The Influence of Natural Sedimentary Layering Upon Solute Transport

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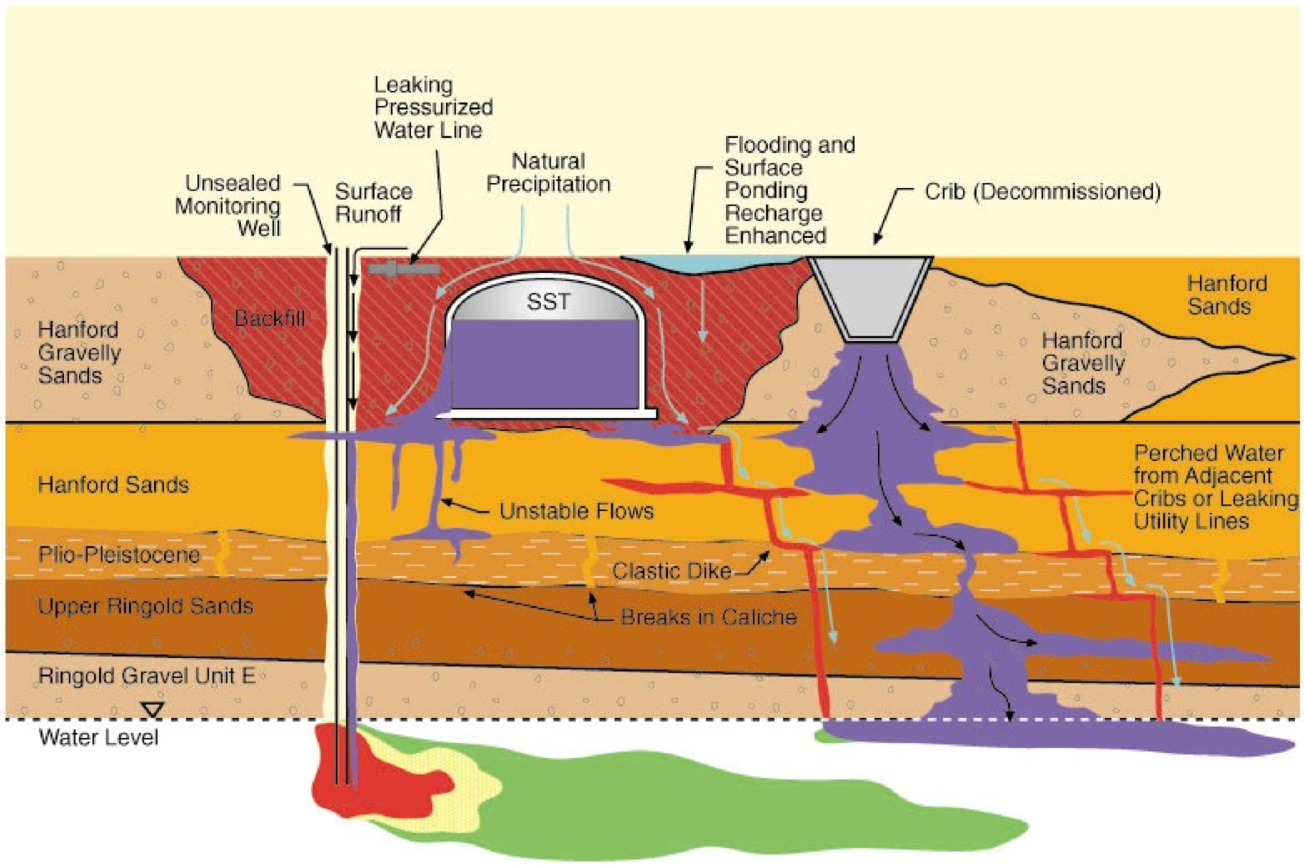
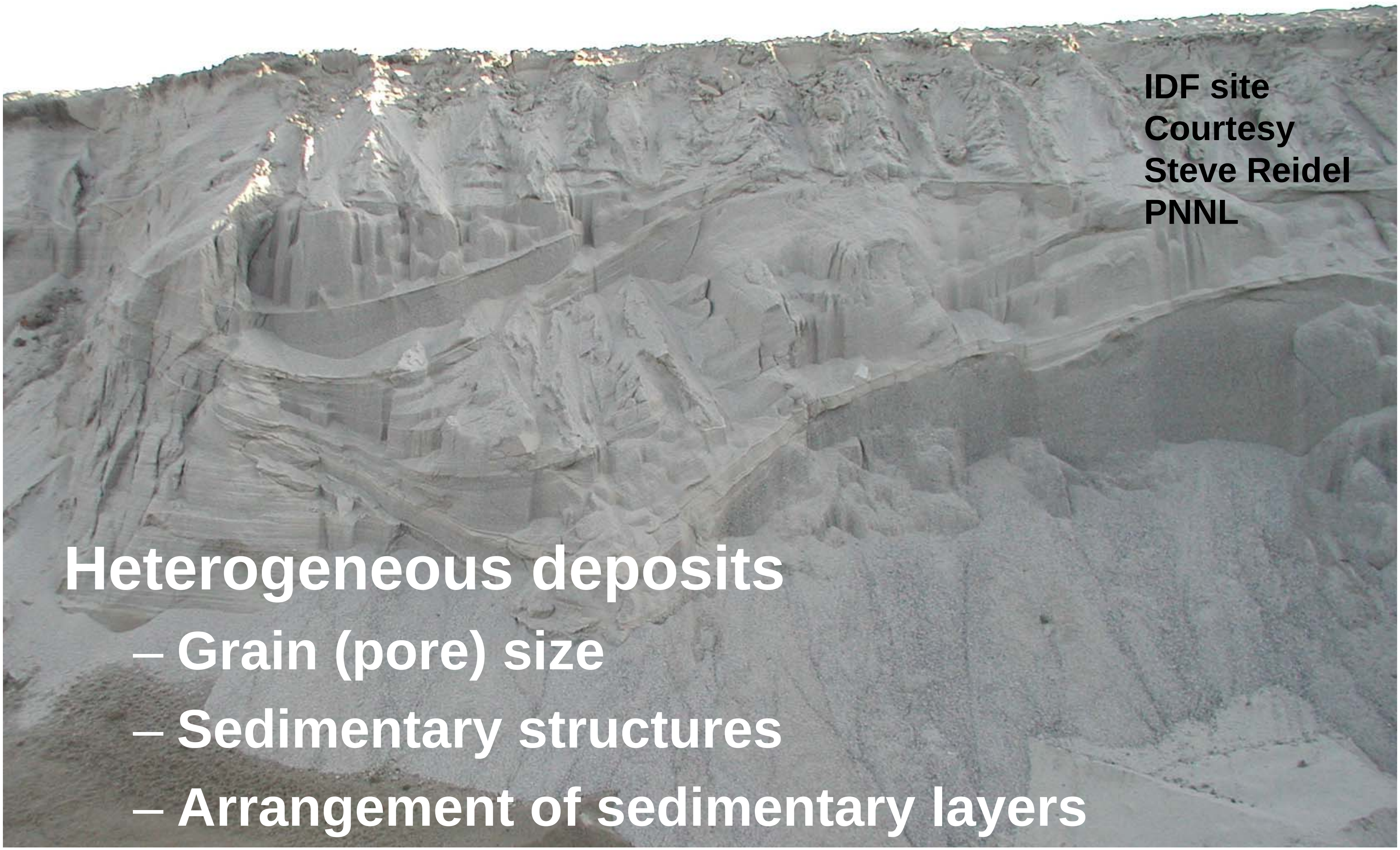
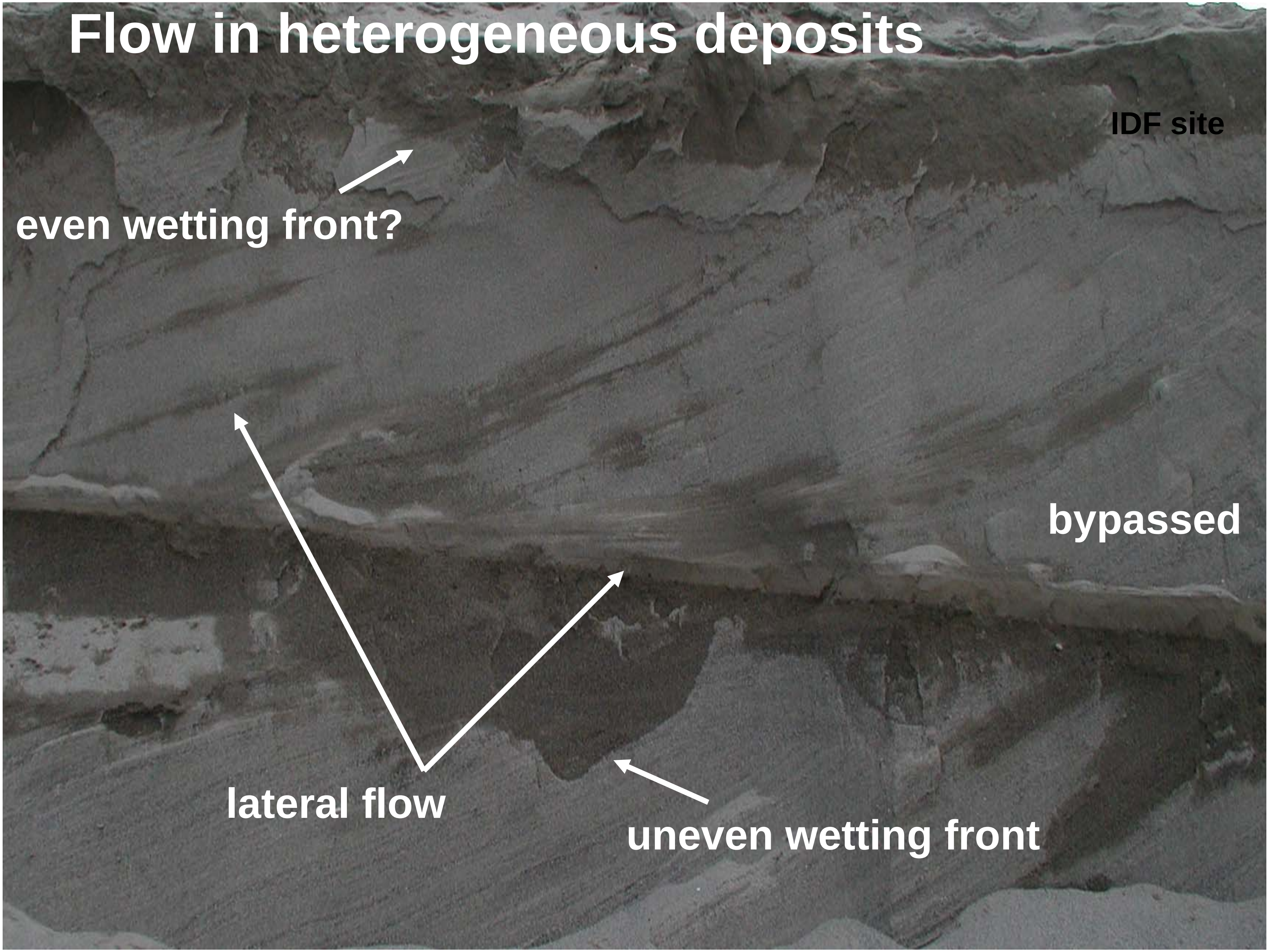
Conceptual Model of Hydraulic Drivers at Single-Shell Tanks (SSTs)

