WERE JEZERO AND GALE CRATERS SUBMERGED BY A MARTIAN OCEAN? QUANTIFIED UNCERTAINTIES IN PALEO-OCEAN LEVELS ON MARS. S.F. Sholes[1], [1]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109 (steven.f.sholes@jpl.nasa.gov).

Introduction: Whether Mars ever had past oceans is still a highly controversial subject, primarily supported by putative shoreline features that encircle the northern plains [1, 2]. The elevation of these features varies by multiple kilometers across the globe [1] which has led to considerable scrutiny over their shoreline interpretation. Prior work has shown that by correcting for the topographic deformation, caused by the rise of the Tharsis volcanic province, these features better conform to an equipotential surface expected of true ocean shorelines [3]. However, there is still considerable variation (multiple kilometers) in the topography even after these modeled corrections [4].

Other studies have used these deformation models in an attempt to provide age constraints on the possible oceans themselves [3] and relative ages of the landing sites of the *Perseverance* and *Curiosity* rovers [5, 6] in Jezero and Gale crater respectively. For example, Jezero' s well-preserved valley network and deltaic system show no observed modification by marine processes. Therefore, if the shoreline of a proposed ocean level were topographically higher than Jezero, the ocean would necessarily have to predate Jezero which has been estimated to be approximately 3.2-3.9 Gyr old [8, 9]. Similarly, Gale also shows no sign of marine modification, so if the ocean's sea level were at a higher elevation than Gale, such an ocean would likely be older than ~3.61 Ga [11].

However, these studies have largely neglected to consider the great amount of uncertainty in the location of the proposed shoreline features.

As shown in [1], there is no standard definition nor map for the different proposed shorelines. This is especially true for the larger-extent older proposed Arabia Level which can vary by >1,000 km laterally between different maps and mappings. Even when each mapped feature is optimized against the percentage of Tharsis complex completed with the deformation models to reduce the root-mean-square-error, the resulting standard deviations are still very large. Thus, because of both the large multiple-kilometer range in elevation within each mapping of the feature and multiple-kilometer range in data between mappings, the use of a single 'mean sea level' is insufficient to address relative timing of the features.

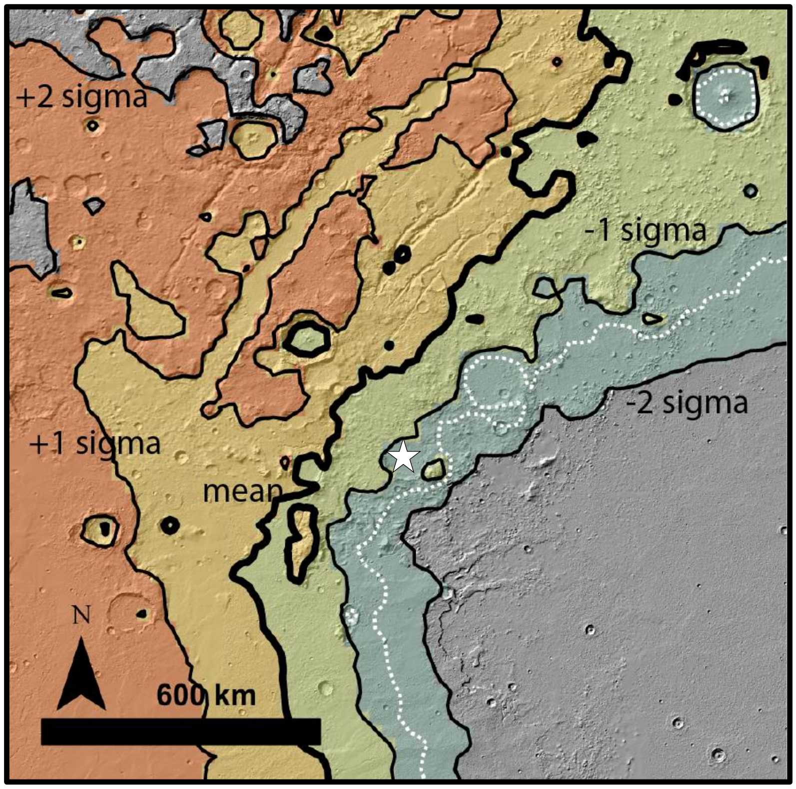

Figure 1: Colorized uncertainties in the elevation of the Arabia Level from [7] as compared to Jezero crater (white star). Bold black line is the mean elevation (-2.51 km) used to constrain whether Jezero would have been submerged by an ocean in the Tharsis-induced deformation model in [5]. Jezero would have been submerged within 2-sgima of the mean elevation and likely flooded at the 1-sigma interval. Blue shaded region is <1-sigma from the mean, green shaded is between the mean and 1-sigma below, yellow is up to 1-sigma above the mean, and red is between 1 and 2-sigma above the mean.

Here, we use a more rigorous approach to test whether Jezero and Gale craters would have been submerged by a potential Arabia Level ocean by testing water levels at the 1- and 2-sigma levels for different digitized versions of the mapped level.

Methods: Given the proposed ages of the Arabia Level, craters, and potential shoreline, we use the Tharsis-induced deformation model presented in [3] to determine the pre-complete-Tharsis paleo-surface elevations of each of the different mappings of the Arabia Level in [1]. Then using the mean and standard deviations of the paleotopography for each mapped level, we fit contours to the 1- and 2-sigma elevations to the pre-Tharsis digital elevation map (DEM).

