MIINERAL LIBERATION ANALYSIS OF STILLWATER NORITE FEED STOCKPILES

by

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- MLA Background
- Gold Project
- Silver Project
- NASA/Lunar Project
- Conclusions

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Mineral Liberation Analysis (MLA)

- Developed by JKTech Center by Dr. Ying Gu at University of Queensland in Brisbane, Australia
- Currently, ~75 systems worldwide

MLA Background

- Software and hardware add-ons to a Scanning Electron Microscope (SEM)
- Requires extra computer and detector(s)
- Two additions to current LEO SEM at Montana Tech
- Only system installed on a LEO
  - Both EDX units are from EDAX (also a first)
  - Both use Apollo 40 Silicon Drift Detectors

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Montana Tech MLA

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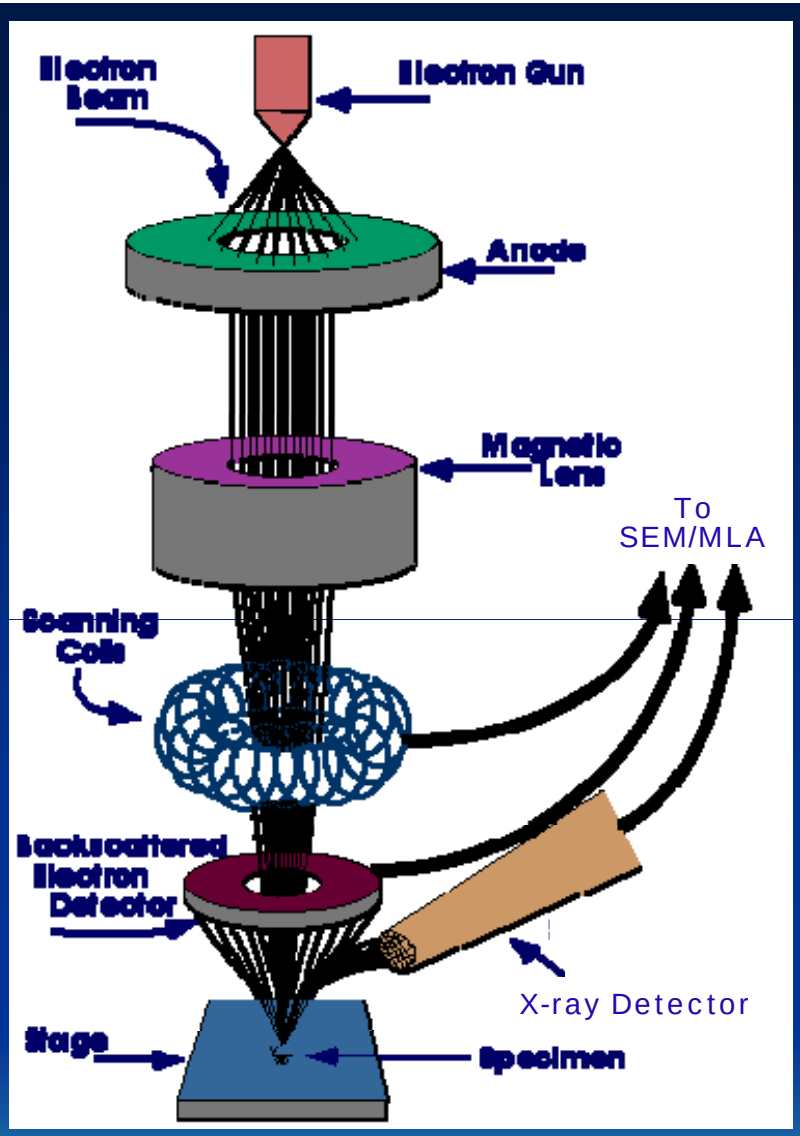
Montana Tech MLA

How does it work?

- It starts with the SEM
- Electron Beam is generated, collimated and focused onto the specimen which can be rotated via the stage
- Specimen surface must be conductive (carbon-coated?) and may be polished flat
- Back-scattered electrons give topographic image
- Energy dispersive X-rays give elemental analysis



Adopted from http://mse.iastate.edu/microscopy/path2.html

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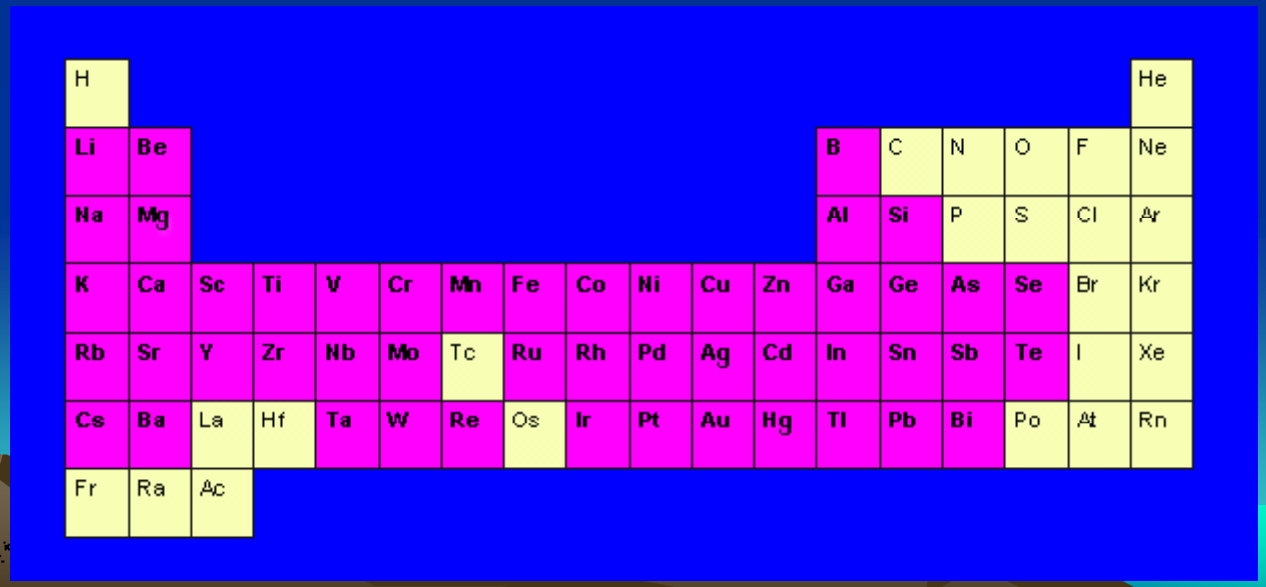
How does it work?

