The new world-class Tizert deposit (Anti-Atlas, Morocco): future supply for copper in Europe?

Poot, Julien; Verhaert, Michele; Dekoninck, Augustin; Oummouch, Abdellah; El Basbas, Abdelaziz; Maacha, Lhou; Yans, Johan

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J. Poot, M. Verhaert, A. Dekoninck, A. Oummouch, A. El Basbas, L. Maacha, J. Yans

MANAGEM

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1. Why study Cu-deposits nowdays?

Copper (Cu) is one of the first metals ever extracted by humans. These uses have been varied over time (coins, ornaments, bronze, Statue of Liberty, ...) and have highly contributed to the sustain and improvement of the society. The **supply** and **demand** of copper have drastically **increased** (Fig.1, [1]) in the past decades. Since early 2000's, **South America**, and more specifically the Andean region, is the most productive copper region of the world (Fig. 2, [2]).

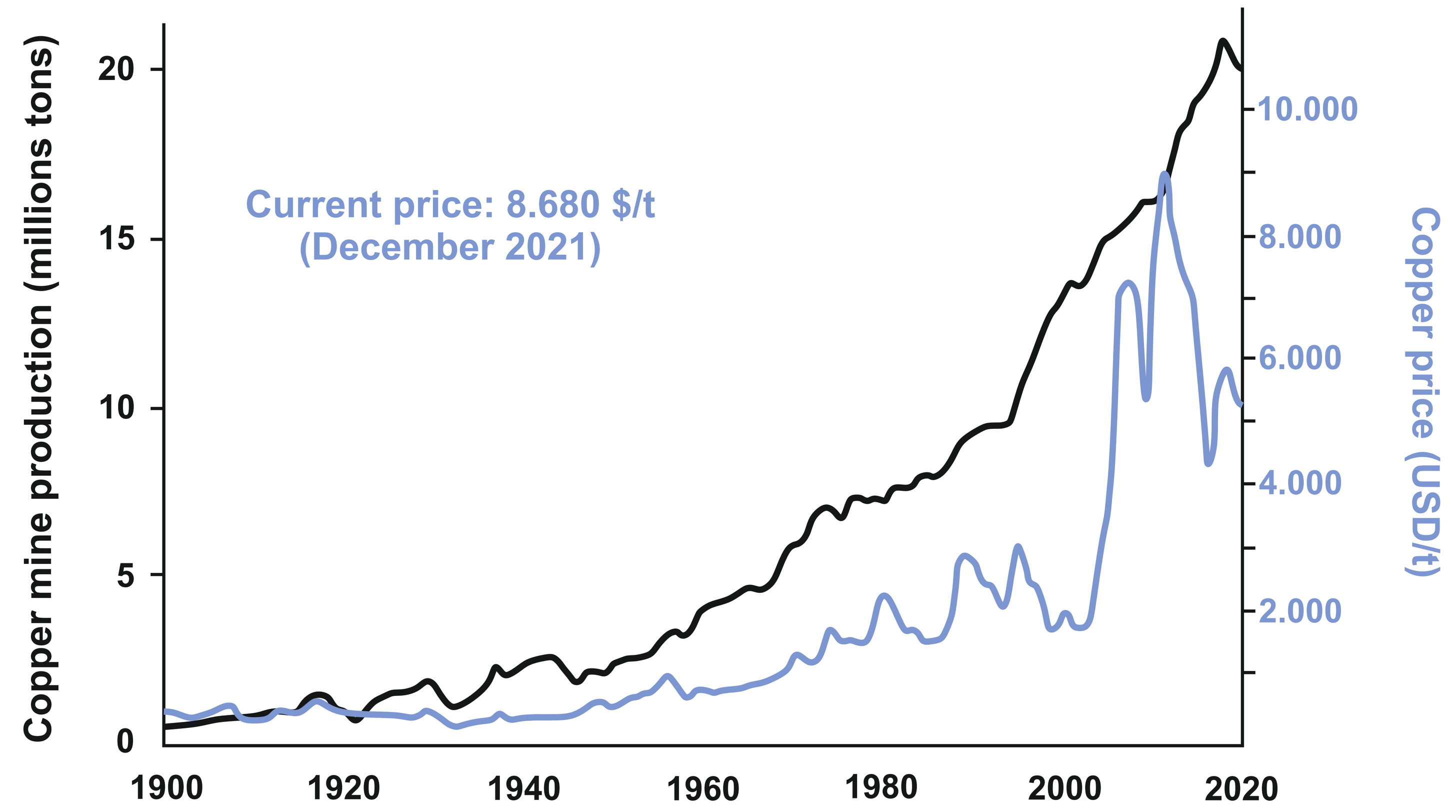

Figure 1 - Evolution of copper mine production (Mt) and price (USD/t) since 1900 [1]

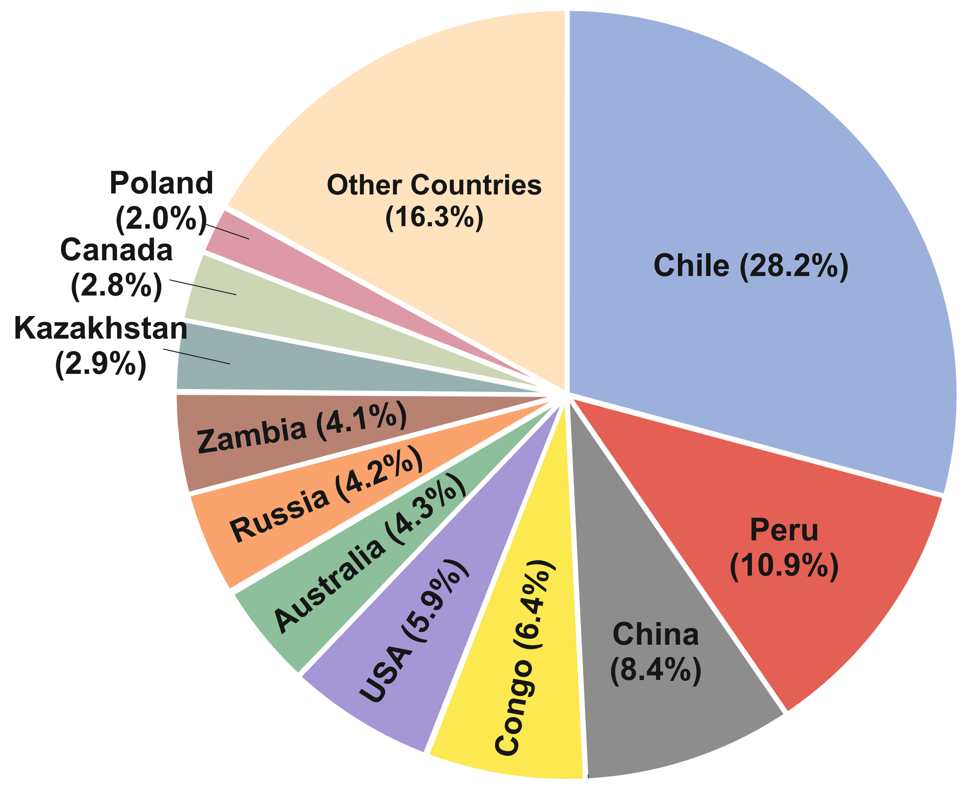

Figure 2 - Mondial copper mine production 2020 [1].

Morocco's copper annual production is relatively low (0.03Mt *vs* 5.7Mt Chile in 2019) but has been growing for the last ten years (data from World Bureau of Metal Statistics). This production could be boosted in the future with the exploitation of **Tizert** area which is considered as the **largest Cu-deposit** of western Anti-Atlas with resources estimated by Managem Group at ~ 57Mt with 1.03% Cu and 23g/t Ag [3]. Morocco is also known for silver production which was about 1.1% of mondial production in 2020 (Data from The Silver Institute).

