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Fission track age of the Og1 Tuff in the Miocene marine sequence of the Arakawa Group in the Karasuyama area, central Japan

Masaki TAKAHASHI[1] and Hideki IWANO[2]

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Abstract: Zircon fission track age was determined for the Og1 Tuff interbedded in the lowest part of the Miocene Ogane Formation in the Karasuyama area. Two fission track ages were obtained as 11.6 ± 0.5 Ma (ED1 method) and 11.7 ± 0.6 Ma (ED2 method) and the weighted mean age was calculated as 11.6 ± 0.4 Ma for the Og1 pyroclastics. This age coincides with a previous K-Ar age of the same tuff sample (11.8 ± 0.2 Ma). The reliable ages give a geochronologic constraint on the CN5a/CN5b boundary of calcareous nannofossil zones.

1. Introduction

Combining the geochronology with magnetostratigraphy and/or biostratigraphy along the same section will present important constraints on geologic time scale, because some serious problems have been pointed out on Cande and Kent's (1995) geomagnetic polarity time scale (Baksi, 1993; Wei, 1995; Takahashi and Danhara, 1997). As there is very limited datable volcaniclastic layers within the deep sea core samples, the volcani-sedimentary sections of some Neogene marine sequences in Japan play an important role for integrated stratigraphic work (Takahashi and Oda, 1997).

The marine sequence of the Arakawa Group (Sakai, 1986), exposed in the Karasuyama area, is one of the most suitable marine sequences for the Miocene integrated stratigraphy. This sequence yields both calcareous and siliceous microfossils, and interbeds many pyroclastic layers, some of which supply suitable materials for radiometric dating.

In this paper, we present newly obtained fission track age of the Og1 Tuff, interbedded in the lowest part of the Ogane Formation (Sakai, 1986), and discuss its stratigraphic significance for constructing a time scale.

2. Geology, stratigraphy and sample

The Karasuyama area is situated in the northern part of central Japan (Fig. 1), where the middle Miocene marine sequence, named the Arakawa Group, is well exposed. This sequence unconformably overlies the pre-Neogene basement and lower Miocene volcanic rocks along the eastern margin. It is covered by the Pleistocene conglomerate of the Sakaibayashi Formation. The Miocene sedimentary rocks are gently tilted and only a few faults were observed throughout the area (Tanaka and Takahashi, 1998).

The more than 700 m-thick Miocene sequence is divided into four formations; Kobana, Ogane, Tanokura and Irieno Formations in ascending order (Sakai, 1986). The Kobana Formation is composed of conglomerate, medium- to fine-grained calcareous sandstone and siltstone, with 30 key tuff layers. Only the lower part is characterized by foreset bedding. Marine molluscs are often yielded, and calcareous microfossils are well preserved, however siliceous microfossils were dissolved due to the overburden. The K-Ar ages of six tuff layers (Kb1, Kb2, Kb15, Kb20, Kb23 and Kb29) were determined (Takahashi *et al.*, 1999, 2000).

The Ogane Formation, conformably covering the Kobana Formation, is characterized by dark gray siltstone. Well-preserved calcareous microfossils are yielded from its lower part, and siliceous microfossils from the upper part. Sixty-one key tuff sets are interbedded in this formation, and the Og1 and Og25 were dated by the K-Ar method (Takahashi *et al.*, 1999).

In contrast, the upper two units (Tanokura and Irieno Formations) are dominated by diatomaceous siltstone. More than forty tuff sets are intercalated in the Tanokura Formation. Among them, Tn18, Tn20, Tn28, Tn38 and Tn44.5 key tuff layers contain biotite.

