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Fission track age of the Kt-7 Tuff in the Miocene Kubota Formation in the eastern Tanagura area, Northeast Japan

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Abstract: The fission track dating was applied for the Kt-7 Tuff, interbedded in the uppermost part of the Miocene Kubota Formation in the eastern Tanagura area, Northeast Japan. The fission track age of the Kt-7 Tuff (10.6 ± 0.3 Ma; 1σ error) is almost equal to the K-Ar and fission track ages of the Kt-1 Tuff, interbedded in the lowest part of the Kubota Formation. These radiometric ages show good agreement with the previously established calcareous and siliceous microfossil biostratigraphy. The integrated stratigraphy based on microfossils as well as K-Ar and fission track ages indicate a high sedimentation rate of the Kubota Formation.

1. Introduction

Microfossil biostratigraphy is one of the most common and useful tool for age determination of marine sediments, although it indicates only stratigraphic relations. If we need a numerical age 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 a geologic time scale based on Cande and Kent's (1995) GPTS, although Baksi (1993), Wei (1995) and Takahashi and Danhara (1997) have pointed out serious problems on the GPTS. Therefore, it is obviously effective to integrate the chronology based on the radiometric dating with the magneto- and/or biostratigraphy. Some Neogene marine sequences in Japan interbed datable volcaniclastic layers, which have a great advantage for constructing a time scale (Takahashi and Oda, 1997).

A Miocene marine sequence is well exposed in the eastern Tanagura area, Northeast Japan (Fig. 1). This sequence is divided into the Akasaka and Kubota Formations (Otsuki, 1975). The Kubota Formation yields microfossils dominantly. Many previous works investigated the detailed biostratigraphy on this formation (Aita, 1988; Taketani and Aita, 1991; Shimamoto *et al.*, 1998; Hayashi *et al.*, 2000; Yanagisawa *et al.*, 2000). Recently, Takahashi *et al.* (2001) first determined K-Ar and fission track ages of the Kt-1 Tuff, interbedded in the lowest part of the Kubota Formation, however the age of the youngest limit of this marine sequence is unclear.

In this paper, we show brief introduction of the geology, litho- and biostratigraphy and newly obtained fission track age of the Kt-7 Tuff, interbedded in the uppermost part of the Kubota Formation. The stratigraphic relations between some important microfossil biohorizons and radiometric ages of two pyroclastic rocks are also discussed.

2. Geology and stratigraphy

The eastern Tanagura area is situated on the southern part of Northeast Japan (Fig. 1). The Miocene marine 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 horizontally. 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

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Keywords: fission track age, biostratigraphy, integrated stratigraphy, Miocene, Kubota Formation, Northeast Japan

