PNNL-SA-77286

# Overview of Physical, Hydrologic, and Geophysical Data at the Hanford 300A IFRC Site

Mark Rockhold

and PNNL IFRC Project Team

Hanford 300 Area IFRC Project Meeting
January 19 - 20, 2011, Richland, Washington

Subsurface Biogeochemical Research

Pacific Northwest NATIONAL LABORATORY

*Proudly Operated by* Battelle *Since 1965*

# Quotes for the day…

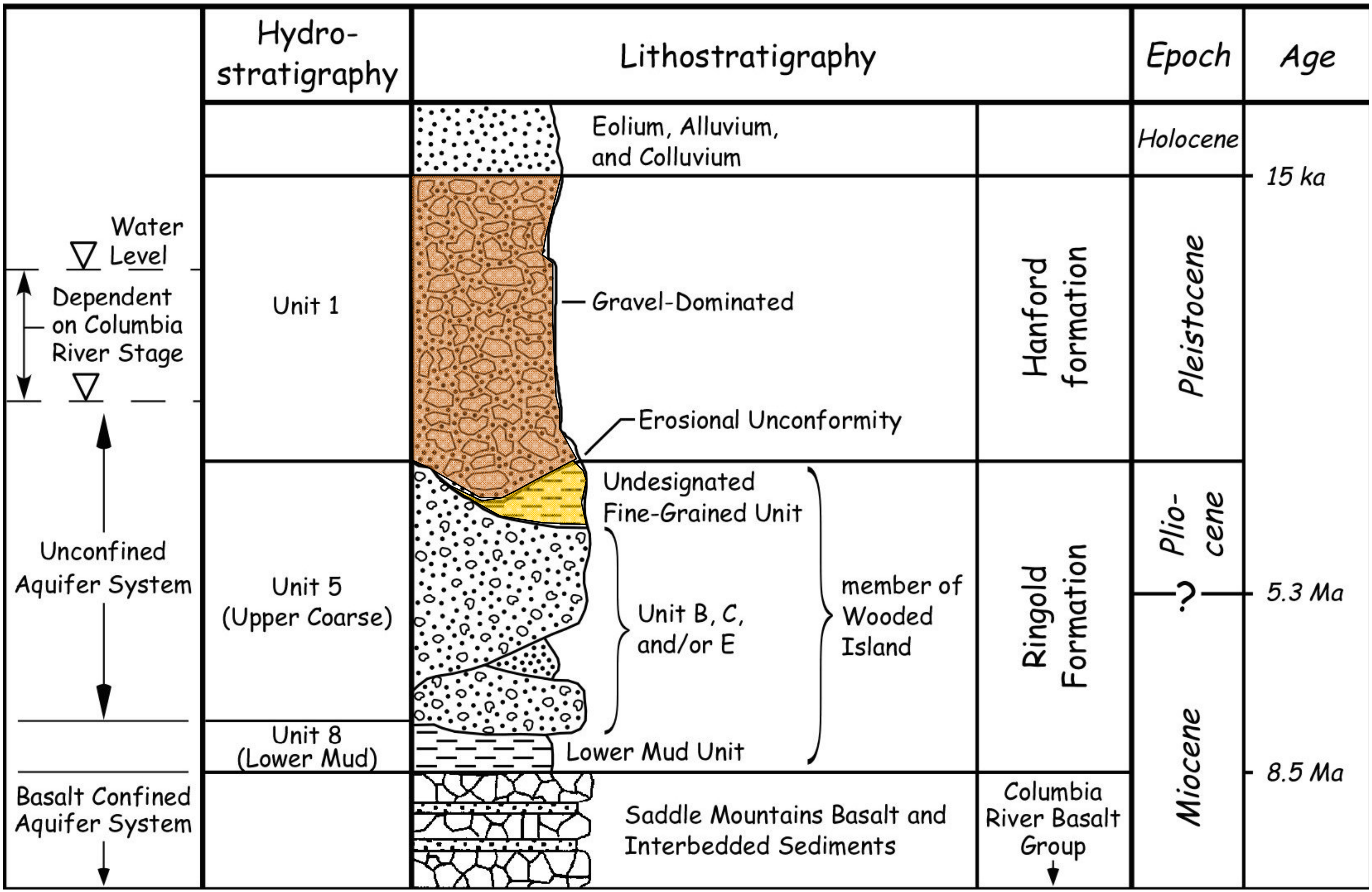
- *"A more complete and accurate characterization of the subsurface can be achieved by using an integrated exploration approach in which borehole and geophysical data sets are jointly interpreted."*
- *"A key step in quantitative hydrogeophysical interpretations is the transformation of the measured geophysical properties into the desired hydrogeological parameters."*

*Lesmes, D.P. and S.P. Friedman, 2005, Relationships between the electrical and hydrogeological properties of rocks and soils. Ch. 4 In Hydrogeophysics, Rubin, Y. and S.S. Hubbard (eds.), Springer.*

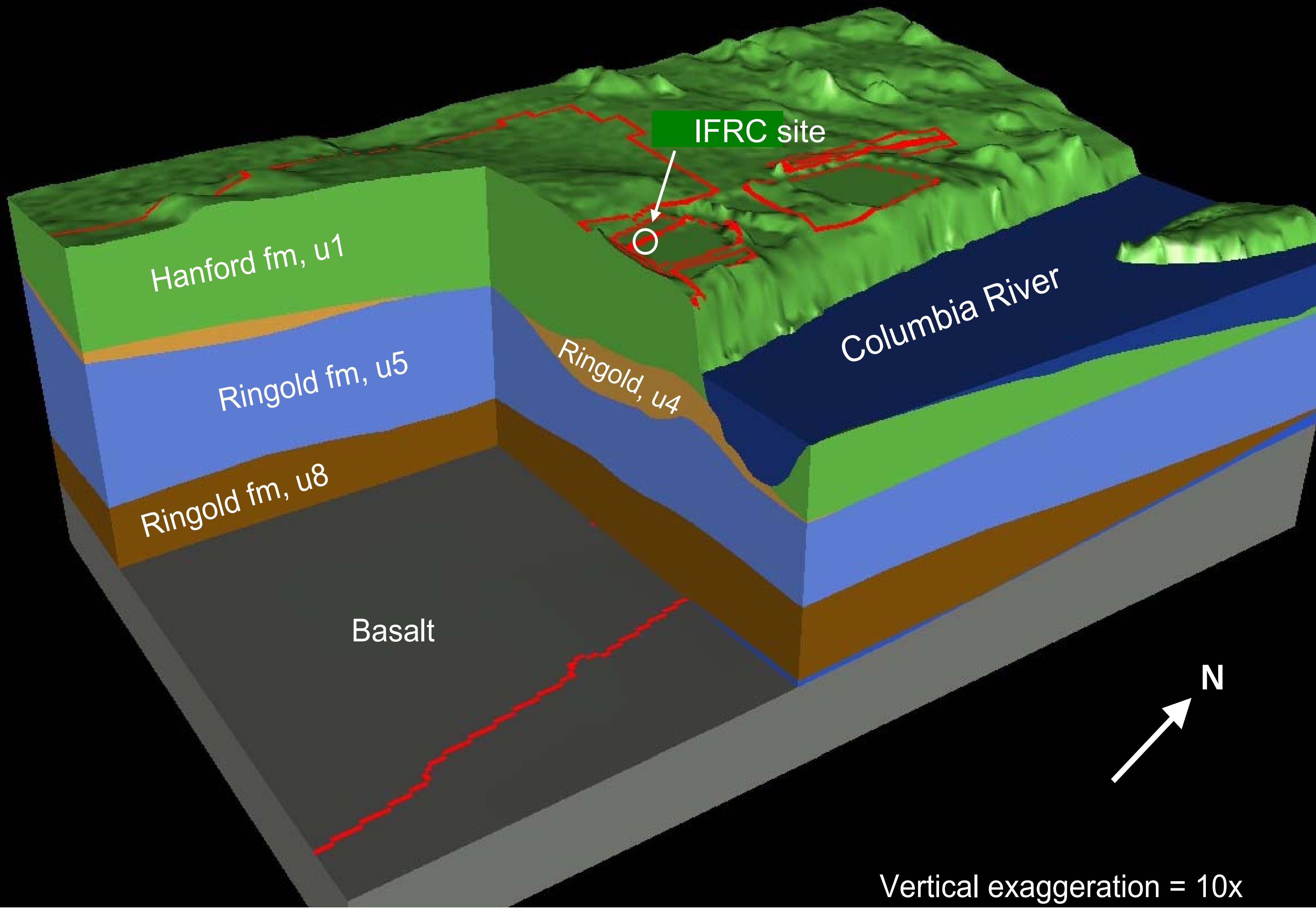
# Outline

- 300 Area site stratigraphy and geologic structure
- Overview of IFRC site characterization data
  - Geostatistics
  - Property correlations
  - Models and parameters

