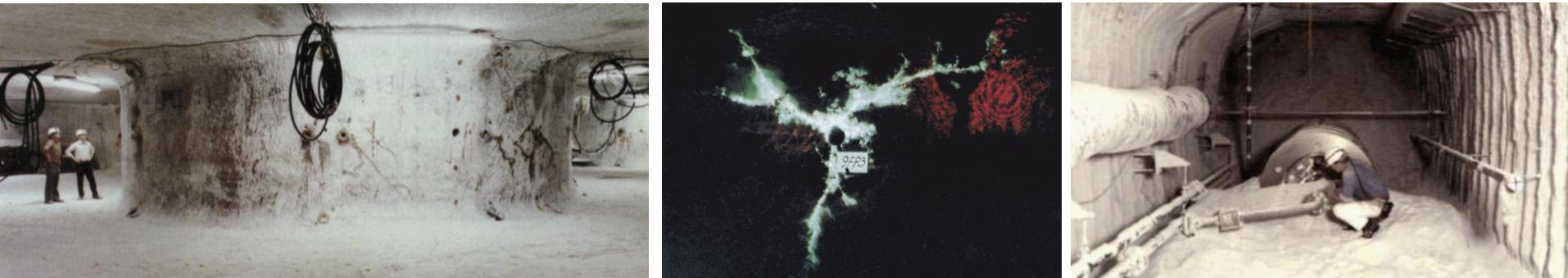


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# Historic Testing Relevant to Disposal of Heat-Generating Waste in Salt

ANS International High-Level  
Radioactive Waste Management  
Conference, April 29, 2013  
Albuquerque, NM

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Sandia National Laboratories, Carlsbad NM



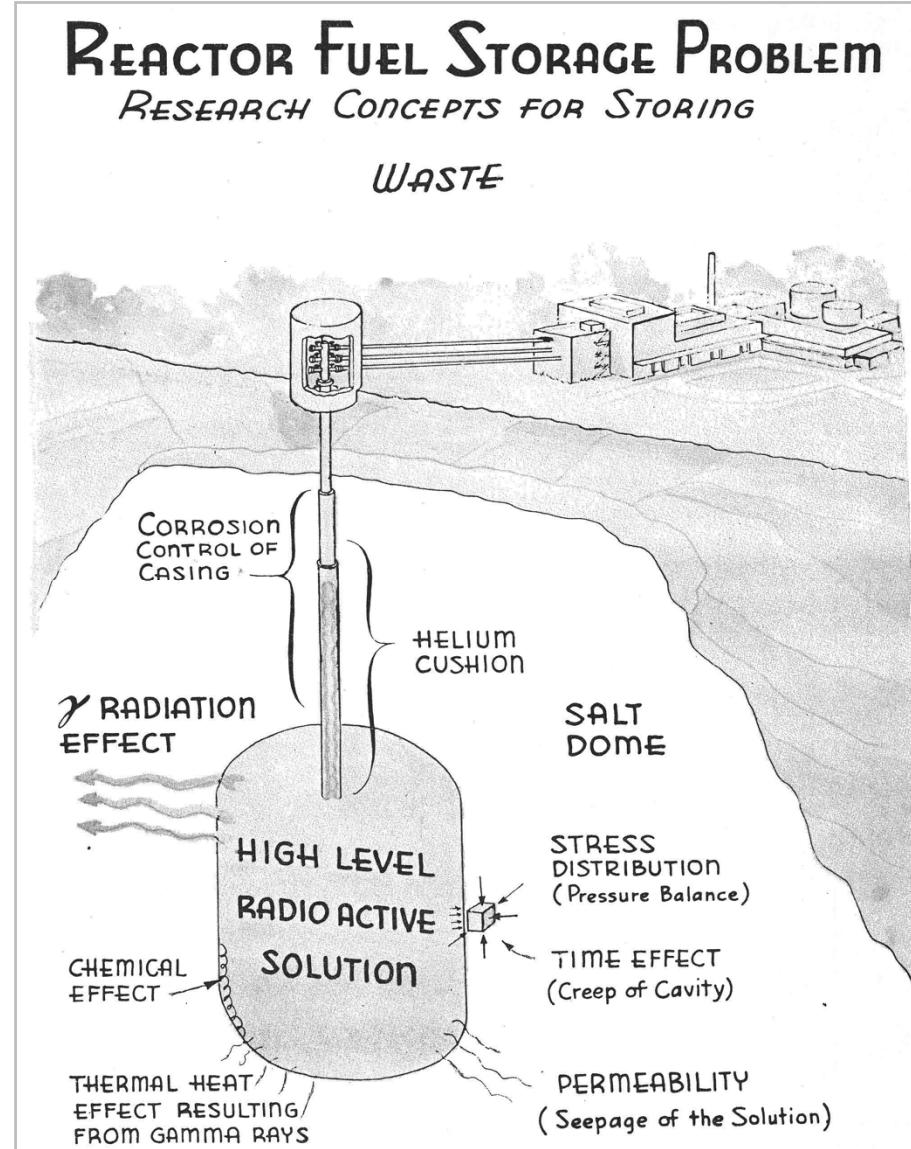
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# Historic Hot Salt Testing

- Early liquid waste tests in salt (late '50s)
- Project Salt Vault demonstration (early-mid '60s)
- Avery Island, Louisiana (late '70s- early '80s)
- Pre-WIPP SNL laboratory testing (late '70s)
- WIPP in situ tests (mid-late '80s)
- Asse in situ tests ('80s and '90s)
- *Only Highlights:* many smaller tests not discussed here

