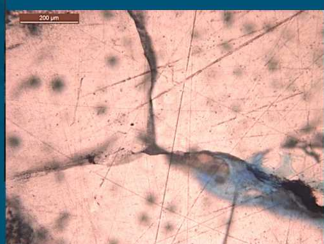
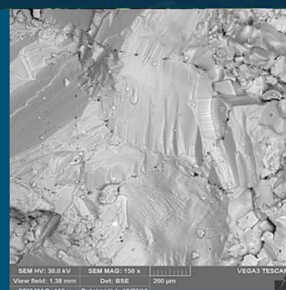
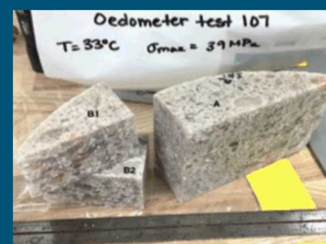
SAND2018-9683C

Characterization of Salt Backfill with Repository Applications







SALTMECH IX

Melissa Mills[1], Dieter Stührenberg[2], Frank Hansen[3]

[1]Sandia National Laboratories, USA

[2]Federal Institute for Geosciences and Natural Resources (BGR), Germany

[3]RE/SPEC, USA

Wednesday, September 12, 2018 Hannover, Germany

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525. This research is funded by WIPP programs administered by the Office of Environmental Management (EM) of the U.S. Department of Energy.

Motivation

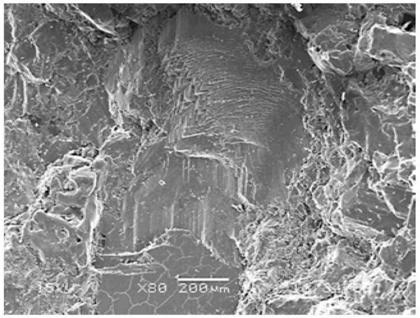
- Ongoing uncertainty in long-term performance of salt repositories for nuclear waste disposal revolves around construction and temporal evolution of geotechnical barriers
  - Barriers are intended to develop tightness properties approaching those of the surrounding host rock

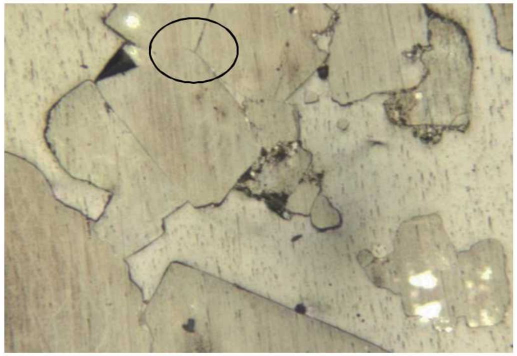
- Residual uncertainty with respect to nuclear waste repository performance exists
  - Large-scale *in situ* experiments for backfill, including performance monitoring, are sparse over sufficient periods to observe porosity and permeability evolution

- Striving to improve manual emplacement construction techniques
  - Obtain high initial density
  - Demonstrate at appropriate scale to add confidence in future salt nuclear waste repository design and performance

Background and Previous Examinations

- **2004: Bechthold et al.**
  - Examined German Potash mine backfill samples emplaced in 1985 of mainly mine tailings
  - Virtually no porosity
  - Fractures through grain rather than grain boundary illustrates high degree of cohesion



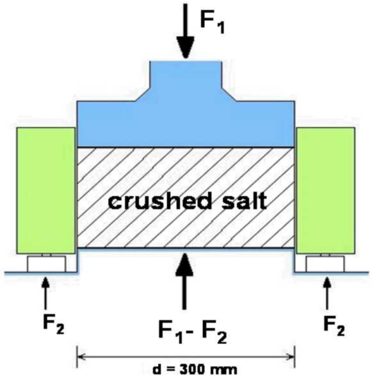


Field of view ~1mm across

- **2014: Hansen et al.**
  - Examined backfill samples from Canadian K2 Potash Mine emplaced by slurry in 1988
  - Estimated closures rates were 1 to 2 inches per year (2.54 to 5.08 cm/year) when samples were obtained 20 years later
  - Photomicrographs conclude perfectly meshed/healed grain boundaries and no apparent brittle processes

