# Role of Oligocene Volcanism in the geological setting of Au-Ag-Cu-Pb-Zn mineralization at the Plomosas District, San Marcial Area, Southwestern Sierra Madre Occidental, Sinaloa, Mexico

**Paula Montoya-Lopera*, Gilles Levresse, Marcio Fonseca, Luis Coto, Marlen Salgado, Javier Villegas, Miguel Díaz, Francisco Testa And Daniel Schrader**

*paula.montoyalopera@utas.edu.au


UNIVERSITY of TASMANIA
CODES
CENTRE FOR ORE DEPOSIT AND EARTH SCIENCES
GR SILVER MINING LTD

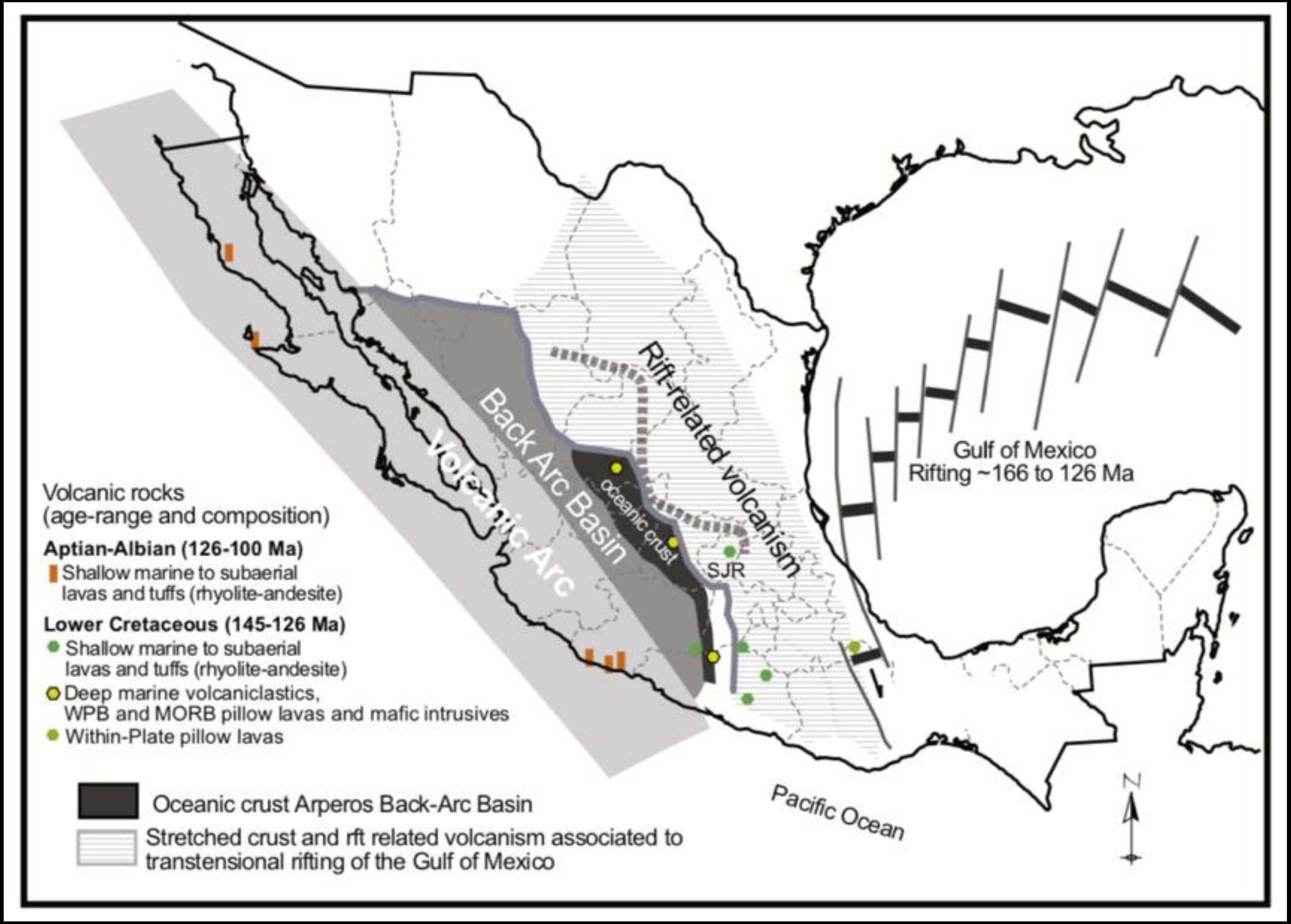
# San Marcial location


## Plomosas and San Marcial area

- Mined since 18th century
- Contains more than two long live hydrothermal breccia system
- Hy breccias width varies from 1 to 15 m for over 1 km long and 1 km deep
- Structural controlled by NW crust faults
- Historical production of 2.5 Mt @ 67,647 ton Pb and 14,700 Oz Ag
- Current resources San Marcial 52 Moz AgEq (Ind.) @ 162 g/t AgEq, 16 Moz AgEq (Inf.) @ 166 g/t; Plomosas 31 Moz AgEq (Ind.) @ 200 g/t AgEq, 17 Moz AgEq (Inf.) @ 175 g/t

CODES

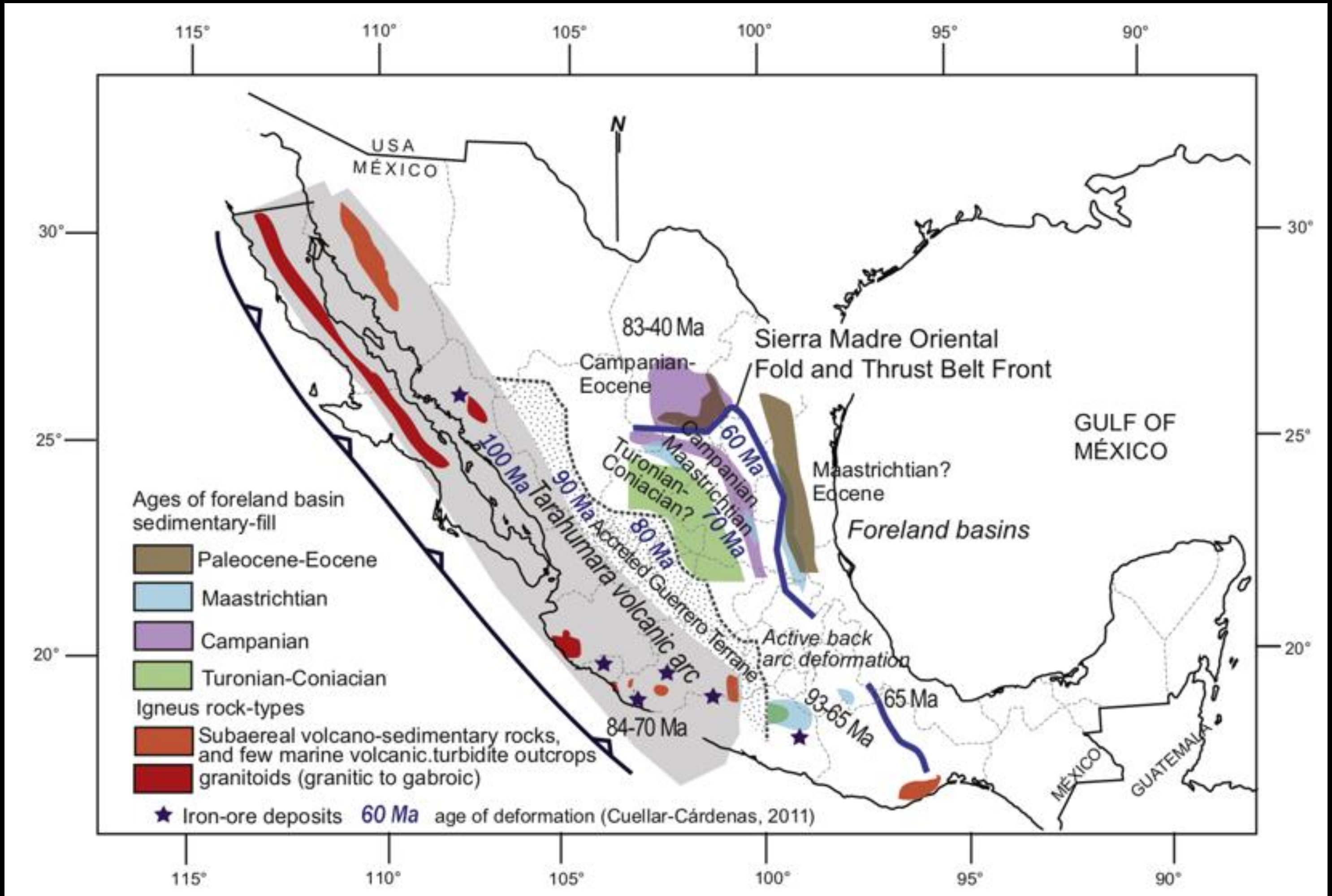
# Terrain Guerrero Suture

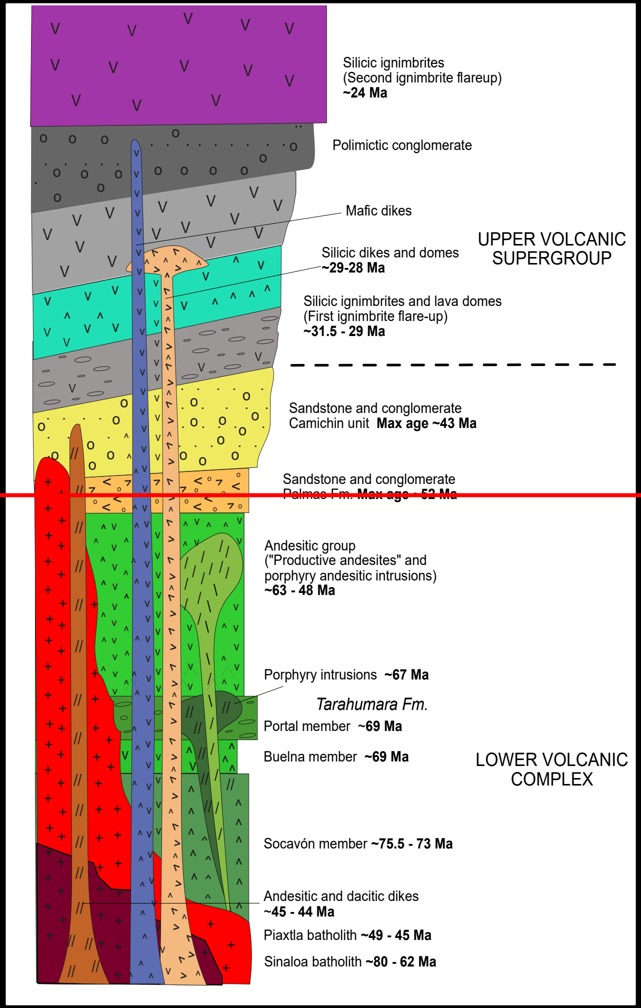



Centeno, 2017

CODES

# Strain and Laramide magmatism at North of Mexico

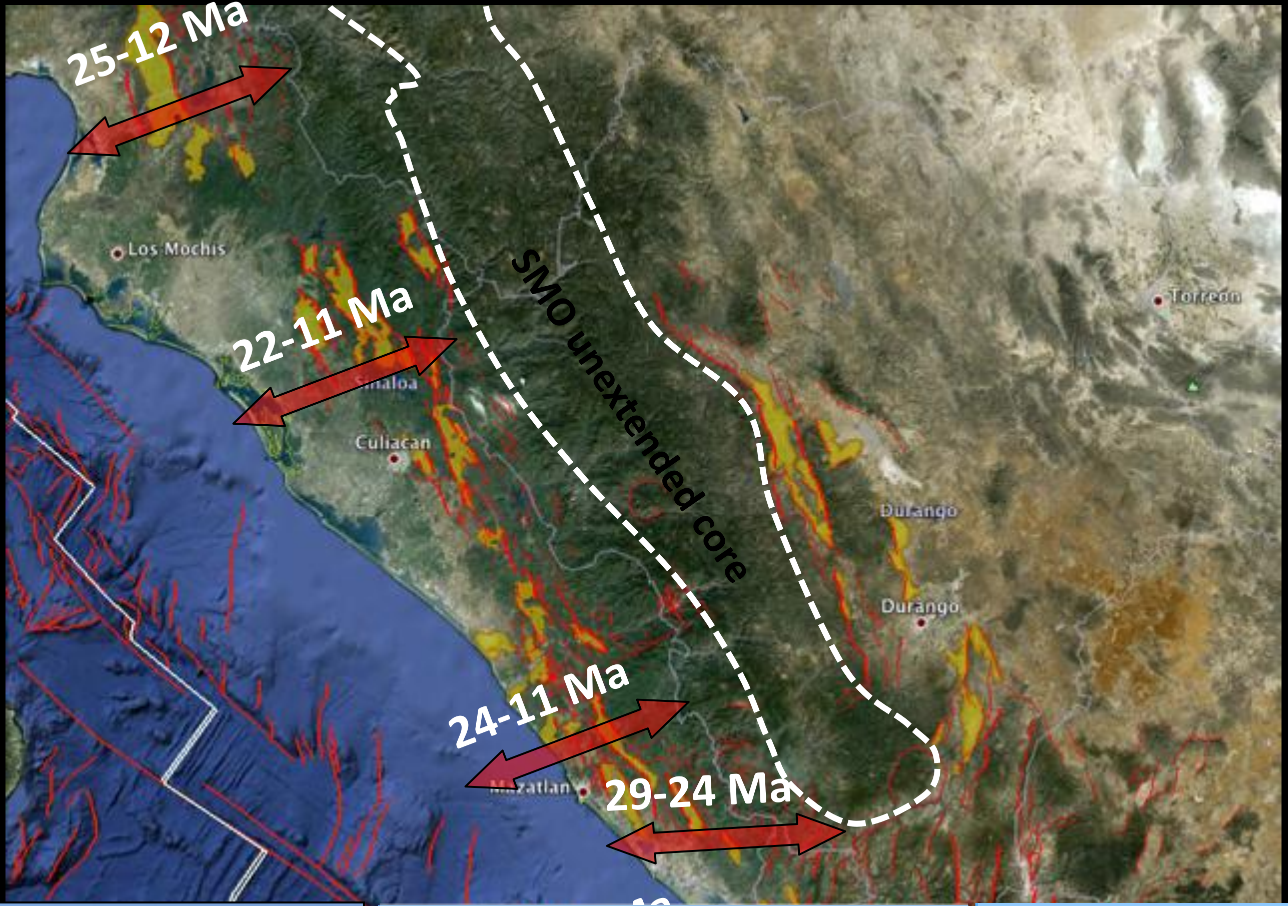



Centeno, 2017

Montoya-Lopera et al., 2019, 2020a,b, 2024, 2025

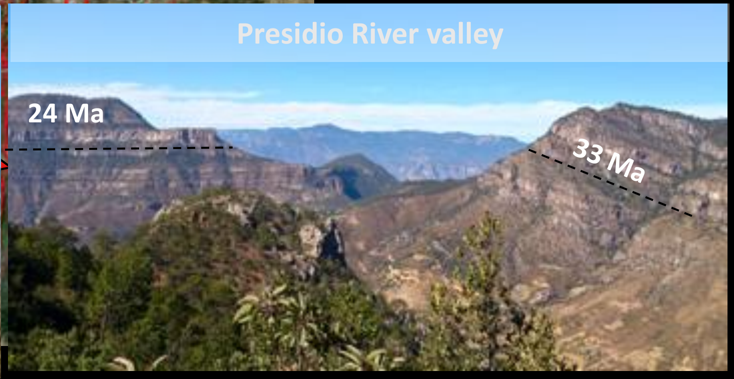
# Oligocene extension




Sinaloa and Nayarit extension begins in the late Oligocene, causing an angular unconformity between the Oligocene (32-29 Ma) and early Miocene (24-20 Ma) ignimbritic sequences

