First U-Pb LA-ICP-MS *in situ* dating of supergene copper mineralization: Case study in Chuquicamata mining district, Atacama Desert, Chile

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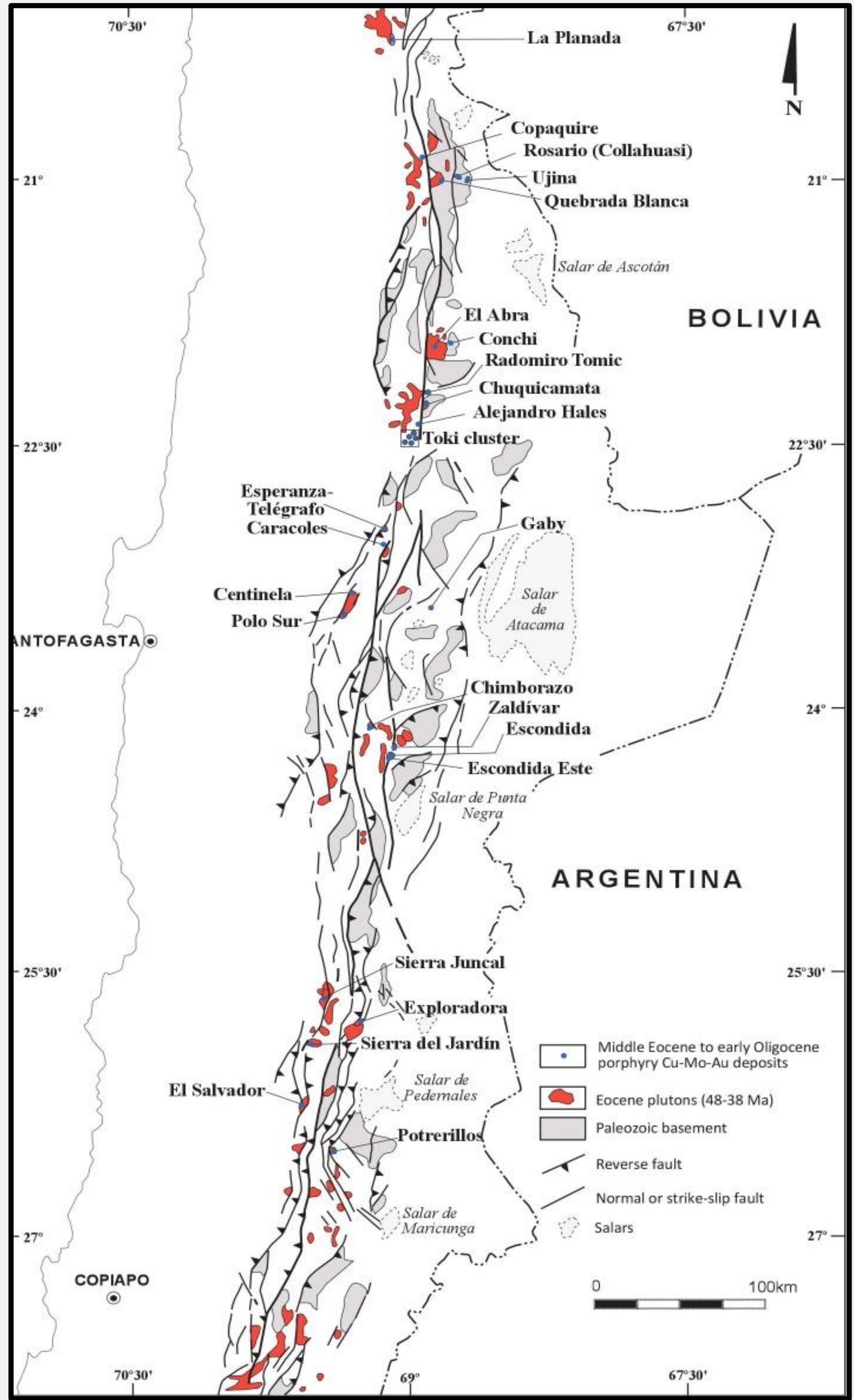
Sampling area



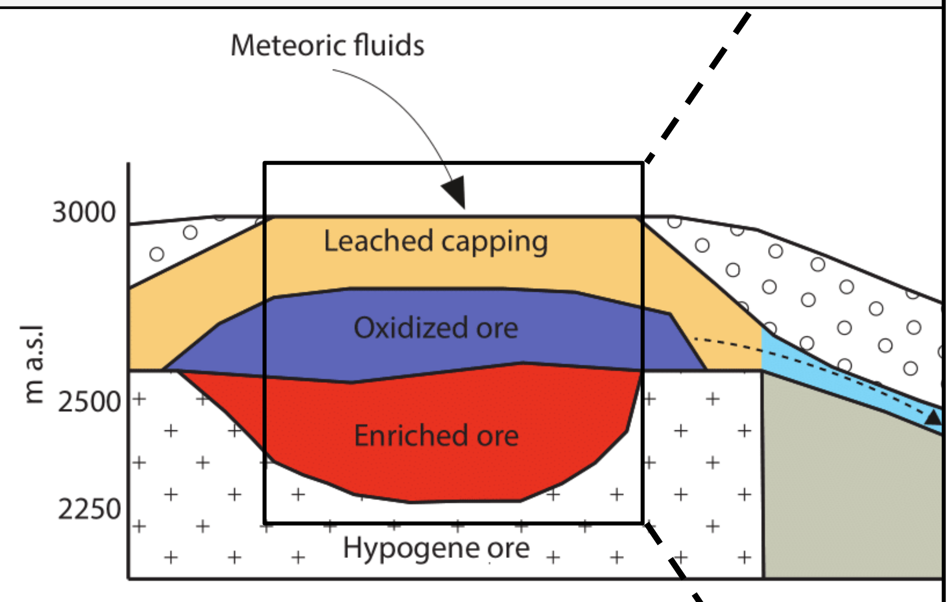
Atacama desert :

