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CHROMITE ORES OF PAKISTAN AND THEIR BENEFICIATION – A CASE STUDY*

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This case study describes the present position of chromite ores of Pakistan with special reference to the Zhob valley and Malakand areas. The study touches upon the general geology, mining, grade, beneficiation and exports. A review on the work previously done on the concentration of Muslimbagh chromite has been included. Work done in the PCSIR on upgradation of low grade chromites of Zhob valley and Malakand on bench as well as on pilot-plant scale has also been described.

INTRODUCTION

Sizeable reserves of high and low grade chromite ore occur at Dargai and Zhob valley. Muslimbagh district in Zohb valley is the only well-developed place for chromite mining. The ore has been mined in this area since 1903 and considerable amount of foreign exchange has been earned through export of high grade chromite ore. In the ultramafic complex of Dargai, mostly exploratory mining has been done.

The depleting trend of high grade chromite has created an alarming situation because of its importance as a source of foreign exchange. In this context the exploration and exploitation of low grade reserve seems to be the only course to meet the future requirements of country.

Various local agencies, belonging to the public and private sectors, have consulted foreign organisations for doing trial beneficiaton work on low grade chromite ore. The bench scale tests carried out abroad neither provide basic data for a concentrator design nor represent the varied types of low-grade chromite reserves of the country.

the PCSIR Laboratories, Lahore, did some beneficiation work on Muslimbagh low-grade chromite samples supplied by the Geological Survey of Pakistan in 1971. But lately, pilot-plant beneficiation studies of indigenous low-grade chromites have been undertaken in a more systematic way. The samples collected from various localities were grouped according to the texture, location, gangue and their chromium content. Beneficiation processes based on gravity, surface characteristics and magnetic properties have been tried on theses samples.

The bench scale and pilot-plant tests carried out in these indicated that the low-grade chromite ores of Pakistan can be economically upgraded to produce metallurgical, refractory or chemical grade concentrates.

The case study gives a brief review of the chromite occurrences, reserves, grade of ores, export figures and the result of the concentration work carried out in Pakistan and abroad on indigenous low-grade chromite.

Occurrence. Chromite bearing ultramafics are exposed in the form of fairly large bodies over an extensive area extending along the western and north-western borders of Pakistan. There are chrome showings also in the southern part of the country about 200 km north-west of Karachi.

Zhob valley is famous for its chromite mining, and is located in the western part of Pakistan near the Afghanistan border.

The other major chromite mining area is Malakand which is located in Dargai ultramafic complex.

Amongst the chromite bearing area, Muslimbagh (Zhob valley) is well-developed for commercial and scientific exploitation and chromite mining has been in operation since 1903. Regular records of production are available from 1915 onwards. Details in respect of mine-productivity over 60 years are as follows: (Table 1)

Exploratory mining in Malakand area was undertaken by Hyesons Company during 1962–68. In 1970 Rossman, Abbas and Ghazanfar prepared a report on Geology and Economic potential for chromite in the ultramafic rock complex near Dargai in Peshawar Division [2]. In recent years, work on detailed geological mapping and exploratory mining has been started by PMDC.

Reserves [3]. The Zhob valley complex is exposed over an area of more than 5180 km^2, extending from Gowal about 6 km from Khanozai in the south-west to the area beyond Nisai in the east of Muslimbagh. The question of economic potentials and ore reserves has always been a

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Table 1. Chromite production in Muslimbagh area [1].

Period	Production (ton)
1915–19	59,361
1920–24	1,08,710
1925–29	78,725
1930–34	45,449
1935–39	81,999
1940–44	1,36,877
1945–49	92,473
1950–54	69,923
1955–59	74,551
1960–64	80,871
1965–69	1,18,742
1970–74	95,076
1975	10,114
61 years	10,52,871

Average 17260 ton/year

mystery throughout the span of seven decades of mining in the Zhob valley. Fermor in 1916 determined the reserves of chromite as 63400 tonnes for the entire ultrabasic area exposed between Gowal and Nisai.

The rate of production throughout the entire period of mining has not changed appreciably, although never at one time in the history, ore reserves were estimated more than 60 – 70 thousand tonnes. However the actual production record reveals that 213,744 tonnes were produced during the last ten years by PCM alone.

