Ferrous Extractive metallurgy

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Introduction of Ferrous Extractive Metallurgy

- **Extractive metallurgy:** is a science of separating metals from their ores (by chemically) and subsequently refining them to make pure form to some extent.
- **The steel** is the most used iron alloy; its production is more than 50 times total production of combined all other metals.
- That is why iron and iron alloy form one group (**Ferrous Metals**), and other metals combination forms other group (**Non-Ferrous Metals**).
- **Ferrous Extractive Metallurgy:** Extractive metallurgy for iron and steel.
- The production of hot metal/pig iron is a partial step involved for **extractive metallurgy of iron**, and it is not completed until its refines.
- **Steelmaking** is a refining process in which impurity elements are oxidized from hot metal and steel scrap that are charged to the process.
- **Hence, ferrous extractive metallurgy has two-stage operations:**
- **Reduction stage,** Ironmaking stage (iron ore reduced to hot metal),
- **Oxidation stage,** Steelmaking stage (hot metal refined to steel).

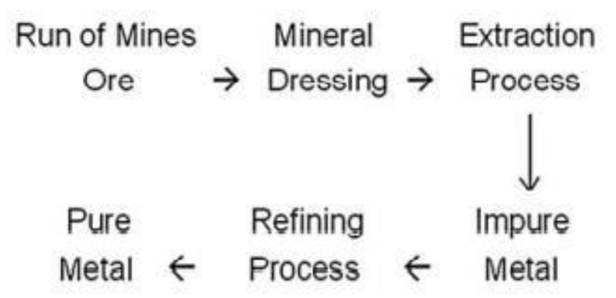
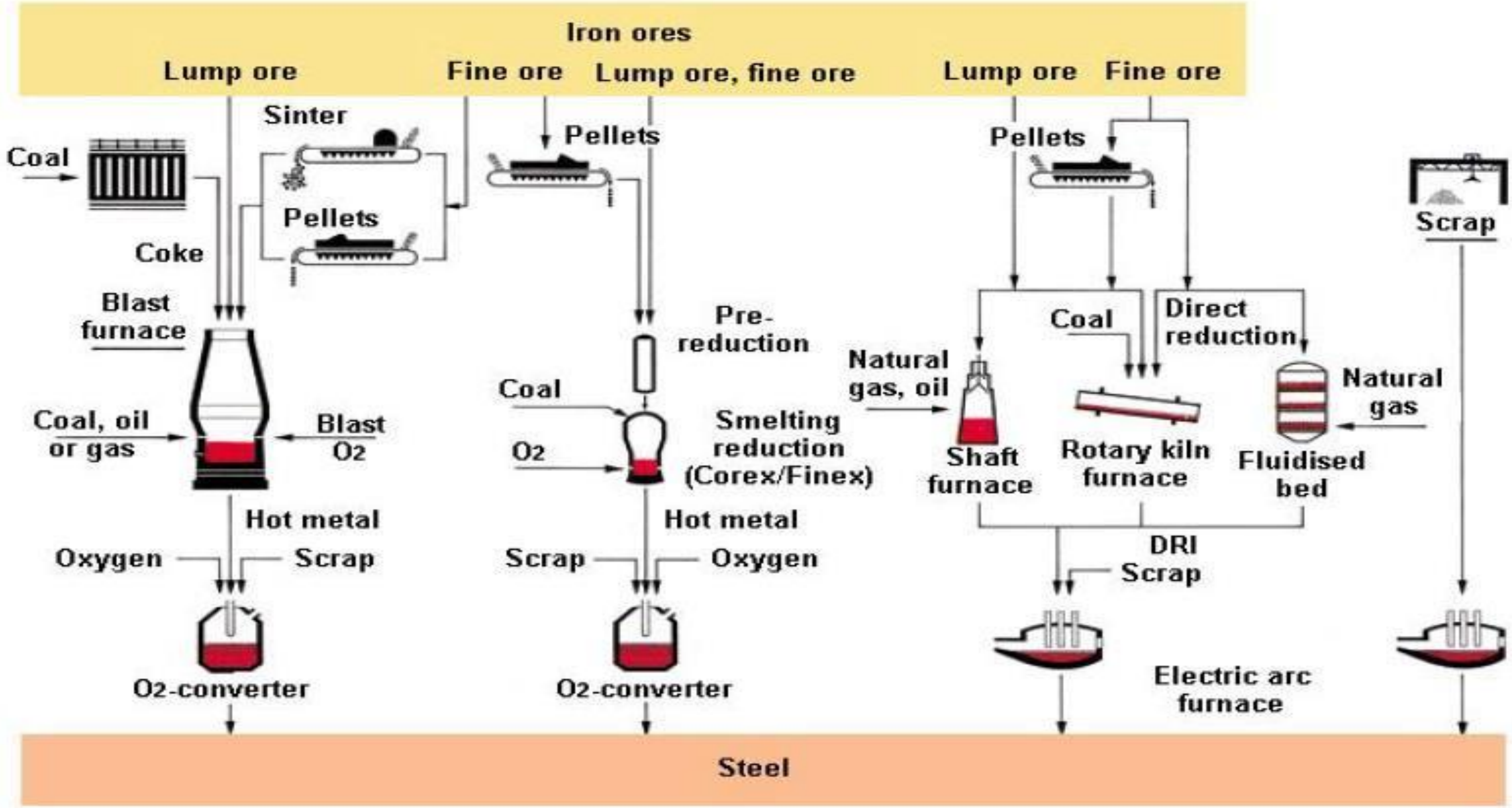
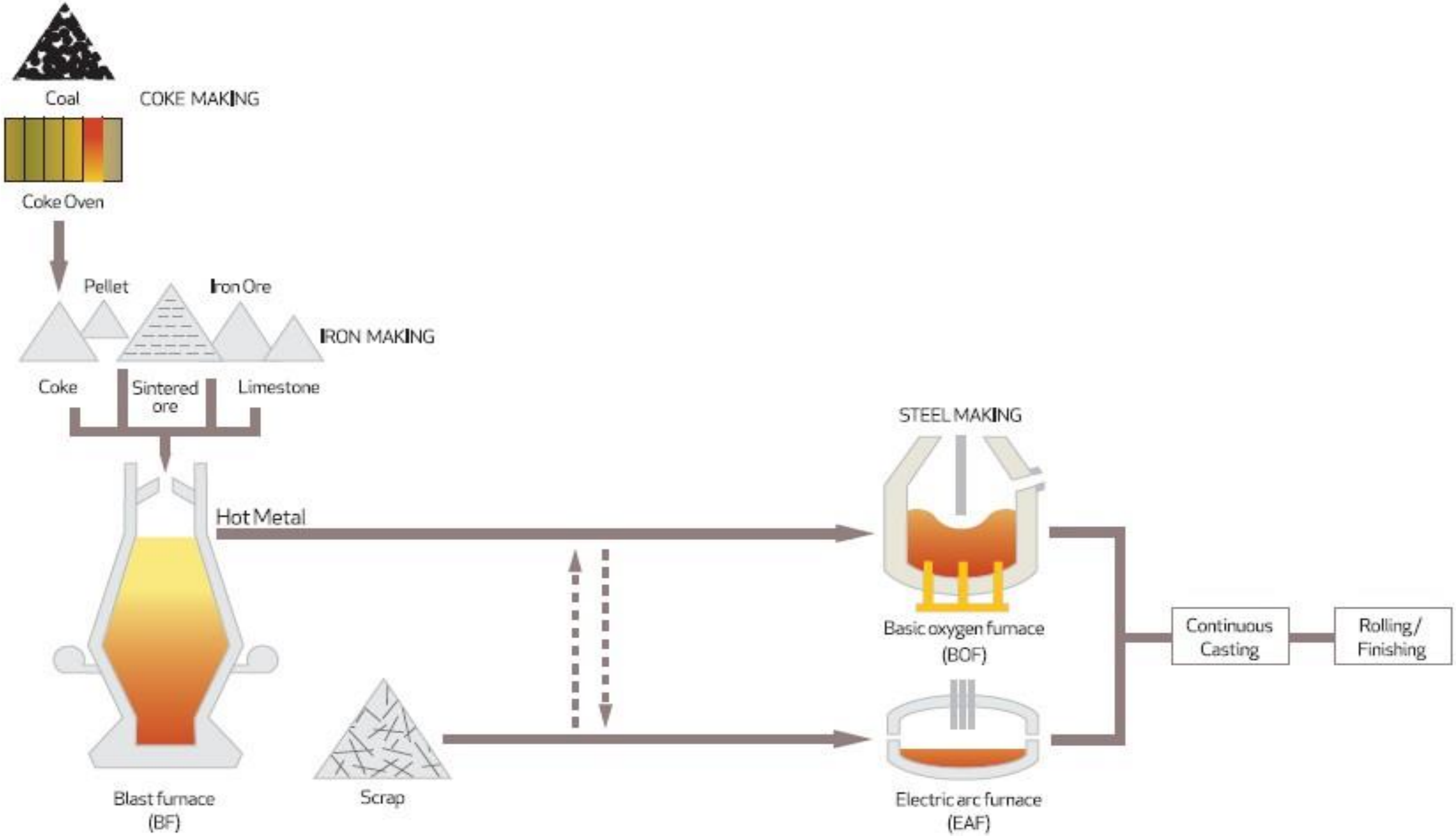


