

A microscopic image showing a dark, textured matrix with numerous small, bright, yellowish-green mineral grains scattered throughout. The grains vary in size and shape, some appearing as small, angular fragments. The overall appearance is that of a mineralized rock sample.

# Ore Mineralogy and Geochemistry of the Midas Mine, Nevada

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Petrology (Geology 422)

May 3, 2016

# MIDAS MINE BACKGROUND

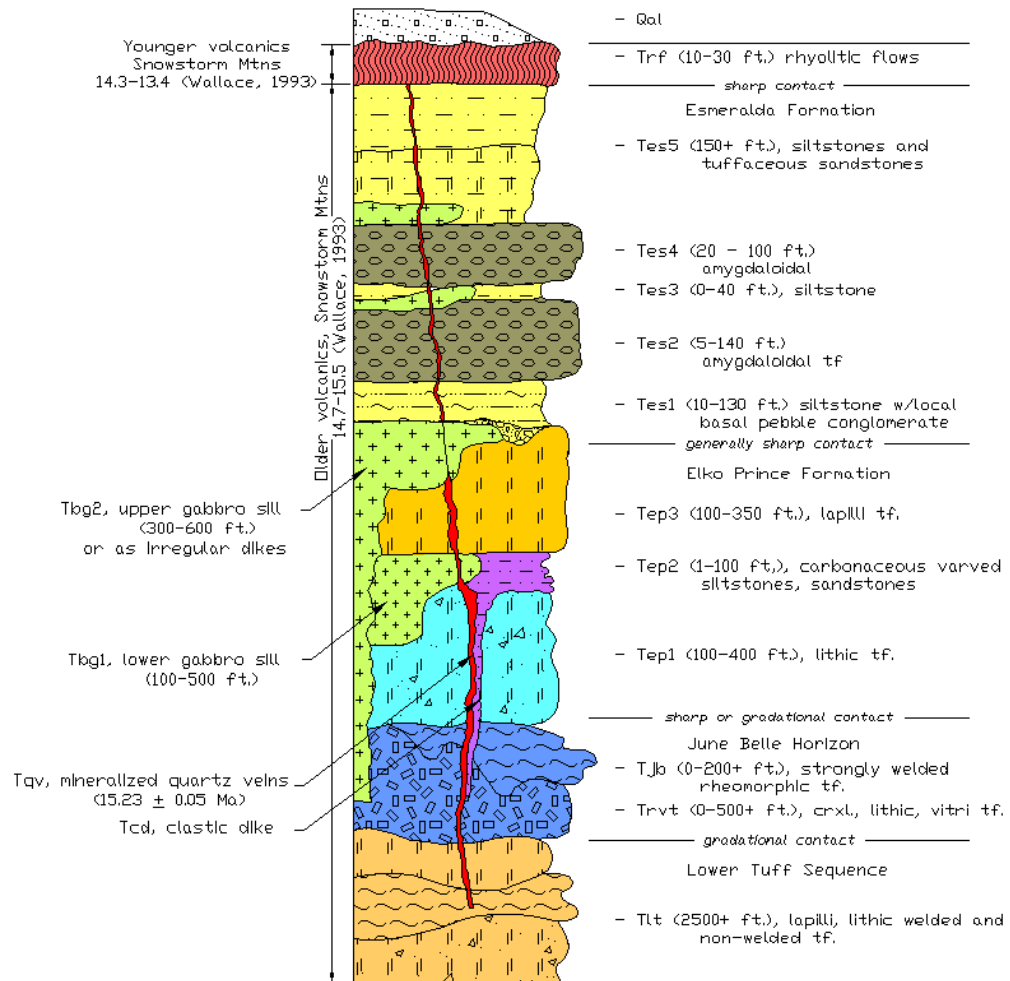
- Discovered in 1994
- Formerly known as the Ken Snyder Mine
- Volcanic-hosted, low sulfidation, selenium rich, gold-silver bearing quartz-adularia vein deposit
- 2,726,800 tons grading
  - 1.115 oz (34.676 g) Au/ton
  - 12.82 oz (398.70 g) Ag/ton

(Goldstrand and Schmidt, 2000)

# MINE GEOLOGY

- June Belle formation
  - Strongly welded felsic ash-flows and/or flows
- Elko Prince formation
  - Lower lithic tuff unit
  - Middle volcanoclastic unit
  - Upper lapilli tuff unit
- Esmeralda formation
  - Thick sequences of sandstone/siltstone/mudstone/ and amygdaloidal tuff
- Gabbroic sills and dikes intrude all 3 formations

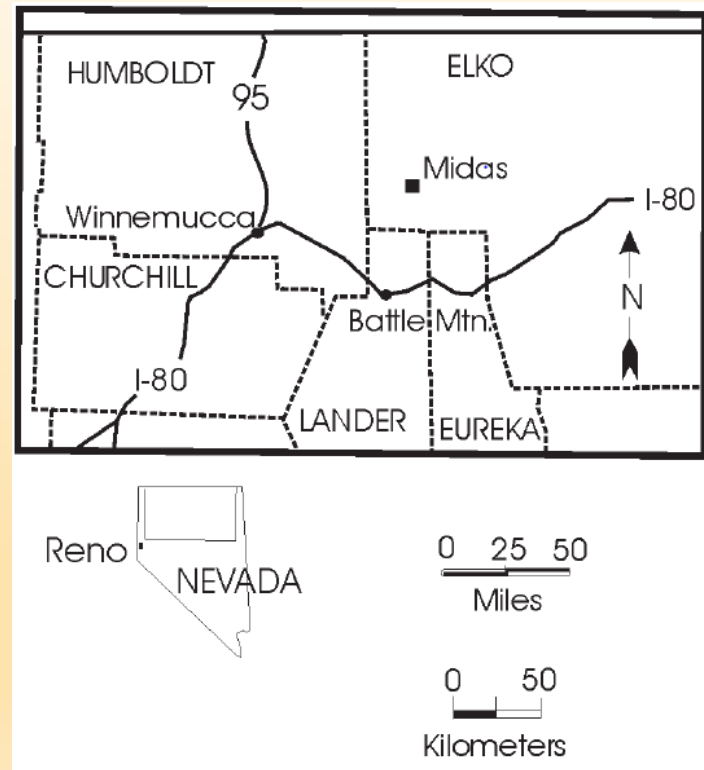
(Goldstrand and Schmidt, 2000)



(Goldstrand and Schmidt, 2000)

# LOCATION

- Midas mining district
- Western Elko County
- North-central Nevada



(Goldstrand and Schmidt, 2000)

# PREVIOUS STUDIES

- Au & Ag selenide ore minerals occur in banded quartz, adularia, and calcite veins
  - Adularia is altered microcline or orthoclase
- Tellurium is present in 33% of drill cores

| Deposit type      | High-sulfidation  | Low-sulfidation   | Low-sulfidation   |
|-------------------|---|---|---|
| Ore mineralogy    | Pyrite, gold, enargite/luzonite, sphalerite, covellite, ±chalcocopyrite, galena, tetrahedrite/tennantite, bismuthanite, stibnite, Au tellurides | Pyrite, electrum, silver sulfides and sulphosalts; local sphalerite, galena, chalcocopyrite | Pyrite/marcasite, arsenopyrite, electrum, gold, Ag selenides and sulfides, stibnite, local pyrrhotite, minor local sphalerite, galena, chalcocopyrite, tetrahedrite, Se sulphosalts |
| Gangue mineralogy | Quartz, opal, chalcedony, barite, local alunite, kaolinite  | Quartz, carbonate, sericite ± adularia, rare chlorite                                       | Opal-chalcedony, quartz, illite/sericite, ±adularia, ±carbonate, ±montmorillinite (John, 2001)  |

# GUIDING QUESTION

- What minerals are found in the Midas Mine mineral assemblage?
- Are there differences in mineralogy among the 3 zones of my sample?

