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3-D Dynamics of a natural gas hydrate system in the western Black Sea

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Abstract

The western Black Sea sub-basin is known for its high hydrocarbon generation potential due to the presence of organic-rich late Oligocene-Early-Miocene Maykop series. Wide shelf and slope area, especially in the northern and western part of the basin, contains multiple paleo-levee systems such as the most prominent Danube delta deep-sea fan comprising abundant sand and debris flow material being the perfect candidate to host gas hydrates. Our 3D basin-scale reconstruction of the western Black Sea sub-basin is built upon large-scale seismic interpretations (basin-scale numerical model) and regional cruise data (high-resolution nested model of the Danube delta region) which provide accurate (paleo-)facies distribution. Here, we investigate the rates of both biogenic and thermogenic methane generation and its migration pathways from the Maykopian source rock towards the slope area and the gas hydrate stability zone (GHSZ).

As a result, we define distinct gas hydrate formation styles in the western Black Sea basin: 1) moderate gas hydrate saturations of 15–25 vol. % predicted on the slope area in water depths of ~600 m coupled with dominant seafloor fluid escape structures and local gas hydrate chimney-like structures with high gas hydrate saturations (>60 vol. %), 2) wide-spread gas hydrate accumulations of moderate to high saturations (~35–78 vol. %) forming at the local plateaus at the base of the buried paleo-channels associated with multiple, but less pronounced gas hydrate chimneys of moderate gas hydrate saturations (>45 vol. %), and 3) enhanced gas hydrate recycling zones in topographic lows progressively building up saturations of up to ~65 vol. % and showing no evidence for seafloor methane seepage.

Transient pressure and temperature effects due to sea-level and bottom water temperature fluctuations are prescribed as changing boundary conditions over the geological history with a high precision of 1 – 100 kyr. Due to ongoing debate on past sea-level stands in the Black Sea region, various sea-level fluctuation trends were tested. The influence of these different boundary conditions on the total methane generation and regional gas hydrate formation is evaluated. Moreover, we performed a detailed examination of biogenic generation kinetics and their sub-parameters (Middelburg formulation, Gaussian distribution, pasteurization temperature, etc.) on the amounts of generated bio-components on a basin-scale.

Numerical simulations were performed using the petroleum system modeling software PetroMod (Schlumberger) which has been previously adapted to investigate complex natural gas hydrate systems and the modelling study was executed within the framework of the German SUGAR project.

Keywords: petroleum system, basin modelling, Black Sea, methane generation