**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)*
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)
Neogene Basinal Stratigraphy
Generalized facies of the Monterey Formation

Generalized Upper Tertiary Facies, Coast Ranges, California

Generalized Basinal Facies of the Monterey Formation
Coast Ranges

Facies of the Monterey Formation, Santa Barbara, California

Facies of the Monterey Formation, San Joaquin Basin, California

Nonmarine Facies

Shallow Marine Facies

Basinal Facies

Shallow Marine Facies

Nonmarine Facies

Siliceous Facies

Phosphatic Facies

Calcereous Facies

Sisquoc Formation

Clayey and calcareous siliceous member

Carbonaceous marl member

Calcereous siliceous member

Rincon Shale

Etchegoin + Santa Margarita Formation

Reef Ridge

Antelope

McLure Member, undifferentiated

Devilwater

Devilwater/Gould undifferentiated

Gould

Temblor Formation

(Pisciotto and Garrison, 1981)

(Isaacs, 1983)

(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

Santa Maria Basin

Long Beach MARS Project: Monterey and Related Sedimentary rocks

Dunham et al. (1991)
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.
Calcareous Microfossils
Long Beach MARS Project: Monterey and Related Sedimentary rocks

Organic Matter & Phosphate
HUGE compositional and lithologic variability

Long Beach MARS Project: Monterey and Related Sedimentary rocks

Isaacs (1985)
Rock Types

- Chert
- Porcelainite
- Siliceous Shale/Mudstone
- Clay Shale/Mudstone
  - (Also: Calcareous and Diatomaceous varieties)
- Diatomite
- Dolostone/Limestone/Marlstone
- Phosphatic/Organic-rich Shale
- Sandstone
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
Ribbon-bedded porcelanite
Natural fractures: 4-5 orders of magnitude

Strickland (2013)
Heterogeneous Fractures
Cherty Porcelainite & Shale
Fractured Chert
Fractured Dolomite

Long Beach MARS Project: Monterey and Related Sedimentary rocks
Fractured Dolomite
Lesson #4

• Burial diagenesis creates major changes in rock properties, including porosity and brittleness, key to reservoir performance.
Long Beach MARS Project: Monterey and Related Sedimentary rocks
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)
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”!!!**