Copper Pitting Corrosion and Pinhole Leaks: A Case Study

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Introduction
Pitting and Pinhole Leaks

Leads to leaks, water damage, mold

Costly plumbing repairs

Complicated

- Material, water quality, microbial

Does not geanerally result in high copper levels

Objective

- Analyze copper pipes that have signs of pitting corrosion (Wynds of Liberty subdivision)
- Suggest mechanism of pitting corrosion
- Future Work

Approach

X-ray Diffraction

- Identification of crystalline minerals
- Crystal size approximation

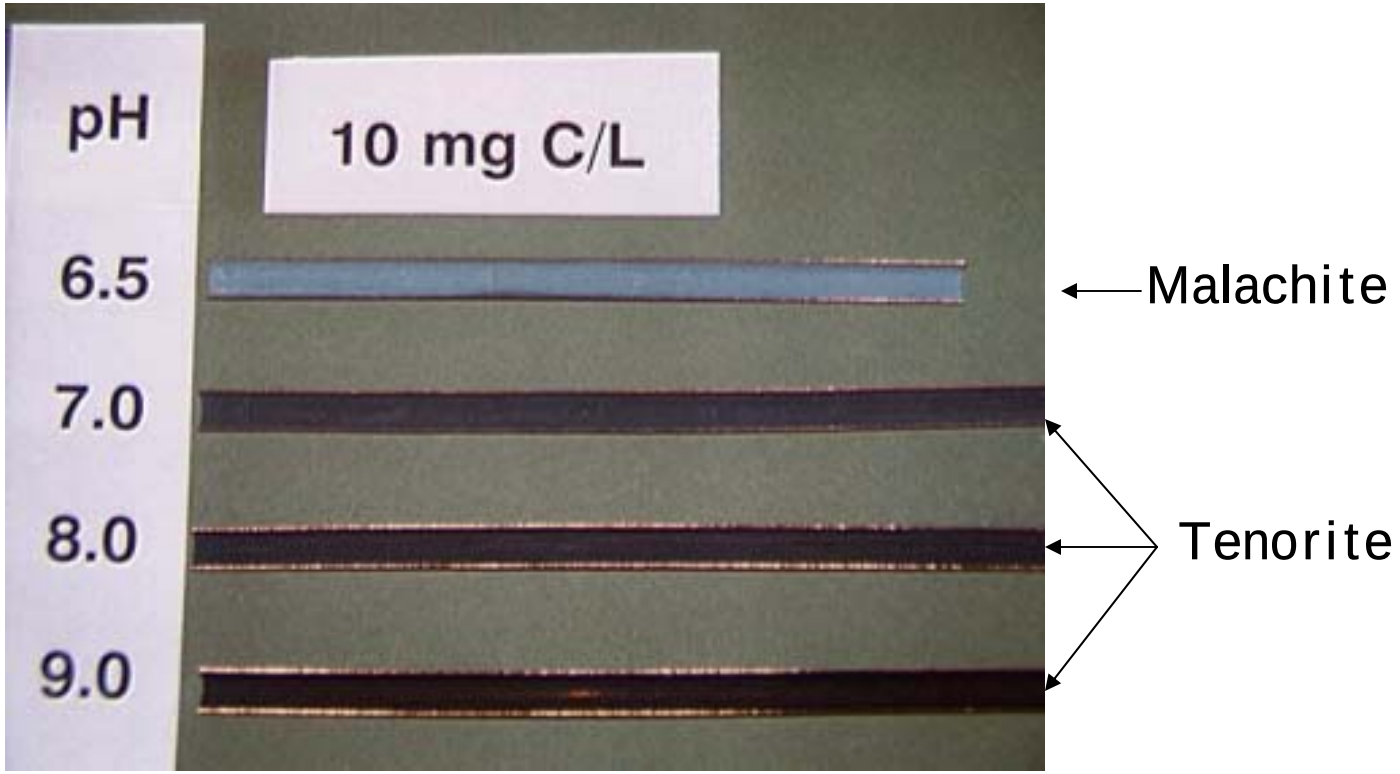
SEM - Energy Dispersive Spectrometry

- High magnification micrographs
- Elemental composition and mapping

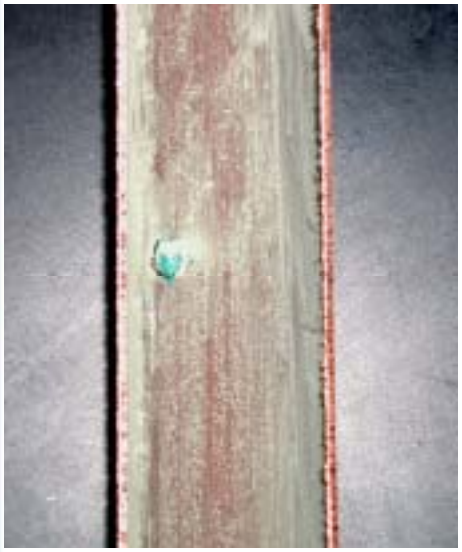
Overview of Copper Corrosion

- Uniform Corrosion
- Erosion Corrosion
- Localized Corrosion (pitting)
  - Type I – Cold Water
  - Type II – Hot Water
  - Type II – Soft Water

