GEOCHEMICAL EVIDENCE OF FRACTURE FLOW IN UNSATURATED TUFF, APACHE LEAP, ARIZONA

by Gregg Davidson

R. Bassett, P. Wierenga and S.P. Neuman
Co-Principal Investigators
University of Arizona

U.S. NRC Supported Research
JOB CODE W6387

NWTRB Workshop
San Francisco, California
June 26-27, 1995

CONFIRMATORY RESEARCH STUDIES

OBJECTIVE:

To independently assess conceptual models and strategies for simulating ground-water flow and transport through unsaturated, fractured heterogeneous rock using specially designed field experiments that focus on key technical uncertainties.

INDEPENDENT DATA COLLECTION TO EVALUATE MODELS

APPROACH:

Conduct field experiments which are designed to collect datasets for evaluating strategies for conceptualizing and modeling heterogeneities focusing on the following approaches and their applicability to performance assessment

- Equivalent Porous Media
- Dual Porosity
- Discrete-Fracture Network
- Dual Permeability
- Stochastic Continua
- Stochastic Effective Continua

(Cooperative effort by the Center for Nuclear Waste Regulatory Analyses, University of Arizona and NRC Staff.)

TECHNICAL ISSUES BEING ADDRESSED

- Uncertainties in modeling ground-water flow through unsaturated, fractured rock caused by the lack of codes tested against field and laboratory data

- Uncertainties associated with estimation of conditions and parameters in the unsaturated zone

- Need for experimental confirmation of the basic physical and chemical concepts of ground-water flow and transport through unsaturated, fractured heterogeneous rock

- Testing and evaluation of new data collection and interpretive techniques for estimating ground-water conditions and model input parameters for unsaturated, fractured heterogeneous rock

- Model confirmation

- Uncertainties attendant in prediction of future states

FIELD EXPERIMENTS BEING PLANNED

- Crosshole Pneumatic and Gaseous Tracer Tests
- 3-Dimensional Hydraulic and Tracer Tests
- Fracture and Pneumatic Characterization Studies
- Isotopic Fractionation and Transport in the Unsaturated Fractured Tuff and Perched Zone
- Tracer Tests & Fracture Flow and Transport Modeling on the 100-Meter Scale at Queen Creek Research Site
- Field Studies of Infiltration, Perched Zone Formation and Watershed Water Balance

