ISSN 0016-7029, Geochemistry International, 2006, Vol. 44, No. 10, pp. 1041–1047. © Pleiades Publishing, Inc., 2006.
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SHORT COMMUNICATIONS

Systematic Differences between U–Pb and ^{40}Ar/^{39}Ar Dates: Reasons and Evaluation Techniques

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Received June 16, 2004

DOI: 10.1134/S0016702906100090

INTRODUCTION

Progress recently achieved in the development of mass spectrometric equipment made it possible to significantly improve the accuracy of radioisotopic dating. For example, the errors of U–Pb and ^{40}Ar/^{39}Ar dates quoted in various publications are often 0.1–0.2% of the age values or, sometimes, even lower. However, these errors are purely analytical and do not involve the uncertainties in the decay constants of the parent isotopes. The errors of the decay constants are systematic when age values obtained by the same techniques are compared, and, thus, these errors can be neglected. However, to accurately compare the data of different dating methods, the researcher should include these errors in the calculation of the overall errors of the age values. Nevertheless, the overwhelming majority of publications present radioisitopic dates with their analytical errors alone, while the actual error can be much greater than these values. In this context, a good illustrative example was published in [1], in which the U–Pb zircon dating of rhyolite from the Keweenawan Province yielded a concordant age of 1097.6 ± 2.1 Ma, whereas the ^{40}Ar/^{39}Ar dating of feldspar from the same rock yielded an age value of 1088.4 ± 4.0 Ma (the ^{40}Ar/^{39}Ar age is quoted relative to a K–Ar age of 98.79 ± 0.96 Ma for the Ga-1550 standard and was calculated using the ^{40}K decay constants approved by the Subcommission on Geochronology of the International Union of Geological Sciences in 1976 [2]). At first thought, these dates seem to be different, but, with regard for all systematic errors stemming from the uncertainties in the decay constants assumed for ^{40}K, ^{238}U, and ^{235}U [2] and the error in determining the *J* parameter for the ^{40}Ar/^{39}Ar method (which follows from the error in the K–Ar age of 98.79 ± 0.96 Ma for the GA-1550 standard), the U–Pb and ^{40}Ar/^{39}Ar ages appear to be statistically indistinguishable: 1097.6 ± 5.3 and 1088.4 ± 15 Ma, respectively [1]. As can be

Table 1. ^{40}K radioactive decay constants

Constant	Reference				
	[2]* according to data from [3]	[5][2*]	[1] according to data from [3]	[1] according to data from [4]	[6][3*]
	Year of publication				
	1977	1997	2000	2000	2002–2003
λ_{β^-} (10^{-10} yr^{-1})	4.962 ± 0.009	4.845 ± 0.015	4.950 ± 0.086	4.884 ± 0.099	n.d.
λ_{Ar} (10^{-10} yr^{-1})	0.581 ± 0.004	0.5814 ± 0.015	0.580 ± 0.017	0.580 ± 0.014	n.d.
λ (10^{-10} yr^{-1})	5.543 ± 0.010	5.428 ± 0.068	5.530 ± 0.097	5.463 ± 0.107	5.54 ± 0.09[4*]
$\beta = \lambda/\lambda_{Ar}$	9.540 ± 0.068	9.34 ± 0.27	9.53 ± 0.33	9.42 ± 0.29	n.d.

Note: λ_{β^-} and λ_{Ar} are the constants of ^{40}K transformation into ^{40}Ca and ^{40}Ar, respectively; n.d. means not determined.

* Values adopted in Earth sciences for age calculations.

[2*] Values quoted in physical reference literature.

[3*] Experimental data of the latest two counting experiments that are completely consistent.

[4*] Recalculated for the ratio ^{40}K/K = 1.17 ± 0.02 × 10^{-4}.

seen, the major contribution to the error of the age is made by the decay constants.

