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Quantitative Mineralogical Analysis and Study of Morphology and Thermal Characteristics of Rock Samples of *Dudhi Nala* and Bokaro river

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ABSTRACT

Beds of Talchir formation are well exposed in the western part of the Bokaro coalfields (*Dudhi Nala*) which comprises tillite, conglomerates, sandstones, with dropstones and turbidite sequences comprising siltstones and shales. This work presents the study of glacigenic Talchir sediments of *Dudhi Nala* section and sediments of Bokaro river. The morphology, major oxides, trace elements, Rare Earth elements and minerals found in these sediments are of great geological importance. The minerals present in these samples have been also investigated. The samples collected from *Dudhi Nala* are enriched in SiO_2 (66-68 wt% compared to 25-60 wt% in the samples of Bokaro river). In contrast to SiO_2, Fe_2O_3 is dominant in the Bokaro river samples. *Dudhi Nala* samples are rich in trace elements like Ba (1047ppm), Rb (219ppm), Sr (312ppm), Zr (256 ppm) and Pb (65ppm), where as Bokaro river samples dominates in Cr (140ppm), Sc (39ppm), V (117ppm) and Zn (90ppm). FESEM/EDX analysis was done to study the morphological characteristics and elemental composition were analysed by FESEM/EDX. Thermal characteristics of the samples were studied by TGA/DSC. Further, XRD analysis confirmed that Calcite and feldspar are the common minerals present in the samples of the both the study areas.

Keywords: Bokaro coalfield, Morphology, Rare earth elements, Minerals.

INTRODUCTION

Damodar Valley Basin, an important storehouse of indian coal, is part of the Gondwana Systems. The beds of Talchir formation are well exposed in the western part of the Bokaro basin, (*Dudhi Nala*) which comprises tillite, conglomerates, sandstones, with dropstones and turbidite sequences comprising siltstones and shales. The lower part of the Talchir formation is believed to be of glacial origin. On the other hand the environment of deposition of the upper part is still not clear and the observed sedimentary features can be explained by sedimentation in a sea or a big lake[1]. The polyplacophoran fossils reported from upper Talchir sediments of *Dudhi Nala* area reveal a marine link of the west Bokaro basin during the Upper Talchir times[2]. However, absence of marine fossils and presence of cross-bedded sandstone and conglomerate in overlying unit (along with a few fish

bones and reptile fossils) which are common in most of the Talchir basins are indicative of glaciofluvial-glaciolacustrine freshwater regime[3]. Stable isotope analysis was carried out[4], suggests that precipitation of the Talchir carbonates took place in a fresh water environment, and the water was suppplied by melting of glacier formed in nearby hills[5]. In this work, chemical composition, morphological and thermal characteristics of the sediments of the Talchir deposits of *Dudhi Nala* has been studied to understand the environment of the sediments. We also focused on some part of Bokaro river to study the variation.

Geologic overview

Dudhi Nala is located in the western part of the Bokaro Coalfields, near the Mandu block of Ramgarh district. An excellent exposure of the Talchir sediments of the Damodar valley basin was found[3] near the confluence of *Dudhi Nala*, *Dube Nala* and Silahi Nala about 0.5 km south of the village Jarwa (lat. 85°27' and long. 23°49') at the western part of the Bokaro sub-basin. The sediments here rest unconformably on the Archaean basement and comprise conglomerate, sandstone and siltstone[6]. Here, bluish-grey siltstones, yellow coloured sandstone bed with hummocky cross stratification, greenish-grey siltstones, bluish-green rhythmite bed is very well exposed. Sediments of Bokaro river are different in colour and texture.

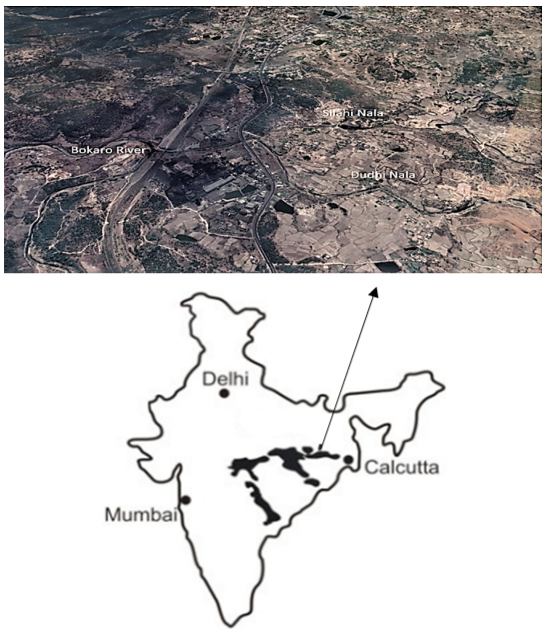

Fig. 1. Showing Gondwana basins and the study areas: *Dudhi nala*, Silahi Nala, and Bokaro river[7]

