MINERALOGY AND CHEMISTRY OF MINE WASTE ROCK PILES IN MINING DISTRICTS IN SOUTHERN COLORADO AND NEW MEXICO

Virginia T. McLemore and Marcus Silva

New Mexico Bureau of Geology and Mineral Resources, New Mexico Tech, Socorro, NM

GEOLOGIC PROCESSES AFFECTING THE CHEMISTRY, ACID POTENTIAL AND PHYSICAL STABILITY OF MINE SITES IN NEW MEXICO AND SOUTHERN COLORADO

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  - U.S. Geological Survey
  - Society of Mining, Metallurgy, and Exploration, Inc.
  - New Mexico Geological Society
- Numerous M.S. theses
- Professional staff and many students who worked on these projects

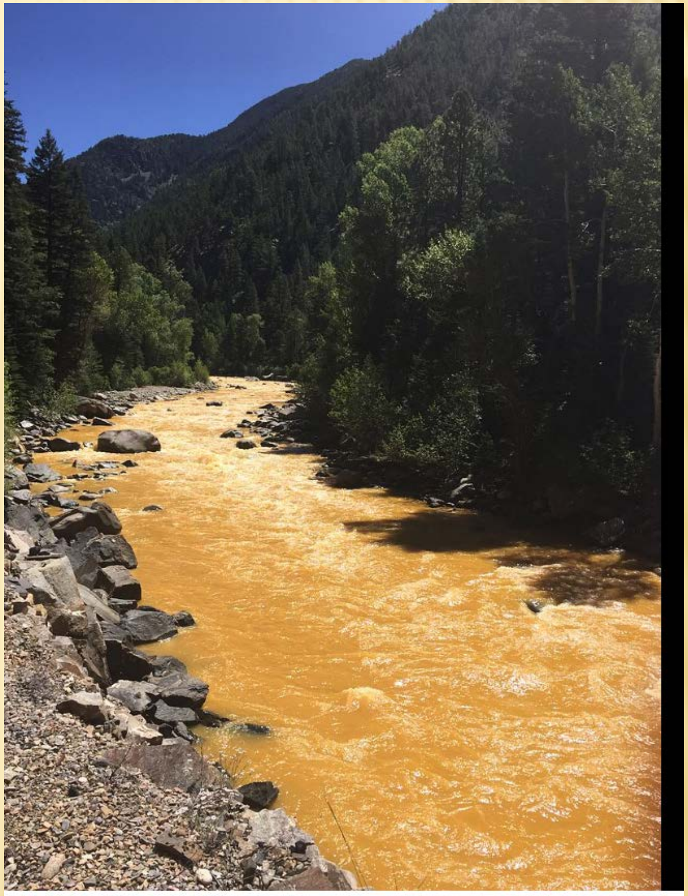
PREVIEW

- Define the problem
- Procedure
- Results
- Conclusions
- Lessons learned

Rosedale tailings, Socorro County

DEFINE THE PROBLEM

Gold King adit



Animas River after Gold King spill

DEFINITION OF AML (ABANDONED MINE LANDS)

- Lands that were excavated and left unreclaimed where no individual or company has reclamation responsibility and there is no closure plan in effect
- Excavations, either caved in or sealed, that have been deserted and where further mining is not intended in the near future, generally >10 yr old
- Includes mines and mine features left unreclaimed on Federal, State, private and Native American lands because the current owner was not legally responsible for reclamation at the time the mine was created
- Also called inactive, legacy, and orphaned mines

PURPOSE OF NMBGMR AML PROGRAM

- History of mining districts
- Mineral collecting
  - Minerals
- Potential environmental issues
  - Physical hazards and stability issues
  - **Potential acid rock drainage and high metal concentrations**
  - Water quality
  - Are the mine wastes suitable for backfilling
  - Health of the ecosystems and people
- Mineral-resource potential
  - Are there any minerals left to mine today or in the future?
  - Are there economic uses of the mine wastes?
- **Understanding geologic processes**

PURPOSE OF NMBGMR AML PROGRAM

Provide data on districts, mines, and mills in New Mexico

- Help plan and assess reclamation procedures
- Determine background concentrations
- Compare trace-element concentrations in mined versus undisturbed areas
- Provide background data that can assist with the planning of future mining and mine reclamation operations

Summit mine, Steeple Rock district, Grant County (operated 2009-2014, on stand by)

- Water quality is directly related to the mineralogy and chemistry of the mine wastes and mineralized rocks
- Source can be both mine wastes and surrounding altered and mineralized host rock

WHAT ARE POTENTIAL ENVIRONMENTAL ISSUES ASSOCIATED WITH AML?

- Mine workings, rock piles, tailings, and heap leach facilities—physical hazards, unstable features
- Acid rock drainage and contamination by metals and other constituents is a problem at some sites in NM and CO
- **Most mines, waste rock piles, tailings, and heap leach facilities examined are safe and have remained stable with little or no environmental impacts**
- However, since there is no complete inventory, we do not the extent of any problems


Hillsboro


Pinos Altos


Hillsboro

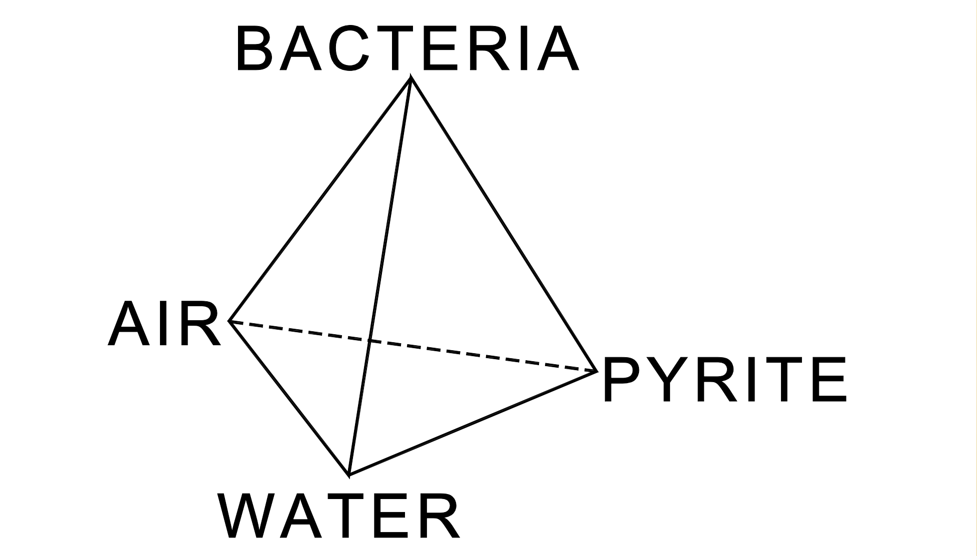

Jicarilla

CAUSES OF UNDESIRABLE IMPACTS FROM AML SITES

- Erosion and weathering—rates?
- Too much water
  - Results in weathering of the rock and soil
  - Can create unstable features and acid drainage
- Need to control water into the mine workings, waste rock piles, tailings, heap leach, and foundation materials
- Poor foundation conditions
  - Weak materials like clay, altered, fractured rock
- Poor understanding of effects of weathering on the degradation of materials
- **Every site is different and must be specifically characterized**

