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Impact of deformation bands on subsurface fluid flow (Provence, France)

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Sandstone reservoirs have always been of particular economic interest in oil, mining and water resources. Many studies have been done on strain localization in porous sandstones and show different types of complex structures due to tectonic deformation described as deformation bands. The geometry of these deformation band networks is variable and their impact on fluid flow remains misunderstood.
In this study, we described two sets of deformation bands associated to different tectonic events and formed in the same porous sandstone in Provence (Boncavaï quarry, South-East Basin, France): a set of reverse Shear Enhanced Compaction Bands (SECBs) associated to Pyrenean Shortening and a set of normal Compactional Shear Bands (CSBs) associated to Oligocene-Miocene Extension. These two sets show different organization, band microstructure, petrophysical properties, and control on the localization of alteration products associated with meteoric water flow under vadose condition. The analysis of the alteration product localization with respect to these two sets of bands allows us to discuss the differences in sealing capacity of these band networks.
The reverse shear-enhanced compaction bands are organized in conjugate and well distributed network. However, these bands are specifically located in coarse and porous sandstone intervals (1 mm grain size and 28%) and cannot compartmentalized the entire sandstone reservoir. Furthermore, the microstructure of the SECBs is slightly cataclastic (small grain comminution, enhancement of microfracture density) and induces low decrease of porosity and permeability ranging, respectively, from 2.5 to 6.5% and from 0 to 1.5 order of magnitude. These bands show no impact on the alteration products localization and then do not act as permeability barrier for subsurface water flow.
The normal compactional shear bands are localized structures. Three types of CSBs can be identified from their geometrical attributes (shear-displacement, thickness, number of strand…) as: single-strand, multi-strand and band clusters. These bands are cataclastic but different intensities of cataclasis have been identified in their microstructure: damage zones, protocataclasis, and cataclasis; differing in grain comminution and porosity. These bands then show different changes in their petrophysical properties: the protocataclastic single and multi-strand bands show porosity and permeability decrease, respectively, less than 10% and 2 orders of magnitude, whereas the cataclastic multi-strand bands and clusters show porosity and permeability decrease ranging respectively from 10% to 25% and from 3 to 5 orders of magnitude. Only cataclastic bands seem to control on the localization of alteration products and constitute permeability barrier for subsurface fluid flow.
These observations show that cataclastic shear bands resulting from tectonic extension can act as high sealing bands, whereas shear enhanced compaction bands resulting from tectonic compression are not sealing bands for subsurface water flow.