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ENRICHMENT AND DISTRIBUTION OF URANIUM IN THAR COALFIELD, SINDH, PAKISTAN

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Abstract

The Thar coalfield is the largest coalfield of Pakistan and that spreads over 9100 sq km in the south eastern-part of Sindh. The coalfield rests on a structural high in the eastern part of the desert. The high is underlain by relatively shallow granitic basement rocks. It is widely accepted that the Uranium in Thar coal has originally been derived from underlying igneous basement.

The Uranium in Thar coal varies from 4.3 ppm in Block-III to 1.8 ppm in Block-II. The results show that coals in Block-I and II have lower concentration of Uranium while Uranium content, in Block-III of Thar coalfield, have relatively higher concentration because of it had leached or transported epigenetically from kaoline or granitic wash from granitic basement.

The studies suggest that the ultimate source of Uranium in Thar coal is granitic basement rock from where Uranium may have migrated to the coal and this Uranium bearing combustion waste can be extracted by various leach methods.

Keywords: Thar coal, Uranium, Bara Formation, XRF, Basement Complex.

1. Introduction

Pakistan lies along the contact between the Indian and Eurasian Plates. It is situated in the north-western corner of the Indian Plate, to its south-east is Indian Plate and to the north the Asian/KaraKorum Continental Plate.

The province of Sindh is situated in the Lower Indus Basin. Lower Indus Basin has number of coal basins. These basins extend westward from Thar coalfield, through Tando Muhammad Khan, Badin to Lakhra-Sonda-Thatta area **(Fig.1-a).** The western part of Sindh falls in the folded belt zone where as most of the eastern part covers the Platform slope. Shelf platform and carbonate deposits ranging in age from Triassic to Recent overlie the basement slope (Kazmi and Jan, 1997).

The Thar coalfield is located between latitudes 24°15'N and 25°45' N and longitudes 69°45' E and 70°45' E in the south eastern part of Sindh. The Thar desert lies in the south-eastern part of Pakistan on the stable western margin of the Indian Plate (Kazmi and Jan, 1997). It is connected with a 515km metalled road upto Nagarparkar from Karachi.

This coalfield is divided into following blocks, in this paper Blocks I, II and III are discussed with reference to Uranium Enrichment.

1. Sinhar Vikian-varvai, (Block-I)
2. Singharo-Bhitro, (Block-II),
3. Saleh Jo Tar, (Block-III)

Uranium in coal has been studied by many workers. Vine and Moore (1952) have studied the Uranium bearing coal of Idaho. (Goldschmidt 1954 and White 1958) analyzed lignite coal of South Dakota by X-ray Diffraction and Moore *et al.,* (1959) had studied Uranium

bearing lignite in southwestern Dakota. Lead and Uranium in coal have been studied by Chow and Earl (1972), Raask (1985), Swaine (1990) and Clarke and Sloss (1992).

Occurrence of Uranium in Pakistan was first reported by Crookshunk (1955) and Jud (1957). Uranium mineralization in Siwalik sandstones from Pakistan had been studied by (Basu *et al.,* 1974).

Geology and potential for surfacial Uranium deposits in Nagarparkar-Tharparkar area .

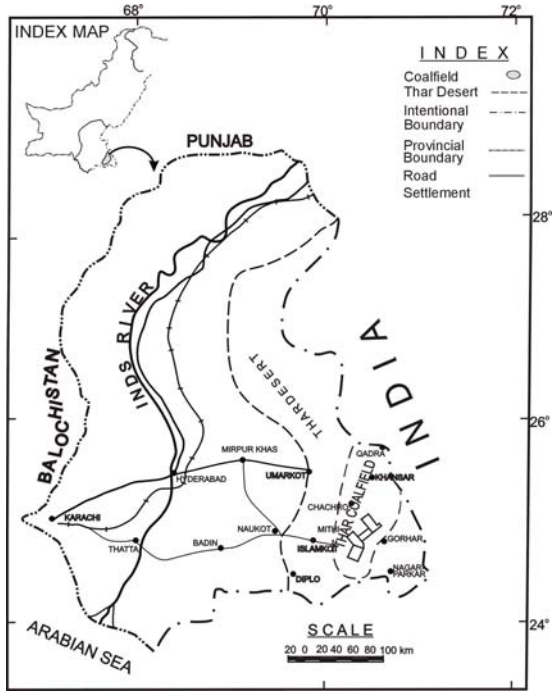


Fig. 1-a. Location map of Thar coalfield.

complex was carried out by Ahmed and (Chaudhary 2007, Siddiqui, 2008) studied the heavy and trace metal concentrations in Thar coal.