- Hardware and software insure the back-scattered electrons (image) and energy dispersive X-rays (spectrum) are coordinated
- The X-rays determine the chemistry and allow for each mineral to be determined and quantified
- Minerals give different grey levels proportional to their average atomic number



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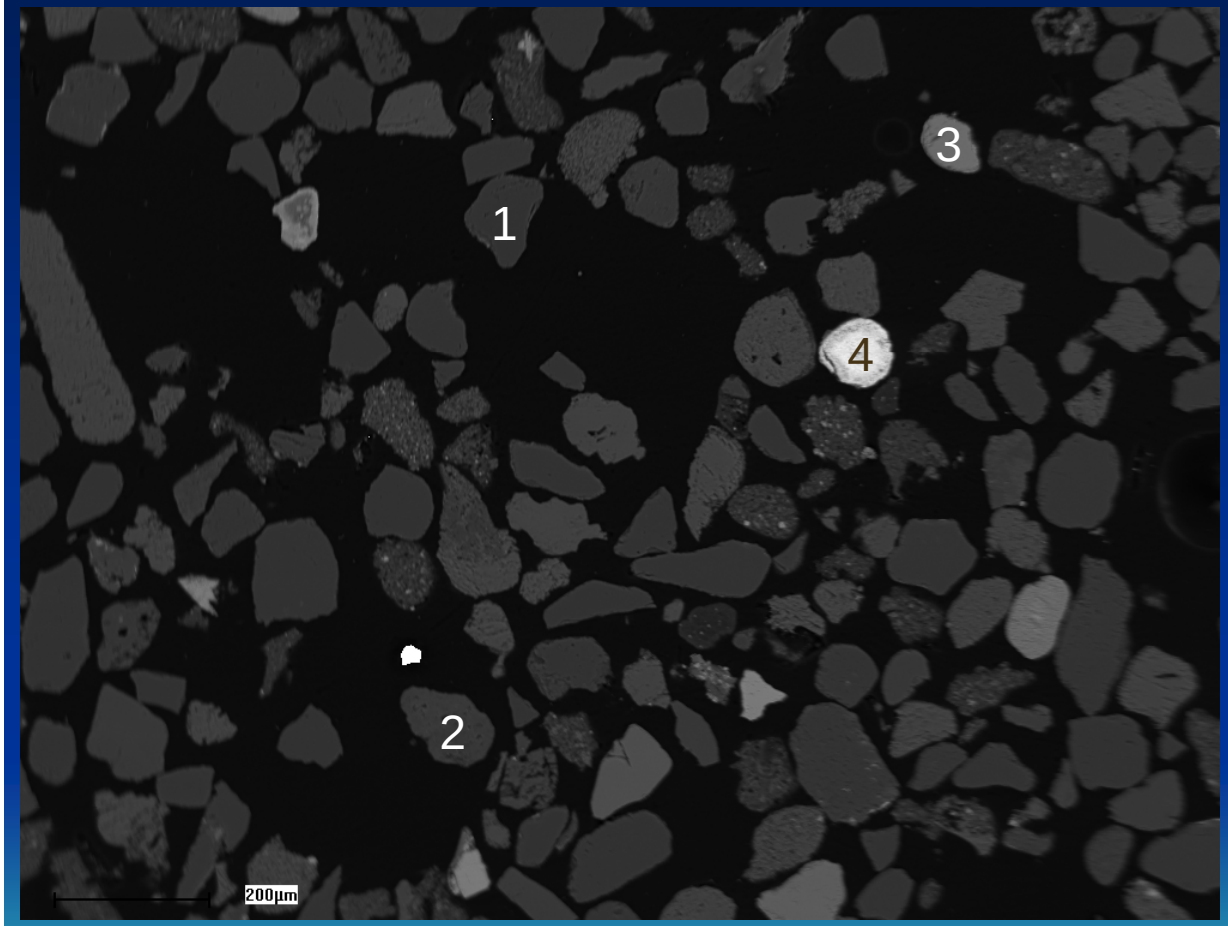
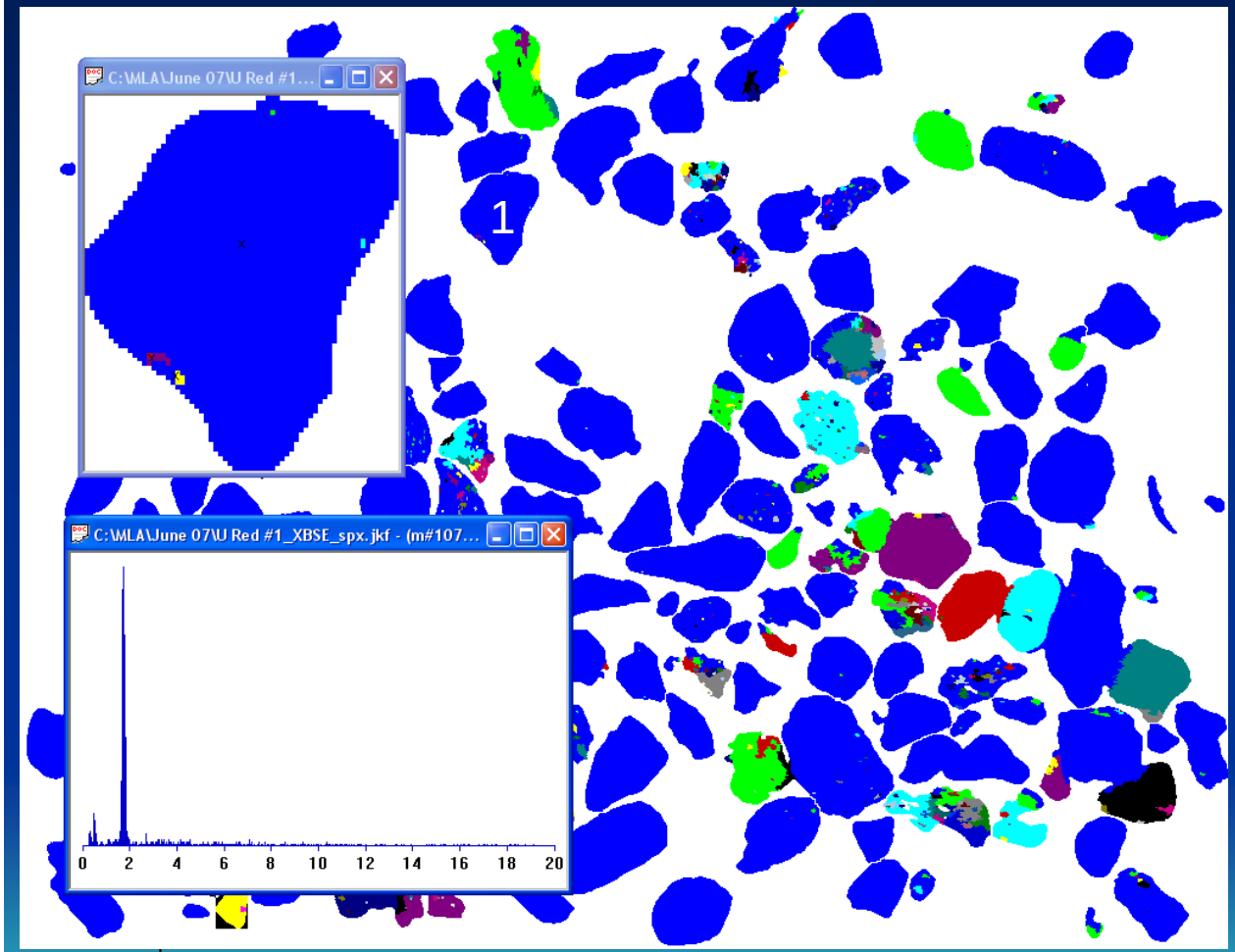
Backscatter Image



- Specimen mounted in epoxy and given a flat polish
- Epoxy and carbon coating removed from image (grey scale < 20 = black)
- Grey scales up to 200 are recorded along with X-rays (brighter = heavier elements)

1. Quartz



- Minerals are identified with grey scale (brightness) as well as X-ray (chemistry)
- Each mineral is given a (false) color
- Quantification is based on surface area and is updated until < 0.1% of image is identified

