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Diagenetic reactions of Fe-species pre- and post petroleum migration: Examples from Permian sandstone reservoirs in northern Germany, Central European Basin System

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Iron may be present in various authigenic minerals, including oxides, carbonates, sulphides, and sheet silicates. Such minerals can be found in most diagenetic settings. Although only rarely important volumetrically, the presence, distribution and relative succession of Fe-bearing minerals can provide us with important information on the nature of pore fluids responsible for their formation. The results of this presentation are part of a comparative study on Permian (Rotliegend) red bed sandstones in the German part of the Central European Basin System. Based on petrographic and geochemical investigations on core samples of numerous wells, supplemented by basin modelling work, this study reveales major differences in diagenetic evolution in areas with and without hydraulic contact to maturing hydrocarbon source rocks. The clastic reservoirs investigated in this project are red bed sandstones which were deposited along the margins of the large Rotliegend intra-continental basin system in Central Europe. The Rotliegend has been buried to about 3500-5000 m. Thick coal-bearing Carboniferous sediments, which are regarded as the main source rocks for most gas reservoirs in that area, are the substrate of the Rotliegend in large parts of the basin. However, these source rocks have locally been eroded prior to Rotliegend deposition, for example in northernmost Germany, at the northern margin of the basin. Three case studies from that area exemplify the diagenetic evolution lacking the influence of organic-rich fluids.

Hematite is the earliest authigenic Fe-species in the diagenetic sequence. It probably transformed from various Fe-hydroxides and Fe-oxides, which typically precipitate in near-surface conditions of semi-arid clastic deposits. Hematite is often associated with early diagenetic clay mineral grain coatings. These clay mineral-hematite coatings are responsible for the red colour of the rocks and typical for Rotliegend sandstones. However, hematite is missing in a significant number of grey reservoir horizons. Grey colours are not related to sedimentary facies but occur only in areas, where source rocks are present close-by. There is good evidence for bleaching of primarily red sandstones by reduction of hematite, but no evidence for in situ preservation of any reaction products, which could be for example magnetite or pyrite. From petrographic observations, major bleaching occurred prior to petroleum migration. Solid bitumen, the relics of former petroleum, are still visible in many samples. After petroleum migration, ferrous iron was incorporated into ankerite, siderite and Fe-rich chlorite. Late Fe-rich diagenetic phases may locally appear in red sandstone horizons, but according to our data, they are widespread only in bleached sandstones. Their distribution and composition is partly related to fault zones. Furthermore, late Fe-rich minerals are absent in case studies from areas where source rocks are absent. In such areas, early diagenetic hematite survived burial down to about 5000 m depth.

It can be concluded that in red bed sandstones, ferric iron is fixed in hematite throughout early and burial diagenesis, if the rocks were not affected by reducing fluids. In cases where red beds are in hydraulic contact to hydrocarbon source rocks, migrating organic maturation products are responsible for conversion of iron redox state of authigenic minerals from ferric to ferrous during burial. Although several processes can be responsible for bleaching of red beds, we think that iron reduction is related to petroleum migration in this case. We conclude that from the co-occurrence and relative timing of bleaching, bitumen staining, and late Fe-rich minerals, together with the spatial relation of these petrographic features to maturing hydrocarbon source rocks. This study was financed by German Science Foundation (DFG) within the research project (SPP) 1135.