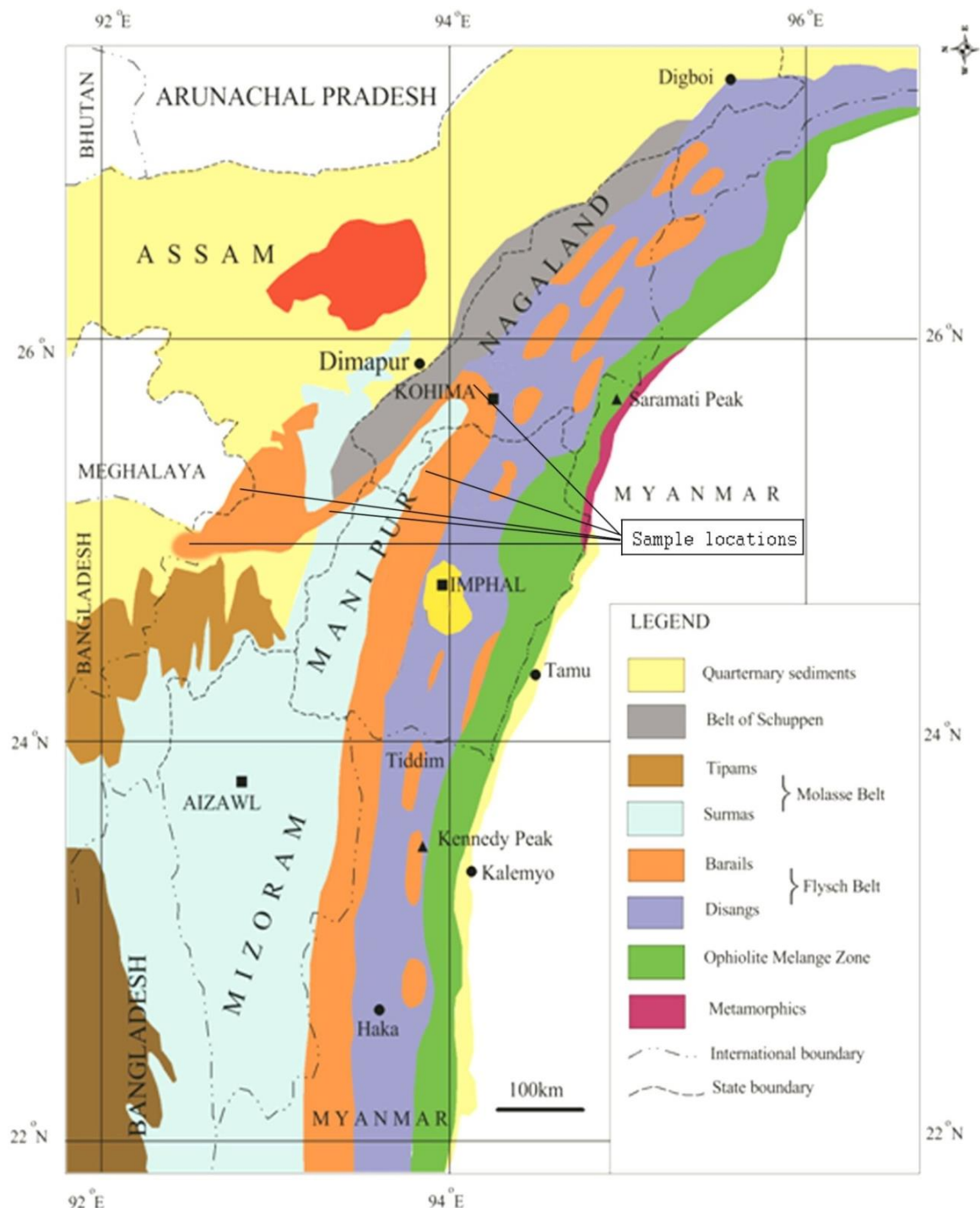


Figure 1: Geological map of NE India (Soibam, 1998) showing sample locations.

fine to medium grained multistoried thickly bedded sandstones, intercalated with siltstone and shale overlying the Disang-Barail Transition.

