ECONOMIC GEOLOGY

e – Learning Material: Unit-4

Dr.J.Saravanavel, Assistant Professor, Department of Remote Sensing,
Bharathidasan University, Email: saravanavel@bdu.ac.in,

FEROUS AND ALLIED METALS

IRON

Iron is the second most abundant metallic element in the Earth's crust and accounts for 5.6% of the lithosphere.

The principal minerals of iron are the oxides (haematite and magnetite), hydroxide (limonite and goethite), carbonate (siderite) and sulphide (pyrite).

Iron, like most metals, is found in the Earth's crust only in the form of an ore, i.e., combined with other elements such as oxygen or sulfur.

Haematite and magnetite are the two important iron ores from which iron is extracted. Of these, haematite is considered to be superior owing to its high grade.

It is rarely found in native state except in meteorites and some eruptive rock

The mineral containing iron must be mineable at profit is called iron ore. The total world iron production in 1990 is 1,008 million tonnes and India is 55.5 million tonnes and nearly 5.5%

The chief ores of iron are its oxides and carbonates

Mineral Name	Formula	Crystal System	Color	Opacity	Lustre	Streak	Hardness	SG	Fracture
Goethite	FeO(OH)	Orthorhombic	Blackish brown, reddish or yellowish brown, brownish yellow	Opaque	Adamantine-metallic to dull	Orange to brownish yellow	5 to 5.5	3.3 to 4.3	Uneven; brittle
Hematite	Fe2O3	Trigonal - Hexagonal	Steel-gray to iron-black, thin fragments deep blood red	Opaque	Metallic, submetallic, dull	Deep red or brownish red	5 to 6	5.26	Subconchoidal to uneven; brittle
Limonite	FeO.OH.nH2O	Amorphous/ Cryptocrystalline	Yellow, brown, brownish-black, orange-brown	Opaque	Non metallic	Yellowish-brown	4 to 5.5	2.7 to 4.3	Uneven, subconchoidal
Magnetite	Fe3O4	Cubic	Iron-black, grayish black	Opaque	Splendent metallic to dull	Black	5.5 to 6.5	5.17	Subconchoidal to uneven; brittle

The chief ores of iron are its oxides and carbonates

Mineral Name	Formula	Crystal System	Color	Opacity	Lustre	Streak	Hardness Low	SG	Fracture
Marcasite	FeS2	Orthorhombic	Pale brass-yellow to tin-white, darkens on exposure	Opaque	Metallic	Greenish black	6-6.5	4.92	Uneven; brittle
Pyrite	FeS2	Cubic	Brass-yellow	Opaque	Metallic	Empty	6-6.5	5.01	Conchoidal to uneven; brittle
Pyrrhotite	Fe1-xS	Monoclinic and hexagonal	Bronze-yellow to bronze-red; tarnishes dark brown	Opaque	Metallic	grayish black	3.5-4.5	4.53	Subconchoidal to uneven; brittle
Siderite	FeCO3	Trigonal	Pale yellowish, pale green, yellowish brown, brown, reddish brown, white	Translucent to subtranslucent	Vitreous, pearly or silky	White	4	3.96	Conchoidal to uneven; brittle

Chemical Formula: Fe

Composition: Molecular Weight = 55.85 gm Iron 100.00 % Fe

Empirical Formula: Fe0+

Environment: In meteorites and rarely basalts that have intruded carbon-rich sediments.

Cleavage: {001} Perfect, {010} Perfect, [100} Perfect

Color: Iron black, Dark gray, Steel gray.

Density: 7.3 - 7.9, Average = 7.6

Diaphaneity: Opaque

Fracture: Hackly - Jagged, torn surfaces, (e.g. fractured metals).

Habit: Disseminated - Occurs in small, distinct particles dispersed in matrix.

Habit: Granular - Generally occurs as anhedral to subhedral crystals in matrix.

Habit: Massive - Uniformly indistinguishable crystals forming large masses.

Hardness: 4-5 - Fluorite-Apatite

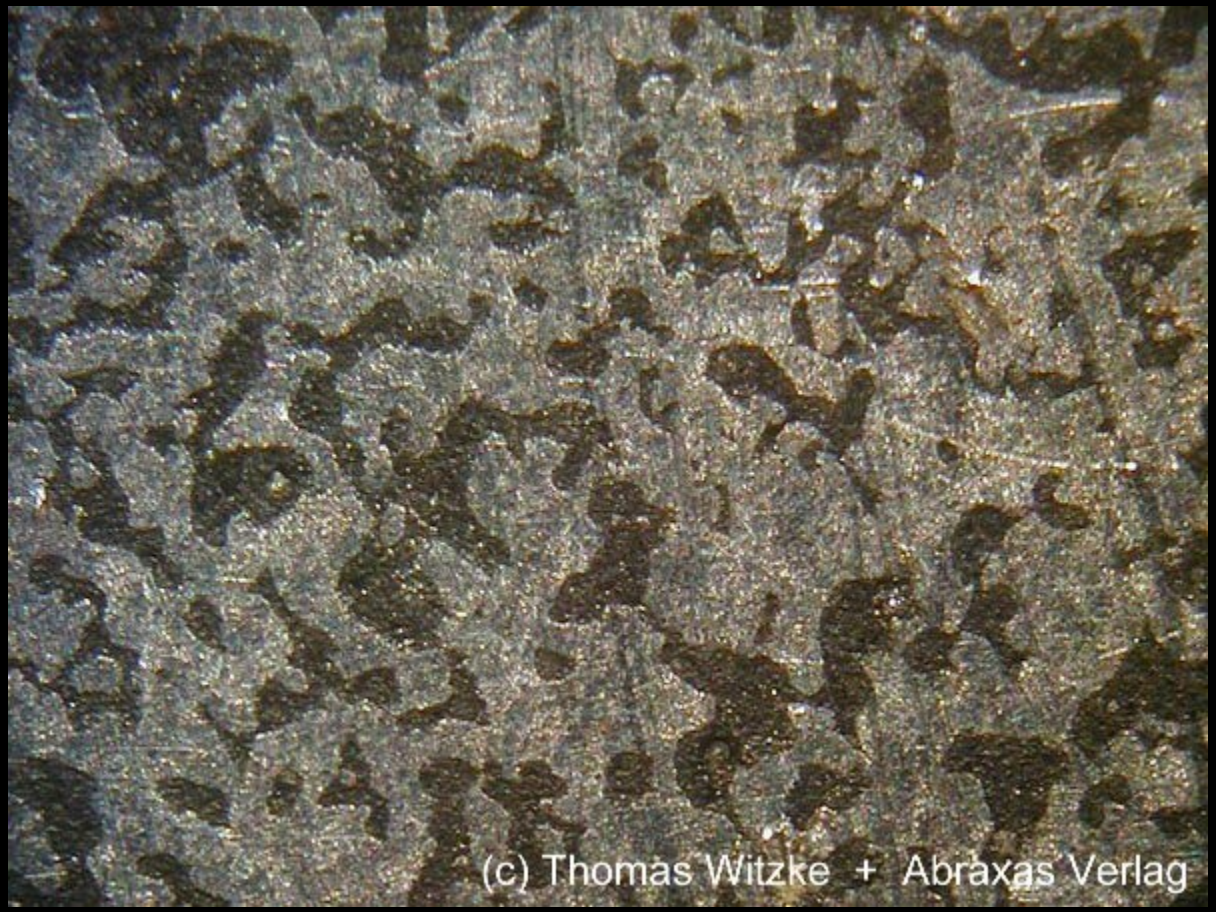
Luminescence: Non-fluorescent.

