SindhUniv. Res. Jour. (Sci. Ser.) Vol. 52 (04)353-362 (2020)

http://doi.org/10.26692/sujo/2020.12.53

SINDHUNIVERSITYRESEARCHJOURNAL(SCIENCE SERIES)

Exploration of Iron Ore Deposits of Aliabad Area Jamshoro District Southern Indus Basin, Sindh, Pakistan

M. A. JAMALI, A. H. MARKHAND, M. R. KHASKHELI[++]*, M. H. AGHEEM, A. G. SAHITO, S. LAGHARI, A. Y. W. ARAIN

Centre for Pure and Applied Geology, University of Sindh, Jamshoro, Pakistan

Received 20th January 2020 and Revised 11th July 2020

Abstract: Geophysical and Geochemical investigations were carried out at the exposed rocks around Aliabad area near Jamshoro city in Sindh, for the exploration of iron ore deposit. An area of 2.5 km2 has been covered through detailed ground magnetic survey at the line interval of 500m and station interval of 100m. Magnetic data interpreted that only 27nT magnetic signature occurs in study area. 2D and 3D magnetic maps interpreted that magnetic response was very low due to the presence of hematite type iron ore deposits. Total eight samples of iron ore were collected along profile with different interval and analyzed in scanning electron microscope (SEM) and energy dispersive x-ray spectroscopy (EDS). SEM data shows the highest peaks of iron, silicon and oxygen. That indicates the composition of quartz and iron, color of samples is dark grey to light grey and texture is medium to fine grains, the whitish color grains indicate the iron and dark grey grains indicate the Quartz is present in SEM image. The discrimination of geochemical data particularly the Harker's bivariate plots indicate the source being rich in silicon dioxide and iron. With a very strict approach it is interpreted that the provenance of the investigated rocks could be clastic rocks of Pre Eocene age. Both geophysical and geochemical data show no any subsurface extension of exposed iron ore deposits in the study area which could be economically exploitable.

Keywords: Iron Ore, Hematite, Magnetic Survey, Southern Indus Basin

1. INTRODUCTION

Iron plays a important role in metal industry and used all over the world and makes approximately 95% of all metal, used per year (Fadare, 1983). Iron and steel are accepted as the main source of industrial development of any nation especially for the socioeconomic growth of any country. World high grade (60-70 weight concentration of iron). Hematite Fe_2O_3 ore are origin of enrichment deposits of Precambrian iron ore formation but these processes are still ambiguous. Many models are varies from both diagenetic and syngenetic deposits (King, 1989). Supergene deposit both ancient and fresh deposits was recommended (Powell, *et al.*, 1999; Barley *et al.*, 1999; Taylor, *et al.*, 2001; Gutzmer, *et al.*, 2002) and deep seated hydrothermal deposits (Morris, 1980; 1985; Van Schalkwyk and Beukes, 1986). The marite and goethite ores of hematite are usually recognized to be the product of supergene enrichment of iron origin mostly they are present at lateritic weathering zone of cretaceous-Tertiary boundary (Morris, 1980; Harmsworth *et al.*, 1990). Subsurface magnetic object like the iron ore can be considered as a source of magnetic anomaly. Magnetic anomaly is defined as the magnetic field generated by the distribution of magnetized mineral or rock in the subsurface. According to (Telford *et al.*, (1990), a volume composed of magnetic material can be viewed as a magnetic dipole. The magnetization that occurs depends on the magnetic induction received when it is in the earth's magnetic field. Iron ore mostly used in the automobiles, structural engineering purpose in maritime and primarily industrial application specially machinery (Hoover, *et al.*, 1989),

The occurrence of rich and poor iron ores is wide spread in Pakistan, Including endogenetic as well as exogenetic deposits. All types of iron ore reserves of Pakistan were initially estimated to be about 430 MT (Asrarullah, 1976). Endogenic iron ores occur in Balochistan basin, axial belt and Northern Montane Area. Whereas, exogenic iron ores are confined to the Indus basin at the areas of (Nayyer, *et al.*, 2006) in the formations of various,

Iron ore occurrences in the Eocene Platform carbonate rocks of the Nooriabad, Thatta and Jamshoro area were identified and sampled during a reconnaissance in January 2004 (Nayyer, *et al.*, 2006). The samples being of good grade iron ore and the mineralization appeared stratform.

The present study area lies within the Gondwanic domain of the tectonic setting of Pakistan and falls in the Foreland sedimentary fold belt. Irregular small-scale open pit mining of red ochre is being carried in the Aliabad area lower

[++]Corresponding author: Email: mujeeb_rehman@ogdcl.com Muhammad.afzal@usindh.edu.pk

*Oil and Gas Development Company Limited, Islamabad (OGDCL)