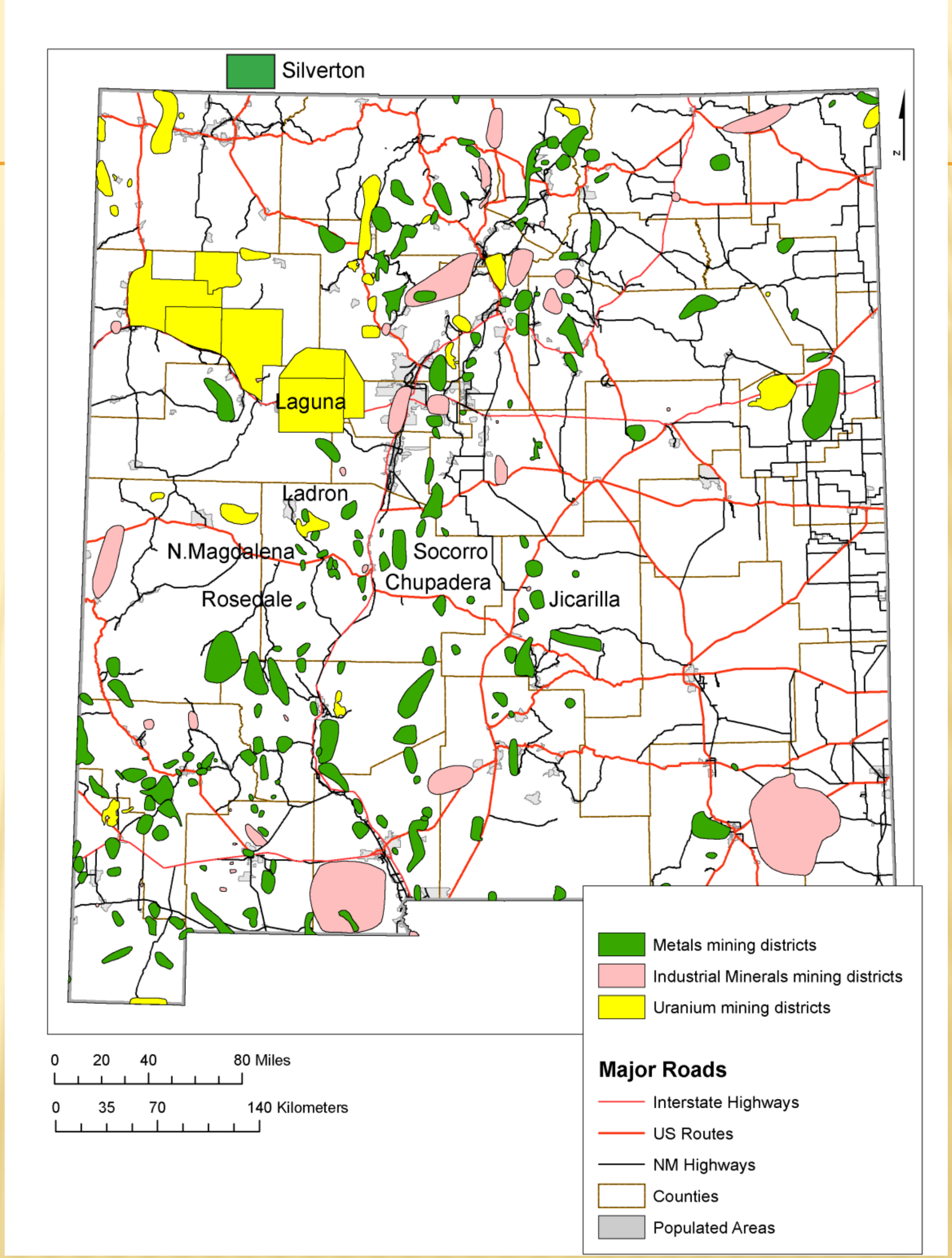
Pyrite characterization

The dissolution of pyrite during weathering is the predominant chemical reaction that results in potential acid forming rocks.



PROCEDURE

Examined samples form Silverton, Rosedale, Jicarilla, North Magdalena, Hillsboro, and Questa districts



STEPS

- Inventory the mines and mine features
  - History of the site (production, commodities, mine methods, processing facilities)
- Map the mine features and mine wastes
- Field descriptions and measurements
- Sampling

SAMPLING

Composite sampling of waste rock piles and tailings at the surface

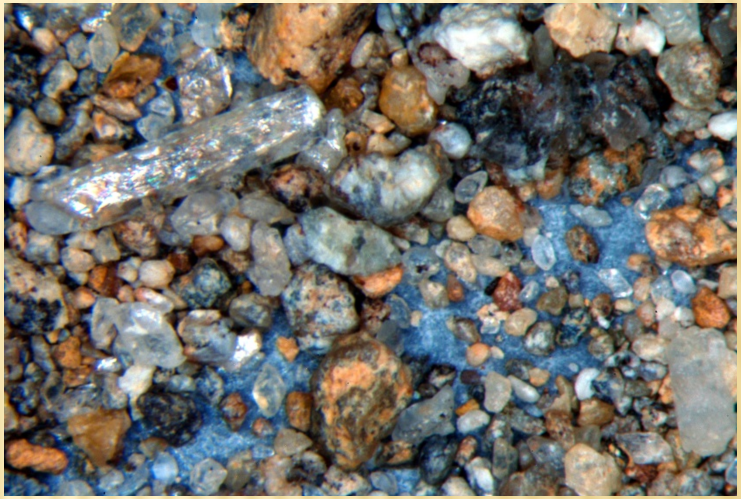
STEPS—LABORATORY TESTS

- Paste pH
  - To determine the pH of a paste made by mixing a known mass of soil with a known volume of deionized water
- Acid-Base Accounting (ABA)
  - To determine the balance between acid-producing and acid-neutralizing potential of the sample
  - Acid Potential (AP)
  - Neutralizing Potential (NP)
- Net Acid Generation (NAG)
  - To determine the net acid remaining, if any, after complete oxidation of the materials with hydrogen peroxide and allowing complete reaction of the acid formed with the neutralizing components of the material

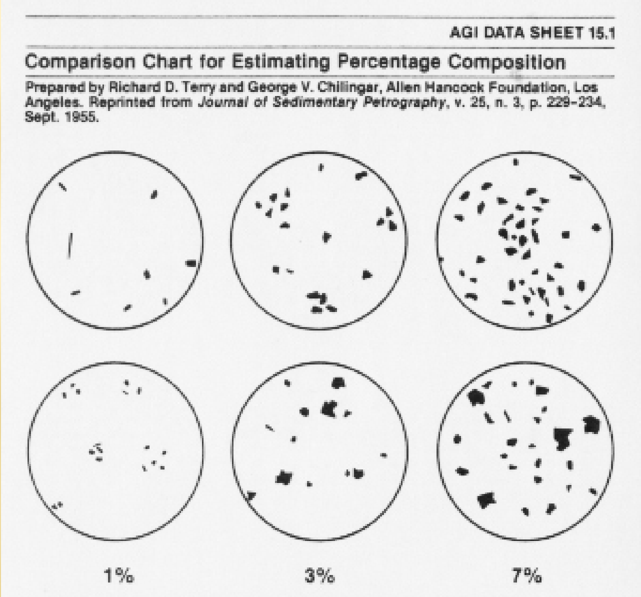
STEPS

- Petrography and detailed mineralogy and chemistry
  - Petrographic analysis of a bulk grab subsample using a binocular microscope
  - Petrographic analysis of thin sections of the rock fragments (including both transmitted- and reflected-light microscopy)
  - Electron microprobe analysis of both the fine-grained soil matrix and the rock fragments
  - Chemical analyses of minerals
  - Whole rock geochemistry
  - Other methods of determining mineralogy (spectral analysis, X-ray diffraction)

