Influence of Tectonics, Burial History and Sediment Composition on the Temperature and Depth of Diagenetic Transition from Opal-A to Opal-CT in the Subsurface San Joaquin Basin, California

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Abstract

Previous studies of diagenetic changes in siliceous mudstones – from opal-A to opal-CT to quartz silica phases – were either performed in strata that were one-directionally buried to maximum depth or were uplifted completely to the surface. Together, these studies found large, overlapping temperature windows for phase changes that make it difficult to predict the depth of the transition zones. However, many subsurface occurrences of biosiliceous rocks with different tectonic and burial histories have experienced more complex histories of burial and uplift and have narrower temperature/depth transition zones. In the Belridge field, San Joaquin Basin, the phase change can occur as much as 2000’ (610m) shallower than what would be predicted from previous studies (c.f. Keller and Isaacs, 1985) with a simple burial history with a constant heat flow. We created 1D models of the burial, uplift and erosional histories, and the paleo- and present-day heat flows in 5 different wells from three structural positions on the Belridge anticline to understand the full subsurface thermal history of these rocks and the depths, temperatures, thicknesses, and character of the opal-A to opal-CT transition zones. These wells contain opal-A to opal-CT transitions zones with tops from 1350’ to 2000’ in true vertical depth and that range from 80’ to 170’ in thickness. To characterize the diagenetic processes that occurred within phase change windows, we use SEM and XRD to identify opal-A, opal-A’ and opal-CT, d-spacing, and related primary and authigenic minerals, as well as processes including fragmentation, dissolution, precipitation, and replacement.

References

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Silica Diagenesis:
it's more than depth and temperature

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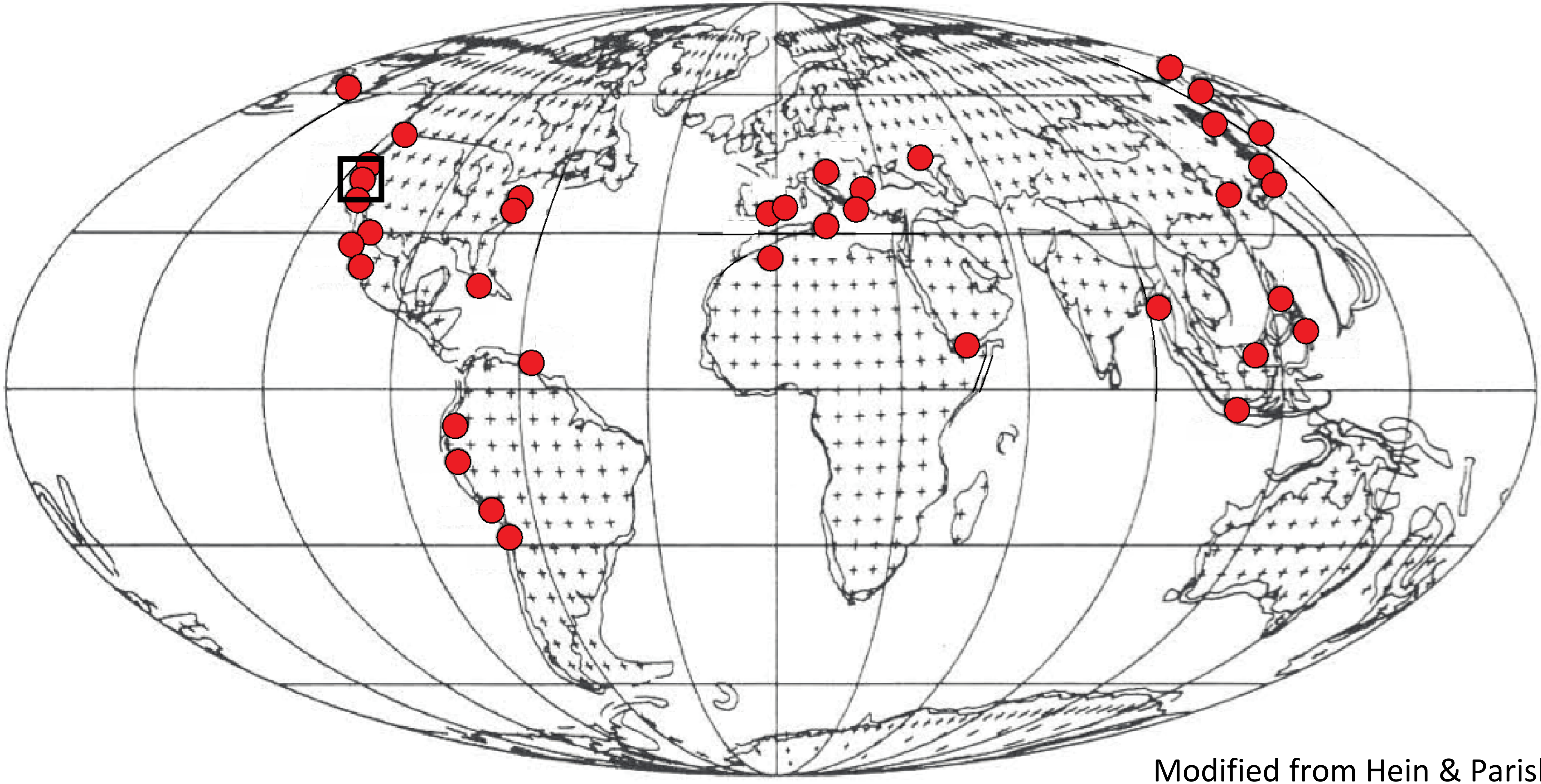
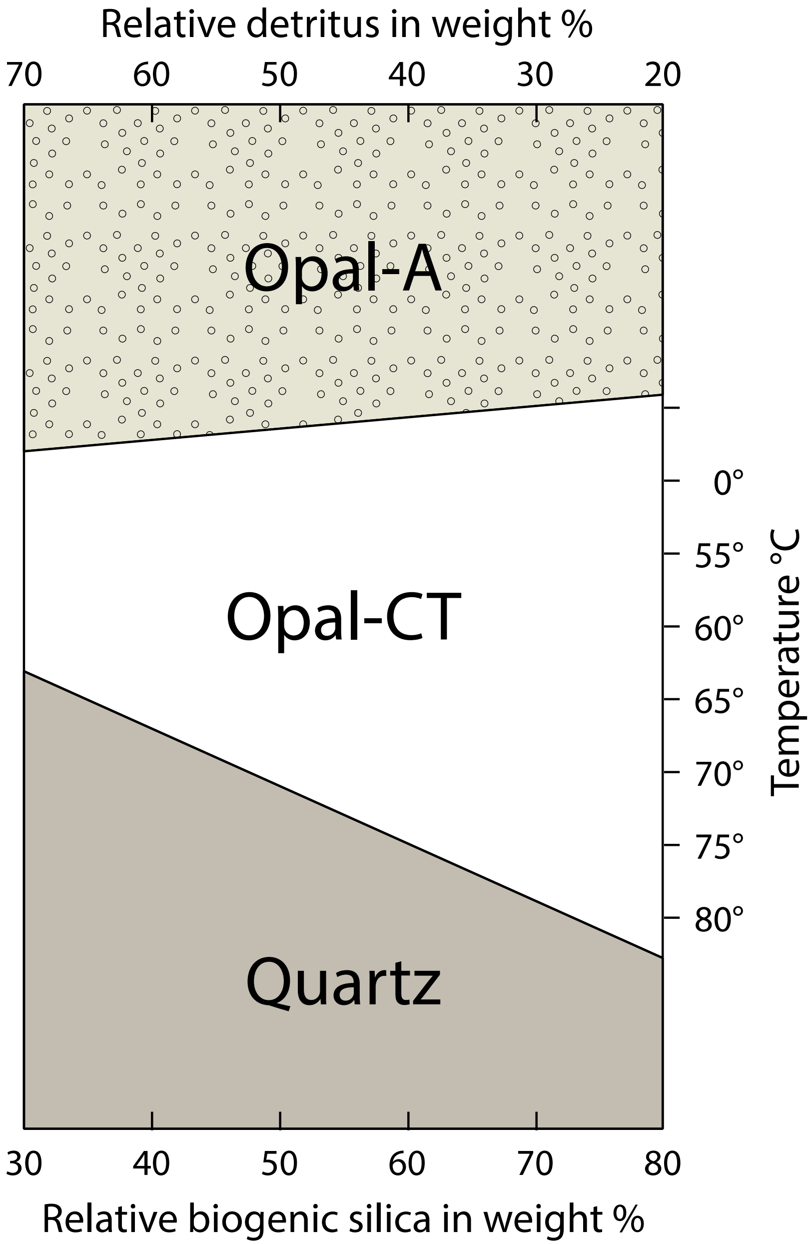
The well-studied Monterey Formation is only one of many Neogene diatomaceous deposits