Luster: Metallic

Magnetism: Naturally strong

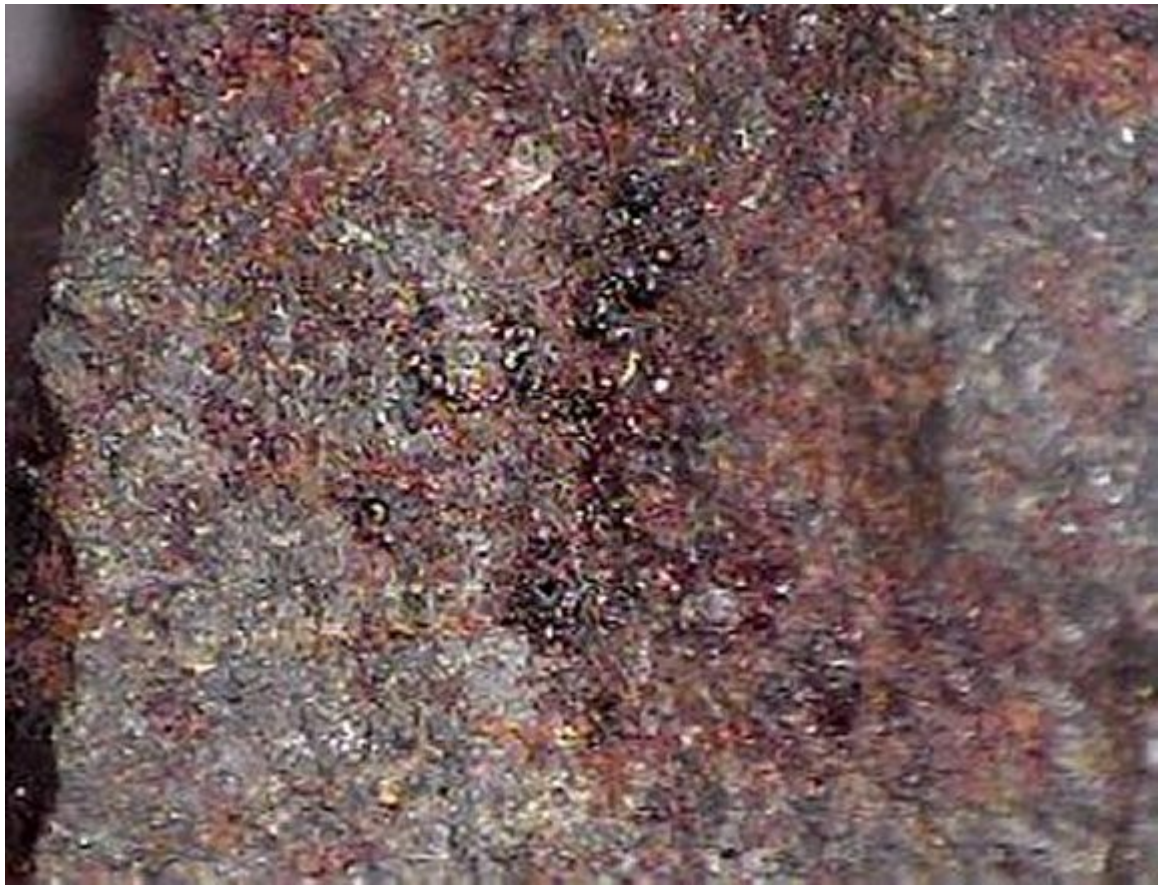
Streak: gray

NATIVE IRON



Iron

Gray metallic native iron in basalt. Cut (but not polished) section.
Origin: B?eimar, Kassel, Hesse, Germany
Picture size: 7 mm
Owner: Thomas Witzke



Mineral:	Iron: Fe
Comments:	Specimen of volcanic rock containing dark gray grains of native Iron. This locality is one of the very few known localities for terrestrial native iron.
Location:	Disko Island, Greenland.
Scale:	Picture size 1 cm.

Mineral:	Defernite: $Ca_6(CO_3)_{2-x}(SiO_4)_x(OH)_7(Cl,OH)_{1-2x}$ ($x=0,5$) Hematite: Fe_2O_3
Comments:	Specular hematite rich with crystalline grains of reddish brown defernite.
Location:	Kombat Mine, Kombat, Grootfontein District, Otjozondjupa Region, Namibia.
Scale:	3.9 x 2.5 cm.

Hematite

Chemical Formula: Fe_2O_3

Composition: Molecular Weight = 159.69 gm

Iron 69.94 % Fe, Oxygen 30.06 % O, 100.00 % Fe_2O_3

Environment: Magmatic, hydrothermal, metamorphic and sedimentary.

Color: Reddish gray, Black, Blackish red.

Density: 5.3

Diaphaneity: Subtranslucent to opaque

Fracture: Conchoidal

Habit: Blocky - Crystal shape tends to be equant (e.g. feldspars).

Habit: Earthy - Dull, clay-like texture with no visible crystalline affinities, (e.g. howlite).

Habit: Tabular - Form dimensions are thin in one direction.

Hardness: 6.5, Luminescence: Non-fluorescent.

Luster: Metallic

Magnetism: Magnetic after heating

Streak: reddish brown

Mineral: Hematite: Fe_2O_3

Comments: Black, platy hematite and minor white magnesite.

Location: Brumado, Bahia, Brazil.

Scale: 9 x 4.5 cm.

Mineral: Hematite: Fe_2O_3
Rutile: TiO_2

Comments: Acicular, golden yellow crystals of rutile epitaxially overgrown on black crystals of hematite. The overgrowths are perpendicular to the trigonal crystallography of the hematite.

Location: Novo Horizonte, Bahia Brazil.

Scale: 4 x 3.5 x 3 cm.

albite

Large, well-formed magnetite crystals to 2.5cm associated with 6 cm frosted quartz crystals and unusual yellow calcite crystals to 2cm.
Origin: Dashkesan, Azerbaijan

Marcasite (FeS2) with Calcite

Marcasite with Quartzite

Marcasite (FeS_2)

Cleavage: {010} Indistinct

Color: Bronze, Light brass yellow, Tin white.

Density: 4.89

Diaphaneity: Opaque

Fracture: Uneven - Flat surfaces (not cleavage) fractured in an uneven pattern.

Habit: Globular - Spherical, or nearly so, rounded forms (e.g. wavellite).

Habit: Stalactitic - Shaped like pendant columns as stalactites or stalagmites (e.g. calcite).

Habit: Tabular - Form dimensions are thin in one direction.

Hardness: 6-6.5 - Orthoclase-Pyrite

Luminescence: Non-fluorescent.

Luster: Metallic

Magnetism: Magnetic after heating

Streak: gray brownish black

Goethite FeO(OH)

Cleavage: {010} Perfect, {100} Distinct

Color: Brown, Reddish brown, Yellowish brown, Brownish yellow, Ocher yellow.

Density: 3.3 - 4.3, Average = 3.8

Diaphaneity: Subtranslucent to opaque

Fracture: Hackly - Jagged, torn surfaces, (e.g. fractured metals).

Habit: Acicular - Occurs as needle-like crystals.

Habit: Radial - Crystals radiate from a center without producing stellar forms (e.g. stibnite)

Habit: Reniform - "Kidney like" in shape (e.g.. hematite).

Hardness: 5-5.5 - Apatite-Knife Blade

Luminescence: Non-fluorescent.

Luster: Adamantine - Silky

Streak: yellowish brown

Occurrence: A common weathering product derived from numerous iron-bearing minerals in oxygenated environments; an important component of ore in weathered iron deposits. Also a primary precipitate in hydrothermal, marine, and bog environments upon oxidation of reduced iron-bearing waters.

Goethite with quartz
Origin: Bottalack, Cornwall, England
Sample size: 6 x 5 x 4 cm

Origin: Nandan, Guangxi Province, China
Sample size: 18 x 10 x 9 cm

Goethite, Laubmannite

Mineral:	Goethite: Fe+++O(OH) Laubmannite: Fe++3Fe+++6(PO4)4(OH)12
Comments:	Reddish brown goethite hosting radiating sprays of olive green laubmannite to 3 cm across.
Location:	Buckeye Mountain, Polk County, Arkansas, USA.
Scale:	10.5 x 7.5 cm.

Goethite
Origin: Mesabi Range, Minnesota, U.S.A.
Sample size: 10.5 x 8 x 6 cm

Mineral: Goethite: Fe+++O(OH)

Comments: Stellate crystalline aggregates of acicular goethite crystals.

Location: Pribram, Bohemia, Czech Republic.

Siderite
$FeCO_3$

Iron
62.01 % FeO

Carbon
37.99 % CO_2

Cleavage: {1011} Perfect,

Color: Yellowish brown, Brown, Gray, Yellowish gray, Greenish gray.

Density: 3.96

Diaphaneity: Translucent to subtranslucent

Fracture: Brittle - Conchoidal - Very brittle fracture producing small, conchoidal fragments.

Habit: Botryoidal - "Grape-like" rounded forms (e.g.. malachite).

Habit: Massive - Uniformly indistinguishable crystals forming large masses.

Habit: Tabular - Form dimensions are thin in one direction.

Hardness: 3.5 - Copper Penny

Luminescence: Non-fluorescent.

Luster: Vitreous (Glassy)

Streak: white

Environment: Primarily bedded, biosedimentary deposits, also in metamorphic and igneous rocks

Siderite **FeCO3**

Iron
62.01 % FeO

Carbon
37.99 % CO_2

Mineral: Arsenopyrite: FeAsS
Siderite: Fe++CO3

Comments: White, metallic arsenopyrite and tan siderite crystals.

