ZIRCONS IN NORTHWEST AFRICA 7034: RECORDERS OF CRUSTAL EVOLUTION ON MARS.

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Introduction: The Earth-Moon system underwent an important stage of crust building ~ 4.3-4.4 Gyr ago based on the ages of the oldest detrital terrestrial zircons and those determined for rocks from the lunar highlands crust **[1-4]**. This time period now seems to correspond to an important period of crust building on Mars as well, as recently confirmed by U-Pb dates on zircons from the martian meteorite Northwest Africa 7533 (NWA 7533; **[5]**). In this contribution, we report results of the U-Pb dating study that was carried out, using the NanoSIMS 50 ion probe, on zircons and baddeleyites in the paired meteorite Northwest Africa 7034 (NWA 7034; **[6]**). A parallel effort using an ims-1280 ion probe for U-Pb dating is presented at this meeting [**7**].

Analytical techniques: Zircon and baddeleyite grains were located using back-scattered electron (BSE) images and X-ray maps of a polished thin section of NWA 7034 using secondary electron microscopy (SEM) at the Open University, UK. U-Pb analyses were carried out using the Cameca NanoSIMS 50 at the University of Rennes 1, France. A general description of the instrument and its configuration for dating purposes is given in Tartèse et al. **[8]**. A 1 nA O^- primary beam was rastered over 2 µm × 2 µm or 3 µm × 3 µm areas, depending on the target size and zoning features of the grains. A mass resolving power of ~ 5000 was achieved, which was sufficient to isolate the major HfSi interferences from the Pb isotopes. The vacuum in the analysis chamber remained constant for the entire session at ~ 4×10^{-9} torr. Analyses were carried out using the NanoSIMS combined mode: the magnetic field was switched to measure background (203.5), ^{204}Pb, ^{206}Pb and ^{207}Pb in an up-mass sequence on the detector EM#2, and species $^{90}Zr_2{}^{16}O$, ^{238}U and $^{238}U^{16}O$ were simultaneously acquired when the magnetic field rested to measure ^{206}Pb. Before analysis, the probe was rastered over 6 µm × 6 µm areas for ~ 5 min to remove any potential surface contamination. Secondary ions were then collected for 14 cycles, resulting in a total analysis time of ~ 23 min. Automatic centering was performed on the $^{90}Zr_2{}^{16}O$ peak at the beginning of each analysis and repeated half way through each run. The ion signals were processed using the NanoSIMS DataEditor software (Frank Gyngard, Washington University, St Louis, USA), and isotope ratios were calculated from total counts. Standards used for data reduction were zircon 91500 **[9]** and Phalaborwa baddeleyite **[10]**.

Results: Zircon grains analysed yielded the following results: NWA 7034 meteorite contains a population of old zircons, dated at 4.37 ± 0.07 Ga (2σ; Fig. 1) through the upper intercept of a discordia anchored at ~ 1.5 Ga. This younger date probably corresponds to an important event in the history of NWA 7034, since this event 1) has disturbed the U-Pb systematics in old zircons and 2) promoted crystallisation of a second generation of zircons. More specifically, U-Pb data obtained on these 'young' zircons define a second discordia whose upper intercept yielded a date of 1.57 ± 0.03 Ga (2σ; Fig. 1), which thus represents the age of this important disturbance event. This second discordia passes through the origin, indicating possible recent Pb loss for these young zircons, likely related to the ejection of NWA 7034 from Mars ~ 5 Myr ago **[11]**.

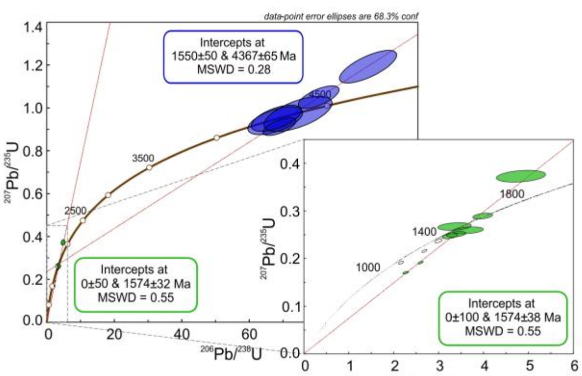

Fig. 1: $^{206}Pb/^{238}U$ vs. $^{207}Pb/^{235}U$ concordia diagram for U-Pb data obtained on zircons in Martian meteorite NWA 7034.

