A REFINED AGE FOR THE GOW LAKE IMPACT STRUCTURE. A. E. Pickersgill[1,2], D. F. Mark[2, 3] M. R. Lee[1], and G. R. Osinski[4], [1]School of Geographical & Earth Sciences, University of Glasgow, Gregory Building, Lilybank Gardens, Glasgow G12 8QQ, U.K.; [2]NERC Argon Isotope Facility, Scottish Universities Environmental Research Centre (SUERC), Rankine Avenue, East Kilbride G75 0QF, UK, [3]Department of Earth & Environmental Science, University of St Andrews, St Andrews, KY16 9AJ, UK. [4]Centre for Planetary Science and Exploration / Dept. of Earth Sciences, University of Western Ontario, London, ON, Canada (annemarie.pickersgill@glasgow.ac.uk).

Introduction: The Gow Lake impact structure, located in northern Saskatchewan, Canada (56°27' N, 104°29' W), is approximately 5 km in diameter, making it the smallest impact crater in Canada to also have a structural uplift [1]. The target rocks in this area are Precambrian granites and Hudsonian gneisses of the Precambrian shield [1]. Impact melt rock mineralogy is dominantly potassium feldspar and plagioclase, consistent with granitic target rocks [2]. This structure appears to be at the transition between the simple and complex crater size in crystalline targets on Earth, and may provide clues to development of crater morphology and the overall formation of impact craters.

An age estimate of 100 Ma was given by [1] based on depth of erosion and comparison with the nearby Deep Bay crater. One attempt has been made to date the impact event using $^{40}Ar/^{39}Ar$ geochronology, and an age was reported of <250 Ma [3].

The Gow Lake impact structure is an intriguing target for $^{40}Ar/^{39}Ar$ geochronology due to challenges including its small size, the silicic composition of the target rock, and the large age difference between the impact event and the target rock (~1.2 Ga). All of these factors have been known to decrease argon mobility and so yield older measured ages than the actual impact age as a result of extraneous ^{40}Ar. In an effort to refine the age of the Gow Lake impact structure, we therefore analysed impact melt rocks using the $^{40}Ar/^{39}Ar$ step-heating and UV laser *in situ* techniques.

Methods: One glassy (GL5.07), and two crystalline (GL5.15, GL2.21B) impact melt rock samples were analysed by $^{40}Ar/^{39}Ar$ step-heating and/or UV laser *in situ* analyses. Glass separates from sample GL5.07 were analysed by step-heating with a CO_2 laser and ion beams were measured on an ARGUS V noble gas mass spectrometer. Polished wafers of samples GL5.07, GL5.15, and GL2.21B were analysed by UV laser with ion beams measured on a Thermo Scientific HELIX SFT noble gas mass spectrometer.

Results: *Step-heating analyses*. 14 aliquots, each containing 15 grains of glass, and 8 aliquots each containing a single grain of glass, yielded saddle-shaped spectra. Four aliquots containing a single grain each yielded plateaus, with a weighted mean of all plateaus at ca. 238.8 Ma. Inverse-isochron analysis of the plateau steps revealed a $^{40}Ar/^{36}Ar$ intercept of 590 ± 200, which is well above the $^{40}Ar/^{36}Ar$ ratio of terrestrial atmosphere (298.56 ± 0.31, [4, 5]). Using the inverse isochron to correct the plateau ages for the high $^{40}Ar/^{36}Ar$ component yields a weighted mean age of ca. 193 Ma (±10%, analytical precision, MSWD = 2.5, p = 0, spreading factor (S) = 15%, $^{40}Ar/^{36}Ar$ intercept = 590 ± 200).

In situ analyses. 50 spots were analysed on three wafers. When all data are plotted on an isotope correlation plot, eight analyses define an inverse isochron, with an age of ca. 198 Ma (±5%, analytical precision, MSWD = 0.54, p = 0.77, S = 67%, $^{40}Ar/^{36}Ar$ intercept = 335 ± 42). Forty-one analyses plot in a loose group under the isochron, with many grouped very close to the x-axis ($^{36}Ar/^{40}Ar \approx 0$). The rejected data form a wedge shape on the isotope correlation plot and clearly define mixing between atmospheric, radiogenic and extraneous ^{40}Ar components.

The step-heating and UV laser isochron ages are indistinguishable relative to analytical uncertainty. Combining the step-heating isochron age with the UV laser *in situ* isochron age yields a weighted mean age of 197 Ma (±5%, external uncertainty).

