Ore Deposits and Mining (GL1301)

40% of a smartphone is made from 23 different metals (as in the periodic table) that need to be mined from the Earth's crust. Electric cables and appliances contain copper that comes from an ore deposit.

Civilization moved through the use of various materials that are employed to label key stages of human evolution such as the 'Bronze Age' and 'Iron Age'. The metals used by primitive and historic civilisations were extracted from rocks available at the surface or by digging few tens of meters deep. This represents the origin of mining and it dates back to 41,000-43,000 years ago (Ngwenya Mine, Swaziland – figure 1).

Figure 1: Ngwenya Mine, in Swaziland. Characteristic stepped structure (open pit) used by bushmen to extract hematite, an iron ore. Source: afro tourism.

The vast majority of the rocks that outcrop at the Earth's surface or lay tens to hundreds of metres below it contains metallic minerals, from which pure metals can be extracted. However, these operations are very costly and only if a set of conditions such as feasible access, favourable local and national legislation, large enough size and concentration of the metal are in place mining operation can start.

Figure 2: Vein with chalcopyrite (brass colour) a copper mineral, surrounded by quartz (white) hosted by a grey limestone rock. FOV 4 cm. Photo G. Solferino.

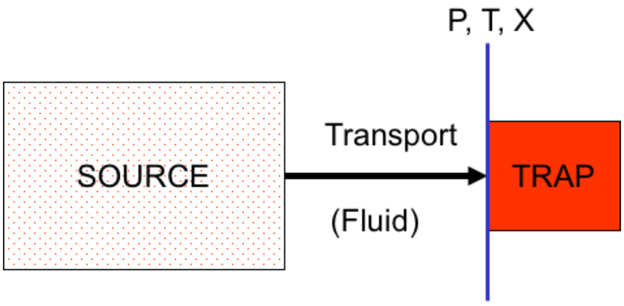
Figure 3: Wolframite (dark grey-black) a tungsten mineral in a quartz vein (white mineral). FOV 10 cm. Photo G. Solferino.

It is impossible to provide a thorough list of all types of ore deposits, especially since new horizons are opening up such as ‘deep sea mining’ and the use of bacteria and/or fungi to remove metals from rocks, but it is worth summarizing some of the main categories of ores currently used for producing the most important metals:

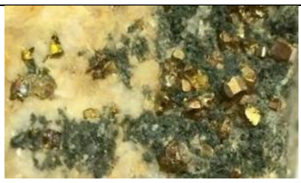
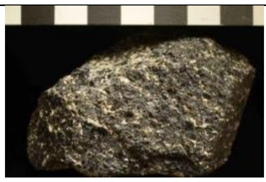
Ore type	**Metals extracted**	**Geologic setting**	**Example**
Layered Mafic Intrusions	Cr, PGE*	Magmatic - intrusive	Bushveld (S. Africa)
Nickel Massive Sulfide	Ni, Cu (PGE*)	Magmatic - extrusive	Kambalda (Australia)
Porphyries	Cu, Mo, Au (Ag, Re)	Magmatic-hydrothermal	El Teniente (Chile)
Greisens	Sn, W (Zn, Pb, Cu)	Magmatic-hydrothermal	Cligga Head (UK)
Volcanic Massive Sulphides	Cu, Zn, Pb	Hydrothermal	Avoca (Ireland)
Mississippi Valley Type	Zn, Pb (Ba, F)	Hydrothermal	Lisheen (Ireland)
Banded Iron Formations	Fe	Sedimentary	Superior Lake (Canada)
Placers	Gemstones, Au	Sedimentary	Skeleton coast (Namibia)

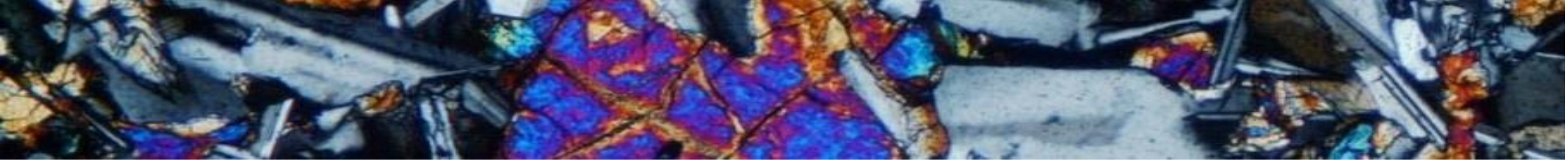
*PGE = Platinum Group Elements (Pt, Pd, Rh, Ru, Ir, Os)

The process that forms an ore deposit is summarized in the figure below:



