SALT DISPOSAL R&D OVERVIEW AND BATS

Kris Kuhlman, SNL

SFWD

SPENT FUEL & WASTE DISPOSITION

Annual Working Group Meeting

UNLV-SEB – *Las Vegas, Nevada*

May 21-23, 2019

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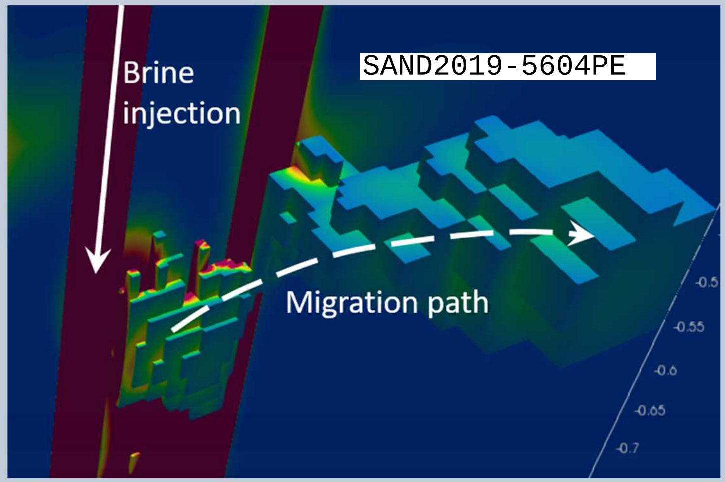
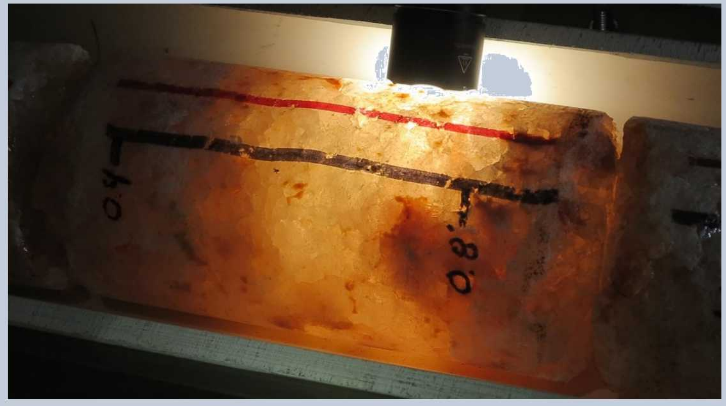




Salt R&D Session Overview

- Intro talk (20 min)
  - Key UFD/SFWST accomplishments
  - Priorities going forward
  - Brine Availability Test in Salt (BATS) introduction
- Individual talks (~10 min each)

Ed Matteo	SNL	EBS
Jonny Rutqvist	LBNL	International
Eric Guiltinan	LANL	BATS modeling
Doug Weaver	LANL/Carlsbad	BATS and WIPP
Hakim Boukhalfa	LANL	BATS geochemistry
Yuxin Wu	LBNL	BATS geophysics
Tom Lowry	SNL	GDSA

- End-of-Session Discussion

TECHNICAL ACCOMPLISHMENTS

- In 2012 FEPs-based ranking of disposal R&D topics

Rank	Index	FEP Title	Media	Score
1	2.2.01.01	Evolution of EDZ	Argillite	8
2	2.2.08.01	Flow Through the Host Rock	Salt	7.73
	2.2.08.02	Flow Through the Other Geologic Units (confining units, aquifers)	Salt	7.73
	2.2.08.06	Flow Through EDZ	Salt	7.73
3	2.2.08.04	Effects of Repository Excavation on Flow Through the Host Rock	Salt	7.1
4	2.2.08.07	Mineralogic Dehydration	Salt	6.49
5	2.2.01.01	Evolution of EDZ	Deep Borehole	6.13

  - These topics are focus of current field test campaign
- March 6-7, 2013 Salt Field Test Workshop
  - FY14 priority: Summarize existing tests/data (complete)
  - Proposed list of 24 field/lab/modeling experiments (~9 addressed by BATS)

