GEOLOGIC HISTORY OF A PALEOLAKE IN KASHIRA CRATER, MARS AND A COMPARISON TO TERRESTRIAL LACUSTRINE MINERALOGY. T.A. Goudge[1], J.F. Mustard[1], and J.W. Head[1]. [1]Dept. of Geological Sciences, Box 1846, Brown University, Providence, RI 02912. Contact: Tim_Goudge@brown.edu

Introduction: Kashira crater is an ~60 km diameter crater located in the Margaritifer Terra region of Mars (**Fig. 1**), and is the site of an ancient open-basin lake, with both an observable inlet and outlet valley [1]. Recent work has shown that the Kashira crater paleolake basin is host to large, light-toned mounds that contain the alteration mineral kaolinite, and are identified as a massive sedimentary unit of possible lacustrine origin [2]. These mounds are embayed by a younger volcanic smooth plains unit [2,3], which was emplaced at ~3.66 Ga [3], subsequent to the end of valley network activity that fed the paleolake [4].

Here we present preliminary results of an analysis of the geology of Kashira crater and its associated deposits. The aim of this work is to test the hypothesis that the large kaolinite-bearing deposits in the Kashira crater paleolake are lacustrine in origin [2], by assessing the expected mineralogy of this paleolake from terrestrial analogs [e.g. 5].

Geologic Context: The Kashira crater paleolake is located in the Margaritifer Terra region of Mars, at 18.29 ^{o}S, 26.87 ^{o}W, and is fed by Samara Vallis [1], which is thought to have been formed by precipitation-recharged groundwater-sapping [6,7]. Samara Vallis also connects 9 open-basin lakes in an integrated lake chain, and Kashira crater is directly downstream of 5 of these open-basin lakes [1]. Both the groundwater source of the input flow and the fact that Kashira crater is at the terminal end of an integrated lake chain have important implications for the expected mineralogical composition of lacustrine sediments within Kashira crater, discussed further below.

Datasets Used: To assess the detailed morphology of the Kashira crater paleolake and its associated deposits, we have utilized CTX images at ~6m/pixel [8], HiRISE images at ~0.25 m/pixel [9], as well as MOLA gridded topography [10] and HRSC-derived stereo topography [11]. Compositions of the deposits associated with Kashira crater were analyzed using hyperspectral data from the CRISM instrument [12]. We have used both full resolution (~18 m/pixel) targeted CRISM observations, as well as along-track oversampled observations, which improve the spatial resolution of CRISM observations, allowing resolutions <10 m/pixel in the along-track direction [13].

Light-Toned Mounds: There are two main outcrops of light-toned deposits on the floor of Kashira crater (**Fig. 1**). These mounds cover a total areal extent of ~480 km^2, extend to a height of ~200-300 m above the crater floor, and are crosscut by linear to arcuate ridges (**Fig. 1B**). The deposits are also embayed by a volcanic resurfacing unit on the floor of the paleolake [2,3] (**Fig. 1B**), indicating that they must have formed prior to ~3.66 Ga [3]. While most of the light-toned deposits are covered in younger aeolian dunes (**Fig. 1B**), there are portions of the deposits that appear to show rough layering at the meter scale (**Fig. 1C**).

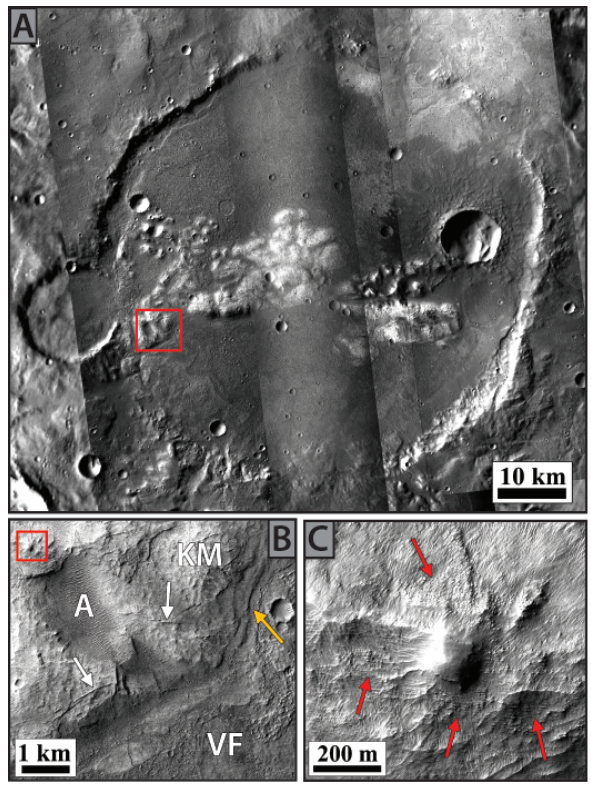

***Fig. 1**: Kashira crater. For all images, north is up **(A)** Context view. Note the two light-toned mound deposits (east and west) and the smooth, volcanic resurfacing unit [2,3]. Red box indicates the location of (B). Mosaic of CTX images B01_010091_1541, B02_010447_1528, B04_011370_1532 and B05_011581_1521 overlain on THEMIS daytime IR global mosaic. **(B)** Light-toned mounds in Kashira crater. KM indicates kaolinite-bearing mounds, A indicates aeolian dunes and VF indicates volcanic floor unit. White arrows indicate ridges, orange arrow indicates volcanic embayment of mounds and red box shows the location of (C). HiRISE image ESP_024965_1525 overlain on CTX image B01_010091_1541. **(C)** Possible meter scale layering in the light-toned mounds. Red arrows indicate possible exposed layers. HiRISE image ESP_024965_1525.*

