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Heating of target at small meteorite impact events

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We investigate the temperatures that develop in small, craterfield-forming meteorite impacts (i.e., craters in a size range of a few meters to several tens of meters diameters formed after atmospheric break-up of the projectile), and where meteoritic and heated material may be distributed within and around the final crater. Knowledge of the theoretical location of meteoritic or fused material at small craters aids retrieval at craters that may be buried or that have been subject to human scavenging of meteoritic iron.

The projectiles causing craters in this size-range have lost much of their initial velocity due to aerodynamic forces during the passage through the atmosphere.

Typical impact velocities for the meteorite fragments that generate crater fields are in the range of 2-4 km/s as calculated for the Campo del Cielo crater field, Argentina [1], the 10m wide Sterlitamak crater, Russia [2] and for the funnel-shaped craters in 10m diameter-range (1-3 km/s) at Sikhote Alin [3]. The most common targets for preserved craters in the size range of interest in our study are sediments or sedimentary rocks. Therefore, we have chosen to compare impacts into two different sediments for which Equations of State (EOS) data are available (wet tuff and limestone). We used the 2-D hydrocode iSALE created by K. Wuennemann and G. Collins. We focused our analysis on the temperature front gradient in the target material during the contact/compression-stage and early excavation-stage of impact. We studied two cases of crater-forming events for each target material. In case 1 the final crater diameter (d) is about 120 m, and for case 2 it is about 10 m. The simulated impacts are assumed to be terrestrial [gravity constant (g) set to 9.81 m/s2], and vertical, as this allows 2-D simulation using radial symmetry. It is known that nearly all crater-forming events (95%) in the size-range of interest are caused by iron meteorites [4]. Thus, the impactor is set to be an iron projectile. The diameters of the projectiles (D), for case 1: D=8m, and for case 2: D=0,5m were obtained through a first set of numerical runs aimed to correlate projectile diameter with final crater diameter.

In all cases, the highest temperature (1900K in the 120-m case and about 1200K in the 10-m case) is reached during contact/compression stage, but remains only for very short time. The temperature gradient is steeper in the limestone target than in the wet tuff. During crater collapse most of the heated material is relocated to the center, where it is buried under slumped crater infill. After one second the crater in wet tuff is about 30% deeper than the limestone equivalent. Eventually, the final crater diameter will also be about 30% wider, partly due to higher degree of collapse. Most of the heated material and meteorite fragments remain within the crater, but slightly more ejection occurs in the limestone case. It is concluded that small impact craters from relatively low impact velocities may still have significant volumes of target material that has been heated to several hundred degrees. Although larger melt bodies may be rare, heated material can exist as, for instance, glass fragments (if siliceous target), or fragments of fired clay. Although some meteoritic fragments and heated material are spread as ejecta the majority remains within the crater structure. This material can be buried at great depth near the center.

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