MORPHOLOGY OF THE MARTE VALLES CHANNEL SYSTEM, MARS

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INTRODUCTION

We are interested in the origins and evolution of the fluvial channels of Marte Valles, located along the southeastern edge of Orcus Patera in the Elysium region of Mars (Fig. 1). Although ancient highland fluvial networks and the dramatic outflow channels such as Kasei Valles on the dichotomy boundary have been intensively studied (e.g., Baker, 1982; Komatsu and Baker, 1997), relatively little effort has been devoted to studying some of the low-relief drainage systems in the northern lowlands. The high-resolution topography data from the Mars Orbiter Laser Altimeter (MOLA) (Zuber et al., 1992; Smith et al., 1998), flown on the Mars Global Surveyor (MGS) spacecraft, allow careful study of lowland channels that were difficult or impossible to distinguish with topography mapped by the USGS using Viking images.

The Marte Valles channel system looks similar in shape if not in scale to the Martian outflow channels of Kasei Valles, which are hypothesized to be the result of volcanically induced catastrophic flooding. Baker and Milton (1974) propose the Channeled Scabland of Washington, site of the glacial Lake Missoula outburst floods, as a terrestrial analogue for the Martian outflow channels. A more recent study of Kasei Valles with MOLA data, however, suggests evidence of repeated flooding over a longer period of time (Williams et al., 2000). Subsequent research has suggested several possible source mechanisms for Martian outflow channels: episodic aquifer release (Carr, 1979), a pluton-driven hydrothermal system (Gulick, 1998), or volcanic-

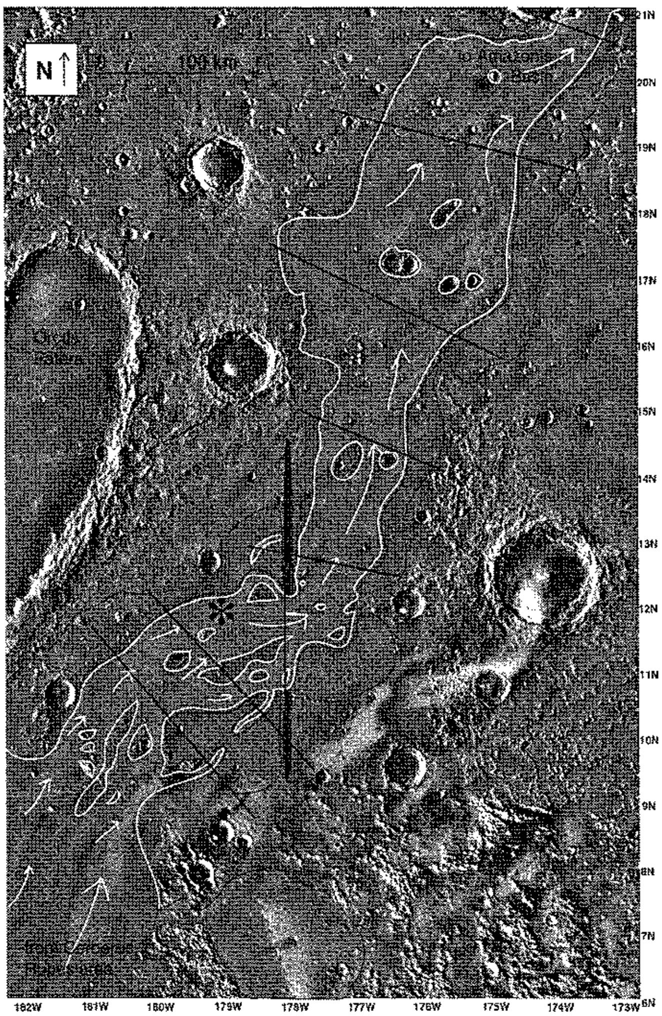

Figure 1: A mosaic of Viking images with superimposed white Marte Valles channel boundaries and white arrows indicating flow directions. Areas circled in thin black show resurfacing adjacent to the channel; filled black ellipses indicate wrinkle ridge remnants. Profiles were taken where thick black lines cross the channel and an ✻ marks the Mars Orbital Camera image location (Figure 2).