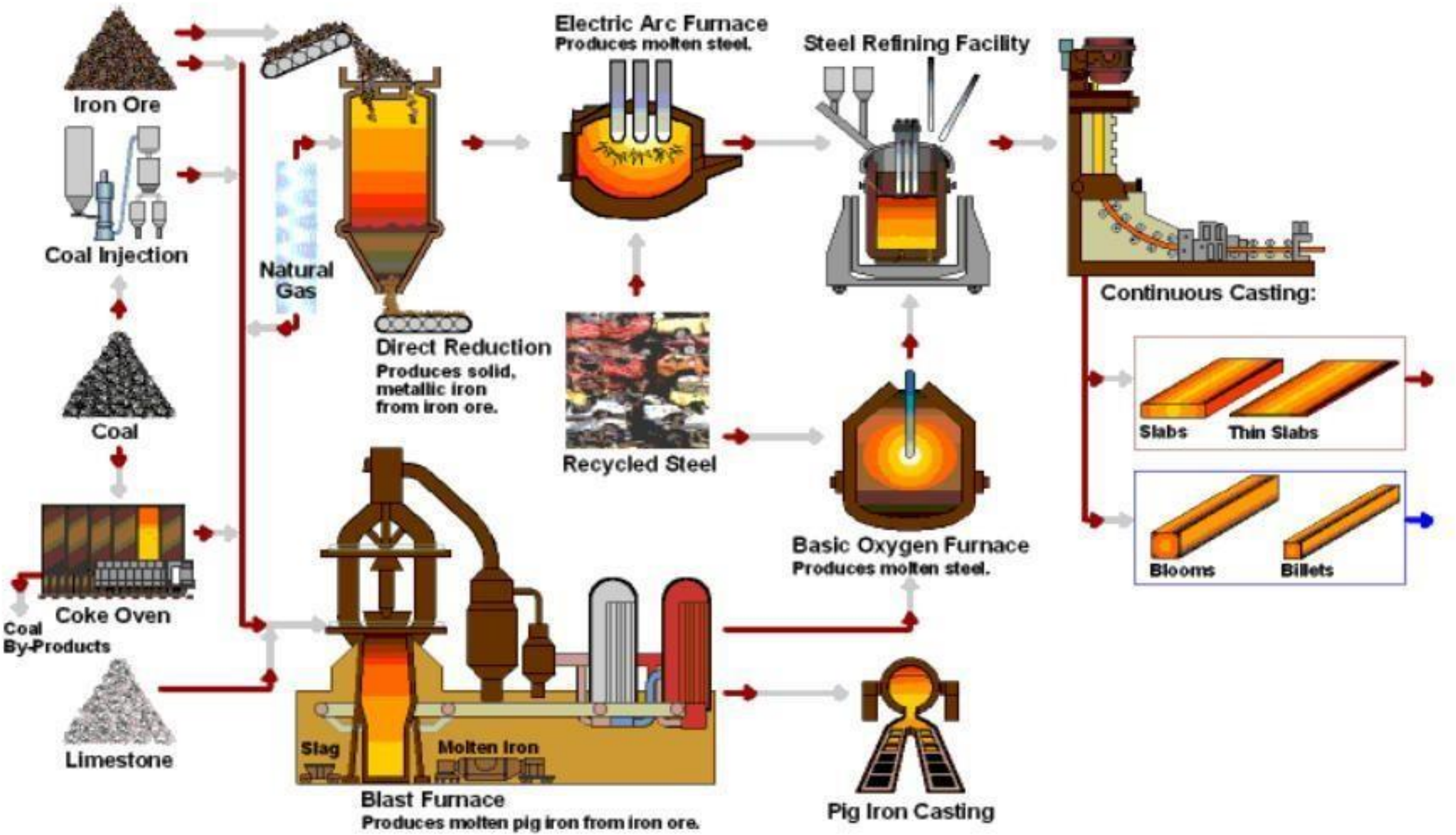
Fig. 1. General flow diagram for extraction of metal from ore