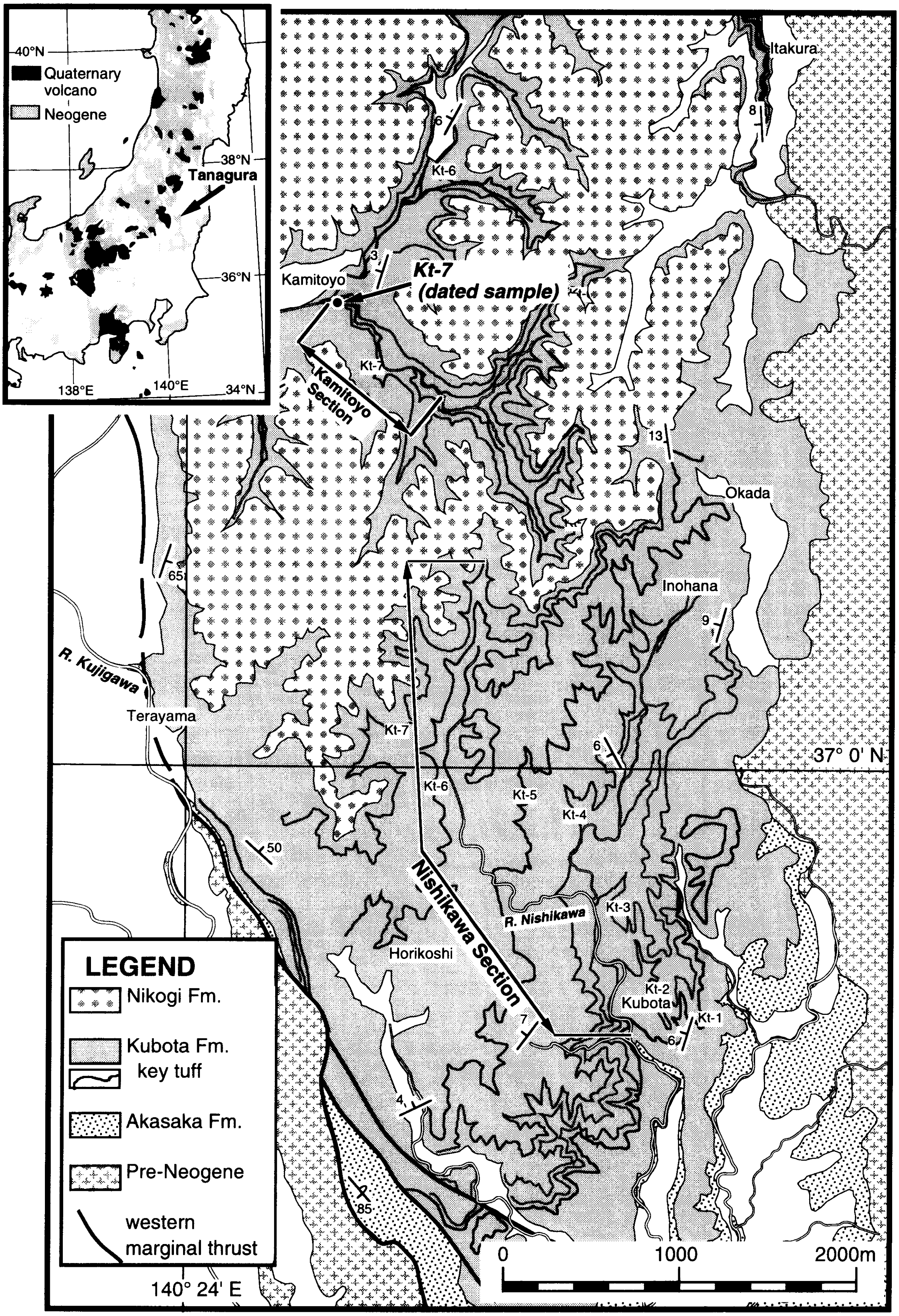

Fig. 1 Sample location on the geological map of the Miocene marine sequence of the Kubota Formation, distributed in the eastern Tanagura area, Northeast Japan (modified from Shimamoto *et al*., 1998). Index map is modified from Yamada *et al*. (1990).

(Otsuki, 1975). 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 yielded, indicating a shallow sedimentary environment. Benthic foraminifers, which suggests an inner sublittoral zone environment (shallower than 50 m), are reported from the Akasaka Formation (Shimamoto *et al.*, 1998).

In contrast, fine-grained sandstone and siltstone with frequent intercalation of thin volcaniclastic layers dominate the Kubota Formation, which conformably covers the Akasaka Formation. More than 20 tuff beds, interbedded in this formation, are all felsic. The volcaniclastic layers of the Kt-1 through Kt-1C Tuffs are alternating beds of coarse-grained biotite-rich volcaniclastics and silty tuff layers. Only the Kt-7 Tuff consists of pumice tuff, while the rest (Kt-2 through Kt6A) are all fine-grained thin tuff beds (Takahashi *et al.*, 2001).

Shimamoto *et al.* (1998) concluded that most of the Kubota Formation is correlative to the planktonic foraminiferal zone N.16 of Blow (1969) or calcareous nannofossil zones CN6 to CN7 of Okada and Bukry (1980). Recently Hayashi *et al.* (2000) re-investigated the planktonic foraminiferal biostratigraphy. They 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 (Shimamoto *et al.*, 1998; Fig. 2). Radiolaria continuously occurred from the middle part of the Kubota Formation. Shimamoto *et al.* (1998) concluded that the middle part of the Kubota Formation is correlative to the *Lychnocanoma magnacornuta* Zone of Motoyama and Maruyama (1998). According to Yanagisawa *et al.* (2000), the stratigraphic interval from the Kt-1 to the middle of the Kt-4B and Kt-4C tuff levels is correlative to the *Thalassiosira yabei* Zone (NPD 5C) of Yanagisawa and Akiba (1998), because of the occurrence of both *Denticulopsis simonsenii* and *Denticulopsis vulgaris* and the absence of *Denticulopsis dimorpha* and *Denticulopsis praedimorpha*. The quite rare occurrence of *Denticulopsis hustedtii* suggests that the lower part of the Kubota Formation is younger than the acme and last common occurrence biohorizons of *D. hustedtii* (D55.8: 10.1 Ma), that is, the upper part of the *T. yabei* Zone. A few occurrences of some important diatom key species also suggest that the upper part of the Kubota Formation (around the Kt-6 Tuff level) also can be correlated to the *T. yabei* Zone (NPD 5C).

