Case History of a CO2 Sequestration Study in Progress, Dickman Field, Kansas

Christopher L. Liner, Tom Bjorklund, and Jianjun Zeng, U. of Houston; Kurt Marfurt, U. of Oklahoma*

Summary

The goal of this project is to apply state-of-the-art reservoir characterization methods to a likely sequestration target in the U.S. mid-continent. The workflow involves seismic processing, inversion, volumetric attributes, log analysis, petrophysics, and, ultimately, reservoir simulation. A regional deep saline aquifer is the primary CO2 sequestration target, with a shallower mature, depleted oil reservoir serving as a secondary objective.

Introduction

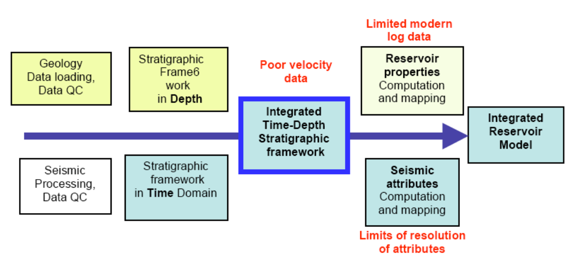
Depleted petroleum reservoirs and deep saline aquifers are prime targets for potential CO_2 sequestration. Specific objectives of the Dickman CO2 project are use of seismic attributes to map 3-D reservoir properties (thickness, porosity, permeability and HC saturation), construction of a reservoir model validated by production history matching, and use of the model to predict CO2 injectivity and storage potential.

The Dickman Filed is located in Ness County, Kansas, and has produced about 1.7 million barrels of oil since its discover in 1962. Fractured Mississippian porous and solution-enhanced shelf carbonates (dolomites) of Mississippian age are oil-productive from a small structural closure, which has an OWC at about 1981 feet subsea and an oil column of about 35 feet. Figure 1 shows a location map, Mississippian time structure, and profile A – A'. The contact between the porous Mississippian and the overlying seal (Pennsylvanian shale and conglomerates of the Cherokee Group) is a karst surface, which is a slight angular unconformity and dips to the west. The Dickman Field reservoir also includes sandstones of the Lower Cherokee group locally deposited on the subaerial karst of the Mississippian-Pennsylvanian regional unconformity. These two reservoirs are the first target of this study. A secondary sequestration target, is a porous 200 to 300 feet thick Mississippian saline aquifer underlying the oil accumulation. A stratigraphic cross section along profile A – A' is shown in Figure 2.

Available data and workflow

Dickman Feld well and seismic data have been used to conduct seismic attribute and well data studies. The seismic survey includes a prestack time-migrated all-stack volume, plus near-, middle- and far-stack volumes, as well as range-limited impedance inversions of the migrated seismic volumes. Geological data include 130 wells, 37 of which have well logs including GR (33), resistivity (18) sonic (5), un-corrected and corrected Neutron (31), and density (4). Seven boreholes have core porosity and permeability analysis for the reservoir property study. Of all wells in the studied area, only three completely penetrated the deeper saline aquifer zone (the second target zone of this study), and there is no check shot survey to tie interpretation in depth and time domains. Moreover, only one borehole contains the full suit of well logs needed for complete reservoir property analysis. These conditions set several challenges to this study. We must obtain the time-depth tie from limited wells with sonic logs and extrapolate the tie through non-conventional methods, calibrate the input data for the reservoir property computation using wells without complete log sets, and due to very limited well-control rely on seismic interpretation and extrapolation from the better-characterized first target zone to understand the second target zone. Figure 3 shows a very preliminary depth-isopach map for the porous Mississippian formation based only on well control. This map should be viewed with caution, since it is likely to contain artifacts of control and contouring method.

The work flow consists of three phases. First, seismic and well data are used to develop an integrated intepretation, taking special care in the areas of log quality control and petrophysics. Second, geometry of the target zones are determined through a consolidated stratigraphic framework in depth tied to time-domain horizon interpretations. Third, reservoir properties are evaluated and the volumetric attributes extracted from elastic impedance inversions and horizon attributes. The result will be a gridded geological model that includes the oil reservoir as well as the deeper saline aquifer. A final stage of the project will involve flow simulation through the geologic model to test CO2 injectivity and retention time for both target zones. The Phase One tasks were completed in 2007. Phase Two and Phase Three tasks are targeted for the first half of 2008. Preliminary results from Phase Two are documented in this paper.