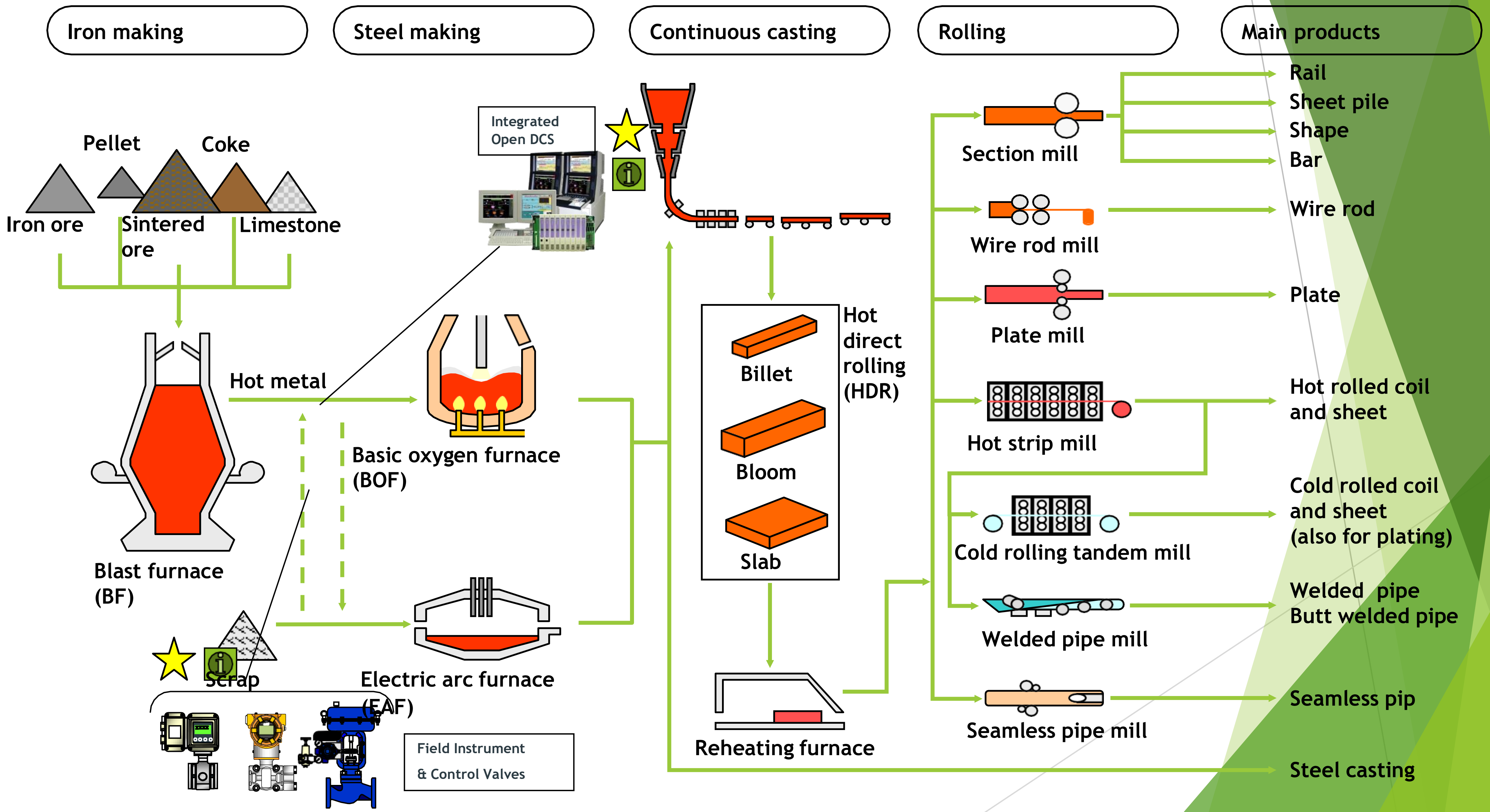
Source: [312, Dr. Michael Degner et al. 2008]



Coal
COKE MAKING
Coke Oven
Pellet
Iron Ore
IRON MAKING
Coke
Sintered ore
Limestone
Hot Metal
Blast furnace (BF)
Scrap
STEEL MAKING
Basic oxygen furnace (BOF)
Electric arc furnace (EAF)
Continuous Casting
Rolling / Finishing


Iron Ore
Coal Injection
Coal
Coke Oven
Coal By-Products
Limestone
Natural Gas
Direct Reduction
Produces solid, metallic iron from iron ore.
Electric Arc Furnace
Produces molten steel.
Recycled Steel
Steel Refining Facility
Basic Oxygen Furnace
Produces molten steel.
Continuous Casting:
Slabs
Thin Slabs
Blooms
Billets
Slag
Molten Iron
Blast Furnace
Produces molten pig iron from iron ore.
Pig Iron Casting

