Used Fuel Disposition Campaign

"EBS experimental update: aluminosilicate phase transformations, corrosion of copper and steel"

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FY'16 Objectives

EBS Program

- Experiment characterization (EBS18, EBS 19).
- Investigate the Fe-saponite, chalcocite growth at metal interface with bentonite.
- Characterize and interpret all experiments.
- Produce 3 more Opalinus clay experiments to finish baseline (304 SS, LCS – 6 wk isothermal 300 C, 304 SS 6 month)
- Cold seal reactors (800 C, 2.5 Kbar) – pressure certified September 2015, electrical safety certified January 2016 – 21 experiments completed

International Program

- FEBEX-DP forensic investigation

TOPICS

Zeolites

Steel

Copper

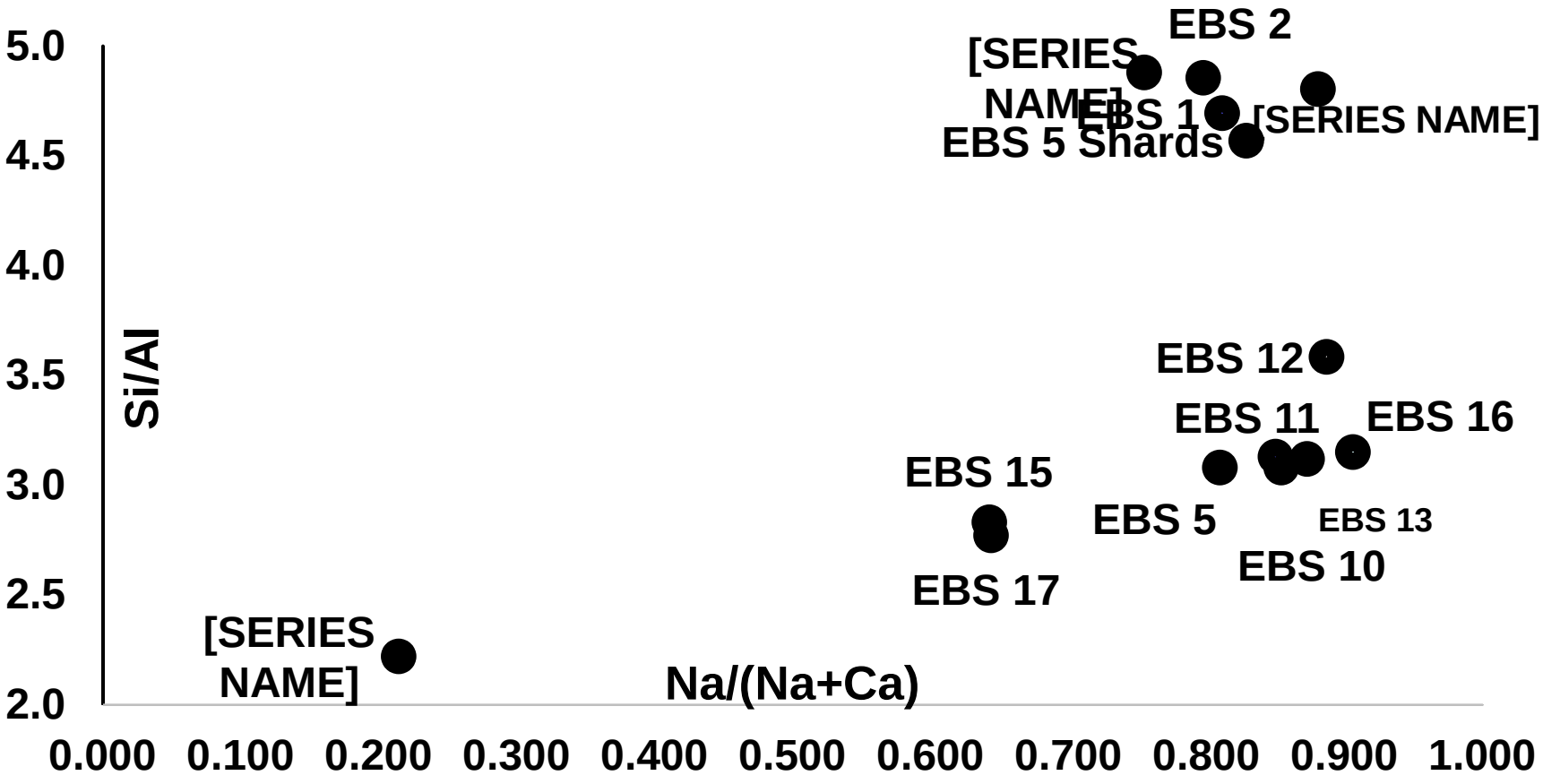
Clays (REMINDER)