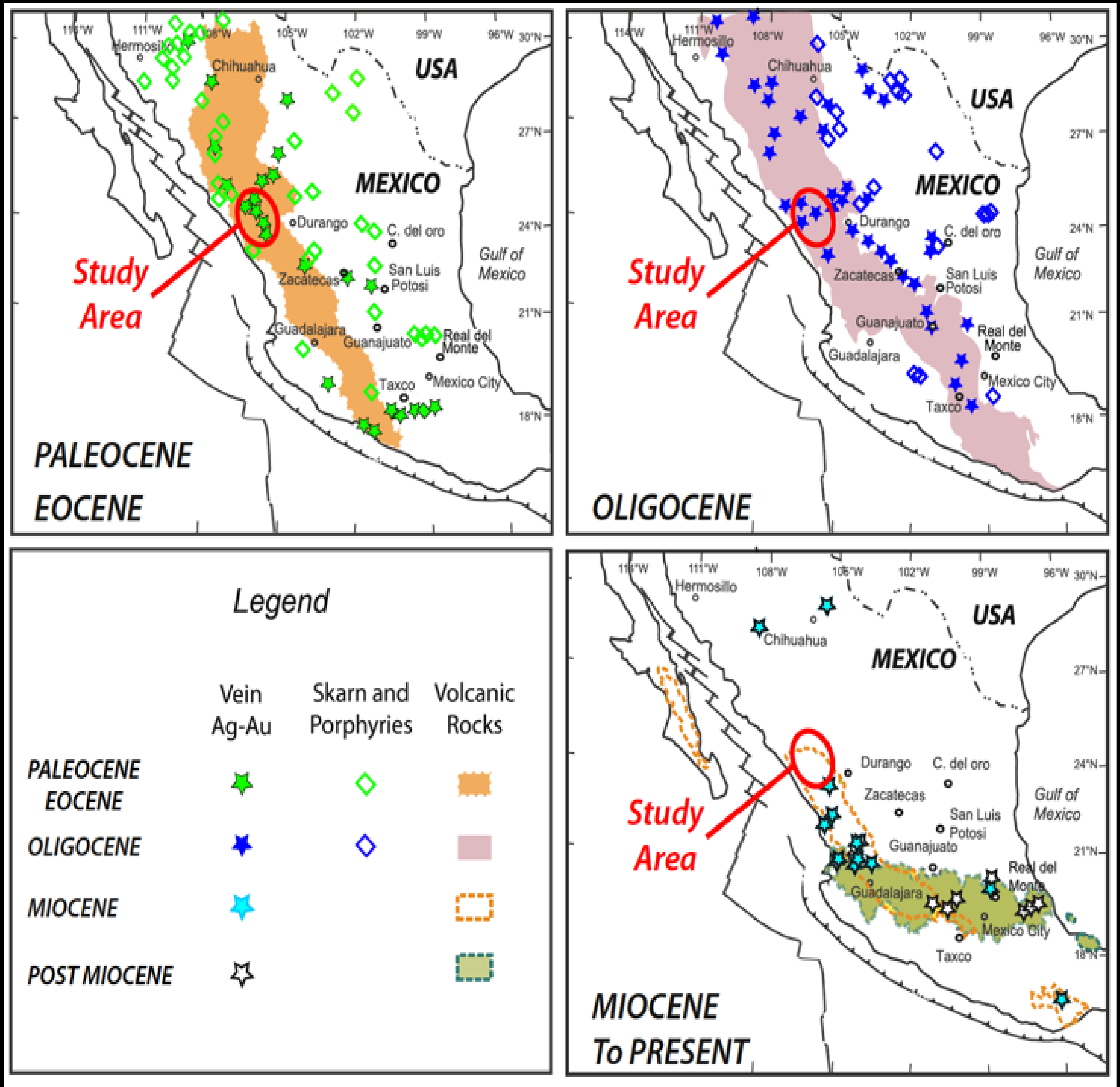
Ferrari et al., 2002, Tectonics
Ferrari et al., 2013, Geosphere
Duque et al., 2015, GSA Bull
Duque et al., 2014, RMCG