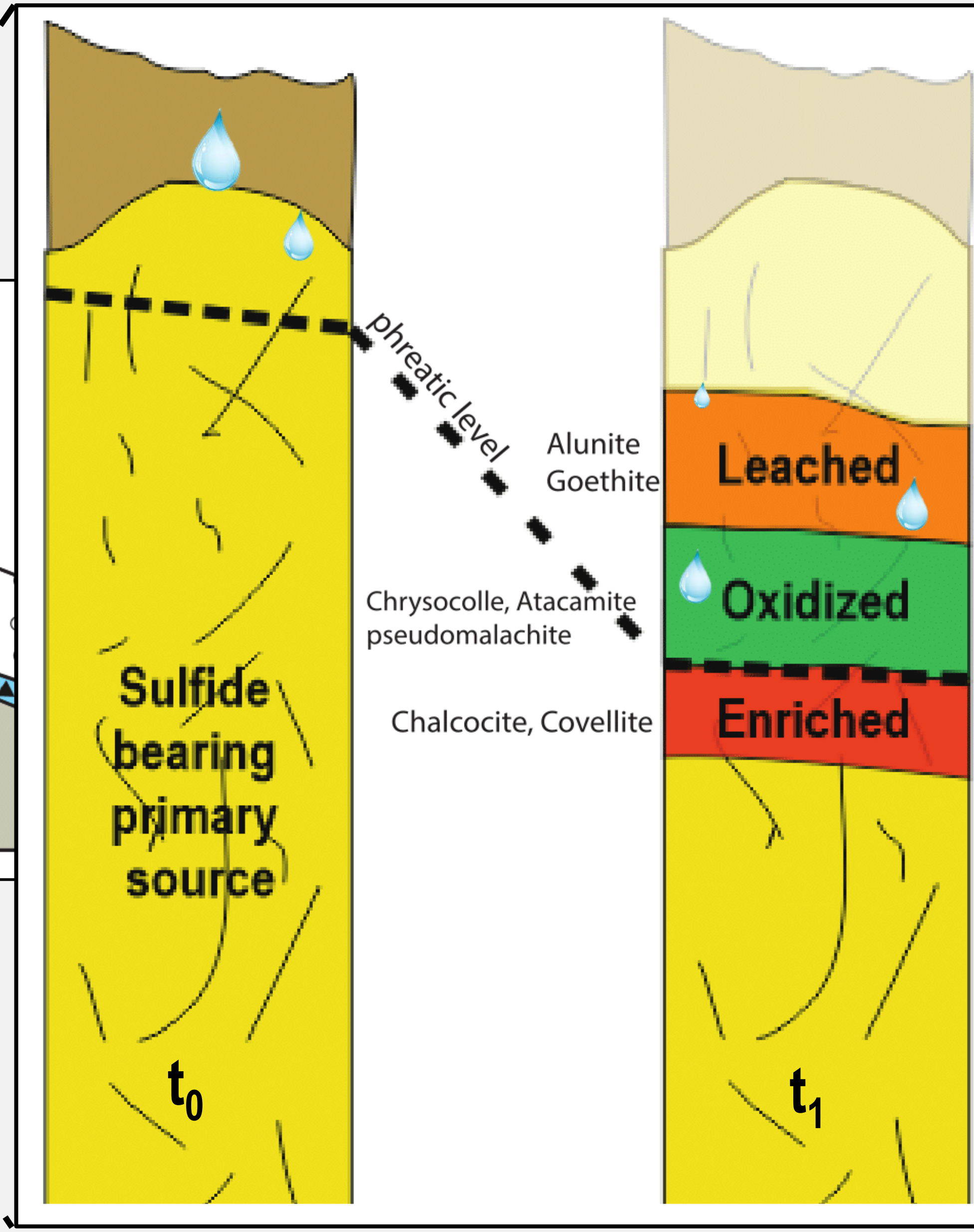
- ✓ **Arid since 45 Ma and hyperarid since ~ 10 Ma**
- ✓ **One third of the world's copper production**

Introduction

- ❑ How do supergene copper mineralization (SCM) form ?

Based on Münchmeyer (1996) and Sillitoe (2005)





✓ Main parameters:

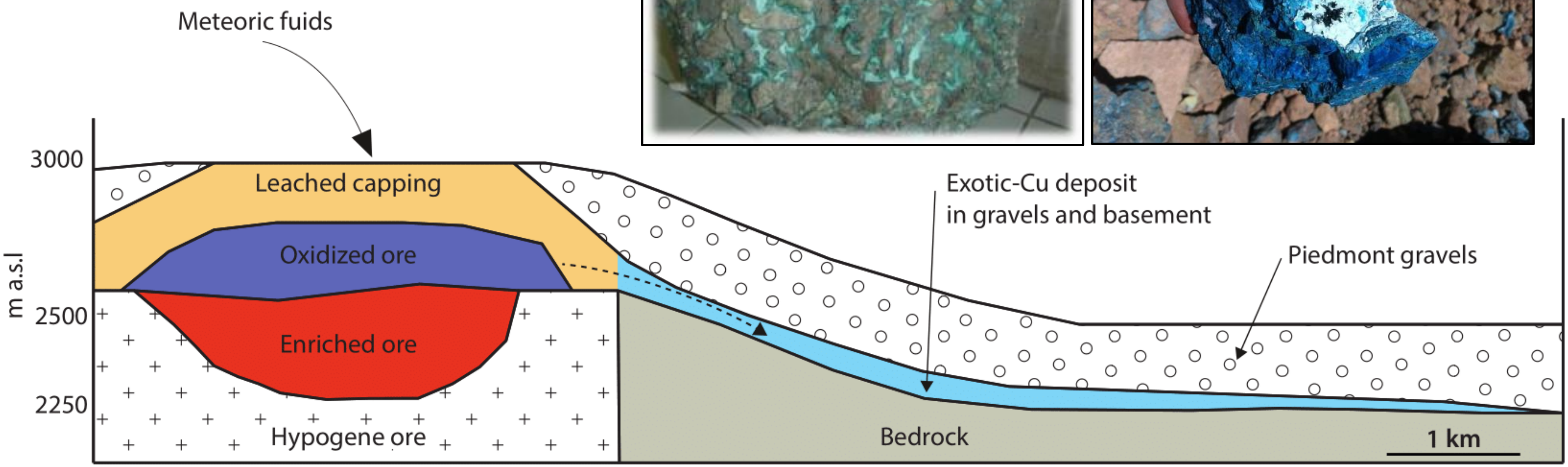
1. Uplift (tectonic effect)
2. Climate (water supply)
3. Erosion

