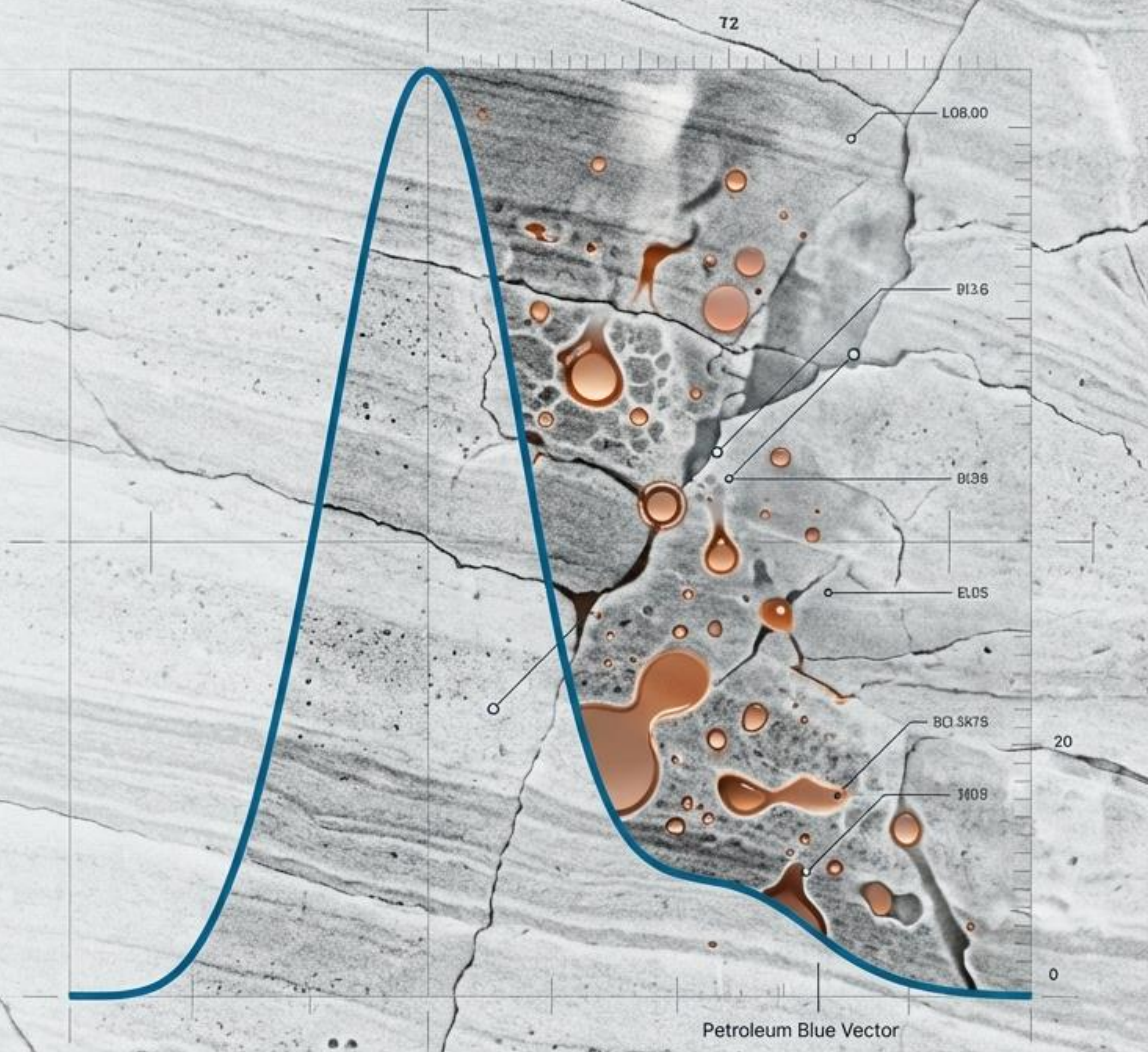
Magnetic Resonance in the Deep

Decoding Reservoir Petrophysics and Fluid Architecture

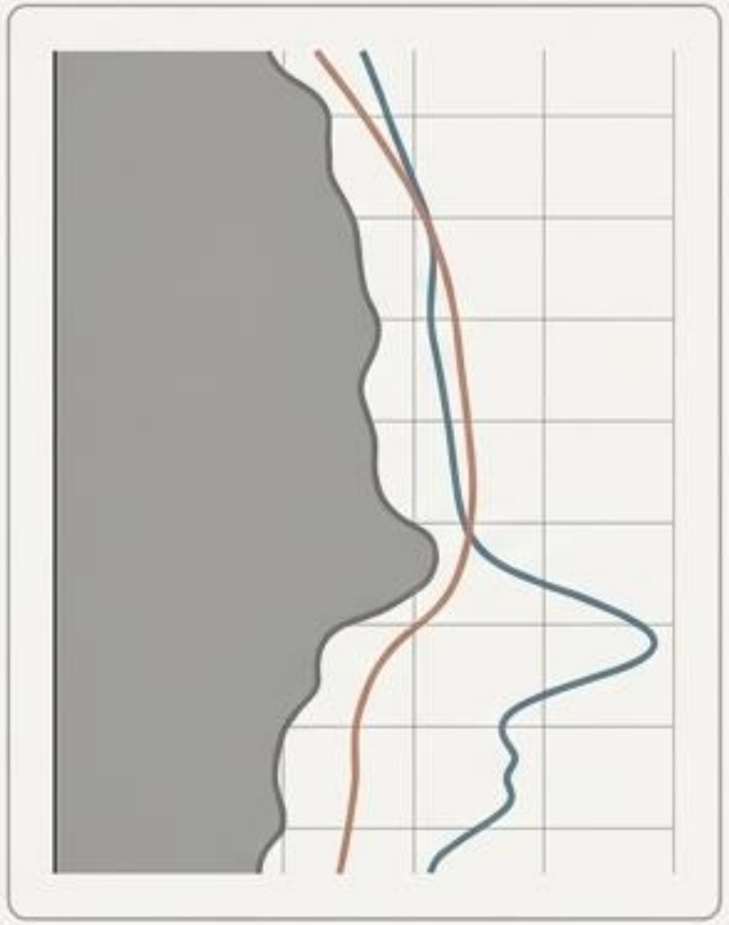
A definitive visual guide bridging quantum NMR physics to macro-scale petroleum geology and shale extraction viability.



RSS NMR

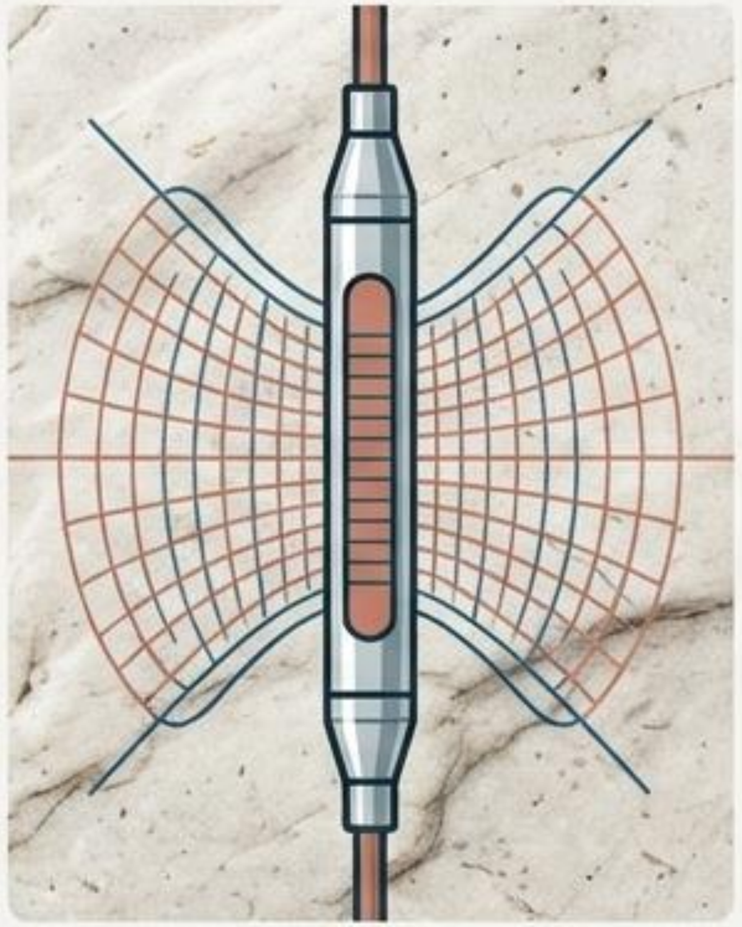
Seeing the Invisible: The Limits of Traditional Logging

The Blind Spot



Traditional neutron and density tools measure bulk porosity. They fail to distinguish between highly profitable, movable hydrocarbons and worthless, immobile clay-bound water.

