SAND2020-7679PE

Two Salt Petrofabric Research Topics



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July 29th, 2020

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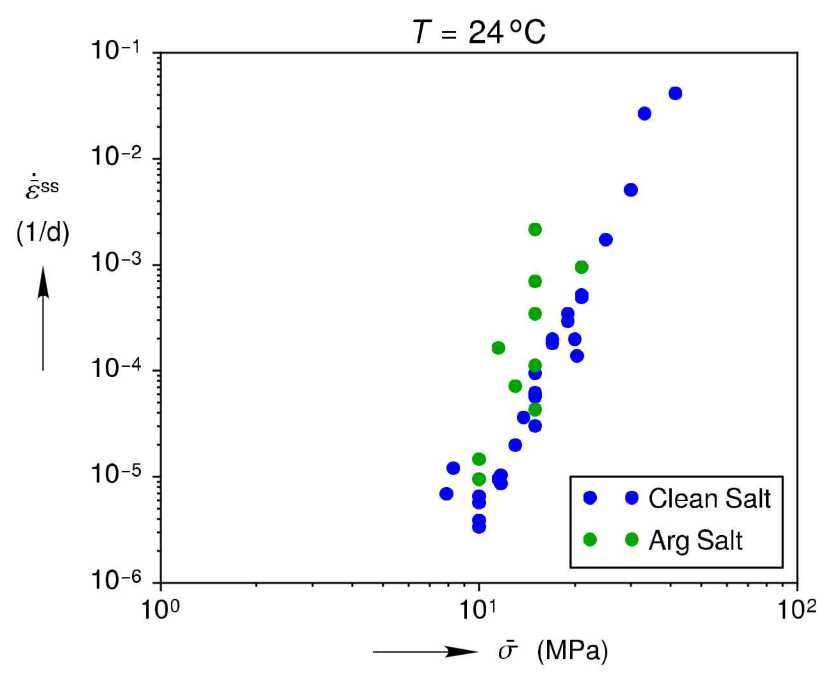
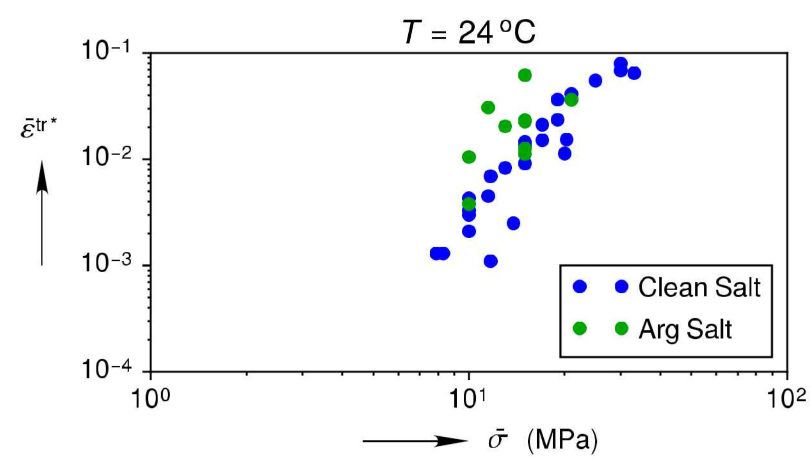
Creep of Argillaceous vs. Clean Salt

Legacy Clean vs. Argillaceous

Steady State Rate



Transient Limit

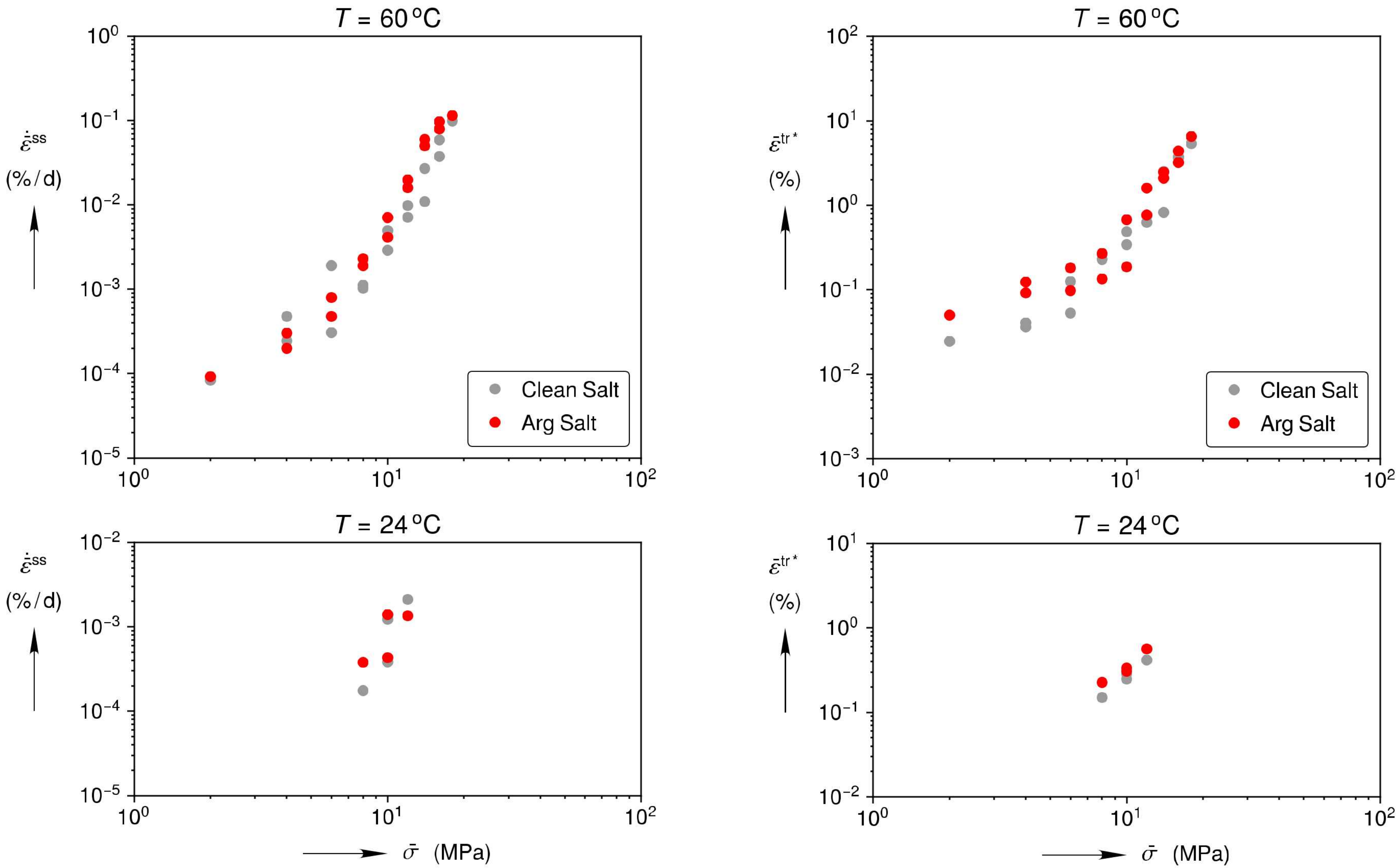


Reedlunn, B., Reinvestigation into closure predictions of Room D at the Waste Isolation
Pilot Plant. Tech. Rep. SAND2016-9961, Sandia National Laboratories, Albuquerque, NM, USA. 2016.

