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Effects of Host Rock Stratigraphy on the Formation of Ring-Faults and the Initiation of Collapse Calderas

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ABSTRACT

Most collapse calderas can be attributed to subsidence of the magma chamber roof along bounding sub-vertical normal faults (ring-faults) after a decompression of the magma chamber, following eruption. It has previously been shown that for ring-faults to initiate, and thus facilitate collapse, the stress field both at surface and around the magma chamber must satisfy specific critical conditions. Here, we present new numerical models that use a Finite Element Method to investigate the effects of variable stratigraphy (lithology/thickness/order of strata) on local stress field distribution. Results are compared with existing criteria for ring-fault initiation. Different subsurface scenarios were simulated by varying the stiffness (Young's modulus) of seven thin crustal layers placed above the magma chamber, and the host rock in which the chamber is seated. We consider the magma chamber to be subjected to a magmatic under-pressure of -15MPa, imposed at the chamber walls, in order to simulate magma withdrawal. Results indicate that for a given geometrical set-up, the magnitude and position of maximum tensional stress at the Earth's surface are influenced by the occurrence and relative distribution of mechanically stiff or soft lithologies above the magma chamber. For example, tensional stress at surface may be reduced by the presence of stiff layers (e.g. lavas), or increased by soft layers (e.g. pyroclastic units) compared to generic simulations using a homogeneous background medium. The observations suggest that the mechanical properties of crustal stratigraphy are therefore a further variable in the rare achievement of the stress field conditions required for ring-fault formation, and may be influential in generating or inhibiting caldera collapse. Therefore an understanding of pre-caldera stratigraphy could provide important insight into the likelihood of future caldera collapse events.