The Lithic Radar

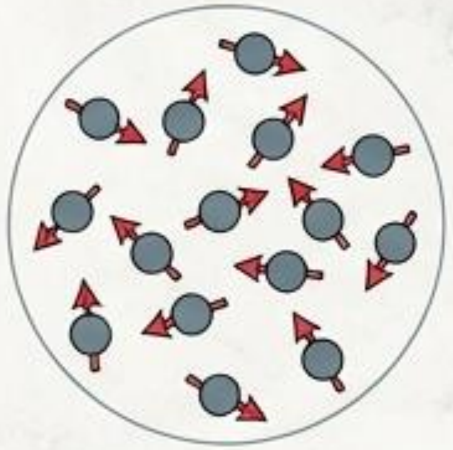


Burnt Amber	Dashboard
	Movable Oil
	Immobile Capillary Water
	Clay-Bound Water

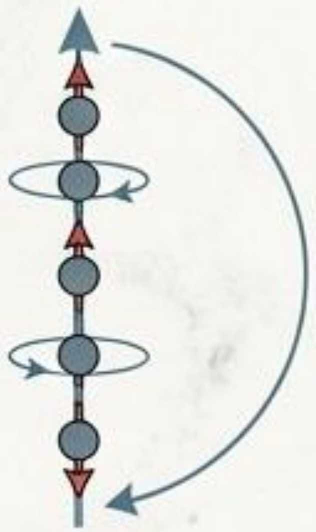
Nuclear Magnetic Resonance (NMR) is lithology-independent. By measuring hydrogen nuclei directly, NMR maps not just how much fluid exists, but its precise mobility and flow architecture.

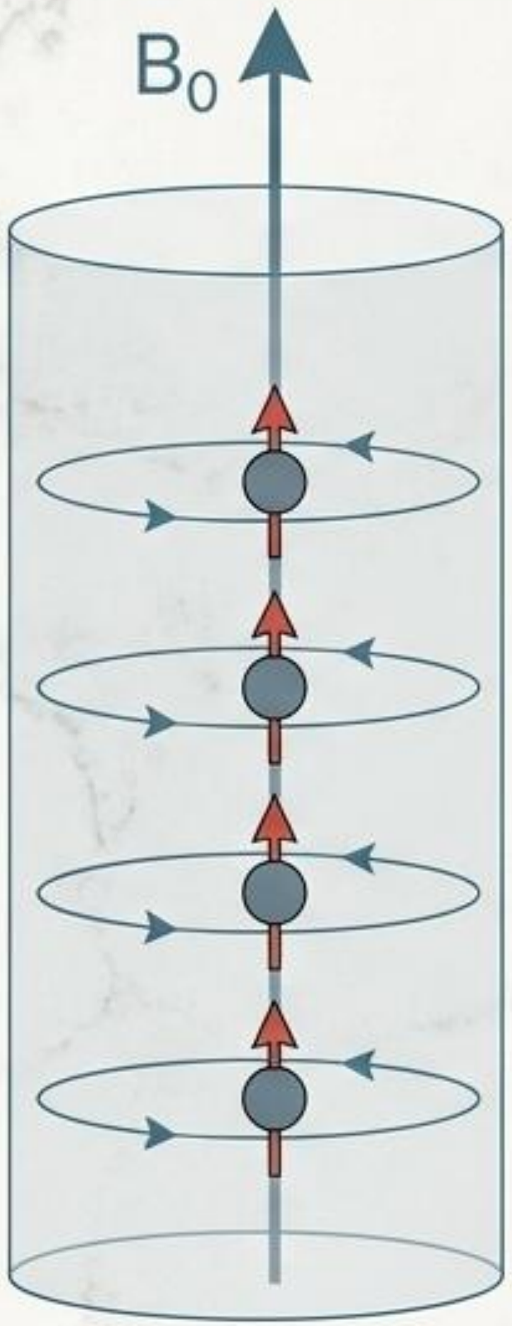
The Micro-Scale: Forcing Hydrogen into Alignment

No Magnetic Field:
Random Alignment



Magnetic Field Applied:
Precession & Alignment





The Target

Hydrogen is abundant in both water and hydrocarbons. As a single proton with a strong magnetic moment, it acts as a microscopic bar magnet.

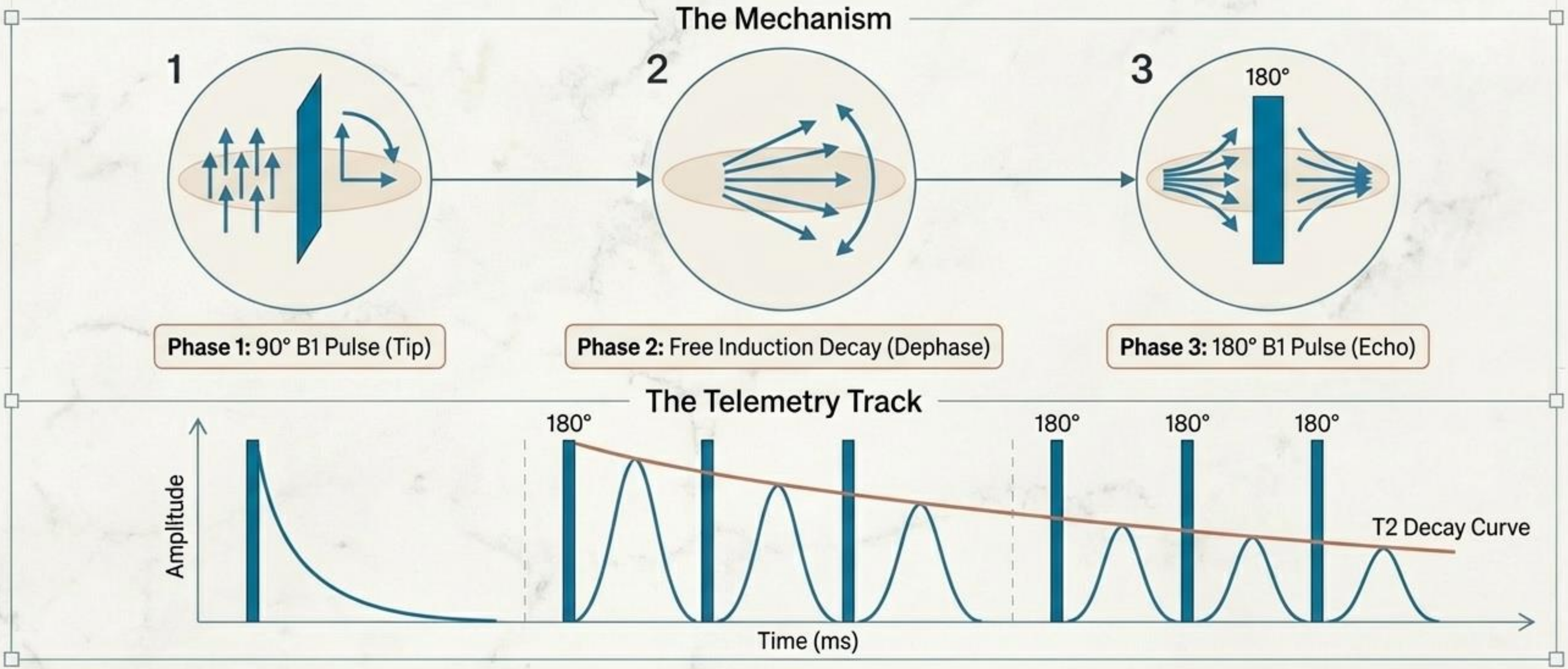
Polarization

The primary magnetic field (B_0) forces protons into high or low energy states, creating measurable bulk magnetization (M_0).

Larmor Frequency

Protons precess (wobble) at a strict frequency dictated by the magnetic field strength, acting like sub-atomic gyroscopes.