Key Accomplishments Since 2010

- Field test evolution of focus:
  - DOE-NE participation in drift-scale DOE-EM disposal demonstration (SDDI)
  - DOE-NE led small modular borehole tests
- Salt program has broadened topics
  - 2010: Demonstration & geomechanical focus (TM – Thermal & Mechanical)
  - 2019: Fundamental understanding of brine migration and chemistry through an evolving DRZ (THMC – includes Hydrologic and Chemical)
- Salt Disposal R&D team has new people
  - New people from SNL, LANL, LBNL, NETL & WIPP
- Salt International:
  - Continued old collaborations: US/German workshop, NEA Salt Club
  - Creating new collaborations: COVRA, DECOVALEX
  - US/German benchmarking projects: WEIMOS, RANGERS, KOMPASS

Current Salt R&D Priorities

- Brine availability test in salt (BATS)
  - Brine availability is the focal point, considering impacts of:
    - (T) Temperature
    - (H) Initial distribution and flow of brine
    - (M) Damage/DRZ evolution (flow pathways)
    - (C) Chemistry
  - Collection of field-relevant datasets in salt
    - Verify we are including the field-relevant processes
    - Provide data for process model comparison (e.g., DECOVALEX)
    - Test applicability of new methods (e.g., geophysics and analytical)
- EBS: salt reconsolidation & salt /cement interactions
- GDSA: process model improvements contribute back into GDSA
- DPC: considering possibly hotter follow-on tests

BATS Salt Field Test Team

Sandia National Laboratories (SNL)

Kris Kuhlman, Melissa Mills, Courtney Herrick, Martin Nemer, Ed Matteo, Yongliang Xiong, Jason Heath

Los Alamos National Laboratory (LANL)

Phil Stauffer, Hakim Boukhalfa, Eric Guiltinan, Doug Ware, Thom Rahn

Waste Isolation Pilot Plant (WIPP) Test Coordination Office (LANL)

Doug Weaver, Brian Dozier, Shawn Otto

Lawrence Berkeley National Laboratory (LBNL)

Yuxin Wu, Jonny Rutqvist, Jonathan Ajo-Franklin, Mengsu Hu

What Are We Doing?

Brine Availability Test in Salt at WIPP (BATS)

Monitoring brine distribution, inflow, and chemistry from heated salt using geophysical methods and direct liquid & gas sampling.

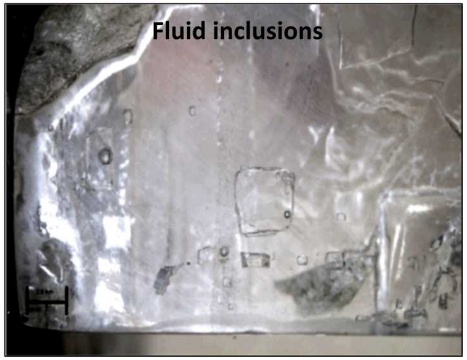
Boreholes currently being drilled in WIPP underground, testing begins June 2019, into FY20. Shakedown equipment tests ongoing.

New BATS core


New BATS boreholes

BRINE IN SALT

- No flowing groundwater, but not dry (≤ 5 wt-% water)
- Water sources in salt
    1. Hydrous minerals (e.g., clay, bassanite)
    2. Intragranular brine (fluid inclusions)
    3. Intergranular brine (interconnected pores)



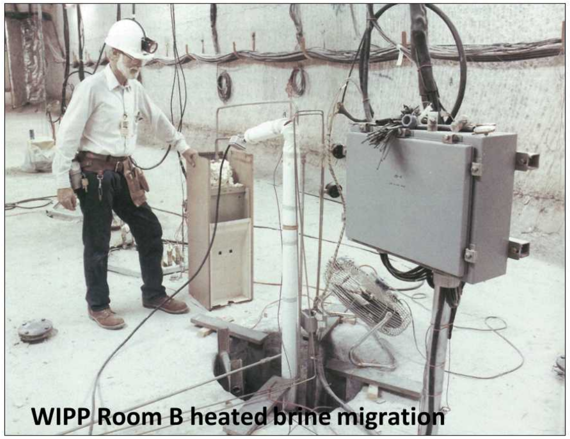
- Brine content correlates with clay content
- Only *intergranular* brine moves under pressure gradient
- Water types respond differently to heat
    - Hydrous minerals evolve water vapor, which can become brine
    - Intragranular brine migrates under thermal gradient
- Brine types have different chemical / isotopic composition

