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Accurate Heavy Oil Volume in Shaly Sands with Variable Water Resistivity

Resistivity- and salinity-independent measurements from Dielectric Scanner service provide accurate hydrocarbon volume in Canadian oil sands

CHALLENGE
Determine the bulk mass fraction of oil (weight percent bitumen) in oil sands with variable formation water resistivity in Canada.

SOLUTION
Obtain Dielectric Scanner* multifrequency dielectric dispersion measurements to accurately calculate water-filled porosity insensitive to water salinity instead of estimating Archie parameters or waiting months for laboratory core analysis.

RESULTS
Accurately determined weight percent bitumen months in advance of laboratory analysis in oil sand reservoirs where shale intervals and variable formation water salinity complicate conventional porosity and resistivity analysis.

Interpretation ambiguity introduced by varying water salinity
Canadian operators needed a more efficient approach to the formation evaluation of heavy oil reservoirs that include some thin-bedded shaly sections. Because the salinity of the formation water varies, current industry practice is to evaluate oil volume using Dean Stark core analysis, and the operators may have to wait several months for the core analysis results. The results are used to determine the parameters required to make conventional saturation calculations match the core data to fill in intervals that were not cored.

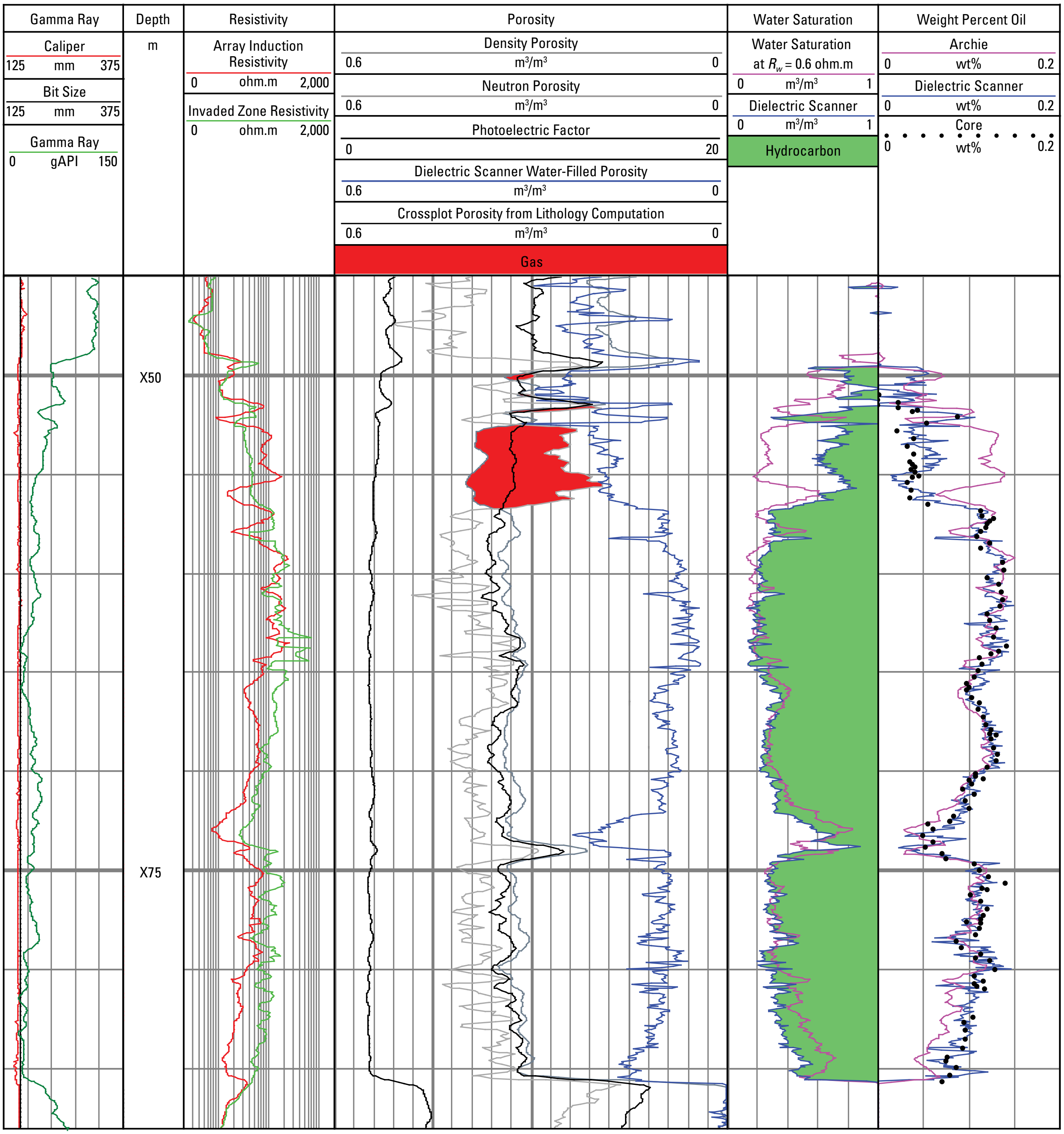
Saturation determination independent of water salinity
Dielectric Scanner service delivers dielectric dispersion measurements at a 1-in [2.54-cm] vertical resolution based on nine attenuation and phase-shift measurements at four frequencies. These multifrequency high-resolution measurements are radially inverted to obtain permittivity and conductivity at each frequency. The resulting determination of water-filled porosity is salinity insensitive because the permittivity of water is readily differentiated from that of rock matrix or hydrocarbons. The conductivity measurements provide reconstructed resistivity and water saturation for the invaded zone. Dielectric Scanner service's measurements also yield useful textural information.

