A CHAOTIC TERRAIN FORMATION HYPOTHESIS: EXPLOSIVE OUTGAS AND OUTLOW BY DISSOCIATION OF CLATHRATE ON MARS. G. Komatsu[1], J.S. Kargel[2], V.R. Baker[3], R.G. Strom[3], G.G. Ori[1], C. Mosangini[1] and K.L. Tanaka[2], [1]International Research School of Planetary Sciences, Universita' d'Annunzio, Viale Pindaro 42, 65127 Pescara, Italy, goro@sci.unich.it, [2]Astrogeology Team, USGS, 2255 N. Gemini Drive, Flagstaff, AZ 86001, U.S.A., [3]Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ 85721, U.S.A.

Introduction: Chaotic terrain, despite its large areal extent, enigmatic morphology and relations with outflow channels, has attracted relatively little attention in the study of Mars. In general, it is perceived that the formation of outflow channels require an immense quantity of water catastrophically drained from chaotic terrain [1]. Chaotic terrain is mostly concentrated at source areas of the Chryse outflow channels in the equatorial region of Mars. Chaotic terrain consists of large areas of depressions, knobs and mesas (Figure 1) [2]. The morphology of chaotic terrain requires rapid outflow of water from the ground. This is achieved by catastrophic melting of ground ice most likely by endogenic (magmatic) heating. The base level of the chaotic terrain may correspond to the bottoms of ground ice zones. Still a question remains whether melting of ice alone can create such destructive landforms.

We propose here that clathrate, a possible component of Martian ground-ice, when decomposed released a large quantity of gases such as CO_2 and CH_4 and this event lead to the explosive pulverization of ground materials. The destroyed ground materials (now sediment) were liquefied and fluidized by rapidly moving water. The released greenhouse gases could have made a significant impact on the Martian atmosphere and climate.

Proposed chaotic terrain formation processes: (The processes are summarized in Figure 2).

a. Melting of ice and dissociation of clathrate. It has been believed that that the melting of ground-ice by high heat flux was responsible for the formation of chaotic terrain [3]. As early as in 1974, Milton (1974) [4] suggested that the melting of CO_2 clathrate might have caused rapid outflows of water and the formation of chaotic terrain. Milton also suggested that a decrease of pressure such as opening of a fracture could have caused decomposition of clathrate. Clathrate has a much wider zone of stability than on Earth [5] and a large quantity of clathrate may have existed in the Martian crust.

b. Liquefaction and fluidization. A sudden collapse of ground has been observed in terrestrial environment. When sediment saturated with water becomes subjected to a stress, a loosely packed grain framework suddenly collapses and the grains become temporarily suspended in the pore fluid. This phenomenon is called liquefaction. If water flows fast enough so that it balances with the settling velocity of grains, the grains are suspended in the stream and the water-sediment mixture behaves like fluid. This is called fluidization. These two processes may have played important roles in the formation of chaotic terrain [6]. The flow velocity vs. grain size threshold of these processes depends on gravity. So for Mars, the required velocities would be smaller than for the Earth.

d. Gas build-up and explosion. If the amount of gas derived from clathrate was large enough and a condition in which gas could build up under a cap of impermeable layer existed, the pressure release of gas could have played a major role in pulverizing rocks and remaining ices. Furthermore fragmented rocks by gas explosion can liquefy easily.

e. Outflow phase. Once liquefied and fluidized the mobilized water-sediment mixture flowed out of the source region catastrophically. In some cases, ponding of water may have occurred in the depressions inside chaotic terrain [2].

An analogous event: Comparison with terrestrial clathrate dissociation: In recent years, the importance of clathrate for understanding climatic changes is increasing [7]. In general, the rapid dissociation of clathrate is caused by a decrease of confining pressure by sea-level fall [8] or by warming of seawater from the atmosphere [9] or both. Seabed pockmarks are circular to semi-circular depressions distributed widely in the continental shelves. Their diameters are typically between 50 and 100 meters and 2-3 meter deep on average [10]. The existence of the pockmarks has been long known to the offshore oil industry because of their close association with gas seepage [10]. Their formation is generally explained by liquefaction/fluidization of seafloor sediments, processes caused by the upwardly moving fluids such as water and gas. Martian chaotic terrain is typically three to four orders of magnitude greater in size and more complex in morphology. However processes of formation may have many common aspects such as gas release, liquefaction and fluidization. Larger scale marine gas release events such as the one considered to have caused the Paleocene Thermal Maximum [9] may have produced gigantic pockmarks similar to Martian chaotic terrain.

References: [1] Baker, V.R. (1982) The Channels of Mars, Univ. Texas Press. [2] Ori, G. and Mosangini, C. (1998) JGR-planet, 103, 22,713-22,723. [3] Mckenzie, D. and Nimmo, F. (1999) Nature, 397, 231-233. [4] Milton, D.J. (1974) Science, 183, 654-656. [5] Kargel, J.S. et al. (2000) LPSC XXXI, this volume. [6] Ori, G. and Mosangini, C. (1997) LPSC XXVIII, 1045-1046. [7] Kvenvolden, K.A. (1993) Rev. Geophys., 31, 173-187. [8] Kayen, R.E. and Lee, H.J. (1991) Marine Geotechnology, 10, 125-141. [9]

Katz, M.E. et al. (1999) Science, 286, 1531-1533. [10] Hovland, M. and Judd, A.G. (1988) Seabed Pockmarks and Seepages, Graham and Trotman.

Figure 1. A transition zone from chaotic terrain to outflow channel. Viking image.

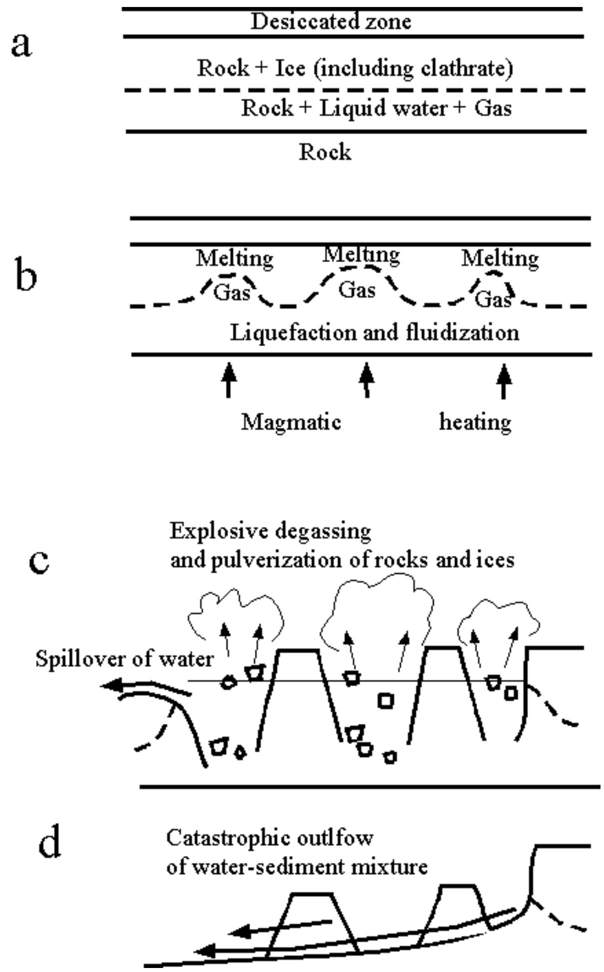

Figure 2. Schematic diagram showing hypothesized processes of chaotic terrain formation.