A COMPREHENSIVE LOOK AT MARTIAN OPEN-BASIN LAKE MORPHOLOGY T.A. Goudge[1], J.W. Head[1], J.F. Mustard[1] and C.I. Fassett[1]. [1]Dept. of Geological Sciences, Box 1846, Brown University, Providence, RI 02912 Tim_Goudge@brown.edu

Summary: Deposits associated with 224 open-basin lakes (OBLs) are classified based on: (1) whether they show evidence for lacustrine deposits; and (2) what post-fluvial-activity processes may have resurfaced them. 104 OBLs show evidence for possible lacustrine deposits that may display primary mineralogy; however, all 224 examined OBLs appear to have been resurfaced to some degree, which may spectrally obscure primary sedimentary minerals.

Introduction: A more active hydrologic cycle on the surface of Mars is frequently called on to explain features observed from orbital images that appear to be related to fluvial activity [e.g. 1-5]. Of those features regarded as fluvially-related in nature, paleolakes are amongst the most interesting, as they imply a large amount of surface water and are prime candidates for recording past habitable conditions [5]. Paleolakes on Mars have been well catalogued in the past, and can be divided into two major categories: closed-basin lakes and open-basin lakes [e.g. 2, 4, 5]. Closed-basin lakes have only a visible inlet, and are inferred to be paleolakes due to observed morphology of the surrounding terrain (i.e. incised inlet valleys) and the associated deposits [2]. Open-basin lakes (OBLs) on the other hand are classified as having both an observable inlet and outlet valley, meaning the water in the basin must have ponded to at least the level of the outlet valley before breaching and overflowing the basin [2, 5]. The presence of OBLs has very important implications as it requires a period of sustained fluvial activity on the surface of Mars [5]. OBLs have been well catalogued, and over 200 have been observed in the ancient Noachian and Hesperian highlands [5]. Here we present a comprehensive study of the characteristics and morphology of the deposits associated with these OBLs in an attempt to help constrain the history of the fluvial activity that formed these paleolakes.

Datasets Used and Methodology: In order to examine the morphology of the OBLs a combination of ~6 m/pixel imagery from the Context Camera (CTX) instrument aboard the Mars Reconnaissance Orbiter spacecraft [6] and ~19 m/pixel imagery from the visible imager portion of the Thermal Emission Imaging System (THEMIS) instrument aboard the Mars Odyssey spacecraft was used [7]. Using these data, each OBL was categorized based on two main aspects of their morphology: (1) what type of process appears to have been the most recent cause of OBL resurfacing; and (2) whether the OBL shows evidence for deposits that appear to be lacustrine in nature.

Here, we assessed three types of resurfacing processes: glacial, volcanic and unknown. OBLs classified as being glacially resurfaced typically exhibit lobate floor texture and lobate ridges [8] (Fig. 1a). These ridges are differentiated from paleo-shorelines based on their lobate morphology that is not constrained by pre-existing topography, as would be expected for shorelines. The glacially resurfaced OBLs also typically exhibit ring mold craters, evidence for past subsurface ice deposits [9] (Fig. 1a). OBLs classified as being volcanically resurfaced exhibit textural evidence for volcanic flow deposits such as lobate margins, smooth plains deposits that embay older floor deposits and wrinkle ridges (Fig. 1b). OBLs left with an unknown process of resurfacing show clear evidence