Joint Project III Clean vs. Argillaceous

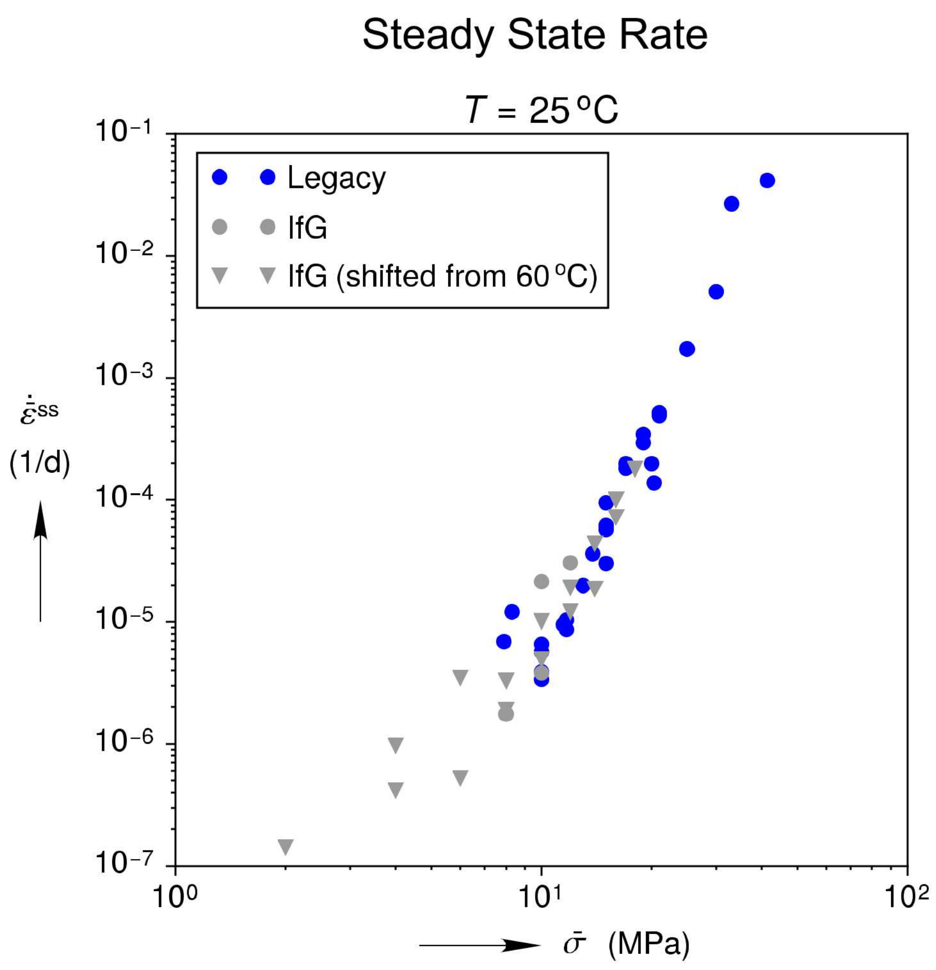
Steady State Rate

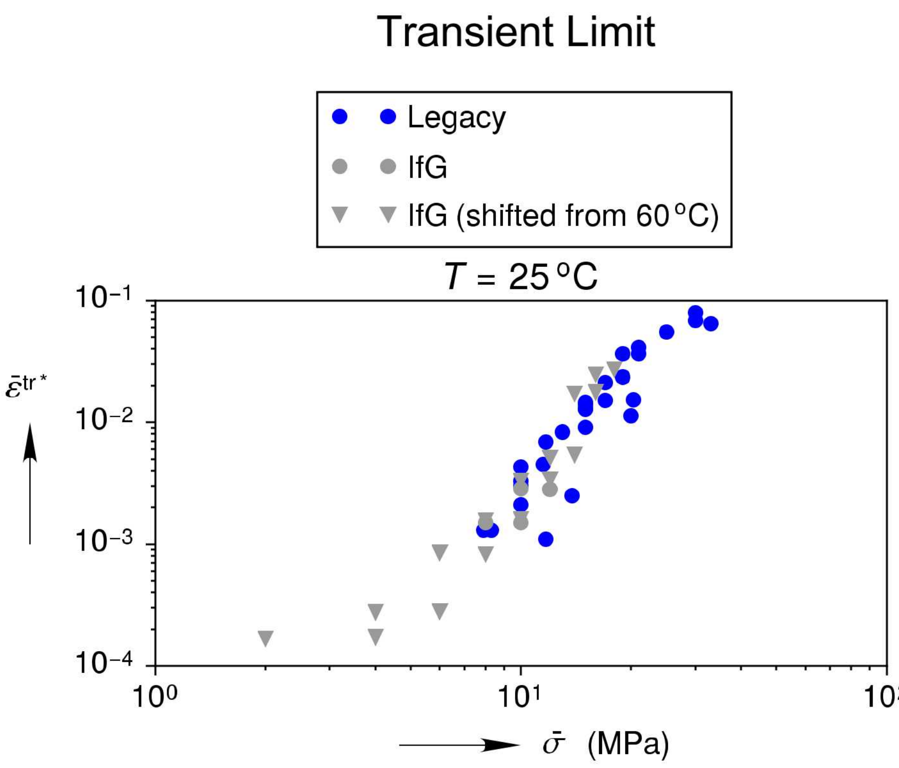
Transient Limit



Reedlunn, B., Reinvestigation into closure predictions of Room D at the Waste Isolation Pilot Plant. Tech. Rep. SAND2016-9961, Sandia National Laboratories, Albuquerque, NM, USA. 2016.

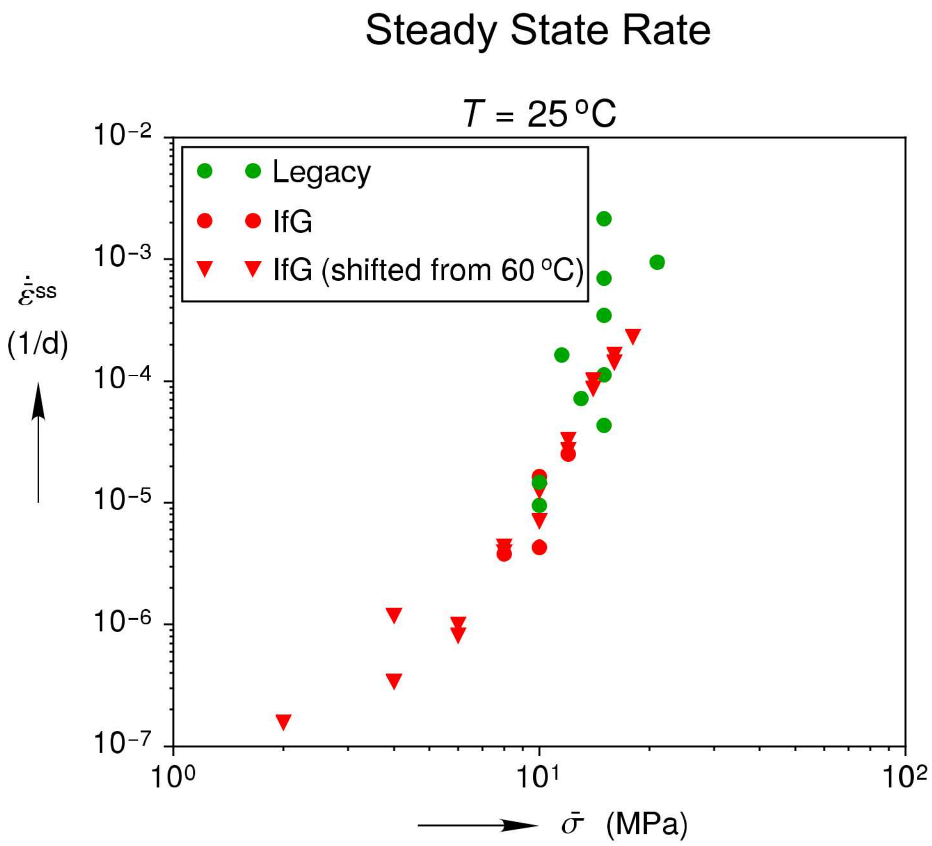
Clean Salt: Legacy vs Joint Project III (IfG)

