QUANTITATIVE AND STRUCTURAL ANALYSIS OF KALABAGH IRON ORE BY PHYSICO-CHEMICAL METHODS WITH REFERENCE TO ITS BENEFICIATION

Part II.—Analysis of Representative Samples of the Iron Ore Obtained from Different Drifts and Levels of the Ore-Field.

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The first step in the chemical examination of an iron ore is the quantitative determination of its constituent elements. For an accurate estimation of iron in samples of iron ore, both before and after beneficiation, a procedure was worked out and described in a previous communication[1] on the calibration of the X-ray fluorescence spectrometer. The procedure was based essentially on the dilution of the sample (by a factor of ten) with calcium carbonate and the introduction of known quantities of cobalt as an internal standard. The present paper describes the application of the X-ray method, as well as of the standard chemical methods, to the analysis of the various random and representative samples of iron ore obtained from different "drifts" and levels of the Kalabagh ore-field.

Preliminary Examination of Hand-Picked Random Samples

For the quantitative chemical estimation of iron in various ore samples, the standard volumetric method using potassium dichromate as the titrant and diphenylamine as an internal indicator was employed.[2] An important advantage of this method lies in the fact that estimations based on it are least disturbed by the presence of interfering elements such as zinc, aluminium, manganese, nickel, cobalt and chromium. Since preliminary qualitative X-ray and chemical analyses of the iron ore under study had shown that it contains a fairly high percentage of aluminium with traces of chromium (cf. Fig. 1), this method of analysis was preferred as the one most suitable for the iron ore samples under study.

The first authentic sample of Kalabagh ore examined in the course of this study was from Mr. Abdul Karim's lease. This particular lease of iron-bearing ore extends over a length of 2 miles, constituting a small portion of 60-mile long stretch of ore body, extending on either side of the Indus river, and commonly referred to as the Kalabagh ore fields. This lease is located 4 miles from Kalabagh and is the most easily accessible area in this belt (Fig. 2(a)). It appears that the ore in this area is somewhat richer than average in iron content, and a hand-picked sample, received through the courtesy of Mr. Abdul Karim, had the reddish appearance corresponding to a rich hematitic ore. In order to find out the important metals present in the ore, a general qualitative analysis of the ore sample was carried out with the X-ray fluorescence spectrometer. Two repeats of this spectrometric record, taken on the most sensitive range of the spectrometer, are reproduced in Fig. 1, and they show in addition to iron the presence of small quantities of titanium, chromium, zirconium and strontium. With the help of the semi-quantitative calibration curve (Part I, Fig. 1), their percentages were estimated at 1.5, 0.5, 0.1 and 0.1 respectively. The elements below atomic number 22 cannot be readily detected, because their characteristic X-rays are strongly absorbed in the air.

The iron content of this sample of the ore was then quantitatively determined by the chemical and the X-ray methods, and it was found to be nearly 54%. This high iron content would seem to indicate that the sample is mainly hematite, in agreement with its reddish colour and friability. Since it was known from previous work [3,4] that the average iron content of the ore in the Kalabagh area, taken as a whole, is below 40%, this sample was evidently much richer than the average. Although a considerable amount of useful information was later obtained from the beneficiation and microscopic study of this particular sample, it was thought necessary for the proper investigation of the ore to obtain at this stage a set of fully representative samples from the ore-field, using proper sampling methods.

