Near-Field Environments and Corrosion

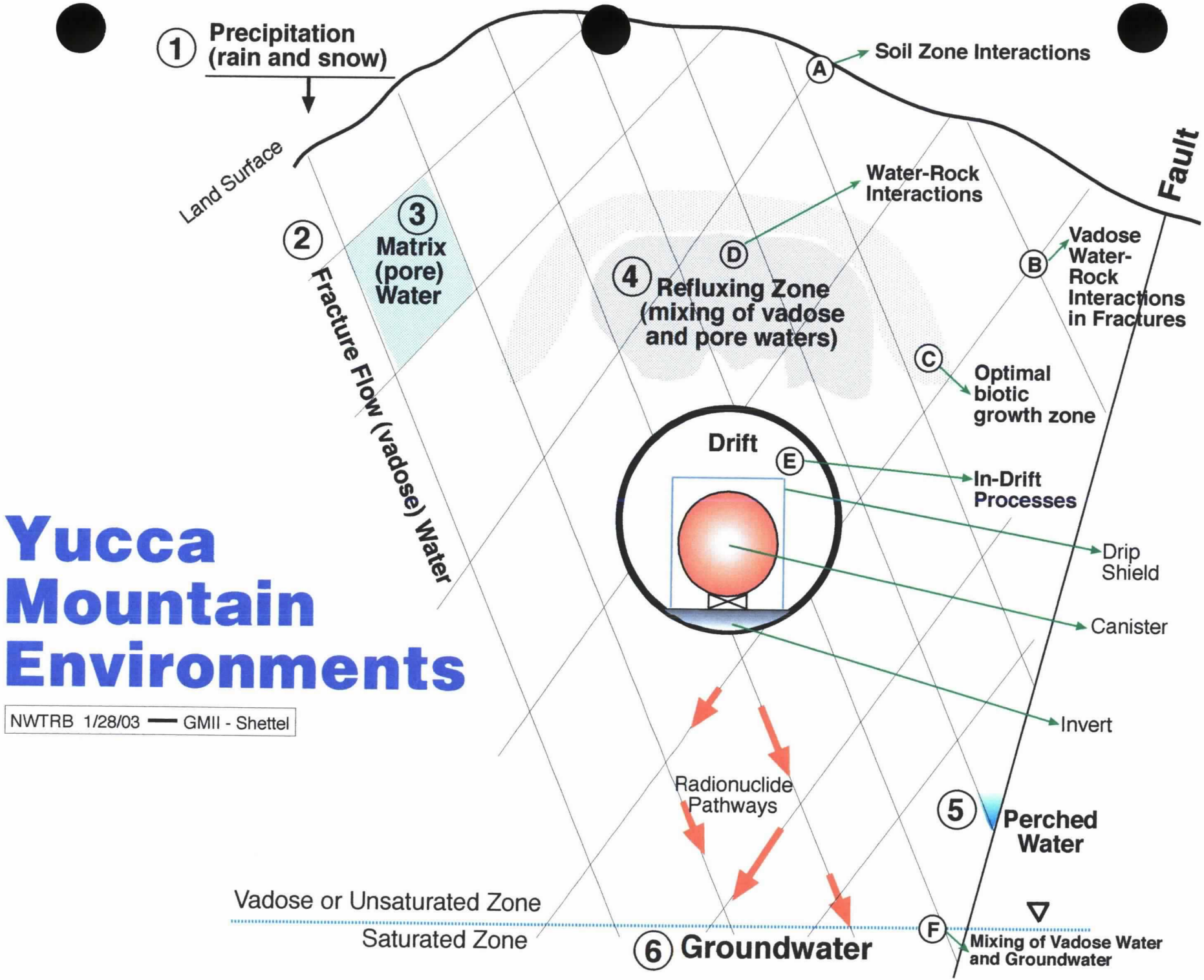
presented to the

U.S. Nuclear Waste Technical Review Board

by

Don L. Shettel, Ph.D.
(consultant to the State of Nevada)
Geosciences Management Institute, Inc.
1000 Nevada Way, Suite 106
Boulder City, NV 89005
702-294-3064; fax -3065
www.geomii.com
dls@geomii.com

28 January 2003


1 Precipitation (rain and snow)
Land Surface
2 Fracture Flow (vadose) Water
3 Matrix (pore) Water
4 Refluxing Zone (mixing of vadose and pore waters)
A Soil Zone Interactions
B Vadose Water-Rock Interactions in Fractures
C Optimal biotic growth zone
D Water-Rock Interactions
E In-Drift Processes
Drift
Drip Shield
Canister
Invert
Radionuclide Pathways
5 Perched Water
Fault
Vadose or Unsaturated Zone
Saturated Zone
6 Groundwater
F Mixing of Vadose Water and Groundwater
Yucca Mountain Environments
NWTRB 1/28/03 — GMII - Shettel

Yucca Mt. Water Types

1. Precipitation (rain and snow)

dilute: Ca - HCO_3
(NO_3 similar to SO_4 and Cl)

2. Fracture flow (vadose) water

3 shallow samples: Na - HCO_3
Composition is generally unknown

3. Matrix (pore) water in Vadose Zone

shallow (above Repository Level): Ca - SO_4 + Cl
deep (below Repository Level): Na - HCO_3

4. Refluxing Zone

Heated mixtures can evolve
Mixtures of most types (except GW & perched)
(from concentrated solutions to dilute condensates)

