What is the Monterey Formation?
and
Why is everyone so excited about it?

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Miocene Monterey Formation

- Important source & reservoir of oil
- Important role in past climate change
- Great thickness (10's – 100's X's thicker than other "shale plays"
- Characteristic sedimentology
  - Thin-bedded,
  - Siliceous
  - Organic-rich
- Age: approximately 17-5 Ma
- Related facies span the Pacific Rim

This is NOT a realistic map of a continuous Monterey tight oil play

The Monterey is far more varied than the Bakken or Eagle Ford, etc.

Hughes (2013)

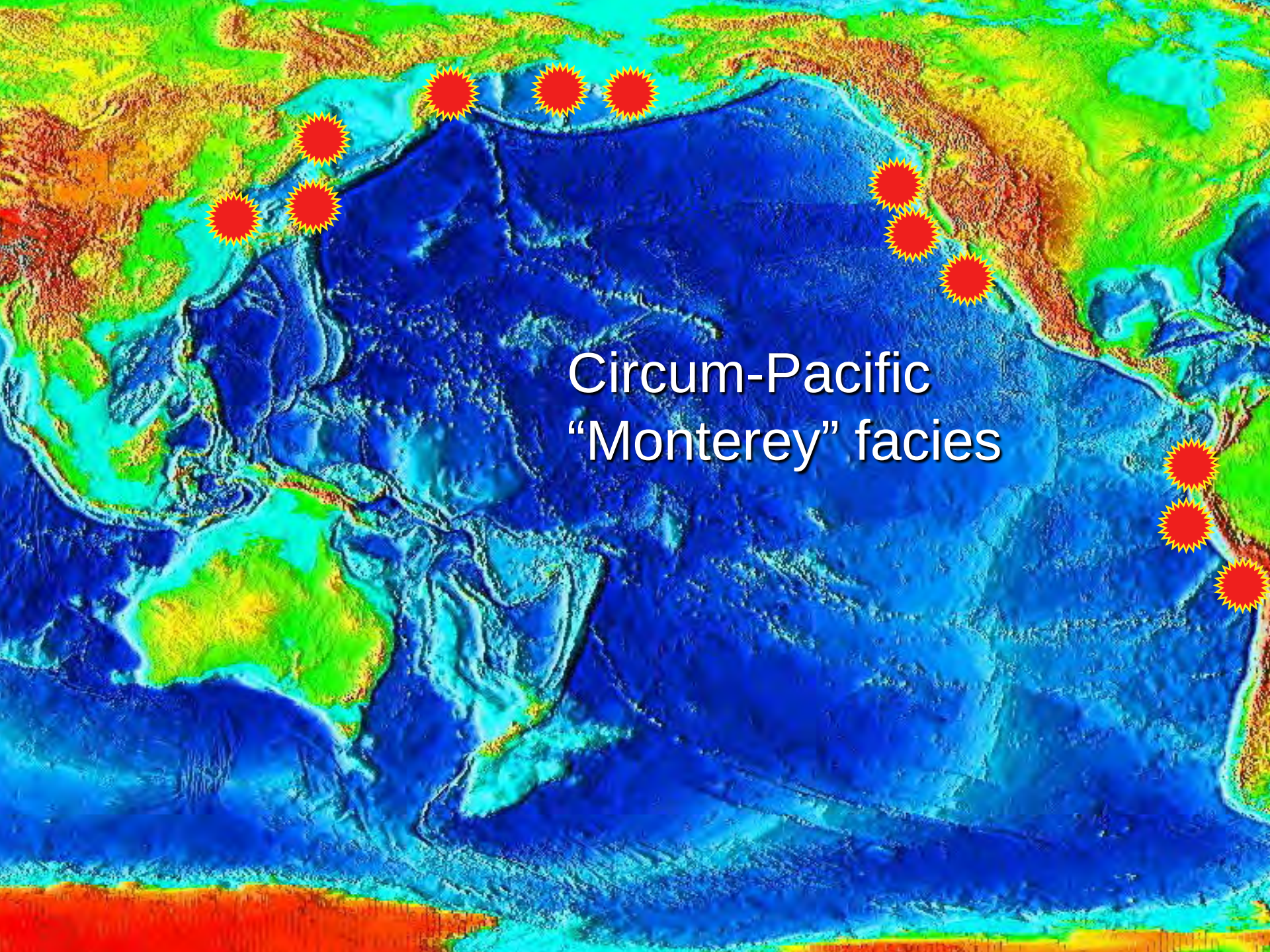
Figure 1. The Monterey tight oil play in California, with relevant sedimentary basins and counties.

Monterey Formation

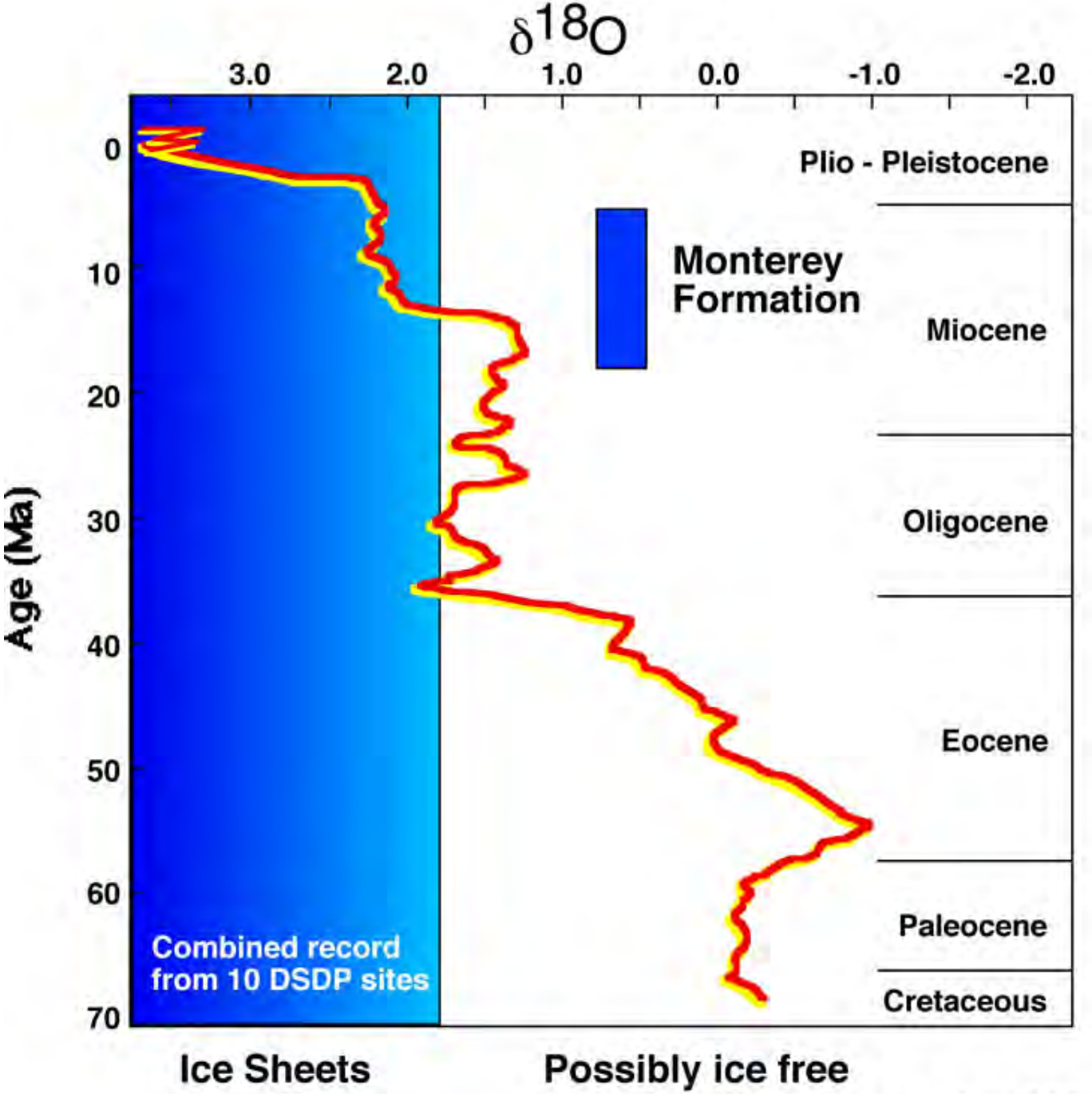
- Unconventional reservoir rock
- Chiefly conventional production
  - Naturally fractured reservoirs

- Tremendous lithologic heterogeneity
  - Mm's to kilometers
  - Varied thickness and composition
  - Range of stress/strain conditions

