# Copper and Bronze Petra Nails

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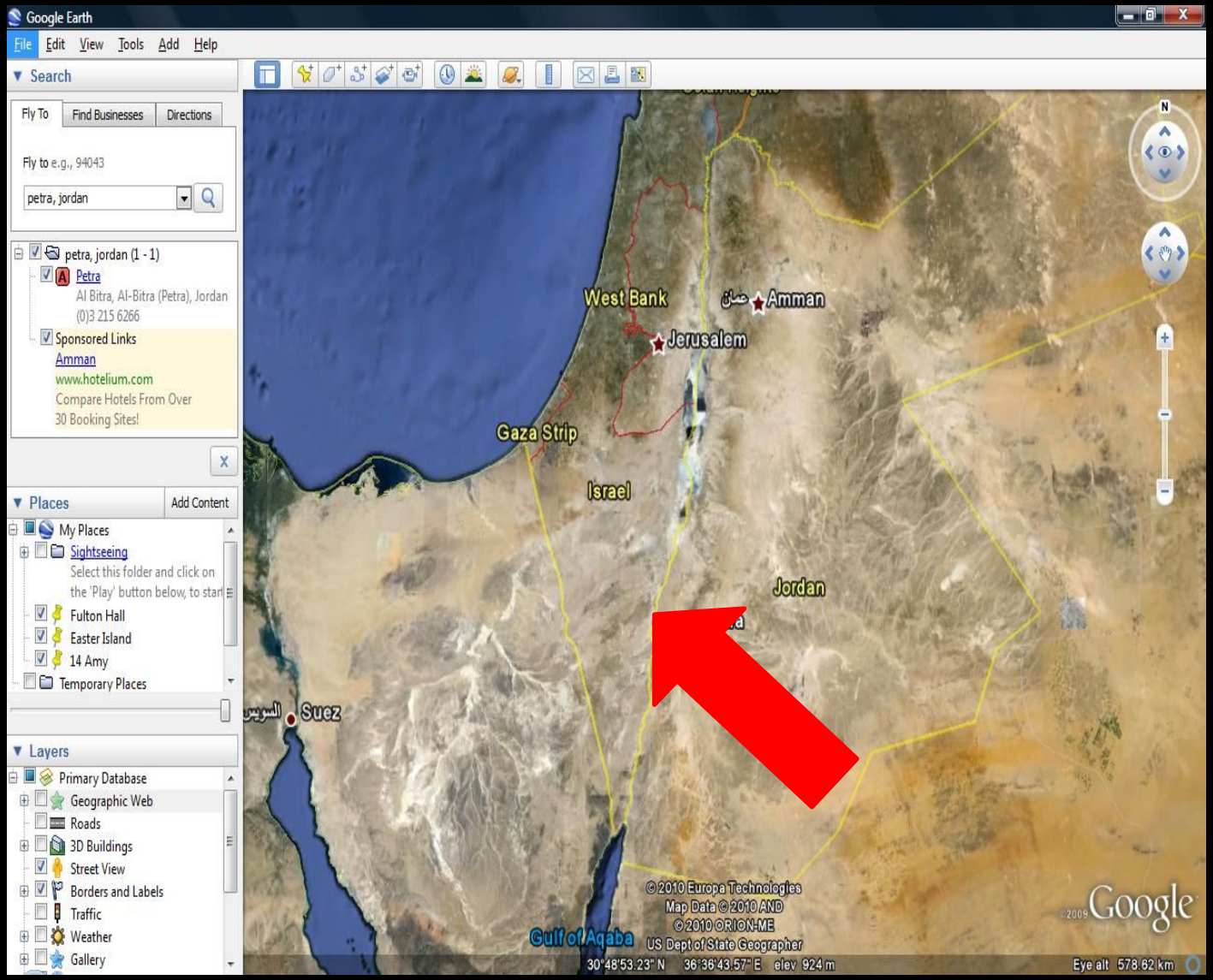
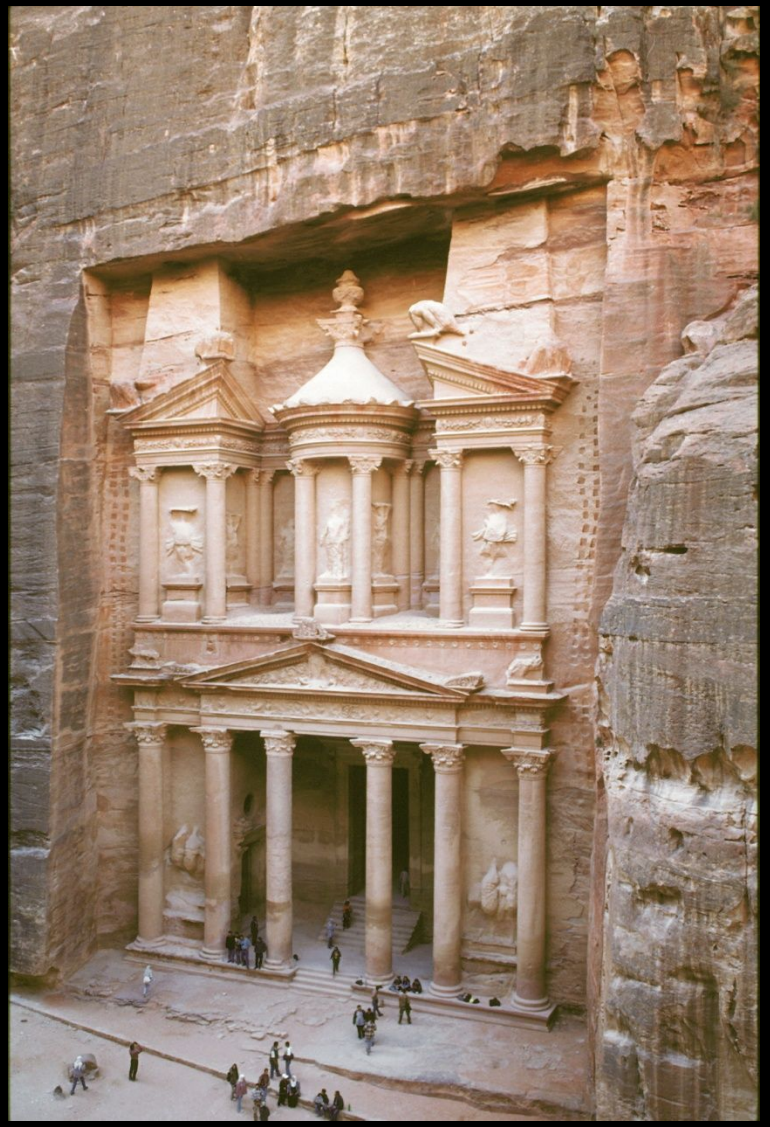
# Petra, Jordan



