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The physics of large eruptions

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Based on eruptive volumes, eruptions can be classified as follows: small if the volumes are from less than 0.001 km3 to 0.1 km3, moderate if the volumes are from 0.1 to 10 km3, and large if the volumes are from 10 km3 to 1000 km3 or larger. The largest known explosive and effusive eruptions have eruptive volumes of 4000-5000 km3. The physics of small to moderate eruptions is reasonably well understood. For a typical mafic magma chamber in a crust that behaves as elastic, about 0.1% of the magma leaves the chamber (erupted and injected as a dyke) during rupture and eruption. Similarly, for a typical felsic magma chamber, the eruptive/injected volume during rupture and eruption is about 4%. To provide small to moderate eruptions, chamber volumes of the order of several tens to several hundred cubic kilometres would be needed. Shallow crustal chambers of these sizes are common, and deep-crustal and upper-mantle reservoirs of thousands of cubic kilometres exist. Thus, elastic and poro-elastic chambers of typical volumes can account for small to moderate eruptive volumes. When the eruptions become large, with volumes of tens or hundreds of cubic kilometres or more, an ordinary poro-elastic mechanism can no longer explain the eruptive volumes. The required sizes of the magma chambers and reservoirs to explain such volumes are simply too large to be plausible. Here I propose that the mechanics of large eruptions is fundamentally different from that of small to moderate eruptions. More specifically, I suggest that all large eruptions derive their magmas from chambers and reservoirs whose total cavity-volumes are mechanically reduced very much during the eruption. There are two mechanisms by which chamber/reservoir cavity-volumes can be reduced rapidly so as to squeeze out much of, or all, their magmas. One is piston-like caldera collapse. The other is graben subsidence. During large slip on the ring-faults/graben-faults the associated chamber/reservoir shrinks in volume, thereby maintaining the excess magmatic pressure much longer than is possible in the ordinary poro-elastic mechanism. Here the physics of caldera subsidence and graben subsidence is regarded as basically the same. The geometric difference in the surface expression is simply a reflection of the horizontal cross-sectional shape of the underlying magma body. In this new mechanism, the large eruption is the consequence—not the cause—of the caldera/graben subsidence. Thus, once the conditions for large-scale subsidence of a caldera/graben during an unrest period are established, then the likelihood of large to very large eruptions can be assessed and used in reliable forecasting.

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