Schlumberger

Dielectric Scanner

Multifrequency dielectric dispersion service

Measurements that speak volumes

APPLICATIONS

- Direct measurement of water volume independent of water resistivity (R_W) at a depth of investigation to 4 in [10 cm], solving for
  - Residual hydrocarbon volume in produced reservoirs
  - Hydrocarbon volume in low-resistivity or low-contrast shaly and laminated sand formations
  - Hydrocarbon volume and mobility in heavy oil reservoirs
  - Water salinity
- Continuous Archie *mn* exponent log from rock texture measurements in carbonates for determining saturations beyond the invaded zone
- Cation exchange capacity (CEC) to account for effect of clay volume in siliciclastics
- High-resolution water-filled porosity for thin-bed analysis

Dielectric Scanner pad antenna configuration. The blue dipoles define the longitudinal polarization and the red ones are the transverse polarization. The two coaxial electrical probes (P_A and P_B) are used for quality control of pad application and for determining the mud and mudcake dielectric properties at the frequencies of interest.

The conventional approach to determining oil volume requires weeks or months for laboratory core analysis or accepting the uncertainty inherent in estimated Archie parameters. With Dielectric Scanner* measurements direct from your reservoir, the wait for accurate formation evaluation answers is over.

Dielectric Scanner service is the first in the industry to employ multifrequency dielectric dispersion science to accurately quantify residual hydrocarbon volume, the Archie *mn* exponent, and formation CEC. Parameters available previously only through core analysis or estimation are now delivered as continuous logs at the wellsite. The dielectric dispersion measurement constructs an accurate radial profile of the close-borehole region, providing new and unique information on rock properties and fluid distribution for advanced petrophysical interpretation. Used in conjunction with traditional logging measurements, Dielectric Scanner dielectric dispersion measurement enables developing a more accurate reservoir description for reservoir evaluation and management.

Multispacing Operation

The heart of Dielectric Scanner service lies in its short, multispacing antenna array pad. Each of the cross-dipole antennas has collocated magnetic dipoles. The transmitters (T_A and T_B) are in the center and the receivers ($R_{A1–4}$ and $R_{B1–4}$) are placed symmetrically around them for optimal measurement accuracy and borehole compensation. To minimize environmental effects, the short, fully articulated antenna pad is applied firmly against the borehole wall by a hydraulically operated eccentering caliper to enable optimal pad contact, even in rugose boreholes. Electromagnetic waves are propagated into the formation at four frequencies and two polarizations for high-resolution, high-accuracy measurements of reservoir properties at up to 4 in from the borehole wall.

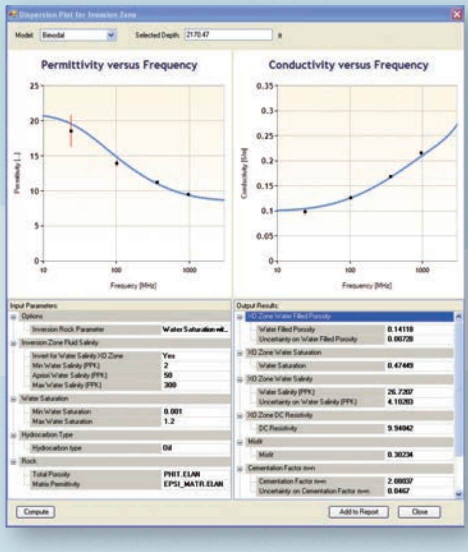
Dielectric dispersion science

One of the revolutionary advances provided by the Dielectric Scanner tool is the continuous measurement of dielectric dispersion, which is the variation of formation dielectric properties as a function of the frequency. High-resolution measurements obtained with the different array spacings, each with two polarizations at four frequencies, are radially interpreted to obtain permittivity and conductivity at each frequency. Conventional dielectric tools make only a single-frequency measurement with limited applications, and its interpretation cannot account for textural effects, invasion, and unknown or variable water salinities.

