THE OUTLETS OF GLACIAL LAKE AGASSIZ: POSSIBLE TERRESTRIAL ANALOGS FOR CATASTROPHIC DRAINAGE SYSTEMS ON MARS. D. W. Leverington[1] and R. A. Craddock[1], [1]Center for Earth and Planetary Studies, National Air and Space Museum, Smithsonian Institution, Washington, DC 20560-0315 (leveringtond@nasm.si.edu).

Introduction: Glacial Lake Agassiz was the largest of the proglacial lakes that formed in North America during the last deglaciation, as continental drainage was impounded against the retreating southern margin of the Laurentide Ice Sheet [1]. The size of Lake Agassiz varied considerably during its 4000-year history, driven by glacio-isostatic rebound, changing ice-sheet configurations, and the opening and closing of drainage routes [2][3] (Fig.1). Recent computer-based reconstructions of the bathymetry of Lake Agassiz show that, at its largest, the lake had a volume as much as seven times that of all the modern Great Lakes combined [4]. At numerous times in the history of Lake Agassiz, extremely large volumes of water (commonly between about 1000 and 9500 km^3, and in one instance as much as 163,000 km^3 [4][5]) were catastrophically released when lake levels dropped after lower outlets were deglaciated.

An understanding of the processes that contributed to the evolution of Lake Agassiz through time, and of the nature of preserved geomorphic features of Lake Agassiz (beach deposits, wave-cut escarpments, and overflow routes), forms the basis for their use as possible terrestrial analogs for processes and features related to drainage systems and hypothetical water bodies of early Mars. The objective of the present research is to use the results of recent and ongoing topographic modeling of Lake Agassiz and its outlet systems to further understand its past, and to apply this understanding toward investigations regarding surficial hydrological processes of early Mars.

The Evolution of Lake Agassiz Through Time: The history of Lake Agassiz can be divided into five major phases: Lockhart, Moorhead, Emerson, Nipigon, and Ojibway [6][7]. During the Lockhart Phase (about 11,700 to 11,000 ^{14}C yr B.P.), drainage was south through the southern outlet to the Gulf of Mexico, via the Mississippi River valley [2]. The largest stages of Lake Agassiz at this time probably had surface areas and volumes no greater than about 140,000 km^2 and 11,000 km^3, respectively [5]. During the subsequent Moorhead Phase (about 11,000 to 10,100 ^{14}C yr B.P.), drainage was east to the Great Lakes region, via the Kaministikwia route to Lake Superior [7][8], and the lake became as large as about 190,000 km^2 and 20,000 km^3 [5]. During the Emerson Phase (about 10,100 to 9400 ^{14}C yr B.P.), drainage was at times northwest to the Arctic Ocean, south to the Gulf of Mexico, and east to the Great Lakes region. During this phase, the largest stages of the lake probably had surface areas and volumes of about 260,000 km^2, and 23,000 km^3 [5]. By the Nipigon Phase (about 9400 to 8200 ^{14}C yr B.P.), the southern and northwestern outlets had been abandoned, and drainage was east through progressively lower outlets to the Nipigon Basin. The waters of Lake Agassiz gradually moved northward during this phase, as they followed the receding southern margin of the Laurentide Ice Sheet. During the Ojibway Phase (about 8200 to 7700 ^{14}C yr B.P.), Lake Agassiz merged with glacial Lake Ojibway to the east, forming a very large water body (with an area and volume of as much as 850,000 km^2 and 163,000 km^3, respectively [4]) that first drained south into the Ottawa River valley, and then catastrophically drained northward into the Tyrrell Sea (modern Hudson Bay), following collapse of the stagnant remains of the confining ice margin [9][10][11].

The Eastern Outlets to the Nipigon Basin: During the Nipigon Phase, drainage from Lake Agassiz was through increasingly northern (and lower) outlets into the Nipigon Basin; the waters that flowed through these outlets ultimately flowed into the Atlantic Ocean via the Great Lakes region and St. Lawrence River valley [2][7]. The outlets into the Nipigon Basin have been divided into five main channel complexes: from south to north, the Kaiashk, Kopka, Pillar, Armstrong, and Pikitigushi [7] (Fig.2); each of these channel systems was cut into Archean granite and Proterozoic diabase of the Canadian Shield. The initial deglaciation and opening of each new outlet into the Nipigon Basin was accompanied by a rapid drop in lake level and a corresponding catastrophic release of water from Lake Agassiz. The largest of these releases into the Nipigon Basin is estimated to have had a volume of about 7000 km^3 [4][5]. Today, extensive cobble and boulder lags are found in river valleys that once acted as eastern-outlet channels for massive outbursts from Lake Agassiz [7].

