Influence of Clastic Dikes on Vertical Migration of Contaminants in the Vadose Zone at Hanford

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Outline

- Background
- Goal
- Scientific Approach
  - Determine spatial patterns
  - Measure hydrogeologic properties
  - Evaluate potential effects on fluid flow through the vadose zone
- Schedule
- Expected Scientific Products

Background

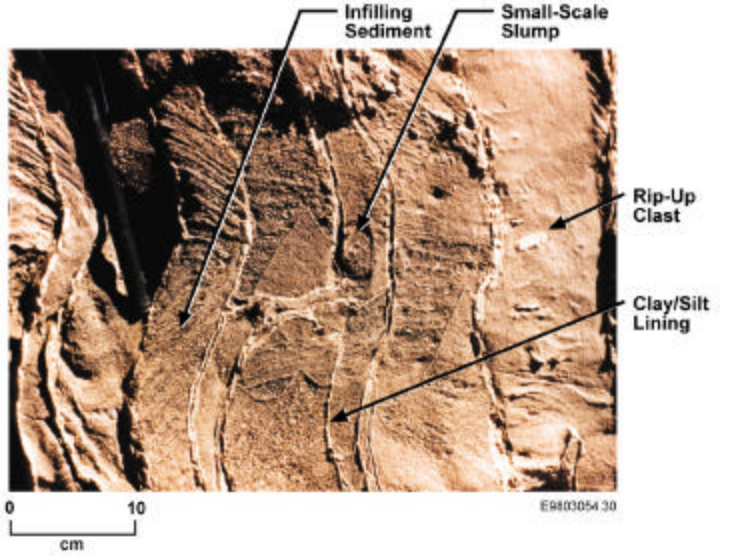
- Contaminants at Hanford have migrated more deeply than expected
- Preferential pathways could explain the discrepancy between predicted and observed travel times
- Clastic dikes are major vertical discontinuities known to exist around tank waste leak sites.

Hypothesis

Clastic dikes in waste management areas at Hanford provide preferential pathways for the faster-than-expected vertical movement of fluids and contaminants through the vadose zone.

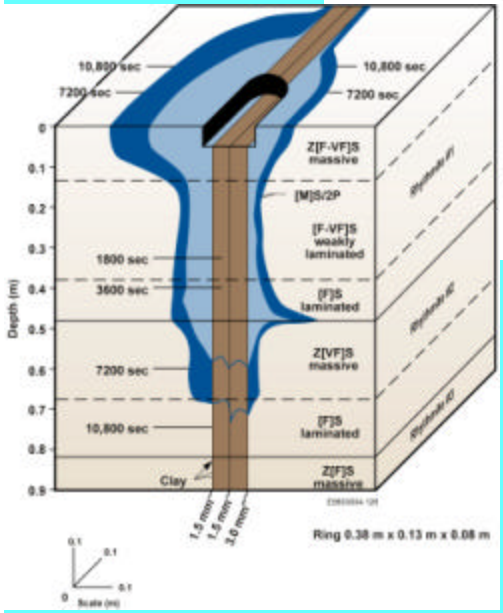
Background (cont.)

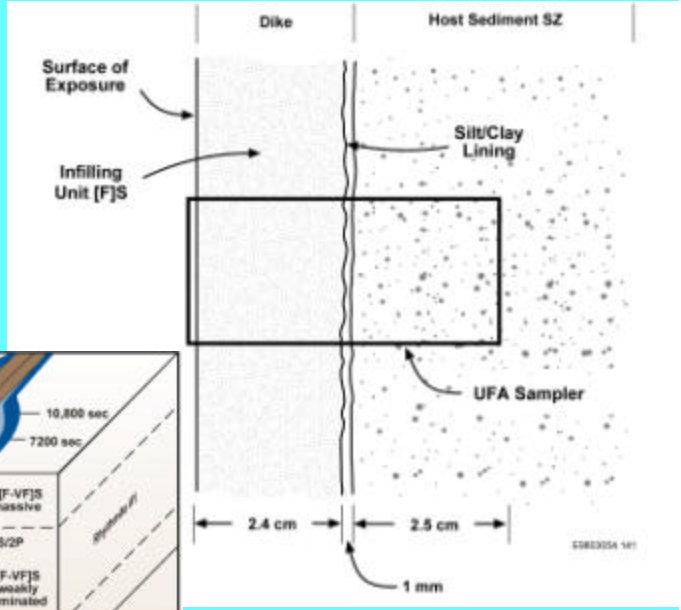
- Characteristics (Fecht et al. 1998)
  - Vertical to sub-vertical sedimentary structures formed after the host sediment was deposited
  - In plan view, dikes can form 4- to 8-sided polygonal patterns, fill existing fissures, and occur randomly
  - Individual dikes are generally composed of multiple layers, each with an outer skin of silt/clay (0.03 to 1 mm thick) and coarser infilling layers (1 mm to 30 cm thick)
  - Nominal Dike Dimensions
    - Width = 0.03 to 1.0 m
    - Depth = 2.0 to > 20 m
    - Lengths = 1.5 to 100 m



Background (cont.)