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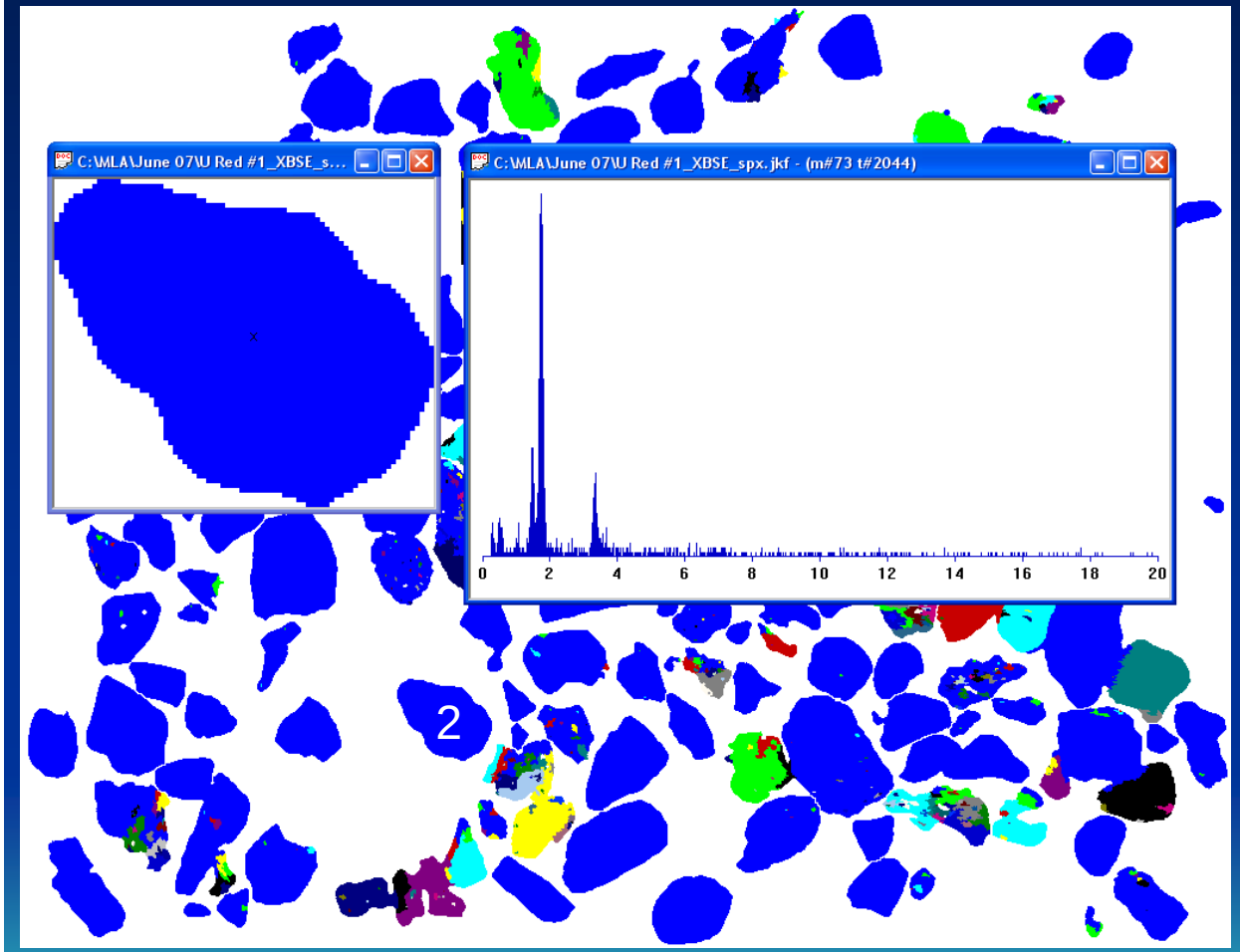
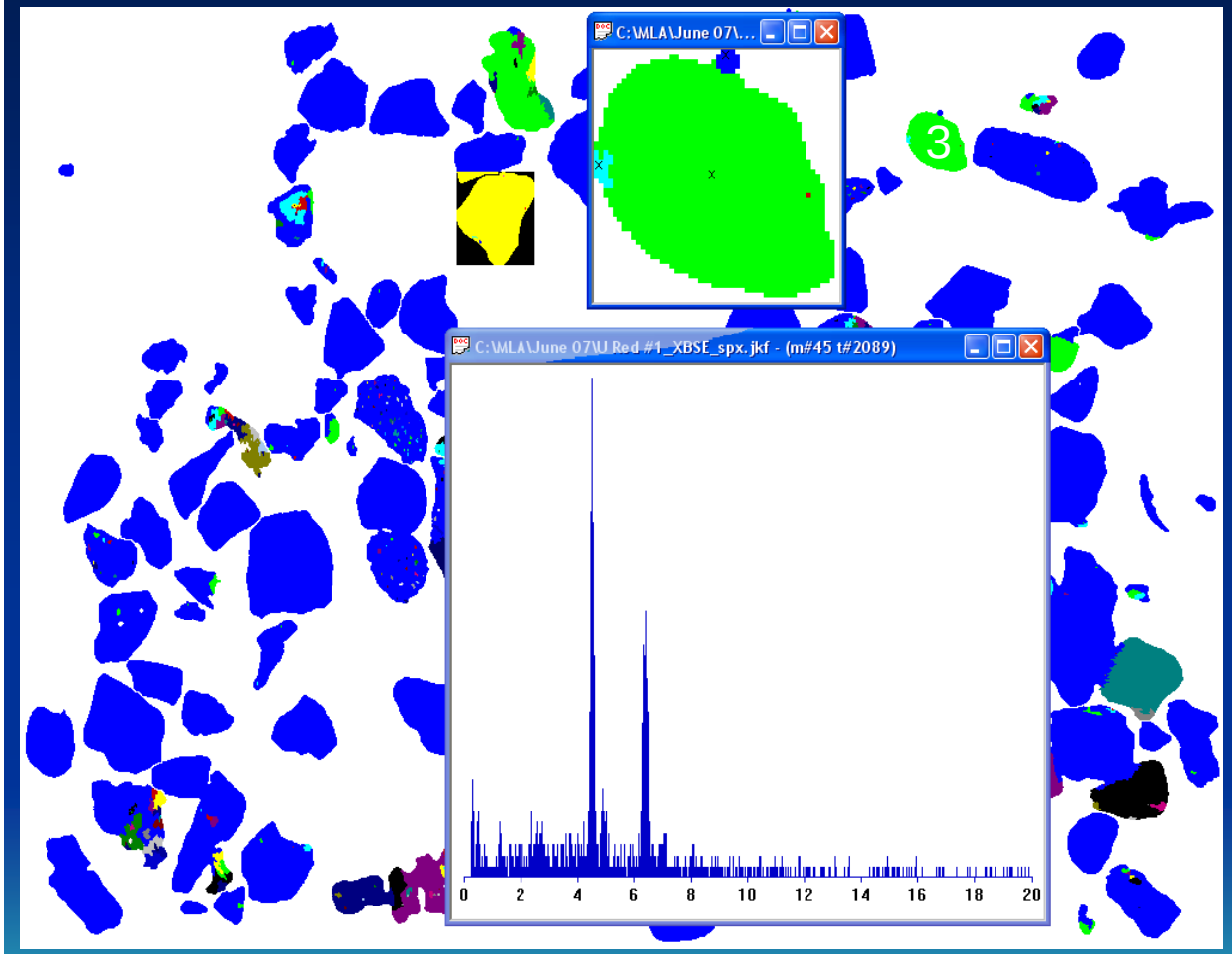
2. Silicate Mineral



- In this case, a silicate mineral is given the same false color as the quartz was given because grey levels were the same
- This will change when EDX spectrum is found to be different
- This is the basis of MLA

