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# Capturing Early Evolution of Salt Openings

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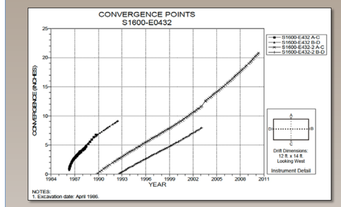
## Background

Radioactive waste disposal in salt has been investigated for >50 years because of the beneficial qualities of salt, including:

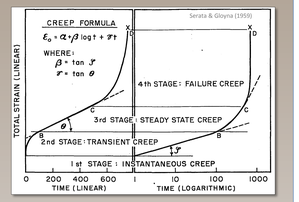
- High thermal conductivity,
- Rapid viscoplastic deformation (creep) and healing, and
- Impermeability to fluid flow when undisturbed.

Although rapid salt deformation of salt contributes to its self-healing capability, this leads to the special need to characterize excavations in salt, focusing on:

- Critical early-time displacement data in rooms,
- Porosity and permeability development due to excavation damage,
- Development of the Disturbed Rock Zone (DRZ), and
- Understanding the "initial conditions" in a drift before subsequent testing, such as in an Underground Research Laboratory (URL).




*>20 years of room closure data at WIPP (left) and primary stages of creep (right)*

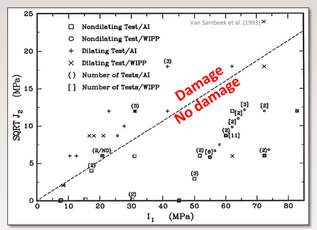



## Salt Damage as Observed in Laboratory Tests

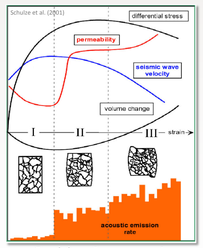
Salt is known to creep and deform, but not all conditions cause an increase in damage, which manifests as an increase in porosity. Salt is essentially impermeable and does not have significant connected porosity under undisturbed conditions. The increase in porosity during damage is the primary source of permeability and porosity observed near excavations.

Hydrostatic stress
$I_1 = \sigma_1 + \sigma_2 + \sigma_3$

Octaheadral shear stress
$J_2 = \tau^2_{oct}$

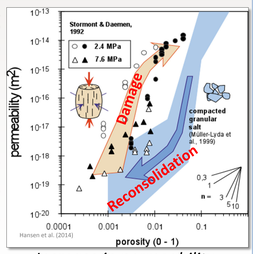



Under confined conditions (below diagonal in figure) no damage is imparted to salt during loading. High deviatoric stress (above diagonal) occurs near excavations, resulting in damage and increased porosity.




*Sudden increase in permeability with strain (zone II) in lab tests.*

Slight increases in porosity during loading and damage can lead to significant increases in permeability, due to the connection of oriented microcracks. We must observe and predict the damage imparted to the salt around an excavation. The sensitivity of permeability to change in porosity makes gas and liquid hydraulic tests useful tools to determine this.

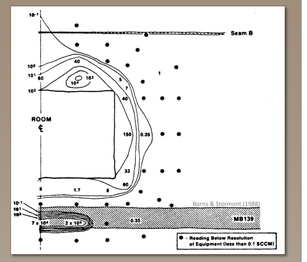



*Increase in permeability with small changes in porosity during damage*

## Salt Damage in Drift Scale Observations and Modeling

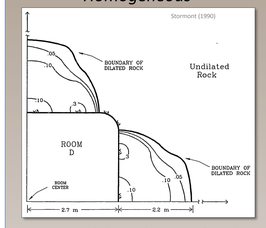
The permeability of salt to gas flow is a measure of the amount of damage imparted to the salt, as a result of creating the access drift. The figure shows contours of gas flowrate (* indicates low flowrate and damage), quantifying the damage surrounding an excavation.

These observations of damage were made long after the access drifts were excavated, and were created from data spanning several drifts of different age, but the distribution of damage around the excavation is still clear.

