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# The Cuban Tektite Revisited

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**Abstract**—A tektite, probably found in Cuba, was previously classified as belonging to the North American tektite strewn field on the basis of chemistry, age, isotopic, and petrographic characteristics. New major element analyses and trace element analyses show that the sample falls within the range of other North American tektites, and is close to the bediasite compositions. There are, however, some differences to normal georgiaites and bediasites. In a $Na_2O/K_2O$ diagram the sample plots between the two distinct fields formed by georgiaites and bediasites. The rare earth elements and some lithophile trace elements are slightly enriched compared to bediasites, and much higher than in georgiaites. The discovery of tektite fragments from locations at Barbados and a DSDP site off the coast of New Jersey makes it likely that the North American strewn field is larger than previously thought, in agreement with microtektite distributions. Thus it is possible that the "Cuban" tektite really originated from Cuba.

## INTRODUCTION

ABOUT 20 YEARS AGO a tektite, reportedly from Cuba, was found in a mineral cabinet at Columbia University. The chipped sample weighed 93 grams and belonged to a collection assembled by Dr. A. Poldervaart at Columbia University. A scrap of paper found with the tektite reads "Tektite Behre probably from north of San Domingo set from Havana, Cuba exact loc.? Given by Senor Pablo Llaguna". The location statement was crossed out on the paper. No other tektites have so far been found in Cuba. An initial description of the sample, together with some analytical data, was published by Garlick *et al.* (1971). The tektite had been chipped, and the original weight is assumed to be in excess of 100 grams. It is thus heavier than other known tektites from the North American strewn field (Baker, 1963). The surface shows pits and grooves, and the surface structure has been interpreted as being due to aerodynamic ablation (Garlick *et al.,* 1971). This does not seem too likely, since a distinction between aerodynamic features and solution etching is not easy. Although aerodynamic ablation features have been reported for bediasites (King, 1964), they are very rare and not very typical among North American tektites. The density of 2.383 g $cm^{-3}$ is within the range of other North American tektites, but rather high (Garlick *et al.,* 1971). Bubbles and probable lechatelierite particles have also been found (Garlick *et al.,* 1971).

Fission track age determinations demonstrated that this tektite is of the same age as other North American tektites—35Ma (Garlick *et al.,* 1971). Thus, the possibility of transportation from or confusion with a tektite from another strewn field, as it had been reported before for tektites allegedly found in Louisiana which were in fact australites (King, 1970), is eliminated. Oxygen isotope ratio determinations and major element analyses (of rather low precision) are compatible with data from bediasites and georgiaites (Garlick *et al.,* 1971). Thus, the question remained if this tektite was just a misplaced bediasite, or if real bediasites may be found at a location far from the bediasite sub-strewn field.

In order to clarify some of the questions associated with the Cuban tektite, some new analyses were performed. New evidence for tektites in the Caribbean region came from the fact that tektite fragments, together with microtektites, have been discovered at Barbados (Glass *et al.,* 1984; Sanfilippo *et al.,* 1985; Ngo *et al.,* 1985; Koeberl and Glass, 1986). These tektite fragments were demonstrated to be directly related to other North American tektites on the basis of chemical and isotopic data (Glass *et al.,* 1984; Ngo *et al.,* 1985; Glass *et al.,* 1986; Koeberl and Glass, 1988) and thus extend the field of tektite finds far to the south, comparable with microtektite occurrences (Glass *et al.,* 1979). Cuba is between the bediasite sub-strewn field and the Barbados site (Fig. 1).

## ANALYTICAL METHODS

Major elements were determined using an automated ARL-SEMQ electron microprobe and standard correction procedures. Li, Be, Cu, Zn, and Pb have been determined using graphite furnace atomic absorption spectrometry, and all other trace elements were determined by instrumental neutron activation analysis. Water was determined by infrared absorption spectrometry, following the method described by Gilchrist *et al.* (1969) and Koeberl and Beran (1988). Precision of the major element analyses is, except for Mn, better than 1%. The precision for trace elements is better than 5%, except for K, As, Sr, Br, and W, where it is better than 10%.

