

Influence of Paleosols on Fluid Flow
and Transport: Perspective on
Alluvial Complexity and
Hydrogeology

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NSF, CA Water Resources Center,
Monterey County Water Resources Agency,
USGS, EPA Center for Ecological Health
Research, UC Agricultural Exp. Station

Collaborators/Contributors

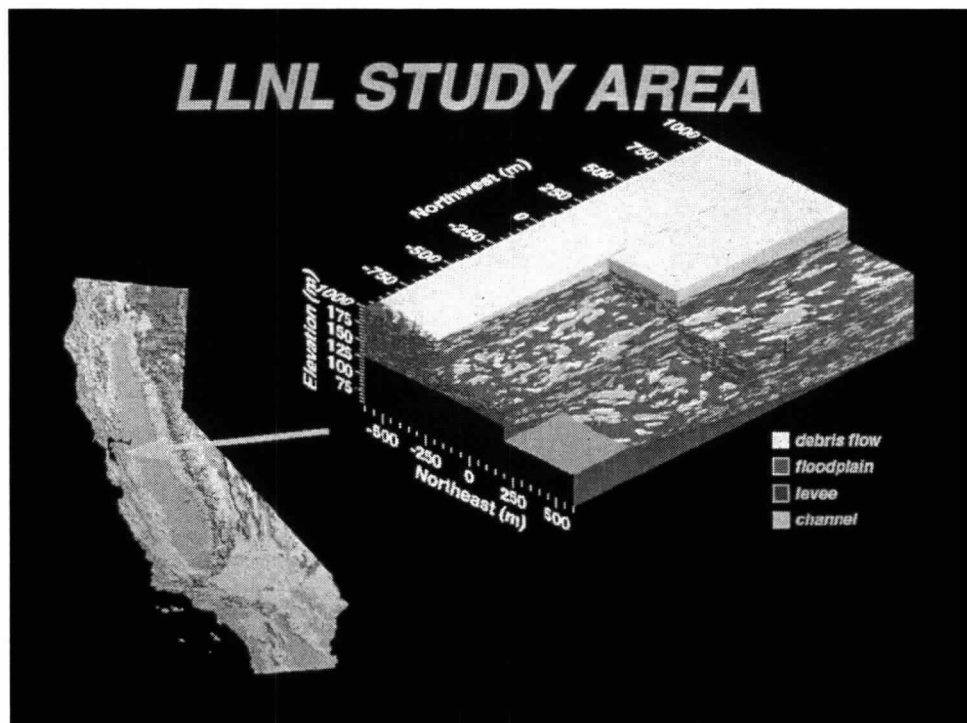
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Eric M. LaBolle*
Steve Carle*
Lisa Maserjian*

Dennis Rolston
Ken Versosub

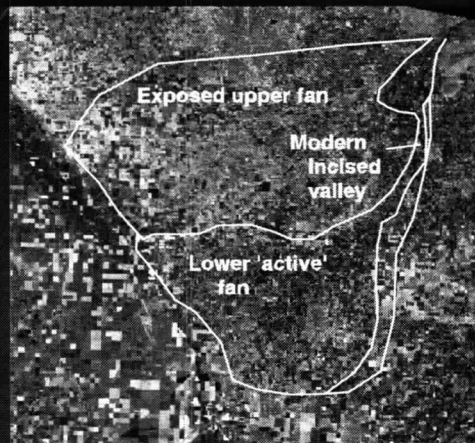
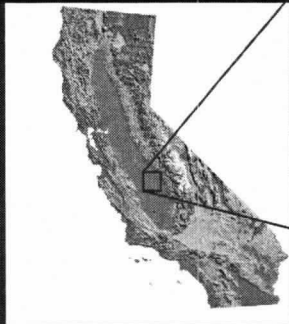
Jeff Mount

* *Thesis/Dissertation work*



Kings River Fan Aquifer System

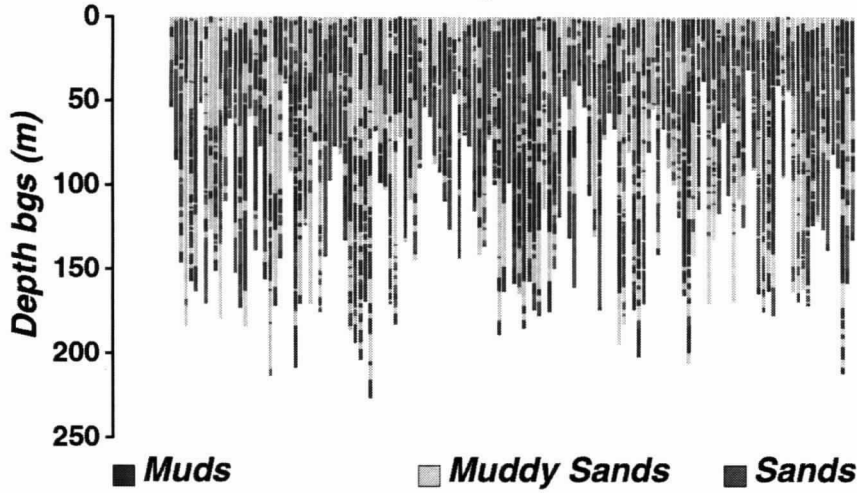
- Stream-dominated alluvial fan system (fluvial depositional system);
- Located southeast of Fresno, California;
- Study area located in medial fan area.



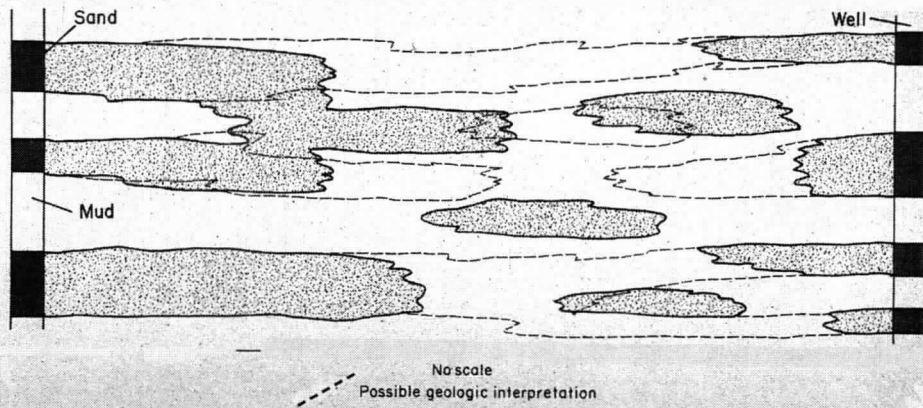
Salinas Valley

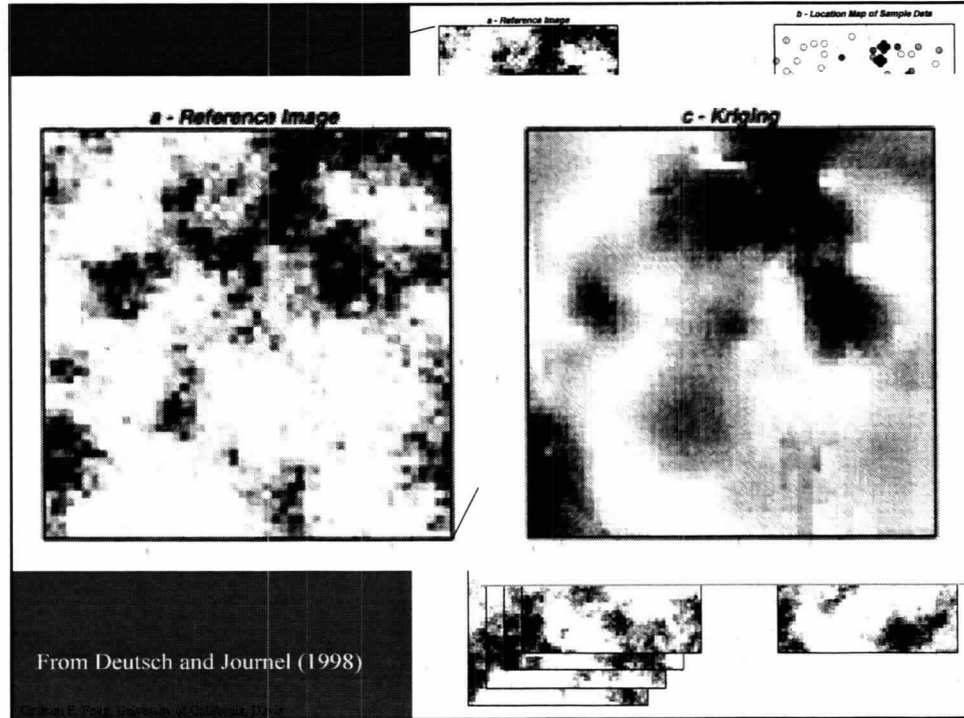


Driller's Logs Salinas Valley, California



To Correlate, Or Not to Correlate?





