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

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Visit our project Web site: http://www.uky.edu/KGS/emsweb/trenton/trnt.html

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Project Summary

Ordovician dolostone bodies localized along faults in central Kentucky provide good analogs to subsurface Trenton–Black River hydrothermal dolostone gas reservoirs in New York, Ontario, 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 2-year project will be completed in June 2004.

Project Goals

– Determine stratigraphic and structural controls on the distribution of tectonic dolomitization

– Determine timing of dolomitization and integrate with structural geology

– Document porosity distribution within dolostones and relative timing of hydrocarbon migration

– Develop a predictive model for structural and stratigraphic controls on tectonic dolomitization

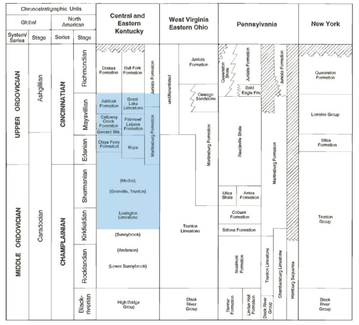
Focus: Tectonic (hydrothermal?) Dolostone Outcrops

The "lightbulb" dolostone, Lexington (Trenton) Limestone, on Ky. Route 627, Clark Co., Ky.

Saddle dolomite crystals lining vug at the "lightbulb" dolostone

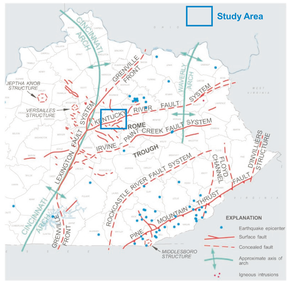
Geologic mapping by Doug Black and other U.S. Geological Survey geologists in central Kentucky first noted the presence of dolostone bodies spatially related to faults within shallow-water limestones of the Ordovician Lexington Limestone (Trenton Limestone equivalent) and overlying carbonates. Black documented about 30 tectonic dolostone bodies in central Kentucky.

Stratigraphy

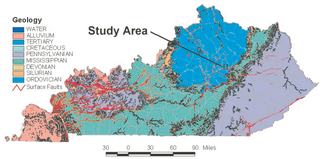


Stratigraphic correlation chart for the Middle and Upper Ordovician in central Kentucky and equivalent units in the Appalachian Basin. Units containing tectonic dolostones are shaded in blue. Tectonic dolostones in the High Bridge Group (Black River equivalent) have not been observed in outcrop in central Kentucky.

Structural Features

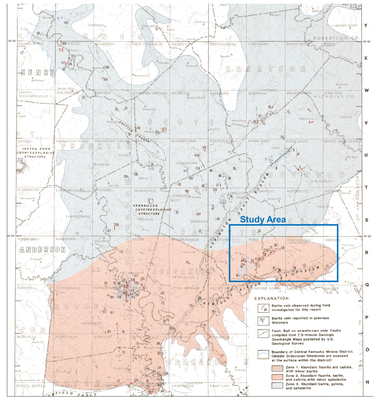


Location Map



The study area is located in Clark and Fayette Counties, Kentucky, on the eastern flank of the Cincinnati Arch. The Appalachian Basin lies to the east.

Central Kentucky Minerals District



Anderson and others, 1982

Study area lies within the larger Central Kentucky Minerals District, and numerous veins containing Mississippi Valley-type mineralization are present. Dolomitization may be related to this mineralization.

Project Implementation

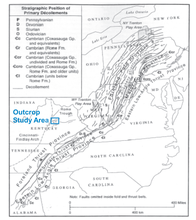
Phase 1: Geological and geochemical characterization of dolostone outcrops and shallow mineral exploration cores
- transmitted light and cathodoluminescent petrography
- trace element geochemistry (microprobe)
- carbon and oxygen stable isotope geochemistry
- fluid inclusion analyses

Phase 2: Geophysical imaging of shallow dolostone bodies
- high-resolution seismic reflection (P and S wave)
- ground-penetrating radar