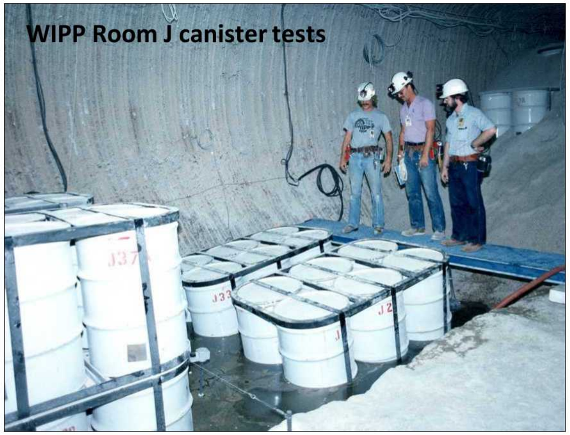
Q: How do 3 water types contribute to *Brine Availability?*

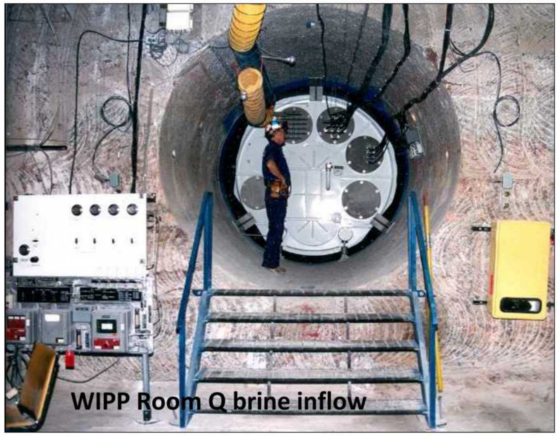
IMPORTANCE OF BATS TO SAFETY CASE

Brine Availability: *Distribution of brine in salt & how it flows to excavations or boreholes*

- Initial conditions to post-closure safety assessment
  - Brine migration and re-distribution
  - Evolution of disturbed rock zone (DRZ) porosity and permeability
- Brine causes corrosion of waste package / waste form
- Brine is primary radionuclide transport vector
- Liquid back-pressure can resist drift creep closure


