Oil and Dolomite in the Monterey Formation of California*

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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 permeabilty 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

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Davies, G.R., and L.B. Smith, 2006, Structurally controlled hydrothermal dolomite reservoir facies; an overview (in Structurally controlled hydrothermal alteration of carbonate reservoirs): AAPG Bulletin, v. 90/11, p. 1641-1690.

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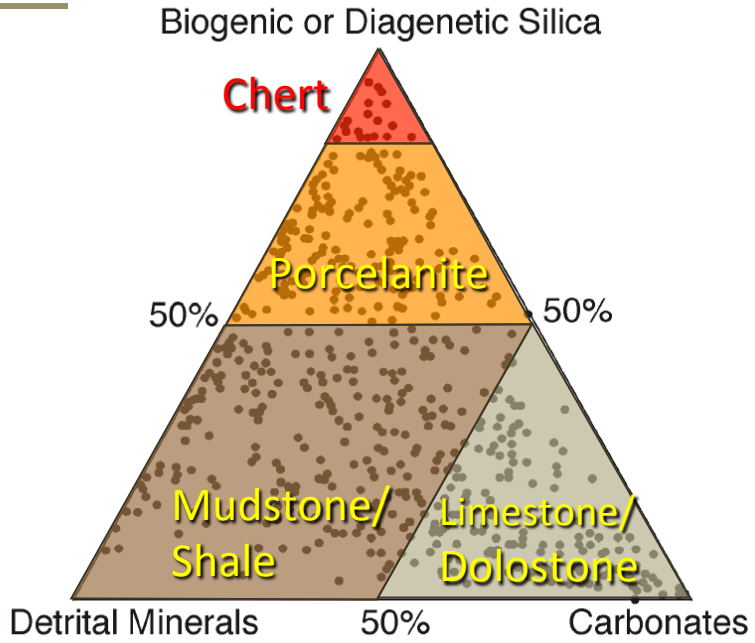
Synopsis

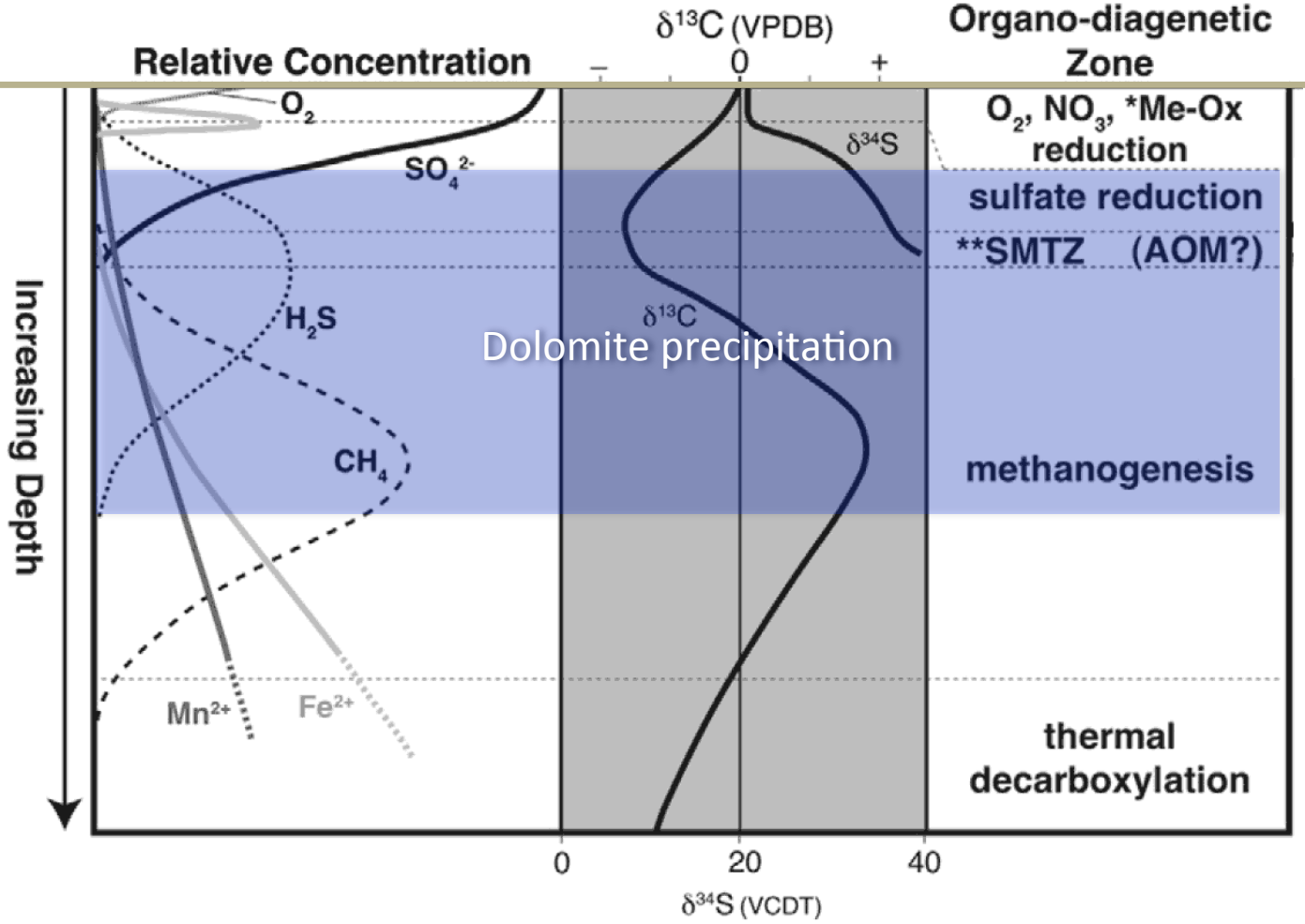
- Dolomite origin
- Dolomite occurrence
- Dolomite and oil
  - Nucleation
  - Fracture and matrix porosity
- Faults, fluid flow & breccias
- A Monterey Hydrothermal Dolomite Play?

Monterey Sedimentary Components

- Detrital
  - Clay
  - Silt
  - Sand
- Biogenous
  - Silica (opal-A)
  - Calcite
  - Kerogen
- Diagenetic / Authigenic
  - Opal-CT / Quartz
  - Phosphate
  - **Dolomite**

