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Coeval ages of Australasian, Central American and Western Canadian tektites reveal multiple impacts 790 ka ago

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Abstract

High resolution ^{40}Ar–^{39}Ar step heating dating of australites and indochinites, representing a large area of the Australasian strewn field, and more recently discovered tektite-like glasses from Central America (Belize) and Western Canada, were carried out. Precise plateau ages were obtained in all cases, yielding indistinguishable ages of 789 ± 9 ka for four australites, 783 ± 5 ka for four indochinites, 783 ± 17 ka for one Western Canadian and 769 ± 16 ka for one Belize impact glass. Concerning major elements and REEs, australites and the Western Canadian impact glass are indistinguishable. If the Western Canadian sample was transported by impact ejection and belongs to the Australasian strewn field, this implies extremely far ballistic transport of 9000 km distance, assuming a source crater in southern Asia. The distinct major element and REE composition of the Belize impact glass suggests formation in another separate impact event. We conclude that the Australasian/Western Canadian impact glasses formed 785 ± 7 ka ago in a single event and Belize impact glass in a separate event 769 ± 16 ka ago. The two impact events forming these two strewn fields occurred remarkably closely related in time, i.e., separated by <30 ka.

1. INTRODUCTION

Cosmic collisions are major events shaping the surfaces of solid bodies in the Solar System. About 180 impact craters have been identified on Earth, but the vast majority of impact structures were lost due to tectonic activity, erosion and weathering. Tektites are natural impact glasses occurring in strewn fields. Three of these strewn fields are associated with large impact craters: North American tektites with the 85 km Chesapeake Bay crater (USA), Ivory Coast tektites with the 10.5 km Bosumtwi crater (Ghana) and Central European tektites with the 24 km Ries crater (Germany). By far the largest strewn field comprises tektites in Australia, Asia, and Antarctica covering about 20% of the Earth's surface, a field for which the source crater has not yet been found.

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Tektites can be distinguished not only geographically, but also by isotopic and trace element signatures. Within each strewn field, tektites show some regional compositional variations as, for example, in the australite or indochinite subgroups of the Australasian strewn field (e.g., Zähringer, 1963; Chapman, 1964; Chapman and Schreiber, 1969; O'Keefe, 1976; Shaw and Wasserburg, 1982; Glass, 1990; Koeberl, 1990; Glass and Koeberl, 2006). Tektites formed by hypervelocity impacts represent primary ejecta of sedimentary target materials (e.g., Koeberl, 1994; Glass and Simonson, 2013). Their origin from upper crustal material is suggested from isotope (e.g., Sr, Nd) and trace element geochemical data (e.g., Shaw and Wasserburg, 1982; Koeberl, 1990), as well as high contents of the cosmogenic isotope Be-10 from atmospheric fallout (e.g., Ma et al., 2004; Serefiddin et al., 2007).

Tektite formation from a terrestrial impact was suggested by Cohen (1961) and the idea was later supported by their chemical composition, which is identical to that of continental crust, and by the distinct terrestrial Ar isotopic composition in their vesicles (Zähringer, 1963; Jessberger and Gentner, 1972). The association of tektites with specific impacts was confirmed by the agreement of radiochronometric ages of tektites and nearby craters, e.g., the Ries impact crater glasses and the moldavites (e.g., Gentner et al., 1963; Jessberger et al., 1978; Staudacher et al., 1982; Schwarz and Lippolt, 2002, 2014; Laurenzi et al., 2003; Di Vincenzo and Skála, 2009; Buchner et al., 2010, 2013). The genetic link between the Lake Bosumtwi impact crater and Ivory Coast tektites is also firmly established, from geochronology as well as isotope geochemistry (e.g., Schnetzler et al., 1966; Shaw and Wasserburg, 1982; Koeberl, 1990; Koeberl et al., 1997). For North American tektites, the Chesapeake Bay structure is the likely source crater (e.g., Poag et al., 1994; Koeberl et al., 1996).

Concerning the Australasian tektite strewn field, the situation is different: Despite the fact that 188 impact structures have been identified so far (Earth Impact Database, 2015), for the Australasian strewn field, which is the largest and youngest among the four major strewn fields, a source crater has not been found, although a location of the impact crater in northern Vietnam or off the coast in the Gulf of Tonkin has been proposed (e.g., Glass and Koeberl, 2006; Glass and Simonson, 2013).

