MELTING OF THE MARTIAN PERMAFROST BY HYDROTHERMAL CONVECTION ASSOCIATED WITH MAGMATIC INTRUSION. Y. Ogawa[1], Y. Yamagishi[2] and K. Kurita[1], [1]Earthquake Research Institute, University of Tokyo 1-1-1, Yayoi, Bunkyo-ku, Tokyo, (Yoshiko@eri.u-tokyo.ac.jp), [2]Institute for Frontier Research on Earth Evolution, Japan Marine Science and Technology Center, Yokosuka.

Introduction: Many surface features on Mars are closely connected with the subsurface permafrost layer. The polygonal fractures and the possible thermokarsts are observed on the martian surface and they are analogous to the terrestrial features located on the permafrost. The rampart and/or fluidized ejecta morphology of martian craters is indicative of subsurface volatiles. Mars should stock much water in a form of ground ice.

The suspected fluvial features on Mars would suggest water (or its mixture), which is coming from the subsurface aquifer or the ground ice. Such a martian hydrothermal system has been the alternative idea to the assumption of precipitation for forming observed fluvial-like features on Mars. The outflow channels, in particular, have characteristics unique to water erosion and clearly indicates the surface runoff of huge amount of water [1], [2], which usual precipitations could not supply. The outflow channels potentially suggest the pre-existence of a substantial amount of liquid water very close to the martian surface to cause a large flood. The idea of supplying such massive liquid water near the ground might be still controversial, however, from many observational facts, we assume that the igneous melting of the martian permafrost layer should have played a significant role. We have numerically simulated the generation of meltwater and are proposing a consistent scenario of forming the outflow channels as well as the headwater regions; chaotic terrains [3].

Igneous Melting of the Subsurface Permafrost Layer: We numerically simulate the melting process of the permafrost layer induced by magmatic intrusion [3]. The shape of the intrusive body has a significant effect on the development of the melt region. The permafrost is modeled as a porous medium in which the matrix is rock and the pores are filled with water ice. Several types of porosity distribution are assumed. The point of our simulation is incorporation of thermal convection in porous media, which has not been modeled well in previous studies of the melting of the permafrost.

Our main results show that convection in the melted zone causes drastic change in heat transfer, which results in focussing the growth of the melt region and enhancement of water generation. The resulting melt zone extends vertically up just next to the surface, like a plume with a single column (mushroom structure) as seen in Figure1. τ is the dimensionless time (normalized by H^2/κ, κ: thermal diffusivity of water) and the zone which is about a size larger than the yellow region corresponds to the melted zone. Lastly, we see, that the hot zone spreads laterally ($\tau > 0.17$) in equilibrium state.

The behavior of the system is mainly controlled by the two non-dimensional parameters; the Rayleigh (Ra) number and the Stefan number (Ste). The Ra represents the strength of the thermally-driven natural convection in a porous medium and the Ste represents the measure of thermal contribution of the phase change [3]. The development of the meltwater volume with the time is shown in Figure 2. The pure conduction case is illustrated as a reference, showing only a gradual rise in water volume with time. This contrasts with an abrupt rise in meltwater production associated with the initial and middle stages of convection. Here the volume shown is normalized by $3H^2D$ (H: thickness of the permafrost layer, D: the depth) and time is non-dimensional.

Martian Hydrothermal Systems: The melting process within the permafrost driven by the thermal conveciton, which we revealed in the previous section, produces a substantial amount of water very close to the surface. In response to compaction in this region, segregated liquid water is expected to form a subsurface pool and may have erupted out of the ground to form the fluvial features. Liquefaction might happen, too, which could result in the similar catastrophic process. Such events would certainly be accompanied by surface destruction, which we can see as chaotic terrain.

We are proposing a consistent scenario of forming surface features around the outflow channels (Figure 3).

The implication of the melting of the permafrost is not restricted to the formation of chaotic terrains. Other features settled in headwater regions of channels could possibly be influenced by this melting process of the subsurface permafrost layer.

We direct our attention to each of such surface features. We will report on results of simulation with more plausible parameters, especially considering the morphology of the magmatic intrusion. Recently Scott et al. [4] and Wilson and Head [5] showed the probable population of giant dikes from the Tharsis area. The sill intrusion was also discussed on the Ascraeus Mons based on the geologic analysis [6]. Considering the newly revealed observational facts, we simulate the melting process for the more realistic case targeting at each of the observed features.

In the modeling, we also modify our previous simple assumptions, introducing the vertical distribution of the porosity of the permafrost layer and evaluating the thermal history of the magmatic body intruded.