## RESULTS AND DISCUSSION

Major element analyses are presented in Table 1 together with comparison data for the Cuban tektite from Garlick *et al.* (1971) and other North American tektites. The major element data for the Cuban tektite are averages from multiple scans of about 25 $\mu m^2$ areas on a thin section. Trace element analyses, together with comparison data, are given in Table 2. Also included are Na and K abundances obtained by neutron activation analysis. The $Na_2O$ value obtained by INAA is 1.18 wt.%, compared with 1.17 wt.% from electron microprobe analysis, $K_2O$ is 2.17 wt.%, compared with 2.09 wt.%, where the larger difference may be explained by the lower precision of the INAA data for K. Rare earth element data are given in Table 3, and the water content, compared to other North American tektites, is given in Table 4.

Figure 2 gives the compositional ranges of bediasites and georgiaites in relation to the composition of the Cuban tektite. From Fig. 2 and Table 1 the Cuban tektite is closer to the composition of bediasites than to georgiaites. Although this is quite obvious for elements like Ti, Al, and Fe there are some interesting differences for other elements like Na and Ca. In the case of Ca, the CaO content of the Cuban tektite is very low compared to other North American tektites.

The $Na_2O$ content in the Cuban tektite is lower than any bediasite value, and within the range of the georgiaites. The agreement between the data of Garlick *et al.* (1971) and the new

TABLE 1. Major element data (wt.%) for the Cuban tektite, and comparison data for other North American tektites.

| | Cuban tektite | | Bediasites | | Georgiaites | | Martha's Vineyard | Barbados | DSDP 612 | Barbados fragments | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | this work (1) | Lit. (1) | average (30) | range (30) | average (8) | range (8) | (1) | range (18) | range (8) | (1) | (1) |
| $SiO_2$ | 75.00 | 74.8 | 76.05 | 71.9–80.2 | 81.4 | 79.8–83.6 | 80.50 | 76.9–85.6 | 71.9–77.8 | 77.4 | 79.5 |
| $TiO_2$ | 0.81 | 0.8 | 0.78 | 0.59–1.05 | 0.49 | 0.42–0.60 | 0.53 | 0.40–0.71 | 0.55–0.85 | 0.71 | 0.59 |
| $Al_2O_3$ | 15.50 | 15.0 | 13.92 | 11.2–17.6 | 10.75 | 9.50–11.7 | 11.20 | 7.97–14.8 | 13.0–15.1 | 13.5 | 12.1 |
| FeO* | 4.30 | 4.4 | 4.07 | 2.29–5.75 | 2.44 | 1.83–3.14 | 2.69 | 1.37–3.98 | 2.7–5.0 | 3.98 | 3.45 |
| MnO | 0.04 | — | 0.04 | 0.01–0.07 | 0.04 | 0.02–0.07 | 0.05 | — | — | — | — |
| MgO | 0.54 | 0.7 | 0.65 | 0.37–0.98 | 0.56 | 0.37–0.69 | 0.69 | 0.13–1.13 | 0.7–1.4 | 0.64 | 0.58 |
| CaO | 0.40 | 1.2 | 0.62 | 0.35–0.96 | 0.50 | 0.40–0.69 | 0.69 | 0.52–0.87 | 0.8–1.0 | 0.59 | 0.57 |
| $Na_2O$ | 1.17 | 1.1 | 1.53 | 1.20–1.98 | 1.17 | 1.00–1.53 | 1.00 | 1.15–1.52 | 0.2–0.6 | 1.26 | 1.29 |
| $K_2O$ | 2.09 | 2.0 | 2.03 | 1.42–2.43 | 2.39 | 2.22–2.51 | 2.37 | 1.73–2.54 | 3.0–3.8 | 1.94 | 1.93 |

