Temporal variability of thermal-cycling induced fracturing in chondrites

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Regolith on asteroid surfaces was thought to be a result of micrometeoroid impacts [1], but some recent studies [2,3] claim that thermal fatigue is the dominant regolith production process on airless bodies. Thermal fatigue is produced by diurnal and/or annual variations on the surface temperature of asteroids and its efficiency depends on the heliocentric distance, the rotation period, and the thermal inertia of the asteroid's surface. A fundamental assumption of previous studies is that thermal fatigue remains effective over thousands, or even millions, of thermal cycles. However, the Kaiser effect, extensively studied in the field of fracture mechanics on terrestrial rocks, states that fracturing on materials ceases when previously exerted load levels are not exceeded [9]. Previous research has demonstrated that the thermal properties of CM2 chondrites depend on their mineralogy [11]. Thus, the thermal expansion coefficient of each mineral at specific temperature changes can be translated into different mechanical loads resulting from thermal fatigue.

We aim to observe the time-resolved crack propagation induced by thermal stresses over subsequent thermal load cycles in meteorites – acting as asteroid analogues – in order to understand the role of thermal fatigue in eroding asteroid surfaces. According to several studies, Ryugu is similar to CI [5,6,7,8] and CM [8] carbonaceous chondrites, and hence provides ground truth observations for these samples. We investigate CI, CM, and, for comparison, LL chondrites to examine the behaviour of thermal fatigue on different petrographic types of meteorites. The samples are subjected to a minimum of 100 cycles at $\Delta T=210K$ as the temperature variation of C-type NEAs is 200K [2]. To identify the spatial occurrence of pre-existing and propagating cracks, the samples are scanned using X-ray tomography.

We aim to use non-destructive testing (NDT) methods to detect the time and frequency of crack initiation and propagation. NDT methods are used in many industries to identify and characterize the integrity of a material's surface and interior without interfering with its destruction [10]. The Kaiser effect predicts a decrease in the number of produced stresses as the number of thermal cycles increases, considering that the previous maximum and minimum temperatures of each cycle remain constant at 170C^{o} and -40C^{o} respectively. If the Kaiser effect is applicable, we expect to see the effects of thermal fatigue wane after a few thermal cycles, suggesting that other mechanisms, such as chemical alteration, are contributing to the breakdown process of asteroids.

References

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