September 3, 2014

Dennis Swift

Re: Analysis of metal used to carve Peruvian burial stones: *Chemoptix #G-MIC-11256.*

Dear Dennis:

The three stones and tool reference materials cited herein have been analyzed via scanning electron microscopy, electron-dispersive x-ray, and a variety of other microanalytical techniques. The results should be of interest:

Analysis Summary:

Scuffed bronze, as well as its weathered counterparts were recovered from incisions on from the Paracas Stone. The metal did not match the tool metals submitted for comparison. The Nazcan Stone, much more severely weathered and subsequently contaminated, did not show metal or weathered counterparts within its incisions.

The materials submitted for analysis are identified as:

Dennis Swift ID	*Chemoptix ID*
Nazcan Stone	--
Paracas Stone	*G-MIC-11256-1; -2*
Souvenir [reference standard]	--
Copper/copper alloy tools [reference standards]	*G-MIC-11256-STD, -B and -C*
Stone tool (1)	--

Methods:

The stone surfaces were examined in their entirety using dissection microscopes equipped with episcopic/incident light illumination (MIC). Incision (carved) regions showing possible reacted metal were tape-lifted using carbon tape and analyzed via scanning electron microscopy coupled with energy-dispersive x-ray, a light-element detector; secondary electron imaging and back scattering (SEM/EDX). Both the reacted metal-like deposits and neat metal were analyzed and compared to similarly-prepared reacted and neat metal recovered from the tool standards.

Results:

Annotated photomicrographs and EDX spectra are presented below.

Nazcan Stone: This stone showed weathering in its carved incisions on all examined surfaces. On a single planar surface, MIC analysis showed the rock-building minerals altering into secondary mineralization with similar habit but exhibiting expanded volumes related to alteration within the incisions. These were similar in structure and extent to altered counterparts on non-incised surfaces. These minerals are suspected to be feldspars; their altered counterparts likely being clay minerals (*Figure 1*). No relict abrasions, metallic or otherwise, were observed in the incisions on this stone. No metallo-oxide/hydroxides derived from iron nor copper were observed.

Results (continued):

Nazcan Stone (continued): Although there were modern paint spatters and other contaminants on the surface of the stone (*Figure 2*) there were no significant mineral residues foreign to the stone within the incisions or other surface relief.

Paracas Stone: This basaltic stone (*Figure 3*) showed small areas of copper mineralization loosely adhering to the regions of carved incisions. The stone incisions also showed abrasion from incision. Although the stone indicated general protection from weathering, copper residues were severely weathered (*Figures 6-9*). Nonetheless, a few intact metallic fragments were observed (*Figures 6, 7*). SEM/EDX analysis indicated both scuffing morphology and spectra for a silver-bronze. Weathered zones adjacent to these particles also showed spectra suggesting derivation from this metal; those further from the metal scuffs presented spectra less relatable to the scuffs (*Figures 8* and *9*) and indicating a more complex mixture of matrix elements and possibly limited diffusion. Perhaps significantly, no arsenic was recovered from the metal scuffs nor the adjacent weathered regions. A clay-like consortium of finely-divided minerals appearing to be foreign to the basaltic material were found to be infilling many of the incisions.

Souvenir: The ‘weathering’ on this stone peripheral to the incised figures was brushed on as a paint/coating. There were no conspicuous metal/metallo-oxides within the incisions upon cursory MIC evaluation. Interestingly, the clay minerals within the carved incisions were very similar to those recovered from the Paracas Stone.

Tool reference standards: EDX spectra (*Figures 10-13*) showed the tools to be weathered copper, but none showed the tin observed within the Paracas Stone:

G-MIC-11256-STD showed mainly copper as its metallic component. Traces of iron, aluminum and magnesium were also observed.

G-MIC-11256-B showed, in addition to copper, traces of arsenic, but no tin nor silver. Curiously, this tool metal appeared to be derived from rolling and punching, and not hammered into shape like the other tools.

G-MIC-11256-C showed the copper accompanied by silver as in the Paracas stone, but no tin nor arsenic was observed.

Discussion:

Ferrous metallurgy did not appear to be involved in the making of the Paracas Stone. That said, it would be a simple matter to make a new carving with an old tool; and different environments both protect/weather contemporaneous materials differently. This analysis is restricted to the metal tooling involved in carving. The Nazcan Stone, reported to have the best provenience, did not show any metal tooling artifacts due to weathering. The stone tool reference standard was not analyzed for this body of work.

Suggestions for further work:

Other than very small amounts of loose material removed by tape-lifts, this has been nondestructive testing. Some of the observed deposits were also left intact pending subsequent analysis. In this investigation, the sizes of the stones have been an impediment to in situ microanalysis well as optical photomicrography. Depending on the goals, a variety of other analyzes, including destructive testing, can be undertaken, should the need arise.

