

Comparison of Australasian tektites with BeLaU-type spherules recovered from the Pacific Ocean Site of the CNEOS 2014 January 8 (IM1) Bolide

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Abstract

An expedition was set out to retrieve remnants of bolide CNEOS 2014 January 8 (IM1), inferred to be interstellar in origin. A fraction of the samples retrieved from the expedition was classified into “D-type” spherules/particles, inferred to be from source material that had undergone planetary differentiation. A subset of the D-type spherules/particles were called “BeLaU”-spherules after their highly enriched incompatible element composition, including Be, La and U, and complete elemental pattern, which did not match that of any well-studied solar system material. Among the various candidate materials, it has been suggested that the BeLaU-signature is related to the Australasian tektite strewn field (Desch 2024a,b; 2025). We therefore report precise elemental data for Australasian tektites to test this hypothesis. Our finding is that the Australasian tektites closely resemble the elemental abundance patterns of the upper continental crust for all the elements analyzed and are demonstrated to be dissimilar to BeLaU.

1. Introduction

An event consisting of three atmospheric detonations was detected by US government satellite sensors 84 km north of Manus Island in January of 2004. One analysis of the event suggested the atmospheric entry of a bolide of interstellar origin, named CNEOS 2014 January 8 (IM1), due to its arrival velocity of more than 45 km/s (Siraj and Loeb, 2022), spurring an expedition to retrieve remnants of the bolide (Loeb et al., 2024). Among the various objects retrieved were over 800 particles that were 0.05–1.3 mm in diameter. The majority (~80%) of these materials consisted of cosmic spherules, categorized into “S-type,” “I-type” and “G-type” spherules of undifferentiated composition and chondritic origins. A fraction of the materials that did not fit into the three archetypal categories were further classified as “D-type” spherules or particles, named after their highly differentiated compositions in comparison to chondrites, characterized by their low Mg/(Mg+Fe) contents. A small subset of the D-type particles was further subcategorized and named “BeLaU,” after their unusual elemental patterns exhibited in particularly high abundances in highly incompatible elements such as Be, La, and U compared to most known terrestrial materials with high abundances in incompatible elements, such as the continental crust. The “BeLaU” composition was proposed to yet be of unknown origin (Loeb et al., 2024).

Desch (2024a,b; 2025) suggested the BeLaU spherules are part of the Australasian tektite strewn field and are microtektites of lateritic soil. Tektites are melt droplets solidified from melt or condensed from vapor due to meteoritic impacts and are characterized as glassy silicate objects

that are round, oblong, flanged-button, dumbbell, or tear-dropped in shape, and black in color. Tektites have in general been established to originate from impacts onto areas with close to average upper continental crust in composition (Mizera et al., 2016 and references therein). Only minor or no traces of the impactor are found in the tektites. Tektites that are less than 1 mm in diameter are referred to as “microtektites” or “microkrystites” depending on the absence or presence of microlites, respectively (e.g., Glass and Simonson, 2012). Among the various types of tektites, Australasian tektites and microtektites are a viable candidate for the BeLaU composition due to the proximity of the sample retrieval expedition site to the extent of the strewn field identified thus far for the Australasian tektites. This field covers parts of China, Indonesia, the Pacific Ocean, the Indian Ocean, Australia, and Antarctica (e.g., Di Vincenzo et al., 2021). The sampling site is also in proximity to the putative impact site for the Australasian tektites, widely suggested to be in Indochina (Mizera et al., 2016; Sieh et al., 2020). To resolve this issue, we report new and precise elemental abundances of Australasian tektites and compare them to the “BeLaU” compositions retrieved from the IM1 site.