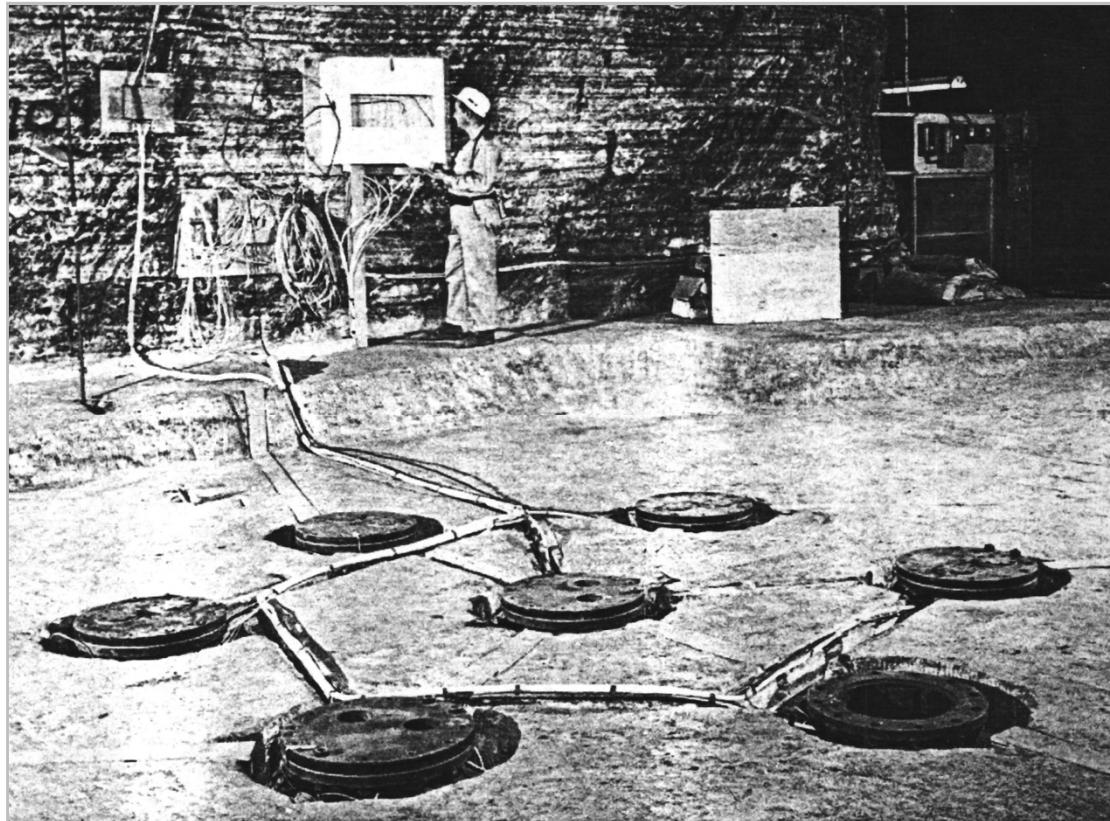
# Early '50s Testing

- NAS panel recommended direct disposal of *liquid* reprocessing waste in salt cavities (Hess et al., 1957).
- U Texas Austin performed early lab testing
  - Creep (up to 410° C)
  - Cavity closure
  - Salt permeability to He, brine, and kerosene
  - Grand Saline Mine (Dallas, TX)
- ORNL performed early liquid waste field tests



# ORNL Project Salt Vault

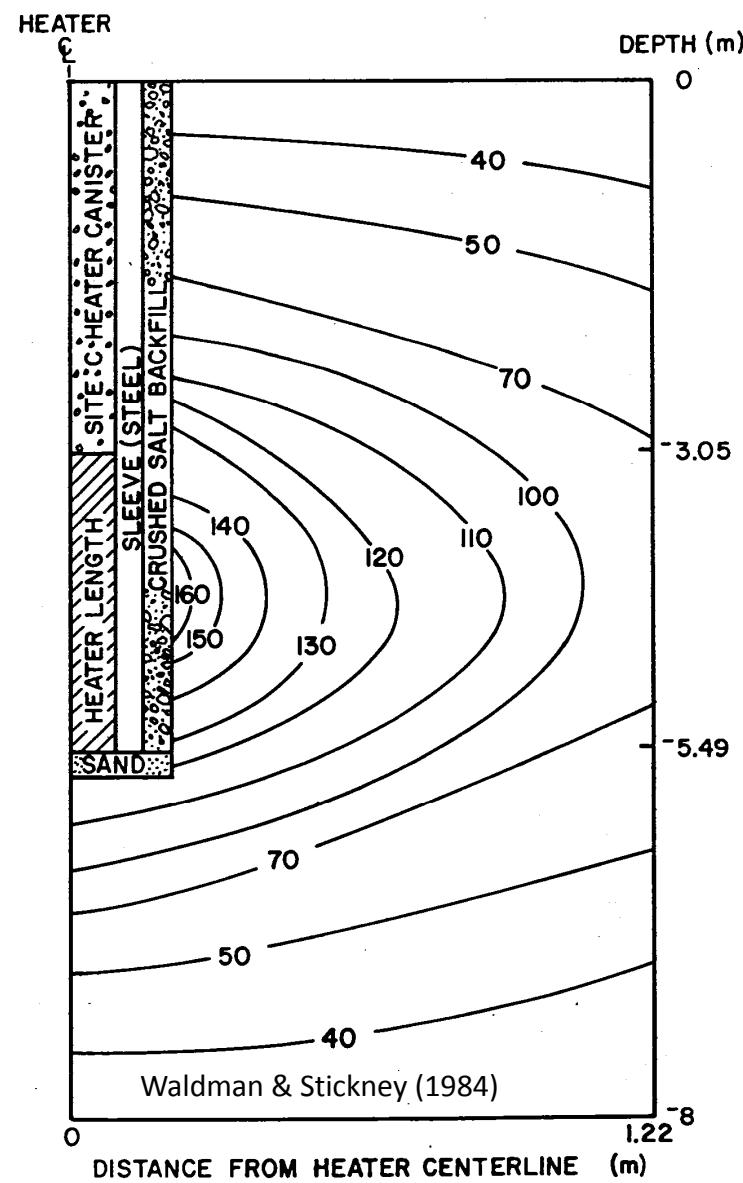
- Carey salt mine (Lyons, KS) for AEC solid waste demonstration
- Hot borehole (July '62)
  - Two 5-kW heaters
  - salt to  $> 350^{\circ} \text{ C}$
  - *Decrepitation!*
- 3 vertical-borehole heater tests ('65 – '67)
  - 7 boreholes (10.5 kW)
  - radioactive sources
  - brine migration
  - salt to  $> 200^{\circ} \text{ C}$
- Heated Pillar ('66 – '67)
  - 33 kW (22 heaters)



Bradshaw & McClain (1971)

