SHOCKED MINERALS IN THE K-T BOUNDARY: IMPLICATIONS FOR OBLIQUITY OF IMPACT
J. Morgan[1] , C. Lana[1], N. Artemieva[2], [1]Imperial College London, UK, j.morgan@imperial.ac.uk, [2]Institute for Dynamics of Geospheres, Moscow, Russia.

Introduction: It is well-known that impact ejecta distribution is the most effective indicator of impact obliquity: while the majority of planetary craters are circular, ejecta distribution is not [1-4]. This is especially true for tektites which, with a mass that is comparable to that of the projectile, carry important information about the early stage of impact. In this study we investigate whether the K-T global ejecta layer is also likely to carry a signature of obliquity of impact at Chicxulub.

We know that the world-wide K-T boundary layer contains vaporised meteorite, impact-derived minerals, and shocked fragments of target rock. The only viable mechanism of producing the observed global distribution of impact-derived particles is through their acceleration to high velocity within a post-impact expanding vapor plume. However, the nature of the mechanics of ejection, as well as the condensation and solidification of material with distance from the impact site, all remain relatively poorly understood. Previous studies of the K-T ejecta have suggested some intriguing asymmetries in the ejecta pattern [5-8]. However, to-date, these observations are based upon data acquired using different analytical procedures, with relatively few well documented sites in the southern hemisphere, and it is difficult to make a quantitative assessment of ejecta asymmetry using these data.

Ejecta analyses: In this study we have systematically documented the size-distribution and degree of shock of quartz at a number of K-T sites worldwide. In Fig. 1a we plot the average number of shocked quartz grains per gram from SEM analyses against apparent paleodistance (partially corrected for the Earth's rotation). The number of shocked quartz grains decreases away from Chicxulub and is best fit by a power law. There is more than an order of magnitude difference between the numbers of shocked quartz in North American sites and the rest of the world, and the next two closest sites, 207 (in the mid Atlantic to the southeast of Chicxulub) and LL44 (in the Pacific to the west of Chicxulub), appear to have anomalously low amounts of quartz. The European sites contain more shocked quartz than expected. These results contrast with previous comparisons between the Pacific and Europe sites (6-7), but it is apparent from our studies that optical and SEM analyses produce quite different results, and that results from unrelated studies cannot easily be compared.

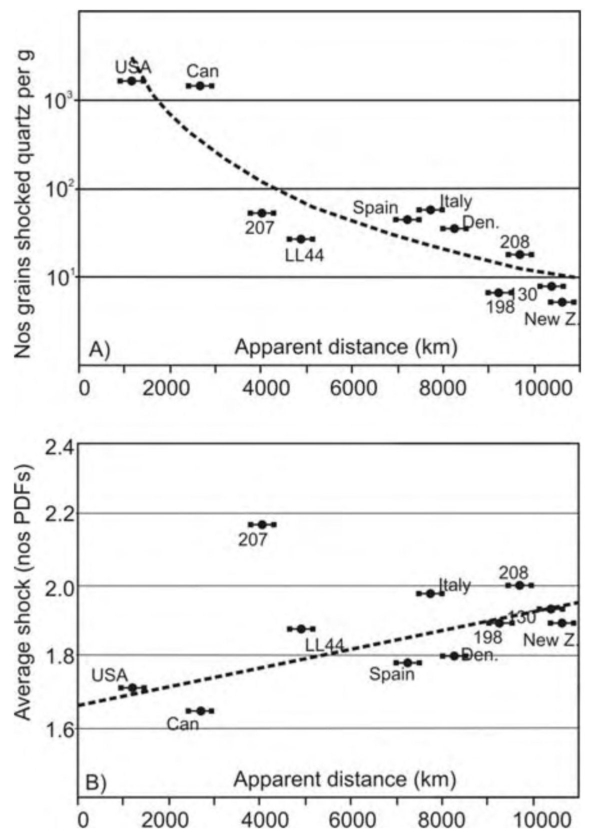

Figure 1

In Figure 1b the degree of shock (average number PDFs) is plotted for each site. The degree of shock increases away from the impact site and is best described by a linear equation. It is clear that the degree of shock at site 207 is anomalous.

