+1-303-279-3211 sales@mountsopris.com

Nuclear Magnetic Resonance – NMR

Borehole Nuclear Magnetic Resonance (NMR or BMR) is the advanced geophysical logging tool available for rent from Mount Sopris in collaboration with NMR Services Australia (NMRSA). This tool provides an accurate characterization of pore structure in the subsurface by measuring signals from magnetic resonance. This measurement can distinguish fluid types, and determine rock

porosity, fluid content and permeability. NMR technology, in the newly developed slimline NMR tool offered by Mount Sopris, can be used in a wide variety of industries.

Applications

Using NMR Logging for Groundwater

BMR can be used to map aquifer hydrogeology for groundwater management. To assess water distribution within an aquifer, a hydrogeologist must determine vertical and lateral variation in total porosity and differentiate the fraction that is occupied by free (mobile) water, versus the remaining fraction occupied by bound (immobile) water. The NMR tool can investigate aquifer flow potential by

calculating hydraulic conductivity, specific yield, and specific retention of the rock *in-situ*. Aquifer permeability can also be derived from analysis of NMR responses.

Borehole NMR is specifically tuned to sense the fluid-filled pores only, so measurement accuracy is completely unaffected by matrix composition, with no special calibrations to formation lithology required. This response capability contrasts completely with the lithology-dependent measurement principle of conventional logging tools.

Brochure for Hydrogeology and Groundwater: Read Here

Example of NMR compared to Packer Testing: Read Here

Using NMR Logging for Iron Ore

NMR can be used to map moisture content, specific yield and dry weight density in iron ore deposits, as well as vadose zone porosity and permeability. These measurements are especially important if extracting ore from below the water table. The insight provided by these distribution models helps to shape drainage strategies, lead to understanding of ore handleability, guide crushing plant design, optimize operational feed and determine extent of blending required for final safe shipment. NMR technology measures specific yield, specific retention, dry matrix density and permeability continuously within the borehole.

Brochure for Iron Mining: Read Here

Using NMR Logging for Coal

The BMR system available from Mount Sopris can be used in mapping coal seam gas content and permeability for coal mining operations. BMR helps mine operators predict under what conditions coal walls may pose outburst risk. Additionally, BMR data allows operators to plan mine layout and ventilation systems in order to minimize methane emission. Furthermore, the system can help determine whether a particular coal requires gas pre-drainage prior to longwall mining. Coal system permeability is also derived from analysis of NMR responses.

Successful gas management plans require closely spaced, accurate measurements to adequately capture gas content and permeability heterogeneity. Total gas content and system permeability can be determined in-situ using Nuclear Magnetic Resonance technology. As borehole magnetic resonance is specifically tuned to sense the fluid-filled structure and coal matrix nano-pores only, the accuracy of the measurement is completely unaffected by matrix composition; BMR does not need to be calibrated for coal type, grade or ash content. A proprietary magnetic resonance excitation pulse sequence and analysis technique, referred to as **T2-StimD**, has been developed to detect and quantify adsorbed gas content in the coal matrix, as well as any free gas content in the structure.

Brochure for Coal Mining: Read Here

For More Information: Borehole Magnetic Resonance in Coal Seams by Tim Hopper

Using NMR Logging for Brine Mining

The BMR system available from Mount Sopris can be used for hydrogeologic mapping for brine mining operations, 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, one needs to investigate flow potential, which depends on hydraulic conductivity, the specific yield and specific retention of the rock. Aquifer permeability can also be determined using magnetic resonance responses.

Brochure for Brine Mining: Read Here

Operating Conditions

Borehole Fluid

[X] Water

[X] Mud

[X] Dry

Casing

[X] Uncased

[X] PVC Borehole

[ ] Steel

Centralization

[X] Required

[ ] Not Necessary

Features & Benefits

NMR technology provides benefit to many industries. Due to high demand and the value of the measurements, Mount Sopris has partnered with NMR Services Australia (NMRSA) to offer a smaller borehole magnetic resonance tool for other industries that operate in slim boreholes. The BMR tool has many benefits for your logging application.