- 137Cs
- 90Sr
- Backfill
- High Level Waste Supernate or Liquid Phase
- Mobile Constituents in Tank Waste, ^{3}H, Na^{+}, $TcO_4^{=}$, $UO_2(CO_3)_2^{=}$, $CrO_4^{=}$
- Natural Precipitation and Movement Along Culturally Disturbed and Natural Pathways



DOE, 1999


IDF site
Courtesy
Steve Reidel
PNNL
Heterogeneous deposits
– Grain (pore) size
– Sedimentary structures
– Arrangement of sedimentary layers


Flow in heterogeneous deposits
IDF site
even wetting front?
bypassed
lateral flow
uneven wetting front

Objective

To determine the influence of heterogeneous sedimentary layering on coupled hydrology and geochemistry of contaminants

- 6 intact sedimentary units

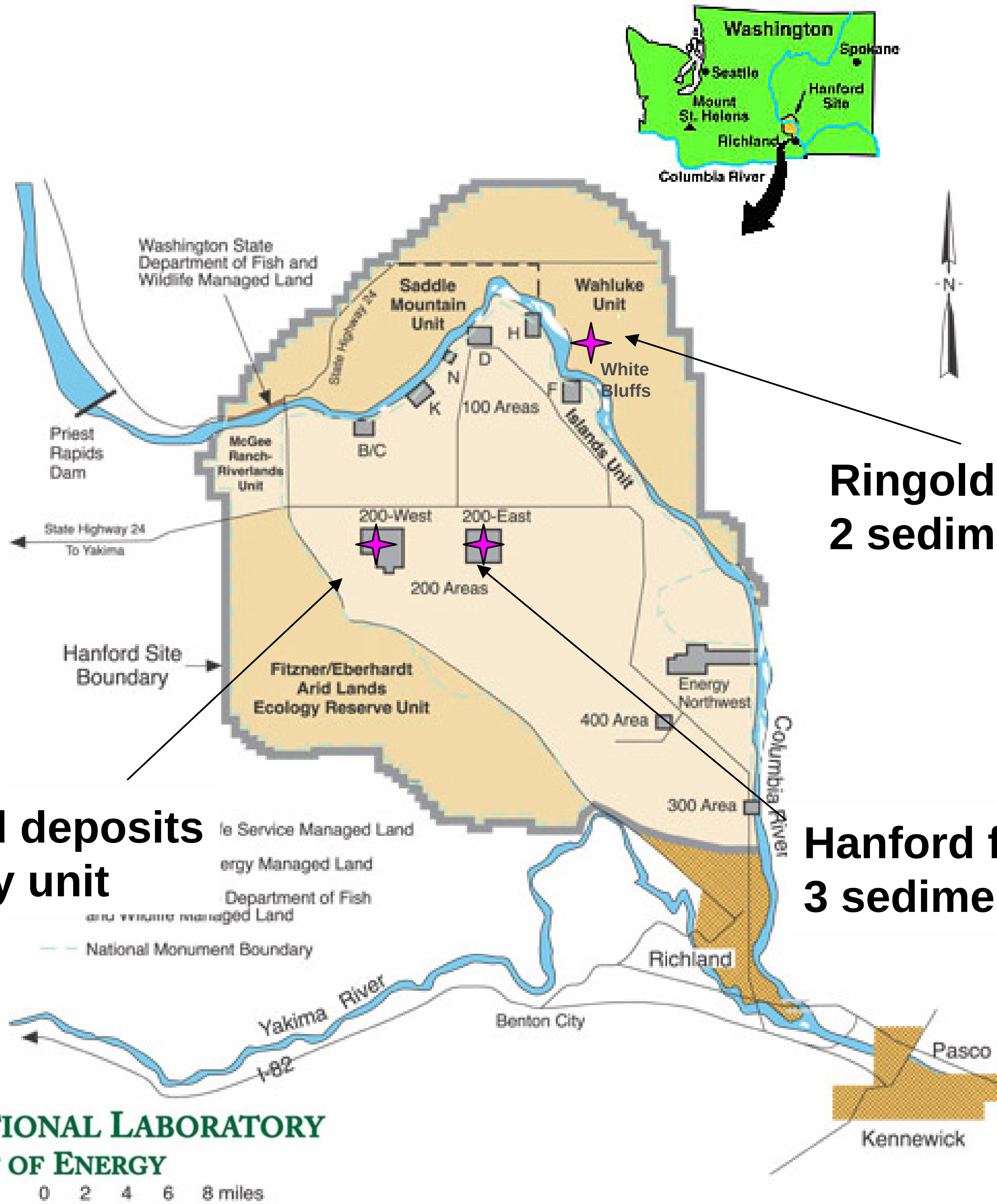
Leveraging

- 3-4 units: EMSP 1999, 2000 and 2002
- 3 units: Tank Farm Vadose Zone Project (CH2MHill Hanford Group) 2004

Methods

Perform quantitative solute transport experiments in intact layered sediment samples

- Determine directionality (anisotropy)
  - Flow bedding parallel (pb)
  - Flow cross bedding (xb)
  - Saturated flow
- Effects of decreasing water content
  - Dispersivity (λ)
- Reactive U(VI) and CoEDTA transport