Rossman pointed out that the size of the chormite deposits so far mined indicates that very large deposits (in the million tonnes range) probably will not be discovered, rather it can be predicted that most of the deposits will fall in the range of several thousand tonnes.

Schmitz of Federal Geological Survey of Germany and Schmidt-Rittershans of M/s Stolberg Ingenieurgera-Tung GmbH of 510 Stolberg, West Germany, conducted a preliminary survey of the area in 1973 and were of the opinion that chromite reserves in Zhob valley could safely be estimated to the order of 4 million metric tonnes.

As regards basis of future mining, aerial photographs of the area, geological mapping, petrological, mineralogical, geochemical and geophysical studies have been carried out on several occasions. Mining of chromite has been practised for quite a considerable period and thousands of chromite prospects were located and proved. In as many as 250–300 mines, the type, trend and disposition of the ore bodies have been established by actual mining. Chemical analyses of more than 500 chrome samples drawn from different deposits in the area are also available to estimate the possible grade of future ore production.

In Malakand, total reserves of 580,098 tonnes of all grades of chromite were tentatively estimated in 1977 by PMDC. However, detailed investigations are required to estimate true reserves in the area.

Attempts towards Beneficiation

After the establishment of Pakistan, concentration of low-grade chromite ore was attempted by a number of agencies. A brief summary of these efforts is: (1) Concentration of Muslimbagh ore was tried by M/s Pakistan Industries Ltd., in collaboration with the Denver Equipment Co., Denver, Colorado, U.S.A. Milling tests were made and a report and flow sheet was recommended for a mill of 50 metric tons capacity per shift [4]. (2) In 1958, concentration of Muslimbagh ore was again tried by Pakistan Mineral Development Corporation [5,6]. (3) Lividari made an attempt to concentrate chromite ore on behalf of Pakistan Industries Ltd., Karachi. (4) Ballamy, formerly U.S. Ceramic Advisor, tried to make refractory bricks from the tailings accumulated at the dichromate plant of the Pakistan Industries, Karachi [7]. (5) In 1972, PCSIR Laboratories, Lahore, were given samples of low grade chromite ore by the Geological Survey of Pakistan. The ore was upgraded from 30–40% Cr_2O_3 with a Cr–Fe ratio of 1.5–2.0 to a concentrate containing 48–50% Cr_2O_3 with a Cr–Fe ratio of 3.0 [8]. (6) Detailed beneficiation study was carried out by a German firm. Their report provided lot of information for future work.

Nature of Chromites of Zhob Valley

The Zhob valley chormites, based on their chemical characteristics, may be divided into five distinct groups (Table 2). Each group has more or less definite chemical composition with some variations in chromium to iron ratio [10].

There is wide range of Cr-Fe ratio in chromites of Khanozai group. Some of the deposits show a Cr–Fe ratio of more than 3:1, while in others the ratio is less than 3:1. Such variations are not found in the chromites of other groups.

Chromites belonging to Jangtorghar group invariably show a Cr–Fe ratio of greater than 3:1. This applies to high as well as low grade chormites.

The Saplailorghar chromites show mostly a Cr–Fe ratio close to 3:1 Chromites from Nisai group exhibit a

Table 2. Partial chemical analyses of chromite from Muslimbagh mining district

Location and mine number	Cr_2O_3 (%)	Cr (%)	Fe (%)	Cr–Fe ratio
Khanozai Group				
I-B	51.4	35.2	11.2	3.15:1
I-F	48.9	33.4	9.5	3.50:1
IE/E	42.4	28.9	10.4	2.77:1
IA	50.9	35.0	10.7	3.25:1
Jangtorghar Group				
11	52.5	35.9	10.7	3.35:1
1348	56.8	38.9	10.3	3.76:1
140 E	49.4	33.8	9.8	3.44:1
199	55.0	37.6	11.7	3.21:1
139 C	44.5	30.5	10.3	2.98:1
Saplaitorghar Group				
29	41.4	28.4	9.35	3.03:1
4 ML	53.7	36.7	10.4	3.35:1
7 ML	47.9	32.7	11.2	2.92:1
37	56.5	38.6	10.7	3.52:1
2 ML	41.4	28.4	10.4	2.70:1
Nisai Group				
128	48.3	33.0	11.6	2.84:1
153	54.2	37.0	11.6	2.66:1
221	33.4	21.7	9.5	2.40:1
5 CPL/2	42.6	29.1	14.5	1.00:1
5 CPL/9	46.8	32.0	10.0	2.94:1
226	30.5	20.9	13.0	1.88:1
Fort Sandeman Group				
Block 106	45.2	30.9	12.7	2.47:1
Block 115	44.6	30.5	12.5	2.44:1
Block 109	46.5	31.8	12.6	2.51:1

