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Geochemical study of Bara Formation from boreholes SB-14-TC and ST-24-TC, Thar Coalfield, Sindh, Pakistan

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Abstract: The coal resources of Sindh are encased into two stratigraphic horizons; Bara Formation (Middle Paleocene) and Sonhari member of Laki Formation (Eocene). Being coal bearing Formation of Thar coalfield, the Bara Formation warrants a detailed geochemical study of its sediments for better understanding of depositional environment and sedimentary processes operational at the time of its deposition. Major elements of twenty samples of Bara Formation from two selected Boreholes SB-14-TC and ST-24-TC were analyzed through X-ray fluorescence. The investigation of major elements (Si, Ti, Al, Na, Ca, K, Mn, Mg, Fe+3, P & S), major elemental ratios and their correlation coefficient (r^2) show that the origin of its constituting silica content is detrital, which is further confirmed by difference in the source of silica and alumina. The studied sediments have potentially deposited along the fringe of basin of deposition in deltaic to near shore depositional environment. The deposition of sediments took place under humid climatic condition, with relatively fast rate of sedimentation, showing better conditions for the growth, accumulation and preservation of organic source material of its coal. The studied sediments are potentially derived from igneous and metamorphic source rocks.

Keywords: Bara Formation, Geochemistry, Thar Coalfield, SB-14 & ST-24 borehole and XRF

1. INTRODUCTION

The proven coal resources of Sindh are enclosed into two stratigraphic layers; the lower being the Bara Formation (Middle Paleocene) and upper constitutes the Sonhari member of Laki Formation (Eocene). The Bara Formation is coal bearing formation at Thar coalfield. The Thar coal field contains approximately (175) billion ton of coal, covering an area of 9000 square kilometers, Ghaznavi (2002). The geochemical investigation of two Boreholes SB-14-TC Block-II and ST-24-TC, Block-III (Fig. 1) of Thar Coalfield was carried out in order to determine the distribution of major elements (Si, Ti, Al, Na, Ca, K, Mn, Mg, Fe+3, S & P), major elemental ratios and correlation coefficient (r^2) of Bara Formation sediments. The studies of these geochemical factors indicate the nature of origin of Bara Formation sediments, the kind of depositional environment and the site of sediment deposition corresponding to the basin of deposition and the nature of the paleoclimate and its impact on the sedimentary processes and the generation of suitable conditions for abundant occurrence of coal in the studied sediments. Besides, the relationship among different elements helps to evaluate the source rock of studied sediments.

