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Assessing the adsorption properties of shales

Ronny Pini
Imperial College London, Chemical Engineering, United Kingdom (r.pini@imperial.ac.uk)

Physical adsorption refers to the trapping of fluid molecules at near liquid-like densities in the pores of a given adsorbent material. Fine-grained rocks, such as shales, contain a significant amount of nanopores that can significantly contribute to their storage capacity. As a matter of fact, the current ability to extract natural gas that is adsorbed in the rock's matrix is limited, and current technology focuses primarily on the free gas in the fractures (either natural or stimulated), thus leading to recovery efficiencies that are very low. Shales constitute also a great portion of so-called cap-rocks above potential CO_2 sequestration sites; hereby, the adsorption process may limit the CO_2 mobility within the cap-rock, thus minimizing the impact of leakage on the whole operation. Whether it is an unconventional reservoir or a cap-rock, understanding and quantifying the mechanisms of adsorption in these natural materials is key to improve the engineering design of subsurface operations.

Results will be presented from a laboratory study that combines conventional techniques for the measurement of adsorption isotherms with novel methods that allows for the imaging of adsorption using x-rays. Various nanoporous materials are considered, thus including rocks, such as shales and coals, pure clay minerals (a major component in mudrocks) and engineered adsorbents with well-defined nanopore structures, such as zeolites. Supercritical CO_2 adsorption isotherms have been measured with a Rubotherm Magnetic Suspension balance by covering the pressure range 0.1-20$\sim$MPa. A medical x-ray CT scanner has been used to identify three-dimensional patterns of the adsorption properties of a packed-bed of adsorbent, thus enabling to assess the spatial variability of the adsorption isotherm in heterogeneous materials. The data are analyzed by using thermodynamically rigorous measures of adsorption, such as the net- and excess adsorbed amounts and a recently developed methodology is applied, where these measures are simultaneously evaluated through a graphical method. The density of the adsorbed phase is estimated and compared to data reported in the literature; the latter is key to disclose gas-reserves and/or potential storage capacity estimates. The comparison with engineered materials highlights the complexity of the adsorption process in rocks. In fact, when evaluated against classic adsorbent materials, these preliminary data show that the adsorption mechanism in shales is further complicated by the presence of resident fluids (such as oil) that can additionally contribute to their total uptake capacity. This further highlights the need of improving our current understanding of the fundamental mechanisms controlling the uptake and release of fluids from these materials, and provides substantial research opportunities under the common goal of providing an efficient and sustainable use of unconventional resources.