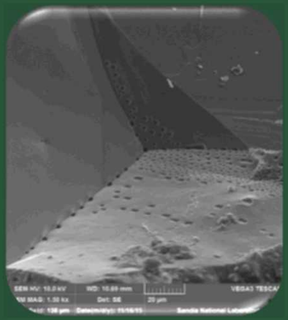
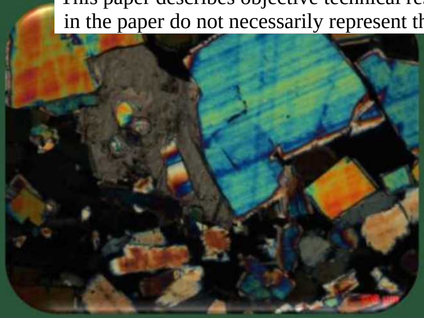
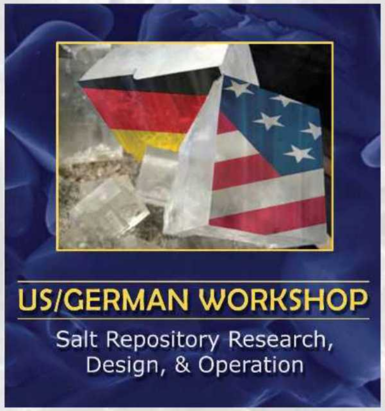




SAND2019-5903C

# DOE-NE WIPP Heater Test Update

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U.S. DEPARTMENT OF ENERGY

Federal Ministry for Economic Affairs and Energy

Kris Kuhlman
Sandia National Laboratories

Rapid City, SD, United States
May 28-30, 2019

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# WIPP Salt Field Test Team


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# 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.*

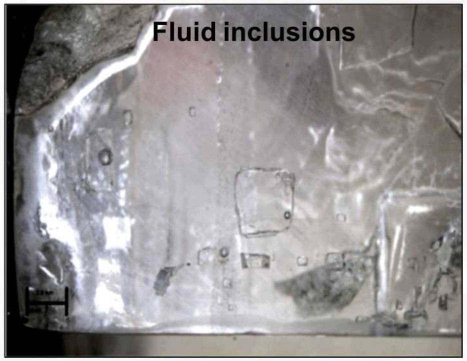
Boreholes drilled Feb-Apr 2019 in WIPP underground, testing begins July 2019, into FY20. Shakedown equipment tests ongoing.

New BATS core


New BATS boreholes

# Brine in Salt

- No flowing groundwater, but not dry ($\leq 5$ 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 to Safety Case

