Silurian "Clinton" Sandstone Reservoir Characterization for Evaluation of CO_2-EOR Potential in the East Canton Oil Field, Ohio

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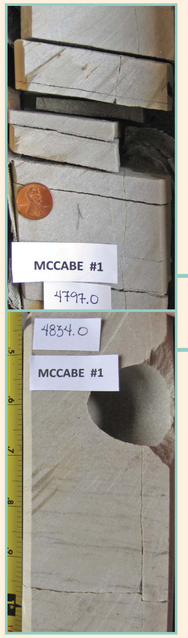
ABSTRACT

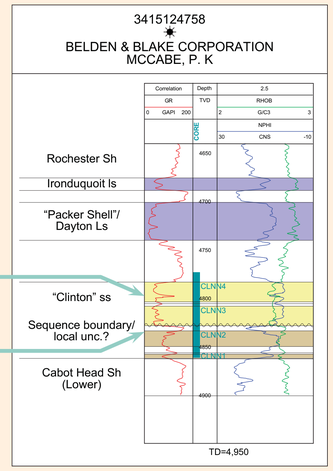
The Ohio Geological Survey has conducted a reservoir characterization and simulation of the Silurian "Clinton" sandstone in the East Canton oil field, in eastern Ohio. The primary objective was to evaluate potential for carbon dioxide-enhanced oil recovery (CO_2-EOR). The East Canton oil field has produced 95 million barrels of oil from 3,100 wells on 175,000 acres. The field is contains over one billion barrels of original oil-in-place. "Clinton" gross thickness is 110 ft; net thickness is 50 to 70 ft. Development is based on primary depletion using hydraulically fractured wells on 40 ac spacing. The reservoir contains matrix porosity of about 7 to 14% and matrix permeability of 0.1 to 0.6 millidarcies. Natural fractures may enhance permeability by as much as 10 times. Initial reservoir pressure ranges from 1,500 to 2,400 psi; existing pressure is 300 psi. The field has not been water flooded.

After a regional geologic study, a detailed local stratigraphic study of a 4-by-4-mile area of interest was developed. Over 250 wire-line logs, mostly gamma-ray/neutron density logs, were analyzed and used to create detailed maps. The five porous sandstone units within this 5,000-ft-deep reservoir were correlated. Structure, lineament, net and gross sandstone, isopach, porosity, permeability, and production maps were constructed.

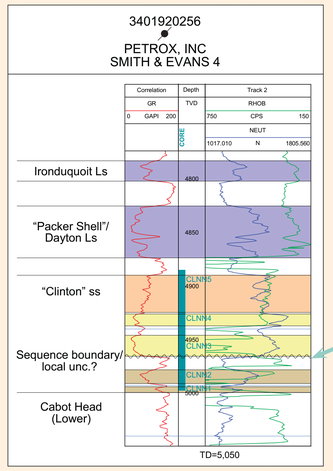
Fekete Associates Inc. constructed a CO_2-EOR simulation model of the "Clinton" reservoir in the area of interest to design a CO_2 pilot flood by examining natural and hydraulic fractures and well spacing, and by evaluating a "Huff-n-Puff" test conducted in the area of interest. The reservoir model incorporated detailed mapping, production, and fracture analyses, as well as "Clinton" fluid properties and relative permeability data from published reports.

During modeling, a history match attempted to confirm the understanding of the impact of natural and hydraulic fractures and also attempted to quantify properties controlling fracture/matrix fluid exchange. The "Huff-n-Puff" provided insight into CO_2 movement and the impact of oil swelling. Simulation of CO_2 pilot flooding evaluated operational parameters impacting flood performance, such as well spacing and pattern configuration. The project would benefit from additional properties testing and more numerical simulation.

