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Sequential formation and propagation of caldera ring-faults analysed in analogue experiments

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Abstract: In a series of analogue experiments, we analysed the formation and propagation of caldera ring-faults with the Digital Image Correlation (DIC) method. The results indicate a clear sequence of faulting during subsidence and show the non-uniform propagation direction of individual faults.

Keywords: caldera volcano, analogue modelling, ring-faults, fault kinematics, Digital Image Correlation (DIC).

The development of collapse calderas is controlled by the formation and propagation of ring-faults. In young caldera volcanoes, however, ring-fault surface expressions can be rarely investigated in detail due to the lack of exposure, structural overprint and coverage by thick pyroclastic material. Thus the ring-faults' subvertical prolongation, interlinkage, and propagation at depth are still one of the unanswered questions of volcanology. In this study, we analysed the kinematics of ring-faults in sandbox models with the Digital Image Correlation (DIC) method. The results allow following the propagation and activity of individual sets of ring-faults during caldera collapse.

Experimental setup

The experiments were performed under scaled conditions in a sandbox where a deflating magma chamber was simulated. These experiments were recorded with a computer controlled camera and processed with the DIC method to calculate the deformation vector and strain fields.

Results

The results show that ring-fault formation follows a sequence that starts with an initial downsag phase followed by the formation of several sets of upward-propagating reverse ring-faults. Then peripheral normal faults initiate from extension fractures at the surface and propagate downwards. Normal and reverse faults link at depth and combine into a single ring-fault that is steeply inward-dipping near the surface and steeply outward-dipping to subvertical at depth.

Discussion and conclusions

The structural configuration is in agreement with previous analogue experiments (e.g. by Komuro, 1987; Roche *et al.*, 2000), field studies of eroded caldera volcanoes (e.g. Lipman, 1984), seismicity of ring-fault systems (e.g. Saunders, 2001), and the observation of caldera formation (Geshi *et al.*, 2002). Our results, however, allow the first direct observation and quantification of the kinematics of ring-fault propagation in scaled analogue experiments. The final configuration has implications for the long-debated question why ring-faults in natural caldera volcanoes (active and eroded) are found to be either inward- or outward-dipping. The observation that the normal ring-faults propagate downward indicates that these faults are pure shear fractures and cannot serve as conduits (ring-dykes) as long as they are not connected to the reverse ring-faults at depth. In contrast, the reverse faults may partly originate as hydrofractures transporting magma from the magma chamber towards the surface. However, the dykes may close again as soon as the normal faults develop and clamp the former ring-faults.

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