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Siderophile Elements in Earth's Upper Mantle and Lunar Breccias: Manifestations of the Same Late Influx

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The platinum group elements (Ru, Rh, Pd, Os, Ir, Pt), Re and Au comprise the highly siderophile elements (HSE). In a hypothetical fertile upper mantle, abundances of HSE are expected to be in approximately chondritic proportions and Re-Os and Pt-Os isotope systematics measured on mantle materials indicate that these three elements have mutually chondritic ratios in undepleted mantle (Morgan, 1986; Brandon et al., 2000). HSE would be removed quantitatively from the silicate Earth by core formation, and their presence in the upper mantle is best explained by late influx of HSE-rich material, chiefly in the form of large planetesimals. A contingent of this population simultaneously bombarded the Moon giving rise to the visible lunar mare basins. Other well-reasoned explanations for the presence of HSE in the mantle have been offered, but these generally do not require the observed chondritic abundance and isotopic relationships, nor do they encompass the lunar evidence.

The abundance distribution of HSE in the Earth's upper mantle is remarkably uniform. A large number of Ir measurements in mantle-derived peridotites are normally distributed with a mean of 6.7 x CI/1000 (Spettel et al., 1991). Spinel lherzolite xenoliths from SW USA, orogenic spinel lherzolites from France and abyssal peridotites have similar distribution of PGE in which Pd/Ir is significantly enriched (Morgan, 1986; Pattou et al., 1996; Brandon et al., 2000). In contrast, peridotites from West Africa and from eastern Australia have chondritic Pd/Ir (Rehkamper et al., 1997; Morgan, 1986). The difference may be in part analytical or due to secondary effects, but also may reflect regional variations. The incompatible HSE and the chalcogens S and Se are variously depleted in all these rocks. If the late influx origin for mantle HSE is accepted, then regional variations could reflect compositional variations in the large infalling bodies and should be manifest in the HSE patterns of ancient lunar breccias. These lunar breccias exhibit variations in Au/Ir between landing sites and suggest that a "graininess" may have existed during the early bombardment of the Earth and Moon. Data for Re, Os, Ir, Pd, Ni and Au in two lithologies within Apollo 17 breccias suggest that the HSE patterns of the impacting bodies differ due to fractionation between a refractory group (Re, Os and Ir) and a normal (Pd, Ni, and Au) group (Morgan & Petrie,1979). For these siderophile elements, the Apollo 17 aphanite lithology has a distribution identical to that of the EH4 chondrites, whereas the pattern in the anorthositic lithology duplicates that of the EL6 type. Comparison of HSE and chalcogen (S, Se) patterns in these lunar breccias and terrestrial peridotites suggest that the "non-chondritic" abundance ratios in the latter may be reflected in the composition of planetesimals striking the Moon in the first 700 Ma of Earth-Moon history. The Apollo 17 aphanites have HSE and chalcogen patterns that closely match those of high Pd/Ir spinel lherzolites, whereas the corresponding distribution in anorthositic clasts, though less distinctive, is similar to peridotites with chondritic Pd/Ir.

The lunar data suggest that the Au abundance in the upper mantle is higher than currently believed. Re-examination of the correlation between Re and Au in fertile xenoliths suggests that the Au abundance in the upper mantle may be 1.5 to 2 times higher than previously estimated.

The following abundances in ppb for fertile mantle are suggested; 0.29 Re, 3.5 Os, 3.5 Ir, 5.8 Ru, 6.5 Pt, 5.7 Pd, 2.3 Au, 63 Se and 210,000 S. When normalized to CI/1000, HSE Re through Pt average 7.3 and other values are 10.2 Pd, 16.4 Au and 3.4 Se and S.

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