Location: Panasqueira (2000, 3rd level), in the region of Beira Baixa, Portugal.

Scale: 11 x 7 cm.

Mineral: Siderite: Fe++CO3

Comments: Bladed siderite crystal groups on crystallized quartz matrix.

Location: Peyrebrune, Tarn, France.

Scale: 8.7 x 6.5 x 4.7 cm.

Classification of Iron-ore Deposits

Metamorphic banded deposits: The major iron ore deposits of India fall within this group. They are typically sedimentary or volcano-sedimentary and metamorphosed rocks consisting of rich iron-ore and siliceous (chert) bands

The banded magnetite quartzite are typical example

The Indian iron ore deposits of Bihar-Orissa belt, Bailadila (M.P) and Karnataka are Indian example

Continental sedimentary deposits: These are assumed to have formed in fresh water (Fluvial or lagoonal) or under brakish swamp (Lacustrine) conditions.

Ironstone of Raniganj and Auranga coalfields are typical examples of this type of deposits

Marine sedimentary deposits such as oolites, detrital, placer and mixed type: The type area is in lorrain, france. The Indian example is magnetite deposits of coastal regions such as at Travancore associated with ilmenite and heavy mineral sand

Volcano-sedimentary: These related to volcanic group of initial geosynclinal magmatism. Insignificant minor pockets of iron ore in Dras-Thasgam area, Ladakh are the Indian Example

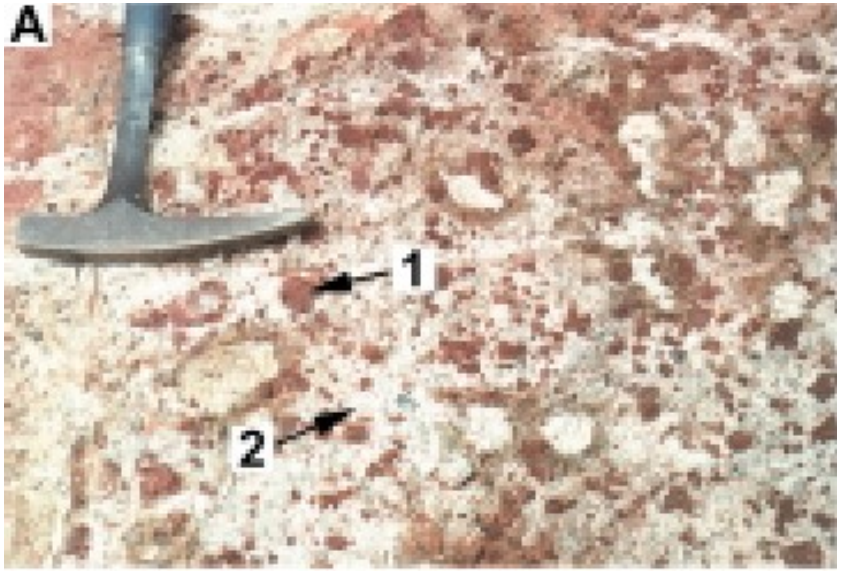
Classification of Iron-ore Deposits

Liquid magmatic deposits: They are during the early crystallizaion of Plutonic rocks, mainly by gravitational differentiation. Tirano-vanadium bearing iron ore deposits of Mayurbhanj district, Orissa

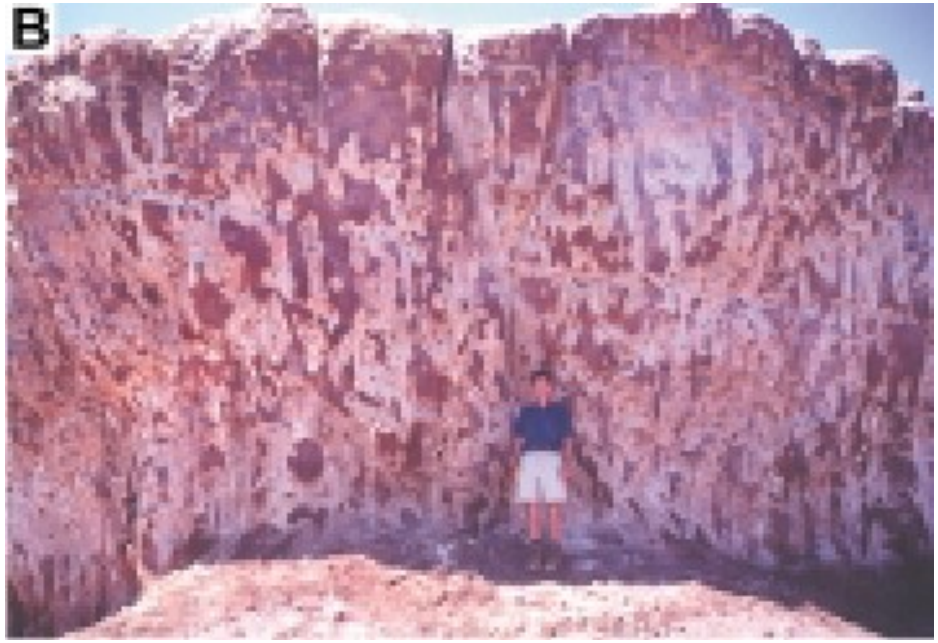
Intrusive magmatic deposits: They are related to alkaline rocks of the Precambrian shields. Apatite – Magnetire rocks of Singhbhum represent this type

Contact metasomatic deposits: The granitoid intrusions within the limestone and are widely distributed. Main ore mineral is magnetite

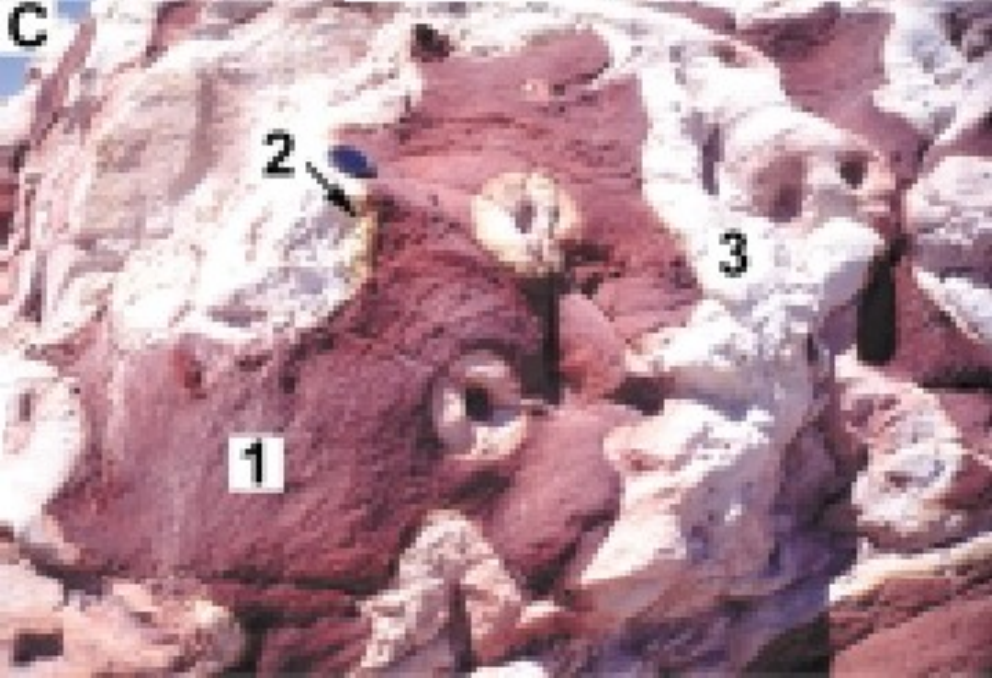
Polymetallic skarn ore deposits: These occur associated with sedimentary deposits which are latter affected by regional metamorphism. No Indian example for this type. Deposit at Utah is best example



