METEORIC BE-10 OF COSMOGENIC ORIGIN IN TEKTITE-LIKE GLASSES FROM BELIZE.

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Summary: Koeberl et al. [1,2] proposed that tektite-like glasses from western Belize, Central America, are of impact origin [1,2]. We measured an average ^{10}Be content of $12 \pm 5 \times 10^6$ atom/g for seven tektite-like glasses from Belize. This value is about 8 times lower than the average of $(100 \pm 36) \times 10^6$ atom/g [3] for coeval Australasian tektites, a difference that supports other data indicating that the two groups of glasses had different sources.

Introduction: Tektites are a sub-group of impact glasses. They are typically less than a few centimeters in size; have geochemical signatures resembling that of the upper continental terrestrial crust; and are widely interpreted as melts of surficial crustal material ejected by extraterrestrial impactors [e.g., 4]. Almost every tektite comes from one of four strewn-fields: the 35.5-Ma old North-American; the 14.84-Ma old Central European; the 1.1-Ma-old Ivory Coast, or the enormous, 0.8-Ma-old Australasian one. Recently, several possible tektites were found in Uruguay [5], well outside the current 'boundaries' of the four main strewn fields. Moreover, during the last two decades, at least 80 glasses with strong tektite affinities were reported from western Belize [6]. Below we will refer to these objects as Tektite-Like Glasses (TLG)

An impact origin for the Belize TLG is supported by their low water content of ~80 ppm [7], their petrography [1], and the size of the collection area, now 6400 km^2 [8]. A few samples have been dated by the ^{40}Ar-^{39}Ar method, yielding total fusion ages of 820±40 ka (2σ) [9], or, in one case, an isochron age 755±18 ka [10]. Although these ages are statistically indistinguishable from those of Australasian tektites, 785±8 ka, the distinct SiO_2 contents [6,7] and Sr and Nd isotopic compositions [2] of the two sets of glasses are most simply if not definitively explained by two separate impact events.

The cosmogenic radionuclide ^{10}Be ($t_{1/2}$ = 1.387 Ma) has been measured in tektites from Australasia [3], the Ivory Coast, and Central Europe [10]. The results suggest that these tektites derive from material bearing ^{10}Be that was produced in the Earth's atmosphere, transported by rainwater, and then adsorbed by relatively fine-grained silicate particles that resided within a few meters of the surface of the target area [e.g., 5,11]). Formation and ejection probably took place prior to the main crater excavation phase [e.g., 4].

In principle, tektites may also contain extraterrestrial ^{10}Be from the impactor. In contrast to many proximal (in-crater) impact glasses, however, tektites contain very low amounts of meteoritic material. Specifically, a detailed platinum-group element (PGE) and Re-Os isotope study of Belize glass samples [12] showed no distinct meteoritic component. Interestingly, both Os concentrations and Os isotope ratios are significantly lower than values typical of the terrestrial upper continental crust. The Os signature of the Belize TLG may reflect the primary influence of the terrestrial precursor material (most likely volcanoes of the Central American arc), rather than of an extraterrestrial one [12].

We set out to analyze the ^{10}Be concentrations of several Belize TLG. A main purpose of the work was to test the hypothesis that like tektites, the Belize TLG contain primarily meteoric ^{10}Be and formed from loosely consolidated surface material.

Samples and Methods: Fragments of seven samples with original total masses of a few grams were taken for analysis. Although the Belize TLG may assume irregular forms [6], all the specimens studied had shapes similar to those of normal splash-form tektites. From each one, we took chips and, in some cases, powder weighing ~200 mg in total. After the addition of ~3 mg of ^{9}Be carrier, the samples were dissolved in a mixture of HNO_3, HF, and $HClO_4$. Beryllium was isolated as an oxide as described by [10].

Table 1. Average ^{10}Be contents (10^6 atom/g) of tektite-like glasses from Belize (this work) and of Australasian tektites [3].

