

**LIQUID IMMISCIBILITY: CAUSE OF COMPOSITIONAL HETEROGENEITY IN TEKTITES.**

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**Introduction:** Compositional heterogeneities within individual tektites on scales >100 microns have been described [1-3] and attributed to incomplete mixing of diverse lithologies in the target during impact melting [4]. During the impact event, these melts were heated (3000°C; ref. 5) far above their liquidus temperatures (about 1350°C; ref. 6,7), and then cooled rapidly to form glass [7]. Some tektites were transported above the Earth's atmosphere and underwent a second heating episode when they re-entered the atmosphere at hypersonic velocity. This second heating episode generated flanges (e.g., flanged australites; ref. 8,9). If, as implicitly assumed by tektite investigators, mixing/dissolution processes dominated during these heating events, *why are compositional heterogeneities better developed in the flanges [3], which are products of two intense heating events, than in the core of the same tektite that underwent only one heating event?* Since chemical diffusion during the second heating event should have decreased the size and magnitude of the compositional heterogeneities, an *unmixing/exsolution* process seems to be more compatible with the observations. The current study has found that trends of element distribution exhibited by *schlieren* (Figures 1a,b) within splash-form tektites are nearly identical to those exhibited by millimeter-scale *layers* in Muong Nong-type tektites (Figure 2). Consequently, it is the view of this abstract that: (a) *schlieren* and *layers* were produced by a single, chemical exsolution process; and (b) the differing length-scales of the compositional heterogeneities reflect different temperature-time histories of the samples.

**Observations:** Microprobe analyses of melt domains in a moldavite tektite (Figure 1a,b) show that the oxide abundances are inversely correlated with SiO<sub>2</sub> abundance. Since these high-precision analyses show that the trends are *not* straight lines, neither two-component mixing [4] nor electron microbeam overlap of two phases during electron microprobe analysis [2] can explain these trends. Since similar elemental trends are observed in tektites of different ages (e.g., australites, moldavites, Muong Nong tektites, and North American tektites), a single physical/chemical process may be responsible for producing these compositional variations within high-SiO<sub>2</sub>, peraluminous melts.

Muong Nong tektites possess alternating layers of optically light- and dark-colored glasses measuring up to several millimeters in thickness [10,11]. We agree with J. T. Wasson [12] that the compositional layering in Muong Nong tektites developed *after* the melt was deposited as a pool on the Earth's surface. Backscattered electron images of these layers *acquired* during the current study show domains of contrasting glass compositions in shapes of flattened globules (e.g., immiscible melt globules) that have been stretched into layers by flow. The boundary between adjacent light-colored, low-SiO<sub>2</sub> layers and dark-colored, high-SiO<sub>2</sub> layers is typically <60-microns wide (Figure 3).

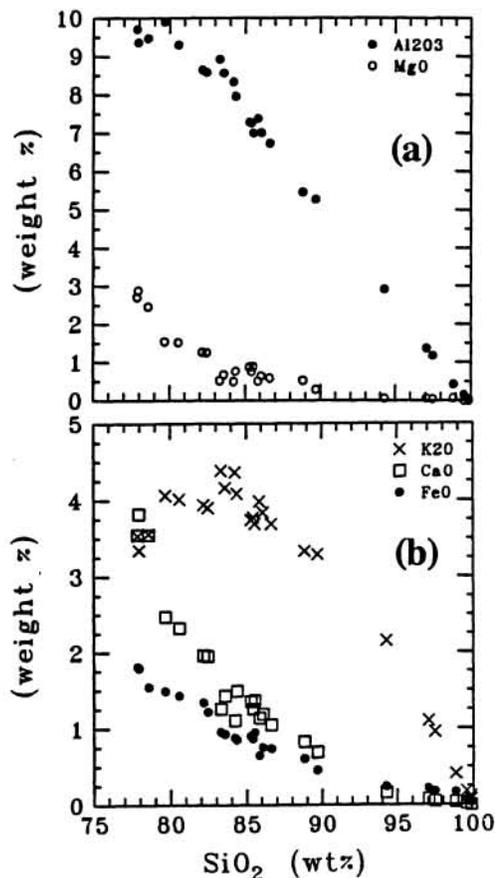
**Liquid immiscibility:** These intra-sample, compositional trends resemble experimental investigations of Soret diffusion [13] and liquid immiscibility [14]. Since element-partitioning during liquid immiscibility and Soret diffusion is controlled by melt structure, the compositional trends in melts produced by both processes will be similar [13]. The fractionation trends measured in this study are not related to the Roedder solvus in the QFL system, and hence not applicable to the 100-nanometer, immiscible melts in zhamanshinites [15]. The behavior of Al as a network-modifying cation (Figure 1a), which is experimentally observed to occur in silicate melts having low abundances of Na and K [13,14,16], causes the fractionation trends to be sub-radial to SiO<sub>2</sub> [17]. In addition, the gradual change in partitioning behavior of K<sub>2</sub>O (Figures 1b, 2) and Na<sub>2</sub>O [3] as a function of SiO<sub>2</sub> abundance in the melt has been experimentally observed [13]. The phase known as *lechatelierite* may not be undissolved, fused silica (quartz) from the pre-impact target rocks [e.g., 18,19], but rather may be an end-member, immiscible melt that expelled the network-modifying cations. The *continuum* of melt compositions (Figures 1a,b; 2) suggests that the exsolution process was (a) spinodal decomposition, (b) a metastable extension of the Greig solvus induced by supercooling [20,21], or (c) stable liquation (e.g., predicted liquation field 'X' of ref. 22), in which quenching occurred prior to completion of the unmixing process.

