

Diverse Mineralization and Alteration Styles at the Pitarrilla, Silver-Zinc-Lead Deposit, Sierra Madre Occidental, Mexico: an Example of a Vertically Zoned Magmatic-Hydrothermal Ore System

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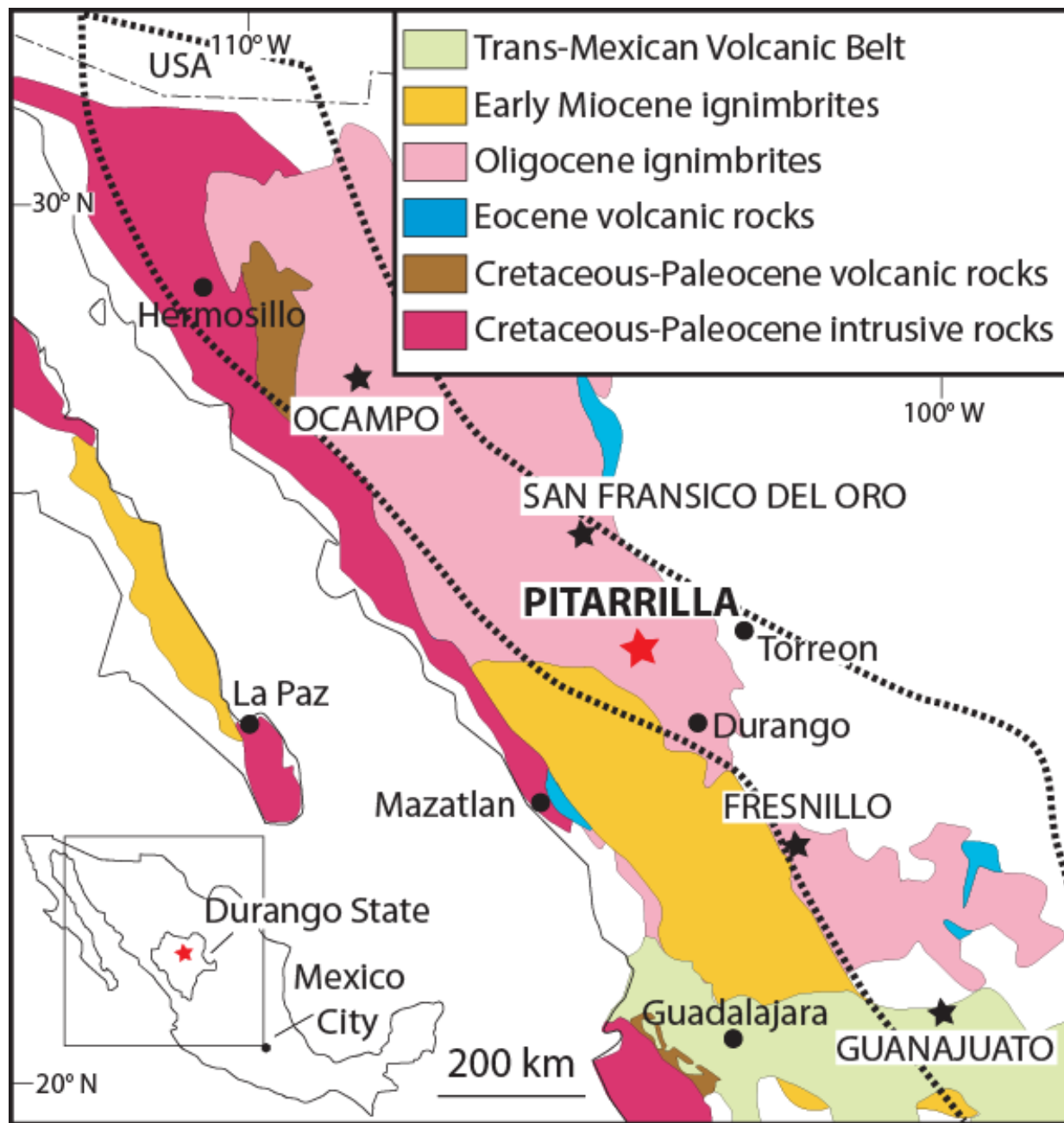
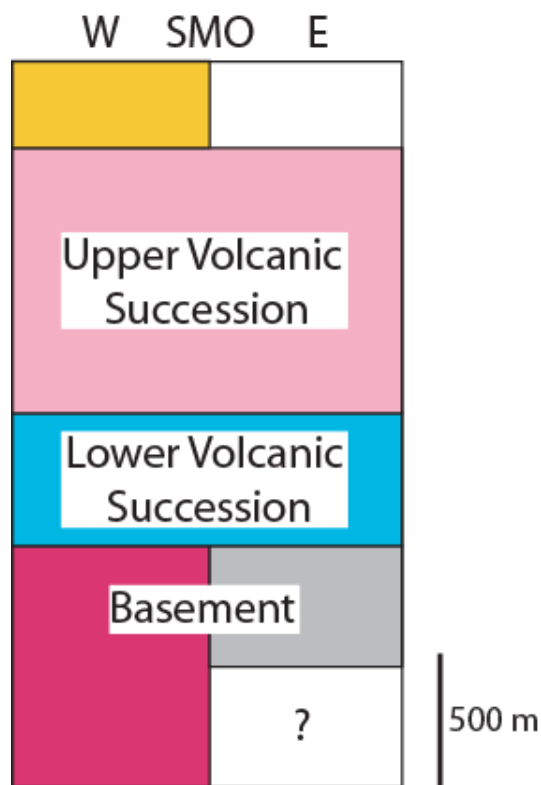
²Silver Standard Resources Inc. (SSRI), Vancouver, Canada



Silver Standard Resources Inc.



Regional Geology



after Ferrari et al. (2007)

Deposit Geology

Intrusions

- Upper mafic sill
- Felsic dikes and sills
- Lower mafic sill

Casas Blancas formation

- Encino rhyolitic dome lithofacies
- Upper volcaniclastic lithofacies
- Lower volcaniclastic lithofacies

Cardenas formation

- Lithic-rich tuff lithofacies
- Stratified tuff lithofacies
- Crystal-rich pumice tuff lithofacies
- Lithic-rich tuff and lapilli tuff lithofacies

Pitarrilla formation

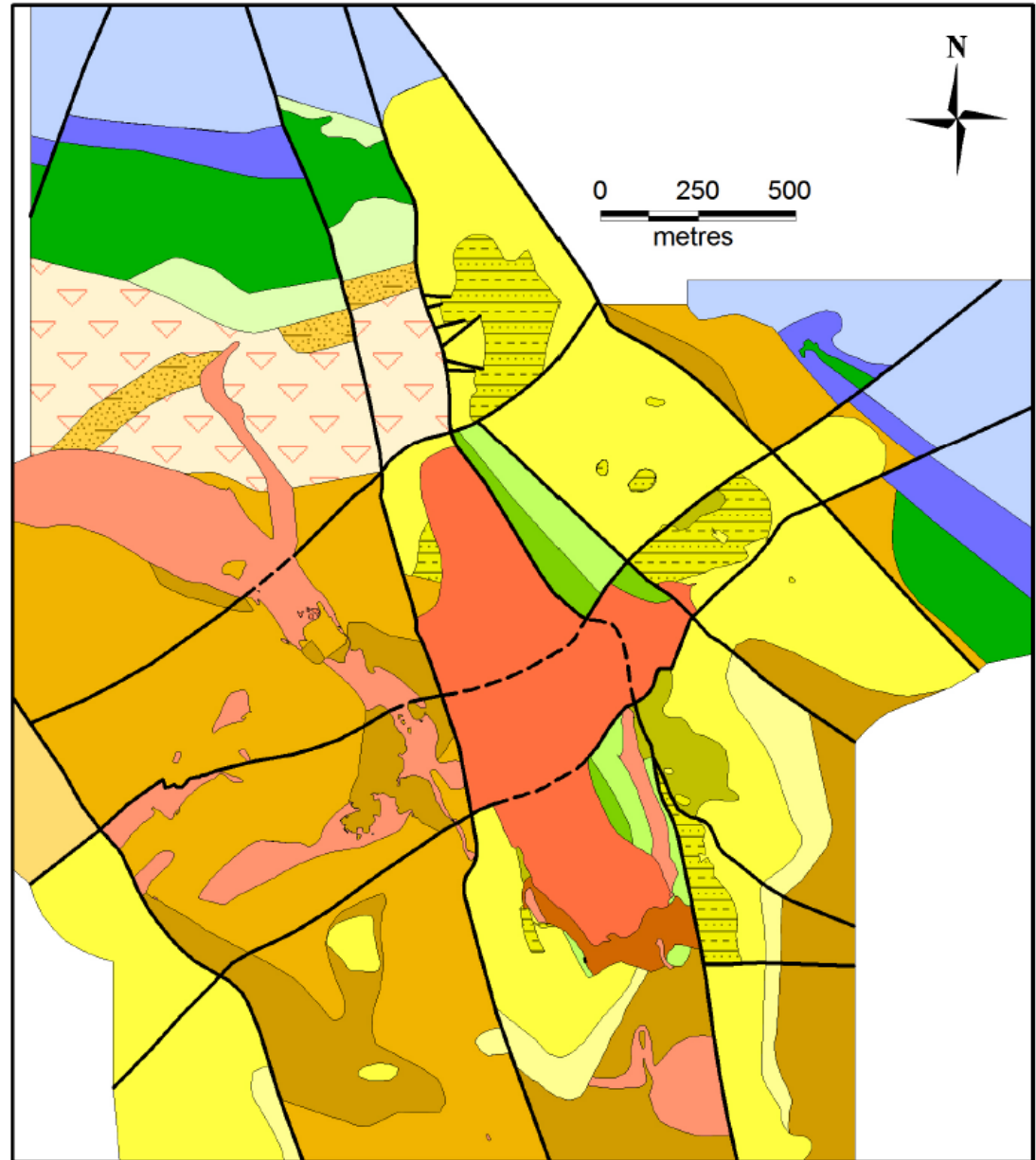
- Upper member
 - Lapilli tuff lithofacies
 - Tuff lithofacies
 - Flow lithofacies
 - Tuff breccia

