CIRCULAR COLLAPSED FEATURES RELATED TO THE CHAOTIC TERRAIN FORMATION ON MARS.
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Introduction: Xanthe Terra region on Mars is known as a site of most drastic evolution related to the formations of huge chaotic terrain and multiple outflow channels. In this region, there are strange circular collapsed features. Some of them have cracked cavity or deep moat along the rim, others have plane blocks or knobby mounds. In several areas, these features are clustered to form a chaotic region. Chaotic terrain has been interpreted as a site for the emanation of large amount of water [1,2]. Costard [3] interpreted the circular collapse as thermokarsts resulting from the magmatic heat degradation of the craters formed in the permafrost. But its relation to the formation of the chaotic terrain is not well clarified. In this study, we examined distribution and morphologies of the circular collapses. We explore a model of its formation and give suggestions how the chaotic terrains were formed and discharged a huge amount of water.

Approach: The studied area is lat: 30 to -30 N, lon: 0 to 45 W, around Xanthe terra region which is mainly consisted of chaotic terrains, outflow channels, and cratered highland (Fig.1) [4]. As for the data sets, we used Viking MDIM 2.1 mosaic image conducted by USGS, and MGS MOC image, MOLA DEM grid map, Mars Odyssey THEMIS IR images. As the software to deal with these data, we used ENVI of RSI.

Result: The circular collapses have several distinct features, for example deep cracks or platy blocks or knobby basal plane inside. The most typical one has deep moat along the circular rim and cracked center plane (Fig.1 Upper left). All these features are not produced by the impact or general degradation processes [5] of impact craters.

Fig.1 shows the geographical distribution of circular collapse. They are dominantly located only in the periphery regions of the chaotic terrain. Partly circular-shaped units are also observed along the periphery of the chaos. The sizes of the circular features have variations in the range of 7 to 160 km in diameter. The distribution is random and irrelevant with their size. In several locations around these features, we can recognize many usual type craters including old one to fresh one, larger one to small one in size. So the circular collapse and the craters of various sizes are intermixedly distributed side by side in the same area.

Some circular collapses are associated with ejecta blanket and the rim height suggests rough tendency of proportion with diameter. Thus the circular collapses are thought as originally impact craters. However, this "collapsed craters" have the morphological features which are not common in usual craters. So these craters are thought to have experienced particular kind of degradation after the impact event.

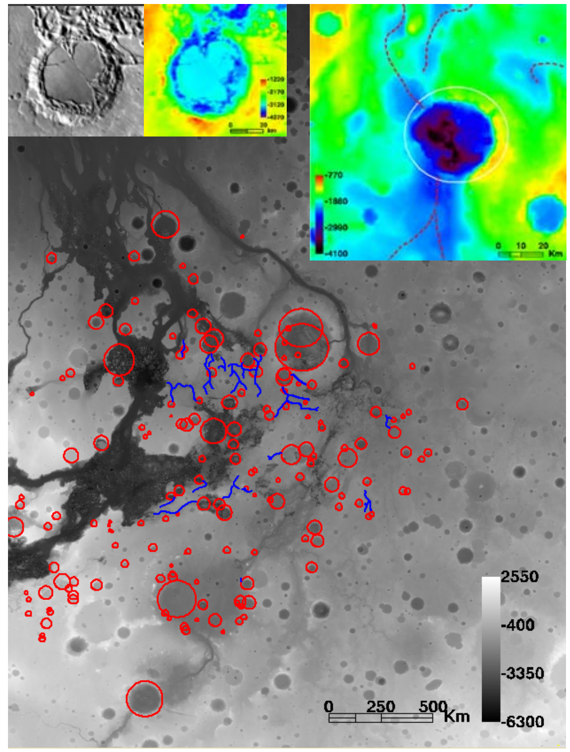

Fig.1 Circular collapse distribution. 30 to -30N, 0 to 45W in MOLA grid map. Left corner view shows the most typical example of circular collapse located at 1.2N 25.6W. Right corner view shows circular collapse along the shallow groove located at 0.21N 28.6W.

Fig.2 is a plot of maximum depth inside the collapsed floor versus diameter. Blue and red dot means the isolated one and clustered one as a chaotic region respectively. The inserted line represents the standard relationship among the fresh craters proposed by Garvin et al. [6]; h=0.36D0.49. This figure shows that there are many collapses deeper than the floor level of the fresh crater mostly in the clustered ones. These facts suggest that the depression occurred by the collapse can reach deeper than the original crater floor and its process acts stronger in the clustered craters which usually form the chaotic regions.