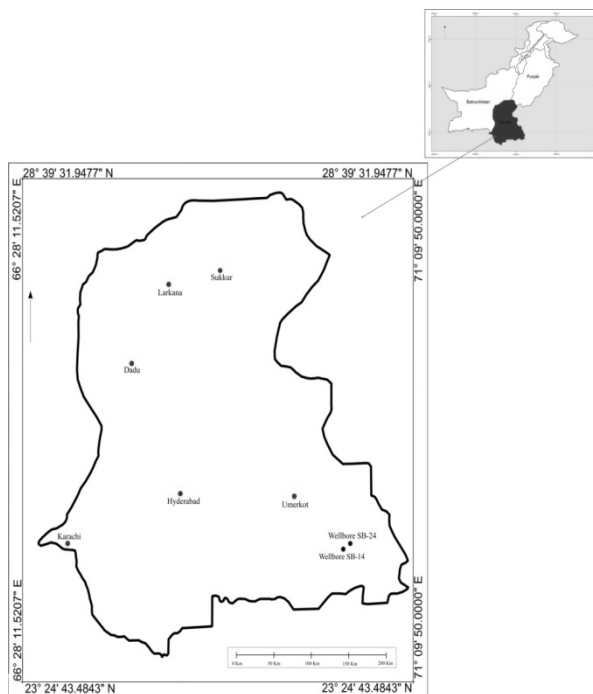


Fig.1: Location Map of Studied Wellbores

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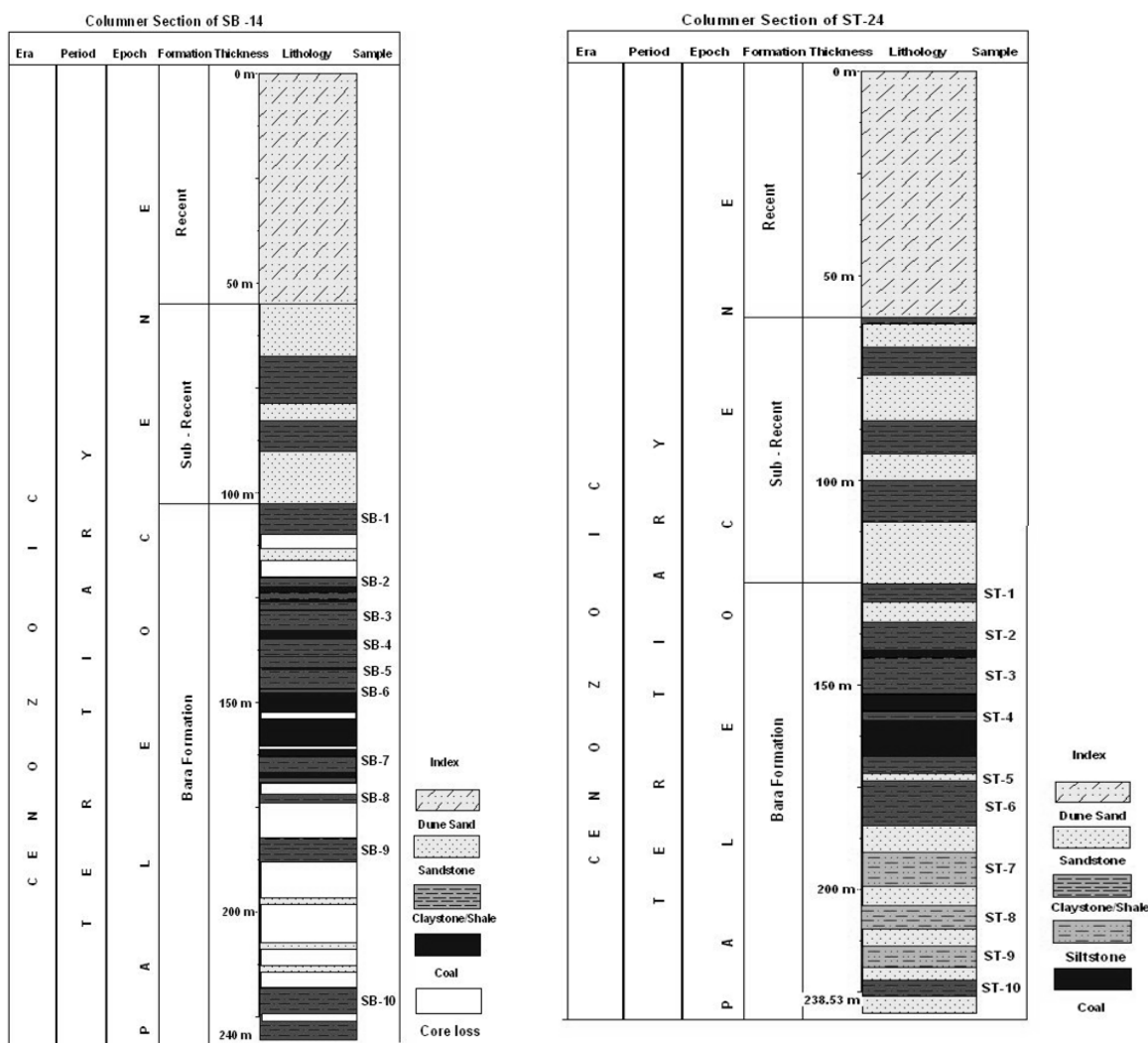


Fig. 2: Columnar sections of Bara Formation, Boreholes SB-14-TC and ST-14-TC, Thar Coalfield.

The Thar coal field is located between, Latitude 24⁰ 15' N to 25⁰ 45' N and Longitude 69⁰ 45' E to 70⁰ 45' E, It can be accessed at about 25 km north east of Islamkot, which is 45 km east of Mithi, Headquarter of District Tharparkar. The Geological Survey of Pakistan (GSP) carried out exploration of coal in four blocks of Thar Coalfield. The upper and the lower contacts of Bara Formation in studied Boreholes are unconformable with the overlying Quaternary deposits and the underlying basement complex, Jaleel, *et.al* (2002). It is composed of claystone, fine-grained sandstone and subordinate amount of shale, carbonaceous shale, siltstone and coal beds of variable thicknesses. Previously, substantial work is being carried out for the exploration and exploitation of coal in Bara Formation. HSC (1961), Cheema *et.al.* (1977) and Wnuk, *et.al* (1993) had studied the stratigraphy and coal potential of Bara Formation. Its bulk clay mineralogy was studied by

Abdullah *et.al* (1997) and Baig *et.al.* (2007). Hakro and Baig (2013), Hakro (2013), Khokhar *et.al.* (2014), Hakro (2014), Hakro *et.al.* (2014), described the depositional environment and processes using the grain size data, bulk mineralogy, geochemistry and the textural maturity of Bara Formation.

2. MATERIALS AND METHODS

Twenty core samples of Thar Coalfield, ten samples each from Borehole SB-14-TC and Borehole ST-24-TC were obtained from the core library of the Geological Survey of Pakistan, Quetta. The total thickness of Bara Formation in Borehole SB-14-TC is 49.5 meters and in Borehole ST-24-TC is 52.77 meters. The samples were taken at five (5) meter interval from the core boxes. Each sample was washed and put in oven for twenty four hours for drying at 110°C temperature. Later on the sample was crushed, grinded and brought to two

hundred (200) mesh size. Pellets of samples were prepared according to procedures of Cosgrove (1973). The measurement of the intensity of the characteristic radiation for particular element gives a value reflecting its concentration in the sample (Tucker, 1988). The preparation, processing and geochemical analysis of studied samples was carried out by utilizing the X-ray fluorescence method with XRF (S-4-pioneer) model, available at the advance research laboratory of Centre for Pure & Applied Geology, University of Sindh, Jamshoro.

3. RESULTS AND DISCUSSION
Silicon (SiO₂)

The silicon content of SB-14-TC and ST-24-TC boreholes of Thar coalfield is shown in (Table 1). Couture (1977), suggested that the low value of SiO₂/Al₂O₃ ratio may show the presence of biogenous/diagenetic silica and the high value may

indicate the presence of detrital component in the sediments. The SiO₂/Al₂O₃ values of studied sediments range from 1.19 to 2.63 showing the dominance of detrital component against biogenous/diagenetic silica. Ronov (1965) used Si/Al ratio to determine the location of deposition of sediments corresponding to the basin of deposition. According to him the higher percentage of silica (quartz) suggests the deposition in near-shore environment as compared to basin sediments. In the present study silica has maximum (63) percentage (Table I) suggesting that the studied sediments were deposited at near-shore depositional conditions. The negative correlation coefficient of SiO₂ with Al, Ti, Fe, Mg, and Na (Fig. 3a, 3b, 3d, 3g) indicates that major part of SiO₂ in studied sediments occur as free silica (Quartz). Further the strong negative correlation of SiO₂ with Al₂O₃ (Fig. 3a, 4b) reveals the different source of sediments as SiO₂ which is present as mineral Quartz whereas the Al₂O₃ occurs as Alumina.

