CMR-MagniPHI

High-definition NMR service

APPLICATIONS

- Storage quantification from lithology-independent porosity
- Reservoir quality determination with pore-size distribution
- Reservoir producibility based on bound- and free-fluid volume indicators
- Identification of hydrocarbon types and their quantification in organic shale plays from continuous T_1 and T_2 measurement
- Selection of lateral drilling landing point and optimization of the completion design and fracturing program
- Identification of thin permeable beds in laminated reservoirs
- Hydrocarbon identification, especially in low-resistivity or low-contrast pay zones
- Improved irreducible water saturation estimate for avoiding water production
- Salt-saturated muds and deviated and horizontal wellbores down to $5\frac{7}{8}$ in

BENEFITS

- The certainty of the most accurate porosity, independent of lithology
- Quantification of reservoir fluids, even in very small pores
- High-efficiency high-speed logging and reduced deployment risk with a short, light tool
- High-definition maps and continuous volumes of water and hydrocarbon fluid types in organic shale reservoirs

FEATURES

- Shortest and lightest tool: 15.6-ft [4.75-m] length and 374-lbm [170-kg] weight
- Shortest echo spacing: 200 us at high frequency (2 MHz)
- Highest NMR vertical resolution: 6 in [15.24 cm]
- High-definition, simultaneous, continuous T_1 and T_2 measurements
- Improved signal-to-noise ratio (SNR) and sensitivity to fluids in small pores

CMR-MagniPHI* high-definition NMR service provides the most accurate lithology-independent porosity from simultaneous, continuous T_1 and T_2 relaxation time measurements. By unlocking the T_1 dimension, CMR-MagniPHI service enables unprecedented determination of shale porosity and reservoir fluid types and volumes for

- movable and nonmovable oil
- high-viscosity hydrocarbon
- free, capillary-bound, and clay-bound water.
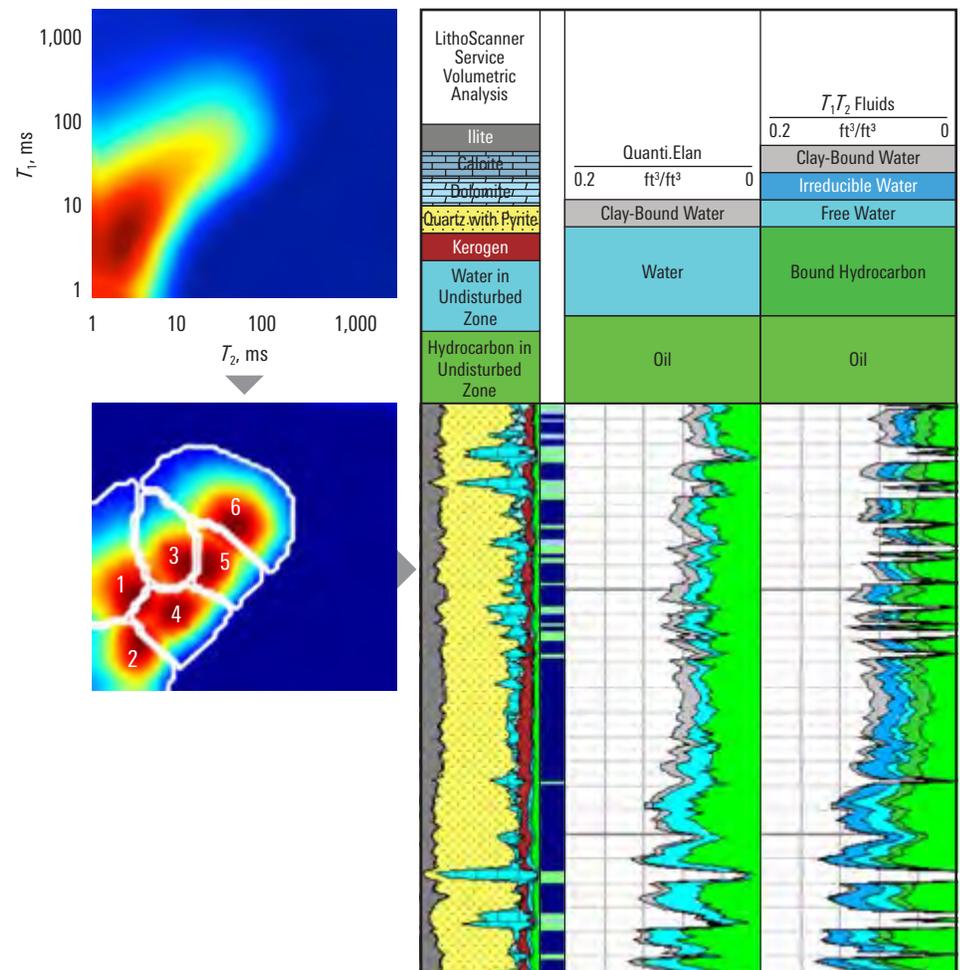
High-definition porosity and fluids profiles are provided by CMR-MagniPHI NMR service. Continuous T_1 and T_2 data are recorded by multiple burst sequences and made available as independent distributions and T_1T_2 interval maps (inversion). The clustering algorithm identifies and quantifies the different water and hydrocarbon fluids (or they can be selected manually); these distinct volumes are also presented as depth logs (Track 4). The fluids volumes from CMR-MagniPHI service can be directly compared with oil and water volumes from other sources, such as total organic carbon (TOC) from Litho Scanner* high-definition spectroscopy service and analysis of multiple logs and minerals by Quanti.Elan* multicomponent inversion solver.

