Subsurface Lithostratigraphy of the Cambro-Ordovician Knox Group in Illinois: Regional Correlation of Potential Reservoirs and Seals for CO_2 Sequestration

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Abstract

As part of a U.S. Department of Energy-funded project, detailed subsurface lithostratigraphic evaluation of the Cambro-Ordovician strata is being conducted in the Illinois Basin to better understand the potential reservoirs and seals for CO_2 storage in the Knox Group. Deep wells penetrating the Knox Group were selected for detailed petrographic examination of well cuttings and available cores. The preliminary results obtained from this ongoing study, along with outcrop data from the edge of the basin, provided important information regarding the lithologic variations in the Knox Group.

In the northern and central parts of Illinois, the Cambro-Ordovician Knox Group (300–1,500 feet thick) is subdivided into alternating carbonate-dominated and siliciclastic-dominated units. The carbonate units, from base to top, include the Cambrian Franconia Formation, Potosi Dolomite, Eminence Formation, and Ordovician Oneota and Shakopee Dolomites. The siliciclastic units include the Cambrian Eau Claire Formation, the Galesville and Ironton Sandstones, the Davis Member of the Franconia Formation, and the Ordovician Gunter and New Richmond Sandstones.

The siliciclastic units thin southward, whereas the carbonate units thicken. In the deeper part of the Illinois Basin, the Knox Group thickens to more than 6,000 feet and is composed predominantly of dolomite with thin shale beds in formations that are difficult to differentiate.

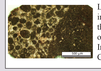
The integrated approach outlined here, which included a detailed petrographic examination, has identified lithostratigraphic and lithofacies variations within the Knox Group that aid in determining the best reservoir and sealing units in the Knox for potential carbon sequestration.

Introduction

Carbon sequestration is becoming an important strategy worldwide for continued utilization of fossil fuel to meet the world's energy demand. Among various methods for carbon sequestration, injection into deep saline formations appears to provide the safest method for storing large volumes of CO_2. Factors favorable to CO_2 sequestration in deep saline formations include 1) high porosity and permeability, 2) laterally extensive, 3) relatively thick intervals, 4) depths of at least 2,500 feet, and 5) thick, effective seals with very low permeability (e.g., shale).

To determine lateral and vertical lithologic variations of the rocks within the Knox Group in Illinois, six deep wells were examined in detail. Well cuttings and available cores of these wells and samples from exposures in west-central Missouri were studied in detail and the results were compared with geophysical logs as shown. The results show that the Knox Group in the Illinois Basin and adjacent Midwestern regions may be an attractive target for CO_2 sequestration because the rocks of the Knox Group 1) are laterally extensive, 2) consist of some porous and permeable dolomite and sandstone intervals, and 3) contain several low-permeability shale and carbonate seals. In addition to being a primary target for CO_2 storage, the porous rocks of the Knox Group can capture CO_2 that may leak from the Mt. Simon Sandstone below, currently a major target for a CO_2 reservoir in the U.S. Midcontinent.

Everton Dolomite



Lime mudstone capped by intraclastic grainstone facies; thin section photomicrograph of a well sample from Texaco Inc., Johnson No. 1, Marion Co., IL (depth 5,570–5,580 ft).

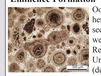
Oneota Dolomite

Coarsely crystalline dolomite with relics of oolites and crinoids; thin section photomicrograph of a well sample from Humble Oil & Refining Co., Weaber-Horn Unit No. 1, Fayette Co., IL (depth 5,345–5,350 ft).

Gunter Sandstone

Thin section photomicrograph of fine- to medium-grained, well-rounded quartz arenite; road cut along Highway 5, MO.

Eminence Formation



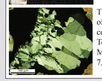
Oolitic chert showing partial hematite replacement; thin section photomicrograph of a well sample, Humble Oil & Refining Co., Weaber-Horn Unit No. 1, Fayette Co., IL (depth 5,690–5,695 ft).

Dedolomitization in a coarsely crystalline dolomite, sample from a quarry in Washington Co., MO.

Potosi Dolomite

Vugular Potosi Dolomite constraining drusy quartz horizons; junction of Highways 21 and 47 south of Potosi, MO.

Close-up view of a vug in the previous image showing the internal drusy quartz fabric.



Thin section photomicrograph of drusy quartz in a fine to coarsely crystalline dolomite; Texaco Inc., Johnson No. 1, Marion Co., IL (depth 7,245–7,250 ft).

