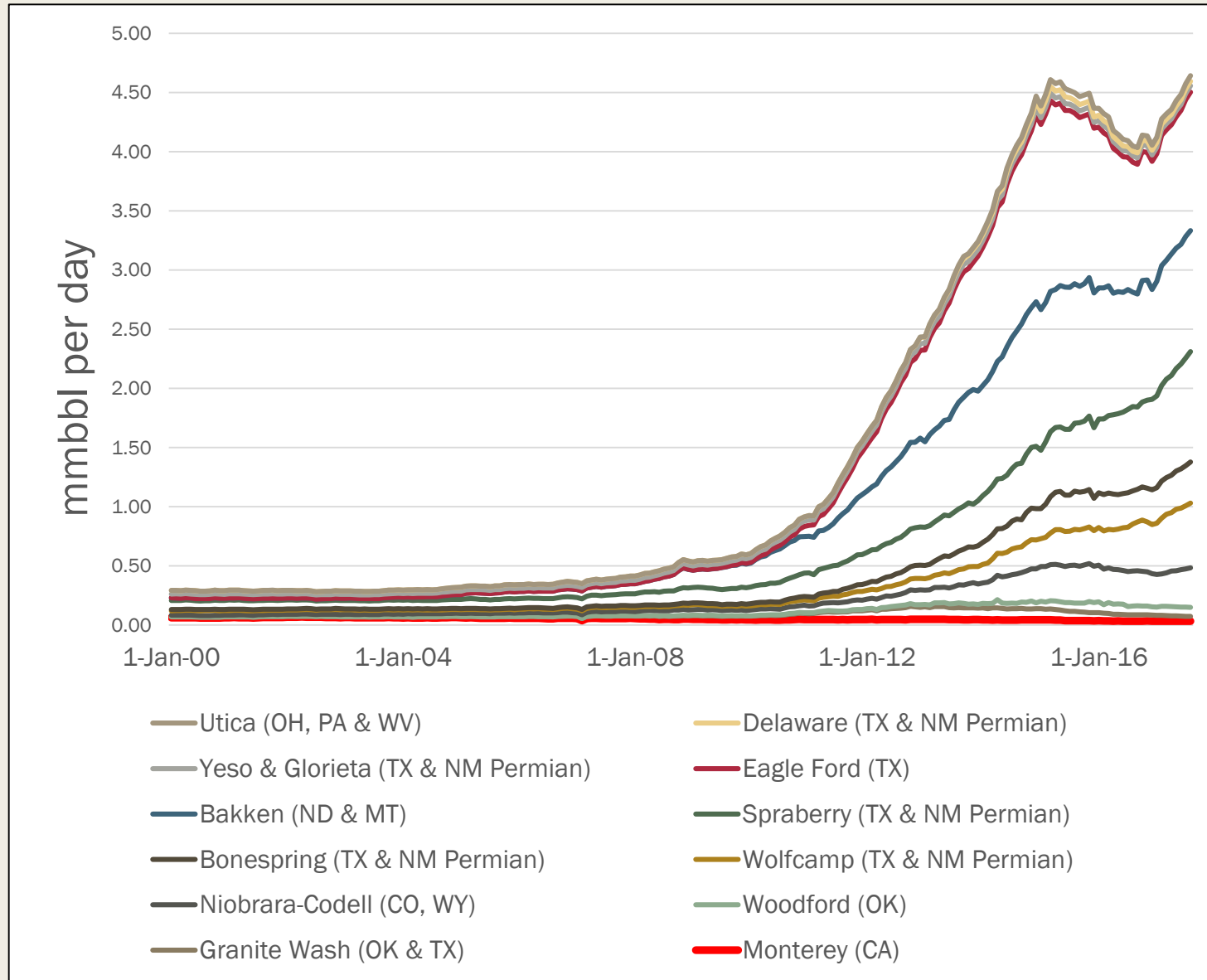


Lateral Facies Variation of Fine-Grained,
Organic-Rich Sediments of the Miocene
Monterey Formation, Belridge Field Area

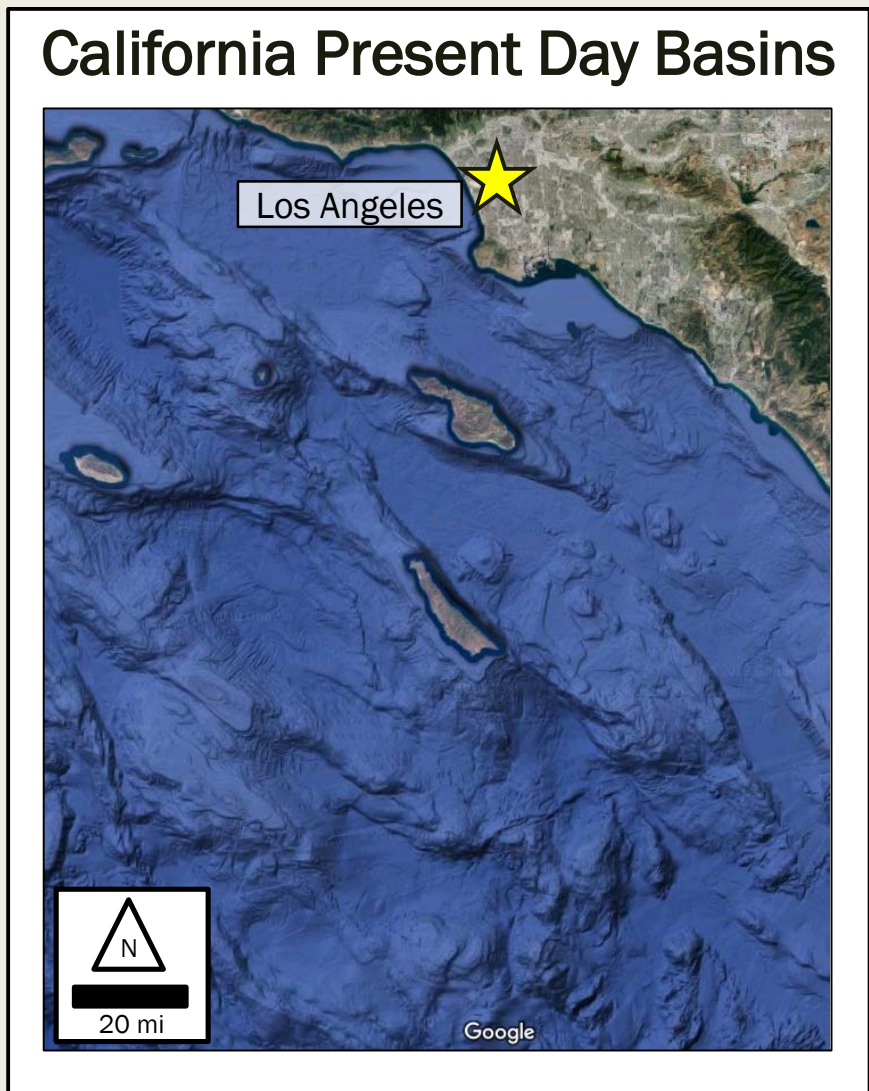
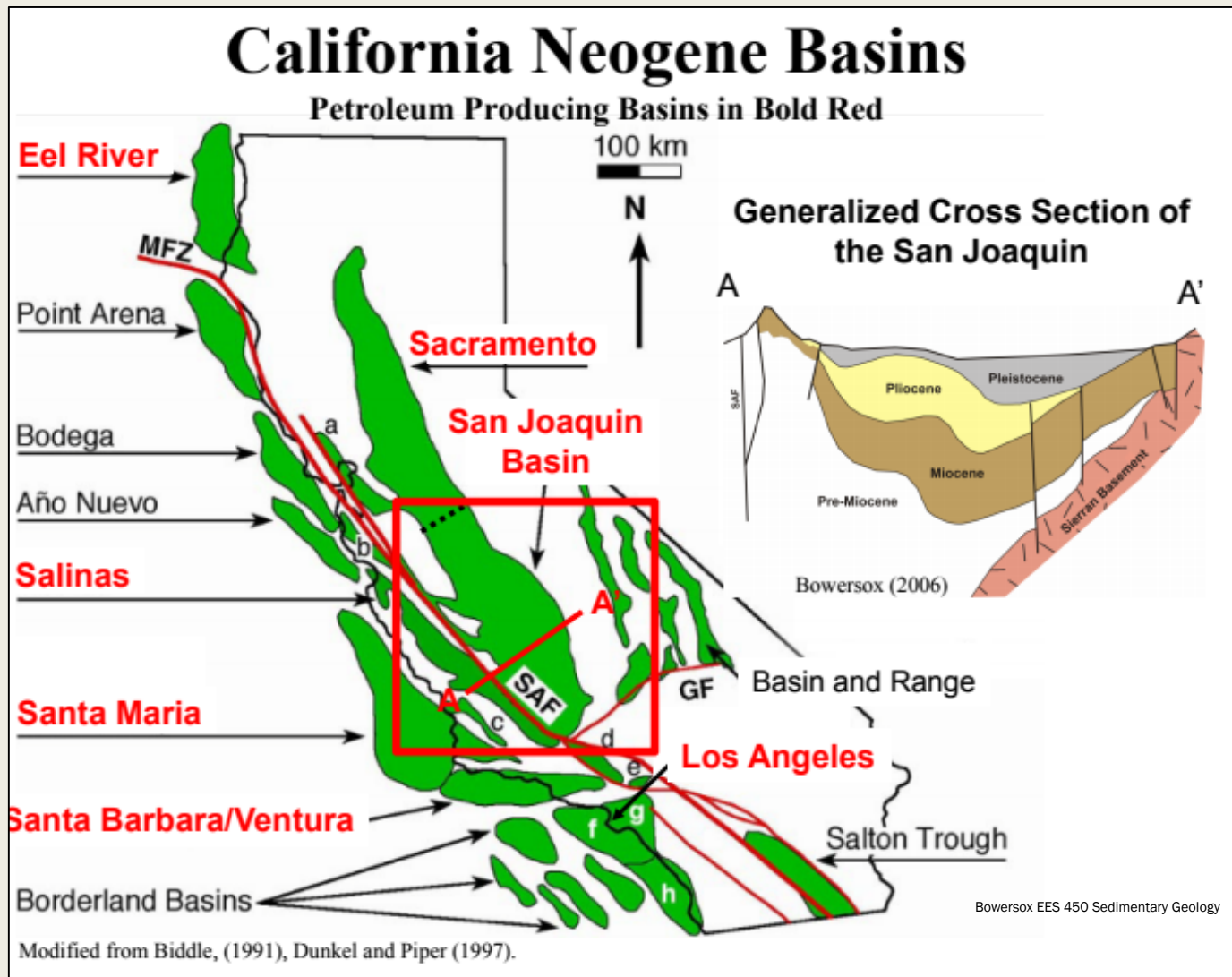
Jack Farrell
Dr. Rick Behl



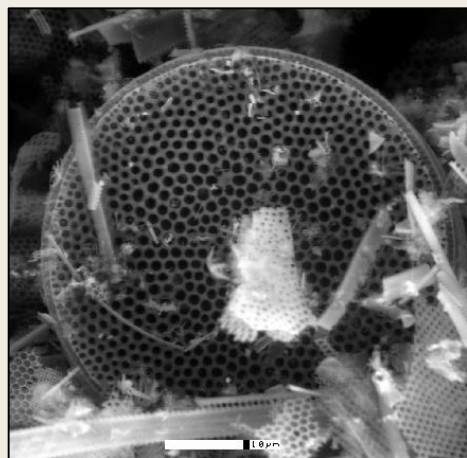
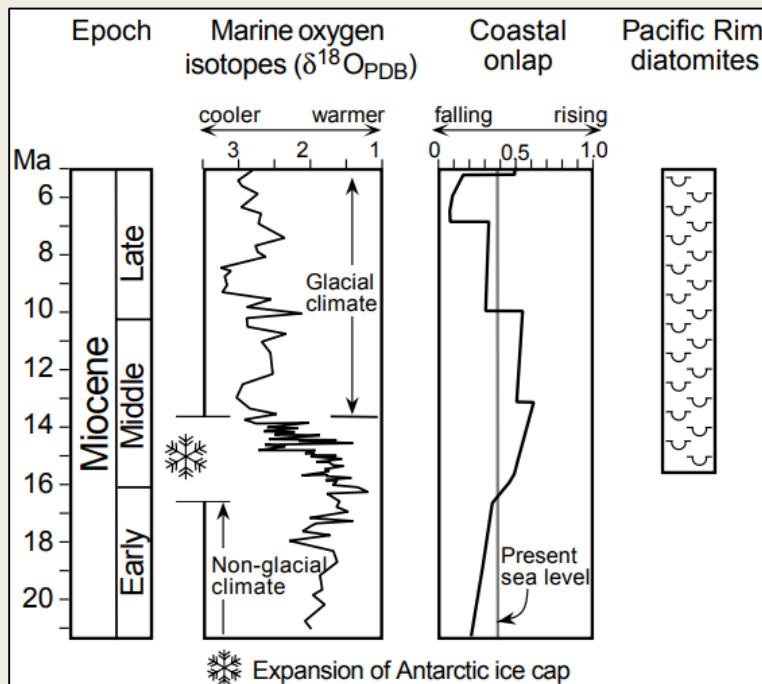
Monterey Fm. Tight Oil Production



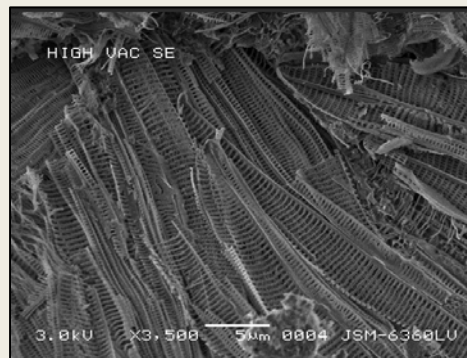
Monterey Fm. Overview



Diatoms + Silica Diagenesis

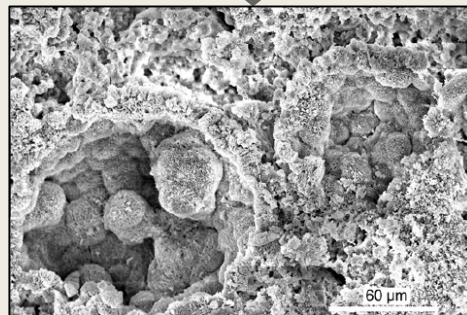


Opal-A Diatomite



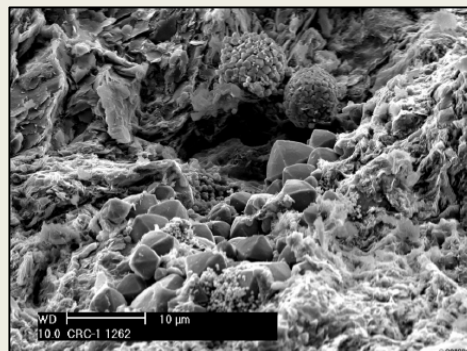
$\Phi = 60 - 75\%$

Opal-CT Phase Porcelanite

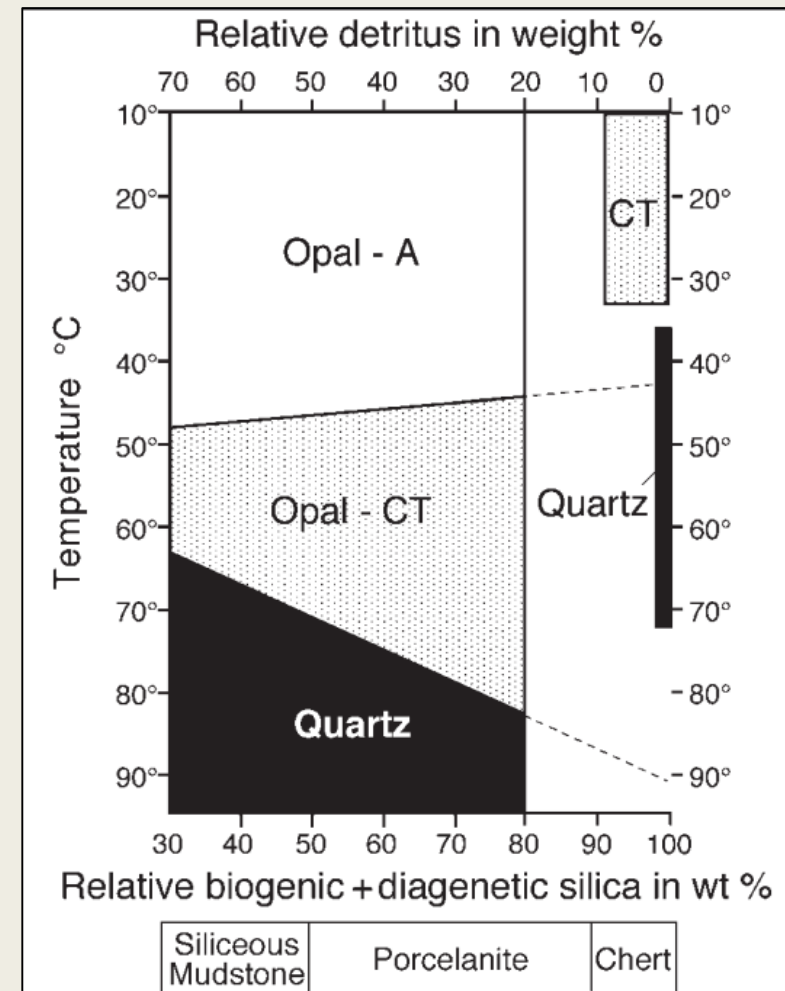


$\Phi = 20 - 25\%$

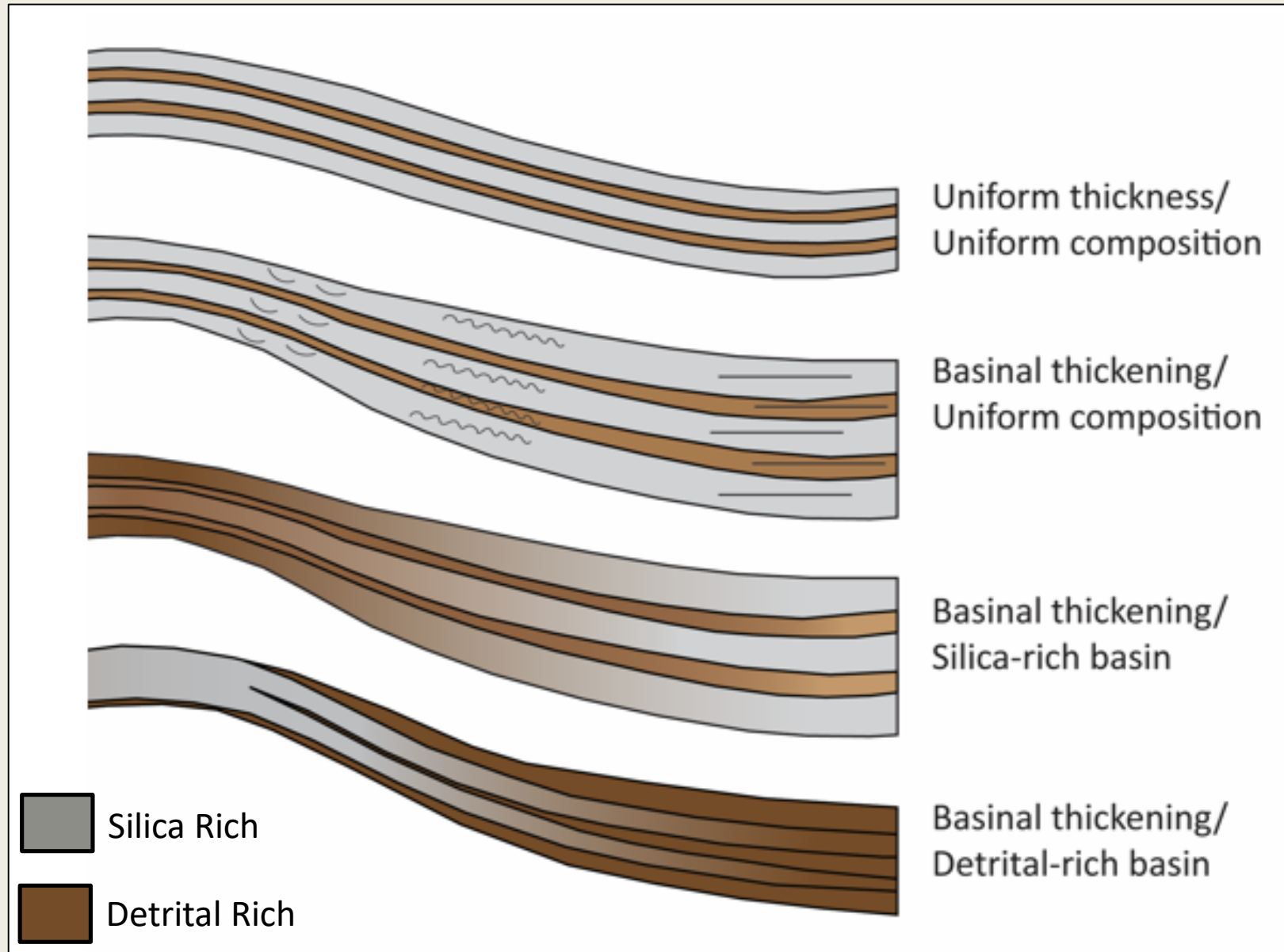
Quartz Phase Porcelanite



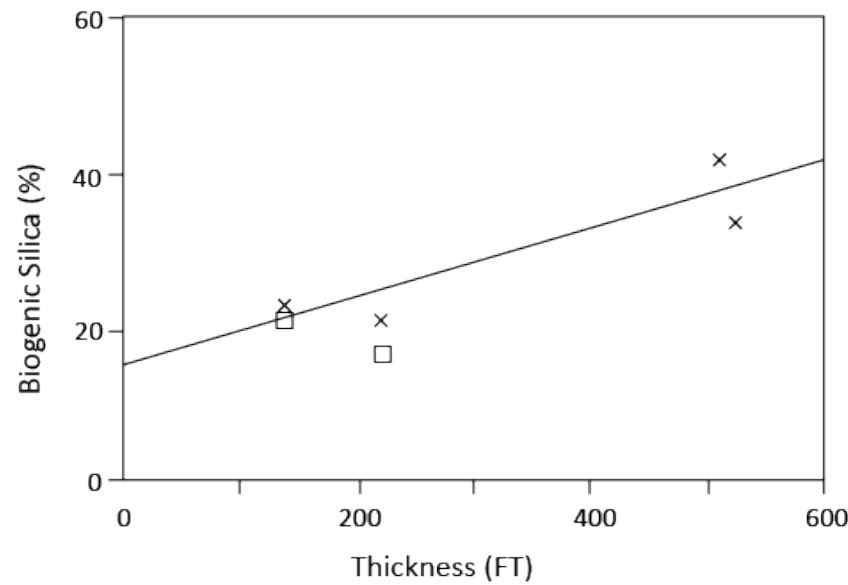
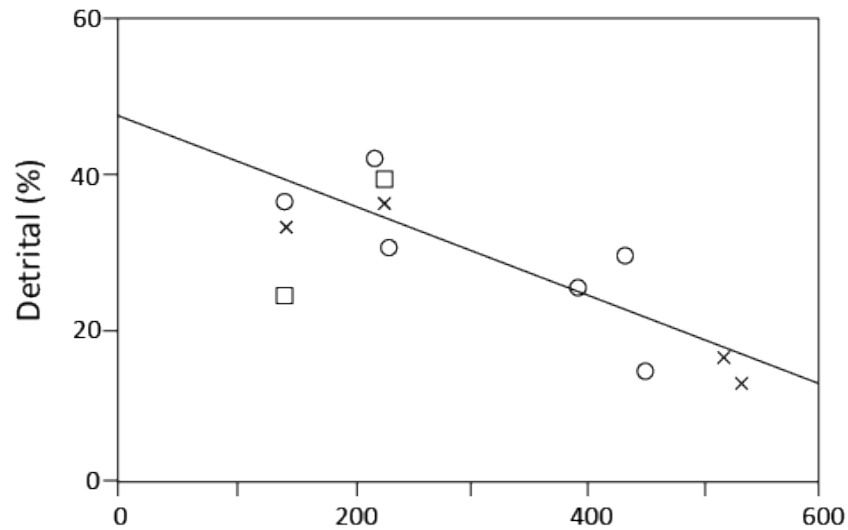
$\Phi = 0 - 20\%$



