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Modeling Uranium Transport in Unsaturated Zone at Peña Blanca, Mexico

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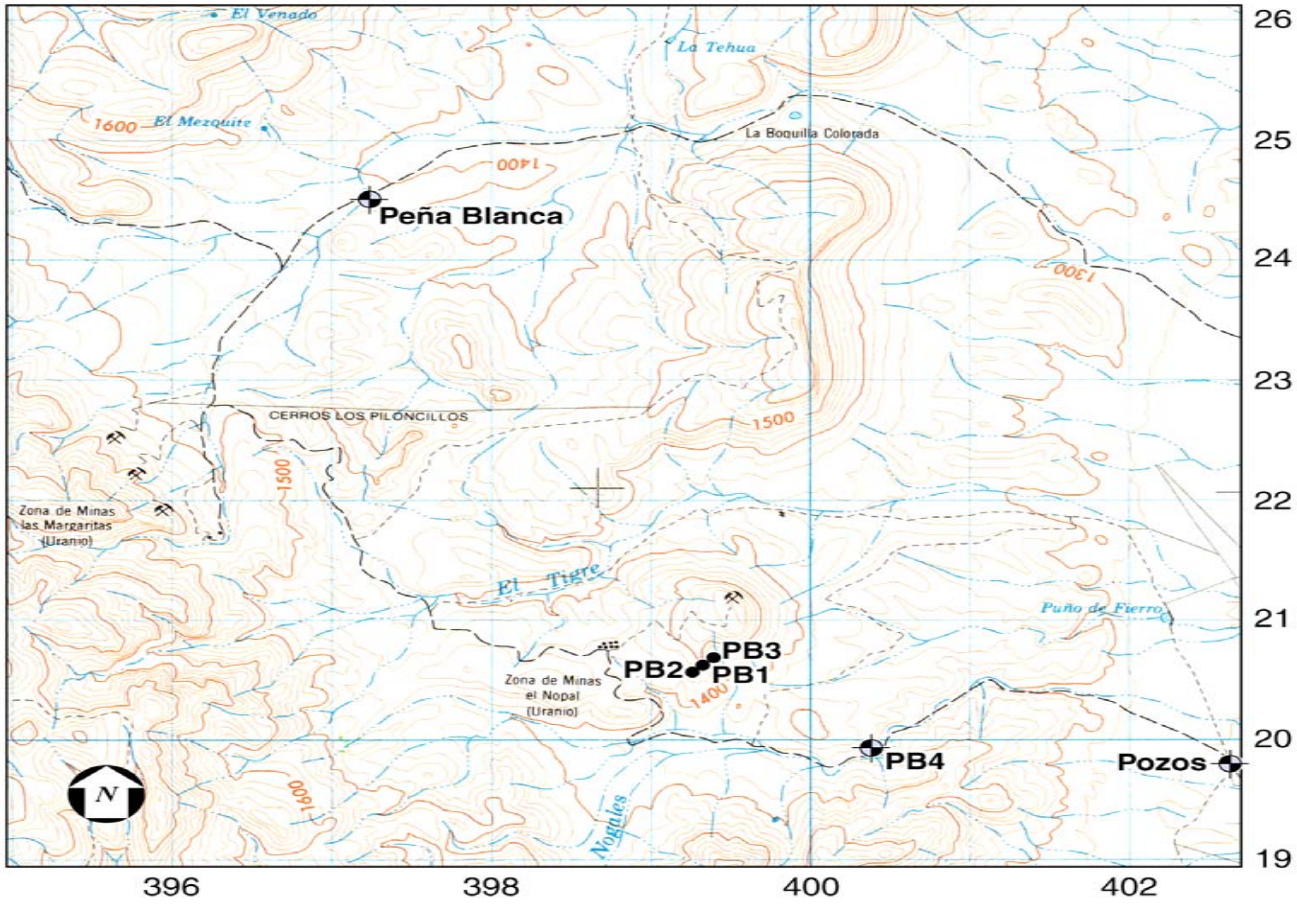
Map of Sampling Site