---

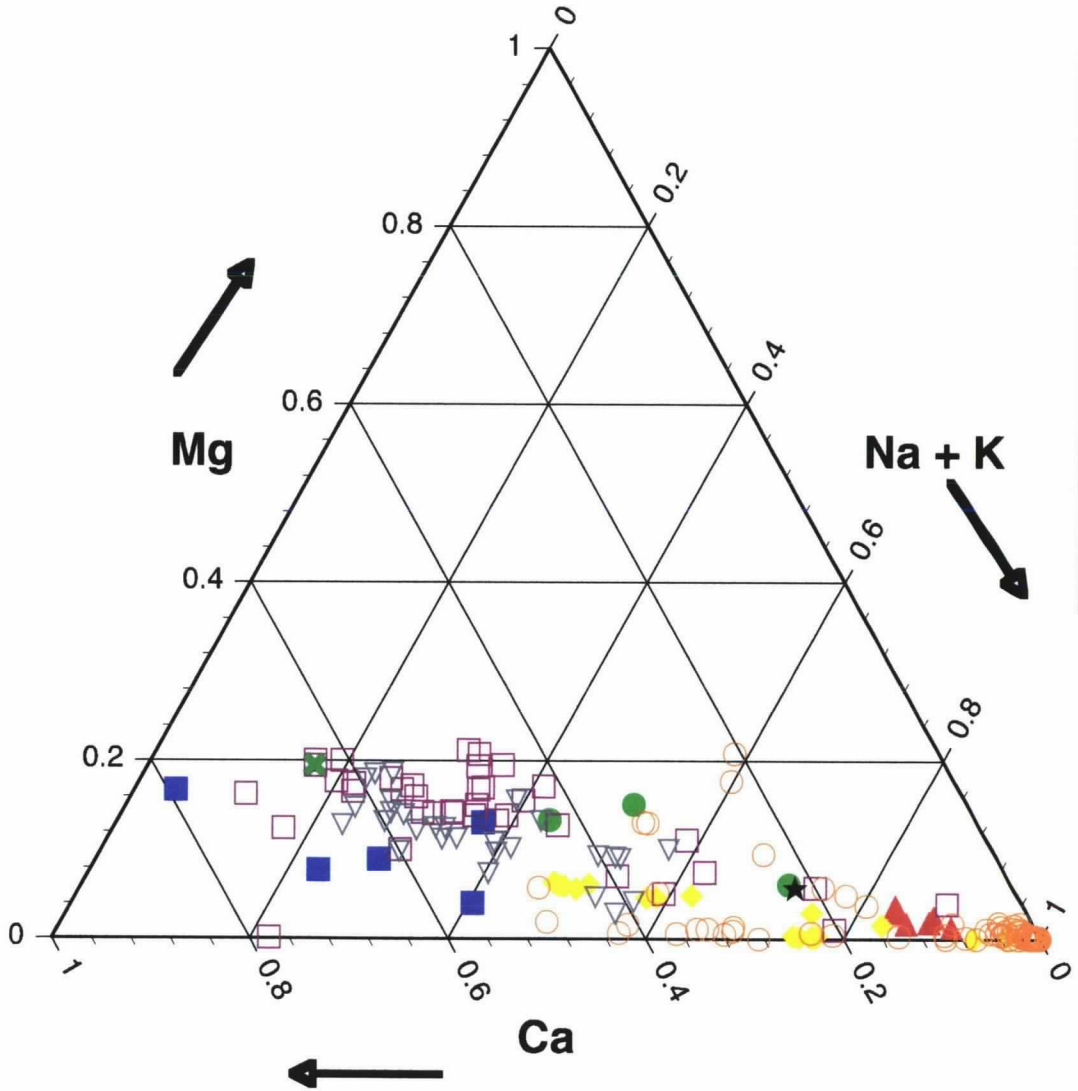
5. Perched Water

Variable, but generally: Na - HCO_3 (similar to groundwater)
(dead-end fracture water comp. unknown)

6. Groundwater

Generally: Na - HCO_3

Yucca Mt. Water Compositions



Cation Ternary of Piper Diagram

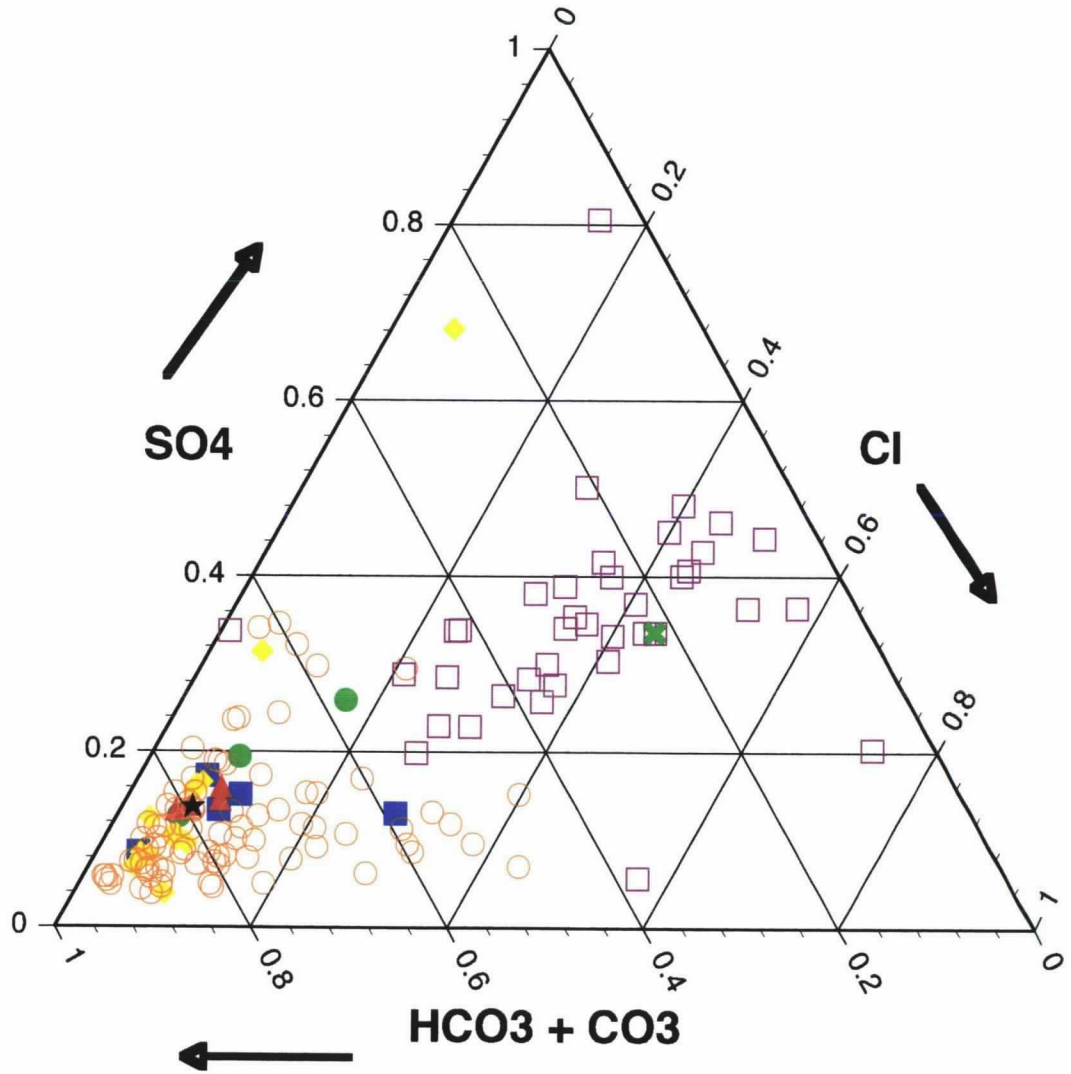
- Precip.
- UZ water (-N2)
- Groundwater at UZ-16
- Perched
- UZ pore water > R.L.
- UZ pore water < R.L.
- ECRB pore waters
- J-13
- UZ pore water (RGK)