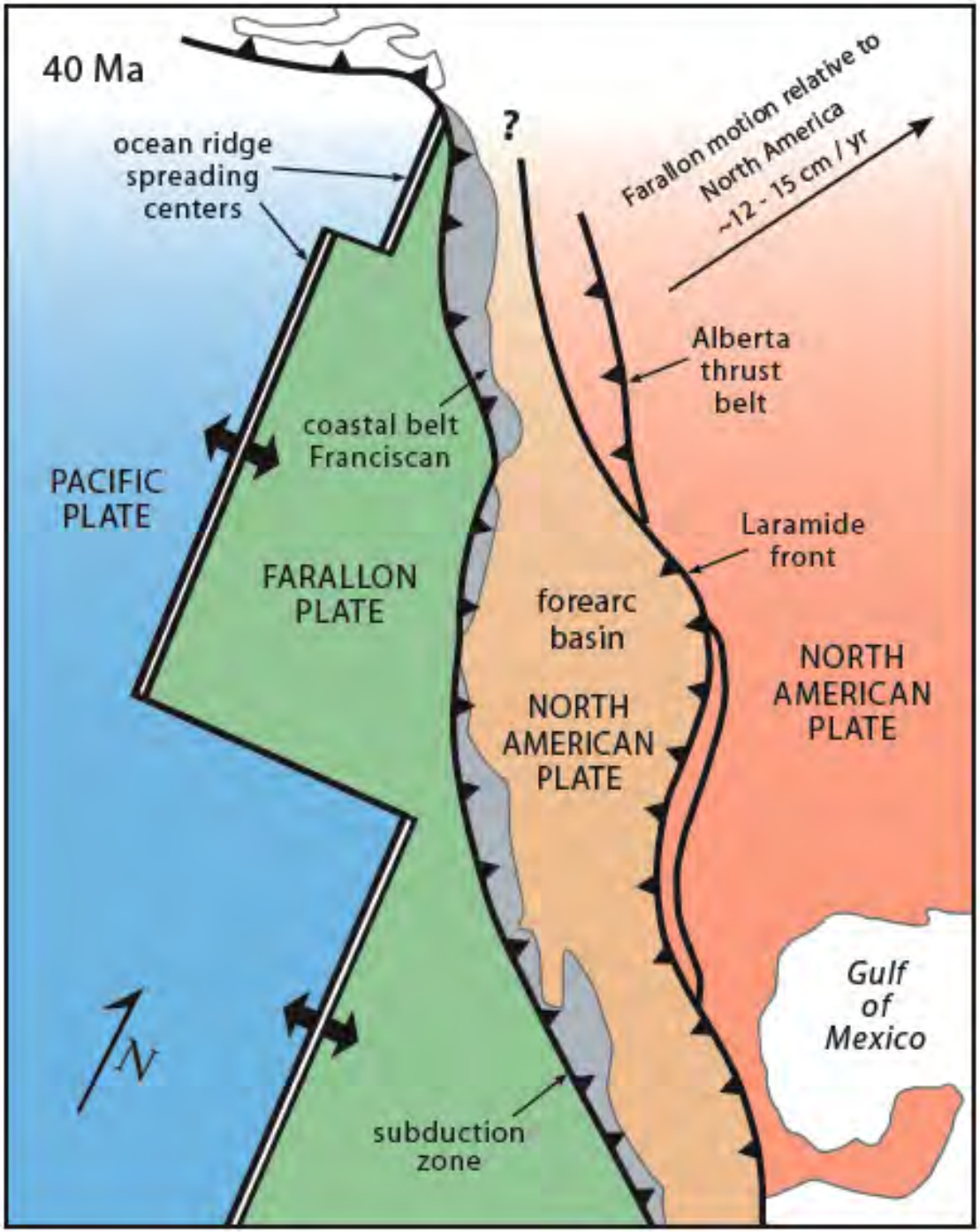
Not your "typical" mid-continent shales


Circum-Pacific
“Monterey” facies

Cenozoic Climate Transition



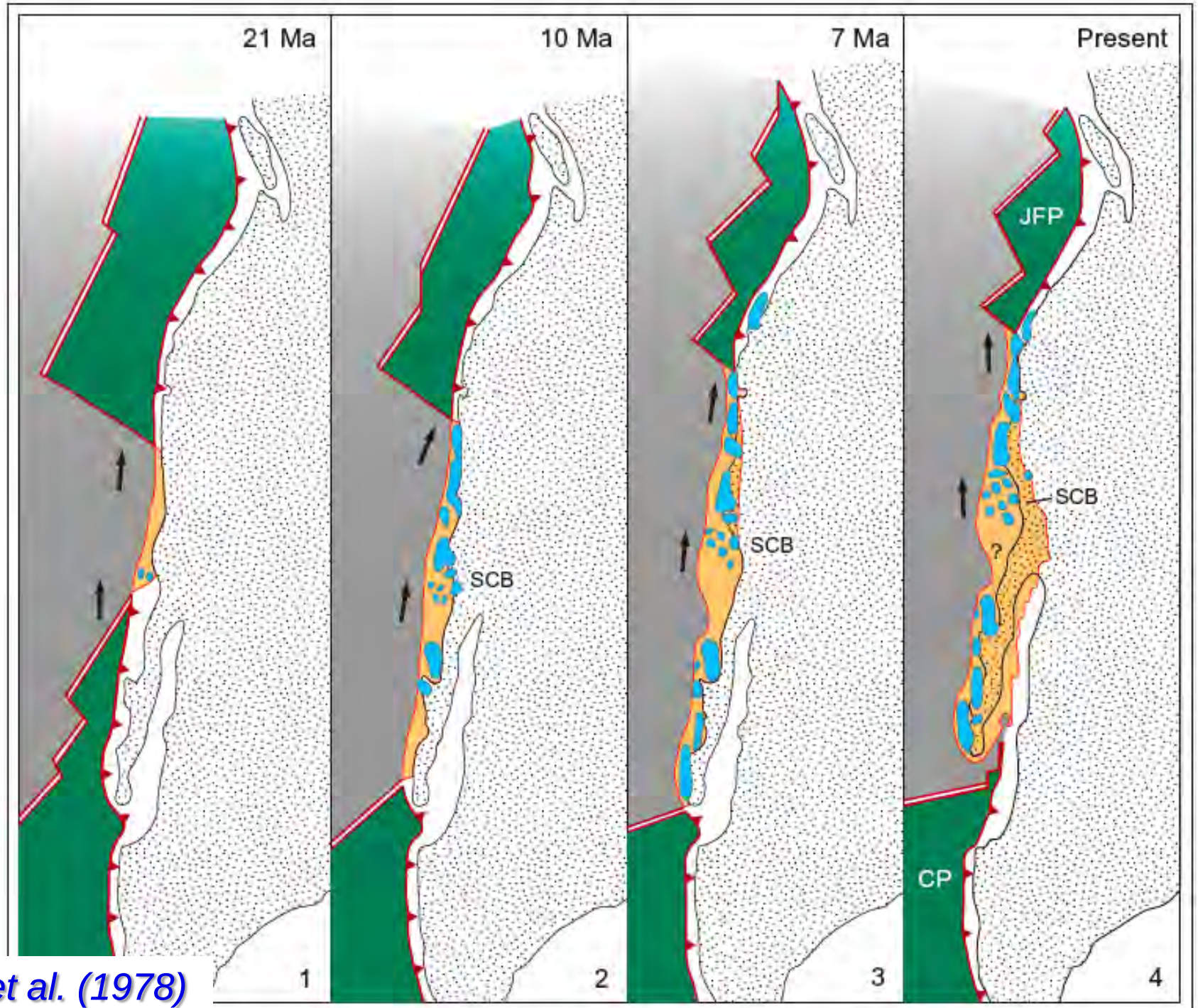
Miller et al. (1987)



Tectonic shift

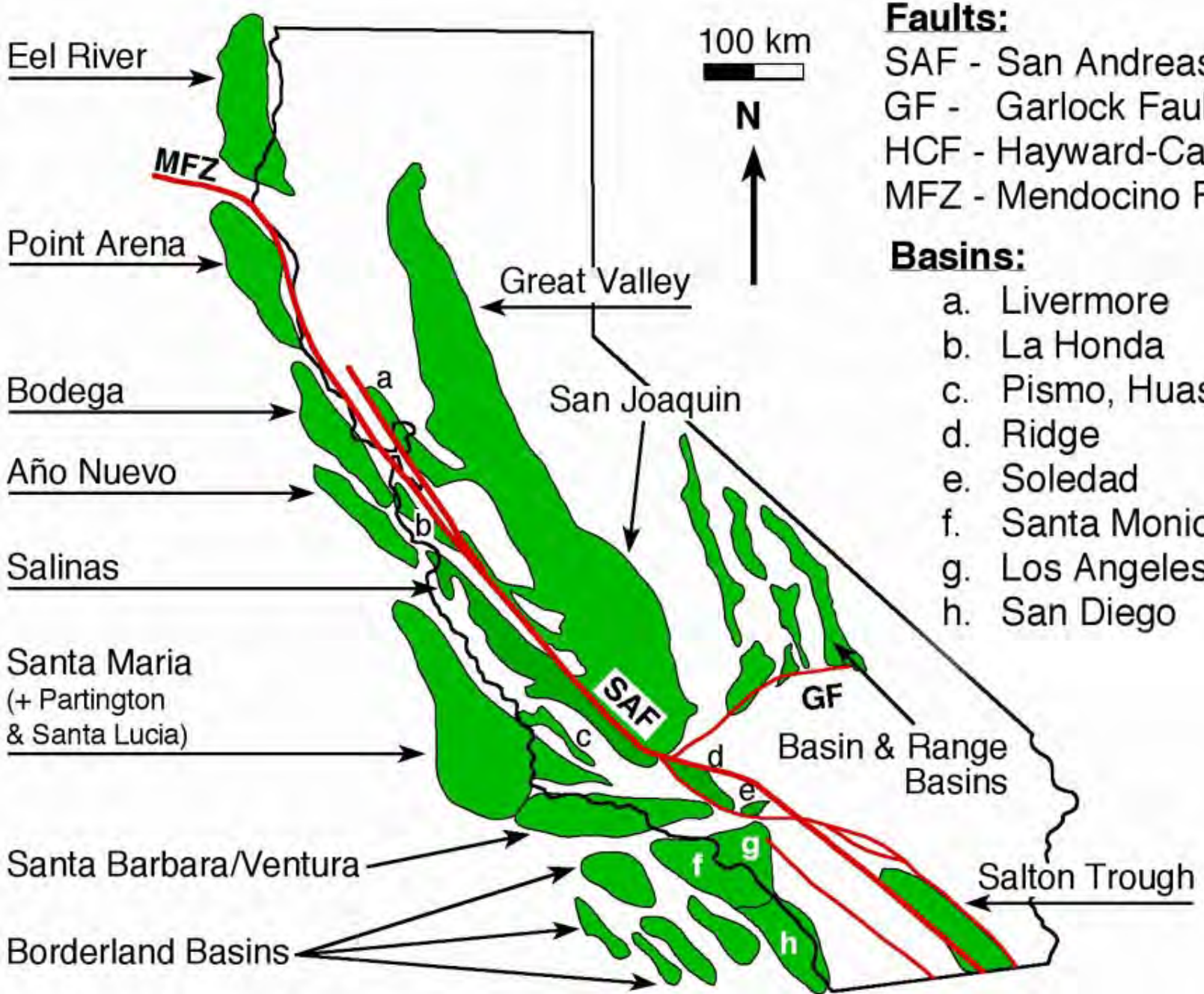
from convergent to transform margin formed numerous basins

Dickinson (1979)



Blake et al. (1978)

Modern Sedimentary Basins



Key:

Faults:

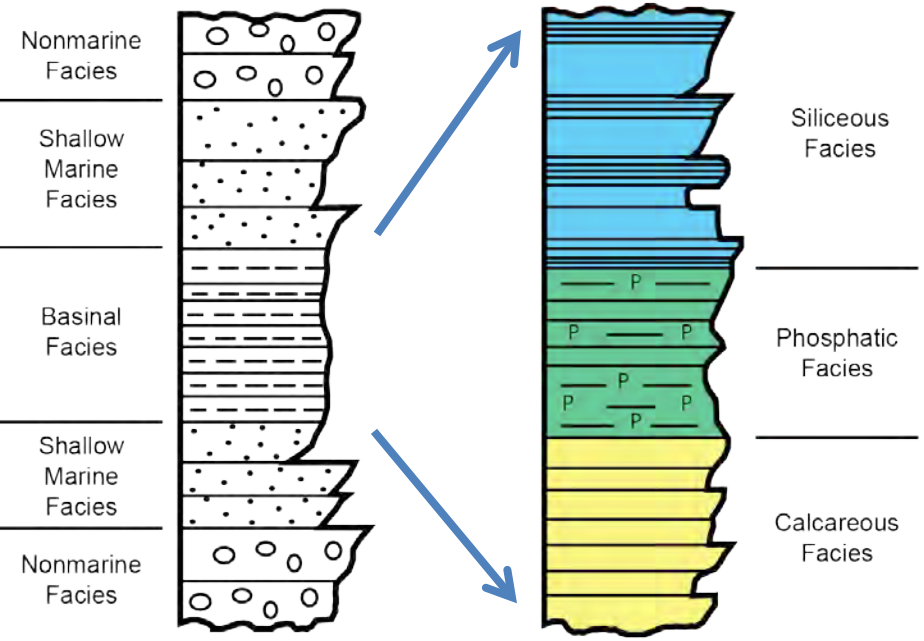
SAF - San Andreas Fault
GF - Garlock Fault
HCF - Hayward-Calaveras Fault
MFZ - Mendocino Fracture Zone

Basins:

a. Livermore
b. La Honda
c. Pismo, Huasna, Cuyama
d. Ridge
e. Soledad
f. Santa Monica, San Pedro
g. Los Angeles
h. San Diego