- Hydrologic Properties (Fecht et al. 1998)
  - Wetting front advance
  - Guelph permeameter
  - Ultracentrifuge



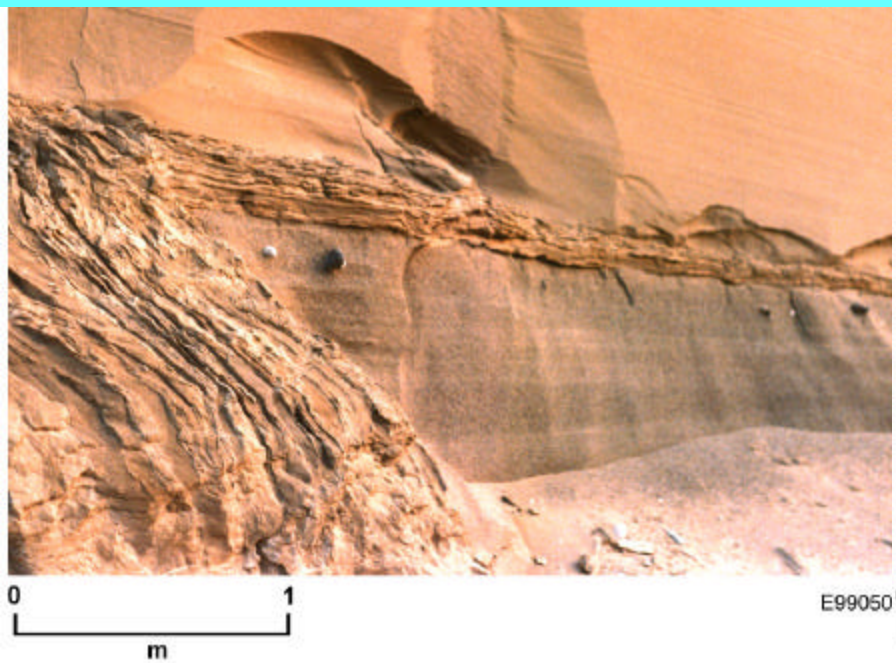


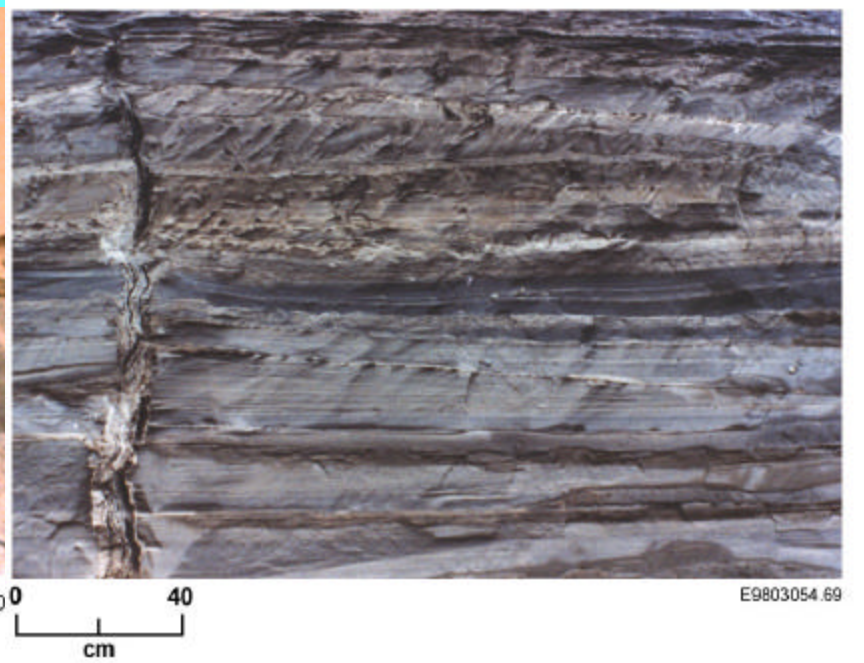
Goal

- Develop a basic scientific understanding of clastic dikes at the Hanford Site and their possible role as preferential pathways for vadose zone contaminant transport

Scientific Approach

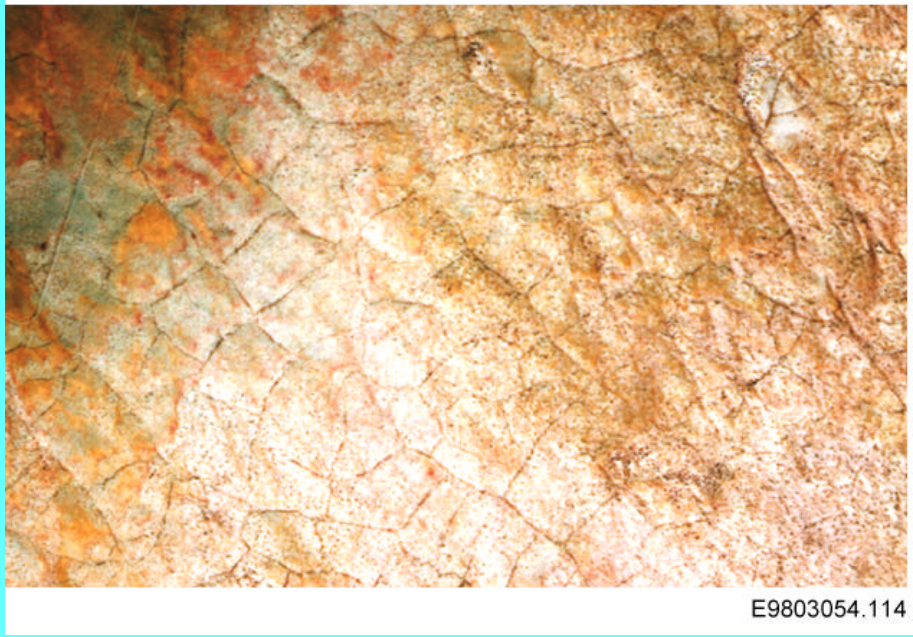
- Determine spatial patterns
- Measure hydrogeologic properties
- Evaluate potential effects on fluid flow through the vadose zone