In fact, the situation with ^{40}Ar/^{39}Ar (as well as K–Ar) dates is even worse. Now geochronologists can use four sets of decay constants published for ^{40}K (Table 1). It is known that the constants used in earth sciences should be revised, because they were calculated from obsolete values of the ^{40}K/K ratio ($1.167 \pm 0.002 \times 10^{-4}$) and the Avogadro constant [1]. Moreover, a statistically more justified approach proposed to take into account the scatter of the measured K activity and the ^{40}K/K ratio ($1.17 \pm 0.02 \times 10^{-4}$) that are used in the calculations of the constants results in four- to tenfold greater errors than those assumed in compliance with the 1976 convention (Table 1). Physical and chemical reference literature quotes decay constants based on other amounts of original experimental data [4–5]. All of these values were calculated from the results of a limited number of counting experiments, all of which were conducted before 1966. A higher value for the total decay constant ($\lambda = 5.554 \pm 0.013 \times 10^{-10}$ yr^{-1}) was obtained experimentally in 2002–2003 [6]. This value was, however, calculated with ^{40}K/K = $1.167 \pm 0.002 \times 10^{-4}$, and if the more conservative value of ^{40}K/K = $1.17 \pm 0.02 \times 10^{-4}$ [1, 5], which is characterized by a higher error, is assumed, the total decay constant becomes equal to $5.54 \pm 0.09 \times 10^{-10}$ yr^{-1}, in compliance with the data of earlier publications (Table 1).

Returning to the example of rhyolite from the Keweenawan Province and to the aforementioned considerations concerning the ^{40}K decay constants, it becomes obvious that the actual error in determining the ^{40}Ar/^{39}Ar age of this rhyolite is 1.5 times higher than the seemingly conservative value of 15 Ma. This highlights a paradoxical situation: if the expected duration of a geologic event is small compared to the age of this event, it is senseless to compare the ^{40}Ar/^{39}Ar dates with the dates obtained for the same event by other radioisotopic methods, because the overall error of the age value can appear to be greater than the duration of this event itself. In a general sense, this problem pertains to all radioisotopic methods [7].

The decay constants for ^{238}U and ^{235}U were determined with the lowest errors, and, thus, it was recommended to refine the decay constants used in other radioisotopic methods on the basis of U–Pb dating [2]. In this publication, we compare the ^{40}Ar/^{39}Ar and U–Pb dates of rocks from the same complexes to demonstrate the existence of systematic differences between these age values, which seem to be related to the overestimation of the total decay constant assumed for ^{40}K.

AGE CALCULATION BY THE ^{40}Ar/^{39}Ar AND U–Pb GEOCHRONOLOGICAL METHODS

Theoretically, the dependence between ^{40}Ar/^{39}Ar and U–Pb dates obtained for the same samples can be of complicated nonlinear character due to certain specifics of the methods. U–Pb ages are calculated by the following three ways:

$$^{238}t = \frac{1}{\lambda_{238}} \ln\left(\frac{^{206}\mathrm{Pb}^*}{^{238}\mathrm{U}} + 1\right), \qquad (1)$$

$$^{235}t = \frac{1}{\lambda_{235}} \ln\left(\frac{^{207}\mathrm{Pb}^*}{^{235}\mathrm{U}} + 1\right), \qquad (2)$$

$$\frac{^{207}\mathrm{Pb}^*}{^{206}\mathrm{Pb}^*} = \frac{\exp(\lambda_{235}t) - 1}{\exp(\lambda_{238}t) - 1} \times \frac{1}{137.88}, \qquad (3)$$

where λ_{235} and λ_{238} are the decay constants of ^{235}U and ^{238}U, and the superscript symbol * marks radiogenic Pb. If zircon or baddeleyite are used for dating, all measured Pb is radiogenic. The data are analyzed on a concordia–discordia diagram. A reliable crystallization age is assumed to be equal to either the concordant values or those derived from the discordia of "high quality". The dating of zircon or baddeleyite from Phanerozoic rocks often yields near-concordant ages (particularly, if the uncertainties of the decay constants for uranium isotopes are ignored [8]). The most reliable age is evaluated by Eq. (1). If other minerals (for example, perovskite) are dated, the measured values of Pb isotopes should be corrected for the isotopic composition of so-called common Pb. This introduces additional uncertainties into the dating results. When stony meteorites are dated, the measured Pb values are corrected for the primordial Pb isotopic composition or isochron techniques are applied. Detailed discussions of the methodical and methodological problems, such as the contamination of meteorites with terrestrial material, inherited zircon in terrestrial rocks, etc., which arise during U–Pb dating, lie outside the scope of this publication. It should only be mentioned that, in spite of all difficulties, the U–Pb geochronological method is one of the most reliable dating tools.

Errors in the ^{238}U and ^{235}U decay constants differently contribute to the results obtained by the three U–Pb geochronometers when they are used to calculate concordant ages [8]. For simplicity, I ignore these errors when U–Pb and ^{40}Ar/^{39}Ar dates are compared in this publication.

