

# **GOLD RUSH – APLICAÇÃO DE FERRAMENTAS GEOQUÍMICAS E ISOTÓPICAS NO COMBATE AO CRIME ORGANIZADO E CONTRABANDO DE OURO NA REGIÃO NORTE DO BRASIL**

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# Outline

- Gold - combination of geological + anthropogenic features
- Provenance and traceability – background and feasibility
- The *Gold Rush* Project – Ongoing studies and perspectives



Garimpo do Lourenço – AP  
Photo MESchutesky







GOLD  
GROUP

# GOLD GEOCHEMISTRY

**GROUP**

IA IIA

*Goldschmidt's Classification*

III A IVA VA VIA VII A VIII A

1 H He

2 Li Be B C N O F Ne

3 Na Mg Al Si P S Cl Ar

4 K Ca Sc Ti V Cr Mn Fe Co Ni Cu Zn Ga Ge As Se Br Kr

5 Rb Sr Y Zr Nb Mo Tc Ru Rh Pd Ag Cd In Sn Sb Te I Xe

6 Cs Ba La Hf Ta W Re Os Ir Pt Au Hg Tl Pb Bi Po At Rn

7 Fr Ra Ac

La Ce Pr Nd Pm Sm Eu Gd Tb Dy Ho Er Tm Yb Lu

Ac Th Pa U Np Pu

**Lithophile** **Siderophile** **Chalcophile** **Atmophile**

|    | Average crustal abundance | Typical exploitable grade | Approximate concentration factor |
|----|---------------------------|---------------------------|----------------------------------|
| Al | 8.2%                      | 30%                       | ×4                               |
| Fe | 5.6%                      | 50%                       | ×9                               |
| Cu | 55 ppm                    | 1%                        | ×180                             |
| Ni | 75 ppm                    | 1%                        | ×130                             |
| Zn | 70 ppm                    | 5%                        | ×700                             |
| Sn | 2 ppm                     | 0.5%                      | ×2500                            |
| Au | 4 ppb                     | 5 g t <sup>-1</sup>       | ×1250                            |
| Pt | 5 ppb                     | 5 g t <sup>-1</sup>       | ×1000                            |

Note: 1 ppm is the same as 1 g t<sup>-1</sup>.

Robb, 2005

LOW ABUNDANCE → CONCENTRATION!