CODES

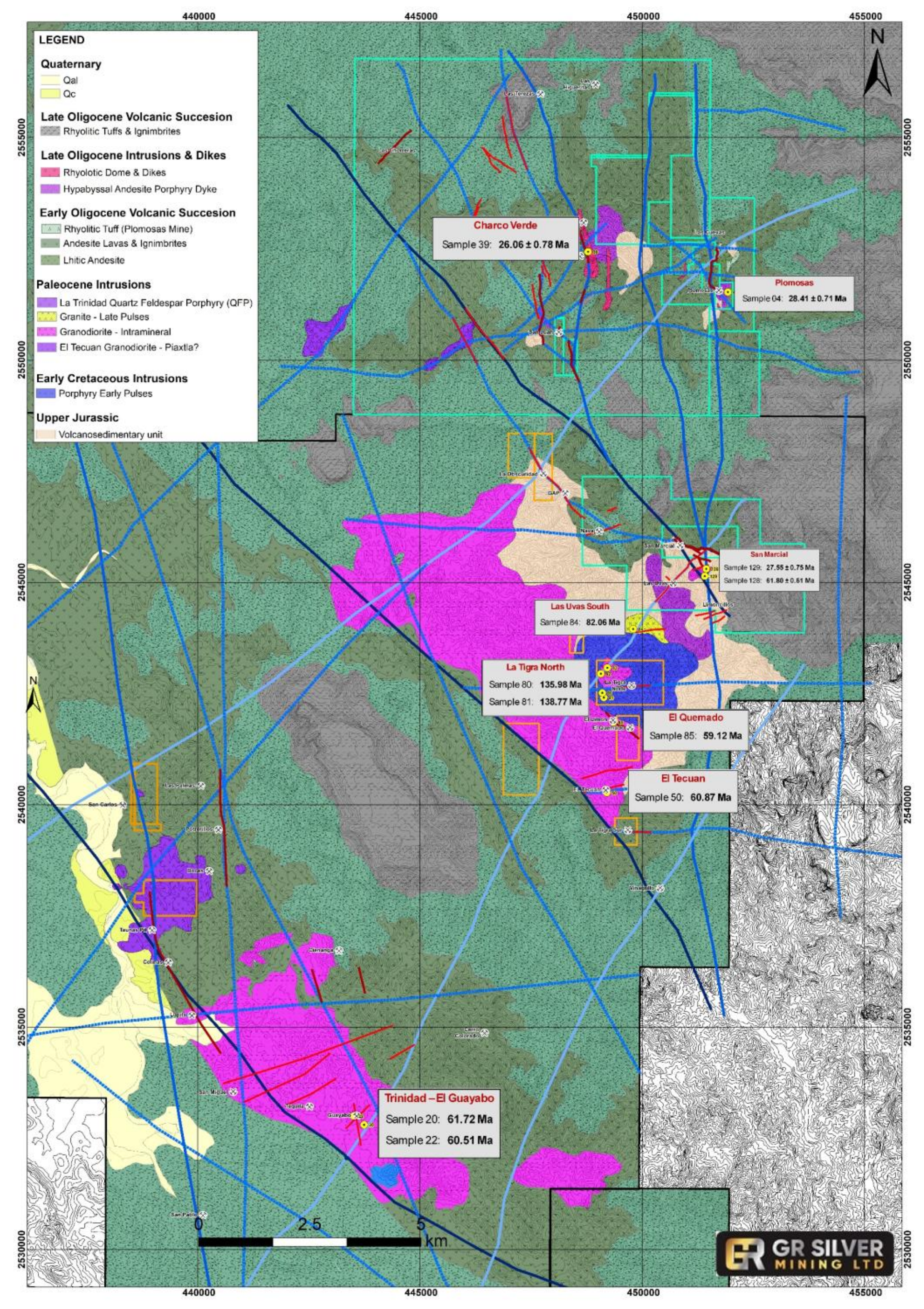
# Magmatism and ore deposit development



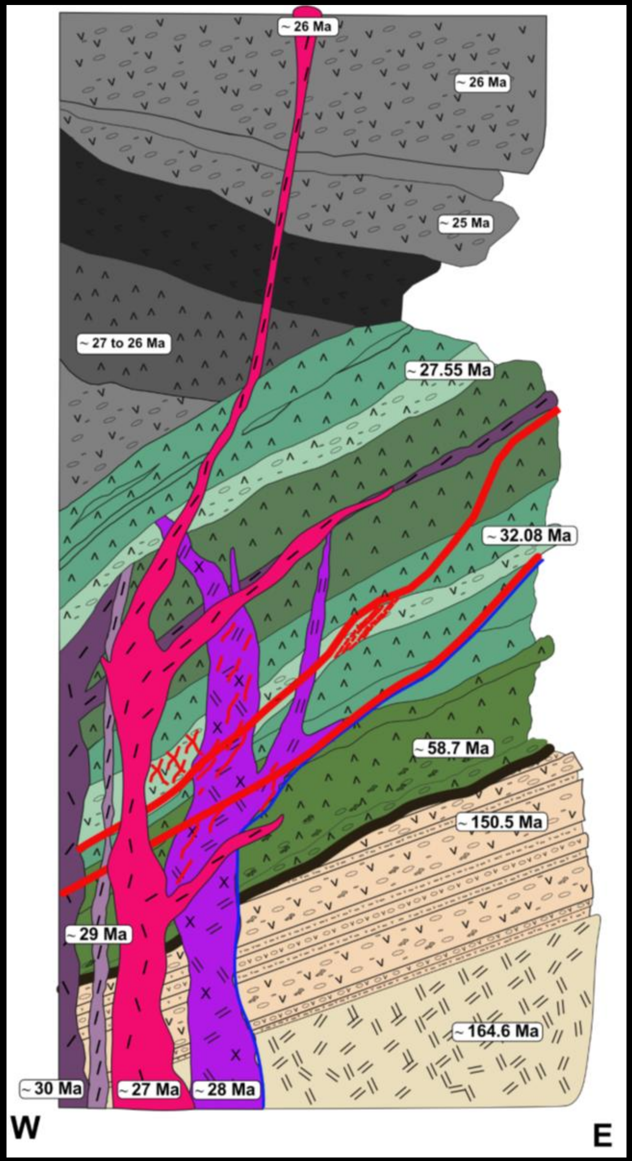

Montoya-Lopera et al., 2019, 2020a, b, 2024, 2025

CODES

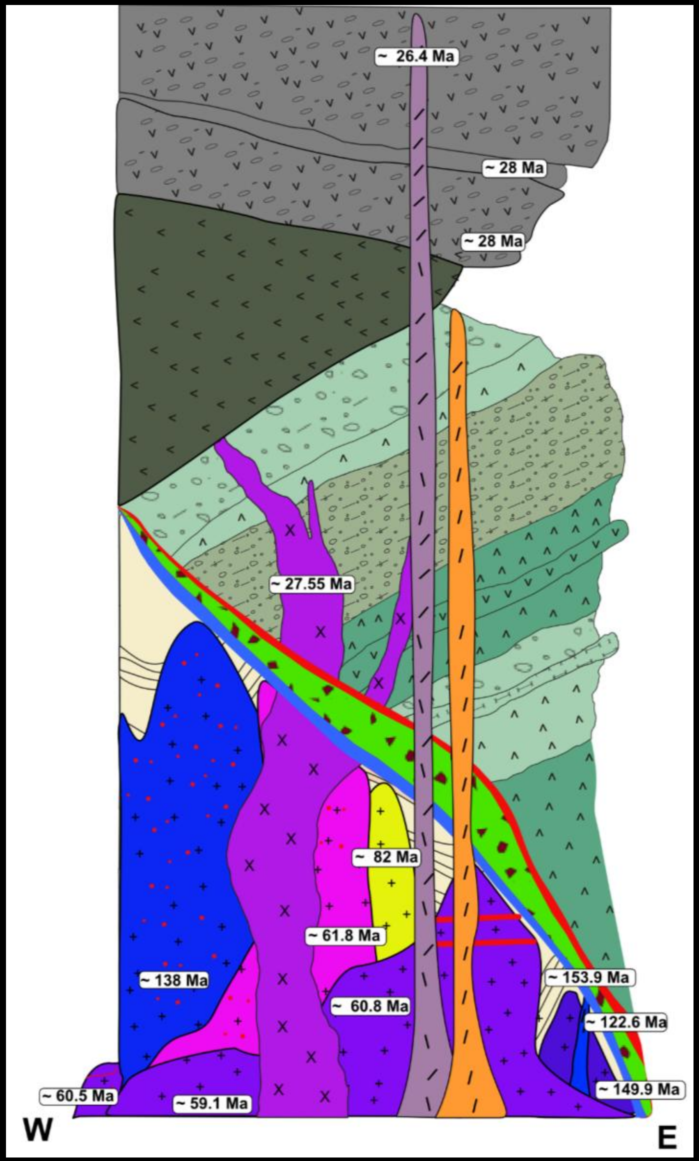
# Local geology




## Plomosas




## San Marcial



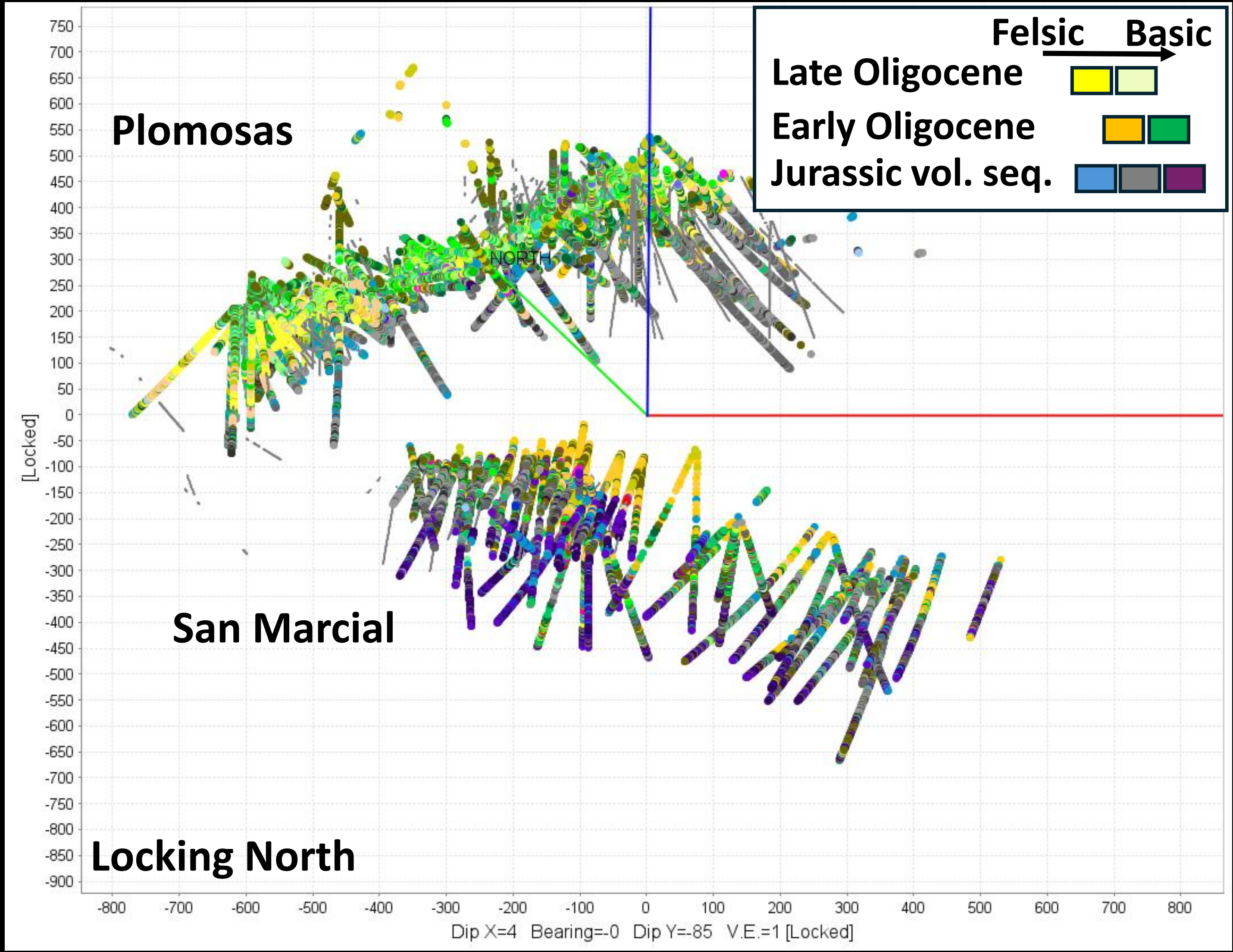

Montoya-Lopera et al., 2025

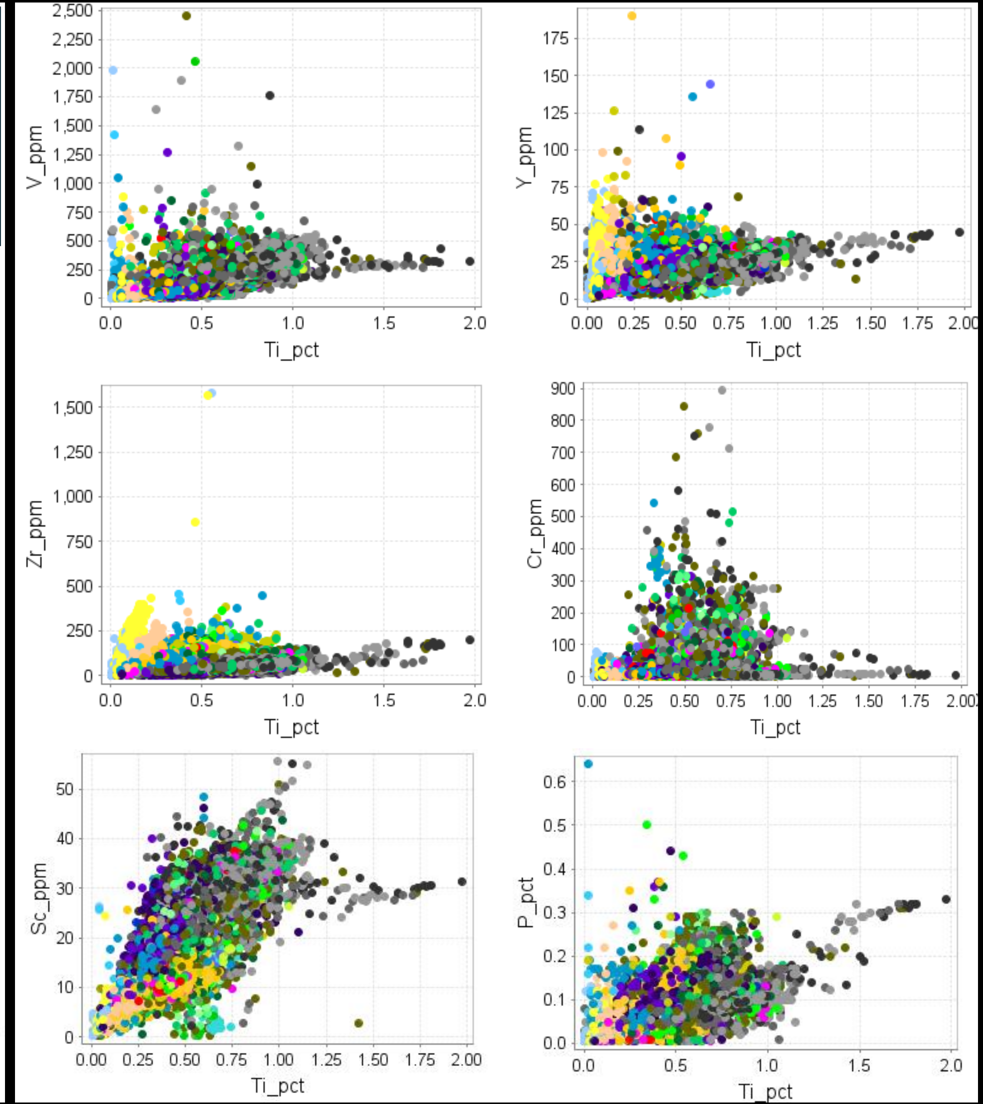
(LA-ICP-MS U/Pb zircon Ages)

CODES

# Lithogeochemistry

## Immobile elements

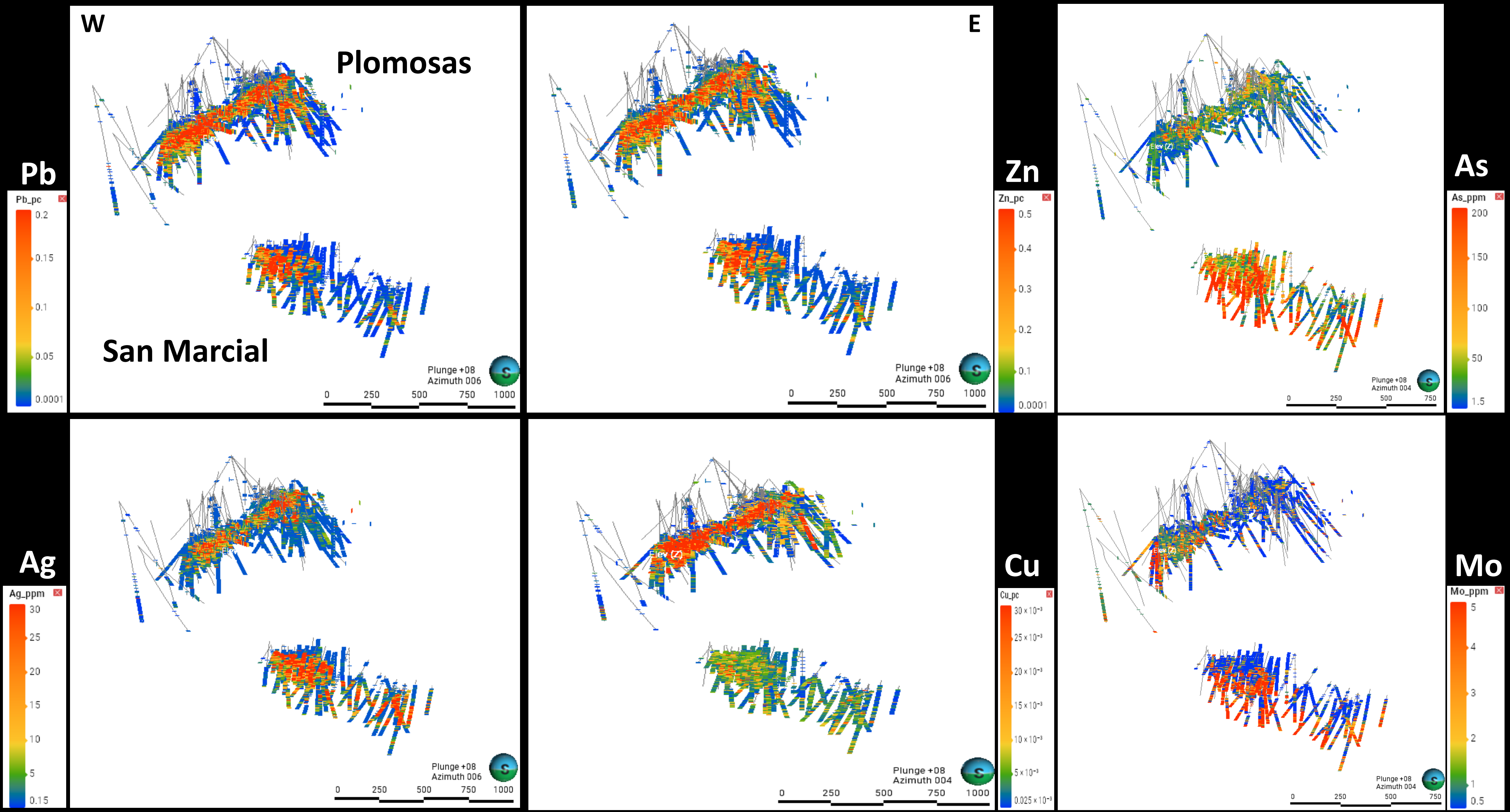



(4 Acid Assays data)

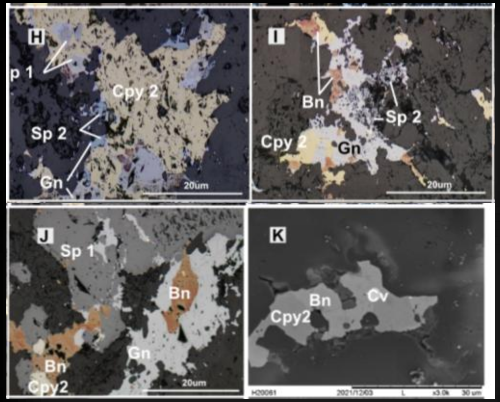
CODES

# San Marcial mineralization distribution

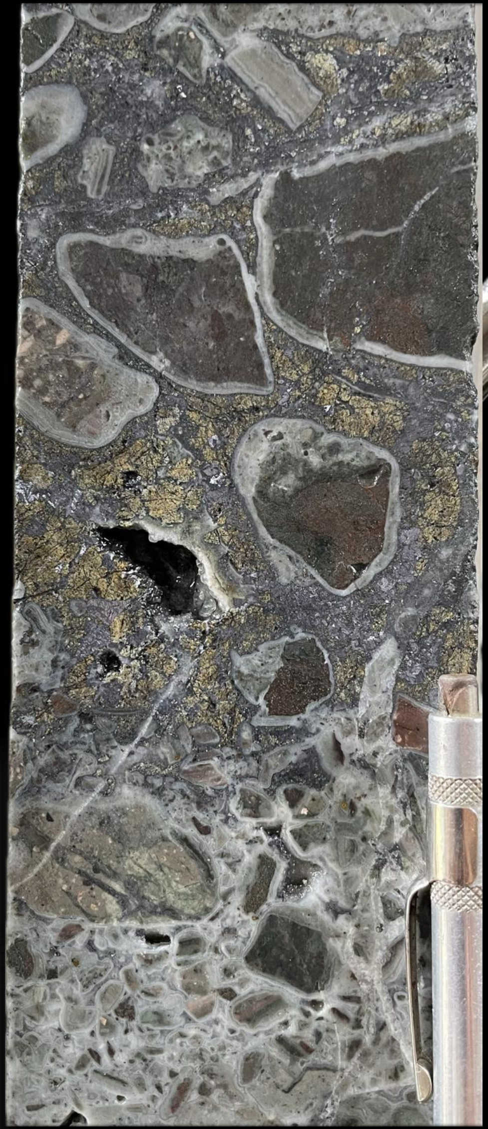


# Plomosas hydrotermal breccia


Stage 1
(Pb-Zn main event)

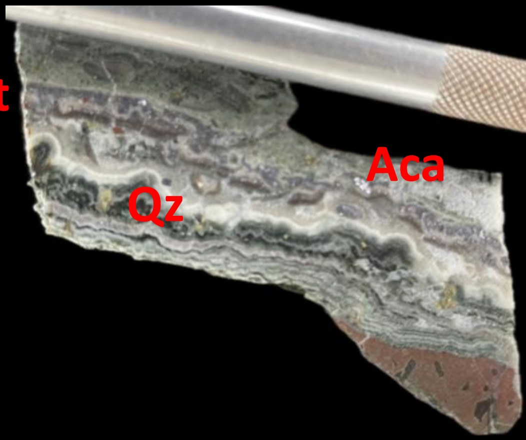

Stage 2
(Cu high grade)



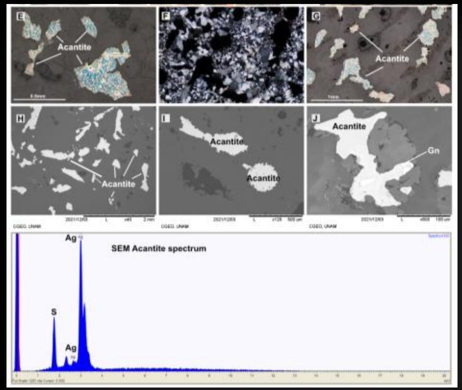
Transition zone

Stage 3
(Ag high grade)

