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Volatile solubility laws in melts can tell us how unique the Earth is

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Volcanic degassing has a first order impact on the atmosphere chemistry and on the formation of surficial chemical environments favourable to life emergence. The Earth is unique in that it hosts life but volcanic activities existed and still exist on other terrestrial bodies. We propose here a brief review of the characteristics and major differences in volcanic degassing occurring on different planetary bodies. These characteristics are then interpreted in the light of volatile solubility laws in basalts for the chemical system C-H-S-O.
Global patterns on which we can confidently rely are (1) that reduced volatile species H_2, CH_4, and CO have negligible solubility in comparison to their oxidized counterparts H_2O and CO_2; (2) that in C-H-S-O systems, the solubility of all volatiles species decreases as pressure decreases ; (3) that CO_2 is the less soluble component followed by water and sulphur species. Such a CO_2-H_2O-SO_2 degassing sequence is often reported as indicative of variable (decreasing) pressure of degassing at active volcanoes. We exploit hereafter the basic conclusion that volcanic gas compositions is primarily controlled by pressure of degassing and that in contrast, the pre-eruptive volatile abundances play a secondary role.
Subaerial volcanic degassing on Venus occurred at the ambient atmospheric pressure, which is of the order of 100 bar. At such pressure, solubility laws in the C-H-S-O system predict that the emitted gas is water poor and dominated by CO_2: Water does not degas and remain in the lavas. On Earth, subaerial volcanic degassing occurring at 1 bar produces compositions dominated by water and with CO_2-SO_2 in equal concentration. If degassing occurs at lower pressure, such as on ancient Mars or on Jupiter's moon Io, sulphur becomes an increasingly abundant species and dominates at venting conditions lower than 0.01 bar. This simple analysis shows that volcanic degassing must occur at pressure similar to 1 bar in order to produces gases dominated by water with a C/S ratio similar to 1.
A specific application will be finally proposed for Io. Jupiter's moon shows gas plumes dominated by sulphur with variable SO_2/S_2 ratios though SO_2 remains the most important species. Inversion of such gas compositions can be performed to evaluate the volatile compositions of the basaltic source magma. It is concluded that volcanic degassing on Io, producing gaseous SO_2 from sulphide anions in the melt sources, is a process leading to irreversible oxygen extraction from the planetary interior with implications on redox evolution of small planetary bodies.