Material properties and analysis of impact-induced porosity in the Santiago Papasquiero meteorite

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Introduction:

The selection and upcoming launch of the NASA *Psyche* mission resulted in piqued interest in cratering of metal-rich materials. As Asteroid (16) Psyche is thought to be made predominantly of metal [1-4], a suite of hypervelocity impact experiments were conducted at the NASA Ames Vertical Gun Range facility [5]. In this work, we focus on the impact experiments that were performed into samples of Santiago Papasquiero [6], an anomalous ataxite, at impact velocities ranging from 2-6 km/s at various temperatures. An unexpected observation from these experiments was extensive cracking through the meteorite volume as a result of the hypervelocity impact. As such, we focus on quantifying and understanding the formation of cracks within Santiago Papasquiero through physical analysis and numerical modeling.

Post-impact *in situ* analysis has been performed via x-ray computed tomography (XCT) at the Materials Instrumentation and Multimodal Imaging Core (MIMIC) Facility at the University of Colorado Boulder. We present three-dimensional renderings of an impacted cube of Santiago Papasquiaro meteorite material. The XCT data were then processed using Dragonfly [7], a scientific imaging software in which inter-connected crack volumes are extracted and computed. We find that approximately 2-3% bulk porosity was introduced to the Santiago Papasquiero meteorite following a single ~5 km/s impact.

In order to numerically simulate the impact experiments, material-specific parameters are required to model the shock-response. Here, we present results from compression, tensile and torsion tests on the Santiago Papasqueiro meteorite which are used in the Johnson and Cook (JC) Strength and Failure models [8-9] to numerically model impacts using iSALE and CTH shock physics softwares. These tests were performed at 77 K and extrapolated through room temperature, making them relevant and useful for a variety of scientific applications — namely, in studying the effects of hypervelocity impacts into Main Belt and Near Earth metal-rich asteroids.

Finally, we attempt to model the hypervelocity impact scenario into the Santiago Papasquiero meteorite using the empirically-derived JC parameters in CTH [10] and iSALE [11-13] shock physics codes. We compare the porosity which is introduced via hypervelocity impact event and find that the current material parameters and impact conditions are not sufficient in reproducing the ~ 2-3% porosity. As such, we explore additional mechanisms or causes for this discrepancy. In particular, we investigate the effect of one or more silicate inclusions within the volume of the target body.

References:

[1] J. Hanuš et al. (2017) *Astronomy & Astrophysics*, 601, A114. [2] A. Matter et al. (2013) *Icarus*, 226, 419. [3] J. Bell. (1989) *Asteroids II,* 921. [4] L. Elkins-Tanton. (2017) *LPS XLVIII,* Abstract #1718. [5] S. Marchi et al. (2020) *Journal of Geophysical Research (Planets),* 125, e05927. [6] Buchwald, Vagn F. (1975) Handbook of Iron Meteorites. University of California Press, 1418 pp. [7] Dragonfly 2020.2 [Computer software]. Object Research Systems (ORS) Inc, Montreal, Canada, 2020; software available at http://www.theobjects.com/dragonfly. [8] G.R. Johnson and W.H. Cook. (1983) *Proceedings 7th International Symposium on Ballistics*, 1983, 541-547. [9] G.R. Johnson and W.H. Cook. (1985) *Engineering fracture mechanics* 21, no. 1, 31-48. [10] J.M. McGlaun et al. (1990) *International Journal of Impact Engineering*, 10, 1-4, pp. 351-360. [11] A. Amsden et al. (1980) *Los Alamos National Laboratories Report*, LA-8095:101p. [12] G. Collins et al. (2004) *Meteoritics and Planetary Science*, 39, 217. [13] K. Wünnemann et al. (2006) *Icarus* 180, 514.