* All Fe as FeO.
References: Cuban tektite: this work and Garlick *et al.* (1971); Bediasites: Chao (1963), Cuttitta *et al.* (1967), O'Reilly *et al.* (1983); Georgiaites: Cuttitta *et al.* (1967), O'Reilly *et al.* (1983); Martha's Vineyard tektite: Cuttitta *et al.* (1967); Barbados tektites: Glass *et al.* (1984), Lerner (1986); DSDP 612 tektites: D'Hondt *et al.* (1987), Koeberl and Glass (1988).

data is generally very good. The analyses reported by Garlick *et al.* (1971) summed up to 97.2% only, so $SiO_2$ had to be calculated by difference. The analyses reported here sum up to 99.93%, so the $SiO_2$ value is probably correct. Only small differences occur for $TiO_2$, $Al_2O_3$, FeO, $Na_2O$, and $K_2O$. The most important differences are present for MgO and especially CaO. Garlick *et al.* (1971) reported a CaO content of 1.2 wt.%, in comparison with 0.40 wt.% in the present work. The data presented here has an analytical precision of 1.2% (std. dev.). The major element data clearly looks like that of a bediasite, with the exception of the $Na_2O$ and CaO compositions.

King (1966, 1968) noted that in a plot of $Na_2O$ *vs.* $K_2O$ bediasites and georgiaites form distinct fields. The Cuban tektite plots between the bediasite and the georgiaite fields in the soda-potash diagram (Fig. 3). The newly discovered Barbados tektites, which are part of the North American strewn field, show no distinct association with either the georgiaite or the bediasite field (Glass *et al.*, 1984; Koeberl and Glass, 1988). The Cuban tektite is within the area occupied by the Barbados tektites. Other tektite fragments, which have been discovered in late Eocene sediments from Deep Sea Drilling Project (DSDP) Site 612 on the continental slope off New Jersey (Thein, 1987; Keller *et al.*, 1987), show $K_2O/Na_2O$ ratios of about 5, which are completely different from all the other North American tektites (Fig. 3). These tektite fragments have extremely low $Na_2O$ contents (0.2–0.6 wt.%), but high $K_2O$ contents (3.0–3.8 wt.%) and are also far from the Barbados samples (Koeberl and Glass, 1988). The soda-potash diagram seems to indicate that although the Cuban tektite is a North American tektite it is neither a bediasite nor a georgiaite, but probably similar to the Barbados variety.

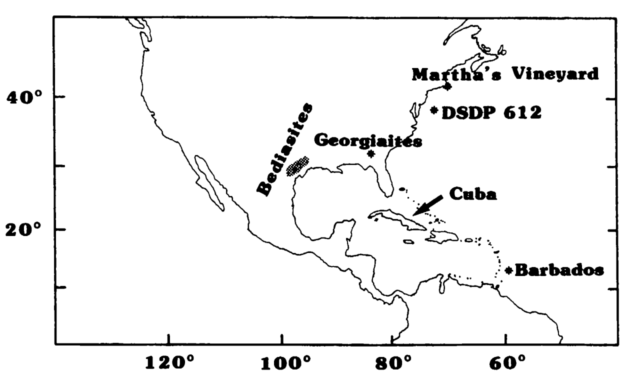


FIG. 1. Map of North America and the Caribbean region showing the location of North American tektites.

TABLE 2. Trace element data for the Cuban tektite and comparison data for other tektites from the North American strewn field.