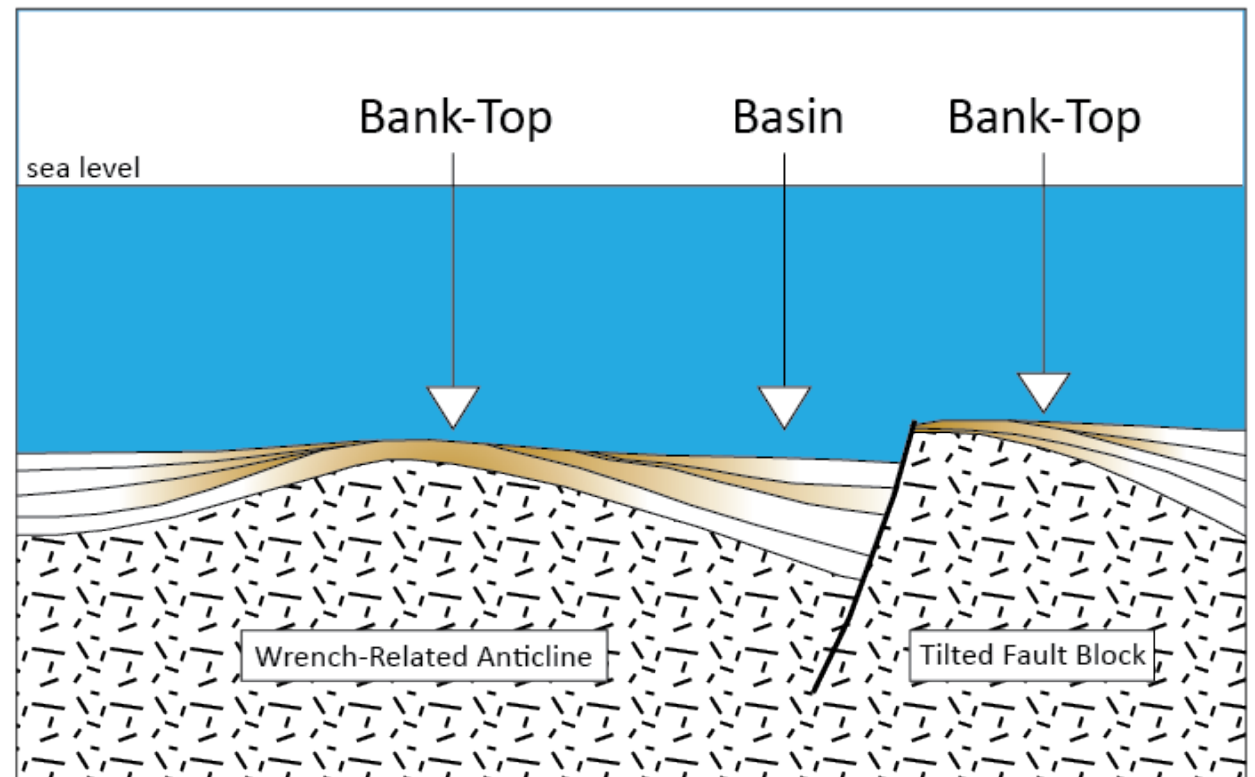
Monterey Fm. Lateral Variation



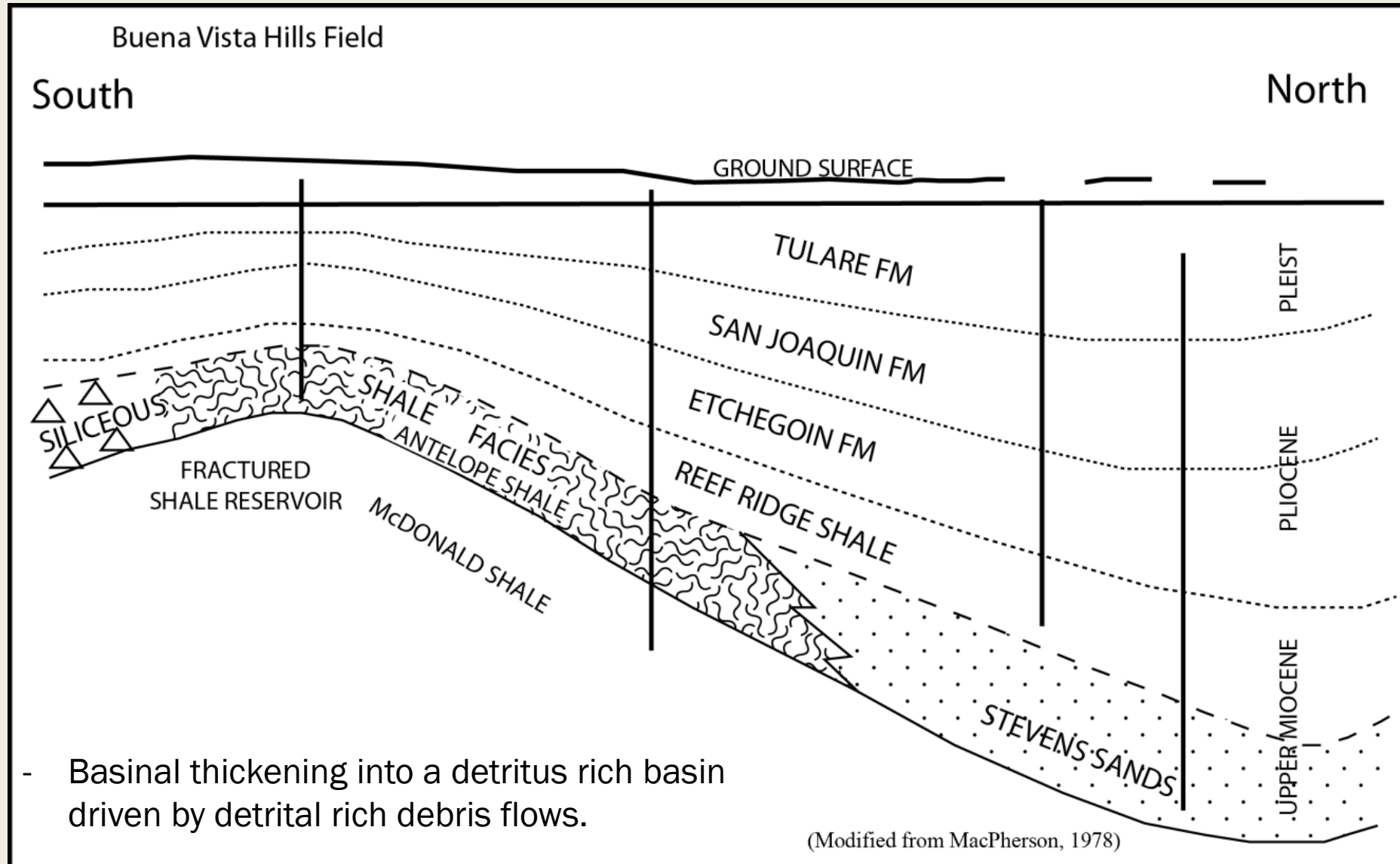
Lateral Variation: Santa Barbara Basin



- Basinal thickening into a silica rich basin
- Positive relationship between thickness and biogenic silica %
- Negative relationship between thickness and % detritus
- Lateral variation driven by winnowing of lower grain density particles

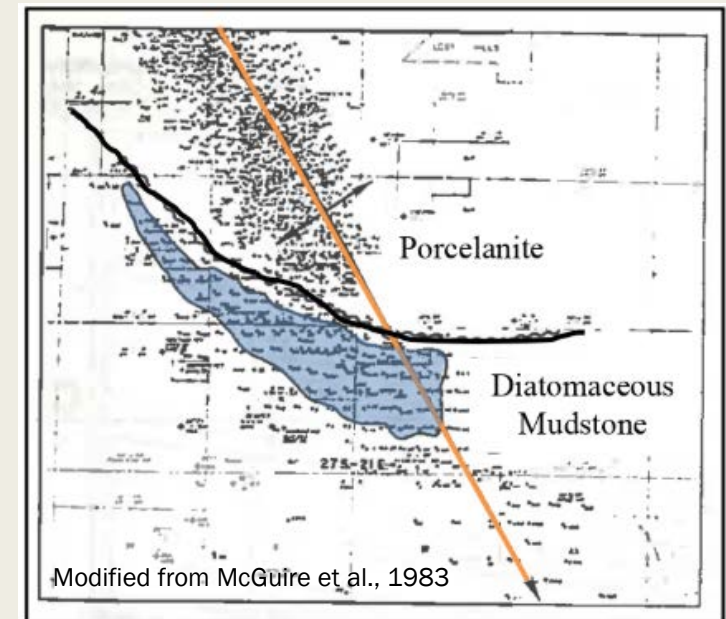
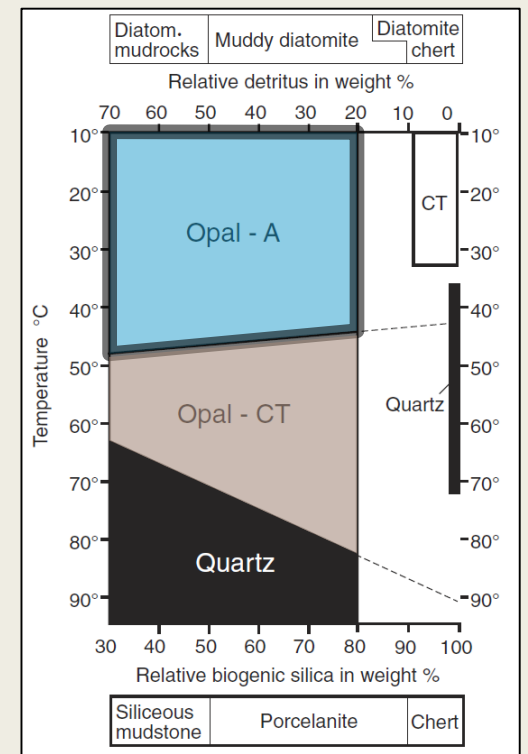
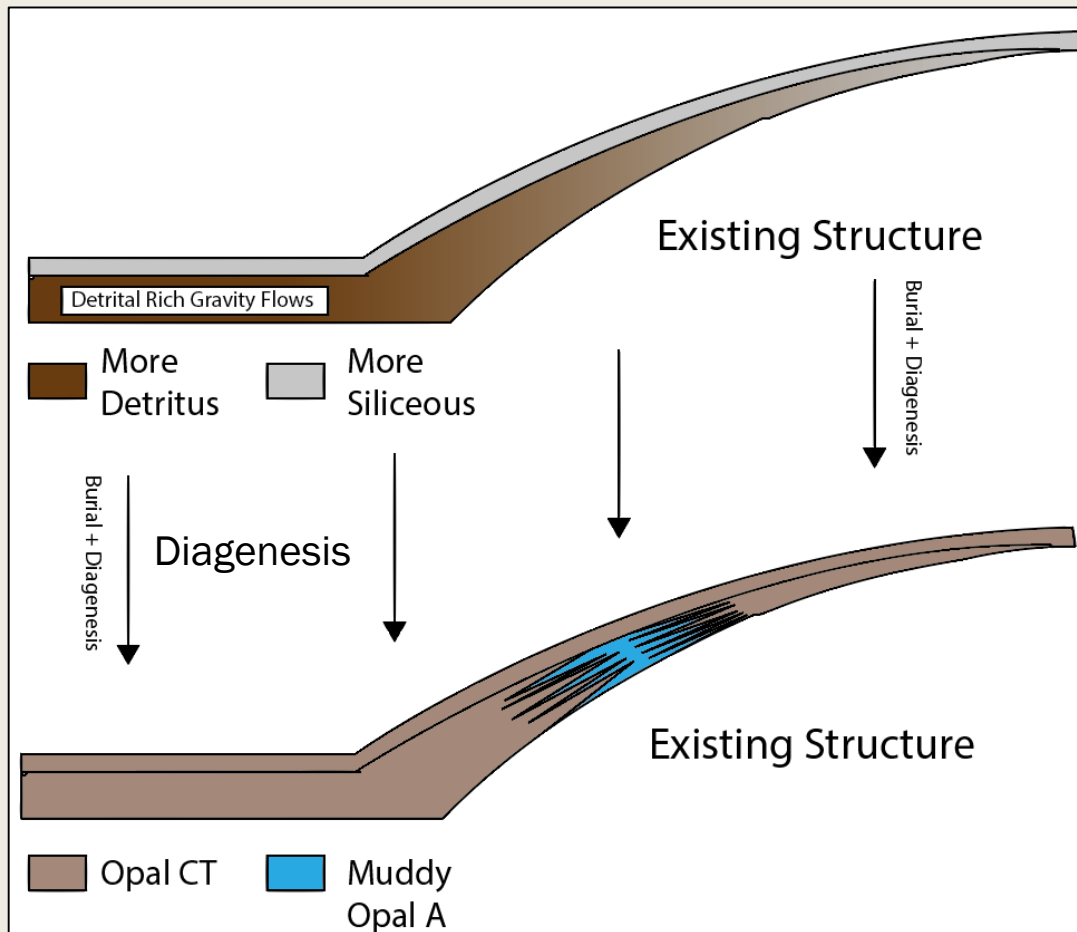


Lateral Variation: Buena Vista Field



Lateral Variation: Lost Hills Field

- Basinal thickening into a detrital rich basin
- Detrital rich gravity flows moving through basin lows
- Diagenetic seal formed through arrested silica diagenesis
- Muddy diatomite (opal-A) retained enough porosity to form economic reservoir



Lateral Variation: Organic Carbon

$$\text{Preserved Organic Carbon} = (\text{Production} - \text{Destruction}) / \text{Dilution}$$

Production

- Diatom production
- Upwelling intensity
- Sea level
- Nutrient availability

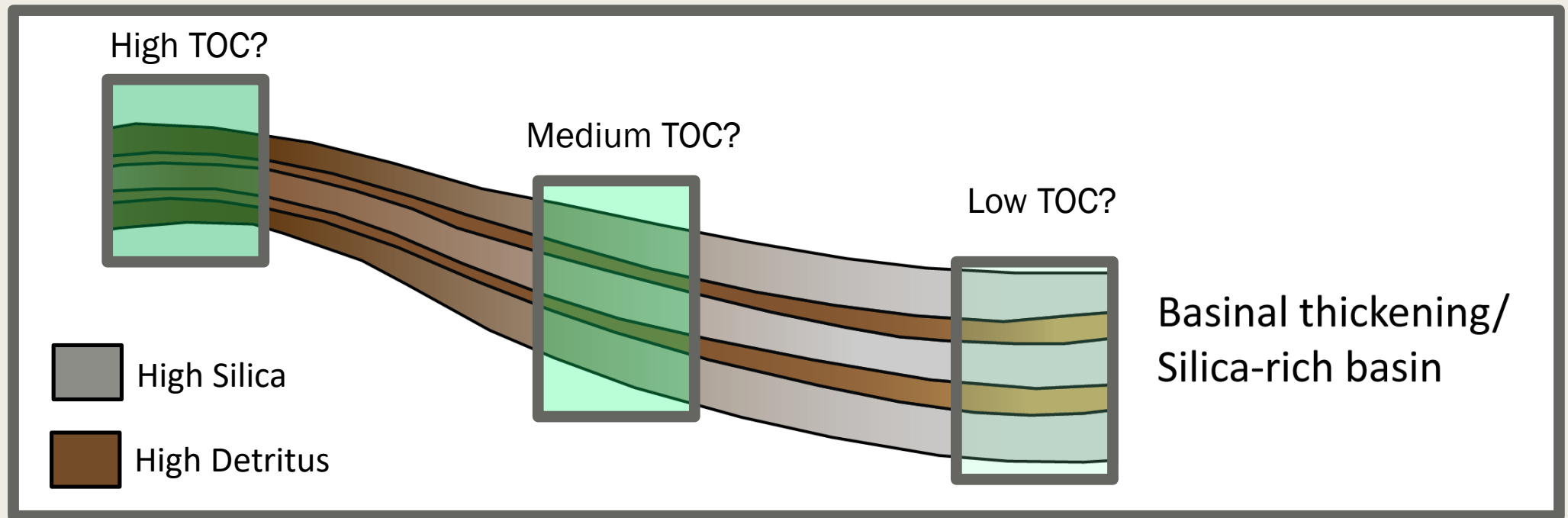
Destruction/Conservation

- Redox conditions
- Clay mineral adsorption

Dilution/Concentration

- Accumulation rates
- Silica dissolution

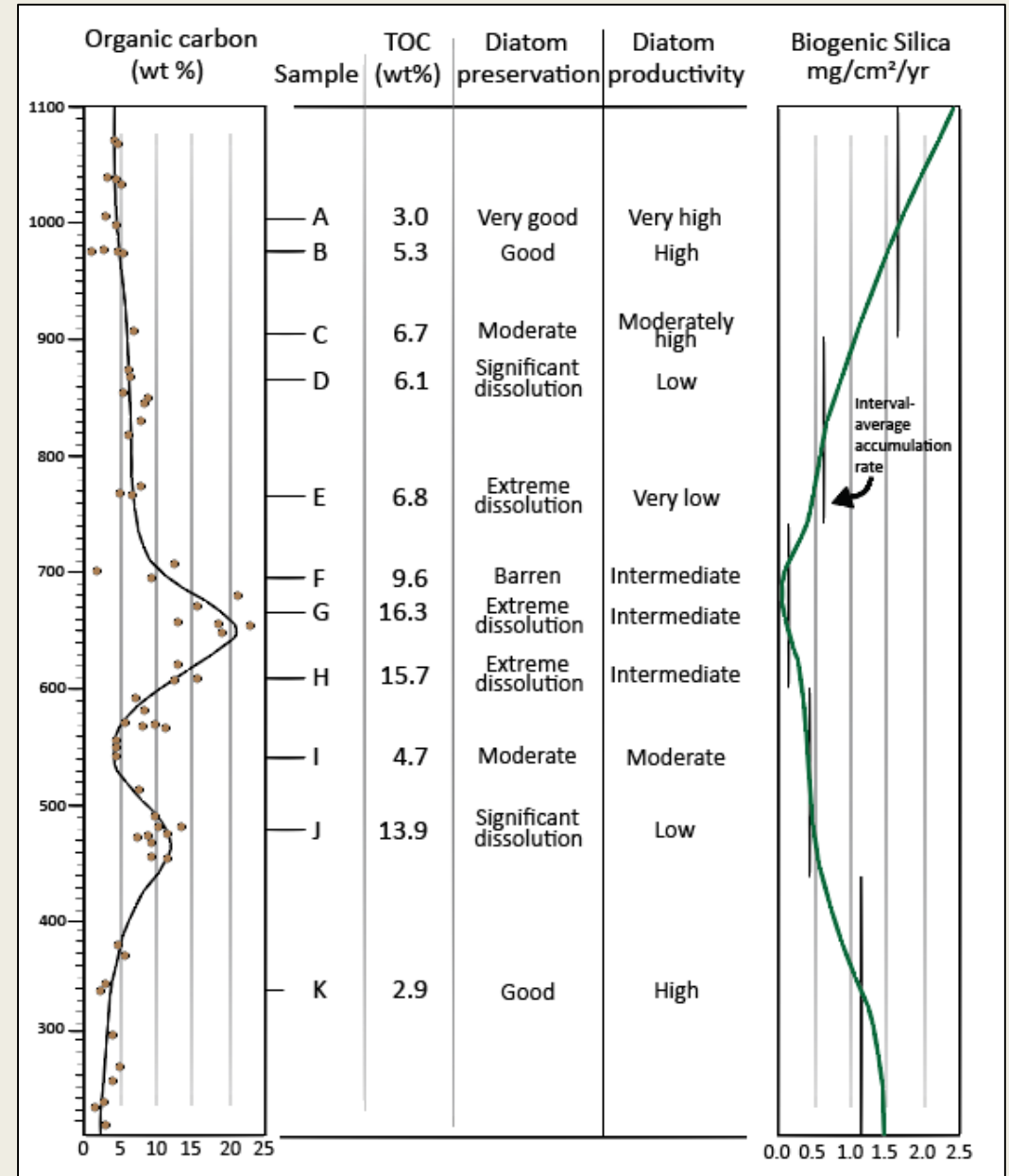
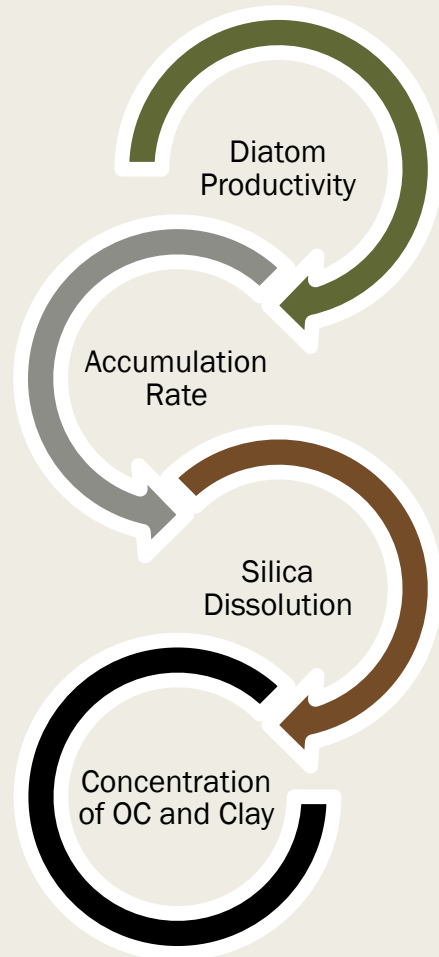
Bohacs (2000)



