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THE INFLUENCE OF OCEANS ON MARTIAN VOLCANISM Peter Mouginis-Mark,
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INTRODUCTION: Geomorphological evidence for episodic oceans on Mars has recently been identified (1, 2). This idea of large bodies of water on Mars is innovative and controversial compared to the more generally accepted view of a "dry Mars", but also enables some of the more enigmatic volcanic landforms to be reinterpreted in a self-consistent model. This hypothesis can be used to develop new models for the mode of formation of several volcanic landforms in the W. Tharsis and S.E. Elysium Planitia regions of Mars (Fig. 1).

BASAL ESCARPMENTS: The Olympus Mons escarpment and aureole materials are enigmatic and highly unusual Martian features (3, 4). Early interpretations of the 7 km high escarpment (5) were that it was a wind-eroded cliff (6) or the remnants of a basal layer of heavily cratered materials (7). More recently, a tectonic origin has been proposed (8). However, Olympus Mons is not the only Martian volcano with a basal escarpment; Apollinaris Patera also has such a feature that varies in height from 0.5 - 1.5 km (9). Together with Hecates Tholus (10), these two volcanoes have the lowest base elevations (<2 km above mean Mars datum for each volcano) of any Martian volcano (11). In addition, all three volcanoes are adjacent to the inferred shoreline of the hypothesized Martian seas (2). These relationships may provide a method for eroding the flanks of the volcano, implying that the basal escarpments could be wave-cut cliffs formed in relatively unconsolidated ash deposits.

OLYMPUS MONS AUREOLE DEPOSITS: Considerable debate has also focused on the mode of formation of the Olympus Mons aureole deposits (Fig. 1). A central issue has been the very long run-out distances of the lobes, which evidently originated as slides off of the main edifice of Olympus Mons. Ideas for the formation of the aureole include gravity spreading (12, 13), gravity thrusts and landslides (14 - 16) and ash flows (17). Each mechanism required low shear strength of the materials in order to facilitate sliding, and no equivalent long run-out rock slide has been identified on Earth (18). Surprisingly, one of the closest morphologic examples (13) is that of submarine landslides which, at least in the case of Hawaiian examples (19), commonly achieved large run-out distances compared to their fall height. In the case of the Olympus Mons aureole materials, all of the deposits occur at low elevations (<1 km above Mars datum; ref. 11) and extend in the down-slope direction from the Olympus Mons edifice (16). In the model for the distribution of shallow seas on Mars (2), the entire N.W. side of Olympus Mons would have been submerged, facilitating the formation of submarine landslides. The Olympus Mons aureole materials may therefore be turbidite deposits generated by the submarine collapse of the submerged basal materials of Olympus Mons.

THE AMAZONIS DEPOSITS: The final enigmatic feature that lies on the "southern shore" of the hypothesized Martian sea is the series of smooth, wind-eroded deposits in Amazonis Planitia. Such materials have been described as ignimbrite sheets (20) and paleo-pole deposits (21, 22), but each idea has been vigorously refuted (23, 24). If large bodies of standing water were to have existed on Mars at the times that Olympus Mons and Apollinaris Patera erupted, it is argued here that eruptions similar to phreatomagmatic activity on Earth would have taken place, with the resultant generation of considerable amounts of fine volcanic ash (as has been documented for terrestrial ignimbrites entering the sea; ref. 25). Were this ash to have approximately the same density as ash on Earth, it seems possible that this material could have remained afloat for many months (26). Although the wind and wave circulation patterns at that time on Mars can only be speculated, it may have been possible for wind or wave action to have concentrated this Martian pumice in a few localities along an ancient shoreline. If this were the case, the distribution of the Amazonis materials is consistent with the inferred shoreline at an elevation of 1 - 2 km above mean Mars datum (2, 11).

CONCLUSIONS: Several aspects of volcano morphology and related deposits appear to be consistent with the hypothesis that oceans once existed in the northern plains of Mars. The basal escarpments around Olympus Mons and Apollinaris Patera may have formed as wave-cut cliffs, the Olympus Mons aureole materials may have been submarine landslides, and the enigmatic Amazonis deposits could be pumice layers that accumulated along the shore of ancient seas. Such ideas seem outlandish, but represent the first consistent explanation for these features and the occurrence of explosive (phreatomagmatic) volcanism not only at Apollinaris Patera, but also during the early stages of growth of other Martian volcanoes that are adjacent to the inferred paleo-shoreline. Hecates Tholus and Alba Patera both show morphologic evidence for explosive eruptions (11, 27), and lie within the area believed to have been periodically flooded (2). With the successful launch of the Mars Observer spacecraft and the ability to image landforms at the meter-scale (28), it may be possible to identify morphologic features that support or refute a model. Observations that would support this model include the identification of desiccation cracks and linear shoreline features on the Amazonis deposits. In order to explain the occurrence of the escarpments, the basal layers of Olympus Mons and Apollinaris Patera must be easy to erode, so that the identification of lava flows in the escarpment cliffs of either volcano would argue against the proposed wave erosion model.

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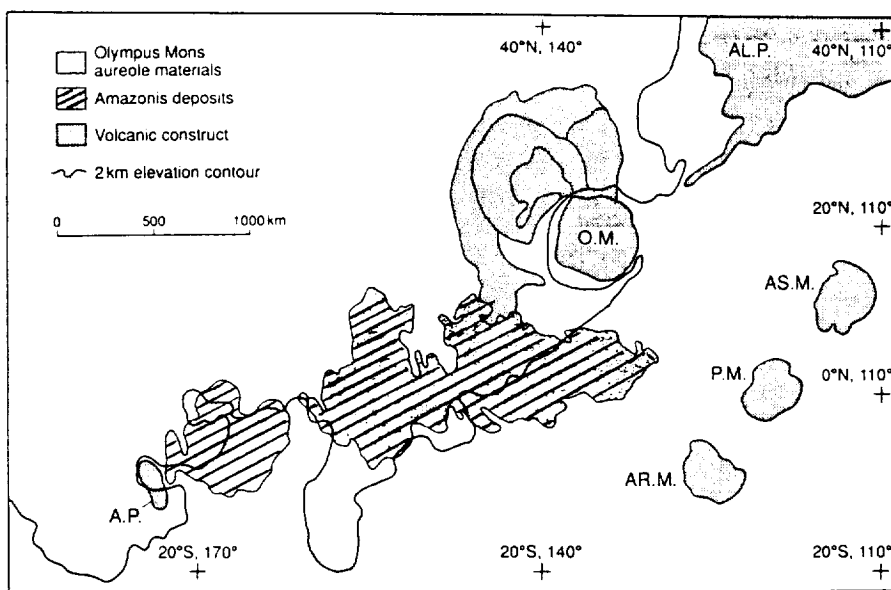


Fig. 1: Distribution of the Olympus Mons aureole materials, the Amazonis deposits, and the major volcanic constructs in Tharsis and Amazonia. Olympus Mons "O.M.", Arsia Mons "AR.M.", Pavonis Mons "P.M.", Ascræus Mons "AS.M.", Apollinaris Patera "A. P." and the recent lava flows from Alba Patera "AL. P." The 2 km contour, thought to be the edge of the transient ocean (2), is also shown.