From Deutsch and Journel (1998)

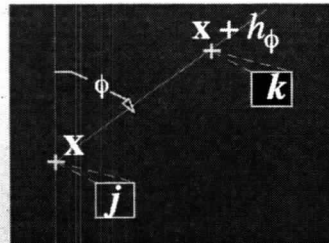
Transition Probability Definitions

From Probability Theory:

$$t_{jk}(h_\phi) = \Pr\{k \text{ occurs at } x + h_\phi \mid j \text{ occurs at } x\}$$

w.r.t. Indicator Variables:

$$t_{jk}(h_\phi) = \frac{E\{I_j(x)I_k(x + h_\phi)\}}{E\{I_j(x)\}}$$



Transition Probability Matrix

Facies →

1

.....

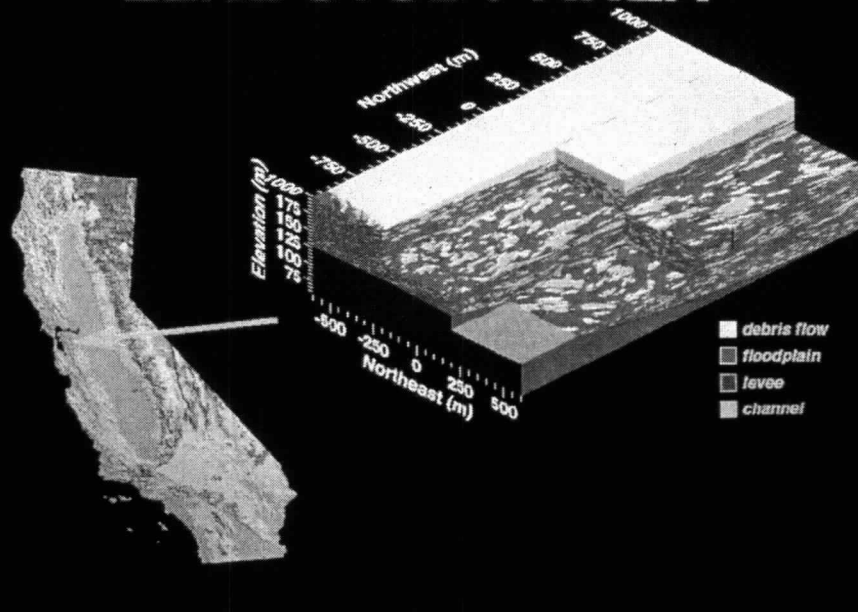
K

$$\mathbf{T}(h_\phi) = \begin{bmatrix} t_{11}(h_\phi) & L & t_{1K}(h_\phi) \\ M & O & M \\ t_{K1}(h_\phi) & L & t_{KK}(h_\phi) \end{bmatrix}$$

↓
1
⋮
K

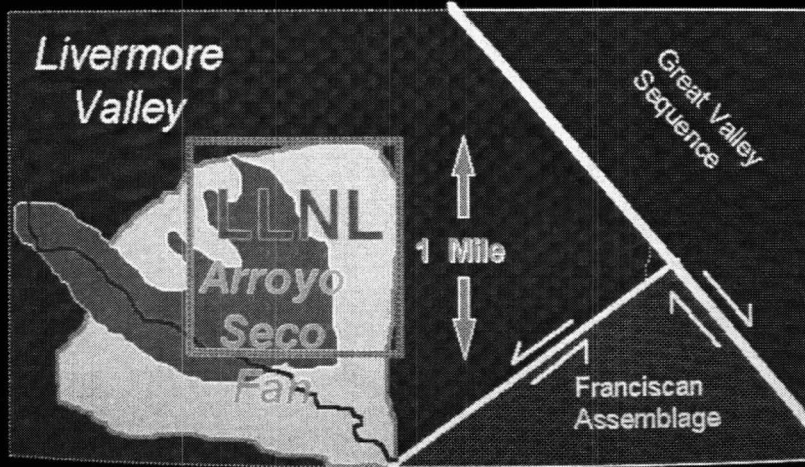


LLNL STUDY AREA

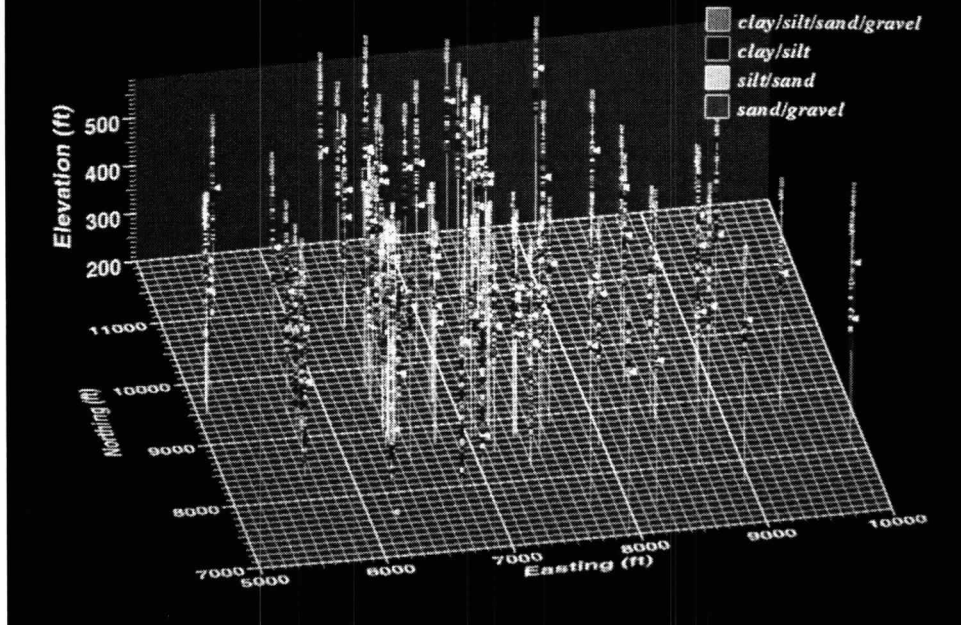


Location Map

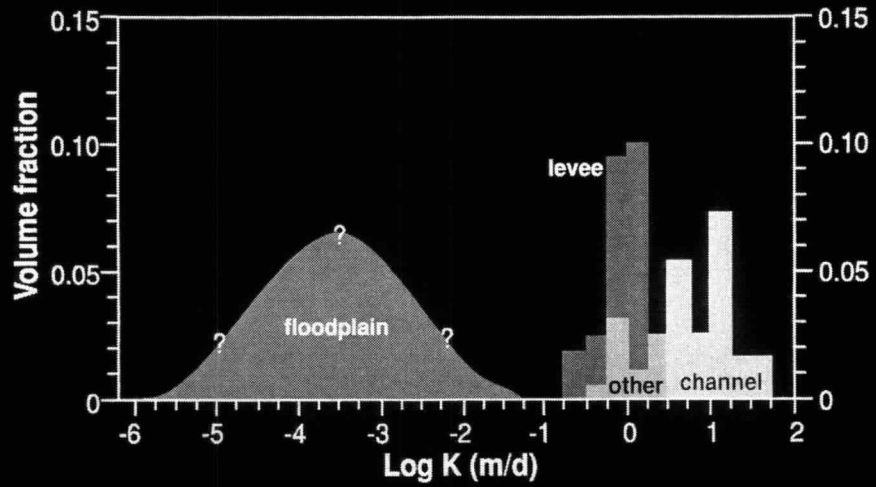
Lawrence Livermore National Laboratory (LLNL)