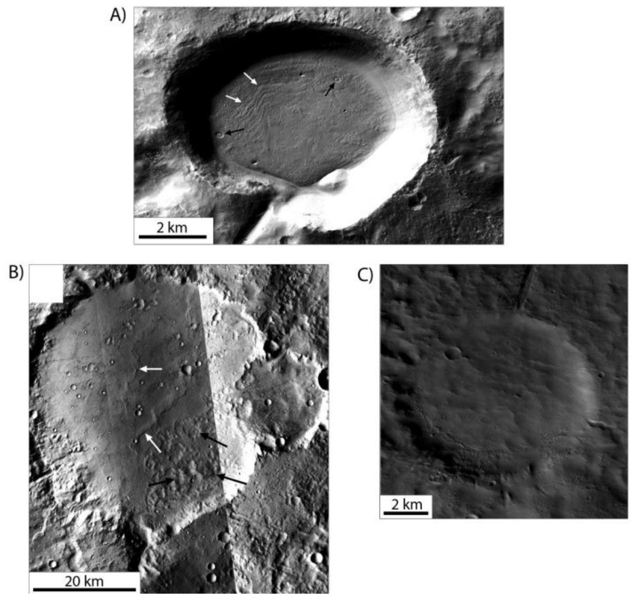

Figure 1 *A) Glacially resurfaced OBL. Lake 286 in OBL catalogue [1], CTX Image P15_006798_1405_XI_39S103W. Black arrows indicate ring mold craters, white arrows indicate glacial flow features. B) Volcanically resurfaced OBL. Lake 96 in OBL catalogue [1], CTX Images B18_016507_1714_XI_08S224W, B06_011839_1743_XN_05S224W, and B04_011272_1736_XN_06S224W. White arrows indicate wrinkle ridges and black arrows indicate embayment of floor deposits C) OBL with unknown process of resurfacing. Lake 274 in OBL catalogue [1]. CTX Image P06_003312_2135_XI_33N338W*

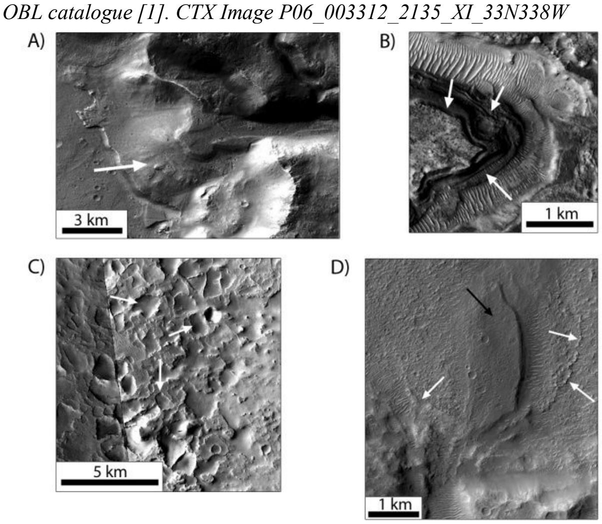

Figure 2 *A) Pristine delta deposit. Lake 182 in OBL catalogue [1], CTX Image P15_006798_1405_XI_39S103W. White arrow indicates delta. B) OBL showing sedimentary layering. Lake 204 in OBL catalogue [1], CTX Image P03_002216_2079_XI_27N292W. White arrows indicate distinct layers. C) OBL showing polygonal fracturing. Lake 62 in OBL catalogue [1], CTX Images P18_008032_1983_XN_18N324W and P13_006173_1979_XN_17N325W, White arrows indicate mantled polygons thought to be due to desiccation D) OBL showing eroded deltaic deposit. Lake 196 in OBL catalogue [1], HiRISE Image PSP_010434_1575. Black arrow indicates remains of deltaic deposit, white arrows indicate eroded delta outline.*

for post-fluvial activity denudation or modification (Fig. 1c), but show no single distinct resurfacing process.

Additionally, OBLs were classified as showing evidence for possible lacustrine deposits if they exhibited morphologic evidence for one of three main deposit types: (1) deltaic deposits; (2) layered deposits; and (3) polygonally fractured terrain possibly due to desiccation (Figs. 2a-c respectively). Deltaic deposits have been observed in numerous other open-basin lakes [e.g. 2,10,11] and provide strong evidence for fluvial activity. Although relatively pristine deltaic deposits can be observed on the surface of Mars [e.g. 10,11] (Fig. 2a), most fan deposits observed in the OBLs showed some degree of weathering and/or resurfacing (Fig. 2d). Similarly, most layered deposits show some degree of weathering and/or resurfacing (by all three types mentioned above) and are typically found only in isolated outcrops of otherwise resurfaced OBLs (Fig. 2b). As polygonally fractured terrain is a very broad morphologic classification that may not be related to fluvial activity, polygonal fractures were only considered as evidence for lacustrine deposits if they have sizes >75 m, which suggests desiccation as the most likely method of formation over thermal contraction [12]

It should be noted that the classification of being resurfaced and having lacustrine deposits are not mutually exclusive, as an OBL can show both evidence for resurfacing and lacustrine deposits.

