Oil and Dolomite in the Monterey Formation of California*

Richard J. Behl¹

Search and Discovery Article #50974 (2014)**
Posted July 7, 2014

*Adapted from oral presentation given at Pacific Section AAPG, SEG and SEPM Joint Technical Conference, Bakersfield, California, April 27-30, 2014
**AAPG©2014 Serial rights given by author. For all other rights contact author directly.

¹California State University, Long Beach, CA (behl@csulb.edu)

Abstract

Dolomite has a unique relationship with hydrocarbons in the Monterey Formation and related deposits of California, both as fractured or matrix reservoir and in the very origin of the mineral. Along with silica, kerogen, phosphate and calcite, dolomite is a key non-clastic component of the Monterey. Yet little is known about the paragenesis of petroleum and dolomite. Nor is much understood about the reason for large intra- and interbasinal differences in abundance. Dolomite generally forms distinct nodules, beds, laminations, veins, and more abundant, but less distinctive dolomitic lithologies (mudstone, diatomite, porcelanite, chert). Most stratigraphic dolomite is authigenic — forming at horizons in organic-rich sediments where pore-water iron, nitrate or sulfate is reduced and bicarbonate or methane is abundant. Nodular dolomite frequently formed around reducing, organic nuclei, such as bones or driftwood or in reactant-limited environments. In many successions, dolostone horizons are remarkably rhythmic in spacing, likely reflecting pauses in sedimentation related to relative sea-level cycles that form parasequences. Irregular, discontinuous dolostone beds are also commonly associated with slumps or other synsedimentary remobilizations that enhanced vertical permeability by disrupting continuous primary lamination. Initially disseminated or laminations of rhombs in siliceous rocks recrystallize and grow in conjunction with the opal-CT to quartz silica phase transition. Additionally, dolomite forms veins, fracture-fillings, and breccias that are either bed-confined or associated with crosscutting fault zones. Oil and dolomite are spatially related in a number of ways. Fracture aperture and permeability tends to be high in dolostones because the greater thickness of mechanical strata than for most other lithologies in the Monterey Formation. Coarsely sucrosic dolomite is commonly composed of dolomite rhombs with nuclei of petroleum, suggesting that hydrocarbon seepage was related to dolomite formation in some locations. The most obviously petroliferous
intervals of many cores are dolomites with highly saturated intercrystalline porosity. In addition, oil is found in cemented dolomite breccias as fluid inclusions, vugs, and as mm- to cm-scale bubble-like spheres surrounded by radiating bladed dolomite crystals in fault zones.

Selected References


Oil & Dolomite in the Monterey Formation of California

Richard J. Behl
Department of Geological Sciences, California State University, Long Beach
Synopsis

• Dolomite origin
• Dolomite occurrence
• Dolomite and oil
  • Nucleation
  • Fracture and matrix porosity
• Faults, fluid flow & breccias
• A Monterey Hydrothermal Dolomite Play?
Monterey Sedimentary Components

- Detrital
  - Clay
  - Silt
  - Sand

- Biogenous
  - Silica (opal-A)
  - Calcite
  - Kerogen

- Diagenetic / Authigenic
  - Opal-CT / Quartz
  - Phosphate
  - **Dolomite**
Organic Matter Diagenesis and Dolomite

Disseminated Dolomite

Concentrated with favorable chemistry or enough time
Dolostone Nodules

In massive mudstone
Gaviota Beach

In thin-bedded rocks
Crystal Cove

Long Beach MARS Project: Monterey and Related Sediments
Early formation shown by differential compaction

Long Beach MARS Project: Monterey and Related Sediments
Formed around reducing nuclei

Driftwood mold

Whale bone

Long Beach MARS Project: Monterey and Related Sediments
Reactant-limited nodular horizon

Gaviota Beach

Long Beach MARS Project: Monterey and Related Sediments
Dolostone Beds

Continuous beds form with enough time and reactants

Long Beach MARS Project: Monterey and Related Sediments
Dolostone Horizons & Parasequences?

