U-Pb DATING OF ZIRCONS AND PHOSPHATES IN LUNAR METEORITES, ACAPULCOITES AND ANGRITES.

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Introduction: Zircon U-Pb geochronology has made a great contribution to the timing of magmatism in the early Solar System [1-3]. Ca phosphates are another group of common accessory minerals in meteorites with great potential for U-Pb geochronology. Compared to zircons, the lower closure temperatures of the U-Pb system for apatite and merrillite (the most common phosphates in achondrites) makes them susceptible to resetting during thermal metamorphism. The different closure temperatures of the U-Pb system for zircon and apatite provide us an opportunity to discover the evolutionary history of meteoritic parent bodies, such as the crystallization ages of magmatism, as well as later impact events and thermal metamorphism.

We have developed techniques using the Cameca IMS-1280 ion microprobe to date both zircon and phosphate grains in meteorites. Here we report U-Pb dating results for zircons and phosphates from lunar meteorites Dhofar 1442 and SaU 169. To test and verify the reliability of the newly developed phosphate dating technique, two additional meteorites, Acapulco, obtained from Acapulco consortium, and angrite NWA 4590 were also selected for this study as both have precisely known phosphate U-Pb ages by TIMS [4,5]. Both meteorites are from very fast cooled parent bodies with no sign of resetting [4,5], satisfsying a necessity for precise dating.

Samples: Dhofar 1442 is a glassy-matrix regolith-breccia that is rich in clasts, including basaltic, granulitic, and felsic lithic clasts [6]. SaU 169 is a KREEP-rich lunar regolith breccia which contains a large clast of high-Th impact melt breccia [7]. With the exception of the impact-melt breccia (IMB) lithology of SaU 169 [7], Dhofar 1442 is the most KREEP-rich lunar meteorite to date [8]. The provenance of SaU 169 and Dhofar 1442 is almost certainly within the Procellarum KREEP Terrane (PKT), likely in the vicinity of a low-Ti mare in the case of Dhofar 1442 [6,7].

Experiment: In-situ isotopic analysis of U-Pb was performed on a large radius magnetic sector multi-collector Cameca IMS-1280 ion microprobe at the Institute of Geology and Geophysics, Chinese Academy of Sciences in Beijing. The procedures for Pb isotopic analysis of small zircons are described in [9,10]. The experimental procedure for apatite followed that of Li et al. [11]. NW-1 apatite (1160Ma) was used as a standard, which comes from the same complex of Prairie Lake where the apatite standard (PRAP) used by Sano et al. [12] came from. The spot size for zircon and phosphate are 3×5μm and 20×30μm, respectively.

Results: *Acapulco:* Seventy three measurements of Pb-Pb isotope composition were obtained on apatite grains in Acapulco (Fig. 1). The weighted mean of $^{207}Pb/^{206}Pb$ ratios is 0.620 ± 0.002, translating to a Pb-Pb age of 4555 ± 5 Ma (uncertainties are reported at 95% confidence level, with a student t-factor applied for number of repeat analyses), assuming a primordial Pb composition for the initial Pb [13].

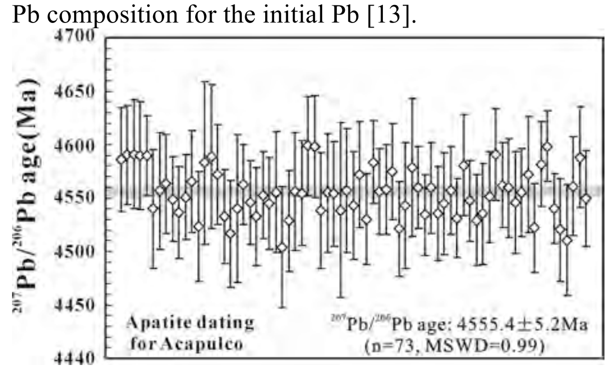

Fig. 1. Average Pb-Pb age of apatite grains in Acapulco. The results from our study (4555.4 ± 5.2 Ma) is consistent with the TIMS results (4556.5 ± 1.3 Ma) [4].

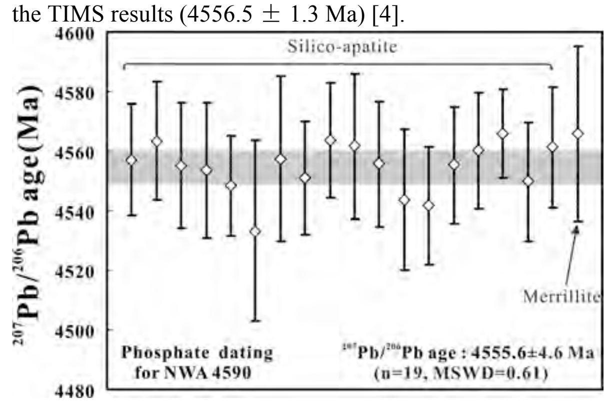

Fig. 2. Average Pb-Pb age of phosphate in angrite NWA 4590. The results from our study (4556.6 ± 4.6 Ma) is consistent with the TIMS result (4557.381 ± 0.066 Ma) [5].

