IDENTIFYING AUTHIGENIC MINERAL PHASES IN EAST-AFRICAN LAKE CORES: A PROXY FOR MARTIAN CONDITONS. K. M. Truss[1], L. J. McHenry[1], and G. R. L. Kodikara[1] [1]University of Wisconsin – Milwaukee Department of Geosciences, 3209 N. Maryland Ave., Milwaukee, WI 53211. kmtruss@uwm.edu

Introduction: On Earth, paleoenvironmental conditions can be interpreted from mineral assemblages of altered volcanics. Zeolites typically form through the alteration of volcanic glass in the presence of water at relatively low temperatures [1]. Authigenic mineral assemblages (zeolites and other phases) from terrestrial analogues give insight into possible Martian paleoclimate and hydrogeochemistry.

Paleolake Olduvai, in Tanzania, East Africa (Figure 1), was a Pleistocene closed-system saline-alkaline lake affected by volcanism from the nearby Ngorongoro volcanic highlands. The climate during deposition was warm and semi-arid. The mineral phases formed during tephra alteration in semi-arid closed-basin environment typically include clay minerals, zeolites (chabazite, erionite, clinopilolite, phillipsite), and even authigenic feldspars (K-feldspar or albite), with less altered intervals containing relict glass and the original volcanic mineral assemblage [2].

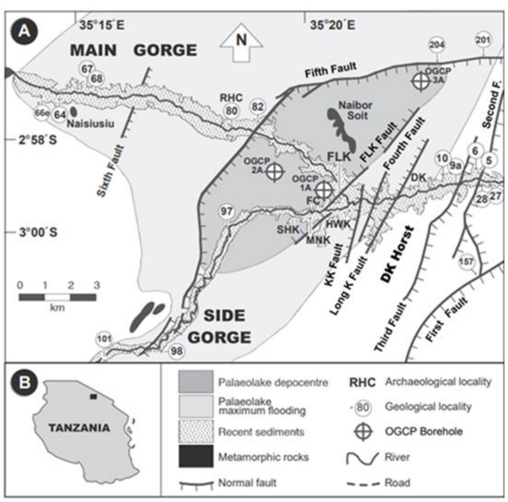

Figure 1: Location of Paleolake Olduvai, with OGCP 2014 borehole positions. Boreholes were positioned in the paleolake depocenter.

Volcanic deposits, of varied types and compositions, have been identified on Mars using orbiters and rovers (including Spirit, Curiosity, and more recently Perseverance). Various Martian craters have been interpreted as both open and closed-basin paleolakes [3]. Zeolites commonly form in closed saline-alkaline lakes [4], but [3] showed that even near-neutral and acidic solutions in closed-basin lakes filled with high-silica volcaniclastic materials could eventually produce zeolites like those in saline-alkaline lakes on Earth.

Multiple samples from a Martian paleolake, located in Gale crater, were analyzed by Curiosity's CheMin X-ray diffractometer (XRD). No evidence for zeolites was found [4]. The absence of zeolites in Gale crater could indicate that the lake waters were not sufficiently alkaline [5]. Other explanations for the absence of zeolites could be attributed to lake duration (too short to produce alteration minerals), zeolite stability (alteration minerals further altering into different assemblages), or detection limits (orbiter/rover methods applied not capable of detecting/mapping zeolites/other phases in low abundance) [4].

There is a lack of evidence (prominent spectral data) for alteration minerals (non-analcime zeolites and other phases) in closed basins on the Martian surface investigated using orbital spectroscopy [3,6]. While it is possible that they formed [3,7], zeolite units may be too thin for detection, buried by younger units, or their spectra may be masked by more spectrally dominant mineral phases like clays, or obscured by dust [4,7]. Paleolake basins are subject to erosion, deposition, and resurfacing, so it is important to use different mapping methods (combining image data sets) to extract more information from orbital data [4,7].

Ground investigations are also crucial to interpret orbital data [4]. Rock units identified as alkaline igneous rocks by Curiosity were a significant part of the Gale catchment [5], but some units were not observed in orbital data [7]. The possibility of zeolite (and other alteration) phases should not be ruled out, as important mineralogical and geochemical indicators of conditions/environment might be missed at the resolutions available to orbiters and even rovers.

Methods: Long sediment cores were collected from the Paleolake Olduvai depocenter by the Olduvai Gorge Coring Project (OGCP) in 2014. The cores record ~2 Ma, including rhyolitic volcanism in the Ngorongoro Formation (Fm) [8]. The cores, stored at the CSD in Minneapolis, MN, were sampled based on detailed core logs [8] in June 2022 for analyses at University of Wisconsin-Milwaukee. All samples studied were from volcanic units in the Ngorongoro Fm, which provides a control on original composition. Selected samples exhibit varying degrees of alteration (based in part on proximity to lake clay intervals). Mineral phases were identified XRD using a Bruker D2. Textural relationships and glass/mineral morphologies of pumice (for select samples) were identified by Scanning Electron Microscopy (SEM) using a Hitachi S-4800 SEM. Future work will characterize major and trace element geochemistry.

