AAPG HEDBERG CONFERENCE

"Geological Carbon Sequestration: Prediction and Verification"
August 16-19, 2009 – Vancouver, BC, Canada

Geologic Uncertainty and Geophysical Challenges in Developing a Carbon Sequestration Project

H.E. Leetaru[a], D. Paddock[b], J. H. McBride[c], and M. L. Couëslan[d]

[a]Illinois State Geological Survey, Champaign, Illinois
[b]Schlumberger WesternGeco, Houston, Texas
[c]Brigham Young University, Provo, Utah
[d]Schlumberger Carbon, Services, Calgary, Alberta, Canada

Sequestration sites are evaluated by mapping the local geological structure and confirming the presence of both a reservoir and an impermeable seal that is not breached by significant faulting. The site selection and development processes of a U. S. Department of Energy-funded carbon sequestration project at Decatur, Illinois, USA are used as a case study for the creation of workflows to evaluate geologic uncertainty. The target reservoir for the Illinois Basin - Decatur Project is the Cambrian Mt. Simon Sandstone. The Cambrian Mt. Simon Sandstone is a regional "blanket" sandstone that underlies large portions of the Midwest of the United States and is the primary saline reservoir with carbon sequestration potential in the region. The Mt. Simon attains a maximum thickness in the Illinois Basin of 792 m (2,600 ft) in east-central Illinois and west-central Indiana and is an ideal target for sequestration. The Eau Claire Formation, directly overlying the Mt. Simon, provides the primary seal that will prevent CO_2 migration into shallower formations.

Deep saline reservoirs, such as the Mt. Simon, are an ideal candidate for carbon sequestration because they commonly have no other economic use, have thick intervals that could contain large volumes of CO_2, and have very few well penetrations that have penetrated the primary seal. There are, however, a number of uncertainties that could increase the risk for successful completion of the project. For example, at least ~548 m (1,800 ft) of topographic relief existed on the top of the basement surface prior to Mt. Simon deposition. The Mt. Simon reservoir and Eau Claire seal are thin or not present where basement is topographically high, whereas the low areas can have thick Mt. Simon and thick Eau Claire. These paleotopographic high areas must be located using reflection seismic profiles in order to reduce the uncertainty in attaining an appropriate stratal thickness.

Knowledge of the tectonic history of the basin can be crucial in understanding the potential pathways for upward migration of CO_2 along faults. In Illinois, the earliest tectonic event was the break-up of the super continent Rodinia in the late Precambrian, the second was the Taconic Orogeny in the Ordovician, the third was the Acadian Orogeny in the Devonian, and the final was the Alleghanian Orogeny in the Pennsylvanian. Faults generated during the Rodinia rifting event do not penetrate the primary seal and are thus not considered a potential leak zone. Any progressively younger faults increase the risk of leaks through the primary (Cambrian Eau

Claire), secondary (Ordovician Maquoketa), and/or tertiary (New Albany) seals. The identification of these faults is limited by the frequency content (hence, resolution) of the seismic reflection data.

The Illinois Basin - Decatur sequestration site is located in an urban setting with adjacent industrial, residential, and educational properties. Acquisition of geologic and geophysical data is more difficult and costly in such an urban setting. Designing a seismic program that meets the site characterization and monitoring objectives of the project is not trivial at such a site. The Illinois Basin - Decatur sequestration site has limited access for seismic surveys as well as high levels of industrial and cultural noise from surrounding plants, traffic, and trains which must be adequately sampled for successful attenuation. The challenges faced in designing a seismic program at the site will be relevant to future commercial projects where CO_2 storage is co-located at a plant site with extensive infrastructure and site access restrictions.

After drilling the injection well, the seismic data will be calibrated using the new well log data. Seismic interpretation, inversion, and geomechanical modeling can be used to derive rock properties, including lithology, porosity, volume of clay, stress, and the effects of pre-existing fractures. Mapping rock properties at locations away from the injector well will identify heterogeneities within the Mt. Simon, such as high porosity zones, that may have a significant effect on the movement of CO_2. It may also help identify stratigraphic features in the Eau Claire, which may affect the long-term storage integrity at the site.

Regional outcrop and borehole mapping of the Mt. Simon in conjunction with mapping seismic reflection data can facilitate the prediction of the reservoir, seal, Precambrian paleotopography, and faults. Therefore, any potential site must, at the minimum before injection can begin, have seismic reflection data calibrated with drill-hole information in order to evaluate the geologic and geophysical uncertainty.