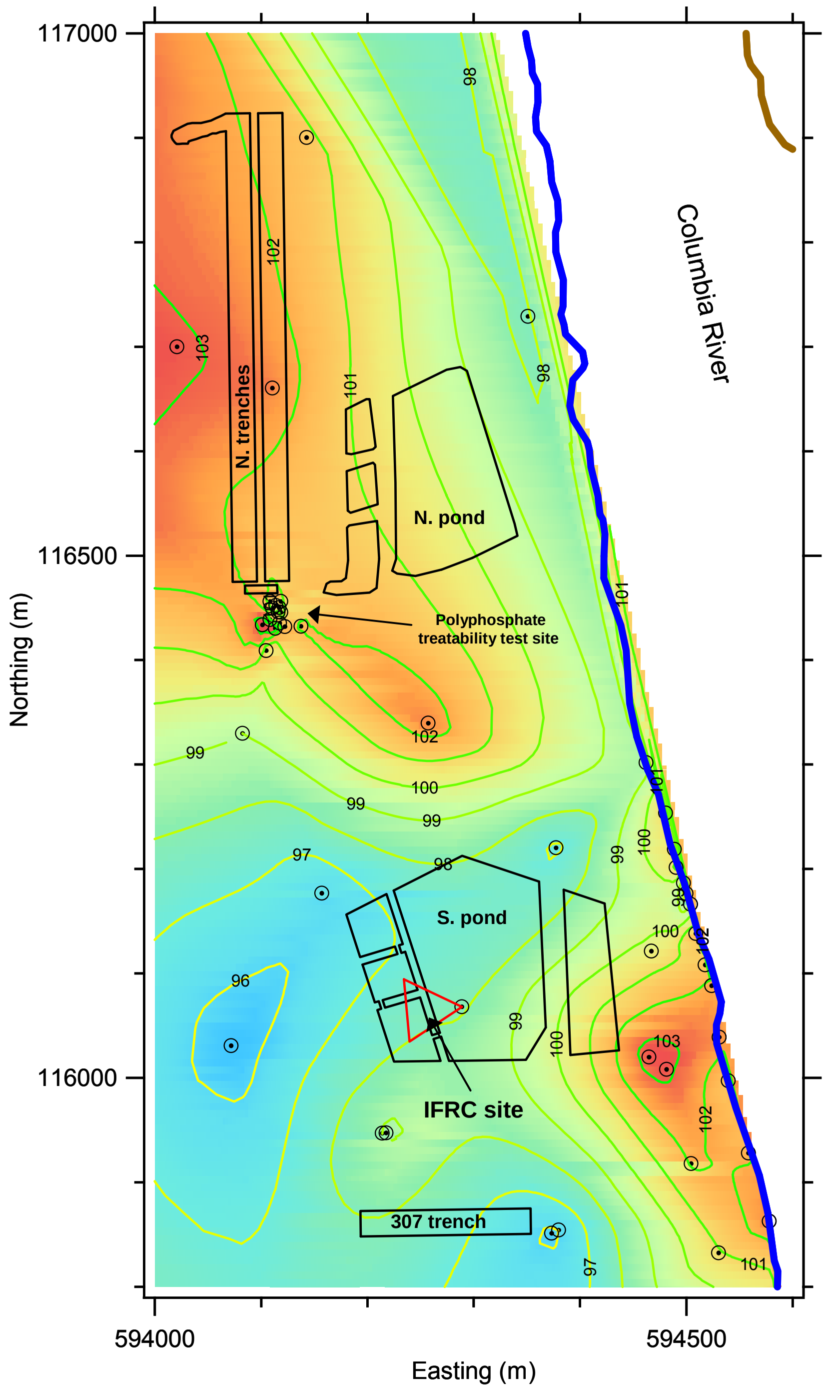
# Site Stratigraphy

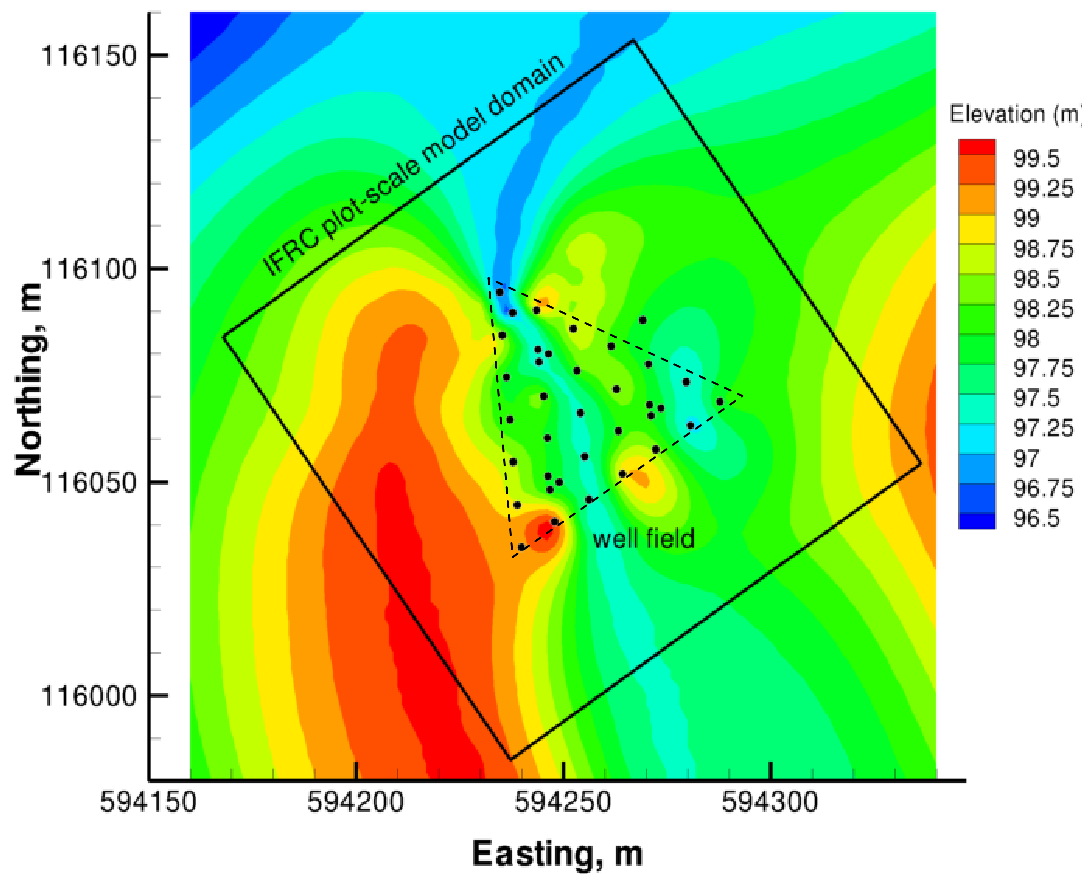


# EarthVision® Model of the Hanford 300 Area



# Structure Contour Maps of Hanford - Ringold Fm Interface



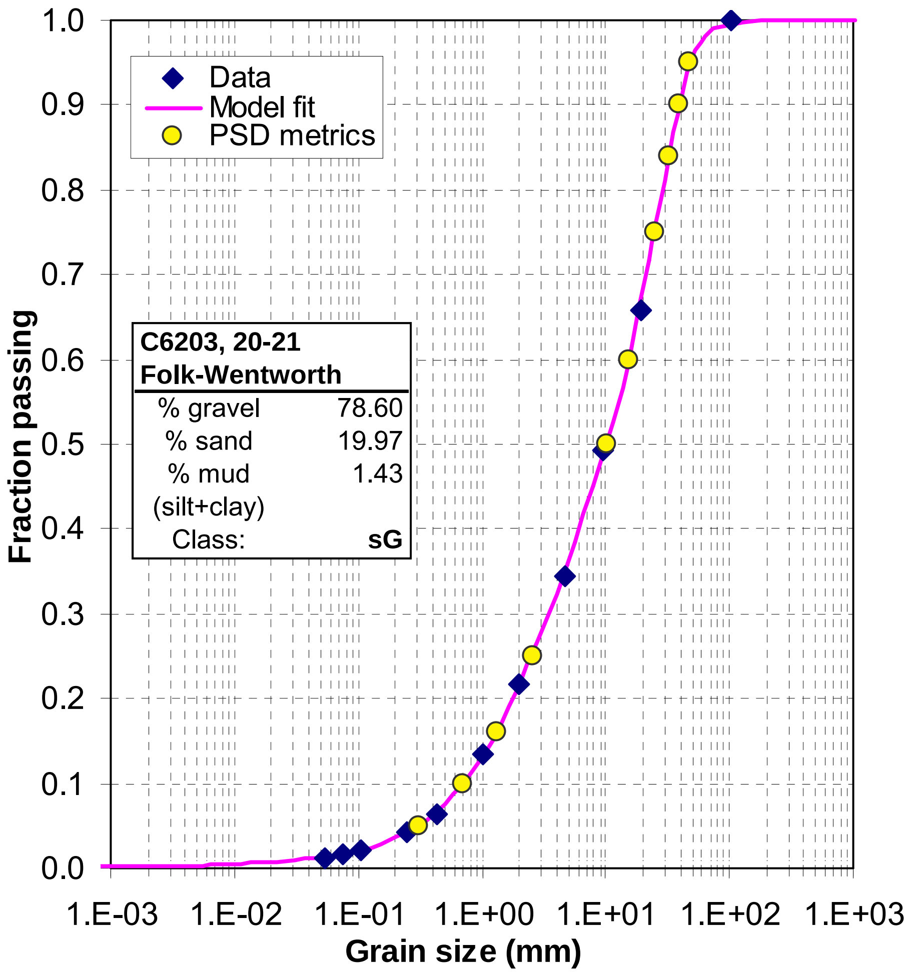
# IFRC Site Characterization Data

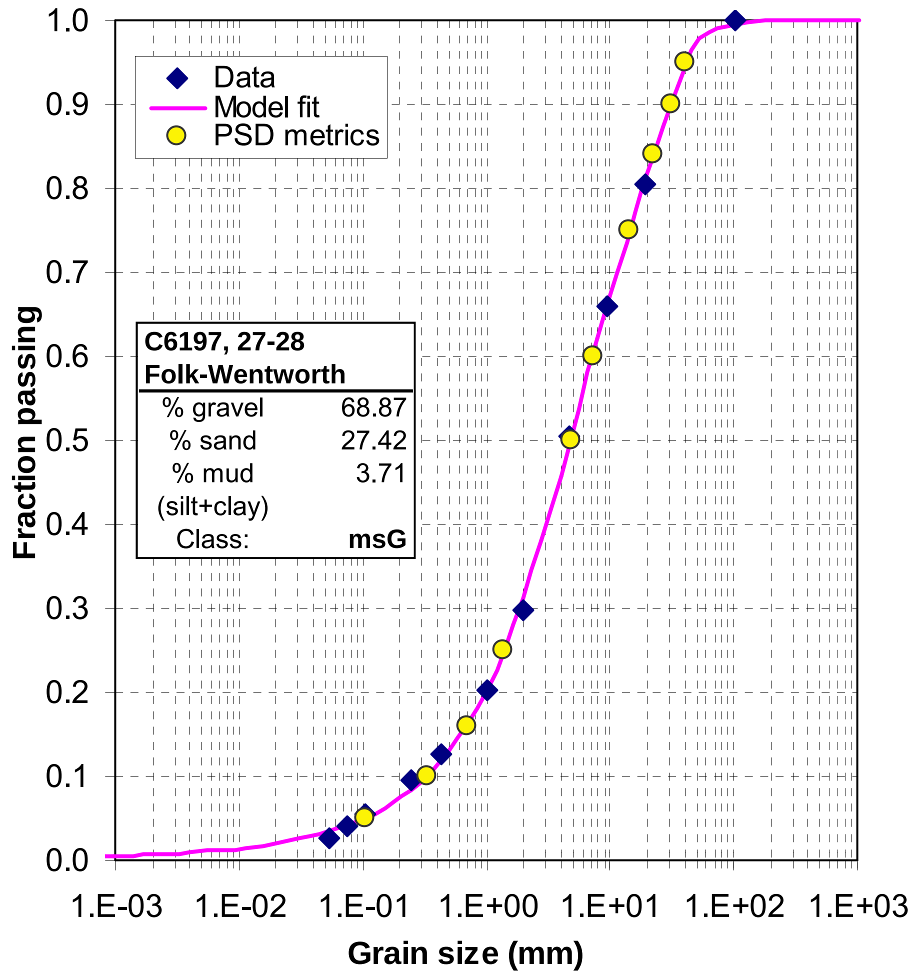
- Sediment and core sample analyses
  - Physical and hydraulic properties
    - Bulk and particle densities, porosity
    - Grain size distributions
    - k-S-p relations
    - Surface areas
  - Geochemical properties (*next presentation by Chris Murray*)
  - Electrical properties at core scale (*measured by Rutgers*)
- Laboratory transport experiments on intact cores
- Aquifer testing
  - Constant rate injection tests (*14 wells*)
  - EBF profiling (*26 wells*)
- Surface, borehole, and cross-hole geophysical measurements
  - Neutron-moisture logs
  - Neutron-density/porosity logs (*for 3 wells installed in FY10*)
  - Spectral gamma logs
  - Electrical resistivity/conductivity/IP and time-lapse 2D ERT
  - Cross-hole GPR (*zero-offset*)
  - Acoustic televiewer
  - EMI
- Field tracer tests and U-desorption experiment
  - Nov-08, Mar-09, Aug-09, Oct-09, Jun-10 (*to be discussed in afternoon session*)

