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FISSION TRACK AGES OF PYROCLASTIC FLOWS IN THE PLIOCENE ASHORO FORMATION AND THE PLIO-PLEISTOCENE IKEDA FORMATION DEVELOPED IN EASTERN HOKKAIDO, JAPAN.

by

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(with 8 text-figures, 3 tables and 4 plates)

Abstract

Fission track ages of the three pyroclastic flow deposits developed in the Tokachi Province, eastern Hokkaido, have been determined by means of grain by grain method of zircon extracted from these deposits. The following results have been obtained; 3.7±0.1 m.y. for the Inashibetsu pyroclastic flow deposits of the Ashoro Formation; 2.8±0.2 m.y. for the Sarubetsu pyroclastic flow deposits; and 2.0±0.1 m.y. for the Chiyoda pyroclastic flow deposits, both the latter two are of the Ikeda Formation.

Pliocene-Pleistocene boundary in this Province must therefore lie somewhere which may be slightly above the horizon of Chiyoda pyroclastic flow deposits of the Ikeda Formation.

Introduction

Youngest Tertiary and Quaternary deposits in the northern part of the Tokachi Province, eastern Hokkaido, have been currently divided into the Honbetsu Formation, the Ashoro Formation and the Ikeda Formation in ascending order.

The Honbetsu Formation has been generally considered as Pliocene in age, because of the presence of *Fortipecten takahashii*-bearing fauna in its lower part.

There has been no palaeontological data for the age of the Ashoro Formation. But Shibata, Yamaguchi and Sato (1976) have given a K-Ar age of 4.1±1.1 m.y. for the Inashibetsu tuff, which we currently consider as a member of the Ashoro Formation.

The age of the Ikeda Formation has been much disputed. Nemoto, Oishi and Watanabe (1933) first assigned their Ikeda Formation as of late Pliocene age. Okazaki (1957, 1958), Mitani (1964) and Tokachi Researchi Group (1978) followed in this concern. Whereas Hashimoto (1954) pointed out the possibility of its assignment to the early Pleistocene on the basis of the occurrence of *Menyanthes trifolia* Linn. in it.

On the other hand, Minato, Hashimoto, Fujiwara and Kumano (1972) conclude that the Olduvai event coupled with cold time is to be sought within the lower part of the Ikeda Formation, thereby indicating that the Formation is Plio-Pleistocene in age. This opinion is further reinforced by Igarashi (1976) who did pollen analytical study. Oka (1976a, b) also considers the Ikeda Formation as Plio-Pleistocene in age. Quite recently Oka and Akamatsu (1979) found *Patinopecten (Fortipecten) takahashii* from beds close to the Chiyoda tuff of Oka (1976a), which are intercalated in the Ikeda Formation. They consider that these molluscan beds are close to the Pliocene-Pleistocene boundary.

The present author has conducted fission track dating on the three pyroclastic flow

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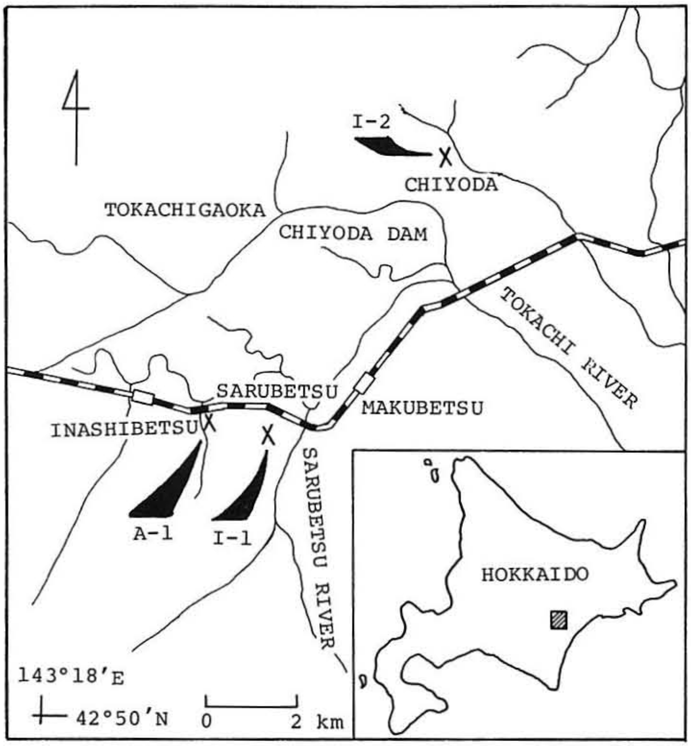


Text-fig. 1. Locality map of the studied area where the samples were collected for fission track dating.

deposits in order to obtain firm chronological basis upon the mentioned problem. Grain by grain method of zircon has been employed in the present study.

The three pyroclastic flow deposits are the Inashibetsu in the Ashoro Formation and the Sarubetsu and Chiyoda in the Ikeda Formation (Text-fig.2). And all these deposits are widely traceable and lithologically very significant in the northern Tokachi Province.