R.L. = Repository Level
RGK = Rosenburg, Gdowski, & Knauss

Data from:
Harrar et al., (1990)
Peterman & Marshall (2002)
Sonnenthal et al. (1998)
Shettel (unpublished)
Yang et al. (1996, 1998)

NWTRB 1/28/03 -- GMII: Shettel

Yucca Mt. Water Compositions (% eq/L)



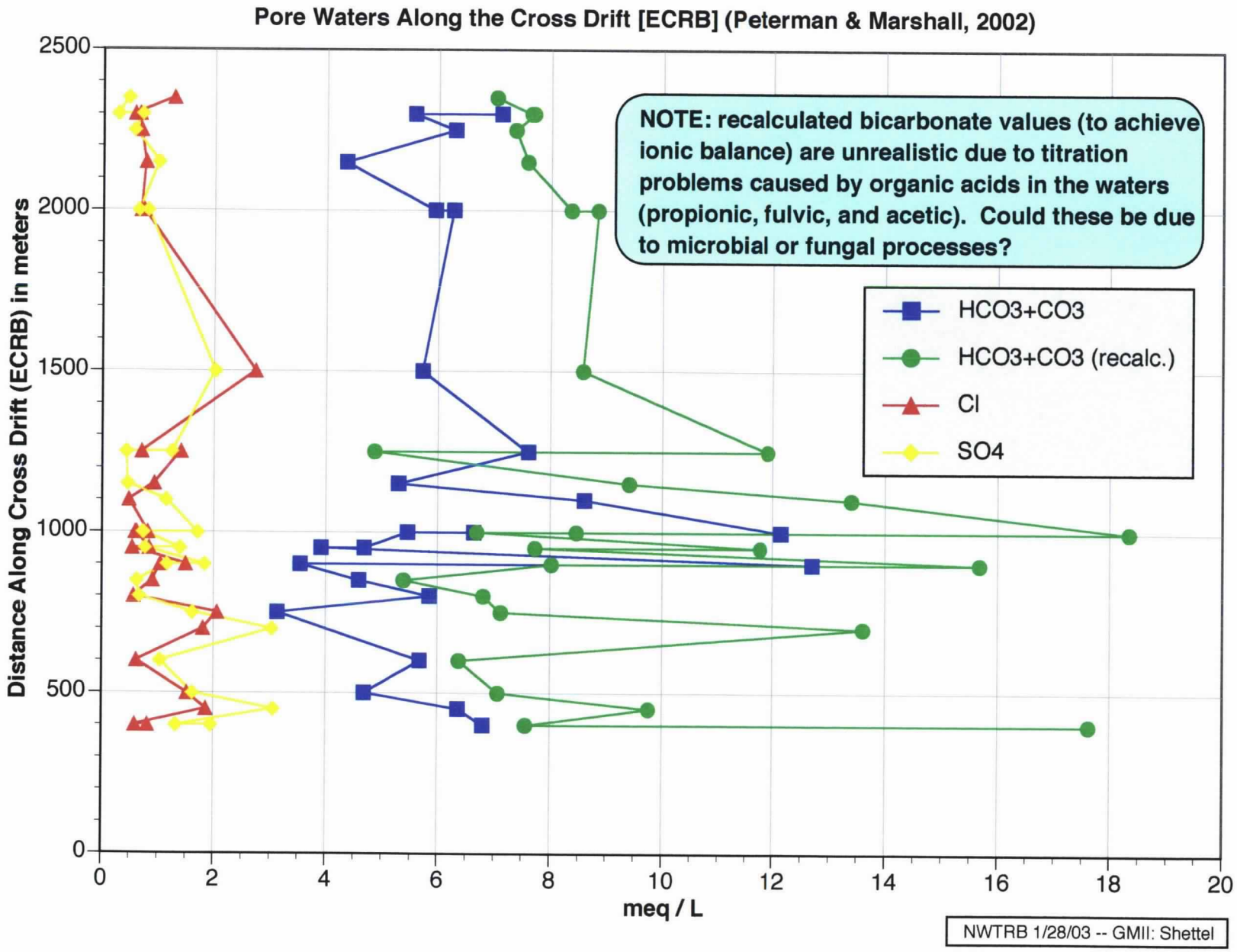
Anion Ternary of Piper Diagram

- Precip.
- UZ water (-N2)
- Groundwater at UZ-16
- Perched
- UZ pore water > R.L.
- UZ pore water < R.L.
- ECRB pore waters
- J-13
- UZ pore water (RGK)

R.L. = Repository Level
RGK = Rosenberg, Gdowski, & Knauss, '01

Data from:
Harrar et al., (1990)
Peterman & Marshall(2002)
Sonnenthal et al. (1998)
Shettel (unpublished)
Yang et al. (1996, 1998)

NWTRB 1/28/03 -- GMII: Shettel


Pore Waters Along the Cross Drift [ECRB] (Peterman & Marshall, 2002)
NOTE: recalculated bicarbonate values (to achieve ionic balance) are unrealistic due to titration problems caused by organic acids in the waters (propionic, fulvic, and acetic). Could these be due to microbial or fungal processes?
HCO3+CO3
HCO3+CO3 (recalc.)
Cl
SO4
Distance Along Cross Drift (ECRB) in meters
2500
2000
1500
1000
500
0
0
2
4
6
8
10
12
14
16
18
20
meq / L
NWTRB 1/28/03 -- GMII: Shettel

