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# EFFECT OF MINERALOGY AND TEXTURE ON THE STRENGTH OF IRON ORE

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## ABSTRACT
*A preliminary investigation on three types of iron ore from the same deposit was carried out. Major minerals in all the three ores are dense martite, microplaty hematite, vitreous goethite, ochreous goethite at varied proportion whereas kaolinite and quartz occur in minor to trace amount. There is a textural variation with micro-porosity. The strength is the maximum (674 kg.f/cm$^2$) in the ore dominated by dense martite and pseudotachylite whereas moderately low (254 kg.f/cm$^2$) in the ore with micro-platy hematite and extensive micro-porosity, and is the lowest (157 kg.f/cm$^2$) for the ore dominated by goethite. Presence of pseudotachylite, reported for the first time, in dense martite iron ore possibly provides additional strength to the latter.*

## INTRODUCTION
Strength of ore is an important physical parameter related to the breakage efficiency of ore in mining and comminution, grindability in comminution, and slime content in the comminution product. It is also related to numerically poorly quantifiable parameters such as mineralogy, texture and structural attributes. The amenability to breakage in an engineering process such as grinding process is expressed in terms of breakage distribution function, work index [1] and preferential breakage, and is used as a parameter of comminution efficiency of the process (or grinding mill efficiency). So, the correlation of mineralogy and texture to engineering parameters such as strength, comminution efficiency, product size, liberation is attempted in last few decades [2-7]. The present investigation is aimed at developing a basic understanding in correlating mineralogy and texture with the strength of hematitic iron ore so that it can be extended to grindability later.

## THE IRON ORE
The hematitic iron ore sourced from the deposit in Bonai-Keonjhar-Singhbhum area in eastern India, belongs to the Iron ore Group of Singhbhum craton of Precambrian age [9,10]. The deposit is indicated as supergene modified hydrothermal type with friable saprolitic ore derived from a precursor 'hydrothermally altered iron ore formation', successively enriched by supergene activity and subsequently altered to the present state [11]. The ore is broadly classified on the basis of its physical attributes. But there is no comprehensive classification catering to the common need of geology, mineralogy, process mineralogy and rheological characteristics. It is comprised of dense martite, microplaty hematite, vitreous goethite, colloform goethite and closely associated gangue minerals such as quartz, kaolinite. As a basic requirement of hematite-goethite mineral system three ores were defined as i) dense martitic ore, (ii) micro-platy hematitic ore and (iii) ochreous goethitic ore based on the dominant mineralogy.

## MINERALOGY AND TEXTURE

In general, majority of the high grade ores in this deposit contain dense martite, microplaty hematite and their altered variant goethite. The low grade ore is dominantly of colloform goethite associated with kaolinite, gibbsite, detrital quartz and goethitic nuggets. In the present three ore-types of hematite-goethite mineral system, major minerals are dense martite, micro-platy hematite, vitreous goethite, ochreous goethite at varied proportion whereas kaolinite and quartz are of minor to trace amount. They contain microporous zones with randomly oriented microplaty hematite of various dimension and intergranular pore spaces of micron size.

'Dense martitic ore' consists dominantly of dense martite, microplaty hematite, trace amount of quartz and kaolinite. Kaolinite appears in the fracture fillings (Fig.1A,B). The abundance of microplaty hematite is correlatable with microporosity in the ore. The dense martite have compact packing with grain-to grain common grain boundary, limited intergranular pore space, thus appear as a zone of uniform reflectance under microscope. Martitic grains are of the size 40-115μm. The microplaty hematitic grains are of size ~20μm X 2μm or smaller. The intergranular pore space between these minerals is very small but voids are of the size ~40-60μm occasionally up to 150μm. There exist micro-bands of dense martite and microplaty hematite giving a lamellar appearance. The darker lamellae represent the zone of enhanced micoporosity. The lamellae show sigmoidal shear zones (Fig.1A). The pseudotachylites with submicroscopic grain size replace the microporous zones in limited scale, concordant and discordant to the lamellae (Fig. 1A,B). There is limited degree of alteration of hematite to goethite along some of the lamellae.

