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Geochemistry of the Transitional beds between Disang and Barail Successions of the Imphal Valley, Indo-Myanmar Ranges

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Abstract

Major and trace element concentrations were studied from the tansitional beds between Disang and Barail Successions of the Imphal valley, Indo-Myanmar Ranges. Various major and trace element ratios and discrinant diagrams were used to descipher paleoclimate, paleo-redox condition and sedimentary depositional environment of the Disang-Barail Transitional beds. SiO_2 vs Al_2O_3+K_2O+ Na_2O diagram and Rb/Sr ratios indicates that paleoclimate during the deposition of the sediments changed from arid to semi-arid and humid climate. Ni/Co, V/Cr, V/(Ni+V), V/Sc ratios suggest that these sediments were deposited in oxic, suboxic to anoxic conditions. V/(Ni+V) vs V/Cr diagram suggests paleo-redox environment dominated by sub-reduction to oxidization during Disang –Barail Transitional deposition. The sediments were deposited in transitional to marine depositional environment.

Keywords: Disang-Barail, Transitional beds, Paleoclimate, Paleo-redox, Indo-Myanmar Ranges, sedimentary environment

Introduction

Geochemistry of siliciclastic rocks is commonly used for provenance interpretation compared to the petrographic approach used for sandstones (Taylor and McLennan, 1985; Culler, 2000; Armstrong-Altrin et al., 2017; Chaudhuri et al., 2020; Devi, 2021). The bulk geochemistry of shales preserves the near-original signatures of the provenance and more faithfully reflect the source-area weathering (Devi, 2022) and diagnostic process; geochemical indices are frequently used in the interpretation of depositional environments (Roaldest, 1970). Most important purpose of geochemistry of the sediments is to evaluate geological processes and determine the sedimentary environment. Sedimentary records provide a useful tool for paleoenvironmental studies because they preserve original lithological characteristics and record the climatic changes during their deposition (Ding et al. 2001; Shilling et al., 2020). Many recent studies have shown relationship between some chemical elements and change in the environments. Element abundance in sedimentary rocks is found to be influenced by many factors, including weathering, erosion, transportation and deposition of the sediments (Algeo and Maynard, 2004; Shurzynski et al., 2020).

The physicochemical properties of different elements are affected by external agents such as climate, biological activity, pH and tectonic setting during weathering and sedimentation (Gao et al., 2017; Quin et al, 2018). The distribution of elements in the rocks depends on the physicochemical properties of the elements and it is influenced by the paleoclimate and paleoenvironment. By selecting those elements or combinations of elements that are sensitive to water conditions and paleoclimate, the sedimentary environment can be studied either quantitatively or semi-quantitatively including paleoclimate and paleoredox condition. Several authors have used geochemical parameters to understand sediments paleo-oxygenation conditions (Jones and Manning, 1994; Nath et al., 1997; Cullers, 2002). The current study presents the geochemistry of the Disang-Barail transitional beds (DBTB) from the Imphal Valley. The samples were analysed for the major and trace elements as well as elemental ratios to determine environment of deposition. Geochemistry of the analysed sediments was used to identify the paleoclimate and paleo-redox conditions of sedimentary environment.

The Indo-Myanmar Ranges comprising of the Naga-Patkai hills, Manipur Hills, Mizo-Chin Hills and Arakan-Yoma Hills. The Indo-Myanmar Ranges (IMR) was formed due to subduction of Indian plate margin below the Eurasian plate. The Imphal Valley (Fig. 1), which is one of the largest valley of the Indo-Myanmar Ranges, was evolved in the later phase of the Indo Myanmar orogeny.

