Stratigraphic control on damage zone width in faulted platform carbonates: an example from the Gozo Island, Malta

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Fault damage zones (DZ) are fractured volumes of rock that surround the fault core(s), and their structure can have an important role on the control of fault mechanics and of the hydraulic properties of the fault zone, with impact on groundwater flow, ore-deposits, hydrocarbon reservoirs, nuclear waste disposal and contaminant transport in the subsurface. It is generally accepted that DZ width is controlled by fault displacement, and that it increases with increasing offset. However, published data on DZ width in faulted carbonates show a scattering over two orders of magnitude, suggesting that this parameter is controlled also by other factors. Here we present the results of a study performed on two units of the platform carbonates of the Malta and Gozo Islands. These two units, that are cross-cut by normal faults, are characterize by different petrographical, petrophysical and mechanical properties and have completely different Damage Zone width along faults characterized by the same tectonic history and with comparable displacement. More competent and rigid grain-dominated carbonates show DZ thickness of several hundreds of meters, while fracturing in the less competent and more elastic micrite-dominated rocks is developed only very close to the fault core, with a DZ width of few tens of meters. In order to explain this counterintuitive facies-controlled behavior, we performed petrophysical (porosity, density, permeability) and geo-mechanical (Uniaxial, Brazilian, Triaxial tests) analyses to characterize the mechanical stratigraphy and develop a numerical modelling study. Results highlight the heterogeneous stress distribution in a multilayer with variable elastic parameters subjected to horizontal extension. The more elastic unit can more easily expand laterally with respect to the less elastic one with the consequence that $\sigma_3$ decrease faster in the last one and this can yield before the more compliant one even if it is stronger. Also the width of the yielding zone is increased in the stiffer layers, leading to a wider DZ.