報 告

K-Ar and fission track ages of the Kt-1 Tuff in the
Miocene marine sequence in the Tanagura area,
Northeast Japan

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Abstract: K-Ar and fission track ages were determined for the Kt-1 Tuff interbedded in the lowest part of the Miocene Kubota Formation in the Tanagura area. A K-Ar age of the Kt-1 Tuff was determined as 10.6 ± 0.2 Ma on biotite. A fission track age was also determined using zircon as 10.7 ± 0.2 Ma. Both ages well coincide with each other, which suggests that the obtained ages represent the eruption age of the Kt-1 pyroclastics. Reported results of the biostratigraphic analysis are concordant with the newly obtained radiometric ages.

Key words: Miocene, Integrated stratigraphy, K-Ar age, fission track age, biostratigraphy, calcareous nannofossil, planktonic foraminifera

1. Introduction

Biostratigraphy is one of the most common and useful tools for age determination of marine sediments, although it indicates only stratigraphic relations. If we need numerical ages of strata based on yielded microfossils, we can estimate the age using a time scale, which is constructed by a combination of magneto-biostratigraphy and geomagnetic polarity time scale (GPTS). Therefore, the reliability of the time scale depends on the accuracy of the GPTS and validity of correlation between

marine magnetic anomaly pattern (GPTS) and magnetostratigraphy. Recently Berggren *et al.* (1995) constructed the geologic time scale based on Cande and Kent (1995)'s GPTS, although serious problems on GPTS (Cande and Kent, 1992, 1995) have been pointed out by Baksi (1993), Wei (1995) and Takahashi and Danhara (1997). Therefore, it is obviously effective to integrate the chronology based on the radiometric dating with the magneto- and/or biostratigraphy. Some Neogene marine sequences interbed datable volcanoclastic layers in Japan, which is a great advantage for constructing a time scale (Takahashi and Oda, 1997).

A Miocene marine sequence is well exposed in the Tanagura area, Northeast Japan (Fig. 1). This sequence is divided into the Akasaka and Kubota Formations. The upper unit of this sequence yields microfossil dominantly. Aita (1988) reported a planktonic foraminiferal biostratigraphy and Taketani and Aita (1991) in-

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Fig. 1 Sample location on a geological map of the Miocene marine sequence in the Tanagura area, Northeast Japan (modified from Shimamoto *et al.*, 1998).

vestigated a radiolarian biostratigraphy based on the same samples as Aita (1988). Shimamoto *et al.* (1998) also reported biostratigraphic study results of planktonic foraminifera, calcareous nannofossil and radiolaria. Recently Hayashi *et al.* (2000) revised the planktonic foraminiferal biostratigraphy. Diatom biostratigraphy was first reported by Yanagisawa *et al.* (2000).

There are seven sets of volcanoclastic layers in the Kubota Formation, as reported by Shimamoto *et al.* (1998), in which we found a datable volcanoclastic layer (Kt-1). In this paper, we present K-Ar and fission track ages of the Kt-1 Tuff and discuss their relationship with the calcareous microfossil biostratigraphy of the Kubota Formation.

2. Geology and stratigraphy

The Tanagura area is situated on the southern part of Northeast Japan (Fig. 1), where the late Miocene marine sequence is well exposed. This sequence unconformably overlies the pre-Neogene granitic and metamorphic rocks along the eastern margin, and is covered by a Pliocene conglomerate of the Nikogi Formation. The Miocene sedimentary rocks are gently tilted northwesterly, but they steeply incline easterly along the western marginal thrust fault (Shimamoto *et al.*, 1998).

The Miocene sequence is more than 500 m in thickness and divided into the following two formations. The Akasaka Formation is composed of conglomerate, medium- to coarse-grained sandstone and siltstone. Cross-bedding structure is often observed throughout this formation. Marine molluscs are often yielded, which indicates a shallow sedimentary environment. Benthic foraminifera are reported from the Akasaka Formation, which suggests an inner sublittoral zone environment (shallower than 50 m).

In contrast, fine-grained sandstone and siltstone with frequent intercalation of thin volcanoclastic layers dominate the Kubota Formation, which conformably covers the Akasaka

Formation. As planktonic microfossils are commonly yielded by this formation, biostratigraphic investigations have been performed. Shimamoto *et al.* (1998) reported the biostratigraphy of the planktonic foraminifera, calcareous nannofossil and radiolaria. They concluded that most of the Kubota Formation was correlative to zone N. 16 of the planktonic foraminiferal zone (Blow, 1969) or CN6 to CN7 of calcareous nannofossil zones (Okada and Bukry, 1980). Recently Hayashi *et al.* (2000) re-investigated the planktonic foraminiferal biostratigraphy, and recognized a key species of *Neogloboquadrina acostaensis*, whose first occurrence (FO) defines the lower limit of zone N. 16, in the lowest part of the Kubota Formation (Fig. 2). Calcareous nannofossil key species of *Catinaster coalitus*, whose FO defines the base of CN6, and *Catinaster calyculus*, whose FO defines the base of CN7, were also reported (Fig. 2). Radiolaria is continuously yielded from the middle part of the Kubota Formation. Shimamoto *et al.* (1998) concluded that the middle part of the Kubota Formation was correlative to the *Lychnocanoma magnacornuta* zone (Motoyama and Maruyama, 1998).

