CALIBRATION AND APPLICATION OF PERMEDIA MPATH FOR MODELING SECONDARY HYDROCARBON MIGRATION

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Simulation of secondary hydrocarbon migration in the subsurface requires suitable representations of subsurface structure, lithologic (seal) properties, and fluid properties. Of these variables, capillary entry pressure and permeability are generally the most poorly constrained. Once a reasonable earth model is constructed, the primary challenge is inversion from well, seismic, and seal-rock databases to obtain rock properties.

Invasion percolation theory provides a numerically efficient framework for describing the control of rock properties on entry-pressure dominated fluid flow. Permedia MPATH uses a modified form of invasion percolation theory by considering the pressures necessary to create a connected stringer of petroleum that spans a network of pores and pore throats across a volume of rock. Advantages of MPath include fast algorithms, the ability to test multiple realizations of models, and the capacity to directly incorporate seismic data in the model. At present, MPATH ignores viscous forces, and is therefore most applicable to hydrocarbon migration over geologic time scales.

We describe below two calibration exercises utilizing Permedia MPATH. In the first exercise (Figure 1), we constructed an MPATH model to mimic a published physical experiment of CO_2 migration through a 60 x 26 x 1cm laboratory sand pack (see Glass et al., 2000, Water Resources Research, v. 36, p. 3121). A digitized version of the sand pack served as a template for the MPATH model. MPATH results are displayed on a scan of the sand pack and are in good agreement with the physical experiment in terms of sequence of fill, migration pathways, and column heights.

In the second exercise (Figure 2), we constructed a simple, basin-scale 2D model with two anticlines. The model consists of two thin sand layers separated by about 1 km and surrounded by shale. Oil is injected into the deepest sand on one side of the model and the evolution of trap fill, spill and leak is captured by a reservoir simulator (Darcy flow model) and MPATH. The model grid for the reservoir simulator is defined by hypothetical flow lines generated for a series of structural form lines, resulting in orthogonal cells of variable size. The grid for the MPATH model is regular, and is defined by the pixels in a graphical image. The two models show a similar evolution of focused flow to anticlinal crests, followed by leak into the top seal once an oil column of sufficient buoyancy is present. The Darcy flow model shows a wider area of invaded cells at the crest, a difference presumably resulting from the effect of viscous forces not captured in the MPATH model. As a result of the greater number of cells invaded, the Darcy flow model lags behind the MPATH model once leakage into the top seal begins.

The calibration exercises described above provide confidence for the use of MPATH models in defining scenarios for hydrocarbon migration in exploration settings. To facilitate sensitivity testing, we have devised several methods for "earth model" construction plus a procedure for post-processing of Permedia Mpath results using visualization technology and ExxonMobil's proprietary Stellar™ basin modeling software. Each methodology captures different degrees of stratigraphic and structural complexity, resulting in variable difficulty in interpreting model results. The most complex models are perceived as most geologically accurate, but are also the most difficult to populate with reasonable seal properties. We seek to integrate the different approaches and develop a probabilistic approach for assigning capillary entry pressure based on interpretation of sedimentary facies.

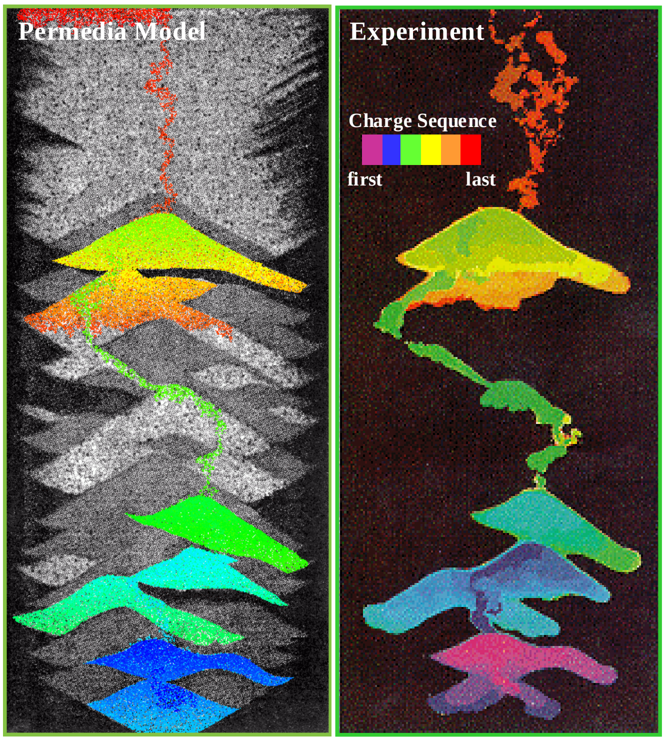

Figure1

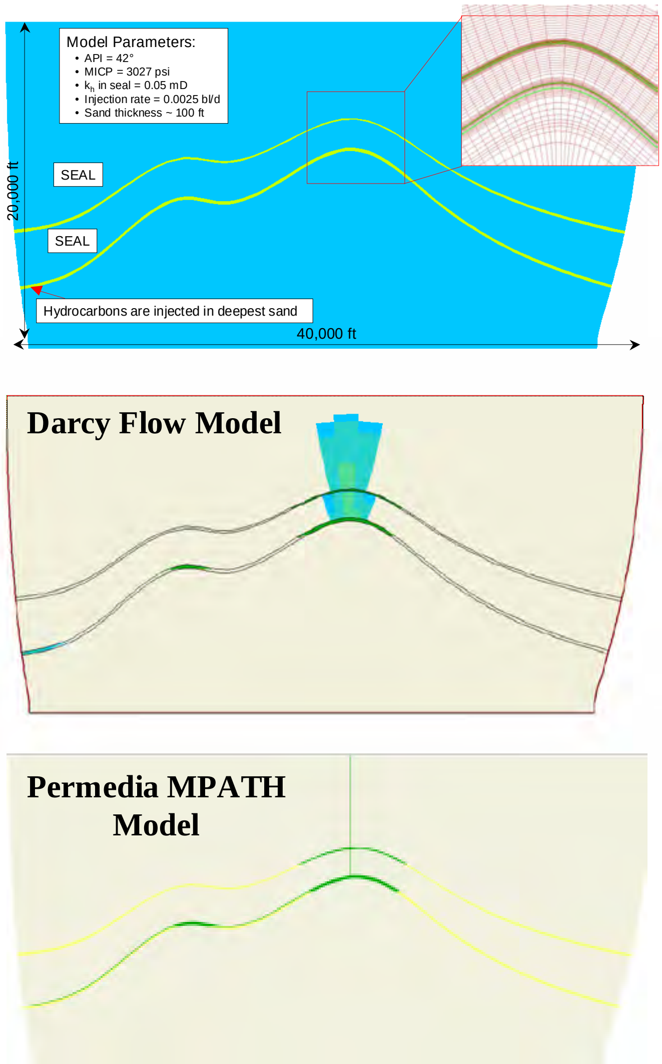

Figure 2