The Barail Group represents a thick sequence of sandstones with shale (500m) in the Barail Range of North Cachar Hills, Assam (NE India, 1932). The Barails are also well exposed along the Patkai ranges

and Dhansiri valley of Nagaland. In Meghalaya, the Barail Group is mainly exposed in the Garo Hills and consists of about 1000 m thick sandstones with minor shale and carbonaceous shale/coal sequences. In Manipur, the Barails (~3200 m) occur on the western half and are also found occurring as outliers forming capping of Disangs in the eastern part of and within the Imphal Valley. The nature of succession suggests that they were formed in flysch and sub-flysch basin and often display typical turbidite character. In Sylhet basin, Barail Group unconformably overlies the Kopilli Formation of Jaintia Group. The Jenam Formation (sandstone, siltstone, and silty shale) forms the lower part of the Barail Group and Renji Formation overlies Jenam Formation. In Tirap district of Arunachal

Pradesh, the rocks of the Barail Group occur in two different depositional environments (Anon, 2010). In Arunachal Pradesh, Barail Group is usually succeeded by the Tipam with an apparent erosional unconformity in the Schuppen belt. The age of this group of rocks may range from Oligocene to Late Eocene. The Surma Group overlies the Barail Group. The rocks of Surma Group are characterised by intercalation of massive sandstone and shales sequence comprising of thin inter bands of shales and siltstone. The Tipams are moderately coarse grained, ferruginous, massive, sometimes faulted sandstones. It overlies the Surma Group with stratigraphic break. The geological succession of the Barail Group from these areas is shown in the Table 1.

Table 1: Lithostratigraphic classification of the Barail Group of rock in NE Indian subcontinent

Age	Group	Formation and lithology				
		Assam Sen et al., 2015	Nagaland Srivastava, 2013	Manipur Soibam, 1998	Shillong Plateau, Ranga Rao, 1983, Mandal, 2009	Sylhet Reimann, 1993, Hossain and Roser, 2006
Lower Miocene	Surma	Sandstones with shale	Sandstone with shale	Sandstone intercala- ted with shale and siltstone	Fine-grained sandstone with shale	Alternation of sandstone, shale and siltstone
unconformity						
Oligocene	Barail	Fine to medium grained, massive and bedded sandstones with shale and laminated sandstones	Sandstone with minor shale	Fine to medium grained, massive and bedded sand- stones with shale and laminated sandstones	Argillaceous sandstone (Renji Fm)  Medium to fine-grained, hard massive sandstone (Jenam Fm)  Medium to fine sandstone within subordinate shale and conglomerate (Laisong Fm)	Yellowish brown sandstone, shale and coal lenses (Renji Fm)  Grey to brownish siltstone, silty shale and sandstone (Jenam Fm)
Late Eocene to early Oligocene	Disang-Barail Transitional sequence	Base is not exposed	Shales with minor sandstones	Siltstone with plant impress- ions intercala- ted with shale and sandstone	Alternating sandstone and black shale	Shale with subordinate sandstone and thin limestone (Kopili Fm)

### Sampling and Analytical Procedures

Fresh samples of the Barail sandstones and shales were collected from outcrops exposed in stream cuts, road cuts and small quarries from the NW

Manipur. Sample locations are shown in the Figure 1. After careful thin section examination under microscope, four sandstone samples of Barail Group and four shale samples were selected for geochemical analysis. Samples with significant diagenetic alteration,

especially with more than 15% secondary carbonate cement, were not considered for geochemical analysis (Devi et al., 2017). The chips of these samples were further powdered to -200 mesh size. Whole rock major elements were analysed using fused pellets glued with polyvinyl alcohol on SIEMENS SRS 3000 sequential X-ray Spectrometer at Wadia Institute of Himalayan Geology, Dehra Dun. Analytical accuracy of the major oxide data is <5% and average precision is always better than 1.5% (Saini et al. 1998). 16 representative shale samples of Barail Group from North Cachar Hills, Assam were analysed in the Department of Instrumentation and USIC by XRFS method. The results after chemical analysis have been studied (Sen et al., 2012).

