5 Economic Minerals and Rocks

Introduction :

The branch of Geology that deals with the economically important minerals is known as Economic Geology. Economic Geology studies the exploration, exploitation and origin of the mineral deposits. Economic mineral deposits are geologic bodies that may be worked for one or more minerals or metals. Many geological processes result in the concentration of minerals and elements that are exploited as natural resources. Minerals are the most important natural resources that dictate the industrial and economic development of a country. There is an ever-increasing global demand for these resources due to improved standards of living, industrialization and the growth of population.

The occurrence of economic minerals is therefore restricted to particular geological process and hence the geographic location. Some igneous processes give rise to the ore deposits containing base metals (Cu-Pb-Zn) whereas the coal and petroleum are formed through sedimentary processes. Diamonds are generally restricted to a rock called Kimberlite and chromite is found in a rock called peridotite. It is therefore necessary to understand the mode of origin of the rocks and explore their mineralogy to find whether the rock contains any economic mineral of exploitable value or not.

There are serious implications of the availability of these resources to development of any civilization. In modern times, the industrial revolution has heavily depended on the availability of natural mineral resources.

Terminology used in economic geology :

An ore is a natural concentration of one or more minerals, i.e. rock from which one or more metals can be extracted economically. i.e. the value of the metal obtained must be more than the cost of mining, transportation and processing. Ores of important metals such as iron aluminium, gold, platinum, copper etc. are part of economic and industrial growth of the country. Ore is explored through systematic knowledge of economic and mining geology.

Ore comprises of ore minerals, gangue minerals, and country rock. Earlier the metal bearing deposits were considered as ores however, more recently, nonmetallic minerals of commercial importance are also considered ore minerals.

Gangue comprises of minerals which are associated with the ore. Gangue minerals are commercially insignificant in a particular period of time, possibly becoming ore minerals at a later date. They are commonly silicates, carbonates, or fluorides, and rarely sulfides.

Tenor is the metal content of the ore. It is generally expressed as a percentage and in case of precious metals, it is expressed in parts per million (ppm). Tenor depends on the price of the metal. Higher the price of the metal, the lower the metallic content necessary and vice- versa. The minimum acceptable cut-off grade of the metal content in an ore depends on various factors like nature and size of the deposit, its location in terms of distance and transportation, metal price and the cost of its extraction.

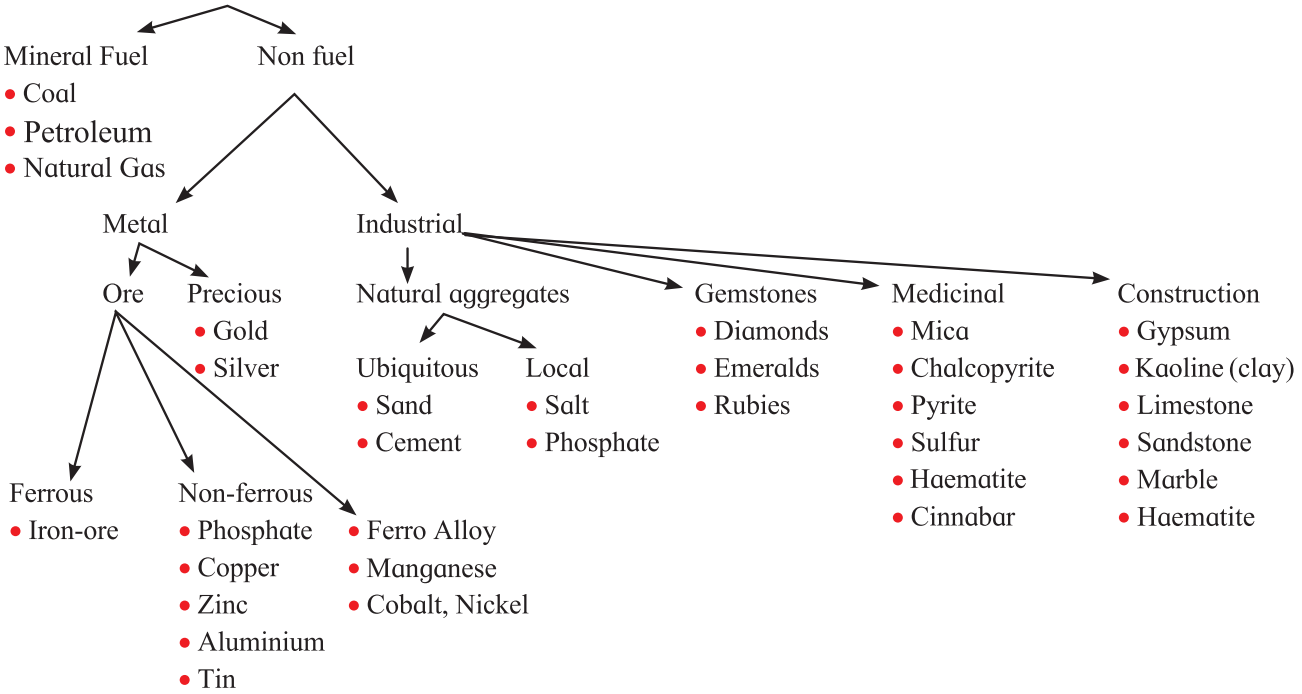
Do you know?

Several government agenies such as GSI, MECL and Mining companies in India carry out geological exploration. The license, records and the economic values of these

minerals are maintained by the government agencies like Indian Bureau of Mines and State Departments of Geology and mining. Minerals that contains elements or metals used in national security and defense industries are Strategic Minerals, and they are mined and exploited by the agencies like AMD and IRE. These regulatory organizations manage the industrial supply and use of these metals in India.

The natural resources of economic values can be classified into fuel, non-fuel, metallic and non-metallic. The resources of particular industrial interests and metallic mineral (ores) are shown in table 1. Metallic minerals (ores) occur in combination with other elements which must be separated. Iron, copper, gold, silver, lead, tin, zinc, aluminum, platinum etc. are metallic minerals whereas, clay, limestone, sand, salt, sulphur, phosphate etc. are non-metallic minerals. The non-metallic minerals can be used in their raw form. Non metallic minerals occur in abundance and are available on a local level for local consumption. Thus while metals are international commodities most of the non-metals rarely enter into world trades (there are exceptions such as diamonds).

