CA-GMT-912-3

Union Science & Technology Division
Union Oil Company of California
376 South Valencia Avenue
P. O. Box 76, Brea, California 92621
Telephone (714) 528-7201

-COPY-

CONFIDENTIAL

union 76

E&P GEOL 82-51

January 26, 1982

Mr. Alex Schriener
Santa Rosa, California

ALEX SCHRIENER
JAN 28 1982

Dear Alex:

K/Ar AGES FOR SAMPLES FROM
MEDICINE LAKE, CALIFORNIA

I am writing this letter in light of our discussions of problems in the interpretation of K/Ar data supplied by Geochron Labs. In reporting age data, Geochron does two things wrong. Firstly, they have retained use of the old "Western" decay and concentration constants, while almost everyone else has switched to the new IUGS constants. Secondly, Geochron attaches unrealistic uncertainties to their ages. This second annoying practice is particularly misleading, for it makes any Geochron K/Ar age look good, regardless of problems with contamination. In order to avoid any ambiguity, it is always a good idea to recalculate ages supplied by Geochron. I will use the diorite(?) from the Medicine Lake area (your sample #ML-2-750) as an example of the recalculation exercise.

The first thing to do is to recalculate the age based on the new IUGS constants. Notice that Krueger uses the following constants: $\lambda_b = 4.72 \times 10^{-10}$ yr-1, $\lambda_e = 0.585 \times 10^{-10}$ yr-1, and $^{40}K/K = 1.22 \times 10^{-4}$ g/g. This last concentration constant is given in terms of weights. This is equivalent to $^{40}K/K = 1.19 \times 10^{-4}$ mol/mol. Table 1 in the enclosed Research Note (Dalrymple, 1979) shows that Geochron is still using the old "Western" decay and concentration constants, so the conversion to new constants is very straightforward. Dalrymple's Table 2 shows that to calculate the correct age, one needs to multiply the "old" date by 1.02666. This yields a "new" corrected date of 7.2 m.y. Notice that this "new" date is not very different from the "old" one. Because you are generally working with such young rocks, the 2.7% age correction is not very important. You may find, however, that correcting all of your ages to the new constants will help when you are trying to compare age data for rocks dated by different labs.

Now that we have the corrected age of 7.2 m.y., let us attach a realistic uncertainty to it. There are two principal origins of this uncertainty: (1) statistical uncertainty in the analyses, and (2) contamination by atmospheric ^{40}Ar. In practice, the second of these problems is by far the most important and this is the uncertainty which is entirely ignored by Geochron.

Furthermore, in hydrothermally altered or weathered samples this ^{40}Ar contamination is almost always severe, so the uncertainty in the age will almost always be larger than that cited by Geochron. Daniel Krummenacher of San Diego State University's Isotope Geology Institute is aware of this problem and he uses the following graph to determine his age corrections:

± ADDED TO AGE:	0.2%	0.5	1.0	1.4	3	6	8	18	40	100	(in % of age)
% ATMOSPHERIC AR:	10%	20	30	40	60	70	80	90	95	98	

Geochron's lab report indicates that the amount of radiogenic ^{40}Ar is 0.039 and 0.061 (2 analyses). By averaging these values (0.05), it is clear that only 5% of the total ^{40}Ar is radiogenic and that 95% of the ^{40}Ar is atmospheric. Reference to the above graph indicates that the uncertainty of this age should be ± 40% of the age, or ± 2.9 m.y. (67% confidence level). We can, therefore, declare a 67% confidence that the true age of this rocks is 7.2 ± 2.9 m.y. To be more confident (95%), we can double the 1 sigma uncertainty. We will be right 19 out of 20 times if we say the rock is 7.2 ± 5.8 m.y. old.

In practice, Bob Varga and I have found that any rock containing greater than 80% atmospheric argon is likely to yield an erroneous K/Ar age. One can avoid this problem in hydrothermally altered terrains by dating large numbers of samples, and by culling those data which do not conform to the general picture (especially if atmospheric ^{40}Ar exceeds 80%). In light of the geological difficulties implied by the 7.2 m.y. date for the sample from the Medicine Lake area, my recommendation is to disregard the date entirely.