Amethyst





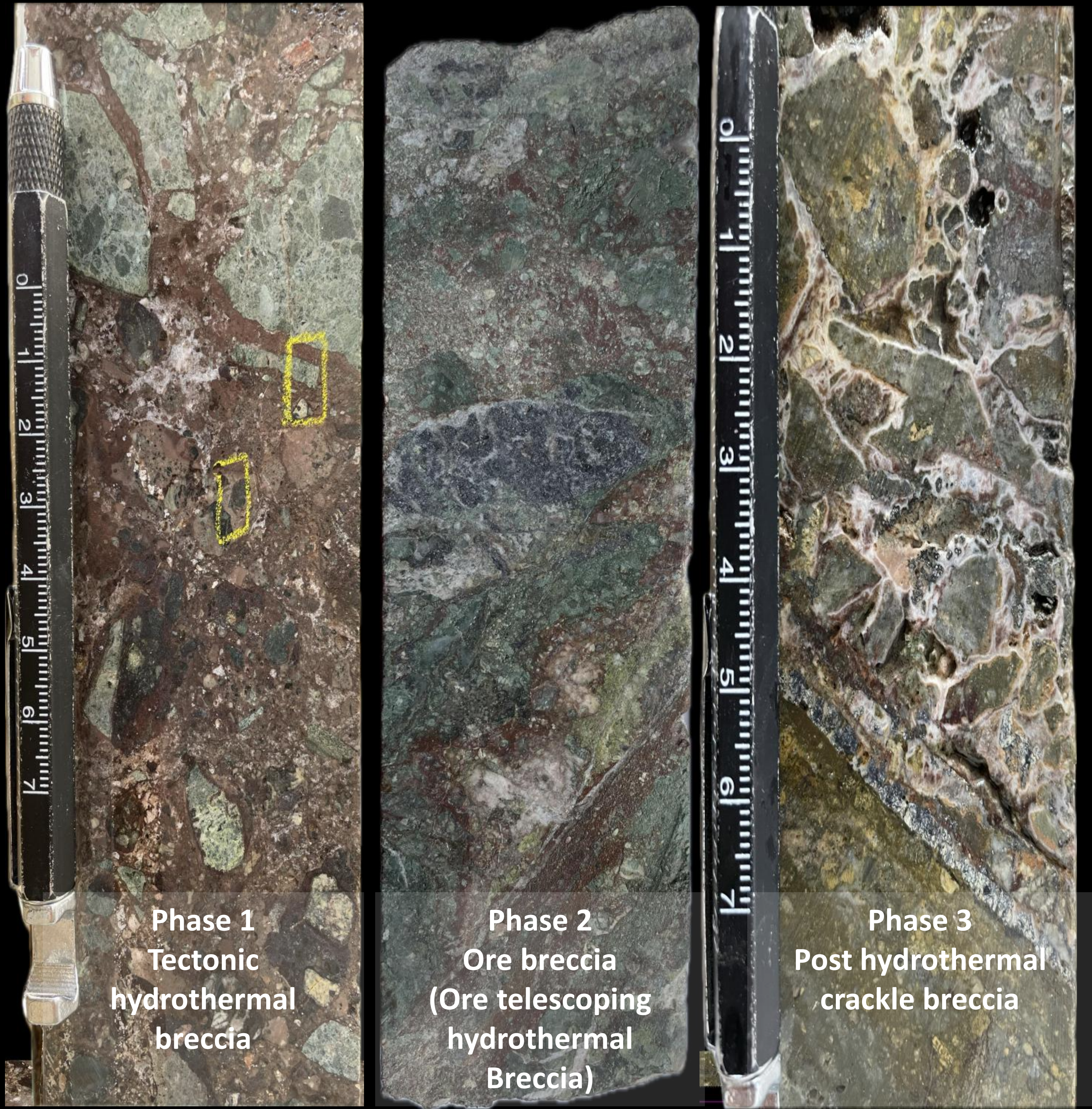



CODES

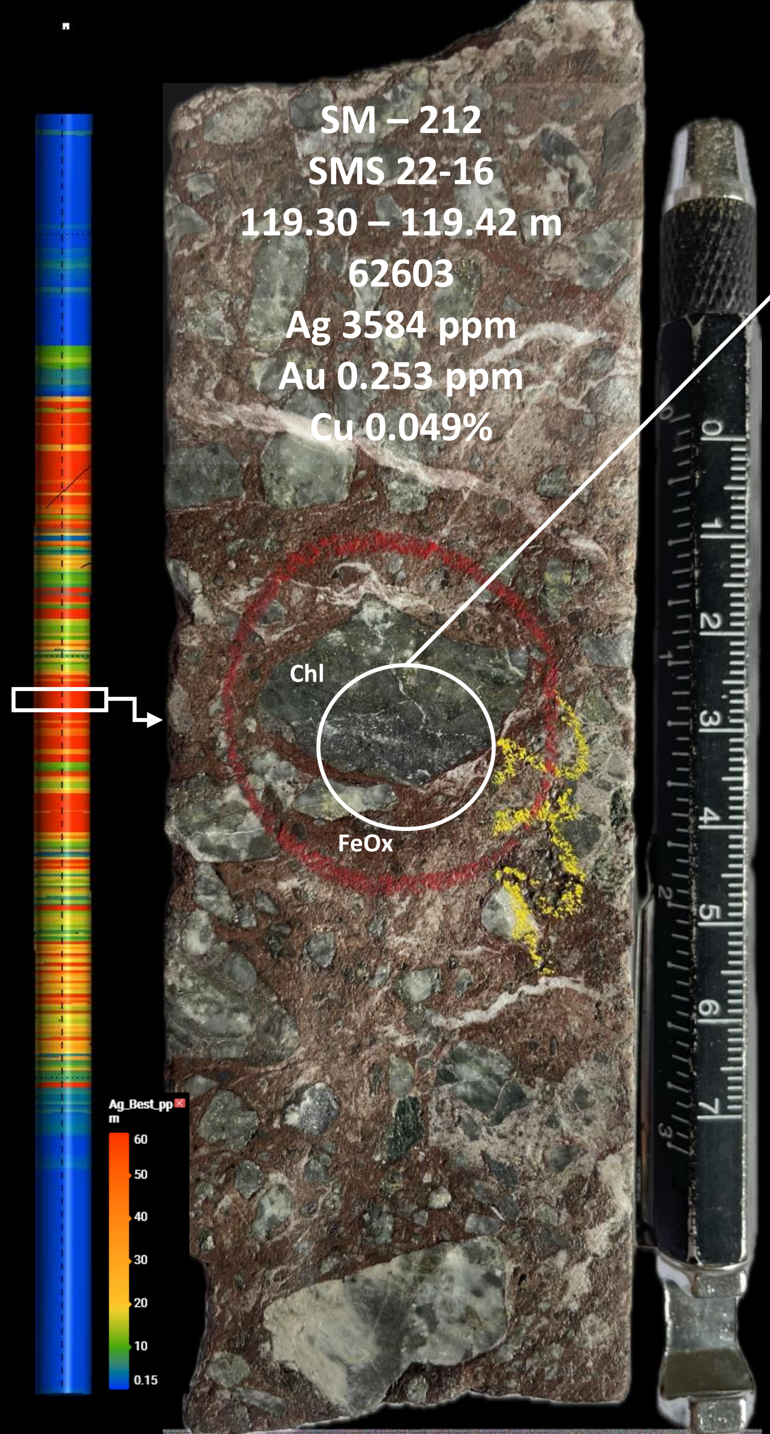
# San Marcial Ag high grade tectonic hydrothermal breccia

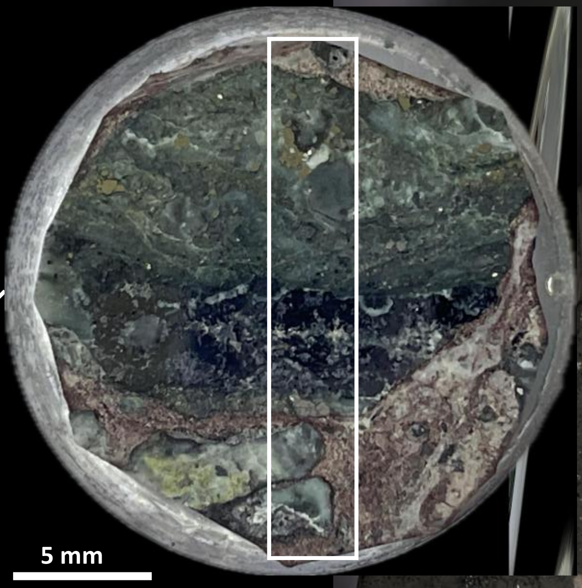
- High angle Hy bx
- Tilted East
- Oligocene ( ~27 Ma)
- Source by (andesitic porphyry int.)

- Stage 3 (pre/ore/close bx)
- Well-preserved high-grade Ag system
- Almost 5 different Ag events
- Green mineral main alt paragenesis (Mg Chl-Ep-Tur-Tr-Ca Amp)
- Hematite rich
- Barite and fluorite



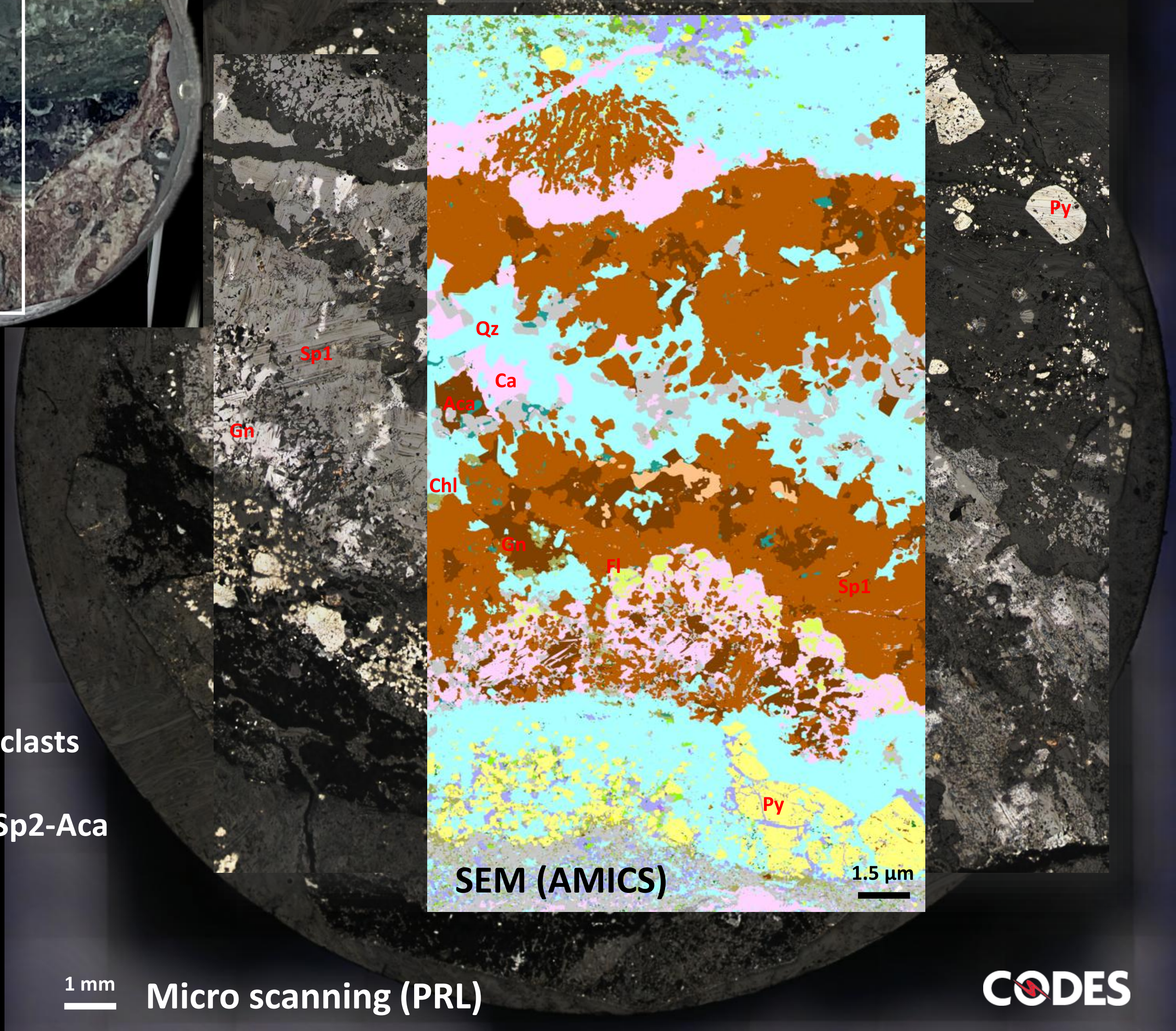
# Ore telescoping breccia (epithermal clasts)