NWA 4590: Eighteen Pb-Pb isotope measurements were obtained on silico-apatite grains [14] and one on a merrillite grain in angrite NWA 4590 (Fig. 2). There is no significant difference between the age of silico-apatite and merrillite. The weighted mean of $^{207}Pb/^{206}Pb$ for silico-apatite and merrillite is 0.620 ± 0.002, translating to a Pb-Pb age of 4556 ± 5 Ma (uncertainties are reported at 95% confidence level). The common lead of the phosphate in NWA 4590 is extremely low and $^{204}Pb/^{206}Pb$ ratio is nearly zero.

SaU 169: Forty five measurements of Pb-Pb isotope composition were obtained on phosphate grains (mostly RE-merrillite) in the IMB lithology of SaU 169, (Fig. 3). The peak age is around 3950 Ma, which appears to be about 30-40 Ma older than the previous measurements of U-Pb and Pb-Pb ages of zircons in SaU 169 [e.g. 15-17].

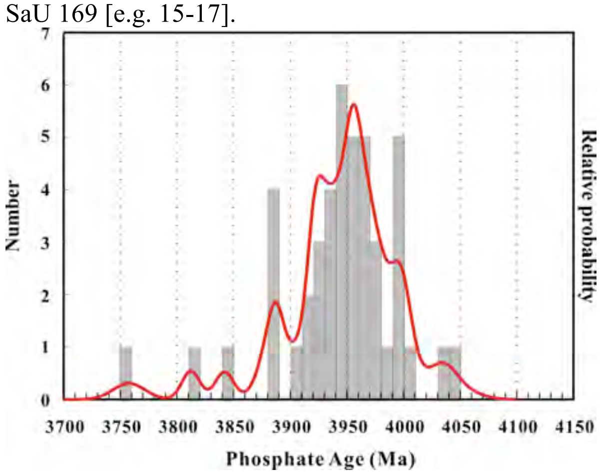

Fig. 3. Pb-Pb age distribution and probability density function of phosphate grains in SaU 169.

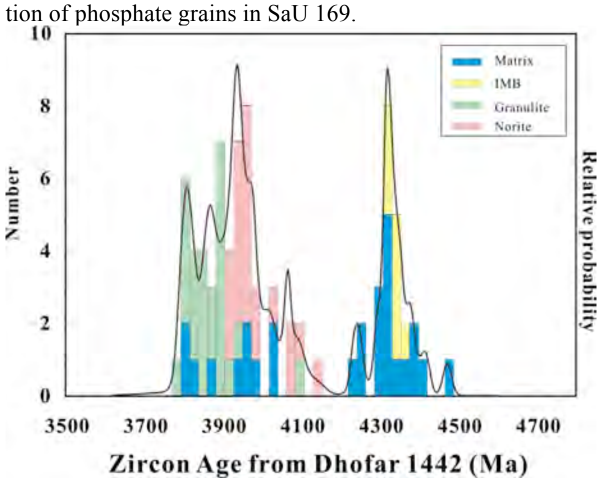

Fig. 4. Pb-Pb age distribution and probability density function of 38 zircon grains identified in a single section of Dhofar 1442. Petrographic classifications shown in color are provisional and more detailed petrographic work will follow.

Dhofar 1442: Eighty two measurements of Pb-Pb isotope composition were obtained on 38 zircon grains and fifty measurements for 46 phosphate grains in Dhofar 1442. Zircon results are presented in Fig. 4. The histogram of zircon ages shows two major peaks at ~3940 Ma and ~4340 Ma. We are processing the phosphate data at this point and hope to report the results by the time of the meeting. As seen in Fig. 4, zircons from the matrix are generally older than those from the norite or granulite clasts, the latter of which feature a recrystallized texture. The only lithic clasts with an ancient age similar to the matrix zircons are impact-melt clasts.

Discussion: Our results for Acapulco (Fig. 1) and NWA 4590 (Fig.2), consistent with TIMS results within analytical error, suggest our phosphate U-Pb dating technique and common lead correction protocol are robust .

When applied to lunar phosphates dating, there appears to be a discrepancy of 30-40 Ma for the peak age between phosphate (Fig. 3) and zircon from SaU 169 [15-17]. The reason is not clear at this point.

The terminal lunar cataclysm at ~3.9 Ga discovered from the Apollo samples [18] is now being increasingly accepted as representing a solar system wide Late Heavy Bombardment (LHB) era. However, the two prominent age peaks of ~3940 Ma for Dhofar 1442 zircons (Fig. 4) and ~3950 Ma for phosphates in SaU 169 are both likely related to the the incorporation of PKT material (more specfcally, probably Imbrium impact ejecta) in these meteorites.

The age of oldest zircon found in the matrix of Dhofar 1442 is more than 4.4 Ga old (4414 ± 11 Ma and 4468 ± 11 Ma), similar to or slightly older than the oldest lunar zircon (4417 ± 6 Ma) reported by Nemchin et al [19]. The peak age of ~4.3 Ga is as prominent as ~3.9 Ga in the zircon age histogram for Dhofar 1442 (Fig. 4). In addition, there appears to be a 4.1 Ga peak in the histogram. Evidences are mounting that LHB may have started early.

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