

MULTI LAYERED EJECTA (MLE) CRATERS OVER ARABIA TERRA, MARS: CRATER AGES AND ITS IMPLICATIONS. Vijayan, S and Rishitosh K Sinha, PLANEX, Physical Research Laboratory, Ahmedabad, India. vijayan@prl.res.in

Introduction: Among the impact craters on Mars, formation of multiple layered ejecta (MLE) crater is considered unique due to its multiple layering patterns. Knowledge of chronology of MLE craters is crucial; mainly to understand whether they are confined to a certain period or their formation occurred over a wide-spread period. Over the equatorial latitudes, MLE distribution, their extent of preservation, and temporal reproducibility has not been determined, which may ultimately help to understand the role of MLE craters in the complex evolutionary history of the planet. This study has been carried out to primarily understand the spatial and temporal distribution of layered ejecta craters over the Arabia Terra (AT) and further infer about the past geological environments in which these craters have evolved. The thinner crust of the AT [2] provides good exposure to the different crustal depth than the other Noachian aged surfaces. Denudation over the AT region is well observed over the northern flank of the region, which merges with the dichotomy boundary. Taken together, all the above factors make AT a good test bed to understand the layered ejecta formation.

Data and methods: In this study, 71 MLE craters (diameter ranging from ~10 to ~111 km) were selected, whose layered ejecta pattern are preserved fully/partially/at least in one direction. These craters are distributed at diverse geographical locations within AT, almost spanning over the entire region (from 0° to 40° N and from ~15° W to 50° E). A renewed examination of MLE craters on the AT region along with the existing catalogs [3,4] was imperative and as a result it has lead to identification of several new MLE craters that were initially not recognized in the previous studies. Our observation makes it quite evident that the MLE crater density is more in AT region in comparison to other regions on Mars. Further, we have analysed the morphological characteristics of MLE craters using MRO-HiRISE and CTX images to discuss the diversity among the observed geomorphic units with respect to the age of craters.

Crater chronology: An absolute best-fit model age is derived for each crater to decipher their formation period. Age estimation is mainly affected by influence of secondary craters and crater clusters. In this study, using the crater count method, we have limited our goal to primarily understand and interpret the relative ages of the craters distributed in the region. Among the mapped 71 craters, 55 craters are suitable

for age estimation, whereas the remaining ones are severely eroded or having indistinguishable ejecta layers from the surrounding terrain. Using the Hartmann and Neukum (2001) production function and Ivanov (2001) chronology function, we estimated the model age of the craters by considering the superimposed craters over the ejecta blanket. In accordance to this, the randomness analysis was carried out as per their respective bins for all the craters, wherein it was noticed that they are almost within $\pm 3\sigma$ of the Monte Carlo derived mean. The chosen craters for the age estimation are neither clustered nor ordered. At $N(D > 500 \text{ m})$, the secondary clusters have less influence over the fit [5]. Therefore, for estimating age, in most of the cases craters larger than $D > 500 \text{ m}$ was chosen, with each bin size containing at least 5 superimposed craters.

Results and Discussion: The age estimation has revealed that MLE craters in the AT region formed during a widespread period between Early Hesperian (~3.66 Ga) to Late Amazonian epoch (~30 Ma) (Fig. 1). While we have age dated all those MLE craters that have preserved the ejecta layers, it was noticed that none of the MLE craters date back to the Noachian period ($> 3.7 \text{ Ga}$). The studied equatorial regions MLE craters are completely lack of sublimation pits over their floors and ejecta. The MLE craters are wide spread over the region and no clustering was observed, which depicts the randomness of the impact events. There is no presence of double layer ejecta (DLE) craters over this region as surveyed by [4] suggesting dominant occupancy of single and multi layered ejecta.

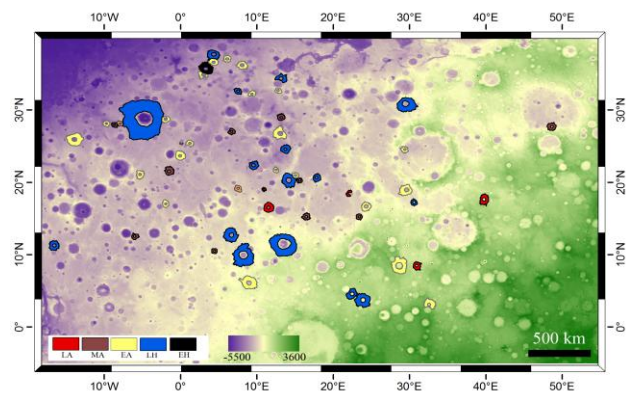


Fig. 1. Distribution of multi layered ejecta craters over the Arabia Terra region and their individual formation age.

