

Characterization and comparison of mine wastes from legacy mines in NM

Presentation by: John Asafo-Akowitz

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Overview

Purpose

Study Area

Methodology

Results

Conclusions

Recommendations

Purpose

Determine and compare the mineralogical and geochemical composition of mine wastes in legacy gold (Au) and uranium (U) mines in the study areas

Determine the possible release of trace elements from the waste rock piles into the environment, and their acid/ neutralizing potential

Relevance of Study

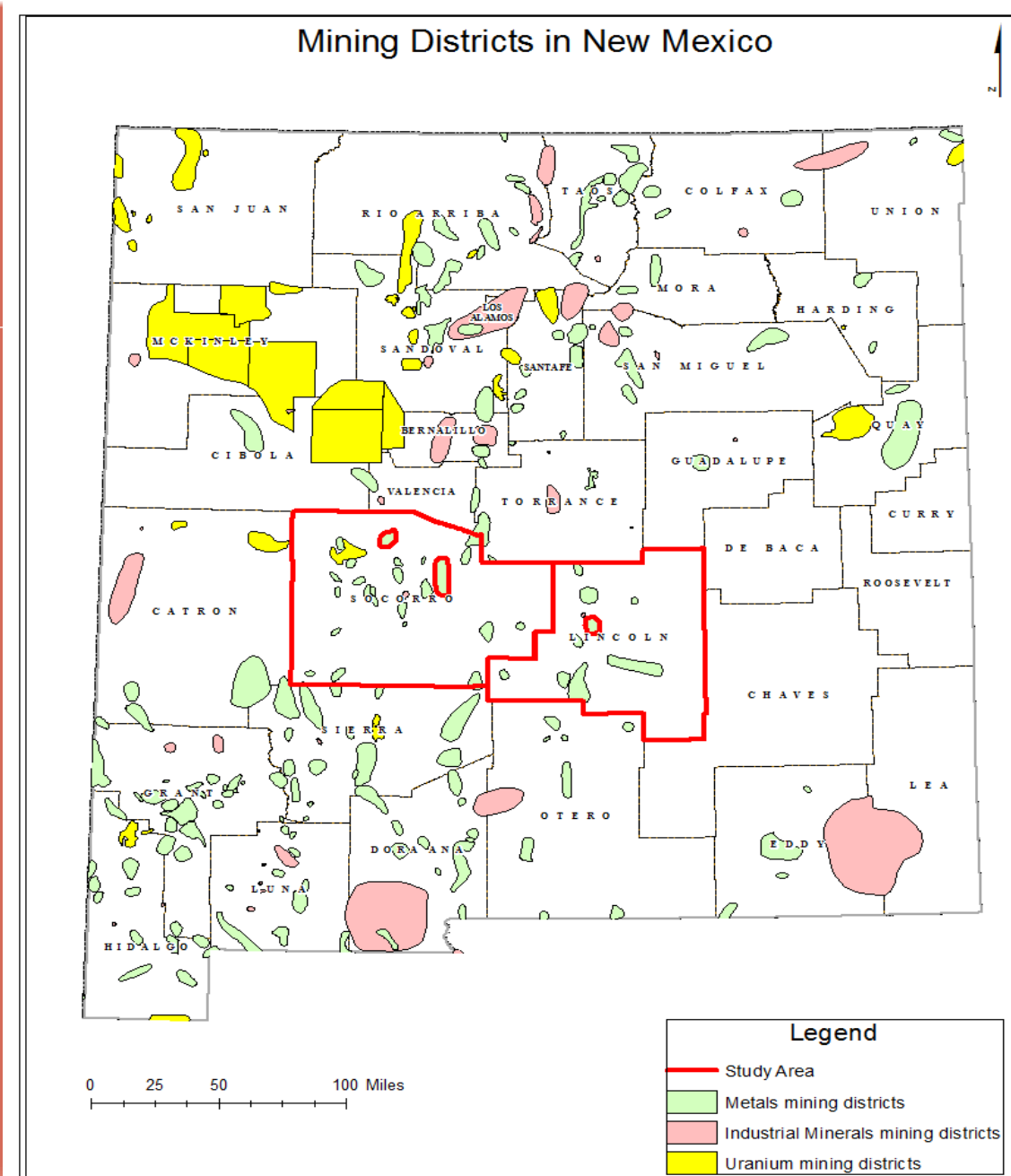
- Understanding the chemistry and distribution of minerals in a waste rock pile is key to characterizing the waste rock pile, predicting the mobility of metals and trace elements into the environment, public health and safety, ecological risk, and risk to ecosystems
- Reclamation efforts have not examined the long-term chemical effects from these mines
- There is still potential for environmental effects long after remediation of the physical hazards, as found in several areas in NM including Jackpile mine, Laguna
- Some of these observations only come from detailed electron microprobe studies

