Tungsten Queen Mine Tailings Evaluation, Vance Co., NC: A Potential Silica Resource

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North Carolina Geological Survey - Open-file report 2017-01

Suggested citation: Reid, Jeffrey C.; Taylor, Kenneth B.; Mensah-Biney, Robert; Simms, Jonathan, and Akbari, Hamid, 2017, Tungsten Queen Mine tailings evaluation, Vance Co., NC: A potential silica resource: North Carolina Geological Survey, Open-file report 2017-01.

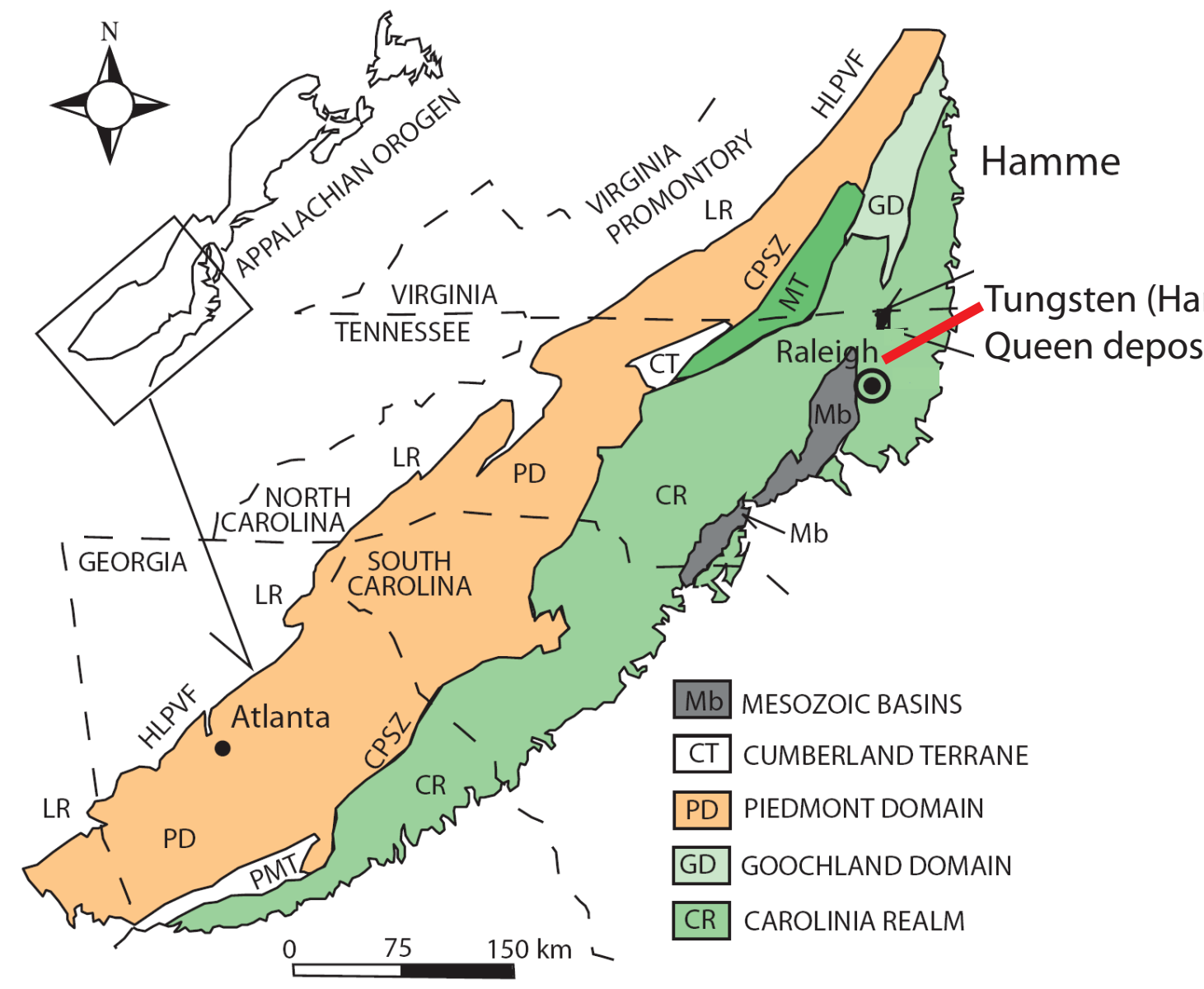
Abstract

The Tungsten (Hamme) Queen mine is located at Tungsten, NC, 16 miles northwest of Henderson, NC, and 2 miles south of the Virginia state line. The ore occurs in a near vertical quartz vein ranging in width from a few inches to several ft. Hübnerite, the principal tungsten mineral, is accompanied by a minor amount of scheelite. Pyrite, the predominate metallic mineral in the quartz veins, is accompanied by subordinate chalcopyrite, galena, sphalerite, and tetrahedrite. Fluorite is a common accessory mineral in the ore and tailings.