'Microplaty hematitic ore' consists dominantly of micro-platy hematite, minor goethite, trace amount of kaolinite and quartz and no dense martite. Micro-platy hematite show random network with wider intergranular space (Fig.1C). The length of micro-platy hematite is 75μm -160μm and width of <5μm -10μm thereby giving a higher length to breath ratio. Often the networking hematites collapse locally to form voids or open surface (micro-foliations / shear foliation?) along which goethitic alteration, clay encrustation, and occasional crystallization of secondary nanometer thick microplaty hematites [12] are observed. The voids are of wider dimension in the range of 43μm -500μm, often interconnected to give a cleaved appearance.

'Ochreous goethitic ore' consists dominantly of goethite, minor amount of microplaty hematite, martite, minor amount of kaolinite and quartz (Fig.1D). These are the secondary alteration product of iron ore fragments and cogenetic regoliths, reconsolidated by colloform goethite. The entrapped mineral component is altered to kaolinite and is found as interlocked phase. There are tubular pores left behind after partial concretion of ochreous goethite.

Broadly, the three ore-types have distinct textural characteristics. The 'dense martitic ore' has a texture with less pore volume, where the development of microporosity is limited and the microplaty hematites are weakly developed up to fine grain size. The connectivity of micropores is limited. The 'microplaty hematitic ore' is highly porous with larger pore-size and extensive pore connectivity. The goethitic ore is dominated by the matrix of goethite enclaving the pockets of hematite, martite, kaolinite and quartz .

## STRENGTH OF ORE

The strength of ore in all the three variants is quite different. Uniaxial compressive strength was found to be 674 kg.f/cm$^2$ for dense martite ore, 254 kg.f/cm$^2$ for microplaty hematite ore and 157 kg.f/cm$^2$ for goethite ore. In comparison to the reported data on iron ore, the strength of these variants is low to moderate.

## DISCUSSION

The data generated for a hematite-goethite mineral system was selectively on texturally different ore-types. The classification of iron ore on the basis of mineralogy and texture were suggested by several workers, lattest

