N091: Carbonate Reservoir Architecture and Applied Carbonate Sequence Stratigraphy *(West Texas and SE New Mexico, USA)*

Instructor(s): Art Saller and Steve Bachtel

Format and Duration

Field - 6 Days
High Physical Demand

Summary

This field course is aimed at geoscientists and engineers (especially in teams) exploring for and developing carbonate reservoirs and has particular relevance to those working in the Permian Basin. This trip visits world-class carbonate outcrops in southeast New Mexico and west Texas and relates them to subsurface examples from the Permian Basin as well as other basins around the world. After taking this course, participants will have an improved knowledge of carbonate stratigraphy and the distribution of carbonate facies which control variations of porosity, permeability and production in the subsurface reservoirs. Understanding the vertical and lateral changes in porosity and permeability in the subsurface is critical for cost-effective development of carbonate reservoirs during primary production, waterfloods and tertiary recovery. All major types of carbonate systems are viewed during this trip while examining thick and laterally extensice (seismic-scale) outcrops and interpreting oil field examples.

Learning Outcomes

Particpants will learn to:

1. To interpret carbonate shelf (ramp) to basin systems to predict the distribution of reservoir and non-reservoir facies in well and seismic data.
2. The relationship of depositional environments to depositional textures and see how they control the distribution of subsurface porosity, permeability and hydrocarbon production.
3. Where subaerial exposure, freshwater diagenesis, marine diagenesis, and early near-surface dolomitization occur and how they affect subsurface porosity, permeability and the overall geometry of reservoir carbonates.
4. To use sequence stratigraphic concepts to predict the distribution of shallow water carbonate and basinal facies in well logs and seismic data and see how those affect hydrocarbon production.
5. How variations in climate and amplitude of sea-level fluctuations cause predictable variations in reservoir facies and early diagenesis that controls porosity.
6. To interpret mixed carbonate and siliciclastic systems using sequence stratigraphic analyses of outcrops, well logs, and seismic data and see how they are a fundamental control of basinal facies.

Training Method

This is a six-day field course in west Texas and SE New Mexico, USA. There is a brief classroom introduction to carbonate grains and systems and to the field area, but 90% of the course is conducted in the field, with long days (typically 10+ hours).

Physical Demand

The physical demands for this class are HIGH according to the Nautilus Training Alliance field course grading system. Fieldwork is in western Texas and southeastern New Mexico where the weather is arid and usually hot, although cold and wet weather is possible in the spring and fall. The course requires

moderate to long walks, frequently over very steep and uneven ground. The walks most days are up to 3.2 km (2 miles) with the longest walk being approximately 13.4 km (8.4 miles) with an ascent of 610 m (2000 ft). In order to gain the full benefit of this class, participants should be fit enough to complete these hikes under these conditions.

Transport on the course will be by SUVs. Most of the driving is on black-top roads, with some driving on graded dirt roads. Day 3 includes a 4 mile section of off-road track driving on a rough, rocky trail.

Who Should Attend

This course is designed for experienced geoscience professionals who need to expand their knowledge of carbonate reservoir systems and has a particular relevance to those working in the Permian basin.

Prerequisites and Linking Courses

Participants should have a basic familiarity with carbonates, as presented in N020 (Carbonate Depositional Systems: Reservoir Sedimentology and Diagenesis).

Related field courses include:

- N059 (Applied Carbonate Geology: Carbonate Facies and Reservoirs (Mallorca, Spain); and
- N134 (Carbonate Faulting and Fracturing Seminar (Central and West Texas).

Experienced carbonate workers should consider:

- N073 (Workshop in Geological Seismic Interpretation: Carbonate Systems - classroom);
- N336 (Carbonate Reservoir Description Based on Core and Well Data - (Nottinghamshire, UK); and
- N391 (Advanced Concepts in Carbonate Stratigraphy - West Texas and SE New Mexico, USA).

Course Content

The mountains of west Texas and southeast New Mexico contain world-class exposures of carbonate shelf to basin systems with little or no structural deformation. Those exposures are used in this course to relate carbonate depositional facies to seismic-scale geometries and sequence stratigraphy.

