SELENITE TRANSPORT IN UNSATURATED TUFF FROM YUCCA MOUNTAIN

James L. Conca
WSU Tri-Cities
100 Sprout Road
Richland, WA

Inés R. Triay
LANL
Box 1663
Los Alamos, NM

OUTLINE

- Determination of Transport Parameters Using UFA
- UFA Validation Experiments
- Tuff Hydraulic Conductivity as a Function of Water Content
- Fracture Flow in Tuff
- Batch Sorption Studies and UFA Retardation Tests
- Summary

UNSATURATED FLOW APARATUS (UFA)

- Combines ultracentrifugation with precision fluid flow through rotating seals
- Attains hydraulic steady-state in hours instead of months to years at low water contents
- Accelaration is a whole body force analogous to gravity so there are no physical changes in sample as occurs with pressure methods - no fracturing, no density changes, no collapsing of internal structure, no grain rearrangement
- -20° to 150°C; 10 to 10,000 g; 400 to 0.001 ml/hr
- Multicomponent and multiphase flow possible with whole body force

The Primary Transport Parameters

K - Hydraulic Conductivity (water permeability)

$$q = K \bullet \nabla\psi$$

water flux = conductivity x pressure gradient

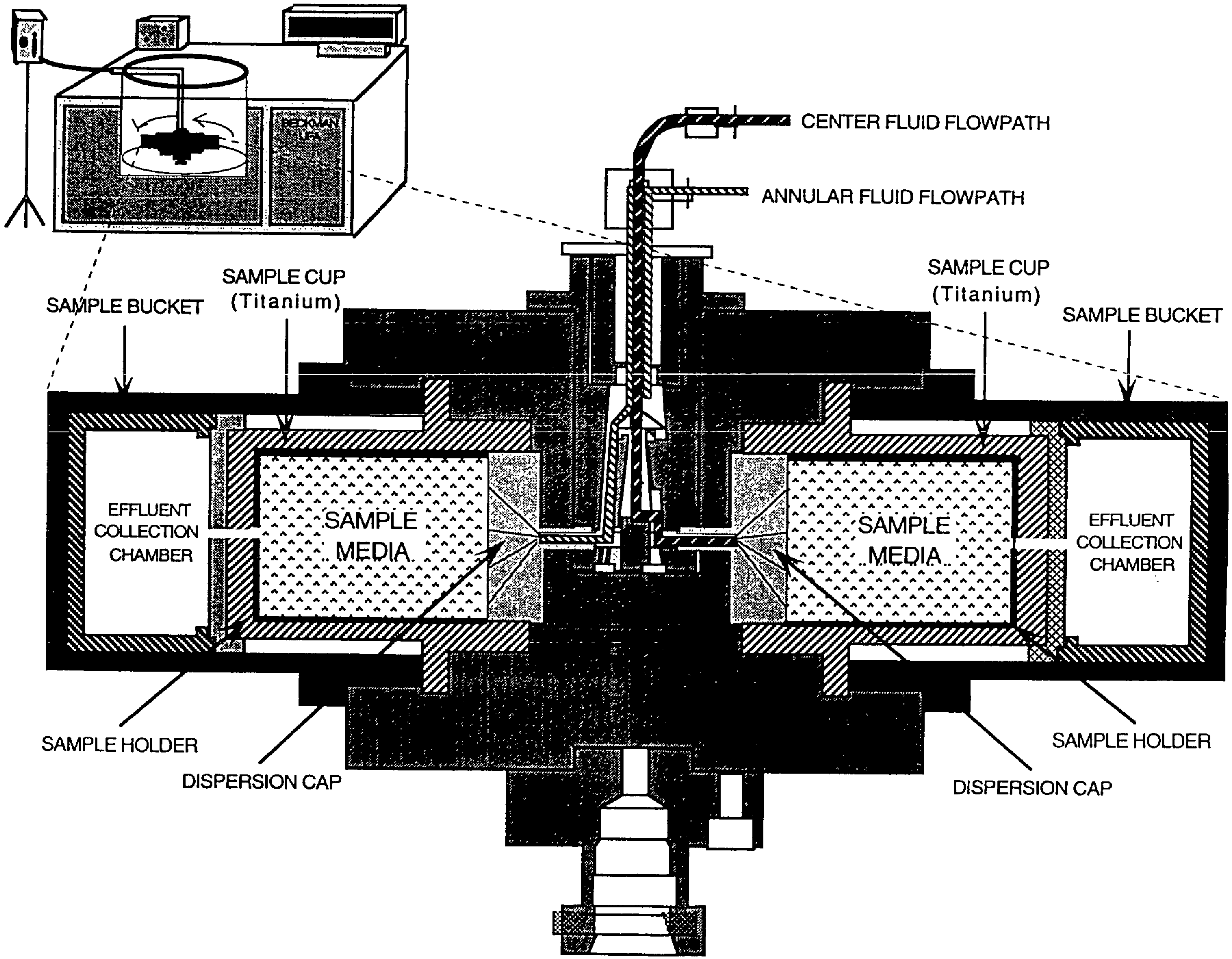
D - Diffusion Coefficient (static diffusion of single ions)