Thank you for your considerable patience during the completion of this interesting project. If you have questions, require elaboration on any aspect of this result, or require additional hard data, feel free to contact me at (503) 636-9251 or via email at stancassell@chemoptix.com .

Respectfully Submitted,

Stan Cassell,
Manager/Microanalyst

Attachments

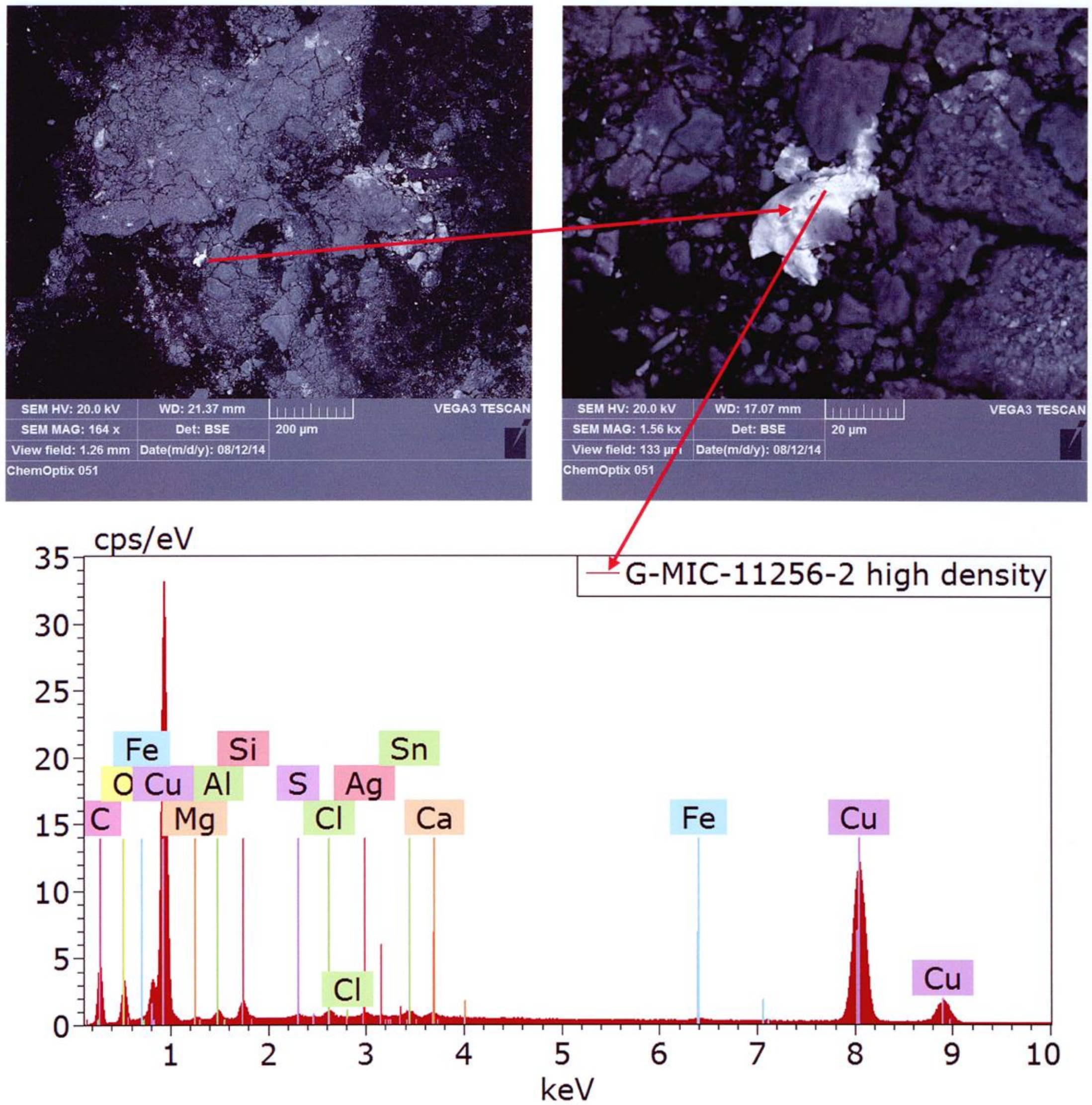
Figure 1: Nazcan Stone, showing altered feldspar-like weathering (white).

Figure 2: Nazcan Stone, opposite face from *Figure 1*. Much of the blemishing discoloration is from paint, oils and other recent contamination.

