Outcrop Analogs in Utah: Templates for Reservoir Characterization and Modeling

Thomas C. Chidsey, Jr., Craig D. Morgan, and Kevin McClure
Utah Geological Survey

Abstract

Utah is unique in that representative outcrop analogs are present for the thrust belt, Uinta Basin, and Paradox Basin for each major oil play. Production-scale outcrop analogs serve as “templates,” often in 3D, of reservoir-facies characteristics and boundaries that determine the overall reservoir rock heterogeneity, and can be applied to reservoirs worldwide. Examples include the Mississippian Madison Limestone, Pennsylvanian Paradox Formation, Jurassic Navajo Sandstone and Twin Creek Limestone, and Tertiary Green River Formation for carbonate shallow shelf, bioclastic, eolian, fractured, and fluvial-deltaic lacustrine reservoirs, respectively.

The shallow-marine shelf, Mississippian Leadville Limestone is a major oil and gas reservoir in the Paradox Basin of Utah and Colorado. Hydrocarbons are produced from basement-involved, northwest-trending structural traps with closure on both anticlines and faults. Excellent outcrops of Leadville-equivalent rocks are found along the south flank of the Uinta Mountains, Utah. For example, like the Leadville, the Mississippian Madison Limestone contains zones of solution breccia, fractures, and facies variations. Hydrocarbons are stratigraphically trapped in heterogeneic bioclasts (mounds) of the Pennsylvanian Paradox Formation, which includes Utah’s largest oil field, in the Paradox Basin. Exposures of the Paradox Formation along the San Juan River of southeastern Utah display mounds and intermound troughs to off-mound detrital wedges or fans bounded by flooding surfaces. These facies also show flow conduits for secondary/tertiary recovery projects, and various horizontal-drilling targets.

In the Utah-Wyoming thrust belt, hydrocarbons are produced from traps formed by discrete subsidiary closures on ramp anticlines along major thrust faults. The most prolific oil reservoir is the eolian Jurassic Nugget Sandstone. Outcrop analogs in the stratigraphically equivalent Navajo Sandstone of southern Utah display large-scale dunes of interdistributary and interdistributary lithofacies such as ripples and plays. These outcrops illustrate how eolian facies might effect petroleum movement and production rates. The low-porosity Jurassic Twin Creek Limestone produces in the thrust belt where extensive fractures are sealed by overlying argillaceous and clastic beds, and non-fractured units within the Twin Creek. The best outcrop analogs for Twin Creek reservoirs are found at Devils Slide and near the town of Peoa, Utah, 20 miles (32 km) west and 9 miles (15 km) southwest, respectively, of producing fields. Closely spaced rhombic and rectilinear fracture patterns developed on bedding planes and within dunes, homogeneous non-porous (in terms of primary porosity) limestone beds of the Rich and Watton Canyon Members.

The Tertiary Green River Formation is the primary oil reservoir in the Uinta Basin. Outcrop analogs in Nine Mile Canyon, just 15 miles (24 km) south of producing fields, display distributary-channel and interdistributary mud-flat deposits. These outcrops show that potential reservoirs can form laterally continuous flow units or pinch out to form flow barriers, all within 40 acres, a common well spacing interval in the basin.

Acknowledgments

The ongoing research is performed as part of a Utah Geological Survey (UGS) project titled Major Oil Plays in Utah and Vicinity. Thomas C. Chidsey, Jr., Principal Investigator, funded under the Preferred Upstream Management Program (PUMPII) of the U.S. Department of Energy, National Petroleum Technology Office, Tulsa, Oklahoma, contract number DE-FC26-97NT15113. The Contract Manager is Rhonda Jacobs. Geologic outcrop interpretations were also contributed by Douglas A. Spindler, Grant C. Wible, and Helmut D. Dobbing, UGS; David E. Ely, Ely Paleontological Consulting, Inc.; Lothar Brinkman, Ulnskroft, Inc.; and Stanley and Colman (1979); Reservoir descriptions incorporated information from Sapers (1980), Ely (1987, 1988), Rupia (1975), Mather (1976), Conner and Grunin (1978), Grunin and Grunin (1978), and Haukensbort et al. (1980). Additional data from the hydrocarbon database are provided by the USGS.

Overview of Utah’s Major Oil-Producing Provinces

**PARADOX BASIN**
- Major Oil Reservoir: Mississippian Leadville Limestone, shallow-shelf marine dolomite and limestone; Pennsylvania Paradox Formation, shallow-shelf marine limestone and dolomite
- Trapping Mechanisms: stratigraphic – carbonates buildups (lateral mounds, shoals, islands) sealed by anhydrite, salt, or organic-rich shale; structural – basement-involved faulted trap/potential anticline
- Source Rocks: black, organic-rich marine shale within the Pennsylvanian Paradox Formation
- First Commercial Discovery: Boundary Butte field, 1947
- Number of Active Fields/Wells: 63 fields/603 wells
- Recent Monthly Production: 353,000 bbls of oil, 1.6 BCF of gas
- Cumulative Production: 538 million bbls of oil, 1.3 TCF of gas
- Best Practices: waterflood, carbon-dioxide flood, waterflood, gas injection, horizontal drilling

**THRUST BELT**
- Major Oil Reservoirs: Jurassic Nugget Sandstone, eolian dune sandstone; Jurassic Twin Creek Limestone, shallow marine limestone
- Trapping Mechanisms: anticlines in the hanging walls of detached (undeformed) basement-involved ramp anticlines, and uplifted subthrust structures (beneath detached and basement-cored faults)
- Source Rocks: Cretaceous Meryow Shale; possibly Permian Phosphorite Formation
- First Commercial Discovery: Pineview field, 1975
- Number of Active Fields/Wells: 7 fields/85 wells
- Recent Monthly Production: 62,100 bbls of oil, 2.4 BCF of gas
- Cumulative Production: 165 million bbls of oil, 3.1 TCF of gas
- Best Practices: gas re-injection to maintain pressure, horizontal drilling

**UINTA BASIN**
- Major Oil Reservoirs: Eocene Green River and Wasatch (Colton) Formations, lacustrine to aluvial channel and bar sandstones
- Trapping Mechanisms: anticlinal at Ashley Valley field, stratigraphic conventional (fluvial-deltaic pinchouts) and basin centered
- Source Rocks: Cretaceous coals and shale, Eocene lacustrine shale
- First Commercial Discovery: Gas at the Ashley Valley field, 1925, and oil at Roosevelt field, 1949
- Number of Active Fields/Wells: 65 fields/420 wells
- Recent Monthly Production: 634,000 bbls of oil, 10.2 BCF of gas
- Cumulative Production: 520 million bbls of oil, 2.2 TCF of gas
- Best Practices: waterflood in the Green River Formation

**Oil and gas fields in the Paradox Basin of Utah and Colorado**

**Drill gas fields, spills, and major thrusts in the Utah-Wyoming thrust belt**

**Oil and gas fields in the Uinta Basin of Utah**

**Schematic block diagram of the Paradox Basin showing trapping mechanisms for the Mississippian Leadville Limestone and Pennsylvanian Paradox Formation**