GEOLOGY OF McLAUGHLIN CRATER, MARS: A UNIQUE LACUSTRINE SETTING WITH IMPLICATIONS FOR ASTROBIOLOGY.
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Introduction: McLaughlin crater is a 92-km-diameter Martian impact crater that contained an ancient carbonate- and clay mineral-bearing lake in the Late Noachian. Detailed analysis of the geology within this crater reveals a complex history with important implications for astrobiology [1]. The basin contains evidence for, among other deposits, hydrothermally altered rocks, delta deposits, deep water (>400 m) sediments, and potentially turbidites. The geology of this basin stands in stark contrast to that of some ancient basins that contain evidence for transient aqueous processes and airfall sediments (*e.g.* Gale Crater [2-3]).

Geologic Setting: McLaughlin Crater is located at 21.9°N 337.63°E, just south of the dichotomy boundary. Among large, ancient craters, it retains a relatively high depth/diameter ratio; it has not been significantly infilled and resurfaced by lava or airfall deposits.

Evidence for an ancient lake: Channels observed on the interior northeast wall of the crater terminate at the edge of a topographic platform which is at an elevation of approximately -4750 to -4700 m, ~450 m above the modern crater floor (-5170 m). While it is possible the channels formed by ice/snow-melt rather than rain, their terminal elevation likely indicates the former lake level, implying the presence of a ~400-500 meter deep lake (Figure 1). HiRISE images of strata in the poorly exposed cliff face (arrow in Figure 1) reveal planar and poorly developed cross-bedding at the scale of 10s of meters, suggesting deposition in running water and possibly in an ancient delta.

Sedimentary rocks: The floor of McLaughlin Crater contains layered, clay mineral-rich deposits, best exposed in the walls of a ~70-meter-deep canyon eroded into the floor (Figure 2). CRISM spectra indicate that these deposits are composed of Fe-rich, dioctahedral, likely expandable clays that may coexist with carbonates [1]. These clay-bearing rocks, contain complex sedimentary structures (Figure 3).

Altered ejecta: Keren is a 28 km-diameter impact crater located on the southern rim of McLaughlin Crater (Figure 1). Keren ejecta located at elevations below the proposed paleolake level of -4700 m within McLaughlin have been intensely altered by water. CRISM spectra of these materials show the presence of Mg-carbonates, and FeMg-rich expandable clays, consistent with alteration within a lacustrine environment.

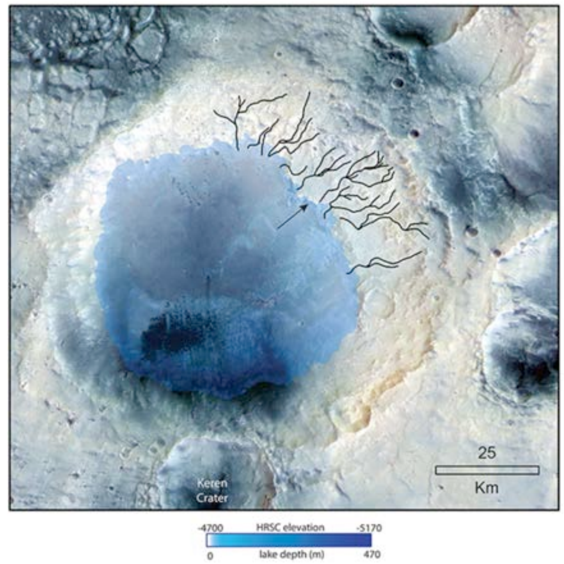

Figure 1: HRSC color image with HRSC DTM data colorized to show a proposed ancient lake level of -4700 m. Mapped channels are overlaid.

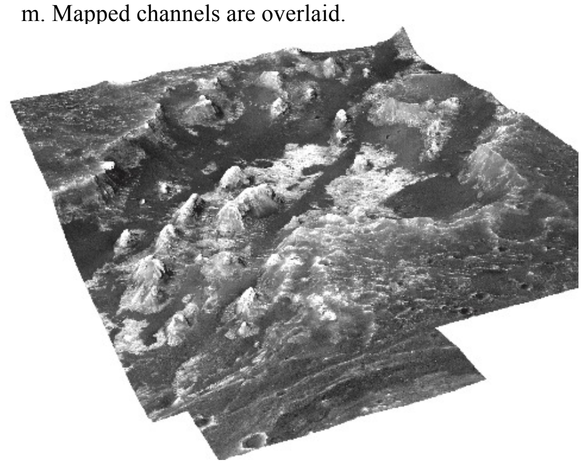

Figure 2: HiRISE DTM data (2x exaggeration) show a canyon eroded into the floor of McLaughlin Crater. Perspective is looking NE.

Serpentine is also detected [4], possibly indicating hydrothermal alteration of the ejecta.

