Baker Hughes

RockView

In-situ mineralogical characterization service

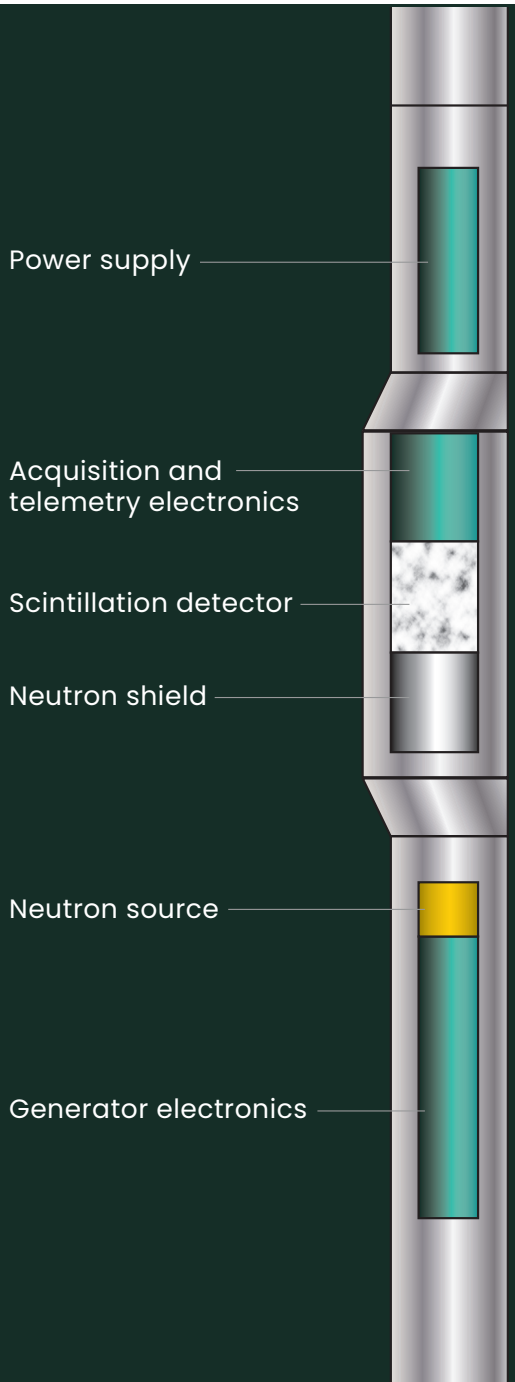
RockView services overview

The Baker Hughes **RockView™ service** is an innovative concept that combines geochemical data from the **Spectralog™ service** and the **Formation Lithology eXplorer™ (FLeX)** measurements. This new leading-edge technology applies the principles of gamma ray spectroscopy to provide accurate in-situ mineralogical characterization of conventional and unconventional reservoirs.

The geochemistry data collected by this service are used to compute the lithology and mineralogy of the rock, helping to resolve the ambiguities of traditional petrophysical evaluation methods. Using a unique expert system for mineral quantification, the RockView service opens up new analysis approaches that can lead to optimal reservoir characterization.

Applications and benefits

- Generate detailed mineralogy analysis in complex reservoirs
- Improve porosity determination with more accurate matrix properties
- Enhance reservoir characterization with improved stratigraphic correlation and lithofacies identification
- Provide direct carbon measurement in conventional and unconventional reservoirs
  - Determine total organic content (TOC) in unconventional shale reservoirs
- Identify heavy oil and bitumen
- Improve completion and/or stimulation design by identification and quantification of minerals that can impact design
- Provide precise lithology and mineralogy data to improve geomechanical analysis
- Improve clay typing and total clay volume determination



