

HYPERVELOCITY IMPACT EXPERIMENTS ON METALLIC BODY. G. Libourel^{1,3}, P. Michel¹, C. Gani-no², A. Nakamura⁴. ¹Université Côte d'Azur, OCA, CNRS, Lagrange, Boulevard de l'Observatoire, CS 34229, 06304 Nice Cedex 4, France, email: libou@oca.eu; ²Université Côte d'Azur, OCA, CNRS, Géoazur, 250 rue Albert Einstein, Sophia-Antipolis, 06560 Valbonne, France; ³Hawai'i Institute of Geophysics and Planetology, School of Ocean, Earth Science and Technology, University of Hawai'i at Mānoa, Honolulu, Hawai'i 96821, USA; ⁴Graduate School of Science and Technology, Kobe University, 1-1 Rokkoudai-cho, Nada-ku, Kobe, 657-8501, Japan.

Introduction: Astronomical observations of asteroid surfaces, compositions of meteorites and recent chronology data provide strong evidence that partial melting and differentiation were widespread among small bodies, i.e., planetesimals, within the initial few millions years of the solar system. Involving the separation of a metallic liquid that forms the core from the silicate that subsequently solidifies and evolves into a mantle and a crust, differentiation of planetesimals results in a wide range of differentiated parent bodies, from which stony (achondrites), stony-iron and iron meteorites are supposed to be originated from. Metal-silicate differentiation is therefore the major chemical event on planetary bodies, and a key process to understand the early evolution of our solar system in defining planetary building blocks.

It is therefore not surprising that the understanding of core formation and mantle crystallization received so many efforts in the last decades. Recently, a robotic spacecraft mission to a metal world, the M-type asteroid (16) Psyche [1], has been even selected by the NASA's Discovery program for directly examining the building block of a differentiated body, which otherwise could not be seen, in the hope of performing fundamental advances in understanding planetary formation and interiors. This is the first time that real images of one of these metallic worlds will be obtained.

On the other hand, there seems to be a lack of metallic asteroids, based on spectral reflectance observations, to explain the enormous diversity of iron meteorites, in particular regarding the ungrouped irons. Weak 0.9 μm and 0.43 μm absorption features on several M-asteroids, including Psyche, have been found, indicating the presence of anhydrous (e.g., orthopyroxene) and hydrous (e.g., serpentine) minerals on their surfaces [2-3]. Moreover, it has been recently found that Psyche itself, like a few other M-types, has a 3 μm band feature attributed to water or hydroxyl [4], which could be interpreted as inconsistent with planetary core material.

Experimental method: According to the long space exposure of main of the iron meteorites, as documented by their cosmic-ray exposure ages [5], we have conducted a set of impact experiments on metallic targets with the objective of determining whether we can shed some light on these issues, and make these observations compatible with the expected metallic

properties of these asteroids as well as their expected abundance in the main belt. Remote observations, laboratory experiments and theoretical models [6-7] having demonstrated that collisions could lead to complex processes of mass transfer and mixing between both projectile and target materials, our projectile was doped with trace elements in order to better track the chemical fractionation at work during these high energy events.

High velocity experimental series were carried out using a two-stage light gas gun at ISAS (Japan), with impact speeds ranging from 3.39 to 6.89 km/s. The targets were manufactured using a SCM 435 steel cylinder with 6.0 cm in diameter. The projectile was one millimeter sized glass beads made from a «phonolitic» glass doped in 28 trace elements (B, Ba, Bi, Cd, Ce, Co, Cr, Cs, Cu, Ga, La, Li, Mn, Mo, Nb, Ni, Pb, Rb, Sb, Sc, Sn, Sr, Ta, V, Y, Yb, Zn, Zr with concentrations ranging from 100 to 1000 $\mu\text{g/g}$). Fig.1 show the impact chamber design and high speed camera images taken by a FASTCAM-PCI (Photron) at 5,000 fps showing both the projectile and the steel target. Impact craters on the target and ejectas (Fig. 2) were characterized using the SEM Philipps FEI XL30 ESEM LaB6 at CEMEF-Mines ParisTech (Nice), while trace element composition of the ejectas were probed using the ICP-MS Thermo Element XR equipped equipped with a laser excimer 193nm Resonetics M-50^E at LMV (Clermont-Ferrand).

Our results will be detailed at the conference but already show that, in this range of impact velocity experiments, i) the melted basaltic projectiles largely coat the craters and are injected in the fractures of the steel target, ii) reduction of the basaltic component occurred, while iii) no volatility-like chemical fractionation is observed in the ejectas. Implications of these findings for M-type asteroids will be then discussed.

Reference: [1] Elkins-Tanton, L.T. et al. 2016. LPSC#1631. [2] Fornasier S. et al. 2010. *Icarus* 210, 655-673. [3] Hardersen, P.S. et al. 2005. *Icarus* 175, 141-158. [4] Takir D. et al. 2017. *Astron. J.*, 153. [5] Eugster O. 2003. *Chem. Erde/Geochemistry*, 63, 3-30. [6] Ebert, M et al. 2014. *GCA*, 133, 257-279. [7] Hamann, C., et al., 2016. *GCA*, 192, 295-317.