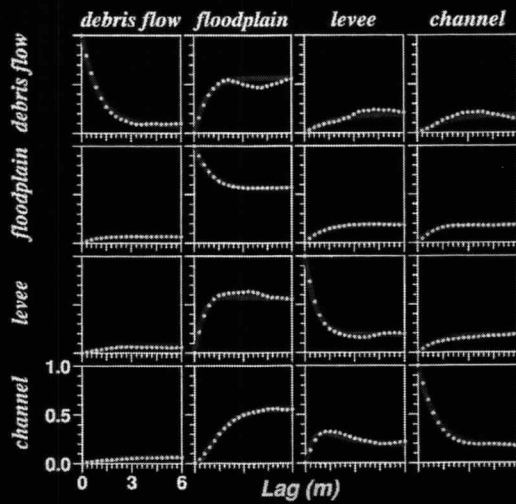
Core Data, Detailed Study Area, LLNL



Hydraulic Conductivity, Adjusted for Proportions



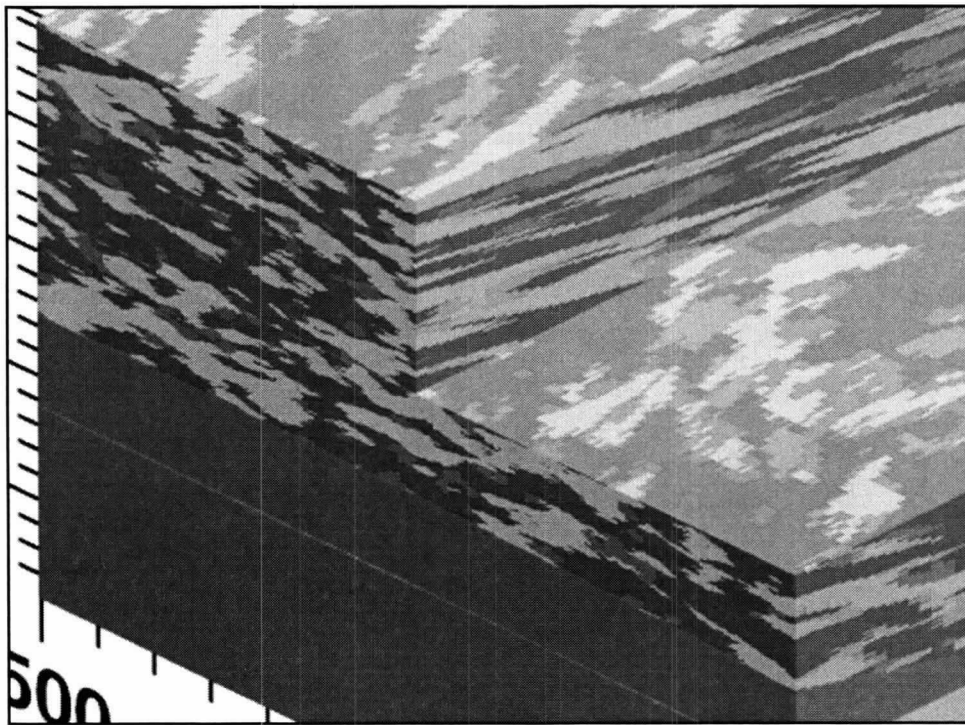
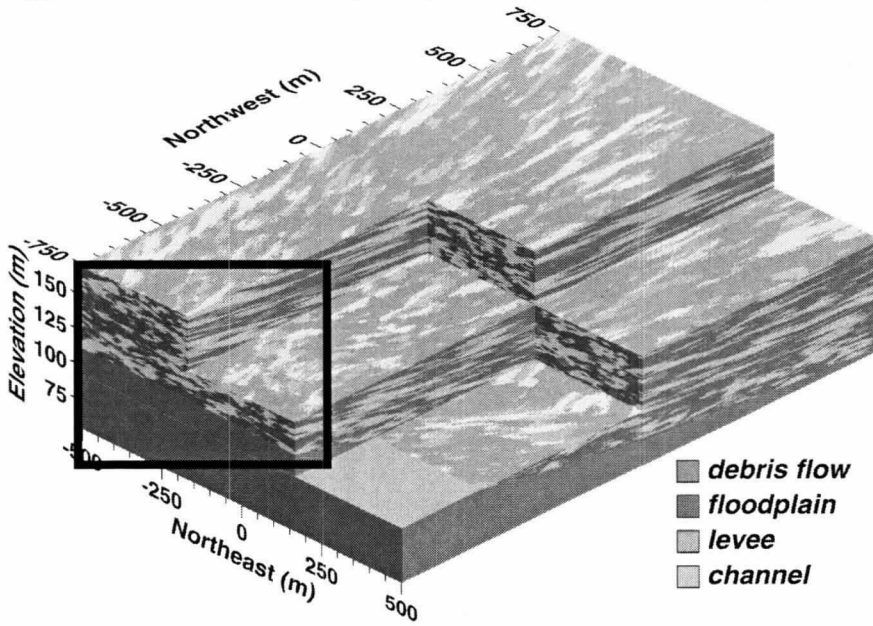
Transition Probability Vertical Direction



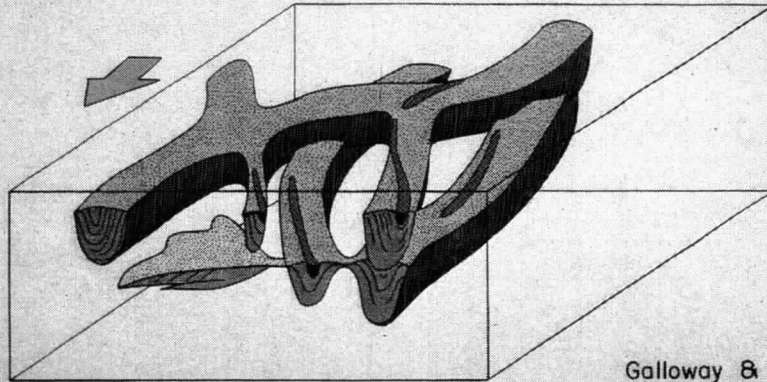
Measured

Markov Chain Model

Typical Subsurface Complexity, LLNL Site (Carle & Fogg, 1996)



FACIES ARCHITECTURE



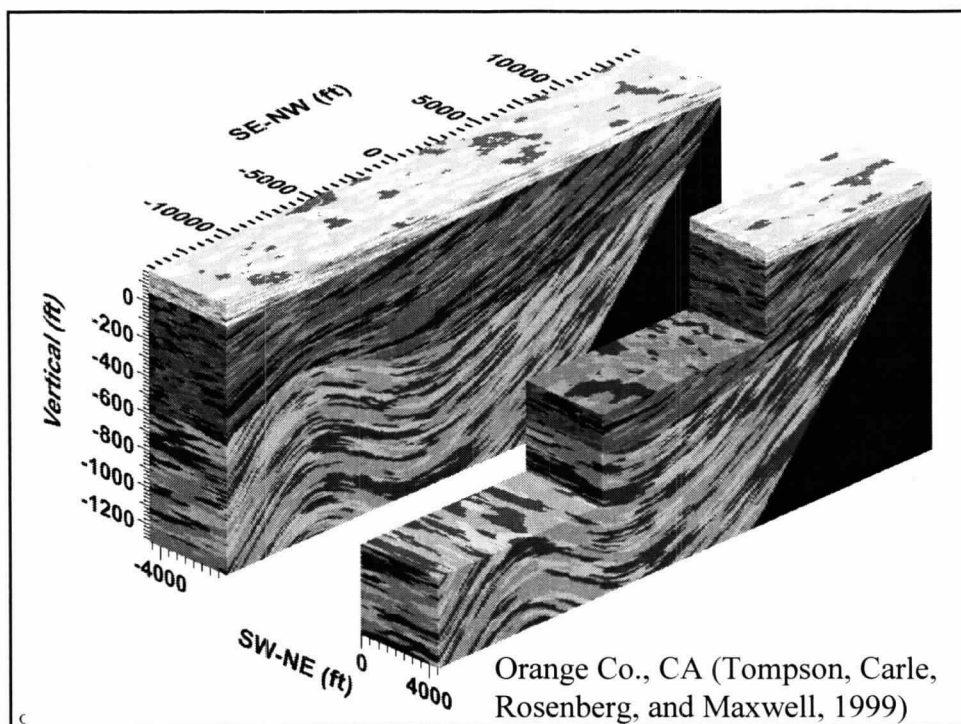
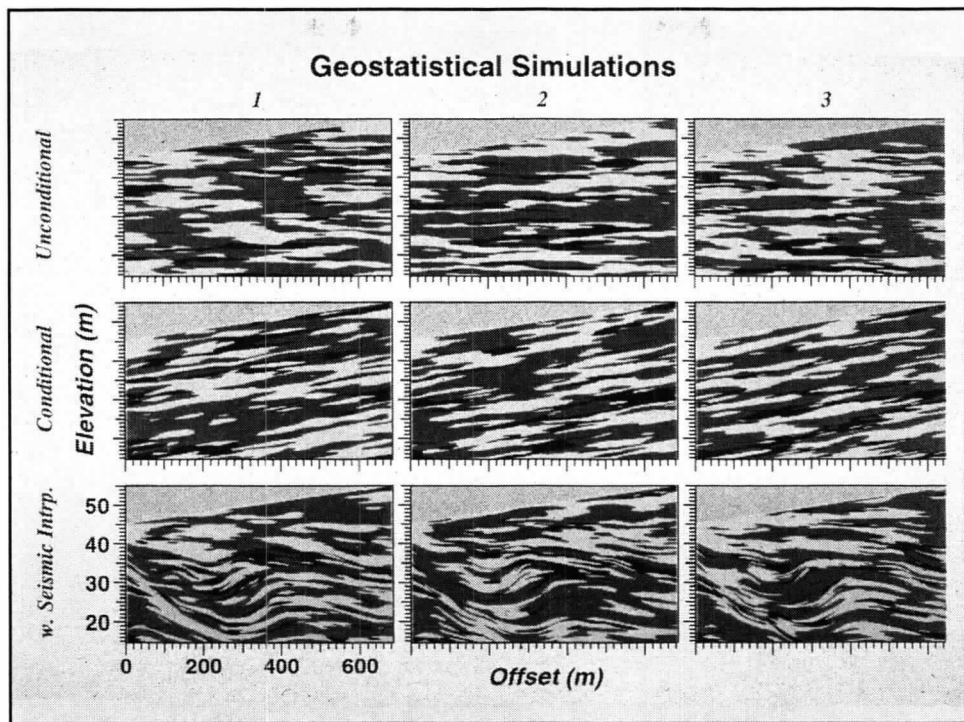
Suspended-load channel

