OPEN-BASIN LAKES ON MARS: A STUDY OF MINERALOGY ALONG A PALEOLAKE CHAIN T.A. Goudge[1], J.F. Mustard[1], J.W. Head[1] and C.I. Fassett[1]. [1]Dept. of Geological Sciences, Box 1846, Brown University, Providence, RI 02912 Tim_Goudge@brown.edu

Introduction: Open-basin lakes (OBL) are defined as having both an observable input and output valley, implying ponding of water in the basin to at least the level of the outlet valley; OBLs have been well documented on the surface of Mars [1]. It has been shown that all of these open-basin lakes show resurfacing to some degree, however approximately 50% of the OBLs show some evidence for possible lacustrine deposits, containing deltas, layered deposits or polygonally fractured terrain [2]. The majority of OBLs (66%) are also contained in one of 37 discrete lake chains [1]. Here we present a study of the mineralogy of six OBLs (Fig. 1) connected in one such chain, named Chain J in [1] and referred to as thus in this work. In an attempt to constrain any aqueous alteration occurring in the OBLs during fluvial activity, the aim of this study is to assess whether there is any variation in mineralogy occurring along a single paleolake chain.

Geologic Context of Chain J: Chain J is located in the Margaritifer Terra region of Mars, an area influenced by ancient fluvial activity [e.g. 3,4]. Previous work in this area has shown evidence for distinct occurrences of a wide variety of aqueous minerals [e.g. 3-5]. Additionally it has been noted that much of the area surrounding Chain J has been subject to late-Noachian to Hesperian-aged lava flows [6,7].

The studied section of Chain J covers a distance of approximately 740 km from Lake 112 in the south to Lake 189 at the termination of the chain; however, not all of the lakes are connected sequentially (Fig. 1). This section of Chain J has two main source regions (inferred from local topography): one to the southeast starting at Lake 112 and one to the southwest starting at Lake 44. Both of these sources converge at Lake 168 which then flows into Lake 189. While these six OBLs contain deposits of possible lacustrine origin, all six also appear to be volcanically resurfaced to varying degrees [2].

Data Used and Methodology: Here we use data from the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) instrument aboard the Mars Reconnaissance Orbiter [8] to investigate the mineralogy of the Chain J OBLs. A combination of full resolution (18 m/pixel) hyperspectral data (Lake 112, 131 and 168) and low resolution (200 m/pixel) multispectral data (Lake 44, 189 and 196) were used [8].

Spectra from the six OBLs were obtained from regions of interest defined by spectral parameter maps [9-11]. In an attempt to reduce the amount of atmospheric and residual artifacts present in the spectra, spectra from the areas of interest were ratioed to spectra of featureless and spectrally neutral terrain within the same image. Additionally, evident spectral artifacts in the 1.65 and 2.00 µm region, from a band pass filter and a CO_2 absorption band respectively [10], have been masked in the spectra presented here.

Results: From the examination of several CRISM image cubes, it was seen that Lakes 44, 131, 189 and 196 are dominated by mafic mineral signatures (Fig. 2), with the common spectra for deposits within Lakes 44, 131 and 196 showing both a 1 and 2 µm absorption. The position of the 2 µm band near 2.3 µm indicates the presence of high-calcium pyroxene (HCP), although the width of the band implies a component of low-calcium pyroxene (LCP) as well. Additionally, the broad 1 µm band and inflection near 1.3 µm for Lake 131 strongly indicate the presence of olivine. Therefore, we conclude that an olivine-HCP rich material, with an LCP component, dominates the surficial deposits of these OBLs.

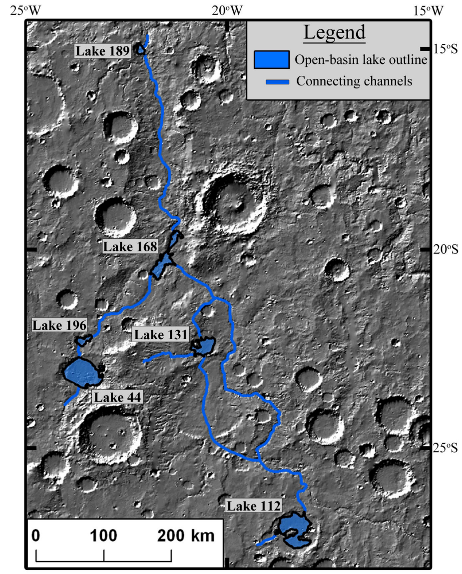

Figure 1 *Geologic context map of the six Chain J OBLs studied in this work. Background is MOLA hillshade [12].*