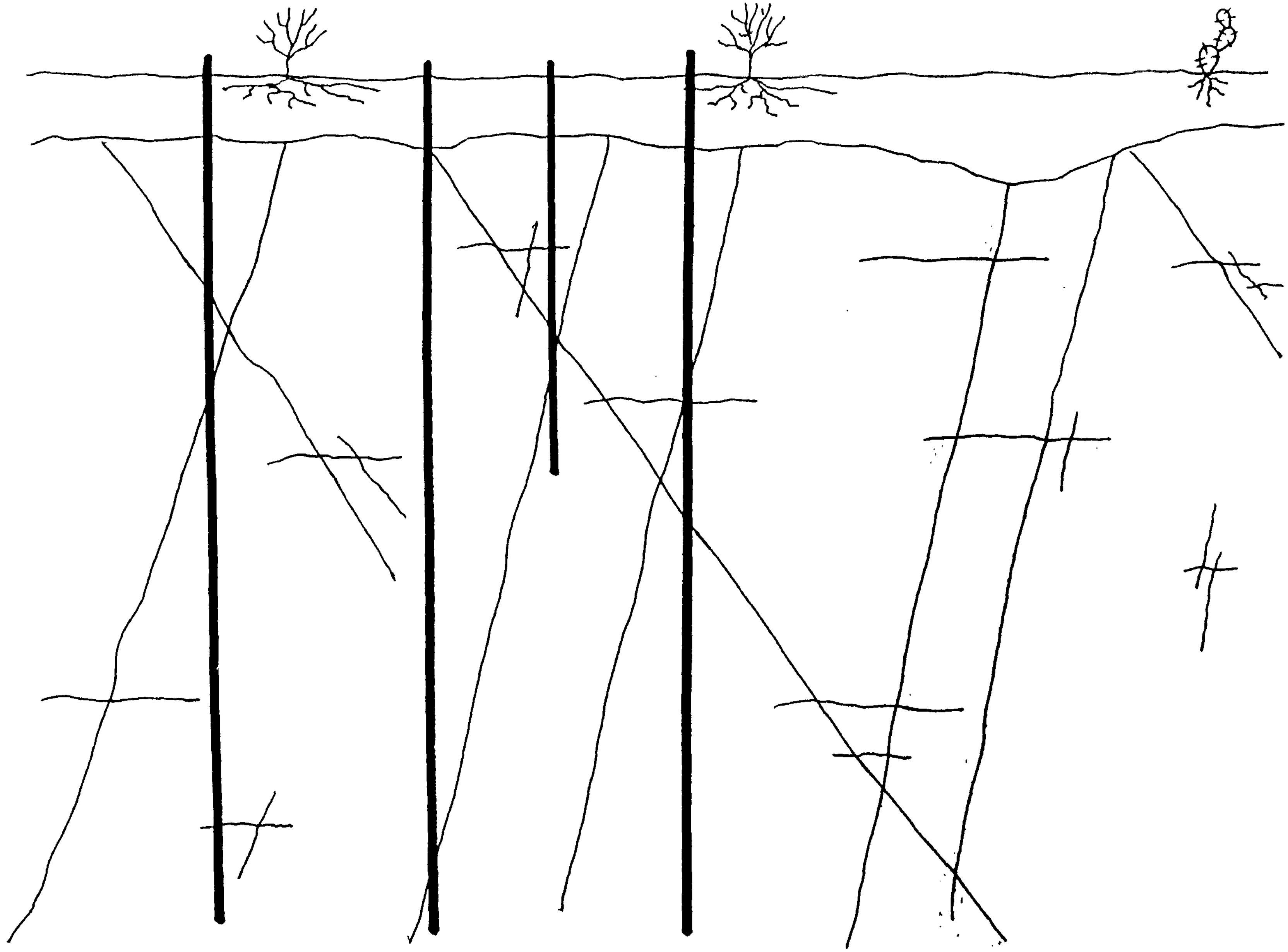
Geochemical Evidence of Fracture Flow in Unsaturated Tuff, Apache Leap, Arizona