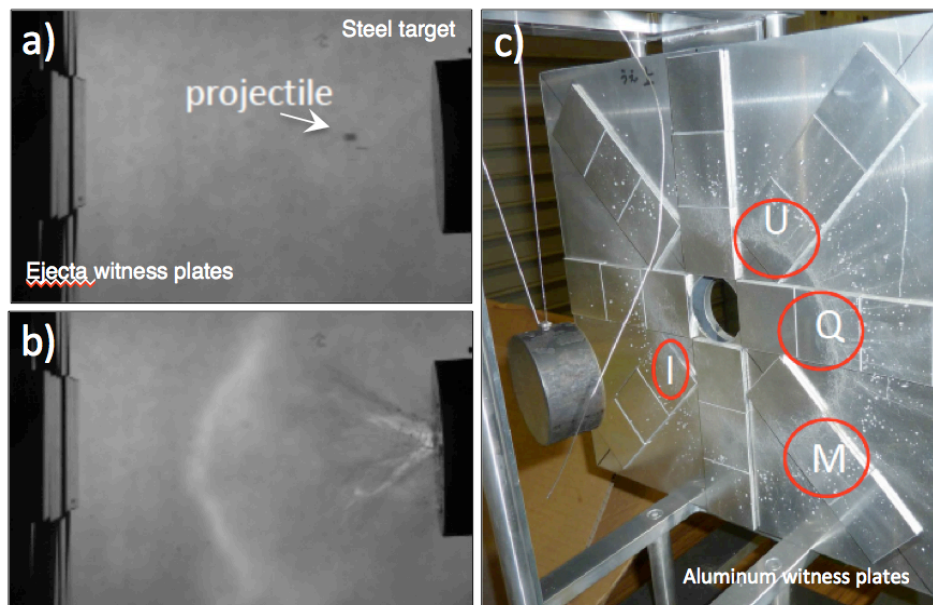


Fig. 1 : a) High speed camera images showing the basaltic-like projectile and steel target during an impact experimental run $n0 = 6.89$ km/s ; b) Shock wave propagation and the launching of the ejectas from the impact crater (same run). c) Experimental set up inside the impact chamber ; view of the ejecta Al witness plates. Notice the numerous secondary impacts on the ejecta catchers.

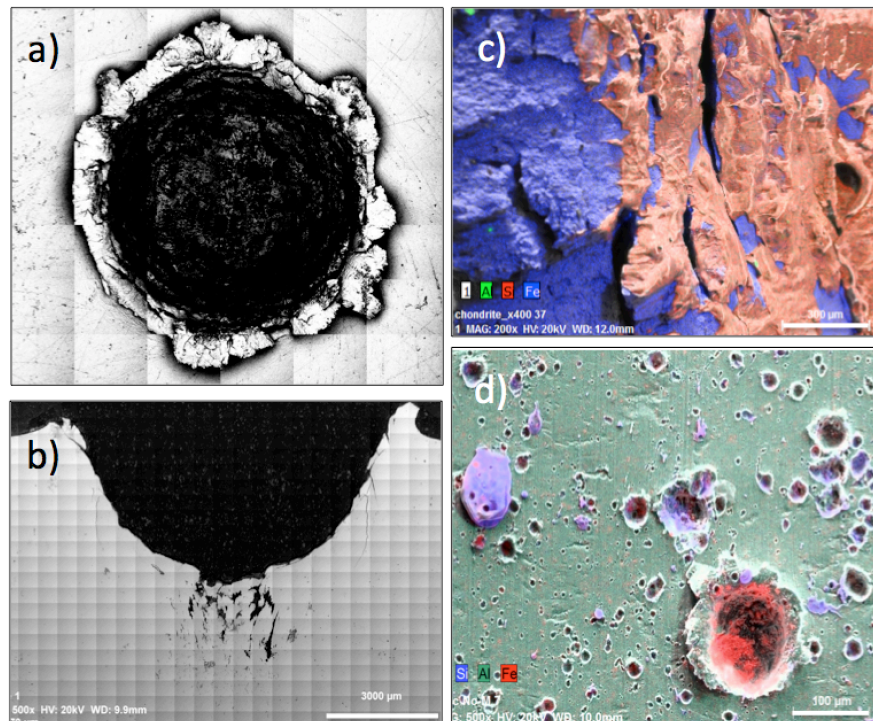


Fig. 2 : a) Impact crater on steel target for the $n0$ experiment ran at 6.89 km/s. Notice the darkening of the interior of the crater ; b) Cross section of the crater. Notice the regular network of listric faults ; c) Detailed X-ray chemical map (red : silicon ; blue : iron ; green : aluminum) of the internal edge of the impact crater showing the very efficient coating of the bottom of the crater by the basaltic-impact melt ; d) ejectas and secondary craters from both basaltic and steel materials on the Al witness plates (fig.1c).