3. Titanium Mineral



- The silicate mineral is identified as K-Feldspar (Si, K and Al are Element #'s 14, 19 and 13)
- This titanium mineral is identified as ilmenite (Ti and Fe are Element #'s 22 and 26)
- Ilmenite will thus be brighter on the MLA image

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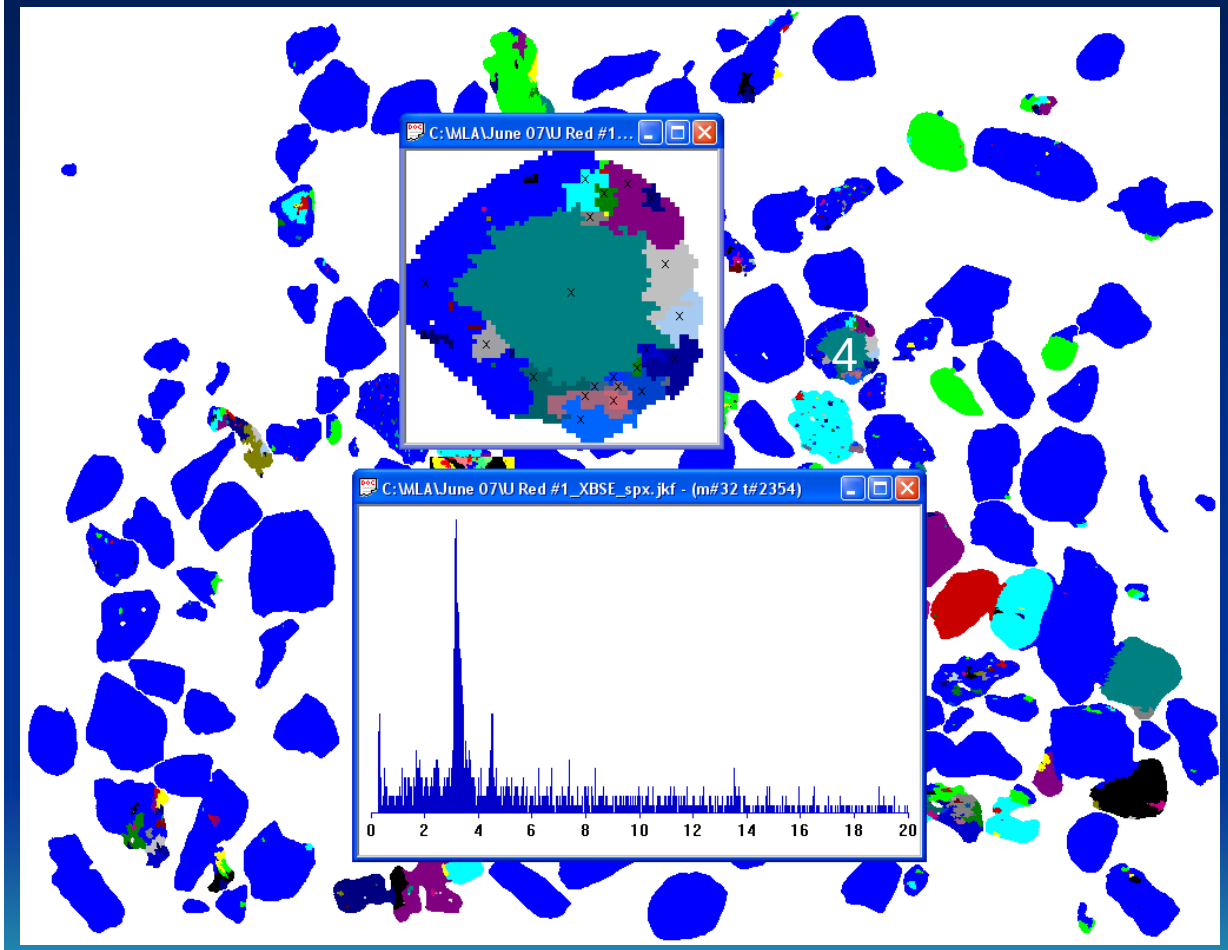
4. Uranium Mineral



- The uranium mineral was identified as uraninite
- Uranium is Element #92 so minerals that contain it are expected to be very bright in the MLA image

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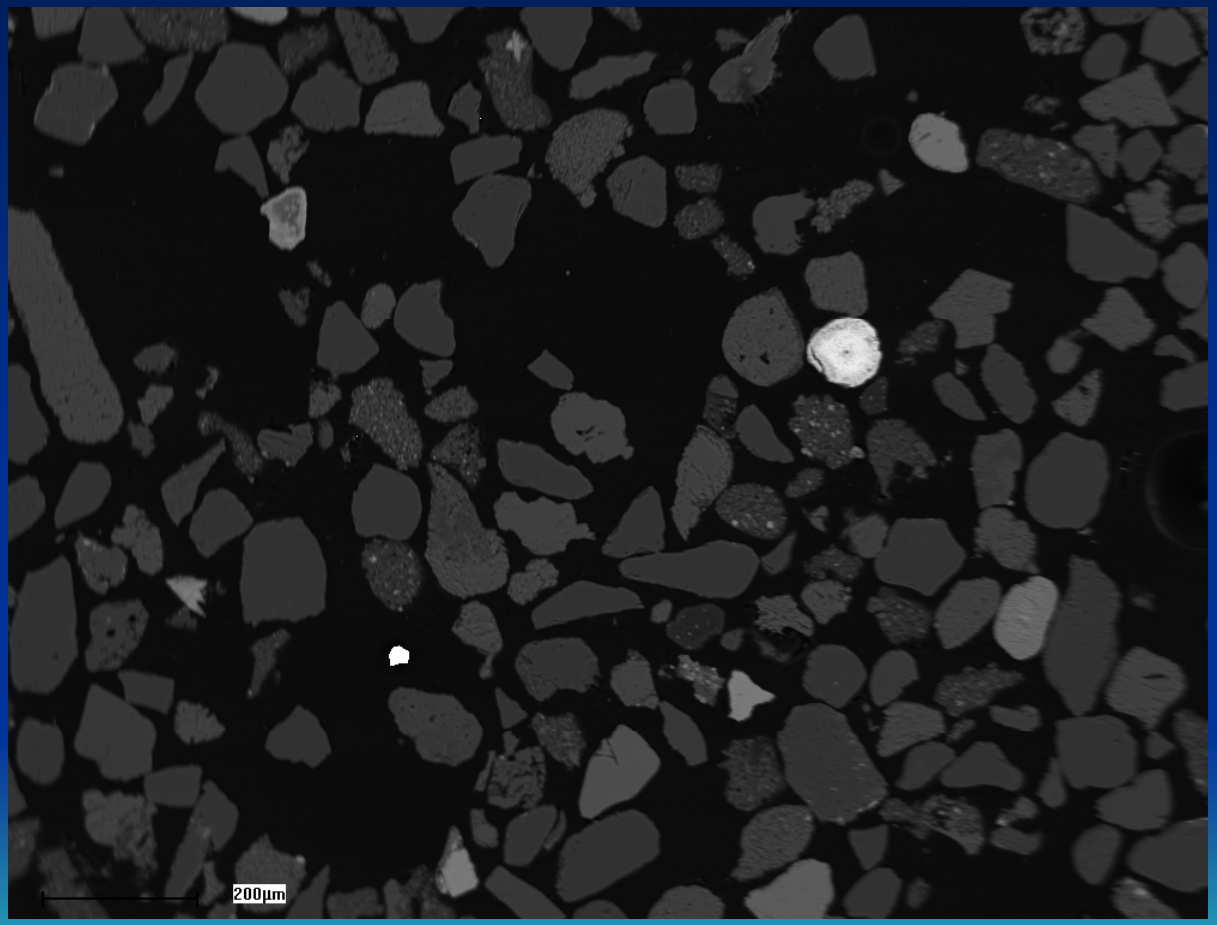
Backscatter Image