Samples of the Oligocene Jenam and Renji formations of Sylhet basin were also taken from cores of hydrocarbon exploration wells (Hossain and Roser, 2006). The Jenam Formation of the lower Barail Group is encountered only in the Atgram-1X well between 4712 m and 4968 m bsl (Petrobangla, 1982), where it consists of indurated dark grey shale/silty shale. The Renji Formation (Barail Group) was intersected from 3975m to 4712m in Atgram-1X and from 4820m to 4977m in the Fenchuganj 2 well. This formation consists mainly of light to dark grey, fine to medium grained indurated sandstone with minor shale and siltstone. The base of the Barail Group was not intersected in these wells. The chipped samples (<10 mm in diameter) were washed with running tap water, after draining, the cleaned samples were then dried in an oven at 110°C for several hours. The oven-dried samples were subsequently crushed in a tungsten-carbide ring mill for 25 to 45 seconds and about 10 g of each powdered sample was then dried at 110°C in oven for 24 hours before gravimetric determination of loss on ignition (LOI). After LOI was estimated in a muffle furnace at 1020°C for at least 2 hours, the ignited materials were disaggregated by hand and gentle grinding in an agate mortar and pestle, and subsequently returned to 110°C temperature in oven for at least 24 hours. The ignited rock samples were then used for preparation of glass fusion beads for the X-ray fluorescence (XRF) analysis. The XRF analyses of the major elements were made using a Rigaku RIX 2000 instrument at Shimane University. Glass fusion beads were prepared in an automatic bead sampler (fusion 240 seconds, agitation 360 seconds), using an alkali flux (80% lithium tetraborate and 20% lithium metaborate), with a sample to flux ratio of 1:2 (Kimura and Yamada, 1996).

Samples of Shillong Plateau were dried in an oven at 50°C for nearly 24 hours (Mandal, 2009). Approximately 20 gm of dried sediment for each sample was crushed with a mortar and pestle to a grain size of <0.63 mm and homogenized to sent to ACME Laboratories Ltd., Vancouver, BC, Canada, for analysis. In the laboratory, samples were analyzed by ICP-emission spectra following lithium metaborate/tetraborate fusion and dilute nitric digestion. Loss of

Ignition (LOI) was calculated by weighing the difference after ignition at 1000° C. Geochemical analysis included 11 major oxides (SiO<sub>2</sub>, Al<sub>2</sub>O<sub>3</sub>, Fe<sub>2</sub>O<sub>3</sub>, MgO, CaO, Na<sub>2</sub>O, K<sub>2</sub>O, TiO<sub>2</sub>, P<sub>2</sub>O<sub>5</sub>, MnO, and Cr<sub>2</sub>O<sub>3</sub>).

### Palaeoweathering and Paleoclimate

Weathering processes also control the composition of clastic sediments. The Chemical index of weathering (CIA, Nesbitt and Young, 1982) is one of the important weathering indices to know the degree of chemical weathering in a source area. The relation between the degree of weathering and the original source rock composition are well assessed by the combination of CIA with the index of compositional variability (ICV, Cox et al, 1995; Potter et al., 2005). The ICV can be used to discriminate source rock type based on major-elemental geochemistry. The high ICV value (ICV>1) indicates that the sediments are derived from compositionally immature source rocks whereas, low value (ICV<1) suggests compositionally mature source rocks. Thus, changes in ICV values may be the result of both variations in the source rock composition and differences in the degree of weathering (Potter et al., 2005). A trend in CIA vs. ICV diagrams (Fig. 2) suggests the source rock composition of the sediments and degree of chemical weathering. In this diagram all the samples are scattered indicating variable effect of weathering from low to high degree and originated from different sources, that is, the sediments of the Barail Group from different areas were derived from different source rocks composition.

Climate is another factor that controls the degree of chemical weathering. Major Oxide elemental data provides useful information on climatic condition that prevailed during the deposition of sedimentary rocks. The bivariate plot (Fig.3) of (Al<sub>2</sub>O<sub>3</sub> +Na<sub>2</sub>O) vs Si<sub>2</sub>O after Suttner and Dutta (1986) differentiate the climatic conditions under which sediments were deposited. Samples plot on this diagram suggests climatic variability from arid to semi-arid/semi-humid climatic condition during deposition of the Barail sediment.