The **source** of metals can vary but it all starts with some rocks at depth (few metres to few kilometres) from which a **transport** medium (e.g. a magma or hot fluids, the latter typically made out of water for > 90%) scavenge those metals away. The transport medium moves through the Earth’s crust toward the surface and it stops when conditions such as pressure (P), temperature (T), and chemical composition of the surroundings (X) force the metals dissolved into it to precipitate and crystallize in the form of minerals (**trap**). The main types of minerals from which metals are extracted are:

	SULPHIDES	OXIDES	CARBONATES	NATIVE METALS
Example	 *Chalcopyrite ($CuFeS_2$)*	 *Chromite ($FeCr_2O_4$)*	 *Cerussite ($PbCO_3$)*	 *Native copper (Cu)*
	Contain sulfur and no oxygen.	Contain oxygen and no sulphur neither carbon.	Contain carbon and oxygen in the form of carbonate ion $(CO_3)^{2-}$	Pure metallic elements and/or alloys (e.g. AuAg)

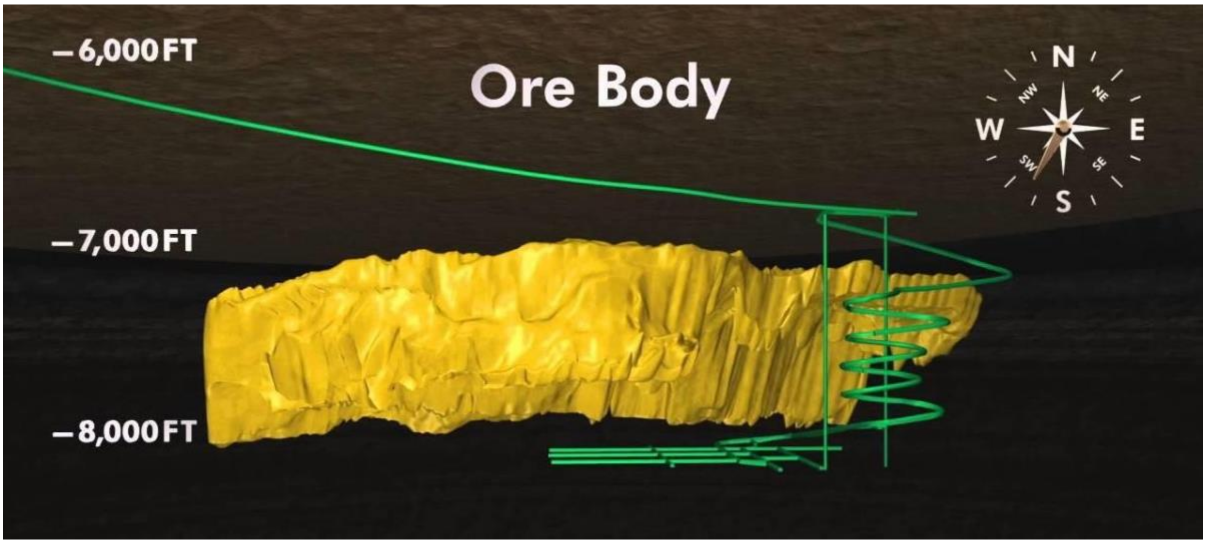


Every mining geologist will have to decide if mining operation to extract the metal contained in an orebody is economically viable sooner or later in their career.

A great exercise to start practicing this and to develop a feeling for the size of an orebody which couldbe mined is calculation of the monetary value of a ‘reserve’. Reserve is the selling price of the actual metal content that can be extracted from an orebody and transformed into ingots or bars (smelting).

For this exercise you are given the following information:

1. The size (volume) of the orebody (see cross-section below): The shape of the ore body is irregular, thankfully using a 3D analysis software somebody computed the approximate volume of the orebody and shifted units into metric system: **229 Mm^3**.



2. The ore mineral that is present in the ore body: Sphalerite (**ZnS**)
3. The average concertation of mineral in the orebody: **1.6 kg/m^3**
4. The total cost of operations (extraction, smelting, post-mining remediation): **298 M$**

Can you calculate the value of zinc inside this orebody and check if it is less or more than thecost of operation, which is equal to 298 M$?

Remember the content of Zn into sphalerite is not equal to its entire weight! You must calculatethe fraction of Zn in sphalerite using the atomic weights of Zn=65.38 and S=32.07.

The market price of Zn, expressed in $ per tonne (1 tonne = 1,000 kg) is available on LME: https://www.lme.com/

Want to know more? We recommend ‘Chapter 23; Earth: An Introduction to Physical Geology, Global Edition, Tarbuck et al.’