Principle of fission track dating

Fleisher et al. (1975) summarized the principle of fission track dating as follwos: The spontaneous track density ρ_s is given by the following equation.

$$\rho_s = (A \cdot \lambda)(N_v \cdot c^{238} \cdot R^{238} \cdot \eta^{238})$$

where

A = time over which spontaneous fisson tracks have been stored,

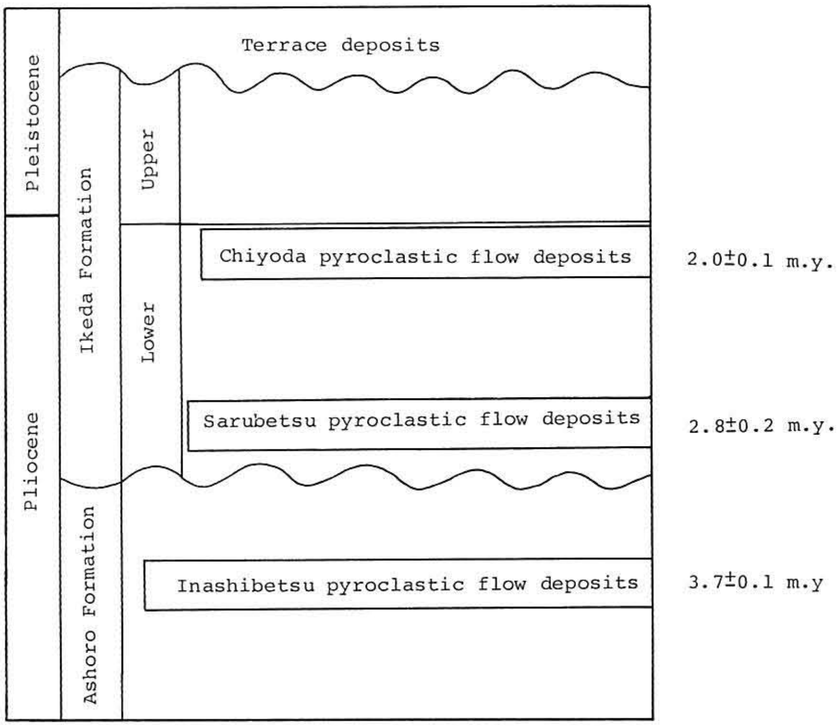
λ = decay rate by fission of ^{238}U,

N_v = number of atoms per unit volume in the material,

C^{238} = fraction of those atoms that are ^{238}U,

R^{238} = length of the etchable track of a ^{238}U fission fragment,

η^{238} = etching efficiency, the fraction of the tracks crossing a surface that are



Text-fig. 2. Generalized stratigraphic column showing horizons of measured pyroclastic flow deposits in the eastern Hokkaido, Japan.

revealed by etching.

On the other hand, the induced track density ρ_i after neutron irradiation is given as

$$\rho_i = (\sigma \cdot \Phi)\,(N_v \cdot C^{235} \cdot R^{235} \cdot \eta^{235})$$

where

$\sigma =$ cross section for inducing fission of ^{235}U with thermal neutrons,

$\phi =$ thermal neutrons per unit area,

C^{235}, R^{235} and η^{235} are defined analogously to those in the first equation.

The above equations can be combined to give the age in terms of the three track densities and a constant:

$$A = \zeta\,(\rho_s/\rho_i)\,\Phi$$

where

$$\zeta = \frac{\sigma}{\lambda} \cdot \frac{C^{235}}{C^{238}} \cdot \frac{R^{235}}{R^{238}} \cdot \frac{\eta^{235}}{\eta^{238}}$$

With the values, $\sigma = 582.2$ barn, $\frac{C^{235}}{C^{238}} = 137.88^{-1}$, $\frac{R^{235}}{R^{238}} = 1$, $\frac{\eta^{235}}{\eta^{238}} = 1$ and $\lambda = 7.03 \times$

10^{-17} y^{-1}, the equation for A would be rewritten as follwos:

$$A = 6.01 \times 10^{-8} \frac{\rho_s}{\rho_i} \Phi$$

Fission track ages

Sampling localities

The sampling localities are shown in Text-fig.1, and their stratigraphic positions are marked in the diagrammatical stratigraphic column shown in Text-fig.2. Details of sampling localities and lithology of each pyroclastic flow unit are described below.

A-1: Inashibetsu pyroclastic flow deposits.
The sampling point is near the mouth of the Poronai creek, some 1500 m west of Sarubetsu, Makubetsu Town. Lithology; gray coloured rhyolitic pumice flow. Essential constituents are volcanic glass, quartz, mica, plagioclase, potash feldspar, hypersthene, pyroxene and hornblende. Accessory minerals are sphene, zircon and apatite.

I-1: Sarubetsu pyroclastic flow deposits.
The sampling point is by a small creek, about 50 m south of Sarubetsu Keishuba Pasture, Makubetsu Town. Lithology; yellowish gray dacitic pumice flow. Essential constituents are volcanic glass (rich), quartz, plagioclase, mica (not so rich as in the Inashibetsu pyroclastic flow deposits), hypersthene and hornblende. Accessory minerals are zircon and apatite.

I-2: Chiyoda pyroclastic flow deposits.
The sampling point is near the mouth of the Chiyoda-Onsenzawa, 250 m east of Chiyoda, Ikeda Town. Lithology; gray- light brown coloured dacitic pumice flow. Essential constituents are volcanic glass, quartz, plagioclase, potash feldspar, mica (not so rich as in the Inashibetsu pyroclasitic flow deposits) and hypersthene. Accessory minerals are apatite, zircon and sphene.

Concentration of zircon

The samples are washed and dried in an oven (60°C). After the samples whose sizes range from 74 μ (200 mesh) up to 177 μ (80 mesh) are sifted and then gathered, heavy minerals are separated by a heavy solution, tetrabromoethane. Next, magnetites are separated from the heavy minerals by a magnet and the nonmagnetic minerals are concentrated. Lastly the zircons are picked up under an optical microscope (X20).