Study Areas

Jicarilla Mountains district

Socorro district

Ladron Mountains district



Study Area

Jicarilla Mountains

Apex Mine Jic410

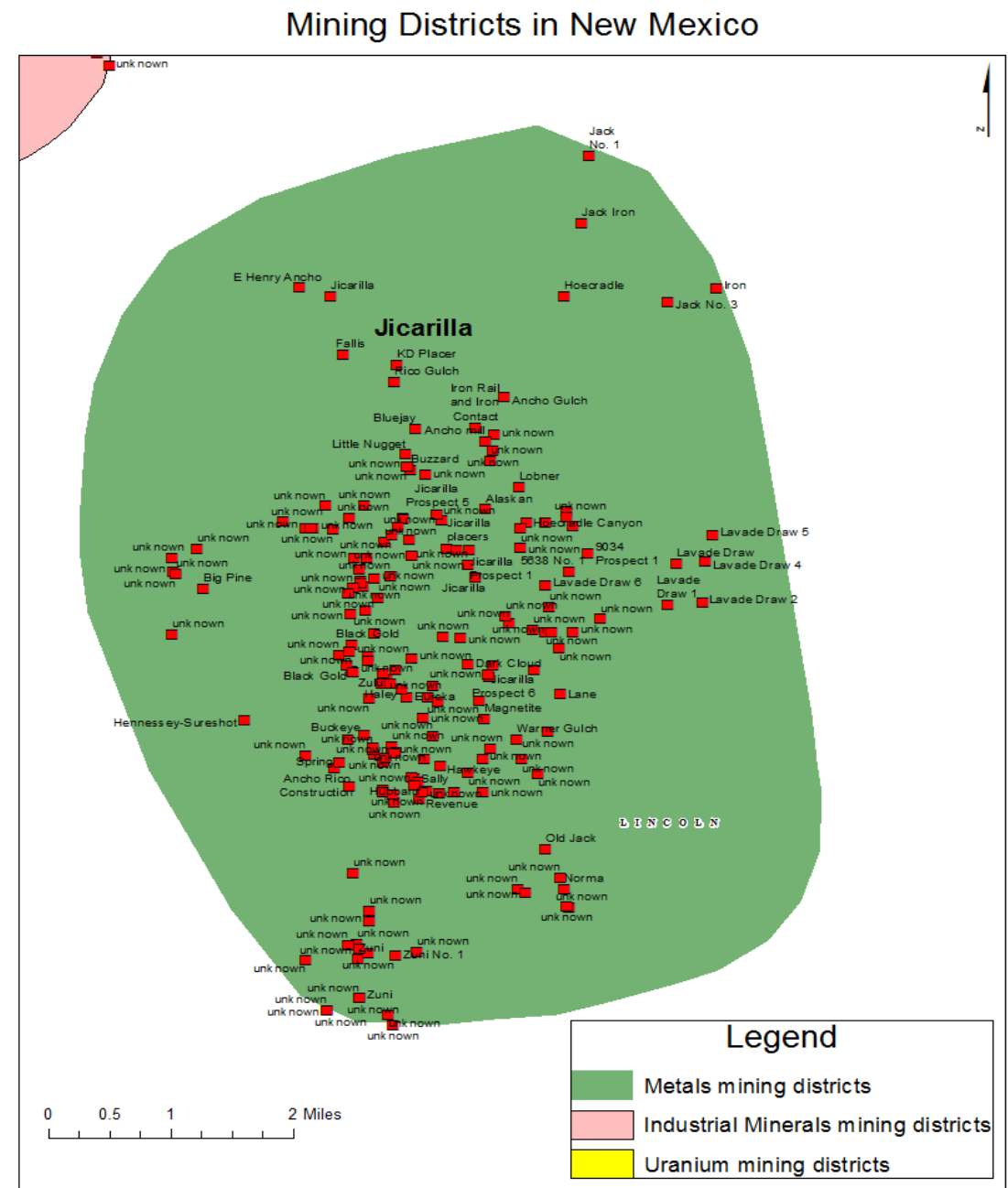
Gold Stain Mine Jic334

Sally Mine Jic413

Approximately 100 miles south-southeast of Albuquerque, NM

About 18 miles north-east of White Oaks, NM

About 155 miles north-northeast of El Paso, Texas



Study Area

Socorro District

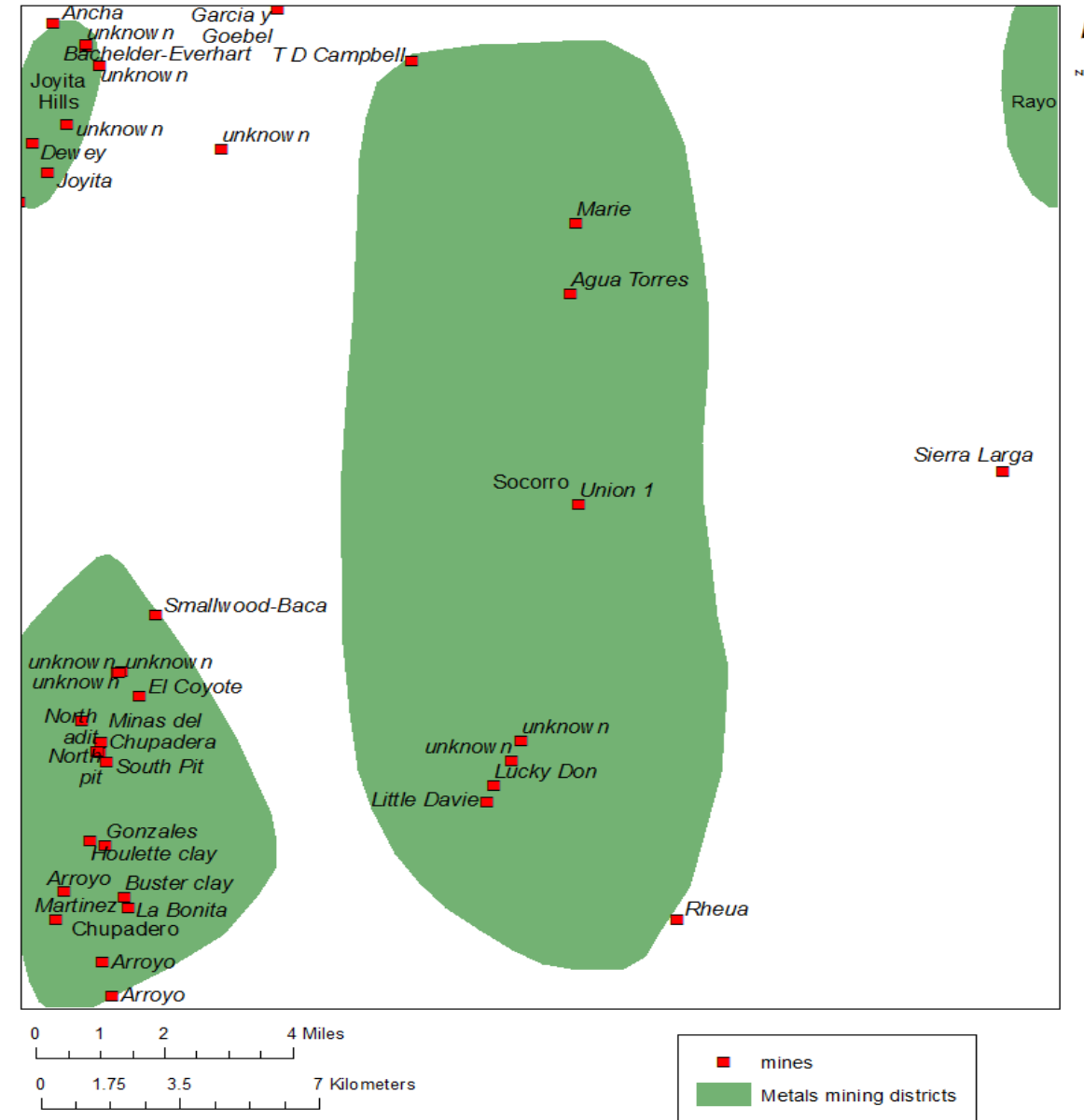
Lucky Don mine

Little Davie mine

Bustos Well 7¹/₂ quadrangle

About 10 miles east of San Antonio, NM

Little Davie is located about ¼ mile south-southwest of Lucky Don



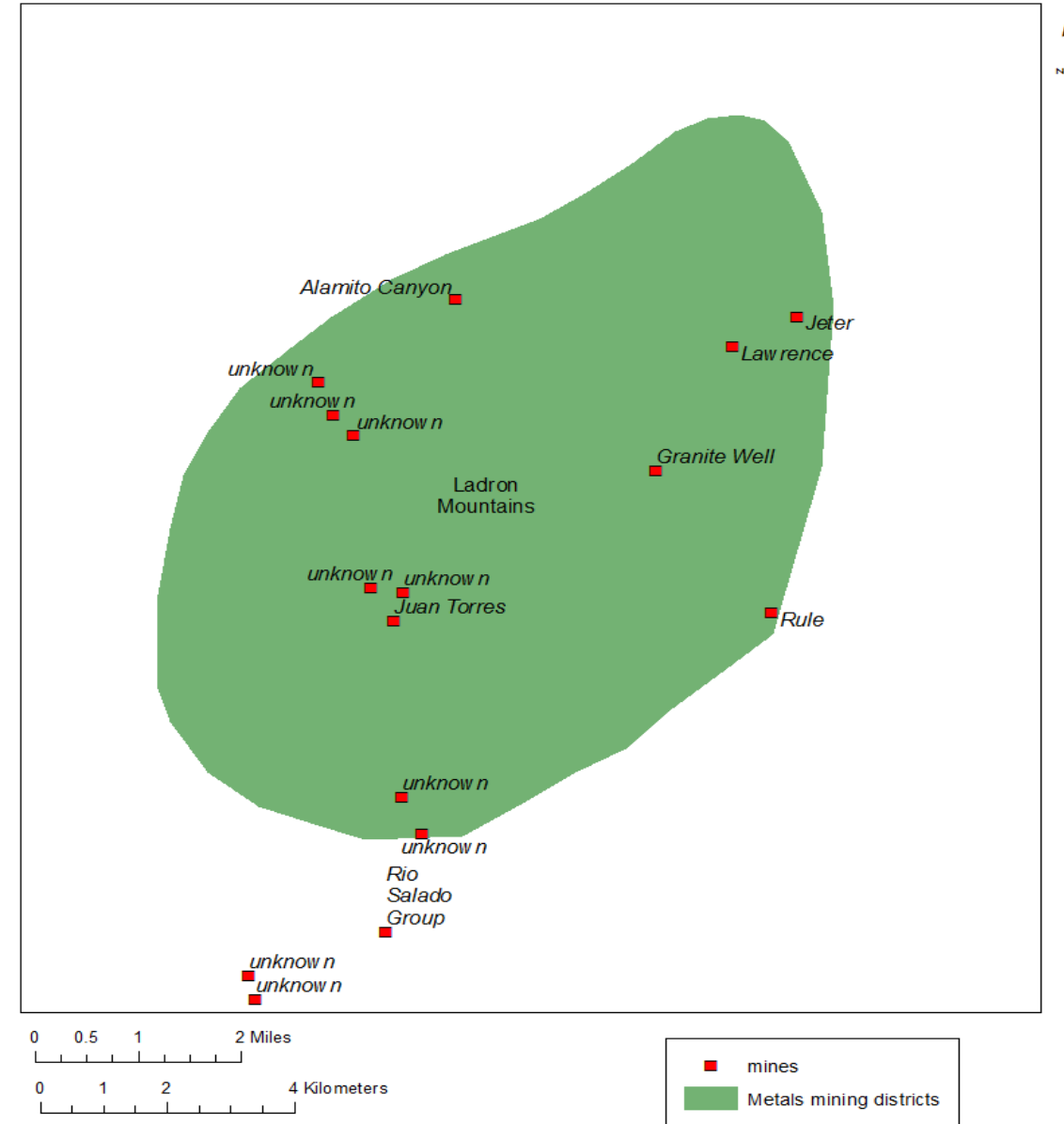
Study Area

Ladron Mountains

Jeter mine

About 27 miles north of Socorro

Lies in section 35, T. 3N, R. 2W



Geology Jicarilla Mountains

Great Plains Margin Gold-Veins (alkaline-type Au veins) hosted by a late-Eocene or early-Oligocene granodiorite

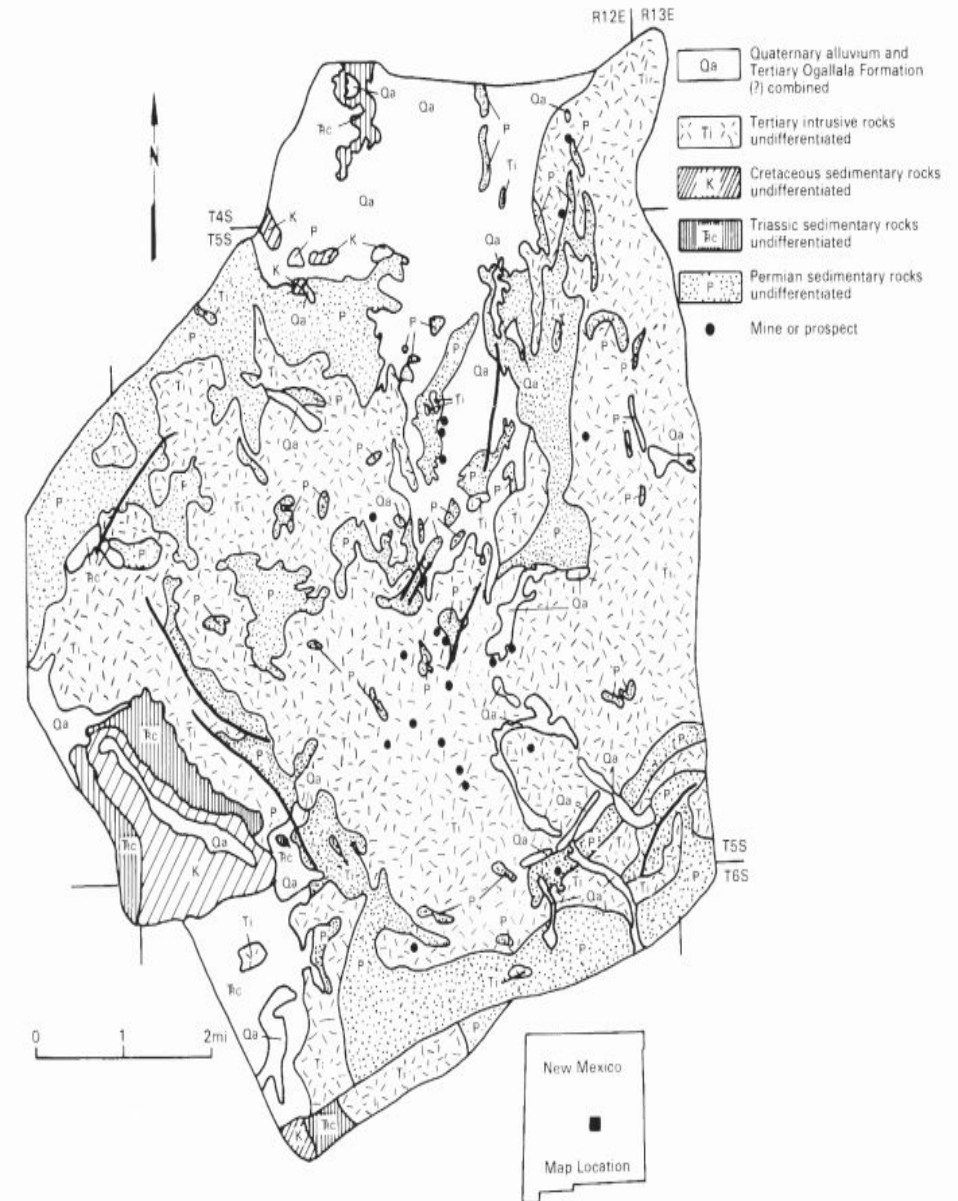
Younger dikes, sills, and laccoliths intruded the granodiorite and the sedimentary rocks

Minor vein deposits of hematite and sulfides, and small disseminations of pyrite have been precipitated from hydrothermal solutions

Placer-gold deposits are of local derivation, found in three separate sedimentary units

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JICARILLA MINING DISTRICT



Source McLemore et al, 1991

Lucky Don & Little Davie mines

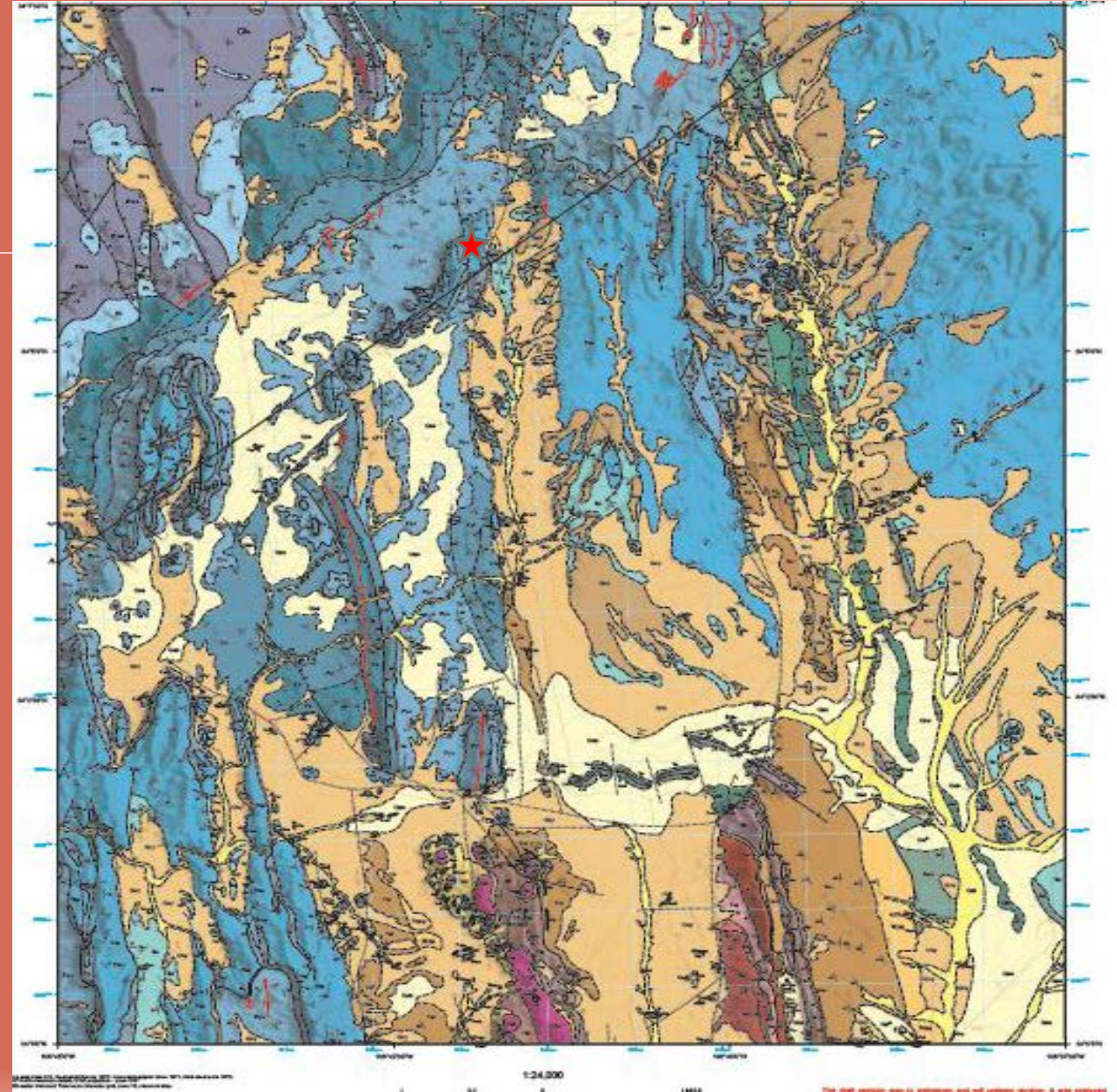
Rio Grande Rift Cu-Ag (U) vein type in Permian San Andres Formation

