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Fluvial reservoir characterization using topological descriptors based on spectral analysis of graphs

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Fluvial systems generate highly heterogeneous reservoir. These heterogeneities have major impact on fluid flow behaviors. However, the modelling of such reservoirs is mainly performed in under-constrained contexts as they include complex features, though only sparse and indirect data are available.

Stochastic modeling is the common strategy to solve such problems. Multiple 3D models are generated from the available subsurface dataset. The generated models represent a sampling of plausible subsurface structure representations. From this model sampling, statistical analysis on targeted parameters (e.g.: reserve estimations, flow behaviors, etc.) and *a posteriori* uncertainties are performed to assess risks. However, on one hand, uncertainties may be huge, which requires many models to be generated for scanning the space of possibilities. On the other hand, some computations performed on the generated models are time consuming and cannot, in practice, be applied on all of them. This issue is particularly critical in: 1) geological modeling from outcrop data only, as these data types are generally sparse and mainly distributed in 2D at large scale but they may locally include high-resolution descriptions (e.g.: facies, strata local variability, etc.); 2) CO_2 storage studies as many scales of investigations are required, from meter to regional ones, to estimate storage capacities and associated risks. Recent approaches propose to define distances between models to allow sophisticated multivariate statistics to be applied on the space of uncertainties so that only sub-samples, representative of initial set, are investigated for dynamic time-consuming studies.

This work focuses on defining distances between models that characterize the topology of the reservoir rock network, i.e. its compactness or connectivity degree. The proposed strategy relies on the study of the reservoir rock skeleton. The skeleton of an object corresponds to its median feature. A skeleton is computed for each reservoir rock geobody and studied through a graph spectral analysis. To achieve this, the skeleton is converted into a graph structure. The spectral analysis applied on this graph structure allows a distance to be defined between pairs of graphs. Therefore, this distance is used as support for clustering analysis to gather models that share the same reservoir rock topology. To show the ability of the defined distances to discriminate different types of reservoir connectivity, a synthetic data set of fluvial models with different geological settings was generated and studied using the proposed approach. The results of the clustering analysis are shown and discussed.