WIPP Room B heated brine migration

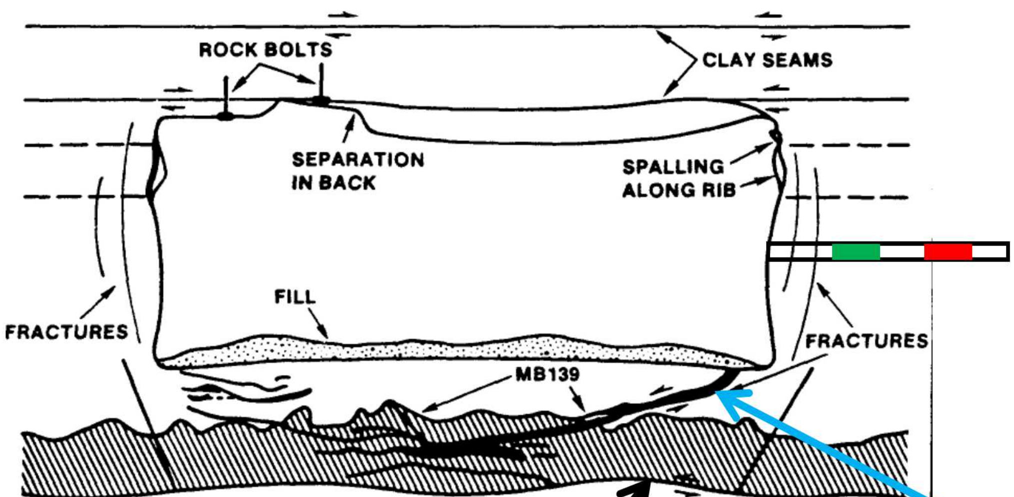

WIPP Room J canister tests


WIPP Room Q brine inflow

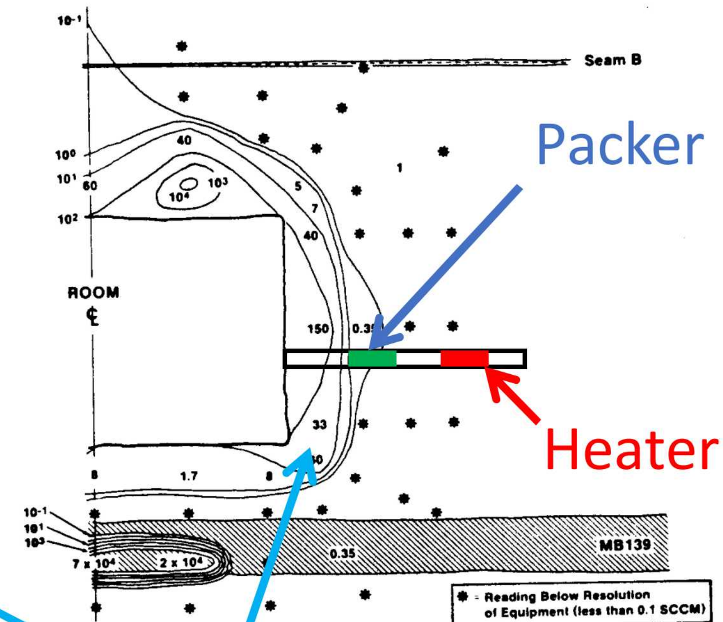
BATS Test in DRZ Conceptual Model

Cartoon representation of test interval relative to observed DRZ at WIPP

Contours of gas flowrate at fixed pressure (i.e., damage)



Borns & Stormont (1988)

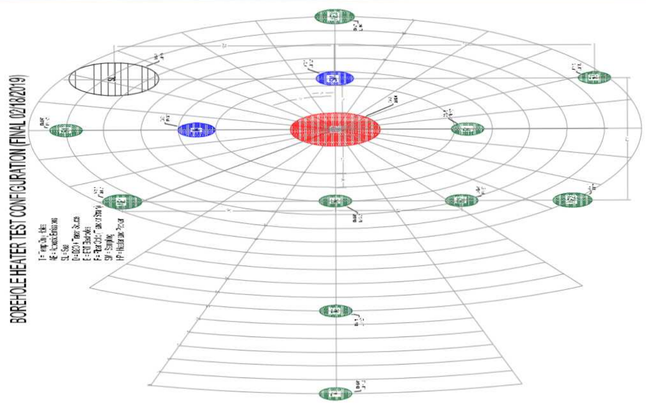


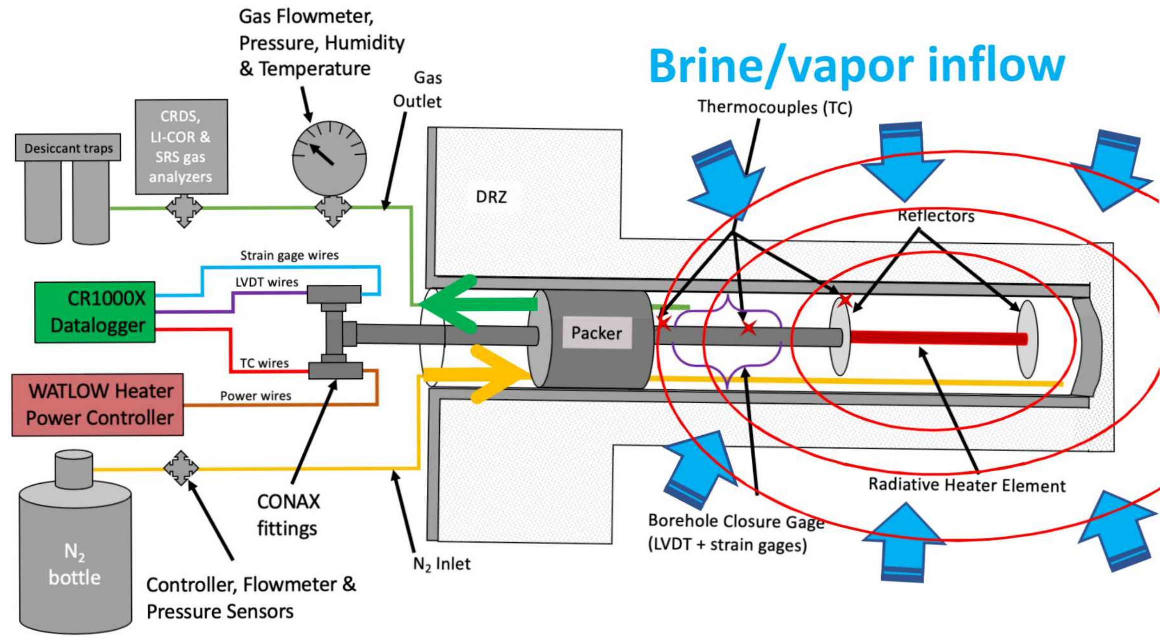
Borns & Stormont (1988)