Uniform Corrosion of Copper



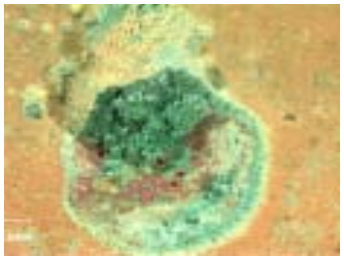
Pitting Comparison

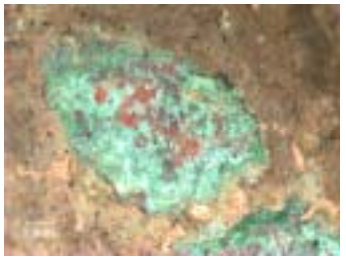


Ohio site #1

Wisconsin

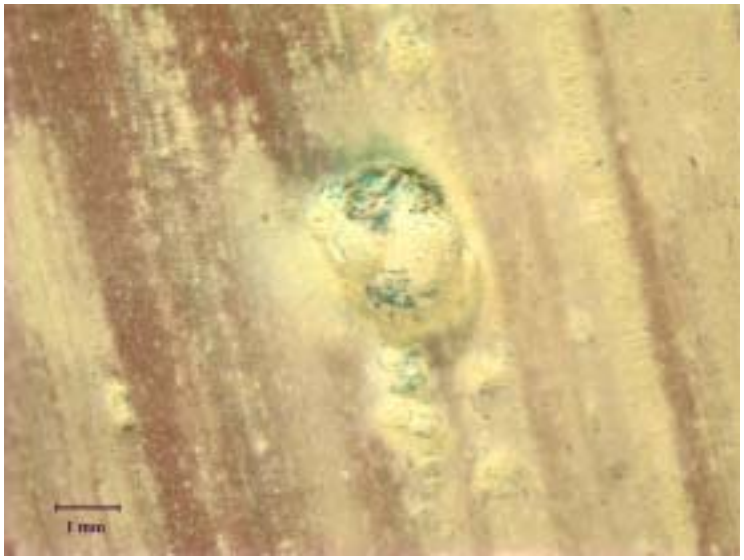
Ohio site #2





All micrographs taken at 10x

Localized Corrosion (Pitting)



Pitting is a localized acceleration of corrosion that results in the thinning of the pipe wall in the effected area.

Localized Corrosion (Pitting)

- Type I – Cold Water Pitting
  - Attacks horizontal runs of cold water pipes in systems using well waters with a high sulfate to chloride ratio
- Type II – Hot Water Pitting
  - Occurs in hot water with a pH below 7.2
- Type III – Soft Water Pitting
  - Occurs in soft water below pH 8.0

Copper Pitting and the Consequences

- Costly Repairs
- Leaks may go undetected in walls or basements
- Pinhole Leaks
  - Mold and Mildew
  - Liability Issues
- Does not lead to high copper levels at the tap

Pinhole Leaks

Pinhole leaks resulting from copper pitting

Case Study
General Observations

- Cold water
- Horizontal runs of pipe
- ¾ and 1/2“ pipe
- Homes are about 7 years old
- Leaks occur near elbows and joints as well as in long runs
- No preference for the top or bottom of a pipe