2. Samples and analytical methods

Four Australasian tektites were chosen for analysis. The tektite samples each originated from Florieton, South Australia and Charlotte Waters, Northern Territory of Australia and two other unspecified origins within Australia. The samples were characterized to be glassy, homogenous, and dark brown or black and oblong or rounded in shape. About 50–100 mg of each specimen was broken and finely crushed with a sapphire mortar and pestle and dissolved in a mixture of concentrated acids consisting of HF-HNO₃ as a first step, followed by a dry down and dissolution in a 1:4 mixture of water and aqua regia and dried down once more, to finally be dissolved in 1.5 M HCl. A small aliquot was sampled from each of the dissolutions to be measured for their elemental abundances using an iCAP TQ triple quadrupole ICP-MS (ThermoFisher Scientific), using 10 ppb In-spiked 2% HNO₃ solutions to correct for instrumental drift.

3. Results and Discussion

The elemental abundances of the four tektites, and average upper continental crust (UCC) are plotted in the order of most incompatible to least compatible elements for 41 elements (elements that have well-defined positions in the compatibility series) and are normalized with respect to the primitive mantle (PM) composition of McDonough and Sun, (1995) in **Figure 1a**. The same four tektite data normalized to the UCC is shown in **Figure 1b**, but in this case the elements (55 elements) are ordered according to increasing atomic number. The BeLaU composition and the average tektite composition are also plotted in this figure for direct comparison. Finally, the averaged BeLaU composition is normalized with respect to the average of the four Australasian tektites measured in this study in **Figure 1c**, in this case also according to atomic number (again 55 elements).

The elemental abundances of the tektites are all very similar with respect to one another (**Figure 1a**), exhibiting enrichment in the highly incompatible elements, and depletion towards more compatible elements in comparison to the PM. The patterns are also similar with respect to the UCC, closely resembling the abundances and depletions in PM-normalized elemental abundances.

In comparison to the UCC, the tektites are depleted in Na and P and exhibit variability in Ca among the specimens.

Variabilities in elemental abundances among the tektites are more apparent in the UCC normalized patterns in **Figure 1b**, where variations in Cd and Sb abundances among the tektite samples are apparent. The UCC normalized plot corroborates previous studies that tektites are generally composed of terrestrial sediments derived from the continental crust (e.g., [Glass et al., 2004](#)). The tektite compositions approach near-unity in terms of the REEs, with flat, but slightly elevated UCC normalized REE patterns in comparison. In addition to Na and P, depletions are apparent for elements such as Cu, Zn, As, Mo, Sb, Tl, Pb, and Bi. Depletions in Tl, Pb, and Bi have been observed for Australasian tektites ([Taylor and McLennan, 1979](#)), interpreted to be due to volatile loss during impact. In the case of Mo, BeLaU and the Australasian tektites exhibit opposite normalized enrichment patterns, with the former enriched, and the latter depleted.

The average BeLaU composition is plotted alongside the tektites in **Figure 1b**. In comparison to the tektites, UCC normalized patterns indicate enrichment in heavy REE compared to the continental crust. While concentrations of Be and U of the BeLaU composition exhibit enrichment compared to the UCC, those of tektites are more similar to the UCC. The strong enrichment in Mo that is present in average BeLaU is also contrasted by their depletion in the Australasian tektites. A direct comparison of the elemental abundances of the tektites and BeLaU (**Figure 1c**) where BeLaU is normalized to the Australasian tektite composition, demonstrate that Australasian tektites are unlikely candidate material for BeLaU.

