Geol. Bull. Univ. Peshawar, Vol. 37, pp. 191-197, 2004

Beneficiation study of the manganese ores of the Saidgi area, North Waziristan Agency, Pakistan

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ABSTRACT: *Manganese is widely used in steel and chemical industries but its use in dyes, paint, battery cells, glass and textile industries is also of great importance. In Pakistan, millions of rupees are spent on the import of manganese di-oxide (MnO_2) every month. Besides its extensive consumption in the steel industry, huge amount of MnO_2 is imported for its use in battery cells, paints, glass and textile industries and poultry feed in Pakistan. Though manganese ores of various grades have been reported in Hazara, Kuram, Bajaur and North Waziristan agencies and Lasbela-Khuzdar, but their proper utilization is not made yet in the various mineral based industries of Pakistan. For this purpose the manganese ores of Saidgi area of North Waziristan have been selected for their beneficiation or up-gradation during the present research work. These ores are of greater economic importance because of having inferred reserves of more than 34 thousand metric tons with MnO_2 contents ranging from 36 to 60 wt%.*

Manganese ore required for the steel industry generally contains 48 wt% of MnO_2. However, much higher grades (≅75 wt% MnO_2) are required for battery making and chemical industries. The manganese ores of Saidgi area are having appropriate amount of MnO_2 required for the steel industry but these ores need beneficiation or up-gradation before being utilized in battery making and chemical industries. During the present study two different techniques (i.e., magnetic separation and gravity concentration methods) were used for the up-gradation of the Saidgi manganese ores. Two samples treated by magnetic separation method were up-graded from 37.98 wt % and 57.36 wt% to 79.1 wt% and 80.44 wt% of MnO_2 respectively while two samples treated by gravity concentration were up-graded from 37.98 wt% and 57.36 wt% to 60.23 wt% 72.19 wt% of MnO_2. It is, therefore, concluded that the Mn-deposits of Saidgi area can very easily be up-graded by the method of magnetic separation for their use in the battery and chemical industries.

INTRODUCTION

Manganese is an essential component of the steel and cast-iron making industry and, therefore, has greater importance from the industrial point of view. It mainly occurs as oxides and hydroxides in the earth crust. Manganese oxide was considered as a variety of iron and was used by the ancient Egyptians and Romans for controlling the color of glass and was also consumed extensively in the production of Chlorine until the later part of the 18th century (Harder, 1910). Umber, a mixture of manganese and iron oxides, has been

reported as a drier for oils as early as the middle of 17th century (Lavino, 1960). The first record of mining of manganese ore in the United States was in 1837 in Hickman County, Tennessee, apparently for the purpose of coloring earthenware.

Robert Mushet introduced manganese in the form of spiegeleisen. Since then, manganese has been necessary to the commercial productions of all steels. Ferromanganese, containing 25 to 30 percent manganese was first produced for commercial use in 1865 by Henderson. The Terre Noire Company improved these earlier processes and started for the first time the production of rich and cheap ferromanganese (Harder, 1910).

Manganese has got a big demand in Pakistan as well as in foreign countries. Steel, paint, battery cells, glass and textile industries are the main consumers of manganese. The consumption of manganese in Pakistan can be judged from the fact that over millions of rupees per month are spent on the import of manganese di-oxides (MnO_2). Besides extensive consumption in steel industries, huge amount of manganese dioxide is imported for use in Battery cells, paints, glass, textiles and poultry feed.. The battery grade manganese is imported from Japan and chemical grade from China and Singapore. The other countries from where Pakistan imports manganese to fulfill its industrial need include Malaysia, Thailand, South Korea and Turkey.

Manganese is used for the production of speigleisen, manufacturing of high-grade steel and chemicals. It can be alloyed with other metals like copper and aluminum, which are used for corrosion-proof reservoirs, ships, screws and aircraft industry. There are many other uses of manganese such as in dry batteries, medicine, carbon mono-oxide gas masks, drying oils, lubricants and wax. It is also used by the glass industries (for discoloring green glass) and for pottery pigments.

Manganese ores of various grades occur in Hazara area of NWFP, Kuram, Bajaur and Waziristan agencies and Lasbela-khuzdar areas of Balochistan. These ores have been geologically investigated in detail by various workers (Khan, 1998; Shah & Khan, 1999; Naseem, 1997; Ahmad, 1992), however, these ores have not been economically evaluated yet. After determining the mineralogy, geochemistry and genesis of the manganese ores of Saidgi and Shuidar areas of North Waziristan agency by Shah and Khan (1999), these ores were needed to be economically investigated. For this purpose the ores of the Saidgi area have been selected for economic evaluation and beneficiation (up-gradation) studies during the present research.

