A fractal model of dike formation and variability based on Cellular Automata

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In the vast majority of cases, magma ascends towards the Earth's surface occurs essentially through dike propagation. The vast majorities of dikes are arrested in the crust, and transform into sills or assemble into plutons and laccoliths. Magmatic fluids are also the primary metal source for the formation of the magmatic-hydrothermal mineralization. These arrested magmatic dikes are essential to the geochemical and geophysical structure of the Earth's crust. In addition, upon arrest, the magma might be strongly out of equilibrium with the ambient condition during the process of solidification. It will immediately start to equilibrate by dissolving materials; as a result, most mineral precipitation can be expected to occur at or close to solid dikes or intrusions.

In this study, we consider the effect of density barriers on the arrest of dike propagation. A cellular automaton model was adopted to simulate the formation of dikes. Magma ascent towards the Earth's surface through a self-organized network of rock cracks as long as the density of the surrounding rocks is greater than that of the magma fluid. If magma rises to a zone with negative buoyancy, it may be arrested, and start to solidify and become immobile; as a consequence, magmatic dikes are formed. Therefore, describing the formation process, and quantifying the irregularity and spatial distribution of the solid dikes are of great significance. Two fractal dimensional measures, Perimeter-Area (P-A) and Number-Area (N-A), were used to quantify the irregularity and spatial distribution of solidified dikes. The fractal dimensional D_{AP} of P-A, as well as the fractal dimensional D_P of the perimeter show that the irregularity of the solid dikes increase as the thickness of the negative buoyancy region increases from 1 km to 5 km. The N-A exponent D reflects the irregular size and spatial scale-invariance of the dikes. The area of dikes is recorded during their temporal evolution, and shows 1/f power spectrum, typical of a fractal process. Results of the numerical model demonstrate that dike formation is a self-organized critical process, and demonstrates that a cellular automaton and fractal model is able to capture and quantify the spatial and temporal evolution of complex dike systems.