$$J = D \bullet \nabla\psi$$

ion flux = diffusion coefficient x concentration gradient

R_f - Retardation Factor (Chemical sorption and exchanges)

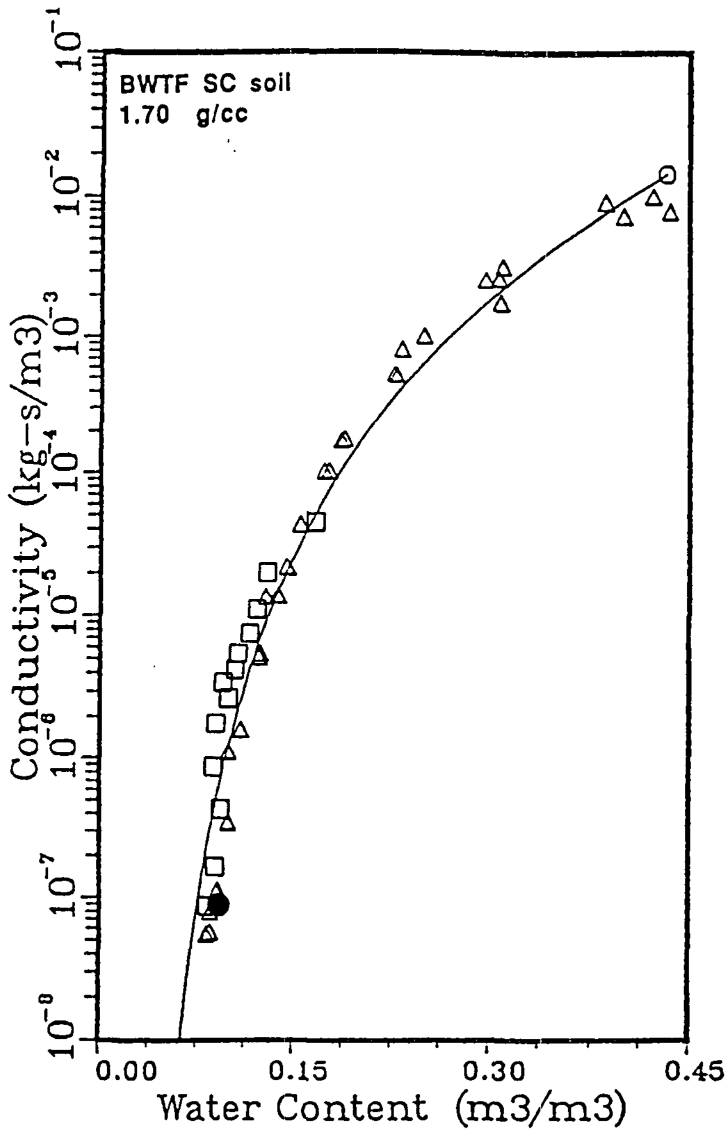
$$R_f = V_{gw} \div V_c$$



UFA Hy-Sed 10.0 Rotor With New Mechanical Seal Design

After the water content is fixed in the sample and the material is at hydraulic steady-state, transport parameters can be determined from a variety of associated methods.

