Mineralogy of the supergene Cu-Pb-Zn Bou Skour deposit (Anti-Atlas, Morocco)

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1. Introduction - Context

The Cu-Pb-Zn Bou Skour deposit is located in the eastern part of the Anti-Atlas belt, approximately 50 km to the east of Ouarzazate city, in the Sidi Flah-Bou Skour inlier. The deposit is divided into five zones, progressing from north to south (Fig. 1): “Panthère”, “Chaigne”, “Anne Marie”, “Chapeau de fer” and “Patte d’Oie”. This last one constitutes the most economically attractive sector of the deposit with mainly Cu sulfides mineralization in Cryogenian to Ediacaran magmatic host rocks: andesite, granite and doleritic dykes (El Azmi et al., 2014) (Fig. 2A).

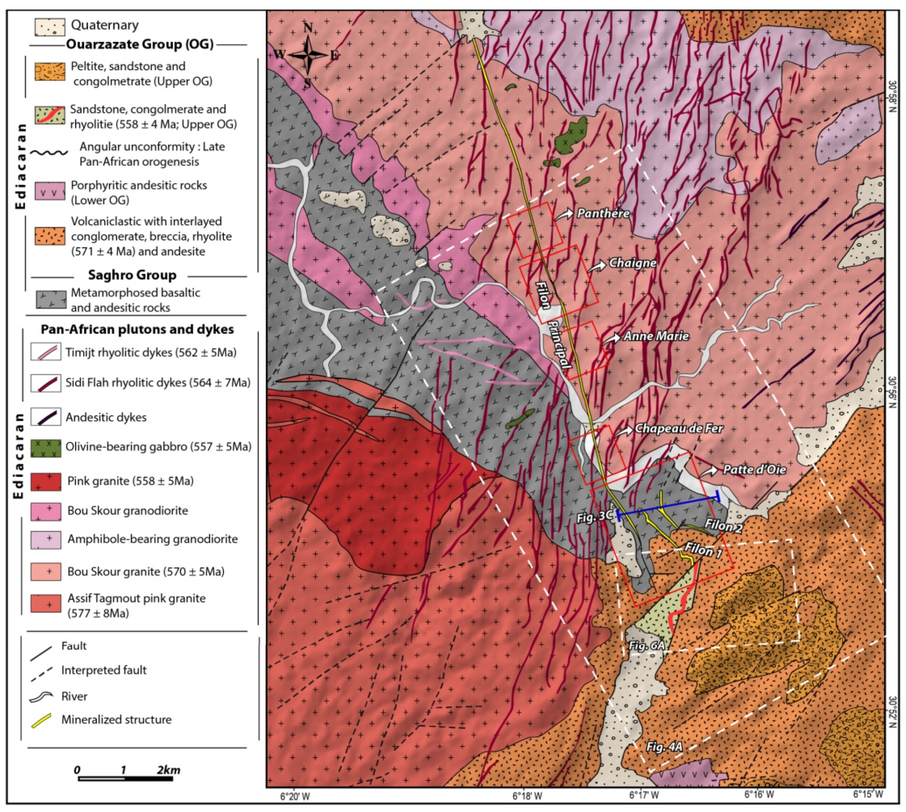

Fig.1 *- Geological map of Bou Skour area (Wash et al. 2008; Aabi et al. 2021).*

2. Mineralogy

Primary assemblage mainly consists of chalcopyrite, pyrite, galena, sphalerite, arsenopyrite and tennatite/tetrahedrite (Figs 2B,C,D). These sulfides undergo rapid oxidation through weathering process and then form a diversified secondary mineralization depending on Eh/pH, enriched metals in the fluid and the involved neutralization (silcates or carbonates).

Among these secondary minerals, secondary sulfides such as bornite (sometimes primary), covellite, chalcocite, djurleite and digenite have been identified (Fig. 2D). Cu-carbonates like malachite and azurite are often observed as thin crusts (Fig. 2E) or in veins. Some smithsonite is also observed (Fig. 2F) associated to iron oxides and sometimes rosasite. About sulfates, brochantite is the most common phases. Jarosite and osarizawaite are rarely observed (Fig. 2G).

Cu-silicates are observed but generally less than carbonates. These are mainly represented by chrysocolla as thin crusts (Fig. 2E) and plancheite usually as matrix associated to Fe-oxides (Fig. 2H) or even chlorite.

