

Water in tektites and impact glasses by fourier-transformed infrared spectrometry

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Abstract—To improve the scarce data base of H₂O content in tektites and impact glasses, we analyzed 26 tektites from all four strewn fields and 25 impact glass samples for their H₂O content. We used the fourier-transformed infrared (FTIR) spectrometry method, which permits measurement of areas of ~40 μm in diameter. Our results show that the tektites have H₂O contents ranging from 0.002 to 0.030 wt% (average 0.014 ± 0.008 wt%). Ivory Coast tektites have the lowest H₂O abundances (0.002–0.003 wt%), and Muong Nong-type indochinites and some North American tektites having the highest contents (up to ~0.03 wt%). Impact glass samples (from the Zhamanshin, Auelloul, and Rio Cuarto craters) yielded H₂O contents of 0.008 to 0.13 wt% H₂O. Typical impact glasses from the Auelloul and Zhamanshin craters have low H₂O contents (0.008 to 0.063 wt%). Libyan Desert Glasses and Rio Cuarto glasses have higher H₂O contents (~0.11 wt%). We also analyzed glasses of unknown origin (*e.g.*, urengoites; glass fragments from Tikal), which showed very low H₂O contents, in agreement with an origin by impact. Our data confirm that all tektites found on land have very low H₂O contents (<0.03 wt% H₂O), while impact glasses have slightly higher H₂O contents. Both glass types are very dry compared to volcanic glasses. This study confirms that the low H₂O contents (<0.05 wt%) of such glasses can be considered good evidence for an origin by impact.

INTRODUCTION

The H₂O content of tektites and impactites has been recognized as a distinguishing quantity between glasses of impact origin and those of volcanic origin (Koeberl, 1992b; 1994). In contrast to glasses of volcanic or mid-ocean ridge basalt (MORB) origin, for which abundant data are available (*e.g.*, Dixon *et al.*, 1988; Sisson and Layne, 1993; and references therein), few measurements of the H₂O content in tektites and impact glasses have been published. Early studies were made using the manometric method (Friedman, 1958, 1963), in which cleaned samples were loaded in Pt vessels and heated in vacuum to temperatures >1450 °C. The results (0.0003 to 0.01 wt% H₂O, average 0.004 wt%) of these measurements seem to have been too low due to incomplete release of all the H₂O (bound as OH) from the silicate glasses (Gilchrist *et al.*, 1969). Chemical methods, while less precise, yielded H₂O contents of 0.02 wt% and higher (Clarke and Carron, 1961; King, 1964).

The first precise measurements of the H₂O that is structurally bound in tektites and impact glasses were reported by Gilchrist *et al.* (1969). They used infrared (IR) spectrometry and showed that the H₂O content of tektites is ~0.01 wt%, which is considerably higher than results obtained before (they remeasured some of the samples previously measured by Friedman, 1958, 1963). These data were of great interest in the debate regarding tektite origin. Considering that most other terrestrial natural glasses contain significantly higher amounts of H₂O, O'Keefe (1964, 1976) argued that the low H₂O content of tektites and the difficulty to expel H₂O out of rocks during melting support his theory that tektites are lunar volcanic glasses. However, determinations of the H₂O content of lunar rocks failed to yield even parts per billion quantities of H₂O (see discussion in Taylor and Koeberl, 1994). Abundances of H₂O in lunar rocks are at least six orders of magnitude below those found in tektites (*e.g.*, Taylor, 1982).