Chemical etching

In chemical etching the most important point is the measurements of the track density of ρ_s and ρ_i under the same condition. However, it has been impossible to maintain the same condition by the etchant hitherto used.

The reasons are as follows. As former etchants for zircon, H_3PO_4 (Fleisher et al., 1964), NaOH (Naeser, 1969) and $HF:H_2SO_4$ (Krishnaswami et al., 1974) have been used. But in case of H_3PO_4 (Fleischer et al., 1964) high temperature (375-500°C) is needed and etching time is very short (few minutes). In case of NaOH (Naeser, 1969), the etchant is highly viscous. And in case of $HF:H_2SO_4$ (Krishnaswami et al., 1974), etching has been carried in a closed tube. In any case, it is hard to decide the suitable etching time.

Gleadow et al. (1976) recently developed an important etching technique; the teflon mounting technique combined with KOH:NaOH eutectic etchant. Consequently, practical difficulties of former etching techniques were overcome.

In this paper, for the purpose of measurement of ρ_s of each grain of zircon, which is mounted in teflon, is etched in 11.5 g KOH : 8 g NaOH eutectic etchant (Gleadow et al. 1976) at 240°C. If spontaneous fission tracks of zircon counted on the etched external surface are observed to be under-etched condition, zircon is again placed to the etching bath. Five to twenty hours are necessary for confirmation of suitable etching for ρ_s in the author's experiment.

Next, these grains of zircon are exposed to thermal neutron together with the standard glass of fixed uranium content. In the present study, neutron irradiation is carried out about 20-70 minutes in the reactor (TRIGA MARK II : $\phi \fallingdotseq 5 \times 10^{11}$ n/sec cm^2) of Rikkyo University. Thermal neutrons per unit area ϕ can be easily measured by standard glass.

After that, induced fission tracks of many grains of zircon are counted on the same surface on wchich previous counting of spontaneous fission tracks is made. Four to fifteen hours are needed for confirmation of suitable etching for ρ_i.

Result

All the data concerning to the age determination are shown in Text-figs.3,4 and 5. and Tables 1,2 and 3. In these tables, Ns means counted spontaneous track number, ρ_s: spontaneous track density (cm^{-2}), Ni: counted induced track number, ρ_i: induced track density (cm^{-2}), ϕ: thermal neutron dose (cm^{-2}).

Although age of each zircon grain was correctly measured, the author treated actually a number of grains of zircon for each pyroclastic flow unit (Text-figs.3,4 and 5, Tables 1,2 and 3). As to the Inashibetsu pyroclastic flow deposits, 10 grains of zircon were measured, for instance. While 12 grains were measured for the Sarubetsu pyroclastic flow deposits and 23 grains were measured for the Chiyoda pyroclastic flow deposits. As a result, the author

Table 1. The data of fission track age determination of zircons found in the Inashibetsu pyroclastic flow deposits. For abbreviation see text. True fission track age is marked with asterisk (see Text-fig. 3).

Ns	ρ_s	Ni	ρ_i	ϕ	Age (m.y.)
81	80.8×10^4	712	7.10×10^6	0.52×10^{15}	3.82
73	82.8	615	6.97	0.52×10^{15}	3.71
59	81.2	509	7.01	0.52×10^{15}	3.62
97	83.7	833	7.19	0.52×10^{15}	3.64
62	77.0	535	6.64	0.52×10^{15}	3.72
66	77.5	582	6.83	0.52×10^{15}	3.50
84	83.9	727	7.26	0.52×10^{15}	3.63
53	86.8	419	6.87	0.52×10^{15}	3.95
					3.7±0.1*
24	22.8	103	0.98	0.52×10^{15}	7.27
18	10.5	12	0.68	0.52×10^{15}	4.83

Table 2. The data of fission track age determination of zircons found in the Sarubetsu pyroclastic flow deposits. For abbreviation see text. True fission track age is marked with asterisk (see Text-fig. 4).

Ns	ρs	Ni	ρ_i	ϕ	Age (m.y.)
18	15.6×10^4	467	4.05×10^6	1.18×10^{15}	2.73
23	16.0	566	3.94	1.18×10^{15}	2.88
26	16.3	743	4.66	1.18×10^{15}	2.48
19	12.8	506	3.41	1.18×10^{15}	2.66
31	18.1	771	4.50	1.18×10^{15}	2.85
17	14.7	406	3.51	1.18×10^{15}	2.97
22	15.4	547	3.83	1.18×10^{15}	2.85
					2.8±0.2*
64	40.1	873	5.47	1.18×10^{15}	5.20
20	14.2	397	2.82	1.18×10^{15}	3.57
19	13.5	274	1.95	1.18×10^{15}	4.91
8	6.8	73	0.62	1.18×10^{15}	7.78
11	8.3	103	0.78	1.18×10^{15}	7.55

Table 3. The data of fission track age determination of zircons found in the Chiyoda pyroclastic flow deposits. For abbreviation see text. True fission track age is marked with asterisk (see Text-fig. 5).