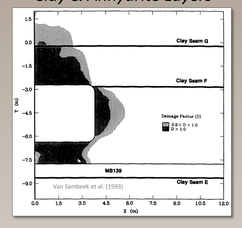



*Contours of normalized flowrate, Characterizing damage and DRZ*

*Homogeneous*




*Clay & Anhydrite Layers*




*Model predictions for change in porosity (left) and damage factor (right) for excavations in WIPP*

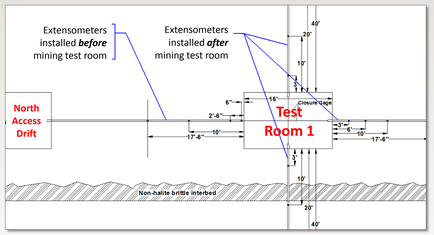
Model predictions can be used to estimate damage and change in porosity or permeability to the rock, but good quality early transient field data are still needed to validate these models.

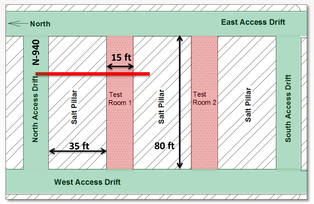
Collecting data to validate these models requires careful planning and execution.

## Plans for Instrumenting Testing drifts to Observe Early Deformation

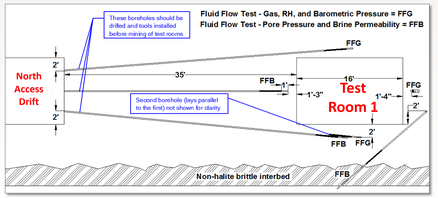
We present a proposed testing arrangement to collect geomechanical and hydrological observations before, during, and after excavation of a test drift in a URL. A series of access drifts will be excavated before the test drifts.

Extensometers will be installed near where the test drift will be mined, to get early time deformation data. Fluid flow test intervals will also be constructed, instrumented and tested through time to observe gas and brine pressure or estimate permeability changes as the DRZ evolves.




*Map view of access drifts (green) and test rooms (red) for proposed URL*

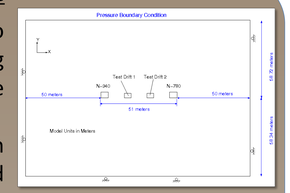



*Cross-sections of instrumentation for displacement (top) and fluid-flow tests (bottom). Cross-section located in map view at red line.*

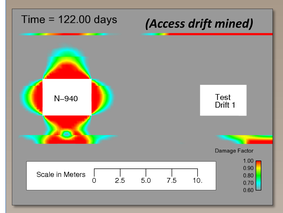
## 2D Geomechanical Model of Transient Excavation Process

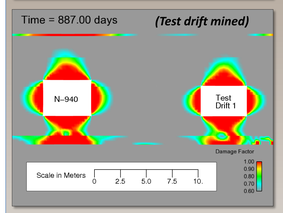
Adagio (SIERRA Mechanics Framework) was used to estimate the mechanical response of the salt to mining the test drift. This information is used to plan the location of instrumentation.

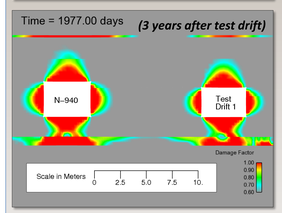
The stratigraphy and drift layout from WIPP is used in the simulation, but the experiment is generic and would be useful at any salt-based URL.

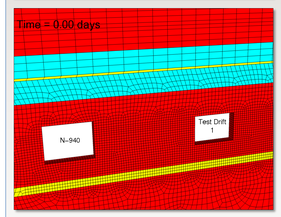



*Geomechanical model domain and boundary conditions*



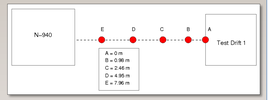

The three figures at left show model results illustrating the damage experienced at three times during the model evolution.

The first plot (122 days) is immediately after excavation of the access drift (labeled N-940). The test drift has not been excavated, yet.

The second plot (877 days) is immediately after excavation of the test drift.

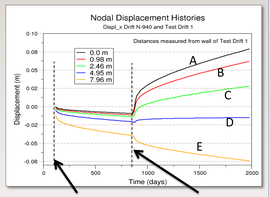
The third plot (1977 days) is 3 years after the test drift was excavated, and shows similar distribution of damage factor. Drift closure can be observed, especially a the corners of the rooms.

The effects of the non-salt interbeds (yellow and blue in figure at lower left) are clearly seen in the model results.




The lower right figure shows model-predicted displacement at extensometers installed from the access drift up to the edge of the test drift.

This illustrates the extensometers should be able to capture the early-time displacement, and shows the effects of the relative motion of the two excavations.




*Model predicted displacement (bottom) at extensometer locations (top)*

## References

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