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Case Study

¾" pipe

½" pipe

Elbows and joints

Water leaks

Pipe Cross-Section

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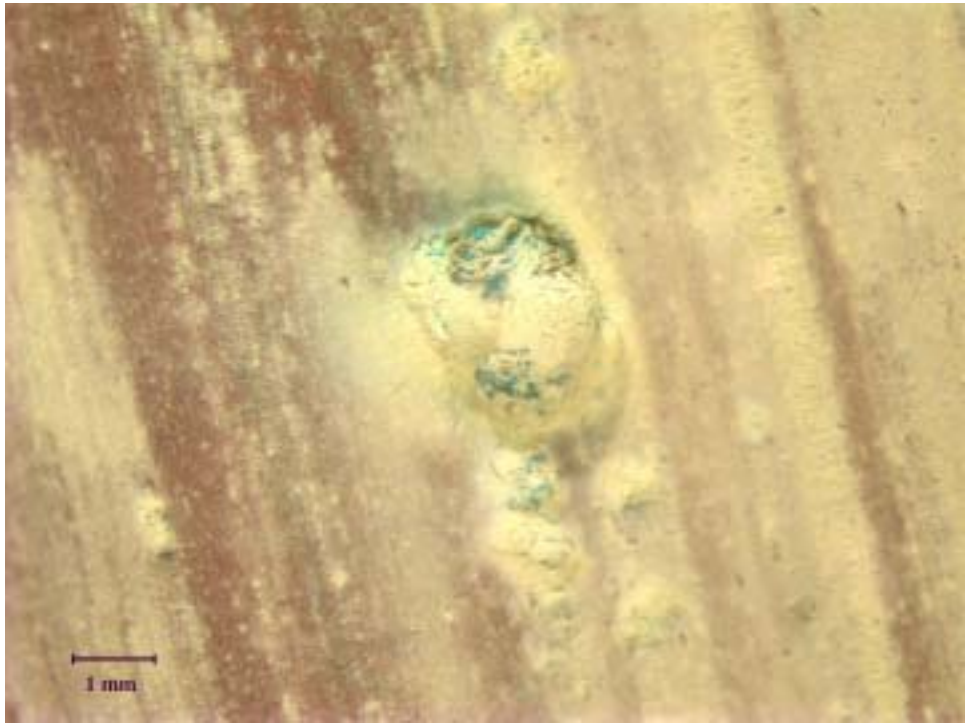
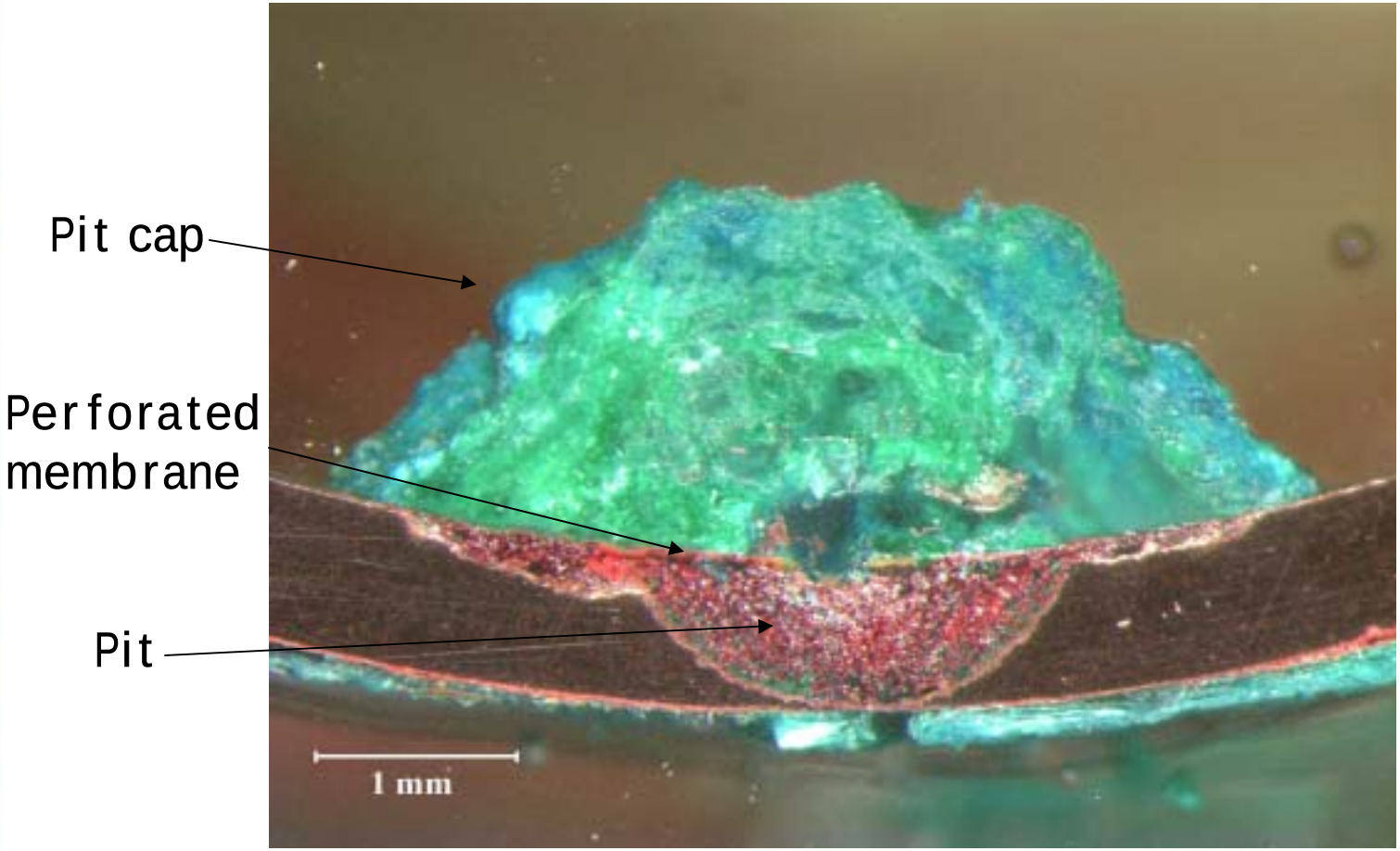
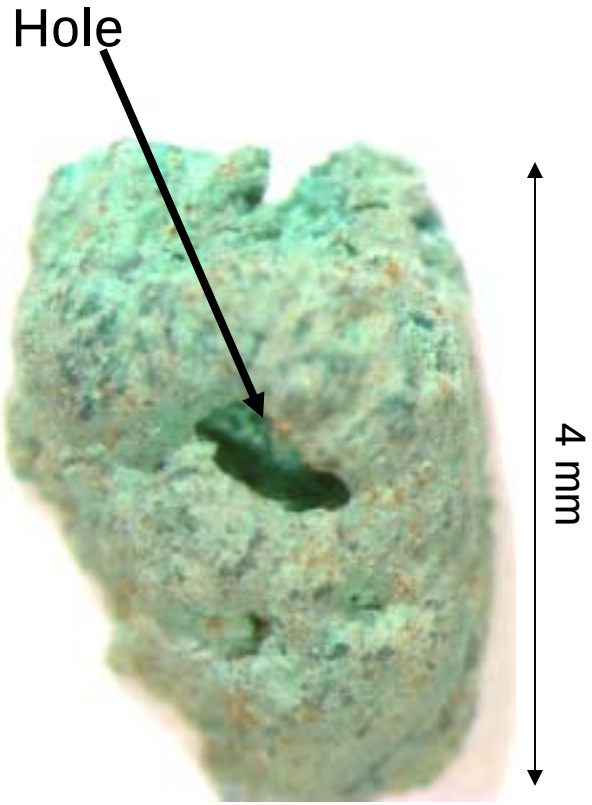
Anatomy of a Pit