Gregg Davidson

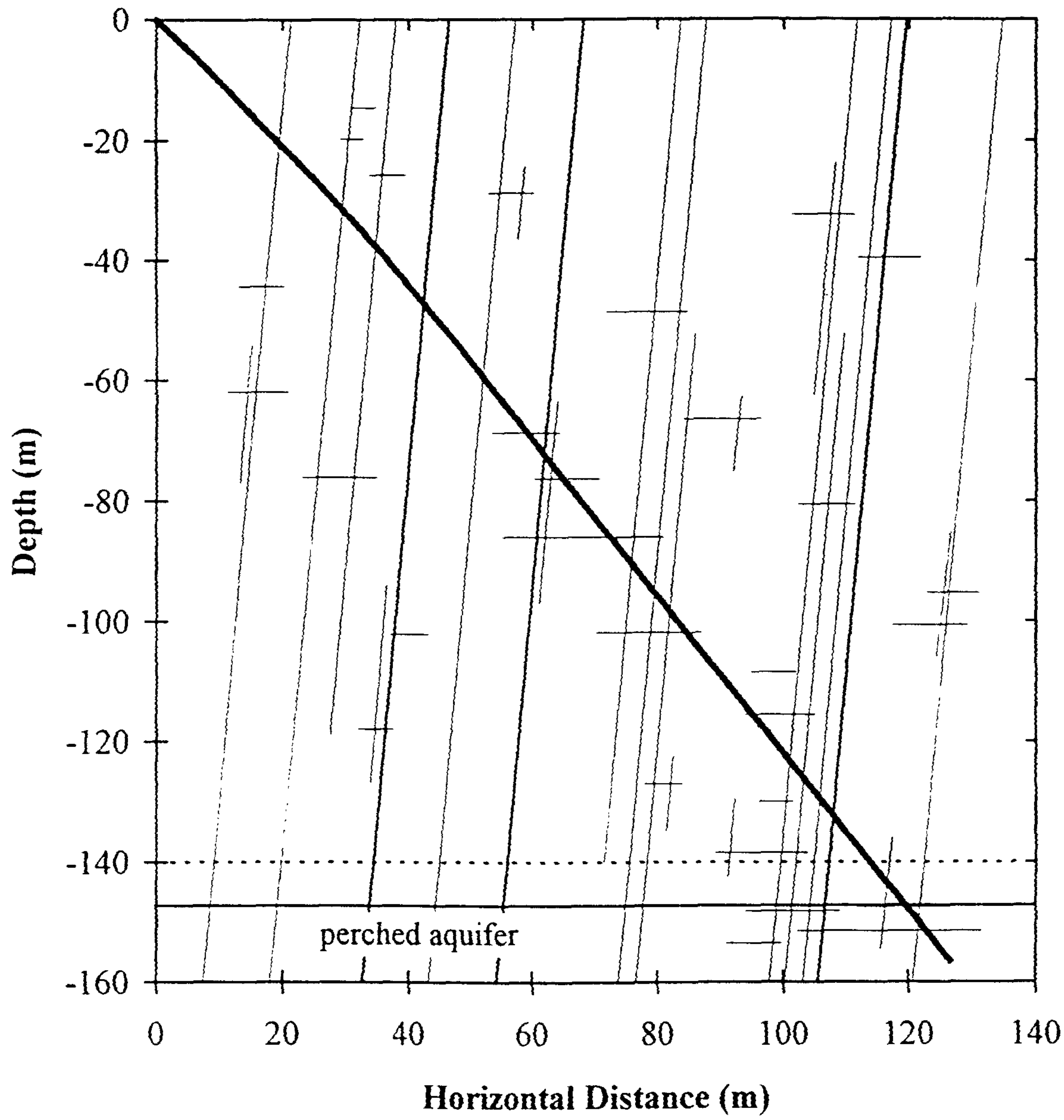
Work performed under contract NRC-04-90-51
Department of Hydrology and Water Resources, University of Arizona
R.L. Bassett (P.I.), S.P. Neuman (Co P.I.) and P.J. Wierenga (Co P.I.)