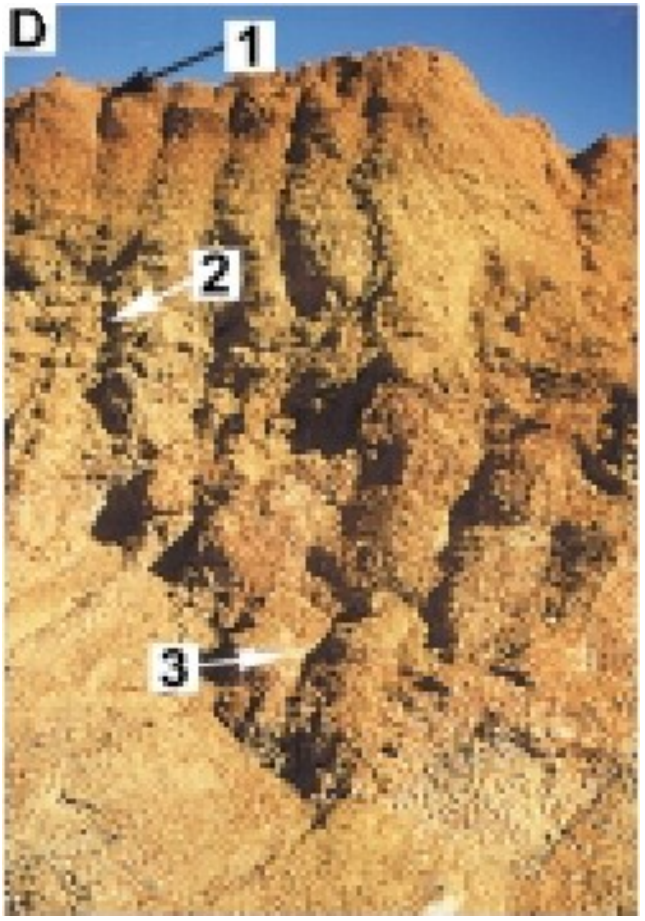
(a) Coarse fragments of goethite–kaolinite-rich mottled saprolite with yellowish-brown cutans characteristic of broad ridge crests. Hammer for scale



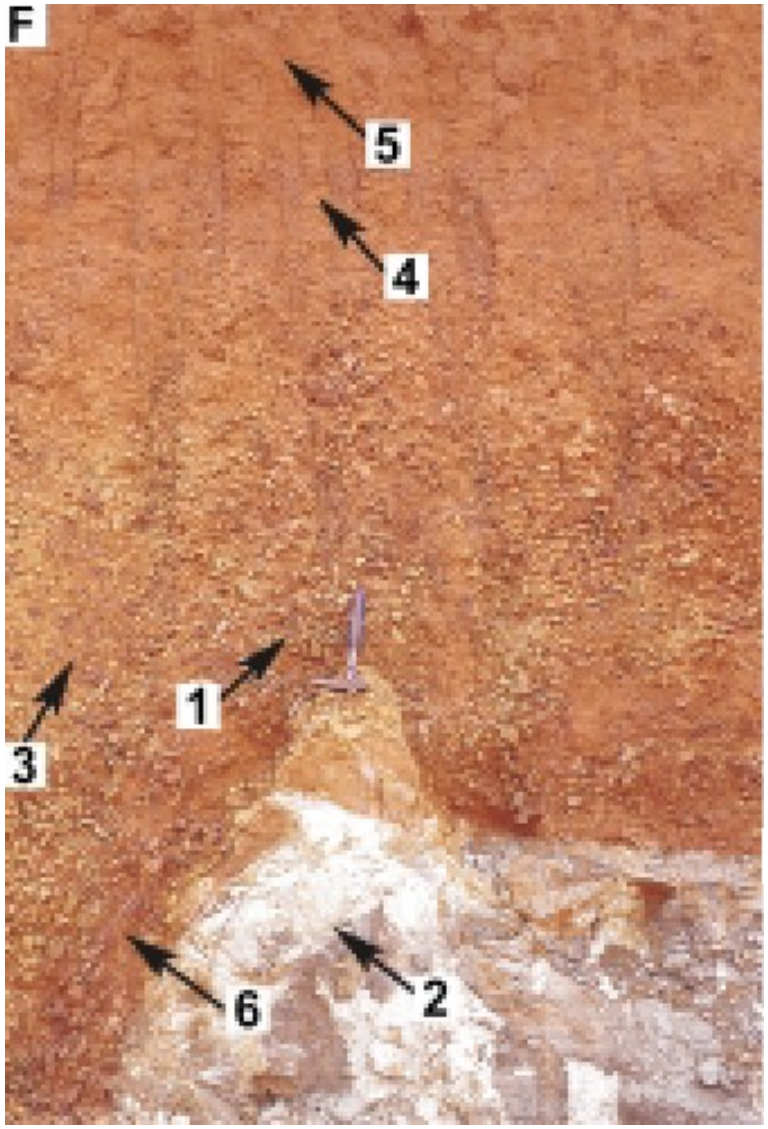
(b) Hematite-rich ferruginous pisoliths and nodules with yellowish- to reddish-brown cutans on upper backslopes



(c) Fine, black hematite–maghemite-rich ferruginous pisoliths



Fe-saprolite, lithic fragments and quartz.



(e) Coarse fragments of ferruginous saprolite

(f) Goethite-rich iron segregations after sulfide-rich rocks

The Indian Iron ore deposits can be classified into six basic type

- Banded ferruginous formation of Precambrian age: The ores can be classified into massive ore, laminated ore and blue dust. This is major type in the country
- Sedimentary iron-ores of sideritic or limonitic composition e.g found in coal fields of Bihar and West Bengal and Tertiary formation of Assam
- Lateritic iron ore: Associated with Deccan trap, also widespread in the country
- Apatite magnetite rocks of Singhbhum Copper belt
- Titaniferous and vanadiferous magnetites: S.E Singhbhum of Bihar, Mayurbhanj of Orissa, Tumkur of Karnataka
- Fault and fissure fillings of hematite of Valdurthi and Ramalkota in Kurnool and in Cuddapah districts

Geological and Geographical Distribution of Iron ore in India

Formation	Types of Deposit	Occurrences/Deposits
Precambrian		
Basic & Ultrabasic	Titaniferous and Vanadiferous magnetite	SE Singhbhum (Bihar), Mayurbhanj (Orissa), Tumkur (Karnataka)
Granodiorite Granite	Apatite-Magnetite rock (Residual)	Singhbhum Copper belt and Mayurbhanj,Assam Jantia Hills
Banded iron ore formation	Hematites (Massive, Shaly, Powdery)	Singhbhum; Bonai, Keonjihar & Mayurbhanj (Orissa); Poonch (J&K); Baster, Durg and Jabalpur (MP), Chanda and Ratnagiri (Maharashtra); Dharwar, Bellary, Sundar, Shimoga and Chikmagalur (Karnataka)
Banded iron ore formation (Metamorphosed)	Magnetite-Quartzite	Guntur (AP), Salem (Tamil Nadu), Shimoga (Karnataka), Mandi (HP)
Bijawar/Gwalier	Hematite & Ferruginous Quartzite	Bijawar, Gwalier, Indore, Rewa (MP); Mohindargarh (Haryana), Jhun-Jhunu, Sikar, Jaipur (Rajasthan); Cuddapah

Geological and Geographical Distribution of Iron ore in India

Formation	Types of Deposit	Occurrences/Deposits
Gondwana		
Barakar - Mahadeva	Ironstone	Birbhum(W Bengal) and Auranga coal field (Bihar)
Ironstone-shale	Ironstone and siderite	Raniganj coal field (W Bengal)
Triassic		
Sirban Limestone	Hematite & Siderite	Udhampur (J&K)
Jurassic		
Rajmahal trap (inter-trappean beds)	Ironstone	Rajmahal (Bihar), Birbhum (West Bengal)
Eocene and Miocene	Ironstone	NE districts of Assam, Kumaon (UP), Travancore and Malabar (Kerala)
Quaternary	Laterite	Several states of India. Derived from different formations including Deccan trap

Table 2.1: World resources of iron ore by Principal countries

Qty: Million tonnes

	Crude ore		Iron content	
	Reserve	Reserve base	Reserve	Reserve base
United States	6900	15000	2100	4600
Australia	15000	45000	8900	28000
Brazil	23000	27000	16000	14000
Canada	1700	3900	1100	2500
China	21000	46000	7000	15000
India	6600	9800	4200	6200
Iran	1800	2500	1000	1500
Kazakhstan	8300	19000	3300	7400
Mauritania	700	1500	400	1000
Mexico	700	1500	400	900
Russia	25000	56000	14000	31000
South Africa	1000	2300	650	1500
Sweden	3500	7800	2200	5000
Ukraine	30000	68000	9000	20000
Venezuela	4000	6000	2400	3600
Other countries	11000	30000	6200	17000
World Total (rounded)	160,000	37,000	79,000	160,000