- Advanced NMR pulse sequences and signal processing provides precise and accurate aquifer pore structure and mobile water content measurements
- A theoretical model is used to estimate intrinsic permeability
- Fast wireline telemetry and powerful analysis software generates a real-time log
- Impressive signal-to-noise ratio gives a large depth of investigation
- Can be run centered in open-hole, fiberglass or PVC-lined boreholes

Renting the NMR from Mount Sopris

Our Mount Sopris sales and support teams include a PhD nuclear magnetic resonance scientists and engineers and we are fully skilled to provide training on

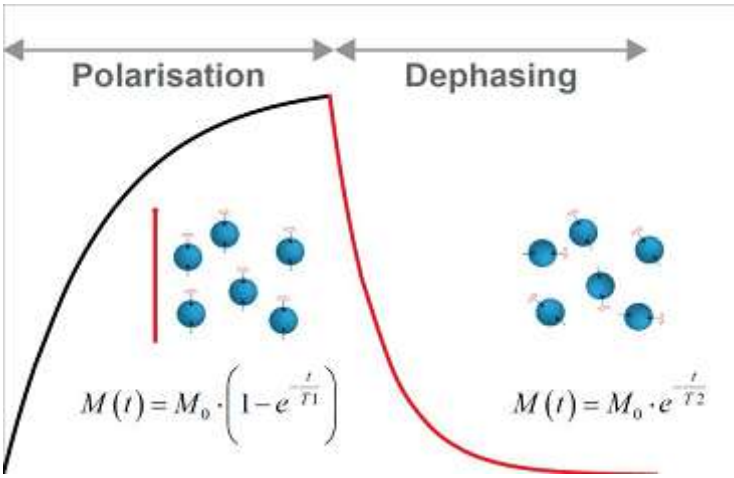
the BMR tool. This training is included with your rental of the BMR tool and can be delivered in-house at our facility in Denver, Colorado. Alternatively, one of our team can travel to your location of choice to provide on-site training.

To support your operation of the BMR tool, and in case any issues should arise when operating the tool in the field, Mount Sopris offers technical support over the phone or by email.

How NMR Works

Watch this brief video which describes the measurement principles of the BMR tool:

Nuclear magnetic resonance (NMR) takes advantage of interactions between hydrogen nuclei and applied (electro)magnetic fields. Hydrogen nuclei possess a magnetic moment, acting like small bar magnets. In water, or other hydrogen-containing fluids, occurring in the pore space of a rock the magnetic fields of the various hydrogen nuclei in the different fluid molecules will be randomly oriented. If an external magnetic field is introduced, these nuclei will align themselves with the external magnetic field, or polarize. If the effect of this external magnetic field is then removed, the nuclei will over time dephase, until they are again randomly oriented.



The peak magnetization detected when the hydrogen nuclei are fully polarized is a direct measure of how much hydrogen in present in the fluids in a rock, this in turn is a function of the water content or porosity. The rate at which the hydrogen nuclei polarize, characterized by the longitudinal relaxation time T1, and

dephase, characterized by the transverse relaxation time T2, is controlled by interactions between the magnetic fields of the individual hydrogen nuclei and other local magnetic fields, most significantly those associated with paramagnetic atoms such as iron and manganese occurring in the rock matrix. The relaxation rates are a measure of how effectively hydrogen nuclei in fluid molecules can interact with paramagnetic atoms in the rock matrix, and so are strongly controlled by pore size, which also controls permeability.

Nuclear magnetic resonance is uniquely suited to evaluate both storage and flow properties of rocks due to this sensitivity to both pore volume and pore size, making it an ideal choice for hydrogeological and other applications.