### Source Rock Composition

Composition of the clastic sediment is mainly influenced by the source rock characteristics, the nature of the sedimentary processes within the depositional basin and the type of deposition paths that link sources area to the depositional basin (Dickinson and Suczek, 1979). Processes like weathering and diagenesis can influence the chemical composition of the sediments (Cullers et al., 1988) and therefore, less mobile element oxides (Al<sub>2</sub>O<sub>3</sub> and TiO<sub>2</sub>) have been widely used to determine source rocks. TiO<sub>2</sub> (%) and Al<sub>2</sub>O<sub>3</sub> (%) bivariate plot is being used significantly for determining source rock compositions (McLennan et al., 1980; Schieber, 1992; Paikaray et al., 2008). The bivariate plot of Ti<sub>2</sub>O vs. Al<sub>2</sub>O<sub>3</sub> (Fig. 4) for the

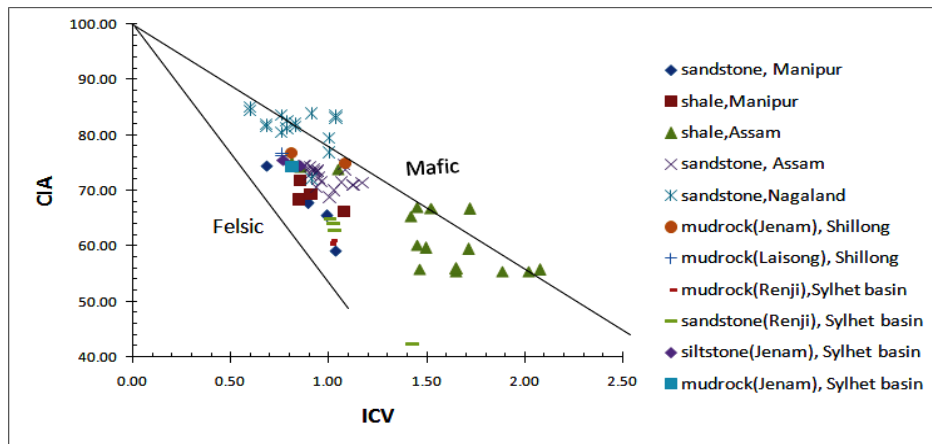


Figure 2: ICV vs. CIA diagram (Potter et al. 2005)

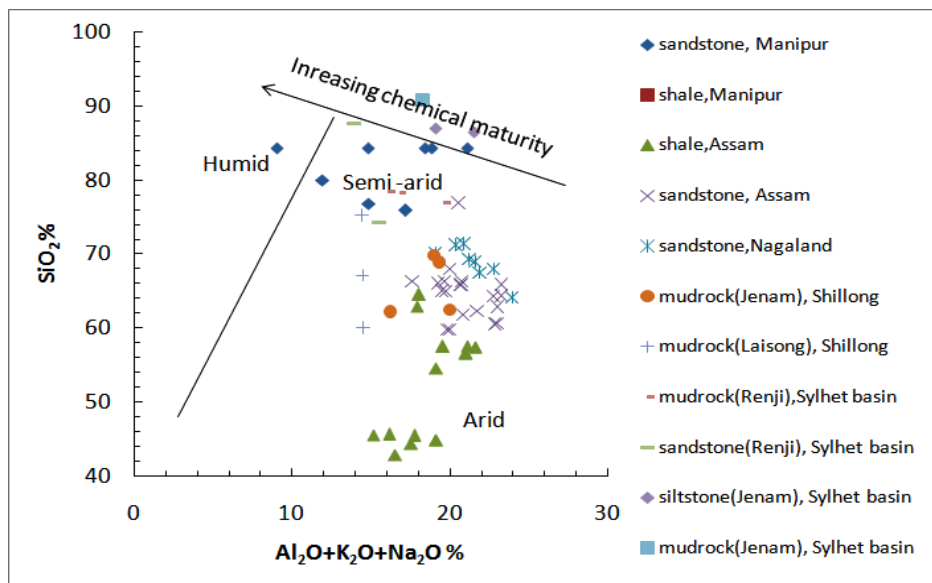


Figure 3:  $Al_2O_3+K_2O+Na_2O\%$  (Suttner and Dutta. 1986).

Barail Group of rocks from different areas indicates that these sediments were originally derived from different source rocks. Less weathered dominantly mafic composition of shale occurs towards the North Cachar Hills (Assam) of the Barail exposures. Samples plot on  $TiO_2$  vs  $Al_2O_3$  (Fig.4) after McLennan *et al.* (1980) and Schieber (1992) indicates that sediment were derived from a mixed source rocks from granitic to basaltic composition.