Discussion:

Extraneous ^{40}Ar. The high $^{40}Ar/^{36}Ar$ intercept of the step-heating plateaus suggests that a significant component of extraneous ^{40}Ar was present in the samples, resulting in older measured ages. A significant component of extraneous ^{40}Ar is also suggested by the saddle-shape of most age spectra plots and the non-isochronous *in situ* data. There are two probable explanations for these data: 1) an excess ^{40}Ar component with ^{40}Ar introduced from outside the system; or 2) an inherited ^{40}Ar component from target rock/mineral clasts that were only partially degassed during impact. The older measured ages are most likely a combination of the two factors, so the complex age spectra and isotope correlation plots are the result of three-part mixing of an atmospheric component, a radiogenic component, and an extraneous component (either excess, or inherited from target rock). Using the method of [6] it is possible to calculate an inherited $^{40}Ar^*$ component of 5-23 % for the *in situ* data, and of 0-27 % for the step-heating data. It takes just 1% of inherited $^{40}Ar^*$ to produce a measured age that is beyond the uncertainty determined for the impact age. The small amount of inherited $^{40}Ar^*$ needed to produce a measured age older than the true impact age supports the conclusions of [6] that inherited $^{40}Ar^*$ is a significant problem for impact glasses from small structures, particularly where there is a large age difference between the formation of the target rock and the impact event. Therefore extra caution should be applied to interpreting ages from such materials.

The age of the Gow Lake impact structure. Given the poor precision of previous age constraints (100-250 Ma [2, 7]) a more precise and accurate age for the Gow Lake impact structure was needed. The larger variety of samples available for this study (compared to previous $^{40}Ar/^{39}Ar$ work of [3]) combined with the complementary use of both the step-heating and *in situ* approaches has produced a significantly more precise age constraint for the Gow Lake impact structure of ca. 196.8 Ma (±5%). Though it is important to acknowledge that this is still relatively imprecise compared to the goal of attaining 2% precision at 2σ [7].

The *in situ* $^{40}Ar/^{39}Ar$ results support the conclusion of [7] that impact-generated glass is the best candidate for $^{40}Ar/^{39}Ar$ dating of small to medium sized impact structures. The data show that impact-generated melt glass, even when derived from a granitic target rock, which typically yields highly viscous melts, can yield geologically meaningful $^{40}Ar/^{39}Ar$ age data. However, it is important to note that out of a large number of analyses (50) of materials presumed to be reset by the impact, only eight provided ages that were not affected by extraneous $^{40}Ar^*$. Even within a very small spatial distribution (all *in situ* analyses were conducted within ~1 cm^2) the effects of extraneous argon are highly heterogeneous, with measured ages differing by up to 200 Ma from analyses only 200 µm apart in visually similar material.

It appears that for $^{40}Ar/^{39}Ar$ age determinations of impactites it is critical to analyse as little material as possible during a single measurement in order to negate the effect of extraneous ^{40}Ar that results from an undegassed (or only partially degassed) progenitor. This study shows that progressively building on the techniques, from multi-aliquot analyses to single grain analyses to *in situ* analyses, allows for the resolution of $^{40}Ar/^{39}Ar$ ages with initial trapped components that overlap with terrestrial $^{40}Ar/^{36}Ar$ and produce a geologically meaningful age.

Conclusions: The effect of inherited argon on dating impact glass was discussed by [6], with an emphasis on inherited argon being more problematic for (1) craters with a large age difference between the impact event and the target rock; (2) relatively small impact structures that had insufficient heat to drive argon diffusive loss for long enough to entirely reset argon systematics of the target rock; and (3) impacts into silicic targets, such as granite, which produce viscous melts. Gow Lake is close to the worst-case scenario for these criteria: the age difference between the impact event and the target rock is ~1.22 Ga; the impact structure is only 5 km in diameter; and the target rock is granitic. However, despite these difficulties, the $^{40}Ar/^{39}Ar$ UV laser *in situ* approach coupled with step-heating has yielded an improved age for the Gow Lake event.

Given the lack of previous age data for Gow Lake, we suggest that this new age (ca. 197 Ma) is the most precise and accurate, and likely cannot be improved upon without using different samples (such as those with fewer clasts, or which experienced less ^{40}Ar retention during the impact event), which may not exist.

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