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

Trenton–Black River Play in the Appalachian Basin

Regional Map of Trenton–Black River Play areas



modified from Schwochow (2000)

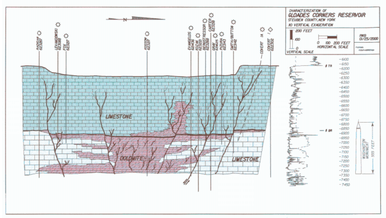
– Ordovician Trenton Limestone and Black River Group hydrothermal dolostone gas reservoirs are fault-controlled, and often occur in narrow grabens

– High production rates have generated wide interest in the play

– Several recent discoveries have been made in interpreted hydrothermal dolostone reservoirs in New York and Ohio. The Trenton discovery (Cottontree Field) by Columbia Natural Resources in Roane Co., West Virginia may be a fractured limestone reservoir, lacking dolomite

– Seismic is the main exploration tool, where it is used to map sags and amplitude anomalies on the Trenton reflector

Gas flare from Trenton discovery well, Cottontree Field, Roane Co., W.Va. IP: 55 MMCFGPD (photo by R. Stollar)



Geologic model for the Gloades Corners Road Field, Steuben Co., N.Y. Model illustrates a fault-bounded graben with dolomitization of Trenton and Black River limestones along faults and fractures. Figure courtesy of Columbia Natural Resources.

Hydrocarbons in Kentucky Outcrops

Oil seeps in upper Lexington Ls. (Trenton), Walker Quarry, Montgomery Co., Ky.

Oil-filled fossil mold in dolomitized Calloway Creek Limestone, Stoner Branch locality, Clark Co., Ky.

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

Numerous mineral exploration cores are available from the study area. These will be used for additional sample control near outcrops. Phase 3 of the project will involve drilling 2 new cored boreholes through dolostone outcrops to better characterize the 3-dimensional variability of the features.

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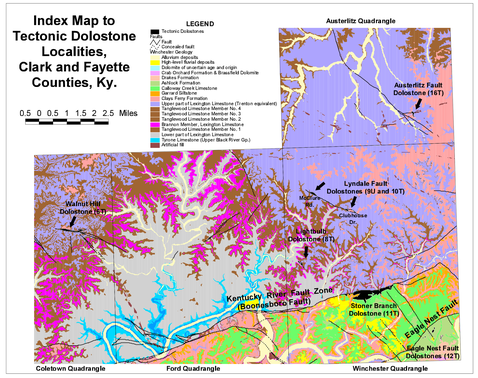
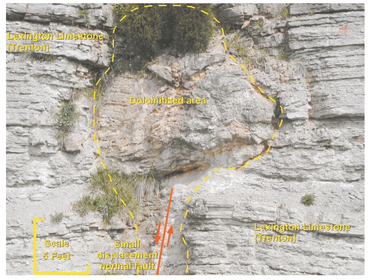
Preliminary Dolomite Petrography and Geochemistry

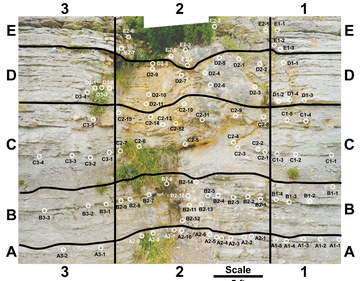


Dolostone Locality Index Map: 7 dolostone bodies have been sampled

The lightbulb structure, Clark Co., Ky.

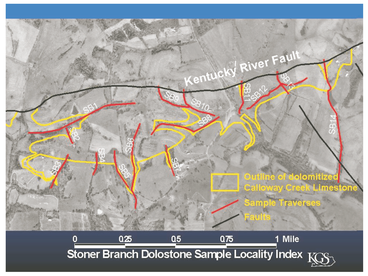


Dolostone is developed above small displacement fault.
It is about 30 ft. tall and 25 ft. wide. It is laterally discontinuous, and is not present along the same fault on the opposite side of the highway. It is probably related at depth to a larger dolostone body to the SW mapped by Black.
Note the sag at top of structure and choatic bedding within due to solution and collapse. These features are common in larger hydro-thermal dolostone bodies also.