Steel Plant



Iron making
Steel making
Continuous casting
Rolling
Main products
Pellet
Coke
Iron ore
Sintered ore
Limestone
Integrated Open DCS
Hot metal
Basic oxygen furnace (BOF)
Blast furnace (BF)
Scrap
Electric arc furnace (EAF)
Field Instrument & Control Valves
Billet
Bloom
Slab
Hot direct rolling (HDR)
Reheating furnace
Section mill
Wire rod mill
Plate mill
Hot strip mill
Cold rolling tandem mill
Welded pipe mill
Seamless pipe mill
Rail
Sheet pile
Shape
Bar
Wire rod
Plate
Hot rolled coil and sheet
Cold rolled coil and sheet (also for plating)
Welded pipe
Butt welded pipe
Seamless pip
Steel casting

The raw materials used for blast furnace ironmaking are mainly (i) iron ore, (ii) metallurgical coke, (iii) limestone, (iv) air and (v) water (for cooling)

Pig iron: Impure iron is produced from reduction of iron ore by means of coke in a blast furnace. The product is a liquid iron, known as hot metal (3.5–4.5% C, 0.5–1.25% Si, 0.5–0.75% Mn, etc.) which is raw material for production of steel. Hot metal is refined by oxidation process to form steel. Hot metal is solidified into a small sized ingots.

The pig iron is very brittle in nature due to high carbon content, which makes it fit only as a casting of some components by adjusting composition.

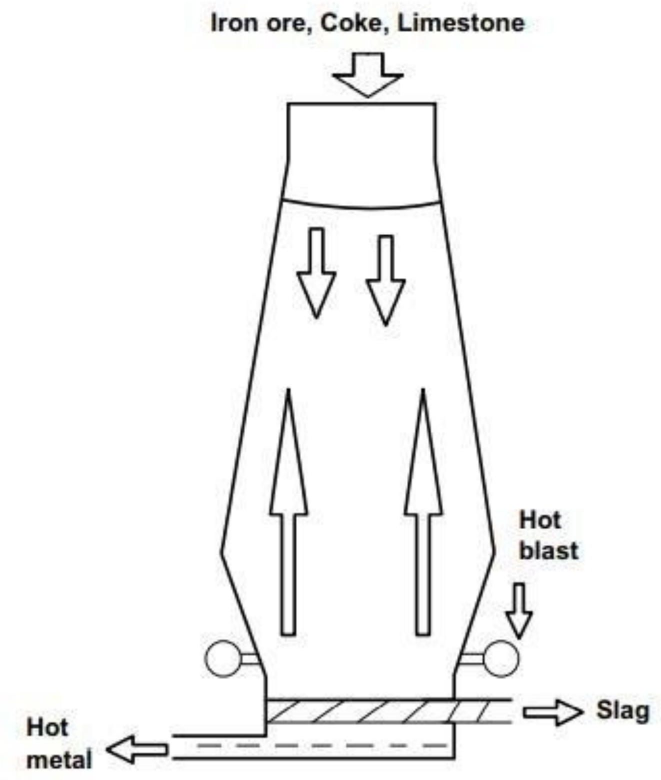


Fig. 2. Schematic representation of a blast furnace

- A wide variety of iron ore deposits have been found all around the world. These total over **350 billion tonnes** at an average iron **(Fe) content of 47%.** A minor fraction of these deposits is currently commercially mined as iron ore with Fe contents ranging from as low as **30 up to 65%.**
- The world's iron ore production and reserves are shown in Table 1.
- World consumption of iron ore grows on **average 10%** per annum with the main consumers **China, Japan, India, Korea, USA and the European Union** [1]. **China** is currently the largest consumer of iron ore in world and establishes as the world's highest steel producer.

Table 1.World iron ore production and reserves (Mt)

Country	Mine production				Reserves	
	Useable ore (2016–2017)		Iron content (2016–2017)		Crude ore	Iron content
Australia	858	880	531	545	50,000	24,000
Russia	101	100	60	60	25,000	14,000
Brazil	430	440	275	280	23,000	12,000
China	348	340	216	210	21,000	7200
India	185	190	114	120	8100	5200
Ukraine	63	63	39	39	6500	2300
Canada	47	47	29	29	6000	2300
Sweden	27	27	16	16	3500	2200
Iran	35	35	23	23	2700	1500
USA	42	46	26	28	2900	760
Kazakhstan	34	34	10	10	2500	900
South Africa	66	68	42	42	1200	770
Other countries	116	110	72	68	18,000	9500
World (total)	2352	2380	1453	1470	170,400	82,630