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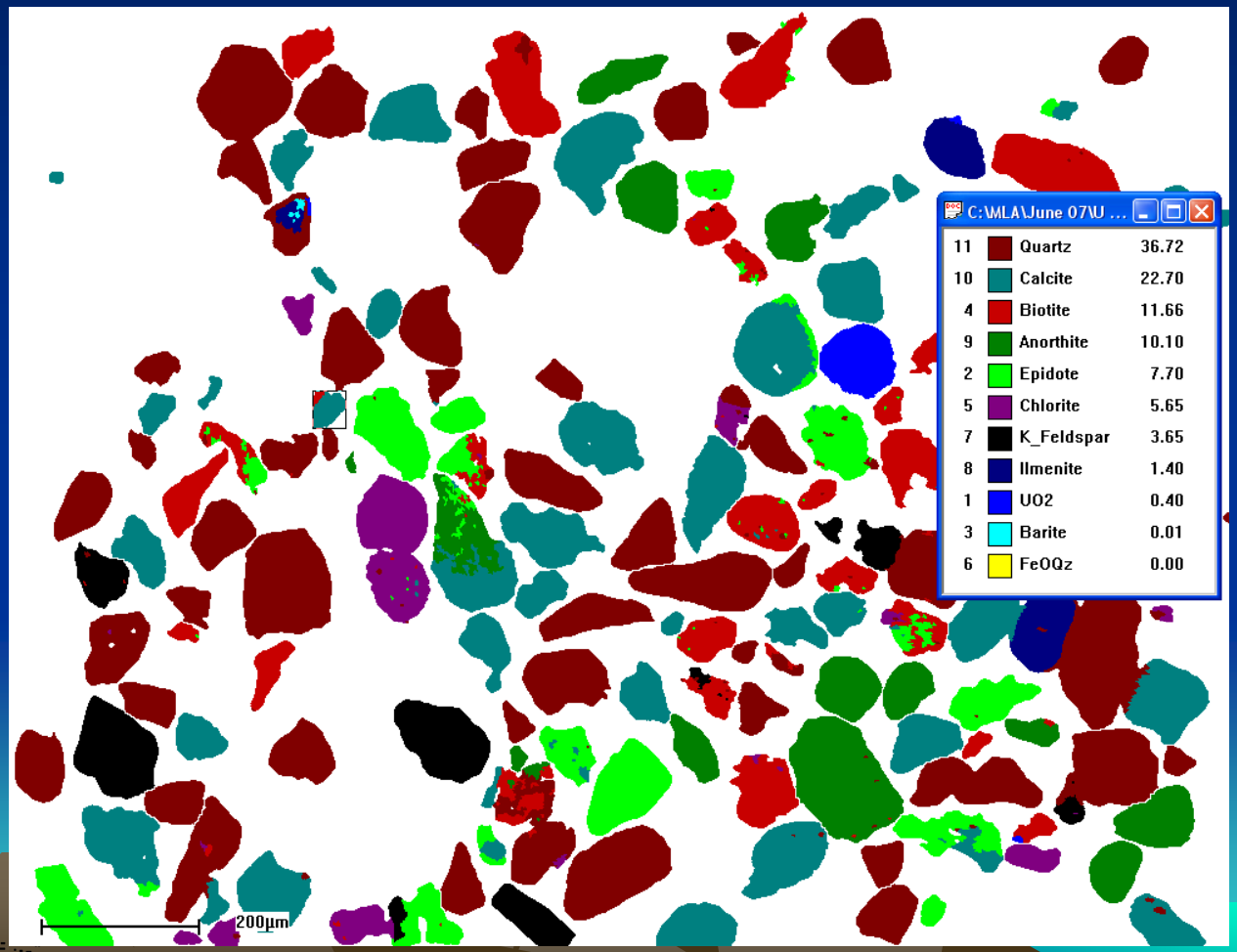
Overall Mineralogy

11 minerals were identified in this case and each are quantified and given a color



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Gold Project

- MLA can reduce time and testing using the automated mineralogy technology known as the “Rare Element” Search
- Software is used to analyze and record only the bright particles (heavy elements with a grey level > 150, in this case)
- Can do several specimens quickly by elimination of common particles (silicates)

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Gold Project

- 3 Size fractions analyzed -200/+270, -270/+325, and -325 mesh
- From MLA data, gold containing particles, along with encapsulatied particles, can be grouped together for size and liberation analysis