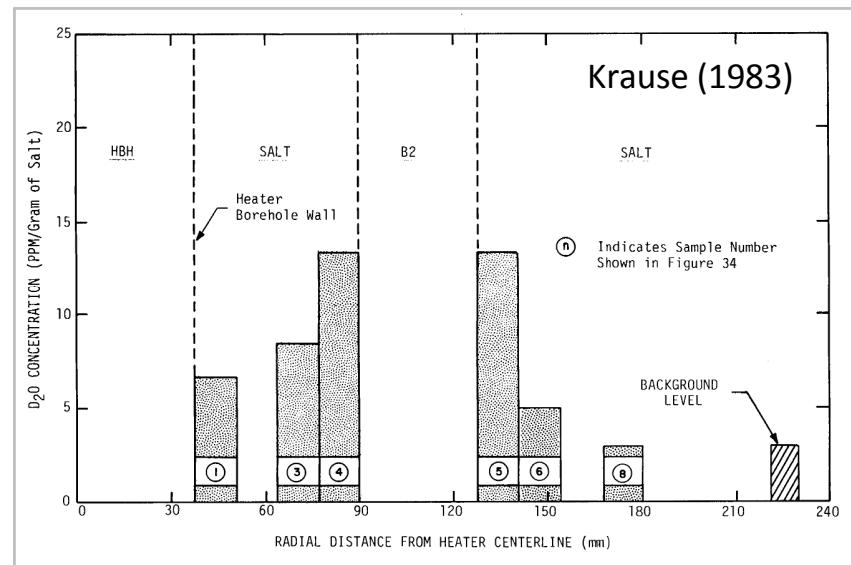
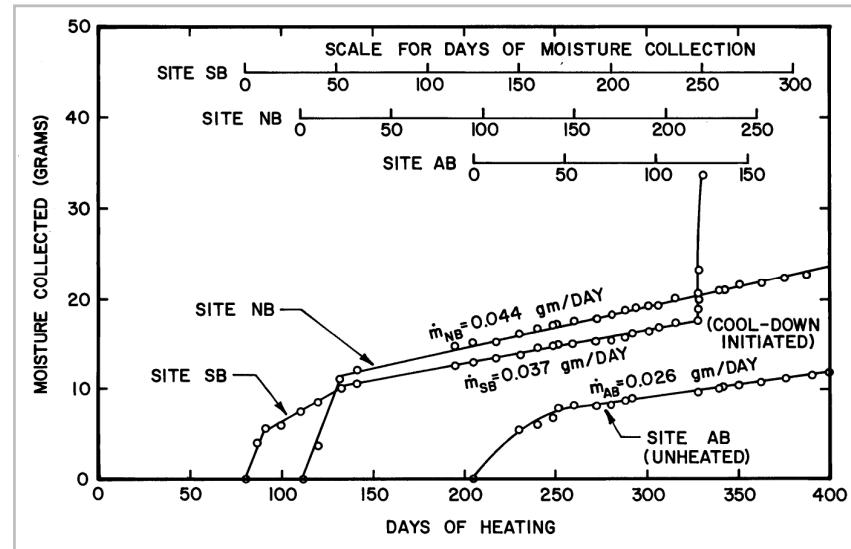
# Avery Island, LA (1)

- OWI/ONWI-led heated salt test ('78 – '83) – site C
  - 4-kW central heater
  - Eight guard heaters (5.6 kW total)
  - Crushed salt backfill
  - Operated 5 years



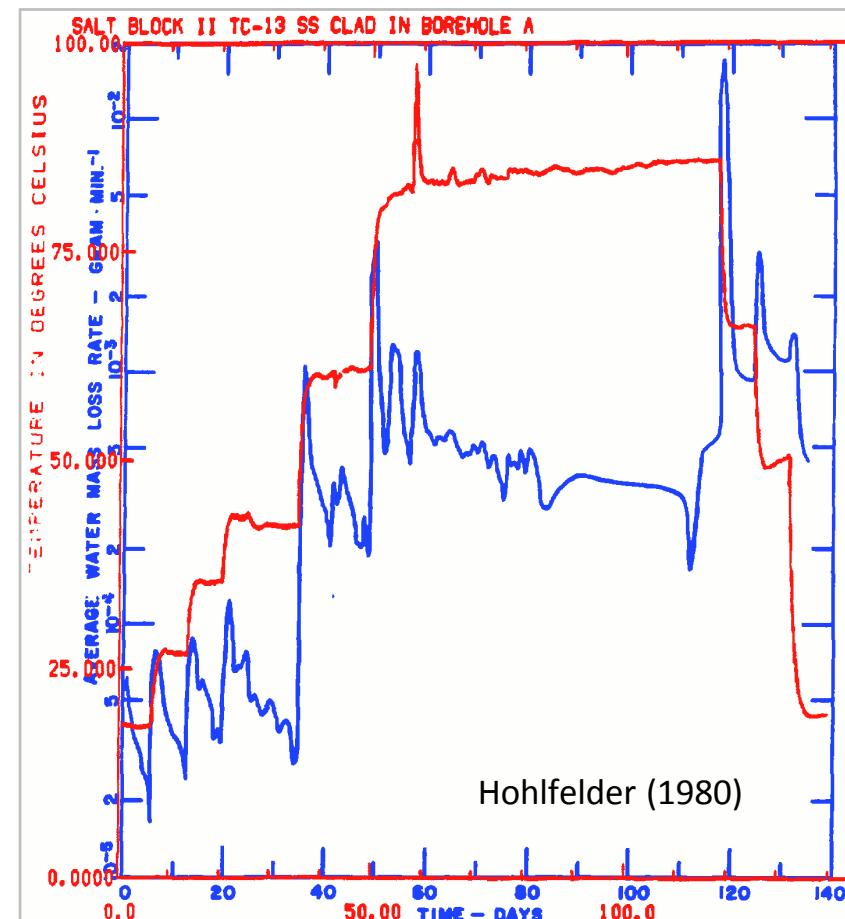
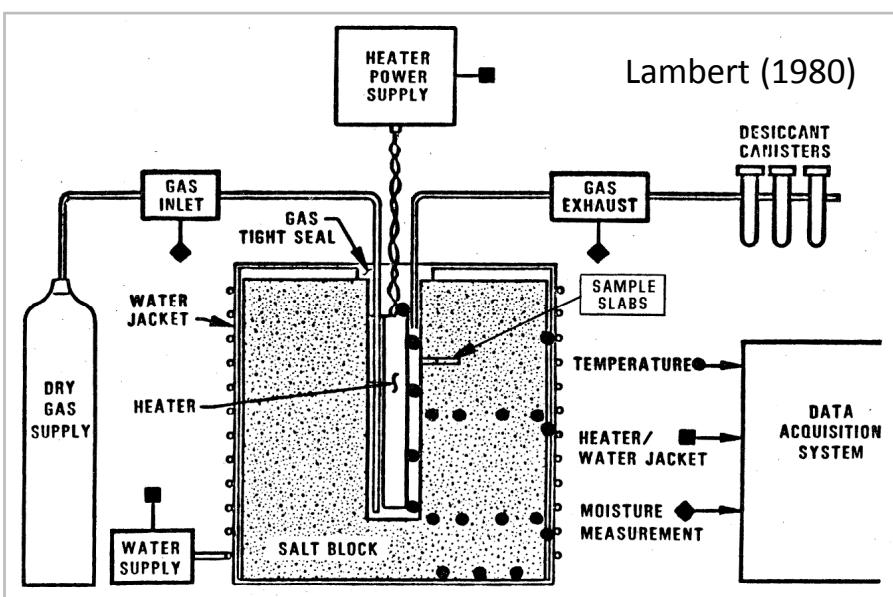
# Avery Island, LA (2)