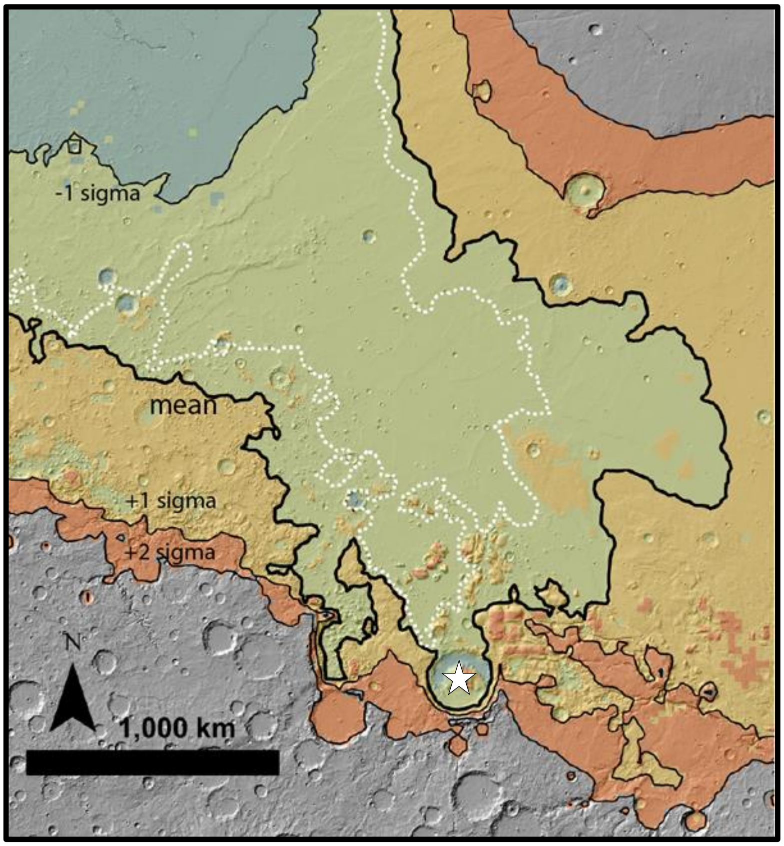

Figure 2: Colorized uncertainties in the elevation of the Arabia Level [7] at Gale Crater. Bold line is the mean pre-Tharsis elevation of the level (-2.51 km), white dashed line is the approximate lowest 'sea level' which would not submerge Gale, at -2.75 km pre-Tharsis elevation (0.22 σ). Blue shaded region is <1-sigma from the mean, green shaded is between the mean and 1-sigma below, yellow is up to 1-sigma above the mean, and red is between 1 and 2-sigma above the mean. Gale crater is marked by a white star on a MOLA hillshade.

This is in contrast to previous studies that tested against a single mapped level [3, 5, 10], which is usually the same relatively small segment from [10] (originally derived from [7]) covering Arabia Terra (and does not actually extend all the way to Jezero crater).

We focus on the Arabia Level, as the other prominently-discussed proposed shoreline, the Deuteronilus Level, is a distinct geological contact that is topographically below both craters.

Jezero Crater: Figure 1 shows the lateral range of elevations that are consistent with up to 2-sigma from the mean elevation of [7]. Here, any potential shoreline that is topographically lower than 1.4-sigma below the mean (a pre-Tharsis paleoelevation "sea level" of -2.51±1.10 km) would fail to submerge Jezero (and thus suggests that such an ocean would predate Jezero). This corresponds to approximately 16% of the possible "sea level" values following a normal distribution of this particular mapped feature.

These results are largely consistent with [5], which modeled a 'sea level' of -2.3 km (a difference caused by the usage of the small segment from [10] rather than the global map of [7]). Our mean elevation contour, i.e., the proposed 'sea level,' matches closely to the prior studies, and if this was taken in isolation would agree with the previous results that such an ocean would completely submerge Jezero. Even at the lower 1-sigma limit, the contour traces the outside western rim of Jezero which suggests that an ocean at this elevation would still just submerge Jezero. However, at the lower 2-sigma level and below, Jezero would not be submerged. Which would not allow for dating of such an ocean relative to Jezero or the Tharsis volcanic rise.

Gale Crater: When we perform the same analysis (using the same map of the Arabia Level from [7]) along Gale crater, the uncertainty whether it would be submerged grows. Figure 2 shows the lateral range of paleoelevations within 2-sigma of the mean. While the mean value would nearly completely submerge Gale, if the putative shoreline's location was actually topographically lower than 0.22-sigma below the mean, it would fail to do so. This corresponds to approximately 41% of the possible "sea level" values following a normal distribution of this particular mapped feature.

Therefore, given the high degree of uncertainty in the placement of the putative shoreline, there is a high likelihood that such an Arabia Level ocean would not submerge the crater (and no marine modification has been noted), thus, limiting the use of such a relative aging model for the putative ocean.

Acknowledgments: MOLA gridded elevation data is available on the Planetary Data System (PDS).

References: [1] Sholes et al. (2021) *JGR: Planets* 126, doi: 10.1029/2020JE006486. [2] Parker et al. (1989) *Icarus* 82 doi: 10.1016/0019-1035(89)90027-4. [3] Citron et al. (2018) *Nature* 555, doi: 10.1038/nature26144. [4] Sholes and Rivera-Hernández (2022) *Icarus* (in review). [5] Baum et al. (2021) *PSJ* 2:128 doi: 10.3847/PSJ/ac01de. [6] Citron et al. (2021) *LPSC LII*, Abstract #1605. [7] Carr and Head (2003) *JGR:Planets* 108, doi: 10.1029/2002JE001963. [8] Fassett and Head (2008) *Icarus* 195, doi: 10.1016/j.icarus.2007.12.009. [9] Mangold et al. (2020) *Astrobiology* 20, doi: 10.1089/ast.2019.2132. [10] Perron et al. (2007) *Nature* 447, doi: 10.1038/nature05873. [11] Le Deit et al. (2013) *JGR:Planets* 118, doi: 10.1002/2012JE004322.