# Petra

· Occupation as early as 1200 BCE
· The Roman Period (106-551 ACE) marked a time of prosperity in which Petra was a bustling trade center
· Nails could have come from anywhere



# Research Questions

- How much control did ancient metal workers have over the conditions in their forge? Was the forge atmosphere homogeneous? How skilled were the individual craftsmen?
- How consistent was manufacture in the ancient Mediterranean region?

By examining the homogeneity of **microstructure, composition, and mechanical properties** along the length of the nails and comparing the two, we hope to answer the above questions.

# Artifacts


1 – Curved Nail

# Artifacts


2 – Straight Nail

# Technique: Optical Microscopy

Grain and inclusion size, shape, and orient

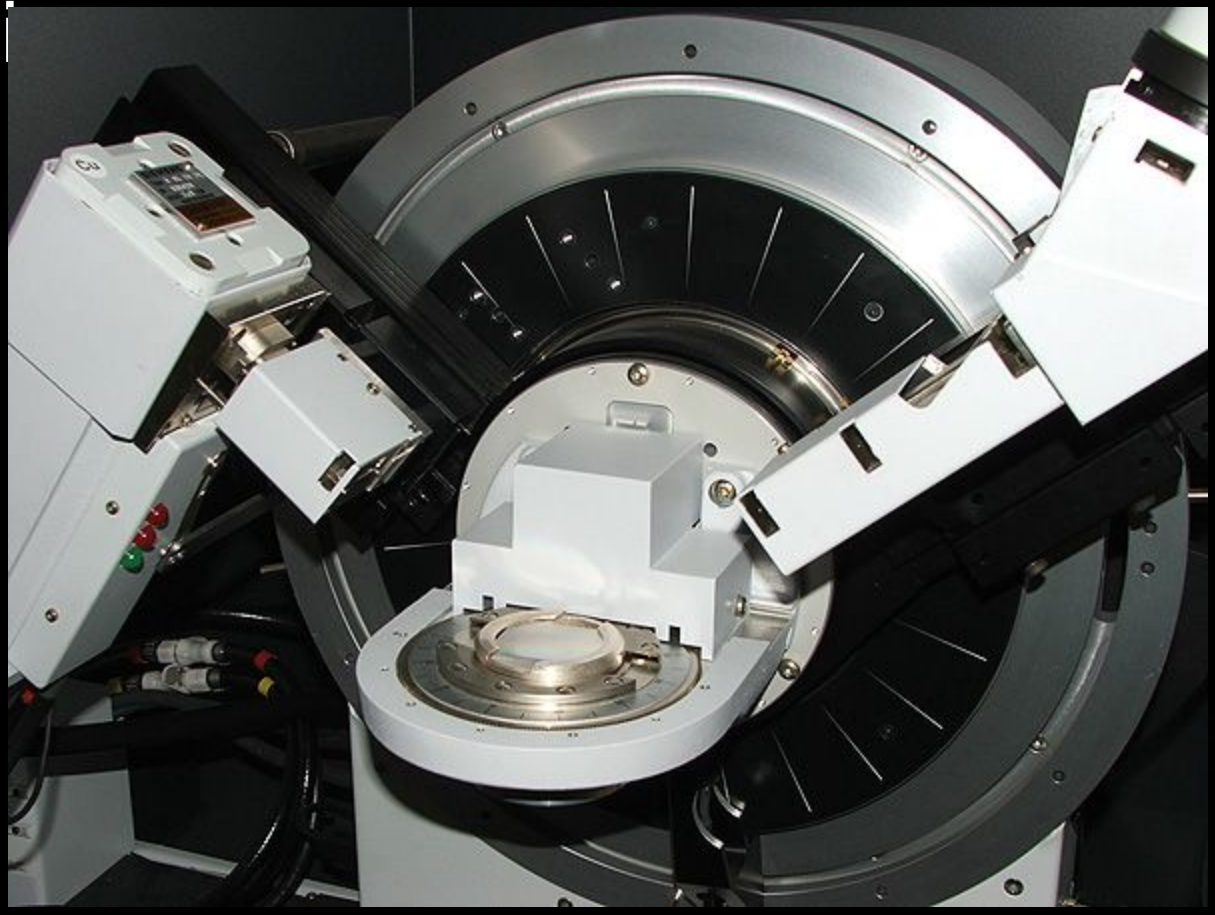

160
x

# Technique: SEM-EDS

Grain and inclusion size, shape, orientation, and local composition

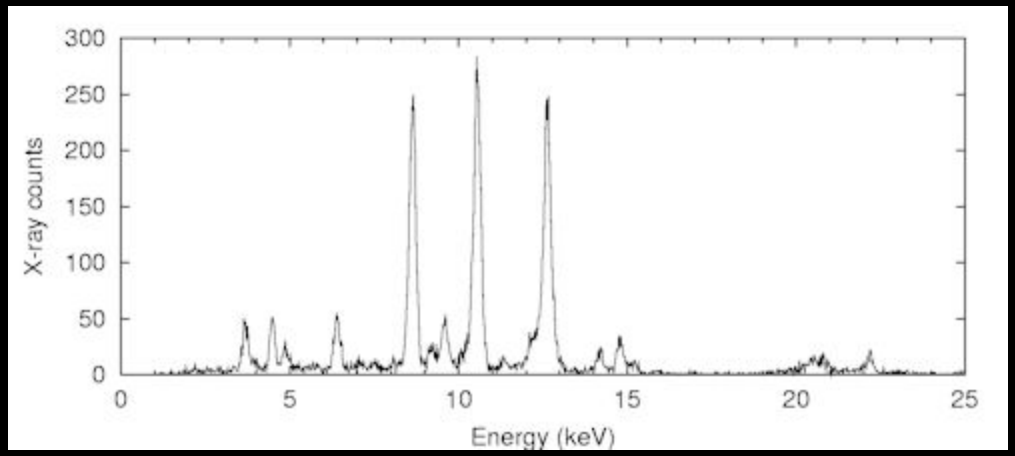
# Technique: XRD

Grain structure and semi-quantitative compositi



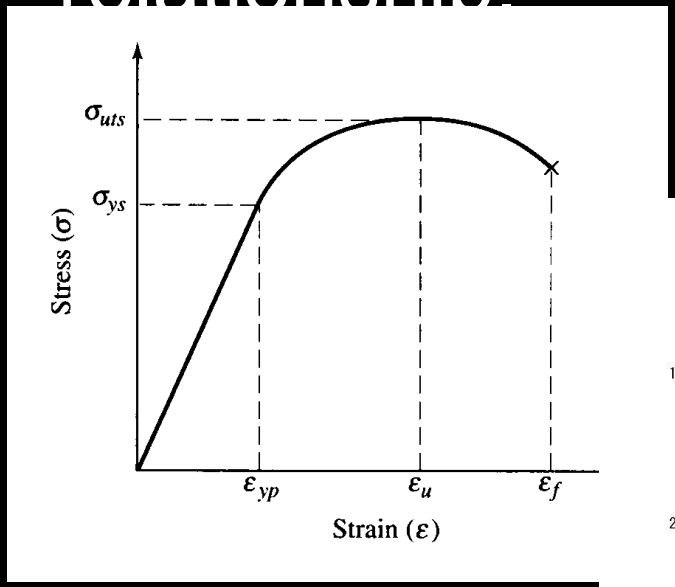
# Technique: XRF

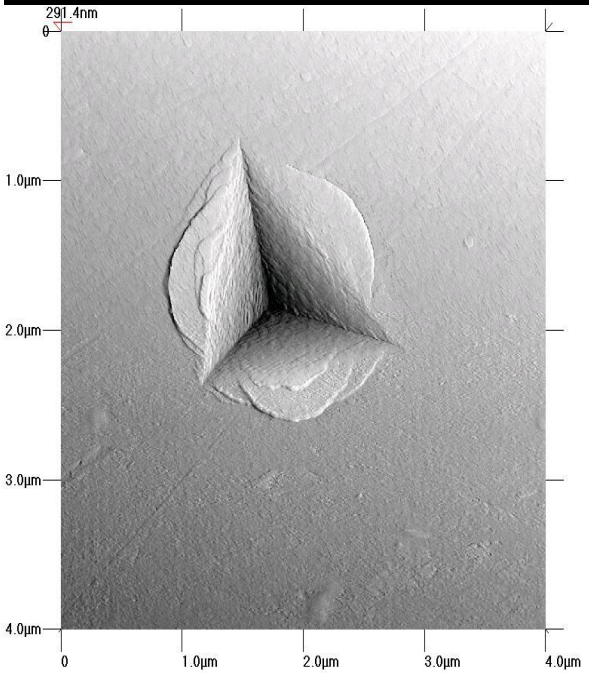
Semi-quantitative composition.