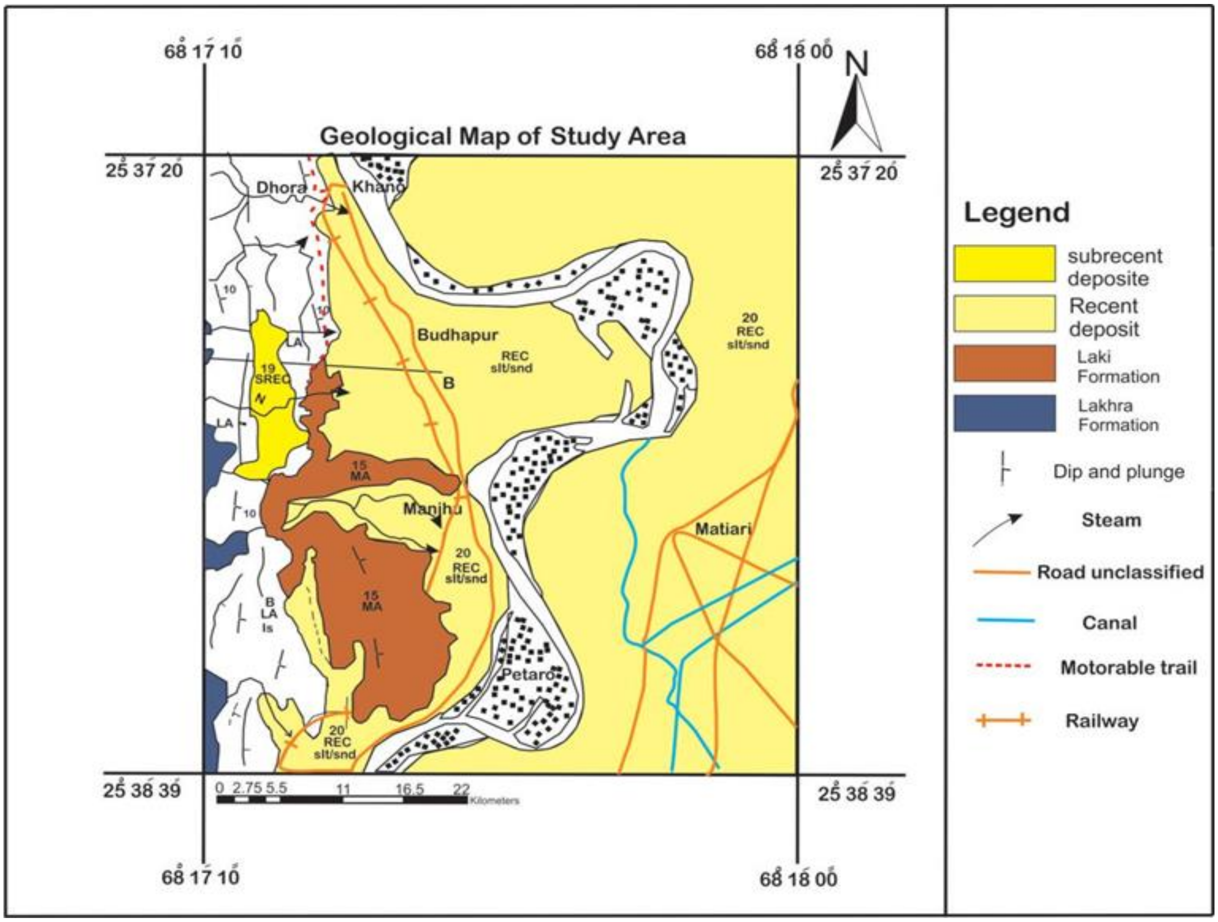


Fig.1. Geological Map of Aliabad Area Jamshoro district Sindh, showing exposures of various rock units. (Modified and reproduced after HSC, 1960)

Indus basin since long but mainly from the lower most clastic rock units i.e., Meting limestone member of Laki Formation of Ypresian-Lutetian age. However, the iron occurrences are reported from the upper most Laki limestone member of the Laki Formation near Aliabad area.

2. GENERAL GEOLOGY OF STUDY AREA

The rocks exposed in the region range in age from middle Paleocene to sub-recent sedimentary rocks dominated by carbonate facies. The Paleocene starta is exposed at Ranikot area in the form of Khadro, Bara and Lakhra Formations with clastic and carbonate lithology. While, the early Eocene age is represented by the exposure of Laki Formation in the study area (Nutall, (1925). Nari Formation of Oligocene age, Gaj Formation of Miocene and Manchar Formation of Miocene-Pliocene ages are exposed at various localities in the district. **(Fig.1).**

3. LOCATION AND ACCESSIBILITY

The study area is located at the distance of about 28 km in the north west of Jamshoro city and lies in the survey of Pakistan Toposheet No.40 C/6 in between the coordinates: Latitude: 25˚ 37′ 20 to 25˚38′39″ Longitude: 68˚ 17′ 10″ to 68˚ 18′ 00″ Study area is easily accessible through Indus highway linking to a metalled road from Khanote and Manjh and town **(Fig.2)**. The area can be approached by four-wheel vehicle in all favorable weather conditions.