Our final bit of immediate business concerns the K/Ar dating of the obsidian sample from Medicine Lake (your sample number ML-1-570). I have arranged for this sample to be analyzed at the Isotope Geology Institute, San Diego State University. I expect to be able to phone you with this data no later than February 5, 1982.

Thanks again for the pleasant and informative tour of the Geysers. I hope that we can get together and do some work which will have a practical payoff in the future. Good health to you, your wife, and your impending proto-Schriener.

Regards,

Brian M. Smith

Brian M. Smith

BMS:ds

RESEARCH NOTE

Critical tables for conversion of K-Ar ages from old to new constants

G. Brent Dalrymple
U.S. Geological Survey
345 Middlefield Road
Menlo Park, California 94025

In 1976, the IUGS Subcommission on Geochronology recommended that a new set of decay and abundance constants be adopted for the calculation of K-Ar ages (Table 1; Steiger and Jager, 1977). These new constants are now used by nearly all K-Ar laboratories.

Prior to the 1976 IUGS recommendation, there were primarily two sets of old constants in use. Nearly all laboratories in the Western world used the ^{40}K decay constants recommended by Aldrich and Wetherill (1958) and the ^{40}K abundance of Nier (1950); these values are given in the column headed "Western" in Table 1. Most K-Ar ages in the Russian literature were calculated using a different value for $\lambda_\epsilon + \lambda'_\epsilon$, and the Western values for λ_β and $^{40}K/K_{total}$; these values are given in the column headed "Russian." For discussions of the origins of these various constants, see Nier (1950), Aldrich and Wetherill (1958), Wetherill (1957, 1966), Beckinsale and Gale (1969), Garner and others (1975), and Steiger and Jager (1977).

The effect of the new constants is nonlinear, so conversion of ages from one set of constants to another is not straightforward. For example, an age calculated with the new IUGS constants is 2.7% older than one calculated with the old Western constants at 1 m.y., but is 1.7% younger at 4,500 m.y. Thus recomputation is required for each age, a troublesome and time-consuming task for most geologists.

Tables 2 and 3 have been prepared as an aid for the rapid and easy conversion of K-Ar ages calculated with either set of old constants to ages based on the new IUGS constants. An "old" age multiplied by the indicated correction factor will give the "new" age (example 1). The tables are arranged as critical tables, and interpolation is not required. Correction factors are given to the nearest 0.02%. For ages that coincide with a tabulated value, use the correction factor on the line above (example 2). The maximum error resulting from use of these tables is 0.01%, which is better than the precision of K-Ar ages by more than two orders of magnitude.

The tables may also be used to convert "new" ages to "old" ages by using the correction factors as divisors (example 3), a procedure that increases the maximum error by only a few thousandths of a percent.

Example 1: Convert an "old" age of 27.7 m.y. to a "new" age (Table 2): 27.7 m.y. × 1.0262 = 28.4 m.y.

Example 2: Convert an "old" age of 108 m.y. to a "new" age (Table 2): 108.0 m.y. × 1.0248 = 110.7 m.y.

Example 3: Convert a "new" age of 825 m.y. to an "old" age (Table 2): 825 m.y. ÷ 1.0128 = 815 m.y.

Tables 2 and 3 do not cover all the published K-Ar ages. Occasionally, the reader may find K-Ar ages in the literature that have been calculated with a different set of old constants than those given in Table 1. These ages may be converted by first calculating a new $^{40}Ar_{rad}/^{40}K$ ratio:

$$\frac{^{40}Ar_{rad}}{^{40}K} = \frac{LK_0(e^{\lambda_0 t} - 1)}{1.167 \times 10^{-4}}, \qquad (1)$$

where L = old $(\lambda_\epsilon + \lambda_\epsilon)/\lambda$, K_0 = old $^{40}K/K_{total}$, λ_0 = old total decay constant $(\lambda_\epsilon + \lambda'_\epsilon + \lambda_\beta)$, and t = old K-Ar age; this new ratio can then be used to calculate the new age T, on the basis of the IUGS constants

$$T = 1.804 \times 10^9 \ln\left(9.541 \frac{^{40}Ar_{rad}}{^{40}K} + 1\right). \qquad (2)$$