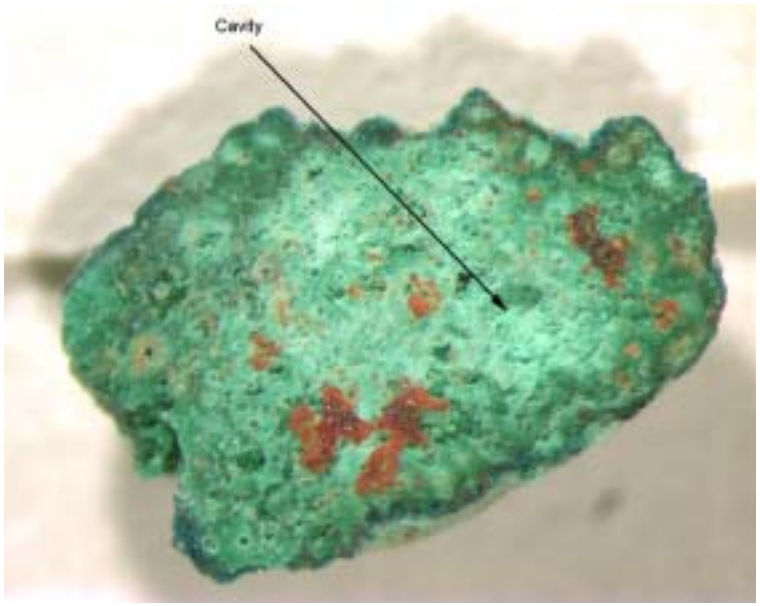


Anatomy of a Copper Corrosion Pit



The Corrosion Cap



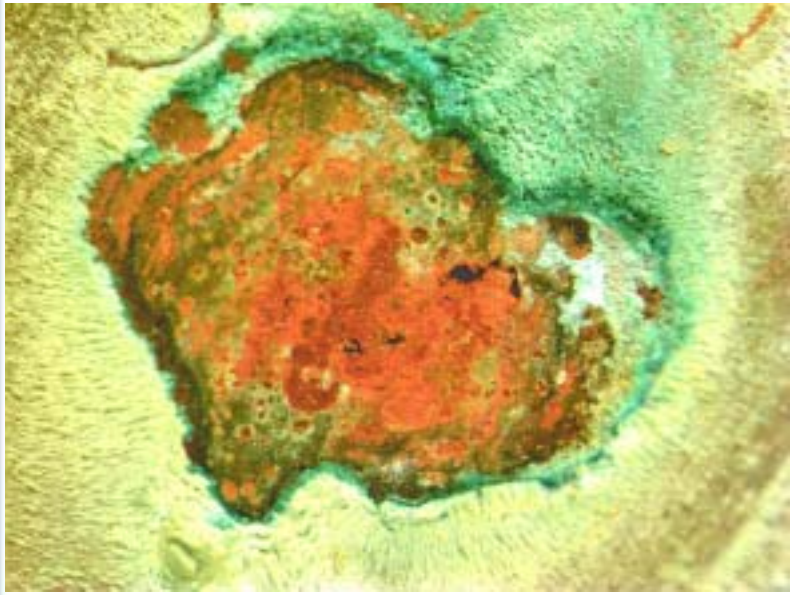


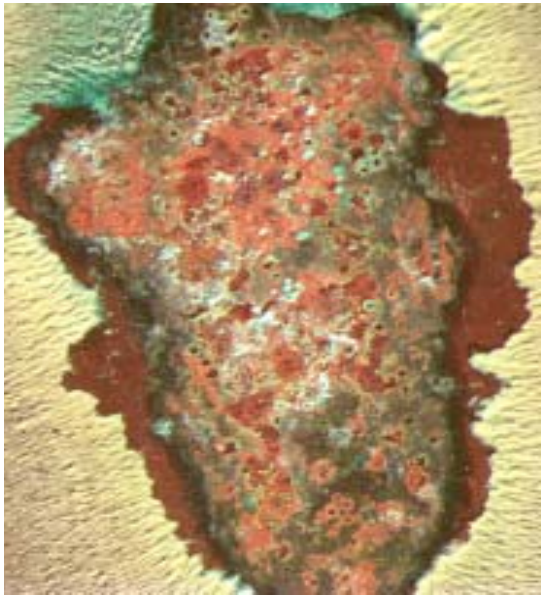
- Brochantite – $Cu_4(OH)_6(SO_4)$
- Ponsjakite – $Cu_4(OH)_6(SO_4)*H_2O$

Cap Analysis

