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A comparison of variance analysis algorithms to quantify spatial heterogeneities of permeability and porosity properties in porous media at pore and plug-scale

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We present a new statistical variance approach to characterize pore space related property heterogeneities in reservoir rocks. Tomography data has been obtained from either synchrotron or lab-based μ-CT measurements of sandstones using advanced image segmentation techniques. The rock samples have been processed according to the Digital Rock Physics concept using the high performance Navier-Stokes flow solver of GeoDict (Math2Market GmbH, Germany). The impact of structural and flow-field matrix modifications due to mineral dissolution, precipitation and gas instrusion in autoclave experiments on permeability and porosity are evaluated. Furthermore, grain pattern alteration and its effects on the representative elementary volume (REV) characterization has been studied. Variances of digital flow-fields and structures in pore (2μm) and plug-scale (13μm) resolution are compared using an algorithm developed to evaluate anisotropic heterogeneities in 3D volumes. Multiple geostatistical tools have been applied to evaluate changes in fluid-rock interactions during the alteration events. Computational steady state flow calculations and flow simulations were performed on the digitized structures. For the REV variance analysis, correlation coefficients of pore-grain composition patterns were coupled with simulated flow velocities in the pore space. A new approach with the objective to merge spatial structure patterns with computed flow field data has been studied.

Probability density functions and variance analyses illustrate a wide variation between flow velocities and pore space geometries in the samples. Precipitation events tend to clog the pore space causing higher local fluid velocities due to decreasing permeability. On the other hand, gas intrusion induces fluid-gas-mineral interactions due to an opening of new pores with decreasing flow-field and pore-grain pattern variances. Furthermore, it becomes apparent that an open porosity is a prerequisite for an accurate evaluation of pore space alteration. Upscaling efforts based on the variance analysis are indicating first reliable results.