Phase 1: Determine Spatial Patterns

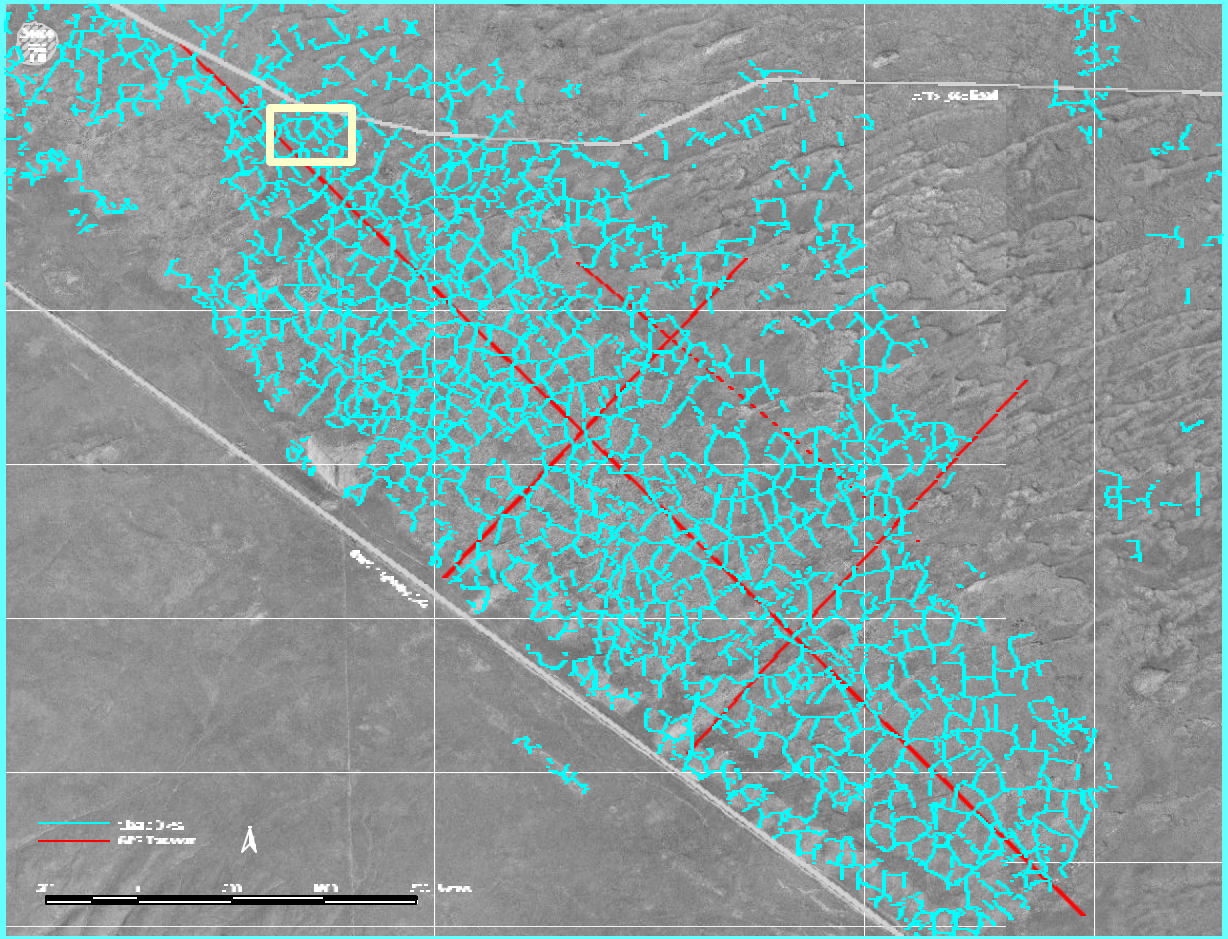
- Digital Mapping of Remote Imagery
- Field Mapping and Transects
- Analysis of Geometry Data
- Modeling of Dike Distribution and Structure



Determine Spatial Patterns (cont.)

- Mapping of Remote Imagery
  - Map aerial photographs into GIS
  - Identify potential transect and experiment sites
- Field Mapping and Transects
  - Verify remote imagery (ground truth)
  - Measure dike thickness and small dikes below resolution of imagery
  - Supplement transect information with GPR
    - check for unexposed dikes
    - map subsurface distribution of dikes in local areas

Mapping of Remote Imagery



Mapping of clastic dikes using remote imagery. Planned GPR transects shown.