### Tectonic Setting and Depositional Basin

The nature and proportion of their detrital components and the bulk composition reflects the tectonic setting of the basin (Sieve, 1979; Roser and Korsch, 1986). Active continental margin sediment are characterized by mixture of arc derived material and old upper crustal sources; whereas, passive margin sediments are generally dominated by old upper crustal sources (McLennan *et al.*, 1990). Tectonic setting of clastic sedimentary rock can be studied from major element oxides (Crook, 1974, Middleton, 1960).  $K_2O/Na_2O$  vs  $SiO_2$  diagram is used to discriminate the

tectonic setting (Roser and Korsch (1986). Roser and Korsch (1986) plot seems to be somewhat better (~32–62% success) than Bhatia's (1983) plots (0–58% success) to determine tectonic setting (Armstrong-Altrin and Verma, 2005; Saha *et al.*, 2010).

In  $K_2O/Na_2O$  vs  $SiO_2$  diagram (Fig. 5), the samples plot in the tectonic setting overlap between passive and active margin, which suggest a complex tectonic activities with mix of less weathered and recycled sediments. Certain major oxides have been used to distinguish depositional environments. The relationship between  $K_2O/Al_2O_3$  vs  $MgO/Al_2O_3$  was used by Roaldest (1970) to differentiate between the marine and non-marine vs sediments. In  $K_2O/Al_2O_3$  vs  $MgO/Al_2O_3$  diagram (Fig. 6) all the samples plotted in marine environment. Thus, from this study, it is can be inferred that the sediments of the Barail were deposited in marine depositional environment with different chemical composition and variable degree of chemical weathering in different parts of depositional basin, which, in turn, suggests the evolutionary history of complex tectonic activities.

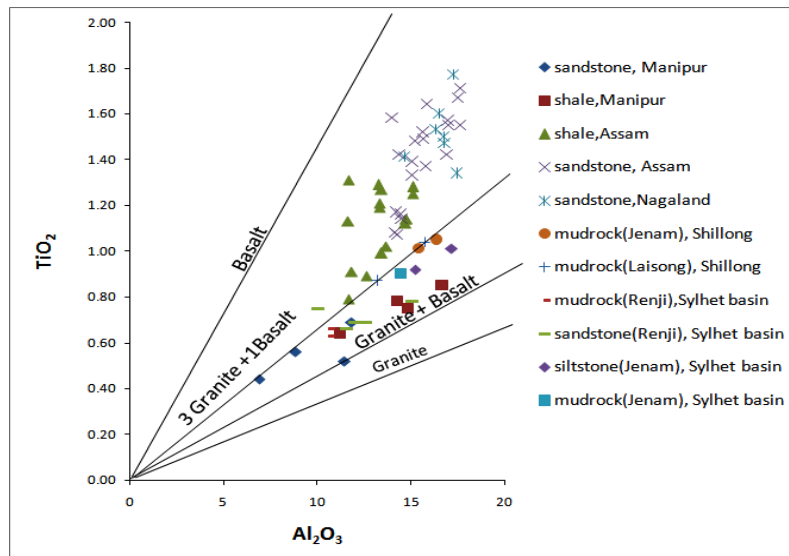


Figure 4:  $Al_2O_3$  vs.  $TiO_2$  diagram (McLennan et al. 1980; Schieber 1992).

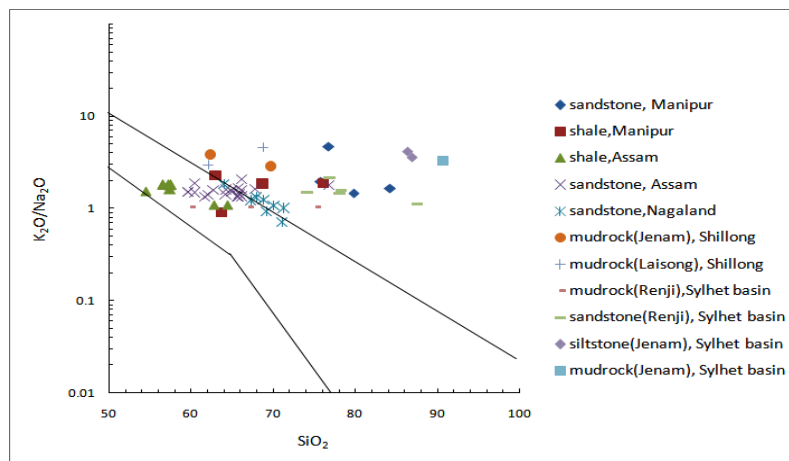


Figure 5: Plot of  $SiO_2$  vs.  $K_2O/Na_2O$  of Barail (Roser and Korsch, 1986).