Source: U.S.Geological Survey, Mineral Commodity Summaries, 2008

Table 3.1: Reserves and Resources of Iron ore in India

Iron Ore	Resources As on 1980	Resources As on 1990	Resources As on 2000	Resources As on 2005
Hematite	11,469	12,197	a. Reserves: 6025	a. Reserves: 7004
			Proved (111): 4421	Proved (111): 4945
			Probable (121): 828 Probable: (122): 774	Probable (121): 995 Probable: (122): 1063
			b. Remaining resources (331, 332, 333,334): 5400	b. Remaining resources (331, 332, 333,334): 7626
			Total: 11,425	Total: 14630 +
Magnetite	6,095	10,590	a. Reserves: 286	a. Reserves: 58
			b. Remaining Resources: 10,396	b. Remaining Resources: 10,560
			Total: 10,682	Total: 10,619 +
Total	17,564	22,787	a. Reserves: 6,311	a. Reserves:7062
			b. Remaining Resources: 17,277	b. Remaining Resources: 18,245
			Total: 23,588	**Total: 25,249**

Table 3.2: Resources of iron ore (haematite) in the major producing states in 2000 and 2005

	As on 1.4.2000 (in million tonnes)	As on 1.4.2005 (in million tones)
Andhra Pradesh	140.01	163.03
Chhattisgarh	2120.02	2736.78
Goa	642.11	712.94
Jharkhand	3044.45	4035.74
Karnataka	1148.32	1676.22
Madhya Pradesh	200.65	204.93
Maharashtra	270.70	265.35
Orissa	3789.39	4760.62

Table - 5. 2. 2: State-wise brief description of iron ore deposits

Name of the State	*General description of deposit*	*Name of the deposits*	*Ore Minerals*
1	2	3	4
JHARKHAND (including BIHAR)	Iron ore, principally haematite in banded iron formation occurs in a number of prominent hills in south western part of Singhbhum district. Besides, titaneferous magnetite and apatite magnetite are also found in SE Singhbhum.	**I. <u>Haematite deposit</u>** A) Singhbhum Distt : Noamundi, Gua, Borajamda, Kiriburu, Neghatuburu, Manoharpur, Chiria B) Ranchi Distt : Sikorda, Bagdanr, Mahantol C) Minor occurrences in Santhal Pargana, Bhagalpur, Dhanbad, Hajaribagh, Sahabad Dists. **II. <u>Magnetite deposit</u>** : **A)** Singhbhum Distt. 1) Ramchandra Pahar, Kudada, Patharghora, Khejurdari 2) Dublabera, Sindurpur. B) Palamau Distt. : Gore village, Sua & Kauria areas, Biwabathan.	Haematite (BIF) Ap-magnetite Ti-magnetite Magnetite
ORISSA	Precambrian Iron Ore Group of rocks of Singhbhum-Keonjhar Bonai belt containing high grade haematitic ore are running through Keonjhar and Sundargarh districts . Apart from haematite, magnetite (Ti bearing)also noted from several places.	**I. <u>Haematite deposit</u>** A) Keonjhar Distt.: Thakurani, Bolani, Jhilling-langallota, Joda, Gandhamardan, Malangtoli, Bansapani, Guali, Gurubera and minor occurrence from Jajang, Joribahal, Katamati, Bhadrasahi, Koira, Kasia, Kurbandh, Dulki, Jolahuri, Baldo etc. B) Sundargarh Distt.: Barsua, Mankarnacha, Balia Pahar, Khondadhar, Mithurda, Patroposi. C) Jajpur Distt. : Tomka, Daitari D) Mayurbhanj Distttt.: Gorumahisani, Sulaipet, Badampahar E) Nawarangpura Distt.: Hirapur Umrakot F) Sambalpur Distt.: Lohakhand-Naibassa Hill G) Dhenkanal Distt.: Malaygiri range	Haematite (BIF)

1	2	3	4
		II. <u>Magnetite deposit</u> a) Ti-bearing magnetite from Kumardubi, Betjharan, Nahapahari and SW of Baripada b) Puri Distt : Chilka Lake c) Dhenkanal Distt : Basudebpur, Murhi	Magnetite (Ti-bearing) Magnetite (Sand) Magnetite (Lateritic)
CHHATISGARH	Precambrian Iron Ore Group of rocks consists of banded haematite-jasper/quartzite, similar to Singhbhum-Keonjhar iron ore belt are found in several parts of MP and Chhatisgarh State. Large deposits of excellent quality of iron ore are found in Bastar and Durg districts.	**I. Haematite deposit** A) Bastar Distt: Rowghat area, Chhotadongar deposit B) Dantewara Distt.: Bailadila range includes fourteen deposits numbered 1 to 14 C) Durg Distt.: Dalli-Rajhara, Kanchar, Jharandali, Kondekosa and minor occurrences near Khairagarh, Berla, Katul Kassa, Jurla Khar etc. D) Kanker Distt.: Ari Dongri. Besides this there are smaller deposits in Dulki, Kalwar, Dongar bar, Lohattar in bordering area of Durg district. E) District with minor occurrence : Jashpur, Bilashpur, Raigarh districts.	Haematite (BIF)
MADHYA PRADESH	Precambrian Iron Ore Group of rocks consists of banded haematite-jasper/quartzite.	**I. <u>Haematite deposit</u>** A) Jabalpur Dist: Kanhwar plateau, Agaria, Bijori, Ghosalpur, Lora hill, Ghoghra, Silondi, Saroli etc. B) Chattarpur Dist: Dalipur, Nimkhera, Deora, Chungwah etc. C) Districts with smaller occurrence: Betul, Jhabua, Nimar, Rajgarh, Sagar, Satna, Sidhi, Tikamgarh, Gwalior, Mandsaur, Narasimhapur etc.	Haematite (BIF)

1	2	3	4
KARNATAKA	Iron ore deposit of Kranataka are classified into three types : 1. Banded ferruginos quartzite of Dharwarian age containing haematite 2.Metamorphosed banded magnetite-quartzite containing magnetite 3.Magnetic deposit containing titaneferous magnetite associated with ultrabasic rock.	I) **Haematite deposit** A) Belary Distt.: Bellary-Hospet deposit B) Chitradurga Distt.: Sivaganga and Hiriyur, Medikeripura, Kadlegudam, Bhimasamudra, Vajra etc. C) Shimoga Distt.: Siddarahalli, Channagiri, Joldhal, Ganpur, Bhadigund, Shankargudda and Kumsi area, Chattanhalli, Agumbe-Visaniguda, Kodachadri, Kotebare. D) Bijapur Distt.: Amingarh, Bassargi, Bisnal, Aihole, Hiremagi-Ramthal E) North Kanara Distt.: Halkhamba, Shiroli, Kunang, Kalinadi, Hudsa, Anmod, Kuveshi-Diggi, Joidu, Talaginkere, Mavingundi, Huntaganis, Yellapur. F) Tumku, district, Karikurikhi, Chikanayakanhalli, Janehara, Kuni, etc. G) Minor occurrences: Bijapur, Dakshin Kannada, Dharwar, Hassan, Mysore districts. **II) <u>Magnetite deposit</u>** A) Chikmagalur Distt.: Bababudam Hill, Kudremukh, Gangamula. B) North Kanara Distt.: Kodalgadde Apsarakonda C) Mandya Distt.: Muddur, Tippur, Husegu & Hullahalli. D) Chikmagalur Distt. Near Masanikere close to Bhadravati.	Haematite (BIF) Magnetite (BIF) Vanediferous magnetite

1	2	3	4
GOA	A large number of iron ore deposits are concentrated here. The banded haematite quartzite rocks of precambrian age are generally confined to pink phyllite horizon. Ore minerals principally are haematite with smaller occurrences of magnetite, limonite and goethite.	From NW to SE more than thirty iron ore deposits have been identified. These are— 1) Advalpale 2) Nanora 3) Bicholem-Sirigao 4) Bordem-Savorna 5) Sanguelim 6) Arvalem 7) Cudnem Dignemsurla 8)Velguem-Pale 9) Pissurlem-Sonshi 10) Usgao 11) Conquirem 12) Poient-Siudem 13) Sacorda 14) Sonal Deven 15) Gavarem-Malpona 16) Balcoruem 17)Bimbol-Sigao 18) Suetioli-Taitoli 19) Codli 20) Samtona-Quirlapale 21) Codli 22Dudal 23) Kalay 24) Manlinguem 25) Tolem-Motto 26) Barazan -Villena 27) Sirigal-Undorna-Angod 28) Rivona-Columba 29) Canvorem-Navelim 30) Sulcorna-Vichundrem 31) Netrolim 32)Camona – Conda 33) Betul	Principally Haematite (BIF) with minor amount of magnetite, limonite and goethite
MAHARA-SHTRA	In Mahara-shtra,iron ore deposits are found associated with IOG of Archean. It comprises older schists and unclassified crystalline overlain by metamorphosed sedimentary rock such as quartzite,BHQ, phyllite etc. Ores are derived mostly from the BHQ by leaching of silica.	**I) <u>Haematite Deposit</u>** A) Sindhudurg Distt. Redi, Tirvade-Ajgaon-Guldave, Satcli-Starda, Satcli-Talwane, Talesane-ajgaon, Kalne, Podye Degve-Banda, Galel, Galel North and Galel South. B) Chandrapur Distt.: Lohara, Pipalgaon, Asola C) Gadchiroli Distt.: Surajgarh, Bhamragarh, Dewalgaon, Puser, Damkodwadvi hill range. D) Bhandara Distt.: Khursipar, Konholi. E) Ratnagiri Distt.: Malvan, Kunda, Savantvadi. F) Minor occurrences from Kolhapur, Nagpur, Satara(N) Nanded, Yeotmal Districts.	Haematite (BIF)