Economic minerals metallic, non-metallic and mineral or fossil fuel



Metallic Resources

Heavy Metals Sp gr > 5		Light Metals Sp.gr. <.< 5	Rare Metals	Nobel Metals
Ferrous	Non-Ferrous	Li	Ta, Nb, Cd,	Au
Fe, Mn	Cu, Pb	Mg	Hg, Pd, Te	Ag
Cr, Va	Zn, Sn	Be		Pt
Mo, W	Sb, Bi	Al		Pa
Ni, Co				
Ti				

Table 1 : Classification of Economic minerals

Mineral deposits in India :

The mineral resources of our country are vast and varied. The minerals that are found abundantly, are exported and those in which India is deficient, are imported.

Some of the important minerals are described with respect to their chemical composition, physical properties, occurrence and State wise distribution in India.

Ore Minerals:

Iron ores :

The word iron itself comes from 'iren' in Anglo-Saxon. Iron is the fourth most abundant element {5.00%} in the Earth's crust by weight.Iron ore is most often found in the forms of hematite and magnetite.

i) Haematite :

Originally named about by Theophrastus from the Greek word 'Haematitislithos' for 'blood stone' in 300/325 BCE. It is possibly the first mineral ever named ending with a '-ite'suffix. Translated in 79 AD Pliny the Elder to haematites, or 'bloodlike' in allusion to the vivid red colour of the powder. It is known as Gairika in Ayurveda. (fig. 5.1)

Fig. 5.1 : Haematite

Chemical Composition : Fe_2O_3

Colour : Steel grey, iron black

Lustre : Submetallic.

Streak : Cherry red.

Form : Reniform, compact microcrystalline or scaly aggregates and sometimes botryoidal.

Cleavage : Absent.

Fracture : Uneven.

Hardness: 5.5 to 6.5.

Specific Gravity : 4.9 to 5.3

Uses : Used as an ore of iron, as a gem stone and in preparation of Ayurvedic medicines.

Occurrence : In metamorphic rocks like Banded Haematite Quartzite (BHQ).

ii) Magnetite :

Originally called loadstone, is a variety of magnetite i.e. natural magnet (fig. 5.2). Named in 1854 by Wilhelm Karl Von Hai dinger after the locality Magnesia, Greece.

Fig. 5.2 : Magnetite

Chemical Composition : Fe_3O_4

Colour : Iron black.

Lustre : Metallic to submetallic.

Streak : Black.

Form : Massive, granular

Cleavage : Absent.

Fracture : Uneven.

Hardness : 5.5 to 6.5.

Specific Gravity : 5.18.

Uses : Magnetite is used as an iron ore, abrasive, fertilisers, pigment in paint and as an aggregate in high density concrete.

Occurrence : As primary constituent in igneous and metamorphic rocks (banded magnetite quartzite) or as a sedimentary deposit.

Geographic Distribution in India :

Iron ores occurs on a large scale in India. Large deposits of haematite are found in Chhattisgarh, Goa, Jharkhand, Karnataka, Maharashtra and Odisha. Most of these ores are embedded in Banded Haematite Quartzite

(BHQ). The ore deposits consist of alternating bands of haematite and recrystallized Quartz. In Maharashtra, the iron ore deposits occur mainly in Chandrapur, Ratnagiri and Bhandara Districts.

Manganese ores :

Manganese is found as a free element in nature. It is often found in combination as a large variety of minerals. The name of manganese may have come either from the Latin word 'magnes' meaning magnet, or from black magnesium oxide 'magnesia-nigra'. It is the 12th most abundant element in the Earth's crust.

India is the world's fifth largest producer of manganese ore with iron. Polymetallic nodules also called manganese nodules, are rock concretions found on the sea bottom. Manganese is chiefly obtained from ore minerals like Pyrolusite and Psilomelane.

i) Pyrolusite :

The name pyrolusite is derived from Greek word 'pyro' means fire and 'louein' means to wash (fig. 5.3). It was used to remove brown and green tints in making of glass.

Fig. 5.3 : Pyrolusite

Chemical Composition : MnO_2 (Manganese oxide).

Colour : Black, Iron grey or dark steel grey.

Lustre : Metallic, dull, Earthy.

Streak : Black, iron black or dark steel grey.

Form : Botryoidal, reniform, massive.

Cleavage : Absent.

Fracture : Brittle, uneven, Earthy.

Hardness : 6 to 6.5

Specific Gravity : 4.4 - 5

Uses : Important ore of manganese.

Occurrence : Large deposits formed in a bog, lacustrine or shallow water environments.

ii) Psilomelane :

The name Psilomelane is derived from Greek word 'psilos' meaning smooth or bald and 'melas' meaning black in allusion to form and colour (fig. 5.4).

Fig. 5.4 : Psilomelane

Chemical Composition : $MnO_2.H_2O$ (Hydrated oxide of manganese).

Colour : Iron black to steel grey, brownish black.

Lustre : Sub- metallic.

Streak : Brownish black

Form : Massive, botryoidal, reniform, stalactitic.

Cleavage : Absent.

Fracture : Uneven.

Hardness : 5 to 6.

Specific Gravity : 3.7 to 4.7.

Uses : Important ore of manganese.

Occurrence : As a secondary mineral formed by the weathering of other manganese bearing minerals, and also as large deposits formed in lacustrine or shallow water environments.

Geographic Distribution in India :

Manganese ores are mostly found in Maharashtra and Madhya Pradesh which together produce more than half of India's manganese.

Copper ores :

Copper gets its name from Latin word 'cuprum' meaning from the island of Cyprus. Copper ranks as the third most consumed industrial metal in the world after iron and aluminium.

Copper was probably the first metal used by human. It is a soft but tough metal, very ductile and malleable and therefore is used in electrical industry and utensils. Copper is used in various alloys like brass (Cu+Zn), bronze (Cu+Sn+Al), and Electrum (Au+Cu+Ag).