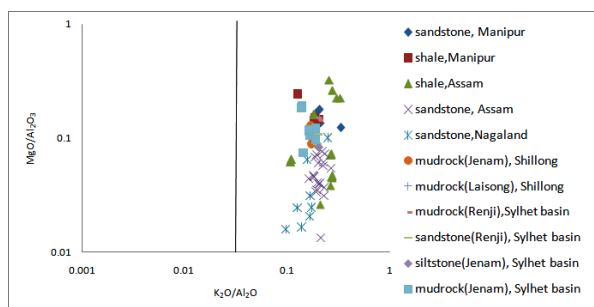


Figure 6:  $\log K_2O/Al_2O_3$  vs.  $\log MgO/Al_2O_3$  plots for depicting depositional environment (Roaldest, 1978).

### Conclusions

Geochemical studies of the Barail Group of sediments from different parts of the IMR show low to high degree of chemical weathering under arid to semi-arid/semi-humid climatic condition. The sediments were derived from multiple source rocks variables from granitic to basaltic composition but dominantly of basaltic composition. The sediments were deposited in a tectonic setting overlapping between passive and

active continental margins in a marine depositional basin. The sediment composition in different parts of the depositional basin of the Barail Group of rocks shows changes in tectonic activities which reflect the complex evolutionary history of the region.

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**Appendix**

Manipur, Devi et al., 2017 (sandstones and shale)

	Sandstone				Shale			
	BL-3	BH-5	BH-7	DL-25	TP-1	BL-2	KK-17	SPA-28
SiO <sub>2</sub>	75.85	79.88	76.78	84.29	63.75	63	68.75	76.19
TiO <sub>2</sub>	0.52	0.56	0.69	0.44	0.75	0.85	0.78	0.64
Al <sub>2</sub> O <sub>3</sub>	11.46	8.86	11.84	6.92	14.84	16.67	14.28	11.24
Fe <sub>2</sub> O <sub>3</sub>	3.81	3.18	2.47	2.14	6.48	5.93	5.34	3.32
MnO	0.048	0.061	0.047	0.039	0.095	0.09	0.073	0.067
MgO	1.41	1.57	1.61	1.15	3.61	2.39	2.13	1.63
CaO	0.34	0.35	0.28	0.3	1.11	0.55	0.57	0.35
Na <sub>2</sub> O	1.94	1.25	0.53	0.8	2.12	1.36	1.45	1.24
K <sub>2</sub> O	3.81	1.83	2.49	1.33	1.9	3.09	2.68	2.33
P <sub>2</sub> O <sub>5</sub>	0.11	0.095	0.065	0.078	0.147	0.153	0.147	0.146

Assam, Sujata Sen et al., 2012, Devi et al. , 2017 (Shale)

	SS1	SS2	SS3	SS4	SS5	SS6	SS7	SS8	SS9	SS10	SS11	SS12	SS13	SS14	SS15	SS16
SiO <sub>2</sub>	45.59	57.58	57.31	54.48	64.48	57.43	45.39	42.79	44.78	56.54	45.52	62.86	44.3	57.33	44.79	56.52
TiO <sub>2</sub>	0.89	1.14	1.25	0.99	1.27	1.02	1.13	0.91	1.19	1.12	0.79	1.29	1.31	1.28	1.21	1.14
Al <sub>2</sub> O <sub>3</sub>	12.63	14.77	15.12	13.43	13.44	13.68	11.64	11.85	13.32	14.7	11.69	13.25	11.69	15.1	13.33	14.75
Fe <sub>2</sub> O <sub>3</sub>	4.43	6.07	6.43	6.17	5.92	5.58	6.01	5.13	6.37	6.01	4.41	5.95	5.59	6.44	6.36	6.03
MnO	0.05	0.13	0.13	0.28	0.16	0.11	0.13	0.12	0.15	0.12	0.05	0.19	0.15	0.12	0.14	0.13
MgO	0.78	0.69	3.98	4.36	2.15	0.52	2.62	0.31	0.94	0.66	0.76	2.14	2.63	3.96	0.96	0.67
CaO	0.64	7.35	7.79	8.08	0.15	7.44	8.26	5.76	7.68	7.3	0.63	6.14	8.22	7.75	7.71	7.29
Na <sub>2</sub> O	2.17	2.27	2.32	2.25	2.2	2.25	2.29	2.2	2.19	2.21	2.15	2.24	2.27	2.34	2.21	2.23
K <sub>2</sub> O	1.37	4.09	4.16	3.45	2.42	3.63	3.85	2.49	3.57	4.03	1.29	2.45	3.58	4.17	3.59	4.02
P <sub>2</sub> O <sub>5</sub>	0.02	0.17	0.4	0.19	0.07	0.12	0.33	0.08	0.39	0.15	0.03	0.09	0.37	0.41	0.4	0.15



