THE INFLUENCE OF CRACK PROPAGATION ON TEKTITE GLASS CORROSION SCULPTURE. A. Krauss and A. Whymark, Consultant Engineer (andreas.krauss@krauss-engineering.de), Consultant Wellsite Geologist (aubrey@tekrites.info).

Introduction: Tektite glass, like all glasses, will corrode in an aqueous environment. This article investigates why some tektites are characterized by pitting and U-grooves whilst others have V-grooves.

Glass Corrosion: Two types of glass corrosion have been recognized: etching and leaching [1]. Etching, which attacks the silica network, is characterized by alkaline attack [1]. Leaching, which attacks the alkali component of the glass, is characterized by acidic attack [1]. It is noted that these two separable processes in fact occur simultaneously [2]. Below pH 9, leaching is the dominant mode of decay [3].

External factors that may influence corrosion include (most fundamentally) the presence or absence of liquid water/steam [3]; pH [2]; solute/ionic content [2-4]; pressure; temperature; humidity [1]; water exchange as influenced by climate [5], seasonality, water table, porosity and permeability of the host rock, exposure time [5]. Microenvironments may occur in circumstances of restricted water exchange with the glass surface. For example, inaccessible crack-tips in which reaction products accumulate [6], reaction products may form barriers [4], encasing iron concretions may form due to Fe-rich waters precipitating iron around corroding glass [1], and impermeable host lithologies.

The tektite also influences corrosion. Glass chemistry [3] and water adsorption rates [1] contribute significantly to susceptibility and may vary within and between specimens. Surfaces may be primary, re-heated, ablated, spalled, broken, previously corroded, abraded, scratched, and fractured by water transportation. The tektite will contain internal stresses due to rapid cooling from the outside-in [7].

Sculpture Origin: The origins of tektite sculpture have been eloquently described [5] and observations herein wholly support the conclusions.

Sculpture is not random: corrosion attacks weaknesses in terms of composition, heterogeneities [5], cracks, fusion joints [8], and stresses [5]. Examples of glass corrosion in tektites (Fig. 1) include pitting, schlieren (corrosion resistant lechatelierite), V-grooves, and U-grooves.

Tektites cooled rapidly from the outside-in, resulting in internal stresses [7]. Using a polariscope at Chennitz University of Technology, Institute of Mechanics and Thermodynamics, it can be demonstrated that Moldavite V-grooves (and associated fine U-grooving with the same pattern) follow lines of internal stress (Fig. 2). Isolated V-grooves are sigmoidal tension cracks. Patterns are commonly radiating towards the cooling center of the body or to a bubble.

Figure 1: Surface features due to corrosion. A U-grooved Billitonite (top left). A Moldavite showing schlieren (top right). Pitted Moldavite and Indochinite (bottom left). A V-grooved Indochinite (bottom right).

Figure 2: Moldavites in reflected light (left); result of stress measurement (middle); comparison of V-groove sculpture (black lines) with areas of higher stress (gray lines) (right).

V-grooves form from actively propagating cracks on pre-existing tensile stresses. A V-groove develops
because the oldest and first exposed part of the crack is most deeply corroded whereas the youngest extremities and deepest part of the crack are only recently exposed and have been subject to the least corrosion (Fig. 3). If internal stresses are reduced and a tensile crack no longer propagates, or if corrosion is proceeding faster than a crack propagates then an initial V-shaped tension gash may become a U-groove (Fig. 3). In these instances, U-grooves may also follow internal stresses.

![Figure 3: The progressive corrosion of non-propagating cracks (solid red line) and heterogeneities (red dot) to form U-grooves (left) and hemispherical pits (middle left) vs. propagating cracks (dashed red lines) due to tensile stresses (green arrows) that form V-grooves as the crack extremities are newly exposed (middle, middle right). A propagating crack may later become non-propagating if stresses reduce or corrosion proceeds faster than crack propagation (right).](image)

Whilst U-grooves may represent an overprint of V-grooves, as outlined above, they are more classically associated with deep and prominent polygonal or radial grooves on the anterior of medial tektites (although also occurring on proximal and distal tektites). These U-grooves are corrosion enhanced cooling and contraction cracks predominantly formed during re-entry. Navels, circular U-grooves, represent corrosion enhanced Hertzian cones predominantly formed due to point pressure focused centrally beneath the triangular / polygonal contraction shell [9]. Cooling / contraction and re-entry pressures are no longer present; therefore, cracks are non-propagating and form U-grooves (Fig. 3). Pitting represents corrosion on pre-existing flaws and heterogeneities. Again, these features do not propagate and so a hemispherical pit results due to even corrosion (Fig. 3). In some instances, V-grooving is superimposed upon U-grooves and pits. This suggests a subsequent increase in tensile stress or decrease in glass strength. This may occur due to changes in (micro-) environment that enhance crack growth.

**Discussion:** Internal stresses are found in all tektites, but cracks form only if internal stresses are greater than the tensile strength of the glass. Cracks may not form if internal stresses are reduced. Removal of peripheral layers of the tektite (e.g. by ablation, etching, or abrasion [7]) resulted in a rapid decrease in maximum tensile stress [5,7].

In Moldavites it was observed that in localities where transportation was insignificant or short then pit-sculptured Moldavites were not frequent [5]. In Moldavites transported very far the pit-sculptured Moldavites prevailed at the cost of grooved Moldavites [5]. In Philippinites, V-grooving is usually found on tektites with a fresh unabraded appearance whereas clearly abraded tektites found in fluvial gravels are often pitted and deeply U-grooved. In Australites, ablated surfaces are typically free of V-grooves.

If V-grooves are initiated, they will tend to propagate. If a V-grooved surface is ground down then exposed to HF a V-groove is produced that connected to the surface V-groove [8]. Once V-grooving is initiated it may propagate and corrode an entire body over time.

The role of pH in promoting tektite crack propagation (and V-grooves) is an area for future research. Alkaline geological environments (e.g., on limestone bedrock or in alkaline clays) are often also indicative of minimal transportation and abrasion. In terms of crack propagation it is the crack-tip pH that is of importance and this may be controlled by the glass composition or the bulk environment [6]. It was noted that the low water content of tektites may make them virtually impregnable to hydration [1] resulting in a relative inertness in aqueous environments. This might suggest the potential for environmental waters to exert a greater influence on the crack-tip pH.

Sculptural elements on corroded tektites are diverse, even in close geographic and stratigraphic proximity, or on a single specimen. This reflects the different formation processes affecting a surface, transportation, host rock, water chemistry and water exchange, all of which may have changed in the geological past through re-transportation, re-deposition, or through climatic changes. The presence of V-grooves is indicative of active crack propagation driven by internal tensile stresses. U-grooves indicate no crack propagation, or corrosion proceeding faster than crack propagation.