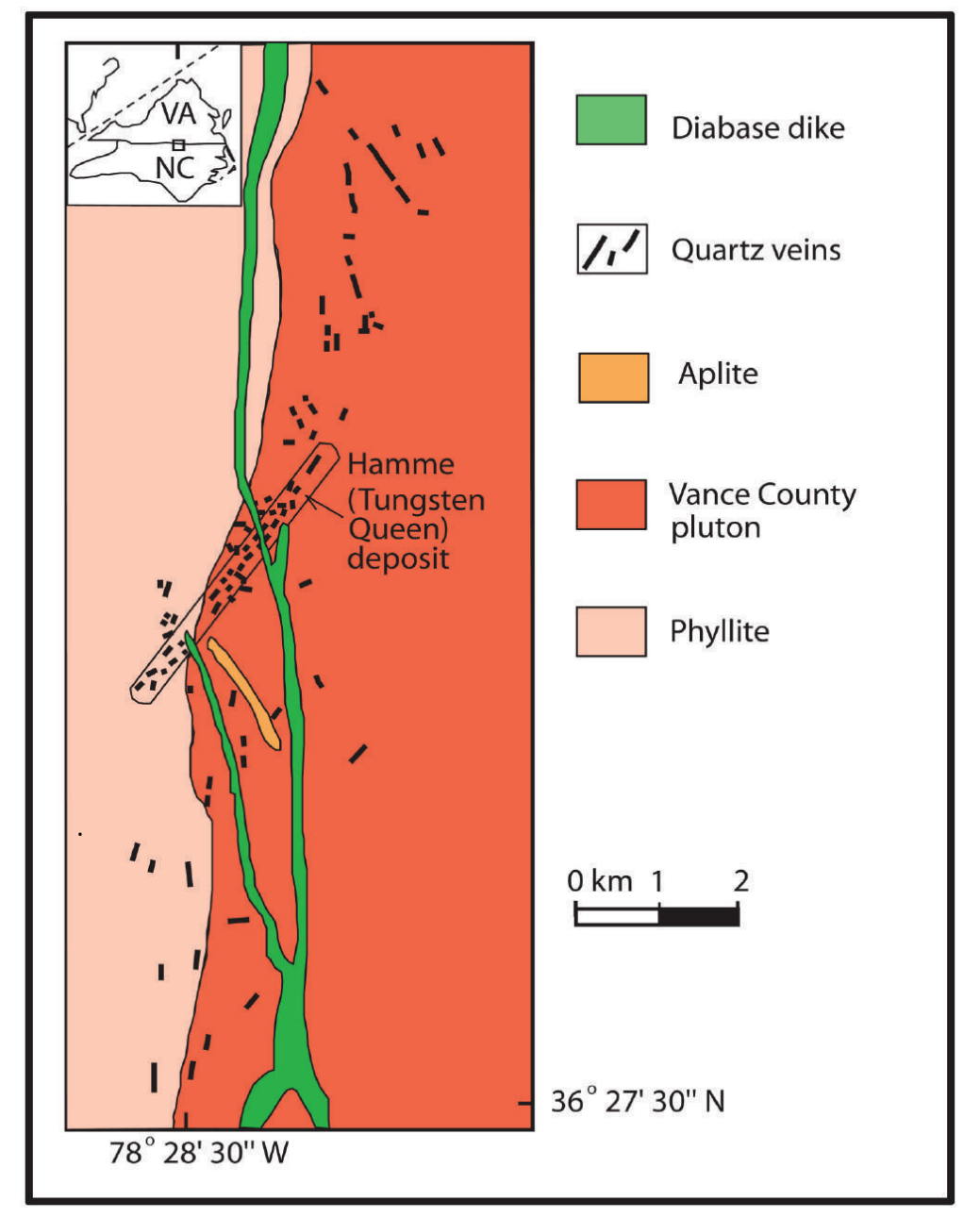
Our objective was a preliminary evaluation to produce a high quality quartz concentrate from the approximately 2 million tons of tailings present. Shallow drilling and pits <6 ft deep recovered ~60-pounds of wet tailings from gridded sites on the tailings fan from just below the mill discharge point.

The quartz concentrate was produced using bench scale beneficiation methods including flotation, magnetic, and gravity separation. Size fractions were evaluated for full mineral liberation and non-quartz species using binocular and petrographic microscopes. Quartz analyses were obtained by ICP mass-spectrometry. A concentration flow chart was developed for the heavy and light specific gravity fractions.

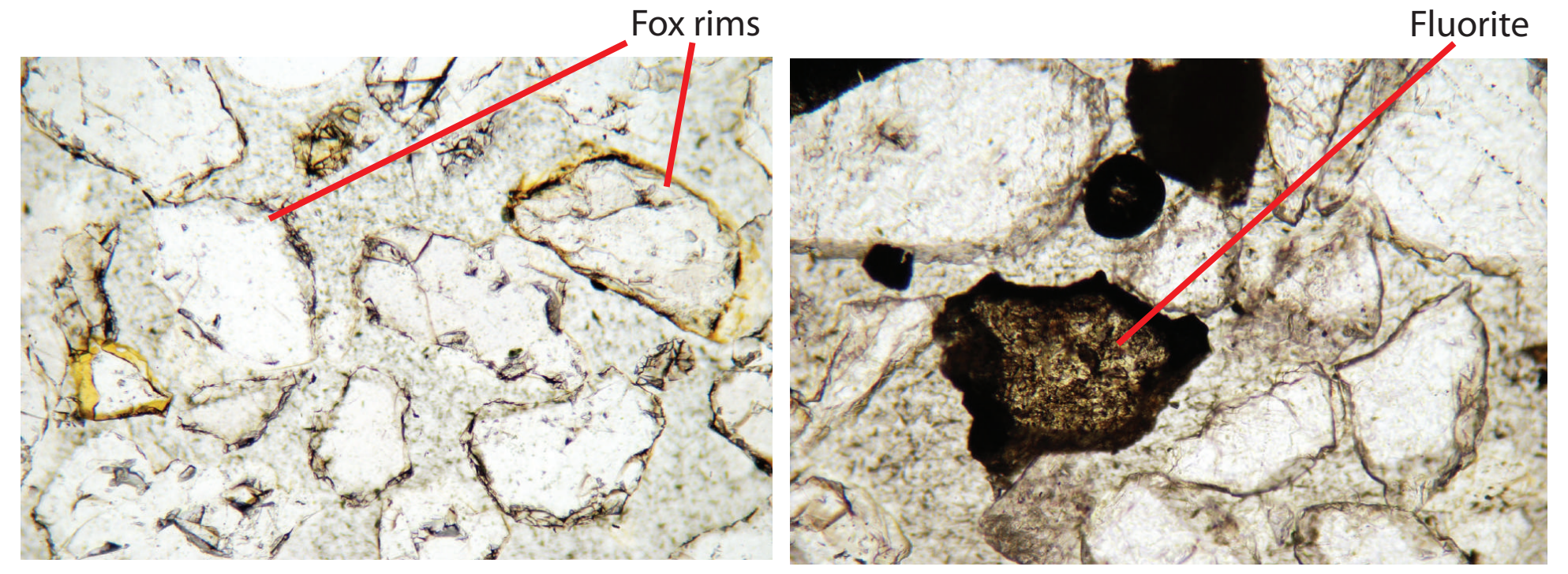
Chemical analysis indicates that the quartz may be suitable for fused quartz and silica glass applications. Fluorite comprises up to ~2.5 wt. % of the heavy fraction and is a potential glass flux and other uses. Accessory hübnerite, scheelite, galena, chalcopyrite, and sphalerite may also be recoverable.



Location of the Tungsten (Hamme) Queen deposit (modified from Espenshade 1947). (After Chaumba and others, 2015).



