GEOMORPHIC INVESTIGATIONS OF MARTIAN OUTFLOW CHANNELS. J. W. Rice[1] and V. R. Baker[2], [1]Planetary Science Institute, 1700 E. Ft. Lowell Rd., Suite 106, Tucson, AZ 85719 (rice@psi.edu) [2]Dept of Hydrology and Water Resources, Harshbarger Bldg Rm 122, PO Box 210011, University of Arizona, Tucson, AZ 85721.

Introduction: During the past several decades numerous scenarios have been proposed for the creation of the Martian outflow channels ranging from volcanic dikes followed by groundwater release, lava flows, debris flows, glaciers, and explosive carbon dioxide outgassing. Today most workers favor water as the major outflow channel forming medium, however considerable uncertainty remains about the amount of sediment involved (e.g., sediment-charged floods or water-rich debris flows). The general consensus is that the Martian outflow channels were formed by catastrophic floods analogous to the megaflood landscapes of the Channeled Scabland in Washington State. However, this result is based primarily on the presence of a suite of erosional landforms (cataracts, longitudinal grooves, streamlined hills). To date no clear Martian flood deposits or bed forms have been identified associated with the outflow channels.

Catastrophic flood flows produce macroforms (scale controlled by channel width) through the erosion of rock and sediment and by deposition (bars). Some examples of erosional macroforms are channel anastomosis, channels with low sinuosity, high channel width-depth ratios, and large scale streamlined residual hills, and scoured surfaces. Examples of depositional macroforms are pendant bars, expansion bars, eddy bars and longitudinal bars.

Catastrophic flood flows also produce mesoforms (*scale controlled by channel depth*) which are also erosional and depositional. Some examples of erosional mesoforms are longitudinal grooves, cataracts, and inner channels. Depositional mesoforms include large scale transverse ripples, pendant forms and slackwater deposits.

Terrestrial catastrophic flood flows typically display macroforms and their superimposed mesoforms. This association most likely results from the nature of the flood hydrograph from catastrophic floods. The hydrograph of most rivers shows a long recession. Depositional bedforms stable at high stage (mesoforms) are washed out, and postflood surfaces show only the highly stable macroforms such as alternate bars. However, some catastrophic floods, such as those responsible for the Channeled Scabland, undergo an abrupt cessation of flood discharge which results in the preservation of many of the mesoforms, especially those located on higher elevation bar surfaces.

Our preliminary photogeologic analysis of the high resolution images indicates that these channels have a rich inventory of erosional and depositional landforms. HiRISE imagery of the Martian outflow channels does show morphological differences, albeit subtle in most cases, between the channel floors and the surrounding regions unaffected by the floods.

Chryse/Acidalia "Rippled" Plains

The most obvious morphologic signature associated with the unconfined outwash regions (basin ward of channel mouths) of the outflow channels is a rippled texture on the plains. This ripple-like texture lies transverse to flow direction. This texture is commonly observed in regions affected by the Ares and Tiu Valles floods in Chryse/Acidalia Planitia. Malin and Edgett (1) noted that the outflow channel surfaces in Chryse and Acidalia Planitia were typically pitted and had a rippled texture. They were not really certain what to make of this texture in terms of flood processes. Here we propose that this rippled texture is the morphologic signature of fluvial bedforms (antidunes or transverse ribs) of the last floods to flow through these regions of Chryse/Acidalia Planitia.

Antidunes, Transverse Ribs (Relict Antidunes) and Critical Flow

Large-scale 'dune-like' transverse ridges have been described from a variety of locations on Earth using satellite, aerial photography and ground surveys (2,3). HiRISE and MOC images of Mars shows transverse ridges that may be analogous to dune-like bedforms on Earth (4,5). Although sometimes called 'ripples' in the older literature, given the scale of these bedforms and the high turbulence levels of megafloods on Earth it is reasonable to conclude that these features are not ripples, but rather they are most likely dunes or antidunes. Both dunes and antidunes develop by erosion of the underlying sediments within the troughs between bedforms and deposition of sediments to form the bedforms (3). Preservation of antidunes indicates rapid recession of flood flow (6).

