Mineralogical Investigation of the Bara Formation from Lakhra Anticline, Sindh province, Pakistan

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Abstract: The present study shows the bulk mineralogical composition of the Bara Formation from Lakhra anticline, near to Lakhra coalfield area of the Sindh province of Pakistan. The petrography, scanning electron microscope and X-ray diffractommeter were used for the detailed mineralogical investigations. Quartz, feldspars, hematite, gypsum, chlorite and goethite minerals were obtained from above methods. Quartz, feldspar and chlorite minerals indicated that the sediments were transported from igneous and metamorphic rocks and the hematite and goethite indicated the continental environment for the studied formation. Mineralogical investigation of the Bara Formation indicates that the sediments were supplied from the Igneous and metamorphic rock terrane. It can be said that the Bara formation sediments were supplied from the Igneous and metamorphic complex which is exposed in the southeastern part of the studied area.

Keywords: Bulk Mineralogy, Bara Formation, Lakhra, Quartz, XRD and SEM.

1. INTRODUCTION

The majority of the Coal resources of Pakistan are present in the Sindh province. Coal is being mined from Bara Formation (Middle Paleocene age) in the Lakhra Coal field on the crest of Lakhra anticline located 30 km NW of Hyderabad. The Coalfields of Lakhra, Ongar, Jherruck, Sonda, Indus East, Badin and Thar are developed in the Bara Formation and hold the largest Coal resources of the country in the Sindh province [1].

The Bara Formation is composed of sandstones, shale and minor amount of siltstone; it is the oldest Formation and occurs in the core of the Lakhra anticline, whereas the Laki Formation is the youngest Formation of this area and occurs on the flanks of the Lakhra anticline. Structurally the Lakhra anticline is a part of long doubly plunging anticline, which runs North-South direction and starts from Survey of Pakistan (SOP) toposheet nos. 40 C/1 to 40 C/4. Stratigraphically, the oldest formation of the studied area is the Bara Formation (Middle Paleocene). The Lakhra Formation, Laki Formation and Mancchar Formation are exposed in the studied area [2]. The stratigraphy of the Lakhra area is tabulated in Table **1**. The exposed section of the Bara Formation in Lakhra areas is 20 meter thick; it is located, near Lailian Nala, and is composed of sandstone, shale and minor siltstone. The sandstones are yellow, purple, white and red in colors, loose, friable, poorly sorted, unconsolidated - consolidated, and cross-bedded [3]. Shale is splintery, fissile and earthy in color. Siltstone is interbedded with shale and Sandstones. Wnuk *et al.* [4] interpreted these sediments as inner-shelf tidal sand waves grading upward into estuarine sediments followed by intertidal and coastal plain deposits containing.

Baqri [5] described the distribution of sulphur contents in the coal of Paleocene of Sindh. Abdallah *et al*. [6] worked on the bulk and clay minerals of Bara Sediments from Thar Coalfield area. Baig and Mujeeb [7] described the types of kaolin and clay minerals of Bara Formation from Thar Coal field area. Hakro [8] reported the sediments of Bara Formation from Ranikot area are composed of quartz (low), hematite, potash feldspar, gypsum and goethite minerals. Hakro and Baig [9-10] described the fluvial-deltaic depositional system of Bara Formation from Lakhra and Ranikot localities. Khokhar *et al.* [11] defined the lithofacies of Bara Formation from Lakhi Rang and concluded that the sediments of Bara Formation are submature to mature from Ranikot locality. Hakro *et al.* [12] investigated and reported the detritus of Bara Formation are derived from igneous and metamorphic source rocks. Previous researchers are worked on Bara Formation with different aspects. Bulk mineralogy of the Bara Formation is investigated in present work from Lakhra anticline. The exposures of the studied formation show their presence only in nala cuttings of Lakhra coal field area. Samples were observed by three ways, petrographic, scanning microscopic and x-ray diffraction method. Sample preparation and observation of petrographic study were completed at Advance laboratory of centre for pure and applied

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ISSN: 1814-8085 / E-ISSN: 1927-5129/16

Table 1: Stratigraphy of the Lakhra Areas

Age	Formation	Lithology
Eocene	Laki Formation (Sonhari member and Meting Limestone)	Limestone, Sandstone, shale
Late Paleocene	Lakhra Formation	Limestone and Shale
Middle Paleocene	Bara Formation	Sandstone, Siltstone, shale

Geology, University of Sindh, Jamshoro. SEM study was completed at the General Centralized Laboratory, University of Karachi, Karachi. The bulk minerals composition of all samples of the studied sections of the Bara Formation was scanned on a Siemens' D-5000, X-Ray Diffractometer, in the laboratories of the Pakistan Council of Scientific and Industrial Research, Karachi.

