The Copper Ridge Dolomite: A Sequestration Backup for the Mount Simon Sandstone?

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Abstract

In the eastern Midcontinent, the Cambrian quartzose sandstone known as the Mount Simon Sandstone is considered by many to be one of the most important potential deep-saline reservoir targets for CO_2 sequestration. In many areas, the Mount Simon is sufficiently deep, thick, and permeable.

Unfortunately, the Mount Simon does not everywhere possess sufficient permeability to assure the kind of injection rates that may be required for successful sequestration efforts. Because there are few well cores from the Mount Simon over much of the eastern Midcontinent, little is known of its regional reservoir characteristics. In several cases, tight sandstone has been encountered. One example is a deep disposal well in Louisville, Ky. Data from the DuPont well there indicate that after extensive testing, the Mount Simon was abandoned as the injection interval in favor of shallower, more permeable, vuggy dolomite facies in the Copper Ridge Dolomite. Though the well is now abandoned, the Copper Ridge at this location readily took the fluids that were pumped into it for several years.

The extent and characteristics of the Copper Ridge vuggy zones are poorly known, but similar facies are also reported from western Kentucky and southwestern Ohio. This potential reservoir needs to be considered as a possible sequestration backup for the Mount Simon, and its extent and characteristics should be assessed as part of phase II studies in the regional carbon sequestration partnerships. Regional equivalents of the Copper Ridge may also include similar vuggy facies in other parts of the country.

Acknowledgements

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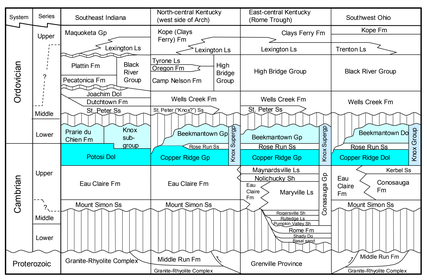
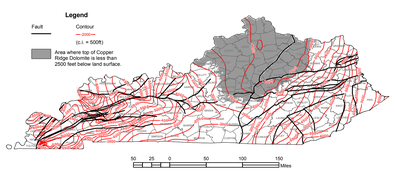


The Copper Ridge Group is a Cambrian dolomite in the lower part of the Knox Supergroup. It is overlain by Beekmantown Group carbonates and equivalents in western Kentucky and Indiana and is separated from the Beekmantown by the Rose Run Sandstone in northeastern Kentucky and Ohio. The Copper Ridge overlies the Eau Claire Formation, which overlies the Mount Simon Sandstone. The Mount Simon is a target for CO_2 sequestration in much of Midcontinent. In Kentucky, however, the Mt Simon is present only north of the Rough Creek and Rome Fault Zones.

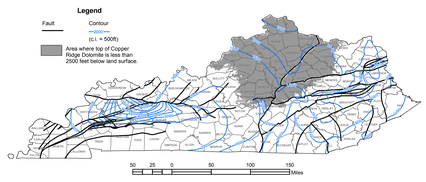
The Copper Ridge is regionally extensive. It is more than 2,500 ft deep in all but the central part of the state (shown in gray on the maps). Thicknesses of the Copper Ridge range from 1,000 to more than 7,000 feet at depths up to 10,000 ft below the surface. Similar relationships occur in adjacent states of the eastern Midcontinent. Most of its thickness consists of dense dolomite, which is why the unit is generally considered a regional confining unit or seal. There is, however, evidence for porosity and permeability in parts of the unit in some areas so that there may also be potential for CO_2 sequestration.

