Establishing the Relationship between Fracture-Related Dolomite and Primary Rock Fabric on the Distribution of Reservoirs in the Michigan Basin

DE-FG26-04NT15513

Goal

The specific goals of this project are threefold:

- To summarize and critically synthesize all of the publicly available data on the geometrical distribution and reservoir quality of dolomitized reservoirs in the Trenton-Black River, Niagaran, and Dundee formations in the Michigan Basin and how they may be related to fractures.
- To perform a scientifically rigorous characterization of the various structural and stratigraphic controls and modes of dolomite formation in the three intervals. This will include evaluation of the impact dolomitization has on reservoir quality and documentation of the regional and field-scale distribution of these reservoirs by using state-of-the-art methods such as isotopic and trace element analysis, fluid inclusion analysis, determination of pore system architecture, and sonic velocity characterization from 6-9 representative fields.
- To develop geological models for the 3-D distribution of reservoir facies for the different types of dolomite reservoirs that will provide operators with a means to high-grade exploration, development, and enhanced recovery efforts in a cost-effective manner.

Performer

Western Michigan University
Kalamazoo, MI

Results

The project is expected to result in 1) the development of sequence-stratigraphic-based geological models that will include the 3-D distribution of reservoir facies for each of the different types of dolomite reservoirs that are common in the Michigan Basin; 2) new models that will enable operators to high-grade exploration, development, and enhanced recovery efforts cost-effectively; 3) results that could be exportable to other U.S. regions producing from dolomite reservoirs.

Benefits

Results of this project should lead to an increased understanding of regional and field scale dolomitized reservoirs in the Michigan Basin and may be exportable to other domestic oil and gas producing basins. Results will likely lead to new, reduced-risk exploration and step-out development play concepts in the Michigan Basin, as well as a better and more complete understanding of the local subsurface distribution of reservoirs to guide enhanced production efforts. Increasing production in the Michigan Basin, and potentially in other domestic basins, has national security implications through the reduction of the amount of foreign oil and gas imports needed to sustain our current national infrastructure. A 10% increase in hydrocarbons produced from the three main

producing intervals in the Michigan Basin alone would result in added production of about 150 million barrels of oil equivalent for the Nation.

Background

The Michigan Basin is a mature hydrocarbon basin that has been recognized by the U.S. Geological Survey as one of the 25 “priority basins” in the United States that contain some 90-95% of known and undiscovered domestic hydrocarbon resources (USGS National Assessment of Oil and Gas Resources Program, 2004).

Current activity in the basin is mostly concentrated on step-out development and enhanced production efforts, although moderate exploration efforts continue to be pursued. Over the past 75+ years, the basin has produced in excess of 1.3 billion barrels of oil and 5.9 trillion cubic feet of natural gas. The most prolific oil producing formations in the basin, with total cumulative production of about 900 million barrels of oil and 4.5 trillion cubic feet of gas, are the Ordovician Trenton and Black River formations, the Silurian Niagara Group, and the Devonian Dundee Limestone. Each of these units comprises volumetrically significant dolomitized reservoir facies for which several models of formation have been pro-posed. To maximize the discovery of new reservoirs and for the recovery of bypassed or stranded hydrocarbons in these intervals, it is critically important that the operator have access to scientifically constrained reservoir models that are able to predict the geometrical distribution of the reservoir facies in the subsurface. Utilization of such models will allow the operator to better pursue new exploration efforts, high-grade placement of step-out development wells, and more accurate orientation of directional or horizontal wells.

It is the goal of this project to fully characterize reservoir dolomites in the three units indicated, specifically to determine the relationship of dolomite to fracture trends/fracture density, and/or to primary depositional facies and to develop improved models for exploration and development of these reservoirs based upon a better understanding of their 3-D distribution in the subsurface.

Summary

The characterization of select dolomite reservoirs has been the major focus of our efforts in the first half of Phase II/Year 2. Fields have been prioritized based upon the availability of rock data for interpretation of depositional environments, fracture density and distribution as well as thin section, geochemical, and petrophysical analyses. The majority of our efforts to date have been in the Devonian and Silurian sections, with the anticipation that enhanced efforts in the Ordovician section currently ramping up.