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

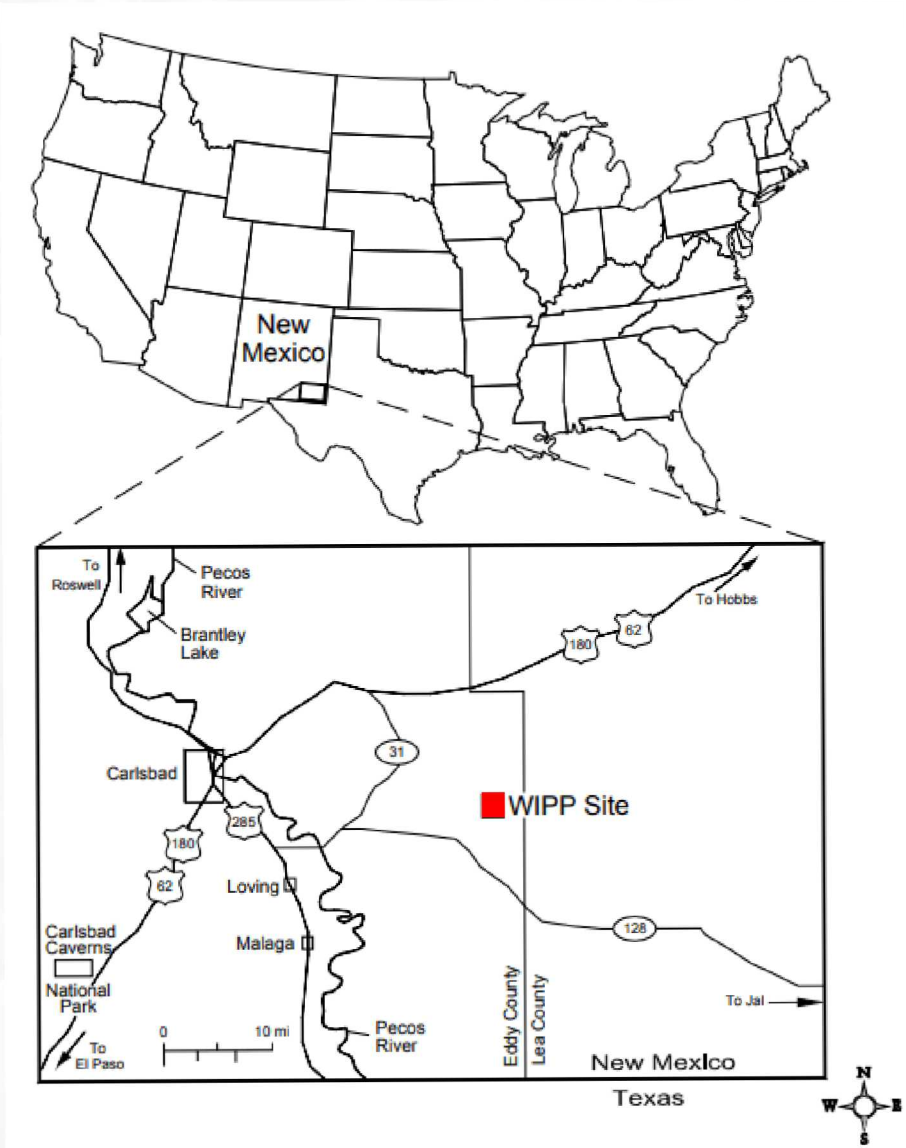
- Initial conditions to post-closure safety assessment
    - Brine migration and re-distribution
    - Evolution of disturbed rock zone (DRZ) porosity and permeability
- Brine causes corrosion of waste package / waste form
- Brine is primary radionuclide transport vector
- Liquid back-pressure can resist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

