Ordivician Tectonic Dolostones in Central Kentucky: Analogs for Trenton–Black River Reservoirs in the Appalachian Basin

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Project Summary

Ordivician dolostones located along faults in central Kentucky provide good analogs to subsurface Teton-Black River (hydrothermal) dolostone gas reservoirs in New York, Ohio, Michigan, and possibly West Virginia. We are currently studying these outcrop exposures to better understand their formation and relation to similar subsurface reservoir dolostones. Very preliminary results are presented here. This 5-year project will be completed June 2003.

Project Goals

- Determine stratigraphic and structural controls on the distribution of tectonic dolomitization
- Determine timing of dolomitization and integrate with stratigraphic and tectonic setting
- Document porosity distribution within dolostones and relative timing of hydrocarbon migration
- Develop a predictive model for structural and stratigraphic controls on tectonic dolomitization

Focus: Tectonic (hydrothermal?) Dolostone Outcrops

Stratigraphy

Central Kentucky Minerals District

Study area

Stratigraphic correlation chart for the Middle and Upper Ordovician on碳酸岩 Kentucky and equivalent units in the Appalachian Basin. Units containing tectonic dolostones are shaded in black. Tectonic dolostones in the Clear Creek Group (Black River Formation) have textural similarities in some cases in central Kentucky.

Project Implementation

Phase 1: Stratigraphic and structural analysis of the Ordovician Black River Formation

- Geologic and stratigraphic characterization of dolostone outcrops and adjacent sandstone sequences

Phase 2: Geophysical imaging of dolostone outcrops

- High-resolution seismic reflection (P and S waves)
- Ground-penetrating radar

Phase 3: Continuous coring of 2 dolostones to sample dolostones at depth and document vertical variability in dolomitization and porosity

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Trenton–Black River Play in the Appalachian Basin

- Ordovician Tectonic Limestone and Black River Group hydrothermal dolostone gas reservoirs are both controlled, and often occur in marine graptolites
- High production rates have generated wide interest in the play
- Several recent discoveries have been made in isolated tectonic dolostone reservoirs in New York and Ohio. The Trenton discovery (Collinsville Field) by Columbia Natural Resources in Roane Co., West Virginia may be a fractured limestone reservoir, making it unique
- Seismic is the main exploration tool, where it is used to map sage and amplitude anomalies on the Trenton reflector

Hydrocarbons in Kentucky Outcrops

- The presence of shows in the Ordovician outcrops will allow some interpretations on the relative timing of hydrocarbon migration to be made

Rhenolithic mineral exploration cores are available from the study area. These will be used for additional sample control and analysis. Phase 1, 2, and 3 coring of Ordovician dolostone outcrops to better characterize the 3-dimensional variability of the features.

The presence of shows in the Ordovician outcrops will allow some interpretations on the relative timing of hydrocarbon migration to be made.
Stoner Branch Locality

The Stoner Branch Dolostone occurs in the Goose Creek Dolostone, above the Lexington Limestone (Dolphin). It is the uppermost formation of the Kentucky River Fault, and it is much larger than the Lightbulb. It is about 2 miles long and 4 miles wide. Dolostone is present in some of the porous dolostones at this locality.

Preliminary Dolomite Petrography and Geochemistry

Initial Observations

- Transparent light and carbonate-metasomatic petrography indicates 3 distinct generations of dolomite separated by formic acid solution:
  - Early dolomite related to mineralogical phases.
  - Interbedded dolomite and early dolomite.
  - Medium to dark transparent dolomite.
  - Medium to dark translucent dolomite.
  - Brighter grains, matrix.
- Formic acid solution:
  - Formic acid with minor non-reacting.
  - Partially replace early dolomite in some samples.
  - The dolomite and matrix is early dolomite.

Replacement of early dolomite by dolosil (early crystalline):

- Late formic acid (barroquel dolomite): Early poro-facies dolomite (early corundum-porous porosity).
- Translating light and carbonate-metasomatic petrography indicates 3 distinct generations of dolomite separated by formic acid solution.

Dolostone facies: Porosities resulting from dissolution of early dolomite.

Preliminary Carbon and Oxygen Stable Isotope Data

Isotopic Data From the Lightbulb Structure, KY

Typical dolomite facies: Dolomite facies resulting from dissolution of early dolomite.

Complete diagnostic sequence: Early dolomite (lower layer). Medium to translucent dolomite.

Observations of dolosil facies: Dolosil facies resulting from dissolution of early dolomite. Lightbulb structure.
Seismic Imaging of Ordovician Trenton-Black River Dolostone Reservoir Analogs: preliminary results

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Research in progress by:
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Seismic imaging of shallow-to-subsurface dolostone bodies will help to apply results of this study to deeper-Trenton-Black River Dolostone reservoirs. Seismic imaging is critical for understanding the geometry and connectivity of the reservoirs and can aid in delineating potential stratigraphic and lithologic controls on dolomitization. Seismic work will utilize P (compressional) and S (shear) profiling to determine subtle seismic features. Seismic imaging is especially useful for imaging stable bodies in the shallow subsurface where boreholes are rarely encountered.

Reflection profiles will be acquired in 2 locations, the Lightbull structure and the Steiner Branch dolostone. Data acquisition has begun in the Lightbull, and will start soon at Steiner Branch. Preliminary data indicate that the reservoir is well imaged.

Seismic data will also be used to help determine the locations of 2 continuously-eroded horizons through the dolostones to be drilled later in 2002.

Acquisition Equipment
- 48-channel Geometrics Stretcher seismograph
- 48 3-kHz P-wave geophones
- 48 30-kHz 3D-pointed geophones
- 18 3-kHz, 3-cable, 16 channel

P-wave Seismic Acquisition Parameters

Source Type: 16-L. Source
Contractor: University of Kentucky
Geophone Spread: 48 feet per station
Receivers/Depth: Two receivers generated at each station (near offsets of +36 m and +76 m)
Sample Rate: 500 Hz
Source Interval: 4 m
Source Energy: 3 mj
Geophone Group: 92 geophones per group
Channel: 2.4 m
Receiver Spacing: Offset
Receivers/Depth: 1,042 m
Site Surveyed: Lightbull structure, Clerk Co, Ky

Field Record

Preliminary P-wave data, lightbulb structure (road level)
Length of line = 625 ft.

Data processed using VISTA 7.0 software package

Processing Steps
1. Reformat
2. Spherical Divergence Gain
3. Elevation Statics (none)
4. Bandpass Filter
5. Sort to CDP Gather
6. F-K Filtering
7. Velocity Analysis
8. First-Break and Surgical Mutting
9. Normal Moveout Corrections
10. Surface Consistent Static
11. CDP Stack
12. Automatic Gain Control

Processing Problems Encountered
1. Road and wind noise
2. Out-of-plane reflections (ranging from outcrop faces)

Future seismic acquisition at the Steiner Branch locality

Seismic data will be acquired across this dolostone body.