Modelling the formation of stylolites as a competition between elastic forces, surface tension and noise

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Stylolites are rough dissolution seams in natural rocks. They are a very common feature with a roughness on a large range of scales. Stylolites are usually used to identify the orientation of the largest compressive stress and the maximum amplitude of their peaks is used to estimate compaction in sedimentary basins. Why and how the stylolite roughness develops in detail is still debated. We present a new numerical model that is used to study the roughness development of stylolites in time and 2D space. A particle model is used with a linear elastic spring network where particles dissolve as a function of elastic and surface energies as well as normal stress on reactive interfaces. An initial quenched noise on the dissolution constants of particles is used to initiate the roughness. The initial configuration in the model is a perfectly flat dissolution surface that represents an initial heterogeneity in the rock. This surface remains flat when no initial noise is used in the system indicating that elastic and surface energies as well as the normal stress on the surface smoothen the interface and prevent roughness development. Systems with an initial noise, however, develop a significant roughness within a relatively short time. Over time the mean position of the stylolites remains fixed whereas their mean and maximum amplitude scale as a function of the square root of time. Elastic energy, normal stress and surface energy influence the roughness growth and thus the scaling properties of the stylolites. Fast Fourier Transforms of time and space series indicate that the stylolites may show self-affinity in both, time and space. We compare the results of the numerical model with natural systems and discuss the implications of our study.

Physical chemistry of replacement: Consequences for petrology and reaction-transport modeling

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Mineral replacement, characteristically preserving both volume and morphological features of the host, is widespread in rocks of all kinds. Crystal aggregates that grow in a rock exert a local stress on adjacent mineral grains as they grow. This *induced stress* depends on the kinetics of crystal growth that causes it, the shape of the aggregate, the pre-existing macroscopic stress, and the host rock's response to the growth (Fletcher & Merino, 2001). Possible responses are pressure-solution, deformation, and fracturing of the host rock.

I. Replacement takes place where the A growing crystals are accommodated only by pressure-solution of adjacent B-host grains. The induced stress between A and B forces the crystal growth rate of A and the pressure solution rate of B to become equal. This is why replacement is always isovolumetric. Adjusting the replacement of B by A on volume often provides unsuspected insight. Adjusting the weathering replacement of feldspar by gibbsite on volume provides the thread to grasp the feedback (between the leaching and the accumulation zones) at the core of all weathering (Merino et al, 1993). It is thanks to this feedback that the two zones remain associated as they dynamically "eat" their way into parent rock, as confirmed by dynamic modeling (Wang et al, 1995), and as observed.

II. If the B host rock has low strength and/or a low dissolution rate constant, then the growing crystal(s) of A are accommodated by local deformation of the B host rock. If A grows as dispersed crystals or nodules their aggregate mechanical effect is to overpressure a large volume of host rock, on a scale much larger than the size of each nodule.

III. If A grows in a host rock subjected to unequal principal stresses, then A grows as displacive *veins*. Vein-shaped growth injects the least strain energy into the host, compared to spherical and rod-like growths. Displacive vein examples: septarian concretions; zebra veins in dolomites, evaporites, serpentinized gabbros; veins normal to stylolites.

Dynamic reaction-transport modeling including the growth-induced stress and its consequences – replacement or displacive growth – can better integrate modeling and petrology (Merino & Dewers, 1998).

References

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