Estimates of climatically important gases released in the Chicxulub Impact Event

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The size and the location of the Chicxulub structure, on the Yucatán Peninsula, Mexico, produced by an impact event that occurred about 65 Ma, has driven many speculations on an impact-related abrupt climate change with catastrophic effects on the biota, resulting in the dramatic extinction event that marks the Cretaceous-Tertiary boundary. We carried out hydrocode calculations of the Chicxulub event using newly developed equations of state of the materials that are believed to play a crucial role in the impact-related extinction hypothesis: Carbonates (calcite) and evaporites (anhydrite). The outcomes of the simulations rule out CO_2 as the major cause for climate changes, as was previously suggested [1] [2], and indicate the S-bearing gases and water vapor are the most dangerous impact-related agents for climate change.

Impact simulations were carried out using Sandia's 2-D hydrocode CSQIII [3] coupled with the semianalytical equation of state ANEOS [4]. The simulations consist in spherical dunite projectiles, 5 or 10 km in radius, impacting vertically at a speed of 20 km/s. Simulations with 0 and 50% porous projectiles were carried out for each projectile size. According to the scaling law of Schmidt and Housen [5] the simulations correspond to transient crater diameters ranging from about 60 to 135 km. Actual estimates of the size of the Chicxulub structure vary between 180 and 300 km [6,7,8,9,10], corresponding to transient crater sizes in the range 90 to 180 km. The target consists of a dunite mantle and an overlying 30-km layer of granitic crust. The local sedimentary sequence of carbonates and evaporites, 2 to 3 km thick, is modeled by alternating layers of calcite and anhydrite, and the shallow sea that covered the site at the time of the impact is modeled with a 100-m thick layer of water. ANEOS equations of state for dunite, granite, and water had been previously developed, while ANEOS equations of state for calcite and anhydrite have been developed for this work. Finally, the atmosphere is modeled by ANEOS air equation of state with the terrestrial temperature profile.

For each run the amount of melt and vapor produced in the projectile and various target materials have been calculated. We assumed an average porosity of 20% for the carbonate layer, in agreement with published values between 14 and 26% [11], and complete saturation with water.

We estimated the amount of climatically important species produced in the impact simulations: CO_2, S, and water vapor. The estimates, increasing linearly with increasing transient crater size, vary from about 360 to 1700 Gt for CO_2, from 300 to 700 Gt for water vapor, and from 60 to 300 Gt for S. A small amount of additional S and water vapor may have been produced from the projectile as well [12].

The CO_2 production from our simulations are one to two orders of magnitude lower than previous 2D experiments [1,2]; the atmospheric injection of such amount would have produced, at most, and increase of 30% in the atmospheric CO_2 inventory at the end of the Cretaceous (about 4 times present values [13]). Because of the lack of an equation of state for S-rich materials like anhydrite and gypsum very little work has been done until now to model the amount of S-bearing gases that would be produced by a Chicxulub-size event. Ivanov et al. [14] gave a possible estimate of the amount of S-bearing sediments degassed by the impact. Our simulations produced results not too far from theirs but consistently higher. Our estimates of the amount of S released in the impact are several orders of magnitude higher than any known volcanic eruption (e.g., Mt. Pinatubo: .01 Gt; Toba: 1 Gt), clearly able to perturb the global climate over timescales of years.

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