Neogene Basinal Stratigraphy
Generalized facies of the Monterey Formation

Generalized Upper Tertiary Facies, Coast Ranges, California

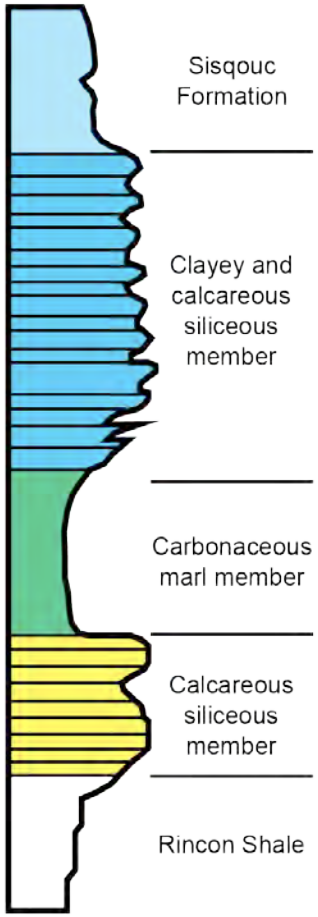


(Pisciotto and Garrison, 1981)

Generalized Basinal Facies of the Monterey Formation

Coast Ranges

Facies of the Monterey Formation, Santa Barbara, California



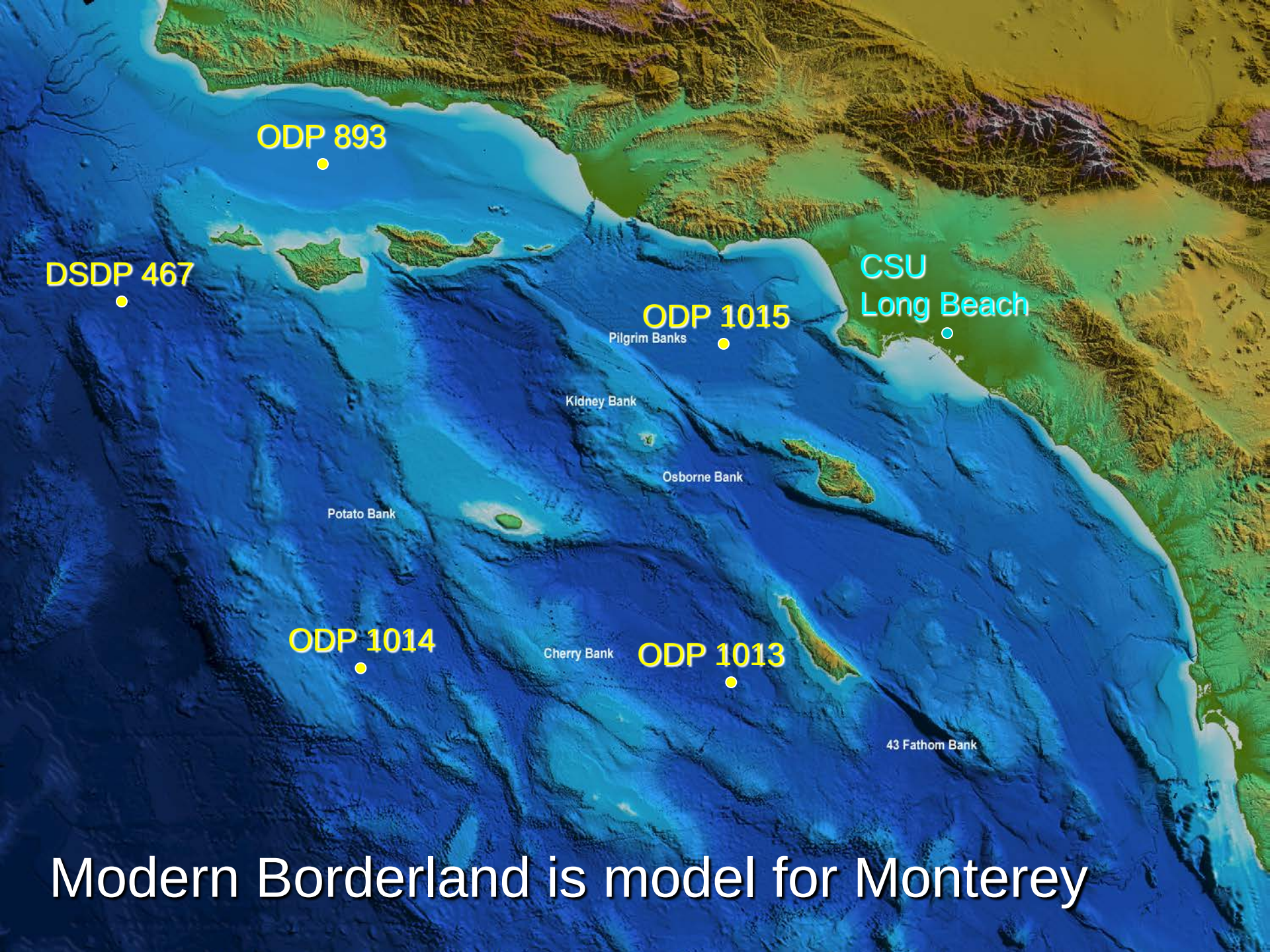
(Isaacs, 1983)

Facies of the Monterey Formation, San Joaquin Basin, California

(Graham and Williams, 1985)

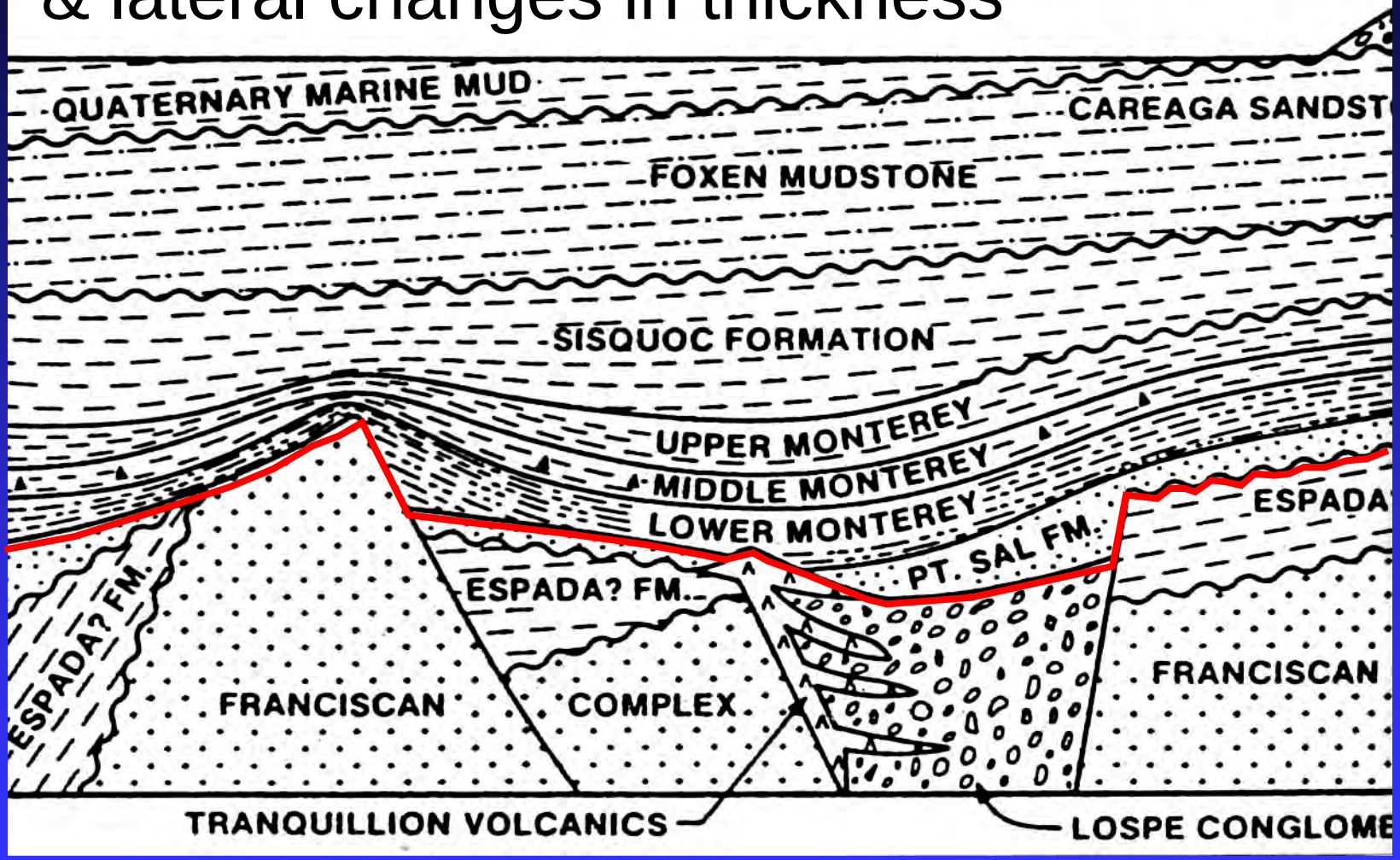
Lesson #1

- Monterey composition varies stratigraphically (vertically) with changed deposition over time



Modern Borderland is model for Monterey

Irregular depositional surface & lateral changes in thickness



Dunham et al. (1991)