Numerical modeling: We model the impact and high-velocity impact ejecta motion using 3D hydrocode SOVA [9] complemented by the ANEOS [10] equation of state for geological materials**.** We use a tracer (massless) particle technique to reconstruct dynamic (trajectories, velocities), thermodynamic (pressure, temperature) and disruption (strain, strain rate) histories in any part of the flow. The motion of ejecta in the post-impact plume is described in the frame of two-phase hydrodynamics: every ejected fragment is characterized by its individual parameters (mass, density, position, and velocity) and exchanges momentum and energy with surrounding vapor-air mixture.

We use a simplified description of the Chicxulub target that is similar to previous model runs [11-13], with a 3-km-thick layer of sediments (calcite EOS), a 30-km-thick crystalline basement (granite EOS) and mantle (dunite EOS). In this study we scale the projectile size with impact angle and then check the resulting transient cavity size with geological measurements. Hence, one more output of this study is a direct control of the transient cavity size versus the projectile size and impact angle.

Modeling Results: To-date we have computed the early stage ejecta only. The distribution of ejected mass and its average velocity in various directions is plotted with respect to projectile trajectory and different impact angles in Fig. 2. While in a vertical impact (90°) ejecta are symmetric, a 30°-degree impact leads to a substantial asymmetry in mass (10 times more ejecta in downrange direction than uprange), and in average ejection velocity (1 km/s downrange, 0.3 km/s – uprange).

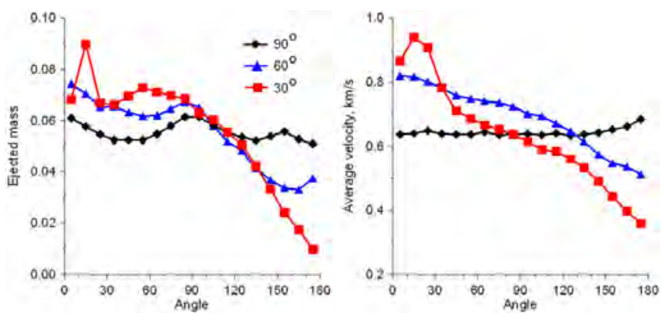

Figure 2: Mass of ejected shock quartz and its velocity as a function of azimuthal angle (0 is downrange, 180 is uprange).

In Fig. 3 we plot the ejection velocity of downrange and uprange ejecta against their maximum compression. Similar ejection velocities are likely to lead to ejecta being deposited at similar distances from the impact site. We see that the uprange ejecta is much more shocked, on average, than downrange ejecta.

Conclusions: The total number of shocked quartz grains per gram in North American sites is an order of magnitude greater than anywhere else (Fig. 1). As we have no sites at similar close distances in any other direction, we cannot be sure whether these high numbers are unusual or expected. However, the relative low numbers of quartz at the next two closest sites in the South Atlantic and North Pacific, suggests that the number of shocked quartz grains at North American sites are probably anomalously high. The number of shocked quartz grains per gram in European sites is slightly higher than expected. In view of the results of the modeling of the early stage ejecta shown in Figs. 2-3, the high degree of shock in site 207 and the size-distribution of the shocked grains are indicative of a downrange direction to the north or northeast of Chicxulub. However, we need to continue the modeling to establish whether the late stage ejecta carries a similar signature of obliquity to that of the early ejecta.

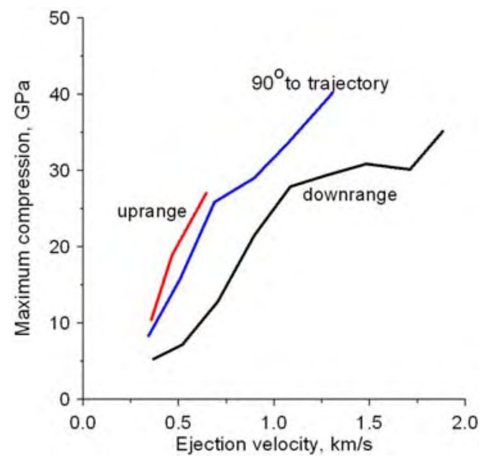

Figure 3: Shock compression of ejecta as a function of ejection velocity. There are no high-velocity ejecta uprange, low-velocity uprange ejecta is compressed to 2-5 times higher pressures than downrange ejecta with the same velocity.

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