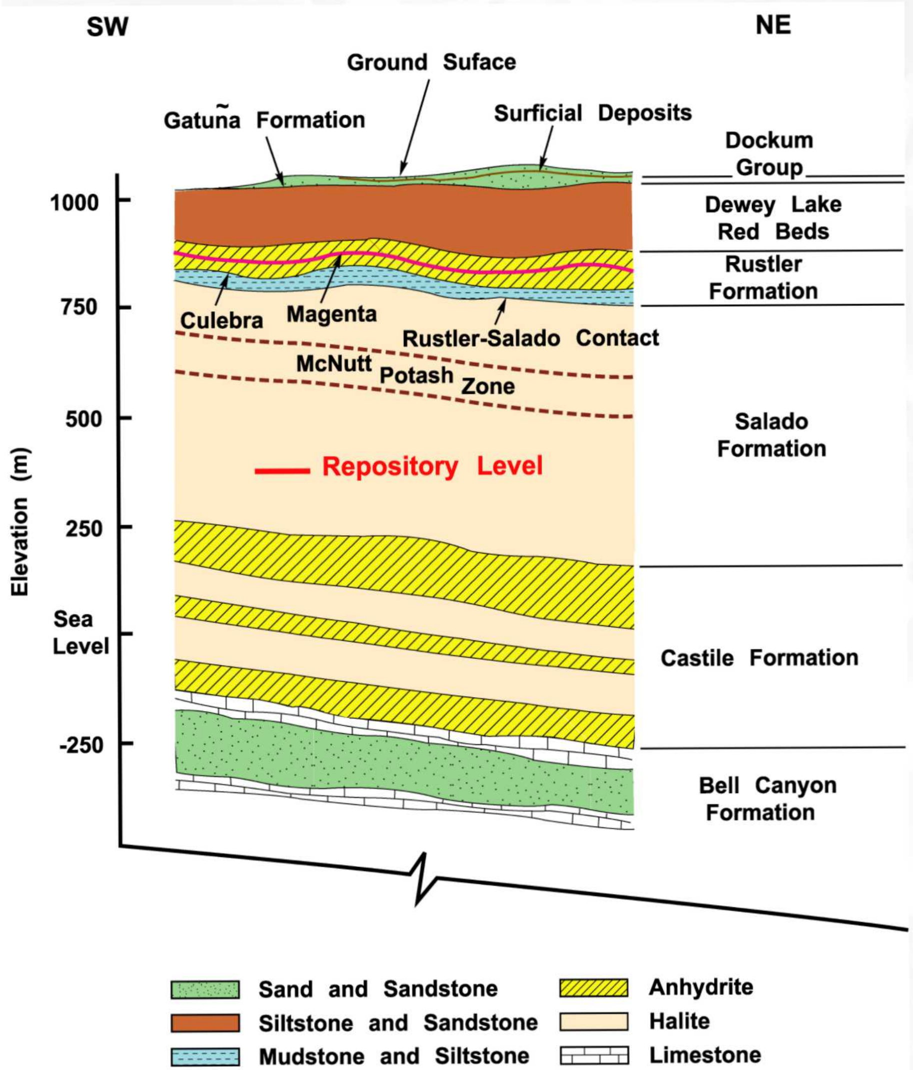

WIPP Room B heated brine migration


WIPP Room J canister tests


WIPP Room Q brine inflow

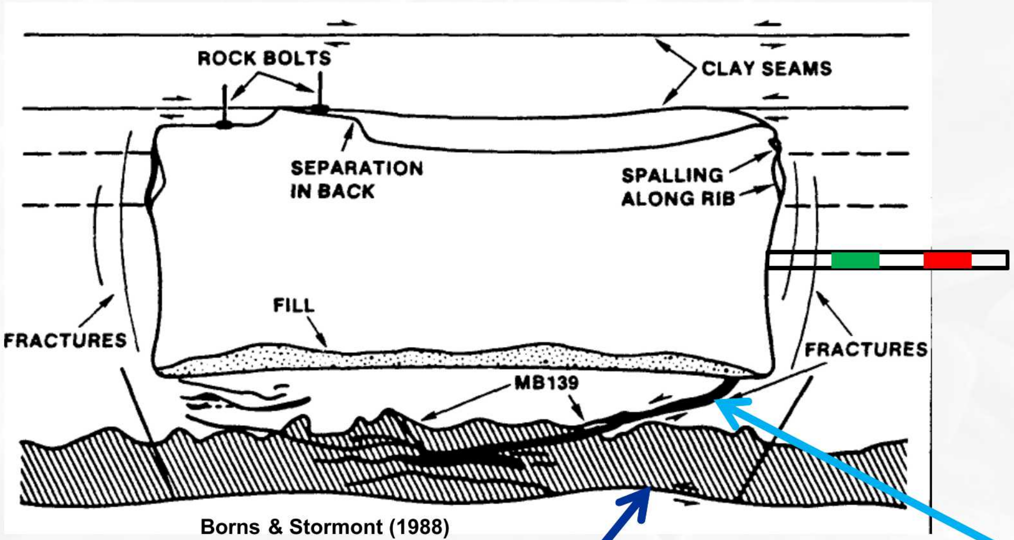
# WIPP Context



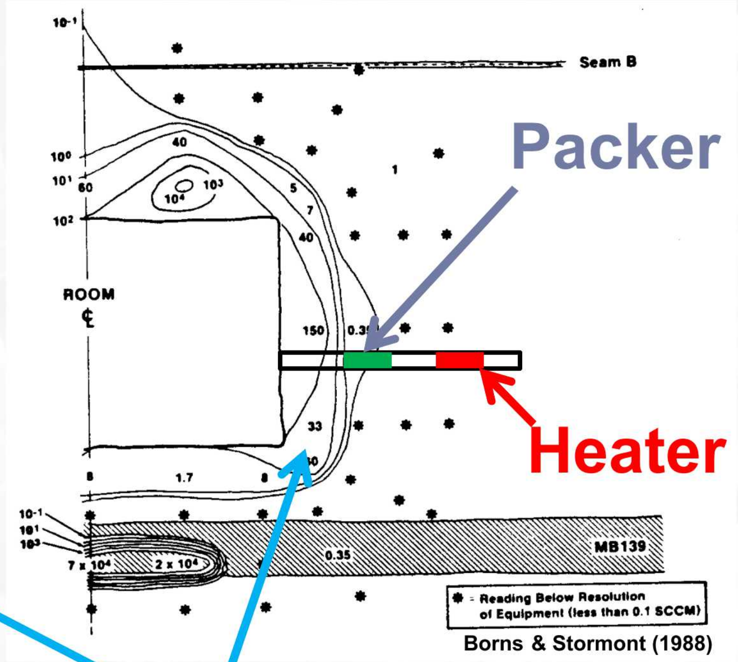



# BATS Test in WIPP DRZ

Cartoon representation of test interval relative to observed DRZ at WIPP



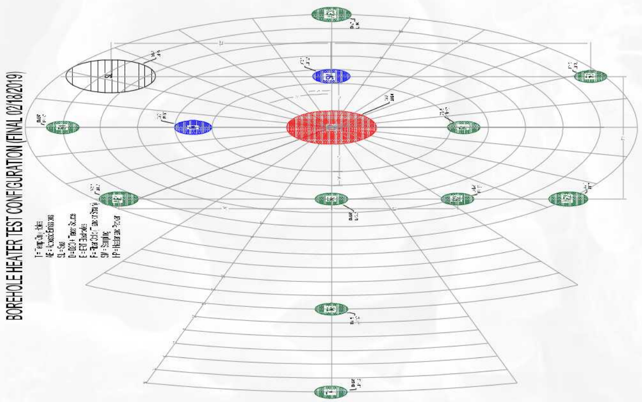

Contours of gas flowrate at fixed pressure (i.e., damage)