CRISM observations over both the eastern and western light-toned deposits show that the deposits themselves have a spectral signature consistent with the presence of kaolinite [2] (**Fig. 2**). This identification is based on a sharp absorption at ~1.4 µm, a doublet absorption at ~2.2 µm, and a weak absorption at ~1.9 µm, which are caused by combinations and overtones of fundamental absorptions due to bound OH and H_2O in the mineral structure, as well as from the Al-OH bond [14]. While the mounds themselves have a signature indicative of kaolinite, the ridges that crosscut the mounds have a distinctly different spectral signature (**Fig. 2**), indicating that they are not compositionally related to the mounds they crosscut. The ridges have a

relatively featureless spectral signature with a possible very broad absorption centered near ~1 μm (**Fig. 2**).

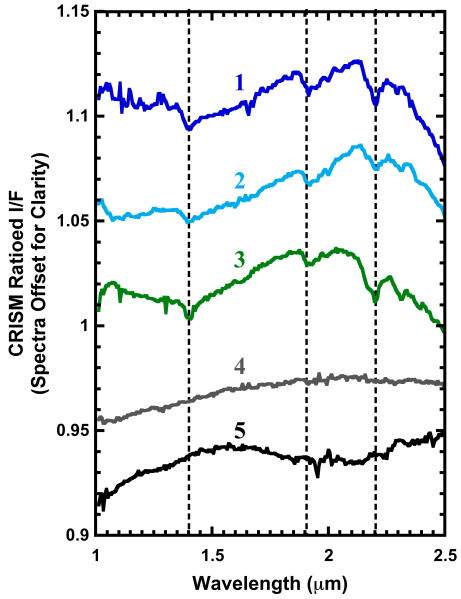

Fig. 2 *Characteristic spectral signatures from the Kashira crater paleolake basin. Spectra 1 and 2 are kaolinite from the eastern light-toned deposit, spectrum 3 is kaolinite from the western light-toned deposit, spectrum 4 is from the linear ridges, and spectrum 5 is from the volcanic floor unit. Plot shows ratioed CRISM I/F spectra from CRISM observations FRT0000C9DB (spectrum 3) and FRT0001EC17 (spectra 1, 2, 4 and 5). Dashed lines are at 1.4, 1.91 and 2.2 μm.*

Basin Floor Unit: Kashira crater is resurfaced by post-fluvial-activity volcanic flows [2], that embay the light-toned deposits (**Fig. 1B**), and have been dated to ~3.66 Ga [3]. CRISM data show that the floor unit has a spectral signature that is indicative of a mixture of olivine and pyroxene (**Fig. 2**), identified by crystal field absorptions centered at ~1 and 2 μm, which are due to Fe^{2+} in octahedral coordination [15-17].

Insights from Terrestrial Analogs: While the origin of the kaolinite-bearing deposits in Kashira crater is unclear, the fact remains that this crater was an open-basin lake early in the history of Mars. We can therefore test the hypothesis that these deposits formed by lacustrine deposition through a comparison to terrestrial analogs.

In terrestrial lacustrine systems, kaolinite deposits are typically composed of transported, detrital sediment in lakes with a heavily weathered watershed [e.g. 5], where kaolinite is expected to be a major component of the soil [18]. While the groundwater sapping source for the feeder valleys of this paleolake might suggest that large amounts of sediment were not delivered to the basin from the watershed, it is noted by [6,7] that there were likely periods of high sediment delivery in this region associated with large precipitation events. However, preliminary mapping of the composition of the watershed indicates no large exposures of kaolinite (or other alteration minerals), which is consistent with the globally sparse distribution of kaolinite [19], and would argue against a detrital origin for these kaolinite-bearing deposits.

Further constraints are provided by the observation that Kashira crater is sourced by precipitation-recharged, groundwater fed valleys [6,7] and that the basin is at the terminal end of an integrated lake chain [1]. Lacustrine sediments in groundwater fed lakes on Earth are typically rich in carbonates and other evaporites, due to the high dissolved ion content of the groundwater [e.g. 20,21], and so the similarly sourced Kashira crater paleolake might also be expected to have lacustrine sediments that are rich in evaporites. Additionally, the dissolved ion concentration of waters within terrestrial lakes increases along a lake chain due to mass accumulation [22,23]. Therefore, the lacustrine sediments in Kashira crater, near the terminal end of its lake chain [1], would be expected to be dominated by evaporites rather than phyllosilicates. While we will not speculate on possible explanations for the lack of observed evaporite minerals in the Kashira crater paleolake as is expected from terrestrial analogs, we do conclude that the massive kaolinite-bearing deposits do not have a mineralogy consistent with what is expected for lacustrine sediment in this paleolake [20-23].

Alternative Modes of Origin for the Light-Toned Deposits: Based on the comparison to terrestrial analogs, it does not appear that the ancient kaolinite-bearing deposits in Kashira crater are likely to be lacustrine. Therefore, other possible modes of origin for these deposits must be considered, including: (1) uplift of ancient, altered bedrock [19] associated with the formation of the Kashira impact crater; (2) top-down weathering of previously unaltered detrital material; and/or (3) hydrothermal alteration of previously deposited sediment related to the volcanic resurfacing of the basin floor and/or the formation of the linear ridges that crosscut the deposits. With further stratigraphic and compositional analyses of these deposits, we plan to test the plausibility of such hypotheses in order to constrain the mode of origin for these anomalous, large kaolinite-bearing deposits that formed early in martian history.

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