JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 87, NO. B12, PAGES 9890-9904, NOVEMBER 30, 1982

Explosive Volcanism on Hecates Tholus, Mars: Investigation of Eruption Conditions

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Evidence is presented supporting the identification of a discrete, well-preserved air fall deposit generated by explosive volcanism on Mars. The deposit is located immediately to the west of the summit caldera of Hecates Tholus (32°N, 209°W), the northernmost of the three volcanic constructs in the Elysium Planitia region. The absence of superposed impact craters larger than the resolution limit of the Viking images (40 m per pixel) indicates a very young age for this eruption, which evidently postdates even the most recent collapse episode of the Olympus Mons caldera (~300 m.y. B.P.; Neukum and Hiller (1981)). From the distribution of craters smaller than 2 km in diameter, it appears that the air fall material mantles an area about 50 × 75 km in extent to an estimated thickness of about 100 m. By adapting numerical models for terrestrial volcanic eruptions to the Martian environment, these dimensions imply an eruption cloud height of about 70 km. In order to attain such an altitude, the mass eruption rate must have been $\sim 10^7$ kg/s and the volatile content either ~1 wt % for H_2O or ~2 wt % for CO_2. Although it is not possible to distinguish between silicic and basaltic volcanism on Hecates, were the volatile species CO_2, the depth of most recent storage prior to eruption of the magma would have to be 50–100 km (due to the solubility of CO_2 in the melt). If H_2O were the driving volatile, a minimum depth of storage would be 0.2–4 km, thereby permitting the possibility of ground water assimilation by the magma.

INTRODUCTION

The possibility that Mars displays a diversity of volcanic landforms as a consequence of differences in magma chemistry, volatile content, and styles of activity has been a recurrent theme in Martian volcanology since the acquisition of the first detailed Mariner 9 images. In general, the large Tharsis volcanoes have received the most attention, due primarily to their great size and similarity (hence interpretable morphology) to terrestrial basaltic shield volcanoes [e.g., *Greeley*, 1973; *Carr and Greeley*, 1980]. Recent investigations of Martian surface features have, however, speculated on the existence of rhyolitic lava flows [*Fink*, 1980] and silicic domes [*Plescia*, 1981]. Explosive volcanic eruptions have also been postulated for Mars, particularly in association with Olympus Mons and the Elysium Planitia volcanoes. Deposits within Amazonis have been described as ignimbrites [*Scott and Tanaka*, 1980], while other forms of pyroclastic flow are thought to be found within the Olympus Mons aureole materials [*Morris*, 1980]. Other surface features have also been interpreted as explosively generated volcanic ash deposits [*Ward*, 1979], ash flows, and welded tuffs [*Peterson*, 1981] or the products of volcanic density currents [*Reimers and Komar*, 1979]. These analyses were, however, based on photogeological data and did not explore the styles of volcanism and magma chemistries that such interpretations would imply. *Malin* [1977] and *Greeley and Spudis* [1981] have described the petrological implications that explosive volcanism would have for Mars; they have argued that, by analogy with terrestrial volcanoes, such activity would suggest the existence of Martian silicic magmas (although *Francis and Wood* [1981] warn that only general inferences about magma chemistry can be made from such a comparison). All of the above mentioned candidate examples of explosive volcanism are, however, relatively old, with their source regions and modes of emplacement unidentified or poorly constrained.

We have reexamined the medium and high-resolution Viking images of Amazonian and Hesperian age volcanic centers on Mars [*Scott and Carr*, 1978] and believe that an excellent example of well-preserved explosive activity does indeed exist close to the summit of Hecates Tholus, the northernmost of the three large Elysium Planitia constructs. A mantled region to the west of the summit caldera appears to be an example of a geologically very recent plinian air fall ash deposit. We present here our morphological evidence for describing this as explosively generated material and also employ numerical models of magma ascent and eruption in the Martian environment [*Wilson and Head*, 1981*a*] to estimate the physical characteristics (eruption cloud height, magma discharge rate, magma volatile content, duration of activity, and vent size) for this event. We also discuss the implications of this eruptive style for the composition of the erupted magma.

MORPHOLOGY OF HECATES THOLUS

Regional Setting

The three Elysium volcanoes (Hecates Tholus, Elysium Mons, and Albor Tholus) surmount the broad Elysium Planitia Rise, which measures approximately 1700 × 2400 km (Figure 1). Hecates Tholus is the northernmost of these constructs and is elliptical in plan with axis lengths 160 × 175 km. The volcano is centered at 32°N, 209°W, and Mariner 9 UVS altimetry estimates [*Hord et al.*, 1974] indicate that the volcano rises about 6 km above the surrounding plain. Both morphometric [*Pike*, 1978] and morphological [*Greeley and Spudis*, 1981] data indicate that Hecates resembles a low shield, which has prompted its comparison to the Tharsis

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Paper number 2B0920.
0148-0227/82/002B-0920$05.00