Iron ores

(a) Haematite (Fe_2O_3): It is also called red ore of iron. The maximum theoretical iron contains 70% and 30% oxygen (for pure Fe_2O_3). In actual deposits, the iron content varies 50–65%. Its specific gravity is about 4.9–5.25. **It is non-magnetic in nature and is more reducible compared to other minerals of iron.**

(b) Magnetite (Fe_3O_4): It is called black ore of iron. **Magnetite, combination of ferrous and ferric oxides (Fe_3O_4 = FeO + Fe_2O_3).** Magnetite contains 31.03% FeO and 68.97% Fe_2O_3. The maximum theoretical iron contains 72.4% and 27.6% oxygen (for pure Fe_3O_4). In actual deposits, the iron content varies from 25 to 70%. A grey metallic lustre is also observed. Its specific gravity is about 4.9–5.2. **It is magnetic in nature,** so it can be easily separated from the gangue minerals by magnet. The main disadvantage of the ore is that it has **very poor reducibility.** Many often magnetite ores required to be agglomerated by sintering or pelletizing before charge into the blast furnace. Due to high-temperature firing, Fe_3O_4 get converted into Fe_2O_3 and hence the poor reducibility of magnetite ore is indirectly taken care of it.

(c) Siderite ($FeCO_3$): It is known as spathic iron ore. It contains 48.2% iron (for pure mineral) with various colours mainly from ash grey to brown. **It requires calcination before charging into the blast furnace to eliminate CO_2 from the ore.** It is often mixed with other carbonates (like $CaCO_3$, $MgCO_3$). Its specific gravity is about 3.7 to 3.9.

(d) Limonite (FeO(OH) nH_2O): **(Fe_2O_3 $3H_2O$).** It is called yellowish-brown ore. **The ore contains actually very low iron. The dehydration occurs by the pre-heating of the ore.** Limonite is relatively dense with a specific gravity varying from 2.7 to 4.3.

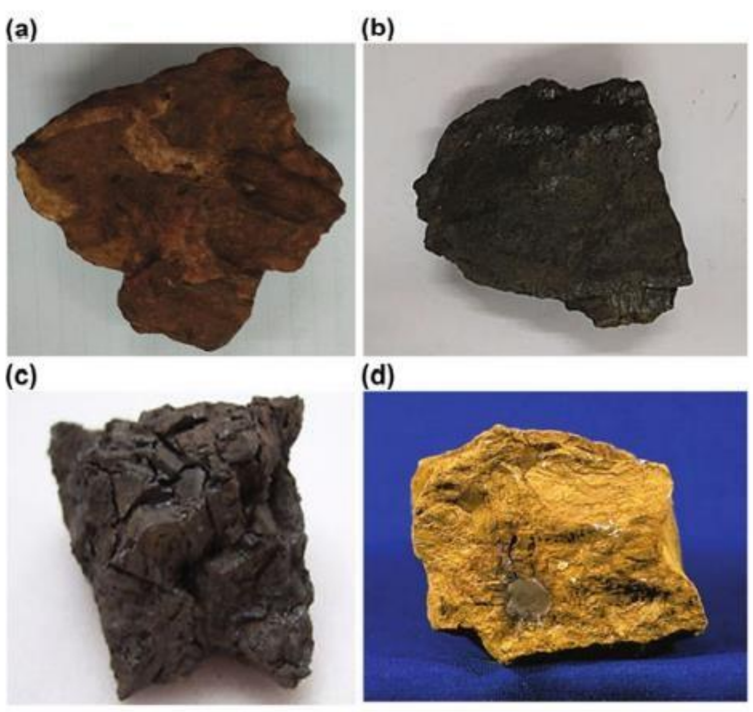


Fig. 3 Iron ores: a) haematite, b) magnetite, c) siderite and d) limonite.

Evaluation of Iron Ore

1) Richness of deposit (% Fe in the ore): generally, **high-grade iron ores;** ores contain more than 50% Fe, **low-grade ores;** ores contain less than 50% Fe.

The metallurgical advantage of using iron ore rich in iron content is well known that for every 1% increase in Fe content, there is 1–3% increase in production and a similar decrease in coke rate.

2) Extent of deposit: Deposit of ore must be in good amount to run the plant for several years.

3) Location of deposit: Location of deposit must be as far as nearer to the plant; otherwise, transportation cost will be increased.

