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Multi-scale fracture networks within layered shallow water tight carbonates

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The work is aimed at deciphering the contribution of background deformation and persistent fracture zones on the fluid flow properties of tight platform carbonates. Taking advantage of 3D exposures present in the Murge area of southern Italy, the fracture networks crosscutting at different scales the layered Cretaceous limestone of the Altamura Fm. were analyzed. The rock multi-layer is characterized by 10's of cm-thick, sub-horizontal, laterally continuous carbonate beds. Each bed commonly represents a shallowing-upward peritidal cycle made up of homogeneous micritic limestones grading upward to cm-thick stromatolitic limestones and/or fenestral limestones. The bed interfaces are formed by sharp maximum flooding surfaces. Porosity measurements carried out on 40 limestone samples collected from a single carbonate bed show values ranging between 0,5% and 5,5%.

Background deformation includes both stratabound and non-stratabound fractures. The former elements consist of bed-perpendicular joints and sheared joints, which are confined within a single bed and often displace small, bed-parallel stylolites. Non-stratabound fractures consist of incipient, cm offset, sub-vertical strike-slip faults, which crosscut the bed interfaces. The aforementioned elements are often confined within individual bed-packages, which are identified by presence of pronounced surfaces locally marked by veneers of reddish clayey paleosoils. Persistent fracture zones consist of 10's of m-high, 10's of cm-offset strike-slip faults that offset the bed-package interfaces and are confined within individual bed-packages association. Laterally discontinuous, cm- to a few m-thick paleokarstic breccia levels separate the different bed-packages associations. Persistent fracture zones include asymmetric fractured damage zones and mm-thick veneers of discontinuous fault rocks.

The fracture networks that pervasively crosscut the study limestone multi-layer are investigated by mean of scanline and scanarea methodologies. The dimensional, spatial and scaling properties of both stratabound and non-stratabound fractures are documented along single beds and bed-packages, respectively. Persistent fracture zones are studied from individual bed-package associations. By computing the intensity, height distribution, aspect ratio, aperture of each fracture/fault set, DFN (Discrete Fracture Network) models are built for the aforementioned different scales of observation. DFN models of single beds and bed-packages include stratabound and non-stratabound fractures. Differently, the DFN model of a bed-packages association also includes persistent fracture zones and related damage zones. To check the results of our computations, we also build up a smaller scale, $1m^3$ geocellular volume in which fractures are inserted one at time in the model. All DFN models do not include the matrix porosity.

Porosity and 3D permeability (Kx, Ky, Kz) values are obtained as outputs of the DFN models. The results are consistent with the most prominet set of non-stratabound fractures being the major control on the petrophysical properties of both single beds and bed-packages. As expected, the persistent fractures zones strongly affect both porosity and permeability of the bed-packages association. The results of ongoing laboratory analyses on representative limestone samples not only will provide a quantitative assessment of the physical properties of the matrix in terms of porosity and permeability, but also will shed new light on the geometry, density and anisotropy of microfractures and their role on fluid flow properties.