Today, the scientific consensus is that tektites have formed during hypervelocity impacts on Earth and represent melts of surficial, pre-

dominantly sedimentary, precursor rocks of upper crustal composition (see Koeberl, 1994, for a recent review). Tektites are found on Earth in four strewn fields: North American (35 Ma old), Central European (15 Ma), Ivory Coast (1.1 Ma), and Australasian (0.78 Ma). For two of those strewn fields, the source craters are known with reasonable certainty: the Central European strewn field is likely derived from the Ries crater in southern Germany, while the Bosumtwi crater in Ghana is the source crater of the Ivory Coast strewn field (see Koeberl, 1994, and references therein). The 90-km-diameter buried Chesapeake Bay impact structure at the lower Chesapeake Bay, eastern United States, is a likely candidate for the source crater of the North American tektite strewn field (Poag *et al.*, 1994; Koeberl *et al.*, 1996). No definite identification has yet been made regarding the Australasian tektite source crater. Impact glasses have been confused with tektites—some workers tend to use the term "tektite" for all glassy objects (or even crystalline materials) of probable impact origin. This is not correct, as tektites are glassy and represent a specific subgroup of impact-produced glasses. A detailed discussion of the distinction between tektites and impact glasses (and an attempt at a definition of "tektites") was given by Koeberl (1994).

Following the work by Gilchrist *et al.* (1969), further IR spectrometric determinations of H₂O in tektites were made by King and Arndt (1977), who studied a moldavite, an irghizite (from the Zhamanshin crater, Kazakhstan), and an obsidian, and by Engelhardt *et al.* (1987), who analyzed several moldavites. Koeberl and Beran (1988) determined the H₂O content of six Muong Nong-type indochinites and five impact glasses from the Zhamanshin crater. Koeberl (1992b) reported on the H₂O contents of glasses from the Haitian K-T boundary and used the low abundances (0.013–0.021 wt%) to argue for an impact origin of these glasses. Claeys *et al.* (1992) and Claeys and Casier (1994) investigated upper Devonian glass fragments and concluded that their low H₂O content supports an origin by impact. Newman *et al.* (1995) used micro-IR techniques to measure H₂O contents along profiles across an indochinite. Given

the paucity of high-precision H₂O determinations for tektites, in the present paper we provide IR spectrometric analyses of the H₂O content for 26 tektite and 25 impact glasses, as well as one obsidian (americanite), and a profile across a Muong Nong-type indochinite.

SAMPLES

Tektites included samples from all four strewn fields. Several chips of Muong Nong-type indochinites MN8309 and MN8317 were used for the present study. Detailed descriptions and compositional data for these, and related, samples were given by Koeberl (1992a). Additional H₂O content data for several Muong Nong-type tektites of this series were reported by Koeberl and Beran (1988). In addition, two chips of a philippinite (P9201; from the Smithsonian collection) were analyzed. Four high Na-K (HNa/K) australites (AN-245, AN-325, AN-371, AN-372), which represent an impact event that is distinct from that of the other Australasian tektites (*e.g.*, Storzer, 1985; Storzer and Müller-Sohnius, 1986), were studied. For some major element and trace element data on these samples, see Chapman and Scheiber (1969).

Three Ivory Coast tektites (IVC-2069, 2113, 3395, from the Museum d'Histoire Naturelle, Paris; see Koeberl *et al.*, 1997, for sample information) and three moldavites (from the Charles University, Prague) were analyzed. From the North American strewn field, we studied two bediasites (BED-8402 and BED-8501-MN; see Koeberl, 1986, 1988a, for further information on these samples), the "Cuban" tektite (see Koeberl, 1988a), a Muong Nong-type georgiaite and two splash-form georgiaites (see Glass *et al.*, 1995), and two fragments from DSDP Site 612 (see Koeberl and Glass, 1988; Glass, 1989).

Regarding impact glasses, we took samples of eight Libyan Desert Glasses (sample details—C. Koeberl, in preparation, 1997), two impact glasses from the Aouelloul crater, Mauritania (collected by C. Koeberl during an expedition in 1989), two impactites from the Rio Cuarto (Argentina) crater field (see Schultz *et al.*, 1994), and seven impact glasses from the Zhamanshin crater, Kazakhstan (see Koeberl and Fredriksson, 1986; Koeberl, 1988b, for chemical data on some samples, and, *e.g.*, Bouška *et al.*, 1981, for background information). We also measured the H₂O content of three possible impact glass types, which were found in Late Pleistocene fluvioglacial sands in Western Siberia near Novy Urengoi ("uren-goites"; Masaitis *et al.*, 1988; Deutsch *et al.*, 1996), and three glass fragments from Tikal, Guatemala, of unknown origin (see Hildebrand *et al.*, 1994), and of one americanite (obsidian).

