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Pressure-Induced Brine Migration in Consolidated Salt in a Repository*

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Within a few years after the emplacement of waste packages in a geologic repository of nuclear waste in salt, salt creep is expected to close the air gap between a waste container and the borehole wall.[1] In this paper we present an analysis of brine migration completely inside consolidated salt, considered here to be a thermoelastic, porous rock.

Salt creep causes consolidation of the crushed salt in the annulus between the waste package and the borehole, resulting in monolithic consolidation of salt around the waste package. Thereafter, neglecting the consumption of brine by container corrosion, brine in grain boundaries near the waste package can only migrate outward into the surrounding salt, under the influence of pressure gradients caused by transient heating of the salt. Figure 1 shows qualitatively the profiles of temperature and brine pressure expected in the salt after consolidation[2]. Hot salt near the waste package expands against the waste package and surrounding salt, resulting in high compressive stresses near the waste package. Grain-boundary brine expands more than does the salt and further increases the local presssure and pressure gradients that cause brine to flow outward into the cooler salt. Such outward flow of brine relieves the pressure gradient on the fluid, which finally relaxes to near-lithostatic pressure. If the waste containers are corroded, then this outward brine movement may become a mechanism for radionuclide transport. To determine the extent to which advection by brine in grain boundaries is an important transport mechanism for released radionuclides, we have estimated the time-dependent migration of brine after salt consolidation.

We consider a spherical-equivalent spent-fuel waste package of 0.72-meter radius in an infinite salt medium. The governing equations for brine migration treating salt as a thermoelastic, porous rock follow those of McTigue.[3]. Chambré obtained analytic solutions to the governing equations[4], and numerical illustrations of the solutions are given here. The parameter values used in the calculations are from McTigue, and shown in Table 1. The heat flux used was 928 watts per square meter.

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Figure 2 shows the superficial brine velocity near a waste package as a function of time. Pressure-induced brine migration within consolidated salt is a transient phenomenon. After about ten years the velocity is nearly zero. Even the highest velocity is of the order of *millimeters per year*, and occurs only within a meter or so of a waste package. At these velocities molecular diffusion may be the dominant transport process for radionuclides in salt. In a companion paper[5] we show the application of diffusional mass transfer to estimating release rates in a salt repository.

References

1. T. Brandshaug, 1987, *Estimate of Consolidation of Crushed Salt Around a Spent Fuel Waste Package,* RE/SPEC Report RSI-315

2. T. H. Pigford and P. L. Chambré, "Mass Transfer in a Salt Repository," LBL-19918, 1985

3. D. T. McTigue, 1986, "Thermoelastic Response of Fluid-Saturated, Porous Rock," *J. Geophy. Res., 91, B9,* 9533

4. P. L. Chambré, to be published

5. P. L. Chambré, Y. Hwang, W. W.-L. Lee and T. H. Pigford, 1987 "Release Rates from Waste Packages in a Salt Repository," UCB-NE-4102, Paper submitted for the 1987 Winter Meeting, American Nuclear Society

Table 1 Parameter Values Used in Calculations
(After McTigue,[3] for the Salado Formation, Delaware Basin, New Mexico)

Property	Value	Units
Conductivity ($\mathcal{K}$)	6.60	$W \cdot m^{-1} \cdot K^{-1}$
Heat Capacity (ρc_v)	1.89×10^6	$J \cdot m^{-3} \cdot K^{-1}$
Drained Bulk Modulus (K)	20.7	GPa
Fluid Bulk Modulus (K_f)	2.0	GPa
Solid Bulk Moduli (K'_s, K''_s)	23.5	GPa
Shear Modulus (G)	12.4	GPa
Porosity (ϕ_o)	0.001	
Fluid Expansivity (α_f)	3.0×10^{-4}	K^{-1}
Solid Expansivities (α'_s, α''_s)	1.2×10^{-4}	K^{-1}
Permeability (k)	10^{-21}	m^2
Fluid Viscosity (μ)	1.0×10^{-3}	$Pa \cdot s$
B	0.93	
Poisson's Ratio (ν)	0.25	
Undrained Poisson's Ratio (ν_u)	0.27	
b'	29.0*	$kPa \cdot K^{-1}$
Fluid Diffusivity (c)	0.16×10^{-6}*	$m^2 \cdot s^{-1}$
Thermal Diffusivity (κ)	3.5×10^{-6}	$m^2 \cdot s^{-1}$
R ($\sqrt{c/\kappa}$)	0.21	

* Calculated for zero mean stress.

