

COMPOSITIONAL VARIATION IN LUNAR ZIRCON IMPACT MELT INCLUSIONS. C. A. Crow¹, D. E. Moser², and K. D. McKeegan ¹University of Colorado Boulder (carolyn.crow@colorado.edu), ²Zircon and Accessory Phase Laboratory, University of Western Ontario, ³University of California, Los Angeles.

Introduction: Lunar zircons have been shown to host a range of impact shock microstructures, the most common of which are curvilinear features (CPFs) decorated with melt inclusions [1-3]. The morphology of the CPFs and melt inclusions are similar to those observed in zircons from the Vredefort impact structure in South Africa, and, thus, are thought to represent adjacent (or nearby) phases that were melted during shock wave rarefaction and entrained in the CPFs [4]. The detailed survey of Vredefort zircon melt inclusions, reported in [5], noted a distinct variation in melt composition between zircons from different regions of the impact structure. Additionally, the inclusion compositions reflected local mineralogy suggesting adjacent minerals or rock are likely the source of the melt.

We have undertaken a similar study of melt inclusions within Apollo 14 zircons to investigate the range of melt compositions hosted in these grains. These samples were chosen because (1) Apollo 14 zircons have the largest range in ^{207}Pb - ^{206}Pb crystallization ages ranging from ~3.9 Ga to 4.4 Ga [e.g. 6-8], and (2) Apollo 14 is the only landing site that has zircons with ages younger than ~4.1 Ga [6]. The goal of this study is to determine if there is a variation in melt inclusion compositions with zircon age, and what information about the number of impacts can be gleaned from these results. Additionally, the vast majority of lunar zircons are detrital and many are loose grains separated from breccia and soil samples out of mineralogical context. The rich source of lunar chronology provided by zircon ages would therefore be stronger if complemented with protolith information.

Sample: We have been allocated a suite of Apollo 14 samples for zircon separation, however, we focus on sample 14311 for the purposes of this study. Impact melt breccia 14311 is an ideal candidate because three distinct age populations have previously been identified in zircons from this sample (4334 ± 10 , 4245 ± 10 , and 3953 ± 10 Ma) [9]. Additionally, the zircons from this sample show a range of textures, including high-temperature granular recrystallization, suggesting the grains have been exposed to a range of pressure and temperature environments. We note that the composition of the impact melt inclusions can be used to further constrain the level of shock heating.

Methods: Zircons were separated using standard crushing and heavy liquid density separation methods outlined in [6] and [8]. The grains were then mounted in epoxy disks and polished for preliminary electron beam

imaging. Based on initial characterization, a suite of 23 grains were selected for further analyses of melt inclusion compositions.

Melt compositions are measured at the Zircon and Accessory Phase (ZAP) Laboratory at University of Western Ontario using semi-quantitative energy dispersive spectroscopy (EDS) following the methods developed by [5]. The melt inclusions are small – sometimes submicron in size. To minimize the excitation volume, the acceleration voltage of the x-ray beam is reduced to 7 kV. The low accelerating voltage has also been shown to reduce alkali mobility, such that the loss of Na and K are negligible [5].

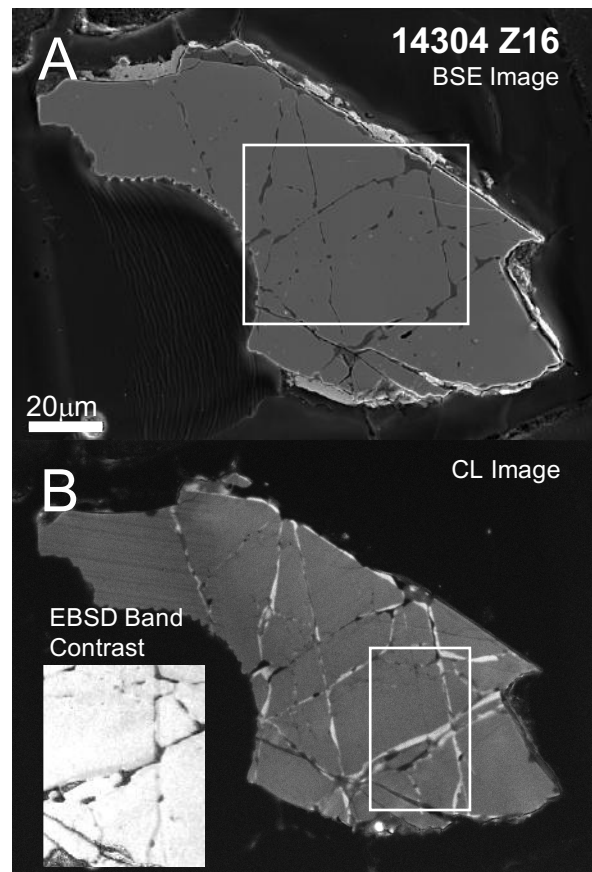


Figure 1: (A) Backscatter electron (BSE) image revealing cross cutting CPFs fully or partially filled with impact melt. (B) CL image showing bright CL margins within the zircon surrounding melt inclusions. These CL bright domains are associated with a reduction in EBSD band contrast (i.e. reduced crystallinity). Adapted from [1].