2. MATERIALS AND METHODS

Two sections of the Bara Formation from Lakhra anticline, one is from the eastern flank near Lailian nala and other is from the western flank near agro nala of the Lakhra anticline were measured for thickness. Twenty two rock samples were collected from the exposed outcrop of the studied formation. The samples were properly labeled, packed in sealed plastic bag and stored in large bag.

Random powder samples from Lakhra anticline were scanned on XRD from 2,2θ, to 65,2θ to detect the presence of non-clay minerals. All non-clay minerals, present in the samples, give their diagnostic XRD reflections between the scanning ranges mentioned above. Non-clay minerals which showed their presence in the sample, were identified by recognizing the characteristics d-spacing of common minerals [13,14,15]. Techniques of the Scanning Electron Microscopy and Optical petrography, were also used in the present study, to identify the minerals, present in the bulk-rock samples.

Four samples were selected for the petrographic study, four samples were selected for the Scanning Electron Microscopy (SEM) and twenty two samples of the studied formation were prepared for the X-ray Diffractometer.

3. RESULTS AND DISCUSSION

Quartz, Plagioclase feldspars and K- feldspars showed their presence in studied samples by petrographic study (Table **2** and Figure **2**). The results of the SEM studies of the studied samples are tabulated and display in the Table **3** and Figure **1**). The results of XRD scanning of the investigated samples and their diffractograms with d-spacing and degrees in (2θ) values are shown in Figures **3** to **4**.

Table 2: Results of Petrographic Study of Selected Samples from Lakhra Sections

S. No	Grain Size	Grain Shape	Grain Sorting	Matrix	Cement	Mineral Content
6La (W)	Medium	Subangular	Moderately	Grain Supported	Siliceous & clayey	Quartz & Plagioclase. alkali feldspar
7 La(W)	Fine	Subangular	Well	Grain Supported	Ferruginous & clayey	Quartz & alkali feldspar
Abandoned						
11La(W)	Coarse	Angular-Subangular	Moderately	Grain Supported	Ferruginous (low) & clayey	Plagioclase, alkali Feldspar, Quartz

Table 3: Interpretation of SEM Results of Selected Samples from Lakhra Sections

Sample	Mineral which has been found in SEM	Sample	Mineral which has been found in SEM
S-8La(E)	Quartz	S-13La(E)	Quartz, Fragments of Kaolinite
S-10La(E)	Quartz,	S-10La(W)	Quartz, Fragments of Kaolinite,
S-12La(E)	Quartz, Fragments of Kaolinite		