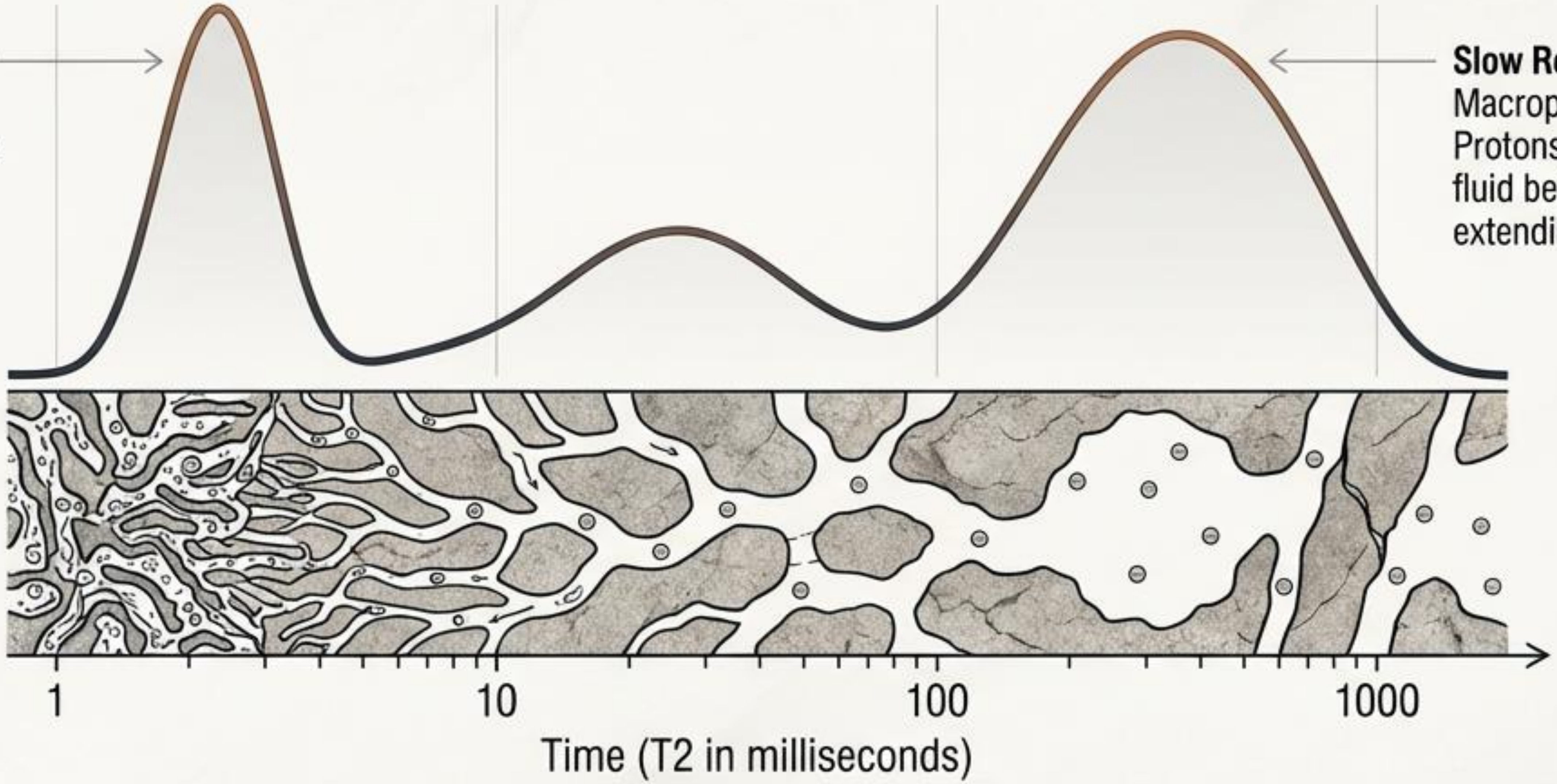
“The Measurement Cycle: Pulse, Tip, and Echo” in Space Grotesk



Briefing: By repeatedly pulsing the aligned protons, we capture a train of magnetic echoes. The exact rate at which these echoes decay (T2) forms our fundamental petrophysical dataset.

The T2 Spectrum Maps Geometric Space

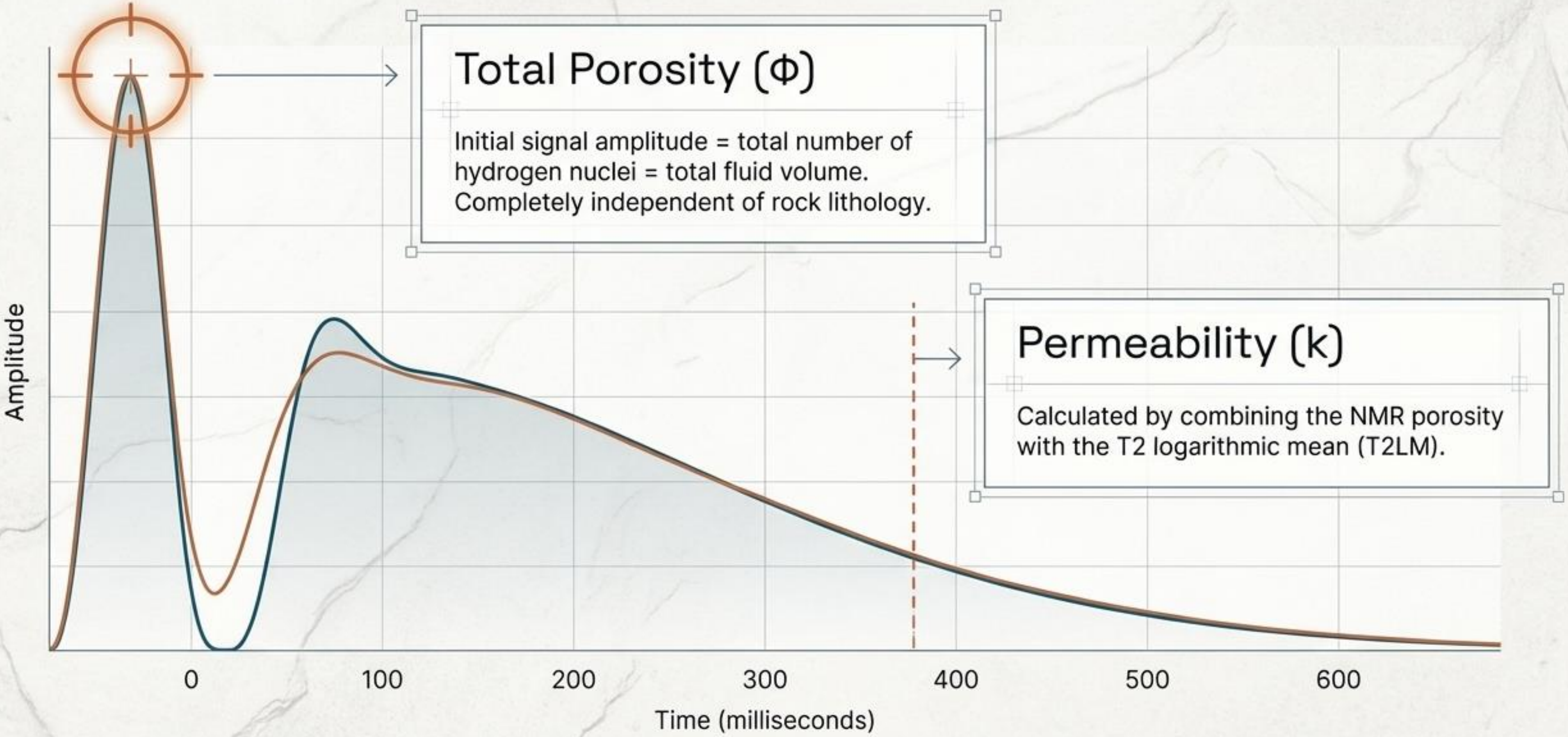
Fast Relaxation: 1-10 ms.
Microscopic Pores.
Protons rapidly collide with rock walls, losing energy instantly.



Slow Relaxation: 100-1000 ms.
Macropores.
Protons wander freely in bulk fluid before hitting a surface, extending decay time.