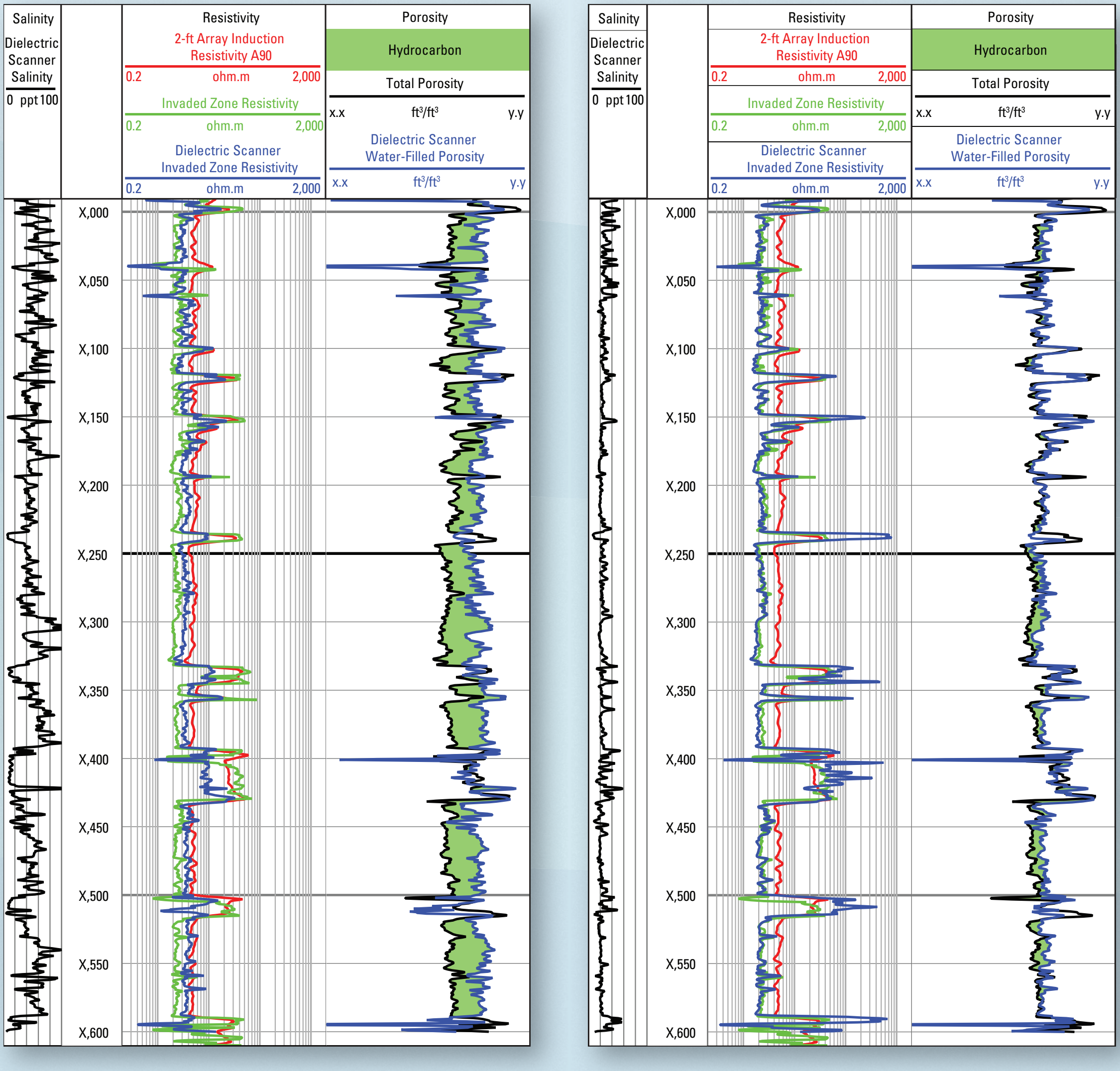
The Dielectric Scanner permittivity and conductivity measurements at each frequency are interpreted using a petrophysical model. The output parameters of the model are water-filled porosity (hence water saturation if the total porosity is known), water salinity, and textural effects in carbonates or CEC in shaly sands. Simultaneously fitting the permittivity and conductivity dispersions frees the water-filled porosity from salinity effects. Rather, water salinity is an additional output of the analysis. For a well drilled with oil-base mud (OBM), the calculated water salinity is the formation water salinity.

In carbonate reservoirs, the dielectric dispersion is driven mainly by the rock texture. In turn, Dielectric Scanner analysis provides a continuous in situ measurement of rock texture, presented as an *mn* exponent log.

In shaly sand reservoirs, processing provides a continuous log of the CEC. In heavy oil reservoirs or in shallow-invasion situations, Dielectric Scanner measurements are made in both the invaded and non-invaded zones, to determine moveable hydrocarbon content.



Dispersion plots of the measured permittivity and conductivity at four frequencies and the fit to the petrophysical model with the estimated parameters.



Previous-generation single-frequency electromagnetic propagation tools, emulated in the log on the left by single-frequency processing, cannot account for textural variation, resulting in the overestimation of invaded zone resistivity R_{XO} (Track 2). In the log on the right, Dielectric Scanner multifrequency mixing analysis correctly matches the water-filled porosity to the total porosity in this water-filled sand in Track 3, as confirmed by the matching R_{XO} values of the Dielectric Scanner and resistivity tools in Track 2.