Tool specifications

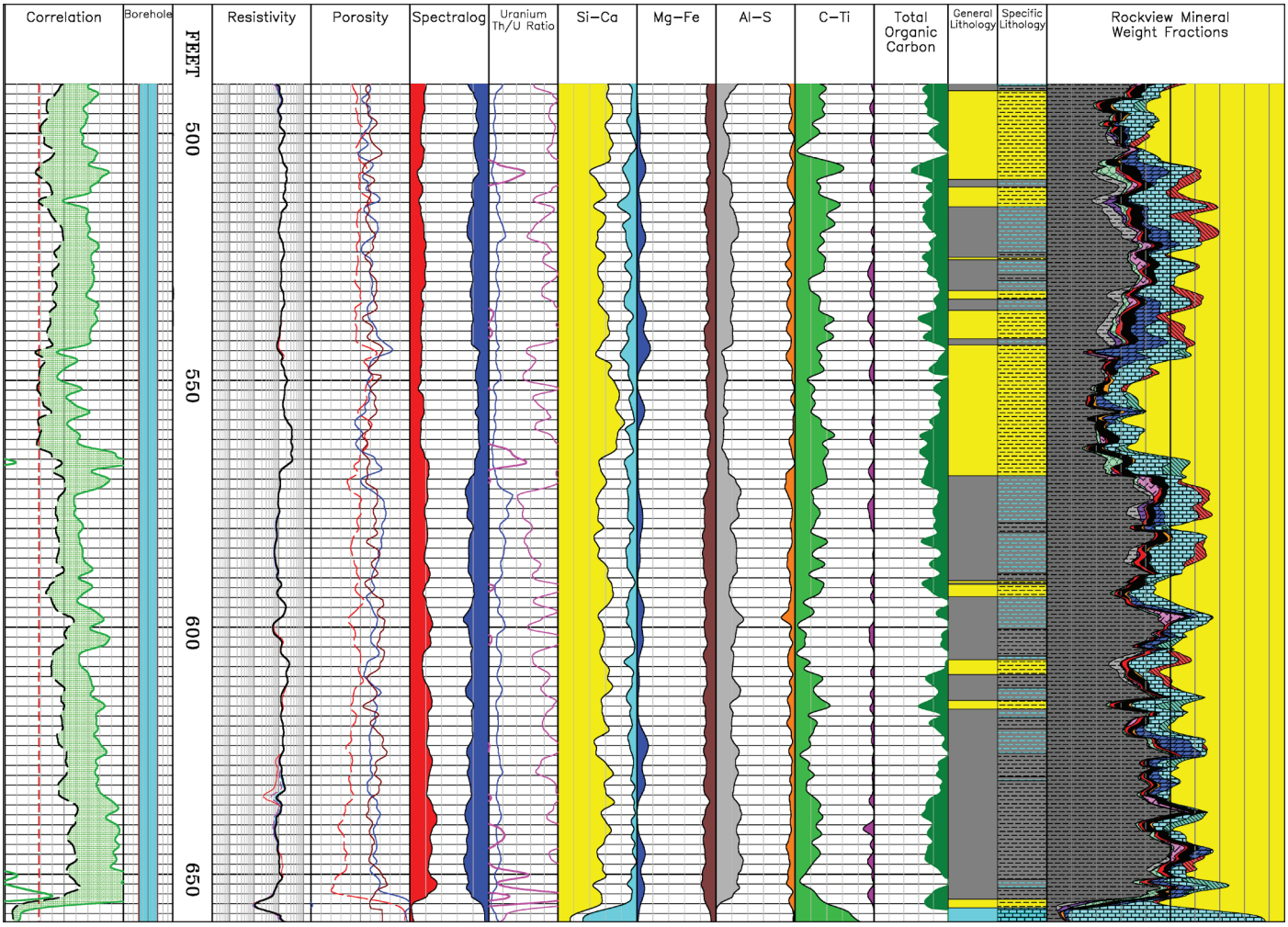
- Length: 15.6 ft (4.8 m)
- Diameter: 4.87-in. (12.4 cm)
- Minimum hole diameter: 6-in. (15.2 cm)
- Maximum hole diameter: 22-in. (55.88 cm)
- Maximum temperature rating 350°F (177°C)
- 8.5-in. depth of investigation inelastic events
- 21-in. depth of investigation capture events
- Recommended logging speed: 10 ft/min. (3.1 m/min.)
- Maximum logging speed: 30 ft/min. (9.1 m/min.)
- Maximum pressure: 20,000 psi (1,379 bar)

Neutron source

- Output: 100 million neutrons/sec.
- Pulse rate: 10,000 Hz
- Neutron energy: 14 MeV

