Mixing of ancient impactor signatures in lunar impact melt rocks

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The surface of the Moon is characterized by large impact basins, most of which are believed to have formed 4.0-3.8 billion years ago [1] [2]. Basin-forming impact events generate large volumes of impact melt rocks and breccias. These rocks contain significant fractions of the meteoritic projectile and hence are enriched in impactor-derived highly siderophile elements (HSE: Re, Os, Ir, Ru, Pt, Rh, Pd, Au) relative to pristine lunar crustal rocks. The HSE composition of lunar impact rocks provides information on the nature of bodies impacting the Moon and, by inference, also the Earth. The detailed relation of specific HSE signatures to distinct lunar impact basins is challenging, especially because the surface of the Moon was heavily reworked by several consecutive impacts, resulting in widespread mixing of HSE derived from different impactor materials. The results of HSE studies [3-7] on Apollo and meteoritic lunar impact rocks reveal the occurrence of three dominant HSE signatures on the Moon: (1) compositions similar to chondritic meteorites; (2) compositions characterized by fractionated HSE patterns similar to iron meteorites; and (3) hybrid HSE compositions between the two with non-chondritic HSE ratios, distinct from known meteorites. The latter have been interpreted to represent impactor materials with compositions different from presently sampled meteorites [4] [6], or alternatively, they may be explained by mixing of chondritic and iron meteorite impactors with type 1 and 2 signatures [5] [7]. The observation of linear trends in plots of HSE ratios from different lunar sites supports the derivation of the type 3 HSE signatures from binary mixing of carbonaceous chondrite-like and suprachondritic iron meteorite-like HSE endmember com-positions. Because both signatures are widespread and occure in impact rocks dated ~4.2 Ga [5] [8], these two chemically diverse impactors likely derive from basin-forming impacts predating the later Serenitatis and Imbrium basins.

[1] Tera et al. (1974) *EPSL* **22**, 1-21. [2] Ryder (2002) *JGR* **107**, 1-13. [3] Norman et al. (2002) *EPSL* **202**, 217-228. [4] Puchtel et al. (2008) *GCA* **72**, 3022-3042. [5] Fischer-Gödde and Becker (2012) *GCA* **77**, 135-156. [6] Sharp et al. (2014) *GCA* **131**, 62-80. [7] Liu et al. (2015) *GCA* **155**, 122-153. [8] Norman and Nemchin (2014) *EPSL* **388**, 387-398.