Recently Tanaka and Takahashi (1998) established the calcareous nannofossil biostratigraphy for the Kobana and lowest part of the Ogane Formations (Fig. 3). They recognized two important biohorizons; last occurrences

[1] Mineral and Fuel Resources Department, GSJ.
[2] Kyoto Fission-Track Co., Ltd. 44-4 Minami-Tajiricho, Kita-ku, Kyoto 603-8832, Japan

Keywords: Miocene, fission track age, calcareous nannofossil, integrated stratigraphy, Arakawa Group, central Japan

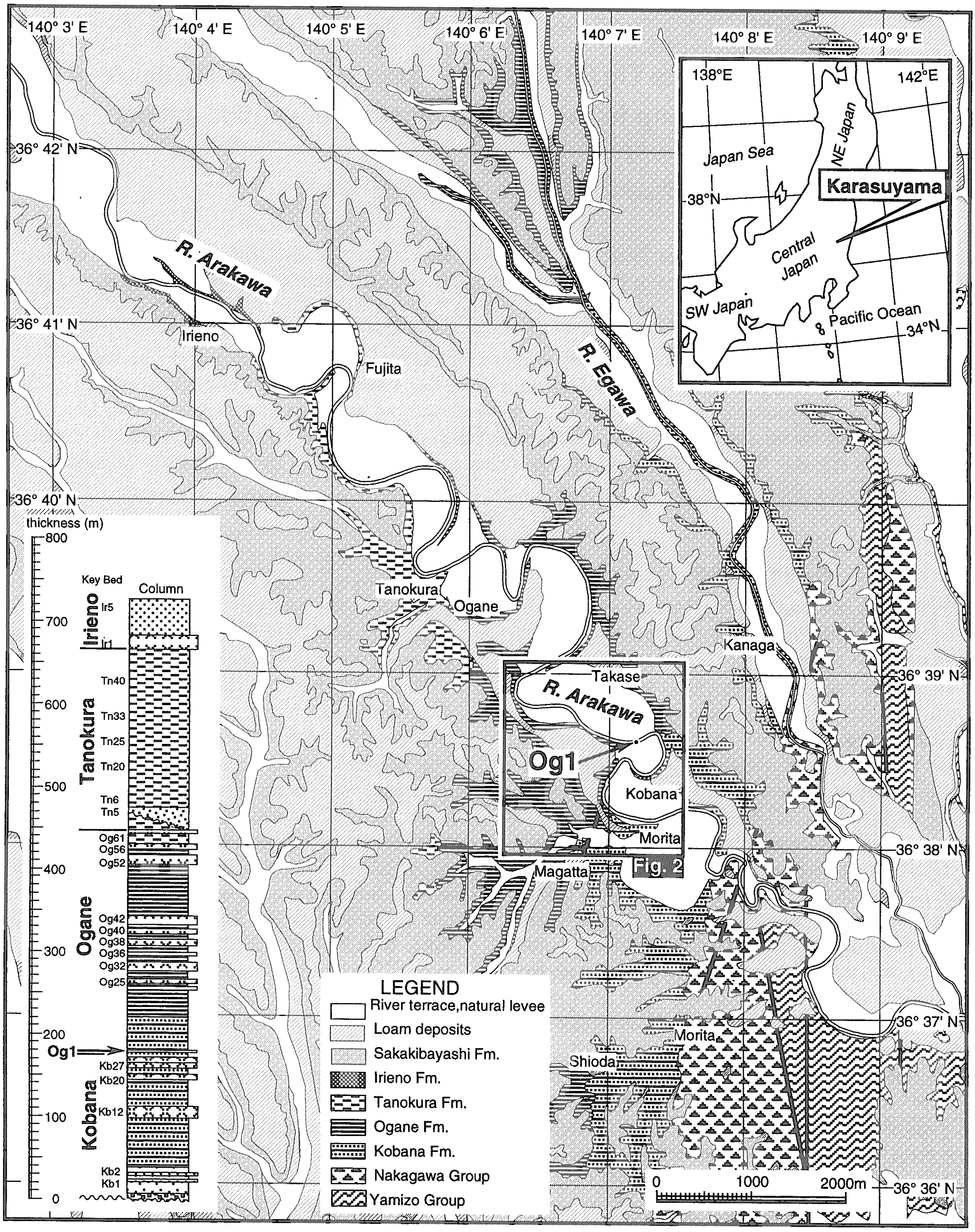

Fig. 1 Sample location on the geological map of the Miocene marine sequence of the Arakawa Group, distributed in the Karasuyama area, central Japan (modified from Tochigi Prefecture Office, 1988, 1991).