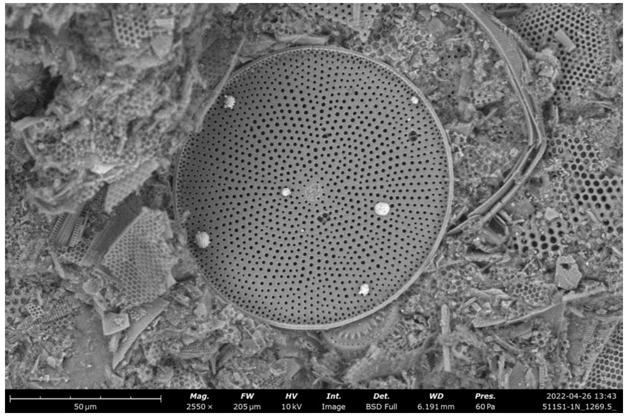


Modified from Hein & Parish, 1987

Depth, temperature and composition are important players in silica diagenesis

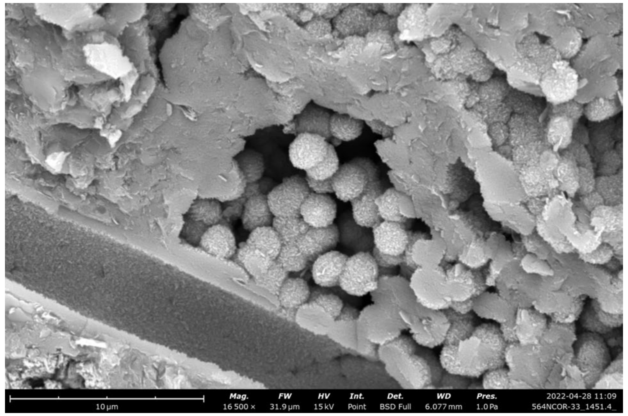


(after Keller & Isaacs, 1985)

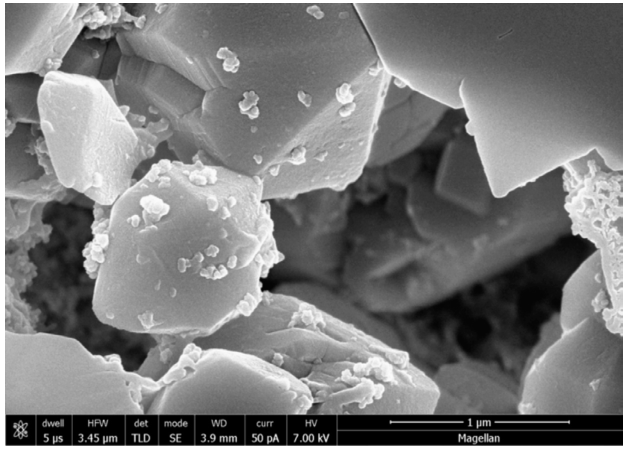


Opal-A

(Crabtree Thesis Work)