Hyperspectral data for Lakes 112 and 168 show prominent aqueous mineral signatures in addition to mafic mineral signatures similar to those discussed above. Two CRISM image cubes (FRT0000C9DB and FRT000103B2) examined for Lake 112 show spectra with distinct 1.4 µm, 1.9 µm and 2.2 µm absorptions in addition to a minor 2.3 µm absorption (Fig. 3a), consistent with laboratory spectra of kaolinite. Al-clay has previously been reported in this crater [13]; however, here we distinctly identify kaolinite. The kaolinite detected in Lake 112 is localized to light-toned mound deposits that extend across the entire basin. These deposits also contain mineralogically distinct ridges and are covered by small, distinct outcrops of a mafic-rich cap unit. Although the spectrum from these light-toned mounds is characteristic of kaolinite, the presence of a 2.3 µm absorption, although small, indicates that the kaolinite in these deposits is present with a mixture of Fe/Mg-smectite.

The CRISM image cube (FRT00017BA7) for Lake 168 shows spectra with a distinct 1.9 µm and 2.3 µm absorption and a weaker 1.4 µm absorption (Fig. 3b), matching laboratory spectra of the Fe/Mg-smectite group phyllosilicates. The Fe/Mg-smectite in Lake 168 is observed in light toned deposits that are stratigraphically below the mafic rich resurfacing unit.

Implications from Mafic Signatures in Chain J OBLs: The studied OBLs appear to be resurfaced by post-fluvial-activity volcanic flows [2], a hypothesis that is supported by the identification of dominant mafic mineral signatures within the OBLs presented here. Furthermore, it can be inferred that the volcanic flows that resurfaced these OBLs are dominated by an olivine-HCP mineralogy; however, other mafic minerals are likely to be present within this material and their presence cannot be ruled out by any of the work presented here. An olivine-HCP signature is typical of Hesperian volcanism [14], and so we interpret these volcanic flows to be Hesperian in age. This is consistent with the stratigraphic mapping completed in this area, which suggests Noachian to Hesperian-aged lava flows [6,7].

Although volcanism is the most probable explanation for the mafic mineral signatures observed here, it is also possible that some other process can explain the presence of mafic minerals. One such explanation is that these signatures are indicative of sedimentary or aeolian deposits rich in Olivine and HCP. It is well known that mafic minerals form a major component of the Martian crust [e.g. 14-16], and so it is possible that mafic rich detritus from the crust was deposited in these OBLs due to fluvial or aeolian activity. Although such an explanation is possible, due to features that appear to indicate embayment by volcanic flows [2], a volcanic origin for the observed mafic minerals is much more likely.

Implications from Phyllosilicate Signatures in Chain J OBLs: The detection of two different phyllosilicate minerals, Fe/Mg-smectite and kaolinite, within two separate Chain J OBLs is very interesting and has several possible implications. Although the phyllosilicate outcrops in these two OBLs are different, they both appear to be older than the volcanic resurfacing discussed above based on stratigraphic relationships. The Lake 112 kaolinite occurs in mounds that show evidence of being embayed by volcanic flows. Additionally, the linear ridges present on these mounds are embayed by the volcanic resurfacing material, suggesting an age that is pre-volcanic resurfacing. The Lake 168 Fe/Mg-smectite is in outcrops that lie stratigraphically below the volcanic resurfacing layer, again suggesting an older age.

In addition to understanding the age of the phyllosilicate deposits, it is important to understand their origin. An impact crater basin defines Lake 112. It is therefore possible that the kaolinite observed here is related to uplifted basement material caused by the impact process. This hypothesis has two end-members: (1) the uplifted basement material was primary crustal material with a mafic mineralogy, which was then altered to kaolinite through some aqueous process, possibly the fluvial activity that formed the OBL; or (2) the basement material was altered to kaolinite prior to uplift, in which case the OBL fluvial activity would not have been the cause for the primary alteration. Alternatively, it is possible that these light-toned mounds represent primary sedimentary deposits associated with the OBL fluvial activity; however, due to the presence of linear ridges and a mafic rich cap rock that appear similar to other examples of uplifted basement rock [17], we argue that an uplifted source of origin is more likely for the deposits observed here.

The phyllosilicates in Lake 168 are likely to have a less complicated history as Lake 168 is not defined by an impact basin, but rather a local topographic low [1]. As this is the case, the Fe/Mg-smectite underlying the volcanic resurfacing material in Lake 168 is either sedimentary in nature or phyllosilicate-rich Noachian basement [18].