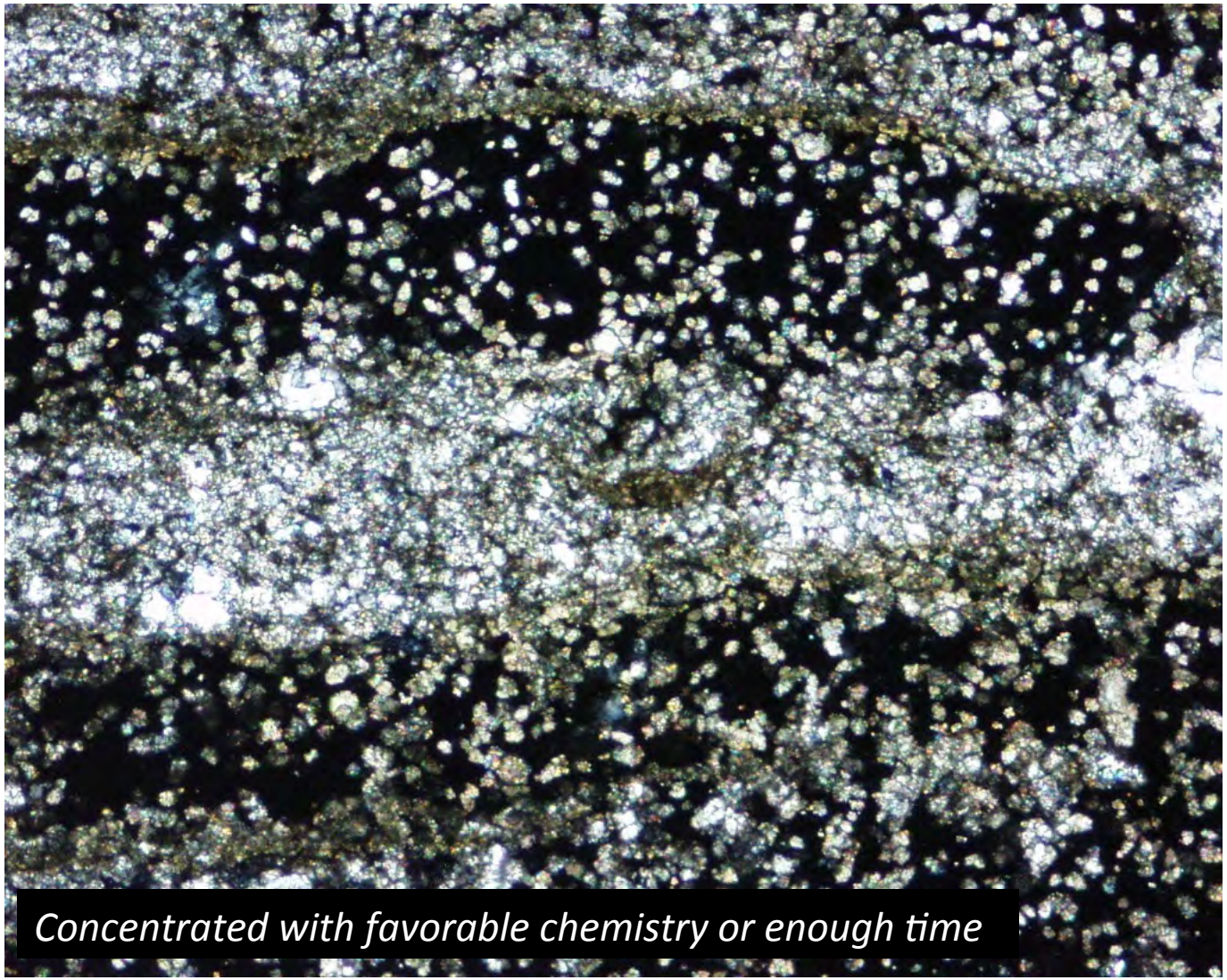


Organic Matter Diagenesis and Dolomite



Loyd et al. (2012), after Claypool & Kaplan (1974), Berner (1984)

Disseminated Dolomite



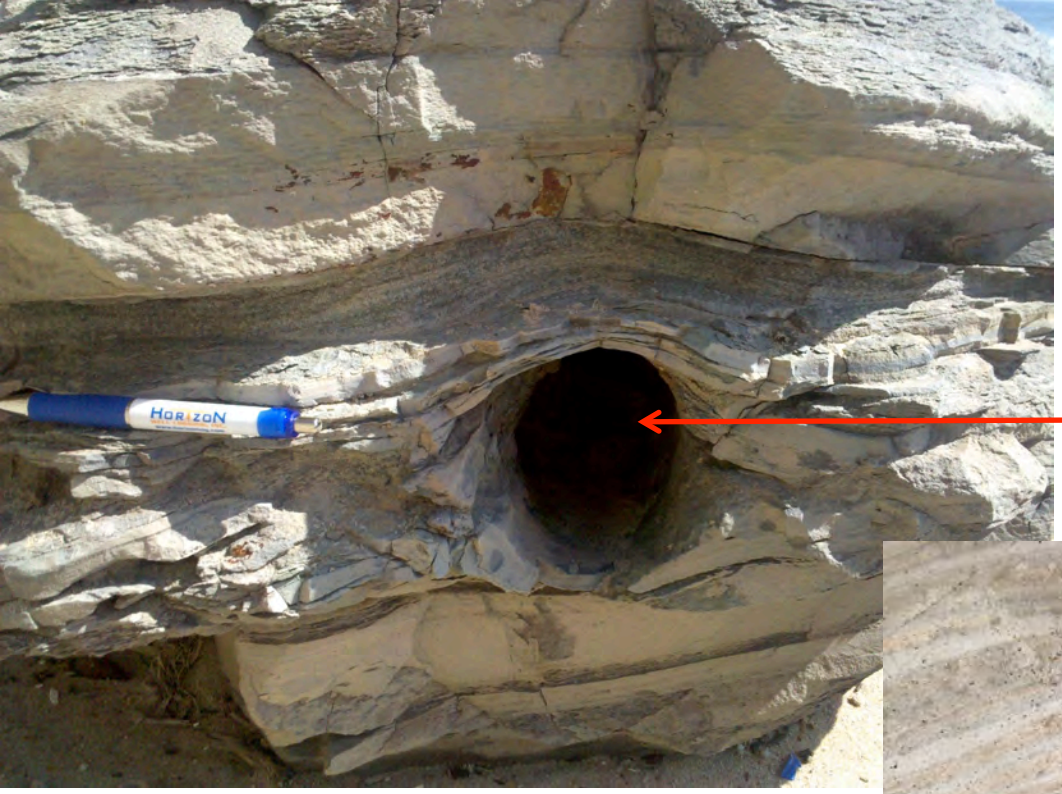
Dolostone Nodules

Gaviota Beach

Crystal Cove

Early formation shown by differential compaction

Formed around reducing nuclei



Driftwood mold

Whale bone

Reactant-limited nodular horizon

Gaviota Beach

Dolostone Beds

Continuous beds form with enough time and reactants

Dolostone Horizons & Parasequences ?

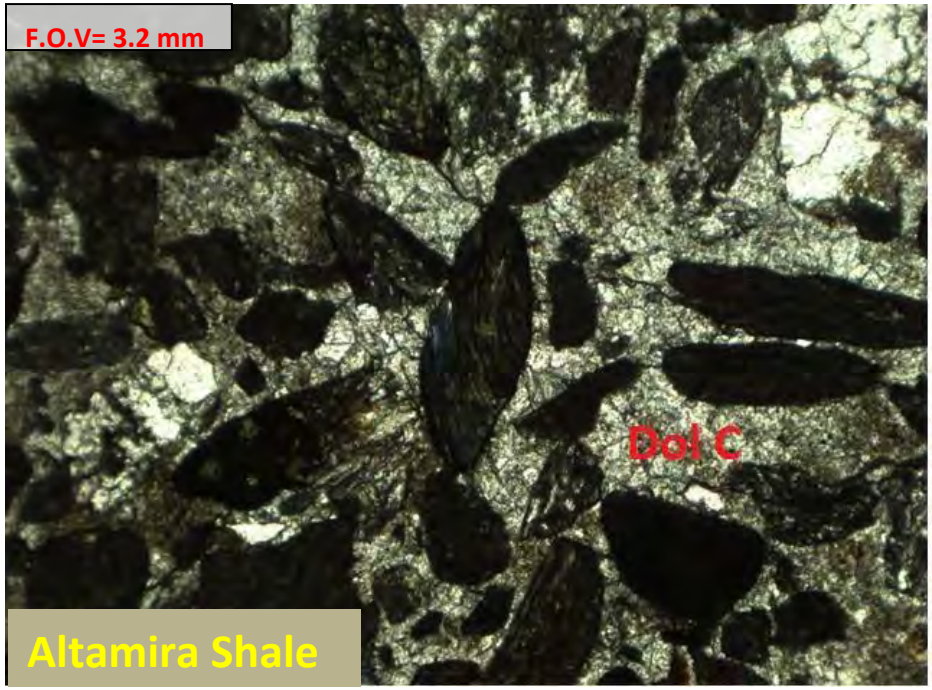
Rhythmic bedding suggests Milankovitch cycles

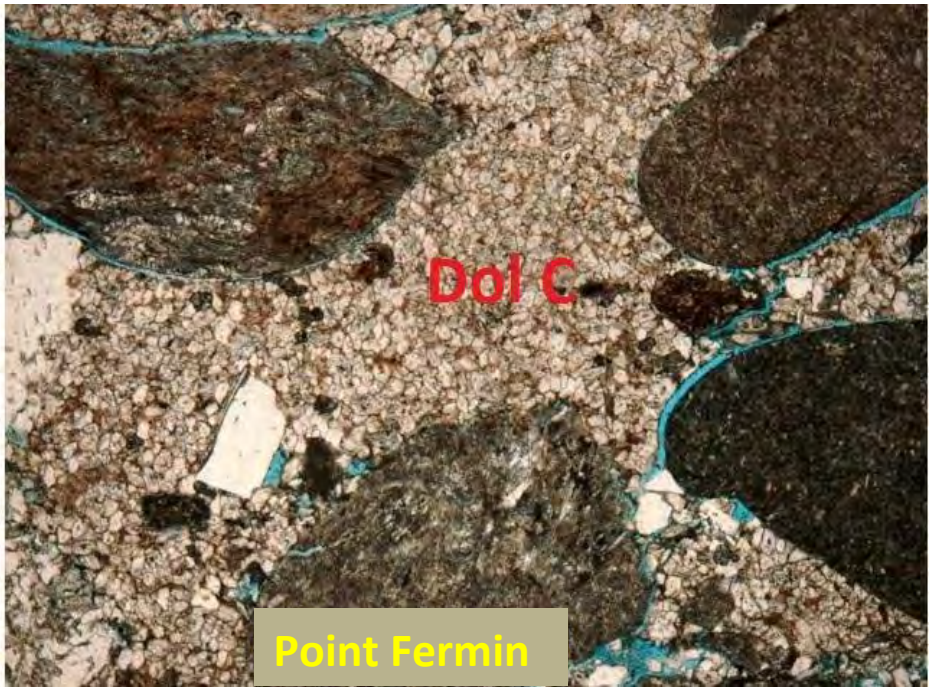
Dolomite or Dolomitic Hiatal Surfaces

Silty-sandy dolomite “yellow beds”