Uranium is a naturally occurring radioactive element. Natural Uranium is a mixture of three types, or isotopes, called U-234 (^{234}U), U-235 (^{235}U), and U-238 (^{238}U). All three types of Uranium are having the same chemical formula, but they have different radioactive properties. U-238 is by far the most common type of Uranium on earth and is the least radioactive. U-234 is the most radioactive type of Uranium. U-235 is used as a fuel in power plants and weapons. The amount of U-234 and U-235 in natural Uranium deposits had increased through a process called enrichment (Frank and Guggin, 2005).

2. Geology of Thar

The Thar coalfield is covered by thick sand dunes with an average depth varying from 14-93 meters resting upon the structural platform in the eastern part of the desert. The structural Platform is underlain by relatively shallow granitic basement rocks **(Fig.1-c).** This granite complex dips down abruptly beneath the western part of the Thar desert and is highly faulted (Fasset and Durrani, 1994).

An unconformity at the base of underlying sedimentary sequence eastward to the point where the Paleocene/Eocene rocks rest directly on the basement granite is present. The geological investigation has proved that coal-bearing strata of Paleocene-Eocene sediments unconformably overlie the Pre-Cambrian basement igneous rocks exposed at Nagar Parkar (Fasset and Durrani, 1994).

The basement rocks are represented by granite and granodiorite at the depth of 110 to 277 meters. The granite is of white, pinkish grey to very light grey in colour and coarse grained, having feldspar altered kaolinite (Jaffery, 1994).

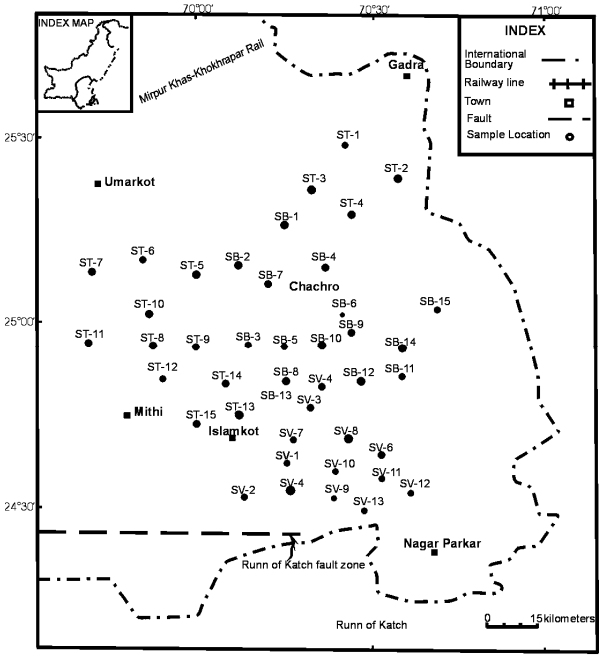


Figure 1-b. Map showing locations of samples collected from Thar coalfield.

The metabasites are medium to coarse-grained volcanics and plutonic rocks that have been metamorphosed to epidote amphibolites and contain acidic dykes of rhyolite to quartz trachyte composition (Jan *et al.*, 1997). The Coal bearing horizon of the Paleocene-Eocene sediments above the basement complex is designated as the Bara Formation **(Table 1).**

The X-ray fluorescent methods have been used for chemical analysis of major elements in geological materials including coal (Kiss, 1966, Kuhn *et al.,* 1975, Gluskoter *et al.,* 1977).

The basic principle of XRF is to bath the coal samples in the broad white radiation spectrum obtained from a standard laboratory X- ray tube.