Saidgi area is located close to the Afghanistan boarder and is about 26km from Miran shah, the capital city of north waziristan (Fig. 1). The manganese ores of Saidgi area are exposed at Tor-kade khel. These ores are hosted by metachert / jasperite following the general trend of host rocks (Fig. 2). The exposed length of the ore body is about 62 meters with variable thickness. The thickness decreases from south to north having an average thickness of about 6 meters. The inferred reserves have, therefore, been calculated as 34,000 metric tons (Khan, 1998). Previous studies show that these ores have MnO_2 ranging from 36-60 wt% with an average content of 52 wt% (see Shah & Khan, 1999; Khan, 1998).

Generally, low grade manganiferous iron ores are only used in the manufacturing of speigleisen (20% Mn), but for other purposes the ore should contain 35-46% Mn (Bateman, 1959). For chemical uses, manganese ore of high purity is required for dry batteries, the

glass industry, paints, pigments, dyes, and fertilizers. In this respect the manganese ores of Saidgi area can be used for many purposes after treating it with further beneficiation processes. This paper represents the outcomes of the experimental work conducted for the up-gradation of the studied manganese ores for their multipurpose uses.

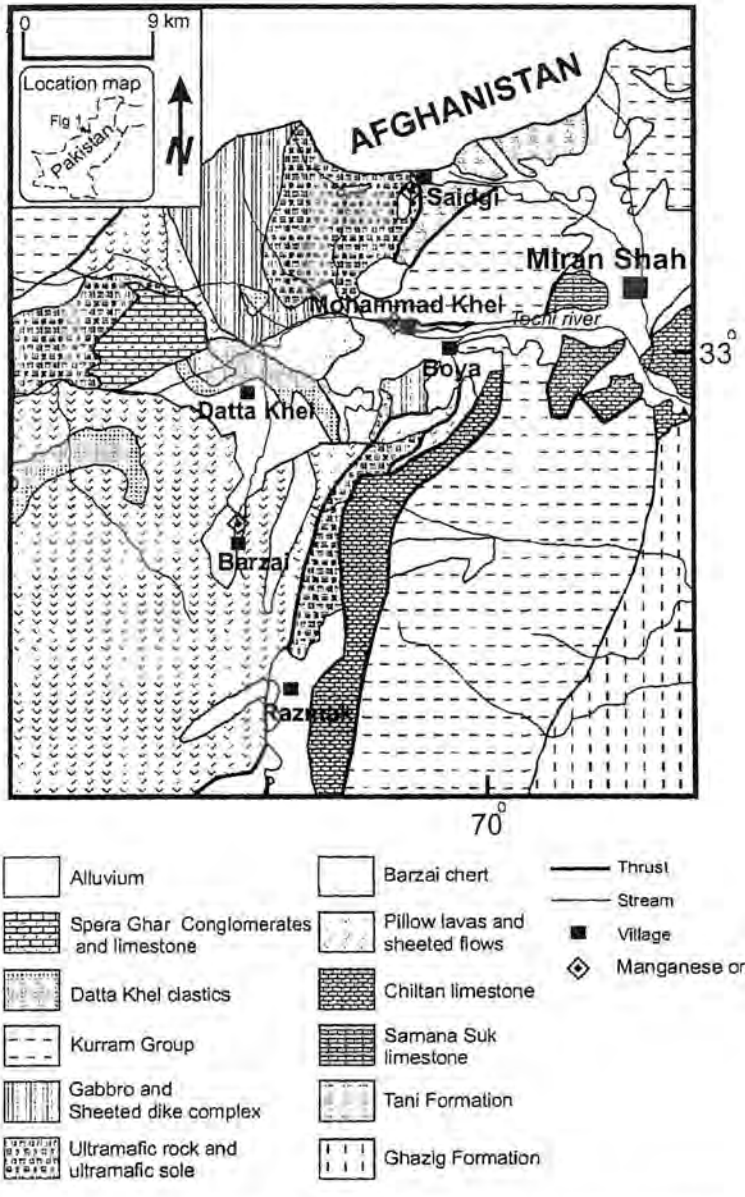

Fig. 1. Geological map of the part of the North Waziristan, N.W.F.P., Pakistan. (Simplified after Badshah, 1985).