Figure 3: Paracas Stone. Arrows indicate regions where copper was recovered.

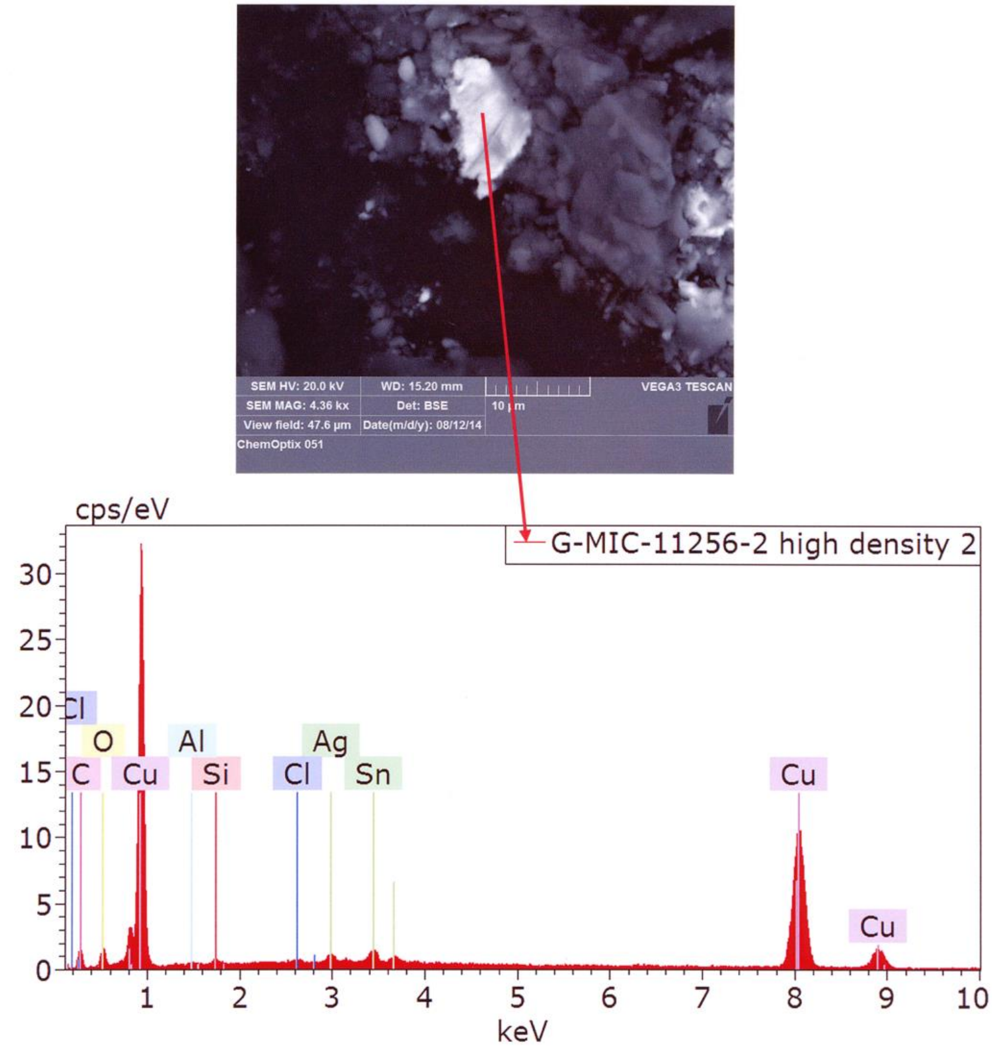
Figure 4: Souvenir. Stylistically and manner of preparation are much different than the other two stones.

Figure 5: Metal tools used as reference standards.



