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Development and scaling relationships of a stylolite population

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Abstract

The frequencies, amplitudes and insoluble residue thicknesses of 4639 stylolites have been measured from ~674.3 m of core from four vertical wells in the Khuff Formation, a Permo-Triassic carbonate reservoir, offshore Abu Dhabi. Although there are similar numbers of stylolites per metre of core in dolomites and limestones, the stylolites in the limestones have approximately double the cumulative amplitudes and insoluble residue thicknesses than the stylolites in dolomites. This indicates that stylolites in the limestones have grown at approximately twice the speed or for twice as long as the stylolites in the dolomites. Stylolite amplitudes in dolomites and limestones together appear to obey a power-law scaling relationship over about one order of magnitude (~20–150 mm). Stylolite amplitudes in dolomites, however, have a higher power-law exponent than those in the limestones, and appear to obey a power-law down to ~10 mm. This indicates that stylolites in the limestones have merged more than the stylolites in the dolomites. The amount of pressure solution, and possibly the scaling of a population of stylolites, may also be controlled by location within the fold, with less pressure solution in the hinge region, into which hydrocarbons migrated earlier than in the limbs.

Keywords: Stylolite; Population; Growth; Scaling

1. Introduction

Stylolites are surfaces on which insoluble residues are concentrated as pressure solution removes such soluble minerals as calcite or quartz (e.g. Stockdale, 1926). The teeth of stylolites point in the shortening direction, and, assuming the stylolites initiated as flat planes and did not propagate out of plane, their amplitudes represent a minimum estimate of the amount of shortening (compaction) that has occurred (Fig. 1; e.g. Fletcher and Pollard, 1981; Rispoli, 1981). Assuming the insoluble material was initially evenly distributed in the rock and that there has been no contamination by circulating fluids, the thickness of insoluble residue along a stylolite would be proportional to the amount of material dissolved and would therefore be proportional to the displacement across the stylolite. Fletcher and Pollard (1981) regard stylolites as a form of fractures with mode-I displacements (cf. Katsman et al., 2005). It is therefore possible to carry out displacement analysis, as for faults.

There has been considerable interest in the relationship between different scales of geological structures. For example, the geometries and mechanics of microscopic fault zones have been shown by Tchalenko (1970) to closely resemble those of continental scale fault zones. Faults are therefore described as being *self-similar* or *scale-invariant*, with the geometry at one scale being very similar to the geometry at other scales. The development of the concept of *fractals* (e.g. Mandelbrot, 1967, 1982; Turcotte, 1990) has provided a method for describing the self-similarity of different scales of structures. For example, the power-law scaling relationship of fault displacements is given by $N = cU^{-D}$, where N = number of faults with a displacement greater than U, c = a constant, and D = the power-law exponent (e.g. Childs et al., 1990; Scholz and Cowie, 1990). The power-law scaling