- **Hydraulic conductivity can be determined from the driving force and flux.**
- **The electrical conductivity can be measured for determination of diffusion coefficients using the Nernst-Einstein equation.**
- **The effluent can be monitored/collected/analyzed for chemical changes, retardation effects, and determination of partitioning.**



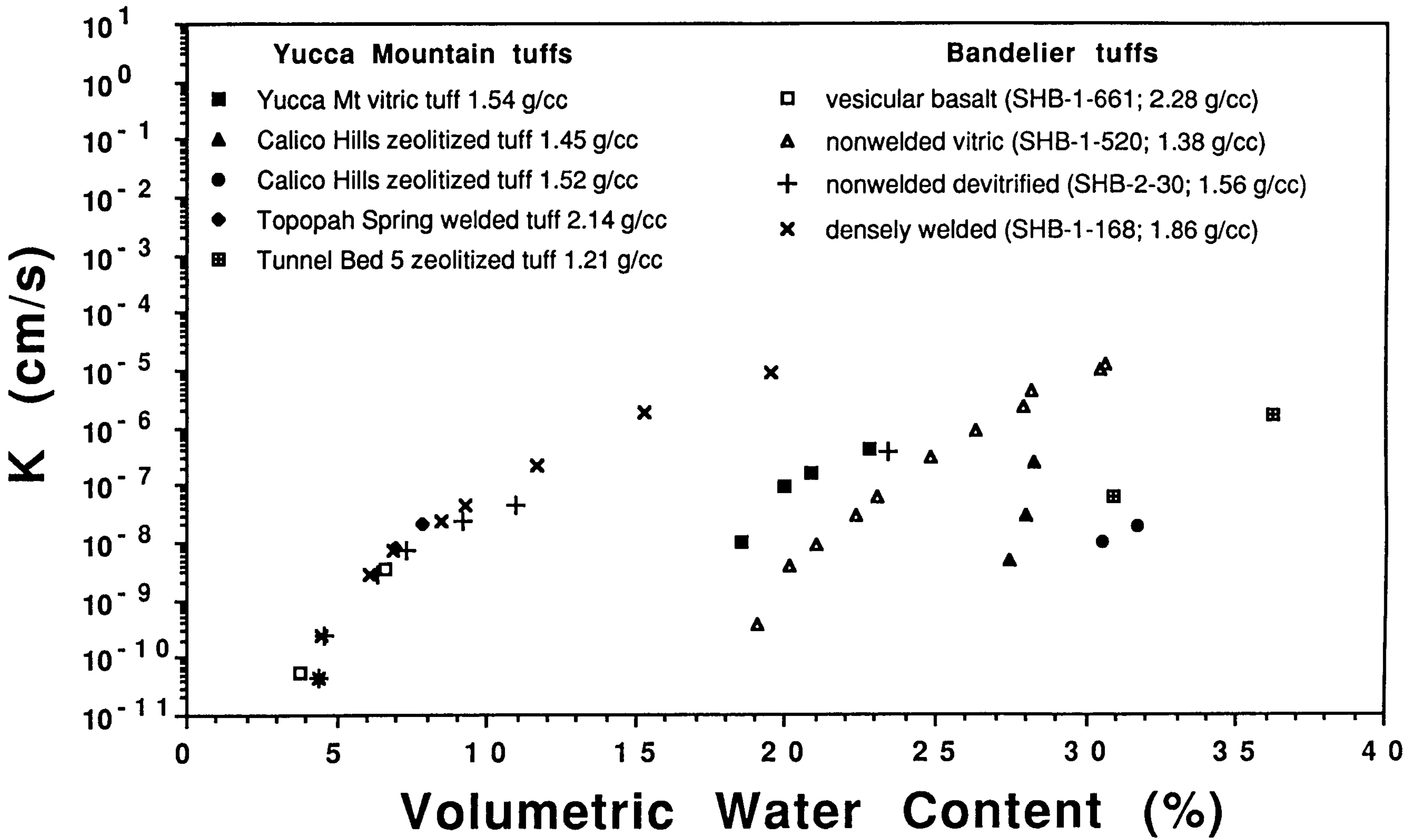
□ UFA™ measurements made over 3-days

Δ Traditional column experiments made over 1-year

● Average of field lysimeter measurements made over 13-years

— Mualem estimation derived from curve-fitted water-retention data made over 6-weeks