Structural mapping and log analysis in the Trenton/Black River (Ordovician) and Dundee (Devonian) suggest a close spatial relationship among gross dolomite distribution and regional-scale, wrench fault-related NW-SE and NE-SW structural trends. A high temperature origin for much of the dolomite in the 3 studied intervals (based upon initial fluid inclusion homogenization temperatures and stable isotopic analyses) coupled with persistent association of this dolomite in reservoirs coincident with wrench fault-related features, is strong evidence in support of these reservoirs being influenced by

hydrothermal dolomitization. Ongoing efforts will be focused on determining whether the hydrothermal dolomite represents the only phase of dolomite in these fault-related fields, or whether there is evidence of low temperature dolomitization as well. In either case, our main concentration is whether the reservoir quality of the dolomite can be tied to primary facies type and/or an established sequence stratigraphic framework, either of which will enhance the predictability of such reservoirs.

For the Niagaran (Silurian), a comprehensive high resolution sequence stratigraphic framework has been developed for a pinnacle reef in the northern reef trend where we had 100% core coverage throughout the reef section. Our next step is to test this sequence framework within a larger reef complex in the southern reef trend (Ray Reef Field). We are finalizing an agreement with Consumers Energy for a 3-D seismic survey over the Ray Reef which will be utilized in conjunction with the geological characterization of 18 cores for development of a 3-D reservoir model in Phase III. Major findings to date are that facies types, when analyzed at a detailed level, have direct links to reservoir porosity and permeability in these dolomites. This pattern is consistent with our original hypothesis of primary facies control on dolomitization and resulting reservoir quality at some level. The identification of distinct and predictable vertical stacking patterns within a hierarchical sequence and cycle framework provides a high degree of confidence at this point that results will be exportable throughout the basin.

The initial stages of data evaluation and synthesis (Task 4) are well underway per our original proposal. Most of the effort on this task has necessarily had to follow results of Phase I results from Tasks 2 and Phase II results of Task 3. We have entered into an agreement with Dr. Matthew Pranter, University of Colorado, who will be collaborating with us on the 3-D modeling efforts during the rest of Phase II and into Phase III.

Technology transfer efforts continue with formal presentations on the state and national levels as well as ongoing advertisement of the project's scope, anticipated results and funding agency on the WMU Department of Geosciences web site. During the first half of Year 2 we presented two papers at the National AAPG Meeting in Houston, TX as well as 2 papers at the Midwest Regional PTTC workshop on carbonate reservoirs.

Current Status (May 2006)
The project is 6 1/2 months into Year 2 (of 3) and is on time and within budget.

Funding
This project was selected in response to DOE's Oil Exploration and Production solicitation DE-PS26-04NT15450-2B, area of interest 2B: Regional Study and Basin Analysis.

Publications
Harrison, W.B., 2006, Michigan Carbonate Reservoirs – Facies and Reservoir Properties, report, PTTC Workshop, Mt. Pleasant, MI

Grammer, G.M., 2006, Enhanced Reservoir Characterization through the Integration of a Sequence Stratigraphic Framework – Examples from Carbonate Reservoirs in the Paradox and Michigan Basins, report, PTTC Workshop, Mt. Pleasant, MI

Sandomierski, A.E., Grammer, G.M., and Harrison, W.B., Evaluating Controls on the Formation and Reservoir Architecture of Niagaran Pinnacle Reefs (Silurian) in the Michigan Basin: A Sequence Stratigraphic Approach, presented at the 2006 national AAPG Meeting, Houston, TX.

Grammer, G.M., State of Michigan DEQ and DNR, Recent Advances in Carbonate Sedimentology and Stratigraphy Applied to the Silurian Niagara Group, Michigan Basin, report, 2005.

Sandomierski, A.E., Grammer, G.M., and Harrison, W.B., Evaluating Controls on the Formation and Reservoir Architecture of Niagaran Pinnacle Reefs (Silurian) in the Michigan Basin: A Sequence Stratigraphic Approach, presented at the 2005 Eastern Section AAPG Meeting, Morgantown, WV.

Barnes, D.A., Grammer, G.M., Harrison, W.B., Gillespie, R., Stewart, J., Wahr, A., and Kirschner, J., Oil Field Structural Mapping and the Distribution of Dolomite in the Dundee Formation (Devonian) of Michigan, presented at the 2005 Eastern Section AAPG Meeting, Morgantown, WV.

Contract Information:

Project Start: 10/01/04
Project End: 09/30/07

Anticipated DOE Contribution: $ 741,369
Performer Contribution: $ 292,106 (28.3 % of Total)
Contact Information:
NETL: Chandra Nautiyal (Chandra.nautiyal@netldoe.gov or 918-699-2021)
Performer: Michael Grammer (Michael.grammer@wmich.edu or 269-387-3667)