The important ores of Copper are Chalcopyrite, Malachite, Cuprite and Native copper.

i) Chalcopyrite :

Name-named in 1725 by Johann Friedrich Henckel from the Greek word 'chalkos' meaning copper and 'pyrites' means strike. Also called Maxika in Ayurveda (fig. 5.5)

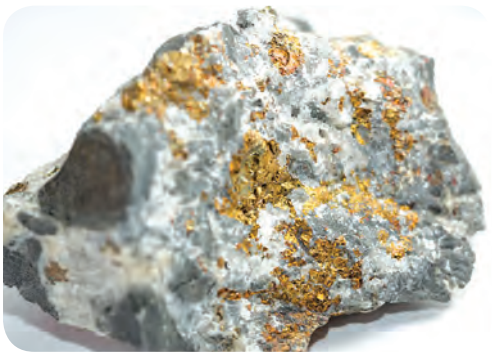


Fig. 5.5 : Chalcopyrite

Chemical Composition : $CuFeS_2$.

Colour : Brass yellow.

Lustre : Metallic.

Streak : Greenish black.

Form : Massive.

Cleavage : Poor or indistinct.

Fracture : Uneven, conchoidal.

Hardness : 3.5 to 4.

Specific Gravity : 4.1 to 4.3.

Uses : Important ore of copper.

Occurrence : It mainly occurs as hydrothermal vein deposit.

ii) Malachite :

Named after the Greek 'mallows' in allusion to the green colour of the leaves. Referred to as Sasyaka in Ayurveda.

Chemical composition : $Cu_2 (CO_3) (OH)_2$

Colour : Bright green

Streak : Pale green

Lustre : Adamantine, vitreous, silky, dull.

Form : Acicular, fibrous, botryoidal, granular

Cleavage : Perfect

Fracture : Conchoidal, uneven

Hardness : 3.5 to 4

Specific gravity : 3.6 to 4

Geographic Distribution in India :

Copper ore is chiefly found in Andhra Pradesh, Jharkhand, Jammu and Kashmir, Kerala, Rajasthan and West Bengal.

Lead ore :

Native lead was probably first discovered in The Langban dist. in the nineteenth century.

The Latin name is also source of the English word 'Plumbing' and 'Plumber' due to the historic use of lead in water pipes. Some researchers have argued that Roman's wide spread use of lead for water pipes and eating utensils have in part contributed to their civilization decline.

Lead is commonly found to be occurring with zinc as polymeric Sulphides (ZnS). The important ore of Lead is Galena (PbS).

i) Galena :

Galena—Named by Pliny the Elder in 77-79 AD. from the Greek word 'galena' meaning 'lead ore' (fig. 5.6).

Fig. 5.6 : Galena

Chemical Composition : PbS

Colour : Lead grey.

Lustre : Metallic.

Streak : Black, lead grey.

Form : Massive, octahedral or cubic crystals, granular.

Cleavage : Three sets, perfect

Fracture : Uneven, sub conchoidal.

Hardness : 2.5.

Specific Gravity : 7.4 to 7.6.

Uses : Used to extract lead. It is mainly used in lead acid batteries.

Occurrence : It is found in structurally disturbed metamorphic terrains and also as hydrothermal deposits. It occurs in pegmatites and limestones and many a times associated with zinc ores.

Geographic distribution in India :

Chhattisgarh, Gujarat, Himachal Pradesh, Rajasthan,Tamil Nadu, Uttar Pradesh and Uttarakhand.

Zinc Ore :

The name Zinc comes from it's Latin name 'Zincum'. Sphalerite is an important ore mineral.

Uses : The important ore mineral is Sphalerite.

i) Sphalerite :

Named in 1847 by Ernst Friedrich Glockerfron the Greek word 'sphaleros' means 'treacherous rock' in allusion to the ease with which dark variety was mistaken for galena,but yielded no lead.

Sphalerite also known as blend or zinc blend, is the major ore of zinc.

Chemical Composition : ZnS.

Colour : Yellow, light to dark brown, black, red brown, colourless, light blue, green.

Streak : Pale yellow to brown.

Lustre : Admantine, resinous.

Form : Massive, granular, crystalline.

Cleavage : Perfect.

Fracture : Conchoidal.

Hardness : 3.5 to 4.

Specific Gravity : 3.9 to 4.1.

Uses : Important ore of Zinc.

Occurrence : It is found in metamorphic, igneous and sedimentary rocks.

Geographic Distribution in India :

Andhra Pradesh, Gujarat, Jharkhand, Karnataka, Madhya Pradesh, Odisha and Rajasthan.

Aluminium ore :

The name aluminium is derived from Latin word 'alumen' means älum. It is the third most abundant element in the Earth's crust. Aluminium is most widely used after iron.

The chief ore of aluminium is Bauxite (fig. 5.7). The term 'Bauxite' is used for a rock made of aluminium oxides and is named after Les Beaux in France, where it was first located. It is mixture of hydrated aluminium oxide minerals like gibbsite, diaspore and bohemite. Large amount of high- grade Bauxite is found in India (around 2500 million tons.)

i) Bauxite :

Fig. 5.7 : Bauxite

Chemical Composition : $Al_2O_3.2H_2O$.

Colour : Yellowish, off-white, pinkish, reddish brown.

Lustre : Dull, Earthy.

Streak : Whitish,yellowish

Form : Pisolitic, Amorphous.

Cleavage : Absent.

Fracture : Uneven.

Hardness : 2.5 to 6.5

Specific Gravity : 2.3 to 3.5.

Uses : Used as an ore of aluminium and in the abrasive, refractory.

Occurrence : It occurs as residual sedimentary deposit, formed as a result of weathering of rocks, under tropical conditions in alternate dry and humid climates. Bauxite occurs as capping on the parent rock.

Geographic Distribution in India :

Andhra Pradesh, Chhattisgarh, Goa, Gujarat, Jharkhand, Madhya Pradesh, Maharashtra, Odisha.

Radioactive minerals :

Radioactive minerals contain natural radioactive elements in excess. The most abundant radioactive mineral is :

i) Monazite :

The name monazite is derived from the Greek word 'monazeis' means to be alone in allusion to it's isolated crystals.

