

MICROTEKTITES AS VAPOR CONDENSATES, AND A POSSIBLE NEW STREWN FIELD AT 5 Ma.

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Introduction: Tektites are predominantly found in several large strewn fields. Tektites found in Texas, Georgia, and throughout many ocean drilling cores make up the North American strewn field, which formed 35.5 million years ago [1], probably created by the Chesapeake Bay crater [2]. Tektites referred to as moldavites are found in Central Europe and date to 14.7 million years ago [3], and tektites dated to 1.07 Ma are found in the Ivory Coast [4], created by the Bosumtwi impact. The strewn field with the widest variety of tektite types is the Australasian strewn field, dated to 770,000 years [5]. New fields are being discovered, including glasses dating from the Pleistocene and Miocene in Argentina [6, 7], and clinopyroxene-bearing spherules found in the Atlantic, Pacific, and Indian oceans that are traced to the 100-km diameter Popigai impact structure in Siberia [8, 9].

Recently about fifty bottle-green microtektites were found in a 20 cc sediment sample recovered from ODP Site 1169A, Leg 189. Incomplete core recovery and discontinuous sedimentation has hindered age determination, but preliminary biostratigraphic evidence suggests an age of 5 Ma, and thus these tektites are not a part of any currently recognized strewn field, and also not correlated with any significant extinction event. The Australasian strewn field is not represented in any of the nearby cores. We have analyzed four of these new microtektites using the MIT JEOL Superprobe calibrated to anhydrous glasses, and on the Boston University laser ablation ICP-MS system for trace elements.

Analytical results: These tektites contain high amounts of alumina and very low sodium and potassium compared to volcanic analogs. These are the hallmarks of tektites, and distinct from volcanic glasses. The tektites from this study lie at the edge of the compositional range of the Australites for all major elements except CaO, in which they are enriched when compared to the Australites. No crystallites, lechatelierite, or other phase inhomogeneities were present. The tektites' outer surfaces are smooth and exhibit no cupping or other evidence of exsolution.

The oxides measured in all analyses taken totaled between 98.7 and 101.2, indicating little or no water content. There is no systematic change in glass analysis totals from rim to core, indicating that if there is a small water content it is not related to seawater contamination or to dehydration during flight. Though there is no systematic change in analysis total from rim to core, there is a measurable change in individual oxide composition from rim to core. See Figure 1.

SiO₂, Na₂O, and K₂O are enriched toward the rim of the tektites, and Al₂O₃, FeO, CaO, and TiO₂ are enriched toward the core.

The REE patterns of these tektites are similar to the patterns found in North American and Siberian tektites, but entirely dissimilar to the Australasian, Moldavite, and Ivory Coast tektites, which all show significant enrichment in Sm and Eu in comparison to their nearest neighbors Nd and Tb. From the dissimilarity of REE profiles, we suggest that these tektites are not from the Australasian strewn field.

Condensation hypothesis: There are several mechanisms that could cause radial compositional depletion or enrichment in the tektites. The three most likely mechanisms are (1) volatile depletion from a hot liquid tektite in flight; (2) migration of oxides within the liquid tektite by Soret diffusion; and (3) radial composition built up by condensation of the tektite from a vapor phase. The first mechanism, volatile loss, can be ruled out immediately. Volatile loss from the edge of the tektite would create a pattern opposite to what is observed. Silica, sodium, and potassium are all volatile elements and should be preferentially depleted near the core, and not enriched, as is seen; alumina and calcium are refractory elements and should be enriched near the rim, not depleted as is seen. The results that would have been expected from Soret diffusion roughly match what is seen in the tektites, but we will demonstrate that in tektites this small there cannot be enough hydrodynamic heating to create significant Soret diffusion. Therefore, we hypothesize that the compositional gradients were caused by condensation from a vapor phase.

