Radionuclide Fractionation in the First Atomic Explosion

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Chemical and isotopic analysis of glassy fallout from nuclear explosions is a powerful forensic tool for identifying nuclear devices, but the composition of glassy fallout only indirectly represents the composition of the device. Much fallout is formed by condensation from the fireball plasma [1], and, thus, chemical volatility is the main control on the incorporation of device material into glassy fallout. Here, we develop an independent scale for tracking the volatility of radioisotopes in the Trinity cloud. We measured major elements, stable trace elements, and U-Pu isotopes in ~20-40 μm glass domains across nine pieces of Trinity debris. The volatility of glass is calculated with a "volatility index" (ratio of volatile to refractory major element concentrations). Using this approach, a small number of Trinity glasses preserve condensates formed over a volatility range spanning nearly 3 orders of magnitude, which is as large as the volatility ranges previously reported [2] for bulk debris from multiple tests. Trace element concentrations and ratios in Trinity glasses increase or decrease systematically as a function of volatility index, allowing for determination of individual and relative volatility trends during fireball cooling. The decrease in Pu/U ratio with volatility index demonstrates actinide fractionation and the lower volatility of Pu. In contrast, the $^{235}U/^{238}U$ ratio is constant over the entire volatility index range, showing that U isotopes were not fractionated during the Trinity explosion. Our major-element-based volatility index approach allows construction of a volatility scale specific to the conditions and environmental composition of any given explosion.

[1] Bonamici C.E., et al. (2017) *Contrib Mineral Petrol* 172:2
[2] Freiling, E.C. (1961) *Science* 133, 1991-1998.