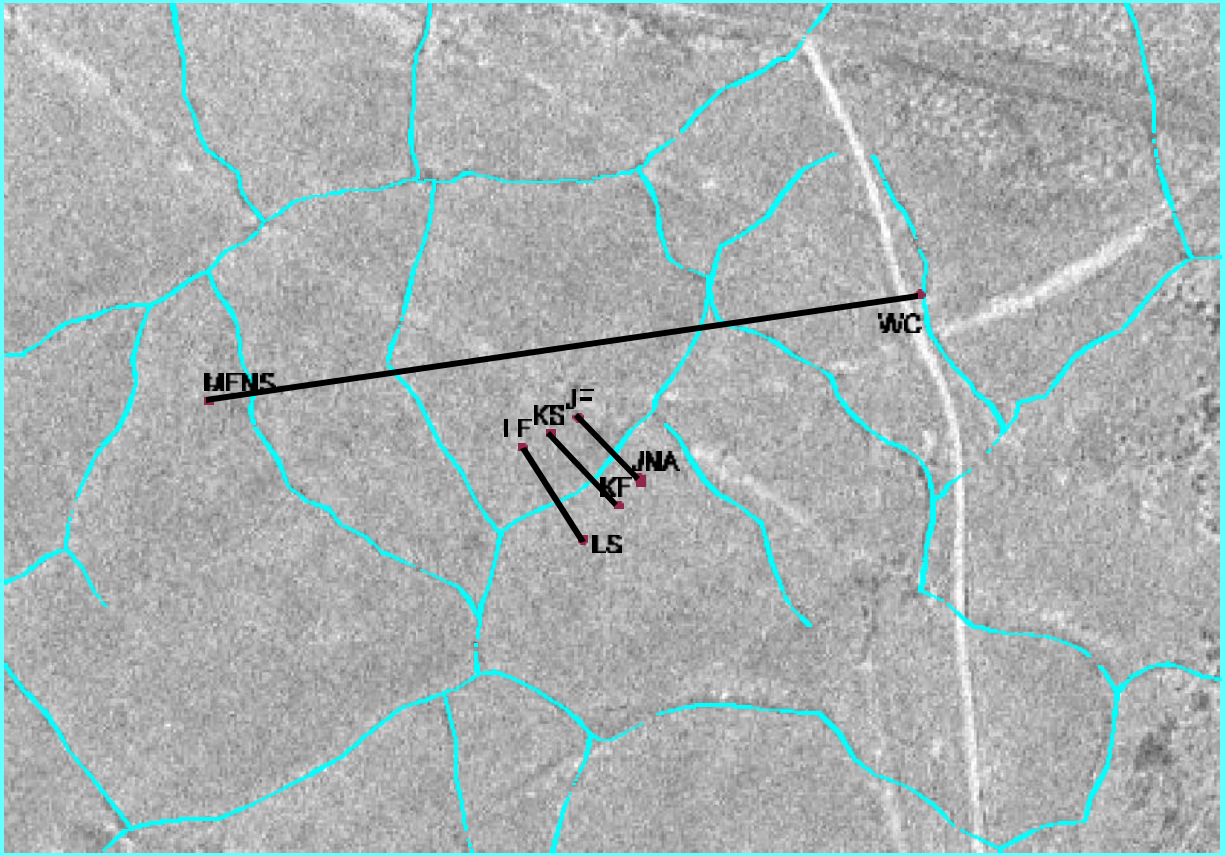
Determine Spatial Patterns (cont.)

- Analysis of Geometry Data
  - Conduct statistical analysis of digitized imagery and transect data
    - characterize geometry of dikes, including length, orientation, and thickness
    - Identify geometry of polygons
  - Conduct fractal analysis of clastic dikes
    - 2-D box counting of dike distribution from digitized imagery
    - analyze dike widths along transects