The Australasian tektite strewn field contains several different subfields and thus tektite types: (I) simple normal or splash-form tektites, also the main type found in other strewn fields (II) aerodynamically shaped tektites ("button-flanged") (III) Muong Nong-type tektites with an irregular blocky and layered structure, and (IV) microtektites from deep sea drilling cores (also known from Ivory Coast and North American strewn fields). Muong Nong-type tektites can be exceptionally large, up to 25 cm in size, have a higher volatile element (e.g., Cl, Br, Zn) and slightly higher water content when compared to normal splash-form tektites and are chemically heterogeneous (Koeberl, 1992). Unlike the aerodynamically shaped australites, which were ejected from the atmosphere and developed flanges upon atmospheric re-entry, Muong Nong-type tektites cannot have travelled far from the site where they were produced. For Australasian tektites, a single source crater of possibly about 50 km diameter in Indochina – in a region extending from southern China through northern Vietnam into the Gulf of Tonkin – was inferred from the distribution of microtektites in deep sea cores (Glass and Koeberl, 2006). Further deep sea core studies (e.g., Lee and Wei, 2000; Prasad et al., 2003) showed that the strategraphic ages of Australasian microtektites agree with total fusion $^{40}Ar/^{39}Ar$ ages of about 0.7–0.8 Ma (Izett and Obradovich (1992). Microtektites, including finds in Antarctica (Folco et al., 2011) at a distance of about 11,000 km distance from the presumed source crater, define the extent of the Australasian strewn field to about >20% of the Earth's surface.

A "Gaussian" histogram of age data of Australasian tektites measured with total fusion methods is shown in Fig. 1. The K–Ar age data of Zähringer (1963) and

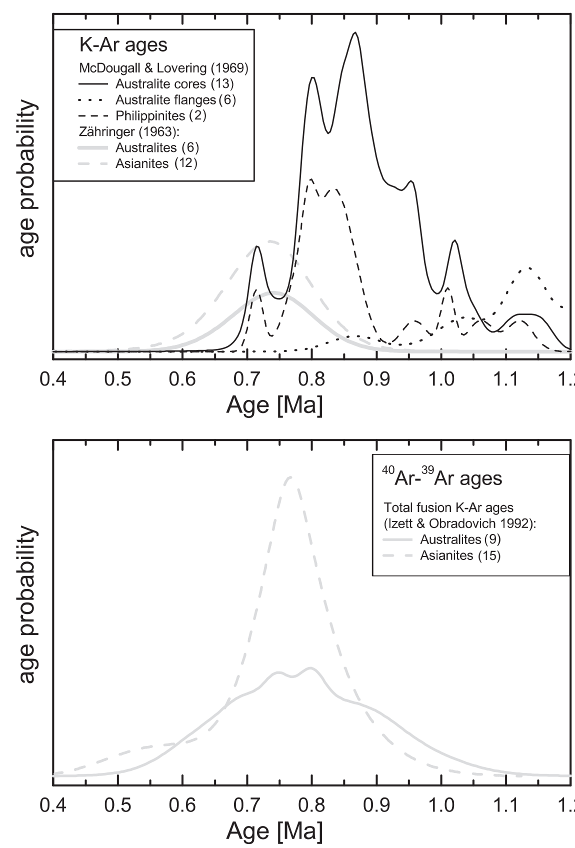

Fig. 1. Australasian tektite K–Ar/^{40}Ar–^{39}Ar age distributions, displayed in terms of "Gaussian" histograms. The curve is the sum of individual age curves, each age value is represented by one Gaussian curve with the age value as the center, the error is the width of the curve. Hence precise ages have sharp high peaks, less precise ages have broad and low peaks. Total fusion laser ^{40}Ar–^{39}Ar dating results by Izett and Obradovich (1992) indicate excess argon in K–Ar ages of bulk samples of flanged-button (aerodynamically shaped) australites measured by classical K–Ar dating (McDougall and Lovering, 1969). Numbers in brackets represent the samples measured (with replicate measurement (2–11) for each sample).