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APPLICATION OF THE FISSION—TRACK—ISOCHRONES METHOD TO ACCESSORY MINERALS OF THE CRYSTALLINE ROCKS OF THE WEST CARPATHIANS

(Figs. 5)

A b s t r a c t: Application of the fission—track isochrones to accessory minerals enables dating of highly inhomogeneous samples in grain—to—grain scale. Method yields a realistic estimate of the uncertainty of the calculated age. A few examples of real apatite and zircon fission—track isochrones are shown.

Р е з ю м е: Апликация трековых изохрон на акцессорические минералы предоставляет датирование высоко негомогенных проб в шкале зерно к зерну. Метод делает возможной реальную оценку при колебании определения вычисленного возраста. Здесь показываем несколько примеров реального апатита и зиркона трековых изохрон.

Introduction

To calculate a fission track age one must determine the density of spontaneous tracks (which depends on the age und uranium content) and the density of neutron—induced tracks (which depends on the uranium content and the neutron dose with the sample was irradiated). If a sample to be dated is homogeneous with respect to its uranium distribution one may split it into two parts — one for the determination of spontanneous tracks and the other for irradiation and determination of induced tracks.

However, nonhomogeneity of uranium distribution is not an exception but a rule a sample of accessory minerals separated from a rock practically each grain shown a different concentration of uranium. If the dispersion on the grain —to—grain scale is serious relying on the averaged values encounters serious problems. This is particularly the case with zircons which are notorious for their nonhomogeneity of uranium.

For such cases the so called external detector method has been developed. A polished sample with etched spontanneous tracks is covered with a sheet of a detector (mica or plastic) and irradiated. After the irradiation the detector is etched and it registers the induced tracks which entered from the mineral. The technique enables grain—by—grain work: for each grain with spontaneous tracks one locates its mirror image in the detector where induced tracks may be counted. Consequently, one may obtain an age for each grain separately.

An age of a sample consisting of a number of small grains examined by the external detector method is obtained either from pooled data (sum of spontanneous tracks sum of induced tracks) or from averaged densities, or else, from averaged ratios.

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Fission-track isochrones

The commonly used simplified formula from which a fission track age is calculated is:

$$t = \frac{p_s \cdot n \cdot \sigma_f \cdot I}{\lambda_f \cdot p_i} \tag{1}$$

where p_s — spontaneous track density, p_i — induced track density, σ_f — cross — section for fission, I — isotopic $^{235}U/^{238}U$ ratio, λ_f — decay constant for spontaneous fission of ^{238}U, n — neutron dose.

Consequently

$$p_s = t \frac{\lambda_f}{\sigma_f \cdot I} \cdot \frac{p_i}{n} \tag{2}$$

which for coeval grains (t = const.) represents a straight line in the p_s versus p_i/n system. Since all the grains within one mount underwent the same irradiation, n may be incorporated into the group of constants, and the system becomes simplified to p_s versus p_i. In the graph each grain is represented by one point with its analytical errors estimated from the Poissonian statistics separately for p_s and p_i. The scatter along the abscissa shows the dispersion of uranium, the values along the ordinate (p_s) depend on the uranium content and the age. Irrespective of the degree of nonhomogeneity of the sample the points representing the crystals of the same p_s/p_i ratio will define a single line which has a meaning of an isochrone. Reliability of the data is indicated by the scatter across the line. The graph may also reveal the cases of mixed populations which may be expected for zircons from some metamorphic rocks.

During the Fission Track Dating Workshop recently held in Pisa (G. Bigazzi, 1980) the track density isochrone plots were presented in three papers, independently by Burchart, Green, and Mailhe and the isochrones shown there were drawn through the origin and the average p_s/p_i ratio. Since then J. Burchart, and J. Kráľ have worked out a procedure of mathematical treatment of data yielding a best — fit line with its errors. The mathematics involved is rather complex and has been adapted from papers by D. York (1967, 1969). Basically it is the least squares regresion procedure but to each point a different statistical weight is assigned (separately for x and y) and also a certain correlation of errors between x and y for each point is taken into account. Our contribution was to scrutinize the sources of analytical errors. Having done this it was possible to modify the computer program based on the York's formulas and prepared by M. J. McSaveney (in G. Faure, 1977) for Rb — Sr isochrones and to adapt it for external detector fission track data.

As a testing material zircons and apatites from the West Carpathian and Caucasus crystalline rocks were taken. A few examples show the method works.

Case 1 (Fig. 1). Large dispersion of uranium distribution on individual apatite grains. Experimental points fairly evenly distributed along the isochrone.