Ns	ρ_s	Ni	ρ_i	ϕ	Age (m.y.)
4	7.42×10^4	212	3.93×10^6	1.67×10^{15}	1.90
6	6.64	299	3.30	1.67×10^{15}	2.02
7	6.76	352	3.40	1.67×10^{15}	2.00
7	6.81	355	3.46	1.67×10^{15}	1.98
6	6.50	309	3.35	1.67×10^{15}	1.95
6	7.12	280	3.33	1.67×10^{15}	2.15
8	7.94	343	3.41	1.67×10^{15}	2.34
7	7.44	340	3.61	1.67×10^{15}	2.07
6	5.38	324	2.91	1.67×10^{15}	1.86
7	7.20	308	3.17	1.67×10^{15}	2.28
6	6.69	300	3.34	1.67×10^{15}	2.01
8	7.29	360	3.28	1.67×10^{15}	2.23
5	6.26	285	3.57	1.67×10^{15}	1.76
5	8.17	259	4.23	1.67×10^{15}	1.94
					2.0±0.1*
22	15.1	552	3.79	1.67×10^{15}	4.00
13	7.4	242	1.38	1.67×10^{15}	5.38
63	32.9	879	4.59	1.67×10^{15}	7.19
8	6.3	274	2.19	1.67×10^{15}	2.93
94	80.3	610	5.21	1.67×10^{15}	15.47
22	11.6	772	4.07	1.67×10^{15}	2.86
3	4.0	112	1.49	1.67×10^{15}	2.69
11	9.8	207	1.84	1.67×10^{15}	5.35
19	20.2	530	5.63	1.67×10^{15}	3.60

Explanation of Plate 1.

Zircon samples for dating from the Inashibetsu pyroclastic flow deposits (Fig. 1), the Sarubetsu pyroclastic flow deposits (Fig. 2) and the Chiyoda pyroclastic flow deposits (Fig. 3). Scale bar: 100μ.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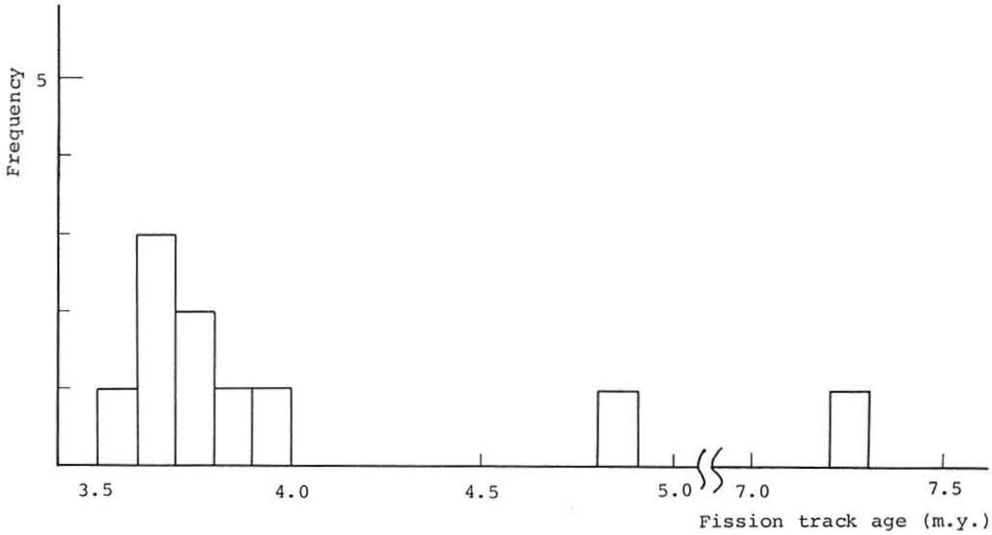
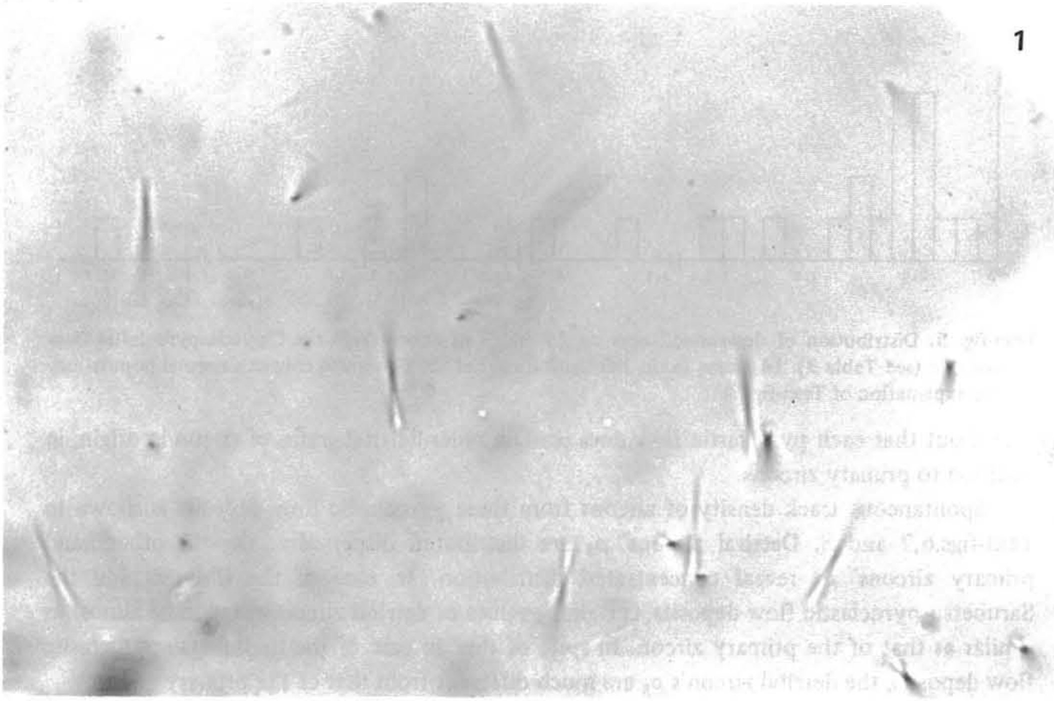