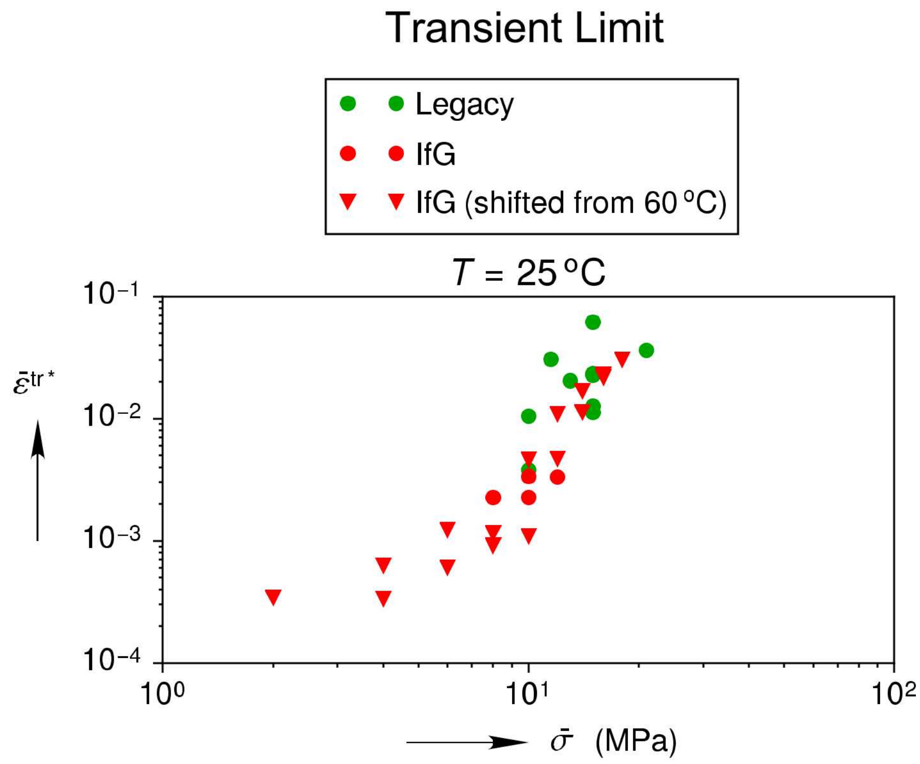




Reedlunn, B., Reinvestigation into closure predictions of Room D at the Waste Isolation Pilot Plant. Tech. Rep. SAND2016-9961, Sandia National Laboratories, Albuquerque, NM, USA. 2016.

Argillaceous Salt: Legacy vs Joint Project III (IfG)





Reedlunn, B., Reinvestigation into closure predictions of Room D at the Waste Isolation
Pilot Plant. Tech. Rep. SAND2016-9961, Sandia National Laboratories, Albuquerque, NM, USA. 2016.

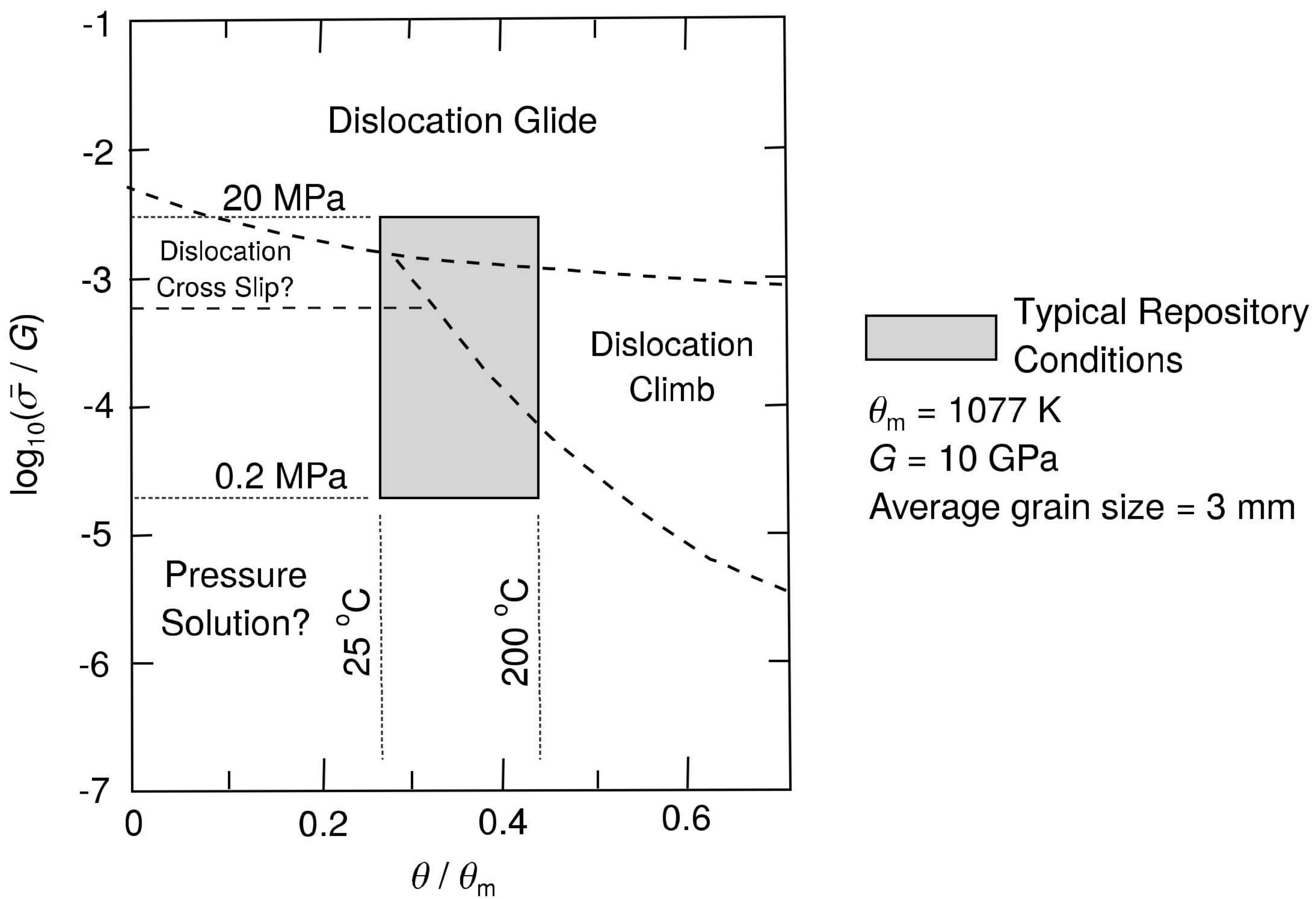
Clean vs. Argillaceous Research Plan

1. Completed
   a. Extracted new clean and argillaceous core from WIPP during Summer, 2020.

2. To Do
   a. Characterize creep behavior
   b. Measure composition differences
      i. Insoluble content
      ii. Water content
   c. Measure spatial distribution of impurities

