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Investigations of illite and small scale fluid-rock interaction in Upper Carboniferous reservoir sandstones from the Lower Saxony Basin, Northwest Germany

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Illite is one of the most important minerals concerning the exploration of hydrocarbons. It is known, that illite reduces significantly porosity and permeability and deteriorates reservoir quality. Therefore the formation conditions are an issue of special interest. The Upper Carboniferous sandstones from the Lower Saxony Basin (LSB) show intense mechanical compaction and thus low porosity values (3-12 Vol.-%) and very low permeability values (0.001-0.1 mD). Petrographic observations indicate that fluid pathways must be hampered, but illite occurs in variable amounts. This study was intended to get a better understanding of the controlling factors of the illite formation in the LSB.

This investigation, funded by the RWE Dea Germany, compares 18 samples of Upper Carboniferous sandstones (Westphalian C & D). These samples originate from three different study areas with varying burial histories within the Lower Saxony Basin (LSB), Northwest Germany. The southern margin offers a deep burial during Cretaceous with subsequent uplift/inversion. The center of the deepest burial is situated north of the southern margin and shows also a post-Cretaceous, but more intense uplift. Also the northern part with shallower burial depths was investigated. The locations have different initial thermal histories and resulting conditions for illite formation. Petrographic analyses revealed a consistent modal composition, which describes sublitharenitic sandstones. Most common authigenic phases are quartz, carbonate cements, and phyllosilicates like illite, kaolinite and locally chlorite.

Several investigation methods were applied to detect differences between the illites from the locations. The age of last illite precipitation was determined by conventional K-Ar dating of clay fractions ($< 2\ \mu$m). Using the burial history (known from literature) the illite age can be linked to the burial depth and related p-T conditions at this time. Additional vitrinite reflectance measurements provide evidence for the maximum burial temperature, which the illites were exposed to. These primary conditions can be compared with other parameters like illite crystallinity (IC) calculated from X-ray diffraction patterns and the related proportion of mixed layers calculated by decomposition of X-ray diffraction patterns. The IC value will be assured by chemical data as potassium content of illite. The calculation of empirical formulae from quantitative microprobe data for illite and muscovite exhibits similar K-Al-relations. The depletion of potassium in corroded muscovite was observed whereas the enrichment of potassium in new grown illite was visible. With this knowledge and the fact of less permeability one could imply an in-situ ion transfer from muscovite sufficient for authigenic illite formation. A model of small (micro-) scale fluid-rock interaction would obviate the need of continuous fluid pathways and thus connected porosity and permeability as requirement for the precipitation of authigenic illite in reservoir sandstones. This assumption is open to be discussed in further studies.