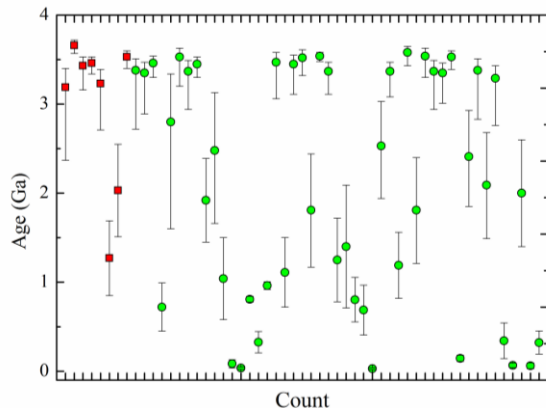


Fig. 2. Model ages for 55 MLE craters formed on the AT region. Red squares- crater ejecta with fluvial channels; circles – crater ejecta with no channels. MLE craters are reproducible in time. The plot suggests Hesperian epoch to be the dominant formation period.

The model ages derived for the MLE craters reveal their temporal reproducibility and formation history over the entire span of the AT region. There are no correlation observed for the morphological changes in the ejecta pattern for the craters formed from past to recent, except the erosional modifications. Several studies in the past decades have suggested that MLE crater formation need volatiles from the subsurface to emplace such fluidized ejecta patterns [6]. From our age estimation, we could show that if subsurface volatile had to be the most essential component for emplacement of ejecta layers, it should be preserved their beneath the AT region for an excessively widespread time span, i.e. from ~3.66 Ga to 30 Ma. In addition it has been postulated that interaction of ejected materials with the thin atmosphere might be another cause for emplacement of layered ejecta [7]. Combination of above said processes has been also suggested for emplacement of MLE [8]. From our age estimation, what has become clear is that irrespective of the volatile content in the subsurface or nature of ejecta interaction with the thin atmosphere, the MLE crater emplacement in AT region has remained same.

The temporal repetitivity of MLE craters was not found to be influenced by a particular location within AT and is rather more reflective of the true signature associated with the surface characteristics, which favored in their formation. During the Hesperian epoch, the MLE craters have formed in almost all the latitudes in variable sizes and their flux naturally reduced during the Amazonian epochs (Fig. 2). The largest layered ejecta crater in this region is Curie crater with distinguishable layered ejecta and secondary craters, but dearth with superposed channels. From our morphologic survey, we could delineate presence of channel

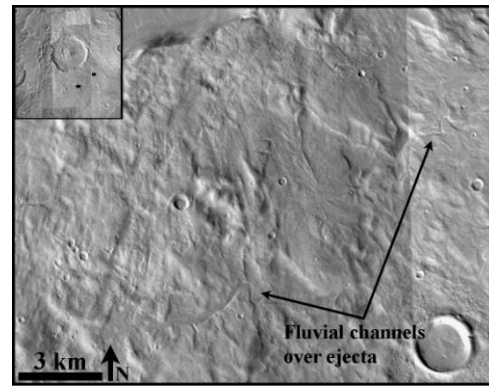


Fig. 3. Example for superposed channels cross cutting ejecta unit on a mid-latitude MLE crater. The crater inset over the left shows the locations of the channel.

networks over some of the craters formed above 30° latitude [9]. These craters (Fig. 3) have age limits varying from ~3.66 Ga to ~1.27 Ga. Within this age scenario, presence of superimposed channels over these high latitude (up to 37° N) MLE craters, drive us closer to interpret that the fluvial activities in the region might have been active even in the Amazonian, a period that is well known to have harboured a cold and dry climatic history. It is important to mention here that the fluvial channels postdate the crater formation and their formation is confined to localized scale. None of the MLE craters in the equatorial region (below 30°N) has revealed such fluvial channels.

Conclusions: The MLE craters distributed over the Noachian aged AT region formed during a widespread period from Early Hesperian (~3.66 Ga) to Late Amazonian (~30 Ma). The age estimates makes it evident that formation of MLE craters is reproducible in time. Upon noticing the temporal repetitivity characteristic of MLE craters, we could suggest that the optimum geological conditions required for emplacement of MLE craters has persisted over time. The lack of Noachian aged MLE craters over this region does not necessarily imply that MLE formation has not taken place in that epoch; rather it portrays the high degree of erosional activity during that period, which has led to degradation of the ejecta in comparison to preservation of MLE craters over Hesperian and Amazonian epochs.

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