SOIL PETROGRAPHY–DETERMINING MINERALOGY AND TEXTURE

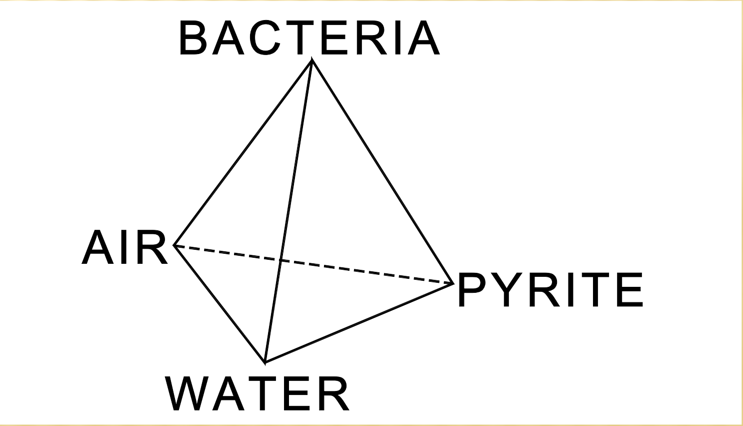


2 mm



Pyrite characterization

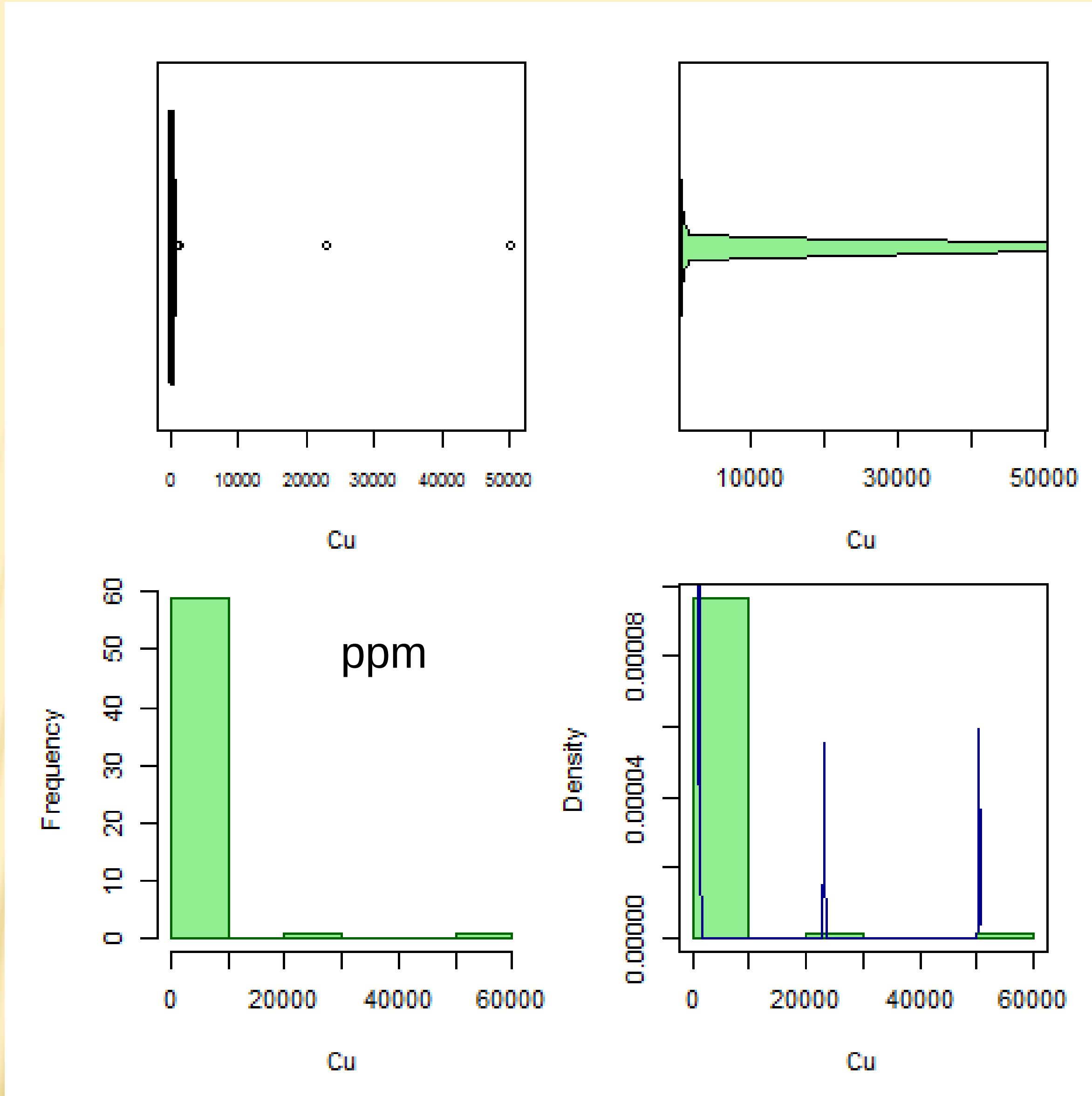
- Evaluate the distribution, form, size, amount, surface area of pyrite in the rock piles



PRELIMINARY RESULTS

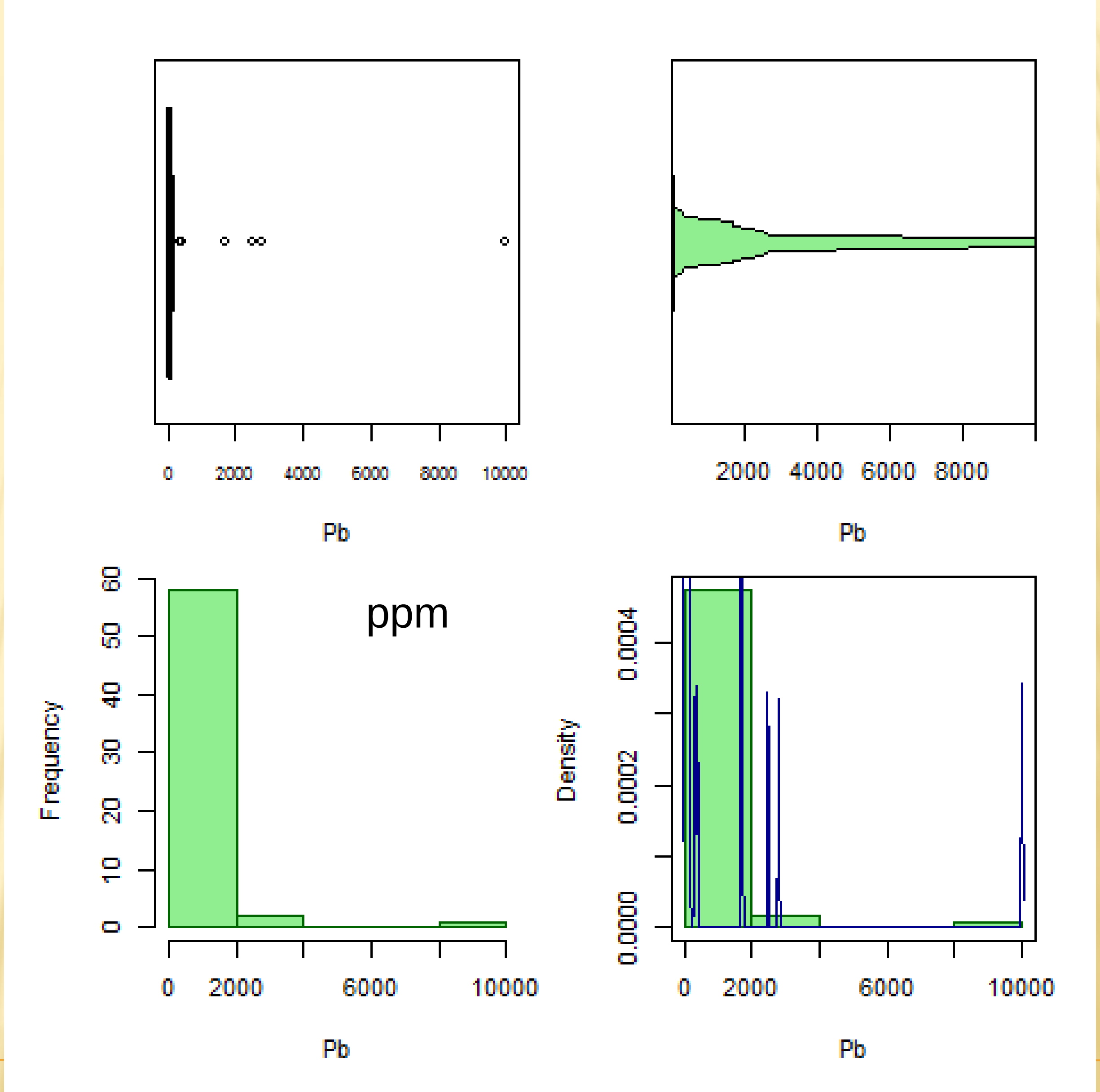
CHEMICAL COMPOSITION

- 61 composite samples
- Average Cu in soils US=25 ppm (USGS PP 1270)
- EPA screening level for Cu in industrial soils=4700 ppm*
- Silverton Cu=347-698 ppm

