1

IRON ORE DEPOSITS OF INDIA

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1
Introduction

Iron is the fourth most abundant element in the earth’s crust after oxygen, silicon and aluminum and is the second most abundant metal next to aluminum in the earth’s crust. Iron constitutes about 5% of the earth’s crust and it is ubiquitous in the lithosphere either as a major constituent or in trace amounts. India was the World's third biggest exporter of Iron ore as in 2013.

1.1 Uses: By far, the most important use of iron is in the making of steel, which is essentially an alloy of iron with carbon and other elements depending on the end use. India is one of the earliest manufactures and users of iron and steel in the world. Iron and steel together account for the largest manufactured products in the world and each of them enters into every branch of industry and is a necessary factor in every phase of our modern civilization. Pure iron has relatively few and quite specialized uses.

The iron and steel producers account for about 98 per cent of the iron ore consumed in the country with about 80 per cent going to independent pig iron and integrated steel units and 18 per cent to the sponge iron industry. The nature of specific demand for iron ore is dynamically driven based on technology in steel/iron making. For
example, in India, the demand for lump ore has grown strongly in the past few years due to a very rapid growth in the sponge iron industry.

1.2 Forms of Iron ore: Iron ore of size more than 10 mm and up to 150 mm is being classified as lump ore which are used mainly in blast furnaces and sponge iron plants. Iron ore of size less than 10 mm is classified as fines. The fines are used either in the production of sinters or pellets. Iron ore of size less than 10 mm and ultra fines in the size range of 0.1 mm to 10 mm are utilized as sinter feeds. The ores of size less than 100 mesh obtained either by grinding of high grade fines to less than 100 mesh or by beneficiating low grade ores/fines followed by grinding to less than 100 mesh, are utilized as pellet feed fines. There is another sub-category of fines called slimes, less than 100 mesh in size, produced during washing of iron ores. These are mainly rejects and wastes. They are generally low to medium grade in terms of iron content and are impounded in the tailing ponds near the mines. These slimes can be used for pelletisation.

2.0 Mineralogy

The following are the iron minerals encountered in the deposits:

2.1 Oxides & hydroxides:
- Magnetite (Fe₃O₄)
- Hematite (Fe₂O₃)
- Specularite (Fe₂O₃) and
- Limonite [Fe₂O₃. nH₂O; Fe (OH)₃]

2.2 Silicate and hydrous silicates:
- Chlorite [FeSi₂O₅ (OH)₄]
- Grenalite [(Fe, Mg) ₆Si₄O₁₀ (OH)₈]
- Chamosite [Fe₄Si₄O₁₀ (OH)₈]
- Minnesotaite[Fe,Mg₃ Si₄O₁₀(OH)₂]
- Grunerite[(FeMg)₇SiO₂₂(OH)₂]
- Stipnomelane [(Ca,Na,K)₀.₅ (Fe⁺²,Mg,Al)₄ Si₄O₁₀(OH)₂. 2H₂O] and
- Olivine Fayalite(Fe₂SiO₄)

2.3 Sulfides:
- Pyrite (FeS₂) and
- Pyrrhhotite (Fe₁₋ₓS)
2.4 Carbonates:

Siderite (Fe CO₃)

Hematite and magnetite are the most important ore minerals in the Indian iron ore deposits. About 59% hematite ore deposits are found in the Eastern Sector and about 92% magnetite ore deposits occur in the Southern Sector, especially in Karnataka. Of these, hematite is considered to be superior because of its higher grade and occurs in massive, laminated, friable and powdery form. In India, major amount of Hematite is found in Orissa, Jharkhand, Chhattisgarh, Karnataka and Goa. Minor amount of Hematite is found in Andhra Pradesh, Assam, Bihar, Maharashtra, Madhya Pradesh, Meghalaya, Rajasthan and Uttar Pradesh. Major amount of Magnetite is found in Karnataka, Andhra Pradesh, Rajasthan and Tamil Nadu. Minor amount of Magnetite is found in Assam, Bihar, Goa, Jharkhand, Kerala, Maharashtra, Meghalaya and Nagaland.

3.0 Iron Formations

Iron ores are sourced from Iron formations, which formed during specific periods of earth’s history. It is therefore pertinent to understand the terminology adopted in the description of iron formations, its distribution in space and time and genesis of iron formation.