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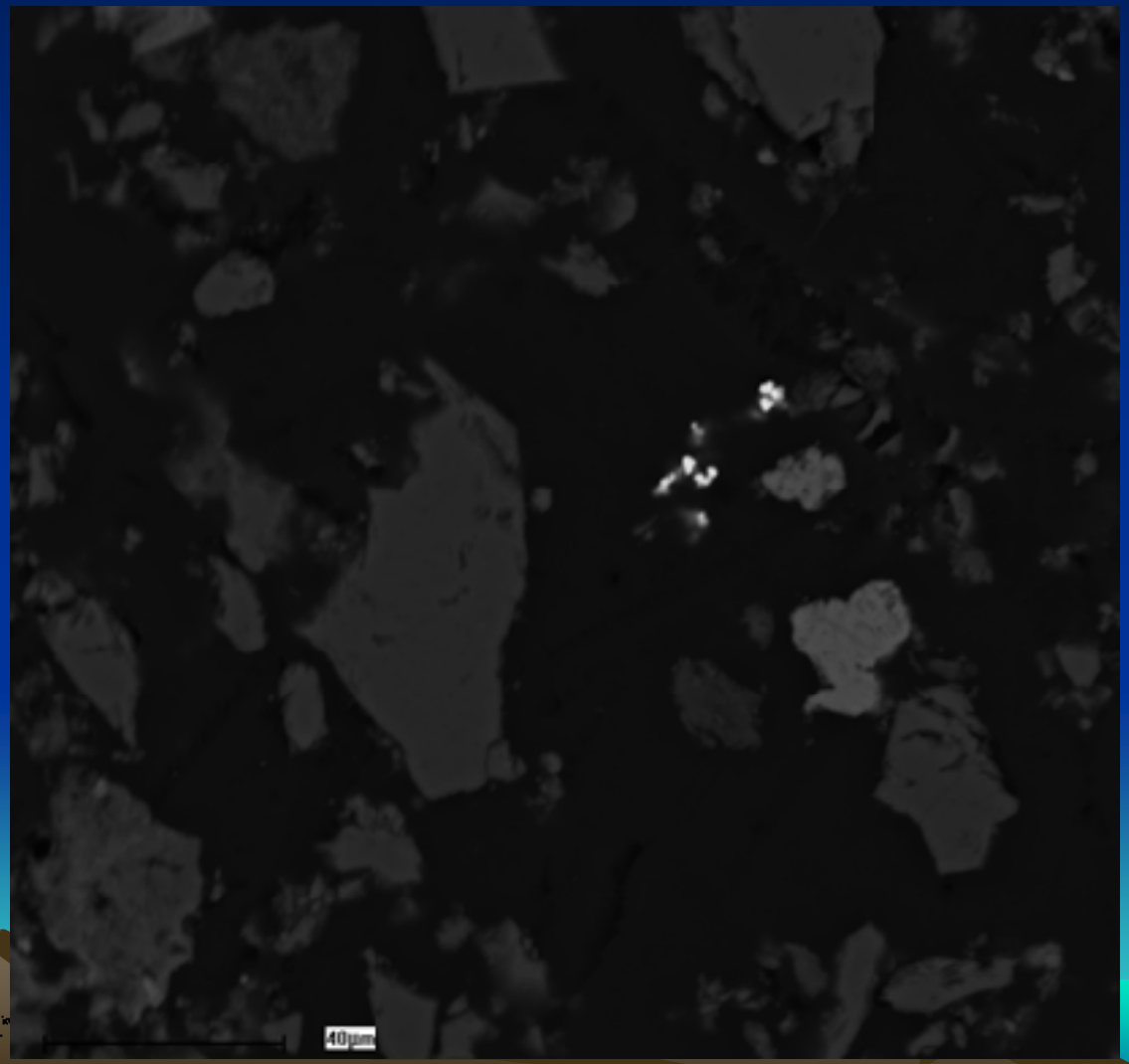
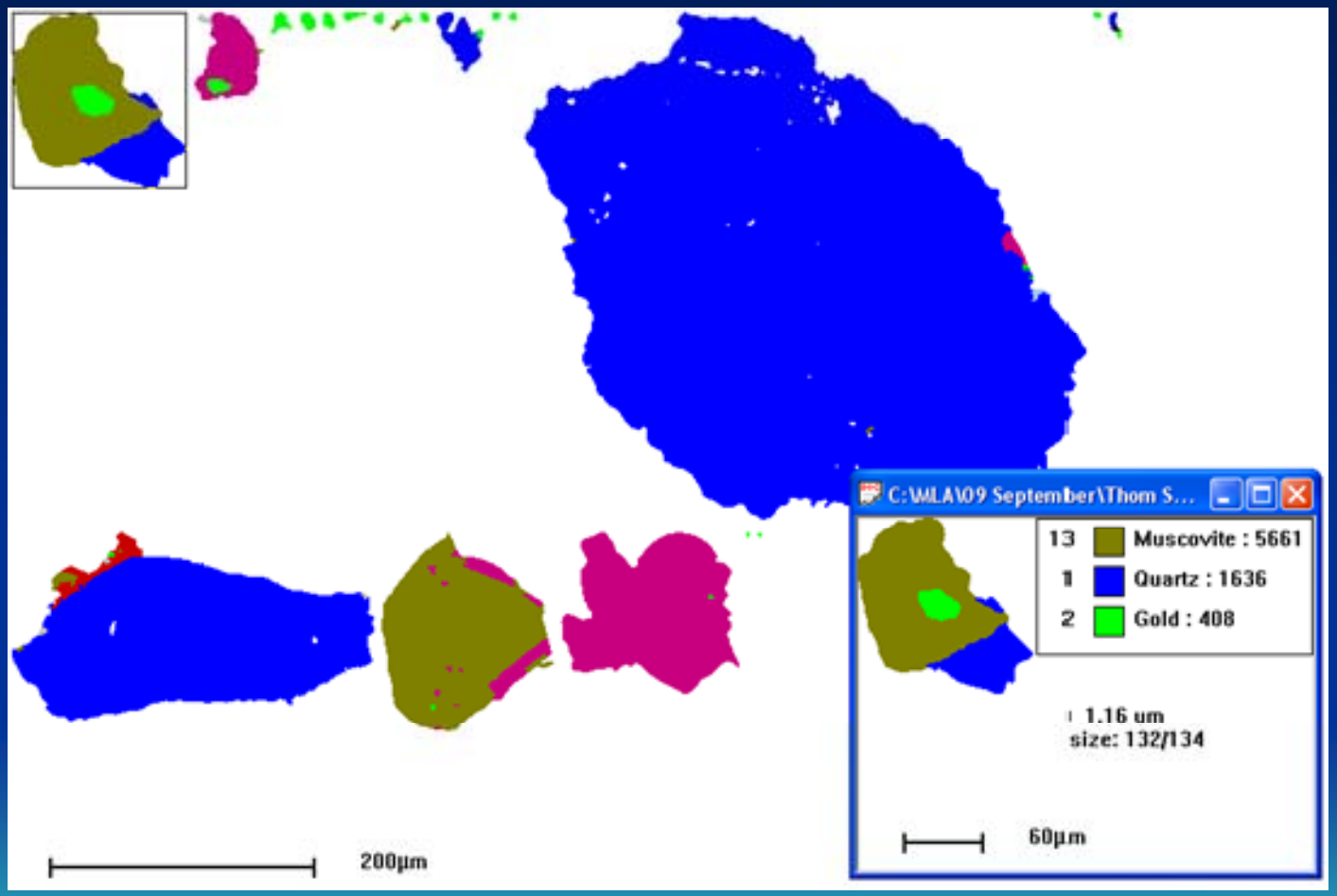
Gold Project



Gold Project



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Gold Project

- According to the MLA data, gold particles were approximately 40 microns in size
- Cyanidation tests were done and compared to MLA results
- Assuming encapsulated (non-liberated) gold equates to leached gold, recovery strongly correlated with MLA data

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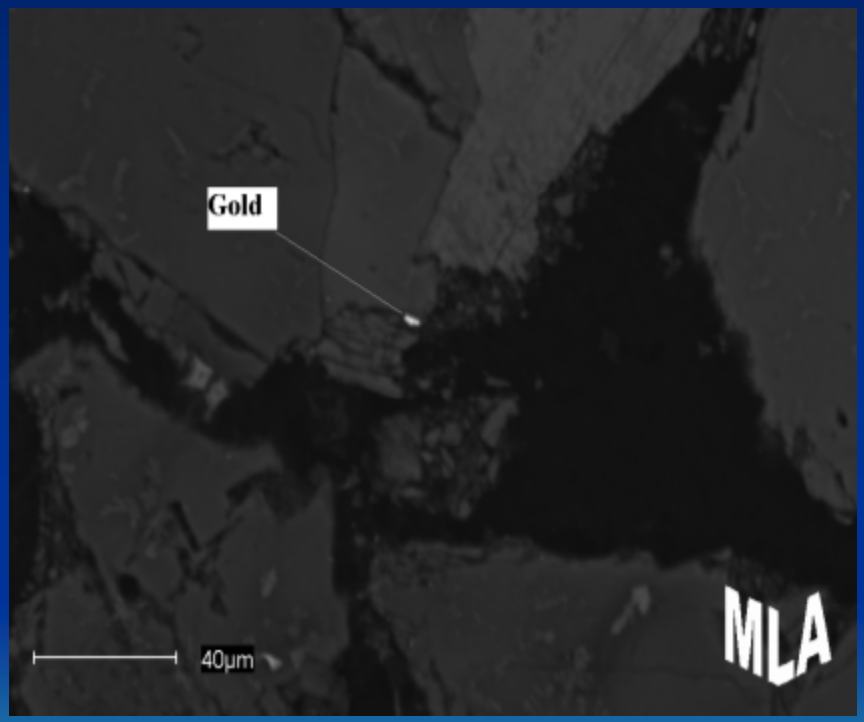
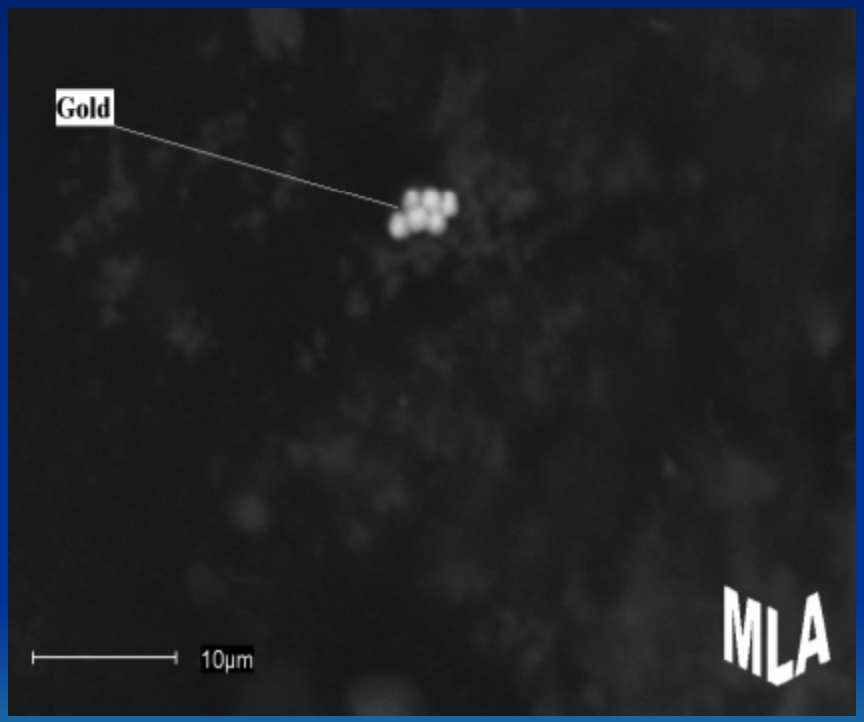
Further testing showed that encapsulated gold particles were also observed to be as small as 1-5 um