Lateral Variation: Organic Carbon

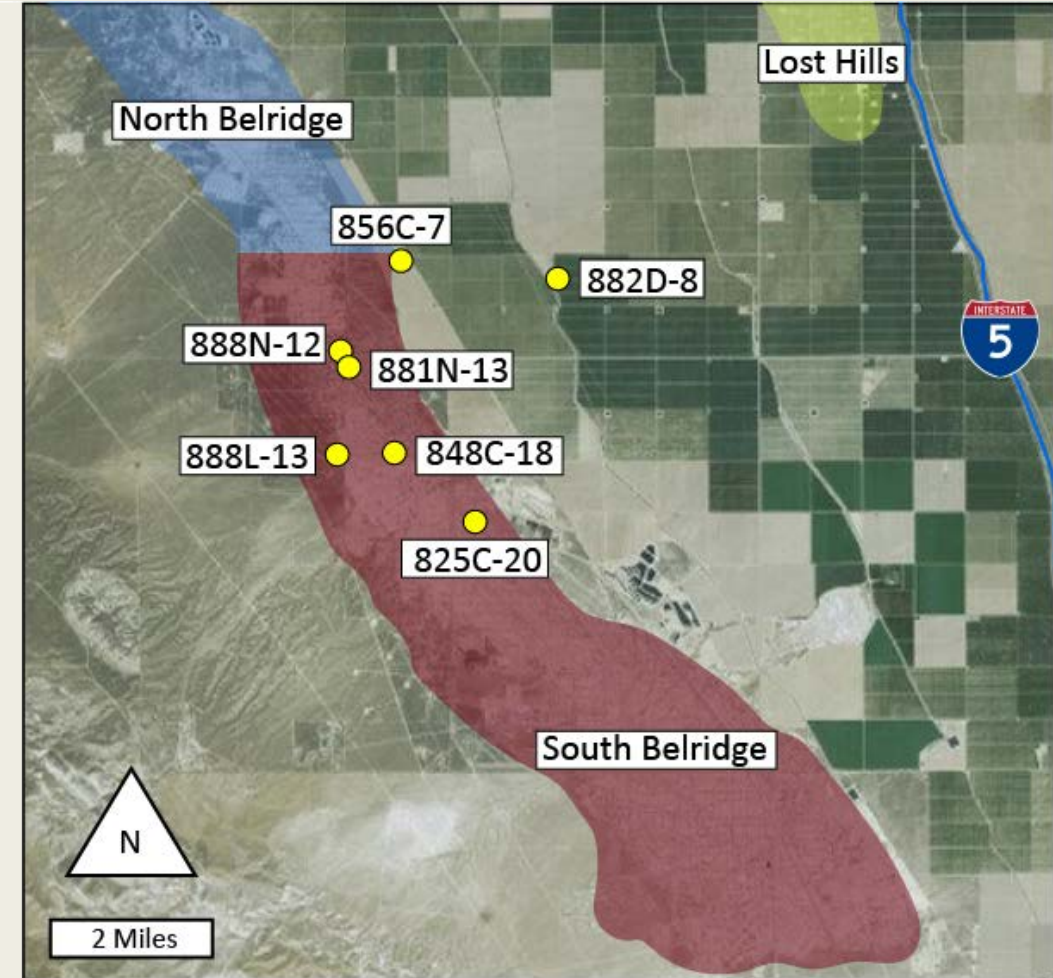
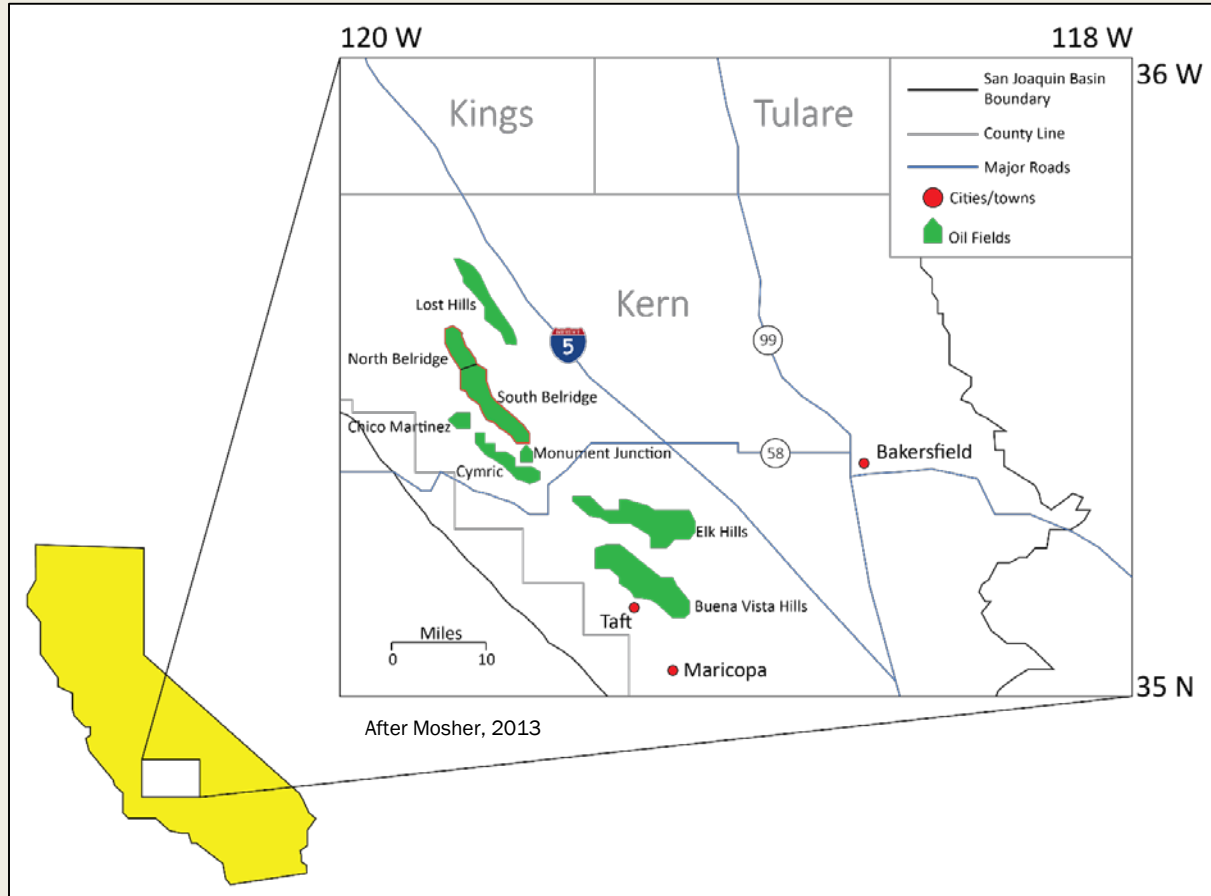
Isaacs, 2001

- Diatom production and sediment accumulation rate are shown to be inversely related to TOC.
- Slow sedimentation rate magnifies the dissolution of silica and enhances concentration of organic carbon



Study Area: Belridge Oil Field

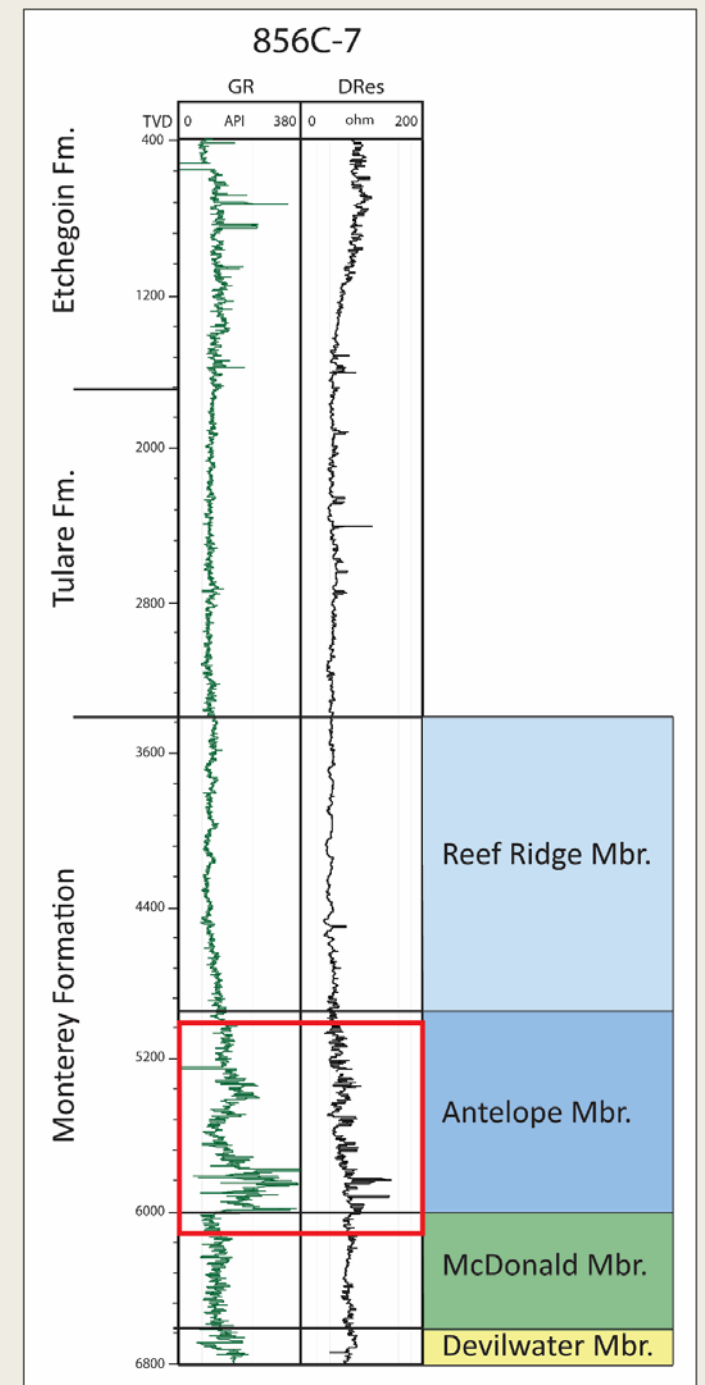
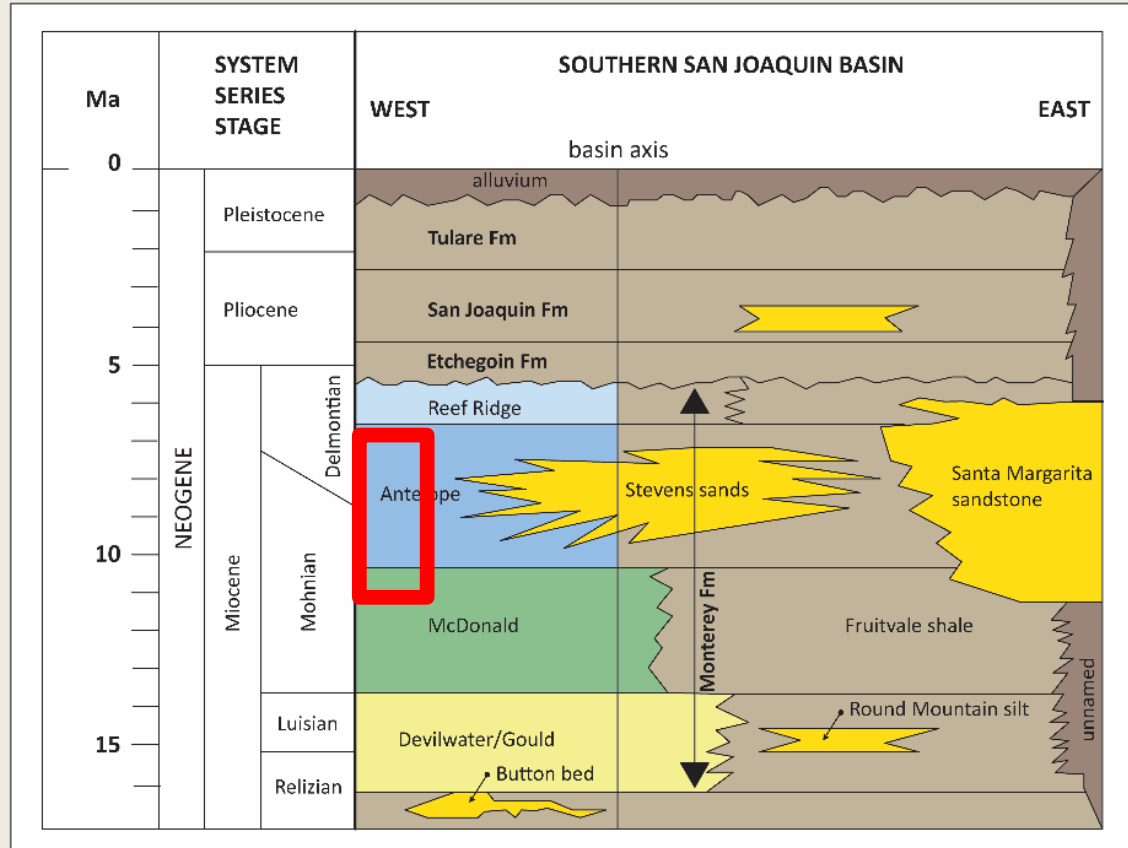
- Over 100 years old
- One of the 10 most productive fields in the U.S.
- 22 miles long and 2.5 miles wide
- As of 2011 field produced 1.6 bbbbls of the 6 bbbbls in place



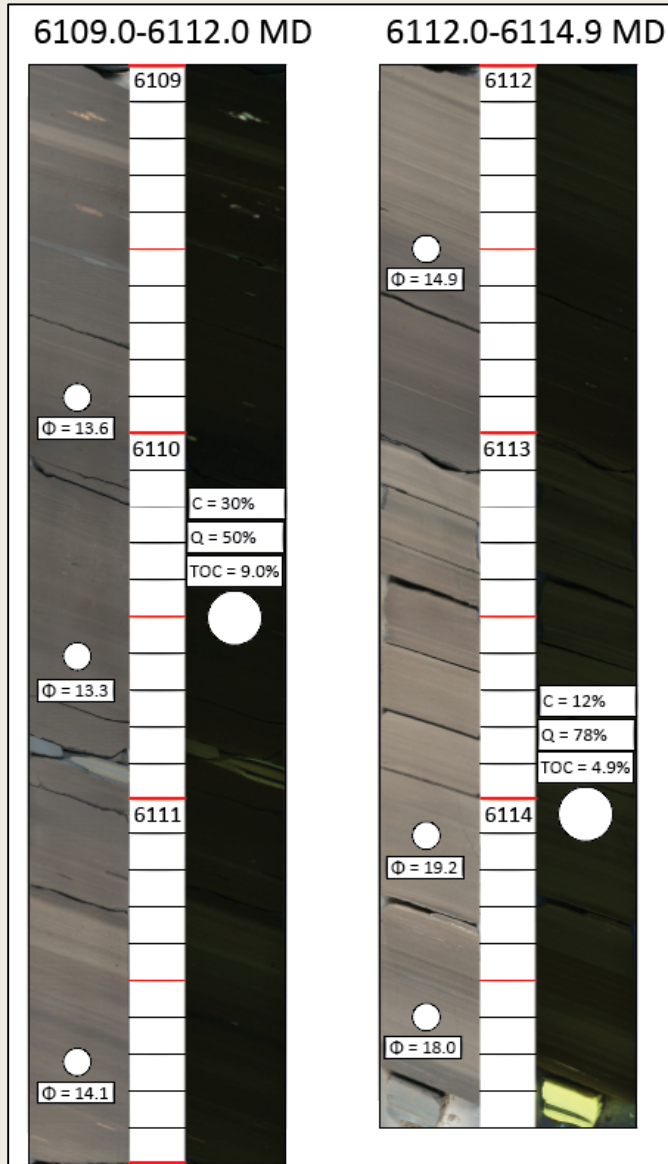
Study Interval: Belridge Oil Field

Data set

- 7 wells
- 4 core (XRD, XRF, Rock eval, conventional core analysis)
- Spectral gamma ray log suite
- Elemental capture spectroscopy log suite
- Triple combo log suite

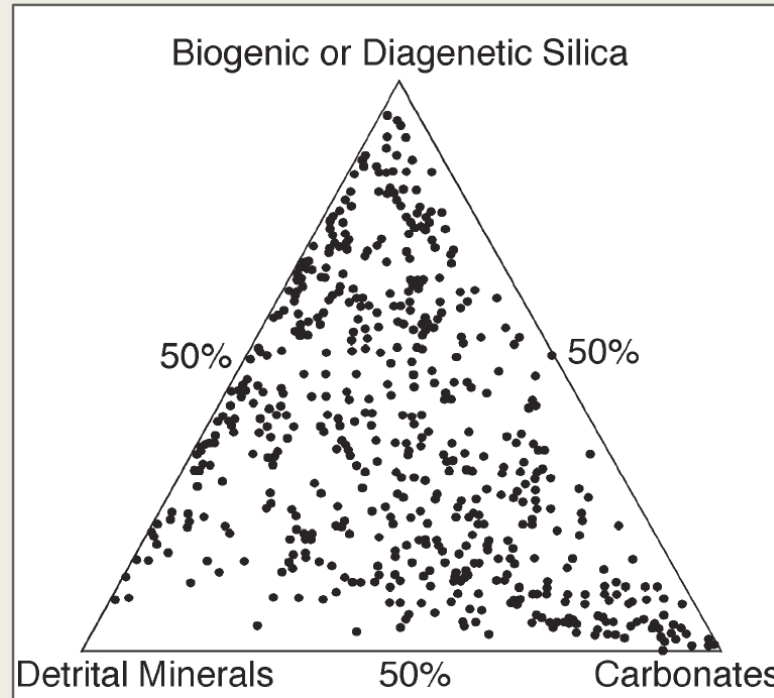


Monterey Fm. Composition



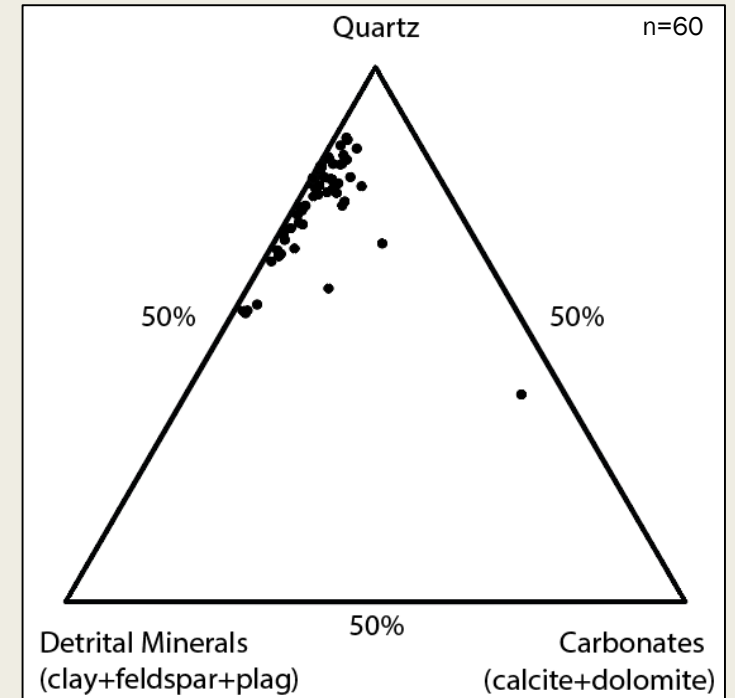
Well 856C-7

Monterey Formation
(SB Basin)

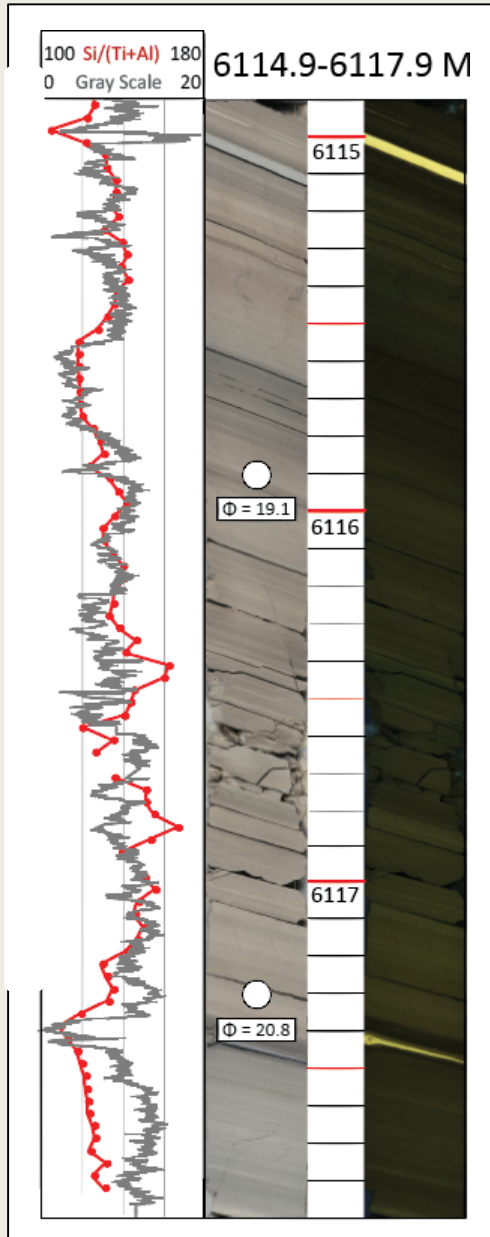


Isaacs, 1985
SB Basin

Study Interval

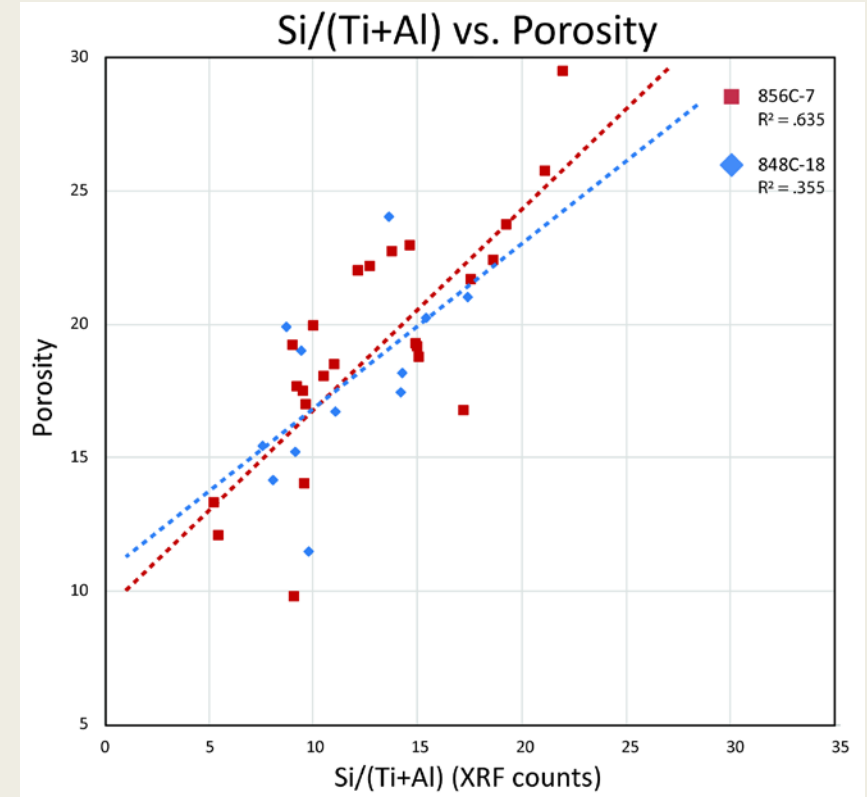
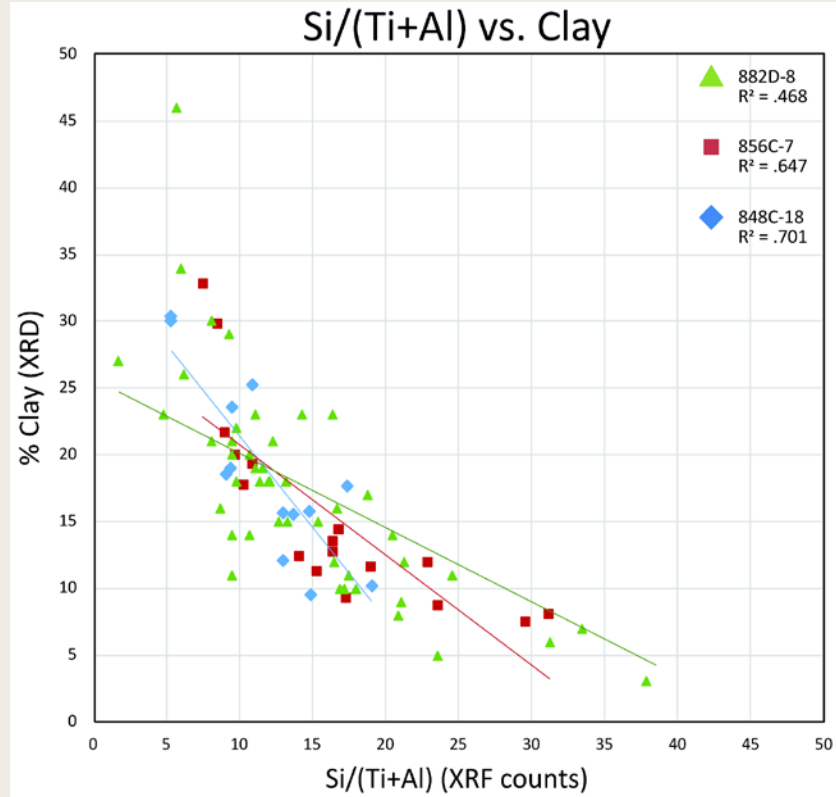