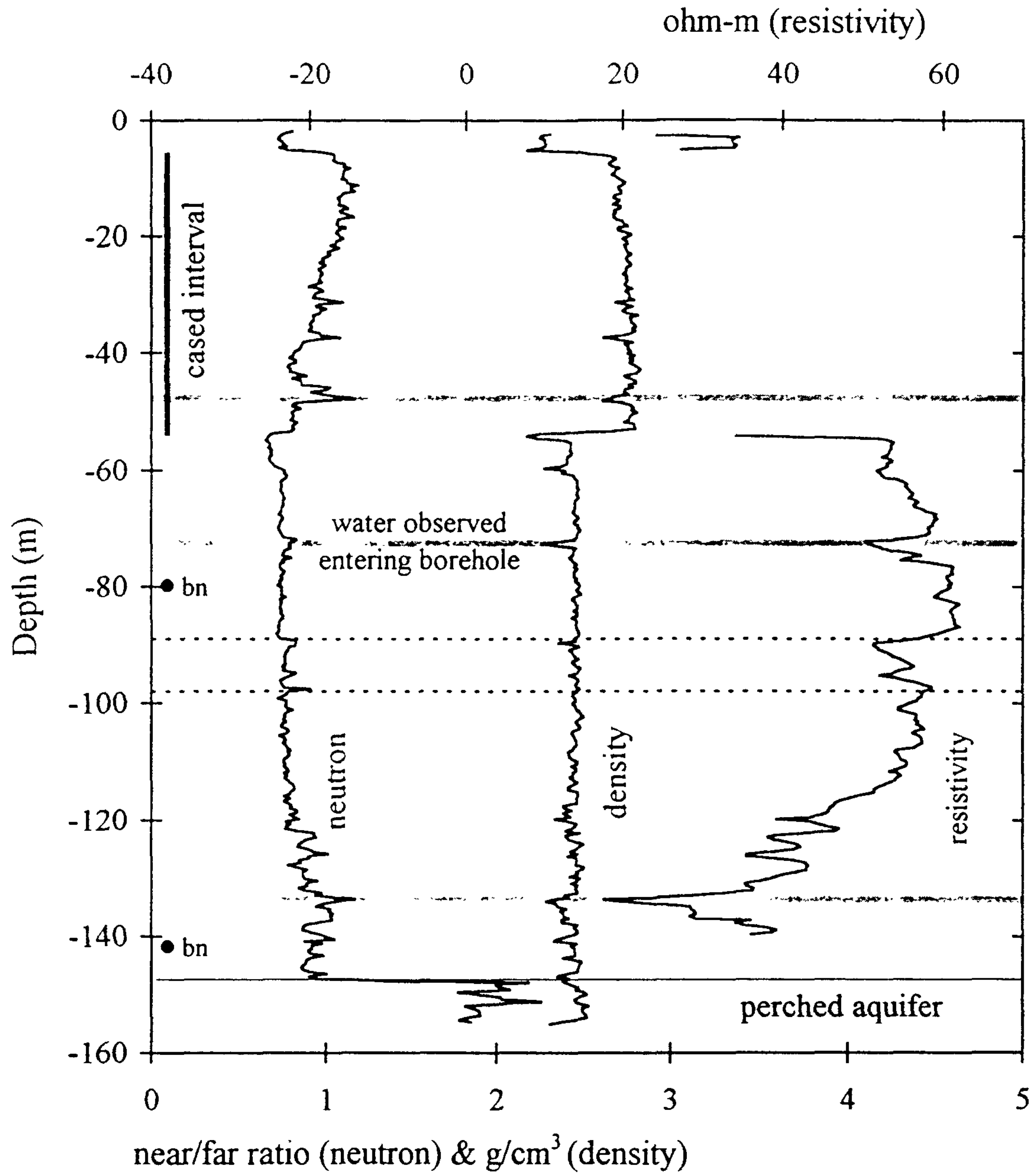
...This meeting will address questions such as:

What measurement techniques can be used to characterize/quantify flow and transport in these environments (i.e. can the "fast" pathways be detected, predicted, and quantified as to their significance) and what are the limitations of these techniques?

