MAGMA-CRYOSPHERE INTERACTIONS ON MARS - AN EXPERIMENTAL INVESTIGATION OF PHYSICAL PROCESSES. S. Tyson, S.J. Lane, L. Wilson and J.S. Gilbert, Lancaster Environment Centre, Lancaster University, Lancaster LA1 4YQ, U.K.

Introduction: Many surface features on Mars (see Fig. 1) are most easily explained [1] by assuming that the planet has a near-universal cryosphere, i.e. a layer where pore spaces in the crustal rocks are at least partially filled with ice.

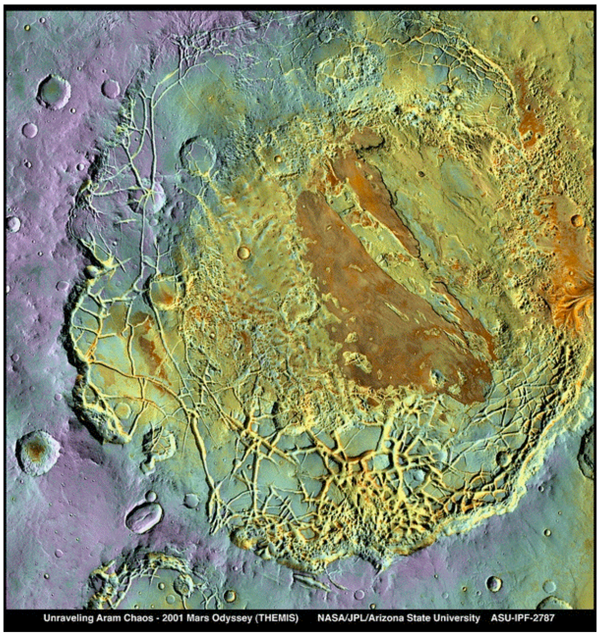

Fig. 1. Aram Chaos, ~280 km diam. area of collapsed ground on Mars likely due to sub-surface ice removal.

Figure 2 shows the distribution of ice and water with latitude and depth on Mars proposed by [2] using a model of pore space variation with depth from [3].

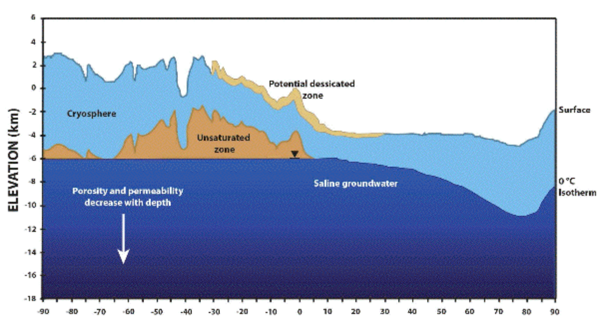

Fig. 2. Variation with latitude and depth on Mars of ice and water content of crust as proposed by [2].

The structure shown in Fig. 2 permits various geometries of interaction of shallow volcanic intrusions (dikes, sills and larger magma reservoirs) with ice- or water-laden crustal rocks. We therefore devised a series of laboratory experiments with a programmable heating element embedded in a simulated cryosphere (various mixtures of sand and ice - see Fig. 3) to explore the various physical processes that can take place during such interactions. The experimental system does not operate at magmatic temperatures and cannot simulate violent processes in the immediate vicinity of a magma-crysphere contact [4, 5], but it can throw light on heat transfer regimes that evolve in the vicinity of intrusions. Initial experiments simulate a sill-like, rather than dike-like, intrusion geometry.

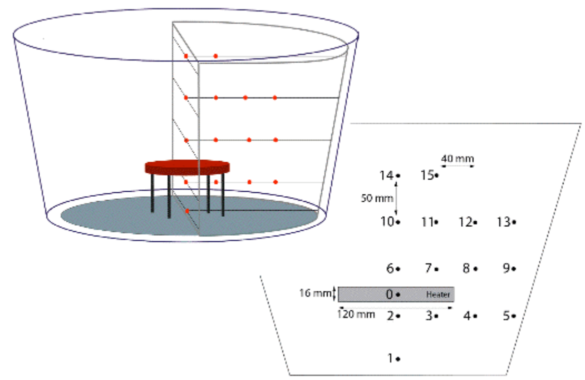

Fig. 3. Experimental system: programable heater + 16 thermocouples supported on insulating frames embedded in cryosphere simulated by a sand-ice mixture.

Experimental Results: At sufficiently low heat transfer rates into the simulated cryosphere heat transport was dominated by conduction, and a near-radial pattern of temperature changes with time was observed (Fig. 4) independent of whether pore spaces contained ice, water or vapour.

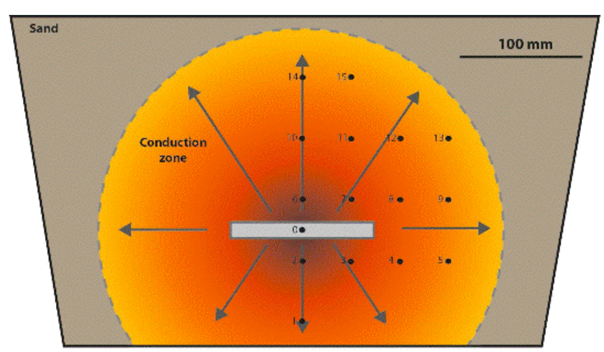

Fig. 4. At low heat flow rates transfer is near-radial and by conduction alone.