Regional Geology

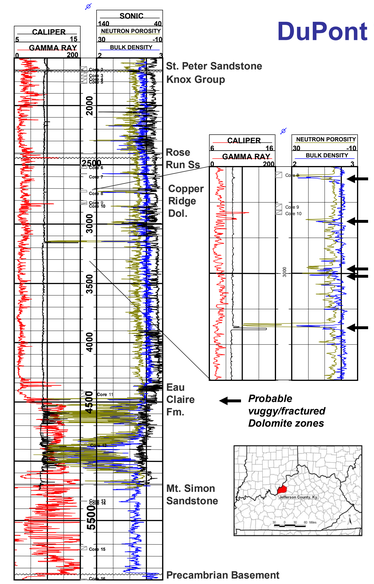
Copper Ridge Structure Map



Copper Ridge Isopach Map

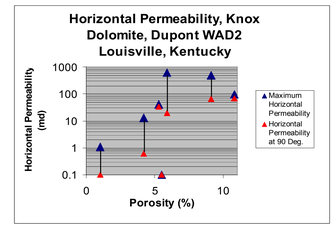


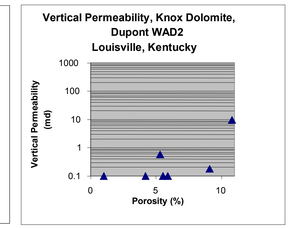
DuPont WAD #1 Waste Injection Well, Louisville, Kentucky

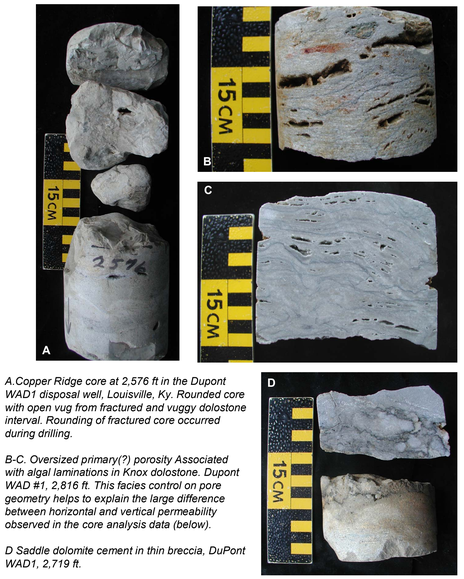


The DuPont deep disposal wells (WAD #1 and #2) in Louisville, Ky. were initially drilled to dispose of industrial liquid wastes in the Mt. Simon Sandstone. Though there is 800 ft of Mt. Simon present, no zones of sufficient permeability were found in which to dispose of the waste. Only zones in the Knox Supergroup had sufficient permeability for injection. Measured permeability from core in porosity zones range from 632 to <1 md, but the average of values at 90 degrees to the maximum horizontal permeability range yield 60 md. The actual injectivity achieved in the DuPont wells, however, was extremely high, indicating a dual porosity system with fracture and vuggy porosity contributing to significantly higher effective permeability (the DuPont # 1 well noted probable injection into cavernous zones). Both of the wells attained injection rates of 150 gallons per minute (5,100 bbls per day) with probably less than 100 psi differential into the zone. The total surface pressure in the #1 well was 175 psi and the #2 well was 100 to 200 psi (much of the pressure drop could have been friction losses). Such a Copper Ridge well would theoretically be capable of sequestering up to 48 MMT of supercritical CO_2, annually.

Note that while porosity and permeability in clastic rocks commonly show a predictable correlation, the relationship in carbonates is often variable. Core analyses are biased toward matrix values, commonly not reflecting vug or fracture permeability.







A.Copper Ridge core at 2,576 ft in the Dupont WAD1 disposal well, Louisville, Ky. Rounded core with open vug from fractured and vuggy dolostone interval. Rounding of fractured core occurred during drilling.

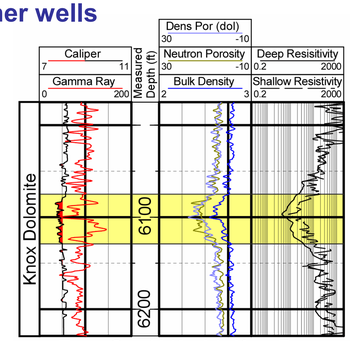
B-C. Oversized primary(?) porosity Associated with algal laminations in Knox dolostone. Dupont WAD #1, 2,816 ft. This facies control on pore geometry helps to explain the large difference between horizontal and vertical permeability observed in the core analysis data (below).

D Saddle dolomite cement in thin breccia, DuPont WAD1, 2,719 ft.

Knox porosity in other wells

Texas Gas No. 1A Kerrick well, McLean County, Kentucky

Although there are relatively few deep wells in Kentucky, southern Indiana, and southern Ohio that penetrate the entire Knox Supergroup, several contain porous and permeable zones. A thick upper Knox porosity zone occurs in the Texas Gas No. 1A Kerrick well in McLean County, Ky. It has 54 ft of net porosity above 4%. Mean density porosity is 9.3% (range 4 -17%). Both the mud cake developed over the zone on the caliper log (shaded red), and the invasion profile of the resistivity logs indicate significant permeability.