- Brochantite – $Cu_4(OH)_6(SO_4)$
- Ponsjakite – $Cu_4(OH)_6(SO_4)*H_2O$

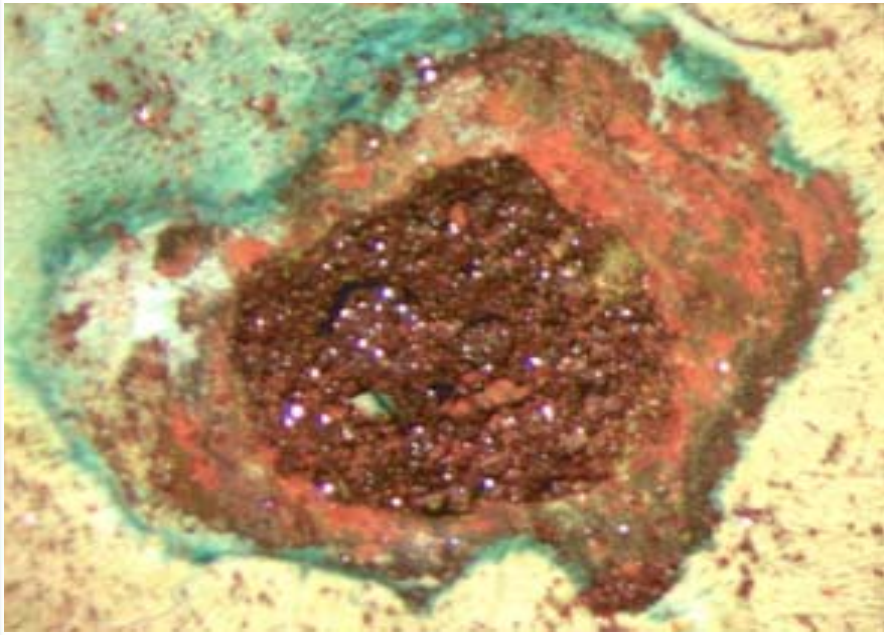
Perforated Membrane

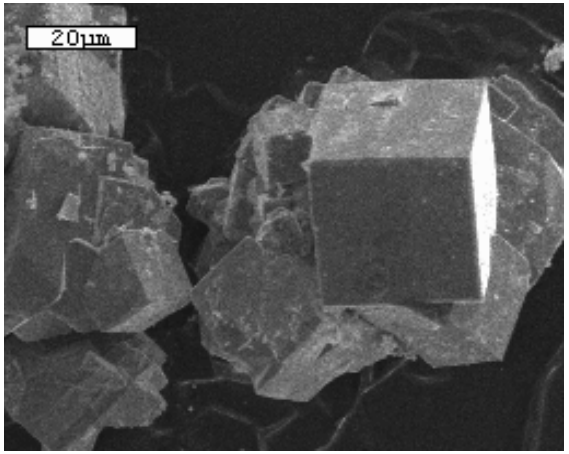


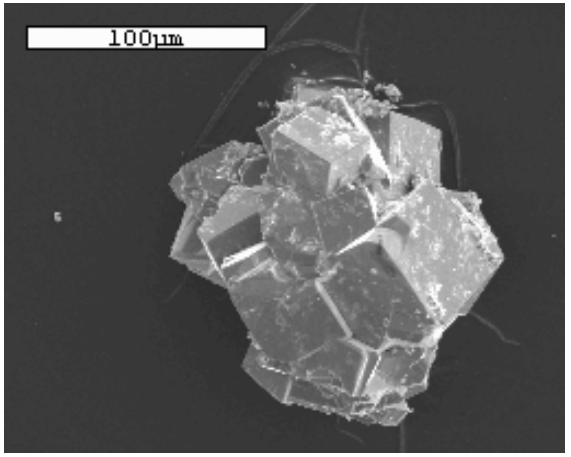


Literature suggests that the membrane consists of cuprite.

