ABSTRACT

Title: **Application of Cutting-Edge 3-D Seismic Attribute Technology to the Assessment of Geological Reservoirs for CO2 Sequestration**

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OBJECTIVES

The goals of this three-year project are to develop innovative 3D seismic attribute technologies and workflows to assess the structural integrity and heterogeneity of subsurface reservoirs with potential for CO_2 sequestration. Our *specific objectives* are the following.

1. Apply advanced seismic attributes to quantify the thickness, porosity, permeability and lateral continuity of CO2 sequestration target reservoirs and generate a reservoir model.

2. Validate the reservoir model with field-based petrophysical and engineering data and simulation studies.

The primary study areas are **Dickman field**, Kansas; **Teapot Dome field**, Powder River Basin, Wyoming; and **Patoka and Sciota fields**, Illinois Basin. These areas represent a range of geologic settings associated with major coal producing and emission generating regions of the United States.

ACCOMPLISHMENTS TO DATE

Due to the large size of the datasets and the piecemeal acquisition of the data, the majority of our work in 2006 has been focused on data assembly, quality control of data and seismic data processing.

Dickman Field: Conventional coherence, inline and cross-line energy gradient, model-based impedance inversion and six different curvature attributes have been generated from a post-stack, time-migrated 3-D seismic data volume over a 2 square-mile area of Dickman field. The attributes reveal subtle, fracture-related lineaments in the porous Mississippian, the CO2 sequestration target. The orientations of the lineaments are approximately N45E and N45W. Geologic and production data suggest that the northeast-trending lineaments are related to clay and silt-filled fractures forming reservoir compartments, while the northwest-trending lineaments are related to open fractures forming conduits for water. The discrimination of open versus sealed fractures within CO2 sequestration reservoirs is critical for the management of injection and storage of CO2 in the reservoir.

In order to automate the attribute analysis process and generate results in a format suitable for reservoir simulation studies, we have applied the topology functionality of GIS technology to the Dickman field seismic and well data. Our initial results are encouraging and indicate that the sum of NE-trending lineament attributes (lineament intensity) near wells generally varies directly with thickness of the karst zone in the well. If further studies substantiate this correlation and can be related quantitatively to permeability trends in the reservoir, this work could

lead to a much-improved reservoir model and better estimates of CO2 reservoir storage capacities and fluid flow characteristics.

Teapot Dome Field: Inlines, cross-lines, and time slices from the seismic data volumes have been examined from a commercially-processed, pre-stack, time-migrated 3-D data volume over the 28 square mile area of Teapot Dome field and indicate good data quality. A preliminary screening of seismic attributes indicates that coherency, various curvature attributes and modified amplitude attributes have the most potential to correlate with the reservoir properties of the Tensleep Formation, the CO2 sequestration target. Possible fracture patterns and faults are evident on attribute maps overlying the Tensleep and near the basement. Similar patterns are not clearly-defined within the Tensleep. In-house reprocessing of the pre-stack 3-D seismic data to improve the resolution potential of advanced attributes has nearly been completed.

Patoka and Sciota Fields: No wells penetrate the Mt. Simon sandstone, our primary CO2 sequestration target, in the Patoka Field area, and a major issue has been the presence or absence of the Mt. Simon in the Patoka area. Correlations between synthetic seismograms from the nearest deep wells and seismic data indicate that the Mt. Simon is indeed present in the Patoka area. To compensate for the lack of deep well data in the Patoka area, we have acquired 3-D seismic data and well data from the Sciota Field, a Mt. Simon gas storage field in the shallow Illinois Basin to use as an analog for the Mt. Simon in the Patoka area.

We have produced 25 attribute volumes from 3-D post-stack seismic data in both fields and have generated a series of positive and negative curvature horizon maps from near the top of the Mt. Simon to below the base of the Mt. Simon for an overview of the quality of the seismic data and the three-dimensional extent of attribute patterns. Positive curvature attribute anomalies correlate well with the main structural features in each field. The significance of secondary attribute anomalies is not yet clear. Processing of pre-stack seismic data at Patoka has shown that ground roll has severely affected the resolution of the post-stack seismic data. The pre-stack processing should remove the ground roll in the Patoka seismic data and result in better correlations between deep wells, Patoka seismic data and Sciota seismic data.

FUTURE WORK

1. Complete the time and depth migrations of the three sets of pre-stack 3-D seismic data.
2. Determine the porosity and thickness distributions of the CO2 sequestration target reservoirs based on integrated analyses of well logs, production data, conventional seismic data and seismic attributes.
3. Critically compare seismic attributes derived from reprocessed, pre-stack migrated seismic data and the original migrated pre-stack and post-stack seismic data.
4. Investigate topological relationships among a range of attributes and reservoir properties determined from well data using GIS applications.
5. Construct structurally and stratigraphically integrated 3-D geomodels of reservoirs.
6. Simulate primary oil production and evaluate effects of CO2 injection in Dickman Field.
7. Prepare final report including a “best practices” workflow for the assessment of CO2 sequestration targets using advanced seismic attributes.

LIST OF PAPERS PUBLISHED, CONFERENCE PRESENTATIONS AND STUDENTS SUPPORTED UNDER THIS GRANT

1. **Paper submitted for publication:** Nissen, S. E., K. J. Marfurt, T. R. Carr and E.C. Sullivan, *in review*, Using 3-D seismic volumetric curvature attributes to identify fracture trends in a depleted Mississippian carbonate reservoir: Implications for assessing candidates for CO2 sequestration, AAPG Special Publication: *Carbon Dioxide Sequestration in Geological Media -- State of the Art.*
2. **Conference oral presentation:** Bjorklund, T., 2006, Reservoir characterization for CO2 sequestration, Center for Applied Geosciences and Energy (CAGE) Annual Meeting, 12/4/2006, University of Houston Hilton Hotel.
3. **Supported students during performance period:** Tayo Akintokunbo, Mingya Chen, Qifeng Dou, Dragan Lazarevic, Damayanti Mukherjee, Jenny Zhou