- Lower member
- Manto Rico member

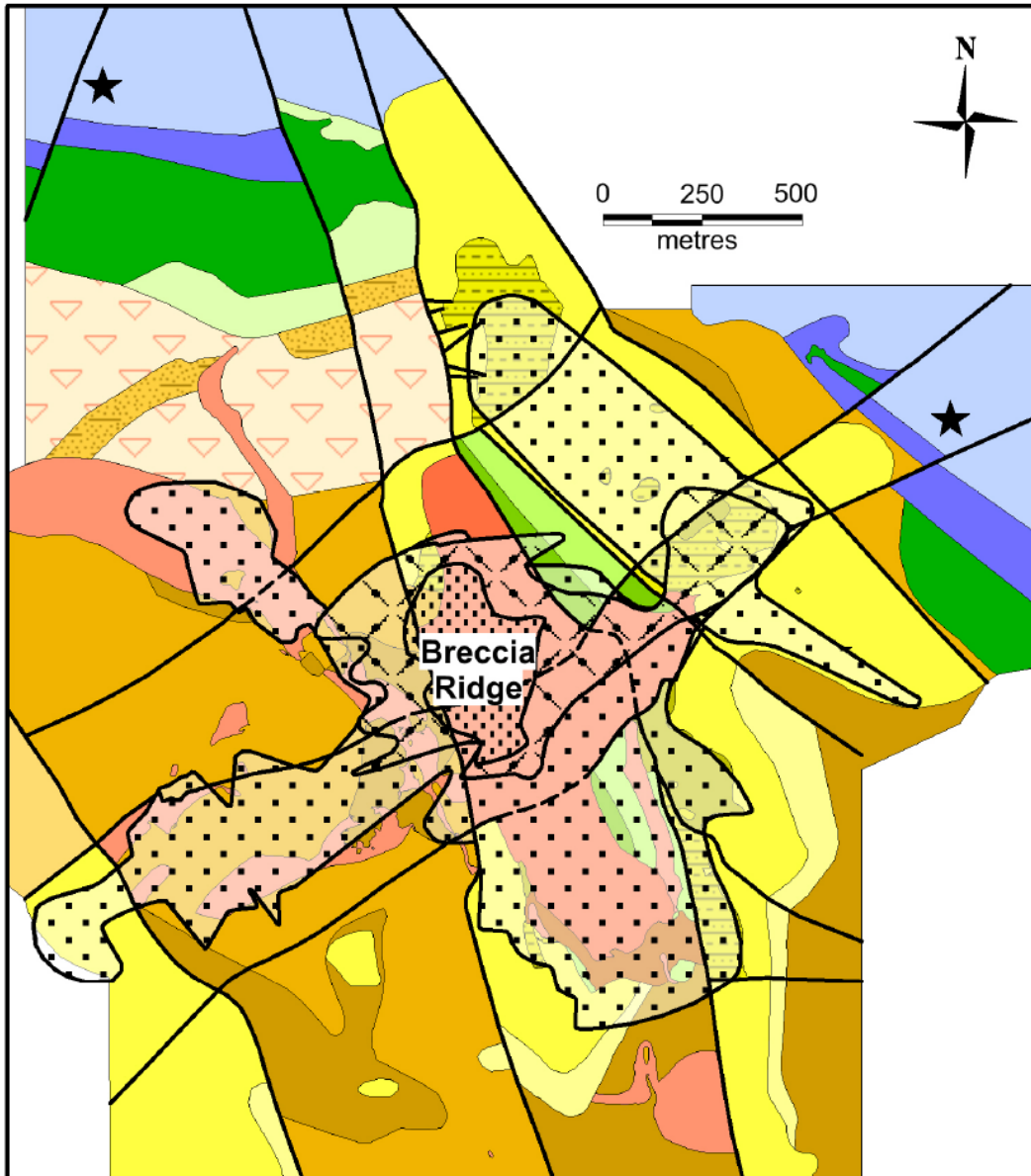
Peña Ranch formation

-

Fault



Mineralization Styles



236 Mt (M+I) with
average Ag grades
between 80 and
125 g/t Ag

Iron oxide-associated mineralization



Sulfide-associated mineralization

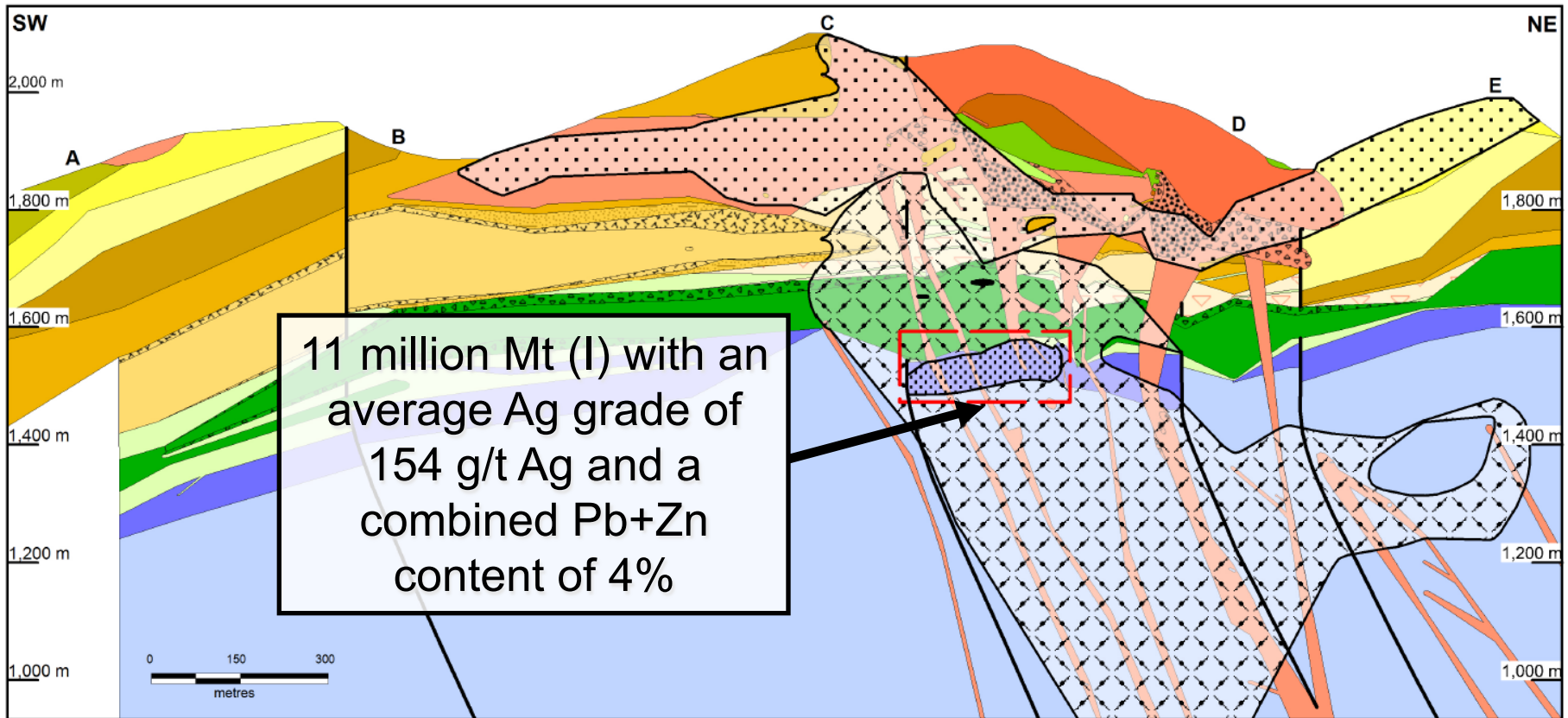


Disseminated and veinlet mineralization






Semi-massive replacement mineralization

Sulfide-Associated Mineralization

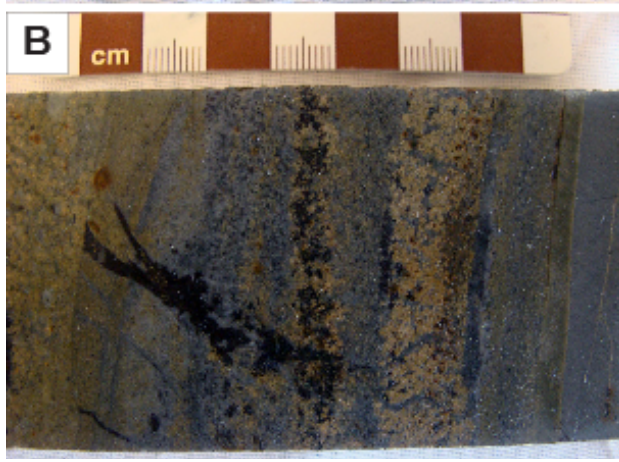
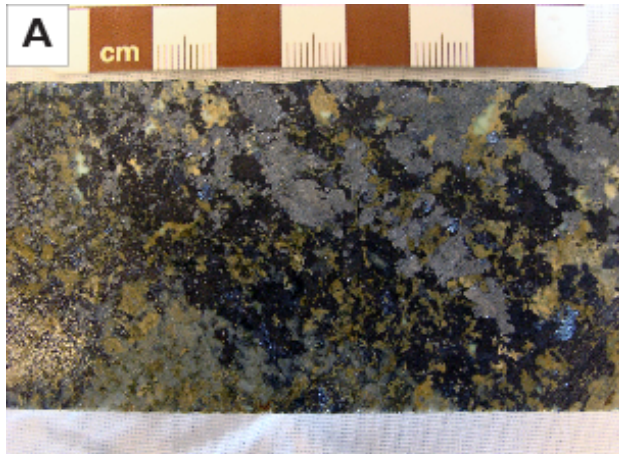