Galloway &
Hobday 1983

Bureau of Economic
Geology QA-2480

Consequences of Heterogeneity

Movie of LLNL results.....



Understanding Alluvial Fans: A Sequence Stratigraphic Approach

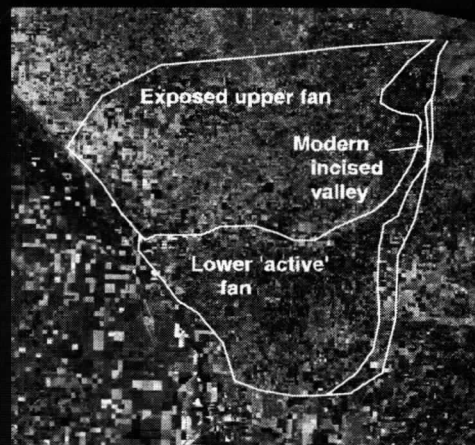
Gary S. Weissmann

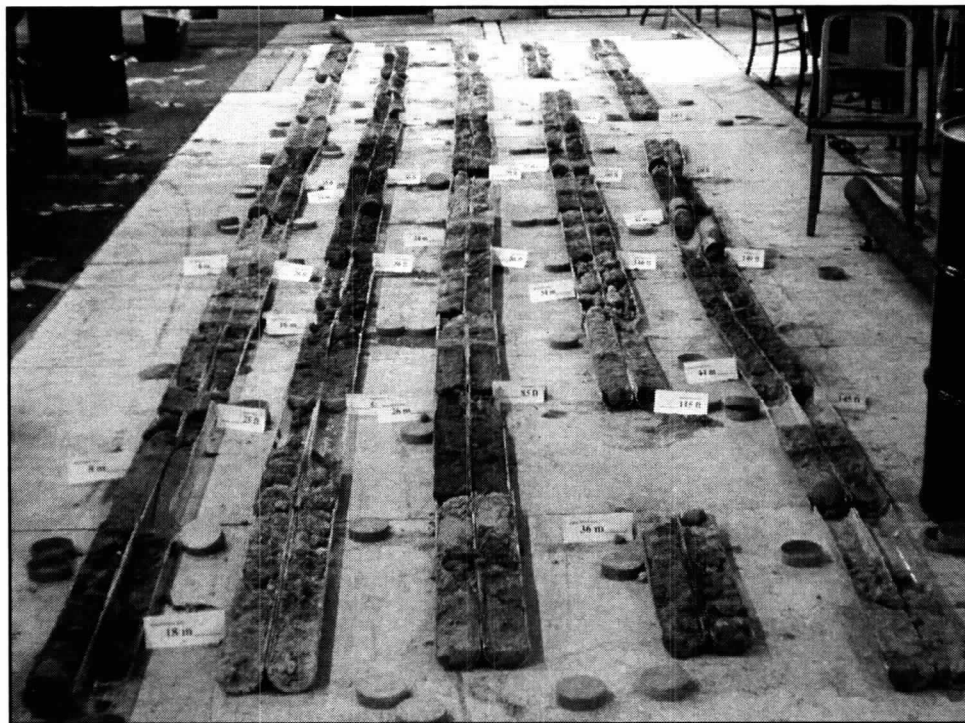
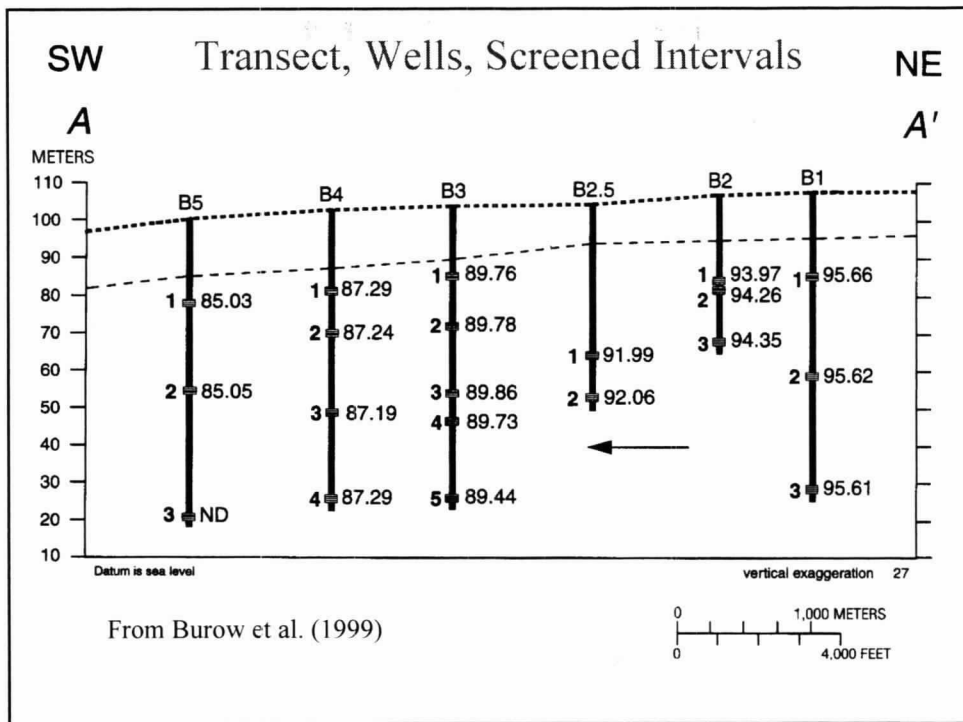
Hydrologic Sciences
University of California, Davis

