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Methane versus ethane competition for micropore volumes in unconventional petroleum reservoirs: Perspectives on subsurface energy storage

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Understanding subsurface pore spaces and the fluids they host is critical for predicting both estimated ultimate recovery of petroleum resources and the subsurface storage capacity available within geologic formations. For unconventional (i.e., source-rock, continuous, shale, or tight) reservoirs, significant knowledge gaps exist in understanding the full pore size distributions (particularly for small pore sizes), relationships between pore size and different host materials (e.g., mineral-hosted vs. organic-hosted), and how fluids (e.g., hydrocarbons, CO_2, H_2) behave in these spaces. These knowledge gaps are driven in part by the difficulty in studying pore size distributions with a substantial volume of micropores (defined by the International Union of Pure and Applied Chemistry as pores with diameters <2 nm), where pore inter-connectivity may be unclear, and fluid densification (i.e., densities exceeding ideality at a set pressure-temperature condition) can occur. Here we present total neutron scattering data for methane and methane-ethane mixtures at reservoir relevant pressures (up to 400 bar) and temperature (60°C) in fine pore networks (pore diameters from 25 nm down to <1 nm) within a sample from the Late Cretaceous Niobrara Formation at the late oil/wet gas thermal maturity level. The Niobrara Formation is an active petroleum play in the Denver-Julesburg Basin, United States, currently producing oil, condensate, and natural gas. Neutron scattering data reveal (i) the degree of accessible vs inaccessible porosity for methane versus ethane, (ii) fractionation between methane and ethane as a function of pore size, and (iii) fluid densification within sample micropores. Our results are discussed in the context of assessing hydrocarbon resources as a function of pore size in unconventional reservoirs, reconciling observed gas composition changes during production, and more broadly, understanding subsurface pore volumes within an energy storage context.