DATING AND MORPHOLOGICAL CHARACTERIZATION OF LAYERED EJECTA CRATERS IN THE CANDIDATE LANDING AREAS OF CHINA'S FIRST MARS MISSION (TIANWEN-1).

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Introduction: Martian impact craters typically exhibit layered ejecta morphologies relative to ballistically-dominated ejecta observed on the Moon and Mercury [1]. These morphologies are divided into three categories: single layer ejecta (SLE), double layer ejecta (DLE), and multiple layer ejecta (MLE) [2]. Layered ejecta craters (LECs) are thought to form from the interaction of the ejecta blanket with the volatile content sourced from the target [1,3] and/or the atmosphere [4]. Ejecta mobility (EM) is a ratio of the ejecta runout distance from the crater rim to crater radius and it is believed to provide key information on the concentration of subsurface volatiles (water/ice) at the impact time [5]. LECs may have formed during an unusual geological epoch and the onset diameter (the minimum diameter of LEC in each area) could reflect the depth of subsurface volatiles at the time [6]. With high-resolution images of Mars becoming available, the age of individual craters can be estimated by measuring the size-frequency distribution of small craters superposing on their ejecta blankets [e.g., 7,8].

In the two candidate landing areas (Fig. 1) for China's first Mars mission (Tianwen-1), we performed crater counting on 78 LECs (from the database [9,10]) and morphological analysis of their layered ejecta to gain a deeper insight into the subsurface ice conditions. Determining the ages of the LECs, measuring their EM values, and calculating their excavation depth are critical to estimating the regional (even global) subsurface volatiles history on Mars.

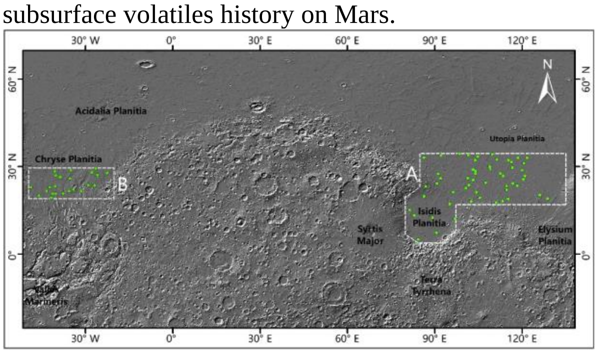

Fig 1. The regional context of the study areas: the Isidis-Utopia Planitia (85°-134°E and 17°-34°N) (80°-98°E and 4°-20°N) connection region (A) and the southern Chryse Planitia (20°-50°W and 20°-30°N) region (B). A total of the 78 LECs (Area A: 54, Area B: 24) were analyzed, as their locations marked by the green points. Basemap is the MOLA shaded relief map.

Data and Methods: To determine the ages of the LECs through the crater counting method, the smaller impacts superposing on the ejecta blankets were measured utilizing the Context Camera (CTX) images (5 m/pix) [11]. We derived the ages from the Hartmann and Neukum (2001) chronology function [12] and Ivanov (2001) production function [13].

EM ratio is defined as the ejecta extent from crater rim (R_e) normalized by the crater radius (R_c) [5].

$$EM = R_e / R_c \quad (1)$$

To estimate the shallowest depth (d_e) of the possible subsurface ice/water table, we adopt simpler relations from Melosh (1989) [14].

$$d_e = crater\ diameter / 10 \quad (2)$$

Results and Discussion: The 54 LECs in the Isidis-Utopia Planitia connection region have derived ages ranging from ~0.12 Ga to ~3.7 Ga (Fig. 2). 8 were formed in the late Amazonian (< 0.3 Ga), 18 in the middle Amazonian (0.3-1.2 Ga), 24 in the early Amazonian (1.2-3.4 Ga), and only 4 LECs were formed in the Hesperian (3.4-3.8 Ga).

The ages of the LECs in the southern Chryse Planitia range of between ~0.15 Ga and ~2.9 Ga (Fig. 2). All were formed during the Amazonian epoch. Only one LEC was formed in the late Amazonian (< 0.3 Ga), 10 in the middle Amazonian (0.3-1.2 Ga), 13 in the early Amazonian (1.2-3.4 Ga), and no LECs were found to date during the Hesperian (3.4-3.8 Ga). The results are consistent with the erosion history of the channel system [15].