Franconia Formation

Sandy glauconitic fine to medium crystalline dolomite; thin section photomicrograph of a well sample, Texaco Inc., Johnson No. 1, Marion Co., IL (depth 7,570–7,575 ft).

Ironton Sandstone

Interlayered peloidal dolomite and laminated fine- to medium-grained quartz sandstone; photograph of a core chip, Northern Illinois Gas Co., Fordyce No. 1, Livingston Co., IL (depth 1,592 ft).

Galesville Sandstone

Fine- to medium-grained mature quartz arenite; photograph of a core chip, Northern Illinois Gas Co., Fordyce No. 1, Livingston Co., IL (depth 1,592 ft).

Eau Claire Formation

Ooid grainstone; thin section photomicrograph of a well cutting, Humble Oil & Refining Co., Weaber-Horn No. 1, Fayette Co., IL (depth 6,375–6,380 ft).

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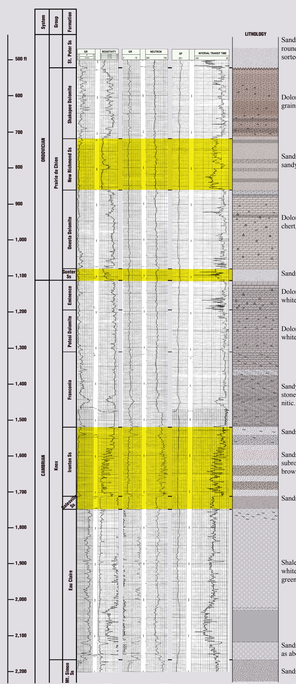
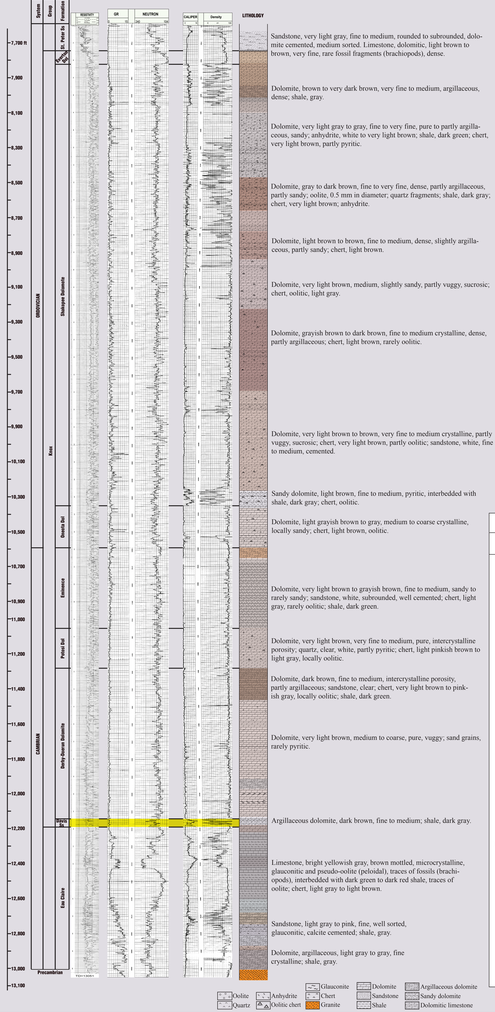
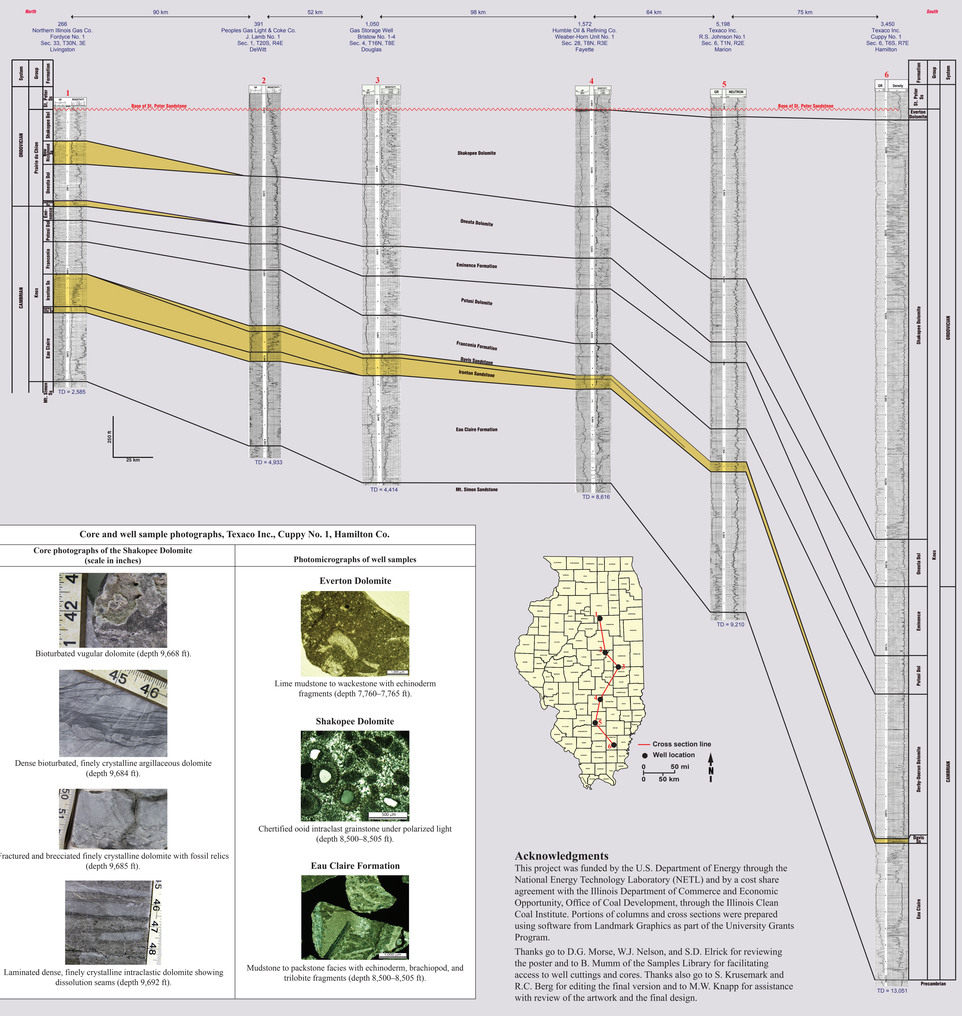
Knox Lithostratigraphy in Northern Illinois, Northern Illinois Gas Co., Fordyce No. 1, Livingston Co.