Takahashi *et al.* (2001) recently determined K-Ar and fission track ages for the Kt-1 Tuff. As the K-Ar age (10.6±0.2 Ma; 1σ error) and fission track age (10.7±0.2 Ma) of the Kt-1 Tuff coincide each other, Takahashi *et al.* (2001) concluded that these ages represent an age of the Kt-1 pyroclastics eruption.

3. Fission track dating

Fission track dating was performed for pumiceous tuff of the lowest part of the Kt-7 Tuff, interbedded in the uppermost part of the Kubota Formation. The Kt-7 Tuff is 5 m-thick, very fine to clayey tuff as shown in Fig. 3. Only the lowest part is pumiceous, and middle part is characterized by thin-bedded very fine tuff and clayey hard tuff set. As the Kt-7 Tuff contains neither sufficient biotite nor hornblende which are suitable for conventional K-Ar dating, we attempted to date it by the fission track method using zircon. About 3 kg of tuff sample was collected from the lowest part of the Kt-7 Tuff (Fig. 3).

Sufficient zircon grains were concentrated by sieving, panning, and standard magnetic and heavy liquid separating techniques. Two types of zircon crystals from this tuff sample were recognized. One is clear, reddish, euhedral and having lower spontaneous track density (ρs). The other is dark, brownish, subhedral and having higher ρs. The former group, approximately 60% of the separated grains, can be regarded as an essential ones, and then we measured 100 zircon grains for this group. Seven zircon grains belonging to the latter group, regarded as reworked ones, were also measured as reference.

Fission track dating was carried out using the external detector method, which is applied to internal (polished) surfaces of zircon grains (ED1 methods: Gleadow, 1981). Ages were calculated following the zeta approach (Hurford, 1990). The experimental procedures and system calibrations were detailed elsewhere (see Danhara *et al.*, 1991; Iwano and Danhara, 1997). The results are listed in Table 1.

4. Results and discussion

Fission track data is shown in Fig. 4. Based on the grain-age histogram and the correlations between spontaneous track counts (Ns) and induced track counts (Ni) as well as between ρs and induced track density (ρi) in Fig. 4, we can obviously distinguish the younger age component from the older age component, which correspond to the above-mentioned reddish and euhedral grains and the brownish and rounded grains, respectively. The resulting ages were calculated to be 10.6±0.3 Ma (1σ error) for the younger and 48.4 ±3.0 Ma for the older. Fission track data for the younger group failed the χ^2-test (Galbraith, 1981) at the 5% significance level. However, this is probably explained by the failing tendency of the χ^2-test in ED1 data that are affected by addi-