Dielectric Scanner service's articulated pad greatly improves contact with the formation in rugose boreholes, a condition that previous mandrel-type electromagnetic propagation tools were sensitive to.

Rugose or washed-out boreholes do not adversely affect Dielectric Scanner service's multifrequency measurements because the articulated pad maintains contact.

Accurate fluid volumes without waiting for laboratory analysis

In Well 1, the resistivity values of the heavy oil reservoir (Track 2) are not definitive below the gas cap, shown at about X55 m in Track 3. The water saturation and weight percent oil (Tracks 4 and 5, respectively) calculated from Dielectric Scanner service's water-filled porosity (Track 3) are in excellent agreement with the core analysis results and provide a more accurate determination of hydrocarbon accumulation than evaluation based on Archie equation estimates because Dielectric Scanner service's measurement is not sensitive to the changing water resistivity (R_w) values. The conventional Archie-derived water saturation is in error at X72–X74 m and X80–X85 m because a constant R_w value was used for the entire interval.



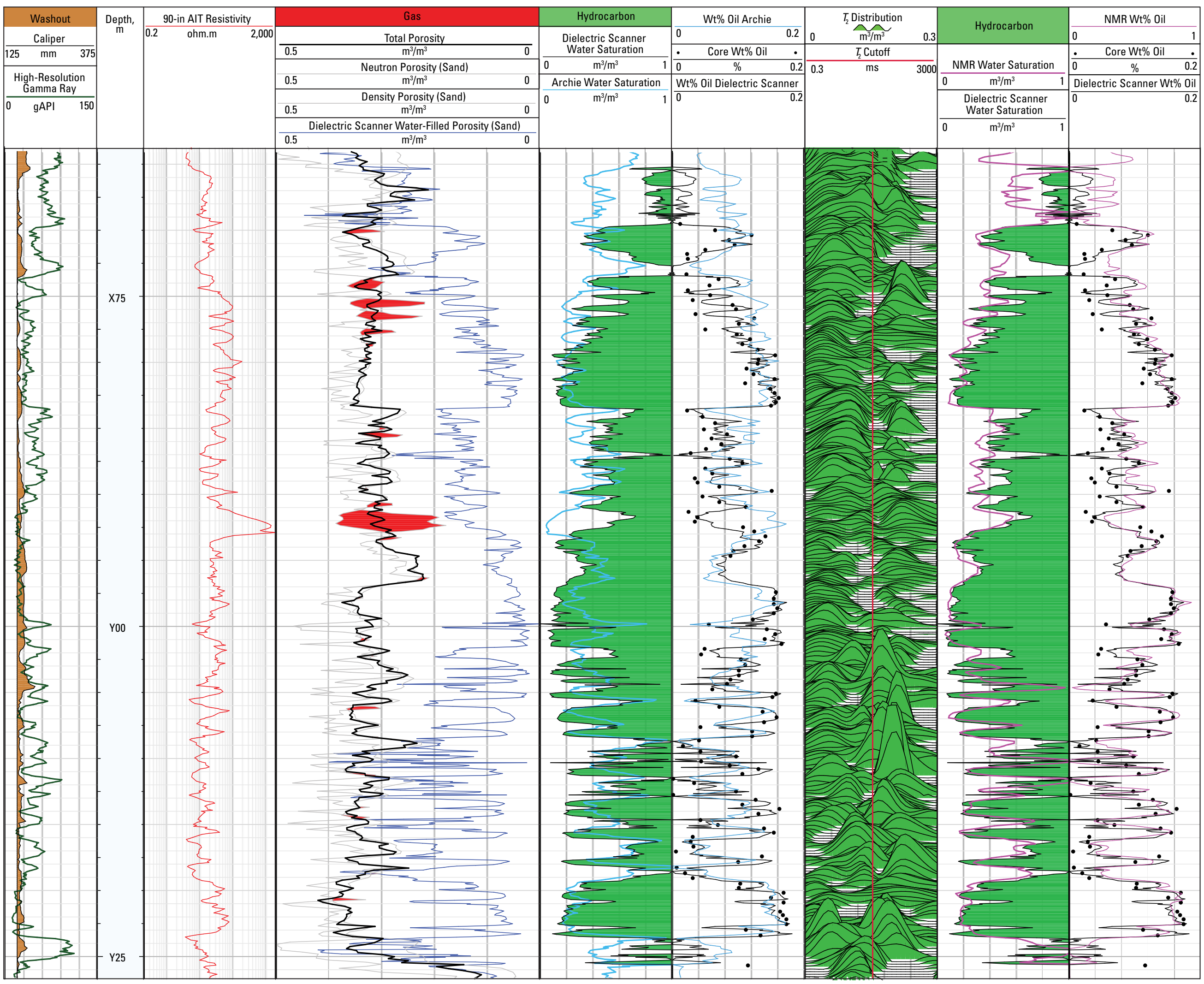
In Well 1, the varying formation water resistivity produced discrepancies in the conventional analysis based on the Archie equation, leading to a pessimistically high calculation of water saturation (Track 4). The weight percent bitumen calculated from Dielectric Scanner service's measurements is salinity independent and shows excellent agreement to core analysis results (Track 5).