**GEOLOGICAL & "ANTHROPOGENIC"**

White, 2013

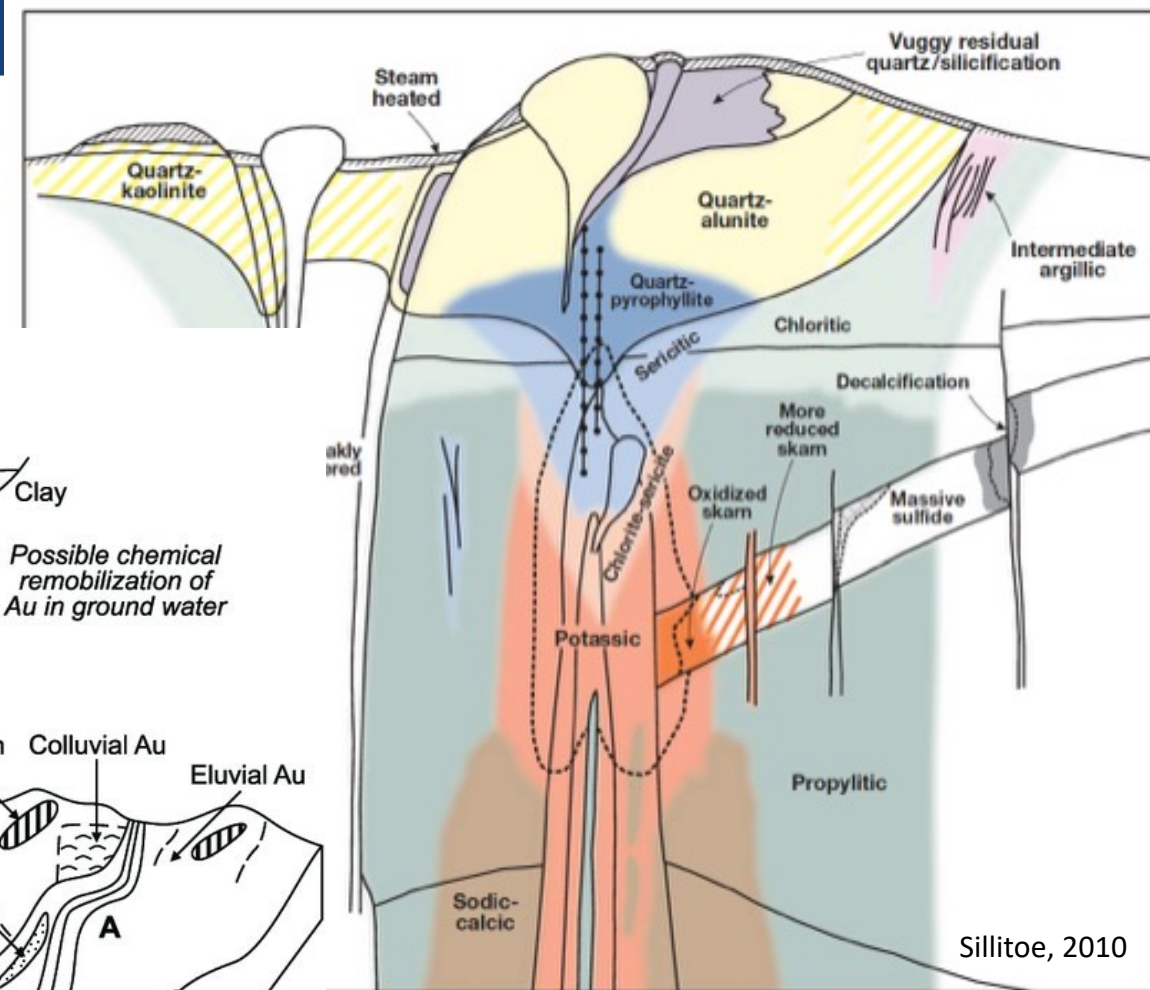
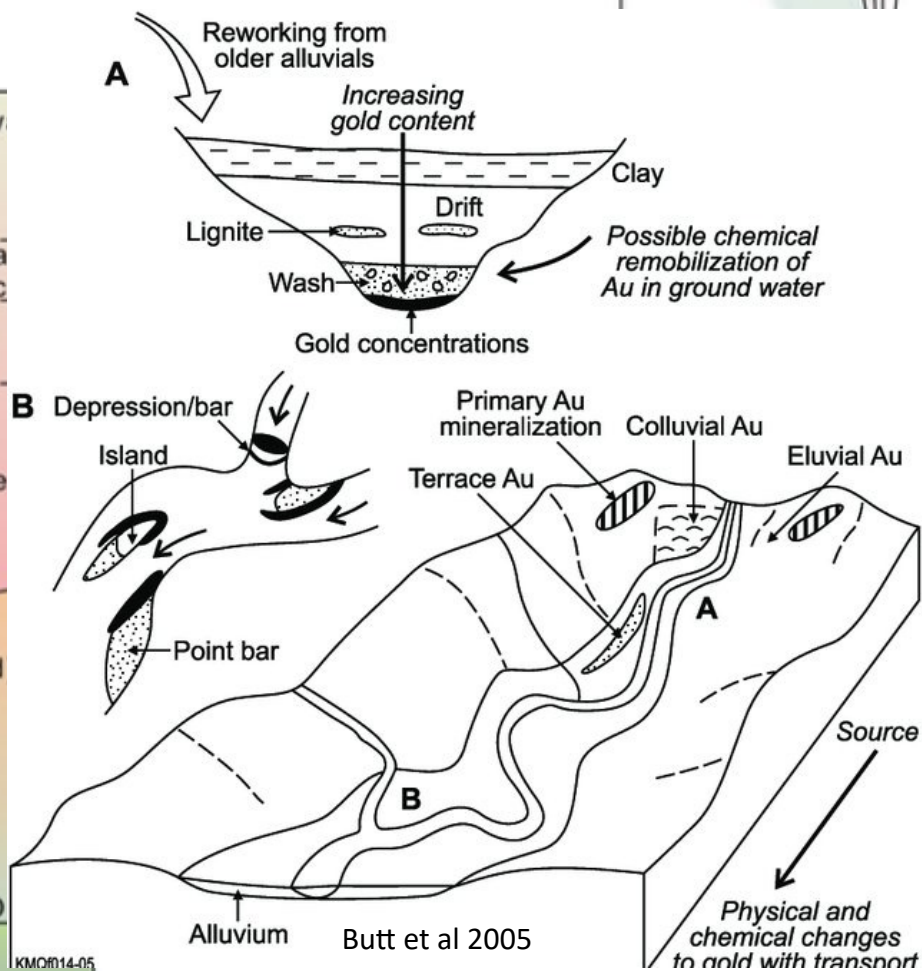
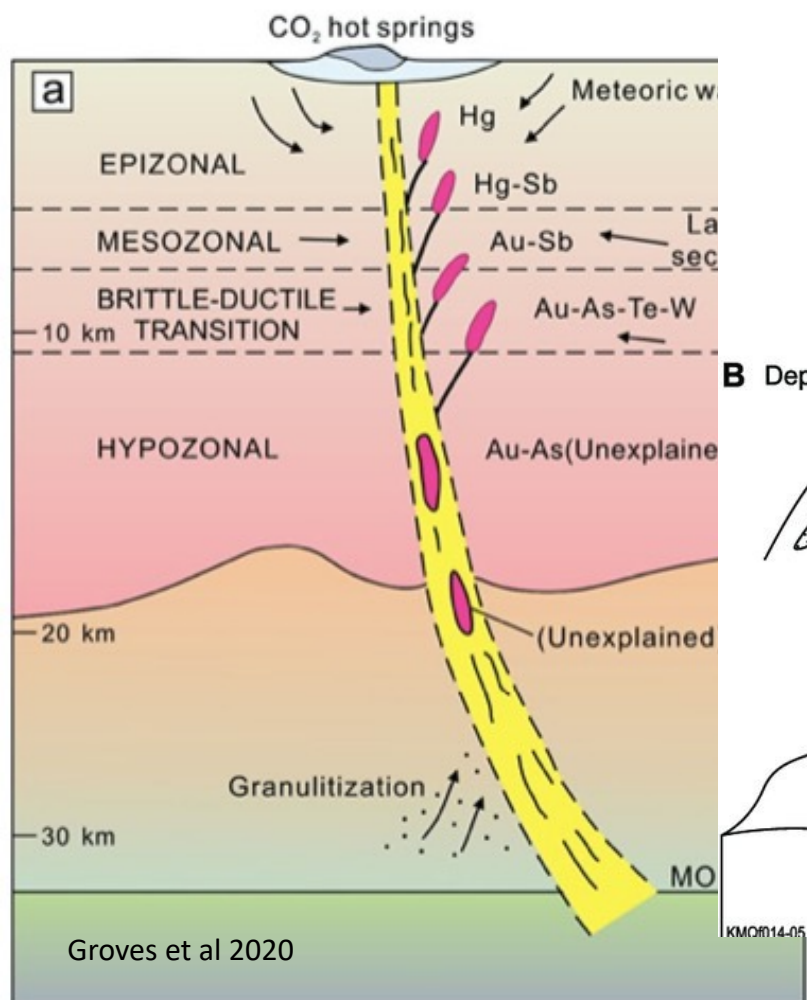
*Note:* 1 ppm is the same as 1 g t<sup>-1</sup>. Robb, 2005