Interestingly, preliminary K-Ar dating carried out on whole rock yielded a date of 1.55 Ga **[11]**, identical to the young U-Pb zircon age. Finally, the old age obtained on zircons is consistent with data published by Humayun et al. **[5]**, who reported U-Pb dates for zircons in the paired meteorite NWA 7533 using the SHRIMP ion probe employing a 7 µm primary beam, and obtained an old age of 4.43 ± 0.03 Ga. On the other hand, the ~1.7 Ga disturbance age they reported was not seen in our study.

Five analyses were performed on 2 baddeleyite grains located in the matrix of NWA 7034, and yielded two distinct upper intercept dates of 4.41 ± 0.02 Ga and 4.31 ± 0.05 Ga (Fig. 2), both discordia passing through the origin, suggesting that these grains suffered recent Pb-loss. On the other hand, U-Pb systems in these two baddeleyite grains have not been affected by the ~ 1.5 Ga event identified in zircon U-Pb data. These U-Pb dates obtained on baddeleyites are more precise than on zircons due to higher U and Pb contents. The 'old' date obtained on zircon is identical to both baddeleyite dates considering uncertainties. However, the baddeleyite data indicate at least two episodes of magma generation in the ~ 4.4-4.3 Ga interval.

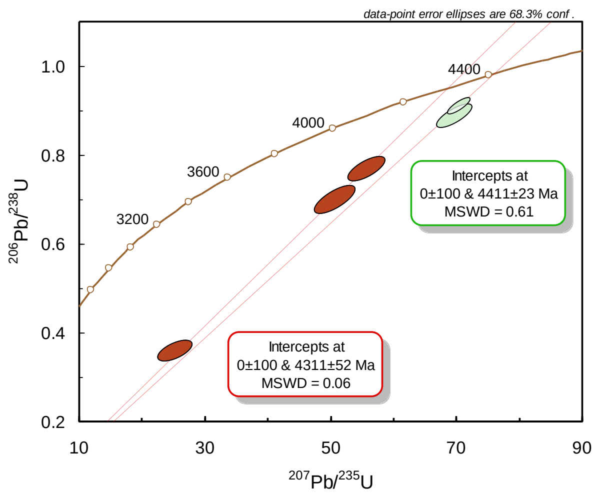

Fig. 2: $^{206}Pb/^{238}U$ vs. $^{207}Pb/^{235}U$ concordia diagram for U-Pb data on baddeleyite in Martian meteorite NWA 7034.

Discussion: NWA 7034 is one of the newest additions to the martian meteorite clan. This meteorite was originally described as a monomict basaltic breccia, and has many similarities with geochemical dataset acquired by various orbital, lander, and rover missions **[6]**. Furthermore, it shares geochemical linkages with the shergottites, providing a modern link between the mission and shergottite dataset. This meteorite also yielded a Rb-Sr whole rock isochron age of 2.1 Ga **[6]**, and was considered critical for understanding martian surface conditions during the transition from the early to middle Amazonian epoch. Upon further examination of NWA 7034, it has become clear that it is a polymict basaltic rock with a mixture of highly rounded and angular clasts of varying size. NWA 7034 is poorly sorted with lithic clasts ranging from larger than 1 cm to grains that are clay-sized. The meteorite has some textural features indicative of being an impactite (presence of armored lapillae and highly rounded, quickly cooled, melt-spherules); however, these textural features can also occur in some pyroclastic rocks.

U-Pb data obtained on zircons and baddeleyites in this study (and by Yin et al. **[7]** and by Humayun et al. **[5]** on paired meteorite NWA 7533) show that this polymict conglomerate in fact records at least ~ 3 Gyr of Martian crustal history (4.4-1.5 Ga), a period that has not been sampled by any other martian meteorite. In this polymict clastic breccia, we notably identified zircons within a preserved igneous basaltic clast that yielded an age of ~ 4.35 Ga (see also **[7]**). Moreover, this basaltic clast was no ordinary basalt, as it was rich in alkali-feldspar as well as plagioclase, and its modal recombination results in a lithologic classification of basaltic trachy-andesite. This chemically evolved volcanic clast also contains minerals indicating crystallisation under somewhat oxidizing conditions, with average oxygen fugacities consistent with an oxidation state defined by the fayalite-magnetite-quartz buffer, similar to those inferred for crust-forming magmas in the Hadean Epoch on Earth **[12]**. The Hadean epoch was a time in which large portions of the Earth were covered in liquid water supplied at least in part by volcanic outgassing. Volcanic outgassing associated with this early martian volcanism would have supplied the surface with H_2O and the atmosphere with CO_2, a stark contrast from the reduced forms of H and C that are typically associated with more recent shergottite-like volcanic outgassing **[13-15]**.

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