Ringold Formation
2 sedimentary units

Hanford flood deposits
1 sedimentary unit

Hanford flood deposits
3 sedimentary units


Ringold Formation
White Bluffs
January, 1999
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U. S. DEPARTMENT OF ENERGY
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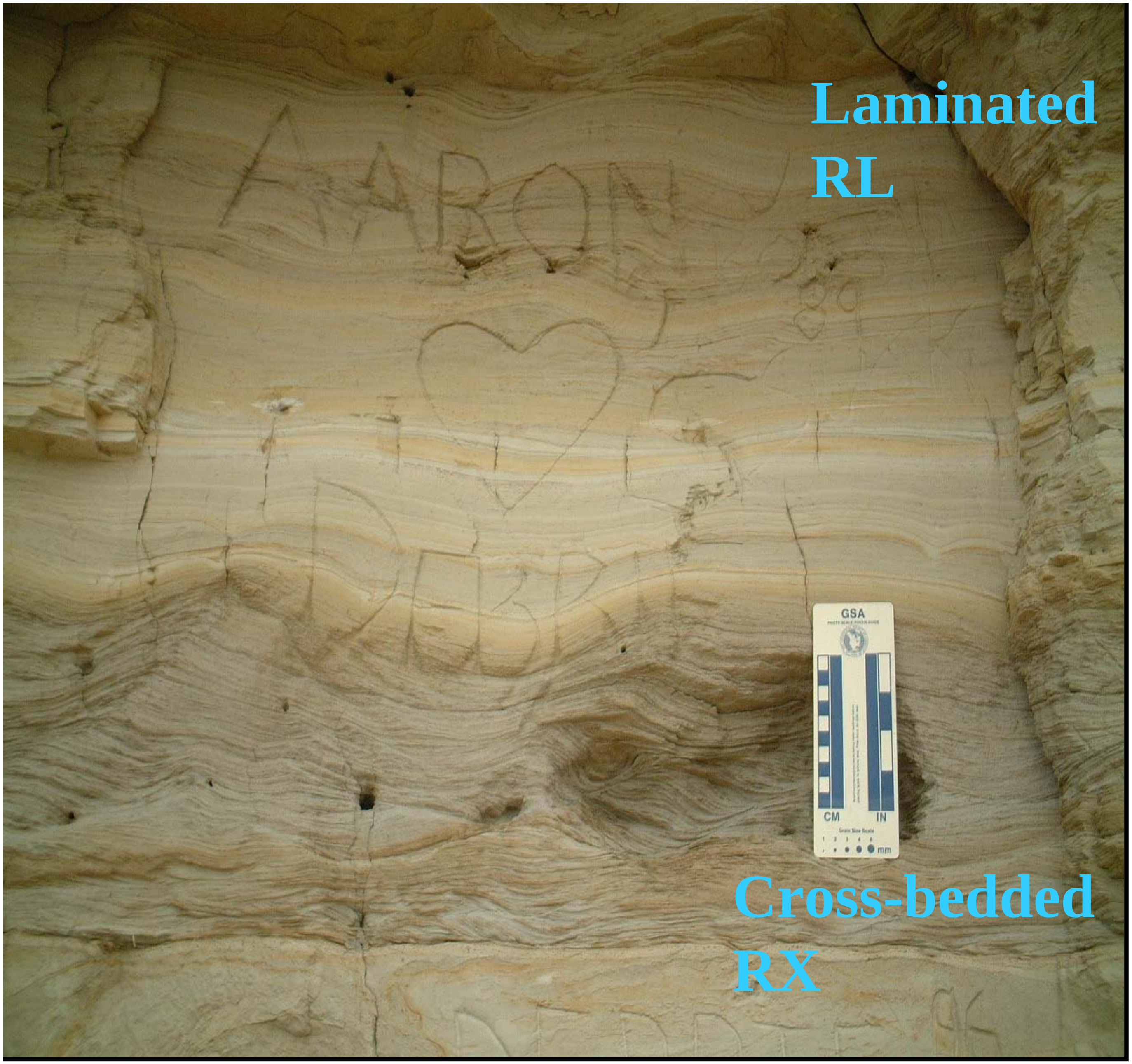

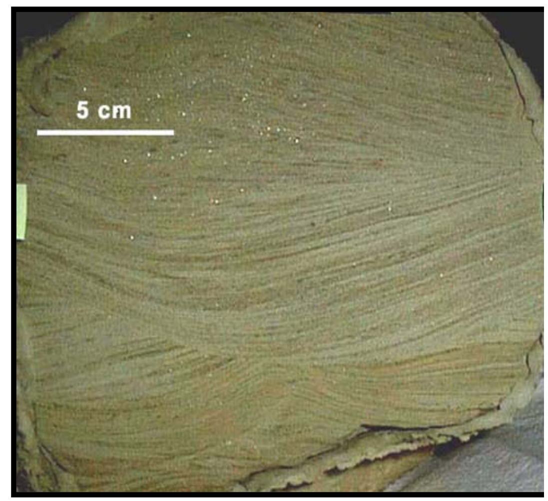

Ringold Formation


Courtesy
Bruce Bjornstad
PNNL
CAT
Hanford flood deposits
200W area, ERDF pit (May, 2003; Aug, 2000)
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ERDF (May, 2003) Hanford Laminated HL

