THE COMPOSITION OF LUNAR BASIN FORMING IMPACTORS: CONSTRAINTS FROM SIDEROPHILE ELEMENTS IN ANCIENT IMPACTITES. P. Gleißner[1] and H. Becker[1], [1]Freie Universität Berlin, Institut für Geologische Wissenschaften, Malteserstr. 74-100, 12249 Berlin, Germany (gleissner@zedat.fu-berlin.de).

Introduction: Core formation depleted the silicate portion of planetary bodies in siderophile elements. Absolute and relative abundances of highly siderophile elements (HSE) and some siderophile volatile elements (SVE) can be used to trace fractionation processes during core formation, but also may constrain the nature of materials accreted after core formation.

Ancient lunar impactites provide constraints on the timing and composition of material accreted late to the Moon and by inference to the Earth and other terrestrial planets. Central questions are: Was the accreted material similar to known solar system objects like the meteorites in our collections? Was it rich or poor in volatile components? When was the material accreted and can we relate compositions to specific impact events and/or basins?

HSE abundances of lunar mare basalts suggest the early accretion of materials of roughly chondritic composition to the source of lunar mare basalts [1]. Significant late accretion after lunar core formation would have also contributed to the budget of siderophile and non-siderophile volatile components like S and H in the bulk silicate Moon. However, abundances and pedigree of these elements are still debated [e.g., 2, 3]. Lunar impact basins and ancient craters suggest significant late accretion after formation of a solid crust. Ancient lunar impactites from the lunar highlands provide direct evidence of large-scale late accretion and in principle their HSE composition can be better constrained than late accreted material in the lunar mantle. However, the origin of variably fractionated HSE patterns in different lithologies and landing sites is still debated [4-8] and the nature of the putative impactors and their volatile content remains poorly constrained.

Analytical methods: We studied siderophile elements in different impact lithologies from Apollo 14, 15, 16 and 17 landing site. Osmium isotopes, HSE and sometimes Te, Se and S were determined after high pressure asher digestion in reverse aqua regia following the procedure of [6, 9]. In addition, SVE like Cu, Ag, Te, Se, S and In together with Ir, Ru and Pt were determined after bomb digestion of other sample aliquots in HF-HNO_3 using separation techniques previously tested for terrestrial and extraterrestrial materials [10, 11]. Concentrations of the elements (except Au and Rh) were determined by isotope dilution from the same digestion aliquot using sector field ICP-MS. Osmium concentrations and $^{187}Os/^{188}Os$ ratios were determined by N-TIMS.

Results and discussion: Impactites from different landing sites display broadly linear correlations of $^{187}Os/^{188}Os$ (representing long-term Re/Os ratios of the samples) and HSE/Ir ratios which range from chondritic to suprachondritic (Fig. 1). The observed compositional range is either interpreted to result from mixing of several ancient impactor compositions [6, 8] or to reflect signatures of compositionally distinct basin forming primitive impactors, some of them outside the range of known chondrites [4, 5].

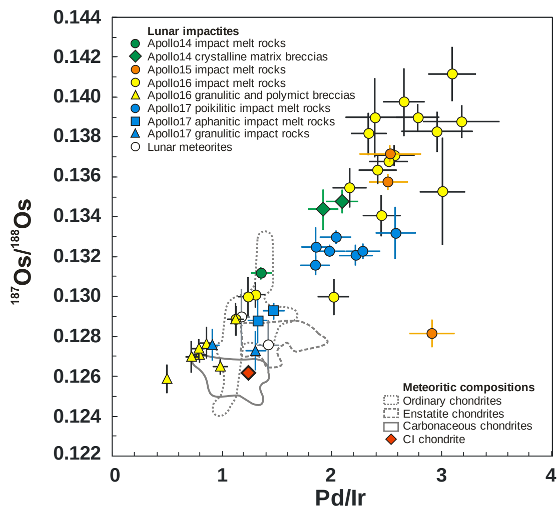

Fig. 1 HSE ratios in bulk lunar impactites (weighted averages of multiple aliquots) [4-8]. The ranges of chondrite classes are given for comparison.

