ORIGIN OF WATER IN THE TERRESTRIAL PLANETS.

M. J. Drake, Lunar and Planetary Laboratory, University of Arizona, Tucson, Arizona 85721-0092, U.S.A.

Introduction: There is no consensus on the origin of water in the terrestrial planets. Earth demonstrably has water. Odyssey has shown vast water ice sheets buried under a thin layer of dust polewards of about 60° of latitude in both hemispheres of Mars [1]. The D/H ratio of Venus is about 100 times that of Earth's oceans [2], and is plausibly explained by loss of H_2O through UV photodissociation at the top of the Venus atmosphere. Mercury and the Moon appear to be bone dry, possibly due to volatile loss in giant impacts.

Sources of water: It has generally been thought that the accretion disk was too hot at 1 AU for hydrous minerals to be stable, although the thermal history of the inner disk is based on models, not observations. Comets had been a popular choice for the source of water, as they demonstrably contain water ice. However, the measured D/H ratios in Hale-Bopp, Hyakutake, and Halley are identical within error and, if these measurements are representative of bulk comets, they constrain the contribution of cometary water to less than 15%. The ratio of Ar/H_2O in comet Hale-Bopp and Ar/O in comet LINEAR imply still lower limits on cometary water if the spectral measurements are reliable. Asteroids are dynamically plausible sources of water, but Os isotopes in Earth's mantle rule out known meteorite types as the source of Earth's water. See Drake and Righter [3] for a more thorough discussion. Inward migration of phyllosilicates has also been proposed [4].

Indigenous source revisited: Let us accept for now that the inner accretion disk was too hot for hydrous minerals to be stable and consider an alternative source of H_2O. The dust in the disk was bathed for some time in a sea of H and O, and some unknown amount of H_2O must have formed, the limit being the equilibrium thermodynamic quantity. It is possible that water from the gas phase could be adsorbed onto grains in the inner solar system and subsequently accreted into the terrestrial planets. Stimpfl *et al.* [5] discuss the plausibility of this mechanism. Ab initio calculations at 0 °K in which the Gibbs free energy of Si – O clusters is minimized and then a H_2O molecule is introduced indicate that strong chemical bonds can be formed between the water molecule and the Si – O cluster [6], making retention of H_2O during the later violent stages of accretion more likely.

Conclusions: These considerations suggest that H_2O may have been obtained by the terrestrial planets directly from the gas phase in the accretion disk, and that Mars, Earth, and Venus all had similar initial water budgets. Accretion of water in the presence of metal will lead to extraction of H into planetary cores and progressive oxidation of planetary mantles [7, 8]. The "feeding zones" of the terrestrial planets would be relatively narrow over most of planetary accretion, consistent with differences in O-isotopes, Cr-isotopes, and major element compositions of Earth and Mars. The "late veneer" could plausibly be of asteroidal origin, consistent with dynamical calculations [9].

References: [1] Boynton W.V. *et al.* (2002) *Science* **297**, 81-85. [2] Donahue T.M. and Pollack J.B. 1983) In Venus, U of A Press, 1003-1036. [3] Drake M.J. and Righter K. (2002) *Nature* **416**, 39-44. [4] Ciesla F.J. *et al.* (2004) LPSC XXXV, abstract 1219. [5] Stimpfl M. *et al.* (2004) *MAPS* **39** (in press). [6] Gibbs G. (2004), personal communication. [7] Drake M.J. (2003) *GCA* **67**, A83. [8] Righter K. (2004) LPSC XXXV, abstract 1674. [9] Morbidelli A. *et al.* (2000) *MAPS* **35**, 1309-1320.