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Hanford flood deposits
200E area, IDF pit (November, 2004)
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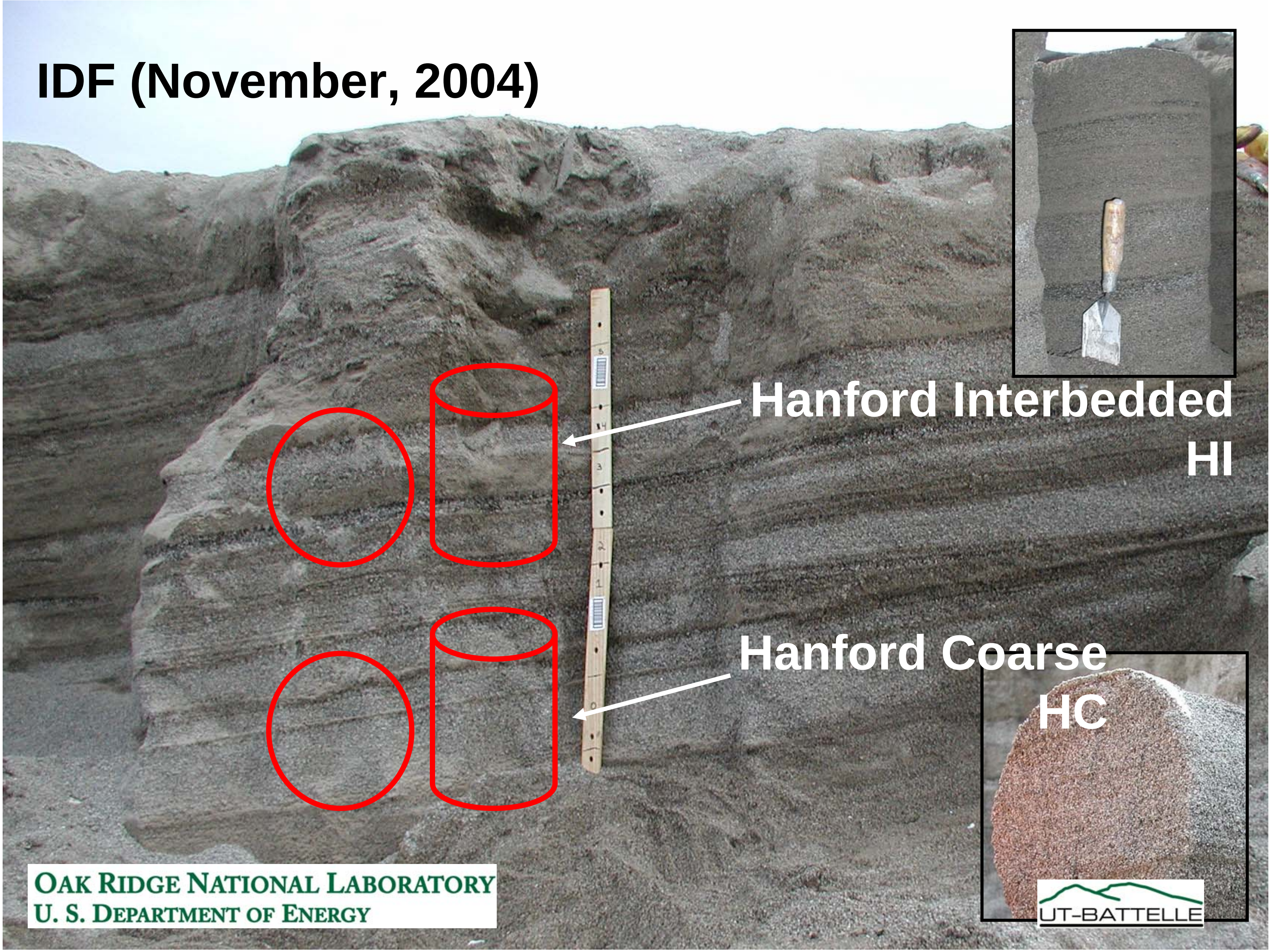
IDF (November, 2004)
Hanford Interbedded
HI
Hanford Coarse
HC
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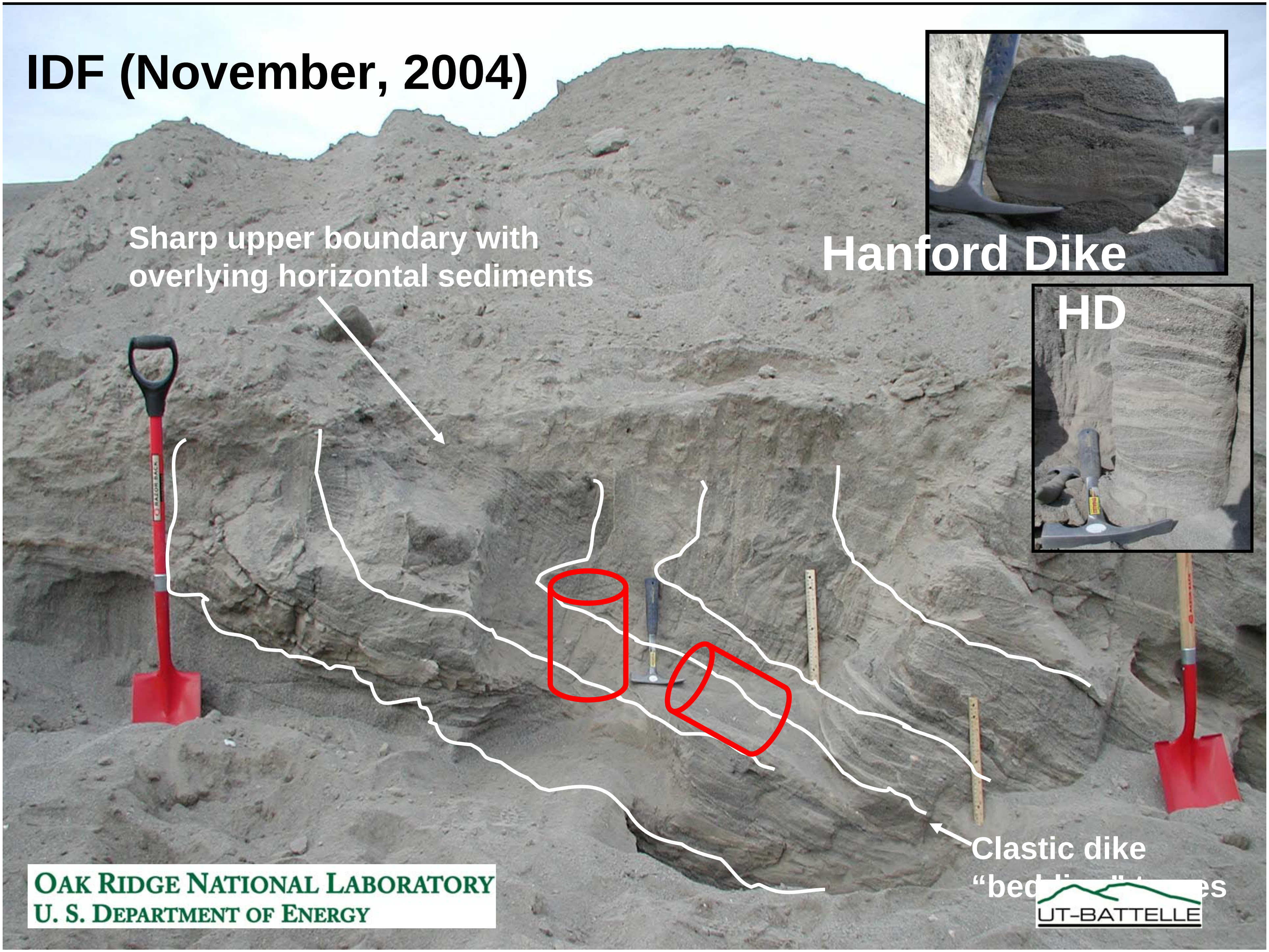
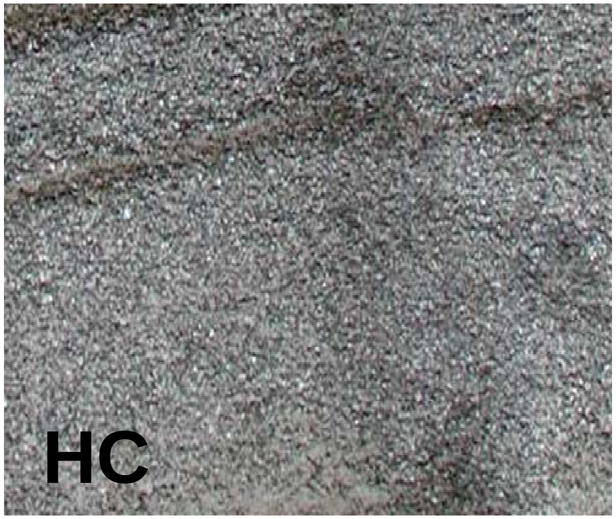
IDF (November, 2004)



6 Sedimentary Units

5 cm

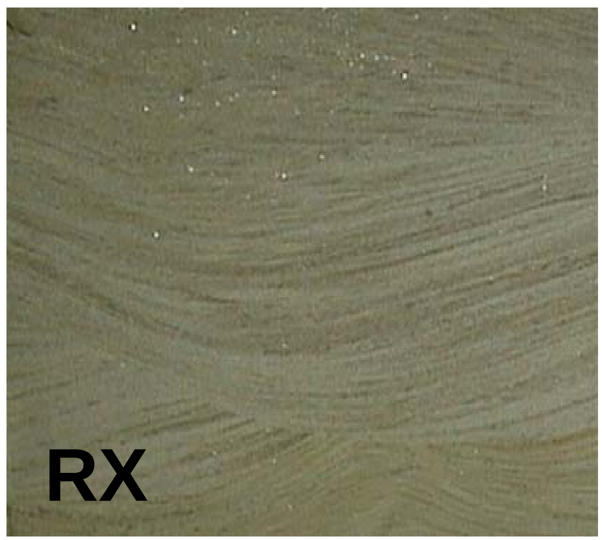


massive coarse sand

interbedded sand/silt

fine sand, clay laminations

clastic dike



cross-bedded sandy loam

laminated silt loam

Name	Formation, Descriptor	Sedimentary Description	sand/silt/clay %
HC	Hanford, Coarse	Massive coarse sand Few textural layers	93/4/3
HI	Hanford, Interbeds	Strongly alternating textural layers Interbedded coarse sands, coarse sands with silt/clay matrix	89/8/4
HL	Hanford, Laminated	Fine-medium sand, clay laminations Similar textural layers	95/4/1
HD	Hanford, Clastic Dike	Strongly alternating textural layers, cemented Medium sands, silt beds, clay "skins"	84/13/4
RX	Ringold, Cross-beds	Cross-bedded loamy sand Alternating layers of light and dark mins	57/42/1
RL	Ringold, Laminated	Alternating textural layers Silt loam, oxides/clays coat bedding planes	42/56/2