Characteristic Curves for the BWTF Soil Obtained Using Four Different Methods

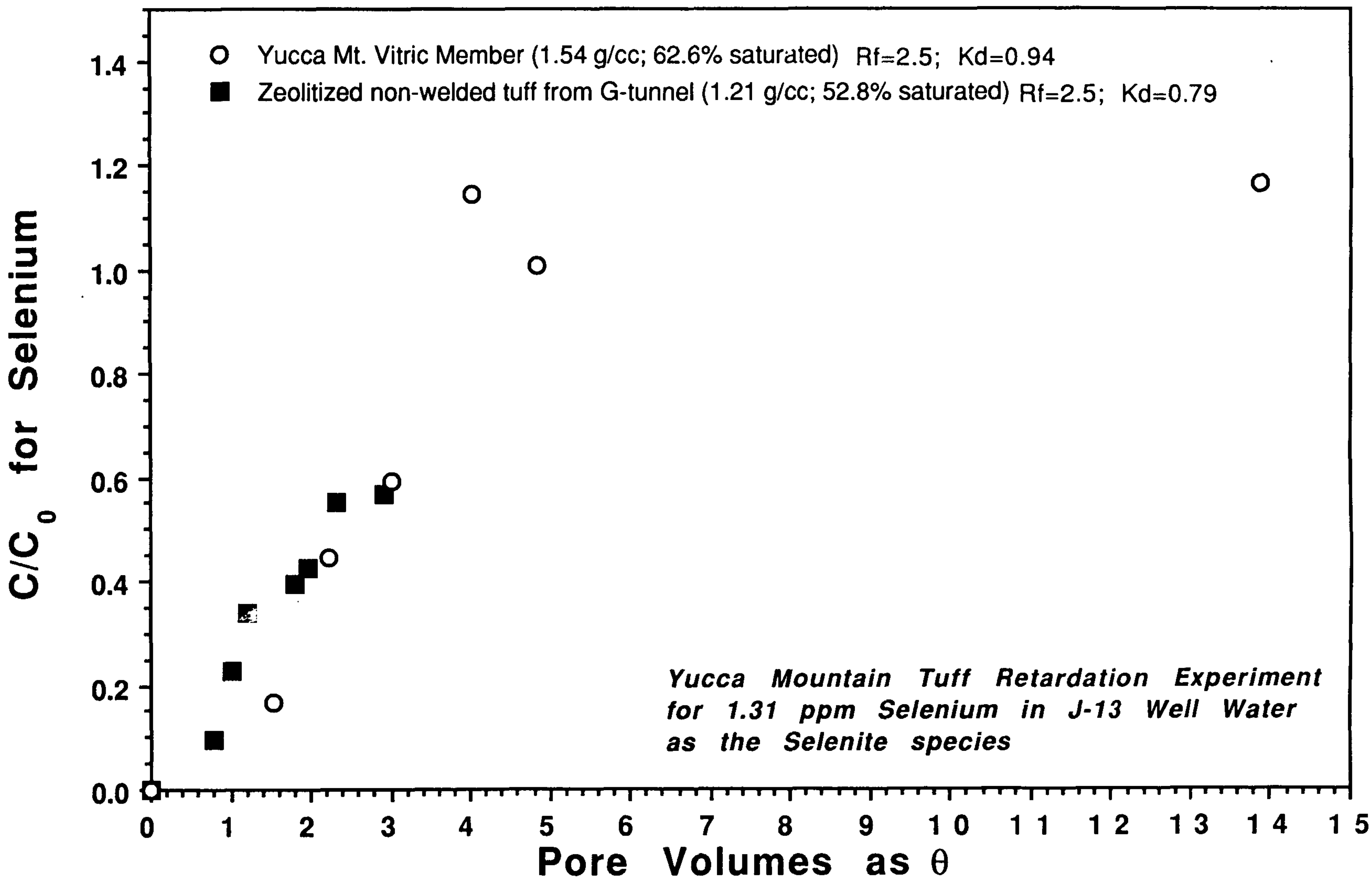


Unsaturated Hydraulic Conductivities for Various Tuffs.

Results of Se Sorption onto zeolitic tuff (from G tunnel) in J-13

Particle size of wet-sieved tuff: 75 - 500 μm

Initial Se Concentration, ppm	Pretreatment Period, Days	Sorption Period, Days	pH after Sorption	Kd (ml/g)
1.1	6.9	0.04	8.4	-0.2
1.1	6.9	0.04	8.4	0.3
1.1	6.8	13.9	8.5	0.0
1.1	6.8	13.9		0.2
0.5	6.8	13.9	8.6	4
0.5	6.8	13.9		3
0.4	6.8	13.9	8.3	20
0.4	6.8	13.9		10
0.02	6.8	13.9	8.3	40
