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RELEASE OF MAGMATIC WATER ON MARS: ESTIMATED TIMING AND VOLUMES; *R. Greeley, Department of Geology and Center for Meteorite Studies, Arizona State University, Tempe, AZ 85287*

The amount of water and other volatiles on and near the surface of Mars and their effects on the climate history have been the focus of the MECA (Mars: Evolution of its Climate and Atmosphere) Project, and the subject of considerable debate and interest (1). As reviewed by Wanke and Dreibus (2) and others, estimates of the total volume of water on Mars have been based on modelling of the distribution of elements in the inner solar system, considerations of the SNC meteorites, and analysis of results from the Viking landers. Estimates of the total amount of water released on Mars based on these various approaches range from <1 m to >50 m for a water layer covering the planet. However, few of these estimates consider the rate or timing of volatile release to the surface of Mars from the interior. The results presented here are inferred from the amounts of volatiles released in association with volcanic eruptions that have occurred during the evolution of Mars, as derived from geological mapping.

Table 1 shows the amount of water released via volcanism during each major interval of the martian geologic time-scale. It is based on: (a) mapping of volcanic units on Mars and estimates of their volumes, (b) crater-count ages of the units, and (c) estimates of the volatile-release associated with the eruption and emplacement of the volcanic units. Mapping of volcanic units was derived from manuscript versions of recently completed 1:15 M-scale geological maps of Mars (3,4,5), supplemented by reviews of martian volcanism (6,7,8). Although a wide variety of volcanic units occur on Mars, for simplicity, a two-fold classification was used here: (a) materials forming central volcanoes (which include all units derived from central vents, such as shield volcanoes) and (b) plains-forming lavas (includes both *flood lavas* presumably fed from fissures, and complex *plains lavas*, involving thin, multiple flows). Volumes of the volcanic materials are difficult to obtain; however, estimates of flow thicknesses, derived by DeHon (9,10), were used for some plains, such as Herperia Planum. In other volcanic plains areas, an average thickness of 1 km was used, based on the thickness of flood lavas in the Columbia River Plateau, which can be considered a terrestrial analog for martian flood-lava provinces. Volumes of the central volcanoes were estimated from their topography. Geological ages for the volcanic units are taken from the mapping (3,4,5), supplemented by data from other crater counts (11). In addition, the paleogeographic sequence for the Tharsis area derived by Scott and Tanaka (12) enabled estimates to be made for the volumes and timing of volcanic units for this part of Mars.

Although magmatic water is commonly released to the atmosphere during volcanic eruptions, the amounts as a function of composition, style of eruption, etc. are poorly known. Most volcanic units on Mars appear to be mafic (6). Using a value of 1.0 percent by weight of water associated with terrestrial basaltic eruptions as a guide (J. Holloway, personal communication) an approximation can be made for the volumes of water released in association with the volcanic units identified from the geological mapping. The total volume released is >10 m, consistent with previous estimates. Although the central volcanoes, such as Olympus Mons, tend to dominate general perceptions of martian volcanism, by far the plains units contain the greatest volume of volcanic materials and made the greatest contribution to the water budget.

The development of the valley networks occurred early in martian history, during the Noachian Period; yet the amount of water released in association with volcanism is relatively small.

This suggests either (a) other sources of water early in martian history (such as cometary contributions), (b) unidentified volcanic units of an early age, or (c) that the valley networks are erroneously dated. Of these, (b) seems most likely. Most of the ancient martian crust has been degraded or buried and, thus, its origin cannot be ascertained. However, by analogy with the Moon, the martian crust probably developed by magmatic differentiation and extrusion of flood lavas. Thus, although few traces of this earliest volcanism are visible in present data, substantial water may have been released early in martian history. The greatest volumes of volcanic materials--and by inference the greatest volumes of water--were emplaced in Mars "middle-life" and coincide with the development of the large out-flow channels. Photogeologic evidence shows that the formation of outflow channels was episodic and extended over a long interval of martian history, a reflection of the availability of large volumes of water at or near the surface.

It is noted that the volumes of water inferred in this study involve only those derived from volcanism as interpreted from surface features. The greatest uncertainties involve the thicknesses of units and the amounts of water associated with different types of volcanic units. Future work will address some of these uncertainties through use of better geochemical models for Mars and additional analysis of high resolution Viking Orbiter images for volcanic units.

TABLE 1. Inferred water released in association with volcanic units through time on Mars. Values given are for equivalent thickness of water layer in meters covering entire surface of planet.

	GEOLOGIC PERIOD	PLAINS	CONSTRUCTS
Young	Late Amazonian	0.28 m	0.53 m
	Middle Amazonian	0.94	0.21
	Early Amazonian	2.64	0.34
	Late Hesperian	1.22	0.05
	Middle Hesperian	2.68	0.17
	Early Hesperian	0.84	0.17
Old	Noachin	0.26	0.00
	Totals	8.58 m	1.47 m

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