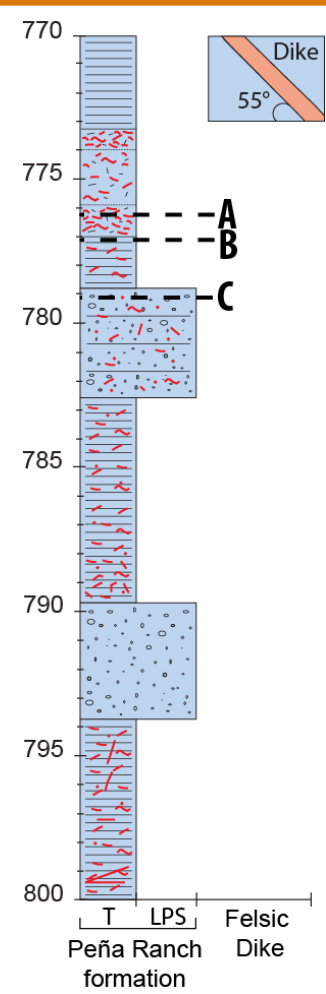
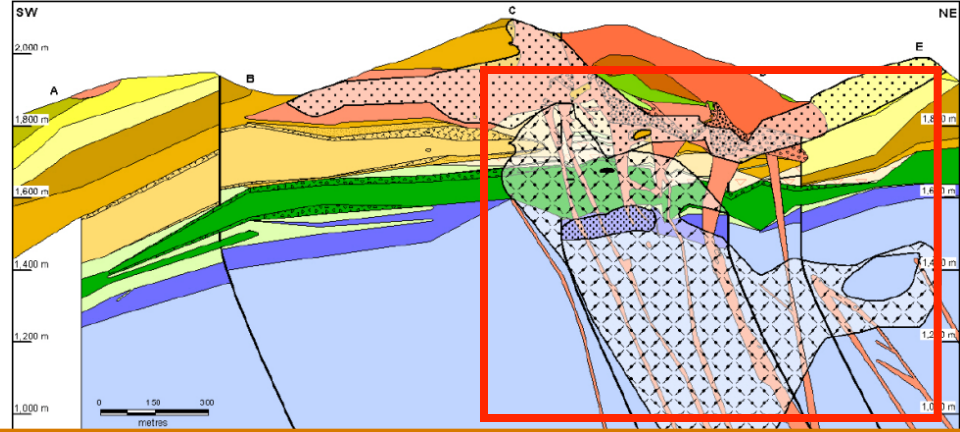


Sulfide-associated mineralization

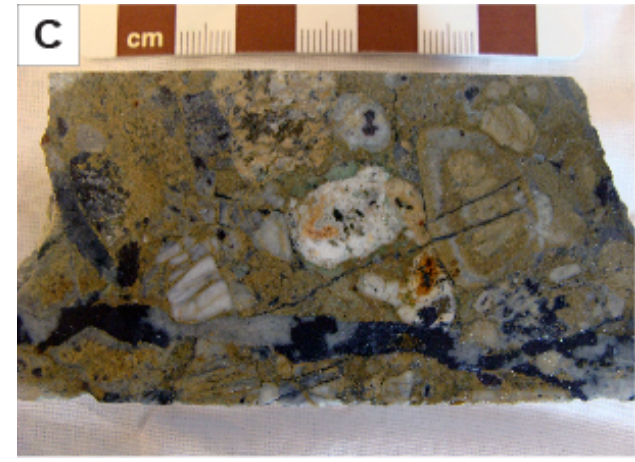
-  Disseminated and veinlet mineralization
-  Semi-massive replacement mineralization
-  Massive sulfide vein mineralization

67 Mt (M+I using 65 g/t Ag cutoff)
with an average Ag grade of 90 g/t Ag and a combined Zn+Pb content of ~ 2.2%

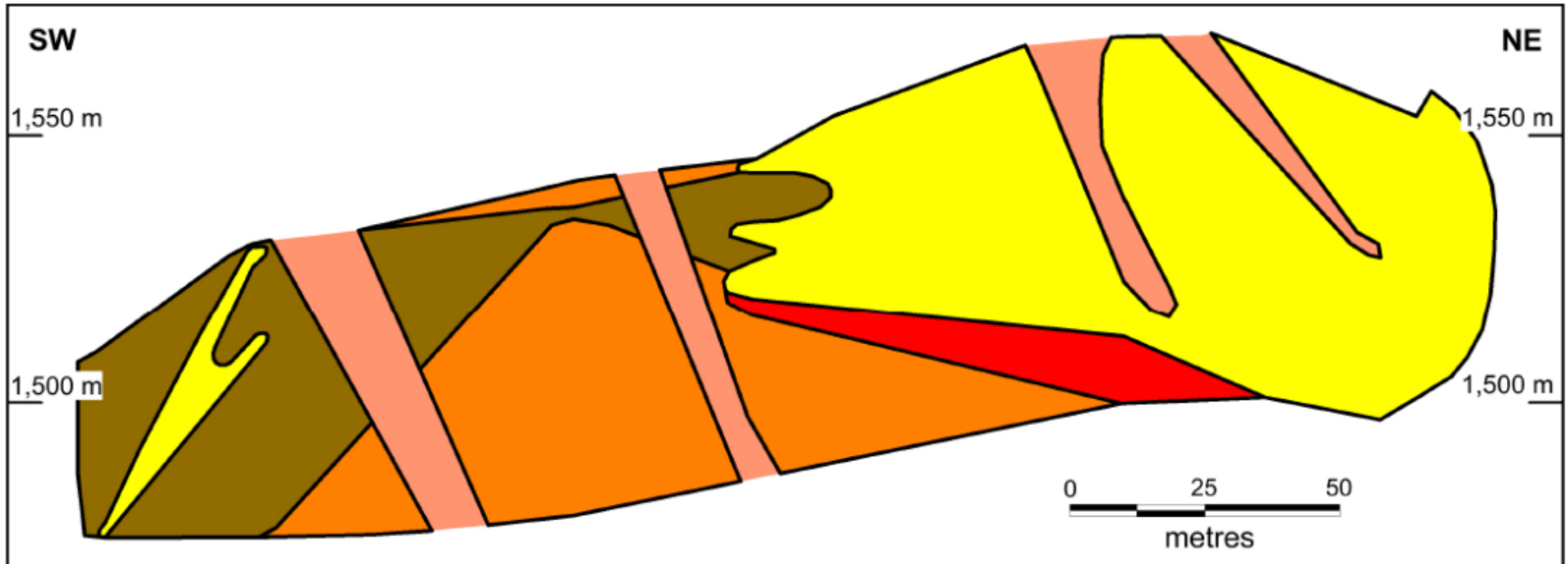
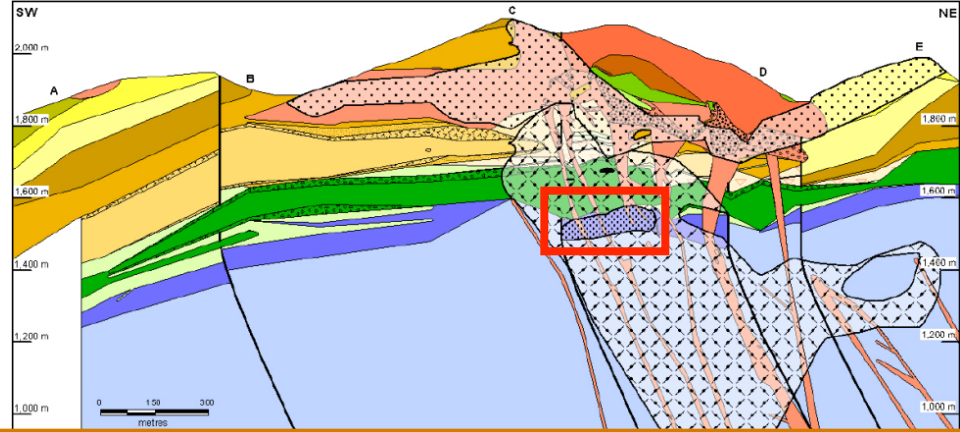
Disseminated/Veinlet Mineralization