Mechanism Change at High Stresses and Strain Rates

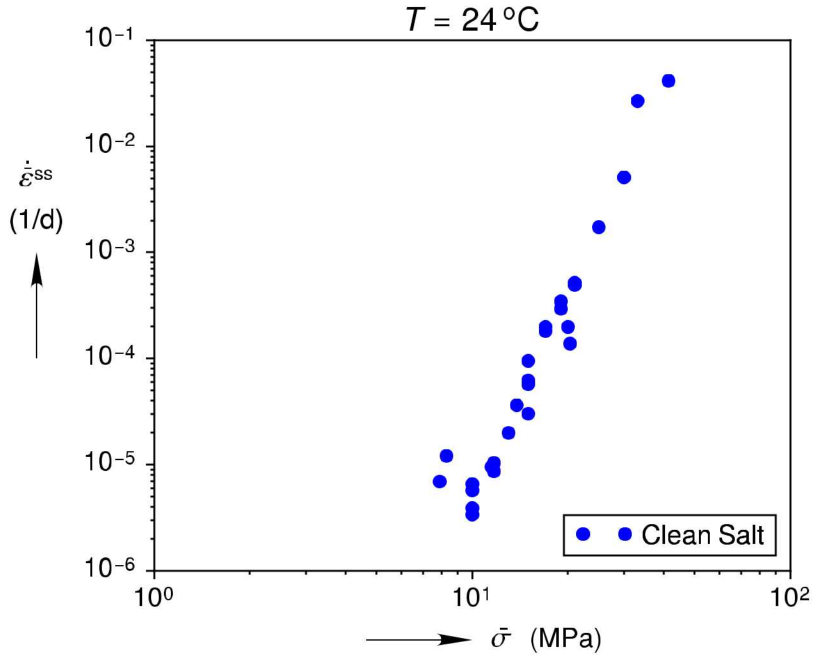
Deformation Mechanism Map



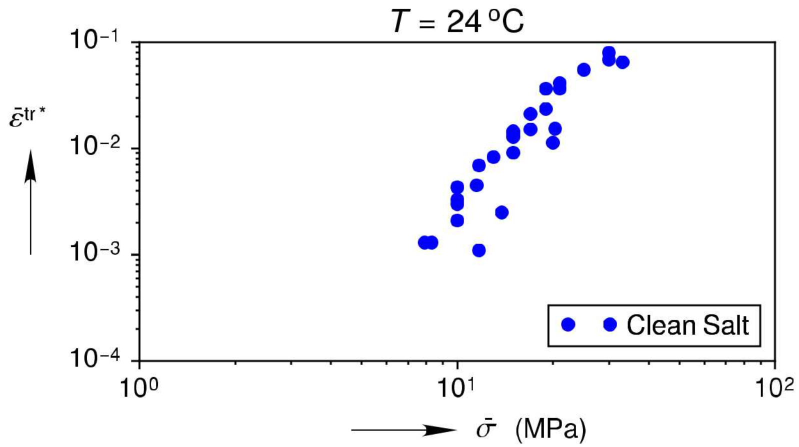
Modified after: Munson, D. (1979). Preliminary deformation-mechanism map for salt (with application to WIPP). Sandia National Laboratories. SAND79-0076

Legacy Creep Tests on Clean WIPP Salt

Steady State Rate



Transient Limit



Reedlunn, B., Reinvestigation into closure predictions of Room D at the Waste Isolation
Pilot Plant. Tech. Rep. SAND2016-9961, Sandia National Laboratories, Albuquerque, NM, USA. 2016.

Constant Strain Rate Tests on Artificial Rock Salt

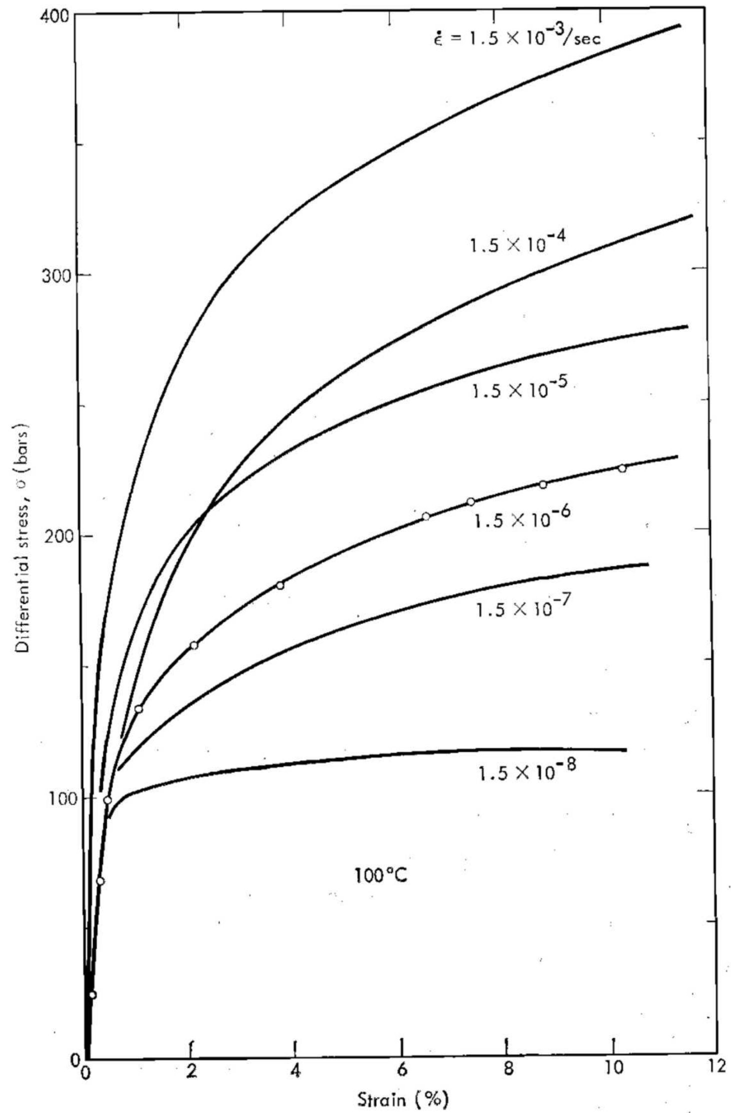
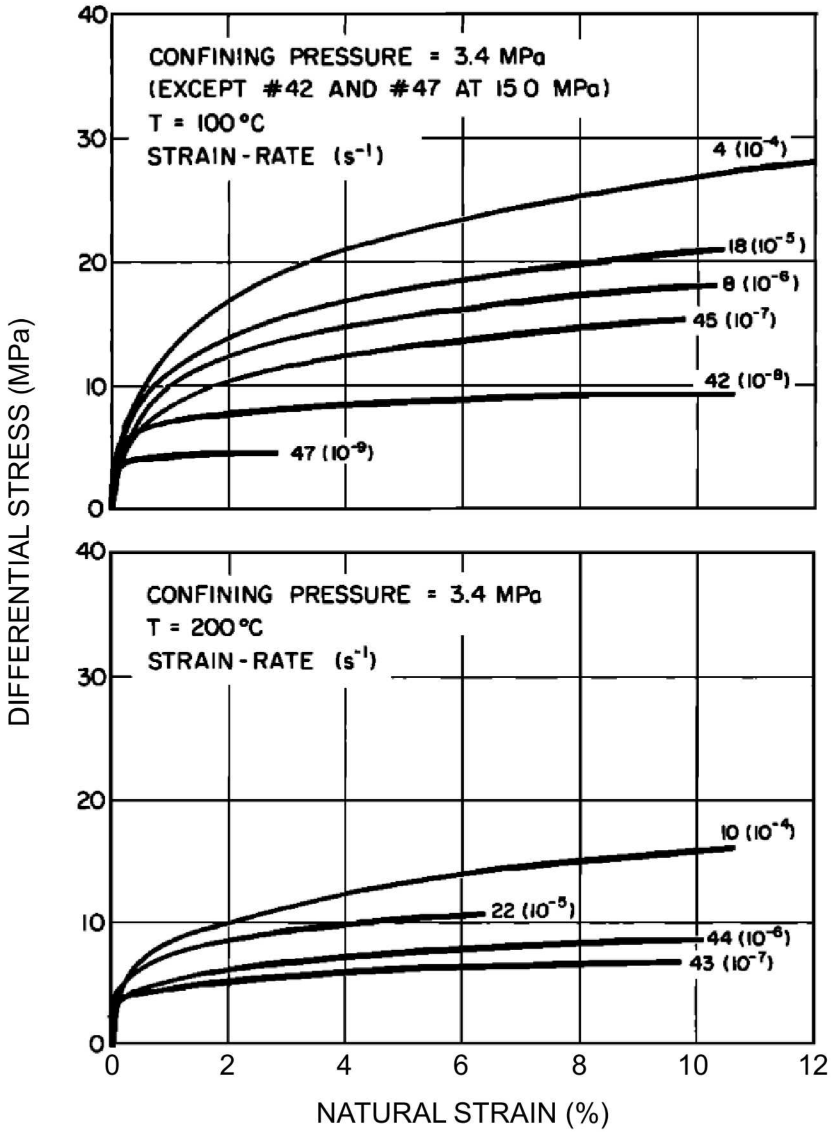


Fig. 1. Differential stress-strain curves for polycrystalline halite extended at 2 kb, $\dot{\epsilon} = 1.5 \times 10^{-3}$ to 1.5×10^{-8} sec^{-1}, and 100°C.