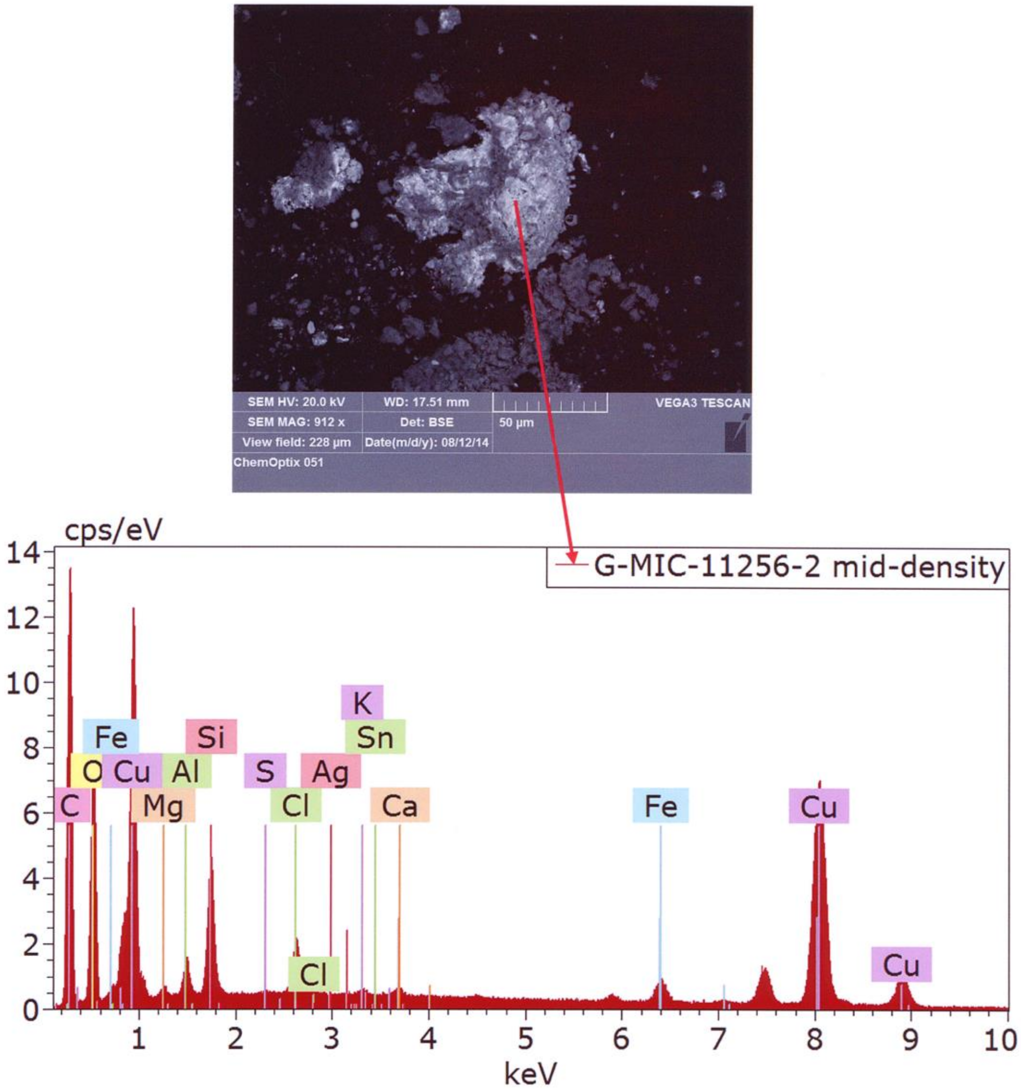
Secondary electron images and energy dispersive x-ray spectrum acquired from sample G-MIC-11256-2.

Figure 6: EDX spectrum on neat metal (exhibiting high-electron density) from the Paracas Stone. This ~25 µm metal particle appears to be a high-silver bronze. The crescent-shape is typical for metal eroded by scuffing contact abrasion.