Point Fermin

Dolomite Cement in Sandstones





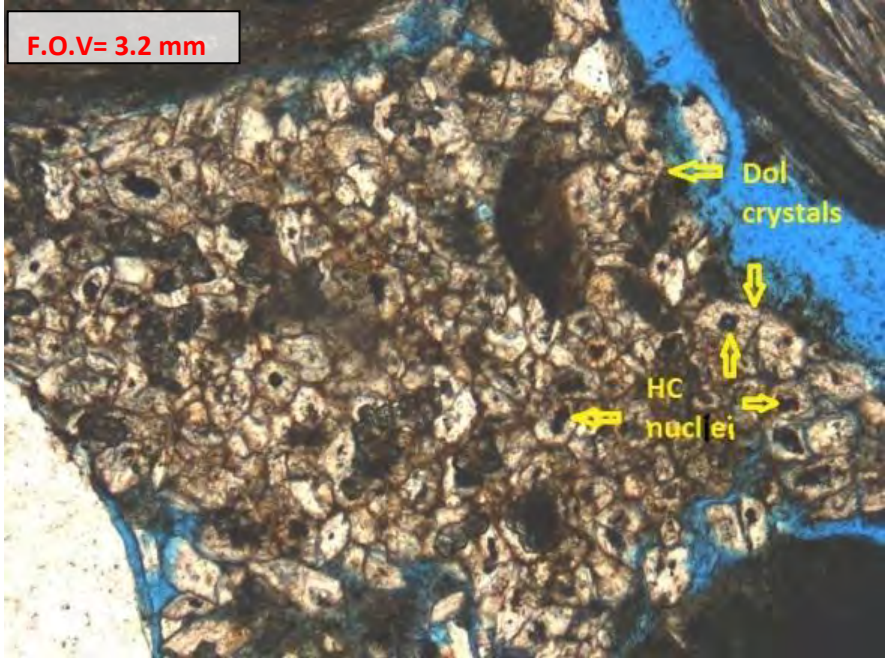
AlShammary (2013)

Floating grains indicate pre-compaction cementation

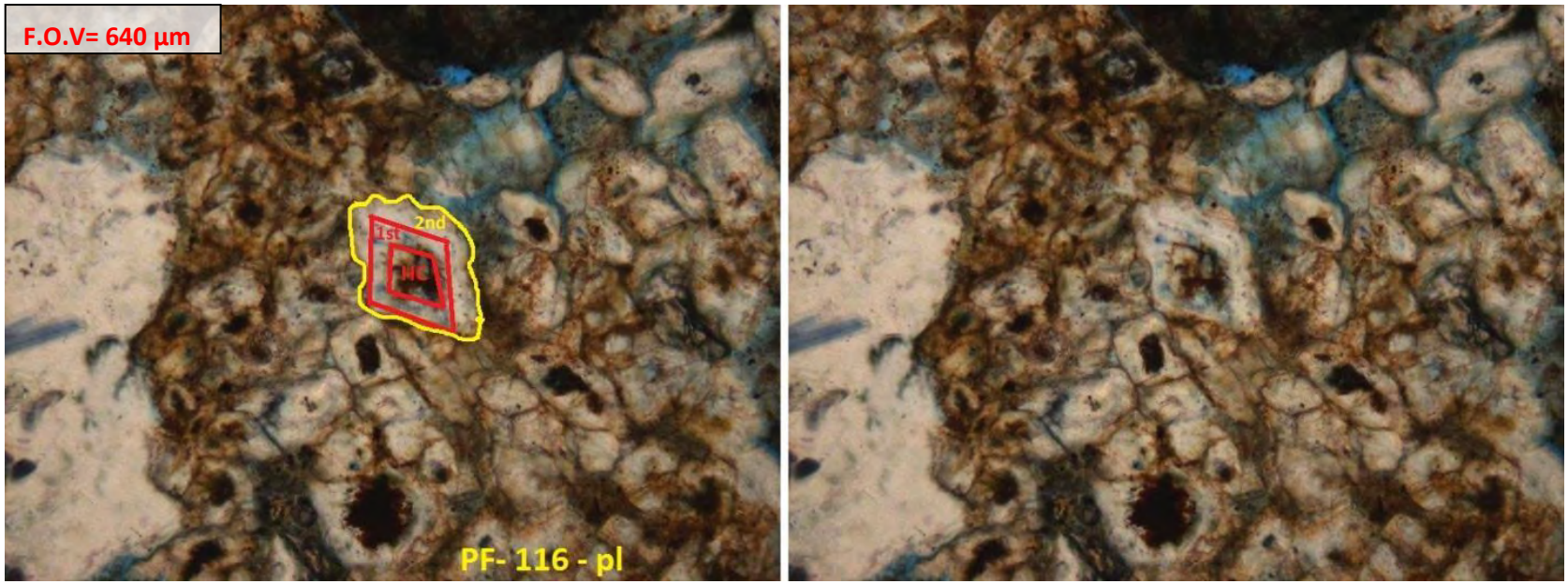
Dolomite (& Calcite) Veins

Opening-mode fractures with single or multiple cementation episodes

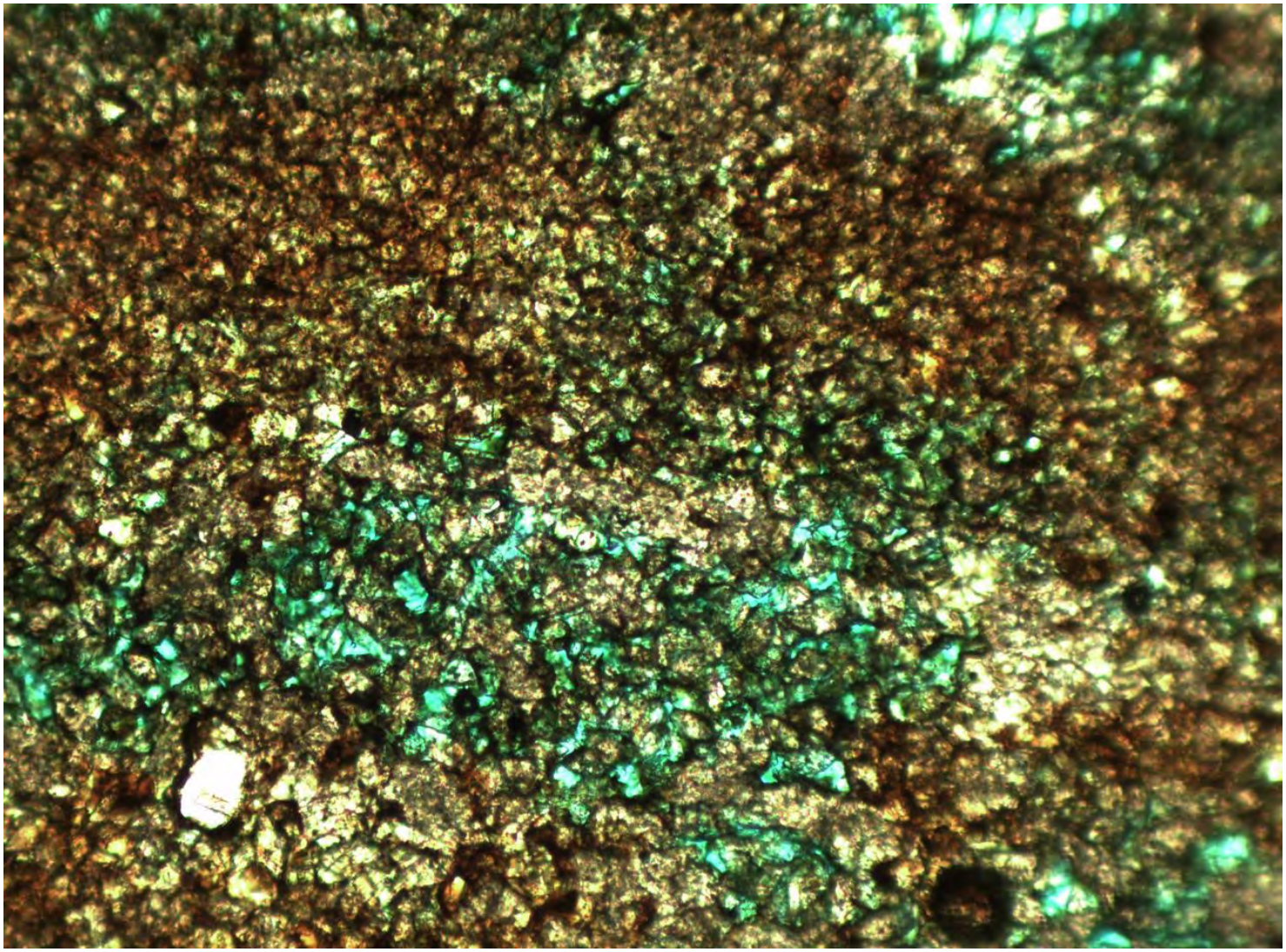
Relation with Oil:
Hydrocarbon-Nucleated Dolomite Rhombs