All is a question of balance

Introduction

- Two type of supergene copper mineralization

Based on Münchmeyer (1996) and Sillitoe (2005)



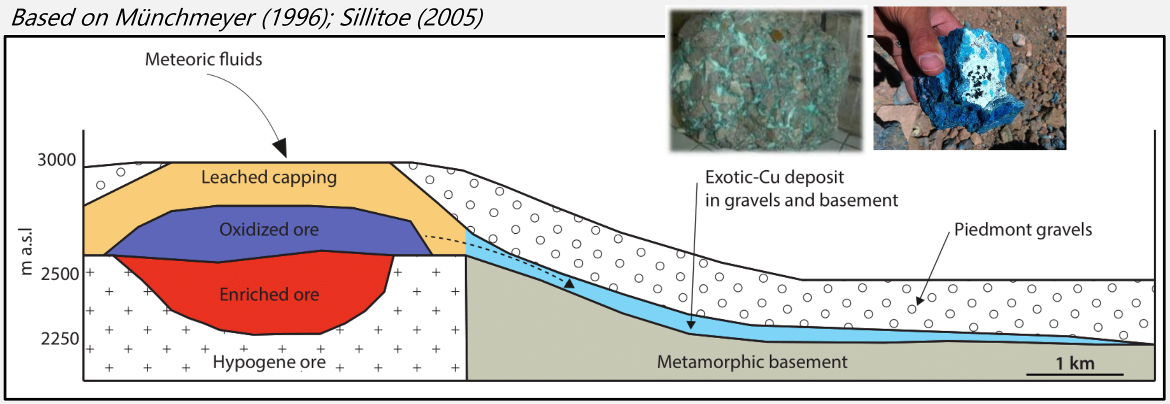
***In situ* supergene Cu mineralization**

Exotic supergene copper mineralization

Aim and Geological Background

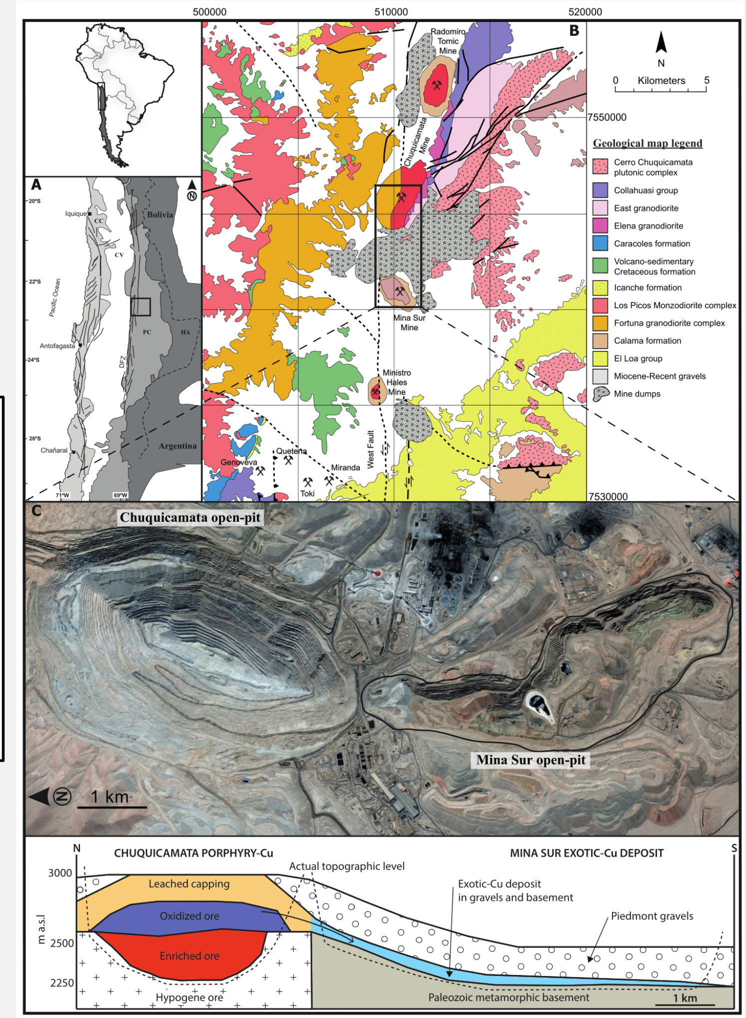
1) What is the age of supergene copper mineralization ?

Based on Münchmeyer (1996); Sillitoe (2005)



***In situ* SCM** **Exotic SCM**

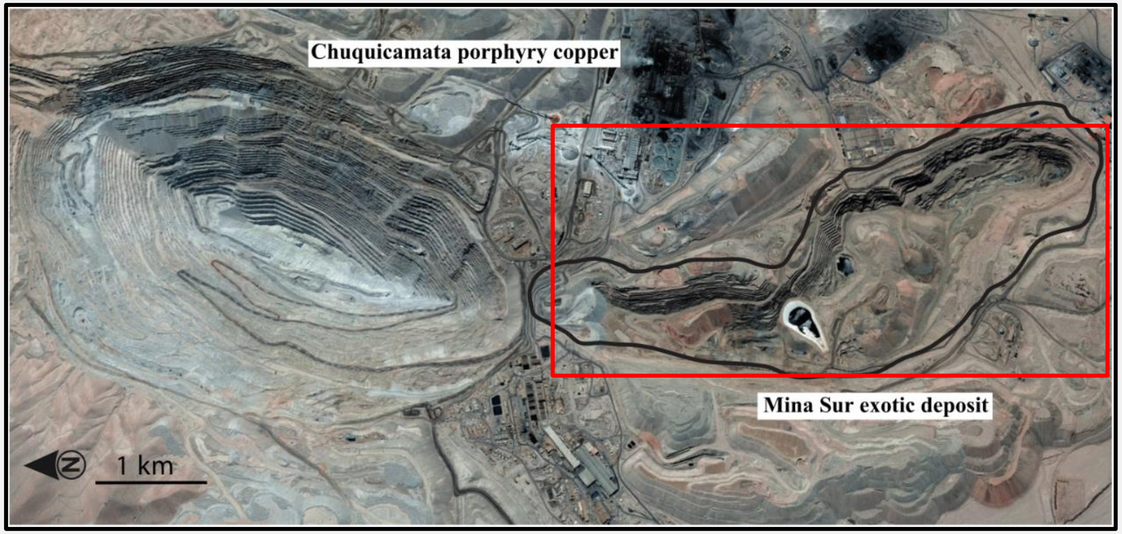
2) Do exotic SCM formation coeval with *in-situ* supergene alteration of porphyry copper ?

