Geophysical Imaging of Precambrian Crust Beneath Illinois Basin Driven by Carbon Capture and Storage

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Abstract

Over the past 15 years, the Illinois State Geological Survey (ISGS) has acquired a wealth of new long-record, high-resolution seismic reflection data (two-dimensional and three-dimensional) in the Illinois Basin. The data were acquired as part of the ISGS' ongoing program of evaluation of potential reservoirs in the Basin for Carbon Capture and Storage (CCS) as supported by the United States Department of Energy. Interpretation of the seismic data is constrained by dedicated borehole information and vertical seismic profiles. Understanding the structure and the tectonic and magmatic history of the Precambrian basement is critical for assessing the suitability of the lower Paleozoic (basal Upper Cambrian) Mt. Simon Sandstone as a target CCS reservoir in the Illinois Basin. Beneath the Paleozoic section of the Basin lies one of the most seismically reflective regions of Precambrian crust in the USA. The ISGS' CCS programs thus have provided an unprecedented opportunity to study deeply buried Precambrian rocks using state-of-the-art industry geophysical technology. The first-order observation comes from long-record (at least 3 s) seismic profiles on which inclined high-amplitude reflectors are imaged within Precambrian basement. These reflectors are several 10s of km long, highly coherent, and, where they extend up to the top of the basement, make an angular unconformity with the base of the overlying Paleozoic section. The reflectors dominate much of the upper Precambrian crust beneath the Basin, are part of a broad, roughly bowl-shaped pattern of basement reflectivity, and are interpreted as mafic igneous sills or the tops of igneous plutons. A second-order observation involves intermittent layered seismic stratigraphy beneath

the base of the Paleozoic section underlain by a strong basement reflector, which thus constitutes a Precambrian “seismic stratigraphic sequence” (e.g., the Centralia Sequence). This sequence can be interpreted as pre-Basin rift strata, volcaniclastic material, or layered felsic and/or mafic igneous rocks. A third-order observation for Precambrian reflectivity is the segmentation and/or irregular shape of strong intra-basement deep (basal) reflectors. These reflector irregularities are interpreted as discontinuities initiated by steps or offsets formed during the igneous intrusive process or caused subsequently by tectonic faulting, or both. Where three-dimensional seismic data are available (Illinois Basin Decatur Project (IBDP), Decatur, Illinois), these discontinuities can be associated with potential deep-seated faults that have propagated up to the interface between Precambrian basement and the overlying Paleozoic sedimentary section. In this way, basement tectonics may influence the development of the highly coherent (and, in places, planar) microseismicity caused by carbon-dioxide injection at the IBDP site.