- All experiments exhibit the same general clay mineral transformations
- Montmorillonite → Smectite ≠ Illite
- Good for this bulk chemistry ONLY(Stripa, WY)
- Good for this P,T,t trajectory
- No reduction in swelling due to illitization
- No change in sorption characteristics

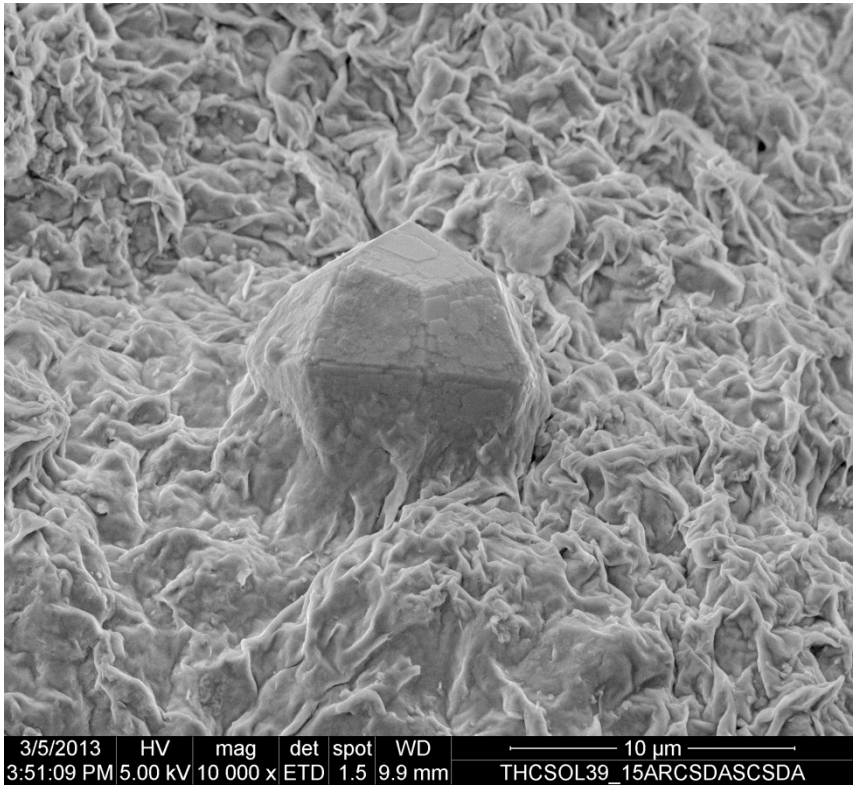
Zeolites

- As Colony EBS material reacts at high P,T new zeolites are formed – Bulk Chemistry Dominated
- Without wall rock, Glass and/or Clinoptilolite → Analcime formed
- With Opalinus Clay wall rock only – Wairakite formed (Ca-Analcime)
- With Opalinus Clay + Bentonite – Analcime-Wairakite ss
- Pollucite – Captures Cs