Mineralization is localized by a northeast-trending fault parallel to major fault, which lies immediately to the west

Total ore produced at both mines amounts to 964.94 tons (U_3O_8 and V_2O_5) worth \$70,000

Lucky Don: 1955-1963

Little Davie: 1955



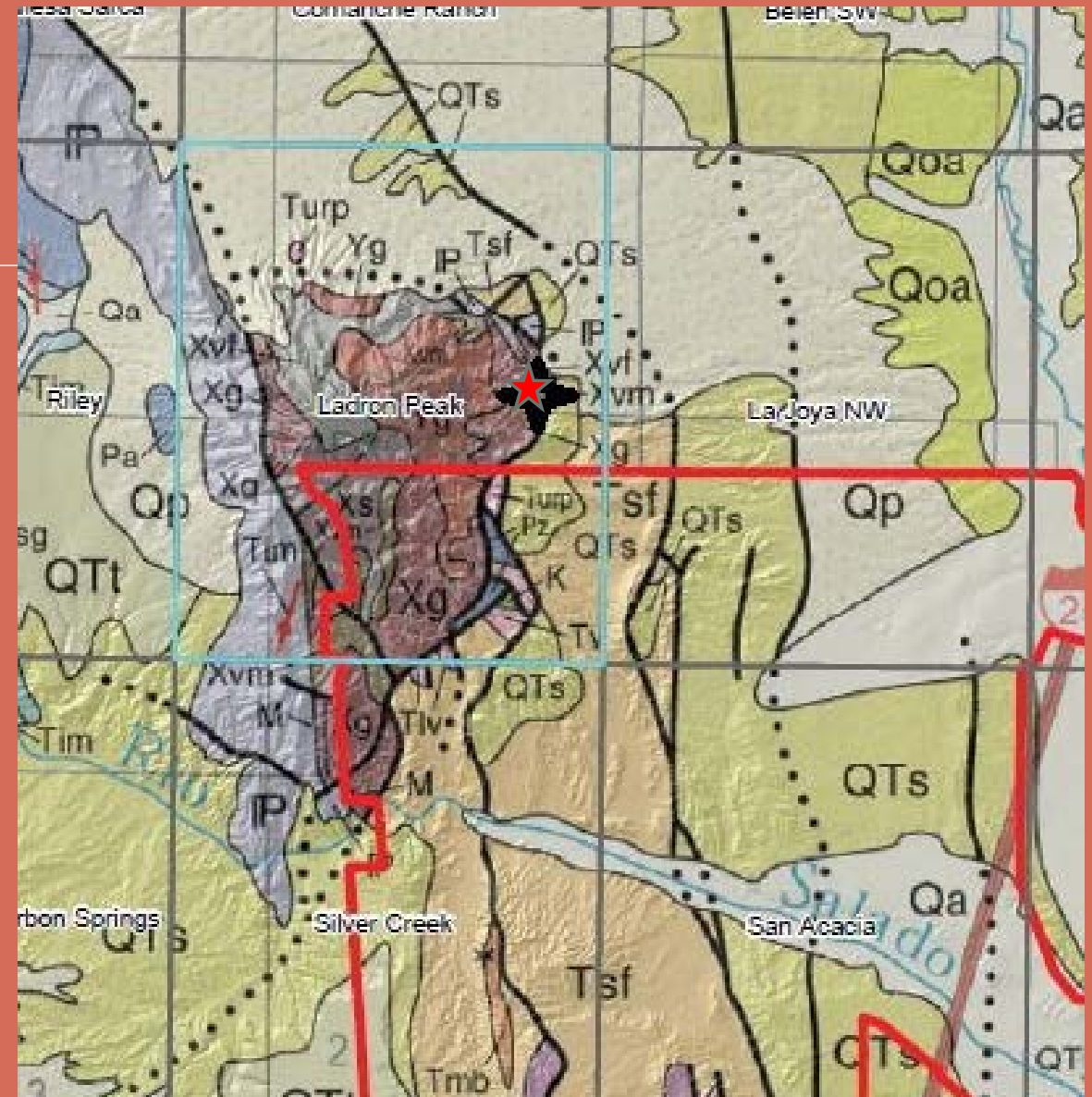
Source Cather et al, 2014

Jeter Mines

Rio Grande Rift Cu-Ag (U) vein type deposit along fault between Proterozoic capirote granite and sediments

Granite has been intruded by a host of fine-grained gray andesitic dikes.

Total ore produced from Jeter mine amounts to 8,826 tons (U_3O_8 and V_2O_5) worth over \$500,000



Source Chamberlin et al, 2007

Methodology

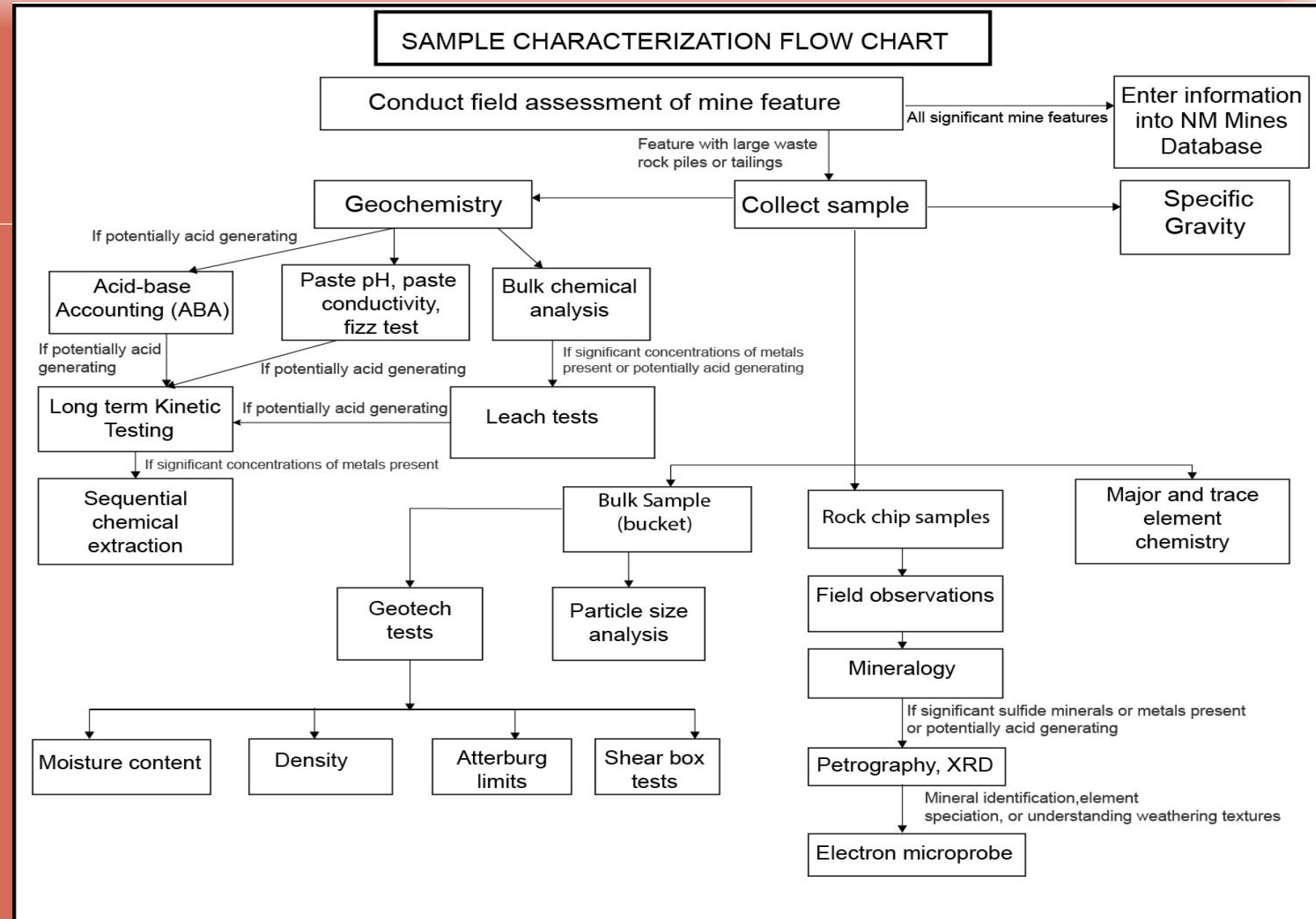
Field Sampling

- Au Mine
 - GPS mapping
 - Waste rock pile sampling
- U Mine
 - GPS/Scintilometer mapping
 - Waste rock pile sampling

Laboratory Analyses

- Paste pH and paste conductivity
- Chemistry – Petrography, total whole rock chemistry, XRD and Electron microprobe

Approach





Loading bin, Lucky Don



Waste pile, Lucky Don



Mine face, Lucky Don

Sampling

Using composite sampling method by Munroe (1999) and USGS

Characterize waste rock piles

Determine the presence of trace elements from the waste rock piles

Determine the suitability of waste rock material to be used as backfill



Field Characteristics of Potential Acid Rock Drainage

ARD forms when sulfide minerals are exposed to oxidizing conditions

Potential ARD waste rock piles in the field will generally have

- pyrite

- jarosite

- low pH

The rate of sulfide oxidation depends on reactive surface area of sulfide, oxygen concentration and solution pH

Test to determine ARD include;

- Acid Base Accounting (ABA) – measures net acid potential

- Net Acid Generation (NAG) – generate a single value

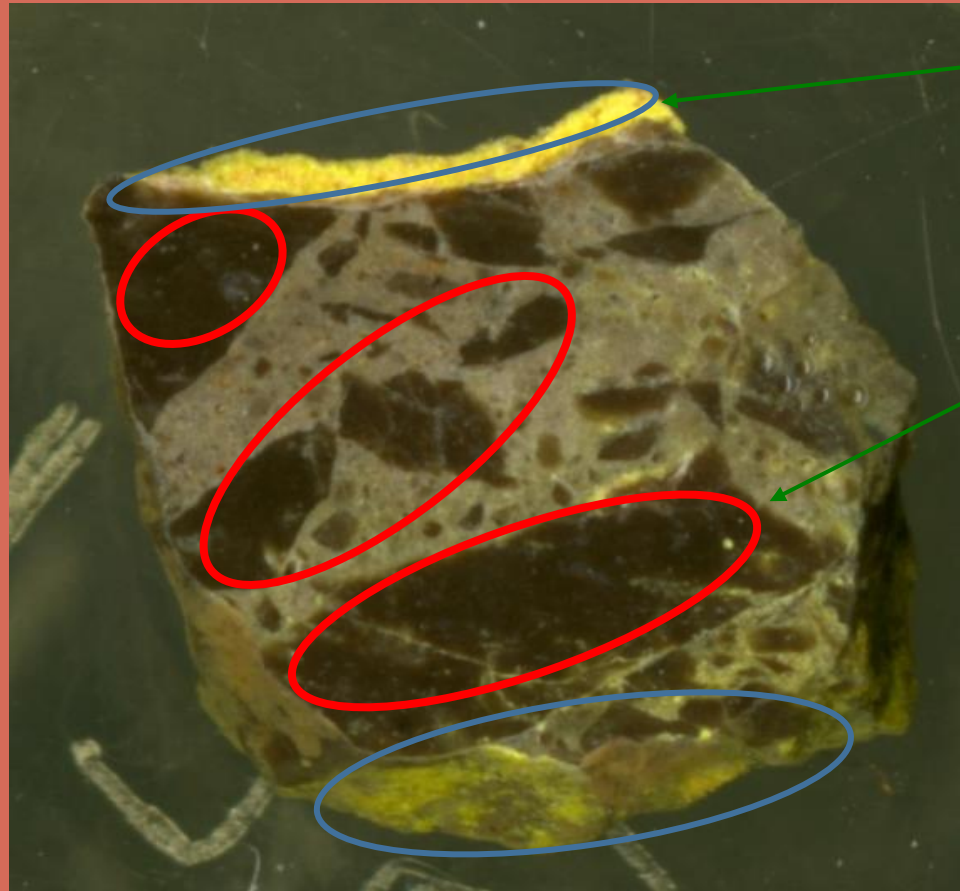
Field Observations - U

Uranium Mine	Mine Feature	Depth of Workings (ft)
Lucky Don	6 stub adits, loading bin, waste/ rock pile, open pit	0–40
Little Davie	Pit, short adit, waste/ rock pile	5–10
Jeter	Concrete platform, 3 waste piles, caved adit, open pit	300