Cr–Fe ratio invariably lower than 3:1 and the variations in the ratio is fairly large.

The Fort Sandeman chromites differ widely in their chemical characteristics from those of the other groups. They show Cr–Fe ratio lower than 3:1. These chromites are characterised by high alumina content (about 20%). Nowhere else in the Zhob valley complex are found chromites having such a high Al_2O_3 content.

An extensive laboratory test work was carried out on ten chromite samples (Table 3). The samples were cursched through a jaw crusher followed by roll crusher. The crushed materials were analysed microscopically for liberation of chromite grains. The concentration tests were carried out on Humphery spirals and Wilfley tables.

Table 5. Percent free mineral particles as a function of mesh size.

Chromite sample	Mesh size	Free Particles (%)	Mesh of liberation	Remarks
1	–44 + 60	75	–44	Altered
2	–72 + 85	83	–60	Massive
3	–44 + 60	73	–44	Altered
4	–60 + 72	74	–60	Five grain
5	–72 + 85	75	–72	Massive, high grade
6	–44 + 60	73	–44	Friable, high grade
7	–30 + 44	81	–30	Low grade
8	–60 + 72	79	–60	Massive, high grade
9	–120 + 150	33	Below 200 mesh	Very fine grain
10	–120 + 150	60	Below 200 mesh	Very fine grain

Table 6. Metallurgical data on medium grade chromite ore.

Product	Wt (%)	Cr_2O_3 (%)	Fe_2O_3 (%)	Cr_2O_3 recovery (%)	Cr–Fe ratio
Chromite conc	40.0	48.5	16.3	63.8	2.91
Middling	12.0	24.5	11.0	9.7	2.00
Tailings	25.0	10.0	7.2	8.2	1.36
Slimes	23.0	24.0	11.8	18.2	1.99

Table 7. Metallurgical data of a pilot-plant test on low-grade chromite

Product	Wt. (%)	Cr_2O_3 (%)	Fe_2O_3 (%)	Cr_2O_3 recovery (%)	Cr-Fe ratio
Conc.	28.0	41.8	15.00	59.40	2.72
Middlings	11.50	20.2	12.50	11.79	1.50
Tailings	33.50	8.8	20.50	15.09	0.42
Slimes	27.00	10.0	8.50	13.70	1.15

able amount of chromium, have not been treated for chromium recovery at this stage. However, methods such as flotation and selective flocculation are under experimentation for recovering fine chromite grains from the slimes.

Several tests were run on pilot-plant scale following the flowsheet mentioned above. The parameters, such as flow rates, circulating loads, per cent solids for the feeds for various units and metallurgical performance of all unit operations are being optimised. The components of pilot-plant, such as jaw crusher, crushing rolls, vibrating screens, spiral and table concentrators, have been designed by the staff members of the Laboratories, and fabricated locally. The pilot-plant has the capacity to treat about 10 – 20 tonnes of chromite ore per day.

CONCLUSIONS

(1) The proven reserves of low-and high-grade chro-

mite ore in Muslimbagh as well as in Malakand areas, are sufficient to meet the future requirement of the country for quite sometime.

(2) Beneficiation tests carried out at these indicate that high-grade concentrates from medium and low-grade chromites can be made.

(3) The PCSIR has designed and fabricated locally a pilot-plant of 20 tonnes per day capacity. The indigineous technology and know-how on the beneficiation has also been developed which will help commercialisation of concentration plants in the country.

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