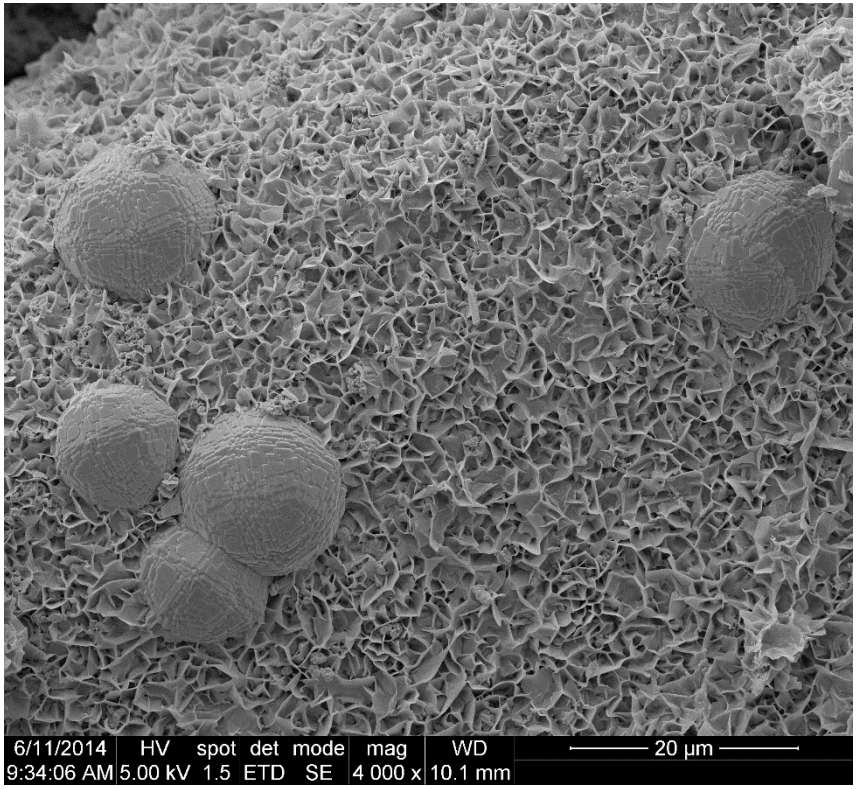
Si / Al ratio to Analcime percentage

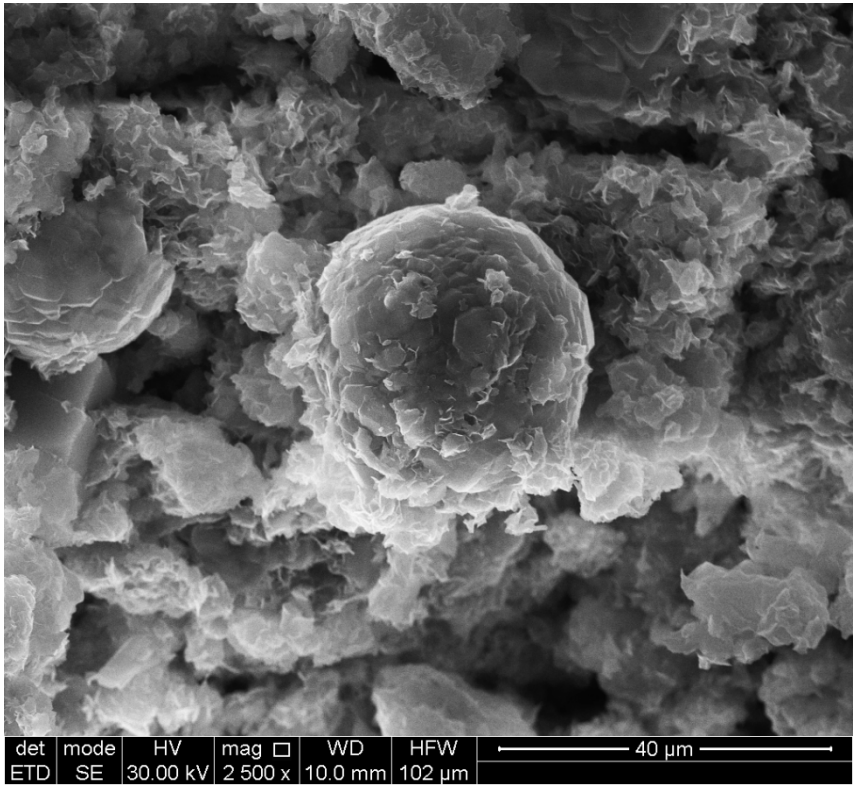


Zeolite images
EBS-4 (Analcime), EBS-14 (Wairakite)