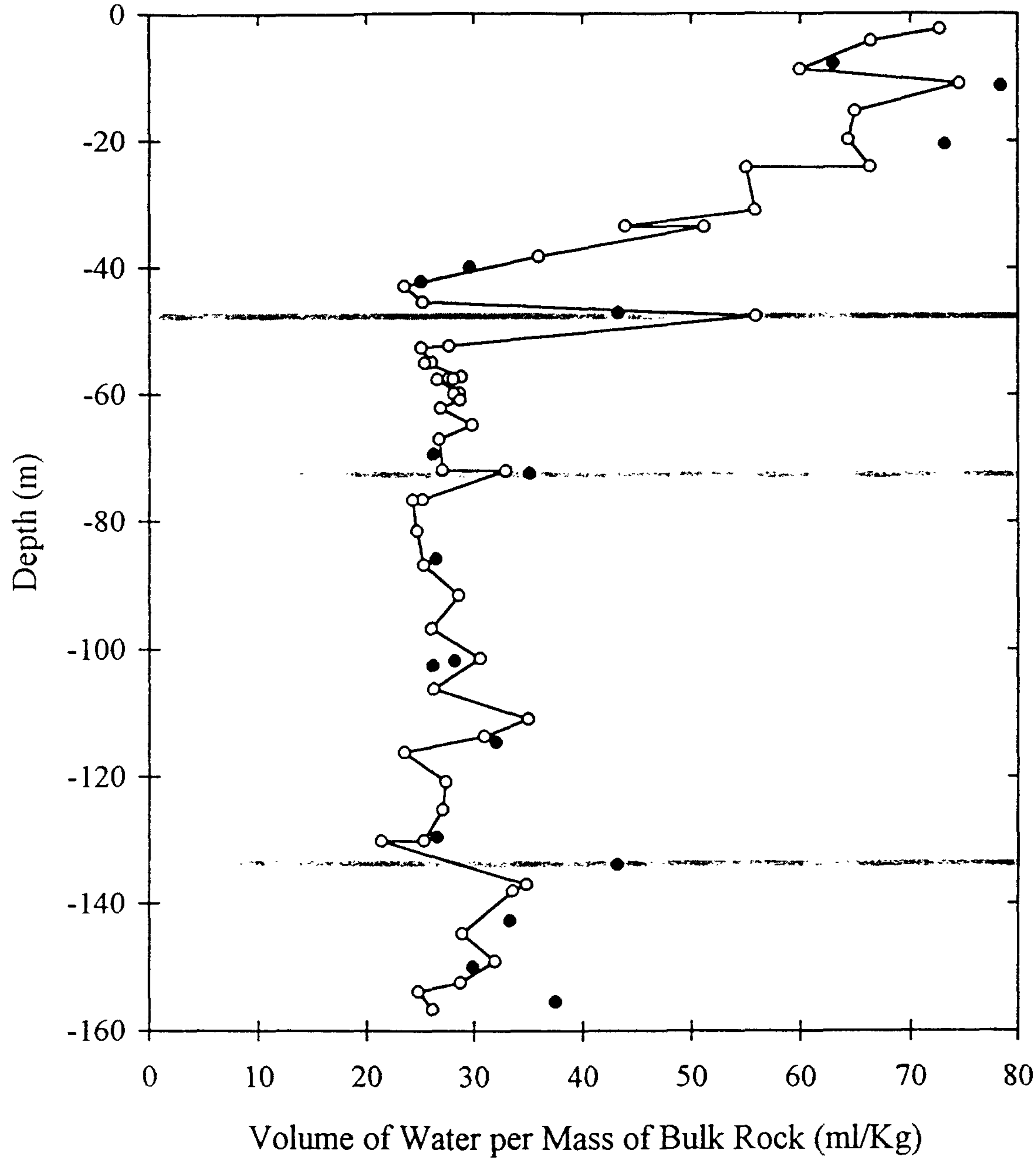


Deep Slant Borehole (DSB-1)