ANALYTICAL METHODS

Small chips (millimeter-sized, if available) of the cleaned glass samples were used to prepare doubly-polished plane-parallel sections with a thickness of, in general, 0.15 to 0.30 mm (for some homogeneous glasses, slightly thicker sections, up to ~1 mm, were used). The H₂O content of all samples was determined by fourier-transformed infrared (FTIR) spectrometry, using a Perkin-Elmer 1760X instrument with an attached FTIR microscope unit. Sixty-four scans were collected for each spectrum across the region from 4500 to 2500 cm⁻¹ (2.22 to 4.0 μm) with a resolution of 4 cm⁻¹. Depending on the sample size, the instrument was used with circular apertures of 0.5 to 1.5 mm diameter, or with the microscope attachment, which allowed to measure sample areas of 40 μm in diameter.

Water in silicate glass is usually present in the form of OH rather than discrete H₂O molecules (*e.g.*, Gilchrist *et al.*, 1969). The dissolved H₂O causes two main bands in the IR spectrum at 2.73

μm (3660 cm⁻¹) and 6.2 μm (1610 cm⁻¹), which are due to the OH stretching vibration and H-O-H bending vibration modes, respectively. In addition, overtone and combination vibrations may result in absorption peaks at 1.43, 1.95, and 2.2 μm (Gilchrist *et al.*, 1969). In tektite and impact glasses (and other of silicate glass), only the 2.73 μm peak is found, in accordance with our observations. Pure silica glass allows the OH groups to vibrate within large voids formed by the Si-O-Si bridges. Addition of alkali atoms causes the Si-O-Si bridges to be broken, and the water-derived OH molecule can be attached to a Si chain, leading to the H being bound by hydrogen-bonding, which causes a peak-shift of the 2.73 μm peak towards 2.9 μm and a reduction in intensity of this peak (*cf.*, Gilchrist *et al.*, 1969).

Quantification of the H₂O content requires the measurement of the thickness of the polished section (to ±0.002 mm) and determination of the intensity of the absorption at the OH band maximum in the IR spectrum. The quantity of H₂O is calculated using the simple Lambert-Beer law, with $\log(I_0/I) = \epsilon \times c \times t$ (I_0 = initial intensity, I = intensity of transmitted light, ϵ = extinction coefficient, c = concentration, t = thickness of section). The linear extinction coefficient, in units of $l \times \text{mol}^{-1} \times \text{cm}^{-1}$, is 77.5 for fused silica, is 70 for silica glass, and was determined to be 74.8 for tektite glass (Gilchrist *et al.*, 1969), in agreement with our own observations (Koeberl and Beran, 1988). In accordance with these earlier studies, we accept $75 l \times \text{mol}^{-1} \times \text{cm}^{-1}$ as a good average value for the extinction coefficient of H₂O in high-silica glasses. Uncertainties in the various parameters used in these calculations, and results obtained in replicate measurements, indicate an analytical precision of ±0.003 wt%, or 5 rel%, whichever is greater, for the present data.

