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Sill intrusion in volcanic calderas: implications for vent opening probability

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Calderas show peculiar behaviors with remarkable dynamic processes, which do not often culminate in eruptions. Observations and studies conducted in recent decades have shown that the most common cause of unrest in the calderas is due to magma intrusion; in particular, the intrusion of sills at shallow depths. Monogenic cones, with large areal dispersion, are quite common in the calderas, suggesting that the susceptibility analysis based on geological features, is not strictly suitable for estimating the vent opening probability in calderas. In general, the opening of a new eruptive vent can be regarded as a rock failure process. The stress field in the rocks that surrounds and tops the magmatic reservoirs plays an important role in causing the rock failure and creating the path that magma can follow towards the surface. In this conceptual framework, we approach the problem of getting clues about the probability of vent opening in volcanic calderas through the study of the stress field produced by the intrusion of magma, in particular, by the intrusion of a sill. We simulate the intrusion of a sill free to expand radially, with shape and dimensions which vary with time. The intrusion process is controlled by the elastic response of the rock plate above the sill, which bends because of the intrusion, and by gravity, that drives the magma towards the zones where the thickness of the sill is smaller. We calculated the stress field in the plate rock above the sill. We found that at the bottom of the rock plate above the sill the maximum intensity of tensile stress is concentrated at the front of the sill and spreads radially with it, over time. For this reason, we think that the front of the spreading sill is prone to open for eruptive vents. Even in the central area of the sill the intensity of stress is relatively high, but at the base of the rock plate stress is compressive. Under isothermal conditions, the stress soon reaches its maximum value (time interval depending on the model parameters) and then decreases over time during the intrusion. However, if we consider the effect of the cooling of magma, with the temperature which decreases with time and the viscosity that increases, we'll find that the stress in the rock above the sill gradually increases with time and becomes higher than in isothermal case. In order to investigate the role of the physical properties of magma and rock above the sill in the generation of the stress field we have carried out different simulations by varying the viscosity of magma and the rigidity of the rock and found that high viscosity magma produces a relatively high stress intensity, as well as a high rock rigidity does.