An ^{40}Ar/^{39}Ar age is calculated in compliance with the following scheme:

$$t = \frac{1}{\lambda} \ln\left(J \frac{^{40}\mathrm{Ar}^*}{^{39}\mathrm{Ar_K}} + 1\right), \qquad (4)$$

$$J = [\exp(\lambda t_s) - 1] / \left[\frac{^{40}\mathrm{Ar}^*}{^{39}\mathrm{Ar_K}}\right]_s, \qquad (5)$$

$$t_c = \frac{1}{\lambda}\ln\left(\beta\left[\frac{^{40}\mathrm{Ar}^*}{^{40}\mathrm{K}}\right]_s + 1\right), \tag{6}$$

where λ is the total ^{40}K decay constant, β is the ratio of the decay constants of ^{40}K into ^{40}Ca and ^{40}Ar (branching ratio) (Table 1), and the subscript index s denotes the age and isotopic ratios in the standard mineral that was irradiated together with the sample selected for dating, and the index * indicates radiogenic Ar in the sample and the standard mineral.

Let x denote $[^{40}\mathrm{Ar}^*/^{39}\mathrm{Ar}_K]$, y denote $[^{40}\mathrm{Ar}^*/^{39}\mathrm{Ar}_K]_s$, and z denote $[^{40}\mathrm{Ar}^*/^{40}\mathrm{K}]_s$ and let Eqs. (5) and (6) substitute into Eq. (4)

$$t = \frac{1}{\lambda}\ln\left(\beta\frac{xz}{y} + 1\right). \tag{7}$$

It can now be seen that uncertainties in the ^{40}K decay constant contribute equally to the age values calculated by the ^{40}Ar/^{39}Ar and K–Ar methods. In addition to uncertainties in the ^{40}K decay constant, errors can be of analytical nature, related to the determination of the $[^{40}\mathrm{Ar}^*/^{40}\mathrm{K}]$ ratio and ^{40}K concentration in the standard mineral (i.e., due to the analytical errors in the determination of the K–Ar age of the standard mineral). Because of this, papers often present different age values for the same standard minerals. In this situation, the ^{40}Ar/^{39}Ar data can be made consistent by means of a modified age equation (see, for example, [9])

$$^{A}t = \frac{1}{\lambda}\ln\left[\left(\frac{\exp(\lambda^{A}t_s) - 1}{\exp(\lambda^{B}t_s) - 1}\right)(\exp(\lambda^{B}t) - 1) + 1\right]. \tag{8}$$

Below, for the sake of the mutual consistency of all of the ^{40}Ar/^{39}Ar dates, they are recalculated with respect to the refined K–Ar age of the GA-1550 standard (98.5 ± 0.8 Ma) [9] or the ages of other standards that are consistent with this value (see [9–10] for discussion of the problem of the standards and error propagation).

SELECTION OF ^{40}Ar/^{39}Ar AND U–Pb DATES FOR COMPARISON

Table 2 reports U–Pb and ^{40}Ar/^{39}Ar dates for coeval complexes of terrestrial rocks. Most of the dates lie within the range from the Late Permian to Early Triassic, because this age span was thoroughly examined in relation to the mass extinction of the Earth's biota and active volcanism [11–19]. The only data on the Precambrian pertain to the Keweenawan rhyolite, whose ^{40}Ar/^{39}Ar date was proved to correspond to the crystallization age of this rock [1]. The data on the Cenozoic pertain to the Fish Canyon tuff, for which numerous age values were obtained by various methods [1, 9, 10, 20–22 and references therein]. The average of the four K–Ar dates available for these tuffs is equal to 27.53 ± 0.15 Ma, which is somewhat lower than the ^{40}Ar/^{39}Ar age of 28.10 ± 0.04 Ma obtained by these authors for sanidine relative to the K–Ar age of 98.5 Ma for the GA-1550 standard [9]. The ^{40}Ar/^{39}Ar age obtained previously for sanidine and calculated relative to the same standard age is 27.94 ± 0.16 Ma [11]. The reason for the difference between the K–Ar and ^{40}Ar/^{39}Ar dates of the Fish Canyon tuff remains obscure.

In addition to the ages of terrestrial rocks, some U–Pb and ^{40}Ar/^{39}Ar dates for the Acapulco achondrite were used [23, 24]. This stony meteorite was examined specifically to test the consistency of its ^{40}Ar/^{39}Ar and U–Pb ages [24].

