Summary of Corrosion Studies for Copper Canisters

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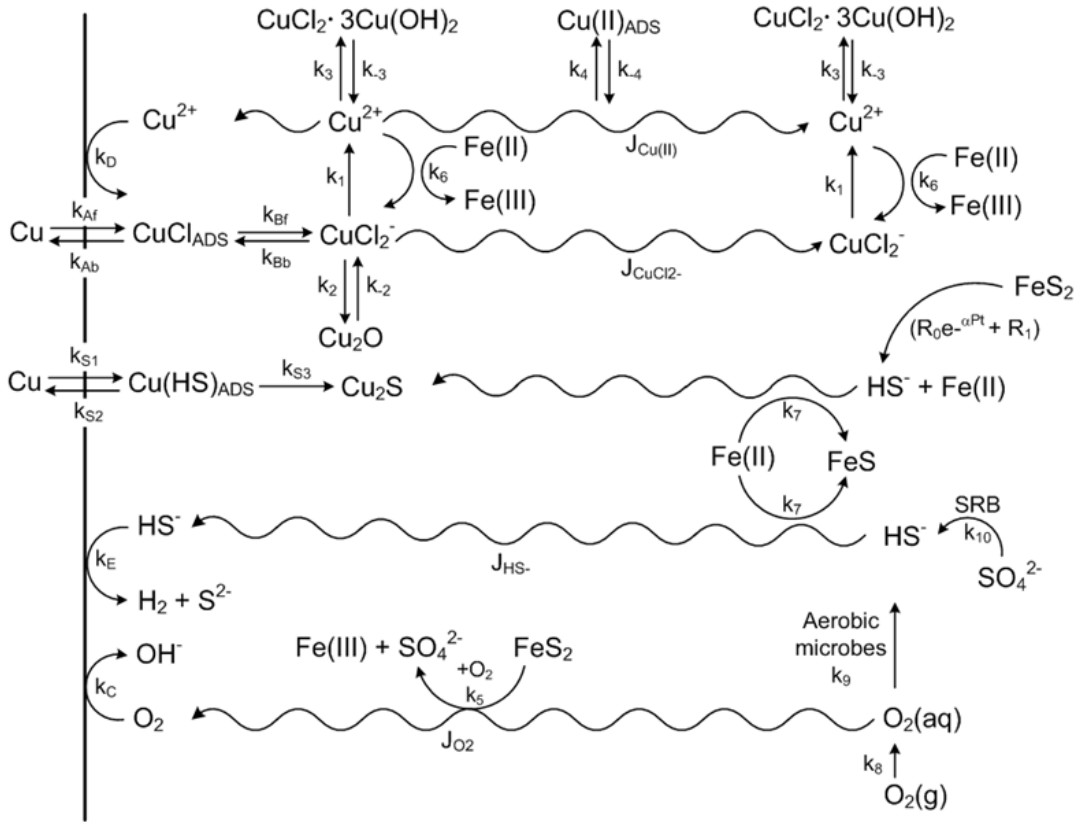
Timeline

- 1978: SKB TR-90 initial corrosion study
  - Swedish Corrosion Institute
- 1983: KBS-3 repository design and updated corrosion assessment
- 1980's: Experimental studies in Sweden, Canada, Switzerland
  - General corrosion, localised corrosion
  - Study of archaeological artifacts
- 1990's: Continued experimental studies and development of models
  - Effects of stress
  - Development and validation of models
- 2000's: Lab and large-scale test at Äspö
  - Effect of microbes, stress, …..
  - *In situ* tests in underground laboratory
- 2010's Continuing investigations of specific issues
  - Corrosion in water, validation of models, …

Corrosion mechanism of copper

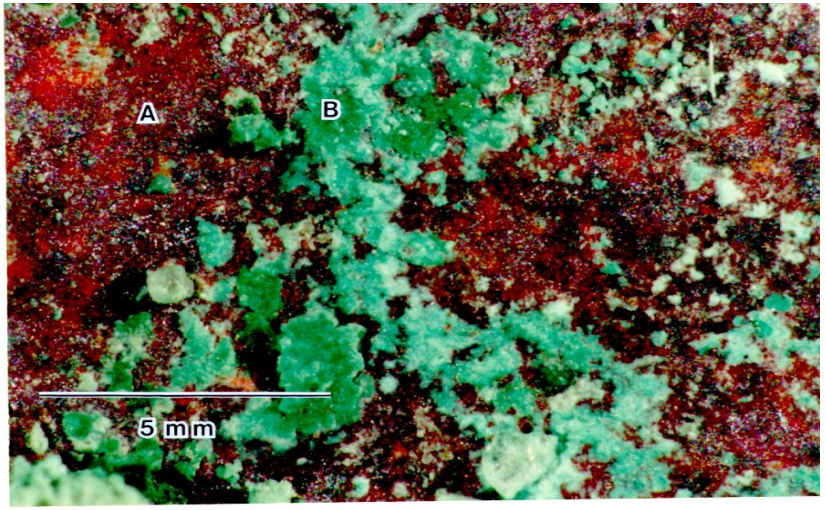
• From all of these corrosion studies we have developed a good understanding of how the canisters will corrode