0.02	6.8	13.9		30



Selenite Breakthrough Curves

Batch Sorption Experimental Procedure

Pre-treatment Step

- 1g of wet-sieved tuff equilibrated with 20 ml of J-13 groundwater
- Phases separated by centrifugation

Sorption Step

- Pre-treated tuff equilibrated with 20 ml of Se solution in J-13
- Phases separated by centrifugation
- Amount of Se in liquid phase determined by ICP-MS
- Amount of Se in solid phase calculated by difference

Controls

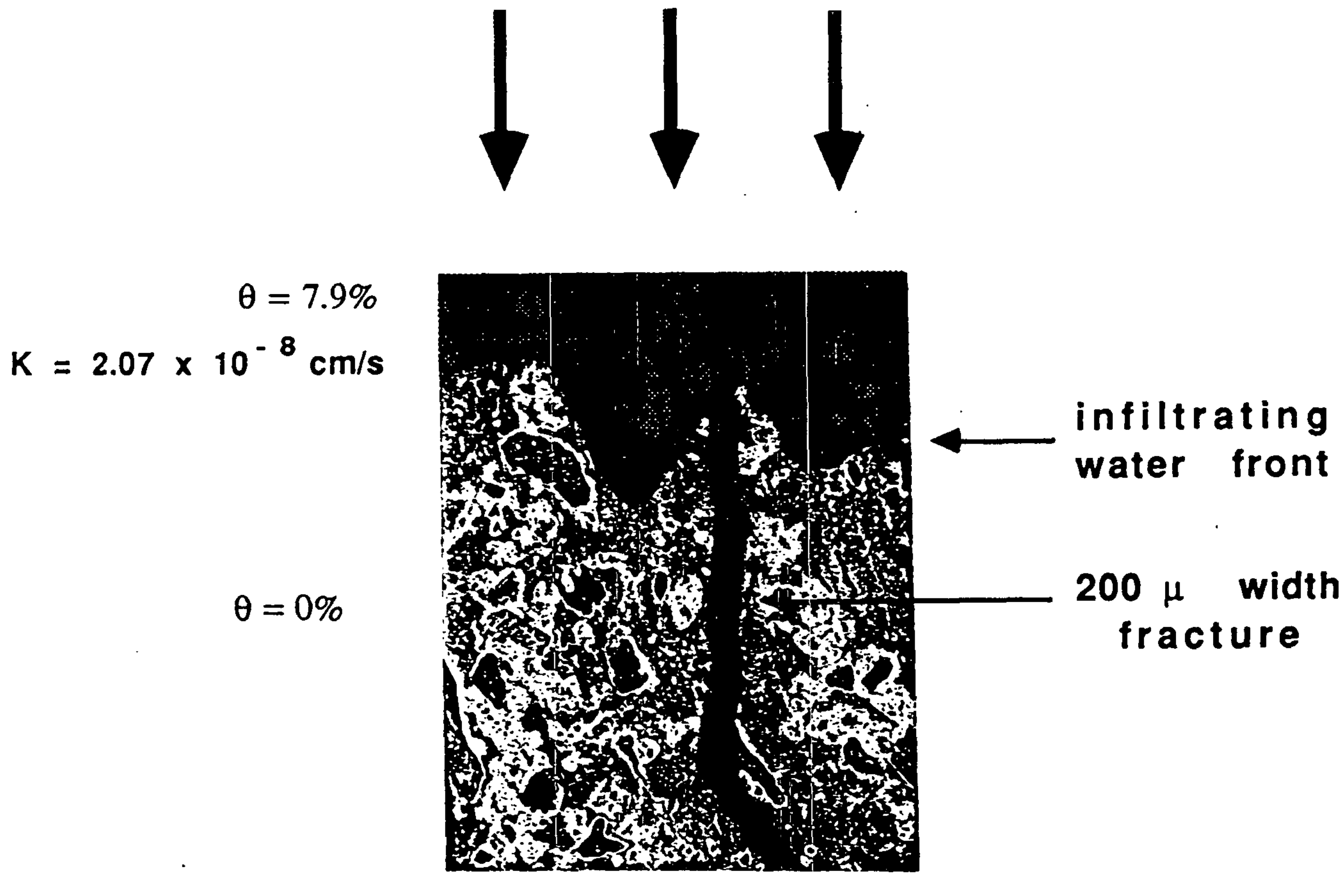
- Containers without tuff material utilized to monitor Se precipitation and/or sorption onto walls

