OPEN-BASIN LAKES ON MARS: IMPLICATIONS OF VALLEY NETWORK LAKES FOR THE NATURE OF NOACHIAN HYDROLOGY. C. I. Fassett and J. W. Head III, Box 1846, Dept. of Geological Sciences, Brown University, Providence, RI 02912 (Caleb_Fassett@brown.edu).

Introduction: Many probable lake basins have been recognized on Mars starting with the analysis of Viking images [e.g., 1,2,3]. The criteria applied for recognizing lakes include a source of water and an enclosed topographic low in which water would have ponded. Lakes sourced by valley networks are particularly interesting because discharge rates in valley networks are comparatively small [4] relative to lake volumes, implying that valley network lakes may have achieved equilibrium with the surface environment for geologically significant periods, probably at least thousands of years [5,6,7].

The global survey that catalogued martian lakes was completed before detailed mapping of Mars' surface topography was obtained [3]. We were thus motivated to re-survey the Martian surface for open basins, utilizing both new image data and new topographic information available from MOLA and HRSC. We have focused our effort on hydrologically 'open' systems (open-basin lakes are those with clear outlet valleys), because in these cases we can be very confident that a lake must have ponded to at least the level of the outlet for it to have formed in the first place. Thus, using the available topographic data, it is possible to directly measure the minimum ponded volume (V) and the surface area for each of the cataloged lakes.

Characteristics of Open-Basin Lakes: To date, our catalog includes 191 open-basin lakes (Fig. 1), two-thirds of which to our knowledge have never before been recognized . A few characteristics of these lakes are worth considering in detail:

Lake Chains. Our mapping of open basins has revealed a large population of valley network-associated lakes that were part of integrated lake-chain systems. Of the 191 open lakes we have mapped, 138 (72%) are part of an integrated lake system (the source of, or sourced by, another open basin). Because outlet valleys for open basins by definition cross basin divides, these lake chains were a significant pathway for integrating the surface hydrology of early Mars. That these open basins were not infilled and destroyed is consistent with the general immaturity of basin development on the martian surface.

Most of the lake chains we map are integrated at length scales of 200-600 km, but a few are longer than 1000 km: (1) Naktong/Scamander/Mamers Valles system at ~4500 km long [8], with 24 separate open basins that ultimately contributed to flow and a total watershed of ~$3x10^6$ km^2; (2) The Samara/Himera Vallis system is ~2000 km long; (3) the ~1200-km long Parana/Loire system (connecting to Samara/Himera at its mouth); and (4) a ~1500-km unnamed valley at 3.5E (22S to 10S) that enters Madler crater, which probably once could be traced for a substantially longer distance to the west (to the crater at -7 E, 9S) but whose course has been destroyed by resurfacing.

The fact that the most integrated valley/lake systems on Mars are concentrated in the region from -40 to 40 E longitude is likely related to regional climate variation ,as was suggested by Irwin et al. [9].

Resurfacing. One of the challenges for attempting to extract information about the surface environment and climate on Noachian Mars is resurfacing processes operating from the Early Hesperian onward. Even in regions where the large crater population would indicate a Noachian age, resurfacing has in many cases led to younger crater retention ages at smaller scales. Moreover, valleys that apparently were last active at the Noachian/Hesperian boundary commonly enter craters with comparatively young floors [10]. Crater counts of some of the basin floors in this study strongly implicate this phenomena. Moreover, wrinkle ridges and other signatures of post-lacustrine resurfacing are common on the floors of open basins we catalogued (e.g., Gusev). We conservatively estimate that resurfacing has effected at least 50% of the lakes we mapped (see, e.g., Fig. 2). Such resurfacing complicates interpretation of putative lacustrine deposits and markers (such as deltas, terraces, etc.).

Groundwater versus Runoff: In the case of 49 basins (25% of those we catalogued), we were able to estimate the contributing watershed area (A_w) (eliminating catalogued lakes with other lakes as a source and those with significant resurfacing),. This allows us to compute the lake volume/watershed area ratio (V/A_w), which is a measure of the time-integrated source discharge per unit area to the lake in excess of infiltration/evaporation. Most lakes had V/A_w ratios of <15 m (38/49). The best-fit power law describing the lakes with $V/A_w < 15$ is $V=0.002(A_w^{\ 0.98})$ (R^2=0.52). Lake volume is essentially directly proportional to watershed area for these lakes, consistent with being predominantly runoff-sourced.

