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# The impact of stylolites on brittle failure of carbonates: mechanical data and numerical simulations

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Stylolites are complex column-and-socket interdigitation features that form as a result of intergranular pressure-solution. They are usually orientated perpendicular to the maximum principal stress (weight of the overburden or maximum tectonic stress). They typically form clay-enriched seams; and can sometimes reach a few hundred metres in length. While the impact of stylolites on fluid flow was recently quantified for several carbonate formations (Heap et al., 2012), there is however a paucity of data on their impact on the mechanical strength of carbonates. Observations in quarries suggest that the presence of stylolites is associated with significant mechanical weakening and anisotropy. The aim of this study was to quantify these effects based on laboratory experiments and numerical simulations.

We used cores from limestone formations surrounding the ANDRA Underground Research Laboratory at Bure in the south of the Meuse district, France. Several different Oxfordian limestones were selected for this study and more than 50 samples were deformed under uniaxial conditions. The selected rocks are microporous and their average porosities range between 2 and 18%. The porosity of the samples with stylolites was found to be systematically larger than the stylolite-free samples. The stylolite-free rock is found to be mechanically isotropic, with comparable Uniaxial Compressive Strength (UCS) values in all tested orientations. We deformed samples with one stylolite in their central part oriented either horizontally (perpendicular to loading), vertically (parallel to loading) or oblique (30 degrees to loading). The samples with a stylolite were always significantly weaker than the stylolite-free samples but no systematic difference was observed in the different orientations. Visual inspection as well as microstructural analysis revealed some complex interactions between the stylolites and stress-induced microcracking. In particular, when the stylolite is oriented orthogonal to the loading, microcracks clearly appeared to nucleate from the stylolite. Whatever the stylolite orientation, the macroscopic fracture appeared to follow only small parts of the tortuous stylolite path.

Numerical simulations were performed using stochastic modelling and the Failure and Process Analysis Code (RPFA). Two dimensional numerical samples (40 mm x 20 mm) consisted of 51200 (320 x 120) square elements were deformed uniaxially. To reflect material heterogeneity on the microscale, each square was assigned a value of strength (tensile and compressive) and Young's modulus using a Weibull probability density function. The model parameters were first set to reproduce the mechanical behavior of the stylolite-free material. Guided by our microstructural analysis we then introduced a weaker layer in several orientations in the numerical samples. The simulations showed good qualitative agreement with the experiments performed on samples with stylolites. Our study showed that stylolites have more impact of the mechanical properties than on fluid flow in the limestone from Bure.