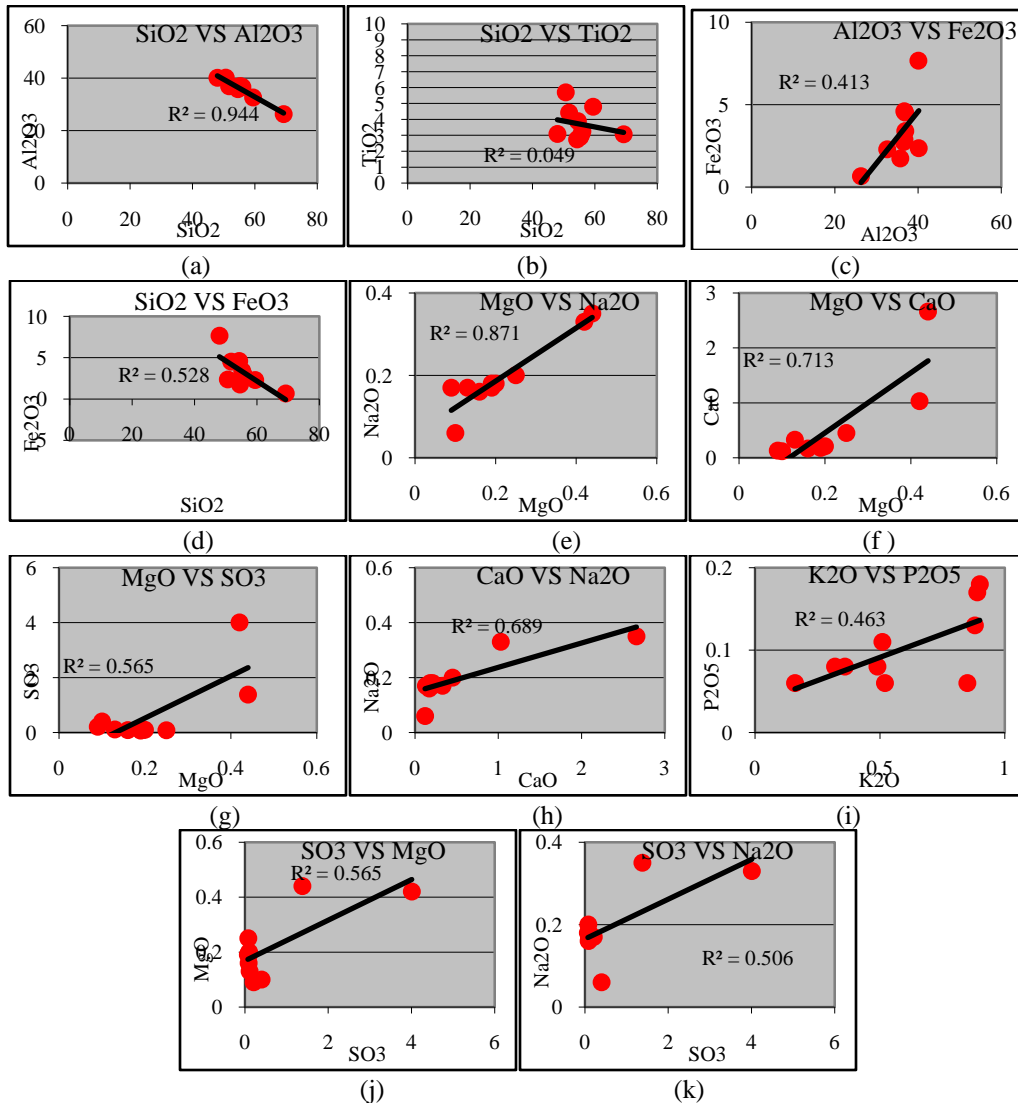


Fig. 3: Bivariate Diagram of Major Elements of Bore Hole SB-14-TC, Thar Coalfield