The U–Pb ages of the Acapulco achondrite and the Precambrian rhyolite from the Keweenawan Province are underlain by Eq. (3) [1, 23]. All U–Pb dates of Phanerozoic samples [12–14], except only two values, are based on Eq. (1). The U–Pb zircon dates for the Meishan type section and the Fish Canyon tuff are concordant age values [11, 22]. I used only ^{40}Ar/^{39}Ar dates whose plateau age values were justified, i.e., whose K–Ar isotopic system was proved closed. The only exception is the date on phlogopite from a mineralized intrusion of the Emeishan traps [16]. The phlogopite yielded a sub-plateau spectrum whose age interpretation is ambiguous. The limited segment of the spectrum selected in [16] corresponds to an age of 256.5 ± 0.3 Ma, but if a greater number of steps is examined, this value can be changed by a few hundred thousand years. Inasmuch as this difference is not principal, we left the original interpretation of the age spectrum.

COMPARISON OF ^{40}Ar/^{39}Ar AND U–Pb DATES

The results of comparison between U–Pb and ^{40}Ar/^{39}Ar dating are presented in the form of $\delta t = [^{Ar-Ar}t/^{U-Pb}t - 1] \times 100$ (Table 2). It can be seen that the δt of Permian–Triassic complexes are negative, except only the values for the Arydzhanskaya suite of the Siberian flood basalts, with a weighted mean equal to –0.89 ± 0.09%. If the Arydzhanskaya suite is excluded, the weighted mean for δt changes insignificantly (–0.90 ± 0.1%). The δt values for the Acapulco achondrite, Keweenawan rhyolite, and the Fish Canyon tuff do not statistically differ from this average (Table 2); i.e., the differences between the U–Pb and ^{40}Ar/^{39}Ar dates remain constant, within the analytical errors, throughout the practically whole geological time span. The deviation of the Arydzhanskaya suite from the general tendency seems to be caused by the fact that its dating on perovskite requires a correction for the isotopic composition of common Pb (Fig. 1).

The analytical error of the K–Ar age of the GA-1550 standard is 0.8%. If the upper limit of the K–Ar age of this standard is assumed, its U–Pb and ^{40}Ar/^{39}Ar dates become practically indistinguishable. The weighted mean δt value for all dates in Table 2 (without the Arydzhanskaya suite) is equal to –0.14 ± 0.09%, but the

Table 2. Comparison of U–Pb and ^{40}Ar/^{39}Ar data on the same geological formations

Locality	U-Pb (Ma)	Reference	^{40}Ar/^{39}Ar (Ma)	Reference	δ*t* (%)
Section D, Meishan, China	251.4 ± 0.3^{z}	[11]	249.0 ± 0.15^{s}	[15]	-0.96 ± 0.13
Mineralized intrusions, ET	259 ± 3^{z}	[12]	256.5 ± 0.3^{ph}	[16]	-0.96 ± 1.15
Norilsk 1 intrusion, ST	$251.2 \pm 0.3^{z,\ b}$	[13]	249.5 ± 1.5^{bt}	[17]	-0.70 ± 0.61
Upper part of the Meymecha vertical section, ST	251.1 ± 0.3^{z}	[14]	$249.1 \pm 0.3^{\dagger\ ph}$	[18]	-0.82 ± 0.17
			249.5 ± 1.2^{bt}	[19]	-0.66 ± 0.49
Guli small intrusions, ST	250.2 ± 0.3^{b}	[14]	247.2 ± 2.1^{pl}	[19]	-1.22 ± 0.85
Bolgokhtokhskaya intrusion, ST	228.9 ± 0.3^{z}	[14]	$226.8 \pm 0.8^{£\ bt}$	[19]	-0.91 ± 0.37
Arydzhanskaya suite, ST	251.7 ± 0.4^{pv}	[14]	252.4 ± 2.6^{wr}	[18]	$+0.29 \pm 1.04$
Weighted mean for Permian and Triassic formations					-0.89 ± 0.09
Weighted mean for Permian and Triassic formations without the Arydzhanskaya suite					-0.90 ± 0.10
Fish Canyon tuffs, United States	$28.42 \pm 0.02^{§z,\ t}$	[20, 21, 22]	28.10 ± 0.04^{s}	[9]	-1.06 ± 0.16
			27.94 ± 0.16^{s}	[10]	-1.64 ± 0.57
Weighted mean for the Fish Canyon tuffs					-1.10 ± 0.15
Acapulco achondrite	4557 ± 2	[23]	4520 ± 18^{pl}	[24]	-0.81 ± 0.40
Palisade rhyolite, Keweenawan	1097.6 ± 2.1^{z}	[1]	1085.1 ± 4.0^{s}	[1]	-1.14 ± 0.41
Weighted mean for all					-0.95 ± 0.08
Weighted mean for all without the Arydzhanskaya suite					-0.95 ± 0.08