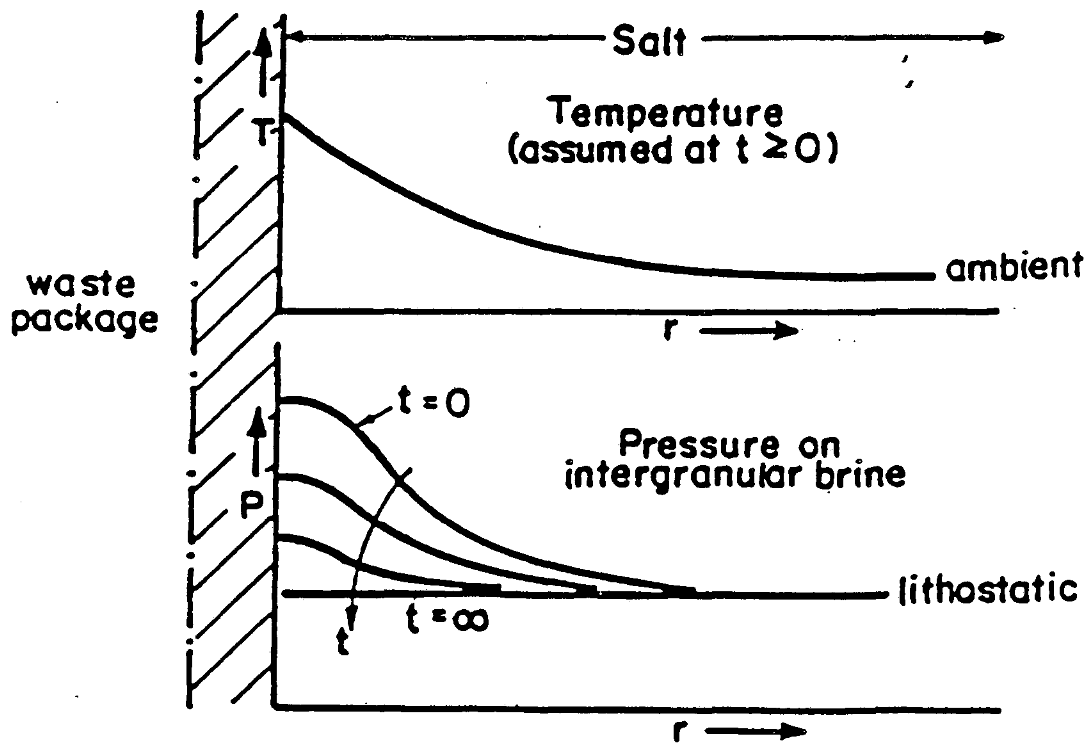

Figure 1. Pressure Profile on Intergranular Brine after Consolidation of Salt in a Salt Repository (from Pigford and Chambré, 1985)

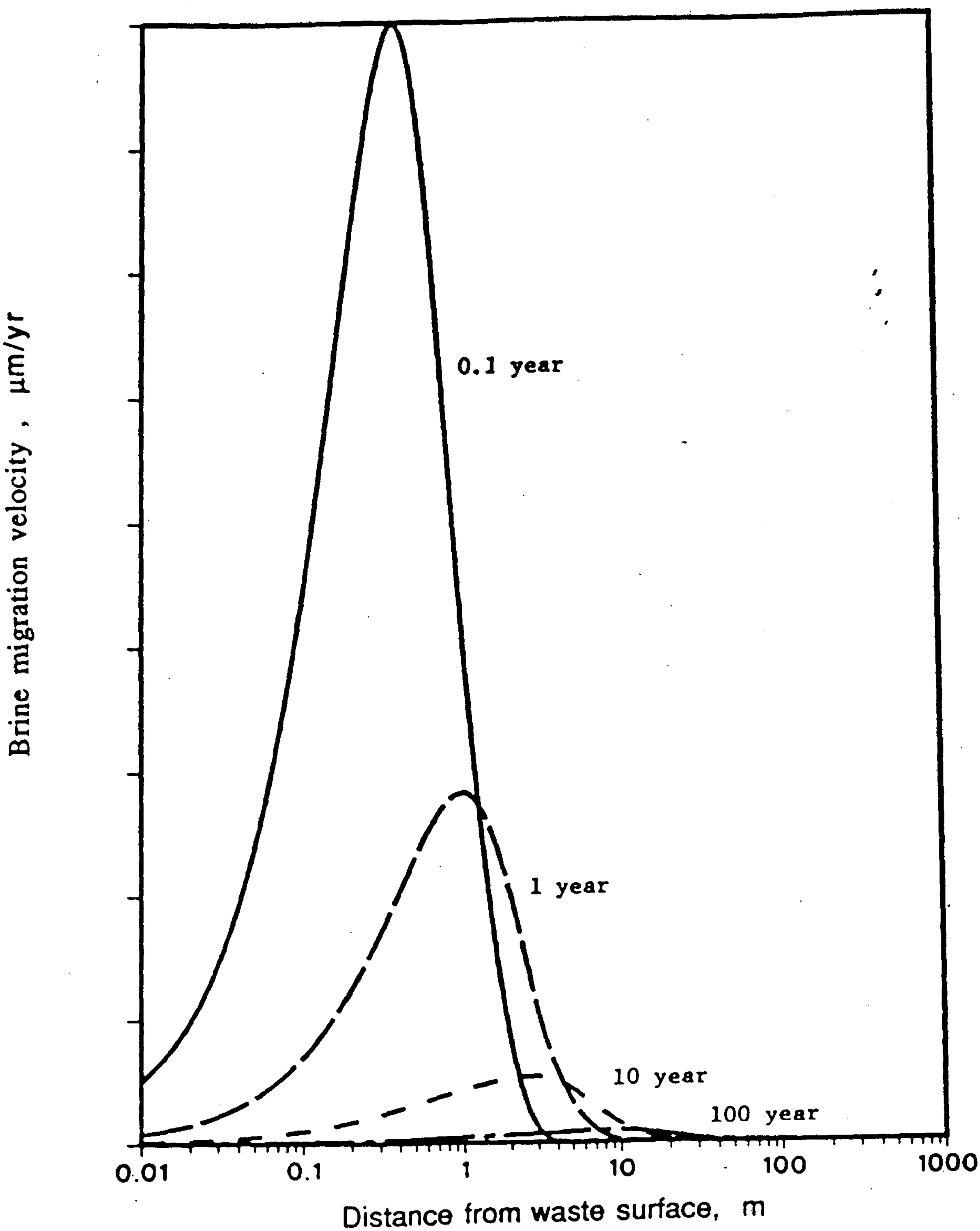

Figure 2. Brine Migration Velocity Away from a Waste Package Due to Pressure Gradient

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