# Exploration for overprinting deposit styles in the Basin and Range;

# Insights from a detailed study of W-Mo-Cu Mineralization in Gold Hill, Utah

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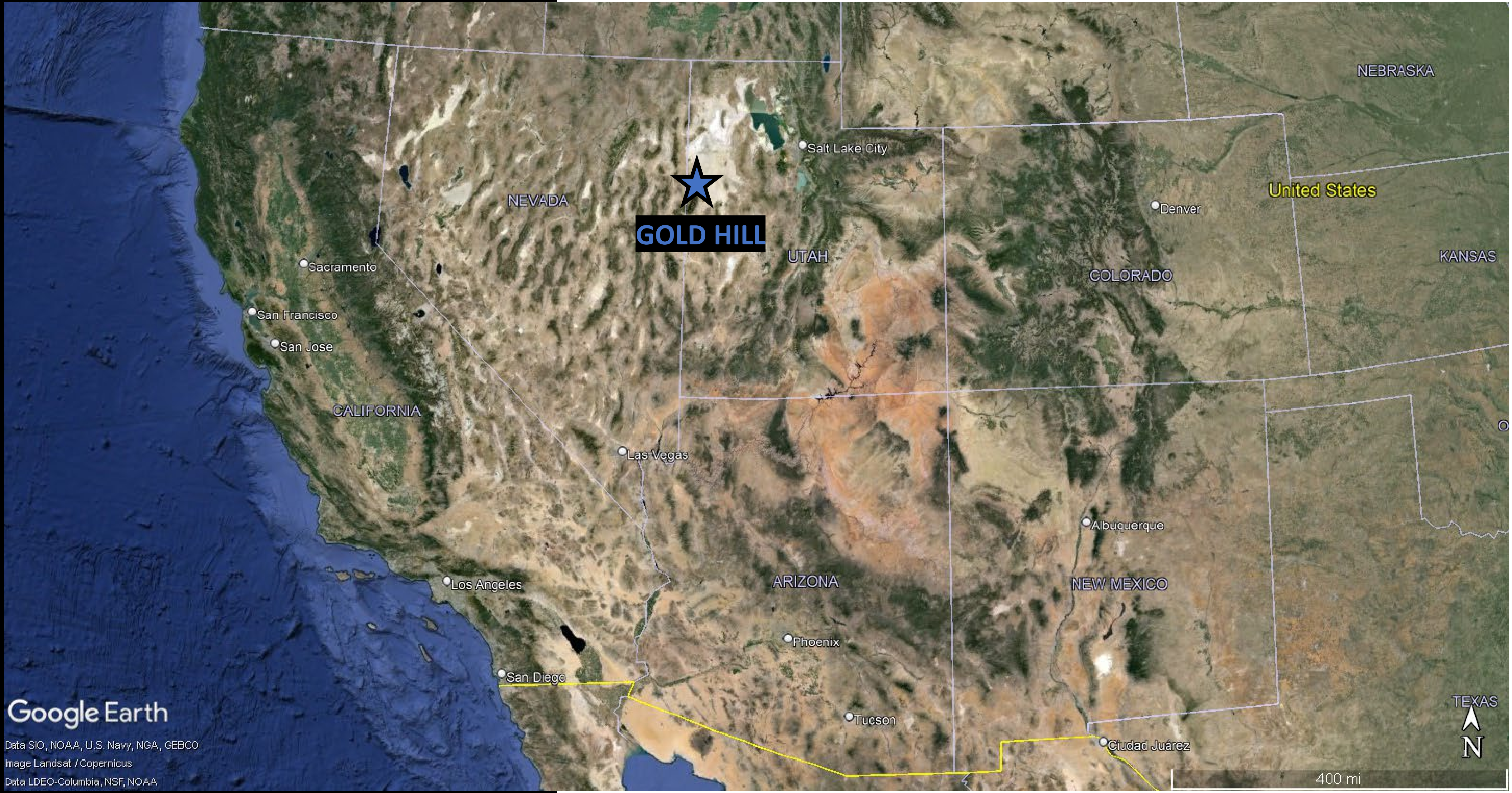
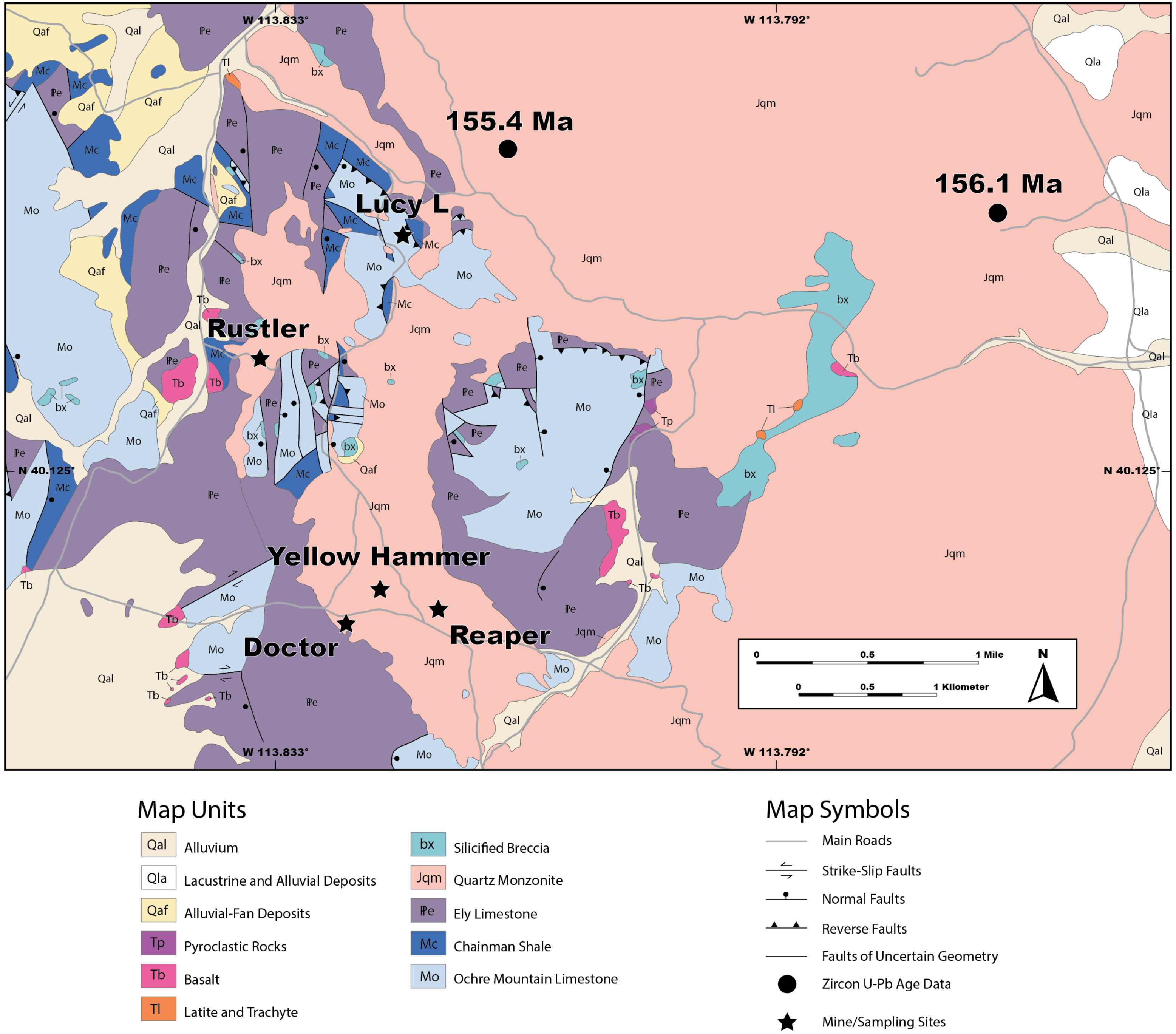
# Basin and Range



# Geology of Gold Hill, Utah

- Jurassic quartz monzonite intruded Paleozoic sedimentary units.
  - Existing zircon U-Pb ages of the quartz monzonite:
    - 155.4 ± 1.8 Ma (Burwell, 2018)
    - 156.1 ± 1.8 Ma (Burwell, 2018)

- W-Mo-Cu deposits studied:
  - Lucy L. (LL)
  - Rustler (RU)
  - Doctor (DR)
  - Yellow Hammer (YH)
  - Reaper (RE)



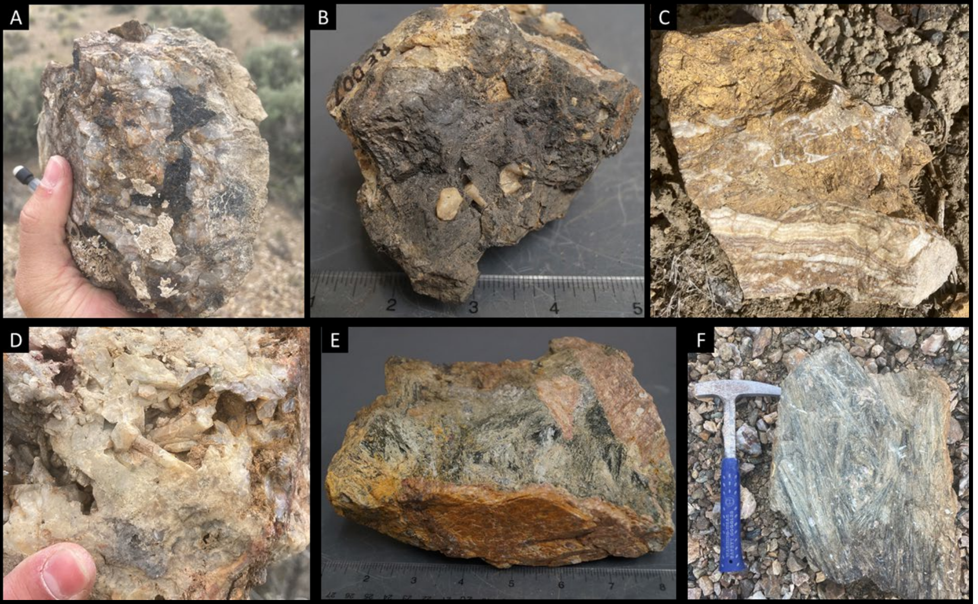
# Main Research Objectives

1. What are the **key mineralization associations** and **mineral paragenesis**?

2. What is the **age** of **W-Mo-Cu mineralization** spatially associated with the previously dated Jurassic intrusion?

3. What are the **deposit types** present and can their evolution be characterized?

# Methods



- **Hand Sample Analyses**
- Optical microscopy (transmitted and reflected light)
- Energy dispersive x-ray spectroscopy using a field emission scanning electron microscope (FESEM-EDS)
- Cathodoluminescence imaging (CL)
- Electron probe microanalysis (EPMA)
- Re-Os molybdenite geochronology (ICP-MS)

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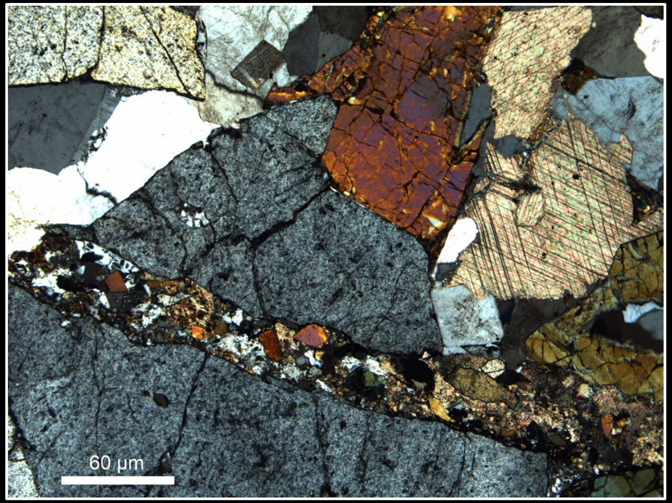
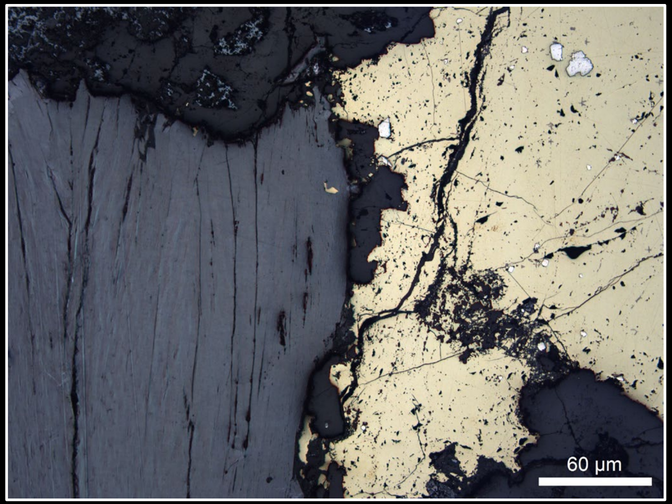