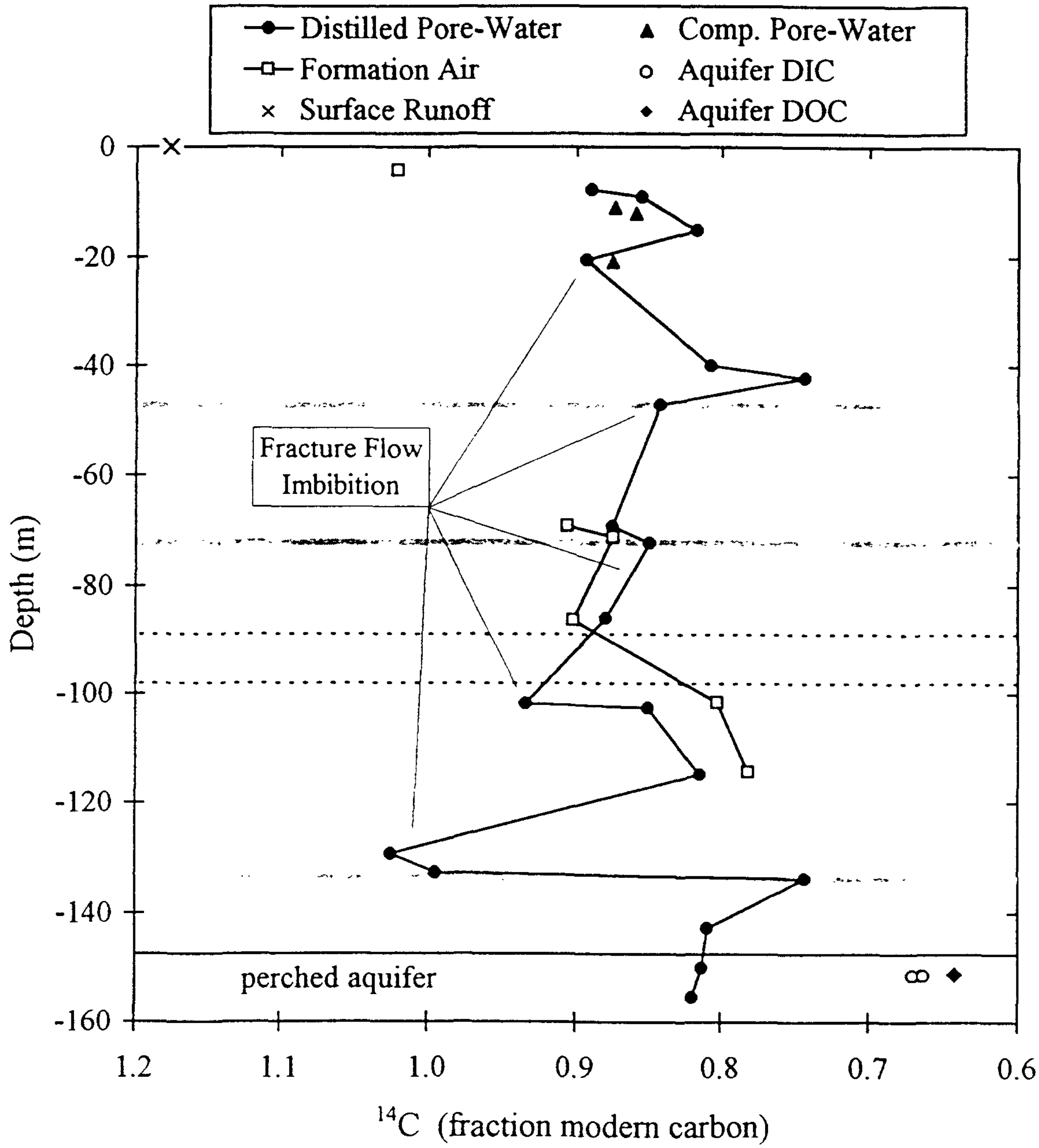


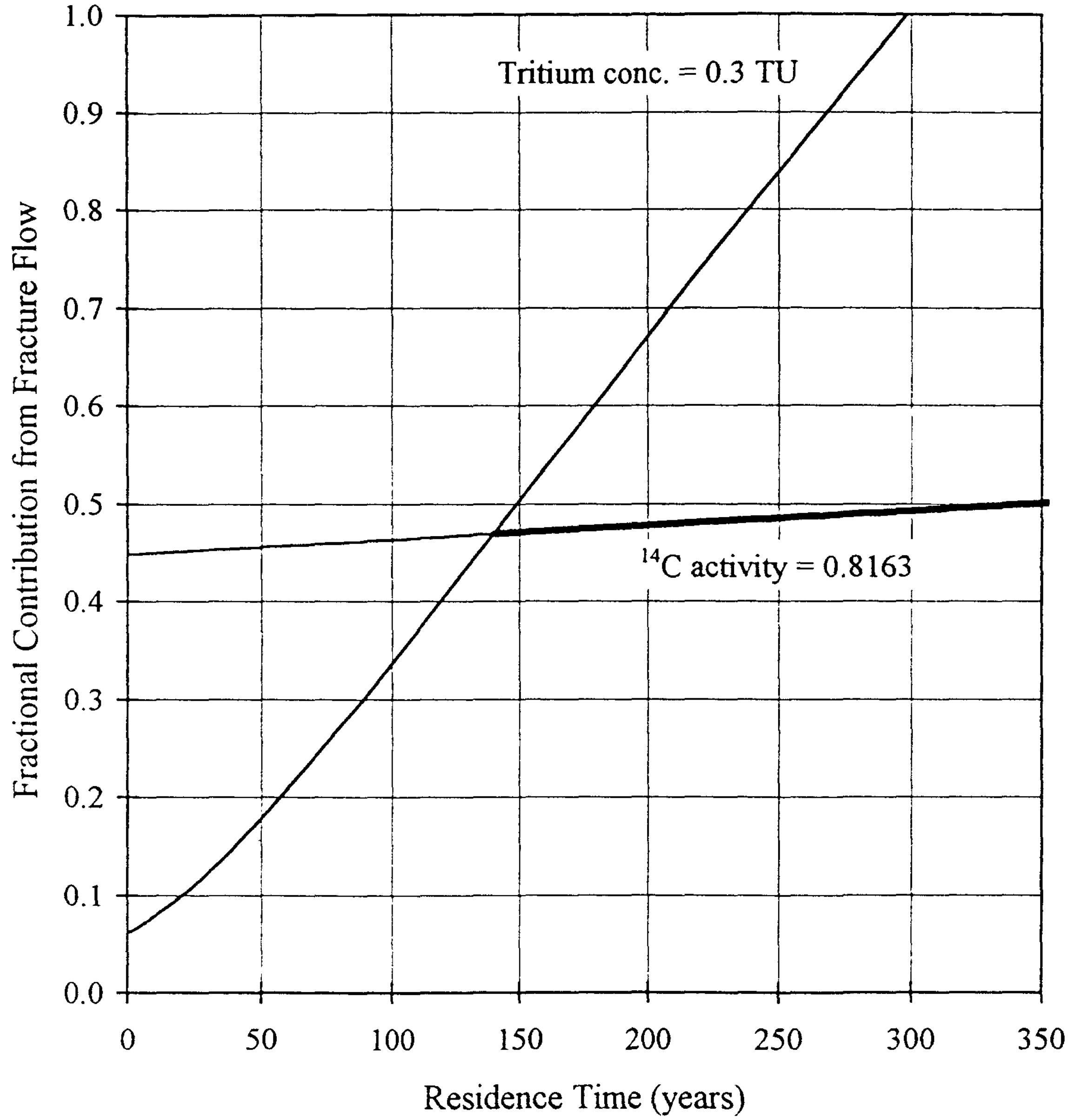


Hardin (1994); Davidson (1995)



open circles: gravimetric data (Geddis, 1994)
filled circles: distillation data (Davidson, 1995)


Distilled Pore-Water
Formation Air
Surface Runoff
Comp. Pore-Water
Aquifer DIC
Aquifer DOC
Fracture Flow
Imbibition
perched aquifer
Depth (m)
0
-20
-40
-60
-80
-100
-120
-140
-160
1.2
1.1
1.0
0.9
0.8
0.7
0.6
^{14}C (fraction modern carbon)



Tritium conc. = 0.3 TU
^{14}C activity = 0.8163
Fractional Contribution from Fracture Flow
Residence Time (years)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
50
100
150
200
250
300
350

Average Compositions (mg/L)			
	Runoff	Pore Water	Aquifer
pH	5.9	7.0	7.3
Na	3.7	53.3	21.9
Mg	1.4	5.4	3.7
K	1.3	2.9	0.9