Heard, H. (1972). Steady-state flow in polycrystalline halite at pressure of 2 kilobars. *Flow and fracture of rocks*. Vol 16. pp 191-209.

Constant Strain Rate Tests on Avery Island Salt



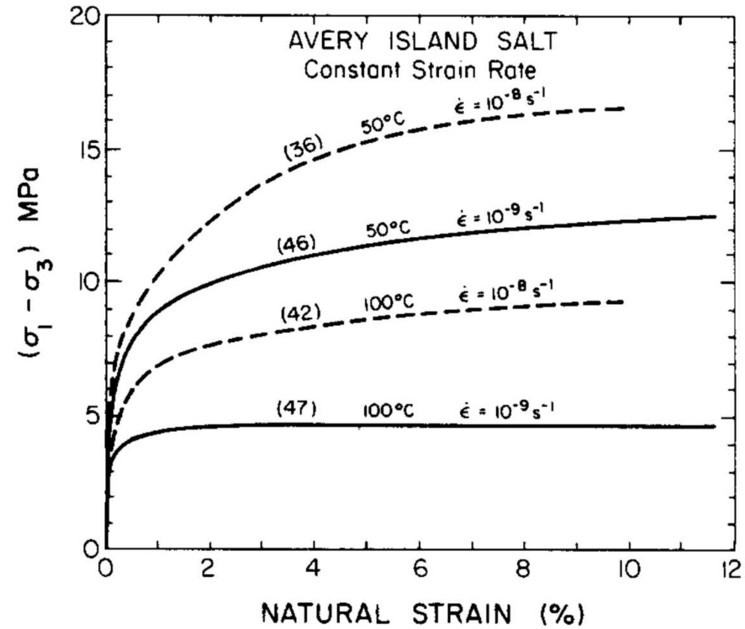


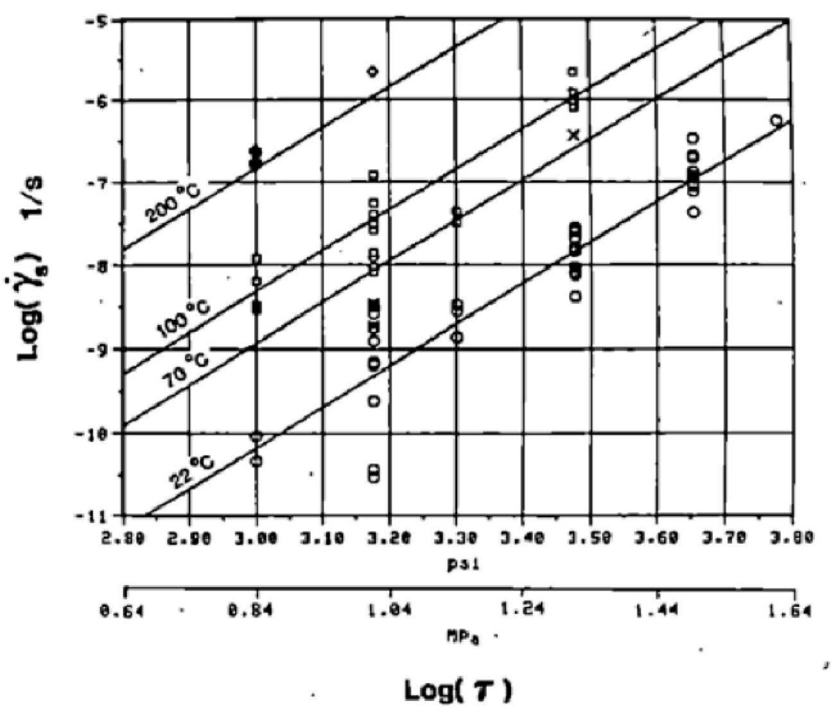
Fig. 3. Stress–strain curves for specimens 46 and 47, deformed at a strain rate of 10^{-9} s^{-1} over a 3.5 year period. Earlier results of Horseman & Handin (1990) at 10^{-8} s^{-1} (dashed curves) are shown for comparison.

Horseman, ST and Handin, J. (1990). Triaxial-compression tests on rocksalt at temperatures from 50 to 200°C and strain rates from 10^{-4} to 10^{-9}/s. Brittle-Ductile Transition in Rocks: The Heard Volume. Vol 56. pp 103-110. (modified)

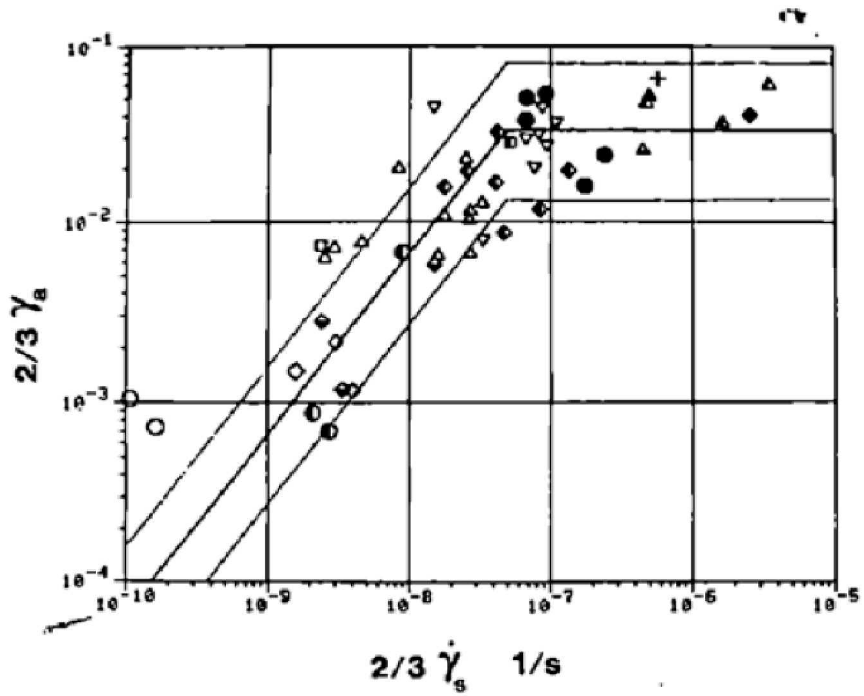
Carter, NL, Horseman, ST, Russell, JE, and Handin, J (1993). Rheology of rocksalt. Journal of Structural Geology. Vol 15. No 9-10. pp 1257-1271.

More Legacy Creep Tests on WIPP Salt

Steady State Rate



Transient Limit



Wawersik, WR, Herrmann, W, Montgomery, ST, and Lauson, HS. Excavation Design In Rock Salt-Laboratory Experiments, Material Modeling And Validations. ISRM International Symposium. 1982

Questions

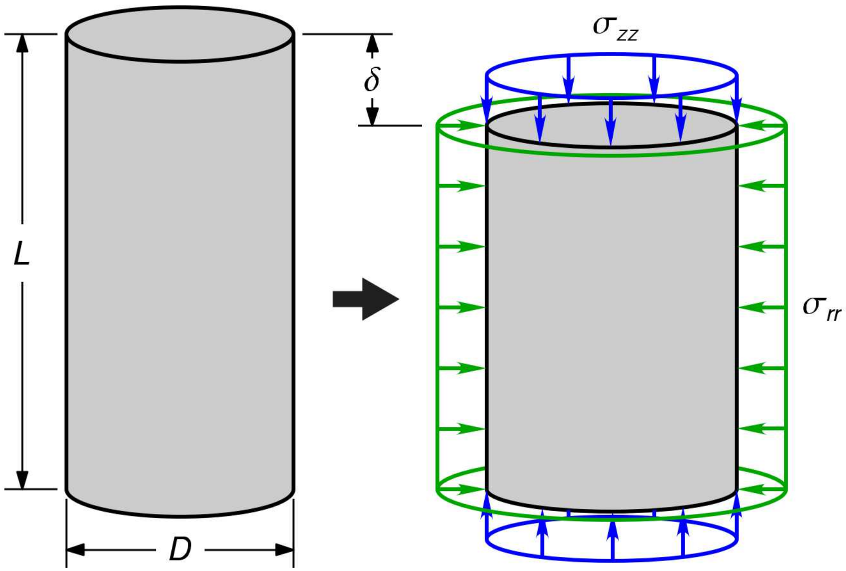
1. Are these behaviors due to a mechanism change?