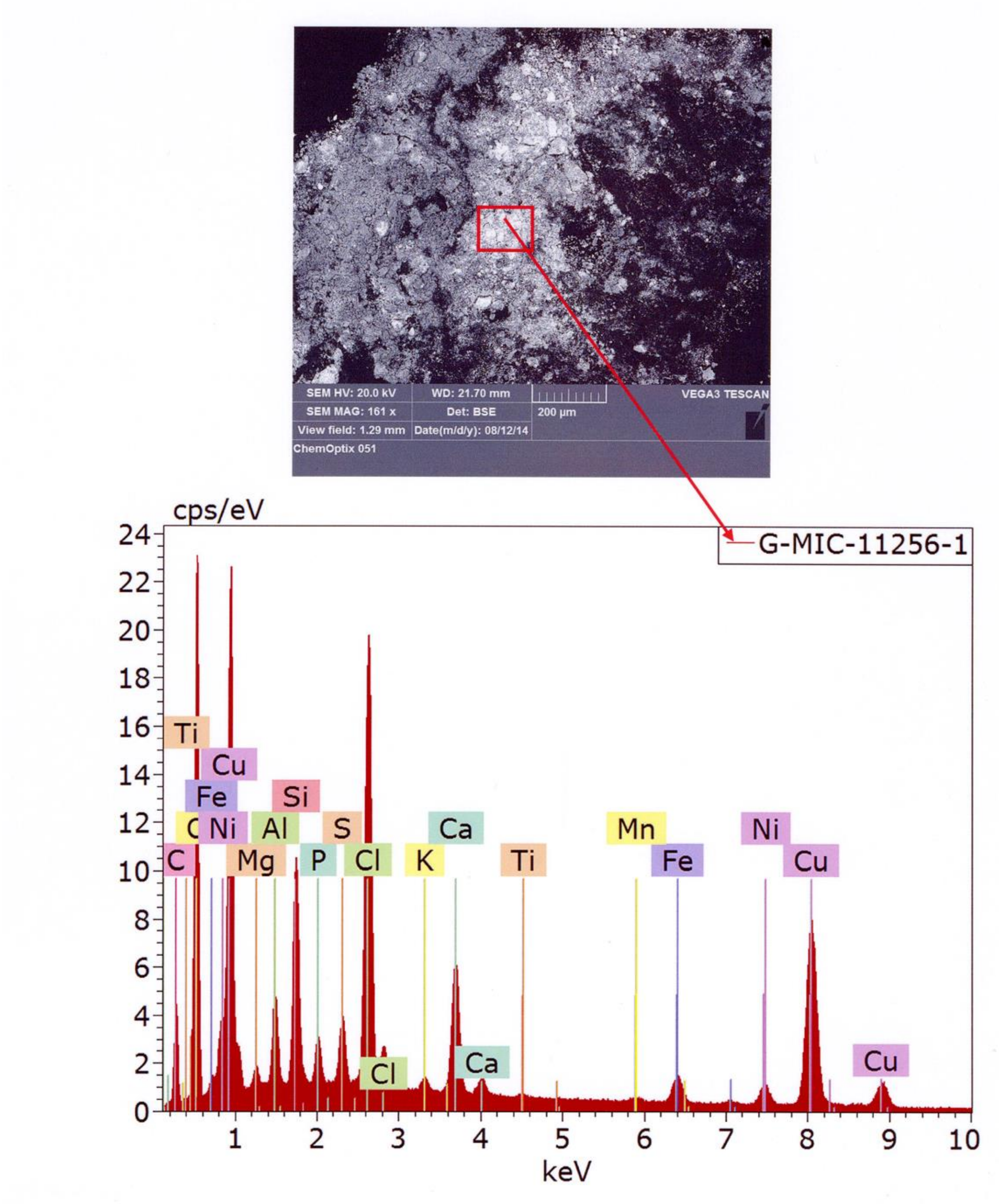
Secondary electron images and energy dispersive x-ray spectrum acquired from sample G-MIC-11256-2.

Figure 7: A second scuff from the Paracas Stone. This ~11µm scuff shows striations from abrasion. Note the similar metallurgy.



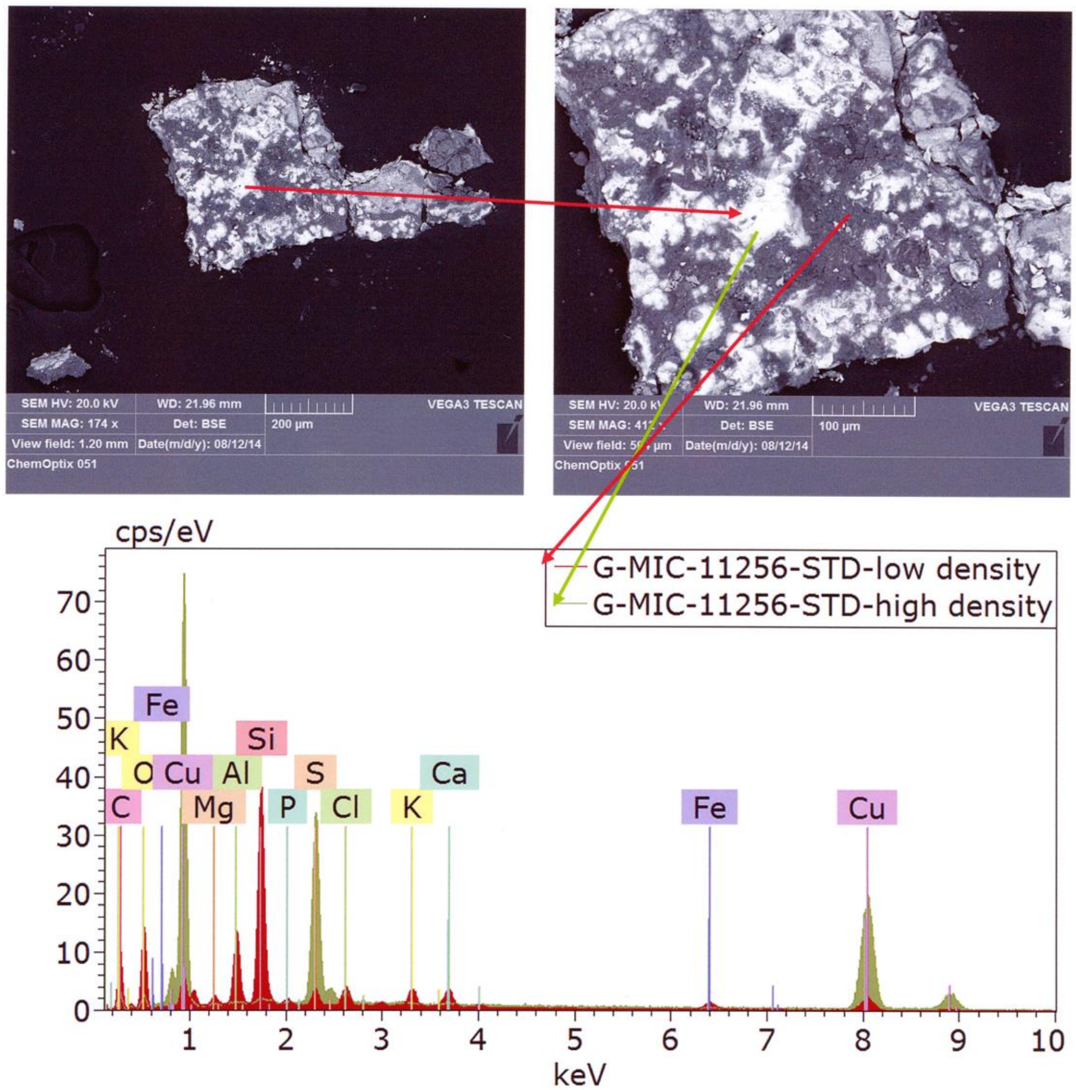
Secondary electron images and energy dispersive x-ray spectrum acquired from sample G-MIC-11256-2.