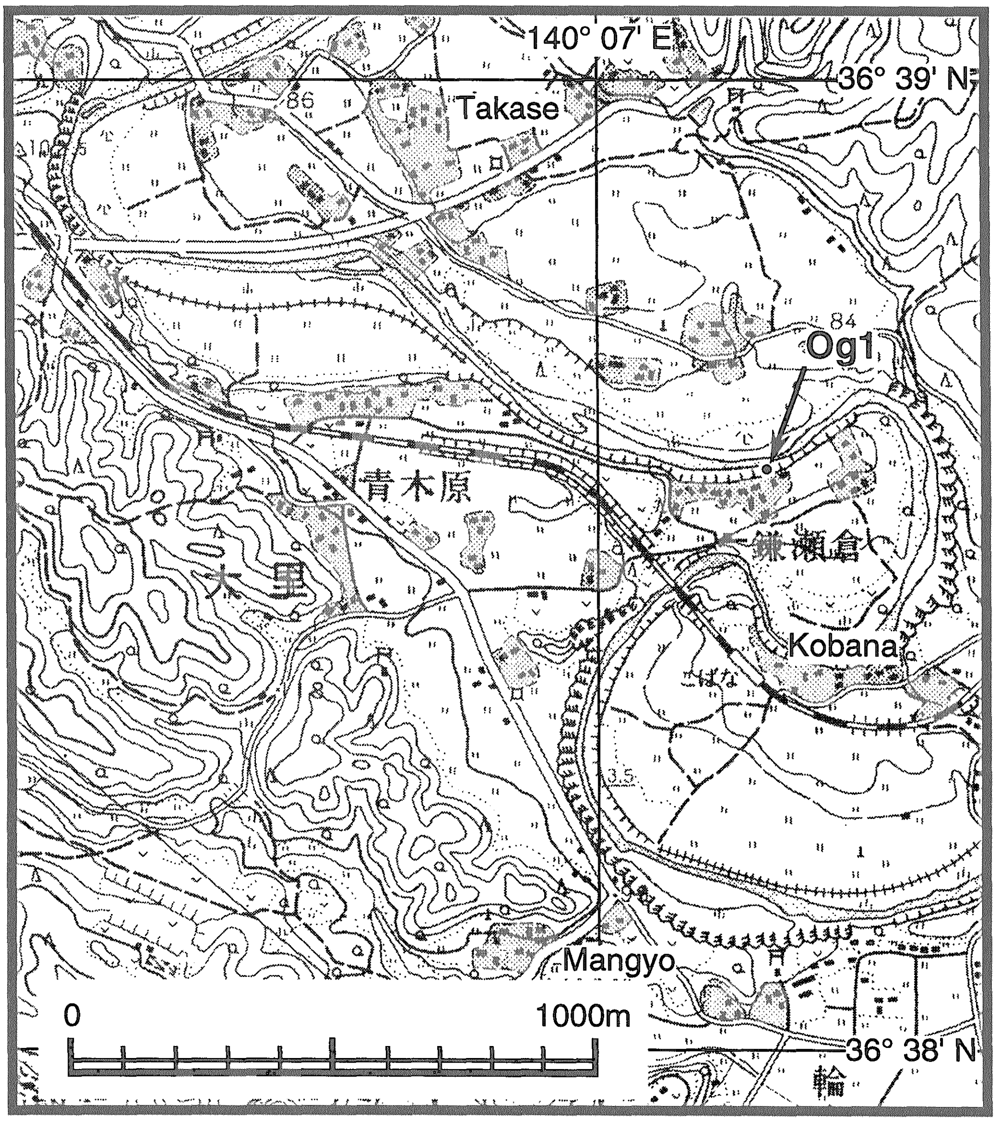

Fig. 2 Map showing the locality of dated tuff (topographic map: "Niita", scale 1/25,000 by the Geographical Survey Institute).