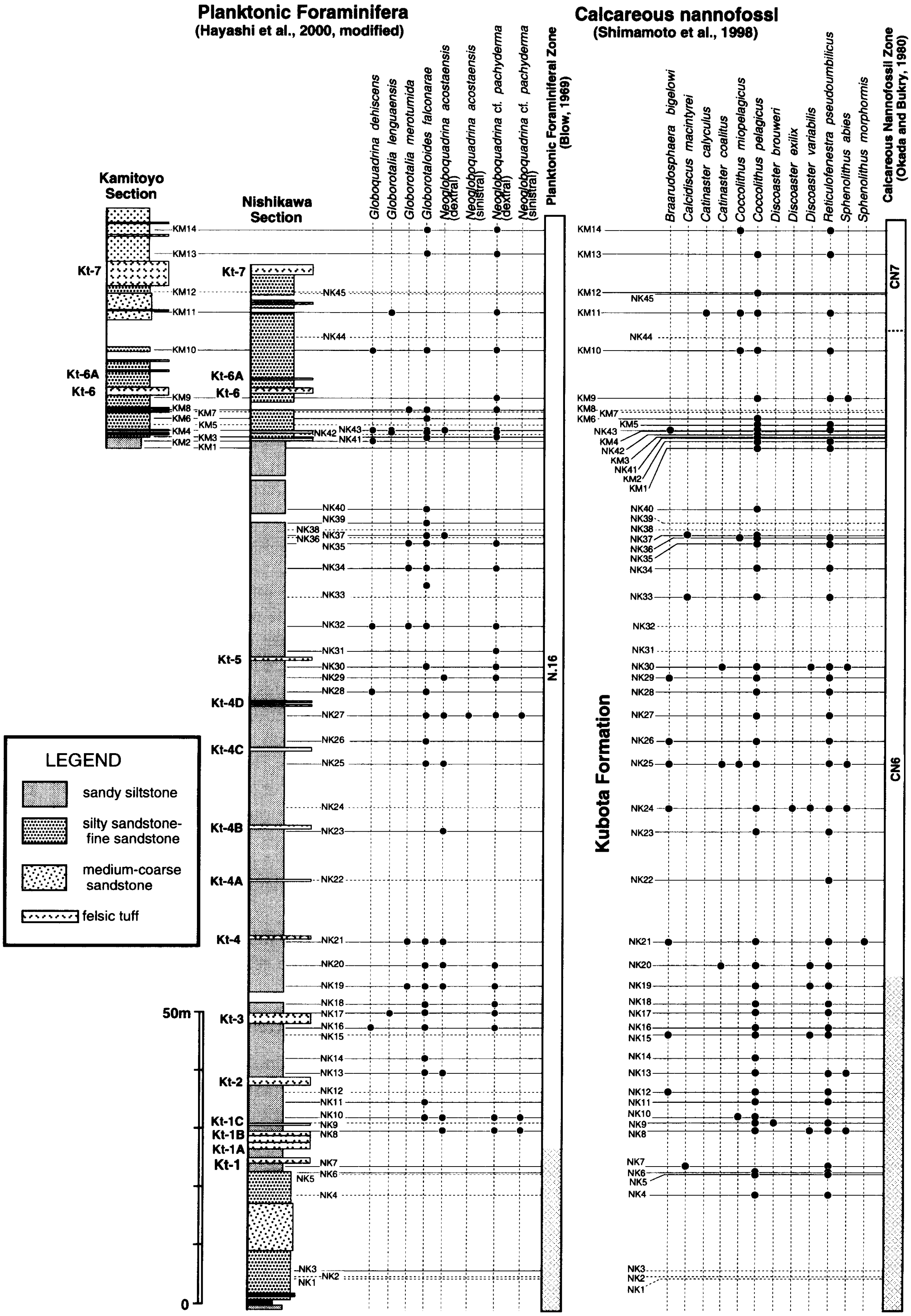

Fig. 2 The stratigraphic distributions of selected planktonic foraminiferal (Hayashi *et al.*, 2000), calcareous nannofossil and radiolarian (Shimamoto *et al.*, 1998) and diatom species (Yanagisawa *et al.*, 2000) in the Kubota Formation. Radiometric ages of the Kt-1 Tuff (Takahashi *et al.*, 2001) and Kt-7 (this work), as well as estimated ages of some important planktonic microfossil biohorizons, are also indicated.