Transmitted Light




Reflected Light

- Petrography
- **Optical microscopy (transmitted and reflected light)**
- Energy dispersive x-ray spectroscopy using a field emission scanning electron microscope (FESEM-EDS)
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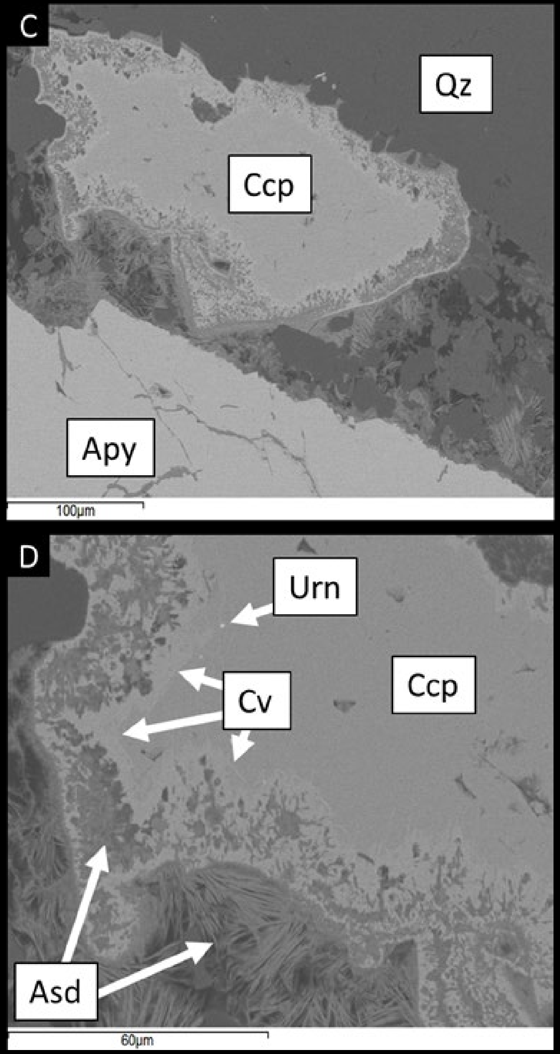


Backscattered Electron Images

- Petrography
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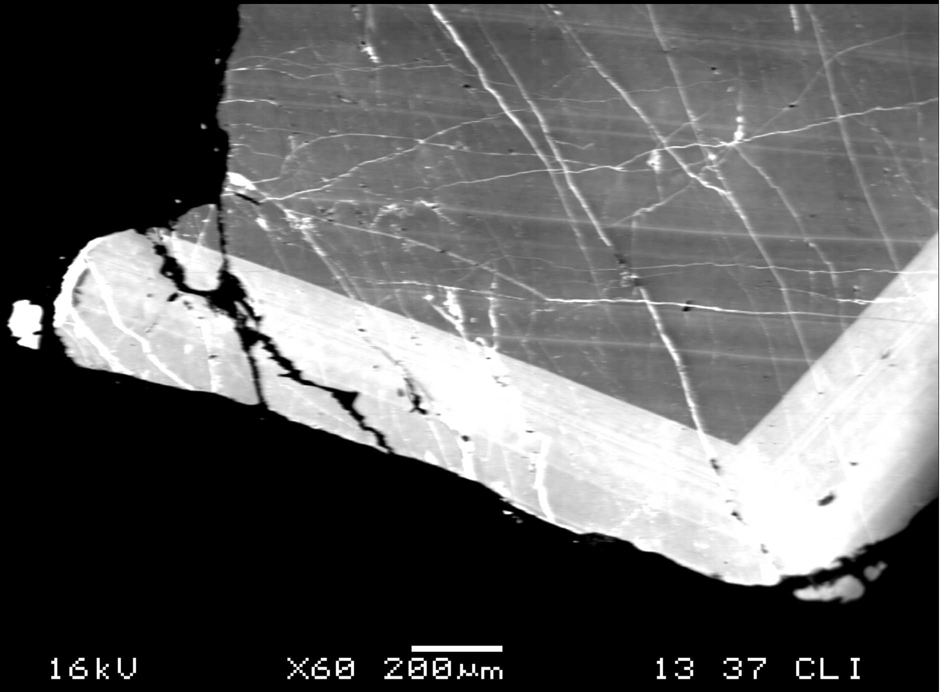


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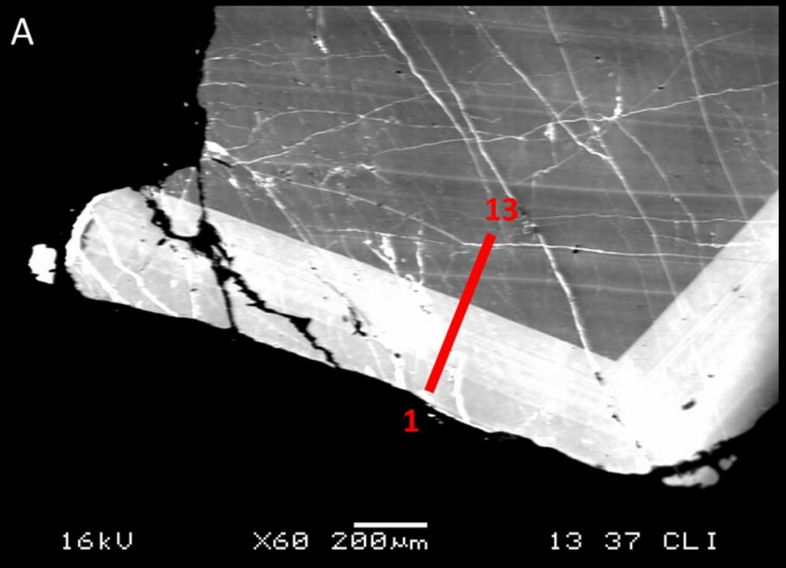


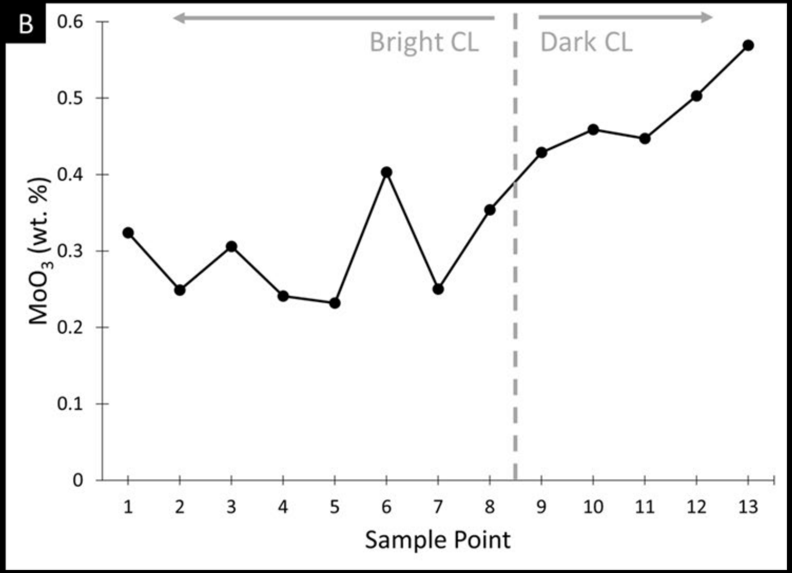


UNLV Electron Microanalysis & Imaging Laboratory

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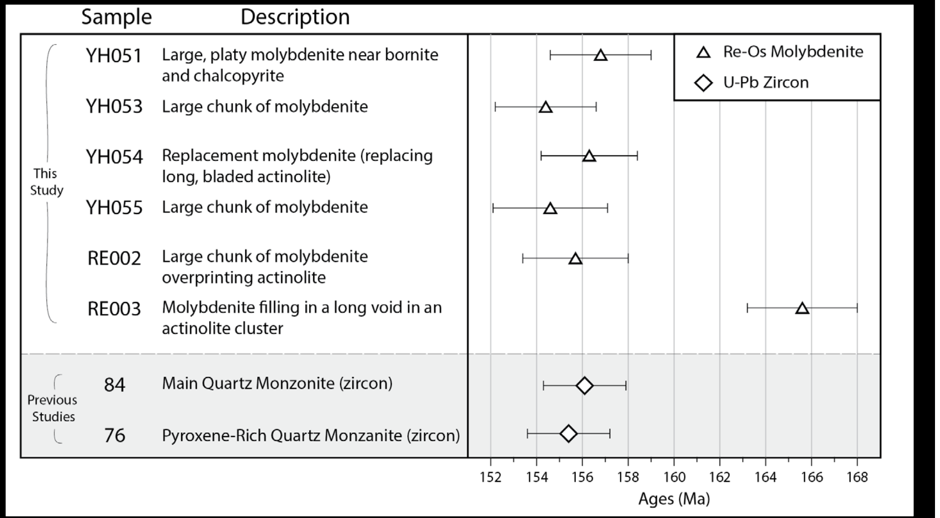


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- **Re-Os molybdenite geochronology (ICP-MS)**

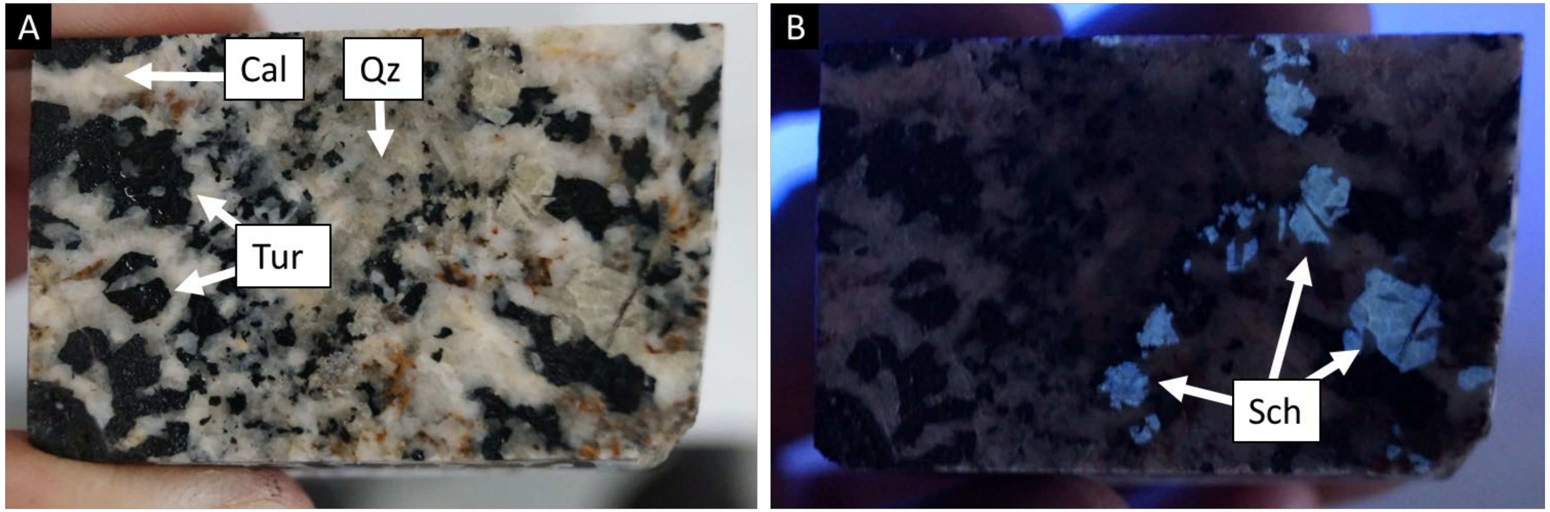
# 1. W-MO-CU MINERALIZATION ASSOCIATIONS AND MINERAL PARAGENSIS

# Tungsten (W) Mineralization and Associations

- Tungsten Ore: Scheelite ($Ca(WO_4)$)

- Scheelite is commonly closely associated with:
  - **Quartz** and **tourmaline** with minor apatite, feldspars, and calcite.
    - And occasionally:
      - Actinolite-magnetite assemblages.
      - Later veins of quartz, anhydrite, pyrite, and chalcopyrite.