Rhythmic bedding suggests Milankovitch cycles

Long Beach MARS Project: Monterey and Related Sediments
Dolomite or Dolomitic Hiatal Surfaces

Silty-sandy dolomite “yellow beds”  Point Fermin

Long Beach MARS Project: Monterey and Related Sediments
Dolomite Cement in Sandstones

Floating grains indicate pre-compaction cementation

Altamira Shale

Point Fermin

AlShammary (2013)
Dolomite (& Calcite) Veins

Opening-mode fractures with single or multiple cementation episodes

Long Beach MARS Project: Monterey and Related Sediments
Relation with Oil: Hydrocarbon-Nucleated Dolomite Rhombs

AlShammary (2013)
Dolostone Matrix Porosity

Inter-crystalline porosity and oil

Long Beach MARS Project: Monterey and Related Sediments
Dolostone Matrix Porosity

AlShammary (2013)
Fractured Dolostone

Crystal Cove

Thick, brittle beds form fractures with greater length & large apertures
Oil in Fractured Dolomite

Naples Beach
Dolomite Breccia

Tightly cemented

Partially cemented

Long Beach MARS Project: Monterey and Related Sediments
Even cement is brecciated and permeable.
Large Isolated Dolomite Masses

At unconformities

Strata-bound from fault-contact

Tmls = massive dolomite

Western Santa Ynez Range

Dibblee & Ehrenspeck (2013)

Long Beach MARS Project: Monterey and Related Sediments
Large Isolated Dolomite Masses

Fault-related

Tmdo = massive dolomite

Tepusquet & Colson Canyons

Dibblee & Ehrenspeck (2013)
Fault-related Hydrothermal Dolomite

Jalama Beach

Cockscomb or saddle dolomite

Long Beach MARS Project: Monterey and Related Sediments
Fault-related Hydrothermal Dolomite

Oil inclusions show episodic hydrocarbon migration with fluids

Jalama Beach

Long Beach MARS Project: Monterey and Related Sediments
Fault-related Hydrothermal Dolomite

Botryoidal dolomite banding with late quartz precipitation during uplift
Hydrothermal Dolomite “bubbles”?
Jalama Beach

Long Beach MARS Project: Monterey and Related Sediments
Oil-filled Dolomite “bubbles”
Hydrothermal Dolomite Play

Ordovician-Devonian of the Michigan, Appalachian basins

Devonian-Mississippian of the Western Canada sedimentary basin

Characterized by: breccia, large vugs, saddle dolomite, sucrosic dolomite, +/- sulfides

Modified from Davies & Smith (2006)
Offshore Santa Maria Basin

Cartoon of Point Pedernales Field

Lower Monterey is very calcareous!
Platform Irene OCS-P0441-A1

Core #18: pred suc dolost w/numerous oil & std frac's, sme chert intertams; amb to brn vis cuts.

Cores #29 + 30: nearly all wht xln dolomite; intensely frac'd; com vugs + voids; abd oil; xlnf cuts.

Core #31: very large gaping voids up to 40cm x 10cm x 3cm, pervasive xlnf vugular porosity, com honeycomb, xtrmly abd free oil + stns w/xlnf cuts; abd drusy linings; tr breccia; tr dolic chert @ 4915.

- ✓ breccia
- ✓ large vugs
- ✓ saddle dolomite
- ✓ sucrosic dolomite
Platform Irene OCS-P0441-A1

1 well... 5 million barrels produced

a hydrothermal dolomite well??

Long Beach MARS Project: Monterey and Related Sediments
Summary

- Many forms of dolomite in the Monterey Formation
  - Disseminated, beds, nodules, veins, breccias, and massive bodies
- Oil and dolomites closely related
  - In dolomitization process
  - In fracture porosity
  - In matrix porosity

- Hydrothermal Dolomite Play established in Paleozoic limestones may apply to lower Monterey Formation
  - In fault breccias
  - In dolomitized aureoles
Research generously supported by the Affiliates of the MARS Project

http://geology.campus.ad.csulb.edu/people/behl/MARS/index.html

• Aera Energy
• Bayswater Exploration & Production
• BreitBurn Energy Partners
• ExxonMobil
• Freeport-McMoRan Oil & Gas
• Occidental Petroleum
• Signal Hill Petroleum
• Venoco, Inc.

Thank you!

Long Beach MARS Project: Monterey and Related Sediments