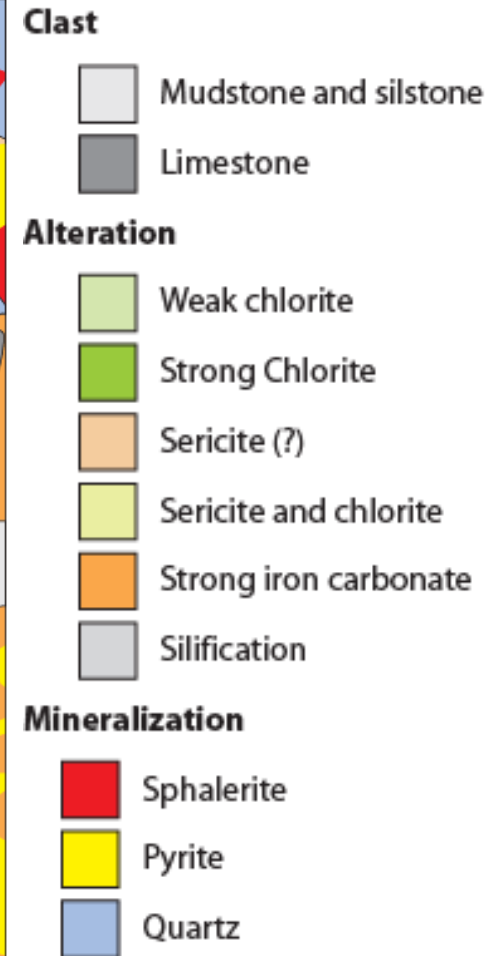
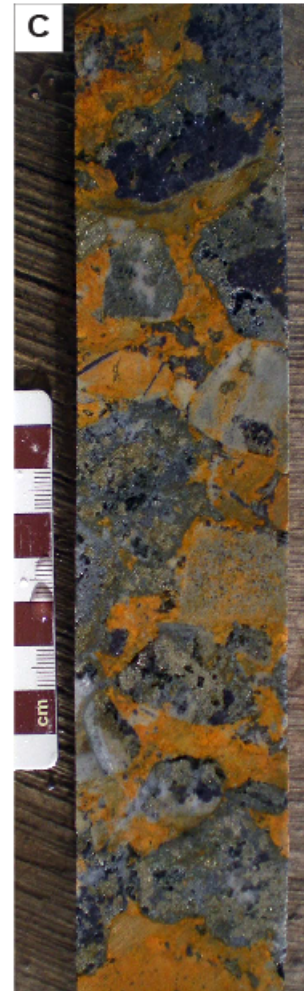
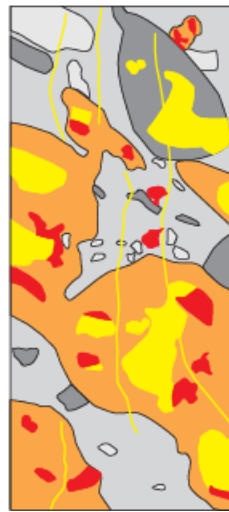
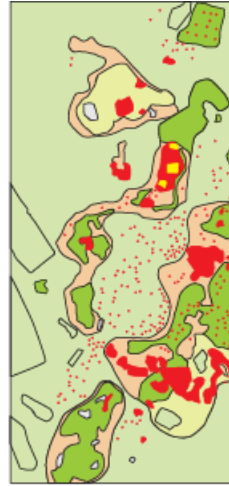
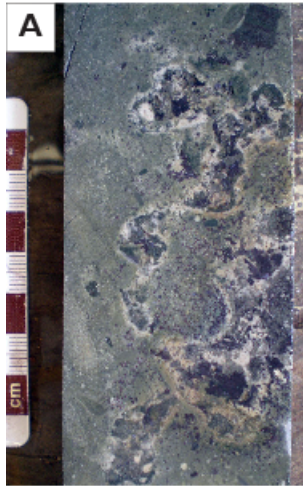
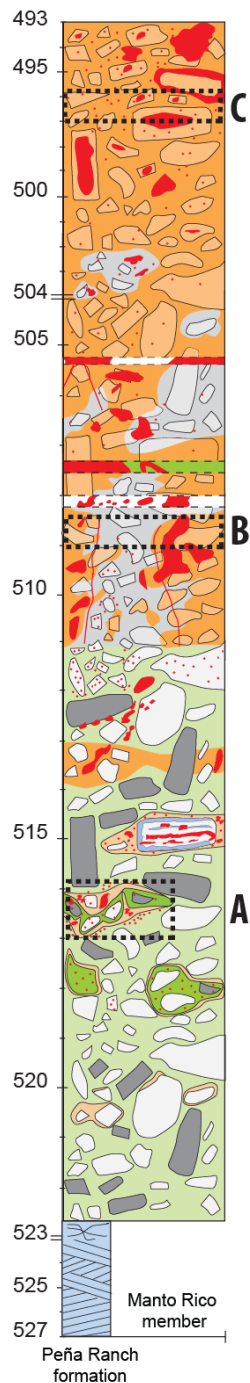
- Ore mineralogy:
Sph, py, mar, gn, ccp, po, asp ± tetrahedrite, boulangerite, ullmannite, gersdorffite, freieslebenite
- Alteration:
Chlorite, iron carbonate, kaolinite, montmorillonite, illite













Semi-Massive Replacement Mineralization



Semi-Massive Replacement Mineralization



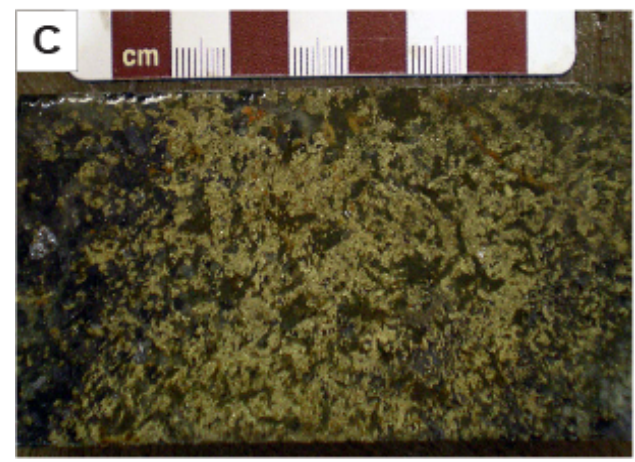
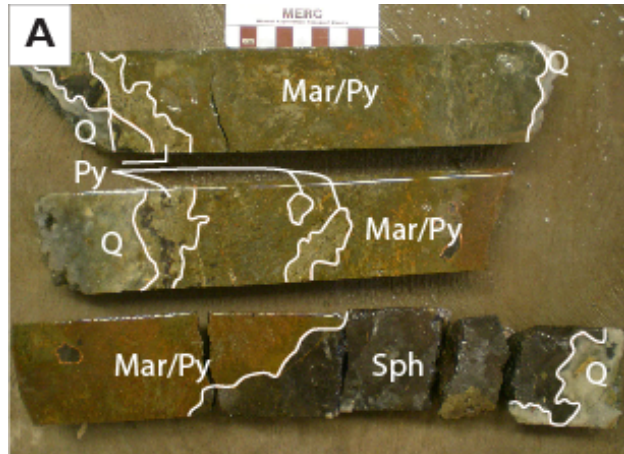
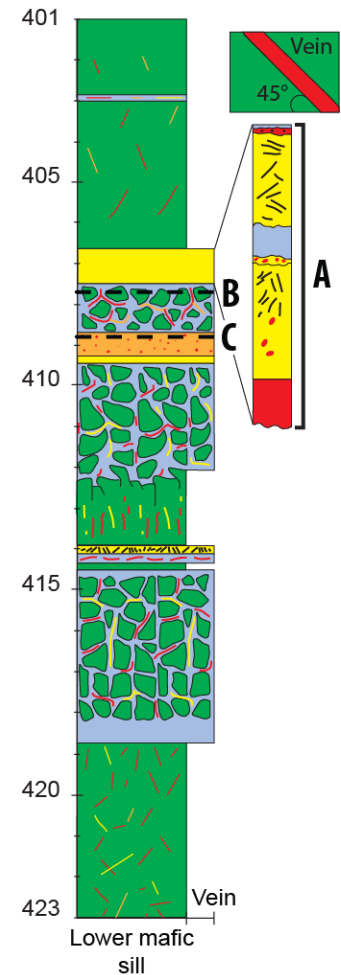
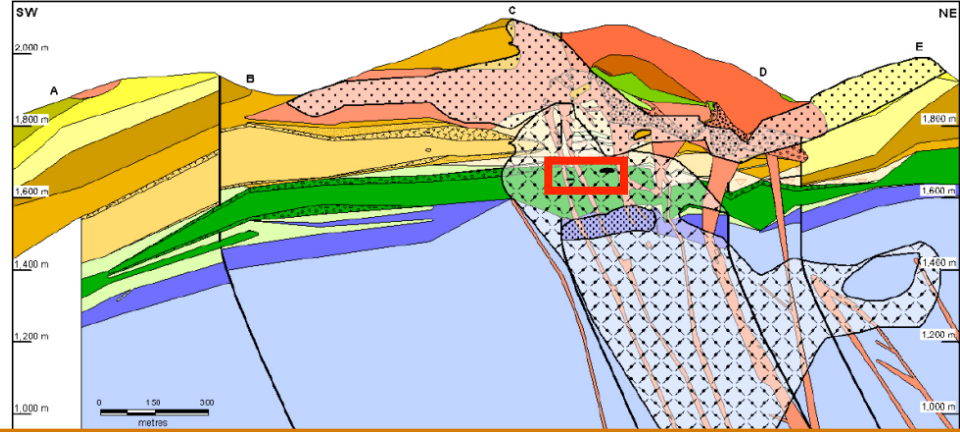
Semi-Massive Replacement Mineralization

MINERAL	EARLY  LATE
Pyrrhotite	
Marcasite	
Pyrite	
Sphalerite	
Chalcopyrite	
Galena	
Tetrahedrite	
Stannite	
Ramdohrite	

200 um



Massive Sulfide Vein Mineralization



- Four types of sharp-walled veins:
 - Chalcopyrite-galena
 - Arsenopyrite
 - Marcasite-pyrite-sphalerite
 - Pyrrhotite-marcasite-pyrite