| | Cuba | BED8401 | Bed.Lit. | Georg. | M.V. | Barb. |
|---|---|---|---|---|---|---|
| Li | 25.0 | 30.7 | 20[b] | 65[a] | 15[b] | — |
| Be | 1.74 | 1.21 | 2.7[b] | 1.61[b] | 1.0[b] | — |
| Na | 0.88 | | | | | |
| Cl | <20 | <20 | 11[c] | — | — | — |
| K | 1.80 | | | | | |
| Sc | 18.2 | 9.16 | 14.5[b] | 9.80[b] | 10[b] | 8.5[d] |
| Cr | 62 | 26 | 40[b] | 27[b] | 31[b] | 40[d] |
| Mn | 168 | 252 | 260[b] | 325[b] | 397[b] | 263[d] |
| Co | 17.0 | 9.1 | 10.3[b] | 8.1[b] | 7.6[b] | 134[d] |
| Ni | <80 | — | 13[b] | 10.7[b] | 8.0[b] | — |
| Cu | 4.0 | 3.1 | 3.7[e] | 4.2[b] | 3.0[b] | — |
| Zn | 16 | 20.2 | 14.7[e] | — | — | — |
| Ga | 13.6 | — | 12[b] | 7.8[b] | 7.2[b] | — |
| As | 0.65 | 1 | — | — | — | 1[d] |
| Se | <0.1 | — | — | — | — | — |
| Br | <0.7 | 0.1 | 0.21[f] | — | — | — |
| Rb | 92 | 73 | 61[b] | 78[b] | 72[b] | 90[d] |
| Sr | 65 | — | 82[b] | 150[b] | 180[b] | — |
| Zr | 290 | 152 | 208[b] | 190[b] | 190[b] | <400[d] |
| Sb | 0.17 | 0.05 | 0.07[h] | — | — | <1[d] |
| Cs | 2.44 | 1.33 | 1.95[b] | 1.73[b] | 1.7[b] | 7[d] |
| Ba | 482 | 450 | 590[b] | 565[b] | 390[b] | <700[d] |
| Hf | 9.0 | 5.1 | 6.9[g] | 4.9[g] | — | 6.7[d] |
| Ta | 1.3 | 0.7 | — | — | — | 2[d] |
| W | 0.35 | — | — | — | — | — |
| Ir | <0.5 | — | — | — | — | — |
| Au | 10 | — | — | — | — | 3[d] |
| Pb | 23 | 10 | <10[b] | 10[b] | 18[b] | — |
| Th | 10.1 | 6.8 | 7.9[g] | 5.1[g] | — | 4[d] |
| U | 1.63 | 1.82 | 2.1[g] | 1.23[g] | — | <4[d] |

All data in ppm, except Na and K in wt.% and Ir and Au in ppb. BED8401: Bediasite, this work and Weinke and Koeberl (1985); Bed.Lit. = comparison data from the literature for bediasites; Georg. = georgiaites; M.V. = Martha's Vineyard tektite; Barb. = Barbados tektite fragment.
[a] Cohen (1959); [b] Cuttitta *et al.* (1967); [c] Moore *et al.* (1984); [d] Koeberl and Glass (1988); [e] Greenland and Lovering (1963); [f] Becker and Manuel (1972); [g] Haskin *et al.* (1982); [h] Tanner and Ehmann (1967).

TABLE 3. Rare earth element data (in ppm) for the Cuban tektite and four comparison samples.

| | Cuba | LET-4 | LET-6 | DGA-1 | 612A |
|---|---|---|---|---|---|
| La | 38.7 | 26.5 | 45.9 | 19.6 | 29.3 |
| Ce | 88 | 59 | 97 | 43 | 55 |
| Nd | 38.8 | — | — | — | 34 |
| Sm | 8.6 | 5.52 | 9.6 | 4.03 | 8.3 |
| Eu | 1.97 | 1.25 | 2.02 | 0.97 | 0.73 |
| Gd | 11.7 | — | — | — | 7 |
| Tb | 1.49 | 0.75 | 1.31 | 0.59 | 1.1 |
| Dy | 9.2 | — | — | — | 6.6 |
| Ho | 2.0 | — | — | — | — |
| Tm | 0.70 | — | — | — | 0.9 |
| Yb | 4.55 | 2.29 | 3.93 | 1.73 | 5.0 |
| Lu | 0.67 | 0.36 | 0.62 | 0.29 | 0.35 |

References: Cuba: this work; LET-4, LET-6: bediasites; Haskin *et al.* (1982); DGA-1: georgiaite; Haskin *et al.* (1982); 612A: tektite fragment from DSDP site 612; Koeberl and Glass (1988).