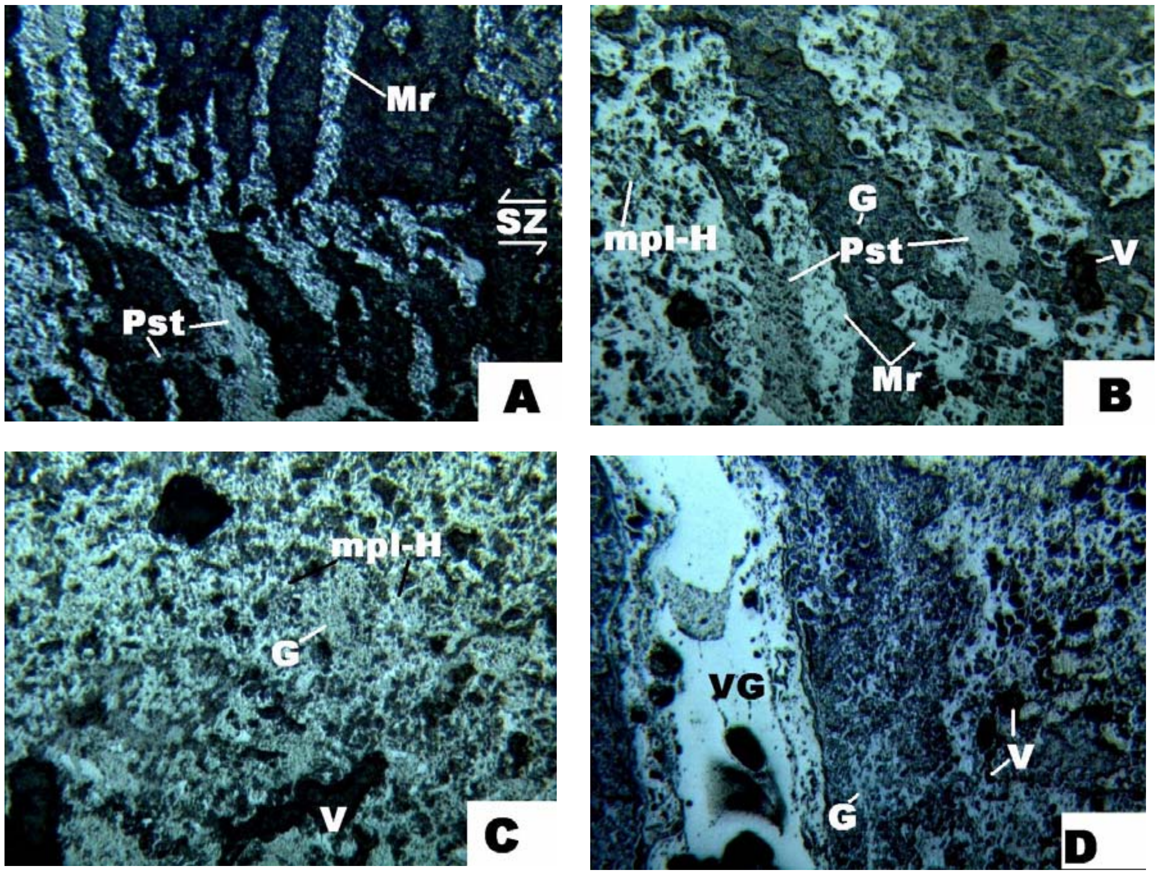


Fig. 1 Mineralogical and textural attributes of 'dense martitic ore' (A,B), 'microplaty hematitic ore' (C ), 'ochreous goethitic ore' (D) under polarizing microscope. Mr= martite, mpl-H= microplaty hematite, G=Goethite, VG= vitreous goethite, Pst= pseudotachylite, V= void, SZ= shear zone. [A] Sigmoid sinistral micro-shear zone shows displacement of dense martite lamellae. Concordant and discordant pseudotachylites fill the voids and weak surface. [B] Dense martitic ore with martite and limited microplaty hematite, low porosity and pseudotachylitic fillings at higher magnification. [C] Microplaty hematite ore shows network of microplaty hematites with lager voids and extensive micropores. [D] Goethite ore shows microplaty hematites altered to goethite and fracture fillings by vitreous goethite. Scale: length of the photograph is 0.45mm in B,C &D, and is 1.8mm in A.

being the Pilbara Iron Ore Classification (PIOC) scheme by Kneeshaw [13] and Clout [14]. Clout [14] added the term hardness, a misnomer to strength, and correlated with the texture of iron ore defined by relative proportion of goethite and hematite. Microplaty hematites are suggested to be defining the schistosity planes related to crystal plastic deformation of hematite during geotectonic process [16]. In this perspective, the present observation of microporous zones and micro-shear zones indicate the laminations to be shear related response of the hematite-martite type ore. Higher the abundance of dense martite, lower is the degree of microporosity and higher degree of grain-to-grain contact area and better is the strength. The networking of pseudotachylite as concordant and discordant fillings lowered the pore volume and possibly added strength to the ore as do the ultramylonites. Due to the lack of colour contrast, such structural features are difficult to be observed in iron ore in the field or in hand specimen. Pseudotachylite in iron ore is reported for the first time. Pseudotachylite is suggested to be the quenched frictional melt generated by seismic faulting related brittleductile deformation process [17-19], and is often associated with crack seal veins [20] as found in the thrusted deep crustal igneous rocks. In the case of iron ore, the pseudotachylite has partly replaced the porous space in dense martitic ore causing further consolidation and enhancement of strength.

## CONCLUSION

The study reveals that the strength of iron ore enhances with the increase of hematite as observed in 'martite ore' and 'microplaty hematite ore' supporting the observation by Clout [15]. The strength further enhances as the abundance of dense martite increases and void size lowers as in 'dense martitic ore'. The replacement of pore space by pseudotachylites in dense martite-microplaty hematite system may be providing additional strength. The present correlation of mineralogical texture to strength will find application in the grindability of iron ore.

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