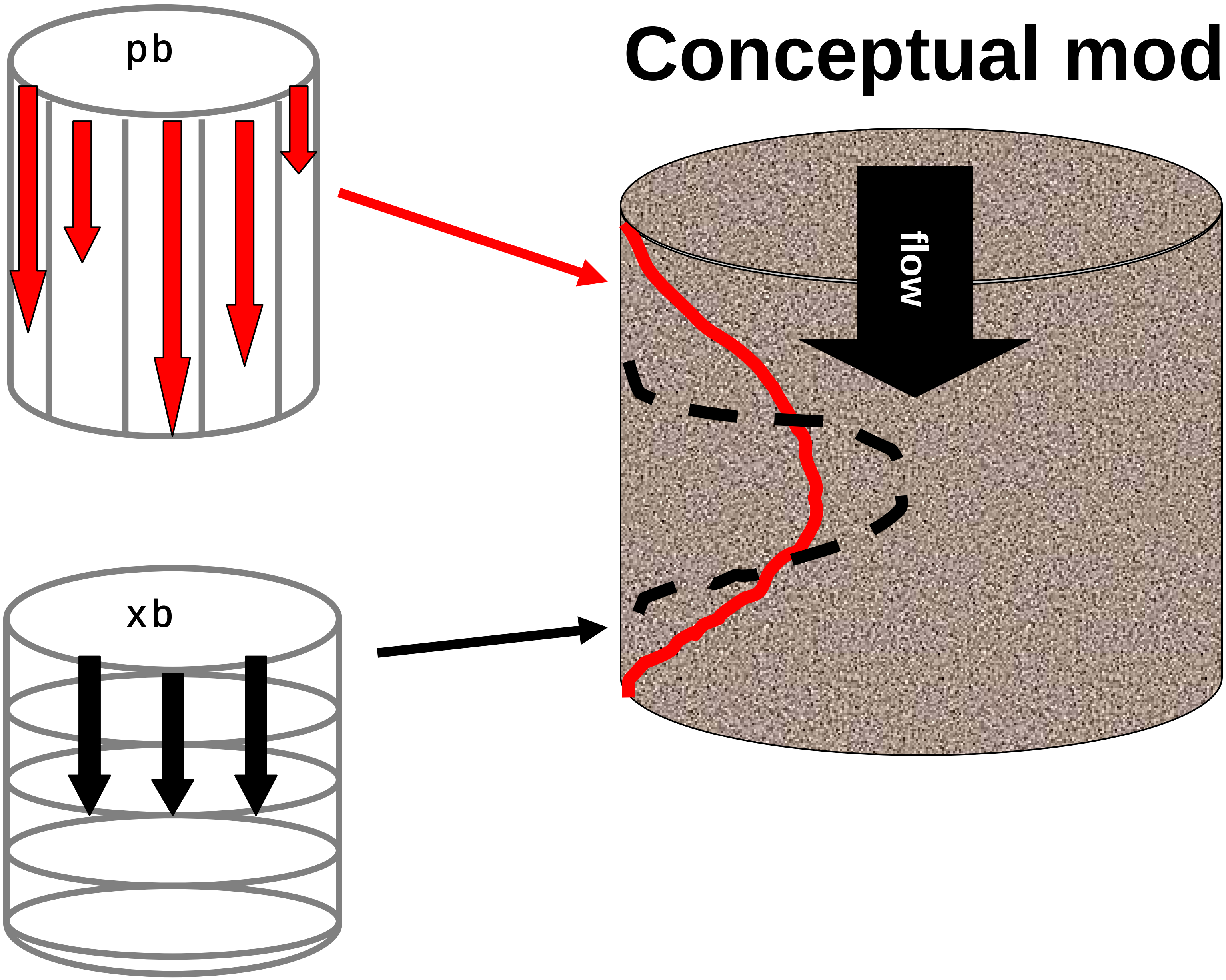
Solute Transport Experiments

- Saturated
  - Nonreactive tracers
- Unsaturated
  - Reactive tracers
  - U(VI), CoEDTA
  - Nonreactive tracers

Results and Discussion

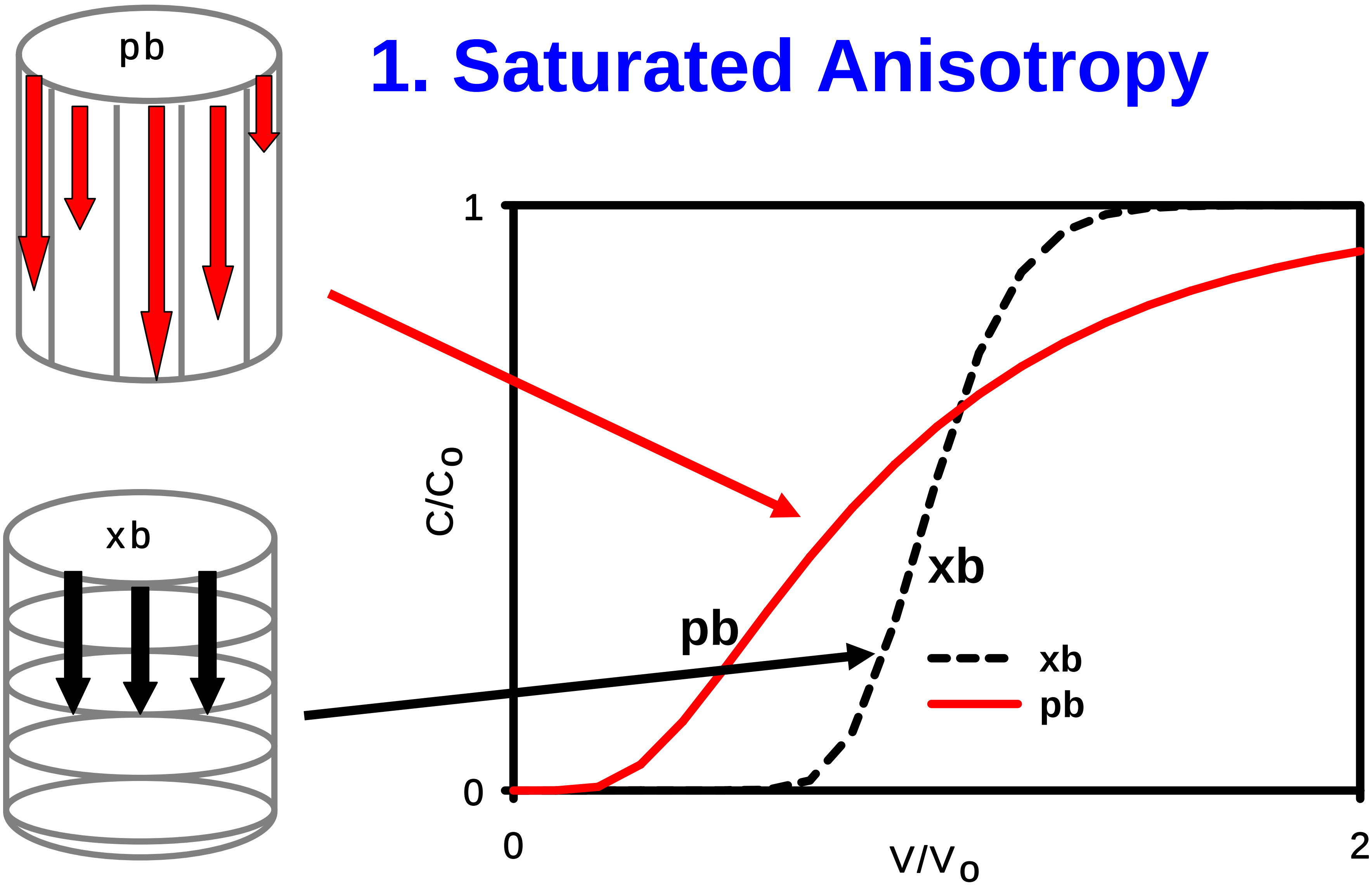
1. **Saturated flow:** anisotropy
2. **Decreasing water content:** dispersivity
3. **Reactivity:** U(VI) and Co(II)EDTA transport