# Split-core photograph showing texture (msG) of Hanford fm sediment from lower vadose zone.

# Split-core photos of 300A gravel and sandy mud

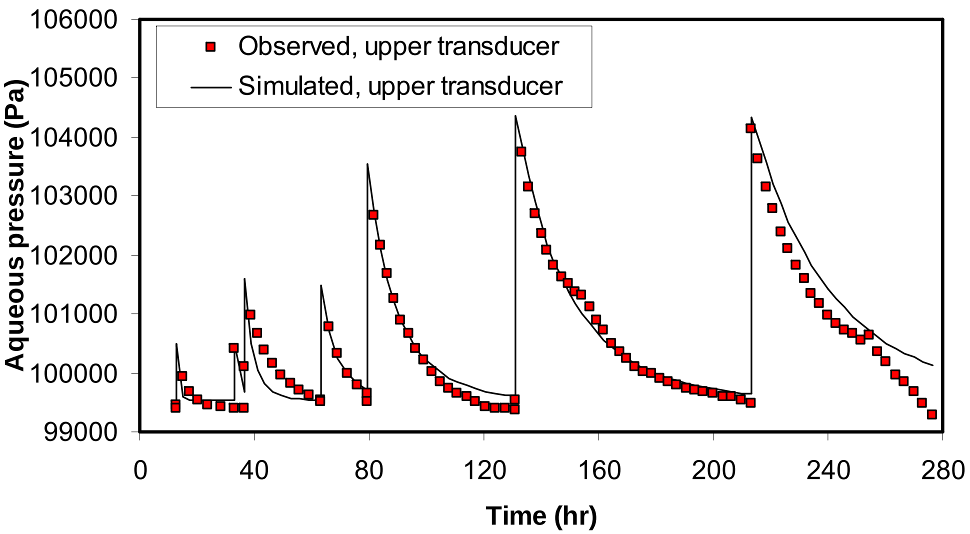
# Grain size distribution examples

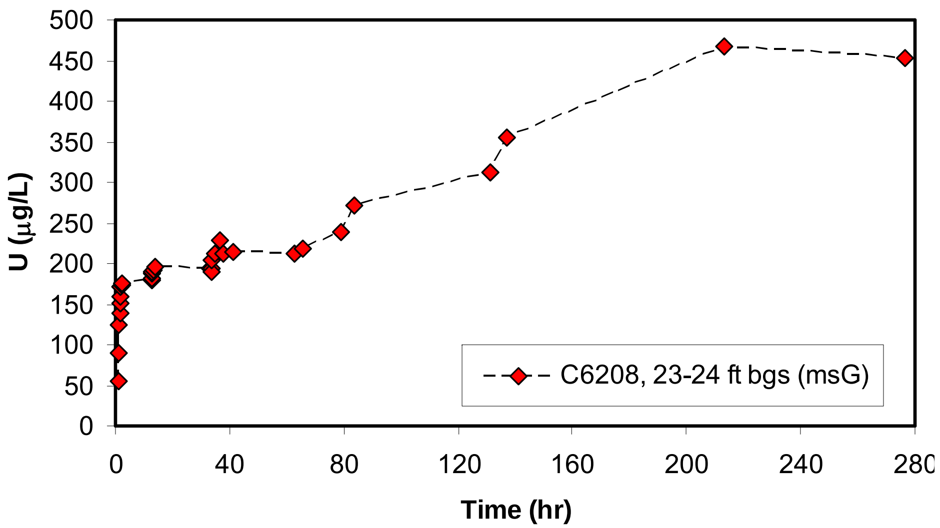


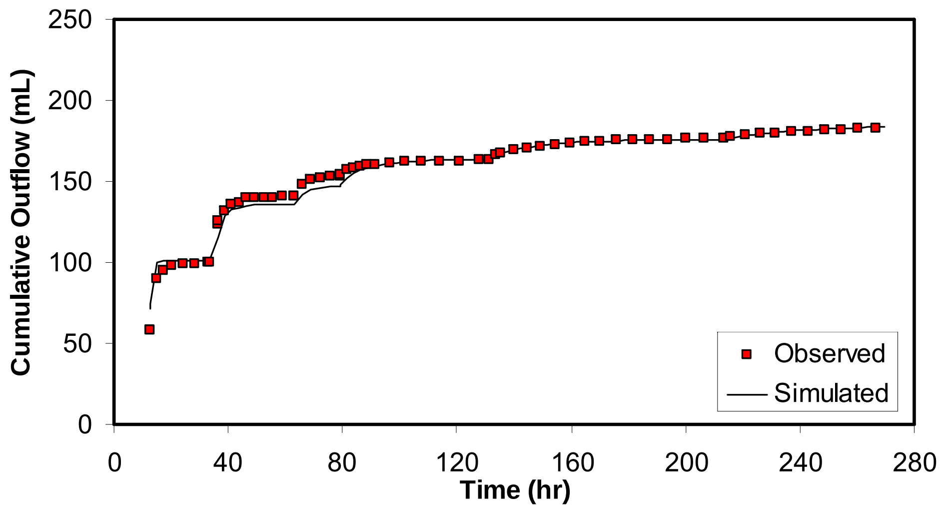



# Lab Hydraulic Property Characterization

## *Multi-Step Outflow Experiments (for k-S-p relations)*

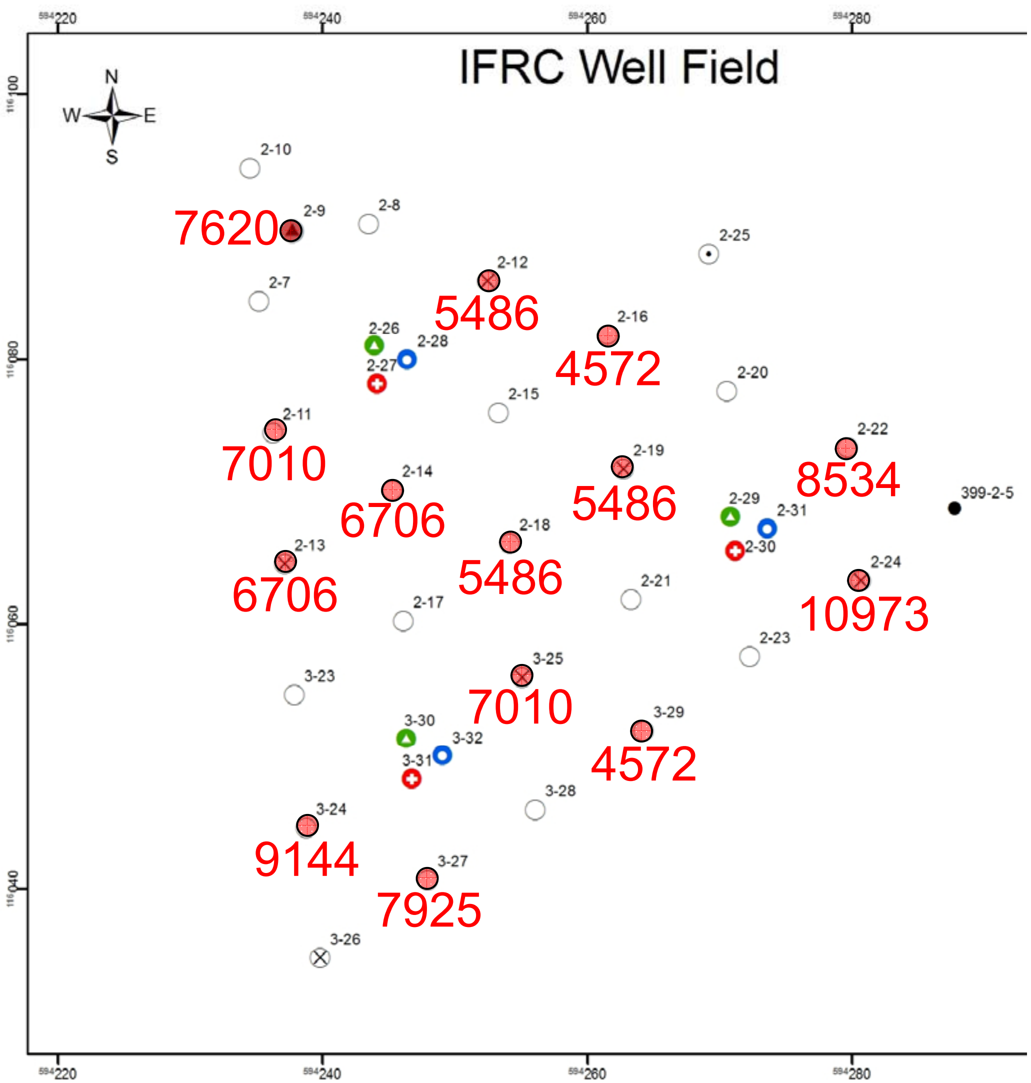


# Aquifer Testing

## *Constant Rate Injection Tests*




- Number wells tested: 14
- Injection rate: 316 gpm
- Test duration: 20 min
- Typical displacement:
  - < 0.1 ft (2-3 cm)
- Methods of analysis:
  - Neuman (1975)
  - Theis (1935)
- Average K ≈ 7000 m/d

Pacific Northwest
NATIONAL LABORATORY

Proudly Operated by Battelle Since 1965

# Aquifer Testing

## *Electromagnetic Borehole Flowmeter (EBF) Profiling*

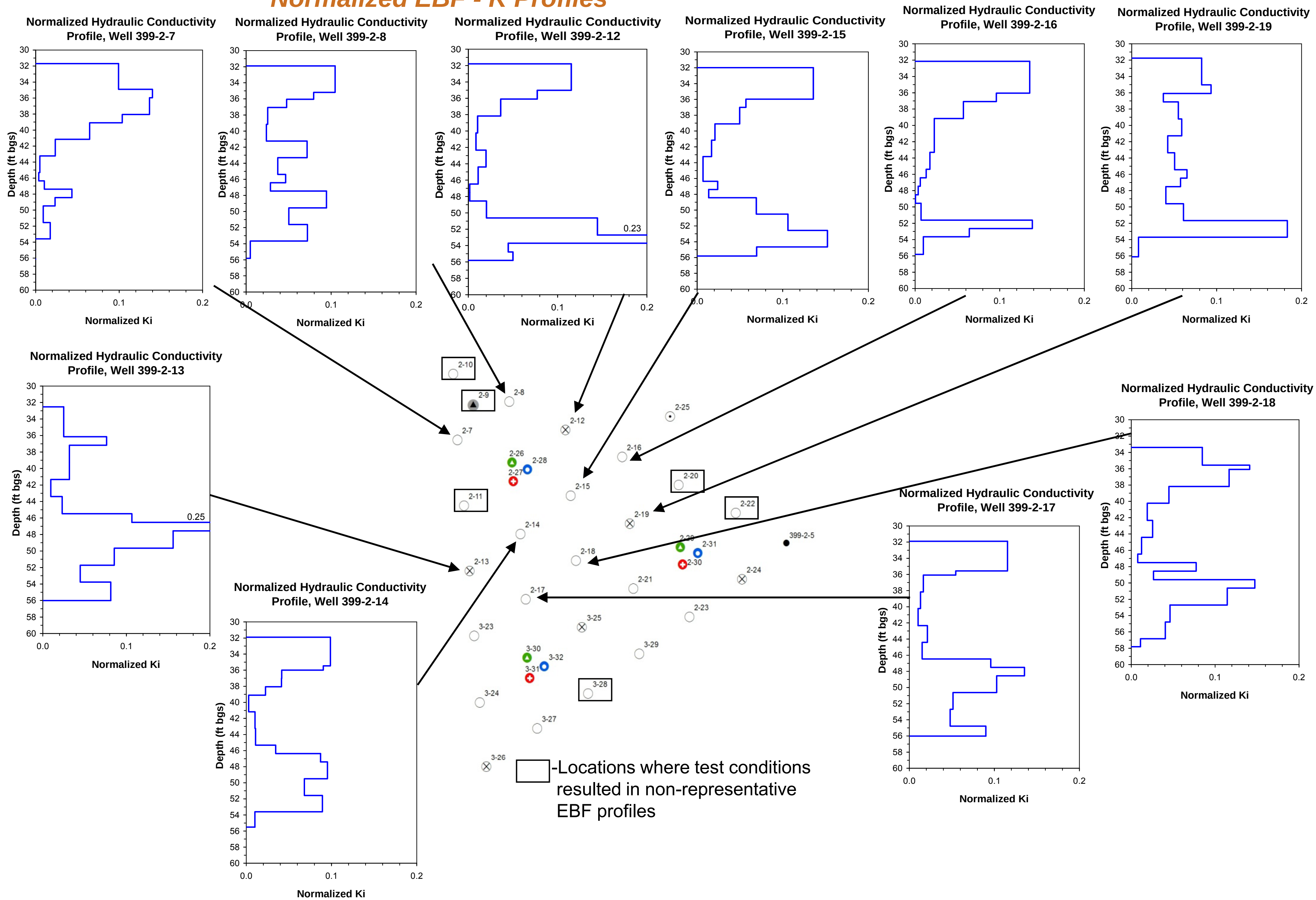
- Number of wells tested: 26
- Extraction rate: 1.04 - 1.55 gpm
- Measurement interval: 1 - 2 ft (~0.3 - 0.6 m)
- Method of analysis:
  - Molz et al. (1994)
- Absolute K estimated from

