ANOMALOUS ^{40}AR/^{39}AR SHOCK AGES IN MBALE: NONINTUITIVE K AND AR BEHAVIOR, IMPLICATIONS FOR THE INTERPRETATIONS OF SHOCK AGES IN SHOCKED METEORITES. M. E. Karageozian, T. Sharp, M. Van Soest, C. McDonald. The School of Earth and Space Exploration, Arizona State University, 781 Terrace Mall, Tempe, AZ 85287 (mekarage@asu.edu).

Intro: Mbale is a meteorite fall sample classified as an L5/6 ordinary chondrite [1] with shock stage ranging from S5 to S6 [2] and an ^{40}Ar/^{39}Ar age of 479 ± 7 Ma [3]. Our section of Mbale has shock veins measuring up to several mm in apparent width. As in other shocked chondrites with S6 shock veins [4], shock effects in Mbale depend on proximity to shock veins [2]. The dating of shocked meteorites, specifically ^{40}Ar/^{39}Ar methods, have constrained the impact history of our solar system [5], but no studies have been conducted to solely showcase the dynamics of K and Ar during shock. Here we discuss Mbale's petrography, shock effects, and ^{40}Ar/^{39}Ar dates in and around a shock vein. Our study documents ^{40}Ar/^{39}Ar age anomalies that result from nonintuitive behavior of K and Ar in shock melt at high pressure. These results have critical implications for the interpretation of ^{40}Ar/^{39}Ar dating results from shocked meteorites with S6 shock veins and deepen our understanding of the behavior of K and Ar under shock conditions.

Methods: A small block of Mbale was used to make facing polished sections; a 7x7mm, 150 µm-thick section and an opposing block. The thick section was irradiated for 100 hrs in the OSU CLICIT reactor. The slab was loaded into the UV laser chamber of an ultrahigh vacuum extraction line attached to a Nu Instruments Noblesse noble gas mass spectrometer in the Group 18 Laboratories at ASU. The sample chamber was pumped down to ultrahigh vacuum and baked overnight. Argon was extracted from the slab using a Teledyne/Photon Machines Analyte Excite UV (193nm) laser and after gas cleanup was analyzed in the mass spectrometer using a Secondary Electron Multiplier (SEM). Data was reduced using the Mass Spec software (Al Deino, BGC) and an in-house spreadsheet and are reported with uncertainties at 2-sigma levels. An optical interferometer was used to obtain ablation pit volumes to determine K and Ar concentrations form the ablation spots. The facing section was used for petrographic and chemical analysis with a JEOL JXA-8530F electron microprobe at ASU's Eyring Material Center. We used backscattered electron (BSE) imaging and energy dispersive X-ray spectroscopy (EDS) to determine the mineralogy, microstructures and for elemental mapping. We used wavelength dispersive X-ray spectroscopy (WDS) for quantitative chemical analyses.

Results:

Petrography. The Mbale sections are comprised of ~30% melt vein. The host lithology is almost entirely comprised of olivine and pyroxene, with plagioclase accounting for ~10% of the bulk mineralogy. Similar to the findings of Hu and Sharp [2], the melt vein lithology is fine-grained and contains high-pressure garnet, high-pressure olivine polymorphs, sulfide/metal droplets, and entrained host-lithology clasts. Maskelynite is abundant outside of the melt vein along the edge

^{40}Ar/^{39}Ar Dating. Dating was completed in three tracks across the melt vein (Fig. 1) sampling both quenched shock melt, host rock, and entrained clasts within the vein. The ablation results produced dates ranging from 444 ± 10 myr to 6845 ± 137 myr. The youngest dates analyzed are from the host rock while the oldest and most variable dates were measured within the melt vein (Fig. 1).

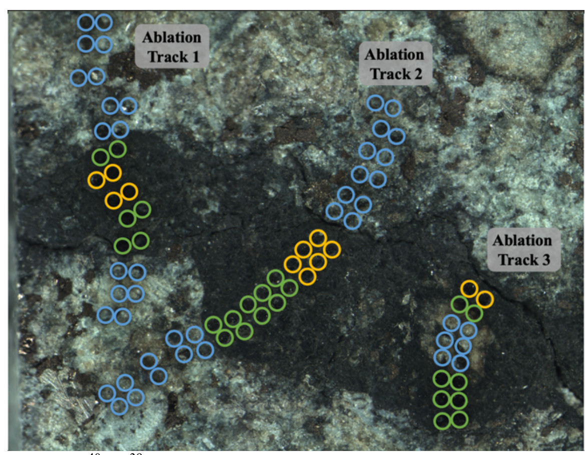

Figure 1. ^{40}Ar/^{39}Ar UV laser ablation tracks, where blue pits are dated from 444 ± 10 to 1604 ± 53 mya, green pits are dated from1832 ± 56 to 4237 ± 293 mya, and the yellow pits are anomalously old from 5287 ± 93 to 6845 ± 137 mya.

Ar measurements within the vein were measured as being significantly higher than quantities outside of the vein (Fig. 2).