Geologic map of the Tungsten (Hamme) Queen deposit area (modified from Espenshade (1947) and Fosse and others (1980). (After Chaumba and others, 2015).



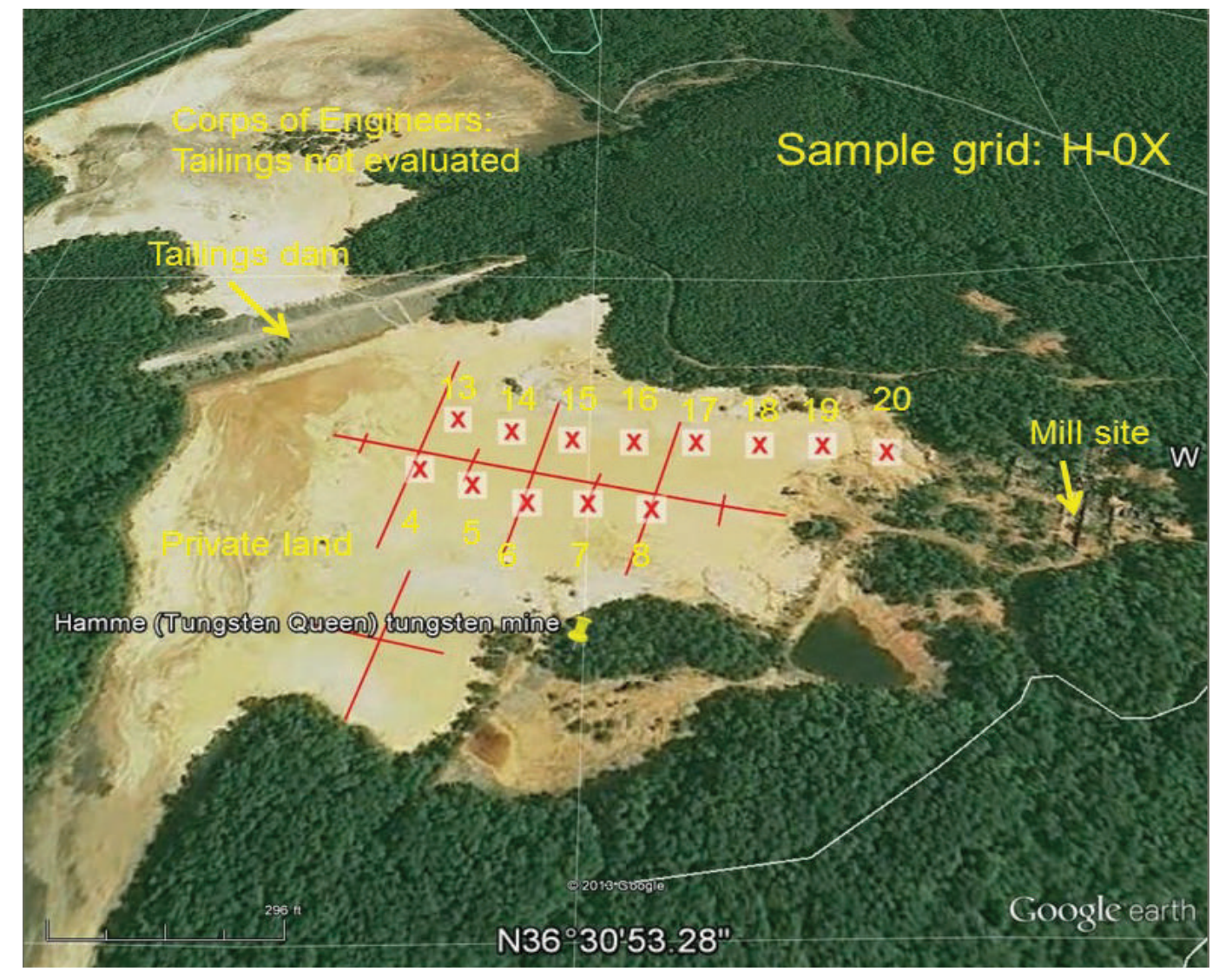
(Left) - Petrographic examination of the light (<2.9 S.G.) fraction showed iron oxide (Fox) rims surrounding some quartz grains (100x, plane light, field of view width - 1.2mm). Fox decreases the quality of the concentrate. Its removal necessitated the more extensive leaching process outlined here. (Right) - Occasional high specific gravity minerals such as fluorite (shown here) and others (galena, huebernite) were noted in early concentrates (100x, plane light, field of view width - 1.2mm). Further concentrate processing was required to remove these impurities also.

Study objectives

Determine if a high purity quartz concentratate could be produced from the Hamme Tungsten (Tungsten Queen) mine tailings.

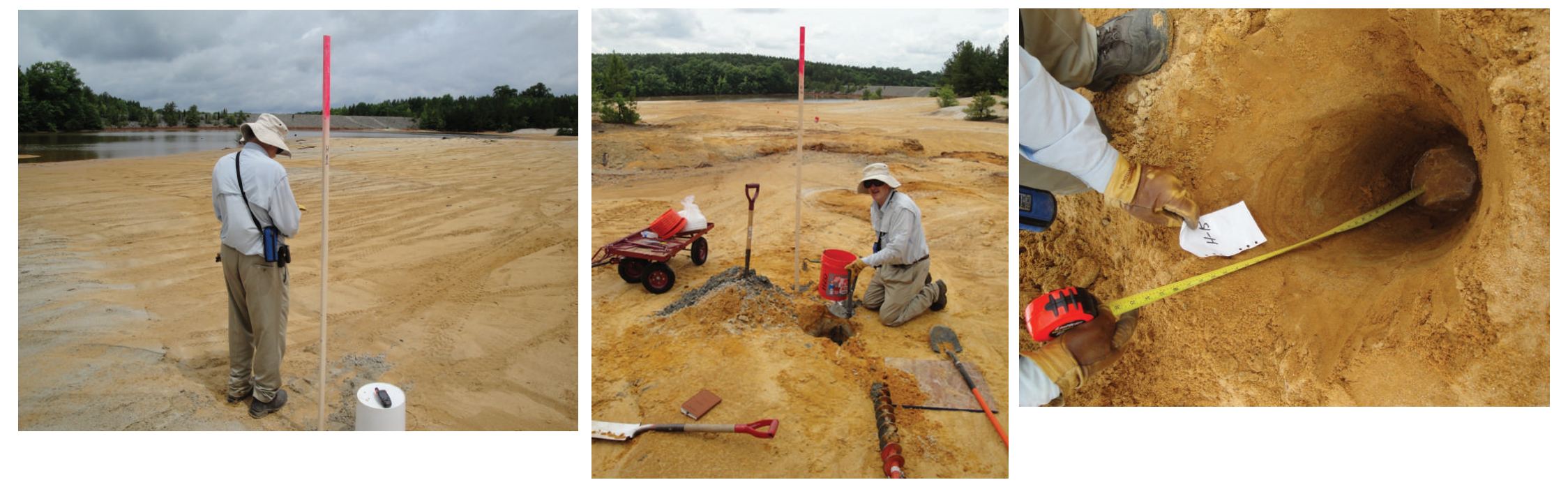
Tailings sampling was part of a statewide tailings sampling project by North Carolina's Minerals Research Laboratory (MRL), Asheville, N.C., to evaluate potential resources statewide. The North Carolina Geological Survey (NCGS) collaborated with MRL to evaluate the Hamme (Tungsten Queen) tailings.