RESULTS AND DISCUSSION

The results for our tektite analyses are presented in Table 1 and are shown in Fig. 1. For comparison, some data for Muong Nong-type indochinites from Koeberl and Beran (1988) are also included. The H₂O contents of all measured tektite samples range from 0.002 to 0.030 wt%, with an overall average of 0.014 ± 0.008 wt%. This result is in excellent agreement with data of Gilchrist *et al.* (1969), who found an average of 0.012 ± 0.004 wt% (24 specimens, range: 0.002–0.020 wt%, excluding a philippinite with 0.11 wt%). On average, the Muong Nong-type indochinites have the highest H₂O contents of all tektite samples, with abundances of 0.009 to 0.030 wt%, with considerable differences between different parts (chips) of the same sample (see Table 1), and between individual samples. The philippinite data (two sections of sample P9201) are in agreement with the results of Gilchrist *et al.* (1969). The HNa/K australites are found in a limited area in Australia within the Australasian tektite strewn field (Chapman and Scheiber, 1969) but have a higher age (8.4 Ma—fission track, 11 Ma—K/Ar) than the other Australasian tektites (Storzer, 1985; Storzer and Müller-Sohnius, 1986; Koeberl *et al.*, in preparation). Thus, they represent a different event. They have very low H₂O contents (0.004 to 0.008 wt%), which, together with chemical and isotopic data (Koeberl *et al.*, in preparation), presents further evidence that they are of impact origin.

The Ivory Coast tektites have the lowest H₂O contents of all measured tektite samples, with only 0.002 to 0.003 wt% (20–30 ppm) in three specimens. No comparison data are available from the literature, as these are the first measurements of H₂O in Ivory Coast tektites (not counting the obviously erroneous measurements of Lacroix, 1934, who reported an average of 0.19 wt% H₂O from three wet chemical analyses). Our moldavite analyses show also

TABLE 1. Water content of tektites from all four strewn fields (by FTIR spectrometry).

Sample	Water (wt%)
1. Australasian Tektites	
<i>Muong Nong-type Indochinites</i>	
MN8309T-1	0.021
MN8309T-2	0.028
MN8309T-3	0.024
MN8317-1	0.025
MN8317-2	0.030
MN8317-3	0.022
MN8302 *	0.015
MN8304 *	0.013
MN8308 *	0.017
MN8310 *	0.017
MN8317 *	0.009
MN8319 *	0.011
<i>Philippinites</i>	
P-9201-1	0.012
P-9201-2	0.011
<i>HNa/K Australites</i>	
AN-245	0.004
AN-325	0.006
AN-371	0.008
AN-372	0.008
2. Ivory Coast Tektites	
IVC-2069	0.002
IVC-2113	0.003
IVC-3395	0.002
3. Moldavites	
Mol-1	0.006
Mol-2	0.009
Mol-3	0.010
4. North American Tektites	
BED-8402 (Bediasite)	0.027
BED-8501-MN (Bediasite)	0.030
MNGaTek (Muong Nong-type georgiaite)	0.007
GT-2 (Georgiaite)	0.020
GT-4 (Georgiaite)	0.020
Cuban Tektite	0.012
DSDP-612 (dark)	0.009
DSDP 612 (light)	0.021

*Data from Koeberl and Beran (1988)

rather low abundances (0.006–0.010 wt%, three samples), in agreement with data of Gilchrist *et al.* (1969; 0.009 wt%, one sample) and Engelhardt *et al.* (1987; 0.008–0.017 wt%, 20 samples). The samples from the North American tektite strewn field show a greater spread, with H₂O abundances ranging from 0.007 to 0.030 wt%. Our two bediasite analyses give slightly higher values (0.027, 0.030 wt%) compared to the results obtained by Gilchrist *et al.* (1969), who found a range of 0.005 to 0.020 wt% for seven specimens. The Cuban tektite, which is of not well documented origin, but clearly belongs to the North American tektite strewn field (cf., Koeberl, 1988a), has a H₂O content of 0.012 wt%. Two fragments of glass from DSDP Site 612 (Glass, 1989) also have low H₂O contents, confirming that they are of impact origin.