Normal Light | Shortwave UV Light



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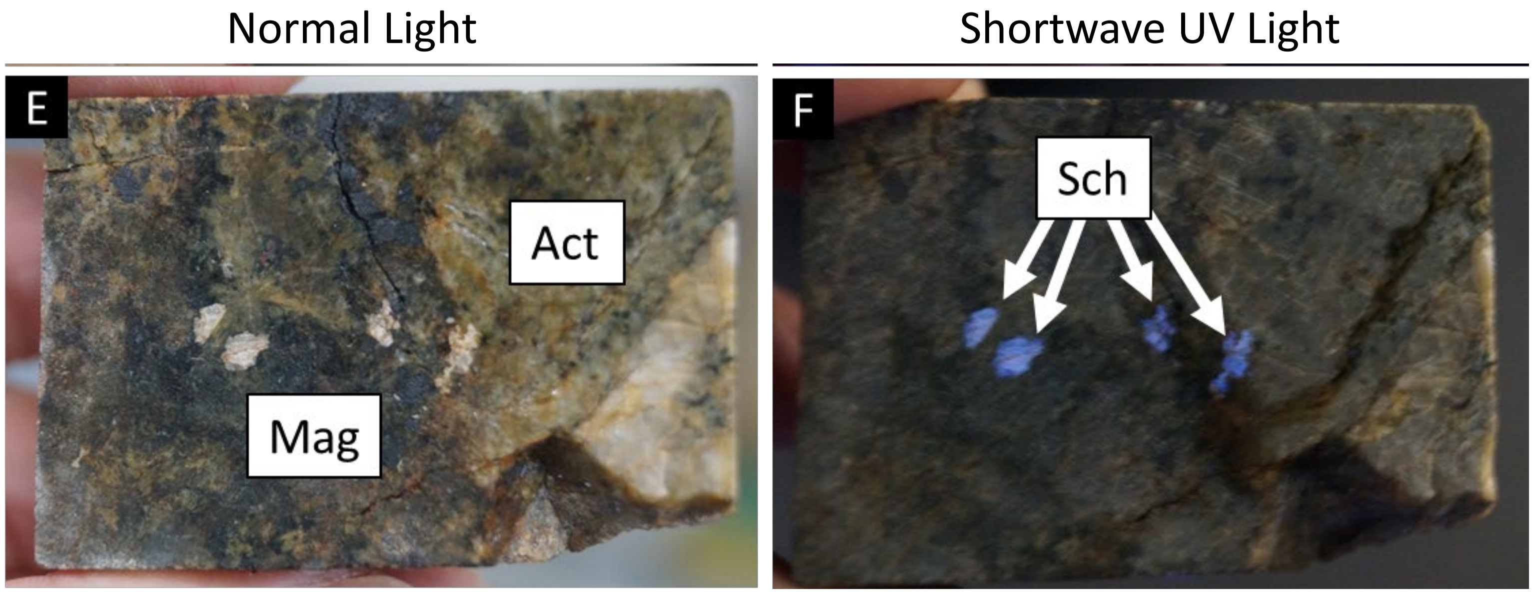

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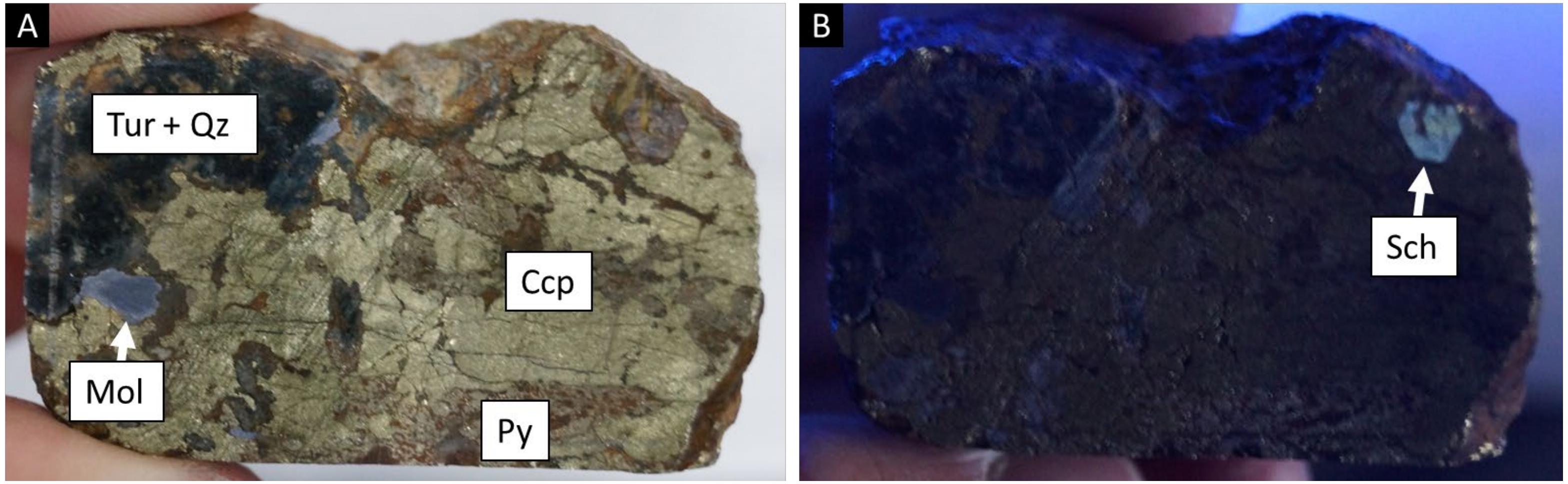
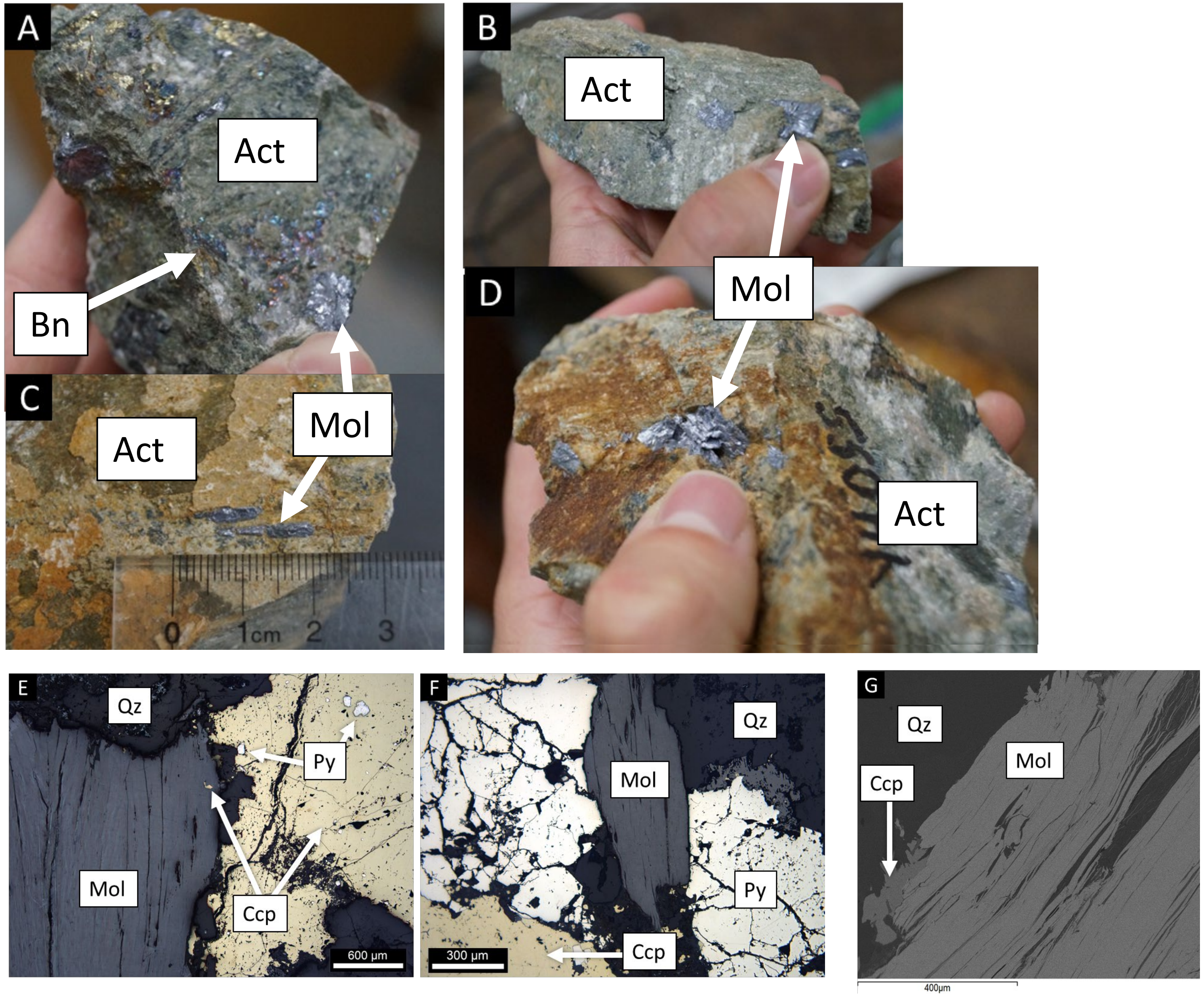
Shortwave UV Light



# Molybdenum (Mo) Mineralization and Associations

- Molybdenum Ore: Molybdenite ($MoS_2$)

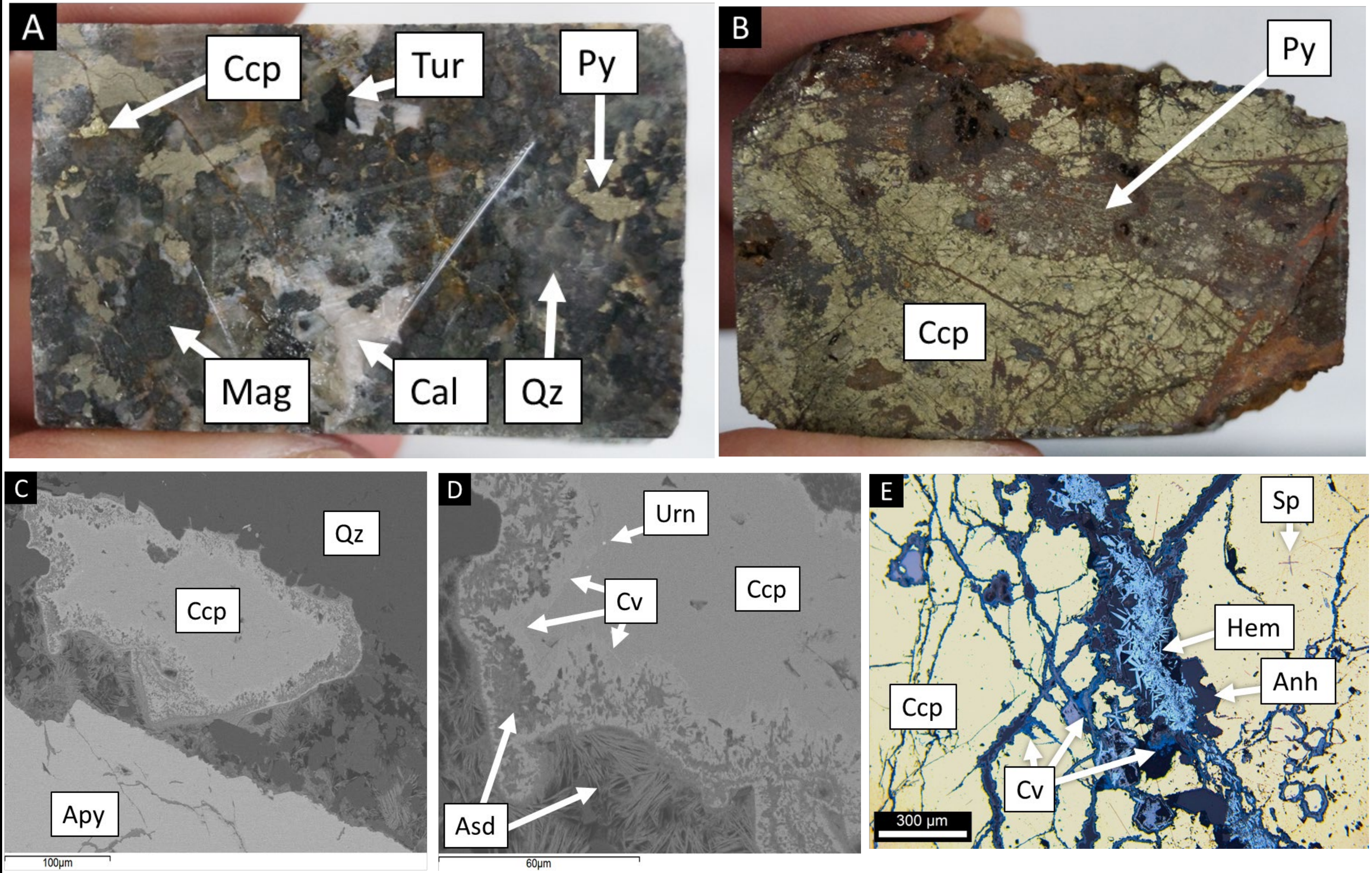
- Molybdenite is typically closely associated with:
  - Actinolite
    - And occasionally:
      - Chalcopyrite, bornite, and pyrite assemblages.




