METAL PARTICLES IN APOLLO 17 IMPACT MELT BRECCIAS: TEXTURES AND HIGHLY SIDEROPHILE ELEMENT COMPOSITIONS.
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Introduction: This study aims to characterize textural and compositional features and highly siderophile element (HSE) abundances of metal particles in a suite of Apollo 17 melt breccias. We imaged the internal distribution of major and minor elements within and around individual metallic particles using electron microscopy, and measured HSE abundances using EMP and LA-ICPMS. The data provide information about impactor signatures inferred from HSE compositions and the cooling history of these breccias.

Samples and Methods: Polished thick sections of four Apollo 17 poikiolitic melt breccias (76035, 76315, 76295, 72435) previously used for LA-ICPMS studies of silicate phases [1] were studied. Metallic phase associations were examined using optical and microscopy and SEM, and X-ray maps of the internal distributions of Fe, Ni, S, and P were acquired by EMP. Color images were compiled using *ImageJ.*and processed in Photoshop. Point analyses of elemental concentrations were obtained by WDS-EMP for major and minor elements, and LA-ICPMS for trace elements. The LA-ICPMS analyses used spot sizes of 32-86 µm, a 5 Hz repetition rate, and the Lombard iron meteorite [2] and the NIST 610 glass for calibration of element sensitivities. Corrections were applied for argide and oxide molecular interferences. Each analysis was normalized to the Fe content of the sample to correct for variations in ablation yield.

Results: The particles studied here consisted of typical assemblages of Fe-metal with variable Ni contents, troilite, and schreibersite [3,4,5]. Element maps revealed intricate compositional structures in all grains typically characterized by small, heterogeneously distributed blebs of high-Ni metal and phosphide, and discontinuous rims and larger blebs of sulfide. Metal grains in 76035 (Fig. 1) were the most heterogeneous whereas those in 72435 were relatively homogeneous in their internal structures.

These textural characteristics are also reflected in the compositions of these grains. Electron microprobe analyses of metal in 76035 range up to 27 wt% Ni and lower Co, with a trend toward high-Ni compositions also seen in 72435 (Fig. 2). In contrast, the 76295 and 72435 grains show trends to higher Co at a constant Ni content (Fig. 2). Trace element compositions measured by LA-ICPMS show some correlations with these textural and compositional characteristics, although the larger ablated volumes cannot resolve the full range of compositional variability in these finely textured grains. For example, 76295 metal has systematically higher W and Ge along with the higher Co (Fig. 3). HSE ratios in the metal grains also vary over a large range. For example, Pd/Pt, Ir/Au, and Ru/Ir of the metal all span a much larger range of compositions than observed in bulk rock samples of the Apollo 17 poikilitic breccias and compared to the compositions of chondritic meteorites (Fig. 4).

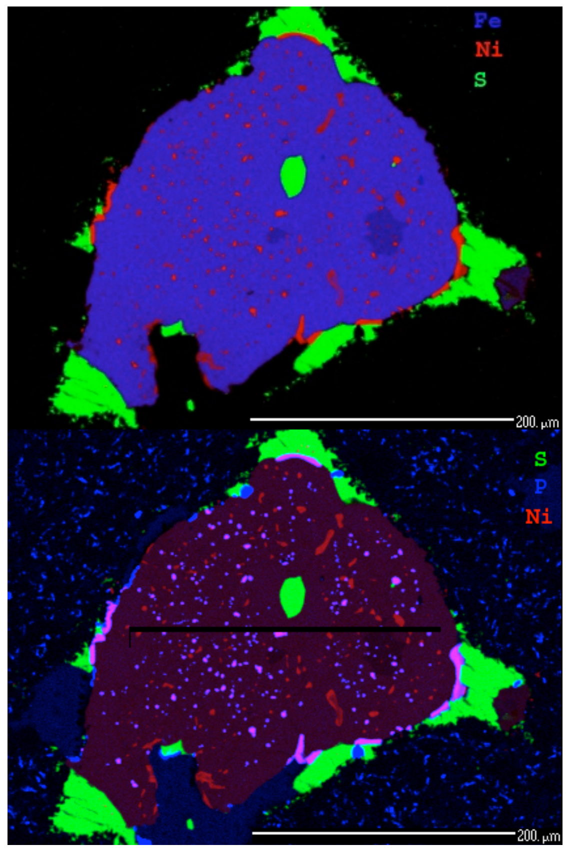

Fig. 1.WDS X-ray map of the distribution of Fe, Ni, and S (upper panel) and Ni, S, and P (lower panel) in a metal+sulfide grain from 76035.

Discussion: The siderophile element compositions of metal in lunar melt breccias might be expected to represent partial to complete equilibration with the silicate melt matrix, followed by further evolution during cooling of the ejecta blanket. Although the metal within a given sample would be expected to dominate the siderophile element composition of the breccia, that metal can apparently be heterogeneous in texture and composition on a variety of scales, even within a single sample. Among the factors that could contribute to this variability include the volume of melt with which a metal particle equilibrates, the concentration of indigeneous siderophiles in the pre-impact target, T-fO_2 variations within the ejecta plume, and heterogeneous cooling of ejecta. For example, the systematically higher Co, W and Ge in 76295 (Fig. 3) might reflect a greater proportion of indigenous siderophiles in this sample, or extraction of these elements into the metal from a larger effective volume of melt.

