INVESTIGATION OF THE NOBLE GAS CONTENT OF URUGUAITE TEKTITES. L. Ferrière¹, M. M. M. Meier², H. Busemann³, C. Maden⁴, and C. Koeberl¹,². ¹Natural History Museum, Burgerring 7, A-1010 Vienna, Austria (ludovic.ferriere@univie.ac.at), ²Naturmuseum St. Gallen, Rorschacher Strasse 263, CH-9016 St. Gallen, Switzerland, ³ETH Zurich, Institute of Geochemistry and Petrology, Clausiusstrasse 25, CH-8092 Zurich, Switzerland, ⁴Department of Lithospheric Research, University of Vienna, Althanstrasse 14, A-1090 Vienna, Austria.

Introduction: Tektites are a very rare type of impact glass found on Earth in only a few distinct strewn fields, namely the Australasian, Ivory Coast, Central European, and North American fields [e.g., 1], as well as in Uruguay [2] and possibly also in Belize [3]. Tektites are distal impactites derived from the surface of the target rocks, with specific petrographic, chemical, and isotopic characteristics, as well as extremely low H₂O content due to their mode of formation, still not fully understood [e.g., 1].

In 2017, Ferrière et al. [2] first reported on a new tektite strewn field located in Uruguay. These tektites were named "uruguaites" after their place of occurrence. Based on two fieldwork campaigns, the extension of the strewn field is still not well defined; however, its largest diameter is at least 230 km. The source impact crater is currently unknown.

Some studies have shown that noble gas content of tektites can provide valuable information about their formation conditions [e.g., 4-5]. As tektites enclose gas from the Earth’s atmosphere (at their time of formation), they could be used as an archive of the evolving noble gas composition of the Earth’s atmosphere through time. Furthermore, because the concentration of the heavy noble gases (Ar, Kr, and Xe) in tektites is determined by the ambient pressure at which they solidify, the altitude at which they ended equilibration with the atmosphere can be determined (up to 40 km for other tektites [5]). The light noble gases (He and Ne) however are thought to re-enter the sample after its deposition, resulting in much higher concentrations [6,7].

Here we report the first noble gas concentrations for uruguaites and compare them with literature values from other tektite strewn fields.

Methods: Analysis was done at the noble gas laboratory at ETH Zurich. The samples were wrapped in Al foil and loaded into the sample holder of the in-house-built "Albatros" mass spectrometer. The sample chamber was evacuated to <10⁻⁹ Torr, and heated to ~80°C over two weeks to remove adsorbed atmospheric gases. Three fragments of ~1 g of distinct tektite samples (named Uru-1, -2, and -3) were then analyzed. Gases were extracted from the samples using a Mo-furnace heated by electron bombardment to 1700°C in a single heating step. Complete melting of the sample was ascertained by visual inspection at high temperature, followed by a re-extraction of the first sample at higher temperature. The released gases were then purified in an extraction line containing Ti-Fe-V getters and LN₂-cold traps.

Results and conclusions: For all three tektite samples, the measured noble gas isotope ratios (see text for definition of F(m)), for the three tektite samples measured. The shaded area shows the range for other tektites from Matsuda et al. [5]. Not shown: fractionation for ⁴He and ⁴⁰Ar.

The purified gases were then admitted into the mass spectrometer and analyzed based on a protocol similar to the one recently described by Riebe et al. [8]. We analyzed all stable isotopes of He, Ne, and Ar as well as ⁸₂,⁸₄,⁸₆Kr and ¹²₉,₁₃₁,₁₃₂,₁₃₆Xe, in two consecutive steps: 1) He and Ne, separated from the higher mass gases by freezing them out with LN₂; 2) Ar, Kr, and Xe. During the He/Ne step, we measured HD, H₂O, ⁴⁰Ar, and CO₂ to correct for potential interferences by doubly-charged and molecular ion species. During the Ar/Kr/Xe step, we monitored ³⁵,³⁷Cl for potential interference correction on ³⁶,³₈Ar, respectively. All interferences proved to be negligible (much smaller than the counting error on the main signals).

Fig. 1. Fractionation relative to ³⁶Ar and the atmosphere (see text for definition of F(m)), for the three tektite samples measured. The shaded area shows the range for other tektites from Matsuda et al. [5]. Not shown: fractionation for ³⁴He and ⁴⁰Ar.
Fig. 2. $^{36}\text{Ar}$ and $^{84}\text{Kr}$ concentrations in samples from this work (closed symbols) and from the literature (open symbols). Nearly all data points plot close to the atmospheric ratio, indicating that the original source of these gases is the atmosphere (and not the impactor). The uruguaite samples plot at the upper end of the distribution, indicating that they might have last equilibrated at a lower atmospheric height (~20 km) compared to other tektites (~20 km).

The measured $^{3}\text{He}/^{4}\text{He}$ ratio in the three samples is much higher than in air (~150 $R_{\text{a}}$). While this might suggest the presence of some primordial He (e.g., derived from the impactor?), we cannot entirely exclude at the moment that the unusually large sample masses (for the spectrometer used for our measurements) mobilized some minor residual $^{3}\text{He}$ from prior analyses in the same instrument, which would not be released in a normal hot blank (the hot blank contribution for $^{3}\text{He}$ is already on the order of 10-25% for the three samples). The Ne isotopic composition of the released gases is identical to air. The $^{36}\text{Ar}/^{38}\text{Ar}$ isotopic ratio is atmospheric, as well, but the sample gas is strongly enriched in radiogenic $^{40}\text{Ar}$ (contributing to about 90% of the total $^{40}\text{Ar}$ in the sample). The resulting K-Ar ages (based on K$_2$O concentrations of 2.93, 2.71, and 3.13 wt% for Uru-1, -2, and -3, respectively) are between 42 and 44 Ma. The isotopic compositions of Kr and Xe are also compatible with the atmospheric ones.

While tektites characteristically have low concentrations of volatiles (especially water), their noble gas contents depend on the noble gas solubility in the silicate liquids from which the tektites solidified. Unlike the case for water, this solubility actually increases with increasing temperature [9]. However, the concentrations of heavy noble gases (Ar, Kr, and Xe) in tektites, including uruguaites, are lower than the theoretical equilibrium solubilities of these gases at 1 bar external pressure. The simplest explanation for this observation, compatible with all experimental work (see [5]), is that the pressure of the atmosphere at the point of last equilibration was <1 bar, i.e., the tektite solidified (or at least cooled to the point where further exchange of the heavy noble gases with the atmosphere stopped) while still high up in the air. Following [5] and using Henry’s law, empirically determined proportionality constants [10], an atmospheric scale height of 8.4 km, and the measured $^{36}\text{Ar}$ concentration, we can estimate that the point of last equilibration with the atmosphere took place at a height of ~3, ~16, and ~22 km above sea-level for samples Uru-1, -2, and -3, respectively (Fig. 2). Note that if full equilibrium with the ambient atmosphere was not reached, these altitudes are lower limits. These altitudes are much lower than observed for other tektites, where altitudes of up to 40 km have been calculated [5]. Kr and Xe concentrations in the samples are higher than for other tektites (Fig. 2), thus, the implied altitudes of last equilibration with the atmosphere from these gases are lower than for Ar, which might either be due to some atmospheric gases adsorbing onto fresh sample surfaces during sample preparation, or perhaps due to equilibration ending at a different point in time for Ar vs. Kr and Xe.

We plan the analysis of additional uruguaite samples, as well as further laboratory experiments, to better understand these processes.

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