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Stylolite aperture scaling – implications for localised pressure solution (and fluid flow).

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Stylolites are rough paired surfaces, indicative of localized stress-induced dissolution under a non-hydrostatic state of stress, separated by a clay parting which is believed to be the residuum of the dissolved rock. Traditionally, stylolites are examined in 2D cross-sections in the outcrop, hand-specimen or thin-section, or their topography is investigated by laser profilometry of mechanically opened interfaces, essentially gaining 1D or 2D information of the roughness of individual interfaces. In the last years several studies were conducted on natural interfaces of mechanically opened stylolites focusing on their scaling properties. It was concluded that natural stylolites show a complex self-affine scaling behaviour over several orders of magnitude. These observations are in good agreement with analytical and numerical investigations which predicted the development of these scaling regimes.

Nonetheless no study has investigated both interfaces and the clay parting lying in between and thus the complete structure. Here we focus on the aperture (stylolite aperture) between the two adjacent stylolite interfaces and its scaling properties. Since the stylolites are reported to act as major fluid conduits for fluid flow along such interfaces the scaling of stylolite aperture it has important implications for e.g. reservoir characteristics.

To obtain stylolite apertures in 3D we study stylolites in limestones which have attained a considerable amount of residuum by means of x-ray μCT. In addition, we use SEM analysis of polished thin-sections to gain insight below the scale of resolution of the μCT.

The results of this study show that, although both interfaces of an individual stylolite show a similar scaling behaviour, the topography on either side of the clay parting can deviate considerably for stylolites with thick residual clay parting. This is in contradiction to fractures with no in plane movement (mode I fractures). As a result the stylolite aperture between stylolite interfaces varies considerably. Our scaling analysis demonstrates that stylolite aperture exhibits a self-affine scaling with Hurst exponents similar to what is observed for fractures. Another intriguing feature of the stylolite aperture is that in some places along the stylolite there is no clay parting (i.e. below of resolution of the μCT) separating the two interfaces whereas in other places clay parting is usually $\sim$1mm.

These observations are hard to explain with the fact that this clay parting is considered to be the residuum of the dissolved host-rock since the amount of clay material in the host-rock is not varying in a similar fashion. We hypothesise that such a variation can only be explained by secondary redistribution of the clay material by fluid flow or imply a localised variation in the pressure solution process due to stress concentrations. Possibly, in highly stressed areas around lowly soluble hard grains (pinning particles), the insoluble residues flow towards the surrounding stylolitic space.