IMPACT CONTAMINATION OF LUNAR CRUSTAL ROCKS. Courtney Jiskoot[1,2], James M.D. Day[1], Frederic Moynier[3], Richard J. Walker[4], Lawrence A. Taylor[5] [1]Scripps Institution of Oceanography, La Jolla, CA 92093-0244, USA (jmdday@ucsd.edu); [2]University of Bristol, BS81RJ, UK; [3]IPG-Paris, Université Paris, France; [4]University of Maryland, College Park, MD 20742, USA; [5]University of Tennessee, Knoxville, TN 37996, USA.

Introduction: Lunar impact-melt breccias (IMB) and melt-rocks can provide valuable information about the compositions of impactors striking the Moon after primary differentiation (e.g., [1, 2]). On the other hand, impact contamination and metamorphism can hamper interpretation of chronology and identification of primary magmatic processes involved in the generation of the lunar crust (e.g., [3, 4]). A study has been initiated to study impact-melt coatings (IMC), present on the exteriors of some lunar crustal rocks: (1) to examine whether or not the chemical nature of impactor compositions recorded in IMC are the same or different from earlier impactors that created IMB; (2) to provide further constraints on the pristinity of lunar crustal samples (c.f., [4, 5]).

Methods: A total of 26 thin- and thick-polished sections of lunar crustal rocks, including 7 ferroan anorthosites (FAN) with IMC (60015, 60025, 60215, 62255, 65035, 65315, 65325) have been examined. Mineral compositions have been determined on a subset of these samples using a Cameca SX-100 electron microprobe. Further work is ongoing on bulk-rock fragments of pristine samples and IMC (e.g., [4]), and for highly siderophile element (HSE) abundances of sulfide/metal/schreibersite phases.

Petrology and chemistry of IMC and host rocks: IMC are vitrophyric, containing abundant vesicles and fragments of host rock, as well as complex rounded segregations of FeNi metal, schreibersite, and sulfide phases (Fig. 1). Host rocks are typically cataclastic, although some samples (e.g., 15455) have matrix material that is partially melted and annealed, but is not vitrophyric. For ferroan anorthosites (FAN) with IMC, the contact between the host anorthosite and melt glass can be either sharp or diffuse, suggesting variable thermal environments at the time of IMC emplacement. Major-element compositions of the vitrophyric IMC material can be highly variable (e.g., 18-33 wt.% Al_2O_3 in 60015), reflecting localized melting of host-rock minerals, and perhaps, analogous to melting processes observed in meteorite fusion crusts [6]. FeNi metals, schreibersite and sulfides in the IMC reflect segregation of an immiscible Fe-Ni-S-P saturated liquid (Fig. 1) and their Co/Ni ratios are consistent with derivation from impactor rather than lunar material (Fig. 2). Prior work has shown that IMC have elevated rare earth element (REE) abundances, compared with host rocks (Fig. 3a). Published HSE abundance data for IMC reveal that they have broadly chondritic relative HSE abundances (Figs. 3b, c).