Breaking Through the Membrane

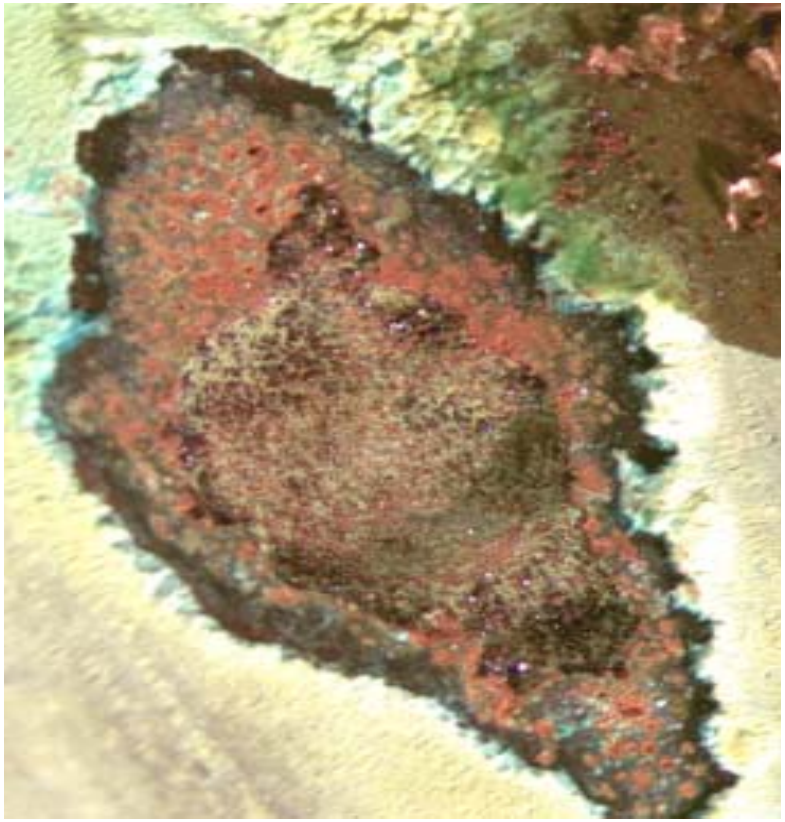




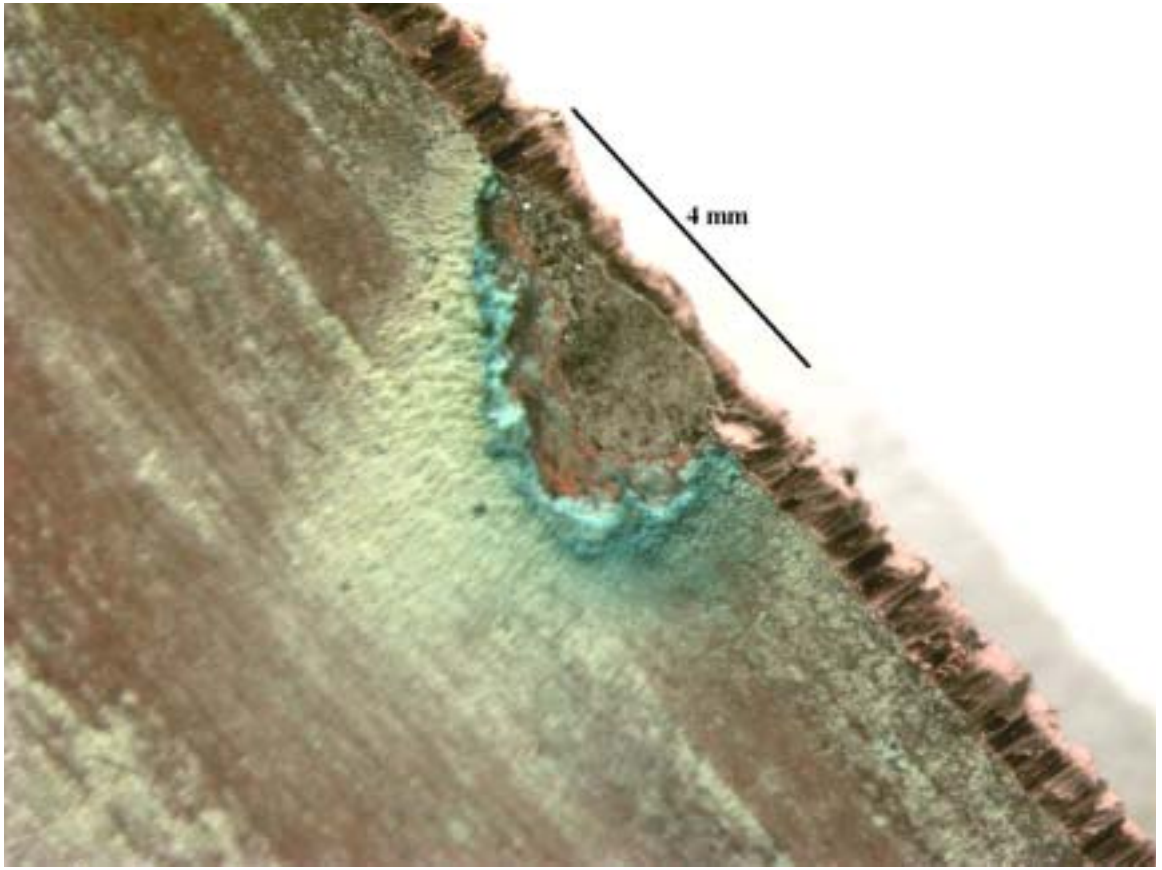


Pits are loosely packed with cuprite crystals beneath the permeable membrane

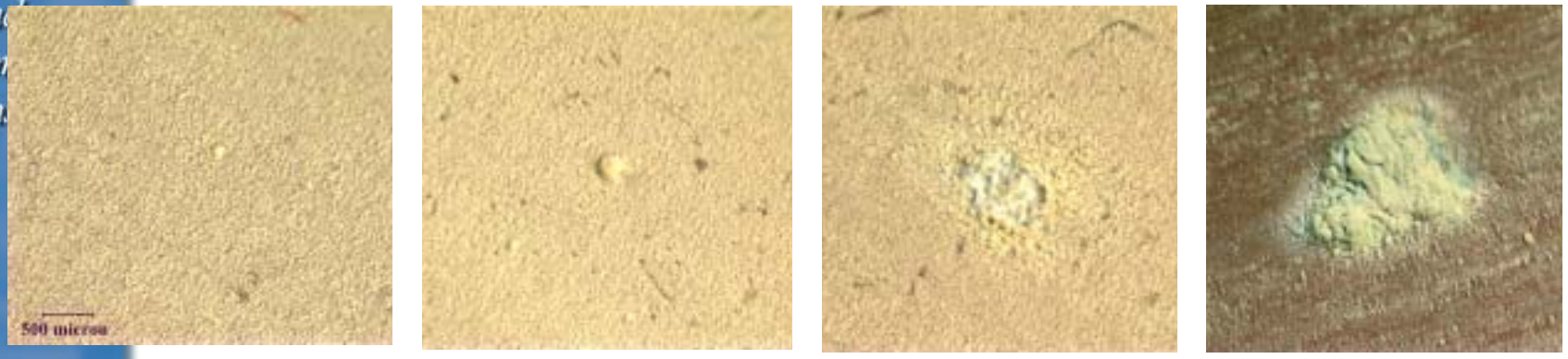
A Dissected Pit Reveals the Extent of the Damage