Hand sample images (A-D), plane polarized reflected light thin section photomicrographs (E-F), and BSE image (G) of sample YH044a. Abbreviations are as follows: Act = actinolite, Bn = bornite, Ccp = chalcopyrite, Mol = molybdenite, Py = pyrite, and Qz = quartz.

# Copper (Cu) Mineralization and Associations

- Main Copper Ore: Chalcopyrite ($CuFeS_2$)
- Chalcopyrite is commonly associated with:
  - Calcite, tourmaline, garnet, quartz, magnetite, pyrite, or arsenopyrite.

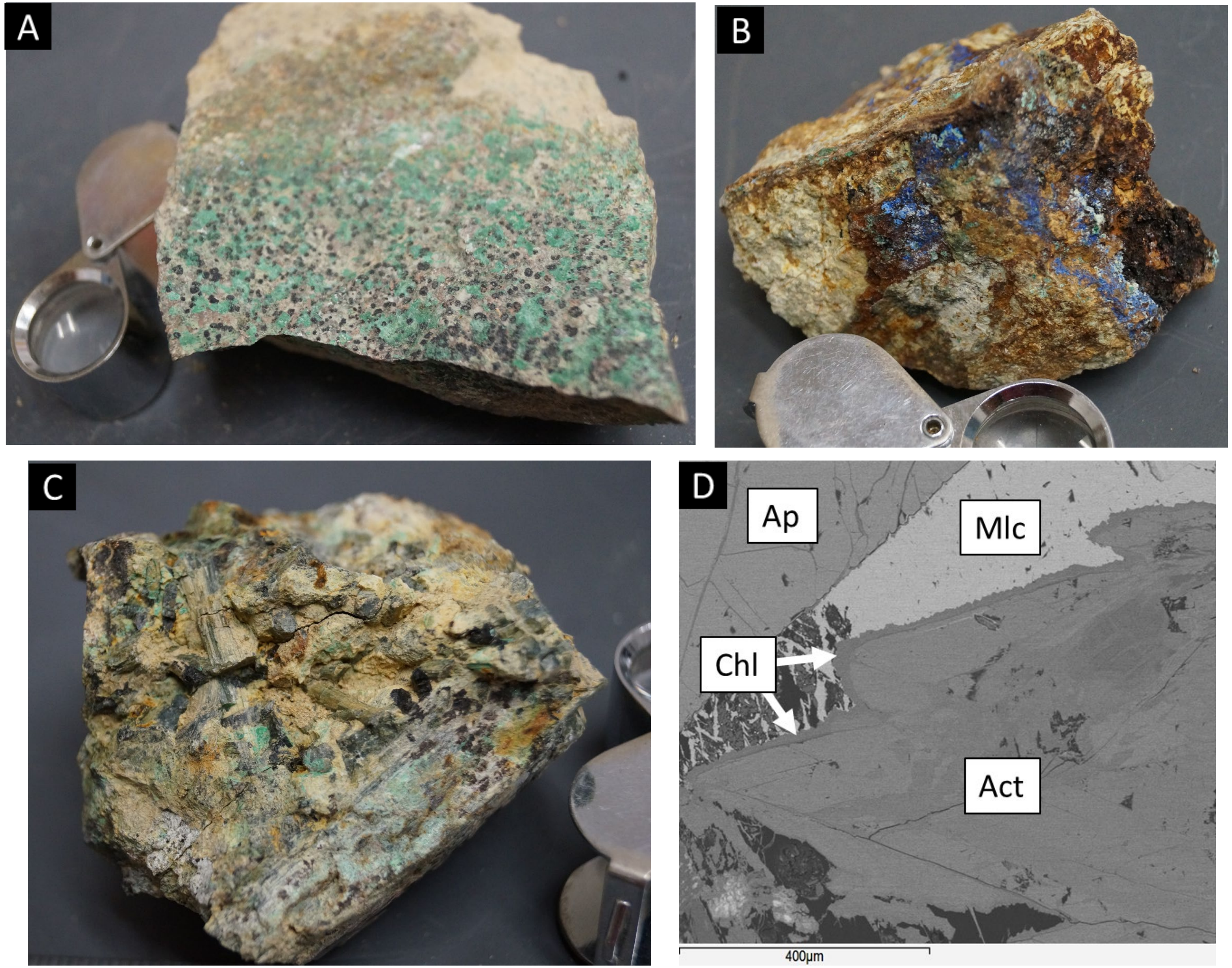



Standard thin section billet images of YH024 and YH042 (27 x 46 mm; A-B), BSE images from YH009 (C-D), and plane polarized reflected light photomicrographs of YH042. Abbreviations are as follows: Anh = anhydrite, Apy = arsenopyrite Asd = arseniosiderite, Cal = calcite, Ccp = chalcopyrite, Cv = covellite, Hem = hematite, Mag = magnetite, Py = pyrite, Qz = quartz, Sp = sphalerite, Tur = tourmaline, and Urn = uraninite.

# Copper (Cu) Mineralization and Associations

- Other Copper Ores: malachite, azurite, chrysocolla, chalcocite, covellite, and bornite.

- Malachite is the most common of these, typically observed overprinting other minerals or filling in empty space.




Hand sample images (A-C) and BSE image (D) from various Yellow Hammer samples. Abbreviations are as follows: Act = actinolite, Ap = Apatite, Chl = chlorite, and Mlc = malachite. Hand lens for scale (A-C).

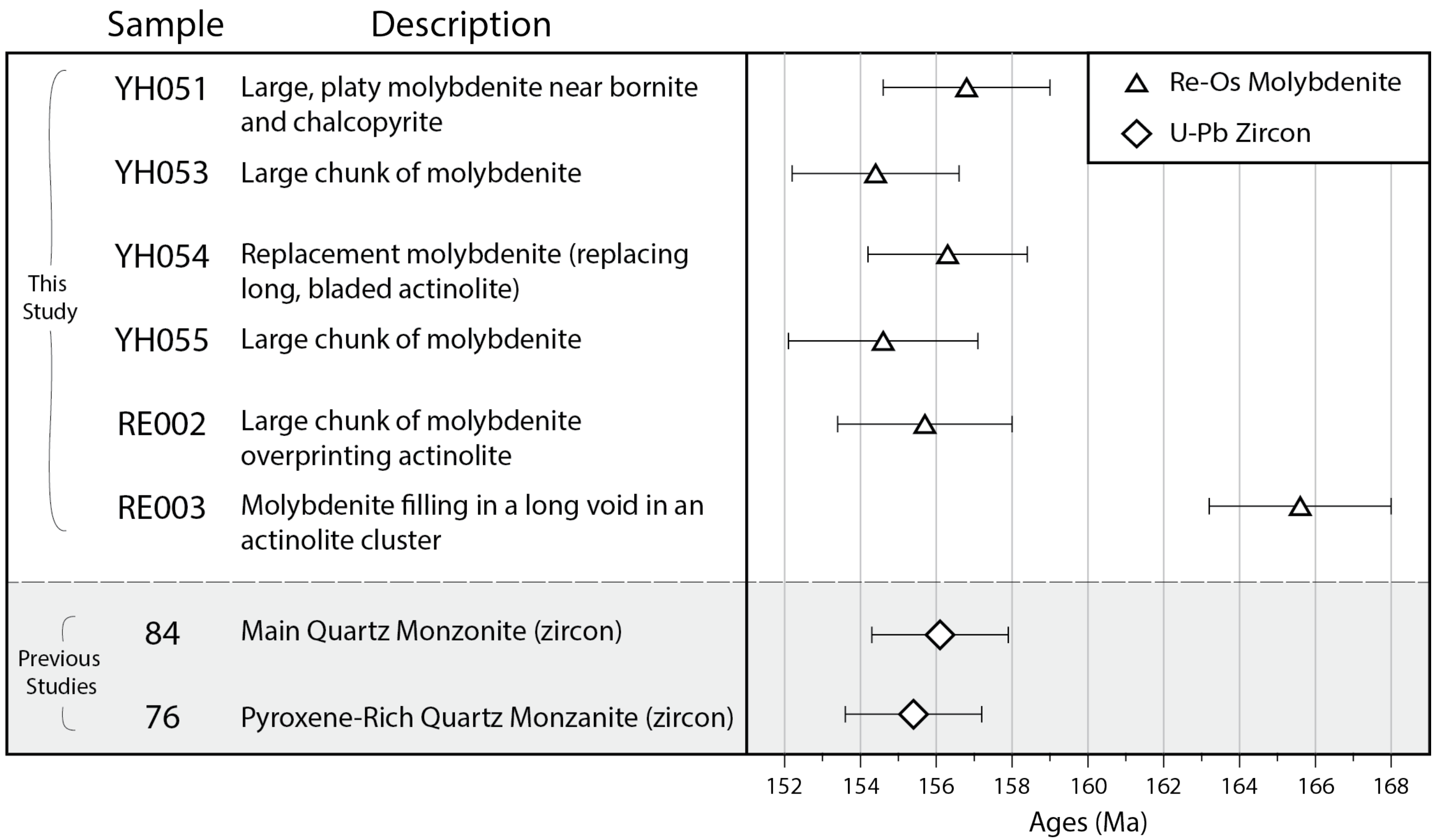
# 2. AGE OF W-MO-CU MINERALIZATION

# Age Constraints

- **Relative mineralization ages:**
  1. Scheelite (oldest)
  2. Chalcopyrite and Molybdenite
  3. Malachite and other copper ore minerals (youngest)

- **Re-Os molybdenite ages:**
  - Five of six are consistent with the existing zircon U-Pb ages for the proximal pluton from Burwell (2018).
  - **Reaper Deposit:** One of the two molybdenite ages is about 10 Ma older…More on this later.

| Sample | Weight (g) | Re (ppm) | Common Os (ppb) | 187 Re (ppm) | 187 Os (ppb) | Age (Ma) |
|---|---|---|---|---|---|---|
| YH051 | 0.10 | 42.43 ± 0.33 | 0.01 ± 0.0005 | 26.67 ± 0.21 | 69.74 ± 0.41 | 156.8 ± 2.2 |
| YH053 | 0.10 | 92.24 ± 0.80 | 0.02 ± 0.0007 | 57.98 ± 0.50 | 149.30 ± 0.90 | 154.4 ± 2.2 |
| YH054 | 0.02 | 37.55 ± 0.27 | 0.33 ± 0.01 | 23.60 ± 0.17 | 61.55 ± 0.36 | 156.3 ± 2.1 |
| YH055 | 0.02 | 54.94 ± 0.57 | 0.58 ± 0.01 | 34.53 ± 0.36 | 89.05 ± 0.61 | 154.6 ± 2.5 |
| RE002 | 0.10 | 17.10 ± 0.14 | 0.009 ± 0.0002 | 10.75 ± 0.09 | 27.91 ± 0.20 | 155.7 ± 2.3 |
| RE003 | 0.05 | 3.62 ± 0.03 | 0.10 ± 0.01 | 2.27 ± 0.02 | 6.28 ± 0.04 | 165.6 ± 2.4 |