$$\overline{K} = \frac{\sum_i K_i dz_i}{b}$$

$$b = \sum_i dz_i$$

# Aquifer Testing

## *Normalized EBF - K Profiles*

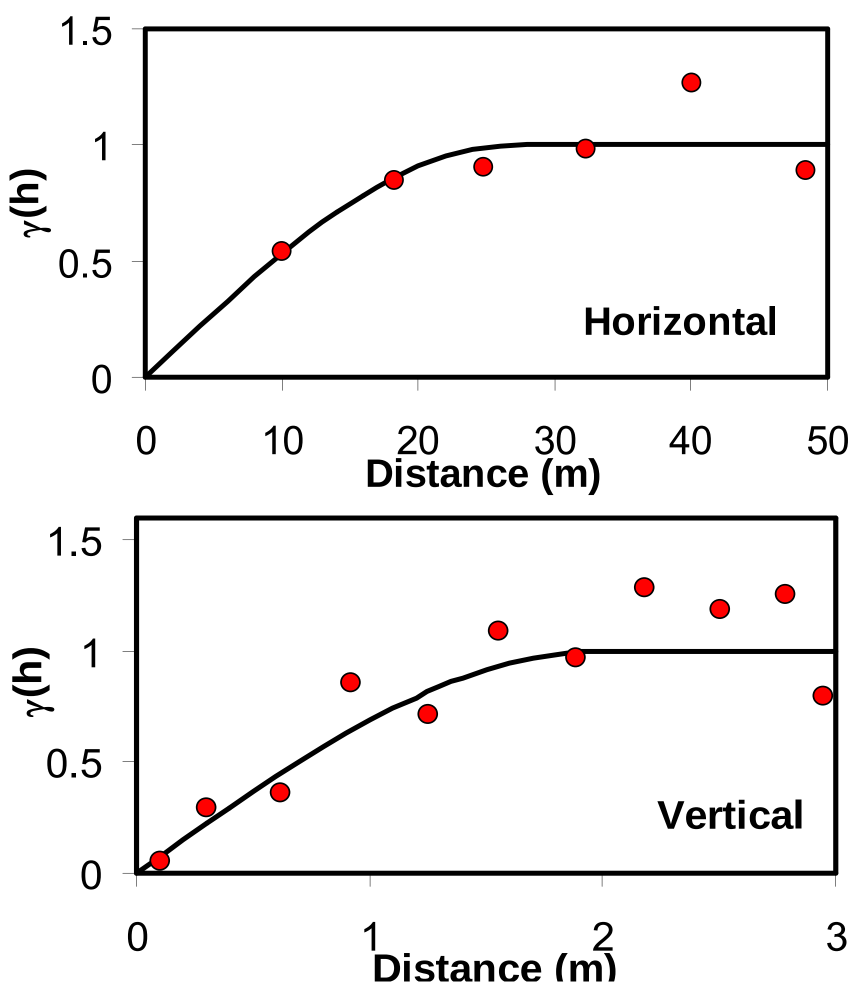


# Geostatistics

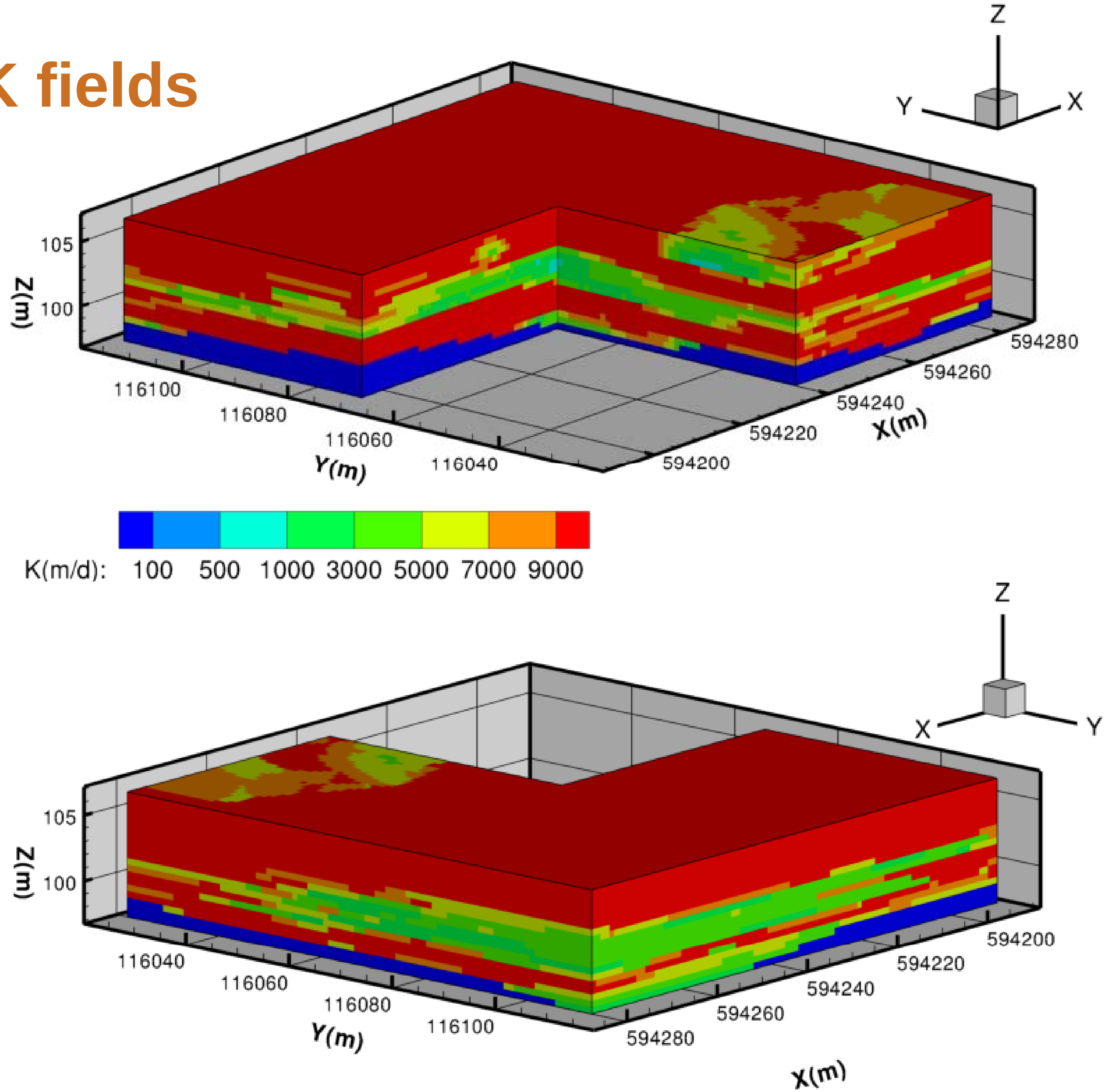
## *Field hydraulic conductivity*

- **Variography** (Hanford fm)
  - Single-structure spherical model
  - Nugget = 0
  - Sill = 1 (standardized)
  - Horizontal range = 27 m
  - Vertical range = 2 m