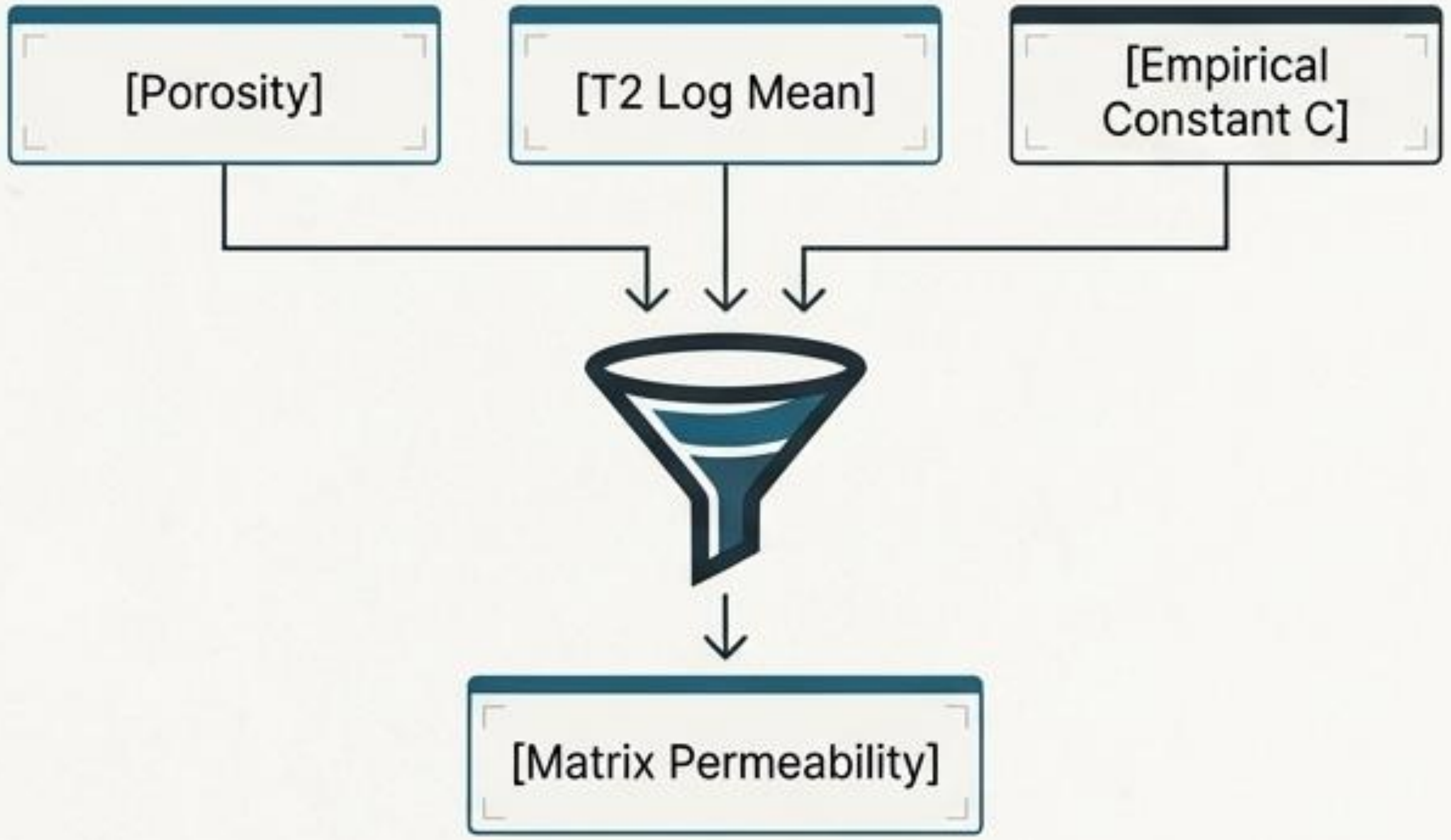
The shape of the T2 curve is a direct, 1-to-1 geometrical blueprint of the rock's pore size distribution.

Extracting Petrophysics from the Waveform



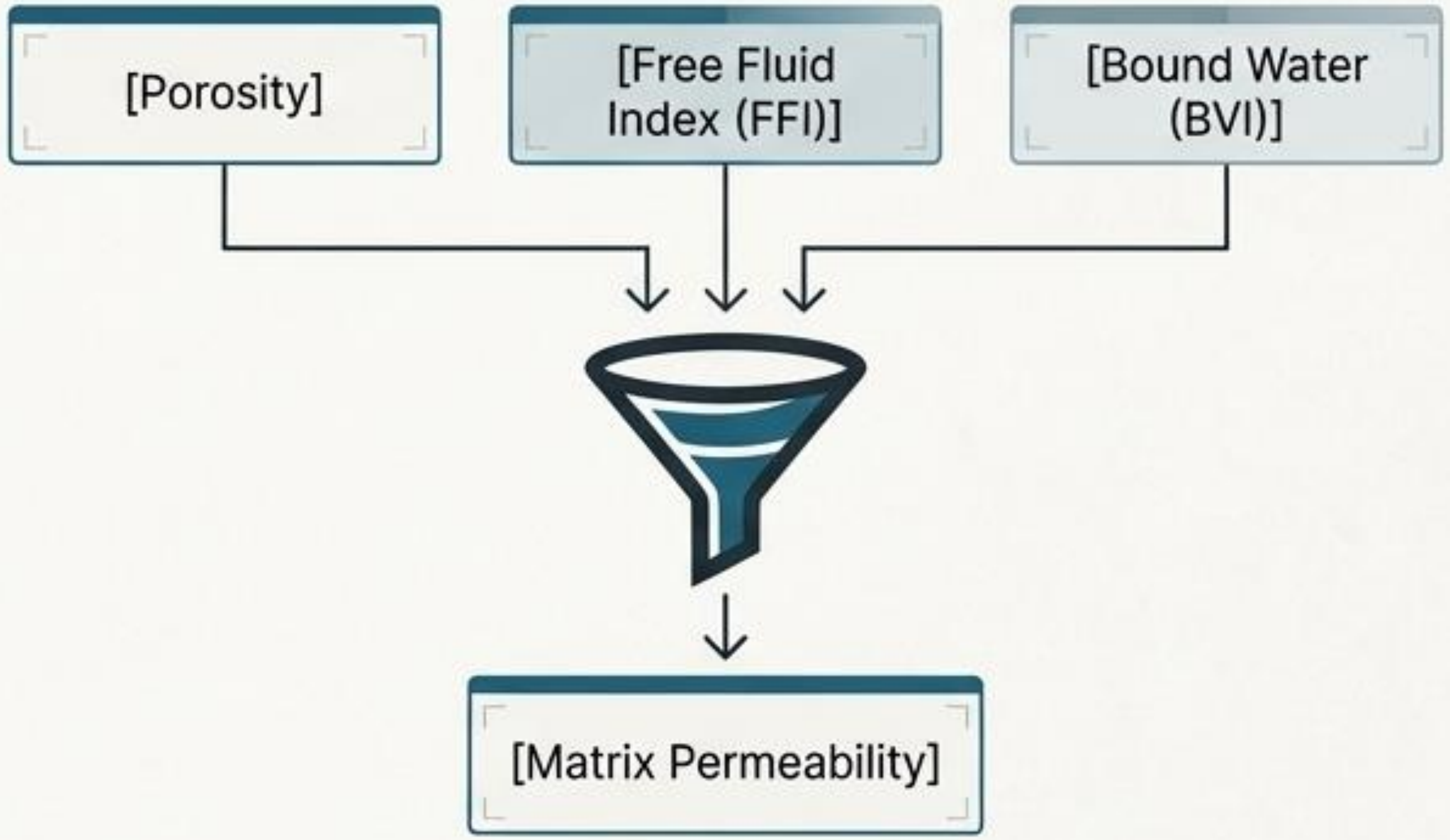
Permeability Logic: SDR vs. Timur-Coates

SDR Model



The Schlumberger-Doll Research (SDR) model relies on the T2 mean, making it vulnerable to oil/gas effects. Fails in Hydrocarbon Zones due to T2LM shift.