GEOLOGICAL SETTING

The Imphal valley and its adjoining areas are made up of the Disang Group (Late Cretaceous to Eocene), Disang-Barail transitional succession (Late Eocene- Early Oligocene) and Barail Group (Oligocene) with an overlying alluvium deposit. The Disang Group constitutes more or less the basement of the alluvium of the Imphal Valley. It consists of dark grey splintery shales with siltstone, sometimes giving rise to rhythmic character. The splintery nature of the shales is due to intense deformation, fracture and jointing. In the Imphal valley, Upper Disang is exposed in a vast area. The contact between the Disang and Barail Group runs nearly parallel to

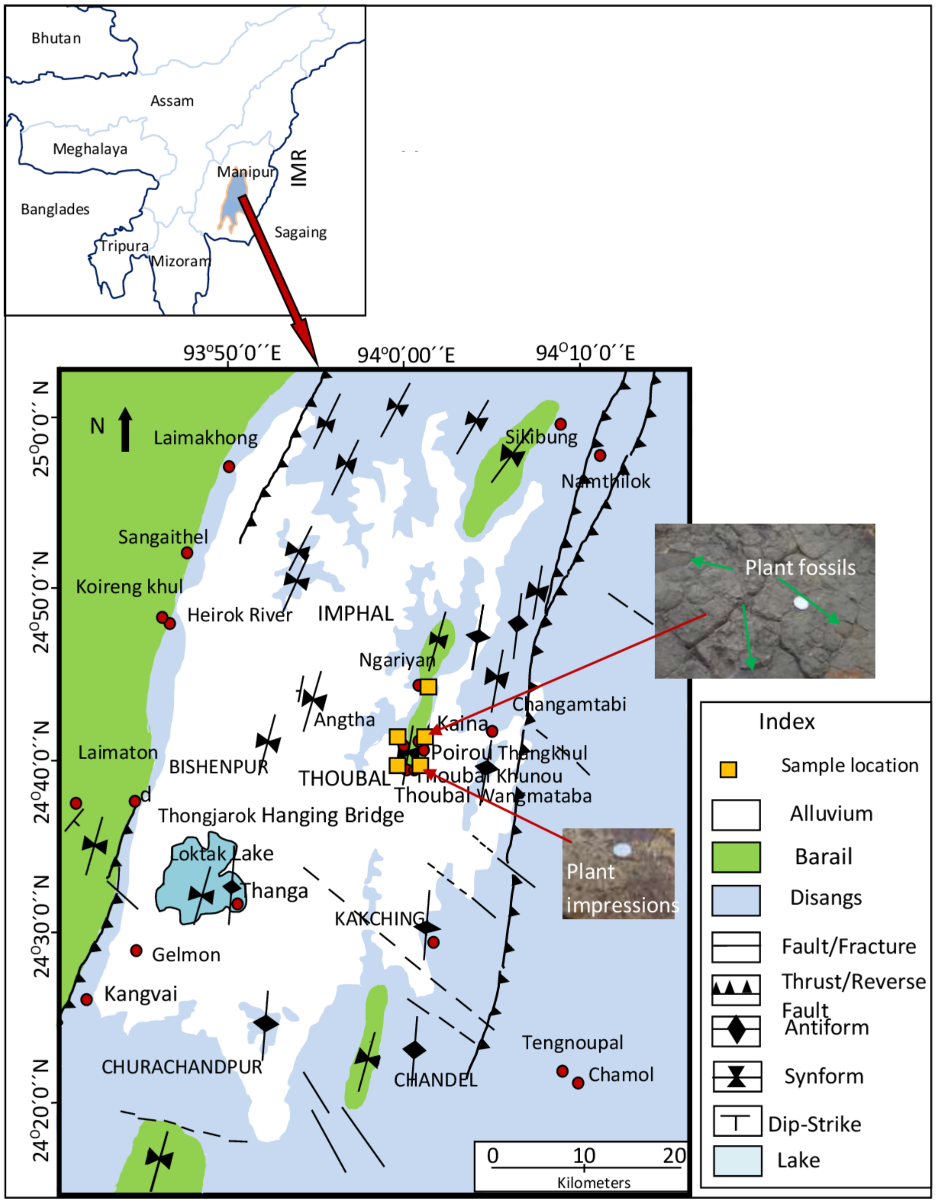

Fig. 1. Geological map of Imphal Valley, Indo-Myanmar Ranges showing the sample locations

