IN-SITU HYDROGEOLOGICAL CHARACTERIZATION AIDED BY BOREHOLE MAGNETIC RESONANCE

SUMMARY

Hydrogeology plays a critical role in determining the economic viability and shaping development strategy of brine mining operations. In particular, to assess distribution and producibility of groundwater brines. Total porosity, specific yield and specific retention can all be directly measured in-situ using lithology-agnostic Nuclear (Borehole) Magnetic Resonance (BMR) technology.

CHALLENGE

Brine mining is the extraction of useful minerals naturally dissolved in brine. Commercial brines include shallow brine beneath saline or dry lakes, and deep brines in sedimentary basins. These brines are pumped to surface and fed into evaporation ponds. Brines are important sources of potash, lithium and other heavier metals and industrial salts. A plentiful lithium supply will be crucial to chartering a future based on automotive and industrial lithium-ion battery energy use as one means of reducing society's carbon footprint, with demand expected to soar fourfold every three years. Potash as a key component of fertilizers is crucial to feeding an increasing global population that is expected to reach +9 billion by 2050.

Hydrogeology plays a critical role in determining the economic viability and shaping development strategy of brine mining operations. In particular, to assess distribution and producibility of groundwater brines, the hydrogeologist must determine vertical and lateral variation in total porosity across the resource, and differentiate the fraction that is occupied by free (mobile) brine, versus the remaining fraction occupied by bound (immobile) brine. To map brine movement the hydrogeologist needs to investigate flow potential, which depends on hydraulic conductivity, the specific yield and specific retention of the rock.

Lithium brine deposit

EXISTING METHODS

Total porosity, specific yield, specific retention and permeability can be directly measured ex-situ on clean, dried core test plugs. However, accuracy of such tests is influenced by core quality, extent of filtrate invasion, damage to cores during retrieval, poor core preservation, scaling effects, test methods and quality of the test apparatus.

Total porosity and permeability can also be determined in-situ. However, bulk density log-derived porosity values are prone to error if matrix density is not precisely known. As it is not possible to measure permeability directly, complex multi-parameter lithology-dependent correlations are used as proxies. These are calibrated against ex-situ measured permeabilities on cores acquired at disparate, discrete depths, which can be prone to errors.

Bulk permeability can also be estimated from monitoring and analysis of in-situ pressure transients induced using pipe or wireline conveyed packer tests which can last hours, even days, to obtain a single measurement.

SOLUTION

Total porosity, specific yield and specific retention can all be directly measured in-situ using Nuclear (Borehole) Magnetic Resonance (BMR) technology which is specifically tuned to sense the fluid-filled pores only, so measurement accuracy is relatively unaffected by matrix composition. This superior response capability contrasts completely with the lithology-dependent measurement principle of conventional logging tools.

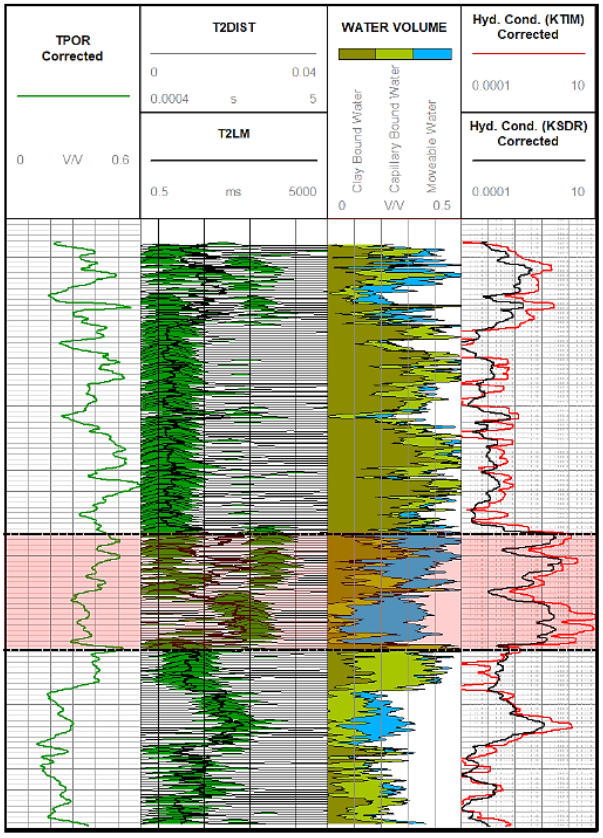
While BMR has been used routinely in the oil and gas logging industry for decades, uptake by the brine mining industry has been hindered by tool size. This capability gap has been addressed through slimline Borehole Magnetic Resonance tool development.

Advanced BMR pulse sequences and signal processing techniques enable aquifer pore structure and mobile water content to be determined with a high degree of precision and accuracy. An appropriate theoretical model is used to also estimate intrinsic permeability.

Ultrafast wireline telemetry, complemented by advanced analysis software, enables a detailed log of these hydrogeological parameters. Despite miniaturization, the BMR logging tool has impressive signal-to-noise (SNR) characteristics, resulting in a large depth of investigation. High SNR, coupled with rapid data acquisition and processing, enables variation in geophysical parameters through the aquifer to be mapped while continuously logging at 1 m/min (~200ft/hr).

IMPACT

The usefulness of BMR logs for lithium brine studies has been realized for many years with its ability to acquire continuous, in-situ porosity and permeability data at reasonable cost with 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 previously unachievable.



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

ALTERNATIVES

	Packer Testing	Core	Logging	BMR*
In-situ	✓	✗	✓	✓
Accuracy	✓ ✓ ✓	✓ ✓	✓	✓ ✓ ✓ ✓
Porosity	✗	✓	✓	✓
Free-water Porosity	✗	✓	✗	✓
Clay-bound Porosity	✗	✗	✗	✓
Capillary-bound Porosity	✗	✓	✗	✓
Permeability	✓	✓	✓	✓
Real-time Data	✗	✗	✓	✓
Continuous Profile	✗	✗	✓	✓
Rig-less Operation	✗	✗	✓	✓
Crane-free Operation	✗	✓	✗	✓
Test Speed	✓ ✓	✓	✓ ✓ ✓	✓ ✓ ✓ ✓
Test Efficiency	✓ ✓	✓	✓ ✓ ✓	✓ ✓ ✓ ✓
Test Cost	$$$$	$$$	$$	$
Cost Benefit	4	3	2	1

**Borehole Magnetic Resonance*