Dickman Field CO2 Project

Preliminary results

The two reservoirs (Lower Cherokee sandstone and Mississippi porous carbonate) immediately above and below the Mississippi unconformity are juxtaposed laterally at channel edges (see Figure 2), and therefore fall within the same time window for seismic attribute computation. Lateral variation in reservoir geometry and rock properties may be indicated by subtle variations in seismic response which can be visualized through seismic attributes (Marfurt, 2006). We have computed volume attributes using a 10 ms operator length (see Figure 4). Preliminary results indicate negative curvature attributes show evidence of a regional fracture framework (aligned N45E and N45W) upon which the Mississippi karst morphology was developed. Geologic and production data suggest the northeast-trending fractures are impermeable (likely clay and silt filled). The northwest-trending fractures are open and form conduits for water to move from the underlying aquifer into the oil zone (Nissen et al., 2006; Nissen et al., in press)

Conclusions

Initial interpretation of volume curvature results indicates this attribute correlates well with the regional fracture framework that penetrates the target formations. To better differentiate the lateral variation of reservoir geometry and properties at the primary target, a smaller operator length (2ms) will be tested in future computations. This same operator will also be used in horizon attribute calculations. Finally, integration of petrophysics, attributes, and impedance volumes will lead to an integrated geologic model for flow simulation.

Acknowledgements

Several current and former University of Houston Department of Geoscience graduate students have contributed to this project, including Zhengyun Zhou and Na Li. This work is funded by DOE (Award DE-PS26-05NT42472-07).

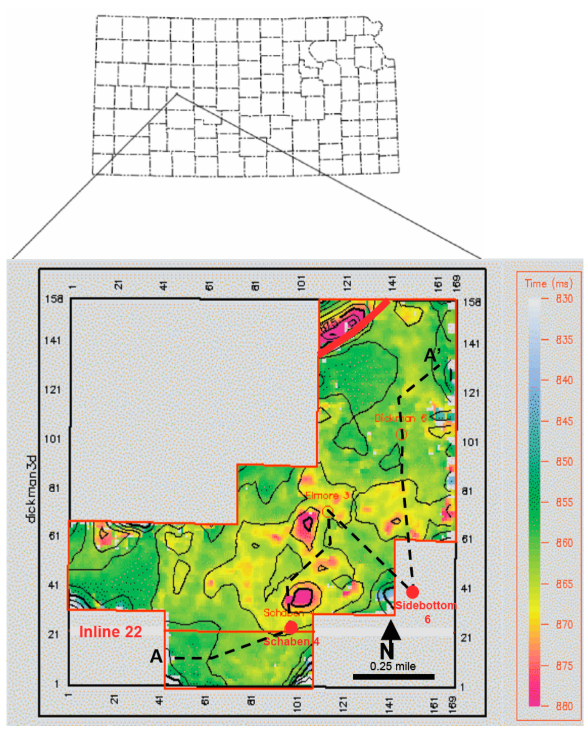


Figure 1: Kansas state map showing counties and study area. Detail graphic shows outline of 3D seismic survey, time structure of Mississippian surface, and profile A – A'.