Source	^{10}Be
Belize	12±5
Australasian	
Laos	59±9
Thailand	71±17
Vietnam	73±13
China	85±24
Indonesia	115±27
Philippines	121±22
Australia	136±30

The ^{10}Be/^{9}Be ratios (atom/atom) of the samples were measured by accelerator mass spectrometry at Purdue University's PRIME Lab. Three procedural blanks had an average

$^{10}Be/^{9}Be$ ratio of 2.4×10^{-15}. The $^{10}Be/^{9}Be$ ratios measured for the samples, $\sim 13 \times 10^{-15}$, were about five times larger than the average blank value.

Results and Discussion: The ^{10}Be concentrations of the samples ranged from 7×10^6 to 21×10^6 atom/g with an average of $(12 \pm 5) \times 10^6$ atom/g, which, when corrected for a $^{40}Ar/^{39}Ar$ age of 755 ka corresponds to $(17 \pm 7) \times 10^6$ atom/g.

The average ^{10}Be content of the Belize TLG is about 8× lower than the average of 100×10^6 atom/g measured for 100 Australasian tektites [3]. While some subgroups of the Australasian tektites have considerably lower ^{10}Be concentrations than the average (Table 1), these subgroups occur in Southeast Asia, i.e., in the geographic area where many workers suspect their source crater to be. As distance from this area to the recovery location increases, the ^{10}Be concentrations tend to increase, a generalization that is difficult to reconcile with the ^{10}Be results for the Belize TLG. We conclude, that the first-order comparison of ^{10}Be concentrations argues for separate origins for the Australasian tektites and the Belize TLG.

In situ production does not appear to be a major contributor to the ^{10}Be inventory in Belize TLG. At the latitude, 17°N, and mean elevation, 173 m, of Belize, the production rate at the very surface is estimated to be ~2 atom $^{10}Be\ g^{-1}\ a^{-1}$. After a few million years, a theoretical *maximum* ^{10}Be concentration of $\sim 4 \times 10^6$ atom/g could be produced, but in this improbable scenario (1) the period of irradiation must have bracketed the time of the glass-forming event; and (2) the source material must have remained close to the surface throughout while avoiding losses due to erosion. We believe that the $^{40}Ar/^{39}Ar$ age (~0.8 Ma) of the Belize TLG sets a more realistic upper bound on the duration of irradiation, which translates to a ^{10}Be concentration of $\sim 1 \times 10^6$ atom/g, or, at most, about 1/6 of the observed values. Measurements of ^{36}Cl could help refine this conclusion.

As noted, an extraterrestrial source for the ^{10}Be in Belize TLG is excluded based on other geochemical measurements.

Just as in Australasian tektites, so too in the Belize TLG the measured concentrations of ^{10}Be point strongly to a meteoric origin for the isotope. A complete analogy between the two sets of glasses would require that both formed from impacts into loosely consolidated target material. By themselves, however, the ^{10}Be concentrations of the Belize TLG do *not* require such material at the time of impact. Volcanic rocks collected in Middle America contain from 0.6×10^6 to $14.5\ 6 \times 10^6$ atom $^{10}Be/g$, from subducted oceanic sediment [13]. The authors of [13] argued against *in situ* production of ^{10}Be on the basis of constant $^{10}Be/^{9}Be$ ratios in mineral separates and against assimilation of soils, although with less certainty, on the basis of low ^{10}Be determinations in geographic regions where assimilation might have been expected. For our purposes, the key point is that the Belize TLG could have been derived from rock formations large enough to screen out local rain water, ground water, and cosmic rays.

Even so, we are not inclined to set much stock in this possibility. The limited ranges of ^{10}Be concentrations in both Australasian tektites and Belize TLG – a factor of two or three perhaps - seem incompatible with the larger ranges likely to result from sampling by impact large volumes of intact rock.

Conclusions: The isotopic investigations performed so far (Sr-Nd [2] and Os) provide no confirmation of an impact origin of the tektite-like glasses from Belize, but indicate a source different from that of the Australasian tektites. Both isotope data sets for the Belize TLG indicate a close relationship to local arc lavas, supporting the claim [1] that the glasses were not transported far from their source (e.g., volcano or impact crater). The primary evidence for the impact origin of these glasses rests, therefore, on the petrographic characteristics and the low water content [e.g., 1, 7]. The evidence from ^{10}Be is consistent with but does not require, a model of formation for the Belize TLG by an impact on loosely consolidated surface sediments exposed to rain.

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