The lithophile trace elements (Sc, Zr, Hf, Th) are enriched in the Cuban tektite compared to almost all other North American tektites, including samples from Barbados. Most elements have abundances very close to bediasite abundances, in accordance to observations from major elements. Cobalt and Cr are slightly higher in the Cuban tektite than in normal bediasites, putting it closer to some Barbados samples (Koeberl and Glass, 1988). Rubidium is higher in the Cuban tektite and is similar to Barbados samples. Also Cs is higher in the Cuban sample than in bediasites, again closer to Barbados samples.

In most cases a connection with georgiaites seems unlikely. The Martha's Vineyard tektite, another sample found far from the original strewn field (Clarke and Carron, 1961; Cuttitta *et al.,* 1967; Kaye *et al.,* 1961), is close to the composition of Georgia tektites, although the location of Martha's Vineyard (Massachusetts) is closer to DSDP Site 612 than to Georgia. The Cuban tektite has a chemistry apparently different from georgiaites, Martha's Vineyard tektite, and DSDP 612 tektites.

Figure 4 shows a chondrite normalized rare earth element (REE) abundance pattern for the Cuban tektite. Analytical data are given in Table 3. The range representing the bediasites was taken from Haskin *et al.* (1982) and is plotted as two broken lines, the upper one being sample LET-6, the lower one LET-4 (Table 3). These samples are probably close to the upper and lower limits of REE contents in bediasites, but the database is limited (Haskin *et al.,* 1982; Weinke and Koeberl, 1985; see also Koeberl, 1986). A Georgia tektite (Haskin *et al.,* 1982) plots well below the bediasite range. The Cuban tektite has a pattern similar to the bediasite upper limit, with some small differences. The abundances of the HREE in the Cuban tektite are slightly higher than in bediasites. This is in agreement with the obser-

TABLE 4. Water content of the Cuban tektite in comparison with other North American tektites.

| Sample | $H_2O$, wt.% | Reference |
|---|---|---|
| Cuban tektite | 0.012 | a |
| Bediasite average | 0.0135 | b |
| Bediasite range | 0.005–0.021 | b |
| Georgiaite USNM 1396 | 0.011 | b |
| Martha's Vineyard | 0.016 | b |

References: (a) this work; (b) Gilchrist *et al.* (1969).

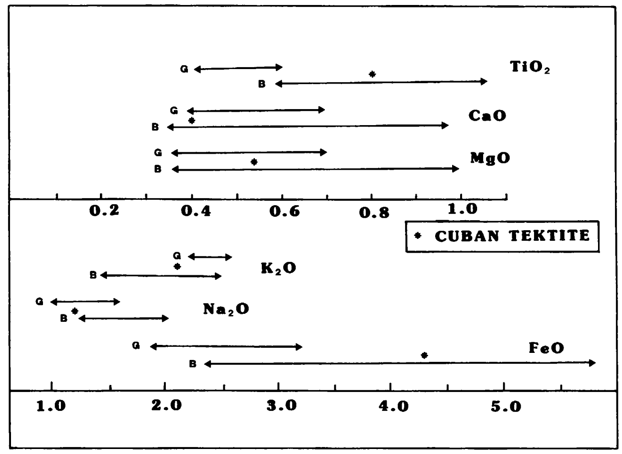


FIG. 2. Abundance ranges of bediasites and georgiaites compared with the Cuban tektite (star). Data and references see Table 1. There is a close similarity to bediasites except for $Na_2O$ and CaO.

vation of higher Sc, Zr, Hf, and Th contents. A higher fraction of zircon-rich material in the part of the parent material would lead to higher HREE abundances. Thus the REE pattern and the absolute REE abundances indicate that the Cuban tektite is different from the Barbados samples.

The Zr/Hf ratio is 32 in the Cuban tektite, and 30 in bediasites, but 39 in georgiaites. Other ratios are not so selective, like the La/Sc ratio (2.12 in the Cuban tektite and thus lower than in most other samples). The Th/Sc ratio in the Cuban tektite (0.55) is higher than in the average bediasite (0.54), but lower than in Barbados tektites (0.66; Koeberl and Glass, 1988) and consistent with the range shown by North American tektites. A larger difference between the Cuban tektite and bediasites or georgiaites is evident in the Th/U ratio, which is higher in the Cuban tektite than in most other samples.