Gamma detector

- 3-in. x 6-in. BGO detector
- Gamma ray energy: 0.5-10 MeV
- Number of channels: 256Neutron energy: 14 MeV



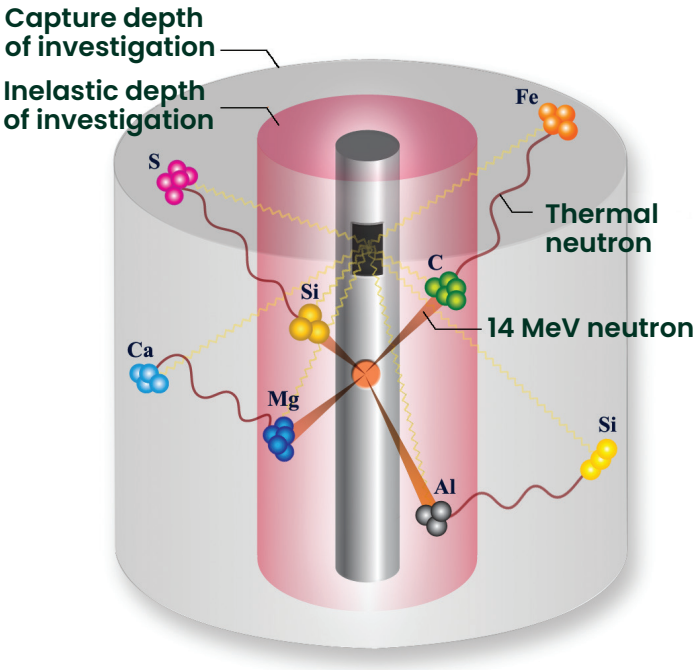
RockView log example provides a detailed mineralogical analysis including a direct determination of the amount of kerogen present in an unconventional shale reservoir in the Barnett Shale.

The technology behind the RockView service

The Spectralog tool uses a Cesium Iodide [CsI (Na)] crystal detector that measures naturally occurring gamma rays produced by the radioactive decay of Thorium (Th), Potassium (K), and Uranium (U) emitted from the subsurface formations. The FLeX tool uses an electronic pulsed-neutron source that generates 14-MeV neutrons, which, upon interacting with the elements in the subsurface strata, produce an array of inelastic and capture gamma rays that are collected by a Bismuth Germanium Oxide (BGO) detector. The resulting gamma ray spectra produced by these reactions are distributed into 256 channels to obtain elemental yields that are then converted into dry elemental formation weight fractions.

The FLeX tool is packaged inside a high-strength titanium housing. Neutron and gamma ray shielding materials are strategically placed inside the housing to prevent detection of signals from unfavorable directions. A recessed, abrasion-resistant boron-carbide (B4C) shield is placed on the housing over the detector section, reducing the capture gamma ray background.

Neutron interactions with the formation



Determine mineral composition

The RockView service uses input from the elemental weight fractions obtained from each quarter foot FLeX and Spectralog measurement to determine lithology and mineralogy. A sequential process determines a general and then a specific lithology classification. This process applies constraints to narrow the probable mineralogy.

The RockView service then determines the most probable mineral composition using principles of mass balance, honoring stoichiometries. This expert system is configured to quantify 17 different minerals common to carbonates, evaporites, sandstones, and shales. A unique benefit of this system is the ease of modification to allow quantification of minerals that are exclusive to individual formations or basins. This feature allows for developing basin-specific mineral models for conventional and unconventional reservoirs.

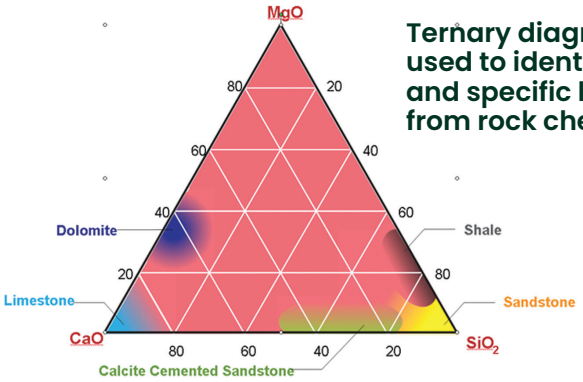
The RockView service also selects and discriminates when computing trace amounts of anhydrite in carbonates; siderite, calcite, or hematite cements in sandstone; apatite found in unconventional shale strata; organic carbon as either oil, kerogen or coal; and halite containing varied amounts of sylvite.