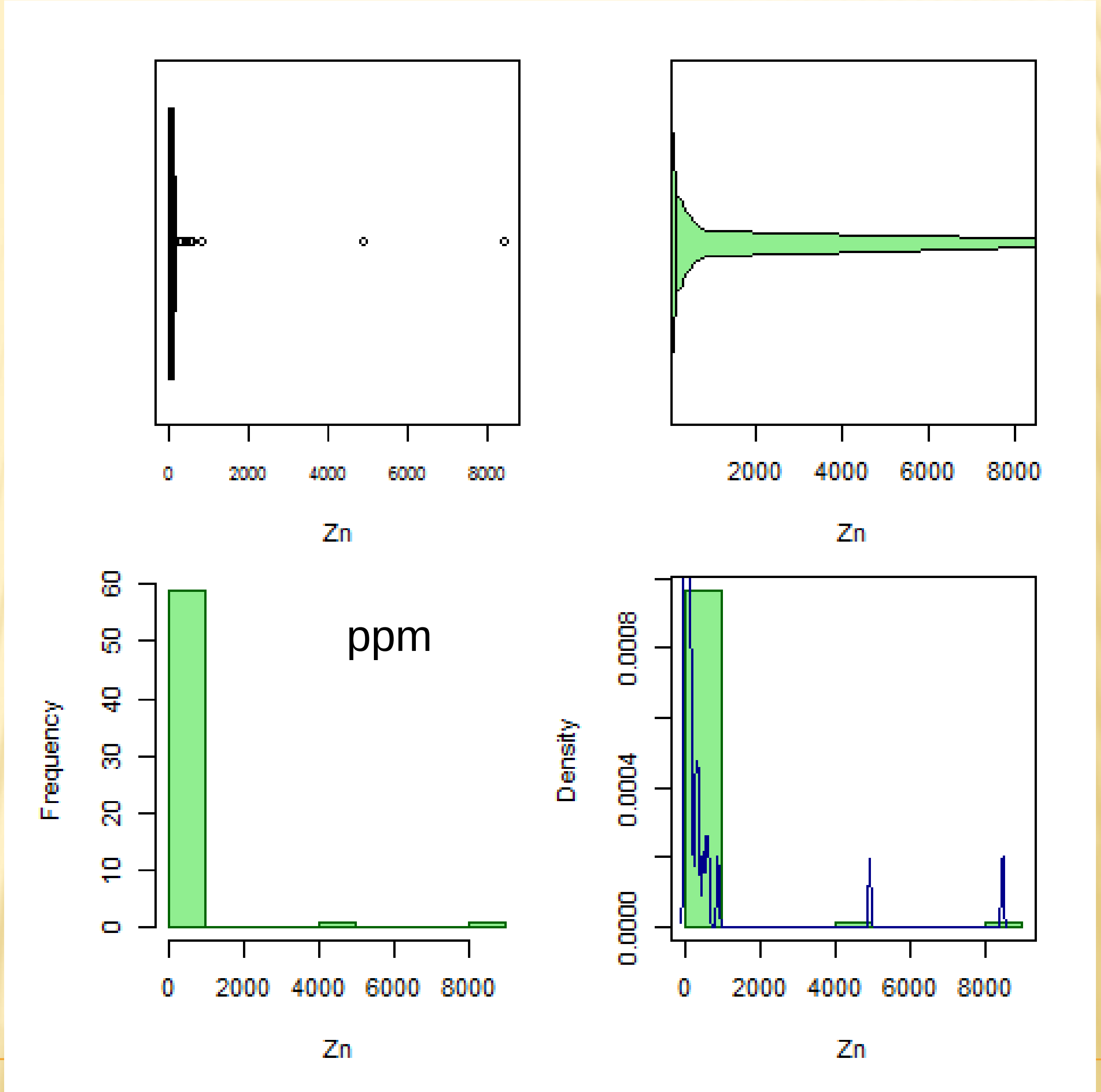


*http://esdat.net/Environmental%20Standards/US/Region_3_6_9/USEPA%20RSL%20June%202017%20THQ%20=%201.0.pdf

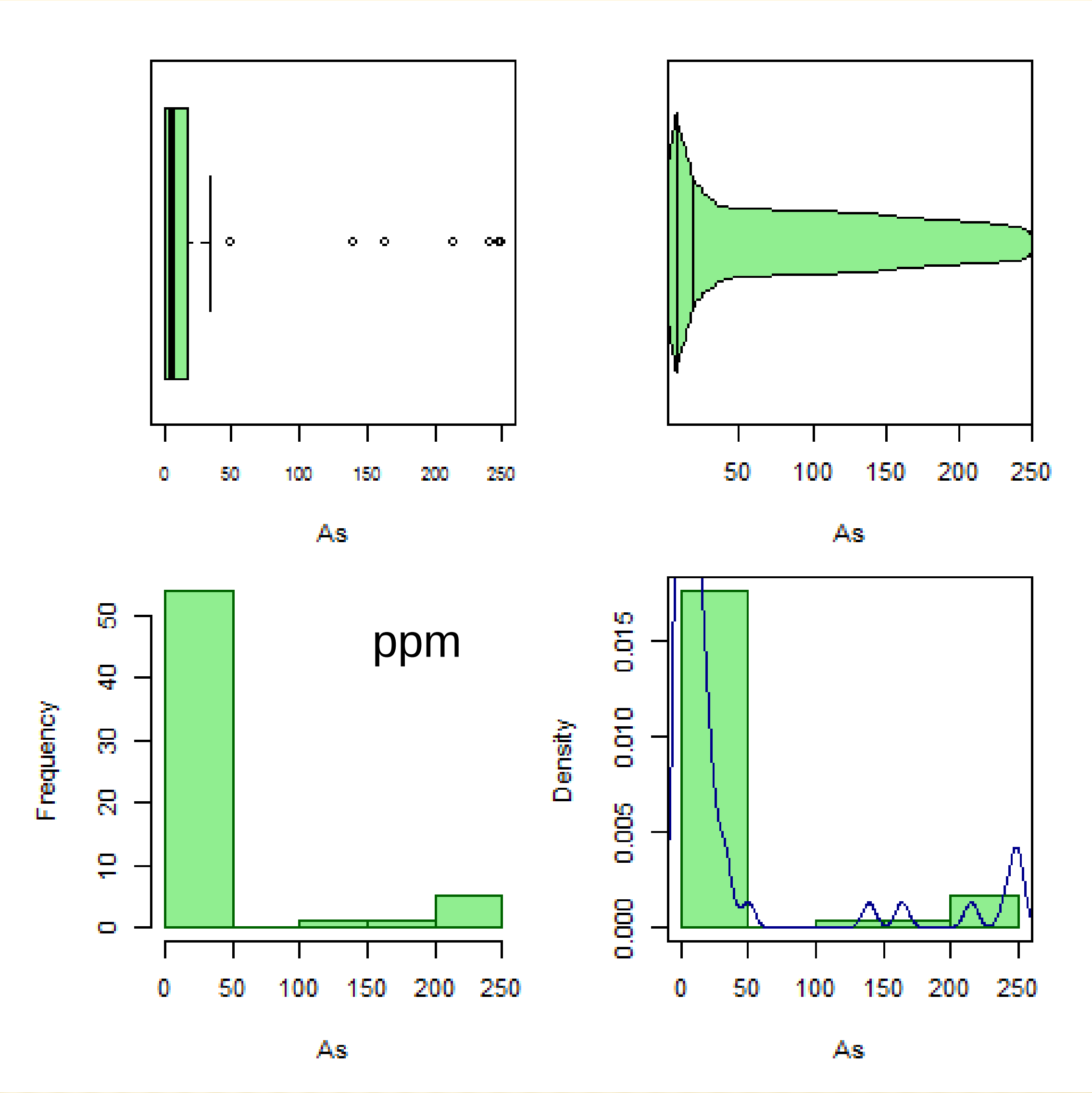
- 61 composite samples
- Average Pb in soils US=19 ppm (USGS PP 1270)
- Silverton Pb=1690->10,000 ppm



- 61 composite samples
- Average Zn in soils US=60 ppm (USGS PP 1270)
- Silverton Zn=308-8480 ppm

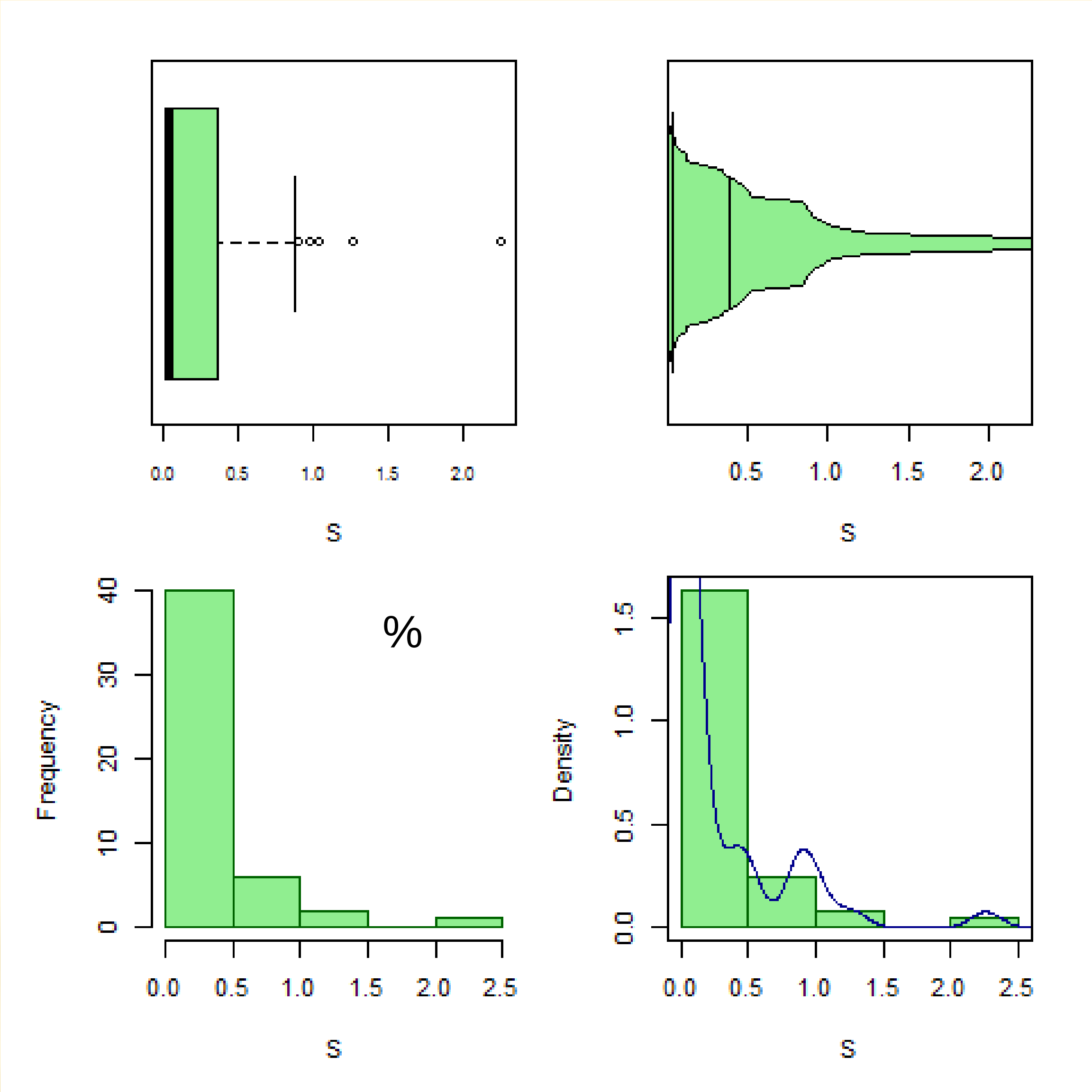


- 61 composite samples
- Average As in soils=7 ppm (USGS PP 1270)
- EPA screening level for As in industrial soils=3 ppm*
- Silverton As=164->250 ppm



