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Changes of scaling relationships in an evolving population: The example of "sedimentary" stylolites

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ABSTRACT

Bed-parallel ("sedimentary") stylolites are used as an example of a population that evolves by the addition of new components, their growth and their merger. It is shown that this style of growth controls the changes in the scaling relationships of the population. Stylolites tend to evolve in carbonate rocks through time, for example by compaction during progressive burial. The evolution of a population of stylolites, and their likely effects on porosity, are demonstrated using simple numerical models. Starting with a power-law distribution, the adding of new stylolites, the increase in their amplitudes and their merger decrease the slope of magnitude versus cumulative frequency of the population. The population changes to a non-power-law distribution as smaller stylolites merge to form larger stylolites. The results suggest that other populations can be forward- or backward-modelled, such as fault lengths, which also evolve by the addition of components, their growth and merger. Consideration of the ways in which populations change improves understanding of scaling relationships and *vice versa*, and would assist in the management of geofluid reservoirs.

1. Introduction

This paper aims to show how the evolution of a population (and the related changes in their scaling relationships) can be modelled in terms of the addition of new components, their growth and their merger. The paper is ***not*** intended to be specifically about stylolites, which are used for ease of modelling. Here, it is envisaged that the amplitudes of horizontal stylolites are sampled along a vertical well, so the modelling is one-dimensional, involving analysis of the tops and bottoms of each stylolite in z coordinates. Other populations require 2D or 3D modelling. For example, modelling fault trace lengths (e.g., Cowie et al., 2006) would require analysis of the tips of each fault in x,y coordinates, i.e., 2D modelling. Also note that the manuscript is also not specifically about:

- *The stylolites in the Khuff Formation of Abu Dhabi.* These are used as a starting point because of data availability (Peacock and Azzam, 2006).
- *Power-law scaling relationships.* These are used for ease of computation and because various natural phenomena (e.g., stylolite amplitudes, fault lengths) *appear* to initially follow power-law scaling relationships. Other scaling relationships could be used. Our aim is to show how a scaling relationship can change as new components are added, they grow and they merge.
- *Power-law scaling of individual stylolites.* This paper is not about the scaling or fractal geometries of *individual* stylolites (e.g., Drummond and Sexton, 1997), but about the scaling of a *population* of stylolites, e.g., including all of the stylolites that would be found in core through a carbonate reservoir (e.g., Peacock and Azzam, 2006).

1.1. Stylolites

Stylolites are dissolution surfaces along which insoluble material (mainly clay minerals, oxides, and organic matter) accumulates during the progressive dissolution of the rock (e.g., Railsback, 1993). Stylolites are especially common in carbonate rocks, which are highly reactive and can be dissolved relatively easily by pressure solution. Bedding-parallel stylolites are typically formed due to overburden loading during burial (*sedimentary* stylolites; e.g., Bathurst, 1995; Rolland et al., 2012; Heap et al., 2014), and can occur as isolated or anastomosing structures composed of several merged

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stylolites (Fig. 1a). In contrast, steeply-dipping stylolites, or those at a high angle to bedding, are commonly referred to as *tectonic* stylolites (e.g., Railsback and Andrews, 1995). It is commonly assumed that the teeth of stylolites point in the compaction direction and their amplitudes represent a minimum estimate of the amount of compaction that has occurred across the stylolite (Fletcher and

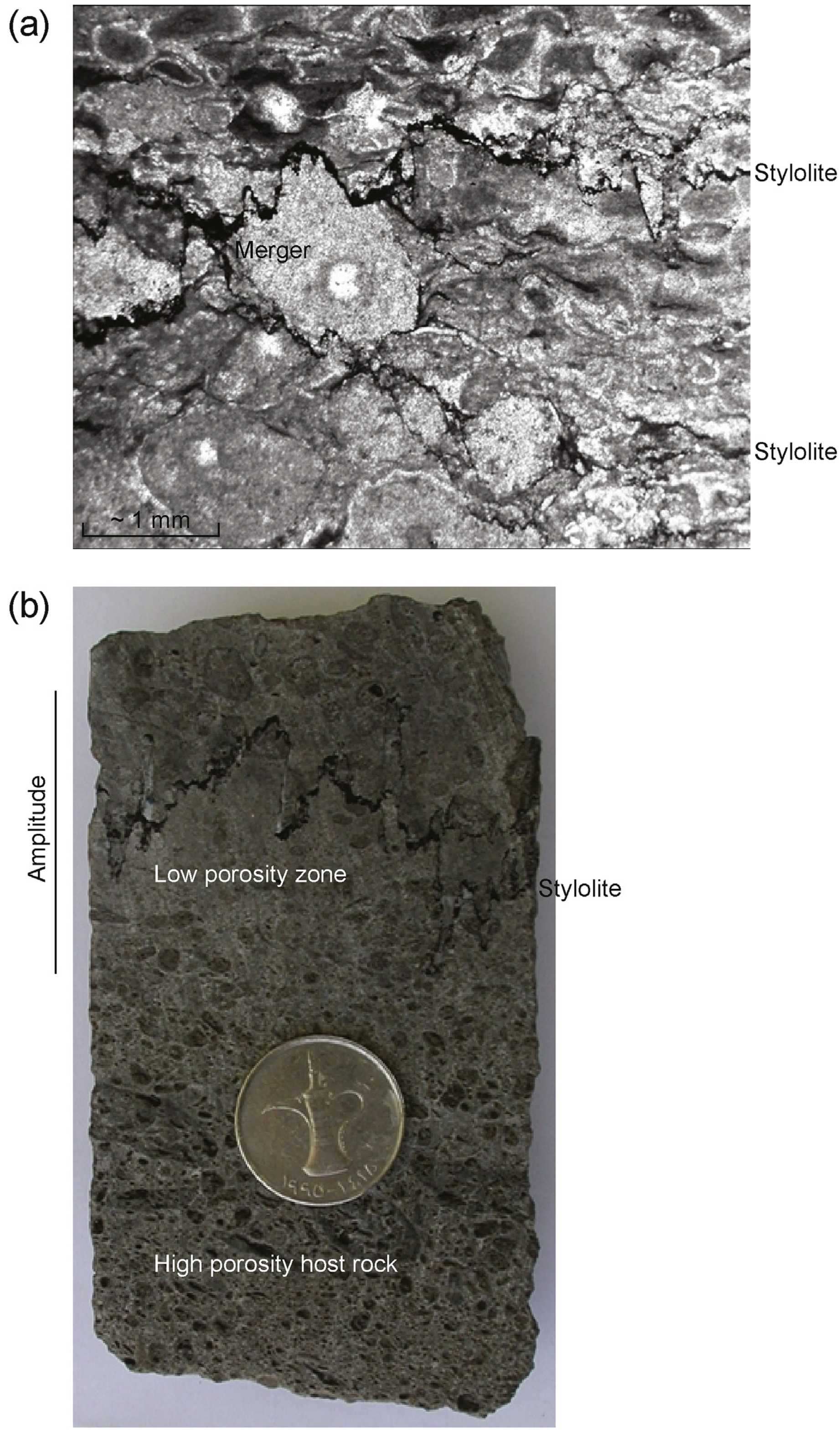

Fig. 1. (a) Photomicrograph of stylolites in a limestone of the Khuff Formation, illustrating the microscopic scale of many stylolites, and the merger of smaller stylolites to form larger stylolites. The field of view is ~5 mm across. (b) Photograph of a stylolite in a limestone grainstone of the Khuff Formation, illustrating the cementation in pores and resultant reduction in porosity around a stylolite (from Peacock and Azzam, 2006).