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Accurate Wellsite Evaluation of Total Organic Carbon in Oil-Base Mud by Litho Scanner Service

Correction methodology accounts for the carbon content of borehole fluids, which varies with borehole size and shape

CHALLENGE

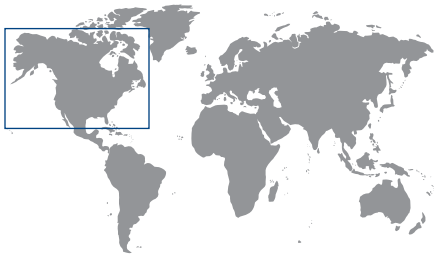
Accurately determine the total organic carbon (TOC) of formations in the presence of a high carbon content from the oil-base mud (OBM) used to drill the well, with the amount of carbon from the OBM varying with fluctuations in borehole size.

SOLUTION

Apply a customized borehole correction for carbon from the mud system that accounts for borehole size and shape to determine an unbiased TOC from the high-resolution mineralogy obtained with Litho Scanner* high-definition spectroscopy service.

RESULTS

Robustly calculated TOC independent of borehole size and carbon content from the OBM system, as confirmed by subsequent analysis of core plugs.



Distinguishing formation TOC from the carbon content of OBM

An operator targeted an unconventional reservoir in an exploration program with the intent of correctly quantifying the TOC content as a reliable indicator of reservoir quality. However, the well had been drilled with OBM, and the mud's high carbon content would bias the measurement. Applying a constant offset to compensate for the carbon content of the borehole fluid would not be sufficient because the borehole varied considerably in size.

Spectroscopy logging to directly determine quantified TOC

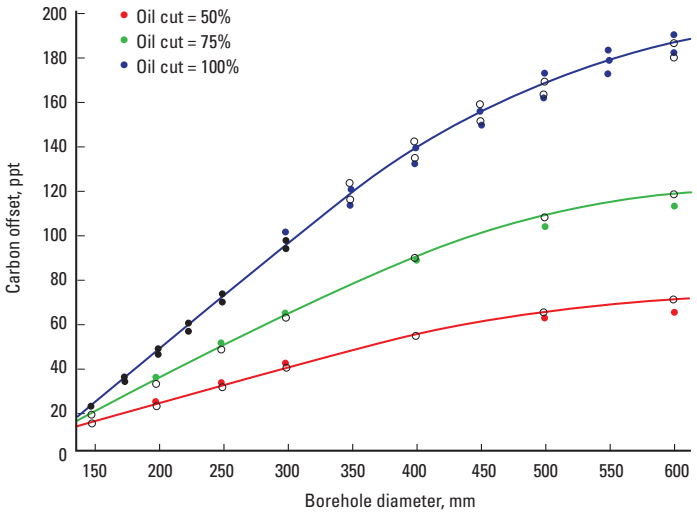
The carbon elemental weight fraction measured in situ by Litho Scanner high-definition spectroscopy service consists of the carbon associated with the mineralogy of the rocks, the organic carbon content of the formation, and the organic carbon in the fluid in the borehole. The first step in the direct determination of TOC from this total carbon measurement is combining all the inelastic and capture elemental yields from Litho Scanner service in an oxide-closure model to calculate the dry-rock elemental concentrations. These fractions are used to determine the dry-weight mineralogy, from which the total inorganic carbon (TIC) in the formation is obtained as

$$TIC = 0.12\ (\text{calcite, wt\%}) + 0.13\ (\text{dolomite, wt\%}) + 0.104\ (\text{siderite, wt\%}),$$

where the coefficients represent the weight fraction of carbon for each mineral. The formation TOC is then calculated as

$$TOC = \text{total carbon} - TIC - \text{borehole carbon offset},$$

where the conventional borehole carbon offset is a constant value obtained in a formation with zero TOC. However, using a constant offset does not account for how the large organic carbon content of OBM in the wellbore varies with borehole size and shape.