Chemical composition : (Ce, La, Nd, Th) (PO_4. SiO_4)

Colour : Reddish brown to brown, shades of green to brown, yellowish brown.

Streak : White

Lustre : Resinous, waxy, vitreous.

Form : Crystalline, granular.

Cleavage : Good to poor.

Fracture : Uneven, conchoidal

Hardness : 5 to 5.5

Specific gravity : 4.6 to 5.4

Uses : Important source of thorium and rare Earths.

Occurrence : In the beach sand. Usually occurs in Igneous (granite, pegmatite) and metamorphic (schist and gneiss) rocks. Monazite grains are resistant to weathering and become concentrated in soils and sediments derived from the primary source. They may also be mined for their rare Earth and thorium content.

Geographic Distribution in India :

Rajasthan, Bihar, Karnataka, Odisha, Andhra Pradesh, Tamil Nadu and Kerala.

Industrial Minerals:

These are non-metalliferous and are used, with or without processing in various industries, for purposes other than extraction of metal. Various industries like petroleum, cement, abrasive, ceramic, refractory and medicine, use these minerals as a major chunk of their raw materials. It includes even those minerals that are used in metallurgical industry as fluxes, e.g. muscovite, asbestos etc.

I) Coal and Petroleum/ Fuel Industry :

Coal and petroleum are considered conventional sources of energy. Coals are oxygenated hydrocarbons. Combustion of coal releases tremendous amount of heat. Therefore, it is used as fuel in thermal power plants and in the cement industry.

Coal is a black, stratified rock made up of hydrocarbons. Coal has basically originated from the decomposition of the vegetable matter. Grade or rank of coal depends on the degree of decomposition. Therefore, it does not possess a fixed chemical composition.

Peat, Lignite, Bituminous Coal and Anthracite are 4 varieties of coal. These varieties are indicative of the maturity of the Coal. During the conversion of Peat to Anthracite, there is general darkening in the colour, compactness, hardness, loss of moisture and volatiles along with an increase of carbon content. Thus, Anthracite is supposed to be the best variety of Coal.

Geographic Distribution in India :

Coal deposits in Maharashtra belong to Gondwana group occurring in Nagpur and Chandrapur districts. At the following coal fields: i) Kamptee coal fields, ii) Umrer coal fields, iii) Bokhara coal fields, iv) Wardha valley coal fields and v) Ghugus-Sasti- Rajura coal fileds.

Petroleum :

The word Petroleum is derived from the greek word 'Petra' meaning rock and 'Oleum' meaning oil. It is not a mineral in the geological sense. It has an organic origin and is a mixture of liquid hydrocarbons of complex composition. Petroleum accumulations are commonly associated with gas such as methane, propane, butane etc. which is called natural gas.

Petroleum is derived from the decomposition and distillation of organic matter, contained in sediments of shallow water, marine origin. It is found to be occurring in the pores and cracks of sedimentary rocks.

The petroleum extracted from the Earth is called as 'crude oil', then it is processed in refineries to separate its constituent 'fractions', each with distinctive properties and uses. Petrol, kerosene, diesel, lubricating oil, paraffin wax and asphalt are some of the products.

Geographic Distribution in India :

Assam, Gujarat, Rajasthan and Off-shore regions

Unconventional source :

Coal Bed Methane (CBM) : It is an unconventional source of natural gas, predominantly methane (CH_4) generated during coal formation and stored or adsorbed in coal seams. It generally does not contain hydrogen sulphide (H_2S). It is considered to be more eco-friendly than other sources.

As India has the fifth largest proven coal reserves in the world, it therefore holds significant prospects for exploration and exploitation of CBM. The Gondwana sediments of eastern India host the bulk of India's coal reserves and all the CBM producing blocks (Jharkhand, West Bengal and Madhya Pradesh).

Shale Gas : The term 'Shale Gas' refers to natural gas that is trapped underground in shale deposits. Shale is a fine grained, very porous rock. These pores are not well connected, which makes extracting the trapped natural gas difficult.

Gas Hydrates : The term 'Gas Hydrates' refers to gas molecules that are encased in ice. These are naturally occurring structures that can be found in permafrost sediments in the Arctic or buried in sediments deep under water.

Hydrocarbon is an organic compound composed exclusively of hydrogen and carbon atoms. Hydrocarbon molecules naturally occur and are found in crude oil, natural gas, coal, gas hydrates and other important sources of energy. Burning hydrocarbons in the presence of sufficient oxygen produces carbon di oxide, water and heat because of which they are desirable as fuels.

Hydrocarbons form naturally from plant and animal remains that are compressed through temperature and pressure over millions of years. Crude oil, tar, bitumen are all liquid forms of petroleum hydrocarbons, while Propane, butane and methane are gaseous hydrocarbons. Conventional petroleum resources are oil and gas deposits that can be extracted using traditional drilling methods. Unconventional petroleum resources are oil and gas deposits that are much more difficult to extract, and require unconventional specialized techniques and tools. For example Coal Bed Methane (CBM), Shale Gas and Gas Hydrates.

II) Cement Industry :

A mixture of limestone and gypsum ground to powder and mixed with water hardens rapidly into stony consistency is called cement. Cement industry utilizes Limestone as the chief raw materials followed by gypsum, bauxite and clay minerals.

Gypsum :

Name Gypsum has originated from the greek word 'Gypsos' meaning plaster. Mineral gypsum found in abundance near Paris is called Plaster of Paris. Gypsum is added to raw materials of Portland cement, because it regulates the setting or hardening time i.e. it prevents the cement from hardening too quickly.

Chemical composition : $CaSO_4.2H_2O$.

Colour : White.

Lustre : Vitreous, pearly, silky.

Streak : White.

Form : Laminated, fibrous, massive.

Cleavage : Perfect 2 sets.

Fracture : Hackly, even

Hardness : 2

Specific Gravity : 2.3

Occurrence : In sedimentary rocks as evaporites.

Geographic Distribution in India :

Jammu and Kashmir, Rajasthan, Tamil Nadu, Uttarakhand.