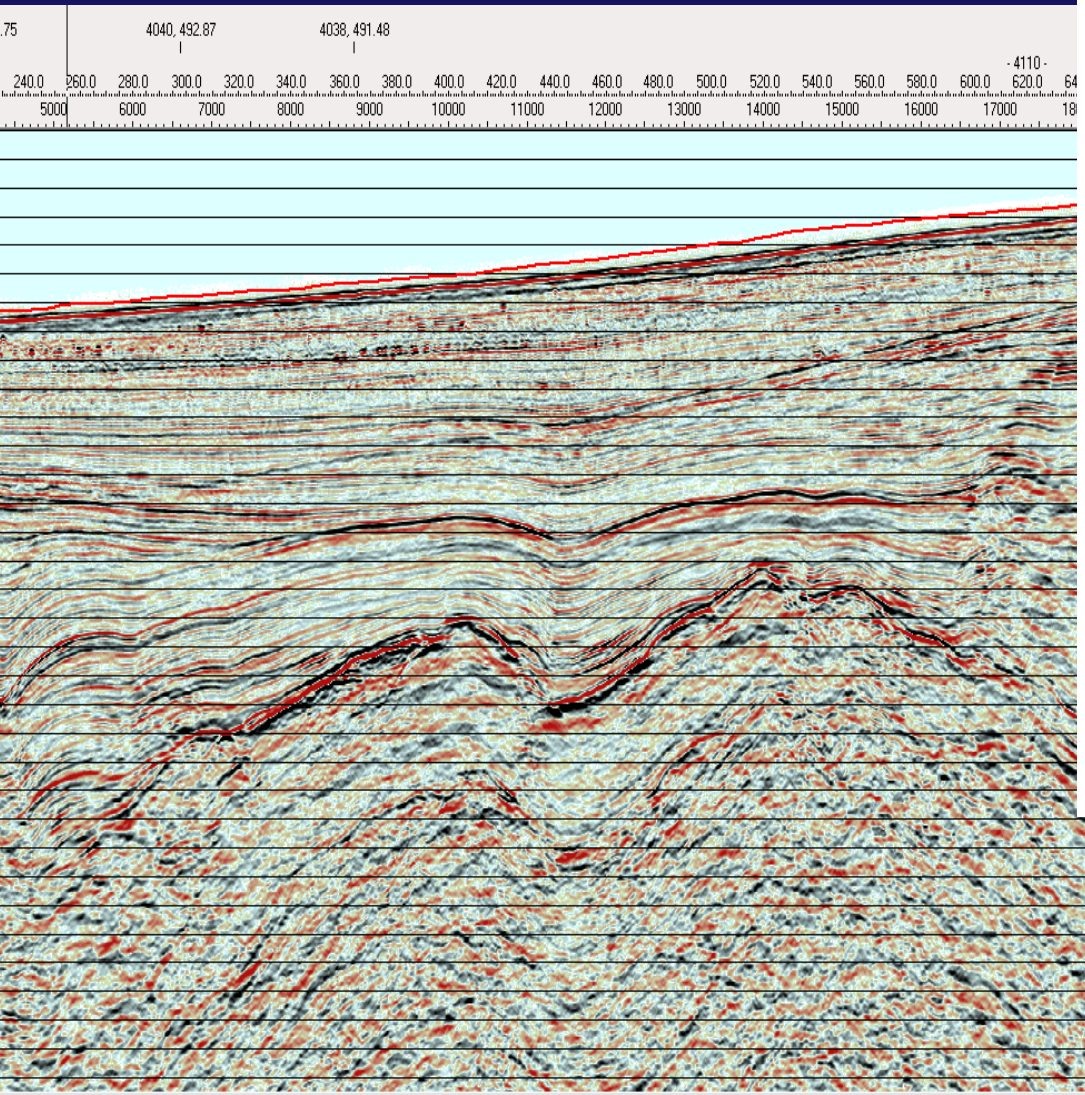
Santa Maria Basin

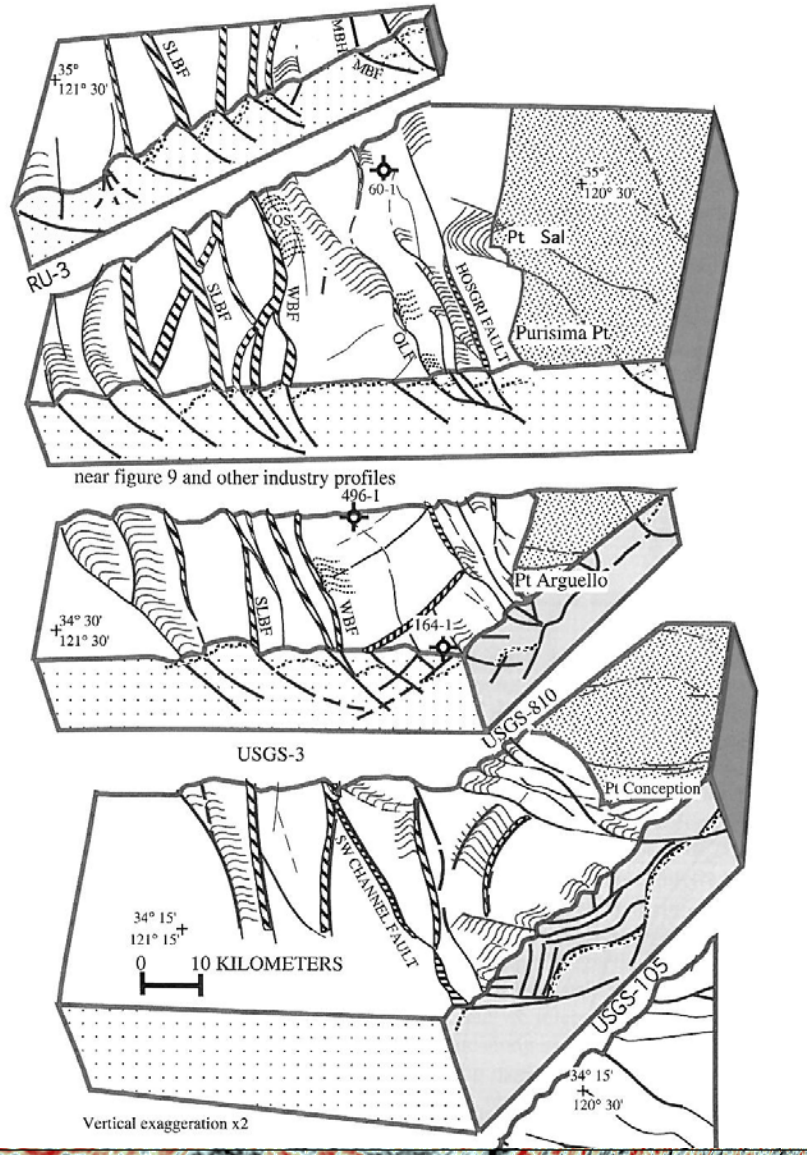
Long Beach MARS Project: Monterey and Related Sedimentary rocks

CSULB Geology

Tilted Fault Blocks of the Offshore Santa Maria Basin

Sorlien et al., 1999





Lesson #2

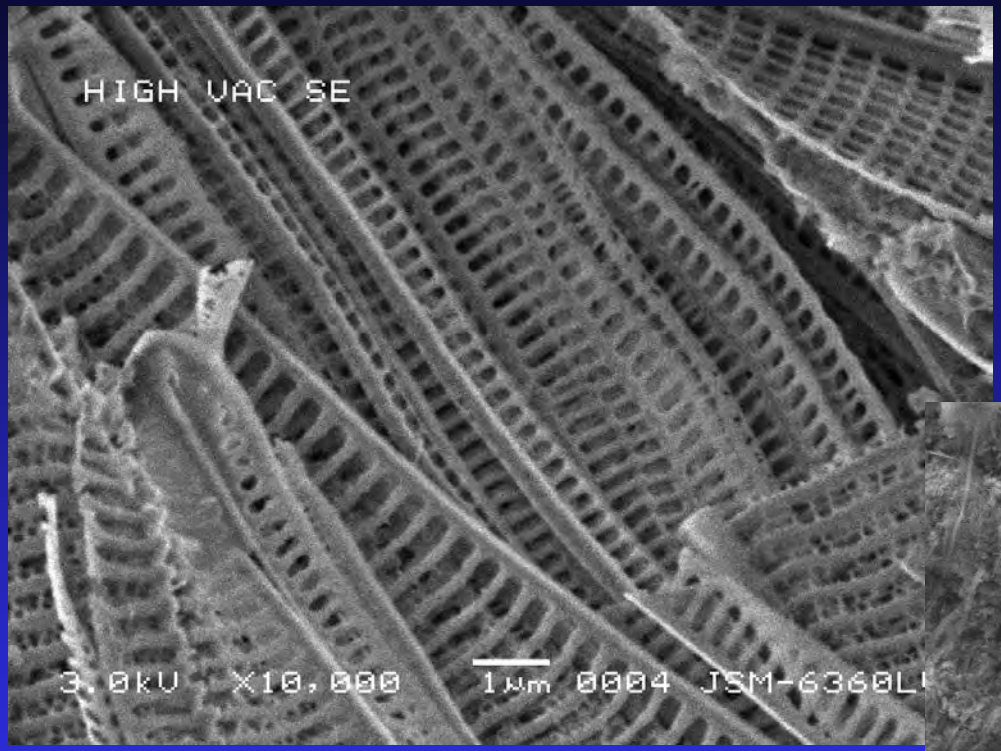
- Monterey composition and thickness varies laterally (spatially)

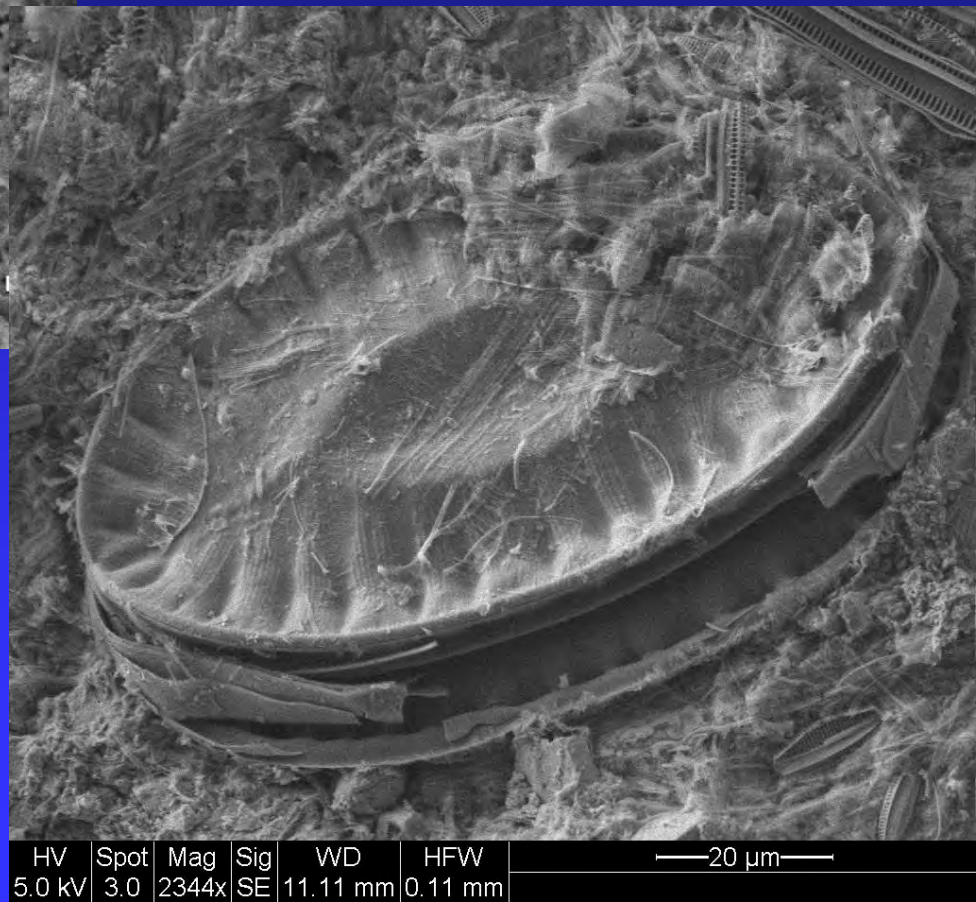
Main Sedimentary Components

- Silica
- Carbonate
- Organic matter
- Phosphate
- Detritus (clay, silt & sand)

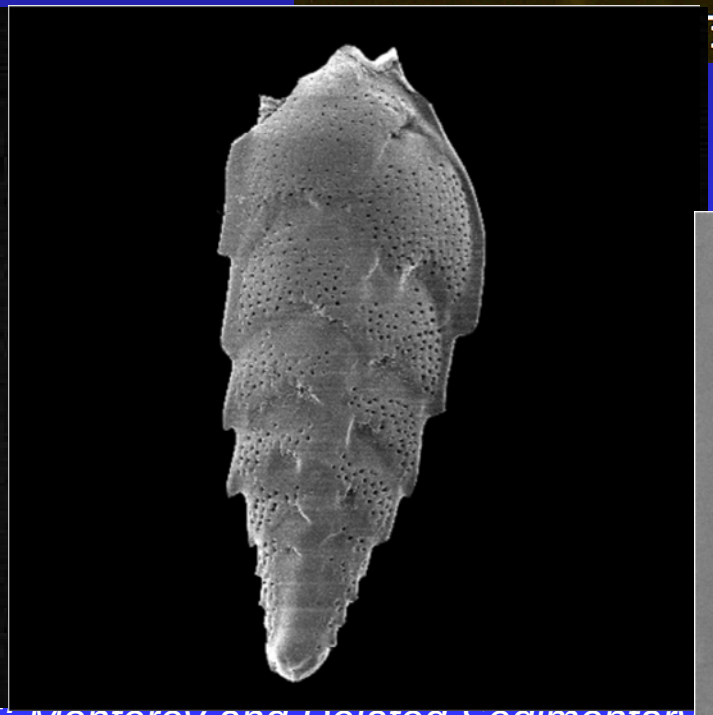
Highly unstable components undergo chemical changes with burial and time

