Lake Toba, Sumatra, and the Origin of Tektites

KAYSING suggested recently[1] that Lake Toba, Sumatra, Indonesia, was a possible source area for the Australian group of tektites. This suggestion was based on extrapolation from the observation of McColl and Williams[2] that the "majority of australite localities in south central Australia are concentrated along a line extending northwestwards .... A second subparallel line may exist in the west of South Australia, separated from the main line by an extensive tract of australite-deficient country". They consider that these lines represent primary distribution patterns, and Kaysing[1] suggests that suitable assumptions about ejection angles and allowance for the Earth's rotation "brings the intersection of the infall lines to Lake Toba".

Lake Toba, the largest lake in Indonesia, is one of the largest terrestrial features ascribed to volcanic action. The lake is 87 km long (the depression within which the lake occurs is 100 km long) and 31 km wide[3]. It is surrounded by a vast deposit of acid volcanic material, interpreted as welded tuff or ignimbrite, covering an area of 25,000 square km, with a volume of 2,000 cubic km[4]. This forms one of the largest occurrences of this type of rock and is matched in volume only by the large welded tuff sheets of the central North Island of New Zealand, the type locality for ignimbrite[5]. The consensus among geologists who have investigated Lake Toba is that it is a volcano–tectonic depression, which subsided after paroxysmal eruptions (Nuée ardente type) of acidic material from an underlying magma chamber. Westerveld[4], in particular, is convinced of the "great parallelism between volcanic phenomena on Sumatra and in Northern New Zealand" and Williams[6], Cotton[7], and Ross and Smith[8] have drawn similar conclusions. Acidic volcanic rocks, similar to those at Lake Toba, but on a reduced scale, occur widely in Sumatra, and in many other parts of the circum-Pacific region[9]. They seem to be an integral part of the calc-alkaline association of volcanic rocks associated with dipping seismic zones and deep trenches, although they are restricted to areas where crustal thickness exceeds about 25 km.

Is Lake Toba a potential source region for tektites? Volcanic theories for the origin of tektites have long been in disrepute[9], principally because the observed distribution is too extensive (up to 4 per cent of the Earth's surface if the microtektite occurrences[10] are included in the strewnfield) to be accounted for by eruptions from volcanoes. Thus Lake Toba would need to be an impact feature, because only meteorite, cometary or asteroidal impacts provide sufficient energy to account for the vast south-east Asia strewnfield. Lake Toba does not seem a particularly suitable candidate for an impact site. It is not circular, but elongated. The welded tuffs surrounding Toba are similar to other areas of undoubted volcanic origin in the circum-Pacific orogenic regions, and differ only in extent.

A decisive test is available from a comparison of the chemical composition of the welded tuffs with that of australites. The available data are collected in Table 1. The Toba analyses are old but probably reliable, and they agree with analyses of other welded tuffs. The central North Island ignimbrites generally have larger amounts of silica, but have similar contents of diagnostic elements such as magnesium[11], and individual matching analyses can be found[12].

An average of twelve australite analyses[13,14] from localities extending from Charlotte Waters, NT, to Florieton, SA, along the line established by McColl and Williams[2] is given in column 5, Table 1. If the lake is the tektite source the compositions of the tuff and the tektites should be identical. It is clear from a study of the data in Table 1 that they are not. Particularly critical elements in this comparison are magnesium, sodium and potassium. The australites contain more than twice as much magnesium and about half the sodium and potassium content of the welded tuffs. There is also a marked difference in the silica content. In order to ascertain whether these differences are dependent on silica content or sampling, I have made a comparison with other australites of similar silica content to the Lake Toba material. These comparisons are given in columns 6–9, Table 1, where typical australite analyses off the McColl-Williams line, but with silica contents of about 70 per cent, are listed. These analyses are again dissimilar to the Lake Toba material particularly for the critical elements magnesium, sodium and potassium.

Table 1. COMPARISON OF CHEMICAL COMPOSITION OF WELDED TUFF FROM LAKE TOBA, SUMATRA (1–4), WITH THAT OF AUSTRALITES (5–9)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
SiO_2	69·91	70·87	70·65	71·25	74·10	70·61	70·63	71·19	69·79
Al_2O_3	16·00	15·05	17·32	14·21	10·90	13·50	13·07	13·28	13·06
FeO	3·35	2·55	4·36	1·19	4·30	4·77	4·95	4·95	5·48
MgO	0·94	0·76	0·39	0·89	1·92	2·31	2·48	2·40	2·89
CaO	2·88	2·28	2·28	2·72	4·00	3·41	3·53	2·95	3·64
Na_2O	3·32	3·41	2·85	3·11	1·20	1·52	1·51	1·51	1·33
K_2O	3·25	4·75	2·41	6·74	2·21	2·46	2·55	2·54	2·80
TiO_2	0·33	0·37	—	—	0·65	0·75	0·78	0·76	0·77
	99·98	100·04	100·26	100·11	99·28	99·37	99·55	99·62	99·34

(1) Welded rhyolite tuff, Lai Renoen, Toba Region[4].
(2) Pumice from rhyolite tuff, Lau Matap, Kano Country, Toba region[4].
(3) Welded rhyolite tuff, Sipak Peninsula, Lake Toba[4].
(4) Welded rhyolite tuff, Central Batak, Toba region[4].
(5) Average of ten australites from McColl-Williams Line. Anal. No. 8, 10, 11, 12, 13, 15, 16 (ref. 13) and Anal. No. 29, 31, 33 (ref. 14).
(6) Australite, Wiluna, WA Anal. 2 (ref. 13).
(7) Australite, Edjudina, WA Anal. 3 (ref. 13).
(8) Australite, Kalgoorlie, WA Anal. 6 (ref. 13).
(9) Australite, Lake Wilson, SA Anal. 26 (ref. 14).
Data expressed as weight per cent oxides, on a volatile free basis. All iron expressed as FeO.

These differences parallel those between the chemistry of tektites and terrestrial igneous rocks as has been repeatedly pointed out[13–16]. The chemical and isotopic composition is consistent with a parent material resembling terrestrial sedimentary rocks[13–16].

The recent chemical, isotopic and age results from the lunar rocks[17–19] show such a wide divergence from the tektite data as to make a lunar origin for tektites very improbable. It is thus necessary to locate another source of the south-east Asian strewnfield. The criteria for such a search have been discussed[20] and would be satisfied by cometary impact on shaly sandstones of Mesozoic age. There is, however, no *a priori* case for considering Lake Toba as a potential source area.

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