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Fluid Evolution in HPHT Settings of the Central Graben, North Sea

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We analyzed the compositional evolution of hydrocarbon fluids on a basin-wide scale using fluid samples and core extracts from high pressure-high temperature (HPHT) reservoirs in the British and Norwegian Sector of the Central Graben. The highly overpressured Mesozoic clastic reservoirs at 4-5 km burial depths are of Triassic and Middle Jurassic age, and reach temperatures up to 194°C. The reservoirs are highly overpressured and contain wet gas condensates and black oils. The hydrocarbon compositions are difficult to explain, as kinetic models predict only the generation of dry gas under these conditions. The problems with hydrocarbon phase prediction probably are caused by incorrect compositional kinetics or wrong models of hydrocarbon expulsion for extreme PT conditions, where temperature-controlled inorganic and organic diagenetic processes increase in rate and dominantly control the evolution and fate of deep sedimentary rocks and their co-evolving pore fluids. Goal of this study was to reproduce the chemical composition of the reservoir fluids in space and time, and their phase behavior, using newly developed compositional kinetic models, based in the framework of 3D basin modeling, PVT modeling and geochemical analyses of core extracts and live fluids. In addition, the thermal and pressure histories were investigated. Maps and additional data provided by industry partners were used to develop a conceptual model for basin modeling. Testing different heat flow histories the burial and temperature histories was modeled and calibrated to well data. The mechanisms of overpressure generation in the North Sea Graben area are still debated. Disequilibrium compaction and volume expansion of the pore fluids caused by gas generation are widely accepted as the two major contributors to overpressure in the

Central Graben. Therefore, pressure development was modeled as a feature of mixed origin, consisting of both gas generation and disequilibrium compaction. We assigned published compositional kinetic models to the different source rock intervals in the basin models to evaluate hydrocarbon generation and phase behavior as a function of time. Compositional predictions from kinetic models in combination with basin models have yet large difficulties in correctly predicting the fluid composition and phase in deep, hot reservoirs, as they predict as present day reservoir fluid a pure gas phase. An enhanced compositional kinetic model of hydrocarbon generation for a marine Type II source rock, based on available compositional data from live reservoir fluids (PVT data) was used in the 3D-models to determine timing of petroleum emplacement, and fluid phase evolution in the reservoir. The data sets for the compositional kinetic models consist of a detailed description of the gas composition (C1-C5), a bulk classification of the C6-C9 boiling ranges and the residual fraction of the petroleum (C7+). The generation of severe overpressure is responsible for the occurrence of the present day encountered undersaturated reservoir fluids. At first charge, the reservoirs contained a vapor dominated two-phase fluid, which became undersaturated after the onset of severe overpressure. The integration of compositional data from open and closed heating experiments together with regional PVT data allowed defining a compositional kinetic model, which enables to reproduce the observed fluid composition and physical properties through time. The combined results from basin modeling, PVT modeling and geochemical analysis allowed the identification of the main processes, which took place during the evolution of the investigated Mesozoic HPHT reservoirs through time and space.