**Implications:** (a) Since tektites have experienced extremes of both temperature and supercooling that have not yet been explored by experimental petrologists, these samples provide data about silicate melt-structure at unfamiliar conditions. (b) *If exsolution processes dominated*, the semi-qualitative temperature-time histories of tektites [e.g., 4,5] need to be *inverted*. For example, millimeter-scale exsolution domains (i.e., layers) in Muong Nong tektites required *more* time to develop (e.g., slower cooling in melt pools), rather than the short heating times previously inferred from the perspective of incomplete mixing/dissolution. This inference is consistent with the observation that Muong Nong tektites contain higher abundances of volatile elements than the splash-form tektites [10,12]

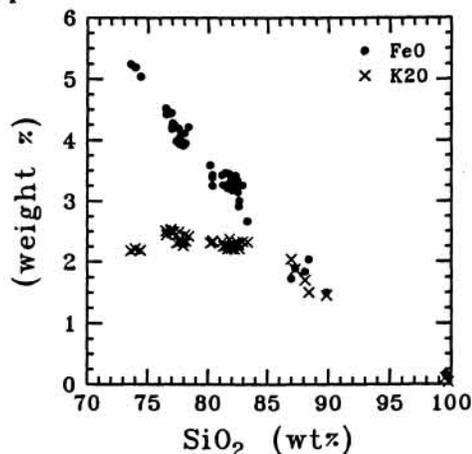
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since volatile-loss, which is in part related to the area/volume ratio of the melt-unit, would have been more effective from centimeter-sized, superheated melt-droplets (splash-form tektites) than from melt-pools (Muong Nong tektites).

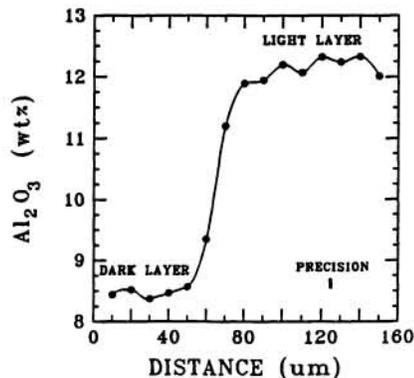
**References:** [1] Glass B. P. (1970) *Earth Planet. Sci. Lett.*, 9, p. 240-246. [2] Glass B. P. et al. (1995) *Geochim. Cosmochim. Acta*, 59, p. 4071-4082. [3] Delano J. W. et al. (1993) LPS-XXIV, p. 397-398. [4] Koeberl C. (1986) *Ann. Rev. Earth Planet. Sci.*, 14, p. 323-350. [5] Barnes V. E. and Pitakpaivan K. (1962) *Proc. Nat. Acad. Sci.*, 48, p. 947-955. [6] Cassidy W. A. (1964) *Geochim. Cosmochim. Acta*, 28, p. 999-1008. [7] Arndt J. and Rombach N. (1976) PLSC 7, p. 1123-1141. [8] Baker G. (1958) *Amer. J. Sci.*, 256, p. 369-383. [9] Chapman D. R. et al. (1962) NASA Tech. Rep. TR-134. [10] Koeberl C. (1992) *Geochim. Cosmochim. Acta*, 56, p. 1033-1064. [11] Futrell D. S. (1986) *Nature*, 319, p. 663-665. [12] Wasson J. T. (1991) *Earth Planet. Sci. Lett.*, 102, p. 95-109. [13] Leshner C. E. and Walker D. (1991) *Adv. Physical Chem.*, vol. 8, Chap. 12, p. 396-451. [14] Hess P. C. and Wood M. I. (1982) *Contrib. Mineral. Petrol.*, 81, p. 103-112. [15] Zolensky M. E. and Koeberl C. (1991) *Geochim. Cosmochim. Acta*, 55, p. 1483-1486. [16] Wood M. I. and Hess P. C. (1980) *Contrib. Mineral. Petrol.*, 72, p. 319-328. [17] Delano J. W. (1992) LPS-XXIII, p. 301-302. [18] Barnes V. E. (1940) *Univ. Texas Publ.* 3945, p. 477-582. [19] Chao E. C. T. (1963) *Tektites*, p. 51-94. [20] Irvine T. N. (1975) *Carnegie Year Book* 74, p. 484-492. [21] Irvine T. N. (1976) *Carnegie Year Book* 75, p. 597-611. [22] Barron L. M. (1991) *Geochim. Cosmochim. Acta*, 55, p. 761-767.



**Figure 1.** Element distributions relative to SiO<sub>2</sub> in a moldavite tektite from Slavice.



**Figure 2.** Distributions of K<sub>2</sub>O and FeO relative to SiO<sub>2</sub> in a Muong Nong tektite. Note the change in partitioning behavior of K by the 'roll-over' at about 80% SiO<sub>2</sub>. A similar effect is observed in a moldavite tektite (Figure 1b).



**Figure 3.** The boundary between adjacent layers in a Muong Nong tektite is <60-microns wide. The dark-colored layers are higher in Si (lower in Ti, Al, Fe, Mn, Mg, Ca) than the light-colored layers.