*http://esdat.net/Environmental%20Standards/US/Region_3_6_9/USEPA%20RSL%20June%202017%20THQ%20=%201.0.pdf

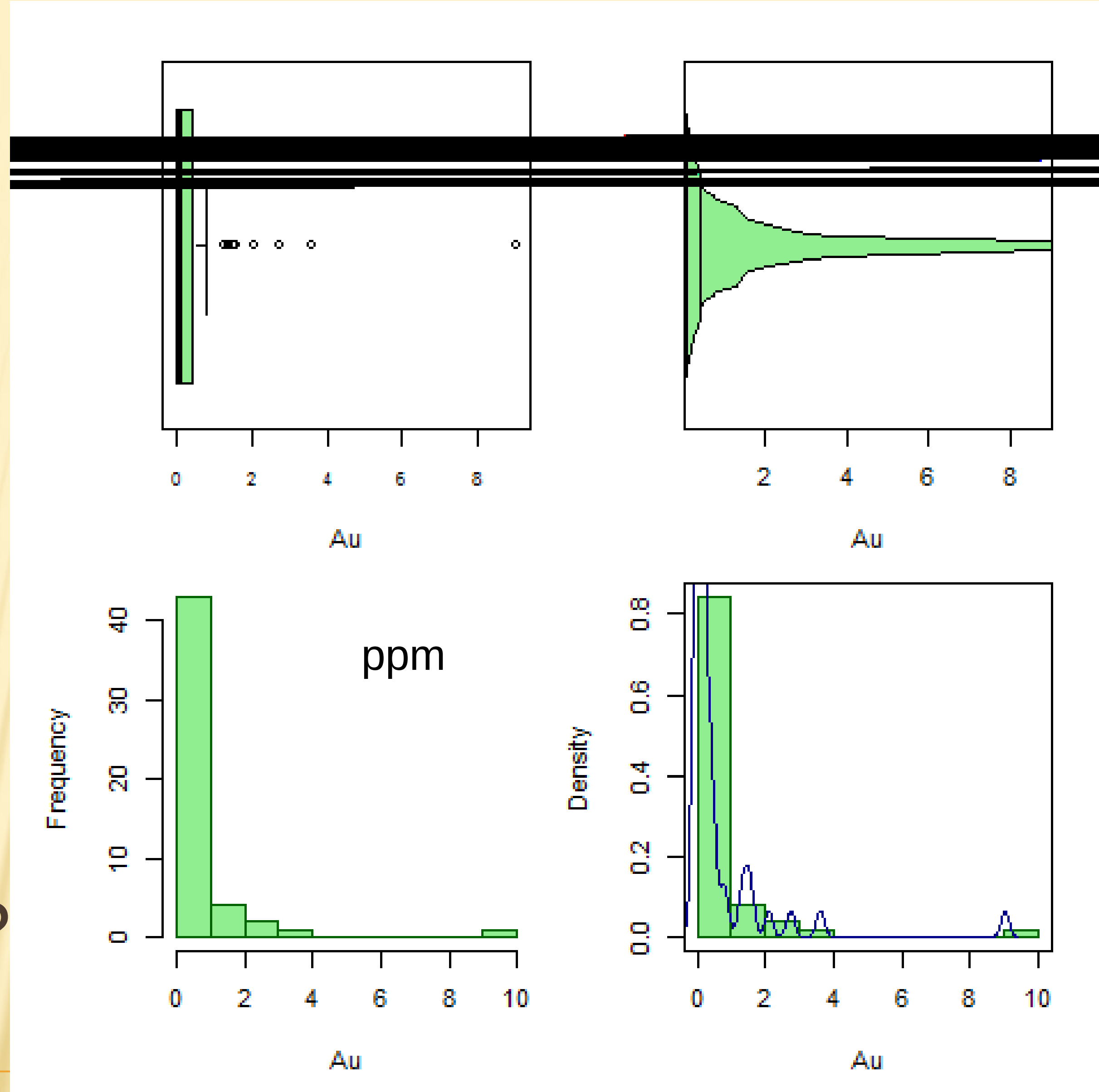
- 61 composite samples
- Average S in soils=1600 ppm (USGS PP 1270)
- Silverton S=0.53-2.2%



*http://esdat.net/Environmental%20Standards/US/Region_3_6_9/USEPA%20RSL%20June%202017%20THQ%20=%201.0.pdf

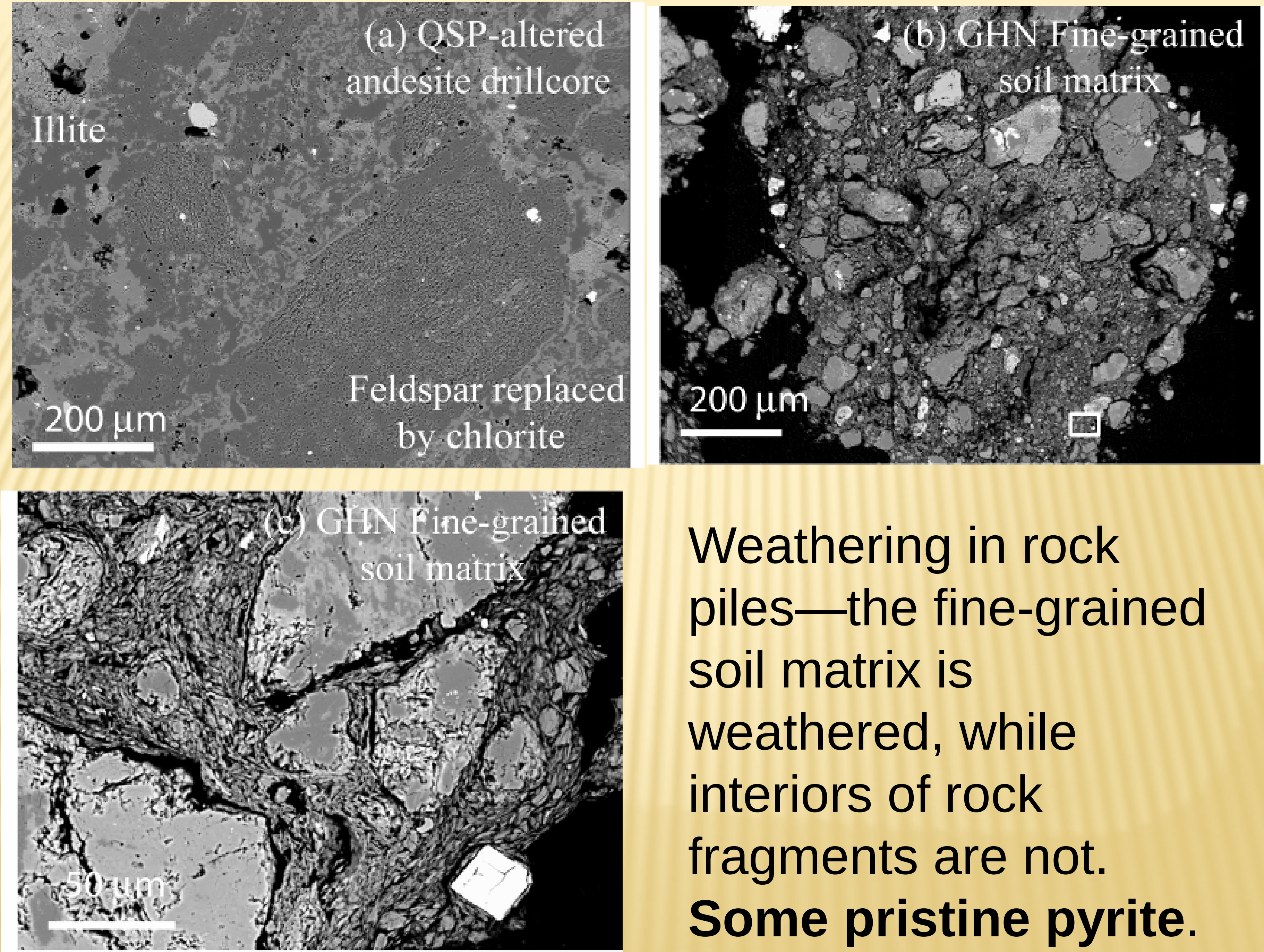
- 61 composite samples
- Silverton Au=0.1-1.5 ppm

- POTENTIAL GOLD RECOVERY?

