Analytical solutions for surface displacements, magma overpressure and flow from a simple damage law using earthquake numbers: application to Piton de la Fournaise eruptions 2004-2018 – implications for eruption prediction

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Eruption prediction methods like FFM (Voight, 1988) often try to fit the pre-eruptive cumulative number of earthquakes to a simple analytical model inferred from the experimental study of damage during the rupture of metal bars in tension (Kachanov, 1958). This model is limited to the progressive rupture of cohesive bodies that have a finite size; this model does not take into account the complexity of the real rupture and often fails to fit the cumulative earthquake number recorded before an eruption. In this work we show that the use of a model for the cumulative earthquake number is not necessary and that this number can be used directly in a damage approach instead, without any model. We infer an analytical solution for surface displacements that allows fitting these data and compute magma overpressure and flow, for the recorded earthquake numbers. We apply these solutions to the earthquake and displacement data recorded for the 2004 to 2018 eruptions of Piton de la Fournaise, la Réunion, France. We show that computing Kachanov's continuity and effective stress, and strain power (Got et al., 2017) greatly helps to infer how the volcano is close to an eruption, even when seismicity and displacement data do not allow to conclude. The various pre-eruptive earthquake patterns are related to the physics of the rock deformation.

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