The Collapse of the Northern Ice Margin and the Demise of Lake Agassiz: Catastrophic northward drainage of lake waters into the Tyrrell Sea is believed to have followed the collapse of the Laurentide ice margin [9]. This release, which may have been initiated in the vicinity of modern James Bay [9], is estimated to have had a total volume of about 163,000 km^3 [4]. If this release took place in about one year, it would have involved an estimated average release rate of about 5.2 sverdrups (where 1 Sv = 10^6 m^3 s^{-1}) [12].

Potential Martian Analogs and Current Research: The complex history of Lake Agassiz involved a variety of processes and landforms that may prove to be useful analogs for Mars. For example, on Mars, discharge through Kasei Valles must have been far greater than that which can be explained by groundwater discharge through a confined aquifer [13]. Although water may have been ponded upslope from Kasei Valles in Echus Chasma [13], the mechanism for releasing this water remains unclear. Using lessons learned from Lake Agassiz, we are pursuing the possibility that ice damming occurred in Echus Chasma, with data from Mars Global Surveyor being used to investigate for potential shorelines and to quantitatively model possible hydrologic scenarios. The final massive release from Lake Agassiz is currently being evaluated as a basis for understanding aspects of ponding and catastrophic outbursts on Mars.

Overflow systems and strandlines associated with the various stages of Lake Agassiz are well preserved in many places [6][7][8]. Understanding the morphology and modification history of these features may help to better understand similar features in the northern hemisphere of Mars [14][15][16], and may compel the re-evaluation of high-resolution MOC images [17]. Computational and field activities in this regard are presently focused on the examination and modeling of features related to the eastern outlets of Lake Agassiz.

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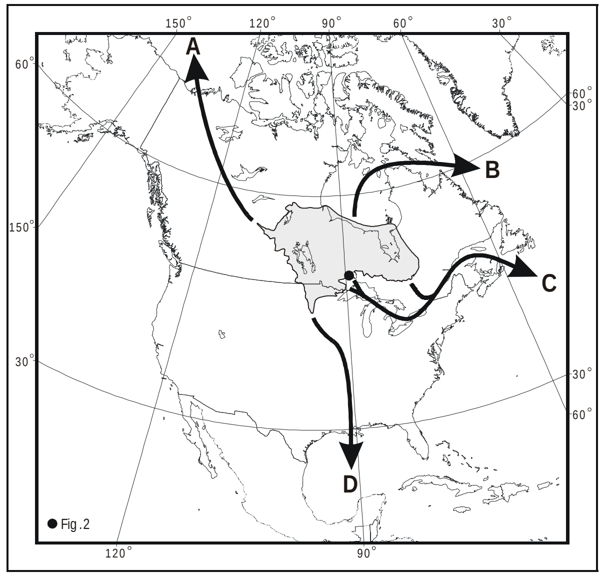

Figure 1. Map of North America showing the total extent of Lake Agassiz over its 4000-year history (shaded) [12]. Primary routes of overflow are labeled: *A*, Mackenzie River valley to the Arctic Ocean; *B*, Hudson Bay to the North Atlantic Ocean; *C*, St. Lawrence River valley to the Atlantic Ocean; *D*, Mississippi River valley to the Gulf of Mexico.

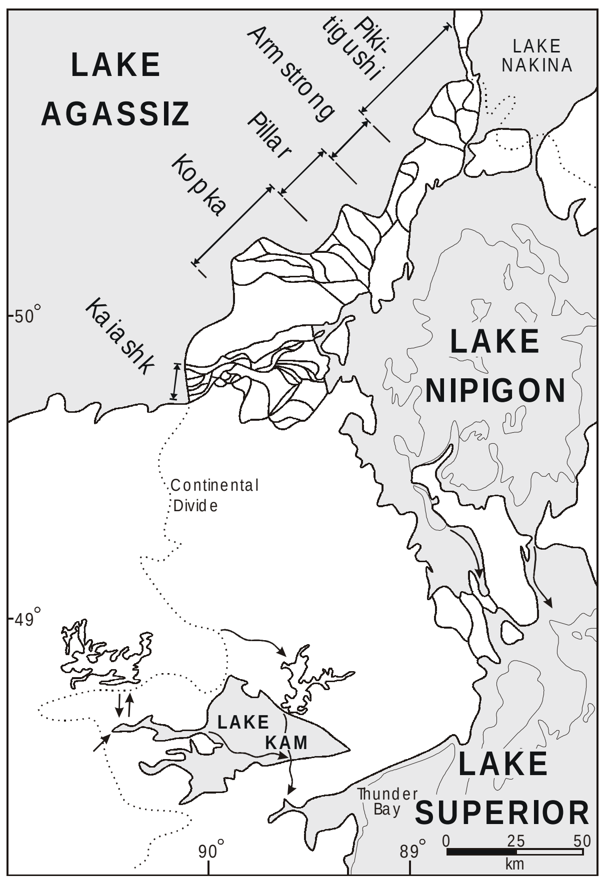

Figure 2. The eastern outlets to the Nipigon Basin [7].