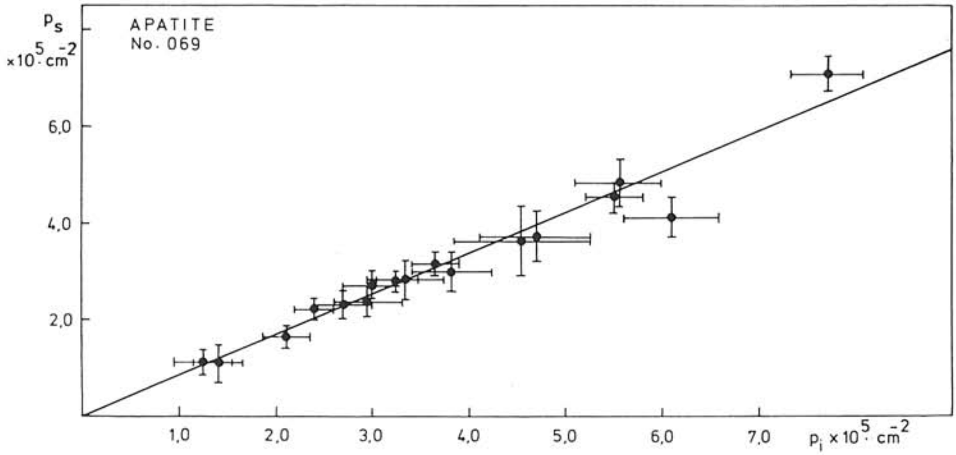

Fig. 1. 17 apatite grains from exotic granitic boulder. Krivá creek, Orava. FT isochrone age: 58 ± 3 m. y. Neutron dose: 2.84×10^{15} n . cm^{-2}. Fission decay constant $\lambda_f = 8.42 \times 10^{-17} . y^{-1}$. Uncertainty of age represents 1 sigma of slope calculated.

Small scatter around the fitted line showing that the actual experimental errors generally do not exceed those predicted from the Poisson statistics. The sample is perfect to dating by the isochrone method.

Case 2 (Fig. 2). Most data points clustered at the low—uranium values with one crystal abnormally rich in uranium. The slope of the fitted line is strongly controlled by this single point. To define a more reliable slope some more U-rich crystals should be looked for and scanned.

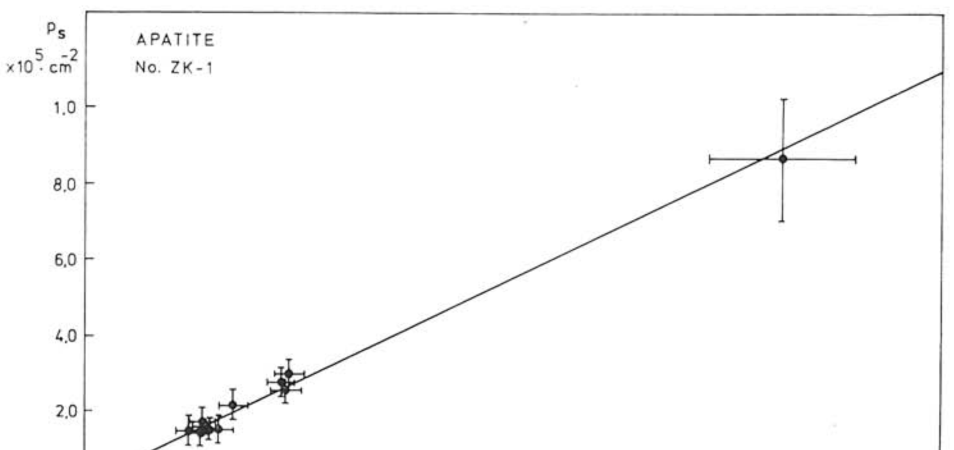

Fig. 2. 11 apatite grains from Tríbeč granit, near Jánova Ves. FT isochrone age 21 ± 1 m. y. Neutron dose: 2.84×10^{15} n . cm^{-2}.

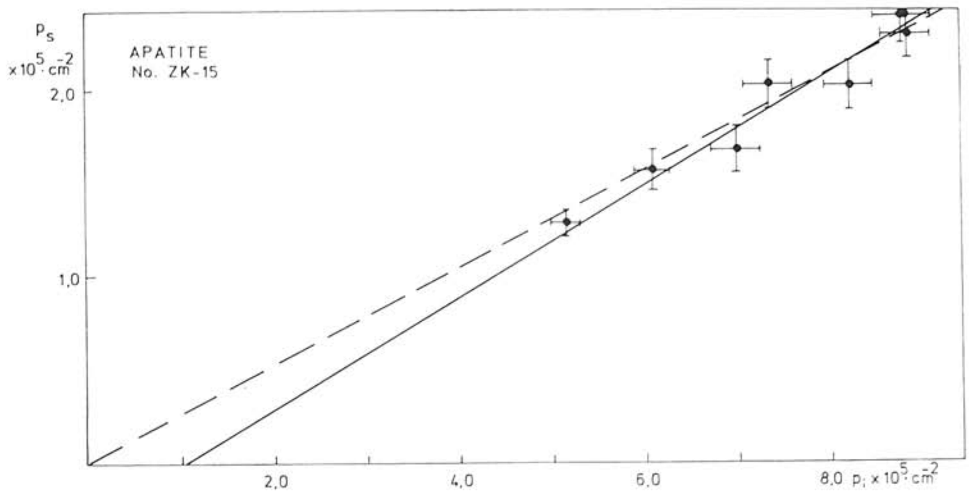

Fig. 3. 7 apatite grains from Považský Inovec Mts. granit. Modrovka. FT isochrone age: 18 ± 2 m. y. (solid line), 16 ± 2 m. y. (dashed line). Neutron dose: 2.07×10^{15} n . cm^{-2}.