2. How best to model this apparent mechanism change?

3. What macroscopic and/or microscopic experiments would help validate one modeling approach versus another?

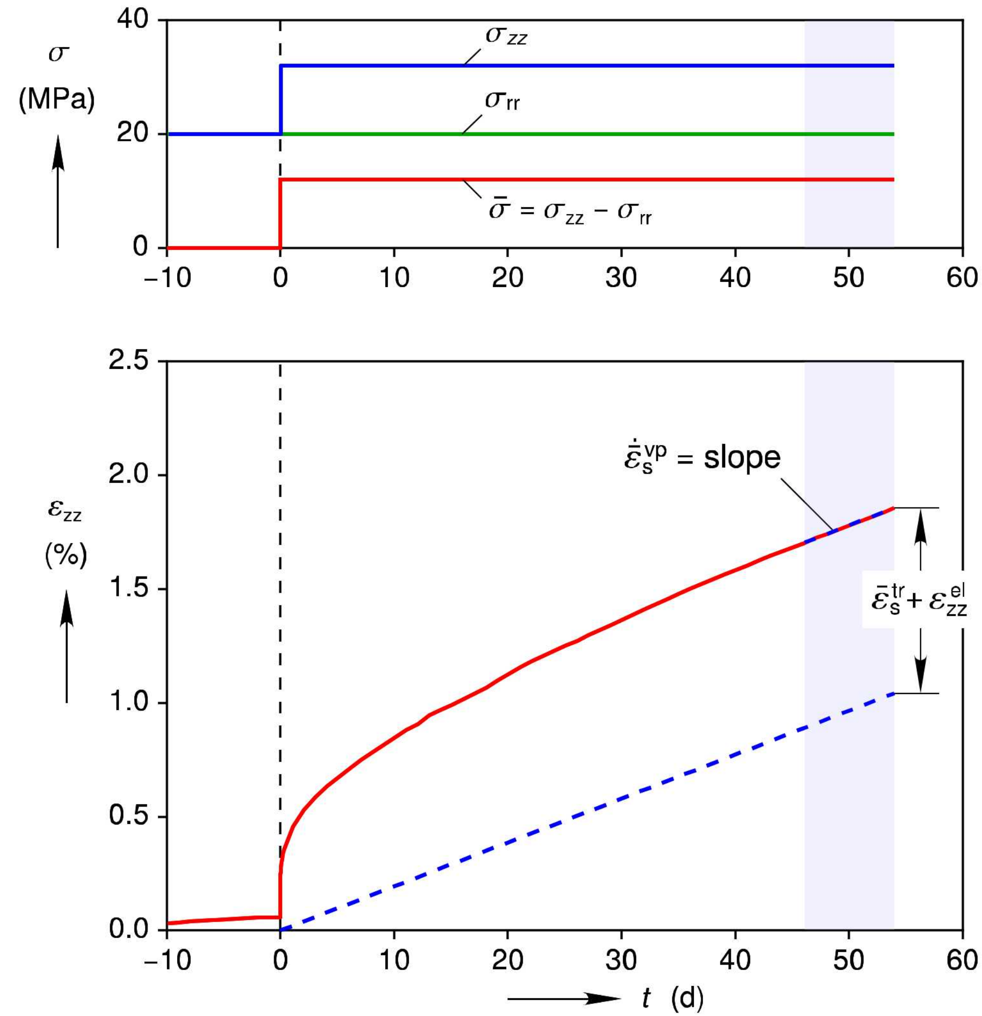
Extra Slides

Constant Stress Tests



$$\frac{L}{D} = 2$$

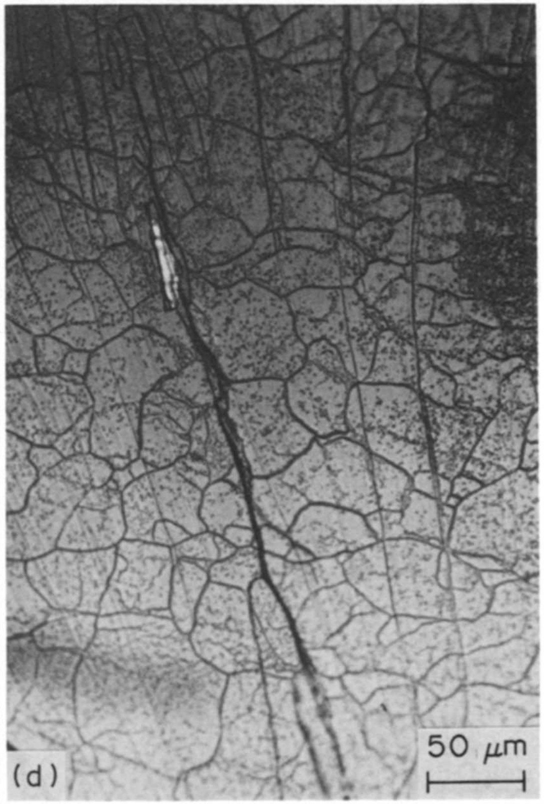
$$\varepsilon_{zz} = \ln\left(1 + \frac{\delta}{L}\right)$$



Microstructural Observations

Dislocation Cross Slip

Dislocation Climb



Dislocation Glide

(Still looking for a nice image.)

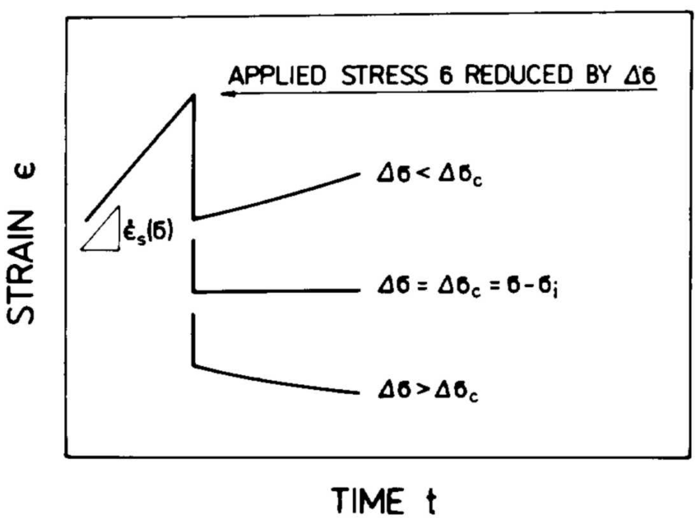
Carter, NL, Horseman, ST, Russell, JE, and Handin, J (1993). Rheology of rocksalt. Journal of Structural Geology. Vol 15. No 9-10. pp 1257-1271.

Back Stress (Internal Stress) Measurements

1D Model with Backstress

$$\dot{\varepsilon}_i^{vp} = E_{i1}\ \exp\left(-\frac{E_{i2}}{\theta}\right)\left(\frac{|\sigma - b_i|}{y}\right)^{E_{i3}} \mathrm{sign}\,(\sigma - b_i)$$

Stress Dip Method



Results on a Metal Alloy

characteristic; the same also applies to the 18Cr–10Ni (AISI type 304) and 16Cr–13Ni–2.5Mo (AISI type 316) austenitic stainless steels dealt with in Section 4.) It can be seen from Fig. 4 that the measured internal stress increases non-linearly with the applied stress; at a given applied stress, it decreases with increasing temperature.