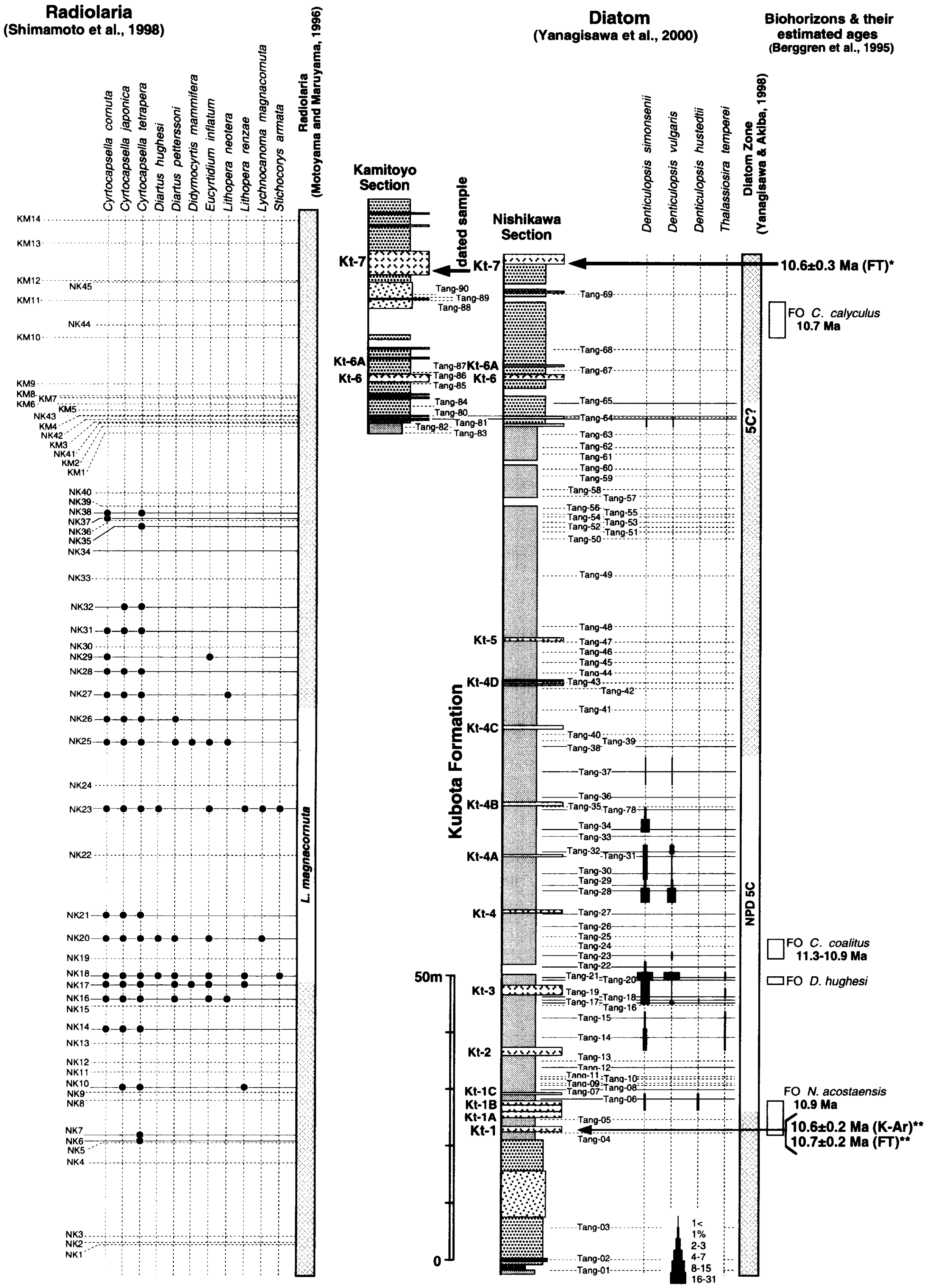

Fig. 2 (Continued)

