**3 lessons. Ores, ore minerals**

An ore may be defined as a naturally occurring aggregate or a combination of minerals from which one or more metals or minerals may be economically extracted.

Many factors determine whether a rock is an ore, including supply and demand, and the location of the material.

Simple ores are ores that yield a single metal.

Complex ores are ores that yield more than one metal.

By-products are the minor metals that are recovered from an ore. Co-products are the major metals obtained from an ore (if > 1)

The economy of extraction generally depends on fundamental factors such as

1. the percentage of valuable metal in the ore,
2. the form in which the metal occurs, i.e., the nature of the mineral in the ore,
3. the percentage of impurities in the ore (i.e., which are difficult to remove and which impart undesirable properties to the metal),
4. the physical condition of the ore,
5. the location and magnitude of the ore deposits,
6. the proximity to transport facilities, and
7. the market value of the metal.

In ancient times, some minerals must have been spotted on the earth’s surface itself because of their striking physical characteristics such as vivid colours and crystalline shapes, whereas those hidden under the soil would have remained unnoticed. Therefore, scientific methods are necessary for an accurate location and a quantitative estimation of mineral deposits. The principal methods employed in mineral exploration are generally based on the magnetic, electrical, and electro­magnetic properties of the ore bodies. Other geophysical methods, namely, gravitational, seismic, and radioactive methods are normally used for oil exploration.

A mineral is a naturally occurring inorganic compound of one or more metals in association with nonmetals such as oxygen, sulphur, and the halogens. A mineral has a fixed composition and well-defined physical and chemical properties.

**Ore Minerals**

***The ore minerals*** are those that contain the desired metals. A list of the common ore minerals is given below.

***The gangue minerals*** are the worthless minerals that have to be mined and then separated from the ore minerals. They are usually the common rock-forming minerals.

*You will encounter many of these minerals in the practicals and should be able to recognise the most common ones.*

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| --- | --- |
| **FERROUS METALS**  |   |
| iron   | magnetite, Fe3O4; hematite, Fe203; goethite, FeO(OH); siderite. FeCO3; chamosite, Fe2AI2SiO5(OH)4  |
| manganese | pyrolusite, MnO2  |
| nickel    | pentlandite (Ni,Fe)9S8  |
| chromium  | chromite, FeCr2O4.  |
| molybdenum | molybdenite, MoS2 |
| tungsten | wolframite, FeWO4; scheelite, CaWO4 |
| vanadium   | roscoelite, V-mica; montroseite, VO(OH); substitution for Fe in magnetite |

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| **FISSIONABLE METALS**  |   |
| uranium  | uraninite (pitchblende), U3O8 |
| thorium | thorite,ThSiO4 |

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| --- | --- |
| **NON-FERROUS METALS** |   |
| copper | chalcopyrite, CuFeS2; bornite, Cu5FeS4; covellite, CuS; chalcocite, Cu2S; malachite, CuCO3.Cu(OH)2; azurite, 2CuCO3.Cu(OH)2; cuprite, Cu2O; chrysocolla, CuSiO3.2H2O  |
| zinc | sphalerite, ZnS  |
| lead | galena, PbS |
| tin | cassiterite, SnO2;stannite, Cu2FeSnS4 |
| aluminium | gibbsile, Al(OH)3; boehmite, AIO(OH) |

|  |  |
| --- | --- |
| **MINOR METALS**  |   |
| antimony | stibnite, Sb2S3 |
| arsenic | arsenopyrite, FeAsS; realgar, AsS  |
| beryllium | beryl, Be3AI2(SiO3)6 |
| bismuth    | bismuthinite, Bi2S3 |
| cadmium  | substitution for Zn in sphalerite |
| cerium   | monazite, CePO4 |
| mercury | cinnabar, HgS  |
| niobium | columbite, FeNb2O6  |
| tantalum | tantalite, FeTa2O6  |
| titanium   | ilmenire, FeTiO3; rutile, TiO2 |
| zirconium  | zircon, ZrSiO4 |

|  |  |
| --- | --- |
| **PRECIOUS METALS** |   |
| gold      | native metal |
| silver | argentite, Ag2:S; and as trace component in galena and native gold  |
| platinum | native metal |

**Primary and Secondary Ores**

***Primary ore minerals*** are those associated with the original episode of ore deposition.

***Secondary ore minerals*** are those deposited during subsequent weathering at or near the surface.

The effect of weathering is to leach many metals from the ore to leave a leached capping or gossan. These metals may then enrich the underlying ore in a process known as secondary enrichment.