Limestone :

Limestone is bulk raw material used in cement industry. For making cement, a naturally clayey Limestone or clay and limestone mixed in correct proportion is burnt. The resultant mass is powdered and mixed with water. A chemical reaction takes place and hardens into dense compact mass. All limestone deposits may not be suitable for the manufacture of cement. The specifications for cement grade are:(a) MgO not more than 2.5%, (b) CaO not less than 42%, (c) SiO_2 not more than 14% and (d) P_2O_5 not more than 1%. Some limestones fulfill these conditions.

Geographic Distribution in India :

Andhra Pradesh, Karnataka, Madhya Pradesh, Maharashtra, Odisha.

Do you know?

The manufacturing of cement requires large amounts of energy. This increases the emission of greenhouse gases in the atmosphere. Hence, substitute materials, such as fly ash and slag, are being used in place of cement.

- Fly ash is a by-product produced in thermal power plants.
- Slag is a by-product produced in iron and steel plants.
- Fly ash and slag, along with other mineral mixtures, are used to substitute cement for making concrete used in construction activities.

III) Abrasive Industry :

An abrasive is a substance which is used for cutting, polishing, grinding and sharpening another substance.

Abrasives are categorized into two types :

i) Natural Abrasives - these include hard and tough minerals. The common abrasives are Diamond, Corundum, Quartz and Garnet.

ii) Artificial Abrasives.

Diamond :

Diamond is named after the greek word ‘adamas’ meaning invincible because of its hardness. Diamond being the hardest mineral, is used as an abrasive.

Chemical composition : Pure Carbon.

Colour : White, colourless, sometimes yellow, red or green.

Lustre : Adamantine.

Streak : Not obtained on the porcelain plate.

Form : Cubic crystals with curved surfaces.

Cleavage : One set.

Fracture : Conchoidal.

Hardness : 10.

Specific Gravity : 3.52.

Geographic Distribution in India :

Andhra Pradesh and Madhya Pradesh

Corundum :

Named after a Sanskrit word ‘kuruvind’ which means ruby. Corundum is next to Diamond in hardness and being cheaper than diamond can also be used in polishing or grinding rough surfaces.

Chemical composition : Al_2O_3.

Colour : Yellow, brown, red, blue

Lustre : Vitreous, sometimes dull on crystal faces.

Streak : Not obtained on the porcelain plate.

Form : Columnar, massive.

Cleavage : Absent.

Fracture : Conchoidal to uneven.

Hardness : 9.

Specific Gravity : 3.9 - 4.1

Geographic Distribution in India :

Andhra Pradesh, Jharkhand, Karnataka and Tamil Nadu

Quartz :

Quartz was used during the stone age. The word quartz is derived from the German word 'Quarz' which came from the Polish dialect term 'Kwardy', corresponding to the Czech term 'Tvrdy' meaning hard. Quartz is the second most abundant mineral in the Earth's crust.

Silica group constitutes 12% to 15% of all rock forming minerals. This group includes crystalline, cryptocrystalline and amorphous minerals. In glass, ceramics, abrasive and refractory industries, piezoelectric crystal plates used in quartz watches and also used as decorative and semi-precious stone.

Flint was used in the manufacture of tools as it had the property of splitting into thin, sharp splinters when struck by another hard object.

Chemical composition : The minerals of this group are characterised by same chemical composition i.e. SiO_2. Crystalline quartz is most abundant.

The composition varies from crystalline to cryptocrystalline silica, i.e. from SiO_2 to $SiO_2 . nH_2O$. Varieties of cryptocrystalline silica are mixtures of cryptocrystalline silica (chalcedony) and hydrous silica (opal).

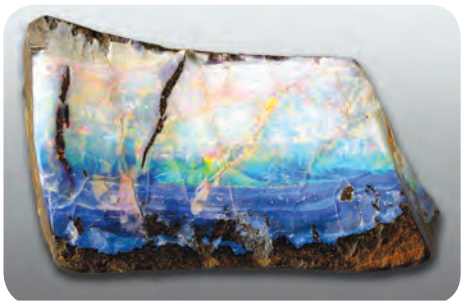


Fig. 5.8 : Opal

Crystalline Silica :

Colour : Colourless or white, also shows variety of colours.

Streak : White.

Lustre : Vitreous, subvitreous, waxy.

Form : Prismatic, botryoidal , massive.

Cleavage : Absent.

Fracture : Conchoidal to subconchoidal, uneven.

Hardness : 5.5 - 7 (variable depending upon silica variety)

Specific gravity : Approx 2.65

Occurrence : It occurs in igneous rocks like granite, pegmatite; as secondary mineral within cavities of basalts; in sedimentary rocks such as sandstone and in metamorphic rocks like quartzite, schist and gneiss.

Geographic Distribution in India :

W.Bengal, Maharashtra, Jharkhand, Rajasthan, Karnataka, Andhra Pradesh, Uttar Pradesh.

Garnet :

Named from 'granatum' (a pomegranate) for its resemblance to seed of this fruit. It is used as an abrasive and gemstone.

Fig. 5.9 : Garnet

Chemical composition : $X_3Y_2Si_3O_{12}$, where X= Ca^{2}+, Mg, Fe, Mn etc., (divalent ions) Y= Al^{3}+, Fe, Cr and Ti (trivalent ions).

Complex silicates of Ca, Mg, Fe, Mn.

Colour : Red, brown, yellow.

Lustre : Vitreous.

Streak : Not determined.

Form : Crystallized, massive (Rhomb dodecahedron).

Fracture : Uneven-Subconchoidal.

Cleavage : Absent.

Hardness : 7.0 - 7.5.

Specific gravity : 3.4.

Occurrence : In metamorphic rocks.

Geographic Distribution in India :

Rajasthan, Jharkhand, Karnataka, Andhra Pradesh.

IV) Ceramic Industry :

Crockery, glazed tiles, sanitary ware, insulators are ceramic products. Ceramic material is also used in electrical, electronic and automobile industries.

Kaolin :

Named as per an ancient chinese type locality 'kaoling (Gaolong)': meaning high ridge.