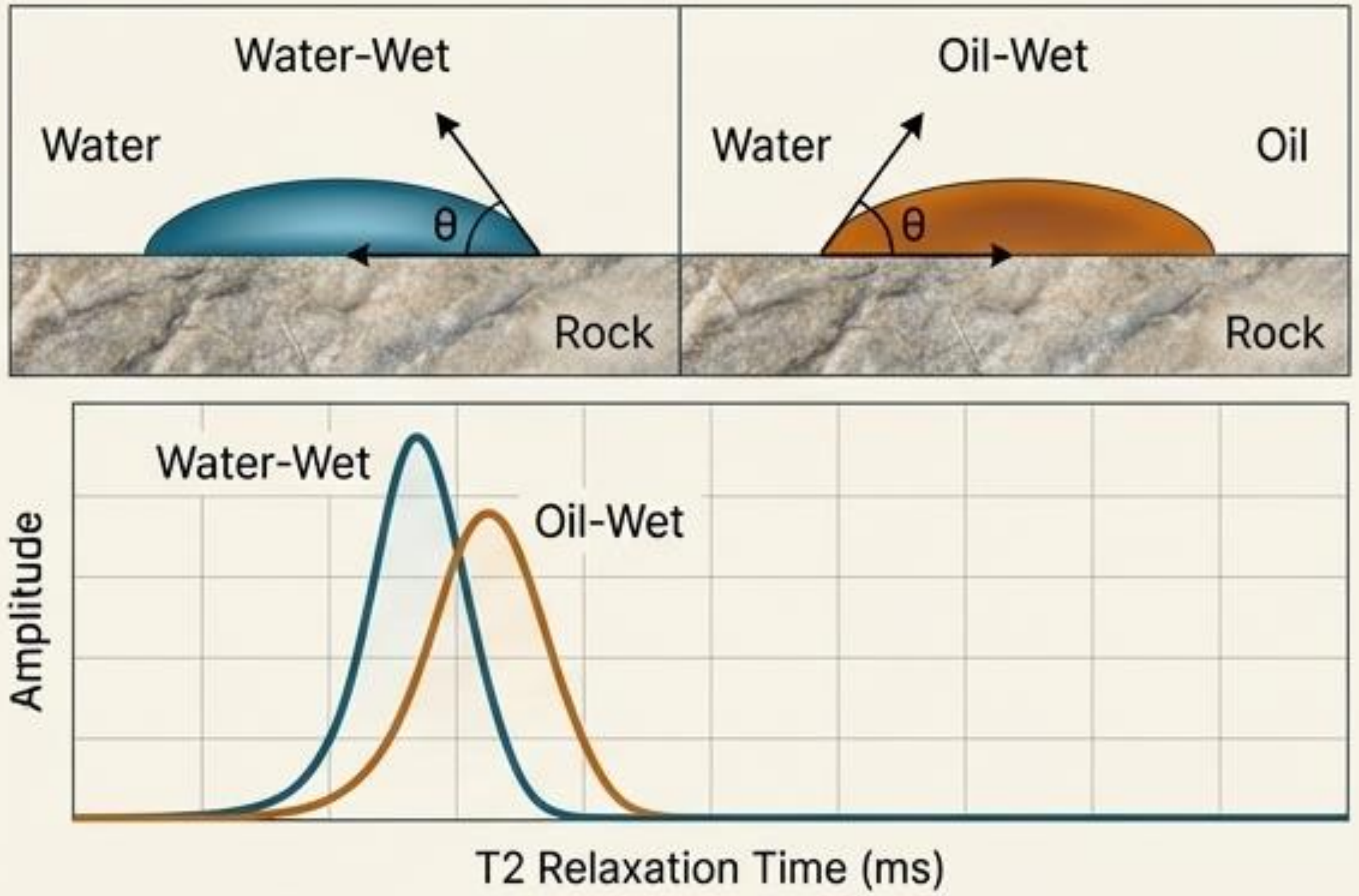
Timur-Coates Model



The Timur-Coates Free Fluid Model uses the ratio of movable to trapped fluids, making it the definitive standard for complex reservoirs. Highly effective in both water and hydrocarbon zones.

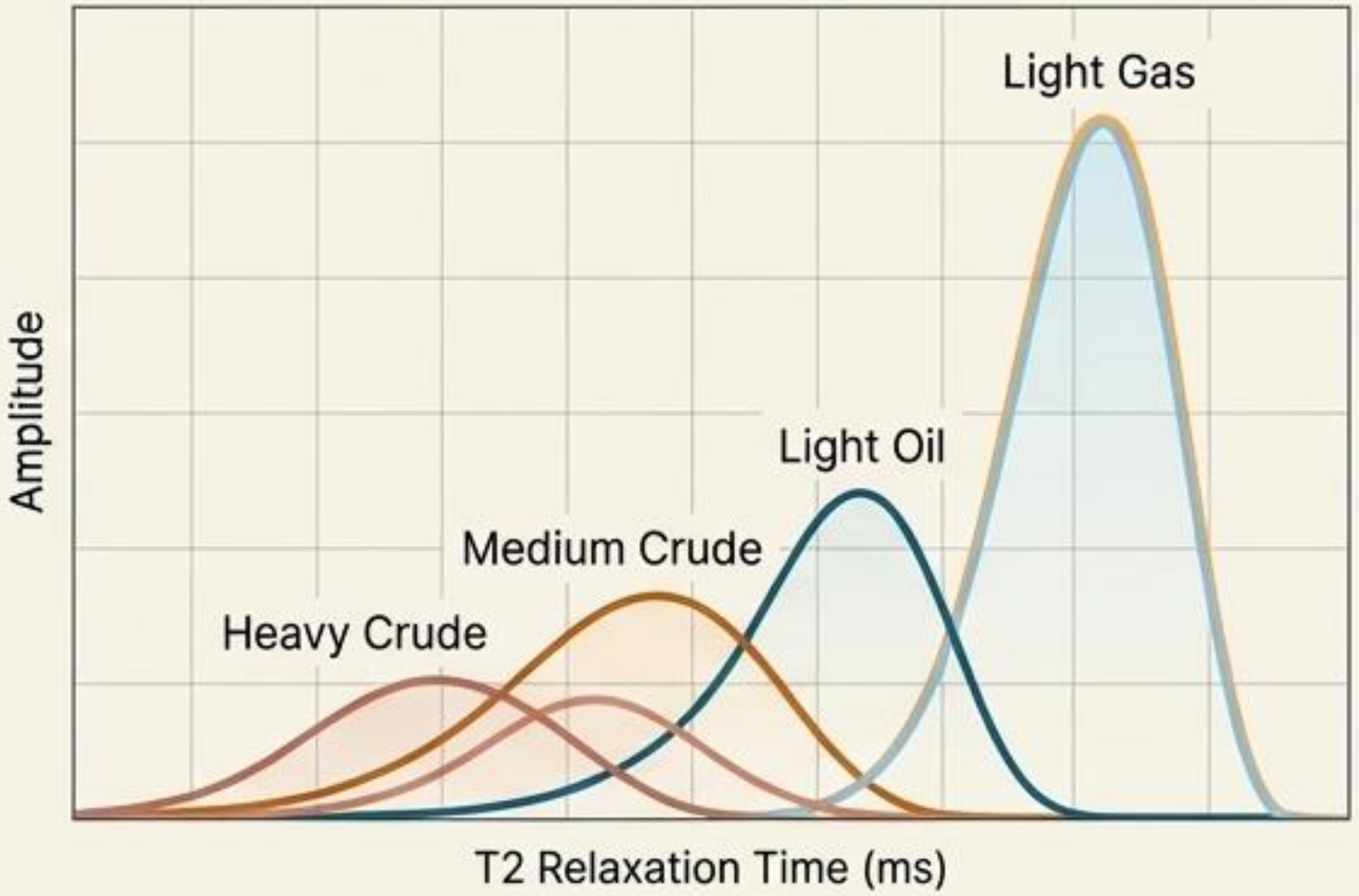
Advanced Diagnostics: Wettability and Viscosity

Wettability



Wettability: The wetting fluid relaxes faster because it physically contacts the pore wall. NMR explicitly identifies preferentially oil-wet vs. water-wet zones.