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Watters, T. R., 1991, Origin of periodically spaced wrinkle ridges on the Tharsis plateau of Mars: Journal of Geophysical Research, v. 96, no. E1, p. 15,599-15,616.
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induced localized precipitation (Plescia, 1993). Marte Valles' proximity to both Elysium Mons and to the dichotomy boundary, combined with the probable presence of ground ice (Brakenridge, 1990; Carr, 1996), makes any of these mechanisms plausible. With high-resolution MOLA data now available, detailed study allows us to quantify channel morphology and better constrain possible methods of formation.

METHODS

The key data set for our study is the gridded compilation of MOLA tracks. Previous topography data, accurate to one kilometer, could not be used to obtain meaningful channel parameters useful for well-constrained flow calculations. Using the program *Gridview* (Roark et al., 2000) to analyze the high-resolution MOLA grid (64 pixels/degree in longitude and 256 pixels/degree in latitude), we can calculate cross-sectional channel area and channel gradient with elevation data precise to within a meter, and thus for the first time quantify the channel morphology. The most useful data extracted from the MOLA grid are cross-channel profiles, which we overlaid on Viking image mosaics (I-1334 MC-8 NW, I-1332 MC-8 SW, I-1582 MC-15 SE, and I-1385 MC-15 NE) to determine the general channel shape. Regional gradients are determined by constructing profiles along various land surfaces and applying a best-fit slope. High-resolution images from the Mars Orbital Camera (MOC) provide a close look at the interaction between lava flows and fluvial channels. Using profiles, regional topography, and MOC images we can gain a better understanding of the morphology of the fluvial system as a whole.

RESULTS

Channel Map. Figure 1 is a Viking mosaic of the Marte Valles channel system in our study area. The fluvial channels shown outlined on the map are a compilation of MOLA grid and profile data as well as albedo variations from the Viking mosaics. Lava flows have previously been mapped in this area (Plescia, 1993) using only the albedo variations visible in the Viking images; however these albedo variations do not consistently correspond with the channels identified using the MOLA data. Our mapped fluvial channels indicate the traceable and clearly identifiable flow paths, beginning in the Cerberus plains (to the southeast of Fig. 1) and continuing through the southern portion of Marte Valles (arrows indicate measured down-channel gradients).

Profile Map. The cross-channel profiles generated in *Gridview* are superimposed on Viking mosaics (Fig. 1). The south channel area reveals a relatively flat, sparsely cratered area without identifiable channels. Downstream, to the northeast, the channels become identifiable in the topography and in many cases correspond with light albedo patterns in Viking images. The channels split and merge around numerous streamlined islands. These islands contain craters visible in Viking images. The channels converge, narrow and deepen as they pass through the remains of what we infer to be an eroded wrinkle ridge (between 177°W and 178°W), after which the channels widen and turn north toward the Amazonis Basin. Between the wrinkle ridge and Amazonis Basin the channels are less clearly incised; the indeterminate resurfaced area bounding the channel is widespread and MOLA topography data are extremely useful in mapping this section. The channels become more evident as they narrow and deepen at the outlet of the system in the northeast corner of the map.

Regional Gradients. Regional profiles were taken with a northeast-southwest strike along the channels and the surrounding land surfaces. The most conspicuous result is that the eroded, apparently resurfaced region between the channels and Orcus Patera shows no discernible slope while the channels have a slope of 0.017°. This indicates measurable downcutting and erosion of the channels into the regional landscape and clearly distinguishes the Marte Valles channels from the overall study area.

Cross-Channel Profiles. The cross-channel profiles (Fig. 1) show a consistent decrease in channel depth and a general trend toward increasing cross-sectional area downstream. Due to the uncertainty in defining an exact upper channel limit, the area measurements are approximations and we assign a conservative uncertainty of +/- one-third to each area value. The channel profiles ranged between 50 and 230 km across and between 50 and 150 m in depth.

MOC Image. One Mars Orbital Camera image within the channel system reveals a close relationship between fluvial and volcanic flows. Keszthelyi et al. (2000) use MOC image SP2-40703 (Fig.