Old K-Ar ages that are converted by using Table 2 or Table 3 or equations 1 and 2 will be no more precise than the number of significant digits in the published age. If possible, it is always desirable to recalculate ages using equation 2 and the original analystical data. Users of equation 2 are cautioned that the quantity $^{40}Ar_{rad}/^{40}K$ is an atomic ratio, usually expressed in mole/mole, and that analyses given in weight percent, parts per million, or cubic centimetres STP must be converted to the proper units (Table 4).

TABLE 1. CONSTANTS USED FOR THE CALCULATION OF K-Ar AGES

Constant*	Old		New
	Western	Russian	IUGS
$^{40}K/K$	1.19×10^{-4} mol/mol†	1.19×10^{-4} mol/mol†	1.167×10^{-4} mol/mol
λ_β	4.72×10^{-10} yr^{-1}	4.72×10^{-10} yr^{-1}	4.962×10^{-10} yr^{-1}
$\lambda_\epsilon + \lambda'_\epsilon$	0.585×10^{-10} yr^{-1}	0.557×10^{-10}	0.581×10^{-10} yr^{-1}

*The old constants did not take into account λ'_ϵ; that is, it was assumed to be zero or negligible.

†Sometimes given as 1.22×10^{-4} weight percent, which is equivalent.

GEOLOGY, v. 7, p. 558-560, NOVEMBER 1979

TABLE 2. CRITICAL TABLE FOR CONVERSION OF K-Ar AGES FROM OLD WESTERN CONSTANTS TO NEW IUGS CONSTANTS

Age	F	Age	F	Age	F	Age	F	Age	F	Age	F	Age	F	Age	F	Age	F	Age	F
0		259		555		889		1270		1712		2233		2865		3656		4693	
	1.0268		1.0218		1.0168		1.0118		1.0068		1.0018		0.9968		0.9918		0.9868		0.9818
5		271		568		903		1287		1731		2256		2893		3692		4741	
	66		16		66		16		66		16		66		16		66		16
15		282		580		918		1303		1750		2279		2922		3728		4790	
	64		14		64		14		64		14		64		14		64		14
25		293		593		932		1320		1770		2302		2950		3765		4840	
	62		12		62		12		62		12		62		12		62		12
35		305		606		947		1336		1789		2326		2979		3802		4891	
	1.0260		1.0210		1.0160		1.0110		1.0060		1.0010		0.9960		0.9910		0.9860		0.9810
45		316		619		961		1353		1809		2350		3008		3840		4942	
	58		08		58		08		58		08		58		08		58		08
56		327		632		976		1370		1829		2373		3038		3878		4994	
	56		06		56		06	78	56		06		56		06		56		06
66		339		645		990		1387	55	1849		2397		3068		3916		5049	
	54		04		54		04		54		04		54		04		54		04
76		350		658		1005		1404		1869		2422		3098		3955			
	52		02		52		02		52		02		52		02		52		
87		362		671		1020		1421		1889		2446		3128		3994			
	1.0250		1.0200		1.0150		1.0100		1.0050		1:0000		0.9950		0.9900		0.9850		
97		374		684		1035		1439	49	1909		2471		3159		4034			
	48		1.0198		48		1.0098	[illegible]	48		0.9998		48		0.9898		48		
108		385		697		1050		1456		1930		2495		3189		4074			
	46		96		46		96		46		96		46		96		46		
118		397		710		1065		1474		1950		2520		3221		4115			
	44		94		44		94		44		94		44		94		44		
129		409		724		1081		1491		1971		2546		3252		4156			
	42		92		42		92		42		92		42		92		42		
139		421		737		1096		1509		1992		2571		3284		4198			
	1.0240		1.0190		1.0140		1.0090		1.0040		0.9990		0.9940		0.9890		0.9840		
150		433		750		1111		1527		2013		2597		3316		4240			
	38		88		38		88		38		88		38		88		38		
161		445		764		1127		1545		2035		2622		3348		4283			
	36		86		36		86	54	36		86		36		86		36		
172		457		778		1142		1563	35	2056		2648		3381		4326			
	34		84		34		84	72	34		84		34		84		34		
182		469		791		1158		1581	33	2078		2675		3414		4370			
	32		82		32		82		32		82		32		82		32		
193		481		805		1174		1599		2099		2701		3448		4414			
	1.0230		1.0180		1.0130		1.0080		1.0030		0.9980		0.9930		0.9880		0.9830		
204		493		819		1190		1618		2121		2728		3482		4459			
	28		78		28		78		28		78		28		78		28		
215		506		833		1206		1636		2143		2755		3516		4505			
	26		76		26		76		26		76		26		76		26		
226		518		847		1222		1655	25	2165		2782		3550		4551			
	24		74		24		74	65	24		74		24		74		24		
237		530		861		1238		1674		2188		2809		3585		4597			
	22		72		22		72		22		72		22		72		22		
248		543		875		1254		1693		2210		2837		3620		4645			
	1.0220		1.0170		1.0120		1.0070		1.0020		0.9970		0.9920		0.9870		0.9820		
259		555		889		1270		1712		2233		2865		3656		4693			

