[Journal of Geophysical Research: Planets]

Supporting Information for

[Pressure and temperature dependence of shock remanence intensity for single-domain titanomagnetite-bearing basalt: Toward understanding the magnetic anomalies produced by impact events]

[Masahiko Sato[1], Kosuke Kurosawa[2], Sunao Hasegawa[3], and Futoshi Takahashi[4]]

[[1]Department of Earth and Planetary Science, The University of Tokyo, Tokyo, Japan, [2]Planetary Exploration Research Center, Chiba Institute of Technology, Narashino, Japan, [3]Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, Sagamihara, Japan, [4]Department of Earth and Planetary Sciences, Kyushu University, Fukuoka, Japan]

Contents of this file

- Description for impact simulation (Table S1 and S2)

Impact simulation

We conducted shock physics modeling to calculate the peak pressure and peak temperature distributions around an impact crater using the iSALE shock physics code (Amsden et al., 1980; Ivanov et al., 1997; Wünnemann et al., 2006). We employed cylindrical coordinates, and we assumed a vertical impact of a dunite projectile onto a basaltic crust. The material model pertaining to basalt is summarized in Table S1. The impact velocity was set to 6 km s^{-1}, which corresponds to the minimum impact velocity onto Mars (Zahnle, 1993).

Because our empirical relationship cannot evaluate the effects of lithostatic pressure and geotherm, zero pressure and uniform temperature in the basaltic crust were assumed to be the initial conditions, which correspond to the craters produced on a laboratory scale. Nevertheless, our simulation may provide a qualitative understanding of the magnetic anomaly profile above the magnetized crater immediately after impact.

Since we needed to continue numerical integration until the end of a crater formation, the computational cost of this simulation is relatively high. To reduce the computational time, the spatial resolution was relatively low, and a relatively large value of gravitational acceleration was employed. The calculation settings are summarized in Table S2.

Table S1. Input parameters for the material models. Note that the parameter set pertaining to the dunite projectile and the basalt target are the same as used by Johnson et al. (2015) and Bowling et al. (2020), respectively.

EOS type	ANEOS[a]	ANEOS[a]
Material	Dunite[b]	Basalt[c]
Strength model	Rock[d]	Rock[d]
Poisson's ratio	0.25	0.25
Melting temperature (K)	1373	1360
Thermal softening parameter	1.2	0.7
Simon parameter, A (GPa)	1.52	4.5
Simon parameter, C	4.05	3.0
Cohesion (undamaged) (MPa), $Y_{coh,i}$	10	20
Cohesion (damaged) (kPa), Y_{coh}	10	10
Internal friction (undamaged), μ_{int}	1.2	1.4
Internal friction (damaged), μ_{dam}	0.6	0.6
Limiting strength (GPa), Y_{limit}	3.5	2.5
Minimum failure strain	10^{-4}	10^{-4}
Constant for the damage model	10^{-11}	10^{-11}
Threshold pressure for the damage model (MPa)	300	300

[a]Thompson and Lauson (1972), Thompson et al. (2019)
[b]Benz et al. (1989)
[c]Pierazzo et al., (2005), Sato et al. (2021)
[d]Collins et al. (2004)

Table S2. Numerical model settings.

Computational geometry	Cylindrical coordinates
Number of computational cells in the *R* direction	500
Number of computational cells in the *Z* direction	500
Number of cells for the extension zone in the *R* direction	200
Number of cells for the extension zone in the *Z* direction (top)	100
Number of cells for the extension zone in the *Z* direction (bottom)	200
Cells per projectile radius (CPPR)[b]	5
Impact velocity (km s^{-1})	6
Layer position	400 cells from the bottom of the computational domain
Artificial viscosity, a_1	0.24
Artificial viscosity, a_2	1.2

References

Amsden, A., Ruppel, H., and Hirt, C. (1980). SALE: A simplified ALE computer program for fluid flow at all speeds, Los Alamos National Laboratories Report, LA﹣8095:101p.

Benz, W., Cameron, G. W., & Melosh, H. J. (1989). The origin of the Moon and the single-impact hypothesis III. Icarus, 81(1), 113–131. https:// doi.org/10.1016/0019-1035(89)90129-2

Collins, G. S., Melosh, H. J., and Ivanov, B. A. (2004). Modeling damage and deformation in impact simulations, Met. And Planet. Sci., 39, 217–231.

Ivanov, B. A., Deniem, D., and Neukum, G. (1997). Implementation of dynamic strength models into 2‐D hydrocodes: Applications for atmospheric breakup and impact cratering. International Journal of Impact Engineering, 20(1−5), 411−430.

Johnson, B. C., Minton, D. A., Melosh, H. J. and Zuber, M. T. (2015). Impact jetting as the origin of chondrules. Nature 517, 339-341.

Pierazzo, E., Artemieva, N. A., Ivanov, B. A. (2005). Starting conditions for hydrothermal systems underneath Martian craters: Hydrocode modeling. in Large meteorite impacts III, eds., Kenkmann, T., Hörz, F., and Deutsch, A.,: Geological Society of America Special Paper, 384, p. 443–457.

Sato M., Kurosawa K., Kato S., Ushioda M., and Hasegawa S. (2021). Shock Remanent Magnetization Intensity and Stability Distributions of Single-Domain Titanomagnetite-Bearing Basalt Sample Under the Pressure Range of 0.1–10 GPa. Geophysical Research Letters, 48, 8.

Thompson, S. L., & Lauson, H. S. (1972). Improvements in the Chart-D radiation hydrodynamic code III: Revised analytical equation of state. pp. SC-RR-71 0714 119 pp., Sandia Laboratories, Albuquerque, NM.

Thompson, S. L., Lauson, H. S., Melosh, H. J., Collins, G. S., & Stewart, S. T. (2019, November 1). M-ANEOS (Version 1.0). Zenodo. https://doi.org/10.5281/zenodo.3525030

Wünnemann, K., Collins, G. S., and Melosh, H. J. (2006). A strain‐based porosity model for use in hydrocode simulations of impacts and implications for transient crater growth in porous targets. Icarus, 180(2), 514−527.

Zahnle, K., Xenological constraints on the impact erosion of the early martian atmosphere, J. Geophys. Res., 98, 10899–10913, 1993.