## GEOLOGICAL & “ANTHROPOGENIC”

White, 2013



# GOLD GEOLOGY

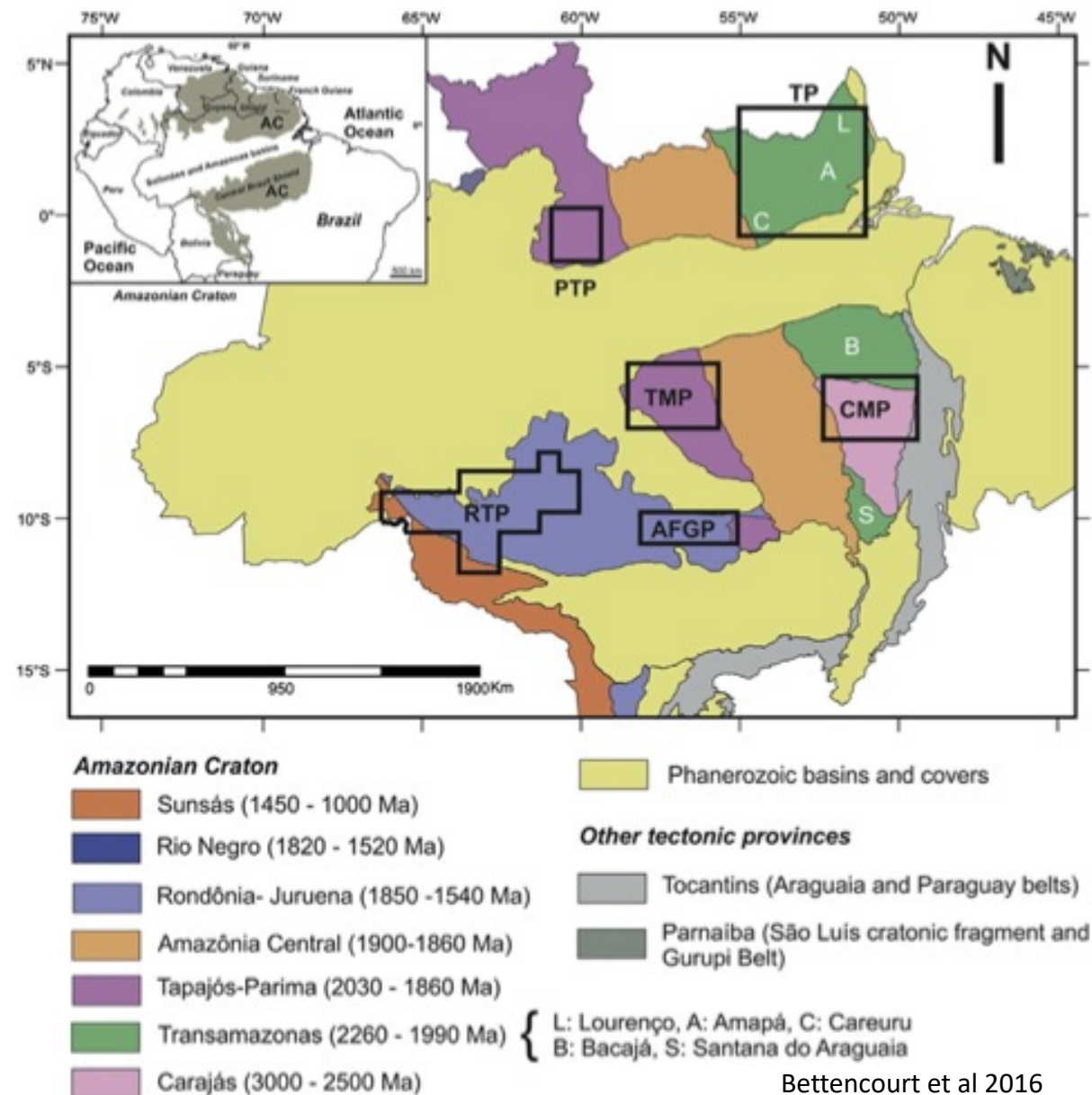




# GOLD – GEOLOGICAL DIVERSITY

## METALLOGENETIC PROVINCES

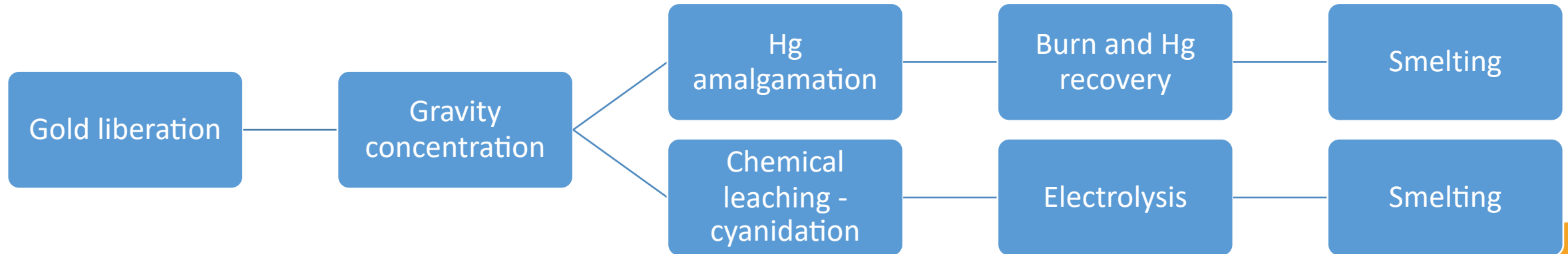
- ORE-FORMING PROCESSES AND DEPOSIT TYPES
- GEOCHEMICAL AFFINITIES





# GOLD – GOLD PROCESSING

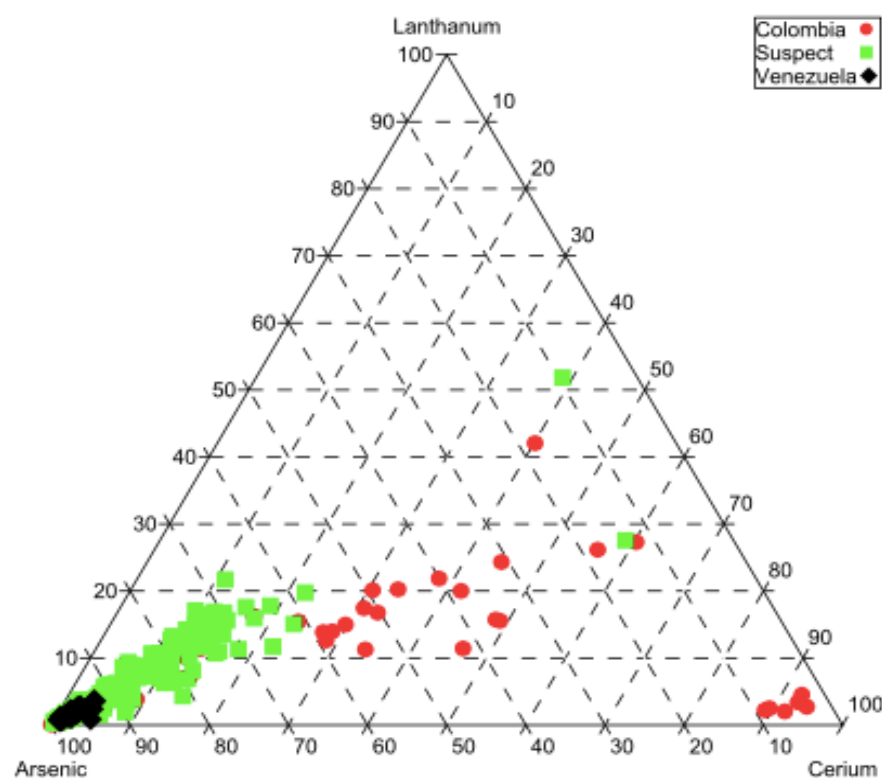
- The anthropogenic concentration in a nutshell:



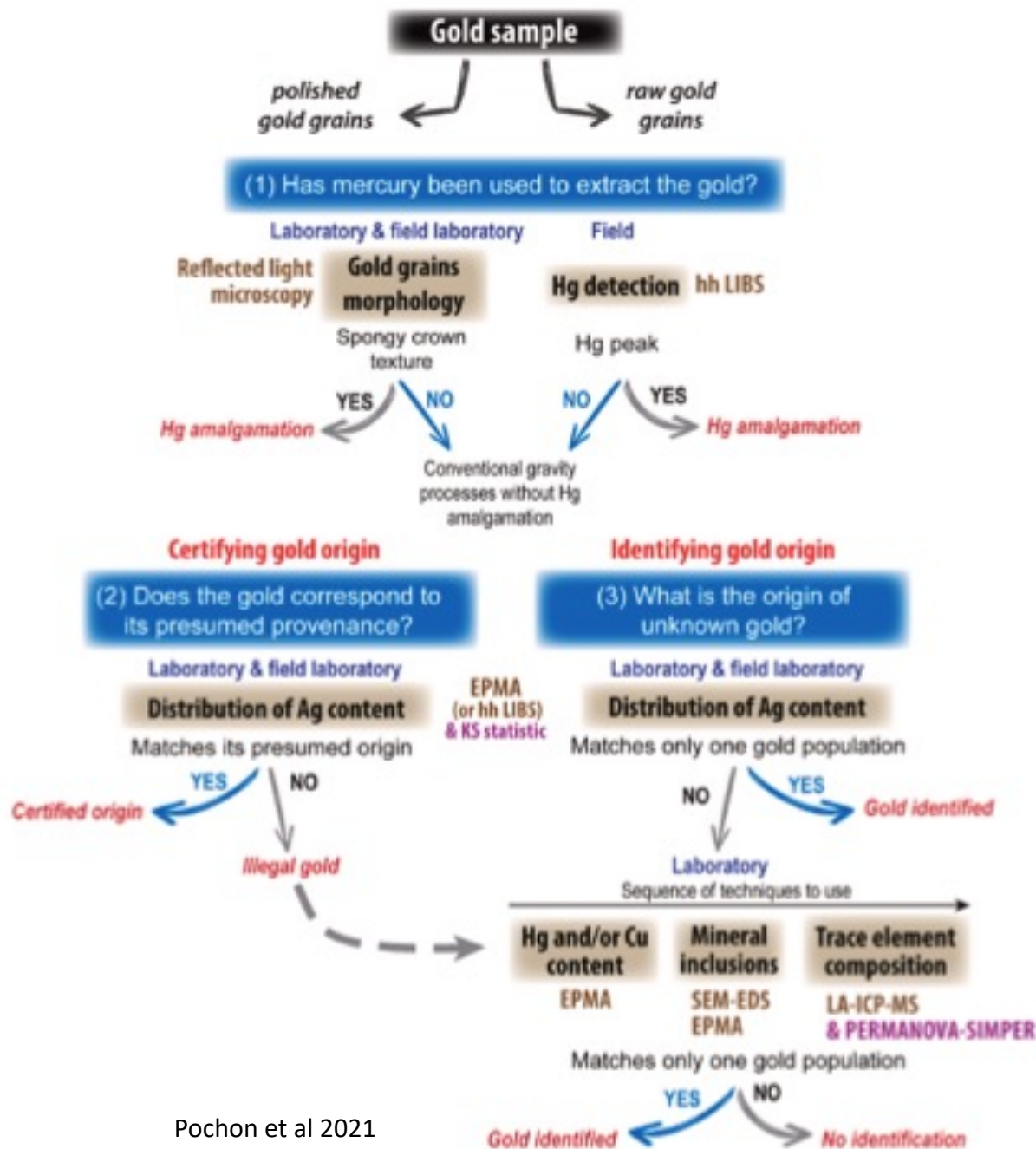


# PROVENANCE AND TRACEABILITY BKG

- FORENSIC CASE STUDIES



Dixon & Merkle 2019



Pochon et al 2021

# THE GOLD RUSH PROJECT – QUO VADIS?





# GOLD RUSH – MAIN QUESTIONS

- GOLD HETEROGENEITY – GEOLOGICAL AND ANTHROPOGENIC INFLUENCE
- GEOCHEMICAL AND ISOTOPIC FRACTIONATION THROUGHOUT GOLD PRODUCTIVE CHAIN  
– Hg AMALGAMATION AND CYANIDATION – FEASIBILITY OF PROVENANCE AND TRACEABILITY STUDIES
- Ag & Cu & Pb ISOTOPES – ADVANTAGES AND PITFALLS
- BIG DATA PROCESSING AND STATISTICS IN GOLD TRACEABILITY

# GOLD RUSH – ANALYTICAL FACILITIES AT UNB

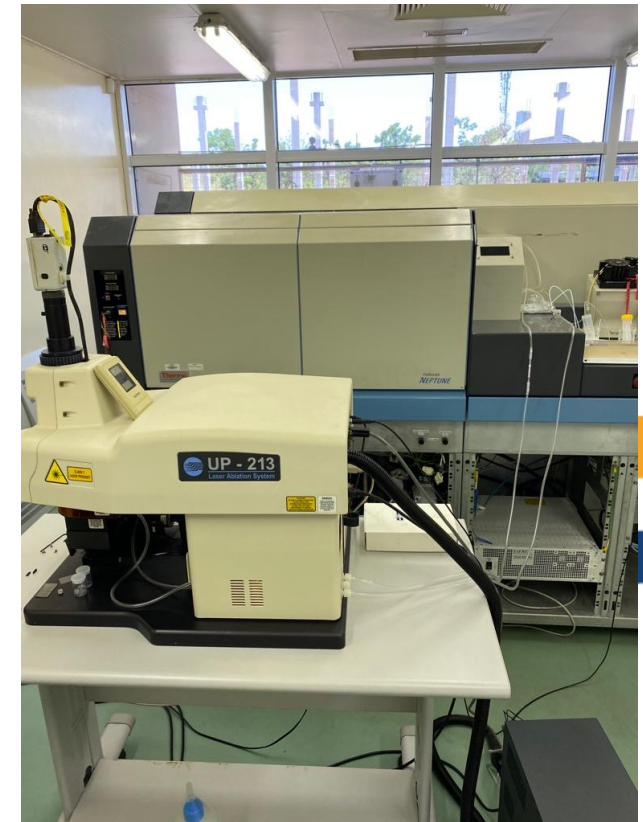
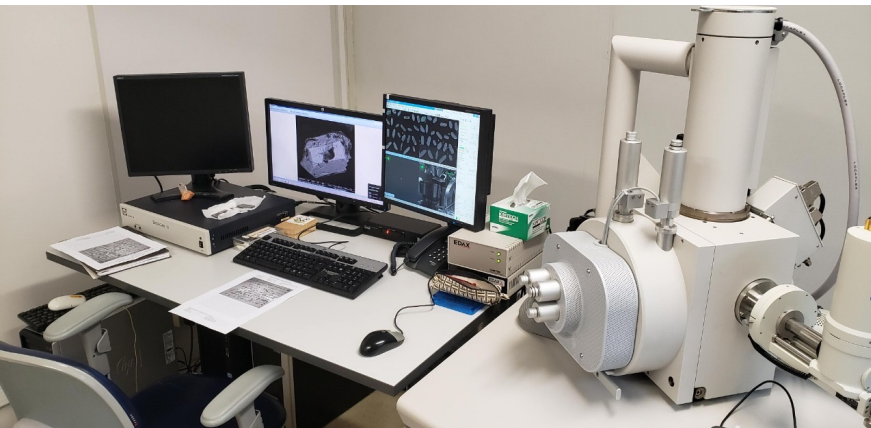