Chemical Composition : $Al_2(Si_2O_5)OH_4$

Colour : white to cream, pale yellow

Lustre : waxy, pearly, dull, Earthy

Streak : white

Form : massive

Cleavage : perfect

Fracture : uneven, conchoidal to sub-conchoidal

Hardness : 2 to 2.5

Specific Gravity : 2.63

Occurrence : occurs in sedimentary rocks

Geographic Distribution in India :

Gujarat, Kerala, Rajasthan, West Bengal, Jharkhand, Andhra Pradesh, Karnataka, Maharashtra and Madhya Pradesh.

Feldspars :

Feldspar is one of the most abundant minerals found in the continental crust. This group constitutes over 50% of the Earth's crust.

The name feldspar is derived from the German word 'Feldspat'. 'Feld' meaning field and 'Spat' meaning a rock (that does not contain ore).

Feldspars are used in the ceramic industry due to their glazed lustre property. They are used in the manufacture of glass, porcelain, sanitary ware and as filler in paints, plastic, rubber and adhesive industries. Feldspars are also used as gemstones e.g., moonstone (orthoclase), sunstone (labradorite) and amazonite (microcline).

Silicate structure : All feldspars are tectosilicates. Ca, Na, K cations also occur in tectosilicates.

Chemical composition : It is expressed as $X(AlSiO)_4O_8$, where X is Ca, Na, K and Ba.

Varieties : This group is sub-divided on the basis of chemical composition and isomorphism into:

i) Alkali feldspars ii) Calc-alkalifeldspars

i) Alkali feldspars or Potassium Sodium feldspars. e.g. orthoclase and microcline. Albite ($NaAlSi_3O_8$) to Orthoclase ($KAlSi_3O_8$) isomorphous minerals. It is a substitution of sodium by potassium.

Orthoclase : Name has its origin in the Greek words- 'Orthos' meaning right, 'Clase'meaning to cleave (cleavages are at right angles) (fig.5.10).

Fig. 5.10 : Orthoclase

Fig. 5.11 : Microcline

ii) Calc-alkali feldspars - Plagioclase series of feldspars or lime soda feldspars, e.g. plagioclase (fig. 5.11) and labradorite (fig. 5.12).

Fig. 5.12 : Plagioclase

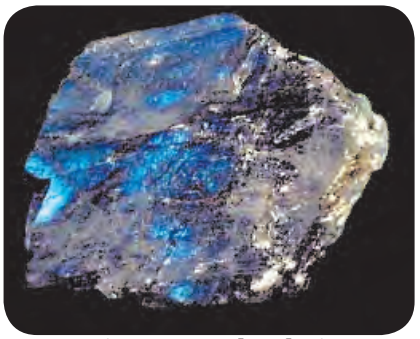


Fig. 5.13 : Labradorite

Plagioclase feldspars : Plagioclase series of feldspar minerals are a homogeneous mixture of albite and anorthite. In this series Na-Si is replaced by Ca-Al. The minerals so formed are called isomorphs. The two boundary minerals albite and anorthite are called end members.

Albite(Ab) ⇆Anorthite(An).

Physical properties of feldspar group :

Colour : Blue, orange, pink, white, green and gray.

Streak : White or pale shade of body colour.

Lustre : Vitreous to sub vitreous

Form : Tabular

Cleavage : Two sets, at right angles

Fracture : Conchoidal to uneven

Hardness : 6 - 6.5

Specific gravity : 2.55 - 2.76

Occurrence : Feldspars are found in igneous rocks (e.g., granite, syenite, pegmatite), sedimentary rocks (e.g., arkose a variety of sandstone containing at least 25% feldspar) and metamorphic rocks (e.g., gneiss).

Use of ceramics :

In recent times, ceramics and glass fibres are replacing iron, steel, copper, aluminium, etc. etc. The following is a brief account of the use of ceramics and glass fibres.

In the construction industry, the use of ceramics in place of cement is increasing. Ceramics are used as insulators, semiconductors and magnets. Mobile phones, computers, television and a number of other electronic products make use of ceramics. The use of ceramics reduces polluting emissions. Ceramic catalytic converters in vehicles help to convert poisonous hydrocarbons and carbon monoxide into harmless carbon dioxide and water. Nowadays, the telecommunication industry uses optical fibres in place of copper wires. Optical fibres increase the speed and volume of transmission. The demand for copper has come down because of the increasing use of this technology. Therefore, the negative impact of copper mining has also decreased.

Do you know?

Lightweight reusable ceramic tiles are used in NASA's space shuttles. These tiles make a thermal barrier that protects the astronauts and the shuttle's aluminium frame from extreme external temperatures (approximately 1600°C) when the shuttle re-enters the Earth's atmosphere on its way back.

V) Refractory Industry:

Refractories are those minerals and mineral products, which can withstand high temperatures of preferably above 1500°C, without softening and fusion.

Refractories are used for lining furnaces, in the manufacture of crucibles for melting metals, wherever resistance to high temperature and corrosion is required. A good refractory should satisfy the following conditions :

a) It should have a very high melting point.

b) It should not crack or soften at high temperatures.

c) It should resist chemical action and physical wear and tear.

d) It should not react chemically with the substance being fused init.

The refractories are classified into three categories :

1) Acidic : Fire clay and Kaolin, Kyanite and Sillimanite.
2) Basic : Bauxite, Magnesite and Corundum.
3) Neutral : Zircon, Chromite and Graphite.

Raw Materials : The raw materials for the refractory industries are Fire Clay, Kyanite, Bauxite and Zircon.

Kyanite :

Derived from greek word 'Kyanos' meaning blue.

Industrial properties : When Kyanite is heated to a temperature of 1545°C, it changes into Mullite ($3Al_2O_3.2SiO_2$). It is stable at high temperatures of above 1800°C and possesses good mechanical strength, low coefficient of expansion and high electrical resistance. Hence, Kyanite is used as raw material in refractory industry.

Chemical composition : Al_2SiO_5.

Colour : Blue, green, bluish grey.