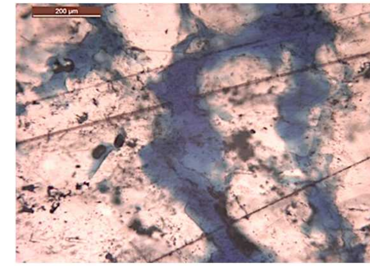
Newly Acquired Samples

- New reconsolidated backfill samples
  - Separate German Potash Mine
  - Obtained by Dieter Stührenberg (BGR) and graciously given to Sandia researchers
  - Backfill emplaced in 1985, re-excavated through hardened material in 2003
  - Backfill was placed on the floor to elevate working platform, had minimal compactive pressure (vehicle travel only) with no specific design
- Also given a portion of an oedometer tested sample from BGR for comparison of structure and porosity
  - Run of Mine WIPP salt at its' natural water content (0.2 - 2%; impurity dependent)
  - 256 days at 33°C
  - Various compaction strain rates (10^{-7} to 10^{-10} s^{-1})
  - Axial stress of 39 MPa



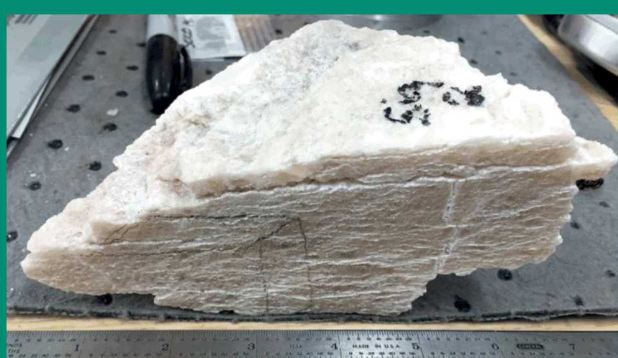
Reference: Stührenberg, *D.* 2007. Long-term laboratory investigation on backfill. The Mechanical Behavior of Salt; 6th Conference, Hannover 2007, 223-229

Sample Preparation

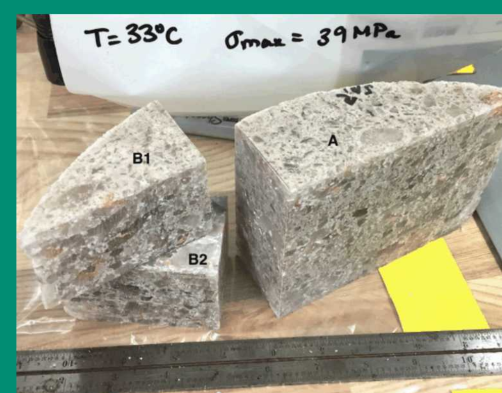


- Sub-sampled with a diamond wire saw
- Impregnated thin sections were made vertical and horizontal to bedding plane to see any disparity

- German Potash Mine (GPM)



- Oedometer 107 (Oed 107)



Porosity Measurements

- Porosity determined by the age-old technique of point counting optical sections

- GPM-1 appeared denser that GPM-2 in macro photos
  - However, on average, the porosities are nearly identical

Sample	Count 1	Count 2	Count 3	Average Porosity
GPM-1-B2-1-V	6.00%	8.33%	9.33%	7.89%
GPM-1-B2-1-H	9.00%	15.67%	9.33%	11.33%
GPM-2-B-V	7.33%	9.33%	10.00%	8.89%
GPM-2-B-H	8.33%	6.67%	12.33%	9.11%
Oed 107 B2-1-V	7.33%	6.00%	4.33%	5.89%
Oed 107 B2-1-H	8.33%	6.00%	6.67%	7.00%