- OWI/ONWI-led brine migration test ('79 – '80)
- Three sites
  - AB: unheated
  - NB: heated natural brine
  - SB: heated tracer brine
- Tracer test (Deuterium)
  - Tracer moved up & down thermal gradient



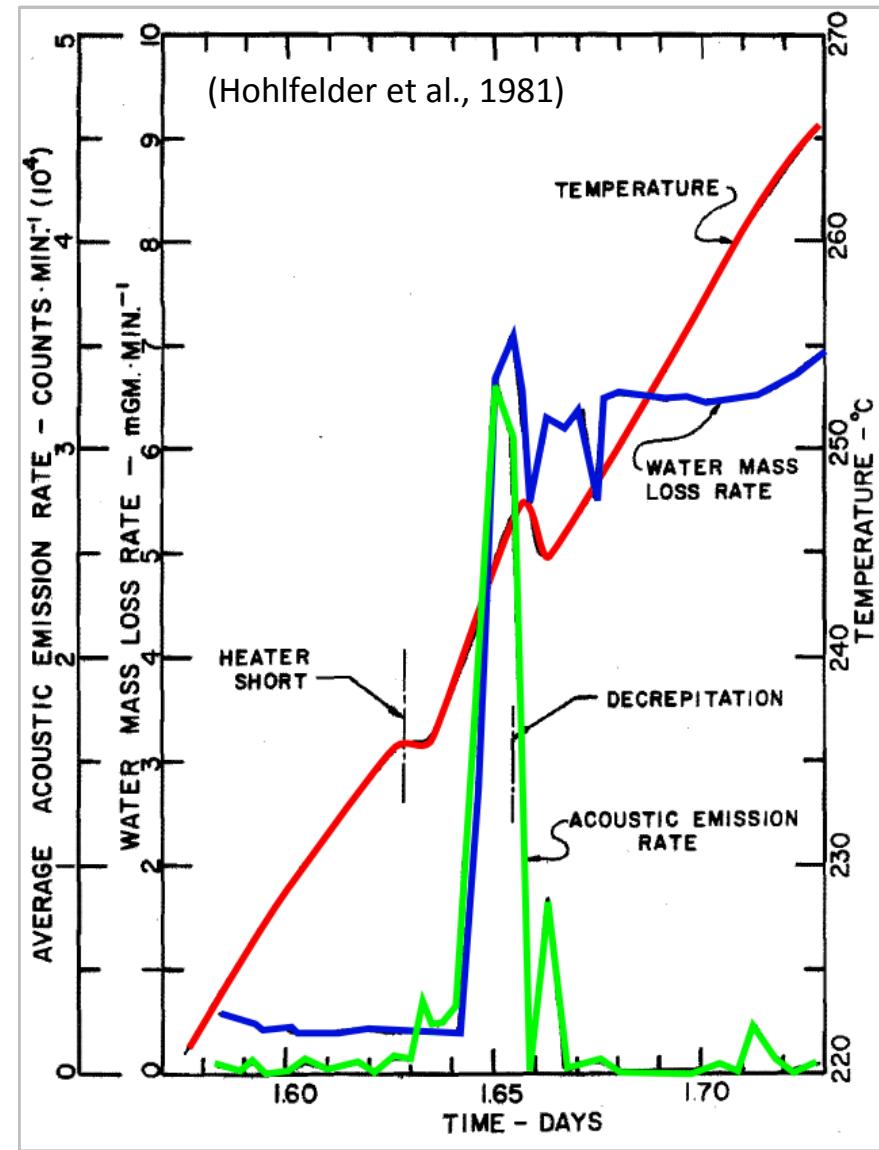
# Lab Test (1): Salt Block II ('78 – '79)

- 1 m × 1 m salt cylinder (1700 kg)
- Axially heated in steps to 200° C
- Cooled in steps
- High-frequency brine monitoring
- Embedded thermocouples



# Lab Test (2): Salt Cracker ('80)

- Two 1.6-kg salt cylinders
- Heated to 200° & 300° C
- Acoustic Emissions
  - Decrepitation
  - Change in heater power
- Brine inflow
  - Decrepitation
  - Change in heater power
- Even after decrepitation, brine inflow spiked during cooling