# 3. DEPOSIT TYPES

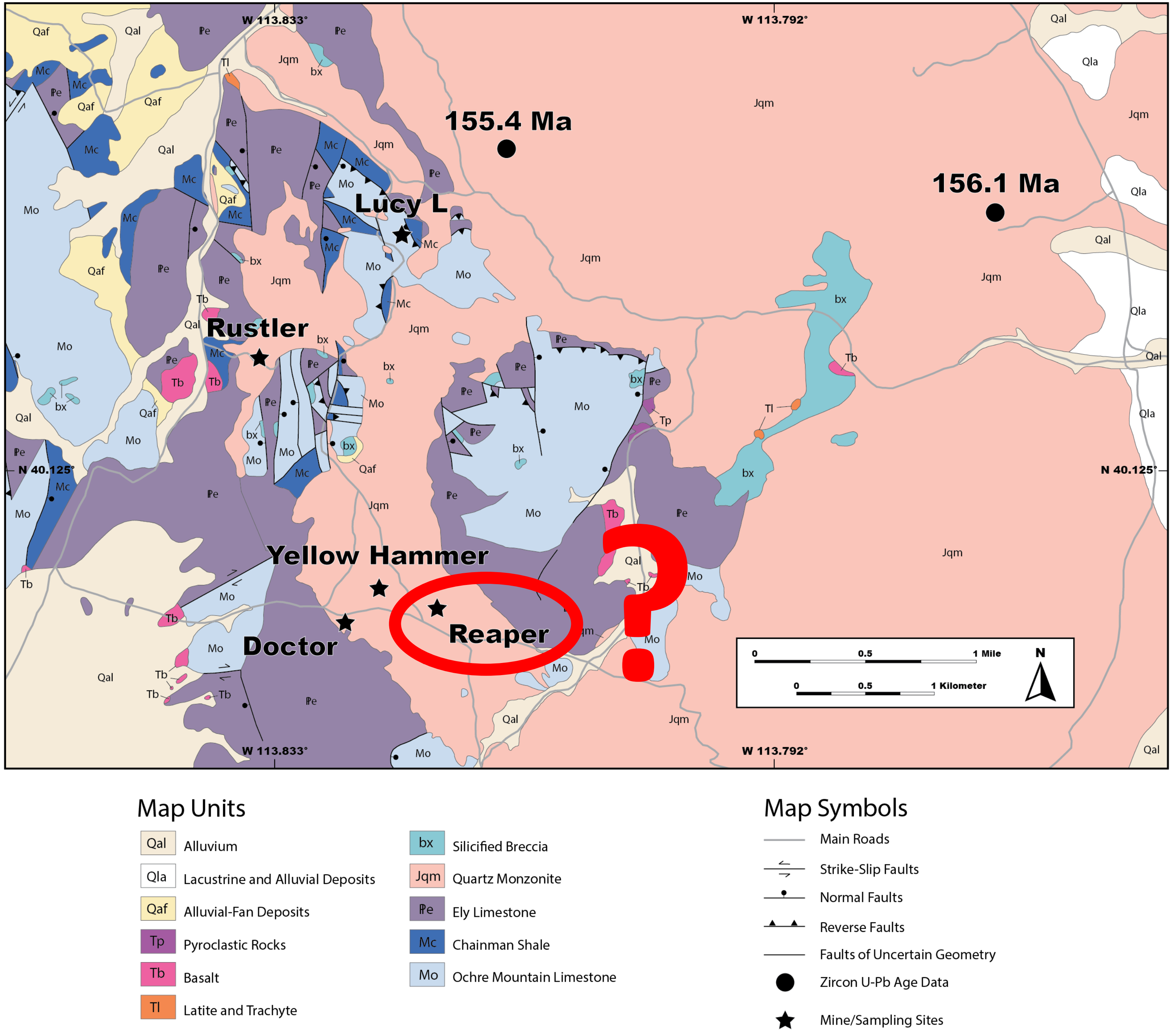
# Deposit Types

## Non-Reaper Deposits:

1. W-Mo-Cu Skarn (~156 Ma)
   - Endoskarn and exoskarn
2. Late Supergene Cu and Oxidation

## Reaper Deposit:

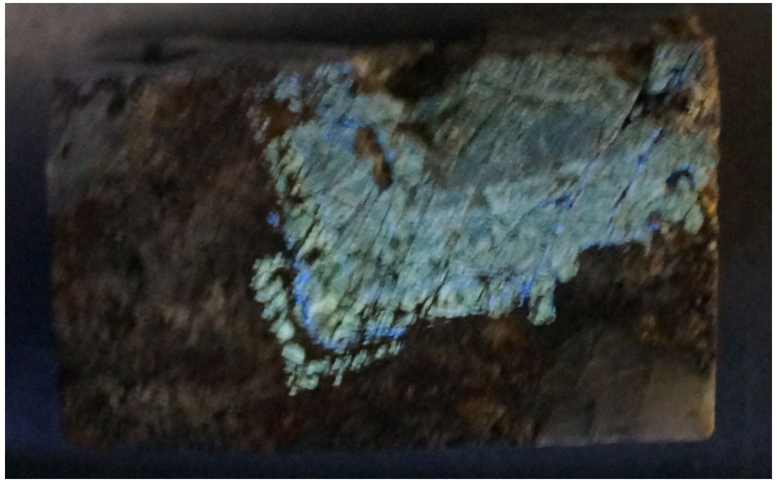
- The Reaper site contains W-Mo-Cu mineralization, but unique textures in hand sample and thin section suggest its genesis varies from the other deposits…
   - Distinct older Re-Os age?



# Reaper Deposit

- Unique Textures:
  - Coarse **pegmatitic** minerals:
    - K-feldspars
    - Actinolite
    - Scheelite
  - **Epithermal**-like quartz textures:
    - Crustiform-colloform banding
    - Hydrothermal breccia (quartz, tourmaline, and iron oxide).

Normal Light



Shortwave UV Light

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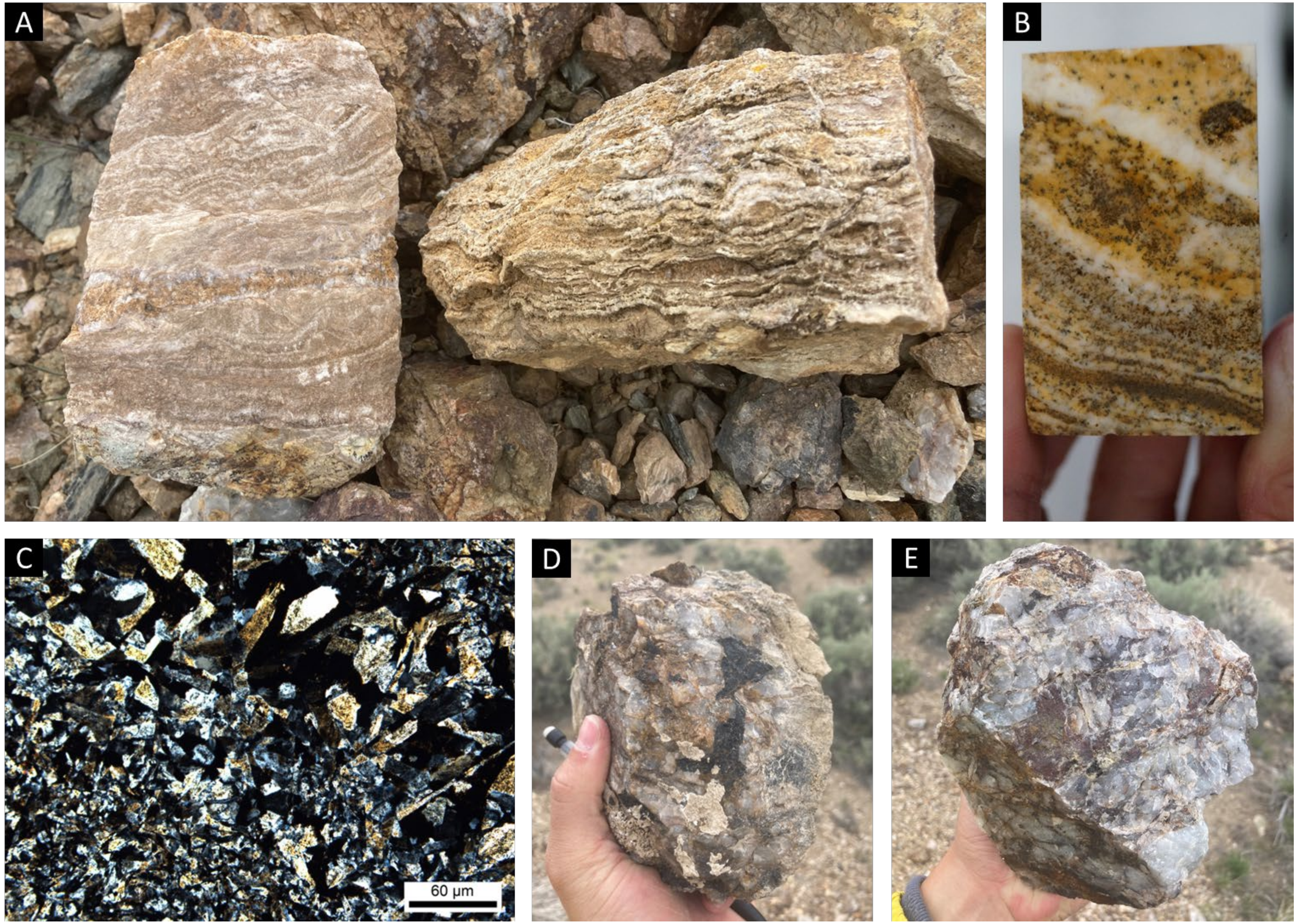

# Revisiting the Outlying Molybdenite Age

Reaper Sample Age: 165.6 ± 2.4 Ma

- Best Explanation:
  - The low Re concentration of sample RE003 reflects Re loss during interaction with later **epithermal-type** fluids, yielding an older age.

NOTE: Crustiform-colloform banding is indicative of boiling fluids (John et al., 2018) and Re loss in molybdenite can occur by interaction with fluids as low as 150° C (McCandless, 1993).