Sampling grid index for the lightbulb

Stoner Branch Locality



The Stoner Branch dolostone occurs in the Calloway Creek Limestone, above the Lexington Limestone (Trenton). It is on the downthrown side of the Kentucky River Fault, and is much larger than the lightbulb. It is about 2 miles long and 0.4 miles wide. Oil is present in some of the porous dolostone at this locality.

Initial Observations

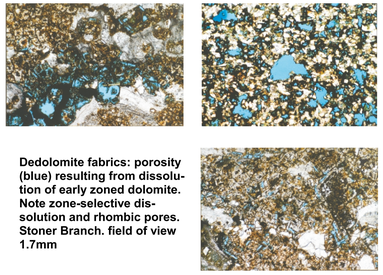
– Transmitted light and cathodoluminescent petrograpy indicates 2 distinct generations of dolomite separated by ferroan calcite cementation:

Early iron-zoned euherdal to subhedral dolomite
- zoned with Fe-rich and non-Fe dolomite
- alteration of Fe-dolomite to iron oxides common
- medium to dull red luminescence
- replaces grains, matrix

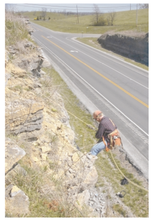
Ferroan calcite cement
- Fe-rich calcite with minor non-Fe zoning
- partly replaces early dolomite in some samples
- fills skeletal molds and vugs in early dolomite
- variable luminescence, orange to red

Replacement of early dolomite by feldspar (timing uncertain)

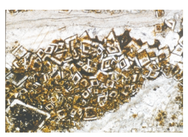
Late ferroan saddle (baroque) dolomite
- final pore-filling dolomite event (reduces porosity)
- ferroan and non-luminescent



Dedolomite fabrics: porosity (blue) resulting from dissolu-tion of early zoned dolomite. Note zone-selective dis-solution and rhombic pores. Stoner Branch. field of view 1.7mm

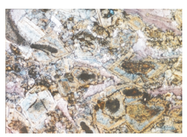


Sampling the Lightbulb!

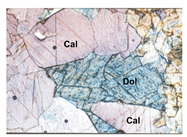


Typical early euhedral dolomite with Fe-oxide zoning resulting from alteration of Fe-dolomite. Stoner Branch. field of view 1.7mm

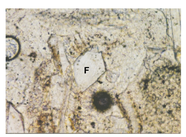
Selectively dolomitized echinoderm with Fe-zoning. Note embayed contact and truncation of zoning by Fe-calcite cement. Stoner Branch. field of view 0.7mm



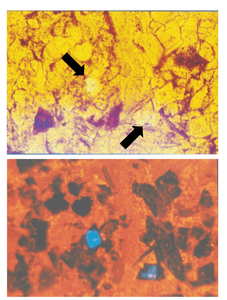
Dolomitized echinoderm grainstone with pore-filling calcite cement. Stoner Branch. field of view 4.13mm



Fe-calcite (purple) and Fe saddle dolomite cement in skeletal mold. Early euhedral dolomite at right. Stoner Branch. field of view 1.7mm

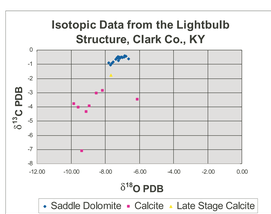


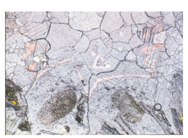
Feldspar replacement of early dolomite. Note relict dolomite at top of rhomb. PPL, Stoner Branch. field of view 0.7mm



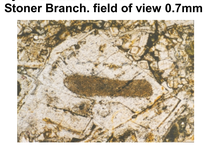
Transmitted light (top) and cathodoluminescence of authigenic feldspar. Feldspar rhombs have blue luminescent cores (detrital) and non-luminescnent rims. Stoner Branch.

