

Need

As ore deposits in the vadose zone are depleted, mining companies are forced to extract ore below the water table, where moisture content is much greater. There is a strong business case for understanding in-situ ore moisture content and dry weight density as well as vadose zone porosity and permeability, and mapping variations vertically and laterally throughout the ore deposit and overburden. The resulting distribution models will benefit a variety of technical disciplines within asset teams responsible for each area of the value chain, from resource evaluation to shipping. Specifically, the insight provided by these distribution models help 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.

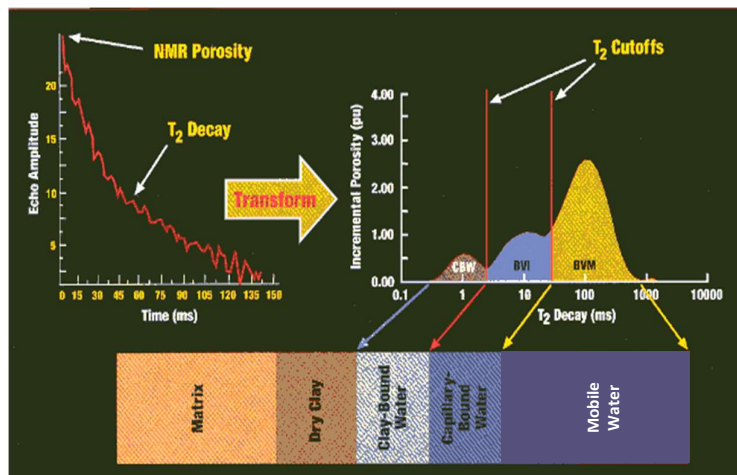


Beneficial uses of 3D moisture content, specific yield & dry weight density distribution models	
Geophysicist	Better resource definition and modeling and distinguish certain ore types (e.g. Geothite)
Metallurgist	More accurate predictions of materials handling, flow properties and ore blending needs for feedstock to the crushers
Hydrogeologist	Better characterization of aquifers and aquitards, enhanced modeling of groundwater recharge rates, improved dewatering strategies, more appropriate sizing and placement of dewatering pumps and better mine planning
Geotechnical	Improved understanding of pit slope stability and easier identification of open and closed fractures (with OTV/ATV)

Blending must comply with the Transport Moisture Limit (TML) specified by the IMSBC Code. There are substantial economic benefits to minimising ore moisture in the final shipped product. Ore porosity can reach ~40%, with moisture content below the water table rising to ~16%. A 1% reduction from 9-8% represents potential savings of \$63M, based on freight costs from Australia to China (680 Mt production at a typical freight cost of \$8/t). For Brazil, with a higher freight cost of approximately \$20/t, the potential savings for 340Mt of iron ore are \$81M. However, the complex nature of local pit geology, coupled with factors affecting ground water movement, leads to a high uncertainty in determining *in-situ* ore moisture, using traditional *ex-situ* measurement techniques.



New In-Situ Method



Traditionally, ore moisture content is determined *ex-situ* by drying samples in an oven and comparing sample mass before and after. This measurement, specific yield, specific retention, dry matrix density and permeability can now all be directly measured *in-situ* using Nuclear Magnetic Resonance (NMR) technology. As borehole NMR is specifically tuned to sense the fluid-filled pores only, measurement accuracy is completely unaffected by matrix composition, and so does not need to be calibrated to formation lithology. This superior response capability contrasts the lithology-dependent measurement principle of conventional logging tools.

BMR Features & Benefits

While NMR has been used routinely in the oil and gas logging industry for decades, uptake by the iron ore industry has, until now, not been possible, due to NMR tool size and cost of the logging service. NM RSA have addressed this capability gap through development of an advanced short, miniaturised borehole Magnetic Resonance (BMR) logging tool.

- Advanced NMR pulsing sequences and signal processing techniques enable iron ore total moisture content, specific yield and specific retention to be determined with a high degree of precision and accuracy.
- Exceptional measurement repeatability enables changes in moisture distribution over time, as a result of site pre-drainage, post dewatering mining operations and groundwater recharge from rainfall, to be tracked through repeat BMR logs.
- Raw data transmission, complemented by a powerful analysis software, enables a detailed log of these geophysical parameters to be generated real-time.
- Despite miniaturisation, 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).

The Right Data for the Best Value

To fit inside the typically small diameter boreholes drilled to explore and delineate iron ore deposits, development of the BMR logging tool necessitated a high degree of hardware miniaturization and implementation of new, advanced NMR excitation and NMR relaxation measurement techniques, posing major technical challenges. These challenges were successfully overcome through pioneering applied research, innovative design and a number of inventive steps. As a consequence of these breakthrough achievements, BMR is able to deliver high quality, high density actionable data on a wide range of geophysical pore-related parameters, providing an in-depth view of moisture content distribution. Furthermore, owing to the simple method of use and minimal support equipment and personnel requirements, the BMT logging service also delivers best value as showcased in the comparison table below.

	BMR Logging	Conventional Logging	Ore Sample Testing
In-situ measurement	✓	✓	✗
Measurement accuracy ¹	✓✓	✓	✓✓✓
Total moisture	✓	✓	✓
Specific yield	✓	✗	✗
Specific retention	✓	✗	✓
Dry weight density ²	✓	✗	✓
Real-time data	✓	✓	✗
Continuous depth profile	✓	✓	✗
Crane-free operation	✓	✗	✓
Test speed ¹	✓✓✓	✓✓	✓
Test efficacy ¹	✓✓✓	✓✓	✓
Test cost ³	\$\$	\$\$\$	\$
Cost benefit ranking	1	3	2

NOTES

1. ✓ = worst, ✓✓✓ = best
2. In combination with bulk density measurements from conventional logs.
3. \$ = least costly, \$\$\$ = most costly