Significance of Fluvial/Alluvial Stratigraphy in Conceptual Models of Monitored Natural Attenuation

Effects on Chlorinated Solvent and 1,4-dioxane Fate and Transport

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From Detailed Fluvial/Alluvial Stratigraphy to a Site Conceptual Model for Monitored Natural Attenuation

1. Environmental Sequence Stratigraphy: roots in the oil and gas world
2. Sequence Stratigraphy in numerical models
3. Upscaling stratigraphy to model properties
4. Capturing uncertainty
5. Benefits of these exercises

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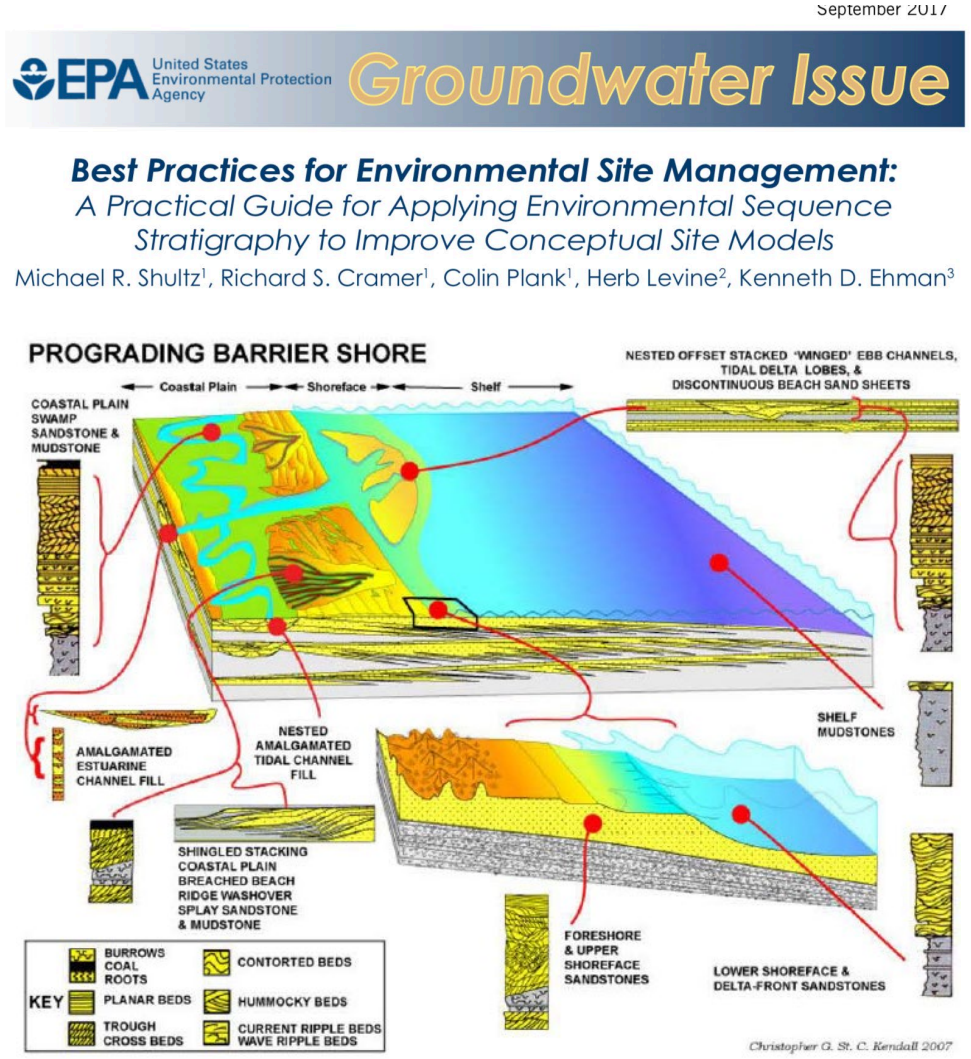
Environmental Sequence Stratigraphy



- Very useful tools for interpretation and site conceptual models.
- Not as easy to apply quantitatively.
- Groundwater models that incorporate high-resolution stratigraphy are challenging (and expensive) to construct
- Key limitation: what is the maximum detail of interpretation supported by the data?
- Other geologic disciplines struggle with the same issues.

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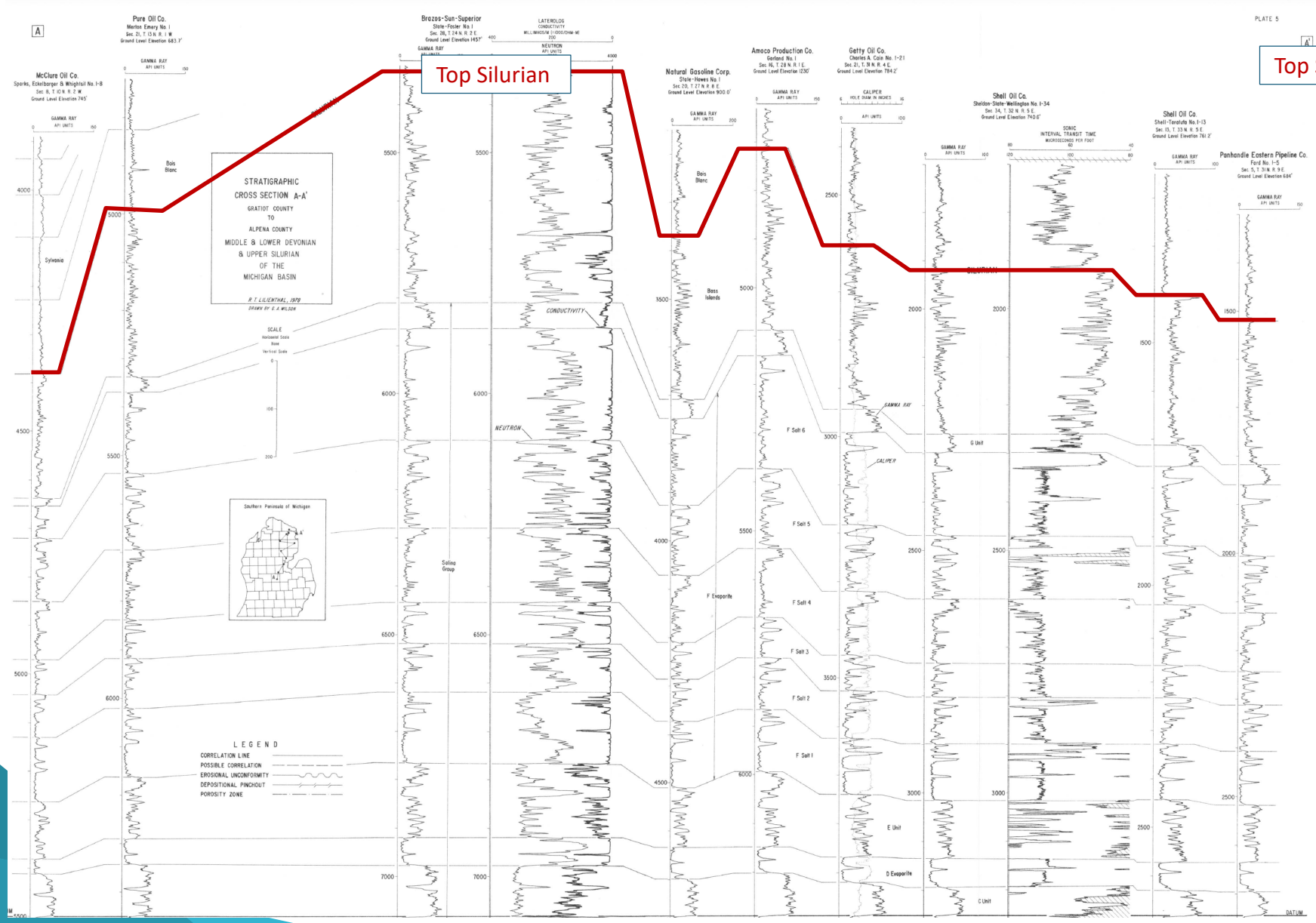
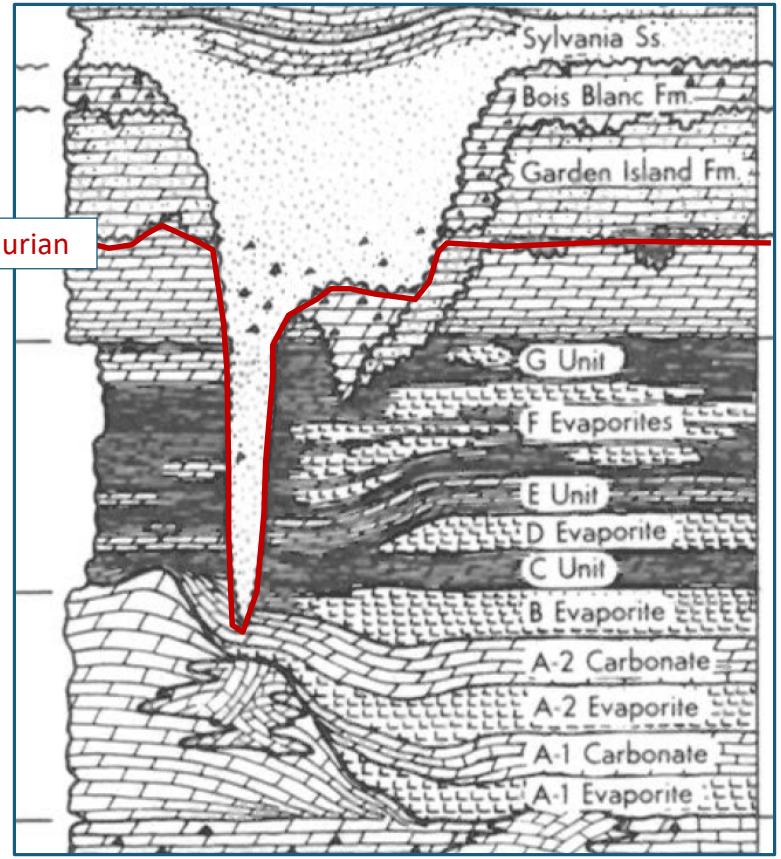
Classic Sequence Stratigraphy: Well Ties