the western margin of the Imphal valley and continue northerly towards the Naga Hills and Mizo-Hills of the IMR. This gradation at contact is related with a gradual change from dominantly argillaceous to arenaceous characteristics. The Barail and the Disang groups have transitional boundary, so the lower part of the Barail and upper part of the Disang-Barail transition have similar characteristics. The Disang-Barail transition beds of the Imphal Valley show numerous intercalation of thin, flaggy siltstone, fine-grained sandstone and sandy or silty shales (Fig. 2) Barail Group represents thick bedded sandstones interbedded with shale and thin bedded siltstone. They occur mainly in the western side of the Imphal valley. Alluvium covers a wide area

Figure 2. Photograph showing intercalation of shale, siltstone and sandstone from Imphal valley and as outliers in the eastern sides of the valley forming cappings of the Disangs.

of the valley. Stratigraphic Succession of the Imphal Valley of the Indo-Myanmar ranges is given in table 1.

Methodology

Samples of sandstone, siltstone and shale were collected from exposures of Disang-Barail Transitional beds from Imphal valley along the road cut and small quarries (Fig.2). Plant fossils are preserved in the siltstones of the Imphal valley (Fig,. 3a). Some weathered sandstones show plant impression (leaves, twig and bargs etc) (Fig. 3 b.).

For geochemical analysis, samples were thoroughly washed, dried and homogenized in an agate mortar by hand. Samples were powdered to 200 ASTM. Major element concentrations for sample TB-2K-1, TB-W-1 and Ng-3 were determined using a RIGAKU ZSX Primus II X-ray fluorescence spectrometer system and analyzed in pressed powder briquettes. The accuracy of major elements

Table 1. Stratigraphic Succession of the Imphal Valley (modified after Soibam, 1997).

Group	Lithology	Age
Alluviums	Dark grey to black clay, silt and sand deposits of fluvial-lacustrine origin. Flood plain deposits of the rivers and streams. Clay, sand, gravel and boulder deposits of the foothills and old river terraces. Possibly including lower deposits of the Imphal Valley.	(Quaternary: Holocene to Pleistocene (?) Older)
--Stratigraphic Break---		
Barails	Shale, sandy shale, massive siltstone, intercalation of bedded sandstone with shales showing turbidite character.	Oligocene
Disang-Barail Transition sequence (Gradational or local tectonic contact) consist of thick siltstone, fine-grained sandstone and sandy or silty shale (Late Eocene –Early Oligocene)		
Disangs	Dark grey splintery shale interbedded with thin siltstone and sandstones showing rhythmite nature.	Late Cretaceous to Late Eocene
~~ Unconformity ~		
Basement Complex	Unseen (?) Early Mesozoic/Paleozoic or Precambrian rocks	(?)Early Mesozoic/ Palaeozoic

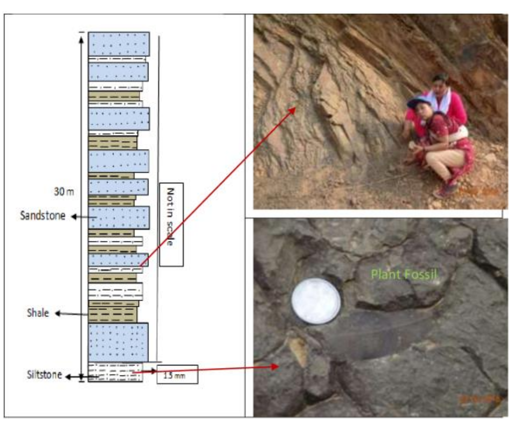

Figure 3 a. Lithostratigraphy column which shows plant fossil.

