PETROLOGIC CONTEXT AND DATING OF 4.2 GA OLD ZIRCON IN LUNAR IMPACTITES – 67955 REVISITED.

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Introduction: Early isotopic dating of lunar rocks led to the hypothesis of a spike in the impactor flux between 3.95 and 3.85 Ga in the inner solar system (lunar cataclysm or late heavy bombardment, e.g. [1-5]). Ages of 4.2 to 4.0 Ga were less common in previous studies of Apollo and Luna samples and lunar meteorites. However, the interpretation of the age data may be biased by resetting of chronometers during impact events and an overall sampling bias of Apollo samples caused by the proximity to the relatively young Imbrium basin (e.g. [6-7] and references therein). To obtain new evidence that may help to address these issues, in-situ U-Pb age data for Zr bearing minerals in well-characterized ancient lunar impactites are useful (e.g. [7-10]). Here, we provide further evidence from zircons for one or several large impact events at ca. 4.2 Ga [7].

Material and Methods: A thin section of the well-characterized breccia 67955 was investigated. The modal composition was determined by QEMSCAN (Quantitative Evaluation of Minerals by Scanning Electron Microscopy) and additional characterization methods were applied (e.g., Raman spectroscopy). U-Pb dating of 7 zircons was performed at the GFZ Potsdam using a CAMECA IMS 1280 HR instrument.

Results and Discussion: Three texturally different domains occur in thin section 67955,48. A granulitic domain (D1) is homogeneous, characterized by up to 3 mm long and 1.5 mm wide plagioclase crystals and interstitial olivine (Ol), orthopyroxene (Opx), clinopyroxene (Cpx) and locally apatite (Ap)., A brecciated domain (D2) comprises various rock clasts embedded in an apatite-bearing, fragment-rich matrix (D3). Troilite locally occurs as interstitial grains up to 30 µm ø (D1) or as speckles in some clasts (D2), but not in the matrix (D3). Minor amounts of Fe-Ni metal occur in all three domains. Some clasts underwent up to two different fracturing events before their final assemblage. Clasts show variable proportions, sizes and textures of Old, Cpx, Opx and Plg. Zircons are rare, anhedral and small in size (3 to 15 µm) and predominantly occur clasts in the clast-rich domain. Few zircons occur in the matrix. A few zircons show concentric to irregular zoning in BSE/CL images. Some display inclusions (possibly Plg). The mean of seven $^{207}Pb/^{206}Pb$ ages is 4.209 ± 0.014 Ga (2sd). Within-run uncertainties are better than 0.018 Ga (2sd). Our results agree well with in-situ U-Pb ages on zirconolite and apatite from the same sample [7], interpreted as reflecting impact events at 4.22 Ga and 3.9 Ga [7].

Conclusions: The three different domains in 67955,48 vary in texture and composition. All contain Fe-Ni metal, suggesting that they represent impactites. The predominance of apatite in the matrix (D3), its distribution in clusters or around clasts indicates that the matrix was not formed by fragmentation of the clasts. The absence of troilite in the matrix and its presence in clasts further supports this hypothesis. Textural and compositional variations of the different clasts imply that portions of this rock comprise different rock types that were mixed and welded together. Due to textural variations we interpret the different zircons to have been formed by crystallization in different impact melt settings. Most likely this requires one [7] or several large impacts at 4.2 Ga. Crystallization of the zircons at ~4.2 Ga predated the fracturing processes and formation of the clast-rich domain, which may have occurred at 3.9 Ga [7]. Our data reiterates that zircons from lunar impactites can provide critical information on the bombardment history of the Moon prior to 3.9 Ga.

References: [1] Cohen, B.A., Swindle, T.D., Kring, D.A. (2005) *MAPS* 40, 755-777. [2] Ryder, G. (2002). *J. Geophys. Res. Planets* 107, 6-1-6-13. [3] Stöffler, D., Ryder, G., Ivanov, B.A., Artemieva, N.A., Cintala, M.J., Grieve, R.A.F. (2006) *Rev. Mineral. Geochem.* 60, 519-596. [4] Tera, F., Papanastassiou, D.A., Wasserburg, G.J. (1974) *EPSL* 22, 1-21. [5] Norman, M.D. (2009) *Elements* 5 23-28. [6] Fernandes, V.A., Fritz, J., Weiss, B.P., Garrick-Bethell, I., Shuster, D.L. (2013) *MAPS* 48, 241-269. [7] Norman, M.D., Nemchin, A.A. (2014) *EPSL* 388, 387-398. [8] Nemchin, A.A., Pidgeon, R.T., Healy, D., Grange, M.L., Whitehouse, M.J., Vaughan, J. (2009) MAPS 44, 1717-1734. [9] Pidgeon, R.T., Nemchin, A.A., van Bronswijk, W., Geisler, T., Meyer, C., Compston, W., Williams, I.S. (2007) *GCA* 71, 1370-1381. [10] Grange, M.L., Nemchin, A.A., Timms, N., Pidgeon, R.T., Meyer, C. (2011) *GCA* 75, 2213-2232.