THE MISSING LINK BETWEEN THE PORE NETWORK TOPOLOGY AND THE RESIDUAL OIL SATURATION

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Summary: X-ray µ-CT 3D images and advanced porous network segmentation algorithms have been used to investigate the effect of porous media topology on the distribution of the non-wetting fluid trapped after a brine spontaneous imbibition. We show that the governing topological property is the neighbouring pore size contrast that can be accessed by computing a semi-variogram that reports pore size variance as a function of neighbour order.

1. INTRODUCTION

Classical macroscopic properties, describing an immiscible two-phase flow in porous media, fail to fully account for the complexity of the displacement mechanisms occurring at pore-scale. Consequently, properties such as the residual non-wetting phase saturation (Snwr) remain tricky to assess. Several studies have attempted to define a correlation between the residual trapped phase and the different parameters driving the imbibition process [1]. While it is acknowledged that there is a generally decreasing trend of residual saturation with increasing porosity the relationship between residual saturation and topological properties is not yet resolved [2]. Yet two main local trapping mechanisms have been observed experimentally [3-4]: the snap-off induced by the collapse of the wetting phase in the pore throat and the by-pass described by the pore doublet model [5].

2. EXPERIMENTAL METHOD

In this work, we have considered the link between local and global topological properties of pore network and the resulting distribution of residual saturation. X-ray tomography and advanced porous network segmentation algorithms [6] have been used to investigate the micro-structure of porous media and the distribution of the non-wetting fluid trapped at the end of an immiscible sweeping. Experiments have been conducted on two clay-free water-wet homogenous sandstone (Bentheimer and Clashach). Micro-plugs with typical dimensions of 20mm in length and 10mm in diameter were imaged at dry condition and at residual oil saturation after a brine spontaneous imbibition using a lab X-Ray facility. 3D images were taken at a resolution of 5 µm. Then pore-scale geometrical properties of the porous media were computed as well as the distribution and the configuration of the oil ganglia trapped in the porous media.

3. RESULTS

The results show that the two rock-types exhibit similar pore network local structural properties, namely pore and throat radius, coordination number and aspect ratio distribution. However the resulting non-wetting phase saturation (S_{nwr}) and the ganglia size distribution are different. As a consequence no straightforward dependencies of the ganglia size distribution neither the S_{nwr} to these statistical parameter is observed. The difference between the two rock-types is clearly observed by analysing the pore neighbouring environment. To access this topological property we have computed a semi-variogram that reports pore size variance of neighbours of order h (for two adjacent pores h=1, cf. Figure 1.b) normalized by the global variance of the pore size distribution. The comparison of the Bentheimer and Clashach semi-variogram (cf. Figure 1.a) shows that the Bentheimer rock-type has a pore layout twice more contrasted (i.e. difference between pore size of close neighbours is more important) than the Clashach rock-type. Linking this property to the by-pass mechanism can then explain the differences observed on the ganglia size distribution. Indeed the by-pass mechanism is governed by the contrast between neighbour pores, as the more the contrast the smaller the trapped ganglia are.

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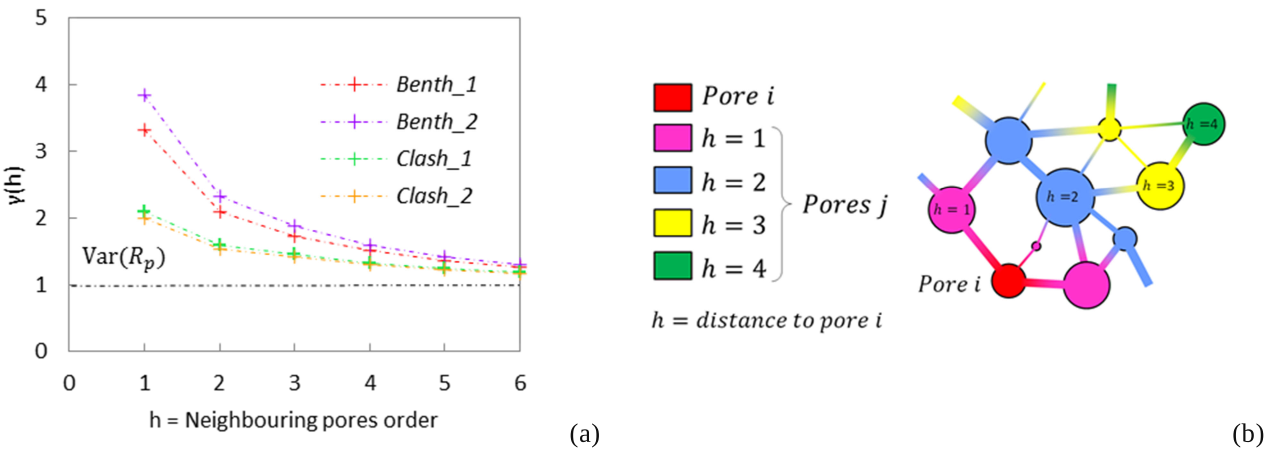

(a) (b)

Figure 1: (a) semi-variogram constructed to characterize the spatial distribution and organization of the pores in the porous media. (b) illustration of the definition of the neighboring order.