N364: Fracture Architecture, Sedimentology and Diagenesis of Organic-rich Mudstones of Ancient Upwelling Zones with Application to Naturally Fractured Reservoirs *(California, USA)*

Instructor(s): Richard Behl and Michael Gross

5 Days	Competence Level: Skilled
Field Course	
Classroom Elements	
MODERATE	Moderate Physical Demand

Summary

This course uses the Monterey Formation as a natural laboratory to understand the origin, distribution and physical properties of biogenic, organic-rich mudrocks as well as the relationship between mechanical stratigraphy and fracture distribution in layered rocks. Participants will learn to distinguish types of siliceous, calcareous/dolomitic, phosphatic and organic-rich rocks and understand relationships between composition, diagenesis, bedding and fracture architecture to enhance prediction of reservoir properties.

Learning Outcomes

Participants will learn to:

1. Judge factors that contribute to a successful unconventional resource play in thin-bedded, brittle, fine-grained rocks.
2. Distinguish cherts, porcelanites, siliceous shales, diatomites, dolomites, calcareous and phosphatic mudrocks.
3. Evaluate depositional setting and facies relationships of hemipelagic/pelagic sediments and their paleoceanographic controls.
4. Characterize key sedimentary structures of mudrocks from different depositional environments.
5. Formulate interpretations of biogenic mudrocks and predict changes in physical properties that occur with diagenesis.
6. Identify components of an active petroleum system, including source rocks, migration pathways, carrier beds and reservoir rocks..
7. Synthesize stratal stacking, sediment composition and diagenetic stage to predict mechanical stratigraphy and potential fracture networks.
8. Recognize the component elements of mechanical stratigraphy and evaluate their impact on fracture development.
9. Conduct surveys of fault and fracture networks in order to evaluate fracture scaling and fracture connectivity, and to design potential landing zones and trends for horizontal laterals in fractured reservoirs.
10. Design conceptual models of a fractured reservoir that incorporate aspects of lithology, mechanical stratigraphy, fracture attributes and structural position.

Duration and Training Method

This five-day course comprises field training (60%), classroom lectures (20%) and hand-sample or core workshops (20%).

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Physical Demand

The physical demands for this class are MODERATE according to the Nautilus field course grading system. The field area is at sea level in central and southern California, where summer temperatures range from cool, damp and foggy to warm and sunny. There will be walks of up to 3.2 km (2 miles), with some wading through shallow water on sandy or rocky beaches required to visit some outcrops. Much field time will be spent on uneven, possibly slippery surfaces of wave-cut beach platforms. The greatest ascent is about 30 m (100 ft) up steep, sandy slopes that will require the use of hands and a rope to aid participants in pulling themselves up the slope. The course will include some long drives of 1-2 hours on mostly paved roads. Transportation by mini bus.

Who Should Attend

The course is aimed at exploration, development and production geoscientists whose focus is on unconventional resources. However, engineers and asset managers who are engaged in production from shale, chert or other unconventional resources and/or conventional fractured reservoirs should also benefit from this course.

Prerequisites and Linking Courses

Participants should have a basic understanding of sedimentology and stratigraphy before attending this course. Prior training or experience in structural geology and/or rock mechanics would add to integrated learning. Nautilus courses that provide this background include N020 (Carbonate Depositional Systems: Reservoir Sedimentology and Diagenesis), N155 (Introduction to Clastic Depositional Systems: a Petroleum Perspective), N171 (Stratigraphic Interpretation of Siliciclastic Reservoirs – an Integrated Approach), N134 (Carbonate and Shale Faulting and Fracturing Field Seminar, Texas, USA) and N266 (Stress and Geomechanical Analyses, West Texas, USA).

Course Content

The course uses spectacular, classic outcrops of different facies of the Miocene Monterey Formation exposed along the coast in southern and central California to train participants in the sedimentology, depositional systems, and climatic and oceanographic control of facies in clastic-poor, biogenic fine-grained deposits. The great heterogeneity of the Monterey Formation permits investigation of siliceous, calcareous, phosphatic and carbonaceous mudrocks. Proximity to the San Andreas fault system has generated tectonic structures with pervasive brittle deformation in the form of faults and fractures.

Participants will learn to characterize lithology, stratal architecture, depositional setting, diagenetic state, mechanical stratigraphy and fracture networks. Field investigation and exercises will be complemented by classroom lectures, sample examination and core description.

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These concepts will be applied to the evaluation of naturally and artificially fractured reservoirs and hydrocarbon production.

Itinerary (subject to change)

Day 0:

Arrive Santa Barbara Airport. Introductory lecture in evening. Overnight in Santa Barbara.

Day 1:

Half day field excursion to examine the Monterey in both relatively undeformed (Santa Barbara Point) and highly deformed states (Carpenteria State Beach), the petroleum system and hydrocarbon migration and seeps along a fault zone and adjacent fractured "damage zone". Half day classroom lecture/workshop. Overnight in Santa Barbara.

Day 2:

Half day field trip to examine multiple lithofacies of organic-rich shale and other biogenic sedimentary rocks at Haskell's Beach and Gaviota State Beach and cross-cutting, oil-charged slope gully sandstone/conglomerate deposit. Regional structure and fracture sets discussed. Half day classroom lecture/workshop. Overnight in Pismo Beach.

Day 3:

Full field day examining interbedded organic-rich carbonaceous mudstone and fractured chert reservoir rocks and unconformity-related sandstone reservoir at Shell Beach. Examine cyclic alternation of thin-bedded siliceous shale and porcelanite facies at Montana de Oro State Park. Investigate primary stratigraphic control of fracture networks and mechanical stratigraphy. Overnight in Pismo Beach.

Day 4:

Examine diatomaceous and diagenetic-silica-stage siliceous rocks at Sweeney Road. Examine detachment folding and faulting at multiple scales in context of regional structure. Half day classroom lecture/workshop. Overnight in Santa Barbara.

Day 5:

Lecture/exercises followed by field study of mechanical stratigraphy and fracture networks at Arroyo

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Field Course

Classroom Elements

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Burro Beach. Investigate different modes of brittle failure in adjacent beds of mudstone and porcelanite, and its relationship to fold development. Examine evidence for episodic water and oil expulsion from deep basin along fault zones and fracture networks. Overnight in Santa Barbara.

Day 6:

Depart Santa Barbara Airport.