EPSC Abstracts
Vol. 13, EPSC-DPS2019-598-1, 2019
EPSC-DPS Joint Meeting 2019

EPSC
EPSC-DPS Joint Meeting 2019
15–20 September 2019 | Geneva, Switzerland

Hypervelocity impacts on iron meteorite targets: understanding impact processes on metal-rich asteroids.

Guy Libourel (1, 6), Akiko M. Nakamura (2), Pierre Beck (4), Sandra Potin (4), Clément Ganino (3), Suzanne Jacomet (5), Ryo Ogawa (2), Sunao Hasegawa (7), Patrick Michel (1).
(1) Université Côte d'Azur, Observatoire de la Côte d'Azur, CNRS, Laboratoire Lagrange, Boulevard de l'Observatoire, CS 34229, 06304 Nice Cedex 4, France. (2) Graduate School of Science, Kobe University, 1-1 Rokkoudai-cho, Nada-ku, Kobe, 657-8501, Japan. (3) Université Côte d'Azur, Observatoire de la Côte d'Azur, CNRS, Laboratoire Géoazur, 250 rue Albert Einstein, Sophia-Antipolis, 06560 Valbonne, France.(4) UJF-Grenoble1/CNRS-INSU, Institut de Planétologie et d'Astrophysique de Grenoble (IPAG) UMR 5274, Grenoble, F-38041, France. (5) MINES Paristech, PSL-Research University, CEMEF-Centre de Mise en Forme des Matériaux/Centre for Material Forming, CNRS UMR 7635, CS 10207, 1 rue Claude Daunesse, 06904 Sophia-Antipolis Cedex, France. (6) Hawai'i Institute of Geophysics and Planetology, School of Ocean, Earth Science and Technology, University of Hawai'i at Mānoa, Honolulu, Hawai'i 96821, USA. (7) Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, 3-1-1 Yoshinodai, Chuo-ku, Sagamihara, 252-5210, Japan. (libou@oca.eu)

Abstract

The apparent deficit of metal-rich asteroids is consistent with the coating of metallic surfaces by melts produced during impacts with speeds typical of those occurring in the asteroid belt. We also show that hypervelocity impacts produce unexpected signatures on metal-rich asteroid surfaces, such as highly vesicular, partially crystallized coatings with or without hydrated features.

1. Introduction

Recent measurements using the ^{182}Hf/^{182}W isotopic chronometer on iron meteorites (1) have shown that a significant fraction of planetesimals experienced silicate-metal differentiation within the first million years after the formation of the Solar System. It is thus generally believed that catastrophic impacts have revealed the metallic cores of many of these bodies. Spectral observations of asteroids show however a deficit of metal-rich objects in the asteroid belt.

It has been proposed that the apparent paucity of metal-rich asteroids based on spectral observations is due to low-velocity collisions that may deposit foreign material on their surfaces (2), thus hiding or altering their metallic characteristics, and consequently biasing their spectral classification. However, in the asteroid belt, low-speed collisions are rare. During their lifetime, all asteroids rather projectile sizes with typical impact speeds about 5 km/s. Looking for a more generic/robust scenario accounting for the most likely impact speeds in the asteroid belt, we conducted a campaign of hyper-velocity impact experiments on metallic targets, using representative impact speeds.

2. Experiments

Impact experiments were performed using a 7-mm bore two-stage light-gas gun at the Institute of Space and Astronautical Science (ISAS) in Japan. A series of impact experiments, all shot vertically to the target surface have been conducted using steel and Gibeon iron meteorite targets as proxies of metal-rich asteroids. Dry vs hydrated glassy basalt and crystallized dunite samples have been used as projectiles to mimic the diversity of asteroid materials, i.e., (carbonaceous) primitive or differentiated, hydrated or dry bodies. Experimental runs were performed with increasing impact speed from 3.39 km/s to 6.89 km/s and different masses of projectile from 0.03 g to 0.08 g resulting in different impact energies. The impact is captured with a high-speed video camera that monitors the experiment. The compositions of impact craters were then characterized by using Scanning-Electron-Microscopy (SEM) observations and Energy-Dispersive X-ray diffraction chemical maps, as well as by VIS-NIR spectral analysis of the crater floor of the metallic target.