THERMO ELEMENT SC-ICP-MS &  
IRIDIA LA

THERMO NEPTUNE MC-ICMP-MS &  
Nd:YAG 213 nm LA

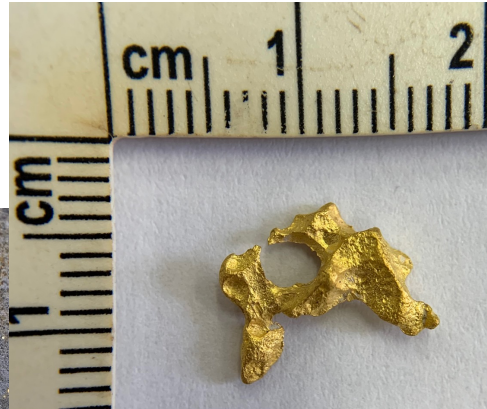
THERMO NEPTUNE XT-MC-ICMP-MS &  
ANALYTE EXCITE LA

FEI SEM + CL + EBSD + EDS





# GOLD RUSH – SAMPLING PROTOCOL

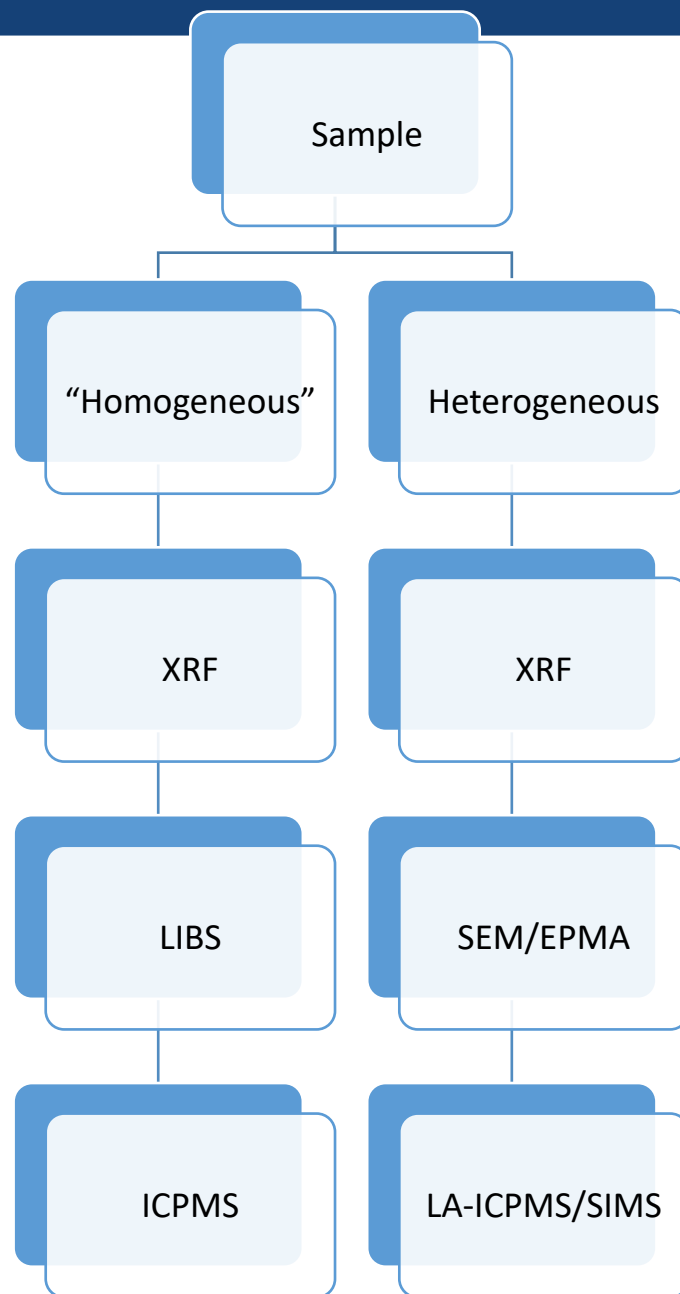


Atuante como sempre,  
necessária como nunca

# GOLD RUSH ANALYTICAL PROTOCOL

DILUTION

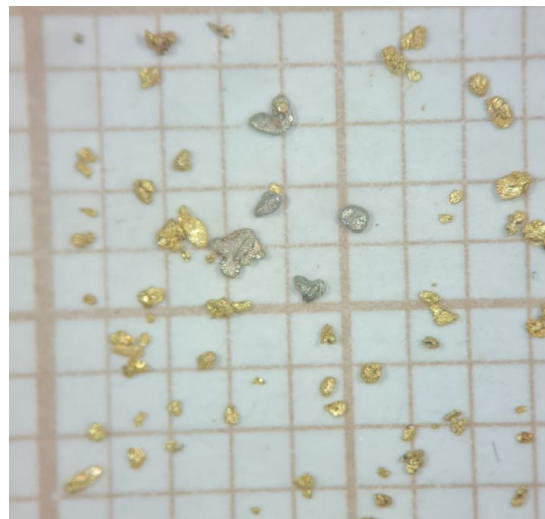
IN-SITU TECHNIQUES



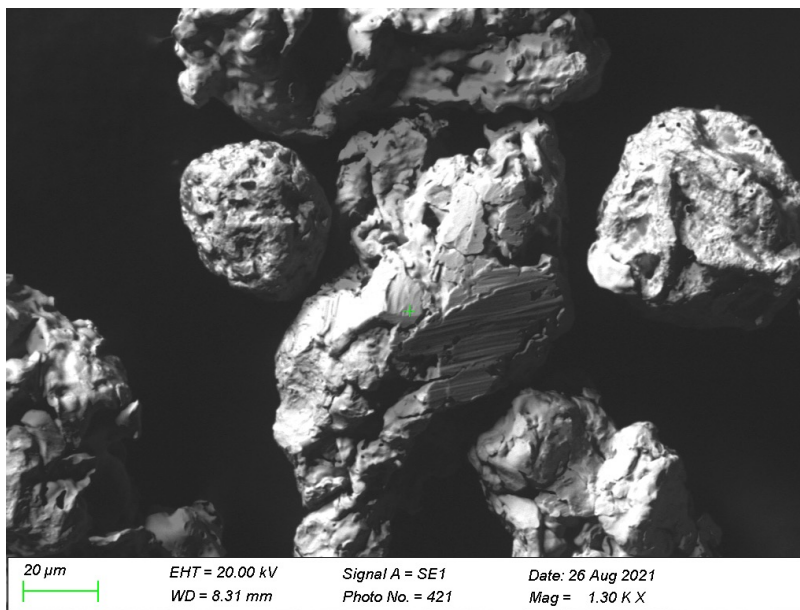


