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Extensive pore modelling (XPM) –a coherent framework for multiscale pore network modelling

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It is not uncommon for porous media to span multiple scales of heterogeneity. Geological formations are examples of such complex systems that may act as natural aquifers, hydrocarbon reservoirs or greenhouse gas sequestration units. Application of conventional single scale modelling approaches is not sufficient for representative prediction of flow in such heterogenous permeable media. Instead, a method that marries features of different heterogeneity scales needs to be established and validated.

Three-dimensional digital images of pore spaces are the foundation for numerical pore scale modelling. Depending on the image resolution and the underlying pore structure, voxel data may not be exclusively binary (void or solid), but rather a collection of grey values that indicate under-resolved porous regions. Traditional pore networks have already demonstrated their efficiency and accuracy when modelling single scale macroscopic properties where the porosity is fully resolved. However, rigorous capture of under-resolved heterogeneity remains a difficult task for this class of models.

In our work, we aim to address this shortcoming by introducing an additional set of entities referred to as Darcy nodes that complement existing pore network macro nodes and throats. Physically, the Darcy nodes correspond to under-resolved regions that are characterized by its porosity and permeability. The proposed novelty is the more systematic consistency and flexibility of the Darcy nodes allocation and integration into the existing pore network modelling workflow in comparison to the previously published methods of microlinks (Bultreys et al., 2015) or very large stochastic explicit networks (Jiang et al., 2013). We established a methodology that unites laminar and Darcy flow mechanisms as well as their transitional behaviour, similarly as it is done in the multiscale Darcy-Brinkman formulation, as shown in Figure 1. The accuracy and robustness of our model, as implemented in the XPM (extensive pore modelling) simulator, is confirmed by a comparison with more physically complicated direct numerical simulation modelling results. Finally, our development is open source that is freely and readily available to the wider audience.

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References

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