A VOLCANIC ORIGIN FOR THE OUTFLOW CHANNELS OF MARS: KEY EVIDENCE AND MAJOR IMPLICATIONS. D. W. Leverington, Department of Geosciences, Texas Tech University, Lubbock, TX, 79409.

Introduction: Among the most extraordinary landforms on Mars are large "outflow channels" formed by voluminous fluid flows from the subsurface. Over the past three decades, aqueous interpretations involving catastrophic floods have remained widely favored by the research community [1-8], with flood sources most commonly surmised to have been large aquifers. Modern hypotheses of aqueous channel development predominantly feature incision by liquid water, though the possibility of associated erosional or depositional contributions by mudflows, debris flows, or glaciers is also incorporated into many models [9,10]. However, despite the existence of a general consensus regarding some of the most basic aspects of outflow channel origins, numerous problems remain associated with aqueous interpretations, and available data instead support alterative volcanic origins.

Weaknesses of Aqueous Hypotheses: Among the most problematic shortcomings of aqueous models of outflow channel development are the following: **1)** processes hypothesized to have triggered sudden development of aqueous floods are not consistent with realistic expectations for megaregolith permeabilities (e.g., the permeabilities required to support estimated discharge rates should approach values that are ~7 orders of magnitude larger than are typical at the regional scale for terrestrial aquifers [8,11]); **2)** although hypothesized sediment concentrations approaching 40% are needed in order to keep proposed near-surface water abundances within acceptable ranges, they are up to several orders of magnitude greater than can be realistically justified [12]; **3)** the location of channel heads far above terminal plains is not consistent with expected variations in the hydraulic head of large well-connected and highly-permeable aquifers [3,13]; **4)** the near-surface water abundances required of aqueous interpretations [e.g., 14] are many times more voluminous than most corresponding estimates derived from the compositions of SNC meteorites and the modern Martian atmosphere [15,16]; **5)** the widespread preservation of minerals that are highly susceptible to aqueous alteration [17-22] is not supportive of the long-term existence of water-saturated cryospheric seals and voluminous underlying aquifers; **6)** the absence of clear examples of fluvial or diluvial deposits along the outflow channels and at terminal basins [4,23-27] is inconsistent with aqueous hypotheses of channel development, particularly in light of the extraordinarily high sediment loads required of these hypotheses; and **7)** there are no known solar system analogs for catastrophic development of large channel systems by outbursts from aquifers.

The Volcanic Origin of Martian Outflow Channels: The volcanic hypothesis for development of the outflow channels of Mars represents the simplest and most realistic means by which these systems can be understood [26,28-31]. Specifically: **1)** clear evidence exists for the eruption of volcanic flows at the heads of the Martian outflow channels [10,26,32]; **2)** the Martian outflow channels show abundant evidence for having conveyed large volumes of magma from channel heads to terminal basins [26,29,32]; **3)** the terminal basins of Martian outflow systems, extensively imaged from orbit and visited by three landers, are mantled by ridged plains with characteristics comparable to those of the lunar maria; **4)** there is excellent correspondence between the characteristics of the Martian outflow channels and those of volcanic analogs of the Moon and Venus [26,28,29]; **5)** the capacity of magma for incision of channels is in accord with the existence of lunar and Venusian analogs, and with the low lava viscosities independently inferred for Mars basalts on the basis of geochemical and geomorphological considerations [32-34]; **6)** the capacity of igneous plumbing systems for surface delivery of large volumes of mafic lava at high rates of flow is already recognized for Venus and the Moon [35-37]; **7)** volcanic development of the Martian outflow channels is compatible with available geochemical and mineralogical data for Mars, and does not require the occurrence of special climatic conditions during the Hesperian or Amazonian; and **8)** the volcanic hypothesis fits within a wider geological framework that economically accounts for the existence and nature of outflow systems located on several bodies of the inner solar system.

Implications of Volcanic Origins: The outflow channels of Mars are presently treated as features distinct from volcanic channels of the Earth, Moon, and Venus, but the volcanic hypothesis asserts that all of these systems are products of the same processes and are, at their most basic level, variations within the same family of landform. A volcanic origin for the outflow channels of Mars further highlights the capacity of ancient igneous systems for voluminous effusion and for significant erosion, and suggests a unification in major effusive volcanic processes and landforms across the inner solar system.

A volcanic origin for the Martian outflow channels implies that associated source features are the surface expressions of magmatic systems rather than the locations of past aqueous outbursts. As igneous features, the outflow channels join the large Martian shields as among the most prominent volcanic landforms in the solar system. The northern lowlands of Mars largely consist of Noachian units mantled by extensive volcanic plains predominantly of Hesperian age [38,39]. A volcanic origin for the Martian outflow channels would imply that these plains are, as recognized for the lunar maria and Venusian lowlands, partly composed of volcanic units sourced from outflow systems.

Volcanic channel interpretations do not rely upon ancient swings in Martian climatic conditions or atmospheric properties, and are therefore consistent with a wide range of possible climatic histories, including the long-term cold and dry conditions implied by global surface mineralogy. Volcanic interpretations undermine hypotheses for the existence of large lakes or oceans during the Hesperian and Amazonian.

Development of life on Mars would have likely required the past existence of environments within which liquid water was stable over an extended period of time [40]. Among the ancient Martian environments previously identified as potentially supportive of past biological activity are the outflow channels themselves and water bodies at system heads and mouths. A volcanic origin for the outflow channels would correspondingly narrow the possible range of environments once supportive of Hesperian or Amazonian life, and could reduce the broader likelihood of past life on Mars by diminishing geomorphological justifications for the existence of unexpectedly voluminous but hidden near-surface water reservoirs.

Outstanding Questions: A volcanic origin for the largest channels in the solar system raises questions regarding the basic nature of involved igneous processes [26,32]. What flow volumes and rates of effusion were involved in the formation of specific Martian systems, and what ranges of physical properties (temperatures of eruption, lava chemistries, lava yield strengths, levels of turbulence) were once associated with these flows? How would the properties of Martian flows have compared with those of flows associated with lunar and Venusian outflow systems? To what relative extents were thermal erosion (involving the melting of substrates by thermal energy) and mechanical erosion (involving the physical removal of substrates by kinetic energy) involved in channel incision? Though erosive processes seem likely to have dominated in the formation of major channel systems, what roles might constructive volcanic processes have also played in system development? Still more fundamental questions arise: what kinds of intrusive igneous bodies would have been necessary to supply inferred flow volumes at required rates of effusion? On the Moon, rapid eruption of large volumes of low-viscosity basalt should have been possible from deep intrusions associated with magma conduits only slightly larger than those common today on the Earth [35-37]. Deep and voluminous source magma chambers have been surmised for the outflow channels of Mars [32,33], but many uncertainties remain.

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