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Reservoir properties and fluid circulation in Buntsandstein aquifer sandstones of the Thuringian Basin in Central Germany

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We present the preliminary results of an integrated study on reservoir quality of aquifer sandstones of the Thuringian Basin and adjacent areas in central Germany. These investigations are part of a joint research project examining the basin wide movement of fluids in the subsurface (INFLUINS – integrated fluid dynamics in sediment basins) combined with data of a DFG-sponsored study ("Long-term impact of CO2 on the stability of mineral assemblages in porous reservoir sandstones").

Storage and reservoir characteristics of fluvial and eolian sandstones of the Lower Triassic Buntsandstein aquifer are analyzed. These studies cover a systematic basin wide acquisition of recent petrophysical aquifer parameters, of data on lithofacies, sediment architecture, aquifer geometries, petrography/mineralogy, diagenetic evolution, pore space evolution and on reactive mineral surfaces exposed to the pore system. Correlation of porosity and permeability data imply a facies and mineralogical control on these petrophysical attributes, and consequently on fluid flow characteristics. A special emphasis is placed on the interpretation of porosity and permeability anisotropies and the definition of preferential facies based fluid pathways. Besides primary, depositional controlled features, like sorting and grain size, investigations on the reactivity of mineral components exposed to fluids during burial diagenesis is one major key in the understanding of fluid migration in these rocks. Such fluid migration will initiate fluid rock reactions, reflected as mineral alteration and/or authigenic mineral formation, thus affecting rock porosity and permeability. Also the evaluation of the spatial distribution pattern of diagenetic provinces will help to identify the general partitioning and circulation of fluids in such basin systems.

The Lower and Middle Buntsandstein in the studied area is composed of aquatic (fluvial, lacustrine) and eolian deposits, which exhibit a distinct cyclicity with coarse clastic-psammitic basal members followed by sandy-silty-argillaceous lithologies. Locally, eolian sandstones occur in the Lower Buntsandstein, most frequently in the lower Middle Buntsandstein. In the upper part of the Middle Buntsandstein massive fluvial channel sandstones become more prevalent. The sandstones analyzed exhibit an overall high mineralogical maturity. The composition is dominated by quartz and feldspars. From this, sandstones are nearly exclusively arkoses and subarkoses, though composition may occasionally tend to quartzarenites in some eolian sandstones. Preferential pathways of fluid migration occur in well-sorted eolian facies intervals that exhibit higher permeabilities compared to fluvial facies intervals. Most obvious examples of fluid migration and fluid/rock interactions are rock bleaching phenomena in the pristine reddish sandstone samples.

Preliminary microscopic and submicroscopic mineralogical analyses (by polarized microscope, microprobe, SEM) reveal some strong sulfate (anhydrite, gypsum) and carbonate (calcite, dolomite) cementation and mineral alteration features linked to complex mineral (rock) - fluid reaction - these include e.g. hydration of anhydrite (formation of gypsum), carbonate and feldspar dissolution, formation of early diagenetic illite-hematite cutanes (preferentially in fluvial sandstones), late diagenetic fibrous and meshwork illite precipitation, and the albitization of potassium feldspars.

Furthermore late diagenetic illitization of detrital micas was found, which occurs preferentially on contacts with pore space due to the access of pore fluids. At some locations kaolinitization of feldspars was also observed.

Overall, the investigation of large scale aquifer geometries, the linkage of facies and petrophysical data, the spatial allocation of storage characteristics in relation to diagenetic phenomena and the type and intensity of rock-fluid interactions form the basis for generic modelling of reactive fluid flow and mass transfer in the Buntsandstein aquifers of the Thuringian Basin.