The water content of the Cuban tektite (Table 4) is comparable with the bediasite range (Gilchrist *et al.,* 1969; Koeberl and Beran, in preparation) and is even close to the bediasite average.

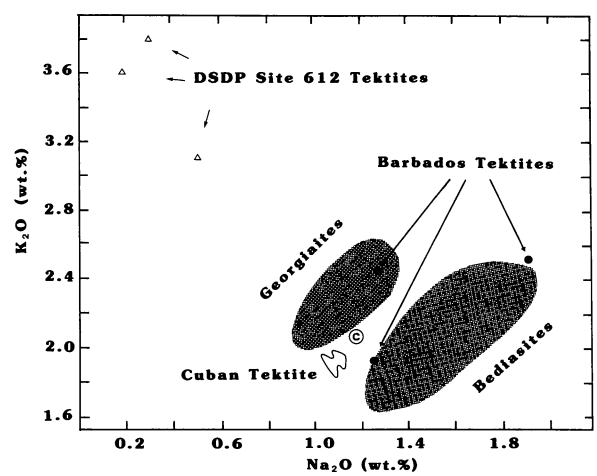


FIG. 3. Soda-potash diagram showing the distinction between bediasites and georgiaites. The Cuban tektite plots between the two separate fields. Tektites from the Barbados site are scattered over the complete field, while DSDP 612 tektites are distinctly different. Data and references see Table 1.

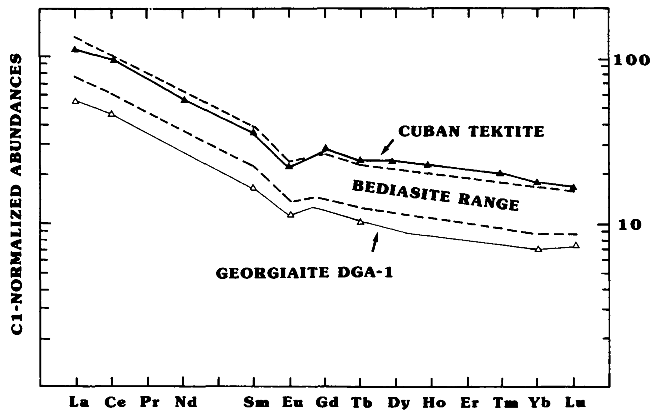


FIG. 4. Chondrite normalized rare earth element abundances for the Cuban tektite (full triangles) and Georgia tektite sample DGA-1 (Haskin *et al.,* 1982). The range of bediasite compositions is given by two dashed lines representing samples LET-4 and LET-6 (Table 3; Haskin *et al.,* 1982). The Cuban tektite is similar to, but not identical with bediasites.

A georgiaite range is not known. The one sample measured by Gilchrist *et al.* (1969) lies within the range of bediasites. Thus, the chemical composition provides no clear picture. Many abundances are close to or comparable with bediasite compositions, but there are some elements that are different—closer to Barbados or even Georgia tektites. The REE and other lithophile elements are higher than in most bediasites. Sodium and Ca abundances are at variance with bediasite or georgiaite compositions (at least in combination with other major element abundances). Some trace element ratios (La/Sc, Th/U) and the soda-potash diagram suggest that the Cuban sample is different from both bediasites and georgiaites.

## CONCLUSIONS

The Cuban tektite appears to be different from both major North American tektite groups. There are some similarities to bediasites, but there are also some similarities to the Barbados tektites. The Cuban tektite may comprise its own distinct subgroup, probably related to the Barbados occurrence, and forming a Caribbean sub-strewn field. On the other hand, this may indicate that there are no sharp distinctions between different sub-strewn fields, and that there is a rather gradual change in composition over the North American tektite strewn field. It is concluded that the "Cuban" tektite is a North American tektite, different from bediasites and Georgia tektites, possibly originating in Cuba.

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