AlShammary (2013)

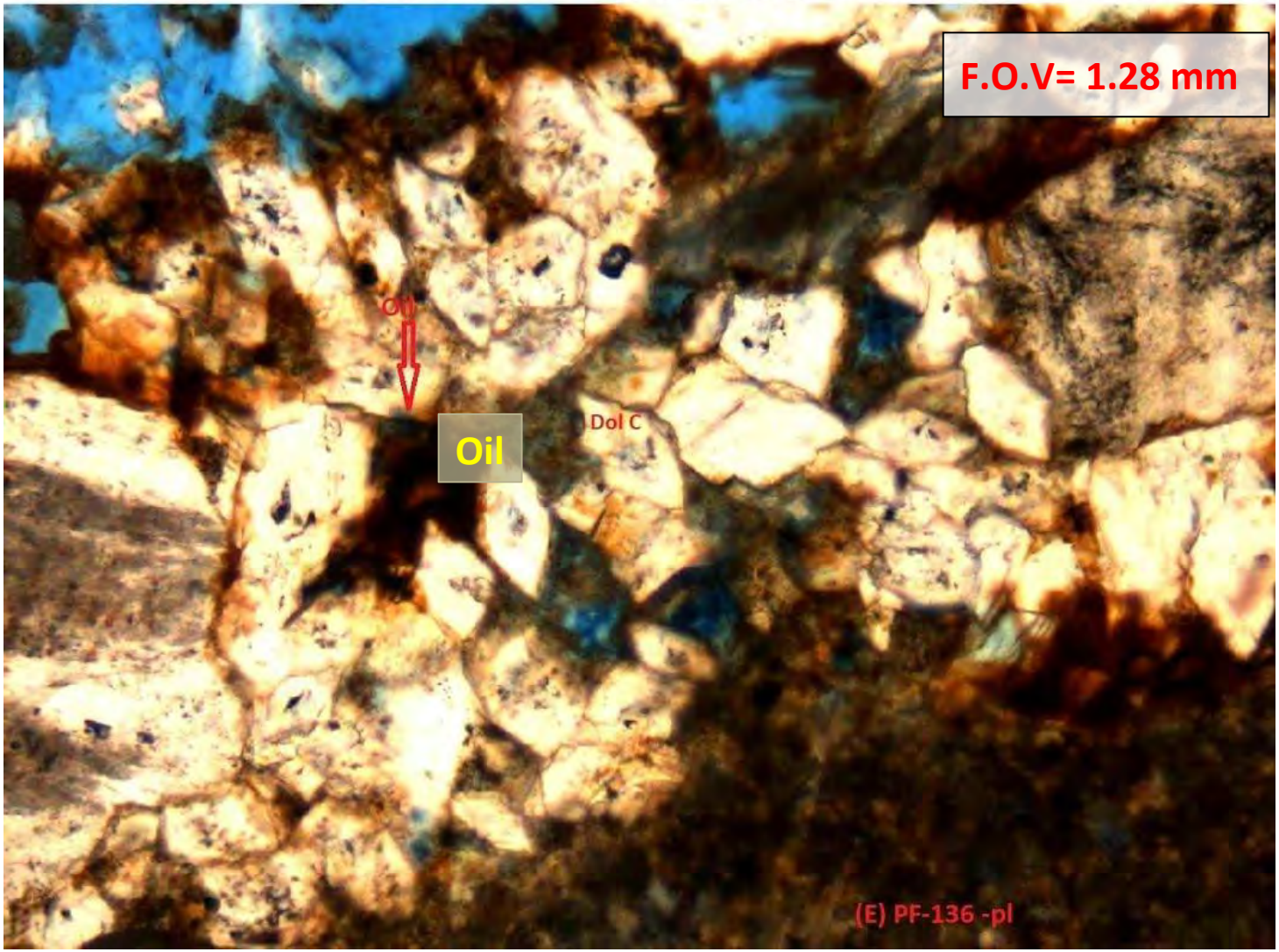


Dolostone Matrix Porosity



Inter-crystalline porosity and oil

Dolostone Matrix Porosity



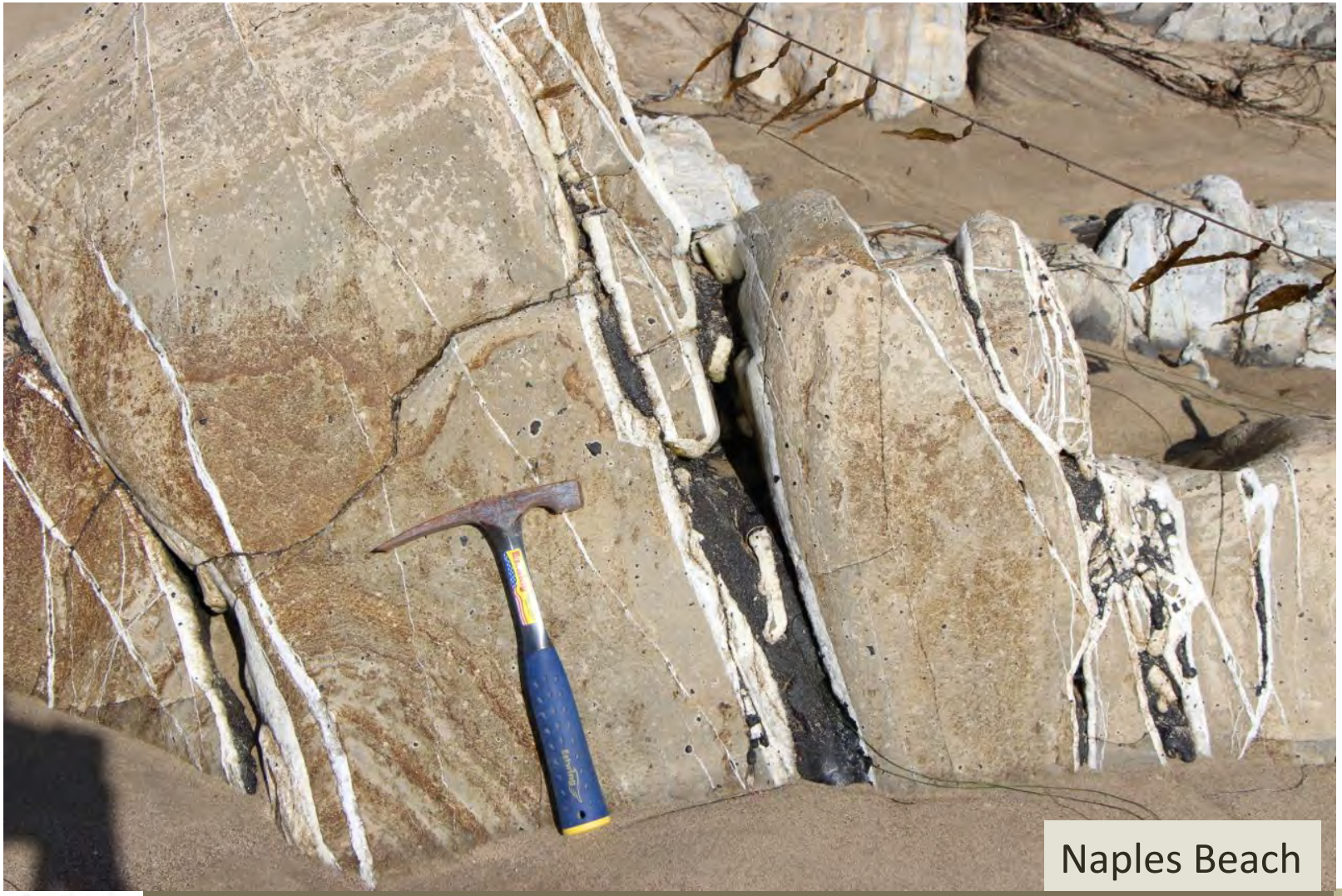
AlShammary (2013)