Yucca Mt. Environments

A. Soil Zone Interactions -

Nitrifying bacteria, evaporative concentration

B. Vadose Water-Rock Interactions in Fractures -

Silica, carbonates, and Mn-Pb-minerals coating fractures

C. Optimal Biotic Growth Zone -

Wet and warm conditions promote maximum bacterial and algal growth (loss of NO_3 and PO_4)

Dynamic - follows temperature changes (~45°C)

D. Refluxing Zone -

Mixing of any vadose waters and pore waters

Precipitation of minerals in boiling zone

Dissolution of minerals in condensation zone

Heated water-rock interactions

Dynamic position with temperature

E. In-Drift Processes -

Dripping / flowing vadose waters from fractures

Relative humidity & temperature variations

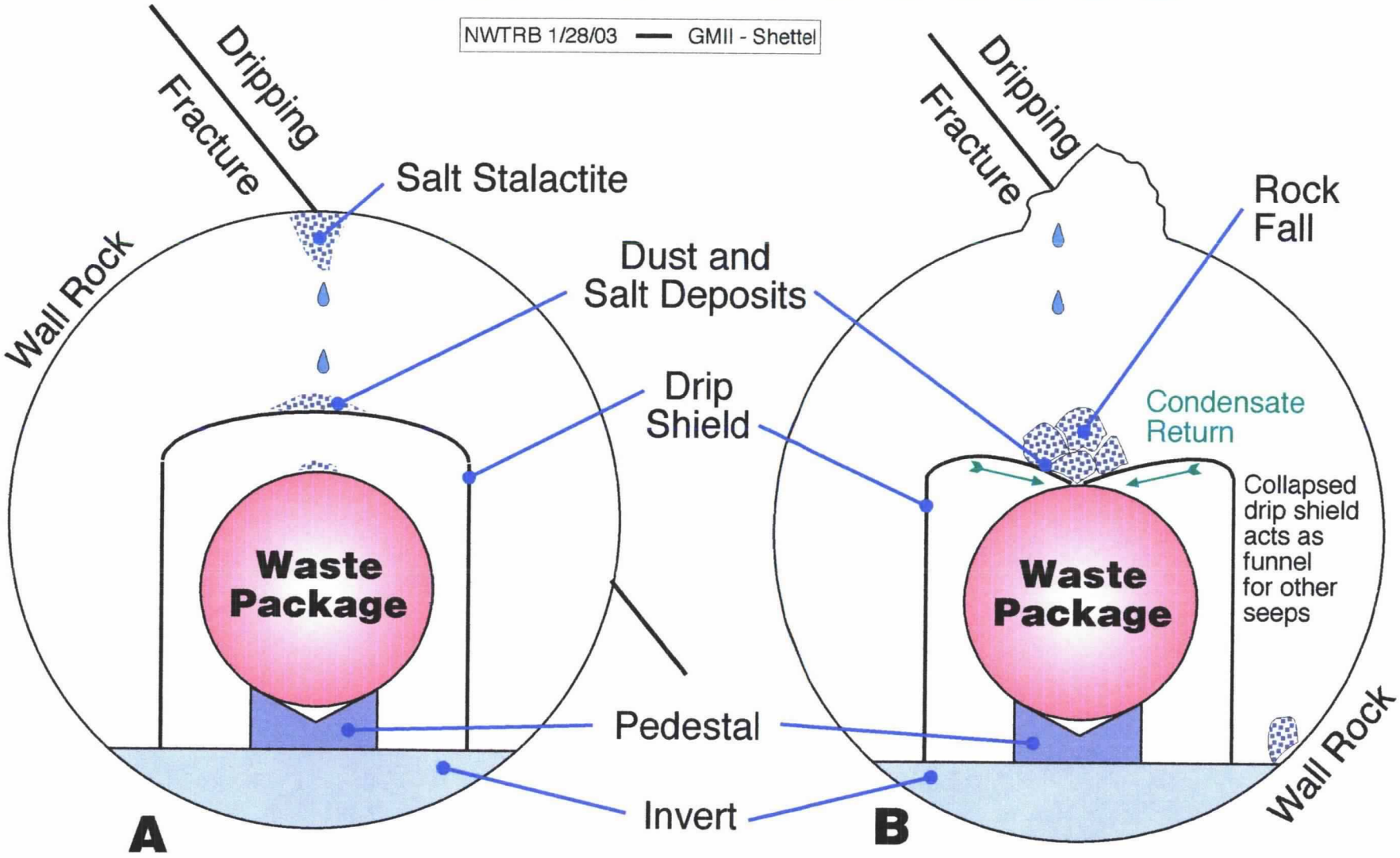
Dust and evaporative salt build-up on surfaces