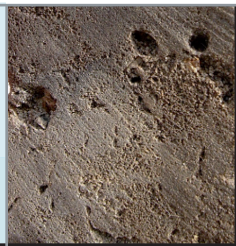
Case studies

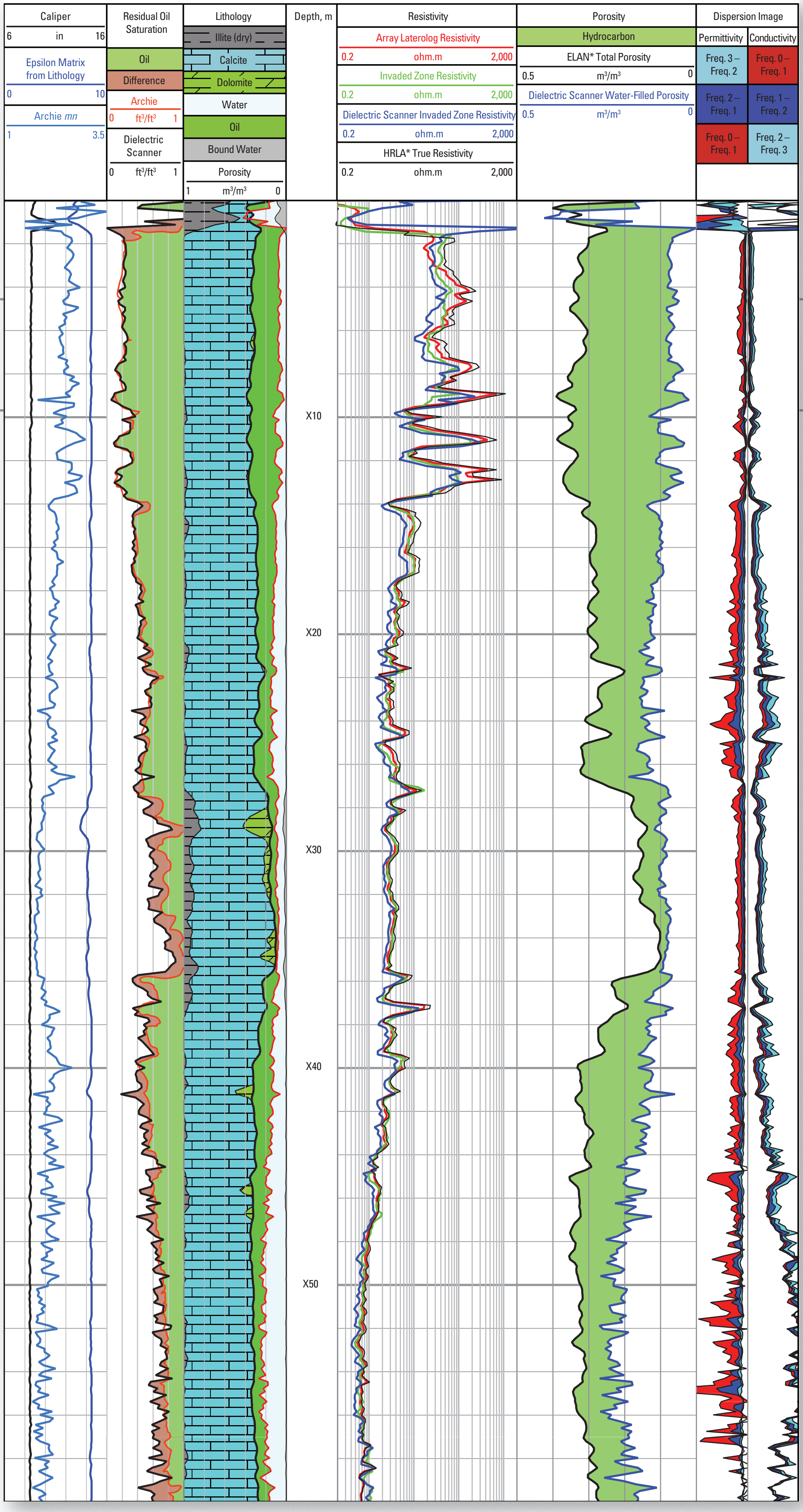
Dielectric Scanner measurements confirm 95% residual hydrocarbon saturation

An operator in the Middle East wanted to improve understanding of the fluid saturations in a high-porosity carbonate reservoir where variability in the Archie *m* and *n* exponents increased the uncertainty in conventional log interpretation. The measurements were also ambiguous because the mud filtrate salinity was approximately 180,000-ppm [-ug/g] NaCl.