Fractured Dolostone

Crystal Cove

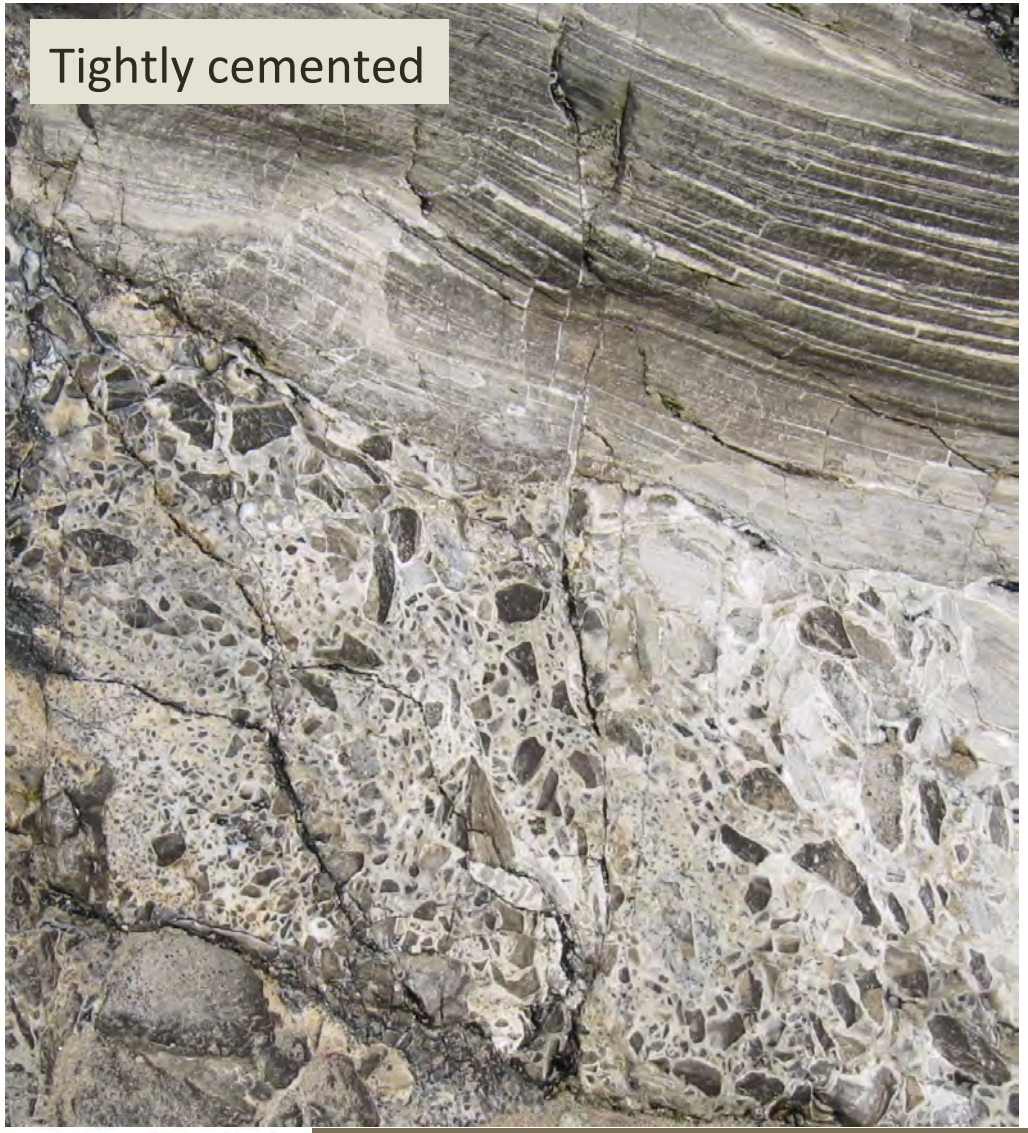
Thick, brittle beds form fractures with greater length & large apertures