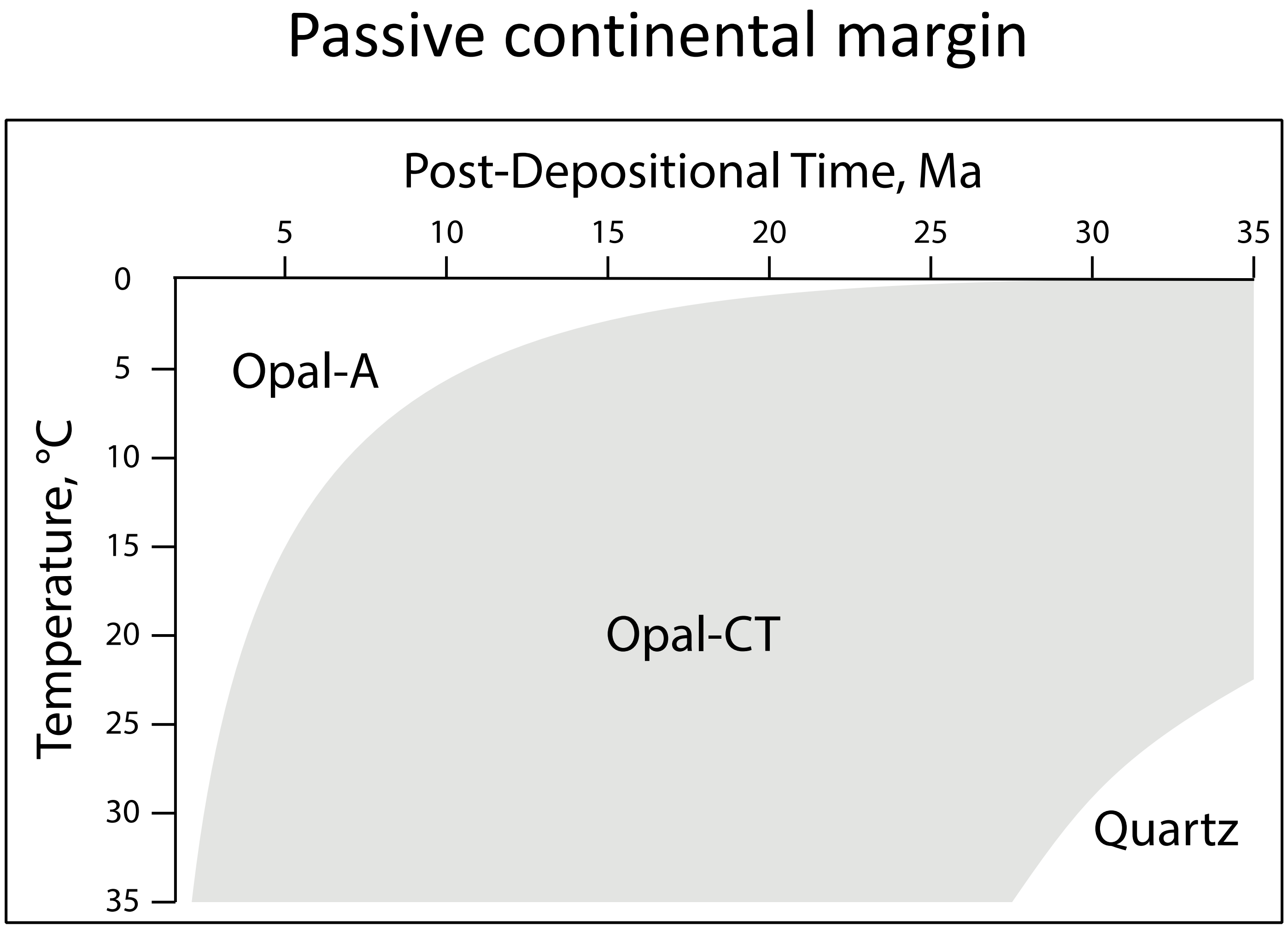


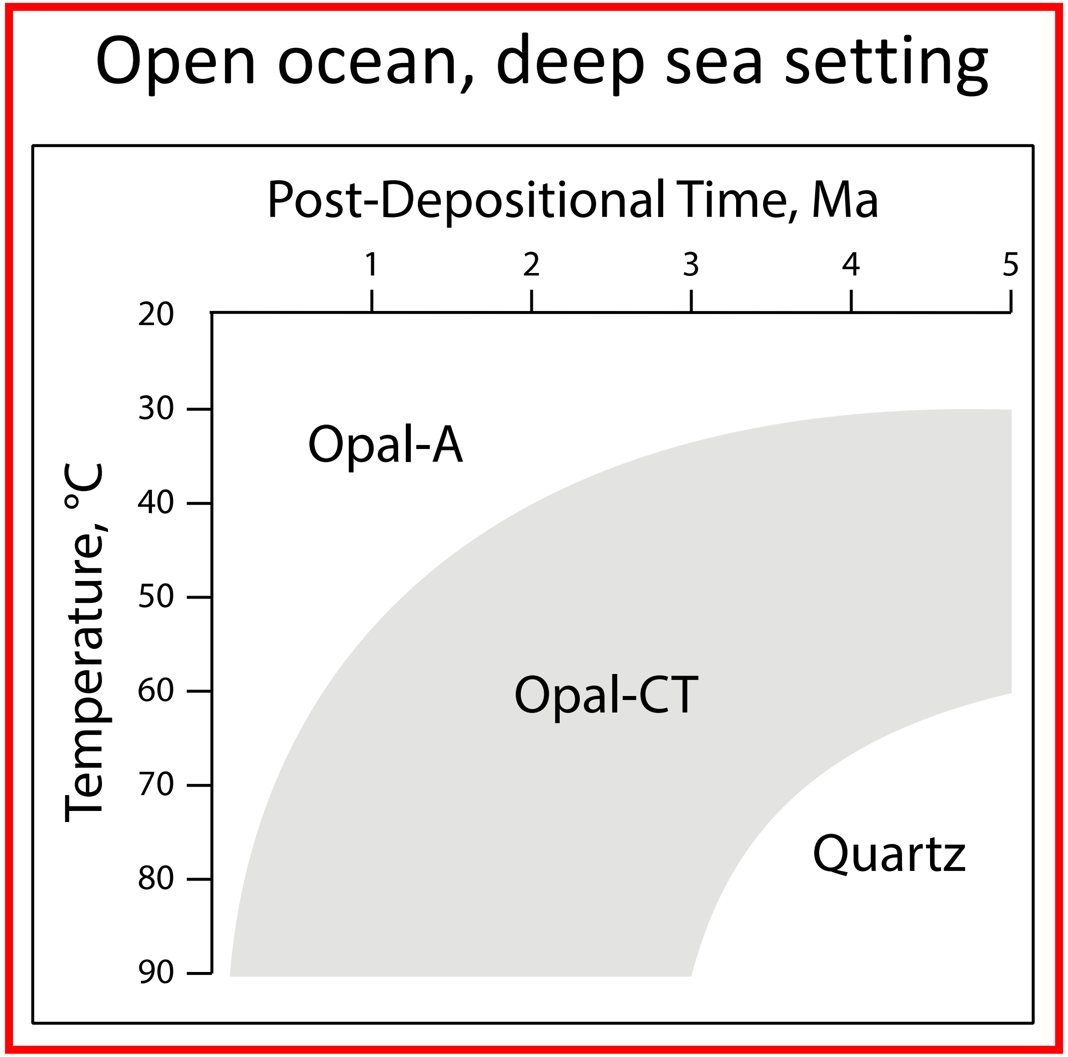
Opal-CT



Quartz

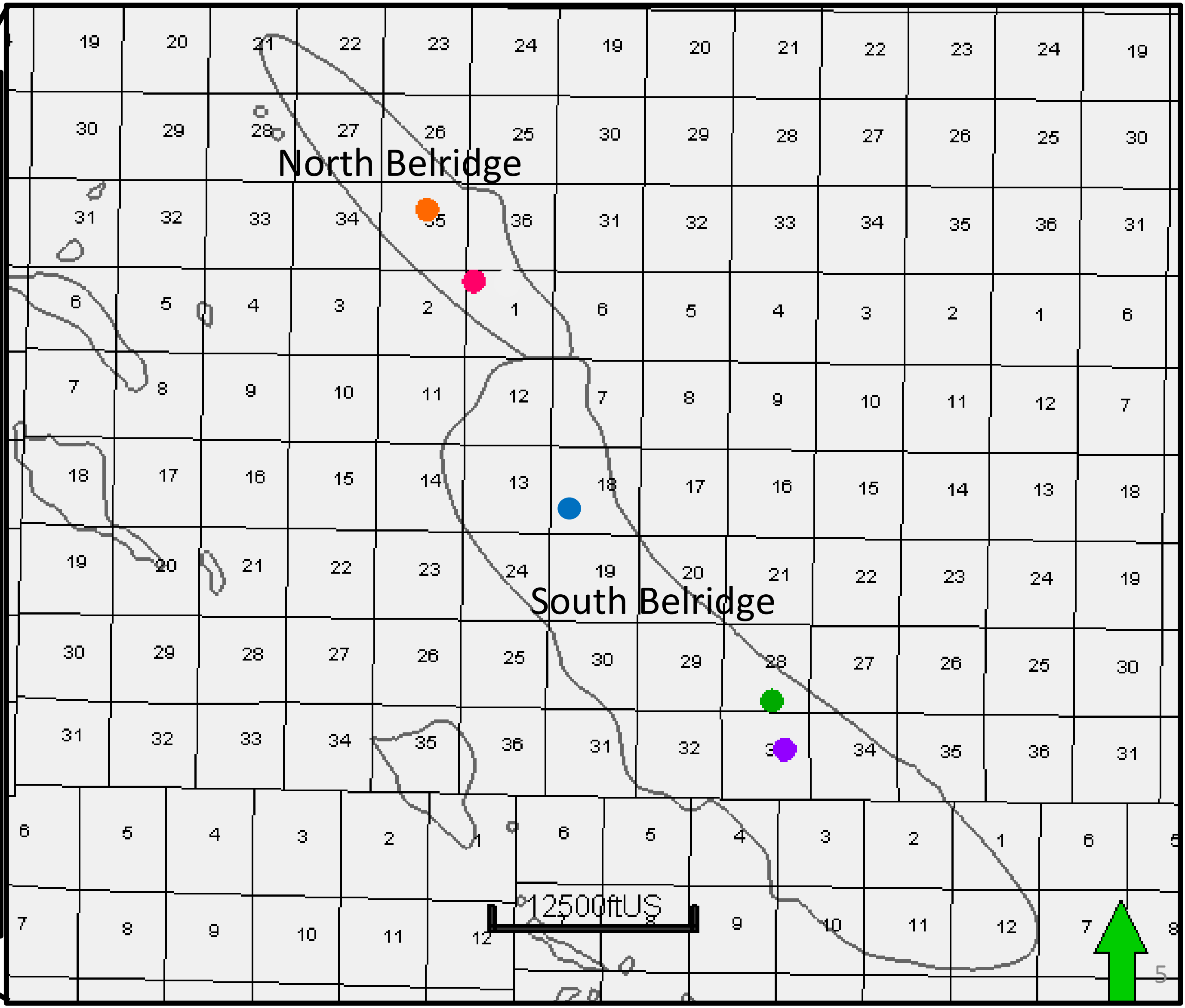
But there's more…time may play a significant role in diagenesis where burial is dependent on tectonic setting



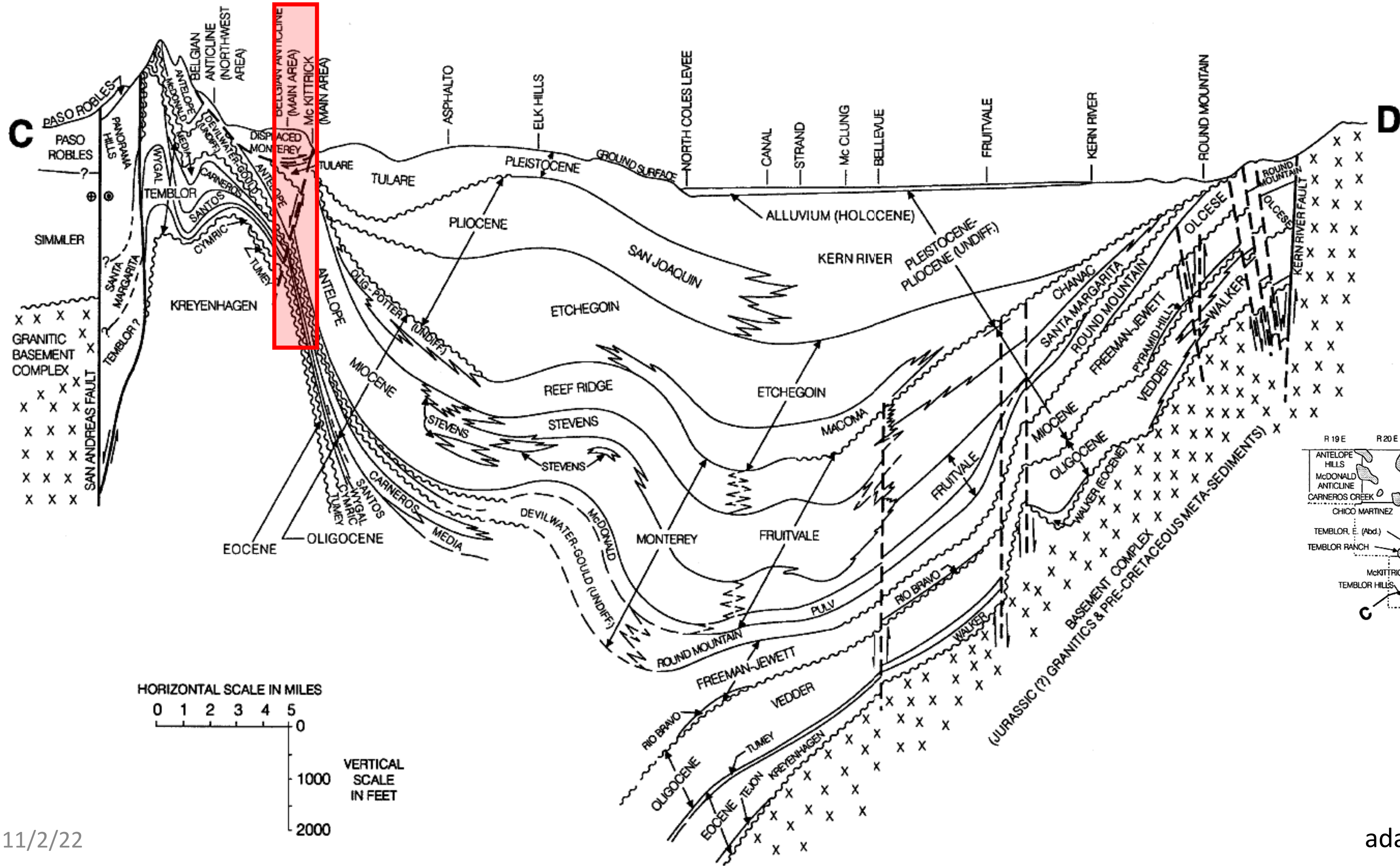


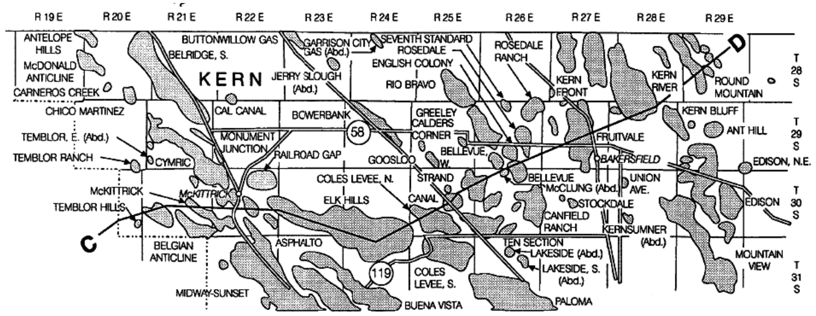
(after Siever, 1983)

The western fold belt potentially holds great variety in diagenetic history as does the chosen study area



CA is quite complex with significant spatial variations in burial history, sedimentation/burial rate, erosion, uplift, heat flow, etc.