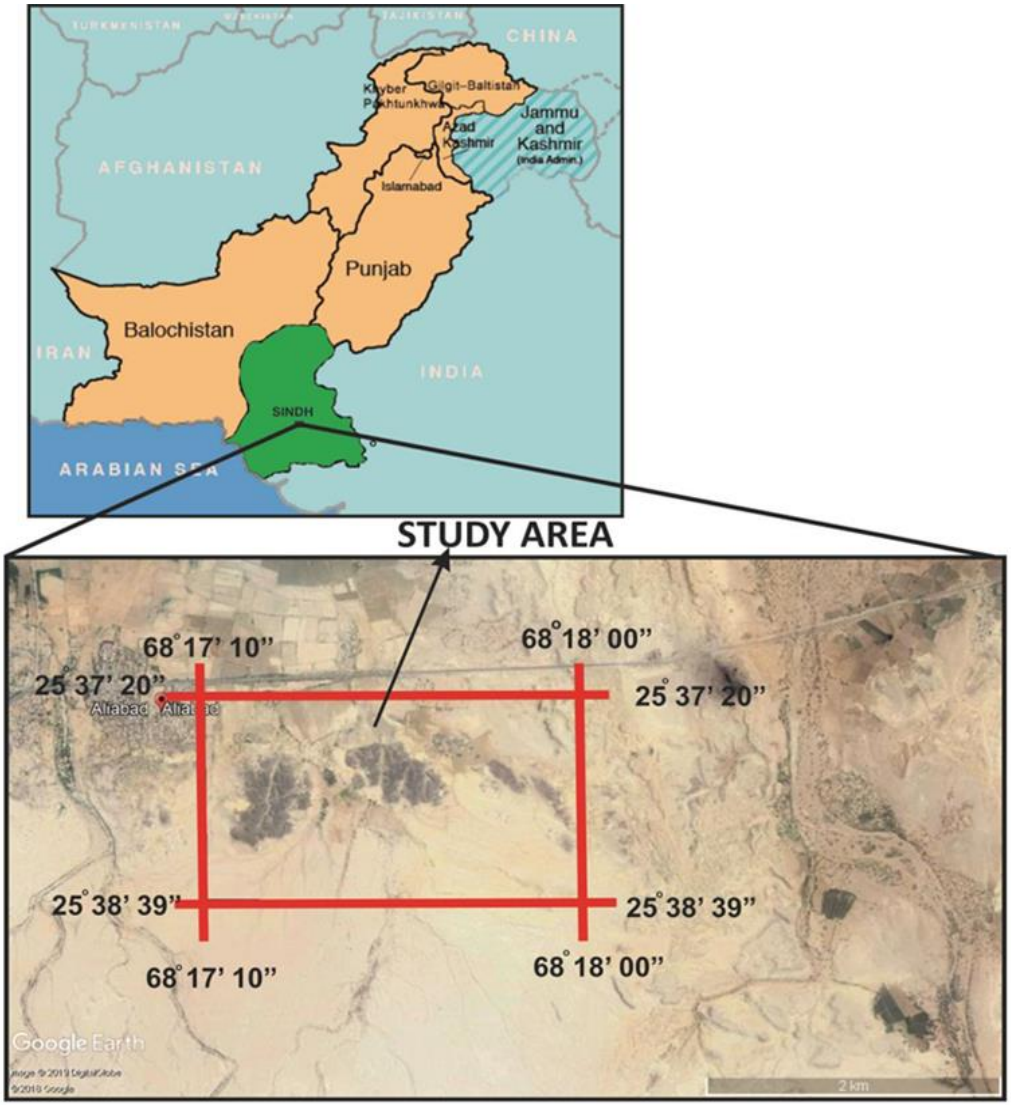


Fig. 2. Location map of Pakistan showing the study area in the inset (source: Google Earth)

4. METHODOLOGY

Geophysical and Geochemical methods used for exploration of iron ore deposits are described as:

4.1 Geophysical Techniques

4.1.1 Magnetic Survey

Magnetic survey used for the exploration of metallic minerals, specially subsurface hidden ore bodies, influence earth's magnetic field and generating magnetic anomalies as a result indicative of potential exploration goal (Keary and Brooks, 1984).Measurements are designed for bigger anomaly, such as mapping of deep anomalous zones or delineation of deep-seated iron ore is measured by aeromagnetic surveys, wherever the spacing and elevation of the profiles depends on the ideal data density. Magnetic survey is engaged for exact position of ores holding magnetic bearing properties like iron ore. Iron ore deposits are ample in wild mines but would be reduced in a few years (Bogdandy and Engel, 1971).

For the exploration of metallic minerals this survey involves mapping contrast in the magnetic field to find out location, size and shape of ore bodies. Magnetic anomalies which are product of intrusion of basic and ultra-basic igneous rocks may represent arching and structural traps in the above strata sediments (Hobson and Tiratsoo, 1985).

4.2 Geochemical Techniques

4.2.1 Scanning Electron Microscope (SEM) and Energy Dispersive Spectroscopy (EDS)

SEM technology is used for the study of textural feature and exterior surface beside with the study of cementing material present in the sample, where EDS study was performed for elemental analysis and mineral ingredient with the imaging. The Scanning electronic microscope with several thousand-time magnification as compared to normal microscope is very helpful for examining the texture and morphology of the grains, finding dissolution effects and authigenic product, examining the nature of pore lining and pore throat blockage by clay minerals and detrital clays (Green Smith,1989).

4.2.2 Point Analysis

An EDS spectrum examining from just a single grain point of (grain/mineral) gives information about the presence of each element in the emission and re-fluorescence volume of the material under probe point analysis, these point analyses may be performed on any particular and a typical grain of micron meter size.

4.2.3 Sample preparation for SEM and EDS

Laboratory analysis for SEM-EDS sample can be minimal and depending on the nature and quantity of sample required for data analysis. SEM analysis include minimum sample preparation and hold of a sample that will fit into SEM chamber and some adjustment to avert the charge build up on electrically insulating sample. Mostly carbon gold or some other metal or alloys are used for electrically insulating sample is coated with a thin layer of conducting material. The criteria to the selection of material for conductive coating rely on the acquired data. While in elemental analysis carbon is most enviable. Metal coating is most efficient for high resolution electron imaging application. An electrically insulating sample can be observed without a conductive coating in an instrument cable of "low vacuum" operation. Total eight samples were taken along major magnetic grid lines from Aliabad area at the interval of 500 m sample number 1 to 8.