From Lilienthal, 1978

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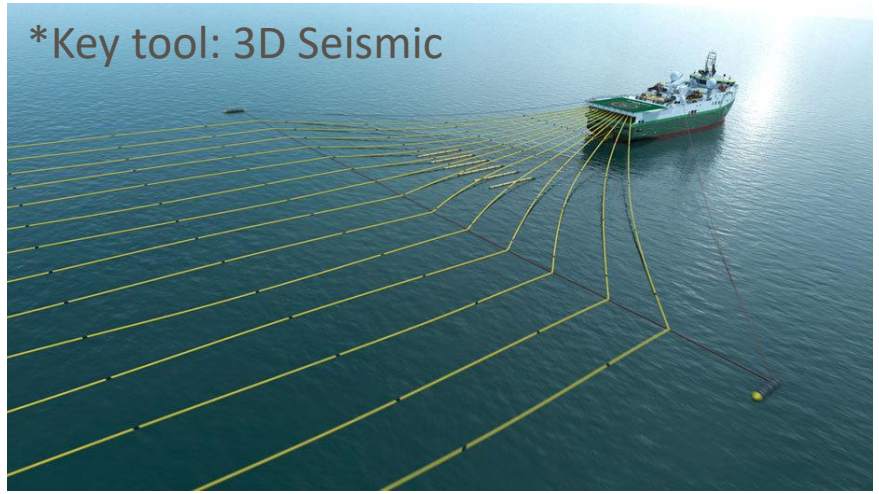
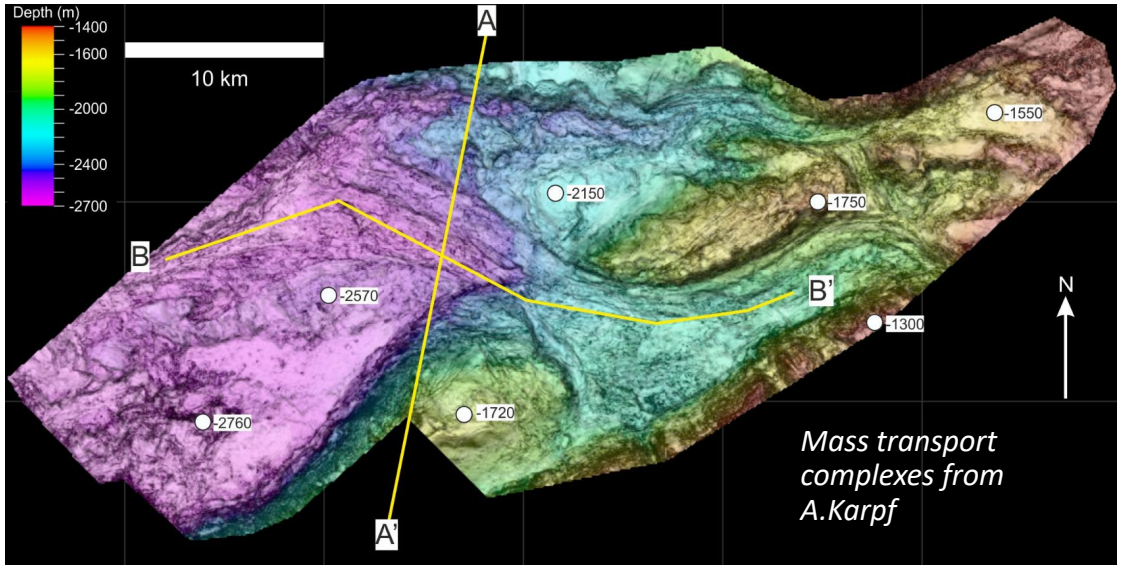
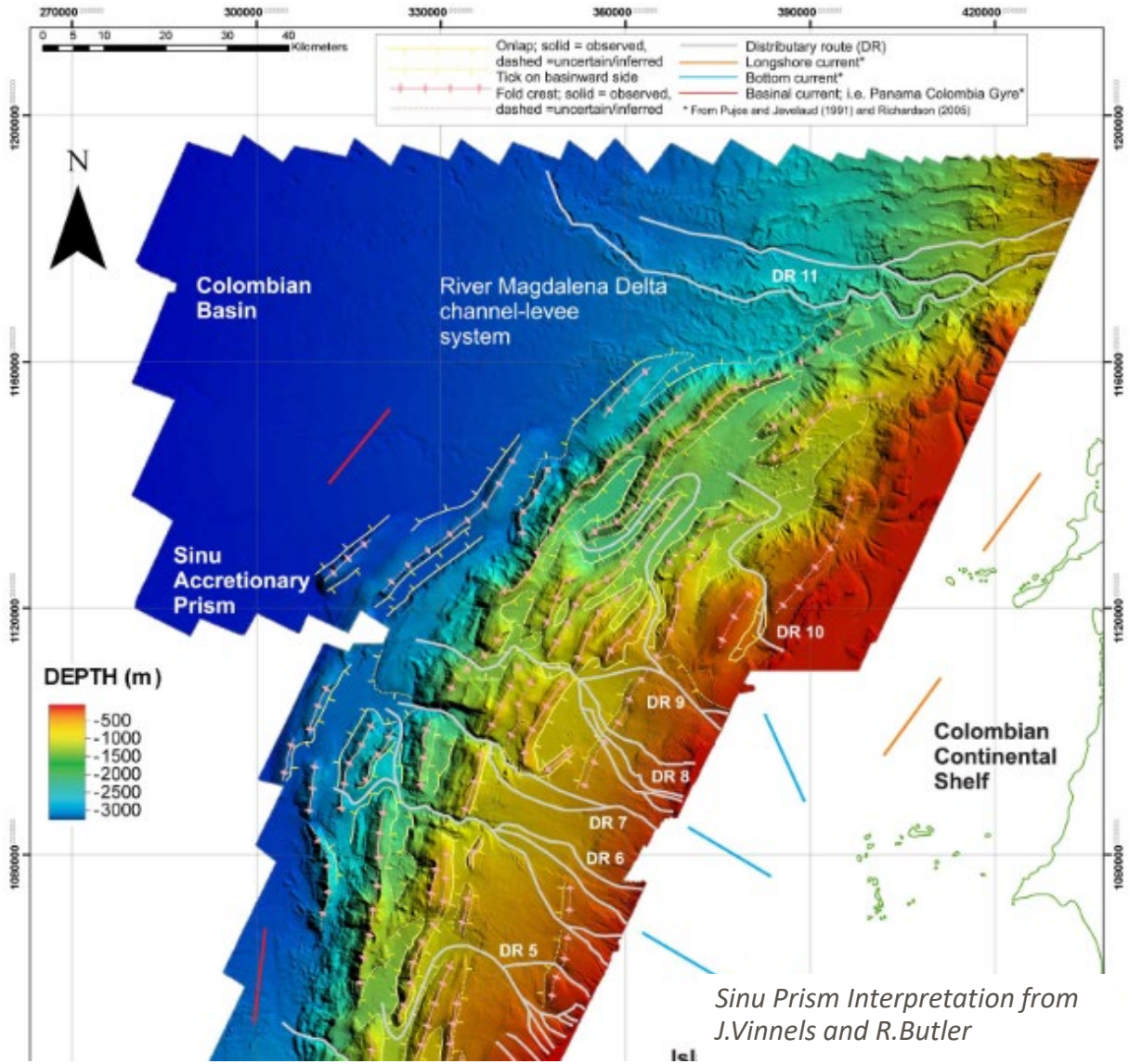
Sequence Stratigraphy with Modern 3D Seismic Surveys