3.1 Terminology: The term iron ore is typically reserved for a rock containing more than ~35 wt% iron.

Banded Iron Formation (BIF) refers to rocks containing more than 20-25% iron with silica in the range of 40-50% occurring in alternate layers and thinly laminated. Banded Iron Formations are known by different names in various parts of world: - Taconite (in USA and Canada), Itabirite (in Brazil) and Jaspillite (in Australia). In Banded Iron Formation, iron may be present as oxides, hydroxides, carbonates and silicates.

Banded Hematite Jasper (BHI) refers to an evenly laminated rock with thin alternate layers of primary hematite and deep brown colored chert admixed with dusty inclusions of hematite granules.

Banded Magnetite Jasper (BMJ) refers to rocks composed of unevenly banded chert, colored brown to reddish brown due to mixture of magnetite dust, with incipient bands of iron oxide, mainly magnetite.
Banded Martite Quartzite (BMtQ) refers to rocks composed of regular alternate layers of iron oxide essentially in the form of martitized magnetite with or without supergene/secondary hematite and silica in recrystallized form.

3.2 Occurrence and distribution: Iron ore deposits are distributed in different regions of the world under varied geological conditions and in different geological formations. Iron formation or Banded iron formations occupy a special position in pre-cambrian sedimentation history of the earth, because they have no similar counterparts in the Phanerozoic era. About 90% of the world’s iron ore production is obtained from Precambrian Banded Iron Formations. Banded Iron Formation has great economic potential, being the host rock for the accumulation of many useful metals like iron, manganese, copper and gold. The Precambrian Banded Iron Formation, subsequent to their deposition, has been subjected to various degrees of metamorphism and surficial leaching. Hence, the iron minerals of Banded Iron Formation, now exposed in different parts of the world could be either sedimentary, diagenetic, metamorphic or supergene origin.

3.3 Genesis of Iron formations: Gross (1965) identified two main types of iron formations from the Precambrian viz: Algoma and Superior types. The Algoma type is dominantly Archean in age and characterized by thin banding and absence of oolitic and granular texture, limited in lateral extent, closely associated with volcanic rocks, greywacke sediments, carbon- and pyrite- rich black shales. The Superior type is characteristic formation of Proterozoic, laterally very extensive and closely associated with clastic sediments like quartzite, dolomite and pelitic rocks without any direct relation with volcanic associations. The Banded Iron Formations of India posses the characteristic of both Algoma and superior types.

Opinions vary as to whether BIFs in specific regions accumulated in open seas, semi-closed seas, lagoons, or lakes. It is generally considered that BIF accumulated in large water bodies. Majority of the iron minerals in BIFs (except some iron-rich silicates) precipitated by chemical/biochemical processes utilizing the dissolved Fe (mostly as Fe$^{2+}$) in water bodies. Iron precipitation was episodic and resulted in alternating iron-rich and silica-rich bands. It is considered that larger and more widespread iron deposits are of sedimentary origin. Volcanic nature of Archean iron formation has also been recognized. A controlling factor for the formation of iron was probably the composition of ocean water.
during the Archean. The period of intense iron deposition was preceded by a long period of accumulation of dissolved iron and silica in sedimentary basins.

Another view is that iron formation is essentially a product of diagenetic replacement of primary carbonate. Although there is evidence of replacement process in the formation of iron, this process cannot account for the vast amount of iron in iron formations.

The character of late Archean–early Proterozoic atmosphere is also taken into consideration for origin of BIF. The atmosphere at that time is believed to have been rich in carbon dioxide, nitrogen and deficient in oxygen. Vast quantities of iron thus got stored in oceans and lakes. Later on when life first appeared, photosynthetic release of bulk oxygen became possible. This oxygen combined with the dissolved iron and precipitated it giving rise to iron rich bands. Once the dissolved iron was used up, there was no further formation of iron. But iron formation as old as 3000 million years indicates that the buildup of oxygen in hydrosphere also took occurred much earlier.

Manganese is commonly associated with iron formation. Sulphide iron formation hosts polymetallic sulphide deposits and some of the BIFs host gold deposits. BIF associated gold and sulphides are widely distributed in the Archaean greenstone belts of South Africa and comparable deposits occur in parts of Karnataka state in India.

4. World and Indian occurrences of Iron ores

4.1 World occurrence: The top ten countries in the world in the order of their iron resources are the Common-wealth of Independent States (i.e., erstwhile USSR), Australia, Canada, USA, Brazil, India, South Africa, China, Sweden and Venezuela.

