EVALUATION OF CANDIDATE CRATER-LAKE SITES ON MARS. D. W. Leverington[1], [1]Center for Earth and Planetary Studies, Smithsonian Institution, Washington DC, 20560-0315, leveringtond@si.edu.

Introduction: The hypothesis that inlet and outlet channels to Martian impact craters were formed as fluvial systems to lacustrine environments [e.g., 1-3] is based on the interpretation that these channels were formed through aqueous processes. Several viable aqueous mechanisms by which channel and valley features on Mars may have formed have been proposed, ranging from surface runoff under relatively warm and wet conditions to sapping processes under cold and dry conditions [e.g., 1,4-9]. These mechanisms have the potential to account for the nature of a wide spectrum of channel types on Mars, but uncertainties remain regarding even the most basic Martian channel-formation processes, and no mechanism or set of mechanisms has yet emerged as a clear means by which channels and valley systems can be confidently said to have formed.

The characteristics of inlet and outlet channels of candidate crater-lake sites are not incompatible with formation by aqueous processes, but they nevertheless do not strongly imply formation as fluvial systems associated with lacustrine environments. For example, inlet or outlet channels that are or were once roofed by rock (e.g., Viking 379S45) are difficult to classify as features formed by the flow of water without appeals to relatively complex karst-like processes. Also, the warm and wet conditions that could have promoted precipitation and widespread surface runoff to large liquid water bodies arguably should have formed large and high-order fluvial networks, rather than the simple and low-order systems that characterize most candidate crater-lake sites [see also, e.g., 7]. A sapping origin is seemingly consistent with the morphologies of some Martian channels and valley systems [e.g., 4,6-8], but such an origin for the inlet and outlet channels of candidate crater lakes would imply that networks of sapping channels conveyed flow over combined distances of thousands of kilometers to and from overflowing crater lakes. Such an implication is not unfeasible, but it is inconsistent with present surface conditions on Mars, and it is not obvious that past environmental conditions would have promoted formation of such sapping networks. Massive past variations in Martian atmospheric and surface properties may be invoked to support this or other aqueous hypotheses for channel formation, but only at some cost in terms of complexity.

The characteristics of interior fill materials of proposed lake sites are not strongly suggestive of lacustrine deposits. The peripheral scarps and pronounced lobate nature of the margins of many interior fill deposits are suggestive of flow and subsidence of materials [10], rather than deposition of sediments in bodies of water. Interior terraces of impact craters are in many cases much larger than would be expected of wave-cut terraces [10], and the open-water conditions required to form them are incompatible with present surface conditions on Mars.

Igneous Origins For Crater-Lake Features?: Volcanic mechanisms for formation of 'crater lake' features and several classes of Martian channels have been proposed [10,11; see also 12,13], and can potentially account for the existence and nature of such features more simply than aqueous processes.

1) Channels. The morphological characteristics of many inlet and outlet channels to candidate crater-lake sites are similar to those of certain lunar and venusian channels, features interpreted as having formed by the flow of lava [e.g., 14-17]. Lunar and venusian sinuous rilles commonly have simple channel forms that follow topographic slopes, have sharp rims, and have widths of several kilometers. These features are also characterized by a wide range of sinuousities, and have lengths that can reach or exceed hundreds of kilometers. Numerous lunar and venusian volcanic channels have features usually considered to be characteristic of fluvial systems, such as levees, meander cutoffs, channel terraces, dendritic or anastamosing reaches, and streamlined islands [e.g., 11,15-18]. It is not uncommon for volcanic rilles to be discontinuously expressed at the surface as a result of incomplete collapse of channel roofs [e.g., 18].

The morphological similarities between lunar and venusian channels and the channels associated with many Martian candidate crater lakes are consistent with common volcanic origins. A constructive origin is possible for some Martian channels directly associated with adjacent volcanic flows, and such an origin would imply that these channels are vestiges of lava conduits that were responsible for emplacement of those flows. Those cases in which channels cross topographic barriers and deposits of differing composition or age suggest that thermal and mechanical processes of erosion by flowing lava may have operated during channel formation. The capacity of the flow of lava for incision and erosion is implied by volcanic channels on both the Moon and Venus [e.g., 10,11,15,16,19,20].

2) Interior Deposits. The characteristics of fill materials of many candidate crater lakes are suggestive of layered accumulations of volcanic materials. At least 20% of the craters of [3] have deposits with wrinkle ridges. Wrinkle ridges are believed to form through horizontal shortening of near-surface layered deposits [e.g., 21,22], and although the occurrence of wrinkle ridges on the terrestrial planets is not in principle restricted to volcanic materials [22], all clear examples of these features are found in materials known or interpreted to be layered volcanic flows [21]. The interior deposits of many sites of [3] gently onlap confining crater basins, but at least 30% of the sites have interior deposits with lobate margins defined by outward-facing scarps that are as great as tens of meters in height. The characteristics of these deposits are in many cases comparable to volcanic flows of the Martian highlands and lowlands, as well as prominent lunar volcanic flows.

Deposits at the mouths of inlet channels, interpreted by some as deltas formed in ancient lacustrine environments [e.g., 2], may be more simply explained as mass wasting or volcanic deposits. For example, deposits at the mouths of Martian and venusian volcanic channels are possible analogs for such features (e.g., Themis V01002003; see also [15]). The interior terraces of some crater-lake sites can be accounted for most simply as aeolian or other accumulations of materials unrelated to the formation of inlet and outlet channels, and some terraces may be the marginal deposits of former lava bodies [10].

3) Geological Contexts and Volcanic Sources. On the Moon, there are numerous examples of impact craters flooded by lava flows from sources both interior and exterior to the craters. This volcanic flooding resulted in some cases in the isolated accumulation of flows in the interiors of individual craters, and resulted in other cases in the flooding and submersion of large regions [e.g., 14,23-25]. On Mars, similar volcanic processes may have been responsible for formation of many of the channels and deposits previously interpreted as having fluvial and lacustrine origins. There is a direct association on Mars between candidate crater-lake sites and ridged plains that mark both source regions and basins of accumulation of massive effusive volcanic events. Some ridged plains are clearly related to major volcanic rises (e.g., Tyrrhena Patera), while others are associated with more local features such as domes (Viking 430S23) and pits (Themis V06574002). However, many of the ridged plains, as with counterparts on the Moon, Venus, and elsewhere on Mars [e.g., 14,24-26], lack obvious source features.

Discussion: Large ridged plains are widespread in the Martian highlands and represent evidence of massive past effusive volcanic events. Many of these volcanic fills appear likely to have overflowed their host basins, suggesting that the channels that link these basins may have been formed by the flow of lava; such an interpretation is consistent with volcanic interpretations of candidate crater-lake sites, most of which are directly associated with these inter-basin channels.

Aqueous models for formation of channels and other features of candidate crater-lake sites are not prohibited by the characteristics of these features. However, issues related to the form and geological contexts of the features, in combination with the past atmospheric and surficial conditions required to support formation of aqueous drainage networks and large surface water bodies, render such models more complex than the volcanic model. The igneous hypothesis for formation of channels and other 'crater lake' landforms involves processes that should be expected to have operated during large effusive volcanic events, and that can operate under a wide range of Martian environmental conditions, including those of the present. While numerous uncertainties remain, the characteristics of many candidate crater-lake sites seem to be most simply attributable to the effects of impact and volcanic mechanisms, overprinted by aeolian and mass-wasting processes.

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