Arsenates (Fig. 2I) are also common minerals at Bou Skour deposit. Among these, there are olivenite mostly in veins (Fig. 2J) and phillisbornite (Figs 2J,K) generally disseminated in the matrix. Some other arsenates are also rarely observed like gebardite, bayldonite, beudantite, duftite or segnitite (Figs 2L,M). Iron oxides are often observed (Figs 2F to H, M, N) and can contain up to 3 wt.% of Cu, As, Pb, Zn, Mn, Co or Bi. Mn oxides (Fig. 2O) are also observed in chicken-wire structure.

Other mineral phases may be encountered very rarely. Some sulfides like acanthite-argentite (Fig. 2 K) or enargite (Fig. 2P). Phosphates include xenotime-Y (Fig. 2Q) and apatite. Carbonates include siderite and dolomite. The latter mineral phase is rarely observed in studied samples, but easily observed in veins in the field (Fig. 2R).

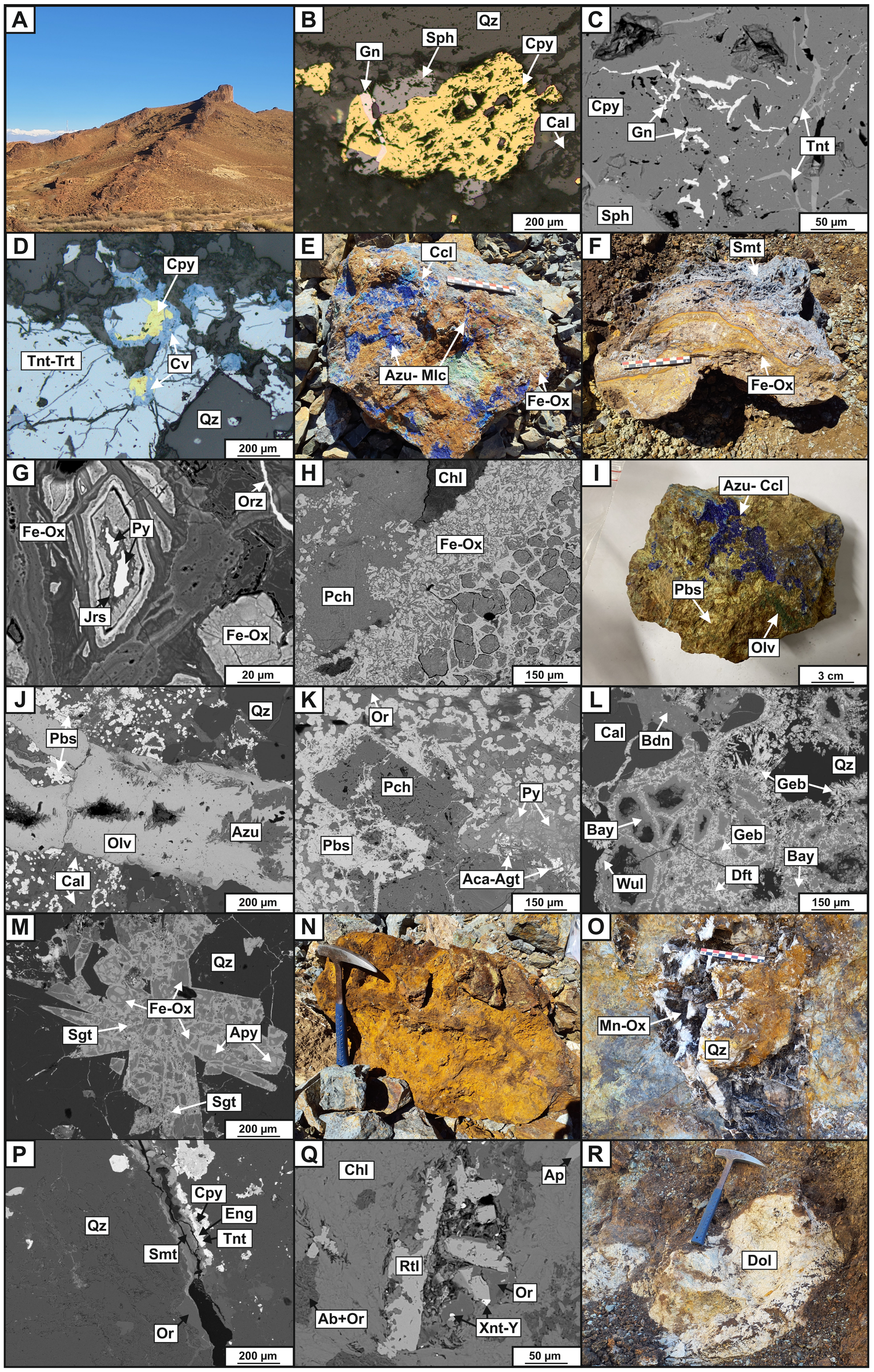

Fig.2 *- Mineralogy of Bou Skour deposit: Field pictures (A,E,F,N,O,R), Reflected light microphotographs (B,D), SEM microphotographs (C,G,H,J to M,P,Q), Sample picture (I).*

