NUMERICAL SIMULATION OF HEATING OF TARGET AT CRATER-FIELD-FORMING IMPACT EVENTS. J. Ormô and A. Lepinette, Centro de Astrobiología (INTA/CSIC), 28850 Madrid, Spain (ormo@inta.es; lepinettea@inta.es).

Introduction: Most studies on the heating of target by cosmic impacts concern melting and vaporization by large hyper-velocity impacts. Here, we investigate the temperatures that develop in small, crater-field-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. 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. Due to nearly insignificant vaporization any remnants of the meteorite most often occur as fragments and, sometimes, as relatively small volumes of melt particles. However, abundant glass with traces of the projectile in the quartz-rich sands of the Wabar crater field, Saudi Arabia, may show that the amount of preserved fused material as well as impactor vaporization may be target dependant [1,2]. 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 meteoric iron.

Numerical simulation: The impact velocities for the meteorite fragments that generate crater fields are much lower than the average for large hypervelocity impacts (approx. 20 km/s). The impact velocity for the projectile that formed a 24x16m crater in the Campo del Cielo crater field, Argentina was calculated to be about 3.7 km/s [3]. A similar velocity (2-4 km/s) was calculated for the 10m wide Sterlitamak crater, Russia [4] and for the funnel-shaped craters in 10m diameter-range (1-3 km/s) at Sikhote Alin [5]. The most common targets for preserved craters in the size range of interest in our study are sediments or sedimentary rocks. This is likely due to poor development in crystalline 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. Wünnemann 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. In addition, cells representing the projectile were marked as tracers for the continued simulation of the excavation- and modification-stages. 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 [6]. Thus, the impactor is set to be an iron projectile with density of 7800 kg/m³. The density of the wet tuff is 1970 kg/m³, and the limestone 2700 kg/m³. The ANEOS (analytical equation of state) [7] and Tillotson model parameters for iron, wet tuff and limestone are used in the code as EOS of the materials. All simulations were conducted with spherical projectiles with 10 vertical cells per projectile radius and the velocity (v) 4 km/s. 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 d=100m, and d=10m respectively. In the case 1, the non-uniform computational grid of the simulations consisted of 300 cells in horizontal direction and 360 cells in vertical direction so that the total number of nodes describes half of the crater domain (axial symmetry). In case 2, the non-uniform computational grid of the simulations consisted of 400 cells in horizontal direction and 390 cells in vertical direction. We increased the mesh size progressively outwards from the center with a 1.05 coefficient multiplier for the mesh extension allowing a larger spatial domain to avoid wave reflection problem at the boundaries. The central cell region around the impact point, where damage is greater, was a regular mesh with 80 nodes resolution in both x and y direction describing half of the damaged zone (axial symmetry). The temperatures are given in Kelvin (K). The simulated impacts occur at 293K (Initial target temperature). Note that the dark blue color is a background color given by the software and does not represent a certain temperature.

Results and discussion: In the 120-m crater case, the highest temperature is reached during contact/compression stage, but remains only for very short time (Fig. 1). The temperature gradient is steeper (i.e., thinner heated zone) in the limestone target than in the wet tuff. Continued crater collapse relocates most of the heated material to the center, where it gets buried under several tens of meters of slumped crater infill (Fig. 2). The crater developed in wet tuff has a significantly larger proportion of the highest heated material than the crater in limestone. 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 (Fig. 2).

The steeper temperature gradient in the limestone case is obvious also in the 10m crater simulations (Fig. 3). In both cases, the rise in temperature lasts only for some tens of milliseconds. Most of the heated material and meteorite fragments remain within the crater, but slightly more ejection occurs in the limestone case. The final crater diameter is approximately the same, but the limestone case gets a V-shape, whereas the wet tuff equivalent is bowl-shaped and flat-floored representing a larger cavity volume. We have not yet managed to recreate the “funnel-shape” observed in craters of this size-range in the nature.

Conclusions: 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.