ESTIMATING HYDRAULIC CONDUCTIVITY FROM DRAINAGE PATTERNS DERIVED FROM A DEM – A CASE STUDY IN THE MARE TYRRHENUM QUADRANGLE ON MARS. B. P. Grudzinski[1], W. Luo[1], [1]Department of Geography, Northern Illinois University, DeKalb, IL 60115, (Z1555588@students.niu.edu, wluo@niu.edu)

Introduction: Hydraulic conductivity *K* is an important parameter in hydrology which describes the ease with which water moves through porous media. This parameter is also important in understanding the hydrology of Mars. On Earth, *K* can be measured by conducting controlled experiments in laboratories or conducting pumping tests in the field. This study introduces a new method of estimating *K* on Mars from drainage dissection patterns derived from a digital elevation model (DEM). This method was previously tested on Earth in the Oregon Cascades and provided accurate results in terms of orders of magnitude and spatial distribution [1]. This study provides a direct estimate for *K* based on DEM data for Mars and is also the first study (to the best of our knowledge) which provides spatial variability of *K* on Mars.

Methodology: Figure 1 illustrates an unconfined aquifer where groundwater discharges into a channel. The assumptions are that (1) the aquifer is effectively drained (i.e., a steady-state dynamic equilibrium has developed over a long time), and (2) groundwater flow is primarily horizontal (i.e., Dupuit-Forchheimer assumptions apply). The aquifer thickness is *H*, the valley depth is *d*, and the effective drainage length is *W*. Under DuPuit-Forchheimer assumptions, the discharge per unit width (u=1) of the valley is *q*' is [2]:

$$q' = \frac{1}{2}K\left(\frac{H^2-(H-d)^2}{W}\right) \qquad (1)$$

where *K* is hydraulic conductivity. Rearranging Equation (1) gives:

$$K = \frac{2q'W}{H^2-(H-d)^2} \qquad (2)$$

In order to scale for Martian gravity the result of *K* is multiplied by .376. Viscosity and density of water are assumed to be the same as on Earth.

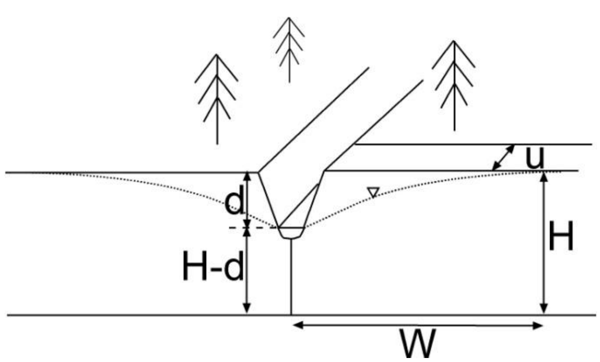

Figure 1. Diagram illustrating DuPuit assumption.

Study Area and Data: The study area is located in the Mare Tyrrhenum quadrangle (*MC-22*) on Mars. Its boundaries are from 90°E to 135°E and 0°S to 30°S. The region contains relatively high drainage density and contains valley networks of the Noachian Age. The two largest Noachian terrains in the study area include Terra Tyrrhenum and Terra Cimmeria. The valley networks are extracted from the DEM using a morphology based algorithm [3]. The DEM data has been gathered by MOLA [4].

Parameter Estimates and Results: Valley depth *d* was estimated using the Black Top Hat Method [5]. The depth is averaged over the watershed that drains into each valley network, as are all other parameters along with *K*. The discharge *q'* (same as recharge under steady-state condition) is estimated from previous studies and ranges from 2mm to 2m per year [6]. The aquifer thickness is also estimated from previous studies and ranges from 50 m to 200 m [7]. The effective drainage length *W* is inversely related to drainage density *D* and has been derived from the DEM in a previous study [8]: *W* = 1/ (2*D*). Figure 2 shows the result of *K* estimated in the study area with the following parameters *q'* = 2 m/year and *H* = 200 m. The mean values of *K* for other parameter values have been calculated (see Table 1) and are consistant with results from previous studies [9] (see Table 2).

Table 1. Mean values of *K* (m/s) and Comparison

	H = 50m	*H* = 100m	*H* = 200m
q' =2mm/year	8.26×10^{-3}	3.94×10^{-3}	1.93×10^{-3}
q' =2cm/year	8.26×10^{-4}	3.94×10^{-4}	1.93×10^{-4}
q' =2m/year	8.26×10^{-5}	3.94×10^{-5}	1.93×10^{-5}

Table 2. Mean values of *K* (m/s) in previous studies

Study Area	Method	K Value m/s	Ref
Circum-Chryse	Aquifer Pressurization	10^{-3} to 10^{-5}	[9]
Martian Surface	Hydrothermal Circulation	10^{-4} to 10^{-5}	[10]
Northern Plains	Hydrosphere Evolution	10^{-3}	[11]
Mangala Valles	Outflow Channel Formation	10^{-2} to 10^{-7}	[12]
Conceptual Model	Groundwater Outflow	10^{-3} to 10^{-7}	[13]

Discussion: The assumptions of this method dictate that this method can only be used to estimate horizontal *K* and for areas where the interplay between surface drainage, groundwater, and topography has established a steady-state dynamic equilibrium [1]. We believe the assumptions are reasonable for past Martian conditions. Our estimates of *K* are consistent with other previous studies and our method has solid theoretical foundation in Darcy's law for groundwater flow.

Uncertainties in this study come from a wide range of estimates for recharge and aquifer thickness. The parameters used in this study have to depend on estimates made in previous studies since there have not been any direct aquifer tests and there is no direct estimate for precipitation. The aquifer thickness ranges by a factor of four and the recharge estimates range by 3 orders of magnitude. Changing precipitation by one order of magnitude changes *K* by one order of magnitude; the order of magnitude of *K* does not change within the 4 factors of aquifer thickness.

