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Modelling secondary porosity generation in sandstones through the advection of low molecular weight organic acids

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The secondary porosity in sandstone reservoirs has been suggested to be mainly caused by low molecular weight organic acids (LMWOA), which are mainly derived from the thermal decomposition of kerogen in mudstones ([1]). Petrographic observations from well core samples within the Eocene Shahejie Formation, Bozhong Depression, Bohai Bay Basin, China, indicate that the secondary porosity is greater in the centre of a sandstone reservoir than near the sandstone boundaries with adjacent mudstones. This observation is contradictory to the hypothesis that the LMWOA, derived from adjacent mudstones, enhances secondary porosity development near sandstone boundaries. This work utilized reactive transport modelling and petrographic data to simulate the flow of LMWOA-rich fluid through the Shahejie Formation. Secondary porosity formation through two possible fluid transport processes was simulated, including (1) diffusion-dominated mudstone-to-sandstone interface transport and (2) advection-dominated intra-sandstone transport. The modelling results indicate that the mudstone-to-sandstone interface transport always leads to higher secondary porosity generation near sandstone boundaries than in central sandstone unit. In comparison, the advection-dominated intra-sandstone transport and early precipitation of carbonate cements near sandstone boundaries more likely cause the observed distribution of secondary porosity. Petrographic observation shows that carbonate cements are greater near the sandstone/mudstone boundary than in the central sandstone unit, leading to lower porosity near sandstone/mudstone boundary or higher porosity in central sandstone unit. Higher porosity leads to higher fluid flux in central sandstone unit. Moreover, the greater carbonate cements lead to the rapid consumption of LMWOA and buffering of acidity in fluids near the sandstone/mudstone boundary. The combination of higher fluid flux through the central sandstone unit and buffering of fluid acidity near the sandstone/mudstone boundary leads to higher secondary porosity generation in central sandstone unit. The LWMOA concentration, thermal decarboxylation of LMWOA and fluid flow velocity are potential factors that influence the generation rate of secondary porosity, but play a minor role on the distribution of secondary porosity. This work provides new constraints on sandstone diagenesis in the presence of LMWOA, indicating that a dynamic interplay between geochemical and physical fluid transport processes are responsible for secondary porosity development.

[1] Meshri (1985), SEPM special publication 38, 123-128.