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Comment

Comment on the “Joint determination of ^{40}K decay constants and ^{40}Ar*/^{40}K for the Fish Canyon sanidine standard, and improved accuracy for ^{40}Ar/^{39}Ar geochronology” by Paul R. Renne et al. (2010)

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Since the call by Begemann et al. (2001), several authors (see e.g., Min et al., 2000; Nägler and Villa, 2000; Grau Malonda and Grau Carles, 2002; Kwon et al., 2002; Trieloff et al., 2003; Kossert and Günther, 2004; Krumrei et al., 2006; Mundil et al., 2006; Schwarz and Trieloff, 2007a,b; Renne et al., 2010) have contributed to the discussion of whether – and if so, in which way – the convention of constants used for K–Ar and Ar–Ar dating by Steiger and Jäger (1977) needs to be reevaluated.

Recently, Renne et al. (2010) presented a new evaluation of the ^{40}K decay constant and the branching ratio for the dual decay into ^{40}Ar by electron capture and ^{40}Ca by β^- decay. Their results are partially based on values for the ^{40}K decay constant from two liquid scintillation counting (LSC) experiments of Grau Malonda and Grau Carles (2002) and Kossert and Günther (2004). An important – though easily overseen – point in these two studies is that the calculated total decay constant in LSC measurements depends on a specifically adopted branching ratio P_β/P_{ec} of the probabilities for β^- decay to ^{40}Ca and electron capture (ec, including both possible decays, electron capture to the ground state and electron capture followed by γ emission) to ^{40}Ar (89.14/10.86%, Kossert and Günther, 2004; 89.3/10.7%, Grau Malonda and Grau Carles, 2002) and a certain ^{40}K/K ratio of 0.01167(2)% (Garner et al., 1975). The result of the total decay constant obtained by LSC changes when different branching and ^{40}K/K ratio(s) are adopted for calculations, since the counting efficiency of LSC experiments is significantly lower for the ec branch than for the beta branch (approx. 0.13 against 0.997). This intrinsic dependency is shown in Fig. 1: for example, a relative decrease in the probability for the ec branch of about 1% leads to a total decay constant that is lower by about 0.1%, when using the same ^{40}K/K ratio of 0.01167. Therefore, the statements in Section 2.4 about the activity data from Grau Malonda and Grau Carles (2002) and Kossert and Günther (2004) and the resulting combined decay constant in Renne et al. (2010) as well as the sentence on page 5356: “Rather, miscalibration of λ_β in the opposite sense is suggested, consistent with the previously discussed LSC data which indicate a $\sim$0.22% larger value ($5.555 \times 10^{-10}\ a^{-1}$) of λ_{tot} than that ($5.543 \times 10^{-10}\ a^{-1}$) recommended by Steiger and Jäger (1977)” are not correct. The decay constant calculated by Kossert and Günther (2004) of $5.554 \times 10^{-10}\ a^{-1}$ ($t_{1/2} = 1.248(3)$ Ga) would decrease to approx. $5.534 \times 10^{-10}\ a^{-1}$, when using the decay branches of 89.52/10.48% recommended by Steiger and Jäger (1977) and down to approx. $5.528 \times 10^{-10}\ a^{-1}$ when using the branching ratio evaluated by Renne et al. (2010) (89.63/10.37%), see Fig. 1. Both values would be significantly lower, than the result of $5.5492 \times 10^{-10}\ a^{-1}$ of Renne et al. (2010). A similar consideration based on the LSC result from Grau Malonda and Grau Carles (2002) can be drawn.

The discrepancy elucidated here between values for the total decay constant obtained by the different methods of Kossert and Günther (2004) and Renne et al. (2010) might be due to an incorrect ^{40}K/K ratio, which would also change the ^{40}K decay constant from Kossert and Günther (2004), or it could be a consequence of insufficient calibration of the value presented by Renne et al. (2010) for the following reason. An important part of the geochronologi-

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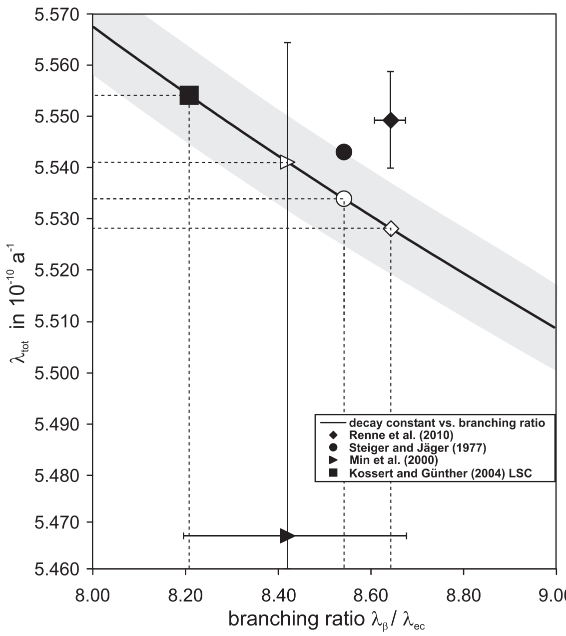

Fig. 1. Dependence of λ_{tot} on adopted branching ratios $\lambda_\beta/\lambda_{ec}$, based on the LSC activity data of Kossert and Günther (2004), with 95% confidence band for the decay constant data. Filled symbols represent original data from literature in which both the branching ratio and the total decay constant were reported. Open symbols display the recalculated LSC values for certain branching ratios from literature. The new value proposed by Renne et al. (2010) is inconsistent within the reported uncertainty (1.7‰).