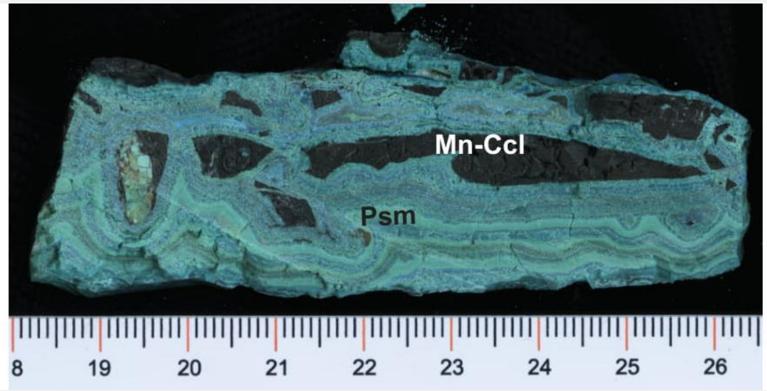


❖ Mina Sur exotic-Cu deposit

- ✓ Located in the Chuquicamata mining district
- ✓ Mina Sur = biggest supergene exotic copper deposit of the world, due to lateral migration of Chuquicamata's porphyry copper solutions
- ✓ Chuquicamata supergene alteration dated from 19.0 ± 0.7 Ma to 15.2 ± 0.5 Ma on supergene alunites (K/Ar; Sillitoe & McKee, 1996)

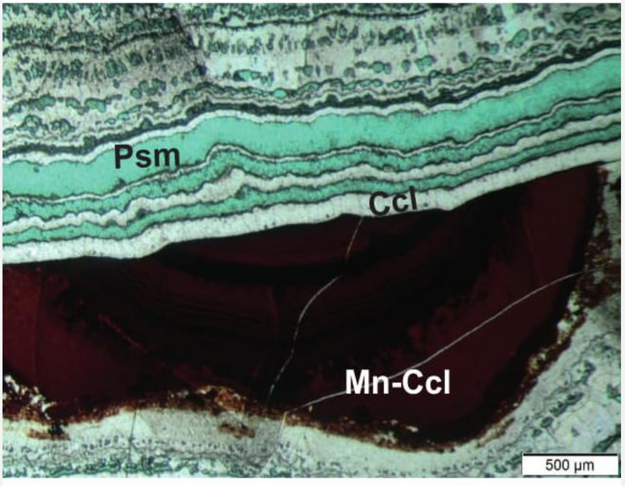
Petrographic results : Mina Sur exotic-Cu deposit

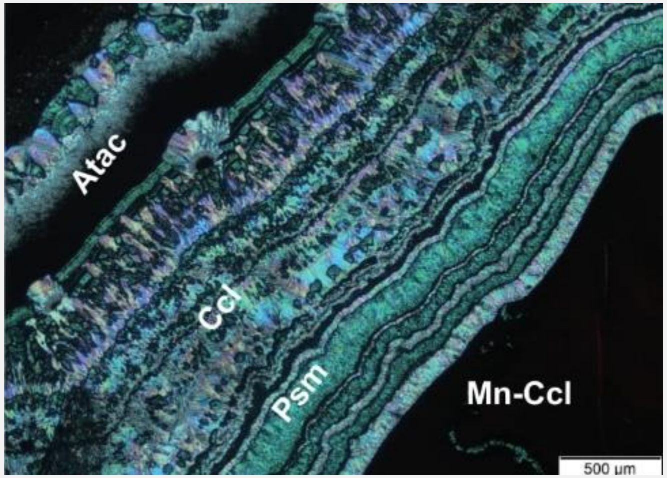


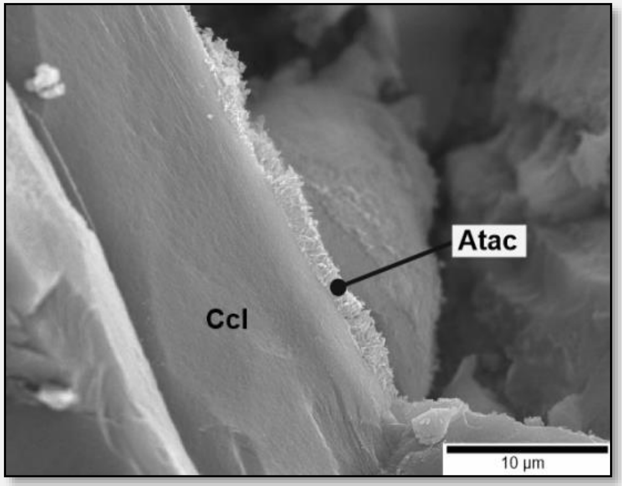


✓ Mn-Ccl : Mn-rich chrysocolla $[(Cu, Mn)_2H_2Si_2O_5(OH)_4 \cdot nH_2O]$ ✓ Atac : Atacamite $Cu_2Cl(OH)_3$