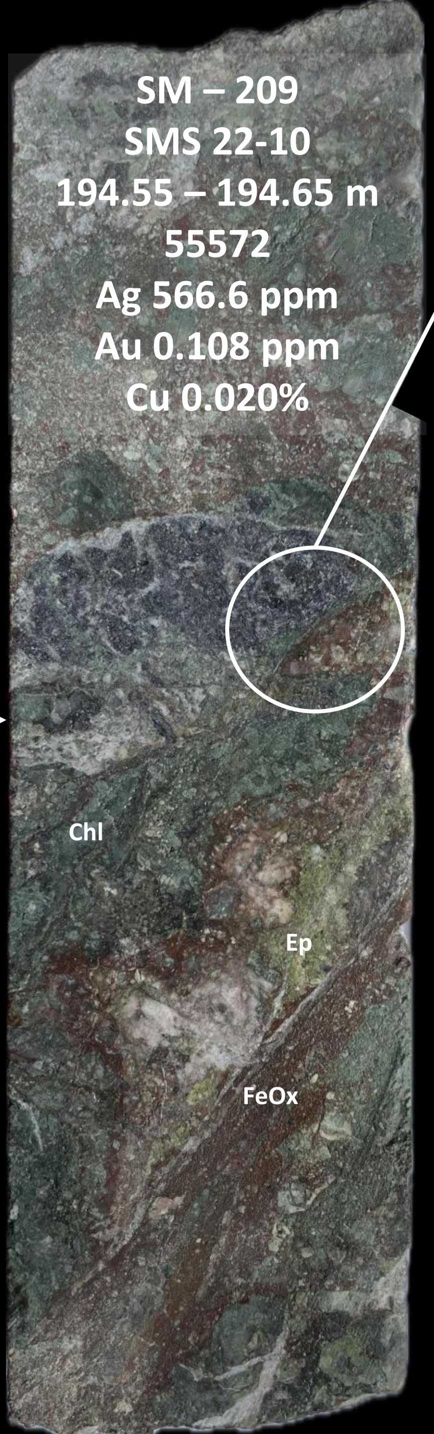

Ag high grade in clasts

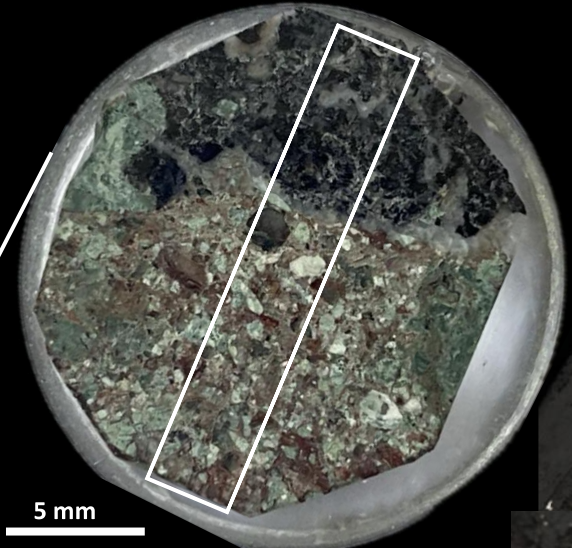
Pb: Cpy-Sp1-Gn-Sp2-Aca

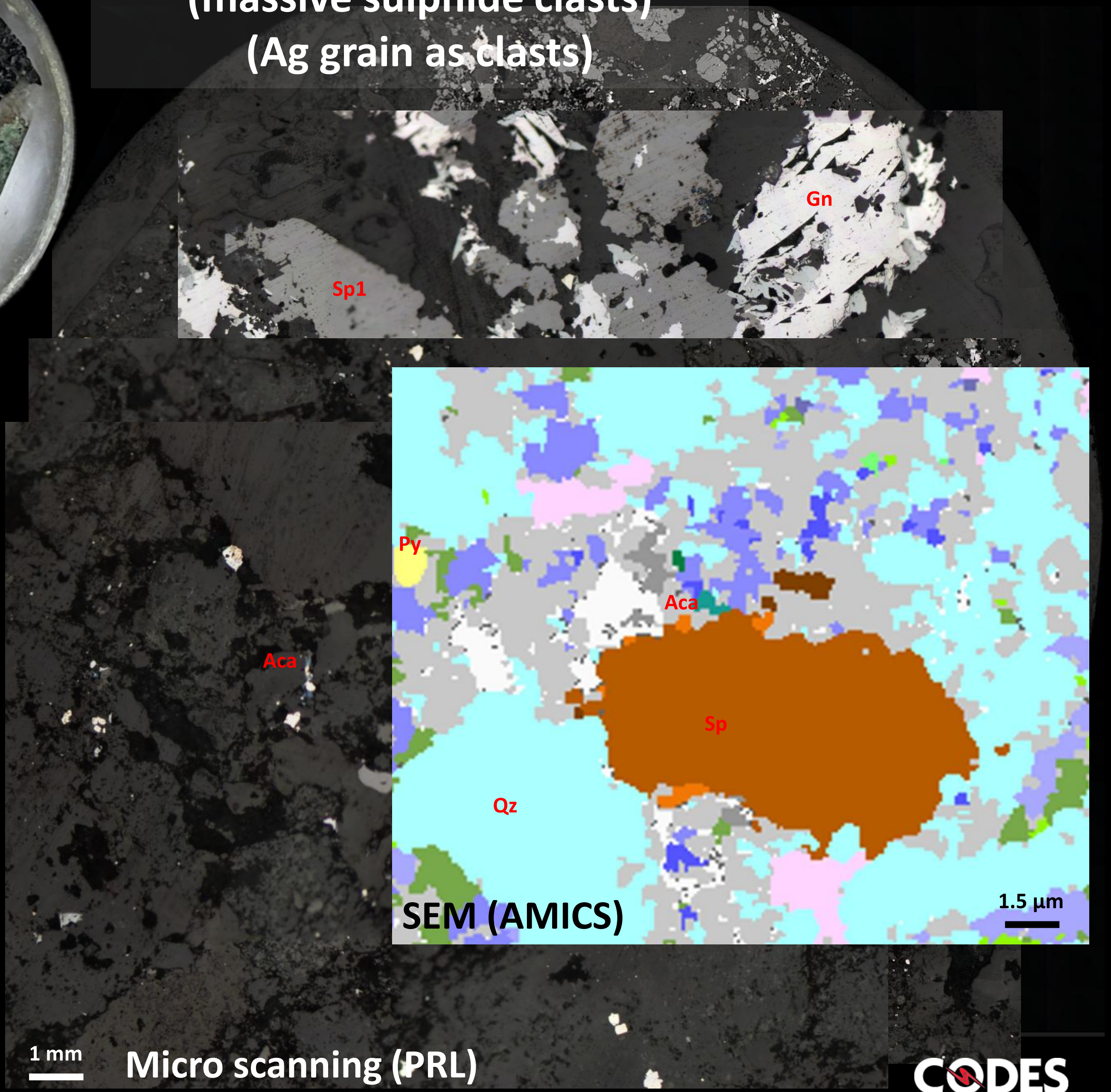


# Ore telescoping breccia (massive sulphide clasts) (Ag grain as clasts)

Micro scanning

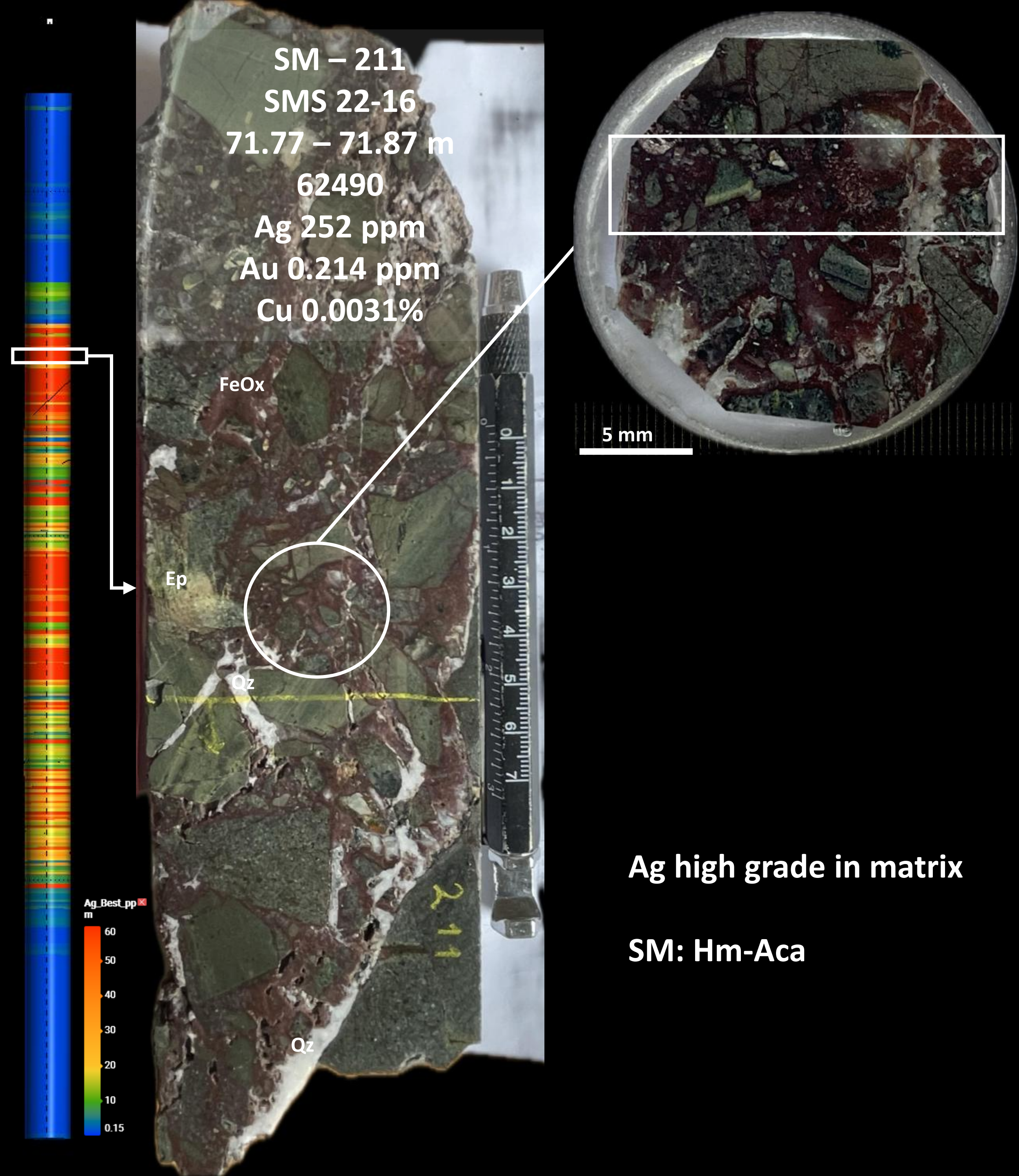




Ag high grade

SM: Aca-Py
Pb: Cpy-Sp1-Gn-Sp2

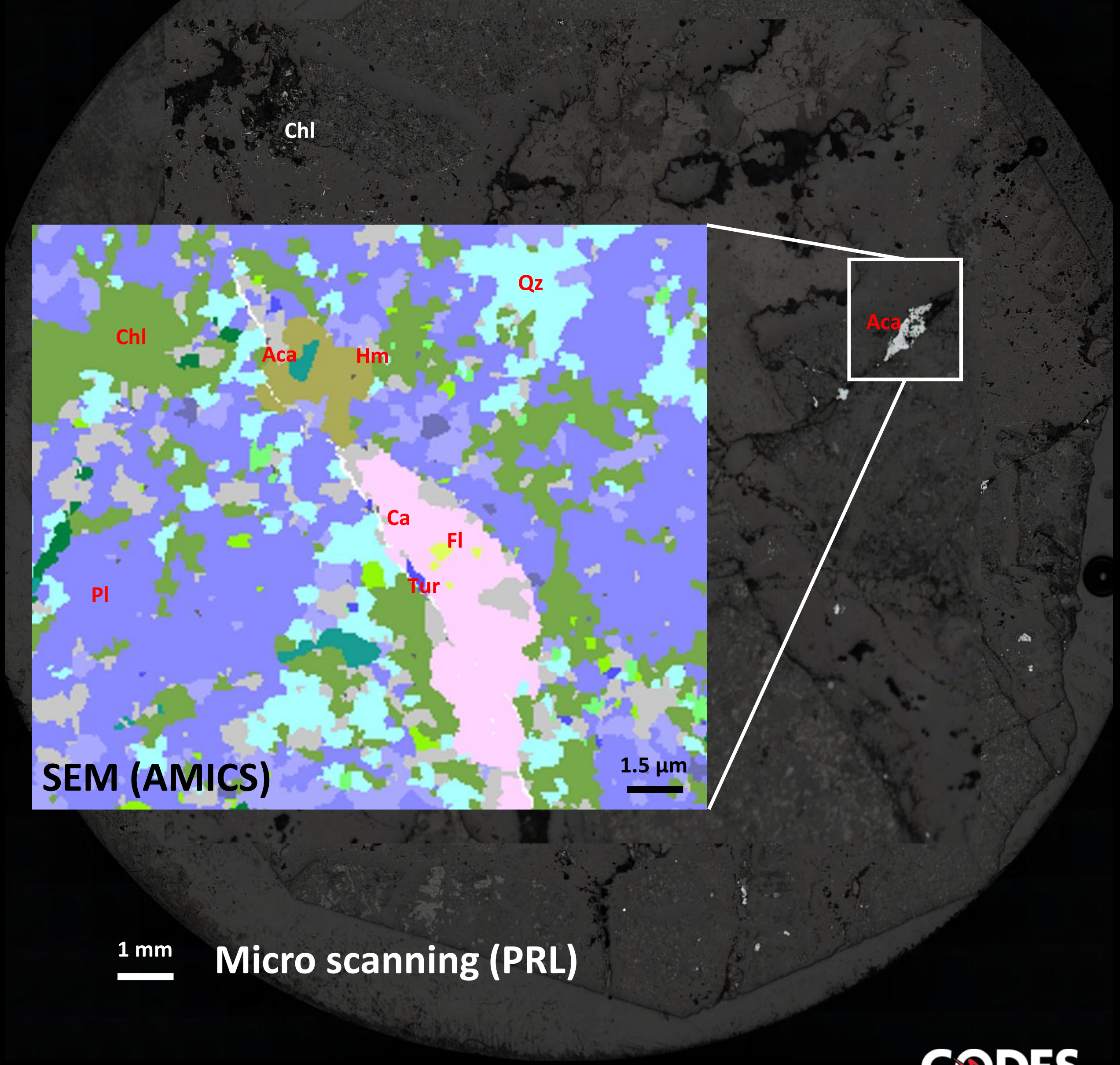
CODES

# Ore hydrothermal quartz – FeOx breccia (primary Aca filling open space)

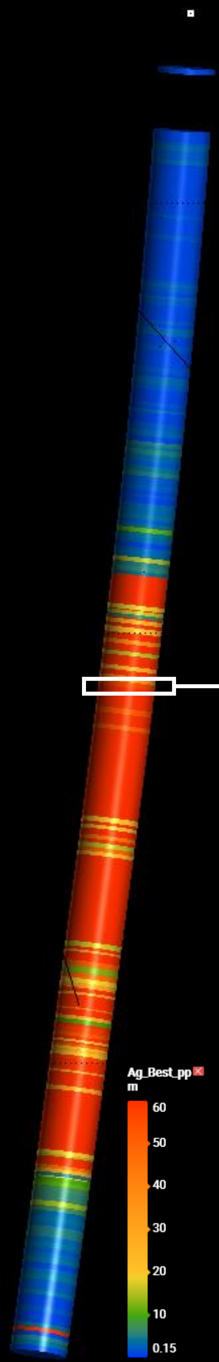


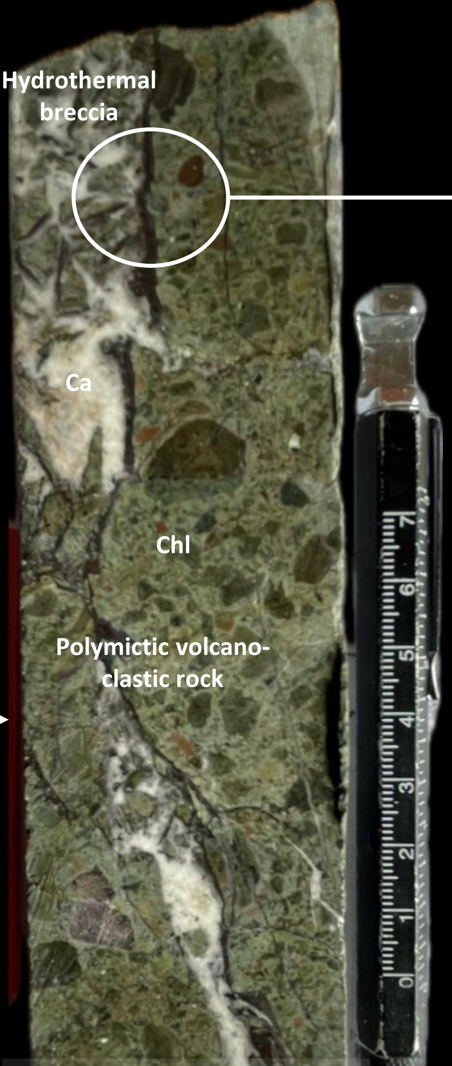

Ag high grade in matrix

SM: Hm-Aca



# Hydrothermal crackle calcite > quartz cemented breccia (primary Aca on Qz thin veins)



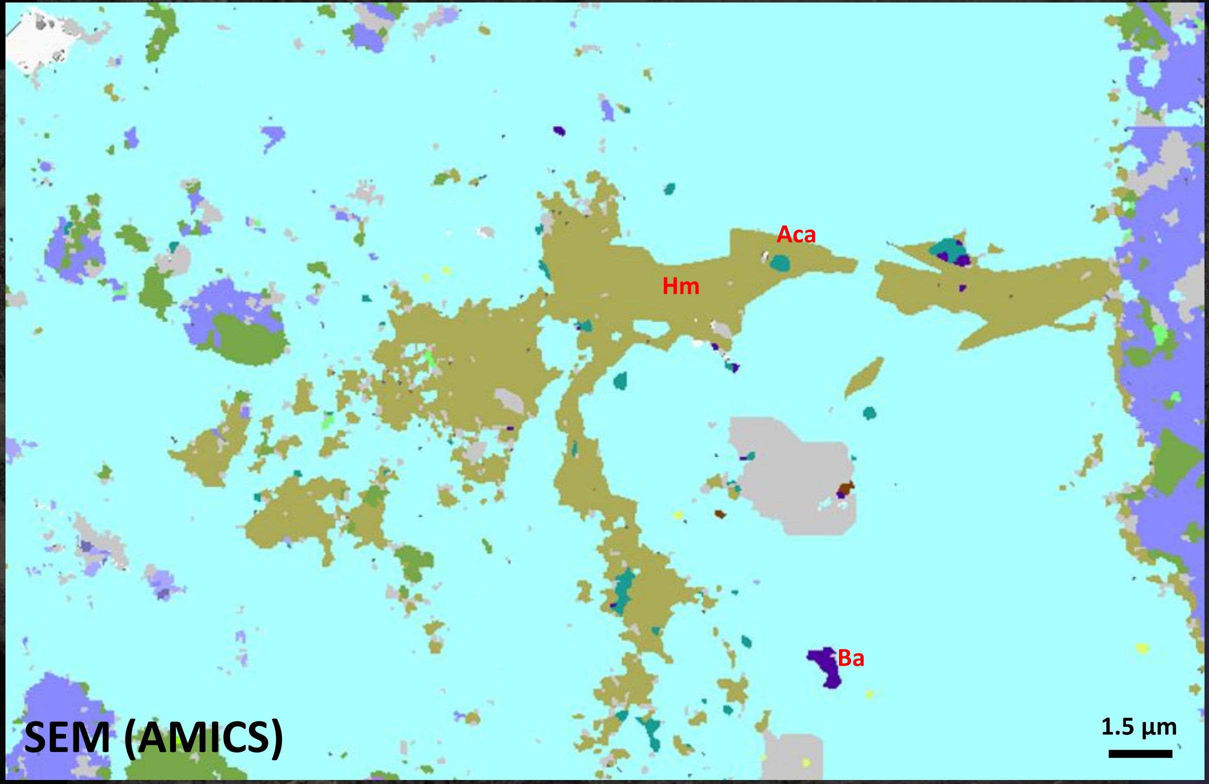





SM – 208
SMS 22-10
119.50 –119.70 m
55420
Ag 117.26 ppm
Au 0.0025 ppm
Cu 0.0038%

Ag high grade

SM: Aca-FeOx

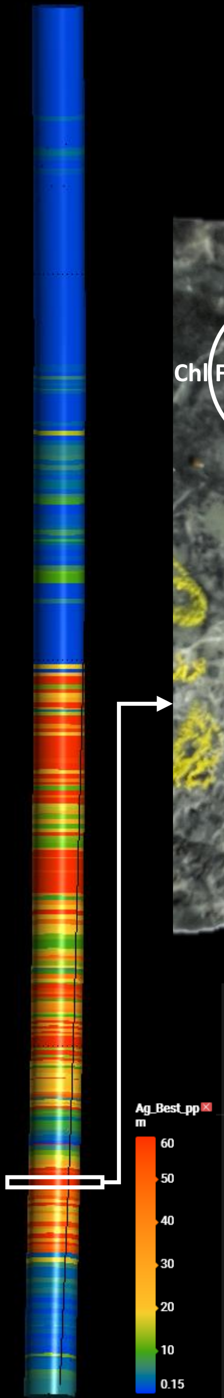



1 mm

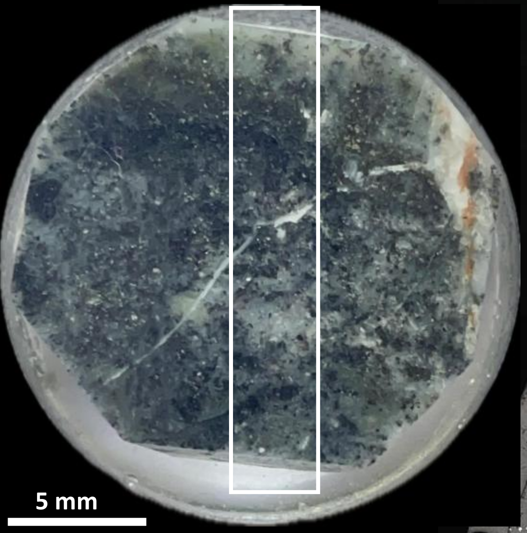
Micro scanning (PRL)