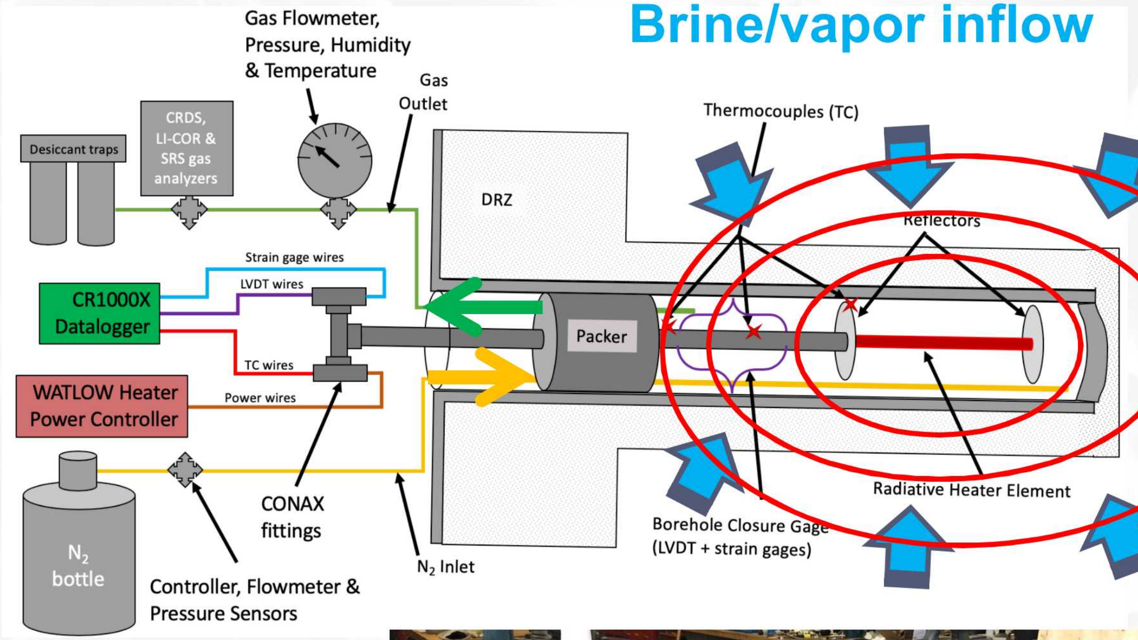


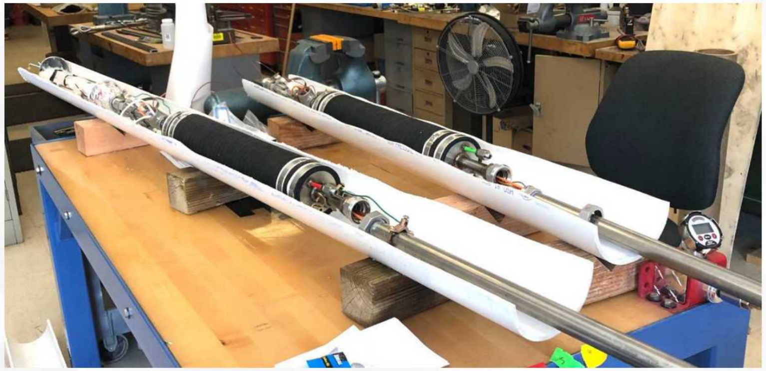

*Horizontal borehole* avoids mapped clay / anhydrite layers (e.g., MB139) in Room A/B vertical heater tests

Near-drift DRZ and damage

# BATS Test Instrumentation



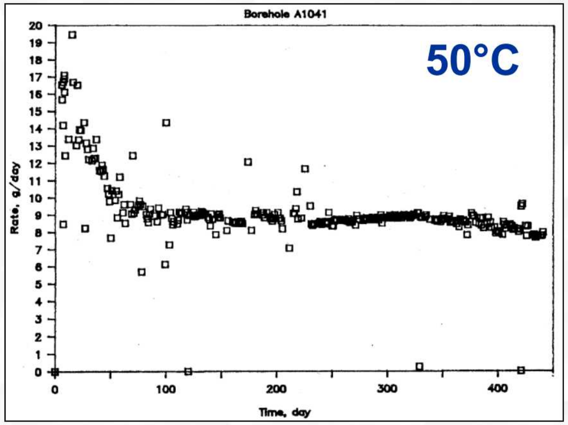
- Two identical arrays
  - Heated (120 C) and Unheated
- Behind HP packer (right)
  - Circulate dry $N_2$
  - Quartz lamp heater (750 W)
  - Borehole closure gage
  - Gas permeability before / after
- Samples / Analyses
  - Cores (X-ray CT and fluorescence at NETL)
  - Gas stream (natural / applied tracers, humidity and isotopes)
  - 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

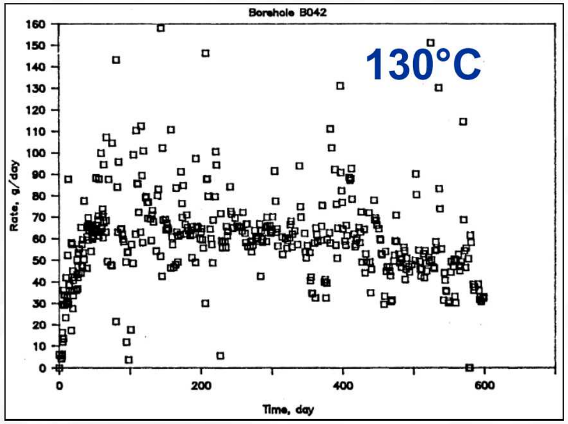
- Brine composition samples / $H_2O$ isotope data
  - Measure change in brine sources with temperature
- Geophysics
  - Map 4D evolution of **saturation** / **porosity** / **permeability**
- Temperature distribution
  - More brine available at high temp (inclusions + hydrous minerals)
  - Thermal expansion 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

- Brine inflow
  - Highest inflow rate initially
  - Exponential decay of rate with time
- More brine inflow at higher temperatures
  - Vapor from dehydration of clay & gypsum
  - Brine from fluid inclusions
- Three forms of water contribute
  - Can we discern chemically/isotopically?