The abundances of most major and trace elements (except Si) in Muong Nong-type indochinites are (in general) lower in the dark layers by factors of 1.2 to 3 compared to the light portions of the

samples (Koeberl, 1992a). To determine if the H₂O contents in Muong Nong-type indochinites show similar variations between differently colored layers as other elements, we used the FTIR microscope to measure a profile across a dark brown layer in sample MN8309. The results are listed in Table 2 and are plotted in Fig. 2. Although the variations are less than a factor of two, the results seem to indicate a correlation between the color of the layer and the H₂O content, with higher H₂O contents in the darker portions of the section. This is in contrast to the results obtained for major and trace elements.

Table 3 contains our results for impact glasses and other natural glasses of suspected impact origin. The H₂O contents of these glasses range from 0.006 to 0.155 wt%, which is, on average, lower than values that are typical for obsidians (e.g., 0.13 to 0.31 wt%; Gilchrist *et al.*, 1969; Engelhardt *et al.*, 1987; and 0.30 wt% for an americanite—Table 3; Fig. 3). Our data for Libyan Desert Glass (0.055 to 0.155 wt% H₂O, eight samples) are similar to those of Gilchrist *et al.* (1969) and Frischat *et al.* (1982), who found values of 0.069 wt% (one sample) and 0.137 to 0.180 wt% (four samples), respectively. However, the average of our data (0.116 ± 0.042 wt%) is lower than that determined by Frischat *et al.* (1982) at 0.164 wt%. The H₂O content of Libyan Desert Glass is higher than that of tektites and well-documented impact glasses (such as from the Aouelloul, Darwin, or Zhamanshin impact craters). However, Libyan Desert Glass was shown to contain traces of meteoritic matter, and it had a high-temperature origin, confirming an impact origin (e.g., Kleinmann, 1969; Storzer and Koeberl, 1991; Rocchia *et al.*, 1996). Thus, the H₂O content of Libyan Desert Glass seems to mark the upper limit for nonhydrated glasses of impact origin. The two impactites from the Rio Cuarto crater field (Schultz *et al.*, 1994) have H₂O contents that are similar to those of Libyan Desert Glass, although they are less silica-rich and more heterogenous in composition.

Our measurements of two Aouelloul impact glasses (0.033, 0.037 wt%) are in agreement with the one previous value (0.025 wt%) of Gilchrist *et al.* (1969). The results for the impact glasses from the Zhamanshin crater indicate little difference in the H₂O content between the irghizites (0.020 wt%, three specimens) and Si-rich zhamanshinites (0.016 wt%, five specimens). Both of these glass types are silica-rich. The millimeter- to centimeter-sized irghizites are homogeneous in composition and similar in appearance to, but smaller than, splash-form tektites (e.g., Bouška *et al.*, 1981). Silicon-rich zhamanshinites are larger, blocky, and similar to Muong-Nong-type tektites, but even more heterogeneous in composition. The Si-poor zhamanshinites (SiO₂ <60 wt%) are similar in appearance to the Si-rich zhamanshinites but often contain partly digested clasts of precursor rocks. The Si-poor zhamanshinite Zh-57/4b has a H₂O content of 0.034 wt%, which is slightly higher than the average of the Si-rich zhamanshinites and is similar to that of the blue zhamanshinites (cf., Koeberl, 1988b). Figure 3 displays a comparison of the H₂O content of Zhamanshin impact glasses and other impact glass samples and shows that the H₂O content of volcanic glasses is significantly higher than that of impact glasses.

We analyzed chips of the three known urengoitites (cf., Masaitis *et al.*, 1988; Deutsch *et al.*, 1996) to help determine if they are of impact or volcanic origin. Their low H₂O contents (0.008–0.024 wt%) indicate an impact origin. Similar results (0.006–0.008 wt% H₂O) were obtained for three chips of glasses found in archaeological excavations at Tikal, Guatemala; however, the unusual chemical and isotopic composition of these glasses have, so far, not permitted the identification of a source crater (Hildebrand *et al.*, 1994).