4.2 Indian Occurrence: BIF has given rise to vast accumulations of commercial grade iron ore deposits in India and more than 90% of the iron ore supplied to the industry comes from the BIF. All the iron ore deposits of India belong to the Iron ore series and their equivalents of the Dharwar group composed of metavolcanics and metasediments. Economic concentrations of iron ore are thought to have been resulted from the enrichment of BIF by supergene lateritization process involving progressive removal of silica.

Major iron ore deposits in India occur in Singhbhum district (Jharkhand), Keonjhar district (Orissa), Bellary district (Karnataka), Bastar district (Chhatisgarh) and Goa. The
different textural types of iron ore within the deposits are (a) massive ore (b) laminated ore and (c) blue dust. In addition, float ore accumulations on the slopes and foot of the hills as a result of disintegration of insitu ore bodies commonly occur. The float ores are of different sizes and of different degree of purity.

Based on their association with rock formations, iron ore formations in India can be broadly classified into two groups:-
1. Those lying within the high-grade region of southern Karnataka, Kerala, Tamil Nadu and Andhra Pradesh.
2. Those confined to Archaean greenstone belts of Madhya Pradesh, Chhattisgarh, Bihar, Orissa, Goa and Karnataka.

Iron Formations in the high-grade metamorphic regions are older formations (3500-3000 million years) and have been subjected to deformation and metamorphism. Minor bands of intimately folded and metamorphosed iron-rich beds occur in such an association. Iron formations in the younger (2900-2600 million years) Archaean greenstone belts form continuous bands and contain rich concentrations of iron.

The geological features of major iron ore deposits of India are described in the following sections.

4.2.1 Jharkhand: In Jharkhand (formerly Bihar) iron ores are essentially represented by haematite and magnetite. Precambrian sedimentary rocks intruded by basic intrusive of the Iron ore group constitute the host rock of iron formations. These rocks are folded and occur as a series of ridges capped with thick deposits of hematite ore. Alternate bands of hematite and jasper (BHJ) occur. Iron ores exhibit a variety of textures and contain varying proportions of iron as follows:-
   a) Massive, compact ores commonly capping ridges contain 66% to 70 % iron.
   b) Shaly ore exhibiting laminated texture and composed of hematite contain less than 50% iron.
   c) Laminated ore with open spaces between laminae and biscuit like contain 55- 66 % iron.
   d) Lateritic ore contain 56-58 % iron.
   e) Blue dust, grayish blue in color and occurring in pockets contain 65-68 % iron.
Iron ores are reported from several areas in Singbhum and Palamau districts of Jharkhand.

In the Singbhum district, important iron ore deposits (principally hematite) occur in a number of prominent hills in the southern part of the district extending from southwestern part of Singhbhum district and continuing into the Keonjhar and Sundergarh districts of Orissa and forming the famous Singhbhum-Keonjhar-Bonai group of deposits. Titaniferous magnetite ores consisting of ilmenite and magnetite are present with minor haematite, rutile and goethite occurring as thin veins, lenses and pockets in gabbroid and ultrabasic rocks. The two important Precambrian formations in the area are the older Iron Ore Series (containing iron formation) and younger Kolhan Series. The rock formations have undergone multiple episodes of deformation. Majority of the iron ores occur in the hinge region of the antiformal fold. The iron ore group of rocks are broadly classified into three based on their mode of origin as: (i) Iron Ore Group of clastic facies, (ii) Iron Ore Group of Transitional chemogenic facies and (iii) Iron Ore Group of volcanogenic facies. The iron formation, which overlies the volcanic pile, consists of beds of jaspilite and haematitic rock and contains varying proportions of iron oxide and silica. Clastic sediments represented by manganiferous shale, Phyllitic shales, succeed the iron formation.

In the Palamau District, three types of iron ores occur: (i) Magnetite occurring as bands in metamorphic rocks, (ii) Siderite and hematite occurring as beds in shale or as concretionary masses in sandstone of Barakar Formation and (iii) Laterite ore on the plateaus. Of these, magnetite ores occurring as fragments and lumps form economic concentrations.


The iron formations along with volcano-sedimentary rock piles constitute the Iron Ore Group (IOG). Banded Hematite Jasper consists of alternate layers of dark bluish-grey haematite and red coloured jasper and the thickness of the bands vary from 0.5 to 1.15 cm. The iron ore bodies are considered to be products of surface alteration of Banded Hematite
Jasper. Iron content of unaltered Banded Hematite Jasper is around 20%-30% while iron content of enriched Banded Hematite Jasper varies from 55%-70%.