The class will visit seismic-scale outcrops, characterize their large-scale geometries, document their facies, and show how similar systems appear in the subsurface. We will also illustrate similar carbonate reservoir facies in core and logs. In addition, participants will view the results of subaerial exposure, marine diagenesis and early near-surface dolomitization and discuss how these processes can affect ultimate reservoir porosity and permeability in subsurface carbonates.

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Itinerary

Day 0:

Participants travel to El Paso, Texas.

Day 1:

Start in El Paso.

- AM: Orientation and review of carbonate facies, sequence stratigraphy, and diagenesis.
- PM: Drive to Cloudcroft, New Mexico and examine Mississippian carbonate pinnacle "reefs" (bryozoa boundstones flanked by crinoidal grainstones).

Day 2:

Pennsylvanian reefal mounds and carbonate-clastic interactions: Classic shelf-margin to shelf-interior profile at Dry Canyon in the Sacramento Mountains of southeast New Mexico.

- Stop 1: Cyclic carbonates and clastics. A roadcut allows excellent exposure of interbedded shelf-interior limestones, shales, and sandstones that are correlative to shelf-margin carbonates. Comparison to subsurface. Similar rocks are prolific producers of oil 200-400 miles to the east in the Midland Basin. Participants will relate subsurface cores, wireline logs and seismic to the outcrops that will be seen later in the day.
- Stop 2: Cclastic lowstand-dominated environment basinward of the shelf margin and traverse onto carbonate reefs on the shelf margin. Variations in facies are related to high-amplitude sea-level fluctuations across the basin-shelf transect.
- Conclude day by driving to Carlsbad, New Mexico.

Day 3:

West Face of the Guadalupe Mountains. Spectacular exposure of a Permian carbonate shelf margin and onlapping deepwater sands of the Brushy Canyon Formation.

- Interpret seismic data of this shelf margin
- Overview of the >1000 m high and 10 km long outcrop. Participants will sketch outcrop geometries and relate to seismic data
- Walk up Shumard Canyon trail and observe
    - slumped deep water carbonate mudstones,
    - grading up to shelf margin wackestones, and packstones,
    - classic unconformity with lowstand sands onlapping the carbonate slope

Day 4:

San Andres Permian Reservoir System on Algerita Escarpment and Last Chance Canyon.

- Walk down and up Algerita Escarpment at Lawyer Canyon noting vertical and lateral variations in reservoir properties of the Permian dolomite reservoir.
- This is a well-documented, large shallowing-upward ramp system composed of numerous meter-scale cycles in a ramp interior setting.
- Relate to subsurface and production data.
- Last Chance Canyon: Overview of the San Andres prograding shelf margin. The walls of this canyon contain a "textbook" sequence boundary with toplap, erosion truncation and onlap in both outcrop and equivalent seismic data. Outcrops also illustrate geometry of inclined flow units.

Day 5:

McKittrick Canyon- Permian Reef Trail.

- Classic facies transect with a consistent upward-shallowing trend. Facies include:
  - basin floor mudstone,
  - slope to fore-reef with a mixture of conglomerates, mud, wacke, and packstones
  - reefal boundstones of the Capitan Formation
  - shelf-top shallowing-upward cycles of subtidal wackestone to shoal grainstone to laminated tidal flat rocks
- This hike allows viewing of facies on beautifully etched surfaces along the trail, and viewing the larger scale geometries on adjacent canyon walls. Perhaps the best one-day carbonates hike in the world.
- Participants will conclude by interpretation of wireline logs and seismic from the Capitan system in the subsurface.

Day 6:

- Outcrops of restricted lagoonal environments equivalent to the Capitan Reef including cyclic unfossiliferous dolomites, and evaporites
- Platform margin wackestone to grainstone to tidal flat cycles in the Capitan backreef
- Karstification associated with Carlsbad Caverns
- Roadcut of the basin-filling deepwater evaporites of the Upper Permian Castile Formation
- Roadcut of debris flow with shelfal carbonate clasts in basinal sandstone
- Roadcut of channel and levee deposits of Brushy Canyon sandstones.

Day 7:

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Participants depart El Paso, Texas.