Site layout



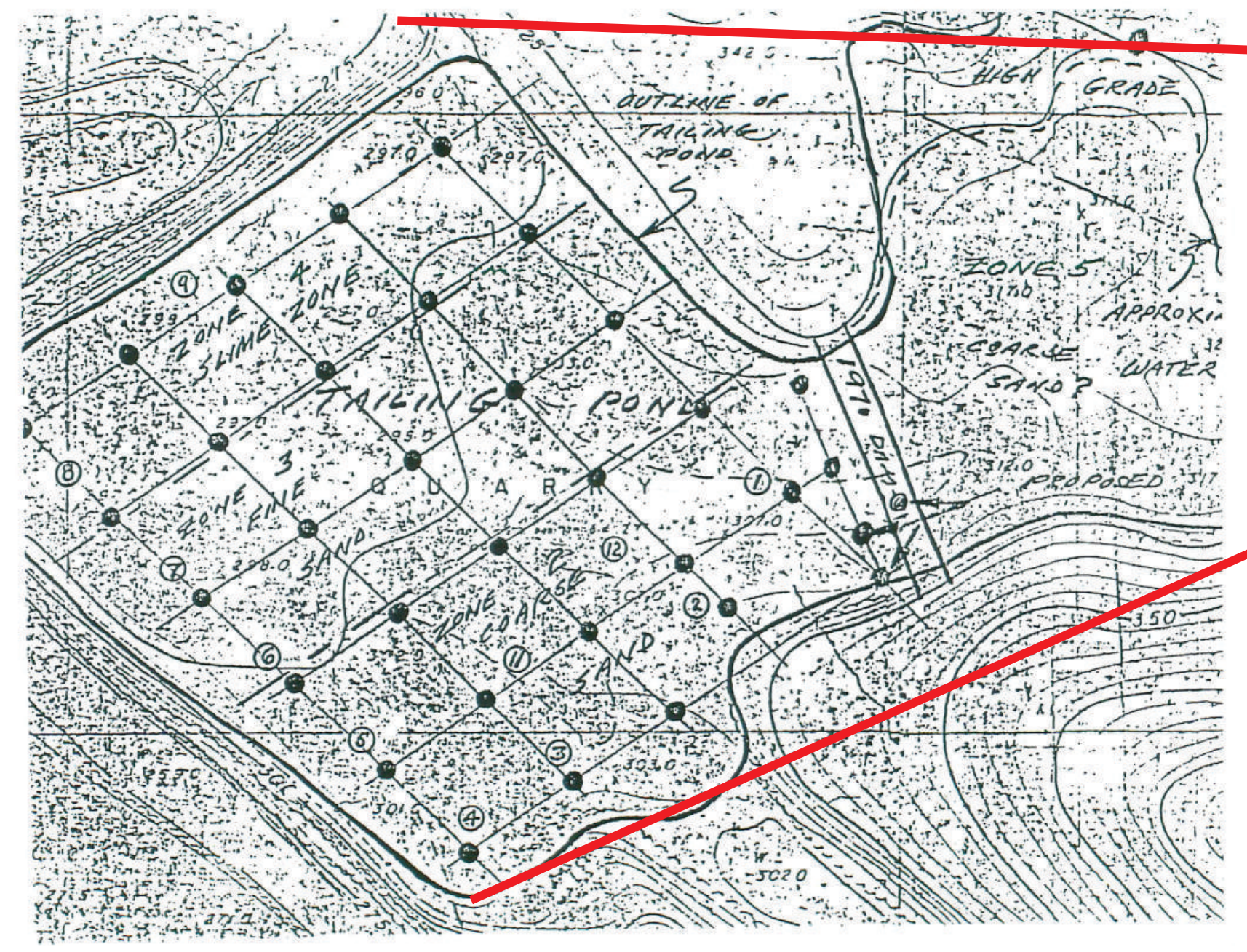
The Google Earth (GE) image shows the overall site layout. The red grid lines on the tailings fan surface show the sample grid established for this study. Samples 1-3 are from the centerline of the unnumbered red cross (sample numbers increase from west to east). GE area corresponds to map below.