Cross-Section of a Pit



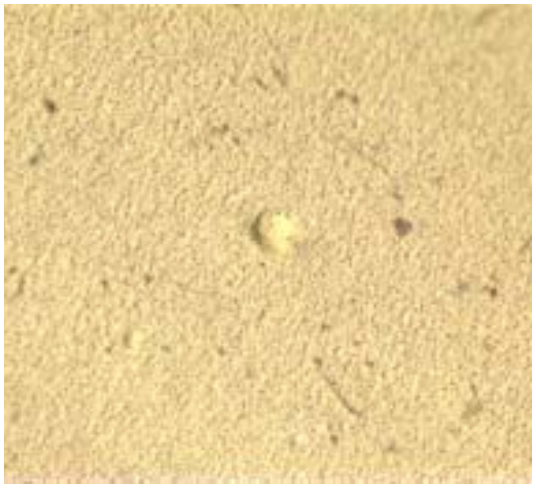
Pit Propagation

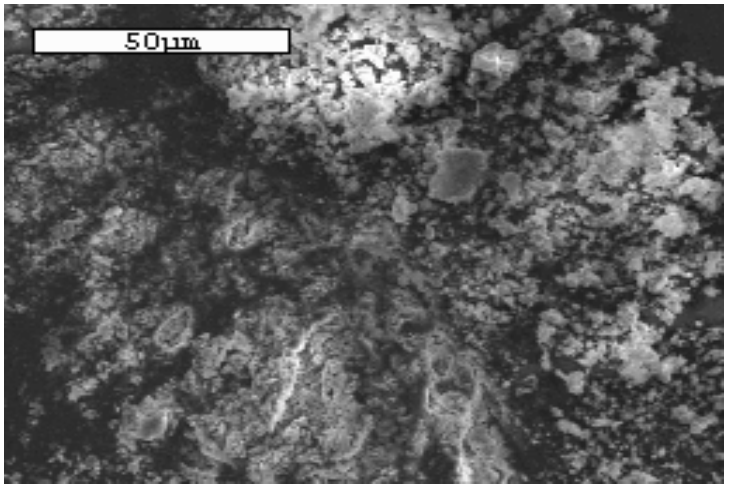


Particle deposition, particle growth, and corrosion cell formation

All pictures taken at same magnification

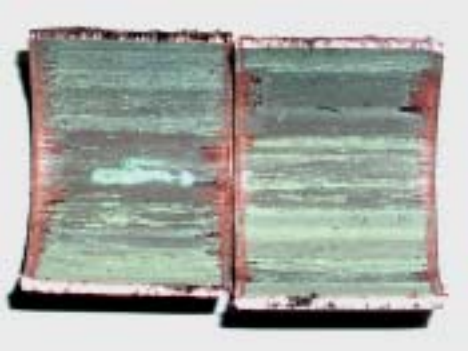
EDS Analysis of Particle

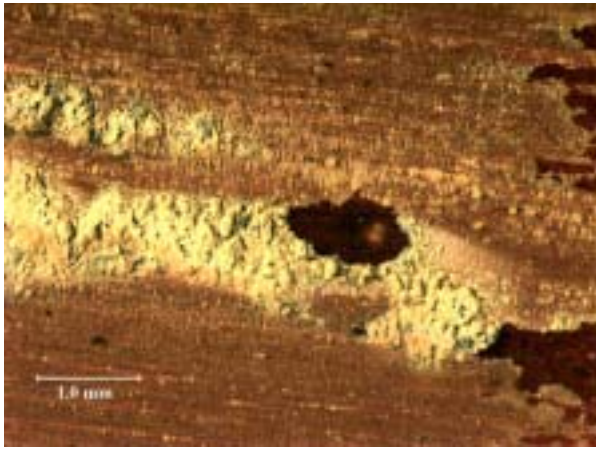


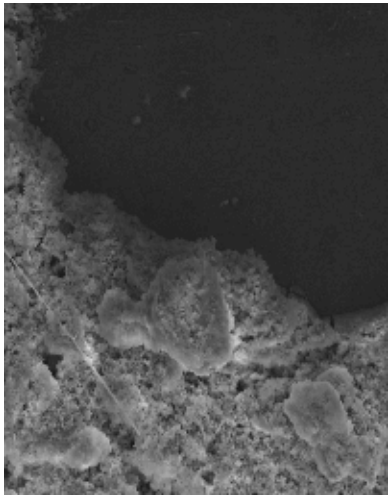


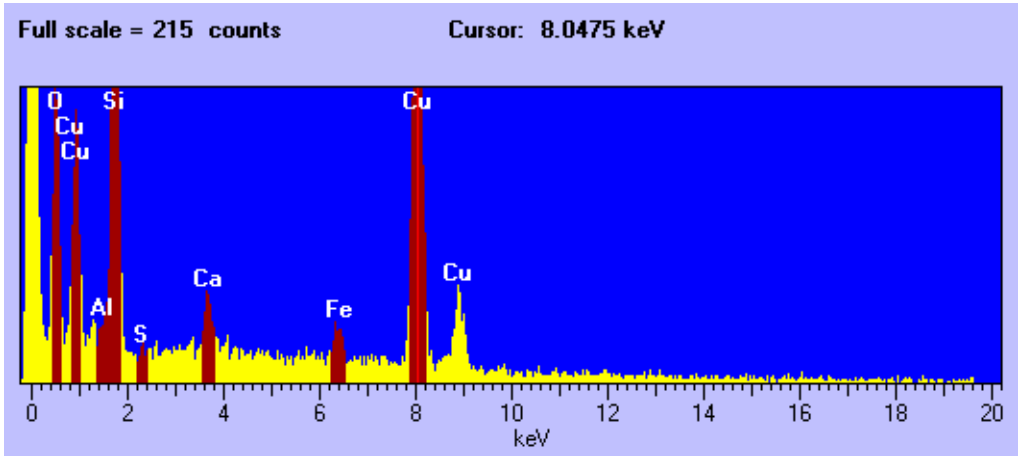
- Copper
- Aluminum
- Silicon
- Magnesium
- Oxygen

Hot versus Cold Water Plumbing

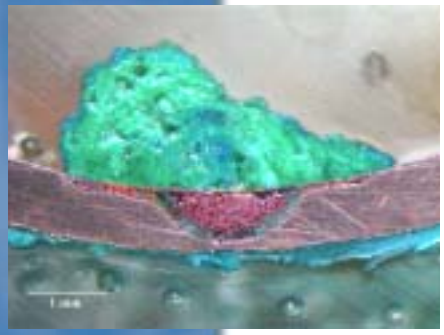








Hot versus Cold Water Plumbing



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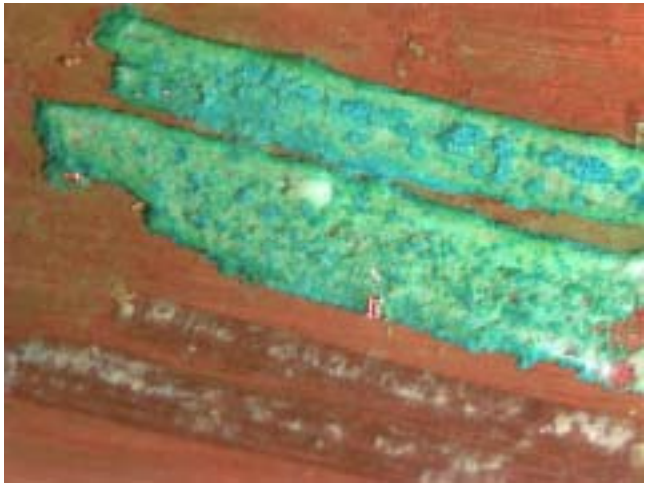