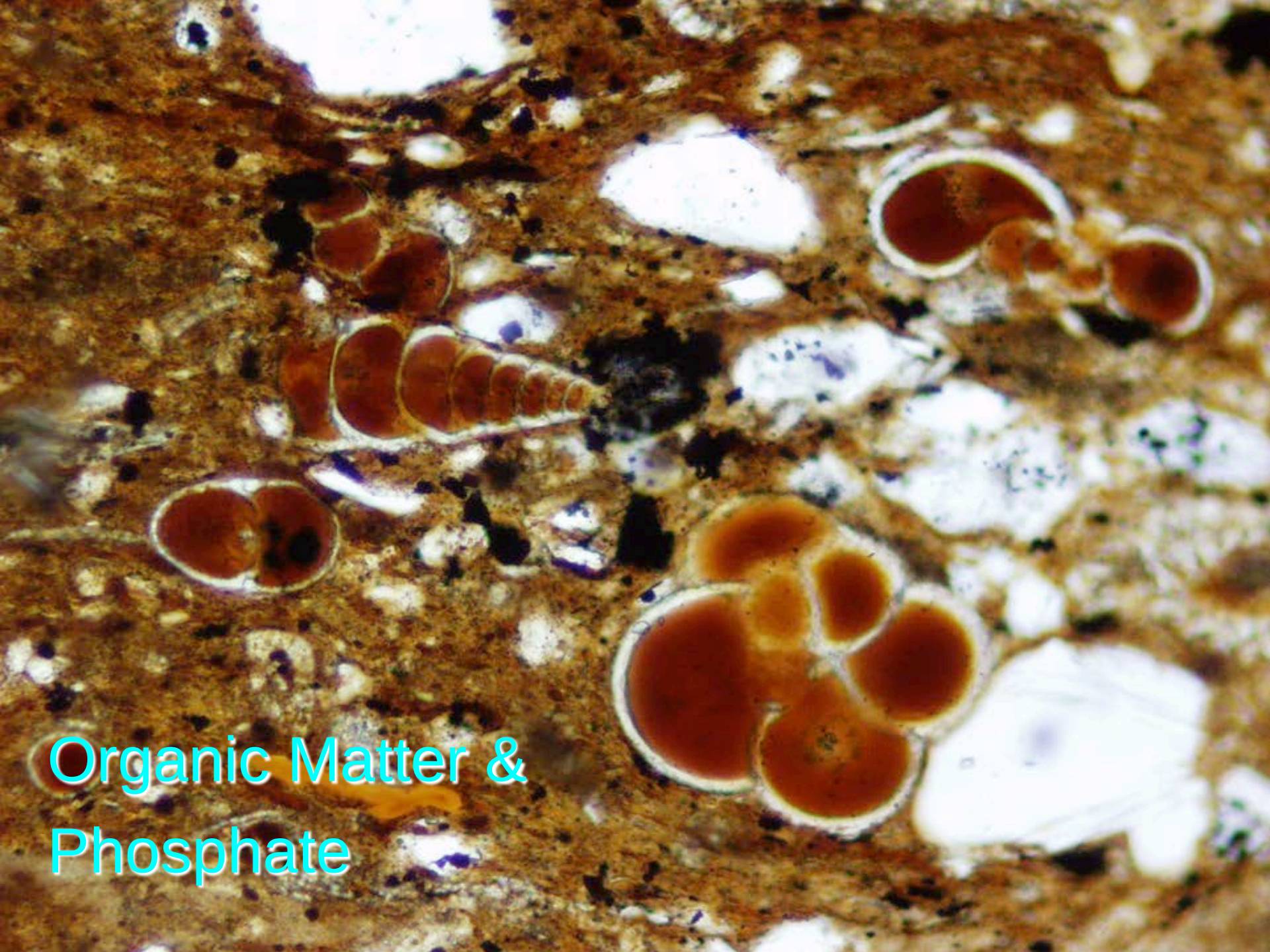
Diatoms

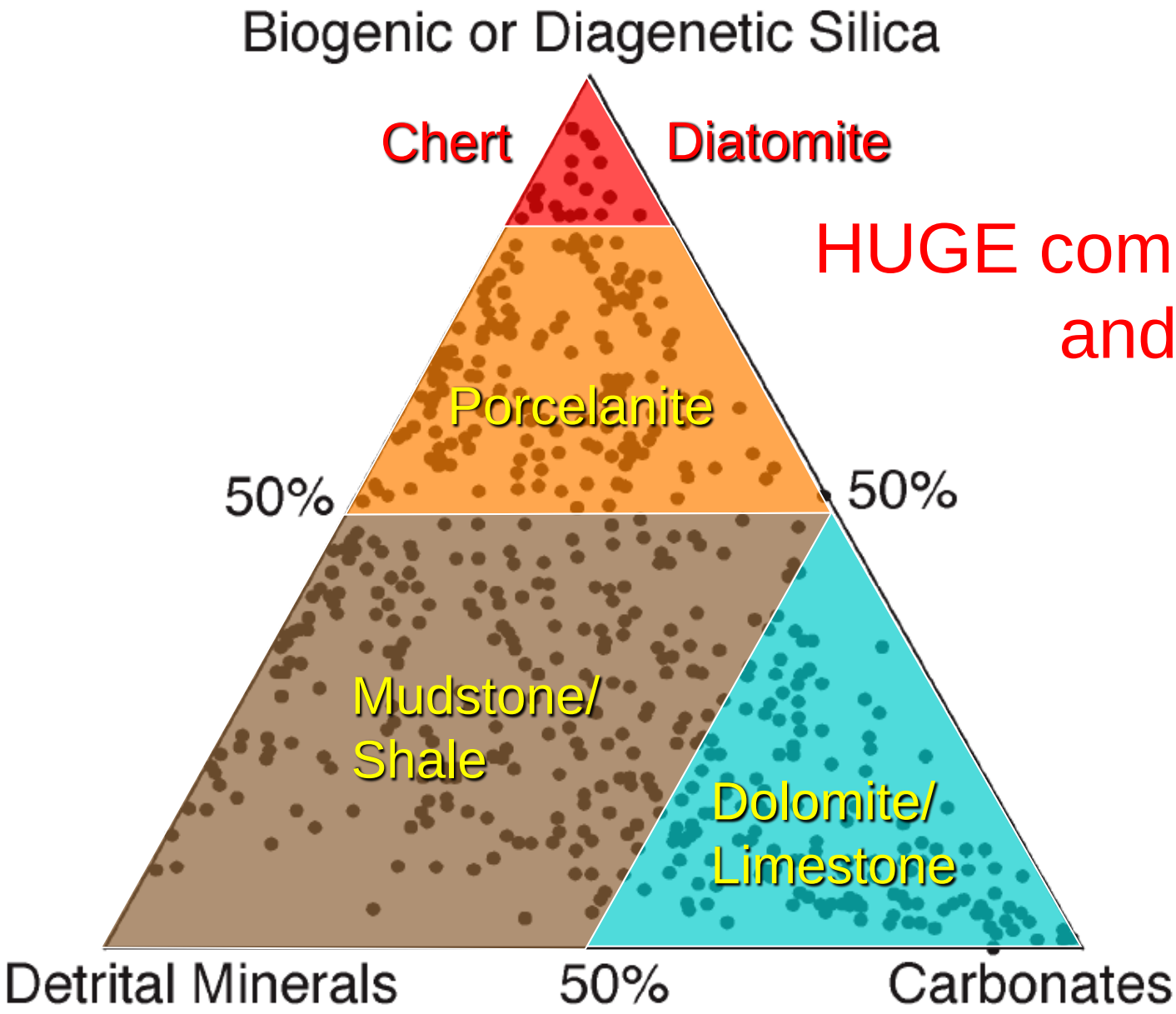

HIGH VAC SE
3.0kV X10,000 1µm 0004 JSM-6360L


HV 5.0 kV
Spot 3.0
Mag 2344x
Sig SE
WD 11.11 mm
HFW 0.11 mm
20 µm

Calcareous Microfossils




Organic Matter &
Phosphate



HUGE compositional and lithologic variability

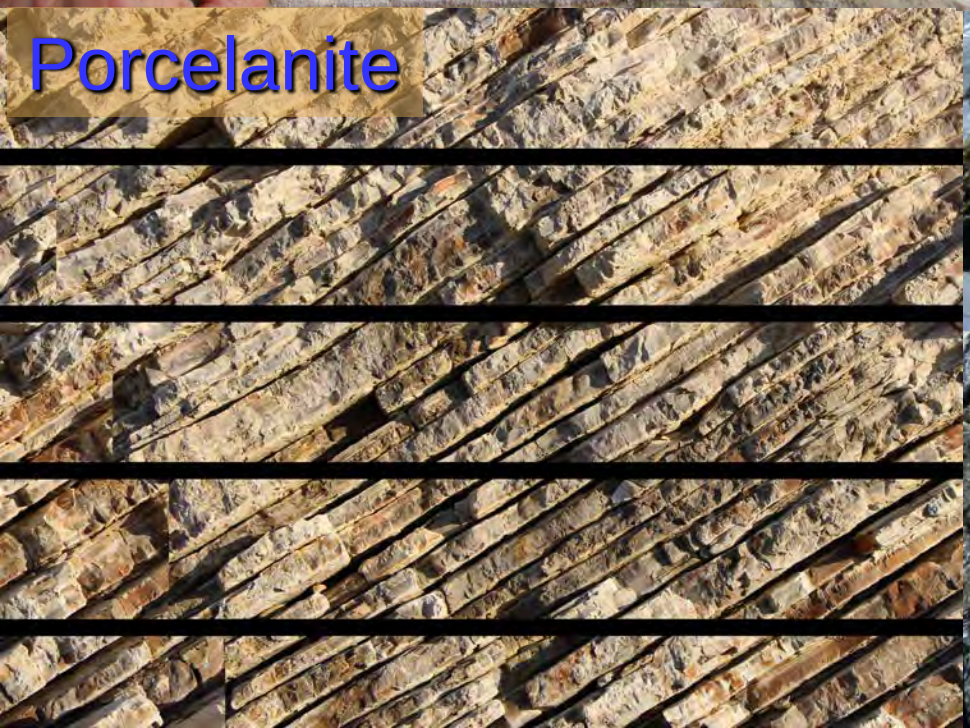
Isaacs (1985)

