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The Influence of Strike-Slip Tectonics on Caldera Formation: An Experimental Approach

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Violent ash-flow eruptions that frequently accompany caldera-volcano formation can devastate adjacent human populations and alter global climate. Although caldera-volcanoes are generally believed to result from catastrophic collapse of a magma chamber roof into an underlying magma chamber, our understanding of precisely how and why this process happens remains limited. Amongst factors in caldera formation to be thoroughly investigated is that of regional-scale faulting. In particular, many caldera-volcanoes have evolved in areas that experienced contemporaneous strike-slip regional deformation and include some of the world's largest and most active. For many such calderas, syn-collapse reactivation of pre-existing regional strike-slip faults is inferred to have had a profound, yet poorly understood influence on caldera development.

In order to address this gap in our understanding, we constructed scaled analogue models of caldera formation in a tectonic regime of transtensional strike-slip faulting. We used fine-grained, well-sorted sand to simulate brittle crust and cream honey to simulate granitic magma. Four experiment series were conducted to identify: 1) structures due solely to caldera collapse into circular and elliptical magma chambers; 2) structures due solely to regional strike-slip deformation; 3) what effect passive magma chambers might have on regional strike-slip structures prior to caldera collapse; and 4) how caldera collapse structures develop after regional strike slip faulting.

In the absence of regional deformation, caldera subsidence was typically asymmetric (trapdoor/piston), with the subsiding area bound by arcuate subsidence-controlling reverse faults and surrounded by a diffuse zone of peripheral normal faults. Arcuate reverse faults above magma chambers with elliptical geometries, as assumed to have underlain many calderas, initiated at the end points of the chamber short axes and propagated to the end points of the long axes.

Pure strike-slip deformation generated a straight-sided zone of en-echelon grabens bound by Riedel shears that were later cut by a main sub-vertical strike-slip fault. With a honey chamber present and a sufficiently high transtensive component, however, additional pull-apart-like half grabens formed above the passive honey chamber and laterally to the main strike-slip system.

Chamber evacuation following strike-slip deformation produced arcuate reverse faults that were occasionally affected by regional structures, but overall had similar geometry and kinematics to arcuate faults formed above elliptical chambers in the absence of regional deformation. Peripheral normal faults, however, frequently exploited pre-existing strike-slip structures and lateral graben faults.

From our results, we raise the possibility that long-lived high-level granitic magma chambers can localise pre-eruptive grabens above them when subjected to transtensional regional strain. We suggest that chamber geometry is the primary structural control on caldera subsidence in strike-slip zones. Pre-existing structures, such as the chamber-localised grabens and regional strike-slip faults, play an important role in peripheral caldera fault development and can cause the final caldera surface expression to deviate from the underlying plan-view chamber geometry.