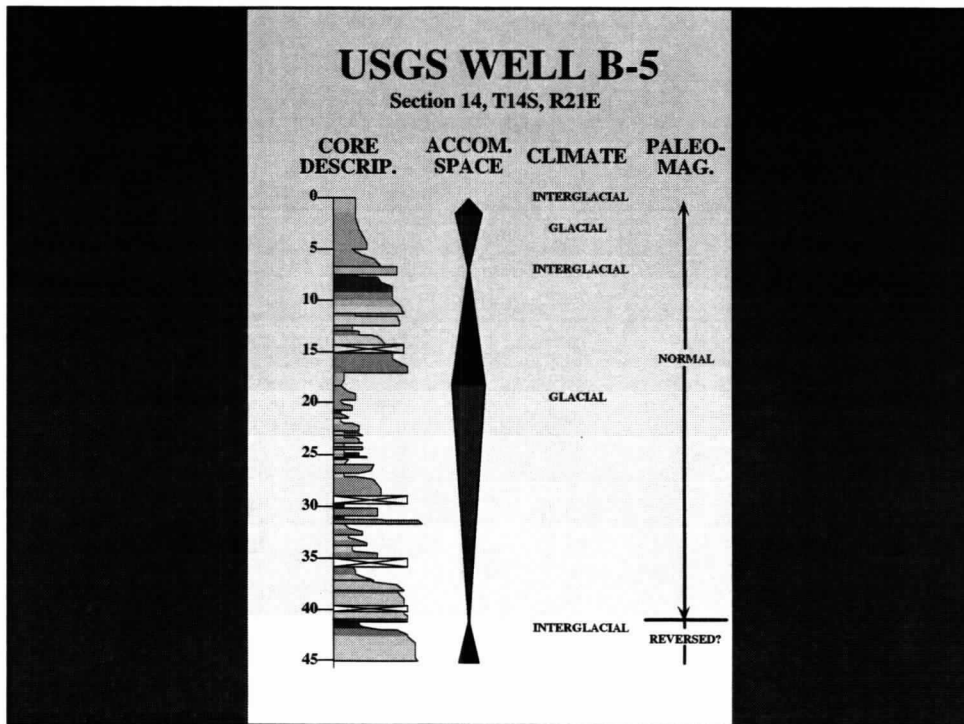
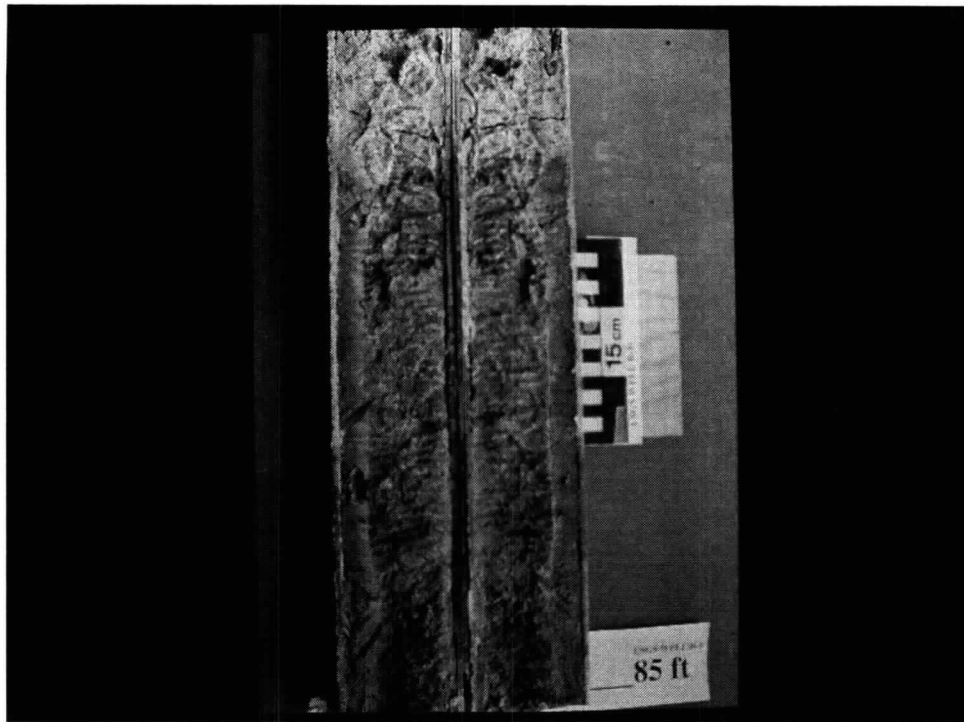
Graham E. Fogg, University of California, Davis

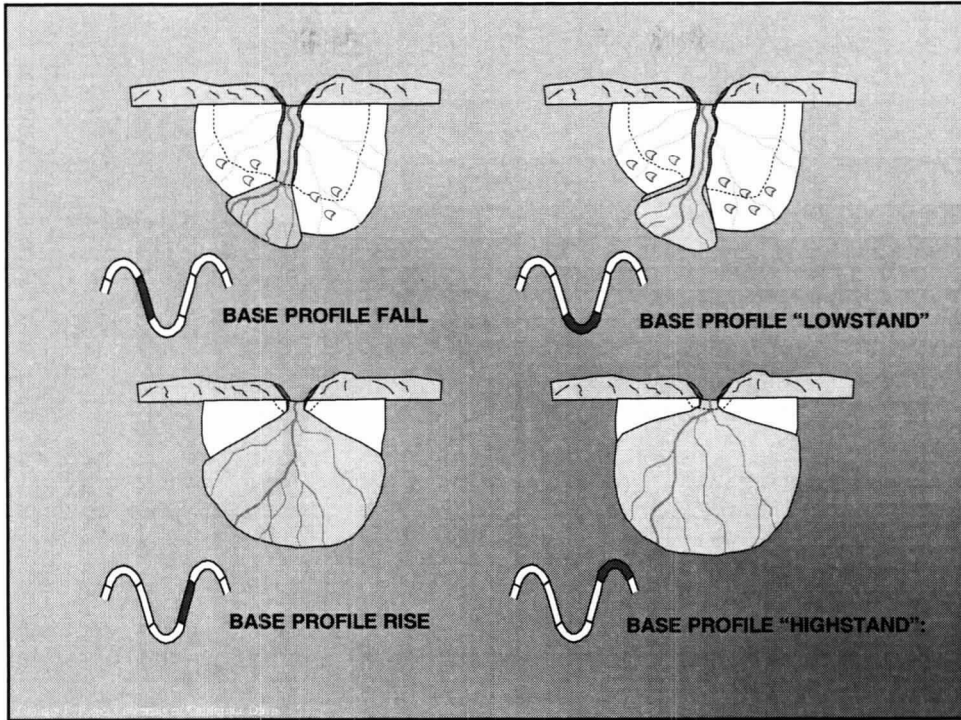
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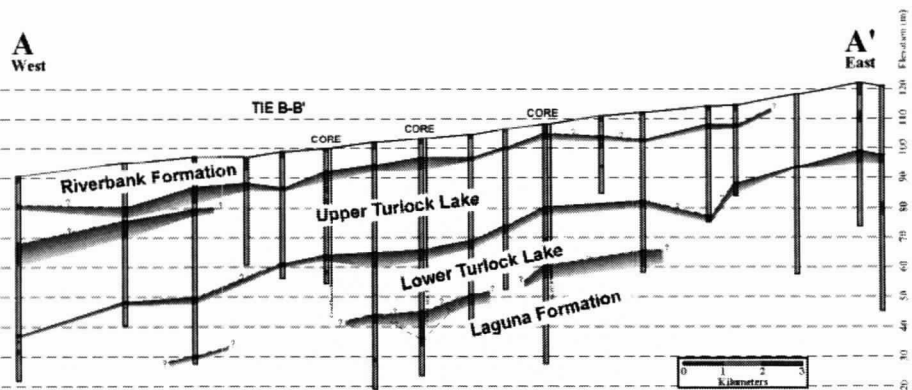