(LOs)of *Sphenolithus heteromorphus* and *Cyclicargolithus floridanus*. The former and latter define the CN4/CN5a and CN5a/CN5b boundaries of the calcareous nannofossil zones (Okada and Bukry, 1980), respectively. Among them, the CN5a/CN5b boundary was precisely determined in the fine-grained sandstone layer, at one meter below the Og1 Tuff, which was dated by the fission track method through this work.

3. Fission track dating

The Og1 Tuff is characterized by biotite and hornblende-rich medium-grained tuff, which is 5 cm thick. Both lower and upper boundaries of this pyroclastics are very sharp, and no lithic fragment within the tuff can be observed. Thickness of the Og1 Tuff is constant throughout the Karasuyama area. We collected 3 kg sample of the Og1 Tuff (Figs. 1 & 2), and carried out the conventional zircon separation by sieving, panning, and magnetic and heavy liquid separating techniques. The Og1 Tuff yielded many zircons, which were reddish, euhedral and had no zonal structures inside.

Fission track dating was done by using the external detector method that was applied to both the internal (polished) and external surfaces of zircon grains (ED1 and ED2 methods, respectively: Gleadow, 1981). The internal surfaces have an advantage of being free from the external effect, which is the contamination of fission tracks originating externally to the dated zircon. On the other hand, the external surfaces have an advantage of easier track identification because all the observed tracks are longer than the half-length of a complete track. The ED2 method is especially suitable for dating volcanic ash or tuff that includes more or less

