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Upper bound on stylolite roughness as indicator for the duration and amount of dissolution

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Stylolites are rough dissolution surfaces abundantly found in carbonates and sandstones. They are characterized by anomalous porosity and permeability with respect to the host rock, and thus play a crucial role in determining both the deformation and permeability of rocks. In spite of their importance and decades of research, their formation is still not well understood.

Existing models (Schmittbuhl et al., 2004; Ebner et al., 2009; Koehn et al. 2009), predict how stylolite roughness develops from an initially flat surface. The models assume that three processes control stylolite roughness evolution: material heterogeneity, which is the main drive for roughening, and elastic and surface energies that smooth the interface. The resulting stylolite surface growth models belong to the well-known Family-Viscek universality class of surface growth models (Barbasi and Stanley, 1995). These surfaces increasingly roughen with increasing amount of dissolution, showing a fractal (self-affine) behavior below a characteristic length scale, χ, called the correlation length. χ is the upper limit for fractal behavior and for an infinitely long surface χ will continuously grow in a predictable manner as the surface continues to dissolve. As χ grows so does the width of surface, i.e. the root mean square of its teeth height. For a finite system size (or stylolite length) L, when χ=L, both χ and the roughness will stop evolving even though dissolution may continue. This means that as long as the correlation length is smaller than system size – it may be directly linked to the amount of dissolution.

In a companion talk we report measurements of stylolite surface roughness at a scale larger than ever measured before (0.01-10m), allowing us to observe the previously unobserved upper bound for fractal behavior. The fractal exponents and χ calculated from our field measurements are used to calculate, based on the models described above, the amount of dissolution which occurred on these stylolites. Comparable dissolution amount is calculated from a simplified mass balance and from measurements of maximum teeth amplitude. Our field and modeling results support formation of stylolites from existing surfaces in our field site rather than in-plain propagation that has been suggested for other cases (e.g., Fletcher and Pollard, 1981; Raynaud and Carrio-Schaffhauser, 1992).

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