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Multiple dyke propagation from single source regions

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Numerous field evidences exist for the propagation of multiple, sub-parallel dykes from a single source region across a wide range of scales and tectonic settings. These include dyke systems that originate from individual volcanic magma chambers, the occurrence of sheeted dyke complexes at mid-ocean ridges and the formation of giant mafic dyke swarms associated with continental breakup and flood basalts. There are also many field observations of dyke interactions, suggestive of simultaneous dyke propagation. Furthermore, analysis of the distribution of dykes in swarms reveals that dyke spacing does not simply follow a fractal distribution but appears instead to be related to a characteristic length scale, which affects how magma is subsequently transported along the swarms. Analogue and numerical modellings have been carried out to investigate the interactions between dykes originating from a single source, and to quantify how these interactions affect dyke spacing. The analogue experiments involved the simultaneous injection of air in parallel, identical and equally-spaced cracks, and the conditions for the propagation of these buoyant cracks were determined as a function of their spacing. The pressure required to simultaneously propagate these buoyant cracks appears to be inversely proportional to the crack spacing, reflecting increasing stress interactions between the cracks as they get closer. These stress interactions were further studied by numerical modelling. Stress interactions between dykes were characterised by calculating the stress intensity factor at their tip. This modelling reveals that dykes which spacing is greater than 5 times their length do not interact and their stress intensity factor depends only on their driving pressure and length. Closer dykes, however, do interact with each other and their stress intensity factor does also depends on their spacing. In this latter case, the stress intensity factor increases, thus reflecting a decrease in stress interactions, with the length of the dykes, their spacing and their driving pressure. This implies that there exists a minimum dyke spacing below which the stress intensity factor at the dyke tip is smaller than the rock fracture toughness and thus below which dykes cannot propagate. The numerical results also suggest that simultaneous dyke propagation is an unstable process that would favours the propagation of longer dykes as well as the merging of adjacent dykes, since this would increase their spacing and thus their stress intensity factor. These findings are in agreement with field data and would explain the common observations that larger dykes in a swarm also tend to be thicker.