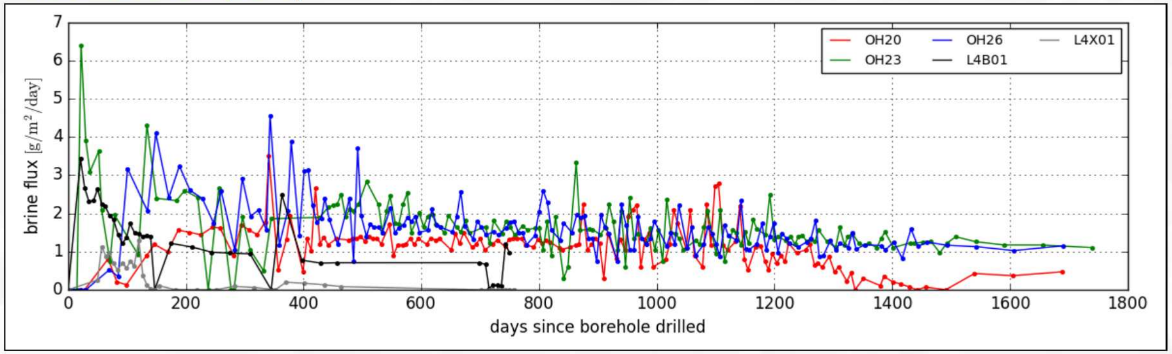



Vertical WIPP boreholes




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

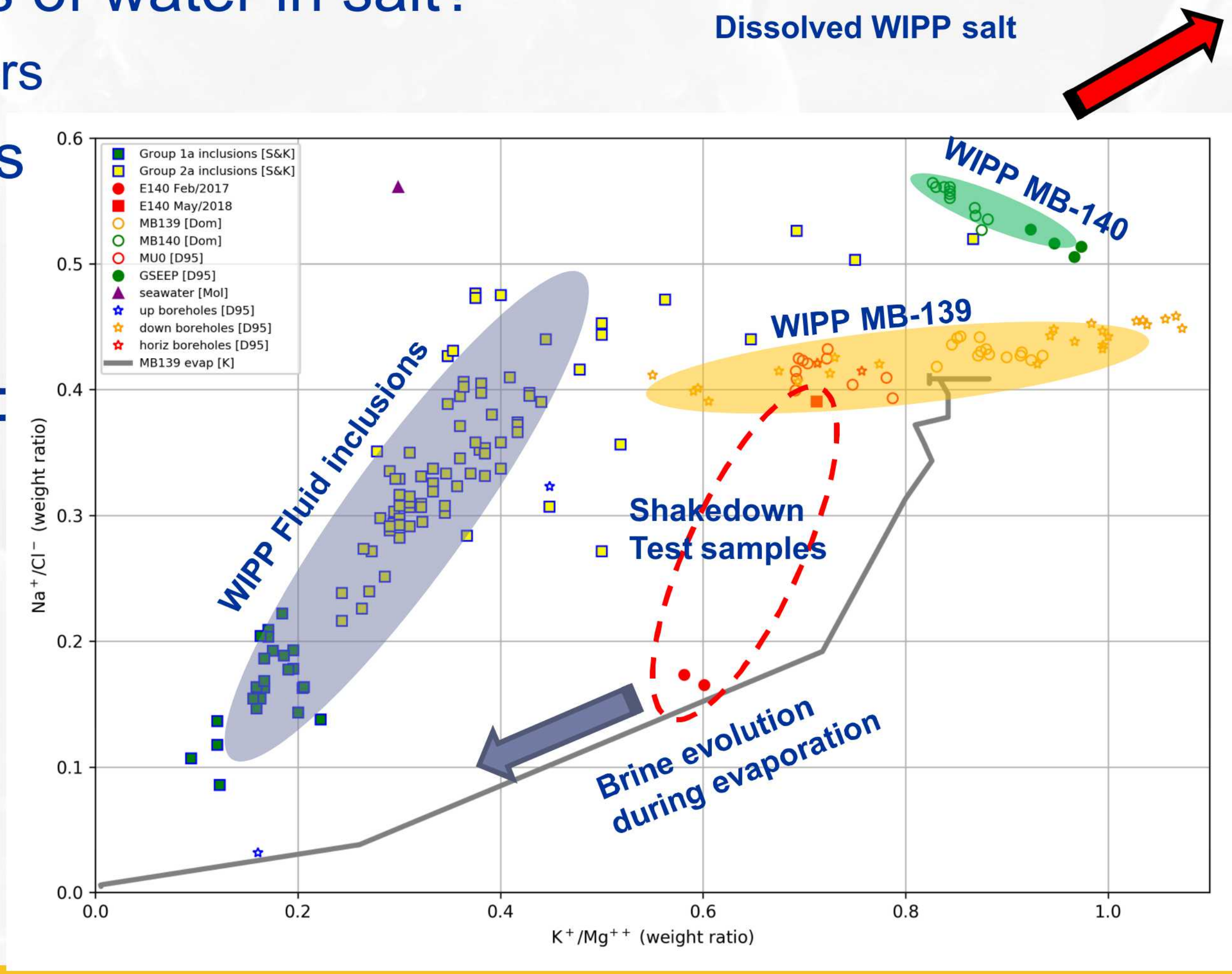
Kuhlman et al. (2017)