# METHODS

- Sample was cut
- Then polished
  - Glass plate
  - Polishing wheel

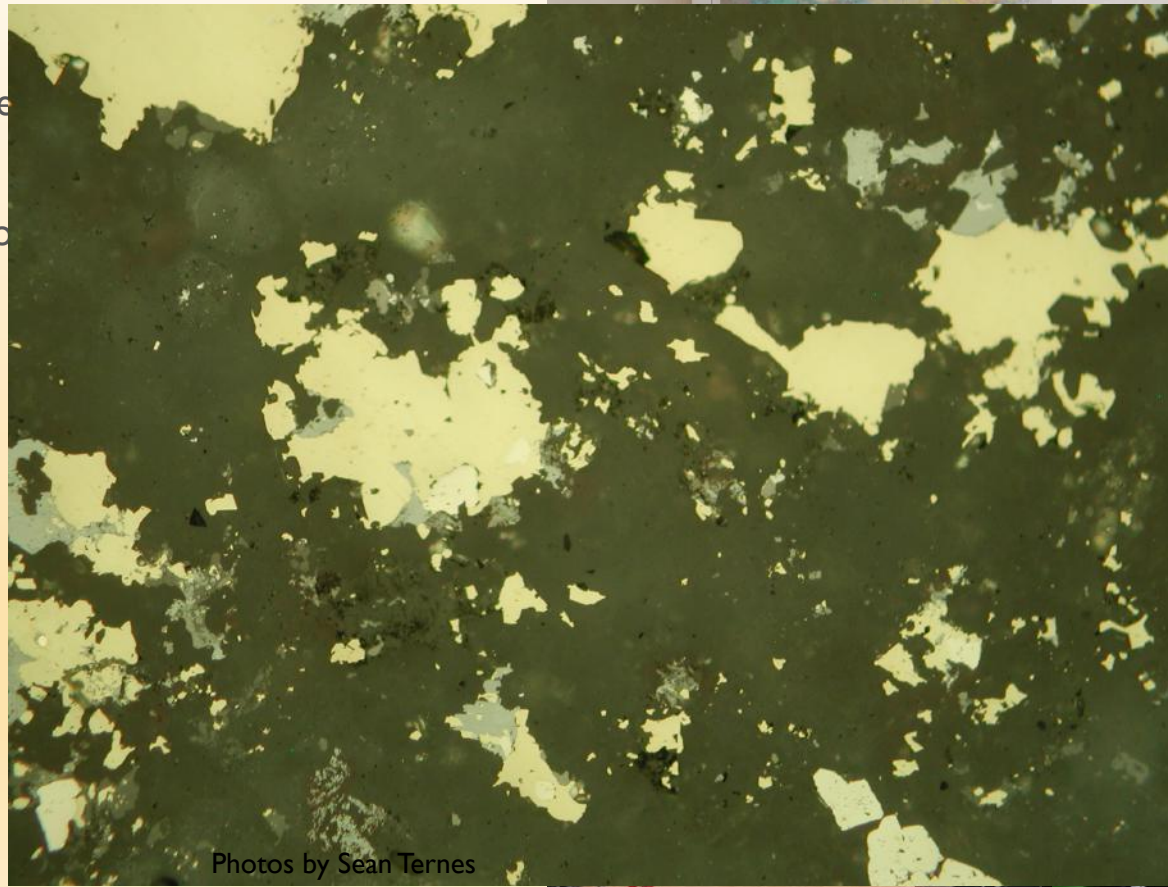
Photos by: Sean Ternes





# REFLECTED LIGHT MICROSCOPY

- Reflected
- Used to



Width: 1 mm

Photos by Sean Ternes



Photos by Sean Ternes

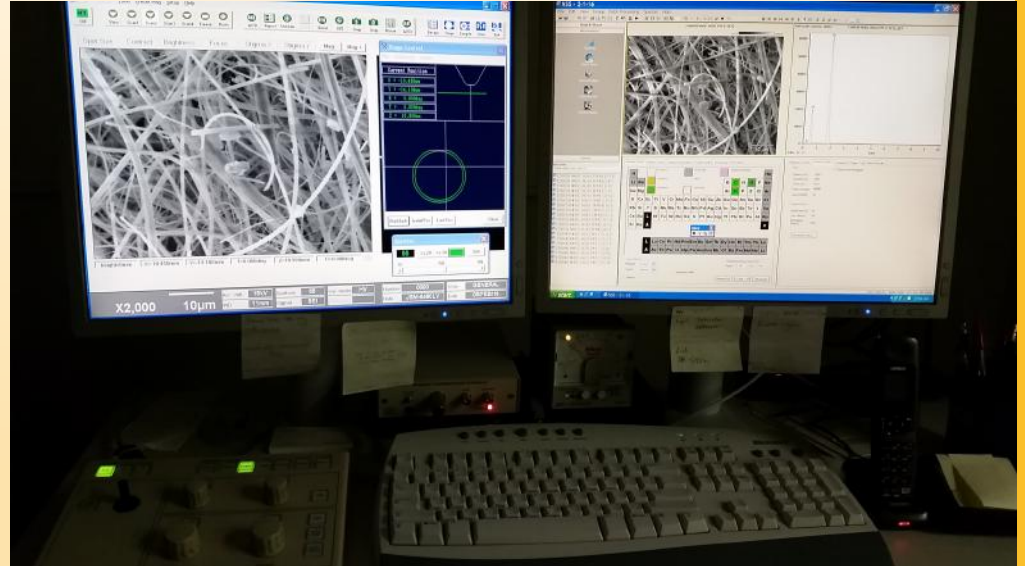
# CARBON COATING FOR SEM

- Thin carbon layer added
- Creates a conductive layer
- Inhibits charging
- Improves secondary electron signal
- Better images



Photos by Sean Ternes

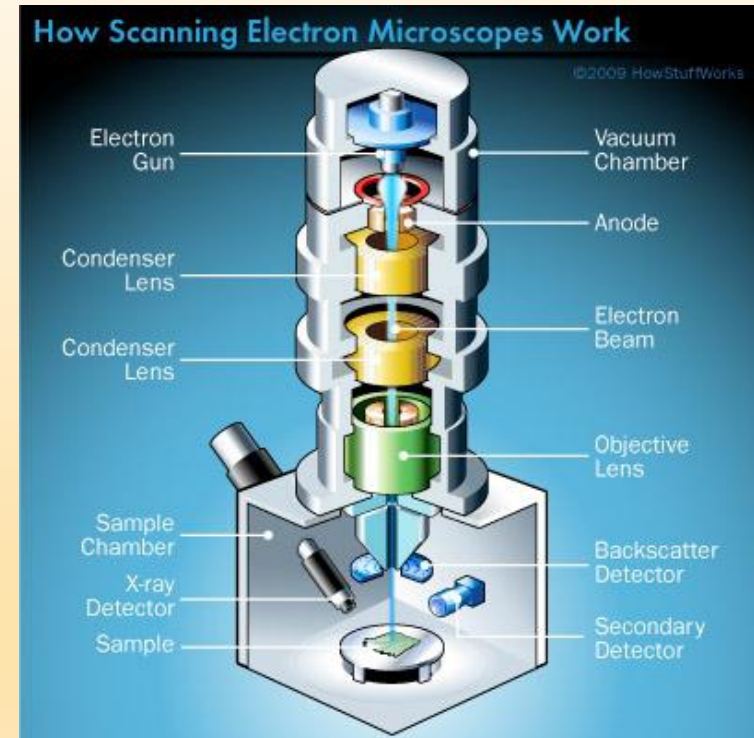
# SEM



Photos by: Sean Ternes

# WHAT IS SEM?

- Scanning electron microscope
- Electron beam shot at sample
- Secondary electrons and backscattered electrons produce an image
- X-rays produce elemental data