Oil in Fractured Dolomite




Mussel Rock

Dolomite Breccia

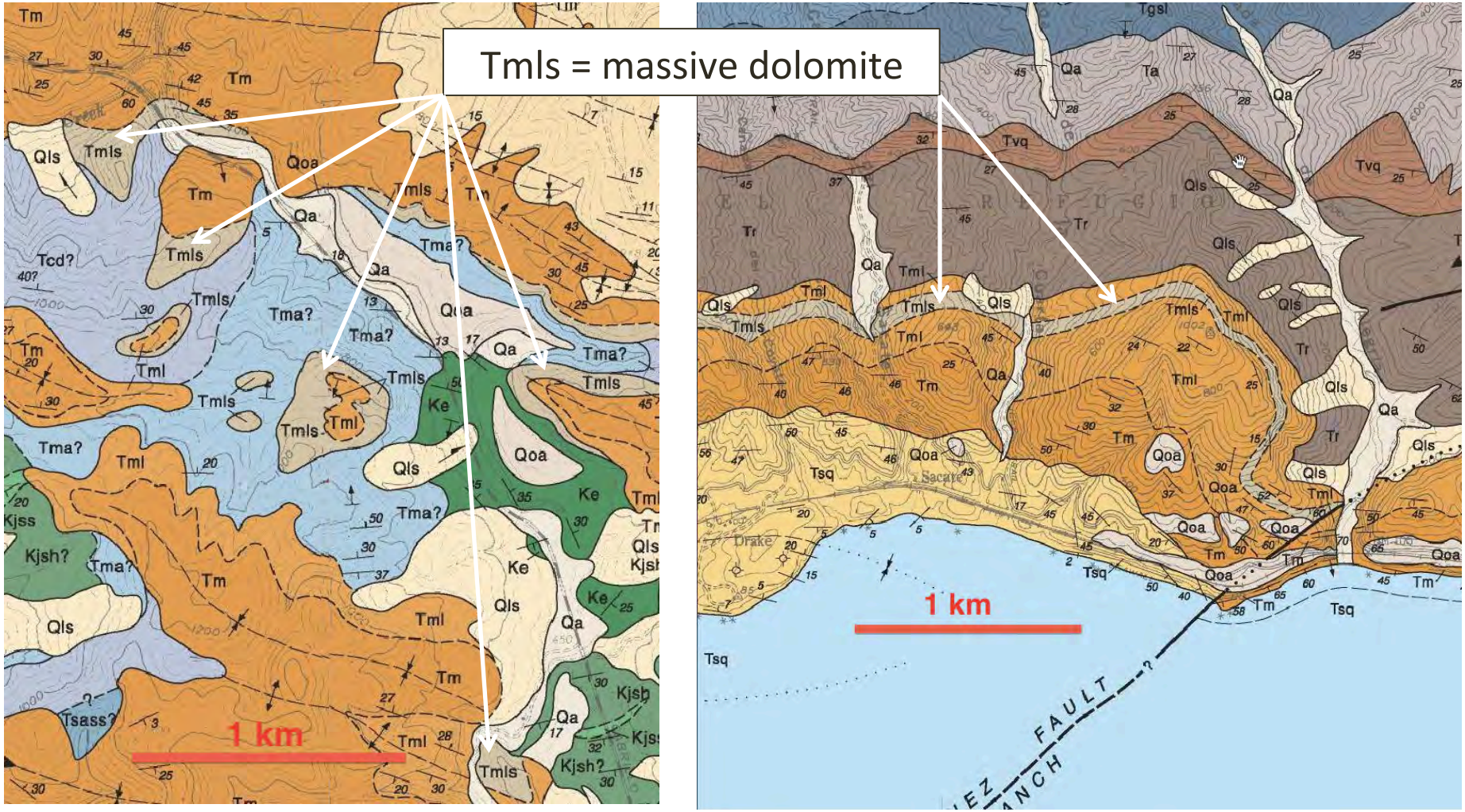


Even cement is brecciated and permeable

Large Isolated Dolomite Masses

At unconformities

Strata-bound from fault-contact

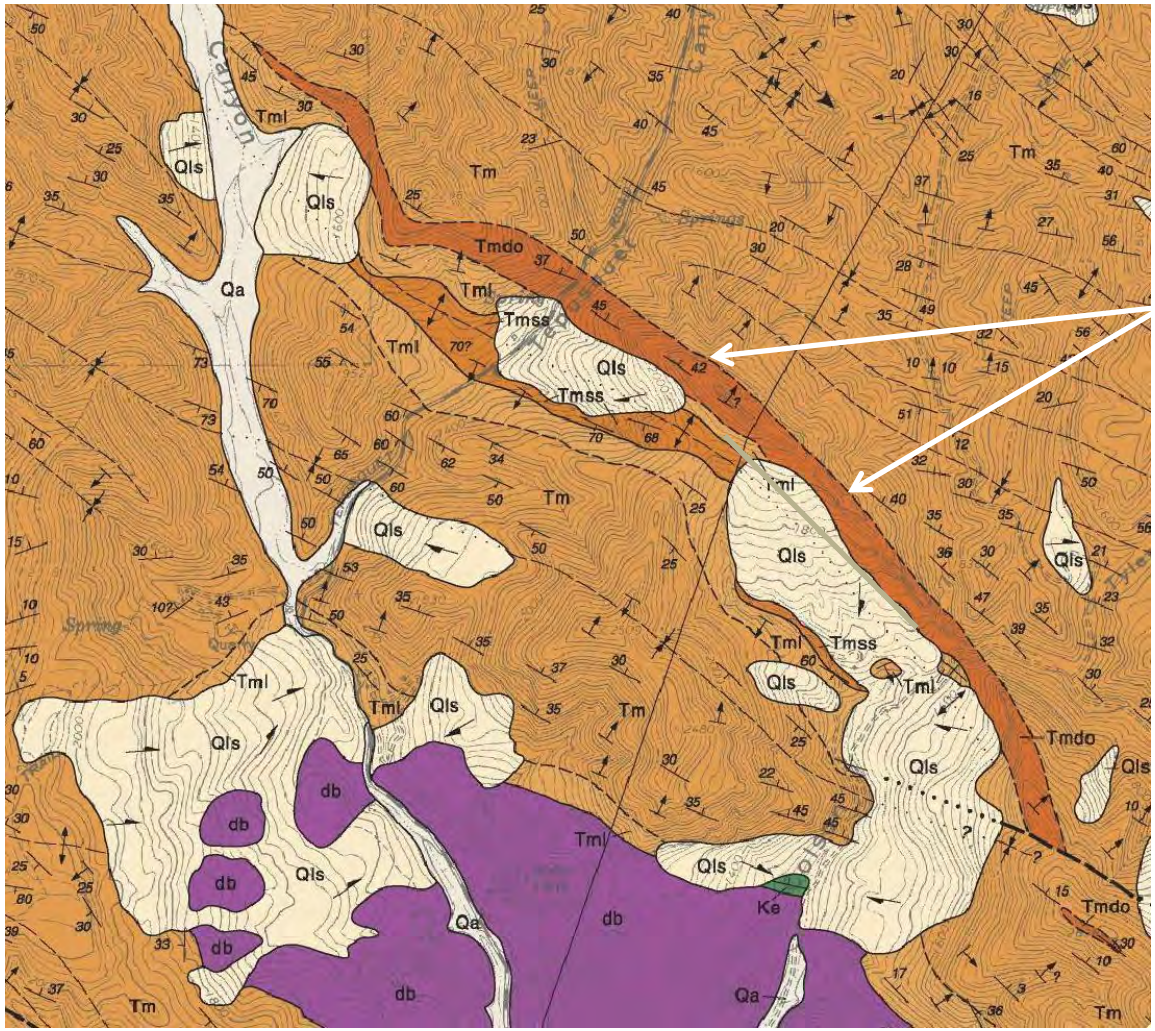


Western Santa Ynez Range

Dibblee & Ehrenspeck (2013)

Large Isolated Dolomite Masses

Fault-related



Tmdo = massive dolomite

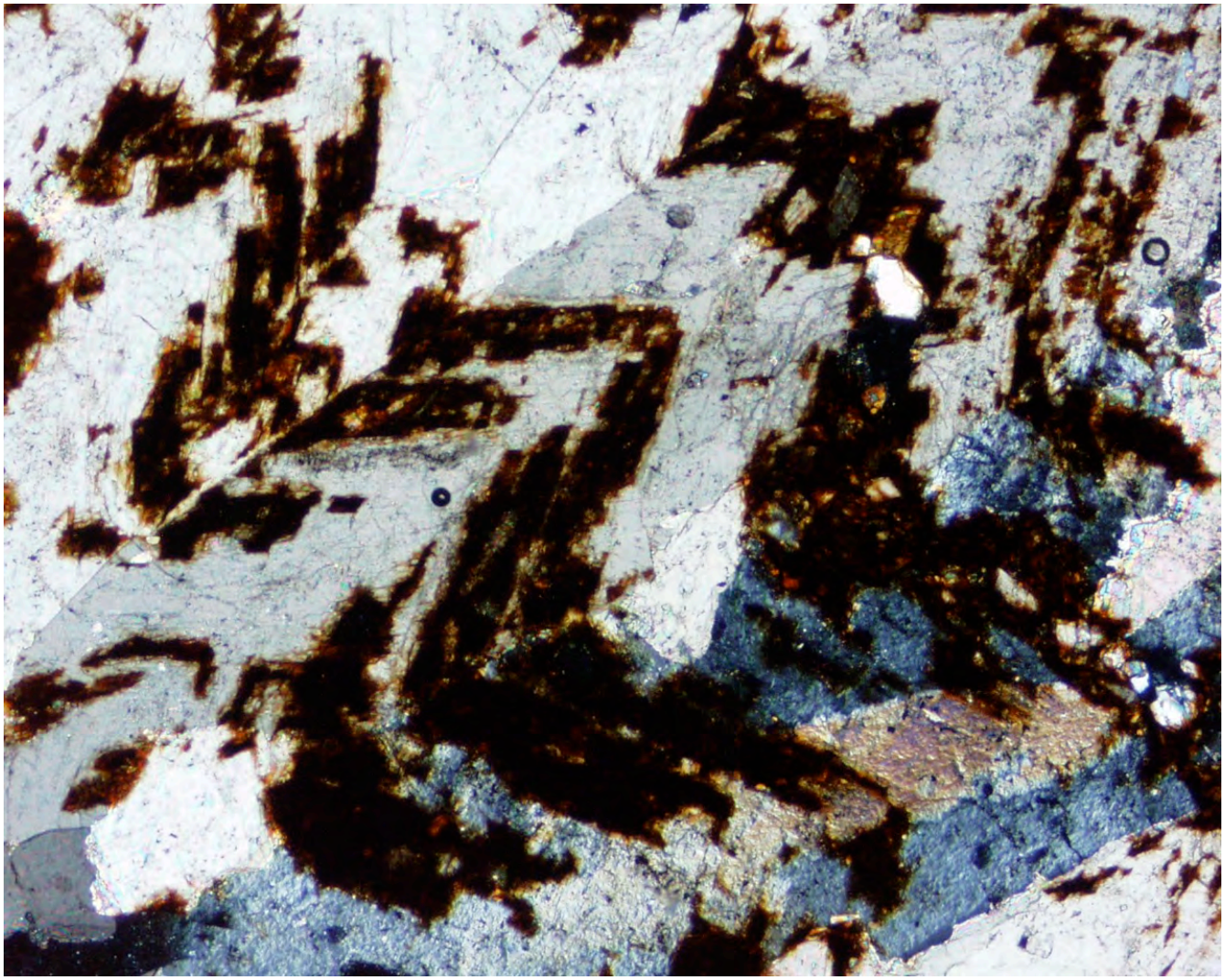
Tepusquet & Colson Canyons

1 km

Dibblee & Ehrenspeck (2013)