5. RESULTS AND DISCUSSION

5.1 Discussion of Magnetic Data

An area of 2.5 Km^2 was covered by Detail Ground Magnetic Survey for the exploration of iron ore deposits followed by geochemical sampling at Aliabad area near Jamshoro city Sindh. Magnetic data was observed along the grid pattern at the line interval of 500 m and station interval was 100 m. Special care has been taken to avoid the effects of noise ratio like civil installations, Metallic pipe lines, Power transmission, Railway track and urban areas, during data observation. After completion of fieldwork data has been stored both in soft and hard forms for further desktop application to process the data. Field Data was processed by applying necessary corrections to remove dropouts, i.e. Diurnal correction and Secular correction, the data has been reduced on the local base station situated within the study area. Processed data has been presented in the form of 2D-contour maps, 2D shaded relief magnetic maps, and 3D-surface maps, using computer software (Golden Surfer 11) for qualitative and quantitative interpretations.

Geologically area comprises of sedimentary rock suits and the tentative depth to basement is more than 5 km^2. As the area investigated was 2.5 km^2 and the north-south length of profiles is 2.5 km^2 which is shorter than the depth to basement so the lateral variation in basement topography cannot be assessed from observed magnetic data. The objective of small area of investigation was to delineate the subsurface extension of the iron ore bearing surface layer which covers the major part of the area.

The total variation in the magnetic field is only 27nT, in the studied area and no any dipole nature magnetic closure has been identified on 2D contour map (Fig.3). Magnetic field gently rises from west to east which suggests that basement dips towards west direction.

Very small variation occurs in area due to presence of hematite type iron ore, hematite is an anti-ferromagnetic mineral, in which dipole coupling is anti-parallel and equal number of dipoles in each direction, the magnetic field of the dipoles are self-cancelling so that there is no outer magnetic effect **(Fig. 3).**

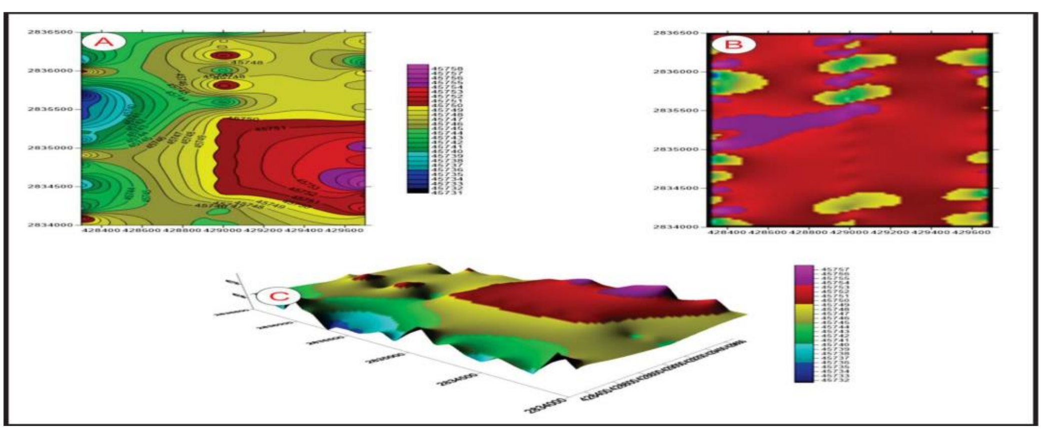


Fig. 3. Total magnetic intensity, Shaded relief magnetic map and 3D magnetic map of study area

5.2 Results of Geochemical data

A total eight representative samples of Iron ore from Aliabad area were processed for geochemical analysis on Scanning Electron Microscope (SEM) and Energy Dispersive Spectroscopy (EDS). The concentration of major elements in the processed samples is given in **(Table 1).**

On SEM Microphotograph the entire sample specified in two minerals, which identified by these surface mineral structure and tones. Mostly all the samples are composed of Quartz and Iron which shows its presence by dark grey and white tones perhaps Quartz also shows angels which indicates its hexagonal crystal system whereas iron show its reflection nature with white tone under SEM Microphotograph which indicate presence of iron **(Fig.4).**

The Surface elementary composition of samples through EDS, indicates a single trend in all the samples as silica, oxygen, and iron is dominated in all the samples which varies in percentage wise as 24.99% to 3.87%, 39.35% to 23.17%, and 57.32% to 18.54%. Presence of silica and oxygen confirms quartz in studied samples whereas in sample no. B (52.97%) and C (57.32%) have high percentage of iron. **(Fig.5,6)**

Selected surface samples from across the mineralized zone were collected separately from the different lithological units. These samples were analyzed at the geochemistry labs in Centre for Pure and Applied Geology, for the concentration of the major oxides.

The measured data were plotted against the bivariate plot's aggregates by Harker's (1909) diagram which is used for the Aliabad study area. It shows the Silica oxides trend with other oxides elements. The concentration (weight %) of the silicon oxides in all the samples range from 8.27 to 59.02. The Mg concentration pattern display in bivariate plot suggests the source being very poor in MgO and comparatively richer in SiO2.The MgO relationship with SiO2 shows the negative correlation which suggests these both the elements were not transported together at a time of deposition of sediments in **(Fig.7)**.

In the Harker diagram of Fig 7, the Fe2O3 values in the samples are in high concentration (ranging from 51.36 to 73.74). There is increase in Fe2O3 with increase in SiO2. This concentration pattern display in bivariate plot suggests the source being richer in Fe2O3, the relationship with SiO2 with Fe2O3, is mostly shows the moderately positive correlation which indicates the both the elements were came together at a same time of deposition of sediments.