4) Composition of the gangue minerals:

- The gangue content in the ore should be as low as possible.
- The silica in the ore goes as waste and increases the slag volume and coke consumption.
- High alumina content in the ore may also increase the slag volume and fluidity.
- The presence of 12–19% Al_2O_3 in the slag gives the desired fluidity for removal of sulphur from hot metal.
- With high phosphorous and sulphur content in the ore, production of quality hot metal becomes difficult.
- 1% increase in gangue content of the ore results in 1.75% increase in coke rate.
- High-grade ore is most welcome by the blast furnace operator provided Al_2O_3/SiO_2 ratio is low.
- High ratio will lead to high Al_2O_3 slag with its associated smelting difficulties.
- Very high Al_2O_3 in slag has a lower de-sulphurizing capacity, and that may lead to undesirable high sulphur in the hot metal.

5) Particle size of ore: Permeability for gas flow in blast furnace depends on size of ore and void fraction. Void fraction again depends on the ratio of smaller and larger particles of charge materials

Metallurgical Coke

The specifications of metallurgical coal, for making metallurgical coke, should be as follows:

Volatile matter: 26% in coal having 15% ash or about 30.59% on ash free basis,

Ash: not more than 15% (it can be acceptable coal with up to 17% ash content),

Phosphorous: not more than 0.15%,

Sulphur: not more than 0.6%.

Fig. 4. Coke.

- Coking: heating coals in absence of air, release volatiles and form strong and porous mass that are known as coke.

- Coke, produced out of coal, contains 21.12% ash, 78% fixed carbon, 0.88% volatile matter, 0.18% P, 0.57% S and 1.4% moisture. The coke with these specifications may be considered as good coke

The average size of the coke is much bigger than the iron ore, and the coke will remain solid throughout the blast furnace process.

Coke is a solid and permeable material up to very high temperatures (>2000 °C), which is of importance in the hearth, melting and softening zones.

Below the melting zone, coke is the only solid material; so, the total weight of the blast furnace charge is supported by the coke.

The coke bed must be permeable, so that hot reducing gases going upward direction through it, and molten slag and iron can flow down easily through coke bed to accumulate at the hearth.

Coals can act as environmentally friendly because of the following:

• Low sulphur content, • Low chorine content, • Low toxic trace elements content.

Functions of Coke

Main functions of coke in a blast furnace are as follows:

(i) It acts as a fuel to provide heat for (a) requirement of endothermic chemical reactions and (b) melting of metal and slag.

(ii) It acts as a reducer by producing of reducing gases (CO, H_2) for the reduction of iron oxides in ore.

(iii) It provides the support the whole burden (in bosh region) during melting of iron-bearing burden.

(iv) It provides a permeable bed through which molten slag and metal droplets come down into the hearth and help hot reducing gases flow upward direction for heating raw materials as well as reduction of iron ore.

(v) It provides the carbon for proper carburization of the hot metal.

To fulfil above functions, the coke should satisfy the following requirements:

• To be a good fuel coke, it **should have maximum carbon content and minimum ash content**;

• To regenerate reducing gases and to produce heat, coke **should have a high reactivity with oxygen, carbon dioxide and water vapour;**