Table 1. The generalized stratigraphic sequence of the Thar coalfield (Jaleel *et al.,* 2002)

Formation	***Age***	***Thickness***	***Lithology***
Dune Sand	Recent	14m to 93m	Sand, Silt and Clay
……. Unconformity …….			
Alluvial Deposits	Sub Recent	11m to 209m	Sandstone, Siltstone, Clay stone
……. … Unconformity ……			
Bara Formation	Paleocene to Early Eocene	+52m (variable)	Clay stone, shale, sandstone, coal, carbonaceous clay stone
…… Unconformity…….			
Basement Complex	Pre-Cambrian	----	Granite and quartz and diorite

3. Materials and Methods

About fifteen core samples of coal from three blocks of Thar coal basin were collected from core library of Sindh regional office of the Geological Survey of Pakistan. Figure1-b shows the location of the samples; depth of each location and analytical results of Uranium are shown in (**Table 2).**

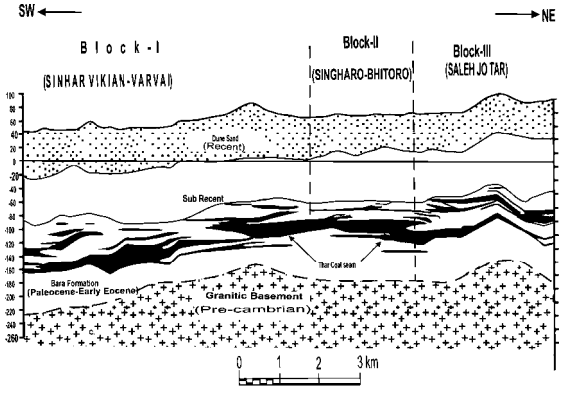


Fig. 1-c. Generalized cross-section of Thar coalfield (Jaleel *et al.,* 2002).

The absorption of the radiation by individual elements is generally by means of excitation of a 1s electron (K-edge) absorption process or a 2s or 2p electron (L-edge) absorption process for higher atomic number elements.

A total of forty three drill core samples were analysed from various blocks (Block-1, II, and III) of Thar coalfield. These samples of coal were grinded in a grinding mill up to 200 mesh size. 10 grams of this powdered sample was taken and mixed with 1.24 grams of a wax that is used as a binder. Finally, 10 grams of this mixture was taken and pressed up to 25 N in a pressing machine to prepare a rounded pressed pellet. These pressed pellets were then put in a steel cup and transferred to the sampling chamber of Bruker-AX, S4-PIONEER machine with the help of computer software. The elements were irradiated with 15- 60Kv and irradiated with 15 - 60Kv and 20-150mA current and analyzed by

Geomajor elements software: write spectra plus softer, geomajor method was used.

4. Results and Discussion

The analytical results of Uranium in coal are shown in Table 2 and displayed in Fig. 2 and 3. In Block-I of the Thar coalfield, the Uranium content in coal varies from 1.0 to 2.1 ppm, in coal seams present at the depths of 178.6 to 179.86 meters. The basement is found at the depth of 256.00 to 260.91 meters. Prior to this a 2 meter thick and thin kaolinized weathered zone of granitic wash has also been noticed (Fasset and Durrani, 1994).

In Block-II of the Thar coalfield, the Uranium concentration in coal varies from 0.9 to 1.8 ppm and the depth of basement rock varies from 256.00 to 260.91 meters. In most of the places kaolinized/weathered zone was encountered just above the basement rock. Basement rocks are mainly granites that is essentially made up of perthitic feldspar, minor plagioclase and quartz. Reibeckite is mainly accessory minerals along with iron oxide, olivine, zirxon, sphene and alenite occurs as accessory minerals (Jaleel *et al.,* 2002).

In Block-III the Uranium content in coal varies from 1.8 to 4.3 ppm, these higher figures indicate that the source rock i.e. granitic basement essentially made up of perthitic feldspar, minor plagioclase and quartz. Reibeckite is mainly accessory minerals along with iron oxide, olivine, zirxon, sphene and alenite occurs as accessory minerals (Jaleel *et al.,* 2002).

