



## Basin sediments of the Wealden, an unconventional hydrocarbon play in NW Germany

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A complete succession comprising 360 m of the German Wealden (Berriasian) has been investigated at site Isterberg 1001 (Bentheim Saddle). Samples have been collected at 1 m spacing in order to better describe the highly variable facies, which changes from clay stones to marls and carbonates within meters. Inorganic geochemical analyses (major and minor elemental composition from X-ray fluorescence) and organic geochemical investigations have been performed; the latter include pyrolysis methods, molecular as well as stable isotope analyses of organic matter and sediment extracts. The investigations aim at a better understanding of Wealden sediments as a possible play as gas or oil shale.

The sediments have been deposited in a predominantly lacustrine environment that however experienced marine ingestions. Sedimentation rates estimated from the amount of organic carbon vary between 0.2 and 270 cm per 1000 yr and suggest 3 million years of sediment deposition of the Wealden in NW Germany. The variable sedimentation rates are likely related to climatically driven precipitation changes, which have lead to lake level variations. High positions of lake levels were associated with the deposition of marls and clay stones in a sub-littoral to basin position whereas during low levels carbonates containing bivalves and gastropods developed in a littoral position. In addition, high-level positions have lead to oxygen deficient conditions in the sub-littoral and basin sediments, which is obvious from higher sulphur concentrations whereas low positions are associated with oxic conditions in the littoral carbonates. The observed depositional changes are associated with variations of the organic facies. During high lake levels, the organic matter of the clay stones and marls is hydrogen-rich and likely derived from aquatic precursors. The associated anoxic to dysoxic water conditions are also obvious from the stable carbon isotopic composition of bulk organic carbon which are highly enriched in  $^{12}\text{C}$  suggesting that a microbial methane cycle had existed during the deposition of the sediments and the organic matter experienced a significant contribution from the microbial pool. Low lake levels were associated with the deposition of hydrogen-depleted organic matter, which either relate to land plant and/or highly oxidized material.

Pyrolysis investigations indicate that the organic matter of the uppermost Wealden 6 touched the onset of the oil window and the base of Wealden 1 is already within the peak-oil generation zone. Biomarker data support this interpretation. Interestingly, extract concentrations clearly show that especially the lower parts of the sediment section are impregnated through migrated hydrocarbons, supported by biomarker data as hopane as well as sterane isomerisation ratios show distinct clusters typical for mixing between hydrocarbons of different source rock maturities. Aquatic organic matter of the Wealden could be a source of the migrated hydrocarbons and lateral up-dip migration from adjacent Wealden sediments could explain the observed data.

Our data indicate that the facies of Wealden sediments are highly variable even in the basin. Favourable targets for the extraction of unconventional hydrocarbons in the NW German Basin could likely be parts of the sections of Wealden 3 and 4. However, the high clay content and up to 20 % of organic matter within Wealden 3 and 4 could be technical challenges with respect to hydrocarbon extraction.