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
Tectonic shift from convergent to transform margin formed numerous basins

Dickinson (1979)
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

- Eel River
- Point Arena
- Bodega
- Año Nuevo
- Salinas
- Santa Maria (+ Partington & Santa Lucia)
- Santa Barbara/Ventura
- Borderland Basins
- Salton Trough
- Great Valley
- MFZ
- SAF
- GF

- Map scale: 100 km
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

Basilan Facies

Shallow Marine Facies

Nonmarine Facies

Siliceous Facies

Phosphatic Facies

Calcereous Facies

(Siscogu 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

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

Dolostone

Marlstone

Calcareous porcelanite

Porcelainite & siliceous shale

Tuffaceous Mudstone

Shaley dolomite
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**

*(Opal-A)*

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