MORPHOLOGY OF FRESH OUTFLOW CHANNEL DEPOSITS ON MARS. J. W. Rice, Jr.[1], T. J. Parker[2], A. J. Russel,[3] and O. Knudsen[4] , [1] Arizona State University, Dept. of Geological Sciences, PO Box 876305, Tempe, AZ 85287-6305, jrice@asu.edu [2] Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Dr., Pasadena, CA 91109, [3] School of Earth Sciences & Geography, Keele University, Keele, Staffordshire, ST5 5BGl; [4] Klettur Consulting Engineers, Bíldshöfda 12, IS 112 Reykjavík, Iceland.

Introduction: Athabasca and Marte Valles, in Elysium Planitia, appear to be among the youngest outflow channel systems on Mars based on crater counts [1]. Crater counts indicate that these channels may only be a few million years old. However, MOC image analysis indicates that a rich and complex history of burial and exhumation as well as fluvial and volcanic processes has occurred in this region of the planet. MOC imagery also shows what appears to be much older fluvial features in the region that may have been exhumed. This region is of great interest to the investigation of the hydrologic, volcanic and possibly even biologic evolution of the planet. Additionally, Athabasca Valles is one of the four final sites being considered for the MER missions.

Plates and ridges: Perhaps the most intriguing and debatable landforms in the region are the plates and ridges seen within the channel margins of Athabasca and Marte Valles. The plates can be up to 5 km diameter and have been rafted apart. The plates can be 'jigsaw fitted' back in place. The ridges are sinuous and up to 10 m wide and a few meters high. The channel floor of Athabasca Valles is covered with large slabs (up to 550 m long and 200 m wide); and intervening troughs (up to 100 m wide). The texture of this surface looks like elephant hide. There appears to be two different types of material on the floor (a more compact slabby surface and a slab and trough surface. The troughs could be pull apart structures or a more fluvially sculpted and smoothed manifestation of the somewhat rougher compact slabby material.

Various investigators have attributed the morphology of the plains material located on the floor of the Elysium basin to a wide range of geologic processes/landforms. [2,3,4,] states that the plains are composed of low-viscosity flood lavas, while [5,6,7,8] argue for a fluvial origin. The plains surface exhibits a "crusty" appearance that many researchers [2,3,4] have attributed to crusted over flood lavas and pressure ridges.

We favor an ice-rich fluvial (hyperconcentrated) flow emplacement process for the plate and ridge forming materials. Simply stated, this is what a fresh outflow channel deposit would look like. The outflow event deposited ice rich sediment in a low gradient plain that then froze in place. We interpret the ridges to be ice pressure ridges analogous in size to ridges formed in pack ice. The plates were slabs of sediment rich ice rafted along in the debris flow. As the surface ice sublimated away it left behind a cast that was filled with the muddy sediment. It is possible that shallow ground ice is still present if a sufficient depth of insulating mantle material is covering the ice. The channel floors also have in places numerous small circular mounds up to 60 m diameter and patterned ground. We interpret the circular mound to be pingos and the patterned ground to the presence or former presence of near surface ground ice. The morphology of these surfaces is not consistent with inflated pahoehoe sheet flows and it is difficult to find direct terrestrial volcanic analogs [9]. We find that the flows are often directly associated with fluvial scour features, such that water appears to have emanated from the flows themselves. This is in contradiction to the interpretation by [2,3,4] that the flows are low-viscosity lavas that fill the pre-existing Marte Vallis channel. Instead, the flows must be the frozen or dried remnants of hyperconcentrated floods or mudflows. We also found that the fluvially scoured regions (channel floors) are dominated by discontinuous ridges up to 1.8 km long. These ridges are spaced 16 to 116 m apart and are from 8 to 24 meters wide, however most ridge widths are in the 8 to 13 m range. If the channel floor were flooded with lava how did the subsequent flood waters completely erode away the lava and leave behind only the discontinuous ridges (remains of the former lava flow)? The gradient is very low (<1°) in this region and we find it hard to reconcile that if the channel floors were covered with lava flows how they could have been so efficiently eroded away.

Icelandic Flood Analogs: We propose to use Icelandic jökulhlaups (catastrophic outburst floods) as models to aid in understanding sedimentation processes of the Martian outwash plains. Recent field work (conducted in the summer 2000 and 2001 by Rice, Russell and Knudsen) along the Jökulsa a Fjöllum jökulhlaup complex in the north central highlands of Iceland has confirmed the passage of more than one large flood (10^5 to10^6 m^3/s) and identified both erosional and depositional landforms analogous to Martian outflow channels. Erosional landforms include streamlined hills, extensive washed / stripped lava flows, and cataracts. Depositional landforms consist of pendant bars, boulder bars, imbricated boulder trains, transverse ribs, and giant current ripples. Morphometric data were also collected on several flood deposited boulder fields (size, form, shape) with individual boulders up to 12.7 m diameter.

Transverse Ribs: Transverse ribs are regularly spaced, gravel/boulder ridges formed in relatively shallow, high-energy fluvial systems and oriented transversely to current direction. Koster [10] interpreted the transverse ribs to be relict antidune bedforms, which formed under sub-critical conditions. He also showed that key paleohydraulic parameters; such as the mean velocity, mean depth, and Froude number, can be calculated from transverse rib data.

Modrudalur Transverse Ribs: We are proposing that the alternating ridges located perpendicular to paleoflow direction near Modrudalur, Iceland are transverse ribs. These ridges are capped by boulders up to 1.8 m diameter and have their a-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. The features have an average wavelength of 27 m, width of 13.7 m, and height of 0.84 m. [10] demonstrated 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 pretty closely. We 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.

Athabasca Valles Transverse Ribs: We are also proposing that the linear features, observed on the floor of Athabasca Valles are transverse ribs based on the morphometric analysis of MOC image (E10-01384). Martian transverse rib average wavelength, in this region, is 53.6 m; rib height can not be determined. The equations developed by [10] will be applied to the Martian 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 visible were probably deposited during the last and most recent flood through this region. This region of Mars has undoubtedly been subjected to multiple flood episodes as evidenced in the terraces along the flanks of the streamlined islands [11]. We can count up to 9 terraces in many places, it is not clear if these are separate rock layers or just the erosion of one type of material from rising and falling water levels. However, based on other MOC imagery in the region, layers are seen in crater walls and along the edges of mesas and buttes which implies that the terraces are indeed formed by the differential erosion and plucking of materials with different strengths. The fluvial erosion along the margins of the higher cratered plains material commonly displays a scalloped appearance.

Conclusions: The combined Icelandic field work and Martian geologic/geomorphic analysis will be used to test the jökulhlaup hypothesis as an analog to explain Martian outflow channel deposits and landforms and to increase the predictive accuracy of surface characteristics of fluvially emplaced sediments from orbit. This will be important in the assessment of future landing sites associated with major discharges of water and sediment.

References:

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