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Silver Project

- Goal was to determine silver mineralogy and mechanisms of loss
- Head samples were analyzed to determine silver mineralogy
- Flotation and leach circuits were analyzed along with resulting final tails
- Silver mineralogy was followed

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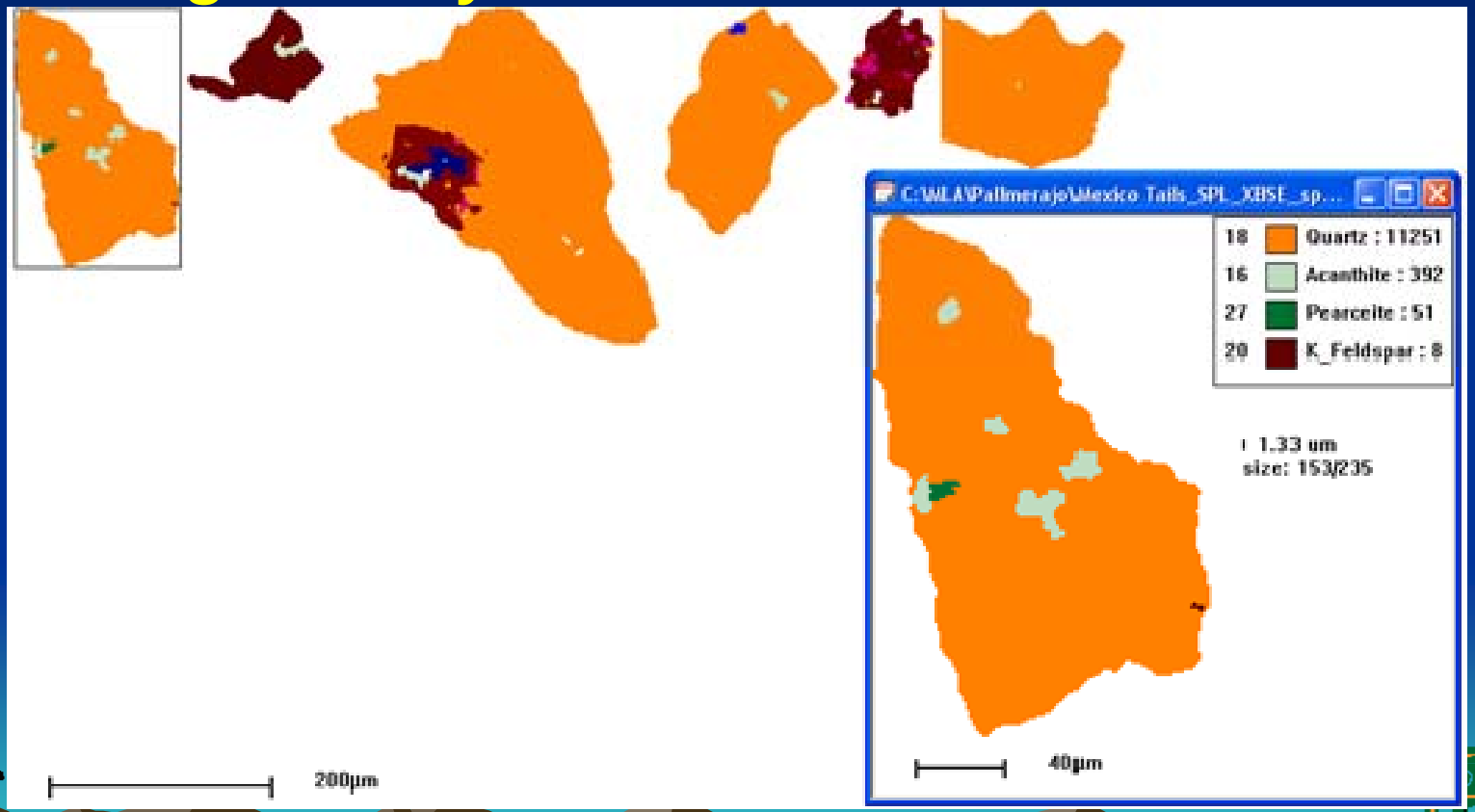
Silver Project

- Four Silver Sulfide Minerals Identified
  - Acanthite (Ag_2S)
  - Jalpaite (Ag_3CuS_2)
  - Polybasite [$(AgCu)_{16}As_2S_{11}$]
  - Pearceite [$(AgCu)_{16}Sb_2S_{11}$]