<http://science.howstuffworks.com/scanning-electron-microscope2.htm>

# SITE 1 (LIGHT ZONE)

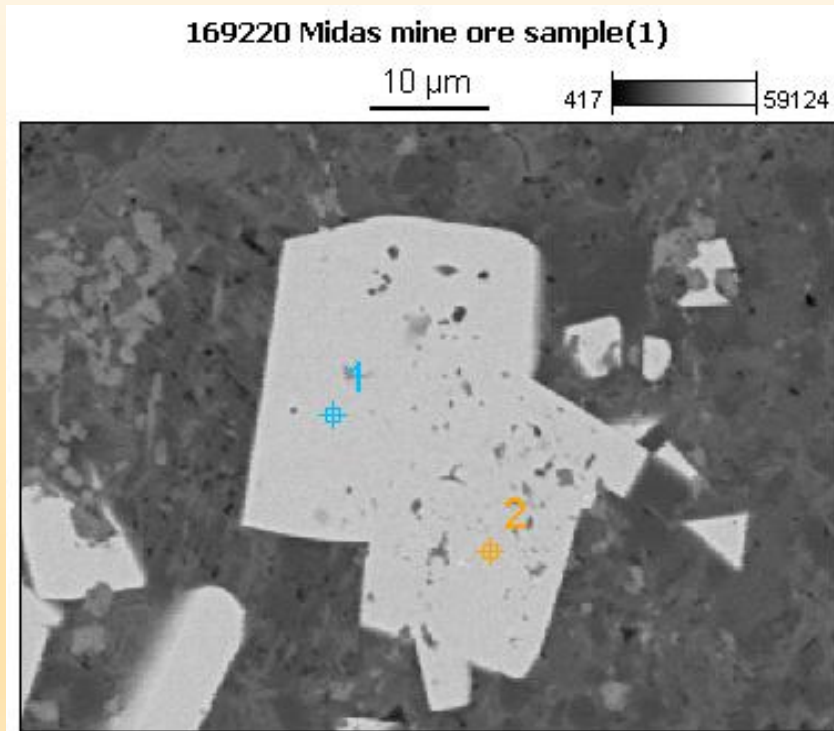


Photo Courtesy of SEM Lab

## MINERALS PRESENT

- Point 1: Pyrite  $\text{FeS}_2$
- Point 2: Pyrite  $\text{FeS}_2$

# STEE 1 (LIGHT ZONE)



Width: 1 mm

Photo by: Sean Ternes

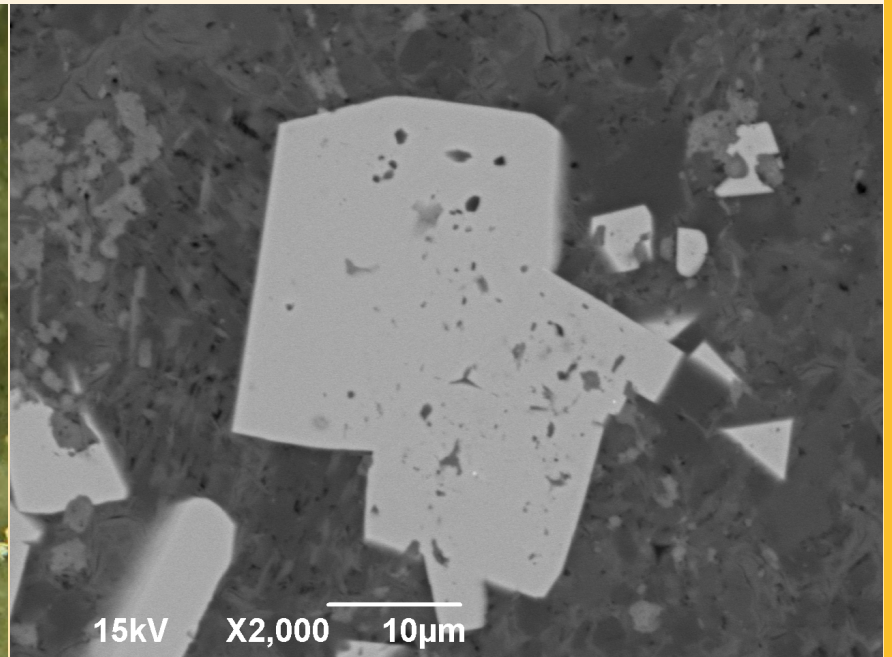


Photo Courtesy of SEM Lab

# SITE 2 (LIGHT ZONE)

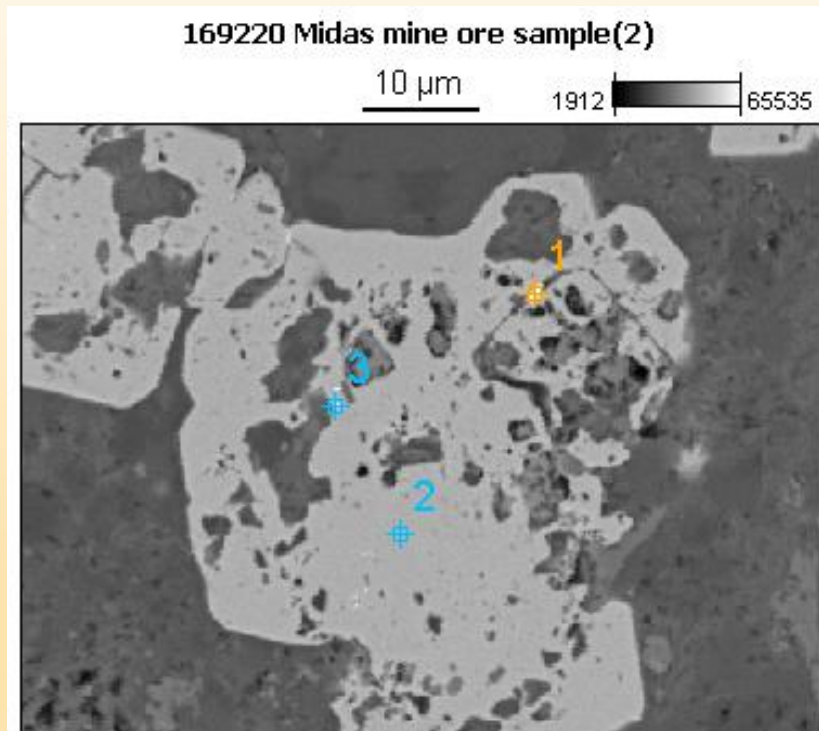


Photo Courtesy of SEM Lab

## MINERALS PRESENT

- Point 1: Naummanite  $\text{Ag}_2\text{Se}$   
Acanthite  $\text{Ag}_2\text{S}$  Solid Solution
- Point 2: Pyrite  $\text{FeS}_2$
- Point 3: Pyrite  $\text{FeS}_2$