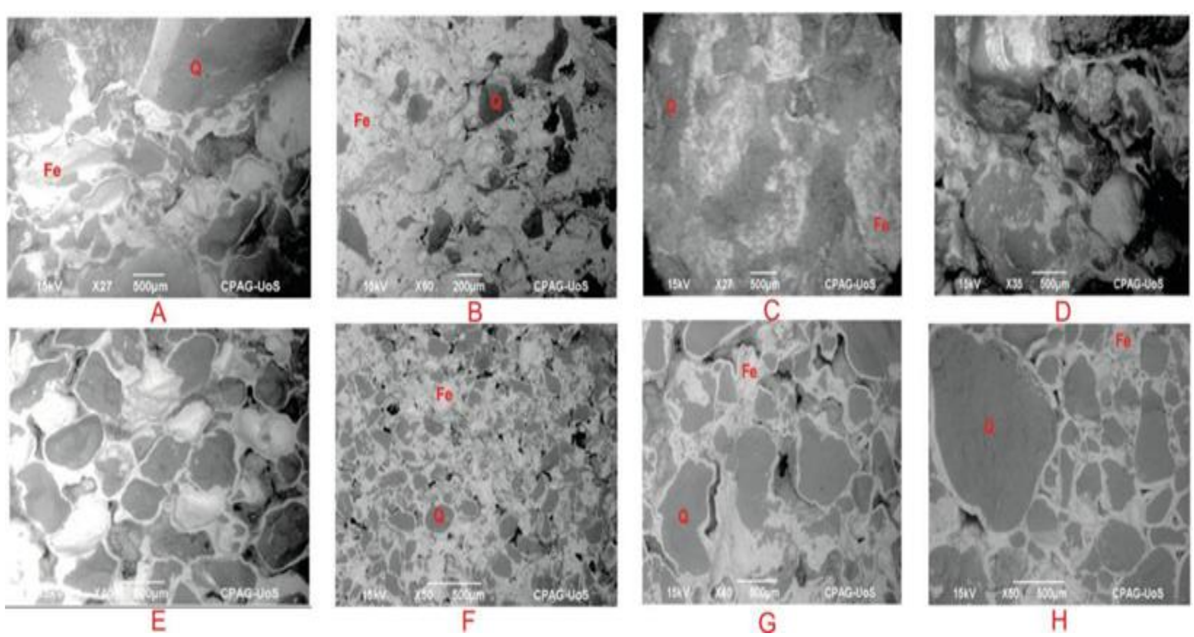


Fig. 4. Selected SEM images of Iron Ore of Aliabad area

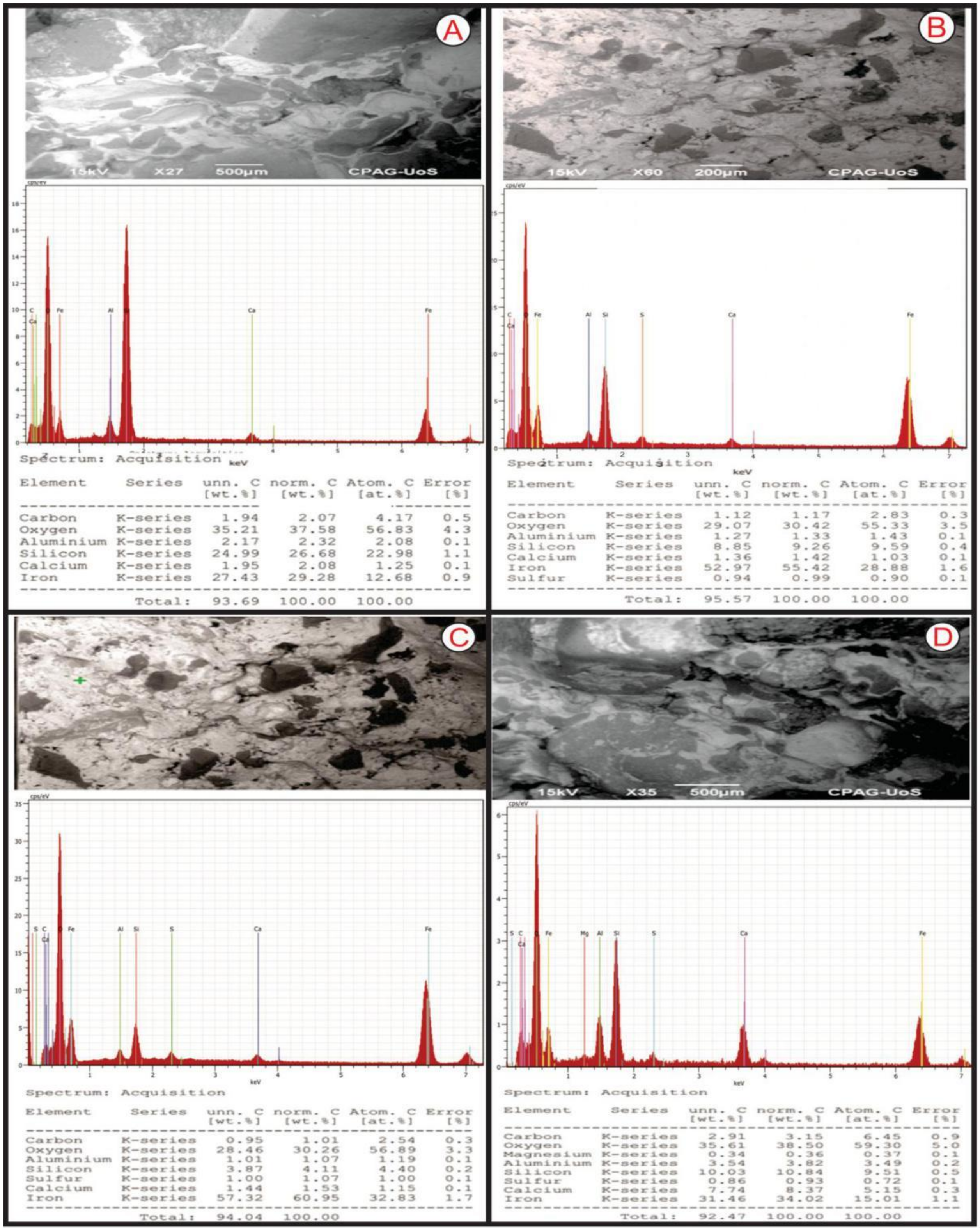
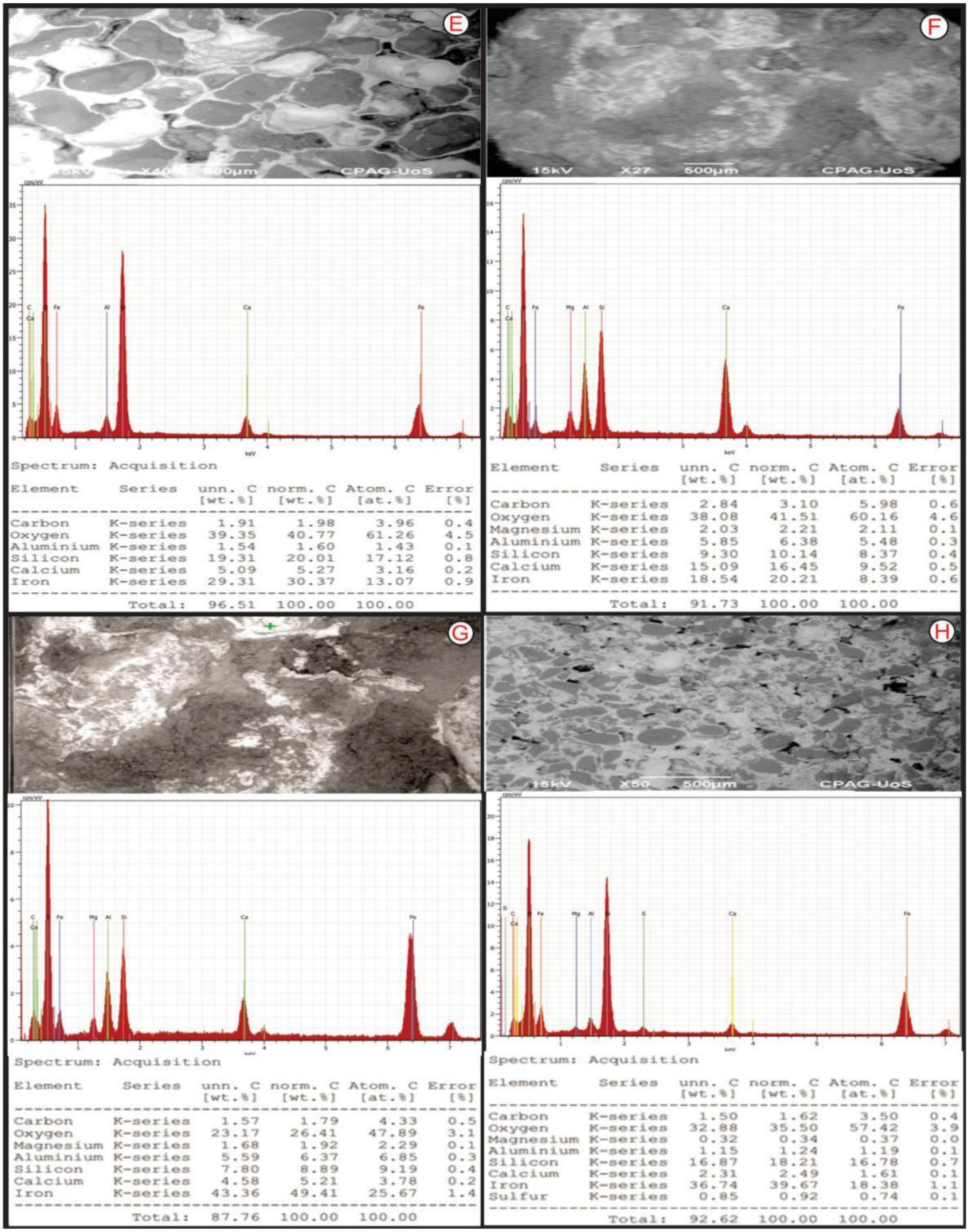


Fig. 5. Point analysis of Iron Ore sample of Aliabad area



E

Element	Series	unn. C [wt.%]	norm. C [wt.%]	Atom. C [at.%]	Error [%]
Carbon	K-series	1.91	1.98	3.96	0.4
Oxygen	K-series	39.35	40.77	61.26	4.5
Aluminium	K-series	1.54	1.60	1.43	0.1
Silicon	K-series	19.31	20.01	17.12	0.8
Calcium	K-series	5.09	5.27	3.16	0.2
Iron	K-series	29.31	30.37	13.07	0.9
	Total:	96.51	100.00	100.00	

