Geophysical Research Abstracts
Vol. 12, EGU2010-8313, 2010
EGU General Assembly 2010
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Magma compaction, gas exsolution and decompression in volcanic conduits

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Gas content, exsolution and segregation from magma strongly influences the dynamics of a volcanic eruption. Recently, magma compaction has been shown to exert a control on gas content and segregation in viscous silicic magmas (Michaut et al, 2009). Dynamics of magma and gas mixtures in volcanic conduit are often studied using homogeneous models, where both phases move at the same velocity, or two-phase flow models, where both phases are at the same pressure, hence where no compaction occurs.
We extend the two-phase flow theory of Bercovici and Ricard (2003) to take into account gas exsolution from magma matrix as well as gas compressibility. Gas solubility is considered to be a function of gas pressure only. The gas is considered perfect and is in the form of bubbles; the drag between phases follows Stoke's law, assuming a constant number of bubbles. We identify two dimensionless numbers: the first one characterizes the viscous resistance to flow and compaction; the second one characterizes the drag between phases.
We compare the results of steady-state two-phase flow models with two limiting cases: homogeneous flow and single-pressure two-phase flow. Starting with negligible amount of gas in magma, gas exsolution and decompression occur over a characteristic distance that increases with the viscous resistance parameter. The compaction term is maximum at the beginning, and, as gas exsolves, it is rapidly expelled by compaction, resulting in a smaller increase in gas content with height in comparison with a single-pressure flow. The difference becomes negligible as viscosity and velocity decrease and initial gas pressure increases. As the amplitude of the inter-phase drag decreases, gas also expels more rapidly at first, but gas decompression and exsolution are more rapid and the characteristic distance over which they occur decreases.
At steady-state and for a given surface pressure, taking into account both compaction and inter-phase drag favors gas escape and leads to less gas content at the exit than in the homogeneous or single-pressure models, and thus requires a larger original volatile content for explosive eruptions.