Contrasting behavior of some elements of different geochemical affinity are observed between some impactites. These chemical differences can be used to constrain the formation place of impactites much better than the location at which the samples were collected. KREEP-rich mafic impact melt rocks and breccias generally display variably fractionated HSE pattern with high Re/Os and increasing HSE/Ir ratios towards moderately volatile HSE like Pd and Au. These impactites display peculiar suprachondritic Ru/Pt ratios, a feature which is observed only in a limited number of differentiated metal-bearing meteorites. Large-scale fractional crystallization of solid metal from S and P rich metallic melt with high P/S in planetesimal or embryo cores is currently the most likely process that may have produced this characteristic HSE composition [8]. The widespread occurrence of this rather uncommon composition (Fig. 1) strongly suggests accretion of larger fragments of differentiated planetesimal core material to a KREEP-rich target region, but also suggests that the HSE budget of impactites, sampled during Apollo missions, is dominated by a small number of large impacts. Accordingly, the HSE budget of many impactites may be biased by tiny amounts of metal with a strongly fractionated siderophile element composition. For this reason, the nature of primitive late accreted material and its volatile content cannot be determined from HSE alone. New data for SVE display a large range of absolute and relative abundances apparently unrelated to HSE inventories. For example in mafic impactites with similarly fractionated HSE patterns Se/Te ratios range from CI chondrite like to strongly suprachondritic values (Fig. 2). The large range of ratios of these SVE indicates admixture of variable amounts of chondrite-like impactor material to mafic crust with strongly fractionated Se/Te. In contrast, granulitic impactites display subchondritic Se/Te ratios, similar to compositions of feldspatic crustal target rocks.

In contrast to KREEP-rich mafic impactites, feldspatic impactites like granulites and fragmental matrix breccias are variably depleted in slightly volatile HSE`s like Rh, Pd and Au [5, 6]. Analyses of multiple aliquots reveal that the HSE budget is mainly dominated by clasts which represent accretion events that occurred before the final assembly of the breccia. Furthermore, many aliquots display depletion of strongly refractory Re and Os compared to Ir, whereas Re/Os ratios are chondritic. No bulk chondrite is known to display similar fractionations; however, similar patterns occur in components of unequilibrated chondrites [e.g., 12]. The preserved impactor signatures apparently stems from accretion of unknown primitive materials to feldspatic highland targets.

The preservation of distinctly fractionated HSE in components of fragmental and granulitic breccias and the apparent decoupling of HSE and SVE in impact melt rocks and breccias support the large-scale mixing model of [6]. Based on our new HSE and SVE data we argue for accretion of primitive material together with fractionated planetesimal core material during early stages of basin formation. Subsequent impacts mixed older impactites, but did not completely homogenize the HSE and SVE budgets of late-formed ejecta blankets.

Summary: Material accreted during the formation of lunar basins comprises primitive and differentiated, metal-rich compositions. Most lunar impactites reflect large-scale mixing of these ancient impactor compositions. Many mafic impactites display a signature of differentiated metal (most likely fragments of planetesimal or embryo cores) accreted to a KREEP-rich target region (PKT?). SVE compositions are consistent with accretion of volatile-depleted and volatile-rich primitive compositions. SVE and HSE in KREEP-poor impactites indicate accretion of primitive compositions to feldspatic targets. Some of the refractory element compositions are different from bulk chondrites and may reflect early fractionation processes in warmer domains of the solar nebula. Similar material may have accreted earlier to the terrestrial planets.

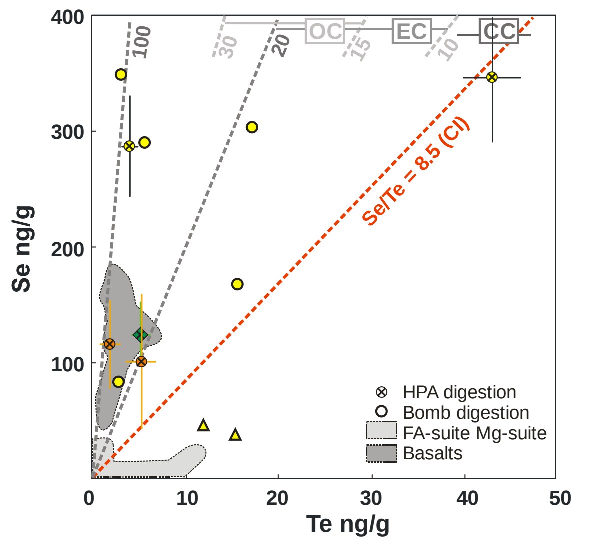

Fig. 2. Se and Te in bulk lunar impactites (weighted averages of multiple aliquots). Symbols as in Fig. 1, the ranges of chondrite classes [9], lunar basalts and feldspatic rocks are given for comparison (RNAA data).

References:

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