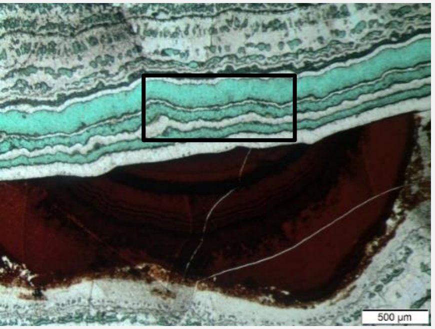
✓ Ccl : Chrysocolla $[(Cu, Al)_2H_2Si_2O_5(OH)_4 \cdot nH_2O]$ ✓ Psm : Pseudomalachite $Cu_5(PO_4)_2(OH)_4$







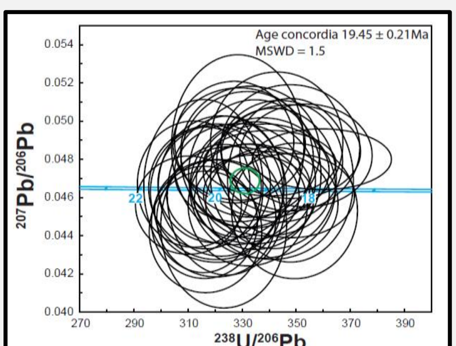
U-Pb dating : Pseudomalachite

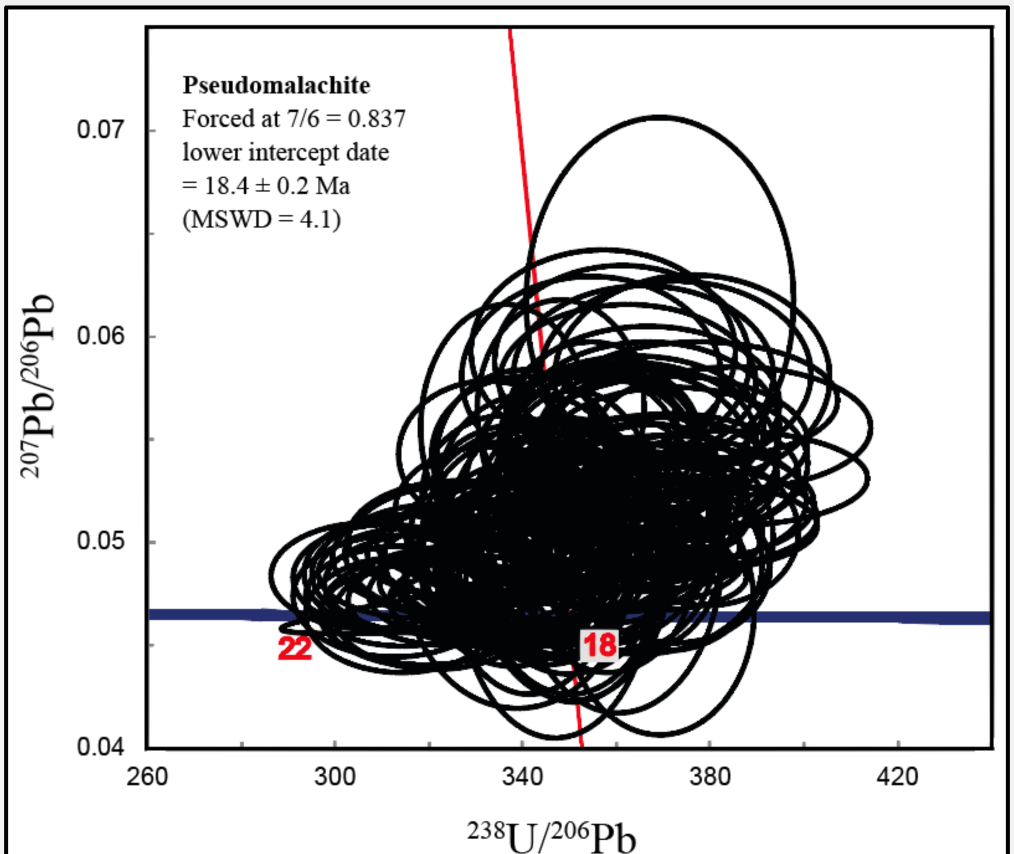


- 126 spots under ns- and fs- LA-ICP-MS (Rennes + Toulouse)
- Apatite as standard reference material