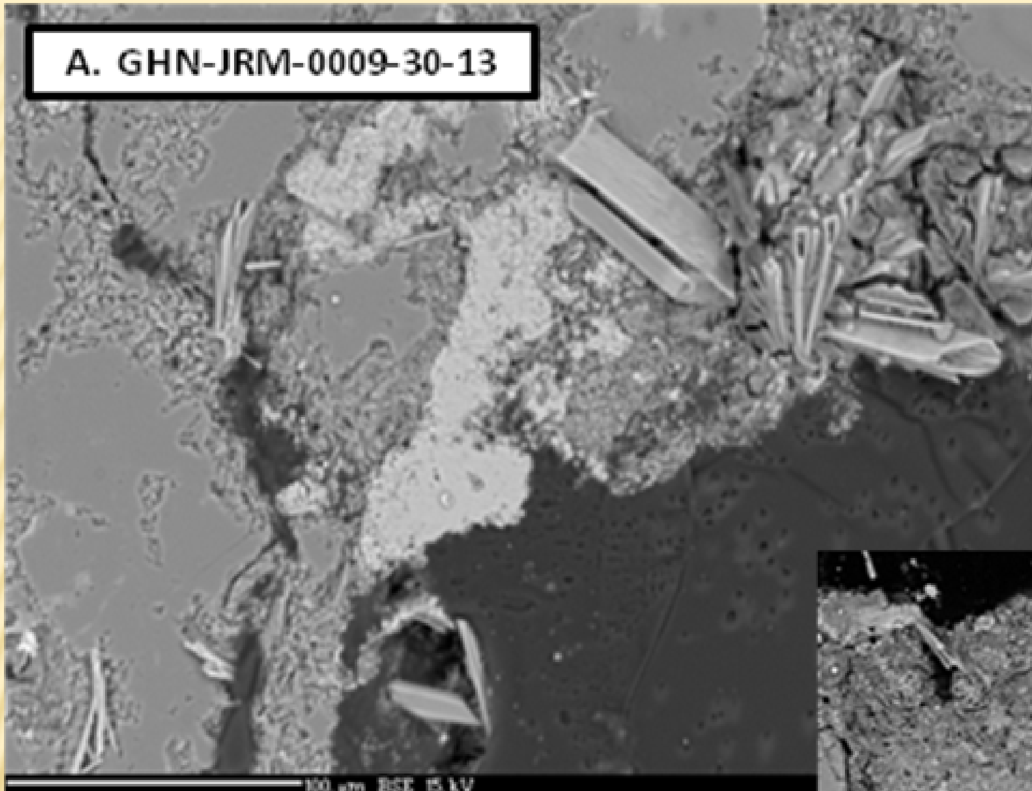


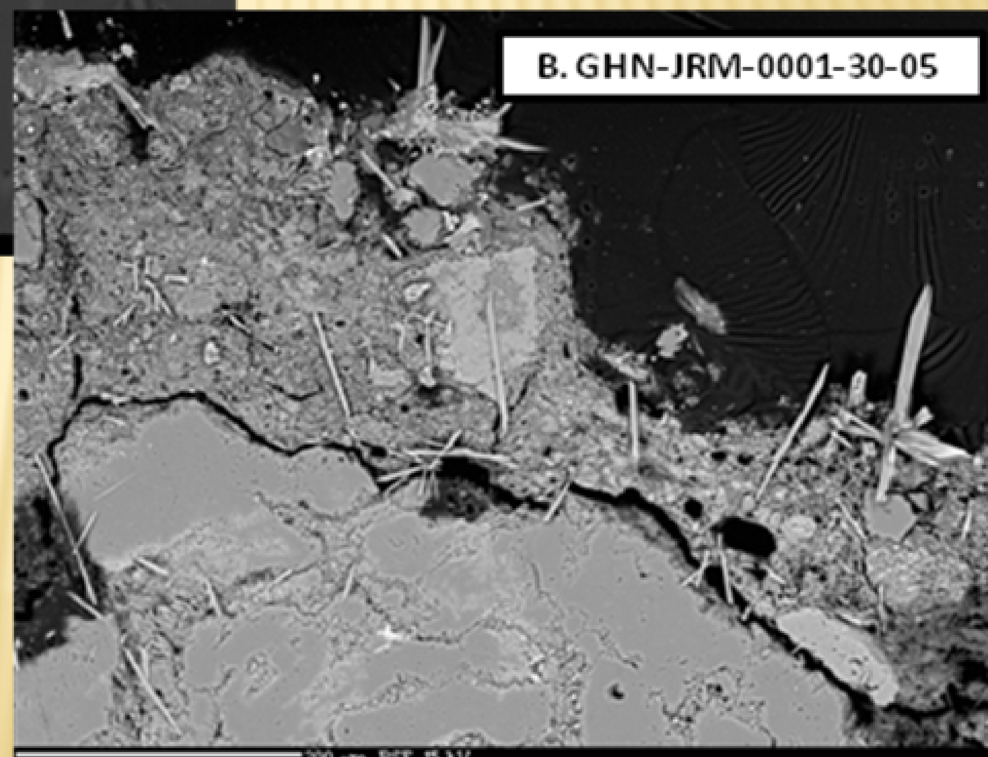
MINERALOGY AND TEXTURE

MICROPROBE ANALYSIS (BSE) IMAGES

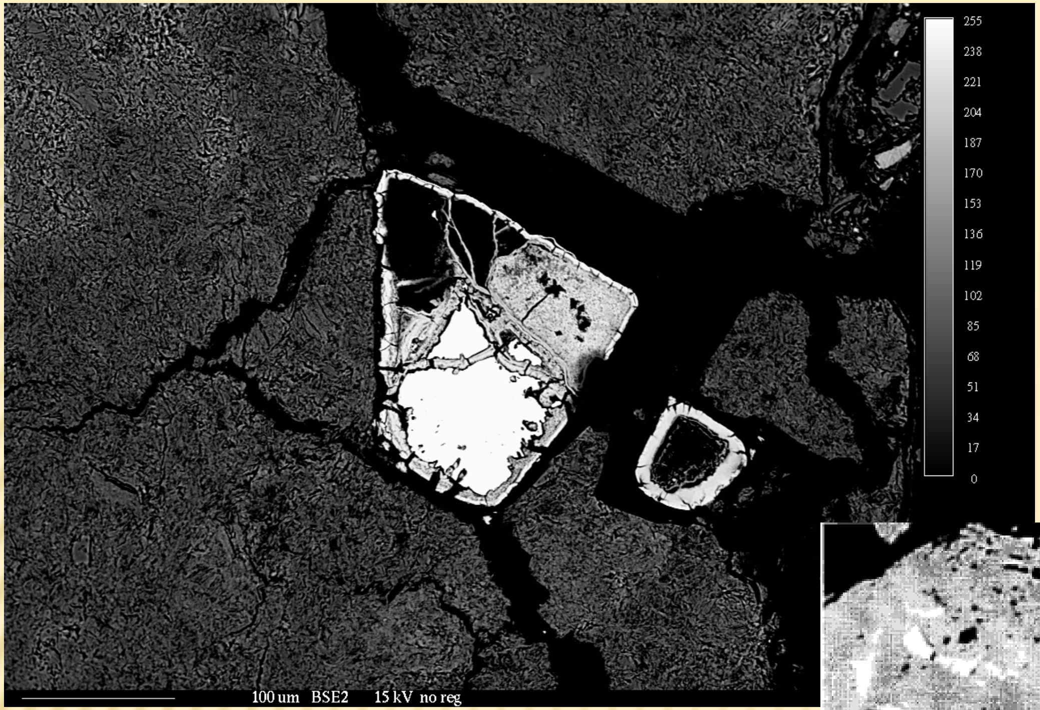


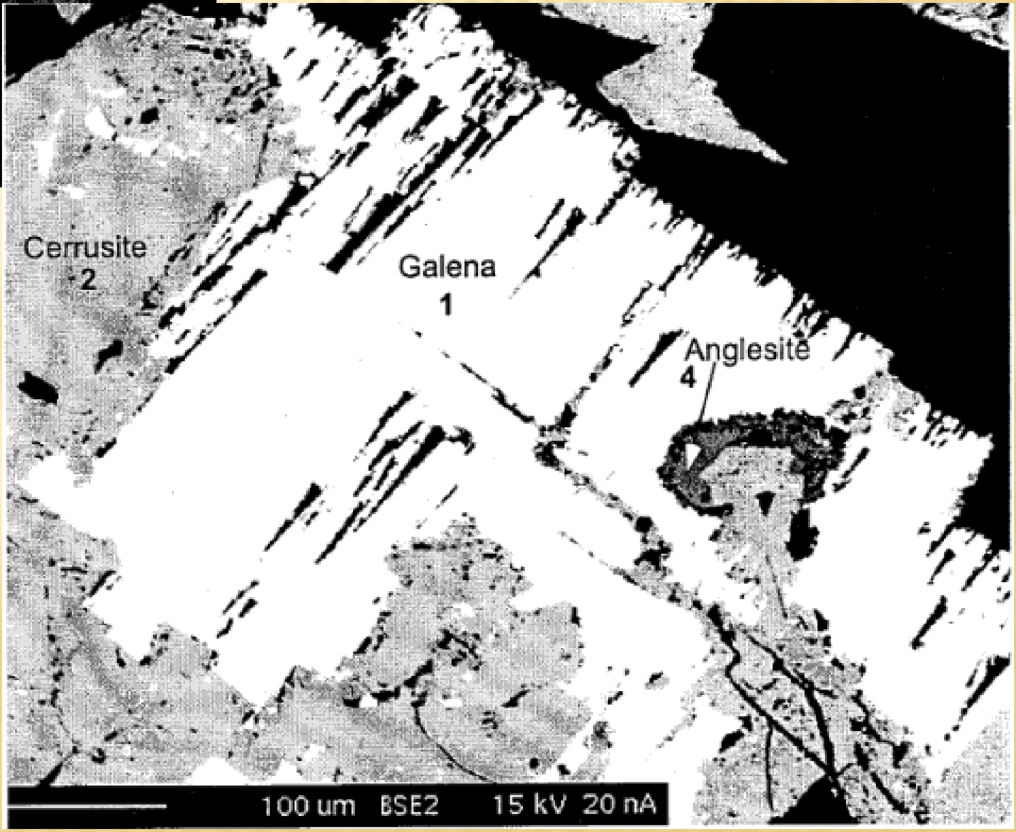
Weathering in rock piles—the fine-grained soil matrix is weathered, while