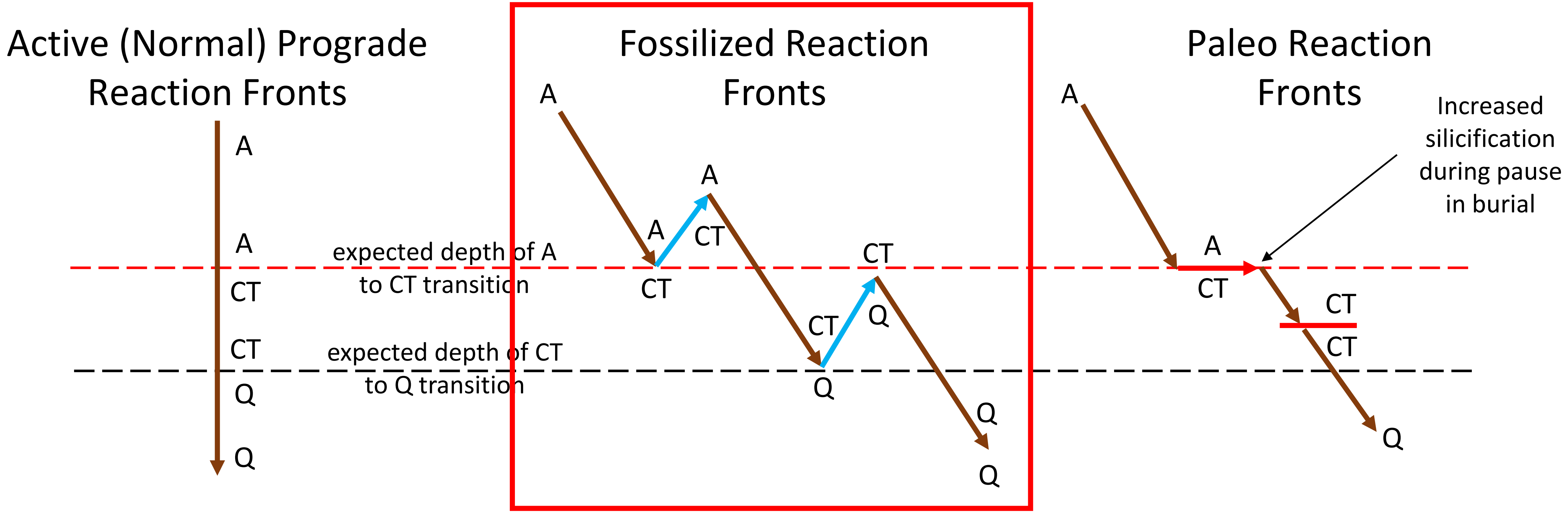




Southern San Joaquin Basin Generalized Cross Section

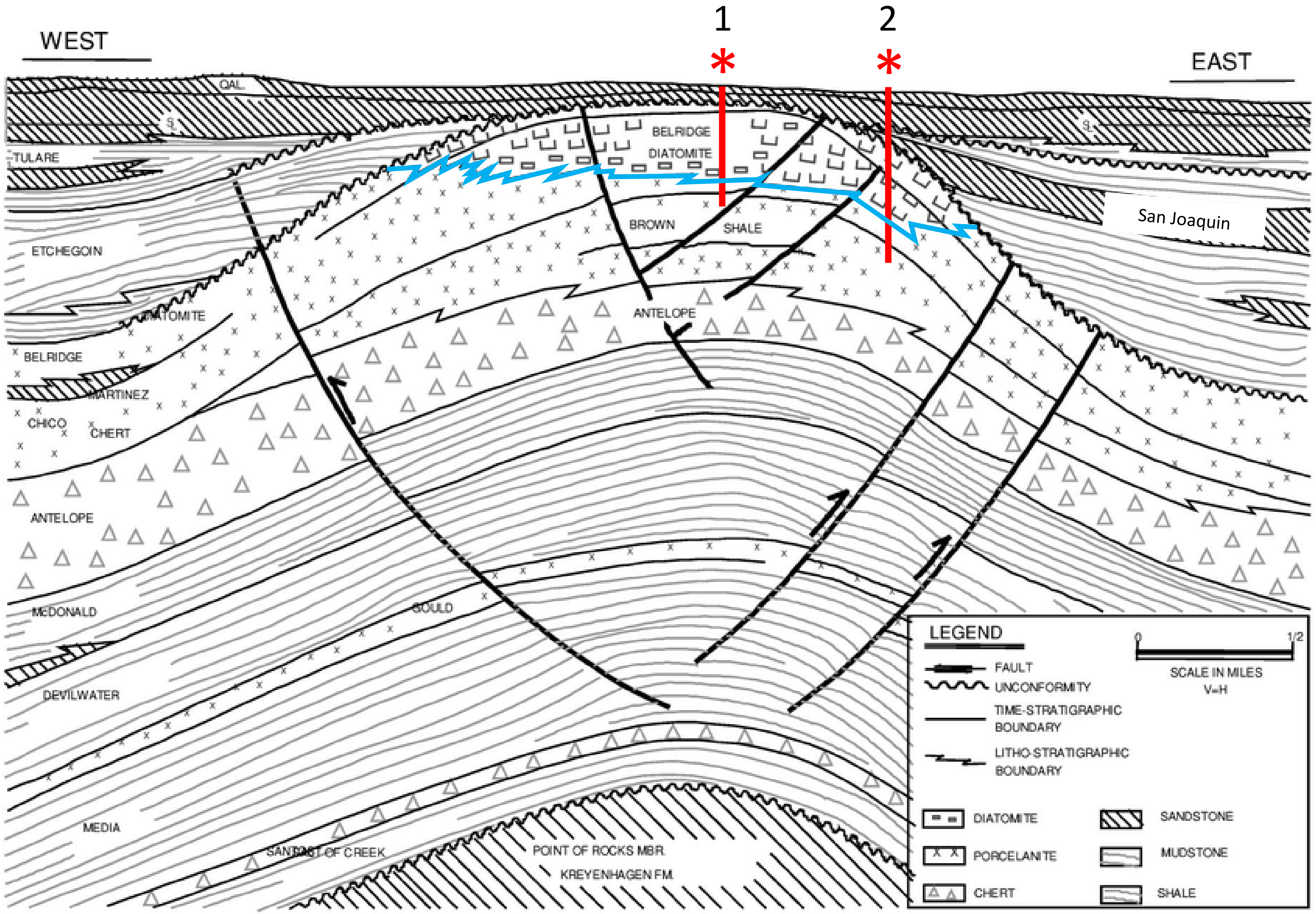
adapted from DOGGR (now CalGEM, 1998)

What is the significance of the history or paths of the diagenetic boundary on silica phase and rock fabric?