# Technique: Nanoindentation

Mechanical properties: stress-strain relationship




# Optical Microscopy Before Etching

HCl, FeCl3

400
x

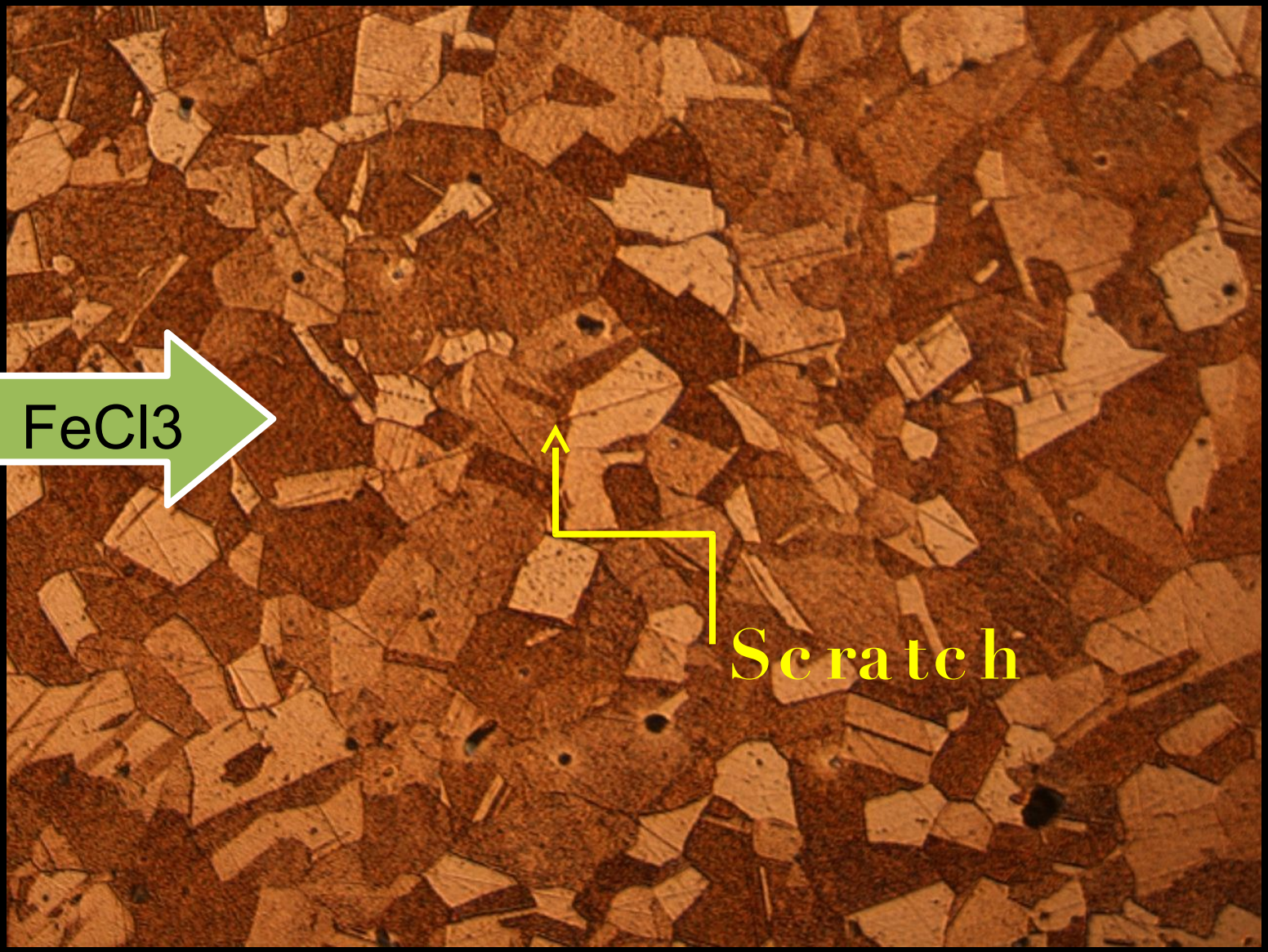

# Etching: 2.2

HCl, FeCl3

Twinning

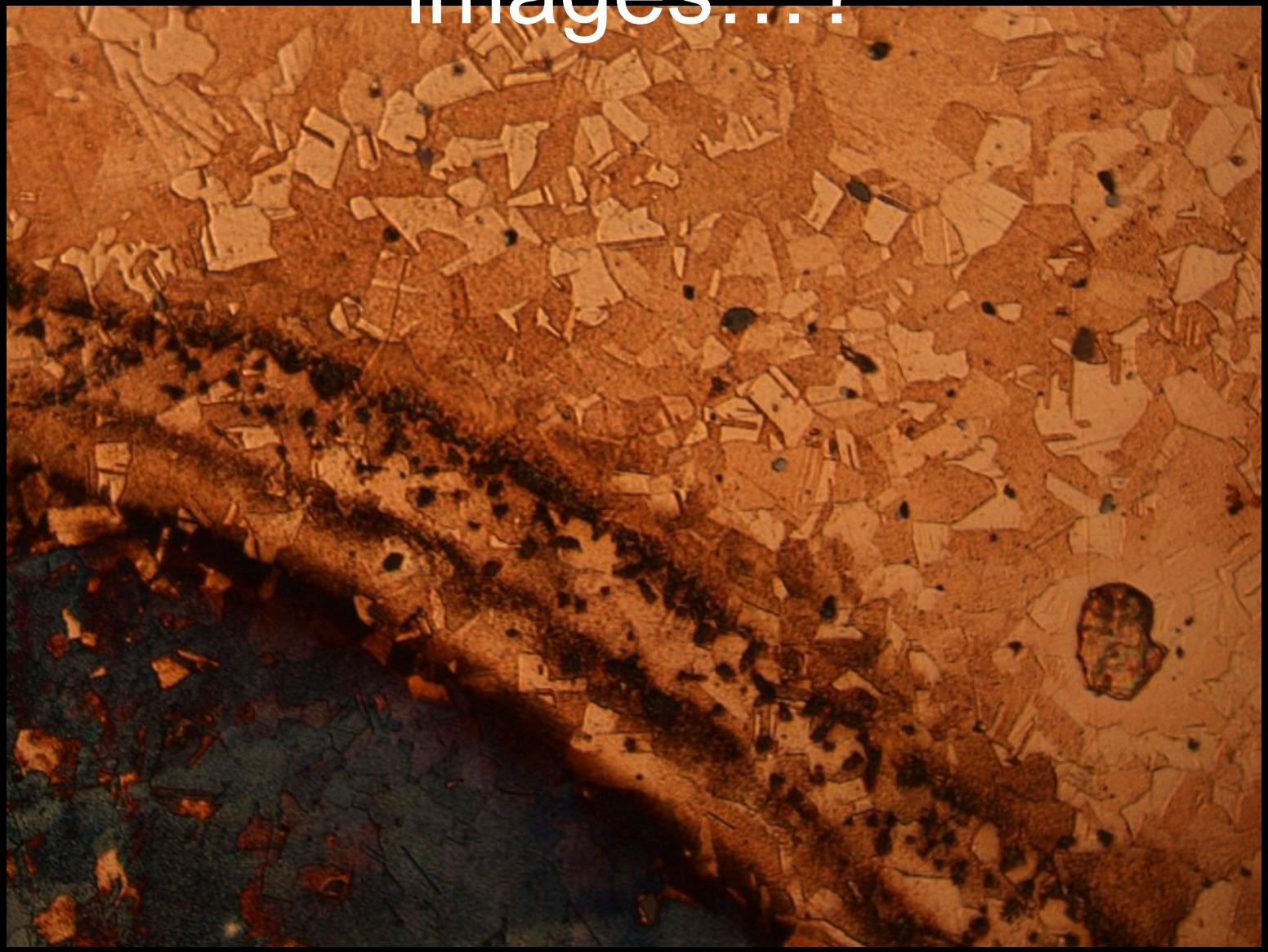
400 x


# Etching: 2.3




400 x

# Some mysterious optical images…?



2.2
400
x

# Some mysterious optical images...2

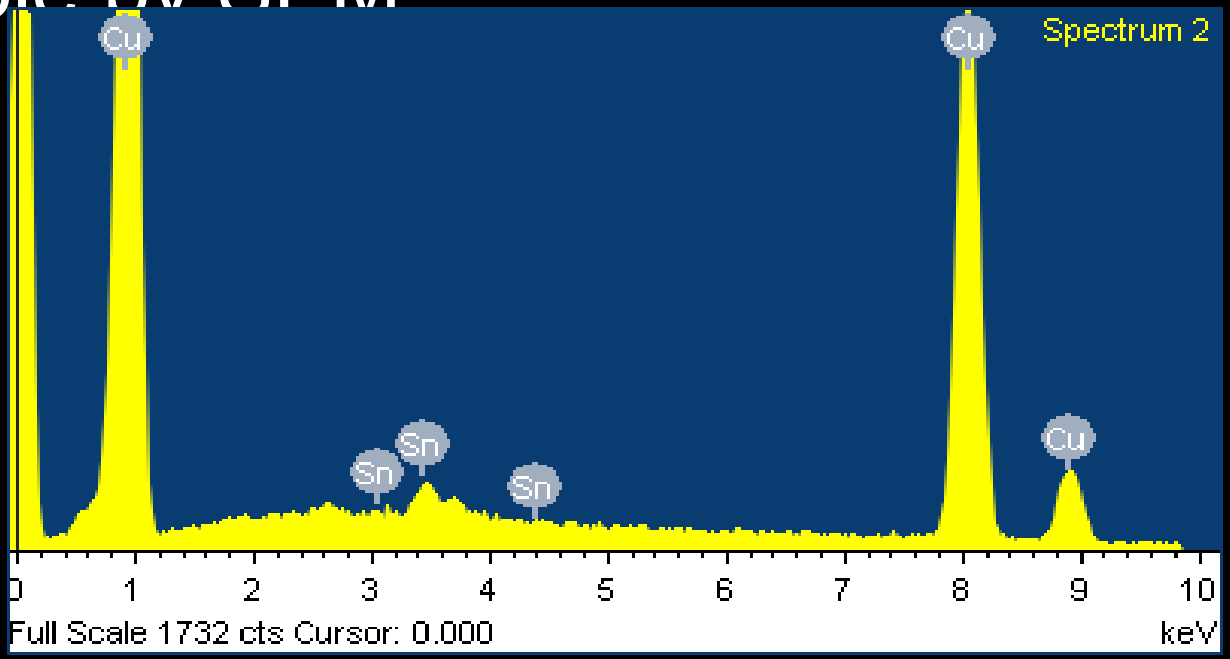
2.2
400
x

# …and some cool images

2.3
160
x