Condensation from a vapor: Traditionally tektites have been referred to as "splash form" or "layered". Splash-form tektites display shapes associated with rotating fluids: spheres, teardrops, peanuts, ovoids, and tori. That the shapes of splash-form tektites correspond to bodies of revolution does not necessarily imply that the tektites were splashed off the ground in fluid form. In a large meteorite impact, the shock wave preceding the meteorite smashes into the Earth first, creating compressive and frictional heating that raises the temperature of the target and the meteorite to temperatures on the order of 10,000 degrees C. Using the scaling laws of Housen, Schmidt, and Holsapple (1983) [10], the plume of vapor that rises instantaneously as a result of this superheated impact has its highest velocity in the center of the impact, and the velocity of the plume drops off exponentially with radius from the impact center. We therefore have a

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superheated vapor plume of homogeneous composition, identical to the target rock (the impactor contributes very little to the large mass of ejecta), rising upward in a tight column with a maximum velocity comparable to the impactor's velocity, that is, between 10 and 40 km/sec. Simultaneously, at the edges of the impact, some target material has been melted but not vaporized, and ejected as a liquid from the crater. This melted material makes up larger tektites, both true splash-forms and layered tektites. The vapor plume spreads and cools, eventually cooling below the condensation temperature of the oxides it contains. There are several sources available in the literature for condensation temperatures of oxides [11, 12, 13, 14, 15, 16]. The larger the plume, the more slowly it will cool. In a large plume, the edges will be cooling and condensing droplets with higher volatile content than will the middle of the plume, which will remain hotter for a longer time. The more slowly a plume cools, the wider the compositional range of the condensate droplets it will produce. In a plume that cools rapidly, on the other hand, the temperature in the plume will drop below the condensation temperature of the more volatile oxides more quickly, and the condensate drops will not have as wide a range of compositions. Therefore the range in compositions of refractory oxides in microtektites for a particular impact event is proportional to the size of the impact. See Figure 2. These normalized oxide ranges make a reasonable proxy for crater size for the four strewn fields with known crater size. By using the normalized ranges of oxide concentration as a proxy for crater size, the crater size for the Australasian strewn field can be estimated at between 40 and 60 km in diameter. This is within the range estimated by Glass and Pizzuto (1994) [17], 30 to 100 km in diameter.

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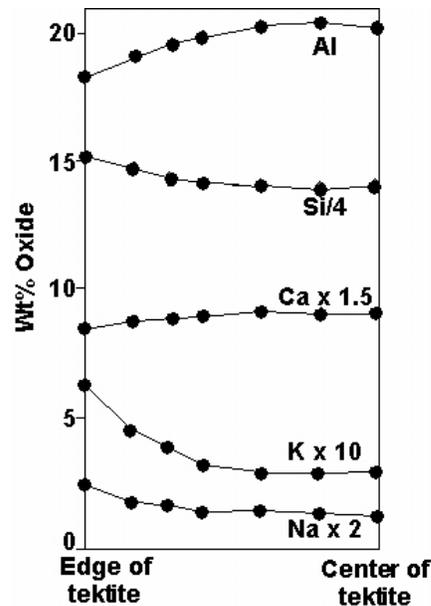


Figure 1. Radial composition profiles for major elements in the new bottle-green microtektites.

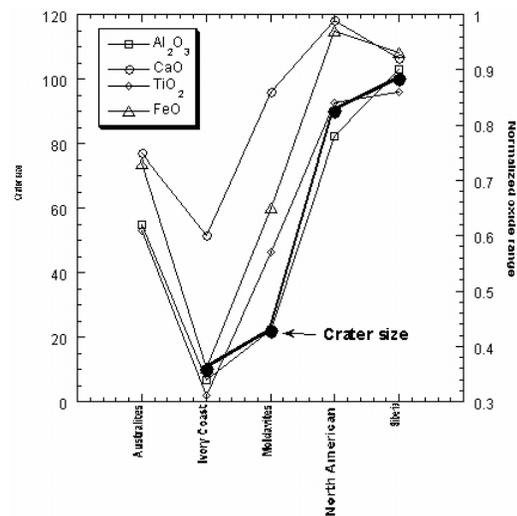


Figure 2. The ranges of oxide compositions for five tektite strewn fields are shown. In each case the range of oxide content for all the data from each strewn field is normalized by the maximum oxide content for that field. The normalized ranges of the oxides are proportional to the sizes of the craters that created the strewn fields.