(after Kassa & Behl, 2016)

South Belridge oil field is an excellent example of the complexity within the San Joaquin Basin



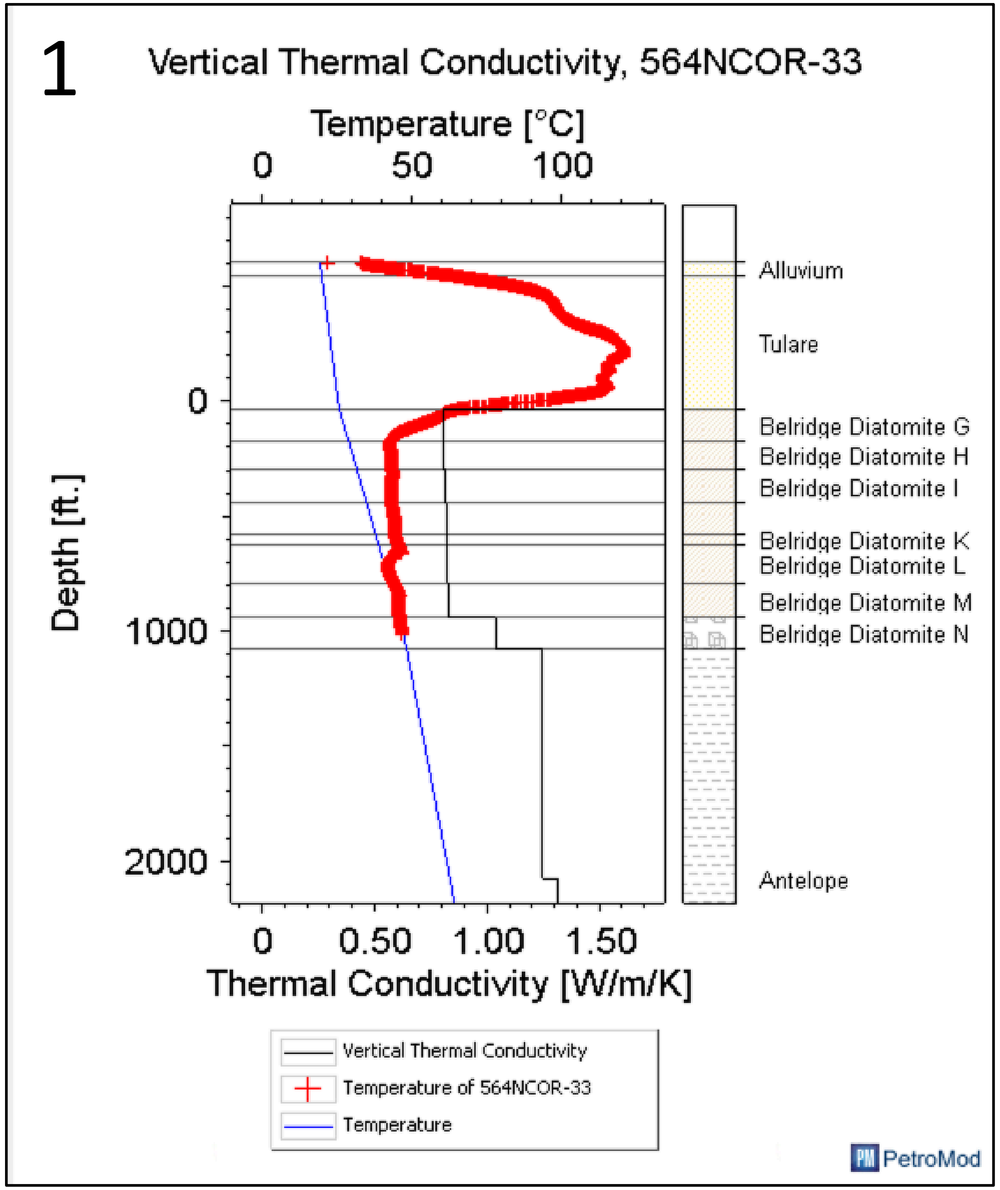
(Schwartz, 1988)

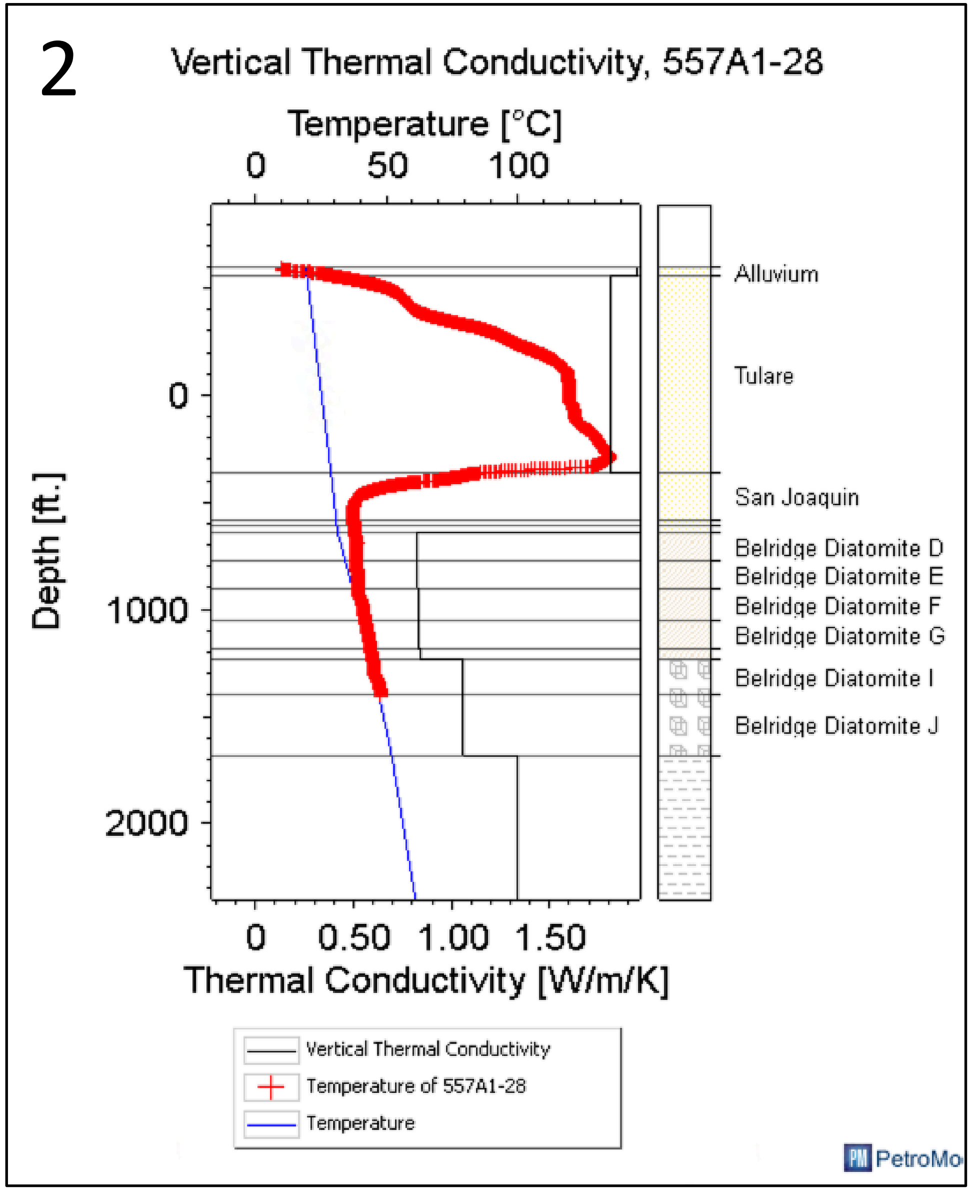
Alluvium deposition
↙ Erosion ↘
↑ Uplift ↑
↓ Burial ↓
Tulare deposition
↙ Erosion ↘
↑ Uplift ↑
↓ Burial ↓
San Joaquin deposition
↙ Erosion ↘
↑ Uplift ↑
↓ Burial ↓
Etchegoin deposition
↓ Burial ↓
Diatomite deposition (Belridge)
↓ Burial ↓
Diatomite deposition (proto-Brown Sh.)

Onset of opal-A to opal-CT diagenesis

SEM images and quantitative XRD analysis were used to constrain and test the following models

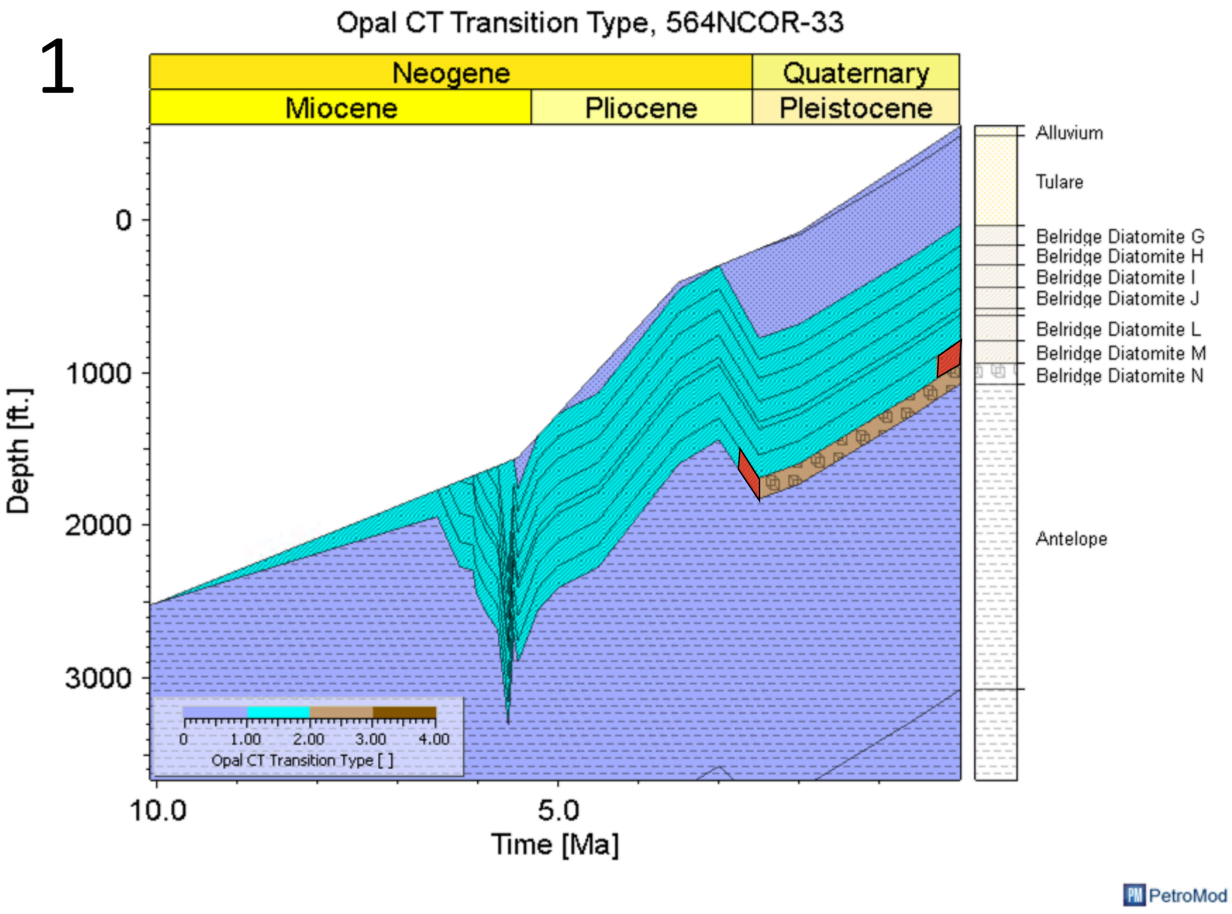
Understanding the diagenetic changes in thermal conductivity is critical in determining the thermal history