3. Radiometric ages

More than twenty tuff layers are interbedded in the Kubota Formation, although only the Kt-1 Tuff contains datable minerals for conventional K-Ar dating. The Kt-1 Tuff is characterized by biotite-rich coarse-grained tuff as shown in Fig. 2. We made a detailed columnar section of the Kt-1 Tuff, and collected samples (about 5 kg) from its middle part (Fig. 2).

Coarse-grained tuff samples were crushed and sieved into the 48-80 mesh size fractions for K-Ar dating. After ultrasonic rinsing, the magnetic fraction of the sample was separated using an isodynamic separator. Fresh biotite fractions were purified using a heavy liquid technique. Quantitative analysis of argon and potassium was performed at Hiruzen Institute for Geology and Geochronology, using the ana-

Fig. 2 Sample horizon in the detailed columnar section of the lowest part of the Kubota Formation. The stratigraphic distributions of selected planktonic foraminifera (Hayashi et al., 2000) and calcareous nannofossil species (Shimamoto et al., 1998) of the Kubota Formation are also shown.

lytical procedure as suggested by Itaya *et al.* (1991). The results are listed in Table 1 and the weighted-mean age with 1σ is also calculated.

Sufficient zircon grains were concentrated by sieving, panning, and standard magnetic and heavy liquid separating techniques. The separated zircons were red, euhedral and very homogeneous, and, therefore, regarded as essential. Fission track dating was carried out using the external detector method, which is applied to both internal (polished) surfaces and external surfaces of zircon grains (ED1 and ED2 methods, respectively: Gleadow, 1981). Two sets of data were obtained independently in different systems (observers). Ages were calculated following the zeta approach (Hurford, 1990). The experimental pro-

cedures and system calibrations were detailed elsewhere (see Danhara *et al.*, 1991; Iwano and Danhara, 1997). The results are listed in Table 2.

4. Discussion

We obtained the K-Ar biotite ages of 10.67 ± 0.25 Ma and 10.44 ± 0.2 Ma for the Kt-1, and 10.56 ± 0.18 Ma as weighted-mean age (Table 1). As for fission track ages, the resultant ages (10.8 ± 0.3 Ma and 10.6 ± 0.4 Ma) are consistent with each other, but the data from internal zircon surfaces (ED1) failed to the χ^2 -test at the 5% level (Table 2). Danhara *et al.* (1991) explained that the main source of the non-Poisson variation in ED1 data could be attributed to the heterogeneity of uranium contents

Table 1 K-Ar biotite age of the Kt-1 Tuff in the lowest part of the Kubota Formation. The K-Ar ages were calculated with the following decay constants (Steiger and Jäger, 1977).

$$\lambda_e = 0.581 \times 10^{-10}/\text{year}, \lambda_\beta = 4.962 \times 10^{-10}/\text{year}.$$

Sample (mineral)	Potassium (wt. %)	Radiogenic argon 40 (10 ⁻⁸ cc STP/g)	K-Ar age (Ma)	Non Radiogenic Ar(%)
Kt-1 (biotite)	4.567±0.091	189.7±2.4	10.67±0.25	19.9
		185.5±2.4	10.44±0.25	20.6
		weighted mean 10.56±0.18		

(error; $\pm 1\sigma$)

Table 2 Fission track data of zircons from the Kt-1 Tuff in the lowest part of the Kubota Formation.

Sampe code	No. of crystals	Spontaneous		Induced		$P(\chi^2)$ (%)	Dosimeter		r	U- content (ppm)	Age ($\pm 1\sigma$) (Ma)
		ρs	(Ns)	ρi	(Ni)		ρd	(Nd)			
		(10 ⁶ cm ⁻²)		(10 ⁶ cm ⁻²)			(10 ⁴ cm ⁻²)				
Kt-1(ED 1)	30	2.40	(3289)	3.09	(4232)	0	7.909	(2430)	0.854	310	10.8±0.3
Kt-1(ED 2)	30	1.56	(1136)	4.33	(3149)	26	7.909	(2430)	0.898	440	10.6±0.4
weighted mean 10.7±0.2											

(1) ρ and N are the density and total number of fission tracks counted, respectively.