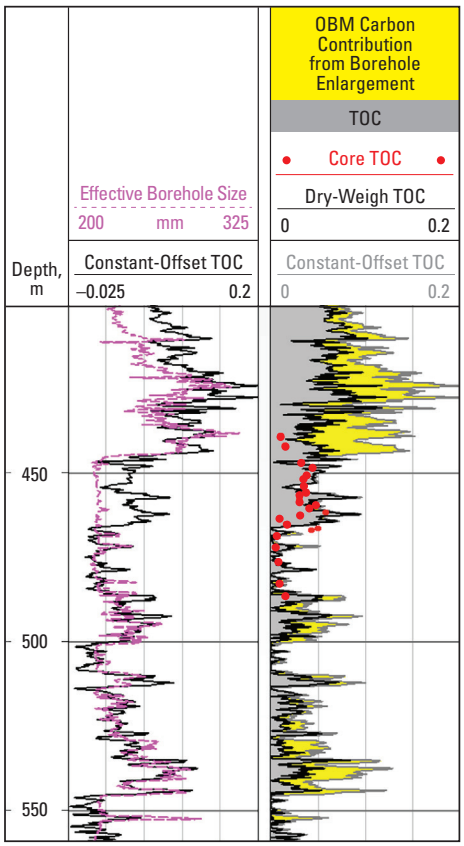
Modeling was used to calculate the carbon offset correction as a function of borehole size and OBM oil/water ratio.

To generalize the offset correction for OBM wells, Schlumberger researchers conducted Monte Carlo modeling that showed a nonlinear relationship between the borehole carbon offset and the borehole size or oil/water ratio in the OBM system. Litho Scanner service's in situ carbon measurement was used in conjunction with borehole caliper data to determine the carbon offset at a fixed hole size and empirically determine the sensitivity of the carbon offset to borehole size. These values were used to normalize the modeling results and customize the correction function for the mud system. The final borehole carbon correction is a function of the borehole size at each depth in the wellbore.

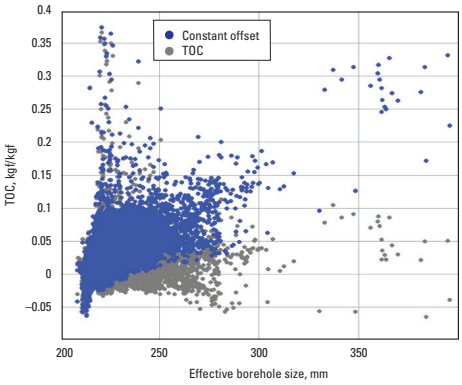
The borehole correction methodology is self-calibrating for systematic caliper offsets or calibration errors. This capability depends on adequate caliper data to define the borehole area, with x-y caliper data required where an elliptical-shaped borehole or single-axis enlargement commonly develops. The methodology assumes that an interval of zero TOC exists within the logged section while taking into account the statistical uncertainty of the carbon measurement. This approach minimizes the log analyst's interaction, with fully automated data fitting conducted in the software to provide a robust, repeatable correction in both OBM and water-base mud systems.

Correcting TOC to accurately account for carbon in the borehole fluid

Applying the borehole correction methodology in the well returned a highly accurate formation TOC, as confirmed by TOC subsequently measured on core plugs. Crossplotting the borehole-corrected TOC from Litho Scanner service against the borehole size verified that the corrected values no longer correlated with borehole enlargement, unlike the uncorrected values.



The conventional constant carbon offset does not track well with the varying borehole size in the left-hand track. In the right-hand track, the good agreement of TOC measurements on core plugs (red dots) with TOC obtained using the borehole correction methodology with Litho Scanner service's measurements (gray shading) verifies the accuracy of the correction. The yellow shading shows the magnitude of the correction for OBM carbon from borehole enlargement.



The borehole-corrected TOC (gray) does not correlate with borehole enlargement, but the constant-offset TOC (blue) does because it fails to account for the variation of the OBM carbon signal with hole size and shape.

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