Normal Scores Variograms



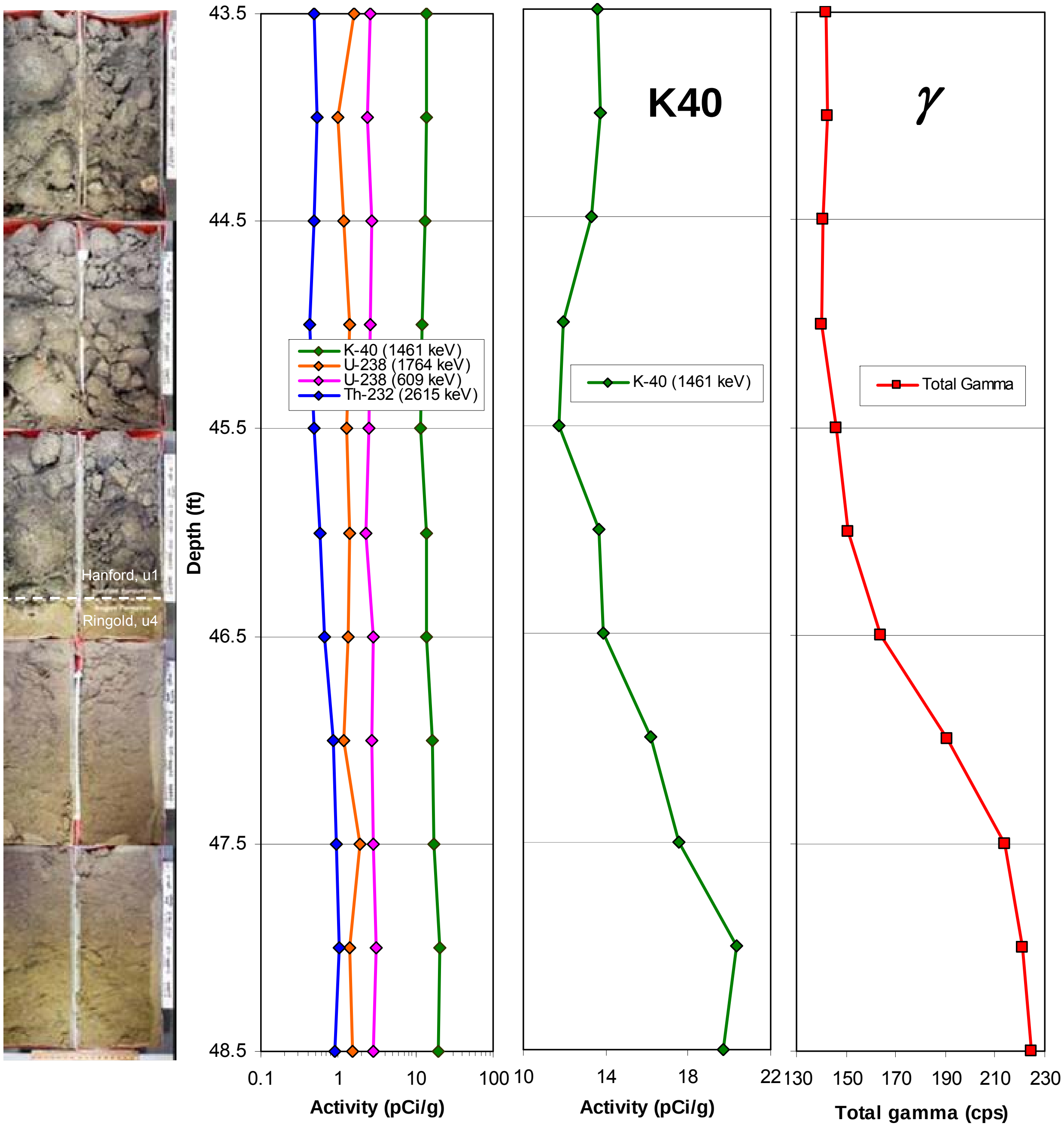
# Example K fields



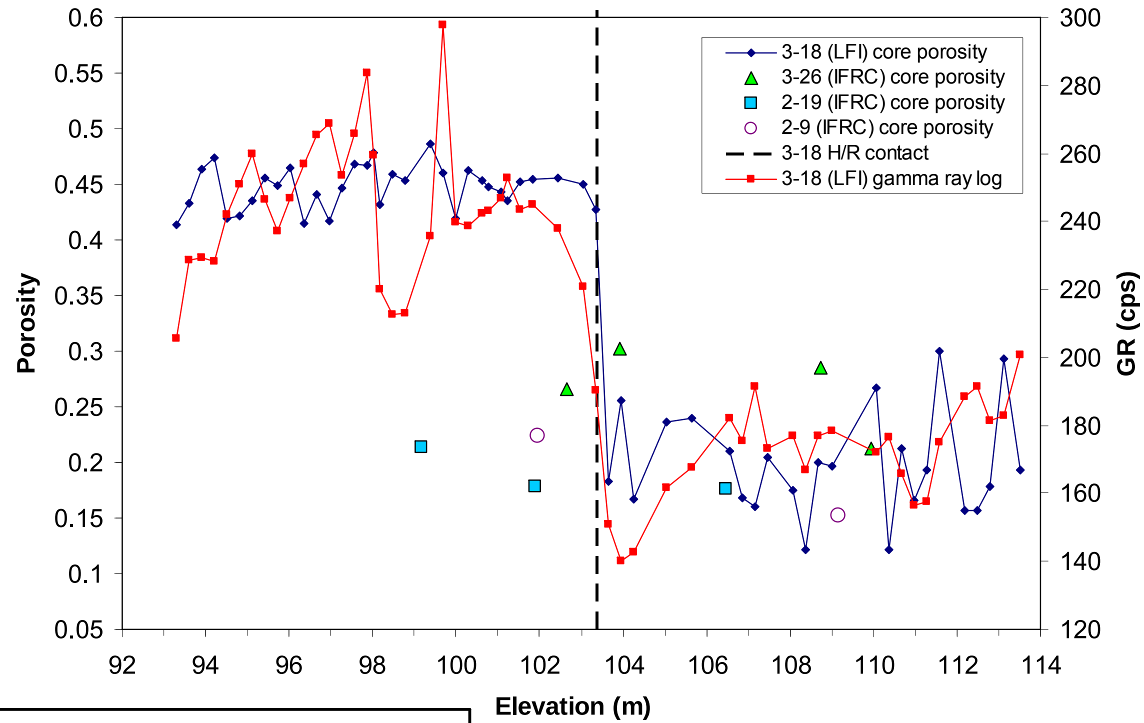
# Geophysical log-based parameterization

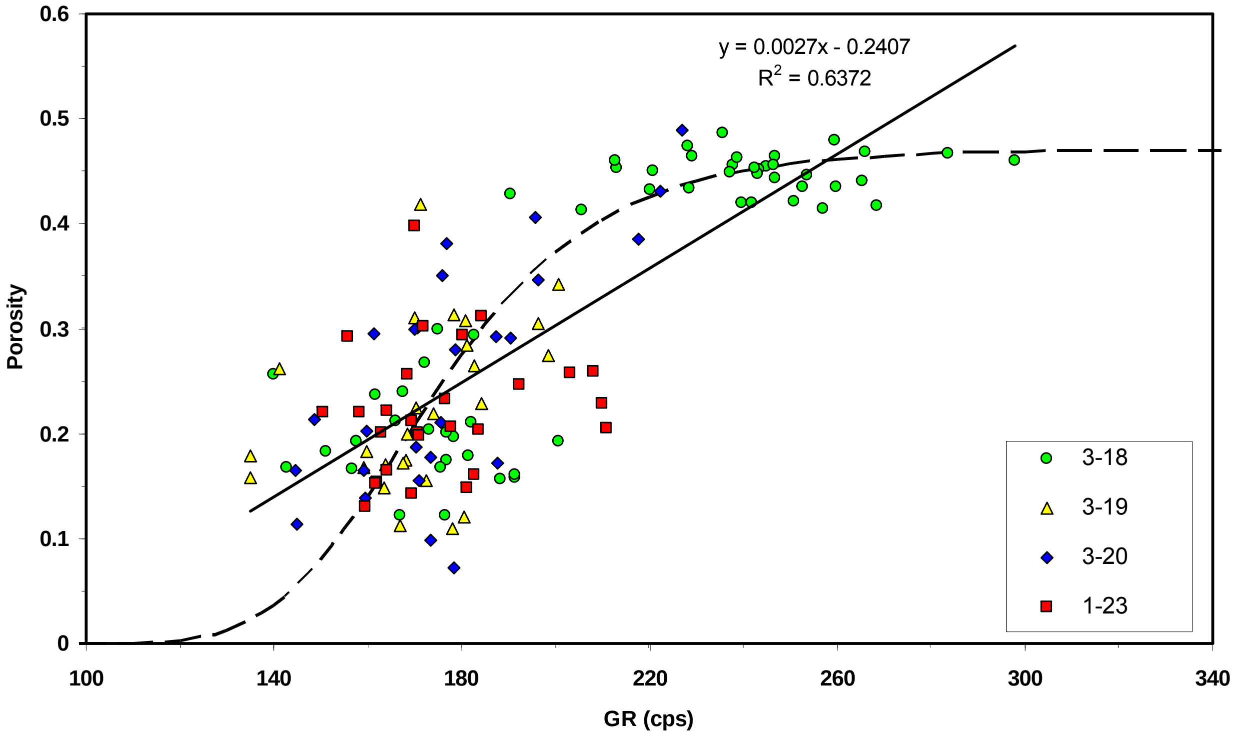
Hanford Gravels

Muddy Sand subunit of Ringold Fm

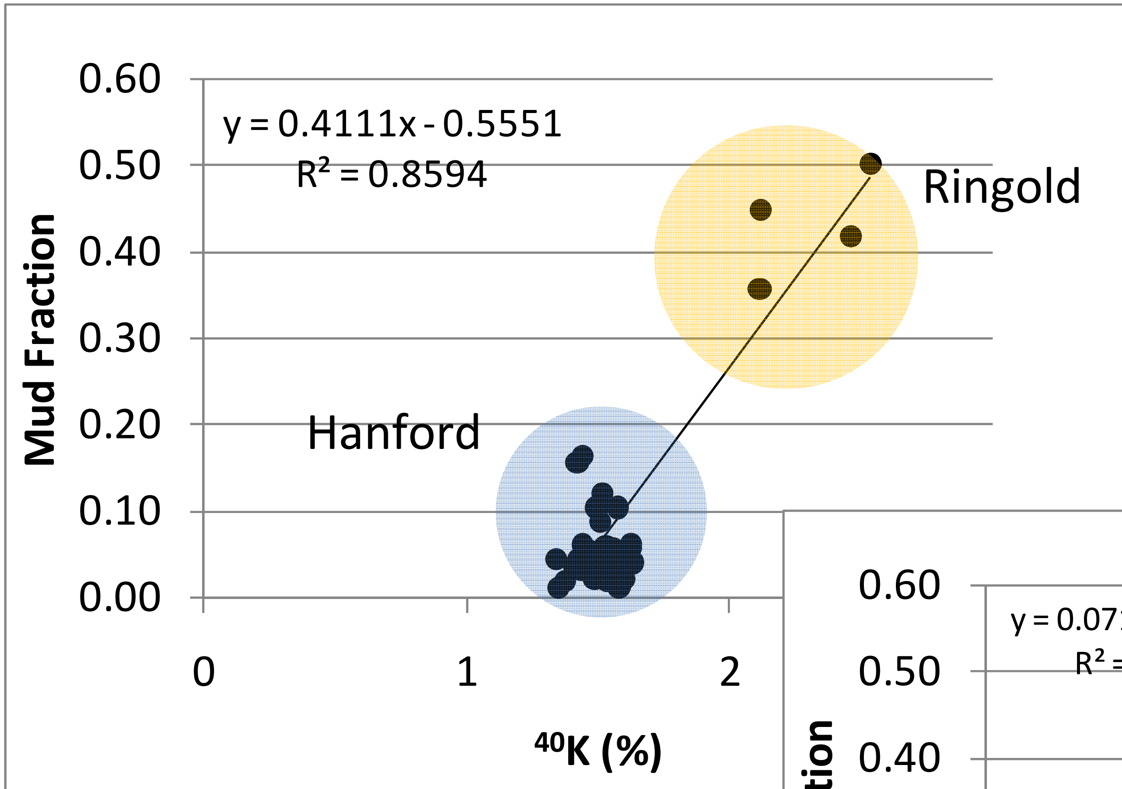


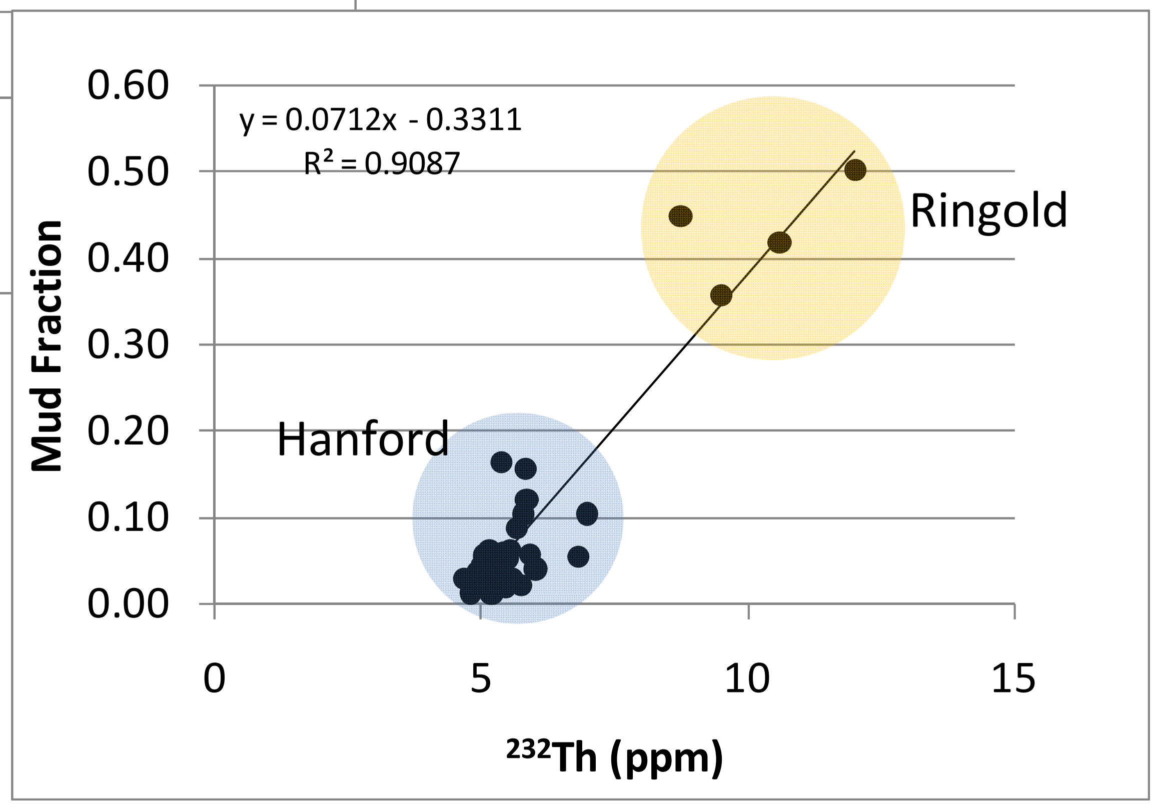
# Correlations between $\gamma$ - log data and porosity



