

FISSION-TRACK DATING OF JANKOV MOLDAVITE USING U AND Th THIN FILM NEUTRON DOSIMETRY

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INTRODUCTION

During the last decade most fission-track (FT) age determinations were performed using the zeta calibration (Hurford & Green, 1983). The use of the zeta calibration is a way of overcoming difficulties related with i) uncertainties on the fundamentals (such as the value of the ^{238}U spontaneous fission decay constant or the approach to be adopted for an adequate neutron dosimetry) as well as on parameters related to some experimental procedures (such as the external detector method). However, the zeta calibration makes the FT method dependent on the other isotopic techniques used for dating the age standards used for the determination of the zeta factor. For this reason research on procedures devoted to enable FT dating to be an independent system with an absolute calibration was encouraged (see, for instance, Hurford, 1998).

One of the crucial points in obtaining an absolute system calibration is the neutron dosimetry. Bigazzi et al. (1999) have shown that the use of natural U and Th thin films can be an efficient alternative for a correct neutron dosimetry. In addition, it has been shown that U and Th thin films make it possible to apply the FT method also when only low thermalization irradiation facilities are available, such as in many research nuclear reactors. The International Union of Geological Sciences (I.U.G.S.) had discouraged the use of such facilities (Hurford, 1990), because of the difficulties related to the determination of the contribution of the U and Th fissions induced by epithermal and fast neutrons to the induced track density.

Recently neutron dosimetry based on U and Th thin films was adopted for dating Durango apatite (Iunes et al., 2002), one of the age standards recommended by the I.U.G.S. Subcommittee on Geochronology (Hurford, 1990). Our result, 29.7 ± 1.1 , was consistent with the reference age, 31.4 ± 0.5 , recommended based on other dating methods.

In the present work, the neutron dosimetry based on U and Th thin films was used for dating Moldavite, the central European tektite also recommended as an age standard for glass (Hurford, 1990).

EXPERIMENTAL

Neutron irradiations were performed in three nuclear reactors: IPEN/CNEN – São Paulo, Brazil (irradiation I27MD and I32MD), LENA – Pavia, Italy (irradiation P4MD) and IPEN – Lima, Peru (irradiation L19MD). The sample-set present in these irradiations was made up by Th thin films, natural U doped glasses (Cornig glass CN1 in irradiations I32MD and P4MD, and Cornig glasses CN2 and CN5 in irradiations I27MD and L19MD, respectively) and two Moldavites (MJ1 and MJ2) from the Middle Miocene deposit of Jankov, southern Bohemia (Bouška, 1994). Moldavite MJ1 and MJ2 were included in irradiation I32MD, only MJ1 was included in the other irradiations. Only in case of irradiation I32MD Moldavite samples were pre-heated for 10h at 560°C in order to erase spontaneous tracks.

Agés were computed using the following equation:

$$T = \frac{1}{\lambda} \ln \left[\frac{\left(\frac{\rho_s}{\rho_i} \right) \lambda R_M}{C_{238} \lambda_F} + 1 \right] \quad (1)$$

$$\text{where, } R_M = R_U + \left(\frac{N_{Th}}{N_U} \right) R_{Th} \quad (2)$$

$$\text{where, } R_U = C_{235} A_{235} + C_{238} A_{238}, \quad (3)$$

$$\text{where, } R_{Th} = A_{232} \quad (4)$$

where λ is the ^{238}U α -decay constant; ρ_s/ρ_i is the spontaneous to induced track areal density ratio; C_{235} (C_{238}) is the ^{235}U (^{238}U) abundance in natural U; λ_F is the ^{238}U spontaneous fission decay constant; N_{Th}/N_U is the Th/U ratio of the sample; A_{235} , A_{238} and A_{232} are the number of fissions per ^{235}U , ^{238}U and ^{232}Th target nucleus, respectively. The following values for the constants of equation 1 were adopted: $\lambda = 1.55125 \times 10^{-10} \text{ a}^{-1}$, $C_{238} = 0.99275$ and $\lambda_F = 8.46 \times 10^{-17} \text{ a}^{-1}$. This λ_F value is in close

agreement with a mean of five determinations carried out using a neutron dosimetry based on natural U thin films, $(8.35 \pm 0.24) \times 10^{-17} \text{ a}^{-1}$ (Guedes et al., 2000).

The R_M values used in the present work were computed from the determinations of R_U and R_{Th} , using in equation 2 a Th/U ratio of 4.41 for Jankov Moldavite (Bouška, 1994).

The R_U values were obtained through natural U doped glasses present in the irradiations quoted above. The calibration of these glasses was carried out irradiating them together with natural U thin films (Bigazzi et al., 1999), which played the role of primary calibrators.

The R_{Th} values were obtained through Th thin films, also present in the irradiations (Bigazzi et al., 1999).

RESULTS AND DISCUSSION

Results of age determinations of Moldavites MJ1 and MJ2 from the Jankov deposit are shown in Table 1. These samples showed a certain degree of reduction of the spontaneous track size in comparison with the induced ones ($D_S/D_I < 1$). Reduced track sizes indicate that the glass suffered a certain amount of partial annealing of spontaneous tracks. In this work the Plateau Method introduced by Storzer & Poupeau (1973) was used for correcting thermally lowered ages. For applying this age correction technique, two splits from each sample – one for spontaneous track counting and the irradiated one – were heated for 24h at 350°C. This heating step produced a significant reduction of track densities. The attainment of the plateau condition – an equal revelation efficiency for spontaneous and induced tracks – is proved by the D_S/D_I ratio value that became close to 1.