Rockfalls, radiolysis, other man-made materials

Acid volatilization, hydrolysis of salts

In-Drift Processes

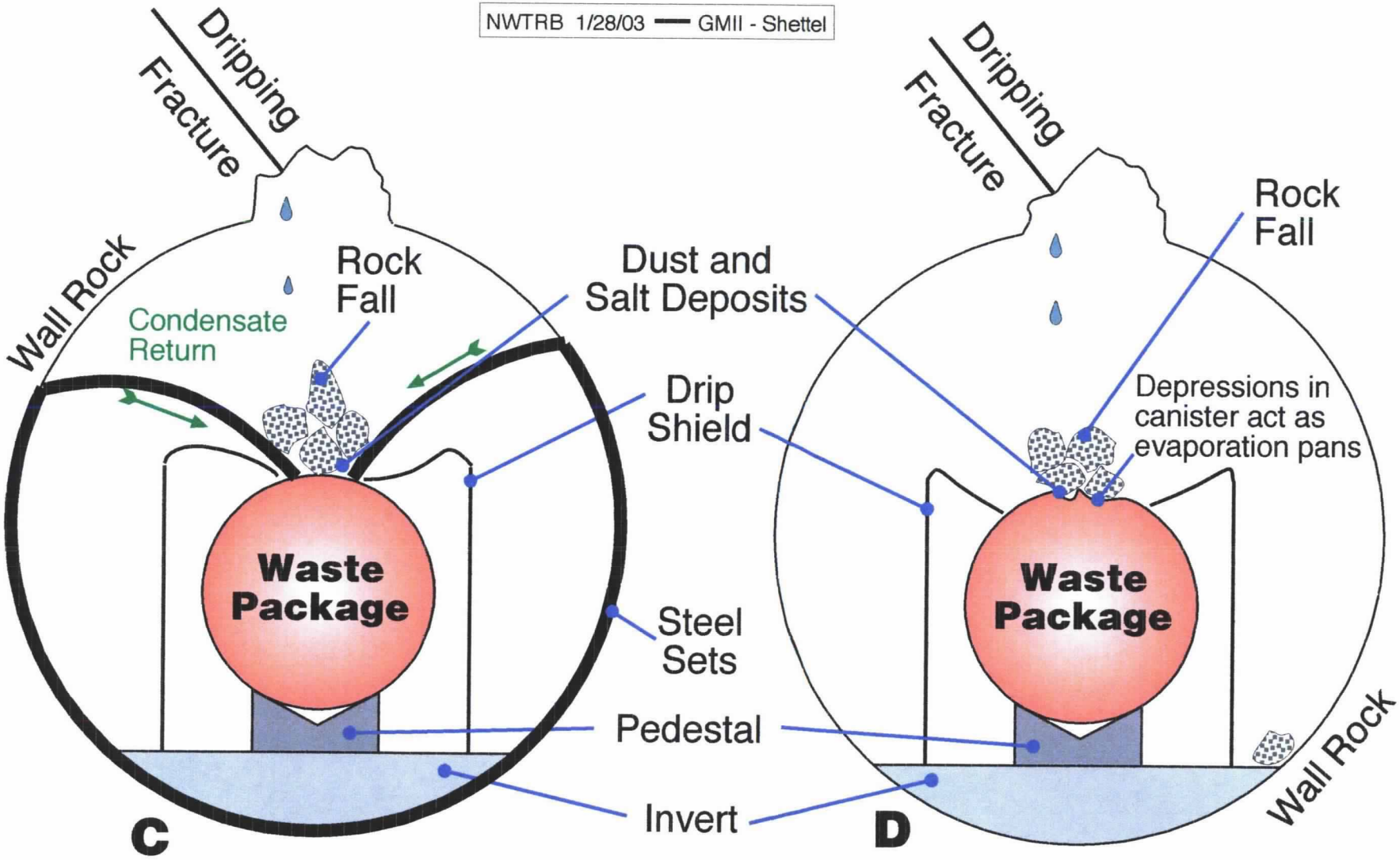
NWTRB 1/28/03 — GMII - Shettel



Cross Section of Emplacement Drifts

In-Drift Processes

NWTRB 1/28/03 — GMII - Shettel



Cross Section of Emplacement Drifts

Conclusions

1. Pre-emplacement waters (precipitation, soil, vadose, matrix, perched, and groundwater) are unevenly characterized chemically.

2. Vadose-Zone Matrix (pore) Waters are extremely variable:
   Ca-rich waters predominate above repository level
   Na-rich waters predominate below repository level
   Above Rep. Level: highest SO_4 + Cl, highest & most variable NO_3

3. Cross drift (ECRB) pore waters have been affected by man: microbiological activity produces organic acids?

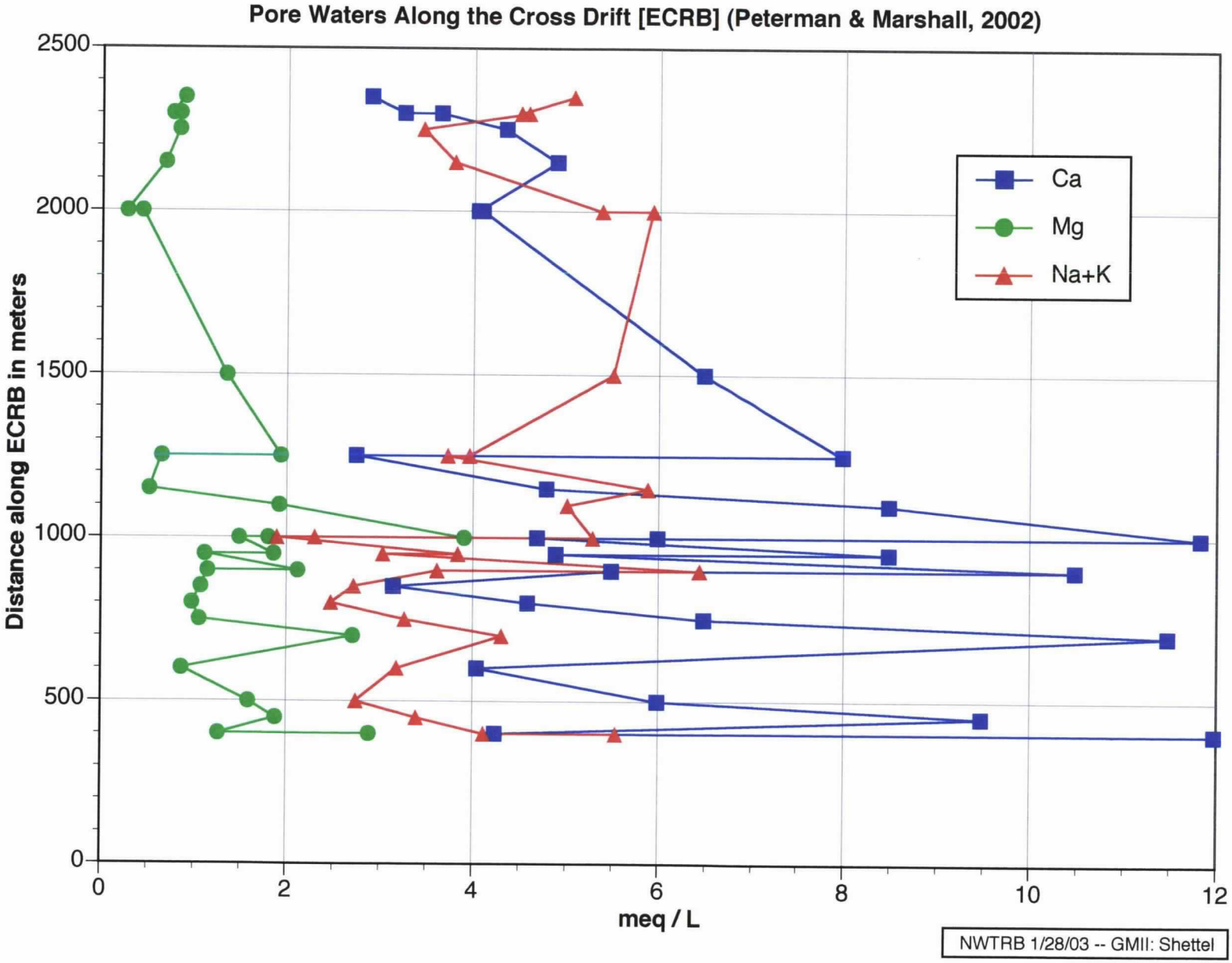
4. Post-emplacement waters evolve from mixtures of above Repository Level pre-emplacement waters modified by:
   Biotic Growth Zone (loss of NO_3 and PO_4, SO_4 reduction),
   Refluxing Zone (heated mixtures of waters reacting with Topopah Springs tuff), and In-drift processes.