- Key issues are:
  - the limited amount of oxygen
  - the slow rate of supply of other corrosive species (sulphide)

Summary of corrosion studies

- General corrosion
  - Limited by availability of oxidizing species (oxygen and sulphide)
- Localized corrosion
  - Surface is rough but does not “pit”
- Effect of stress
  - Canister will not crack
- Effect of microbes
  - Microbes activity is extremely limited
- No preferential corrosion at welds

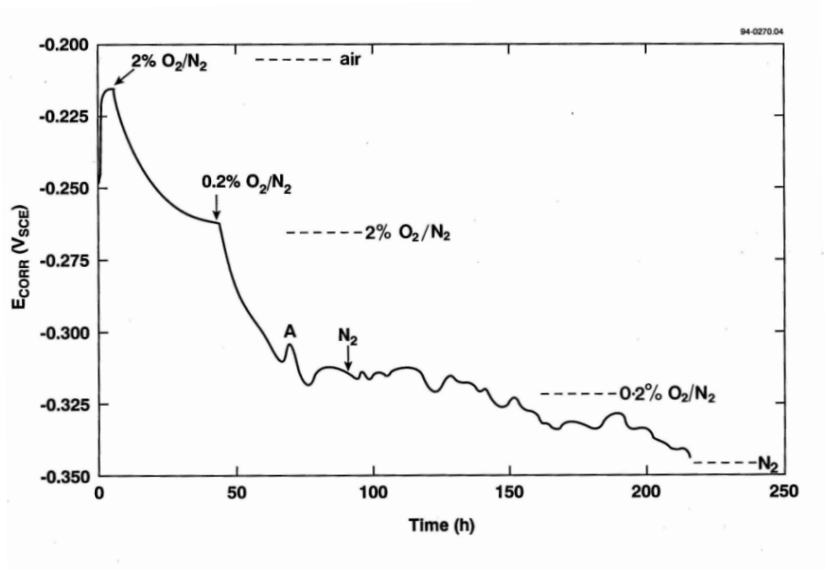


Confidence building

- Robustness of canister lifetime prediction
  - Similar lifetimes predicted by different approaches
- Validation of models against:
  - Short-term experimental data
  - Intermediate-term data from *in situ* underground research laboratory (URL) experiments
  - Long-term archaeological analogues
- Analogues
  - Archaeological
    - Bronze Age artifacts
    - Bronze cannon from “Kronan” and other copper artifacts
  - Natural
    - Native copper deposits

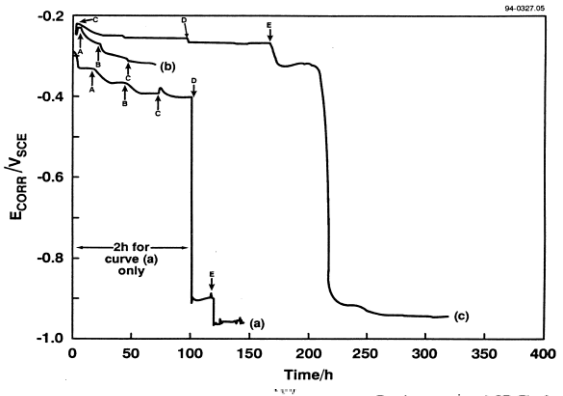
Validation of mechanism against short-term laboratory data

- Comparison of measured and predicted corrosion potentials
  - In presence of oxygen

