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Trinitite redux: Mineralogy and petrology

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Abstract

Trinitite is the glass formed during the first atomic bomb test near Socorro, New Mexico, on July 16, 1945. The protolith for the glass is arkosic sand. The majority of the glass is bottle green in color, but a red variety is found in the northern quadrant of the test site. Glass beads and dumbbells, similar in morphology to micro-tektites, are also found at the Trinity site. The original description of this material, which appeared in *American Mineralogist* in 1948, noted the presence of two glasses with distinctly different indices of refraction (n = 1.46 and 1.51–1.54). Scanning electron microscopy (SEM) and Quantitative Evaluation of Minerals by SCANning electron microscopy (QEMSCAN) analysis is used to investigate the chemical composition and fine-scale structure of the glass. The glass is heterogeneous at the tens of micrometer scale with discrete layers of glass showing flow-like structures. The low index of refraction glass is essentially SiO_2 (high-Si glass), but the higher index of refraction glass (low-Si glass) shows a range of chemical compositions. Embedded in the glass are partially melted quartz (α-quartz as determined by X-ray diffraction) and feldspar grains. The red trinitite consists of the same two glass components along with additional Cu-rich, Fe-rich, and Pb-rich silicate glasses. Metallic globules are common in the red trinitite

In terms of viscosity, the high-Si and low-Si glasses differ by several orders of magnitude, and there is minimal mixing between the two glasses. QEMSCAN analysis reveals that there are several chemical subgroups (that can be characterized as simple mixtures of melted mineral components) within the low-Si glasses, and there is limited mixing between these glass subgroups. The red trinitite contains regions of Fe-rich glass, which show sharp contact with surrounding Fe-poor glass. Both the textural and chemical data suggest that these two glasses existed as immiscible liquids. The metallic droplets in the red trinitite, which consist of variable amounts of Cu, Pb, and Fe, show textural evidence of unmixing. These metals are largely derived from anthropogenic sources—Cu wire, Pb bricks, and the steel tower and bomb casing. The combination of mineralogical and chemical data indicate that temperatures on the order of 1600 °C and pressures of at least 8 GPa were reached during the atomic detonation and that there was a reducing environment during cooling, as evidenced by the presence of native metals, metal sulfides, and a low-Fe^{3+}/Fe^{2+} ratio. Independent estimates of maximum temperature during the detonation are on the order of 8000 K, far higher than suggested by the mineral data. This discrepancy is probably due to the very short duration of the event. In all respects, the trinitite glasses are similar to tektites and fulgurites, and by analogy one conclusion is that temperature estimates based on mineralogical observations for these materials also underestimate the maximum temperatures.

Keywords: Trinitite, fused arkose, glass melting, heterogeneous glasses, liquid immiscibility, melt viscosity, QEMSCAN