Geophysical Characterization

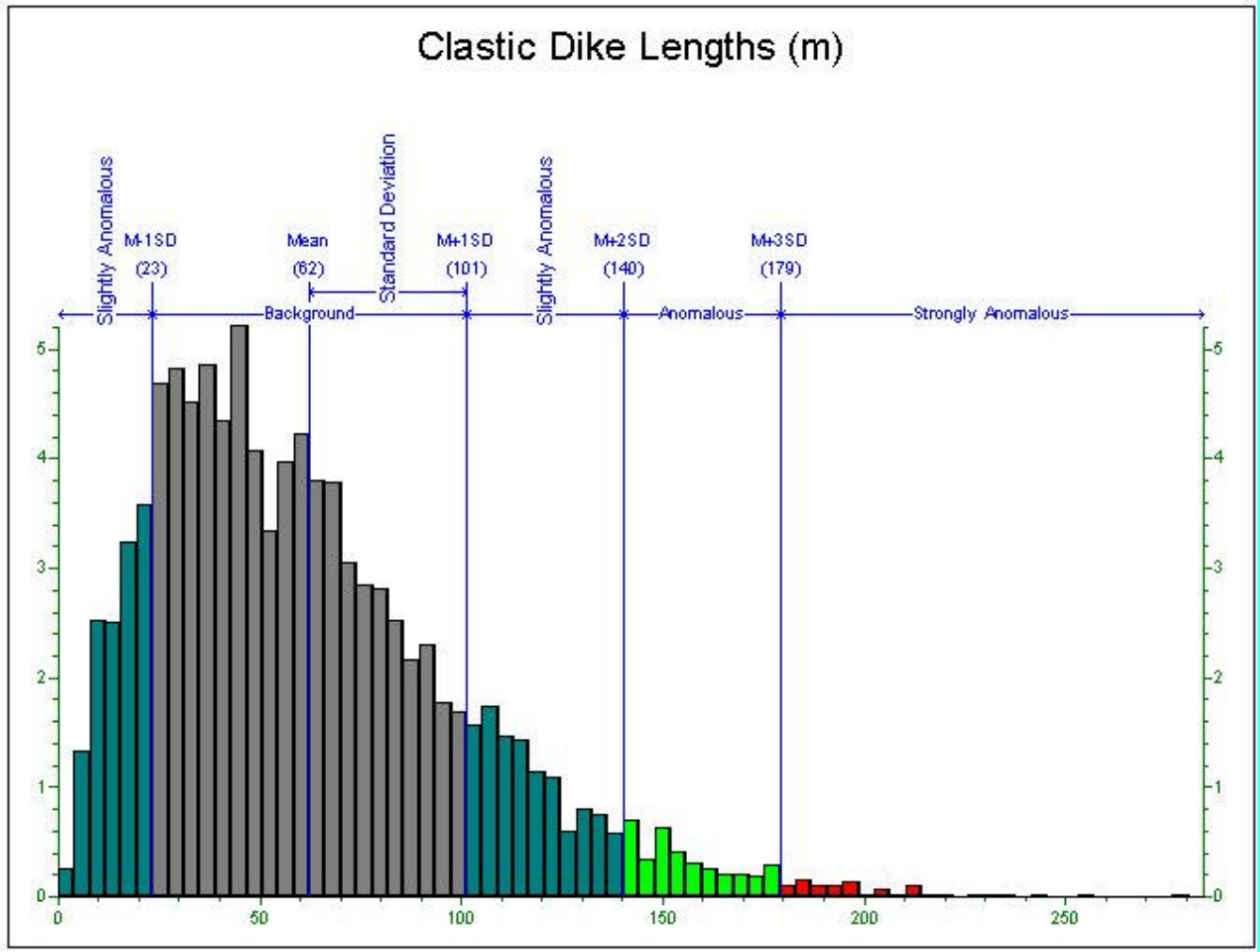
- GPR transects at Goose Egg Hill area
  - km-scale transects to be recorded by Boise State Univ. (see map on previous slide)
  - limited survey already performed by LBNL (next slide)
  - supplement geologic transect information
  - check for unexposed dikes
  - map subsurface distribution of dikes in local areas
- Collaborative effort with funded EMSP project
  - high frequency EM impedance technique
  - SNL/LBNL/UW-Madison project (Newman et al.)
  - deeper penetration than GPR

Geophysical Characterization (cont'd)



Location of GPR lines near Goose Egg Hill recorded by LBNL. EM survey also planned at that location by SNL/LBNL/UW-M EMSP project. Photomap area highlighted in yellow on previous image.

Preliminary Data Analysis



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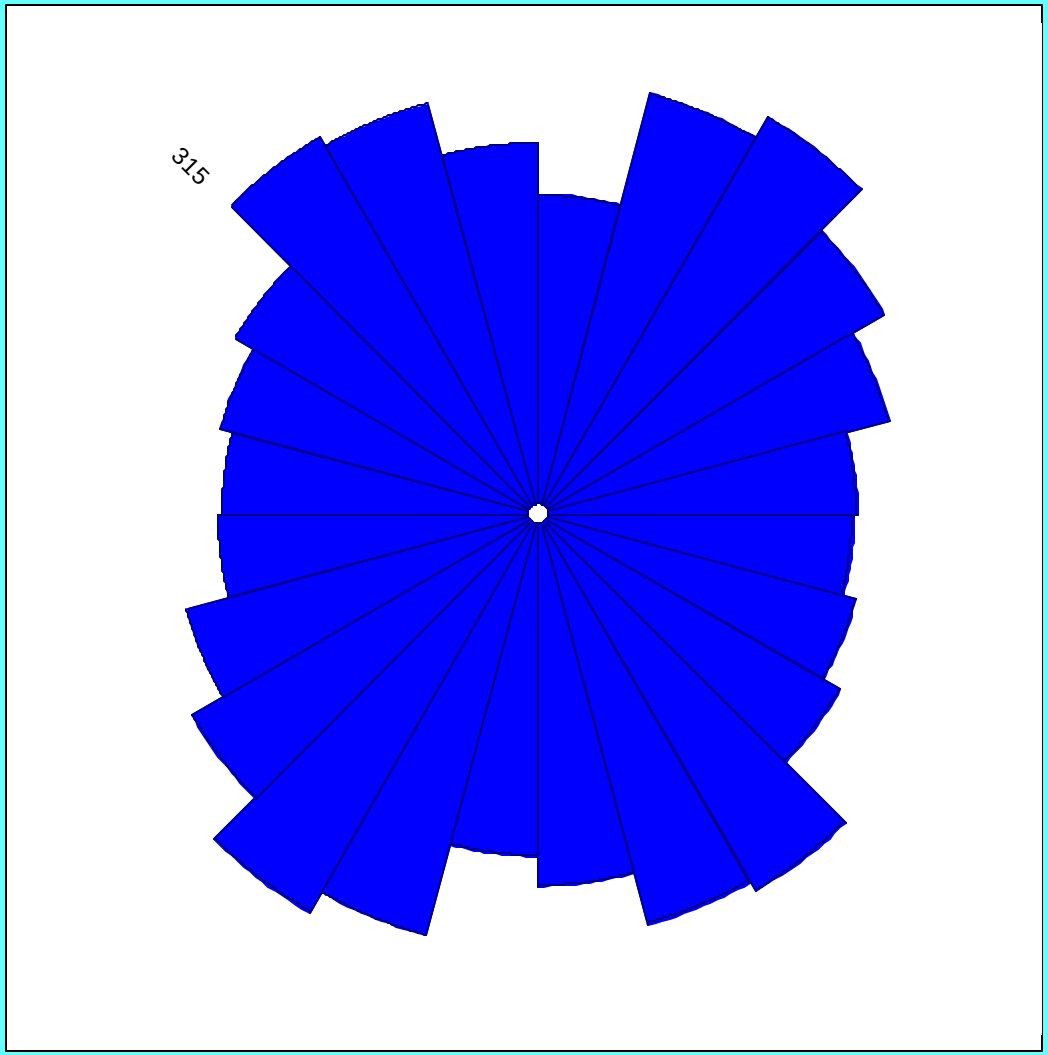
Preliminary Data Analysis (cont'd)



