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Please fill in your manuscript title.	The Digital Rock Analysis of Fluid Flow Controls in Late Carboniferous Sandstones of Central Saudi Arabia

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Abstract

Objectives/Scope:
Late Carboniferous sandstones have become an increasingly important trap for oil and gas in Saudi Arabia. The primary diagenetic phases in these sandstones are quartz overgrowths, fibrous and flakey illite, kaolinite, carbonates, and sulfates. This stratigraphy is highly heterogeneous as a result of depositional setting, facies changes (both laterally and vertically), and diagenetic overprint. The dominant porosity type in these reservoirs is intergranular porosity together with porosity resulted from grain dissolution and microporosity. Precipitated pore-lining, pore-filling and grain replacing clays are kaolinite, illite and chlorite. Sixteen core plugs were selected to evaluate the controls of sandstones flow properties. This paper presents an integrated workflow combining conventional core examination techniques (e.g., thin sections, mercury intrusion and SEM) and digital rock physics (DRP) technology.

Methods, Procedures, Process:
The DRP analysis deploys multiscale imaging from the full-plug to the sub-micron scale with X-ray micro computed tomography machine. The coarse full-plug imaging helped to identify various lithological textures to select sub-volumes for higher resolution tomography at micron scale. The 3D sample tomograms were segmented to define quartz and clays particles as well as open and isolated porosity. Thin sections, scanning electron microscopy, and mercury injection capillary pressure analyses were utilized to refine the pore sizes and rock types. The machine learning technique was applied to understand the relationship between the rock components: grains, clay minerals and porosity. The extracted pore networks of sub-volumes were combined into the larger scale network to evaluate rock permeability and interconnectivity.

Results, Observations, Conclusions:
The digital rock analysis showed that both depositional (grain size and sorting) and diagenetic (cement and cement type) factors are responsible for the porosity-permeability trends. Coarser sandstones with little or no depositional matrix and low to moderate amounts of quartz overgrowth cement dominate samples at the high-porosity/high permeability end together with the sandstones, where the clays dissolution is observed. Quartz overgrowths are less well-developed in these sandstones and their porosity is higher. Sandstones with similar grain size and sorting but with less clay are more cemented with quartz overgrowths with reduced porosity and permeability.

Novel/Additive Information:
This study confirms the use of combining the DRP technology with standard core studies to enhance the prediction of fluid flow controls and petrophysical properties. The results of the modeling improve estimation of porosity, permeability and pore size distribution as well as rock typing.