References: [1] Fassett, C. and Head, J. (2008) *Icarus*. 198: 37 [2] Goudge, T. et al. (2011) *LPSC XLII* Abstract 2131 [3] Milliken, R. et al. (2007) *AGU Fall Meeting*. Abstract P12A-02 [4] Murchie, S. et al. (2009) *JGR*. 114: E00D06 [5] Milliken, R. et al. (2008) *Geology*. 36: 847 [6] Scott, D. and Tanaka, K., (1986). *USGS Misc. Inv. Ser*., Map I-1802-A [7] Tanaka, K. (1986) *JGR*. 91:E139-E158 [8] Murchie, S., et al. (2007) *JGR*. 112: E05S03 [9] Pelkey, S. et al. (2007) *JGR* 112:E08S14 [10] Ehlmann, B. et al. (2009) *JGR* 114:E00D08 [11] Salvatore, M. et al. (2010) *JGR* 115:E07005 [12] Smith, D. et al. (2001) *JGR* 106:23,689 [13] Wray, J., et al. (2009) *Geology*. 37: 1043 [14] Mustard, J., et al. (2005) *Science*. 307: 1594 [15] Bibring, J.P., et al. (2005) *Science*. 307: 1576 [16] Bandfield, J., et al. (2002) *JGR*. 107:E65042 [17] Head, J. and Mustard, J. (2006) *Meteorics & Planet. Sci*.. 41:1675 [18] Poulet, F., et al. (2005) *Nature*. 438:623 [19] Murchie, S. et al. (2006) *NASA PDS* MRO-M-CRISM-4-SPECLIB-v1.0

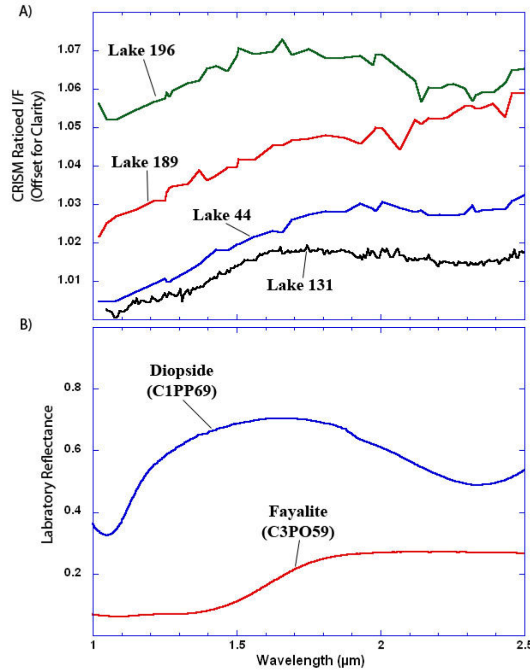

Figure 2 *A) CRISM ratioed spectra for the four Chain J OBLs with dominant mafic mineral signatures. Spectra are from CRISM images MSP00005B25, MSP000058D2, FRT0000AC56 and MSP0000CFB3 for Lakes 189, 44, 131 and 196 respectively. B) CRISM Relab library reflectance spectra for diopside (HCP) and fayalite (olivine) [19]*

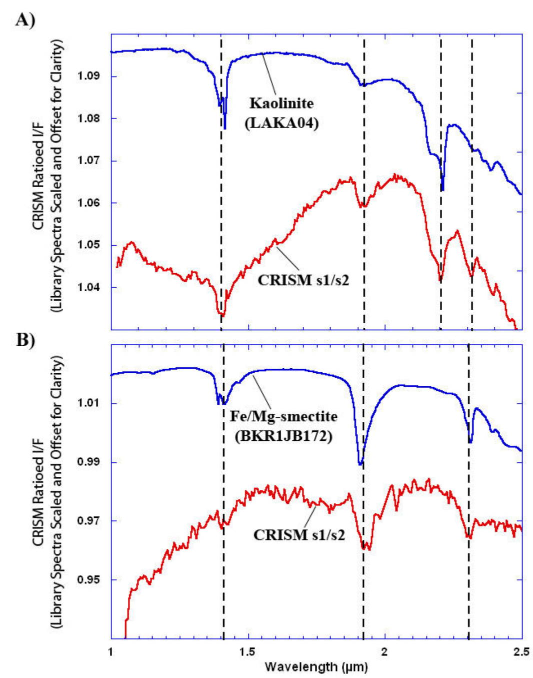

Figure 3 *A) CRISM ratioed spectrum from Lake 112 (FRT0000C9DB) compared with a kaolinite CRISM Relab library spectrum (scaled and offset for clarity) [19]. Dashed lines are located at 1.41 μm, 1.92 μm, 2.20 μm and 2.31 μm. B) CRISM ratioed spectrum from Lake 168 (FRT00017BA7) compared with an Fe/Mg-smectite CRISM Relab library spectra (scaled and offset for clarity) [19]. Dashed lines are located at 1.42 μm, 1.92 μm, 2.31 μm.*