Advanced Digital Rock Physics Analysis of Unconventional Reservoirs with Rich Kerogen Content

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Abstract

A digital rock physics workflow has been developed in order to extract petrophysical properties from high resolution 3D FIB-SEM (focused ion beam – scanning electron microscopy) images of organic-rich mudrocks. This type of images was selected in order to resolve the micro features such the pore network within the rock matrix and within the organic matter (mainly kerogen) as well as to visualize the texture of the rock including the morphology of the kerogen deposited in these rocks. Three rock samples from formations with different maturity were used for this study to examine the rock's micro pore network evolution with maturity, and to study the effect of maturation on the porosity-kerogen content relationship.

After acquiring and processing the 3D FIB-SEM images for each of the samples, the rock image was segmented into three main rock components: rock matrix, pores (including matrix and kerogen pores), and kerogen (organic matter where hydrocarbon is generated and trapped). The voxel resolution of the rock images is 50 nanometers. From the segmented images, volumetric parameters were extracted for each rock component which included the volume fraction and the specific surface area. Volume fractions were used to estimate porosity and kerogen content while the specific surface area was used to understand the relationship between the different rock components and how the contact surface between them affect the evolution of porosity.

The last step of the methodology is to subsample the image into 8, 27, 64, and 125 subsamples in order to generate enough data that could develop trends. For each of the subsamples, the volume fractions and specific surface area properties were extracted. Then, different plots were generated: kerogen content versus porosity, kerogen specific surface area versus kerogen content, kerogen specific surface area versus porosity, and pores specific surface area versus porosity. These plots reveal any hidden trends and show how the relationship between these properties change with maturity across the three samples.

The results of computing porosity and kerogen content show good agreement with wireline data and were within the expected range for these rocks. The plots revealed significant information that could indicate direct links to the porosity-kerogen-maturity relationship. This workflow takes advantage of the advancement in computational methods for rock analysis where conventional core analysis are inefficient due to the high content of soft rock components (clay and kerogen) and extremely low porosity and permeability.