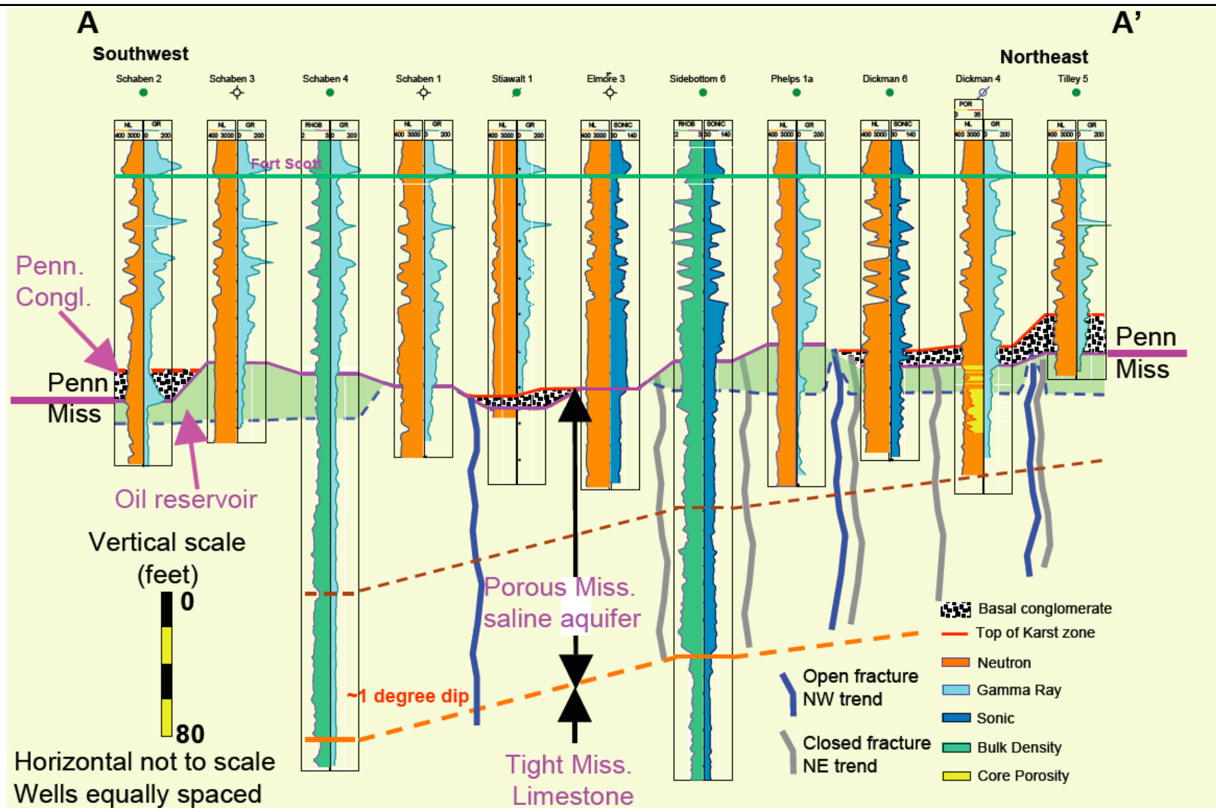


Figure 2: Stratagraphic profile along A – A' in Figure 1. The CO2 injection targets under study are the depleted Mississippian oil reservoir and the deeper porous Mississippian saline acquifer.

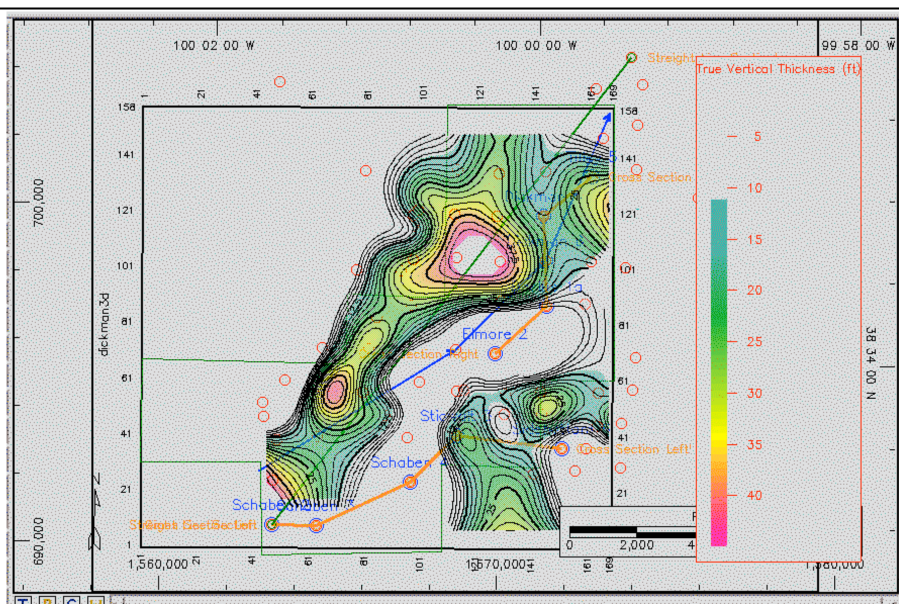


Figure 3: The Mississippi porous carbonate reservoir mapped using well control only (49 data points with both the oil and water contact and the top of Mississippi Unconformity). The Lower Cherokee reservoir is mainly within the area of zero thickness of the Mississippi porous carbonate reservoir.