Conceptual model

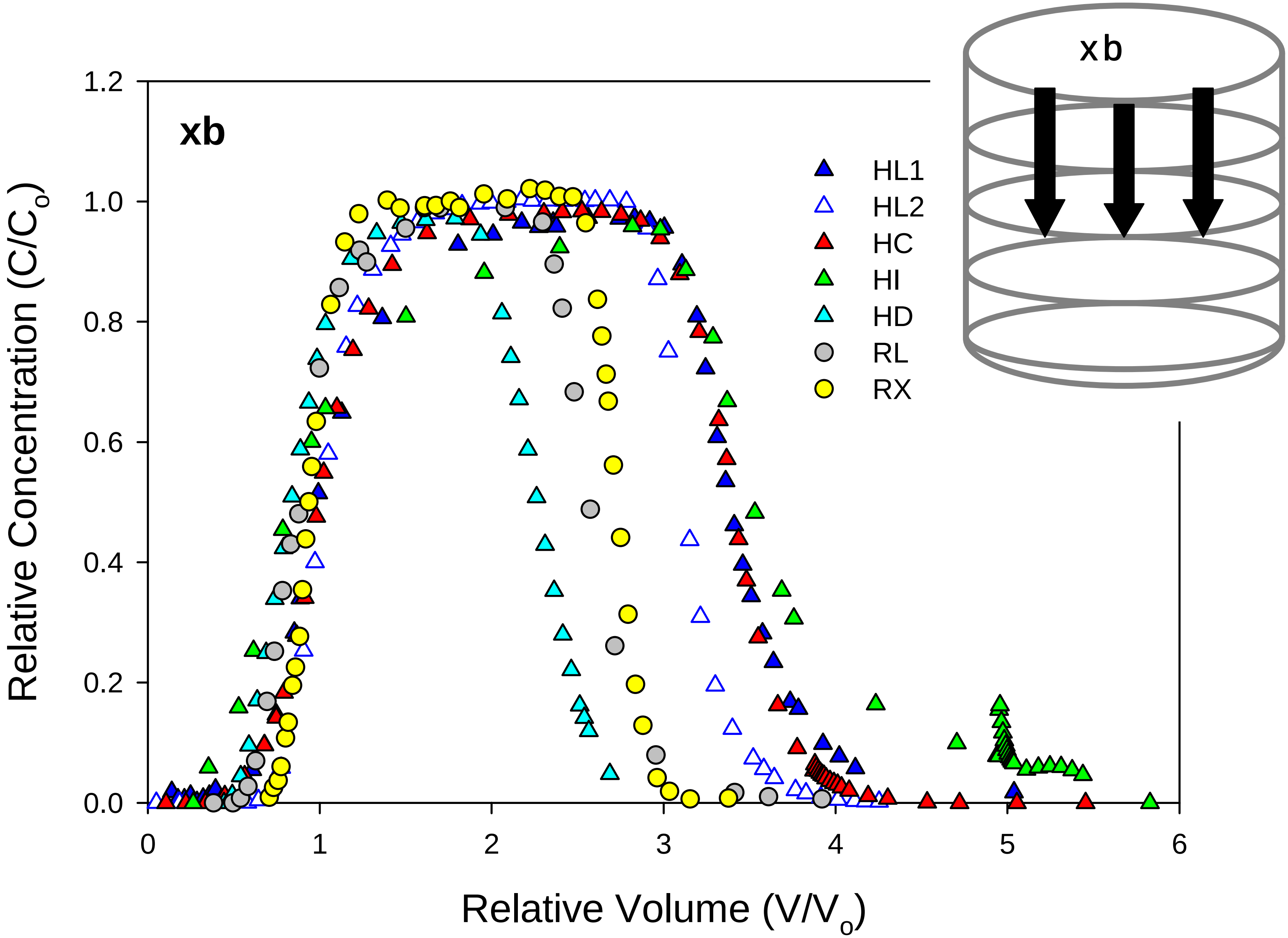


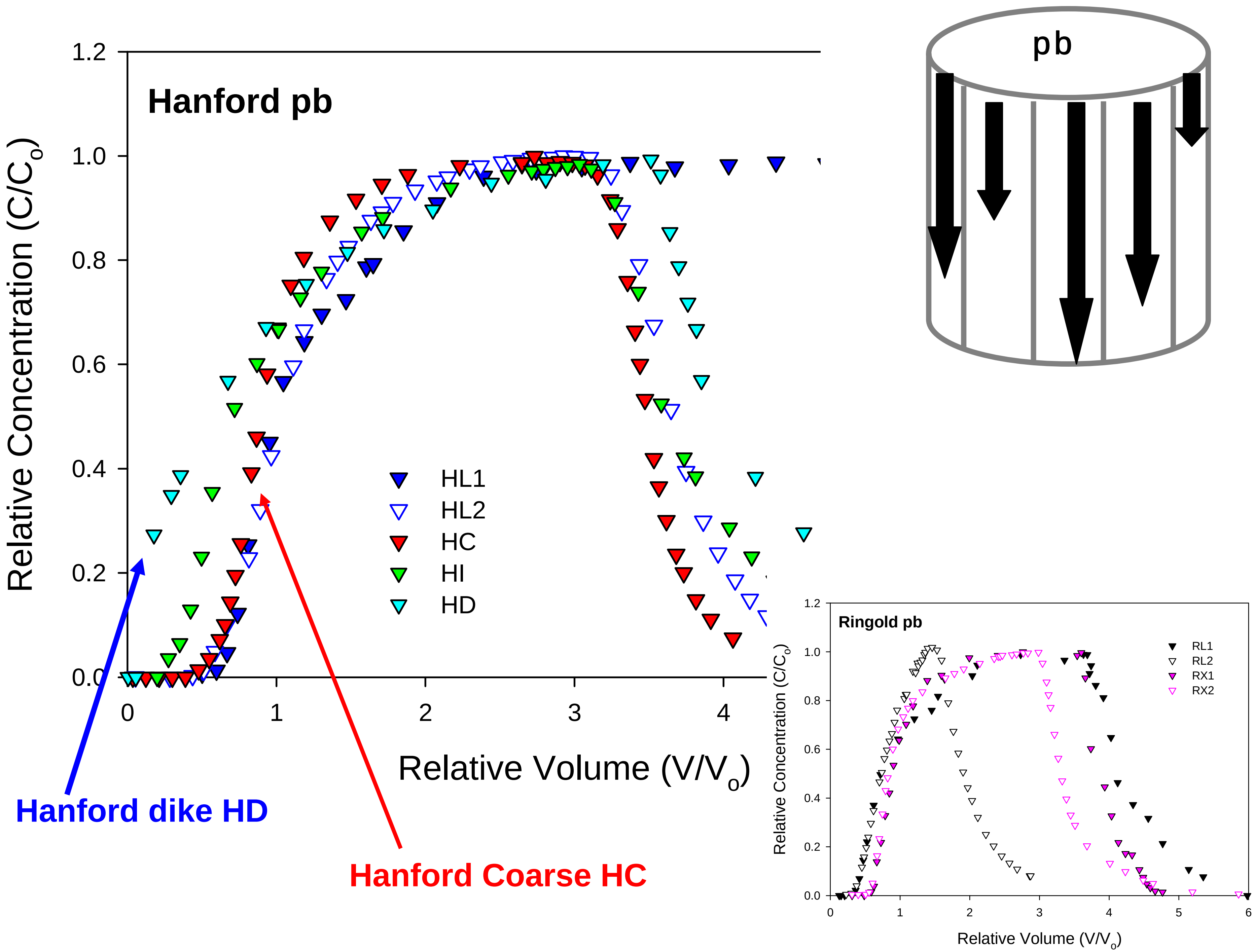
Mayes et al., 2003; Pace et al., 2003

1. Saturated Anisotropy

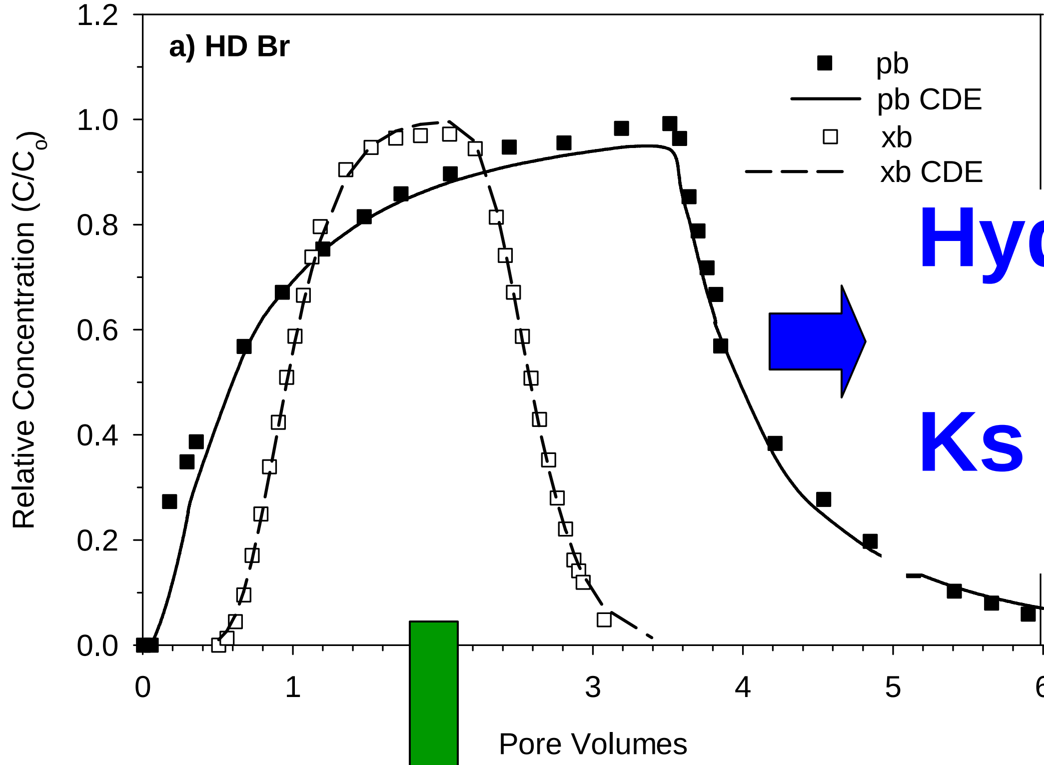


Mayes et al., 2003; Pace et al., 2003


xb
Relative Concentration (C/Co)
Relative Volume (V/Vo)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
1
2
3
4
5
6
HL1
HL2
HC
HI
HD
RL
RX
xb