F

Element	Series	unn. C [wt.%]	norm. C [wt.%]	Atom. C [at.%]	Error [%]
Carbon	K-series	2.84	3.10	5.98	0.6
Oxygen	K-series	38.08	41.51	60.16	4.6
Magnesium	K-series	2.03	2.21	2.11	0.1
Aluminium	K-series	5.85	6.38	5.48	0.3
Silicon	K-series	9.30	10.14	8.37	0.4
Calcium	K-series	15.09	16.45	9.52	0.5
Iron	K-series	18.54	20.21	8.39	0.6
	Total:	91.73	100.00	100.00	

G

Element	Series	unn. C [wt.%]	norm. C [wt.%]	Atom. C [at.%]	Error [%]
Carbon	K-series	1.57	1.79	4.33	0.5
Oxygen	K-series	23.17	26.41	47.89	3.1
Magnesium	K-series	1.68	1.92	2.29	0.1
Aluminium	K-series	5.59	6.37	6.85	0.3
Silicon	K-series	7.80	8.89	9.19	0.4
Calcium	K-series	4.58	5.21	3.78	0.2
Iron	K-series	43.36	49.41	25.67	1.4
	Total:	87.76	100.00	100.00	

H

Element	Series	unn. C [wt.%]	norm. C [wt.%]	Atom. C [at.%]	Error [%]
Carbon	K-series	1.50	1.62	3.50	0.4
Oxygen	K-series	32.88	35.50	57.42	3.9
Magnesium	K-series	0.32	0.34	0.37	0.0
Aluminium	K-series	1.15	1.24	1.19	0.1
Silicon	K-series	16.87	18.21	16.78	0.7
Calcium	K-series	2.31	2.49	1.61	0.1
Iron	K-series	36.74	39.67	18.38	1.1
Sulfur	K-series	0.85	0.92	0.74	0.1
	Total:	92.62	100.00	100.00	

Fig. 6. Point analysis of Iron Ore sample of Aliabad area

Table. 1. The major elements concentration (wt%) in the studied samples.

Major oxides	Sample-1	Sample-2	Sample-3	Sample-4	Sample-5	Sample-6	Sample-7	Sample-8
SiO_2	17.3712	8.2791	19.1896	13.4563	16.6866	13.4135	14.0553	59.0236
Al_2O_3	4.5158	1.9084	6.0652	2.8153	10.5621	2.0784	5.1771	2.6075
FeO	61.0053	73.7415	56.7213	57.982	55.7821	51.3695	52.7589	65.984
CaO	1.1333	2.0148	2.7424	2.7984	6.4083	11.7672	8.8709	1.5391
MgO	-	-	-	0.1492	2.7856	-	-	-
LOI	42.79	44.10	44.73	44.08	43.40	42.55	45.18	44.39

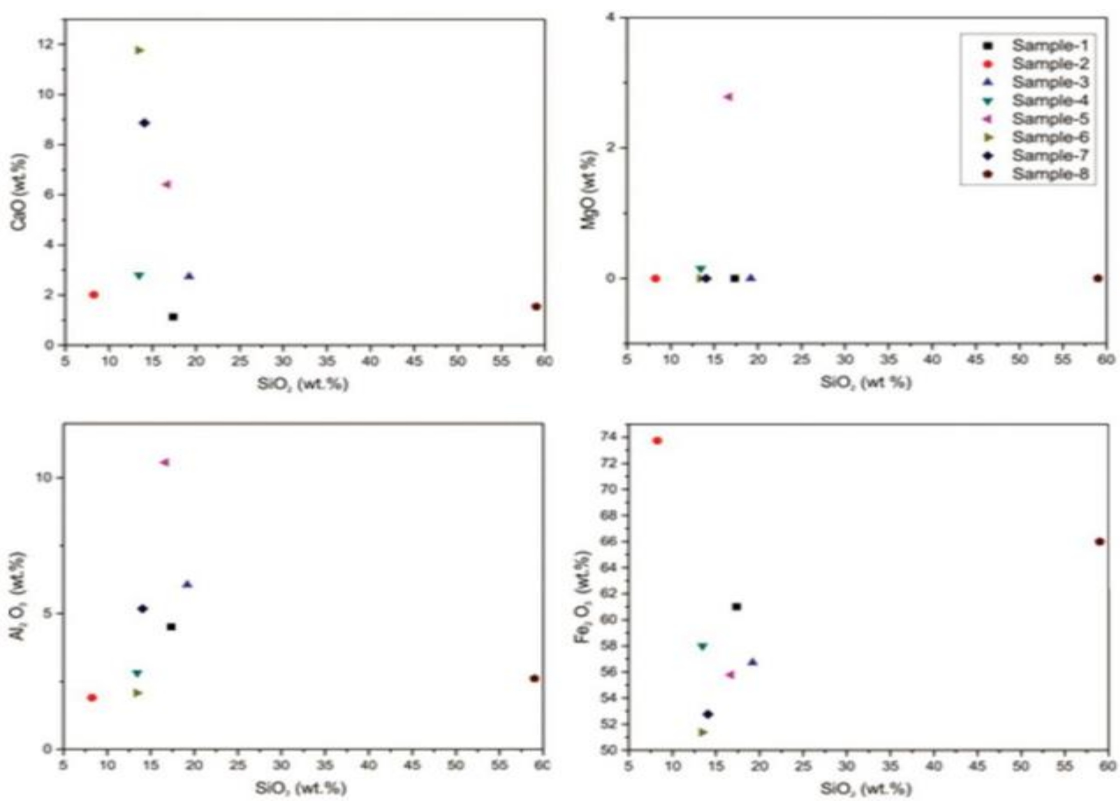


Fig. 7. The bivariate plots showing the major oxide concentration in the studied area. (after Harker, 1909)

6. CONCLUSIONS

On the basis of ground magnetic results and geochemical samples analysis results, it is concluded that:

- Geophysical magnetic data interpretation indicates the occurrence of Hematite type of iron ore around Aliabad area, as evident by the very low magnetic response of existing rock suits which are generally covered with thin layer of oxidized iron ore.
- Magnetic results show no any subsurface extension of exposed iron ore.

