Validation of primary and secondary migration models using upscaled stochastic modelling techniques.

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Summary

Possible models for describing primary and secondary migration include Darcy flow, Darcy flow in stringers, percolation flow and flow within the water phase. Experimental verification of several of these flow types have been achieved in laboratory studies. These verification studies are over smalll distances and over short times e.g. core plug migration over days or weeks. Oil and gas migration in geologic basins occur over large distances and over long time periods. This makes verification of the primary and secondary migration processes from source to trap very difficult to achieve. One may find cases where cores in exploration wells may have been drilled through migration pathways, but there is always some uncertainty as to how representative the observations are for the basin scale migration processes. This uncertainty is also present in the case of seep observations.

Oil and gas fields represent the most important observation points that prove that migration has occurred in a basin. These observations have been used qualitatively to support different conceptual models of oil and gas migration in numerous publications. It should be possible to use these observations also quantitatively to assess how well different conceptual models fit the observations. In this paper we will use this approach to compare two conceptual models. The first model is extremely simple: migration is driven by buoyancy through a dynamic 3D entry pressure field over geologic time and the migration efficiency is 100% with no migration retention along the pathways (**model A**). The second model also assumes buoyancy driven migration through the same 3D entry pressure field over geologic time, but adds the complexity that some of the oil and gas is **retained** in the pore space during secondary migration. The retention is modelled from migration in stringers using Darcy two-phase flow with relative permeabilities (**model R**). The retentions are calculated dynamically from the flowrates, permeabilities, entry pressures and the geometries of the carrier stringers through geologic time. Both migration models use the same source rock properties and the same oil and gas generation histories within the same geologic basins.

Our experience in performing 3D charge modelling case studies have led us to conclude that it is possible to deterministically match most charge models quite well to observations, but that very few models are possible to match perfectly to the observation data. In this comparison between the two migration models (models A and R) we use a stochastic approach to the modelling and data matching. The by now well known Monte-Carlo simulation technique is used to derive many realisations of the model. Two different measures of fit are proposed to validate model A versus model R: the minimum misfit approach (I) and the best x% approach, where x is e.g. 5% (2). In approach (2) the assumption is that more simulation realisations will achieve a good match to the observation data for the more likely conceptual model. Thus, if model A provides the minimum misfit estimates we will conclude that most likely the actual oil and gas secondary migration process is more efficient than the string migration model.

The value of the described workflow increases significantly with the number of datasets analysed and the number of conceptual models tested. Here we describe the results from two datasets in the North Sea using only two conceptual models for migration. The work involved in this approach is significant and in order to use the

approach to possible rank the different process descriptions (Darcy, percolation etc) in terms of “relative importance”, a community approach is needed. Such an approach would be welcomed and could lead to significant improvements in our understanding of migration processes in geologic basins.