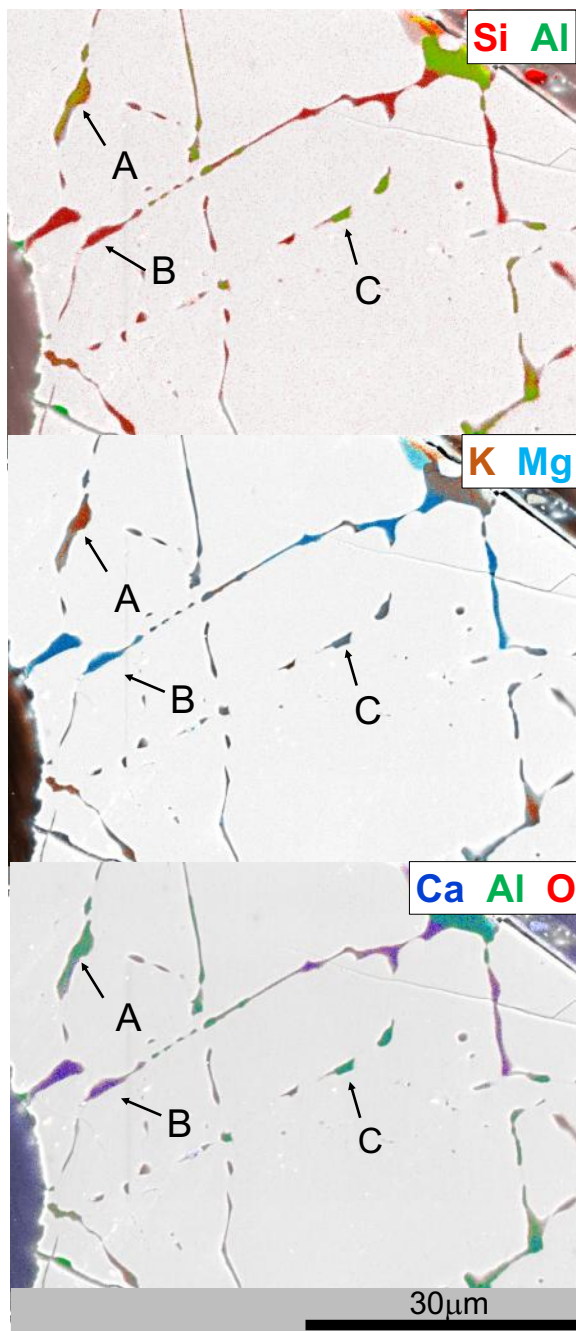


Figure 2: EDS maps of zircon 14304 Z16. Three different melt compositions were identified: (A) K-Al-Si, (B) Mg-Ca-Si, and (C) Mg and Al with no Si.

Preliminary Results: We reported the first compositional analysis of lunar zircon impact melt inclusions in [1]. The sample was a zircon from clast-rich impact melt breccia 14304, and has a ^{207}Pb - ^{206}Pb age of 4246 ± 26 Ma [7] and an extensive network of crosscutting CPFs that are partially to totally filled with impact melt

(Fig. 1). The cathodoluminescence (CL) image of Z16 (Fig 1. B) reveals bright zircon margins along the CPFs; these regions are associated with reduced band contrast in electron backscatter diffraction (EBSD) analyses. Further geochronology work is ongoing to refine the U-Pb systematics of this grain at higher spatial resolution.

The semi-quantitative EDS maps in Fig. 2 reveal three distinct compositions of melt glass. Assuming that these melts reflect local or adjacent phases, we can look at the mineralogy of clasts within breccia 14304 to try to better understand the source of these three melt compositions. The first (A) is a K-Al-Si phase that is similar in composition to melt veins described in an alkali norite clast from 14304 (“g”) [10]. The second (B) is a Mg-Ca-Si phase, which is consistent with the composition of pyroxenes within this same alkali norite clast [10]. The third (C) phase is mainly Mg and Al and appears to have no Si, which may suggest a spinel-like pre-cursor. The composition of the melt inclusions suggests this zircon may have been entrained in a similar alkali norite clast prior to being impacted. A 4108 ± 44 Ma Sm-Nd age was reported for the alkali norite clast (“g”) from [10] [11]. This age would be consistent with the zircon forming prior to incorporation into the norite clast, and a subsequent impact younger than 4108 ± 44 Ma resulting in the melt compositions A and B. Alternatively, the zircon may have come from an older noritic component. Regardless, a mafic protolith host for the zircon is indicated.

On-going Work: We will present the results of a more extensive compositional survey of melt inclusions in a suite of zircons from impact melt breccia 14311. These data will be used to identify compositional groups and to evaluate variations in melt composition between the three age populations identified by [9]. The melt compositions will also be compared with the petrology of significant clasts to better constrain the impact history of the zircons within this sample.

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