1	2	3	4
ANDHRA PRADESH	Most of iron ore deposits are found associated with rocks of Dharwar sediment or Purana formations. However low grade iron ore are also known from upper Gondwana and laterite cappings on Deccan Traps. Both haematite and magnetite deposits occur in the state.	**I) <u>Haematite deposit</u>** A) Anantapur Distt.: Balapuram, Siddapuram, Rayadurg Taluk, Malapanangudi, Velpurnadugu, Kambadur, Gollapalle, Oddapalem, Muchalapalle B) Cuddapah Distt. : Chabali area, Rajampet, Ponduluri Venkatapalli, Erraguntakota, Mantapampalle, Pendlimari and Pagadalapalle C) Kurnool Distt. : Veldurti, Ramallakota. D) Nellore Distt.: Rassnapalem, Chundi hill, Polenane, Cheruvu, Swarnamukhi valley. E) Khammam & Warangal Distts.: Cheruvupuram, Kottagudem, motala Timmapur, Nilanche, Bayyaram, Opulapuram **II) <u>Magnetite deposit</u>** 1) Prakasham Distt. a. Ongole Gr- Pernametta, Ongole, Konijedu, Sanampudi bands. b. Gundal kamma gr.– Byrepalle, Errapale, Timmavaram and Manikeshvaram. 2) Khammam Distt. : Utla, Tatraiyapalli, Gopalpur 3) Vishakhapatnam Distt- Sitarampur, Darbanblom Konda 4) East Godavari Distt -Addatigala, Devipuram. Besides above deposits. iron ores are also reported from Adilabad, Chittoor, Guntur, Karimnagar, Krishna, Medak, Nizamabad, Vishakhapatnam, Srikakulam,and Warringal districts of Andhra Pradesh.	Haematite (BIF) Magnetite (BIF)

MANGANESE

- The metallic manganese on earth is rated as the 12th most abundant element in the lithosphere, estimated around 28.46x1018 tonnes or so i.e., 0.1087% by proportion of weight.
- Thus it almost becomes a scarce one, so far as its deposits are concerned. Industrially manganese metal is a vital component of steel and its major use is for metallurgical purpose.
- The 96% of global production of manganese today is from barely 7 countries viz. CIS,RSA, Brazil, Gabon, Australia, China and India in decreasing order of tonnages raised annually.
- The global resource base is close to 12 billion tonnes including Indian reserve of about 240 million tonnes.
- Indian manganese ores are preferred by many as they are generally hard, lumpy and amenable to easy reduction. The deposition of manganese in varying geological processes but the sedimentary mode of formation far outweighed other methods such as supergene enrichment etc.

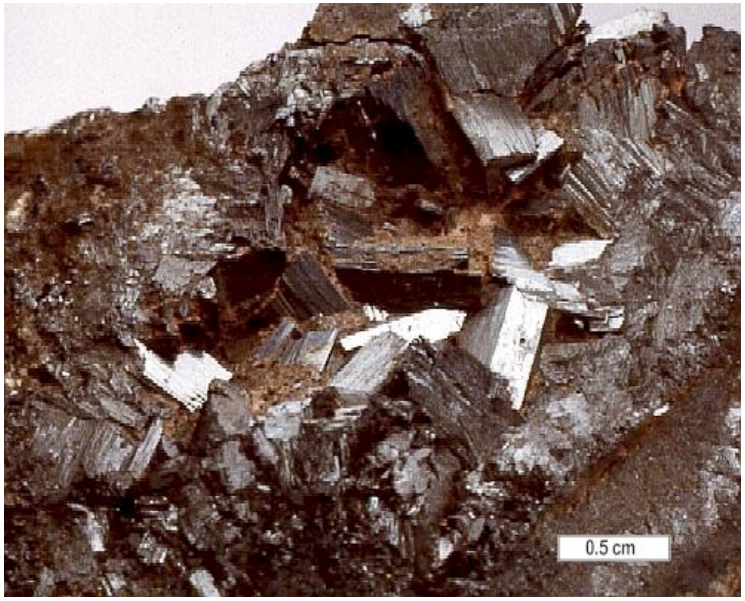
In nature, manganese does not occur in the native state

The following are the common Manganese minerals

Mineral Name	Formula
1. Oxides	
Pyrolusite	MnO_2
Psilomelane	Hydrated oxide of Mn $(Ba,H_2O)_2Mn_5O_{10}$
Manganite	$MnO(OH)$
Brownite	Mn_2O_3
Hausmanite	Mn_3O_4
2. Carbonate	
Rhodocrosite	$MnCO_3$
3.Silicate	
Rhodonite	$MnSiO_3$

Pyrolusite and Psilomelane are two important ores of Manganese

Pyrolusite (MnO_2) Manganese



A mass of silvery-metallic pyrolusite composed of many smaller crystals with some open specimen with larger crystals up to 3mm or so.

Mineral: Pyrolusite: MnO_2

Comments: Steel-gray metallic prismatic pyrolusite crystals.

Location: Hori Blatna, Czech Republic.

Pyrolusite (MnO_2)

Cleavage: {110} Perfect

Color: Steel gray, Iron gray, Bluish gray.

Density: 4.4 - 5.06, Average = 4.73

Diaphaneity: Opaque

Fracture: Brittle - Generally displayed by glasses and most non-metallic minerals.

Habit: **Dendritic** - Branching "tree-like" growths of great complexity (e.g. pyrolusite). **Earthy** - Dull, clay-like texture with no visible crystalline affinities, (e.g. howlite). **Reniform** - "Kidney like" in shape (e.g.. hematite).

Hardness: 6-6.5 - Orthoclase-Pyrite

Luminescence: Non-fluorescent.

Luster: Sub Metallic

Magnetism: Nonmagnetic

Streak: black

Formed in low-temperature hydrothermal or hot-spring manganese deposits.

OCCURRENCES: As a weathering product, typically as botryoidal masses, in unconsolidated deposits -- *e.g.*, residual clays.

Psilomelane	Hydrated oxide of Mn (Ba,H2O)2Mn5O10

Cleavage: None

Color: Iron black, Dark steel gray.

Density: 4.4 - 4.7, Average = 4.55

Diaphaneity: Opaque

Fracture: Uneven - Flat surfaces (not cleavage) fractured in an uneven pattern.

Habit: Botryoidal - "Grape-like" rounded forms (e.g.. malachite). Reniform - "Kidney like" in shape (e.g.. hematite).

Hardness: 5-6 - Between Apatite and Orthoclase

Luminescence: Non-fluorescent.