Sampling of the Main Iron-Bearing Vein in the Ore-Field

For this purpose, a survey of the main ore-body was undertaken, and nearly two-thirds of

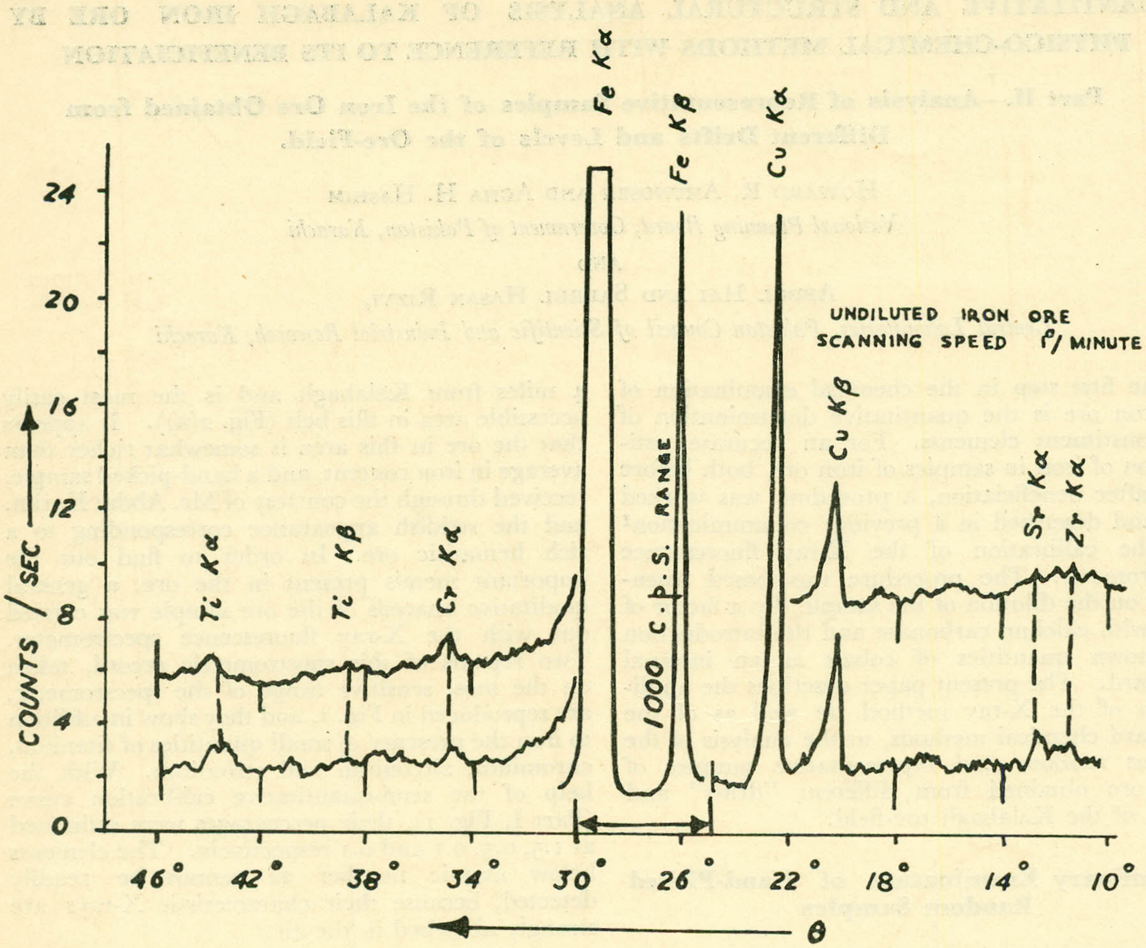

Fig. 1.—X-ray spectrometer record of rich ore sample from the Kalabagh area, showing traces of titanium, chromium, strontium and zirconium. The record from 25.5° to 30° is taken with a very much reduced sensitivity, and the rest of the record has been repeated with an upward shift of the background zero.

the entire ore-field was explored. It appeared that the major area upon which the iron mining programme can be established is the Kuch-Khartop area, which is presently being developed by the Pakistan Industrial Development Corporation and is contiguous with Mr. Abdul Karim's lease referred to above. There is nearly 2750 yards of exposed outcrop in the Kuch area and another 1750 yards of outcrop in the Khartop area. (A conservative estimate made by Dr. E.R. Gee, Director, Geological Survey of Pakistan, puts the ore reserve in this area at over 7 million tons[5]). Fig. 2(a) gives a sketch of the Kuch-Khartop area, which is easily accessible and is located approximately 6 miles from the rail-road sidings at Kalabagh, and 5 miles from the Indus river. There is an elevation of about 1000 ft. in the 5 mile distance from the river, and a motorable road can connect the actual ore site with the railway siding. A mineral water source flowing at the rate of 500 litres per minute is available nearby. It thus appeared to be an easily workable mining site, and representative samples suited for ore-dressing were therefore collected from this area, an elevation of which is shown in Fig. 2(b).