Analcime/ Wairakite (EBS-15) / Pollucite (DB -16) Formation





Steel Corrosion

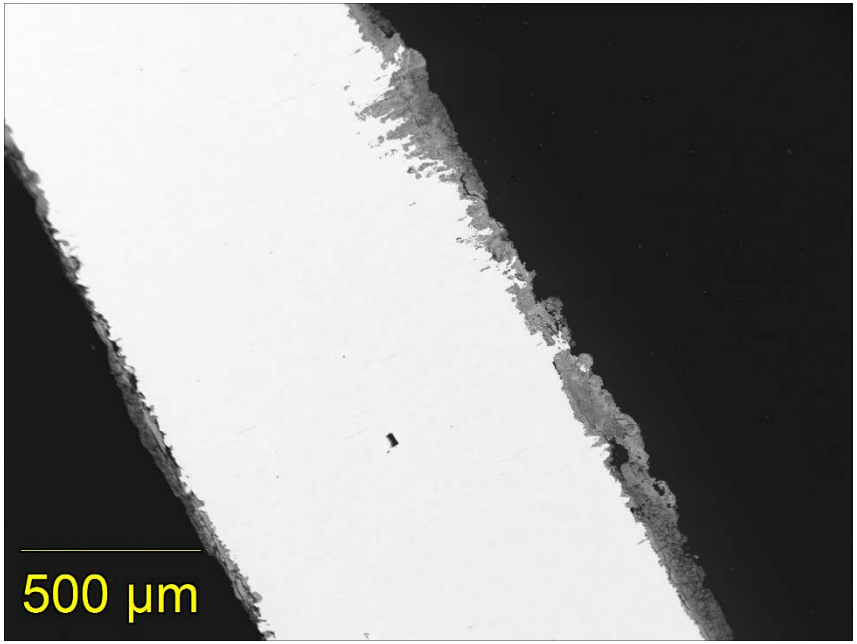
- **At high P,T conditions – Bentonite + Steel → Fe Saponite + Pentlandite +/- Pyrrhotite**

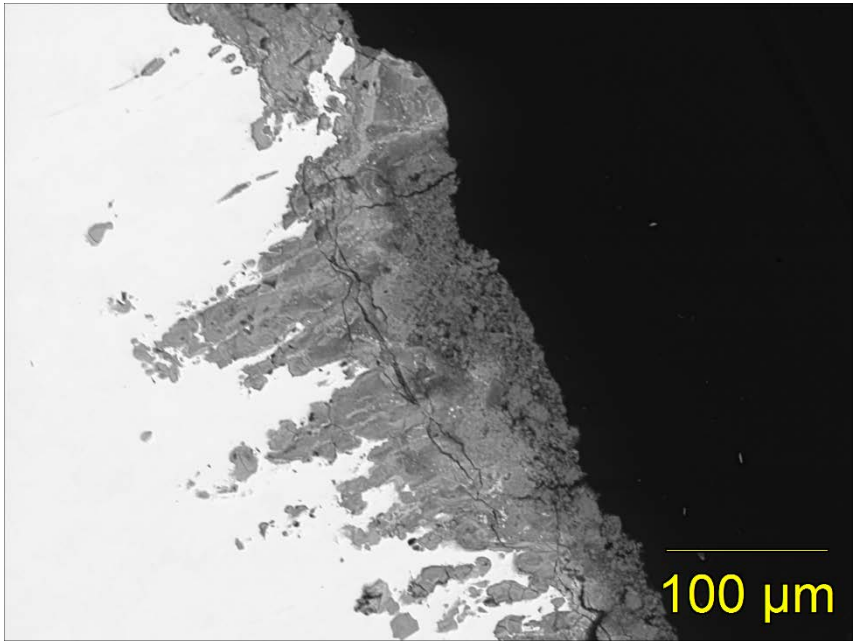
- **Fe Saponite is the dominant reaction, with Fe leaching from steel rim**
  - Steel corrosion rates - 0.1 μm d^{-1} (43 μm a^{-1}) SS
    - 0.6 μm d^{-1} (214 μm a^{-1}) LCS