Viscosity

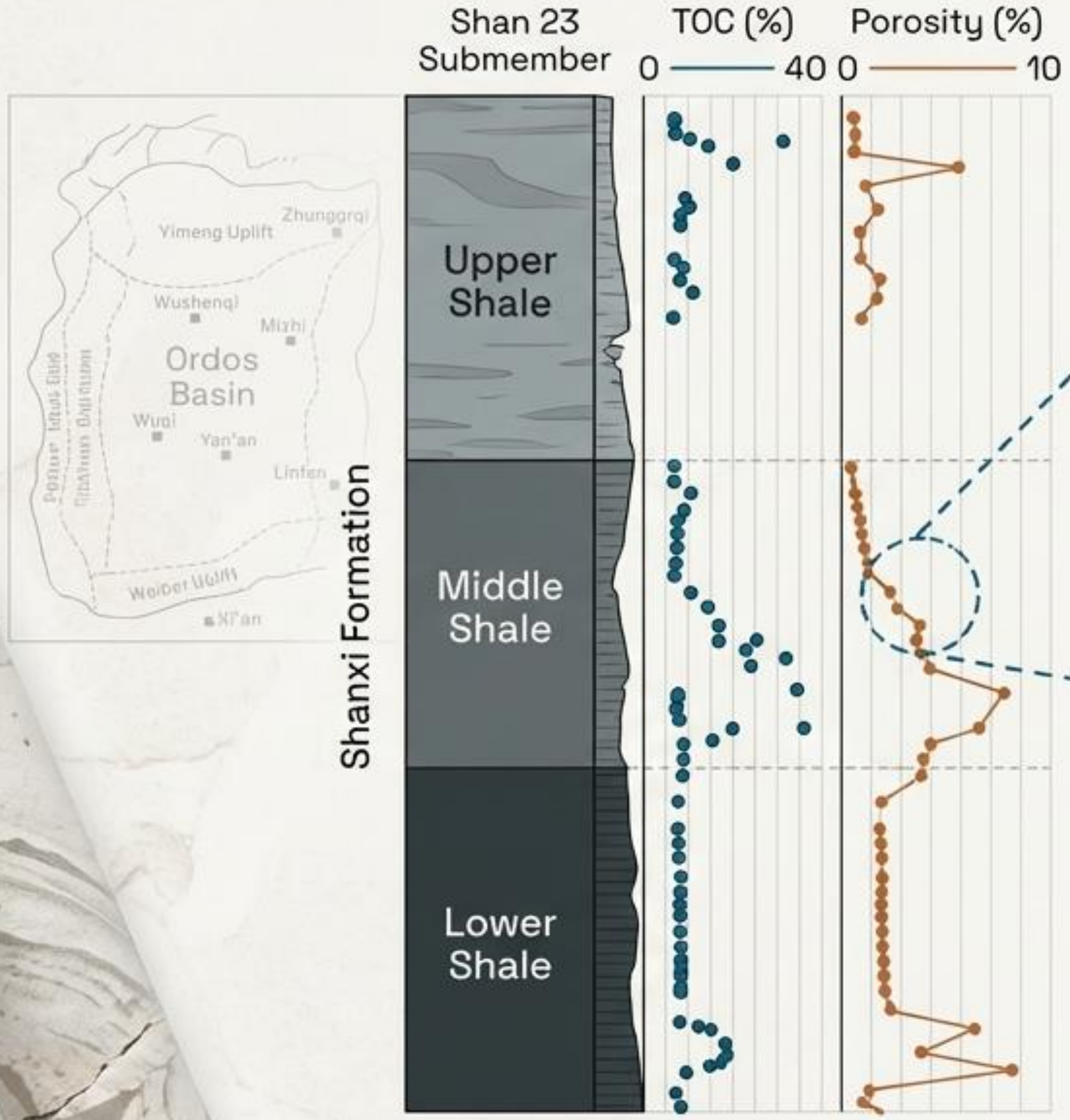


Viscosity: Bulk relaxation is dictated by molecular mobility. Heavy, viscous oil severely restricts proton movement, resulting in rapid T2 decay.

The Reservoir Fluid Signatures Matrix

Fluid Type	T1 (ms)	T2 (ms)	Typical T1/T2 Ratio	Hydrogen Index (HI)	Diagnostic Note
Brine	1-500	1-500	~2	1.0	Controlled by surface relaxation.
Crude Oil	3000-4000	300-1000	~4	1.0	Broad distribution based on viscosity.
Gas (Methane)	4000-5000	30-60	~80	0.2 - 0.4	Massive ratio due to spin-rotation relaxation.

The Frontier: Unconventional Transitional Shales



The Complexity

Shales contain nano-scale pores, high clay volumes, and solid organic matter (kerogen). Traditional tools misread this complexity.

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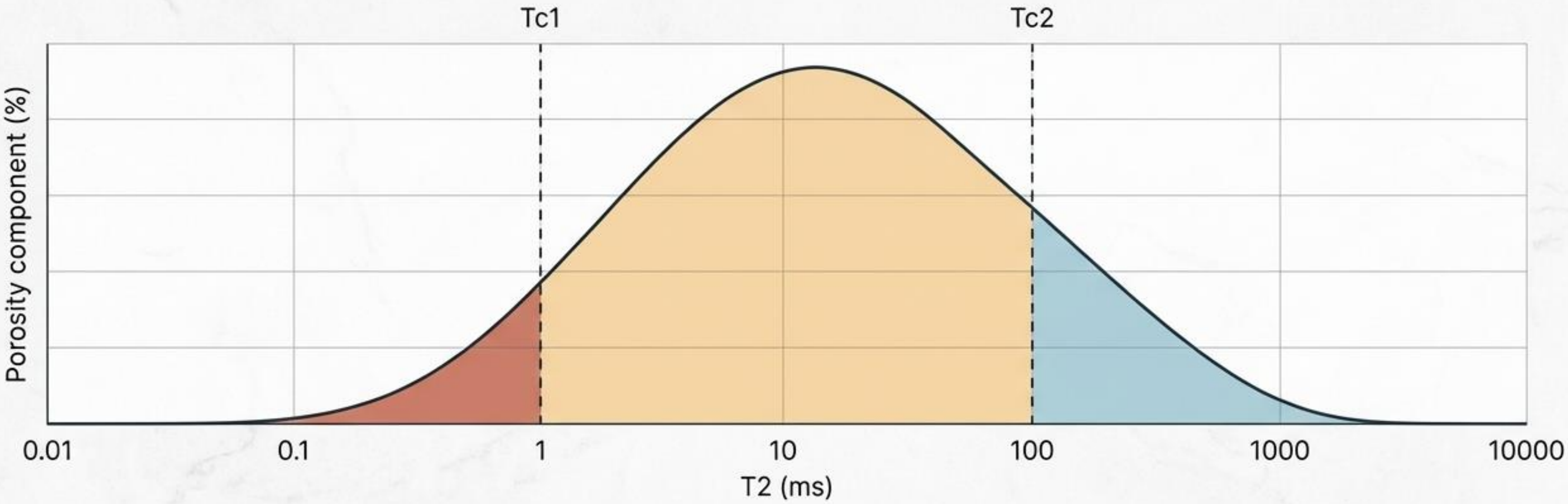
The Target

The Lower Permian Shan 23 transitional shale (Ordos Basin, China). High TOC and extreme thermal maturity make the Middle and Lower shales prime targets, with lost and desorbed gas accounting for 80% of total gas content.

The T2 Cutoff: Mapping Fluid Extractability



Immovable (Clay Bound)

Trapped within the physical lattices of clay minerals. Cannot be produced.

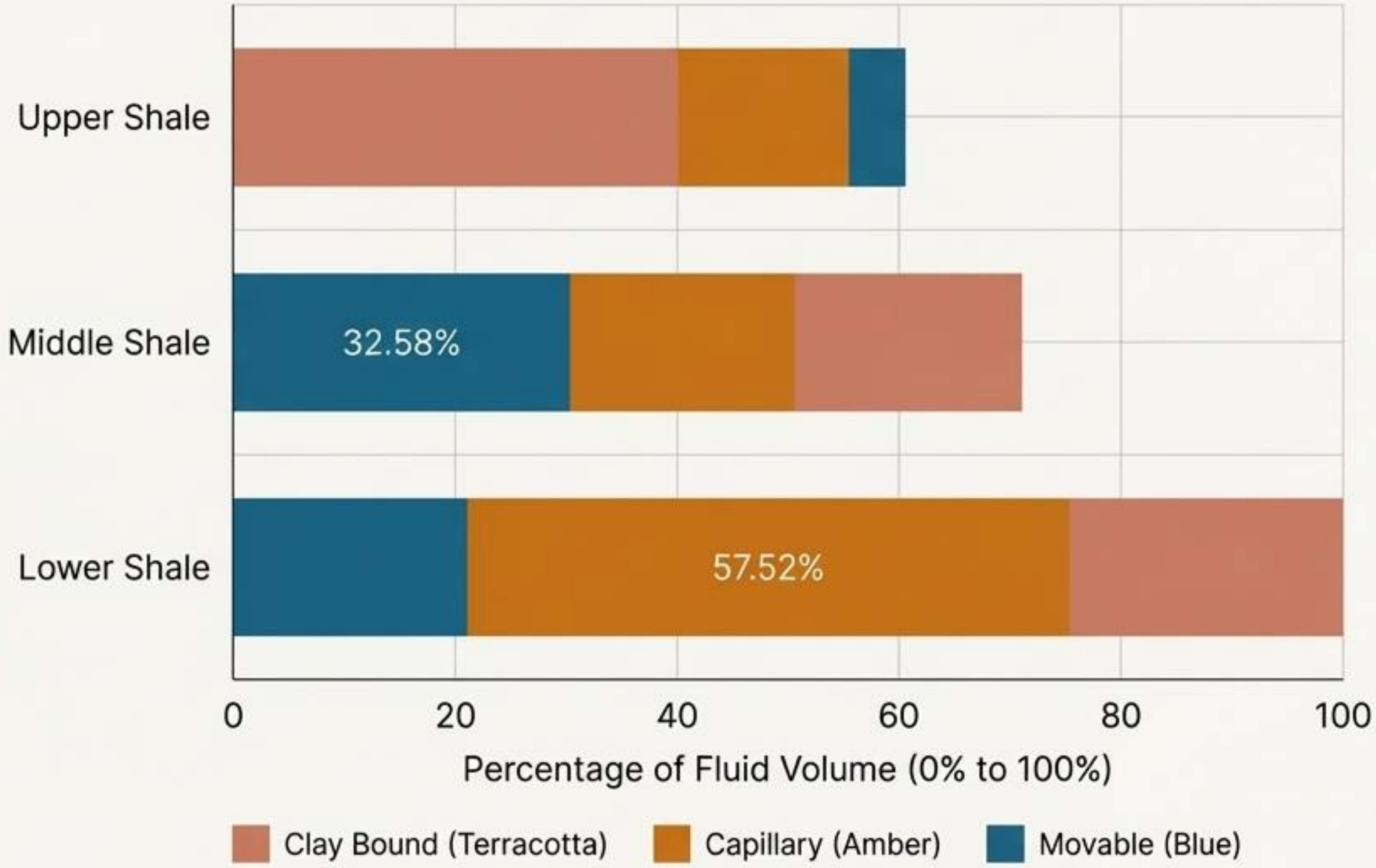
Bound (Capillary)