H=Horizontal, V=Vertical

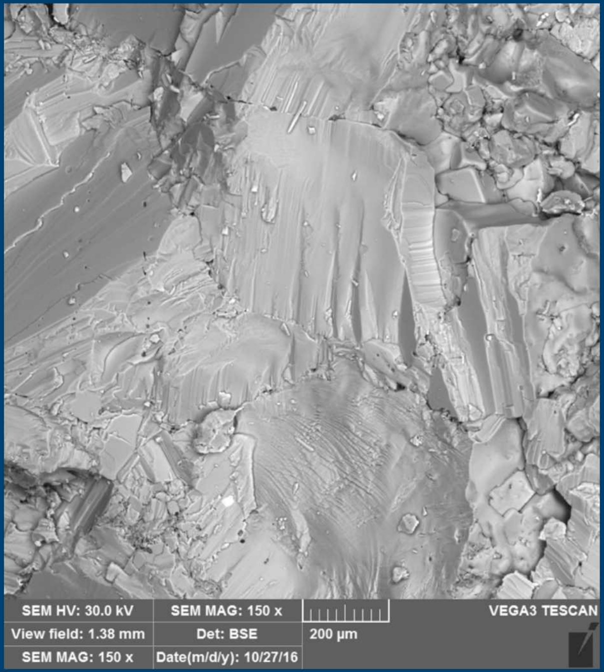
- Pycnometer tests on two subsamples from Oed 107 at BGR revealed an average porosity of 3.57%
  - Point counting values likely higher due to the incorporation of isolated pores becoming accessible after further cutting

Photomicrographs: Field Sample

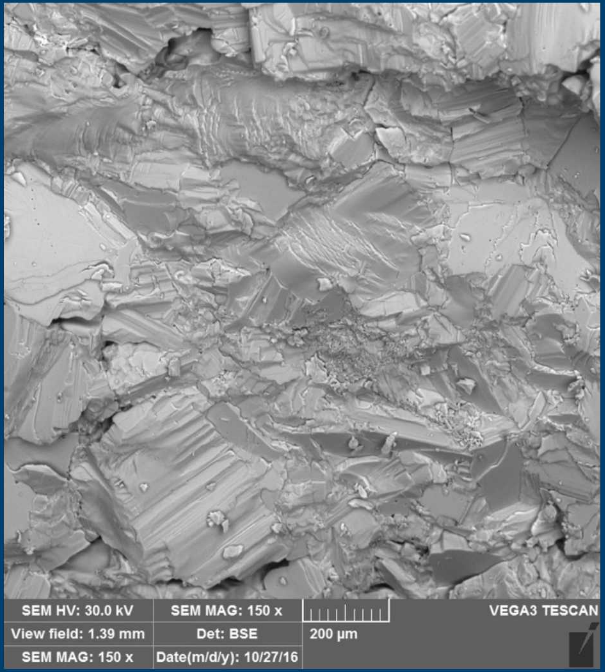
- Substructures characterized by scanning electron microscope (SEM)

Hand-broken Aggregates

GPM-1



GPM-2



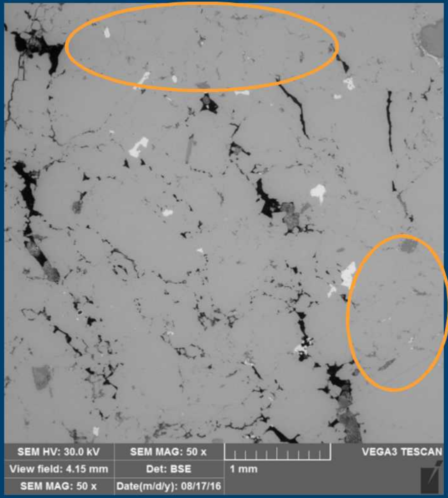
- Display of tight grain boundaries, little porosity, crystallographic cleavage surfaces indicating high degree of cohesion

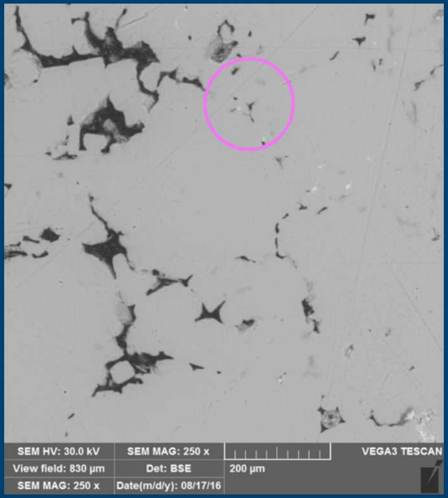
Photomicrographs: Field Sample Continued