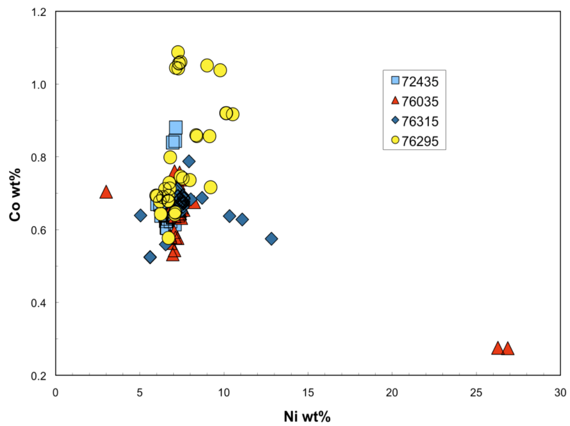

Fig. 2 Ni and Co contents of Fe-metal grains in four Apollo 17 melt breccias measured by EMP.

Impactor fingerprinting: Understanding the types of impactors responsible for the early bombardment has significant implications for solar system dynamics, with the relative proportions of HSE in lunar melt breccias used to fingerprint these impactors. A significant problem has been the wide range of HSE compositions of the breccias and the puzzling abundance of 'non-meteoritic' compositions. A better understanding of the metal in these breccias may provide at least a partial explanation for this, as localized variations in the history of metal particles appear capable of producing considerable diversity in their siderophile element patterns (Fig. 4). The small samples of lunar breccias typically used for these types of analyses may not provide a meaningful measure of the primary impactor composition, and a fuller understanding of the complex process responsible for generating the textural and compositional diversity of metal grains in lunar melt breccias [4] may be necessary to extract useful information about impactor provenance.

References: [1] Lawrence et al. (2007) *LPS 38*, #1696 and (2008) *LPS 39*, #1521. [2] Gilbert et al. (2012) Geostds Geoanal. Res., doi:10.1111/j.1751-908X.2012.00170.x [3] Goldstein & Blau (1973) *GCA 37*, 847-855 [4] Misra et al. (1976) *LPSC 7*, 2251-2266. [5] James et al. 2007 *LPS 38*, #1094. [5] Norman et al. (2002) *EPSL 202*, 217-228.

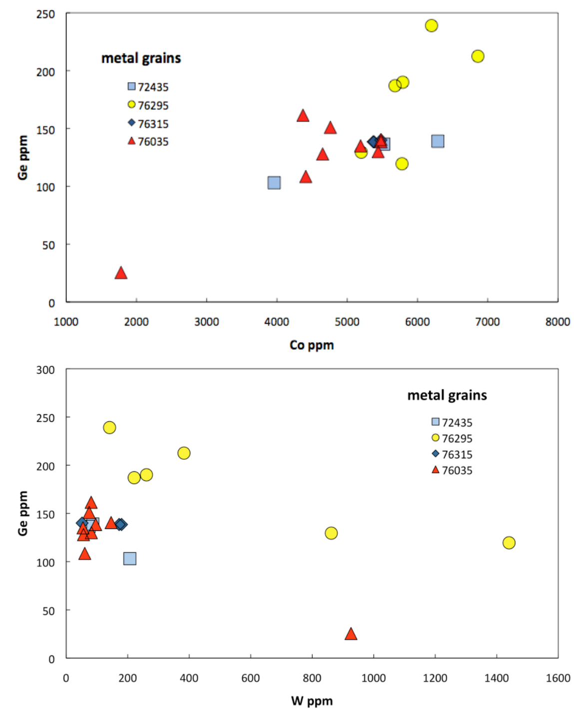

Fig. 3 Co, W and Ge contents of Fe-metal grains in four Apollo 17 melt breccias measured by LA-ICPMS.

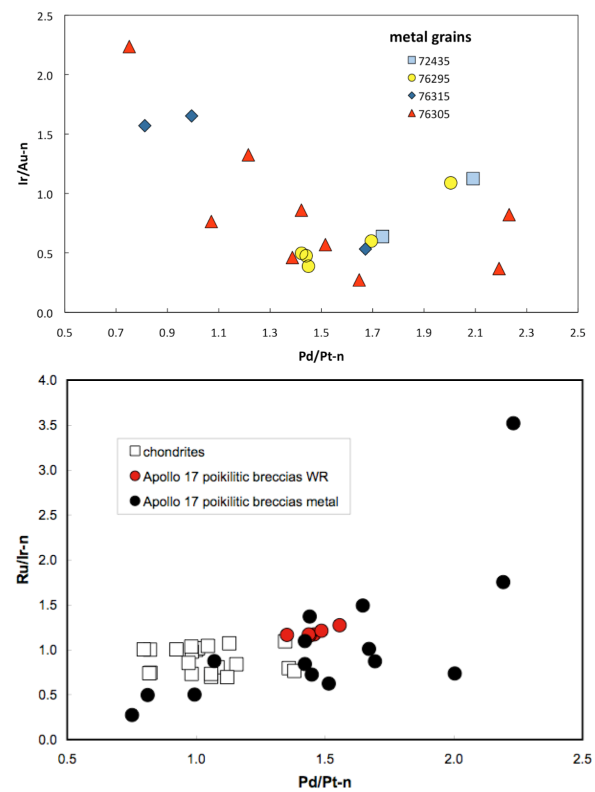

Fig. 4 Chondrite-normalized ratios of platinum-group elements and Au of the metal grains compared with the whole rock compositions of Apollo 17 poikilitic breccias and chondritic meteorites [5 and refs therein].