Summary: We have quantitatively assessed the effect of thermal convection on enhancing and focusing heat transfer in melting of the permafrost on Mars. The resulting melt zone extends up to just beneath the surface, creating a plume with a mushroom structure. The resulting volume of meltwater is several times as much as that expected in the conduction case. These two characteristics mean that substantial amount of meltwater could exist very near to the surface, which should effect on the possible hydrothermal systems on Mars considerably. We applied our numerical simulation to the plausible area on Mars where the interaction of magma and permafrost is expected, modifying our model and introducing the more realistic parameters based on the latest observation.

References:

[1] Baker, V. R. and Milton, D. J. (1974) *Icarus*, *23*, 27-41. [2] Baker, V. R. (1982) *The channels of Mars*, Univ. of Texas Press. [3] Ogawa, Y. et al. (2003) *JGR*, 2002JE001886 (in printing). [4] Scott, E. D. et al., (2002) *JGR*, *107*, (E3), 10.1029/2000JE001431. [5] Wilson, L. and Head, J. W. (2002) *JGR*, *107*, (E8), 10.1029/2001JE001593. [6] Scott, E. D. and Wilson, L (1999) *JGR*, *104*, 27,079-27,089.

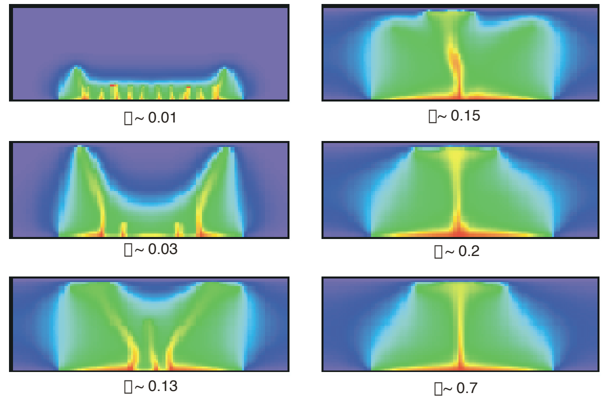

Figure 1. Evolution of temperature field within the martian permafrost layer with igneous heating, quoted from Ogawa et al., 2003. □ is dimensionless time and the zone which is about a size larger than the yellow region corresponds to the melted zone. The zone extends vertically with time and extends almost to the surface. Lastly, the hot zone spreads laterally (□> 0.7) in equilibrium state.

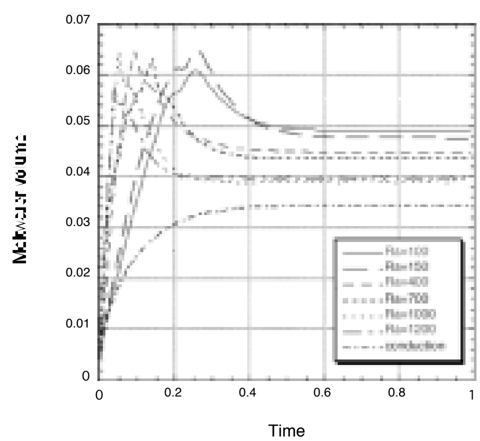

Figure 2. Production of meltwater as a function of time for various Ra: 100-1200, quoted from Ogawa et al., 2003. The pure conduction case is illustrated as a reference, showing only a gradual rise in water volume with time. This contrasts with an abrupt rise in meltwater production associated with the initial and middle stages of convection. Volume is normalized by $3H^2D$ (H: thickness of the permafrost layer, D: the depth). Time is non-dimensionalized by $H^2/$□ (□: thermal diffusivity of water).

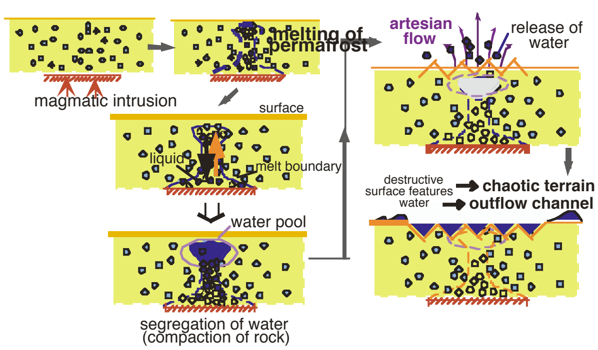

Figure 3. A scenario for the origin of chaotic terrain and outflow channels, quoted from Ogawa et al., 2003.