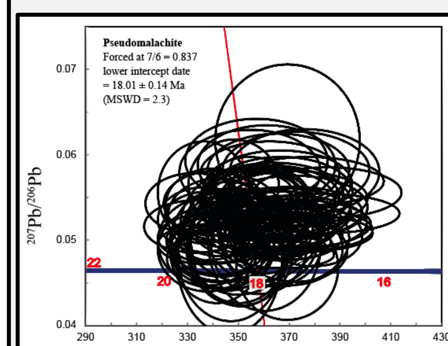
- **Intercept date at 18.4 ± 0.2 Ma**

ns-LA-Q-ICP-MS

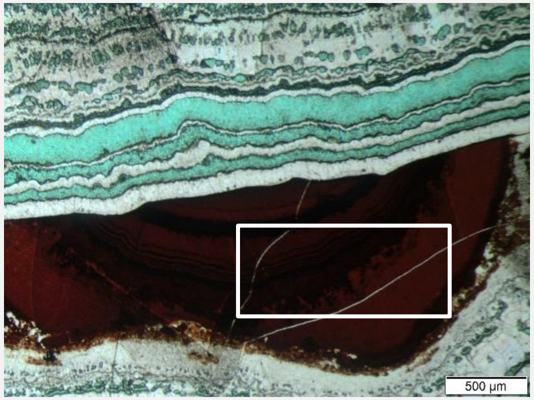




fs-LA-HR-ICP-MS



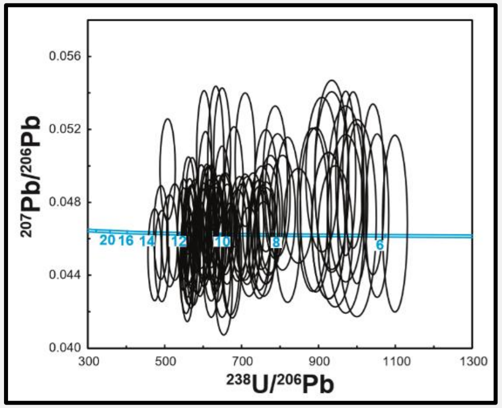
U-Pb dating : Mn-rich chrysocolla clast

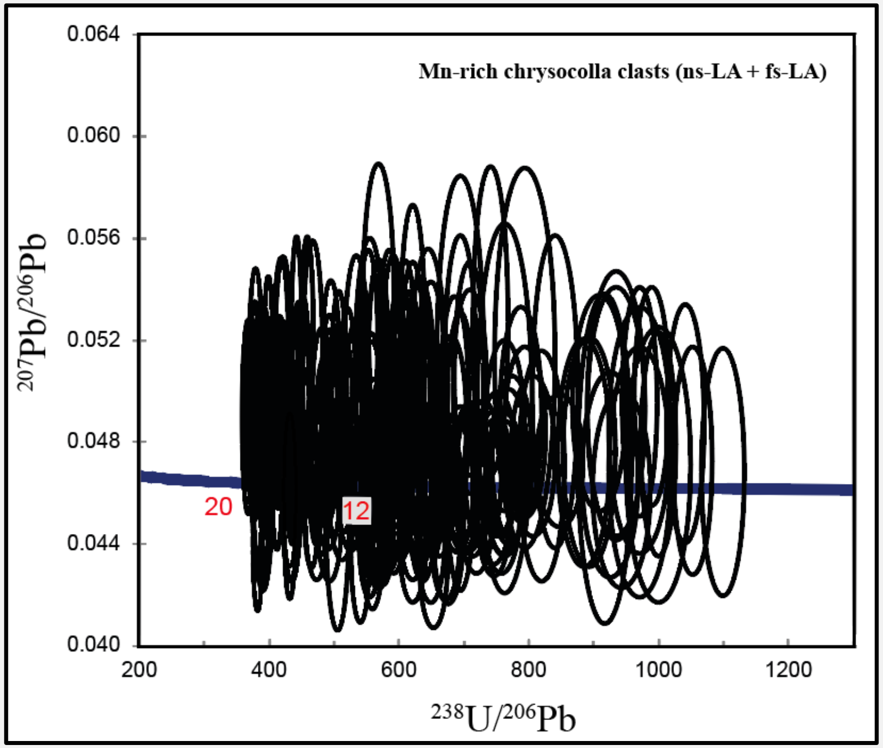


- 177 spots under ns- and fs- LA-ICP-MS (Rennes + Toulouse)
- Zircon as standard reference material

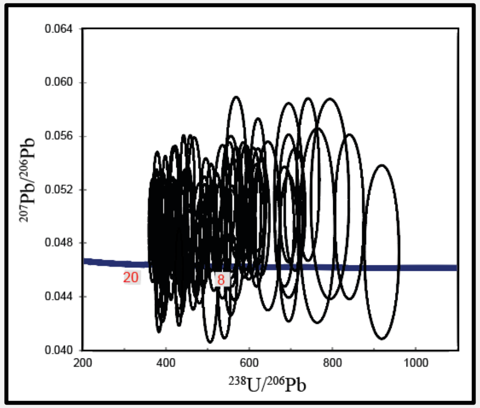
- **Apparent ages: 17.5 ± 0.2 Ma to 5.8 ± 0.1 Ma**