Considering only the plateau age determinations of irradiation I32MD, the weighted mean of the ρ_S/ρ_I ratios is 0.422 ± 0.019 . Using this value and the R_M value of Table 1, a mean plateau age of $13.31 \pm 0.83 \text{ Ma}$ is computed through equation 1.

For irradiation P4MD two thermal treatments were imposed for the plateau age determinations – 4h and 24 h at 350°C, respectively. In both cases the plateau condition was attained ($D_S/D_I \sim 1$). The weighted mean of the ρ_S/ρ_I ratios is 0.688 ± 0.043 , and the corresponding mean plateau age is $14.2 \pm 1.1 \text{ Ma}$.

Considering the mean ages of irradiations I32MD and P4MD and the ages determined through irradiations L19MD and I27MD as independent determinations, the weighted mean of these four plateau ages is $13.98 \pm 0.58 \text{ Ma}$, with a λ^2 of 2.2 for three degrees of freedom ($p(\lambda^2) \sim 0.50$). In other words, the four independent determinations agree within experimental errors.

The mean value of the plateau FT ages of the Jankov Moldavites studied in this work agree with the mean value of 17 determinations made using the K/Ar and $^{40}\text{Ar}/^{39}\text{Ar}$ methods before 1995 ($14.82 \pm 0.32 \text{ Ma}$; Storzer et al., 1995) and with a recent datum based on several determinations on Moldavites from different sediments, including the Jankov deposit ($14.37 \pm 0.37 \text{ Ma}$, $^{40}\text{Ar}/^{39}\text{Ar}$ method; Laurenzi et al., 2001).

CONCLUSIONS

The age of the Moldavite from the Middle Pliocene deposit of Jankov determined in this work is in close agreement with the more recent independent $^{40}\text{Ar}/^{39}\text{Ar}$ determination made on Moldavites. The results of this work confirm those previously obtained through the analysis of another age standard - Durango apatite - and indicate that a neutron dosimetry based on natural U and Th thin films turns to be a reliable tool to be used for an absolute approach in FT dating.

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Table 1. Fission-track dating of Moldavites from the Middle Miocene deposit of Jankov. R_M is the value computed through equation (2); Heating is the thermal treatment imposed for the plateau age determination; N_S (N_I) and n_S (n_I) are the number of spontaneous (induced) counted tracks and the corresponding number of observed fields of view; $P(\chi^2)$ is the probability of obtaining λ^2 value testing induced track counts against a Poisson distribution; ρ_S (ρ_I) is the spontaneous (induced) track density; D_S / D_I is the σ .
* Values refer to ρ_{S+I} measurements.

Irradiation	R_M ($\times 10^{-9}$)	Sample (Heating)	N_S n_S	$P(\chi^2)$	ρ_S ($\times 10^4 \text{ cm}^{-2}$)	N_I n_I	$P(\chi^2)$	ρ_I ($\times 10^4 \text{ cm}^{-2}$)	D_S / D_I	T (Ma)
I32MD	2.65 ($\pm 4.2\%$)	MJ1 (no heating)	342 80	0.30	1.145 ($\pm 5.4\%$)	577 56	0.50	2.76 ($\pm 4.2\%$)	0.901 ($\pm 3.1\%$)	13.1 \pm 1.0 ($\pm 8.0\%$)
		MJ1 (24h350°C)	515 200	0.20	0.689 ($\pm 4.4\%$)	505 76	0.50	1.788 ($\pm 4.4\%$)	0.991 ($\pm 3.0\%$)	12.23 \pm 0.92 ($\pm 7.5\%$)
		MJ2 (no heating)	950 195	0.50	1.304 ($\pm 5.1\%$)	788 70	0.40	3.01 ($\pm 3.6\%$)	0.876 ($\pm 3.3\%$)	13.66 \pm 0.87 ($\pm 6.4\%$)
		MJ2 (24h350°C)	537 150	0.60	0.959 ($\pm 4.3\%$)	452 60	0.60	2.017 ($\pm 4.7\%$)	0.985 ($\pm 3.5\%$)	15.0 \pm 1.2 ($\pm 7.7\%$)
P4MD	1.733 ($\pm 4.6\%$)	MJ1 (4h350°C)	322 98	0.40	0.880 ($\pm 5.6\%$)	538* 66*	0.75*	1.30 ($\pm 8.2\%$)	0.985 ($\pm 3.2\%$)	14.0 \pm 1.5 ($\pm 10.9\%$)
		MJ1 (24h350°C)	497 177	0.60	0.752 ($\pm 4.5\%$)	835* 122*	0.75*	1.081 ($\pm 6.7\%$)	1.061 ($\pm 3.1\%$)	14.4 \pm 1.3 ($\pm 9.3\%$)
L19MD	0.949 ($\pm 5.2\%$)	MJ1 (24h350°C)	540 193	0.90	0.750 ($\pm 4.3\%$)	627* 133*	0.10*	0.512 ($\pm 11.5\%$)	1.021 ($\pm 2.5\%$)	16.5 \pm 2.2 ($\pm 13.4\%$)
I27MD	1.591 ($\pm 5.3\%$)	MJ1 (24h350°C)	352 127	0.40	0.742 ($\pm 5.3\%$)	923* 145*	0.60*	0.962 ($\pm 7.1\%$)	0.957 ($\pm 3.4\%$)	14.6 \pm 1.5 ($\pm 10.4\%$)