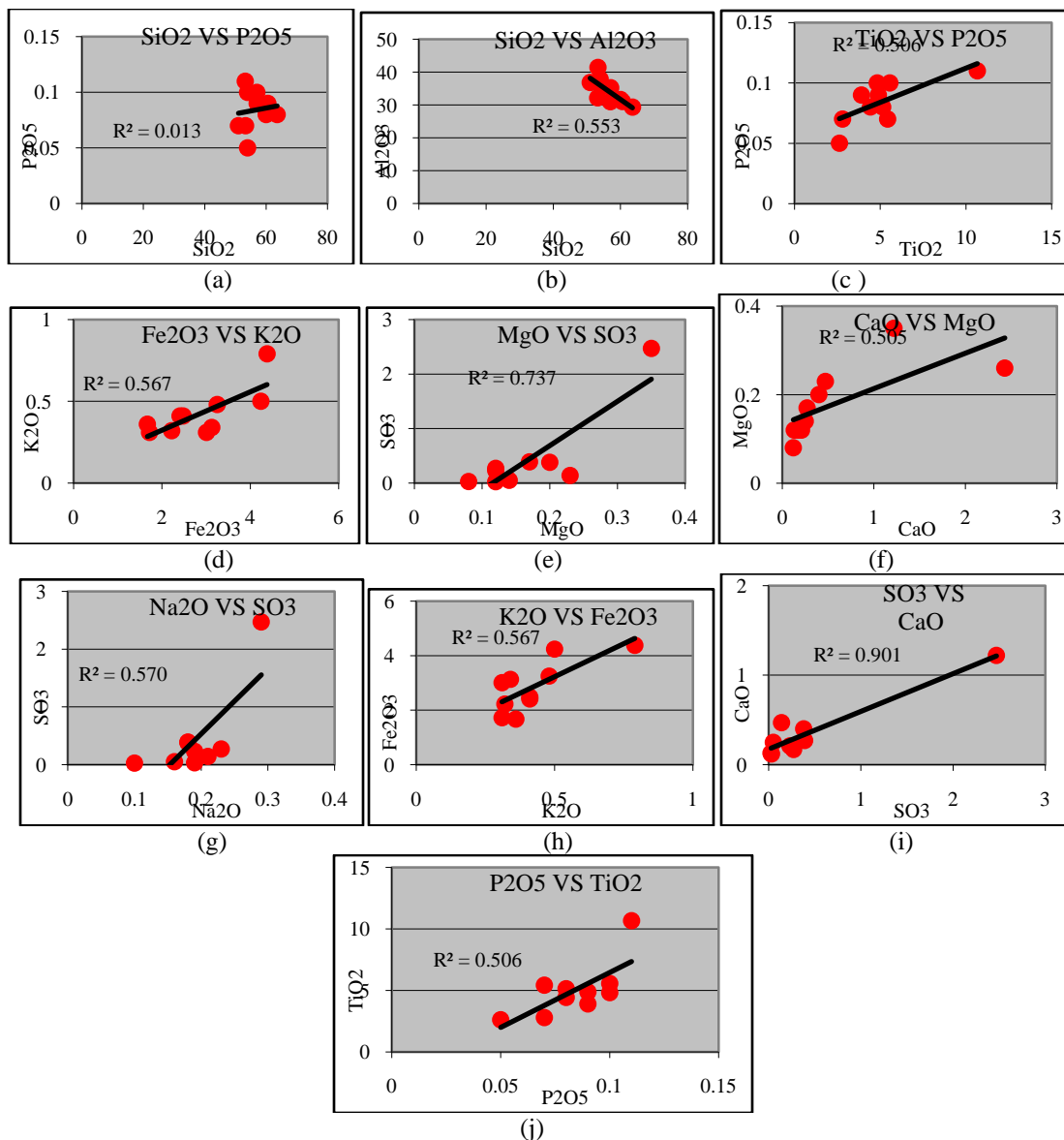


Fig. 4: Bivariate Diagram of Major Elements of Bore Hole ST-24-TC), Thar Coalfield

Titanium (TiO_2)

The content of TiO_2 of SB-14-TC and ST-24-TC boreholes of Thar coalfield is shown in (Table 1). Spears (1964) used the $\text{TiO}_2/\text{Al}_2\text{O}_3$ ratio for grain size analysis of the sediments, the ratio increases from mudstone, siltstone, to sandstone. The values of $\text{TiO}_2/\text{Al}_2\text{O}_3$ ratio suggest that the studied sediments are composed of medium to fine grained particles same is confirmed by the presence of quartz. Migdisov (1960) used the $\text{TiO}_2/\text{Al}_2\text{O}_3$ ratio for the study of paleoclimatic conditions. The high values of $\text{TiO}_2/\text{Al}_2\text{O}_3$ (Table 2) and high concentration of TiO_2 and Al_2O_3 (Table 1) in studied sediments suggest humid climatic conditions at the time of deposition. The weak positive to negative correlation coefficient (Table 3) of TiO_2 with Al_2O_3 in studied sediments indicates that TiO_2 is weakly

associated with the clay minerals. TiO_2 also showed a weak positive correlation with MgO , CaO , Mg and S ; further confirms its association with clay minerals. Its negative correlation with Si , K indicates that TiO_2 is not associated with other silicate minerals present in these sediments.

Aluminum (Al_2O_3):

The content of Al_2O_3 of SB-14-TC and ST-24-TC boreholes of Thar coalfield is shown in (Table 1). The high (41.14) amount of Al_2O_3 (Table 1) has been considered as the indicator of the presence of clay minerals. Pettijohn (1957) used the $\text{Al}_2\text{O}_3/\text{Na}_2\text{O}$ ratio as a measure of sediment maturity. The studied sediments show the values of ratio ranging from 4.9 to 5.43 (Table 2) indicates less maturity; therefore these sediments had

encountered fewer cycles of sedimentation. The positive correlation of Al_2O_3 with, Fe, Ca, Na, and K (**Table 3**) indicates its association with clay minerals (**Fig. 3c**). Al_2O_3 also shows a strong negative correlation with SiO_2 (**Table 3**) suggesting that there is no relationship between Al_2O_3 and SiO_2 because the SiO_2 occurs as free Quartz in the studied sediments (**Fig. 4b**).