For Well 2, the log on this page compares the Archie water saturation (calculated using porosity, resistivity, and a constant R_w value) with the saturation calculated using Dielectric Scanner service's measurements (Track 4). Overall, the results are in good agreement at the top and bottom of the reservoir, but there is a discrepancy in the interval from X94 to Y02 m. The difference resulted because the Archie-derived saturation does not account for the change in formation water resistivity in the interval.

Comparison of the weight percent bitumen calculated from the salinity-independent Dielectric Scanner service's measurements with the core analysis results in Track 5 shows excellent agreement.

In heavy oil reservoirs, hydrocarbon volume can also be calculated by using nuclear magnetic resonance (NMR) data, but the cutoff must be carefully selected to remove the heavy oil signal included in the transverse relaxation time (T_2) distribution (Track 6). In Well 2, the NMR-based saturation and weight percent bitumen results (Tracks 7 and 8, respectively) agree well with Dielectric Scanner service and core results over most of the reservoir. However, the NMR-based results in the shaly intervals at X72–X74 m and X83–X89 m are too optimistic compared with the core and Dielectric Scanner service. Oil volume calculated from Dielectric Scanner service's total water-filled porosity clearly provides the best match to the core measurements.

A review of the calculated water saturation curves (Track 4) suggests that the results from Dielectric Scanner service are at significantly higher resolution than either the NMR- or Archie-derived results, especially in the interval from X75 to X98 m.