Northern part of Orissa being occupied by the cratonic block of Singhbum is also a repository of iron ore. The Iron Ore Group of rocks with rich deposits of iron ore occurs in Keonjhar, Sundargarh, Jajpur, Mayurbhanj, Nawrangpur and Sambalpur districts.

4.2.3: Iron ores of Chattisgarh: Large deposits of excellent quality iron ores are found in Bastar, Durg, and Dantewara districts of Chhatisgarh. Smaller deposits occur in Raigarh, Raipur, Bilaspur, Rajnandgaon, Kanker and Jashpur districts. Majority of the iron ore deposits of Bastar and Durg districts are associated with Bailadila Iron Ore series of Archaean age. The Bailadila iron Ore Series of rocks resembles iron ore series of Singhbhum-Keonjah-Bonai of Orissa and Jharkhand.

The Bastar craton forming part of the central Indian peninsular shield comprises high grade metamorphic rocks including metasediments, metabasites, charnockites and gneiss-migmatite complex referred to as the Bengpal group. The Bengpal group is overlain by Banded Iron Formation - greenstone sequence referred to as the Baildiala group. The Bailadila iron ore series forms a synclinorium with N-S axis and a central eroded anticline flanked by two synclines, which form ridges with prominent bands of iron ore. Most of the iron deposits are composed of haematite ore, while a few are small deposits of magnetite ore. The ore bodies are not confined to any particular horizon. The iron formations have close similarity in lithological association and tectano-metamorphic history with the iron formations of other belts. The oldest Banded Iron Formation occurring as enclaves within the gneissic complex is grouped under Bengpal group. The Bailadila group which contains bulk of the iron formations comprises of quartz sericite schist, arkosic quartzite at the base, followed by Banded Iron Formation associated with shale-siltstone carbonaceous shales and interbedded tuffs, intruded by greenstones and granites. The main Banded Magnetite Quartzite formation stands out boldly above ferruginous schists and grunerite quartzites, and forms the highest ridges of the Bailadila range. All the rocks of the Bailadila iron ore series, with the exception of basal quartzites, are markedly banded with alternate bands of hematite and quartz, hematite and grunerite, grunerite and quartz. Primary sedimentary structures such as ripple marks and current bedding have been observed in these iron formations indicative of sedimentary origin.
The Kaucha iron ore deposit is the largest in the Durg district. The iron-ore deposit occurs associated with the Dharwarian banded hematite quartzite belonging to the Bailadila iron-ore series. The Banded hematite quartzite is overlain and underlain by ferruginous shales and phyllites. The Banded Hematite Quartzite formations form prominent ridges and have been folded into a series of anticlines and synclines. Several ore bodies comprising of massive and laminated hematite are found at or near the top of the ridges; earthy-limonitic, brecciated and lateritic type iron ores are present in subordinate quantities.

Iron ores exhibit laminated and massive textures. Blue dust ores are formed by physical degradation of laminated ore; laminated type ores are generally associated with shales. High grade lateritic iron ores are encountered at the surface, which are underlain by massive ores. Float ore in large quantity is also found on the hillsides surrounding major deposits.

4.2.4 Iron ores of Karnataka: The most important iron ore deposits of Karnataka occur in the Sandur hills of Bellary-Hospet sector in Bellary District and Bababudan hills and Kudremukh-Gangamula range in Chikmagalur district. Other districts which contain smaller iron ore deposits are Chitradurga, Shimoga, Bijapur, North Kanara, South Kanara, Hassan. The principal ore minerals found in the various types of deposits are magnetite, haematite, limonite, siderite and pyrite.

Based on their mode of occurrence, iron ores of Karnataka may be classified into the following types:-

1. Sedimentary type mainly in the form of banded haematite quartzite and magnetite quartzite rocks encountered generally in the Archaean greenstone belts of Karnataka in three district horizons: (a) Greywacke association in parts of Ranibennur, Haveri, Gadag, (b) Chitradurga Group in Chikkanayakanahalli and Chitradurga areas, and (c) Bababudan Group in Kudremukh and Sandur areas.

2. Metamorphic type occurring in association with the granulites as Magnetite-Quartzite encountered in high grade metamorphic rock formations referred to as Sargurs.