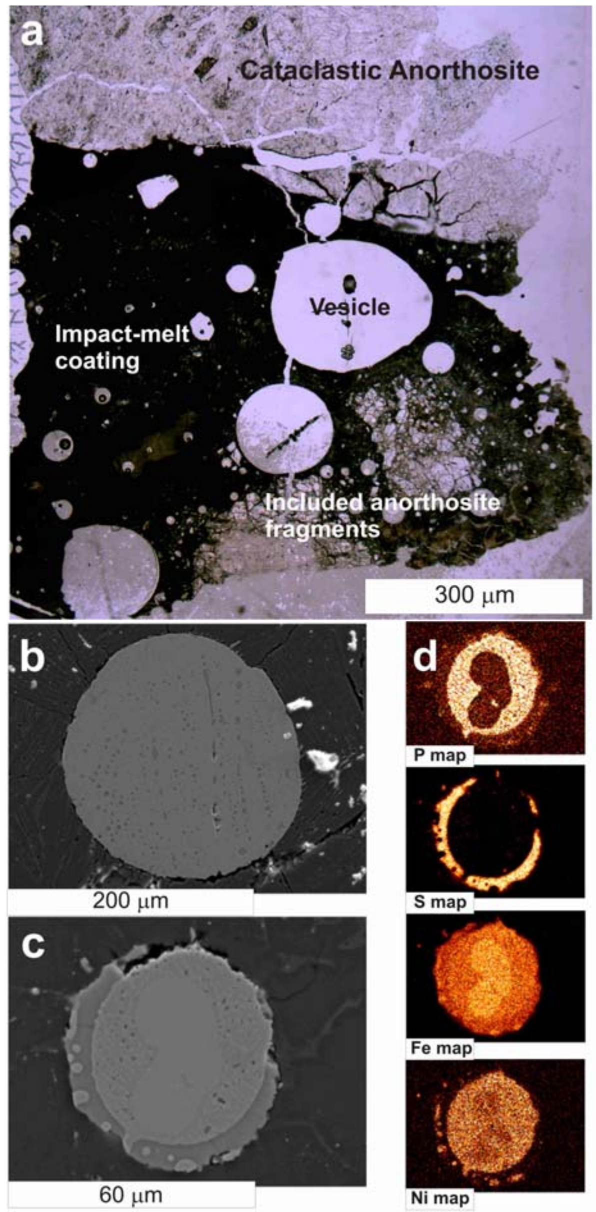

Figure 1: (a) Plane-polarized light image of the impact-melt coating of 60015 showing the abrupt boundary between interior cataclastic anorthosite and exterior IMC. BSE images of (b) a large FeNi metal bleb with S-rich exsolution and (c, d) BSE and X-ray maps of a differentiated FeNi metal-schreibersite-sulfide assemblage similar to that observed for 64435 by [7].

IMC and IMB: The interpretation of chemical data for IMC is simplified relative to IMB for several reasons. The first is that the low-indigenous host-rock HSE contents [4] and petrological evidence for localized melting indicate that some IMC formed during a single impact rather than during multiple-impact events. Second, IMC formed and cooled fast enough that no potential crystal-fractionation effects could modify IMC compositions. Third, IMC likely reflect later impact events compared with those of IMB.

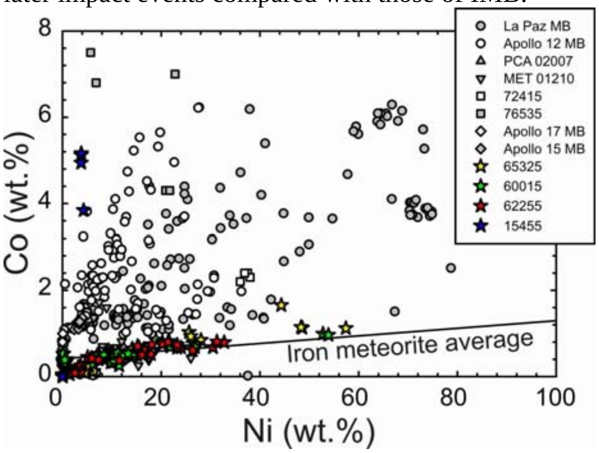

***Figure 2**: Ni-Co compositions in metal grains from 65325, 60015, 62255 IMC and 15455 matrix versus mare basalts (MB) and lunar breccia meteorites.*

Impact compositions and processes: Although the data are limited, prior work has shown that IMC have similar HSE contents to IMB, but that the Os/Ir and Pd/Ir ratios for IMC are much closer to estimates for Earth's primitive mantle (Fig. 3b). The different chemical compositions of IMC and IMB can be interpreted in one of two ways. The first is that IMC likely formed later than IMB and so reflect the addition of impactor material closer in composition to modern-day chondrites than the non-chondritic Pd/Ir of many IMB (e.g., [2,11,12]). Alternatively, the presence of sulfide-metal droplets in fast-cooled IMC indicate that larger, slower cooled impact melt sheets and IMB could have resulted in segregation of these phases (e.g., metal-rich rock 14286, 11 [13]). Since HSE have high affinity for FeNi metal/sulfide, the non-chondritic Pd/Ir ratios of IMB could reflect different incompatibilities of the HSE into segregated FeNi metal-sulfide phases. This possibility requires further study, but illustrates that IMC can provide new and complementary insights to IMB regarding impact processes on the Moon.

