Goldschmidt 2026 Abstract
https://doi.org/10.46427/gold2026.35840

Reheating of Vesta's crust triggered by the formation of an insulating surface layer: constraints from zircon geochronology and thermal evolution modeling

MAKIKO K. HABA[1], WLADIMIR NEUMANN[2,3] AND MARIA SCHÖNBÄCHLER[4]

[1]Institute of Science Tokyo
[2]Technische Universität Berlin
[3]Macau University of Science and Technology
[4]ETH Zürich

Vesta is a differentiated asteroid that is widely regarded as the parent body of the HED meteorites. Chronological constraints indicate crust formation within a few million years after CAI formation [1]. High-precision ID-TIMS U–Pb zircon geochronology shows that zircons in a non-cumulate eucrite crystallized at ~4552.5 ± 0.7 Ma [2], and cumulate eucrites yield ages between 4539 and 4553 Ma [3]. Combined chronological and thermal constraints, derived from zircon crystallization [4] and U–Pb closure of ~900–1000°C, indicate that the high temperatures persisted beyond 14 Ma after CAI formation across a substantial vertical extent of crust. Such conditions are not reproduced by existing thermal evolution models for Vesta [5].

We propose that the formation of an insulating surface layer delayed cooling and reheated the upper crust. If the deep crust remained hot, a low-thermal-conductivity surface layer would reduce outward heat flux, allowing heat from below to exceed surface loss and raise upper-crustal temperatures. Because conductive heat transfer requires time, peak temperatures occur after insulating-layer formation. This mechanism could explain widespread thermal metamorphism in basaltic eucrites and the timing of zircon crystallization.

To test this hypothesis, we conducted thermal evolution calculations assuming that Vesta accreted at 0.5 Ma after CAI formation and varying the deposition time and the thickness of a porous regolith layer. The results indicate that formation of a ~2 km–thick surface regolith (40% porosity) at ~4 Ma reproduces the zircon ages and corresponding crystallization temperatures recorded in eucrites, as well as metamorphic conditions in basaltic eucrites (~700–1000°C [6]). The inferred timing is broadly consistent with intervals of enhanced impact flux in the early Solar System [7], which may have contributed to the formation of a thick insulating layer on Vesta.

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