Figure 8: compounded copper from areas adjacent to the metallic copper recovered in the Paracas Stone and depicted above. Note the traces of silver and tin. The mid-density exhibits the compounded state for copper. Carbon and oxygen are likely presented as carbonate, hence this spectrum likely represents the mineral malachite (hydrous copper carbonate). MIC showed this mineral to be green.



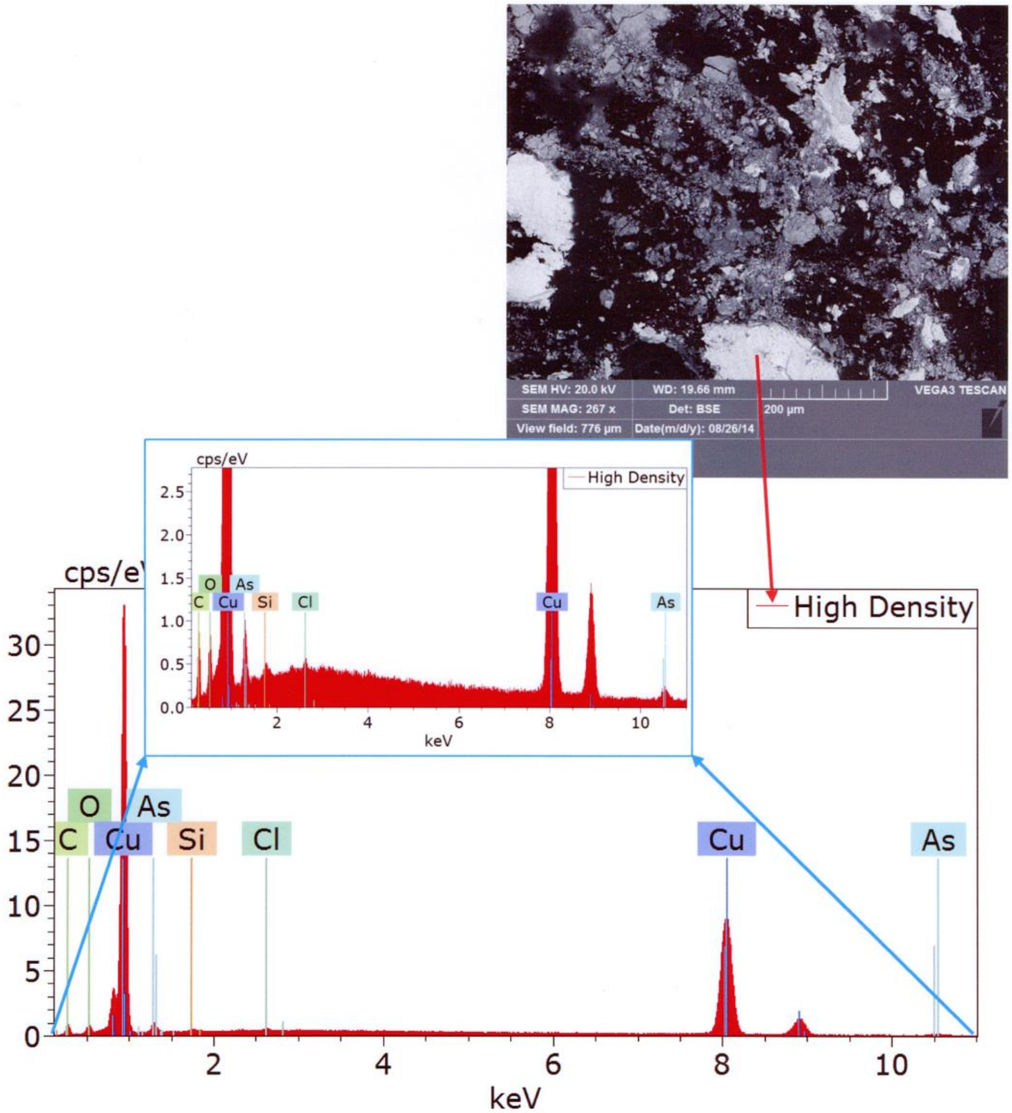
Secondary electron images and energy dispersive x-ray spectrum acquired from sample G-MIC-11256-1.

