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3D Imaging of Reservoir Core at Multiple Scales; Correlations to Petrophysical Properties and Pore Scale Fluid Distributions

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Abstract

The prediction of hydrocarbon recovery is related to both the detailed pore scale structure of core material and fluid interfacial properties. An increased understanding of displacement efficiencies and overall recoveries requires an ability to characterize the pore structure of reservoir core in 3D and to observe fluid distributions at the pore scale.

Micro-CT imaging is capable of acquiring 3D images of the pore structure of sedimentary rock with resolutions down to the micron scale. This allows the 3D pore-space of many reservoir rock samples to be imaged at the pore scale. The 3D pore-space of tighter clastics and carbonate core material includes a significant proportion of microporosity—pores at the submicron scale which are not *directly* accessible via current micro-CT capabilities. Porosity at all scales can affect fluid flow, production, recovery data and log responses. It is important to characterize pore structure and connectivity in a continuous range across over six decades of length scales (from nm to cm) to better understand these petrophysical and production properties. In this paper we describe 2D and 3D imaging studies of reservoir core via micro-CT coupled with complementary petrographic techniques (thin section, mercury intrusion) and high resolution focused ion beam (FIB) scanning electron microscopy studies of a range of reservoir core. Results are given which illustrate the importance of pore structures at varying scales in determining petrophysical properties.

Microtomography is then used to observe pore scale fluid distributions within the core material. Displacement experiments under controlled wettability conditions are undertaken. The local pore-scale fluid distributions identified via 3D tomographic imaging experiments. These results provide insight into the role of rock microstructure in determining recovery and production characteristics.

Introduction

Micro-CT (μ–CT) imaging [1,2] is becoming increasingly popular for characterising many macroscopic properties of porous media. From μ–CT images one is able to compute petrophysical properties such as porosity, permeability, conductivity, elasticity, and mercury injection capillary pressure (MICP). Rock properties derived from fragments of a range of cores including homogeneous and reservoir sands have been compared with conventional laboratory measurements and shown to be in good agreement [3,4]. In more complex cores (e.g., carbonates, heterogeneous sands, tight gas) one must consider the role of pore structure in a continuous range across over many decades of length scales (from nm to cm) to better understand these processes. For example, in carbonate rocks, the processes of sedimentation and diagenesis produce a complex spatial distribution of pores and pore connectivity across several decades of length scales. Therefore developing a reliable petrophysical interpretation for predicting the transport properties and producibility of complex cores such as carbonates remains difficult. In this paper we describe 2D and 3D imaging studies of complex reservoir core material via μ-CT coupled with complementary petrographic techniques (thin section, SEM) and high resolution focused ion beam tomography (FIBT). We utilize a newly developed image registration technique for aligning high-resolution 2D microscopy (SEM, Optical) images of core thin sections with the corresponding region of the micro-CT 3D image of the core. The integration of aligned high resolution (nm scale) data with 3D μ-CT data has the potential to increase the accuracy of the physical properties predicted from the 3D μ-CT image analysis.