At greater heating rates, hindered convection of liquid water and wet steam at temperatures up to 100 °C occurs in a region close to the heater (Fig. 5). This region extends to greater distances laterally than vertically. Convection can disturb the grain-supported matrix and, coupled with the volume change on ice melting, this can allow compaction to occur leading to disturbance and collapse at the cryosphere surface. At sufficently great distances from the heat source conduction replaces convection as the dominant heat transfer mode.

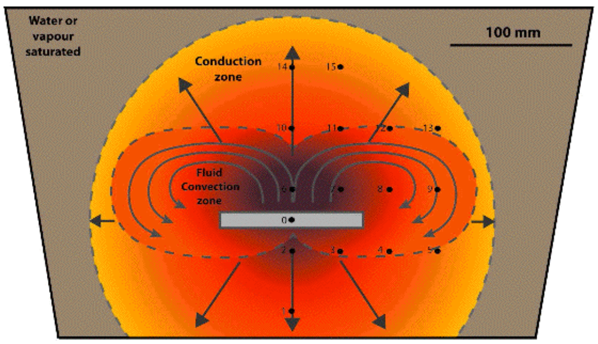

Fig. 5. At intermediate heat flow rates a region of hindered water convection occurs near the heat source, merging into a conduction-only zone further out.

At the greater heating rates temperatures exceed 100 °C near the heater and dry steam is present. In this case steam advects heat almost directly upward above the heater with the other two regimes being present where the temperatures are lower (Fig. 6).

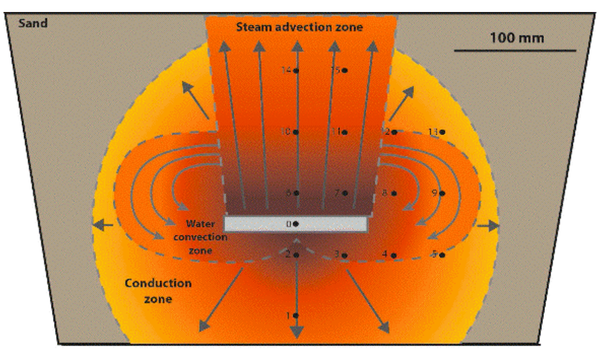

Fig. 6. At high heat flow rates from the heat source dry steam is produced and a steam advection zone forms above the heater, grading into the water convection and pure conduction zones seen at smaller heat fluxes.

Implications: The observations from the experiments described above have implications for what happens as a function of time after the emplacement of an intrusion within the cryosphere as it cools. A key parameter for sill-like intrusions is likely to be the ratio of the horizontal extent of the intrusion to the depth of its top below the surface. Thus if the influence of a steam advection zone extends to the surface then the area of any surface disruption or subsidence will be similar in size to that of the source (Fig. 7), whereas if the influence of the steam advection zone is only minimally felt at the surface then the area of surface modification may extend to significantly greater horizontal distances than the size of the intrusion (Fig. 8) and may exhibit a greater range of textures.

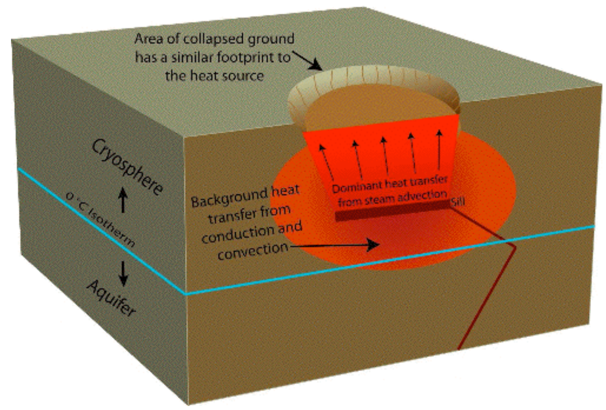

Fig. 7. Steam advection dominates from a shallow sill intrusion: the surface effect zone is the same size as the intrusion.

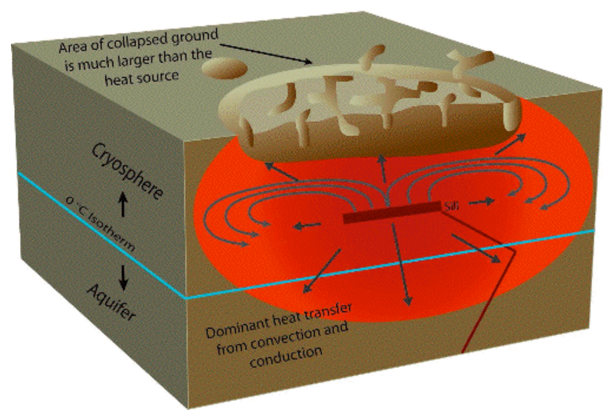

Fig. 8. Convection dominates from a deep sill intrusion: the surface effect zone is wider than the intrusion.

Future work: We plan to scale results from these experiments to help quantify the geometries and burial depths of volcanic intrusions on Mars.

References: [1] Carr M. H. and Head J. W. (2010) *EPSL, 294,* 185-203. [2] Clifford S. M. and Parker T. J. (2001) *Icarus*, *154*, 40–79. [3] Clifford S. M. (1993) *JGR*, *98*, 10,973–11,016. [4] Wilson L. and Mouginis-Mark P. J (2003) *JGR*, *108*(E8), 5082. [5] Wilson L. and Head J. W. (2004) *GRL*, *31*(15), L15701.