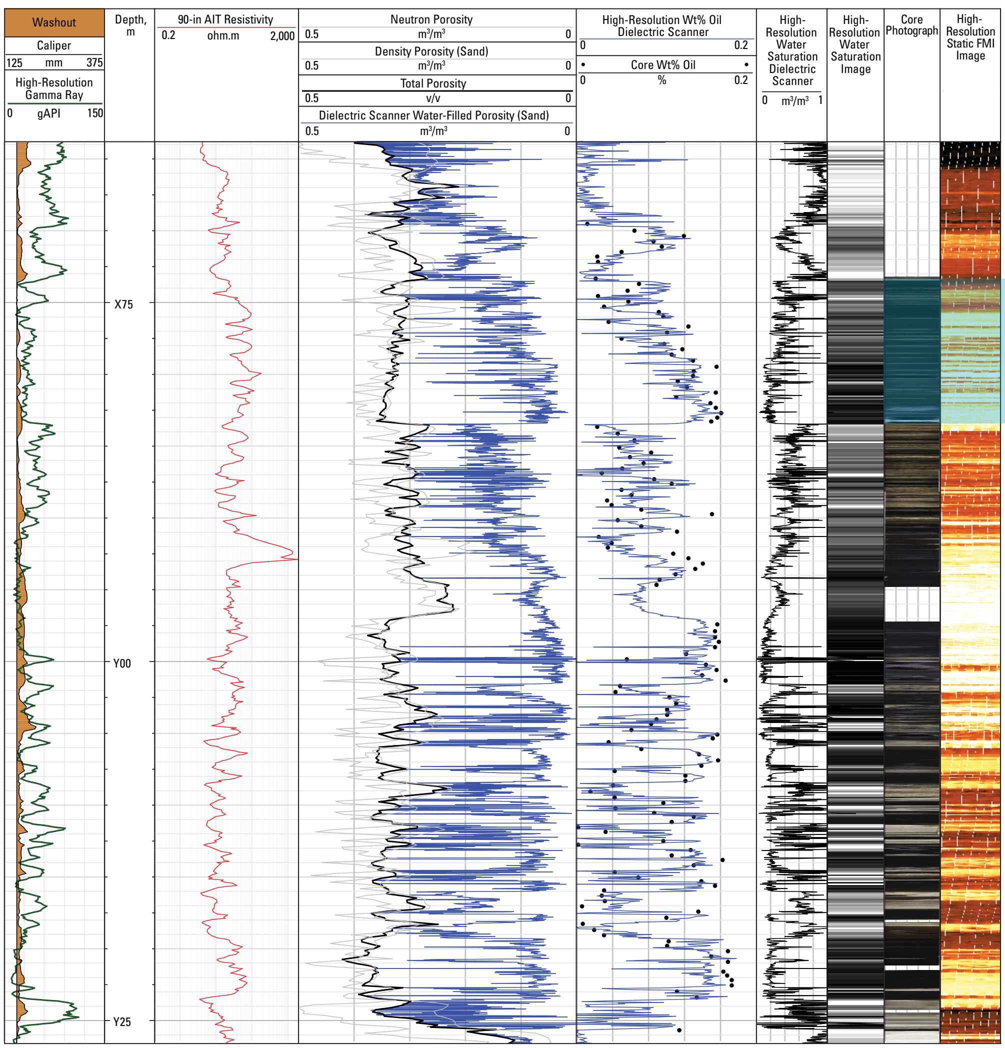


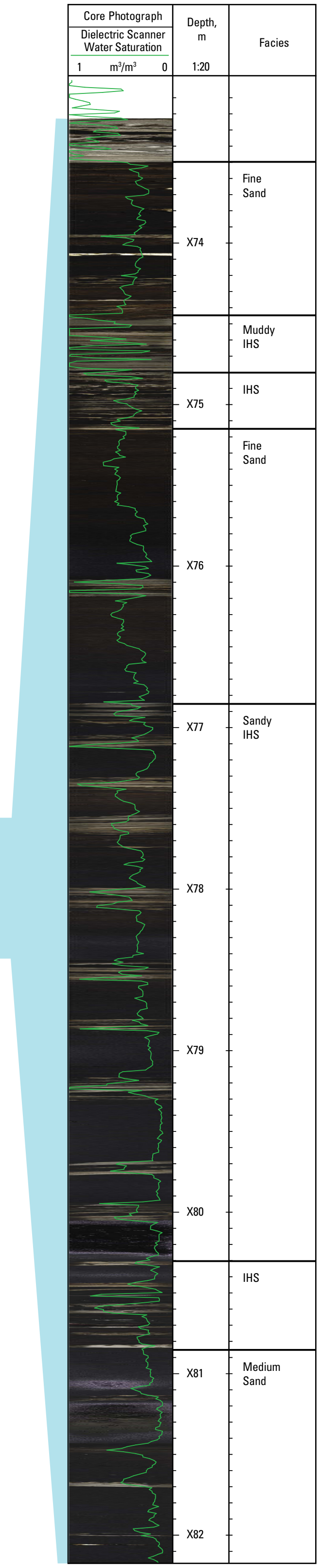
In Well 2, water saturation and hydrocarbon volume calculated from salinity-insensitive Dielectric Scanner service's measurements provide higher resolution, more accurate answers than those derived from the Archie equation or NMR data.

A second log comparison for Well 2 on this page shows the high-resolution Dielectric Scanner service's water-filled porosity in Track 3. The corresponding high-resolution weight percent bitumen improves on the agreement with the core data presented on the preceding page. The high-resolution water saturation presented in Track 5 drives the saturation image in Track 6, with dark colors representing high oil saturation. The layered nature of the reservoir is confirmed by the FMI* fullbore formation microimager's static image and core photograph.

In this reservoir, the geology is characterized by considerable lateral variability. Migrating channel deposition resulted in the widespread occurrence of inclined heterolithic stratification (IHS), which has a significant effect on steam chamber development. The 1:20 expanded-scale comparison to the core photograph shows the excellent match of Dielectric Scanner service's water saturation curve to the thin shale streaks in the IHS facies of the reservoir.

Dielectric Scanner service's analysis is available within a few days, providing critical information months before typical core analysis turnaround. With the accuracy and speed of these answers, Canadian operators can confidently consider a reduction in coring frequency and the number of core analysis points for their multiwell projects.





In Well 2, the high-resolution weight percent bitumen calculated from Dielectric Scanner service's measurements shows excellent agreement to the 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.

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