METHODS

Damoder valley basin contains a sub chain of stratigraphic sequences of Talcher deposits. An interesting deposit appears near the village Jarawara dudhinala, Dubey nala and Silainala. Large number of samples were collected from *Dudhi Nala* and Bokaro river[8], out of which 8 samples of geological significance based on petrography were subjected for the analysis. Rock samples were powdered using mortar and pestle and sieved to very fine powdered form. Samples were dried in a hot air oven to remove the moisture content in the samples, then different analysis were carried out. Majority of the analysis, FESEM/EDX, TGA, DSC and XRD were carried out in the Central Instrumentation Facility, Birla Institute of Technology Mesra, Ranchi. Major and trace elements were analysed at the XRF-IRMS lab, Department of Earth Sciences, Indian Institute of Technology, Kanpur.

Petrography

A typical petrography photograph is shown in Figure 2.

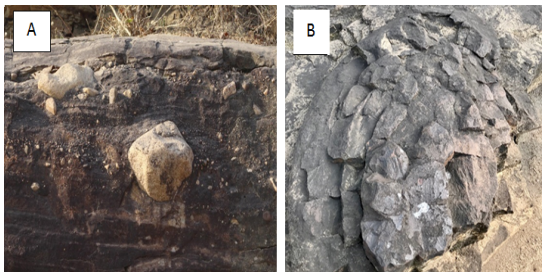

Fig. 2. Typical photographs of rock outcrops on (A) *Dudhi Nala* and (B) Bokaro river

FESEM and EDX Study: FESEM ans EDX studies were conducted by taking eight samples. A typical FESEM and EDX analysis of sample S2 from *Dudhi nala* and sample S6 from Bokaro river are shown in the Fig. 3 to Figure 6 respectively.