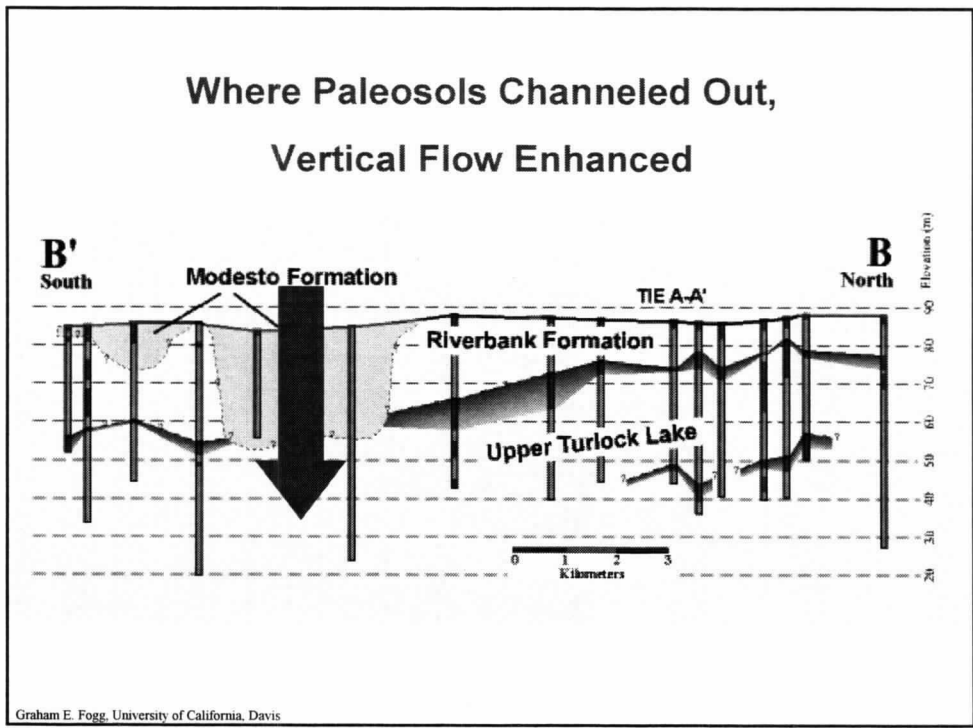
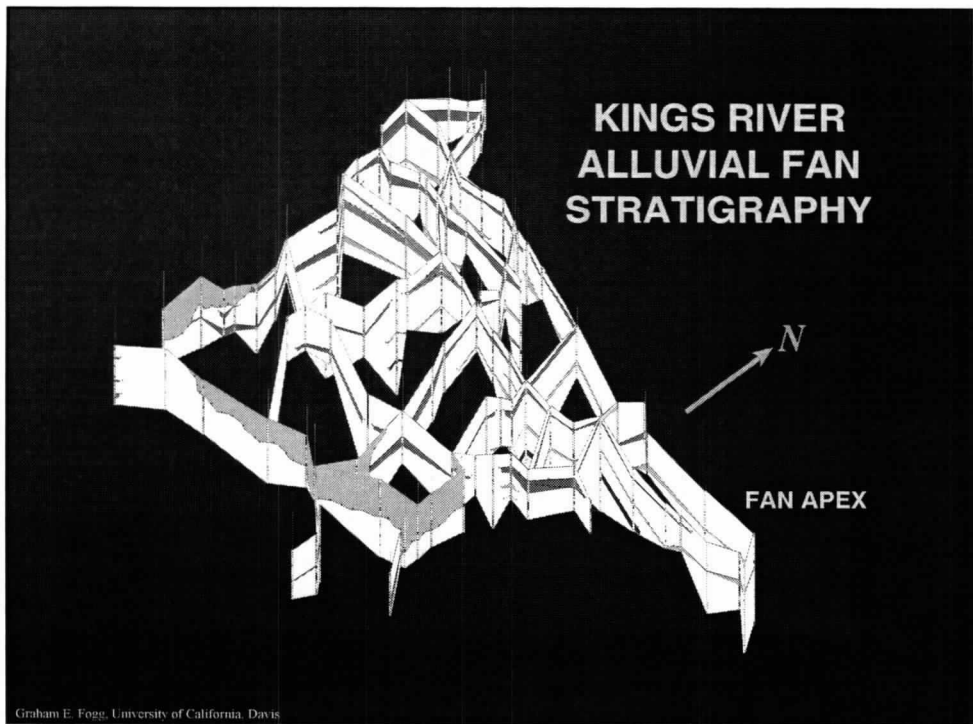


Sequence Stratigraphic Organization; Paleosol Aquitards

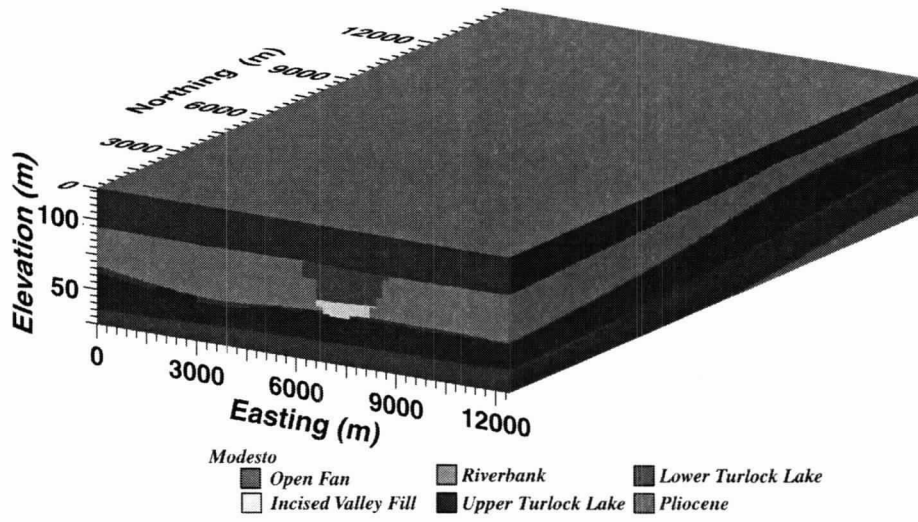


Weissmann & Fogg, 1999

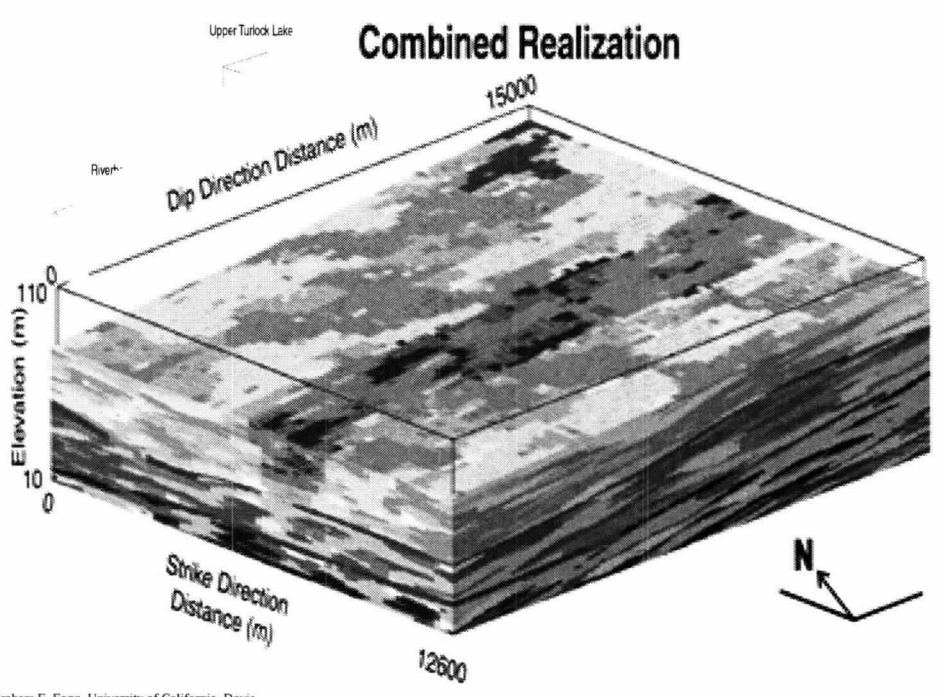
Graham E. Fogg, University of California, Davis