Held by immense capillary forces in microscopic pores. Requires aggressive fracturing to access.

Movable (Free Fluid)

Producible hydrocarbons and water that flow naturally through the pore network.

Profiling the Shan 23 Reservoir



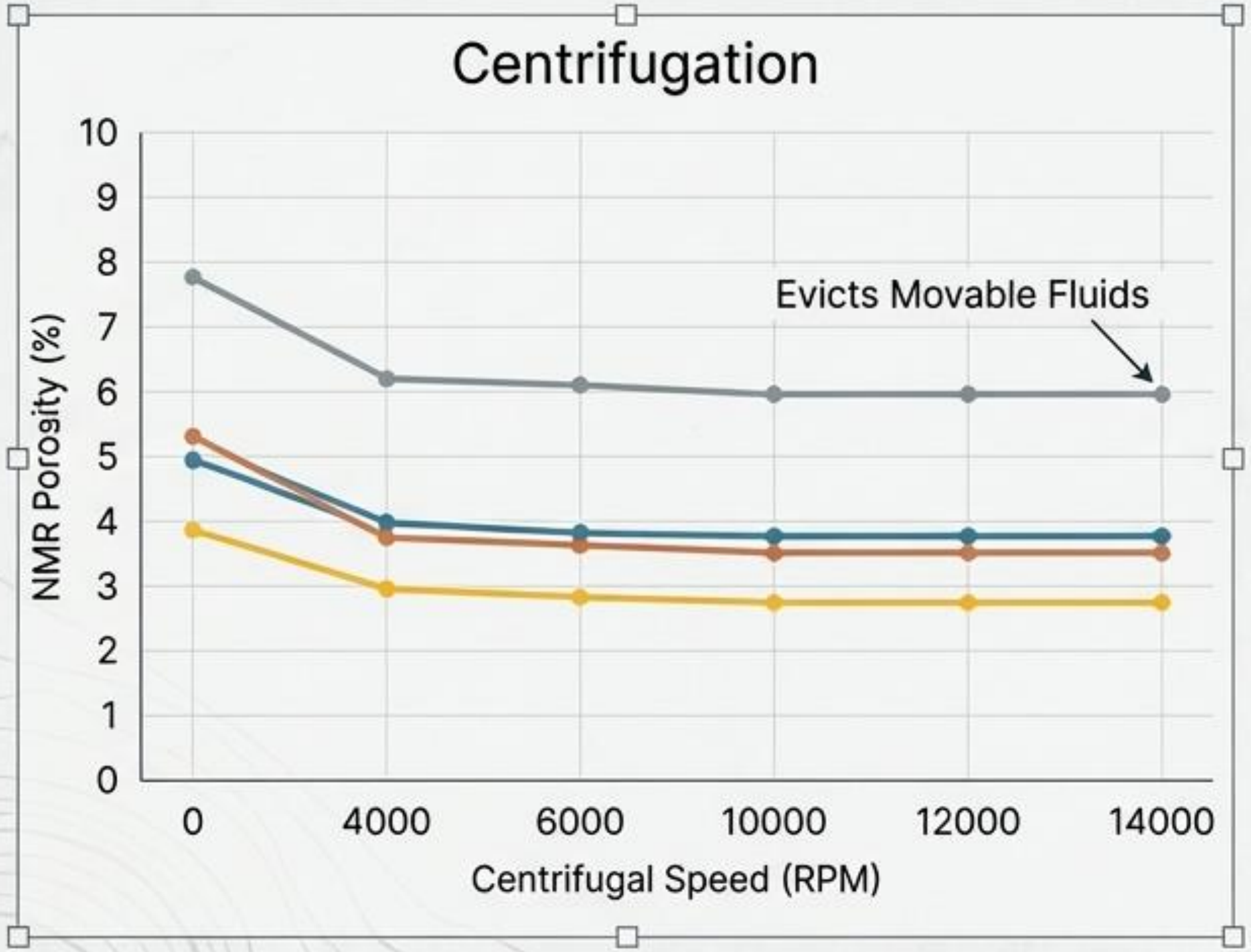
Middle Shale Advantage:

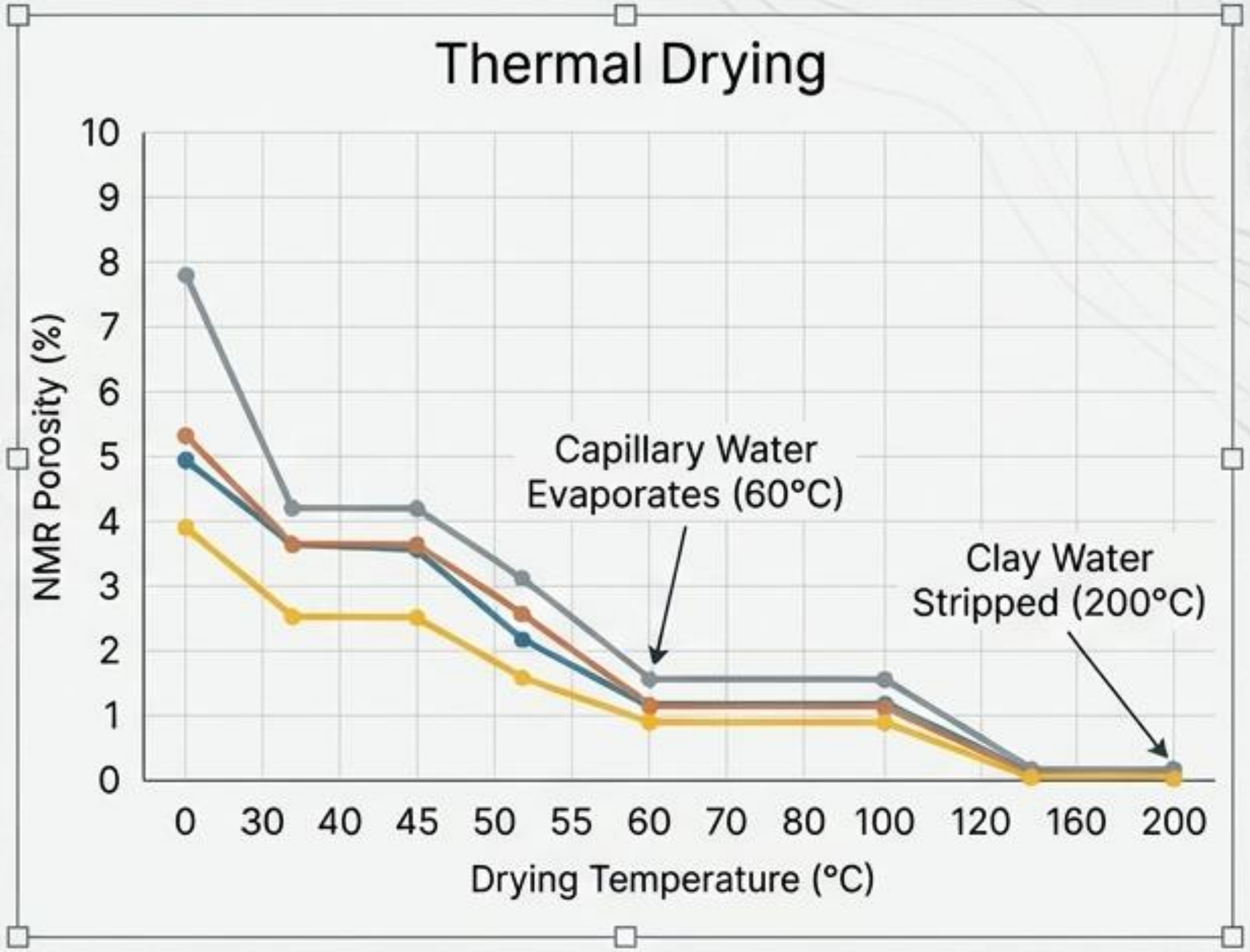
The Middle shale exhibits the highest percentage of movable fluids and a high brittleness index (average 52.3), making it highly fracable.