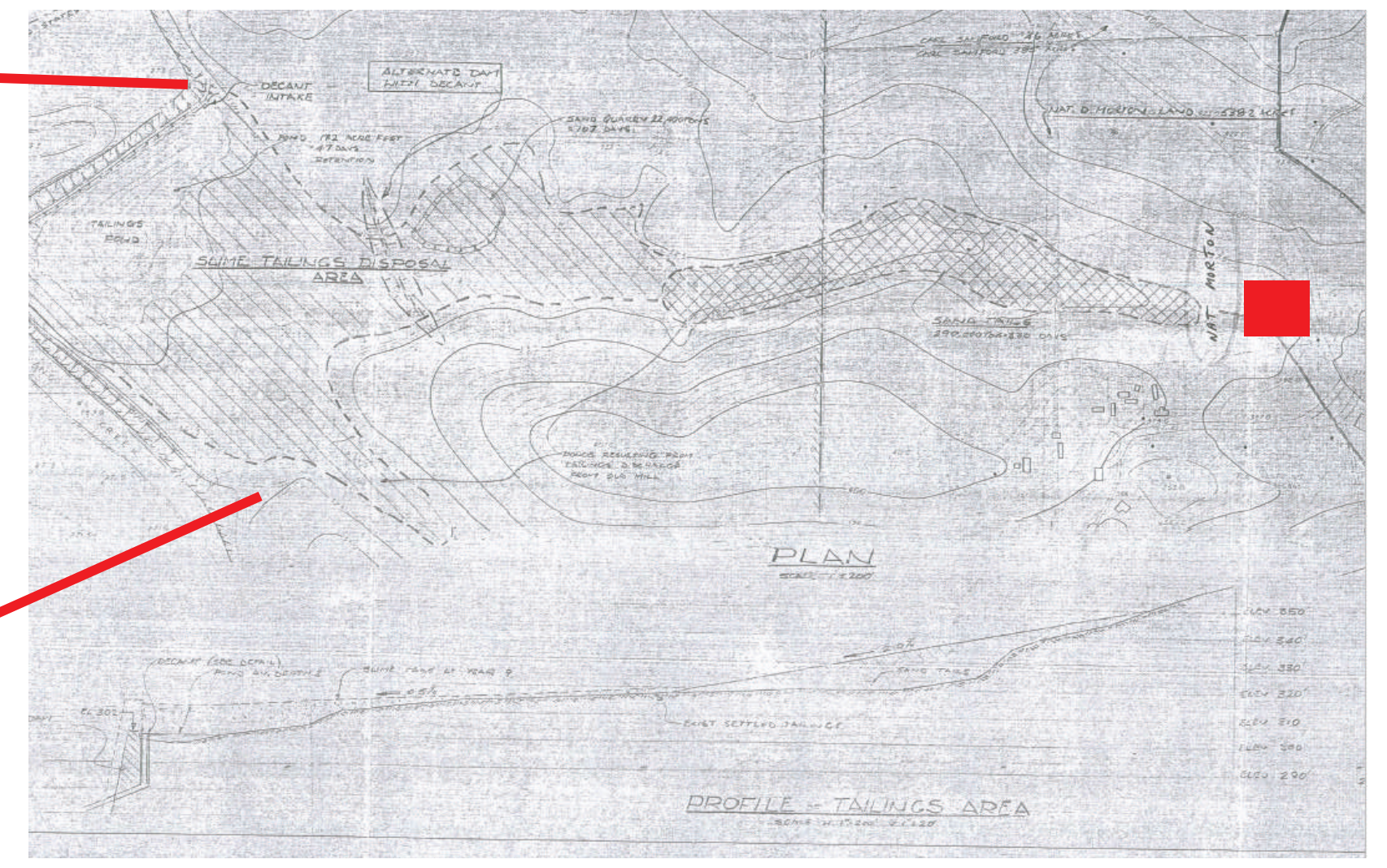
Sample collection



Samples with a weight of about 60 pounds were collected along a paced grid with GPS-controlled sample stations. Sample collection on 13 June 2013 used a power auger and shovel. Samples were collected in a 5-gallon plastic pail.

Samples were collected from stations H4-H8, and H13-20 (see Google Earth image for locations). Water was encountered in most drill holes at a depth of <5 feet.



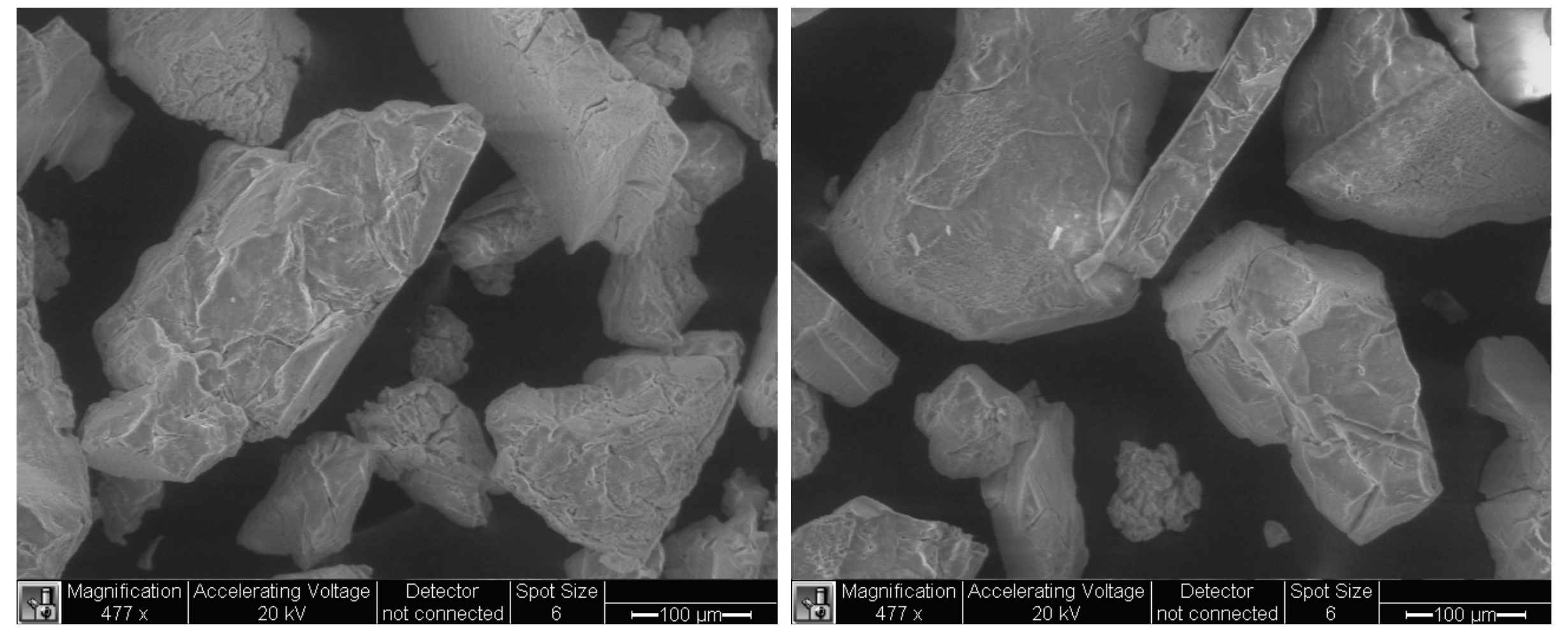


(*Left*) is an enlargement of the tailings area corresponding to Myertons' two million ton tailings resource. The red square indicates the approximate point where the mill discharged tailings. The tailings and bedrock profile (above) provide some estimate of tailings thickness.

