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Compaction and local fluid flow variations estimate through a new stylolite classification

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Pressure solution is a mechanism commonly affecting sedimentary rocks, developing rough surfaces called bedding-parallel stylolites (BPS) when the stress originates from strata burial. In the Zechstein 2 carbonate units, an important lean gas reservoir in the southern Permian Zechstein basin in Germany, stylolites influence local fluid flow, mineral replacement reactions and hence the permeability of the reservoir. The geometrical growth of the roughening of layer dominated BPS has been modeled numerically in order to understand their structural evolution. Our simulations demonstrate that layer-dominated stylolites can grow in three distinct stages: an initial slow nucleation phase, a fast layer pinning phase and a final freezing phase if the layer is completely dissolved during growth. Dissolution of the pinning layer and thus destruction of the stylolite's compaction tracking capabilities is a function of the background noise
in the rock and the dissolution rate of the layer itself. Low background noise needs a slower dissolving layer for pinning to be successful but produces flatter teeth than higher background noise. From comparison between roughness as resulting from the models and as observed in nature, we present a comprehensive classification of BPS that bound the final morphology of a stylolite to its impact on chemical compaction and on local permeability variation. BPS falls into four classes: (1) rectangular layer type, (2) seismogram pinning type, (3) suture/sharp peak type and (4) simple wave-like type. Our results show that the capability of a stylolite to consistently track the amount of chemical compaction is dependent on the linearity of their growth law. As a result, rectangular layer type stylolites are the most appropriate for chemical compaction estimates because they grow linearly and record most of the actual compaction, Seismogram pinning type stylolites also provide good tracking capabilities, with the largest teeth tracking most of the compaction. The local impact on permeability is linked to the collection of sealing material along the stylolites, which will make them act as barriers as they intensify sealing capabilities of pinning layers. However, the development of teeth and spikes offsets and thus destroys continuous stylolite seams so that the permeability across the stylolite becomes very heterogeneous and they are no continuous barriers. This behavior is best shown in rectangular layer and seismogram pinning type stylolites that develop efficient fluid barriers at teeth tips but destroy sealing capabilities of layers by offsetting them at the flank, leading to a permeability anisotropy along 2-D stylolite planes. Based on the natural observations in the Z2 carbonates, we propose that our classification can be used to realistically estimate chemical compaction in reservoirs and gives an indication on how heterogeneous the permeability of BPS can be during its growth.