# SITE 2 (LIGHT ZONE)



Width: 2 mm

Photo by: Sean Ternes

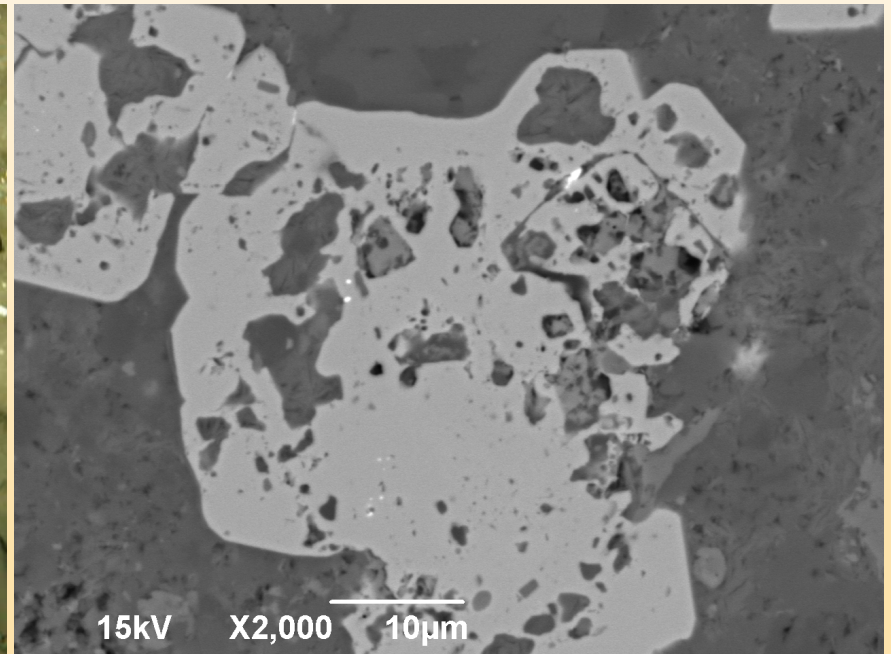


Photo Courtesy of SEM Lab



# SITE 3 (LIGHT ZONE)

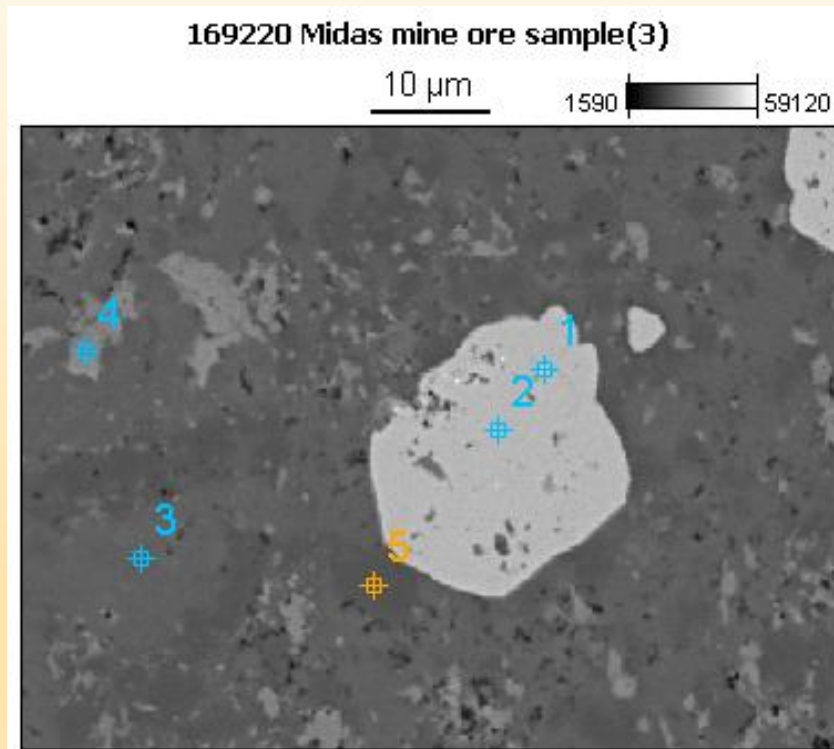


Photo Courtesy of SEM Lab

## MINERALS PRESENT

- Point 1: Pyrite  $\text{FeS}_2$
- Point 2: Pyrite  $\text{FeS}_2$
- Point 3: Adularia  $\text{KAlSi}_3\text{O}_8$
- Point 4: Perovskite  $\text{CaTiO}_3$  Solid solution
- Point 5: Albite  $\text{NaAlSi}_3\text{O}_8$