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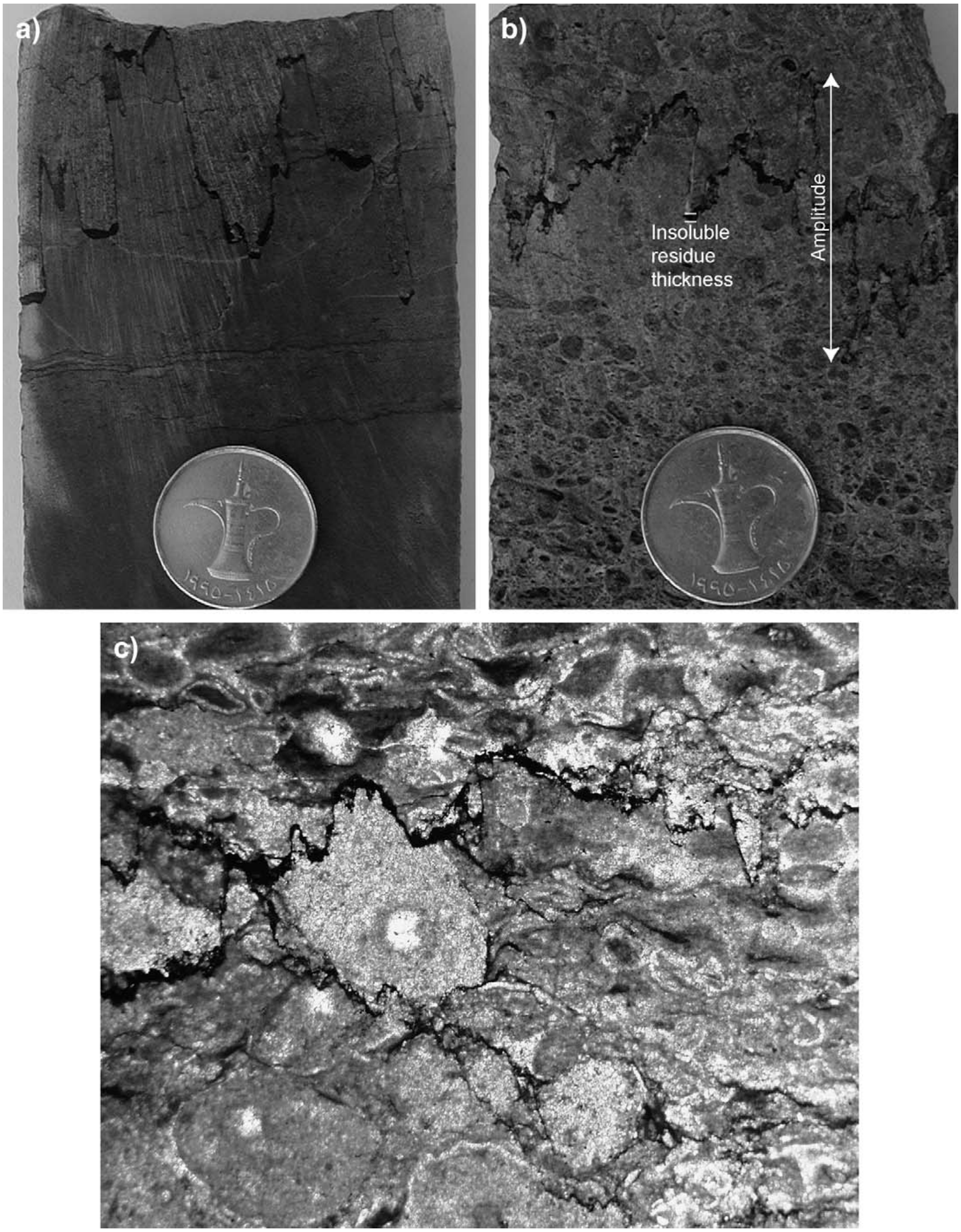

Fig. 1. Examples of stylolites observed in slabbed core from the Khuff Formation. (a) Different lithologies occur on either side of the stylolite, illustrating why stylolite amplitude gives a measure of the minimum amount of material removed by a stylolite. (b) Porosity is greatly reduced near a stylolite, with stepping portions of the stylolite linked by sub-vertical calcite veins. Amplitude and insoluble residue thickness are marked. (c) Photomicrograph of stylolites in the Khuff Formation, illustrating the microscopic nature of many stylolites, and the merger of smaller stylolites to form larger stylolites. The field of view is ∼5 mm across.

relationship for fault displacements has been used to estimate the numbers of faults above and below the scale of resolution of a particular survey, and hence to estimate the total fault-related extension or contraction in a region (e.g. Marrett and Allmendinger, 1992; Walsh and Watterson, 1992). Other examples of the self-similarity of faults include fault trace lengths (e.g. Villemin et al., 1995) and the ratio of fault trace lengths to maximum displacements for a fault population (e.g. Dawers et al., 1993). Note, however, that it is possible some fault populations show non-fractal (e.g. negative-exponential, log-normal, etc.) size-frequency distributions for displacements or trace lengths (e.g. Nicol et al., 1996; Spyropoulos et al., 1999).

Previous work on the scaling of stylolites has focused on the geometries of individual stylolite surfaces and on the spacing between stylolites. Several papers have shown that