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# Volcanic chemical gas speciation and atmospheric redistribution on terrestrial planets

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The internal constitution of rocky exoplanets can be inferred only indirectly via their atmospheric composition. To address this issue with confidence requires the coupling of interior and atmospheric models to each other. In the past, various atmospheric redistribution models were developed to determine the composition of exoplanetary atmospheres by varying element abundance, temperature and pressure.

However, these models neglect that present-day atmospheres were formed via volcanic degassing and, consequently, element abundances are limited by thermodynamic processes accompanying magma ascent and volatile release. Here we combine volcanic outgassing with an atmospheric chemistry model to simulate the evolution of C-H-O-N atmospheres in thermal equilibrium below 650 K. These volatiles can be stored in significant amounts in basaltic magmas and are the most commonly degassed species. Sulfur molecules are not stable at low atmospheric temperatures and are therefore not included in our calculations.

For the present study, we built a basic model to calculate possible atmospheric compositions by varying oxygen fugacity, melt and surface temperature and volatile abundances. Furthermore, we consider the solubility of each phase, atmospheric processes such as water condensation, graphite precipitation, hydrogen escape and the effect an already existing atmosphere may have on further degassing. Our model suggests that the most common atmospheric type is composed of $CO_2$, $N_2$, $CH_4$, and (dependent on surface temperature) $H_2O$. Furthermore, we show that the evolving atmospheric pressure and composition are highly dependent on the oxygen fugacity of the melt because of its influence on gas speciation and solubility. Reduced conditions produce $H_2$, $NH_3$, $CH_4$ and $H_2O$ dominated atmospheres with extremely low atmospheric pressures. Oxidized conditions lead to atmospheres consisting of $H_2O$, $CO_2$, $N_2$ and small amount of $CH_4$ with high atmospheric pressures. $O_2$ is never produced since carbon or hydrogen are still available in sufficient amounts to form $H_2O$, CO or $CO_2$. Hence it is not possible to form abiotically $O_2$ dominated atmospheres unless $O_2$ degassing occurs in the case of super oxidized magmas with low carbon and hydrogen abundances. Low hydrogen abundances are found to produce another atmospheric type consisting of $CO_2$, CO, $CH_4$ and $N_2$.