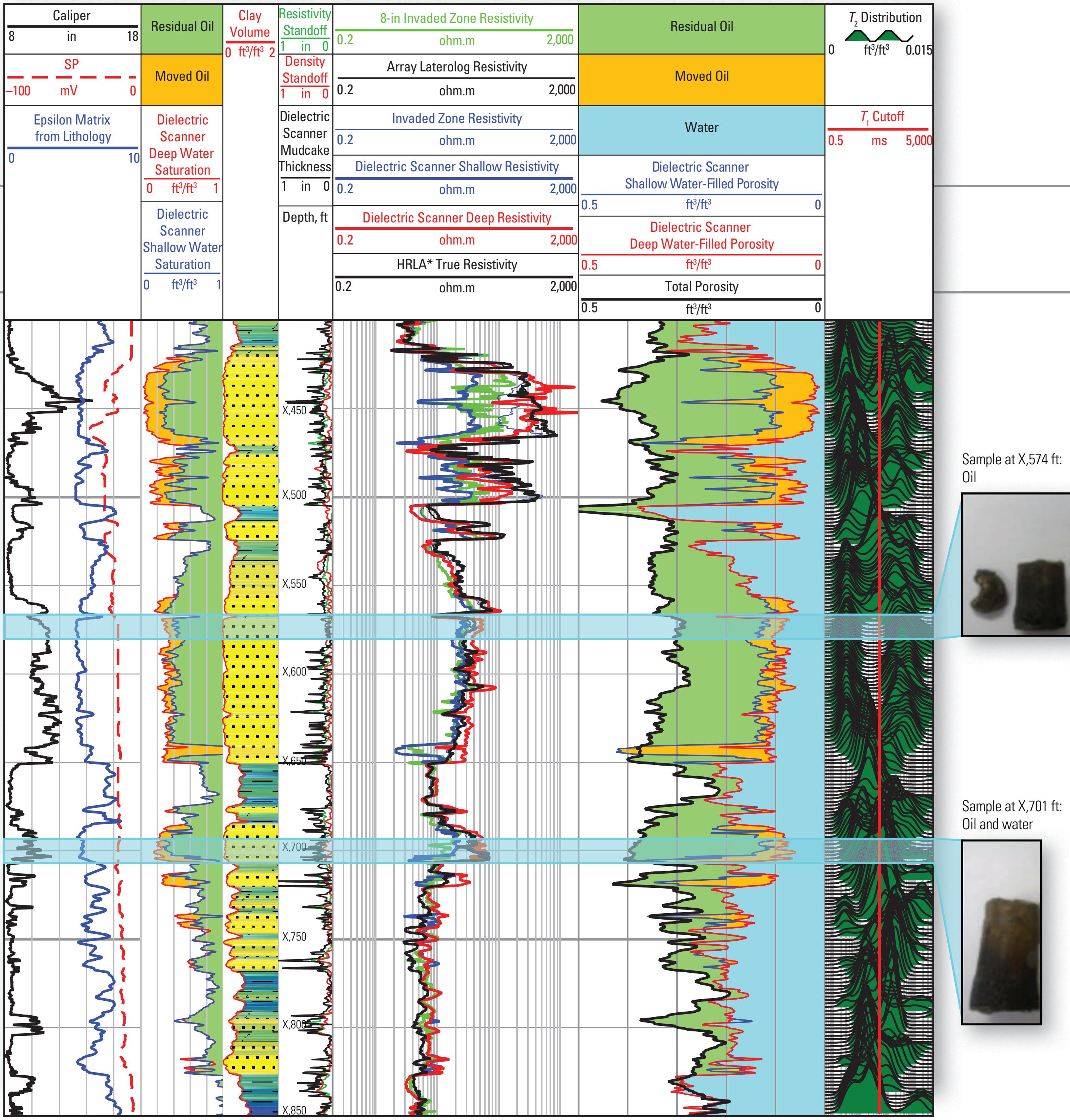
The carbonate textural information provided by Dielectric Scanner service enabled accurate *mn* determination instead of relying on potentially incorrect estimations from conventional log analysis or waiting for laboratory core analysis. Having accurate values of the Archie exponents is important because they are the basis for calculating saturation values from resistivity.

As shown by the porosity curves in Track 5, the significant difference between Dielectric Scanner water-filled porosity (blue curve) and the total porosity calculated from standard porosity measurements indicates a large volume of residual hydrocarbon in the formation. In Track 2 the Dielectric Scanner hydrocarbon saturation accounts for variation in the Archie exponents across the reservoir and confirms up to 95% residual hydrocarbon. Conventional saturation determination using constant values of the Archie *mn* exponents does not account for their variation, as shown by the difference shaded red where the conventional and Dielectric Scanner residual oil saturations do not match. Confirmation of the high residual saturation is in Track 4, where the R_{xo} measurements from Dielectric Scanner and conventional resistivity logging closely match each other.