Legend

- Existing Wells
- New Peña Blanca Boreholes

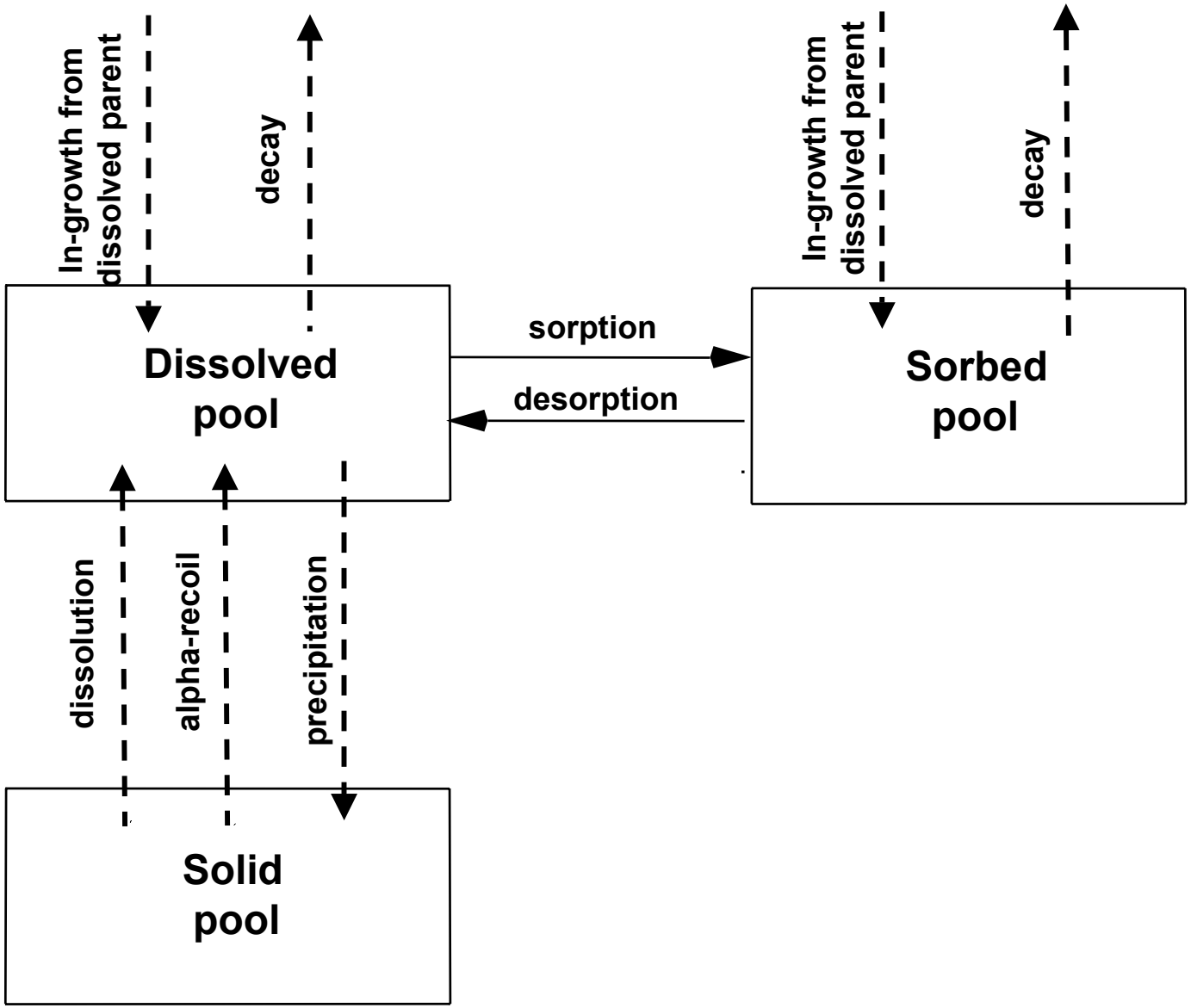
0 1 Km

Contour Interval = 20 Meters

El Sauz 1:50,000 Topographic Map (H13C46)
North American 1927 datum

NA04-001

A Scheme of Rock-Water Interaction



Radionuclide Transport Model

Assumptions

1) Radionuclides reside in four pools: dissolved, colloidal, sorbed, and solid.
2) Radionuclides are released via dissolution and α-recoil at rate *P*.
3) Nuclide transport is retarded by sorption-desorption-precipitation.

Time rate of change of radionuclide concentration in groundwater:

$$\frac{dC^*}{dt} = P - \lambda R_f^* C^* \qquad (1)$$

***C**= *C* + C_c = concentration in dissolved and colloidal pools and R_f^* is effective retardation factor (R_f^* = 1 for conservative tracer.)**

Solving:

$$\frac{A^*}{P} = \frac{\left(1 - e^{-\lambda R_f^* \tau_w}\right)}{R_f^*} \qquad (2)$$

***A**(=λ*C**) is radionuclide activity and τ_w is water-rock interaction time.**

Derive R_f^* and τ_w from U-series isotopes in water.