The steady state creep rate $\dot{\epsilon}_s$ of the alloy under consideration varies with the applied stress as $(\sigma/G)^n$, where the stress exponent $n = 5.4 \pm 0.1$, and is obviously controlled by lattice diffusion [19]. This is demonstrated in Fig. 5 in which the normalized steady state creep rate $\dot{\epsilon}_s b^2 kT/\bar{D}_L G\Omega$ is plotted against

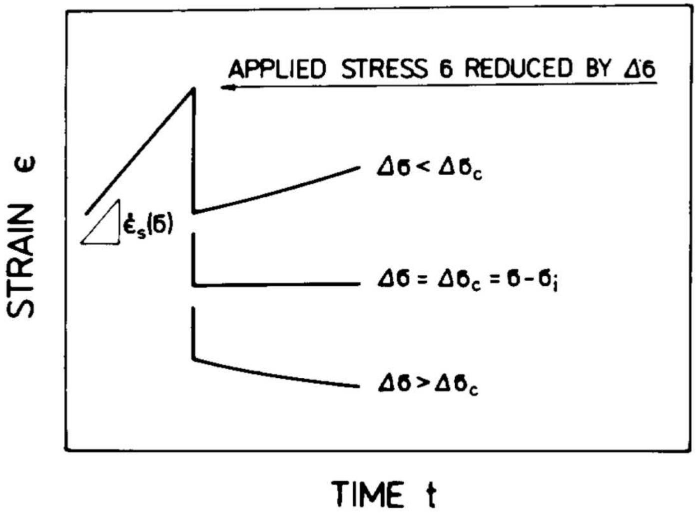
Cadek, J. (1987). The back stress concept in power law creep of metals: a review. *Materials Science and Engineering.* Vol 94. pp 79-92.

Back Stress (Internal Stress) Measurements

1D Model with Backstress

$$\dot{\varepsilon}_i^{vp} = E_{i1}\, \exp\left(-\frac{E_{i2}}{\theta}\right)\left(\frac{|\sigma - b_i|}{y}\right)^{E_{i3}} \operatorname{sign}(\sigma - b_i)$$

Stress Dip Method



Results on Rock Salt

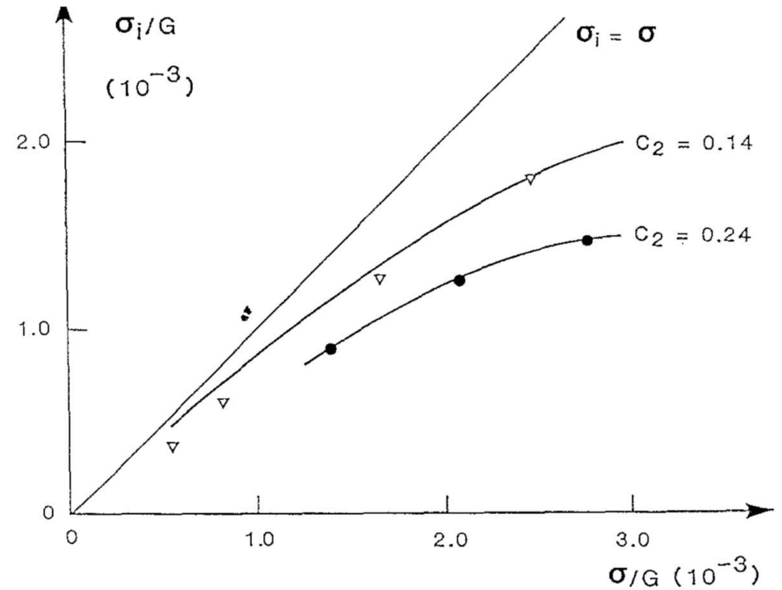


Fig. 4. The slow decrease of the σ_i/σ ratio with the increase of stress, at steady-state; ▽ Avery Island salt (No. 4, 5, 6, 7); ● artificial salt (No. 1, 2, 3); data are taken from Table 1 (see text for explanations)

Aubertin, M., Gill, DE, and Ladanyi, B. (1991) An internal variable model for the creep of rocksalt. *Rock Mechanics and Rock Engineering.* Vol 24. No 2. pp 81-97

Stress Drop Experiments

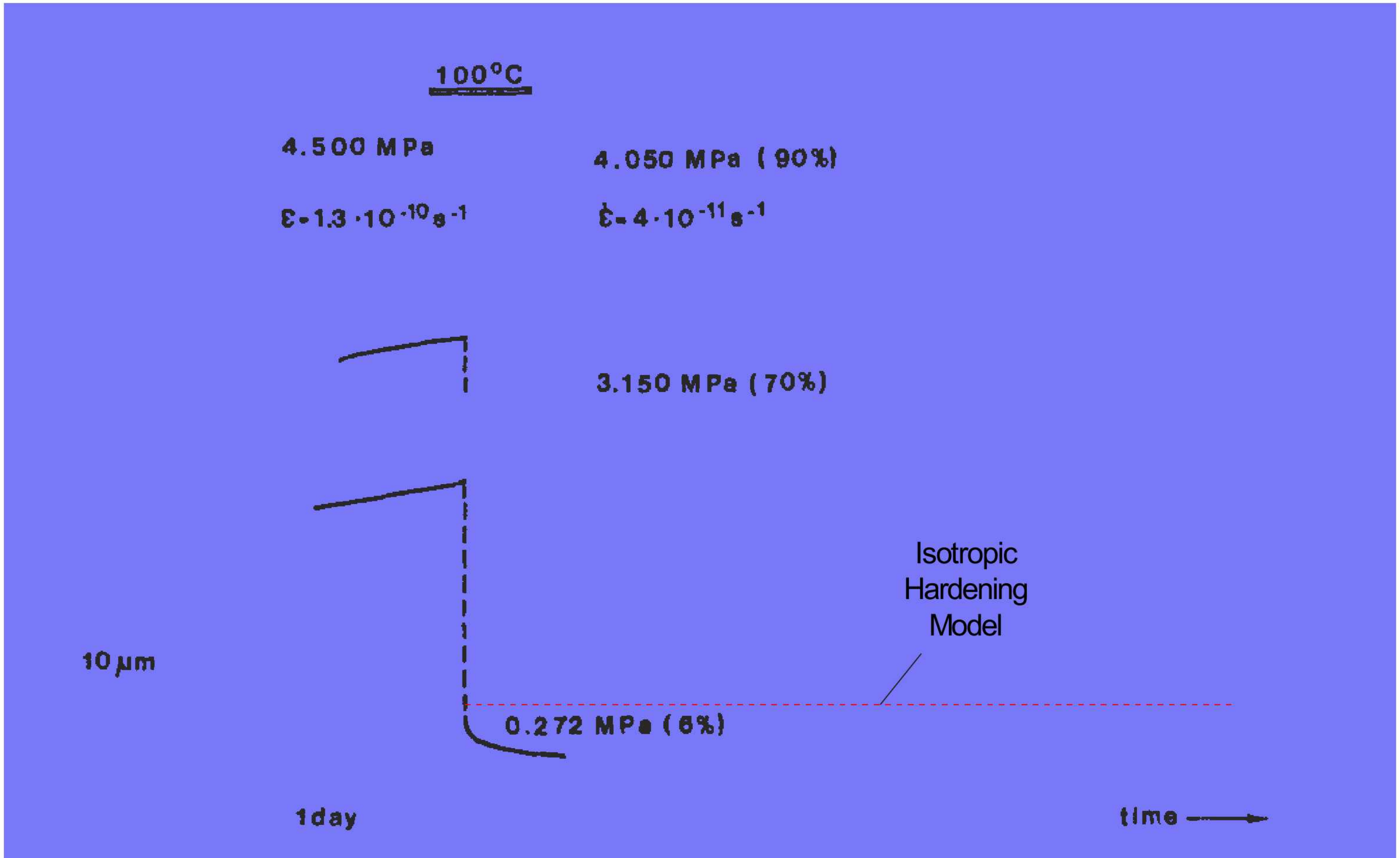
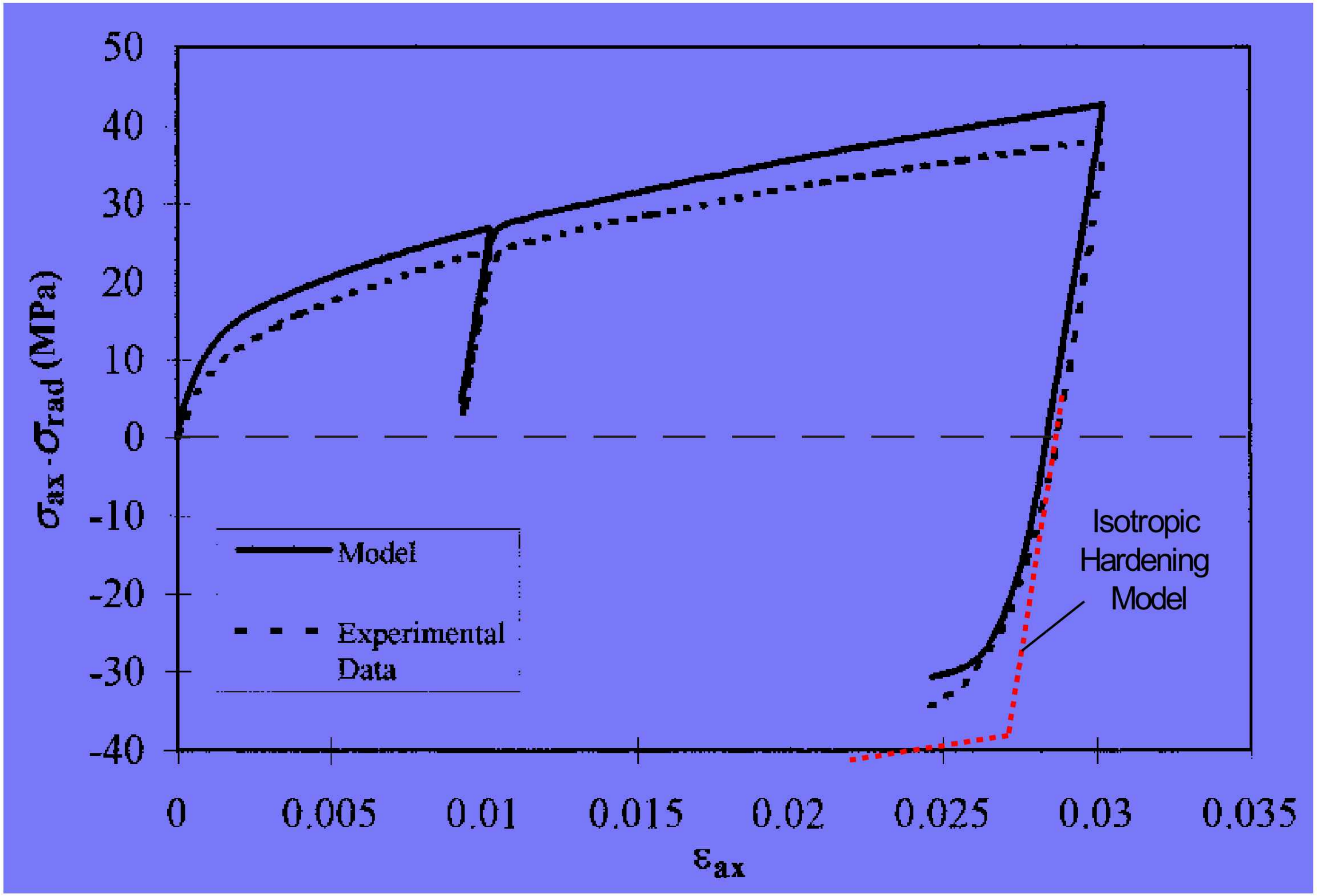