Monterey Fm. Composition

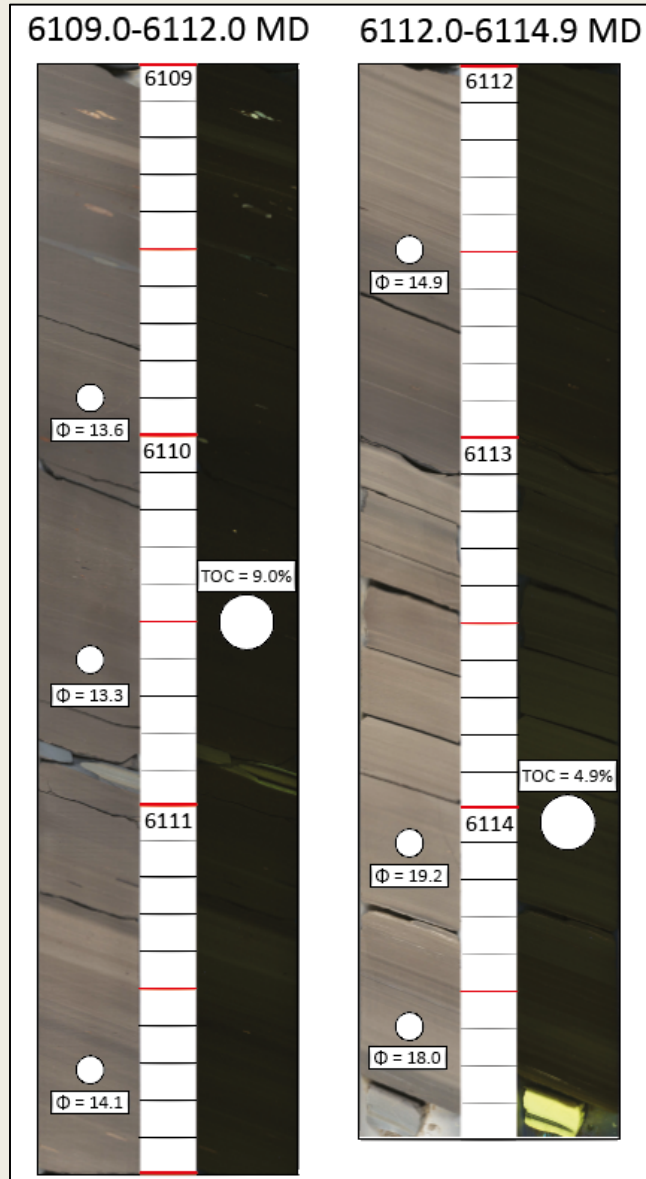


Weller, 2018

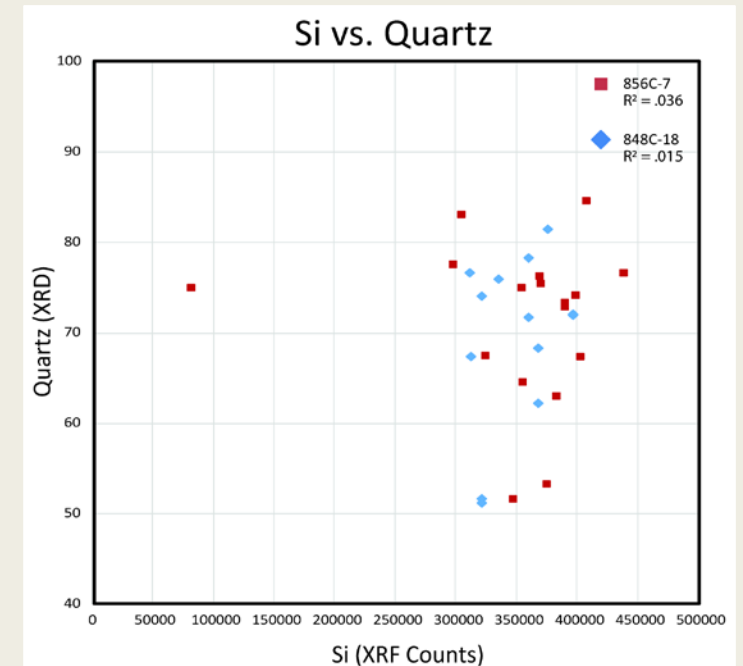
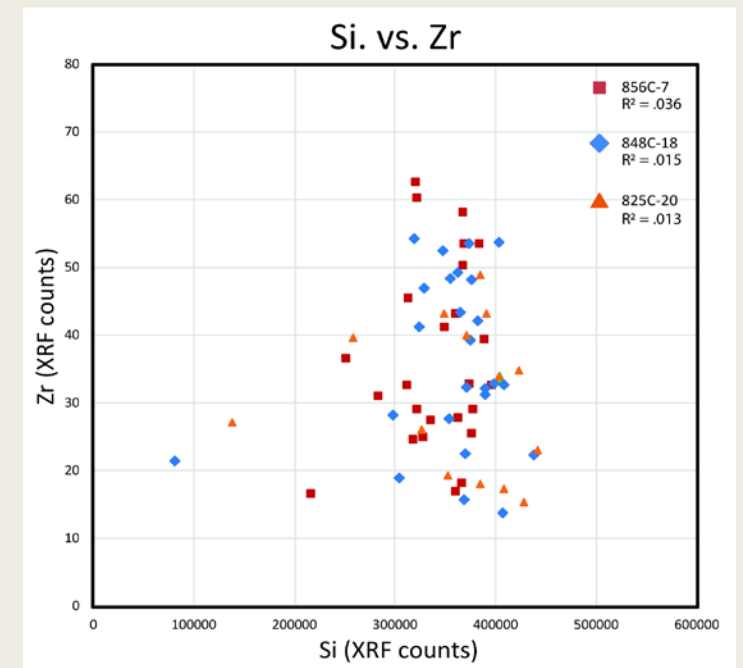
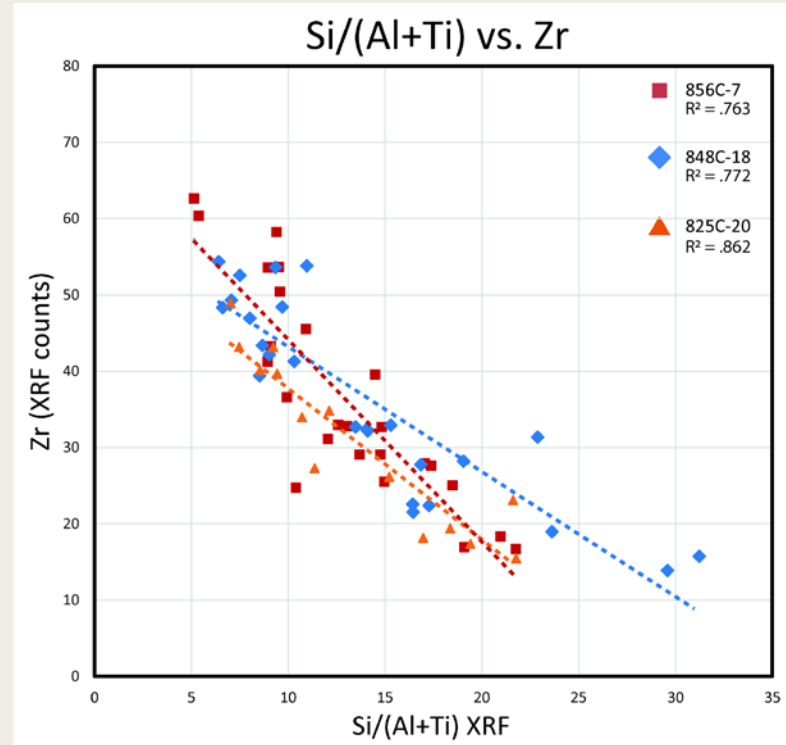
Well 856C-7



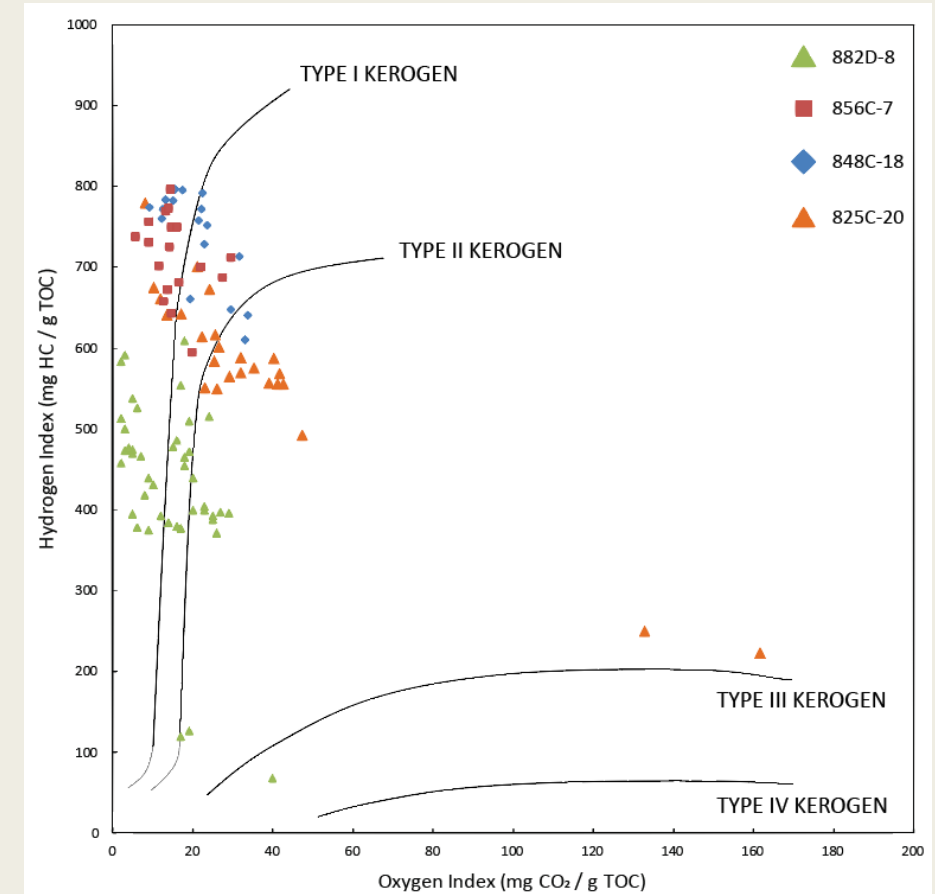
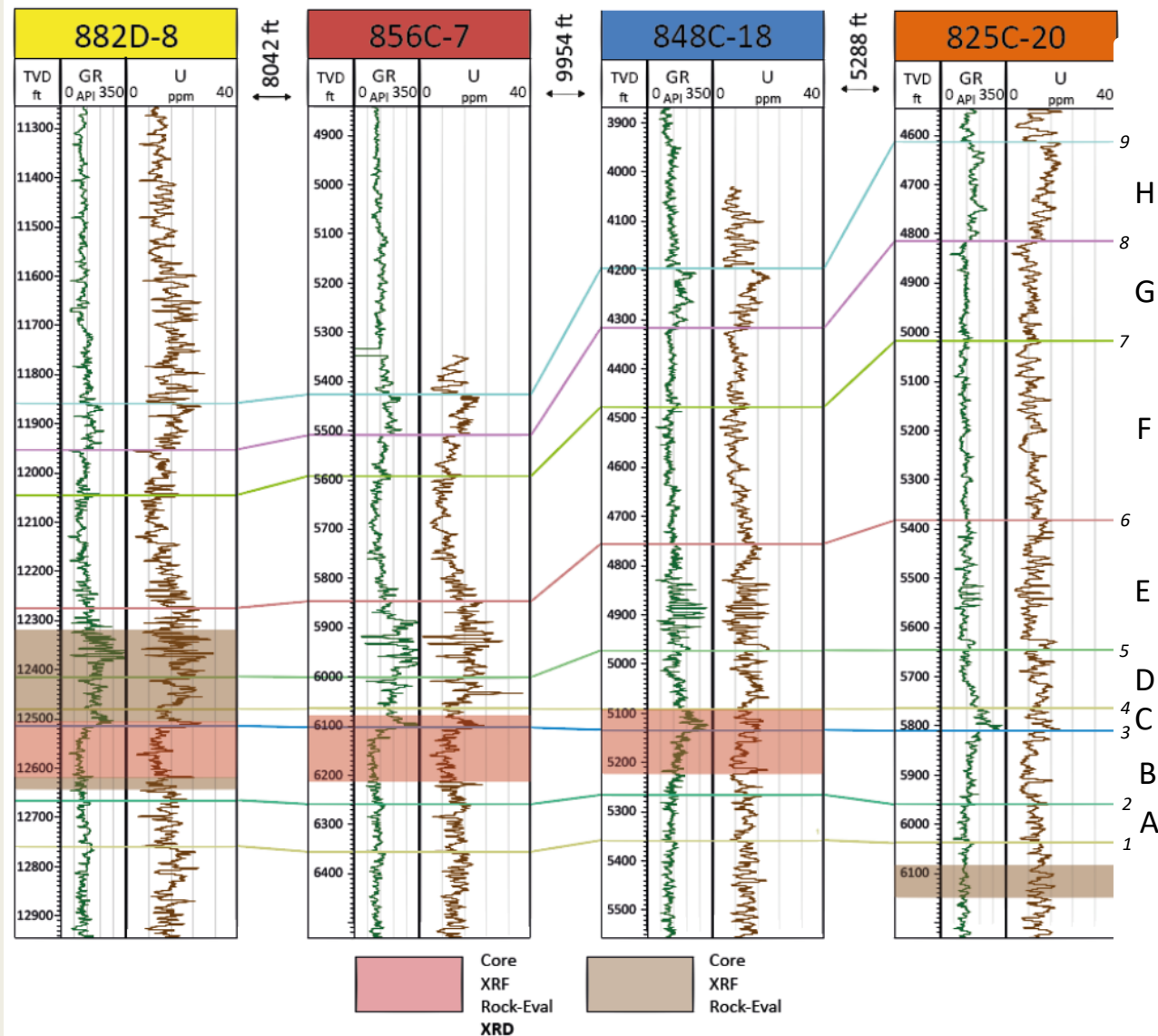
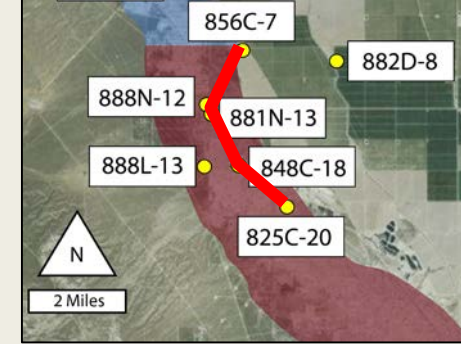
Monterey Fm. Composition



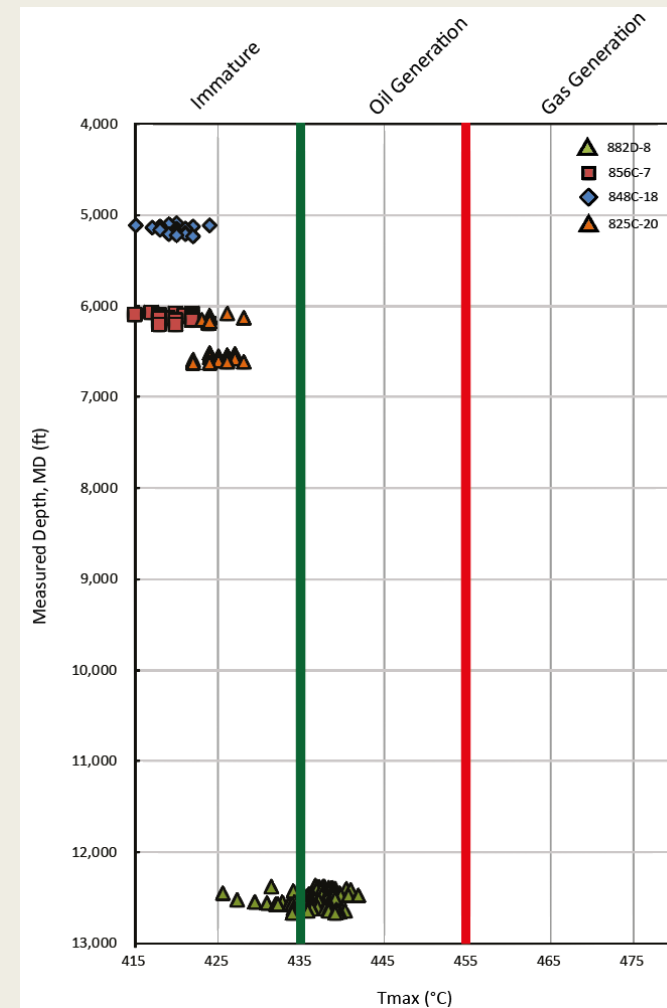
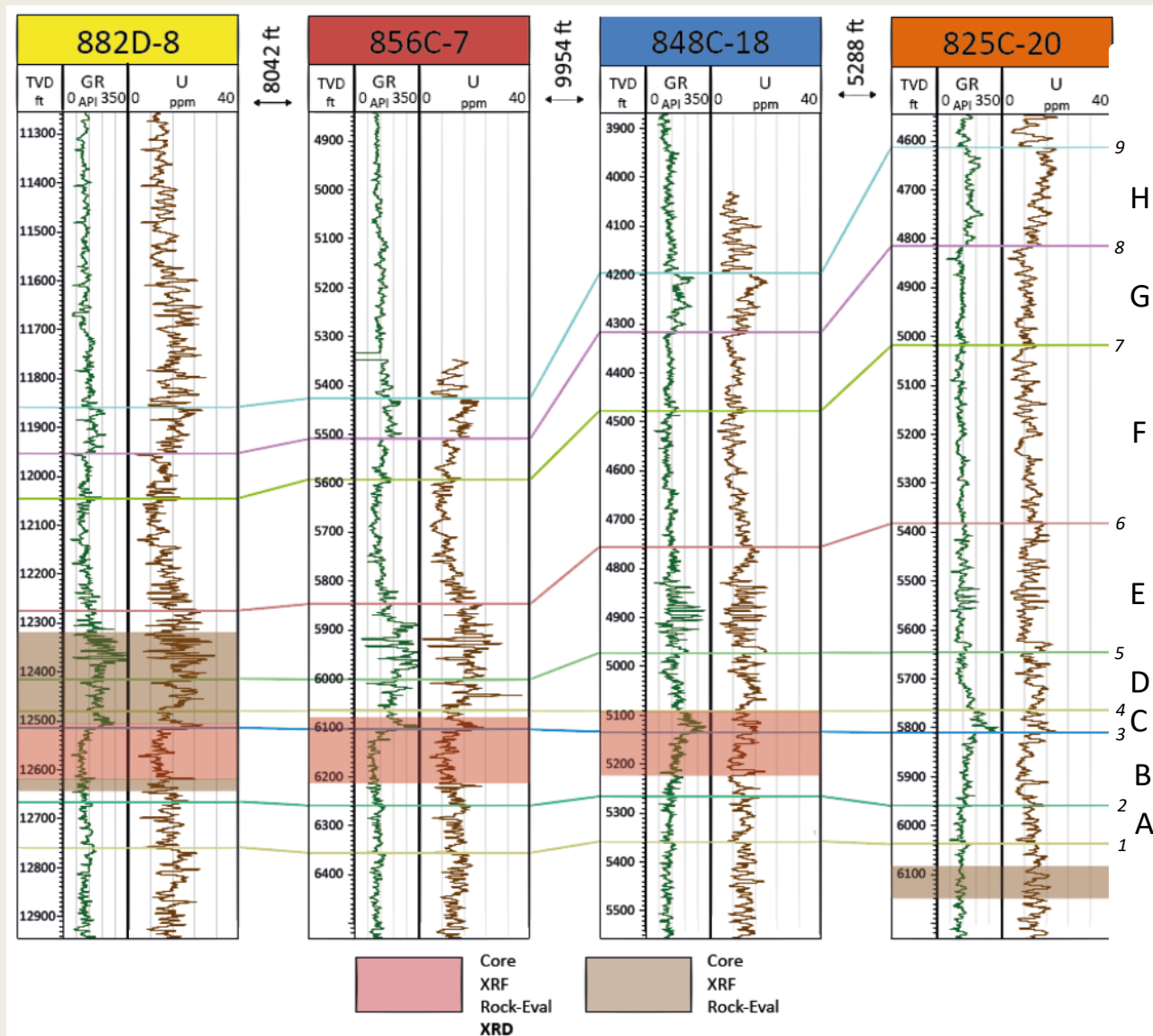
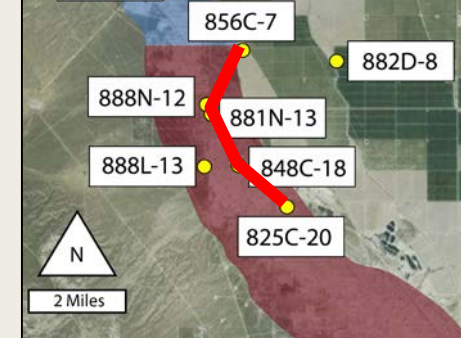
Well 856C-7