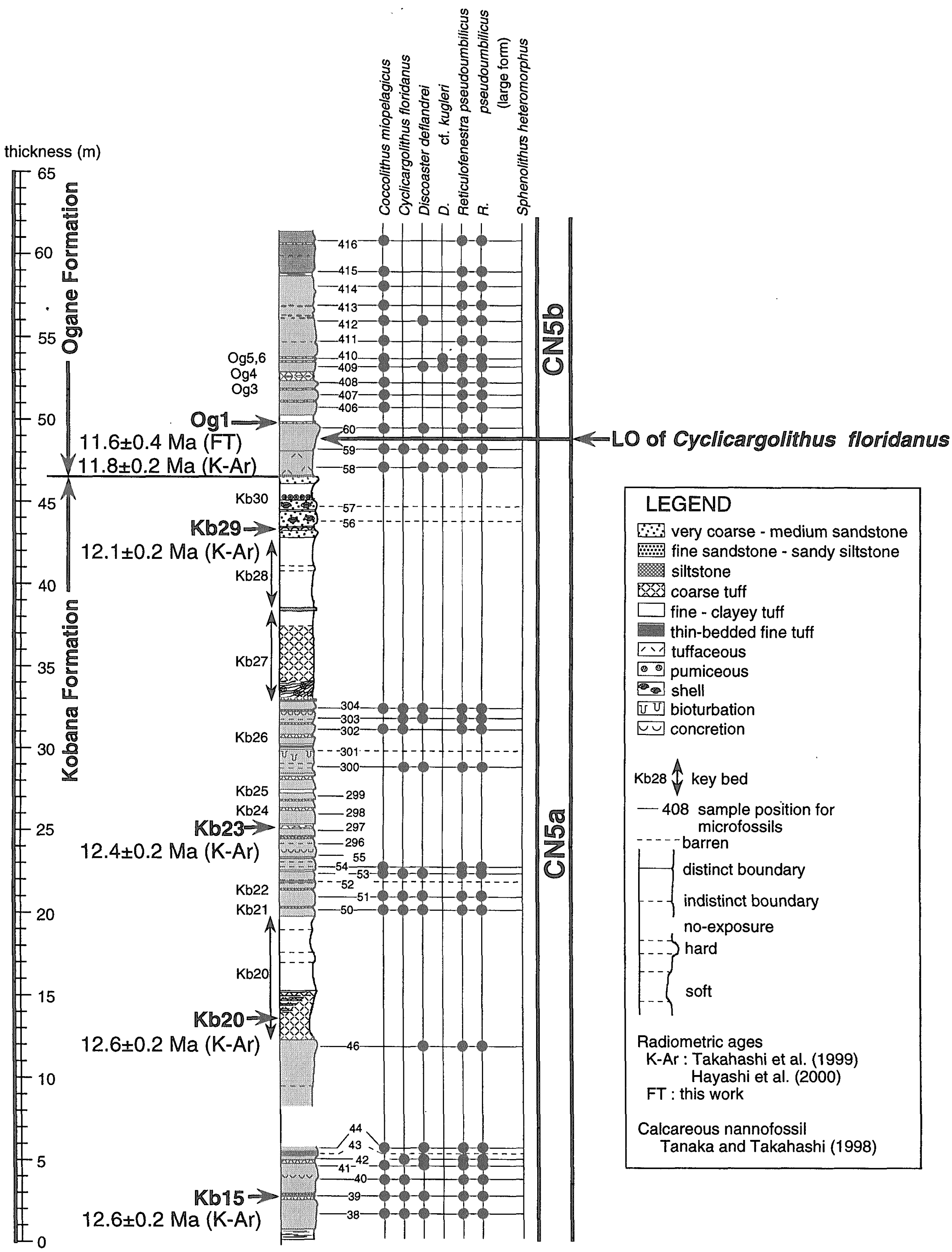

Fig. 3 Stratigraphic distributions of selected calcareous nannofossil species on the detailed stratigraphic composite column of the upper part of the Kobana to lowest part of the Ogane Formations (partly revised from Tanaka and Takahashi, 1998). Stratigraphic positions with ages of the Og1 Tuff and previously reported dated volcaniclastics are also shown.

