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The effect on core formation of the extreme thermal and rotational states of planets after giant impacts

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During accretion, almost all terrestrial planets experience collisions with other planet-sized bodies, so-called giant impacts. Giant impacts are the most energetic events growing planets experience, driving large thermal and chemical perturbations and fundamentally shaping the properties of the final planets. In particular, it is the aftermath of such collisions that provides the setting for core formation. Giant impacts typically deposit large amounts of metal into the mantle of the largest remnant and melt a substantial fraction of that mantle, providing the opportunity for metal to segregate to the core. The thermodynamic and dynamic conditions in the aftermath of giant impacts therefore control how different elements partition between the core and mantle, affecting the long-term thermal and chemical evolution of planets, the potential for magnetic dynamos, and our interpretation of geochemical tracers of accretion.

In this work, we explored the thermal outcomes of a representative set of collisions between Moon- to super-Earth-mass bodies and their implications for core formation. We used updated ANEOS equations of state with the SWIFT hydrocode and HERCULES planetary structure code to more accurately describe the temperatures, pressures, and heat budgets of post-impact planets. We find that a substantial fraction of the mantle is heated above the Fe-MgO solvus for impacts with specific energies $>10^6$ J/kg, implying that a thermodynamically miscible layer should form at the core-mantle boundary (CMB) for many giant impacts. We present scaling laws for the efficiency of impact heating, mantle/core heat partitioning, and CMB pressures and temperatures. We find that post-impact pressures are generally lower than previously assumed for CMB conditions, due to both thermal and rotational effects. The comparatively low internal pressures after giant impacts have a significant effect on the conditions for metal-silicate equilibration, and our work strongly implies that Earth's core-mantle equilibration occurred close to the CMB, much deeper than previously inferred.