Hanford pb
Relative Concentration (C/C$_o$)
Relative Volume (V/V$_o$)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
1
2
3
4
HL1
HL2
HC
HI
HD
Hanford dike HD
Hanford Coarse HC
pb
Ringold pb
Relative Concentration (C/C$_o$)
Relative Volume (V/V$_o$)
0
1
2
3
4
5
6
RL1
RL2
RX1
RX2



Hydraulic conductivity

$$Ks = \frac{flowrate}{\pi r^2} \times gradient^{-1}$$

Fit data to convective-dispersive equation

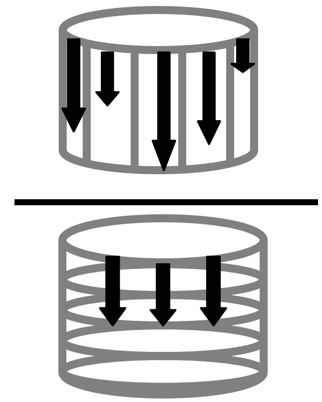
Dispersivity λ

Core	D $cm^2\ h^{-1}$	r^2	Ks $(m\ s^{-1})$
HC pb	101+/- 14.0	0.990	4.41E-05
HC xb	143+/- 41.3	0.974	8.97E-05
HI pb	67.4+/- 8.22	0.992	6.72E-06
HI xb	64.1+/- 7.59	0.992	5.76E-06
HL pb1	55.7+/- 21.2	0.967	1.39E-05
HL pb2	40.2+/- 10.1	0.978	1.60E-05
HL xb1	9.60+/- 2.18	0.980	5.80E-06
HL xb2	9.28+/- 1.74	0.994	1.50E-05
HD pb	9.66+/- 1.37	0.984	2.87E-07
HD xb	0.41+/- 0.03	0.998	1.62E-07
RX pb1	14.9+/- 3.47	0.975	6.86E-06
RX pb2	2.12+/- 0.41	0.975	8.30E-07
RX xb	0.68+/- 0.18	0.964	1.22E-06
RL pb1	2.03+/- 0.26	0.990	2.56E-07
RL pb2	0.09+/- 0.02	0.964	3.55E-08
RL xb	0.10+/- 0.03	0.966	5.25E-08

Dataset varies over 4 orders of magnitude

Pace et al., 2003;
Mayes et al., 2003

$$Anisotropy = \frac{pb}{xb} =$$



A > 1

pb flow

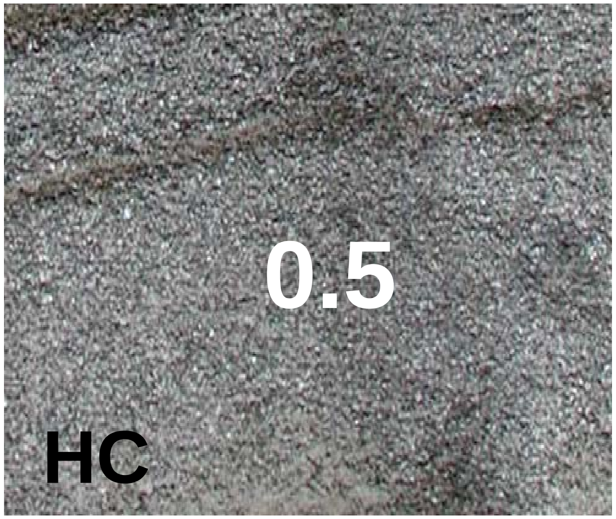
heterogeneous layers?