Application to U Transport in Unsaturated Zone

For ^{238}U, ($\lambda R_{f^*} \tau_w$) << 1, Eq. (2) can be simplified as:

$$A_{U238} = \lambda_{U238} \tau_w P_{U238} \quad (3)$$

For ^{234}U, alpha-recoil input (P_r) during a non-flushing period (τ_o) should be considered:

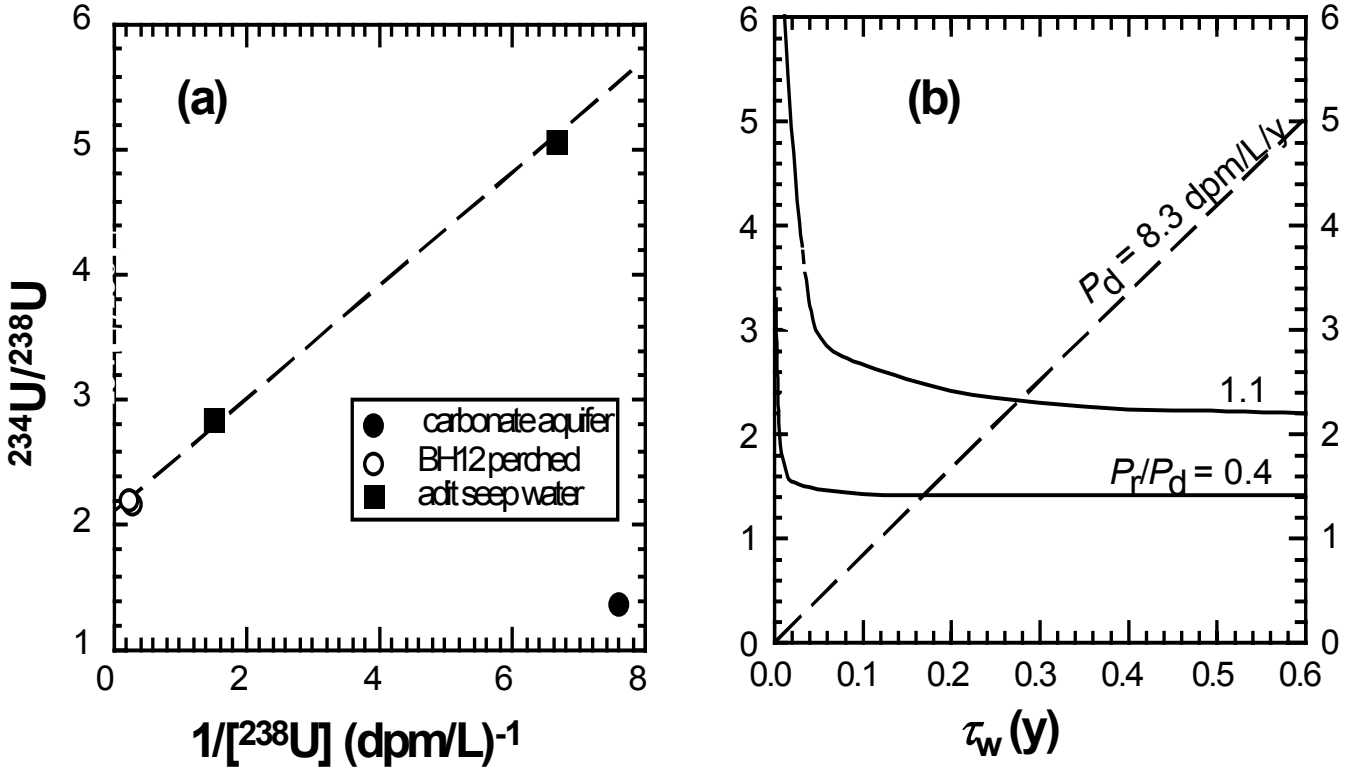
$$A_{U234} = \lambda_{U234} \tau_0 P_r + \lambda_{U234} \tau_w P_{U234} \quad (4)$$

Combining Eqs. (3) and (4),

$$\frac{A_{234U}}{A_{238U}} = \frac{a}{A_{238U}} + b \quad (5)$$

$a = \lambda_{U234} \tau_o P_r$ and $b = (\lambda_{U234} P_{U234})/(\lambda_{U238} P_{U238})$, both can be determined by plotting ($^{234}U/^{238}U$) vs. $1/^{238}U$