Preliminary Carbon and Oxygen Stable Isotope Data

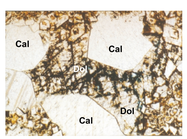




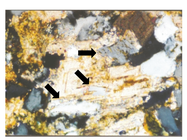
Limestone sample showing Fe-calcite cement overgrowths on echinoderm grains. Note early inclusion-rich calcite zone and thin non-Fe calcite zone. Stoner Branch. field of view 1.7mm



Close-up of dolomitized echinoderm grain. Stoner Branch. field of view 1.7mm



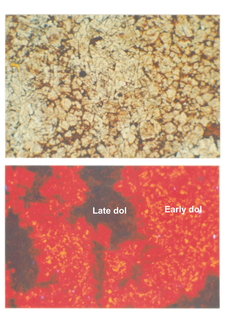
Pore-filling calcite and saddle dolomite cements. Note alteration of Fe saddle dolomite to form Fe oxides along cleavage planes. Stoner Branch. field of view 1.7mm



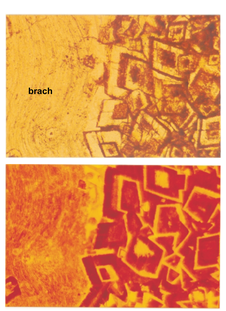
Partial replacement of early zoned dolomite by feldspar (low birefringence) Stoner Branch. field of view 0.43mm

Crossed nicols of above. Note feldspar twinning. Stoner Branch. field of view 0.7mm

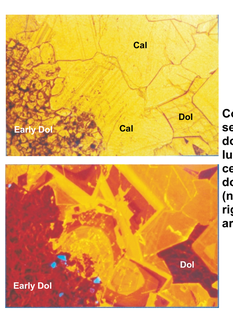
Opposite face of lightbulb roadcut illustrating lateral variability of dolomitization. Small fault is present but dolostone is not developed. Minor saddle dolomite is present in fractures and small vugs on this side of the outcrop.



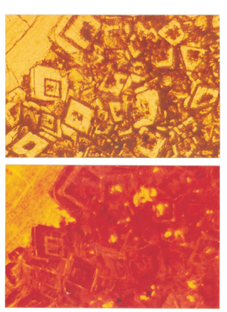
Transmitted light/CL pairs: Early dolomite (red lum.) and late non-luminescent dolomite. Lightbulb structure.



Early zoned dolomite (red/yellow lum.) with possible late dolomite overgrowths on left edge (non-luminescent). Stoner Branch.



Complete diagenetic sequence: early euhedral dolomite in lower left, luminescently-zoned calcite cement, with final saddle dolomite pore-fill cement (non-luminescent) in lower right. Blue luminescent grains are feldspars. Stoner Branch.



Typical luminescence of early zoned dolomite. Zoning is defined by iron oxides from oxidation of Fe-dolomite. Stoner Branch.

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Seismic Imaging of Ordovician Trenton-Black River Dolostone Reservoir Analogs: *preliminary results*

Funding provided by U.S. Department of Energy, National Energy Technology Laboratory

Research in progress by:
Dr. Ed Woolery
William Reid
Department of Geological Sciences, University of Kentucky

Seismic imaging of shallow tectonic dolostone bodies will help to apply results of this study to deeper Trenton–Black River exploration targets. It will also help to determine the structural controls on dolomitization. Seismic work will utilize P (compression) and SH (horizontally-polarized shear wave) energy sources. Shear wave reflection surveys are especially useful for imaging subtle features in the shallow subsurface (<100 m) because they are frame-work waves, not affected by the degree of water saturation.

Reflection profiles will be acquired in 2 localities, the lightbulb structure and the Stoner Branch dolostone. Data acquisition has begun at the lightbulb, and will start soon at Stoner Branch. Preliminary data from the lightbulb structure is shown to the right.

Seismic data will also be used to help determine the locations of 2 continuously-cored boreholes through the dolostones to be drilled later in 2003.