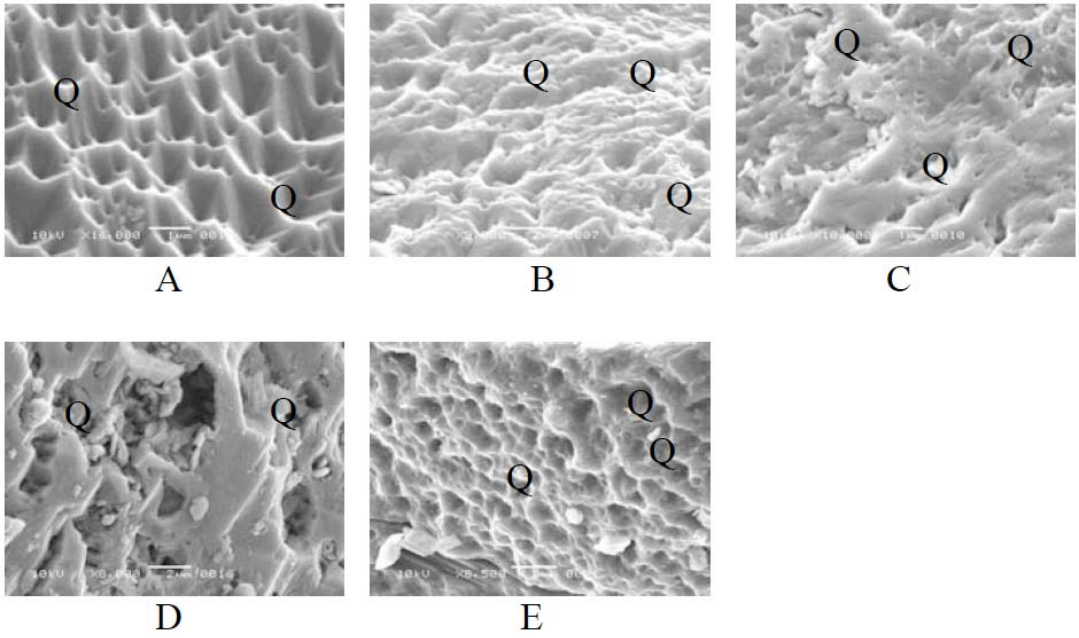

Figure 1: SEM images of Bulk-rock minerals of the Bara Formation from Lakhra Areas.

A = S-8La(E) (B)Quartz , B = S-10 L(E) (B)Quartz , C = S-12La(E) A-Quartz, D = S-13La(E) D-Quartz , E = S-10La(W) A-Quartz.

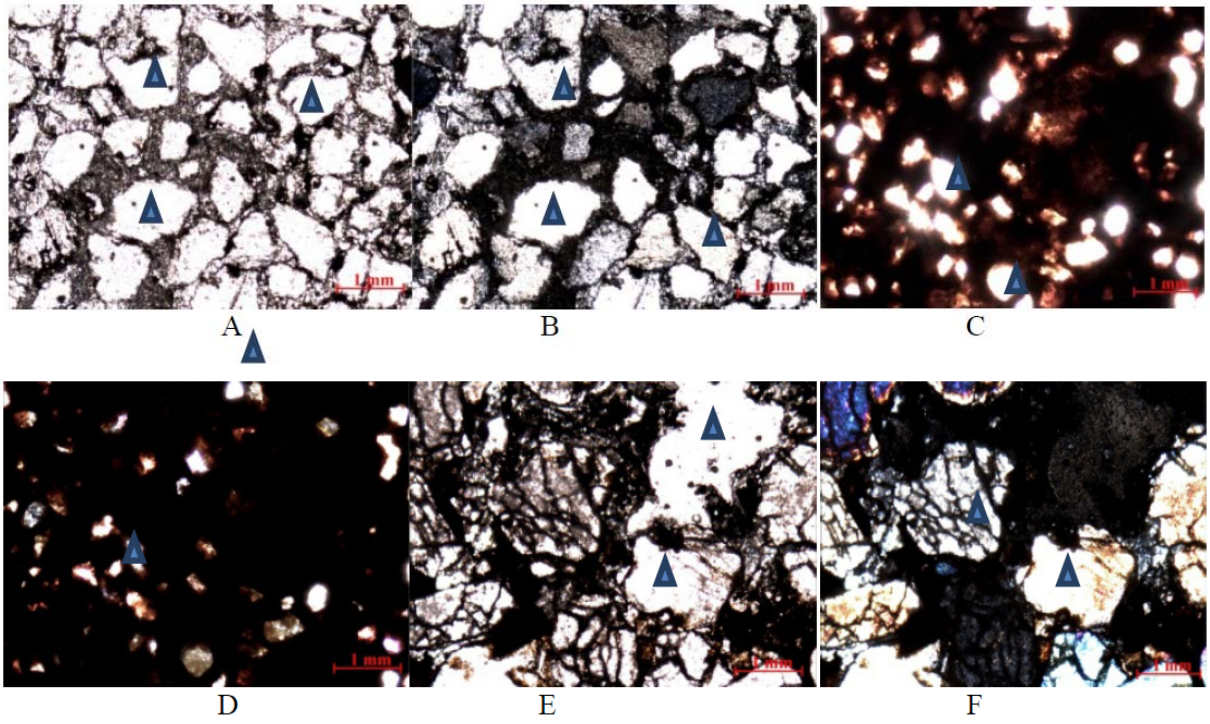

Figure 2: Microphotograph of samples of Lakhra areas.

Quartz=

A=Ordinary light Photomicrograhof S.6La(W)Lakhra westSection,B=Polarized light photomicrograph of S.6La(W)Lakhra west Section,C= Ordinary light Photomicrograh of S.7La(W)Lakhra westSection,D= Polarized light photomicrograph of S.7La(W)Lakhra west Section,E= Ordinary light Photomicrograh of S.11La(W)Lakhra eastSection,F= Polarized light photomicrograph of S11La(W)Lakhra east Section.