CODES

# Thin calcite vein on host rock
# (primary Arg filling thin Ca veins)



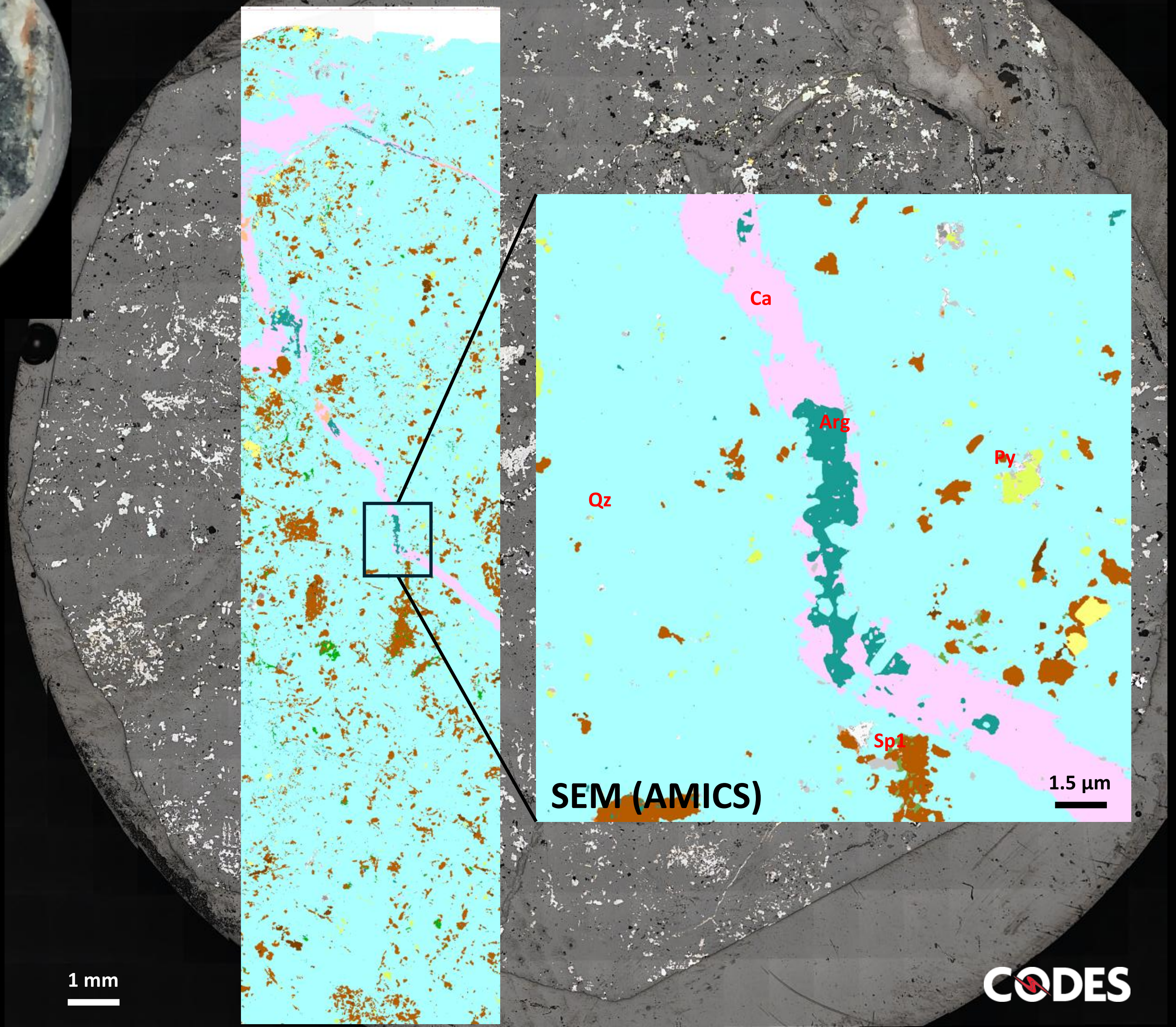




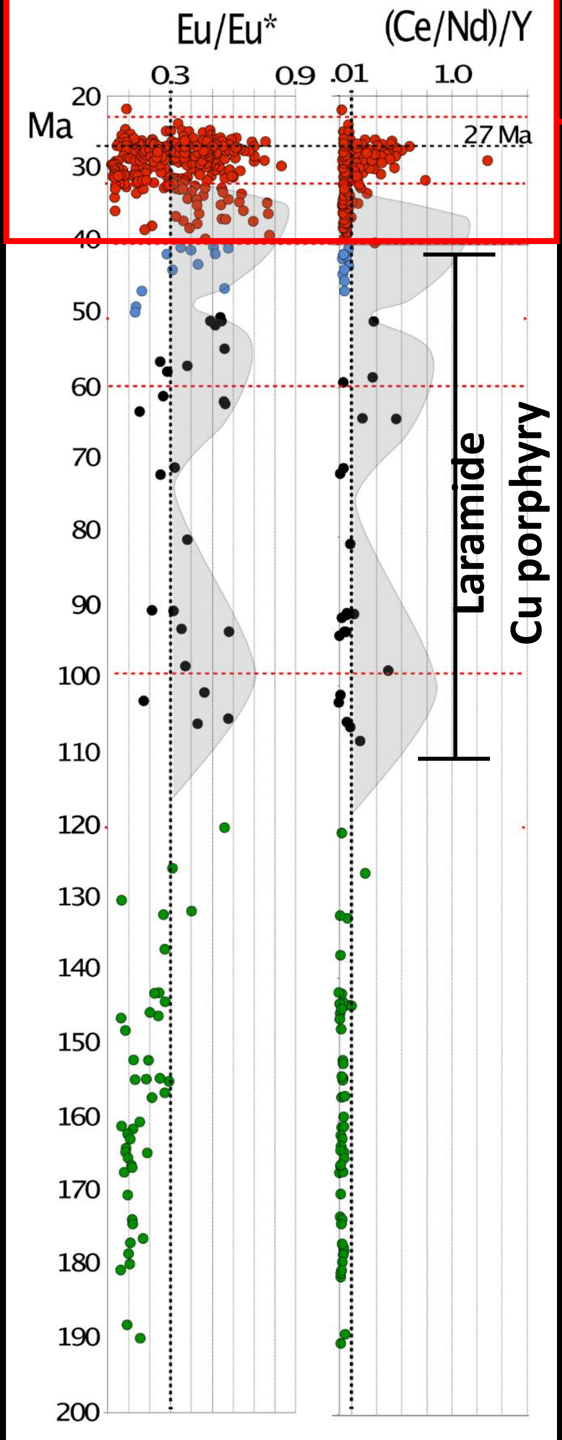

SM – 219
SMS 22-23
254.75 – 254.84 m
111066
Ag 113 ppm
Au 0.154 ppm
Cu 0.006%
As 778 ppm

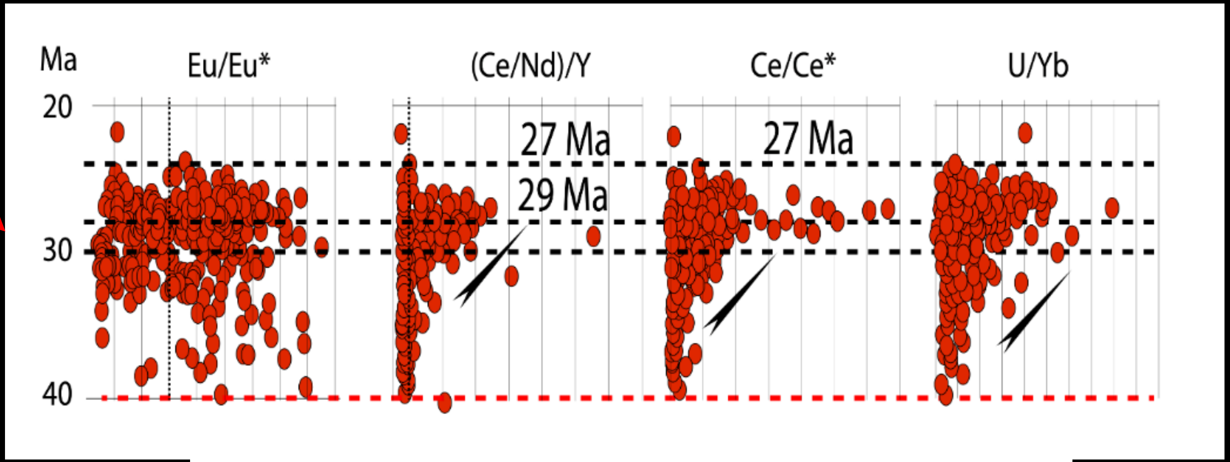
Parallel Ag high grade

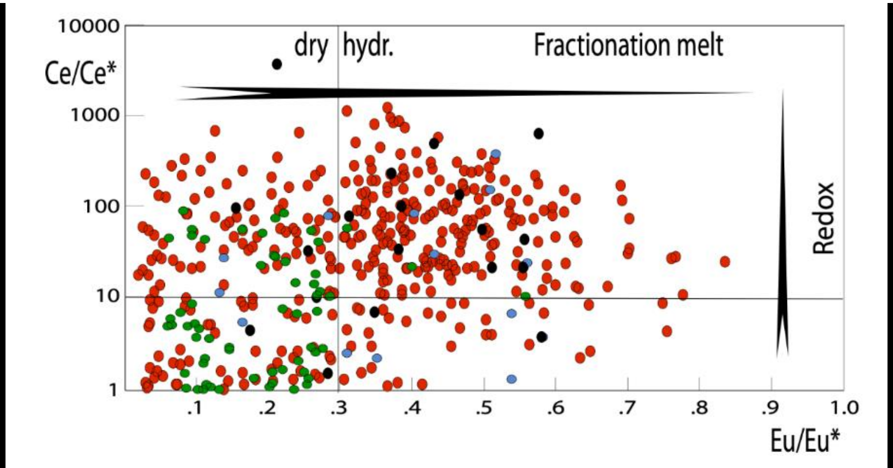
M3: Ca-Arg
M2: Sp1-Py2
M1: Py1

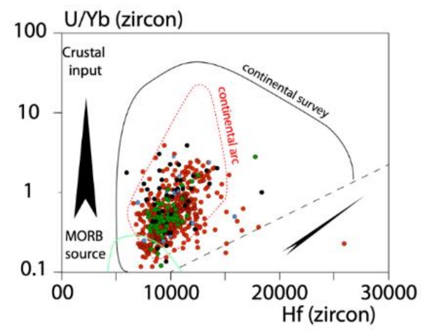


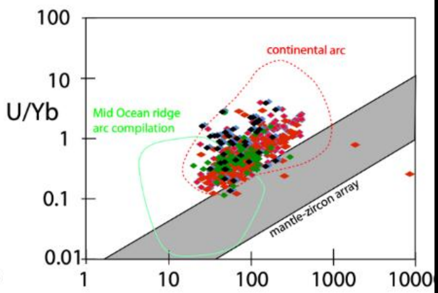
# San Marcial area geochronology fertility events



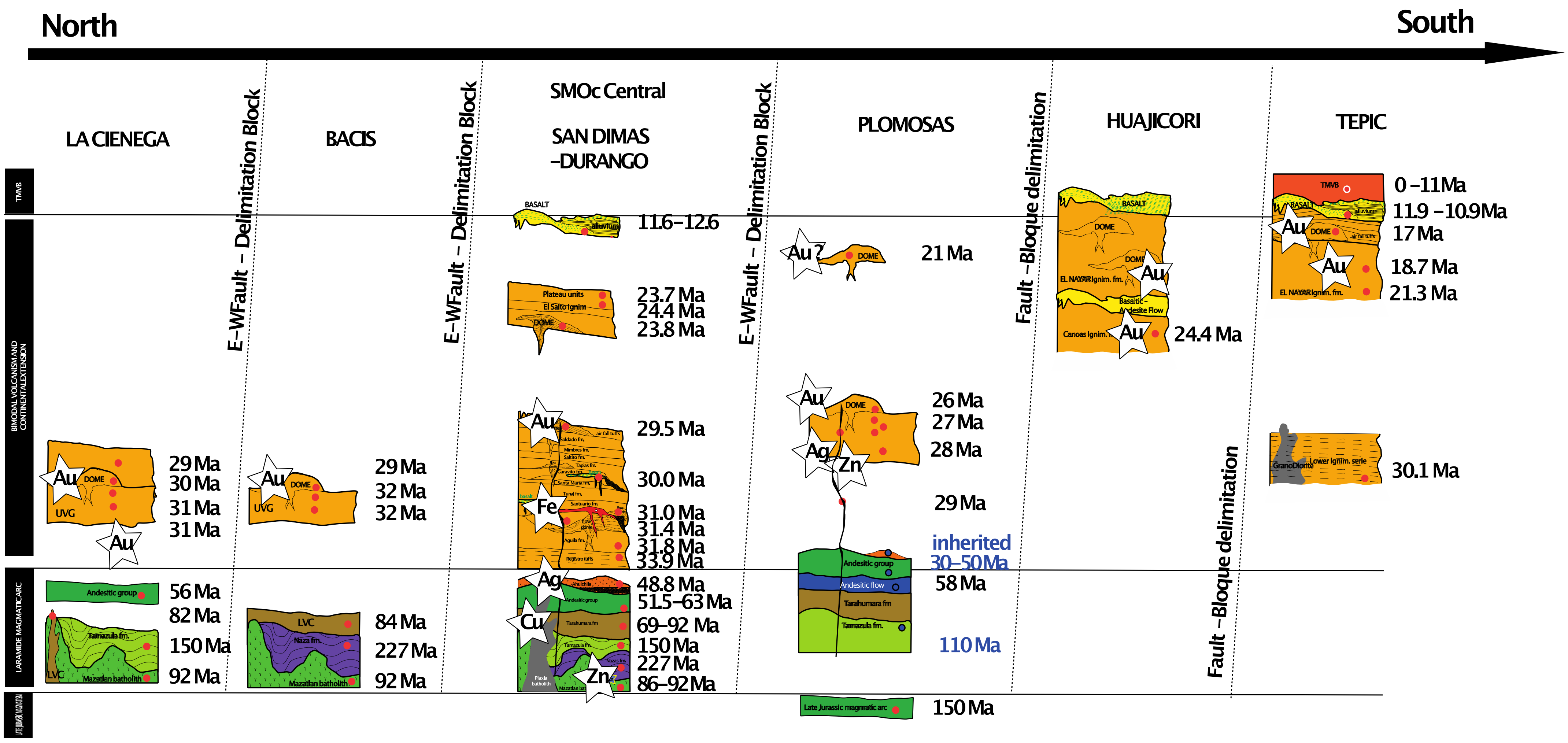




**Montoya-Lopera et al.,** ***manuscript***

CODES

# In a regional context




Montoya-Lopera et al., *manuscript*

CODES

# Role of Oligocene Volcanism in the geological setting of Ag-Au-Pb-Zn-Cu mineralization at the Plomosas District, San Marcial Area, South-Western Sierra Madre Occidental, Sinaloa, Mexico

# THANKS

Paula Montoya-Lopera*, Gilles Levresse, Marcio Fonseca, Luis Coto, Marlen Salgado, Javier Villegas, Miguel Díaz, Francisco Testa and Daniel Schrader

*paula.montoyalopera@utas.edu.au


UNIVERSITY of TASMANIA

CODES
CENTRE FOR ORE DEPOSIT AND EARTH SCIENCES

GR SILVER MINING LTD


Questions?
18TH SGA Biennial Meeting
2025
Colorado School of Mines
Golden, Colorado USA
August 3-7, 2025
UNIVERSITY of TASMANIA
CODES
CENTRE FOR ORE DEPOSIT AND EARTH SCIENCES
GR SILVER MINING LTD

# Appendices

# Lithogeochemistry


*Economic Geology*, v. 115, no. 3, pp. 489–503

## Mapping Magmatic and Hydrothermal Processes from Routine Exploration Geochemical Analyses

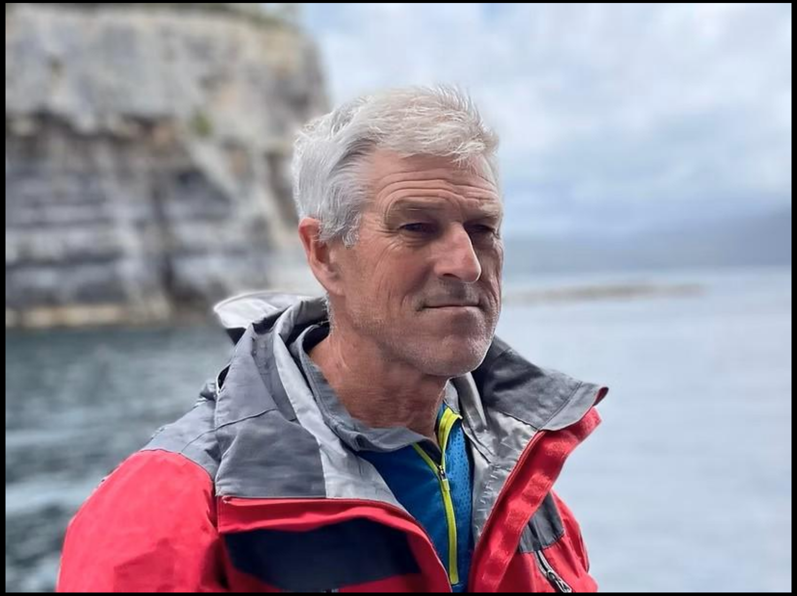
Scott Halley[1,2,†]

[1]*Mineral Mapping Pty Ltd., 109 Joyce Street, Hawley Beach, Tasmania 7307, Australia*

[2]*Centre for Ore Deposit and Earth Sciences (CODES), University of Tasmania, Hobart, Tasmania 7001, Australia*

**Abstract**

Analytical methods used by commercial assay laboratories have improved enormously in recent years. Inductively coupled plasma-atomic emission spectroscopy and inductively coupled plasma-mass spectrometry methods now report analyses for half of the periodic table with exceptional detection limits and precision. It is becoming commonplace for mining companies to use such methods routinely for the analysis of drill samples throughout mineral deposits. Improvements in software and computing power now allow rapid interrogation of upward of 100,000 assay samples. Geochemical analyses are quantitative, are independent of observer bias, and can form the basis for robust geologic and mineralogical models of mineral deposits, as well as shed light on scientific questions. In particular, consistently collected, high-quality geochemical analyses can significantly improve and systematize logging of lithological and hydrothermal alteration mineralogic changes within drill core. In addition, abundant, high-quality geochemical data provide insights into magmatic and hydrothermal processes that were previously difficult to recognize and that have obvious applications to mineral exploration and improved genetic models of ore deposits. This paper describes a workflow that mining industry geologists can apply to their multielement analysis data to extract more information about magma compositions and gangue mineralogy.