Stilpnomelane (mixed Fe) growth on Fe

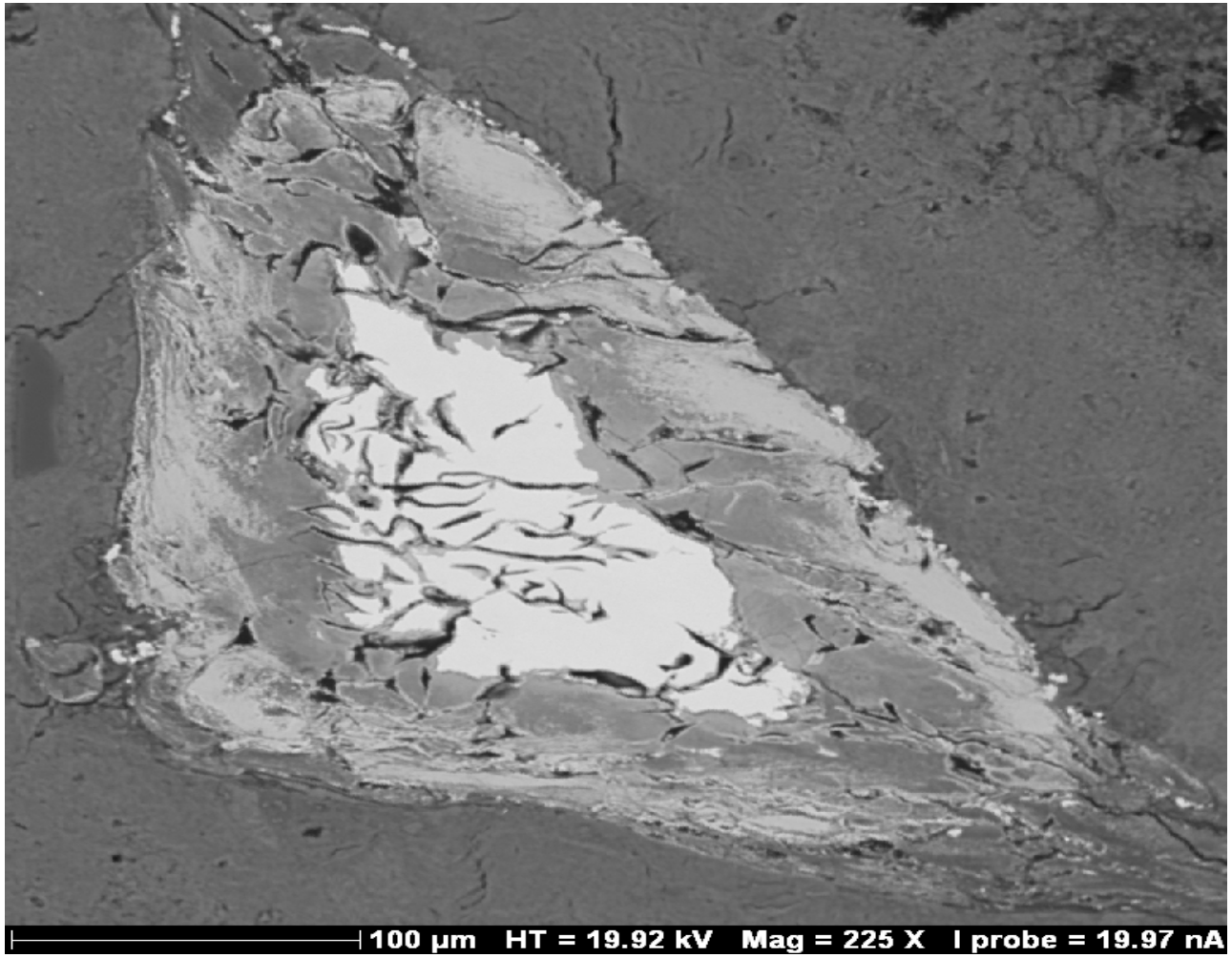
- **Preliminary data – No corrosion rate (or mode) difference between 6 week and 6 month experiments**

Pit Corrosion on Low Carbon Steel (EBS-18) Fe oxide, Pentlandite, Fe Saponite





Stipnomelane ($K(Fe^{2+},Mg,Fe^{3+})_8(Si,Al)_{12}(O,OH)_{27}$) reaction on native Fe