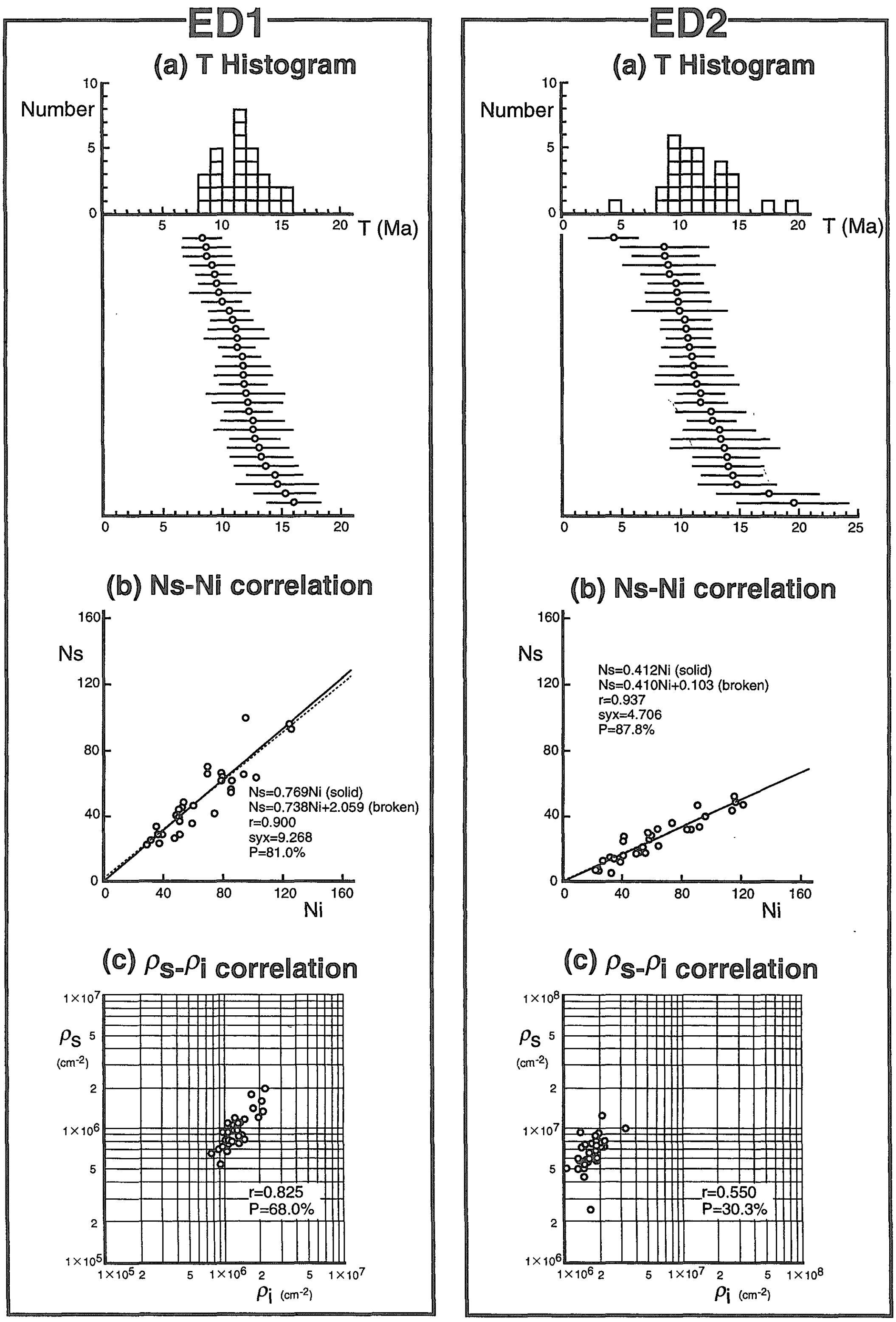

Fig. 4 Grain-by-grain plots of fission-track data for zircon from the Og1 Tuff using the external detector method applied to the internal surface (ED1: left) and external surface (ED2: right). (a) Histograms of grain-age (above) and its analytical error (below), (b) correlation of spontaneous track counts (Ns) and induced track counts (Ni), and (c) correlation of spontaneous track density (ρs) and induced track density (ρi) are given. Statistical values of correlation coefficient (r), standard deviation (syx) and percentage of variation (P) are also shown. The grain-age distribution and linearity of Ns/Ni and $\rho s/\rho i$ correlation demonstrate that the Og1 Tuff zircon has a single age population without a contamination of detrital (older) grains.