For obtaining the representative samples, the easily workable area of the ore-body was selected, its outer fringes being set by an estimated lower limit of 20% iron content. The outcrop from which the samples were collected was roughly 2-mile long and provided for a 7-foot square tunnel to be driven into it, the tunnel being entirely in the ore-bed. This criterion is quite important because it eliminates : (a) the waste-rock problem and (b) support by timbering, which is not necessary so long as the drifts remain in the ore-bed.

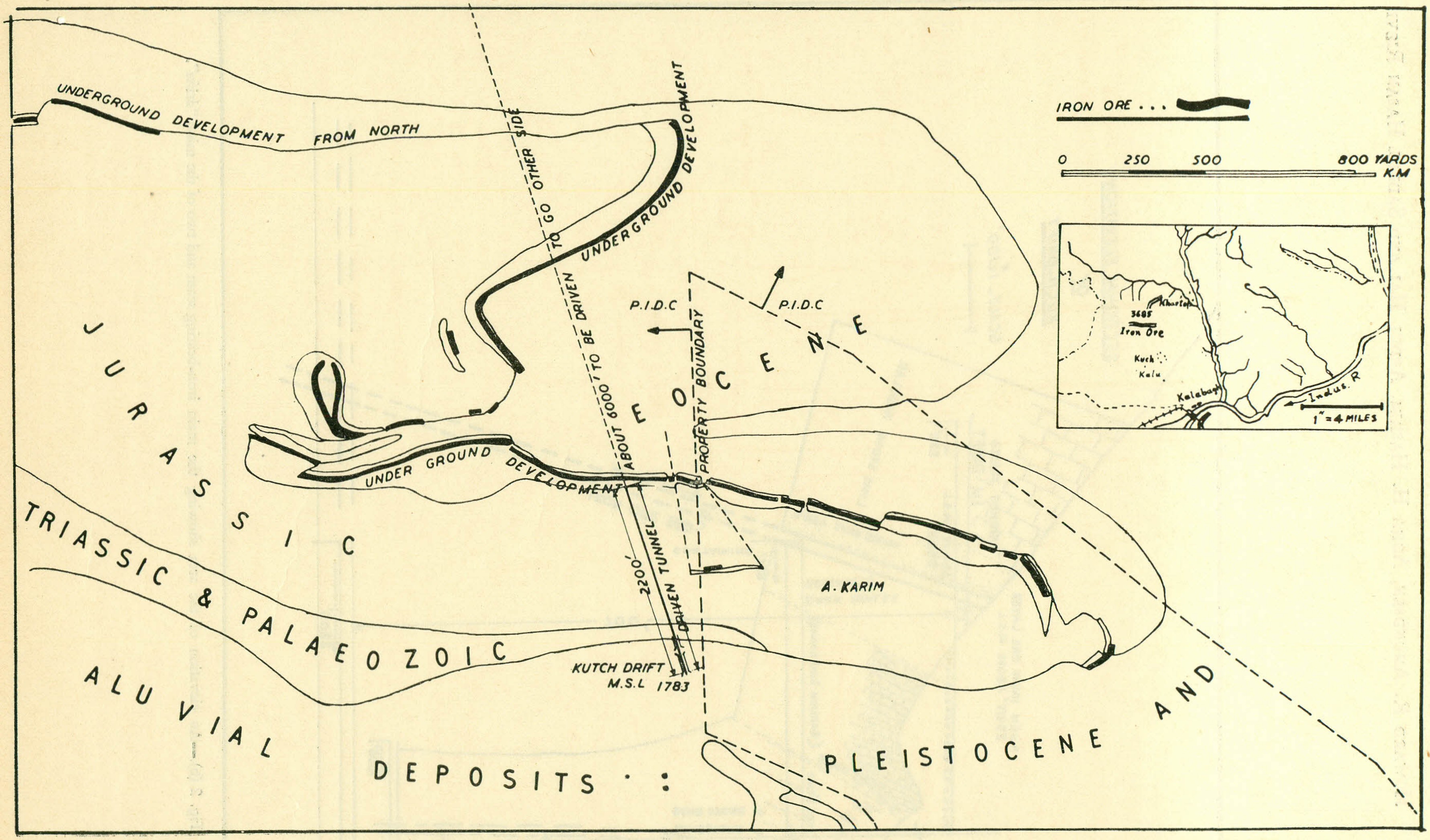

Fig. 2(a).—Sketch of the Kutch-Khartop area of the Kalabagh ore fields.