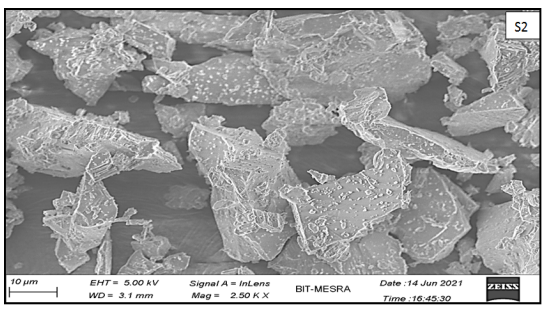

Fig. 3. FESEM micrograph of sample S2 collected from *Dudhi Nala*

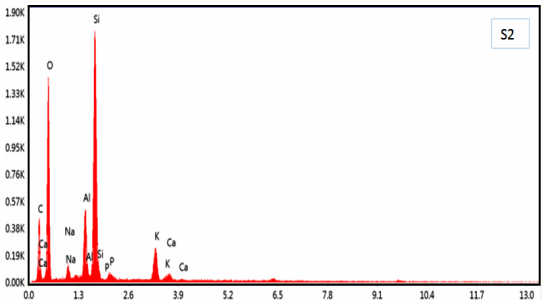

Fig. 4. EDX peaks of sample S2 collected from *Dudhi Nala*

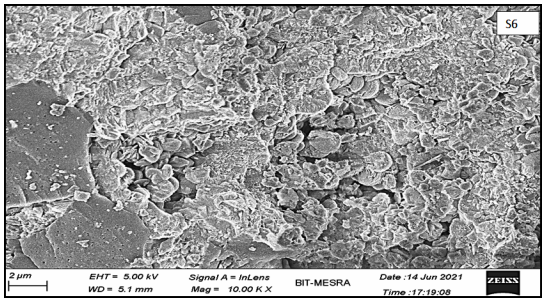

Fig. 5. FESEM micrograph of sample S6 collected from Bokaro river

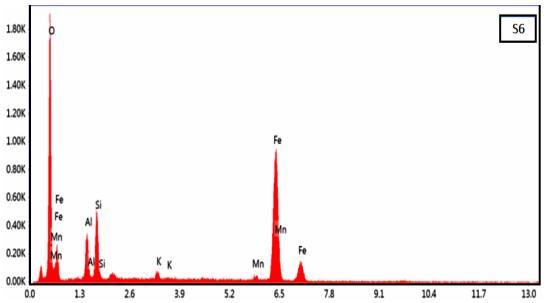

Fig. 6. EDX peaks of sample S6 collected from Bokaro river

The rock outcrops consist of the Dropstones, Potholes, Concretions, and Hummocky cross stratification. The difference in morphology in the samples collected from both the study areas is clearly evident from the FESEM images and EDX data, Si is dominant in the samples collected from the *Dudhi Nala* section with lower concentrations of Ca, Na, K. Fe is dominant in the samples collected from Bokaro river, with lower concentrations of Si, Mn, Al and K. Quartz grains can be easily observed in the FESEM image of sample S1 and sample S2 of *Dudhi Nala*.

Thermal analysis (TGA & DTA)

The TGA and DTA analysis of sample S2 and S6 are shown in Fig. 7 and Fig. 8 shows multi stage decomposition in both the samples[9]. Total weight loss in sample S2 collected from *Dudhi Nala* was observed to be -11.660%, within the temperature range of 30-1000^{0}C. While, in the same temperature range, total weight loss was observed to be -18.467%. Also the DTA curve vary in both the samples.

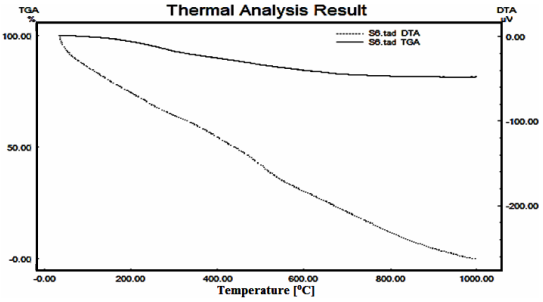

Fig. 7. Showing TGA & DTA analysis of sample S2 collected from *Dudhi nala*

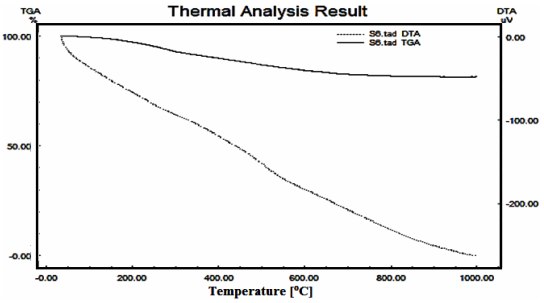

Fig. 8. Showing TGA & DSC curve of sample S6 collected from and S6 of Bokaro river

The DSC analysis of sample S6 shows an endothermic peak, with Peak temperature of 273.43°C. Onset was observed at 227.42°C. Enthalpy normalised was found to be:37.222 J/g. The endothermic peak, hints about the presence of Clay minerals in the sample. The sample S8 shows three peaks. Peak temperature for the first peak is observed at 39.13°C. Enathalpy normalised is 6.8964 J/g, and Onset is observed at 31.81°C. Peak temperature for the 2nd peak is 147.11°C. Enthalpy normalised is 1.0004 J/g, and onset is observed at 125.69°C. Peaks hint about the presence of clay minerals.

X-ray diffraction study: A typical X-ray photographs of sample S2 is shown in Fig. 9 and that of sample S6 is shown in Figure 10.

From XRD Analysis it is clear that the samples collected from *Dudhi Nala* are dominant with Quartz with minor amount of Feldspar, Calcite and Zircon. And in the case of Bokaro river samples, Magnetite and Quartz are the major minerals with minor amount of feldspar and Zircon.