Iron (Fe_2O_3):

The content of total Fe_2O_3 of SB-14-TC and ST-24-TC boreholes of Thar coalfield is shown in (**Table 1**). Baig (1984) used $\text{Fe}_2\text{O}_3/\text{Al}_2\text{O}_3$ ratio as an indicator of the association of iron with clay minerals. $\text{Fe}_2\text{O}_3/\text{Al}_2\text{O}_3$ in studied sediments (**Table 2**) suggests the weakest association of Fe_2O_3 with the clays. Sulaiman (1972) studied the Mn/Fe ratio and noticed that the near-shore sediments rich in kaolinite contents showed the lowest (0.012) value of Mn/Fe. He further observed that the off-shore sediments showed the highest (0.019) value of this ratio. These values of Mn/Fe ratios (**Table 2**) indicate that the studied sediments were deposited in near-shore depositional environment. The total Fe_2O_3 showed a very weak positive correlation with Al, Mg, Na and S, and a negative correlation with Si that indicates that the total iron (Fe_2O_3) is associated with clay minerals particularly with the Chlorite (Fe and Al rich) and Si, which may be due to the occurrence of SiO_2 as mineral quartz.

Magnesium (MgO):

The content of MgO of SB-14-TC and ST-24-TC boreholes of Thar coalfield is shown in (**Table 1**). The $\text{MgO}/\text{Al}_2\text{O}_3$ ratios (**Table 2**) of studied sediments show that Magnesium is present in lesser amount as in Mg^{+2} containing clay minerals, same is confirmed by the presence of Montmorillonite and Chlorite. The correlation coefficient suggests strong positive correlation of MgO with Na, Ca, S, Ti, Fe, and P (**Fig. 3e,3f,3g,4e**) referring its association with Chlorite and Feldspars. The negative correlation coefficient of MgO with Si and K, shown in (**Fig. 3e**) indicates that MgO is not associated with K-feldspar. A very strong positive correlation of MgO with Na_2O suggests its association with Na-feldspar. The MgO also shows a strong positive correlation with CaO (**Fig. 3f**) indicating that MgO is associated with Chlorite, because of substitution of ionic radii's of these elements.

Calcium (CaO):

The content of CaO of SB-14-TC and ST-24-TC boreholes of Thar coalfield is shown in (**Table 1**). The strong positive correlation coefficient of CaO with MgO , Na_2O , SiO_2 , and TiO_2 (**Fig. 3h,4f**) indicate its association with feldspars and chlorite. Its negative correlation with Si and K indicates that it is not related with quartz. The positive correlation of CaO with Si, Ti, Fe, Na, P and Mg in Bore Hole ST-24-TC indicates its association with Chlorite (Fe & Al-rich). The strong positive correlation of CaO with MgO (**Fig. 4f**) suggests that the CaO is substituted for Mg in the inter-layers of either Montmorillonite or Chlorite.

Sodium (Na_2O):

The Na_2O content of SB-14-TC and ST-24-TC boreholes of Thar coalfield is shown in (**Table 1**). The lower amount of Na_2O in studied sediments might be due to possible exchange by K^+ , Spears (1964). The correlation coefficient (**Table 3**) indicated a very strong positive correlation of Na_2O with Mg, Ca, S (**Fig. 4g**), and also a weak positive correlation with Al, Fe and P. These correlations demonstrate that Na_2O is associated with the lattices of clay minerals and other aluminosilicates. Its negative correlation with Si, Ti, and K suggested that Na_2O is not associated with K-feldspar. (**Fig. 3e**) shows the relationship of Na_2O with Mg and Ca.

Potassium (K_2O):

The potassium content of SB-14-TC and ST-24-TC boreholes of Thar coalfield is shown in (**Table 1**). Bloxam and Thomas (1969) used the Na^+/K^+ ratio to study the rate of sedimentation, the high value of ratio indicates the high rate of sedimentation which depends on the rapid supply of the detritus. Fast rate of deposition is further confirmed by the higher proportion of sandy-silty material and affluent concentration of quartz (56.34) The highest value (299.87) of the Na^+/K^+ ratio (**Table 2**) suggests high rate of deposition of studied sediments. Besides, highest values of $\text{K}_2\text{O}/\text{Al}_2\text{O}_3$ ratio suggest the presence of higher contents of clay fraction in the sediments. The correlation coefficient (**Table 3**) of Borehole ST-24-TC shows a very strong positive correlation K_2O with Fe (**Fig 4h**), and a medium strong positive correlation with Al, Mg, S and P_2O_5 (**Fig. 3i**) indicates its association with chlorite (Fe-rich) and (Mg) containing montmorillonite. K_2O .

Table 1: Major Elements of Bore Hole SB-14-TC and ST-24-TC samples, Thar Coal Field