# Correlations between $^{40}K$, $^{232}Th$ and mud fraction

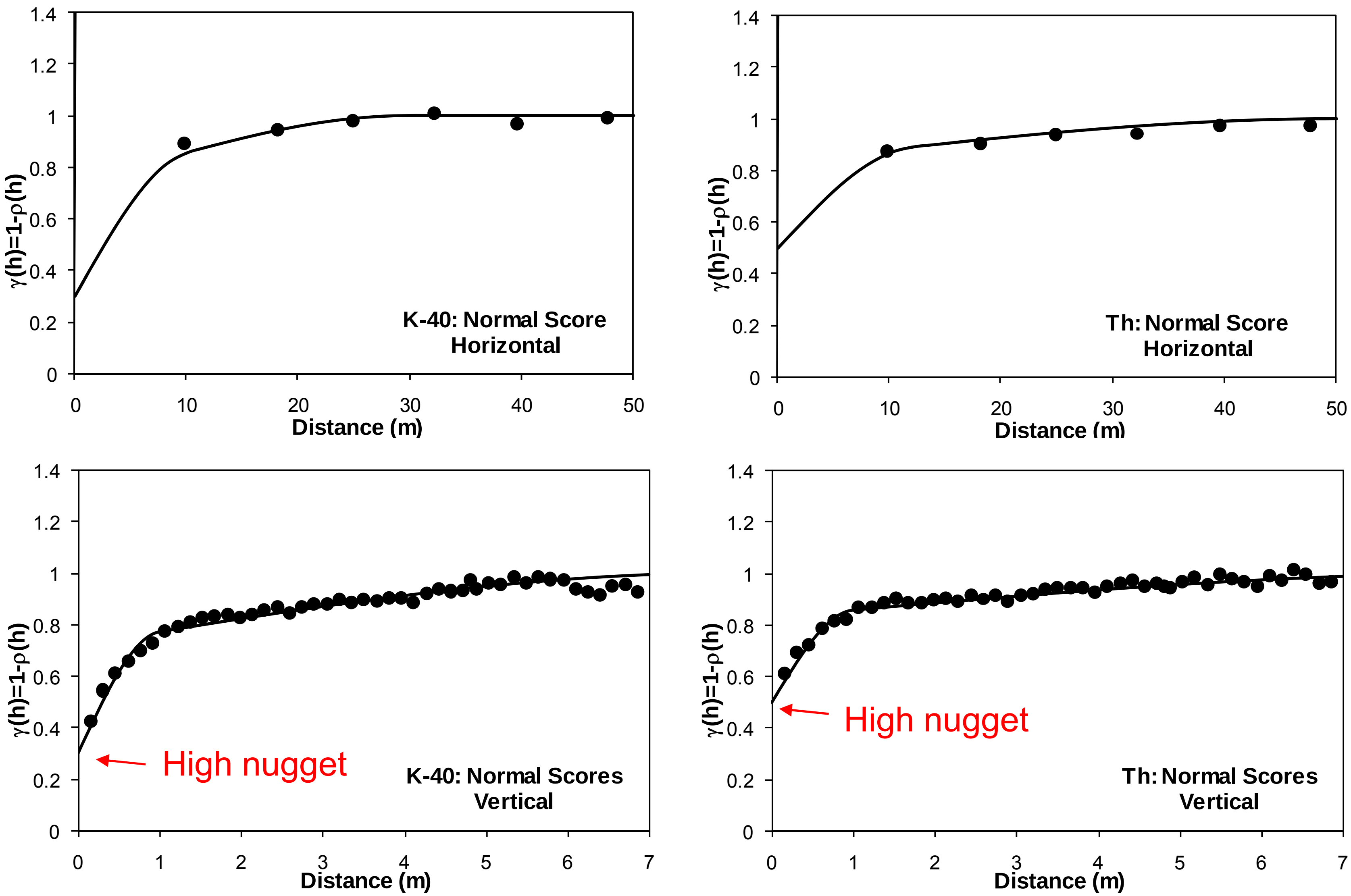


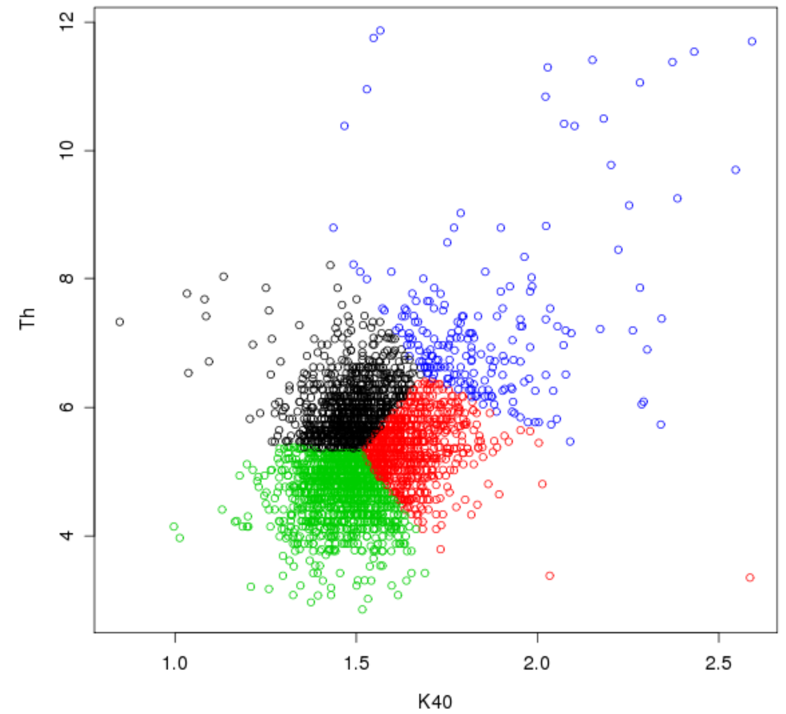

Figures from Andy Ward

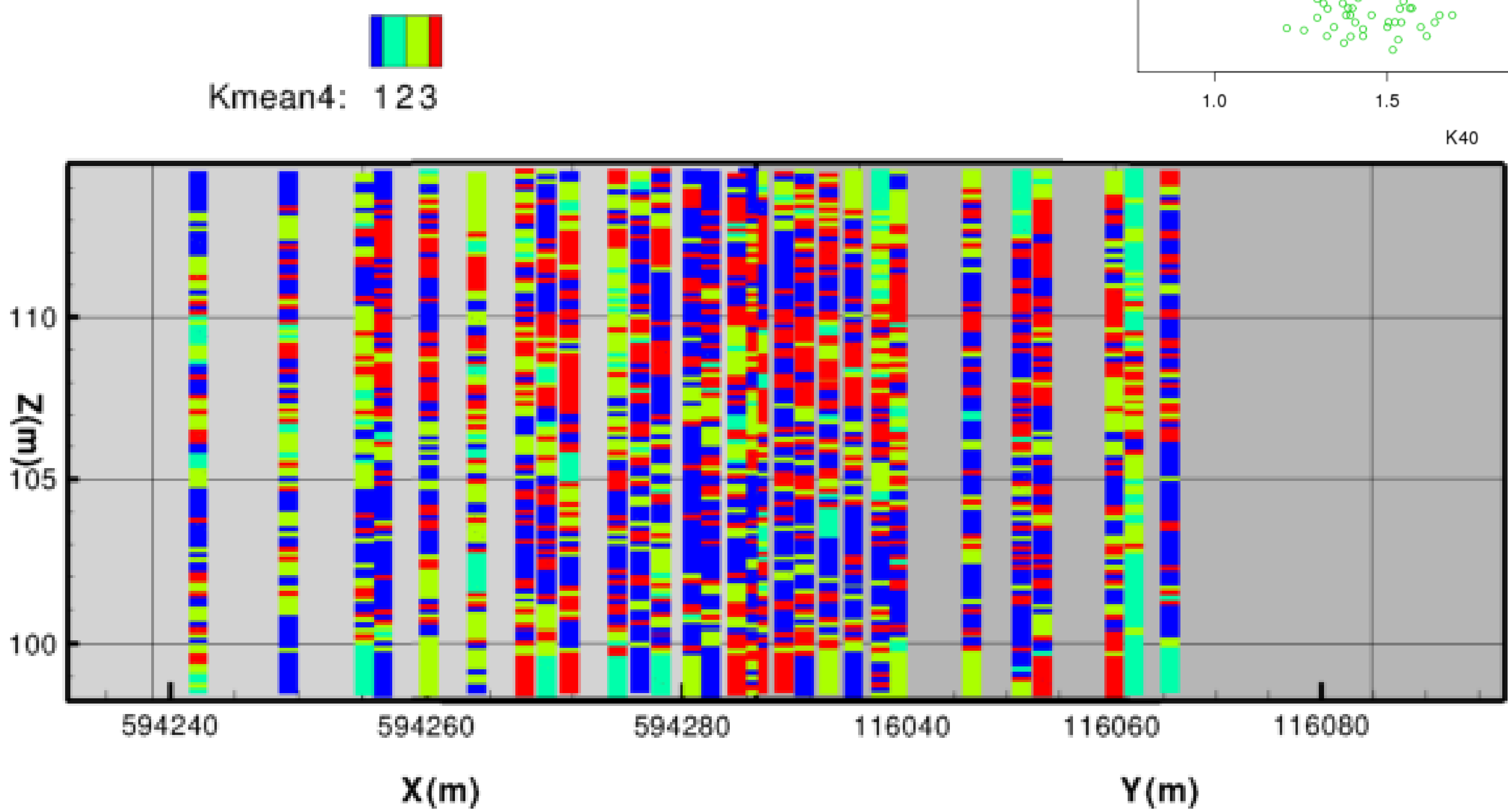
# Geostatistics

## *$^{40}K$ and $^{232}Th$ (Hanford fm only)*



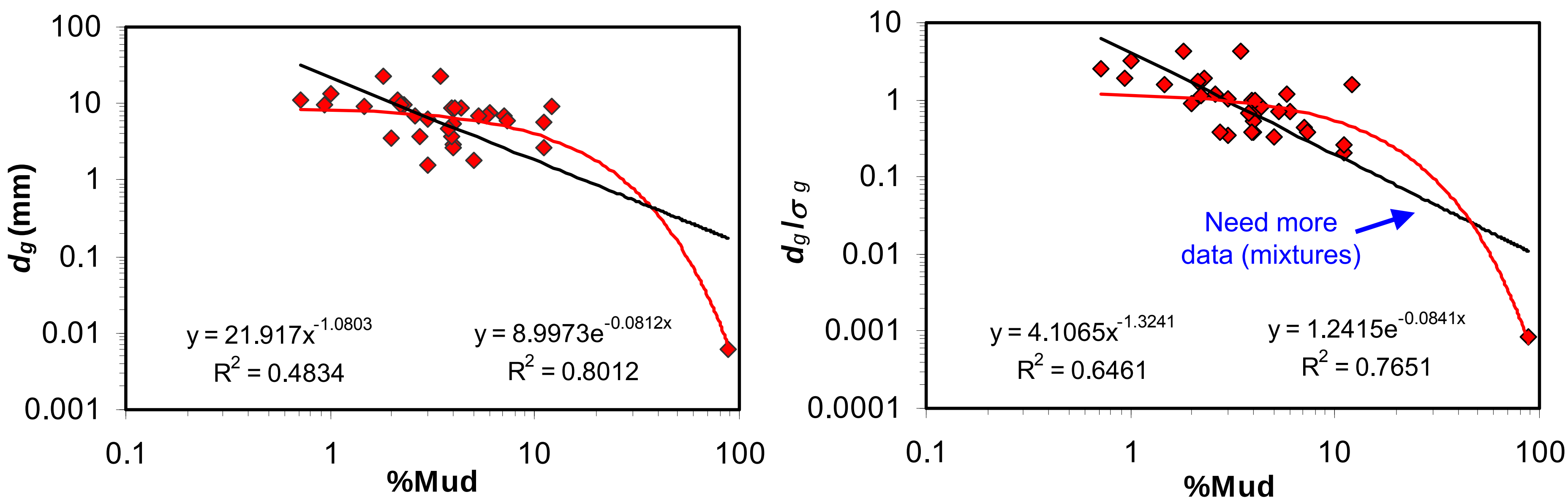
# Cluster analysis with $^{40}K$ and $^{232}Th$ data (Hanford fm only)