Figure 3 - Creep Experiment at 100 °C with Different Stress Drops. Sample ASSE 8/6.1.

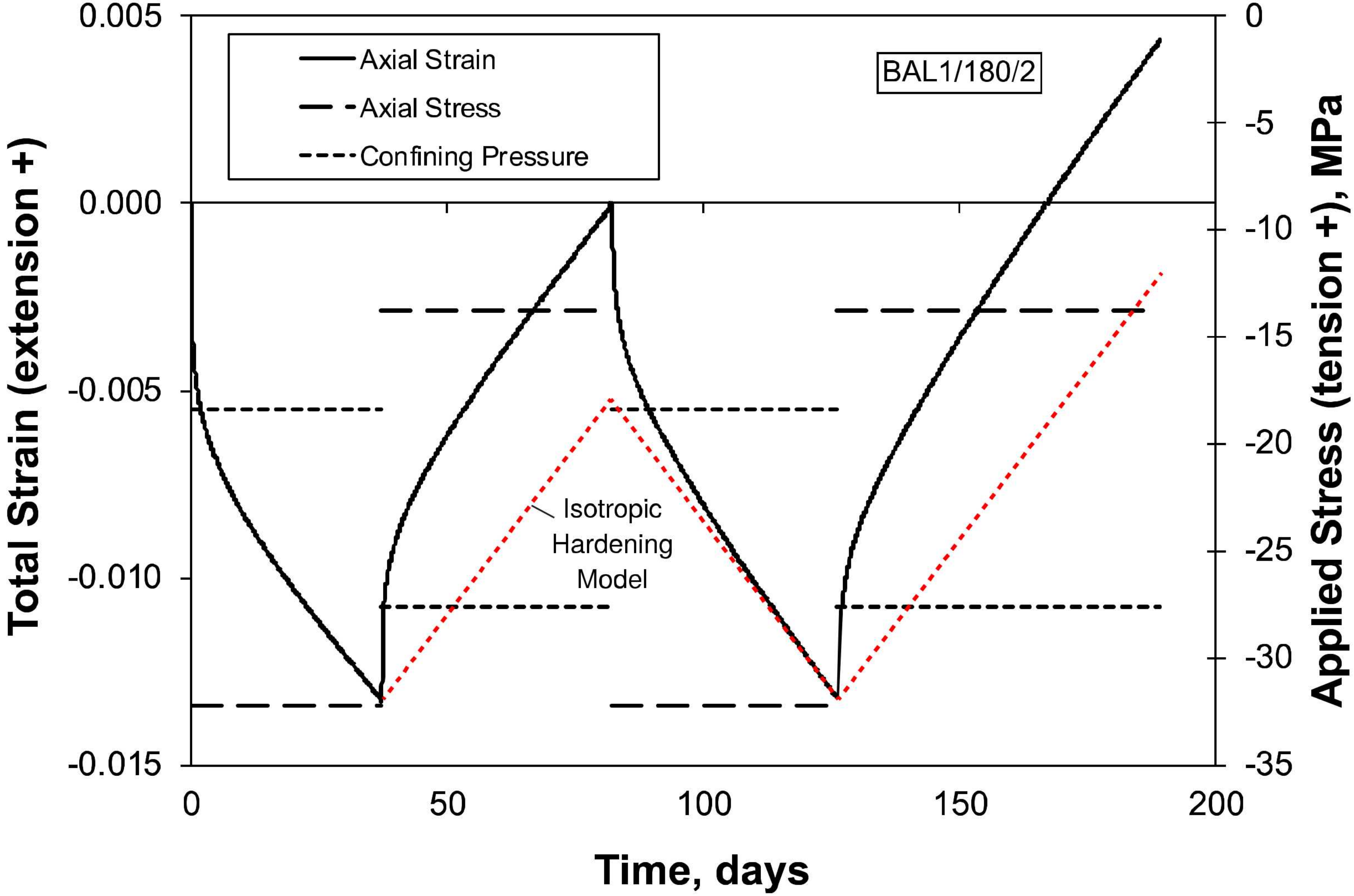
Hunsche, U. 1988. Measurement of creep in rock salt at small strain rates. Proceedings of the 2nd Conference on the Mechanical Behavior of Salt. Pg. 187-196 (Modified)

Bauschinger Effect



Yahya, O., Aubertin, M., and Julien, M. 2000. A unified representation of the plasticity, creep and relaxation behavior of rocksalt. International Journal of Rock Mechanics and Mining Sciences. Vol. 37. No. 5. Pg. 787-800 (Modified)

Triaxial Compression / Extension Cycling



Mellegard, K., DeVries, K., and Callahan, G. 2007. Lode angle effects on the creep of salt. Proc. 6th Conference on the Mechanical Behavior of Salt. Pg. 9-15 (Modified)