PTTC
TECHNOLOGY CONNECTIONS
PETROLEUM TECHNOLOGY TRANSFER COUNCIL

RECOGNIZING RESERVOIR COMPARTMENTALIZATION INCREASES PRODUCTION

BOTTOM LINE

Unanticipated reservoir heterogeneity may significantly hinder fluid production. A variety of techniques are available to help operators accurately describe reservoir compartments and their distributions. Integrated analysis considering results from varied techniques increases understanding of reservoir compartments, and ultimately raises production.

PROBLEM ADDRESSED

Reservoir heterogeneity at a variety of scales can be caused by structural complexity, stratigraphic stacking patterns, or diagenetic alteration of pore system continuity. This heterogeneity commonly causes barriers or baffles to fluid flow. Such heterogeneity, often manifested as compartments at the reservoir scale, hinders production if not properly anticipated. Varied techniques exist to assist operators in developing an accurate description of compartments and their distribution. Integrating results from varied techniques improves an operator's ability to predict reservoir compartmentalization, occurrence, distribution, and fluid types. Ultimately, this understanding will improve location of wells, allowing more efficient production of the reservoir.

KEY WORDS:
Compartmentalization
Fluid Discontinuity
Pressure Compartments
Structural Compartments
Diagenetic Overprint
Discontinuous Porosity
Wrench Faults
Valley Fill
Baffles

TECHNOLOGY OVERVIEW

Production often falls short of expectations. Thorough re-evaluations by multidisciplinary teams frequently reveal that geology is more complex than anticipated, with compartmentalization often the culprit. Compartmentalization affects field economics at all stage. But as field development continues, new techniques and information have become available to evaluate the impact of compartmentalization.

Based on a workshop sponsored by PTTC's Rocky Mountain Region and Rocky Mountain Association of Geologists on November 13, 1998, in Denver, CO.

SPEAKERS:

Reservoir Compartmentalization:
Roger Slatt, PTTC Rocky Mountain Resource Center

Geochemical Recognition of Compartments:
Janell D. Edman, Marathon Oil Co.

Wattenberg Field - Denver Basin:
Thomas J. Birmingham, HS Resources, Inc.

Williston Basin - South Dakota:
Robert W. Bogle, Thomasson Partner Associates, Inc.

Jonah Field - Green River Basin, Wyoming:
Edward M. Warner, Consulting Geologist

Valley Fill Reservoirs:
Roderick W. Tillman, Consulting Geologist

Integrated reservoir description is by far the most useful method to identify compartmentalization. Helpful techniques include: identifying near-horizontal, very-thin shales, and analyzing the stratigraphic architecture (using stacking patterns, facies, the effects of sea level fluctuation, and paleogeography). It is also helpful to determine fault-bounded flow boundaries (barriers) and overpressured zones. Other useful methods involve modeling of clay distributed along fault traces, and identifying altered pore systems.

LESSONS LEARNED

1. Case studies from different basins and reservoirs of different ages show that compartmentalization is a common occurrence, created by several geological factors.

2. Reservoir compartments might be caused by various depositional and stratigraphic controls, such as flooding in paleovalley fills, and diagenesis related to exposure surfaces. Other factors include changes in pore-system connectivity related to diagenetic events or to depositional facies, intersecting structural and depositional patterns, hydrodynamic gradients, and overpressure.

3. Integrated studies using many technologies can identify the presence of reservoir compartments, such as sedimentological studies using core, diagenetic analysis, and pore system studies. Other methods range from wireline logs to geochemical analysis of reservoir fluids, to drillstem and production test results.

FIELD RESULTS

1. Geochemical data provide a rapid, low-cost means of identifying reservoir compartmentalization, which is valuable early on in finding the optimal positions for wells. Geochemical techniques provide data for examining reservoir fluid continuity, rather than the geometry of the porous rock that contains the fluids. Examples from the Gulf of Mexico show that differences in whole oil-gas chromatograms—used in conjunction with pressure, seismic, and log data—can identify reservoir compartments. Both oil and gas chromatographic data were needed to identify compartments in the Permian Basin. The entire spectrum of molecular weight components must be analyzed to segregate reservoir compartments.

