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Mineralogy and textural impact on beneficiation of goethitic ore

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ABSTRACT

The effect of mineralogy and texture on the beneficiation of goethitic ores from two different origins is highlighted. Sample A having 54.47% Fe with 8.57% loss of ignition (LOI) indicates the presence of vitreous and ochreous goethite, martite and microplaty hematite as the major minerals. Sample B contains 56.90% Fe with 14.4% LOI. There is a pisolithic laterite containing vitreous and ochreous goethite, quartz, kaolinitic clay and there is no hematite mineral. The liberated minerals in −150 + 100 μm size class are 74% for Sample A and 37% only for Sample B which shows that the Sample A appears to be more amenable to beneficiate. A concentrate of 46.7% with 63.22% Fe could be recovered from Sample A while subjected to gravity separation followed by wet magnetic separation. The Sample B does not respond to gravity and magnetic separation due to its complex mineralogy. However, calcination of the Sample B followed by magnetic separation gives the encouraging results. Thus, anomalous behaviour of the goethite dominated ores in beneficiation is attributed to the different textural and liberation characteristic.

1. Introduction

Iron ore is the basic raw material used for iron and steel making. The principal impurities associated with iron ores are silica, alumina, sulphur and phosphorous. The high grade hematite iron ores require simple crushing and washing. As the grade of ore is declining, run-of-mine ore needs intense washing before shipment. Depending upon the origin and mineralogical characteristics of the ore, beneficiation methods vary from simple crushing and screening to complex concentration processes. Basically, the processes based on gravity and magnetic separations and flotation have been used for concentration of low grade iron ores. Today the low grade iron ores are goethitic/lateritic in nature. Goethite is one of the important ferruginous mineral in lateritic rock, lateritic iron ore and important part of the iron ore slimes. It occurs as vitreous goethite and ochreous goethite. It is formed during chemical weathering of iron ores and banded iron formation. It can incorporate variable amounts of other elements such as Al, Mn, P, Si, Cd, Ni, Cr, V, Zn and Co in the crystal structure due to its adsorption capacity [1–3]. The processing of these types of iron ore does not respond to the conventional techniques of gravity or magnetic separation. As the demand of iron ore is increasing, it is necessary to recover the resources from the lean grade iron ore or goethitic ores through beneficiation. The correlation of mineralogy and texture to engineering parameters such as strength, comminution efficiency, product size and liberation was attempted [2–4]. The type of mineralogical complexity appeared from the characterization studies of the lean grade/goethitic iron ore causes difficulty in beneficiation and conventional route of beneficiation might not be effective to improve the iron grade in the concentrate. Beneficiation of these types of ore through conventional process is a challenging task and interesting research work is in progress [5–7]. Beneficiation of any ore depends not only on the chemistry of the feed material but also on the texture and associated minerals.

The concept of the paper is to assess the impact of mineralogical and textural effect for ascertaining the possible beneficiation scheme for the goethitic types of ores from different origins.

2. Materials and methods

2.1. Materials

Iron ore samples with contrasting chemistry from two different origins of eastern and middle part of India were taken in the present investigation. The Sample A represents 54.47% Fe with 4.90% SiO_2, 7.26% Al_2O_3 and 8.57% loss of ignition (LOI). The second Sample B possesses about 2.5 unit higher Fe (56.9%) with less silica and alumina (Table 1). However, LOI in the Sample B is significantly high as 14.4%. Characterizations of the samples were carried out to identify the mineral phases and their association (Table 2).

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Table 1
Chemical composition of goethitic iron ore samples.

Constituent (%)	Fe (T)	Fe_2O_3	SiO_2	Al_2O_3	CaO	MgO	Mn	P	LOI
Sample A	54.47	78.46	4.9	7.26	0.046	0.058	0.016	0.096	8.57
Sample B	56.70	80.26	1.79	1.77	1.34	0.13	0.21	0.05	14.4

Table 2
Mineral phases in goethitic iron ore samples.

Sample	Mineral phase
A	Vitreous & ochreous goethite, martite, microplaty hematite, kaolinitic clay, quartz
B	Pisolithic laterite, vitreous & ochreous goethite, quartz, kaolinitic clay, but no hematite

2.2. Methods

2.2.1. Characterization of Sample A

The mineralogical and optical characterization of the Sample A were studied through optical microscopy technique to establish the characteristics of hematite and/or goethite dominated ore types. The ore fragments exhibit various ore textures. Some of the grains are of high grade exhibit a texture of dense martite, microplaty hematite and goethite-martite. The fragments of low grade (lateritic ore) exhibit ochreous goethite-vitreous goethite texture. Goethite occurs with colloform structure, fracture fillings/-cavity fillings and pisolith enclaving clay at the core (Fig. 1a–d). At places, pisoliths of clay of varied size are cemented by goethite giving an intimate interlocking of clay and goethite to a scale of <10 μm. The observations reveal that the interlocking of goethite and clay within a size less than 50 μm may lead to poor liberation. The processing at the finer size possesses difficulty and reduces the efficiency of the process.