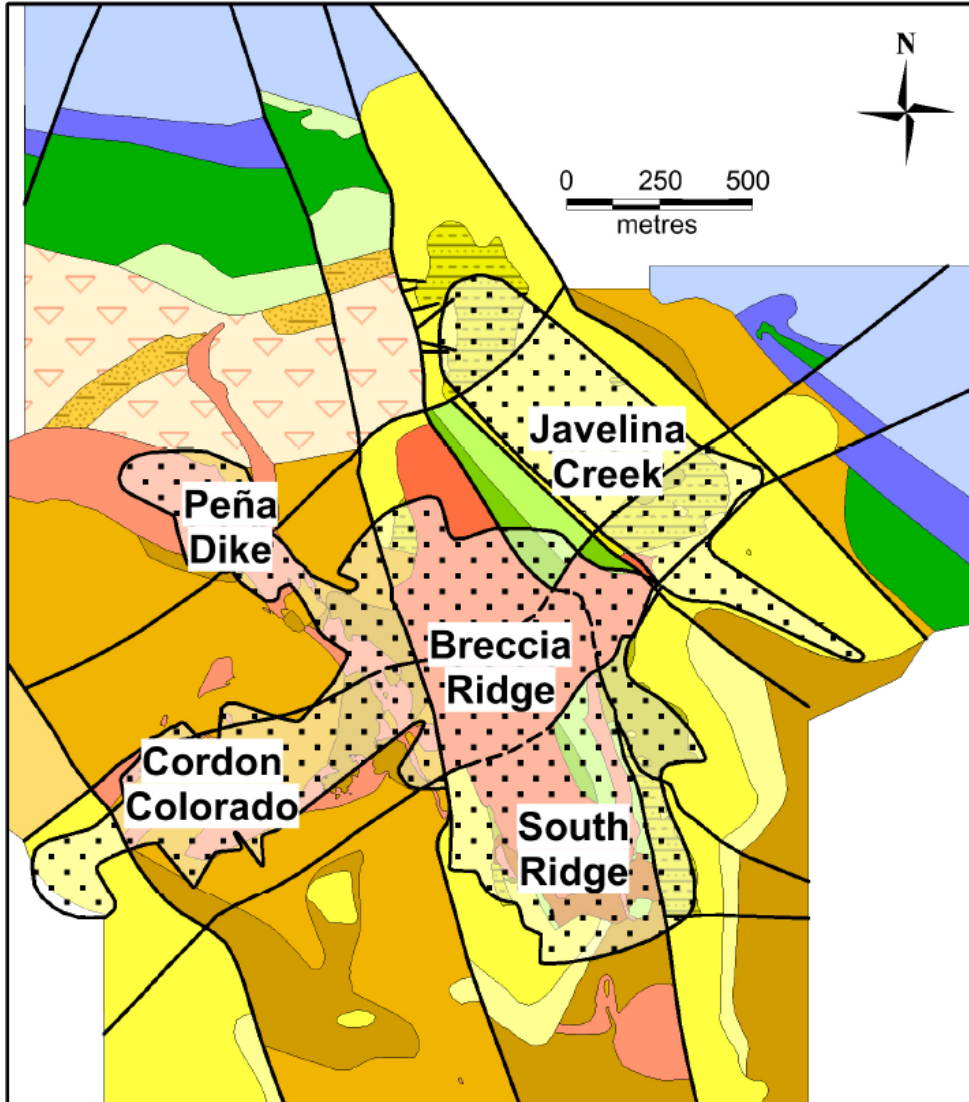
Massive Sulfide Vein Mineralization

MINERAL	EARLY → LATE
Pyrrhotite	_____
Marcasite	_____
Pyrite	_____
Arsenopyrite	_____
Sphalerite	_____
Chalcopyrite	_____
Galena	_____
Tetrahedrite	_____
Miargyrite	_____

200 um



Iron Oxide-Associated Mineralization



- 5 zones:
 - Breccia Ridge
 - Cordon Colorado
 - Peña Dike
 - Javelina Creek
 - South Ridge

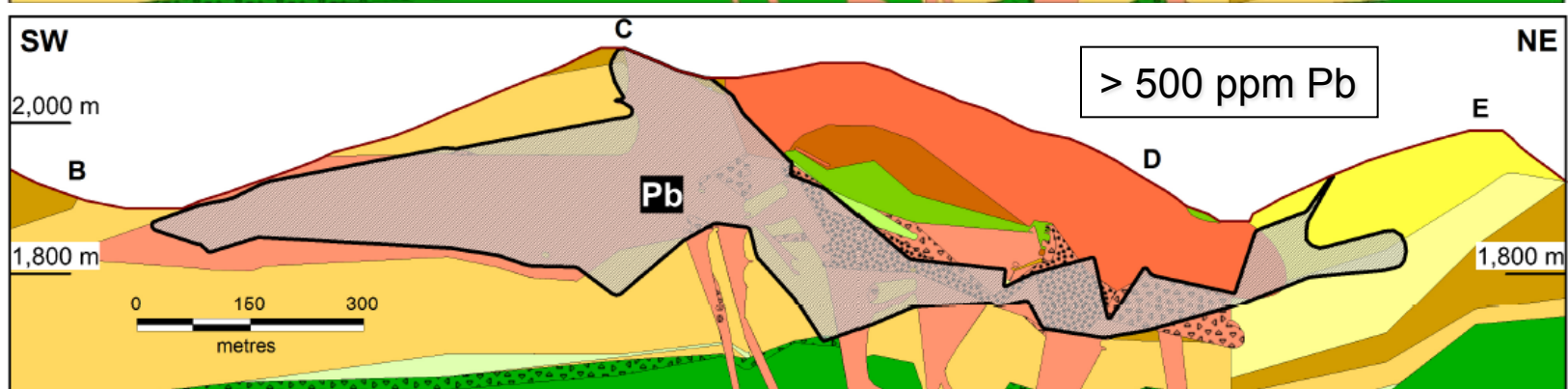
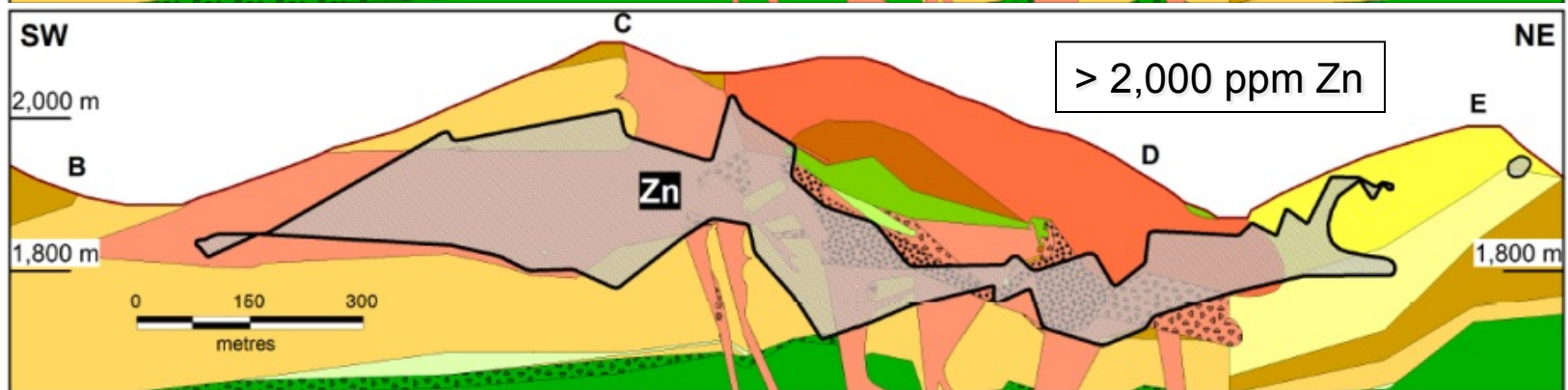
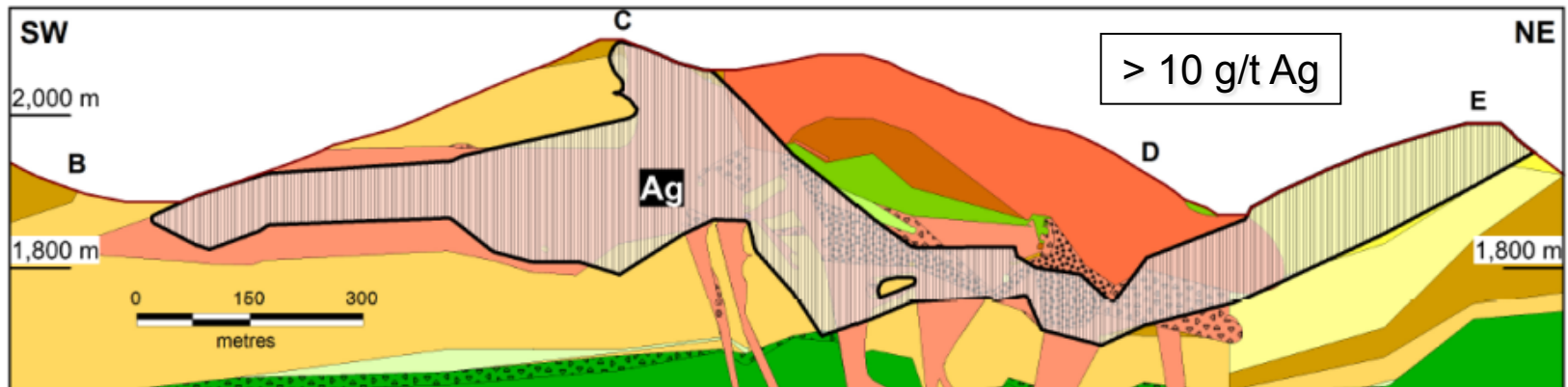
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169 Mt (M+I using 40 g/t Ag cutoff) with average Ag grades between 80 and 125 g/t Ag

