EMPLACEMENT OF KT-BOUNDARY SHOCKED QUARTZ FROM CHICXULUB CRATER

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We propose that only high velocity, steep trajectories of shocked quartz grains could explain their occurrence in the upper of the two distinct KT boundary layers found in the US western interior and the higher abundance of shocked quartz at sites in the Pacific Ocean than at European sites the same distance away toward the east. The velocities and angle of launch required are greater than those needed to emplace the ejecta in the lower of the two KT boundary layers in the western interior, the presumed impact-melt ejecta. Such conditions of angle and velocity are difficult to explain by impact cratering dynamics in a homogeneous target medium, and are particularly difficult to reconcile with flow solely in a ballistic ejecta curtain launched at ~ 45° angle. We present a model in which the acceleration is provided by expanding gas (CO_2 + H_2O) from shock devolatilization of the 3 km limestone layer that overlies crystalline basement at Chicxulub.

KT boundary shocked quartz has been compellingly tied to the Chicxulub Crater, but two problems remain in understanding its distribution: (a) In the western interior of North America shocked quartz is confined to a separate layer immediately overlying the main KT ejecta layer [1; 2]. (b) Shocked quartz grains are much more abundant at sites in the Pacific Ocean [3] than at European sites the same distance away toward the east. We propose that acceleration of shocked quartz grains to high velocity on steep trajectories [4] could explain both problems: (a) Shocked quartz would arrive in western North America later than ejecta on moderately inclined trajectories because of longer travel times for steep trajectories than for ejecta-curtain material launched at about 45° elevation angle. (b) Because of the Earth's rotation, ejecta on steep trajectories is excluded from a forbidden zone east of the launch site (Figure). This introduces a travel-time sorting that may explain the double layer of the western interior, but not if the organic traces in the lower layer represent the roots of plants which grew between two falls which would thus be separated by at least one growing season [5;6]. However, the crystallization ages on zircons from the upper layer do argue strongly that the two layers both originated at Chicxulub [7] and must therefore be separated by probably less than one day. We suggest instead that the organic traces may mark the stems of plants which burned during the arrival of the particles of the lower layer, and which had fully burned and collapsed before the fall of the second layer.

If correct, our shock quartz emplacement mechanism places constraints on the nature of the Chicxulub cratering event, requiring low-velocity launch of the shocked quartz, so that the shock lamellae do not anneal or the quartz melt. A simple cratering model would predict that shocked quartz would be launched with lower ejection velocities than shock-melted quartz and target rock, and that it be thoroughly intermixed with the melt during flow in the ballistic curtain of ejecta.

Thus, the quartz launched during the shock-rarefaction events in the immediate cratering event must have been subsequently accelerated to high-velocities and to steep (nearly vertical) trajectories. This acceleration cannot come from the silicate-vapor plume (fireball) where temperatures are extreme and would cause annealing of the lamellae. We present a model in which the acceleration is provided by expanding CO_2 and H_2O gas from shock devolatilization [8] of the 3 km limestone layer that overlies crystalline basement at Chicxulub. The gas from the devolatilized region would form a second plume, which we term a "cold plume" that follows the hot fireball upward. Plume dynamics, atmospheric dynamics and complex interactions with transient air and water waves from the impact would complicate, and probably dominate, over the initial cratering launch dynamics.

Shocked quartz grains originating in the basement immediately below the limestone cover would be mixed with the expanding CO_2 and H_2O vapor in this "cold plume" and strongly accelerated upward. Chicxulub ejecta would thus be launched by three different processes — Ir in the fireball, impact glass in the ejecta curtain, and shocked quartz in the cold plume.

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Figure. Reimpact patterns of ballistic ejecta launched at Chicxulub, shown on a map of continental positions at the KT boundary, ignoring atmospheric effects, which occur only at the times of launch and re-entry. For a launch angle of 70° above the horizon, thin lines show reimpact loci for launch velocities at 1 km/sec increments. Heavy lines show the limit of the forbidden zone at 70°, as well as for 60° and 45° launch angles; in the latter cases reimpact loci are omitted to avoid clutter. Squares mark sites with coarse shocked quartz (>250 μm); circles mark sites with abundant fine shocked quartz; crosses mark sites with rare, fine shocked quartz; diamonds mark sites where shocked quartz has been reported, but with insufficient information to determine its abundance. The asymmetrical distribution of shocked quartz grains, heavily concentrated west of the impact site, can be explained if most grains were launched an angle steeper than about 65°.