

TEKTITE GLASS FROM THE CRETACEOUS-TERTIARY BOUNDARY IN HAITI;

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The global event which marks the Cretaceous-Tertiary (K/T) boundary has left a striking signature of world-wide mass extinctions of marine biota and a pronounced geochemical anomaly in the sedimentary record. Hypotheses put forward to account for these phenomena include (i) the impact of a large asteroid on the Earth¹, and (ii) a pulse of severe volcanism^{2,3}. However, because of poor preservation of K/T boundary sediments, neither volcanic nor impact-derived glassy materials, such as glassy tephra or tektite glasses, have hitherto been found to provide unambiguous evidence of the nature of the catastrophic event or the chemical composition of the source region. We present the first chemical data on very well preserved glass particles from the marine K/T boundary at Beloc, Haiti, where the boundary deposit forms a 10 to 50 cm thick layer containing glass particles up to 6 mm in diameter. The large size of the spherules and their occurrence in a relatively thick layer may be an indication of the close proximity of this outcrop to the source region. These Haiti glasses are among the earliest preserved glasses on Earth and the oldest known tektites. The glasses display a linear compositional trend, which can be attributed to mixing of two impact melts derived from a heterogeneous source region. The most common glasses resemble australite tektites in composition and are broadly granodioritic or andesitic in composition, whereas rare high-Ca glasses are attributed to melting of marl, accompanied by catastrophic CO₂ release to the atmosphere. These results are consistent with an impact on a continental shelf region, overlain by carbonate-rich sediment.

The glass-bearing rock is pale brown to buff in colour, containing abundant glassy particles in a silty marl. The glass particles are generally spherical in shape, although ellipsoidal, elongated, tear-drop and bar-bell shaped forms are also present. They have a very smooth outer shell and vesicle infillings of light grey to brownish smectite of variable thickness (<0.5 mm). Beneath the smectite shell, the exposed glass surface has fine ridges and furrows, probably produced by solution etching after deposition and during the alteration process from glass to smectite. About 2% of the glasses are amber to yellowish in colour. The spherules are entirely crystal-free, but may contain 0.05 to 0.2 mm diameter vesicles. In some spherules the vesicles are very rare (<5 vol %), while the yellow glasses have up to 30% vesicularity. In their lack of crystalline inclusions, the Beloc glasses resemble tektites but not volcanic glasses. The black glass contains about 66 to 68% SiO₂, is enriched in alkalis and slightly alumina-enriched. The rare amber to yellowish glass is enriched in Ca (30 wt. %), FeO, and MgO, but relatively depleted in SiO₂ (44 %). This high-Ca glass occurs as isolated fragments and as streaks in some black glassy spherules.

Silicate liquid compositional trends such as those exhibited by the Beloc glasses could result from fractional crystallization of magma, magma mixing, vaporization fractionation of an impact melt at superliquidus temperatures, or the mixing of impact melts derived from a heterogeneous source. The first two causes are excluded on the basis of the total absence of crystals from the glasses, the difference between typical magmatic compositional trends and those of the Beloc glasses, and the very high CaO content (up to 30.7 wt.%) observed in the Beloc glass low-silica endmember. Furthermore, the relative order of enrichment of oxides other than CaO is inconsistent with that predicted for a vaporization fractionation process. The glass range can, however, be modeled as a mixing line between two endmember compositions with the most calcic endmember resembling a CO₂-depleted marl in composition and the silicic glasses derived from the complete melting of upper continental crust of broadly granitic composition. A granitic source is also consistent with the shocked mineral assemblage found in the impact layer at the

K/T boundary⁴. The compositional characteristics of these glasses are broadly consistent with the lithologies of the proposed K/T boundary impact structures at both Manson, Iowa^{5,6} and the Yucatan peninsula in Mexico⁷.

The suggestion has been made that the Western U.S. K/T boundary claystone is the product of alteration from glass⁸. If the Beloc tektites are the precursor to the 1 to 2 cm thick claystone band observed in K/T boundary marine and continental sediments, then the composition of the Haiti glasses can provide clues to the relative mass of impact ejecta and the nature of the volatile fraction released to the atmosphere. The total glass fraction of the Beloc layer is a minimum of 0.5 g/cm³, and the yellow glass is about 2%, or 10 mg/cm³. If we adopt 1 cm mean thickness of the claystone layer globally as a conservative estimate⁵, the total glass fallout, based on the 500 mg/cm³ mass fraction in the Beloc sediment, is 2.5×10^{15} kg globally, corresponding to about 1000 km³ of rock. This estimate is at the lower end of the range estimated for a bolide mass of 0.6×10^{15} kg¹ (10^3 to 4×10^4 km³)⁹. The yellow glass component of the global fallout layer is estimated as 5×10^{13} kg (20 km³ rock) on basis of its abundance in the Beloc section, on a CO₂-free basis. In keeping with our marl hypothesis, the CO₂ liberated to the atmosphere from the proposed marl at the time of impact would constitute an additional 4.6 km³. This suggests that about 8×10^{14} moles CO₂ were emitted to the atmosphere at the time of the impact, or double the current annual anthropogenic production rate.

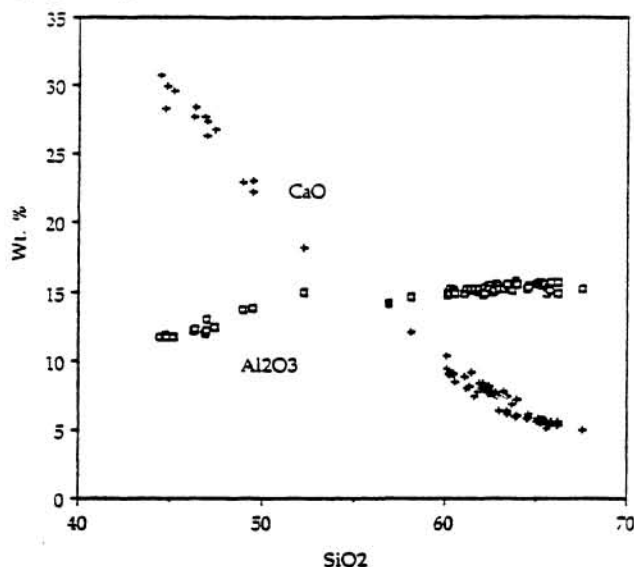


Figure 1: An oxide variation diagram for Beloc glasses. Shown for comparison are the compositions of H/NaK Australite tektite glass (black square)¹⁰ and average whole-rock Earth andesite composition (black triangle)¹¹.

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