# SITE 3 (LIGHT ZONE)

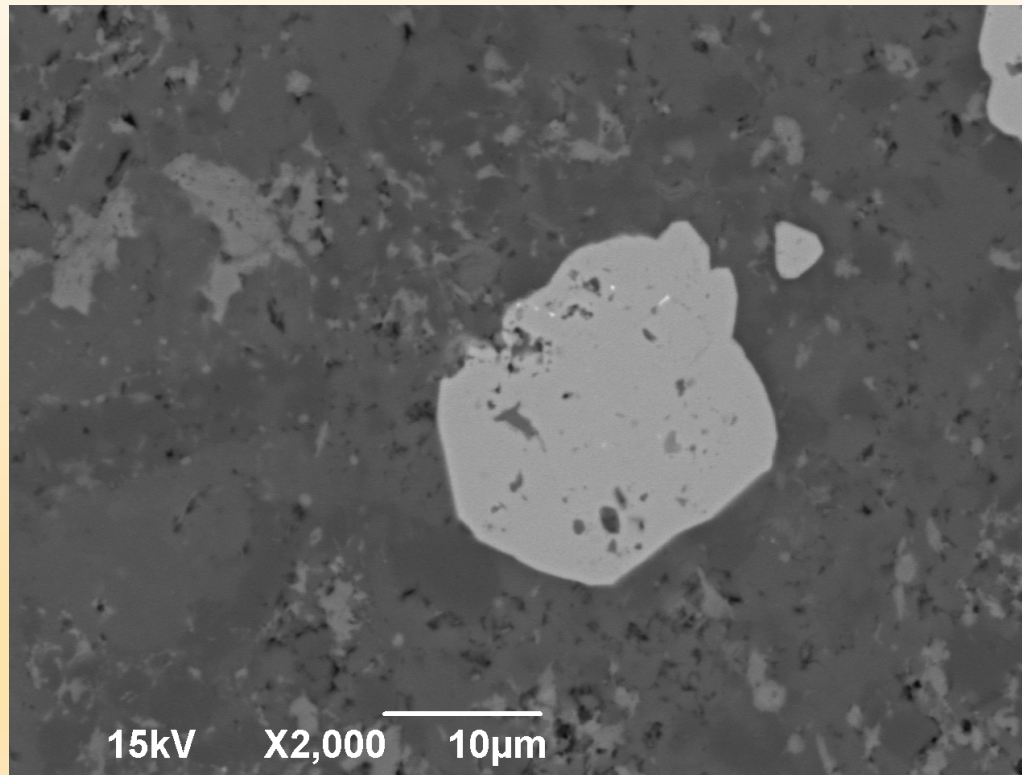


Photo Courtesy of SEM Lab

# SITE 4 (INTERMEDIATE ZONE)

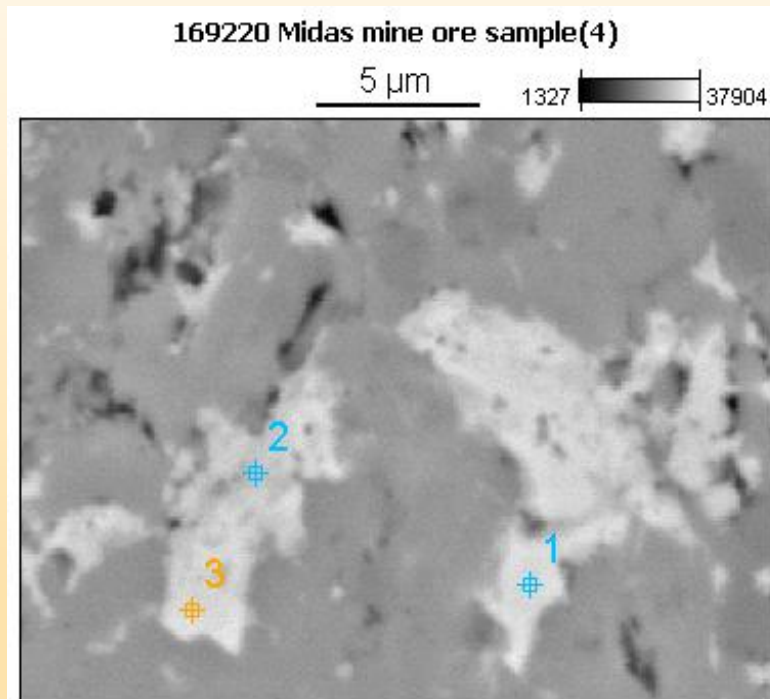


Photo Courtesy of SEM Lab

## MINERALS PRESENT

- Point 1: Rutile  $\text{TiO}_2$
- Point 2: Titanite Solid Solution  
 $(\text{Ca}_{0.78}, \text{K}_{0.14}, \text{P}_{0.08})(\text{Ti}_{0.96}, \text{Fe}_{0.04})(\text{Si}_{0.87}, \text{Al}_{0.13})\text{O}_5$
- Point 3: Rutile  $\text{TiO}_2$

# SITE 5 (INTERMEDIATE ZONE)

169220 Midas mine ore sample(5)

25  $\mu\text{m}$

1346

65535

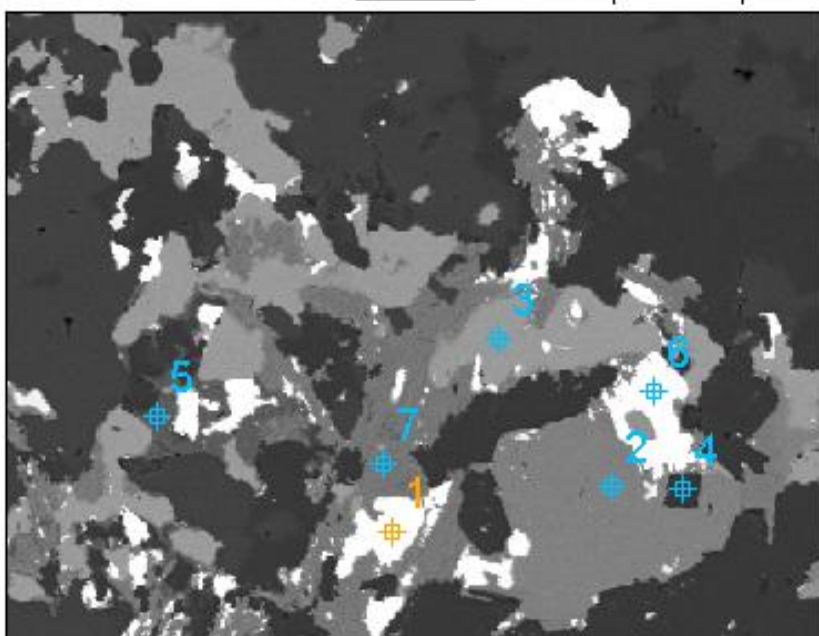
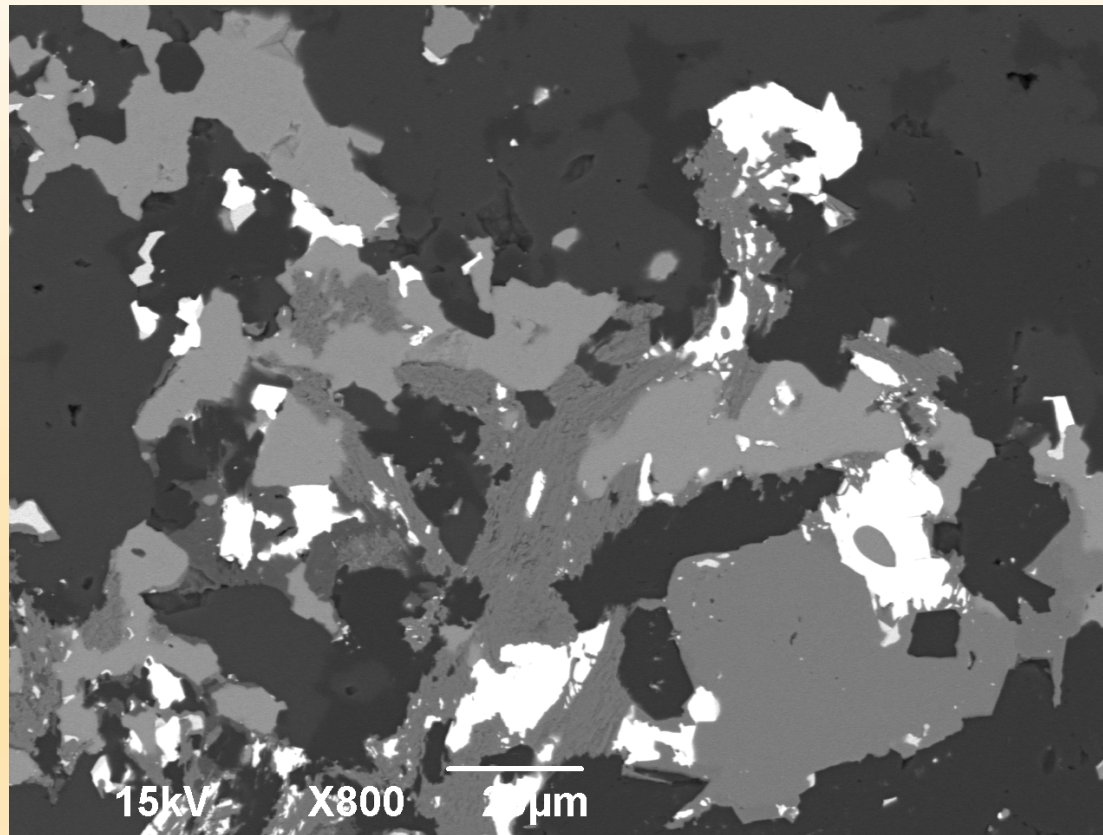