Table-2. Showing depth and Uranium concentration in Thar coal.

Sample No.	BLOCK-I		BLOCK-II			BLOCK-III		
	Depth from coal obtained (in meters)	Uranium (in ppm)	Sample No.	Depth from coal obtained (in meters)	Uranium (in ppm)	Sample No.	Depth from coal btained (in meters)	Uranium (in ppm)
SV-1	223.60	1.2	SB-1	209.09	1.5	ST-1	218.64	2.3
SV-2	224.66	1.4	SB-2	224.3	1.7	ST-2	227.68	1.8
SV-3	240.06	2.1	SB-3	203.00	1.3	ST-3	230.61	3.1
SV-4	221.15	1.7	SB-4	215.19	1.4	ST-4	224.77	2.7
SV-5	224.85	1.3	SB-5	215.67	1.1	ST-5	224.51	1.9
SV-6	227.71	1.7	SB-6	215.19	1.2	ST-6	230.61	2.6
SV-7	221.44	1.2	SB-7	218.72	1.3	ST-7	217.50	1.9
SV-8	218.24	1.6	SB-8	221.28	0.9	ST-8	224.81	3.8
SV-9	224.15	2.1	SB-9	215.52	1.5	ST-9	249.20	4.1
SV-10	221.61	1.0	SB-10	221.28	1.7	ST-10	221.40	2.7
SV-11	230.75	1.7	SB-11	223.29	1.2	ST-11	245.24	2.6
SV-12	230.76	1.8	SB-12	233.48	1.4	ST-12	233.96	2.8
SV-13	240.00	1.2	SB-13	215.67	1.6	ST-13	228.66	4.3
			SB-14	239.57	1.8	ST-14	228.80	3.1
			SB-15	219.94	1.3	ST-15	251.76	2.9

It Block-III the uranium content varies from 1.8 to 4.3 ppm, these higher figures indicate that source i.e granitic basement is at the depth of 256.00 to 260.91 meters. The encountered basement rock is weathered granite of white to pinkish gray to very light gray in colour, coarse grained; having altered feldspar to kaoline, mafic

grains and basic dykes of doleritic composition have also been found that also contain Uranium in some amount. In this block kaoline/granitic wash also contains grains of quartz, feldspar in kaolinitic matrix. Granite wash also contains a few black, fine ferromagnesian grains (Jan *et al.*, 1997). It is present above and below the coal bearing horizons at shallow depth. also contains a

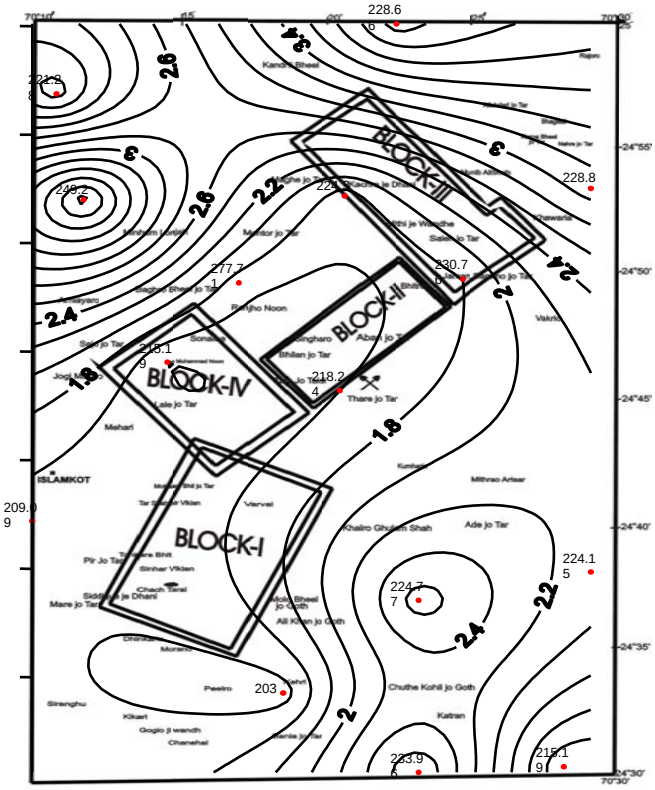


Fig.2 Isopach map showing arial distribution of Uranium in various Blocks of coal at Thar.

