POLYCRYSTALLINE ZIRCON IN LUNAR METEORITE DHOFAR 458: ORIGIN AND IMPLICATIONS.
Aicheng. Zhang[1], Weibiao Hsu[2], Xianhua Li[3], Houli Ming[2], Qiuli Li[3], Yu Liu[3], and Guoqiang Tang[3] [1]School of Earth Sciences and Engineering, Nanjing 210093, China (aczhang@nju.edu.cn); [2]Faculty of Earth Sciences, China University of Geosciences, Wuhan 430074, China; [3]Institute of Geology and Geophysics, Chinese Academy of Sciences, Beijing 100029, China.

Introduction: Lunar breccias provide important information for us to understand chemistry of the lunar surface and impact history of the Moon. Dhofar 026 and its paired stones (Dhofar 457-468) are lunar breccias with unique and complex petrographic features. In previous investigations, the classification of Dhofar 026 was of controvercy. It was classified as an impact melt rock by [1] and a strongly shocked granulitic breccia (or a fragment breccia consisting almost entirely of granulitic breccia clasts) by [2-3]. Zircon has been considered as an important index of shock metamorphism in terrestrial impact craters (e.g., [4]). Recently, we observed a polycrystalline zircon in Dhofar 458. Here, we report its origin and implications for the classification of Dhofar 458 and impact history of the lunar surface.

Analytical methods: We used Hitachi II Scanning electron microscope to study the petrography of Dhofar 458 and used a Renishaw RM2000 micro-Raman Spectrometer to identify zircon and other mineral phases. The zircon was also measured for U-Pb isotopic systematics using the Cameca IMS-1280 SIMS at the Institute of Geology and Geophysics, China, following the procedure by [5]. The O^{2-} primary ion beam was accelerated at -13 kV, with an intensity of ca. 220 pA. The ellipsoidal spot is about 5 ×8 μm in size and a Gaussian illumination mode was used in order to obtain this small beam size. Monocollecter mode was used to measure secondary ion beam intensities. Correction of common Pb was made by measuring ^{204}Pb and using a common lead composition of $^{206}Pb/^{204}Pb$ = 18 ±2 and $^{207}Pb/^{206}Pb$ = 0.858 ±0.2 (c.f., [6]).

Results: Petrographic features of Dhofar 458 are similar to that of Dhofar 026. Dhofar 458 consists mainly of intergrowths of olivine-plagioclase and pyroxene-plagioclase, and plagioclase fragments. Pyroxene-plagioclase globules, large grains of olivine and ulvöspinel-chromite-spinel solid solution are also common. Our observations show that in olivine-plagioclase and pyroxene-plagioclase intergrowths, acicular olivine and pyroxene are usually interstitial to the plagioclase, respectively. In addition, plagioclase laths penetrate into the margin of pyroxene-plagioclase globules. Fragments of olivine and ulvöspinel-chromite-spinel solid solution usually exhibit a polycrystalline texture at their margins.

A polycrstalline zircon aggregate, about 60 μm in size, was also observed in recrystallized plagioclase (Fig. 1a). The polycrystalline zircon is highly porous(Fig. 1b). A few ovoid baddeleyite grains occur at the margin of the polycrystalline zircon aggregate (Fig. 1c). Reidite, cubic high temperature polymorph of ZrO_2, high-pressure orthohombic II polymorph of ZrO_2 were not observed in this study.

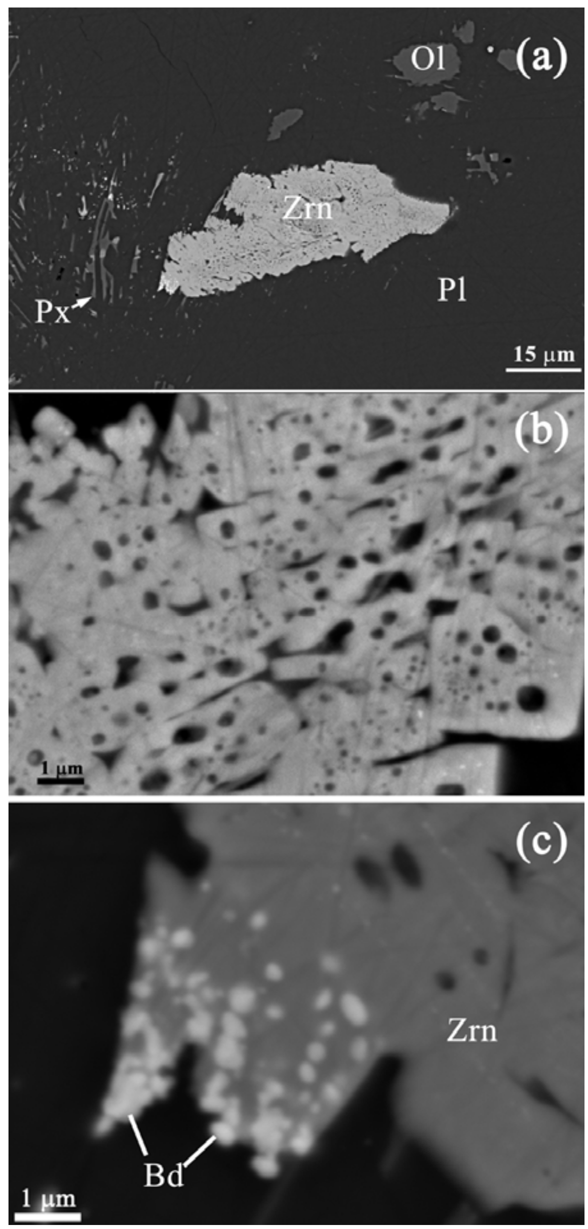

Figure 1. BSE image of polycrystalline zircon.