Photo Courtesy of SEM Lab

## MINERALS PRESENT

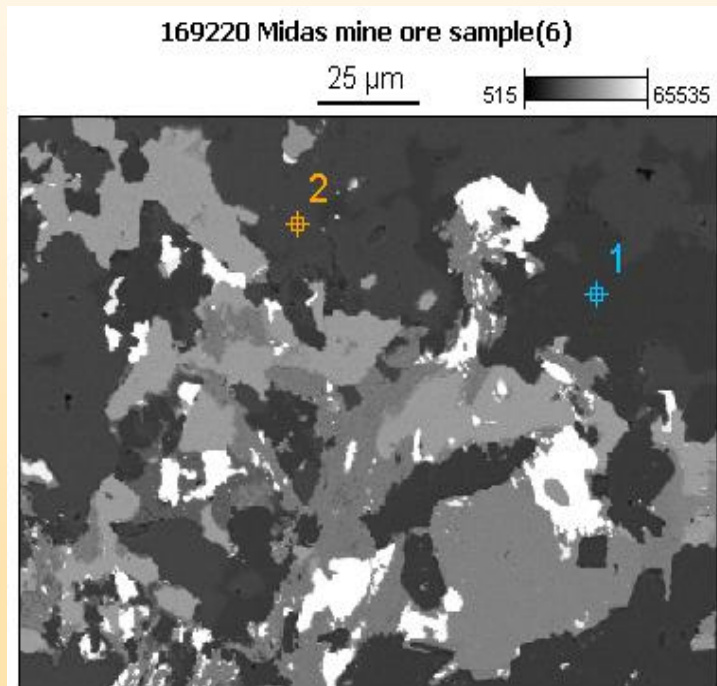
- Point 1: Galena  $\text{Pb}(\text{S}_{0.91}, \text{Se}_{0.09})$
- Point 2: Pyrite  $\text{FeS}_2$
- Point 3: Sphalerite  $(\text{Zn}_{0.68}, \text{Fe}_{0.16}, \text{Ca}_{0.15})\text{S}$
- Point 4: Quartz  $\text{SiO}_2$
- Point 5: Andradite  $\text{Ca}_3\text{Fe}_2(\text{SiO}_4)_3$
- Point 6: Galena  $\text{Pb}(\text{S}_{0.93}, \text{Se}_{0.07})$
- Point 7: Hematite  $\text{Fe}_2\text{O}_3$

# SITE 5 (INTERMEDIATE ZONE)



Photos Courtesy of SEM Lab

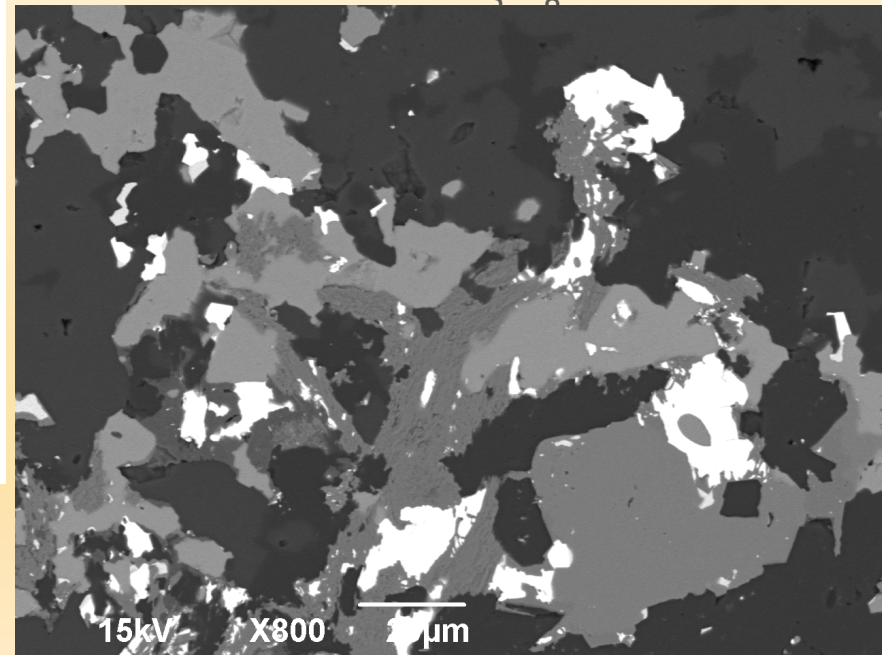
# SITE 6 (INTERMEDIATE ZONE)



Photos Courtesy of SEM Lab

## MINERALS PRESENT

- Point 1: Quartz  $\text{SiO}_2$
- Point 2: Adularia  $\text{KAlSi}_3\text{O}_8$



# SITE 7 (DARK ZONE)

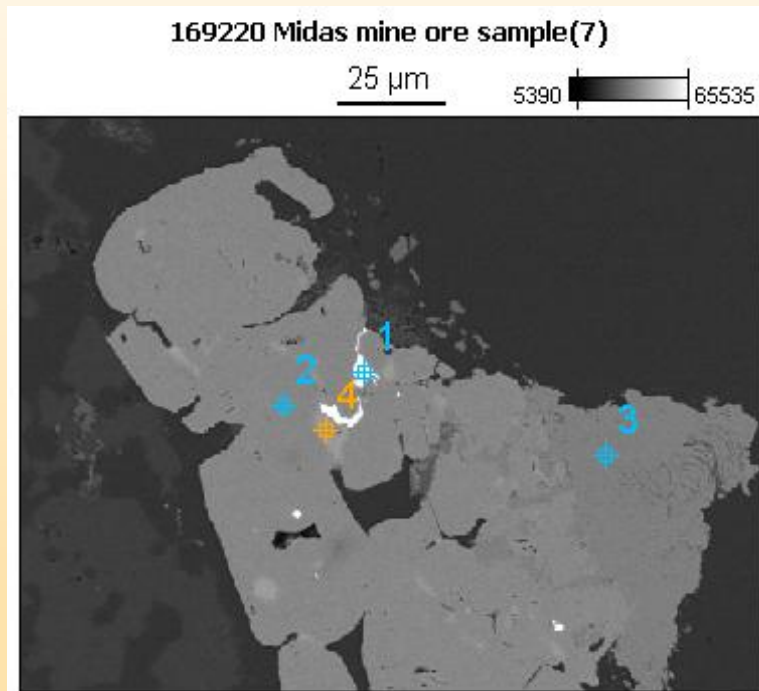


Photo Courtesy of SEM Lab

## MINERALS PRESENT

- Point 1: Bismuthanite  $\text{Bi}_2\text{S}_3$
- Point 2: Pyrite  $\text{FeS}_2$
- Point 3: Hematite  $\text{Fe}_2\text{O}_3$
- Point 4: Chalcopyrite  $\text{CuFeS}_2$

