

Pore Space Evaluation from 3D Digital Rock Analysis and Well Logs Using Deep Learning Approaches

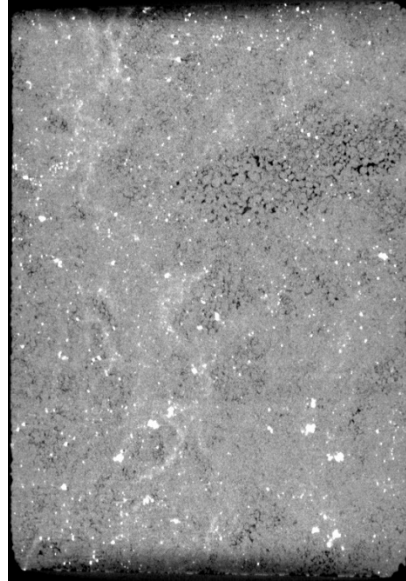
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The Deadwood Formation of the Williston Basin has been one of the best candidates for CO₂ storage and geothermal energy in recent years, evidenced by a number of commercial and pilot projects in Alberta and Saskatchewan. With variation of depth and thickness across the two provinces, the formation is primarily characterized as quartz-rich fine/coarse rounded sandstones interbedded with siltstones and shale, interpreted to range from deeper water marine (shales) to upper and lower shoreface settings (siltstones to sandstones). The basal sandstone unit of the Deadwood is composed of a conglomerate and sandstone zone, which unconformably overlies the Precambrian basement (Kreiss 2004). The siliciclastic portions of the Deadwood, carbonate beds and cementation, are more commonly seen within the middle and upper zone.

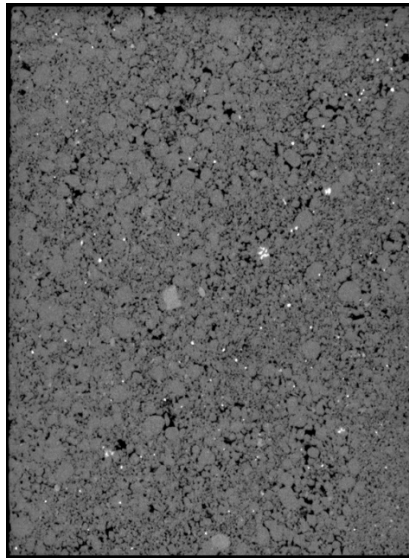
The pore space quality, which is quantified by the formation's porosity and permeability, is the determining geological factor for the success of a CO₂ storage or geothermal project. Historically, characterization of Deadwood formation has been suffered from scarcity of drilled wells and even less cored samples. This work summarizes a continuation of our efforts on developing an integrated pore space evaluation strategy for 3D digital rock analysis and well logs using deep learning approaches. While well logs are available for every drilled well, they are indirect and have low precision from tens of centimeters to several meters. On the other hand, advanced micro-CT directly "3D visualizes" cores at resolution of tens of micrometers that are comparable to pore space sizes. Integration of these two groups of information enables calibration of large sample size with low accuracy by small sample size with high accuracy.

This strategy has been applied on the cores from the Aquistore project in Estevan and from the wells in Regina where geothermal development is being examined. During drilling of these wells, a robust diamond core and sidewall coring program was undertaken. Typical core analyses of porosity, permeability, and fluid composition were taken and have been reported. There are also comprehensive well logs conducted on the wells. Core plugs taken from different intervals were subjected to micro-CT scanning at PTRC Sustainable Energy's new Energy Innovation Hub facility. As seen from below figure of two example CT images at 25-um resolution, the 3-dimensional lithological, mineralogical, and geophysical information can be derived from these CT scans using deep learning approaches. Then such information is used to calibrate well log-derived petrophysical properties.

With literally dozens of potential CCS storage projects going into the Deadwood and specifically the Basal Cambrian Sandstone equivalent from Alberta, Regina to North Dakota, this work will be very important in evaluating future CO₂ storage or geothermal sites, and gaining a better understanding of existing locations at Aquistore and anywhere the Deadwood/BCU is utilized for this purpose.



Plug 1, sandstone is intercalated with clay laminae and thin shale beds. This plug has porosity of 11.9% and permeability of 0.13 mD.



Plug 2, poorly sorted, semi-angular, coarse to granular quartz arenite. Scatter shiny spots may be iron-rich minerals such as pyrite. This plug has porosity of 14.1% and permeability of 102 mD.