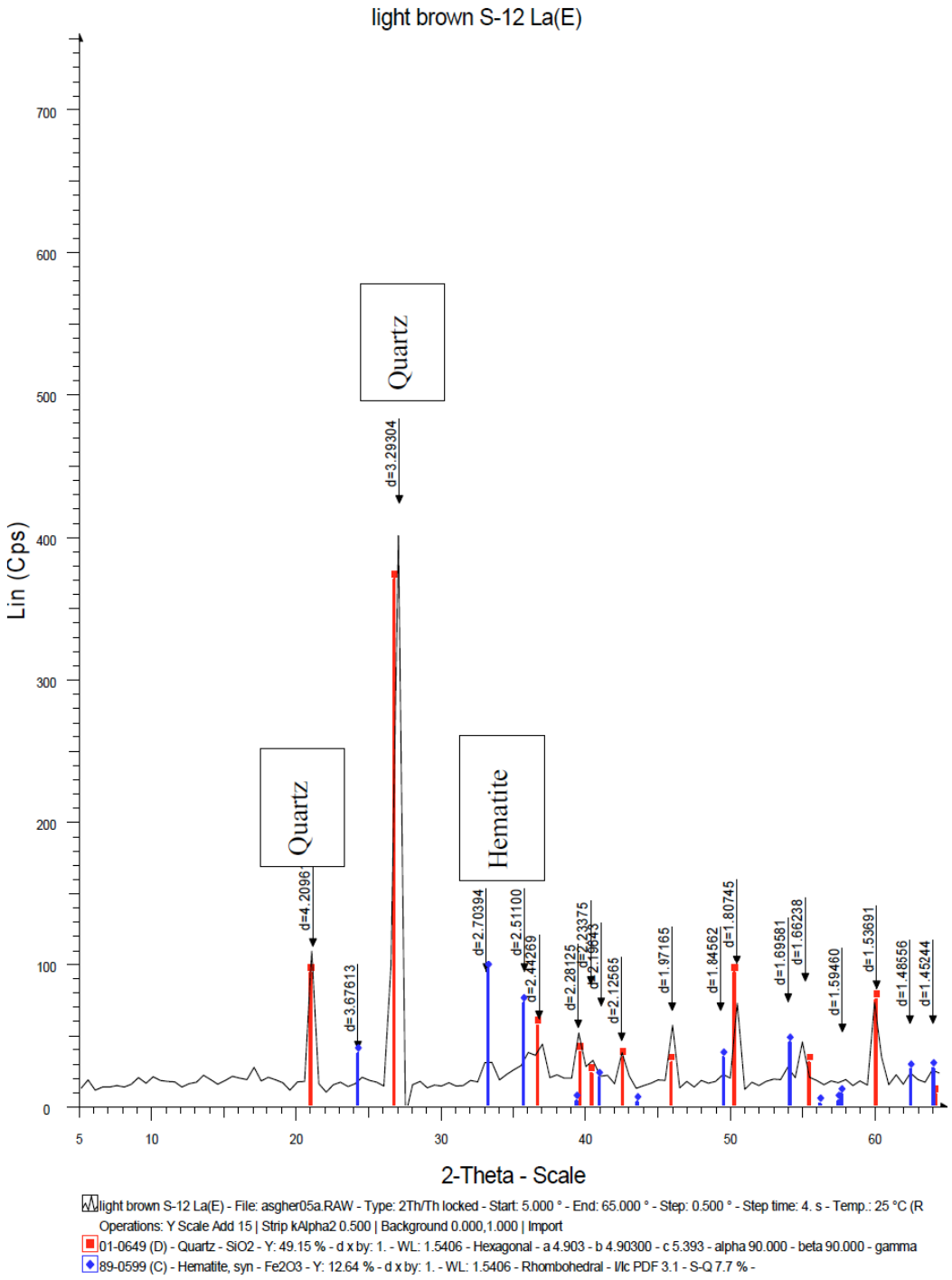

Figure 3: Diffractograms of sample S-12 La (E) of Lakhra East Area.

Thin sections study showed that the quartz and feldspars are the major components (Figure **2**), with minor amounts of silt and clay matrix. Minerallogically these samples are sub-mature sandstones with loosely to semi compacted cement of siliceous, clayey and ferruginous nature. Reddish-brown patches indicate the presence of ferruginous cement; all suggested that the studied sandstones were deposited under fluvial environments. SEM imagination showed the presence of Quartz and broken parts or fragments of the Kaolinite, see Figure **1**.