EM values could indicate how subsurface volatiles concentration has changed over time [5]. Our results show that the average EM values fluctuate between ~2.0 and ~1.7 over time in the Isidis-Utopia connection region. The least-squares fitted trend line of each average EM value shows that the average EM value has a slight decreasing trend over time (Fig. 3a). This might indicate that the concentration of subsurface volatiles has not changed over time or has not changed enough to be detected. The formation of relatively young LECs with onset diameters of 5 km might indicate that that subsurface ice could still be present in this region at depth of ~500 m.

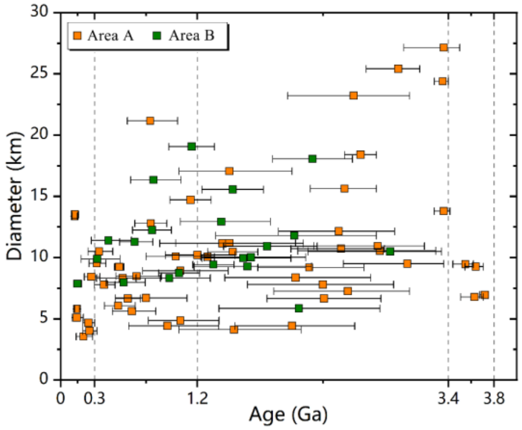

Fig 2. Ages of LECs versus crater diameter in the Isidis-Utopia connection region (Area A) and the southern Chryse Planitia (Area B). Bins are based upon the epochs of Michael (2013) using the Neukum chronology: < 0.3 Ga (late Amazonian), 0.3-1.2 Ga (middle Amazonian), 1.2-3.4 Ga (early Amazonian), 3.4-3.8 Ga (Hesperian), and > 3.8 Ga (Noachian).

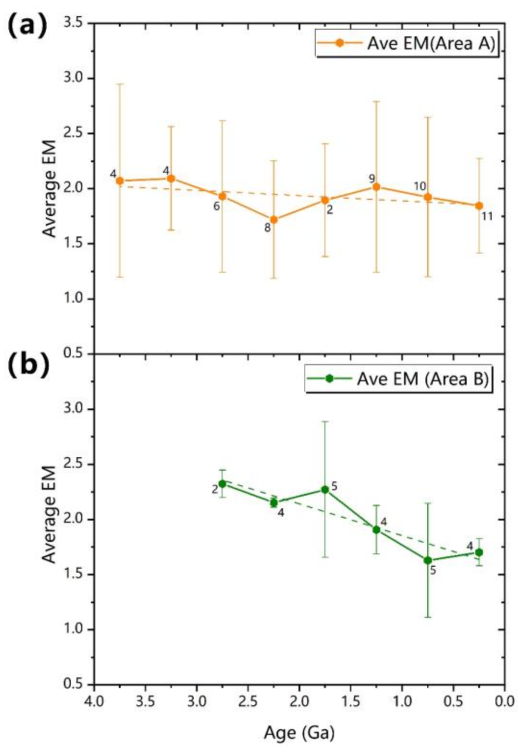

Fig 3. (a) Average EM values for each interval time (0.5 Gyr) in the Isidis-Utopia connection region. (b) Average EM values for each interval time (0.5 Gyr) in the southern Chryse Planitia. Dash line shows the least-squares fitted trend line for each average EM value. Error bars are one standard deviation and the numbers next to the data points are the number of LECs in each interval time.

The average EM values fluctuate between ~2.3 and ~1.6 over time in the southern Chryse Planitia. The least-squares fitted trend line of each average EM value shows that the average EM value has a distinctly decreasing trend over time (Fig. 3b). This might indicate that the depth of subsurface ice table is increasing over time. A relatively young (~0.15 Ga) LEC with onset diameters of 8 km indicates that subsurface water/ice may still be present in this region at depth of ~800 m.

Conclusions: Measuring the ages and the EM values of Martian LECs could increase our understanding of the evolution history of regional subsurface volatiles concentrations. Our results show that the subsurface volatile conditions in the Isidis-Utopia Planitia connection region and southern Chryse Planitia might have undergone different evolution histories. The concentration of subsurface volatiles in the Isidis-Utopia Planitia connection region suggested a stable trend over time, while that in the southern Chryse Planitia shows a downward trend over time.

A combination of ages and onset diameter of LECs suggests that a layer of subsurface water/ice may still exist at a depth of ~500 m in the Isidis-Utopia Planitia connection region, and at a depth of ~800 m as inferred for the southern Chryse Planitia.

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