Caldera development during explosive eruptions

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An interesting question is the likelihood that an explosive eruption results in caldera formation. Large eruptions emitting 10^2-10^3 km^3 of magma invariably form substantial surface subsidence structures, but smaller eruptions emitting 5-10 km^3 may not. These smaller events show variable behaviour, which is generally unpredictable, ranging from well-developed caldera structures (e.g., Pinatubo) to no calderas at all (e.g., Huaynaputina). For such events, is it possible to establish, during or even prior to the eruption, the probability that a caldera will form? Such an assessment is important, as the style of the eruption depends in part upon whether a caldera forms. One clear control is depth to the top of the magma reservoir; as depth increases, surface subsidence is reduced due to the crustal column between the surface and the top of the reservoir. A second important consideration is the amount of eruptable magma in the reservoir. An eruption that efficiently drains such eruptable magma from the reservoir may suddenly cease, putting a halt to caldera development. The caldera volume is commonly smaller than the volume of erupted magma, and this is a reflection of the mismatch between efficient magma extraction and surface caldera response. There is general recognition that many volcanic systems are underlain by a series of magma reservoirs stacked vertically in the crust and connected at times. There may thus be a balance between the relative roles of a shallow reservoir at 4-10 km depth and a second reservoir at deeper crustal levels which together may influence surface conditions including caldera subsidence. If the shallow chamber is small or largely crystallized, then the deeper reservoir may play a greater role in controlling the nature and size of the eruption. If the shallow chamber is large or largely liquid, then its influence will dominate. A fundamentally important aspect of this stacked magmatic system is that the shallow and deeper reservoirs are connected, allowing magma to be transferred from the deep to the shallow reservoir. The connection may be established, before, during, and/or after the eruption. Large explosive eruptions commonly appear to have this connection established prior to the eruption, allowing deep magma to (a) interact and mobilize shallow magma and (b) trigger the eruption. Magma erupted from the shallow reservoir unloads the system, providing a feedback for inflow of magma from below, perhaps at accelerating rates at later stages of the eruption and immediately afterward. Forecasting caldera formation during an eruption may be possible. Since surface caldera development is commonly a late-stage eruptive phenomenon which is preceded by subsurface faulting and subsidence, geophysical approaches (e.g., seismology, geodesy, gravity) may be used to identify subsurface processes such as faulting and development of voidspace which migrate upward in time.