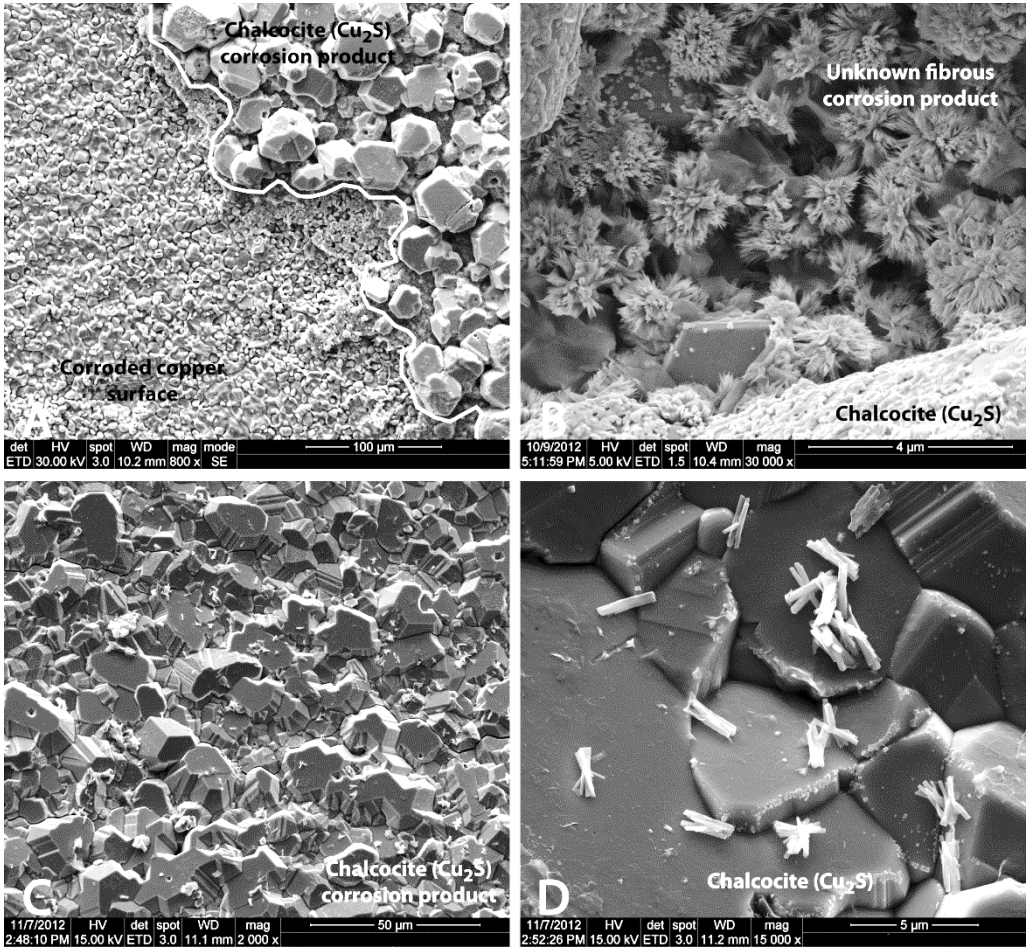


Copper Corrosion

- Copper metal + H_2S +Cl → Chalcocite (Cu_2S) + Atacamite ($Cu_2Cl(OH)_3$
- H_2S formed from breakdown of pyrite in bentonite
- corrosion rates- 8.8-116 µm/yr. dependent on run time, brine composition, and bulk composition

Used Fuel Disposition

Cu Corrosion images



SUMMARY

- Copper corrosion rates developed for defined composition and P,T,t (Chem Geol)
- Initial steel corrosion interface phases for generic EBS, Opalinus Clay wall rock
- First experimental data of Analcime-Wairakite ss from bentonite at repository conditions
- Pollucite generated from Cs contaminated Bentonite buffer

Future Work – FY17

- Finish host rock-bentonite baseline experiments and analyses.
- Continue with post-maximum temperature cooling effects.
- Quantify corrosion kinetics (SEM, EMP, Aqueous chemistry). Large data base needs analysis. Optical measurements needed
- Submit 1 journal articles on steel corrosion. Copper corrosion submitted to Chemical Geology
- Evaluate the steel corrosion products' chemical properties.
  - Thermodynamic constants
  - Radionuclide adsorption
  - Examine maximum passivation thickness
  - Evidence for pitting
- Investigate radionuclide 'zeolites' from engineered bentonite buffers.

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