40Ar/39Ar systematics in an exhumed ultra-high pressure terrane: implications for the timing of exhumation

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40Ar/39Ar dating of white mica is commonly used to elucidate the timing of cooling of metamorphic rocks. Single
grain fusion and spot muscovite and/or phengite data from mafic eclogites and their host gneisses in the Nordfjord
region of the Western Gneiss Complex, Norway, show that apparent ages may vary significantly both between and
within grains from within the same sample.

Calculated 40Ar/39Ar phengite ages of 440-750 Ma from mafic eclogites are significantly older than previously
reported U-Pb zircon constraints on the timing of peak pressure metamorphism in the region (ca. 400-405 Ma).
These apparent “old” ages are readily attributable to excess argon contamination and metamorphic evolution of the
white mica in an environment in which efficient removal of Ar from the grain boundary is hindered by a lack of
fluid and/or suitable permeability.

The calculated 40Ar/39Ar age range in phengites and muscovites from the felsic host gneisses is from ca. 385
to 420 Ma, spanning the timing of peak metamorphism. Numerical modeling of Ar diffusion in an open system,
constrained by previously reported pressure-temperature-time data for the Nordfjord region, suggests that a 2-
4 Ma age range should be expected for the measured grain size distribution (0.5-2mm diameter) and expected
uncertainties on the cooling rate (10-50°C Ma⁻¹). The 15-35 Ma range of calculated ages in each sample is
instead most readily reconciled with a model of limited within-sample permeability during exhumation, causing
heterogeneously distributed Ar grain boundary concentrations and differences in apparent 40Ar/39Ar age on a <cm
scale. Most of the host gneiss samples yield similar “youngest” apparent 40Ar/39Ar ages of 387-385 Ma. These
apparently youngest grains may be those that contain the least excess Ar and hence may represent the most likely
timing corresponding to the “true” open system cooling age.

The entire dataset suggests a 15-10 Ma timescale for exhumation of the Western Gneiss Complex in Nordfjord
from mantle to mid-crustal depths. The combination of high spatial resolution 40Ar/39Ar data and numerical mod-
eling based on independent pressure-temperature-time data provides great potential for unraveling the complexities
of metamorphic exhumation. In contrast, step-heating experiments may only yield an average apparent age, poten-
tially leading to an over-estimation of the timing of cooling and hence cooling rates.