2) to show the termination of an individual lava flow that partially occupies a fluvial channel with multiple terraces. This flow overlies previously deposited fluvial sediments.

DISCUSSION

The available topographic and photographic evidence does not point to one clear method of channel formation. There is ample evidence of catastrophic flooding in the anastamosing channels and streamlined bedforms visible in the Viking images. Yet multiple terraces on a meter scale indicate a constant flow at a variety of depths. Additionally, there is a general increase in channel area downstream that indicates inflow from multiple sources and does not indicate catastrophic flooding.

Our hypothesis of channel formation accounts for the evidence of catastrophic flooding and recurrent flow, but it is a bit more complicated. The originally released water flowed across the plains south of Orcus Patera and pooled behind the wrinkle ridge (see Fig. 1). This ponding resurfaced the western edge of the channel and accounts for the lack of slope. The dam broke in a catastrophic flow that flooded the area downstream of the wrinkle ridge, resurfaced the area outside the channel boundaries, and then carved the channels as the flood drained northeast into the Amazonis Basin. Subsequent lava flows used the channels as a path from their source to the Amazonis Basin. Some of these lava flows have been dated to as recently as 10 million years ago (Hartmann and Berman, 2000) and are thought to be the youngest volcanics on Mars. These lava flows are interwoven with sedimentary deposits, indicating that fluvial and volcanic processes alternated repeatedly during the active life of the channels

The evidence of fluvial action and volcanism in the same location and on a similar time scale suggests a cause-and-effect relationship. Fluvial action could result from the melting of ground ice in the Elysium region by a magma plume (Gulick, 1998), by flood lavas or magmatic sills (Squyres et al., 1987), or by the release of ice-confined aquifers (Carr, 1979). The proximity of both Elysium Mons and the Cerberus Rupes vents suggests a complex relationship of intrusions and volcanics. A catastrophic flood event points to high volume water release and broad regional volcanism while subsequent flows seem causally related to geologically recent flood lavas that are likely of local origin. A general picture of regional and local volcanic-ground ice interactions best fits the channel system, with the magnitude of activity decreasing in intensity over time.

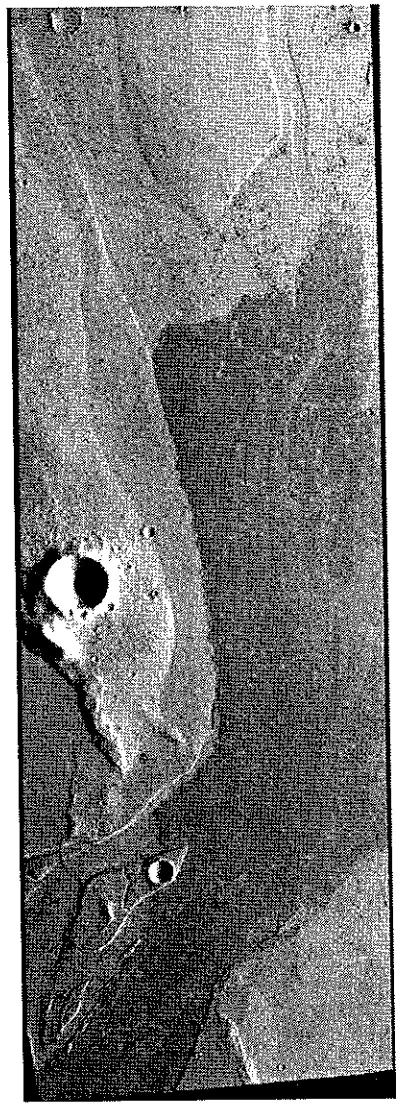

Figure 2. MOC image SP2-40703 shows the termination of a lava flow in a terraced fluvial channel. Image is 12.40 km wide. Location marked in Fig 1.

CONCLUSIONS

The Marte Valles channel system, although similar in appearance to catastrophic outflow channels, was not formed by this mechanism entirely. We hypothesize the formation of a local lake in the upper channel region, confined by a wrinkle ridge. The failure of this confining structure caused a massive flood through the lower channel region, not merely carving out the channels currently visible but resurfacing a broad area to either side. Subsequent to this flood, repeated episodes of volcanism and water release resulted in the interfingered deposits now evident in the channels.