5. Importance to Corrosion: Post-emplacement waters cannot be sampled nor analyzed; therefore, cannot be characterized. Modeled?

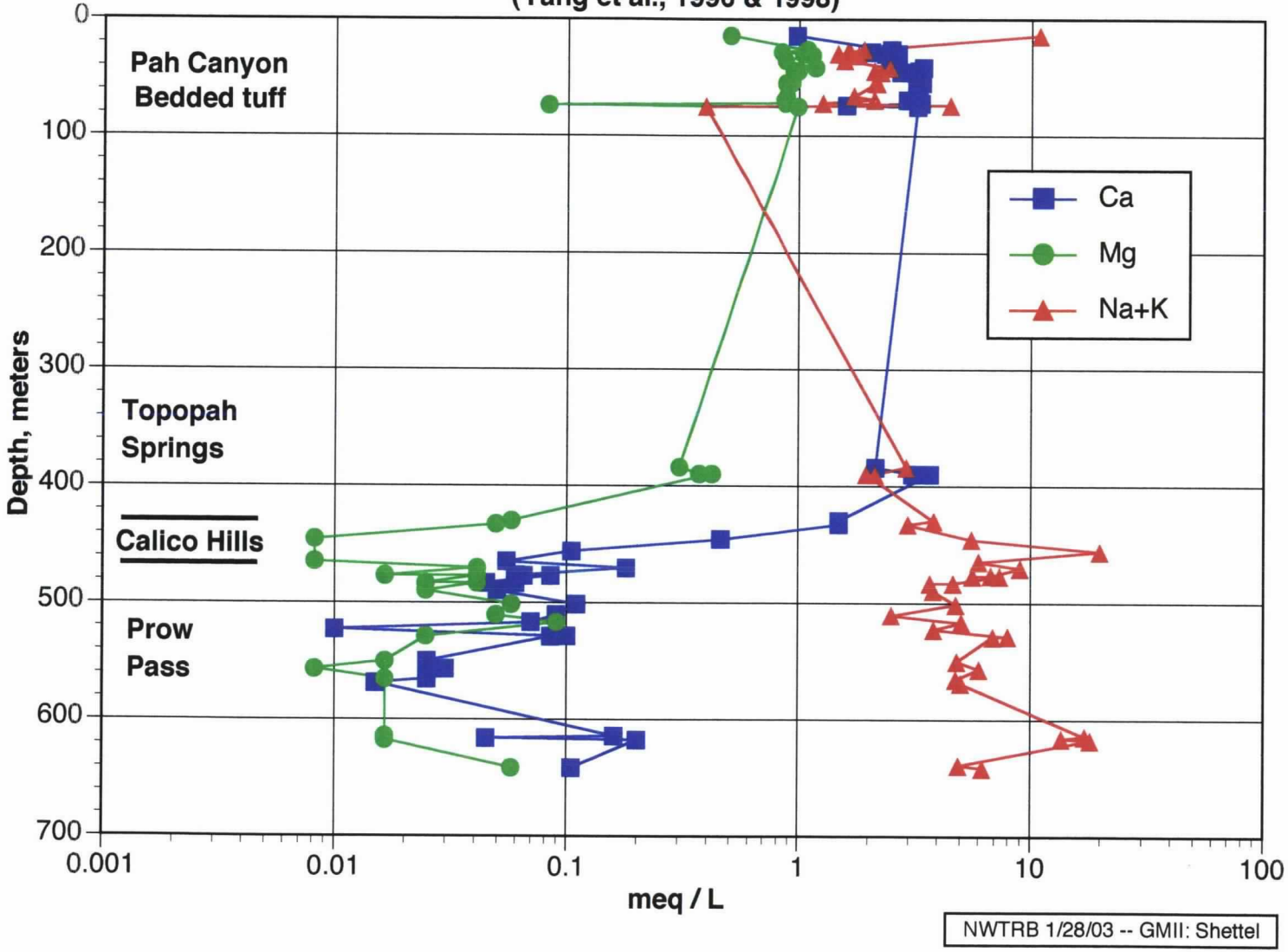
6. Corollary: sub-boiling, immersion testing of EBS materials in ground-water is BOTH unrealistic and non-conservative.