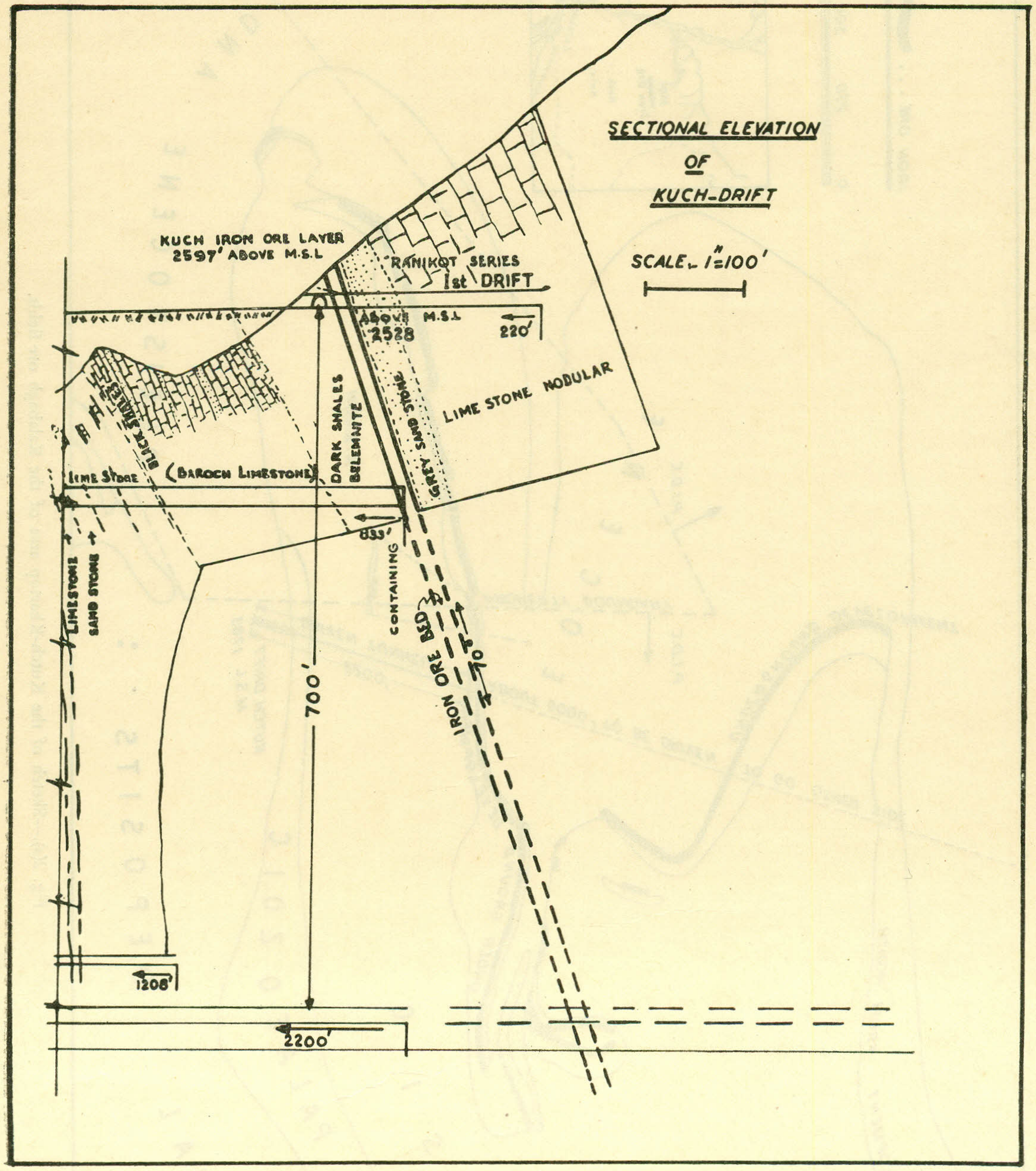

Fig. 2 (b).—An elevation of the area showing the main iron-bearing seam and two of the mine "drifts".

The sampling of the ores from individual levels was carried out by the "Breast sampling" technique, so designed as to simulate the actual production conditions and thus to get a faithfully representative sample. The sampling process can best be illustrated with reference to Fig. 3.

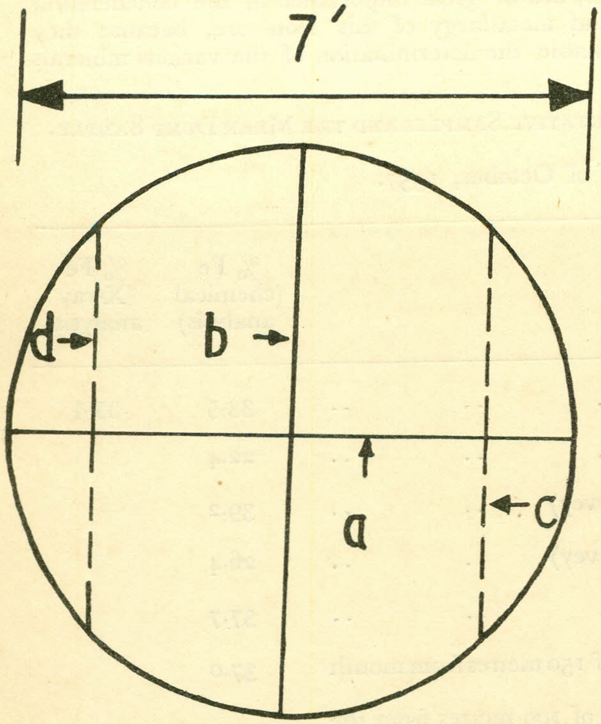

Fig. 3.—Sketch showing the mode of sampling adopted for obtaining representative samples.

From the almost circular cross-section, four individual lot samples were collected, two along the two diameters at right angles to each other (shown by 'a' and 'b' in the figure) and the other two along the two chords (shown by dotted lines 'c' and 'd' in the figure) located 'by judgement' near the periphery of the section. The four samples, thus collected, were then mixed, crushed and sectioned in order to reduce the bulk by a factor of eight and to obtain a small sample of 10 lbs. representative of this cross-section. In general, one such sample was taken from each level, and the adequacy of this sampling technique was substantiated by the fact that there was less than 1% difference between the iron contents of the mine dumps and the mean of the representative samples obtained as above (Table 1). Over a dozen such representative samples were collected from several levels spread uniformly over the working area of the outcrop (roughly 2-mile long). These samples were found to be adequate for giving definite ideas about the quality of the ore.

Analysis of Representative Samples

Each of the series of thirteen samples obtained as described above was further individually sampled to obtain still smaller (representative) samples for the analytical work. These samples, as also the mean sample from the mine dump, were then carefully analysed by chemical methods and some of the values were confirmed with the X-ray spectrometer. The mean values of iron content of each sample obtained from a number of analyses are given in Table 1.

