ORIGIN OF RIDGED DEPOSITS PROXIMAL TO MANGALA FOSSA, MARS. A.C. Neather, L. Wilson & A.S. Bargery. Environmental Sci. Dept., Lancaster Univ., Lancaster LA1 4YQ, U.K. (A.Neather@lancaster.ac.uk)

Background: Sites of water release to form giant outflow channels on Mars were commonly either areas of chaos in the Hesperian [1] or graben in the Amazonian [2]. While tectonic processes [3] have been proposed for graben initiation, it is clear that many graben were generated by stress changes due to dike intrusion [4-7], and sill intrusion is a natural explanation for areas of chaos [8-11]. Formation of fractures allows release of water from pre-existing aquifers where the water was trapped by the presence of the cryosphere [12, 13] and pressurized either by topographic gradients or downward growth of the cryosphere [14].

Various interactions between intruded magma and aquifer water are possible. These include direct mixing to produce phreatomagmatic explosive eruptions [15] and transfer of CO_2 from a dike or sill to nearby aquifer water as the intrusion cools and crystallizes [16]. The exsolution of dissolved CO_2 as water rises through a fracture has the potential to produce a major fountain as water emerges at the surface [16]. The much greater potential contact area in the case of a sill makes that the favored configuration for maximizing the CO_2 content of released water, but the better focused location of the water release, along a linear graben boundary fault, makes the dike configuration more attractive for recognizing surface features associated with a water fountain. Given the likely origin of the Mangala Valles channel [17] system as a result of water rapidly flooding into the Mangala Fossa graben [7] we examined all available images of the north and south rims of Mangala Fossa to identify the locations and morphologies of unusual surface deposits near the graben rims that might be associated with water release events (Fig. 1). There are two types of deposit, both of which have been recognized before. The distal ones at the east end of the graben (right side of Fig. 1) consist of regularly spaced ridges, and have been ascribed to pyroclastic surges due to phreatomagmatic explosive activity [15]. The proximal ones (left side of Fig. 1) are characterised by irregularly spaced ridges, previously described as morraines and tills left by ice formed from water overflow and condensation [18]. Here we explore an alternative emplacement mechanism for the ice.

Locations & morphologies of deposits: Figure 2 shows proximal deposit locations in red. Photoclinometry has been used to estimate the heights of the characteristic ridges. Those in Fig. 1 (THEMIS vis. image V06597003) have an average height of ~6.5 m and the average spacing is ~210 m; those in Fig. 3 (from THEMIS image V04762003) have an average height of 4.4 m and the average spacing is ~400 m.

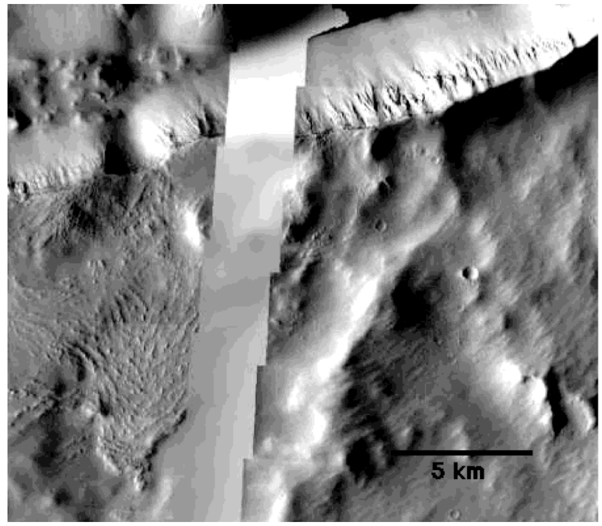

Figure 1. Examples of proximal (left) and distal (right) ridged deposits outside rim of Mangala Fossa graben.

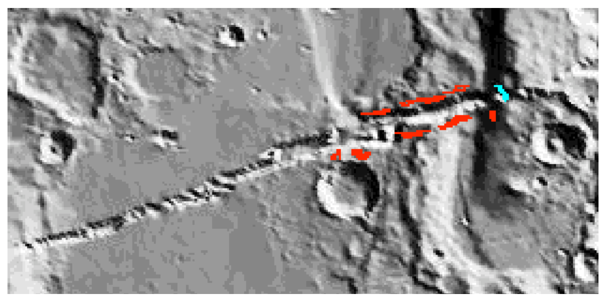
Figure 2. Locations of proximal (red) and distal (blue) ridged deposits near the eastern part of Mangala Fossa.

