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A probabilistic petrophysical modeling and coupled thermal-geomechanical study of the Deadwood and Winnipeg Formations

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Summary

The Aquistore Project is a deep saline CO_2 storage project into the Deadwood and Winnipeg Formations in southeastern Saskatchewan. CO_2 injection generates a dynamic environment in the reservoir, in which pore pressure increases, the effective stress decreases, and temperature changes as a function of injection rate, time, and the distance form the well. It is now recognized that such geomechanical processes may influence fluid flow, cap-rock integrity and well integrity (Zhang et al., 2019).

To model the behavior of the CO_2 in the subsurface, assure the safety of the operation, and assist in tracking the advancement of the CO_2 plume, a better understanding of the subsurface conditions (mineralogy, water saturation, capillary pressure) need to be attained. In addition, the constitutive law of the rock (the relationship between stresses and deformation) and its affect on flow rate need to be investigated. This paper presents the preliminary stages of development for a comprehensive petrophysical - thermal - geomechanical model for the Deadwood and Winnipeg Formations in the vicinity of the Aquistore well in southern Saskatchewan.

Methods

A petrophysical model based on downhole well-logs was built using the software GAMLS. This model provides a regional lithostratigraphic and petrophysical framework and identifies rock-types end members within the Deadwood and Winnipeg Formations. Based on this model, a multimineral analysis was performed to calculate the effective porosity (storage capacity) as well as capillary and clay bound water saturation which are important for flow modeling. The petrophysical model, together with hyperspectral core scans and core description guided samples selection for routine and special core analysis and thermal-geomechanical and flow testing.

Results, Observations, Conclusions

A petrophysical GAMLS model based on GR, bulk density (RHOB), neutron porosity (NPHI), and the photoelectric effect (PEF) curves clearly identified 6 rock-types end members in the Winnipeg and Deadwood section (figure 1). Helium pycnometry and nitrogen permeability as well as simple geomechanical testing (direct shear and Brazilian tensile strength tests) performed on the core retrieved from the Aquistore injection well confirmed the existence of several of the end members depicted by the petrophysical model. Water saturation was calculated with a multimineral analysis and will be compared and verified with future NMR (Nuclear Magnetic Resonance) work on samples taken from a nearby well.

Geomechanical testing will continue with the goal of generating a constitutive law for each rock type. In addition, high pressure-high temperature Triaxial testing will continue and provide more information on the mechanical behavior of the rock at reservoir condition, as well as information on the effect of stress and temperature on fluid flow in the reservoir.

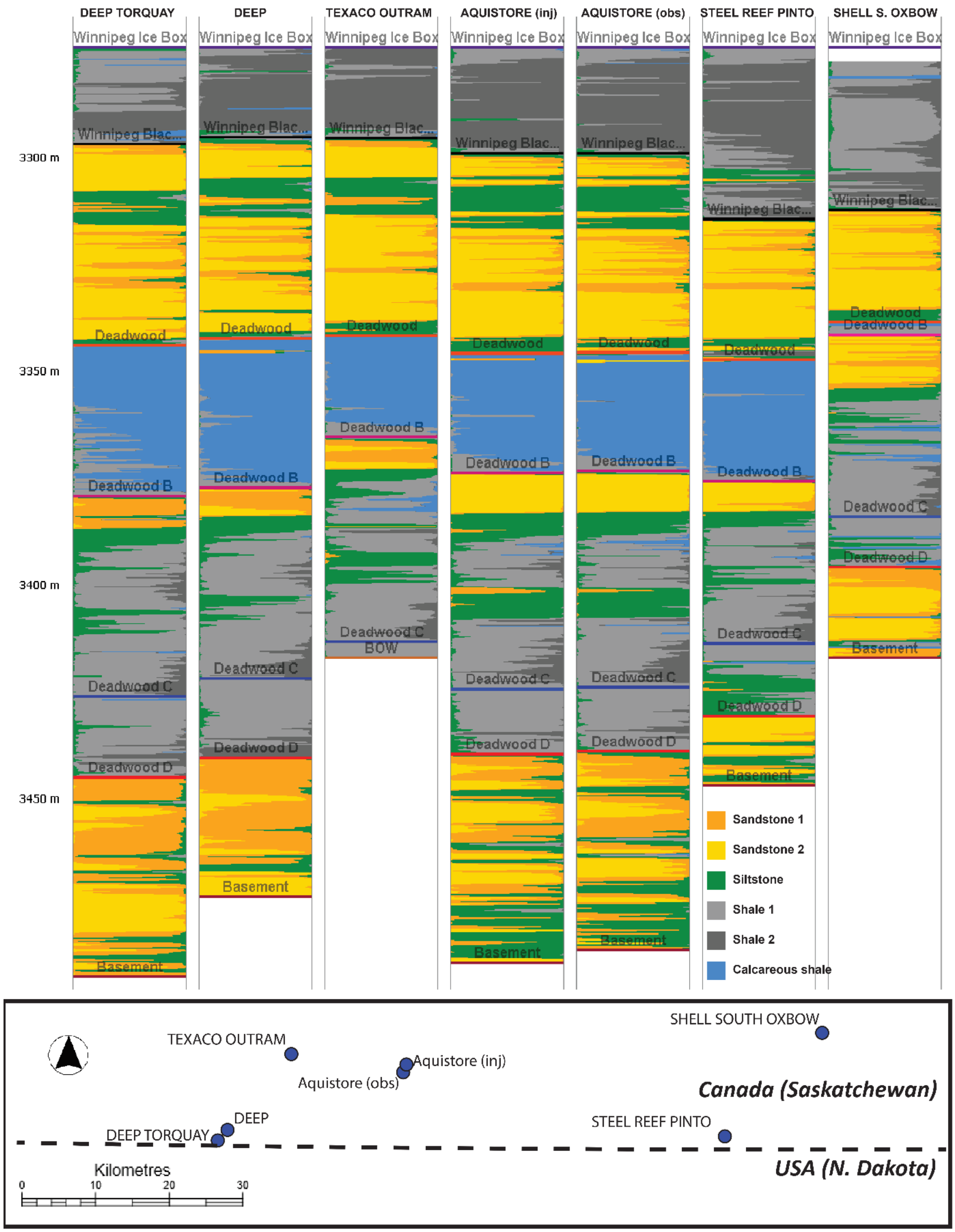

Figure 1: A cross-section through the regional probabilistic model for the Aquistore project area. The model is based on well logs and identifies 6 rock types in the sequence.

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References

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