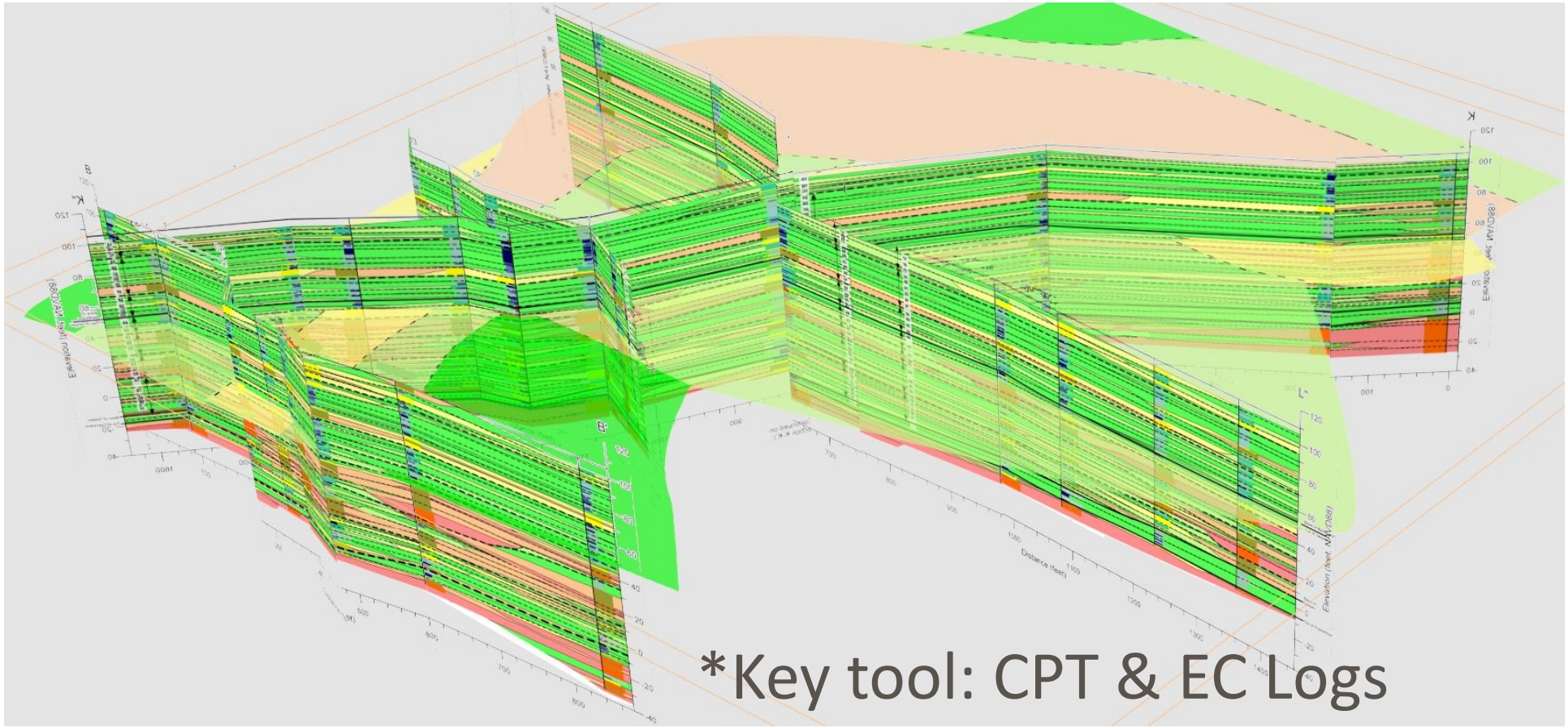




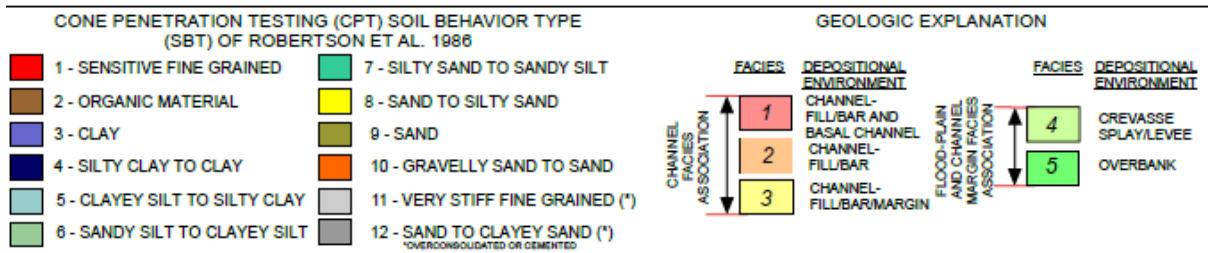
Sinu Prism Interpretation from J.Vinnels and R.Butler

Examples from Virtual seismic atlas: www.seismicatlas.org

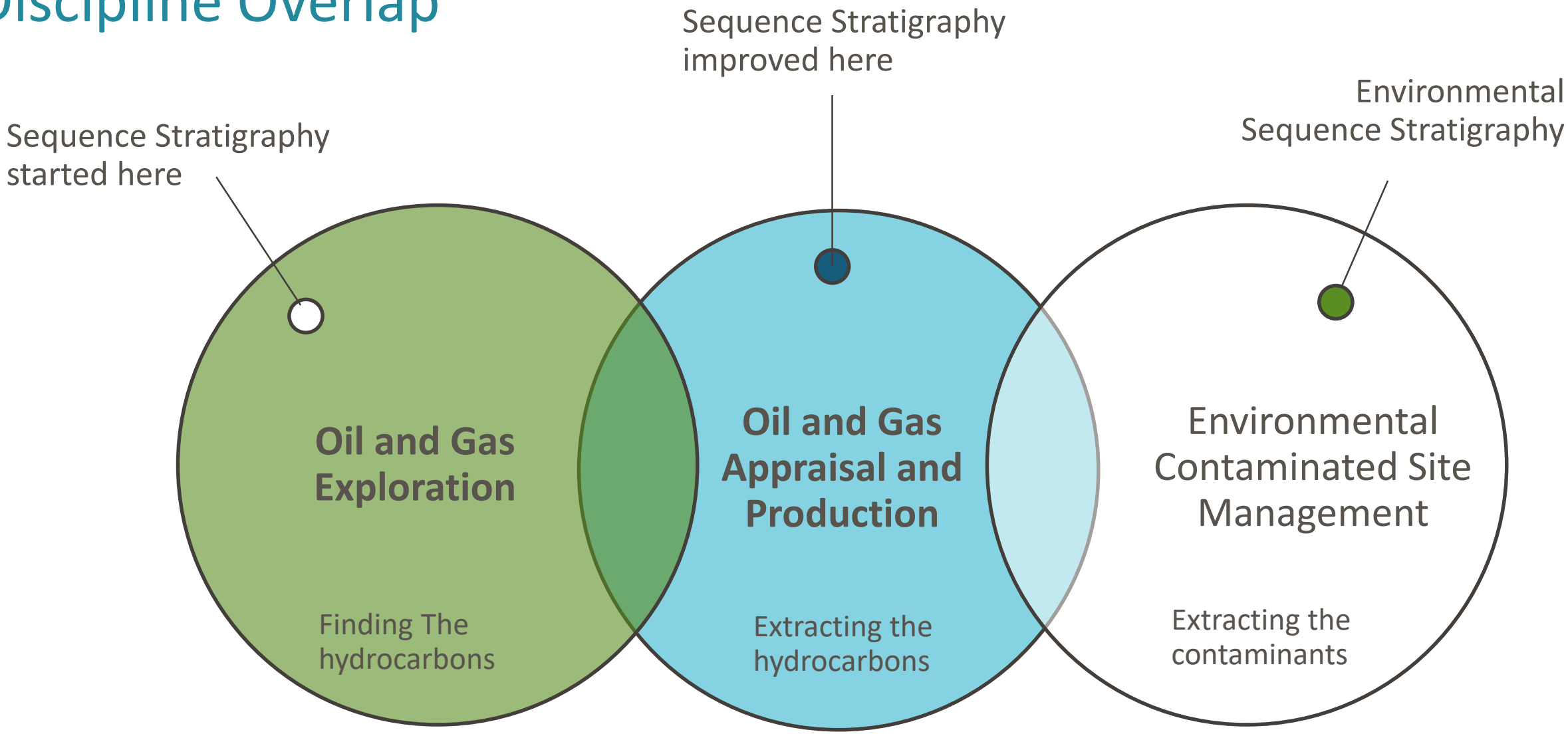
Environmental Sequence Stratigraphy



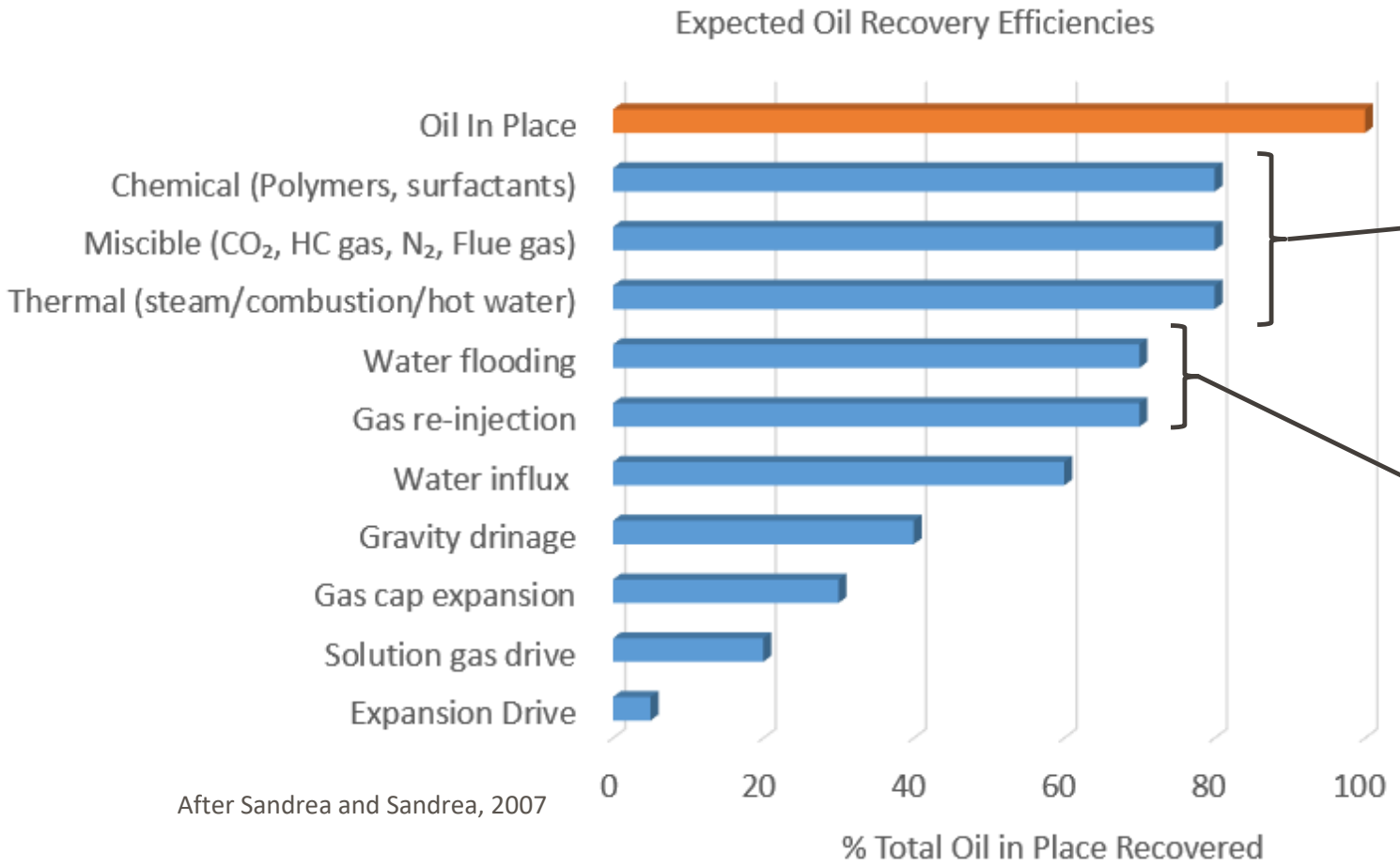
3D stratigraphic interpretation, Dominguez Sequence aquifers, Los Angeles Basin



Discipline Overlap



Discipline Overlap: Oil Recovery Efficiency (= NAPL Recovery)



After Sandrea and Sandrea, 2007

Oil:

Tertiary Recovery

Environmental:

Groundwater Recirculation, Surfactant Flush, etc..