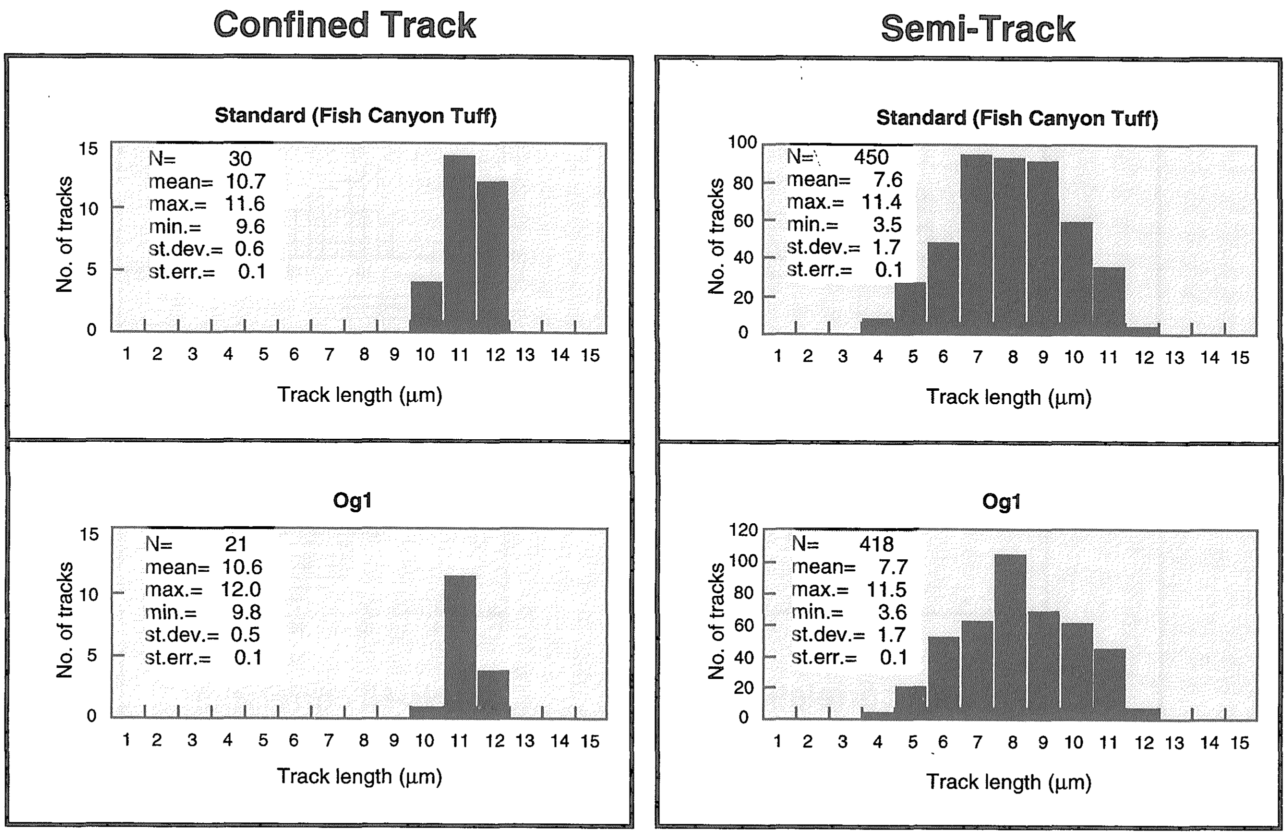

Fig. 5 Comparison of length distributions of spontaneous tracks in zircon for confined track (left) and semi-track on external surfaces (right) between the Og1 Tuff and Fish Canyon Tuff (standard).

Table 1 Fission track data of zircons from the Og1 Tuff in the lowest part of the Ogane Formation.

Sampe code	Mineral	No. of crystals	Spontaneous ρs ($10^6 cm^{-2}$)	(Ns)	Induced ρi ($10^6 cm^{-2}$)	(Ni)	$P(\chi 2)$ (%)	Dosimeter ρd ($10^4 cm^{-2}$)	(Nd)	r	U-content (ppm)	Age (±1 σ) (Ma)	Method
Og1 ED1	zircon	30	1.01	(1512)	1.31	(1965)	70	8.54	(2625)	0.825	120	**11.6±0.5**	ED1
Og1 ED2	zircon	30	0.680	(772)	1.65	(1874)	83	8.54	(2625)	0.550	160	**11.7±0.6**	ED2
										weighted mean		**11.6±0.4**	
Fish Canyon Tuff													
FCT ED1	zircon	20	5.44	(3567)	2.90	(1903)	50	8.61	(2645)	0.932	270	**28.3±1.0**	ED1
FCT ED2	zircon	20	3.22	(1660)	3.23	(1665)	28	8.58	(2637)	0.665	300	**28.5±1.2**	ED2

(1) ρ and N are the density and total number of fission tracks counted, respectively.
(2) Analyses were made by the external detector method using a geometry factor of 0.5 for $2\pi/4\pi$ (ED1) and 1 for $2\pi/2\pi$ (ED2).
(3) Ages were calculated using a dosimeter glass SRM612 and age calibration factors ζ (ED1) = 352 ± 3 and ζ (ED2) = 334 ± 4 (Iwano and Danhara, 1997).
(4) $P(\chi^2)$ is the probability of obtaining the χ^2-value for ν degrees of freedom (where ν = number of crystals-1).
(5) r is the correlation coefficient between ρs and ρi.
(6) Samples were irradiated using TRIGA MARK II nuclear reactor of St. Paul's University (Rikkyo Daigaku), Japan.
(7) The reference age adopted for the Fish Canyon Tuff is 27.8 ± 0.2 Ma (Hurford and Hammerschmidt, 1985).

