Application of Pulsed Neutron Elemental Spectroscopy Measurements in Heavy Oil and Shale Gas Reservoir Evaluation

Grant Ferguson*
Baker Hughes, Calgary, AB
grant.ferguson@bakerhughes.com

and

David Jacobi, Matt Bratovich and Brian LeCompte
Baker Hughes, Houston, TX, United States

Introduction

A new generation elemental spectroscopy tool (Formation Lithology Explorer^{sm}) which utilizes a pulsed neutron source permits the measure of gamma rays emitted by the interactions with the neutrons in both the inelastic and capture energy spectra. Additional elements are able to be quantified by measurement of both spectrums including Mg, Al and C. The Rockview^{sm} service utilizes the results from the FLEx device and Spectralog II to determine formation lithology and mineralogy. In certain types of reservoirs the amount of elemental carbon measured exceeds the amount necessary for the mineralogy of the rock itself and is presented as 'Excess Carbon'. The measurement of carbon and excess carbon along with mineralogy determination have applications for Heavy Oil and shale gas reservoir evaluation.

Theory and/or Methodology

Pulsed neutron tools have been ran in the cased hole environment for estimating hydrocarbon content in the formation since Dresser Atlas a predecessor company of Baker Atlas introduced the technology to the industry in 1963. The theory of the measurement is well known and in common use in the Industry so only a brief discussion of the theory of the measurement will be given.

The application of this technology in a wireline tool designed for use in open hole permits the use of a much larger detector to improve the count rates of the gamma rays emitted from the elements present in the formation as a result of their interaction with the neutrons with which the tool 's source bombards the formation. The energy levels of the gamma rays are characteristic of the element from whose nucleus it is emitted. In the open hole environment where the sonde is placed immediately opposite the formation and shielding is applied to the tool minimizing borehole effects. Detailed information on the tool theory, design and processing can be found in the Pemper et al paper "A New Pulsed Neutron Sonde for Derivation of Formation Lithology and Mineralogy", SPE 102770, presented in San Antonio in 2006.

From the inelastic spectrum the new Formation Lithology Explorer (FLEx)^{sm} is able to uniquely provide a formation weight percentage of elemental carbon (C) in the formation as well as much more robust measures of Magnesium (Mg) and Aluminium (Al) then were previously available to the industry. These measures when combined with the elements that are quantifiable through the use of the capture spectra permit for a more robust estimation of the lithology and mineralogy of the formation.

The RockView^{sm} interpretation system differs from previous methods in that uses a sequential approach which systematically builds upon initial conclusions. Using the elemental weight fractions as input the interpretation system first defines a general lithology for each record then follows by a more detailed classification of a specific lithology. Mineralogy is then systematically determined for each record by sequentially using the measured elemental weight fractions that are available. The process obeys the principles of mineral stoichiometry. The RockViewsm interpretation is based soley on the measured geochemistry and does not require input from other wireline logging devices. The Rockview^{sm} expert system can be easily modified to account for unique basin or formation lithologies or mineralogy. The resulting mineralogy from RockView can then be further incorporated with additional logging measurements for further petrophysical evaluation and reservoir characterization.

The elemental weight fraction of carbon is one output of the FLEX ^{sm} tool. Carbon may occur as part of the dry rock matrix or in the pores. The RockView processing determines the amount of the measured carbon that is required as a component of the dry rock mineral components of each record. Any remaining carbon fraction is classified as “excess” carbon. This ability to quantify the amount of carbon and excess carbon can be used in numerous ways depending upon the operator’s particular production and formation issues. To date applications that have been discussed and / or utilized are for a prediction of hydrocarbon in place in heavy oil reservoirs, an indicator of total organic carbon content (TOC) in shale gas plays and identification of bitumen plugged zones in gas plays.

Examples

Shale Gas – US Examples

Athabasca Tar Sand – Canada Examples

Bitumen Plugging – Canada Examples

Conclusions

The introduction of a pulsed neutron spectroscopy measurement designed for the open hole environment allows for a more comprehensive measurement of common formation elements. This additional information can be input into a new expert system interpretation software that provides a better definition of the lithology and mineralogy then has been previously available to the industry from wireline measurements.

The measure of carbon and excess carbon weight fractions gathered through the inelastic spectra coupled with the mineralogy has numerous potential formation evaluation applications.

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