Lustre : Pearly

Streak : White

Form : Bladed

Cleavage : Two sets

Fracture : Uneven

Hardness : 4 - 7

Specific Gravity : 3.58 to 3.65

Geographic Distribution in India :

Jharkhand and Maharashtra

Bauxite :

(For physical properties refer to page no. 66)

Industrial properties : Bauxite is the chief source of Alumina. It is very hard, resists high temperature and is poor conductor of heat and electricity. Hence, Bauxite is added to clay in the manufacture of high alumina bricks, that are used to line furnaces to withstand high temperatures upto 1800ºC.

Zircon :

Industrial properties : Due to their resistance to corrosion , high thermal shake stability and low ability to generate defects in glass it is widely used in refractories and glass furnaces, refractory coatings, ceramic dentures and other dental procedures.

Chemical Composition : $ZrSiO_4$

Colour : Usually yellow, brown or red, colourless, blue and green

Lustre : Vitreous to adamantine, sometimes oily

Streak : colourless

Form : tabular, prismatic crystals, massive

Cleavage : imperfect

Fracture : uneven

Hardness : 7.5

Specific Gravity : 4.6 – 4.7

Uses : Ore of zirconium metal, ore of zirconium dioxide, whitening agents, gemstone, radiometric dating.

Occurrence : Occurs in igneous (pegmatite), metamorphic and sedimentary rocks.

Geographic Distribution in India :

Andhra Pradesh, Tamil Nadu, Kerala, Odisha.

VI) Medicine Industry :

Medicinal minerals : Use of minerals in ayurvedic system of medicine is known since about 2500 years and this branch of ayurvedic pharmacology is called 'Rasashastra'. It is a science and art of manufacturing drugs from minerals and native metals, for the preparation of ayurvedic medicines the minerals have to go through very definitive refining procedures or

'samskaras' before they can be incorporated into medicine. Some of the samskaras are shodhana, marana.

A systematic and scientific treatment of mineral medicines has been presented by Vagbhata in the 14th century.

Do you know?

Vagbhata's 'Rasaratna Samuchchaya' gives systematic and easy presentation of minerals. Vaghbata has classified minerals employed in medicine into Maharasas, Uparasas, Sadharanaras.

Minerals of Rasashastra are classified, generaly based essentially on their degree of utility in preparation of mineral recipes.

But the basis of such classification is not well documented. Whether the frequent employment of such items has qualified these materials or their importance in Rasashastra in order to qualify them to be classified as Maharasas is not clear.

It has not been possible to understand the basis of Vagbhata's classification of Uparasas. However, the suffix 'Upa' would suggest that these substances are not so important as the Maharasas.

However, the basis of classification is wanting as in the case of other rasas.
Sadharanrasas may mean that these items may be used sparingly in Ayurveda medicine.

Some of the important minerals in **maharasas** are —

Mica (Abhraka), Chalcopyrite (Maxika), Pyrite (Vimala) and Malachite (Sasyaka).

Some of the important minerals in Uparasas are — Sulfur (Gandhaka) and Haematite (Gairika).

One of the important minerals in sadharanarasas is— Cinnabar (Hingula).

A) Maharasas :

There are four Maharasas Mica, Chalcopyrite, Pyrite and Malachite.

Mica :

Micas are important rock forming minerals. They can be cleaved into thin elastic plates. Name Mica has its origin in the Latin word 'Micare' meaning to flash or glisten.

Chemical composition : Micas are silicates of Al and K with Mg or Fe. Some varieties contain Na, Li or Ti. Hydroxyl group is present in micas and is partially replaced by fluorine.

Mica is popularly called 'abhraka' in ayurveda. It is grouped into different varieties based on its changes during heating, namely such as Pinaka, Naga, Manduka and Vajra.

Abhraka which separates into packed layers by the contact of fire is called 'pinaka'.

Abhraka which gives out hissing sound when heated is called 'naga'.

Abhraka which produces sound of frog and jumps on heating is called 'manduka'.

Abhraka which will not change when heated is called 'vajra'. The vajra is the best employed in medicinal preparation.

Muscovite : Hydrated silicate of Aluminium and Potassium with Fluorine and is silvery white in colour. Name Muscovite originated from 'Muscovy glass' because it came from Muscovy province of Russia (fig. 5.14).

In Ayurveda muscovite is termed as 'shewta abhraka' due to its white colour.

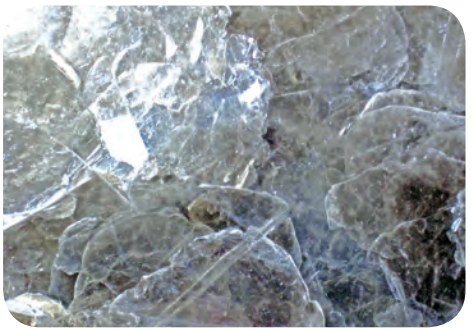


Fig. 5.14 Muscovite

Biotite : Hydrated silicate of Mg, Fe, Al, and K with F, black to brown in colour (fig. 5.15).
In ayurveda biotite is termed as 'krishna abhraka' due to its black colour.

Fig. 5.15 Biotite

Physical properties of mica group :

Colour : Colourless, silvery white, dark green, brown, black.

Streak : White, colourless.

Lustre : Pearly, silky.

Form : Foliated, flaky, lamellar

Cleavage : One set, perfect

Fracture : Uneven.

Hardness : 2 - 3

Specific gravity : 2.76 - 3.1

Occurrence : In igneous rocks, it occurs in pegmatite and granite; in sedimentary rocks such as sandstone and in metamorphic rocks like schist and gneiss.

Uses : As insulator in electrical industries, as filler in rubber, in lubricants and paints, has wide applications in ayurvedic medicines. Mica is used as medicine for treating diseases like anemia, bronchial asthma, low blood pressure, pleurisy, tuberculosis and coronary cardiac failure. It is also a heart tonic.

Geographic Distribution in India :

Andhra Pradesh, Jharkhand and Rajasthan.

B) Uparasas

Sulfur :

The name sulfur is derived either from the Sanskrit word 'sulvari' or the Latin word 'sulfurium'. In ayurveda, it is termed as 'gandhaka'.

Sulfur is used to make sulfuric acid, fungicide, in skin medicine, in vulcanization of rubber, gun powder, matches, fire works. Sulfur base concretes, cements and wall coatings are used where resistance to chemical attack is important.