Field Observations - U

Uranium Mine	Background Radiation (cps)	Min Radiation (cps)	Max Radiation (cps)
Lucky Don	20-50	100	4,435
Little Davie	20-50	120	771
Jeter	10-30	80	1,640

Field Observations—U Mineralized Sample



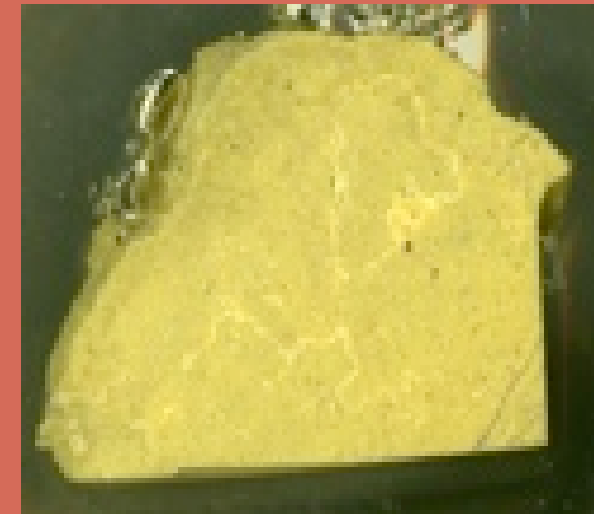
Carnotite

U,V
(uraninite?)

A mineralized sample from Lucky Don mine (4,435 cps)



Samples of waste pile rocks with disseminated carnotite from Lucky Don



A mineralized sample from Little Davie mine (771 cps)

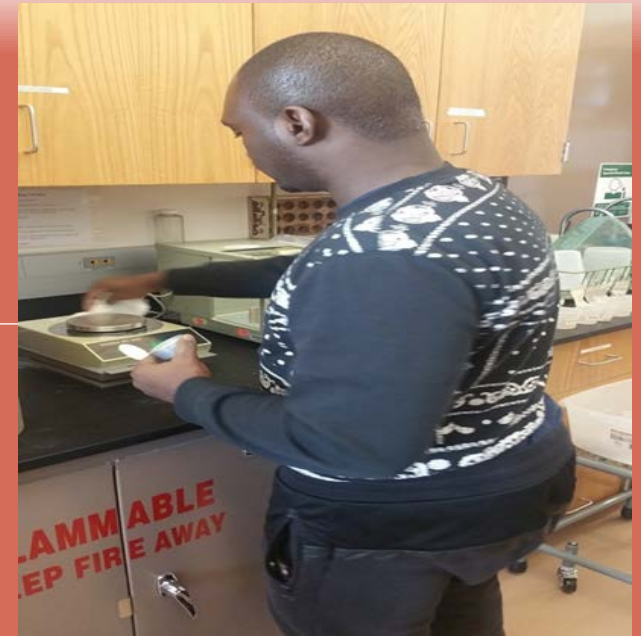
Field Observations – U Mines

Uranium Mine	Ore Minerals	Field evidence of potential acid drainage
Lucky Don	tyuyamunite, carnotite, uraninite, Cu minerals, uranophane	No
Little Davie	tyuyamunite, carnotite, uraninite, Cu minerals, uranophane	No
Jeter	carnotite, tyuyamunite, alunite, pitchblende, malachite, Fe-Mn oxides, clay, azuritite, barite, calcite	No

Laboratory Analyses

Paste pH

Used to determine geochemical behavior of waste rock
The paste conductivity values were converted to total dissolve solids (TDS)



Weighing samples for paste pH

XRD Technique

Conducted on to determine the mineralogy.
Samples were grinded into a well homogenized material
A five minute absolute scan analysis was run

Whole Rock Chemistry

Analytical methods include whole rock by fusion, ICP-MS, Leco and ICP-AES

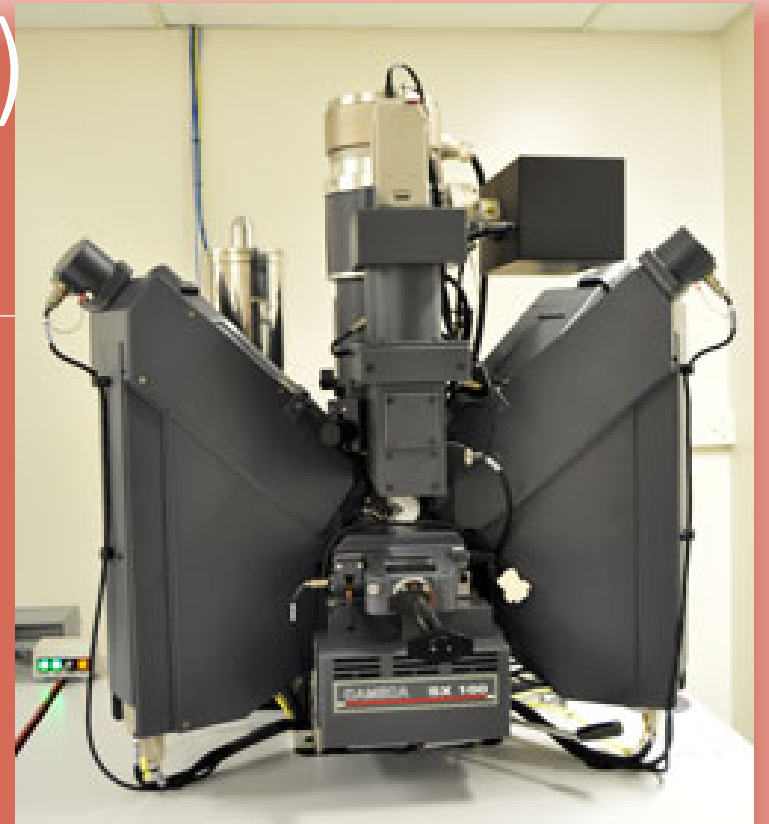
Laboratory Analyses (continued)

Electron Microprobe Analyses

Qualitative and quantitative analyses

Heavy minerals were first viewed in backscatter electron image (BSE)

Quantitative and qualitative analyses were used to determine textures and chemical composition of the minerals



Cameca SX681

NURE Data & EPA Screening Level 2016

National Uranium Resource Evaluation (NURE) Data – 1980.

Mineral	Range in common soil (ppm)	Range in Ladron sediments (ppm)	Anomaly Threshold (ppm)
U	0.6-4.8	1.93-6.62	4.5
V	15-250	34-358	225
Cu	10-100	11-163	45
Au	0.004-0.005	All<0.4-0.1	0.03

Source: Chamberlin, 1982

EPA – Regional Screening Level (RSL) Summary table, 2016

Mineral	Resident soil (mg/kg)	Industrial (mg/kg)
U	230	3,500
V	460	380,000,000
Cu	3,100	47,000
As	0.68	3

Paste pH and chemistry – Au Mines

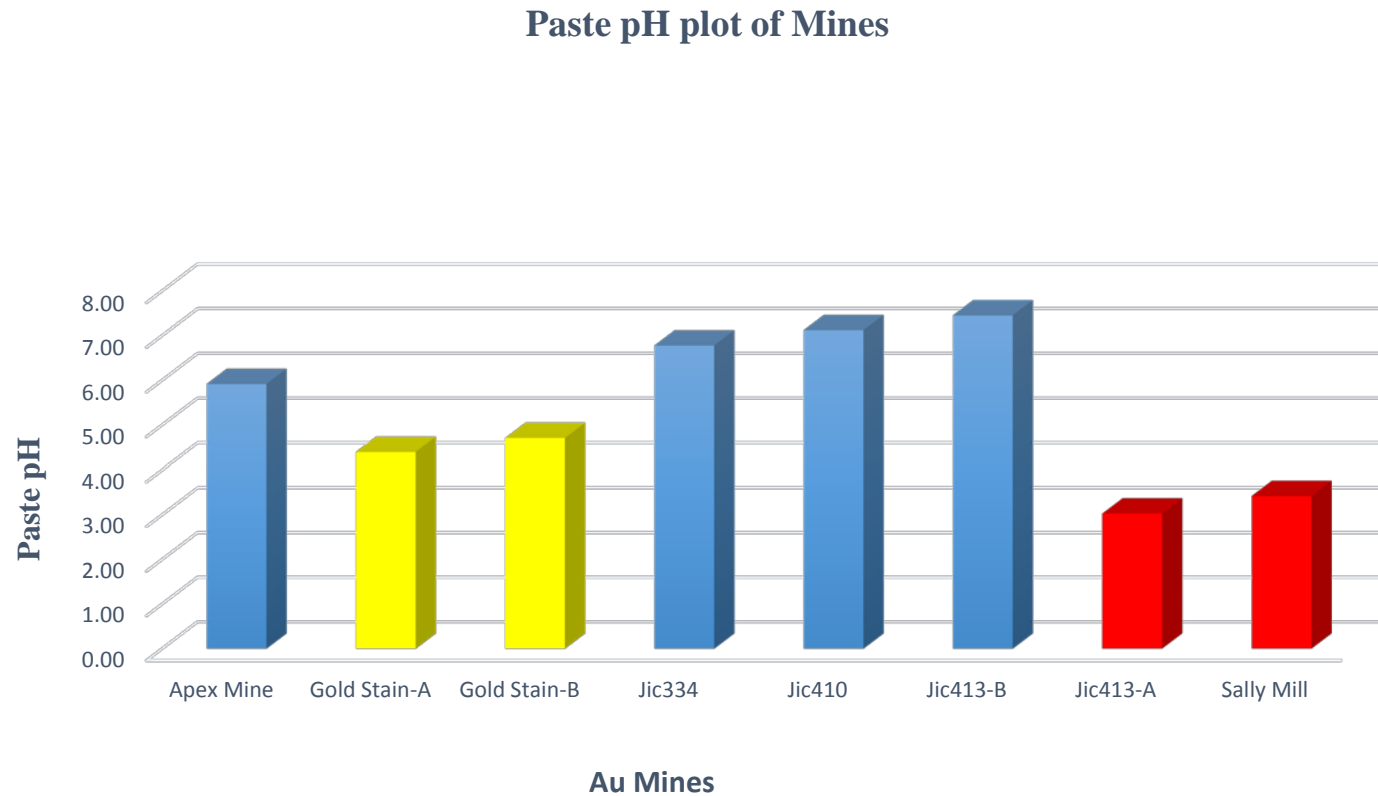
EPA – Regional Screening Level
(RSL) Summary table, 2016

