Estimating Reservoir Permeability through Small-Scale Geological Heterogeneity Modelling and Upscaling: Methodology and Case Studies

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Permeability is a scale-dependent property of sedimentary rocks because heterogeneity exists at different scales. Core plug measurements are extremely biased because of non-uniform sample location and sample size. Simple averaging (e.g., harmonic and arithmetic) of core plug data and well log data does not result in reservoir-model-scale permeability that reflects geological reality. We present a new methodology for upscaling core plug permeability data to reservoir model scales, whereby reservoir heterogeneities at sampling scale are explicitly considered, and their impact to fluid flow is represented as scale and litho-facies dependent K_v/Kh.

The geological modelling based approach to estimating reservoir permeability consists of three steps. Step one is to interpret litho-facies in terms of bedding structure types and to define flow-unit boundaries. Step two is to build near-well-bore 3D bedding structure heterogeneity models, based on predefined templates in SBED and on the porosity/permeability data of each rock type. Information from step one is used to fine tune the bedding structure models, which should also honour local dip and azimuth data. The sequential Gaussian simulation method is used to generate porosity and permeability grids, which are also conditioned by the trend in the bedding structural grid. In step three, a steady-state flow simulation is applied to the heterogeneity model, with different boundary conditions (fixed, periodic, or linear), to derive effective permeability in the x, y, z directions or for a full tensor. Upscaling the relative permeability from core plug (rock-type scale) to reservoir grid has also been developed, and is shown to be more important in predicting the production profiles of enhanced oil recovery projects.

Examples of applying effective permeability derived from small-scale modelling and upscaling are presented, using case studies in North Sea and Western Canadian reservoirs. Improved estimates of effective permeability, especially K_v/Kh, and relative permeability curves are found to be key factors in predicting the production profiles for heterolithic reservoirs.