Horizontal borehole avoids mapped clay / anhydrite layers (e.g., MB139) in Room A/B vertical heater tests

Near-drift DRZ and damage

BATS Test Instrumentation





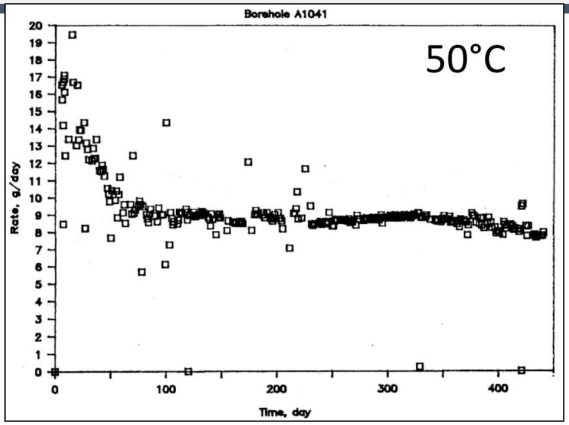
- Two identical arrays
  - Heated (120 C) and Unheated
- Behind HP packer (right)
  - Circulate dry N_2
  - Quartz lamp heater (750 W)
  - Borehole closure gage
  - Gas permeability before / after
- Samples / Analyses
  - Cores (X-ray CT and fluorescence at NETL)
  - Gas stream (natural / applied tracers, humidity and isotopic makeup)
  - Liquid brine (natural chemistry and natural / applied tracers)
- Geophysics
  - 3× Electrical resistivity tomography (ERT)
  - 3× Acoustic emissions (AE) / ultrasonic travel-time tomography
  - 2× Fiber optic distributed strain (DSS) / temperature (DTS) sensing
  - +100 thermocouples

BATS Test Data

- Brine composition samples / H_2O isotope data
  - Measure change in brine sources with temperature
- Geophysics
  - Map 4D evolution of **saturation** / **porosity** / **permeability**
- Temperature distribution
  - More brine available at high temp (inclusions + hydrous minerals)
  - Thermal expansion brine driving force
  - Salt dry-out near borehole
- Gas permeability and borehole closure
  - Thermal-hydrological-mechanical evolution of salt during heating
- Tracer migration through salt
  - Estimate rate of brine / vapor movement through salt DRZ
- Post-test overcoring
  - Cement seal, tracer distribution around source, damage

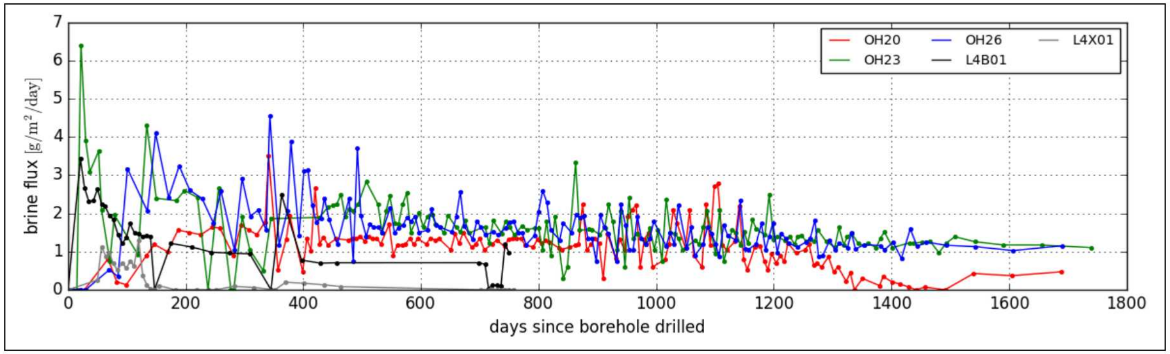
Brine Inflow Expectations

- Brine inflow
  - Highest inflow rate initially
  - Exponential decay of rate with time
- More brine inflow at higher *T*
  - Vapor from dehydration of clay & gypsum
  - Brine from fluid inclusions