Lower Shale Capacity:

The Lower shale contains the highest overall fluid volume, but heavily skewed toward toward capillary-bound water, demanding optimized fracturing technologies to unlock.

Laboratory Validation: Physical Stress Testing

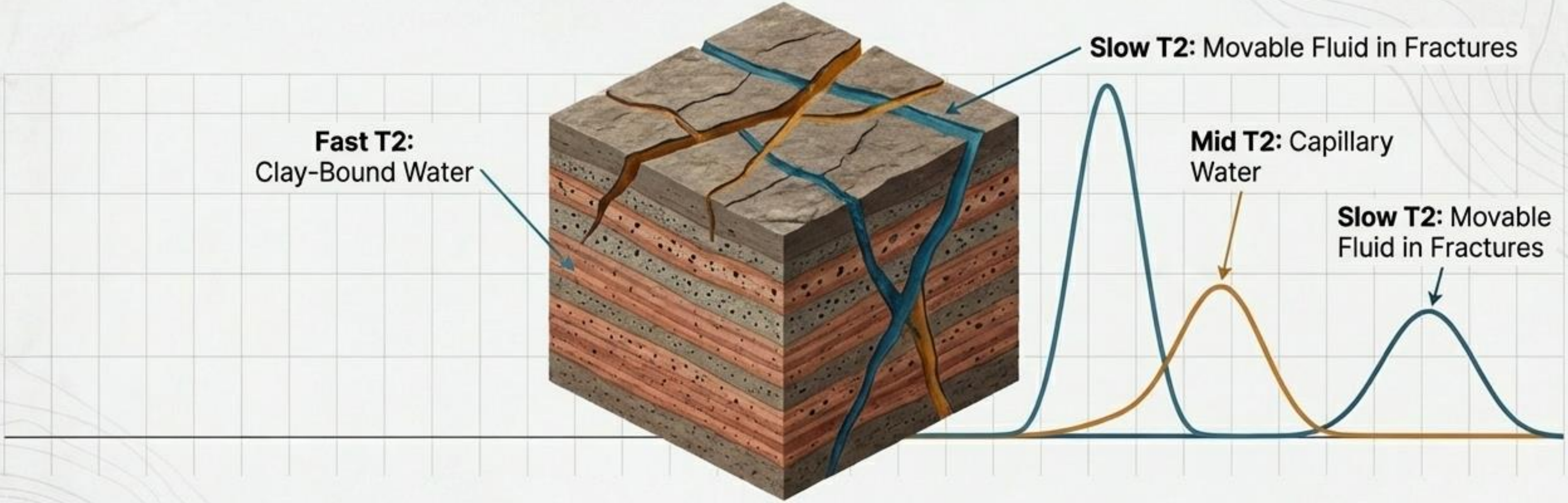




Centrifugal Force: Spinning samples at 14,000 RPM provides the mechanical force necessary to completely evacuate movable water from macropores.

Thermal Gradients: Low-temperature drying (60°C) effectively evaporates capillary-bound water. Extreme heating (200°C) is required to physically strip water bound within clay mineral lattices.

The Complete Reservoir Blueprint



The Ultimate Diagnostic: Nuclear Magnetic Resonance bridges the gap between quantum physics and macroscopic geology.

Actionable Intelligence: By non-destructively mapping pore geometries, defining fluid extractability, and profiling reservoir wettability, NMR delivers the definitive blueprint for exploiting the world's most complex energy reserves.

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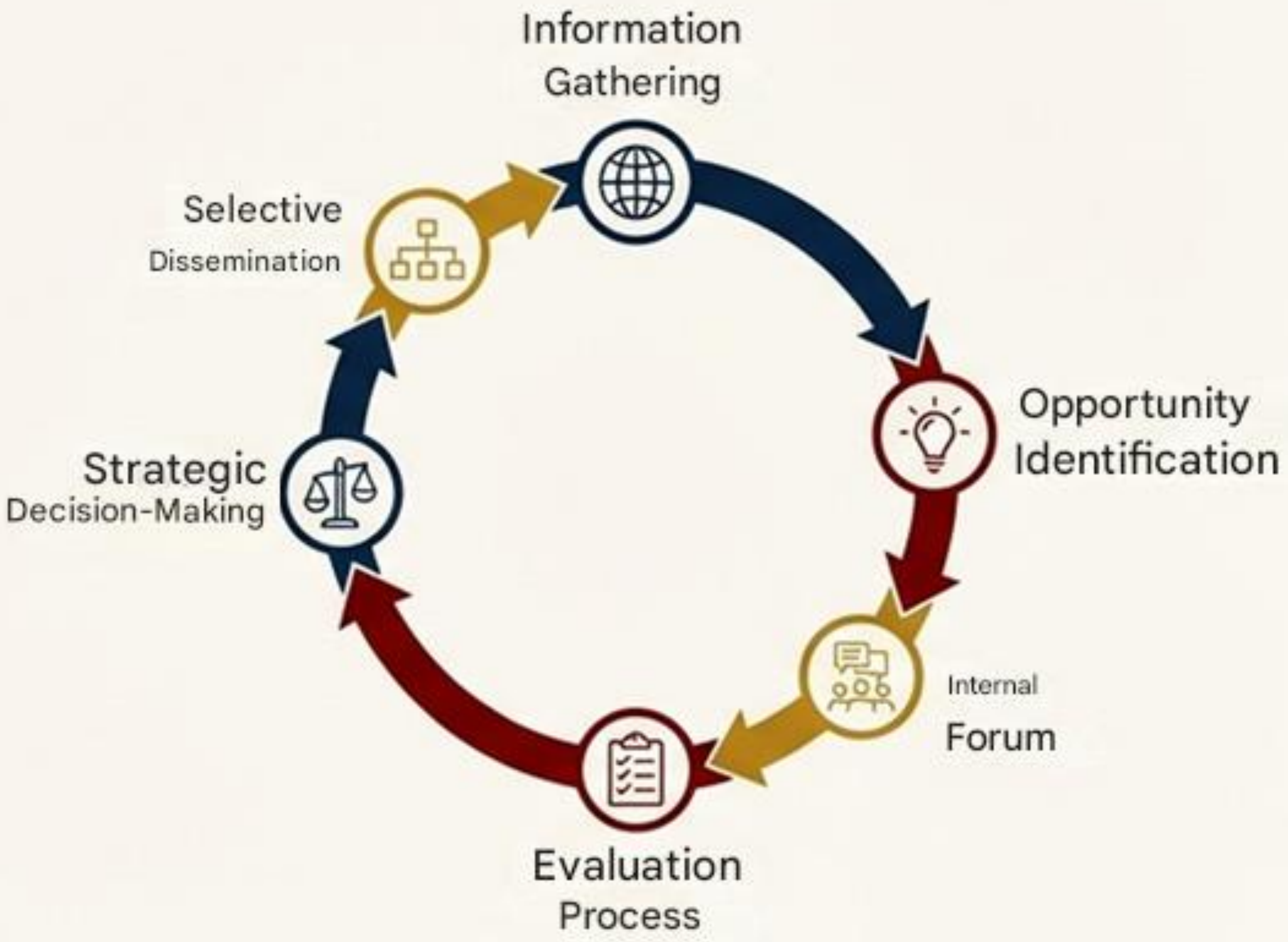
Proactive Economic Intelligence



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