Confirmation of 95% residual hydrocarbon by R_{xo} match. The R_{xo} curve from Dielectric Scanner service in the carbonate reservoir agrees closely with the conventional R_{xo} measurement in Track 4, supporting the determination of 95% residual hydrocarbon saturation.



Moveable heavy oil confirmed by sidewall cores. Although the resistivity in Track 5 and NMR in Track 7 cannot readily distinguish between oil and formation freshwater below the oil-bearing interval from X,430 to X,500 ft, Dielectric Scanner measurements of fluid volumes (Track 6) and the resulting saturations (Track 2) clearly reveal significant moveable heavy oil down to X,720 ft, as confirmed by sidewall core analysis.

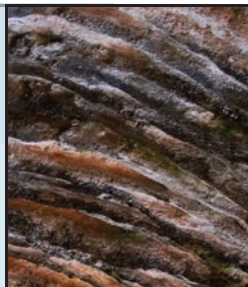
Additional 150 ft of pay revealed by Dielectric Scanner dispersion measurements

The production potential of a laminated reservoir in the Orinoco belt of Venezuela could not be fully determined with conventional logs. Thinly bedded shale and sand layers decreased resistivity measurements, masking pay zones and resulting in pessimistic interpretations of hydrocarbon volume. In this heavy oil reservoir, NMR logs measured a reduced apparent formation porosity, which in turn adversely affected fluid saturation determinations.

An additional complication was the highly rugose borehole, as shown by the caliper in Track 1, but the pad of the Dielectric Scanner tool maintained good contact with the formation, and the measurements were not compromised. The high resistivity in Track 5 in the oil-bearing interval from approximately X,430 to X,500 ft had been observed in other wells in the area. However, resistivity values below this interval are uniformly low. Similarly, the NMR log in Track 7 has a strong oil signature in the upper interval, but the apparent porosity is reduced with increasing depth.

The Dielectric Scanner log dispelled uncertainty about the reservoir quality of the lower interval, revealing moveable oil over a 150-ft section, from X,560 to X,650 ft and again from X,690 to X,720 ft. Sidewall samples confirmed the Dielectric Scanner measurements.

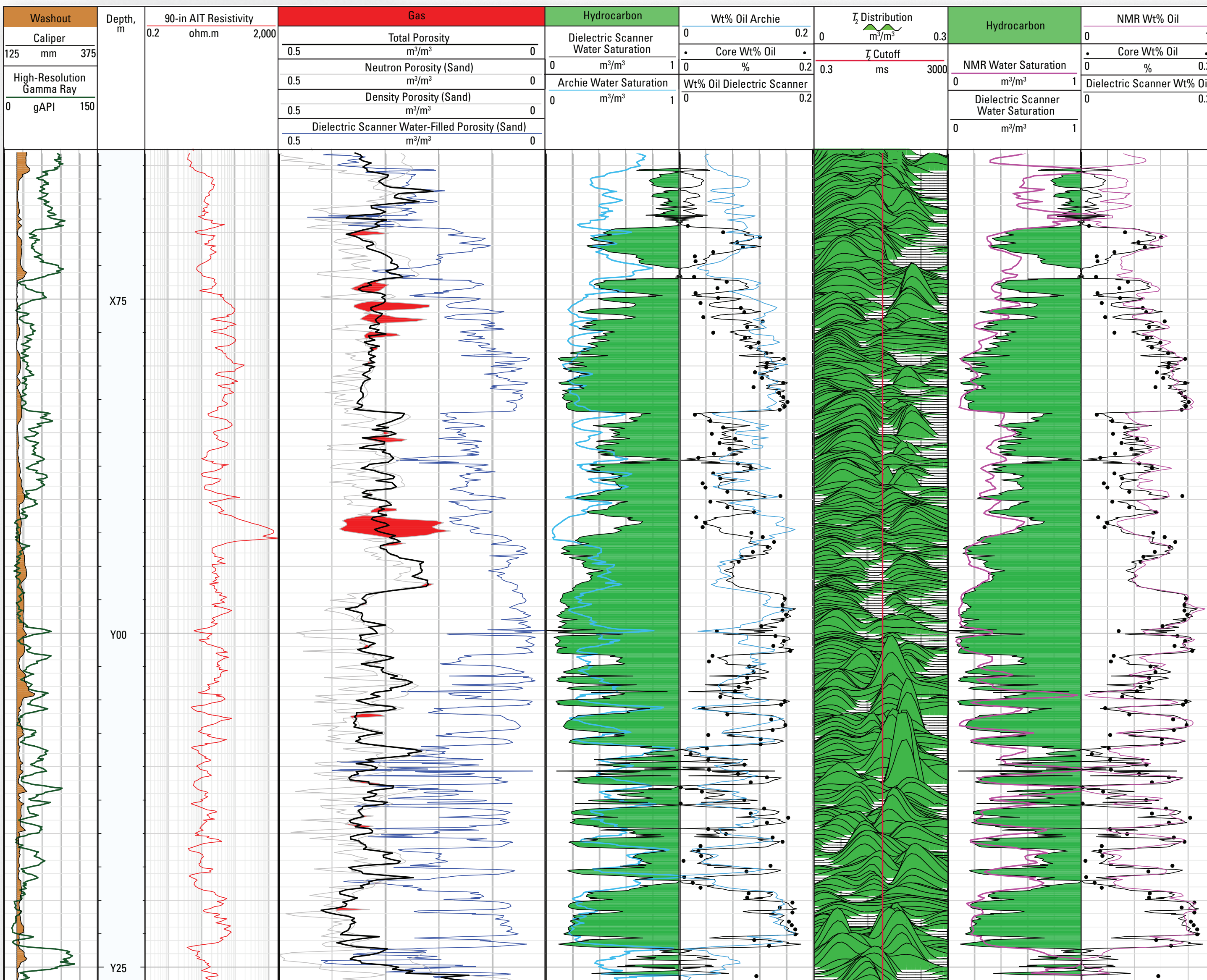
High-resolution water-filled porosity and radial profiling delivered by multifrequency measurements without the errors introduced through the estimation of Archie formation factors