Luster: Sub Metallic

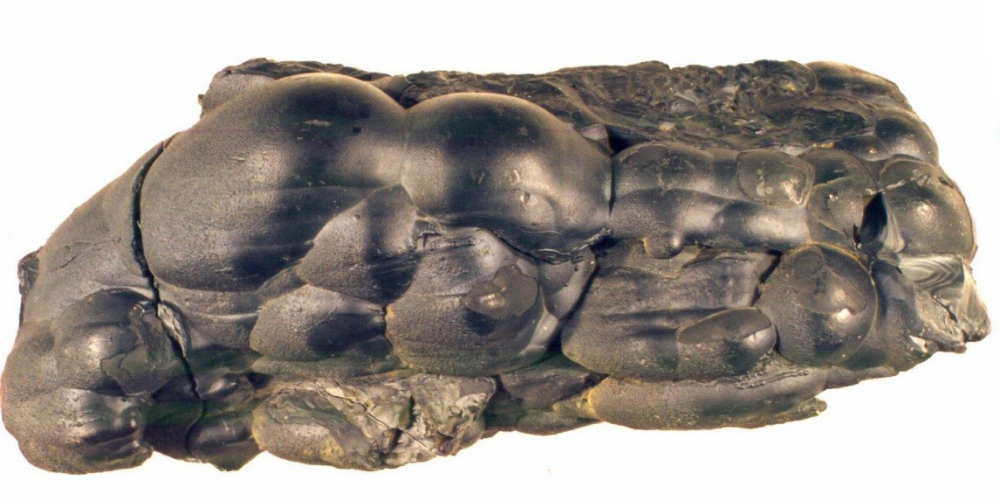
Magnetism: Nonmagnetic

Streak: brownish black

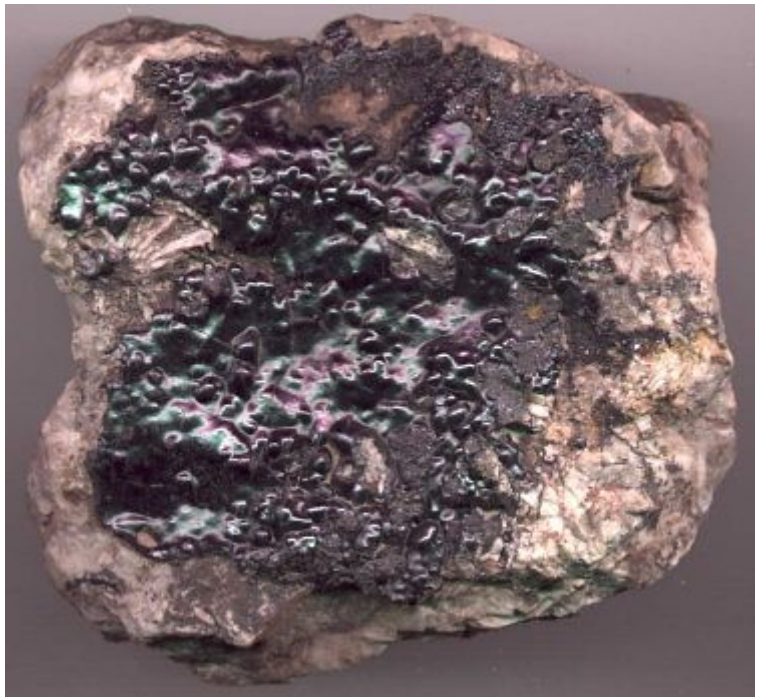
Mineral: Psilomelane: (Ba,H2O)2Mn5O10

Comments: Banded massive psilomelane.

Location: Compton, Virginia, USA.



Botryoidal form - Psilomelane



Psilomelane on massive barite.

Manganite	MnO(OH)

Cleavage: {010} Perfect

Color: Black, Gray, Grayish black.

Density: 4.3 - 4.4, Average = 4.34

Diaphaneity: Opaque

Fracture: Brittle - Generally displayed by glasses and most non-metallic minerals.

Habit: Massive - Fibrous - Distinctly fibrous fine-grained forms. Prismatic - Crystals Shaped like Slender Prisms (e.g. tourmaline). Pseudo Orthorhombic - Crystals show an orthorhombic shape.

Hardness: 4 - Fluorite

Luminescence: Non-fluorescent.

Luster: Sub Metallic

Magnetism: Nonmagnetic

Streak: dark brown

Environment: Formed in low-temperature hydrothermal or hot-spring manganese deposits.

Mineral: Manganite: MnO(OH)

Comments: Lustrous feathery crystals of manganite to 0.75 cm.

Location: N'Chwaning Mine, Kalahari Manganese Field, Northern Cape Province, South Africa.

Mineral: **Manganite: MnO(OH)**
Sudoite: Mg2(Al,Fe++ +)3Si3AlO10(OH)8

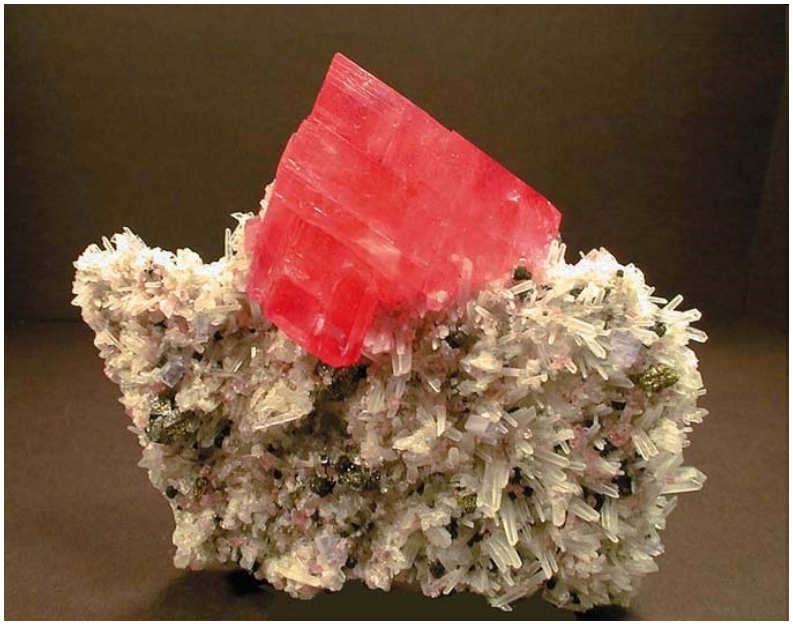
Comments: **Pinkish to nearly white earthy sudoite with dark manganite.**

Location: **Ilfeld, Nordhausen, Erfurt district, Harz Mts, Thuringia, Germany.**

Manganite - Ilfeld, Germany

Mangenite
Shiny, black prismatic needles in vugs & veins of reddish brown host rock.
Crystals sparkle, tips could be semi-opaque.

Rhodocrosite	$MnCO_3$



Cleavage: Perfect

Color: Pinkish red, Red, Rose red, Yellowish gray, Brown.

Density: 3.69

Diaphaneity: Translucent to subtranslucent

Fracture: Brittle - Conchoidal - Very brittle fracture producing small, conchoidal fragments.

Habit: Botryoidal - "Grape-like" rounded forms (e.g.. malachite), Columnar, Massive - Granular

- Hardness: 3 - Calcite

Luminescence: Non-fluorescent.

Luster: Vitreous (Glassy)

Streak: white

Rhodochrosite - Wolf Mine, Herdorf, Germany

Rhodochrosite replacing barite
Origin: Huaron, Pasco, Peru
Sample size: 13 x 6 x 6 cm

Rhodochrosite with quartz

Rhodonite	$MnSiO_3$

Cleavage: {110} Perfect, {110} Perfect

Color: Pink, Rose red, Brownish red, Black, Yellow.

Density: 3.5 - 3.7, Average = 3.6

Diaphaneity: Transparent to translucent

Fracture: Uneven - Flat surfaces (not cleavage) fractured in an uneven pattern.

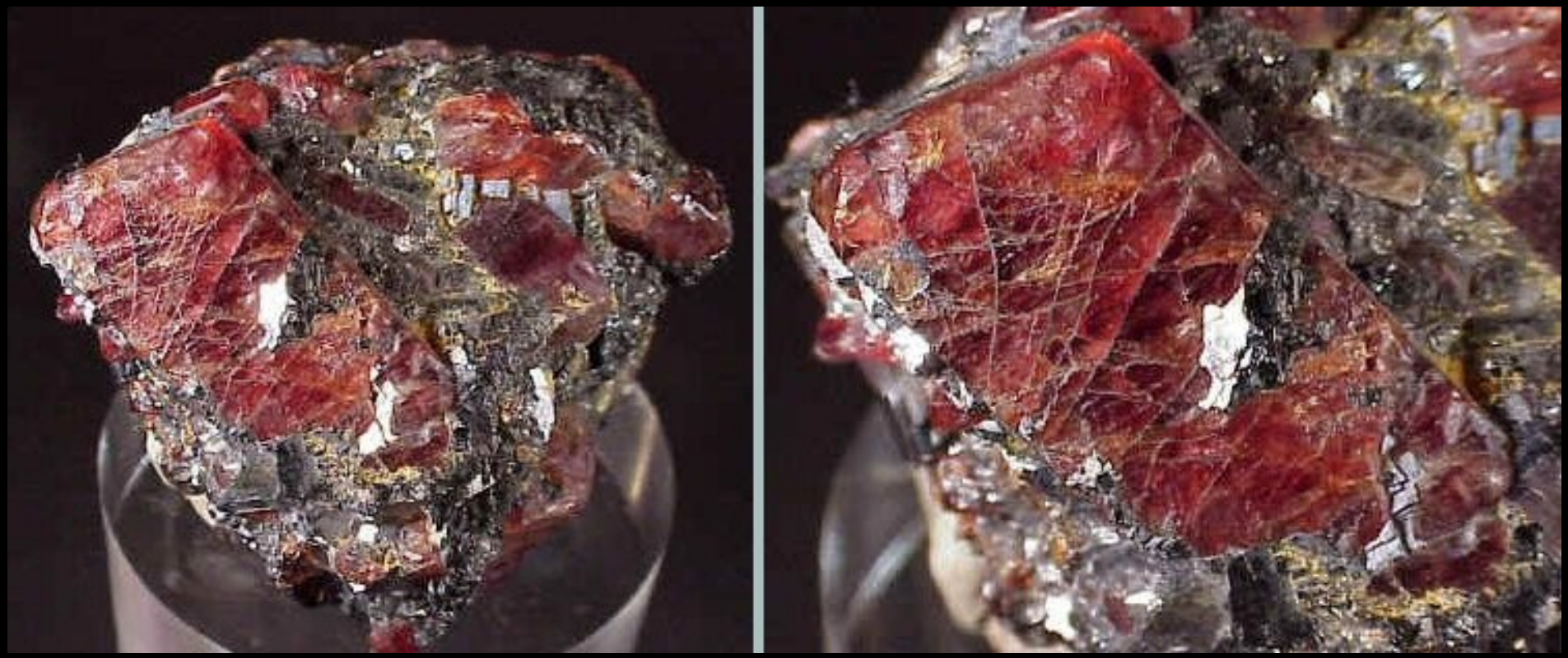
Habit: Massive - Granular - Massive - Uniformly indistinguishable crystals forming large masses. Tabular - Form dimensions are thin in one direction.