These independent geochemistry-derived estimates of lithology and mineralogy can then be used to correlate with other conventional logging measurements, and can also be used as input into integrated petrophysical models for refining the petrophysical characterization of a reservoir.

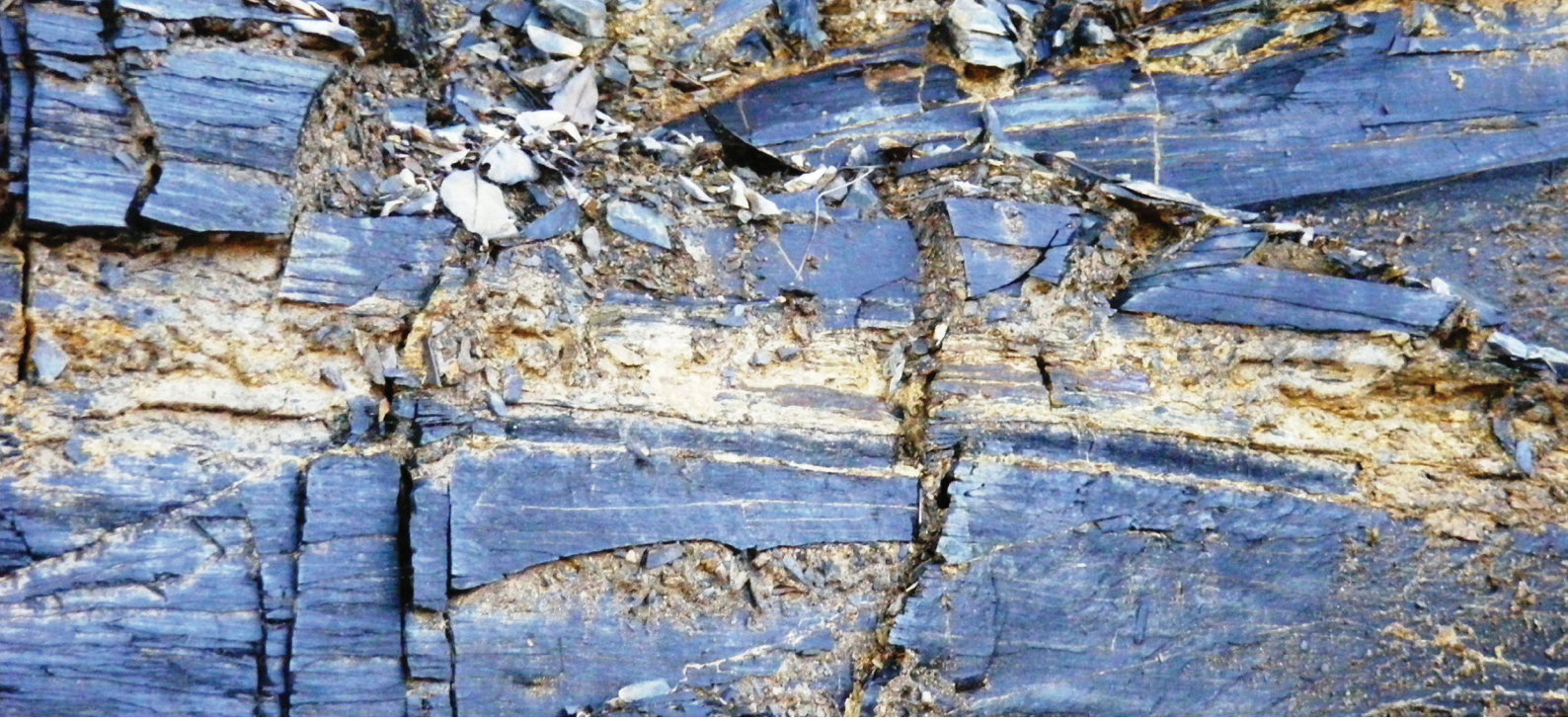
Elements detected by Spectralog and FLeX instruments