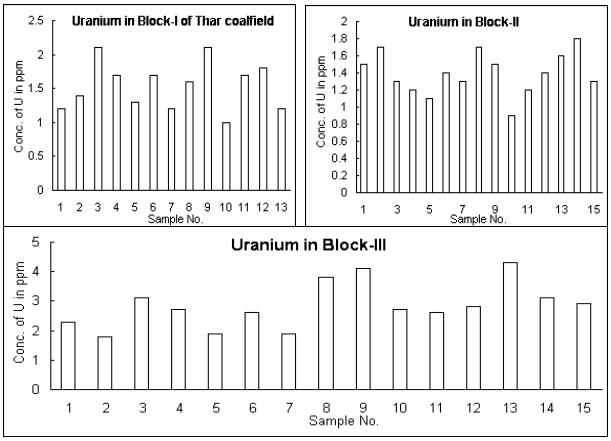


Fig. 3. Uranium in coal of block I, II and III of Thar coalfield.

few black, fine ferromagnesian grains (Jan *et al.*, 1997). It is present above and below the coal bearing horizons at shallow depth.

Based on the studies concerning the concentration and dispersion of Uranium in Thar coal it can be suggested that the Uranium entered the coal in aqueous solution as a complex alkali or alkaline earth UO_2 CO_3 and that UO_2^{++} ion was absorbed by the coal and reduced to UO_2. Studies revealed that UO_2 is dispersed throughout the coal.

In this regard three hypotheses given by Denson (1959) explaining the occurrence of Uranium in some coals:

Syngenetic: The Uranium was deposited from surface waters by living plants or in dead organic matter in swamps prior to coalification.

Diagenetic: Uranium was introduced into the coal during coalification by water bearing the Uranium from areas marginal to the coal deposits or from the consolidating enclosing sediments.

Epigenetic: Uranium was introduced in the coal after coalification and after consolidation of the enclosing sediments by groundwater deriving Uranium from hydrothermal sources or from unconformably overlying volcanic rocks (Ahmed and Chaudhary, 2007).

5. Conclusion

Low-temperature hydrothermal fluids were important factor for the enrichment of Uranium in coal. Veined minerals including quartz, calcite, ankerite, pyrite and also clay minerals, could lead to the enrichment of Uranium in coal from low-temperature hydrothermal fluids. A typical XRD pattern of Thar coal; indicate that the main minerals i.e. quartz, calcite and kaolinite (Siddiqui and Shah, 2009), and these minerals are the carriers of Uranium in coals. The enrichment of Uranium in Thar coal had been caused by the kaolin/granite wash containing grains of quartz and feldspar in white kaolinitic matrix. Kaolin is found above and bellow the coal beds with in Bara Formation. It is revealed that Uranium in Thar coal might had migrated epigenetically from the Indian shield i.e. igneous basement rocks.

There is possibility of Uranium occurrence in veins and pegmatites as in Karai gabro, Nagarparkar, uranium had migrated from hydrothermal solution.

As the Uranium may cause radioactivity during the coal combustion for power generation, it may cause various environmental and health problems, particularly Uranium bearing fly ash is of great environmental concern. The combustion of Thar coal will generate significant amounts of Uranium-bearing waste (Bottom ash and Fly ash). The Uranium from Thar coal can be extracted and recovered with various in situ leach methods. The Uranium contained in fly ash is soluble in simple acid extraction solutions (such as sulfuric acid).

This method will focus on refining the leaching, filtering and ion exchange processes. As the lime (calcium carbonate) is used to remove the sulfur dioxide produced during the combustion of coal and, as a result, is often present in the residual ash. This will react with the acid to produce significant amounts of gypsum (calcium sulfate) and iron oxide, which require removal from the leached solutions by filtration, before they are passed through the ion exchange system.

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