Oil:

Secondary Recovery

Environmental:

Pump and treat, Soil Vapor Extraction

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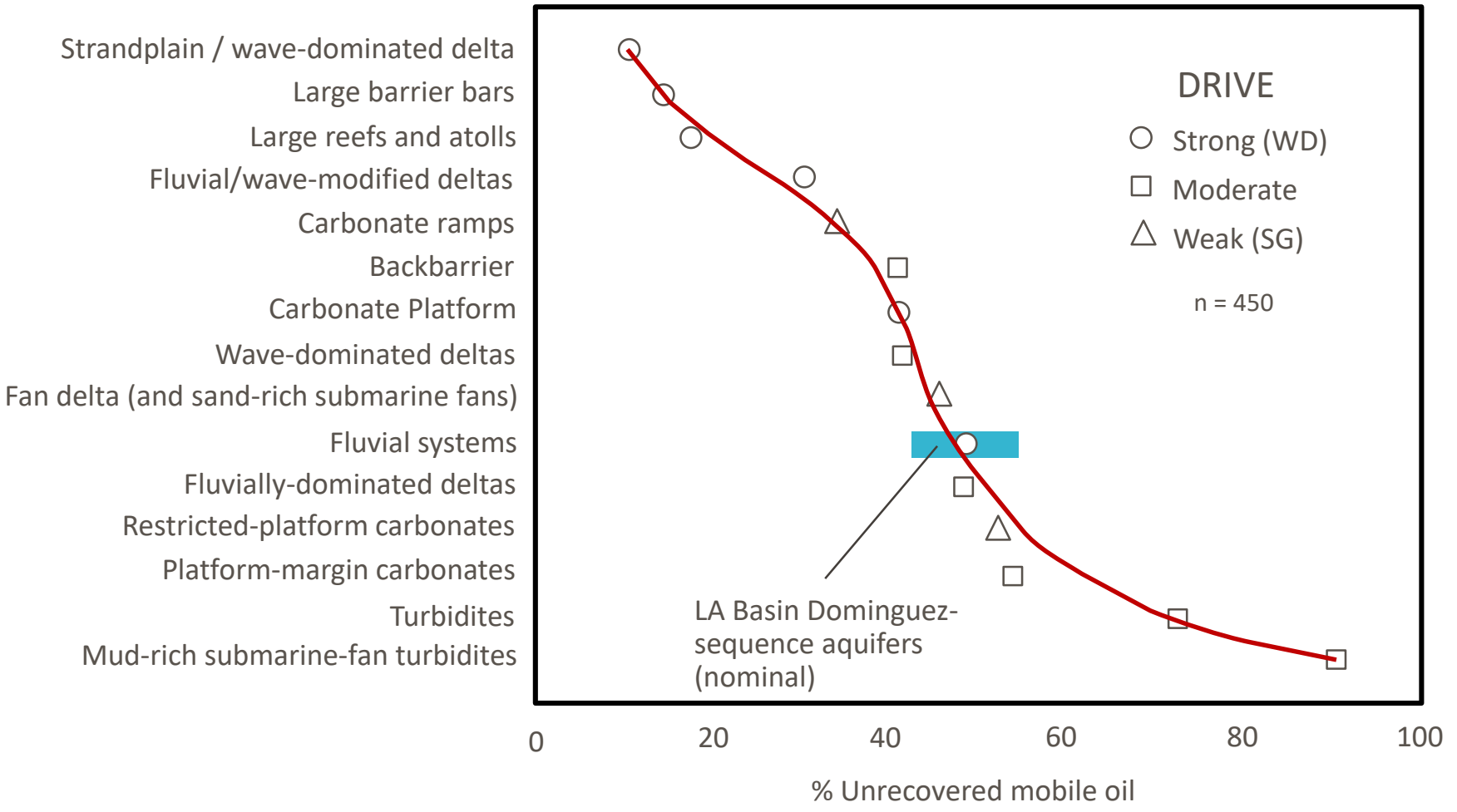
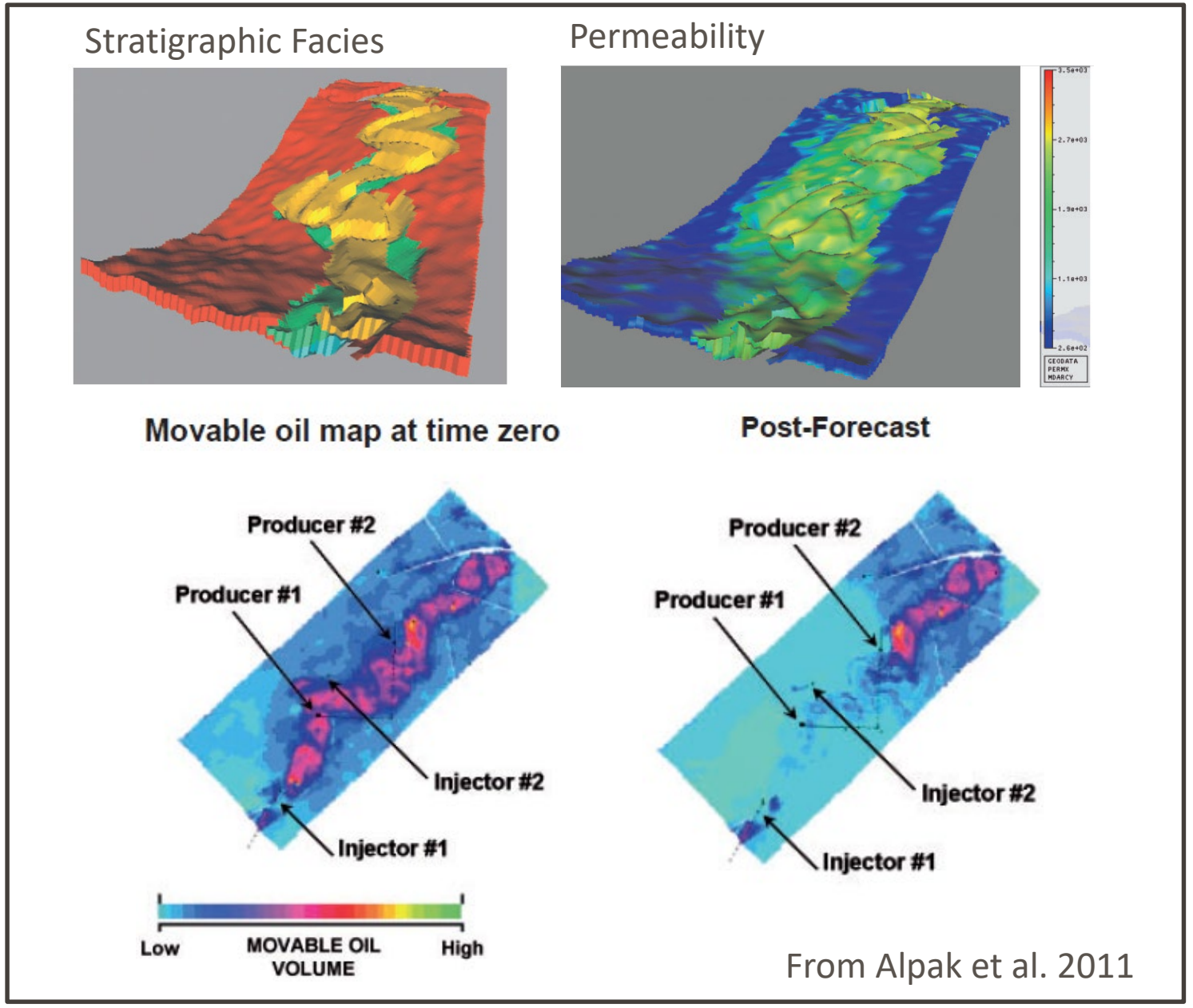
Relationship between NAPL recoverability and geologic facies



From Tyler and Finley, 1992. 'Architectural Controls on the Recovery of Hydrocarbons from Sandstone Reservoirs.' SEPM

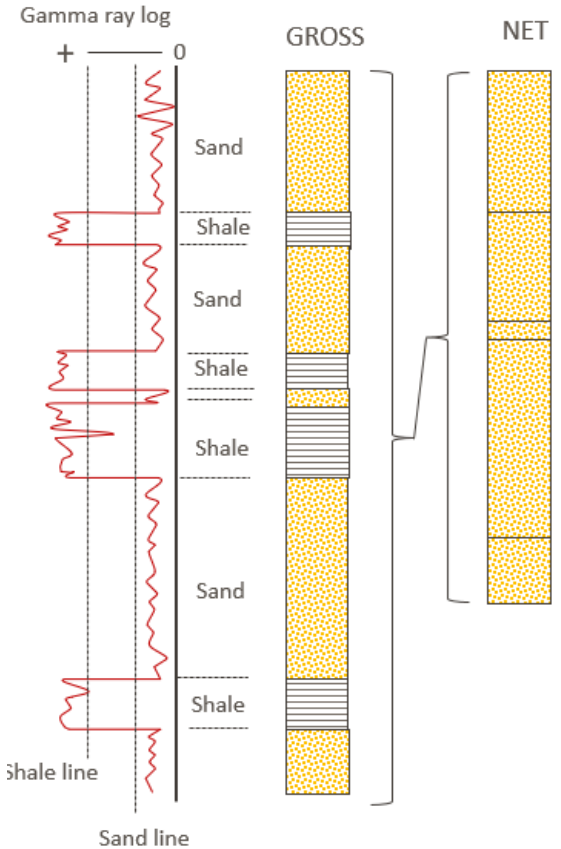
Numerical Models: Oil and Gas Reservoir Simulations