Bore Hole SB-14-TC												
S.No	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	MnO ₂	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅	SO ₃	Total
SB-TC-1	47.98	3.09	40.08	7.67	0.05	0.25	0.45	0.2	0.16	0.06	0.08	100.1
SB-TC-2	55.97	3.26	36.55	2.74	0.03	0.19	0.18	0.18	0.85	0.06	0.07	100.1
SB-TC-3	54.29	2.75	36.4	4.6	0.02	0.2	0.21	0.18	0.89	0.17	0.1	100.1
SB-TC-4	55.7	3.08	36.42	2.87		0.19	0.2	0.17	0.9	0.18	0.098	100.1
SB-TC-5	55.25	2.9	36.63	3.4	0.02	0.16	0.17	0.16	0.88	0.13	0.09	100.1
SB-TC-6	59.43	4.8	32.59	2.29	0.03	0.1	0.12	0.06	0.52	0.06	0.4	100.4
SB-TC-7	69.2	3.07	26.27	0.66	0.02	0.09	0.13	0.17	0.32	0.08	0.21	100.2
SB-TC-8	54.55	3.89	35.75	1.74	0.05	0.44	2.66	0.35	0.49	0.08	1.38	101.4
SB-TC-9	51.72	4.42	36.59	4.52	0.05	0.42	1.03	0.33	0.51	0.11	4.008	104
SB-TC-10	50.65	5.7	40.16	2.36	0.07	0.13	0.33	0.17	0.36	0.08	0.112	100.1
Bore Hole ST-24-TC												
S.No.	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	MnO ₂	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅	SO ₃	Total
ST-TC-1	53.93	2.62	37.87	4.38	0.01	0.12	0.13	0.1	0.79	0.05	0.025	100
ST-TC-2	53.29	2.8	41.14	1.72	0.01	0.08	0.12	0.19	0.31	0.07	0.03	100
ST-TC-3	63.56	4.43	29.35	1.67	0.04	0.12	0.21	0.19	0.36	0.08	0.23	100.2
ST-TC-4	56.66	5.56	31	3.13	0.04	0.26	2.43	0.17	0.34	0.1		99.99
ST-TC-5	53.17	10.66	32.17	3.01	0.05	0.12	0.17	0.23	0.31	0.11	0.27	100.3
ST-TC-6	53.96	4.82	36.44	3.25	0.05	0.23	0.47	0.21	0.48	0.1	0.14	100.2
ST-TC-7	60	5.14	31.64	2.22	0.05	0.14	0.25	0.16	0.32	0.08	0.05	100.1
ST-TC-8	60.54	4.89	31.04	2.41	0.05	0.17	0.27	0.18	0.41	0.09	0.39	100.4
ST-TC-9	57.05	3.9	35.26	2.48	0.04	0.2	0.4	0.18	0.41	0.09	0.38	100.4
ST-TC-10	50.97	5.43	36.54	4.24	0.07	0.35	1.22	0.29	0.5	0.07	2.47	102.5

Table 2: Ratios of Major Elements of Bore Hole SB-14-TC and ST-24-TC samples, Thar Coalfield

Bore Hole SB-14-TC									
S.No.	Al ₂ O ₃ /SiO ₂	Al ₂ O ₃ /Na ₂ O	Fe ₂ O ₃ / Al ₂ O ₃	MnO ₂ / Fe ₂ O ₃	MgO/Al ₂ O ₃	K ₂ O/ Al ₂ O ₃	SiO ₂ /Al ₂ O ₃	Na ₂ O/K ₂ O	TiO ₂ / Al ₂ O ₃
SB-TC-1	0.83	200.4	0.19	0.006	0.006	0.003	1.19	299.9	1.19
SB-TC-2	0.65	203.1	0.07	0.01	0.005	0.02	1.53	65.84	1.53
SB-TC-3	0.67	203.9	0.12	0.004	0.005	0.02	1.47	61	1.47
SB-TC-4	0.65	216	0.07	0	0.005	0.02	1.51	61.88	1.51
SB-TC-5	0.66	230.8	0.09	0.005	0.004	0.02	1.49	62.78	1.49
SB-TC-6	0.54	543.2	0.07	0.01	0.003	0.01	1.82	114.3	1.82
SB-TC-7	0.37	154.5	0.02	0.03	0.003	0.01	2.63	216.3	2.63
SB-TC-8	0.65	102.1	0.04	0.02	0.01	0.01	1.52	111.3	1.52
SB-TC-9	0.71	111.8	0.12	0.01	0.01	0.01	1.4	101.4	1.4
SB-TC-10	0.79	236.2	0.05	0.02	0.003	0.008	1.26	140.7	1.26
Bore Hole ST-24-TC									
S.No.	Al ₂ O ₃ /SiO ₂	Al ₂ O ₃ /Na ₂ O	Fe ₂ O ₃ / Al ₂ O ₃	MnO ₂ / Fe ₂ O ₃	MgO/Al ₂ O ₃	K ₂ O/ Al ₂ O ₃	SiO ₂ /Al ₂ O ₃	Na ₂ O/K ₂ O	TiO ₂ / Al ₂ O ₃
ST-TC-1	0.83	400.8	0.1	0.002	0.002	0.01	1.19	0.12	0.06
ST-TC-2	0.65	192.4	0.04	0.005	0.002	0.008	1.53	0.61	0.07
ST-TC-3	0.67	193.2	0.04	0.02	0.003	0.009	1.47	0.52	0.12
ST-TC-4	0.65	216	0.08	0.01	0.007	0.009	1.51	0.5	0.15
ST-TC-5	0.66	160.6	0.08	0.01	0.003	0.008	1.49	0.74	0.28
ST-TC-6	0.54	155.2	0.09	0.01	0.007	0.01	1.82	0.43	0.14
ST-TC-7	0.37	164.2	0.08	0.02	0.005	0.01	2.63	0.5	0.19
ST-TC-8	0.65	198.6	0.06	0.02	0.004	0.01	1.52	0.43	0.13
ST-TC-9	0.71	204.9	0.06	0.01	0.005	0.01	1.4	0.43	0.1
ST-TC-10	0.79	138.5	0.1	0.01	0.008	0.01	1.26	0.58	0.13
10La(W)	0.63	17.5	4.84	0.002	0.08	0.08	1.56	0.65	0.04
11La(W)	0.07	4.98	3.42	0.005	0.2	0.17	13.41	1.16	0.08

Table 3: Correlation Coefficient (r^2) of Major Elements of Bore Hole SB-14-TC and ST-24-TC samples, Thar Coalfield

