IN-SITU PORISITY & PERMEABILITY FROM BOEHOLE MAGNETIC RESONANCE LOGS FOR CARBON SEQUESTRATION

SUMMARY

Carbon capture, utilization and storage (CCUS) seeks to reduce the impact of carbon dioxide (CO_2) emission on the climate by capturing and storing the CO_2 in subsurface reservoirs for future industrial application utilization. Borehole magnetic resonance (BMR) technologies offer insightful in-situ measurements useful to those perusing the perfect subsurface reservoir.

PROBLEM

Just like any gas project, CCUS requires the perfect structural trap to contain the CO_2 within the potential storage site. These sites can include non-producing oil and gas reservoirs, deep coal seams and saline aquifers. In all cases the requirements are similar with a porous / permeable layer bounded by an upper and lower impermeable layers, forming the gas seal.

A simplified CCUS lithological reservoir (blue) and cap rock (yellow)

Site evaluation must consider the effectiveness of the seal along with porosity, permeability and pore distribution of the reservoir being investigated.

Evaluation of the seal and reservoir lithologies has primarily relied on laboratory porosity measurements from core samples. Being both costly and time consuming, these laboratory tests are generally limited in number and more random in distribution along the borehole length. The condition of the core sample also affecting the result usability.

A petrophysical approach, from wireline log data, of calculating the porosity from density (DPOR) or p-wave velocity (SPOR) is heavily reliant on the correct matrix coefficients being applied. Any variability, both laterally and vertically, in the matrix coefficients will need to be considered if reliable porosity estimates are to be produced.

Other intervention techniques, such as packer testing, have also been used with varying degrees of success. Success largely been reliant on correct packer placement which requires other priori information, like wireline logs, to achieve.

SOLUTION

Borehole magnetic resonance (BMR) is a downhole geophysical tool that accurately measures water contained within the formation. It is specifically tuned to sense fluids within the pore network, enabling precise determination of the formation's total porosity along with bound and free fluid content. The formation permeability and hydraulic conductivity can also be derived without the need for other wireline log data.

As BMR data delivers a decomposition of the total porosity into fluid volumes of different mobilities it is possible to estimate the "drainable" porosity as a primary output from the wireline log.

Although the BMR data can be useful as a stand-alone data set, the combination of this data with other wireline logs like; density, sonic velocities and acoustic televiewer imaging can greatly enhance the combined physical property

Safety | Range of Services | Depth of Service | Training | Experience & Knowledge interpretation of the intersected formations. The BMR measured porosities can also be empirically modeled against laboratory core measurements to fine tune local and borehole specific influence.

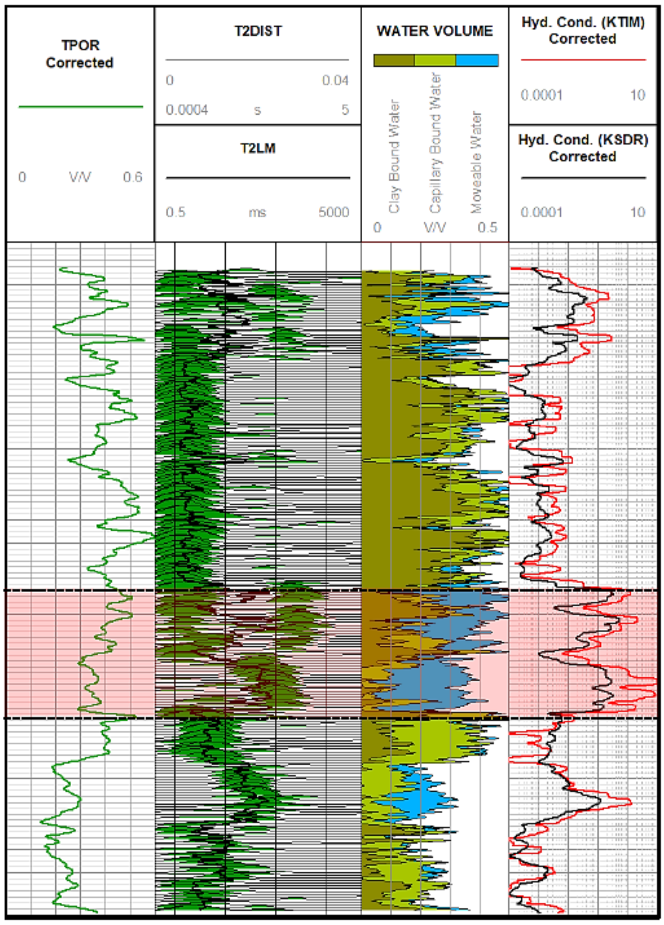
IMPACT

The usefulness of BMR logs for CCUS studies has been realized for many years with its ability to acquire continuous, in-situ porosity and permeability data at reasonable cost and shorter turnaround times on results. The fact that the data is measured in-situ on a continuous basis adds a new level of certainty to the final models and interpretations not achievable before.

TECHNOLOGY

Borehole Magnetic Resonance: (BMR) measures the spin of hydrogen protons in water molecules. BMR instruments perturb the static magnetic field using a combination of permanent magnets and radio frequency induction coils (antennae). The permanent magnets on the tool create a static "background" magnetic field, which causes the hydrogen nuclei in the water of the formation to align with the magnet. An oscillating magnetic field is created by the antennae, which transmit precisely timed bursts, or pulses, of radio-frequency energy. The energy pushes the hydrogen nuclei out of alignment with the background applied, static field. The spins of the protons return to their original state during a relaxation phase. As protons "relax," they emit a signal that is measured by the BMR tool (Dlubac et al.2013).

The BMR logging tool measures both the magnetization strength and the relaxation time. The initial signal strength is directly proportional to the total amount of water present. T2 is the relaxation time associated with the decay of the magnetization in the direction perpendicular to the background applied static field. Long relaxation times correspond with large pores and more mobile water, while shorter relaxation times correspond with small pores and less mobile water (IRTC,2015).



Typical BMR plot with highlighted intersection of formation with increased free / movable fluid volume, indicating increased permeability and hydraulic conductivity.