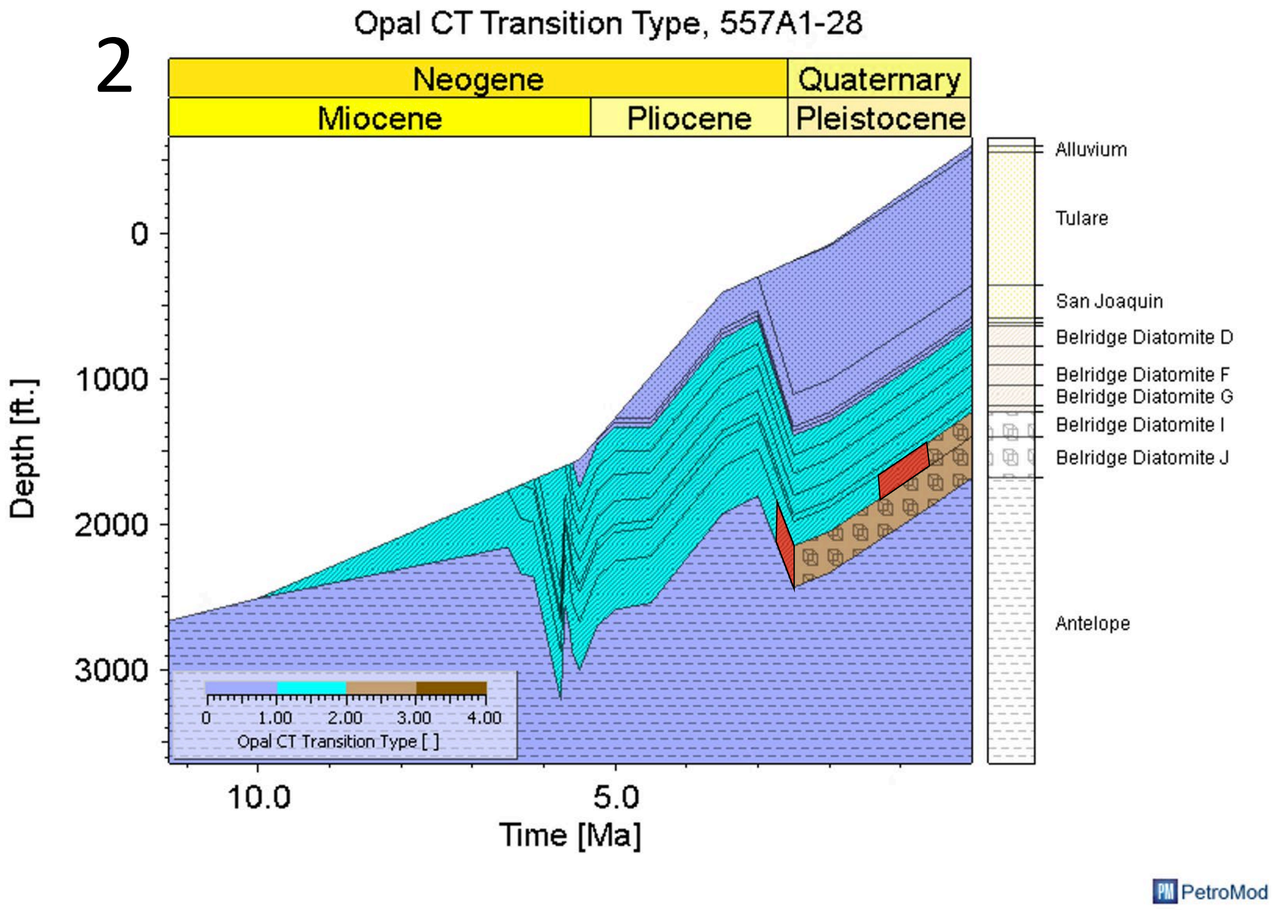
Pliocene uplift has a major effect on the depth of the opal-A to opal-CT diagenetic boundary

1



Initial transition zone top: ~2100’