Table 1. J13 WellWater Chemistry* Spiked with Selenite for Retardation Experiments

Na	44.3 ppm
K	4.0
Mg	1.81
Ca	12.1
Si	28.7
Se (as SeO_2)	1.40
Sr	0.036
B	0.141
pH	7.8
F	2.2
Cl	7.5
SO_4	19.0
NO_3	2.9
NO_2	14.0
HCO_3	119

*IC and ICP emmission by Karl Pool at PNL

J13 Well Water
5 ml/hr
7500 rpm



Paintbrush Tuff

$\rho = 2.41\ g/cm^3$

THE RETARDATION FACTOR

$$R_f = V_{groundwater}/V_{contaminant} = 1 + \rho K_d/n$$

R_f = retardation factor

V = velocity

n = porosity

ρ = bulk density

K_d = contaminant distribution coefficient

Which porosity should be used for n?

total (θ_s)

volumetric water content (θ)

effective (mobile vs. dead-end pores)

FRACTURE FLOW IN THE UFA™

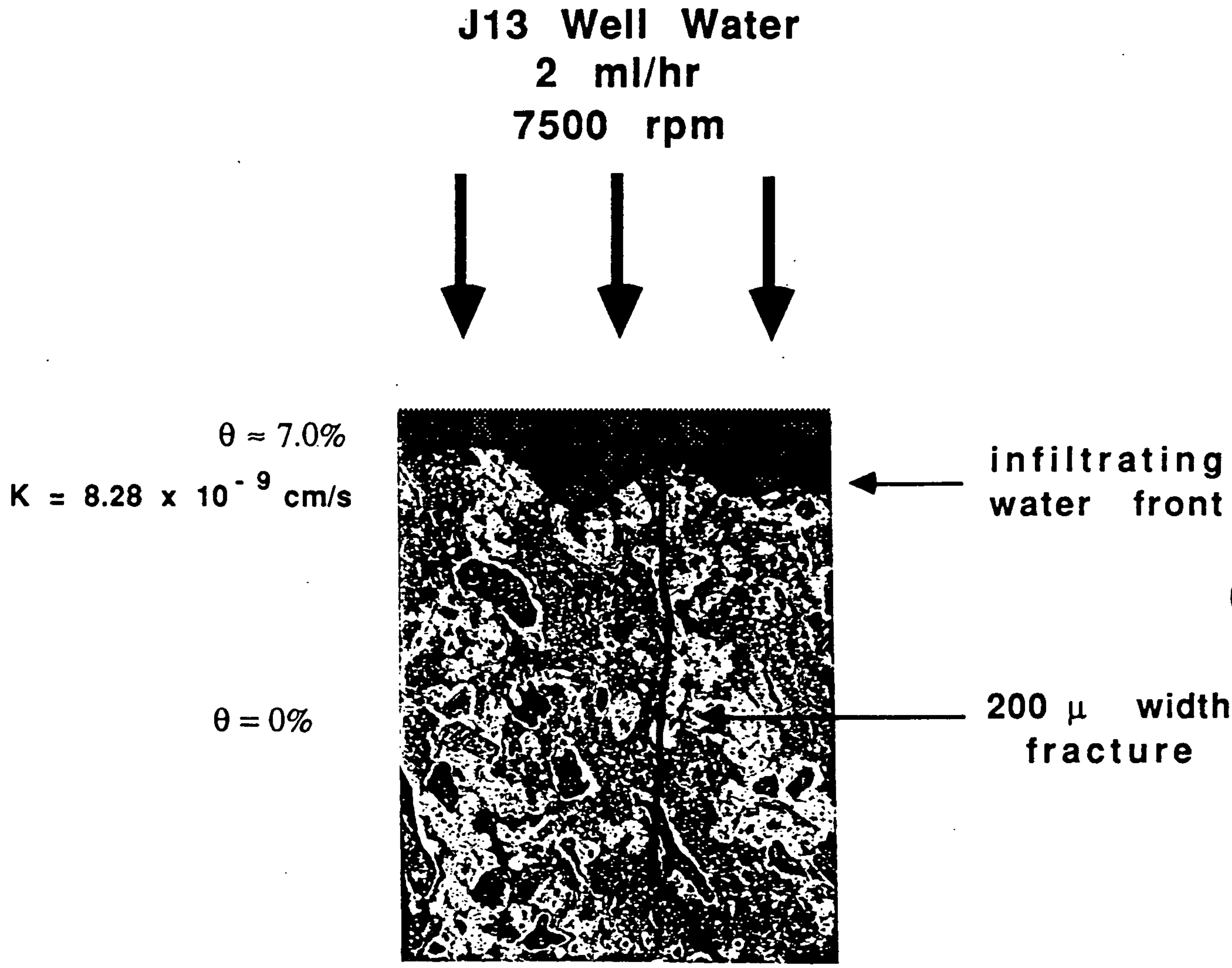
- The UFA™ can effectively uncouple the matric potential from the Darcy driving force.

- In the UFA™, in situations where $d\psi/dr \ll \rho\omega^2 r$, the centrifugal force is the dominant Darcy driving force, radially-symmetric and 1-dimensional.

- However, the matric potential, while no longer important as a Darcy driving force, still acts in 3-dimensions and still is important in redistributing water and determining fluid flow paths.

  Therefore, observed capillary phenomena are the same in the UFA™ as in the field, e.g., fractures desaturate in a stepwise manner with decreasing aperture size.

- Care must be taken when investigating synthetic materials that have ideal, smooth-walled, planar fractures radially symmetric to the axis of rotation, situations not encountered in natural systems.



Paintbrush Tuff

$\rho = 2.41$ g/cm^3

SUMMARY

- **Available information suggests that batch sorption data can be used to predict transport under unsaturated conditions**
- **UFA is being utilized to further assess the validity of batch sorption data under unsaturated conditions**
  - **Se and U in J13 well water at ppb to ppm**
  - **Topopah Spring, borehole G4 - 268.6', 272.5'**
  - **Calico Hills, borehole G4 - 1503.9', 1510', 1529'**
- **UFA will be used to study unsaturated soluble and colloid species transport through fractured tuff**
  - **UFA is conservative with respect to colloids**