- Rose diagram of clastic dike orientations

Determine Spatial Patterns (cont.)

- Modeling of Dike Distribution and Structure
  - model will depend on spatial statistics of clastic dike distribution
  - fragmentation process will be used for simulation if fractal distribution is present
    - Acuna and Yortsos 1995
  - multiple-point stochastic simulation algorithm will be used if the dikes are non-fractal
    - reproduce complex, polygonal geometry
    - Wang (1996), Guardiano and Srivastava (1993)

Phase 2: Measure Properties

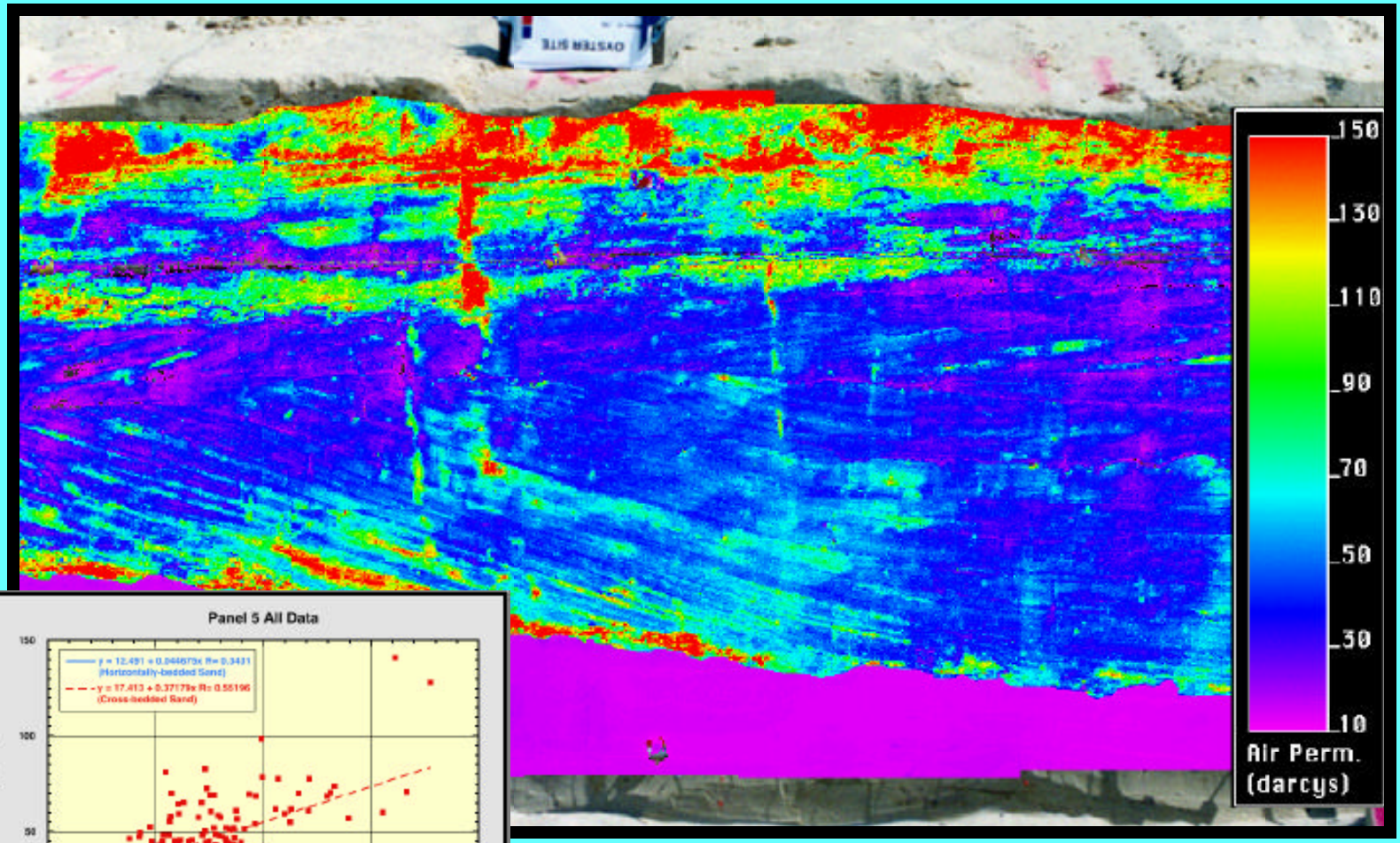
- Permeability Measurement and Estimation
  - Small scale (1 to 100 mm)
  - Variability
- Field Infiltration Experiment
  - Large scale (0.1 to 10 m)