 Represent pH 4-3
 Represent pH 5-4

 Au >1ppm

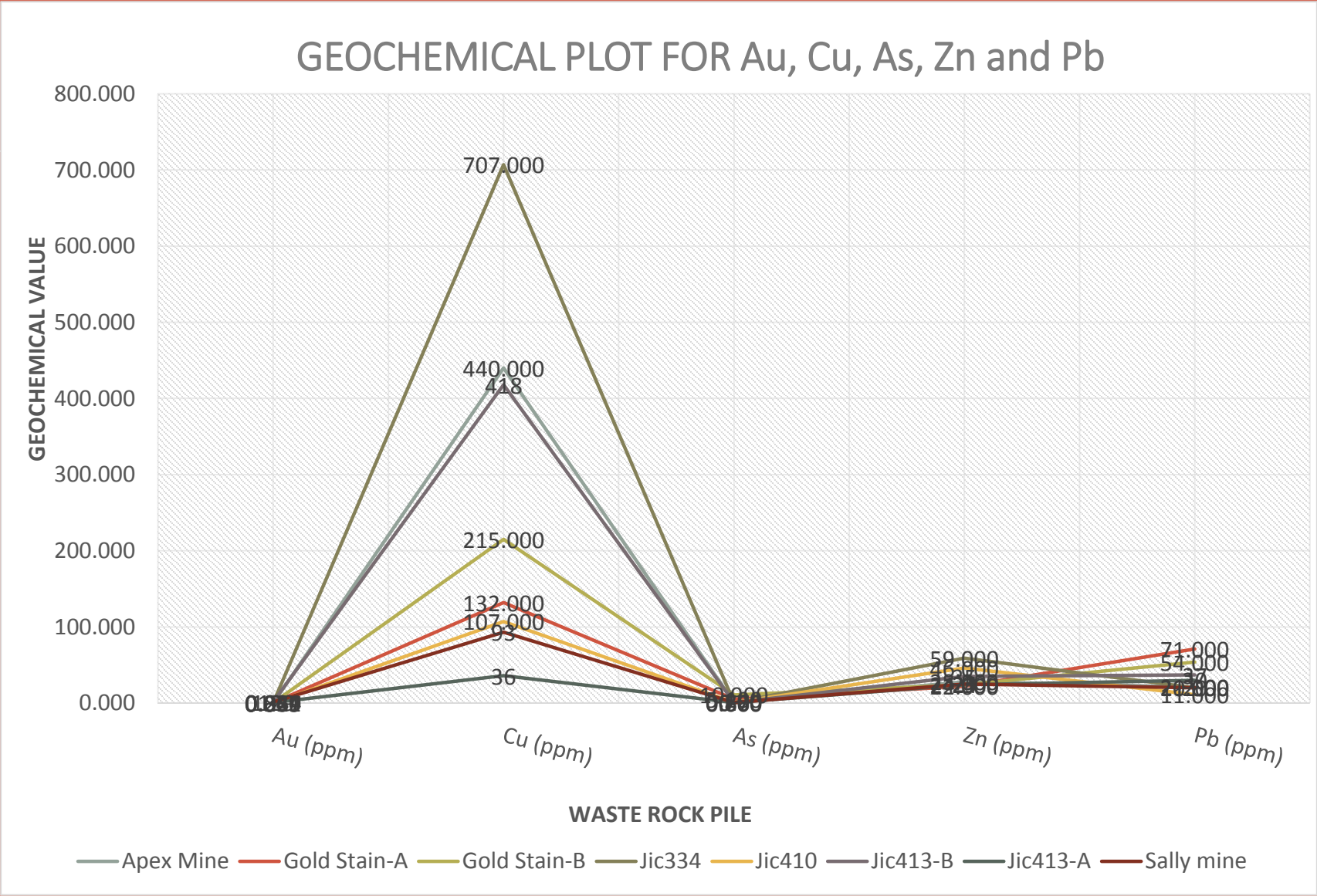
Mineral	Resident soil (mg/kg)	Industrial (mg/kg)	Waste Rock Pile	Paste pH	Total Dissolve Solids (ppm)	Au (ppm)	As (ppm)
U	230	3500	Apex mine	5.92	119	0.030	0.8
			Gold Stain mine-A	4.40	81	0.341	5.1
			Gold Stain mine-B	4.71	55	0.229	10.9
V	460	380,000,000	Jic410	7.13	79	0.067	0.7
Cu	3,100	47,000	Jic413-A	3.03	152	0.820	0.6
			Jic413-B	7.46	209	1.290	0.7
			Jic334	6.78	253	0.049	0.7
As	0.68	3	Sally mine	3.43	156	1.400	0.8

Paste pH graph – Au mines



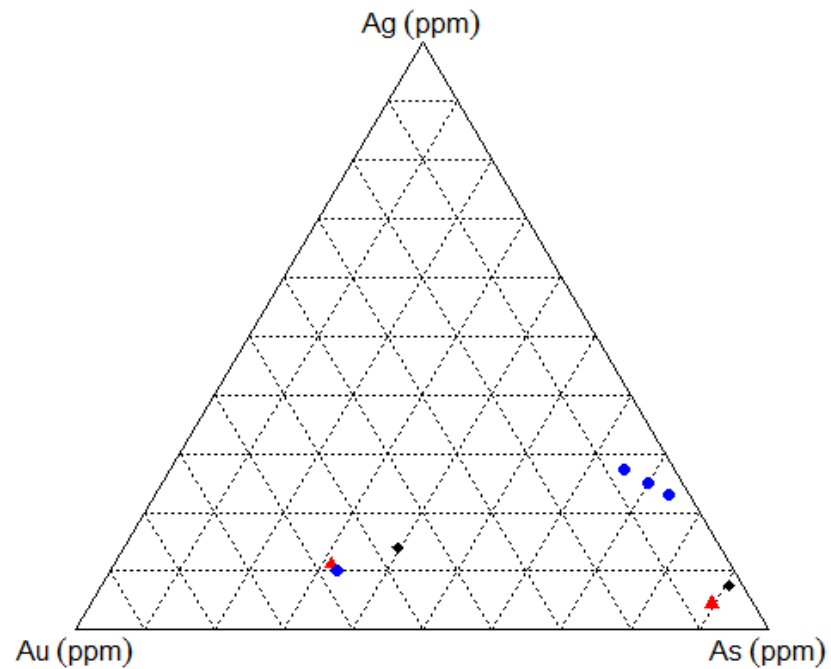
Geochemical value plot for Au, Cu, As, Zn & Pb – Au mines

EPA – Regional Screening Level (RSL) Summary table, 2016		
Mineral	Resident soil (mg/kg)	Industrial (mg/kg)
U	230	3500
V	460	380,000,000
Cu	3,100	47,000
As	0.68	3
Zn	23,000	350,000
Pb	400	800



Ternary plot for Au, Ag & As– Au mines

Number of
samples (n) = 8



Paste pH, and chemistry Analyses – U mines

EPA – Regional Screening Level (RSL) Summary table, 2016

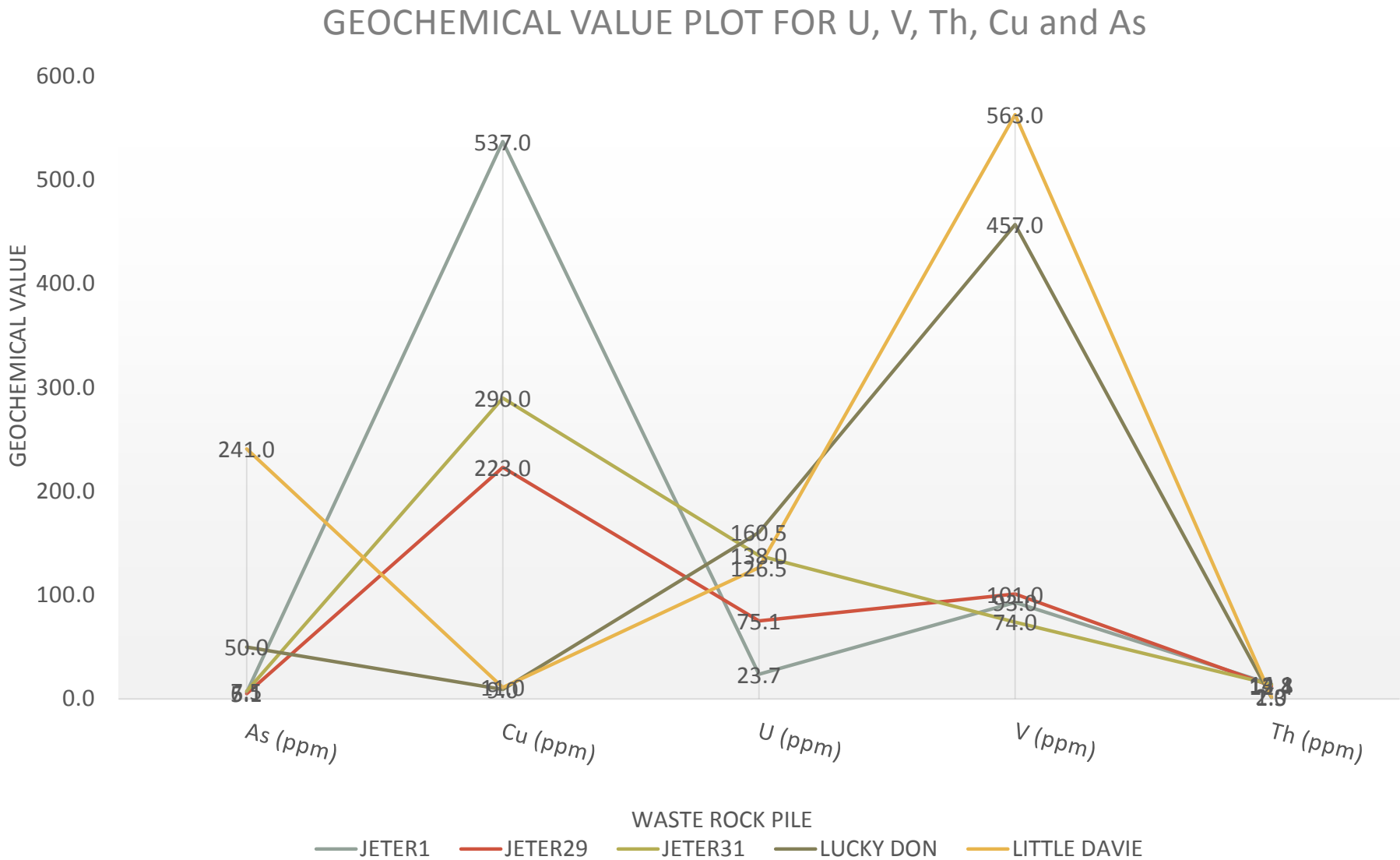
Mineral	Resident soil (mg/kg)	Industrial (mg/kg)
U	230	3500
V	460	380,000,000
Cu	3,100	47,000
As	0.68	3

Waste Rock Pile	Paste pH	Total Dissolve Solids (ppm)	U (ppm)	V (ppm)	Th (ppm)	As (ppm)
Jeter1	7.77	1	23.7	93	14.1	6.1
Jeter29	7.85	1	75.1	101	12.4	5.1
Jeter31	7.50	428	138	74	13.8	7.5
Little Davie	8.24	98	160.5	457	1.32	50
Lucky Don	8.16	92	126.5	563	1.96	241

Geochemical value plot for U, Th & V– U mines

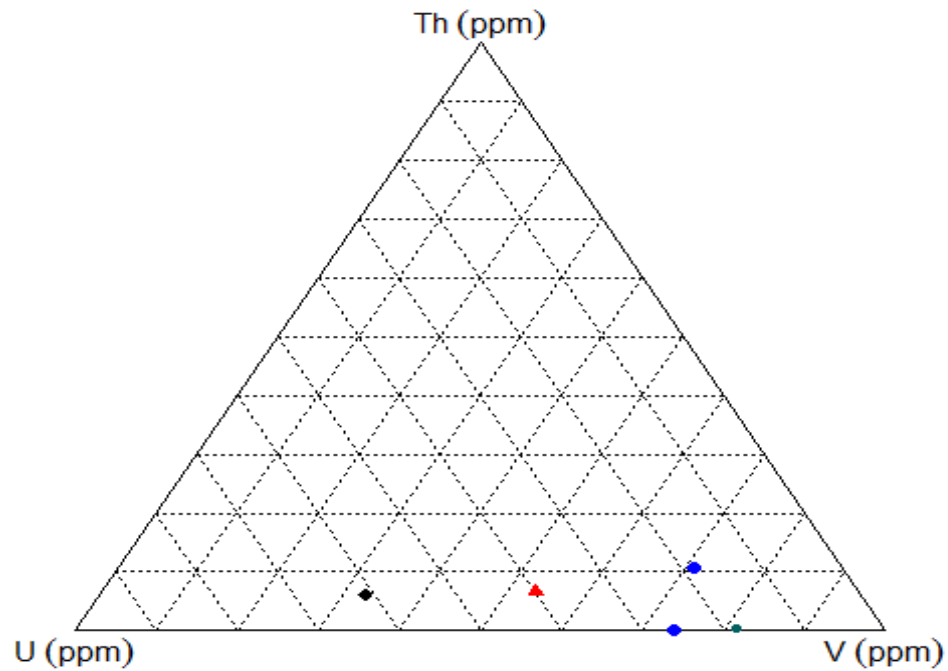
EPA – Regional Screening Level (RSL) Summary table, 2016