Fault-related Hydrothermal Dolomite

Fault-related Hydrothermal Dolomite



Jalama Beach

Oil inclusions show episodic hydrocarbon migration with fluids

Fault-related Hydrothermal Dolomite

Botryoidal dolomite banding with late quartz precipitation during uplift

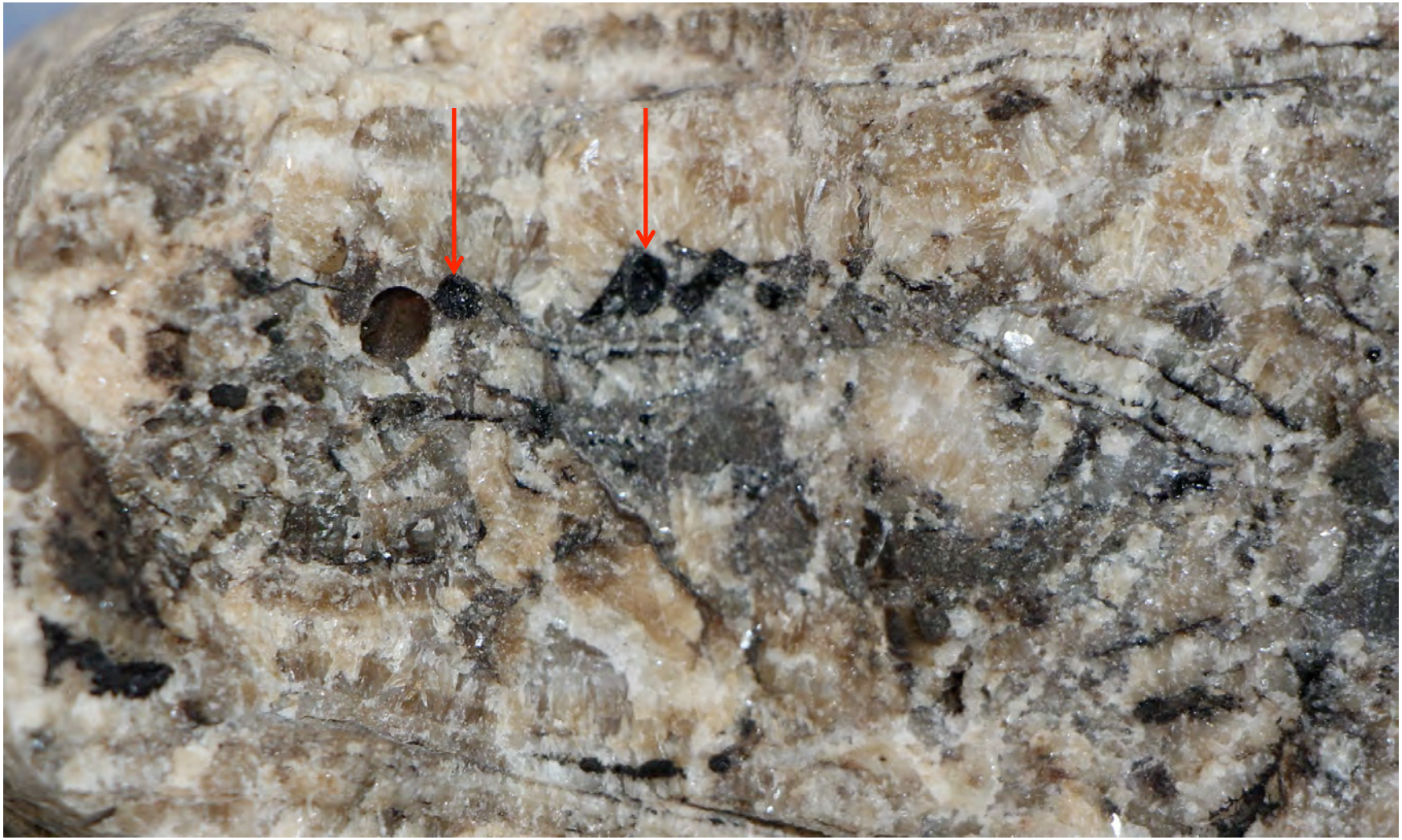
Hydrothermal Dolomite “bubbles”?

Jalama Beach

Geology CSULB

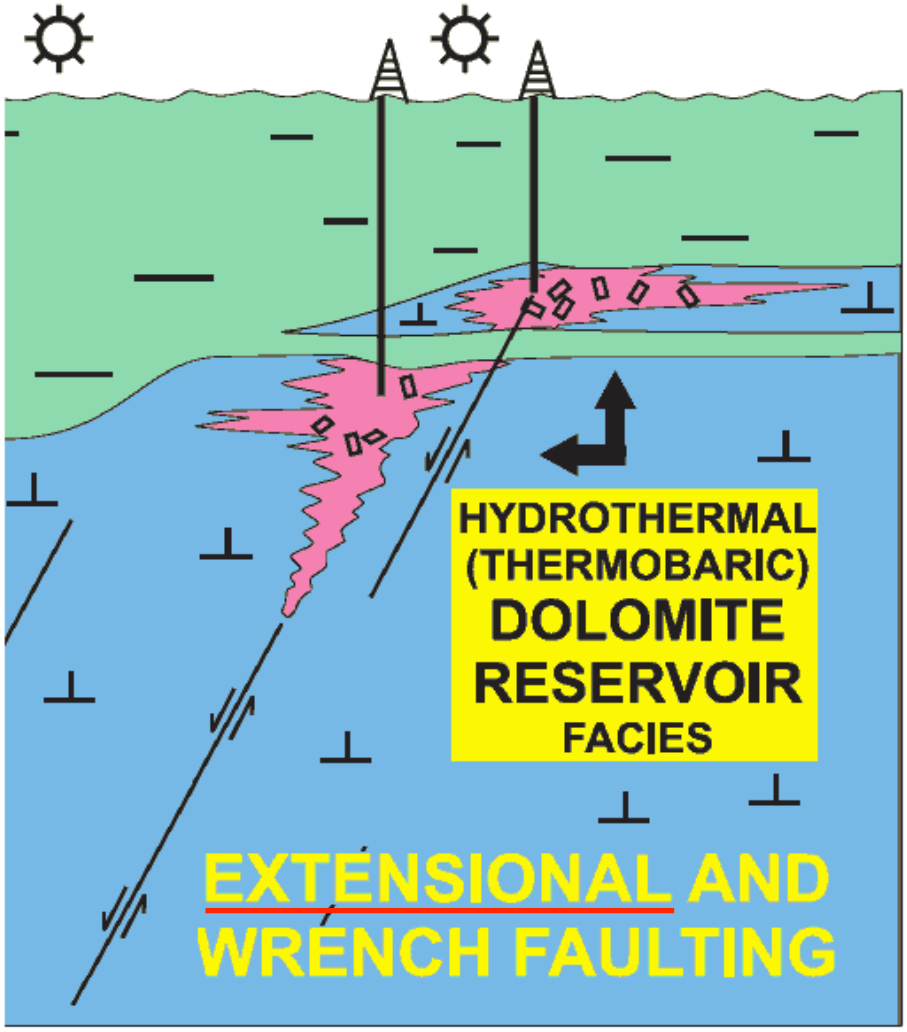
Long Beach MARS Project: Monterey and Related Sediments

Oil-filled Dolomite “bubbles”