# Waste Isolation Pilot Plant\*

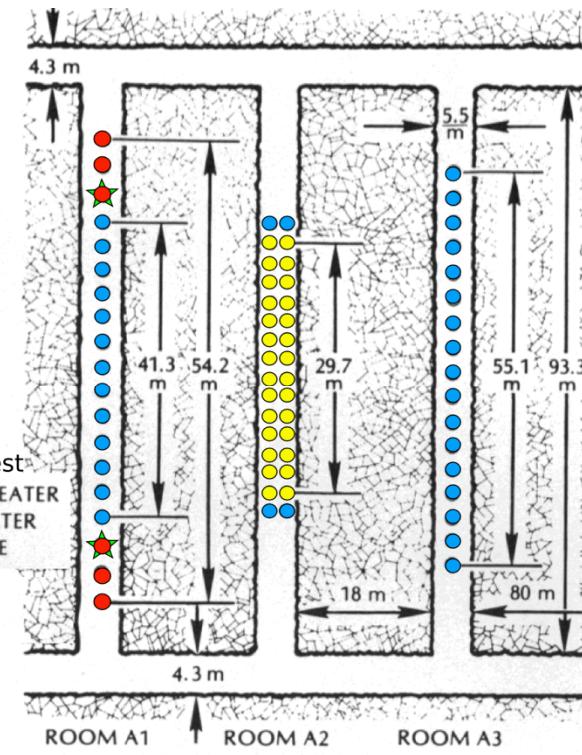
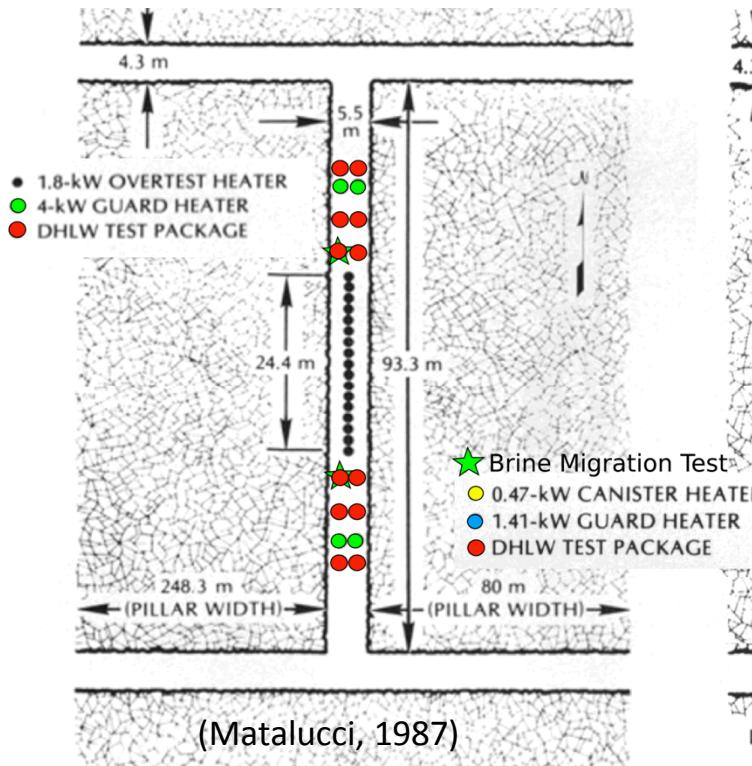
- Thermal/Structural Interactions Tests (TSI)
  - Rooms A1-A3 (18 W/m<sup>2</sup> DHLW mockup)
  - Room B (DHLW “overtest”)
  - Room H (Heated axisymmetric pillar)
  - Room D (~Isothermal version of Room B)
- Waste Package Performance Tests (WPP)
  - Room T (Transuranic waste mockup)
  - Room J (Transuranic waste “overtest”)
  - DHLW materials tests piggybacked with TSI in Rooms A1/B
    - Waste Package materials tests
    - Borehole backfill materials tests
- Plugging and Sealing Program (PSP)
  - Brine migration test piggybacked with TSI in Rooms A1/B

\* Tyler et al. (1988)

# WIPP (1): Rooms A/B

- Room A2: “design” DHLW thermal load (470 W heaters)
- Room B: “overtest” conditions (1800 W heaters)
- 4 brine migration tests
- 18 Waste Package Performance tests (11 retrieved)

**Room B**  
 17 @ 1.8 kW  
 4 @ 4.0 kW  
 8 @ 1.5 kW  
**58.6 kW total**

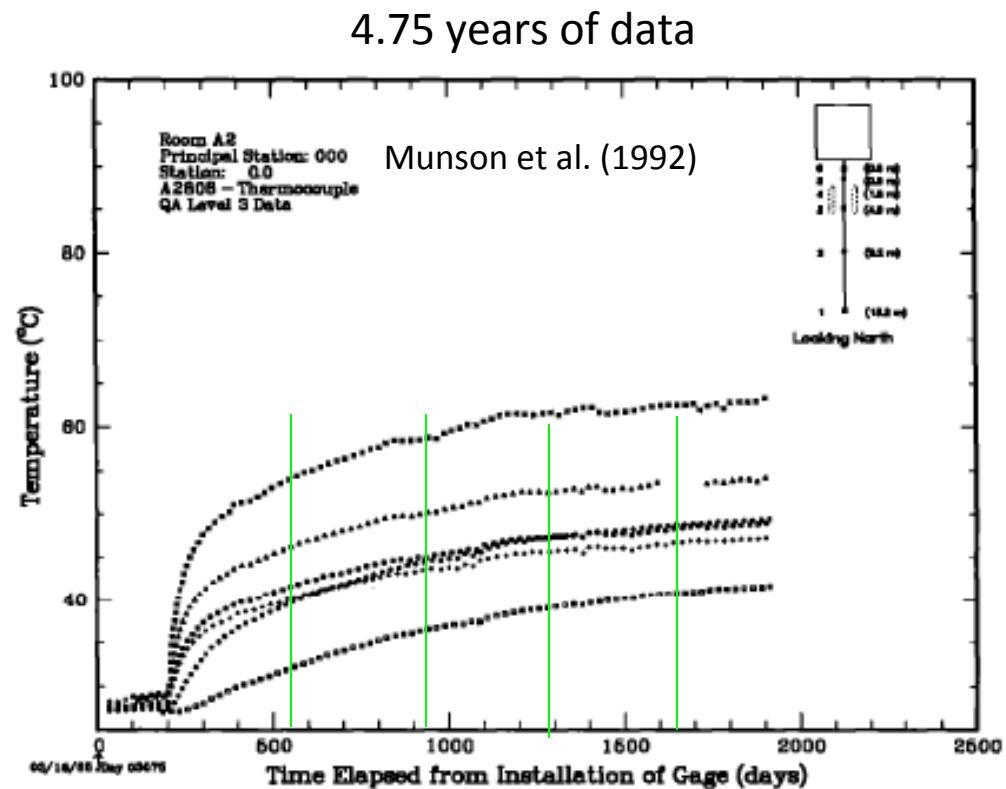
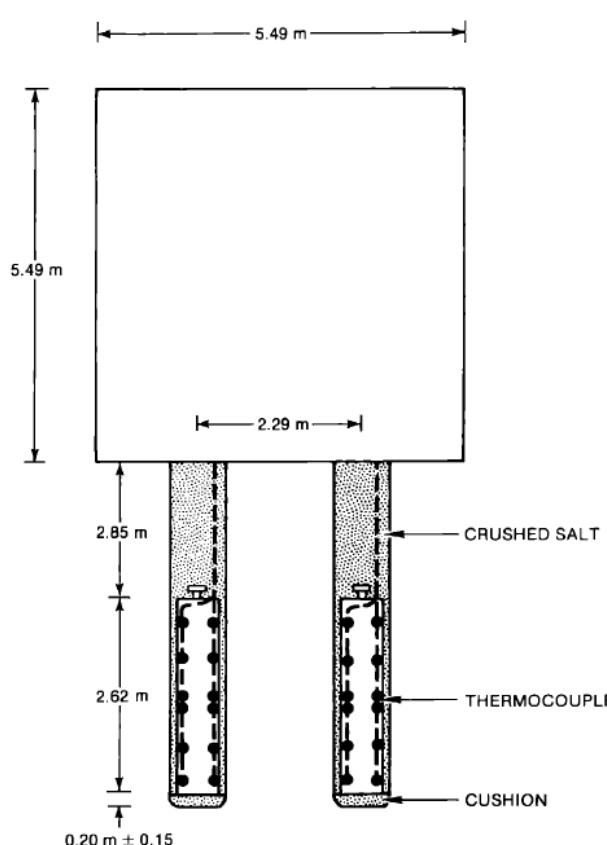