2. Supergene ores - weathering

Supergene ore deposits form near the surface of the Earth and are associated to **oxidizing** conditions and meteoric fluids (mostly rainwater, downward migration). It results in modifications of **hypogene** ores (= primary sulfides sulfides), which are only stable under **reducing** conditions at shallow depth. This phenomenon is called **weathering** and can also be observed in everyday life (Fig. 4).

The **extraction** of supergene ores is **easier** and **faster** than for hypogene ores thanks to their **near-surface situation** and their metal grade higher than in the primary ore (Fig. 5, [4]). Moreover, the environmental impact is generally lower. The supergene/secondary enrichment is often related to episodes of **uplift** which triggered the exhumation of hypogene/primary mineralization, hence their **oxidation** and release of **acidic fluids** (H_2SO_4) and **cations** (Cu, Zn, ...). Afterwards, the precipitation of secondary minerals is possible by partial or total **neutralization** of these acidic fluids.

Figure 4 - Cu sulfates and carbonates (weathering) give the characteristic green color to the Statue of Liberty.

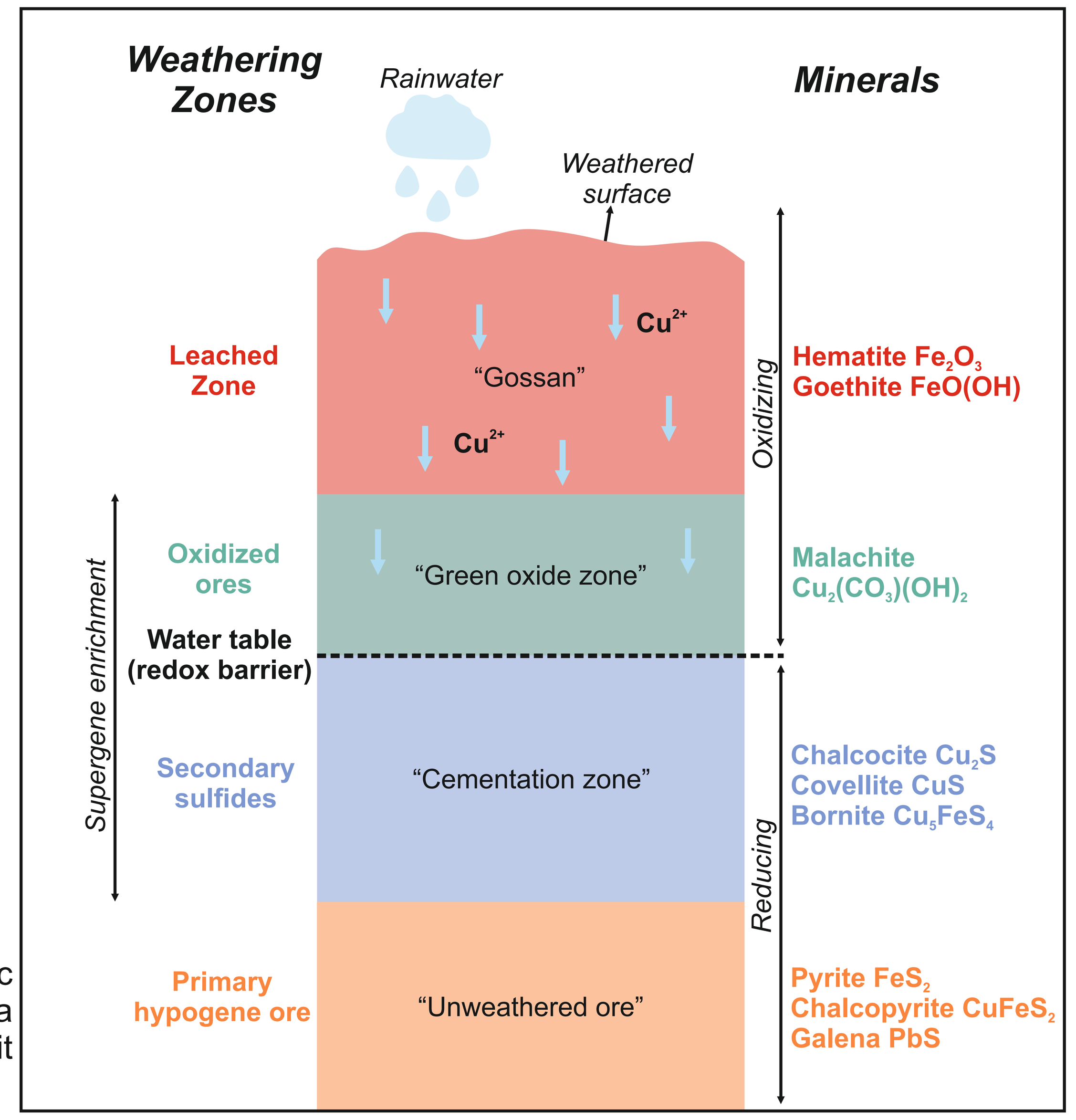

Figure 5 - Schematic weathering profile of a typical copper deposit (Redraw from [5])

3. Tizert deposit