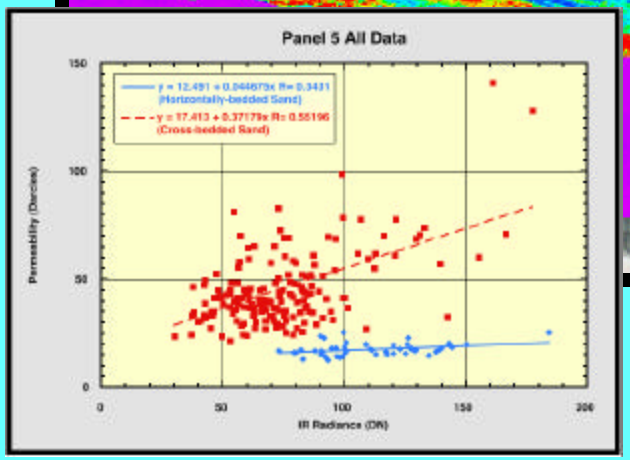
Measure Properties (cont.)

- Permeability Measurement and Estimation
  - Measure exposed dike and enclosing matrix
    - small scale (1 to 100 mm)
    - large sample size
    - spatial variability
  - Air-minipermeameter
    - large, but limited, number of accurate permeability measurements
  - Infrared imaging
    - continuous imaging of exposure
    - cm-scale resolution

Air-minipermeameter/IR Imaging

Air-miniperm./IR Imaging (cont.)





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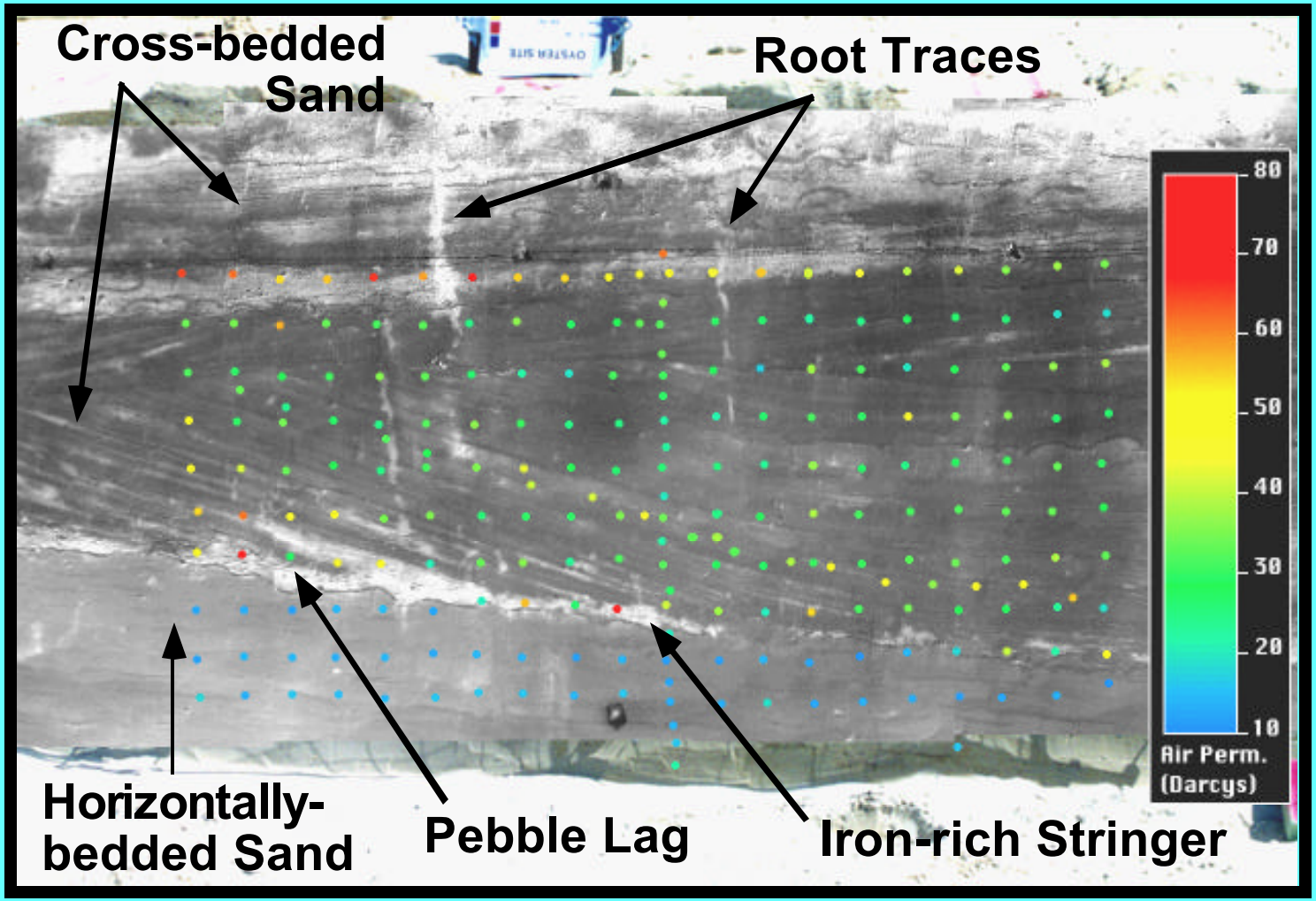
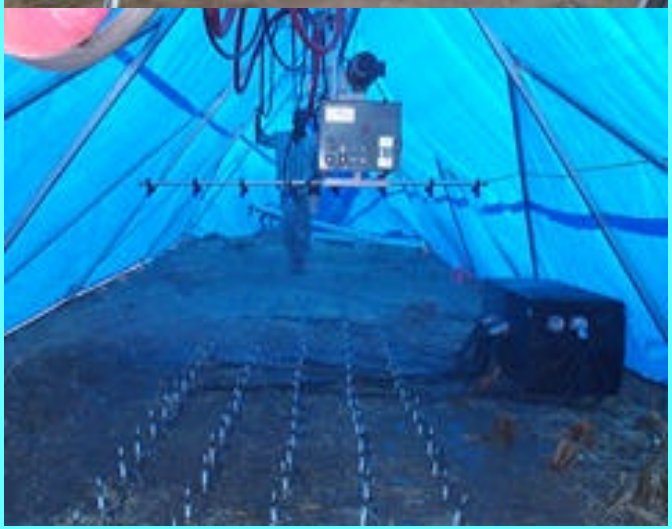
Air-minipermeameter/IR Imaging (cont.)



