Decay-constant uncertainties of ^{40}K and the $^{40}Ar/^{39}Ar$ age equation

JAMES K.W. LEE

Department of Geological Sciences and Geological Engineering, Queen's University, Kingston, Ontario, Canada K7L 3N6 (lee@geol.queensu.ca)

Inconsistencies between mineral dates from the same rocks using different isotopic systems have necessitated a careful reassessment of the accuracy and precision of some radioactive decay constants. ^{40}K undergoes a branched decay in 3 currently recognized modes: (1) electron capture to ^{40}Ar, with corresponding decay constant λ_e; (2) positron decay to ^{40}Ar (λ_p); and (3) beta decay to ^{40}Ca ($\lambda_ß$). In earth science, the currently accepted values of the ^{40}K decay constants [$\lambda_{e+p} = 0.581\pm0.004 \times 10^{-10}$ a^{-1} and $\lambda_ß = 4.962\pm0.009 \times 10^{-10}$ a^{-1}, yielding a total decay constant $\lambda = 5.543\pm0.010 \times 10^{-10}$ a^{-1} (1σ)] were adopted by convention [Steiger and Jäger, (1977) EPSL 36:359 (SJ)] and are based solely on an earlier compilation of experimental data by Beckinsale and Gale (1969) [EPSL 6:289 (BG)]. However, in nuclear physics, the currently accepted values (ENSDF 2000) are $\lambda_{e+p} = 0.595 \times 10^{-10}$ a^{-1} and $\lambda_ß = 4.884 \times 10^{-10}$ a^{-1}, with $\lambda = 5.479 \times 10^{-10}$ a^{-1}. As has been recently discussed [e.g. Renne et al. (1998) Science 282: 1840], severe filtering of the experimental data by BG has primarily led to these differences.

A statistical analysis of the experimental data used by BG shows that the quoted decay constant uncertainties are too optimistic, since they include only uncertainties associated with the measurement errors of the activities of the various decay modes. A full error-propagation analysis of the ENSDF data incorporating uncertainties in all fundamental parameters including the atomic masses and abundances (f_{39}, f_{40}, f_{41}) of the K isotopes shows that decay-constant uncertainties should be about 5 times greater that those quoted by BG [$\lambda_{e+p} = \pm0.015 \times 10^{-10}$ a^{-1}, $\lambda_ß = \pm0.049 \times 10^{-10}$ a^{-1}, with $\lambda = \pm0.052 \times 10^{-10}$ a^{-1} (1σ)]. Of the total variance associated with λ, 67% comes from the uncertainty in f_{40}, 26% from the measured $ß^-$ activity, and 7% from the electron-capture activity. A comparison of uncertainties shows that the error in an $^{40}Ar/^{39}Ar$ age <u>solely</u> due to decay-constant errors monotonically increases from 0 Ma to ±14 Ma (1σ) at 4.6 Ga for BG but to ±49 Ma (1σ) for ENSDF. Of this error, the uncertainty associated with λ_{e+p} typically accounts for 90-100% of the total decay-constant error. Finally, differences in the ^{40}K decay constants between BG/SJ and ENSDF result in age differences ranging from 2.4% at 5 Ma to 0.13% at 4.6 Ga, reaching a maximum age difference of 20 Ma at ~2 Ga. As valid comparisons between different isotopic systems must include decay-constant errors, it is clear that significant improvements to ^{40}K decay-constant and $^{40}Ar/^{39}Ar$ age uncertainties can be made by more accurate and precise determinations of: (a) the atomic abundance of ^{40}K, and (b) the decay constants of ^{40}K, with particular attention to reducing the uncertainty in λ_e.

Comparative Thermal Models for Subduction Zones: evaluation of Slab Contributions to Volcanic Arc Magmas

W.P. LEEMAN[1], S. HUANG[1], AND S. TONARINI[2]

[1]Dept. Earth Science, Rice University, Houston, TX USA (leeman@rice.edu)
[2]Inst. Geoscienze e Georisorse, CNR, Pisa, Italy

We present numerical models comparing the thermal structure of representative SZs with varied geometry, convergence rates (V_c), slab ages (A), etc. The models incorporate actual slab geometry, and thermal contributions from radiogenic heating and induced mantle convection, and allow us to contrast temperatures below the respective volcanic arcs and to assess relative roles of slab melting and fluid evolution in the formation of associated primitive arc lavas.

Absolute Ts depend heavily on inferred thickness of the 'static' lithosphere lid (t_L), which controls the depth to which heating by wedge convection is significant. This effect was evaluated numerically. MLR analysis allows extrapolation of our model results to other SZs for which A, V_c, and t_L can be inferred. Predicted slab surface temperatures (SSTs) at 100 km depth vary widely (~300-700ºC) between arcs.

Rarely in modern SZs do temperatures approach melting conditions for subducted materials, and then only if water-saturated conditions occur. Thus, melting of modern slabs is considered unlikely if extensive dehydration occurs at shallower depths. In the absence of melting, the principal slab contribution to arc magma sources is water-rich fluid, which may carry significant quantities of solute material. Below arcs, the extent of this contribution should vary inversely with SST. Using the element boron as a tracer of slab-derived fluids, we find that both its enrichment relative to non-fluid-mobile elements (e.g., B/Zr) and its isotopic composition ($\delta^{11}B$) are inversely correlated with predicted SST. These relations can be used to assess relative fluid contributions, or to predict $\delta^{11}B$ in those fluids. Also, the association of B-poor lavas with the warmest SZs implies melt contributions from warm convecting mantle wedge material.