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Interplay between cataclasis, clay mineral diagenesis and porosity reduction in deformation bands in unconsolidated arkosic sands

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As a response to tectonic and gravitational stresses, unconsolidated sediments can develop zones of localized deformation, commonly described as deformation bands. These are tabular fault zones in high porosity rocks and sediments characterized by small offsets causing reduction of porosity through grain rotation, translation and fracturing. Classified by deformation mechanism and depth of formation, there are two main types of deformation bands: disaggregation bands, where compaction is achieved only by grain rotation and translation, and cataclastic bands, which show intense grain size reduction by grain fracturing. In various examples the porosity and permeability reduction in these fault zones inhibits the flow of fluids. The timing of deformation band formation relative to diagenesis and fluid migration is relevant in relation to the quality and connectivity of hydrocarbon or groundwater reservoirs.

The investigated outcrop in a sandpit near Eisenstadt (Eisenstadt-Sopron Basin, Austria) exposes numerous conjugate deformation bands, which are formed in lower Miocene uncemented, arkosic sands and gravels. These deformation bands formed at shallow burial depth (< 1km) and are kinematically related to the nearby Eisenstadt Fault. This outcrop offers the unique possibility to investigate deformation bands with identical kinematic boundary conditions in highly variable sediments, i.e. with a wide range of different grain sizes from fine sand to coarse gravel, variable porosity and mineral content, different stages of diagenesis and carbonate-free or carbonatic sediments.

The fact that cataclasis is one of the dominant mechanisms at these shallow depths (< 1km) is unusual and an exception to most cataclastic bands described in literature. This is probably related to the composition, coarse grain size and the high porosity of the sediments. The coarse host sediment mainly consists of detrital quartz, albite, biotite, sericite, muscovite and metamorphic lithoclasts. The dominant deformation mechanisms and the magnitude of porosity reduction in the carbonate-free lithologies are controlled by the initial mica content, mean grain size, level of alteration and albite content in the host rock. The studied deformation bands show a preferred fracturing of sericitized albite grains and the smearing of micas into the pore space. These processes increase the amount of phyllosilicates in the pore space and facilitate the growth of various authigenic clay minerals like smectite, vermiculite, kaolinite and illite. Because of the changed petrophysical properties the deformation bands show a different diagenetic evolution in comparison with the host rock. We identified 4 steps in the development from a high-porosity host rock to a low porosity deformation band. The measured reduction in porosity by up to 18% is associated with a permeability reduction, reflected in the retention of fluids along the deformation bands with the highest content of authigenic clay minerals.