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Delineating Shale Reservoir Through Electrofacies Analysis: A New Approach

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ABSTRACT

Reservoir characterization plays major role in evaluation of a field and to exploit the remaining hydrocarbon in development phase. Facies analysis is an important methodology accepted worldwide to properly characterise the reservoir. Standard industry practices for facies analysis involve lithofacies, biofacies, organofacies, seismic facies etc. A recent development in this field is a combined approach of petrofacies and electrofacies analysis.

In this study, petrofacies is developed by Heterogeneous Rock Analysis (HRA), a clustering workflow to define rock classes based on multivariate input data. It runs Principal Components Analysis (PCA) to transform the input data onto independent axes front-loading the variance, ensuring that the data used in the clustering are functionally independent. Subsequently, the principal components are used in a clustering algorithm to create HRA classification. There are several plots to quality control the clustering process and choose the number of clusters required to best classify the rock.

A practical and theoretically sound methodology is applied in the workflow to identify and characterize hydraulic units within mapable geological units (facies) of the shale reservoir. This methodology uses core data to develop an understanding of the complex variations in pore geometry within different lithofacies. Variations in pore geometrical attributes, in turn define the existence of distinct zones (hydraulic units) with similar fluid flow characteristics. A hydraulic (pore geometrical) unit is defined as the representative elementary volume (REV) of total reservoir rock within which geological and petrophysical properties that affect fluid flow are internally consistent and predictably different from properties of other rock volumes. The key thing for this approach is that, the hydraulic units are directly related to (a) geologic facies distribution and (b) petrophysical properties like porosity, permeability and capillary pressure. Hydraulic units are often defined by geological attributes of texture, mineralogy, sedimentary structures, bedding contacts and nature of permeability barriers.

In this work, we explore an innovative approach of well log cluster analysis using Heterogeneous Rock Analysis (HRA) and electrofacies probabilities for integrating quantitative sedimentological description from cores and cuttings with conventional well log data. The work has two aims, first (a) to build a robust model involving well logs and core data to predict petrofacies and electrofacies in un-cored wells and then (b) to delineate the shale reservoir into distinct units based on petrofacies and electrofacies to identify the sweet spots. We used lithology, density and porosity indicating logs in HRA module to delineate the reservoir into six different clusters (petrofacies). Subsequently available core data like gas filled porosity and permeability are incorporated to generate Reservoir Quality Index (RQI) and Flow Zone Indicator (FZI). These are the key parameters to characterise the reservoir on the basis of hydraulic units.

From the workflow output, distinct facies are identified and classified according to their hydrocarbon richness and flow potential. Based on this classification, certain facies are identified as the best productive facies, which are resolved along the wellbores for the entire zone of interest across the study area. Summing up these best productive facies thickness, an isopach map is generated which represents the areal distribution of sweet spots within a shale reservoir. Another application of this work is to predict the proper landing point for laterals and geo-steer the well within best productive facies. To exploit a shale reservoir effectively, it is really important to land the lateral in the sweetest zone (with respect to hydrocarbon richness and higher fraccability) and remain in that zone throughout the entire lateral length. This work simultaneously stands as a post-drill analysis for already drilled wells or wells under production, and also as a predictive tool for future development wells.