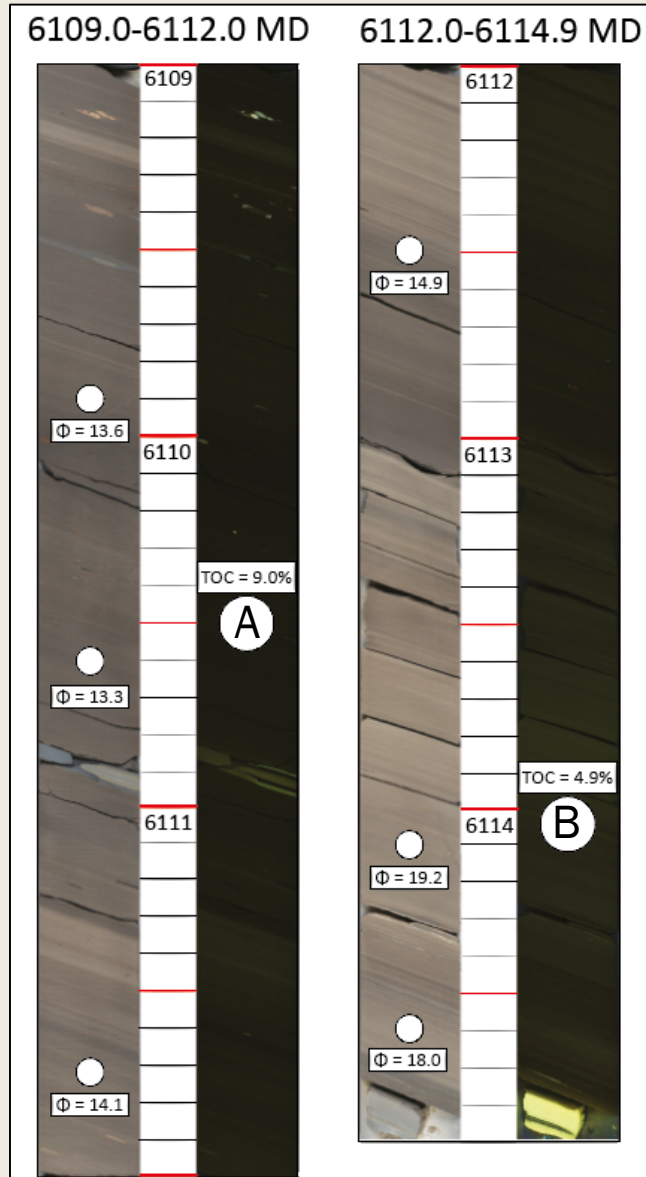
Monterey Fm. Composition



Monterey Fm. Composition

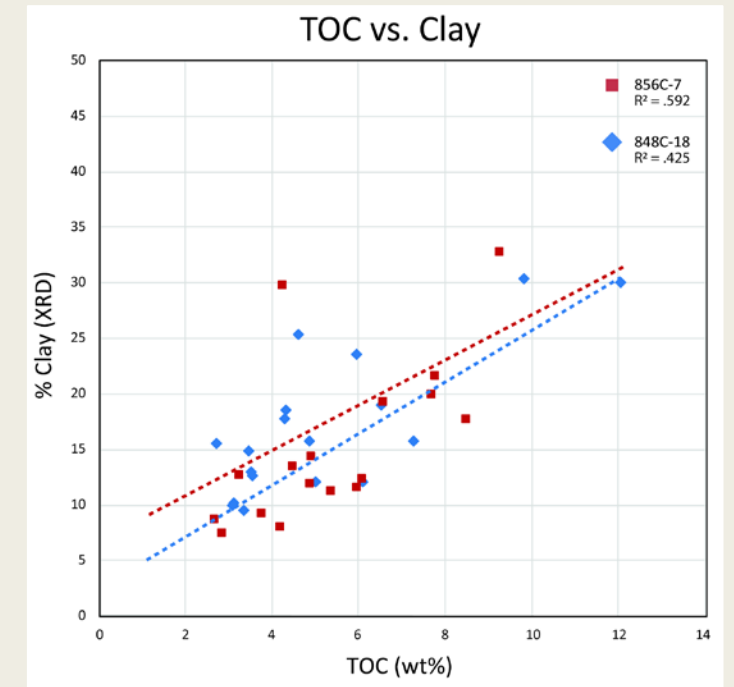
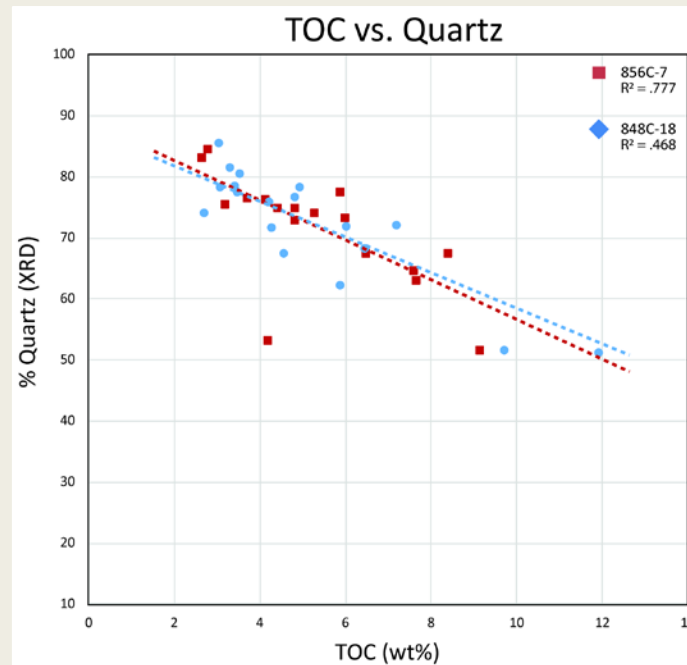
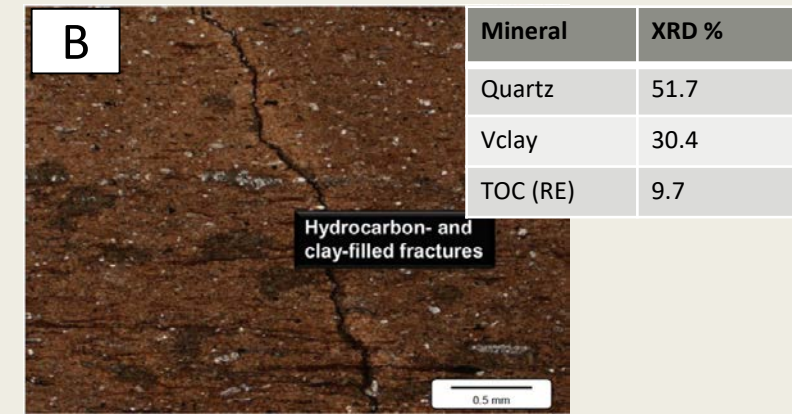
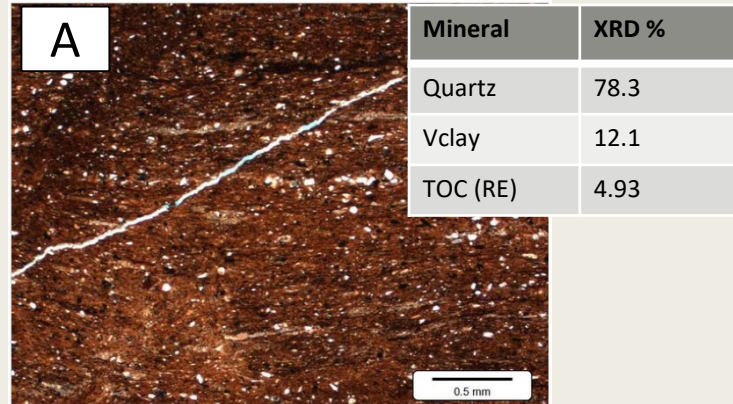


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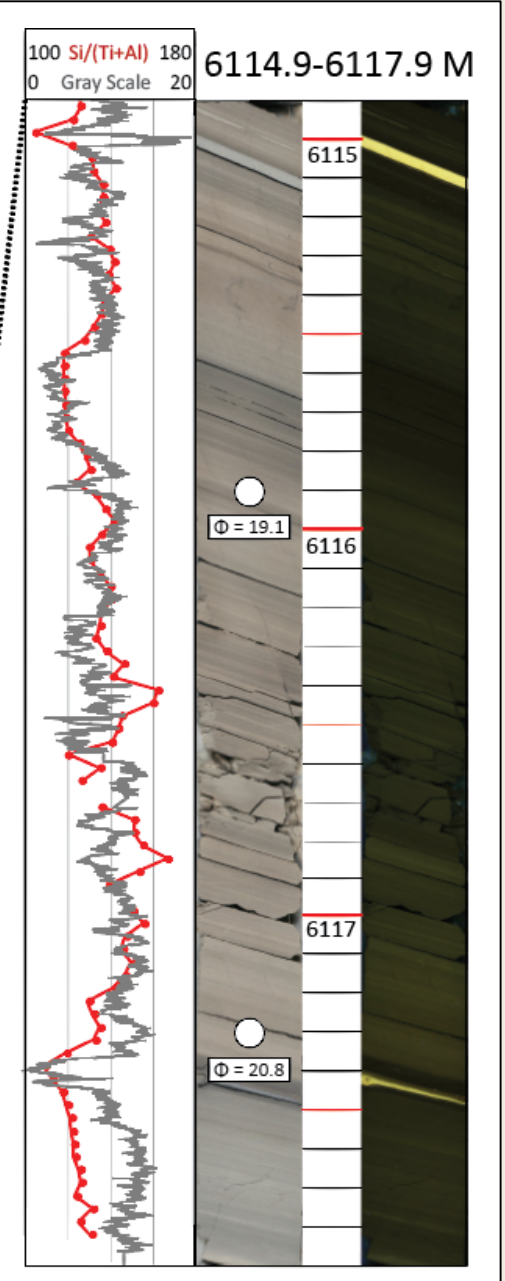
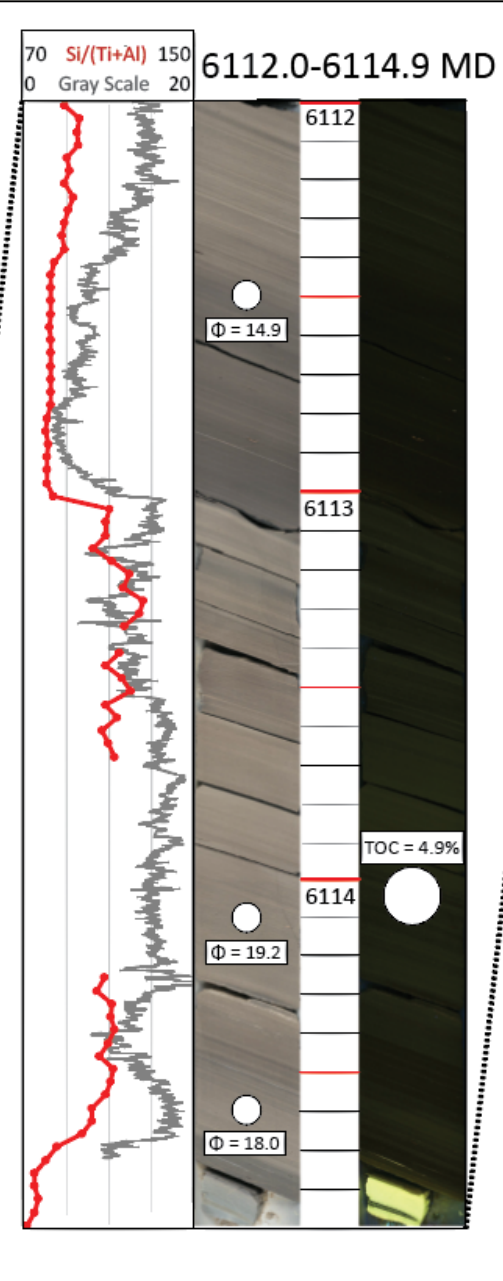
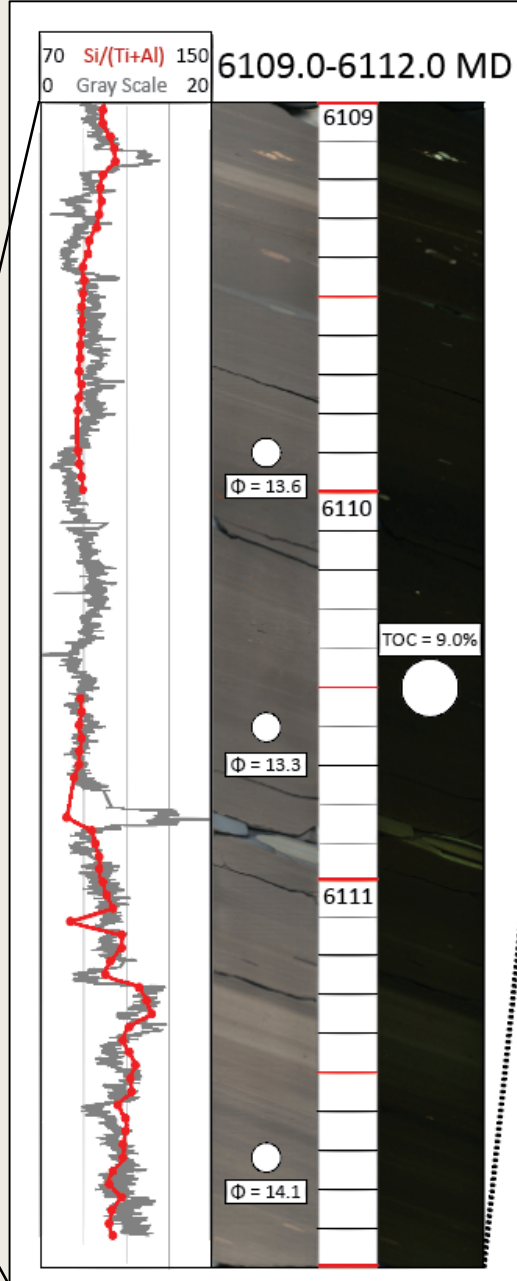
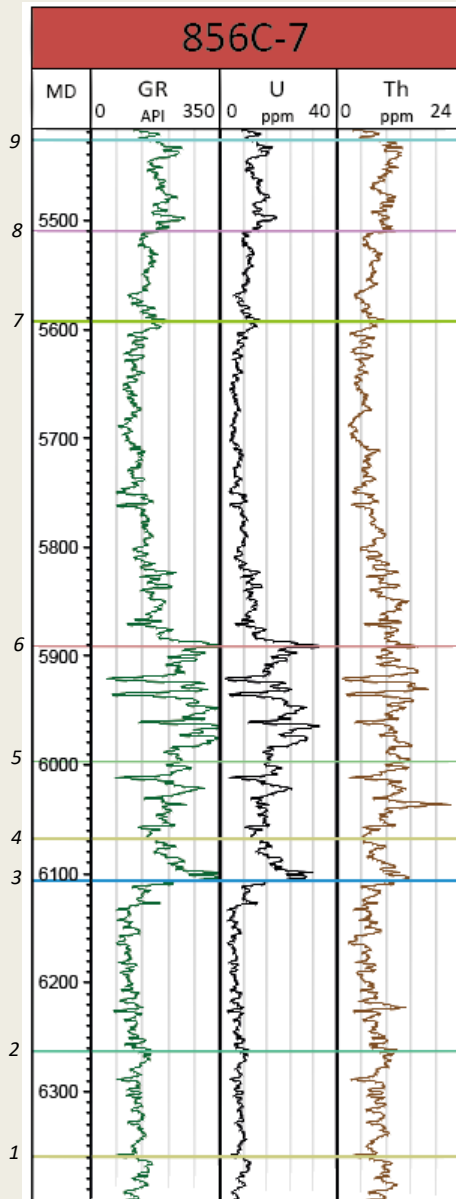


Weller, 2018

Well 856C-7

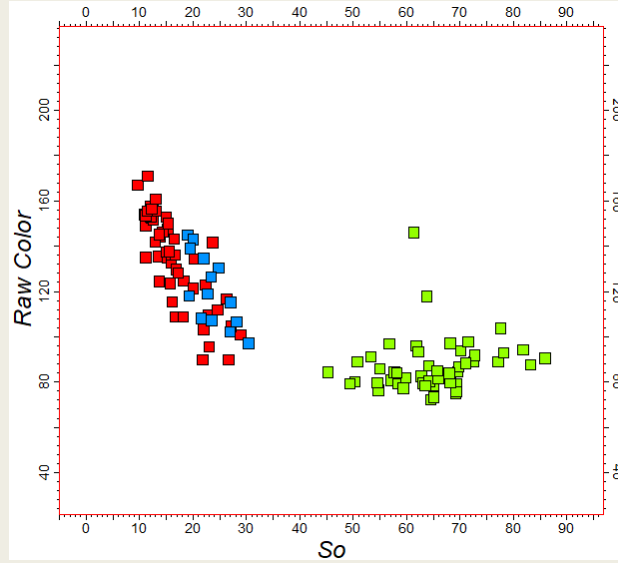


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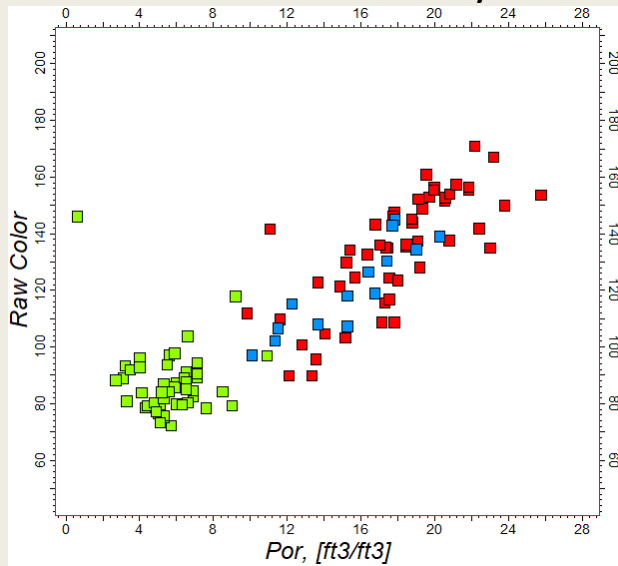


Core Panel

Color vs So

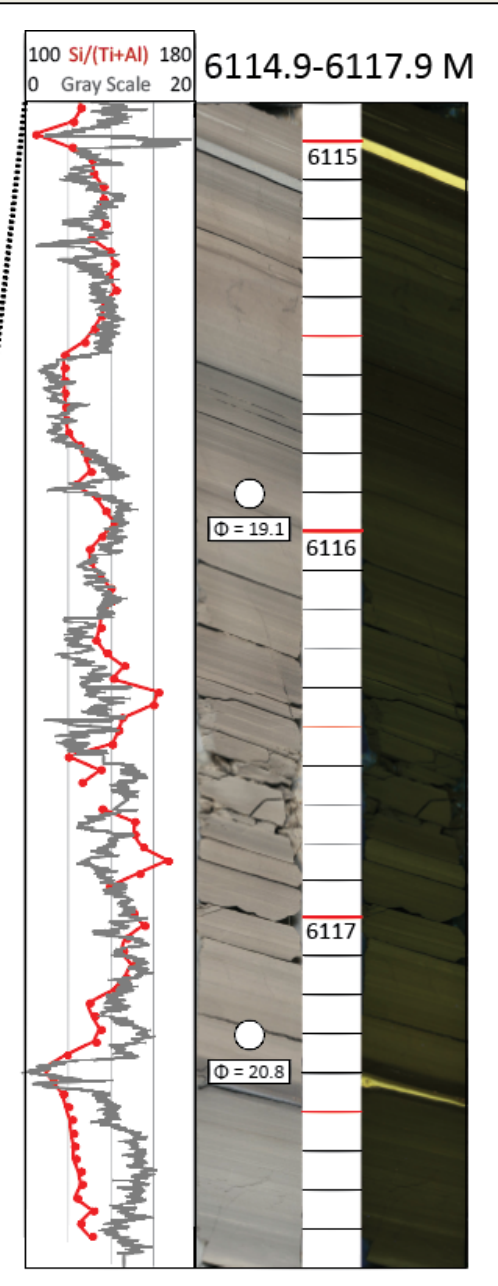
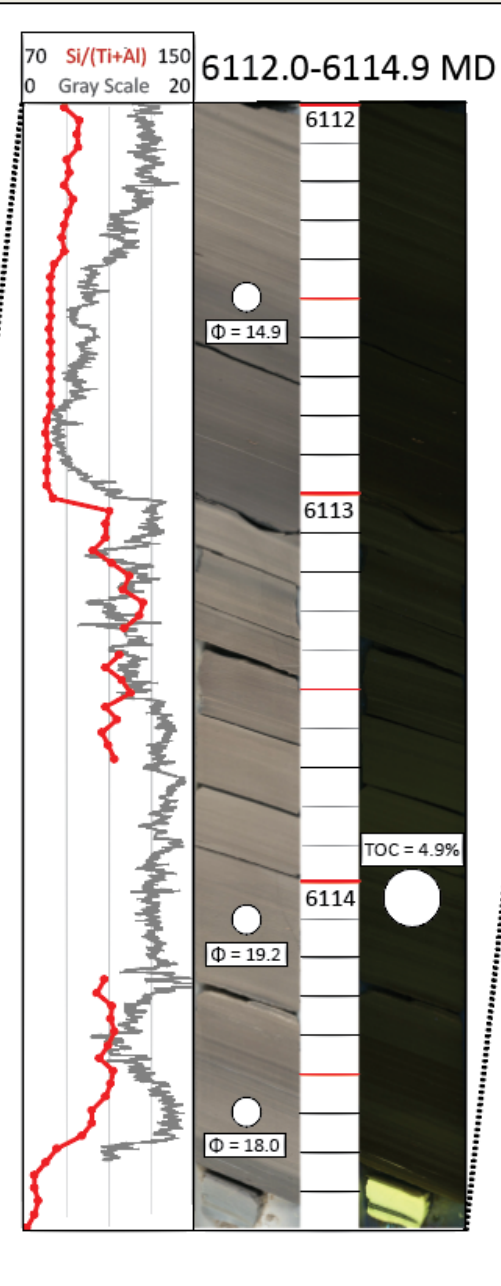
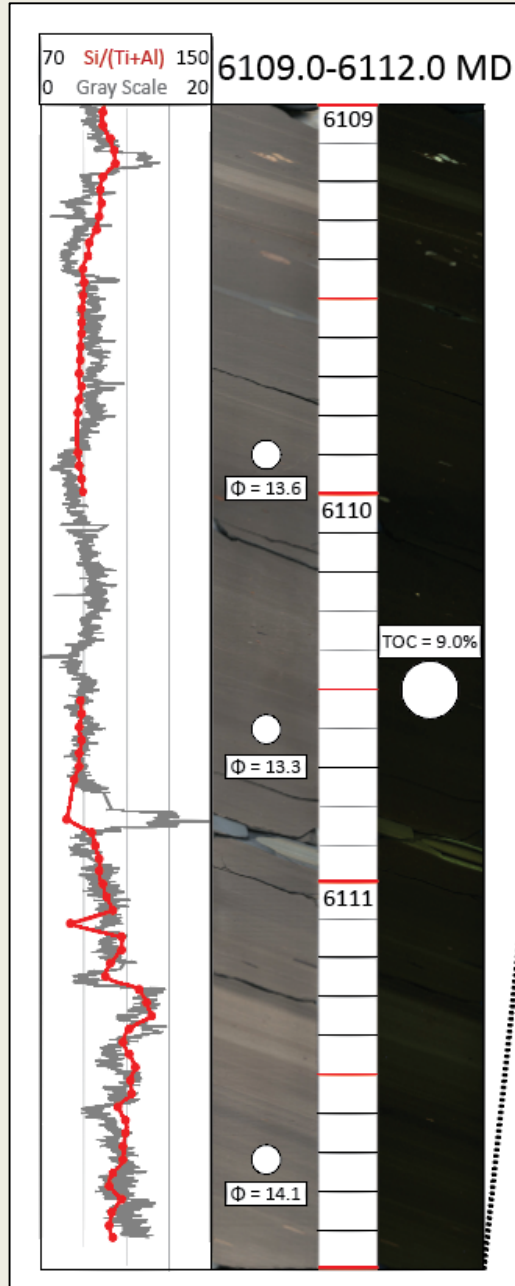


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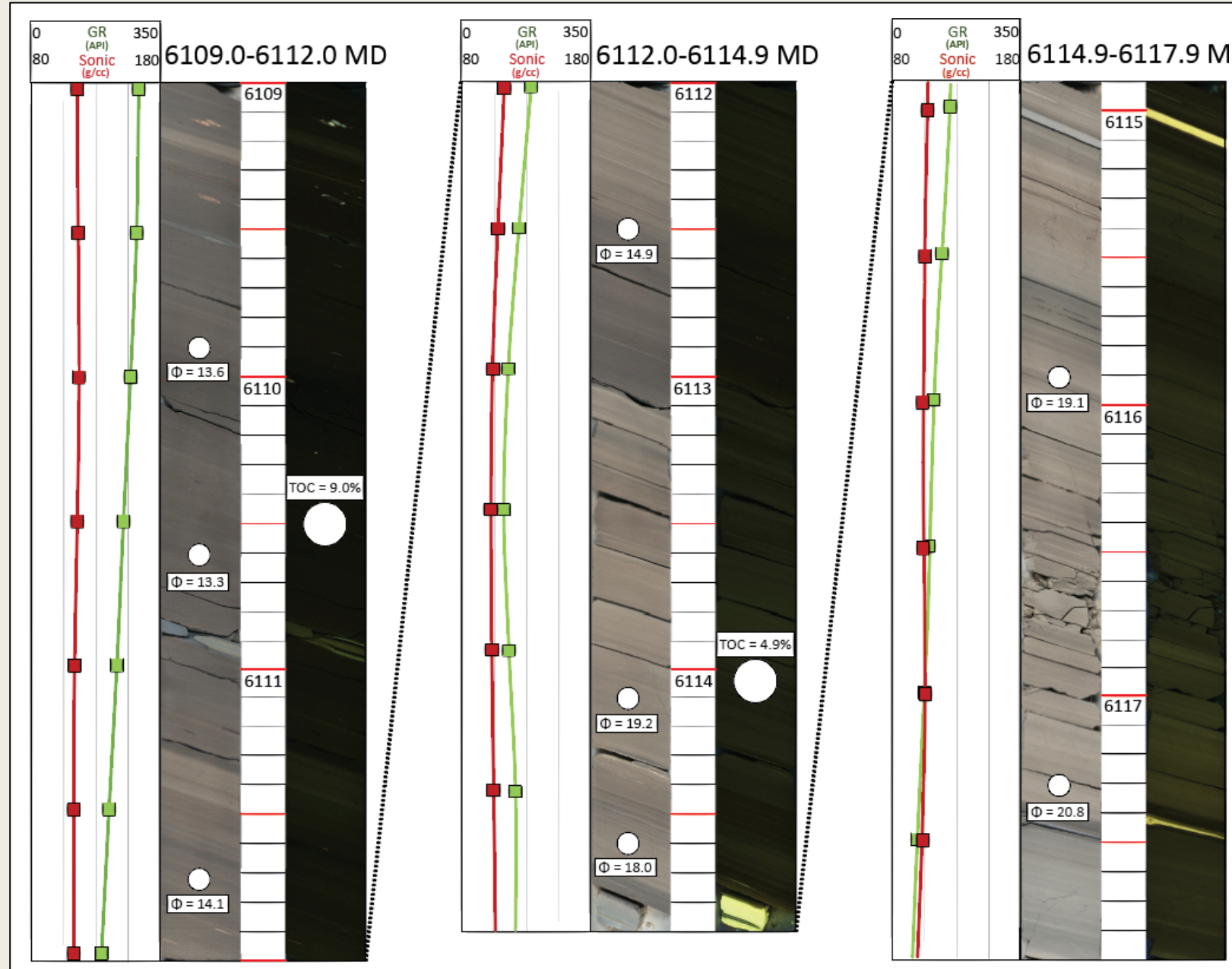