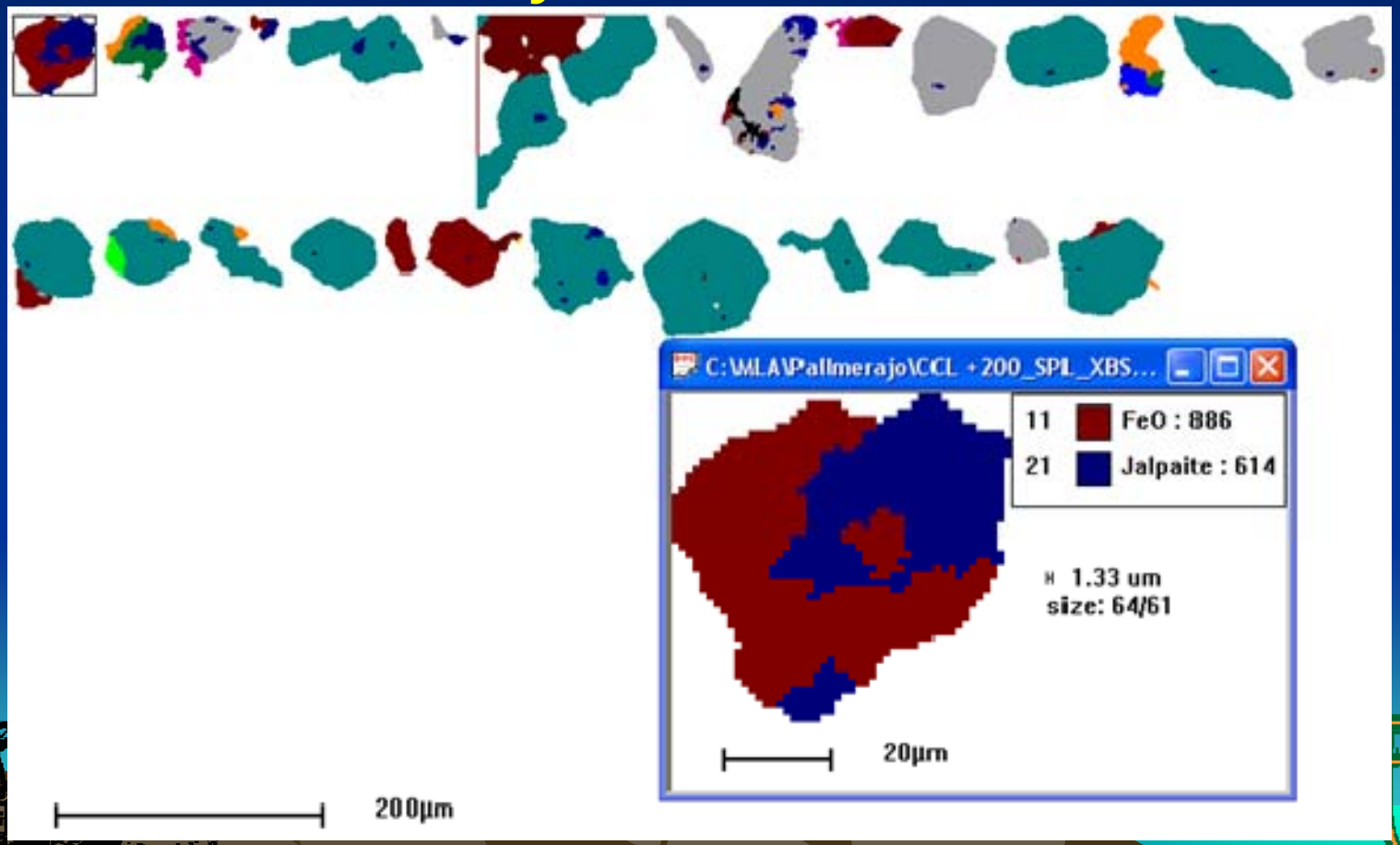
Silver Project

- Tailings Analysis - +100 mesh



Silver Project

- +74 Mesh Analysis



Silver Project

- Most of the Acanthite and some of the Pearceite is encapsulated and can not be “seen” by either flotation or leaching
- Preferential leaching of the Iron Oxide (Hematite?) over Jalpaite likely occurred
- Very little Polybasite was found in the tailings so most silver recovery was due to this mineral

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Host particles even take on the shape of USA including the Mississippi River

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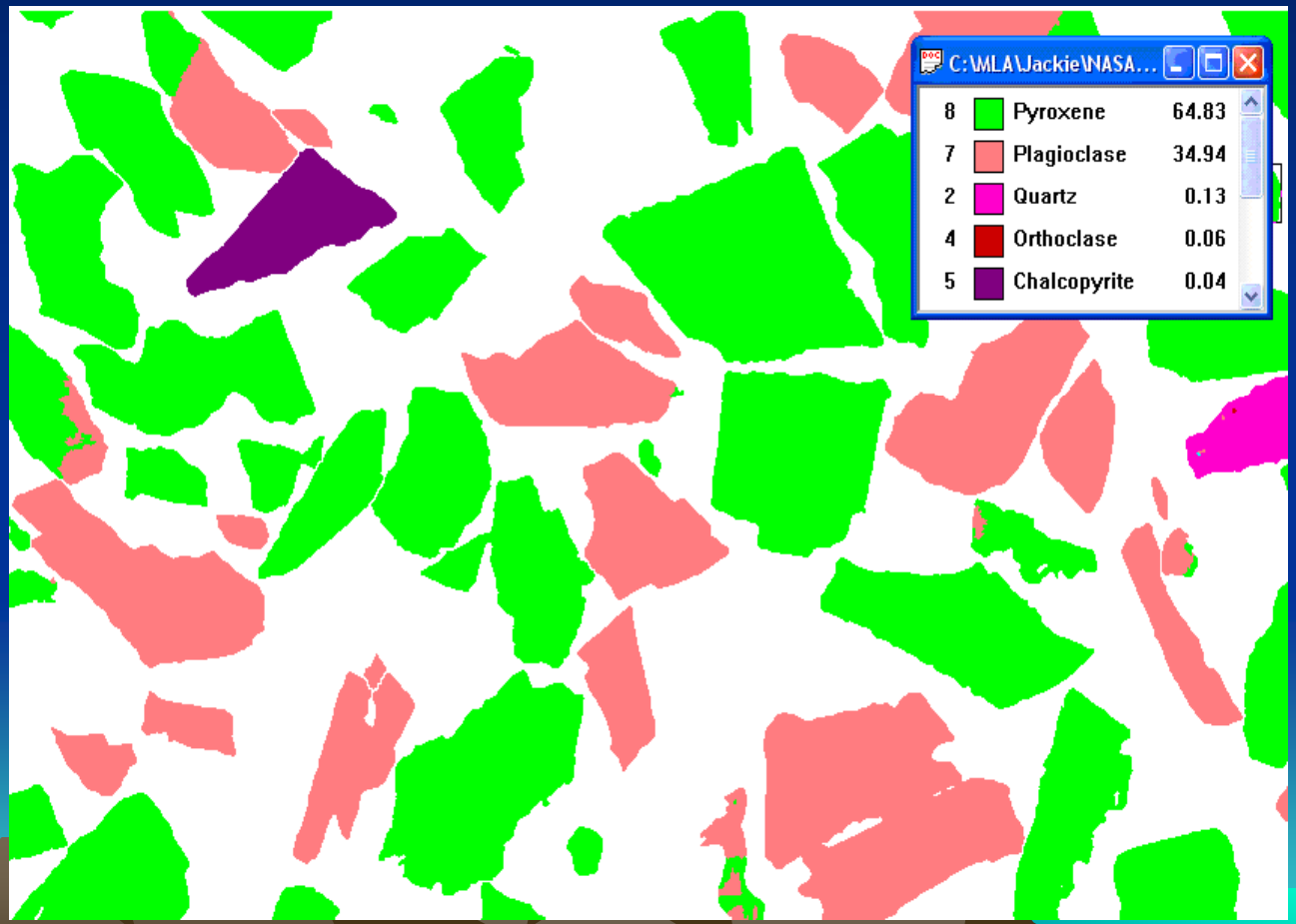
NASA/Lunar Project

Stillwater norite stockpile contains at least 5 minerals



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Conclusions

- MLA is a very powerful analytical tool which can be used for ore bodies, concentrates and tailings including lunar soil and rock
- For the gold project, industrial procedures can not be modified to increase recovery
- For the silver project, industrial procedures might be modified to increase recovery
- Smaller particles for both projects tended to be encapsulated and explain low recoveries

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MLA Pros and Cons

Pros

- Automated Microprobing
- Rare Element Searches
- Identifies minerals by EDAX chemistry
- Gives “semi” quantitative of mineral ore bodies
- Can handle amorphous materials
- Build up personal library including mixed phases

Cons

- Struggles with certain minerals: hematite vs magnetite vs goethite, rutile vs anatase, etc.
- Similarly, carbonates can be difficult: siderite vs hematite
- Takes time to prep samples: comminution, screening and mounting
- Cost of SEM/MLA - not many users worldwide

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