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


# Brine Composition

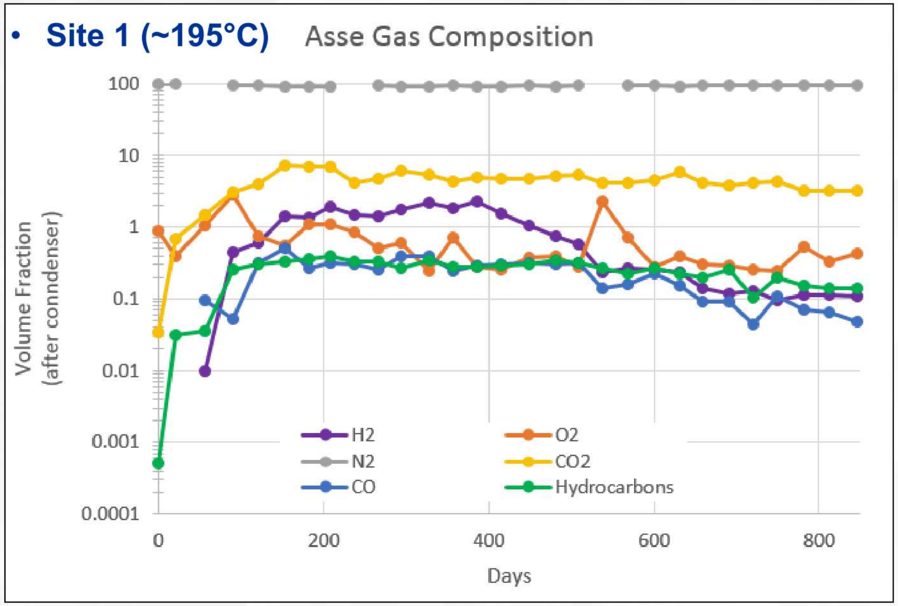
- Liquid brine samples
- Distinguish sources of water in salt?
  - Distinct endmembers
- Added liquid tracers
  - $NaReO_4$
  - Fluorescent tracer
- Data on processes:
  - Advection
  - Reaction
  - Diffusion




# GAS COMPOSITION

- Gases enter borehole 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 $H_2O$
  - Isotopically spiked water breakthrough
    - Transport time through salt
    - Fractionation in borehole
- Analyze gases real-time
  - Mass spectrometer
  - $H_2O$ / $CO_2$ infrared analyzer
  - Picarro water isotope analyzer

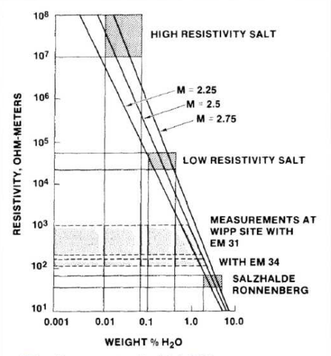
**SRS quadrupole mass spec gas analyzer**