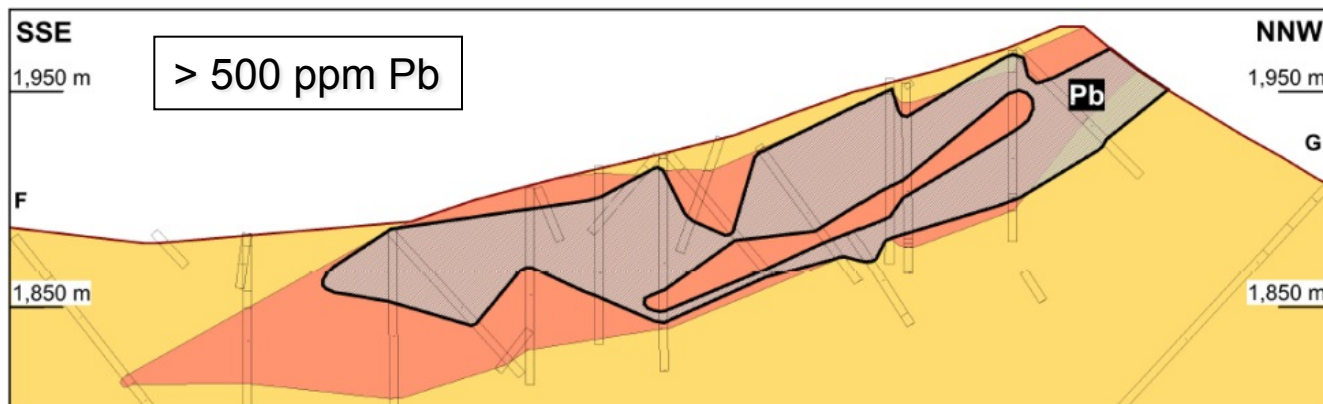
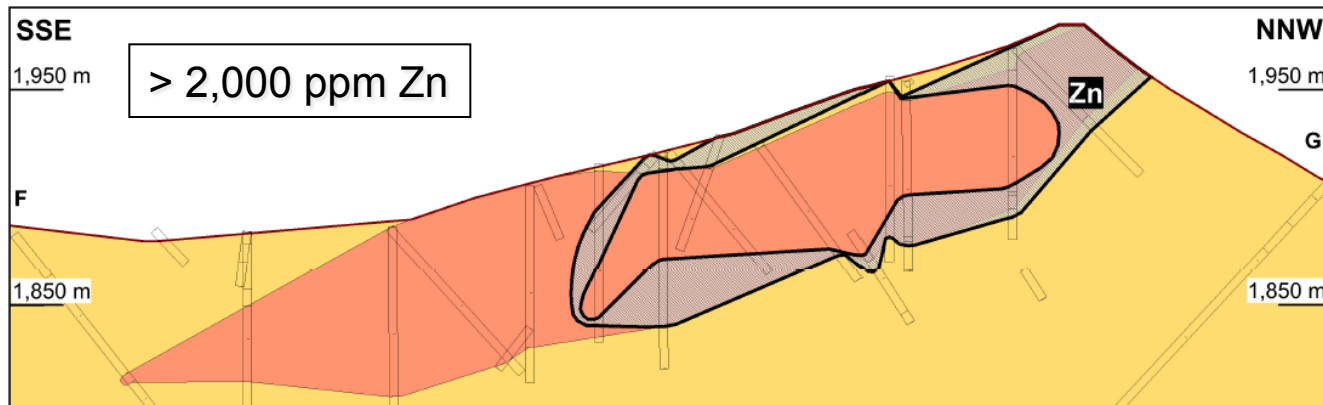
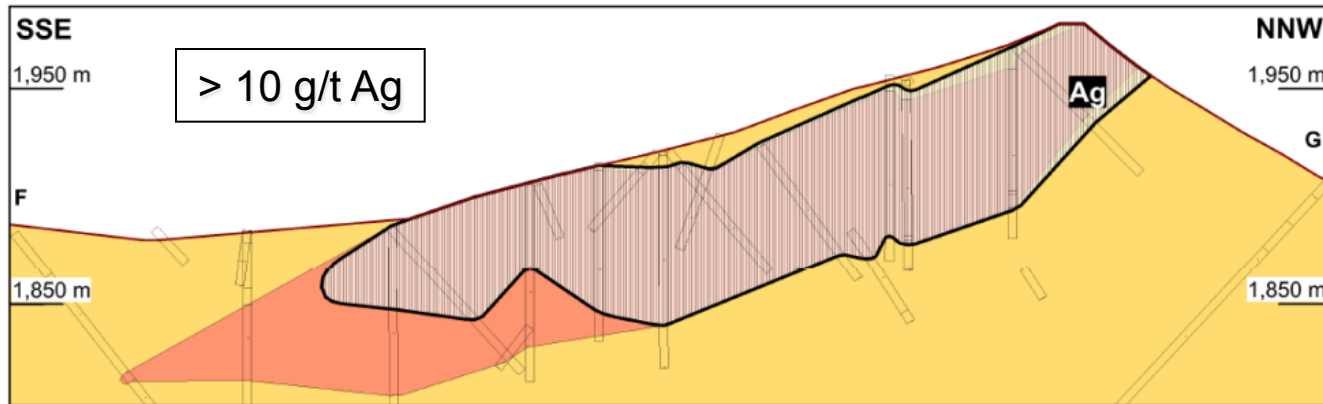
Iron oxide-associated mineralization



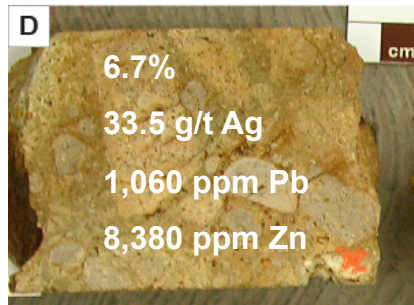
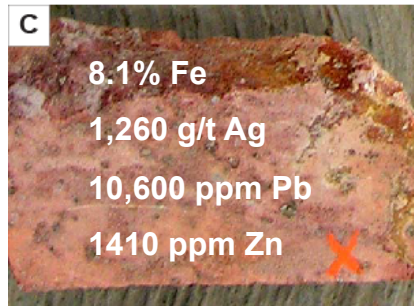
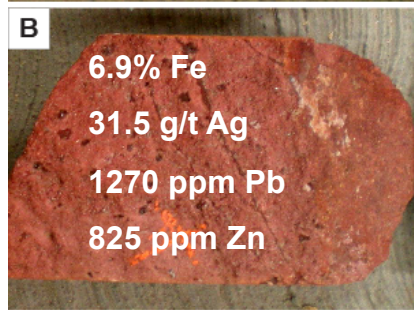
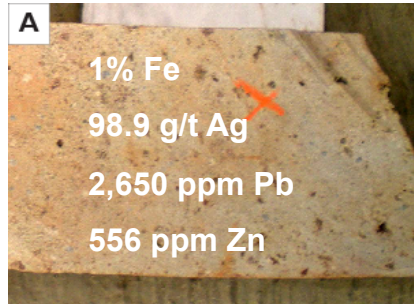
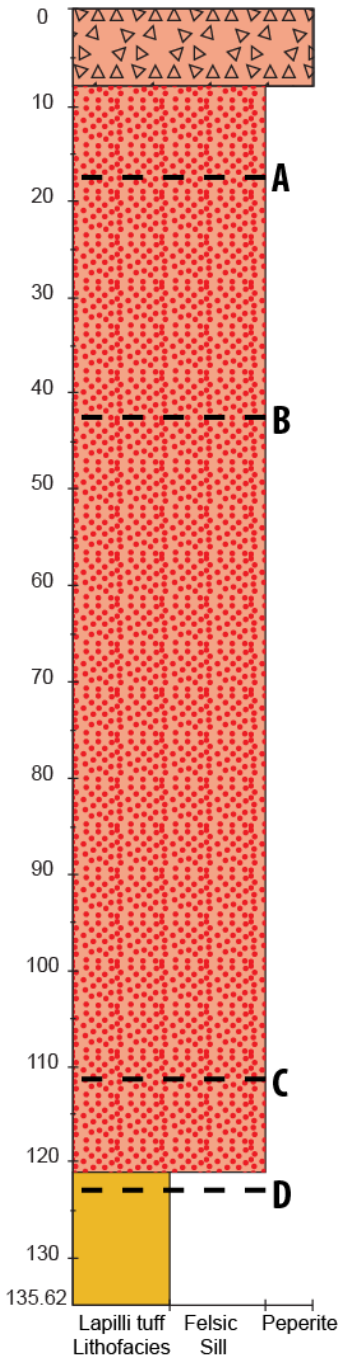
Iron Oxide-Associated Mineralization



Iron Oxide-Associated Mineralization



Iron Oxide-Associated Mineralization



- Ore Mineralogy:**

- Base Metal Sulfides:

Py, sph, gn, ccp ± cinnabar, covellite

- Silver sulfide and selenides:

Silver sulfide: Acanthite (Ag_2S)

Silver sulfide-selenide: Aguilarite (Ag_4SSe)

Silver selenide: Naumannite (Ag_2Se)

- Silver halides:

Silver iodide: Iodargyrite (AgI)

Silver chloride: Chlorargyrite (AgCl)

Silver bromide: Bromargyrite (AgBr)

- Silver-Mercury:

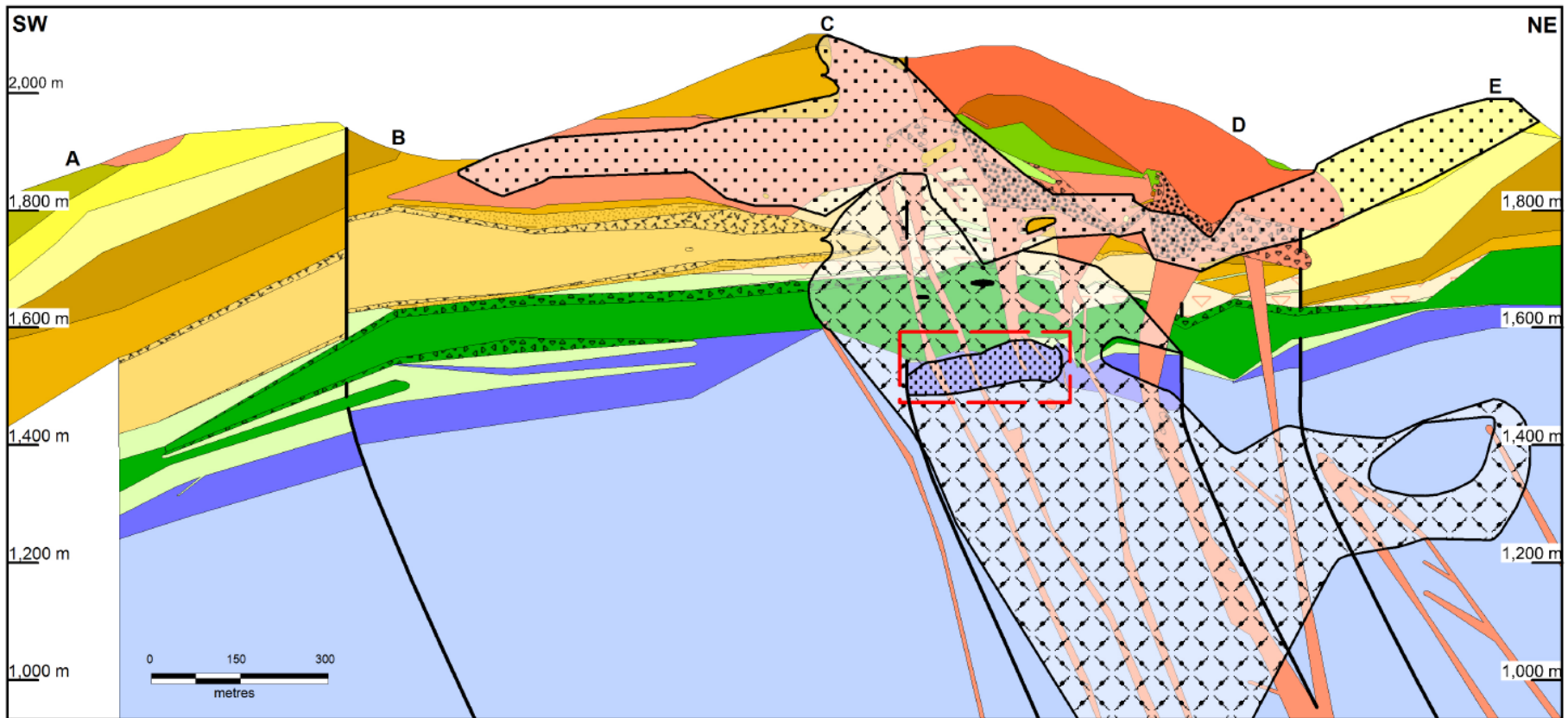
Imiterite (?): Ag_2HgS_2

AgHgSI (?)