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CMR-MagniPHI High-Definition NMR Service

Measurement Specifications

Output	Continuous measurements of longitudinal relaxation time (T_1) and transverse relaxation time (T_2) distributions
	Total porosity
	High-definition maps and continuous logs:
	- Movable and nonmovable oil
	- High-viscosity hydrocarbon
	- Free, capillary-bound, and clay-bound water
	Multiple permeability correlations (e.g., SDR, Timur-Coates, carbonate equations, factor analysis, and CIPHER methods)
	MRF* magnetic resonance fluid characterization station log for oil, gas, and water volumes; oil viscosity; water and oil T_2 distributions; hydrocarbon-corrected permeability; oil and water log-mean T_2 distributions
Logging speed	Bound-fluid mode: 1,800 ft/h [549 m/h]
	Long T_1 environment: 800 ft/h [244 m/h]
	T_1T_2 mode: 450 ft/h [137 m/h]
Range of measurement	Porosity: 0 to 100 pu
	Minimum echo spacing: 200 us
	T_2 distribution: 0.3 ms to 8.0 s
	Nominal raw SNR: 32 dB
Vertical resolution	Static: 6-in [15.24-cm] measurement aperture
	Dynamic (high-resolution mode): 9-in [22.86-cm] vertical resolution, three-level averaging
	Dynamic (standard mode): 18-in [45.72-cm] vertical resolution, three-level averaging
	Dynamic (fast mode): 30-in [76.20-cm] vertical resolution, three-level averaging
Accuracy	Total NMR porosity standard deviation: ±1.0 pu at 75 degF [24 degC], three-level averaging
	NMR free-fluid porosity standard deviation: ±0.5 pu at 75 degF [24 degC], three-level averaging
Depth of investigation	Blind zone (2.5% point): 0.50 in [1.27 cm]
	Median (50% point): 1.12 in [2.84 cm]
	Maximum (95% point): 1.50 in [3.81 cm]
Mud type or weight limitations	None
Combinability	Combinable with most tools

Mechanical Specifications

Temperature rating, degF [degC]	350 [177]
Pressure rating, psi [MPa]	20,000 [138]
	High-pressure version: 25,000 [172]
Borehole size—min., in [cm]	Without integral bow spring: 5⅞ [14.92]
	With integral bow spring: 7⅞ [20.00]
Borehole size—max., in [cm]	No limit, but must be eccentered
Outside diameter, in [cm]	Without bow spring: 5.3 [13.46]
	With bow spring: 6.6 [16.76]
Weight, lbm [kg]	Without bow spring: 374 [170]
	With bow spring: 413 [187]
Tension, lbf [N]	50,000 [22,410]
Compression, lbf [N]	50,000 [22,410]

Adding a new dimension

Building on the capabilities of the industry-benchmark CMR-Plus* combinable magnetic resonance tool, CMR-MagniPHI service pairs technological advancements with improvements in efficiency and reliability. It introduces the new dimension of simultaneous, continuous T_1 longitudinal relaxation time measurements at an echo spacing of just 200 us. Combining T_1 longitudinal relaxation with standard T_2 relaxation captures high-definition NMR data from the smallest pores in organic shales to improve the identification of different fluid types. In addition to greater certainty in reserves calculations, new insight is brought to selecting the lateral drilling landing point and designing engineered completions and fracturing operations in shale reservoirs.
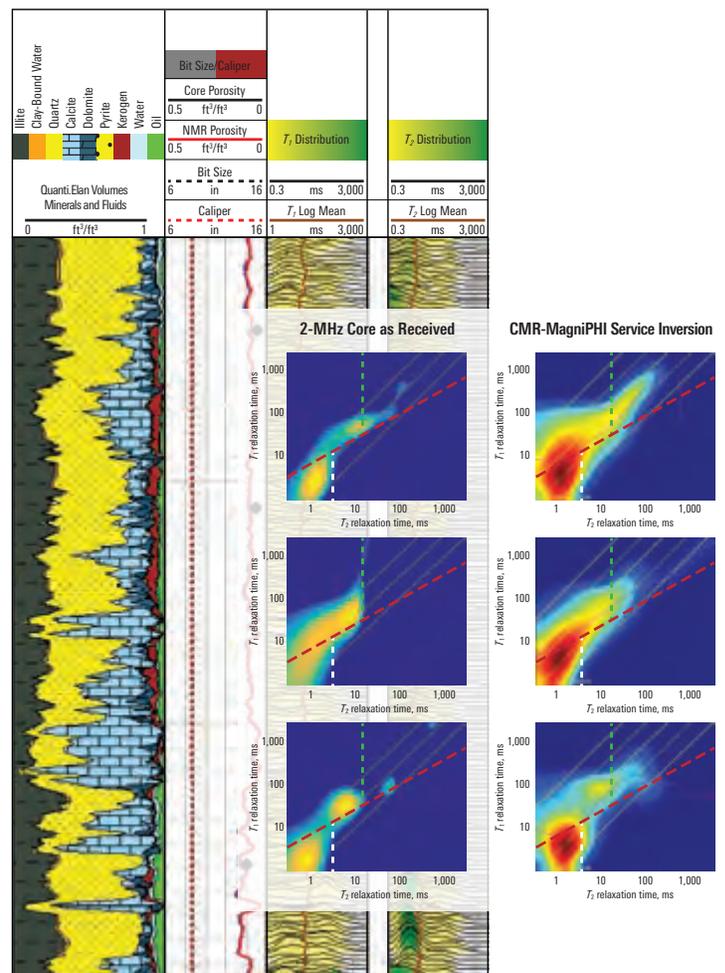
T_1 and T_2 data from the CMR-MagniPHI service are displayed as distributions versus depth and as maps over selected intervals. Comparison with 2-MHz NMR T_1 and T_2 data, taken on core in its native "as received" state, highlights the excellent correlation of the identified fluids in the core samples and by CMR-MagniPHI service.

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