Jalama Beach

Hydrothermal Dolomite Play



Ordovician-Devonian of the Michigan, Appalachian basins

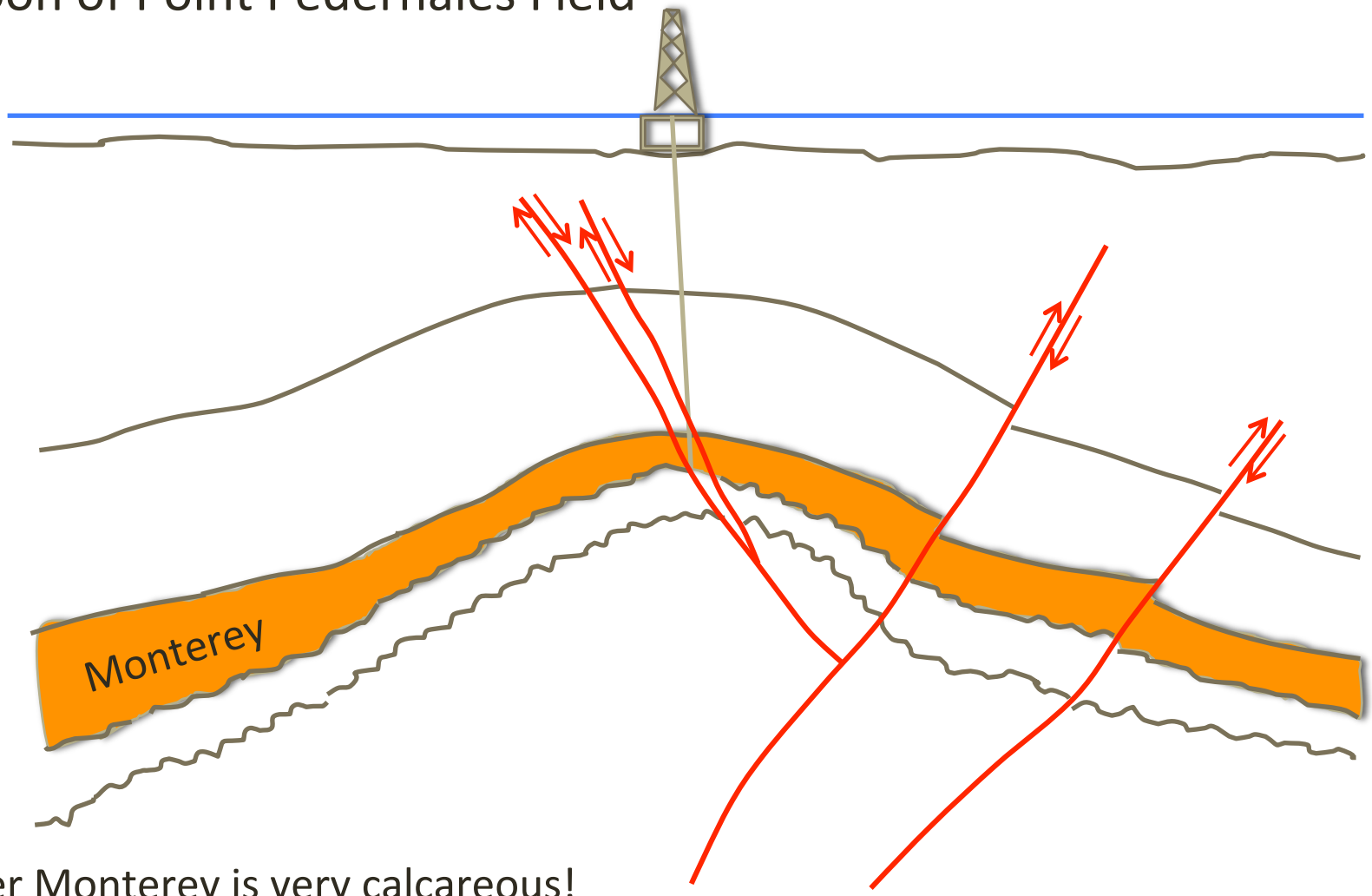
Devonian-Mississippian of the Western Canada sedimentary basin

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

Modified from Davies & Smith (2006)

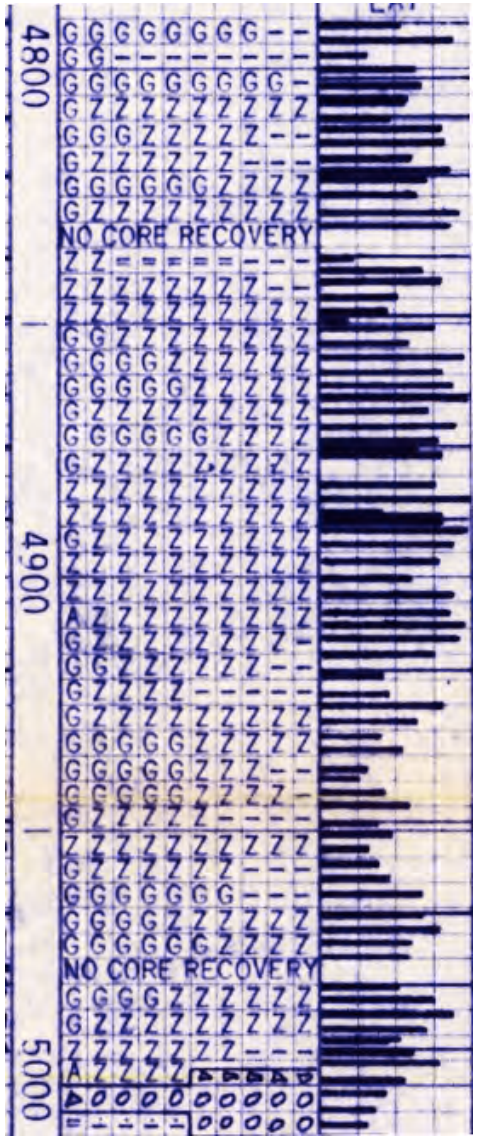
Offshore Santa Maria Basin

Cartoon of Point Pedernales Field



Lower Monterey is very calcareous!

Platform Irene OCS-P0441-A1



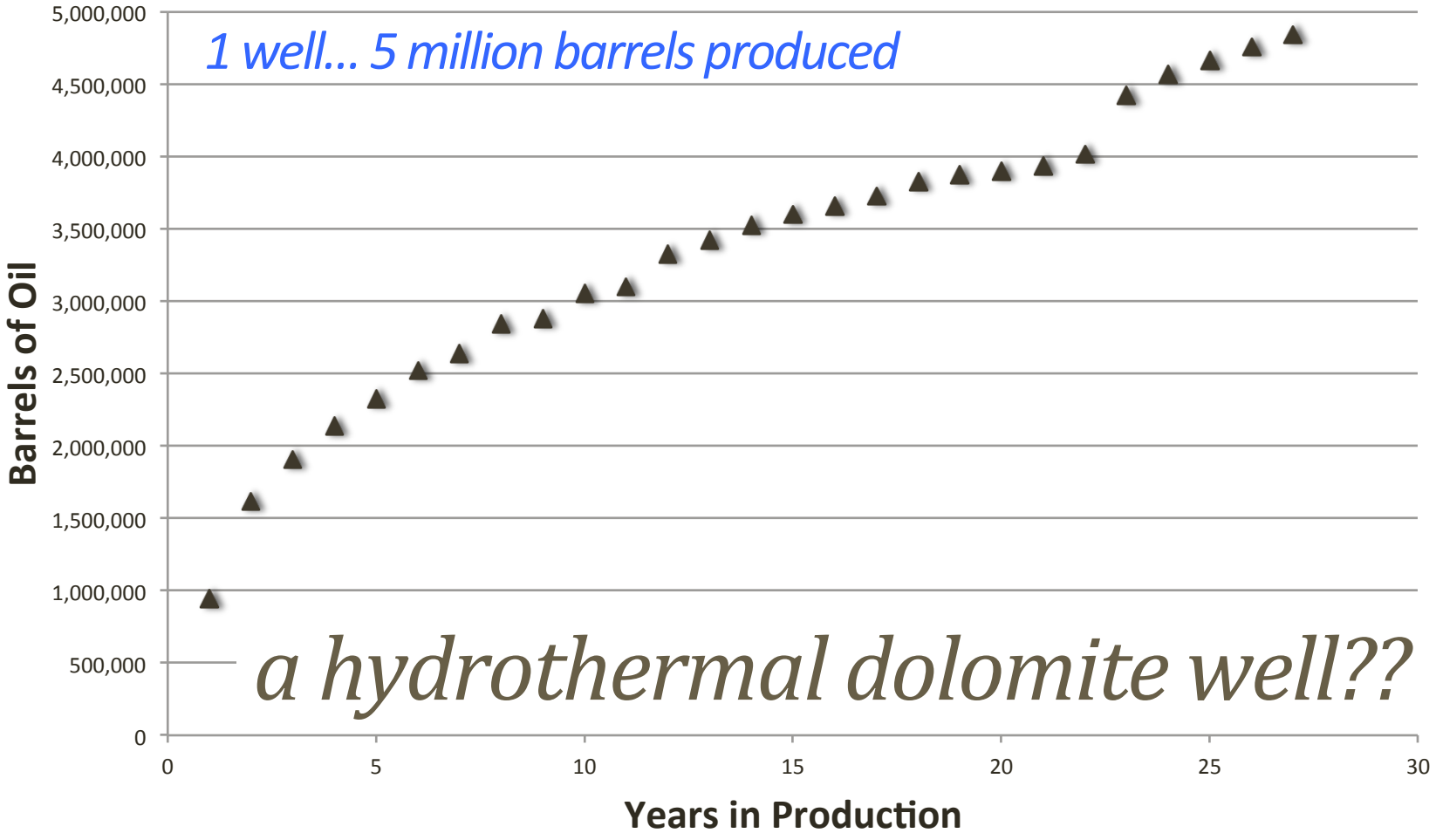
Core #18: pred suc dolost w/numerous oil stnd frac's, sme cht interlams; amb to brn vis cuts.

Cores #29 + 30: nearly all wht xln dolomite; intensely fracd; com vugs + voids; abd oil; xlnt cuts.

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

- ✓ *breccia*
- ✓ *large vugs*
- ✓ *saddle dolomite*
- ✓ *sucrosic dolomite*

Platform Irene OCS-P0441-A1



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
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- Occidental Petroleum
- Signal Hill Petroleum
- Venoco, Inc.

Thank you!