3. Results

For all tested impact speeds, X-ray chemical maps indicate that the metallic crater floor is covered by a thin, more or less continuous, layer of impact melt (now glassy) mainly made of projectile material. The coating covers the entire inner surface of craters in both steel and iron meteorite targets, including the walls to the crater's rims (Fig. 1). The coating is glassy and free of any crystalline phases, irrespective of the tested impact speed and of the nature of the target (iron meteorite or steel) and the impactor (dunite or basalt, crystallized or glassy). Spallation and fracturing are the other characteristics of the studied impact craters on both types of targets.

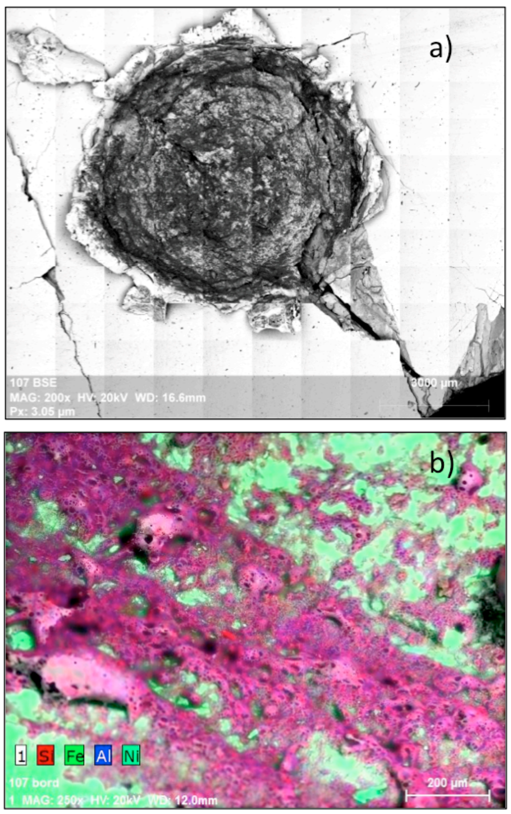

Figure 1: Example of crater obtained by an hypervelocity experiment on Gibeon iron meteorite target. a) basalt @ 5.08 km/s at 131K. Notice the compositional change of the inside of the crater due to the impact melt coating. Concentric cracks are also present. b) Electron backscattered SEM image showing the basalt-like glassy coating (pink) of the above crater. Notice here the heterogeneous thickness of the glassy coating and its foamy texture (iron-rich materials are in green).

All crater VIS-NIR spectra present a spectral signature very distinct from the starting material, with the appearance of a strong red slope, typical of specular reflection on metallic surfaces. Combined with these purely geometric effects, the presence of a silicate glass draping the crater also modifies the spectral signature. Reflectance spectra acquired from hypervelocity experiments in the range of 5 km/s using dry versus hydrated basaltic projectiles also reveal that the impact glass in the crater produced by hydrated impact projectiles exhibits a clear 3-µm absorption feature attributed to the absorption of hydroxyl by the glassy coating.

4. Discussion

The main result of this study is that coating of metallic surfaces by basaltic-like impact melts occurs for typical asteroid belt impact speeds (≈ 5km/s), and does not require less likely low-velocity impact scenarios. We thus propose that glassy coating is a generic outcome of typical impacts experienced by any metal-rich asteroid in the belt. Leading to a camouflage, this would offer a way to bias the interpretation of spectral observations against a high abundance of metal-rich asteroids.

The surface of a large iron-rich asteroid such as (16) Psyche must be then composed of smooth impact-related depressions, consistent with a metal-rich bedrock, and covered from place to place by a highly vesicular, partially crystallized, hydrated or not glassy coating and by an heterogeneous particulate regolith composed of these impact products that have degraded and later been dislodged and shattered by subsequent impacts during their long collisional lifetime in the belt. Unless systematizing radar measurements, spectral observations from the ground can be deceiving to identify iron-rich bodies.

References

[1] T. S. Kruijer et al., Protracted core formation and rapid accretion of protoplanets. Science 344, pp.1150-1154, 2014.

[2] Z. A. Landsman et al., Asteroid (16) Psyche: Evidence for a silicate regolith from spitzer space telescope spectroscopy. Icarus 304, pp.58-73, 2018.