- Alteration:**

Hematite, limonite, nontronite, halloysite, montmorillonite, kaolinite, buddingtonite ± muscovite, alunite, anhydrite

Pitarrilla Mineralization Styles



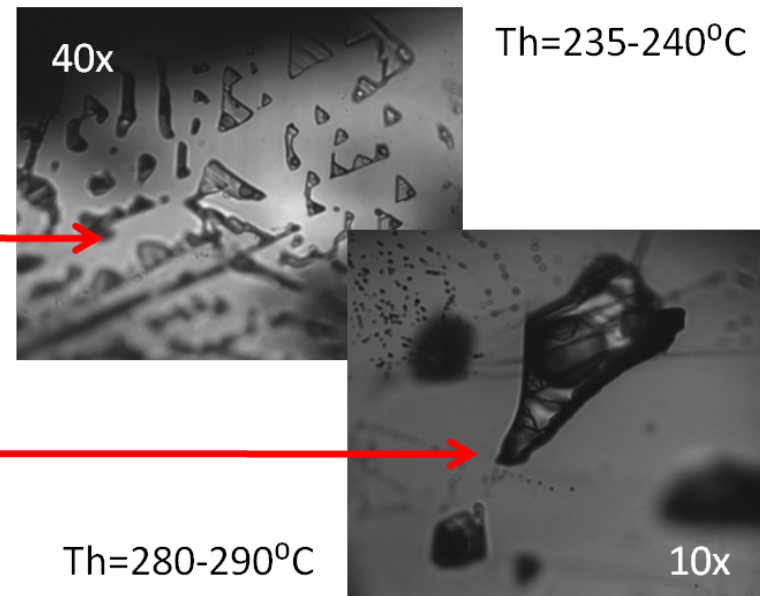
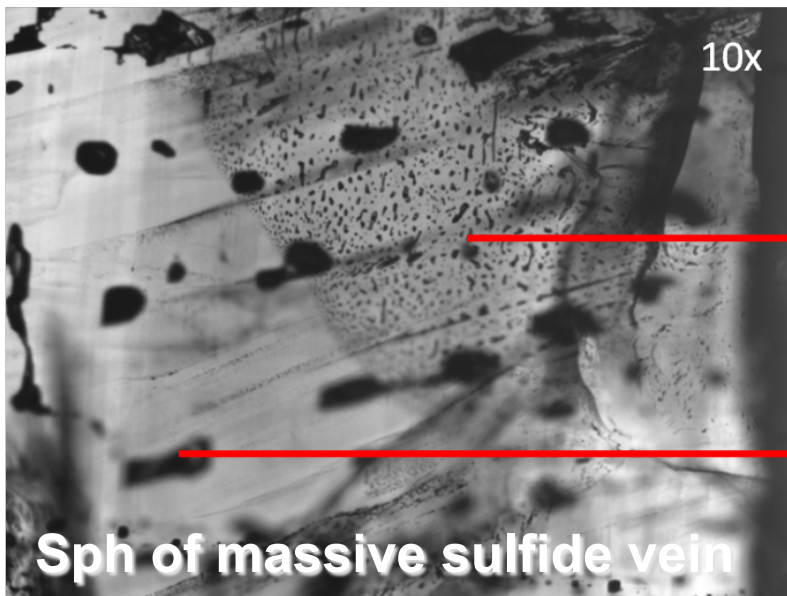
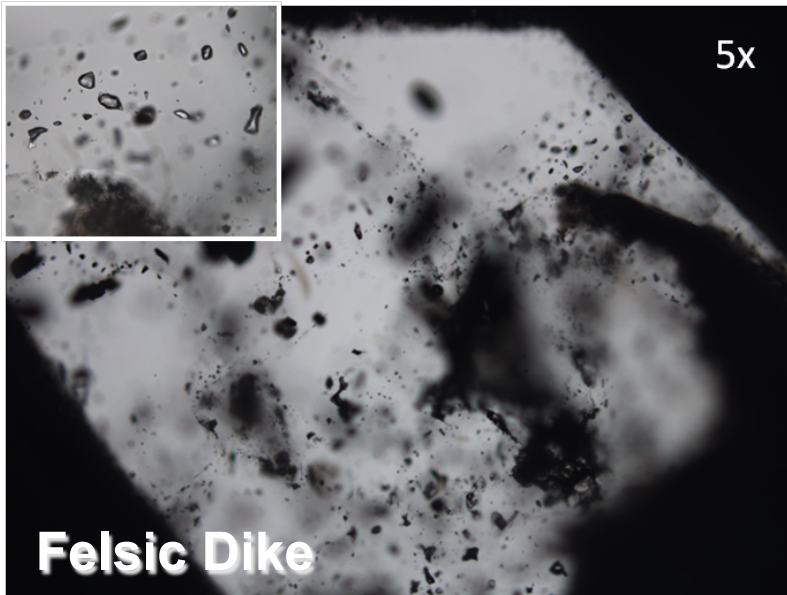
Sulfide-associated mineralization

-  Disseminated and veinlet mineralization
-  Semi-massive replacement mineralization
-  Massive sulfide vein mineralization