(*Above*) - Myertons (1975) conducted a preliminary investigation of the tungsten content of the Tungsten Queen tailings pond. He excavated thirteen pits in the pond using a backhoe. Samples were taken from each pit for grain size and chemical analyses. The image shows the backhoe pit locations. (*Above - Right*) Myertons concluded that there are "...2,038,000 tons of material averaging 0.218% WO_3 for a total content of 445,600 STU WO_3. This is classed as a probable reserve rather than 'proven' or 'possible' reserve."

The backhoe pits ranged from five- to eight feet deep, and nowhere reached the bottom of the sand according to Myertons. He indicated that "...Pond material appears to be about thirty feet deep over most of the pond, increasing to forty feet in (sic) narrow zone under the 1970 tailing dam. This implies that the value of the tungsten that could potentially be recovered depends on recovering -400 mesh-size huebernite and separating it from sericite and mica according to Myertons.

The approximately two million tons of tailings is significant because with the the current concentrate grade this resource may be economic as a silica resource. Further work may use GPR, and other seismic techniques, supplemented by vibracore drilling to fully confirm tailings sediment thickness.



SEM-EDS

(*Left of this column*) Final MP-4 quartz grain concentrate viewed using a variable pressure SEM. The grains in the left most image tend to have been etched comparatively more deeply ("More etched grain example") than those shown in the right image ("Less etched grain example") during the beneficiation process.

(*Right of this column*) SEM-EDS analysis show no chemical distinction at the grain-size level.

Deleterious elements such as Al, K, and Fe were not detected by the EDS (elemental peak postions shown on spectra).