Figure 9: Area peripheral to *Figure 8* region (Paracas Stone). Copper is still present as malachite or related mineralization, but silver and tin did not diffuse into this region of the sample.



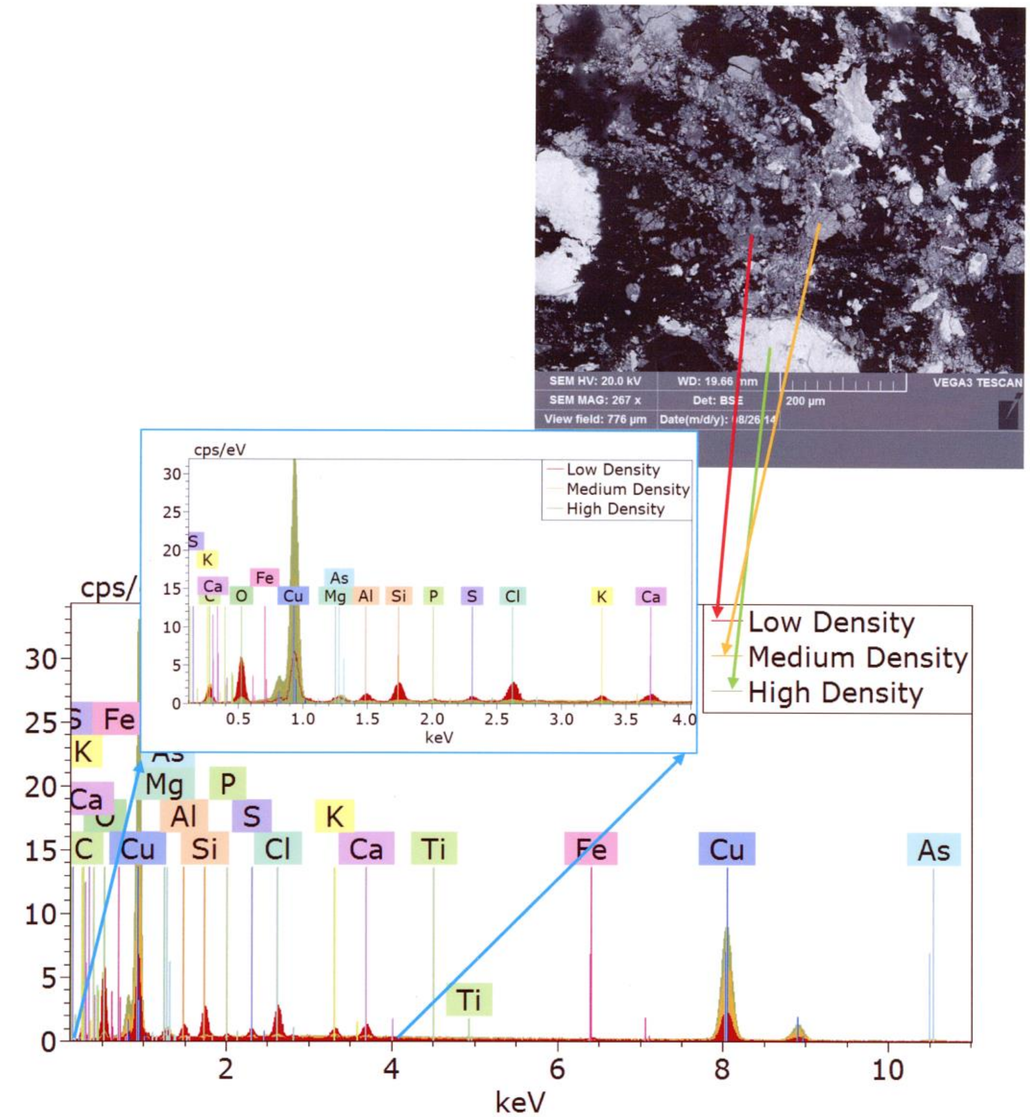
Secondary electron images and energy dispersive x-ray spectrum acquired from sample G-MIC-11256-STD.

