

Mathematical Modelling of Surtseyan Bombs: Fire, Earth, and Water

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Abstract

A Surtseyan bomb is a lump of very hot magma that trails steam behind it when erupted. These bombs are observed alongside cock's tails and cypress tree-like steam and magma emissions that are also features of eruptions where magma interacts with lots of water.

Surtseyan ejecta are formed in shallow sub-aqueous eruptions. They occur when a combination of liquid water and sediments penetrates into molten magma during an eruption, and is then ejected from the volcano as an inclusion inside a ball of magma. After ejection there is a large temperature gradient between magma and inclusion. As the temperature of the inclusion increases, the liquid water vaporises causing a pressure increase inside the ejected ball.

The volcanological question is whether the ball of magma ruptures. Simple lumped calculations indicate the steam pressures could far exceed the tensile strength of rock. However, there is evidence of intact ejecta so we know that rupture does not always occur. Hence a more careful modelling approach is needed to explain and inform observations.

We present partial differential equations that model transient changes in temperature and pressure in Surtseyan ejecta. These equations are reduced by ignoring small parameters, and then solved numerically and asymptotically to explore the parametric conditions for rupture of ejecta.