The carbon peak reflects the mounting medium. The K peak location is within that of the C peak, but no K is present (see sprectra and analyses - to right).

```
Spectrum: hammel-rough surface- 11.spx

El AN  Series      Net unn. C norm. C Atom. C Error (1 Sigma)
                       [wt.%]  [wt.%]  [at.%]          [wt.%]
--------------------------------------------------------------
C   6  K-series   16137  13.25   13.86   20.38           1.77
O   8  K-series  321699  51.27   53.64   59.20           5.51
Al 13  K-series    8381   0.31    0.33    0.22           0.04
Si 14  K-series 1083611  30.70   32.12   20.19           1.33
K  19  K-series     375   0.02    0.02    0.01           0.03
Fe 26  K-series     162   0.02    0.02    0.01           0.03
--------------------------------------------------------------
                 Total:  95.58  100.00  100.00
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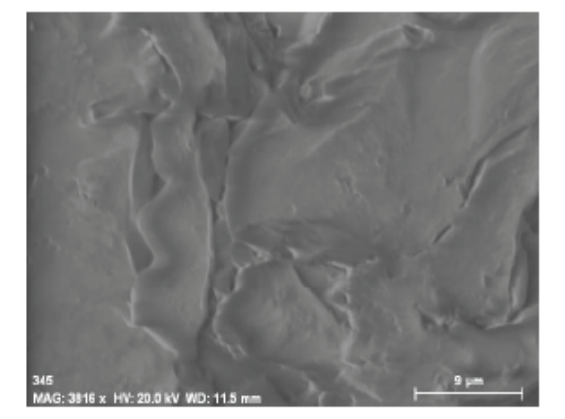

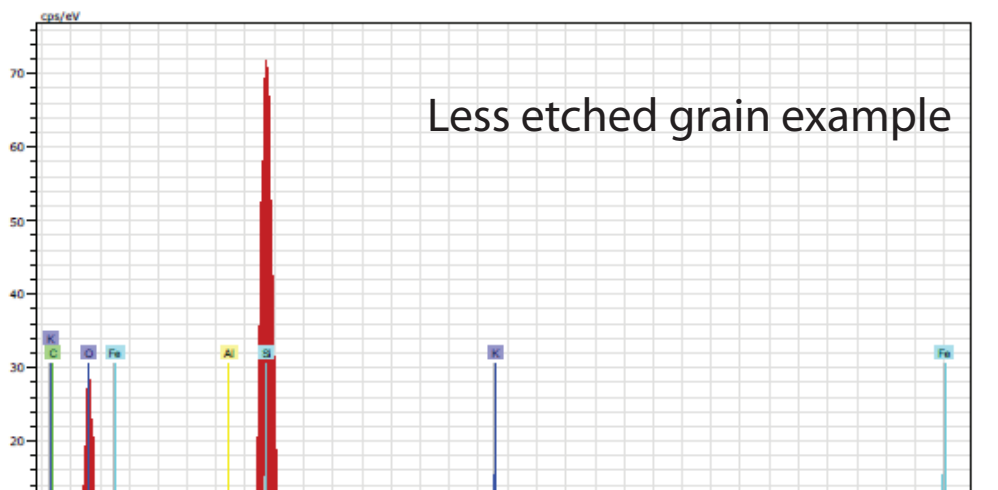

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Spectrum: hammel-smooth surface- 12.spx

El AN  Series      Net unn. C norm. C Atom. C Error (1 Sigma)
                       [wt.%]  [wt.%]  [at.%]          [wt.%]
--------------------------------------------------------------
C   6  K-series   29056  28.87   22.98   31.81           3.59
O   8  K-series  249029  63.51   50.55   52.52           6.88
Al 13  K-series    5993   0.29    0.23    0.14           0.04
Si 14  K-series  830410  32.95   26.23   15.52           1.43
K  19  K-series     177   0.01    0.01    0.00           0.03
Fe 26  K-series     121   0.01    0.01    0.00           0.03
--------------------------------------------------------------
                 Total: 125.65  100.00  100.00
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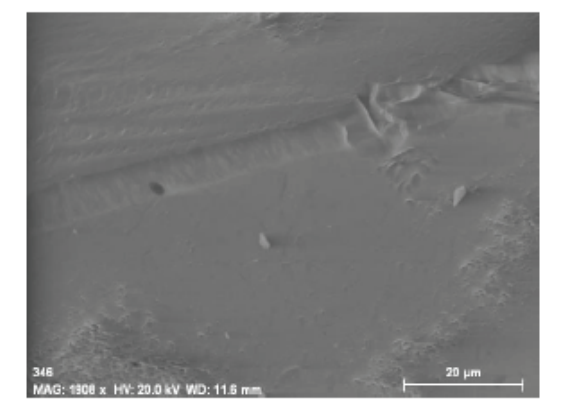


Beneficiation of Hamme tungsten quartz (H13 - concentrate MP-4)

Summary of processing methods and procedures used in July 2016. Sample H13 is near the tailings dam, and among the most distal from tailings discharge from the now abandoned gravity mill.

Gravity Separation
Raw ore was processed through a gold miser to remove heavy minerals (tungsten, fluorite, galena, etc.) from the sand (quartz). The quartz product was saved and used for subsequent beneficiation processes to produce the high quality quartz product.

Screening
H13 feed was screened over a 30 mesh sieve. The minus 30 mesh fraction (-30 x 0 mesh) was advanced to wet magnetic separation to remove magnetic mineral impurities.

Wet Magnetic Separation
The minus 30 mesh material was passed 3 times through the Eriez Wet Magnetic Separator set at 70 volts. Non-mags were collected for subsequent froth flotation processing.

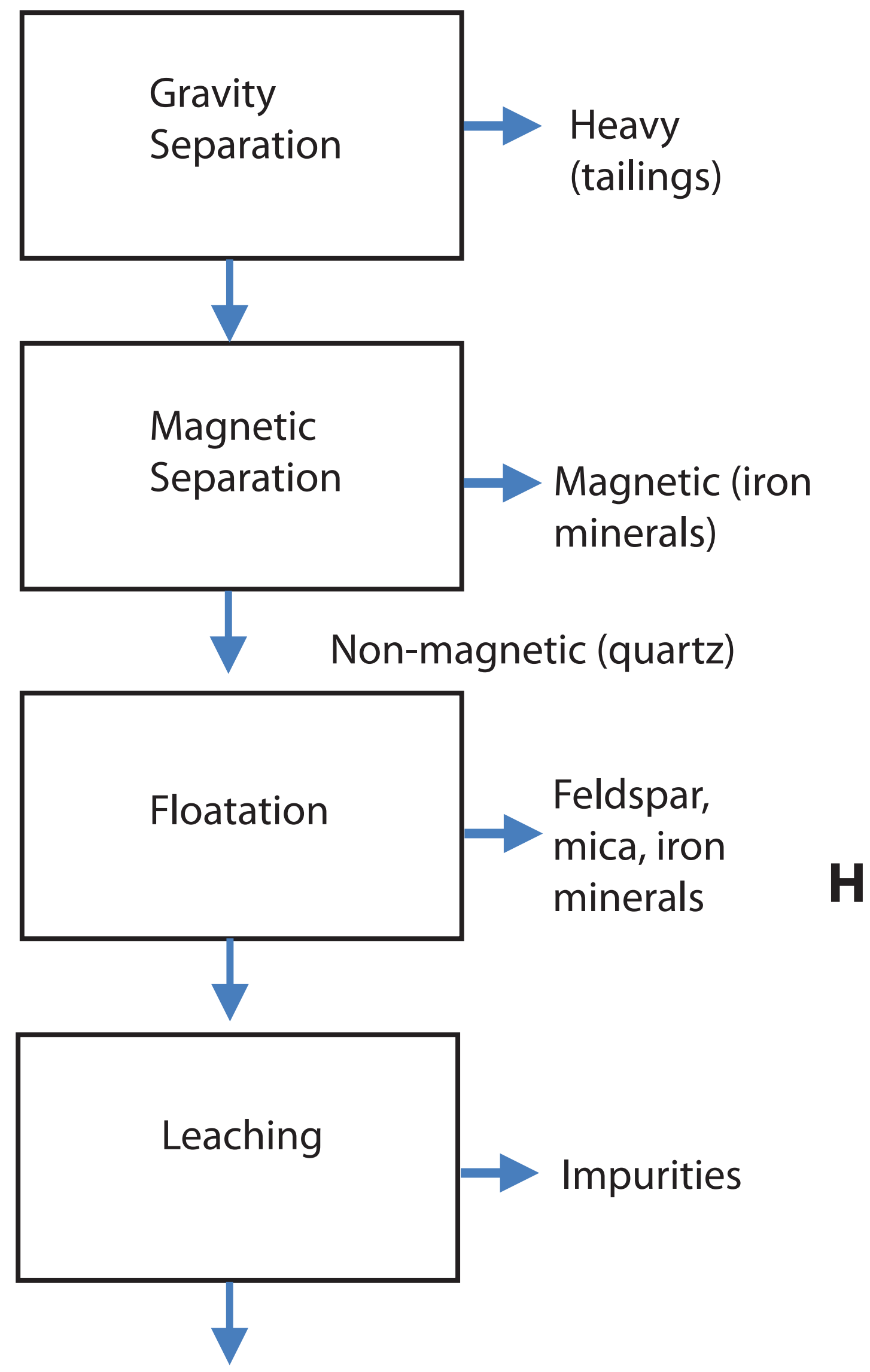
Froth Flotation
The flotation process followed the following steps:
1. Scrubbed for 5 minutes @~65% solids.
2. De-slimed 3 times over 200 mesh sieve.
3. Conditioning at <3.0 pH with (HH-70) petroleum sulfonate for Iron Float #1.
4. Iron Flotation #1.
5. Conditioning at <3.0 pH with (HH-70) petroleum sulfonate for Iron Float #2.
6. Iron Flotation #2.
7. Conditioning at <3.0 pH with amine for Mica Float #1.
8. Mica Flotation #1.
9. Conditioning at <3.0 pH with amine for Mica Float #2.
10. Mica Flotation #2.
11. Conditioning with HF and amine for Feldspar Float #1.
12. Feldspar Flotation #1.
13. Conditioning with HF and amine for Feldspar Float #2.
14. Feldspar Flotation #2.

Note: All reagents used, except collector HM-70, were 2.5% concentration.

The final quartz product (flotation tailings) was dried and advanced to dry magnetic separation to remove additional magnetic impurities.

Dry Magnetic Separation
