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# TL DATING: ERROR IMPLICATIONS IN CASE UNDETERMINED U-TH CONCENTRATION RATIO IN POTTERY SAMPLES

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## Introduction

Fleming (1976), while summarizing the present state of art of TL dating technique in archaeology, has put the error estimate of TL age determination at ± 7 to 10% contributed by uncertainties in factors such as spurious TL, alpha efficiency, supralinearity, anomalous fading, water uptake and radon escape. In routinue work there is often a tendency to do away with the absolute determination of Th and U impurity contents in the pottery and measure only the gross alpha activity and calculate the dose rates assuming a TH/U weight ratio of about 3.16 (Aitken, 1976); this will be yet another factor contributing to the error limits for the TL age determinations. There is also a practice of assuming the entire alpha activity of the pottery as due to uranium and an error estimate of about 6% is often quoted for the final TL age obtained (Tite, 1968). Aitken and Alldred (1972) assumed that the fraction of total alpha counts which arises from the $^{232}Th$ series is (0.35 ± 0.1) and accordingly have given error limits for their dose rate conversion factors to take care of the uncertainty in Th/U ratio.

In this paper the error in the TL age is estimated when the Th/U ratio is not determined but only the gross alpha count rate is measured from an infinitely thick sample as has been suggested by Tite and Waine (1962); the best value to assume for the Th/U ratio is taken to be that for which the dose rate is the median value between the extreme limits Th/U = 0 and Th/U $=\infty$.

## Dose rate conversions

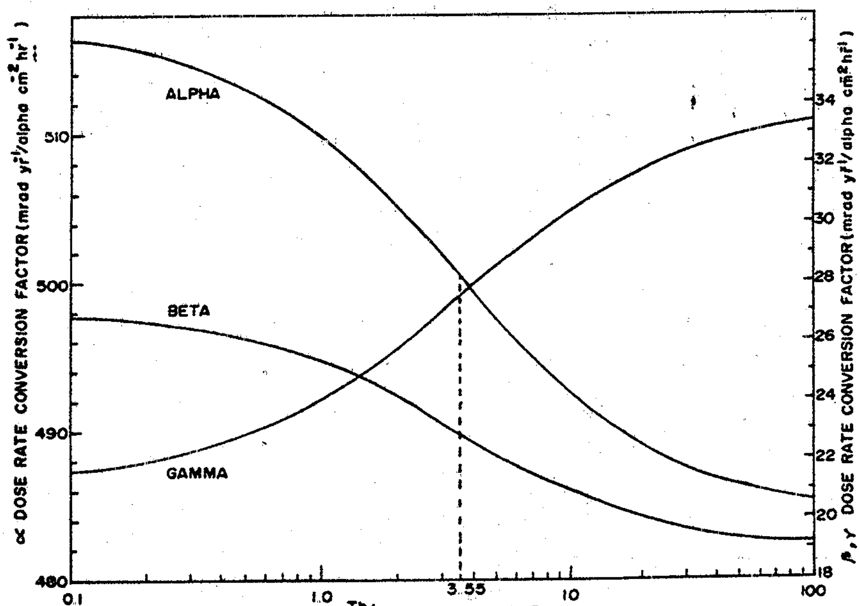
Bell (1976, 1977) has calculated the conversion factors from gross alpha count rates to annual dose rates from alpha, beta and gamma radiation for a typical pottery containing Th and U in the ratio of 3.167. Making use of the same basic data provided by him, calculation of dose rate conversion factors for the gross alpha count rates are made for arbitrary Thorium and Uranium concentrations at Th/U weight ratios covering the entire range $0 \leq Th/U \leq \infty$ and assuming secular equilibrium conditions (Table 1).

In practical applications when a particular gross alpha count rate is obtained on a pottery sample, one is interested to know the conversion factor to be used to obtain the dose rate and the uncertainty involved owing to the unknown relative concentrations of Th and U in the sample. This is best illustrated by a plot of the dose rate conversion factors against Th/U concentration ratio (Figure 1). All the three curves for α, β, and γ approach asymptotically the limiting values corresponding to $0 \leq Th/U \leq \infty$ and the median values for the three components correspond to a Th/U concentration ratio of about 3.55 as shown in the figure. In the absence of a knowledge about the relative concentrations of Th and U when only the gross alpha surface emission rate $C_\alpha$ is known, it then follows that the relevant dose rates ($D_\alpha$, $D_\beta$ and $D_\gamma$) should be obtained as follows:

$$D_\alpha = 500.6\ C_\alpha \pm 3.3\%\ \text{mrad. yr}^{-1} \quad \ldots\ldots\ldots (1)$$
$$D_\beta = 23.0\ C_\alpha \pm 18.3\%\ \text{mrad. yr}^{-1} \quad \ldots\ldots\ldots (2)$$
$$D_\gamma = 27.5\ C_\alpha \pm 22.5\%\ \text{mrad. yr}^{-1} \quad \ldots\ldots\ldots (3)$$

