Role of the Crust in the Evolution of the Martian Atmosphere. Kevin S. Hutchins and Bruce M. Jakosky, Laboratory for Atmospheric and Space Physics and the Department of Geological Sciences, University of Colorado, Boulder, CO 80309.

We have examined the plausibility of the Martian crust as a source of atmospheric volatiles, particularly \(^{36}\text{Ar}\), \(^{36}\text{Ar}\), and \(^{20}\text{Ne}\). Previously, we developed an atmospheric evolution model for Martian argon and neon which included fluxes of volatiles from the mantle via intrusive and extrusive volcanic outgassing and loss of volatiles to space by collisional sputtering from the exobase (Hutchins and Jakosky, 1996). Due to the importance of sputtering loss on the lighter noble gases (independent of the possibility of an early intrinsic magnetic field, Hutchins and Jakosky, 1997), we found that additional sources of \(^{40}\text{Ar}\), \(^{36}\text{Ar}\), and \(^{20}\text{Ne}\) would be required to match the present-day abundances measured in the Martian atmosphere. Our previous model results indicated that the additional sources must supply between 4 and 100 times the argon and 40 and 1800 times the neon outgassed by intrusive and extrusive volcanic activity.

Release and transport of volatiles from the crust via groundwater circulation represents a likely candidate for the required additional source. Volatiles trapped by incomplete magma degassing (particularly for intrusions) and volatiles produced radiogenically (\(^{40}\text{Ar}\)) are released from crustal minerals by diffusion and chemical alteration. Once released, the volatiles are available for transport to the surface and the atmosphere via groundwater circulation which can reasonably extend to depths of 10-15 km (Clifford, 1993).

Using our previous model of argon evolution (including \(^{40}\text{Ar}\), \(^{36}\text{Ar}\), and \(^{38}\text{Ar}\)) and a crustal concentration of potassium ranging from 350 ppm to 2500 ppm (the lower limit represents no preferential crustal partitioning of potassium during differentiation, while the upper limit is that inferred from a shergottite model of the crust), we calculated the crustal production of \(^{40}\text{Ar}\) directly from our model. Thus, the production and release of radiogenic argon from the crust is directly constrained by an independent assessment of the crustal concentration of potassium.

Based on preliminary model calculations, we find that between 5 and 25 km of crust must have released \(^{40}\text{Ar}\) to the atmosphere. This corresponds to approximately 5-70\% of the total crust depending on the estimate of crustal thickness, which is poorly constrained at present.

Having calculated the \(^{40}\text{Ar}\) supplied by crustal outgassing, we can apply the observed atmospheric \(^{40}\text{Ar}/^{36}\text{Ar}\) ratio as a constraint on crustal outgassing of \(^{36}\text{Ar}\). Using this constraint, we found that crustal concentrations of \(^{36}\text{Ar}\) ranging from \(\sim 6.0\times 10^{-9}\) cm\(^3\) STP/g to \(1.5\times 10^{-8}\) cm\(^3\) STP/g were necessary for the same volumes of crust. These concentrations are not inconsistent with the concentration of \(^{36}\text{Ar}\) measured in the Shergotty or Nakhla meteorites (Ott, 1988). Higher crustal concentrations of noble gases may be possible given the lack of volatile recycling via plate tectonic activity.

Crustal release of neon is not as rigorously constrained. In order to match the observed atmospheric abundance of neon given our previous sputtering model and the above model of crustal release, the same volume of crust must (a) have a \(^{20}\text{Ne}\) abundance of between \(\sim 2.5\times 10^{-9}\) cm\(^3\) STP/g and \(3.5\times 10^{-8}\) cm\(^3\) STP/g, which is not unreasonable with respect to the concentrations measured by Ott (1988), and (b) have been outgassed within the last 100 Myr in order to be consistent with the short residence time of neon in the crust and the atmosphere and the measurement of the atmospheric neon abundance.

In summary, sputtering has dramatically influenced the evolution of the Martian atmosphere. In light of this loss, sources in addition to intrusive and extrusive volcanic outgassing are required to satisfy the available constraints on outgassing such as the crustal potassium concentration and the observed \(^{40}\text{Ar}/^{36}\text{Ar}\) ratio, allows for more rigorous justification of these results (a substantial improvement over our previous efforts). Groundwater outgassing also may provide a viable source of additional neon, but is not as rigorously constrained. Groundwater cycling of volatiles may also have played a distinct role in the evolution of Martian climate as CO\(_2\) was sequestered (Griffith and Shock, 1995) and possibly, later released back to the atmosphere.