Data from Pickett and Murphy (1999)



(a) Slope = a = 0.45 dpm/L ==>> P_r = 9 dpm/L/y

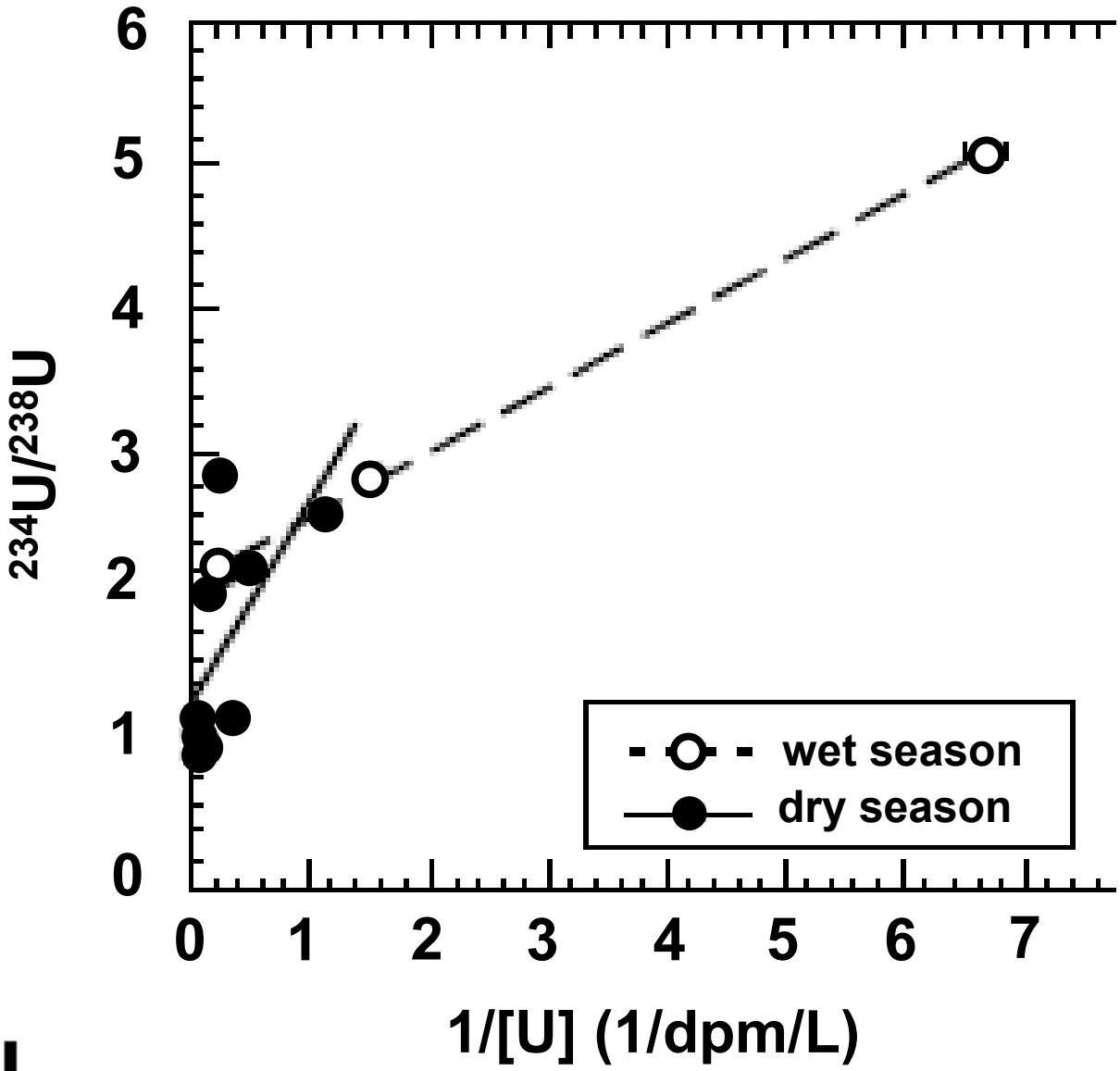
Intercept = b = 2.1 ==>> P_d = 8.3 dpm/L/y

(b) Water transit time in vadose zone (τ_w):