**Appendix... cont.**

Assam, Sujata Sen et al., 2015 (Sandstones)

	SS1	SS2	SS3	SS4	SS5	SS6	SS7	SS8	SS9	SS10	SS11	SS12	SS13	SS14	SS15	SS16	SS17	SS18	SS19	SS20
SiO <sub>2</sub>	60.53	59.68	65.8	62.17	65.98	64.3	67.86	64.98	65.78	66.25	61.73	59.67	62.77	64.92	66.22	65.72	64.25	76.82	66.22	60.48
TiO <sub>2</sub>	1.57	1.39	1.71	1.64	1.58	1.55	1.14	1.17	1.49	1.08	1.48	1.33	1.67	1.42	1.07	1.52	1.42	1.16	1.37	1.55
Al <sub>2</sub> O <sub>3</sub>	16.98	15.09	17.67	15.89	14.01	17.65	14.51	14.21	15.68	14.18	15.25	15.09	17.54	14.38	14.27	15.66	16.92	14.49	15.82	17.03
Fe <sub>2</sub> O <sub>3</sub>	7.41	8.45	7.33	6.98	7.99	6.55	5.8	7.98	6.91	6.77	7.83	8.37	6.52	7.78	5.89	6.89	6.44	5.83	6.89	7.39
MnO	0.12	0.29	0.2	0.22	0.18	0.68	0.13	0.27	0.06	0.57	0.26	0.26	0.67	0.2	0.65	0.06	0.21	0.24	0.06	0.13
MgO	0.53	1.02	0.71	0.21	1.06	0.62	0.53	0.81	0.71	0.62	0.61	1.08	0.59	0.88	1.04	0.72	1.02	0.78	0.74	0.67
CaO	0.51	0.36	0.48	0.48	0.36	0.46	0.58	0.51	0.61	0.67	0.47	0.44	0.49	0.52	0.59	0.65	0.45	0.51	0.66	0.39
Na <sub>2</sub> O	2.1	1.92	2.12	2.44	2.17	2.17	2.1	2.11	2.15	1.13	2.41	1.98	2.13	2.09	2.1	2.13	2.42	2.18	2.11	2.36
K <sub>2</sub> O	3.91	2.86	3.52	3.4	3.1	3.46	3.38	3.2	2.89	2.33	3.22	2.96	3.38	3.29	3.33	2.87	3.42	3.9	2.84	3.5
P <sub>2</sub> O <sub>5</sub>	0.23	0.26	0.28	0.28	0.24	0.29	0.26	0.22	0.25	0.55	0.26	0.47	0.24	0.52	0.27	0.28	0.25	0.23	0.26	0.23