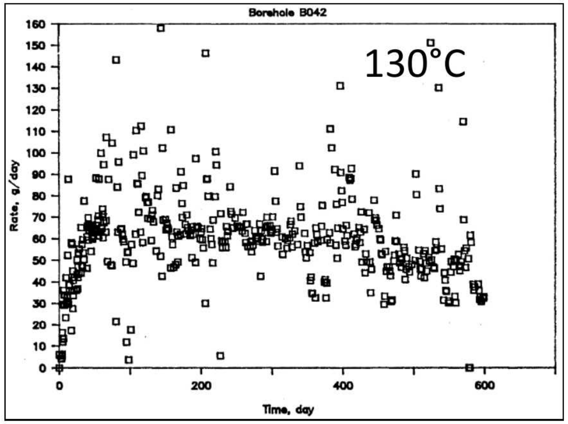


Vertical WIPP boreholes

Kuhlman et al. (2017)



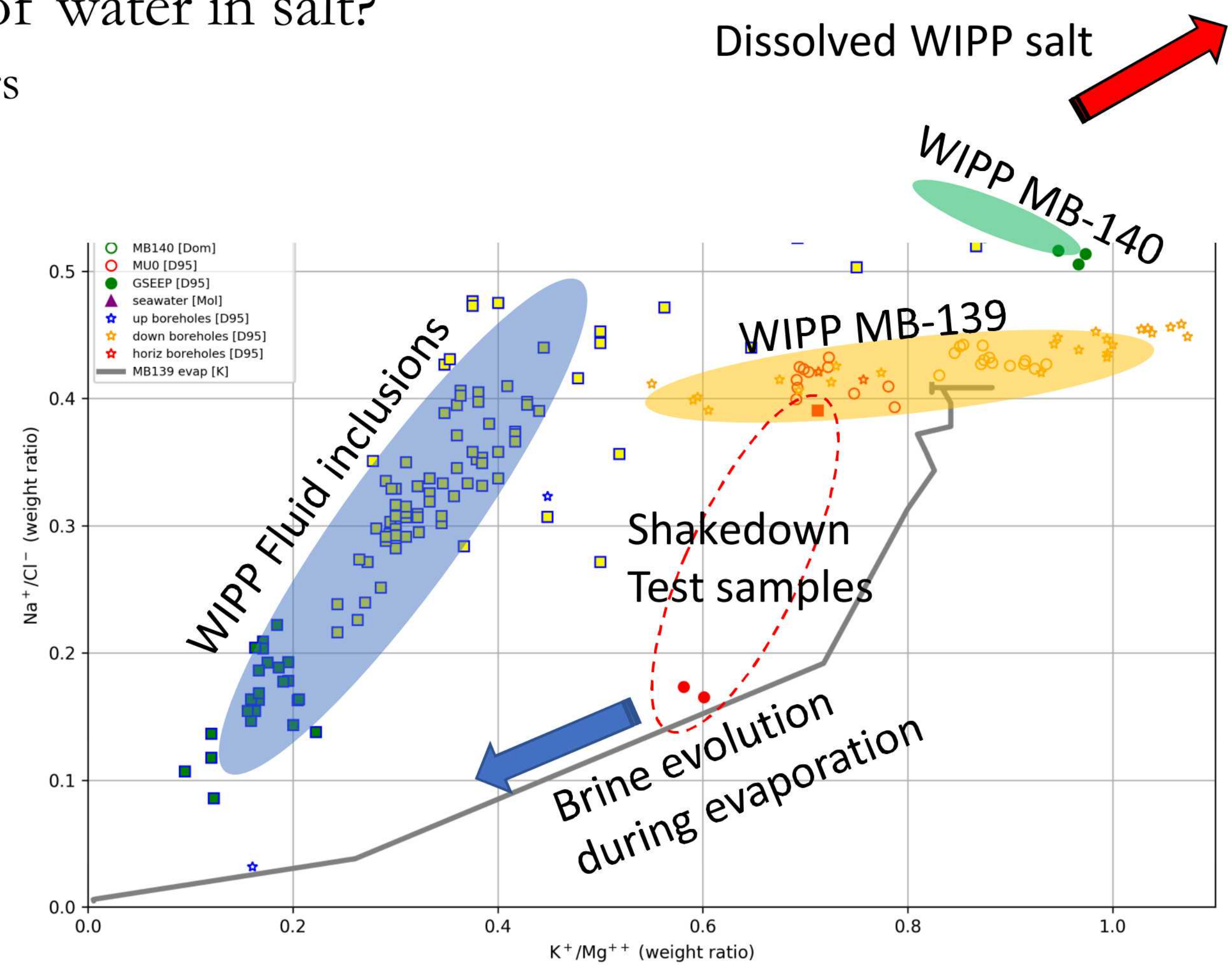
Unheated borehole brine inflow at WIPP in MU-0 (did not cross mapped clay layer)