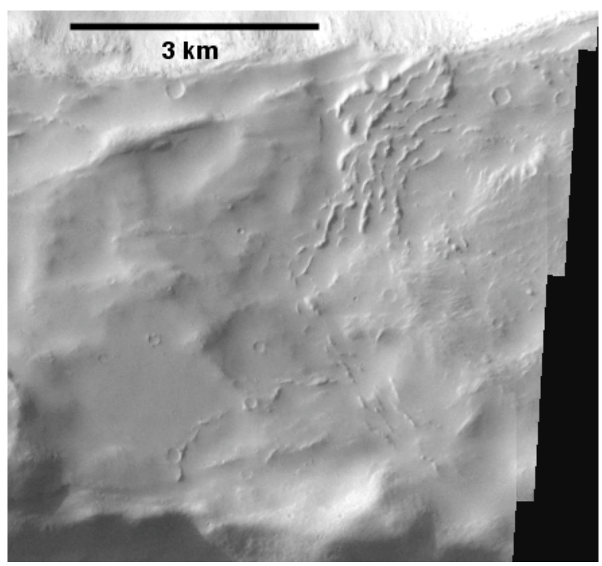

Figure 3. Proximal ridged deposits on the south side of Mangala Fossa at 210.6° E, 18.6° S.

Overall, ridge heights generally appear to be less than 10 m and spacings range from 300 to 1000 m, averaging ~550 m. The thicknesses of the inter-ridge deposits are estimated to be typically no more than ~3 m, and the total surface area occupied by all of the 12 identified deposits of this type is ~440 km^2, making the total volume of the deposited material ~1.3 km^3.

Interpretation: We assume that the material forming these deposits was emplaced by an explosive process utilizing the boundary faults of the graben. It is possible that the proximal deposits were emplaced by the same kind of phreatomagmatic volcanic activity suggested for the distal deposits [15]; however, their more localized distribution and irregular structure argue against this [18], and we suggest violent water release driven by exsolution of CO_2 transferred into the water from adjacent magma [16]. The optimum time for this may have been shortly after emplacement of the dike that initiated graben subsidence [7], while rising aquifer water was in contact with rapidly chilling magma at the edge of the dike.

Figure 1 shows that in places the ridged material has flowed down-slope subsequent to its initial emplacement, developing lobes with raised levees and depressed central channels. Neglecting these extensions to the deposits, the maximum ranges to which material must have been thrown ballistically is ~8 km and assuming the optimum 45 degree ejection angle this implies a launch speed of ~170 m/s. Given the evidence for deformation after emplacement, it is possible that ejecta may have been thrown to only ~4 km and then spread in all directions; if so, the required launch speed is only ~120 m/s. Using [16]'s model of the relationship between water CO_2 content and eruption speed at the surface, a speed of 120 m/s implies a CO_2 content of ~2 mass % and 170 m/s implies a CO_2 content of ~4 mass %. Both values are much less than the maximum solubility (~7-8 mass %) of CO_2 in water at pressures relevant to depths of a few km.

Although water is inferred to have been involved in the emplacement process, there is no indication of the presence of ice in the deposits, so the bulk of what is present now must be silicate material. Thus the fluid that came up the graben boundary fault fractures was effectively dilute mud. The rise speed of the undisrupted fluid in the fracture prior to fragmentation would have been slower than if it were pure water because both its bulk density and bulk viscosity would have been greater than those of water. The presence of solids would not have greatly influenced the fragmentation process itself since this is controlled almost entirely by the kinetics of the expansion of the bubbles of exsolved CO_2. However, after disruption of the continuous liquid phase by the expanding bubbles, the presence of the silicates would have reduced the final speed at which the vapor-liquid-solid mixture emerged at the surface. Thus greater CO_2 contents than the ~2-4 mass % mentioned above would be needed. However, it is unlikely that the water contained more than ~5-10 volume % solids [19], increasing the bulk density by only 10-20 % and thus increasing the required CO_2 mass fraction by the same percentage.

Droplets in the inner parts of the muddy water fountains that we envisage are shielded from radiating to their surroundings and very little cold atmospheric gas gets mixed in to the central part of the fountain, so these droplets land as liquid muddy water. Droplets in the outer parts of the fountain can radiate to the surroundings and have contact with cold atmospheric gas mixing into the outer edge of the fountain. Some of these droplets will freeze and land as dirty hailstones. Thus the deposit that accumulates on the ground will always have some solid component and its solid fraction will be progressively greater towards its distal part where the proportion of hailstones increases. The presence of the solids will give the accumulating deposit a non-Newtonian rheology, especially in its distal parts. Evaporation and contact with the cold ground will cool the liquid water and cause ice crystals to grow so that the whole assemblage will become increasingly non-Newtonian with time. We intend to explore whether this developing non-Newtonian rheology was the origin of the ridges.

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