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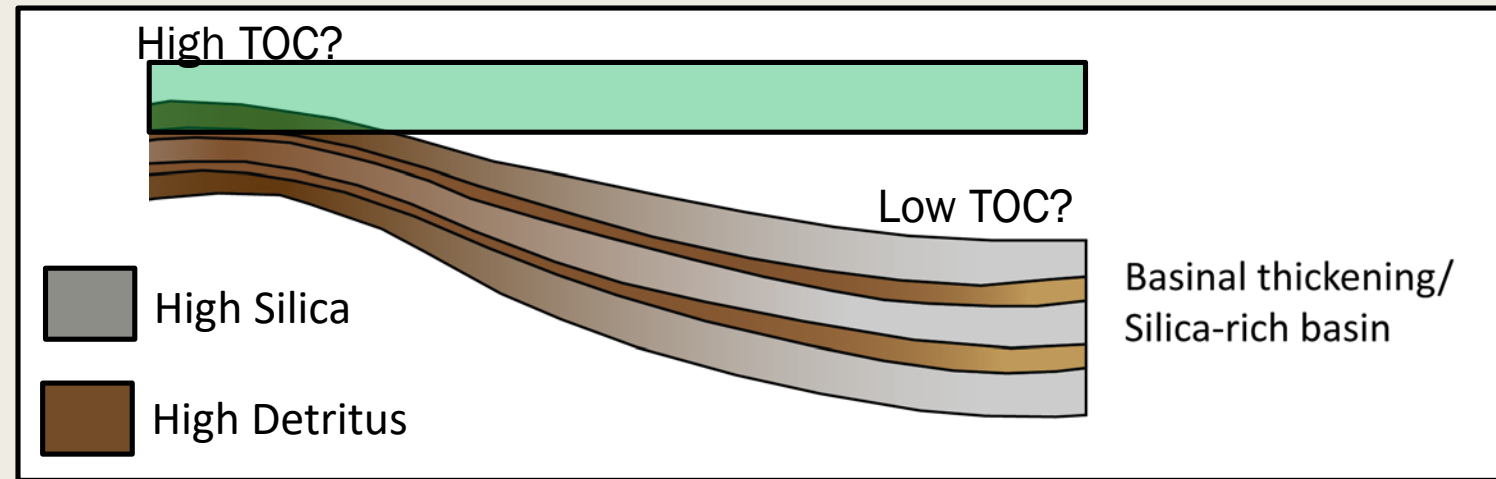
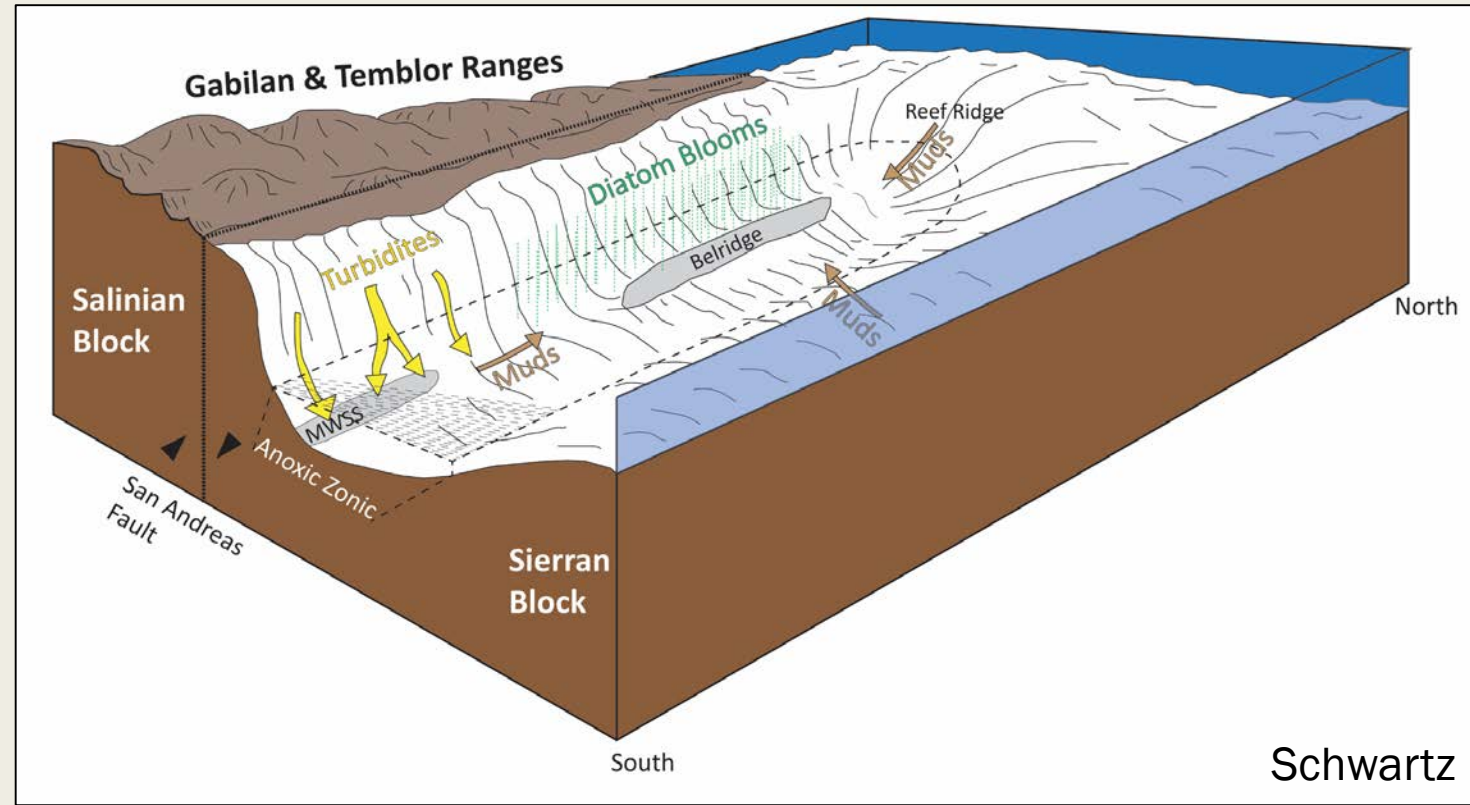
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- Por vs. Raw Color (856C-7)
- Por vs. Raw Color (848C-18)



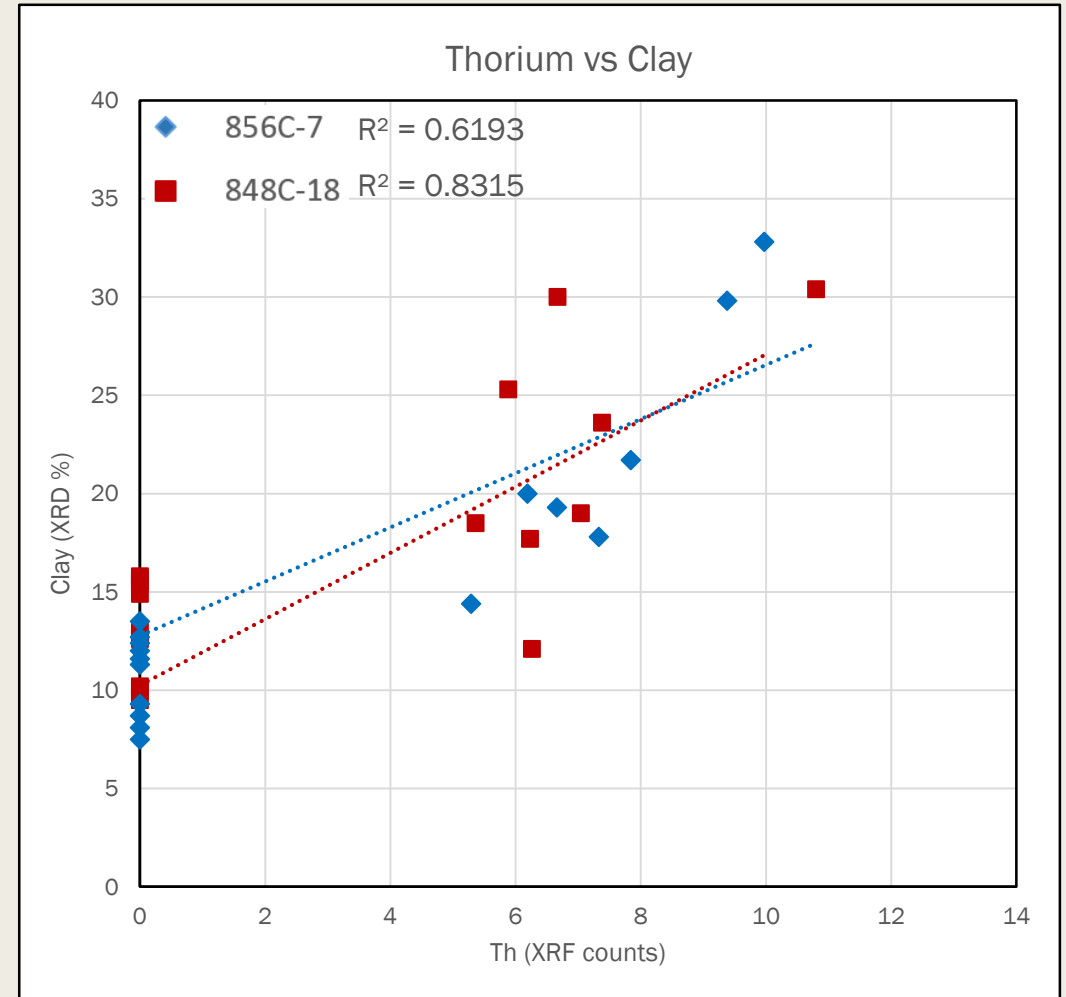
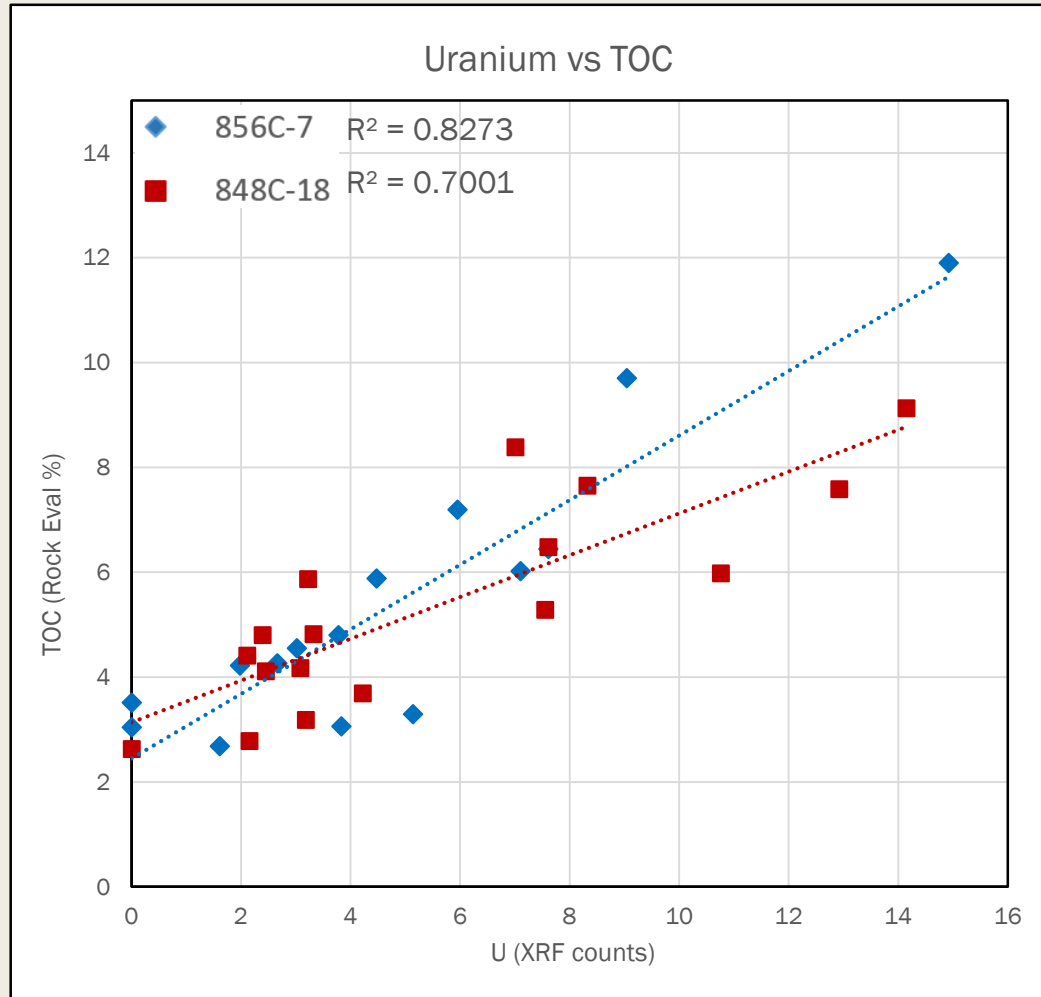
Well Log to Core



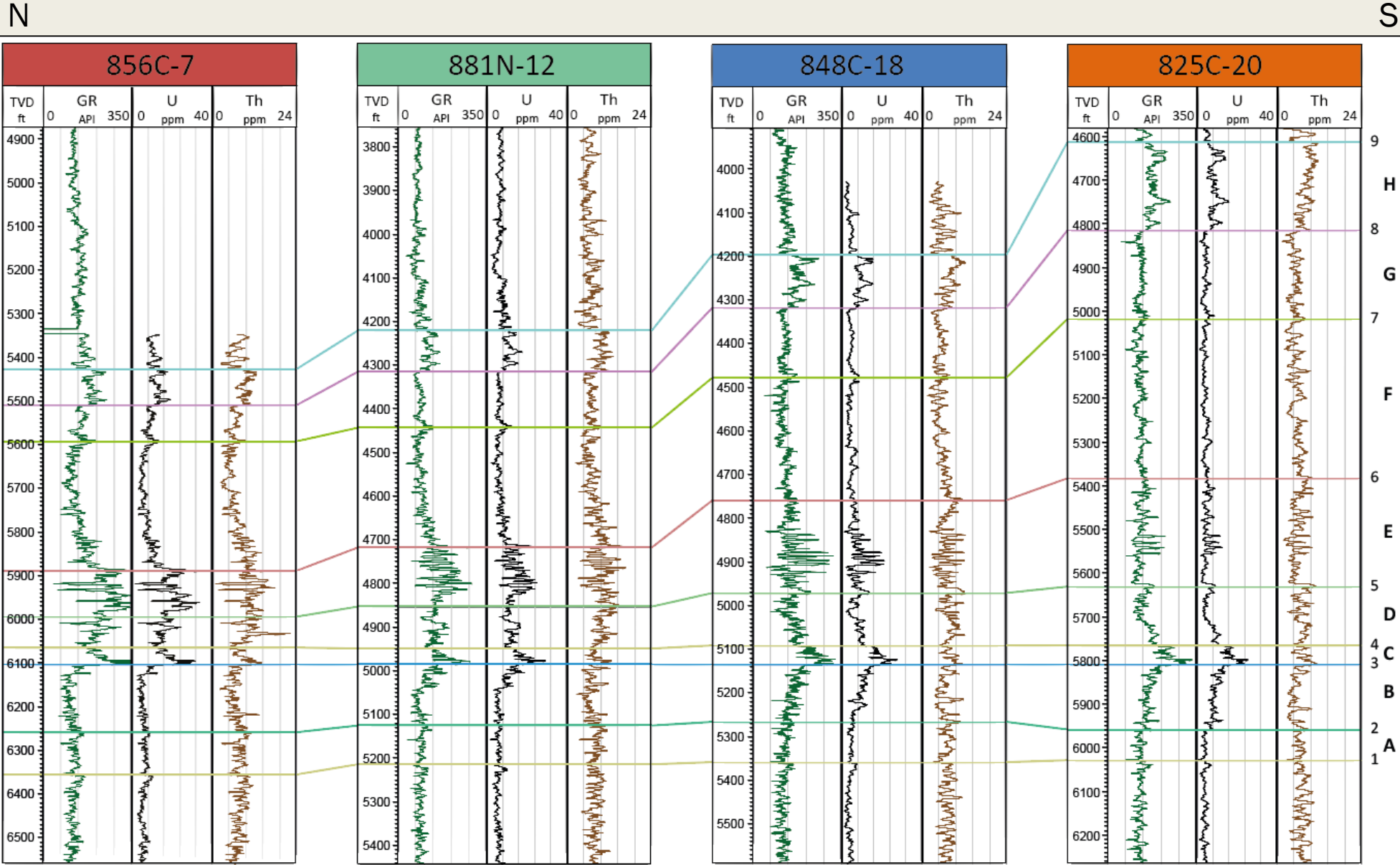
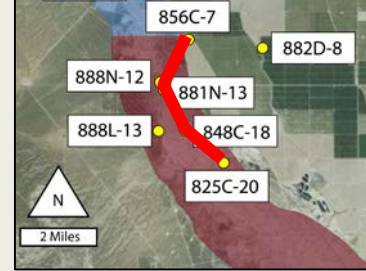
Lateral Variation