Figure 10 EDX of tool reference material: red indicates low electron density; green, metal. Note the lack of silver as well as tin.



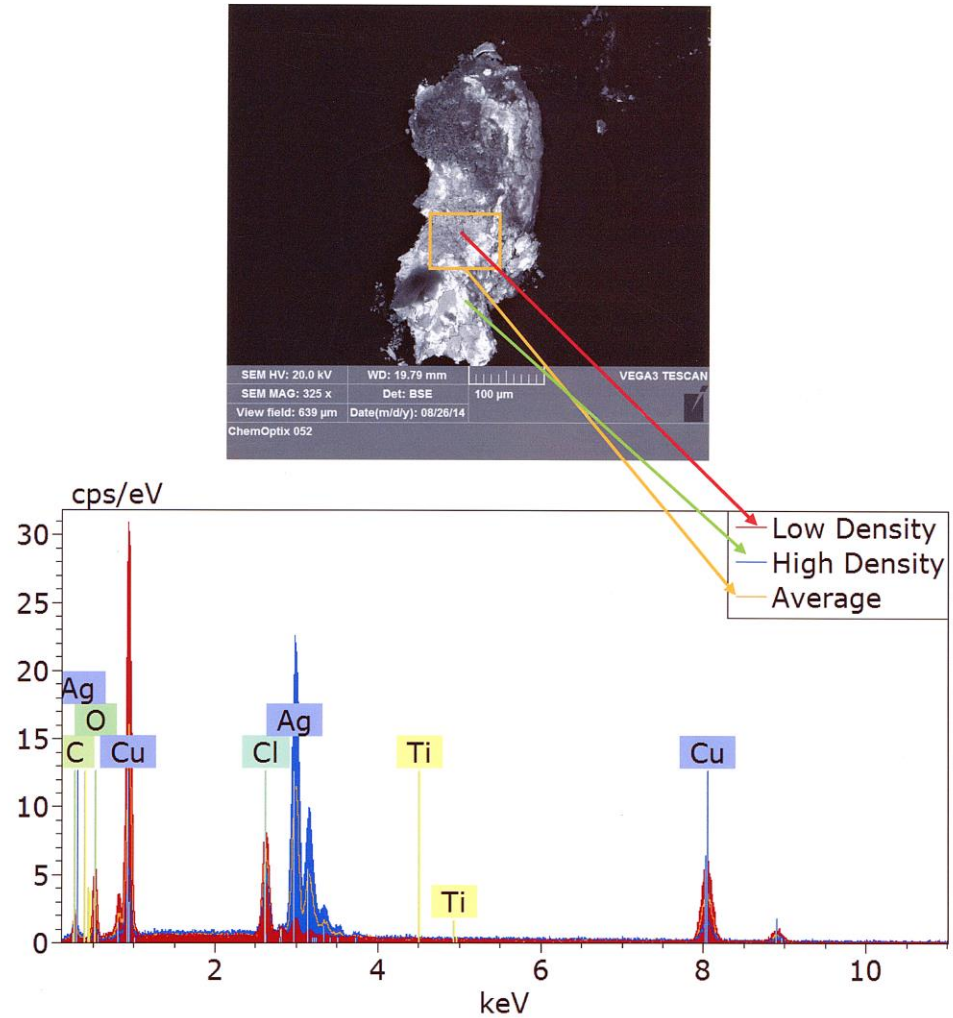
Backscattered electron image and an energy dispersive x-ray spectrum acquired from sample G-11256-B.

Figure 11: Metal spectra of reference tool sample shown at two voltages to show the arsenic but lack of tin and silver.



Backscattered electron image and energy dispersive x-ray spectra acquired from sample G-11256-B.

Figure 12: Composite EDX spectrum of *Figure 11* tool steel and peripheral compounded mineralization. Traces of arsenic are seen but no silver, nor tin.



Backscattered electron image and energy dispersive x-ray spectrum acquired from sample G-11256-C.

Figure 13: EDX spectrum of the third tool reference. Although silver is well represented, tin is not, thus this reference material does not match the Paracas Stone either.