detrital grains because detrital grains have a shorter surface-track length distribution caused by thermal heating, and can be easily identified. Age-calibration was made on the basis of the zeta approach recommended by the IUGS Subcommission on Geochronology (Hurford, 1990). Experimental procedures and system calibrations were explained in detail in Danhara *et al.* (1991) and Iwano and Danhara (1997). The Fish Canyon Tuff, one of the age standard materials (Hurford, 1990) was also prepared to check the age calibration and compare the track length distribution.

4. Results and Discussion

The spontaneous track density of the Ogl zircon was homogeneous among grains for each dated mount (ED1 and ED2). In addition, no possible detrital grains having higher track density and shorter track length on the external surfaces were recognized. Thirty grains were randomly selected and measured for each method. Grain-by-grain analytical data are shown in Fig. 4. We can see that the Ogl zircons have a single age population with no detrital grains.

The resulting fission track ages are 11.6 ± 0.5 Ma for ED1 and 11.7 ± 0.6 Ma for ED2, and consistent with each other. Both data pass through the χ^2-test at a 5% level. The results of the age standard also showed good agreement with the reference value, implying that both ED1 and ED2 calibrations were reasonably executed (Table 1). Moreover, no track shortening was found for either the confined tracks (internal surface) or semi-tracks (external surface) in zircon (Fig. 5). This indicates that the Ogl zircons have never been affected from thermal heating, and should record the formation age of this tuff sample. Therefore, we adopted a weighted mean age of 11.6 ± 0.4 Ma for the Ogl pyroclastics (Table 1).

Kasuya (1987) first reported fission track age of the Ogl Tuff as 11.8 ± 1.0 Ma. However, this age is regarded as invalid one at present, because the zeta calibration was not adopted in Kasuya (1987). Recently, Takahashi *et al.* (1999) determined the K-Ar biotite age as 11.8 ± 0.2 Ma. Our newly obtained fission track age (11.6 ± 0.4 Ma) coincides with the K-Ar age, which suggests that these ages are reliable and represent the age of the Ogl pyroclastics eruption.

The LO of *C. floridanus,* defining the CN5a/CN5b boundary, is located one meter below the dated tuff (Tanaka and Takahashi, 1998). As the mean sediment accumulation rate at the lowest part of the Ogane Formation was estimated as 1.6 cm/1000 yr (Takahashi *et al.*, 1999), the numerical age of the CN5a/CN5b boundary can be regarded as the same as the radiometric age of the Ogl Tuff (11.6-11.8 Ma). This estimation is well concordant with Berggren's (1995) time scale (CN5a/CN5b=11.8 Ma).

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栃木県烏山地域に分布する中新世海成層(荒川層群)に挟在する Og1 凝灰岩のフィッションツトラック年代

高橋雅紀・岩野英樹

要　旨

栃木県烏山地域に分布する中新世海成層荒川層群の大金層最下部に挟在する珪長質凝灰岩(Og1)より抽出したジルコンについてフィッショントラック年代を測定し、11.6 ± 0.4 Ma (1 σ error)の年代値を得た．同一試料について測定されたK-Ar年代値(11.8 ± 0.2 Ma; Takahashi *et al.*, 1999)とよい一致を示すことから，得られたフィッション年代値はOg1凝灰岩の噴出年代を示すと判断される．年代決定されたOg1凝灰岩の1メートル下位に石灰質ナンノ化石の *Cyclicargolithus floridanus* の終産出が確認されていることから，得られた年代は，同生層準により規定されるCN5a/CN5b境界(Okada and Bukry, 1980)年代を示すと判断される．