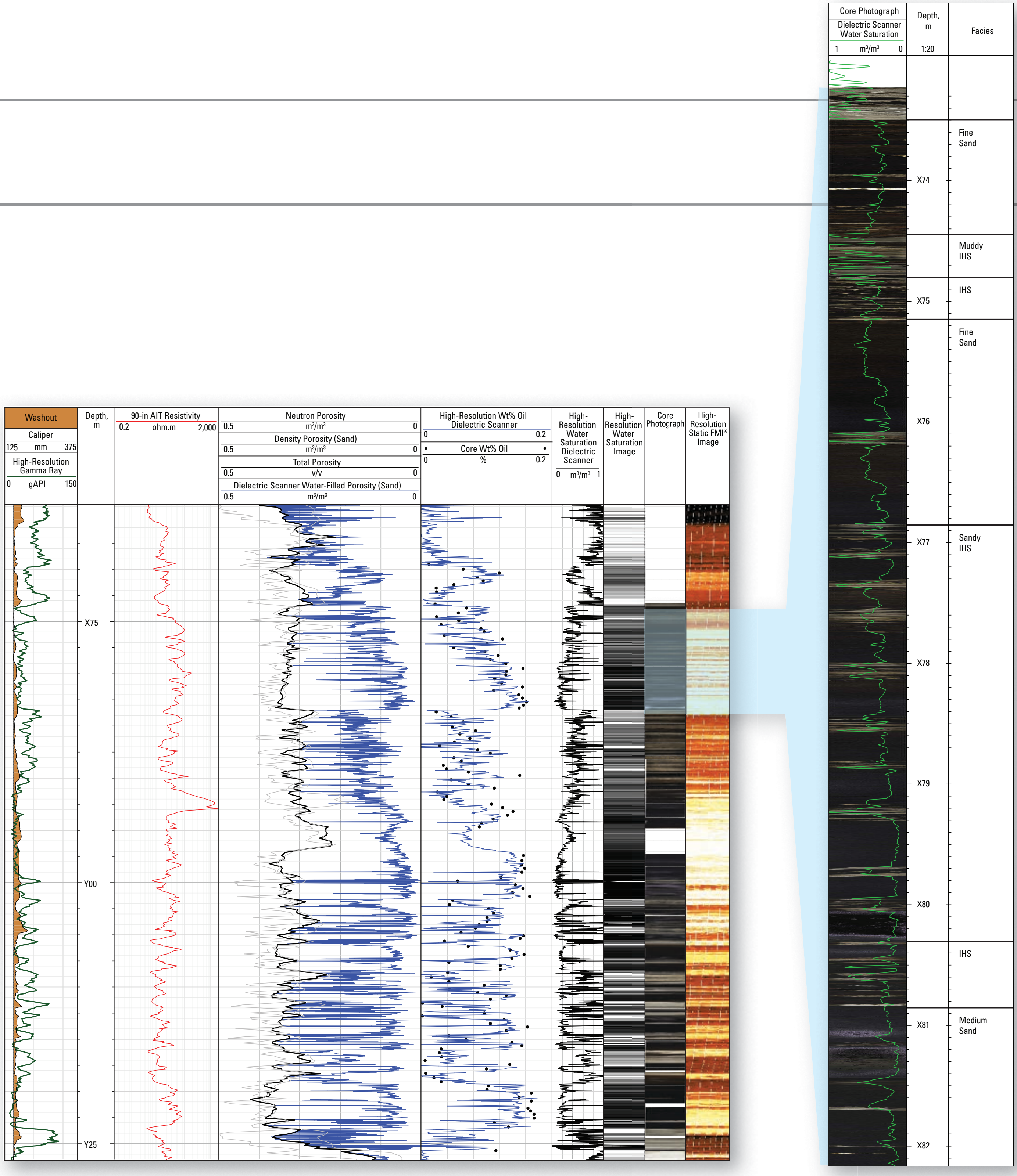
Weight percent bitumen quickly, accurately determined in Canadian oil sands

