American Mineralogist, Volume 93, pages 784–795, 2008

Precise dating of biotite in distal volcanic ash: Isolating subtle alteration using $^{40}Ar/^{39}Ar$ laser incremental heating and electron microprobe techniques

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Abstract

Precise dating of K-rich minerals in volcanic rocks via the $^{40}Ar/^{39}Ar$ geochronometer has become crucial to resolving many geological problems. In some cases, ash beds containing biotite phenocrysts but lacking sanidine are the only datable horizons at key stratigraphic intervals, necessitating comparison of sanidine and biotite ages within the same chronostratigraphic framework. To assess the integrity of biotite and evaluate the accuracy of ages obtained from this often problematic mineral, incremental heating $^{40}Ar/^{39}Ar$ experiments were performed on large, millimeter-sized, euhedral biotite crystals from four key Eocene tuffs in the Green River and Wind River Basins and are compared with sanidine $^{40}Ar/^{39}Ar$ ages. Unaltered biotite crystals with homogenous K-compositions from two tuff beds yielded concordant plateau ages that are indistinguishable from cogenetic sanidine ages. In contrast, biotite crystals from two other tuffs yielded discordant spectra, with relatively young initial steps followed by older, down-stepping apparent ages. Plateau ages from the discordant experiments are older than the sanidine ages by 1 to 14%. Integrated (total fusion) ages from these experiments exhibit scatter toward both younger and older ages that correlate with the degree of spectral discordance. Electron microprobe transects reveal that biotite crystals yielding discordant age spectra contain 1–10 μm thick K-depleted (<8% K_2O) alteration zones along internal cleavage planes that are absent in biotite crystals yielding concordant age spectra. We propose that these altered zones promote open-system behavior. Phenomena such as loss of K or $^{40}Ar^*$, $^{39}Ar_K$ recoil into internal K-depleted phases, and $^{39}Ar_K$ recoil entirely out of internally corroded biotite crystals are all potential mechanisms that can be related to this alteration. Due to the presence of these multiple potential pathways that promote the gain or loss of isotopes, such altered biotite crystals are unsuitable for high-resolution $^{40}Ar/^{39}Ar$ dating, comparisons with sanidine ages, or calibration of the geomagnetic polarity timescale.

Keywords: Biotite, sanidine, $^{40}Ar/^{39}Ar$, recoil, Bridger Formation, Wagon Bed Formation, Wind River Formation, EPMA, tephra, tuff, volcanic ash