ns-LA-Q-ICP-MS



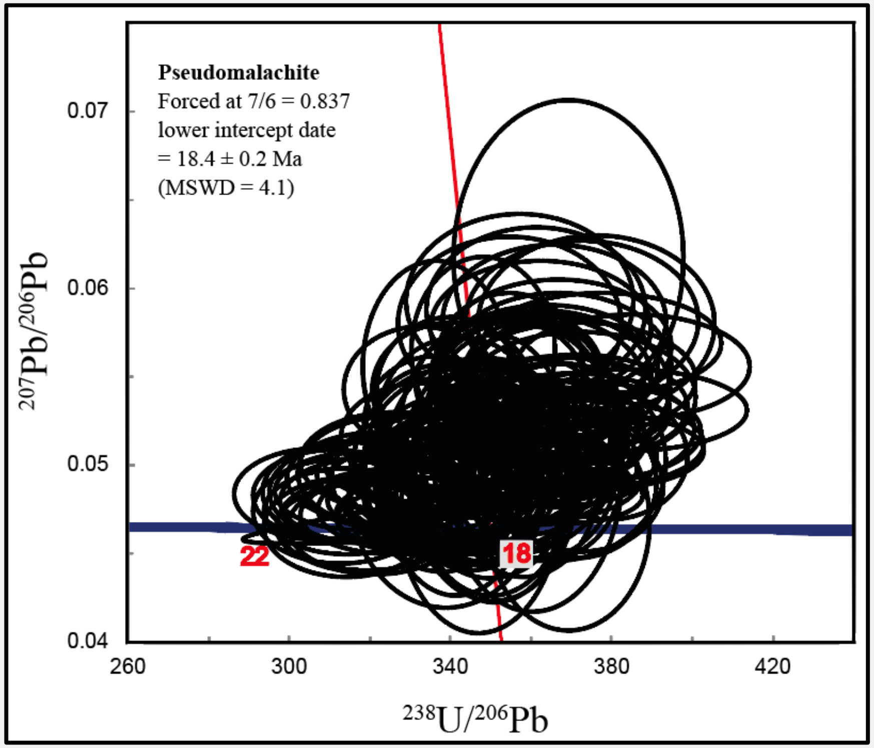


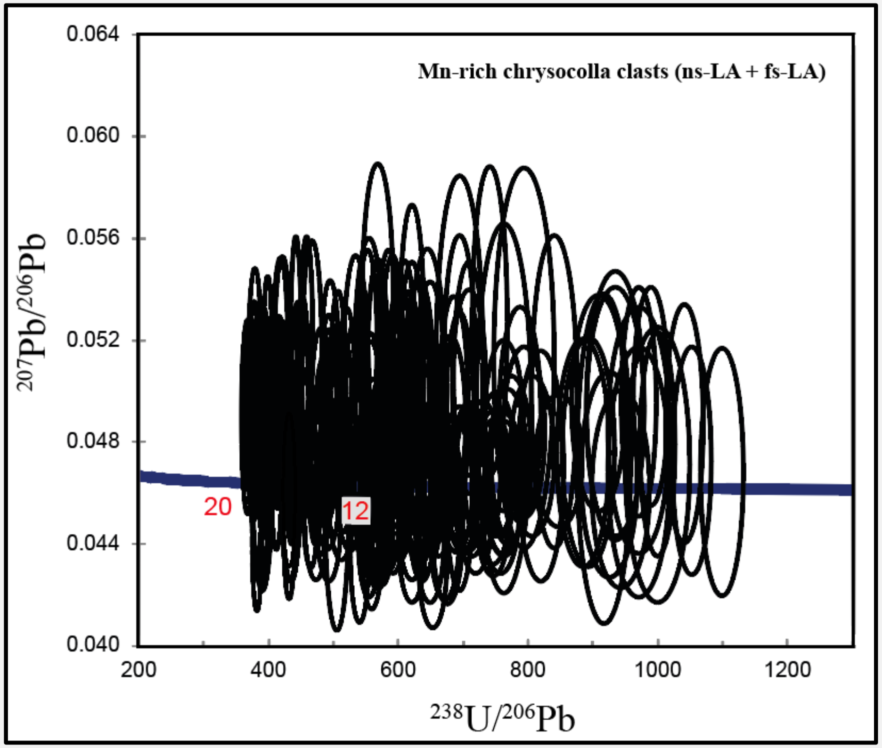
fs-LA-HR-ICP-MS



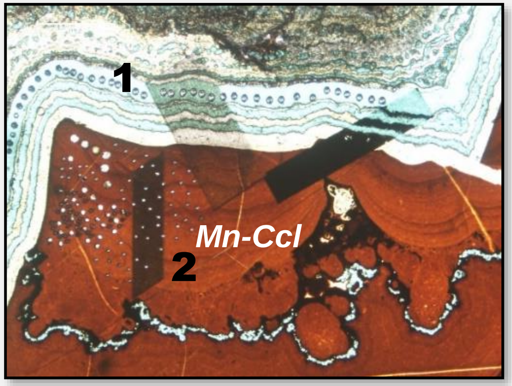
U-Pb dating : Conclusions

- ✓ **Both Mn-rich chrysocolla clasts and pseudomalachite bands have a chronometric potential given U and radiogenic Pb content and the almost absence of common Pb**
- ✓ **For pseudomalachite, intercept date at 18.4 ± 0.2 Ma can be interpreted as crystallisation age of the pseudomalachite bands**
- ✓ **Spreading of the apparent ages observed on Mn-rich chrysocolla clasts could be due to U and/or Pb mobility by late fluids circulation**



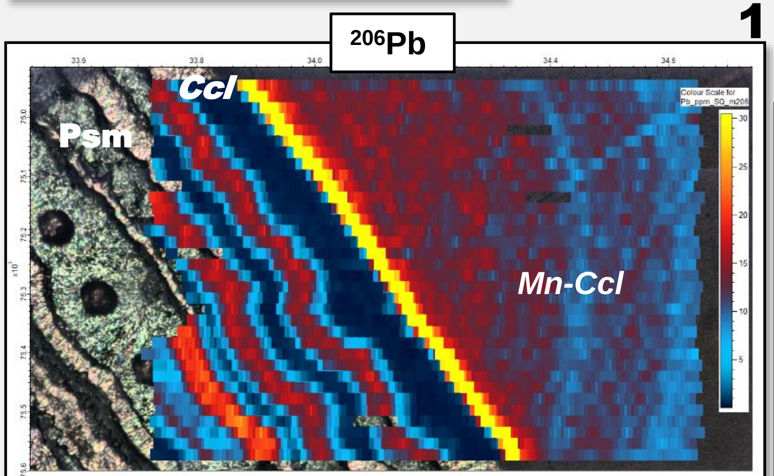


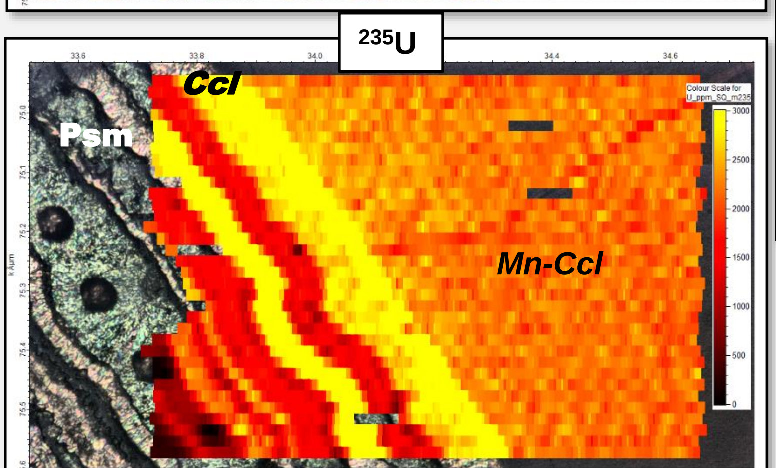
U-Pb mapping by ns-LA-Q-ICPMS



- NIST 610-612, 91500 Zircon, Basalt Glass (BCR2G), Mada and Durango Apatites as standard reference material
- 12 * 12 µm raster
- Pb (206, 207), U (235, 238), Si, P, Al, Mn…

