Modeling complex Petrophysical properties transition across facies borders

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Petroleum reservoirs geological models are usually built in two steps. First, a 3D model of geological bodies within which rock properties are expected to be quite homogeneous is computed. Such geological domains are referred to as "facies" and are intended to characterize the depositional environment. In a second step, Petrophysical properties are distributed within each facies. Spatial statistical parameters of Petrophysical properties, such as histograms and variograms, characterize each domain and should be significantly different from one facies to another. In many cases, it can be observed that contrasts in Petrophysical properties in different facies are much lower than expected, with important histograms overlap and smooth transitions at facies borders. Such configurations are common in carbonates and/or when the available facies are defined from sedimentological criteria only. This paper details a methodology for analyzing and modeling complex statistical relationships between Petrophysical properties across facies borders, taking into account existing border effects. It is illustrated on synthetic data, corresponding to various configurations, to highlight the methodology benefits for QCing data and models, and its ability to model complex spatial distributions of properties.

Demonstration Case Study is based on a sedimentological facies distribution in an off-shore carbonate field. Several synthetic distributions of Porosity have been generated, for each sedimentological facies, corresponding to various configurations:

1. Continuous Porosity distribution at field scale, independent from facies;
2. Independent Porosity distribution within each facies, with high contrast between facies;
3. Independent Porosity distribution within each facies, with low contrasts between facies (histograms overlap) ;
4. Contrasted but correlated Porosity distribution from one facies to another, with strong border effects.

Random samples have been extracted from the different synthetic Porosity distributions to serve as experimental data sets, which are studied by mean of domaining tools commonly used in Mining industry. These tools allow quantifying the evolution of the Porosity difference between two points, as a function of the distance between the points, the two points being in two different facies. Such an analysis is very efficient to detect and characterize a border effect, i.e. a smooth Porosity transition at the contact between two facies. The border effect analysis response to the various Porosity distribution configurations is detailed, and the potential use of this tool for real data analysis is discussed. Several workflows for modeling Porosity, or any other continuous parameter, taking into account more or less complex border effects are detailed and illustrated. Some of these workflows are using auxiliary data such as the distance to the edge of connected facies bodies, computed using mathematical morphology algorithms. Note that the data analysis tools and modeling workflows have been intentionally restricted to the combination of existing algorithms available in commercial software, for an easy use in real case studies.