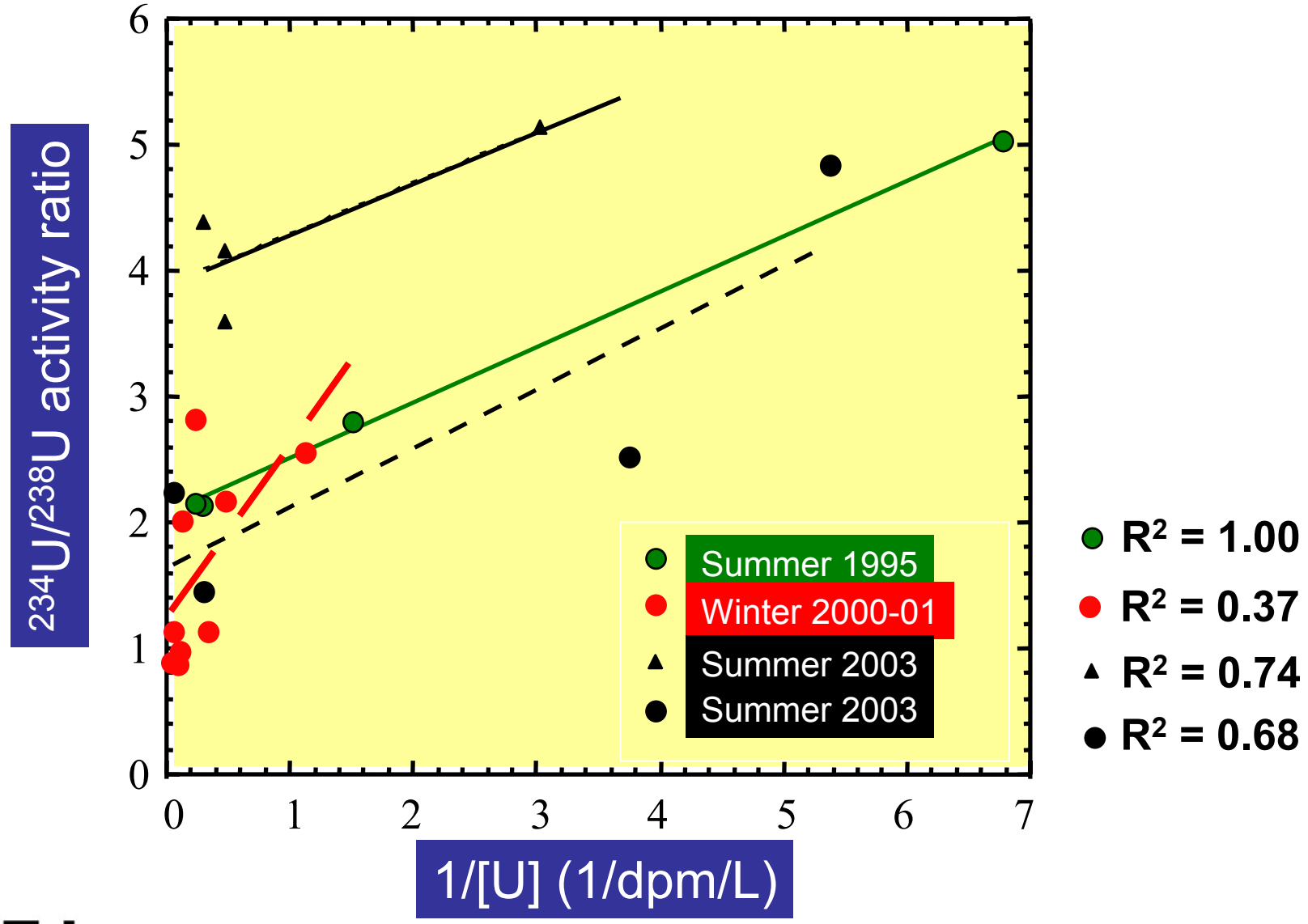
Seep water site: 6–29 days

Perched water site: 0.4–0.5 years.

Additional Data from Dry Winter Season 2001-02



All Adit Waters from Unsaturated Zone



Conclusions

- Removal of ^{234}U and ^{238}U from unsaturated-zone (UZ) solids takes place during major rainfalls.

- Waters from each of these rainfalls passing through the UZ can be modeled to have $^{234}U/^{238}U$ inversely related to [U].

- Given the non-flushing period between two rain events, the model can estimate the alpha-recoil input of ^{234}U, dissolution rate of U, and water transit time in the UZ.

- Further testing of the model requires sampling of UZ waters from discrete major rainfalls.

ACKNOWLEDGMENTS

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