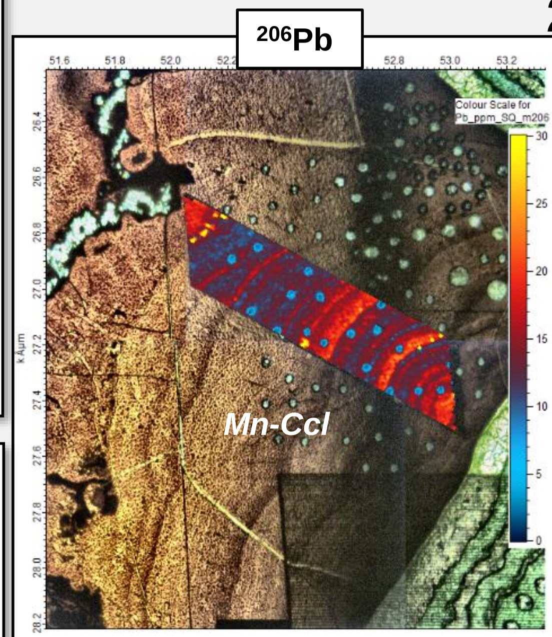
1

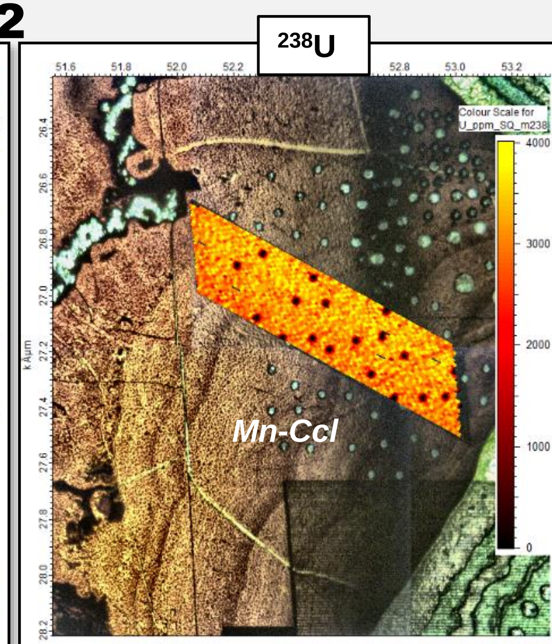




- **Homogenous distribution of ^{235}U and ^{206}Pb in chrysocolla and pseudomalachite**
- **Heterogenous distribution of ^{206}Pb in Mn-rich chrysocolla clasts and homogenous distribution of ^{238}U in Mn-rich chrysocolla clasts**

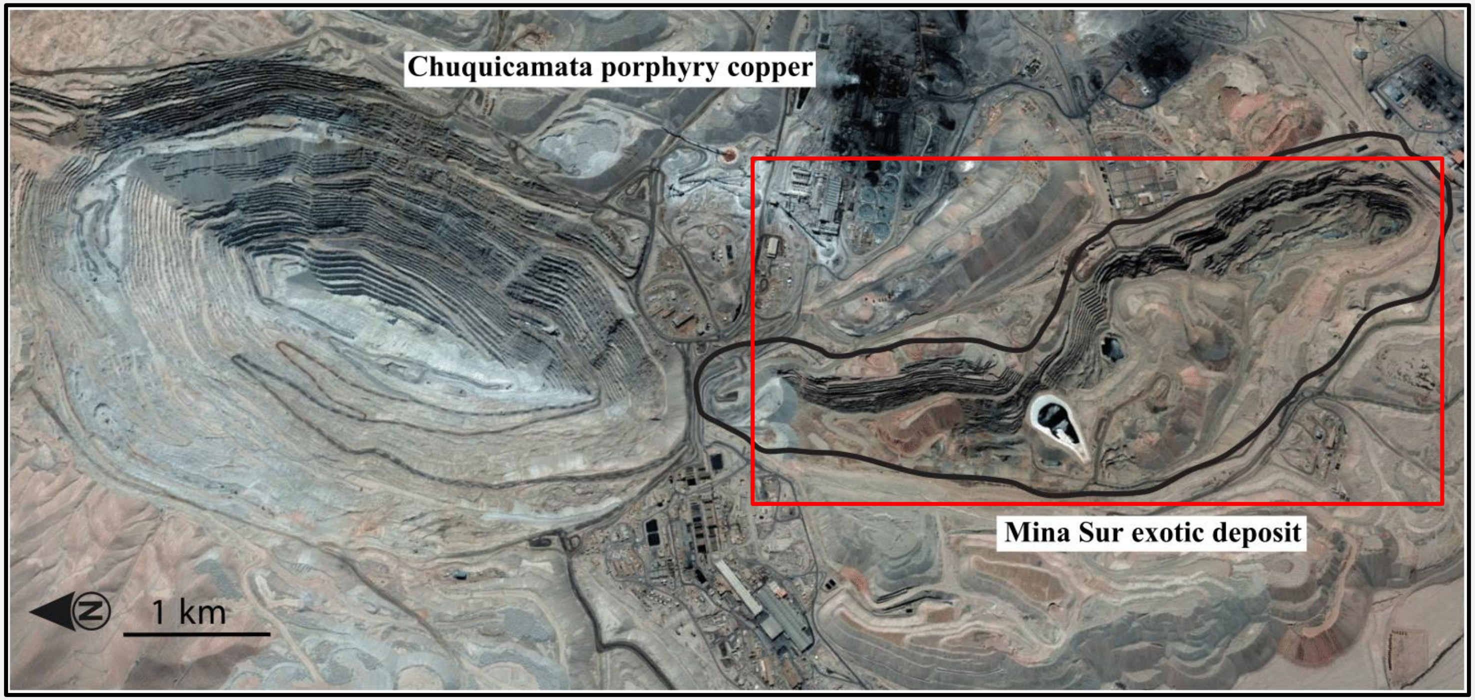
2





✓ **Spreading of the apparent ages observed on Mn-rich chrysocolla corresponds to radiogenic lead variation associated to oscillatory growth zoning, unbalanced by U zoning. This suggests late U homogeneization caused by fluids circulation**

Take home messages



- ❖ **Formation of pseudomalachite's Cu-exotic deposit at ca. 19 Ma is coeval with supergene alteration in the mining district (19.0 ± 0.7 and 15.2 ± 0.5 Ma; K/Ar on supergene alunites in the leached cap; Sillitoe and McKee 1996)**

- ❖ **U-Pb system does not record Mn-rich chrysocolla crystallization, but possibly a late fluid circulation ?**

Next step is therefore Oxygen stable isotope mapping and Cu isotopic analysis to decipher the playing role of fluids …

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