Text-fig. 3. Distribution of determined ages of 10 grains of zircon from the Inashibetsu pyroclastic flow deposits (see Table 1). Eight grains in the left hand corner of the figure will consist a normal population. A true fission track age is given by $\bar{x} \pm t_{0.05} \dfrac{\hat{S}x}{\sqrt{n}}$
where; $\bar{x}$: sample mean, $\hat{S}_x^2$: sample variance, $t_{0.05}$: 5% point of t-distribution.

Text-fig. 4. Distribution of determined ages on 12 grains of zircon from the Sarubetsu pyroclastic flow deposits (see Table 2). Seven grains in the left hand corner of the figure will consist a normal population. See explanation of Text-fig. 3. for the equation to calculate a true fission track age.

Explanation of Plate 2.
Spontaneous fission tracks (Fig. 1) and induced fission tracks (Fig. 2) on zircon of the Inashibetsu pyroclastic flow deposits. The area shown in the figure 1 corresponds to that shown in the figure 2. Scale bar: 10μ.



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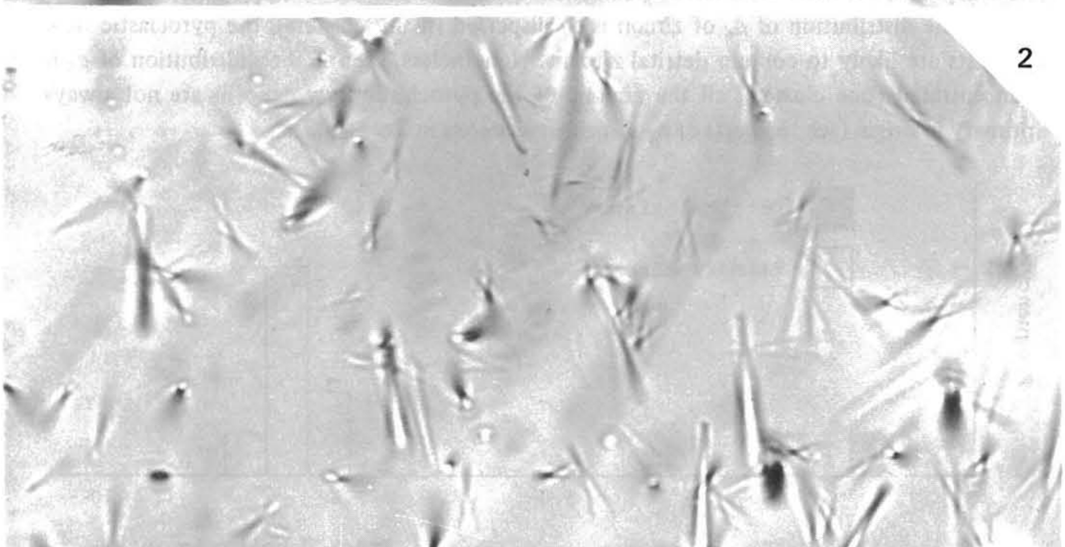

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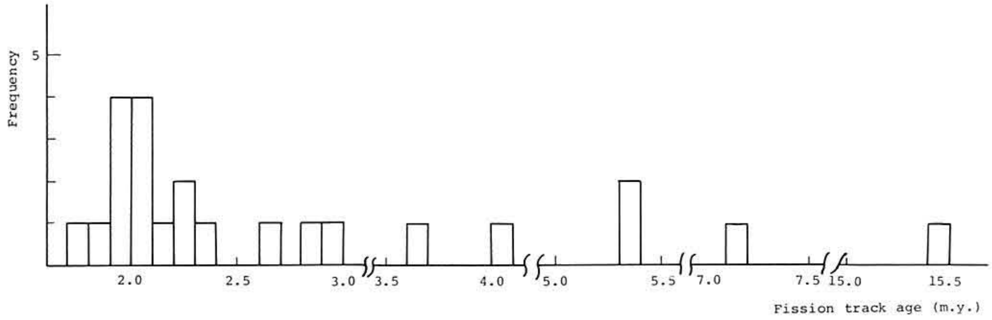
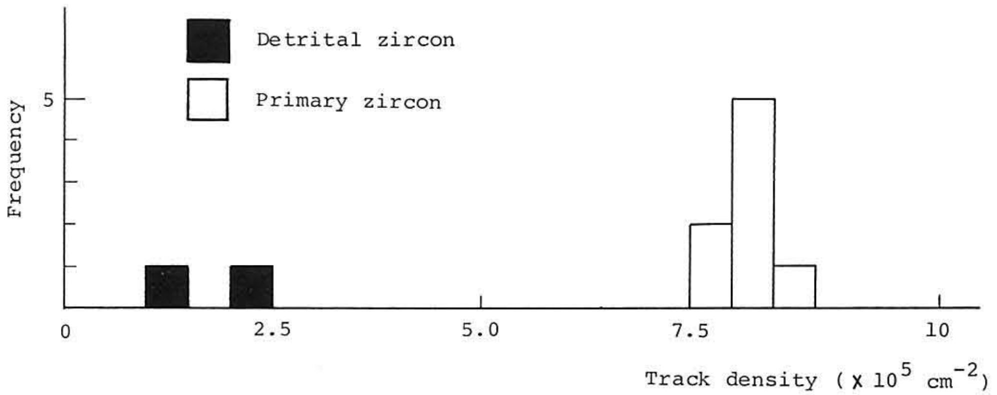