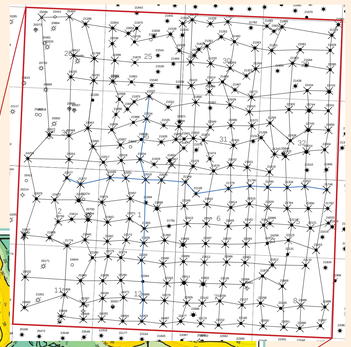




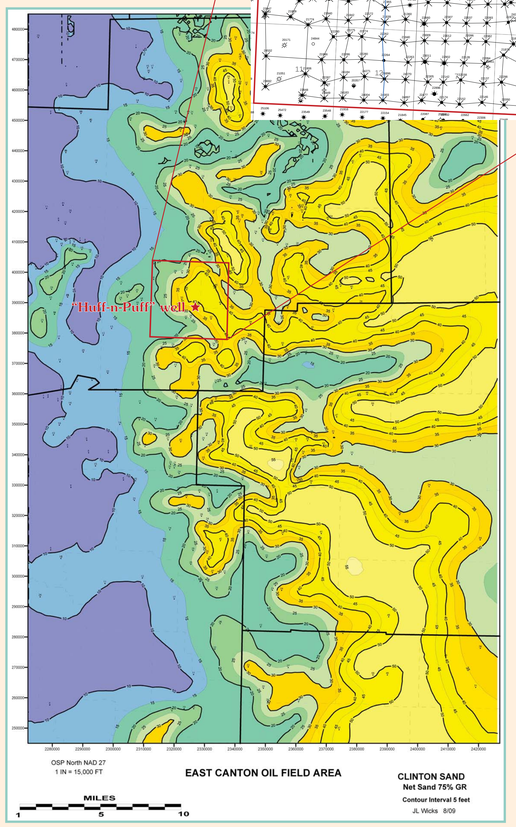
Wireline log of the McCabe #1 cored well showing the formation/unit boundaries of the "Clinton," overlying, and underlying intervals. The oriented core photos (left) illustrate fractures in the "Clinton" interval, which are important for production in this tight reservoir.



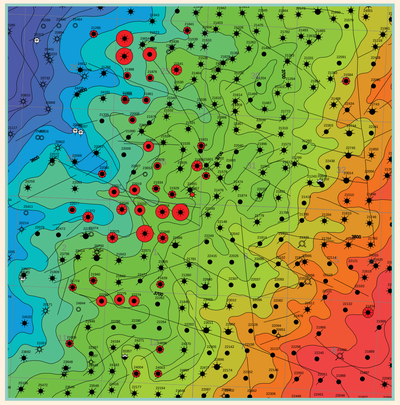
Wireline log of the Smith and Evans #4 cored well showing the formation/unit boundaries of the "Clinton," overlying, and underlying intervals. The core photograph (right) shows the sharp boundary at the base of the "Clinton" reservoir unit 3 and the underlying shale unit. This sharp contact (S3 of Ryder, 2004) is thought to represent a sequence boundary or a local unconformity.



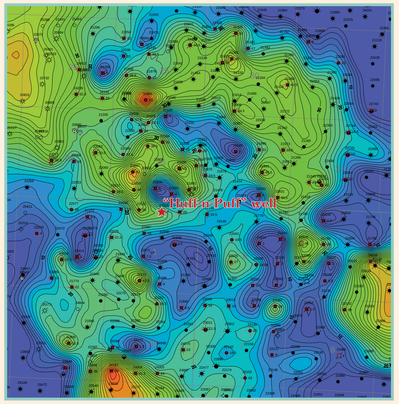
Location map of the area of interest showing all the "Clinton" penetrations and the cross section lines. Also shown is the CO_2 cyclic test ("Huff-n-Puff").



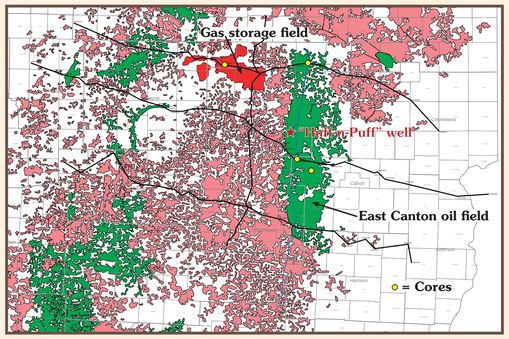
Regional net sandstone map of the "Clinton" interval based on a gamma ray curve cutoff of 75%. Also shown are the 16-section area of interest and the "Huff-n-Puff" test.



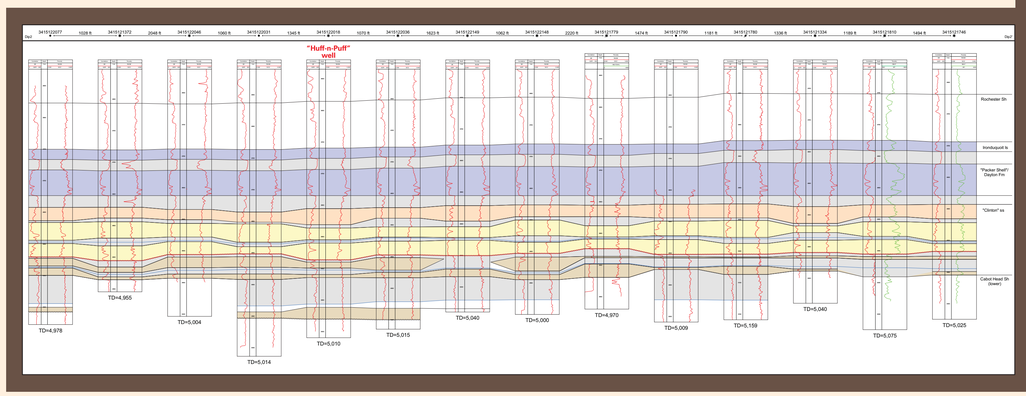
Structure map on the base of the "Packer Shell"/ Dayton Formation with interpreted lineaments from structure contours, LiDAR, and DEM. Also shown is a bubble map of cumulative production (red circles).