Element	Capture spectrum	Inelastic spectrum	Natural spectrum
Aluminum		Al	
Calcium	Ca	CA	
Carbon		C	
Chlorine	Cl		
Gadolinium	Gd		
Hydrogen	H		
Iron	Fe	Fe	
Magnesium	Mg	Mg	
Manganese	Mn		
Oxygen		O	
Potassium	K		K
Silicon	Si	Si	
Sulfur	S	S	
Thorium			Th
Titanium	Ti	Ti	
Uranium			U

Elements shown in green are the primary outputs from the RockView analysis.



Ternary diagrams are used to identify general and specific lithologies from rock chemistry.



Applications in conventional reservoirs

Traditional formation evaluation techniques combine the responses from multiple logging devices, such as the compensated formation density, compensated neutron, acoustic, natural gamma ray and resistivity tools to determine lithology and improve the accuracy of petrophysical calculations for a variety of parameters including porosity, water saturation, and permeability. These techniques yield good results when reservoir lithology and mineralogy are simple but become much more uncertain as reservoir heterogeneity increases. Incorporating the mineralogical results from the RockView service into these calculations reduces uncertainties.

Porosity determination using compensated formation density, compensated neutron, and acoustic logging responses requires accurate matrix values. These are the specific log values (Pma for the density device, ΔTcma for the acoustic, CNCma for the compensated neutron) for the rock at zero percent porosity. These matrix inputs can be directly calculated at each quarter foot interval throughout the reservoir based on the weight percentages of the minerals detected by the RockView service. This process can significantly reduce the uncertainty in porosity determination in both clastic and carbonate lithology reservoirs.

Detailed reservoir characterization for both clastic and carbonate reservoirs often involves attempts to identify the reasons for the variations in log readings that exist across a reservoir. Lithofacies are interpreted, which identify portions of the reservoir that have unique porosity or permeability characteristics, unique mineral compositions, grain sizes, geologic depositional environments, or consistent petrophysical parameters such as cementation or saturation exponents.

Incorporating the mineralogical results from the RockView service into this process reduces the uncertainties in the classification method in each well.

Accurate determination of water saturation in shaly sand reservoirs continues to challenge petrophysicists. Depending upon the approach selected, the analyst must select representative “shale or clay” device specific values appropriate for each reservoir. The RockView analysis provides both the total clay content of the rock and identification of the major clay minerals present in the reservoir, which provides guidance to the selection and proper application of the parameters needed for water saturation determination.