Text-fig. 5. Distribution of determined ages on 23 grains of zircon from the Chiyoda pyroclastic flow deposits (see Table 3). 14 grains in the left hand corner of the figure will consist a normal population. See explanation of Text-fig. 3.

found out that each pyroclastic flow does contain older detrital grains of zircon in origin, in addition to primary zircons.

Spontaneous track density of zircons from these pyroclastic flow deposits is shown in Text-figs.6,7 and 8. Detrital zircons' ρ_s are distributed dispersedly. On the other hand primary zircons' ρ_s reveal concentrated distribution. In case of the Chiyoda and the Sarubetsu pyroclastic flow deposits, certain ρ_s values of detrital zircon seems to be almost as similar as that of the primary zircon. In spite of this, in case of the Inashibetsu pyroclastic flow deposits, the detrital zircon's ρ_s are much different from that of the primary zircon.

If the distribution of ρ_s of zircon is so dispersed (many clusters), the pyroclastic flow deposits are likely to contain detrital zircons. Nonetheless, even if the didtribution of ρ_s is concentrated (one cluster), all the zircons of the pyroclastic flow deposits are not always primary in origin (see the parts of ρ_s of primary zircons in Text-fig.7).



Text-fig. 6. Histogram of spontaneous fission track density of zircons from the Inashibetsu pyroclastic flow deposits.

Explanation of Plate 3.

Spontaneous fission tracks (Fig. 1) and induced fission tracks (Fig. 2) on zircon of the Sarubetsu pyroclastic flow deposits. The area shown in the figure 1 corresponds to that shown in the figure 2. Scale bar: 10μ.

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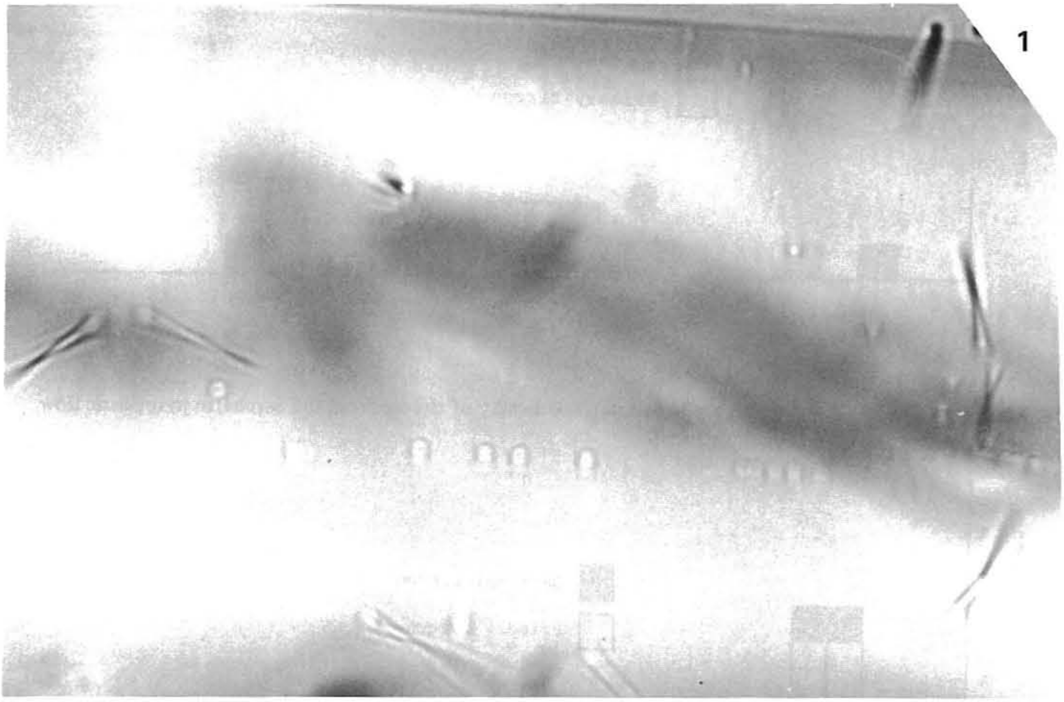