Because the formation water salinity and resistivity vary in heavy oil reservoirs with thin-bedded shaly sections, Canadian operators had to wait several months for the results of Dean Stark core analysis. Without the analysis results to adjust conventional saturation calculations, using a constant R_W value led to errors in the water saturation determined for uncored intervals.

With water-filled porosity calculated from Dielectric Scanner dispersion measurements, the weight percent of bitumen is accurately determined months in advance of laboratory core analysis turnaround. The operators can confidently consider a reduction in coring frequency and number of analysis points in their multiwell projects.



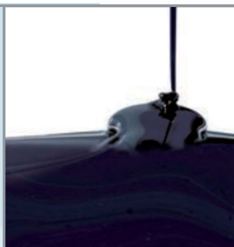
Accurate answers quickly. Water saturation and hydrocarbon volume calculated from Dielectric Scanner dispersion measurements provide higher resolution, more accurate answers than those derived from the Archie equation or nuclear magnetic resonance (NMR) data.



High vertical resolution. The high-resolution weight percent bitumen calculated from Dielectric Scanner measurements shows excellent agreement to the subsequent core analysis results in Track 4, even in the thin shale intervals identified in the core photograph by the lighter colors within the black bitumen-rich core. IHS = inclined heterolithic stratification.

It Speaks Volumes about **Heavy Oil**

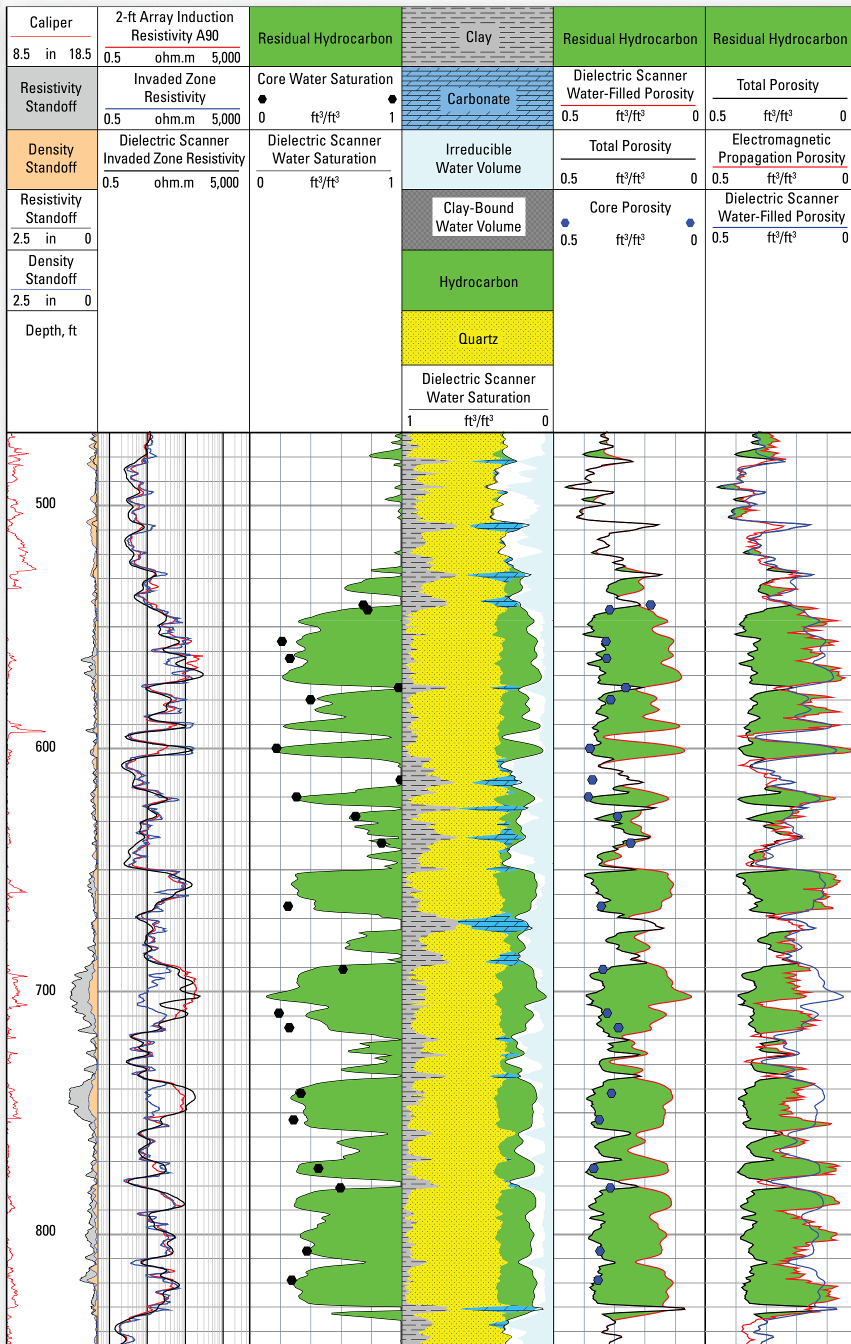
Heavy oil saturation and mobility from high-resolution measurements insensitive to oil viscosity and formation water resistivity