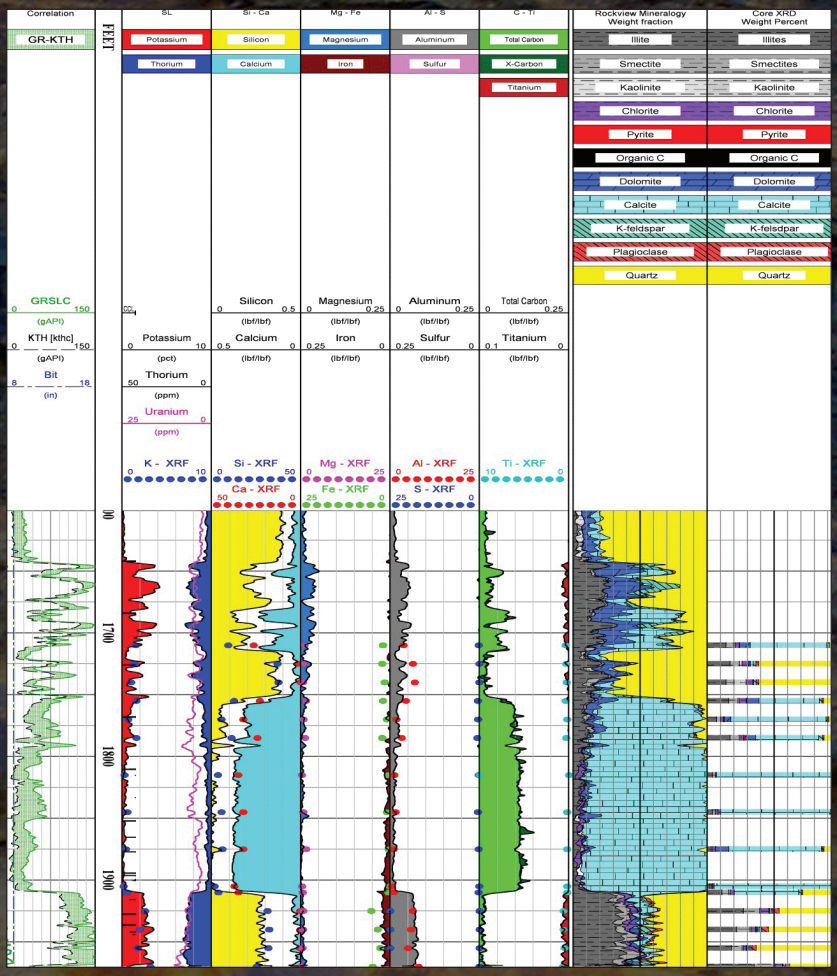
Regardless of reservoir type, the presence of certain minerals may impact the design of the most productive completion or stimulation program. As an example, knowledge of the presence of iron-rich minerals such as siderite or chlorite in a reservoir would alert the production engineer to avoid exposing the reservoir to acid because iron would precipitate into the pores and perforations, seriously risking productivity in that well. Adding the RockView service to evaluation programs reduces the risk of a poor completion or stimulation performance.

Case study: West Texas

Baker Hughes logged a West Texas well that penetrated carbonate and clastic lithologies. The RockView interpretation not only accurately identified both the carbonate and clastic intervals but illustrated the variability in mineral composition that was present. The elemental weight fractions determined by the FLeX measurements were verified by X-ray fluorescence analyses performed on core samples from the well.

The RockView interpretation determined both a general and specific lithology and a detailed mineralogy for the reservoirs. The mineralogy indicated the presence of multiple minerals in both the clastic and carbonate reservoirs. Core mineralogy was measured by X-ray diffraction analysis and displayed on the plot adjacent to the RockView-computed mineralogy. Comparison of the two mineralogies indicates that the RockView mineralogy not only correctly identified the types of minerals present, but also provided the weight fractions of each mineral that were in good agreement with the core measurements.

Another benefit of the RockView service is that it provides a more accurate porosity measurement in complex reservoirs. The composite Pma of the rock was computed from the RockView mineralogy every quarter foot by multiplying the measured weight fraction of each identified mineral by its appropriate standard mineral density and summing the results. The resulting composite matrix density was then used with the compensated formation density data to compute total porosity. The porosity measurements from the core plug analyses were then compared to the mineralogy-derived porosities and found to be in excellent agreement.



Excellent agreement is shown in this comparison of FLeX-measured elemental weight fractions, the RockView service-derived mineralogy, and RockView-computed porosity to the equivalent data from core measurements.

Applications in unconventional reservoirs

Unconventional shale reservoirs

Quantitative mineral characterization is important in unconventional shale reservoir evaluation. Most unconventional shale reservoirs are heterogeneous mixtures of clay-silt-sized detritus minerals. The variations in the mineral composition are significant in several ways. For instance, the variation makes some intervals preferable for fracture stimulation. Other intervals are more favorable for kerogen accumulation.

One evaluation requirement in unconventional shale reservoirs is to quantify both the amount and distribution of the total organic carbon (TOC, or kerogen) present in the reservoir. The gas-in-place (GIP) calculation is often determined by a correlation directly to the TOC values. Traditional methods to determine TOC values correlate core measured TOC values to a log response such as compensated density or Uranium content. One of the unique capabilities of the FLeX instrument is its ability to directly measure the amount of carbon in the rock from the inelastic gamma energy spectrum.