**Rooms A1-A3**  
 34 @ 0.47 kW  
 34 @ 1.41 kW  
**63.9 kW total**

# WIPP (2): Room A2 ('85 – '90)

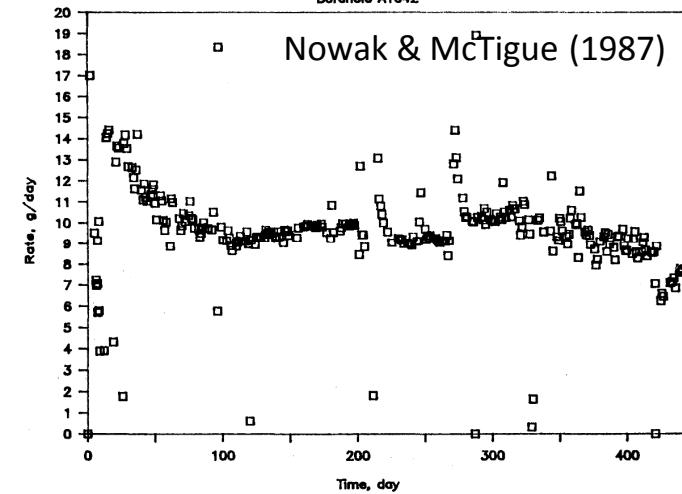
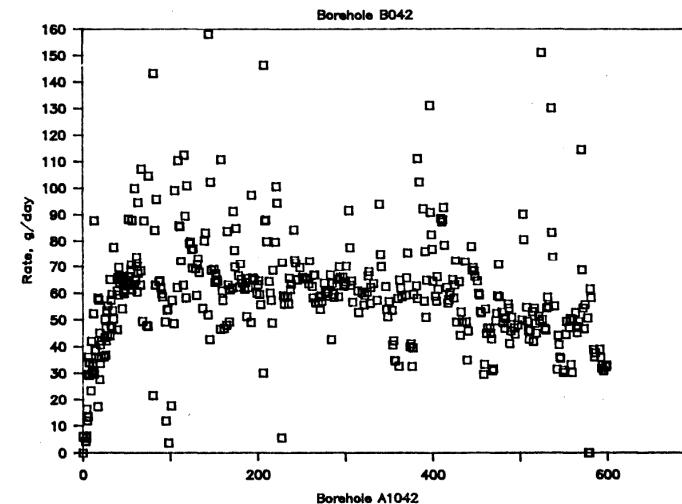


# WIPP (3): Room A2



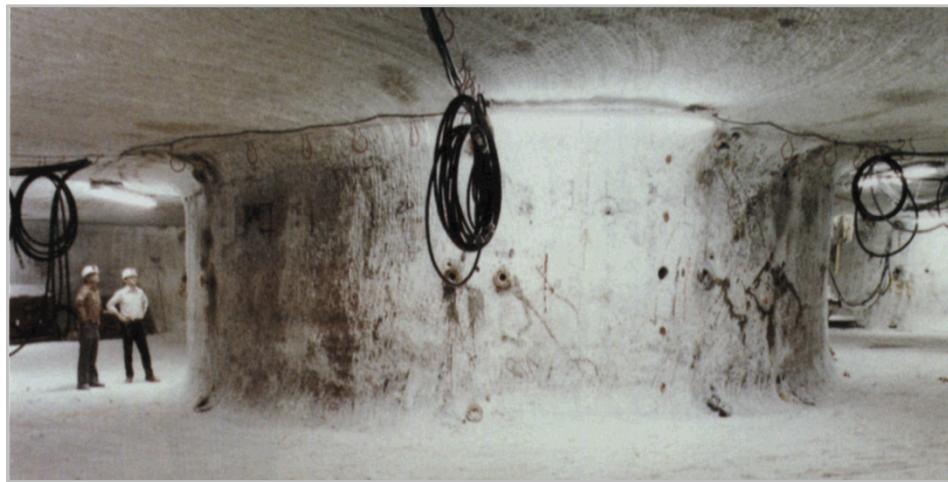
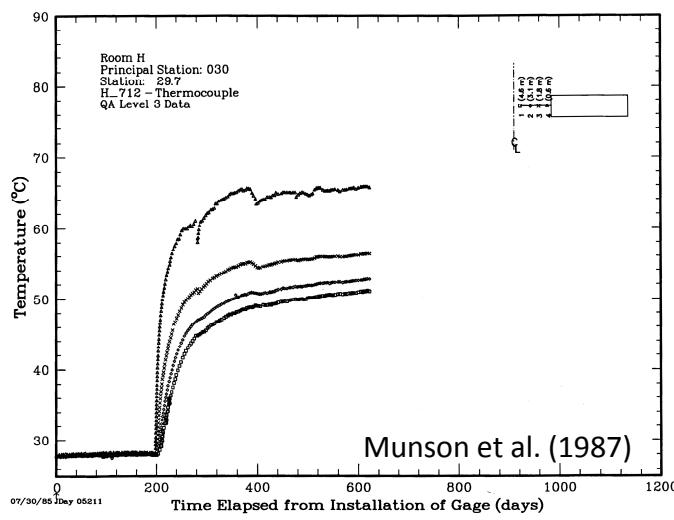
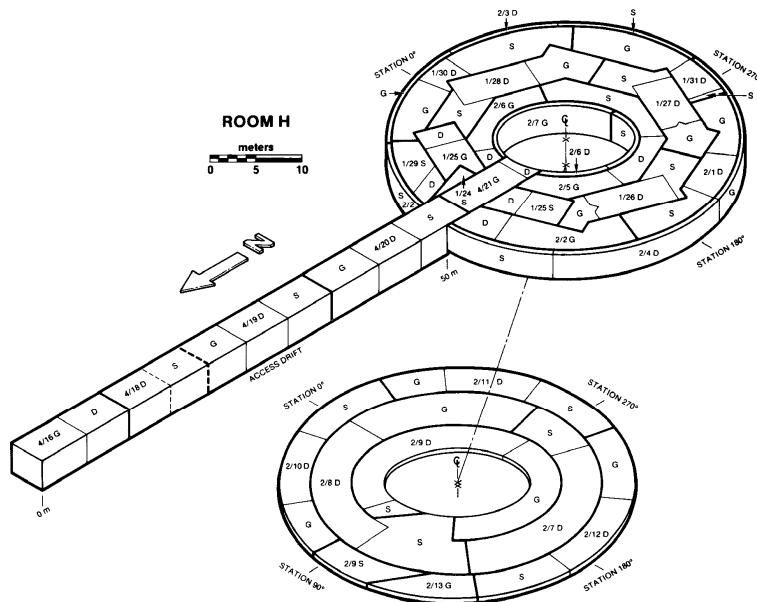
- Rooms A/B included *thousands* of measurement points:
  - Temperature, differential creep, oriented stress (pressure), brine inflow, room closure, heat flux, and heater power.