Overlooked pay found in washed-out zones in heavy oil reservoir

Washed-out borehole intervals in a heavy oil reservoir in Cymric field, California, USA, were adversely affecting logging. Washouts caused separation in the resistivity curves that could be confused with invasion, as shown at 700 and 745 ft in Track 2. Water-filled porosity measurements made with a conventional, mandrel-type, single-frequency electromagnetic propagation tool were suspect because the tool would not have been able to maintain good contact in these rugose conditions.

Porosity and saturation calculated from Dielectric Scanner measurements in Tracks 5 and 3, respectively, correct the previous washout-impaired porosity, as confirmed by sidewall core analysis (black dots). With accurate porosity values, the pessimistically high water saturation value was corrected by 23%.



Accurate resistivity and porosity measurements in a washed-out borehole. The articulated pad of the Dielectric Scanner tool is not affected by rugose hole conditions and obtained the actual R_{xo} measurement, proving that the difference between the other two resistivity curves in Track 2 was not caused by invasion. Similarly, the Dielectric Scanner porosity in Track 5 accurately measured water-filled porosity across washed-out intervals, unlike the previous-generation mandrel tool.

Dielectric Scanner interpretation and quality control software

Dielectric Pro* software provides quality control and advanced interpretation for Dielectric Scanner service. After preprocessing and applying quality control to the raw data, Dielectric Pro software performs a robust radial interpretation of the different spacing and polarization measurements to provide the dielectric dispersion data. A multimineral analysis for lithology and porosity that integrates measurements from different tools is performed in the same application to determine the total porosity and formation matrix permittivity. These outputs are used together with the dielectric dispersion in a final interpretation step, in which petrophysical models determine water-filled porosity, water salinity, and textural parameters.

Following a carefully engineered, efficient workflow, Dielectric Pro software delivers reliable petrophysical answers for complex environments in minimum time.

Pore-fluid analysis
- High-resolution residual saturation and invaded zone water salinity
- Hydrocarbon saturation profile in heavy oil reservoirs or shallow invasion environments

Matrix analysis
- Carbonates: *mn* log for cementation exponent estimation
- Shaly sands: high-resolution CEC for clay content

Structural analysis
- Thin-bed analysis
- Structural anisotropy in very thin beds

Dielectric Scanner

Specifications	
Output	Relative dielectric permittivity and conductivity at four frequencies
Logging speed	3,600 ft/h [1,097 m/h]
Vertical resolution†	1 in [2.5 cm]
Depth of investigation	1 to 4 in [2.5 to 10 cm]
Accuracy at the highest frequency	Corresponding to 0.002-ft^3/ft^3 [0.002-m^3/m^3] water-filled porosity Permittivity: ±1% or ±0.1 Conductivity: ±1% or ±5 mS
Range of measurements at the highest frequency	Permittivity: 1 to 100 Conductivity: 0.1 to 3,000 mS
Combinability	Platform Express* integrated wireline logging tool Most openhole tools
Max. temperature	350 degF [177 degC]
Max. pressure	25,000 psi [172 MPa]
Outside diameter	4.77 in [12.12 cm]
Borehole size—min.	5.5 in [14 cm]
Borehole size—max.	22.0 in [55.9 cm]
Minimum restriction	5.25 in [13.3 cm]
Borehole fluid	Both water- and oil-base muds‡
Length	11.27 ft [3.44 m]
Weight	262 lbm [119 kg]
Max. tension	50,000 lbf [222,411 N]
Max. compression§	4,400 lbf [19,572 N]
Conveyance	Wireline, TLC* tough logging conditions system, or tractor

† 1 in depending on frequency
‡ Oil-base mud under specific conditions; contact your Schlumberger representative
§ 8,000 lbf [35,586 N] with TLC stiffener kit

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