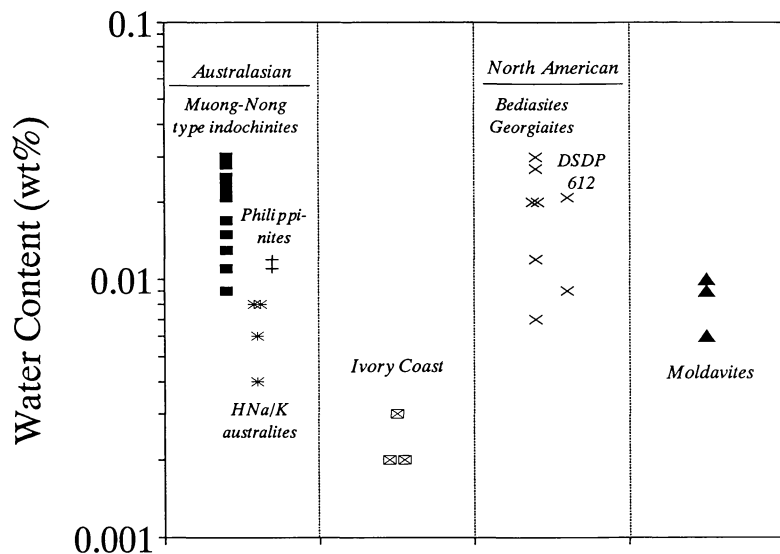


FIG. 1. Water content of tektite samples from all four Cenozoic strewn fields.

TABLE 2. Water content across a section of Muong Nong-type indochinite MN8309.

Point	Distance (mm)	Water (wt%)
MN8309-1	0.5	0.021
MN8309-2	1.0	0.022
MN8309-3	1.5	0.020
MN8309-4	2.0	0.022
MN8309-5	2.5	0.030
MN8309-6	3.0	0.027
MN8309-7	3.5	0.031
MN8309-8	4.0	0.031
MN8309-9	4.5	0.033
MN8309-10	5.0	0.032
MN8309-11	5.5	0.031
MN8309-12	6.0	0.030
MN8309-13	6.5	0.028
MN8309-14	7.0	0.023
MN8309-15	7.5	0.017

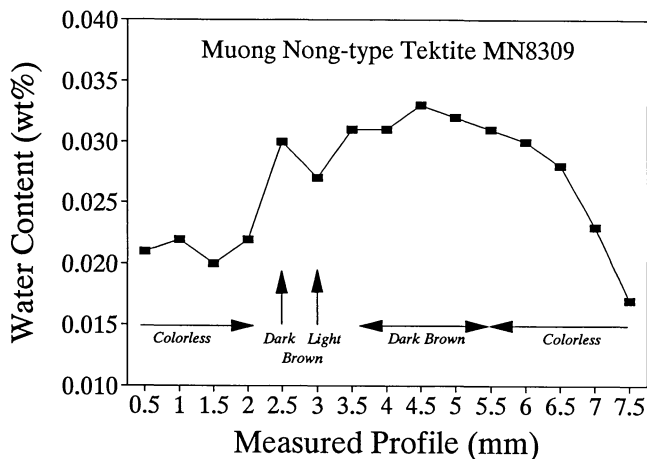


FIG. 2. Water content profile measured with a FTIR microscope unit across a dark and light zone in Muong Nong type tektite MN8309.

TABLE 3. Water content of various impact glasses and an americanite (by FTIR spectrometry).