*(**A**) Doleritic dykes in Bou Skour area. (**B**) Primary sulfides cluster (galena, sphalerite and chalcopyrite) in granite borehole sample. (**C**)Tennantite and galena veinlets in chalcopyrite and sphalerite matrix. (**D**) Secondary sulfide (covellite) in replacement of chalcopyrite and tennantite-tetrahedrite. (**E**) Malachite, azurite, iron oxides and chrysocolla as thin crusts on weathered andesite. (**F**) Botryoidal smithsonite crust on weathered granite cut by iron oxides veins. (**G**) Oxidized pyrite replaced by jarosite with iron-oxides and osarizawaite veinlets. (**H**) Wide range of plancheite with fractured area of plancheite with Fe-oxides occurences. (**I**) Weathered andesite with arsenates crusts and fill (philipsbornite and olivenite), and some thin crusts of azurite and chrysocolla. (**J**) Olvenite and azurite veins in calcite and quartz matrix of weathered host rock with disseminated philipsbornite. (**K**) Plancheite and philipsbornite fill associated with some residual pyrite and acanthite-argentite. (**L**) Fractured matrix of quartz and calcite fill with wulfenite and arsenates (bayldonite, beudantite, gebhardite and duftite. (**M**) Segnitite and iron oxides cluster with residual arsenopyrite in quartz vein. (**N**) Typical iron oxides powdery crust (”Ouad”) on weathered andesite. (**O**) Chickenwire structure fill with manganese oxides. (**P**) Smithsonite surrounded by primary sulfides (chalcopyrite, tennantite and enargite) in weathered granite. (**Q**) Rutile/Anatase and xenotime-Y cluster in granite. (**R**) Dolomite veins and clusters in andesite.*

References

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Acanthite (Aca): Ag_2S
Argentite (Agt): Ag_2S
Arsenopyrite (Apy): FeAsS
Azurite (Azu): $Cu_3(CO_3)_2(OH)_2$
Bayldonite (Bay): $PbCu_3(AsO_4)_2(OH)_2$
Beudantite (Bdn): $PbFe_3(AsO_4)_2(SO_4)(OH)_6$
Calcite (Cal): $CaCO_3$
Chlorite (Chl): $(Fe,Mg,Al)_6(Si,Al)_4O_{10}(OH)_8$
Chalcopyrite (Cpy): $CuFeS_2$
Covellite (Cv): CuS
Djurleite (Dg): Cu_9S_5
Digenite (Dj): $Cu_{31}S_{16}$
Duftite (Dft): $PbCu(AsO_4)(OH)$
Dolomite (Dol): $CaMg(CO_3)_2$
Enargite (Eng): Cu_3AsS_4
Orthose (Or): $KAlSi_3O_8$
Gebhardite (Geb): $Pb_8(As_2^{3+}O_5)OCl_6$
Galena (Gn): PbS
Jarosite (Jrs): $KFe_3(SO_4)_2(OH)_6$
Malachite (Mlc): $Cu_2(CO_3)(OH)_2$
Olivenite (Olv): $Cu_2(AsO_4)(OH)$
Osarizawaite (Orz): $PbCuAl_2(SO_4)(OH)_6$
Philipsbornite (Pbs): $PbAl_3(AsO_4)_2(OH)_5.2H_2O$
Plancheite (Pch): $Cu_8Si_8O_{22}(OH)_4.H_2O$
Pyrite (Py): FeS_2
Quartz (Qz): SiO_2
Rutile (Rtl): TiO_2
Rosasite (Rss): $(Cu,Zn)_2(CO_3)(OH)_2$
Segnitite (Sgt): $PbFe_3(AsO_4)_2(OH)_6$
Sphalerite (Sph): ZnS
Tennantite (Tnt):$Cu_6As_4S_9$
Tetrahedrite (Ttr): $Cu_6Sb_4S_9$
Wulfenite (Wlf): $PbMoO_4$
Smithsonite (Smt): $ZnCO_3$
Xenotime-Y (Xnt-Y): YPO_4