To the best of our knowledge, this study is the first study which uses dissection patterns derived from DEM data to estimate *K* on Mars and it is grounded in Darcy's law. Along with providing an estimate which matches previous estimates of *K*, it also shows spatial variability in *K* for the first time on Mars.

References: [1] Luo, W. et al. (2009) *Geology*, in press. [2] Deming, D. (2002) Introduction to Hydrogeology, McGraw-Hill. [3] Molloy, I. and Stepinski, T. (2007) *Computers and Geosciences*, 33, (6), 728-738. [4] Smith, R. P. et al. (2003) *Tech. Rep*., NASA Planetary Data System. [5] Rodriguez, F. (2002) *JRL* doi: 10.1029/2003JB002855. [6] Howard, A.D., Abstract: *Reports of the Planetary Geology and Geophysics Program*, NASA TM 4210 [7] Luo. W. and Howard. A.D. (2008) *JGR* doi: 10.1029/2007JE002981 [8] Luo. W. and Stepinski, T. (2008) *Geomorphology, 99,* 90–98.
[9] Hanna, J.C. and Phillips R.J. (2004) *JGR* doi: 10.1029/2004JE002330. [10] Harrison, K.P., and Gimm, R.E., (2002) *JGR* NO.E5, 10.1029/2001-JE001616 [11] Carr, M.H., 1979, *JGR*., 84, 2995-3007. [12] Zimbelman, J.R. et. al. (1992) *JGR* 97, 18,309-18,317. [13] Gulick, V.C., (1998) *JGR* 108, 8, 19365-19,387.

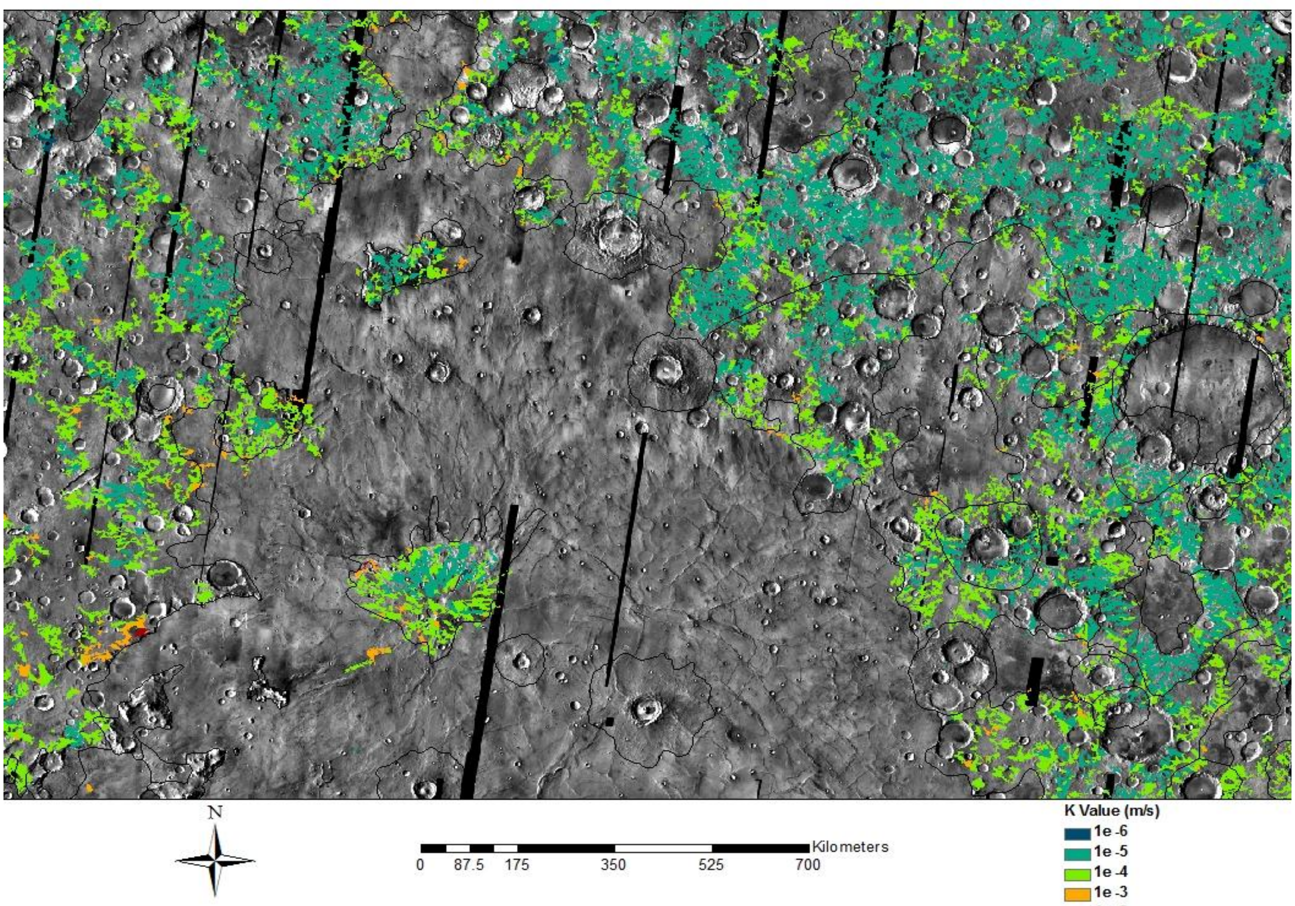

Figure 2. Hydraulic conductivity (*K*) estimate (*q'* = 2 m/year, *H* = 200 m) draped on THEMIS IR image. Geologic unit boundaries are also shown.