(2) Analyses were made by the external detector method (Gleadow, 1981) using geometry factors of 0.5 for $2\pi/4\pi$ (ED 1) and 1 for $2\pi/2\pi$ (ED 2).

(3) Ages were calculated using a dosimeter glass SRM 612 and age calibration factors ζ (ED 1) = 352 ± 3 (Iwano and Danhara, 1997) and ζ (ED 2) = 372 ± 5 (Danhara *et al.*, 1991).

(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 a correlation coefficient between ρs and ρi .

(6) Samples were irradiated using the TRIGA MARK II nuclear reactor at St. Paul's University (Rikkyo Daigaku), Japan.

Fig. 3 Stratigraphic relationship between the Kt-1 Tuff and some important biohorizons of calcareous microfossils. The K-Ar and fission track ages of the Kt-1 Tuff and the numerical age of each biohorizon, estimated on the basis of the Berggren *et al.* (1995)'s time scale, are also indicated.

above and below the observed internal surfaces using age standards with no contamination of detrital grains. We think that the main reason for the result of the χ^2 -test is not the contamination of detrital grains but the heterogeneity of uranium contents inside the grain as mentioned above. In fact, the ED2 data passed the χ^2 -test. At this stage, we adopted a weighted-mean age of 10.7 ± 0.2 Ma (Table 2). This value well coincides with the K-Ar age of the same tuff. Therefore, we can conclude that the obtained ages are reliable and indicate the eruption age of the Kt-1 pyroclastics.

Recently Hayashi *et al.* (2000) recognized *Neogloboquadrina acostaensis* from almost the same horizon as the dated Kt-1 Tuff (Fig. 2). The FO of *N. acostaensis* defines the lowest limit of zone N. 16, which is estimated as 10.9 Ma (Berggren *et al.*, 1995). Therefore, the age of the Kt-1 Tuff (10.6–10.7 Ma) is biostratigraphically constrained to be 10.9 Ma or younger. Thus the stratigraphic relation between the planktonic foraminiferal biostratigraphy and obtained radiometric ages is very consistent (Fig. 3).

As for the calcareous nannofossil biostratigraphy, some important biohorizons were recognized by Shimamoto *et al.* (1998). The FO of *Catinaster coalitus*, defining a CN5b/CN6 boundary, estimated as 11.3–10.9 Ma (Berggren *et al.*, 1995), was recognized at the middle level between the Kt-3 and Kt-4 tuff horizons, about 30m above the Kt-1. The FO of *Catinaster calyculus*, defining the base of CN7 whose age was estimated as 10.7 Ma, was reported at the upper part of the Kubota Formation. The other important biohorizon of the last occurrence (LO) of *Coccolithus miopelagicus* (estimated as 11.0–10.8 Ma) is located at the uppermost part of the Kubota Formation. Thus the estimated ages of each biohorizon almost coincide with the radiometric age of the Kt-1 Tuff, which strongly suggests a high sediment accumulation rate of the Kubota Formation. About 200-m thick marine sediments of the Kubota Formation may be deposited during a

very short time interval (the error of the radiometric ages; ca. 0.4 m.y.).

5. Conclusion

K-Ar and fission track ages were determined for the Kt-1 Tuff, interbedded in the lowest part of the Miocene Kubota Formation in the Tanagura area. The K-Ar biotite ages (10.7 ± 0.3 Ma and 10.4 ± 0.3 Ma and the weighted-mean age of 10.6 ± 0.2 Ma) and fission track ages (10.8 ± 0.3 Ma (ED1), 10.6 ± 0.4 Ma (ED2) and the weighted-mean age of 10.7 ± 0.2 Ma) coincide with each other, suggesting the reliability of the ages obtained. The radiometric ages show good agreement with the previously established calcareous microfossil biostratigraphy.

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* in Japanese with English abstract.

** in Japanese.

要 旨

棚倉地域に分布する中新世海成層に挟在する
Kt-1 凝灰岩の K-Ar およびフィッション
トラック年代

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福島県棚倉地域に分布する中新世海成層の久保田層最下部に挟在する珪長質凝灰岩 (Kt-1) より黒雲母を抽出し K-Ar 年代を測定した結果、 10.6 ± 0.2 Ma (誤差 $\pm 1\sigma$) の年代値を得た。さらに同一試料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、 10.7 ± 0.2 Ma (誤差 $\pm 1\sigma$) の年代値を得た。両年代値はよい一致を示すことから、それらは Kt-1 凝灰岩の噴出年代を示すと判断される。さらに、既報の浮遊性有孔虫化石層序および石灰質ナノ化石層序との層序学的関係について考察した。