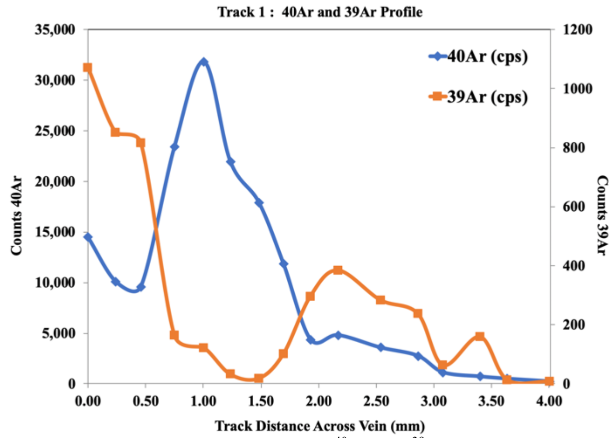

Figure 2. Mass spectrometer counts of ^{40}Ar and ^{39}Ar with distance of measurement across the melt vein.

Microprobe Analyses. On the polished facing section, WDS and EDS maps and spot analyses were performed measuring the K content of the shock melt, maskelynite, and host plagioclase. WDS maps reveal a nearly K-free melt vein surrounded by K-rich maskelynite. The K_2O content of the maskelynite and plagioclase decreases with distance from the melt vein. The average K_2O content in maskelynite on the vein rim is around 1.5 wt% while K_2O within the melt vein averages around 0.02 wt% (Fig. 3).

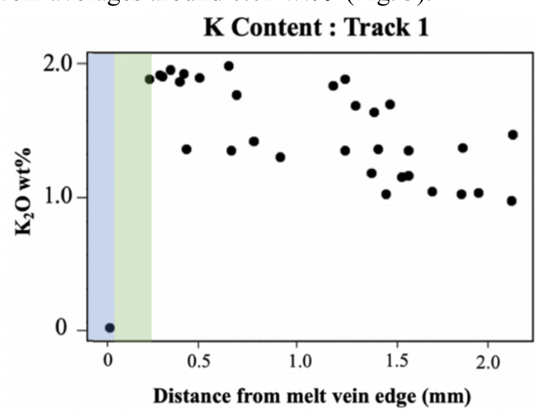

Figure 3. K_2O content of maskelynite and plagioclase correlated with Ar track 1, using WDS analysis. The blue region highlights measurements from within the shock vein, and the green region shows measurements at the shock vein edge.

Discussion: The $^{40}Ar/^{39}Ar$ age results within the melt vein yield anomalously old ages; older than that of our solar system. Using microprobe and mass spectrometry analyses, we confirmed that there is retention of Ar combined with significant loss of K from the melt vein. The scatter in the K_2O profile data may reflect complex geometry of shock melt within the sample as well as contributions from subsurface minerals that intersect the X-ray excitation volume.

The preferential loss of K, vs. Ar from the shock melt suggests that K is less soluble in high-pressure (20-25 GPa) silicate melts than Ar. This is supported by measurements of K-rich maskelynites reported adjacent to shock veins in other meteorites [6]. S6 shock veins, which generally quench at high pressure, appear to have little capacity to retain K. Plagioclase glass, either diaplectic glass or normal glass, accepts this excess K expelled from the vein. Farther from the melt vein, in regions that experienced lower shock temperatures, crystalline plagioclase does not appear to have excess K. Our $^{40}Ar/^{39}Ar$ dates, combined with the K and Ar distribution results, imply that shock melt crystallizing at high pressure and temperature, preferentially loses K and retains Ar, which results in anomalously high shock ages within the vein. A similar result was reported for the Peace River L chondrite in 1988 by McConnville et al. [7]. Their 1060-nm laser results from a shock melt vein produced dates as old as 7 Ga, however, they did not document the loss of K to the surrounding maskelynite.

Conclusion: Our laser $^{40}Ar/^{39}Ar$ dates, combined with K and Ar measurements demonstrate that K loss and Ar retention in S6 shock veins results in anomalously high ages in Mbale. Based on this work and previous work [6, 7] we expect to see this effect in any shocked meteorite that contains S6 shock veins that quenched at high pressure. This work illustrates the importance of determining how specific shock effects can redistribute both K and Ar during impact events.

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References: [1] Wlotzka et al. (1993) *Met. Soc. Bull. 75.* [2] Hu & Sharp (2017) *Geochimica et Cosmochimica Acta 215. 277–294.* [3] Korochantseva et al. (2007) *Meteorit. Planet. Sci. 42, 113–130.* [4] Bischhof et al. (2018) *Meteorit. & Planet. Sci. 1–14* [5] Swindle et al. (2014) *Geol. Soc. Lond. Spec. Publ. 378, 333–347.* [6] Chen, M., and El Goresy, A. (2000) *EPSL* 179, 489-502. [7] McConville et al. (1988) *Geochimica et Cosmochimica Acta 52. 2487-2499.*