# GOLD RUSH MINERALOGY

- TYPOMORPHIC STUDIES
- HEAVY MINERALS



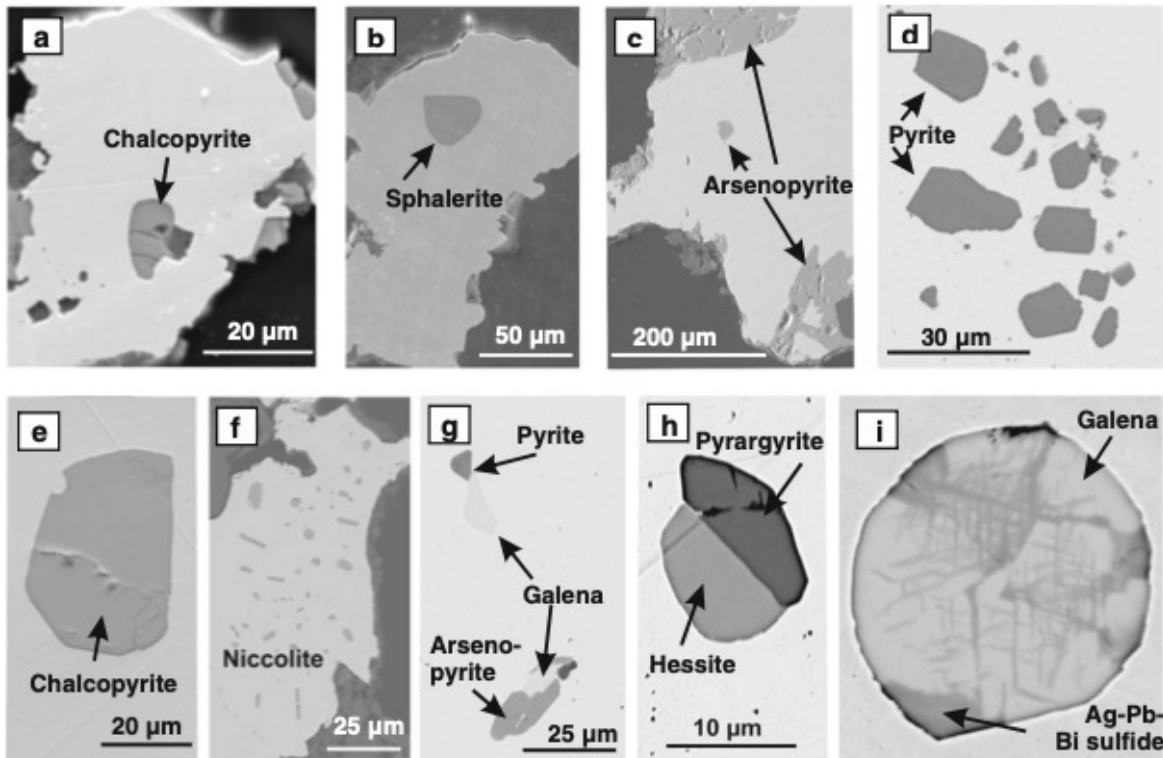
COLUMBITE-TANTALITE



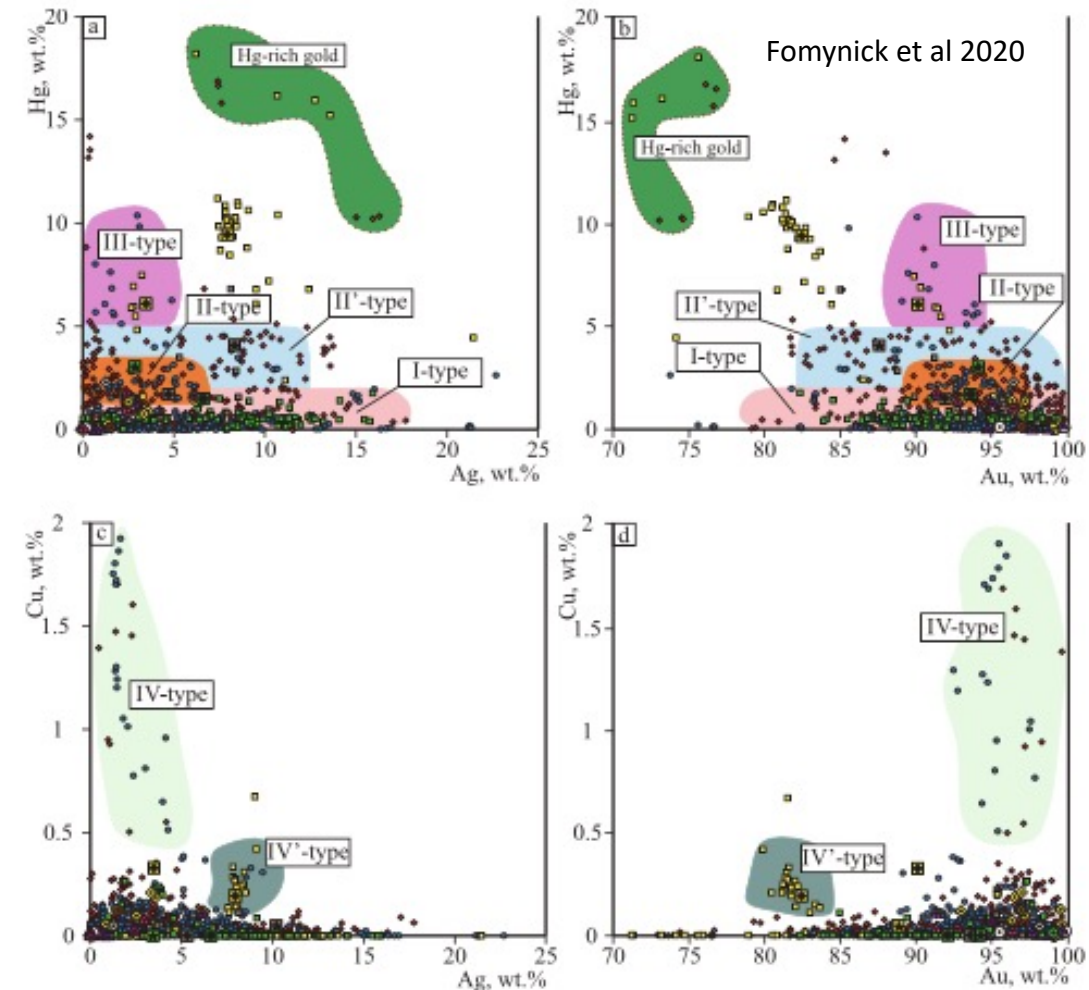
CASSITERITE

# GOLD RUSH – IN SITU GEOCHEMISTRY

- MICROINCLUSIONS AS A POTENTIAL SOURCE DISCRIMINATOR



Chapman et al 2021

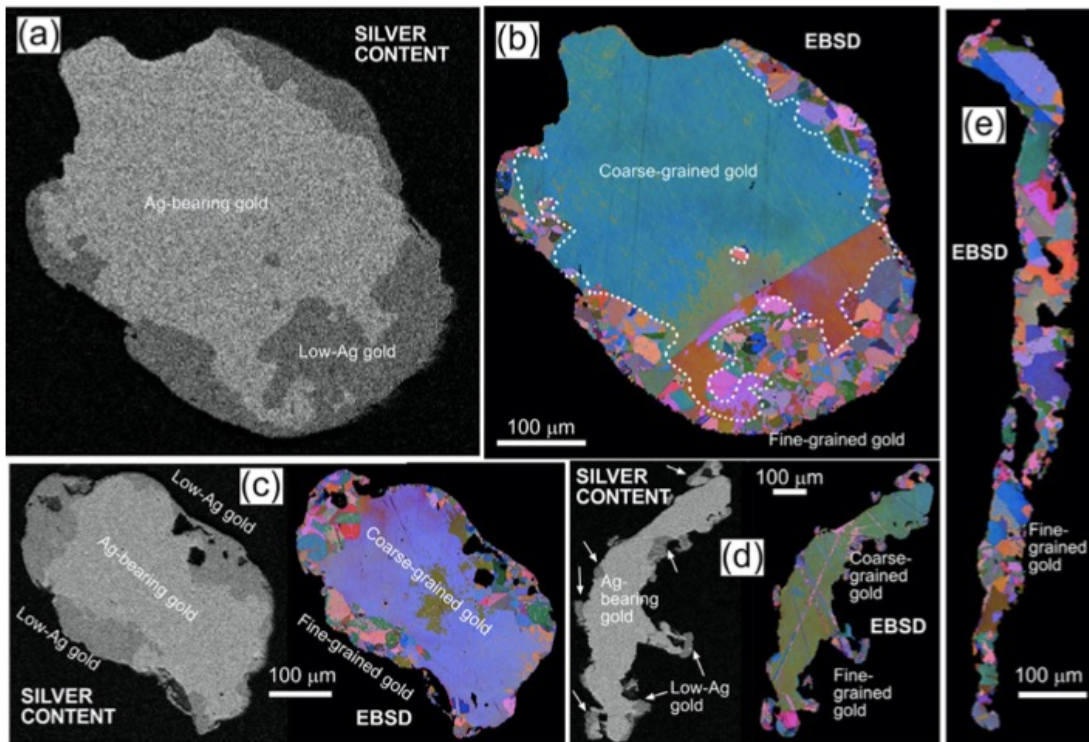




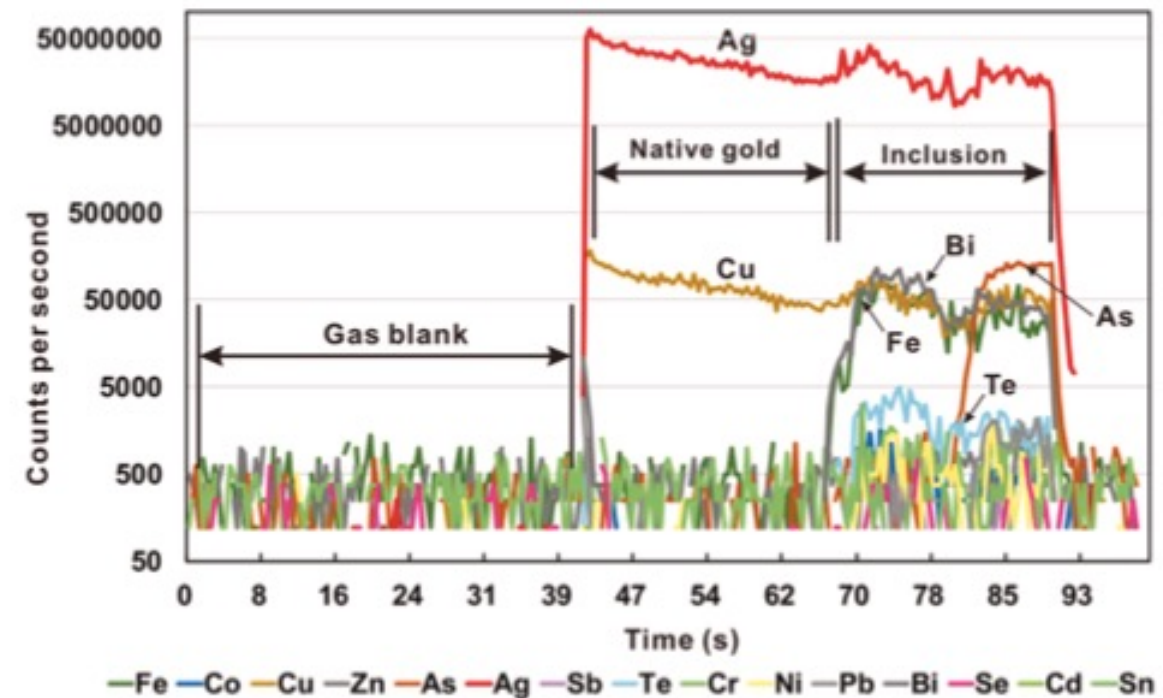
# GOLD RUSH – IN SITU GEOCHEMISTRY

- IMAGING TECHNIQUES + IN SITU TRACE ELEMENT PROFILING

Liu et al 2021