Bore Hole SB-14-TC										
	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅	SO ₃
SiO ₂		0.049(-)	0.94(-)	0.52(-)	0.22(-)	0.05(-)	0.10(-)	0.001(+)	0.003(-)	0.27(+)
TiO ₂	0.049(-)		0.03(+)	0.06(-)	0.001(+)	0.02(+)	-0.05	0.17(-)	0.17(-)	0.09(+)
Al ₂ O ₃	0.94(-)	0.03(+)		0.41(+)	0.10(+)	0.01(+)	0.04(+)	0.009(+)	0.017(+)	0.001(+)
Fe ₂ O ₅	0.52(-)	0.06(-)	0.41(+)		0.07(+)	0.01(-)	0.012(+)	0.02(-)	0.006(+)	0.01(+)
MgO	0.22(-)	0.001(+)	0.10(+)	0.07(+)		0.71(+)	0.87(+)	0.008(-)	0.0006(+)	0.56(+)
CaO	0.05(-)	0.02(+)	0.01(+)	0.01(-)	0.71(+)		0.68(+)	0.04(-)	0.02(-)	0.25(+)
Na ₂ O	0.10(-)	-0.05	0.04(+)	0.012(+)	0.87(+)	0.68(+)		0.02(-)	0.0007(+)	0.50(+)
K ₂ O	0.001(+)	0.17(-)	0.009(+)	0.02(-)	0.008(-)	0.04(-)	0.02(-)		0.46(+)	0.02(-)
P ₂ O ₅	0.003(-)	0.17(-)	0.017(+)	0.006(+)	0.0006(+)	0.02(-)	0.0007(+)	0.46(+)		-0.05
SO ₃	0.27(+)	0.09(+)	0.001(+)	0.01(+)	0.56(+)	0.25(+)	0.50(+)	0.02(-)	-0.05	
Bore Hole ST-24-TC										
	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅	SO ₃
SiO ₂		0.022(-)	0.55(-)	0.42(-)	0.10(-)	0.01(-)	0.14(-)	0.10(-)	0.01(+)	0.16(-)
TiO ₂	0.022(-)		0.21(-)	0.006(+)	0.007(+)	0.01(+)	0.23(+)	0.18(-)	0.50(+)	0.01(+)
Al ₂ O ₃	0.55(-)	0.21(-)		0.07(+)	0.0006(-)	0.04(-)	0.001(+)	0.15(+)	0.26(-)	0.01(+)
Fe ₂ O ₅	0.42(-)	0.006(+)	0.07(+)		0.30(+)	0.10(+)	0.008(+)	0.56(+)	0.06(-)	0.24(+)
MgO	0.10(-)	0.007(+)	0.0006(-)	0.30(+)		0.50(+)	0.32(+)	0.01(+)	0.02(+)	0.73(+)
CaO	0.05(+)	0.01(+)	0.04(-)	0.10(+)	0.50(+)		0.03(+)	0.01(-)	0.06(+)	0.90(+)
Na ₂ O	0.14(-)	0.23(+)	0.001(+)	0.008(+)	0.32(+)	0.03(+)		0.13(-)	0.11(+)	0.57
K ₂ O	0.10(-)	0.18(-)	0.15(+)	0.56(+)	0.01(+)	0.01(-)	0.13(-)		0.40(-)	0.01(+)
P ₂ O ₅	0.01(+)	0.50(+)	0.26(-)	0.06(-)	0.02(+)	0.06(+)	0.11(+)	0.40(-)		0.02(-)
SO ₃	0.16(-)	0.01(+)	0.01(+)	0.24(+)	0.73(+)	0.90(+)	0.57	0.01(+)	0.02(-)	

Sulphur (S):

The Sulphur content of SB-14-TC and ST-24-TC boreholes of Thar coalfield is shown in (Table 1). The sulphur showed strong positive correlation coefficient (Table 3) with Mg and Na (Fig. 3j,3k) a medium positive correlation with Si and Ca (Fig. 4i) and a weak positive correlation with Ti, Al, and Fe, suggests that sulphur is associated with the elements of Lithophile group. Shishkina (1964) stated that high content of the organic matter and high accumulation rate of the sediments is the main reason for the existence of sulphides in certain Pacific Ocean trenches; same is the case with studies sediments.

Phosphorous (P₂O₅):

P₂O₅ content of SB-14-TC and ST-24-TC boreholes of Thar coalfield is shown in (Table 1). Weaver *et al* (1973) mentioned that phosphorous may be present as adsorbed on the surfaces of the clay minerals. The association of phosphorous with clay minerals may also be due to ferric-oxide coatings on the clay minerals, which is a well-known fact explained by Price (1976). The P₂O₅ showed a very strong positive correlation, with K and weak positive correlation with Al, Fe, Mg, Na and Ti (Fig. 4c) suggesting the presence of clay minerals. The negative correlation of P₂O₅ with Si, Ti (Fig. 4j) and Ca suggested that P₂O₅ is not associated in the lattices of aluminosilicates.

4.**CONCLUSION**

The silica (Quartz) of studied sediments was originated and transported in detrital mode rather than having biogenic or diagenetic origin. The detrital nature of silica is further confirmed by relationship between Alumina and Silica suggesting different source rock of these elements. The studied sediments have potentially deposited along the fringe of basin of deposition in deltaic to near shore depositional environment same is confirmed by the Si/Al ratio, high percentage of silica and grain size that ranges from medium to fine grain. The deposition of sediments had occurred in humid climatic condition, under relatively fast rate, yielding immature sediments. These conditions were ideal for the generation, accumulation and preservation of woody organic material, source for one the world's biggest Thar Coalfield. The source rocks of studied sediments are potentially the igneous and metamorphic rocks as shown by secondary clays, feldspar, and quartz, probably derived from the Indian shield, which is present at the close vicinity of studied Boreholes.