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ERUPTION CONSTRAINTS ON A CHANNELED LAVA FLOW IN MARTE VALLIS, MARS, FROM MARS ORBITER LASER ALTIMETER AND MARS ORBITER CAMERA DATA

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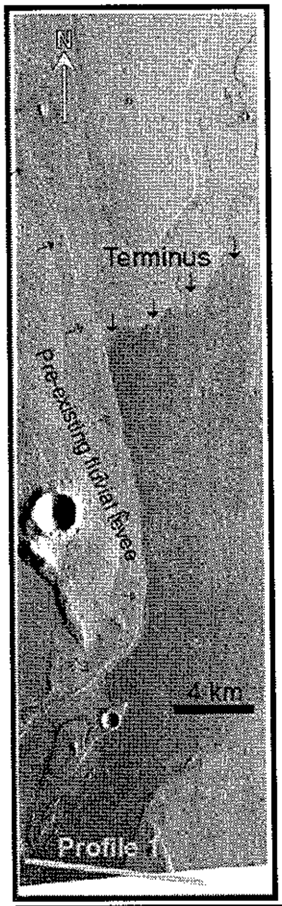

INTRODUCTION

Lava flow emplacement is a fundamental geologic process on Mars and other planetary bodies. By studying the surface morphology of lava flows, we gain insight into eruption parameters and ultimately a region's geothermal history. Images from the Mars Orbiter Camera (MOC) instrument [*Malin et al.*, 1998; *Malin et al.*, 1992] on the Mars Global Surveyor spacecraft show relatively young lava flows in the Marte Vallis region of Mars. These lava flows were recently estimated to be 10 million years old [*Hartmann and Berman*, 2000], suggesting a more recent volcanically active Mars than earlier believed [*Garvin et al.*, 2000].

In this study we attempt to constrain flow rates and velocities for a recent channeled flow in Marte Vallis shown in MOC image SP240703, which was acquired in July 1998 at a resolution of 18.47 m/pixel. Using Mars Orbiter Laser Altimeter (MOLA) [*Smith et al.*, 1998; *Zuber et al.*, 1992] topographic data, channel dimensions we measured included down-flow gradient, channel width, and channel depth. From these, flow rates and velocities were calculated using the rectangular channel flow model of Gregg and Sakimoto [1998, 2000; *Sakimoto and Gregg*, in prep.].

Marte Vallis, located between 170-190°W longitude and 0-20°N latitude, is a region characterized primarily by channels of possible fluvial origin [*Tanaka and Scott*, 1986]. Later volcanic activity, in the form of flood basalts and long lava flows, utilized these channels to transport lava distances as great as five hundred kilometers or more [*Plescia*, 1990] on slopes $<0.01°$ [*Gregg and Sakimoto*, 2000; *Sakimoto and Gregg*, in prep.]. Our study area is the northeasternmost section of Marte Vallis, to the east of Orcus Patera [*Greeley and Guest*, 1987], where these fluvial discharges and lava flows debouched onto Amazonis Planitia [*Plescia*, 1990]. The flow studied is located in the southern half of MOC image SP240703, which is centered at 19.22°N and 174.61°W. In the southernmost portion of the MOC image, a distinct dark lava flow and its terminus are clearly visible within the higher-albedo fluvial channel (Figure 1).

FIGURE 1: MOC Image SP240703 showing a young lava flow in the Marte Vallis region of Mars. The MOC image has a resolution of 18.47 meters per pixel. A distinct dark lava flow and its terminus, the subject of this study, are clearly visible within the higher-albedo fluvial channel. The flow terminus is identified with black arrows. And one of the pre-existing fluvial levees is identified with red arrows. Profile 1 shown in Figure 2.

METHODS

Using the program *Gridview* [*Roark et al.*, 2000], five topographic profiles of the channel were created from MOLA data gridded at 64x256 pixels/degree. At the time of this study, the footprints of our profiles were between 600 and 700 meters apart, and the topography was accurate to within a meter. These profiles reveal the channel levees and are used to determine the dimensions of the channel for input into an analytical model to determine lava flow rates and velocities.