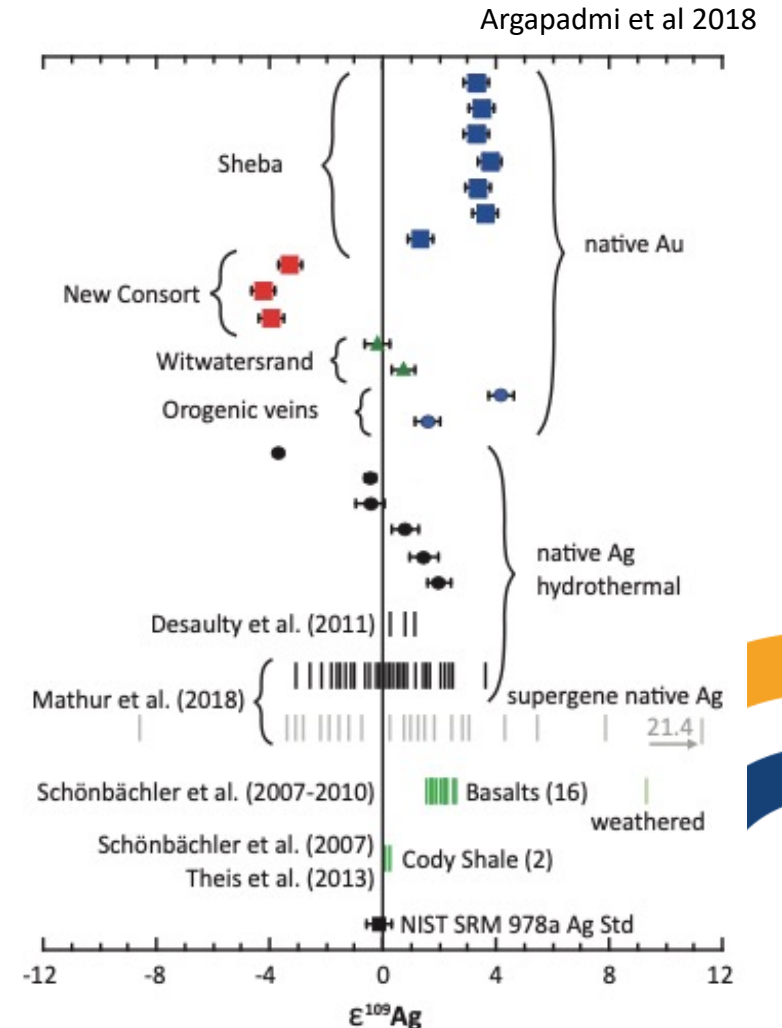
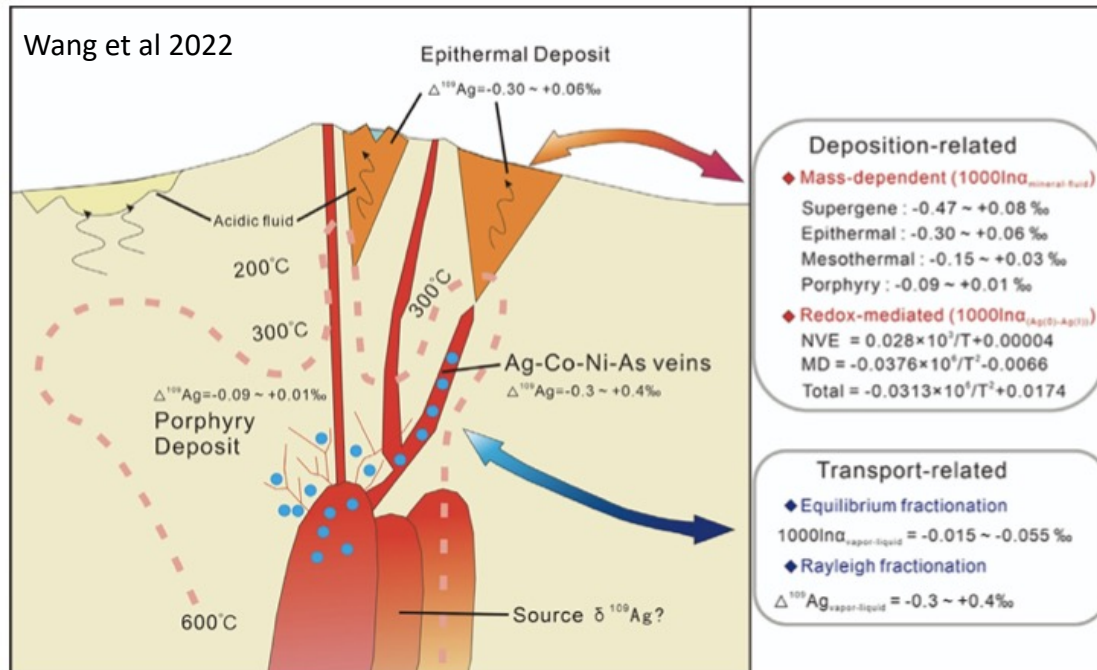


Stewart et al 2017



# GOLD RUSH – Ag & Cu ISOTOPES

- PLANETARY SCIENCE AND COSMOLOGY, TO ARCHAEOLOGICAL STUDIES.
- POTENTIAL ISOTOPIC TRACER: SYNTHETIC MARKERS/TRACERS
- GEOCHEMICAL AND ANALYTICAL ADVANTAGES

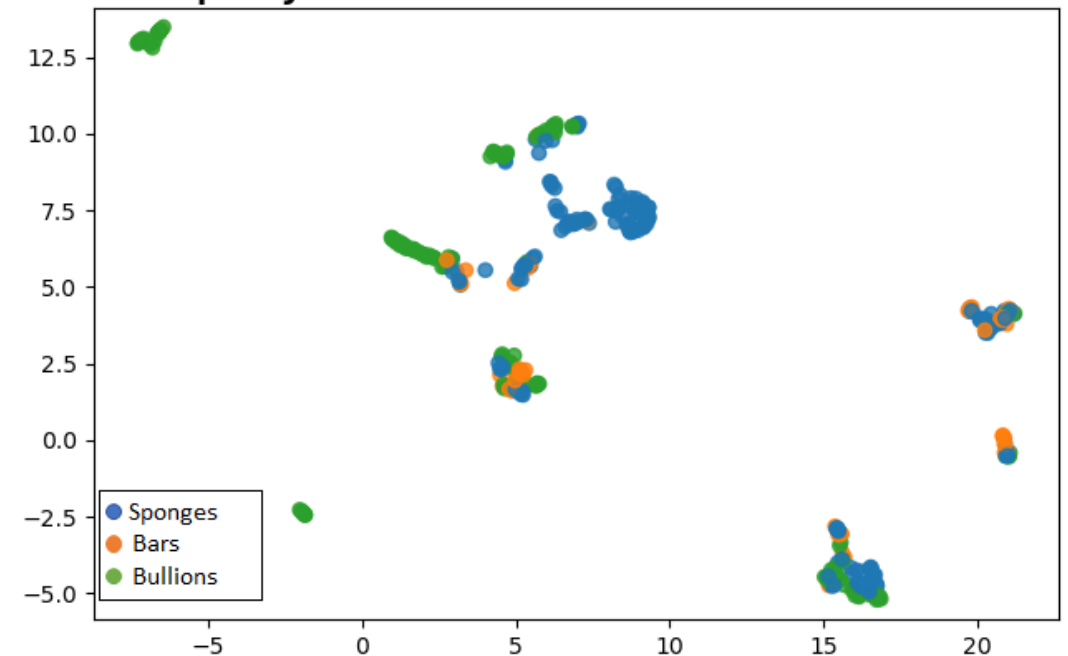




# GOLD RUSH – BIG DATA AND STATISTICS

- 2D EMBEDDING OF 14 ELEMENTS FROM AMAZONIAN GOLD SAMPLES BASED ON THE TOPOLOGICAL STRUCTURE OF THE DATA.
- CHEMICAL SIMILARITIES BETWEEN DIFFERENT TYPES OF SAMPLES (IN A HIGH DIMENSIONAL SPACE) REGARDLESS OF THE ANTHROPOGENIC PROCESS THAT THEY HAVE BEEN THROUGH.

UMAP projection of Gold from Amazonas





# GOLD RUSH – NEAR FUTURE & BOTTLENECKS

- FURTHER SAMPLING;
- DEVELOPMENT AND SHARING OF REFERENCE MATERIALS FOR GEOCHEMICAL AND ISOTOPIC ANALYSIS;
- LABORATORY INTERCALIBRATION AND SCIENTIFIC KNOWLEDGE EXCHANGE AMONG RESEARCH INSTITUTES AND UNIVERSITIES;
- DATABASE – FROM RAW MATERIAL TO BULLION.





**Obrigado(a).**