The quartz product from the flotation was passed 3 times over a PermRoll Separator to produce the 30 x 200-mesh non-magnetic quartz product. This non-magnetic quartz product was subjected to sink-float procedure (Heavy Liquid Separation) to remove additional heavy minerals.

Leaching
Finally the hiqh quality quartz product was subjected to a proprietary hot acid leaching procedure to remove additional soluble impurities.



Gravity Separation → Heavy (tailings)

Magnetic Separation → Magnetic (iron minerals)

Non-magnetic (quartz)

Floatation → Feldspar, mica, iron minerals

Leaching → Impurities

High Purity Quartz (HPQ)

This white concentrate color of the leached quartz (left) is contrasted to the unleached concentrate(right). This is because the iron content (a serious impurity) was greatly reduced by the leaching process.

Typical High Purity Quartz (HPQ) applications

The main applications for high purity quartz are:
- Semiconductors (fillers and silicon metal),
- High temperature lamp tubing,
- Telecommunications and optics,
- Microelectronics, and
- Solar (panel) silicon industries.

Analytical results

Analytical results (ppm) of the leached quartz concentrate follow. Analysis was by ICP-MS.

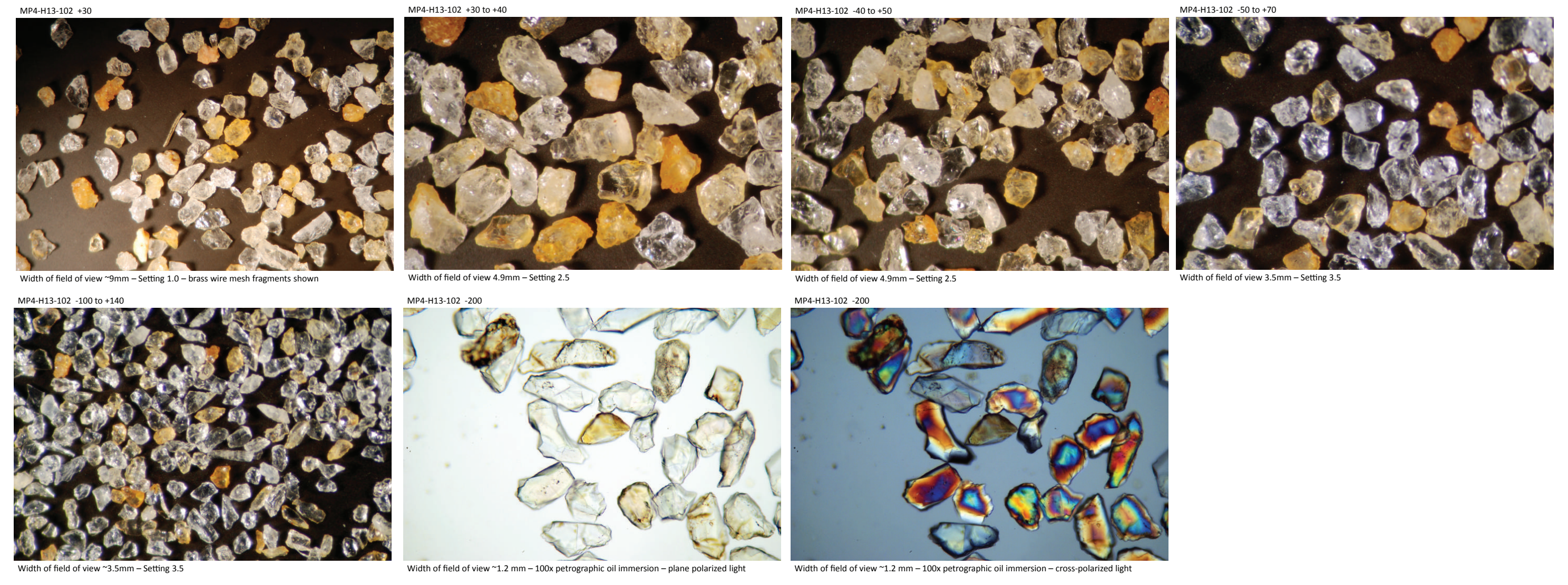
7Li	23Na	24Mg	27Al	39K	44Ca	47Ti	52Cr	55Mn	57Fe	60Ni	65Cu	66Zn	90Zr
0.884	3.774	2.809	35.47	12.53	76.98	6.695	0.033	1.789	13.26	0.023	1.52	1.485	0.085

Acknowledgements

Jae Ahn of The Quartz Corp. graciously provided us preliminary quartz concentrate analyses as well as the quartz analysis presented here.

James A. Bailey permitted access to the site for this study.

Petrography of fractions



Binocular- and petrographic examination of different size fractions was used to assess mineral concentrate effectiveness. In this series of size fractions, iron oxide coats quartz grains at all size fraction ranges. This observation led to the need for leaching in order to remove this impurity, to improve the concentrate quality. Petrographic oil immersion of grains at -200 mesh revealed that iron oxide coated grains in this fraction also. Lower magnification binocular examination indicated that some feldspars remained, and identified a brass screen mesh fragment. These observations resulted in further concentrate floatation and leaching leading to a significantly improved concentrate shown below with its accompanying ICP-MS analysis.

High purity quartz: Applications, impurity levels, market size, and price

Application	SiO_2	Other Elements		Market Size	Typical Price
	Minimum (%)	Maximum (%)	Maximum (ppm)	Mtpa	US$/tonne
Clear glass grade (fibers and ceramics)	99.5	0.5	5,000	>70	30.00
Semiconductor filler, LCD, and optical glass	99.8	0.2	2,000	2	150.00
"Low grade" HPQ	99.95	0.05	500	0.75	300.00
"Medium grade" HPQ	99.99	0.01	100	0.25	500.00
"High grade" HPQ	99.997	0.003	30	<0.1	>5,000

Note 1: HPQ = high purity quartz; Mtpa = million tonne per annum; tonne = metric tons.
Note 2: "High grade" high purity quartz with <30ppm other elements is the standard high purity quartz produced by Unimin Corp. and TQC at Spruce Pine, North Carolina.
Reference (credit): Silica and High Purity Quartz Information, Verdant Minerals, Ltd.

Summary and conclusions

A high purity quartz concentrate was produced using bench scale beneficiation methods including flotation, magnetic, and gravity separation.

Chemical analysis indicates that the quartz may be suitable for fused quartz and silica glass applications. Fluorite comprises up to ~2.5 wt. % of the heavy fraction and is a potential glass flux and other uses. Accessory hüebnerite, scheelite, galena, chalcopyrite, and sphalerite may also be recoverable.

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