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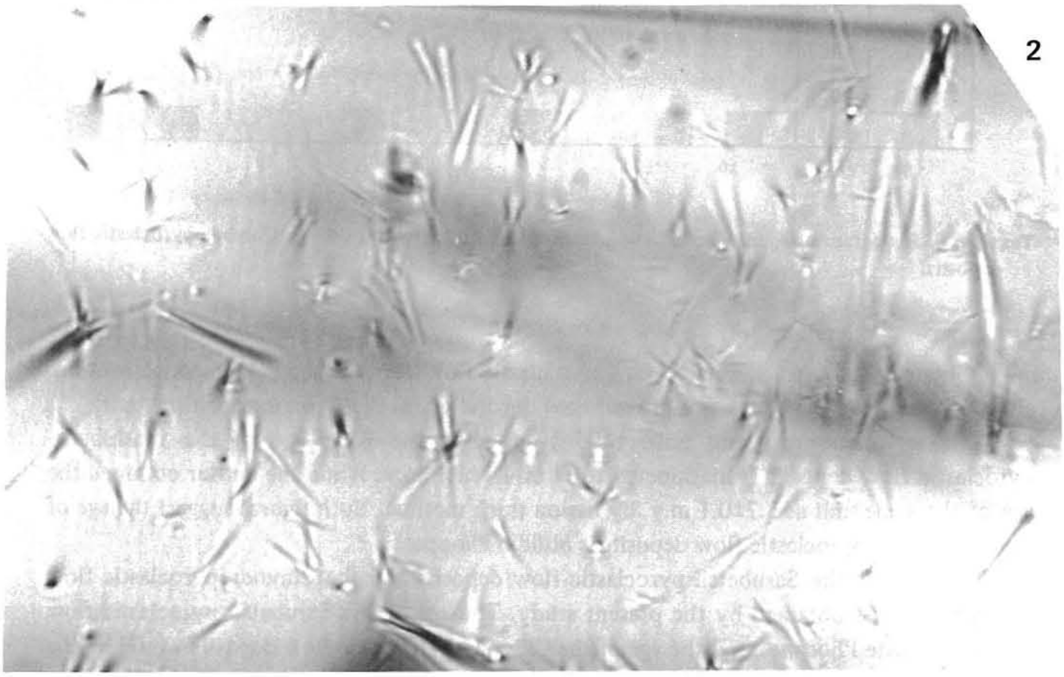
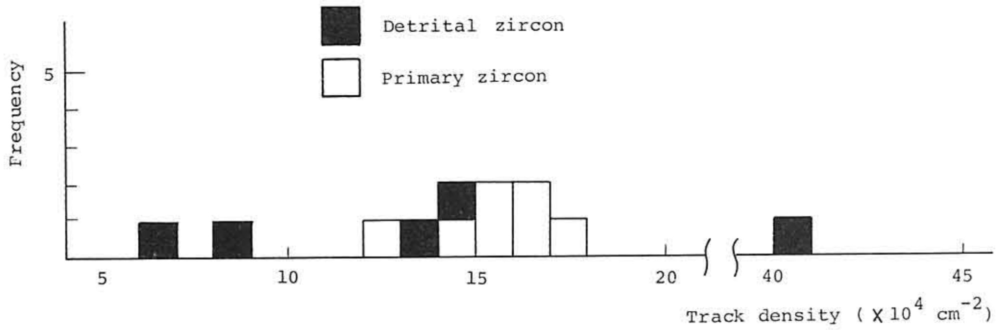
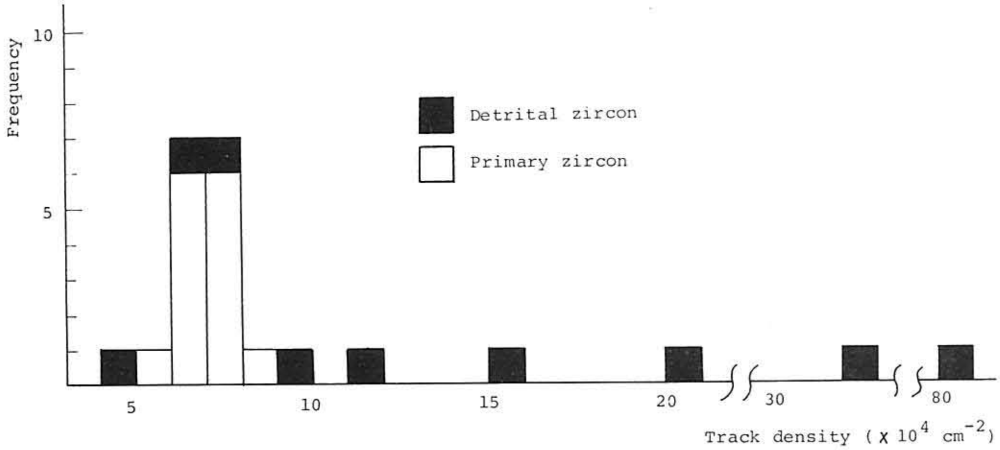




Text-fig. 7. Histogram of spontaneous fission track density of zircons from the Sarubetsu pyroclastic flow deposits.



Text-fig. 8. Histogram of spontaneous fission track density of zircons from the Chiyoda pyroclastic flow deposits.

Conclusions

Obtained fission track ages of each pyroclastic flow deposits show good concentration, although they reveal the presence of reworked detrital grains of zircon in each flow unit.

Shibata, Yamaguchi and Sato (1976) reported the K-Ar age of the Inashibetsu pyroclastic flow deposits (=Inashibetsu tuff) as 4.1±1.1 m.y. While the author obtained the age of the same unit as 3.7±0.1 m.y. by fission track method. Both figures suggest the age of the Inashibetsu pyroclastic flow deposits is Middle Pliocene.

The ages of the Sarubetsu pyroclastic flow deposits and the Chiyoda pyroclastic flow deposits are first obtained by the present study. The age of the Sarubetsu pyroclastic flow deposits is Late Pliocene. And the age of the Chiyoda pyroclastic flow deposits would be the Latest Pliocene.