Nagaland, Srivastava, S.K., 2013

Sp. No.	R96/3	R96/10	R96/13	R96/27	R97/58	R97/99	R97/101	R97/113	R97/131	R97/133	R97/134	R97/137	R97/139	R97/110	R97/188	R97/189
SiO <sub>2</sub>	70.8	76.34	76.9	74.39	86.33	77.78	77.02	77.28	81.27	76.42	71.62	82.16	87.18	78.49	72.68	81.93
TiO <sub>2</sub>	1.21	1.03	1.09	1.23	0.55	0.87	0.9	0.89	0.69	1.01	1.16	0.71	0.5	0.76	1.03	0.59
Al <sub>2</sub> O <sub>3</sub>	17.64	13.6	14.77	13.1	8.35	13.11	13.79	14.37	11.42	15.04	17.33	11.32	7.64	12.82	16.72	11.65
Fe <sub>2</sub> O <sub>3</sub>	7.3	2.99	1.11	4	0	2.29	2.31	1.32	0.66	1.39	2.68	1.57	1.15	1.17	1.19	0.77
MnO	0.04	0.14	0.04	0.32	0.01	0.05	0.04	0.02	0.05	0.03	0.04	0.04	0.02	0.03	0.02	0.03
MgO	1.3	0.11	0.5	0	0.3	0.41	0.44	0.43	0.53	0.49	0.63	0.35	0.21	0.41	0.59	0.26
CaO	1.2	0.37	0.36	0.94	0.25	0.4	0.42	0.32	0.57	0.28	0.37	0.17	0.14	0.25	0.21	0.13
Na <sub>2</sub> O	0.55	0.54	0.45	0.66	0.37	0.47	0.46	0.42	0.43	0.47	0.56	0.41	0.4	0.49	0.52	0.38
K <sub>2</sub> O	2.07	1.62	1.59	2.11	0.55	1.37	1.37	1.27	1.12	1.56	2.24	1.1	0.6	1.46	2.37	1.1
P <sub>2</sub> O <sub>5</sub>	0.13	0.15	0.13	0.2	0.2	0.14	0.13	0.13	0.12	0.14	0.14	0.13	0.11	0.15	0.12	0

**Appendix... cont**

Shillong Plateau, Mandal, S., 2009

	Jenam Fm		Laisong Fm	
	SM 15	SM19	SM22	SM24
SiO <sub>2</sub>	60.22	62.68	71.62	66.26
TiO <sub>2</sub>	1.01	1.05	0.87	1.04
Al <sub>2</sub> O <sub>3</sub>	15.44	16.38	13.2	15.74
Fe <sub>2</sub> O <sub>3</sub>	9.59	6.39	4.71	5.41
MnO	0.18	0.08	0.05	0.03
MgO	1.98	1.81	1.17	1.68
CaO	0.46	0.32	0.19	0.26
Na <sub>2</sub> O	0.92	0.76	0.77	0.65
K <sub>2</sub> O	2.63	2.9	2.29	2.97
P <sub>2</sub> O <sub>5</sub>	0.14	0.13	0.11	0.09

Sylhet Basin, Zakir Hossain, H.M and Barry Roser, 2006

	Renji Formation								Jenam Formation		
	Mudstone			Fine sandstone					Siltstone	Mudstone	
	ZH-44	ZH-45	ZH-46	ZH-115	ZH-116	ZH-117	ZH-118	ZH-119	ZH-10	ZH-12	ZH-11
SiO <sub>2</sub>	76.2	76.1	76.14	64.67	71.18	70.82	72.42	69.98	66.74	63.98	68.83
TiO <sub>2</sub>	0.66	0.63	0.63	0.78	0.69	0.69	0.66	0.75	0.92	1.01	0.9
Al <sub>2</sub> O <sub>3</sub>	10.64	10.67	10.6	15.09	12.04	12.64	11.59	10.07	15.22	17.18	14.48
Fe <sub>2</sub> O <sub>3</sub>	4.09	4.02	3.97	6.24	4.84	5.25	4.76	3.75	6.5	6.17	5.63
MnO	0.05	0.05	0.05	0.08	0.06	0.06	0.06	0.24	0.09	0.06	0.04
MgO	1.28	1.29	1.26	2.27	1.71	1.89	1.67	1.09	1.36	1.44	1.21
CaO	0.9	0.94	0.95	1.34	0.99	0.88	0.94	4.7	0.3	0.23	0.22
Na <sub>2</sub> O	1.88	1.9	1.89	1.46	1.6	1.71	1.58	1.83	0.84	0.84	0.89
K <sub>2</sub> O	1.95	1.96	1.95	3.1	2.49	2.49	2.35	2.03	3.03	3.51	2.92
P <sub>2</sub> O <sub>5</sub>	0.09	0.09	0.09	0.12	0.12	0.12	0.1	0.09	0.14	0.12	0.11