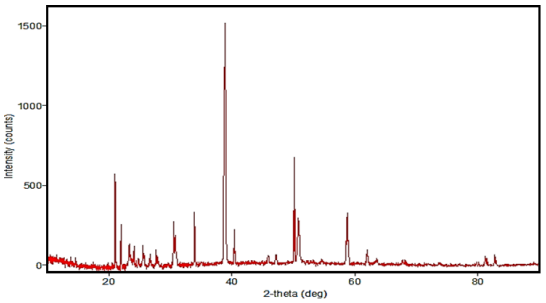

Fig. 9. Showing XRD peaks of Sample 2 collected from *Dudhi Nala*

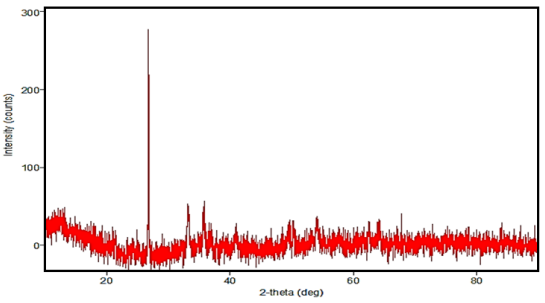

Fig. 10. Showing XRD peaks of sample S6 collected from Bokaro river

X-ray fluorescence

X-ray fluorescence analysis data is shown in Table 1. It is clear from the Table 1 that SiO_2 is the dominant oxide present in the *Dudhi Nala* Samples, and Fe_2O_3 is the major oxide, present in the samples of Bokaro river. Al_2O_3 is the common major oxide present in the samples of both the study areas. From the XRF Data it was evident that many trace elements, and Rare Earth Elements are present in the samples of both the study areas. A comparison of rare earth trace element of *Dudhi Nala* and Bokaroriver is shown in Fig. 11. Concentration of Ba (1047ppm), Ce (92ppm), La (53ppm),Rb (219ppm), Sr (312ppm), Th (22ppm), Y (37ppm), Zr (256ppm) and Pb (65 ppm) is higher in the Quartz dominated, samples of *Dudhi Nala*. Concentration of trace elements like Cr (140ppm), Sc (39ppm), V (117ppm), Zn (90ppm), is higher in the samples of Bokaro river.

Table 1: XRF data of major oxides and Trace elements. Dashes means that the elements were not analysed

Major oxides and Trace elements	Sl	S2	S3	S4	S5	S6	S7	S8
AJ_2O_3	12.68	11.77	12.82	12.11	9.62	10.60	16.56	19.45
CaO	0.59	0.72	1.33	0.74	0.42	0.17	1.04	0.11
Fe_2O_3	1.73	1.18	4.99	56.63	61.50	68.08	5.76	3.22
K_2O	4.99	6.39	2.65	0.88	0.91	0.59	2.95	2.76
MgO	1.01	0.13	3.28	0.35	0.52	0.24	2.03	0.53
Na_2O	3.65	3.09	2.31	0.87	0.00	0.88	2.19	0.74
P_2O_5	0.06	0.00	0.17	0.00	0.00	0.04	0.12	0.08
SiO_2	67.68	68.75	66.98	25.34	24.11	18.42	68.15	60.99
T_iO_2	0.43	0.11	0.65	0.65	0.34	0.29	0.71	0.45
NiO	0.001	0.000	0.002	0.003	0.00	0.006	0.003	0.003
MnO	0.05	0.05	0.09	1.12	1.67	1.46	0.07	0.05
Total	92.85	92.19	95.27	98.70	99.09	100.77	99.57	88.36
Ba	921	1047	748	287	386	198	930	301
Ce	74	-	92	31	30	41	59	67
Cr	106	81	81	58	36	43	78	140
La	46	-	53	18	14	26	50	44
Rb	219	210	93	28	31	22	93	54
Sc	-	-	10	38	35	39	12	12
Sr	225	312	104	-	9	-	69	-
Th	22	3	16	7	3	6	14	6
V	39	-	90	95	70	68	94	117
Y	37	36	34	-	5	-	28	15
Zr	151	54	256	71	41	-	144	66
Zn	26	21	55	70	59	90	74	41
Pb	41	65	25	16	19	11	20	8

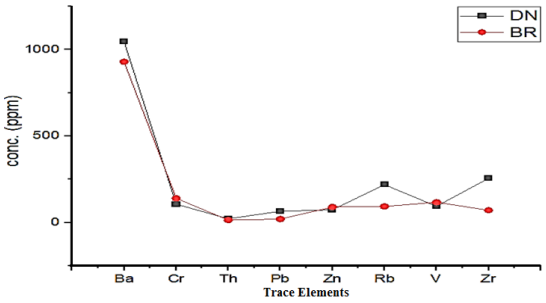

Fig. 11. Comparison of the concentration (ppm) of Trace Elements in both the study areas: *Dudhi Nala* and Bokaro river