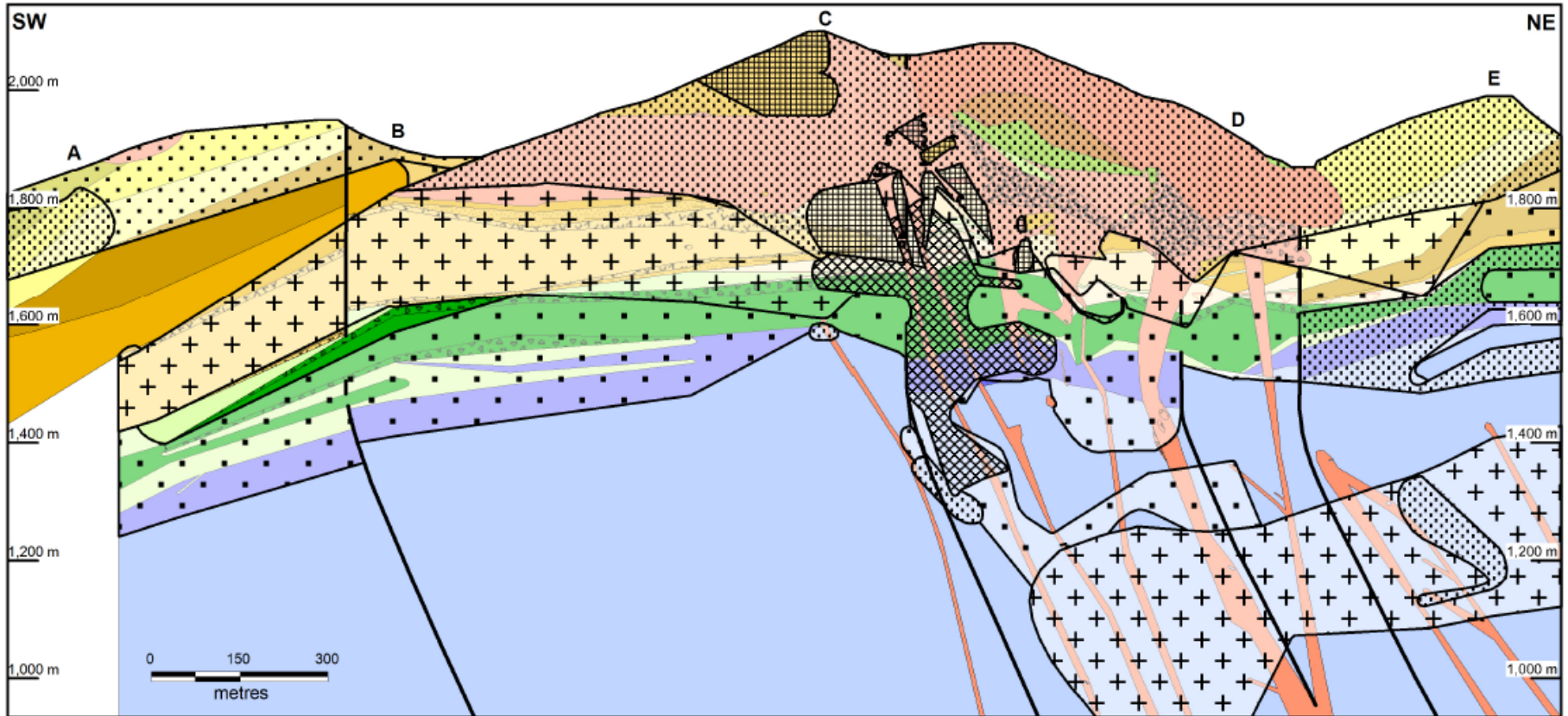
Iron oxide-associated mineralization



Fluid Inclusion



Hydrothermal Alteration



Hematite alteration



Weak argillic alteration



Tourmaline alteration



Limonite alteration



Weak chlorite alteration



Iron carbonate alteration

Montmorillonite

Illite

Chlorite



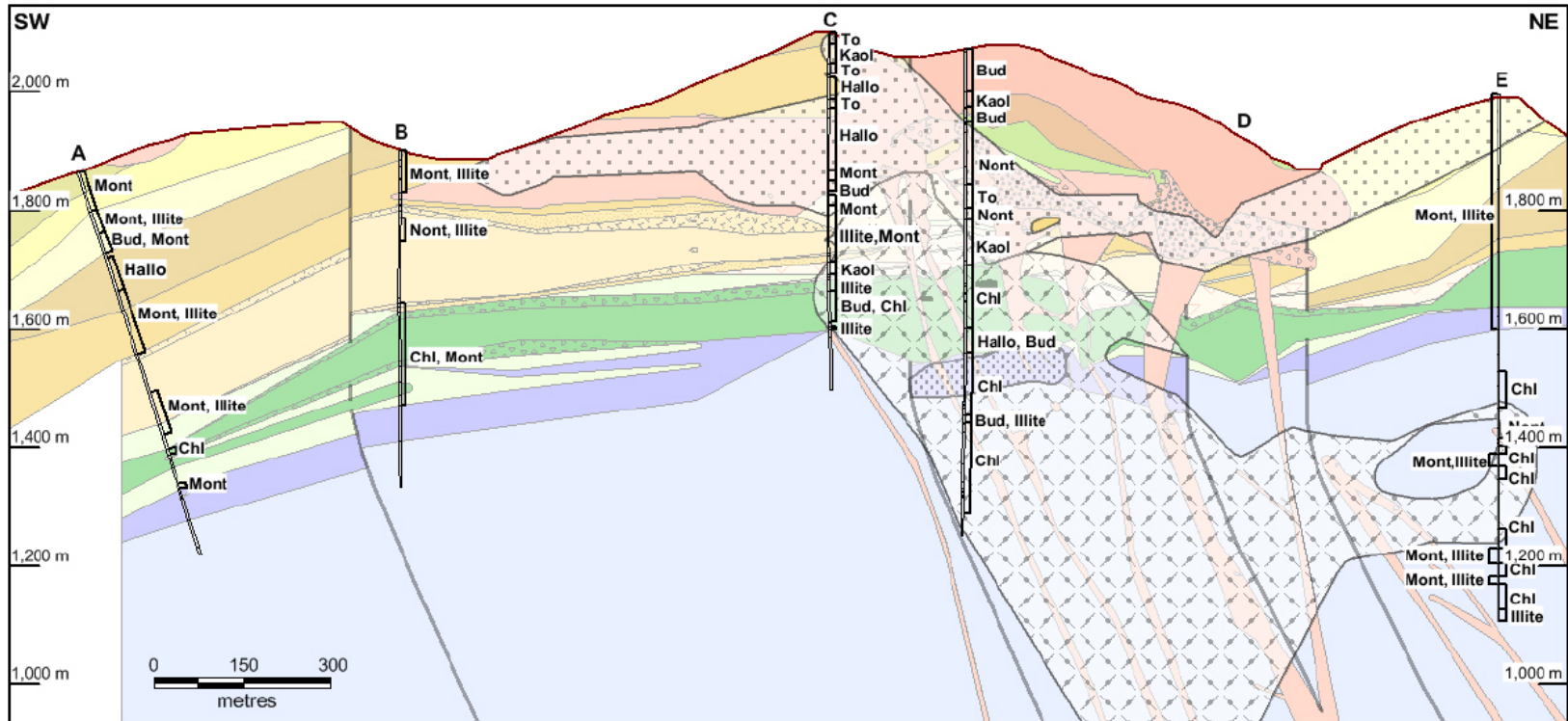
Buddingtonite, Tourmaline,
Halloysite, Kaolinite,
Nontronite, Chlorite, Illite ±
Muscovite, Alunite, Anhydrite



Montmorillonite

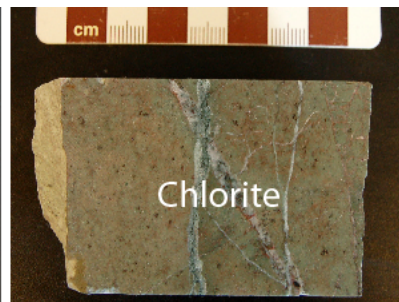
Illite

Chlorite



Distal Alteration (<600m)

Proximal Alteration





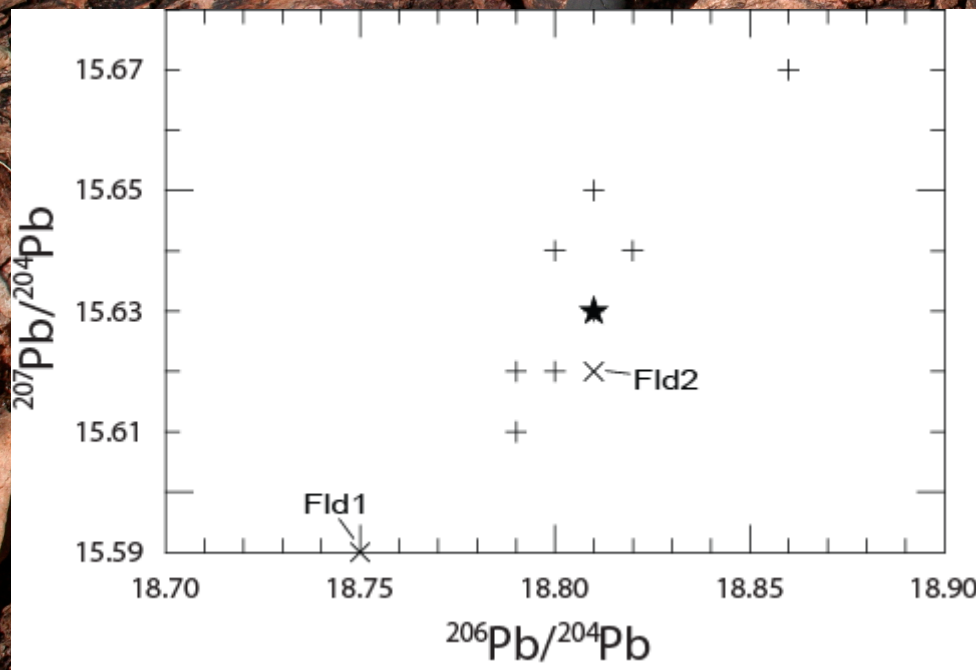
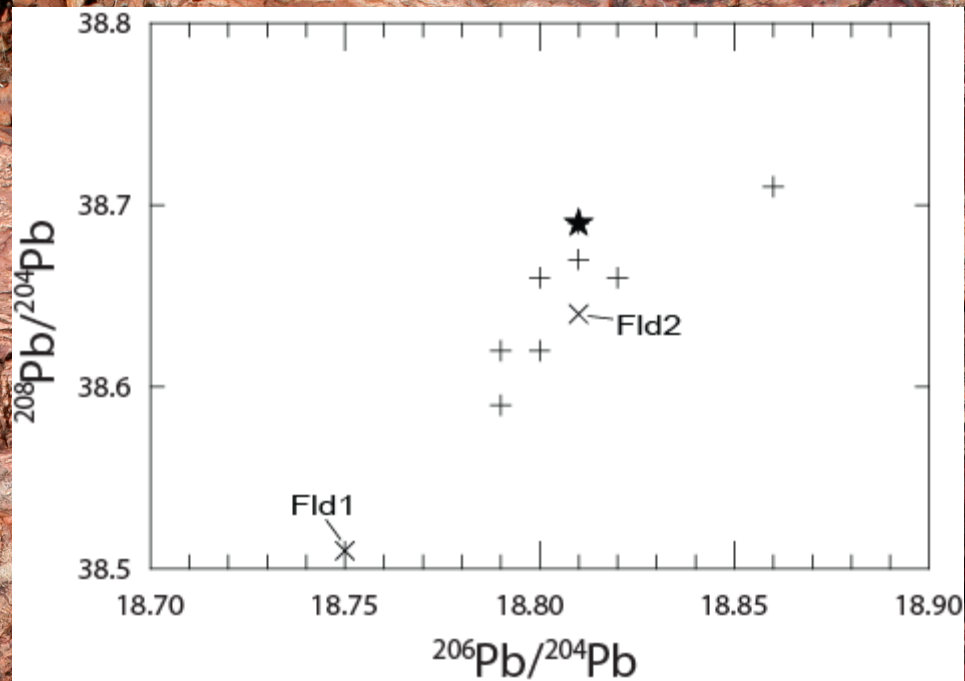
Hydrothermal Alteration

- Common to other Mexican epithermal deposits:
 - Argillic alteration such as kaolinite, illite, montmorillonite, halloysite
 - Chlorite
- Uncommon to other Mexican epithermal deposits:
 - Buddingtonite
 - Nontronite
 - Iron carbonate
 - Tourmaline

Pitarrilla Deposit

- Common to other Mexican epithermal deposit:
 - Location within the Mexican silver belt
 - Association with calc-alkaline arc magmatism and extensional setting
 - Large variation in silver and base metal contents
 - Large range in sulfide and sulfosalts minerals and similar paragenetic sequence
 - Argentiferous sulfide mineralization
 - Massive sulfide vein and manto mineralization style
 - Similar alteration types
- Uncommon to other Mexican epithermal deposit:
 - Iron oxide-associated mineralization, iron carbonate and tourmaline alteration

Pitarrilla Deposit



Intrusion

- ★ Rhyolitic dikes and sills
- ⬡ Upper andesitic sill
- ⊕ Lower andesitic sill

- + Galena of Pitarrilla sulfide mineralization from McCreery (2007)
- x Feldspar of Pitarrilla sulfide mineralization from McCreery (2007)

Conclusions

- Mineralization shows spatial/temporal association with Oligocene rhyolitic dome and related felsic dike-sill complex
- Vertical stacking of different mineralization types over several hundreds of meters
- Styles of mineralization dictated by structural/lithological/chemical control on host rocks
- Iron oxide-associated mineralization can indicate underlying sulfide-associated mineralization. Oxide resources are likely under-appreciated and could represent potentially significant resources
- If the tourmaline at Pitarrilla is a product of an early or contemporaneous porphyry system, the mineralization and alteration styles at Pitarrilla may have resulted from a hybrid epithermal-porphyry system
- Occurrence of buddingtonite or ammonium anomalies, tourmaline alteration, and iron oxide-associated mineralization may be important

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- Michel Jébrak, Gary Beakhouse, Elisabeth Ronacher