- Tend to focus on engineering aspects
- Multi-phase flow
- Key property is relative permeability
- Analogous to numerical models for NAPL recovery



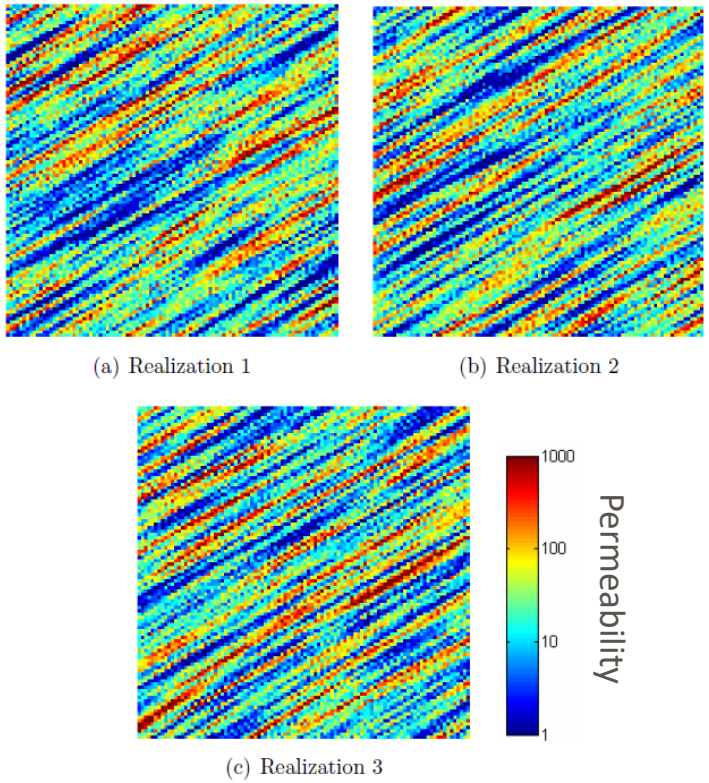
Assigning properties in reservoir simulations