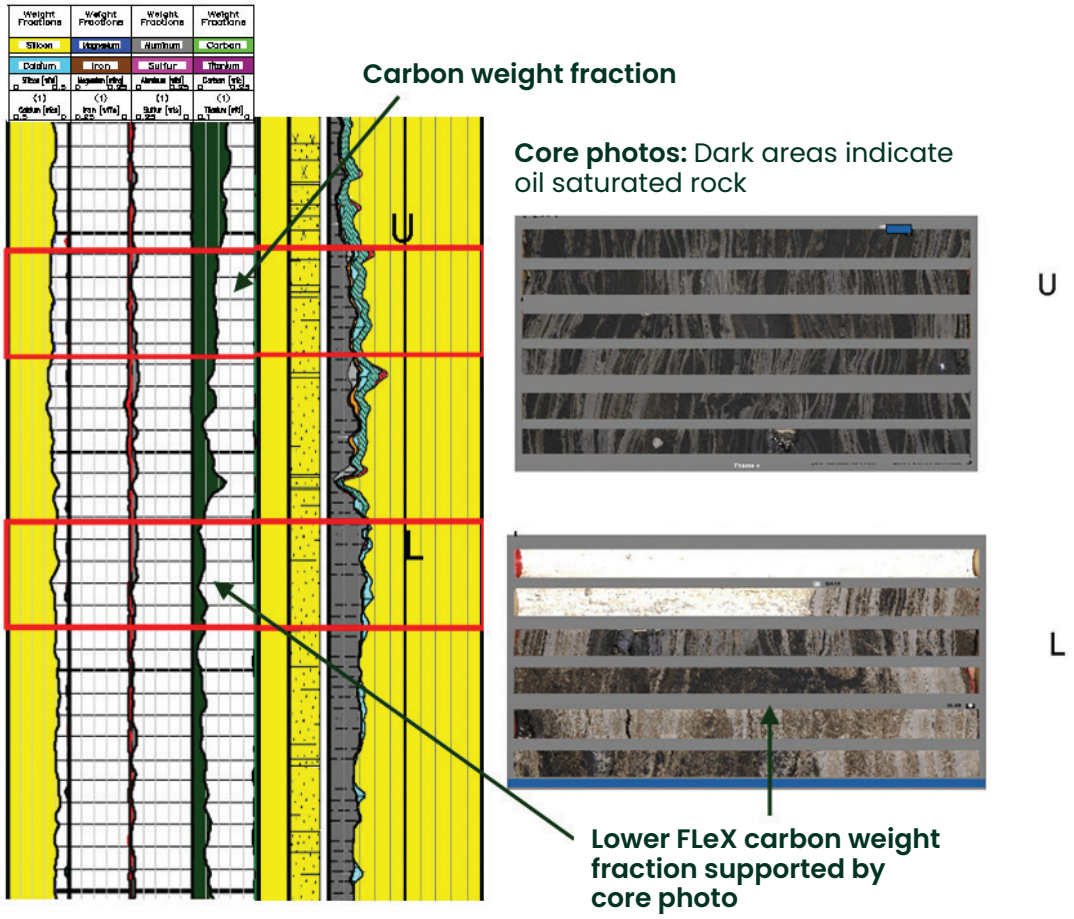
Then the amount of carbon required for the weight fractions of inorganic minerals present, which have carbon as an elemental component (such as calcite, dolomite or siderite) is subtracted from the total carbon measurement. Kerogen density in unconventional shale reservoirs is not a constant. When our nuclear magnetic resonance service, the Baker Hughes **MR eXplorer™ (MReX™)**, is added to the RockView service, the actual density of the kerogen can be determined.

Coalbed methane

Coalbed methane (CBM) evaluation also benefits from accurate mineralogical description. Mineral composition is one of the factors that determines the productive quality (or rank) of a coalbed. This rank depends not only on the actual weight fraction of carbon (coal) in a bed, but also the amount and type of clays and detrital minerals present. The RockView analysis provides an accurate quantification of the minerals present in the coalbeds and is an integral component of CBM evaluation.

Heavy oil

The ability to directly quantify carbon is very useful in evaluation of heavy oil or tar sand reservoirs. The RockView service has been successfully used in the Canadian tar sands to delineate the top and base of the bitumen column and to identify the zones with higher bitumen content. The weight fractions of bitumen calculated from the RockView analysis have also compared favorably with core-measured bitumen assay results.



bakerhughes.com