**Suggests a epithermal overprint after W-Mo-Cu Skarn mineralization.**

| Sample | Re (ppm) | Age (Ma) |
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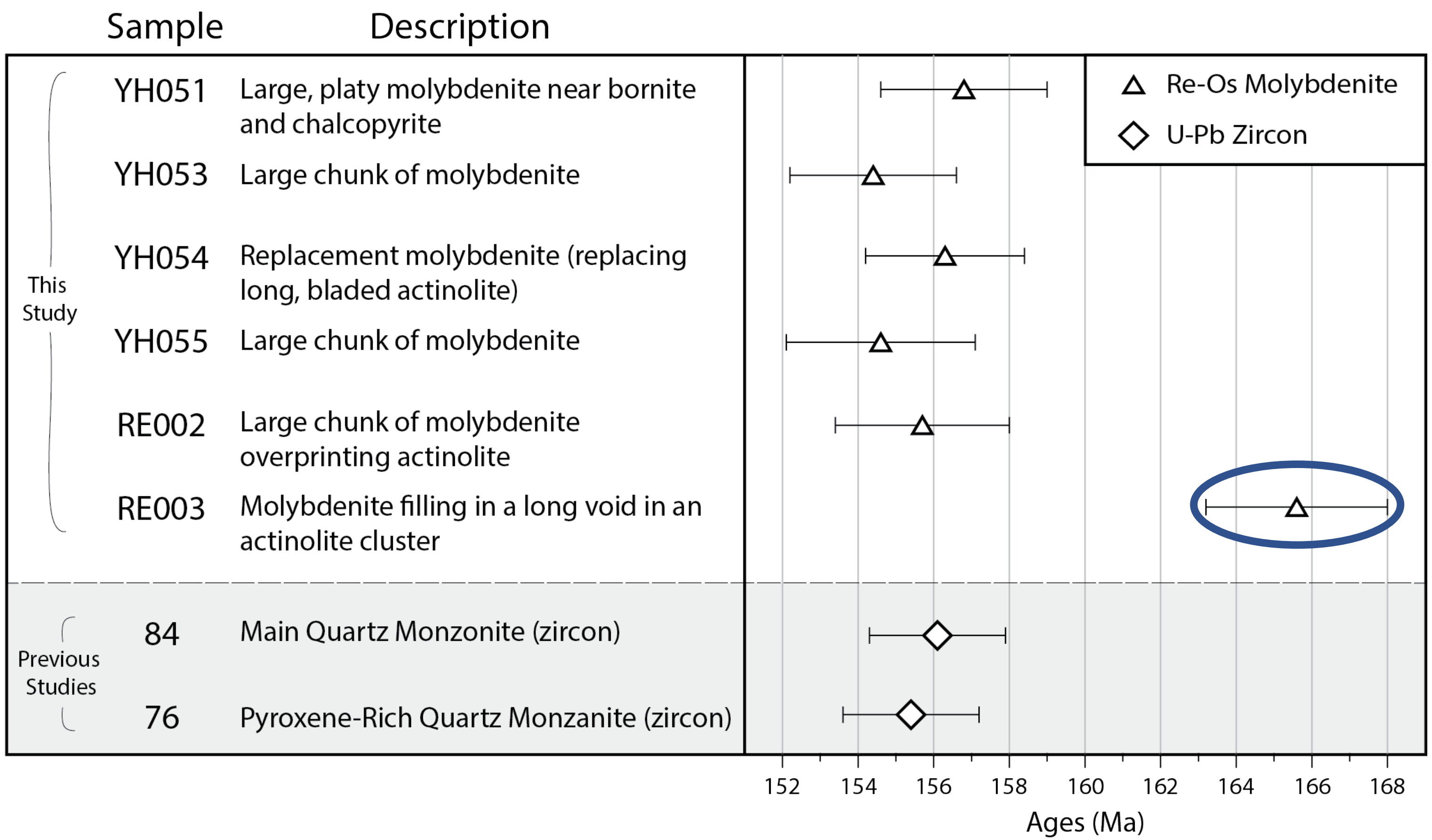
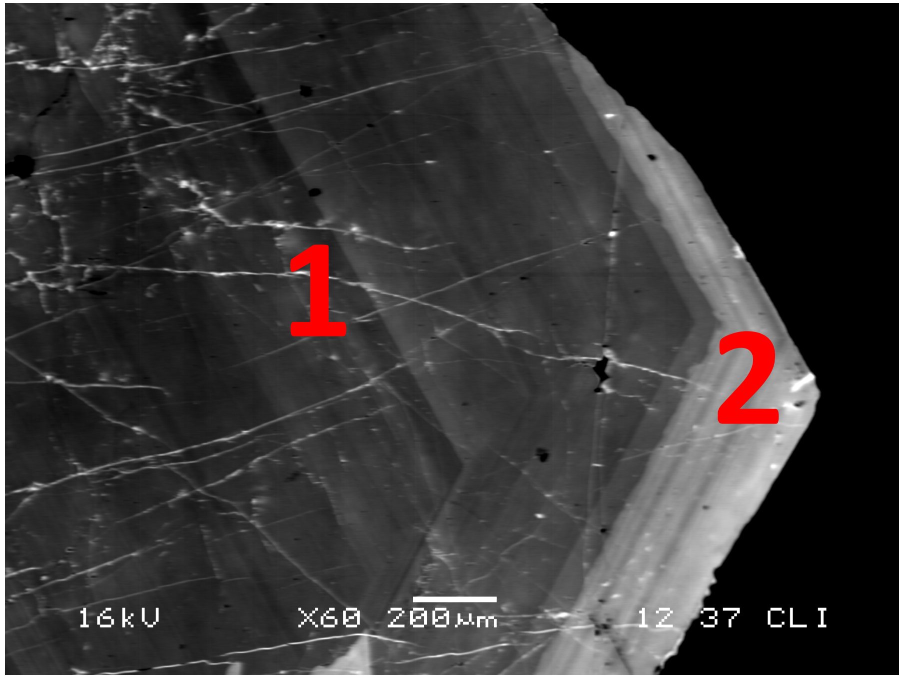



Okay…now what about those coarse pegmatitic minerals?

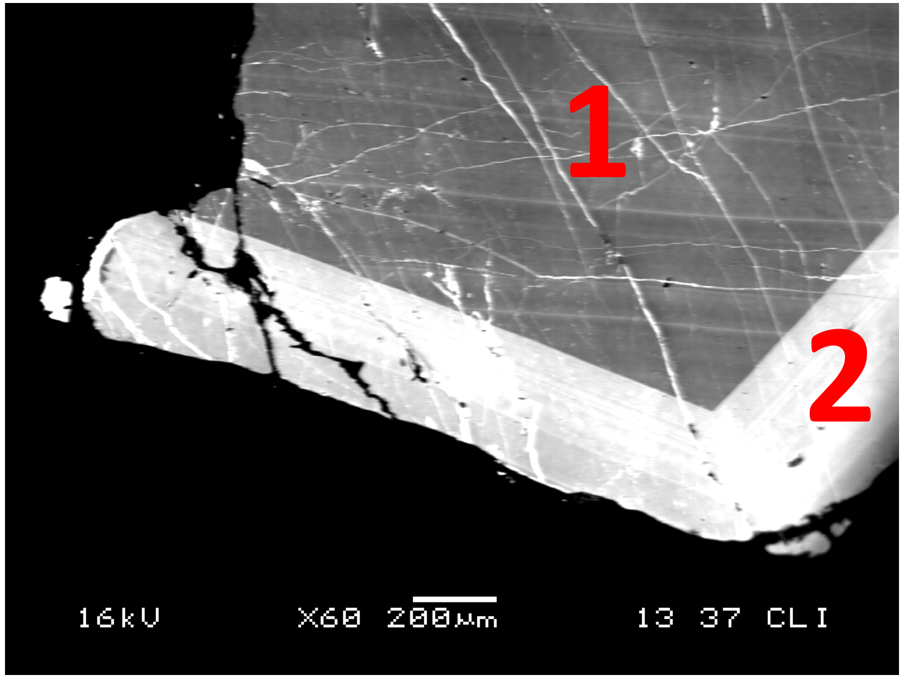
# Scheelite Cathodoluminescence Imaging

**Non-Reaper Deposits:**

- Two phases of oscillatory zoned scheelite:
  - Zoning indicative of fluctuating fluid compositions, common in skarn environments (Poulin et al., 2016).




Doctor Scheelite



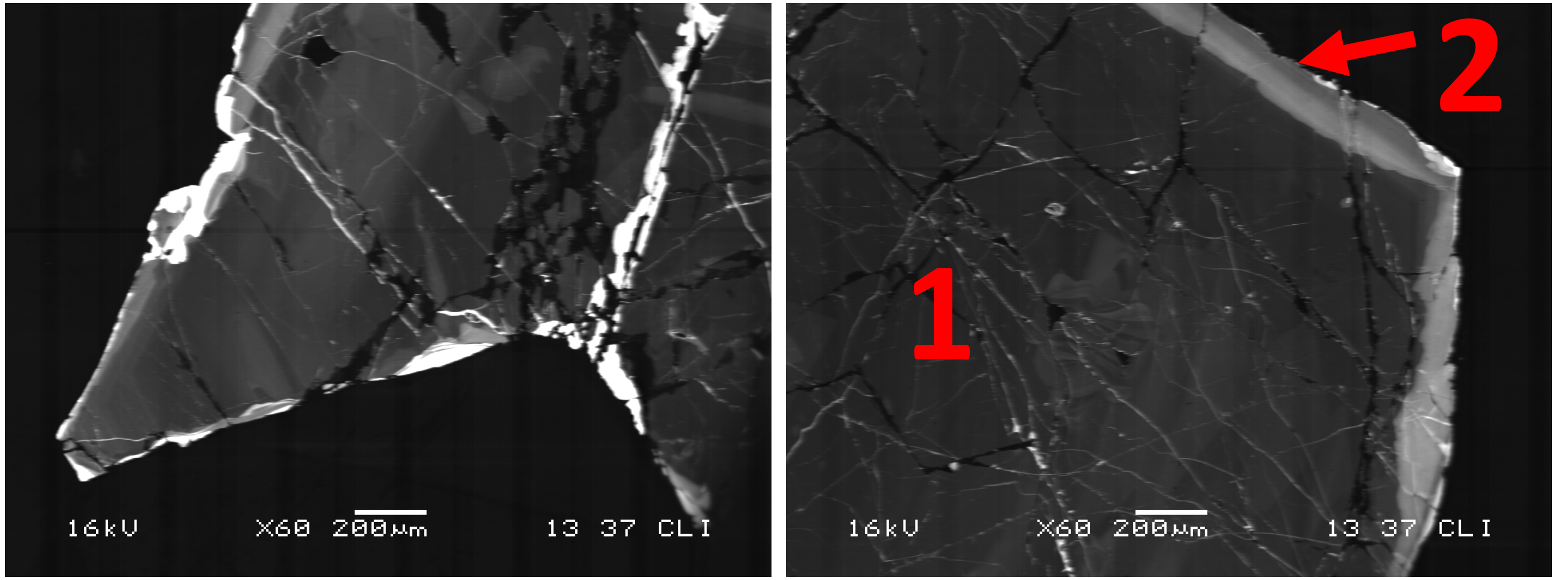

Rustler Scheelite

(1) Dark oscillatory zoned core and
(2) Bright oscillatory zone rim

# Scheelite Cathodoluminescence Imaging

**Reaper Deposit:**

- A homogeneous core indicates that the fluid composition was not fluctuating during growth (Poulin et al., 2016).