**Scott Halley**
**Adjunct Professor at CODES/UTAS**

# Periodic Table of Elements and Oxides for Petrologists

| Atomic # Symbol Element Atomic Wt. | • Valence state • Ionic radii (nm) for oxygen coordination numbers (e.g. VI) • Pauling % ionic character of bond with oxygen | Average composition of oxide (weight percent) or element (ppm) in various rock types . See caption for sources. | Average composition of oxide (weight percent) or element (ppm) in various reservoirs . See caption for sources | Valence Oxide Formula Formula Wt. |
|---|---|---|---|---|

Links to other Periodic Tables
- Royal Society of Chemistry Periodic Table
- IUPAC Periodic Table of the Elements and Isotopes
- The Earth Scientist's Periodic Table of the Elements and Their Ions
- Michael Dayah Dynamic Periodic Table

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 H 1.008 | | | | | | | | | | | | | | | | | 2 He 4.003 |
| 3 Li 6.941 | 4 Be 9.012 | | | | | | | | | | | 5 B 10.81 | 6 C 12.011 | 7 N 14.007 | 8 O 15.999 | 9 F 18.998 | 10 Ne 20.18 |
| 11 Na 22.990 | 12 Mg 24.305 | | | | | | | | | | | 13 Al 26.982 | 14 Si 28.085 | 15 P 30.974 | 16 S 32.06 | 17 Cl 35.45 | 18 Ar 39.948 |
| 19 K 39.098 | 20 Ca 40.078 | 21 Sc 44.956 | 22 Ti 47.987 | 23 V 50.942 | 24 Cr 51.996 | 25 Mn 54.938 | 26 Fe 55.845 | 27 Co 58.933 | 28 Ni 58.693 | 29 Cu 63.546 | 30 Zn 65.38 | 31 Ga 69.723 | 32 Ge 72.630 | 33 As 74.922 | 34 Se 78.971 | 35 Br 79.904 | 36 Kr 83.798 |
| 37 Rb 85.468 | 38 Sr 87.62 | 39 Y 88.906 | 40 Zr 91.224 | 41 Nb 92.906 | 42 Mo 95.95 | 43 Tc 98 | 44 Ru 101.070 | 45 Rh 102.906 | 46 Pd 106.42 | 47 Ag 107.868 | 48 Cd 112.414 | 49 In 114.818 | 50 Sn 118.710 | 51 Sb 121.760 | 52 Te 127.60 | 53 I 126.904 | 54 Xe 131.293 |
| 55 Cs 132.905 | 56 Ba 137.327 | 57-71 | 72 Hf 178.49 | 73 Ta 180.948 | 74 W 183.84 | 75 Re 186.207 | 76 Os 190.23 | 77 Ir 192.217 | 78 Pt 195.084 | 79 Au 196.967 | 80 Hg 200.592 | 81 Tl 204.38 | 82 Pb 207.2 | 83 Bi 208.980 | 84 Po 209 | 85 At 210 | 86 Rn 222 |
| 87 Fr 223 | 88 Ra 226 | 89-103 | 104 Rf 267 | 105 Db 268 | 106 Sg 269 | 107 Bh 270 | 108 Hs 269 | 109 Mt 278 | 110 Ds 281 | 111 Rg 280 | 112 Cn 285 | 113 Nh 286 | 114 Fl 289 | 115 Mc 289 | 116 Lv 293 | 117 Ts 294 | 118 Og 294 |
| | | | 57 La 138.905 | 58 Ce 140. 116 | 59 Pr 140.908 | 60 Nd 144.242 | 61 Pm 145 | 62 Sm 150.36 | 63 Eu 151.964 | 64 Gd 157.25 | 65 Tb 158.925 | 66 Dy 162.500 | 67 Ho 164.930 | 68 Er 167.259 | 69 Tm 168.934 | 70 Yb 173.045 | 71 Lu 174.967 |
| | | | 89 Ac 227 | 90 Th 232.038 | 91 Pa 231.036 | 92 U 238.029 | 93 Np 237 | 94 Pu 244 | 95 Am 243 | 96 Cm 247 | 97 Bk 247 | 98 Cf 251 | 99 Es 252 | 100 Fm 257 | 101 Md 258 | 102 No 259 | 103 Lr 262 |

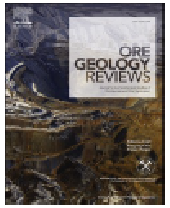
MORB Values
- 0.1-100 wt%
- 10-1000 ppm
- 0.1-10 ppm
- < 0.1 ppm
- n.a.

ELSEVIER

Contents lists available at ScienceDirect

Ore Geology Reviews

journal homepage: www.elsevier.com/locate/oregeorev




Check for updates

# Simple graphical tools to understand the relationship between porphyry composition, hydrothermal alteration, mineralogy and copper-gold grades in porphyry copper deposits

Ross R. Large

*CODES, Earth Sciences, University of Tasmania, Tasmania 7005, Australia*

A R T I C L E   I N F O

*Keywords:*
Porphyry copper deposits
Diorite porphyry
PCD alteration plot
Albitisation
Lithogeochemistry
Peschanka
Kharmagtai

A B S T R A C T

Alteration zonation in porphyry copper deposits is a standard tool to establish spatial relationships with respect to the best Cu-grade core of the magmatic-hydrothermal system. With the development in recent times of low cost and good quality whole-rock multi-element ICP-MS analysis, large databases of drill hole litho-geochemistry have become available from drilling campaigns of porphyry copper targets. Here I propose some simple graphical tools that use multi-element datasets to evaluate alteration type and their relationship to Cu grades. I suggest a five part methodology; 1) determine the original least altered porphyry composition(s) by using the AI vs CCPI plot, 2) use the molar K/Al vs Na/Al plot to discriminate the basic alteration type, 3) check for alunite and anhydrite using the Ca-Fe-S plot, 4) follow-up with the porphyry copper alteration plot [K/(K + Ca) vs K/(K + Al)] to finalise the discrimination of alteration type. 5) plot all data with Cu > 0.5 % on the K/(K + Ca) vs K/(K + Al) diagram (4 above), as a density plot, to evaluate the relationship between Cu grades and alteration type.

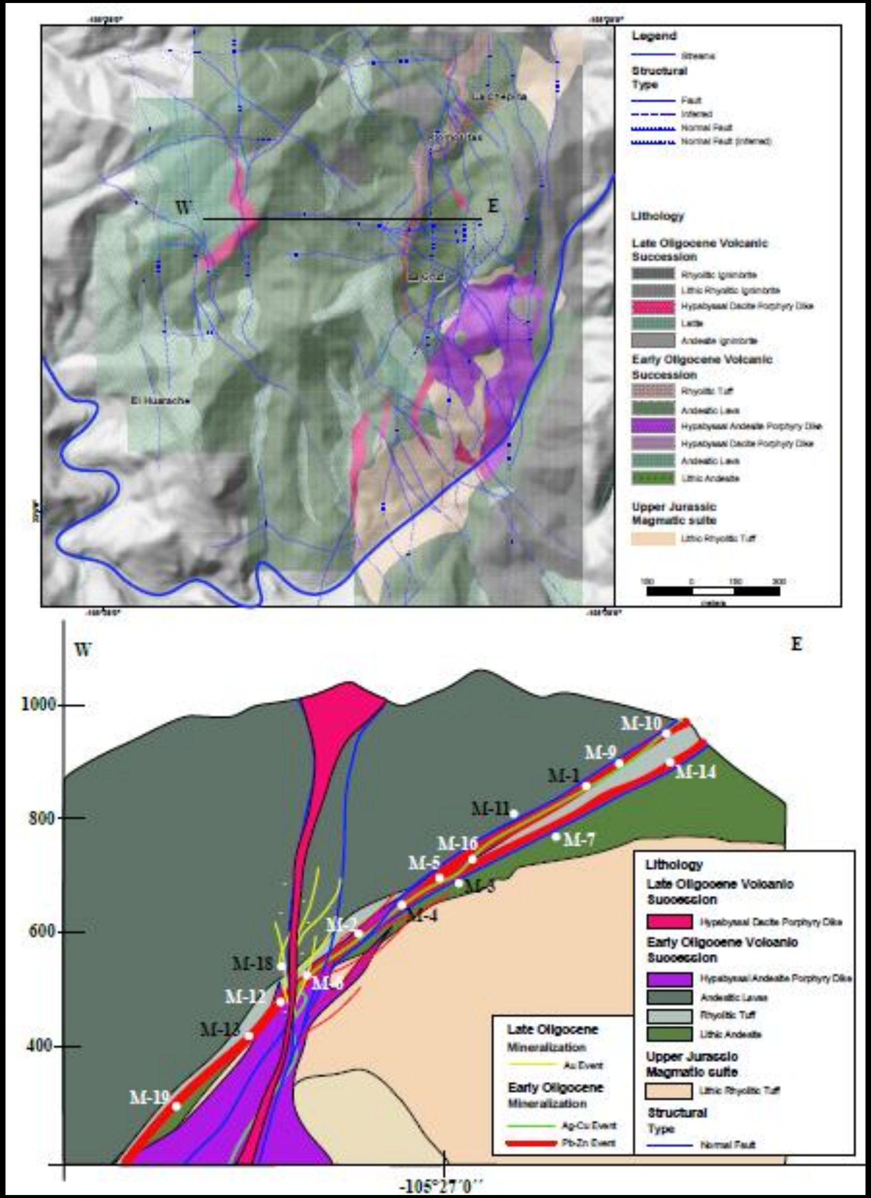
Three case studies are provided that outline the methodology and show the importance of the composition(s) of the host porphyry intrusion(s) in controlling the relationship between Cu-grades, bulk mineralogy and alteration type. Based on these case studies it is clear that not all, or even most, of the samples with greater than 0.5% Cu are always concentrated in the potassic alteration type.

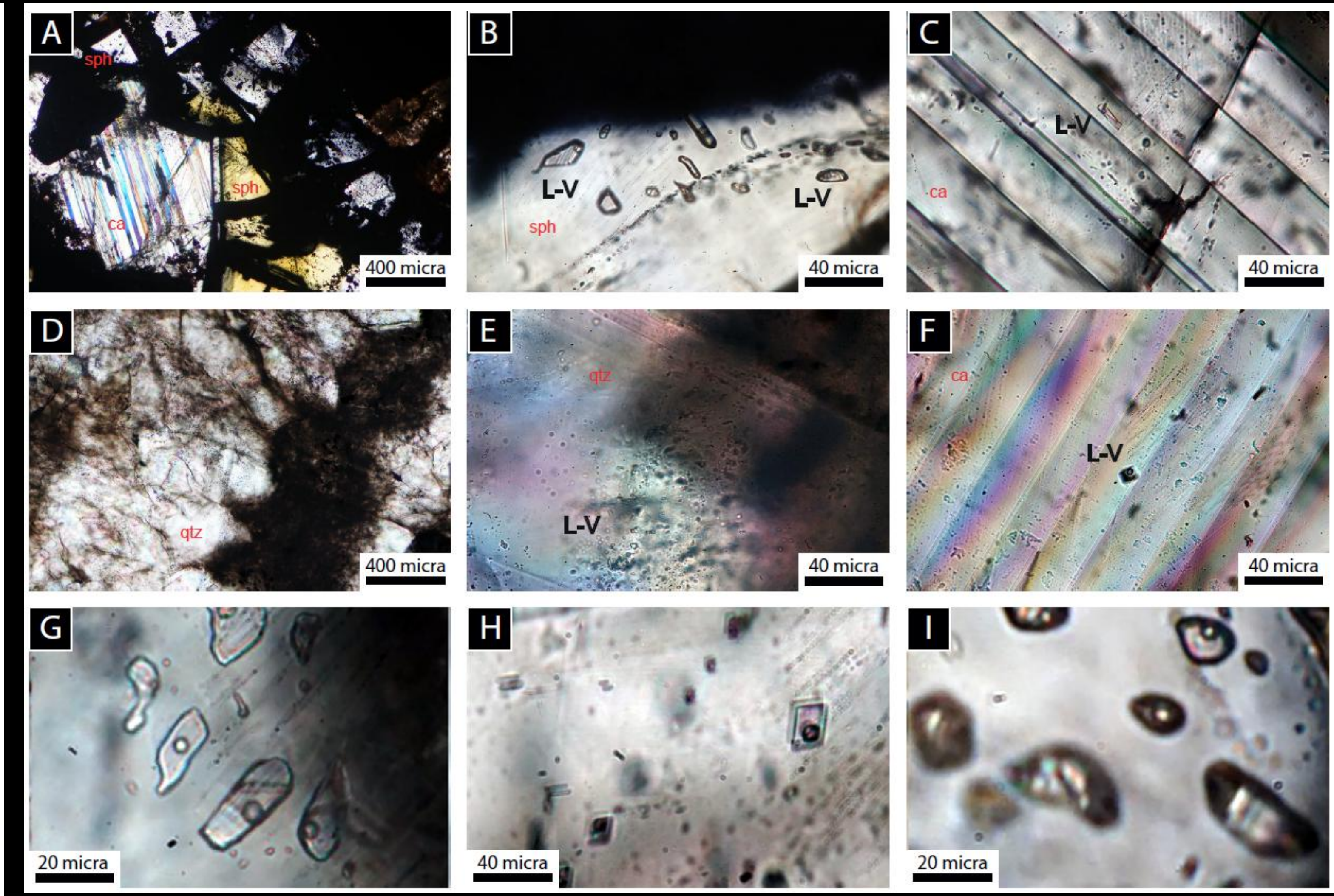
Application of the MINSQ computer program has enabled mineral concentrations to be estimated and plotted on the alteration type diagram K/(K + Ca) vs K/(K + Al) in each of the case studies. This approach suggests that in monzonite and granodiorite based porphyries, K-feldspar replacement of plagioclase subsequently overprinted by white-mica is the key process in the Cu core of the porphyry deposit, whereas in diorite-based porphyries, albitisation of plagioclase is suggested as the dominant alteration process, producing a Cu-Au- bearing sodic-calcic core with little, or only minor, K-feldspar alteration.