Upscaled Borehole Interpretation



From M. Shepherd. AAPG Memoir 91

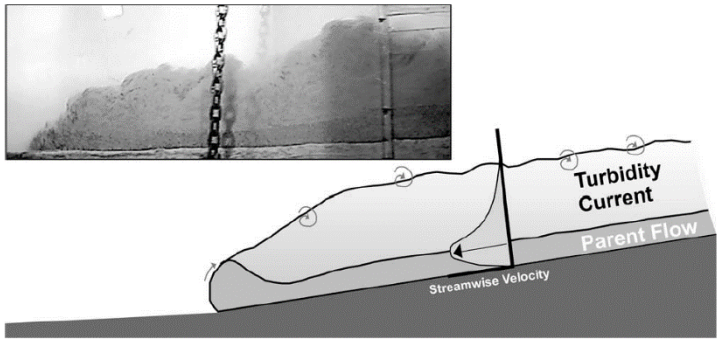
Geostatistical Models



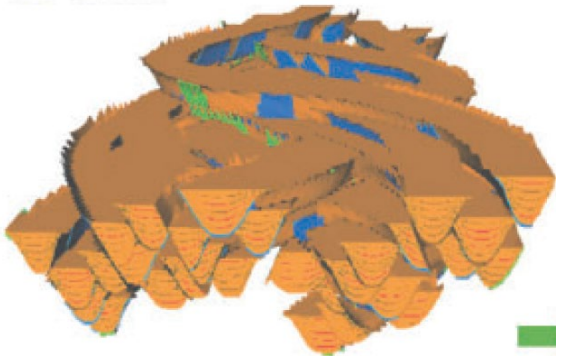
From Chen, 2009

- Have the same statistical properties as geologic analogs

Process-Based Models



Mohrig and Marr, 2003



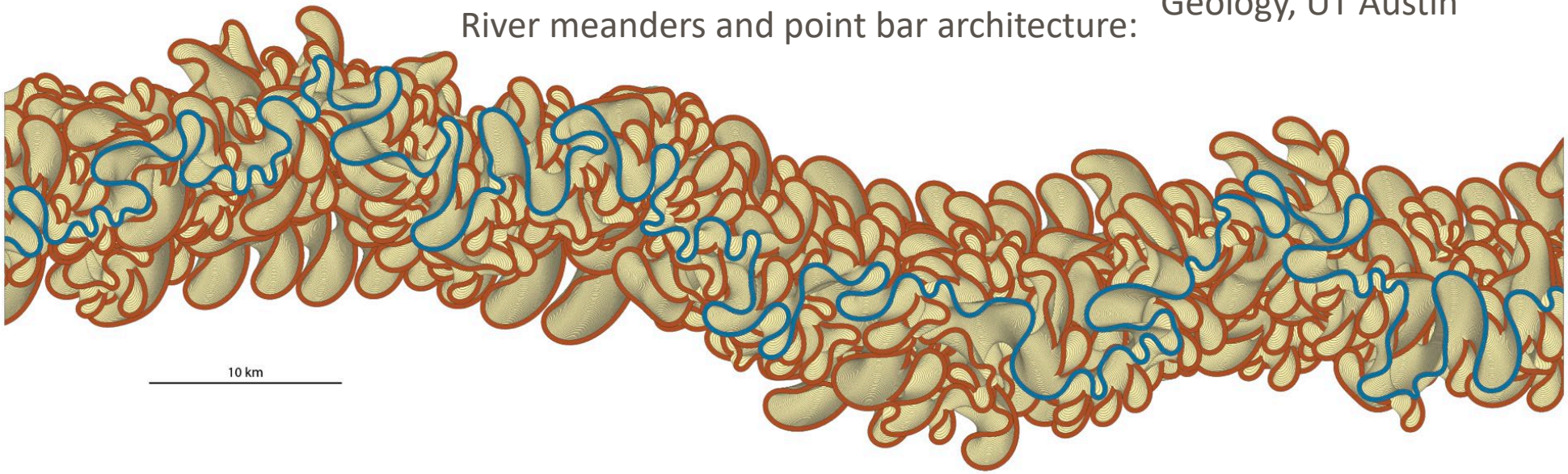
From Alpak et al., 2011

- Created from models of geologic processes

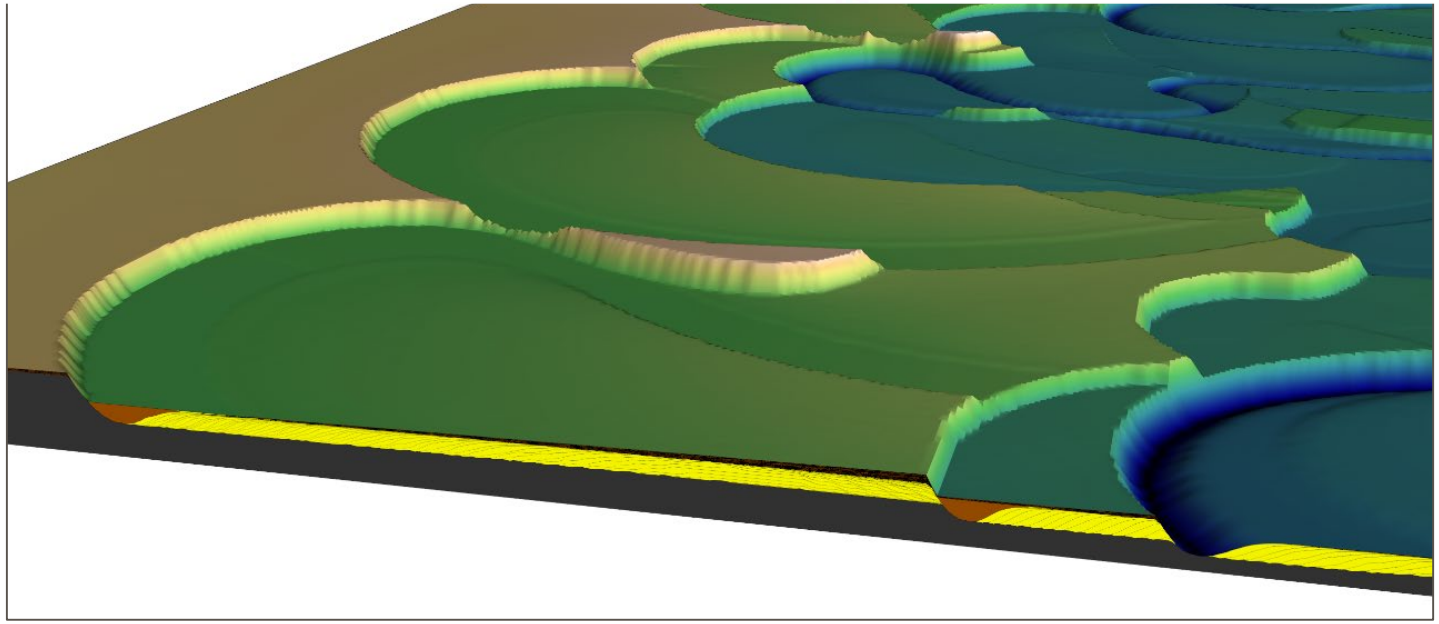
Process Based Stratigraphic Modeling

From Z. Sylvester, Bureau of Economic Geology, UT Austin

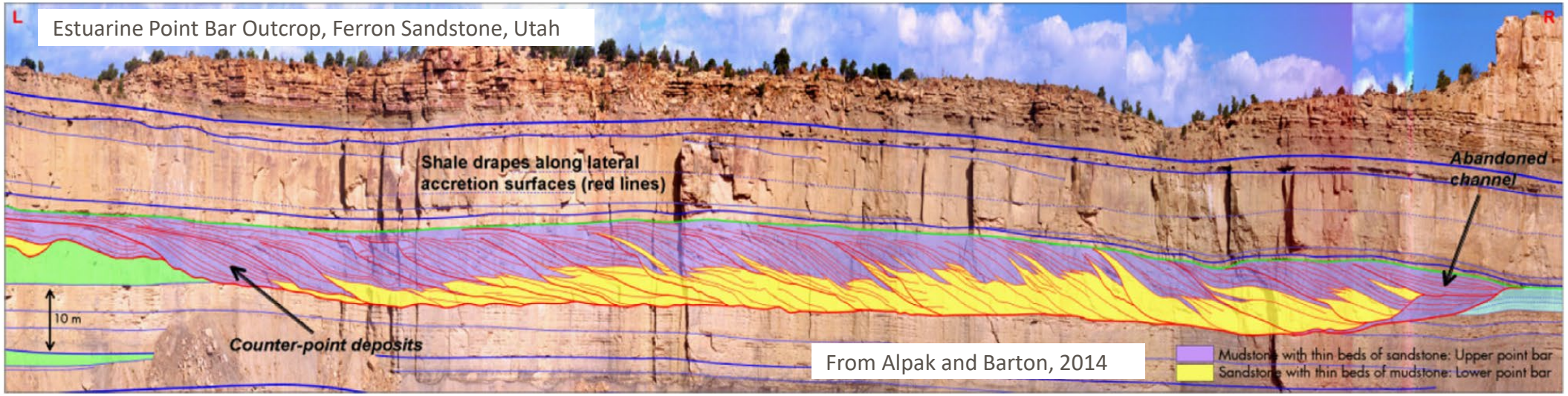
River meanders and point bar architecture:



3D model of incised meandering river:

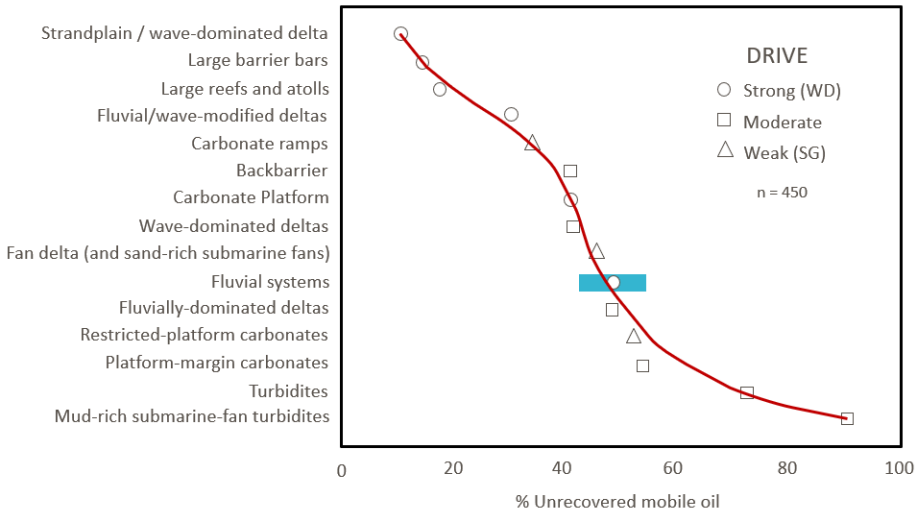


When building a model: is one interpretation enough?



Model results less sensitive to stratigraphic details

Model results more sensitive to stratigraphic details



Stochastic Modeling: Look at many similar models

Many (+tens of thousands) numerical simulations of similar models that fit the observations

→

Sensitivity analysis of results – **what details of the geology actually affect the outcome**?

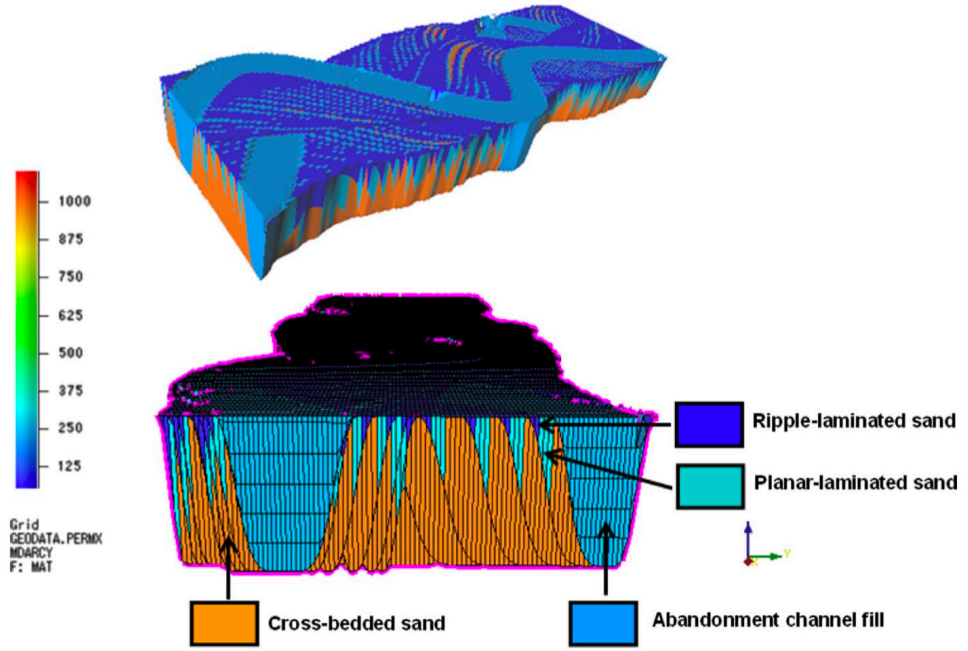
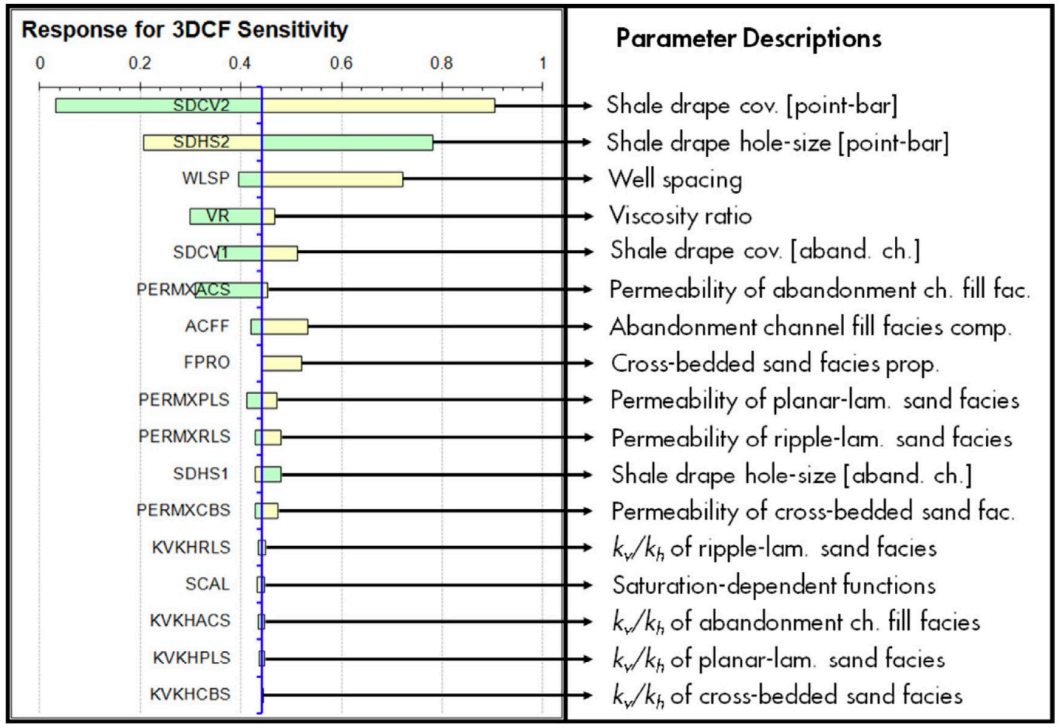


Fig. 5. Example 3D views of the mid-case estuarine point-bar model. Legends show permeability and facies information.

From F.O. Alpak and M.D. Barton, 2014.



↔ Large range: details critical

↔ Small range: geologic details less important

* This is sometimes called “Flow-Based Upscaling”