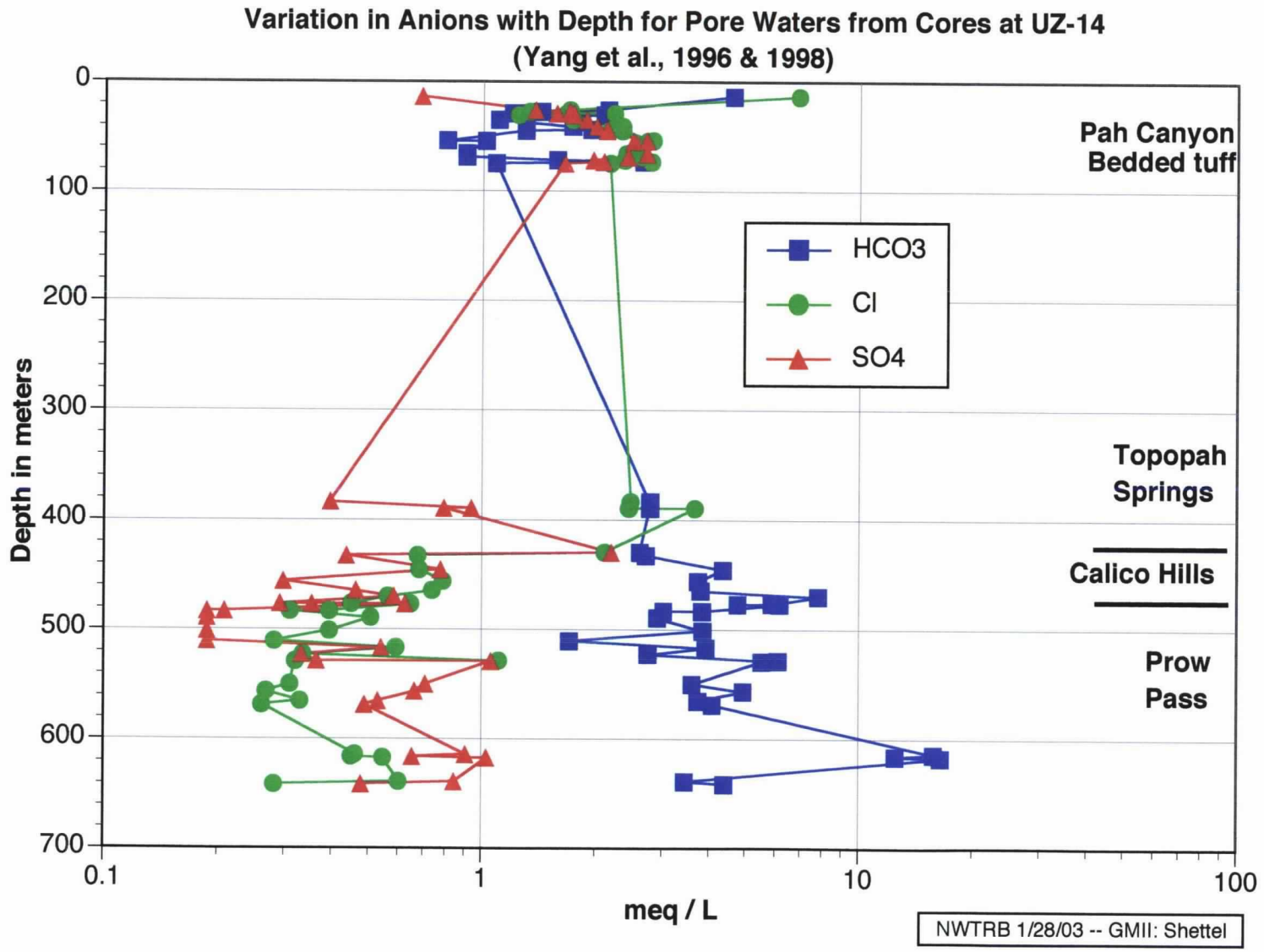
Back Up Slides

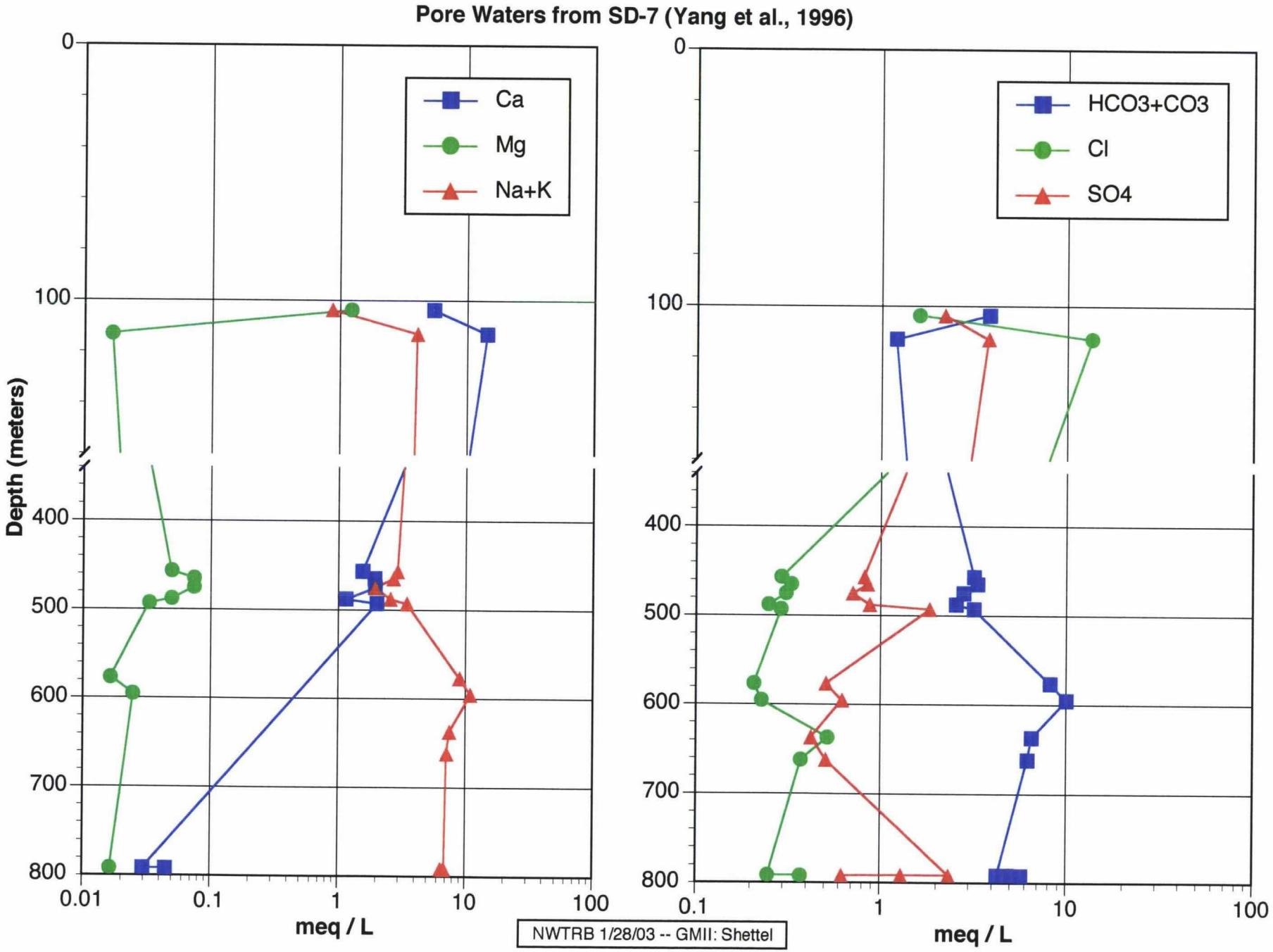
For D.L. Shettel's
Presentation to the
U.S. N.W.T.R.B.
1 / 28 / 03