Note: To convert an age based on the old Western constants to one based on the new IUGS constants, multiply by the indicated correction factor (F). Ages are in 10^6 yr.

Old Western constants: $\lambda_\varepsilon + \lambda'_\varepsilon = 0.585 \times 10^{-10}$ yr^{-1}, $\lambda_\beta = 4.72 \times 10^{-10}$ yr^{-1}, $^{40}K/K_{total} = 1.19 \times 10^{-4}$ mol/mol.

New IUGS constants: $\lambda_\varepsilon + \lambda'_\varepsilon = 0.581 \times 10^{-10}$ yr^{-1}, $\lambda_\beta = 4.962 \times 10^{-10}$ yr^{-1}, $^{40}K/K_{total} = 1.167 \times 10^{-4}$ mol/mol.

TABLE 3. CRITICAL TABLE FOR CONVERSION OF K-Ar AGES FROM OLD RUSSIAN CONSTANTS TO NEW IUGS CONSTANTS

Age	F	Age	F	Age	F	Age	F	Age	F
		588		1410		2551		4338	
			0.9738		0.9698		0.9658		0.9618
0		624		1458		2620		4457	
	0.9776		36		96		56		16
10		660		1506		2692		4581	
	74		34		94		54		14
39		697		1556		2765		4708	
	72		32		92		52		12
68		734		1606		2839		4841	
	0.9770		0.9730		0.9690		0.9650		0.9610
98		772		1657		2916		4978	
	68		28		88		48		08
128		811		1710		2994		5120	
	66		26		86		46		
158		849		1763		3074			
	64		24		84		44		
189		889		1817		3156			
	62		22		82		42		
220		929		1871		3240			
	0.9760		0.9720		0.9680		0.9640		
252		969		1927		3327			
	58		18		78		38		
284		1011		1984		3415			
	56		16		76		36		
316		1052		2042		3506			
	54		14		74		34		
348		1095		2102		3600			
	52		12		72		32		
381		1138		2162		3696			
	0.9750		0.9710		0.9670		0.9630		
415		1181		2223		3795			
	48		08		68		28		
448		1226		2286		3897			
	46		06		66		25		
483		1271		2350		4003			
	44		04		64		24		
517		1316		2416		4111			
	42		02		62		22		
552		1363		2483		4223			
	0.9740		0.9700		0.9660		0.9620		
588		1410		2551		4338			

Note: To convert an age based on the old Russian constants to one based on the new IUGS constants, multiply by the indicated correction factor (F). Ages are in 10^6 yr.