Hardness: 6 - Orthoclase

Luminescence: Non-fluorescent.

Luster: Vitreous (Glassy)

Streak: white



Mineral: Rhodonite: (Mn++,Fe++,Mg,Ca)SiO3

Comments: Deep red blocky prismatic crystals of rhodonite to 3cm.

Location: Broken Hill mine, New South Wales, Australia.

Uses

- Manganese ore are important raw materials in iron and steel industry and as ferro-manganese alloy
- It improve strength, toughness, hardness and workability of steel
- The 90 % of world Mn is used for iron and steel metallurgy
- Mn used for dry cell batteries
- It is used in cotton industry as dye
- Also used in medical, glass industries, etc.

Based upon the utilisation in the user industries, an Expert Group of the Dept. of Minesr ecommended the following specification for the manganese ore

1.	**Battery Grade**	MnO_2 (dry basis)	72% min.
		Fe(dry basis)	7% max.
		Cu,Pb,Cr and Ni	Trace
		Form of Ore	Gamma
2.	**Chemical Grade**	MnO_2	75%
		Fe	1.5 max.
		Cu	Traces
3.	**Ferromanganese Grade**	Mn	46% min.
		Mn : Fe ratio	4.6:1 min.
		P	0.2% max.
4.	**Blast Furnace Grade**	Mn	25-35%
		P	0.2% max.
		Al_2O_3	7.5% max.
		SiO_2	13% max.
		Size	10-40 mm
5.	**Medium Grade**	Mn	35-45%
6.	**Conditional Ore**	Mn	less than 25%

Annual consumption in India

Table 2 : Consumption of manganese ores in India

Type of Use		Quantity(tonnes)	Consumer Unit Nos.
1.	Alloy Steel	200	2
2.	Battery making	24,900	10
3.	Chemical Industry	2,700	7
4.	Ferro-alloys	576,000	13
5.	Iron & Steel	574,900	
6.	Lead-Zinc Smelters	2,900	3
7.	Other Ceramics e.g. fire-clay, glass, paints	300	14
	Total	1,181,900	

Mode of Occurrence

The greenstone hosted manganese deposits are older in age and have general close association of Banded Iron Formation such as in the Dharwarian rocks of Karnataka, Goa as also the Iron Ore Supergroup of Orissa, namely in Benai-Keonjhar tracts of North Orissa.

The time sequence changes over from Archaeau to Protuozoic, both the Khoudalit-hozted as well as the Adilabed beds of ore with the Penganga sequence have no association of iron or BIF, indicate progressive separation of iron from manganese.

Tertiary-Quaternary lateritisation processes with alternates wet and dry spells of climate, had affected the manganiferous sequences of the subtrata. Thus the ‘lateritoid’ ores are situated over some gondites and the Khondalite hosted material as also on the BIF-associated greenstone hosted ore material.

- The manganese ore deposits of M.P.-Maharashtra belt, Visakhapatnam-Srikakulam belts of Andhra Pradesh, Gangpur Manganese belt of Orissa and a part of North Kanara deposits are bedded type.

- The deposits of Singhbhum-Keonjhar-Bonai belt, Bellary-Hospet and North Kanara belt of Karnataka are mainly of lateritoid type.

- Manganese ores of Bonai-Keonjhar belt are known for their low phosphorous content.

- More than 50% of the manganese ore deposits of M.P and Maharashtra are of high grade.

The state-wise ore reserves of recoverable material as per National Mineral Inventory (NMI) compiled by Indian Bureau of Mines (IBM) as on 01-04-1990 are as under:

NMI of Manganese Reserve (Provisional) (x 10^3 Tonnes)

State	Proved	Probable	Possible	Total
Andhra Pradesh	6.5	4157.1	3368.1	7531.7
Bihar	0.2	–	2298.0	2298.2
Goa	2150.7	11432.3	9976.0	23559.0
Gujarat	–	–	1477.3	1477.3
Karnataka	2262.3	10427.4	51858.2	64547.9
Madhya Pradesh	9712.2	2510.3	4818.0	16544.5
Maharashtra	10138.1	5662.4	3373.1	19173.6
Orissa	4792.7	7604.9	28438.5	40836.1
West Bengal	–	–	100.0	100.0
Total	28566.7	41794.4	105707.2	176068.3

Additional ore reserve of Karnataka and Goa worked out by GSI but not included in the NMI of IBM. The total resources of Indian manganese ore, as on data, may hence be deemed to be around 240 million tonnes.

INDIAN OCCURANCES of Mn ore

Adilabad district, Andhrapradesh

The Mn ore occur as this lenses with chert and jaspar within limestone. Deposits are minor nature with low phosphorous content

Srikakulam district, Andhrapradesh

The Mn ore associated with Kodurite rock (Garnet Granulite) forming a part of Khondalite formation and ore formed due to supergene enrichment. The ore is low grade due to high phosphorous content

Visakhapatnam district, Andhrapradesh

The Mn ore associated with Kodurite and Khondalite formation

Singhbhum district, Bihar

Associated with rocks of Iron ore and Kojham formation as lenticles parallel to bedding and as lateritic materials at places

Goa

The deposits are of Lateritoid type found at surface or near

Panch Mahal, Vadodara district, Bihar

The ore are partly lateritid and partly primary associated with less metamorphosed Dharwars

INDIAN OCCURANCES of Mn ore

Bellary, Chitradurga, Uttarkannad, Dharwad, shimoga, Tumkur districts, Karnataka

The deposits are of varying dimensions, associated with limestones, schistose grits and ochery-schists of the Shimoga-Chitradurga schist of Dharwar group. The ore are of lateritoid type and the indvidual deposits are lenticular and impersistent

Balaghat district, Madhya Pradesh

They represent gondite type of deposits associated with metamorphosed Dharwar rocks

Bhandara, Nagpur districts, Maharashtra

The ore bodies are banded braunite-quartzite and grade on to quartz spessartite – rhodonite bearing gondite. Waethering has given rise to residual enrichment deposits

Ratnagiri district, Maharashtra

They represnet secondary enrichment deposits associated with lateritised Dharwarian metasediments, composed of quartzite, banded hematite-quartzite and phylite. The ore generally more ferruginous

INDIAN OCCURANCES of Mn ore

Sundargarh & Keonjhar (Bonai-Keonjhar area) districts, Orissa

The ore bodies occur as lenses or in irregular shape in shales, brecciated cherts and laterites capping them belonging to Iron-ore group of rocks.

Bonai-Keonjhar belt of north Orissa contributes 90% of the production of manganese ore of the State whose share comes to 36% of the country's total production. This belt is one of the most important manganese ore producing region of India because of its low phosphorus content in the ore.

Bonai-Keonjhar iron ore manganese belt forms a 60 km long & 25 km wide synclinorium. The banded iron formations; which broadly define the outline of the synclinorium. Manganese ore bearing shales occur within the core region of the fold

Koraput, Kalahandi, & Bolangir and Patua districts, Orissa

The ore bodies associated with Khondalite suite of Eastern Ghats group

Sambalpur District, Orissa: The deposits are associated with laterites on the meta sediments

Banswara district, Orissa

The deposits are associated with laterites on the meta sediments