Mineral	Resident soil (mg/kg)	Industrial (mg/kg)
U	230	3500
V	460	380,000,000
Cu	3,100	47,000
As	0.68	3

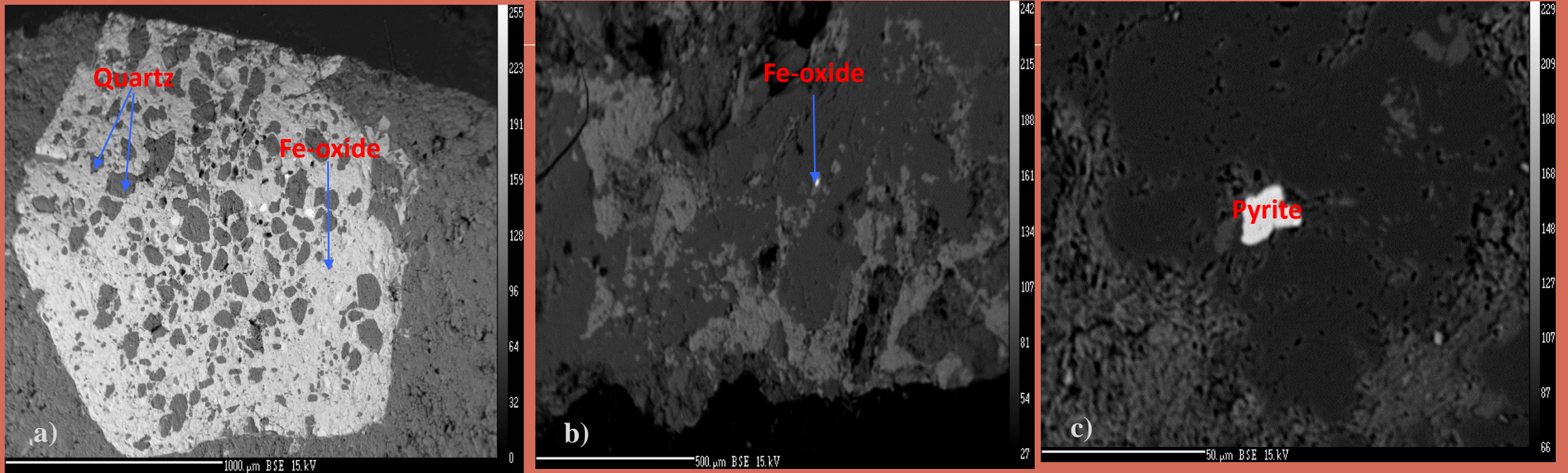


Ternary plot for U, Th & V– U mines

Number of
samples (n) = 5



Microprobe Analysis (BSE) images of Au Samples

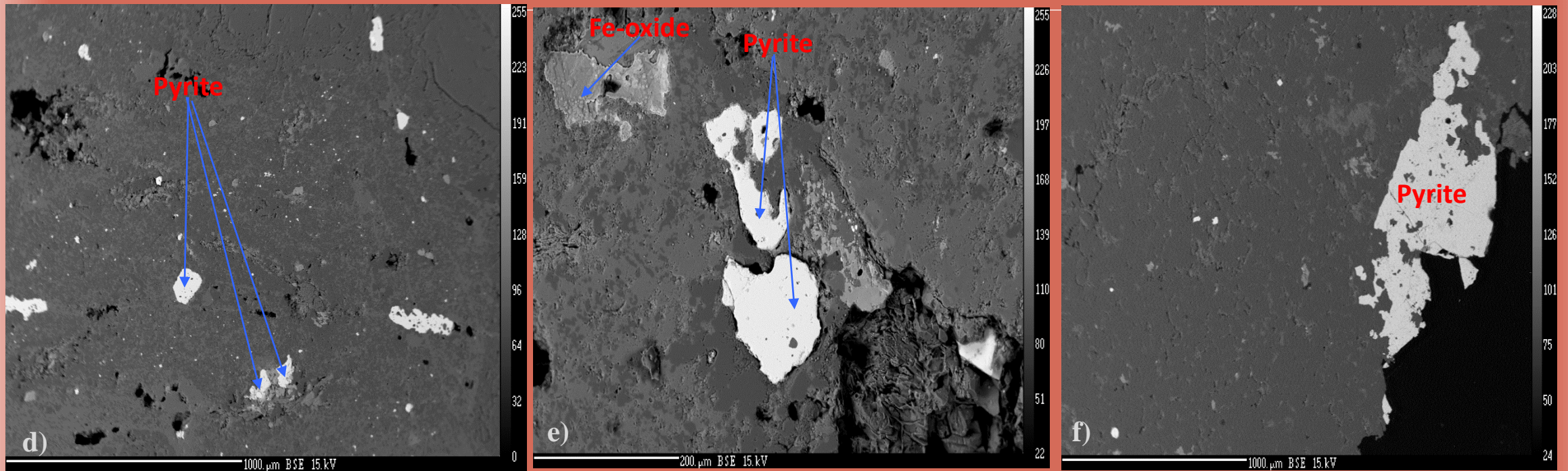


Figures a) Backscattered electron images of quartz grain replacing Fe-oxide in sample Jic410. This is likely supergene replacement.

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 Jic412 c. Note how pristine the pyrite grain is.

Microprobe Analysis (BSE) images of Au Samples



Figures d, e & f) Backscattered electron images of pyrite and Fe-oxide grains distribution in sample Jic802. Note how pristine the pyrite is in Figure d, but pitted in Figures e and f.

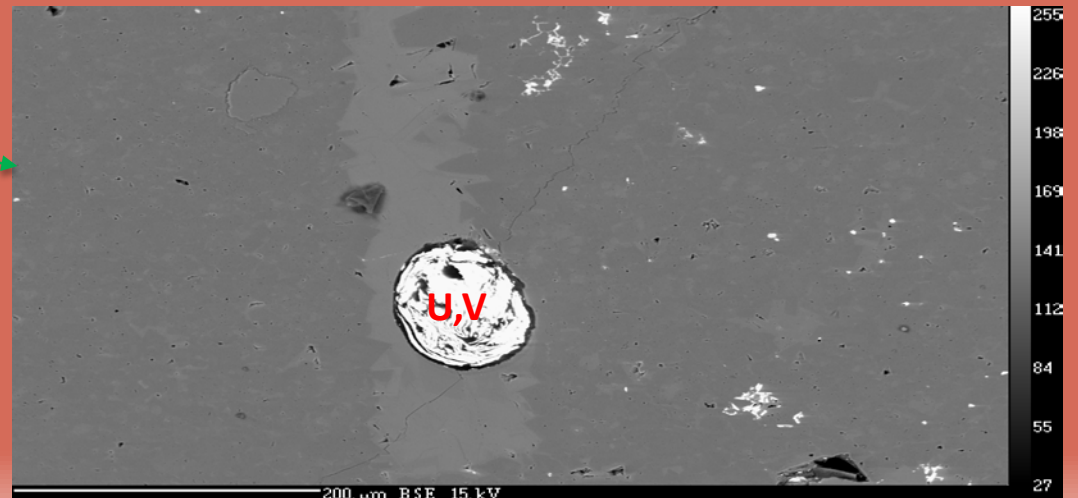
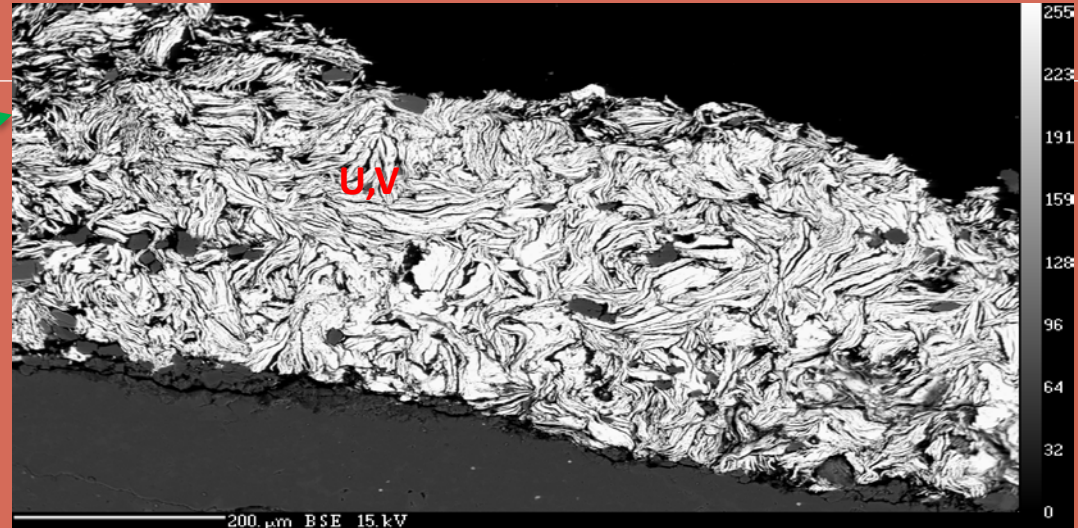
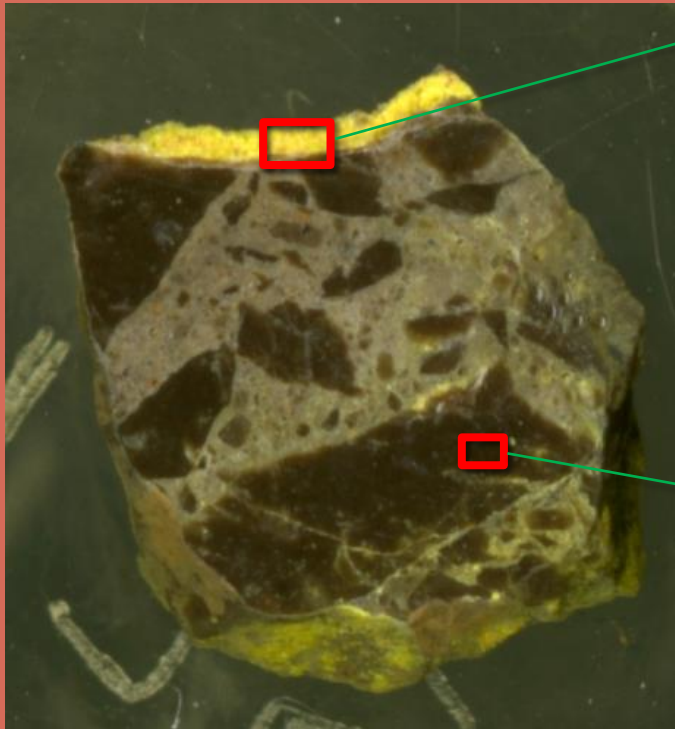
Microprobe Analysis Quantitative Analyses - Au