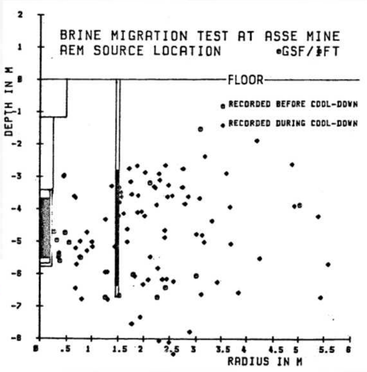

**Data from Coyle et al. (1987) BMI/ONWI-624**

# ERT / AE Expectations

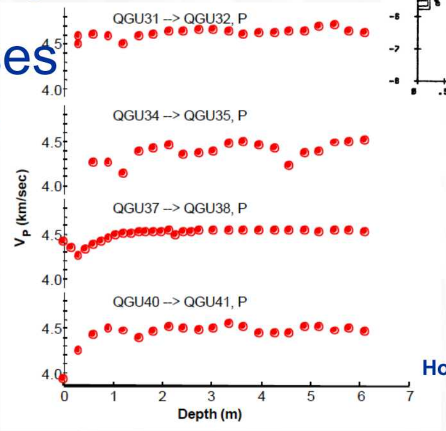
- Electrical Resistivity Tomography (ERT)
  - ERT electrodes cemented into 3 boreholes
  - Salt apparent resistivity
  - Reisitivity: reveal porosity and brine saturation
- Conduct 3D ERT surveys through time
  - Estimate evolution of porosity / saturation
- Acoustic Emissions (AE)
  - AE monitoring (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)



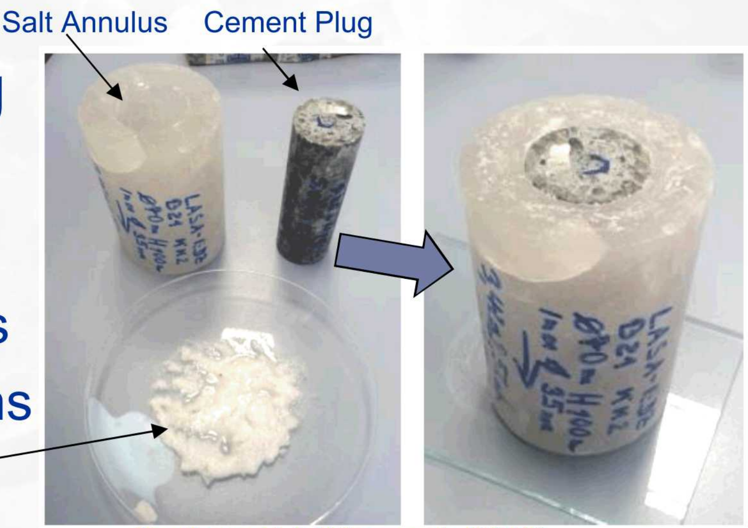

Rothfuchs et al. (1988)




Holcomb et al. (2001)

# Cementitious Seals

- Emplace Pre-fabricated Cement Plug
  - Snug fit into satellite borehole
  - Tubing embedded in plug (perm. test)
  - Monitor seal evolution as borehole closes
  - Parallel tests: ambient + heated conditions
- Upscale GRS Lab Seals Tests
  - GRS test monitored permeability evolution
  - We will implement at borehole scale
- Overcore Post-test to Analyze Interfaces
- Collaboration with GRS
  - Use same cement formulas in field as lab experiments
  - Send WIPP salt and brine recipe to GRS for lab experiments




Czaikowski & Wieczorek (2016)

# Proposed DECOVALEX Task

- DECOVALEX 2023: Proposed Task H
- Construction/Testing
  - New boreholes cored/driled Feb-Apr 2019
  - Test constructed/installed in new boreholes (June 2019)
  - Heated test conducted for ~6 months (two phases)
  - Unheated test conducted ~12 months

- *2019:* Initial test execution
- *2020:* Distribute initial test data
- *2021:* Simulate single processes (+ thermal)
  - Brine production, $D_2O$ transport
  - Thermal-Hydrologic, Thermal-Mechanical, Thermal-Chemical
  - Follow-on test data available
- *2022:* More coupled processes
  - Salt permeability/porosity as a function of damage
- *2023:* Include data from ERT/AE/brine composition

- Interested Parties
  - US (SNL, LANL, LBNL), Germany (BGR, GRS), UK (RWM), Netherlands (COVRA)