Note: ET—Eimenshan traps, China; ST—Siberian traps, Russia; † weighted mean of eight measurements; $^{£}$ weighted mean of two measurements; § weighted mean of four measurements; superscript indices ^{z}, ^{b}, ^{t}, and ^{pv} denote U–Pb age values on zircon, baddeleyite, titanite, and perovskite, respectively; superscript indices ^{pl}, ^{s}, ^{ph}, ^{bt}, and ^{wr} denote ^{40}Ar/^{39}Ar age values on plagioclase, sanidine, phlogopite, biotite, and whole rock, respectively. All dates were calculated with conventionally adopted decay constants according to [2]. Only analytical errors are reported, uncertainties in the decay constants of U and K isotopes are neglected, as also are the errors in the determination of the K–Ar age of the standard minerals used in the ^{40}Ar/^{39}Ar dating to determine the *J* parameter. The ^{40}Ar/^{39}Ar dates are reported relative to the K–Ar age of the Ga-1550 standard equal to 98.5 Ma.

difference between the ^{40}Ar/^{39}Ar and K–Ar dates of the Fish Canyon tuff, thereby, increases. Thus, the systematic difference between ^{40}Ar/^{39}Ar and U–Pb dates cannot be explained only by the inaccuracy of the used K–Ar age values for the GA-1550 standard.

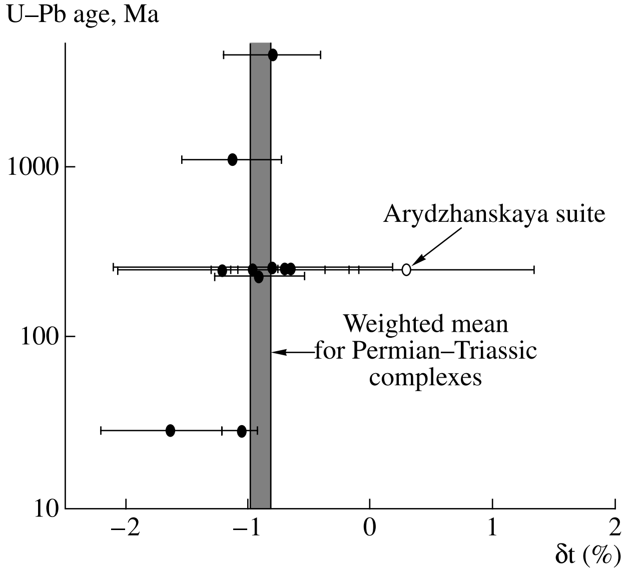

Fig. 1. Variations in δt relative to the U–Pb age of dated rocks (based on the data of Table 2).

The insignificant decrease in the δt value of the Fish Canyon tuff relative to the δt of the Permian–Triassic complexes can be accounted for by hypothetical apparent overestimation of U–Pb ages [1, 9, and references therein] and also by the inaccuracy of the assumed β constant [2]. The difference between the U–Pb and ^{40}Ar/^{39}Ar ages of Cenozoic rocks can be eliminated if this value is slightly decreased.

It seems to be impossible to explain the systematic difference by the loss of radiogenic Ar, because older samples should have greater Ar losses. Moreover, the samples selected for the comparison presumably had closed K–Ar systems. The author additionally used dates obtained for various minerals with different ranges of their closure temperatures (Table 2). In view of these considerations, the most plausible explanation of the constancy of the δt value within a broad range of age values is that the ^{40}K total decay constant used for the calculation of ^{40}Ar/^{39}Ar (K–Ar) ages is overestimated. The use of a value of 5.49×10^{-10} yr^{-1} instead of the conventional value of 5.543×10^{-10} yr^{-1} [2] results in nearly zero values of the δt for all of the aforementioned rocks (except only the Arydzhanskaya suite of the Siberian flood basalts). The K–Ar age of the Fish

Canyon tuff, thereby, increases from 27.53 to 27.9 Ma and approaches the U–Pb age of this rock (Table 2). The ^{40}K total decay constant of 5.49×10^{-10} yr^{-1}, which is consistent with U–Pb dates, is 0.9% lower than the value utilized to calculate age values in compliance with the convention [2] and lies within the range of the latest experimental values (Fig. 2).

