Workflow for Shale Gas Petrophysical Analysis using Standard Log Measurements

Khaled H. Hashmy
Weatherford International, Houston, TX
and
Jos Jonkers
Weatherford Canada, Calgary, AB

World-wide interest has been generated by the success in North America of commercial gas production from numerous oil or gas-bearing shales. Legacy logs are almost invariably available in most of the earlier penetrations of wells drilled in the productive shales in the basin. Additionally, new development wells drilled for shale gas may also have a restricted log suite, possibly limited to the triple- or quad-combo suite. This paper targets shale gas wells with log suites defined above.

The challenge for petrophysics in productive shale reservoirs is that the formation serves simultaneously as the source, reservoir and cap rock. This requires that Petrophysicists be weaned from the concept that in all instances, the porosity and hydrocarbon saturation necessarily trend to zero as shale content increases.

Shale gas reservoirs have the added complexity of containing both “free gas” in the pore spaces and “adsorbed gas” in the matrix of the organic shale. The latter is produced when it recharges the pores and fractures as the pressure in the formation is lowered. To handle this issue, another departure from conventional well log analysis is the requirement to assess the Total Organic Carbon (*TOC*) from well logs. This necessitates the determination of several measurements from core analyses. Concepts of Reflectance Coefficient (R_o), Level of Maturity (*LOM*) and Langmuir Isotherms need to be considered in our well log analysis. Controlled desorption of core or cutting samples yields the adsorbed and total gas content per ton of shale which has a linear relationship with TOC, providing us with the link to log derived parameters.

Productive shale reservoirs are composed of clays, silt, quartz, calcite, occasionally dolomite and almost always, significant amounts of organic kerogen. They are often characterized by the presence, in substantial amounts, of pyrite, apatite and other accessory minerals adding complexity to well log analysis. This paper describes the application of the core-log relationships developed by the Gas Research Institute and incorporating these into a modified and improved workflow to achieve a comprehensive, quantitative analysis of such reservoirs using only the measurements available from the basic log suite (density, photoelectric cross-section, neutron, gamma ray, and resistivity).

Maximum reservoir contact is of paramount significance for these rocks with nano-Darcy permeabilities, necessitating horizontal drilling and massive, focused multi zone stimulations in order to achieve suitable deliverability. Consequently, sonic derived elastic properties are used to help establish the brittleness and stress regime. These parameters added to porosity, permeability and gas content are used to identify preferred zones to be stimulated, and in conjunction with micro-resistivity imaging, anisotropy and principal stress orientation determination, help the operators place the horizontal well in an appropriate direction in to a suitable section of the organic, gas-bearing shale.

Micro-seismic techniques have been available for sometime now to monitor the initiation and progression of hydraulic fractures and the opening up of natural fractures. The technique is capable of tracing the extent of development of hydraulically induced fractures in shale producers and is particularly useful for monitoring the efficacy of multistage frac operations. The fracture controlled drainage area can also be delineated with micro-seismic investigations.

In effect, these low porosity rocks with nano-Darcy permeabilities demand an intricate and exquisite synergy of core and well log analysis if the gas in place reserves are to be predicted and produced with any measure of certainty.