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Kerogen flexibility, a key to understand hydrocarbon expulsion from shale reservoirs?

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A common assumption in recent molecular simulation based investigations of hydrocarbon transport in kerogen is that the latter behaves as a rigid matrix [1-4]. In other words, its porosity remains relatively constant and irrespective of temperature, lithostatic (or external) pressure or fluid (or adsorption) pressure. This implies that the matrix isolates the fluid from external pressure effects and that, diffusion and transport are only affected by the free pore volume, a lower amount of adsorbed fluid implies a higher amount of free volume and thus a higher diffusion coefficient [3]. However, it was shown that, immature kerogen, in particular, can retain a high (soft) aliphatic content and present low stiffness [5], typical of compressible media. Here we use an amorphous hydrogenated carbon model with high aliphatic content as a proxy for immature kerogen and characterize its poroelastic behavior in large ranges of temperature, lithostatic pressure and fluid pressure and determine the sorption isotherms of methane accounting for swelling. Results show that the pore space depends considerably on the three parameters and that the matrix behaves as an ideal adsorbent (linear increase of sorbate amount with the fluid pressure) up to very high pressures due to considerable swelling. An important consequence of swelling is that instead of decreasing with loading as is the case in rigid frameworks, the self diffusion coefficient of methane actually increases with loading. Furthermore, simulation of methane desorption at kerogen/macropore interfaces reproduces the well-known productivity decline of shale-oil plants when matrix flexibility is accounted for while the conventional fickian regime is obtained in the rigid approximation. We associate this anomalous transport phenomenon to a macroscopic deformation of the matrix taking place during fluid desorption.

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References

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