interiors of rock fragments are not. **Some pristine pyrite**.



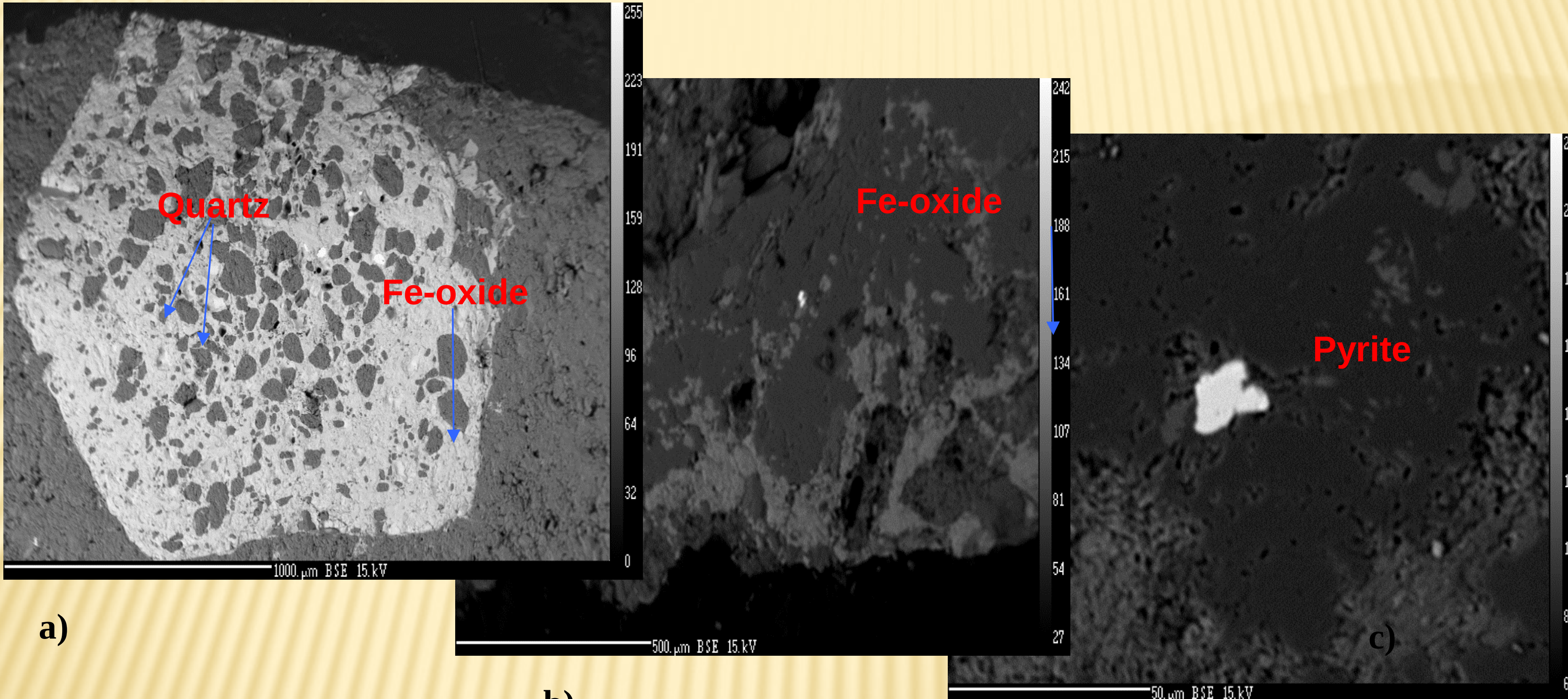


These are typical weathering textures. Note the lack of weathering of the rock fragments.





Other minerals can armor the original crystals and prevent further weathering of sulfides

