An overlooked heat source in impact events and its effect on the degree of devolatilization of natural calcite carbonates

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Mutual collisions between two small planetary bodies at the main belt region at velocities higher than several km s^{-1}cause heating of their surface materials, resulting in a variety of thermal metamorphism. Given that we have understood the relation between the degree of thermal metamorphism and impact condition accurately, analyses of thermally-metamorphic features recorded in meteorites allow us to decode the impact environment in the solar system through its history. Recently, Kurosawa and Genda (2018) found that plastic deformation of the shock-comminuted rocks during decompression from the peak shock state efficiently converts the kinetic energy in the impact-driven flow field into the thermal one, resulting in a higher degree of shock heating than previously thought. If a temperature rise due to plastic deformation is also significant in natural impact events, impact histories derived from thermal metamorphism would need to be revised. This new finding was obtained based on a modern shock physics code, which can treat elasto-plastic behavior of rocky materials. In this study, we validated the numerical results by comparing the numerically-calculated CO2 production with the experimental data pertaining to natural calcite blocks by Kurosawa et al. (2012). We simulated the seven impacts performed in the experiment by using the iSALE-2D. The “ROCK” model in the iSALE package was used to simulate pressure-temperature dependent elasto-plastic behavior of calcites. We varied the von-Mises limit Y_{lim} as a free parameter to explore the roles of material strength on the numerical results. The CO_2 production in the simulation was calculated based on temporal entropy under an assumption that the system is in a thermal equilibrium. Total 35 runs with 4 different Y_{lim} values and without material strength (i.e., purely hydrodynamic) were performed. We found that the calculated CO_2 production in the case of hydrodynamic is systematically lower than the experimental results. In contrast, if we used Y_{lim} = 1 GPa, the calculated values are close to the experimental results at impact velocities ranged from 2 to 7 km/s, strongly suggesting that the additional heating during decompression due to plastic deformation is significant in natural impact events.

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