Impact Shocking of a Zircon-Sanidine Mixture and Investigations of Pb Mobility I. Szumila[1,2], M. Miller[1], D. Trail[1], J. Simon[3], M. Cintala[3], F. Cardenas[2], R. Montes[2], F. Horz[3], M.M. Wielicki[4], L. Danielson[2] [1]University of Rochester (iszumila@gmail.com), Rochester, NY, [2]Jacobs, JETS, JSC, 2224 Bay Area Blvd, Houston, TX, 77058, [3]Astromaterials Research and Exploration Science, NASA JSC, Houston, TX 77058, USA., [4]University of Alabama, Tuscaloosa, AL, 35487

Introduction: The purpose of this project is to explore the mobility, mixing, and possible clumping of Pb isotopes during laboratory impact shock experiments. Impact events are a common planetary occurrence and their effect on istotope systematics and subsequent geochronology is not fully understood. By artificially shocking mixtures of zircon and sanidine and investigating the sample products, it may be possible to understand if and how Pb is mobilized during impact shock. Isotopes of Pb are the final daughter products of the decay chains of ^{238}U, ^{235}U and ^{232}Th and therefore understanding how mobile the daughter product is during impact events could have consequences for dating impact events. These investigations will also reveal if Pb isotopes can be mixed between minerals.

A metamorphism scale for degrees of impact shock was established by [1] who studied the Coconino sandstone around Meteor Crater, Arizona. The scale starts at Class 1 which indicate only physical damage and fracturing. Class 2 refers to the formation of maskelynite, while Class 3 is where plagioclase in the rock melts, and Class 4 is where both plagioclase and pyroxene melt. Class 5 is defined by nearly total melting and recrystallization of the shocked material. For the purposes of artificial shock via an accelerator gun, these scales have been further calibrated via [2] who shocked both massive basalt from Lonar crater and granular lunar basalt pulverized from a chip of the basaltic Apollo sample 75035. Granular material experiences the classes of metamorphism at lower pressures than massive material. Thus Class 2 metamorphism is reached above 20 GPa for massive material but near or below 20 GPa for particulate.

Previous Work and Justification: Some previous investigators (e.g [3]) have shocked zircon before. This research benefits from previous researchers. Our own experiments are unique by studying isotope mixing between phases and using modern analytical techniques such as Laser Ablation-Inductively Coupled Plasma-Mass Spectrometry (LA-ICP-MS) and Atom Probe Tomography (APT) to learn more about the recovered shocked material.

Other workers [4] examined the possibility of using shocked lunar zircons to date lunar impact events while [5] examined zircon inclusions in shocked monazite using information known about the zircons to place constraints on the microstructures in the host monazite. Clumping of Pb was reported by [6] who found clumping at nano-meter scale via APT. These Pb clumps are not located with hotspots of U and Th and appear to have formed by a process such as volume diffusion, possibly into structural defects in the crystal latice. We wish to learn if these Pb clumps could have formed by the diffusion and exchange that occurs during impact shock.

Methods: Zircons were picked out of the matrix of a host rock sourced from Keuhl Lake, Canada. Keuhl Lake (KL) is the source region of the 91500 zircon geochron standard and therefore zircon from this area is a well characterized material (see [7]) Large zircons (appox mass of two different individual grains used was 0.362 g, and 1.25 g) were individually picked or chiseled out of the host rock. The other material used was sanidine from the Bishop Tuff. This material was picked since it is very well characterized in Pb isotopes [8].

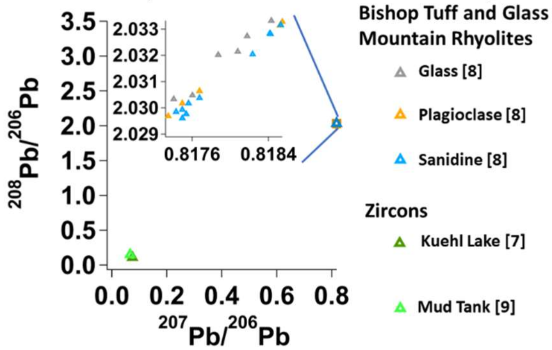

Figure 1. Graph of ^{207}Pb/^{206}Pb vs. ^{208}Pb/^{206}Pb for materials considered for this project. The two selected for initial experiments were Bishop Tuff sanidine from the Long Valley Caldera and zircon from Keuhl Lake, Canada. Bishop Tuff materials are shown in the inset.