### The Grade of an Ore

***The grade of an ore*** is the fraction by mass of the valuable material it contains. If:

The mass of the ore = M
The mass of valuable material contained = m
Then the grade (in %) = m/M \* 100

Sometimes, the ore is described in terms of its ore mineral content. It can then be converted to metals grade using the appropriate relative atomic masses.

For example, a rock containing 1% of chalcopyrite (CuFeS2) would have a grade of:

1 x 63.5
(63.5+ 56 +2x32)

= 0.34% Cu

where the atomic masses of Cu, Fe and S are 63.5, 56 and 32 respectively.

The grade above which a given deposit is not economic to mine is known as the **cut-off** grade. Ores well above this value are termed **high-grade**; those close to this value are termed **low-grade**.

The multiplication factor needed to reach the cut-off grade from the average crustal abundance is known as the **concentration factor**. As shown below, this can vary greatly from metal to metal. In general, the greater the concentration factor, the more expensive the metal.

|  |  |  |  |
| --- | --- | --- | --- |
|    | Ave. crust | Ave. cut-off (%) | (%)Conc. factor |
| Aluminium (AI)  | 8 | 30 | 3.75 |
| Iron (Fe)  | 5 | 25 | 5 |
| Copper (Cu) | 0.005 | 0.5 | 100 |
| Tin (Sn)  | 0.0002 | 0.2 | 1000 |
| Gold (Au)  | 0.0000004 | 0.0008 | 500 |
| Mercury (Hg)  | 0.000008 | 0.2 | 25000 |

3.3 Size-Grade Characteristics

Grade-tonnage plots usefully depict the metal available in a given deposit for different cut-off grades. There are two extreme deposit types: dispersed and confined. The grade-tonnage plots demonstrate how a small reduction in cut-off grade for the dispersed deposit can generate a significant increase in metals. Secondary enrichment also converts rock to ore.

|  |  |  |  |
| --- | --- | --- | --- |
| Cut-off grade (per cent) | Reserves of ore/M tonnes ores | Average grade of reserves (per cent) | Reserves of metal/M tonnes metal |
| 4.0 | 0.04 | 5.0 | 0.002 |
| 3.0 | 0.3 | 3.3 | 0.010 |
| 2.0 |   |   |   |
| 1.0 | 1.0 | 2.2 | 0.022 |
| 0.5 | 1.1 | 2.1 | 0.023 |

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1. a naturally-occurring aggregate of minerals - естественно встречающийся агрегат минералов
2. extract – извлекать,
3. profit – прибыль
4. expectation – ожидание
5. a rock – камень, скала
6. ore – руда
7. supply - применение
8. demand – спрос, потребность
9. Simple ore – простая руда
10. Complex ore – комплексная руда
11. Yield – выход, выработка, производить
12. By-products – побочные продукты
13. Co-products – основные металлы, извлекаемые из руд
14. the desired metals – желаемые, искомые металлы
15. The gangue minerals – пустая порода,
16. the worthless minerals - бесполезные минералы
17. mine – 1) мой, 2) шахта, 3) добывать
18. separate - разделять
19. the common rock-forming minerals - обычные породообразующими минералы
20. encounter – столкнуться
21. The effect of weathering - Эффект выветривания
22. Leach – выщелачивание
23. underlying ore – нижележащая основная руда
24. capping or gossan - вскрыша, поверхностный окисленный слой руды
25. enrich – обогощать
26. secondary enrichment – вторичное обогащение