- The constituent iron ore minerals were presumably the weathering products of iron bearing crystalline rocks, which were transported by ground water. The soluble material may eventually have precipitated in the solution cavities/depressions of pre-existing carbonate platforms in favorable physical and chemical conditions.
- The geochemical results particularly in the oxide form also support the geophysical interpretation and reaffirm the occurrence of iron ore.
- The discrimination of geochemical data particularly the Harker's bivariate plots indicate the source being rich in silicon dioxide and iron. With a very strict approach it is interpreted that the provenance of the investigated rocks could be clastic rocks of Pre Eocene age.
- It is not expected that this type of mineralization can come up as large deposits for its exploitation to supplement the requirement of iron ore at the commercial level. However, the deposit has suitable grade and chemical composition for its use as additive mixture in cement and paint industry.

REFERENCES:

Asrarullah, 1976 Iron ores in Pakistan, Unpublished Report, Geological Survey of Pakistan, 25Pp

Barley, M. E., A. L. Pickard, S. G. Hagemann, and S. L. Folkert, (1999). Hydrothermal origin for the 2 billion year old Mount Tom Price giant iron ore deposit, Hamersley Province, Western Australia, Mineralium *Deposita*, 34: 784-789.

Bogdandy, V. L, and H. J. Engell, (1971). The reduction of iron ores, Chapmann and Hall, 326- 354

Fadare, V.O. (1983). "Iron Ore Formations – The Okene – Ajaokuta – Lokoja Areas of Kwara State. A Potential Supply Base for the Steel Plant at Ajaokuta". *Journal of Mining and Geology*. 20: 209 –214

Gutzmer, J, S. Netshiozwi, and N. J. Beukes, (2002). Hydrothermal origin of high-grade iron ore bodies hosted by the Paleoproterozoic Penge Iron Formation, Thabazimbi, South Africa, in 16th International Sedimentological Congress Abstract.

Harker, A, (1909). The Natural History of Igneous Rocks. Methuen, London.

Harmsworth, R.A., M. Kneeshaw, R.C. Morris, C. J. Robinson, and P. K. Shrivastava, (1990). BIF-derived iron ores of the Hamersley province, in Geology of the Mineral Deposits of Australia and Papua *New Guinea*, Mining and Metallurgy: Melbourne 617-642

Hobson, G. D, and E. N. Tiratsoo, (1985). Introduction to Petroleum Geology Gulf Publishing Company Houston, Texas, 814-823

Hoover, D. B, P. K. Douglas, and C. David, (1989). Geophysical Methods in exploration and Mineral Environmental Investigations. Geophysics, 1012 -22

HSC, (1960), Reconnaissance Geology of Part West Pakistan: Colombo Plan Cooperative Project for Government of Pak. Government of Canada, 550 Pp.

Keary, P, and M. Brooks (1984). An Introduction to Geophysical Exploration ELBS edition, 171 – 197.

King, H F, (1989). *The Rocks Speak*, (The Australasian Institute of Mining and Metallurgy: Melbourne. 316Pp

Morris, R C. (1980). A textural and mineralogical study of the relationship of iron ore to banded iron-formation in the Hamersley iron province Of Western Australia, *Economic Geology*, 75: 184-209.

Morris, R C, (1985), Genesis of iron ore in banded iron-formation by supergene and supergene-metamorphic processes – A conceptual model, in Handbook of Strata-Bound and Stratiform Ore Deposits, Vol. 13, 73-235 (Elsevier: Amsterdam).

Nutall, W.L.F., (1925) Stratigraphy of the Laki series (lower Eocene) of parts of Sindh and Baluchistan (India); with a description of larger foraminifera contained in those beds: Geol. Soc. London Quart. Jour, Vol. 81, 417-453.

Nayyer, S., S. Ashan, A. Ghazanfar, A. R. Memon, T. Akhtar, (2006). Exploration of Iron Ore Occurrences near Nuriabad, Thatta-Dadu Districts, Sindh, Pakistan, IR, N 830.

Powell, C Mc A, N H S. Oliver, Z. X. Li, D. McB. Martin, and J. Ronaszecki, (1999). Synorgenic hydrothermal origin for giant Hamersley iron oxide ore bodies, *Geology*, 27:175-178.

Taylor, D., H. J. Dalstra, A.E. Harding, G.C. Broadbent, and M. E. Barley, (2001). Genesis of high-grade hematite orebodies of the Hamersley Province, Western Australia, *Economic Geology*, 96:837-878.

Telford W. M., L.P. Geldart and R. E. Sheriff (1990. Applied Geophysics. 2nd Ed. Melborne: Cambridge University Press.

Van Schalkwyk, J F and N. J. Beukes, (1986). The Sishen iron ore deposit, in Mineral Deposits of Southern Africa, 157-182 (Geological Society of South Africa: Johannesburg).