3. Magmatic type consisting of Vanadium and titanium bearing magnetite bands associated with gabbroic-ultramafic layered complex forming a component of the ancient in Sargurs.
In the Bellary-Hospet area, the Sandur schist belt is characterized by a thick pile of volcanic rocks with minor amount of sedimentaries. Volcanics are represented by basic to acid varieties whereas the sedimentaries are both mechanically transported and chemically precipitated type. Iron ore and ferruginous chert/quartzite are intimately associated with metabasalt. The iron ore deposits, which form part of the spindle shaped Sandur schist belt are confined to two main bands. The banded haematite quartzites have been lateritized giving rise to cappings of hard, compact haematite. The following types of iron ores are reported:-

(1) Primary ore: Hard massive ore with Fe content 62% - 68%
(2) Secondary ore: (a) Lateritic ore with 50% - 55% Fe
(b) Thickly and thinly laminated ore with 62%-68% Fe
(c) Shaly ore with 55%-58% Fe
(d) Biscuity ore and blue dust with 60%-69% Fe

In the Chikmagalur district, major iron ore deposits occur in (1) Bababudan hill range and (2) Kudremukh-Gangamula range. Magnetite and haematite quartzite ore bands occur all along the 40 km stretch of the horse shoe covering an area of 400 sq km in the Bababudan belt consisting almost entirely of the rocks of Dharwar Supergroup and composed of quartzite, basic lava and iron association. Bedding and penecontemporaneous slumps are primary structures encountered in Banded magnetite quartzite bands consisting of alternate bands of magnetite (partly oxidized to haematite, limonite in top layers) and fine to medium grained quartz.

The Kudremukh-Gangumala range consists of metasediments and metavolcanics of Dharwar Super-group. Two main types of BIF are recognized - cherty type and shaly type. The iron ore formations have been lateritized and the depth of weathered zone varies from place to place and is thicker in ridge than in valleys. The soft weathered zone varies in depth from 30 to 50 m. Beds of magnetite quartzite range in thickness from 120 to 200 m and is traceable along the strike for nearly 50 km forming the lofty ranges.

Apart from the residual concentration of iron ore over the sedimentary banded iron formation, there is another class of deposits ore associated with mafic and ultramafic rocks in several parts of Karnataka. The chief among these occurrences are those forming the Nuggihalli schist belt. Here titaniferous ore occurs in the form of continuous beds associated with anorthositic gabbro and contain titanium and vanadium with magnetite.
4.2.5 **Iron ores of Goa:** The iron ores of Goa can be considered as the northernmost extension of the Chitradurga Group of Dharwar Supergroup of Karnataka and range in age from Archaean to Proterozoic era. Precambrian formations in Goa consist of quartzite, quartz-sericite-schist, metavolcanics, metagreywacke, conglomerate, pink phyllite with lenticular bodies of banded ferruginous quartzite and limestone intruded by ultrabasic and basic sills and dykes. All these formations are intruded by younger granite, pegmatite and vein quartz. The pink phyllite horizon (of Bicholim Formations) with banded ferruginous and manganiferous quartzite constitutes the main manganese and iron ore bearing horizon and extends over the entire length of Goa from north to south. Lateritization is all pervasive and the pink phyllites show large scale ferruginization because of extensive secondary enrichment of iron, leading to the development of soft iron ores. The iron ores of Goa have been classified into 4 types:

1. Lateritic ore derived from weathering of ferruginous phylllite with 48-50% Fe.
2. Lumpy hard ores, massive and laminated, cherry red in color with about 60% Fe.
3. Friable or biscuity ore, derived by extensive leaching which is porous, soft and crumples easily, containing about 60% Fe.
4. Blue dust or powdery ore consisting essentially of skeletal, flaky, loose hematite or sometimes magnetite, with occasional fragments of hard ore or siliceous bands, containing 63-68% Fe.

Lateritic iron ores which constitute the main source of iron are essentially of two types- lumpy ore essentially made up of haematite and powdery ore essentially made up of magnetite. Goethite and limonite occurs as alteration products. Near the surface, iron ores consist of hard lumpy ore followed at depth by friable and powdery ore (blue dust).

**5.0: FUTURE OUTLOOK**

Mining of iron ore, an essential raw material for Iron & Steel Industry is arguably of prime importance among all mining activities undertaken by any country. With the total resources of over 28.52 billion tonnes of hematite (Fe2O3) and magnetite (Fe3O4), India is among the leading producers as well as exporters of iron ore in the world.

India's iron ore production is set to witness a moderate growth of 10-12% to touch a level of 150 million tonnes in 2014-15 after witnessing a minor decline in the fiscal ending March 2014.
6.0: CONCLUSIONS

Iron ore being the backbone of steel industry is one of the most sought after metal and plays a vital role in the economy of a country.
India is bestowed with rich deposits of iron associated with various rock formations of differing ages.
Lateritic iron ores constitute economic concentrations in India.