Observations of fossil charged-particle tracks in principal rock forming minerals (feldspars, pyroxenes and olivines) up to depths of 10 cm in several lunar rocks are reported. Experimental data refer to both partial and total recordable track lengths. The latter information has been obtained using the TINT method for revealing a complete track, having both the track tips within the crystals. The TINT method was used to study the charge composition of nuclei within the iron group (V, Cr, Mn, Fe, Co, Ni). Incomplete tracks, i.e., those in which only one track tip lies within the crystal were studied for measuring the abundances of nuclei of Z > 30.

The track density of V, H nuclei at low energies, up to 50 MeV/n are governed by the rate of erosion and is in dynamic equilibrium with the track formation rate. Figure 1 and 2 in the accompanying paper illustrate this point where the surface exposure ages for a few sun-tanned rocks are shown as a function of depth. In Fig. 2 the track production rate obtained fromSurveyor glass, up to 500 microns has been used. These figures amplify the existence of an erosion equilibrium at x < 0.1 cm. The observed spread in absolute track densities at 10^{-3}-10^{-1} cm depth can be understood mainly as being due to variations in the rock orientation during surface exposure.

Track densities at depths greater than 1 mm do not reach an erosion equilibrium. As an illustration Fig. 1 shows the observed track profile as well as that expected on the basis of energy spectrum given earlier for the case of rock 14305. Track densities higher than about 50 \times 10^6 cm^{-2} were measured by the replication technique and are appropriately normalised to conform with the optically observed track density at 200 microns. The energy spectrum up to 1 BeV/n has been obtained using the large rocks 14321 and 14310. Although most of these rocks are fragmental, no evidence has been found for their significant pre-irradiation as individual fragments. The deduced energy spectrum of VH-nuclei agrees well with that obtained from Apollo 12 rocks.

A systematic study was also undertaken to examine variations in the distribution of the recordable track lengths as a function of shielding. For this purpose we selected rock 12233, which besides leaving a single exposure history was mineralologically suitable. Crystals taken from 0-1 mm, 1-2 mm, 2-4 mm and 1 cm have been studied by using the TINT method. The track lengths group around 5, 8, 12 and 15 microns. The largest peak appears at 11-12 microns and is probably due to iron nuclei, although a definite charge assignment cannot be made at present. The majority of 15 micron tracks in samples where track densities are less than 5 \times 10^6 cm^{-2} are believed to be fissionogenic, due to spontaneous fission of U235. A definite increase in the abundances of Mn, Cr nuclei relative to Fe nuclei.
occurs in deeper samples indicating fragmentation effects.

In Figure 2, we show similar track length distribution of TINTS in pyro-oxenes (sp. gr. 5.3 g cm$^{-3}$) for two cases of track densities, for $\rho > 10^7$ and $< 10^7$ cm$^{-2}$. The observed grouping in recordable lengths are similar in characteristic to those shown in Figure 2. Furthermore the peaks are at the same lengths as reported earlier$^4$. With the present considerably increased statistics, the results give creditability to the assigned peak in recordable lengths at $\approx$ 12 microns as being due to iron nuclei and about 5 micron length difference per charge in the iron group region. Increased statistics in other meteorites confirm our earlier results$^4$ and strengthen the application of TINT/TINGLE methods to the study of the charge composition of cosmic rays and fissionogenic tracks in pyro-oxenes due to U$^{238}$ and superheavy transuranic elements.

Fig. 1. The observed track densities in a through section of rock 14303 are shown for the feldspar crystals. $\perp$Z and XYZ refers to $\perp$ 90 and random orientations of the crystals. Track densities based on replication technique may be progressively larger at depths less than 200 microns. The solid line shows the expected track profile (arbitrary units) for a vertical and radial slice based on energy spectrum deduced from Apollo 12 rocks and St. Severin meteorite$^4$. 

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References


Fig 2. The TINT length distribution in Patwar Pyroxenes (sp. gr
3.3 g.cm$^{-3}$) estimated
 to be at a depth of 2 cm
($\rho > 10^7$ cm$^{-2}$) and 6 cm ($\rho < 10^7$
 cm$^{-2}$)