Geomechanical Characterization of an Acid Gas EOR, CO_2 Sequestration and Monitoring Project, Zama Field, Alberta

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Summary

A comprehensive monitoring, mitigation and verification (MMV) plan is critical to the success of any geological carbon sequestration project utilized as a method of reducing CO_2 emissions to the atmosphere. Beginning in October, 2005 and running through September, 2009 the Zama Oil Field in northwestern Alberta, Canada has been the site of acid gas (approximately 70% CO_2 and 30% H_2S) injection for the simultaneous purpose of enhanced oil recovery (EOR), H_2S disposal, and sequestration of CO_2. The Plains CO_2 Reduction (PCOR) Partnership has conducted MMV activities at the site throughout this period while Apache Canada Ltd. has undertaken the injection and hydrocarbon recovery processes. This project has been conducted as part of the US Department of Energy (USDOE) and National Energy Technology Laboratory (NETL) Regional Partnership Program and includes the participation of Natural Resources Canada, the Alberta Department of Energy, the Alberta Energy & Utilities Board and the Alberta Geological Survey.

In an effort to research caprock integrity and the risk of leakage during these field operations a first order geomechanical characterization has been undertaken of the injection reservoir, comprising the Keg River Formation and its Zama Member, and the overlying Muskeg Formation caprock. This poster will summarize key data obtained from a laboratory and wireline log-based analysis of the petrophysical and mechanical properties, and the in-situ stress state in this setting.

Vertical stress estimates were determined by integrating bulk density logs in the area, while accounting for the unlogged portion above the surface casing shoe. Horizontal stress magnitudes in the caprock and reservoir were estimated from regional and local stress data for this part of Alberta.

Dedicated stress tests such as a mini-frac, a microfrac profile, or an extended leak-off test have not been conducted in the caprock to date in this field. Minimum and maximum in-situ horizontal principal stress orientations in the Zama field and surrounding area, measured within and above the injection interval, were determined from borehole breakouts.

Vertical and horizontal in-situ stress changes have occurred within the reservoir and surrounding caprock due to initial production in the pinnacle reef, subsequent water flooding, and most recently acid gas injection. The prediction of these stress changes is a complex function of the reef geometry, the poro-elastic response of the reservoir, pore pressure changes over time in the reef and reservoir, and possibly temperature changes. For this poster, only the horizontal stress changes due to poro-elastic effects have been considered. 3D geomechanical modelling will be used to simulate the more complex problem once the mechanical properties and in-situ stresses are adequately constrained.

Basic porosity and unstressed permeability distributions from two cored intervals through the Zama Member and Keg River Formation in two pinnacle reefs in the setting are summarized. Ultrasonic shear and compressional wave velocity measurements have been made under unconfined and confined stress conditions on anhydrite and dolomite from the Muskeg Formation caprock. Triaxial rock strength and unconfined compressive strength (UCS) tests are summarized using Mohr Coulomb and Hoek Brown failure criteria. Static and dynamic elastic properties measured under anisotropic stress conditions are compared. A Schmidt rebound hammer was used to develop a profile of pseudo-static Young's moduli and UCS though the Muskeg Formation caprock and portions of the Keg River Formation in two wells.

Dynamic log-derived elastic properties and their static equivalents were determined for the Muskeg and Keg River Formations in two wells. In order to do this a synthetic shear velocity relationship was developed using recent data from an offset well in the region. These log-derived properties are compared to the static laboratory and Schmidt hammer derived data.

Pore volume compressibility tests were also made on a select number of core plugs of the Keg River Formation under relevant reservoir pore pressure and stress conditions, along with stress-dependent permeability and elastic properties.

Statistical relationships describing the petrophysical and mechanical properties of the rocks investigated in this study are presented. Key learnings with regard to the heterogeneity of the vuggy dolomitic reservoir versus the evaporitic caprock are highlighted.

The data presented in this poster have a variety of applications to EOR and CO_2 sequestration in pinnacle reefs of the type being investigated in the Zama field. In addition to caprock integrity, the data can be used to assess optimal injection strategies, design well drilling, completion and stimulation programs, develop and interpret reservoir monitoring data, and conduct coupled geomechanical-reservoir simulation studies of acid gas injection.