Quartz, Hematite, Gypsum and Potash feldspar showed their presence in the studied samples by their diagnostic XRD reflections, see Figures **3** & **4**. Quartz (low) was detected in all the samples of both sections by its characteristic XRD peak positions at 26.60°, 2θ (3.34Å), 20.81°, 2θ (4.26Å); and also 50.20°, 2θ

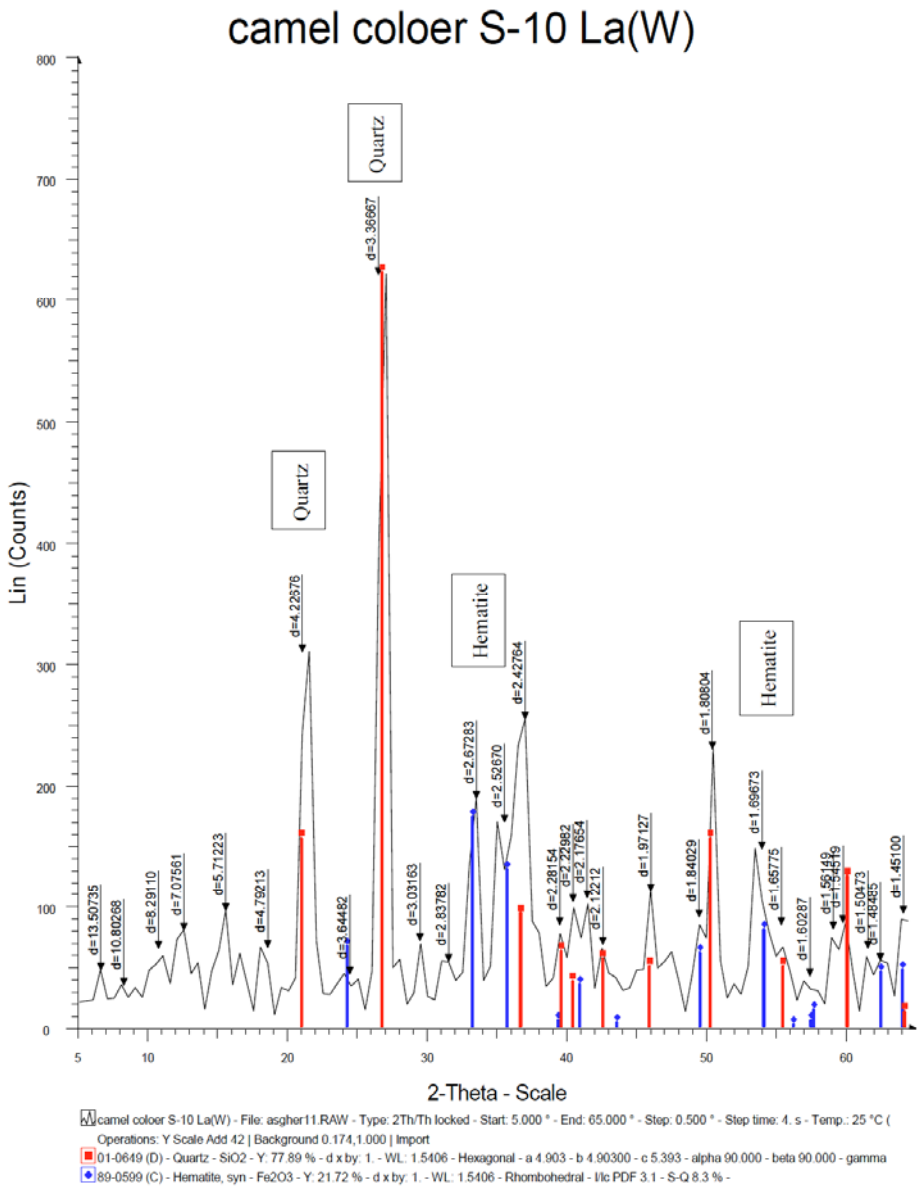

Figure 4: Diffractograms of sample S-10 La (W) of Lakhra West Area.

