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The Rb contents of the K-feldspar grains being measured in optical dating

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Abstract: *A value of 400 ± 100 $\mu g{\cdot}g^{-1}$ for the rubidium content of K-feldspar grains is recommended for use in the dose-rate calculation in the absence of more detailed information. The corresponding dose rate is 0.15 ± 0.04 $Gy{\cdot}ka^{-1}$, multiplied by the absorbed energy fraction. This fraction is < 1, even for sand-sized grains, thus calculations of this fraction are needed.*

Introduction

Following suggestions by Mejdahl (1983, 1985), sand-sized K-feldspar grains are often separated and used for dating. A large fraction of the dose rate in such grains arises from the β particles emitted by the potassium within the grains, and Huntley and Baril (1997) earlier recommended the use of a value of 12.5 ± 0.5 % K for calculating the dose rate from this potassium. This recommendation was based on the measurements of the K contents of separated grains, scanning-electron-microscopy element maps to determine the fraction of the grains that were actually K-feldspar, and the observation that grains with the highest K contents gave the most luminescence (Prescott and Fox, 1993; Spooner, 1992).

Mejdahl (1987) pointed out that the β particles emitted by the Rb within the K-feldspar grains also make a significant contribution to the dose rate, and this must also be evaluated. Here we address the question of what Rb content should be assumed in the absence of detailed information.

Rb and K have the same outer electronic structure and very similar ionic radii, and consequently accompany each other during geochemical processes, just as different isotopes of the same element do. Their ionic radii are relatively large and this restricts the lattice sites which they can occupy. The result is that the Rb/K ratios are about the same for different minerals formed from a given magma. With this in mind one could imagine that there would be a universal Rb/K ratio for all rocks and sediments. It is not so.

Smith and Brown (1988, pp.348-353) summarized a large number of Rb analyses of a wide range of feldspars. They observed that K/Rb ratios vary from 4 to 17,000. The reader is referred to this book for detailed summaries for feldspars from various rock types. Our particular interest is restricted to feldspars with high K contents, and for these most Rb contents lie in the range 100-3000 $\mu g{\cdot}g^{-1}$, although values outside this range occur. Mejdahl (1987) reported K and Rb contents for 27 samples of feldspars extracted from pottery, burnt stone and sediments; he found a good linear correlation and suggested using this for estimating Rb contents. For those samples for which the K content was above 10%, the Rb contents were in the range 300-600 $\mu g{\cdot}g^{-1}$, the average being about 400 $\mu g{\cdot}g^{-1}$.

Here we use a different approach to the problem. The method used is similar to that used by Huntley and Baril (1997) to obtain the K-content recommendation, and the samples used are the same ones. In Table I the first four columns list the sample names, K contents of the separated grains, the fraction of the grains that were found to be K-feldspars using scanning-electron-microscopy element maps, and the deduced K contents of the actual K-feldspar grains. These are the same data that appeared in Huntley and Baril (1997).

The next column lists the Rb contents of the separated grains determined by neutron activation analysis. Next we assume that all the Rb is actually in the K-feldspar grains, i.e. that it is not in the quartz or plagioclase grains that are also present in the separates, and use the fractions of column 3 to calculate the Rb contents of the K-feldspar grains. The results are in the column labelled 'Rb in K-feldspar grains'. Some idea of the reproducibility of the technique can be obtained by comparing results from samples which are expected to