2.2.2. Characterization of Sample B

Characterization study of the Sample B under zoom microscope indicates the occurrence of goethitic pisoliths within a goethite-clay matrix. The pisoliths exhibit concretionary colloform structure with alternate shells of clay and goethite under microscope. These pisoliths are fractured and subsequently filled with the secondary goethite enhancing the concretion (Fig. 2a). Very often, a matrix of fracture filling is dominated by clay (Fig. 2b). Such texture leads to a high degree of interlocking of the ore and gangue minerals. The textural study indicates the interlocking of clay within goethite in a scale of 25 μm or smaller. The extensive interlocking at fine size leads to a poor liberation.

2.2.3. Liberation characteristics

The association of gangues with the iron bearing minerals were studied through liberation using wild zoom stereo microscope (Leica make). Degree of liberation of two samples in the ore crushed to 1.68 mm was studied for various size fractions. Each fraction was subjected to modal analysis of liberated ore mineral, liberated gangue mineral and interlocked grains. Percentage of liberated and locked grains in the size fractions were presented in Fig. 3. Liberation study of the Sample A in the size class of −1200 + 300 μm indicates around 53% liberation and it improves to 74% in the size class of −100 + 74 μm and 86% in the size range of −63 + 32 μm. In case of Sample B, presence of goethitic pisoliths and clay within the matrix of goethite indicates the extensive interlocking at very fine size and leads to poor liberation. In the size class of −63 + 32 μm, liberation is 61% only (Fig. 3). Adequate liberation required for beneficiation can be achieved only at ultrafine size (below 10 μm). However, efficiency of the process drops drastically at ultrafine range. This reveals that liberation characteristic of the Sample B is inferior to the Sample A even at a fine size.

3. Sample preparation and methodology

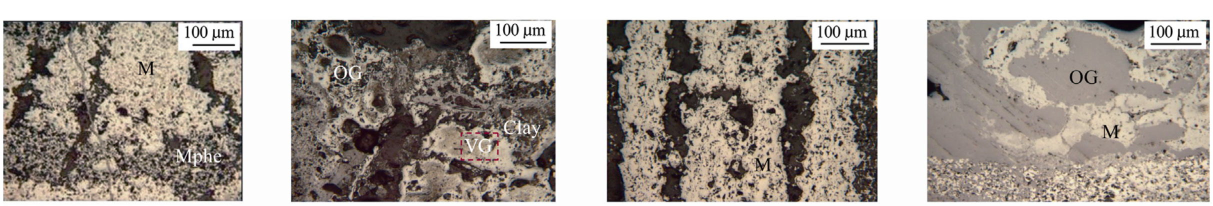
3.1. Sample A

The top size of the as-received Sample A was −10 mm. It was crushed in stages to produce −6.3 mm for subsequent scrubbing and washing study. The washed sample was sieved at 1 mm to produce different size classes for unit operations. The −6.3 + 1 mm washed fraction was subjected to gravity concentration using mineral jig in two stages. The reject from the gravity concentration and −1 mm washed fines were ground to 0.15 mm and deslimed using 2″ hydrocyclone. The deslimed product was subjected to wet high intensity magnetic separation (WHIMS) to recover the iron rich concentrate.

The beneficiation study of Sample A was also carried out by direct crushing and grinding of the as received ore sample to −0.15 mm followed by hydrocycloning and wet high intensity magnetic separation. Magnetic field intensities were varied while carrying out the magnetic separation experiments for producing the concentrate with desired grade.

3.2. Sample B

In view of the poor liberation characteristics of the Sample B, conventional beneficiation study was carried out by crushing and grinding of the sample at finer sizes viz, 150, −74 and 44 μm for assessing the response of the magnetic separation. The thermogravimetric and differential thermal analysis of the sample was studied to assess the effect of heat treatment. Sample B was also processed through heat treatment using direct feed sample



(a) Dense martite (M) and microplaty (Mphe) hematite in coarse fragment
(b) Lateritic fragment with ochreous goethite (OG),vitreous goethite (VG) and clay
(c) Martite-quartz association as bands showing interlocking
(d) Goethite-martite texture showing ochreous goethite-dense martite with interlocked clay

Fig. 1. Photomicrograph of low grade ore fragments in Sample A.