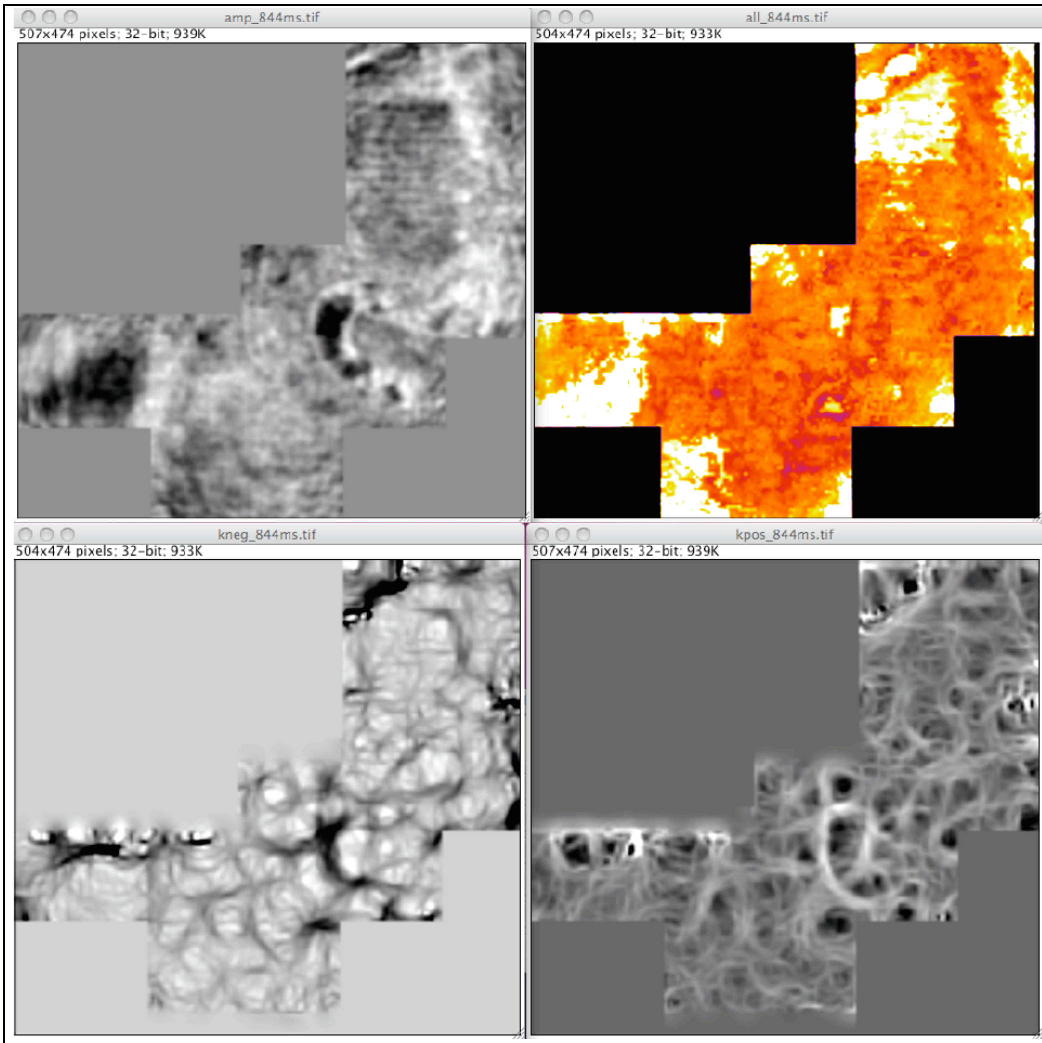


Figure 4: Selected seismic attributes from the 3D data at the Mississippian level (844 ms). Clockwise from upper right: Amplitude, impedance computed from full-range PSTM stack (orange to white is low to high value), negative curvature, and positive curvature. In all grayscale images, white is max positive and black is max negative. See Figure 1 for scale.