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Evaporite dissolution and pore fluid pressure as controls on diagenesis in complex fluvial HPHT reservoirs

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Continental depositional systems influenced by salt movement are characterized by rapid lateral and vertical facies changes that are difficult to predict at reservoir scale. The Triassic Skagerrak Formation of the Central North Sea, UK is an excellent example of how the onset of Permian Zechstein salt movement strongly influenced the thickness, stratigraphy and facies distributions of this large fluvial system. However, the Zechstein salts and intercalated evaporites of the Skagerrak Formation also influenced the reservoir quality of the Skagerrak Formation by controlling many diagenetic reactions. Fluvial channel sandstones of the Skagerrak Formation possess anomalously high porosities for their present-day depth of burial and sedimentary depositional setting. The reservoirs with high overpressures often have high porosities, contain less macroquartz cement, and have some component of secondary porosity. Pores pressures within the Skagerrak Formation can exceed 70 MPa at depths of 4000 mbsf where temperatures are above 120˚C. A retained primary porosity up to 35% can be found in many of the fluvial channel sandstones.

Here we report the results of investigations into the interaction of evaporite dissolution, saline brines and pore fluid pressure in controlling diagenesis in the complex fluvial HPHT reservoirs of the Skagerrak Formation. Our studies on petrographic (thin sections, SEM, EDS), formation water chemistry and pore pressure evolution have shown that the Skagerrak fluvial sandstones have undergone a complex diagenetic and pore pressure history that has helped to preserve the high porosities. There have been four phases of overpressure build-up during periods of rapid burial since deposition of the Skagerrak, in the Late Triassic, in the Late Cretaceous, from the Eocene into the Oligocene, and from the mid-Pliocene to the present. Overpressure development combined with dissolution of Permian and Triassic evaporites was key to the maintenance of high primary porosities in the Skagerrak reservoirs. In the channel and sheet flood sandstones, only a small amount of porosity has been lost due to cementation, in the range from 2% to 10%. The typical pore water chemistry varies from brackish Cl-Na to hypersaline Cl-Na-Ca water types, with an unusually low concentration of SO_4^{2+} and very high concentrations of Ca^{2+} and K^{+}. Pore fluid with high salinity also accelerated the dissolution of calcite cement and the development of secondary porosity. Deposition of macroquartz and clay mineral cements has been inhibited by a combination of factors: the presence of early grain-coating cements, early development of overpressure, high pore fluid salinities, flushing with super-saline solutions, and possibly hydrocarbon migration. Quartz overgrowth and partial grain dissolution reduce from 6% and 8% of the total volume, respectively, in areas where overpressure is about 22 MPa to 2% and 3%, respectively, in areas where overpressure is about 40 MPa.