# Lithogeochemistry

Ross Large
Emeritus Professor at
CODES/UTAS

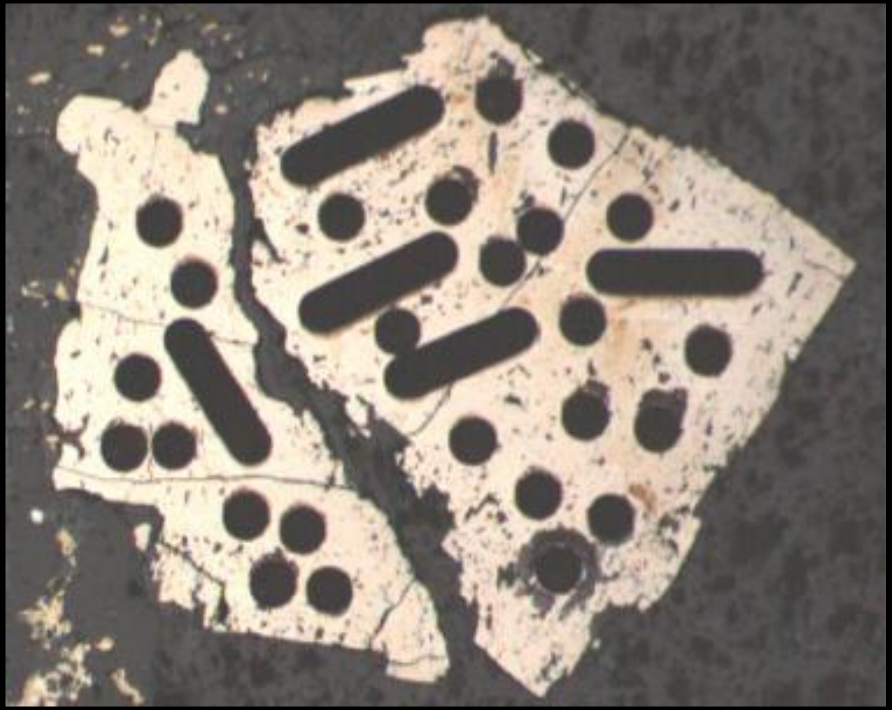
# Fluid inclusion studies



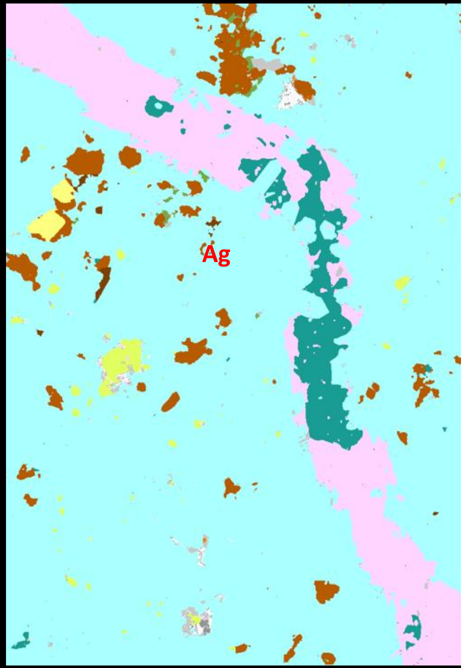

Montoya-Lopera et al., (manuscript)

# LA-ICPMS methods for trace element analysis and imaging



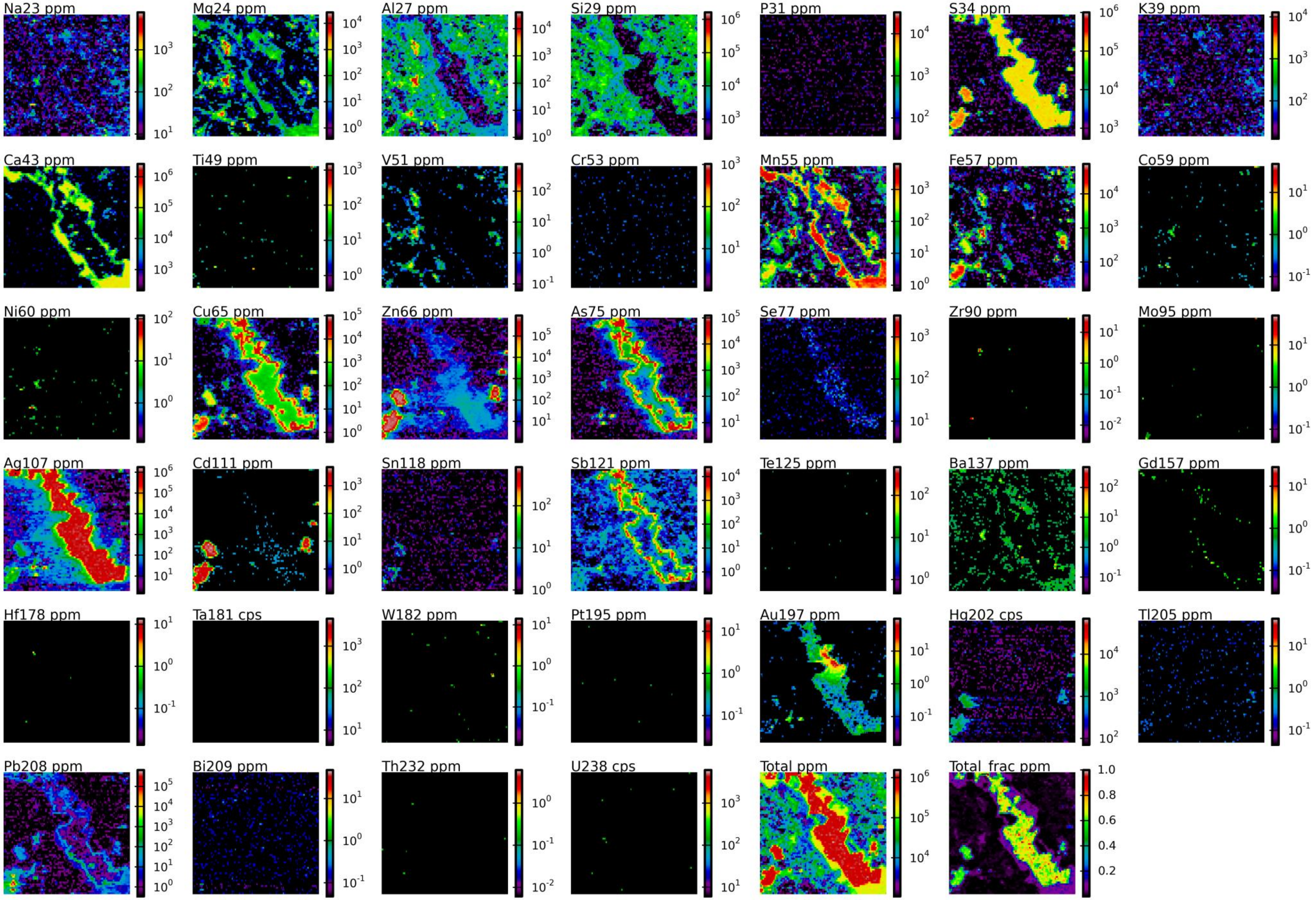
Ivan Belousov (CODES)

# SM-219




## San Marcial Ag signature of parallel veins!

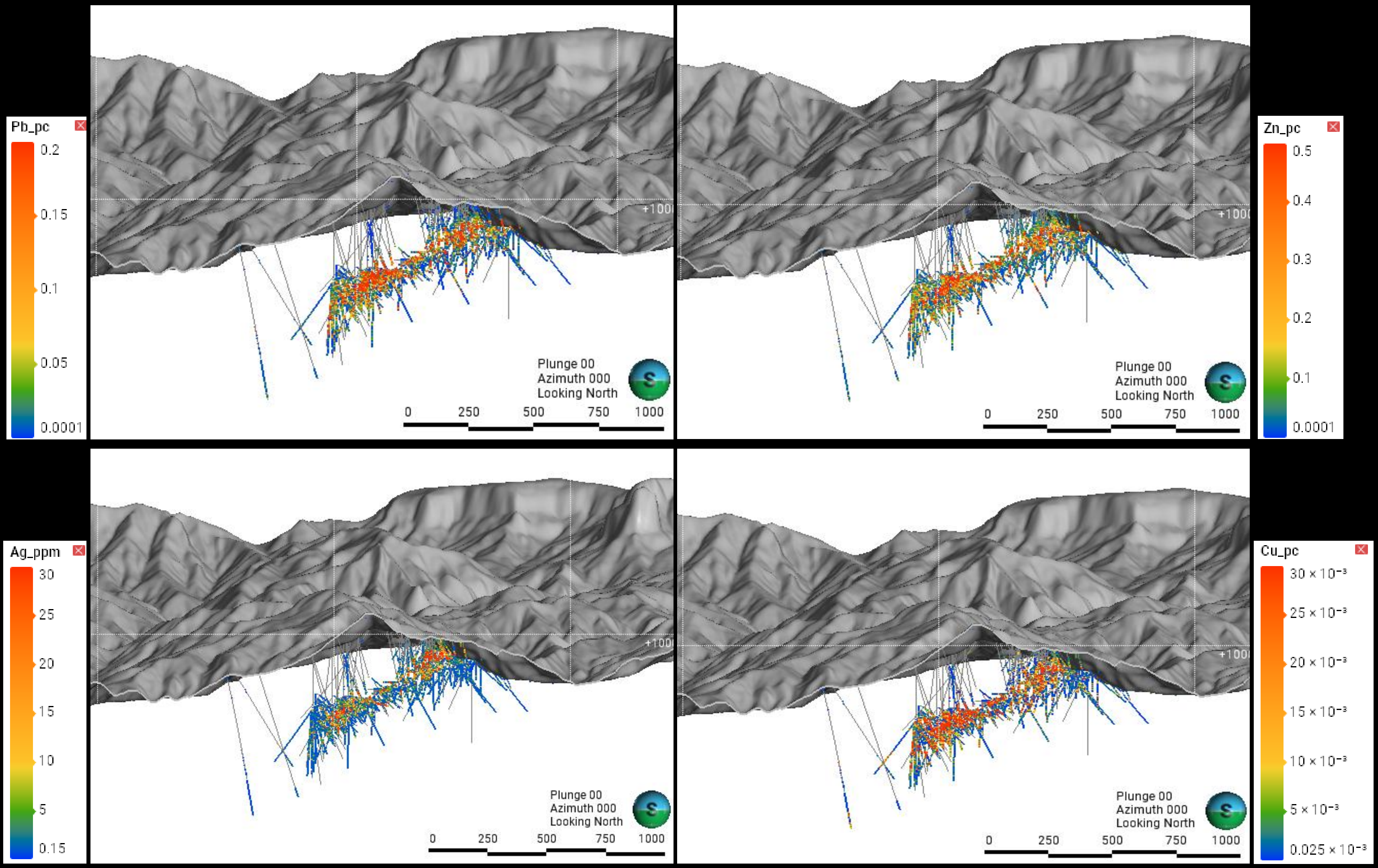
8/07/2025



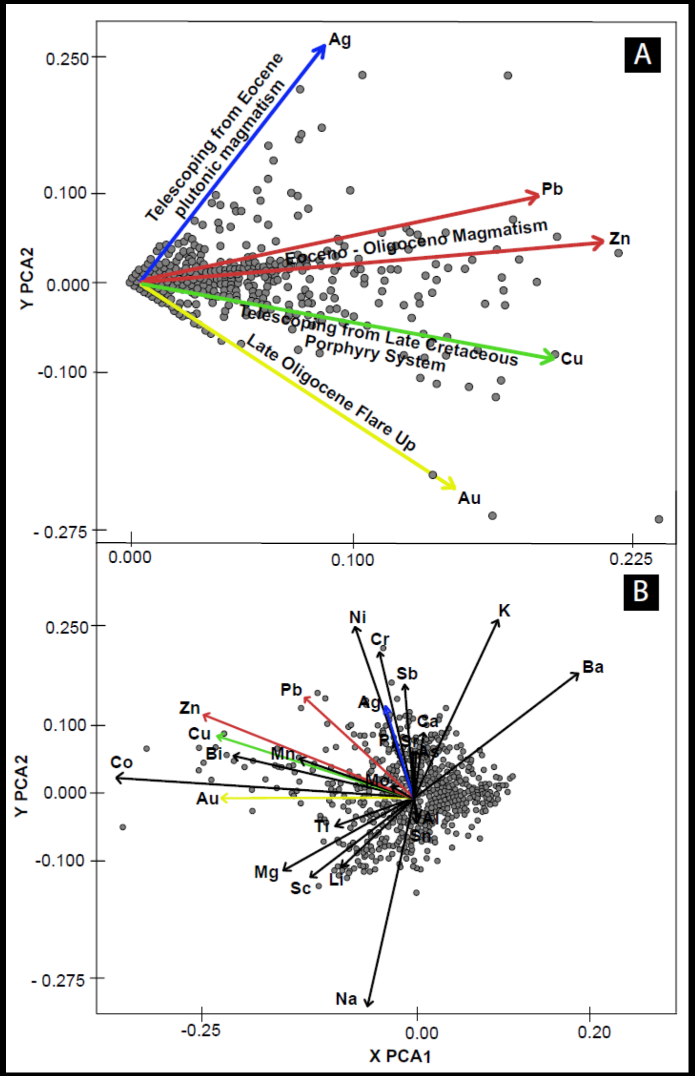
# Plomosas mineralization distribution

W

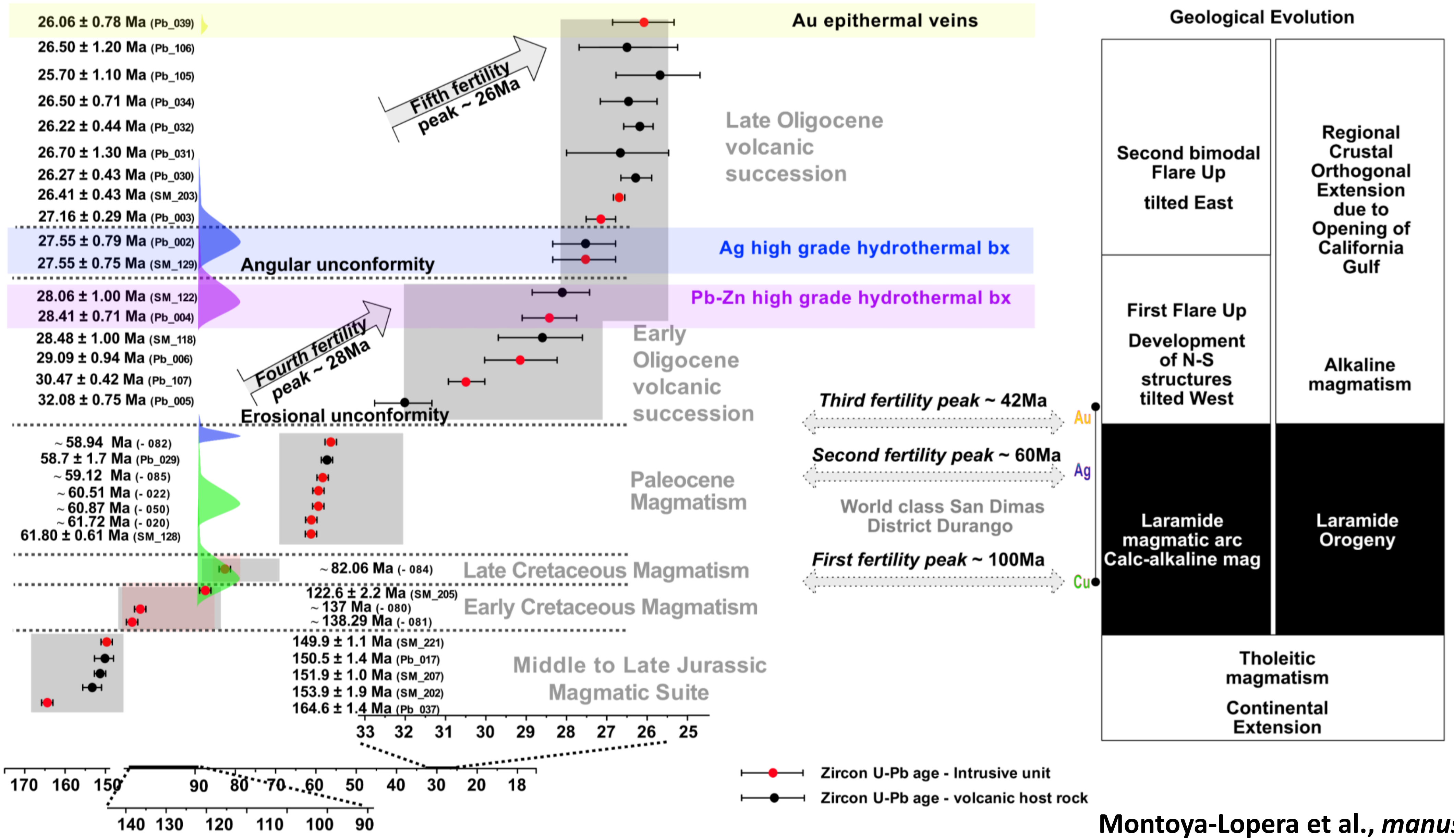
E




## Pathfinders



# Plomosas and San Marcial Geological Evolution




Montoya-Lopera et al., *manuscript*