THE IDENTIFICATION OF TRACKS DUE TO Th–U COSMIC-RAY NUCLEI IN OLIVINE FROM PALLASITES; V.P. Perelygin, S.C. Stetsenko; Joint Institute for Nuclear Research, Dubna I43680, USSR

The experimental study of fossil tracks due to the heaviest Galactic cosmic-ray nuclei in meteoritic olivine crystals has been performed at the Laboratory of Nuclear Reactions, JINR, during 1980-1987 in order to identify anomalously long tracks from the $Z \geq 110$ nuclei (1,2). The crystals from the meteorites—pallasites Marjalahti and Eagle Station were used. Before etching, these crystals were annealed at 430°C during 32 h. The semiempirical dependence of the volume etchable track length on atomic number $Z$ was based on only one experimental point for $^{132}Xe_{\alpha}$ - $L=26.5 \pm 2.5 \mu m$. In the first experiment (1) in the track length spectra obtained under these annealing conditions (fig.1a) one can see the track groups at $120-140 \mu m$. These groups were attributed (1) respectively, to Pt-Pb and Th-U cosmic-ray nuclei; in addition, one anomalously long track, $L=365 \mu m$, has been found. In a further study (2), the number of tracks with $L \sim 210 \mu m$ exceeds 1100, and the number of tracks with $L \sim 350 \mu m$ reaches 10 (fig.1b). For identifying of the tracks with $L \sim 210 \mu m$ and to clarify the origin of tracks with $L \sim 350 \mu m$ it was necessary to calibrate meteoritic olivine crystals with accelerated Au, Pb and U nuclei. The first experiment of this kind was carried out at the Bevalac accelerator (LBL, Berkeley) in November 1987 (3). The energy of $^{238}U$ nuclei was 30 and 70 MeV/n, the angle of incidence was 25° and, for some crystals, 10° to the polished olivine surface. The annealing, etching and tracks measuring procedure were the same, as in previous experiments (1,2). The results of track measurements in 83 crystals from the Marjalahti meteorite are shown in fig.1c, the maximum of the $^{238}U$ track length spectrum corresponds to $230\pm25 \mu m$ (3).

Both the shape and half-width of this spectrum agrees with those for "fossil" track group $210\pm20 \mu m$ in length (figs.1a,1b). For 32 olivine crystals from Eagle Station pallasite we observe rather good incidence of the track length spectrum of $^{238}U$ and the group of "fossil" tracks ($220 \mu m$ and $210 \mu m$).

The longest track in the $^{238}U$ spectrum has a length of up to $330-370 \mu m$ (fig.1c). But the thoroughful analysis of the crystals containing the longest $^{238}U$ tracks shows that these tracks oriented very closely to the (010) main crystal planes of the olivines. This does not take place for at least 50% of $350 \mu m$ fossil tracks. Thus, the problem of the origin of the longest fossil tracks still remains unsolved and needs further investigations.

Fig. 1
THE IDENTIFICATION OF TRACKS DUE TO Th–U: Perelygin V.P. and Stetsenko S.G.

For the purpose of a more detailed study of the thermal stability of 238U and 208Pb tracks (crystals were irradiated at UNILAC, GSI, Darmstadt) in olivines were carried out experiments on annealing such crystals during 32 h at temperatures of 450°C. The results of this annealing study are presented in fig. 2. For annealing at temperatures 450°C the mean 238U track length is 120±20 μm and 70±15 μm for 208Pb track respectively. One can compare these track length spectra with fossil track length spectra (fig. 2b, LTr = 115 μm) in olivine crystals, annealed in the same conditions.

Turning to the analysis of the results obtained, one can conclude that, first, the fossil tracks with a mean length 210 μm (figs. 1a,b) have been formed by the cosmic-ray nuclei group of Th–U, formed in r-process events in our Galaxy during last 200 MY of its history.

Second, the calibrations of olivine crystals with 238U nuclei provide a quantitative basis of a new method of investigating galactic cosmic-ray nuclei (Z ≥ 50) by studying tracks in extraterrestrial crystals. This method surpass in sensitivity all other known methods.