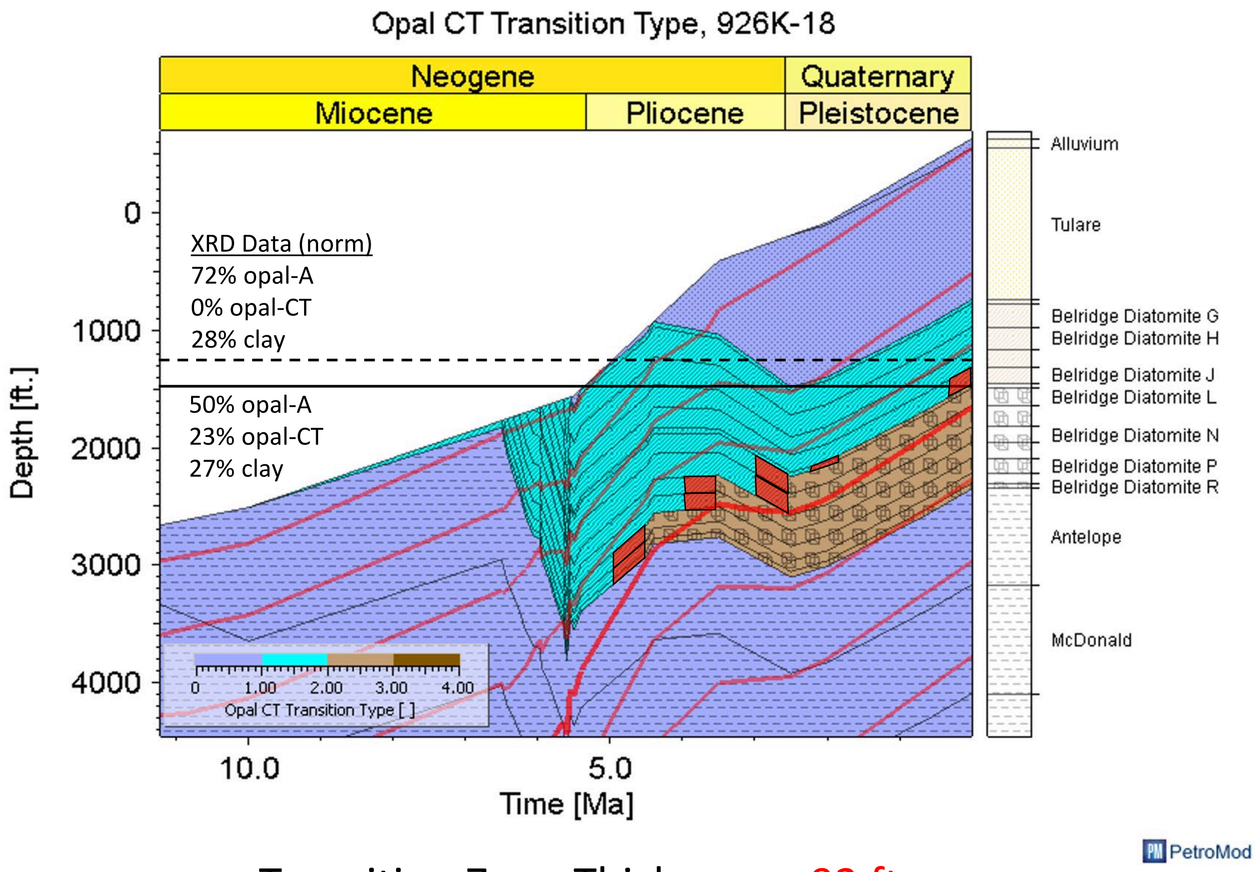
2



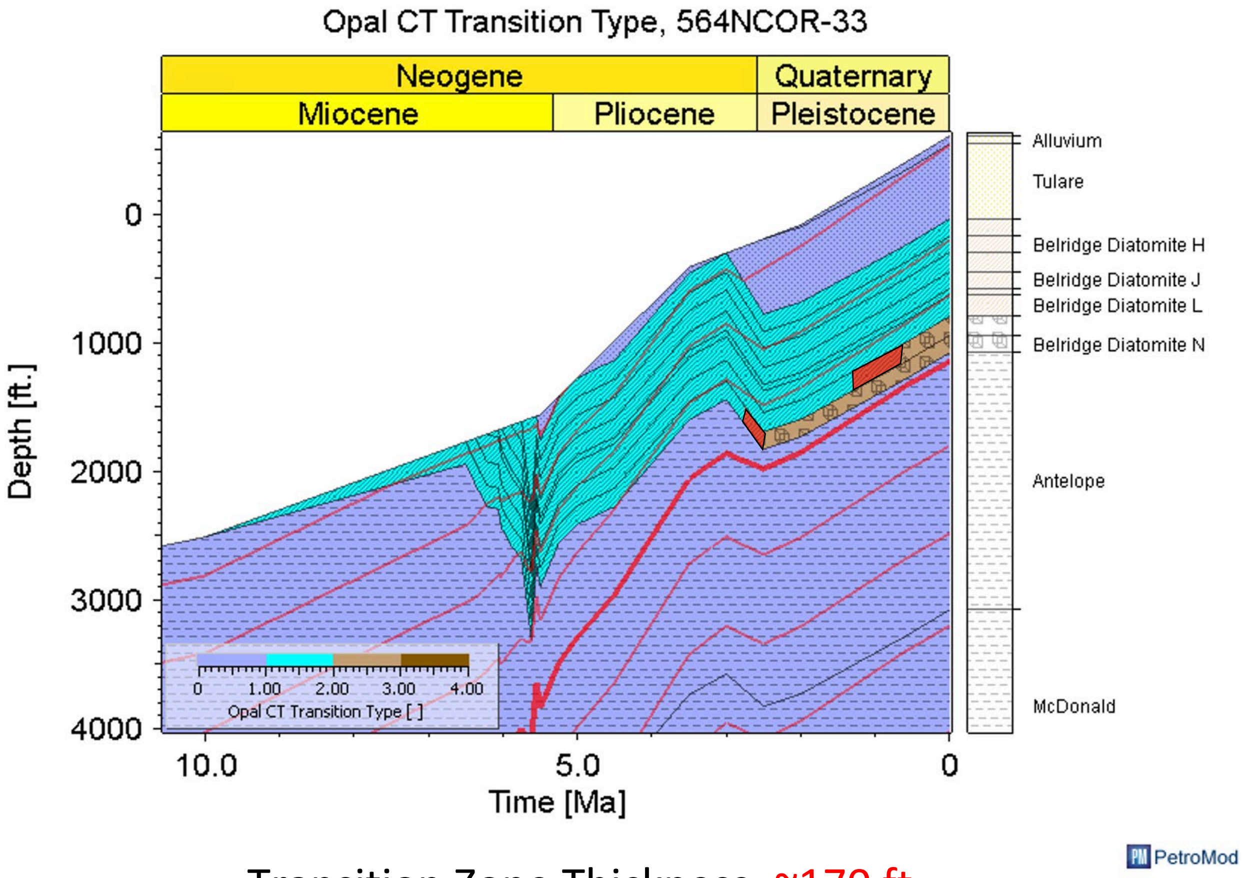
Initial transition zone top: ~2500’

Sedimentation and structural development were contemporaneous throughout the middle and late Tertiary (Schwartz, 1998)

Burial history is certainly a key driver in determining the present-day depth, thickness and character of the transition zone.



