LUNAR ZIRCONS: WHAT’S THE BIG PICTURE?  C. A. Crow1, K. D. McKeegan1, and D. E. Moser2, 1University of California, Los Angeles (595 Charles Young Drive E, Box 951567, Los Angeles, CA 90095; cerow@ucla.edu), 2University of Western Ontario (Biological & Geological Sciences Building, 1151 Richmond Street N, London, Ontario, Canada, N6A 5B7).

Introduction: Zircon is a late stage accessory mineral that incorporates radiogenic parents such as uranium and thorium, while preferentially excluding their daughter product lead, allowing for precise U-Pb and Pb-Pb ages to be determined for individual grains [1]. Zircons also incorporate other trace elements such as the rare earth elements (REEs) and titanium, which can reflect the composition and temperature of the parent magma [2]. Microstructural studies of terrestrial and lunar impact zircons found that some types of shock deformation may result in increased Pb mobility, but the extent to which these microstructures affect radiogenic ages and/or trace element compositions in lunar grains is still unclear (e.g. [3-6]).

The lunar zircons analyzed to date have Pb-Pb ages that range from 3.9 to 4.4 Ga (e.g. [6-8]). These relatively old ages, predating the hypothesized late heavy bombardment (LHB) [9], and the ability of these grains to retain primary crystallization ages and signatures of secondary impact processes, make them suitable for investigating the early magmatic and impact history of the Moon. We have conducted an extensive U-Pb, REE, and microstructural survey of Apollo zircons that, in combination with previous studies, represents a robust lunar zircon dataset from which we can draw constrains regarding the duration of KREEP magmatism, zircon formation mechanisms, and possibly the early impact history of the Moon.

Methods: Zircons were separated from Apollo 14, 15, and 17 samples by crushing and heavy liquid density separation. We sampled six breccias (14304, 14305, 14321, 15405, 15455, 72275), one saw cutting (14163), and two soils (14259, 15311). All grains were imaged by scanning electron microscopy (SEM) to search for cracks, inclusions, and regions of cathodoluminescence (CL) variation. After preliminary characterization, U-Pb and Pb-Pb ages for 155 zircons and trace elements of 89 zircons were collected with the UCLA Cameca IMS-1270. A selection of 30 grains were then searched for the presence of crystallographically-controlled shock microstructures at the University of Western Ontario, Zircon and Accessory Phase Lab (ZAP Lab) by using a combination of secondary electron (SE), low kV backscatter electron (BSE), CL, and electron backscatter diffraction (EBSD) mapping.

Results:

Microstructures. The 30 zircons survived for shock microstructures were from breccias 14305, 14321, and soils 14259, 15311. Of these zircons only one grain exhibited granular texture and none have crystal-plastic deformation greater than 8°, which are features thought to result from recrystallization during shock metamorphism and strain during crater relaxation respectively. Both are thought to cause significant Pb-loss in impact zircons [5]. Shock microtwins have also been suggested to be a pathway of Pb-loss [5]. Three of the grains contained shock microtwins, but all have concordant ages >4.24 Ga. Only a small fraction of the grains exhibit microstructures that afford disturbance of the pre-shock U-Pb ratios.

Trace elements: Increased resolution of SEM imaging allowed us to identify impact melt inclusions down to the submicron scale. After removing REE analyses where SIMS spots overlapped inclusions or cracks, and analyses with >600ppm Fe, the lunar zircons can be characterized by one REE pattern with varying total REE concentration. The trace elements also exhibit trends indicative of formation by fractional crystallization, which is consistent with, but not uniquely indicative of, crystallization in a KREEP like magma [10].

Ages. The vast majority of the lunar zircons have U-Pb ages that are concordant within error (typically 4%). The distributions of the corresponding Pb-Pb ages in our study are not homogeneous amongst the Apollo landing sites. This is in agreement with previously published Apollo 14 and 17 zircon ages [1]. Our Apollo 15 and 17 samples only contain zircons that are older than 4.1 Ga, while Apollo 14 also samples a younger population of grains that have ages ranging to as young as ~3.9 Ga. Only 10% of the zircons are in this younger population, and they are typically smaller grains (<50 microns) or show evidence of Pb loss or impact crystallization textures. As an ensemble, the crystallization ages and REE patterns suggest a widespread, extended period of KREEP magmatism spanning from ~4.4 to ~4.1 Ga but that only Apollo 14 zircons have a significant younger population that may represent extension of magmatism for another ~200 Ma or that this population was reset by LHB era impacts. Regardless, Apollo 15 and 17 zircon Pb-Pb ages are not largely affected by LHB era basin forming impact events.