Grains from each material were individually crushed and then sieved to isolate grains approximately 125 to 250 μms in size. A zircon-sanidine mixture was loaded into stainless steel target with sample wells 1 cm wide and 0.7 cm deep. The mixture was loaded into the stainless steel target and shocked via the JSC Experimental Impact Lab's (EIL) flat-plate accelerator. A flat-plate accelerator pressurizes the sample in such a way that the pressure experienced by the sample is largely uniform. The target mixture was approximately ~97%-sanidine, ~3%-zircon by mass. The pressure was set to 25 GPa and the measured velocity of the flyer plate during the experiment indicates that the actual pressure reached was 23.5 GPa. This experiment was successful and shocked material was able to be recovered. Sample material from the target was examined thoroughly, specifically to locate interacting grains of zircon and sanidine. Resultant materials were selected, mounted in epoxy, then analyzed and imaged via Scanning Electron Microscopy (SEM). Some shocked sanidine material was also analyzed via LA-ICP-MS to ascertain if Pb ppm levels had changed. Analysis of diffusion couples was conducted via LA-ICP-MS on a 193 nm photon machines laser and an Agilent 7900 mass spectrometer.

Results from LA-ICP-MS: LA-ICP-MS analysis of the unshocked KL zircon showed Pb isotopes that yielded an age of about 1 Ga confirming that these samples are from KL and similar to the zircon 91500 standard. Unshocked sanidine has a total Pb content of 30.3 ppm with at 2 S.E. of 0.65. Shocked sanidine, including some laser spots near co-located zircon, had a total Pb content of 31.1 ppm with 2 S.E. of 0.65.

Results from SEM: Many grains were analyzed via SEM and backscatter electron detection (BSD) techniques were used to learn about the composition of the grain. Energy dispersive x-ray spectroscopy (EDS) maps were also collected for interesting regions. The goal was to locate zircon grains in the primarily sanidine mixture to examine how the two phases interacted during the shock process.

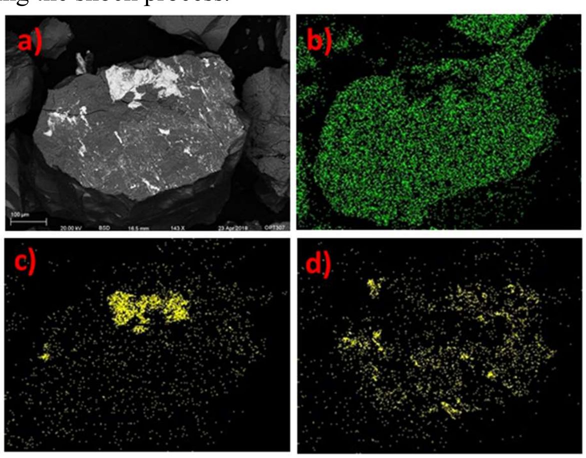

Figure 2 (a,b,c,d). a) A shocked zircon grain co-located with a shocked sanidine grain imaged in BSD. b) An EDS map of Al, c) EDS map of Zr, d) EDS map of Cr

Figure 2a, shows one of these grains. At first zircon grains appeared to be almost painted on the surface of sanidine material, but after mounting in epoxy and polished, co-located zircon and sanidine grains were found. There is also some Cr (Fig 2d) probably from interactions with the stainless target during impact shock.

Atom Probe Tomography: Samples will also be analyzed via APT at the University of Alabama in early January of 2019. We hope to present data from atom probe tips sourced from unshocked zircon and sanidine as well as the post-shock zircon and sanidine. Particularly we wish to evaluate both the mixing of Pb isotopes during the impact shock process and determine if there is any observed Pb clumping in shocked zircon vs. unshocked zircon.

Pb mixing: Figure 3 shows a possible mixing curve between zircon and sanidine feldspar.

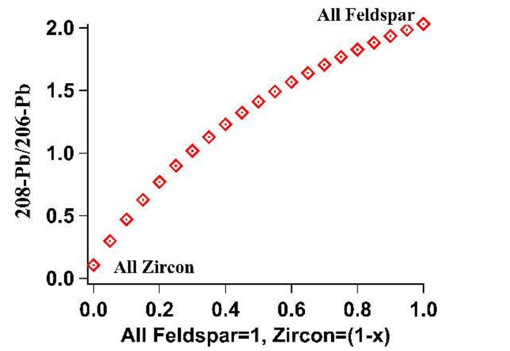

Figure 3. This figure shows anticipated Pb mixing between sanidine and zircon based on their Pb isotopic abundances and ratios.

Depending on the relative amounts of mixing between the two phases, the resultant 208/206 Pb ratio should fall somewhere along this line.

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