Quantitative scan for
pyrite

High S and Fe
percentages

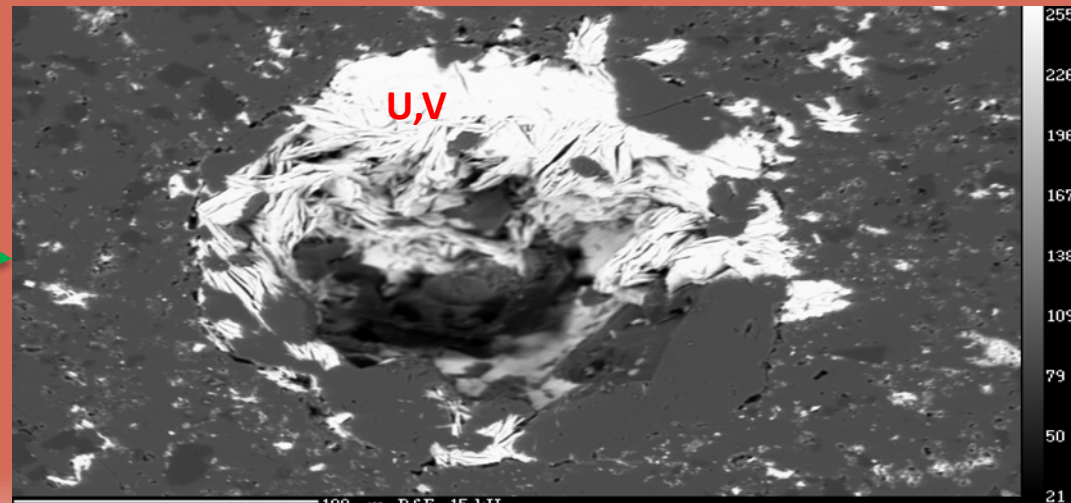
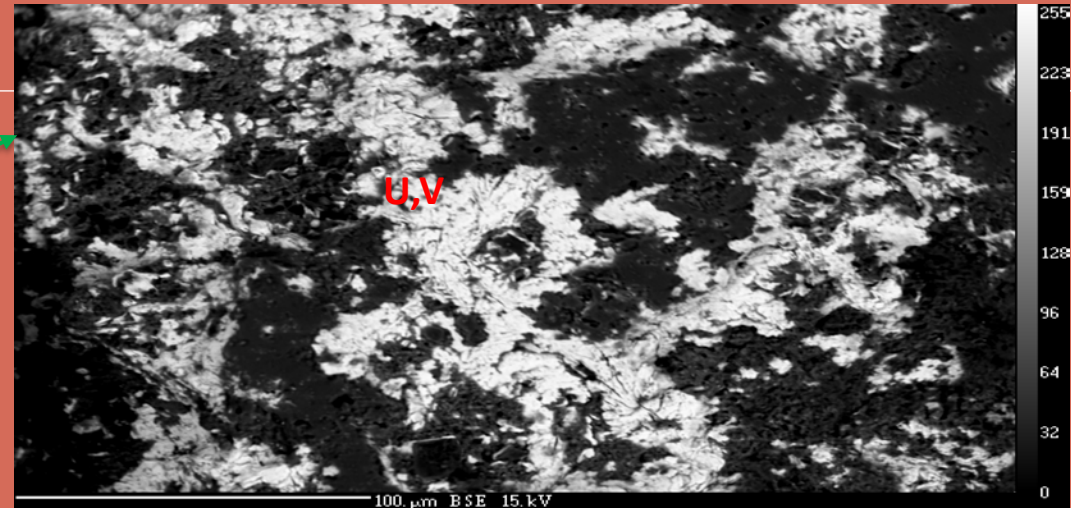
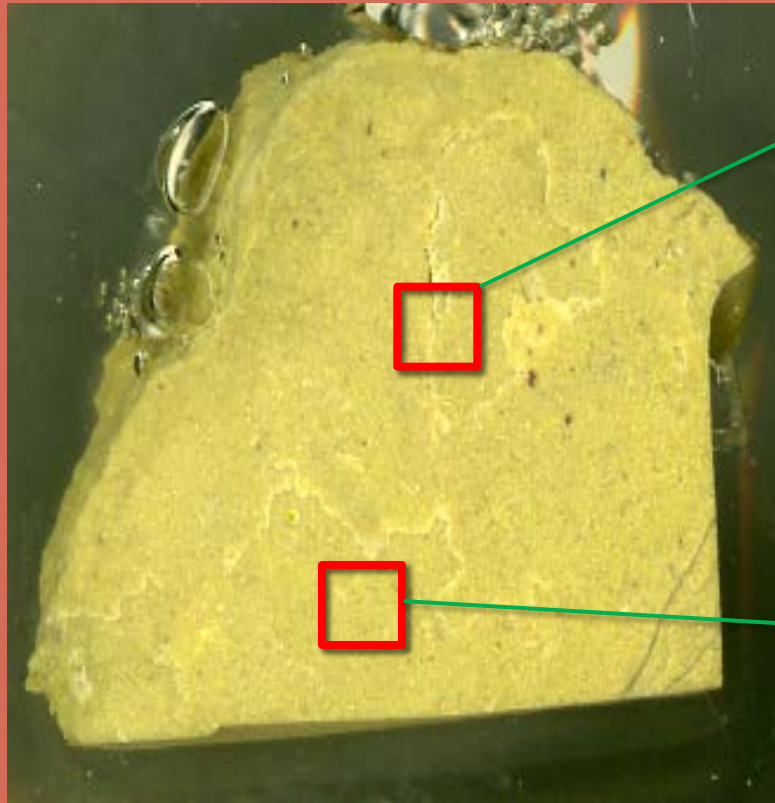
Sample Number	S(%)	Fe(%)	Cu(%)	As (%)
Gold Stain-A-01	53.07	47.36	0.08	0.03
Gold Stain-A-02	33.63	31.11	32.90	0.02
Gold Stain-A-03	54.67	45.84	0.03	0.02
Gold Stain-B-01	52.56	47.50	0.01	0.02
Gold Stain-B-02	52.52	47.59	0.01	0.02
Gold Stain-B-03	52.68	47.09	0.02	0.03
Jic413A-01	53.69	47.39	0	0.02
Jic413A-02	53.02	47.47	0	0.03

Microprobe Analysis (BSE) images of U Samples



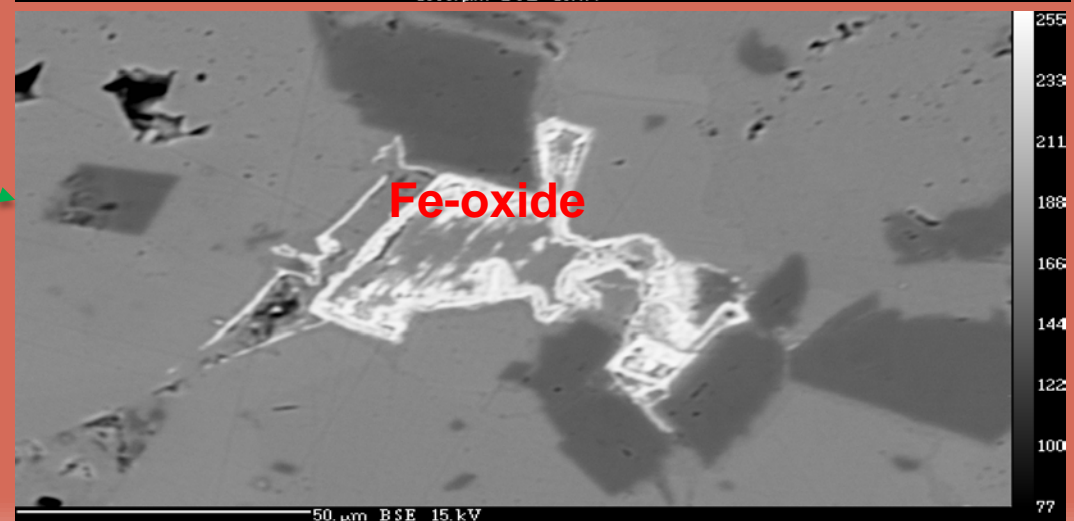
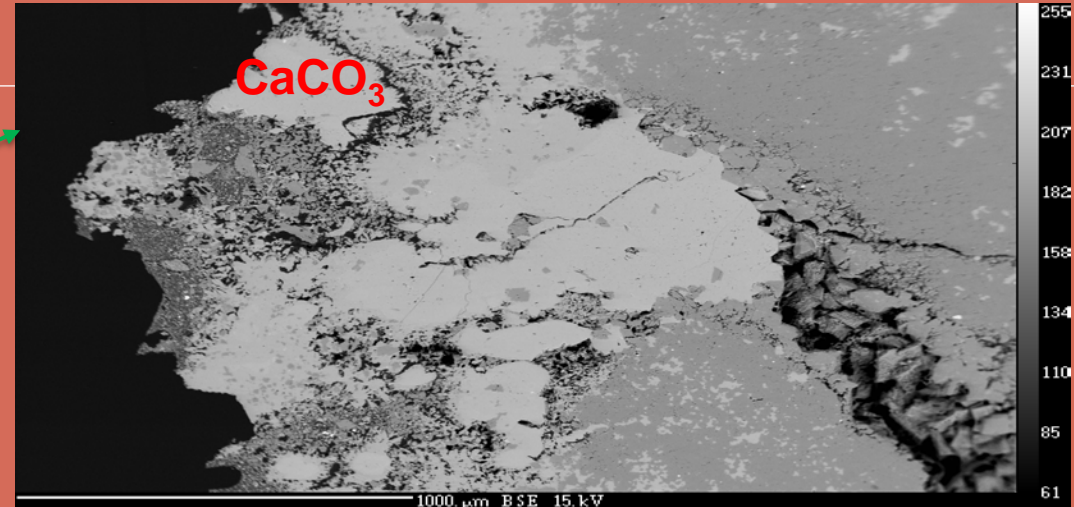
Pristine uranium and vanadium minerals

Microprobe Analysis (BSE) images of U Samples



Dissolved uranium and vanadium minerals

Microprobe Analysis (BSE) images of U Samples



BSE images of CaCO₃ and Fe-Oxide grains

Net Neutralization Potential (NNP) - U

AP (Kg CaCO₃/tonne) = 31.25 x S (%), NP (total C) = C (%) x 83.3, NNP = NP – AP, NPR = NP/AP Assuming all C in sample are CaCO₃

Waste Rock Pile	S (%)	C (%)	AP (Kg CaCO ₃ /tonne)	NP (total C)	NNP	NPR
Jeter1	0.05	0.13	1.5575	10.829	9.2715	6.95
Jeter29	0.24	0.75	7.476	62.475	54.999	8.36
Jeter31	0.05	0.21	1.5575	17.493	15.9355	11.23
Little Davie	0.03	10.45	0.9345	870.485	869.5505	931.50
Lucky Don	0.05	5.45	1.5575	453.985	452.4275	291.48

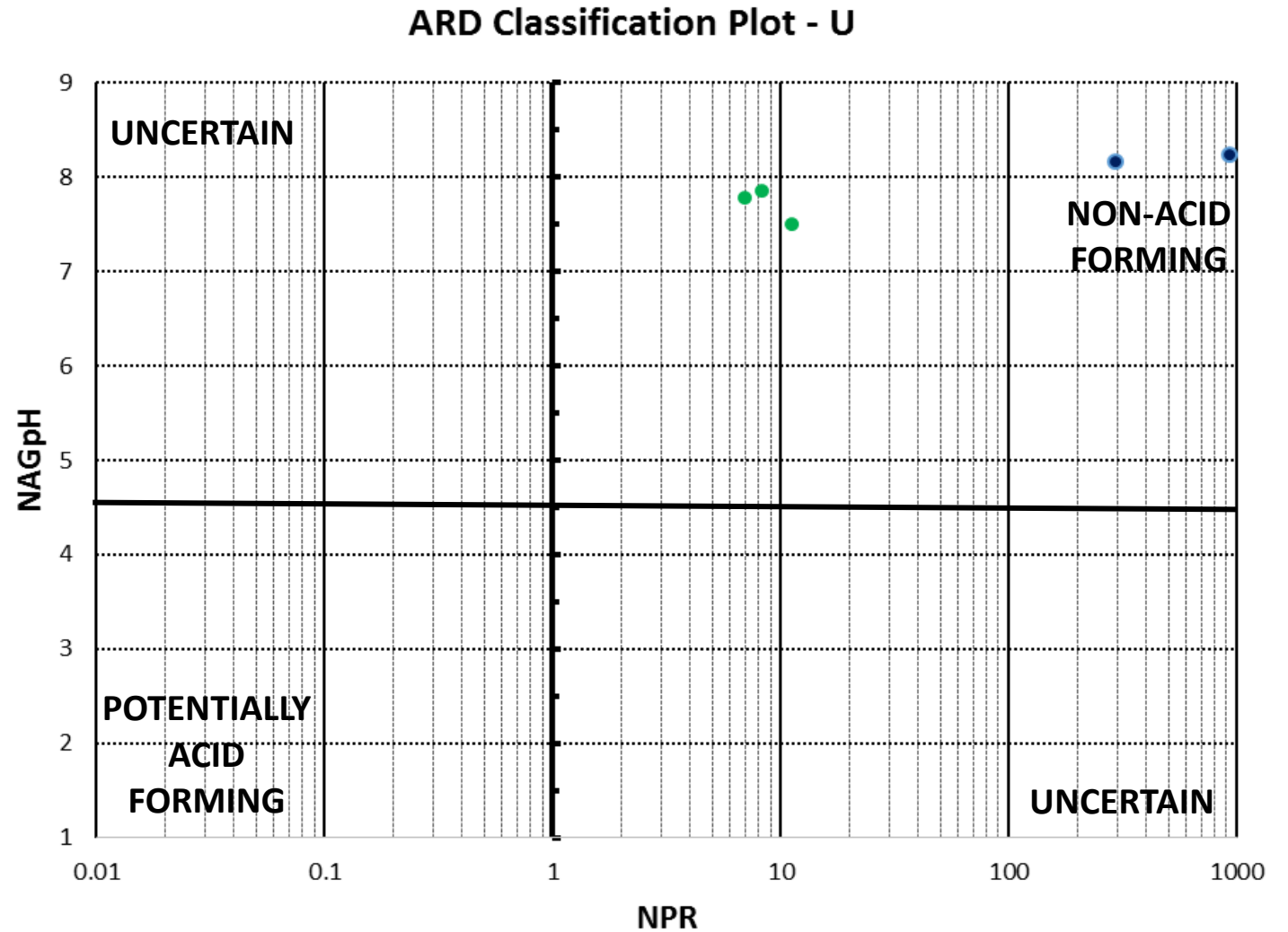
Acid Rock Drainage (ARD) U waste rock pile Classification Plot