The mean iron content of 33.5% of the ore is in agreement with the results of previous investigations,[4] and is indicative of its rather low grade. It thus becomes important to study and estimate the other constituents of the ore, for example aluminium and silicon. Accordingly, a detailed quantitative chemical analysis of three typical samples of the ore was undertaken, the three samples chosen being: (i) the mean sample containing 33.5% Fe, (ii) the poorest sample containing 22.4% Fe and (iii) the richest sample containing 39.2% Fe. The results of these analyses are given in Table 2.

TABLE 2.—DETAILED ANALYSES OF THREE TYPICAL ORE SAMPLES.

	Mean sample	Poorest sample	Richest sample
Fe ..	33.5%	22.4%	39.2%
Al_2O_3 ..	13.0%	—	11.0%
SiO_2 (total) ..	24.2%	—	15.2%
CaO ..	1.1%	2.3%	3.5%
Loss on ignition	12.6%	11.1%	12.5%
CO_2 ..	11%	6%	6%

Conclusion

This analysis brings out some significant characteristics of the ore. A comparatively high loss on ignition (roughly 12%) coupled with the fact that, on treatment with acids, the ore gives off nearly 10% carbon dioxide leads to the conclusion that an appreciable percentage of some carbonate is present in the ore. Because the percentage of calcium and other metals is very low, most of the CO_2 would be in combination with the iron, giving nearly 26% of Fe CO_3 in the mean sample. Further, the analysis of the mean sample indicates only traces of free silica, and therefore the major portion of the silica (24.2% found in Table 2) can be expected to be combined with aluminium in the form of some alumino-silicate. (The percentages of aluminium and silicon are seen to be nearly in the right proportion to form such a compound). Both these conclusions were later fully confirmed by X-ray diffraction and mineralogical studies which showed that a considerable portion of the iron is associated with the alumino-silicate in the form of chamosite. These structural studies, which will be described in Part III of this series, are of great importance in the beneficiation and metallurgy of this iron ore, because they enable the determination of the various minerals

TABLE 1.—IRON CONTENT OF THE THIRTEEN REPRESENTATIVE SAMPLES AND THE MEAN DUMP SAMPLE.

All samples taken in the second half of October, 1957.

Sl. No.	Origin of Sample	% Fe (chemical analysis)	% Fe (X-ray analysis)
1	East limestone hill area (A. Karim)	33.5	33.4
2	Kutki stage ; Jurassic (A. Karim)	22.4	
3	Kuch outcrop (sample taken by Geological Survey)	39.2	
4	Kuch outcrop (sample taken by Geological Survey)	26.4	
5	Limestone hill area ; main layer (A. Karim)	37.7	
6	Kuch (1st drift), West; collected at a distance of 150 metres from mouth	37.0	
7	Kuch (1st drift), West ; collected at a distance of 100 metres from the main tunnel	34.2	34.0
8	Kuch (1st drift), East; collected at a distance of 160 ft. from the main level	35.3	
9	Kuch (1st drift), East ; collected at a distance of 120 metres from the mouth	34.7	
10	Kuch (1st drift), East air level ; collected at a distance of 20 metres from the opening ; thickness of iron layer = 10 ft.	29.2	
11	Kuch (1st drift), East air levels ; 90 meters across the dip from foot wall to hanging wall *i.e.*, 0-9 ft.	31.4	
12	Kuch (1st drift), West higher level ; collected at 365 ft. from its mouth ; thickness of iron layer = 8 ft.	38.4	38.4
13	Kuch (1st drift), West higher level ; collected at 450 ft. from mouth ; thickness exposed in the mine = 6 ft. 4 inches, actual thickness being more	36.9	
14	Mean of 13 samples	33.4	
15	Mean dump sample	33.5	

constituting the ore and the distribution of iron among them.

Acknowledgements

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