Pliocene-Pleistocene boundary would be placed at a horizon somewhat higher than the

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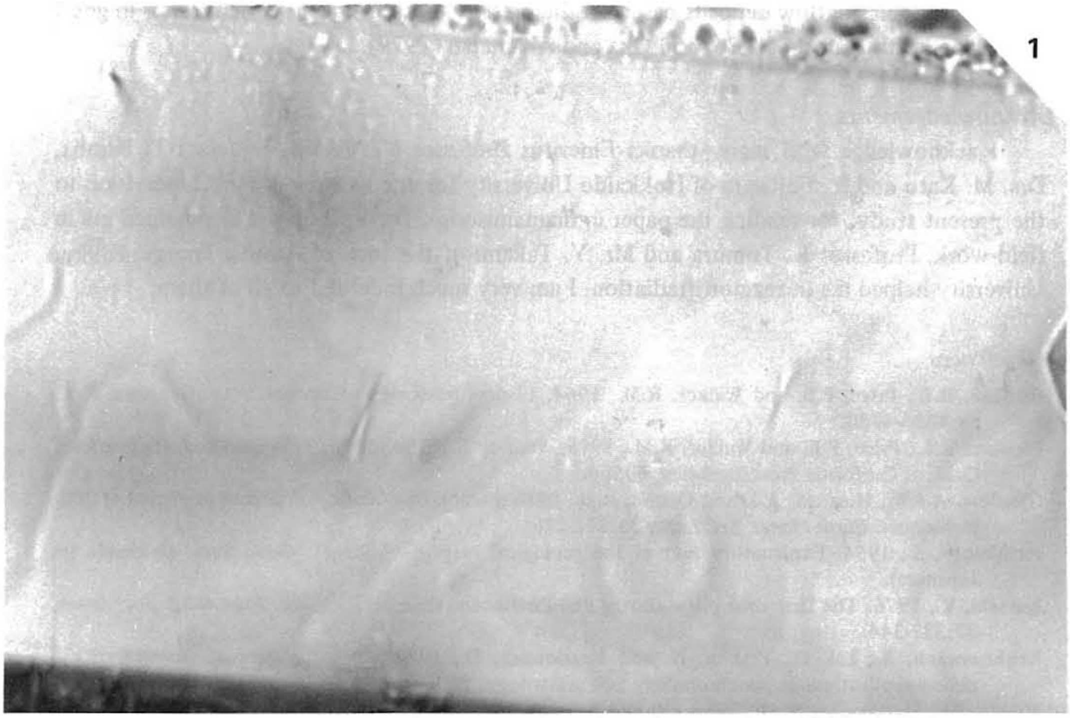
Explanation of Plate 4.
Spontaneous fission tracks (Fig. 1) and induced fission tracks (Fig. 2) on zircon of the Chiyoda pyroclastic flow deposits. The area shown in the figure 1 corresponds to that shown in the figure 2. Scale bar: 10μ.



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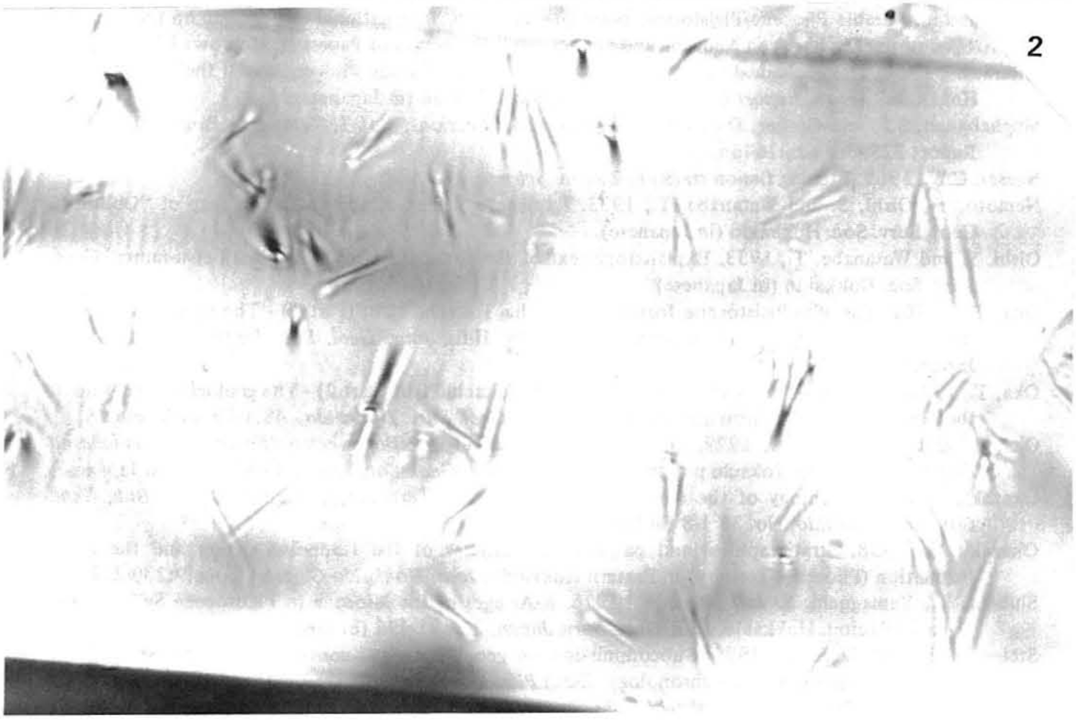

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Chiyoda pyroclastic flow deposits based on the present study. And this conclusion is in good accordancè with Igarashi (1976) and Oka and Akamatsu (1979).

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