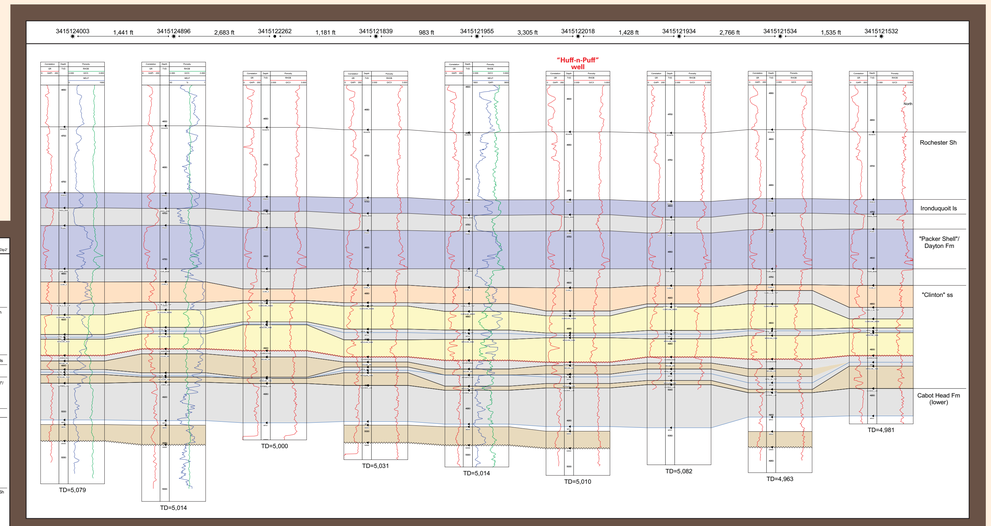


Net sandstone map of the entire "Clinton" interval using a RHOB cutoff of 2.55 gm/cc.



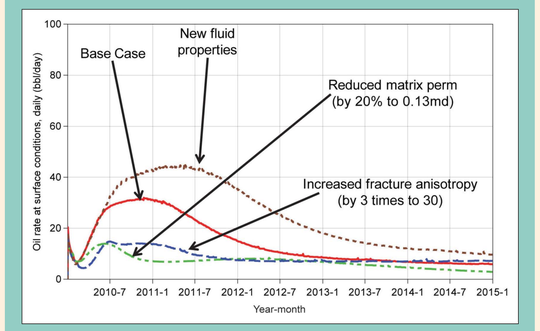
Map of northeast Ohio showing all of the "Clinton" oil and gas fields, "Clinton" cores, and the regional cross section lines.





Detailed stratigraphic cross sections trending east–west (left) and north–south (above) through the area of interest (see blue line in the inset map at upper left). These sections illustrate the heterogeneity of the "Clinton" interval and the five sandstone units that were correlated and mapped. Datum is the base of the "Packer Shell"/ Dayton Formation.

RESERVOIR SIMULATION MODELING



Forecast of oil production rate for the East Canton oil field pilot area central producer for the five-year simulation period showing the Base Case and three sensitivity study cases. Modified from Fekete Associates, Inc. (2009).

SOME OUTPUT FROM SENSITIVITY TESTS
(reservoir parameters and pilot design were varied)

- Rock and fluid properties have a significant effect on oil production. In particular, for the rock, lower matrix permeability or a larger fracture anisotropy ratio could lead to a significant increase or reduction in oil production rate.
- Lowest oil production is realized from the pilot area when matrix permeability is reduced to 20 percent of the Base Case (0.13 md compared to 0.65md).
- Significant reduction in forecasted production occurs when the permeability anisotropy ratio in the fractures is increased from the Base Case of 10 up to 30. If a value of 30 is used, greater preferential movement of CO2 occurs along the fractures, and consequently less oil is displaced towards the central producer.
- If reservoir fluid properties differ from assumed, oil production could be significantly higher.
- Shutting in offset producing wells did not improve capture of displaced oil by the central producer.
- Shutting in the water injectors did not reduce oil production significantly. The potential for creating a water shield should be further evaluated.

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