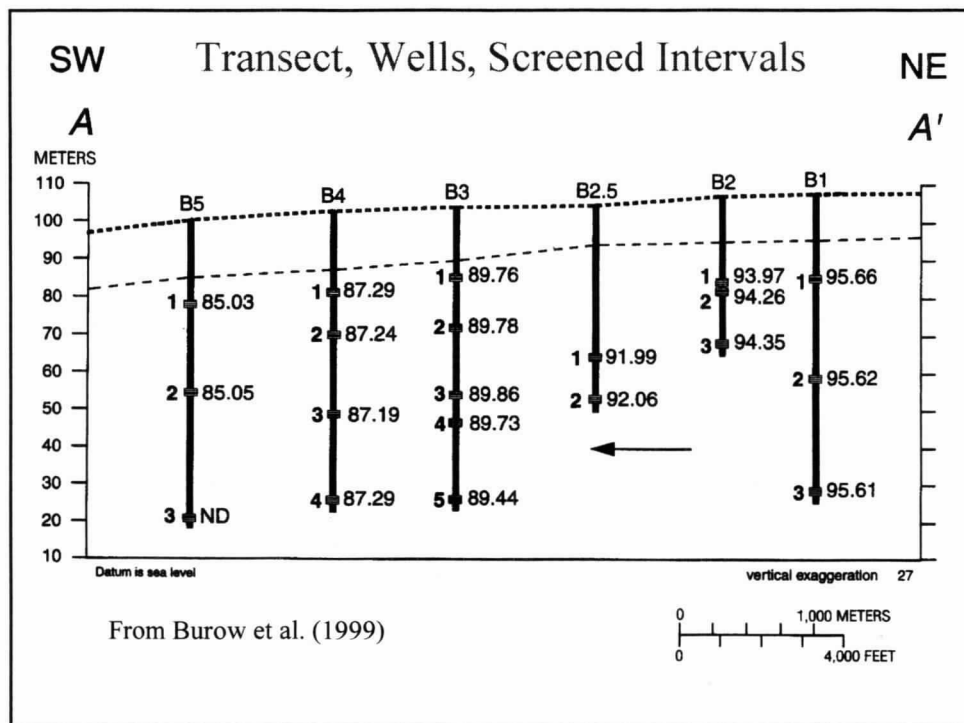
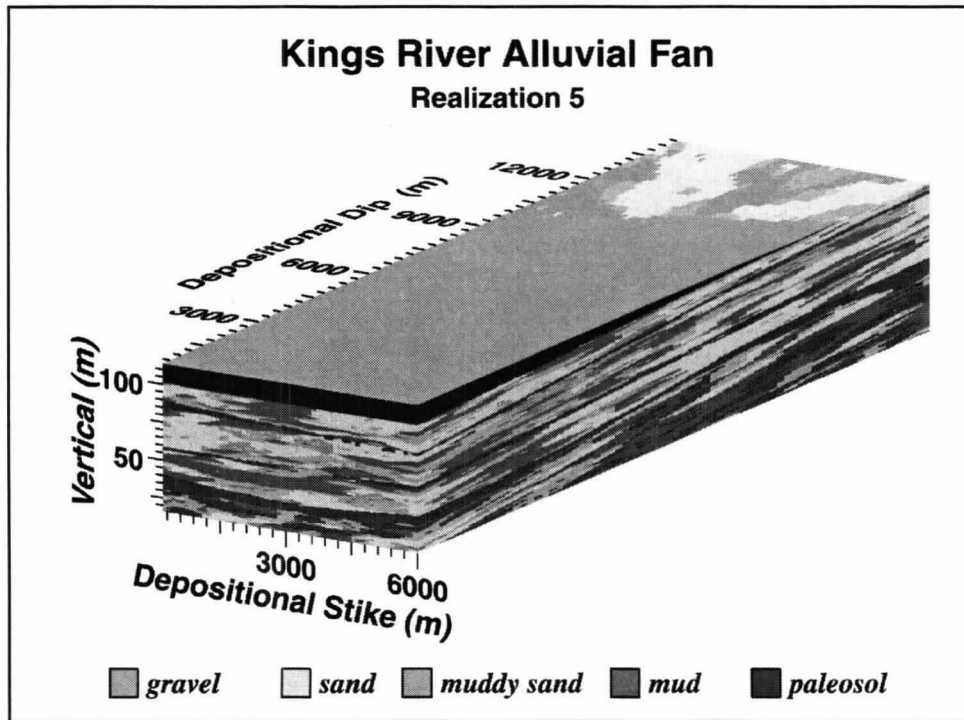


Sequence Stratigraphic Units for Non-Stationary Conditional Simulation



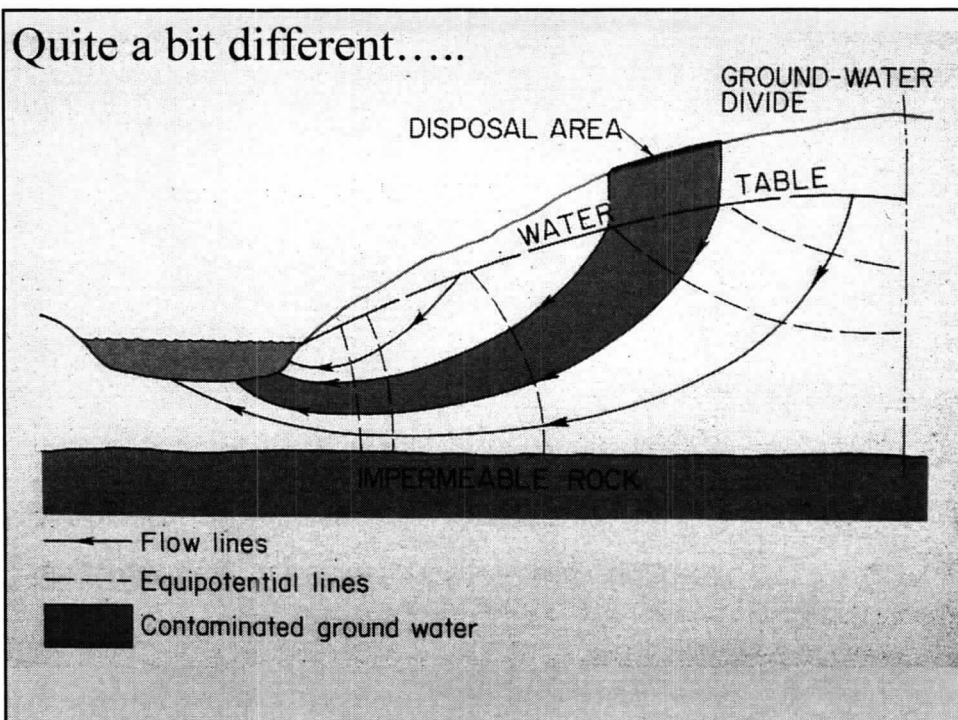
Combined Realization





Groundwater Age:

Elapsed time since a water
“particle” entered the
saturated zone.



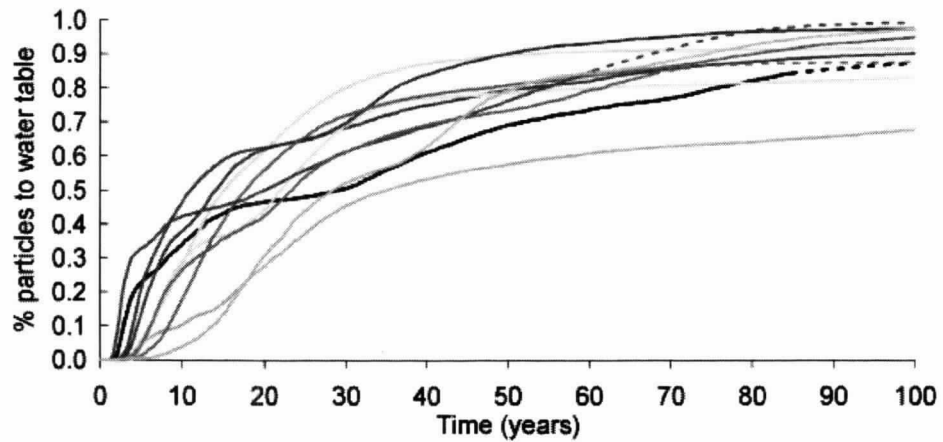
Backward Tracking Results: Heterogeneous

QuickTime™ and a GIF decompressor are needed to see this picture.