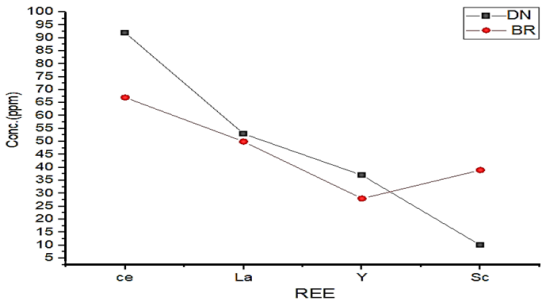

Fig. 12. Comparison of the Rare Earth Elements concentration in the samples of *Dudhi Nala* and Bokaro river

The comparision of rare earth element concentration in *Dudhi Nala* and Bokaro river sample is shown in Fig. 12. It is evident from the graph that the concentration of Ce, La, Y is higher in the samples of *Dudhi Nala*. While, Sc concentration is higher in the Bokaro river sample.

RESULTS AND DISCUSSION

There is a clear difference in the morphological characteristics[10-12] and thermal characteristics of the permo-carnboniferous Talchir sediments collected from the *Dudhi Nala* section and sediments of Bokaro river[13-16], which is evident from the Petrographic investigations and through TGA/ DSC studies. FESEM images reveals fine grains of Quartz in the *Dudhi Nala* samples, with rounded to sub rounded grains of Zircon. The nodules of *Dudhi Nala* are composed of quartz, feldspar and heavy minerals with minor amount of clay minerals. Biotite, Aragonite and zircon could be identified by the XRD analysis. SiO_2 is the dominant oxide found in the nodules of Dudhi Nala while, Fe_2O_3 is the major oxide present in the nodules of Bokaro river. The EDX analysis indicate a significance presence of iron in S6 while the XRD analysis of the same sample shows prominent quartz peak indicating substantial amount silica may be attributed to the multicomponent mixture usually contain overlapping peaks, crystal size and scan duration.

Al_2O_3 concentration is similar in the samples of both the study areas. SEMEDX analysis shows significant presence of iron in sample S6 while XRD analysis shows prominent peak of silica, which may be attributed to the intensity of X-ray diffraction line depends on minerals composition, nature of samples and scan duration. The rock samples contains a mixture of different compositions of iron contents therefore diffraction peaks of these minerals shows overlapping and favours XRD peaks of lower intensity.

High silica source rocks[19-20] tend to contain higher concentrations of REE, Th, Hf and Ba, lower concentration of Co, Fe, Sc and Cr, and more negative Eu anomalies than the low silica source rocks[17-18] High SiO containing rock samples of *Dudhi Nala* has higher concentration of Ba (1047ppm), Th (22ppm), Zr (256ppm), Sr(312ppm) and Pb (65ppm). And High Fe_2O_3 containing rock samples of Bokaro river has higher concentration of Sc (39ppm) and Zn (90ppm). Concentration of Rare Earth Elements, Ce (92ppm), La (53ppm), Y (37ppm) is higher in the nodules of *Dudhi Nala* and concentration of Sc (39ppm) is higher in the nodules of Bokaro river. Therefore, REE concentration and their pattern in the sediments are very useful for identification of source rock types.

CONCLUSION

This study of glacigenic Talchir sediments of the Bokaro district *Dudhi Nala* section shows morphology variations, major oxides, trace elements and Rare Earth elements are of great geological importance. The samples collected from *Dudhi Nala* are enriched in SiO_2 (66-68 wt% compared to 25-60 wt% in the samples of Bokaro river). In contrast to SiO_2, Fe_2O_3 is dominant in the Bokaro river samples. Dudhi Nala samples are rich in trace elements like Ba (1047ppm), Rb (219ppm), Sr (312ppm), Zr (256ppm), Pb (65ppm), while Cr (140ppm), Sc (39ppm), V (117ppm), Zn (90ppm) concentration is found to be more in the Bokaro river samples. It was confirmed that Calcite and feldspar are the common minerals present in the samples of the both the study areas.

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Conflict of interest

The authors declare that there is no conflict of interest to be reported.

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