Measure Properties (cont.)

- Field Infiltration Experiment
  - Large scale (0.1 to 10 m)
  - Controlled Fluxes (water followed by KCl solution)
  - Independent measures (ERT; TDR) of water content and matric potential
  - Post experiment excavation and characterization of dike physical properties



Phase 3: Evaluate Effects

- Construct geostatistical model of experiment site
- Numerically model the infiltration experiment using multiple conceptual models

Geostatistical Model of Experiment Site

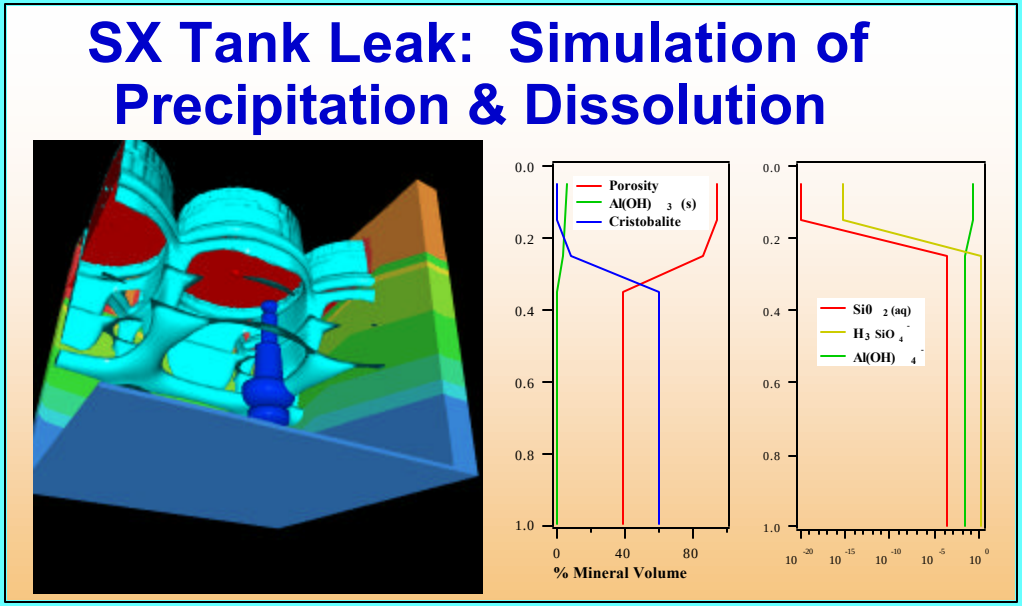
- Analyze spatial continuity of moisture and porosity
  - derived from ERT, TDR, and core samples
- Variogram analysis
  - separate analysis performed for matrix sediments and clastic dikes
    - anisotropy of two systems expected to be at right angles to one another
  - anisotropy ratios of each system estimated from infrared imaging and air-minipermeametry data

Geostatistical Model (cont.)

- Stochastic simulation of experimental site
  - borehole measurements treated as “hard” data
  - ERT will form more extensive “soft” data set
  - simulations performed using Markov-Bayes indicator simulation algorithm
    - reproduce expected cross-correlation between hard and soft data
  - provide detailed 3-D numerical grids of porosity and initial water contents
    - used as input to numerical flow modeling

Numerical Model of Experiment

- STOMP90
  - Fortran 90 with “parallel” directives
  - Scaler or parallel
  - Can handle as many as 108 nodes
  - Complex boundaries



Schedule/Status

- Year 1
  - Acquire and interpret aerial/satellite imagery (complete); conduct geological and geophysical field transects (in progress); data analysis (in progress); locate sites for air permeability and infiltration testing
- Year 2
  - Complete statistical, geostatistical, and fractal analyses of dike network data; install sensors for field infiltration and conduct testing
- Year 3
  - Produce geostatistical models of infiltration site; model infiltration test; evaluate hypothesis

Anticipated Scientific Products

- Large-scale fractal/geostatistical models of clastic dike distribution
- Detailed models of hydraulic property distribution within clastic dikes
- Integrated field/modeling studies of moisture flux through clastic dikes
- Determination if clastic dikes provide preferential flow paths in the vadose zone at Hanford

Acknowledgements

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