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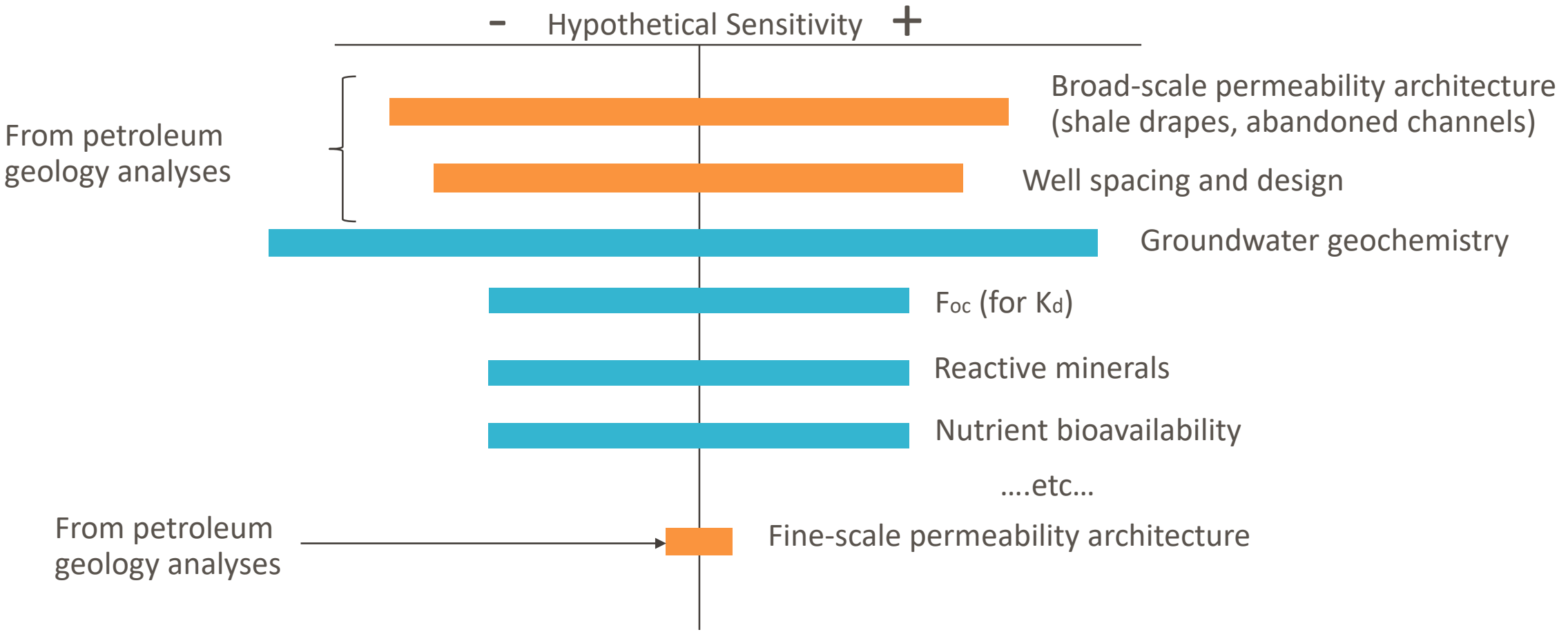
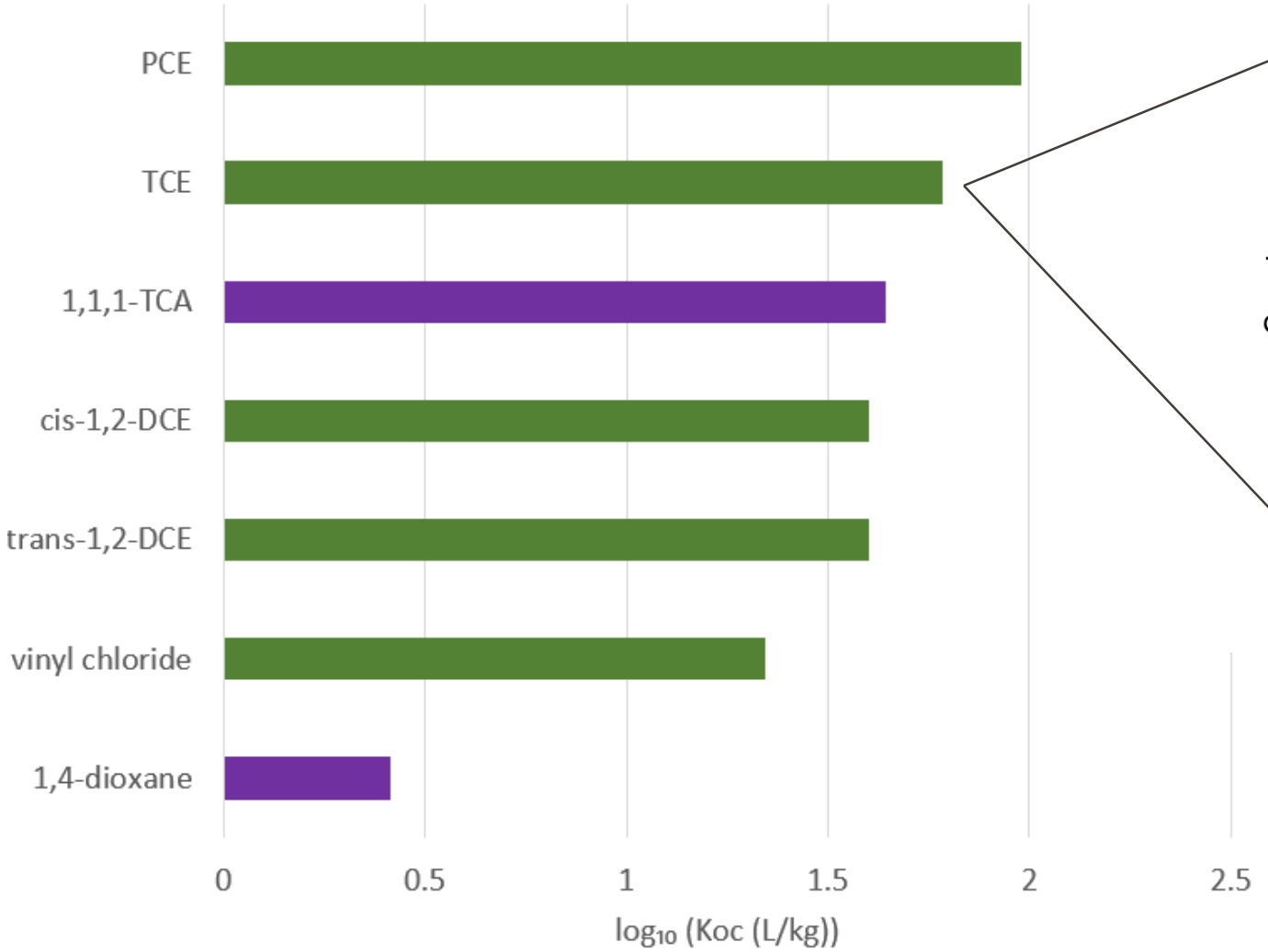
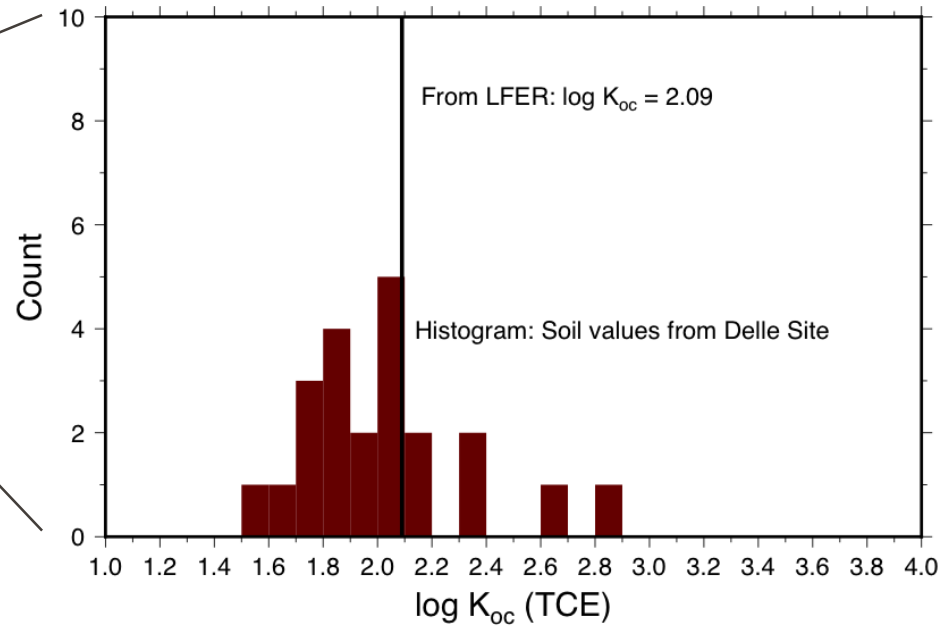
Question: What sequence stratigraphy variables affect contaminant fate and transport?