# WIPP (4): Room A1/B Brine Inflow



Room B:  $130^\circ \text{ C}$ , 35 L brine/borehole  
Room A1:  $50^\circ \text{ C}$ , 4.5 L brine/borehole

# WIPP (5): Room H ('86 – '95)

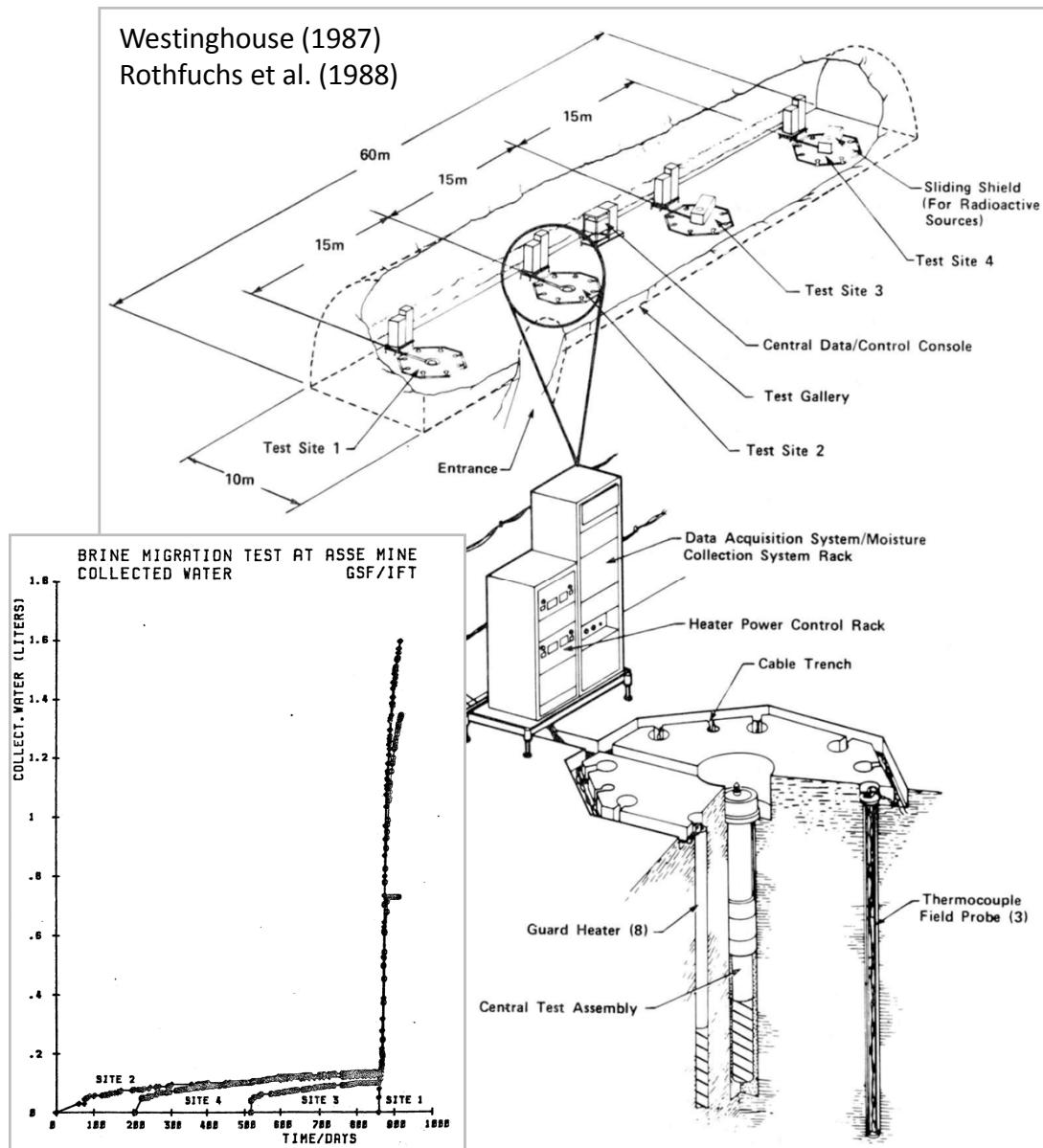


# Asse II Mine (Germany)

- Heated Brine Migration test ('83 – '85)
- Waste Emplacement Demonstrations (BAMBUS I & II)
  - Vertical Boreholes (DEBORA-1 and DEBORA-2)
    - One-year heated tests ('97 – '98)
    - Crushed salt reconsolidation in boreholes
  - In-drift, backfilled with crushed salt (TSDE)
    - Ten-year heated test ('90 – '99)
    - Six large heated canisters in two drifts
    - Backfilled drifts with crushed salt