Ridged Plains near Tiu Valles

We have conducted some preliminary quantitative studies of a mesoscale bedforms (ridges), observed on the rippled plains near the mouth of the Tiu Valles outwash region in Chryse Planitia. We propose that features are antidunes/transverse ribs based on the morphometric analysis. We measured these features and found that the transverse ribs average wavelength, is 53.6 m. The equations developed by (7) were then applied to these features in order to calculate and help constrain the velocity, depth and Froude number of the floods. The following results were obtained by using these equations: mean velocity of 6 m/s; flow depths ranging from a minimum of 5.5 m to a maximum of 19 m; and Froude numbers ranging from 0.7 to 1.3, which is the range associated with antidune flow. The transverse ribs measured here were most likely deposited during the last floods through this region.

Modrudalur, Iceland

We measured a series of alternating ridges, located on a large open plain, oriented perpendicular to the Jokulsa´ a´ Fjollum paleoflood flow direction near Modrudalur, NE Iceland. Rice et al. (4) determined that these ridges are transverse ribs capped by boulders up to 1.8 m diameter and have their a-axis (longest axis) predominately aligned parallel to flow. The fines located on the ribs are smaller and rounder than the fines located in the inter-rib regions. These features have an average wavelength of 27 m, width of 13 m, and height of 0.84m.The Modrudalur field site is located 150 km downstream from the glacial outburst flood breakout point at Vatnajokull. It is worth noting that the context of this region provides a reasonable analog to the vast open outwash plains of Chryse/Acidalia Plainita located downstream from the mouths of the Martian outflow channels.

Koster (7) demonstrated that the origin of transverse ribs are antidunes because they have a strong tendency for average width of ribs to be slightly less than half of the mean wavelength. This relationship is predictable assuming an antidune origin for the transverse ribs. The ribs we measured follow this relationship quite closely. Rice et al., (4) obtained the following results for the floods: mean velocity of 6.4 m/s; flow depths ranging from a minimum of 2.5 m to a maximum of 8.5 m; and Froude numbers ranging from 0.7 to 1.2, which is the range associated with natural antidune flow. Alho et al., (8) reconstructed this same flood using HEC-RAS hydraulic modelling and HEC-GeoRAS flood mapping techniques with a Digital Elevation Model (DEM) derived from ERS-InSAR data and field-based wash limit evidence. Their results compare quite closely for mean flood depth (3m to 5m) and mean velocity (5m/s to 6 m/s) to what we calculated (see above) using Koster's method (7). This flood had a peak discharge on the order of 0.9 x 10^6 m^3/s (8).

These examples mentioned above illustrate the potential for understanding palaeoflow hydraulics from the location, form, stratigraphy and sedimentology of megaflood landforms on Earth and Mars. This information will allow us to reconstruct the paleoflood depths and velocities for the outwash plains of Chryse/Acidlalia Planitia. This information when combined with our hydraulic modeling task for the five outflow channels in our MDAP funded research will provide new data on the nature and dynamics of these Martian paleofloods.

Some of the most important issues involving the formation of fluvial landforms on Mars relate to the water source, which mechanisms and processes combined to modify the surface, and the ultimate fate of the water and sediment after transport into depositional sinks. Our investigations will focus on the outflow channels, which are the largest fluvial features observed on the surface of Mars. The primary purpose of our research is to conduct a detailed high resolution geomorphic investigation of the Ares, Tiu, Simud, Shalbatana and Ravi Valles outflow channel systems in order to improve our understanding of catastrophic flood processes. These results will enable us to more fully understand the role water played in the origin and evolution of the outflow channels and aid in reconstructing the global hydrologic cycle of Mars.

References:

[1] Malin, M. C., and K. S. Edgett (2003)Science, v. 302, 1931-34. [2] Baker, V.R. (1973) GSA Paper, 144, 79pp. [3] Carling, P. A.(1999) Journal of Sedimentary Research, 69, 534–545. [4] Rice, J. W., et al.,(2002), Lunar Planet. Sci. XXXIII,abstract 2026.[5] Burr, D.M, etal., (2004) Icarus, v. 171, p. 68-83. [6] Alexander, J. and Fielding, C. (1997) Sedimentology, 44, 327–337. [7] Koster, E. H.(1978) Canadian Society of Petroleum Geologists Memoir, 5, pp. 161–186. [8] Alho, P., et al. (2005) Quaternary Science Reviews, v. 24, p. 2319-2334.