Assumption: pH = pH after reaction
(NAG pH)

Lucky Don & Little Davie

• samples

• Jeter mine samples



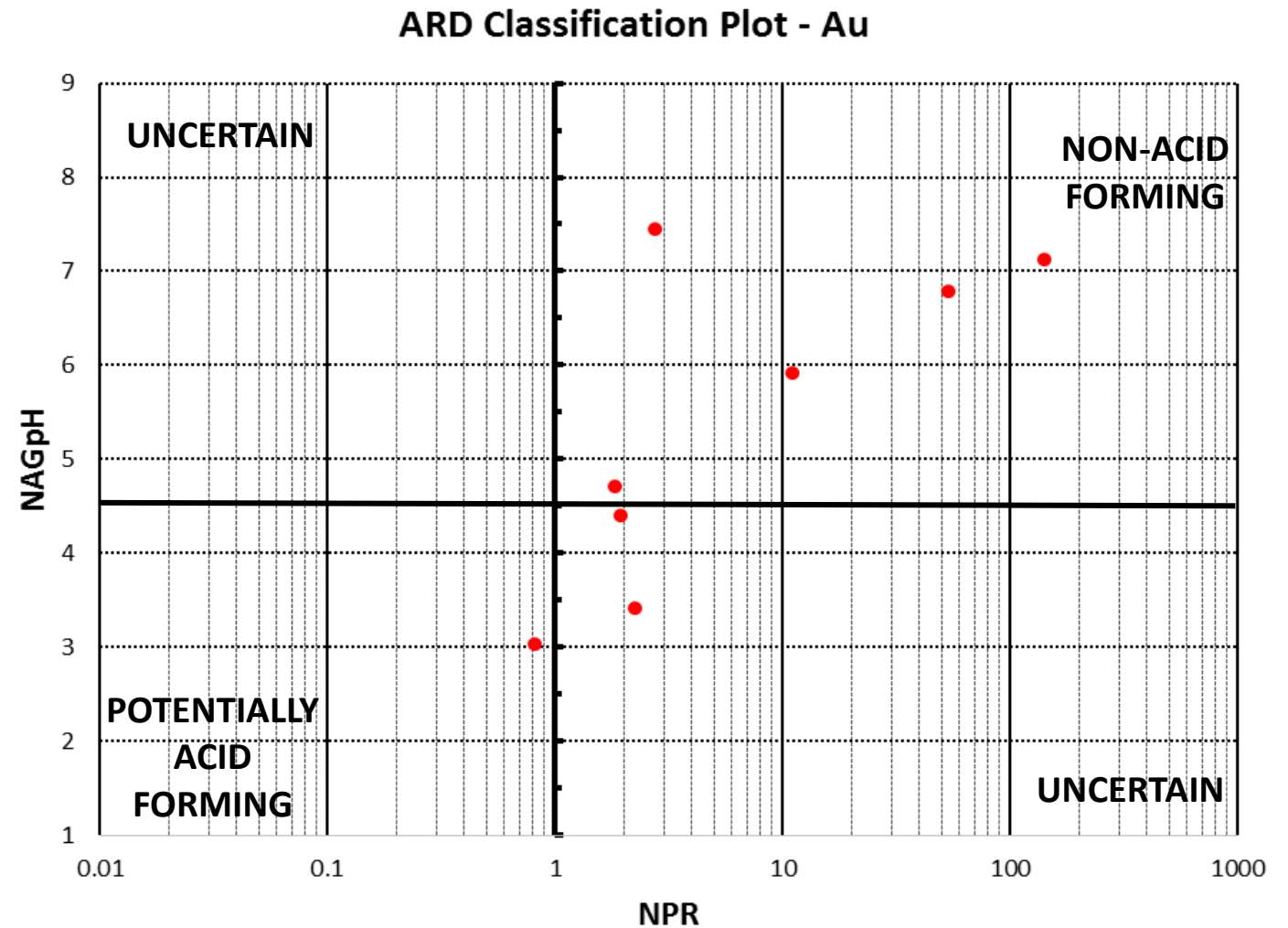
Net Neutralization Potential (NNP) - Au

Waste Rock Pile	S (%)	C (%)	AP (Kg CaCO3/tonne)	NP (total C)	NNP	NPR
Apex mine	0.08	0.33	2.492	27.489	24.997	11.031
Gold Stain mine-A	0.36	0.26	11.214	21.658	10.444	1.931
Gold Stain mine-B	0.35	0.24	10.903	19.992	9.090	1.834
Jic410	0.01	0.53	0.312	44.149	43.838	141.730
Jic413-A	0.85	0.26	26.478	21.658	-4.820	0.818
Jic413-B	0.5	0.51	15.575	42.483	26.908	2.728
Jic334	0.01	0.2	0.312	16.660	16.349	53.483
Sally mine	0.43	0.36	13.395	29.988	16.594	2.239

Acid Rock Drainage (ARD) Au waste rock pile Classification Plot

Assumption: pH = pH after reaction
(NAG pH)

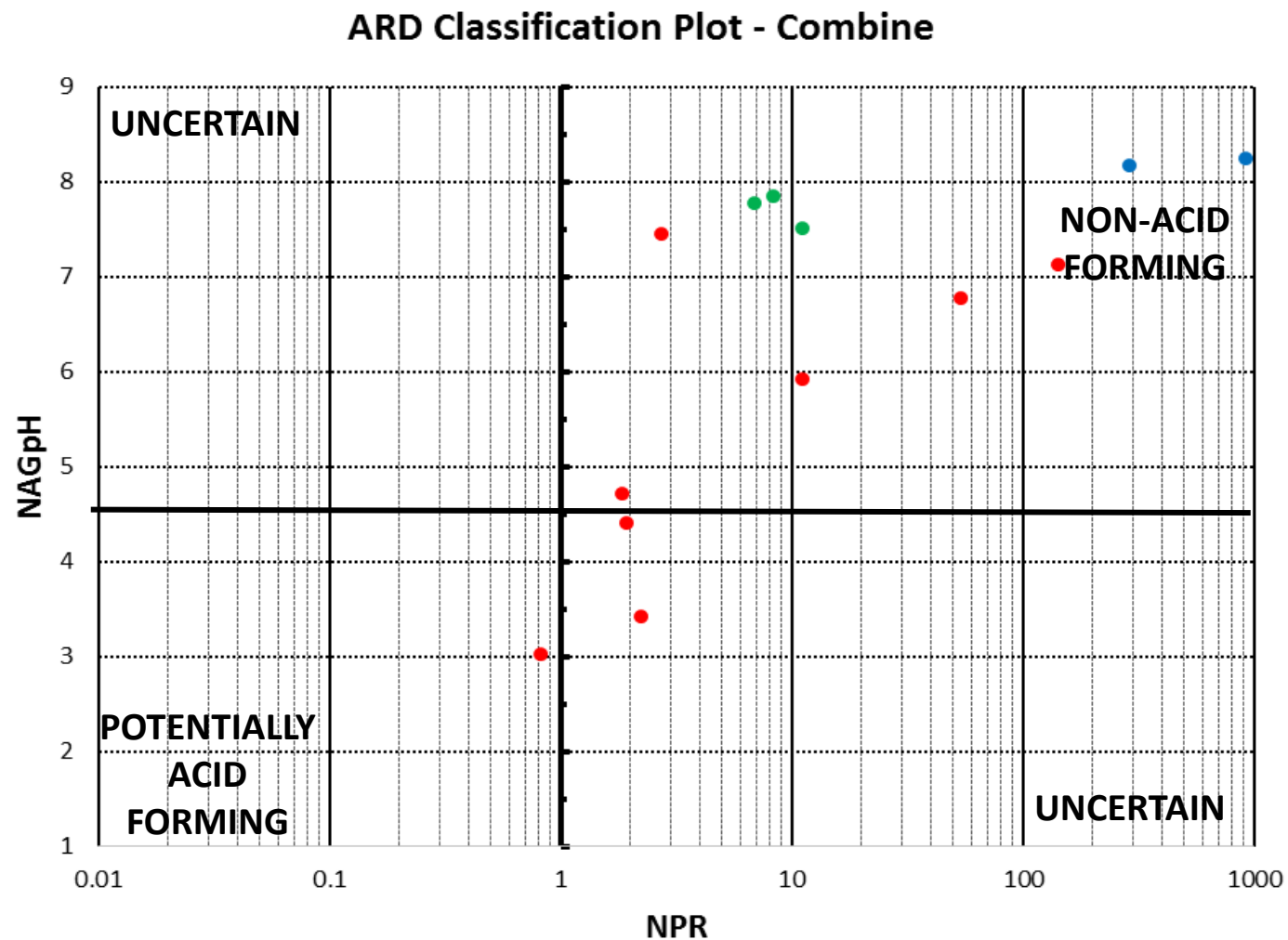
- Jicarilla samples



Acid Rock Drainage (ARD) Au & U Comparison

Assumption: pH = pH after reaction
(NAG pH)

- Lucky Don & Little Davie samples
- Jeter samples
- Jicarilla samples



Conclusion – U Mines

No evidence of potential acid drainage from field observations (hosted by limestone)

No pyrite identified in XRD and electron microprobe analysis

Waste rock pile samples from all U mines plotted in the non-acid forming zone on the ARD classification plot inferring non-acid producing rock piles

Dissolved U and V grains in electron microprobe analysis

Elevated radioactivity (scintillometer mapping) in some waste rock piles

Waste piles with high radioactivity from scintillometer should be covered

Conclusion – Au Mines

Jarosite was observed in sample Jic413A, pyrite was identified in numerous waste rock piles during field investigations

XRD and electron microprobe analyses identified pyrite grains in waste rock pile samples with $\text{pH} < 5$, some with whole rock arsenic (As) values between 0.8-10.9 ppm

Pitted textures in microprobe analyses are consistent with arsenic being leached from pyrite

Jic413A plotted in the potentially acid forming zone, Sally and Gold Stain-A mines plotted in uncertain zone and the rest of the Au samples plotted in the non-acid forming zone on the ARD classification plot

Waste rock piles with $\text{pH} > 5$, and plotting in non-acid forming zone can be used as backfill

Recommendations

Leaching tests are recommended to determine the leachability of acid from Jic413A, Sally and Gold Stain-A waste rock piles into the environment

Sediment survey to determine the movement of U, V and trace elements into the environment

Further field studies needed to determine the mineral potential of rock piles with elevated Au values

Appreciation

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New Mexico EpSCOR

New Mexico Geological Society

New Mexico Abandoned Mine Lands
Program

Thank you

Questions