PROBING MAGMA OCEAN CRYSTALLIZATION IN ROCKY PLANETS USING ZIRCONIUM ISOTOPES – PRELIMINARY RESULTS FROM ANCIENT ZIRCONS FROM EARTH AND MARS

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Terrestrial planets are believed to have experienced episode(s) of large-scale melting early in their history resulting into the formation of deep magma oceans [1]. Magma ocean crystallisation can lead to the formation of an unstable, chemical stratification of the primitive mantle due to the progressive iron enrichment of the cumulate layers from the bottom upward, which may result in cumulate overturn, melting and extraction of a primordial crust [1]. Unravelling the timescales of these processes is key for a full understanding of planet formation processes. With a half-life of 36 Myr [2], the ^{92}Nb-to-^{92}Zr decay system is ideally suited to probe planetary differentiation processes, including magma ocean crystallisation. Indeed, Nb and Zr can be fractionated from each other by magma ocean crystallisation processes, which may lead to the establishment of mantle and/or crustal reservoirs with variable Nb/Zr ratios. However, given the relatively low initial Solar System abundance of the parent ^{92}Nb nuclide [3], fully utilising of the ^{92}Nb-^{92}Zr decay system to probe early planetary differentiation requires significant improvement in currently used methods for high-precision analyses of the zirconium isotope composition of silicate materials.

Zircon is a powerful tool for understanding early silicate differentiation processes in terrestrial planets, including the stabilization and reworking of primordial crustal reservoirs [4]. Indeed, zircon can be accurately dated using the U-to-Pb decay system and is resistant to secondary alteration processes. Moreover, this mineral is rich in Hf and Zr, making it ideally suited for concomitant studies of the ^{176}Lu-^{176}Hf and ^{92}Nb-^{92}Zr systematics of its source reservoir. Taking advantage of new protocols for high precision analysis of Zr isotopes by MC-ICPMS, we report on the ^{92}Nb-^{92}Zr systematics of ancient zircons from Earth and Mars to better understand the timing and style of differentiation of these bodies. Our sample suite includes 8 zircons from the Jack Hills metasedimentary belt that record concordant U-Pb dates defining ^{207}Pb/^{206}Pb ages ranging from 4260.3±0.9 Ma to 3953.8±0.7 Ma and initial Hf isotope composition at the time of crystallization (εHf_T) varying from –1.68±0.18 to –4.91±0.11. In addition, we have investigated 7 zircons from the NWA 7034 martian breccia with mostly concordant U-Pb dates that define ^{207}Pb/^{206}Pb ages ranging from 4476.3±0.9 Ma to 4429.7±1.0 Ma and εHf_T varying from –0.71±0.32 to –2.06±0.26 [5]. In this contribution, we report the Zr isotope composition for the 8 Jack Hills zircons and for one of the NWA 7034 martian zircons – results for the remaining martian zircons will be presented at the meeting.

The Zr isotope data were obtained on the same sample digestions utilized for the U-Pb ages and Hf isotope measurements. In brief, following the U-Pb chemistry, a Zr cut was separated from the U-Pb washes using a single stage TEVA-spec ion exchange chemistry that provides >90% recovery of the Zr and ensures adequate separation from potentially interfering species. The accuracy and external reproducibility of our approach was assessed by repeated analyses of aliquots of the 91500 zircon standard processed through our entire chemical purification procedure. The Zr isotope composition of our samples was analysed using a Neptune Plus MC-ICPMS either at the Centre for Start and Planet Formation (Copenhagen) or Institute of Geochemistry and Petrology, ETH (Zurich). A total of 13 aliquots of the 91500 standard defines an external reproducibility estimate (2SD) of ± 7.1 ppm for μ^{91}Zr, ± 3.7 ppm for μ^{92}Zr and ± 24.5 ppm for μ^{96}Zr for quantities of Zr comparable to that present in our samples. Our preliminary data shows that 3 Jack Hills zircons have resolvable deficits of <10 ppm in μ^{92}Zr and normal compositions for the μ^{91}Zr and μ^{96}Zr. The anomalous Jack Hills zircons have the most ancient U-Pb ages in our suite, namely ranging from ~4.1 to 4.3 Ga and unradiogenic εHf_T requiring formation of their source reservoir ≥4.4 Gyr ago. Similarly, a NWA 7034 zircon with ^{207}Pb/^{206}Pb age of 4429.7±1.0 Ma defines a resolvable deficit in μ^{92}Zr of 7.7±3.7 ppm, a normal μ^{91}Zr composition and an anomalous μ^{96}Zr value of 34.7±24.5 ppm, which is consistent that inferred for Mars based on ordinary chondrites [6]. For both Earth and Mars, our data suggest that the zircons with anomalous μ^{92}Zr were derived from a reservoir with a subchondritic Nb/Zr ratio extracted within the first ~100 Myrs of the Solar System. Although this timescale is consistent with a rapid formation of the primordial crust of Mars <20 Myr of Solar System formation, it is difficult to reconcile with a late Moon-forming event [7] and, hence, global remelting and homogenization of the early Earth at ~4.4 Ga. Alternatively, the anomalous μ^{92}Zr of some of the Jack Hills zircons may reflect the preservation of a signature associated with the initial differentiation of the proto-Earth prior to the Moon-forming impact.

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