(1) Homogenous core => a **pegmatitic pipe?**

(2) Oscillatory zoned rim => **skarn formation**

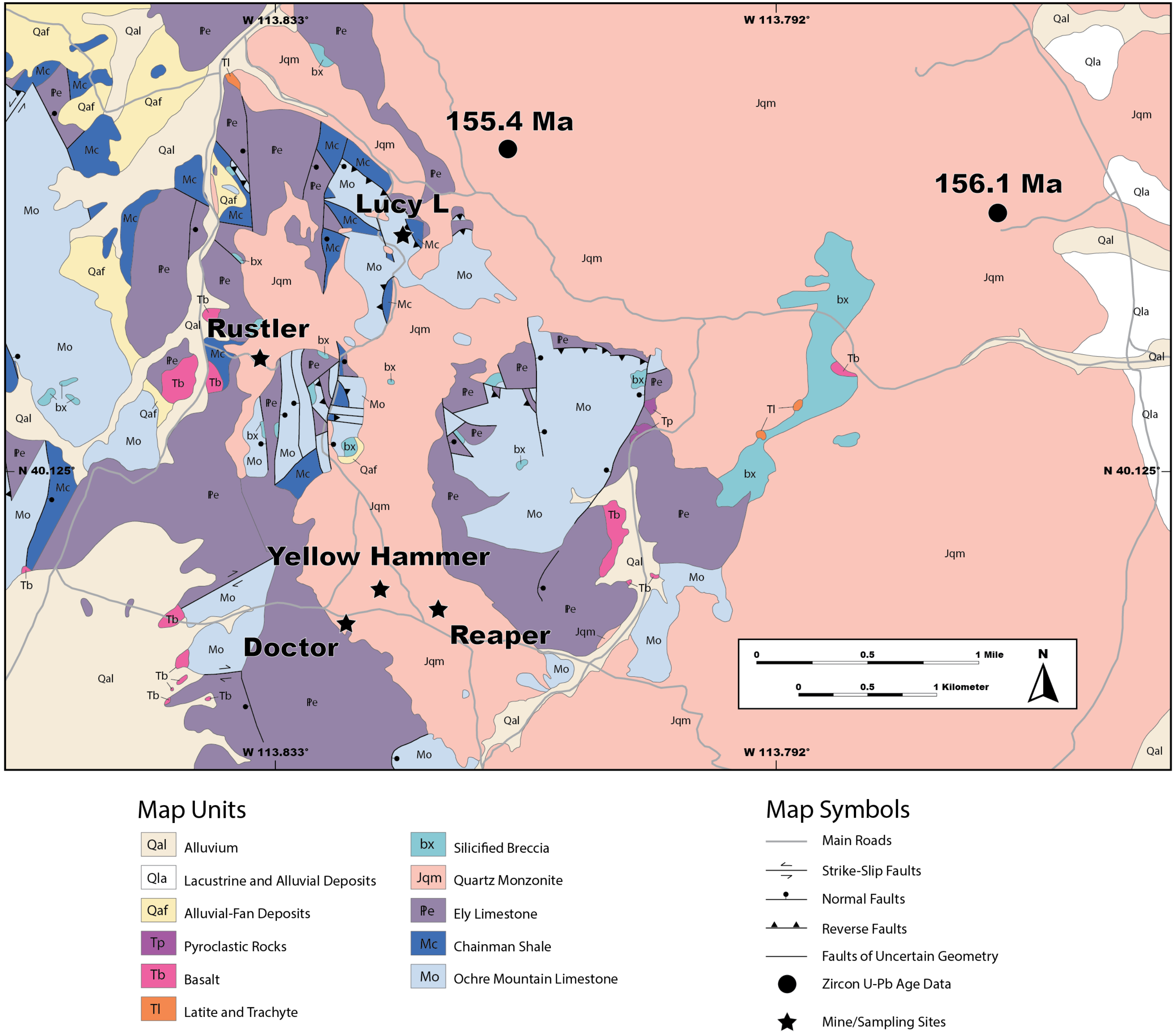
# Deposit Types

## Non-Reaper Deposits:

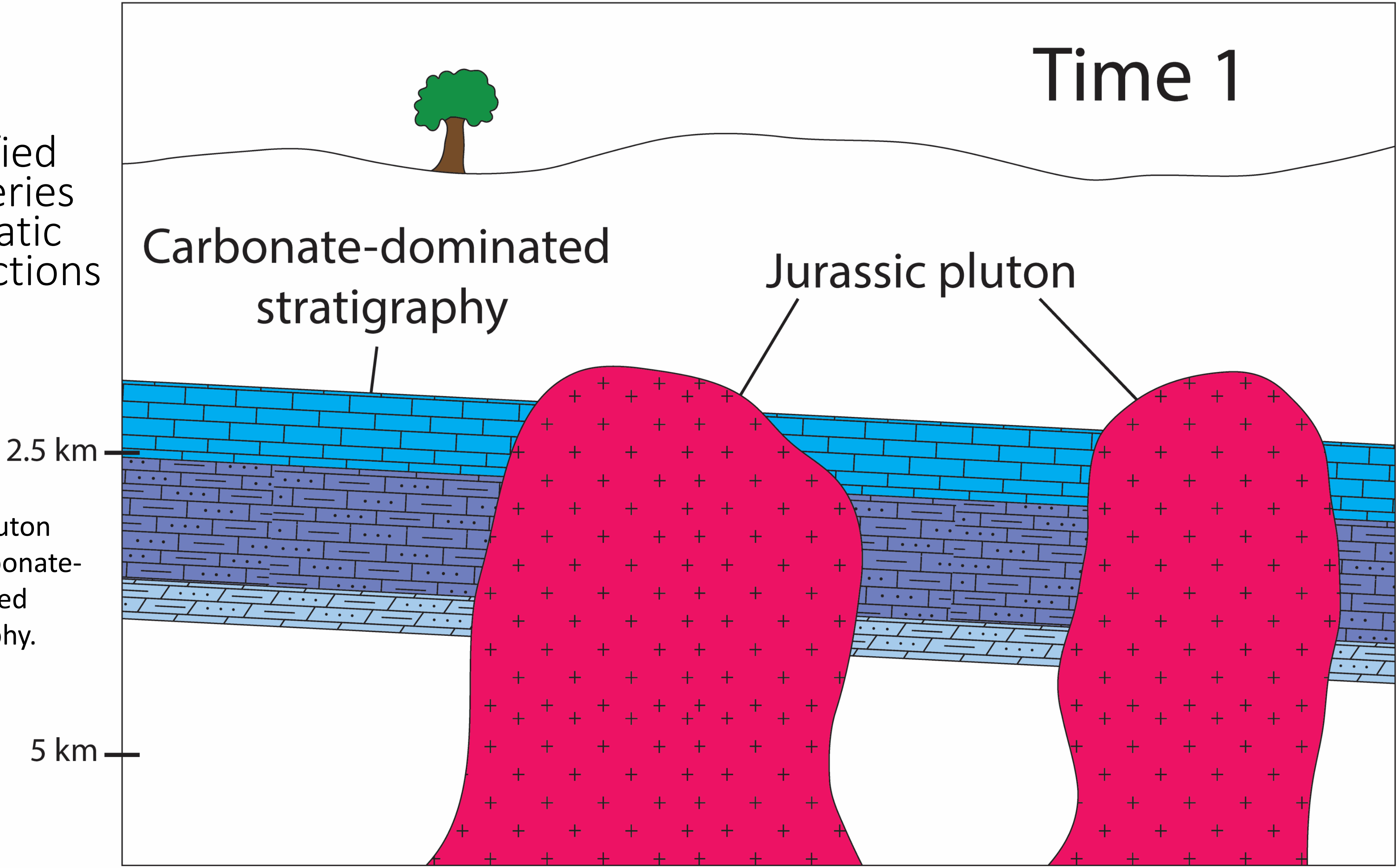
1. W-Mo-Cu Skarn (~156 Ma)
   - Endoskarn and exoskarn
2. Late Supergene Cu and Oxidation

## Reaper Deposit:

1. Formed initially as a **W-rich pegmatitic pipe…**
2. That was **overprinted by W-Mo-Cu skarn** mineralization…
3. And later **overprinted by epithermal-type mineralization** and **supergene Cu remobilization.**

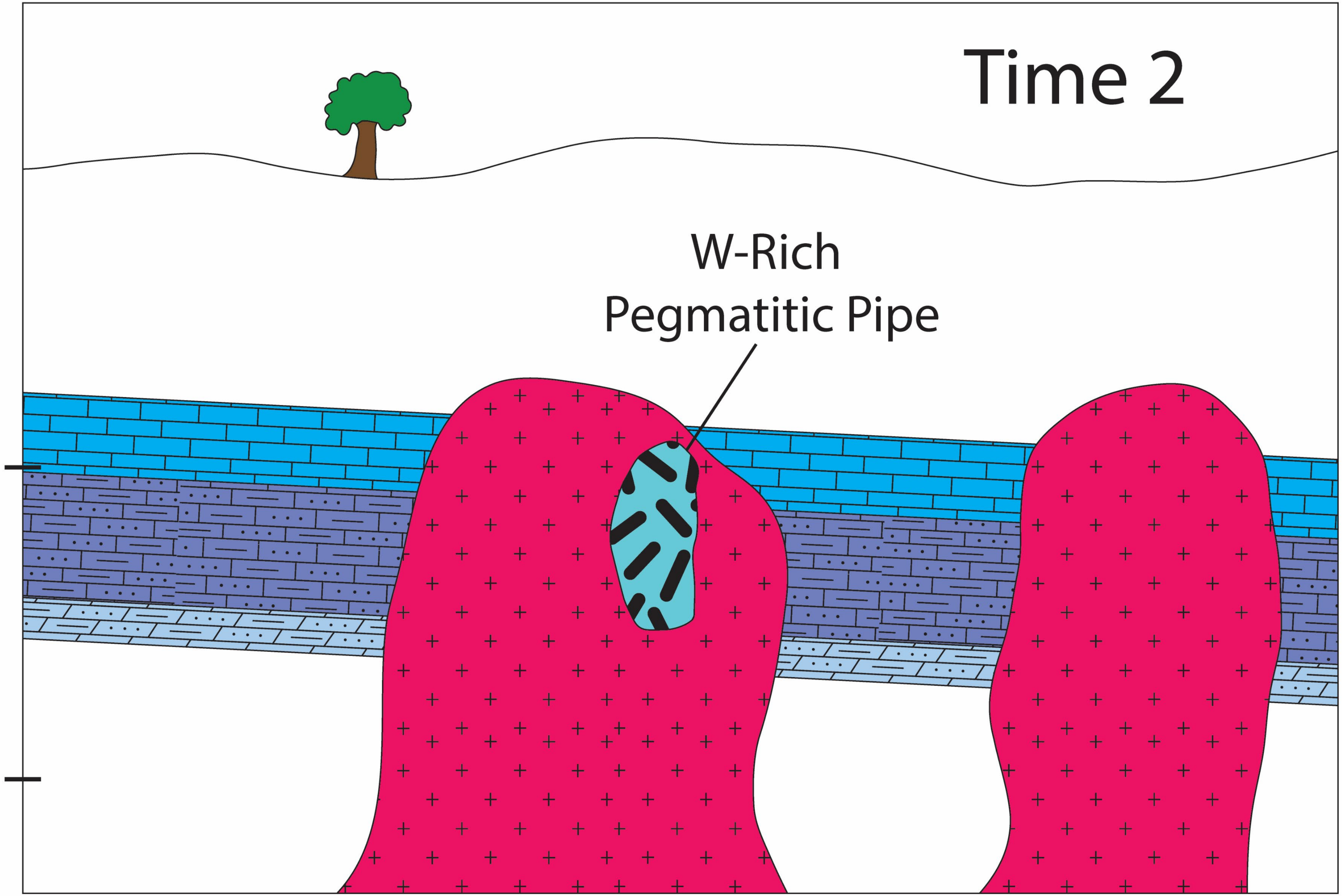


Simplified Time-Series Schematic Cross-Sections




Jurassic pluton intrudes carbonate-dominated stratigraphy.

Simplified Time-Series Schematic Cross-Sections




Formation of W-rich pegmatitic pipe during initial cooling of pluton.