The deposit was discovered in 1969. The site was first studied between 1970 and 1975 by the **BRPM** (Bureau Des Recherches Pétrolières et Minières) using mining galleries (Fig. 6A). Since 2011, exploration has been carried out by **Managem Group**. In their first characterization of the deposit, the focus was on the **primary mineralization**, the grades and tonnage of the deposit [3]. Our study was to characterize the **supergene mineralization**, **weathering processes** associated and the possible enrichments. These observations were made from different drilling samples (Fig. 6B).

Tizert is characterized by **Cu mineralizatio**n carried by **malachite** (Fig. 6C), chalcocite, covellite, bornite and chalcopyrite. This Cu-mineralization is observed in the **Tamjout Dolomite** (Fig. 6D) and in the sandstones and siltstones (Fig. 6E) of the **Basal Series**; rocks dated at about 540 Ma. The deposit is characterized by an abundance of malachite (carbonate, "green oxide zone", Fig. 5) due to the **rapid neutralization** of acidic meteoric water by carbonate host rock (Tamjout Dolomite) and chlorite present in sandstones and siltstones. **Secondary sulfides** (cementation zone, Fig. 5) such as **covellite**, **bornite II**, or **chalcocite II** are less observed as they required **lower pH** and more **reducing conditions**. Iron oxides ("*gossan*", Figs 5 and 6F) are almost not observed because the leached zone has been partially eroded.