DISCUSSION

The approach applied in this research to evaluate the ^{40}K decay constant is not mathematically rigorous and is employed here, first of all, to demonstrate that systematic differences between U–Pb and ^{40}Ar/^{39}Ar (K–Ar) dates at the scale of analytical errors do exist. In other words, this work is aimed at attracting attention to the problem of the inconsistencies between the ^{40}K decay constants assumed in geochronology (according to the convention [2]) and the actual values. This problem was first clearly formulated when a method was developed for the dating of continuous sedimentary sequences with the use of the astronomic calibration. It was hypothesized in earlier papers devoted to astronomic dating that the ^{40}K total decay constant can be 5–7% overestimated [25]. Later, an age of 28.15 ± 0.19 Ma was proposed for the Fish Canyon tuff based on the comparison of the ^{40}Ar/^{39}Ar and astronomic dates [26]. This value does not statistically differ from that quoted in this paper, i.e., points to an overestimate in the ^{40}K total decay constant [2] by 0.9%.

The method of astronomic calibration is underlain by the assumption that the cyclicity of sedimentation depends on variations in the Earth's orbital parameters (precession and eccentricity). It is traditionally believed that these orbital parameters of the Earth are the main factors controlling its climate, including the periodicity of glaciations (Milankovitch's hypothesis). With regard for the variability of the sedimentation rate, sedimentary sequences are "tuned" to fit calculated orbital parameters using paleoclimatic markers found in the sediments. However, the universal applicability of this assumption to oceanic sediments was questioned lately. In particular, warming sometimes occurred earlier than was predicted based on orbital data [27] and the data could be erroneously "tuned" [28]. In other words, the method of astronomic calibration itself requires experimental testing and validation. Nevertheless, the greater reliability of this method for Late Cenozoic is assumed *de facto,* as can be seen from the principles underlying the stratigraphic chart [29].

The refinement of the ^{40}K decay constant by comparison with U–Pb dates was carried out in [1, 24]. For example, based on the results obtained on the Acapulco achondrite [24], the conclusion was drawn that the decay constants reported in [5] are more accurate. This conclusion was later criticized because the age values newly obtained for the Acapulco achondrite were inconsistent with its thermal history, and with the thermal histories of other achondrites [30] as well. It was admitted in [30] that the ^{40}K decay constants may be lower than those reported in [2] but higher than in [5]. In fact, the insignificant discrepancies between the values of the ^{40}K total decay constants recommended in [24] and here are caused by different values of the K–Ar ages for the used mineral standards.

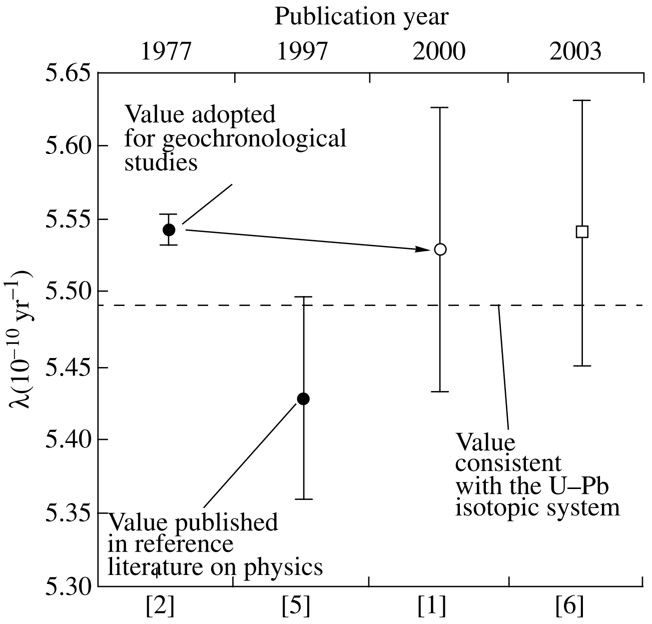

Fig. 2. ^{40}K total decay constants recommended in the literature compared with the value consistent with the U–Pb isotopic system. Solid circles—constant conventionally used in Earth sciences and physics; open circles—constant in [2] recalculated with the refined values of the K atomic weight, ^{40}K/K ratio, the Avogadro constant [1], and the statistically justified error; open square—two recently obtained experimental values that are mutually fully consistent.