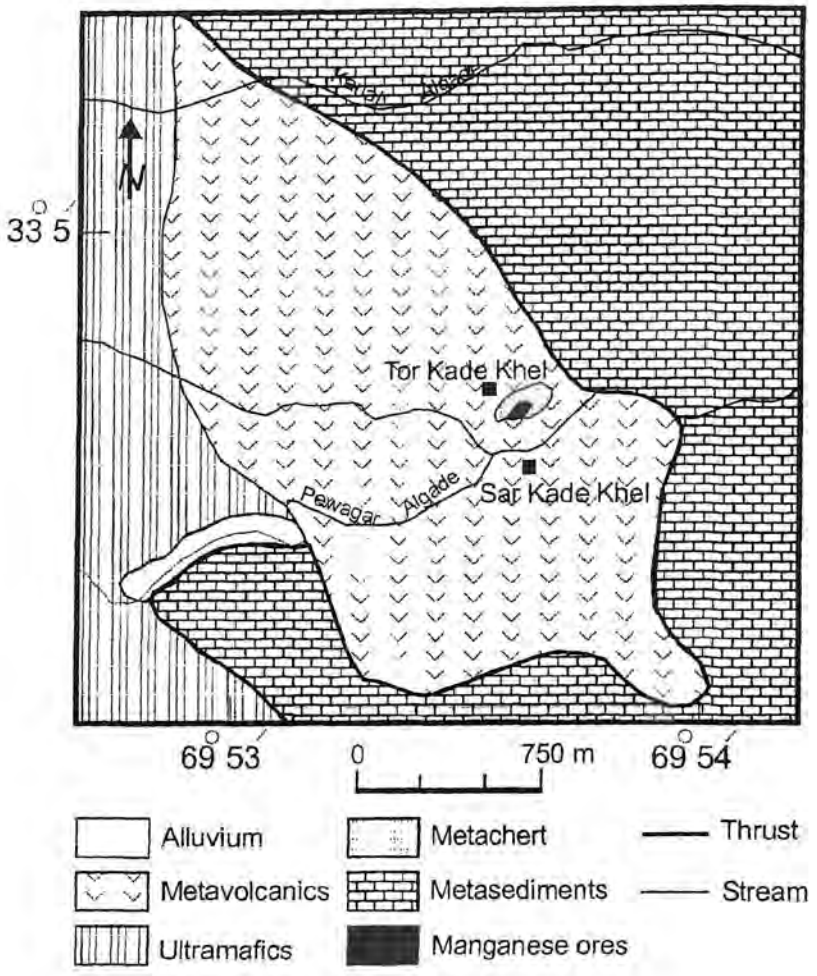

Fig. 2. Geological map of the Saidgi area, North Waziristan.

METHODOLOGY

Two samples of different grades 37.98 wt% and 57.36 wt% MnO_2 (10 kg each) were crushed in the laboratory scale jaw crusher up to < 1.8 cm size. The material after jaw crusher treatment was reduced up to 2mm size by the roll crusher. This product was then split further through riffle box to prepare the final sample for further processing. One kilogram each of both the samples was grinned in the rod mill for up to 5-10 minutes. This grinding gave material varying in size from -100 to +200 #.

The -100 to +200 # size products of both the samples, obtained by the automatic sieve vibrating machine, were passed on to the magnetic separator having belt speed of 1-5 RPM and roll distance of 3mm, current intensity of 15-20 amp and potential difference of 20 volts. Magnetic separator gave three products of each sample, (1) Concentrate (2) Middling and (3) Tail.

The -100 to +200 # products of both the samples were also treated by gravity concentration method by using mozely shaking table for 12 minutes. The above-mentioned facilities were availed at the Mineral Testing Laboratory, Hayatabad, Peshawar. The end products (Concentrate, Middling and Tail) were analyzed for MnO_2, Fe_2O_3 (Total) by Atomic Absorption spectrometer and SiO_2 by colorimetric method in the Geochemistry Laboratory of the National Centre of Excellence in Geology, University of Peshawar.

RESULTS AND DISCUSSION

Beneficiation / up-gradation of ore is the pre-concentration of target metal within the ore deposits up to the desired level. Various techniques are being used throughout the world for up-gradation of many types of ores as per requirement of many industries. The manganese ores of the Saidgi area, having MnO_2 in the range of 36 to 60 wt% (Shah & Khan, 1999), can be cost effective if pre-concentration studies have been conducted on these deposits. The manganese ores required for the steel industry generally contain 48% MnO_2. However, much higher grades are required for Battery making industry (MnO_2 = 78-84 wt%) and chemical industry (74-84 wt% MnO_2). Keeping these grades under consideration, the manganese ores of Saidgi area can be utilized in steel making industry and are, therefore, already supplied or being supplied to the Pakistan steel industry at Karachi. However, the experimental studies were conducted for the up-gradation of the ores for their utilization in battery making and chemical industries and the results are discussed as below:

Table 1 and Table 2 shows the results of two samples, which are treated by magnetic separation and gravity concentration techniques respectively. It is clear from the Table 1 that the sample No. MB-1, having 37.98 wt% MnO_2, after treated by magnetic separator gave three products (i.e., Concentrate, Middling, and Tail). It is clear from this table that the Concentrates, Middling and Tail have 79.10 wt%, 39.50 wt%, 22.12 wt% MnO_2 respectively. In this process the SiO_2 has been retained in the Middling (47 wt%) and Tail (62 wt%). The recovery of MnO_2 in concentrate is 94.24% while the middling and tail have very low recovery of 3.99 wt% and 1.77 wt% respectively (Table 1). It is also clear from Table 1 that the sample No. MB-2, having relatively higher amount of MnO_2 (57.36 wt%) after treated by magnetic separator, gave similar results as that of the previous low grade ore-sample. The concentrate of this sample has been up-graded to 80.44 wt% MnO_2 and Middling and Tail contain 21.85 wt% and 5.36 wt% MnO_2 respectively. The recovery of MnO_2 in Concentrate of this sample has been calculated as 97.32 wt%. The Middling and Tail have low recovery of 2.24 wt% and 0.44 wt% respectively.

Table 2 shows the results of the same two samples (MB-1 & MB-2), which have been treated by a gravity concentration method. It is clear from this table that the sample No. MB-1, having 37.98 wt% MnO_2, has 60.23 wt% MnO_2 in the concentrate with the recovery of 89.05% while the Middling and Tail have 7.05 wt% and 3.90 wt% MnO_2 respectively. The sample No. MB-2, having 57.36 wt% MnO_2, has been upgraded to 72.19 wt% MnO_2 in the concentrate with the maximum recovery of 94.84 wt%. The Middling and Tail have 28.78 wt% and 22.12 wt% MnO_2 respectively.

TABLE 1. UPGRADATION OF TWO MANGANESE ORE SAMPLES OF SAIDGI AREA BY MAGNATIC SEPARATION METHOD

Sample No. MB-1

	Feed assay	Assay after treatment			Recovery after treatment		
		Concentrate	Middling	Tail	Concentrate	Middling	Tail
Wt(gram)	250.0	217.0	18.4	14.6			
Wt(%)		86.80	7.36	5.84			
MnO_2	37.98	79.10	39.50	22.12	94.24	3.99	1.77
Fe_2O_3	2.45	10.30	0.45	0.24	99.48	0.37	0.16
SiO_2	57.00	12.50	47.00	62.00	60.51	19.29	20.19

Sample No. MB-2

	Feed assay	Assay after treatment			Recovery after treatment		
		Concentrate	Middling	Tail	Concentrate	Middling	Tail
Wt(gram)	148	127.6	9.7	10.7			
Wt(%)		86.22	6.55	7.23			
MnO_2	57.36	80.44	21.85	5.36	97.32	2.24	0.44
Fe_2O_3	0.80	3.20	0.12	0.15	99.37	0.32	0.31
SiO_2	35.67	3.45	67.34	64.20	25.59	42.36	32.04

TABLE 2. UPGRADATION OF TWO MANGANESE ORE SAMPLES OF SAIDGI AREA BY GRAVITY CONCENTRATION METHOD

Sample No. MB-1

	Feed assay	Assay after treatment			Recovery after treatment		
		Concentrate	Middling	Tail	Concentrate	Middling	Tail
Wt(gram)	250.00	217.00	18.40	14.60			
Wt(%)		86.80	7.36	5.84			
MnO_2	37.98	60.23	56.23	39.22	89.05	7.05	3.90
Fe_2O_3	2.45	5.34	2.56	1.34	94.56	3.84	1.60
SiO_2	57.00	15.67	54.00	74.00	62.11	18.15	19.74

Sample No. MB-2

	Feed assay	Assay after treatment			Recovery after treatment		
		Concentrate	Middling	Tail	Concentrate	Middling	Tail
Wt(gram)	148.0	127.6	9.7	10.7			
Wt(%)		86.22	6.55	7.23			
MnO2	57.36	72.19	28.78	22.12	94.84	3.21	1.96
Fe2O3	0.80	2.78	0.56	0.67	96.78	1.65	1.57
SiO2	35.67	3.67	78.12	56.78	26.00	46.93	27.07

After treating these two samples by both the methods (i.e., magnetic separation and gravity concentration methods), it has been concluded that the manganese ores of Saidgi area can very easily be upgraded with a very high recovery (97%) for battery and chemical grade by the simple technique of magnetic separation.

Acknowledgement: We are very thankful to the management of the Mineral Testing Laboratory, Hayatabad for providing facilities for processing the samples for beneficiation studies, and the Director N.C.E. in Geology, university of Peshawar for providing the analytical facilities.

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