Table 4: Minerals Identified by XRD of Samples Bara Formation from Lakhra

Sample Number	Mineral Composition	Sample Number	Mineral Composition
1La(E)	Quartz (low)	7La(E)	Quartz low, K-feldspar
2La(E)	Quartz (low)	8La(E)	Quartz (low) Hematite & K-feldspar(1p)
3La(E)	Quartz (low)	10La(E)	Quartz (low),K-feldspar
4La(E)	Quartz (low), Hematite	12La(E)	Quartz (low), Hematite
6La(E)	Quartz (low), Gypsum	13La(E)	Quartz (low,) feldspar
2La(W)	Quartz low, Hematite	7La(W)	Quartz (low)
3La(W)	Quartz (low), Gypsum	8La(W)	Quartz (low)
4La(W)	Quartz (low)	9La(W)	Quartz (low)
5La(W)	Quartz low,	10La(W)	Quartz low, Hematite
6La(W)	Quartz low	11La(W)	Quartz low

(1.81Å). Hematite showed its presence by XRD reflections at 23.84°, 2θ (3.72Å) and 32.98°, 2θ (2.71Å). It showed its presence in the samples numbers (4, 8, 10, 12 La (E) and (10 La (W) and also present in other samples (2, 4, 6, 8 & 11 La (W)) but it showed low peak intensity and only one peak. Gypsum indicated its existence only in Sample (6 La (E). It was detected by its XRD reflections at 11.65°, 2θ (7.58Å) and 29.12°, 2θ (3.06Å). Potash feldspar indicated its presence only in one sample number 13 La (E). It showed its presence on X.R.D diffractograms by its diagnostic peak positions at 21.16°, 2θ (4.19Å) and 27.00°, 2θ (3.29Å).

Quartz (Low) showed strong peaks on X-ray diffractograms which suggested that quartz (low) is well crystalline. Higher amount of Quartz (low) in these sediments, [2,16,17], may be due to near-shore type of deposition. Alpha quartz is present in samples of the whole-rock. It has been contributed by the weathering of the pre-existing igneous complexes [7]. Kaolinite is less abundant in ancient sediments as compare to younger sediment and it must therefore be changed to some other clay mineral [18]. Weaver [15] summarized the detrital origin of clay minerals in sedimentary rocks and they strongly reflect their source material and only slighty modified in their depositional environment. Kaolinite generally is formed during the weathering and the alteration of Potassium feldspar which is an essential ingredient of granite. Kaolinite probably was supplied to the detritus of the studied sediments from the Nagarparkar Igneous and Metamorphic Complex. Presence of Kaolin mines in the surroundings of the Nagar Parker area supports the above statement. Van Houthen [19] stated that the load of ferric hydroxide colloid present in many streams, and transported in rivers and the near-shore ocean as a dilute suspension or adsorbed on the surfaces of clay minerals, may be the source of origin of iron minerals in soils. According to him after deposition, the ferric hydroxide spontaneously de-waters to form limonite; if complete dehydration occurs then hematite is formed. The presence of gypsum in the studied samples may indicate the occurrence of high salinity in pockets, during the deposition of the studied sediments. Hematite showed its presence as a cementing material (ferruginous) during the microscopic investigation of samples of Lakhra sections. Hematite may be present as coatings on the sand grains or minerals, present in the studied samples. Gypsum showed its presence only in two samples. The presence of gypsum provided information regarding the salinity, temperatures and the pressures existed in the environments of deposition for the studied sediments. The potash feldspar is essential minerals of granite an igneous rock. K-feldspar is much more common in granites and gneisses, therefore it may be assumed that potash feldspar in the samples of Lakhra sections was supplied from the granites/ gneisses exposed in the Nagarparkar Igneous and Metamorphic complex.

4. CONCLUSION

Presence of Quartz (low), Hematite, Gypsum and Potash feldspar in the studied samples are indicated that quartz and potash feldspar supplied from the area where granites are well exposed and hematite indicates the oxidation phase of the mineral processes. In the above discussion it is concluded that the detritus of the minerals are supplied from the Indian shield rocks which is exposed in the southeast of the studied area.

ACKNOWLEDGEMENTS

The authors are grateful to the Scietific officcer, Mr. Kamalludin Shaikh, PCSIR laboratory Karachi and Mr.Yousuf of General Centralized Laboratory (GCL), University of Karachi, for the permission of using the XRD Lab facilities and his fruitful suggestions are also acknowledged. The author is indebted to offer his sincere thanks to Prof. Dr. Mohammed Atique Ahmed Baig, for the guidance, encouragement patience for reading and correcting the first draft of this paper and his valuable suggestions. Author is also thankful to the Prof. Dr. Sarfraz H. Solangi, Director, Centre for Pure and Applied Geololgy, University of Sindh, Jamshoro, for his moral support.

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Received on 17-03-2015 Accepted on 18-11-2015 Published on 15-01-2016

http://dx.doi.org/10.6000/1927-5129.2016.12.01