PARAMETRIC STUDY OF MARTIAN FLOODS AT CERBERUS FOSSAE

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Introduction: The detailed topographic relief and gradient data from the Mars Orbiter Laser Altimeter (MOLA) allows greatly improved hydraulic surface flow modeling for Mars, and many recent papers have modeled Martin fluvial flow [e.g. 1, 2]. In particular, much attention has been given to Cerberus Fossae [e.g. 1,2], due to the suggested young ages of the surfaces [13, 17] and suggested volcanism/water interactions. Athabasca Valles, a channel system to the south of the fissure, is belived to have been caused by an outflow event from Cerberus Fossae. Several recent estimates for the water outflow volume from Cerberus Fossae, Mars [1], range from 1×10^{6} [1] to 2×10^{6} [2] m^3/s. These flow estimates are based on many assumed values and their applicability to Mars is not known with certainty. The preliminary results of this study suggest that physically plausible values for volumetric flow rates range four orders of magnitude suggesting that Martian hydraulic flow rates are not yet well constrained.

Method and Approach:

Hydraulic Model: The parameters discussed in the introduction are used in governing equations for the model. First, the flow through the aquifer is computed via the groundwater flow equation,

$$\frac{\partial h}{dt} = \frac{k_h g}{\nu S_s}\frac{\partial^2 h}{\partial x^2} \qquad (1)$$

which controls flow within the aquifer itself. The function is time variant, one dimensional with respect to distance from the fissure, and outputs head (h) at various distances from the fissure. Numerical methods are used to find the gradient of the hydraulic head from (1), which is put into an adapted form of Darcy's equation,

$$q = \frac{-k_h gH}{\nu}\frac{\partial h}{\partial x} \qquad (2)$$

to determine flow the flow rate per unit fissure length. The flow rate from (2) can be assumed as equal to the flow in the fissure, which itself is assumed to be governed by the flow between two rough plates,

$$q = \sqrt{\frac{2h_0 g w^3}{fD}} \qquad (3)$$

and can be solved for the head at the bottom of the fissure, ($h_{@x=0}$).

Parameter Determination: The critical parameters used in previous studies [1][2] were compared to existing terrestrial parallels (Table 1). Many values which were assumed in previous studies are representative of only a small range of terrestrial values. This is not true of all parameters, however, as the MOLA has allowed for detailed topographic data to be compliled for the planet. To this end, reliable values can be found for the fissure length (L_f) the peak backwater extent of flow (B) and the slope of the valley (s).

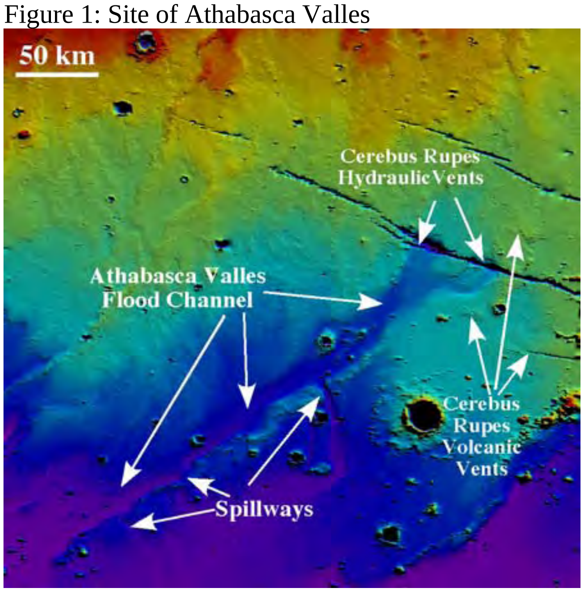
Most parameters in these systems, such as the horizontal permeability (k_h), specific storage (S_s), aquifer head, depth, and thickness ($h_{@t=0}$, D, H), kinematic viscosity (ν), fissure width (w), and Manning's number (n), are not known with a large degree of certainty for the Martian envirnoment.

Table 1: Parameter Value Summaries

Parameter	Symbol	Units	Typical Terrestial Minimum	Typical Terrestial Maximum	Prior Assumed Martian Value
Horizontal Permeability	k_h	m^2	1.5×10^{-9} [10]	9×10^{-21} [10]	10^{-9} [1]
Specific Storage	S_S	m^{-1}	5×10^{-4} [8]	2.7×10^{-6} [9]	10^{-6} [1]
Aquifer Head	$h_{@t=0}$	m	0 [6]	130 [6]	5×10^{3} [18]
Aquifer Depth	D	m	55 [7]	2000 [6]	5×10^{3} [1]
Aquifer Thickness	H	m	16 [5]	3×10^{3} [6]	5×10^{3} [18]
Kinematic Viscosity	ν	m^2/s	0.658×10^{-6} [2]	1.78×10^{-6} [2]	1.5×10^{-6} [18]
Fissure Width	w	m	*N/A*	*N/A*	2.0 [1]
Manning's Number	n	None	0.012 [2]	0.05 [2]	0.04 [15]

Revised Parameter Estimates: In order to account for the lack of certainty concerning environmental parameters for the Athabasca Valles and Cerberus Fossae region, a survey of various terrestrial values were found and used as bounds for the possible Martian values. This process does not guarantee that the actual parameters on Mars will fall within these values, but it will allow for a better sense of of the rough values for parameters than that which has been previously available.

Figure 1: Site of Athabasca Valles



Results and Discussion: For the range of input parameter values shown in Table 1, the equations discussed in the methodology section were solved for the flow rate. As Table 1 demonstrates, typical terrestrial values for horizontal permeability, specific storage, aquifer head, aquifer depth, aquifer thickness, kinematic viscosity, and Manning's number vary by several orders of magnitude. This variance of the parameters translates into a variance of several orders of magnitude for the outflow rate from the Cerberus Fossae fissure. Preliminary results show a myriad of flow rates across four orders of magnitude, ranging from 10^6 to 10^2 m^3/s. Additionally, the behavior of flow rates varied over time based on the input values. In some cases, the flow rate remained nearly constant for multiple hours. During other tests, particulary when a small k_h was used, both the flow rate and pressure declined rapidly with time. This is most likely a product of permeability rapidly draining the available water and pressure from the buried aquifer under Cerberus Fossae.

Prior studies have used a limited subset of physically reasonable ranges, for assumed Martian values, thus artificially constraining Martian flow rates to a limited range. Given the lack of applicable measured Martian values, the allowed range of parameters, given in Table 1, is likely similar to those actually found on Mars. Future studies will be needed to properly ascertain these values, as well as those for head and backwater extent, with greater certainty. Additionally, better accuracy and insights into fluvial modeling can be found with the application of a more powerful model, such as the Advanced Circulation Model (ADCIRC). Until such advances are made, a wide parameter range should be used in order to ensure a reasonable range of flow rates through Athabasca Valles.

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