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Self-similar clustering distribution of structural features on Ascraeus Mons (Mars): implications for magma chamber depth

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The occurrence and spatial distribution of monogenic eruptive structures within volcanic areas are linked to fracture systems and associated stress fields.
Moreover, they testify the presence of deep crustal or subcrustal magma reservoirs directly connected to the surface by a percolating fracture network. The correlation between vent distribution and fracture network properties (the so called backbone) can thus be studied in terms of self-similar (fractal) clustering.
Self-similarity in vent distribution is described by a power law distribution with fractal exponent D and defined over a range of lengths (l) comprised between a lower limit (lower cutoff, Lco) and an upper limit (upper cutoff, Uco). The upper cutoff (Uco) for fractal clustering was compared with the respective crustal thickness obtained by existing independent geophysical data in the East African Rift System (Mazzarini and Isola, 2010). The computed Ucos for this sector well match the crustal thickness in these volcanic fields. More in detail this computational model verified the strong linear relationship existing between the upper cutoff of the power law distribution and the magma source depth.
This method was thus applied to Ascraeus Mons on Mars, which displays basaltic magmatism and hundreds of collapse pits and vents around its flanks, giving a robust statistic to the calculations. Basing on a structural mapping performed on HRSC (High Resolution Stereo Camera onboard the ESA Mars Express mission) at 12 m/px and CTX (Context Camera, Mars Reconnaissance Orbiter mission) at 6 m/px mosaics, more than 2300 collapse pits and vents were analysed. Data analyses displayed a clustering in the structures distribution, showing two distinct populations.
The obtained Uco values revealed the presence and the likely depth of both a deep big magma chamber and a small shallower chamber placed below the main caldera.
Moreover, the resulting magma source depths are completely consistent and comparable with those obtained by FEM (Finite Element Method) calculations on the stress field caused by magma chamber overpressure. In fact, the opening of cracks on Ascraeus flanks, suitable for sill injections and vent formation, as well as their peculiar distribution are the surficial manifestation of depth-dependent magma chamber stress field (Pozzobon et al., in prep.).
Estimates by two different independent approaches (self-similar analysis and FEM modelling) converge giving thus a strong constrain on the presence and position of the magma sources below Ascraeus Mons.