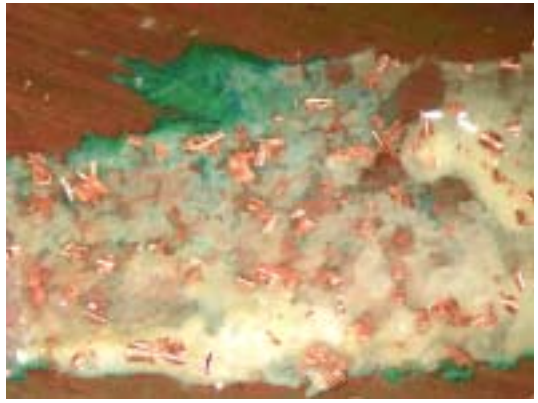

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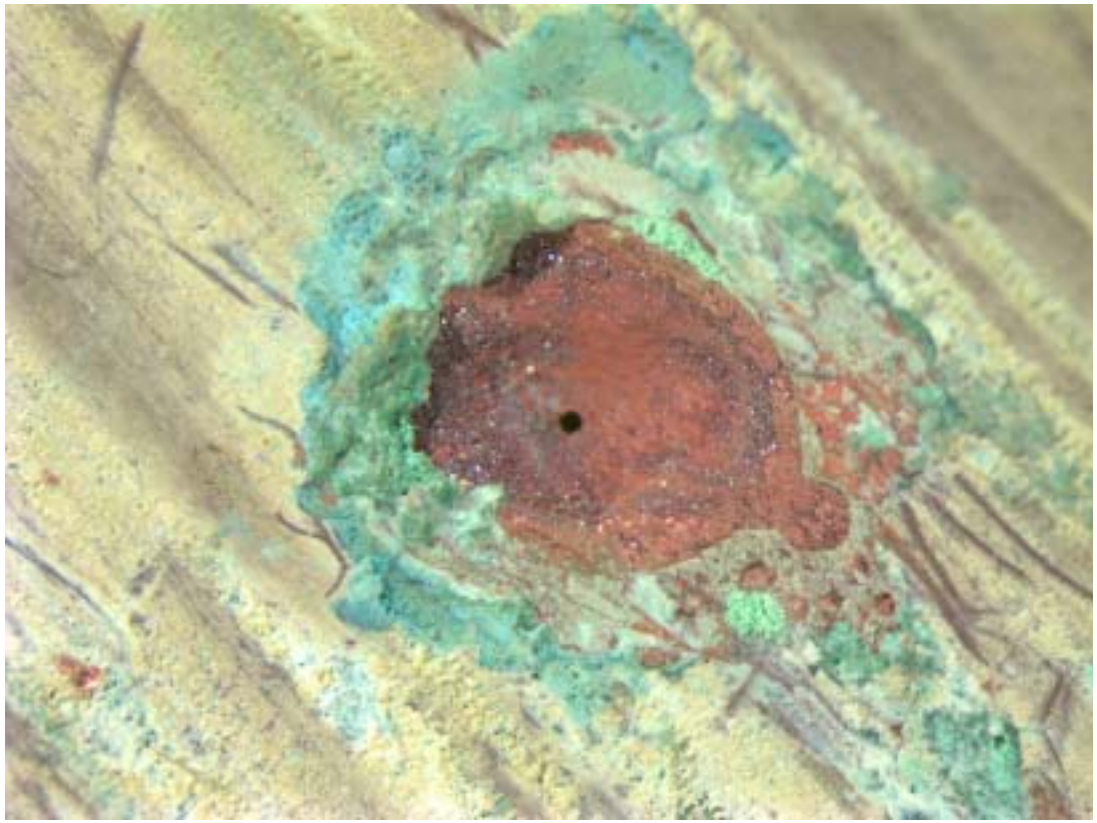

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Future Work

- Survey individuals
- Contact plumbers and plumbing suppliers
- Examine more pipe
  - Carefully remove pipes
  - Microbiological analysis
- Water heater solids
- Sample distribution system water
- Cement Leaching Study

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Acknowledgements

Michael R. Schock – U.S.EPA

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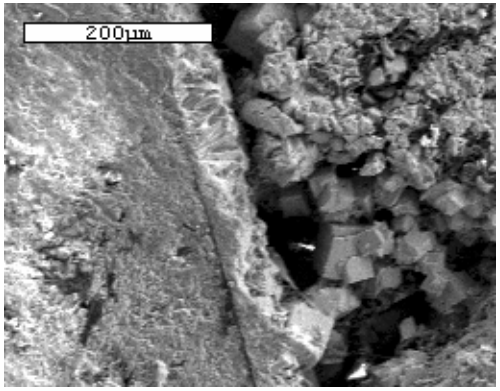

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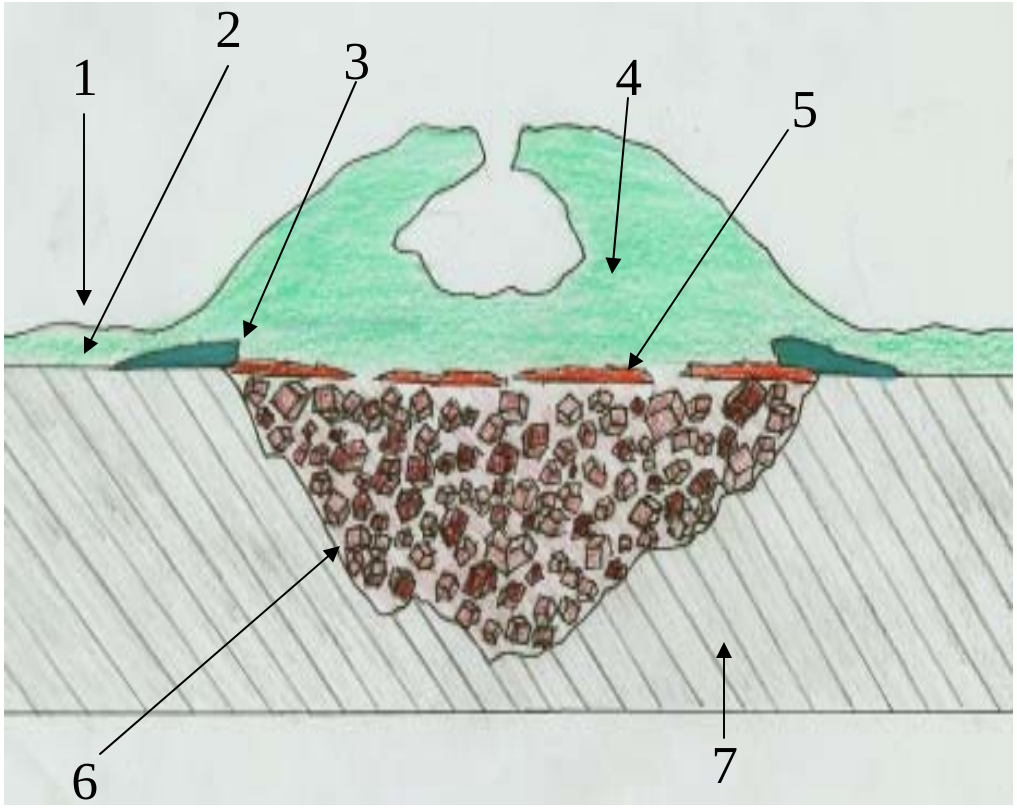
Thank You

Schematic View of a Copper Corrosion Pit



1. Diffusion Barrier – Calcium Carbonate
2. Uniform Corrosion Scale
3. Cu, Al, Si, Mg rich solid
4. Corrosion Cap – Bronchantite [$Cu_4(OH)_6(SO_4)$], Ponsjakite –[$Cu_4(OH)_6(SO_4)*H_2O$
5. Brittle Perforated Membrane
6. Corrosion Pit Filled with Cuprite
7. Pipe Wall