The double-edged sword of ultra-high precision $^{40}\text{Ar}/^{39}\text{Ar}$
geochronology: Investigating previously unresolved complexities in sanidine age distributions

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Improvement in the precision of $^{40}\text{Ar}/^{39}\text{Ar}$ sanidine geochronology has demonstrated that single crystal sanidine dates from ignimbrites are dispersed, leading to ambiguous interpretations of eruption ages. This inhibits interpretation of temporally closely spaced geologic events such as nearly coeval caldera forming eruptions, paleomagnetic reversals, extinction events, etc. Possible age dispersion sources related to (1) neutron dose differences between individual sanidine grains, (2) mineral and melt inclusion variations between grains, and (3) mass spectrometry and data reduction details have been evaluated via detailed laboratory experiments on multiple sanidine bearing ignimbrites. The accuracy of derived eruption ages is cross validated through stratigraphically constrained 27 – 28 Ma ignimbrites from the San Juan Volcanic Field that may differ in age by less than 15 ka.

The $^{40}\text{Ar}/^{39}\text{Ar}$ method is based on irradiating a sample to convert $^{39}\text{K}$ to $^{39}\text{Ar}$ with the $^{40}\text{Ar}/^{39}\text{Ar}$ value being proportional to age. However, multifarious neutron flux, spatially and temporally, leads to no two grains receiving the same neutron dose, thus, variation in grain-to-grain dosage is a possible source of age dispersion. Irradiation of Fish Canyon tuff sanidine (FC-2) grains in a tightly spaced geometry significantly reduced dispersion from the typical grain-to-grain date range of up to ca. 100 ka to as low as ca. 30 ka. Although better constraining the irradiation geometry demonstrated that neutron flux variation is a large source of age dispersion, in detail, populations still show excess dispersion that likely correlates to geologic complexities.

Geologic dispersion is evaluated by handpicking inclusion-free and inclusion-rich sanidine grains. Inclusion-rich grains are characterized by having visible melt and mineral inclusions when viewed under a microscope. Detailed experiments of FC-2 revealed no significant age difference or degree of dispersion between populations with and without inclusions. Numerous other mid-Tertiary ignimbrite samples were analyzed in the same manner and yield results comparable to FC-2. Although inclusion-rich grains revealed more chemical variability, the general observation is that there is no significant difference between inclusion-free and inclusion-rich grains.

The ability of the mass spectrometer and associated analytical methods to yield a normal distribution of dates is evaluated by two methods: (1) a standard gas with an argon isotopic composition similar to typical sanidine and (2) by crushing coarse-grained sanidine crystals to construct a homogeneous geologic sample. Standard gas ultra-high precision analyses yields normally distributed isotopic measurements, indicating that when provided with a homogeneous sample, a homogeneous result can be achieved. Crushed and homogenized FC-2 aliquots yield normally distributed ultra-precise results, reinforcing the robustness of the mass spectrometer when dating a geologic sample and supporting that analytical protocols are not a major cause of single crystal age dispersion.

Experiments on temporally equivalent volcanic eruptions indicate that mid-Tertiary units that differ by as little as 10-20 ka can be accurately delineated, however, challenges remain in determining what part, if any, of a dispersed dataset yields an accurate eruption age.


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