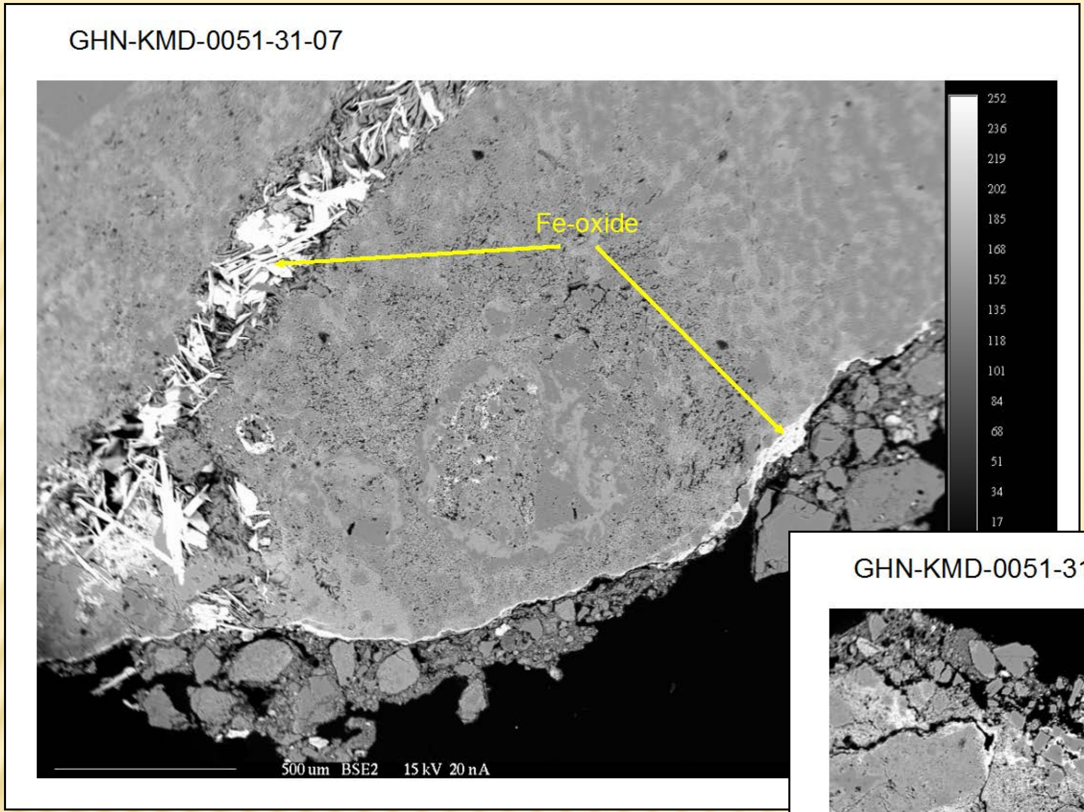


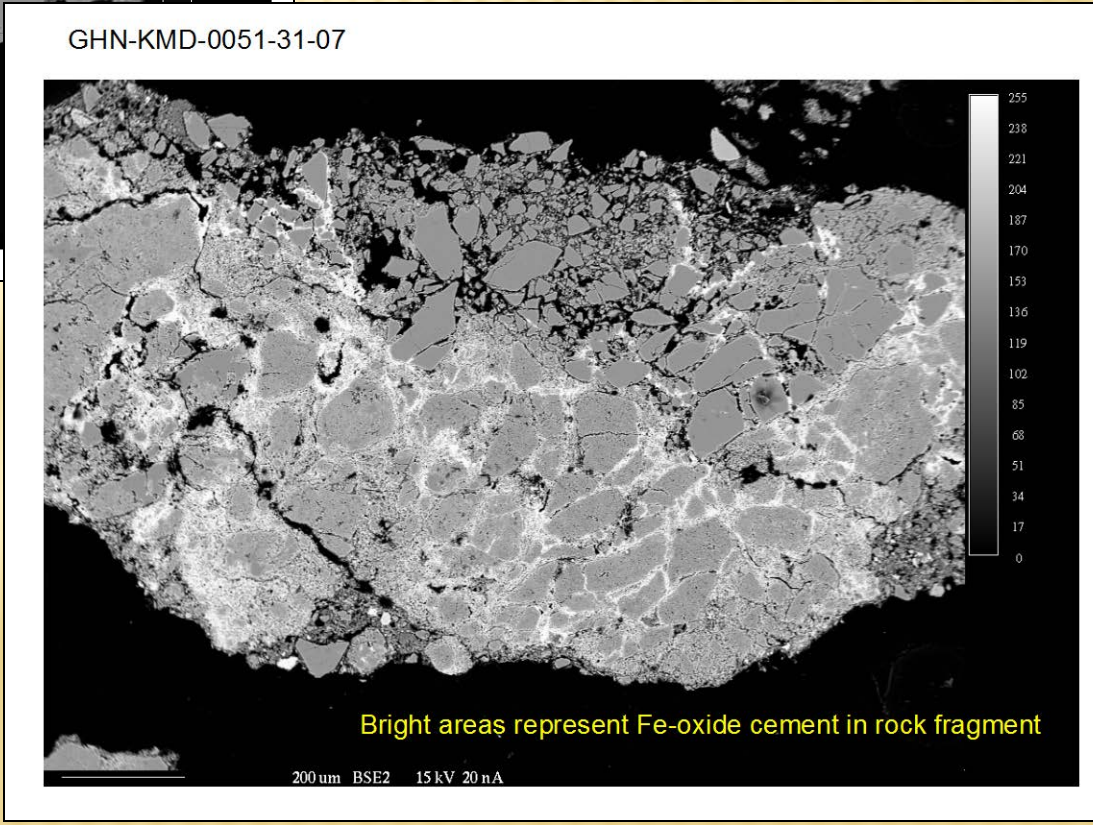
a)

b)

c)

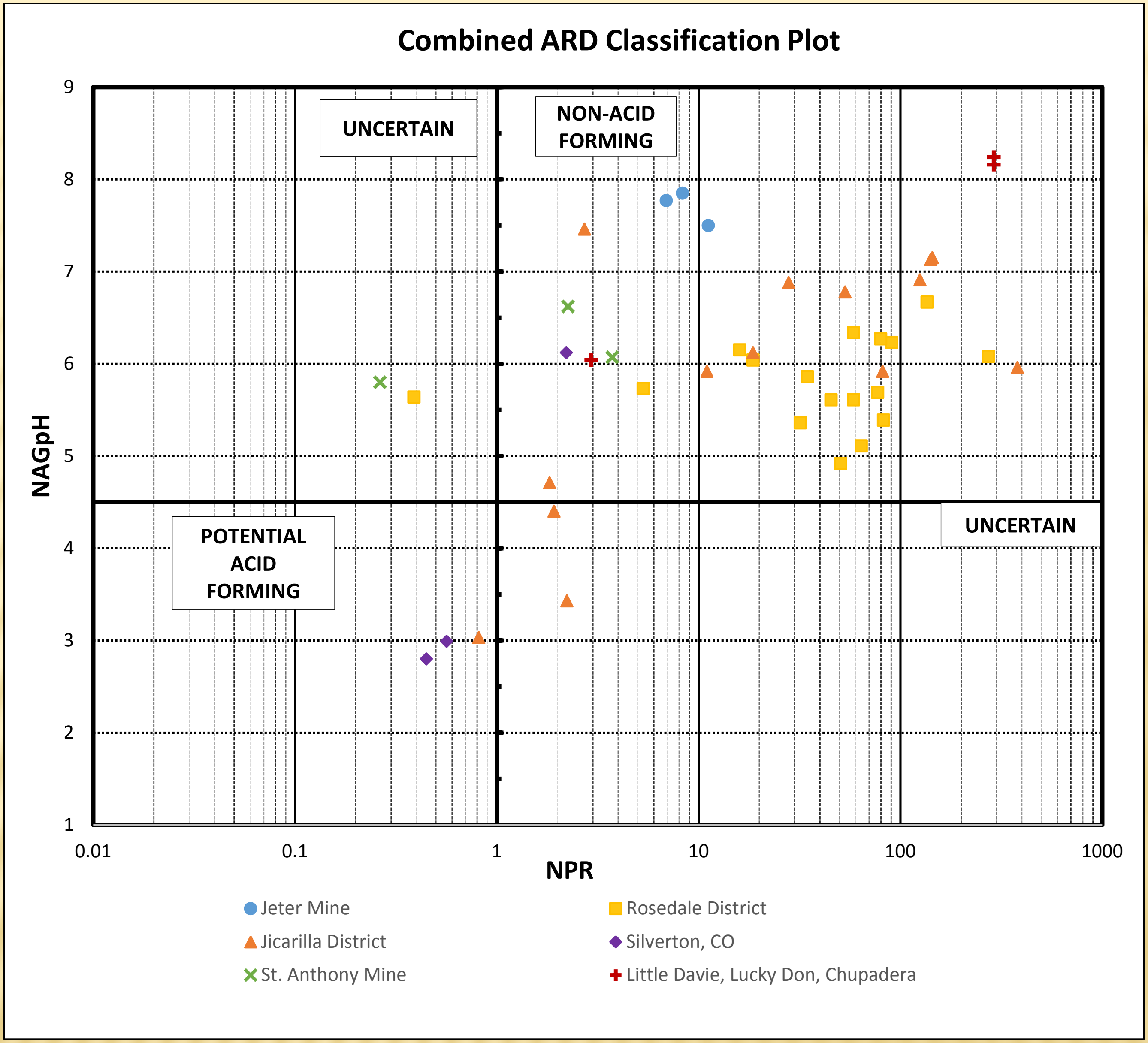
a) Backscattered electron images of quartz grain replacing Fe-oxide in sample Jic410. This is likely supergene replacement.
b) Backscattered electron images of Fe grain in sample Jic412. Note how altered and pitted the grain is.
c) Backscattered electron images of pyrite grain in sample Jic412c. Note how pristine the pyrite grain is.





Fe oxides and gypsum cementing the exterior and interior of rock fragment

ABA TESTS



Acid Rock Drainage (ARD) plot of waste rock pile at mines examined during the NMBGMR AML project. NPR is a calculated ABA parameter

Generally, Acid Potential (AP) depends on the amount of pyrite and other sulfide minerals and Neutralizing Potential (NP) depends upon the amount of calcite and other acid-neutralizing minerals. Samples that have higher concentrations of pyrite are more likely to have a higher acid generation capacity. But, no single component controls the ABA and NAG tests.

PRELIMINARY CONCLUSIONS

- A few sites examined have potential to generate acid drainage and additional sites are physically dangerous and require proper safe guarding
- Most of the waste rock piles surrounding the mine features are suitable for backfill material
- Weathering reactions coats and surrounds the rock fragments and prevents further weathering of the rock fragments, especially pyrite and galena crystals
- Little or no weathering of the rock fragments, which comprise much of the rock pile material
- Samples that have higher concentrations of pyrite are more likely to have a higher acid generation capacity

LESSONS LEARNED

- Sulfide oxidation can be slow in some areas and metal release can be low, but other areas are the opposite—characterization of mine wastes is important
- Examination of mining districts for environmental issues should include chemistry, petrography and full inventory of all mine features
- Results in evaluation of potential environmental issues and mineral-resource potential assessment, including potential resources in the mine wastes

LESSONS LEARNED

- Every site is different and must be specifically characterized
- Need to understand the geologic processes (i.e. weathering) that release metals into the environment
- Then need to understand the pathways of those elements into the ecosystem
  - Must understand the source of the acid generation and metals release

WHAT IS NEXT?

- What are the erosion rates?
- How long do these reactions take?

FOR MORE INFORMATION

- http://geoinfo.nmt.edu/geoscience/hazards/mines/aml/home.html
- http://geoinfo.nmt.edu/staff/mclemore/projects/environment/home.html