THEORETICAL MODELLING OF PLINIAN ERUPTION PLUMES ON EARTH AND VENUS.

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Modelling of Plinian eruption columns has improved our understanding of their dynamics, and the influence of parameters such as volatile content and vent radius on subsequent plume development. By adapting the model to take account of the environmental conditions likely to obtain on Venus, the behaviour of Venusian plumes can be investigated.

The mathematical model (1) uses four simultaneous differential equations, which are solved using a Runge-Kutta-4 numerical integration scheme. The equations are based on conservation of mass, momentum and energy, with an equation for the bulk density of the plume.

The results of the model show that the basic plume behaviour is similar for Earth and Venus, with the plume velocity, temperature, density and radius showing the same variations with height on both Earth and Venus.

By comparing the plume heights in a tropical atmosphere with those achieved in a temperate atmosphere, the effects of the atmospheric structure on plume behaviour can be investigated. The two atmospheres have different values of the atmospheric lapse rate and tropopause height, both of which affect the plume heights. A lower atmospheric lapse rate reduces the plume height; plumes entering the tropopause encounter a zero lapse rate, thus the tropopause height influences plume heights.

Tests were also carried out using different initial eruption temperatures, which influence the amount of thermal energy available to the plume. Plumes with lower initial eruption temperatures achieve lower heights, which reflects the reduction in the thermal energy available to the plume for sustaining convection.

On Venus, the high atmospheric pressure (9 Mpa in the lowlands, 5 Mpa in the highlands) inhibits the exsolution of volatiles from the magma and the subsequent expansion of the gas bubbles. This results in higher volatile contents being required to produce sufficient magma disruption for Plinian eruptions (2), and also leads to lower eruption velocities for a given volatile content (assuming H_2O as the volatile species) than would be the case for Earth. If the volatile species is assumed to be CO_2, then the eruption velocities are less than those for H_2O.

The high atmospheric density and pressure also mitigate against high convective plumes occurring; if convection does not occur, gas-jets of a few kilometres high feeding pyroclastic flows are predicted (3).

The results for Venus show that high convective plumes are most likely to occur if
1) the volatile is H_2O,
2) the volatile content is greater than 0.05 (by weight),
3) the eruption occurs at high elevations (where the atmospheric pressure is lower), and

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4) the eruption temperature is greater than 1000 K.

If the volatile content is CO_2, magma disruption is only expected to occur at higher altitudes (2), and higher eruption temperatures and volatile contents are required to produce high convecting plumes than would be the case for H_2O.

If the results from the Magellan mission show evidence of Plinian air-fall deposits, the global and altitude distribution of the associated vents should give some indications of the conditions under which convecting plumes could be produced. The theoretical study suggests that high altitude vents are most likely to produce high convective plumes, but assessments of the volatile content and eruption temperature will be difficult to make. If Plinian air-fall deposits are found associated with low-altitude vents, this would imply very high volatile contents or high eruption temperatures.

Work on modelling particle dispersal from such plumes is currently under way, and the geometry of air-fall deposits may help in finding the eruption plume characteristics (4, 5), although there may be insufficient data for the analysis.

References
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