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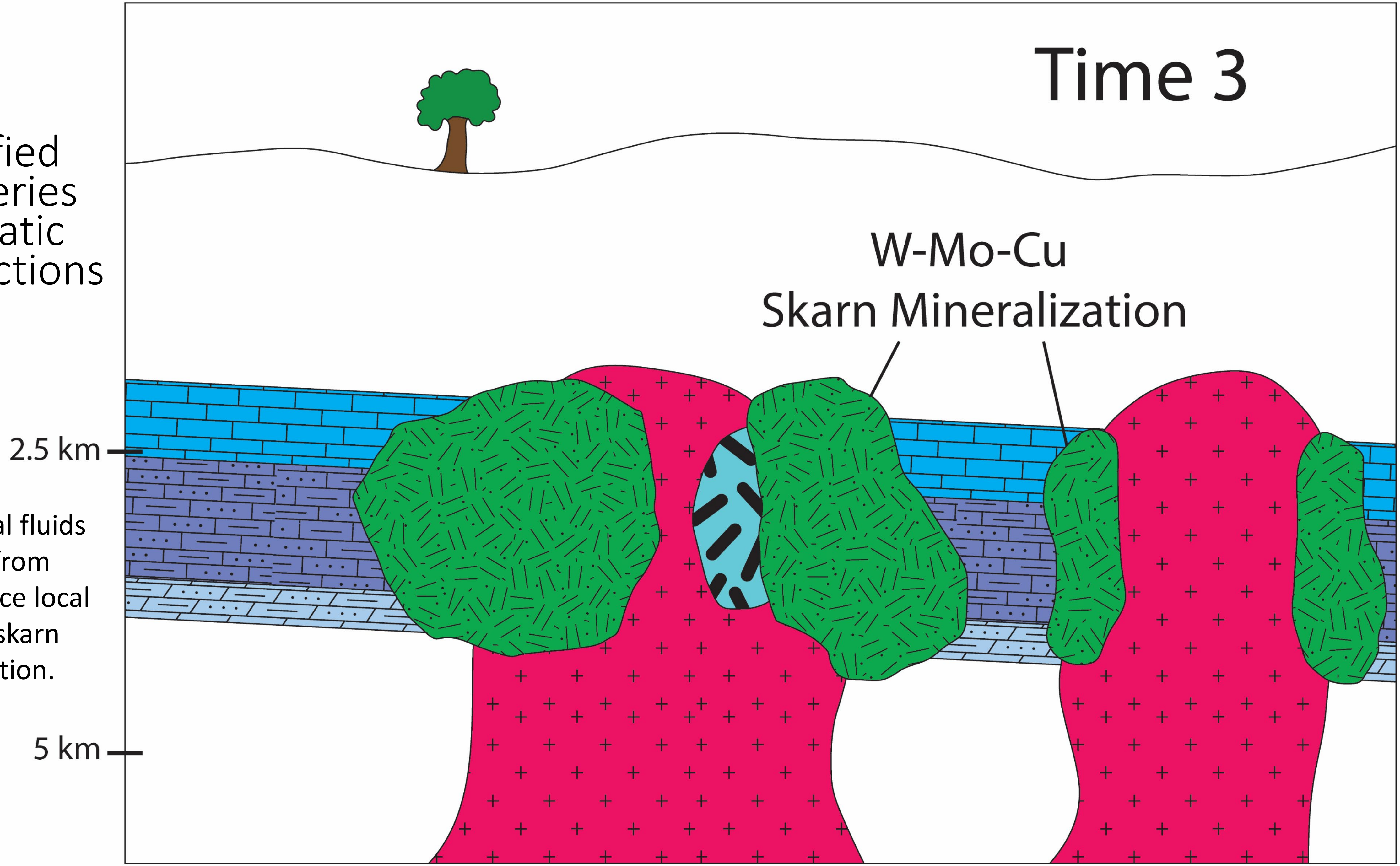
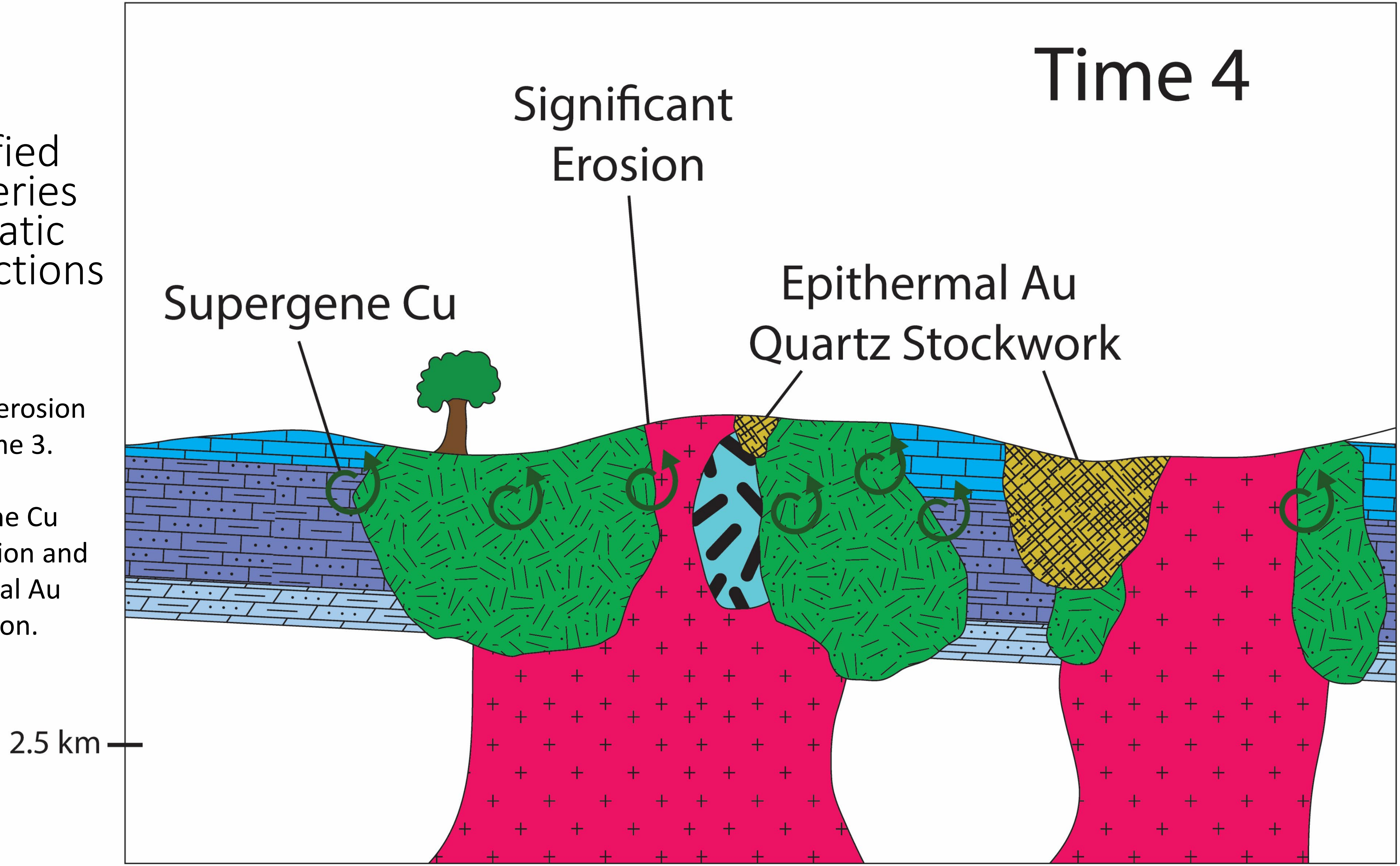



Hydrothermal fluids exsolved from pluton produce local W-Mo-Cu skarn mineralization.

Simplified Time-Series Schematic Cross-Sections

Significant erosion since Time 3.

Supergene Cu remobilization and epithermal Au formation.

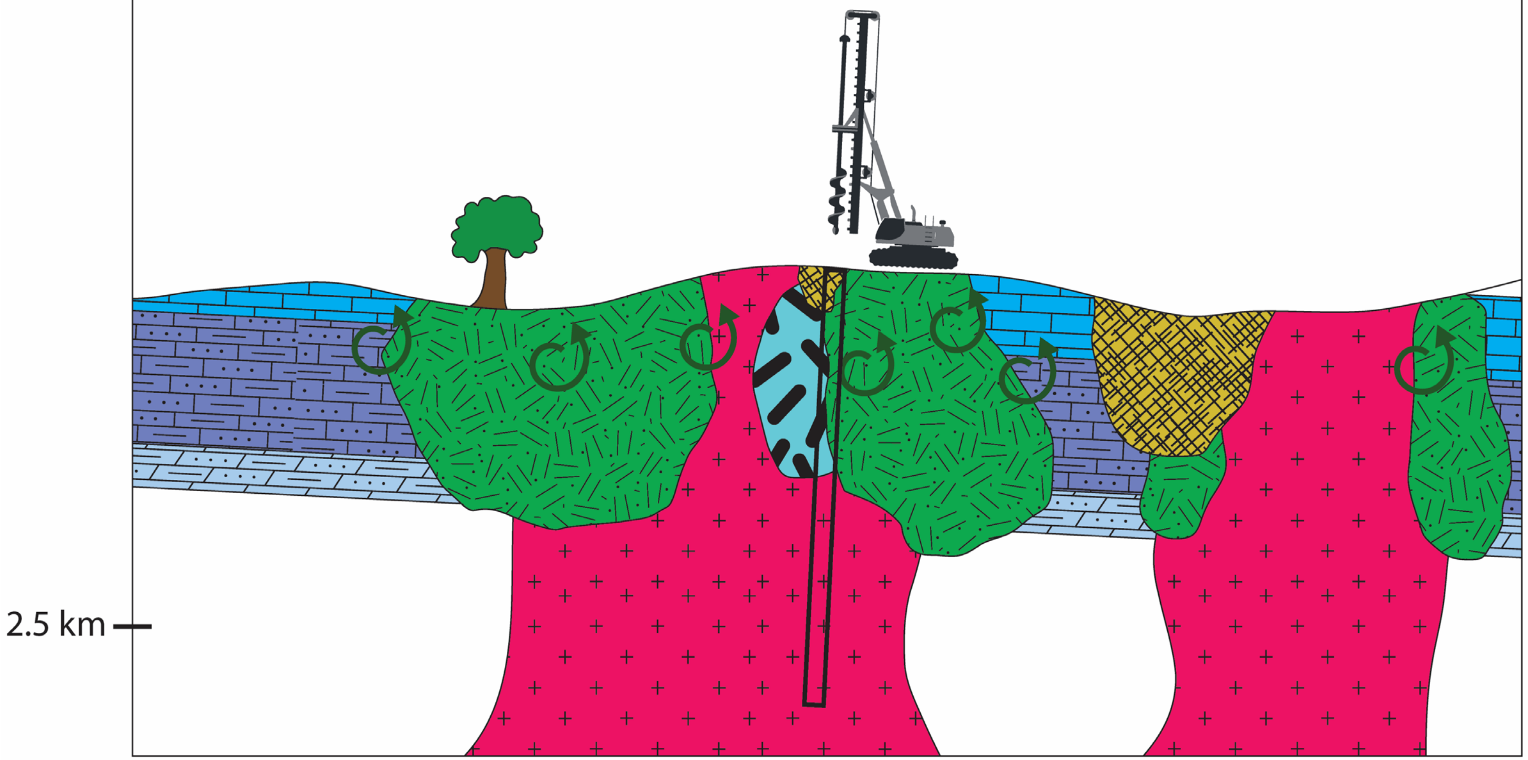


# Implications for Regional Exploration

- The Basin and Range Province has a complex tectonomagmatic history.
    - Result: mining districts with overprinting deposit types of various ages and commodity types (e.g., Gold Hill).

- Here, we demonstrate that **OBSERVATIONS** from one deposit can be used to develop **NEW TARGETS** for other deposit types within a larger mineral system.

Imagine you were exploring for skarn targets and drilled through a deposit like *Reaper*... How could you use that drill-core to develop new targets within the larger mineral system, rather than just moving to the next skarn target?



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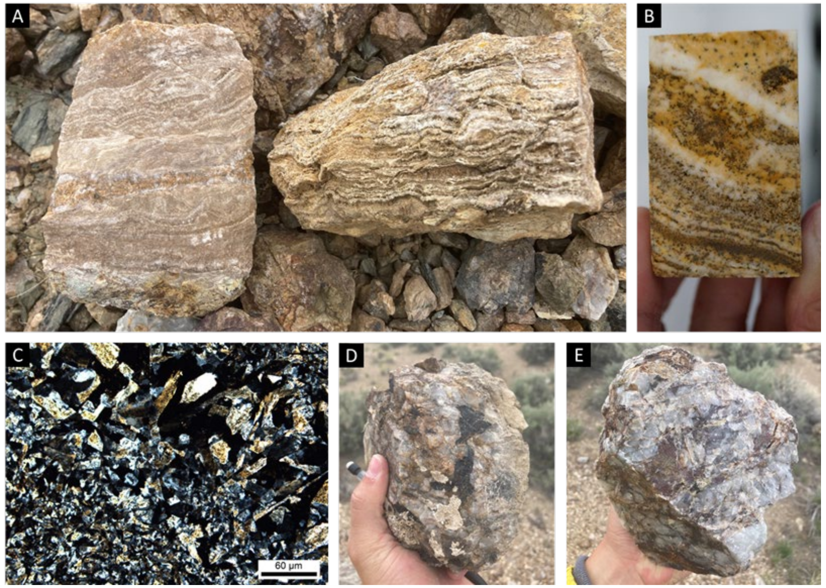
**OBSERVATIONS:** Unique rock/quartz textures => Re loss in molybdenite.

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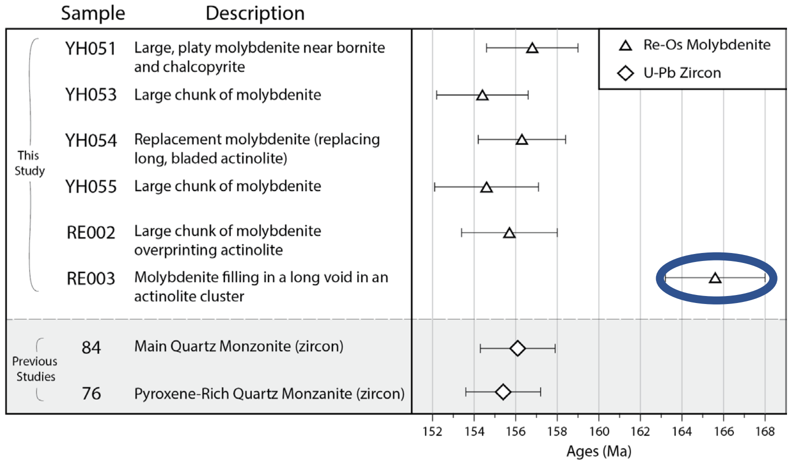


**NEW TARGET:** nearby younger epithermal gold deposits.

- Kiewit low-sulfidation epithermal gold mine is just one mile east of Reaper. Would you have discovered it?


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UNLV Department of GEOSCIENCE

GEOLOGICAL SOCIETY OF NEVADA

ARIZONA GEOLOGICAL SURVEY AZGS


Image – Simon Jowitt