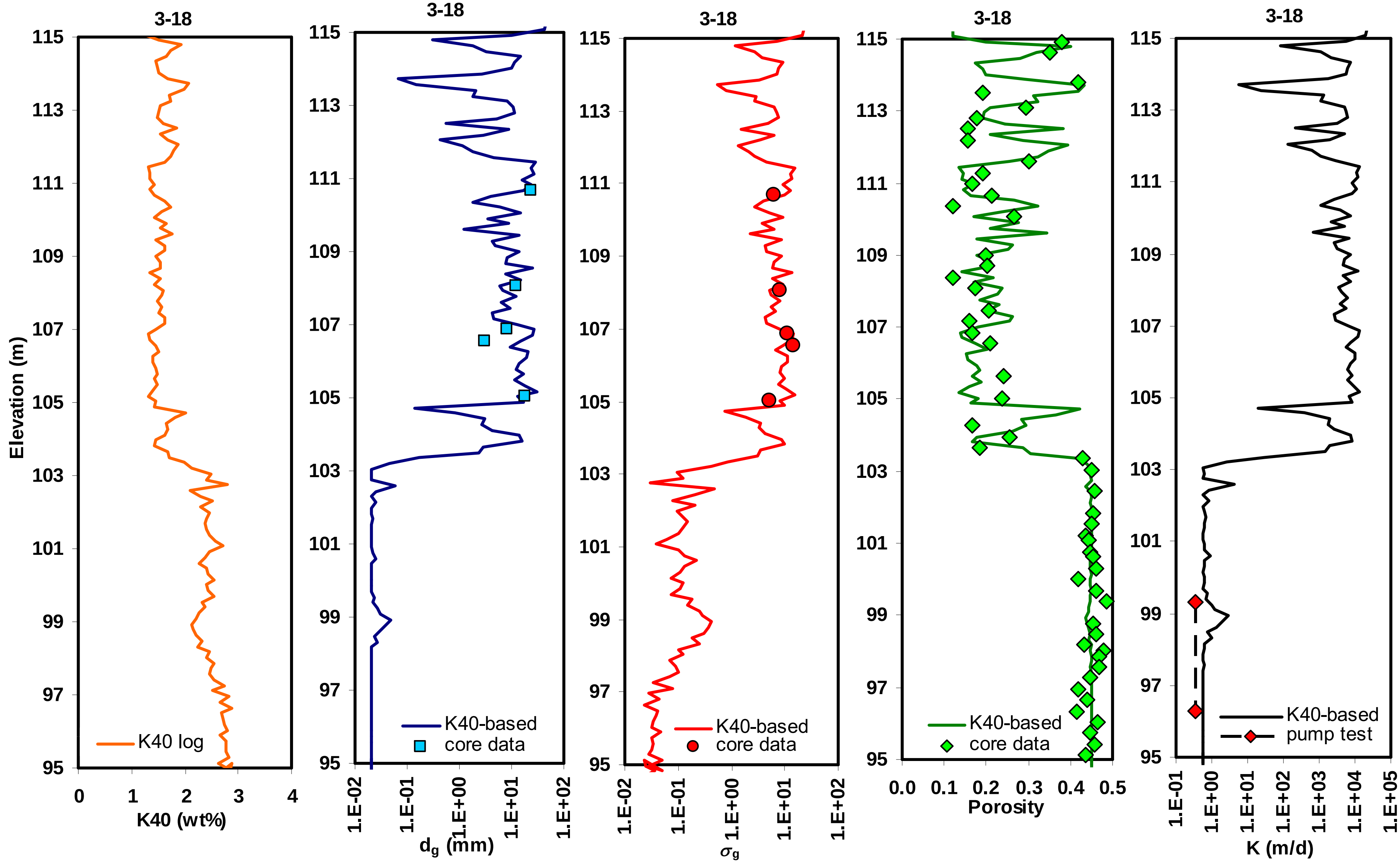
# Other property transfer functions

- %mud = $f(^{40}K, ^{232}Th)$
- $d_g$, $d_g/\sigma_g = f(\%mud, ^{40}K, ^{232}Th)$
- CEC, SA, k-S-p params. = $f(d_g/\sigma_g)^\dagger$
- $\phi = f(d_g, \sigma_g, \gamma\text{-logs}, \%mud)$
- $K_s = f(\phi, d_g)$ [e.g. Kozeny-Carman]



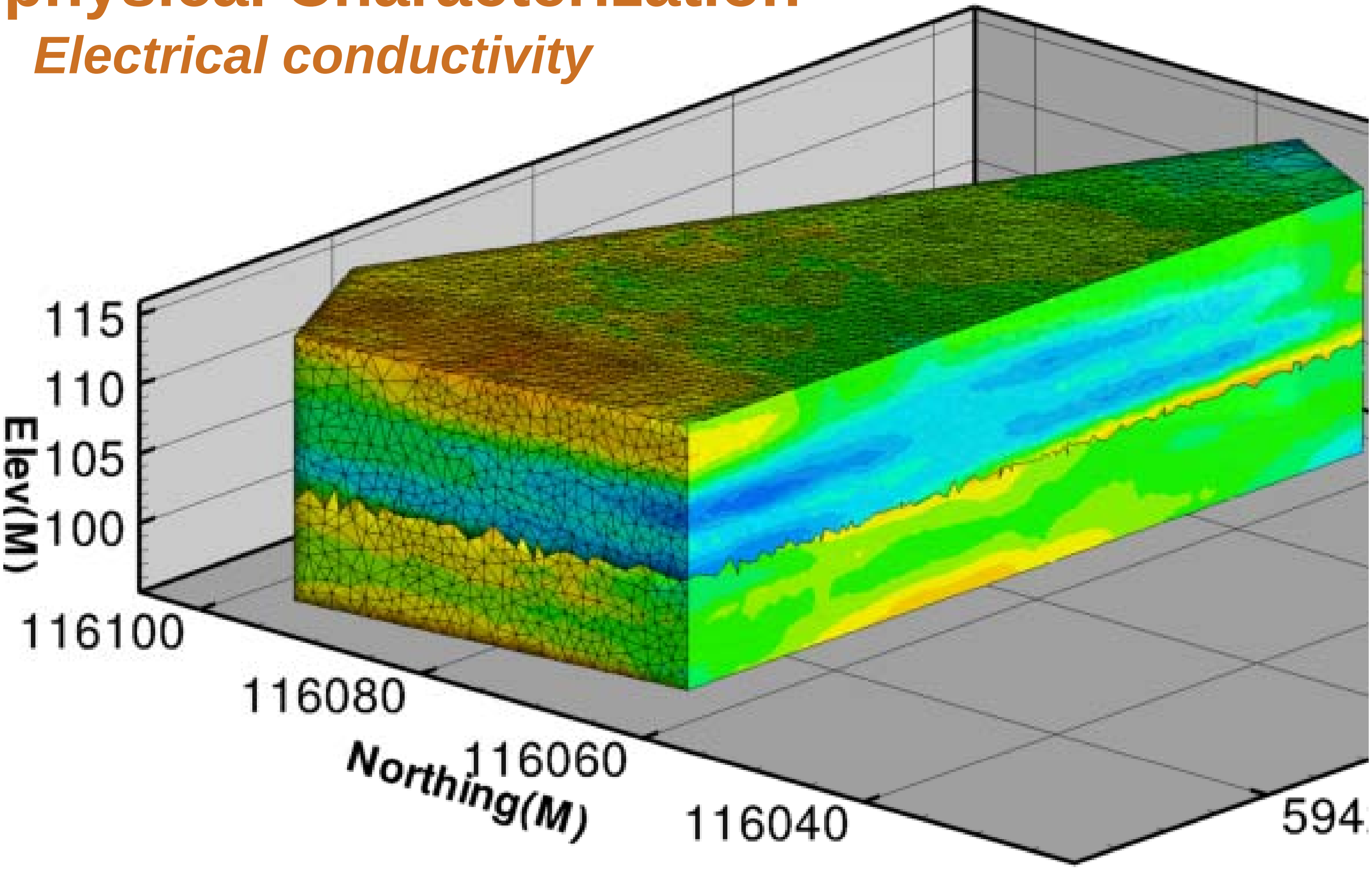

† Ward et al. 2006. Vadose Zone Transport Field Study: Summary Report. PNNL-15443, Pacific Northwest National Laboratory, Richland, Washington.

# Geophysical log-based parameterization

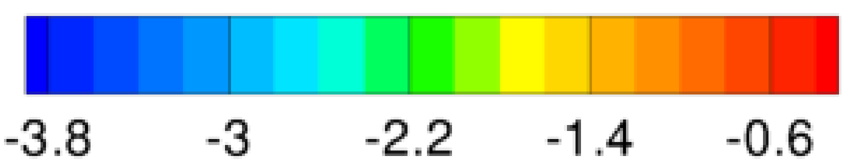


# Geophysical Characterization

## *Electrical conductivity*




EC results from Tim Johnson



# Electrical conductivity models[†]

- Modified Archie's law (Archie, 1942; Schön, 1996)

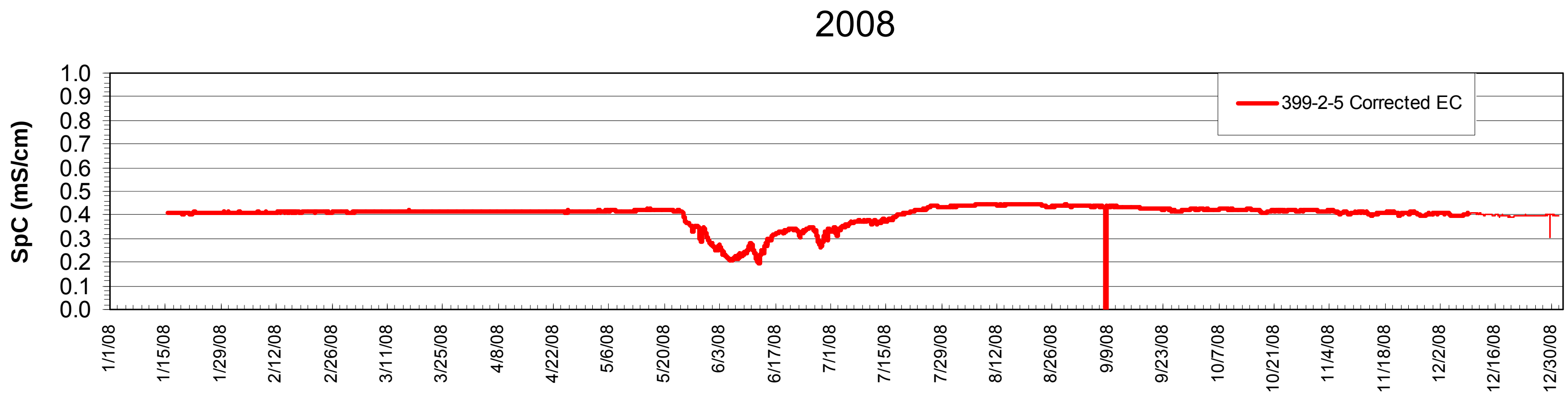
$$\sigma_{eff} = \frac{\sigma_w}{F} S^d \qquad F = \phi^{-m}$$

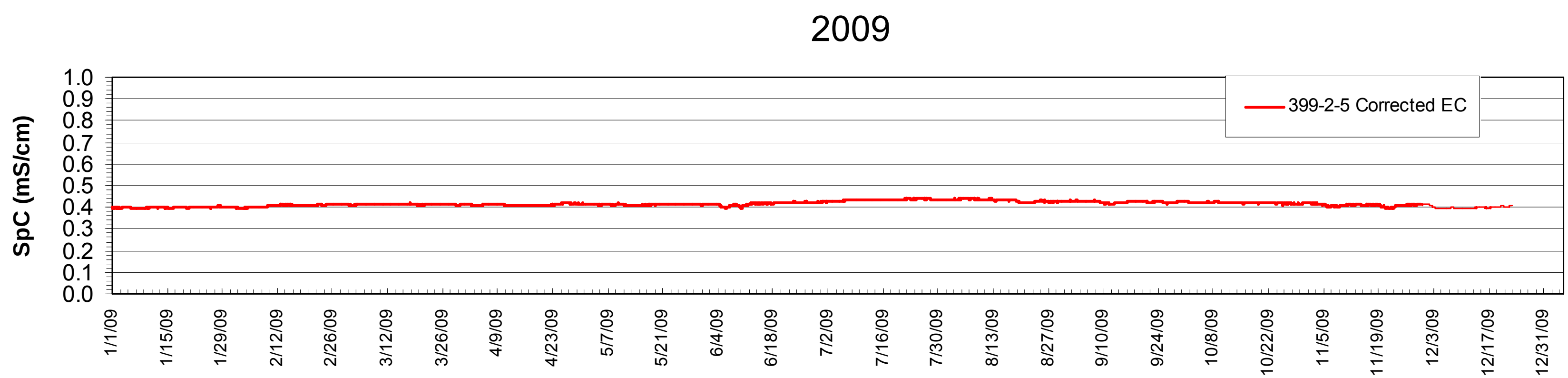
- with surface conduction (Waxman and Smits, 1968; Sen et al. 1988; many others)

