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Rigid rotation of quartz grains in a low-porosity calcarenite: an indicator of early deformation?

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Reservoir rocks, such as carbonates, are rapidly becoming key elements for the energy transition. The damage of these reservoir rocks when placed under a stress field must be characterized, to better predict storage capacity distribution. In the shallow subsurface, carbonate rocks accommodate the stress by developing structures at the mesoscale, such as fractures, deformation bands or stylolites, depending on porosity or fluid content. Those are localized, showing a finite damaged area, outside which the relative host rock can accommodate the applied stress in a different way, usually overlooked in low temperature and pressure conditions.

In this study, we highlight a new marker of accommodation of shortening, characterized by heterogeneous quartz grain rotation in non-porous carbonate matrix. The studied rock is an upper Cretaceous bioclastic calcarenite from the Cotiella Massif (Spain). This rock is composed of 85% carbonate (micrite and recrystallized microsparite), 10% quartz, and <5% of nanometric porosity. It hosts a fracture pattern including fractures, stylolites and deformation bands that correspond to different tectonic stages. However, we focus on investigating the quartz grain orientation in the grains outside the deformation bands, in both the far-field and near-field host rock. We investigated the fabric (typology, distribution and orientation) of thousands of quartz grains using X-ray microtomography on cylindrical cores of 8-26 mm diameter. Each segmented quartz grain is approximated with a best-fit ellipsoid whose major axis (L1) and minor axis (L3) give us information about the average orientation of the quartz grain. We show that the typology of the quartz grains, namely the size and average shape is similar in all our samples.

The average orientation of all quartz grains at the core scale reveals subtle preferences, without clear correlation to the orientation of neither the stylolites nor the deformation bands. We observe that in half of the samples studied, the quartz grain fabric is not controlled by the bedding. Instead, there are two distinct patterns of grain orientation, with the quartz grain fabric either reflecting the early burial stage or revealing a later reorientation perpendicular to one of the major shortening directions. These directions are either striking parallel to the local shortening flow (NE-SW) or to the regional orogenic flow (N-S), that is attributed to the Pyrenean orogeny. Evidence of dissolution-recrystallization are observed in quartz, but the diagenetic conditions constrainthis mechanism from being a robust hypothesis to explain the change of quartz fabric, but rather

favour the rigid rotation of quartz in a micritic matrix. The examination of both the quartz grains and the carbonate matrix with EBSD suggests a local strain accumulation within the carbonates in the vicinity of quartz grains. Although the mechanisms causing this rotation need to be better understood, measuring the grain typology and orientation on a considerable number of grains with the aid of X-ray microtomography could result in a new method of deformation quantification in carbonate rocks.