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REFERENCES:

Abdallah, R.M., M.A.A. Baig, A.R. Abro, A. P. M.A. Saghair, and M.R. Ahmed, (1997), Mineral composition

- and provenance of the sediments of Thar Coal Basin, Geol. Bull. Univ. Peshawar, Vol.30, 97-106Pp.
- A.A.A. DAHAR HAKRO *et al.*
Baig, M.A.A. (1984), Some Critical atomic ratios of elements and their application in tracing the provenance of Clays from Southern England. Mehran. Univ. Res. Journ. Engg. & Tech. Vol. 3 (2): 77-92.
- Baig, M.A.A., and A Mujeeb,. (2007), Identification of Kaolin Polytypes and other minerals in sediments of Thar Coalfield, Sindh, Pakistan. Pak. J. Sci. Ind. Res. 50(6), 355-363.
- Bloxam, T.W. and R.L. Thomas (1969), Palaeontological and geochemical facies in the *Gastriocerassubrenatum* marine-band and associated rocks from the North crop of the South Wales coalfield. Q. J. Geol. Soc. London. V:124, .239-281.
- Cheema, M.R., S.M. Raza, and H. Ahmad, (1977), Stratigraphy of Pakistan: Memoirs of the Geological Survey of Pakistan, Vol. 12, 138 Pp.
- Cosgrove, M.E. (1973), The geochemistry of the Red Beds of South-West England, including the Permian volcanics. Unpubl. Ph.D. Thesis, University of Southampton. 136 pp.
- Couture, R.A., (1977), Composition and origin of Palygorskite-rich and Montmorillonite-rich zeolite-containing sediments from the Pacific Ocean, Chem. Geol. Vol. 19, 113-130 Pp.
- Ghaznavi, M.I. (2002). An overview of coal resources of Pak., Pre Publication Issue of Record V. 114, 167-172 .
- Hakro, A. A. D. and M. A. A., Baig, (2013), Depositional Environment of the Bara Formation, Fort Ranikot Area, Sindh, Sindh Univ. Res. Jour. (Sci. Ser.) Vol.45 (1): 83 - 94.
- Hakro, A. A. D., (2013), Mineralogical Investigation of the Bara Formation of Sindh, Pakistan, Sindh Univ. Res. Jour. (Sci. Ser.), Vol. 45 (3), 580 - 588
- Hakro, A.A.D., and M.A.A. Baig, (2014), Depositional environments of the Bara Formation from Lakhra areas Sindh, Pakistan. Pak. J.Sci. Ind. Res. Ser. A: Phys. Sci. 2014 (57) 1, 20-31.
- Hakro, A.A.A.D., Q.D. Khokhar., A.S. Mastoi, A.H. Markhand, S.A. Shaikh, G.N. Shaikh (2014), Major elements of Bara Formation at Ranikot Fort, Southern Indus Basin, Pakistan. Sindh Univ. Res. Jour. (Sci. Ser.), Vol.46 (2) 239-248.
- Hunting Survey Corporation Limited, (1961), Reconnaissance geology of part of West Pakistan: Colombo Plan Cooperative Project, published for the Government of Pakistan by the Government of Canada, Oshawa, Maracle Press, 550 Pp.
- Jaleel, A., S.G. Alam, M.T. Hasan, (2002). Coal resources of four blocks in Thar coalfield, Sindh, Pakistan. Geo. Surv. Pak. Recs. V-115. 74 pp.
- Khokhar. Q. D., A. A. D. Hakro, S. H., Solangi, I. A., Brohi, A.H., Markhand, (2014), Textural Maturity and Depositional Environment of Bara Formation at Ranikot, Sindh. Sindh Univ. Res. Jour. (Sci. Ser.), Vol.46 (1) 71-76.
- Migdisov, A.A., (1960), On the titanium/aluminum ratio in sedimentary rocks, Geochemistry (U.S.S.R), English Transl. Vol.2, 178-194 Pp.
- Pettijohn, F.J., (1957), Sedimentary rocks, 2nd Edition, New York (Harper and Brothers), 628 pp.
- Price, N.B. (1976), Chemical diagenesis in sediments. In: J. P. Riley & R. Chester (Editors): Chemical Oceanography. V:6, Academic Press: London. pp. 1-58.
- Ronov, A.B., Y. P. Girin, G.A Kazakov,. and V.I., Ilyukhin, (1965), Comparative geochemistry of geosynclinal and platform sedimentary rocks. Geochem. Int. Vol. 2, 692-708 Pp.
- Shishkina, O.V. (1964), In B. Price (1976), Chemical diagenesis in sediments. Chemical Oceanography, Vol. 6, 44 Pp.
- Spears, D.A. (1964), The major element geochemistry of the Mansfield marine band in the Westphalian of Yorkshire. Geochem. Cosmochim. Acta. Vol.28, 1679-1696 Pp.
- Sulaiman, A.M.A., (1972). The Geochemistry of the Namurian Argillites. Thesis, Southampton University, Southampton (unpublished).
- Tucker, M., (1988), Techniques in Sedimentology, Cambridge, Blackwell Science, 394Pp.
- Weaver. C. E., and Pollard, L.B., (1973), The chemistry of clay minerals Elsevier. New York 213Pp.
- Wnuk. C., J. R, Sanfilipo, A. H. Chandio. S. F. Fatmi. (1993), The Stratigraphy and Coal resources potential of the Bara Formation in the Fort Ranikot Area, Sindh Province, Pakistan: A Progress Report, (Jointly Prepared Report), Project Report (IR) Pk-105, Published by the GSP, USGS, U.S Agency for International Development. 73-76.