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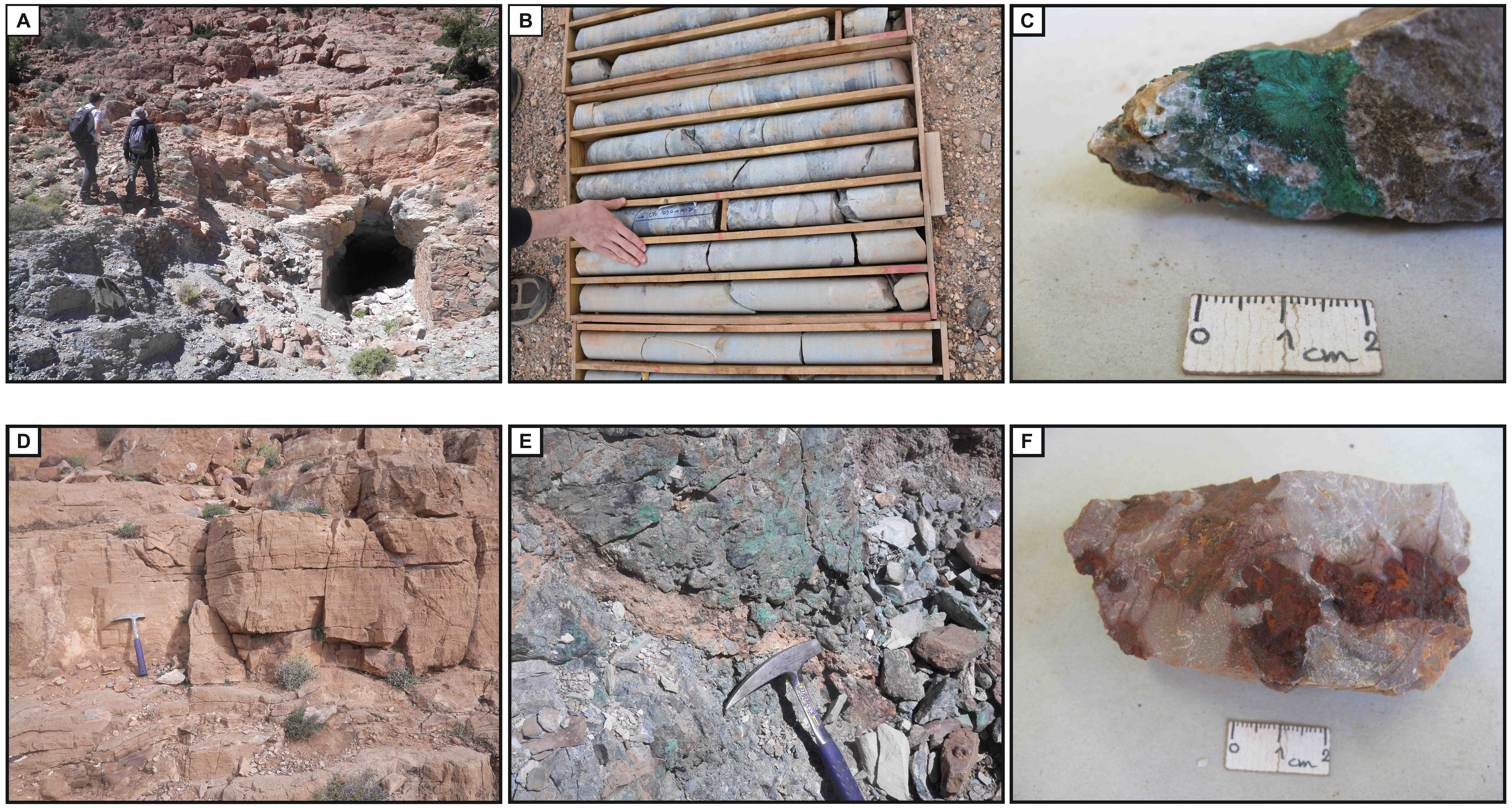

Figure 6 - **(A)** Mining gallery from BRPM exploration in 1970, **(B)** Example of drilling cores observed for this study, **(C)** Malachite (Cu-carbonate) mineralization in Tamjout Dolomite, **(D)** Typical outcrop of Tamjout Dolomite (host rock), **(E)** Outcrop of mineralized sandstones and siltstones from the Basal Series, **(F)** Iron oxides (gossan) in quartz vein of Tamjout Dolomite.

4. Conclusions

Since 2000s, the increasing request in **metals** for **new technologies** restarted the interest in supergene deposits. This type of deposits are easier to mine due to their near-surface situation, lower environmental impact and metals enrichment compare to hypogene ores.

The Tizert Cu deposit consists of a **homogeneous** and simple **mineralization** (e.g. **malachite** in the "green oxide zone") but also **huge reserves (57 Mt)**. This accounts for **potentiel mining**, **compete** with other world-class Cu deposits and maybe supply of Cu to Europe.

For more informations