Vertical boreholes intersected clay layers (Rooms A & B)
Nowak & McTigue (1987)

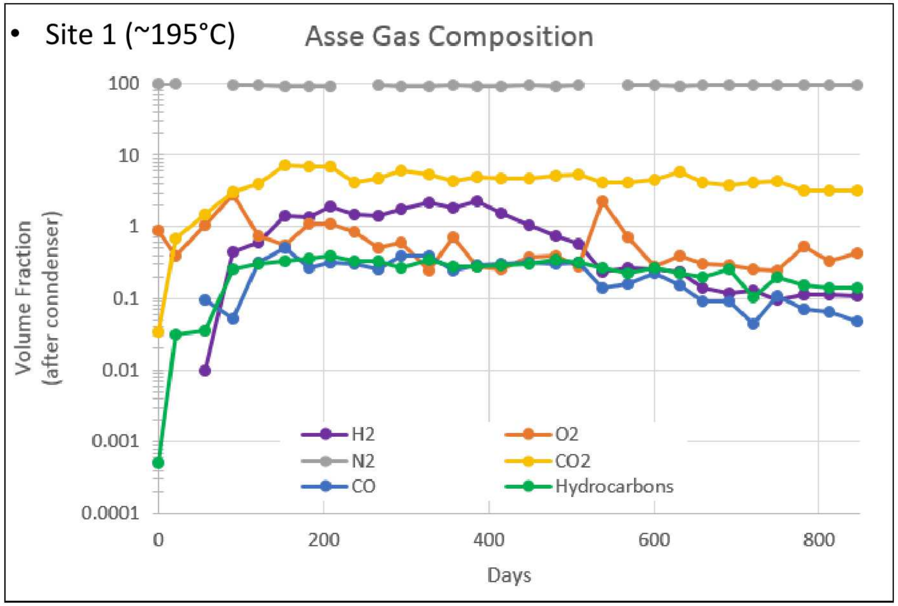
Brine Composition Expectations

- Liquid brine samples
- Distinguish sources of water in salt?
  - Distinct endmembers
- Added liquid tracers
  - $NaReO_4$
  - Fluorescent tracer
- Data on processes:
  - Advection
  - Reaction
  - Diffusion



Gas Composition Expectations

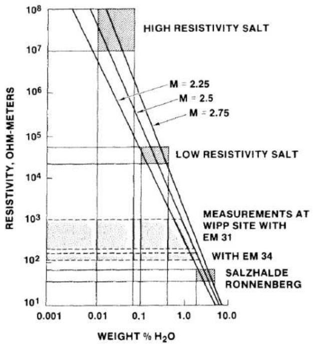
- Gases from
  - Dissolved gas in brine (~15 MPa pore pressure in far field)
  - Geogenic gases from salt (e.g., He & Ar)
  - Added gas tracers (Xe, Ne, Kr & SF_6)
- Water Vapor from brine
  - Natural H_2O
  - "Light" traced water breakthrough
    - Transport time through salt
    - Fractionation in borehole
    - D_2O tracer at Avery Island salt dome (Krause, 1983)
- Acid gas from salt / brine
  - Decomposition of hydrous Mg salts
  - Equilibration of $P_{HCl(g)}$ into condensed steam