The cracks inside the plane block of each collapsed craters show mostly linear shape and irregularly connected with other cracks of different directions. Some cracks show cross-cutting. At the terminal portion of the cracks, the width is abruptly reduced and shows theater head shape just like a sapping channel head (Fig.3). Upside from the head, there is a narrow stria which width is about 200m and extends in same direction as its parental crack. Some cracks show discontinuous shape along the stria and some show pit craters at the terminal portion. These crack features suggest that initially there are series of faults and then the erosion which produces subsurface void or the erosion like sapping acted along the faults.

The remaining surface of crater floor is extremely flat and smooth with no streamlines or scour marks except the stria extends from the cracks. The bottom part of the collapse also shows no features like channel or terrace which shows the evidence of the flow of surface water. These facts indicate that the floors of collapsed craters were kept in relatively dry state.

In many cases, low altitude depressed area which looks like shallow grooves runs continuously connecting the isolated collapsed craters and leading to the chaotic region (Fig.1 Blue lines). The mean width of these grooves is about 35 km (20-40 km) and the mean depth is about 500 m (200-1200 m). The surface texture of this low area has no streamlines or terrace or fault scarps, and is continuous with outer plane. Most collapsed craters located near the groove have the deepest part of the bottom in the closest point to the groove center (Fig.1 Upper right). Thus it is interpreted that the collapse are enhanced especially near the groove and the grooves itself were also caused by surface subsidence.

Discussion: At several locations in this area, it is observed that group of collapsed craters unite together to grow into a larger chaotic region. It can be interpreted that chaotic terrain originally started as a form of collapsed crater. Although the chaotic regions are mostly located at the source region of the outflow channels and are suspected as a place for groundwater discharge [1,7], the precursory collapsed craters show no evidence of the flow of surface water.

To produce the deep depressions or cracks inside the crater, two possibilities are suggested; erosion of subsurface materials and meltdown or sublimation of surface materials which is extremely rich in volatile. Considering that the difficulties to make partial collapse much deeper than the fresh crater cavity in same crater floor, and to allocate the large amount of volatiles consistently with the intermixed distributions with common old craters, the subsurface erosion should be more likely. From the fact that the distributions of collapsed craters and the shallow grooves show strong correlation and both features are considered as the results of subsidence, subsurface erosion and consolidation could have occurred along the pathway of groundwater flow which lies beneath the grooves. The appearance of the cracks inside the collapsed craters shows pit crater chain and sapping like channel along the faults. These features also could be explained by the groundwater activity like sapping or subsurface erosion along the pre-existing faults. The shallow grooves are usually extends into the chaotic regions which show no evidence of surface water flow inside but locate in the source region of the outflow channels. Thus the subsurface water could have emanated from the terminal edge of the chaotic region, causing the collapse through subsurface.

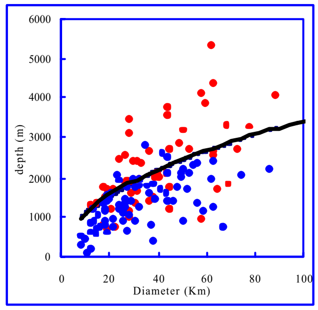

Fig.2 A plot of maximum depth inside the collapse versus diameter. Blue dot is isolated one, and red dot is clustered one. The curve is the relation for fresh craters, $h=0.36D^{0.49}$ from Garvin et al, [2003].

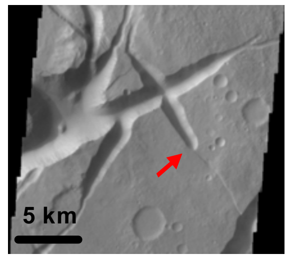

Fig.3 Themis Visible image of the cracks inside the circular collapse located at 2.8N 23.0W.

Based on the individual interpretations of observational facts, we propose a model of groundwater migration as follows; from several huge water storage areas, the water migrated through subsurface pathway, carrying large amount of sediment along the pathway and the adjacent craters, and eventually a pounded groundwater spill out from the temporally storage area like a cluster of craters at the low altitude, and the runoff water forms the outflow channels.

In this model, water source areas are not all chaotic area but only several exclusive areas, for example Ladon basin, Gangis chasma, Eos chasma, Aurorae chaos. And we think most collapse is formed through subsurface with dry surface without a drastic blowout of subsurface water. So the collapsed crater could be a kind of tracer of ground water pathway.

References: [1] Baker V. R. (1982) *Univ. of Tex. Press.* [2] Komar P. D. (1979) *Icarus, 37,156-181.* [3] Costard P. F. (1986) *123-131.* [4] Scott D. H. and Tanaka K. L. (1986) *U.S. Geol. Surv. Misc. Invest. Map, I-1802-A.* [5] Craddock R. A. and Howard A. D. (2002) *JGR, 107, E11, 5111.* [6] Garvin J. B. et al. (2003) *6th Mars Conf., 3277.* [7] Carr M. H. (1996) *Oxford Univ. Press.*