Nine analyses on the polycrystalline zircon gave $^{207}Pb/^{206}Pb$ ages ranging from 3417 to 3483 Ma (average at 3434 ±15 Ma). The data plot on a well defined discordia yielding an upper intercept of 3425 ±29 Ma (Fig. 2) and a lower intercept almost through the coordinate origin. We prefer the $^{207}Pb/^{206}Pb$ age (3434 ±15 Ma) as the age of the polycrystalline zircon because the $^{207}Pb/^{206}Pb$ age is not affected by the possible fractionation of U and Pb during the measurements.

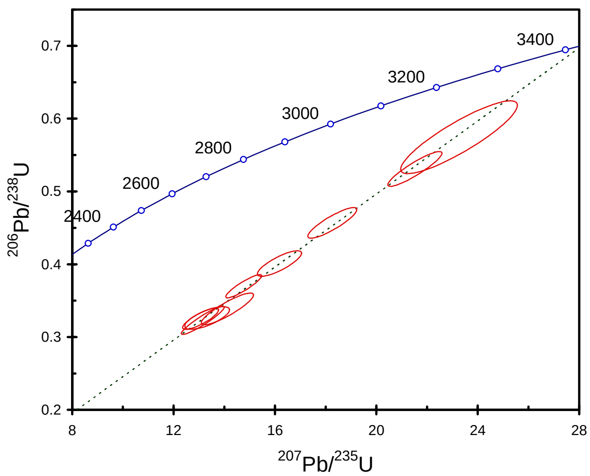

Figure 2. Concordia plot of the ion microprobe U-Pb age data from the polycrystalline zircon in Dhofar 458 showing the time of the impact event and recent lead loss. All errors are at 2σ level.

Discussion: The polycrystalline texture of zircon and the occurrence of baddeleyite are difficult to be interpreted as formed during igneous crystallization and thermal metamorphism. Instead, they can be interpreted as a product of shock-induced melting, as suggested for similar features found in terrestrial impactites (e.g., [4]). The porous texture of zircon must involve melting and degassing processes [7]. Occurrence of small baddeleyite grains at the margin of the aggregate also supports the melting origin. In terrestrial impactites, baddeleyite grains were also observed occuring at margins of zircon grains [4] and were interpreted as decomposition products of zircon at extremely high post-shock temperature. This interpreation could also be suitable to the case in the present study.

Because the whole rock of Dhofar 458 is feldspathic, the presence of decomposition of zircon to ZrO_2 with granular textures may indicate shock pressure is higher than ~60 GPa and post-shock temperature is above ~1700 °C. The inferred shock pressure and post-shock temperature are high enough to melt whole rock. The decomposition of zircon to ZrO_2 was also considered as a diagnostic feature of impact melt (c.f., [4]).

Our petrographic observations show that the margins of olivine grains in olivine-plagioclase intergrowths are interstitial to the plagioclase, indicating melting and recrystallization of both plagioclase and olivine. Similar textures along margins of pyroxene-plagioclase globules and in pyroxene-plagioclace intergrowths could also due to melting and recrystallization. In addition, large polycrystalline rims of olivine and ulvöspinel-chromite-spinel solid solution in Dhofar 458 could be also closely related to impact melting. Thus, melting of most components in Dhofar 458 were shock-induced and Dhofar 458 should be classified as a clast-rich impact melt rock.

At the very high shock pressure and post-shock temperature (>~60 GPa and >~1700 °C, respectively). the U-Pb system of recrystallized zircon must have been extensively reset, if not totally reset. The U-Pb isotopic data of the polycrystalline zircon plot on a well-defined discordia between 3425 Ma and 0 Ma. This result supports that the U-Pb system of the zircon in Dhofar 458 was completely reset. Thus, the age of 3434 Ma could be the time of a strong impact event that totally reset U-Pb isotopic systematics of zircon.

Compared to zircons from lunar rocks and other lunar meteorites (e.g., [8-14]), the polycrystalline zircon in Dhofar 458 is the youngest so far. This age is consistent with one of the age peak (~3.4 Ga) of impact melt clasts determined by Cohen et al. [15] and the age of Luna 16 basalt surface [16] (Stöffler et al. 2006). Considering the difference of the lithologies between the Luna 16 basalt surface and Dhofar 458 and impact melts in other lunar meteorites reported in [15], this age of ~3.4 Ga might record a widespread and intense impact event on the lunar surface.

References:

[1] Warren P. H. et al. (2005) *MAPS*, 40, 989-1014. [2] Cohen B. A. et al. (2004) *MAPS*, 39, 1419-1447. [3] James O. B. et al. (2007) *MAPS*, 42, 1029-1032. [4] Wittmann A. et al. (2006) *MAPS*, 41, 433-454. [5] Liu Y. et al. (2010) *JAAS*, (in press). [6]Nemchin A. A. et al. (2009) *MAPS*, 44, 1717-1734. [7] Bohor B. F. et al. (1993) *EPSL*, 119, 419-424. [8] Meyer C. et al. (1996) *MAPS*, 31, 370-387. [9] Gnos E. et al. (2004) *Science*, 305, 657-659. [10] Pidgeon R. T. et al. (2007) *GCA*, 71, 1370-1381. [11] Nemchin A. A. et al. (2008) *GCA*, 72, 668-689. [12] Nemchin A. et al. (2009) *Nature geoscience*, 2, 133-136. [13] Grange M. L. et al. (2009) *GCA*, 73, 3093-3107. [14] Liu D. Y. et al. (2010) *41st LPS*, Abstract #2477. [15] Cohen B. A. et al. (2000) *Science*, 290, 1754-1756. [16] Stöffler D. et al. (2006) *RMG*, 60, 519-596.