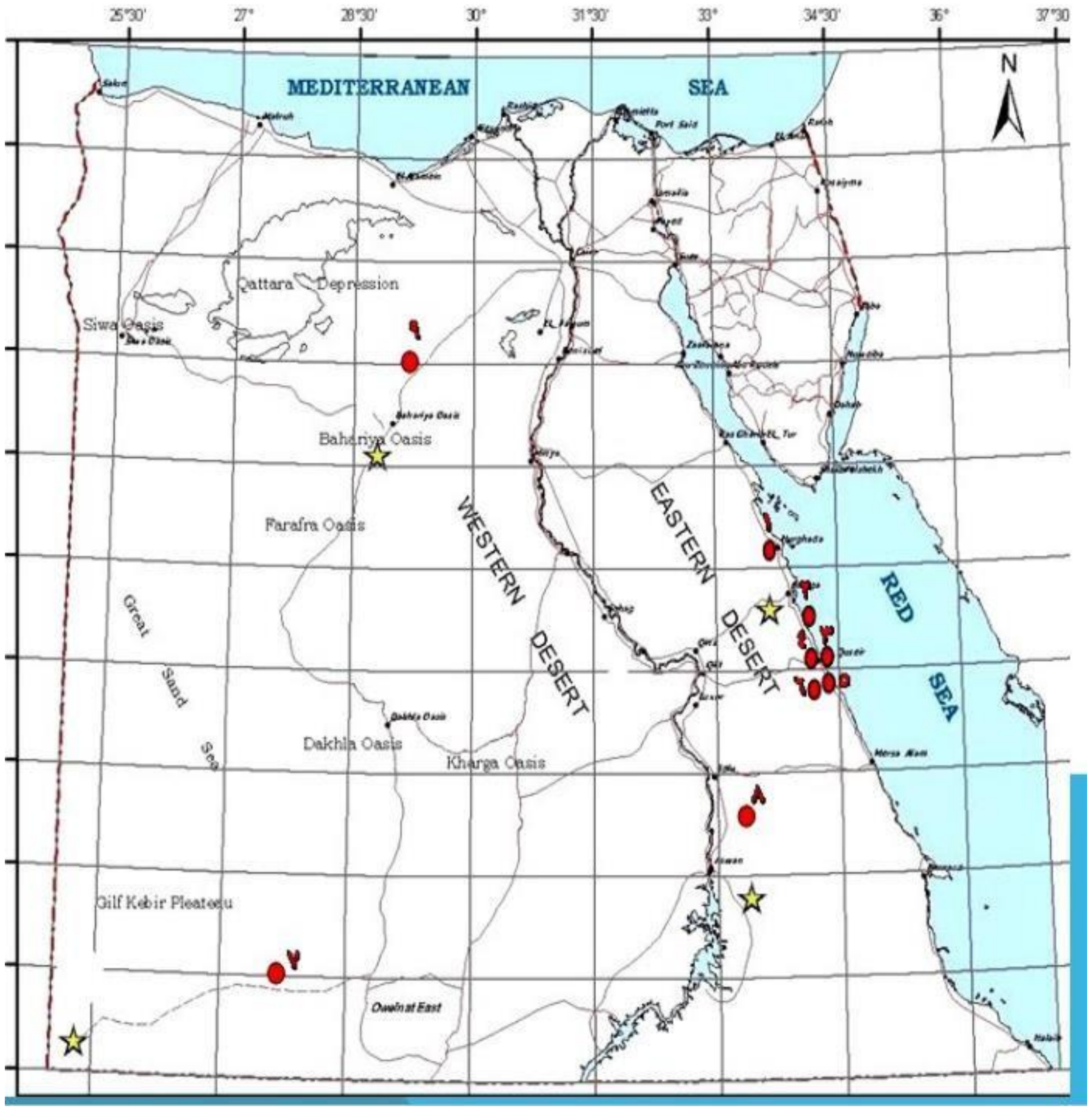
• In bosh region, permeability of the charge is maintained by the coke alone because other materials, except coke, are either semi-fused or molten stage. Hence, coke **should be remained solid until it burns at the tuyere level**.

The role of coke as a fuel as well as a generator of reducing gas can be considerably reduced using higher blast temperature and injection of auxiliary fuels in the blast furnace. This reduces the coke rate considerably from 700 to 900 kg/tonne of hot metal (kg/thm) to 400–500 kg/thm.

Combustion efficiency of coke is evaluated through the off-gas analysis. The combustion efficiency would be 100% if off-gas of BF contained only CO_2 gas.

$$\text{Combustion efficiency} = (CO_2) / (CO + CO_2)$$

location map to Iron ore in Egypt, There are nine occurrences



IRON ORE IN EGYPT

area 1 - Abu Marwat

area 2 - Wadi Karim

area 3 - Wadi El Dabbah

area 4 - Umm Ghamis El Zarga

area 5 - Gabal El Hadid

area 6- Um Nar

area 7 - El Ewinat

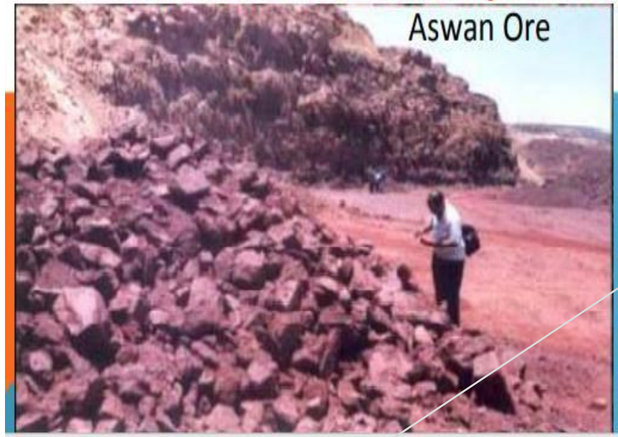
Aswan area –8

Bahariya area – 9

G. El Hadid

The Iron ore ranges between 38 % to 55 % of iron oxide and It .becomes economic

Iron is used in Ferrous Alloys and steel industries




Thank You!