Porosity, permeability and methane sorption capacity of oil and gas shales at different stages of thermal maturation

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Introduction

Shale gas and shale oil reservoirs are unconventional hydrocarbon plays composed of a variety of fine-grained sedimentary rocks including shales, mudstones, marls, silcaceous shales, limestones and siltstones (Javadpour et al., 2009). Despite considerable gas-in-place (GIP) estimations for shale gas plays, these complex, heterogeneous reservoirs require innovative exploration and completion strategies to produce natural gas or oil economically (Chalmers et al., 2012). Economic gas flow rates in these reservoirs, which commonly have permeability coefficients down to the nDarcy-range, are still technically difficult to achieve, partially due to the poor understanding of the fluid transport processes in these lithotypes (Amann-Hildenbrand et al., 2012; Esme et al., 2012; Swami and Settari, 2012). Very few studies have experimentally investigated the fluid flow mechanisms in the matrix of organic-rich shales and the characteristics of fluid flow processes within the fracture and matrix systems of these lithotypes are still poorly understood due to the difficulty of measuring the low and extremely-low permeability of shales (e.g. Chalmers and Bustin, 2012; Tinni et al., 2012).

Experimental

Here, we report data on a sample set of black shales (Posidonia Shale, Lower Jurassic, North German basin) which reached maturity levels between 0.5 and 1.45 % vitrinite reflectance. Laboratory studies were conducted to investigate the porosity as well as storage and transport of gas. Permeability measurements were performed at effective stresses ranging between 6 and 37 MPa and a temperature of 45°C. The effects of different controlling factors including permeating fluid, maturity, anisotropy, moisture content and effective stress on the fluid conductivity were analysed and discussed.

Results and Discussion

Permeability coefficients measured perpendicular and parallel to bedding (3×10⁻² - 9.7×10⁻¹⁷ m²) were within the range previously reported for other shales and mudstones. Among the sample suite studied, the lowest porosity and permeability coefficients were measured on samples of intermediate thermal maturity (0.88% VRr, oil-window). Permeability coefficients (He, CH4) measured parallel to bedding were up to more than one order of magnitude higher than those measured perpendicular to bedding (Ghanizadeh et al., 2014).

Conclusions

The methane sorption capacities (in dry shales) show a linear positive trend with TOC but significant deviations from this trend exist that are linked to the overprinting effect of thermal maturity (Fig. 1). No correlation was observed between the clay content and sorption capacity to methane and we conclude that clay minerals only play a minor role in methane sorption (Gasparik et al., 2014). Results of sorption experiments were implemented into a petroleum systems model (PetroMod®) in order to calculate methane sorption capacities and gas contents in the Posidonia Shale in NW-Germany and the Netherlands on a basin-wide scale, based on a previously published 3D basin model (Bruns et al., 2013).

References