Table 1 Dose rate conversion factors

| U ppm | Th ppm | Th/U | Gross alpha surface emission rate $cm^{-2}\ hr^{-1}$ | Dose rate conversion factors mrad. $yr.^{-1}$ per alpha emitted per $cm^2hr$ | | |
|---|---|---|---|---|---|---|
| | | | | alpha | beta | gamma |
| | | | $C_\alpha$ | $D_\alpha$ | $D_\beta$ | $D_\gamma$ |
| 0.00 | 1.00 | ∞ | 0.1525 | 483.93 | 18.75 | 33.70 |
| 0.01 | 0.30 | 30.0 | 0.0511 | 487.44 | 19.64 | 32.40 |
| 0.10 | 2.00 | 20.0 | 0.3588 | 488.92 | 20.02 | 31.85 |
| 0.10 | 1.50 | 15.0 | 0.2826 | 490.28 | 20.36 | 31.35 |
| 0.10 | 0.90 | 9.0 | 0.1916 | 493.33 | 21.13 | 30.22 |
| 1.00 | 5.00 | 5.0 | 1.3005 | 497.73 | 22.24 | 28.59 |
| 0.50 | 1.50 | 3.0 | 0.4978 | 501.96 | 23.30 | 27.02 |
| 1.50 | 3.00 | 2.0 | 1.2645 | 505.22 | 24.13 | 25.81 |
| 1.00 | 1.00 | 1.0 | 0.6905 | 509.92 | 25.31 | 24.07 |
| 0.50 | 0.30 | 0.6 | 0.3148 | 512.44 | 25.95 | 23.14 |
| 0.40 | 0.12 | 0.3 | 0.2335 | 514.67 | 26.51 | 22.31 |
| 1.00 | 0.00 | 0.0 | 0.5380 | 517.29 | 27.17 | 21.34 |




VARIATION IN DOSE RATE CONVERSION FACTORS FOR VARIOUS Th/U CONCENTRATION RATIOS IN POTTERIES. (THE MEDIAN VALUES FOR THE CONVERSION FACTORS OCCUR WHEN Th/U CONCENTRATION RATIO IS 3.55)

FIGURE 1

The constants in the above equations refer to conversion factors obtained at a Th/U ratio of 3.55 in Figure 1; the extent of variations possible in the conversion factors when the actual Th/U ratio lies anywhere between 0 and $\infty$ are indicated by the percentage factors. At half the given error variations, the Th/U concentration ratio limits correspond to 1.2 and 10.5 as can be seen from the figure and these represent more or less the practical range in which most of the pottery samples can be found to possess the Th and U impurities. Hence for all practical purposes, the errors involved in the dose rate estimates due to uncertainty in the Th/U ratio will be only ± 1.7%, 9.2%, and 11.3% respectively for the $\alpha$, $\beta$ and $\gamma$ components.

The equations arrived at above are of most general applicability and the error limits are significantly different, compared to what can be surmised from the findings of Aitken and Alldred (1972):

$$D_\alpha = 146.0\ C'_\alpha \pm 0.7\%\ \text{mrad. yr}^{-1} \quad \ldots\ldots\ldots \quad (1)$$
$$D_\beta = 6.2\ C'_\alpha \pm 3.9\%\ \text{mrad. yr}^{-1} \quad \ldots\ldots\ldots \quad (2)$$
$$D_\gamma = 8.8\ C'_\alpha \pm 6.8\%\ \text{mrad. yr}^{-1} \quad \ldots\ldots\ldots \quad (3)$$

where $C'_\alpha$ is the gross alpha counts per kilosecond (for a thick source of diameter 42 mm and for 85% counting efficiency) and the constants refer to conversion factors obtained assuming the fraction of the total counts which arises from the $^{232}$Th series to be (0.35 ± 0.1).

## Error in TL age estimates

To calculate the error component in the TL age estimates of pottery samples due to the above recommended dose rate conversion factors for gross $\alpha$ count rate, the two usually adopted TL dating procedures have to be separately considered: (1) In the fine grain dating method, it can be assumed that the archaeologically significant equivalent dose is constituted by a 50% alpha component and a 10% beta component from Th and U chains in equilibrium; (2) In the quartz inclusion dating method, it can be assumed that the archaeologically significantly equivalent dose is constituted by a 25% beta component from the Tb and U chains in equilibrium. The above assumptions are borne out of available published data on a large number of pottery samples (Aitken et al., 1968; Fleming, 1970; Zimmerman, 1971; Aitken et al., 1971; Sasidharan et al., 1975). Accordingly, the error components that will be reflected in the TL age estimate are given below in Table 2.

Table 2 Error component in TL age estimate

| TL dating method | Error component involved in the age estimate if a nominal Th/U weight ratio of 3.55 is assumed for the gross alpha activity | |
|---|---|---|
| | when $0 \leq$ Th/U $\leq \infty$ | when $1.2 \leq$ Th/U $\leq 10.5$ |
| 1. Fine grain method | ± 3.5% | ± 1.8% |
| 2. Quartz inclusion method | ± 4.6% | ± 2.3% |

It is obvious that in rare occasions when there is not much K in a pottery sample, the error component due to uncertainty in Th/U ratio will be substantially more.

## Conclusion

Thus, the calculations presented above lead to the following recommendations for TL age estimations using (Th + U) gross alpha count rates (under secular equilibrium): (1) the dose rate conversion factors to be used for $\alpha$, $\beta$ and $\gamma$ components of (Th + U) present in pottery are respectively 500.6, 23.0 and 27.5 mrad. $yr^{-1}$ per alpha emitted per $cm^2 hr$, and these correspond to a Th/U concentration ratio of 3.55 and (2) the error component appearing in the final TL age estimate due to the above assumption will be ± 4% to 5% for $0 \leq Th/U \leq \infty$ and will be practically only about ± 2% (for $1.2 \leq Th/U \leq 10.5$) in most of the samples.

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