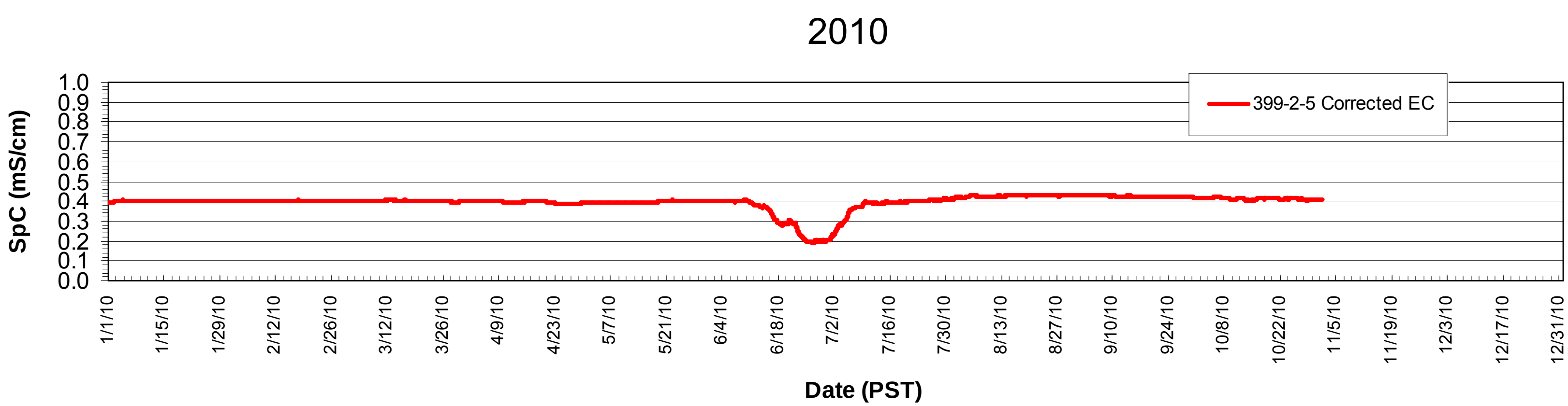
$$\sigma_{eff} = \frac{S^d}{F}\left(\sigma_w + \frac{BQ_v}{S}\right) \qquad B = \frac{1.93m}{1 + 0.7/\sigma_w}$$

*† Lesmes, D.P. and S.P. Friedman, 2005, Relationships between the electrical and hydrogeological properties of rocks and soils. Ch. 4 In Hydrogeophysics, Rubin, Y. and S.S. Hubbard (eds.), Springer.*

# Specific conductance data from well 399-2-5

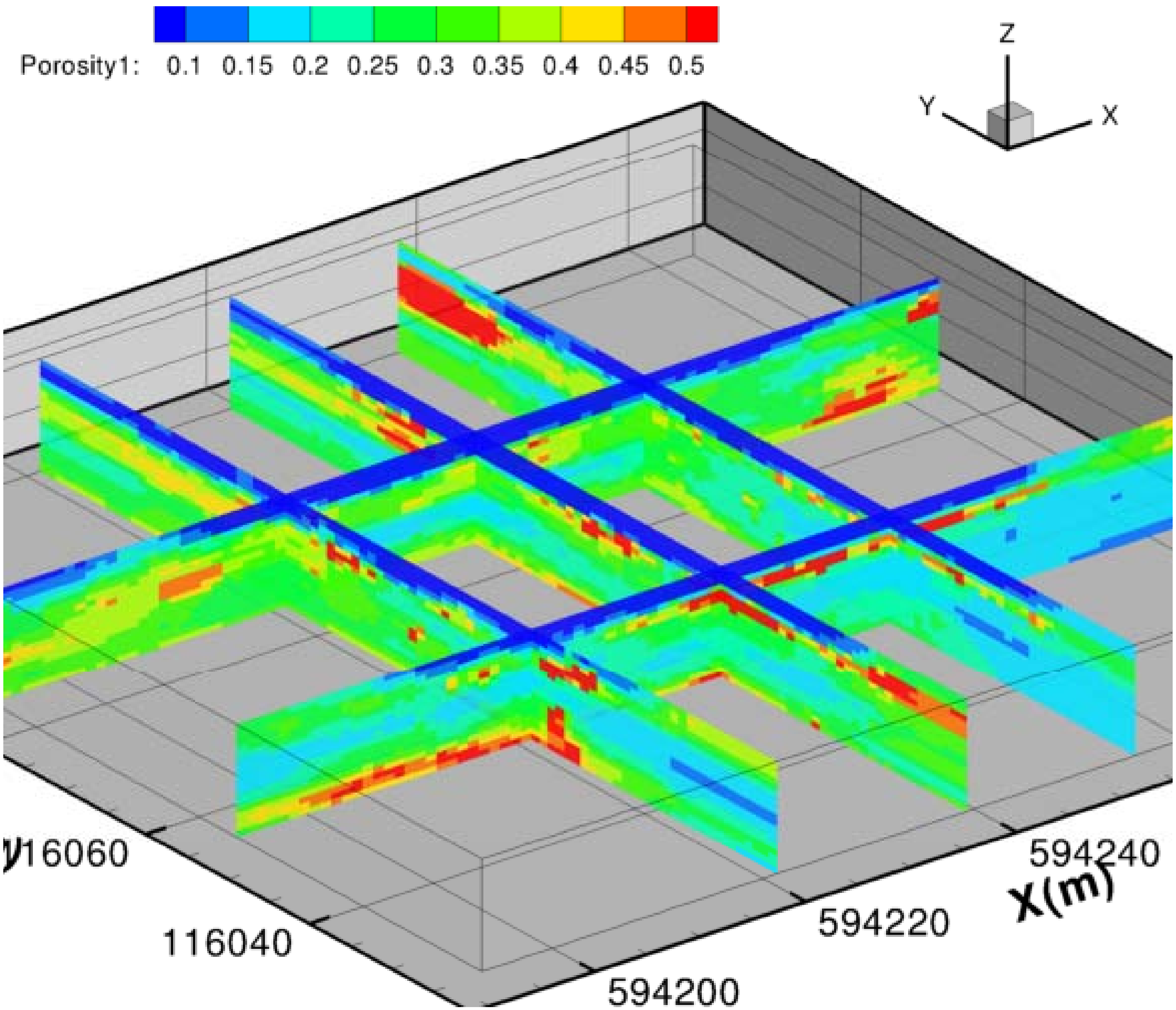


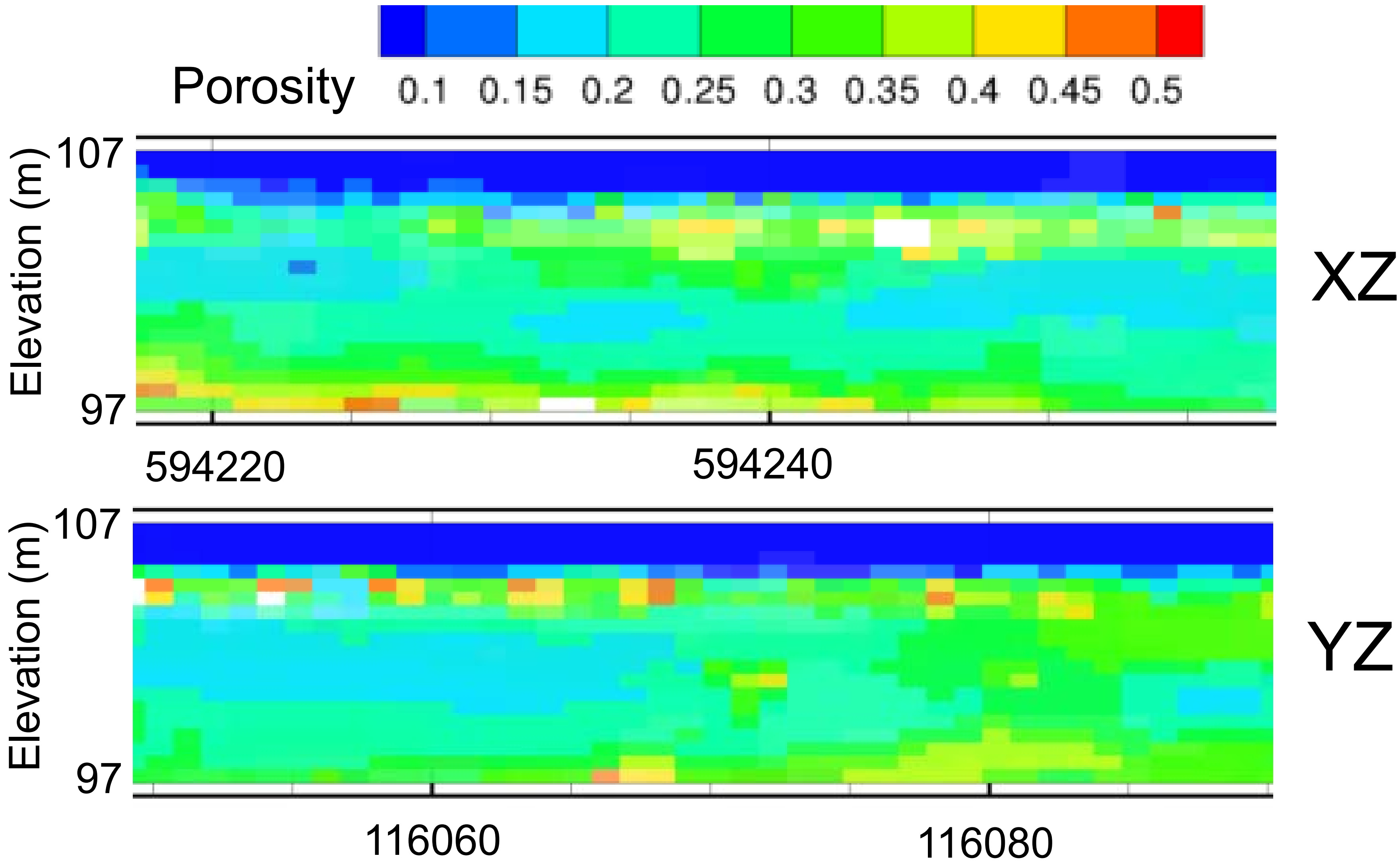
# EC-derived porosity fields

## *from modified Archie's law*



# EC-derived porosity fields

## *from modified Archie's law*



# Summary

- IFRC site aquifer testing
  - Robust field-scale data set for aquifer K
- Lab physical and hydraulic properties
  - Data for development of correlation functions
  - Need more analyses for Ringold fines, and sediment mixtures
- Geophysical logs and log-based parameter estimation
  - Advantages
    - High spatial resolution
    - SGLS data can be used to develop correlation functions for just about everything, including vadose zone hydraulic properties
  - Disadvantages
    - Large random component (nugget effect) in SGLS data
    - Uncertainty can be compounded by use of many regression functions
    - Porosity is not well estimated using SGLS data alone – requires use of packing models with additional parameters
- Field resistivity/electrical conductivity
  - Looks promising for estimating porosity
  - Improved site-specific petrophysical data/core measurements are needed