Acquisition Equipment

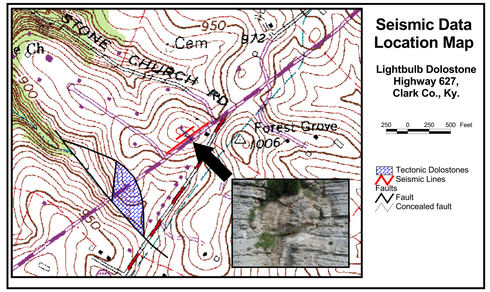
- 48-channel Geometrics Strata Visor seismograph
- 48 40-Hz P-wave geophones
- 48 30-Hz SH-polarized geophones
- 10 lb. hammer, steel plates, H-beam

P-wave energy source (sledge hammer and steel plate)

48-channel seismograph

Geophone array along road at lightbulb locality

SH-wave energy source (sledge hammer and H-beam)

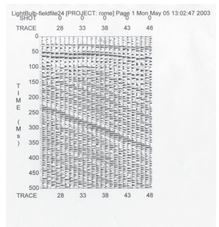


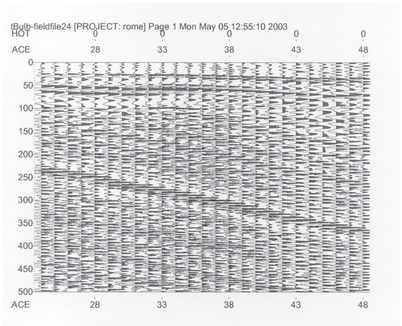
Sesimic location map for the lightbulb structure, Ky. 627, Clark Co., Ky. Data is being collected along the road and across the hill above the structure.

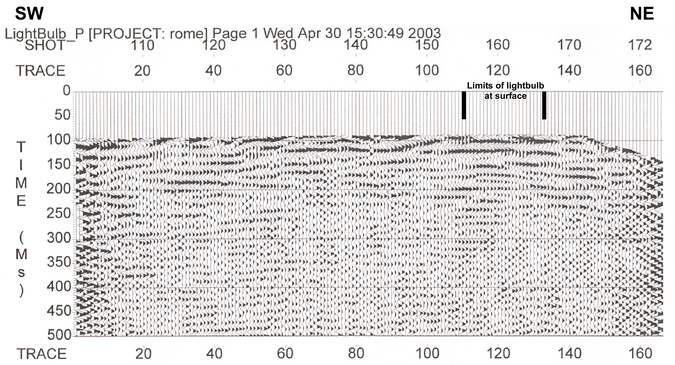
P-wave Seismic Acquisition Parameters

Source Type:	10 lb. hammer
Contractor:	University of Kentucky
Date of Survey:	April 2003
Source Deployment:	4-6 times per station
Receiver Deployment:	Two records generated at each station (near offsets of ~30 m and ~74 m)
Sample Rate:	0.50 ms
Source Interval:	2 m
Group Interval:	2 m
Geophone Group:	40 Hz phone per group
Channels:	2 x 24
Receiver Geometry:	Off-end
Record Length:	1.024 ms
Nominal Fold:	12
Site Surveyed:	Lightbulb structure, Clark 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

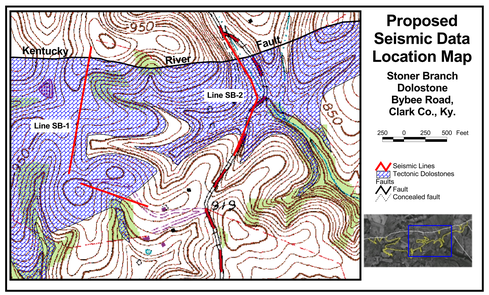
Processing Steps

1. Reformat
2. Spherical Divergence Gain
3. Elevation Statics (none)
4. Bandpass Filter
5. Sort to CDP Gathers
6. f-k Filtering
7. Velocity Analysis
8. First-Break and Surgical Muting
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 (ringing from outcrop faces)

Future seismic acquisition at the Stoner Branch locality



Sesimic location map for the Stoner Branch dolostone, Clark Co., Ky. Two lines will be acquired across this dolostone body.

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