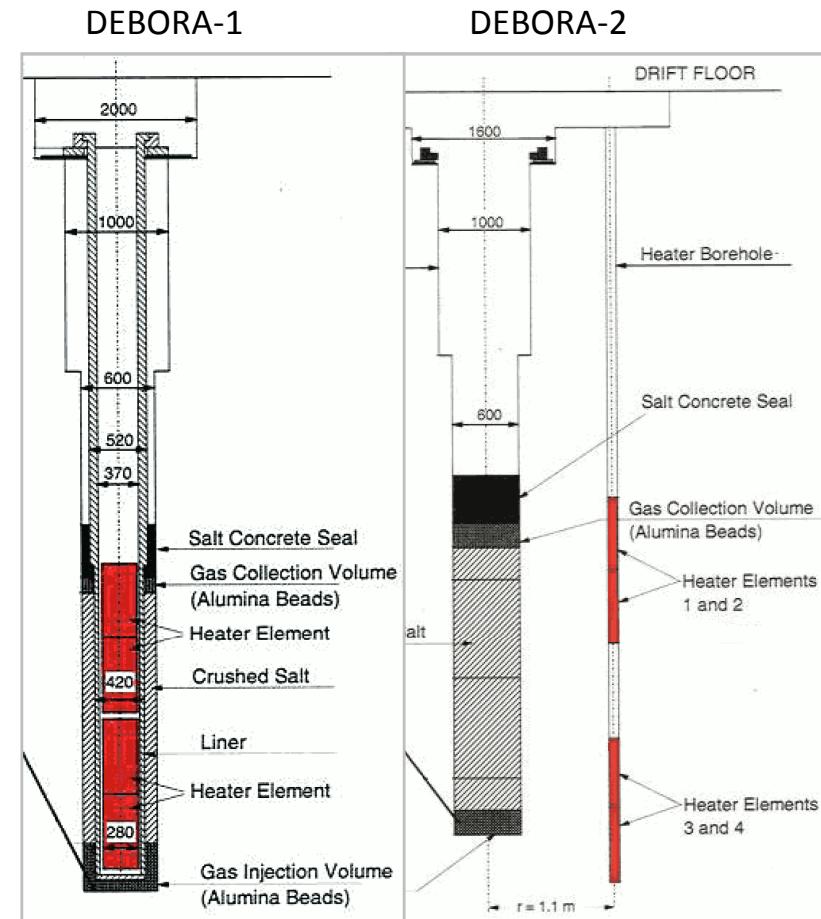
# Asse (1)

- Brine Migration Test
- Four heated sites
  - Two with  $^{60}\text{Co}$  sources
  - Two sites pressurized
- Measurements of:
  - Room closure
  - Temperature
  - Brine inflow
  - Borehole gas content
  - Acoustic emissions
- <200 mL brine inflow during tests per borehole
- 90% of brine collected during cooling



# Asse (2)

- DEBORA-1 (Feb '97 – Mar '98)
  - 9-kW heater in borehole
  - Crushed salt compaction @ 185° C
    - Reconsolidated: 38% → 9%
    - Permeability reduction:  
 $5 \times 10^{-12} \rightarrow 7 \times 10^{-14} \text{ m}^2$
- DEBORA-2 (Sep '97 – Dec '98)
  - 15-kW heaters around borehole
  - Crushed salt compaction @ 135° C
    - Reconsolidated: 37% → 12%
    - Permeability reduction:  
 $1 \times 10^{-10} \rightarrow 4 \times 10^{-13} \text{ m}^2$

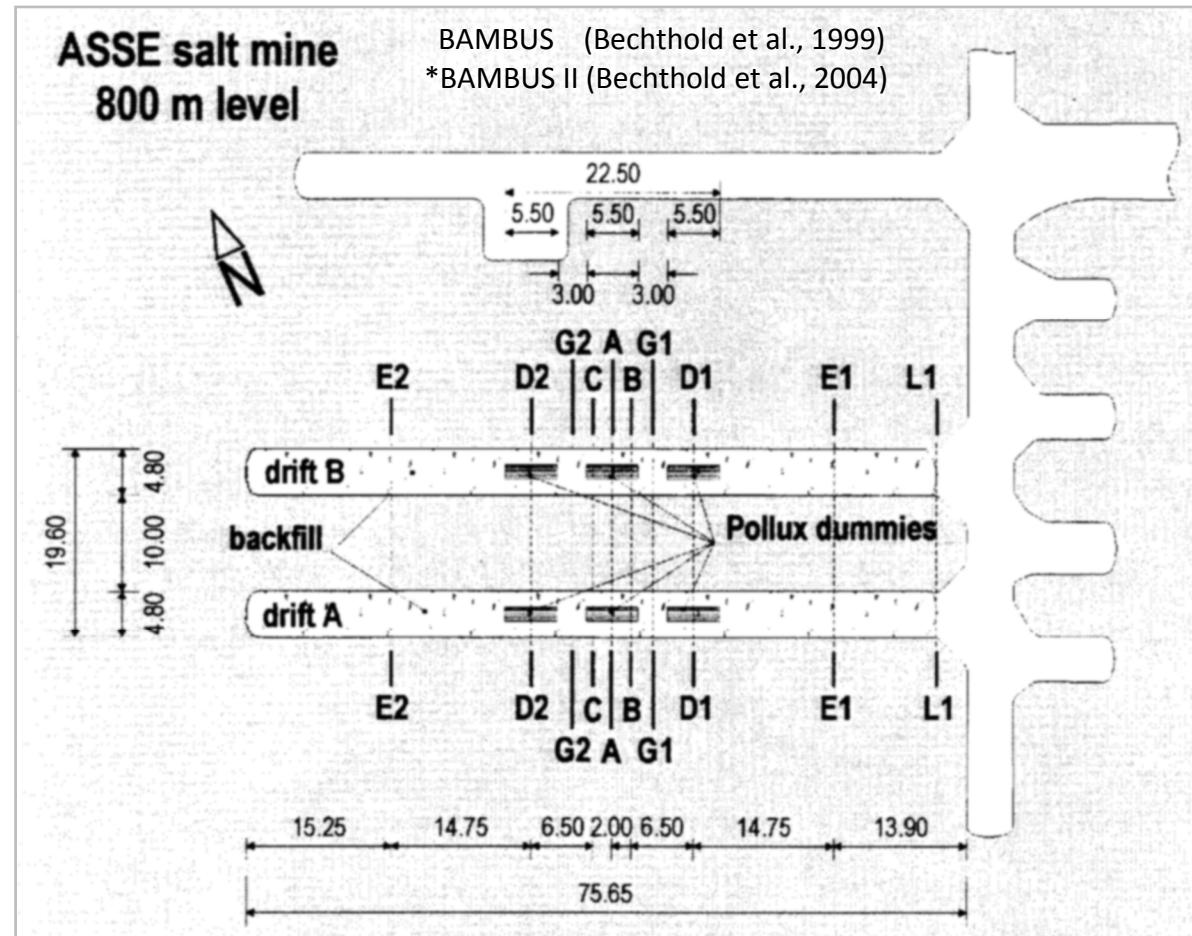


Bechthold et al. (1999)

**Measured:** corrosion, temperature, pressure, borehole convergence, and salt gas permeability in crushed salt.

# Asse (3)

- Thermal Simulation of Drift Emplacement (TSDE)
- Six POLLUX casks
  - $1.5 \text{ m} \times 5.5 \text{ m}$
  - 6.4-kW heater
  - 65 tons
- Crushed salt backfill
- Instrumented
  - Temperature
  - Closure
- Observation bores completed from nearby drifts
- Extensive Post-mortem tests\*



# 50+ years of testing!

## Thank You

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