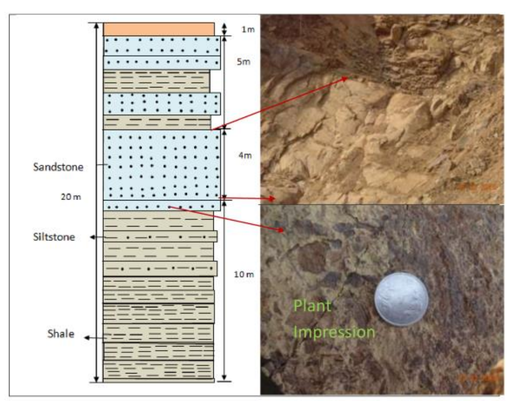

Figure 3 b. Lithostratigraphy column which shows plant impressions.

were evaluated using the rock standard Argillite whose values range from 102.6 to 93%, with the exception of Na_2O (70.0%), P_2O_5 (73.1%) and K_2O (89.3%).

For trace element analysis TB-2K-1, TB-W-1 and Ng-3, ~ 0.2 g of whole-rock powder of each sample was taken in 3 ml savillexR vials, supra pure acid mixture of $HF+HNO_3+HCl$ in 7:3:1 proportion was added, and heated for about 48 h on a hot plate at a temperature of 110°C with lids closed. The samples were repeatedly treated with HNO_3 + HCl until clear solutions were obtained. The solutions were dried, re-dissolved with 2% HNO_3 and diluted to 50 ml in polypropylene (PP) storage bottles. The stock solution was further diluted to ~7500 times with 2% HNO_3, and trace and REE concentrations were measured using Inductively Coupled Plasma-Quadrapole Mass Spectrometer (ICP-MS, Thermo X-Series) at the Department of Earth Sciences, Pondicherry University. USGS standards AGV-2, BCR-2, SCO-1 and multi-element standards were used for calibration, and 10 ppb Rhodium solution was used as an internal standard. To check the accuracy of data, USGS standard BHVO-2, AGV-2 were repeatedly analysed as unknown and the replicate analysis show precision of 2% for the REE, and better than 5% for other elements.

The major and trace elements of RNK3 and RTH1 were analysed by Wave Length Dispersive XRF system (Siemens SRS 3000) at Wadia Institute of Himalayan Geology, Dehra Dun. Analysis was carried out using pressed powder pellets glued with polyvinyl alcohol. Approximately 5-6 gms of the sample powder was mixed with 2-3 drops of polyvinyl alchohol solution and the mixture was pressed under the hydraulic pressure of 2000 kg/cm^2 to get a durable sample pellet and the resulted pellets were dried in a hot box maintained at 60-70 ^{o} C overnight to drive off excess water in the pellets. The accuracy and precision was ±1-3% for major oxides, and for trace ±5-10%.

Table 2. Major element oxides of the DBTB of Imphal Valley

	TB-2K-1	TB-W-1	Ng-3	RNK3	RTH1
SiO_2	72.239	70.903	69.046	64.67	56.61
TiO_2	0.708	0.691	0.707	0.70	0.81
Al_2O_3	11.437	10.485	11.559	14.71	19.49
Fe_2O_3t	4.971	4.93	5.245	6.93	7.61
MnO	0.06	0.113	0.078	0.04	0.05
MgO	2.627	2.87	3.24	3.59	2.77
CaO	0.783	1.643	1.505	0.41	0.48
Na_2O	2.531	2.252	2.916	1.35	0.66
K_2O	0.79	0.801	0.898	1.89	3.15
P_2O_5	0.134	0.121	0.135	0.15	0.12
P x C	3.51	4.84	4.5	6.27	9.42

Table 3. Trace element composition of the DBTB of Imphal Valley

	TB-2K-1	TB-W-1	Ng-3	RNK3	RTH1
Sc	7.76	12.52	11.90	13	16
V	47.0	92.0	91.4	114	155
Cr	201	548	526	277	194
Co	9.8	16.8	18.4	16	22
Ni	12	24	28	151	205
Cu	8.02	17.62	24.14	29	49
Zn	31	68	68	86	110
Ga	2.70	5.28	5.41	14	24
Rb	23.2	34.9	38.0	83	145
Sr	53	96	109	80	110
Y	9.4	17.2	18.9	26	34
Zr	38	115	96	207	151
Nb	3.52	7.76	7.31	10	12
Ba	52	89	93	154	258
Rb/Sr	0.44	0.36	0.35	1.04	1.32