Results: From the 224 OBLs examined [5], 104 show some evidence for lacustrine deposits, 98 show no evidence for lacustrine deposits and 22 have a basin definition, image quality or image coverage that is too poor to accurately use for classification; however, all of the classified OBLs do show some evidence for at least partial resurfacing. Discounting the 22 OBLs that are unclassified, 51.5% of the OBL catalogue shows some evidence for lacustrine deposits. A further breakdown of the observed statistics can be seen in Fig. 3.

Discussion and Future Work: Although all of the examined OBLs do show some degree of resurfacing, it is clear that the slight majority of OBLs show some evidence for lacustrine deposits with possible exposure of primary sedimentary minerals. These lacustrine deposits are a very exciting area of study as they represent some of the best areas for recording habitable conditions on the surface of Mars [5, 14].

Additionally, some of these candidate lacustrine deposits have been shown to contain a large variety of aqueous alteration minerals [e.g. 13-15], which are important as they are frequently the best materials for preserving organic matter [14, 16, 17]. Therefore, it is very important to understand the nature of the aqueous alteration minerals associated with OBL deposits, i.e. allochthonous vs. autochthonous. Although there are a large number of OBLs with possible lacustrine deposits (104), there are very few OBLs (~16) that show deposits with aqueous alteration minerals. This represents two possible scenarios: (1) resurfacing materials, such as volcanic flows or aeolian dunes, are spectrally obscuring aqueous minerals within the lacustrine deposits; or (2) the majority of OBL lacustrine deposits are composed of some material besides aqueous alteration minerals, such as unaltered crustal material. Determining which of these two endmembers is dominating the OBL deposits observed here is a very important area of future work and will help constrain the origin of the observed aqueous alteration minerals.

It is also important to note that only a handful of OBLs appear to be resurfaced by glacial activity, all of which are confined to mid to high-latitudes (±35°), consistent with the latitude dependence of these types of ice-related deposits [18].

Furthermore, it is clear that a large number (45.54%) of OBLs appear to be resurfaced by volcanism based on textural evidence. These OBLs appear to show some concentration around Elysium Mons and Olympus Mons, which may be possible sources of the volcanic flows. One important area of future work is determining the timing of the volcanic resurfacing based on crater counting. This will help to constrain the timing of the fluvial activity that defines the OBLs.

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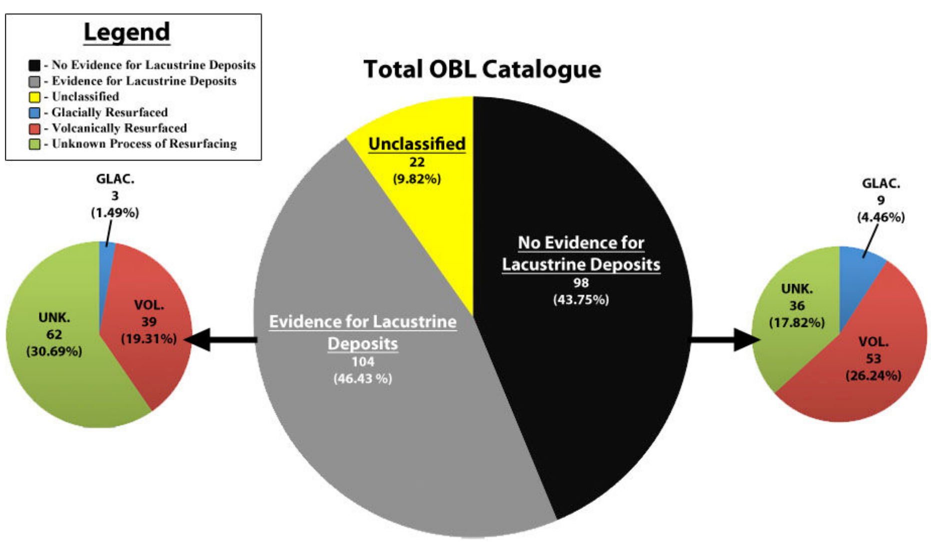

Figure 3 *Pie charts showing the statistical breakdown of classified OBLs.*