CAN CHONDRITIC CLASTS IN LUNAR METEORITE ALLAN HILLS A81005 CONSTRAIN EARLY SOLAR SYSTEM PROCESSES? EVIDENCE FROM OSCILLATORY ZONING IN OLIVINE

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Introduction: The Moon's surface, a key proxy for the early Earth, preserves a record of the early, dynamic environment of our Solar System and thus the early geological evolution of terrestrial planets [1]. Fragments of projectiles, relicts of asteroids and comets that bombarded the surfaces of the early Moon, can be found in the lunar regolith. These relict clasts provide direct information about the type and source of exogenous material that was delivered to the early Earth-Moon system [2]. Lunar meteorite ALHA 81005 is a polymict, anorthositic regolith breccia from the lunar highlands [3,4], possibly from the lunar farside [1]. Among its rock and mineral fragments, non-lunar material has been found [5]. Here we report the study of a new, possibly chondritic fragment, called *Clast Z1*, and draw conclusions about its origin in the early Solar System.

Method: Quantitative analyses and element X-ray maps were taken with the SX100 microprobe at the American Museum of Natural History (AMNH). High resolution BSE images were taken with the FE-SEM at the AMNH Micro Imaging Facility.

Results: Clast Z1 is ~300 x 150 μm in size. Texturally clast Z1 is porphyritic, mainly composed of euhedral to subhedral olivine grains set within a matrix rich in glass and/or plagioclase. Olivine ranges in size from 30 μm to <5 μm and is shown oscillatory zoning in FeO and MgO (Fo85-65), with some grains showing up to 5 oscillatory cycles. The oscillatory bands have widths ranging from ~1–5 μm. The core of some olivine grains contain very small (< 1 μm) inclusions of sulfides and metal. The Fe/Mn ratio of olivine is ~ 49-70. The clast also contains pockets of sulfides that range in size from 40–5 μm. Sulfides shows exsolution lamellae of pentlandite and FeNi metal (49–51wt% Ni).

Discussion and Interpretation: Clast Z1 appears to be chondritic in nature. The olivine Fe/Mn ratio does not fit the lunar trend of ~87-140 but falls within the range of CR chondrites [6]. In addition, the metal has a chondritic Co/Ni ratio of ~0.03. The assemblage phyrrotite, pentlandite, (both absent in pristine lunar rocks) and FeNi metal is typical of Fe–Ni–S monosulphide solution that underwent exsolution during cooling [7] and points to very low temperatures for clast Z1. Oscillatory zoning of FeO and MgO in olivine is rare in general, and has only been described once for chondritic olivine [8]. The oscillatory zoning in olivine in clast Z1 could be explained by changing oxidation conditions in the solar nebula during crystallization as suggested by [8]. However, multiple growth layers in olivine could be expected to arise in a model where chondrules are the products of multiple short, high-temperature melting events [9].Further analyses of clast Z1 will yield insights into the early evolution of the Solar Nebula, its processes, and the origin of chondritic olivine.

References: [1] Korotev 2005, *Chemie der Erde*, 65, 297-346; [2] Joy et al. 2012; *Nature* 336, 1426-1429; [3] Treiman and Drake 1983, *Geophy. Res. Lett.* 10, 783-786; [4] Warren et al. 1983, *Geophys. Res. Lett.* 10, 779-782; [5] Gross and Treiman 2010, 41th *LPSC*, #2180; [6] Berlin et al. 2011; *MaPS* 1-21; [7] Day et al. 2006, *GCA* 70, 5957-5989; [8] Lubsy et al. 1987. *J. Geophys. Res.* 92, E679-E695. [9] Wasson and Rubin 2003, *GCA* 67, 2239–2250.