Timing: Crater statistics [5-7] provide constraints on the timing of formation of McLaughlin, Keren and the lacustrine environment. It is not possible to count craters over the McLaughlin basin and its ejecta, because the ejecta are not preserved, but craters were counted over a circle (A = 1.26 x 10^4 km^2) centered on

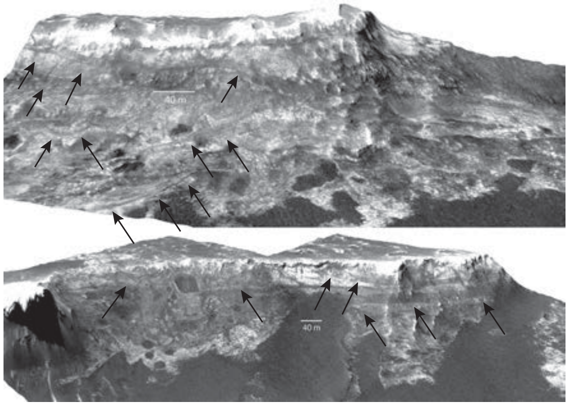

Figure 3: HiRISE DTM data (2x exaggeration) showing sedimentary structures in the southern wall of the canyon (north-facing wall). Arrows point to bedding exposed in the cliffs. Note the evidence for planar, and either convoluted or disrupted cross-bedding (arrows).

the crater center, extending out to ~1.5 crater radii from the crater rim, where ejecta once existed. The age of McLaughlin based on those crater statistics is 4 Ga or older. The age of Keren Crater was estimated based on two different counting areas. The first area, which includes only the detectable ejecta that can be traced directly to Keren, yields and age estimate of 3.7 Ga (Figure 4). Because many of those ejecta have been partially eroded, we counted an area corresponding to a circle centered on Keren, extending out to ~1.8 crater radii from the rim. Those statistics suggest an age of ~3.8 Ga for Keren Crater, thus the lake in McLaughlin must have existed either at the time of the Keren impact, or after (or both) in order to alter Keren's ejecta deposits. Finally, craters were counted within the dark-toned, McLaughlin crater-floor deposits in order to estimate age when the lake would have ceased to exist. These statistics suggest an age of ~3.6 Ga.

Implications for astrobiology: McLaughlin Crater formed at 4 Ga and had a lake at ~3.7-3.8 Ga, which ceased to exist by ~3.6 Ga. The lake may have been ephemeral or could have existed for up to 300 My. This lake was deeper (>400 m) and more voluminous (>1200 km^3) than >90% of Martian lakes, and likely fed by groundwater, as only small channels inside the basin fed the lake [8] that was neutral to alkaline (indicated by the presence of serpentine and carbonates).

Within the floor deposits of McLaughlin Crater are lobate features suggestive of northward transported flows. They follow the trend of the emplacement direction of ejecta from Keren Crater, but they reach a distance >5 crater radii from Keren's rim. These deposits compose the uppermost 10-100s of of meters of the floor deposits – those exposed in the canyon wall. These deposits likely formed through subaqueous flows (density currents, e.g. turbidites), though the question of whether they were generated by the Keren impact or some other seismic event is not known. Given the frequency of impacts during the Late Heavy Bombardment, generation of density currents by impact-related seismic activity should be expected and in this case, there is strong empirical evidence that they occurred. Such a process would have resulted in rapid burial of lake-floor materials, which is a critical consideration for the preservation potential of organic material that might have existed in the lake.

The age of the McLaughlin Crater lake corresponds to the timing of the earliest evidence for life on Earth – though on Earth, such evidence is significantly obfuscated by later metasomatism and metamorphism [9-10]. Unmetamorphosed clay-carbonate lacustrine sediments in McLaughlin Crater provide an important window into early Solar System chemical processes.

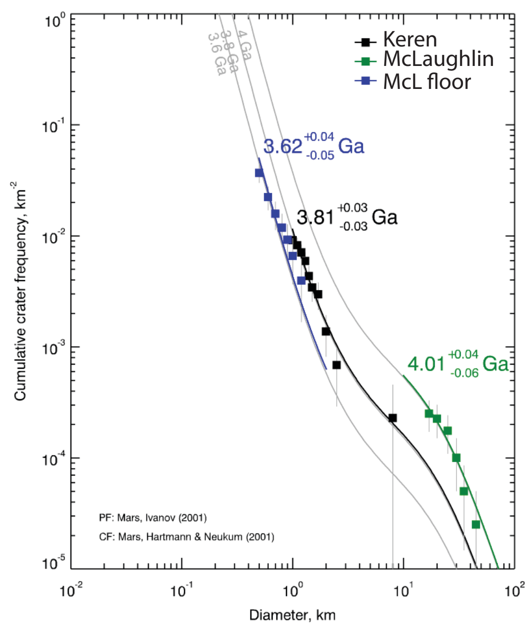

Figure 4: Cumulative crater size-frequency diagram and fitted isochrons for Keren and McLaughlin Craters.

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