

would further desiccate on eruption and contact with the dry atmosphere. Also, the O isotopic composition of water released at high temperature from SNC meteorites suggests that some fraction of the water they contain is not magmatic, but is due to alteration by water already in the crust [6]. Thus bulk water contents are of little use in assessing how much water has actually been delivered to the surface. What is needed is an estimate of the water contents of SNC magmas prior to near-surface degassing and interaction with crustal water.

Many SNC meteorites contain crystals formed at depth and the cores of these crystals contain now-solidified pockets of trapped melt. Some melt inclusions contain daughter crystals of hydrous amphibole (kaersutite), a phase that does not appear in these meteorites outside the inclusions. Phase equilibria for kaersutite [7] indicate that it is only stable at pressures above 1.5 kbar, corresponding to depths on Mars of 11 km. This is below the self-compression depth for martian crust, and magma trapped at such depth is unlikely to have experienced vesiculation or interaction with crustal water. Kaersutite crystallizes only when the water contents of inclusion melts reach 4 wt% [7]. From the extent of inclusion solidification before the onset of kaersutite crystallization, we can estimate the amount of water in the magma at the time of trapping. The solidification histories for melt inclusions from SNC meteorites have been modeled using linear regression methods to solve a system of mass-balance equations [5,7]. The results for SNC melt inclusions typically indicate 50–75% crystallization before kaersutite forms, corresponding to initial water contents in these magmas of approximately 1.4 wt%.

If we assume that SNC magmas are representative of martian volcanism, we can combine this water content with visual estimates of the total volume of martian igneous materials [8] to obtain an outgassed water depth of approximately 200 m. This water estimate also rests on the assumption that intrusions in the subsurface effectively degassed, and may serve as a refined lower limit for martian water outgassed since 3.9 b.y. ago. Geological evidence for greater amounts of surface water [3,9] would then imply significant outgassing before formation of a stable crust or heterogeneous accretion of a veneer of cometary matter.

These data also have implications for the water content of the martian interior. The 36 ppm water for the mantle estimated from the geochemical model of [2] seems too low because it would imply an implausibly small degree of melting (0.2%, if water is perfectly incompatible and no subsequent fractionation of the magma occurred) to produce SNC magmas. For a more reasonable 10% melting, a magma with 1.4% water requires a source region containing 1400 ppm water. This value is too high because SNC meteorites clearly formed from fractionated magmas, but it does suggest that the martian mantle is significantly wetter than has been inferred from some past geochemical and geologic models [9], perhaps having a similar water content to the terrestrial mantle. This suggestion is not really surprising considering the enrichment of other volatiles in Mars [2], but it may require that water reacted incompletely with Fe during core formation. The conclusion that the martian mantle may have been quite wet (even as late as 1.3 b.y. ago, the age of SNC meteorites) is important in assessing its capacity to outgas significant amounts of water prior to 3.9 b.y. ago.

**References:** [1] Huguenin R. L. and Harris S. L. (1986) *LPI Tech. Rpt. 86-07*, 31–32. [2] Dreibus G. and Wänke H. (1987)

*Icarus*, 71, 225–240. [3] Fanale F. P. et al. (1992) *Mars*, 1135–1179. [4] McSween H. Y. (1985) *Rev. Geophys.*, 23, 391–416. [5] McSween H. Y. and Harvey R. P. (1993) *Science*, 259, 1890–1892. [6] Karlsson H. R. et al. (1992) *Science*, 255, 1409–1411. [7] Johnson M. C. et al. (1991) *GCA*, 55, 349–366. [8] Greeley R. and Schneid B. D. (1991) *Science*, 254, 996–998. [9] Carr M. H. and Wänke H. (1992) *Icarus*, 98, 61–71.

20-91 N94-21679610  
 THE YOUNG SUN AND PHOTOCHEMISTRY OF THE PRIMITIVE MARTIAN ATMOSPHERE. H. Nair, M. F. Gerstell, and Y. L. Yung, Division of Geological and Planetary Sciences 170-25, California Institute of Technology, Pasadena CA 91125, USA.

Many investigators of the early martian climate have suggested that a dense CO<sub>2</sub> atmosphere was present in order to warm the surface above the melting point of water [e.g., 1]. However, Kasting [2] recently pointed out that previous thermal models of the primitive martian atmosphere had not considered the condensation of CO<sub>2</sub>. When this effect was incorporated, Kasting found that a purely CO<sub>2</sub> greenhouse is an inadequate mechanism to warm the surface.

Observations of young stars, both premain sequence and early main sequence, indicate that their ultraviolet luminosities are much higher than the present ultraviolet output of the Sun. If such behavior is a normal phase of stellar evolution, we may expect that the Sun also had a substantially enhanced ultraviolet luminosity in its youth [3]. This has significant implications for the martian atmosphere as CO<sub>2</sub> is rapidly dissociated by ultraviolet photons shortward of 2000 Å.

Our photochemical model shows that under the influence of the early solar ultraviolet spectrum, an initial reservoir of CO<sub>2</sub> is decomposed to the extent that CO and O<sub>2</sub> become the major components of the atmosphere. Large ozone densities arise due to the increased O<sub>2</sub> abundance. Similar investigations for the early terrestrial atmosphere have also shown that CO, O<sub>2</sub>, and O<sub>3</sub> concentrations are markedly enhanced when the model atmosphere is subjected to more intense ultraviolet fluxes [4,5].

We will investigate the climatology of an atmosphere where CO<sub>2</sub> is a minor constituent but still the key radiative species. The thermal structure of the dust-free atmosphere is estimated by employing a simple radiative-convective model similar to that used by Gierasch and Goody [6]. Radiative heating rates are computed using the Caltech/JPL one-dimensional photochemical model. Thermal cooling rates for a martian atmosphere containing O<sub>2</sub>, O<sub>3</sub>, H<sub>2</sub>O, N<sub>2</sub>O, CO, and CO<sub>2</sub> are calculated using FASCODE [7] and k-distribution methods [8]. The effects due to pressure broadening of the infrared absorption lines of CO<sub>2</sub> by CO and O<sub>2</sub>, as well as the radiative effects of increased ozone densities in the atmosphere, will be examined.

**References:** [1] Pollack J. B. et al. (1987) *Icarus*, 71, 203–224. [2] Kasting J. F. (1991) *Icarus*, 94, 1–13. [3] Zahnle K. J. and Walker J. C. G. (1982) *Rev. Geophys. Space Phys.*, 20, 280–292. [4] Canuto V. M. et al. (1982) *Nature*, 296, 816–820. [5] Canuto V. M. et al. (1983) *Nature*, 305, 281–286. [6] Gierasch P. and Goody R. (1968) *Planet. Space Sci.*, 16, 615–646. [7] Clough S. A. et al. (1986) *Proc. Sixth Conf. on Atmospheric Radiation*, 141. Deepak, Williamsburg, Virginia. [8] Goody R. et al. (1989) *J. Quant. Spectrosc. Radiat. Trans.*, 43, 539–554.