Below I discuss some implications of the systematic underestimations of ^{40}Ar/^{39}Ar dates. In thermochronological studies, U–Pb dates are usually interpreted as the crystallization age of a magmatic body, and the ^{40}Ar/^{39}Ar ages are thought to correspond to the time when the K–Ar system closed. The differences between these dates are used to calculate the cooling rate of the body. This approach is accurate only if all systematic errors of the U–Pb and ^{40}Ar/^{39}Ar dating are taken into account and otherwise can result in misleading conclusions.

Let us consider an example randomly selected from the literature. The U–Pb and ^{40}Ar/^{39}Ar methods were applied to date the same dike that cuts across the Dufek layered intrusion in the Ferrar igneous province [31]. The crystallization age of the dike was evaluated at 182.7 ± 0.4 Ma using concordant U–Pb zircon dates. The weighted mean of two ^{40}Ar/^{39}Ar determinations is equal to 180.3 ± 2 Ma (in recalculation with respect to a

K–Ar age of 98.5 Ma for the GA-1550 standard). Proceeding from the small difference between the U–Pb and ^{40}Ar/^{39}Ar dates, the cooling rate was calculated to be equal to 100 °C/Ma (the original ^{40}Ar/^{39}Ar date relative to a K–Ar age of 520.4 Ma for the Mmhb-1 standard was 179 ± 2 Ma [24]). However, the value of δt for these dates occurs to be as low as –1.3 ± 1.1%. This value does not differ from the systematic difference between the U–Pb and ^{40}Ar/^{39}Ar dates reported in that paper. In other words, the cooling rate was calculated inaccurately.

The simultaneous utilization of the results of the U–Pb and ^{40}Ar/^{39}Ar dating methods is quite common in the publications of national researchers [32–34 and others]. Thereby the ^{40}Ar/^{39}Ar dates are usually reported relative to the K–Ar age of the MGA-11 standard, which is consistent with the K–Ar age of 127.8 Ma for the LP6 standard (A.V. Travin, personal communication). If the age value of 127.5 Ma is used for the LP6 standard, which is consistent with an age of 98.5 Ma for the GA-1550 standard [9], the dates published in [32–34] should be decreased by 0.2%; i.e., the ^{40}Ar/^{39}Ar dates [32–34] should also become systematically lower than the U–Pb dates. However, this hypothesis can be tested only after the MCA-11 standard is calibrated, and, until then, ^{40}Ar/^{39}Ar dates based on the MCS-11 standard can be compared with U–Pb dates only if all systematic errors are taken into account.

It should be emphasized that the publication of ^{40}Ar/^{39}Ar dates without specifying the standard relative to which they were measured and its assumed age can lead to the principal impossibility of the further comparison of the results.

CONCLUSIONS

^{40}Ar/^{39}Ar dates calculated relative to the K–Ar age of 98.5 Ma for the GA-1550 standard are systematically (by 0.9%) lower than the respective U–Pb dates, with this difference remaining virtually unchange throughout the practically whole geological time. If the adopted decay constant of U isotopes are accurate enough, then the most probable reason for the systematic differences between the dates should be the overestimation of the λ value for the ^{40}K total decay constant. A decrease in this parameter by approximately 0.9% relative to the value approved by the Subcommission on Geochronology at the International Union of Geological Sciences [2] in 1976 leads to consistency between U–Pb and ^{40}Ar/^{39}Ar dates if the latter are calculated relative to a K–Ar age of 98.5 Ma for the GA-1550 standard. ^{40}Ar/^{39}Ar dates calculated relative to other age values of this standard or relative to any ages of other standards calibrated against the GA-1550 standard can also be easily made consistent with U–Pb dates. To reveal the potential nonlinearity between ^{40}Ar/^{39}Ar (K–Ar) and U–Pb dates and to statistically reasonably refine the decay constants of U and K isotopes, specialized geochronologic research should be carried out with the use of the same samples with a broad range of age values.

ACKNOWLEDGMENTS

This research was financially supported by the Foundation for the Support of National Science. Constructive criticism expressed by the anonymous reviewer helped me to improve the text of the manuscript.

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