Results

Major and Trace elements

SiO_2 values range from 56.61 to 72.23. Al_2O_3 has highest value of 19.49 and Fe_2O_3 ranges from 4.93 to 7.61. Major oxides of SiO_2, Al_2O_3, K_2O and Na_2O are used in study of paleoclimate. Major element oxides are shown in table 3. Trace elements, Rb values range from 23.2 to 145 and Sr values range from 52 to 258. Rb/Sr ratios were used as the main paleoclimate proxies. The highest value of Rb/Sr ratio is 1.32 in the samples with plant impression. The trace elements are presented in table 3.

Paleoclimate

In SiO_2 vs $Al_2O_3+K_2O+$ Na_2O diagram (Suttner and Dutta ,1986, Fig. 4), the sediments were deposited in semi-arid condition.

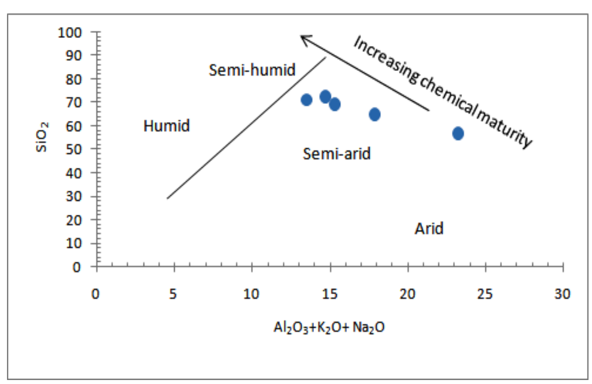

Figure 4. SiO_2 versus $Al_2O_3+K_2O+$ Na_2O diagram indicates deposition mainly in semi-arid climate (modified after Suttner and Dutta ,1986).

The Rb/Sr ratio can reflect the chemical weathering process and also reveal the change of depositional environment and paleoclimate. High Rb/Sr ratio is generally indicative of warm and humid climates, in which Rb is relatively stable while Sr is often lost due to high precipitation and low Rb/Sr ratio indicates arid climate conditions, since little Sr is lost in the low precipitation environment (Jeong et al., 2006; Du et al., 2011; Chang et al., 2013). Based on existing research that uses the Rb/Sr ratio to reconstruct the paleoclimate, 0.45 is suggested as a threshold value, below which the climate is relatively dry and cold while above this value the climate is relatively wet and warm (Shen et al., 2006). In this study, the samples with plant impressions have higher values than 0.45 indicating deposited in the warm and humid climate, while other samples have ratios less 0.45 suggesting arid and hot climate (Table 3). Based on this, it can be inferred that the DBTB should have experienced humid and arid climate conditions. The flora in diverse form comprising of gymnospermous, monocotyledonous and dicotyledonous from the Imphal Valley also indicates tropical to subtropical climate (Singh et al., 2012).

Paleo-redox conditions

The paleo-redox environment has been mainly determined based on the analysis of elements that are sensitive to redox conditions such as V, Ni, Cr, Co, Fe, and Zn (Jones and Manning, 1994). In this study, Ni/Co, V/Cr, V/(V + Ni), and V/Sc ratios were used as proxies for the paleo-redox environment. In general, V is vulnerable to precipitation under reduction conditions and dissolution under oxidation conditions, and Ni is more stable than V in both conditions (Arthur and Sageman, 1994). The V/(V + Ni) ratio has been used as tool related to reducibility (Hatch and Leventhal, 1992; Jones and Manning, 1994), with a value range of 0.84 indicating water stratification in the anaerobic reduction environment. The DBTB is identified to be mainly formed in sub-reduction to oxidation environment (Fig. 5). The V/Cr ratio is another important proxy for the redox conditions (Jones and Manning, 1994; Scheffler et al., 2006), with a value of 4.25 indicating a reduction environment. As shown in Fig. 5 (Zou et al., 2021), the DBSB is identified to be mainly deposited in sub-reduction to an oxidation environment. These results of the redox condition are similar tp the values which indicate oxic to anoxic environment (Table 5).