sample	K in separated grains wt.% (± 5%)	K-feldspar fraction	K in K-feldspar grains wt.%	Rb in separated grains μg·g-1	Rb in K-feldspar grains μg·g-1	K in whole sample % (± 5%)	Rb in whole sample μg·g-1	11 % x sample Rb ÷ sample K μg·g-1
TTS	4.8	0.44 ± 0.05	10.9 ± 1.2	116 ± 2	264 ± 30	1.08	25 ± 2	255
TTS3	9.05	0.68 ± 0.05	13.3 ± 1.0	158 ± 4	232 ± 18	1.02	28 ± 2	302
CBTS2	9.6	0.68 ± 0.05	14.1 ± 1.0	177 ± 3	260 ± 20	1.01	28 ± 2	305
FHTS-3	4.7	0.35 ± 0.04	13.4 ± 1.7	93 ± 8	266 ± 38	1.12	25 ± 3	246
KHTS-1	5.7	0.46 ± 0.04	12.5 ± 1.2	93 ± 6	202 ± 22	1.11	20 ± 1	198
KHTS-2	3.9	0.28 ± 0.04	13.4 ± 1.7	71 ± 3	254 ± 38	1.24	22 ± 3	195
SW6-01	7.6	0.55 ± 0.05	13.8 ± 1.2	225 ± 4	409 ± 38	1.36	44 ± 2	356
SAW94-32	6.2	0.47 ± 0.05	13.2 ± 1.4	165 ± 4	351 ± 38	1.50	47 ± 2	345
SAW94-37	8.3	0.64 ± 0.04	13.0 ± 0.8	236 ± 4	369 ± 24	1.48	42 ± 2	312
SAW94-62	2.4	0.37 ± 0.05	6.5 ± 0.9	54 ± 3	146 ± 21	1.70	72 ± 7	466
MELVL93-5	10.7	0.74 ± 0.04	14.5 ± 0.8	348 ± 5	470 ± 26	2.19	136 ± 4	683
CPIW	6.0	0.44 ± 0.05	13.6 ± 1.5	233 ± 4	530 ± 61	1.03	39 ± 2	417
TAG2	7.9	0.60 ± 0.06	13.2 ± 1.3	176 ± 4	293 ± 30	1.25	44 ± 2	387
CTL2	2.3	0.15 ± 0.04	15.3 ± 4.0	46 ± 3	307 ± 84	1.55	39 ± 2	277
DY24	11.5	0.93 ± 0.02	12.4 ± 0.3	374 ± 7	402 ± 12	2.28	80 ± 2	386
SN30	11.9	0.97 ± 0.02	12.3 ± 0.3	380 ± 20	392 ± 22	0.57	23 ± 1	444
SN55	11.4	0.96 ± 0.02	11.9 ± 0.3	370 ± 20	385 ± 22	0.59	23 ± 2	429
SN4d	3.4	0.28 ± 0.05	12.1 ± 2.2	109 ± 3	389 ± 70	0.52	19 ± 1	402

Table I: *Column 6 lists Rb contents of the sand-sized K-feldspar grains in grain separates used for optical dating, calculated from measured Rb contents of the separates and the fraction of those grains that are K-feldspars. The last column lists alternative estimates based on the Rb contents of the bulk samples, made as described in the text. The first 6 samples are from tsunami-laid sands from British Columbia and Washington State (Huntley and Clague, 1996; Baril, 1997). Samples SW6-01, SAW94-32 and SAW94-37 are from interdune and dune sands from the Great Sand Hills region of Saskatchewan (Wolfe et al., 2001). Sample SAW94-62 is loess from the base of the Cypress Hills nearby. Sample MELVL93-5 is from the Melville Gap site, California, U.S.A. (Rockwell et al., 2000). Samples CPIW and TAG2 are from a sand wedge and a fluvial deposit respectively from the Mackenzie River delta. Sample CTL2 is from the Coutlee section near Merritt, British Columbia. Sample DY24 is from an aeolian deposit on a terrace by the Lena River near Yakutsk, Siberia. The SN samples are from Sandy Neck, Cape Cod, Massachusetts, U.S.A. (van Heteren et al., 2000)* be similar; these are: samples TTS and TTS3, KHTS-1 and KHTS-2, SAW94-32 and SAW94-37, and the three SN samples.

Most of these Rb estimates lie in the range 200-400 μg·g^{-1}. Our average value is lower than that found by Mejdahl (1987), presumably reflecting differences in our samples. Combining our two data sets, the overall picture that emerges is that a value of 400 ± 100 μg·g^{-1} Rb covers most of the range observed at ± 2σ, and this is the value recommended for the dose-rate calculation if the actual Rb content is not available. With the assumption that all the β energy is deposited within the grains, the dose rate for this concentration of Rb is 0.15 ± 0.04 Gy·ka^{-1}, calculated using the conversion factor of Adamiec and Aitken (1998).

