EXTENSIVE AQUEOUS FLOODING FROM THE CERBERUS FOSSAE, MARS, AND ITS IMPLICATIONS FOR THE MARTIAN HYDROSPHERE. D. M. Burr[1] , A. S. McEwen[1] , L. P. Keszthelyi[1] , P. D. Lanagan[1] [1]Lunar and Planetary Lab, University of Arizona, Tucson AZ 85721, USA. (dburr@pirl.lpl.arizona.edu)

Introduction: Viking images of streamlined forms led various workers [e.g., 1] to hypothesize that young aqueous floods occurred in the vicinity of the Cerberus Plains (0-20N, 175-210W). Data from the Mars Global Surveyor spacecraft indicate that aqueous floods occurred recently in three locations around this basin [2], Marte Vallis, Athabasca Vallis, and an unnamed northern channel (FIGURE 1).

Topographic evidence. Topographic data from the Mars Orbiter Laser Altimeter (MOLA) of Marte Vallis and the unnamed northern channel show anastomosing channels; this planview form is found in the catastrophic flood terrain of the Channeled Scabland, northwestern USA, where floods breached interfluve divides [3]. Athabasca Vallis is a linear channel due to confinement of the floodwater by an Elysium Mons wrinkle ridge; distributary channels are found where the floods breached the ridge [4].

Primary geomorphic evidence: streamlined forms and longitudinal grooving. Mars Orbiter Camera (MOC) images show streamlined forms in all three channel systems. In Athabasca Vallis, they are predominately flat-topped features often with an impact crater on the upslope end [4]. The downslope parts have topographic layers ~10 m thick [4]. Because of the flat upper surface and the impact craters, which would produce stagnation downstream in fluid flow, these features most likely formed by deposition of flood-entrained sediment [4]. MOC images also show extensive longitudinal grooving on the floors of Athabasca Vallis [4] and the unnamed northern channel system; (such grooving cannot be seen in Marte Vallis due to the lava that embays that channel). These two morphologies, also found in the Channeled Scabland [3], represent the most definite geomorphic evidence for catastrophic flooding.

Secondary geomorphic evidence: rootless cones. Rootless cones are seen throughout Athabasca Valles and the unnamed northern channel system, as well as in Amazonis Planitia, into which the Marte Vallis debouches [5]. Rootless cones form when lava flows over and intimately mixes with wet substrate, volatilizing the water which then erupts up through the overlying lava flow [5]. Rootless cone fields within the channels, but not on the surrounding terrain, suggest that the water for their formation was emplaced by aqueous flow within the channels.

Discharge: Assuming bankfull flow and no incision or filling during flooding, one can estimate channel discharge from the present topography. Using Manning's equation modified for Martian gravity [6] and the U.S. Army Corps of Engineers HEC-RAS model modified for Martian gravity [7], we estimated the volumetric discharge to be on the order of 10^6 - 10^7 m^3/s for each channel system [2, 4].

Age: The three channels are all Upper Amazonian in age [8]. Lava flows in the southwest Cerberus Plains which embay the distal ends of Athabasca Vallis have crater ages of ~10Ma or less [9]. The lavas that embay Marte Vallis are younger than 100 Ma [10]. Rootless cones probably associated with these lavas are found in the distal reaches of each channel [5]. Ground ice is subject to sublimation on Mars [11], so the rootless cones suggest that the flood water did not long precede the lava flows.

Origin of the floodwater: MOLA data show both Athabasca Vallis and the unnamed northern channel originating at locations along the fissures, near 10N 203W and 16N 198W, respectively. MOC images downslope of these locations show fluvial gemorphic features, whereas MOC images immediately upslope do not. Thus, MGS data indicate that the floodwaters for two channels emanated from the Cerberus Fossae.

The origin of Marte Vallis is less clear. Today the channels appear to originate in the extreme eastern Cerberus Plains, but this region is extensively covered with very young lavas [e.g., 12], and no specific breakout location is apparent. Previously proposed mechanisms, such as rainfall [12], cannot readily provide the sudden release of large amounts of water implicit in the discharge estimates. We propose that, as with the other two channels, a (now buried) section of Cerberus Fossae in the eastern Cerberus Plains is the most likely source for Marte Vallis' floodwaters.

Mechanism for water release: The Cerberus Fossae extensional fractures could have resulted from graben formation over volcanic dikes, as with Valles Marineris [e.g. 13], or from Elysium Mons uplift [14]. Because the channels originate at the Cerberus Fossae, we examined water release mechanisms associated with each of these modes of formation, i.e., melting of ground ice by the dikes, or groundwater flow through a highly permeable basalt, respectively.

Melting of ground ice. In the former case, dike intrusion could produce structures like Valles Marineris [13], but the melting is too slow to release water suddenly, so the meltwater must collect somewhere[13]. We do not see evidence for a surface lake, so only subsurface collection is plausible.

Flow through a porous medium. If formed by uplift [14], the fissures would provide an easy route for gravity-induced waterflow down from Elysium Mons;

but the water would have to flow through the porous medium of the surrounding subsurface to the fissure. We modeled this flow with Darcy's equation [15]. If the water were circulated by magmatic heating [e.g. 16], the hydraulic gradient could equal the topographic gradient of Elysium Mons, ~.005 (5 m/km) to Athabasca Vallis. For *both* sides of the fissure, we used its length from its highest visible point to the channel origination point (~120km) as the maximum possible length of the contributing subsurface volume of porous material. We used the thickness of the Martian crust to the self-compaction level (~10km [17]) as the maximum thickness of the contributing porous volume, and the maximum hydraulic conductivity for highly permeable basalt (2×10^{-2} m/s or ~2000 darcies) [14]. We found that, though thus maximized, the discharge rate for this mechanism (~0.24×10^6 m^3/s) cannot deliver water to the fissure at the rate estimated for the flood channels.

Conclusions: Cerberus Plains floodchannels indicate that 1) the entire volume discharged must have been collected in a liquid state before flood onset; and 2) the aquifers must have been deep, because no subsidence is apparent near the fossae. We suugest that the mechanism most likely to be able to deliver water to the surface at the volumetric rate estimated for the surface channels is tectonic tapping by the Cerberus Fossae into deep, subsuface aquifers [1]; although the water must still flow through the more or less permeable substrate to exit the aquifer, preliminary calculations indicate that overburden-pressure-induced flow can account for the volumetric flow rate. This suggests that the origin at the fossae of both lava and water floods is due to extension which both extrudes lava onto the surface and taps into the aquifer(s). The possible existence of deep, subsurface aquifers would not only be an important component of the hydrosphere of Mars, but may be an environment conducive to pre-biotic or biotic activity. If the streamlined forms are depositional [4], they may contain rocks from within these aquifers.

References:

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Figure 1: Viking basemap of the Cerberus Plains region (0-20N, 175-210W). Image is 2000 km across.