Thin Sections

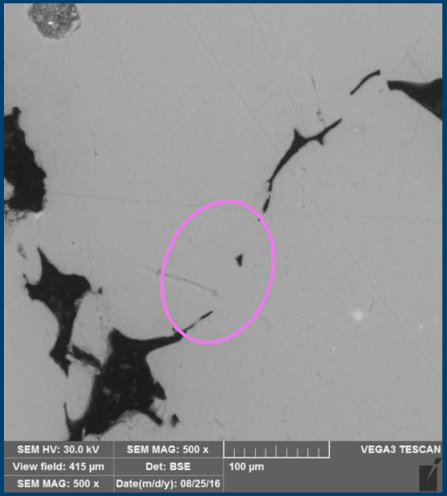
- Moderate porosity
- Grains in contact are fused together
- Areas of nearly completely healed grain boundaries (pink)
- Regions of more highly compacted areas (orange)

GPM-1



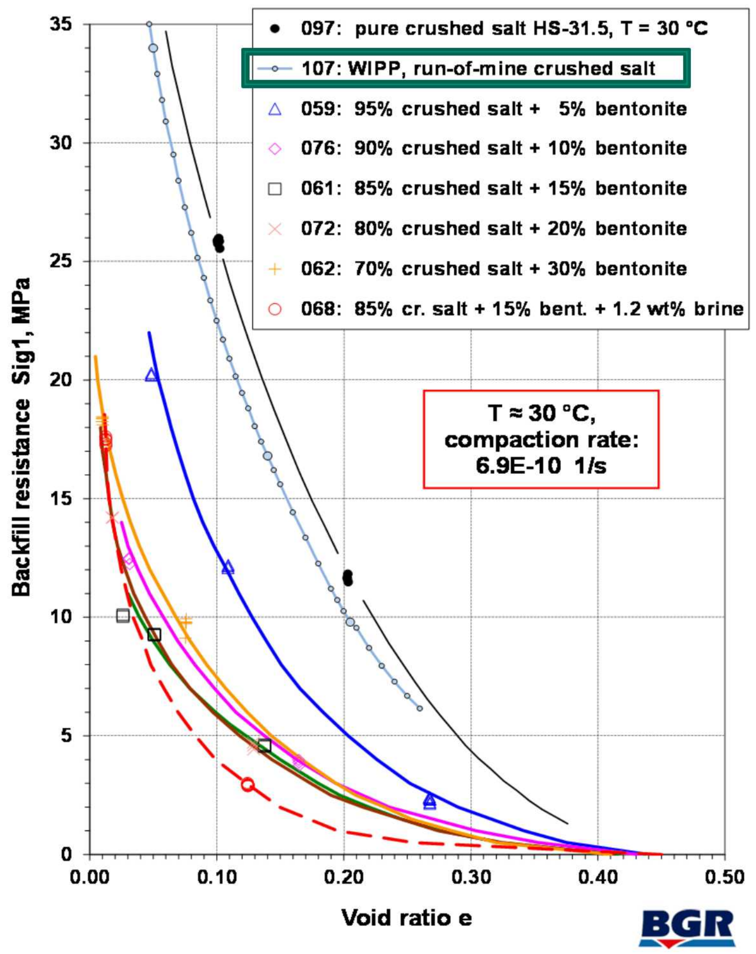


GPM-2



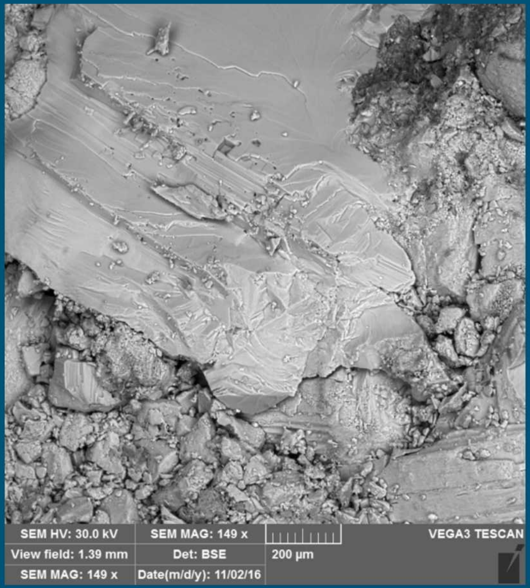
Oedometer Test Results

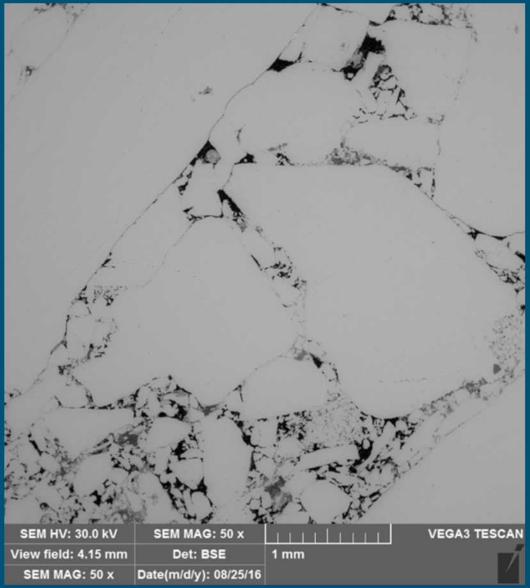
- Oedometer 107 results compared against other tested laboratory mixtures with added bentonite and brine
  - Pure crushed salt curve is plotted for comparison
- Results clearly document the favorable effects of additives by reducing backfill resistance significantly when void ratio decreases

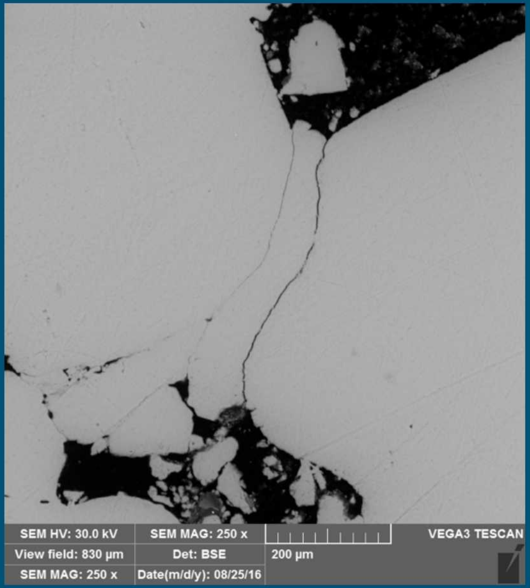


Oedometer Photomicrographs

- Photomicrographs display areas of grinding and abrasion between grains with brittle communition, or reduction of grain size, and rearrangement
- Grains deformed plastically and appear more angular than potash mine samples
- Grain boundaries not nearly as cohered







Outcomes

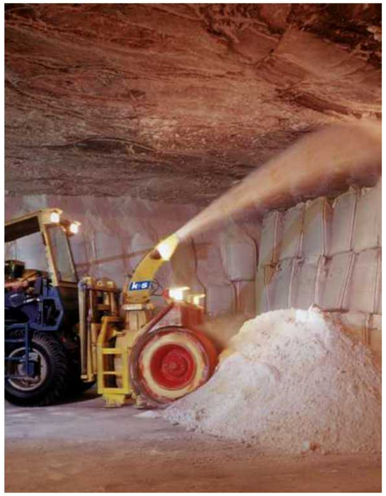
- Based on the number of observations made here, consolidation from large-scale field application demonstrates effective consolidation with minimal engineering and can be achieved at low stresses

- Moisture or other additives can be readily combined with run of mine salt to ensure consolidation, while creating minimal backstress

- Backfill salt material with sufficient moisture available is expected to consolidate at a rate essentially equal to closure of the opening at the time of construction

Roller compactor

Fletcher miner with compression plate



K + S site for hazardous waste disposal