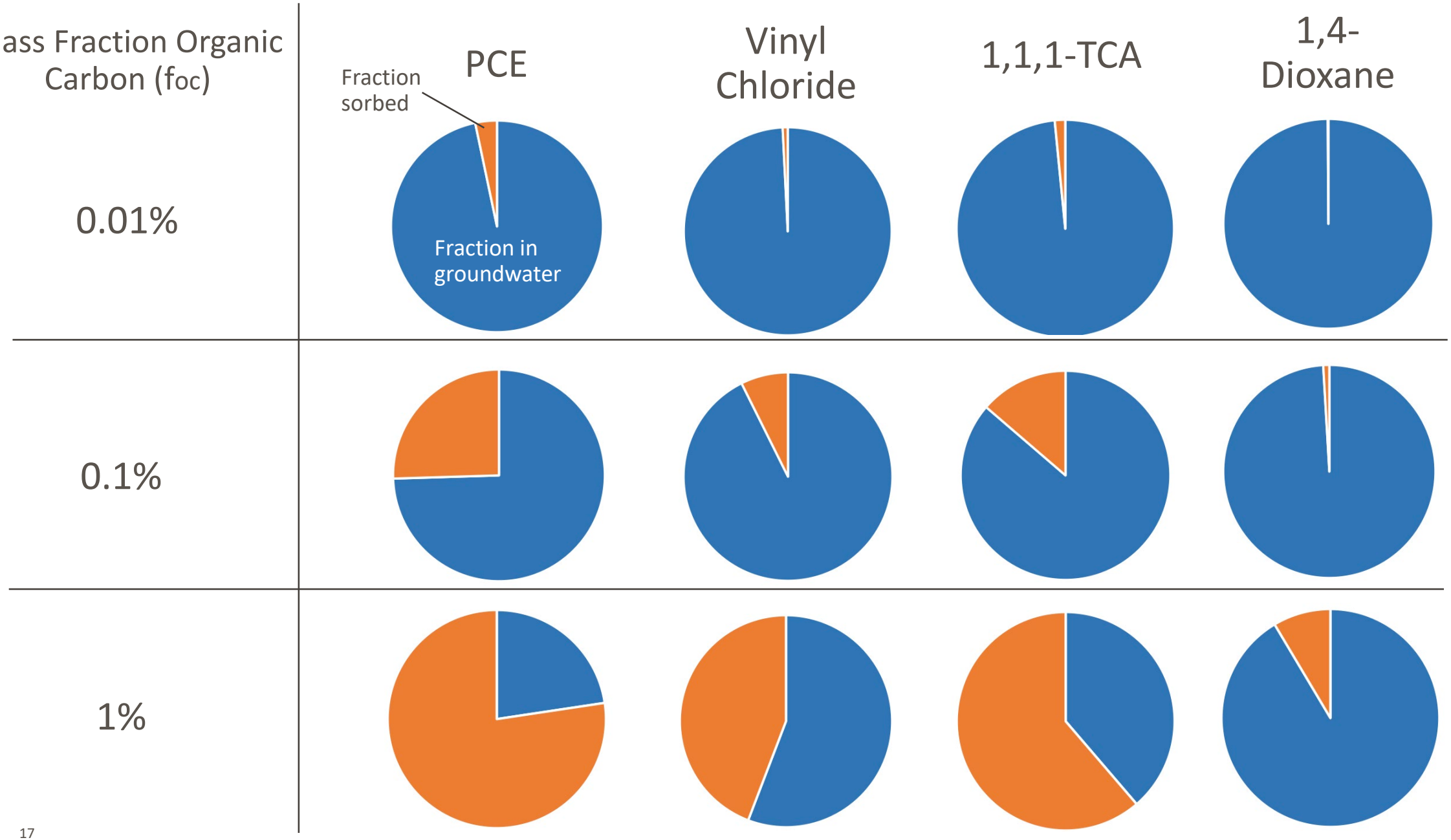


Contaminant mobility as a function of soil organic content: Koc



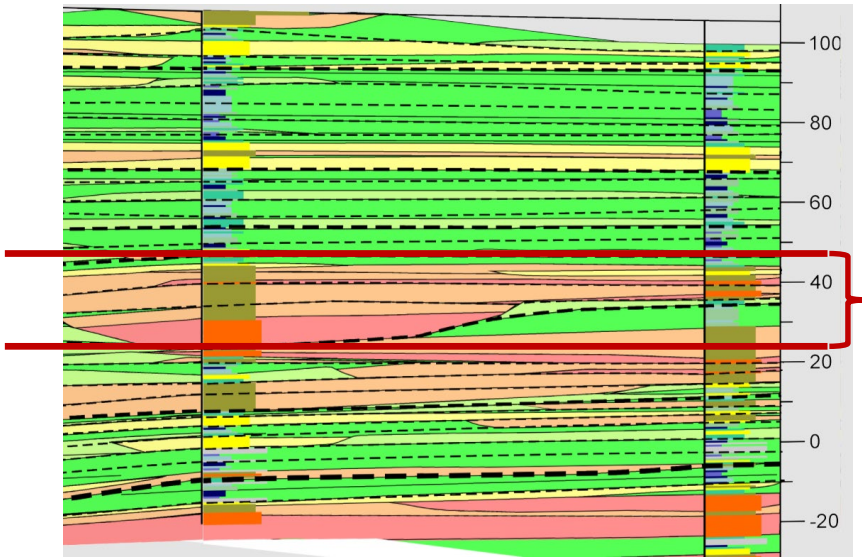


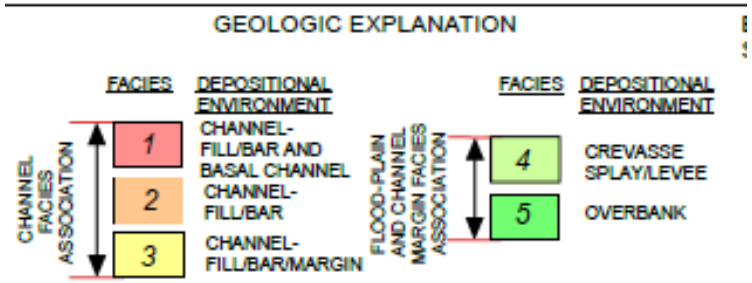
*Type of organic matter is also important


Mass Fraction Organic Carbon (foc)
PCE
Vinyl Chloride
1,1,1-TCA
1,4-Dioxane
Fraction sorbed
Fraction in groundwater
0.01%
0.1%
1%

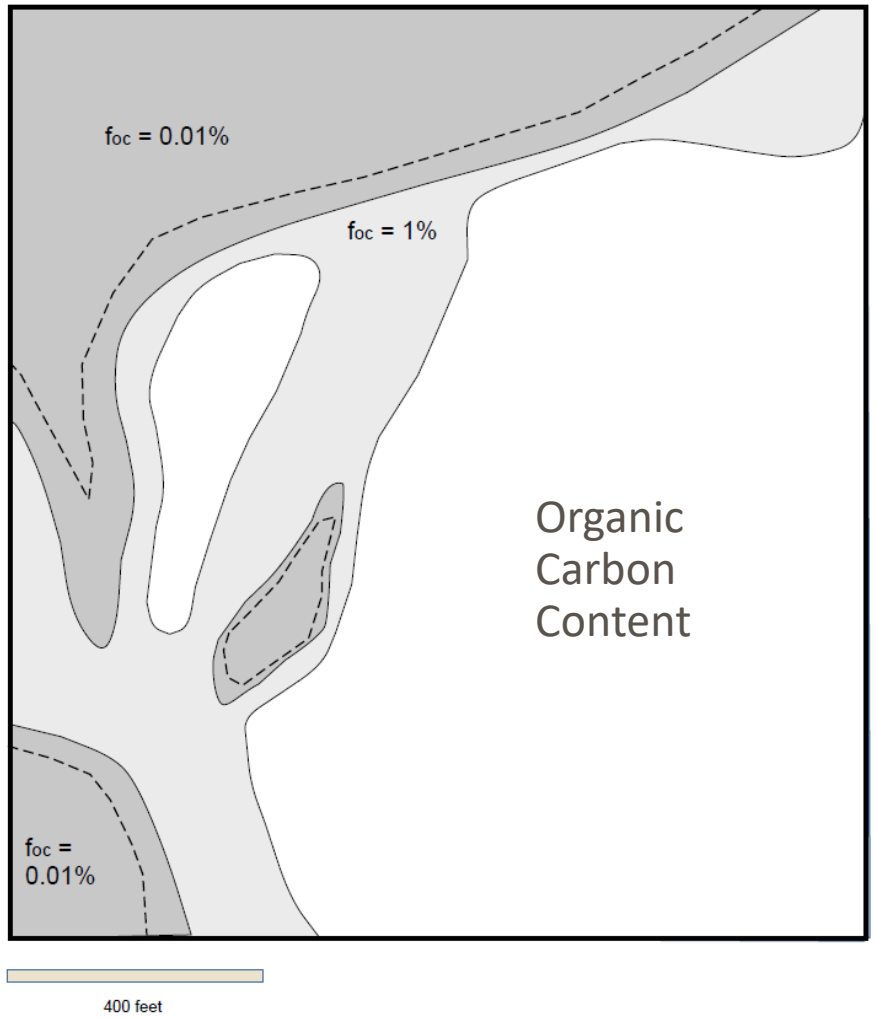
Upscaling: Dominguez Group Aquifers, LA Basin

Sequence-Stratigraphic Cross Section

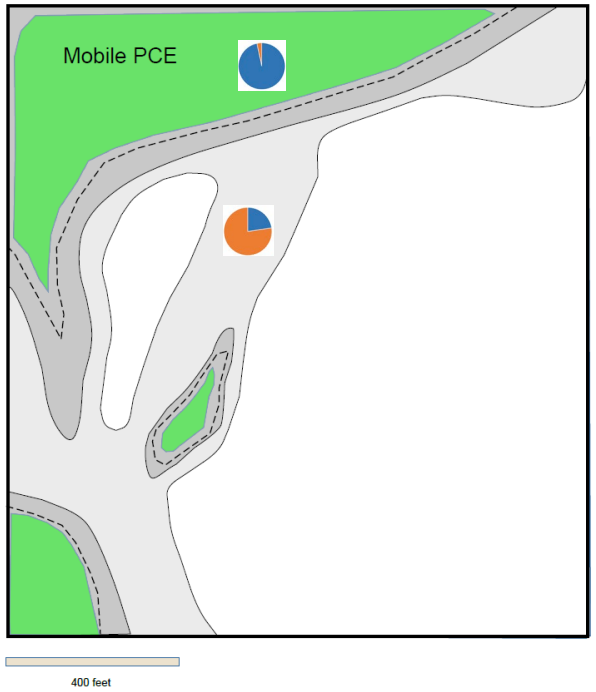


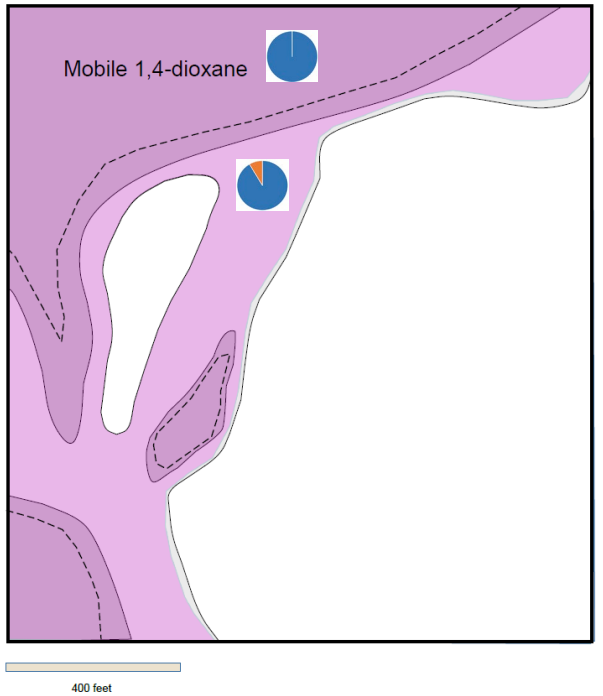


Map for Gross Section Interval



Organic Carbon Content





(Figures are schematic)

Conclusions

1. Instructive to consider oil and gas roots of sequence stratigraphy
2. Many ways to make detailed models, need to define the cost/benefit
3. Exploring variability by using many simulations: a useful path.
4. Key environmental parameters: permeability, porosity, mineral composition, f_{oc}, and others all vary with facies
5. On the horizon: Process-based stratigraphic modeling

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