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Fractal analysis: tool for the discrimination of morphologically convergent mound-like features on Mars

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The investigation of the Martian surface through remote sensing allowed the identification of mound-like topographically positive features that, based on geomorphological observations, have been ascribed to different phenomena. New observations will be performed in the forthcoming future by the CaSSIS camera onboard the TGO-ExoMars mission to look for possible methane sources, hence, discriminating morphologically similar features is a key objective to profitably investigate the Martian surface. However, interpretations are not always univocal due to morphological convergences of such features that can belong to both volcanic and periglacial environments. Hence, in order to address this problem, we performed fractal analysis on four Martian fields of mound-like features that have been quite unambiguously interpreted respectively as mud volcanoe (Oehler and Allen, 2010), pingos (Balme and Gallagher, 2009), rootless cones (Page and Murray, 2006) and monogenetic volcanic vents (Bleacher et al., 2009). Such technique is able to assess if the distribution of analyzed features have fractal clustering and thus if they are related to underlying systems of connected fractures, whose extension in the subsurface can be estimated (Mazzarini and Isola, 2010). Fractal analysis is therefore completely unbiased by the morphological characteristics of the observed objects and it links the mound-like fields to the eventual parent fracture networks which allowed the resurgence of the materials that generated the surface features. Additionally, the identification or not of the connection with fracture systems plus the evaluation of the fractured medium thickness beneath the fields allow to infer which processes are most likely to have occurred for each study area. In particular we observed: mud volcanoes, which are expected to be linked to systems of connected fractures reaching around 10-20 Km depths; pingos, which are not expected to be linked to fractures; rootless cones, which are expected to be linked to cracks involving only the thickness of the inflate lava flow that generated them (around maximum values of 200 m); and volcanic vents, which are expected to be fed by magma chambers that can sit several tens of kilometers below the surface. Our study successfully validates the major interpretations of mud volcanoes, pingos and volcanic vents perfectly matching the foreseen subsurface behavior, while the analysis of rootless cones outputted less unequivocal data leading to infer that either previous geomorphological interpretation were not accurate enough or the phenomenon is more complex than expected.

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