However, there are significant exceptions (see Fig. 3, 4; four lakes have $V/A_w > 100$ m). We interpret lakes with large V/A_w (>15) as likely having been significantly sourced by groundwater effluent (sourced by infiltration from outside their watershed). The largest cataloged open basins on Mars by volume (Eridinia [11] and Antoniadi (Fig. 3)), fall into this category. Moreover, lakes which were potentially sourced by groundwater appear preferentially at lower elevation

(Fig. 4C). The interpretation that groundwater transport and effluent was an important source for these lakes on early Mars implies that a vertically-integrated hydrosphere existed for at least some period of time [12], suggesting a hydrosphere more closely resembling Earth than modern Mars.

Conclusions: A new survey of open-basin lakes on Mars indicates that (1) in many places the surface hydrology of Mars was integrated in large lake chains, from hundreds to thousands of kilometers in length; (2) these volumetrically-significant lake chains must have been filled in order for their outlets to be active; this is most consistent with a scenario in which the surface supported liquid water for at least thousands of years; (3) later resurfacing has altered many basin floors; (4) groundwater appears to have been a major source for the largest lakes on Mars.

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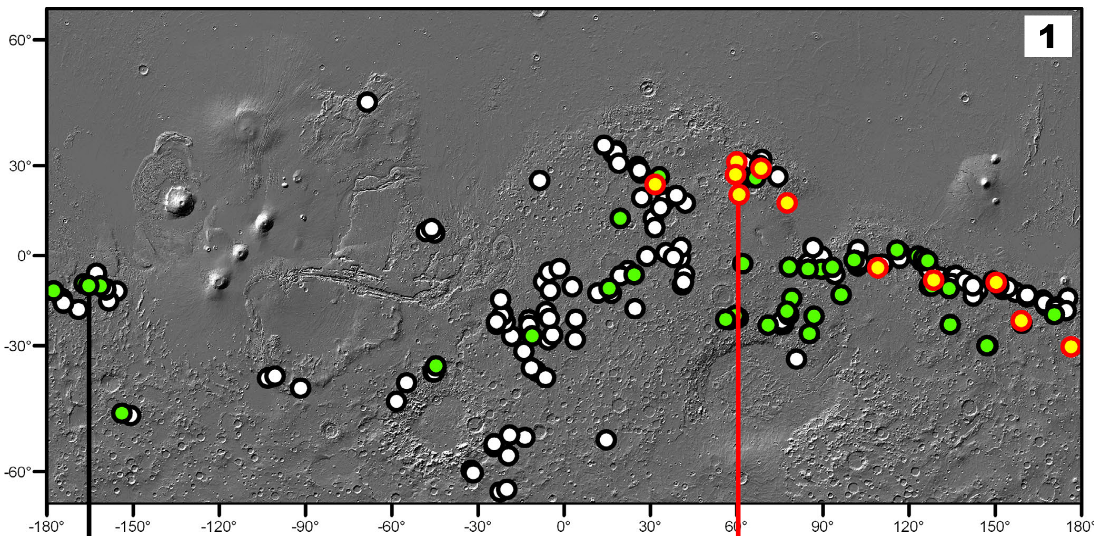

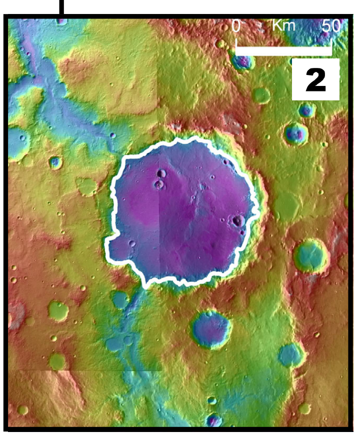

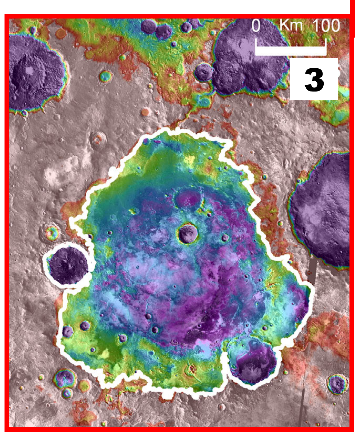

Fig. 1. Distribution of all catalogued open basins on Mars. In orange are lakes with V/A_w>15 m and in green are those with V/A_w<15 m (white circles did not have A_w measured).

Fig. 2. An open-basin lake [2] sourced by a large watershed and prominent valleys; V/A_w~2.7 m. Note that its floor appears to have been partly resurfaced (wrinkle ridges).

Fig. 3. Antoniadi crater; one of the largest open basins on Mars and likely sourced by groundwater (V~56). The outlet drains to the north into a chain of lakes.

Fig. 4. Floor elevation vs. V/A_w for the lakes where the watershed was measured.

Fig. 5. Frequency distribution of V/A_w.

Fig. 6. Histogram of data in Fig. 4, illustrating that possible groundwater-fed lakes are mostly at lower elevation than those dominated by runoff.