A. Hydraulic conductivity Ks

B. Dispersivity λ

A. Anisotropy conductivity (Ks)

5 cm

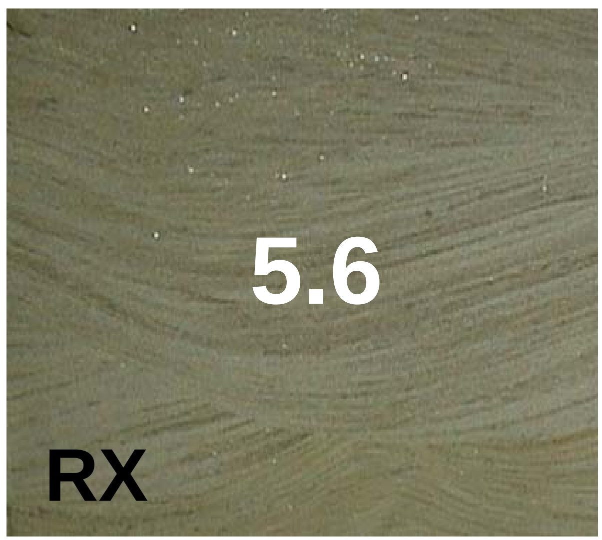


massive coarse sand

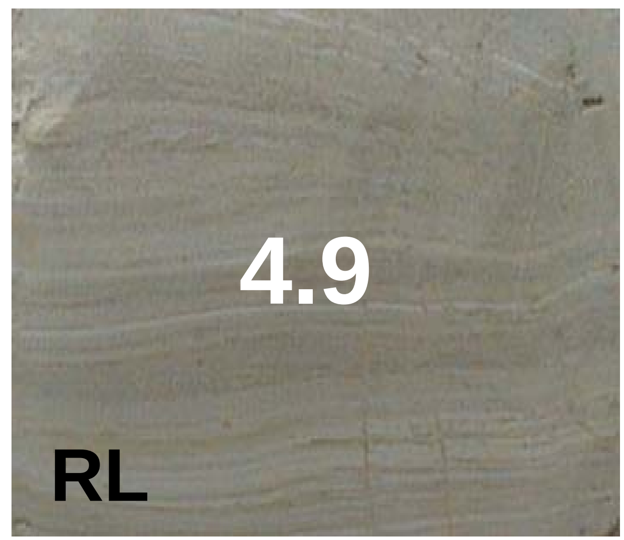
interbedded sand/silt

fine sand, clay laminations

clastic dike



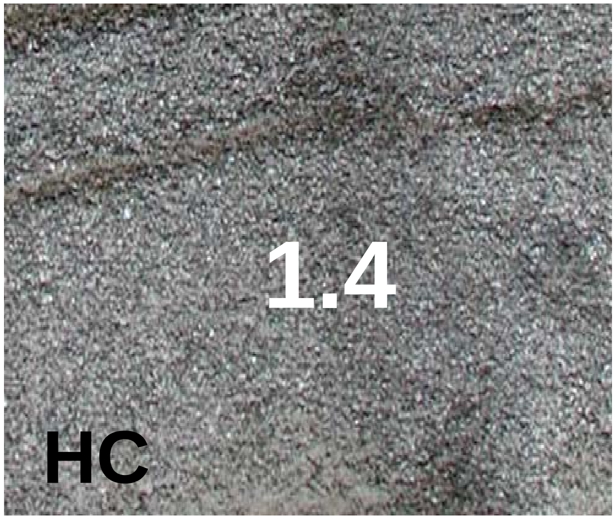
cross-bedded sandy loam



laminated silt loam

B. Anisotropy dispersivity (λ)

5 cm



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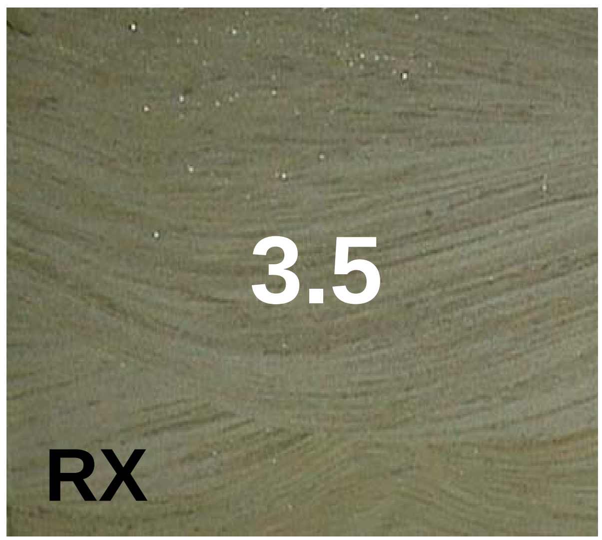
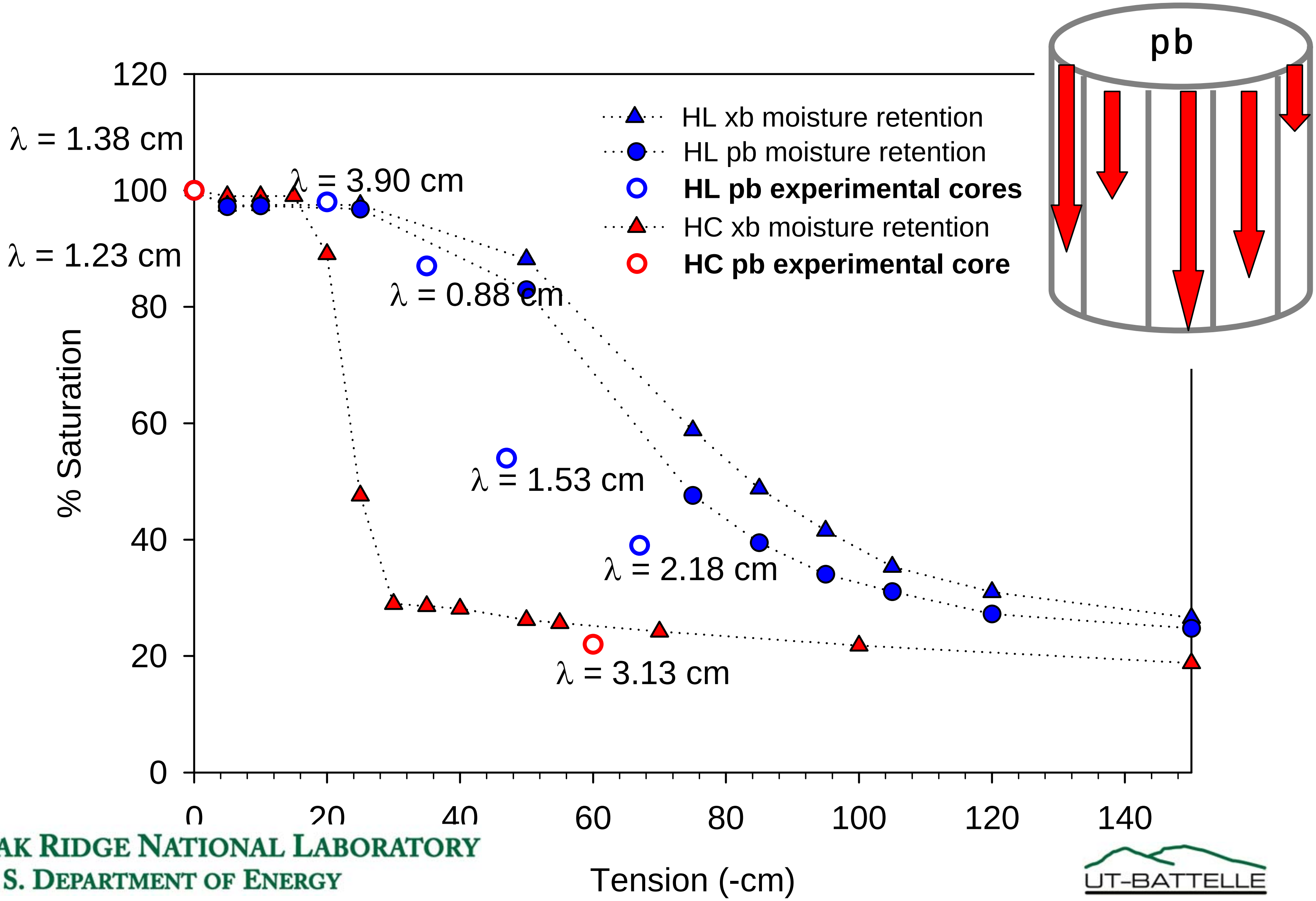


cross-bedded sandy loam

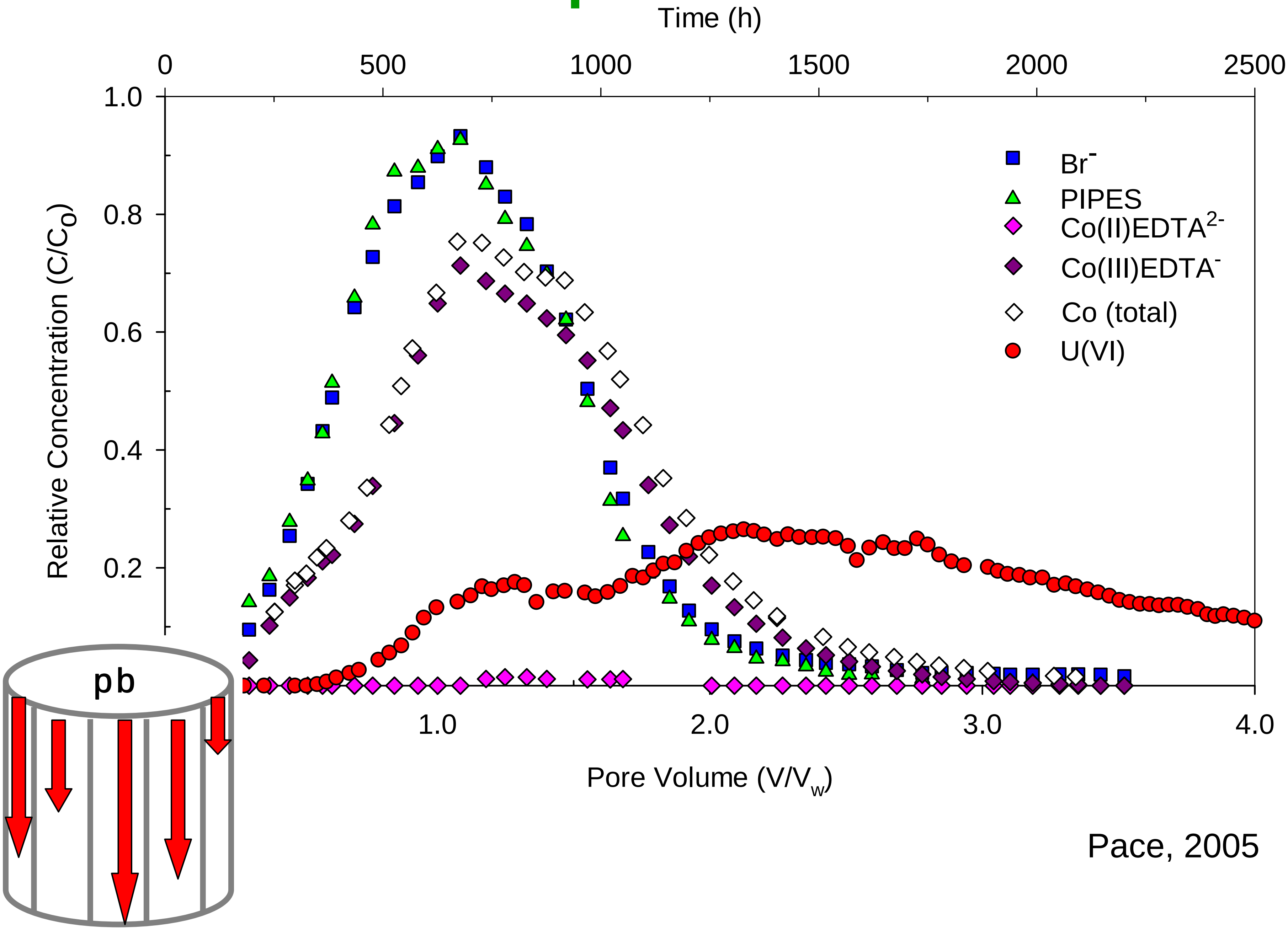
laminated silt loam

2. Dispersivity λ as f(water content)



3. Reactive Transport

HL: 39% moisture



Pace, 2005

Conclusions

- Value of leveraging research
- Communication with site contractors
- Improved scope of study
  - Anisotropy is related to sedimentology
  - Increasing dispersivity with decreasing water content (?)
  - Influences on reactive transport
- New ERSP research

thank you!

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