Rock Types

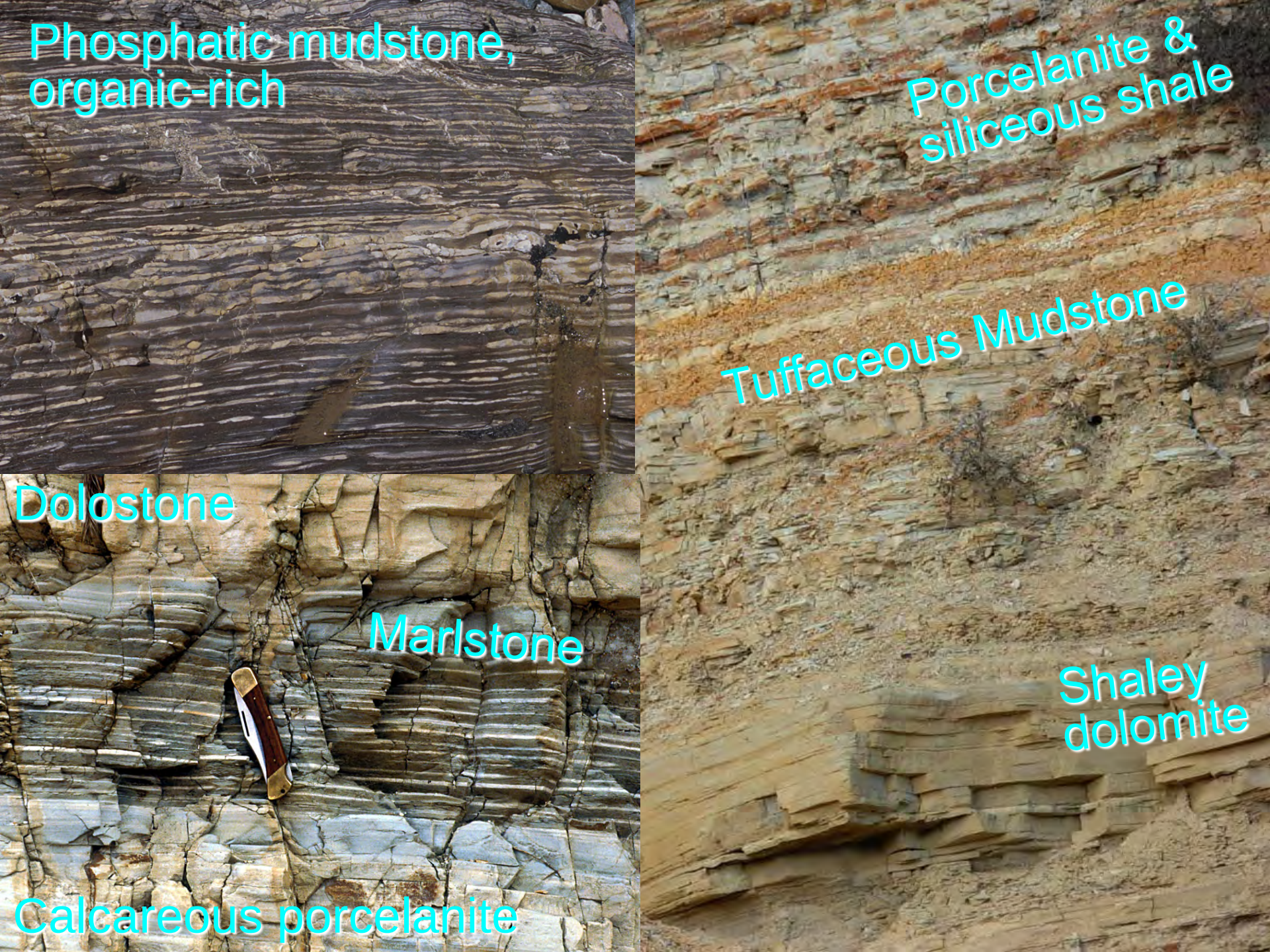
- Chert
- Porcelanite
- Siliceous Shale/Mudstone
- Clay Shale/Mudstone
  - (Also: Calcareous and Diatomaceous varieties)
- Diatomite
- Dolostone/Limestone/Marlstone
- Phosphatic/Organic-rich Shale
- Sandstone


Diatomite


Siliceous Shale

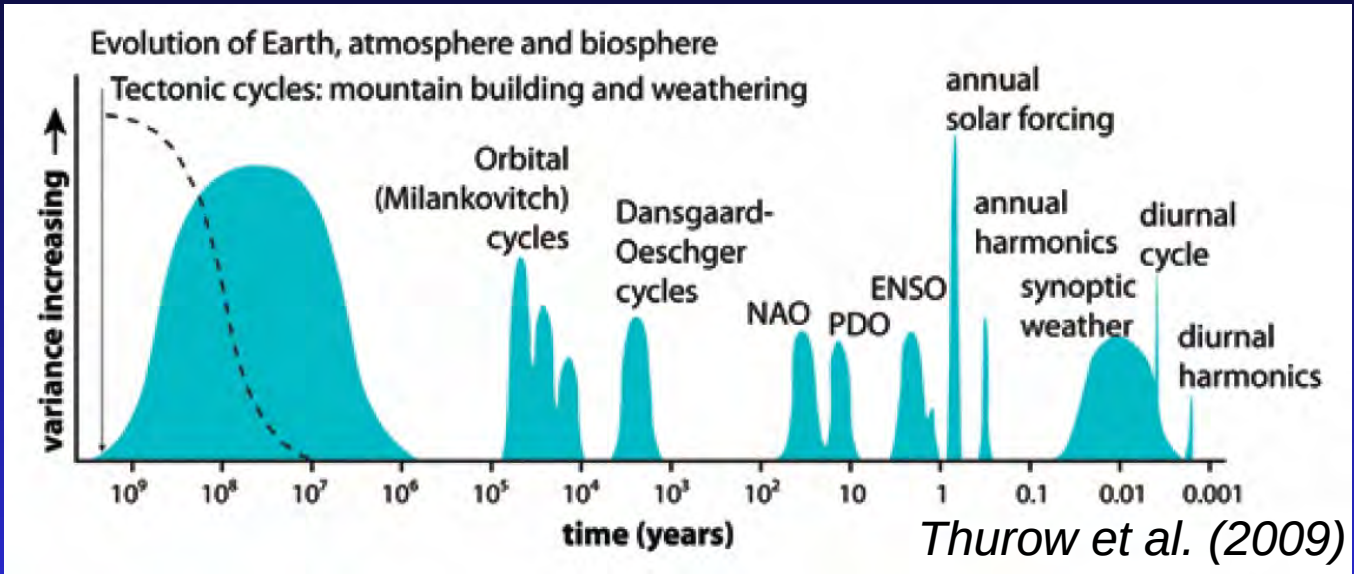

Porcelanite


Chert


Phosphatic mudstone, organic-rich
Porcelanite & siliceous shale
Tuffaceous Mudstone
Dolostone
Marlstone
Shaley dolomite
Calcareous porcelanite


Phosphatic organic-rich shale/mudrocks

Climate Cycles & Litho-cyclicity



Thurow et al. (2009)

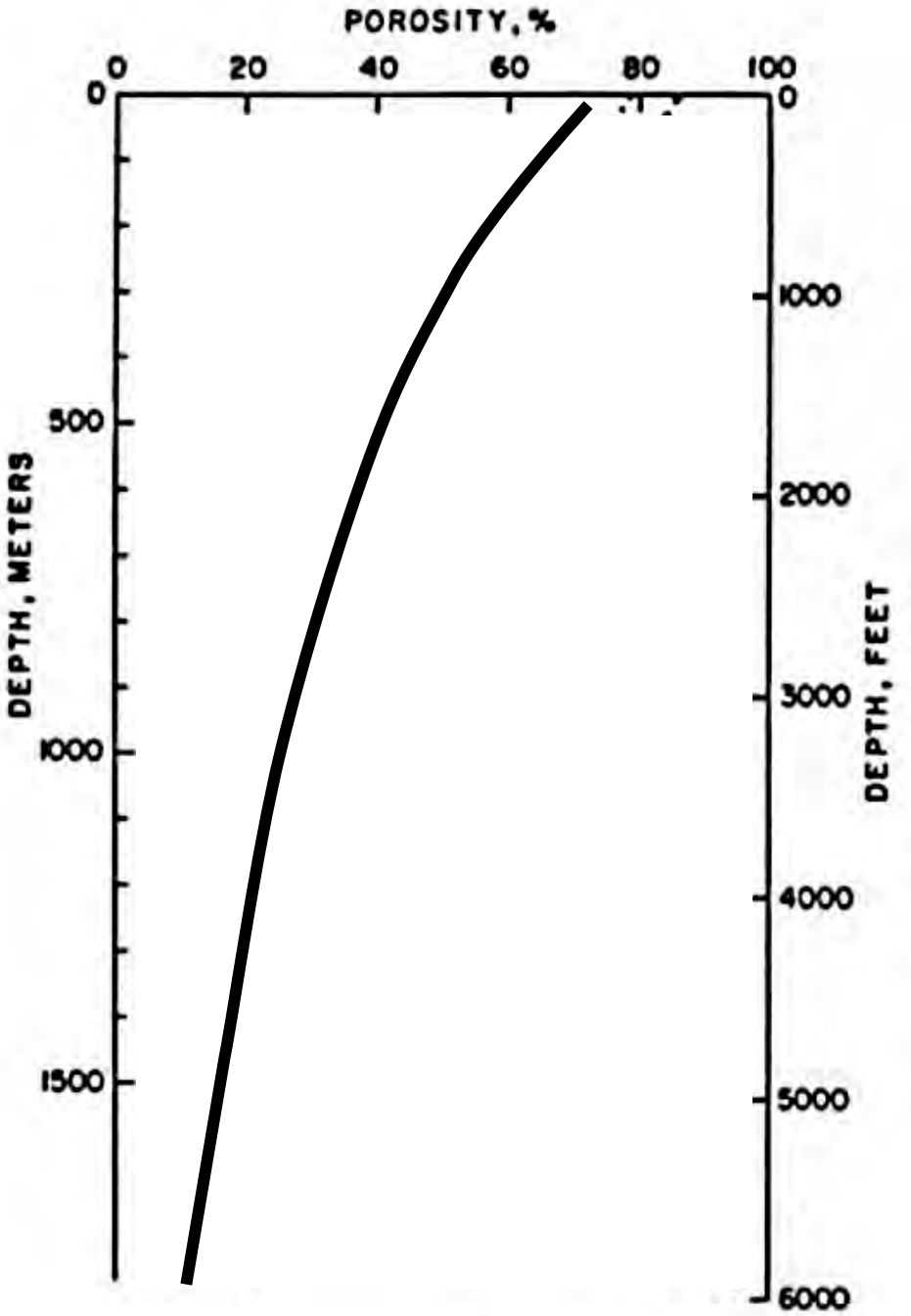
Lesson #3

- Monterey composition is complicated and thinly interbedded with many different rock types