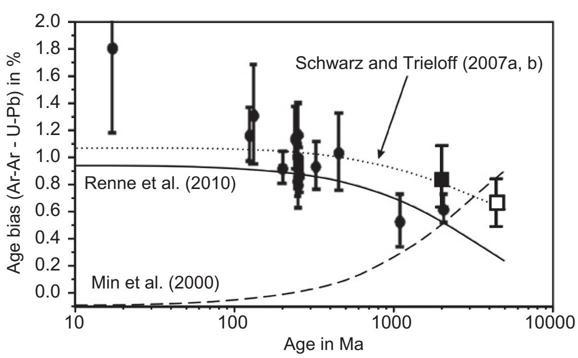

Fig. 2. Age bias of Ar–Ar and U–Pb ages. Correlation lines calculated with different sets of partial decay constants λ_β and λ_{ec} (see text) and $^{40}K/K$ ratios: 1.1672×10^{-4} (Renne et al., 2010), 1.167×10^{-4} (Schwarz and Trieloff, 2007a,b) and 1.17×10^{-4} (Min et al., 2000). The closed circle points are data from Renne et al. (2010), the open square point from H chondrites: Trieloff et al. (2003), Göpel et al. (1994) and Taylor et al. (1987); closed square point from Vredefort impact structure: Trieloff et al. (1994) (Ar–Ar age) and Kamo et al. (1996) (U–Pb age).

cal approach calibrating the partial and total decay constants is the systematic age discrepancies between Ar–Ar ages – using the Steiger and Jäger convention – and U–Pb ages (referred to below as "bias") of samples of varying age. In respect thereof, it is important to note that two independent partial decay constants (i.e. both λ_β and λ_{ec}) must be calibrated, and that the relative contributions cannot be resolved unless the Ar–Ar and the U–Pb age bias is precisely evaluated for samples of very different absolute ages. Fig. 2 demonstrates this circumstance in detail: the calibration curve calculated from the λ_β and λ_{ec} pair presented in Renne et al. (2010) is drawn (solid line). Additionally two further lines were plotted exemplarily, which have been suggested as revised constants in the recent decade (Min et al., 2000; Schwarz and Trieloff, 2007a,b) showing the potential difference for decay constants and calibration curves. The curve by Min et al. (2000) is upward shaped, as they revised λ_β rather than λ_{ec} downwards (see also Fig. 1 in Renne et al. (2010)). The downward-shaped curves by Schwarz and Trieloff (2007a,b) and Renne et al. (2010) result from decreasing λ_{ec} and/or increasing λ_β. It clearly can be seen, that the decay constant(s) calculation is very sensitive for samples with higher ages, especially for the β-branch and both young and old samples are needed to evaluate the precise shape of the curves. For example, samples up to 500 Ma old – like most data presented by Renne et al. (2010) – are well suited to determine the absolute offset, but not necessarily the branching ratio itself. The latter can only be clearly evaluated by comparing the bias (between Ar–Ar and U–Pb data) at ages greater than 1 Ga (see Fig. 1 in Renne et al. (2010)). Here, only 2 data points are presented by Renne et al. (2010) – the oldest being approx. 2.1 Ga.

The bias data between Ar–Ar and U–Pb ages in Fig. 2 are shown from the literature. The closed circle points are from data presented in Renne et al. (2010). The closed square symbol is from Trieloff et al (1994) (Ar–Ar age) and Kamo et al. (1996) (U–Pb age) for the Vredefort impact structure in South Africa of approx. 2 Ga age and the open square point from Trieloff et al. (2003) and Göpel et al. (1994) for the H chondrite parent body cooling (approx. 4.5 Ga ago). The H chondrite data point is actually the result of a set of U–Pb–Pb and Ar–Ar-age data, as well as metallographic (e.g., Taylor et al., 1987) and ^{244}Pu fission track cooling rates of several rapidly and slowly cooled chondrites, for which the cooling history is known with high precision and consistent with a theoretical parent body cooling model (Trieloff et al., 2003). The presence and abundance of ^{244}Pu fission tracks in the phosphate merrillite (with retention temperatures as low as 390 K) furthermore excludes any significant secondary reheating of these H chondrite samples, a circumstance that is not ascertained for many terrestrial samples, even if these are rapidly cooled. All in all, the cooling history for the H chondrite parent body is one of the best known and provides a highly relevant data point for the calibration of the ^{40}K decay constant(s).

Both rapidly and slowly cooled H chondrites yielded an age bias of about 30 Ma (approx. 0.65%) between the K–Ar and U–Pb system at a total age of 4.5 Ga. Calculating the bias of a 4.5 Ga old sample with constants presented in Renne et al. (2010) yields 13 Ma (only 0.28% of the Ar–Ar–U–Pb bias), only consistent at a 3σ uncertainty level for the 30 Ma bias (including the uncertainty of the decay constant given in Renne et al. (2010)). The aforementioned data for the Vredefort impact structure result in an offset by

17 Ma (approx. 0.85%) at 2 Ga age. Hence, inclusion of these values (plotted in Fig. 2) in the calculation of Renne et al. (2010) would change the decay parameter set towards a lower total decay constant and a slightly higher ec and/or a lower β branch. This would much better fit the recalculated total ^{40}K decay constant from Kossert and Günther (2004), using the specific branching ratio(s) mentioned above.

Thus, it is evident that the new ^{40}K decay constant presented in Renne et al. (2010) should not be used for calculation in Ar–Ar dating before these issues are clarified and before a general consensus is reached on a new ^{40}K decay constant including an official recommendation by the Subcommission on Geochronology. It should be also clear that an independent determination of the branching and ^{40}K/K ratios (e.g., Nägler and Villa, 2000) is necessary before comparing geochronological (Ar–Ar versus U–Pb ages) and physical data, e.g., by means of LSC measurements.

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