Mejdahl (1987) states that the assumption that all the β energy is absorbed within the grains is valid for grains of 100 μm diameter and larger. This is in contradiction to the equation of Bell (1979, equation 8) from which one deduces that for a 100 μm diameter grain only 57% of the β energy is absorbed by the grain. The average β energy is 0.082 MeV, and the corresponding range is 0.013 g·cm^{-2}, or about 50 μm in feldspar. It is clear that a significant fraction of the energy from β particles originating in a 100 μm diameter grain will be deposited outside that grain, and Mejdahl's statement is untenable. There is a clear need for a proper calculation of the absorbed energy fractions as was done by Mejdahl (1979) for the β particles from K, U and Th.

The last three columns of Table I show the results of an attempt to find out whether or not an estimate of the Rb content can be made using a much simpler method. We return to the idea of a fixed K/Rb ratio for all the minerals from a particular igneous source. The K/Rb ratio of the feldspar grains should then be the same as the K/Rb ratio of the bulk sample. Fig.1 shows a comparison of these two ratios for the present samples. While the expected correlation is found, there is a clear tendency for the K/Rb ratios of the separated grains to be higher than in the bulk sample. The Rb contents of the grains are thus a little lower than would be obtained using the assumption that the ratios were the same. We deduce that the best estimate of the Rb within the K-feldspar grains is calculated as (11 %)(Rb content of the sample ÷ K content of the sample), and these figures are shown in the last column of Table I. A comparison of these Rb content estimates with the determined Rb contents is shown in Fig.2. These estimates seem surprisingly good in view of the assumptions made, and are better than the fixed value for the Rb content suggested above. The figure of 11 % was simply chosen to provide the best fit to the data.

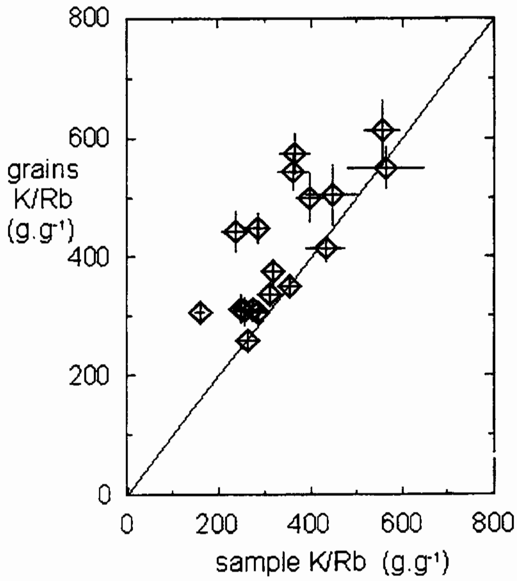

Figure 1.

Comparison of the K/Rb ratio of the separated grains with the K/Rb ratio of the bulk sample. There is a clear tendency for the former to be higher than the latter. The solid line represents perfect agreement.

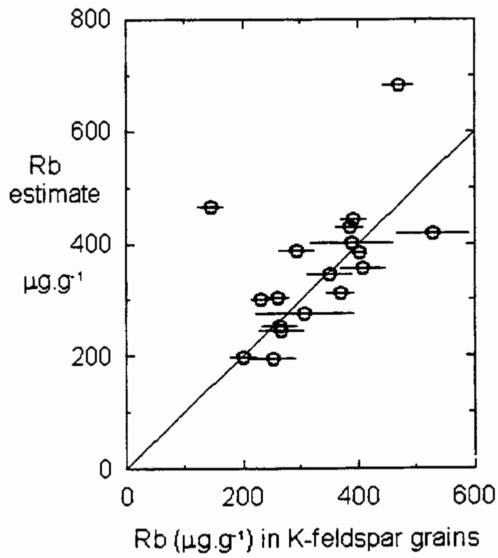

Figure 2.

Comparison of Rb contents of K-feldspar grains as determined by:

abscissa: measurements of Rb contents of the grains themselves

ordinate: an estimate calculated as Rb content of the bulk sediment x(11% ÷ K content of the bulk sediment).

The solid line represents perfect agreement.

If the sediment of interest is derived from a single igneous source, this procedure should yield the Rb contents of all the grains. If, on the other hand, the sediment is derived from two or more sources this procedure would yield an average Rb content, but not necessarily the Rb content of any particular grains, and in particular not necessarily the Rb content of the particular size of K-feldspar grains selected for dating. We note finally that the luminescence being measured is dominated by a small number of the thousand or more grains of an aliquot, and it is possible that these grains have Rb contents that are either higher or lower than typical Rb ones. This is a problem that needs to be pursued.

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