XRD Results: XRD results (Figure 2) show the degree of alteration. Fresher samples were largely located farther from the lake sediment interface and are dominated by volcanic glass (broad hump), with anorthoclase to sanidine feldspar and occasional quartz (original volcanic assemblage). Slightly altered samples may also contain clay minerals (smectites). Altered samples lack an amorphous glass hump and contain primary volcanic minerals (anorthoclase to sanidine, quartz) and authigenic minerals (zeolites erionite and chabazite and clay minerals). Intermediate alteration is seen as a combination of altered and unaltered patterns, with a small glass hump but also authigenic minerals.

SEM Results: SEM results (Figure 2) show the degree of alteration based on the amount of relict glass vs. authigenic minerals observed. Altered samples were dominated by zeolite minerals (chabazite and erionite) and clays. Relatively unaltered samples contained little to no zeolites and intermediate alteration yielded both relict glass textures and authigenic minerals (zeolites chabazite and erionite, and clays).

Discussion: Results indicate that XRD patterns do display varying degrees of alteration based on proximity to the lake sediment interface, but some important authigenic mineral phases (e.g. zeolite erionite) observed in SEM are below detection for XRD (Figure 3). Thus, samples that appear unaltered may still have some degree of alteration. This could potentially be a problem with rover detection, as important mineralogical and geochemical indicators of conditions/environments might be missed at the resolutions available to orbiters and even rovers.

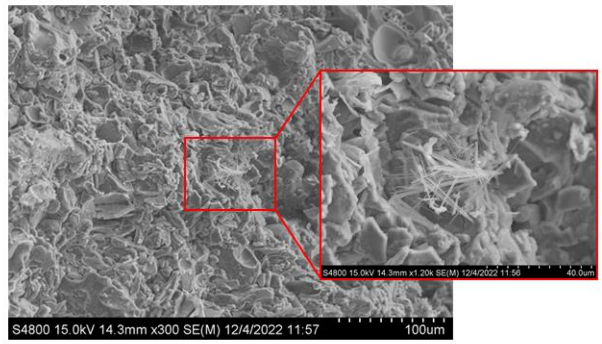

Figure 3: Zeolite (erionite) observed in SEM image (below detection in XRD).

The only rover capable of XRD analysis is Curiosity. Future sample return (cores drilled by Perseverance) is needed to apply tools like XRD and SEM. Because XRD can typically only detect minerals at ~5% or greater abundance, important environmental indicators (e.g. minor mineral phases formed during incipient alteration) may be missed if abundance is too low. Authigenic mineral phases not detected by XRD may be observed by SEM.

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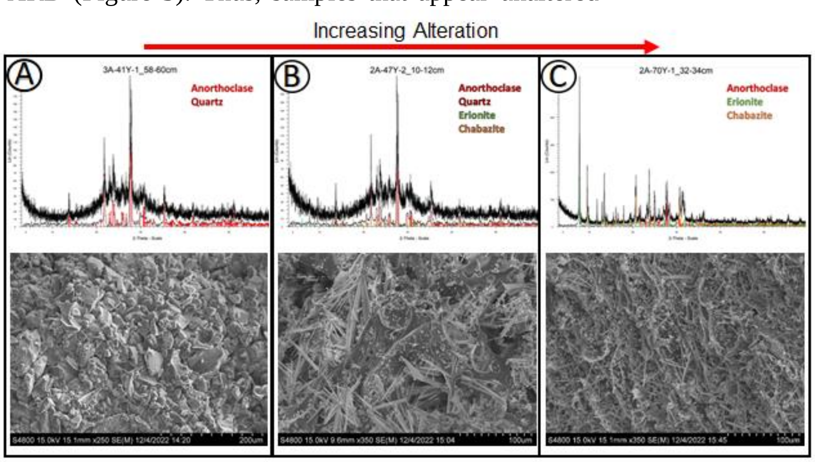

Figure 2: Varying degrees of alteration (XRD and SEM results) based on proximity to lake sediments in cores. A) Unaltered, amorphous hump, primary volcanic minerals (anorthoclase), and illite. B) Intermediate alteration, with slight amorphous hump and primary volcanic minerals (anorthoclase and quartz) and zeolites chabazite and erionite. C) Altered, no amorphous hump, primary volcanic anorthoclase, and zeolites erionite and chabazite.