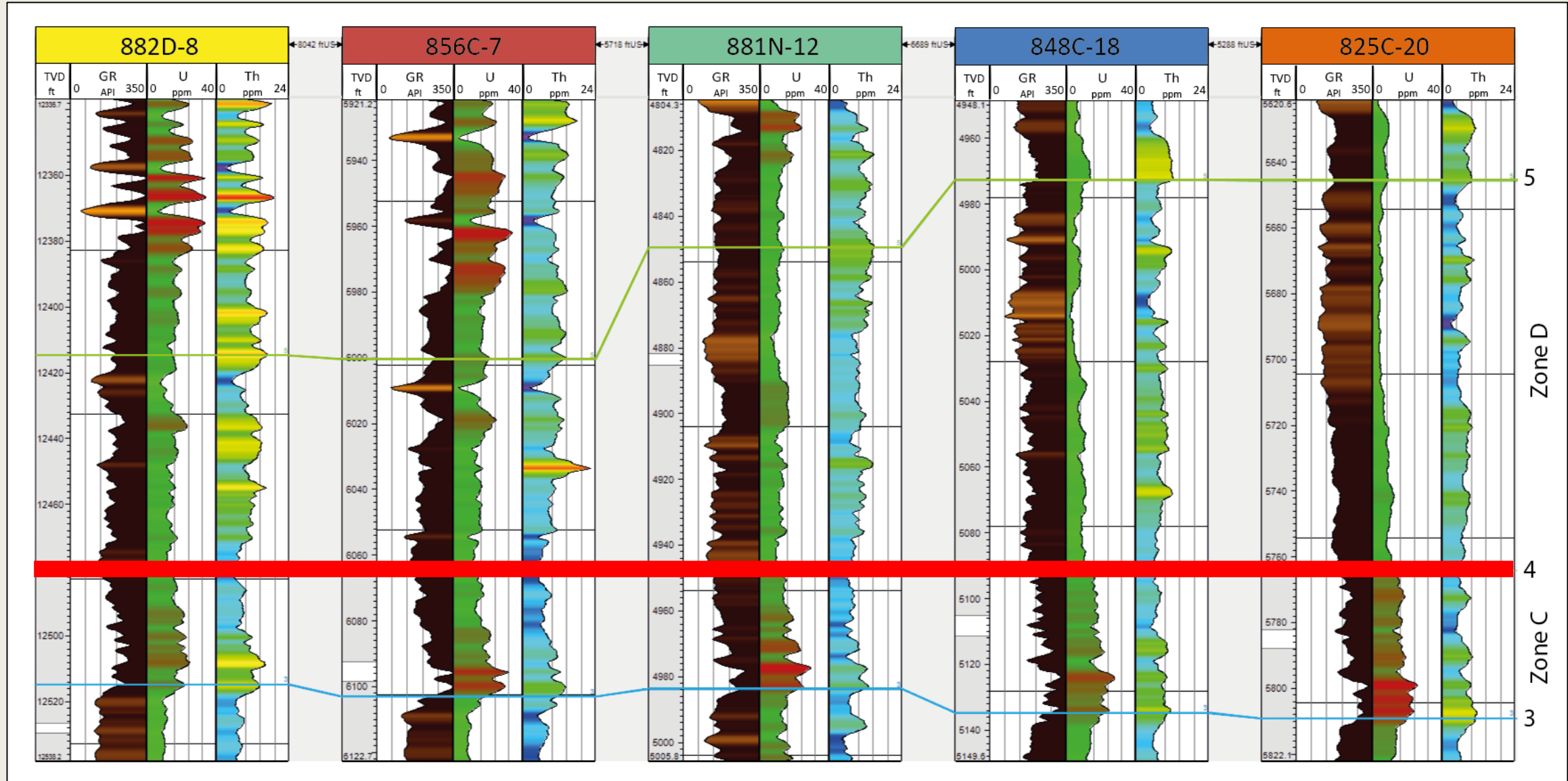
Spectral Gamma Ray Logs



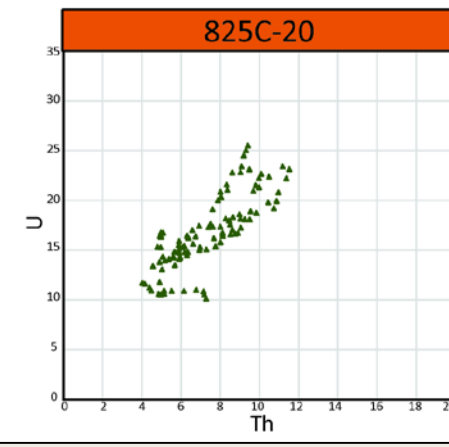
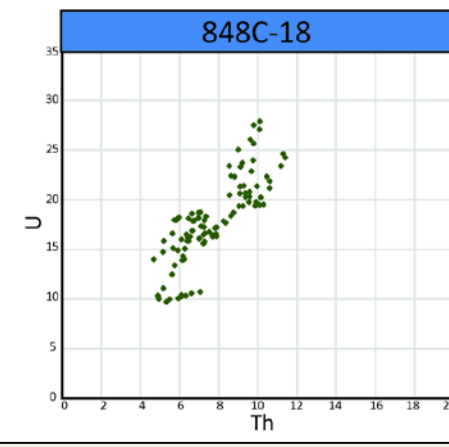
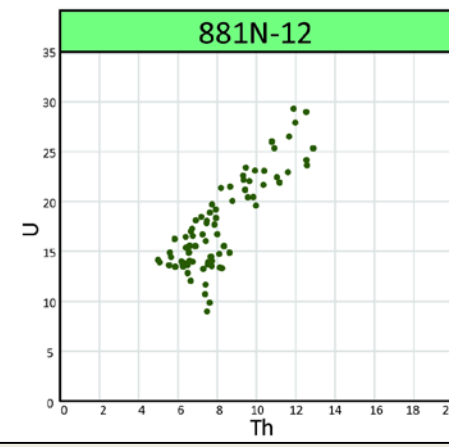
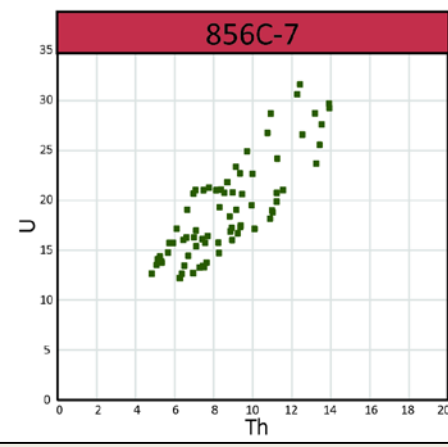
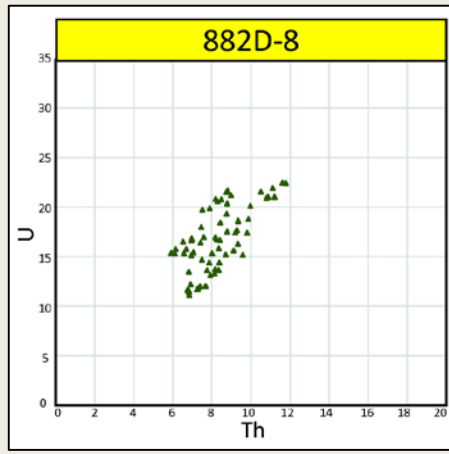
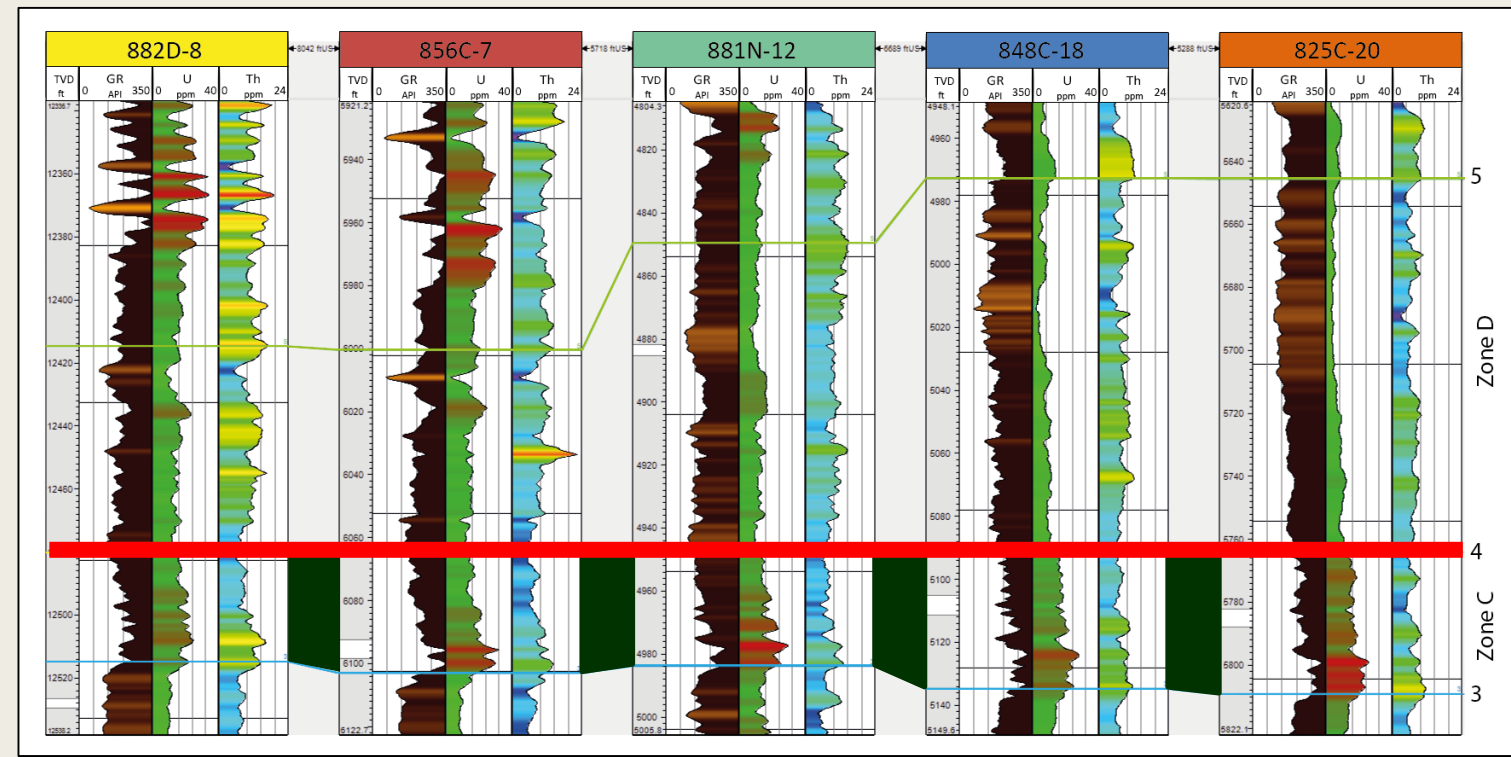
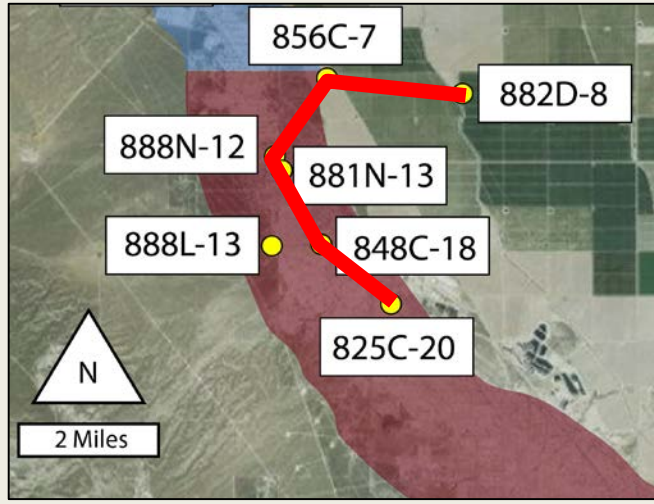
X-Section



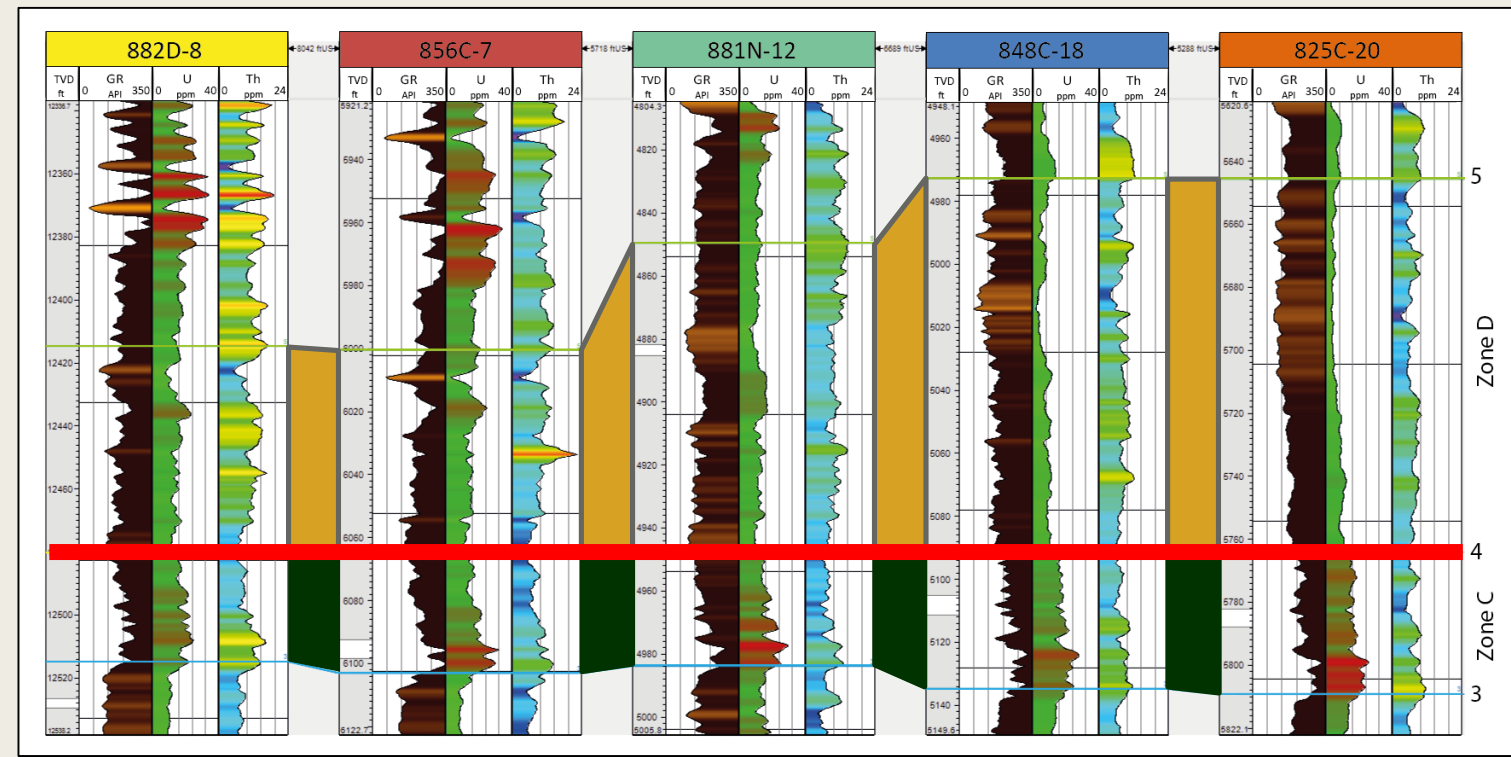
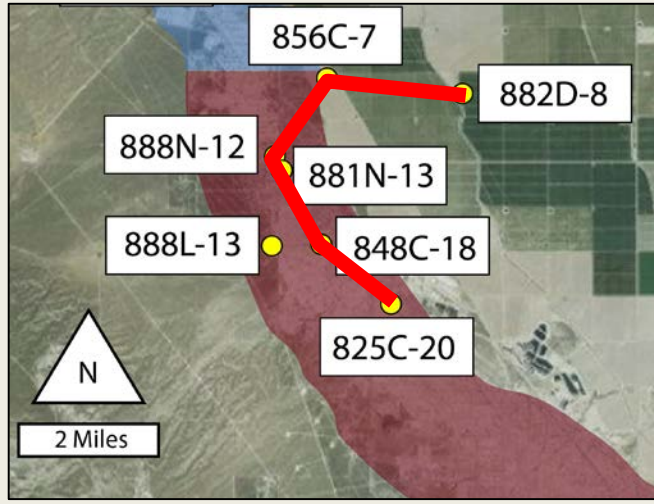
Lateral Variation: Zone C & D



Lateral Variation: Zone C & D

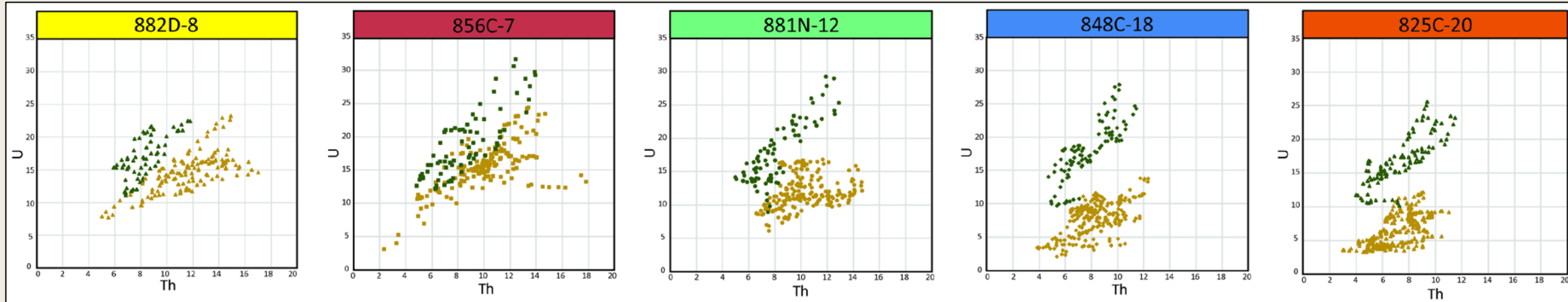


Lateral Variation: Zone C & D

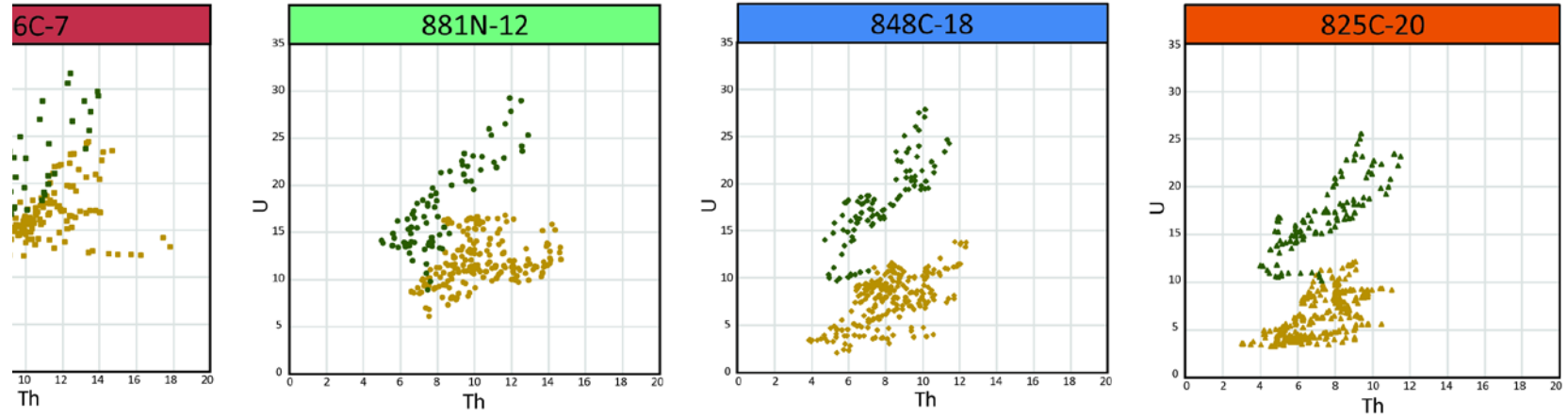
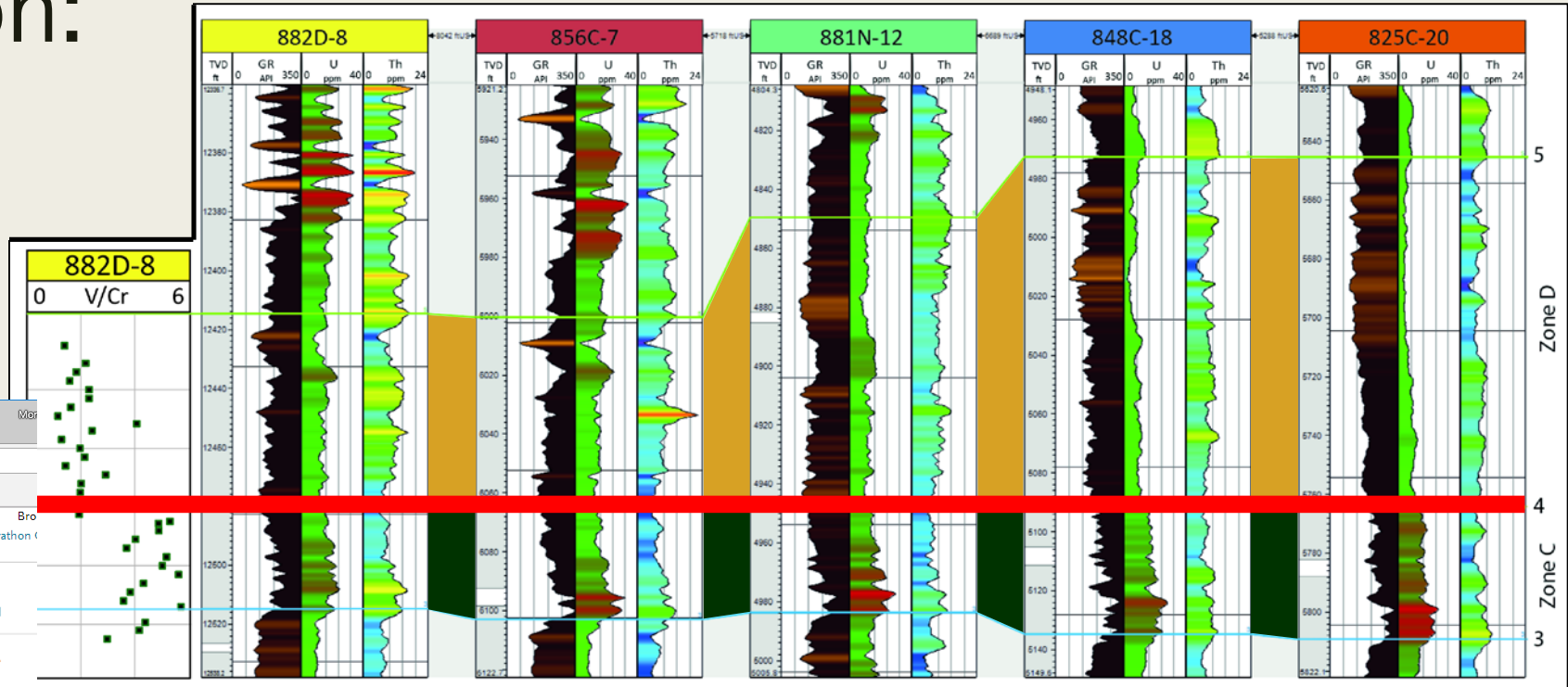
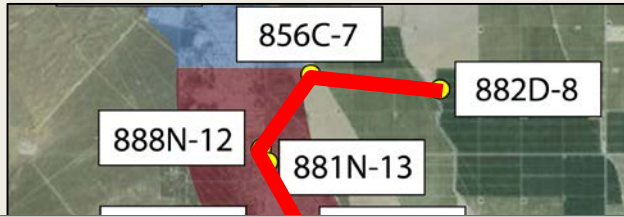


North

South



Lateral Variation: Zone C & D



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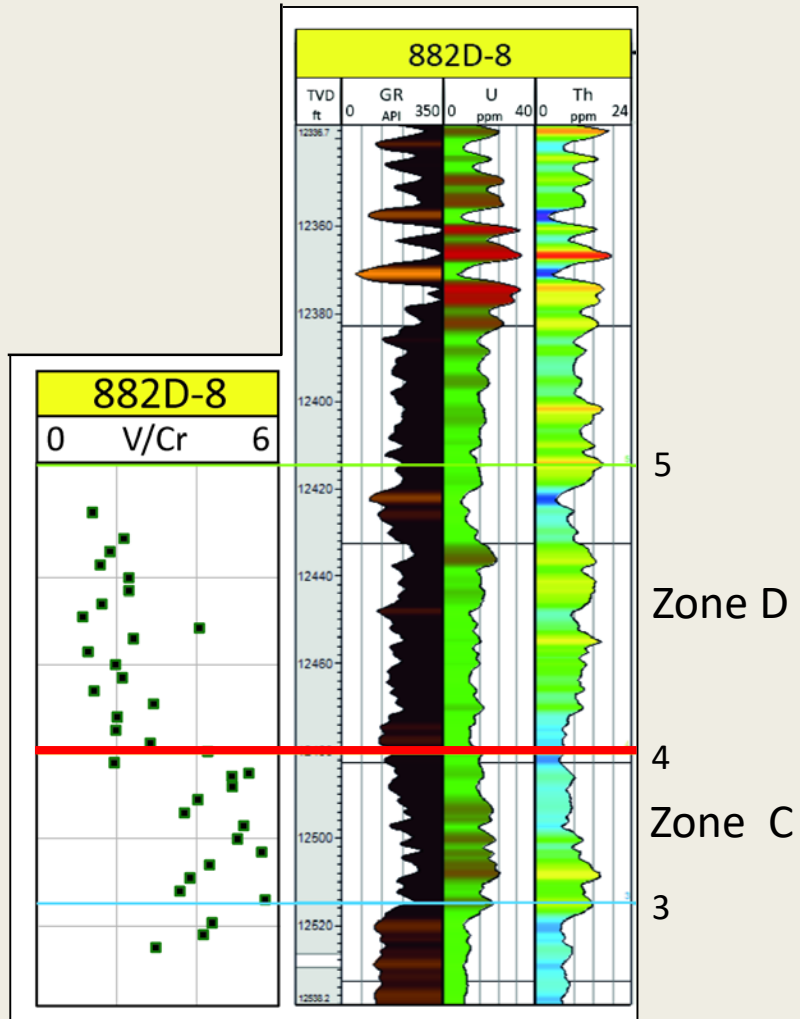
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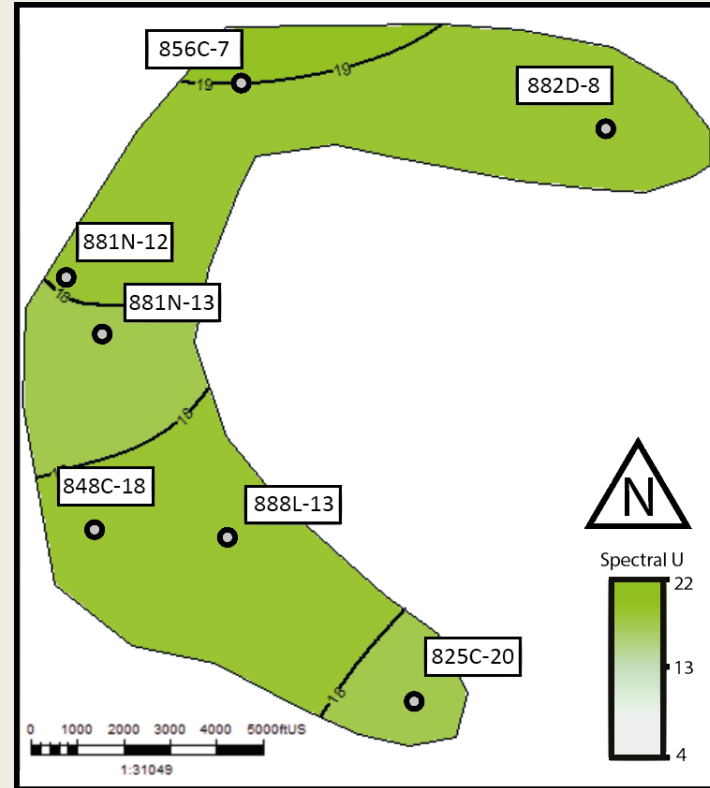
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C/S, U/Th, authigenic uranium, V/Cr, Ni/Co, Ni/V and (Cu+Mo)/Zn means of factor analysis, to identify the most reliable. DOP, U/Th, Cr and Ni/Co form an internally consistent set and are recommended indices. Ni/V, C/S and (Cu+Mo)/Zn convey little palaeo- and are not regarded as reliable.