# SEM-EDS

- EDS on nail 2: ~4.05 wt% Sn: Nail 2 is a low-Sn bronze?
- Charging led to no grain structure being visible by SEM



# XRF Results (ppm)

| | Nail 1 | +/- | Nail 2 | +/- |
|---|---|---|---|---|
| Ti | 7060.5 | 355 | 2657.5 | 237 |
| Cr | 390.5 | 35.5 | 109.5 | 21.5 |
| Mn | 1216 | 52.5 | 215.5 | 25.5 |
| Fe | 49828 | 980.5 | 9577 | 303.5 |
| Cu | 790344.5 | 31203.5 | 344280.5 | 8783 |
| Zn | 429 | 683.5 | 1617.5 | 158.5 |
| As | 1086.5 | 56 | <LOD | 73 |
| Sn | <L D | 176 | 70 3 | 201.5 |
| Pb | 10 .5 | 14 | 52 | 27 |

Pure Copper

Low-Sn Bronze

Under t in g, Cd, Hg, Se

Trace: Rb, Sr, Zr, Mo, Sb

Ignored (Corrosion, Styrofoam, or “Seal Wrap”): K, Ca, Ba, P,

# Future Directions

- Grinding, polishing, etching, and imaging the other six samples
- Quantification of grain sizes
- Nanoindentation to determine mechanical homogeneity along the length of the nails
- XRD to determine grain structure and perhaps composition along the Cu and the Bronze nail