Old Russian constants: $\lambda_\varepsilon + \lambda'_\varepsilon = 0.557 \times 10^{-10}\ yr^{-1}$, $\lambda_\beta = 4.72 \times 10^{-10}\ yr^{-1}$, $^{40}K/K_{total} = 1.19 \times 10^{-4}$ mol/mol.

New IUGS constants: $\lambda_\varepsilon + \lambda'_\varepsilon = 0.581 \times 10^{-10}\ yr^{-1}$, $\lambda_\beta = 4.962 \times 10^{-10}\ yr^{-1}$, $^{40}K/K_{total} = 1.167 \times 10^{-4}$ mol/mol.

TABLE 4. CONVERSION FACTORS

To convert	To	Multiply by
Weight percent	ppm	10^4
ppm	weight percent	10^{-4}
percent K	percent K_2O	1.205 K_2O/K
percent K_2O	percent K	0.8301 K/K_2O
moles ^{40}Ar/gram	ppm ^{40}Ar	4.000×10^7 gram ppm/mole
moles Ar	cc STP Ar	2.241×10^4 cc STP/mole
cc STP Ar	moles Ar	4.462×10^{-5} mole/cc STP
cc STP ^{40}Ar/gram	ppm ^{40}Ar	1.785×10^3 gram ppm/cc STP
ppm ^{40}Ar	moles ^{40}Ar/gram	2.500×10^{-8} mole/gram ppm
ppm ^{40}Ar	cc STP ^{40}Ar/gram	5.602×10^{-4} cc STP/gram ppm

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ACKNOWLEDGMENTS

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MANUSCRIPT RECEIVED MAY 23, 1979

MANUSCRIPT ACCEPTED SEPT. 4, 1979

KRUEGER ENTERPRISES, INC.
GEOCHRON LABORATORIES DIVISION
24 BLACKSTONE STREET • CAMBRIDGE, MA. 02139 • (617)-876-3691

PRIORITY BASIS
POTASSIUM-ARGON AGE DETERMINATION — REPORT OF ANALYTICAL WORK

Our Sample No. F-6056 — Date Received: 12/30/81

Your Reference: letter of 12/21/81 — Date Reported: 12/31/81

Submitted by: Alex Schriener
Union Oil Co. of Calif.
P.O. Box 6854
Santa Rosa, Calif. 95406

Sample Description & Locality: Chips (cuttings?) of dacite or granodiorite.
Sample ML-2-750

Material Analyzed: Feldspar concentrate, -100/+200 mesh.
Treated with dilute HF and HNO_3 to remove any alterat

Ar^{40*}/K^{40} = .000409 — AGE = 7.0 ± 0.5 M.Y.

Argon Analyses:

Ar^{40*}, ppm.	Ar^{40*}/ Total Ar^{40}	Ave. Ar^{40*}, ppm.
.000762	.039	.000749
.000735	.061	

Potassium Analyses:

% K	Ave. %K	K^{40}, ppm
1.500	1.500	1.830
1.501		

Constants Used:

$\lambda_\beta = 4.72 \times 10^{-10}$/ year

$\lambda_e = 0.585 \times 10^{-10}$/ year

$K^{40}/K = 1.22 \times 10^{-4}$ g./g.

$$AGE = \frac{1}{\lambda_e + \lambda_\beta} \ln\left[\frac{\lambda_\beta + \lambda_e}{\lambda_e} \times \frac{Ar^{40*}}{K^{40}} + 1\right]$$

Note: Ar^{40*} refers to radiogenic Ar^{40}.
M.Y. refers to millions of years.

WEST JORDAN OFFICE

ROCKY MOUNTAIN GEOCHEMICAL CORP.