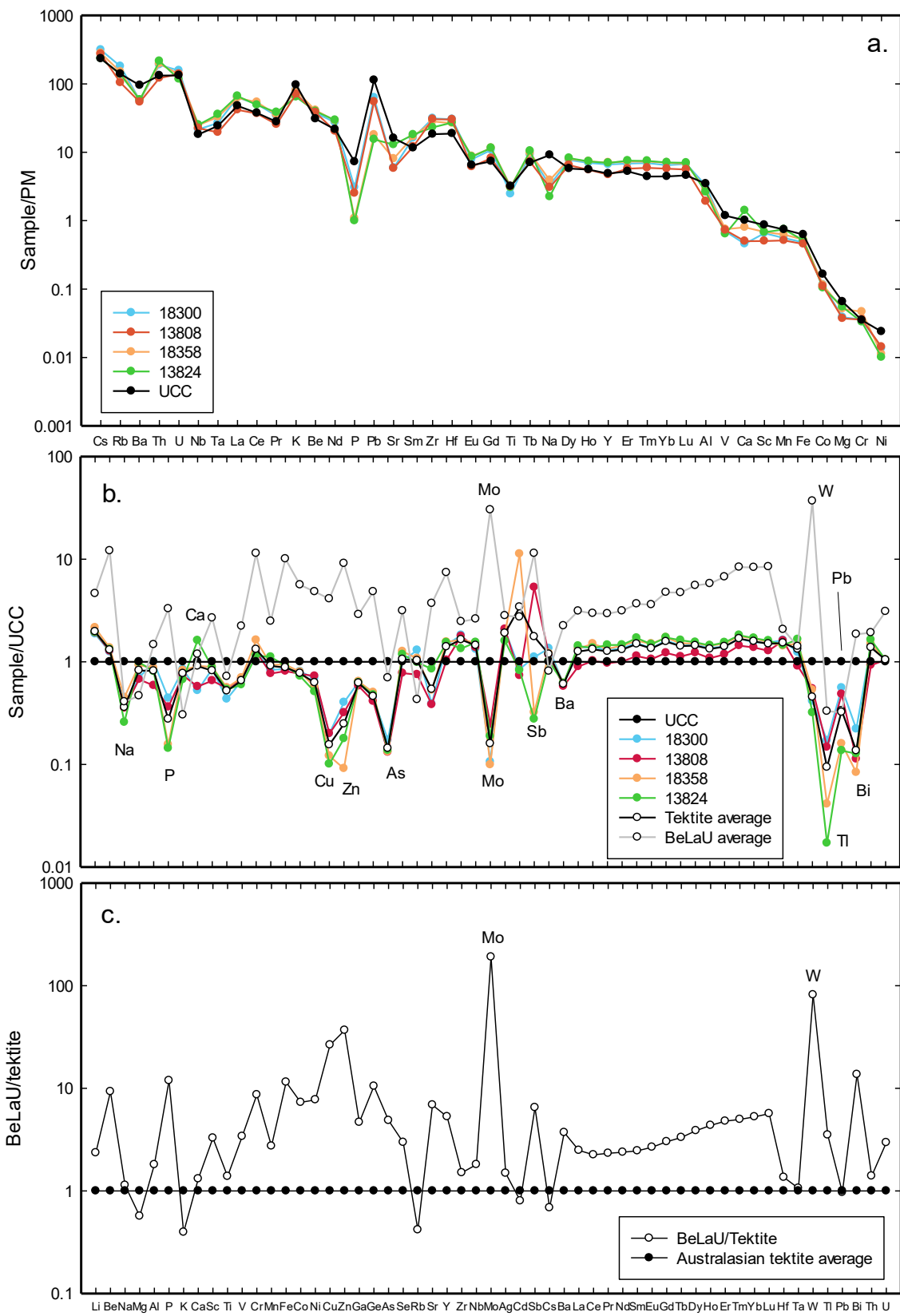


Figure 1. Panel (a) Primitive mantle normalized (using [McDonough and Sun 1995](#) values) elemental compositions of Australasian tektites compared to the UCC ([Rudnick and Gao, 2014](#)), arranged in order of most incompatible to most compatible elements. Panel (b): The UCC normalized elemental patterns of the individual tektites (red, green, blue, and orange) and the average of the four specimens (white symbols, black line). The number “1” represents the UCC (dark symbols), plotted alongside the average BeLaU abundance pattern (white symbols, grey line) normalized with respect to the UCC. Panel (c): Australasian tektite normalized elemental compositions of BeLaU (white symbols). Here, the number “1” (dark symbols) represents the average of the Australasian tektites measured in this study.

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