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Depositional and diagenetic factors affecting the development of bed-parallel structures in Oligo-Miocene ramp carbonates (Maiella Mountain, central Italy)

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In several geological contexts, rocks are characterised by both diffused and localized strain, which can be represented by background deformation and fault zones, respectively. The combination of diffused and localised deformation may form a discontinuity network that affects the hydraulic rock properties.
With regards to background deformation, in carbonates the primary control on fracture types, spacing and connectivity is provided by the grain/matrix assemblage, heterogeneities such as bedding or inclusions, and lateral/vertical variations in cementation and porosity. The progressive burial of carbonate sediments, subsequently to deposition, is responsible for the progressive change of the boundary conditions (i.e. stress field, pressure and temperature, fluid composition) which control the diagenetic processes. The interplay between boundary conditions and rock rheology is responsible for the development of compressive structures within the rock under lithification. These structures, oriented parallel to bedding, are explained as anti-cracks and consist on pressure solution seams and/or compaction bands. Also related to background deformation, bed-perpendicular structures such as joints and/or pressure solution seams are also widespread in layered carbonates. The frequency and distribution of bed-perpendicular structures (i.e. length and spacing) is controlled by bed-parallel mechanical interfaces formed by bed surfaces, compaction bands, pressure solution seams. In other words, bed-parallel depositional and/or tectonic structures act as surfaces against which the various types of fractures may abut. For this reason, their distribution play a critical role controlling both length and spacing of bed-perpendicular structures. Most of the overburden-related bed-parallel structures form barriers to fluid flow. This behavior is due to the fact that pressure solution seams include claysh residual, insoluble material, whereas compaction bands are characterized by lower values of porosity with respect to the surrounding host rock.
In this contribution we report a study conducted in the Maiella Mountain, central Italy, specifically on a large variety of carbonate facies of the Oligo-Miocene Bolognano Formation, ranging from shallow-water skeletal grainstones to hemipelagic mudstones. These carbonates were deposited in a non-tropical carbonate ramp belonging at that time to the Apulian platform realm. With the objective to assess the control exerted by environmental, sedimentological, diagenetic and petrophysical properties on the development of bed-parallel pressure solution seams and compaction bands, we integrate stratigraphic, sedimentological and structural field analyses with laboratory tests such as optical microscopy, HCl testing, diffrattometric and digital image analyses.
The main results of this research are summarized below:
- Under a vertical loading, intergranular pressure solution was strongly enhanced by the presence of small amounts of clay (2-4% in volume) in fine-grained, grain-supported carbonate rocks (grainstones, packstones), as well as by the good sorting and sphericity of individual carbonate grains. The influence of these factors on pressure solution development is recorded by longer, more connected, and less spaced bed-parallel seams.
- Bed-parallel compaction bands formed only in poorly-cemented, porous carbonate grainstones (porosity > 15%). The dimensional parameters of the bands (i.e. length, spacing, thickness), however, were strongly controlled by specific pore types and distributions which, in turn, are affected by the skeletal grain assemblage of the rock.
In conclusion, based upon a pre-existing knowledge on (i) depositional environment, (ii) biota evolution, (iii) depositional processes, (iv) diagenetic evolution, (v) rock components and (vi) petrophysical rock properties, it is possible to infer (directly or indirectly) both type and distribution of the structural discontinuities pertaining to the background deformation and, therefore, assess the hydraulic properties of the carbonate rock masses.