1323 W. 7900 SOUTH • WEST JORDAN, UTAH 84084 • PHONE: (801) 255-3558

Certificate of Analysis

RMGC Numbers:

Local Job No. 81-37-36-SL

Foreign Job No.:

Invoice No. M 104573

ALEX SCHRIENER
DEC 7 1981

Date: December 3, 1981

Client: Union Oil - Geothermal
1450 Guerneville Road
Santa Rosa, California 95401

Attn: Alex Schriener

Client Order No.: none

Report On: 41 Cutting Samples

Submitted by: Alex Schriener

Date Received: 11/17/81

Analysis: Arsenic, Copper, Zinc and Mercury.

Analytical Methods: Arsenic determined by hydride. Remaining elements determined by atomic absorption.

Remarks:

enc.

cc: file (2)

GJC/lw

KRUEGER ENTERPRISES, INC.
GEOCHRON LABORATORIES DIVISION

24 BLACKSTONE STREET • CAMBRIDGE, MA. 02139 • (617)-876-3691

PRIORITY BASIS

POTASSIUM-ARGON AGE DETERMINATION **REPORT OF ANALYTICAL WORK**

Our Sample No. F-6056 **Date Received:** 12/30/81

Your Reference: letter of 12/21/81 **Date Reported:** 12/31/81

Submitted by: Alex Schriener
Union Oil Co. of Calif.
P.O. Box 6854
Santa Rosa, Calif. 95406

Sample Description & Locality: Chips (cuttings?) of dacite or granodiorite.
Sample ML-2-750

Material Analyzed: Feldspar concentrate, -100/+200 mesh.
Treated with dilute HF and HNO_3 to remove any alterati

Ar^{40*}/K^{40} = .000409 AGE = 7.0 ± 0.5 M.Y.

Argon Analyses:

Ar^{40*}, ppm.	Ar^{40*}/ Total Ar^{40}	Ave. Ar^{40*}, ppm.
.000762	.039	.000749
.000735	.061	

Potassium Analyses:

% K	Ave. %K	K^{40}, ppm
1.500	1.500	1.830
1.501		

Constants Used:

$\lambda_\beta = 4.72 \times 10^{-10}$/ year

$\lambda_e = 0.585 \times 10^{-10}$/ year

$K^{40}/K = 1.22 \times 10^{-4}$ g./g.

$$AGE = \frac{1}{\lambda_e + \lambda_\beta} \ln\left[\frac{\lambda_\beta + \lambda_e}{\lambda_e} \times \frac{Ar^{40*}}{K^{40}} + 1\right]$$

Note: Ar^{40*} refers to radiogenic Ar^{40}.
M.Y. refers to millions of years.

Sample No.	ppm Arsenic	ppm Copper	ppm Zinc	ppb Mercury
ML-2-81 0	3.4	35	25	79
20	4.5	70	60	51
40	1.3	60	45	17
60	0.5	70	55	15
80	0.3	75	60	29
100	2.1	35	25	12
120	1.2	30	20	15
140	1.1	25	15	12
160	0.9	25	25	18
180	0.8	45	50	43
200	1.3	40	40	39
220	1.2	35	35	46
240	1.2	35	30	20
260	1.3	35	35	20
280	0.8	35	25	12
300	0.7	40	30	18
320	0.6	40	40	15
340	0.4	35	25	9
360	0.6	35	25	14
380	0.6	35	20	22
385	0.6	35	20	18
400	3.5	40	20	20
420	3.3	40	20	28
440	3.5	35	20	30
ML-2-81 460	3.7	40	20	84

Client Un.on Oi. - Geo ermal Date 12/3/81 RMGC Job No. 81-37-36-SL

Sample No.	ppm Arsenic	ppm Copper	ppm Zinc	ppb Mercury
ML-2-81 480	3.6	35	15	14
500	3.5	40	15	18
520	3.6	40	15	11
540	3.6	50	20	15
560	3.9	50	20	15
580	0.5	50	20	13
600	3.5	55	25	20
620	3.8	50	20	20
640	3.5	35	25	22
660	3.8	95	25	20
680	3.6	35	20	22
700	3.7	40	25	13
705	3.6	45	30	12
720	3.6	50	30	15
ML-2-81 740	3.8	65	25	16
MSHA-6-12-80	0.8	25	30	26

By Jim Cardwell
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