Knox Lithostratigraphy in Southern Illinois, Texaco Inc., Cuppy No. 1, Hamilton Co.





Conclusions

- The Everton Dolomite is up to 60 feet thick in the Cuppy well, Hamilton County. It thins northward and pinches out in Weaber-Horn No. 1, API No. 1572, Fayette County.
- The Shakopee Dolomite is up to 2,300 feet to the south of the Illinois Basin at Cuppy No. 1, API No. 3450 in Hamilton County, but thins to the north.
- New Richmond, Gunter, and Galesville Sandstones are present only in the northernmost part of the study area.
- Oneota and Shakopee Dolomites (about 400 to more than 2,500 feet thick) exist in all of the wells studied.
- Eminence Formation, Potosi Dolomite, and Franconia Formation are present in all wells, but they all thicken southward and become more of a sandy dolomite to the north.
- The carbonates of the Knox Group studied so far are generally tight, but some intervals are vugular or may be fractured, thus enhancing their potential for CO_2 storage.
- Sandstone within the Knox Group and the overlying St. Peter Sandstone may have the highest potential for CO_2 sequestration.
- More work is needed to delineate the porous and permeable intervals within the Knox Group.

Core and well sample photographs, Texaco Inc., Cuppy No. 1, Hamilton Co.

Core photographs of the Shakopee Dolomite (scale in inches)

Bioturbated vugular dolomite (depth 9,668 ft).

Dense bioturbated, finely crystalline argillaceous dolomite (depth 9,684 ft).

Fractured and brecciated finely crystalline dolomite with fossil relics (depth 9,685 ft).

Laminated dense, finely crystalline intraclastic dolomite showing dissolution seams (depth 9,692 ft).

Photomicrographs of well samples

Everton Dolomite

Lime mudstone to wackestone with echinoderm fragments (depth 7,760–7,765 ft).

Shakopee Dolomite

Chertified ood intraclast grainstone under polarized light (depth 8,500–8,505 ft).

Eau Claire Formation

Mudstone to packstone facies with echinoderm, brachiopod, and trilobite fragments (depth 8,500–8,505 ft).

Acknowledgments

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