Sample	Water (wt%)
1. Libyan Desert Glass	
LYD-8501	0.141
LYD-8503	0.086
LYD-8504	0.166
LYD-8505	0.139
LYD-8506	0.155
LYD-5893	0.055
LYD-5895	0.134
LYD-6256	0.055
2. Auouelloul Crater	
AOL-6	0.033
AOL-9	0.037
3. Zhamanshin Crater	
<i>A. Irghizites</i>	
I-8502	0.017
I-8503	0.018
USNM6200 *	0.026
<i>B. Si-rich Zhamanshinites</i>	
Zh-30a	0.009
Zh-30a/2	0.035
Zh-36/2-S	0.016
Zh-57/2b	0.008
USNM-6014	0.014
<i>C. Si-poor + blue Zhamanshinites</i>	
Zh-57/4b *	0.034
Zh-31/6b *	0.063
BZ8601 *	0.050
BZ8602 *	0.050
4. Rio Cuarto Craters	
AR-2	0.129
AR-3	0.115
5. Urengoites	
UR-1	0.008
UR-2	0.024
UR-3	0.016
6. Tikal Glass	
Tikal-12T	0.008
Tikal-20M	0.006
Tikal-24F	0.007
7. Americanite	
	0.30

*Data from Koeberl and Beran (1988), for comparison.

Our data support the suggestion that impact glasses (*i.e.*, those found closely associated with an impact crater) have higher H₂O contents than tektites (*i.e.*, distal glassy ejecta formed during an impact event but not spatially associated with an impact crater), reinforcing the conclusion that tektite melts had relatively higher temperatures than impact glass melts (*cf.*, Koeberl, 1994). The present study also supports the observation that tektites and impact glasses are extremely dry compared to volcanic glasses.

O'Keefe (1964, 1976) cited the low H₂O content of tektites as a primary obstacle to the terrestrial impact theory, because H₂O supposedly cannot diffuse out of melts fast enough during the tektite formation process. Formation of tektites in an impact event requires reassessment of the (still valid) problem of H₂O diffusion in tektites. It was suggested (Vickery and Browning, 1991) that the

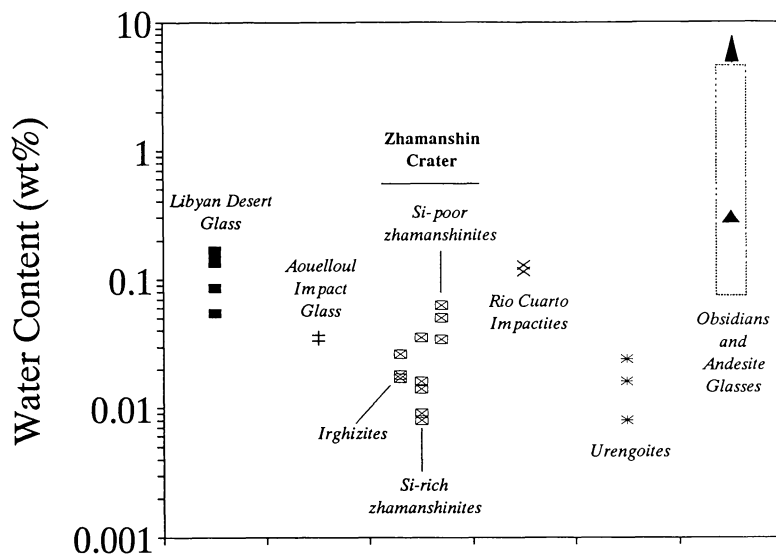


FIG. 3. Water content of various impact glasses (Auouelloul, Zhamanshin, and Rio Cuarto craters), Libyan Desert Glass, and glass samples of unknown origin (urengoites). Also included is the range for obsidians and andesitic volcanic glasses (see text). The solid triangle marks the water content of an americanite sample (obsidian).

H₂O molecules are fragmented into their atomic components. Under such conditions, and using melt temperatures of tektites that may involve superheating ($\gg 1800$ °C), calculations show that there is no problem to drive H₂O out of target rocks that contain up to a few weight percent of H₂O (Vickery and Browning, 1991). In addition, experimental evidence shows that it is possible to form dry glasses from wet rocks. Gilchrist *et al.* (1969) studied glasses formed in a solar furnace by heating soils, clays, and various minerals and rocks for 10 to 60 s, and found that the H₂O content of these glasses is between 0.022 and 0.063 wt%. Glass *et al.* (1986, 1988) found that atomic bomb glass, formed in a very short time from normal sediments, is very dry (0.007 wt% H₂O). Thus, theoretical and experimental evidence is in agreement with impact glasses being very dry.

