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Stress field conditions for ring-fault initiation: A new perspective

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During the last decades, calderas have been analyzed through field studies, analogue models and numerical simulations. This has permitted considerable improvement of our knowledge on caldera formation and particularly, on the stress conditions that lead to the formation of ring faults. Earlier results from numerical modelling of collapse caldera formation using linear elasticity indicate that in order to encourage the initiation of sub-vertical, normal ring faults, the stress field must satisfy three conditions simultaneously: **1**) The minimum value of compressive stress (σ_3), i.e. the maximum tension, must occur at the Earth's surface, **2**) The maximum value of shear stress ($\sigma_1 - \sigma_3$) must occur at the lateral margins of the magma chamber, and **3**) The maximum tension (minimum σ_3) at surface, must peak approximately above the lateral ends of the magma chamber. In essence, it has been shown that only few geometric configurations dominated by the relation between source depth and source aspect ratio yield conditions that fit these "ideal" stress conditions. As a consequence, caldera-formation should be a rarely achievable phenomenon. However, this conclusion stands in stark disagreement with abundant field and analogue experimental data of collapse caldera formation. The latter investigations show that caldera subsidence does not necessarily require specific geometries of the analogue reservoir to initiate ring fault formation and collapse. An open question thus remains as to a potential misinterpretation of numerical models of caldera collapse. The main objective of this work is to investigate contradictory results from numerical and analogue models as well as from field constraints. For this, we refer first to mining subsidence studies, to inform on the most relevant concepts that may help us to understand collapse initiation. Second, we report on results from a new set of experimental investigations on the first stages of roof subsidence and associated initial surface structures that have yet been poorly studied. Finally, we compare the experimental results with results from dedicated numerical models to inform on collapse initiation. Our results indicate that numerical collapse models assuming linear elasticity do not allow to predict the position of ring fault initiation, but rather depict to loci of near-surface ring fractures delimiting a potential collapse region. Our findings are in agreement with time-lapse data from recent caldera collapses on Miyakejima island (Japan) and La Reunion island (France). We conclude that linear elastic models cannot be applied to determine the geometric conditions for caldera formation since such models are in fact not applicable to predict the locus of ring-fault formation at the ground surface.