Chemical composition : S_8

Colour : Yellow, Beownish or greenish yellow, orange, white.

Streak : Colourless

Lustre : Resinous, greasy

Form : Tabular, massive, reniform, spheriodal

Cleavage : Imperfect

Fracture : Uneven, conchoidal

Hardness : 1.5 to 2.5

Specific gravity : 2.0 to 2.1

Geographic Distribution in India :

Bihar, Rajasthan and Ladakh

C) Sadharanarasas

Cinnabar :

Name- From Persian 'zinjifrah', original meaning lost (dragon's blood). Referred to as Hingula in Ayurveda.

It is an important ore of mercury. Used in ayurvedic medicine, pigment and jewellery and ornaments.

Chemical composition : HgS

Colour : Tint or shade of red, cochineal red, brownish red.

Streak : Red-brown to scarlet.

Lustre : Metallic, adamantine to dull.

Form : Crystals-rhombohedral, massive, granular.

Cleavage : Perfect.

Fracture : Uneven, subconchoidal.

Hatdness : 2 - 2.5

Specific gravity : 8.17 to 8.20

Geographic Distribution in India :

Rajasthan and Gujarat

Mineral /rock based industries :

The Industrial Policy initiatives were

undertaken by the Government of India in 1991, to meet the International Standards and compete in the world market. For the sake of efficiency and economy of production, it is important that the location of industry should be suitably selected. Various factors affect the choice of particular locations for individual industries. The major factors that govern the criteria for the selection for localization of establishing industry are as follows :

1) **Raw Materials :** The total cost of the raw material includes, the amount spent on its transportation to the factory. Those materials that lose considerable weight during manufacture are known as 'weight-losing materials', while those which retain weight are known as 'pure materials'. In order to avoid loss during transportation, the industries are generally located near the market. The 'weight- losing' materials may be immediately processed, if they are located close to the industries. For example in case of cement industry, most of the manufacturing units are located near the limestone deposits. Limestone being the important raw material used in the manufacture of cement. Similarly, iron and steel industries are located near the iron ore and coal deposits.

2) **Market :** Some industries need to be located near the markets. Industries manufacturing fragile products like glass, ceramics or pottery need to be established near the market, in order to avoid the loss during transportation due to damage or breakage.

3) **Skilled Labour :** A manufacturing industry requires skilled, sufficient and efficient labour. Industries are attracted to regions where cheap and capable labour is available. For example, glass industries are located near Agra.

4) **Site and Service :** The physical, geographical and geological conditions are very important, since the ground has to be sufficiently stable for supporting the foundation of the factory.

5) **Capital :** Effective and competitive production requires quality production in minimum time. Advanced technology and skilled labour required, are available at high costs, thus, sufficient capital is required.

6) **Government Policy :** Before establishing an industry, the Industrial policy and provisions, plus renewal etc. need to be considered.

Summary :

The prosperity of any nation is measured on the availability of natural resources within its geographical boundaries. Wars are fought till this day to acquire lands rich in mineral resources. Minerals which are industrially important directly contribute to the GDP of a nation which are in turn decides the living standards of the citizens of that country. The exploration and judicious exploitation of economic or industrially important mineral resources is intrinsically the job of a geologist.

India is a land blessed with a range of mineral resources and has substantial reserves of yet to be exploited materials. We are among the world leaders in having reserves of coal, iron ore, aluminum ore and clay minerals. India also has the largest deposit of monazite sands, which is a source of thorium for nuclear power generation. There are many other minerals which are available in India, though not in huge amounts, but important from a national security and hence of strategic importance, like petroleum, and we explore and exploits that too. Minerals also play an important role in the formulations of medicines used in Ayurveda.

EXERCISE

Q. 1 Choose the correct alternative :

1) Tenor of ore is ……..
   a) natural concentration of one or more minerals
   b) metal content of an ore
   c) deposit from which metal can be extracted profitably
   d) vein of metal

2) a) Iron ore minerals are Pyrolusite and Psilomelane
   b) Iron ore minerals are Pyrolusite and Magnetite
   c) Iron ore minerals are Pyrolusite and Haematite
   d) Iron ore minerals are Magnetite and Haematite

3)

a) Sphalerite	i) $Al_2O_3.2H_2O$
b) Chalcopyrite	ii) Pbs
c) Galena	iii) ZnS
d) Bauxite	iv) $CuFeS_2$

   A) a-iv, b-i, c-iii, d-ii
   B) a-ii, b-iii, c-i, d-iv
   C) a-iii, b-iv, c-ii, d-i
   D) a-i, b-ii, c-iv, d-iii

a) Diamond	i) Cement industry
b) Limestone	ii) Ceramic industry
c) Kyanite	iii) Abrasive industry
d) Feldspars	iv) Refractory industry

   A) a-iv, b-ii, c-i, d-iii
   B) a-iii, b-i, c-iv, d-ii
   C) a-i, b-iii, c-ii, d-iv
   D) a-ii, b-iv, c-iii, d-i

Q. 2 Answer the following questions :

1) What is an ore mineral? Give an example.
2) Name the 2 manganese ore minerals giving their chemical composition.
3) Write the chemical composition of mineral malachite.
4) What is a radioactive mineral? Give an example.

Q. 3 Answer the following questions :

1) What is the role of mineral gypsum in the cement industry? Add a note on its geographical distribution in India.
2) Give the physical properties of corundum.
3) Give the uses of feldspars and its distribution in India.
4) List the physical properties of mineral zircon?

Q.4 Answer the following questions :

1) Name the ore minerals of lead, zinc and aluminium, listing their physical properties, occurrence and use.
2) Describe in detail radioactive mineral monazite
3) Describe the unconventional source of petroleum?
4) Describe sulphur/cinnabar as minerals used in medicine

Q. 5 Answer the following questions :

1) Explain Iron/ manganese ore minerals in detail.
2) Describe copper ore minerals in detail.
3) Give a brief account of the fuel industry.
4) Describe in detail, the raw materials used in the cement industry.
5) List and describe the physical properties of any two abrasive minerals and give their distribution in India.