Transition Zone Thickness: ~92 ft

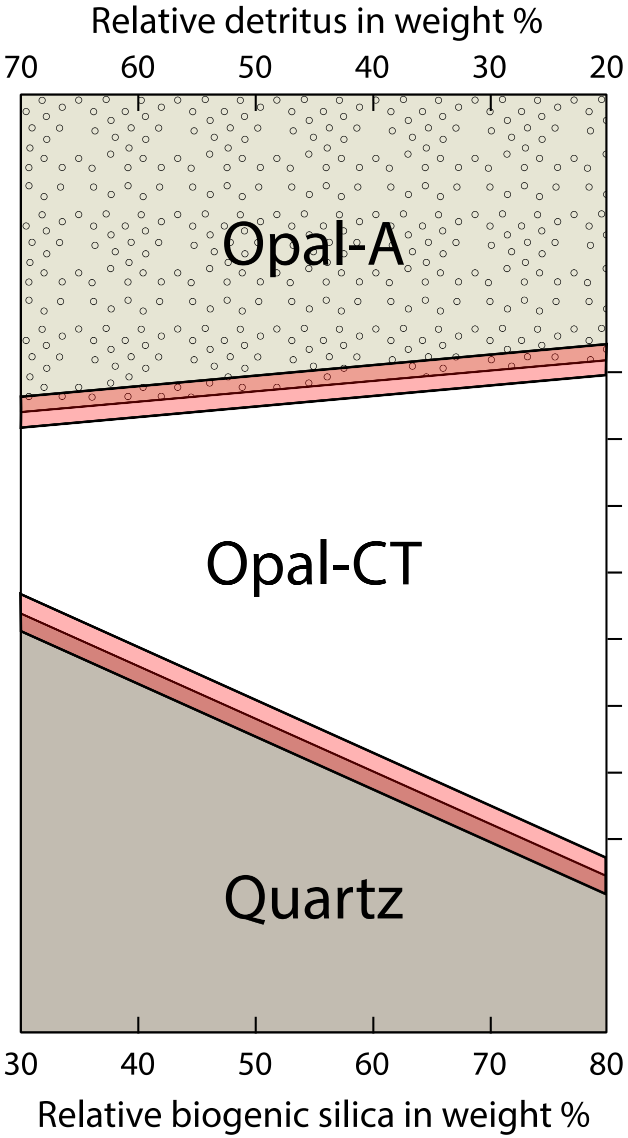


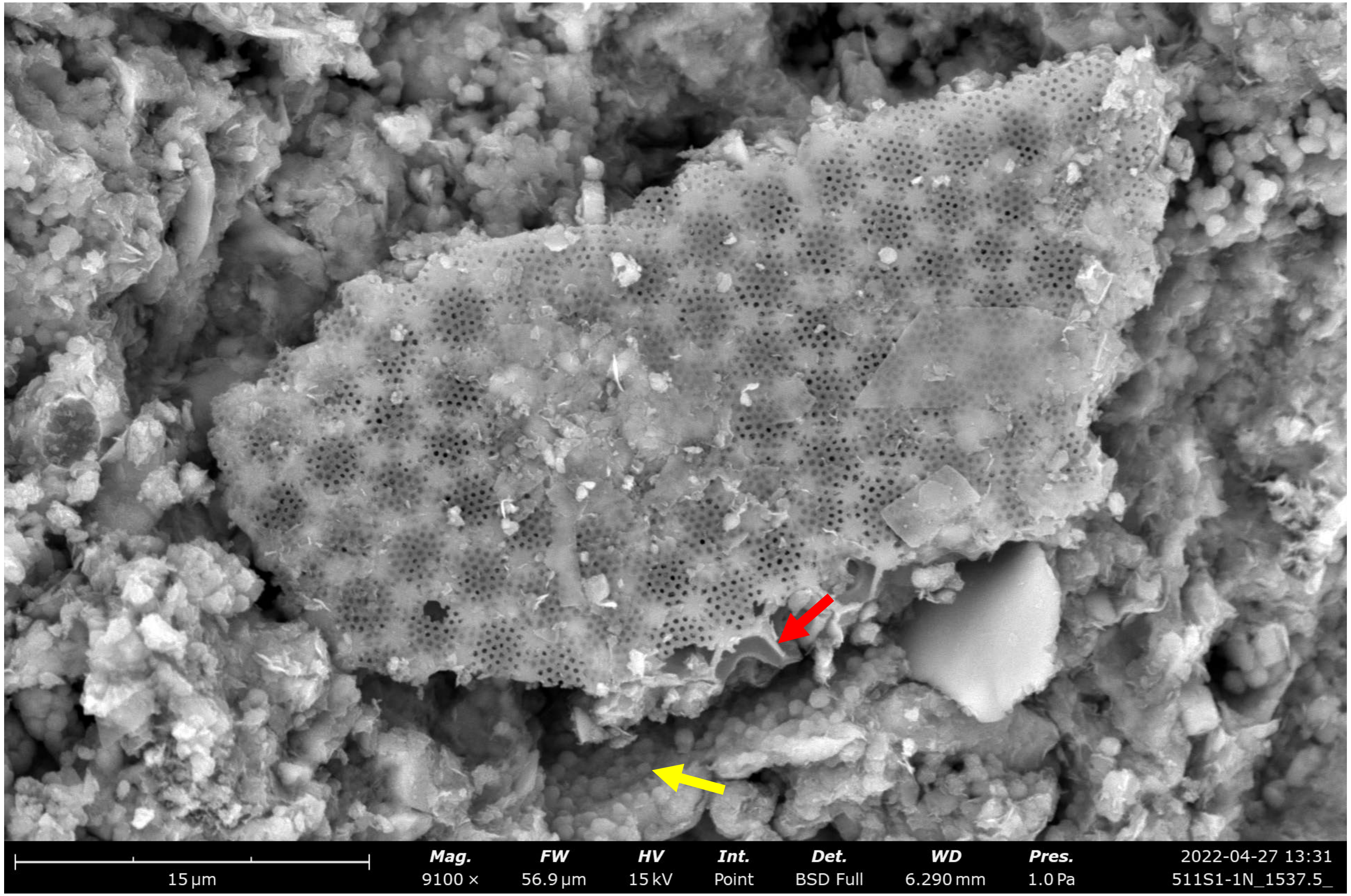
Transition Zone Thickness: ~170 ft

isotherms

SEM and XRD analysis along with digital well logs were used to determine the thickness of the transition zone

The boundary is not abrupt in each strata. Opal-A and CT exist within the same beds with CT gradually replacing A.

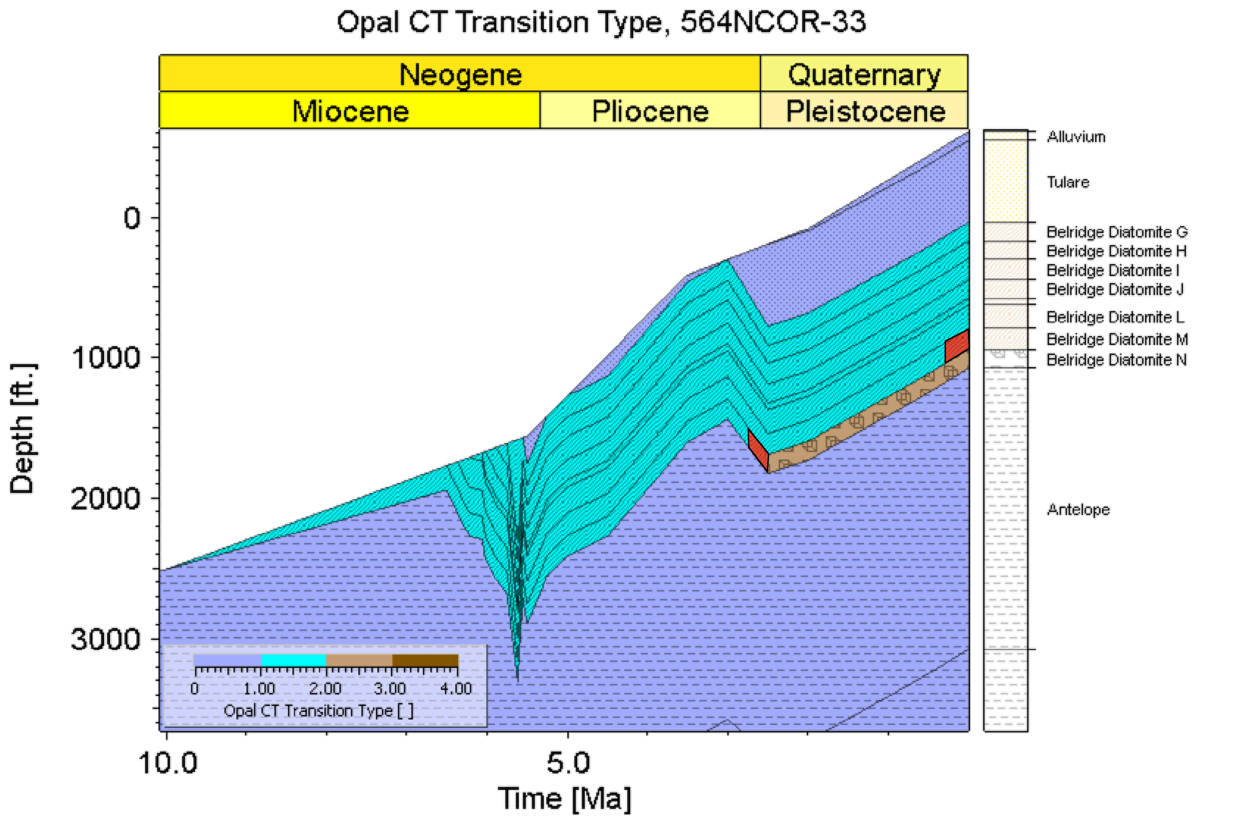




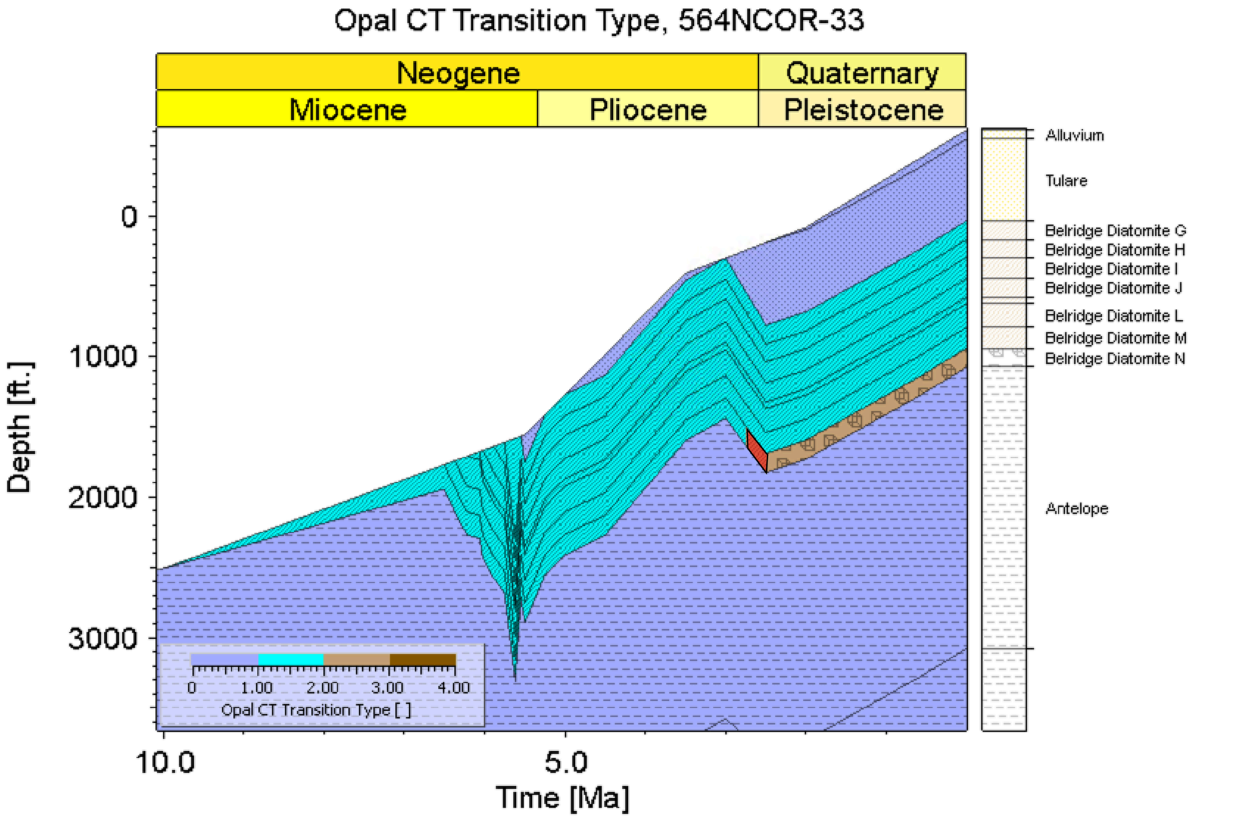
red arrow: opal-A; yellow arrow: opal-CT

Can I now estimate a smaller temperature window in which the transition occurs within these more heterogenous rocks?

44°C – 44.3°C (~111°F) based on weight percent of detritus between 20% and 23% for this well



20% relative detritus by weight



23% relative detritus by weight

*the average clay content from the 564NCOR-33 XRD data was 22% in the diatomite

What is the importance of this study?

→ Tests the Keller & Isaacs Model in the San Joaquin Basin

→ Shows Impact of Burial History on Transition Zone

→ Reaffirms an Understanding of Erosion in the Belridge Fields

→ Highlights an Inferred Understanding of Transition Zone Character

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