Shale Diagenesis

Progressive compaction

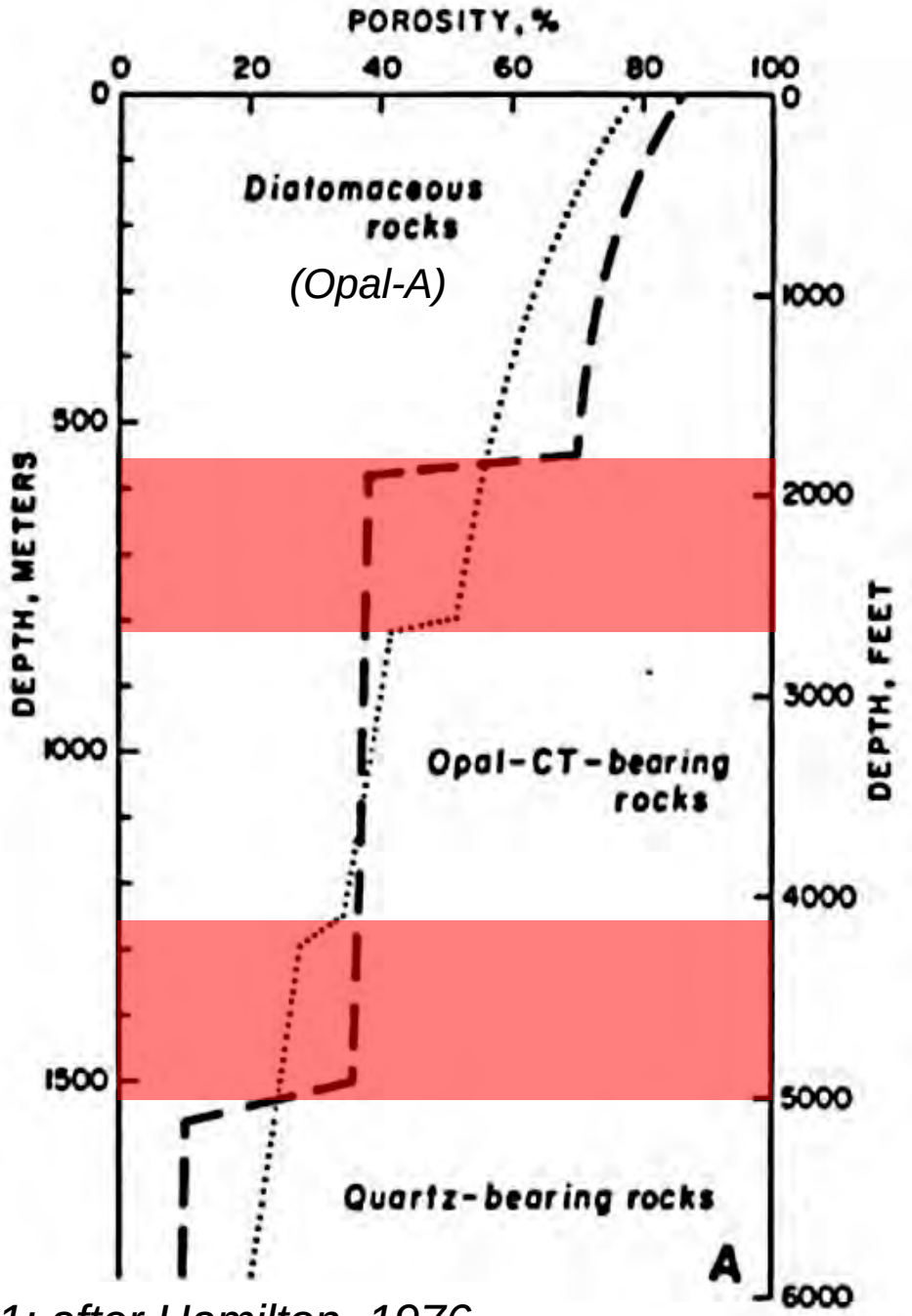
Gradual decrease in porosity with burial depth



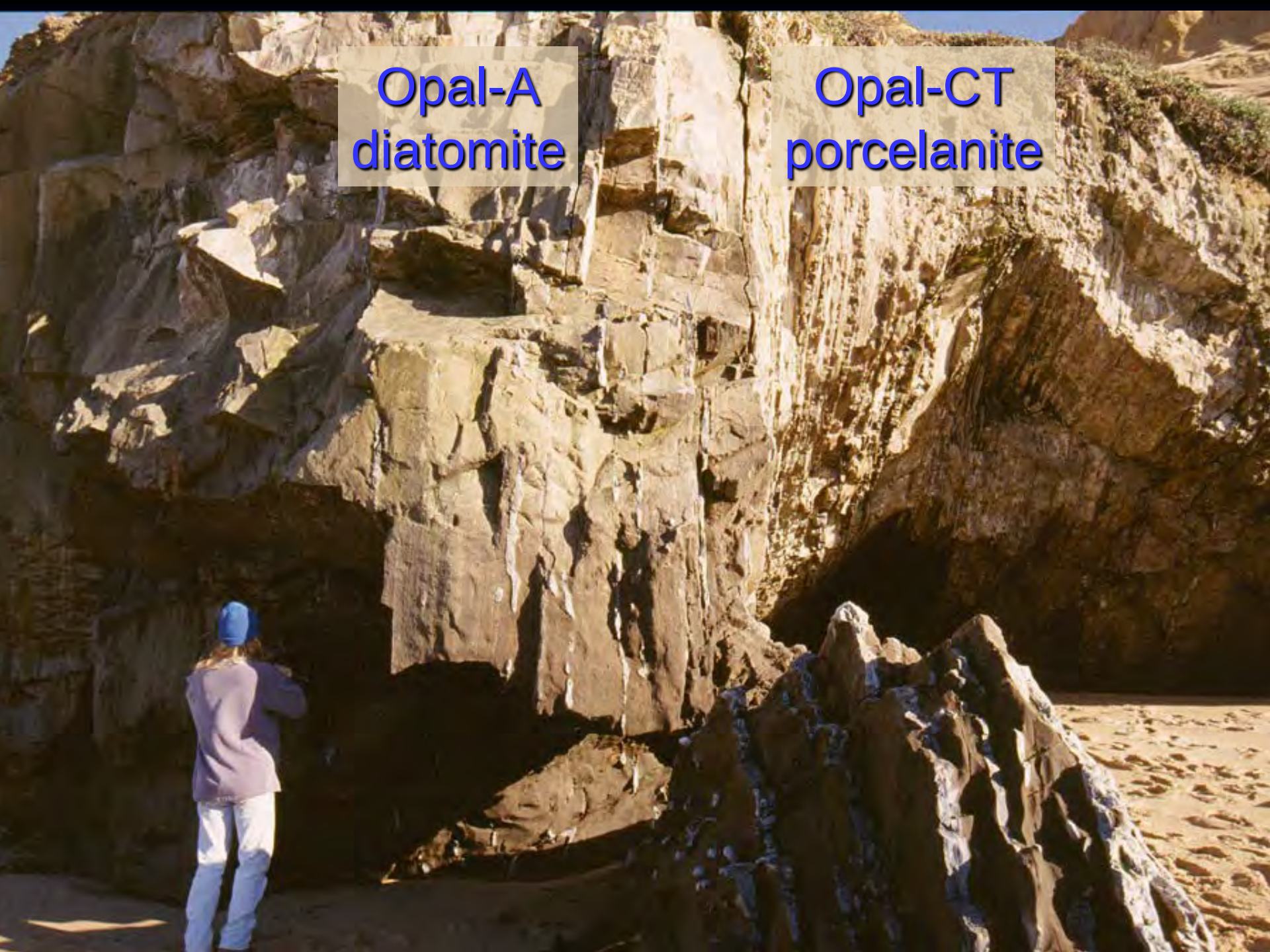
Silica Diagenesis

2-step dissolution/reprecipitation:

Stepped decreases in porosity with progressive burial



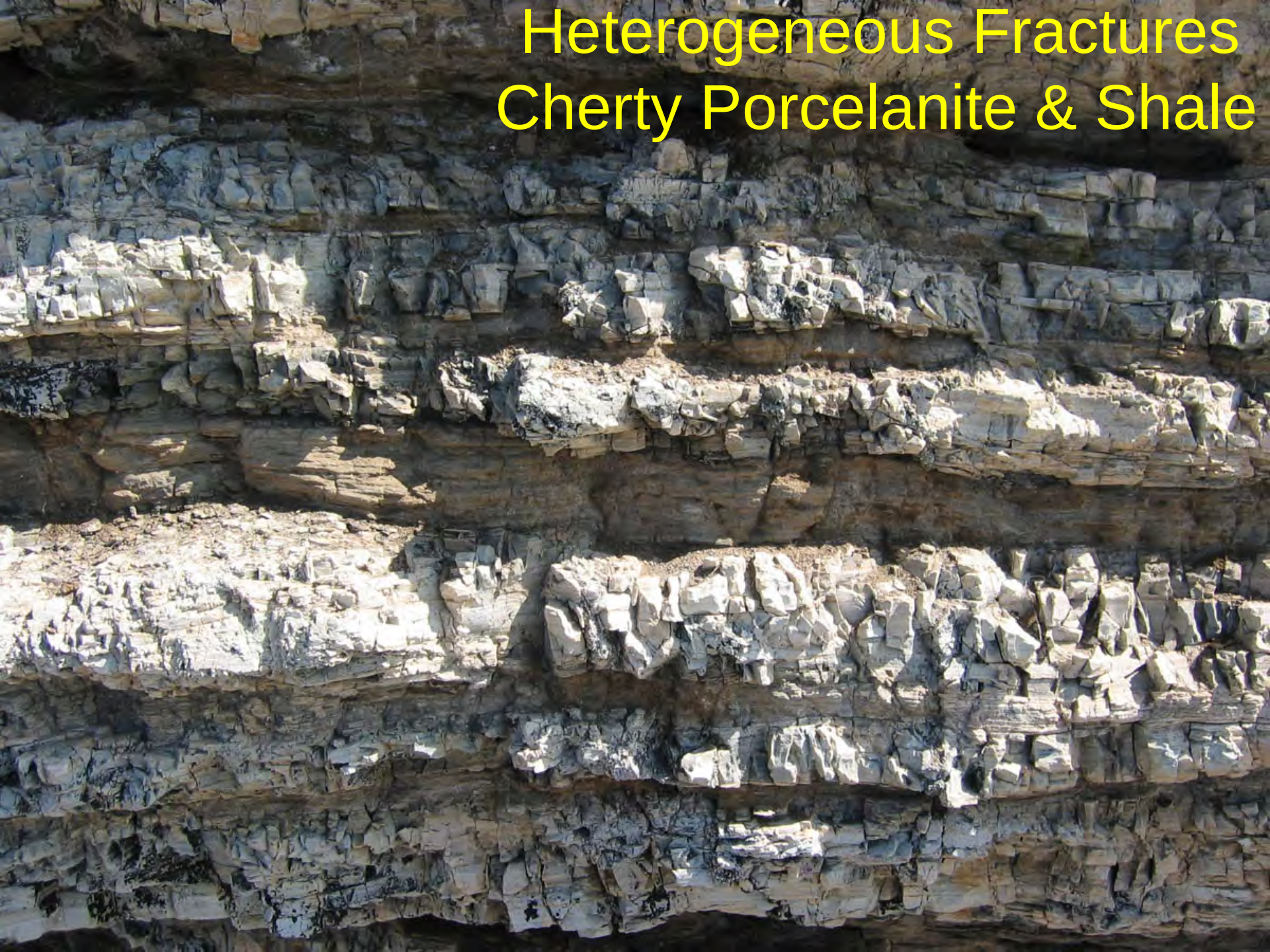
Isaacs, 1981; after Hamilton, 1976

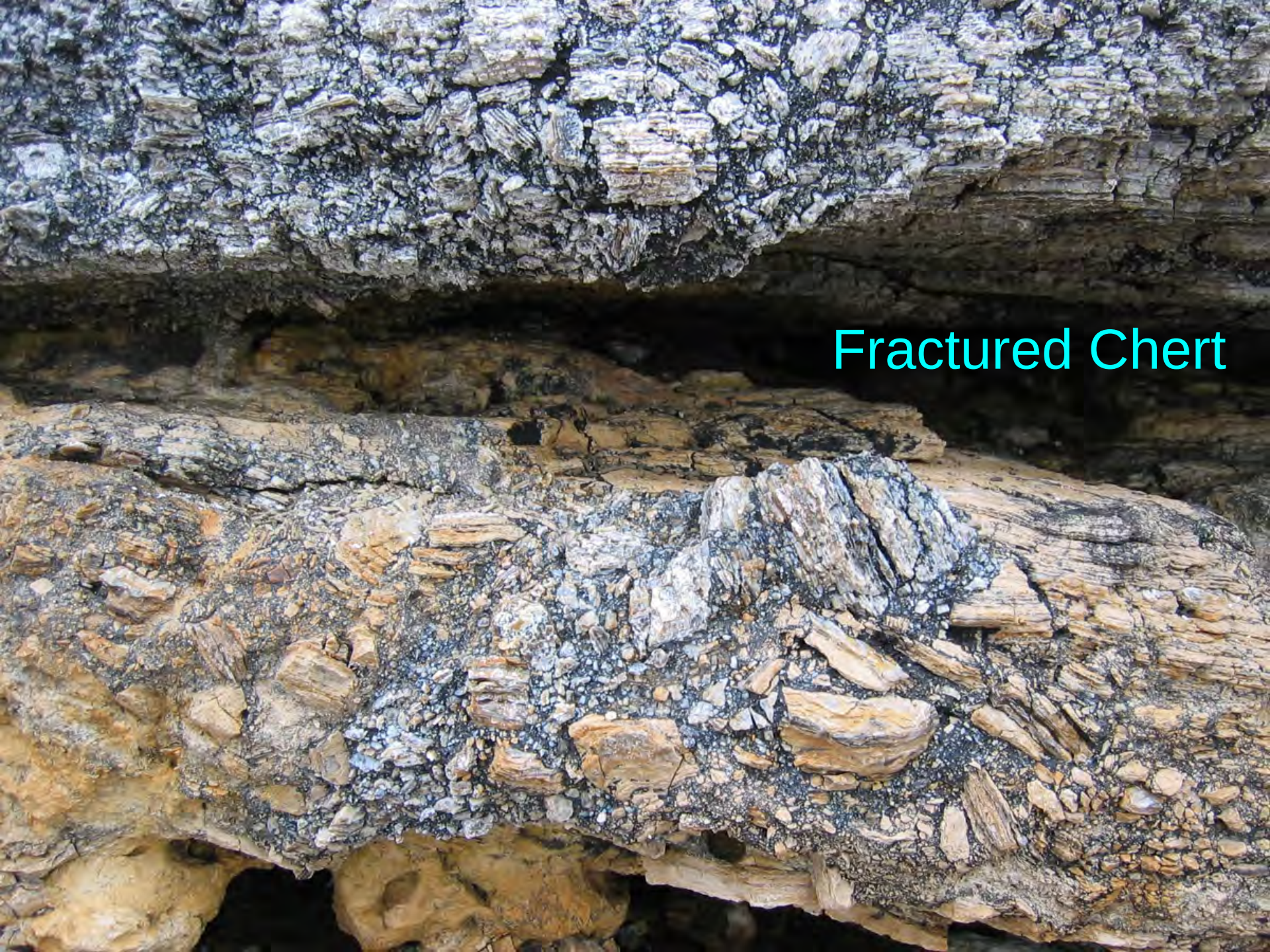

Opal-A
diatomite
Opal-CT
porcelanite

Ribbon-bedded porcelanite

Natural fractures: 4-5 orders of magnitude

Strickland (2013)


Heterogeneous Fractures
Cherty Porcelanite & Shale


Fractured Chert


Fractured Dolomite


Fractured Dolomite

Lesson #4

- Burial diagenesis creates major changes in rock properties, including porosity and brittleness, key to reservoir performance


35
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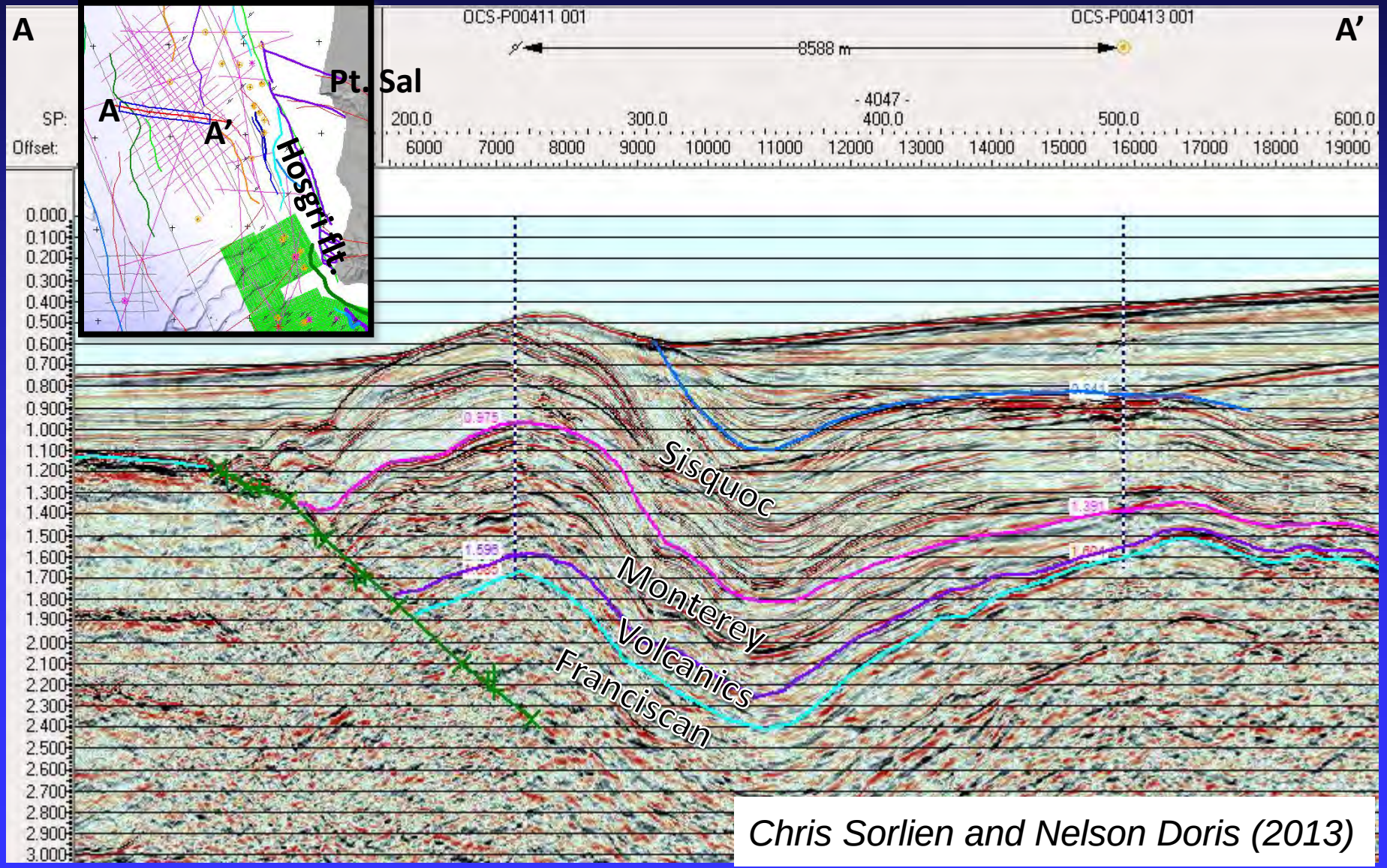
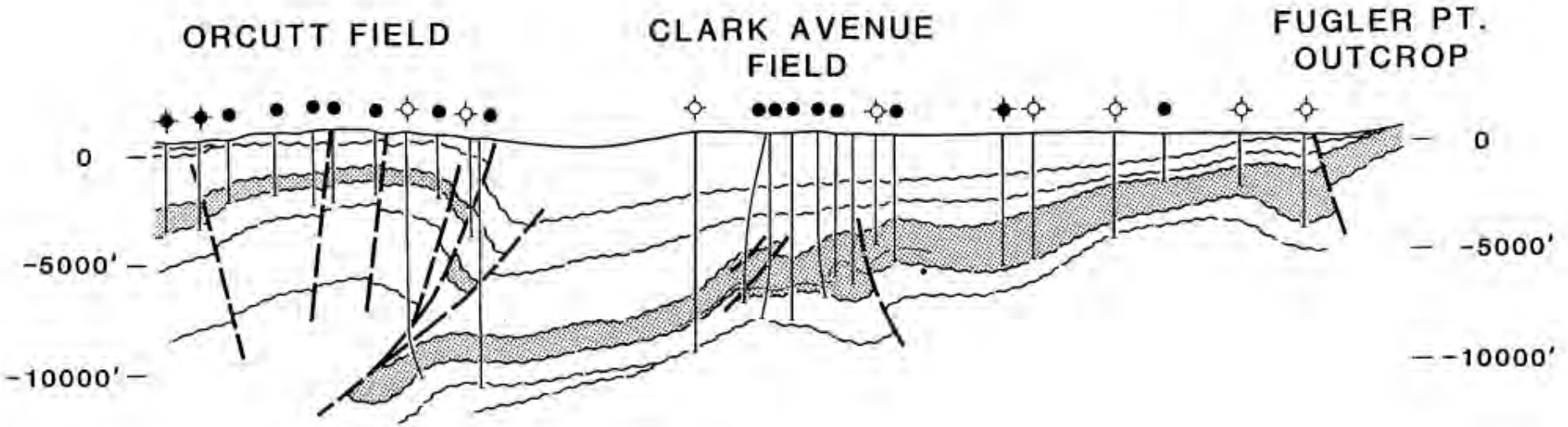
101
Guadalupe
Santa Maria
Santa Maria Valley
Orcutt
Casmalia
Jesus Maria
Four Deer (Abd.)
Lompoc
Cat Canyon
Sisquoc Ranch (Abd.)
Careaga Canyon
Los Alamos
Zaca
Barham Ranch
SANTA MARIA BASIN
Cuyama, Central (Abd.)
Cuyama, S.
CUYAMA BASIN
SANTA BARBARA
Morales Canyon
Russell Ranch
Capitola Park
Cienaga Canyon
Los Lobos
Pioneer
San Emigdio (Abd.)
Eagle Rest
San Emigdio Creek (Abd.)
Yowlumne
Refugio Cove (Abd.)
Molino Offshore (Abd.)
Gaviota Offshore
Caliente Offshore (Abd.)
Alegria (Abd.)
Point Conception
Conception Offshore (Abd.)
Cuarta Offshore (Abd.)
Alegria Offshore (Abd.)
Sacate Offshore (Fed.)
Pescado Offshore (Fed.)
Capitan
Hondo Offshore (Fed.)
Naples Offshore (Abd.)
Las Varas Canyon (Abd.)
Elwood
Goleta (Abd.)
Elwood, Offshore Area
Glen Annie (Abd.)
Elwood,S. Offshore
La Goleta
Santa Barbara
Mesa (Abd.)
Summerland Offshore (Abd.)
Dos Cuadras Offshore (Fed.)
Pitas Point Offshore (Fed.)
Carpinteria Offshore
Santa Clara Offshore (Fed.)
Hueneme Offshore (Fed.)
Sockeye Offshore (Fed.)
Santa Cruz Is.
VENTURA
Summerland
Canada Larga
Rincon Creek (Abd.)
Oakview (Abd.)
Rincon
San Miguelito
Ventura
El Rio (Abd.)
West Montalvo

Tectonic deformation during sedimentation leads to extreme variation in thickness and composition of reservoir and source rocks



Chris Sorlien and Nelson Doris (2013)

Largely conventional traps
(with unconventional rocks)



Lesson #5

- Most Monterey production is from conventional traps
- Most Monterey-sourced oil is produced from associated sandstone reservoirs
- Truely unconventional or “continuous” resource plays in the Monterey may be limited

Do NOT expect continuous distribution of Monterey tight oil exploration and development

Monterey plays will be far more targeted than other “shales”.

Hughes (2013)

Figure 1. The Monterey tight oil play in California, with relevant sedimentary basins and counties.

Monterey Summary

- Important link to global change & tectonics
- Spans the Pacific Rim
- Organic-rich, highly siliceous, fine-grained
- Vertical and lateral lithofacies variations
  - Global and local controls
- Thin-bedded and cyclic bedding
- High diagenetic potential of silica, carbonate, phosphate & organic matter
- Composition and diagenesis controls physical properties of sediments and mechanical stratigraphy

NOT a simple "shale"!!!