# SITE 7 (DARK ZONE)



Width: 2 mm

Photo by: Sean Ternes

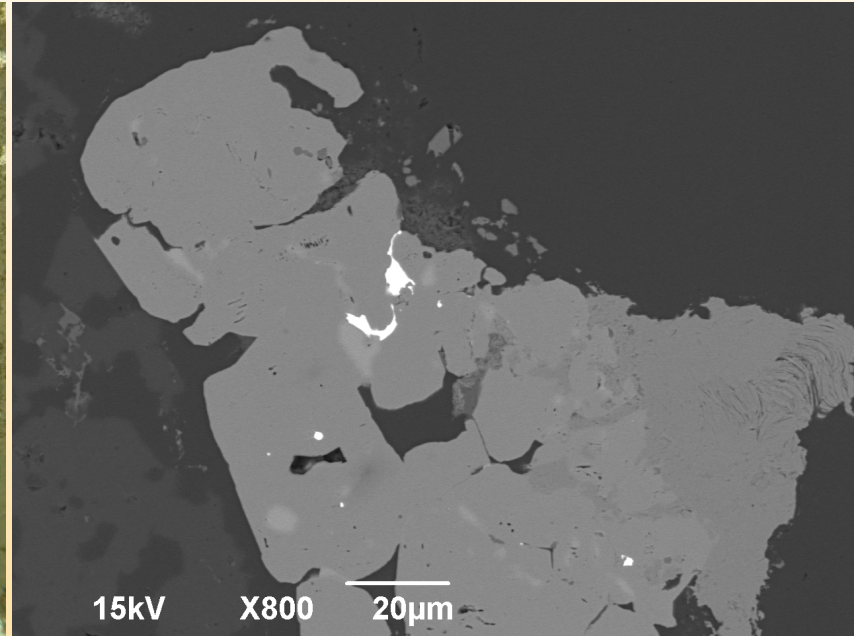


Photo Courtesy of SEM Lab



# SITE 8 (DARK ZONE)

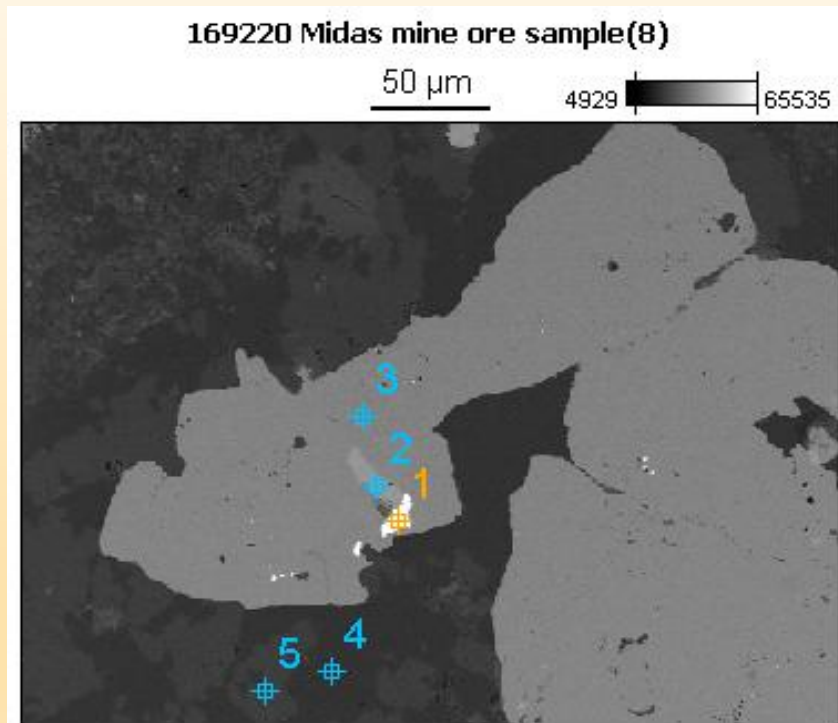
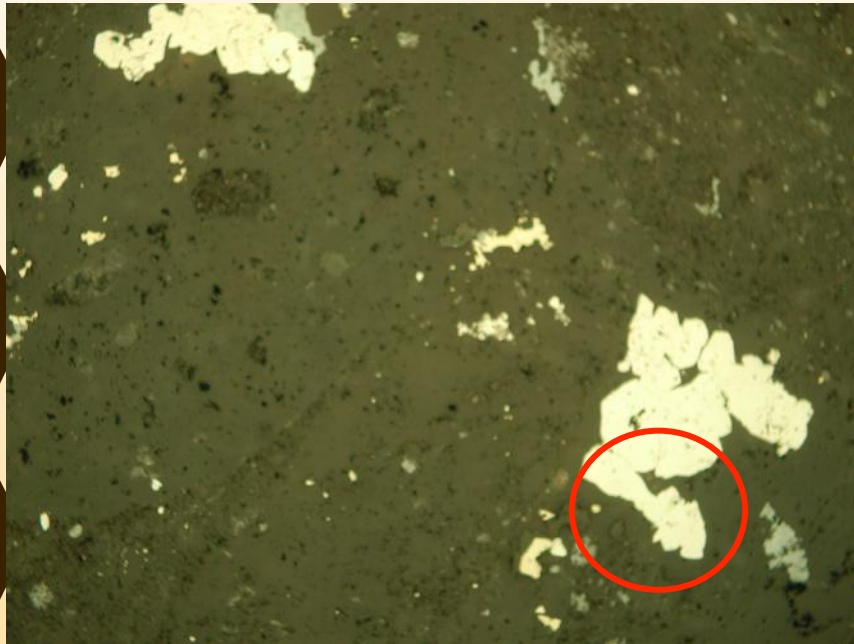


Photo Courtesy of SEM Lab

## MINERALS PRESENT

- Point 1: Galena  $\text{Pb}(\text{S}_{0.94}, \text{Se}_{0.06})$
- Point 2: Chalcopyrite  $\text{CuFeS}_2$
- Point 3: Pyrite  $\text{FeS}_2$
- Point 4: Quartz  $\text{SiO}_2$
- Point 5: Adularia  $\text{KAlSi}_3\text{O}_8$

# SITE 8 (DARK ZONE)



Width: 2 mm

Photo by: Sean Ternes

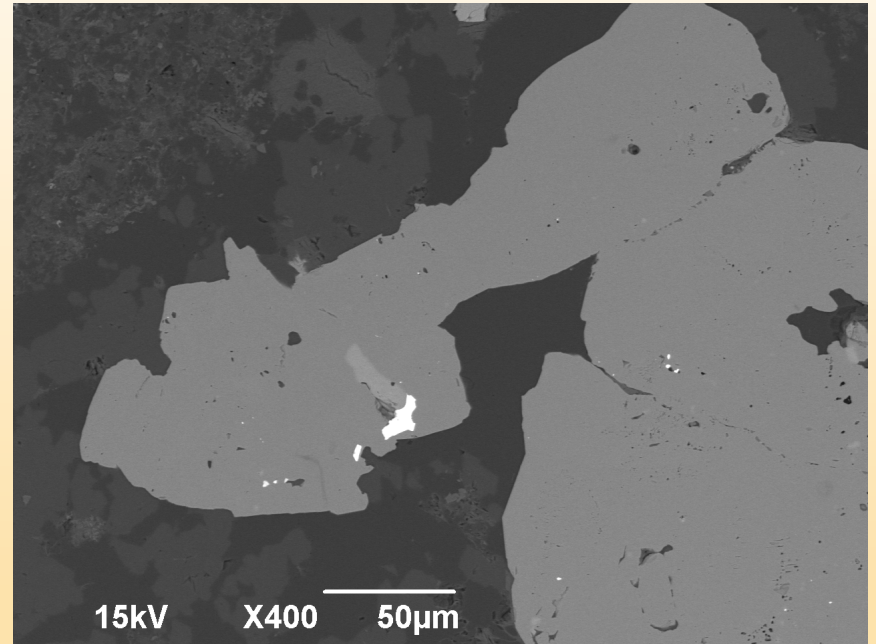


Photo Courtesy of SEM Lab

# CONCLUSION

- Ore Minerals:
  - Pyrite
  - Chalcopyrite
  - Galena
  - Spahlerite
  - Naumannite/acanthite
  - Bismuthanite
- Gangue Minerals
  - Quartz
  - Adularia
- Other Minerals
  - Hematite
  - Perovskite
  - Albite
  - Rutile
  - Titanite
  - Andradite

# CONCLUSION

- Light Mineral Zone (Sites 1-3)
  - Pyrite rich
  - Silver ores
- Mixed Zone (Sites 4-6)
  - Many different ore minerals
  - Overall highest diversity of minerals
- Dark Zone (Sites 7 & 8)
  - Common ore minerals (pyrite, galena, chalcopyrite)
- Gangue minerals consistent through all 3 zones
- No Tellurium found
- Selenium also present in ore minerals in my sample

# THANK YOU

- Dr. Eidukat for the use of his lab, reflected light microscope, and for sharing his knowledge
- Scott Payne and Jayma Moore for their help with the SEM and for letting me use the facility

# DATA

- Site 1: Sulfides

| Atom %          | S-K   | Fe-K  |
|-----------------|-------|-------|
| Site 1: Point 1 | 69.58 | 30.42 |
| Site 1: Point 2 | 69.37 | 30.63 |