Ca	5.0	24.6	20.2
Cl	2.3	35.9	4.2
NO_3	<0.5	8.6	1.1
SO_4	18.0	40.5	1.9
SiO_2	32.3	55.4	58.1
HCO_3	2.8	84.1	120.9
TDS	67	314	228

Minerals Considered	
Dissolution	**Precipitation**
plagioclase	kaolinite
biotite	chlorite
hornblende	smectite
CO_2 gas	illite
	SiO_2

	Runoff	DSB-1	Tunnel*	Oak Flats*
^{14}C (a)	1.18	0.67	0.69	0.68
^{3}H (TU)	5	<0.1	1.2	1.9
$\delta^{34}S$ (‰)	-4 to +1	6 to 7	2 to 4	7
Cl/SO_4	0.1 to 0.2	2.1 to 2.3	0.4 to 0.9	2.4

* Bassett et al. (1994)

Example NETPATH* Solutions			
surface runoff	98.2%	98.2%	98.1%
pore water from 15.6 m	1.8%	1.8%	1.9%
evaporate	1.45X	1.45X	1.43X
An_{32}	0.975	0.975	0.889
biotite	0.532	0.044	
hornblende			0.029
CO_2	1.881	1.881	1.880
chlorite	-0.260		
smectite		-0.207	-0.073
illite	-0.927		
SiO_2		-1.737	-2.076

*Plummer et al. (1991)