Case 3 (Fig. 3). Lack of low—uranium points and a small dispersion of uranium contentresults in a rather poorly defined slope as shown by the negative intercept (solid line). Constrained fit (the line passing through the origin) is shown by the dashed line.

Case 4 (Fig. 4). Some of experimental errors obviously exceed those explained by the Poisson statistics. The suspect points should be checked and, possibly,

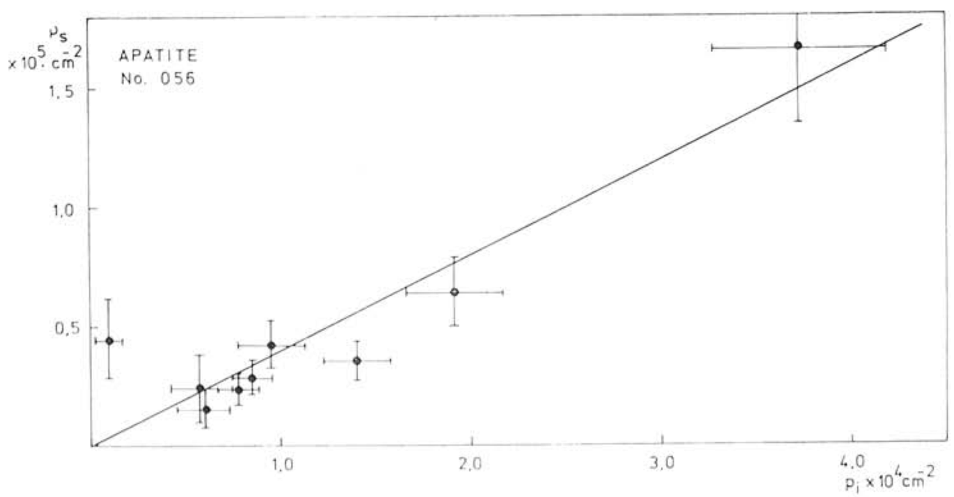

Fig. 4. 9 apatite grains from Caucasus granit. FT isochrone age: 26 ± 5 m. y. Neutron dose: 2.65×10^{15} n . cm^{-2}.

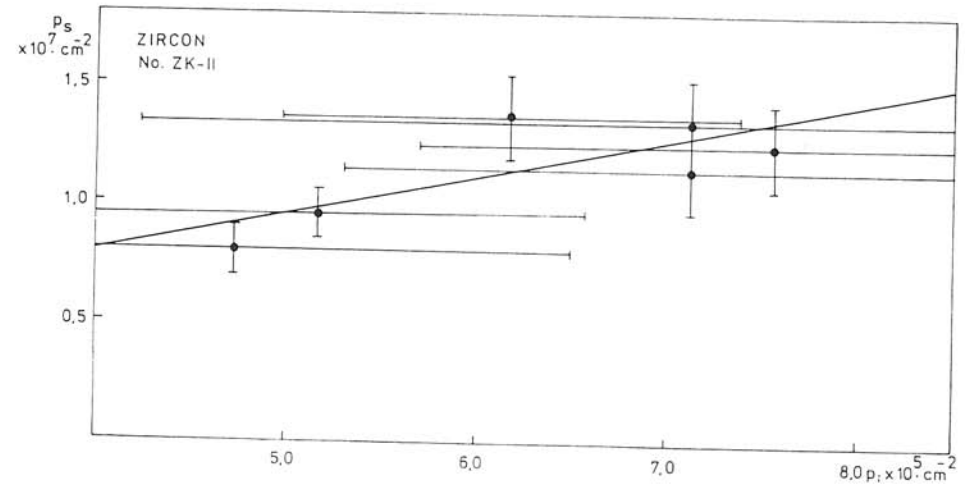

Fig. 5. 6 zircon grains from Čierna hora Mts. granit. FT isochrone age: 49 ± 17 m. y. Neutron dose: 1.27×10^{15} n . cm^{-2}.

eliminated. It seems that the slope is strongly controlled by the single uranium — rich crystal.

Case 5 (Fig. 5). Few grains, very large errors, particularly for p_i, small dispersion of uranium content. Consequently the slope of the fitted line has a large confidence interval.

Conclusion

As shown by the examples the major advantages of the method are:

— it makes possible to date highly nonhomogeneous samples (the more nonhomogeneous the better).

— it provides an experimental prove of the linear correlation between p_s and p_i.

— it will show any possible age differences among the crystals (mixed populations which may be sometimes encountered in zircons from metamorphic rocks).

— it helps to analyse the sources of experimental errors and clearly shows any suspect data which should be re—checked: generally it gives a good-insight into the situation within the sample.

— it yields a realistic estimate of the uncertainty of the calculated age, by taking into account various factors involved: number of grains, statistical weight of each point, dispersion, partial correlation of errors.

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