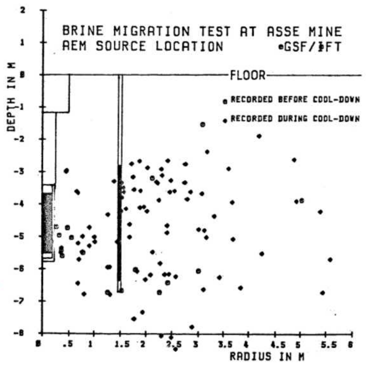
- Data from Coyle et al. (1987) BMI/ONWI-624

ERT / AE Expectations

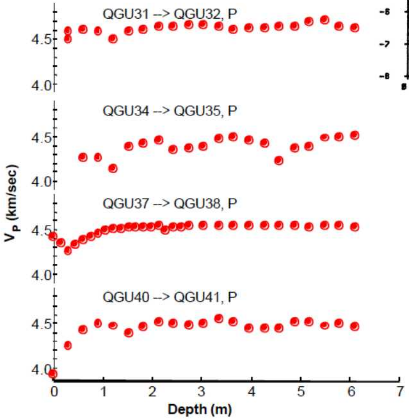
- Electrical Resistivity Tomography (ERT)
  - ERT electrodes cemented into 3 boreholes
  - Salt apparent resistivity
  - Reisitivity: reveal porosity and brine saturation
- Conduct 3D ERT surveys through time
  - Estimate evolution of porosity / saturation
- Acoustic Emissions (AE)
  - AE monitoring (especially during heat up & cooldown)
  - Locate AE sources near heated borehole
  - AE correlated with permeability increases
  - AE system installed in heated test only
- Ultrasonic Wave Travel-time Data
  - Estimate extent/evolution of DRZ



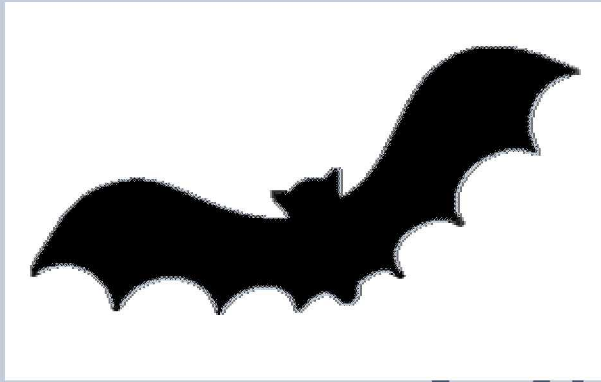
Skokan et al. (1989)

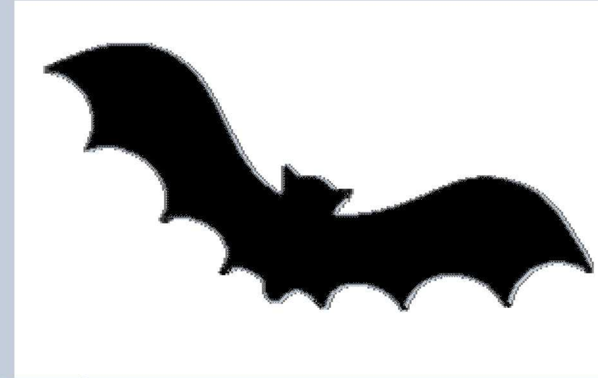


Rothfuchs et al. (1988)

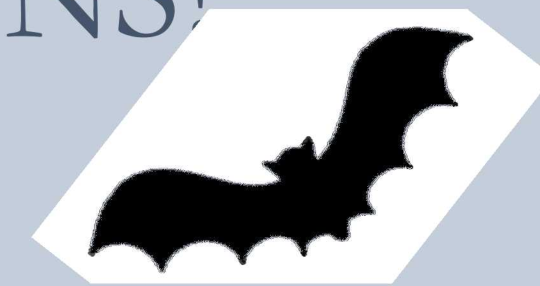


Holcomb et al. (2001)





Questions?



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