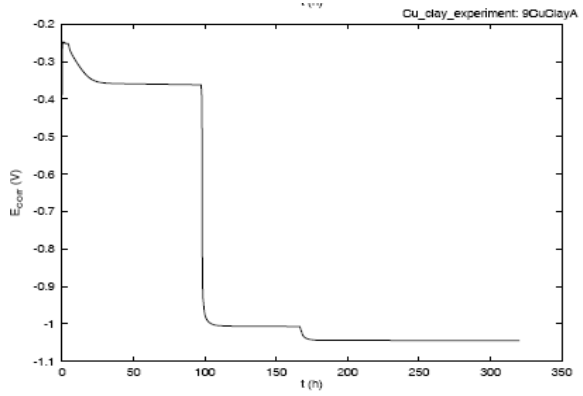


  - In presence of sulphide

Experiment

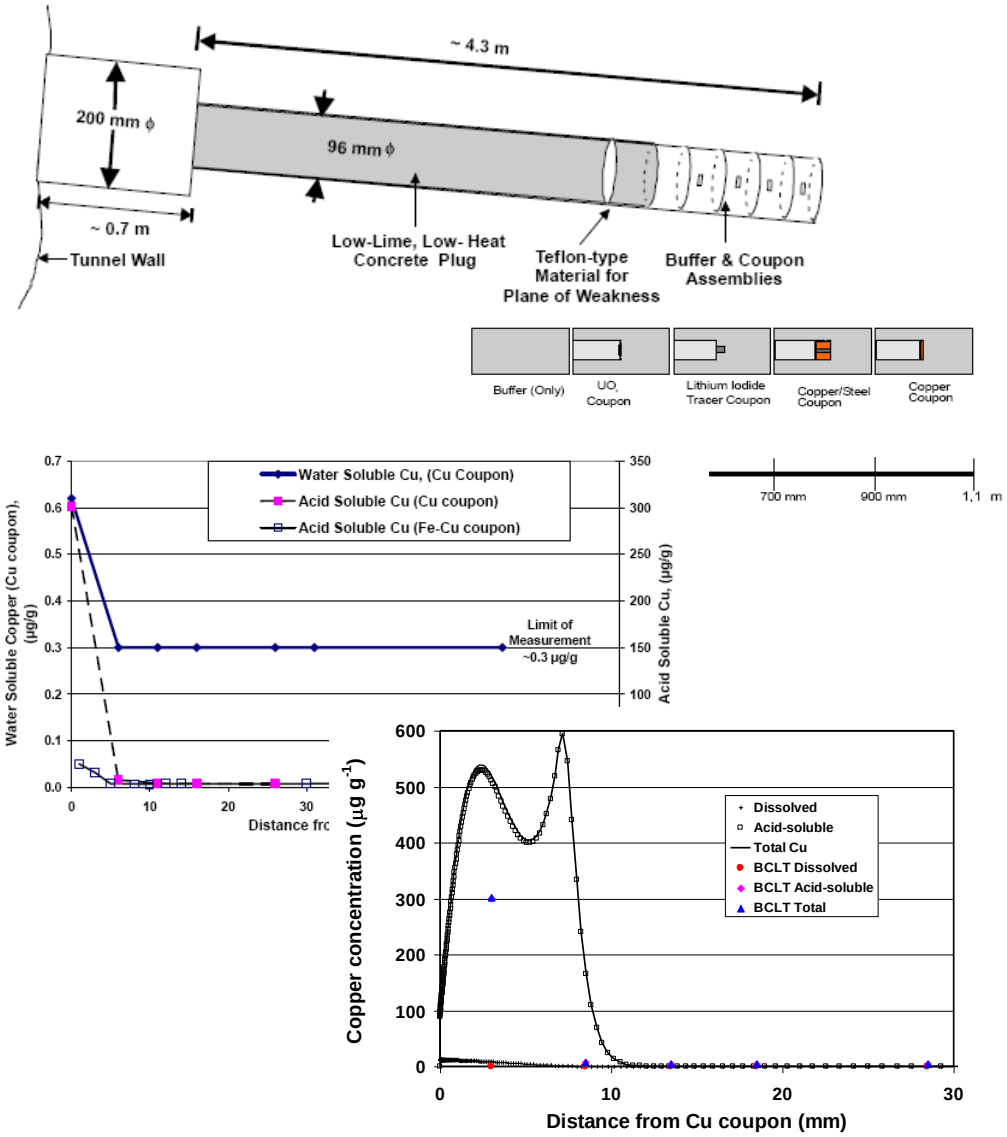


Model



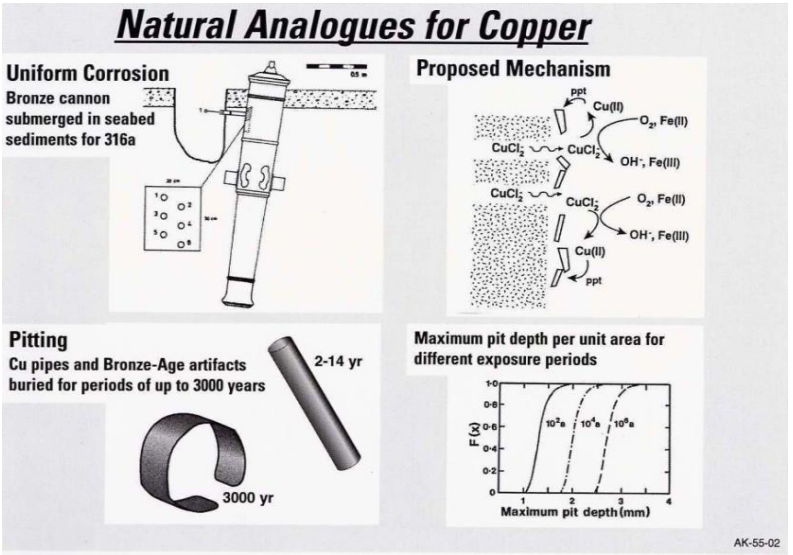
Model validation against *in situ* URL data

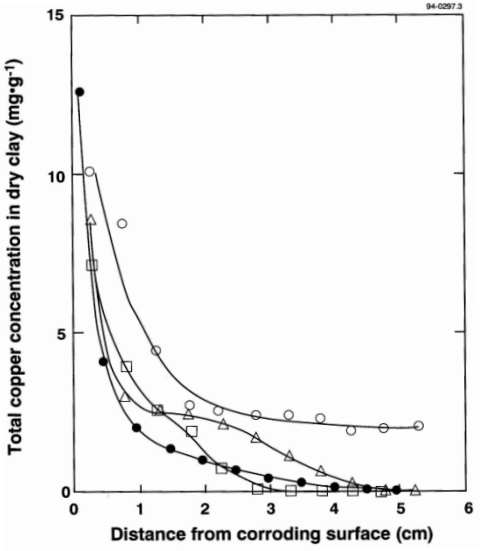
- Buffer-Container Long-term Test (BCLT)
  - Ran in AECL's Underground Research Lab, Canada for 18 months
    - Correctly predicted Cu(I)/Cu(II) speciation
    - Reasonably predicted Cu diffusion distance
    - Accurately predicted the corrosion rate
      - Observed 0.21-0.48 μm/yr
      - Predicted 0.17-0.48 μm/yr

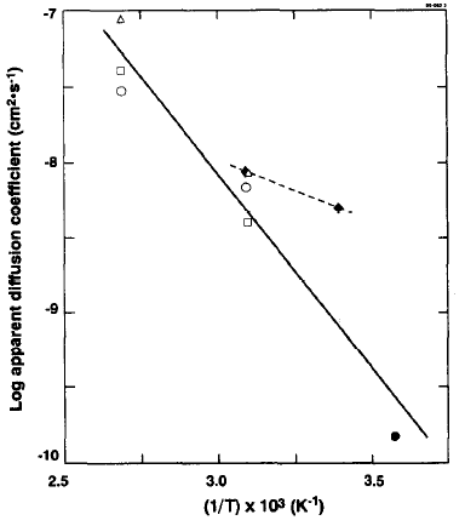


Archaeological and natural analogues

- Evidence from natural and archaeological artifacts provides supporting evidence for corrosion mechanisms and longevity of Cu alloys in natural environments
  - Native Cu deposits
  - Bronze cannon
    - General corrosion mechanism
    - D_{EFF} of Cu(II) in clay sediments
  - Bronze Age artifacts
    - Localized corrosion
  - NBS long-term underground corrosion studies
    - Localized corrosion







Summary

- Long history of copper canister corrosion studies in Sweden and internationally
  - 1978: SKB TR-90 initial corrosion study
  - 1983: KBS-3 repository design and updated corrosion assessment
  - 1980's: Experimental studies in Sweden, Canada, Switzerland
  - 1990's: Continued experimental studies and development of models
  - 2000's: Lab and large-scale test at Äspö
  - 2010's Continuing investigations of specific issues
- Developed a good <u>understanding</u> of corrosion mechanisms
- <u>Confidence building</u> through testing models against different types of data
- <u>Continuing study</u>