Pore Waters Along the Cross Drift [ECRB] (Peterman & Marshall, 2002)
Distance along ECRB in meters
2500
2000
1500
1000
500
0
0
2
4
6
8
10
12
meq / L
Ca
Mg
Na+K
NWTRB 1/28/03 -- GMII: Shettel

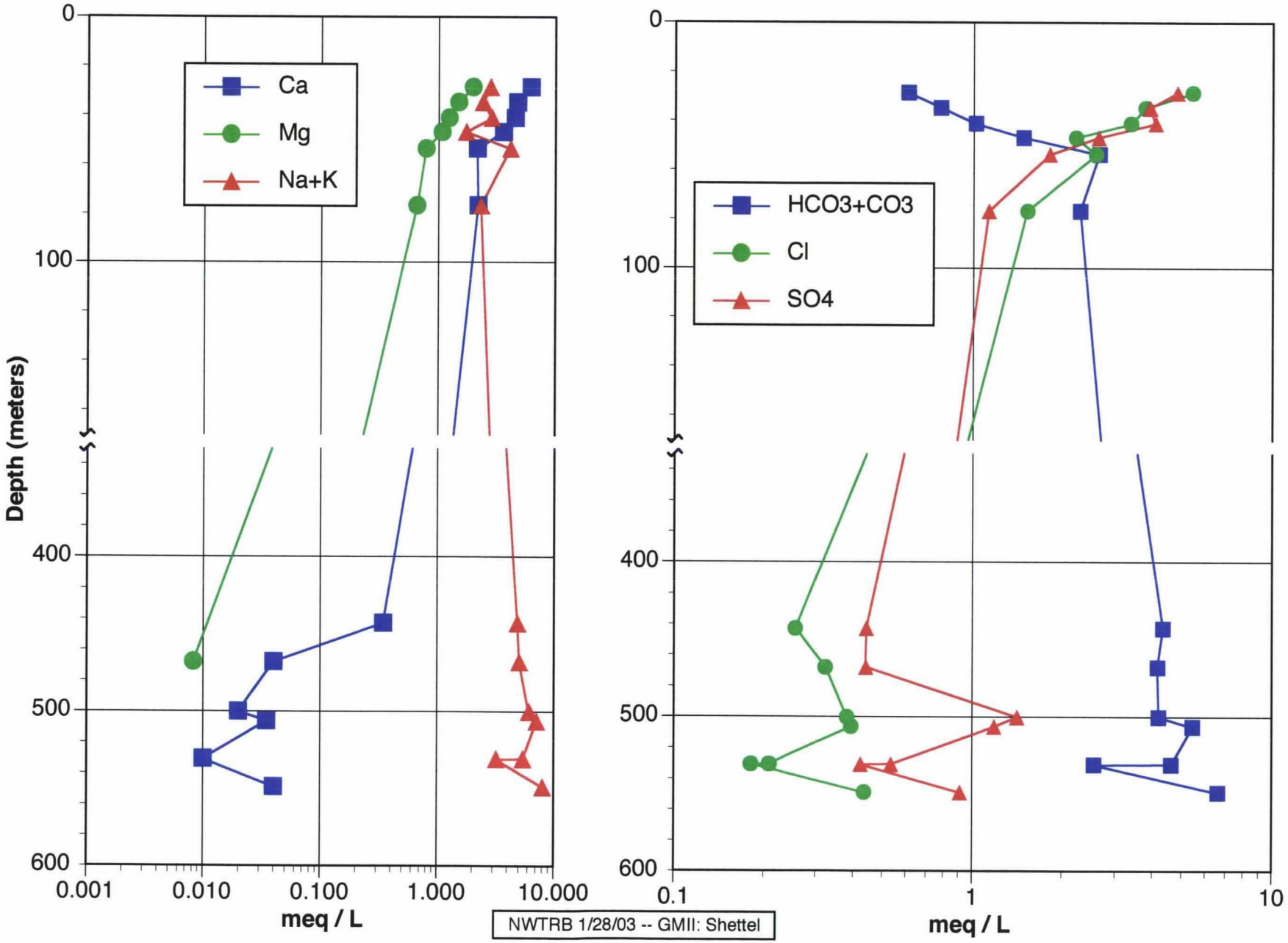
Variation in Cations with Depth for Pore Waters from Cores at UZ-14
(Yang et al., 1996 & 1998)




Variation in Anions with Depth for Pore Waters from Cores at UZ-14
(Yang et al., 1996 & 1998)
Depth in meters
0
100
200
300
400
500
600
700
0.1
1
10
100
meq / L
HCO3
Cl
SO4
Pah Canyon
Bedded tuff
Topopah
Springs
Calico Hills
Prow
Pass
NWTRB 1/28/03 -- GMII: Shettel


Pore Waters from SD-7 (Yang et al., 1996)
Depth (meters)
0
100
400
500
600
700
800
Ca
Mg
Na+K
0.01
0.1
1
10
100
meq / L
HCO3+CO3
Cl
SO4
0.1
1
10
100
meq / L
NWTRB 1/28/03 -- GMII: Shettel

Pore Waters from SD-9 (Yang et al., 1996)



NWTRB 1/28/03 -- GMII: Shettel