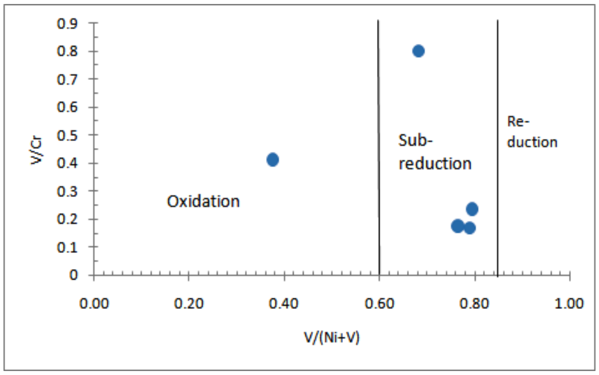

Figure 5. V/(V + Ni) versus V/Cr ratios plot to determine paleo-redox condition

Table 4.The average trace element values of the samples analysed in comparison to the standard parameters of paleo-redox conditions.

	Oxic	Dysoxic	Suboxic to anoxic	Euxinic	Average values of the samples from the study area
Ni/Co	<5	5 to 7	>7		3.64 -oxic
V/Cr	<2	2.4 to 4 .25	>4.25		0.36- Dyoxic
V/(Ni+V)	<0.46	0.46 to 0.60	0.54 to 0.82	>0.84	0.66- Suboxic to anoxic
V/Sc	<9.1				7.48- oxic

The change of paleo-redox environment is influenced by tectonic setting and depositional environment. Figure 6 (Zuo, 2020) shows that the samples with plant impressions indicate transitional depositional environment to the marine environment and samples without plant impressions indicate the marine environment. Singh et al. (2012) also suggest that the geological succession with diverse plant remains belong to the Upper Disang and Laisong formations of the Lower Barail Formation characterized by the rhythmic intercalations of dark grey splintery shale, siltstone and fine grained sandstone of shallow marine origin, while the latter has sandy shale and fine grained sandstones of shallow marine to fluvio-deltaic origin (Chandra and Kushwaha, 2008).

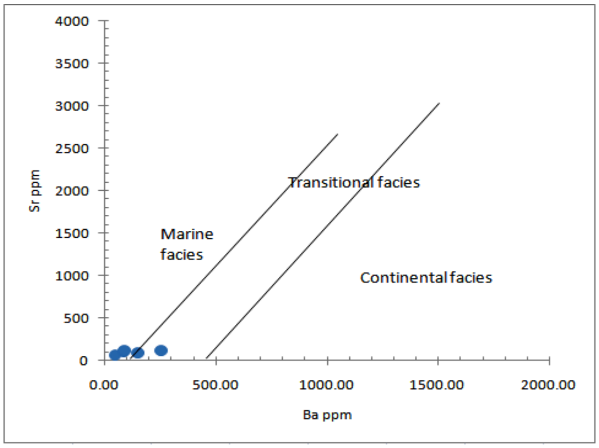

Figure 6. Sr versus Ba diagram of the sedimentary rock of the Imphal Valley

Conclusions

In this study, the paleoclimate, paleo-redox and sedimentary depositional environment of the Disang-Barail Transitional beds of the Imphal Valley, Indo-Myanmar Ranges was reconstructed based on geochemistry using the analysis of major and trace elements. Alternating semi-arid, arid and humid climates were suggested during deposition of DBTB by paleoclimate proxies. The palaeoredox environment during the DBTB deposition was dominated by sub-reduction, although there was a trend of oxidization, based on the V/(V + Ni) and V/Cr ratios. The DBTB is suggested to be deposited in the environment transitional to the shallow marine environment. Results of this study are expected to help better understand the paleoclimatic, paleo-redox and paleoenvironmental condition during DBTB deposit by furthering the research with more sample analyses.

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