References: [1] Norman et al. (2002) *EPSL*, **202**, 217. [2] Puchtel et al. (2008) *GCA*, **72**, 3022. [3] Borg et al. (2011), *Nature*, **477**, 70. [4] Day et al. (2010) *EPSL*, **289**, 595. [5] Warren & Wasson (1977) *PLSC*, **8th**, 2215. [6] Day et al. (2006) *GCA*, **70**, 1581. [7] Grieve & Plant (1973) *PLSC*, **4**, 667. [8] Morris et al. (1986) *JGR*, **90**, E21. [9] Ebihara et al (1992) *PLPSC*, **22**, 417. [10] Fischer-Godde & Becker (2012) *GCA*, **77**, 135; [11] Becker et al. (2006) *GCA*, **70**, 4528. [12] Liu & Walker (2013) *LPSC*, **44**, 1837. [13] Warren (2012) *LPI*, 9034.

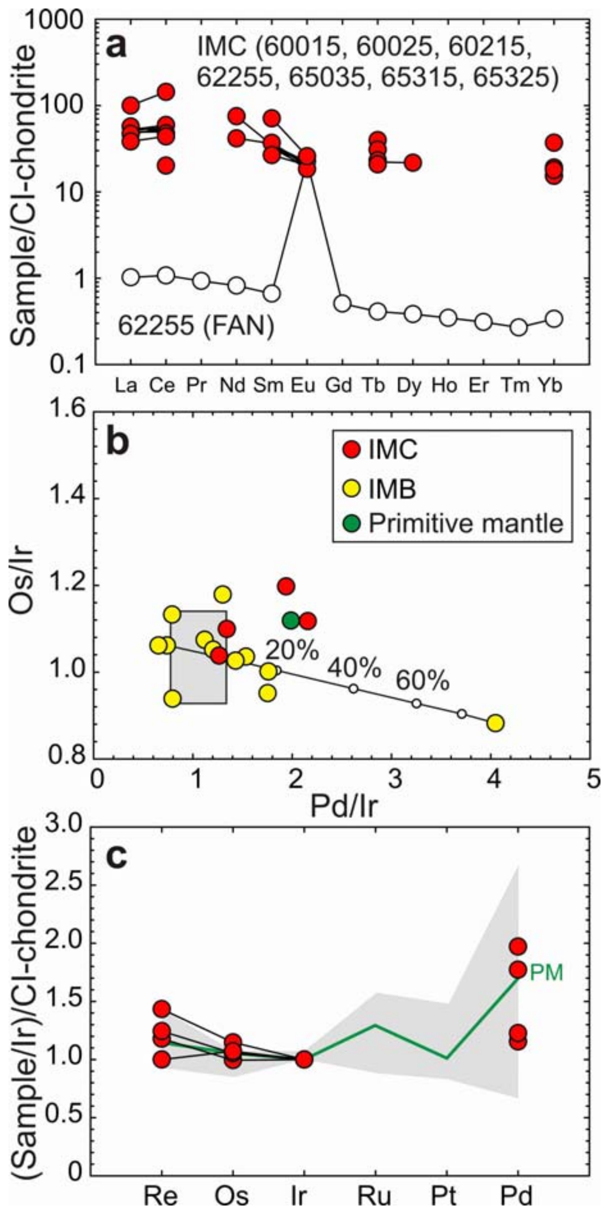

***Figure 3:** Geochemistry of IMC. (a) Rare earth element (REE) plot for IMC [8] versus new data for pristine FAN 62255. (b) Plot of Pd/Ir versus Os/Ir for IMC [9] versus compiled IMB data [10]. Also shown is a mixing model between IMB with extreme Pd/Ir. (c) Double-normalized (chondrite and to Ir) for IMC versus the range of measured IMB (gray-shaded region from [12]) versus PM.*