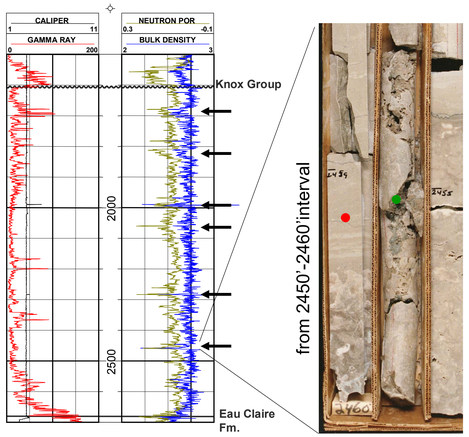


Texas Gas 1A Kerrick: Knox Zone

Porosity zones like these should not be overlooked in future Mt. Simon exploration, as there may be potential for additional "back-up" capacity in the Knox carbonates.

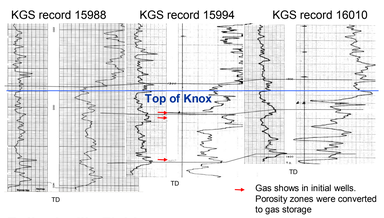
Ohio Division of Geological Survey No. 2627 stratigraphic test well, Warren County, Ohio

Numerous vuggy and/or fractured zones were cored in the Knox in the Warren County well (indicated by arrows on the log). Vuggy and/or fractured zones commonly alternate with dense, impervious zones of dolomite, so that sealing is achieved within the same formation. Examples of the vuggy/fractured zone are shown in the vicinity of the green dot and impervious zones in the area of the red dot on the core at the right.

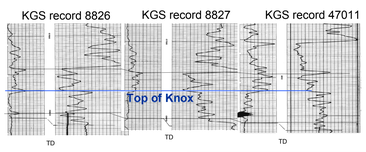


Knox gas storage fields in Kentucky

There are several gas storage fields in the upper Knox (Beekmantown Group) on the Cincinnati Arch. Although these known Beekmantown porosity zones are too shallow for supercritical CO_2 sequestration along much of the Arch, they are perspective reservoirs farther south, west, and east in Kentucky where they are deep enough for such injection. There may also be similar types of widespread porosity and permeability in similar shallow marine facies in the lower Knox (Copper Ridge) carbonates over an even larger area where supercritical CO_2 could be injected (see maps to the left). Note also that the Beekmantown contains both reservoir and seal within the same unit. The overlying dense dolomites prevent upward migration of the gas in the storage fields. It is likely that these dolomite seals would act in a similar fashion with stored CO_2. To date, however, this has not been tested.



Ballardsville Field, Oldham County, Kentucky



Eagle Creek Field, Grant County, Kentucky

Summary

1. The DuPont WAD wells in Louisville, Kentucky offer an example of the need to examine Cambro-Ordovician carbonates as potential CO_2 sequestration targets where basal Cambrian sandstones are tight or thin.
2. Most of the deep saline reservoirs studied in the Phase I regional carbon sequestration partnerships were sandstone reservoirs, but the DuPont wells show that carbonates also offer deep saline sequestration opportunities that, in some cases, could be far superior to some of the sandstone reservoirs.
3. At least five types of porosity can occur in the Knox dolomites— intercrystalline, moldic, vugular, fracture, and hydrothermal-related porosity—that can produce significant permeability. The combination of several types of these porosities can result in exceptional permabilities.
4. In existing gas storage fields, surrounding and overlying dense dolomites of the Knox Supergroup act as seals. The fact that reservoirs and seals occur in the same thick "stratigraphic" unit should not be overlooked in searching and identifying CO_2 storage reservoirs and seals.
5. The Knox dolomites need to be tested for their abilities to serve both as potential reservoirs where they are permeable due to vugginess and fracturing and as very tight, thick, impervious seals where capping dolomites are dense and unfractured.
6. Carbonate rocks will react to some degree with carbonic acid produced through dissolution of CO_2 in saline pore waters. The type and extent of these diagenetic reactions will depend on the chemistry of the host rock and pore fluids. Geochemical modeling will be required before sequestration begins.