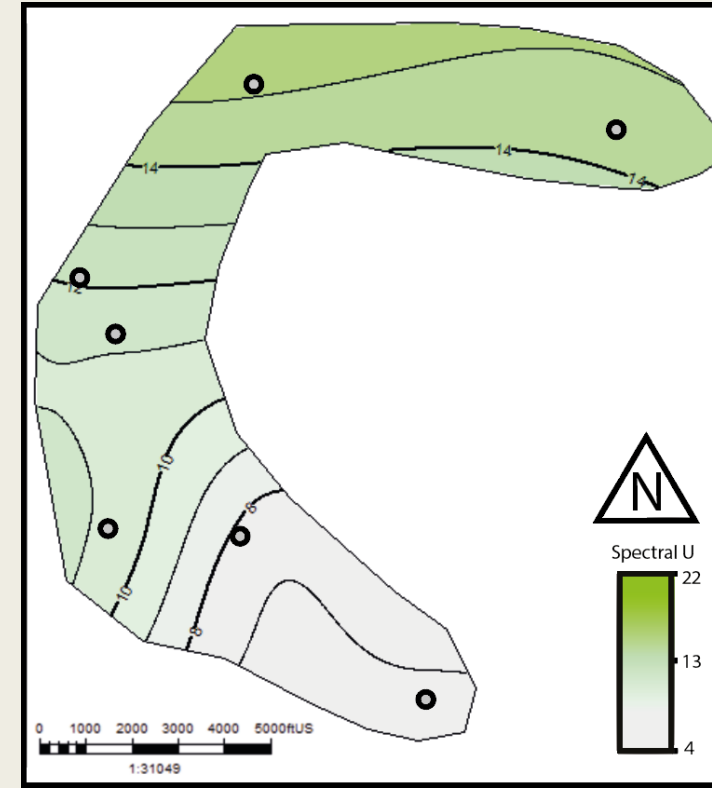
Lateral Variation: Zone C & D



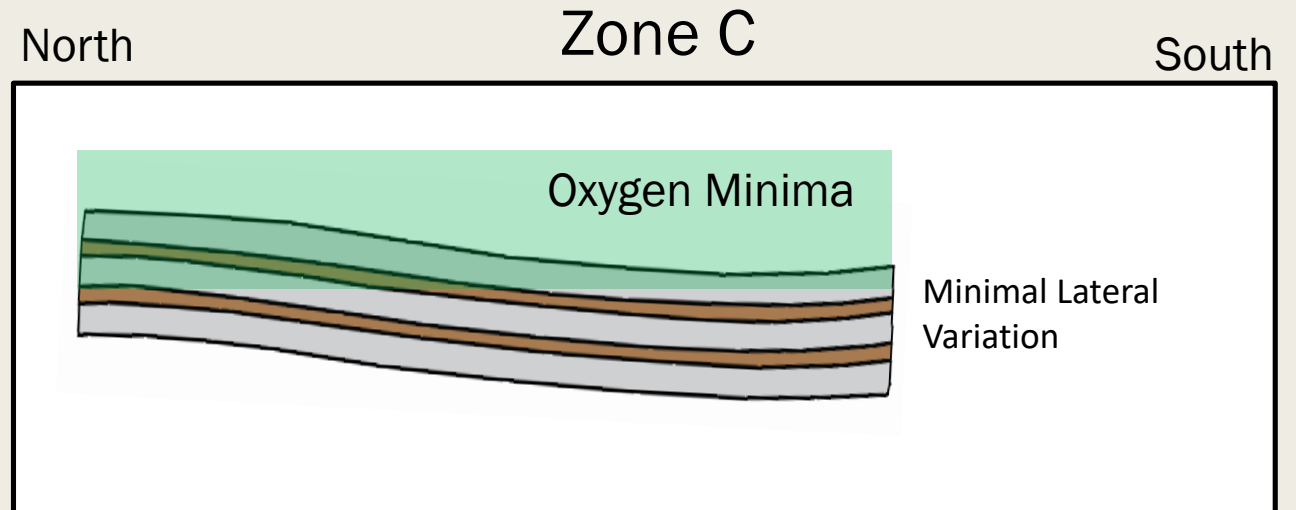
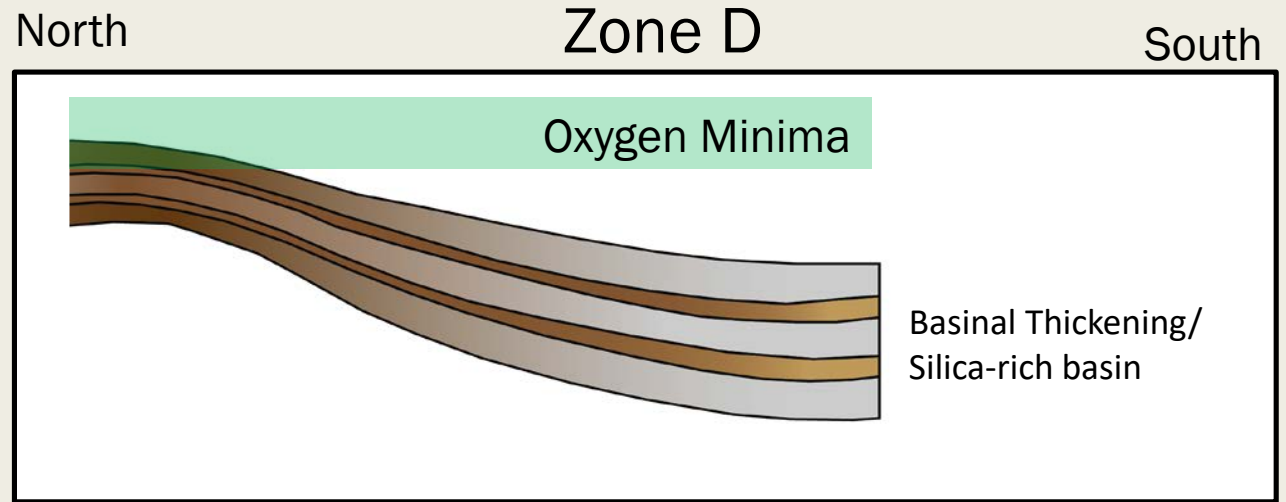
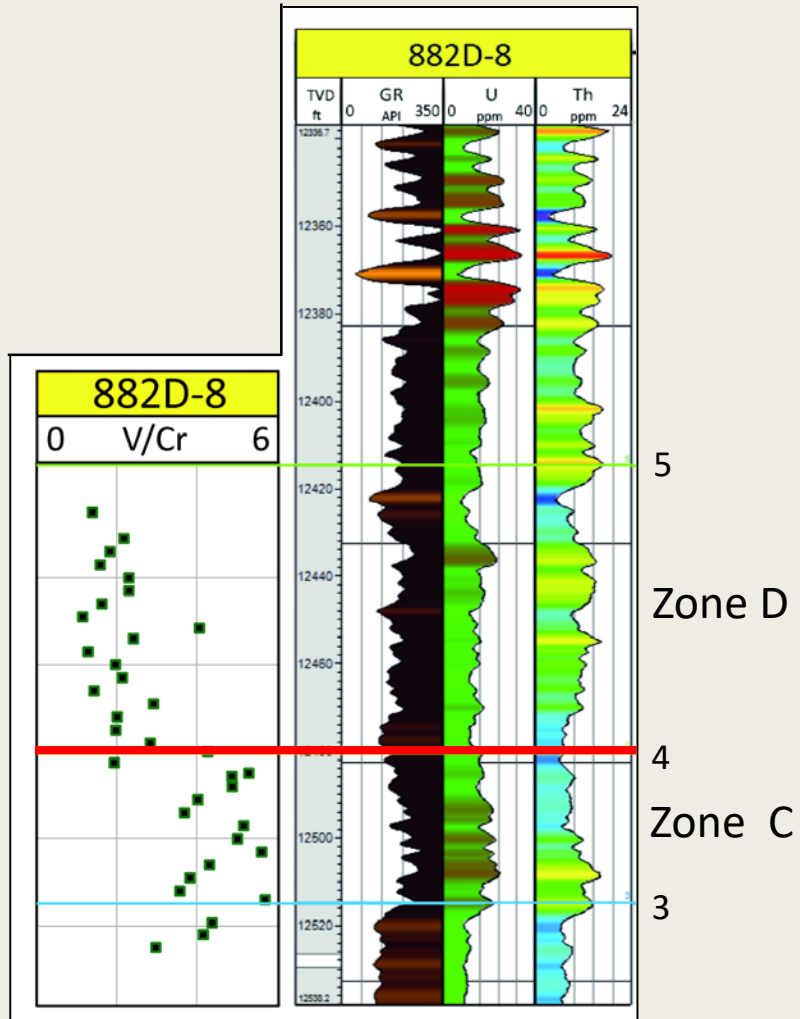
Zone C Spectral U



Zone D Spectral U

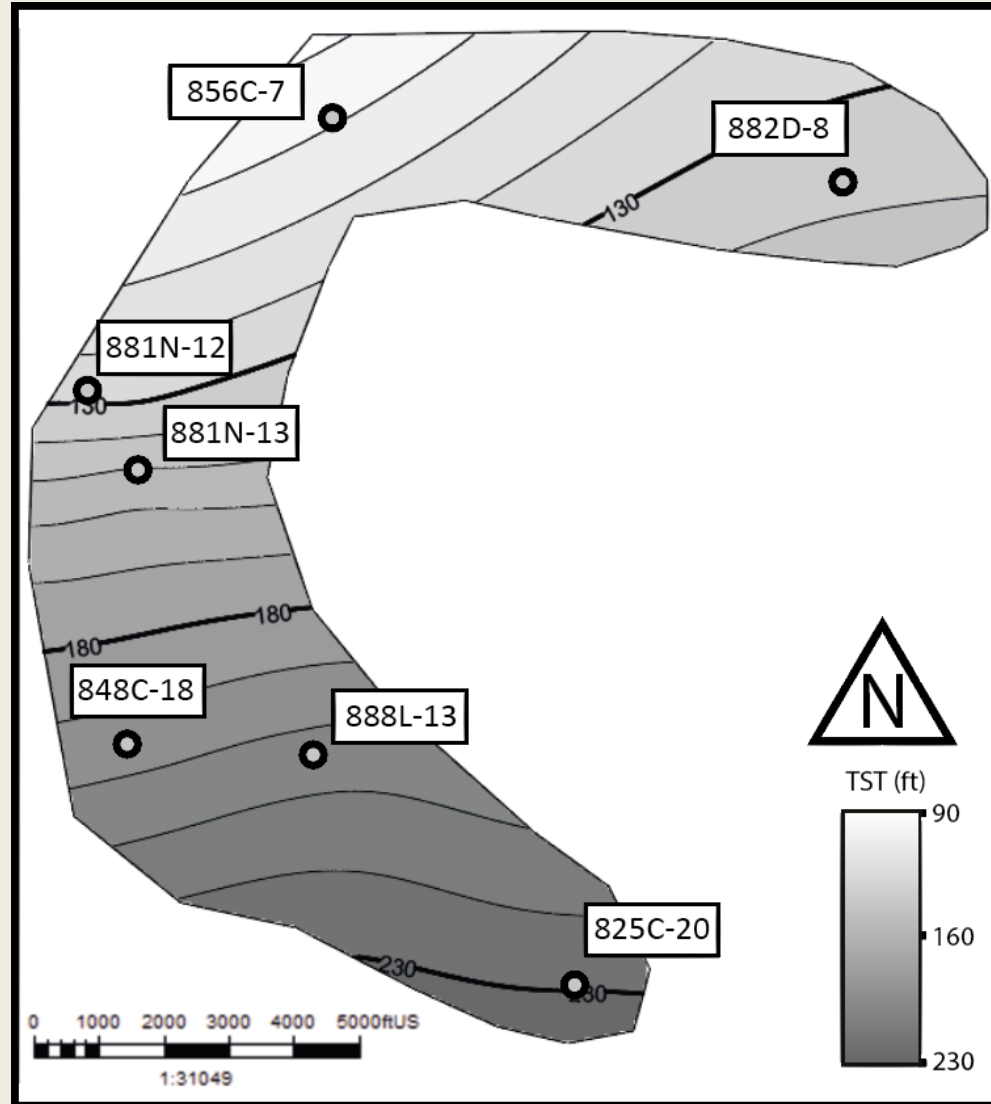


Lateral Variation: Zone C & D

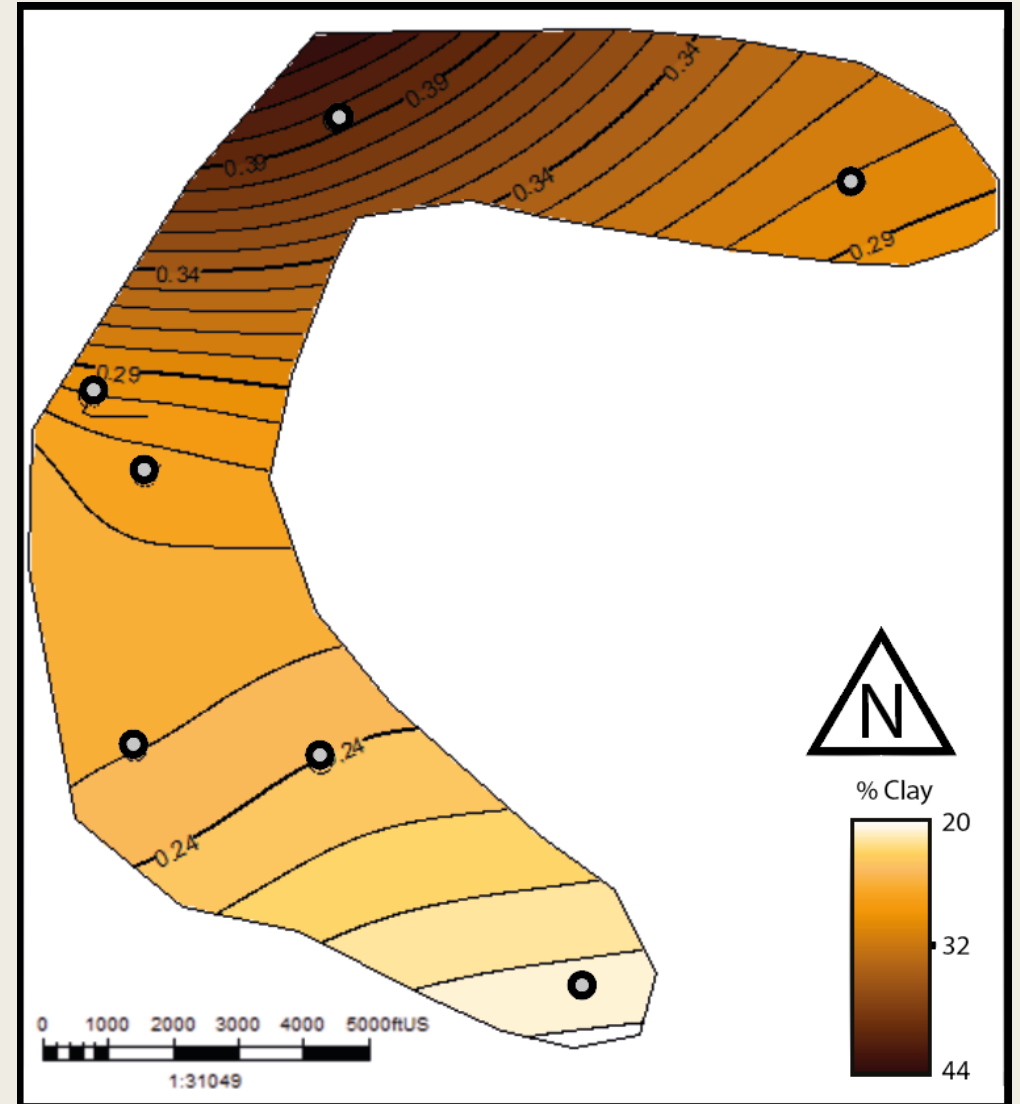


Lateral Variation: Zone E

Thickness (TST)



Clay Concentration (ECS Logs)



Lateral Variation: Zone E

N

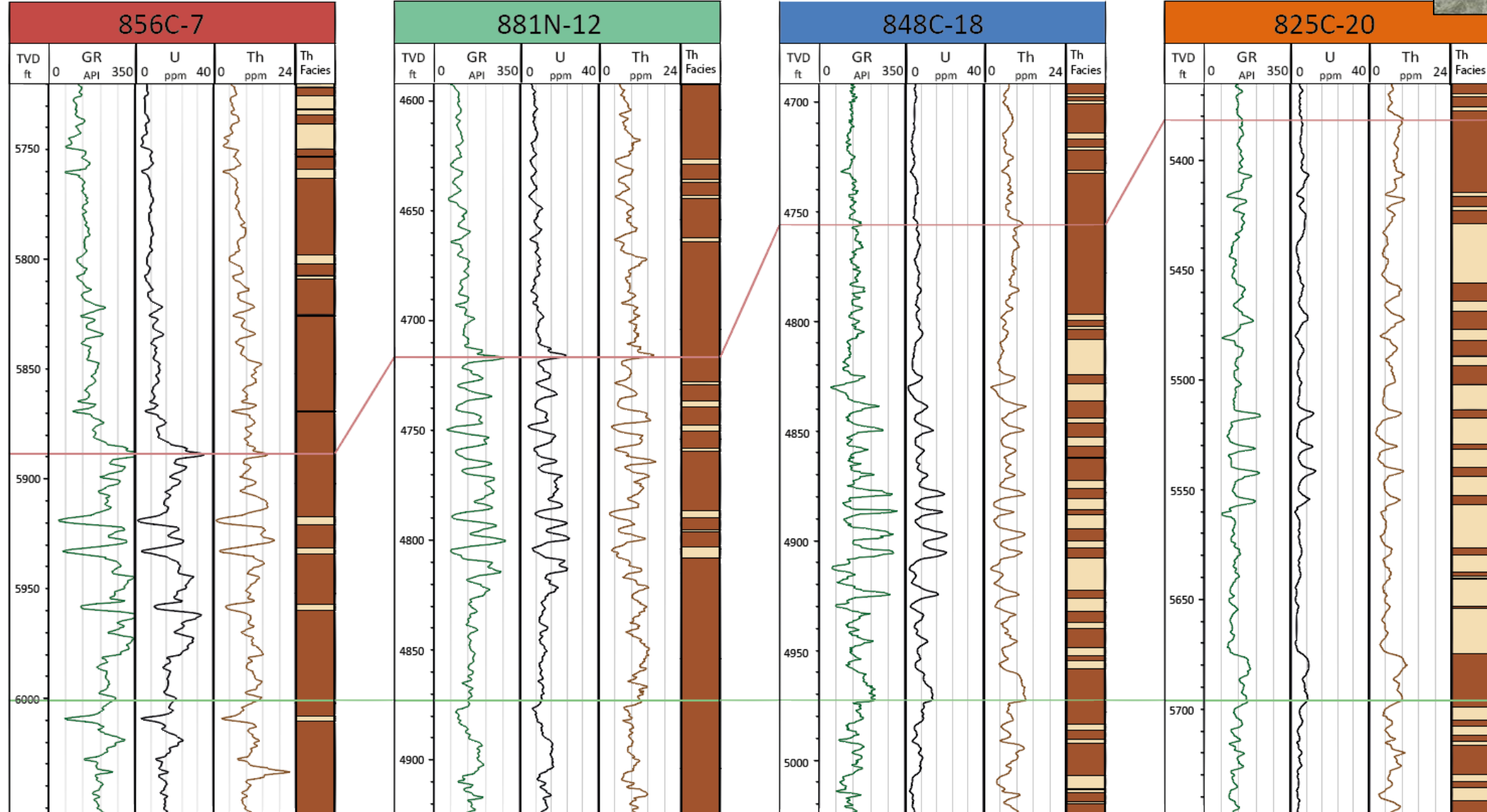
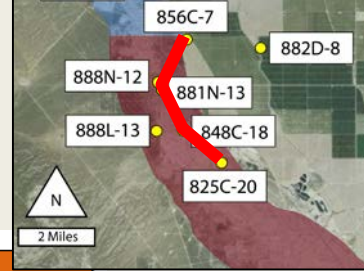
Feet between wells



< 6 ppm Th (siliceous)



> 6 ppm Th (clay rich)



6

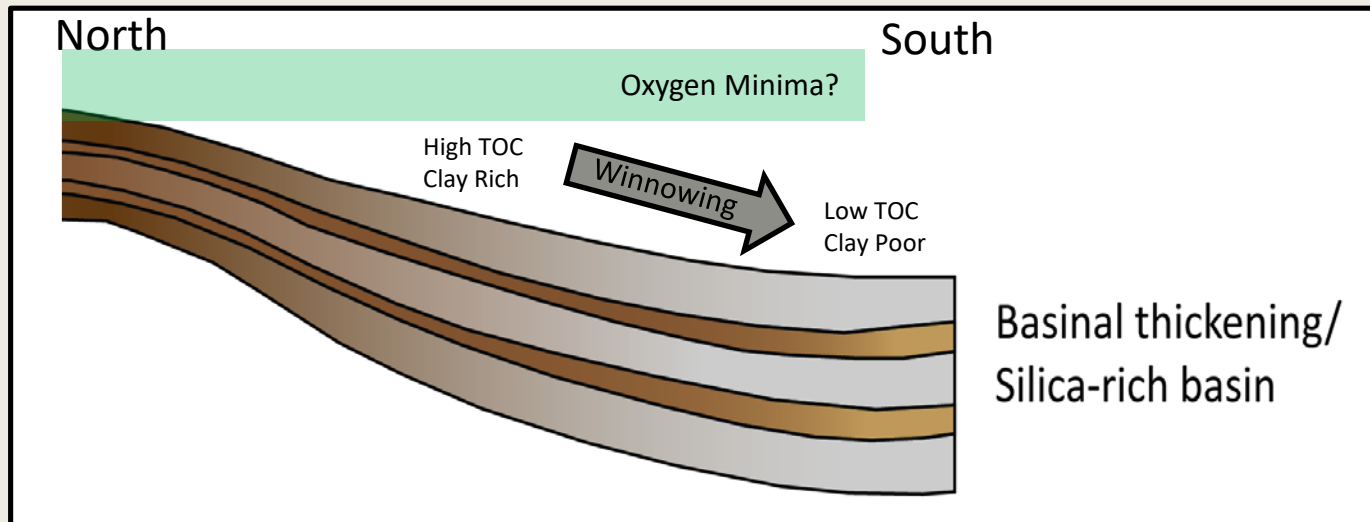
Zone E

5

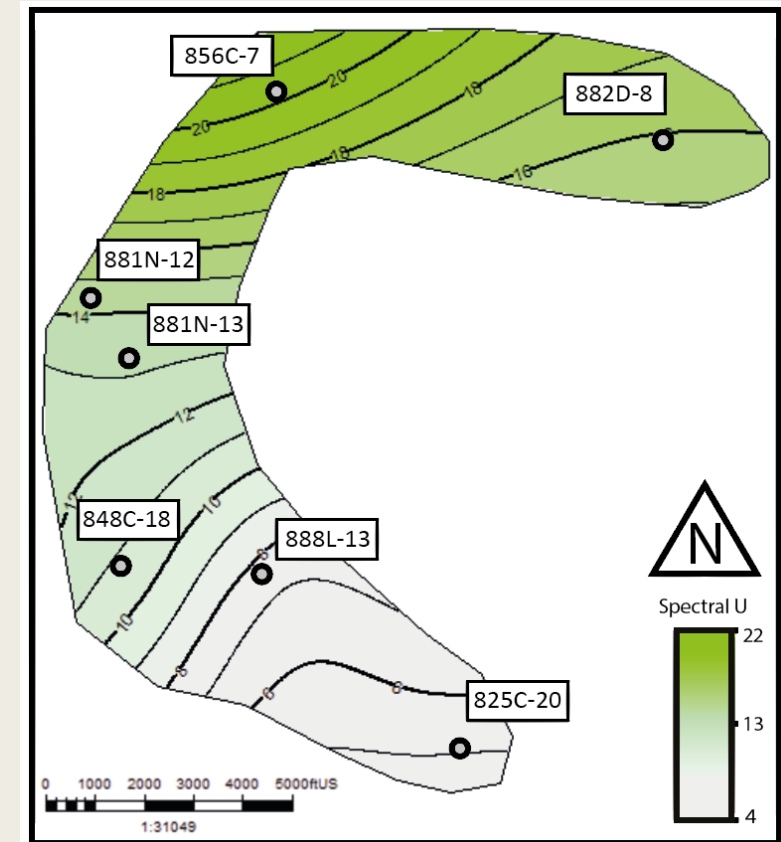
Lateral Variation: Zone E

- Stratigraphic thinning to the North accompanied by an increase in clay concentration
- Higher U in the north, more focused organic matter preservation due to higher degree of silica dissolution

Well	856C-7	881N-12	848C-18	825C-20
Average U (ppm)	20	13	8	5



Spectral U Map (Zone E)



Conclusions

- A positive relationship between organic carbon (U) and clay (Th) is directionally consistent within the study interval
- Study interval contains multiple forms of lateral variation controlled by paleo bathymetry, redox conditions and diatom productivity
- Zone C marks the beginning of southward thickening and structural growth of the Belridge anticline in the study area
- Winnowing of diatomaceous material is likely a major control on accumulation rates -> silica dissolution -> organic carbon + Vclay
- Consistent relationship between stratigraphic thickness and uranium (TOC)