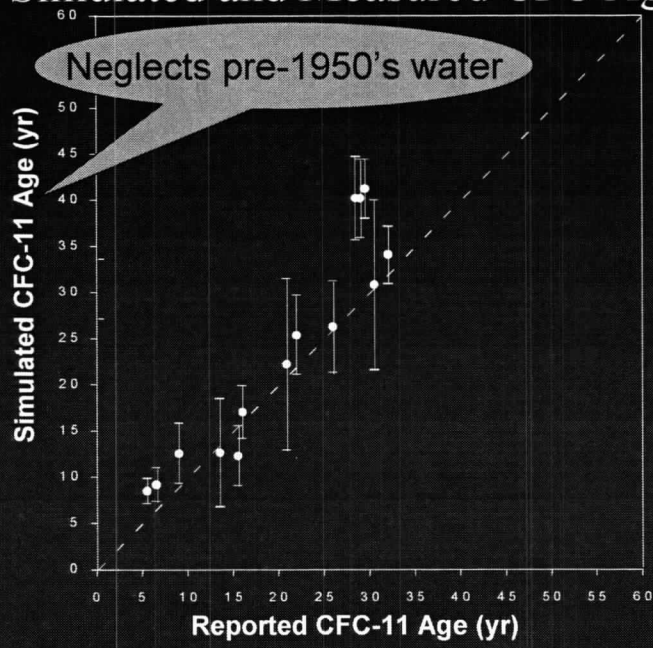
Graham E. Fogg, University of California, Davis

Groundwater age distributions for well B4-2 (screen depth: 35.1 m)

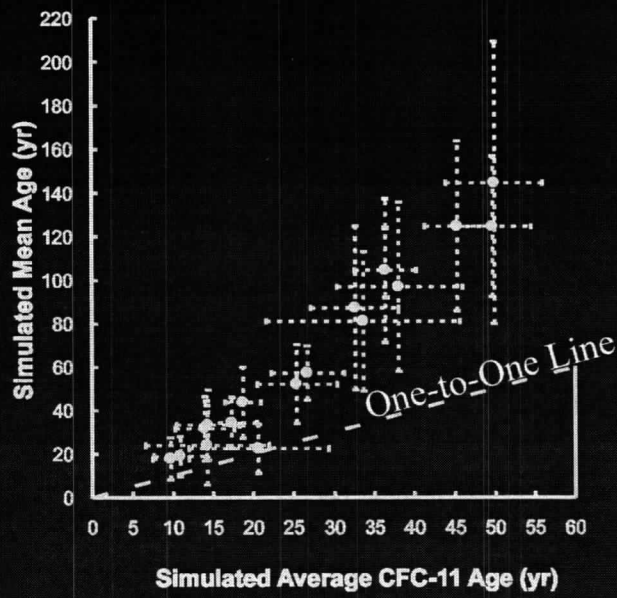
C. WELL B4-2



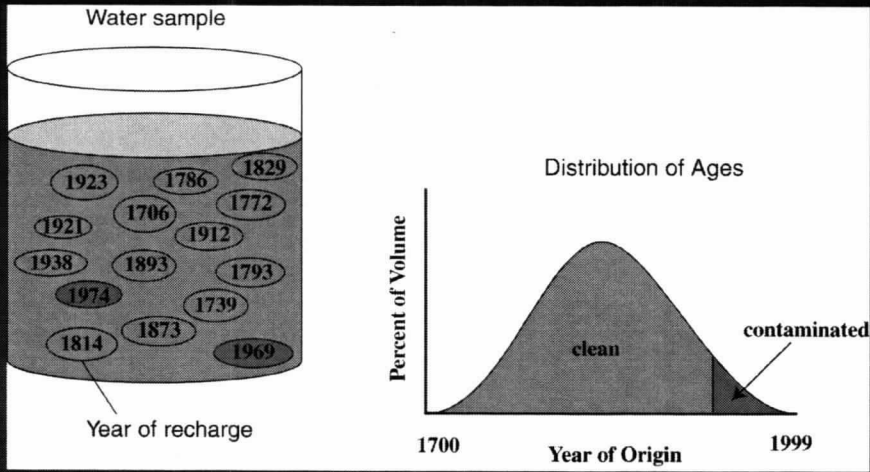
Simulated and Measured CFC Age



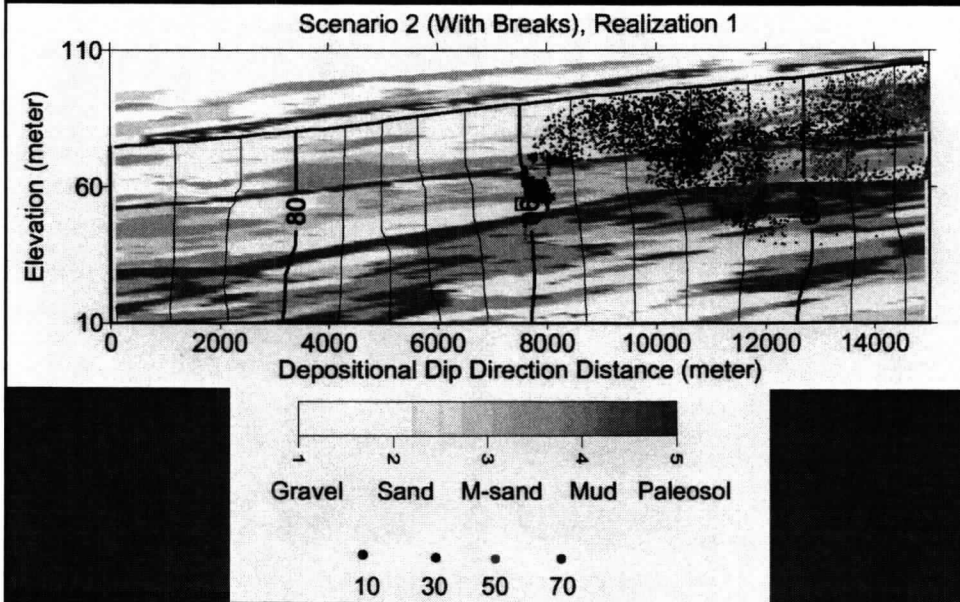
Simulated Mean Age vs Simulated CFC Age



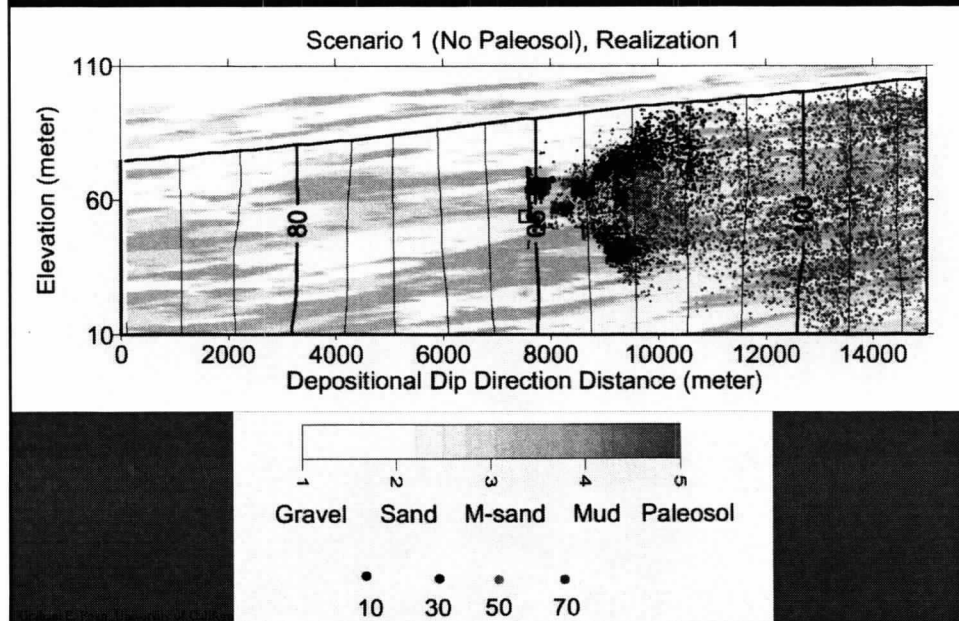
Essence of an Age Distribution



Backward Tracking Results: Heterogeneous, Paleosols



Backward Tracking Results: Heterogeneous, No Paleosols



Summary

- Hydrofacies (geologic) approach provides added perspective on hydrogeologic processes.
- Transition probability, Markov chain method (TProGS) generates heterogeneous models (realizations) that honor the data AND geologic fundamentals.
- TP-MC approach allows relatively easy incorporation of geologic information.
- Sequence-stratigraphic approach enhances characterization of the Kings River alluvial fan.
- Paleosols can be mapped regionally in KRF and are aquitards.

Summary continued

- Typical alluvial heterogeneity leads to significant dispersion of groundwater ages within water samples, even when samples are collected from short-screen wells.
- Significant age dispersion confounds interpretation of estimated or inferred groundwater ages.
- Conventional, nearly-homogeneous models of groundwater flow and transport can be grossly misleading when used to forecast groundwater travel times.