- Site 2: Sulfides

| Atom %          | Mg-K | Si-K | P-K  | S-K   | Ca-K | Fe-K  | Se-L | Ag-L  |
|-----------------|------|------|------|-------|------|-------|------|-------|
| Site 2: Point 1 | 0    | 1.39 | 0    | 55.88 | 0    | 24.68 | 3.22 | 14.84 |
| Site 2: Point 2 | 0.38 | 0    | 0    | 68.95 | 0    | 30.66 | 0    | 0     |
| Site 2: Point 3 | 0    | 0.58 | 3.51 | 61.14 | 6.24 | 28.53 | 0    | 0     |

# DATA

- Site 3: Sulfides

| Atom %          | Na-K | Mg-K | Al-K | Si-K | P-K | S-K   | K-K | Ca-K | Ti-K | Fe-K  |
|-----------------|------|------|------|------|-----|-------|-----|------|------|-------|
| Site 3: Point 1 | 0    | 0    | 0    | 0.65 | 0   | 68.56 | 0   | 0    | 0    | 30.79 |
| Site 3: Point 2 | 0    | 0    | 0    | 0    | 0   | 69.50 | 0   | 0    | 0    | 30.50 |

- Site 3: Silicates

| Atom %          | O-K   | Na-K | Mg-K | Al-K | Si-K  | P-K  | S-K | K-K  | Ca-K | Ti-K  | Fe-K |
|-----------------|-------|------|------|------|-------|------|-----|------|------|-------|------|
| Site 3: Point 3 | 61.82 | 0    | 0    | 7.57 | 23.44 | 0    | 0   | 7.16 | 0    | 0     | 0    |
| Site 3: Point 4 | 64.38 | 0    | 0.57 | 2.60 | 8.21  | 0.24 | 0   | 2.25 | 1.22 | 19.48 | 1.07 |
| Site 3: Point 5 | 61.14 | 8.44 | 0    | 7.56 | 22.72 | 0    | 0   | 0    | 0.13 | 0     | 0    |

- Site 4: Silicates

| Atom %       | O-K   | Al-K | Si-K  | P-K  | K-K   | Ca-K | Ti-K  | Fe-K |
|--------------|-------|------|-------|------|-------|------|-------|------|
| Site 4: Pt 1 | 66.05 | 0.71 | 2.38  | 0    | 00.66 | 0.49 | 29.71 | 0    |
| Site 4: Pt 2 | 62.95 | 2.26 | 11.11 | 0.86 | 1.44  | 8.00 | 12.79 | 0.58 |
| Site 4: Pt 3 | 66.13 | 0.70 | 2.23  | 0    | 0.55  | 0.44 | 29.95 | 0    |

# DATA

- Site 5: Sulfides

| Atom %          | Na-K | Al-K | Si-K | S-K   | Ca-K | Fe-K  | Cu-K | Zn-K  | Se-L | Pb-M  |
|-----------------|------|------|------|-------|------|-------|------|-------|------|-------|
| Site 5: Point 1 | 0    | 0    | 0    | 43.93 | 0    | 2.01  | 0    | 0     | 4.10 | 49.95 |
| Site 5: Point 2 | 0    | 0    | 0    | 69.70 | 0    | 30.30 | 0    | 0     | 0    | 0     |
| Site 5: Point 3 | 0    | 0    | 0    | 53.68 | 0    | 7.55  | 7.15 | 31.62 | 0    | 0     |
| Site 5: Point 6 | 0    | 0    | 0    | 44.88 | 0    | 2.43  | 0    | 0     | 3.60 | 49.09 |

- Site 5: Silicates

| Atom %          | O-K   | Na-K | Al-K  | Si-K  | S-K | Ca-K  | Ti-K | Fe-K  | Cu-K | Zn-K | As-L | Se-L | Pb-M |
|-----------------|-------|------|-------|-------|-----|-------|------|-------|------|------|------|------|------|
| Site 5: Point 4 | 66.64 | 0    | 33.19 | 0     | 0   | 0     | 0    | 0.17  | 0    | 0    | 0    | 0    | 0    |
| Site 5: Point 5 | 59.78 | 0    | 2.59  | 14.58 | 0   | 15.68 | 0    | 7.36  | 0    | 0    | 0    | 0    | 0    |
| Site 5: Point 7 | 59.38 | 2.45 | 0.78  | 1.80  | 0   | 0     | 0    | 35.60 | 0    | 0    | 0    | 0    | 0    |



# DATA

- Site 6: Silicates

| Atom %          | O-K   | Na-K | Al-K | Si-K  | K-K  |
|-----------------|-------|------|------|-------|------|
| Site 6: Point 1 | 66.67 | 0    | 0    | 33.33 | 0    |
| Site 6: Point 2 | 61.61 | 0.30 | 7.44 | 23.32 | 7.34 |

- Site 7: Sulfides

| Atom %          | Al-K | Si-K | S-K   | Fe-K  | Cu-K  | Se-L | Bi-M  |
|-----------------|------|------|-------|-------|-------|------|-------|
| Site 7: Point 1 | 0    | 0    | 71.49 | 14.47 | 0     | 2.44 | 11.60 |
| Site 7: Point 2 | 0    | 0    | 69.38 | 30.62 | 0     | 0    | 0     |
| Site 7: Point 4 | 0    | 0    | 58.47 | 25.55 | 15.98 | 0    | 0     |

- Site 7: Silicates

| Atom %          | O-K   | Al-K | Si-K | S-K | Fe-K  | Cu-K | Se-L | Bi-M |
|-----------------|-------|------|------|-----|-------|------|------|------|
| Site 7: Point 3 | 60.26 | 0.61 | 1.29 | 0   | 37.84 | 0    | 0    | 0    |

# DATA

- Site 8: Sulfides

| Atom %          | Na-K | Al-K | Si-K | S-K   | K-K | Fe-K  | Cu-K  | Se-L | Pb-M  |
|-----------------|------|------|------|-------|-----|-------|-------|------|-------|
| Site 8: Point 1 | 0    | 0    | 0    | 43.53 | 0   | 3.99  | 0     | 2.71 | 49.78 |
| Site 8: Point 2 | 0    | 0    | 0    | 53.91 | 0   | 24.04 | 22.05 | 0    | 0     |
| Site 8: Point 3 | 0    | 0    | 0    | 69.65 | 0   | 30.35 | 0     | 0    | 0     |

- Site 8: Silicates

| Atom %          | O-K   | Na-K | Al-K | Si-K  | S-K | K-K  | Fe-K | Cu-K | As-L | Se-L | Pb-M |
|-----------------|-------|------|------|-------|-----|------|------|------|------|------|------|
| Site 8: Point 4 | 66.65 | 0    | 0.07 | 33.27 | 0   | 0    | 0    | 0    | 0    | 0    | 0    |
| Site 8: Point 5 | 61.69 | 0.35 | 7.48 | 23.37 | 0   | 7.11 | 0    | 0    | 0    | 0    | 0    |

# REFERENCES

- Goldstrand, P.M., and Schmidt, K.W., 2000, Geology, mineralization, and ore controls at the Ken Snyder gold-silver mine, Elko County, Nevada, *in* Cluer, J.K., Price, J.G., Struhsacker, E.M., Hardyman, R.F., and Morris, C.L., eds., *Geology and Ore Deposits 2000: The Great Basin and Beyond: Geological Society of Nevada Symposium Proceedings, May 15-18, 2000*, p. 265-287.
- John, D., 2001. Miocene and Early Pliocene Epithermal Gold-Silver Deposits in the Northern Great Basin, Western United States: Characteristics, Distribution, and Relationship to Magmatism. *Economic Geology* 96, 1827-1853.