Read More- Haliburton NMR Logging Principles and Applications

Access NMR Research and Publications on our Library Page

Understand- Qteq's simple explanation of Borehole Magnetic Resonance

Specifications – Metric/English

Specification	QL40-BMR60	QL40-BMR90
Diameter	60 mm / 2.36"	90 mm / 3.54"
Length	2.01 m / 79.1"	2.16 m / 85.0"
Weight	19 Kg / 42 lbs	25 kg / 55 lbs
Max. Temp.	100°C / 212°F	100°C / 212°F
Max. Pressure	200 bar / 2900 psi	200 bar / 2900 psi

Borehole Diameter Range: BMR60: 75 – 186 mm (3 – 7.25"); BMR90: 122 – 312 mm (4.75 – 12.25")

Logging Speed: 60-120 m/hr (200-400 ft/hr)

Vertical Sensor Aperture: BMR60: 11.5 cm (4.5"); BMR90: 23.8 cm (9.37") or 9.8

cm (3.88")

Diameter of Investigation: BMR60: 23 cm (9.1”); BMR90: 36 cm (14.1") or 22 cm (8.7")

Echo Spacing (TE): BMR60: 450 µs; BMR90: 600 µs or 250 µs

Wait Time (TW): Multi

T2 Range: 0.5xTE – 5 seconds

Porosity Range: 0 – 100 pu

Total Porosity Precision: 2 pu – 2 level averaging

Specifications	QL40-BMR-60		QL40-BMR-90			
Physical Dimensions						
Tool Diameter	60 mm	2 ⅜ in	90 mm		3 ⅝ in	
Tool Length	2.01 m	6.6 ft	2.16 m		7.1 ft	
Operating Pressure	200 bar	2,900 psi	200 bar		2,900 psi	
Operating Temperature	100 °C	212 °F	100 °C		212 °F	
NMR Field						
Diameter of Investigation*	230 mm	9 $^{1}/_{16}$ in	360 mm	14 ⅛ in	220 mm	8 ⅝ in
Vertical Sensor Aperture	11.5 cm	4 ½ in	23.8 cm	9 ⅜ in	9.8 cm	3 ⅞ in
Echo Spacing (TE)	450 µs		600 µs		250 µs	
Wait Time (TW)	Multi		Multi			
T2 Distribution	0.5 x TE – 5 seconds		0.5 x TE – 5 seconds			
Porosity Range	0 – 100 pu		0 – 100 pu			
Total Porosity Precision	2 pu – 2 level averaging		2 pu – 3 level averaging			
Well Parameters						
Hole Sizes	75 – 186 mm	3 – 7 ¼ in	122 – 312 mm 4 ¾ – 12 ¼ in		122 – 176 mm 4 ¾ – 6 ⅞ in	
Hole Condition	Open hole, Fiberglass or PVC casing					

Development Team

For over 60 years, Mount Sopris Instruments has delivered innovative borehole logging solutions to drillers, miners, engineers and researchers in over 120 countries. With an extensive product range and industry-leading customer support, Mount Sopris is

dedicated pushing the boundaries of science to improve productivity and data integrity.

Advanced Logic Technology is a software and hardware development company bringing innovative solutions to the geoscience industry since 1993, including best-in-class log composite software, WellCAD, and industry-leading imaging probes.

Based in Australia, NMR Services Australia (NMRSA) was founded on the premise that technical and commercial innovation successfully underpins sustainable, responsible resource development. Their unique Borehole Magnetic Resonance tools characterize the storage and flow capacity of subsurface formations, with applications in the groundwater, oil and gas, mining, and coal sectors.

Documentation

NMR Tool Brochure: Read Here

Brochure for Hydrogeology and Groundwater: Read Here

Example of NMR compared to Packer Testing: Read Here

Brochure for Iron Mining: Read Here

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Brochure for Coal Mining: Read Here

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Read More: Haliburton NMR Logging Principles and Applications

INSTRUMENTS

4975 East 41st Avenue
Denver, Colorado 80216 USA
+ (1) 303.279.3211
Contact Us

ASSOCIATIONS

EAGE

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