2. A system of intersecting high-frequency listric, reverse, and wrench faults break the Codell and Terry sandstones within Wattenberg Field (Denver Basin) into many compartments. The predominant sealing mechanism is clay smearing along the fault planes in the Codell, and a combination of calcite cement and clay smearing for the Terry. A modified version of the Shale Gouge Ratio (SGR) is useful for calculating probabilities for fault sealing prior to drilling. The SGR can be verified using bottom-hole pressure bombs, pressure transient analyses, gas-oil ratios, and production comparisons. The SGR has good potential for predicting compartmentalization in sandstone reservoirs that contain moderate to high clay contents and are intersected by frequent fault trends.

3. Reservoir compartments at Lantry Field, South Dakota, in the Upper Ordovician Red River Formation, have a discontinuous lateral and vertical distribution of secondary porosity and oil saturation. Compartments are the result of a diagenetic imprint that coincides with two trends: a) northwest-plunging structural nose, and b) northeast-southwest trending pinchout of a regional laminated porosity. The best wells are located near the intersection of the two trends. Evidence for compartments is based on wireline logs, core analyses, drillstem test results, and production records. Oil accumulation at Lantry Field may have been modified by the local hydrodynamic gradient.

4. Jonah Field, in the Green River Basin (Sublette County, Wyoming), produces gas condensate from abnormally pressured Upper Cretaceous sandstones, primarily from the Lance Formation. Initially considered to be a basin-centered gas accumulation, recent 3-D seismic and well-bore data confirm that the field is a complicated wrench-fault-bounded structural trap, with the bounding faults acting as lateral seals to a large pressure compartment. Overpressured gas migrated into the thermally immature upper Lance Formation from underlying Mesaverde shales. The upper Lance is characterized by an alluvial plain complex consisting of extremely thin sandstone units bounded by scour surfaces. The sandstones combine into thick sequences separated by silty mudstones.

5. Compartmentalization occurs in the tidal, back-filled, paleovalley-fill reservoirs in the Grieve (Muddy) sandstone in Sun Ranch Field in the Wind River Basin, Wyoming. Clay deposited during slack tides and shales deposited in sheet-like topography-filling deposits cause much of the compartmentalization. Within the field, numerous tidal valley-fill deposits are separable, both laterally and vertically. The valley contains compound fills of at least two generations. Up to a dozen flow-separated sandstones are identifiable. Producing intervals in most wells are interrupted by horizontal shaly beds that form baffles or barriers to vertical fluid flow. These beds are attributed to periods of minor sea level rise, which caused the estuary to be flooded. They are easily recognized in core, but not on most logs. Compartmentalization is indicated when large amounts of updip injected gas do not affect any downdip wells, oil production is above gas in some wells, or output is highly variable among adjacent wells.

For information on PTTC's Rocky Mountain Region and its activities contact:

Roger Slatt, Department Head, Geology/Geological Engineering
Colorado School of Mines, Golden CO, 80401-1887
ph 303-273-3822, fax 303-273-3859, e-mail rslatt@mines.edu

CONNECTIONS:

Denver Basin:
Janell D. Edman, Marathon Oil Company
PO Box 269, Littleton, CO 80160
ph 303-694-1446

Thomas J. Birmingham, HS Resources, Inc.
1999 Broadway, Suite 3600, Denver, CO 80202

Williston Basin:
Robert W. Bogle, Thomasson Partner Associates, Inc.,
1100 Stout St., Suite 1400, Denver, CO 80204

Green River Basin:
Edward M. Warner, Consulting Geologist
1401 17th St., Suite 1200, Denver, CO 80202

Wind River Basin:
Roderick W. Tillman, Consulting Geologist
2121 E. 51st St., Suite 112, Tulsa, OK 74105
ph 918-749-3184, fax 918-749-3184
e-mail rootillman@worldnet.att.net

The not-for-profit Petroleum Technology Transfer Council is funded primarily by the US Department of Energy's Office of Fossil Energy, with additional funding from universities, state geological surveys, several state governments, and industry donations. No specific application of products or services is endorsed by PTTC. Reasonable steps are taken to ensure the reliability of sources for information that PTTC disseminates; individuals and institutions are solely responsible for the consequences of its use.

Petroleum Technology Transfer Council, 2916 West T. C. Jester, Suite 103, Houston, TX 77018
toll-free 1-888-THE-PTTC; fax 713-688-0935; e-mail hq@pttc.org; web www.pttc.org