On the other hand, tektites and impact glasses may be subjected to hydration in the geological environment, considering that they have formation ages of several million years. For quite some time, researchers believed that tektite glass does not form alteration products but is simply dissolved (*e.g.*, Glass, 1974, 1984, 1986; LaMarche *et al.*, 1984; Barkatt *et al.*, 1984, 1986, 1989) with the dissolution rate being determined by the chemical composition of the glass (*e.g.*, El-Shamy, 1973; Barkatt *et al.*, 1984). The recent discovery of partly altered impact glasses at the K-T boundary, however, demonstrated that, under some diagenetic conditions, glasses with specific chemical compositions can undergo alteration (*e.g.*, palagonitization; cf., Glass and Bohor, 1995). In addition, Mazer *et al.* (1992a,b) have shown by transmission electron microscope studies that clay layers (with a thickness of a few nanometers) do actually form on tektites, but that, under most geological conditions, the formation rate for these clays is slower than that for dissolution.

Recently, Glass *et al.* (1997) described some hydrated tektite fragments (*e.g.*, from DSDP Site 612) and microtektites and argued that this discovery negates the argument that a low H₂O content is a distinctive feature of tektites. However, it has to be considered that the experimental database of H₂O contents in tektites and impact glasses (mainly Gilchrist *et al.*, 1969; Engelhardt *et al.*, 1987; Koeberl and Beran, 1988; and this work) shows that practically all measured

tektites and impact glasses are dry. It is likely that tektite glass undergoes hydration (or palagonitization) only under very specific circumstances and is related to the glass composition and geological environment. In this relation, it is interesting that the Late Devonian (≈ 367 Ma) impact-derived microspherules have not undergone hydration but are still dry at ~ 0.01 wt% H₂O (Claeys and Casier, 1994). Thus, we see no reason to discredit the conclusion that a dry glass (≤ 0.03 wt% H₂O) is most likely of impact origin. Of course, the argument cannot necessarily be inverted (*i.e.*, glasses with higher H₂O contents may still be of impact origin but may have undergone hydration).

SUMMARY AND CONCLUSIONS

We have analyzed 26 tektite and 25 impact glass samples for their H₂O content, using high-precision FTIR spectrometry. The tektites include samples from all four known Cenozoic strewn fields and have H₂O contents ranging from 0.002 to 0.030 wt%, with Ivory Coast tektites showing the lowest H₂O abundances, and Muong Nong-type indochinites and some North American tektites having the highest contents.

The data for the impact glass samples, from the Zhamanshin, Auouelloul, and Rio Cuarto craters, as well as Libyan Desert Glass samples, show a broader variation in H₂O content, from 0.008 to 0.166 wt% H₂O. Typical impact glasses (*i.e.*, from the Auouelloul and Zhamanshin craters) are low in H₂O, from ~ 0.008 to 0.063 wt%. Libyan Desert Glasses have higher H₂O contents, with an average of ~ 0.11 wt%, which is similar to the data for the Rio Cuarto glasses. Glasses of unknown origin (and sources), urengoites (possible tektite-like glasses from Western Siberia) and glass fragments from Tikal (Guatemala), were also analyzed and yielded very low H₂O contents, in agreement with an origin by impact.

Our data confirm that all tektites found on land, as well as some fragments of tektite glass from DSDP Site 612, which probably belong to the North American tektite strewn field, are very dry (on the order of < 0.03 wt% H₂O), much dryer than glasses of volcanic origin. Impact glasses have slightly higher H₂O contents but are still very dry compared to volcanic glasses. We suggest that the H₂O content of glasses of unknown origin can be diagnostic, in the sense that very low H₂O contents (< 0.05 wt%; under certain circumstances < 0.1 wt%) are very good evidence for an origin by impact.

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