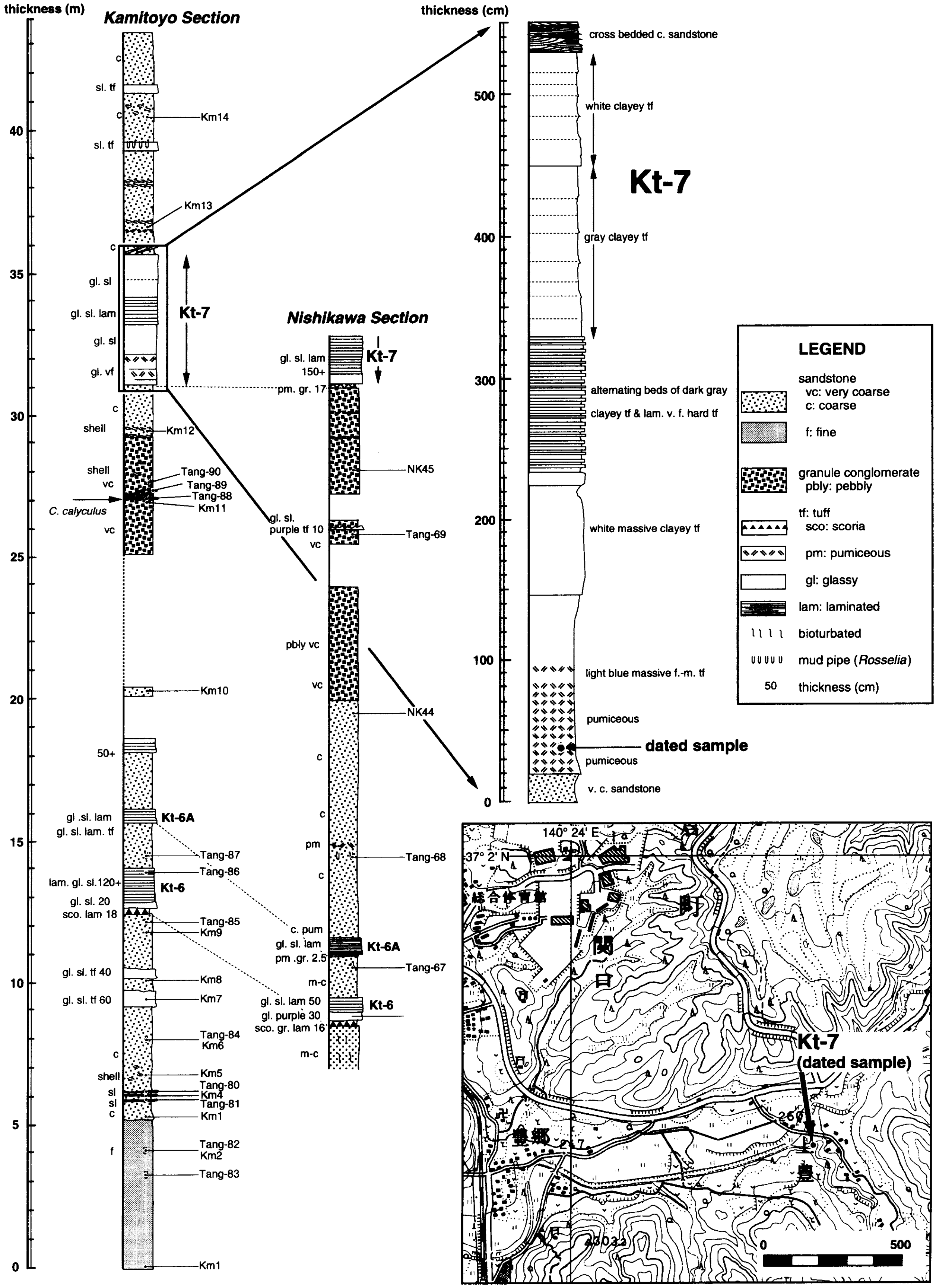

Fig. 3 The columnar sections of the upper part of the Kubota Formation. The stratigraphic position of dated sample is indicated on the detailed column of the Kt-7 Tuff. The location of tuff sample is also shown on the geographical map (topographic map: "Tanagura", scale 1/25,000 by the Geographical Survey Institute).

Table 1 Fission track data of zircons from the Kt-7 Tuff in the uppermost part of the Kubota Formation. Two types of zircon crystals were recognized. One is clear, reddish, euhedral and having lower spontaneous track density (ρs). The other is dark, brownish, subhedral and having higher ρs. The former group, approximately 60% of the separated grains, can be regarded as an essential ones, and then we measured 100 zircon grains for this group. Seven zircon grains belonging to the latter group, regarded as reworked ones, were also measured.

Sampe code	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 ($\pm 1\sigma$) (Ma)	Method
Kt-7(essential)	100	1.59	(4286)	2.14	(5779)	2	8.130	(2498)	0.902	210	**10.6±0.3**	ED1
Kt-7(detrital)	7	6.53	(1352)	1.92	(398)	6	8.130	(2498)	0.878	180	48.4±3.0	ED1

(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).
(3) Ages were calculated using a dosimeter glass SRM612 and age calibration factors ξ (ED1)$=352\pm3$ (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.

tional variation other than the Poisson variation in track counts. Danhara *et al.* (1991) pointed out that the main source of the non-Poisson variation in ED1 is the difference in uranium contents above and below the observed internal surfaces. If we omitted two more grains with the oldest grain-age from the younger group, in spite of the euhedral shape and reddish color crystals, the re-calculate age of 10.5 ± 0.3 Ma using the rest 98 grains shows no significantly change although the data passed the χ^2-test. Therefore, we adopted here the obtained age of 10.6 ± 0.3 Ma calculated from all of 100 grains as an eruption age of the Kt-7 pyroclastics in this report.

The fission track age of 10.6 ± 0.3 Ma shows almost the same ages of the K-Ar as well as fission track age of the Kt-1 pyroclastics, intebedded about 200 m below the Kt-7 Tuff. Thus the high sediment accumulation rate for the Kubota Formation is suggested (Fig. 5).

Hayashi *et al.* (2000) recognized *Neogloboquadrina acostaensis* at almost the same horizon as the dated Kt-1 Tuff (Fig. 2). The FO of *N. acostaensis* defines the base of zone N. 16, and is estimated at 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 of the Kt-1 Tuff is consistent (Fig. 5).

As for the calcareous nannofossil biostratigraphy, three important biohorizons were recognized by Shimamoto *et al.* (1998). The FO of *Catinaster coalitus*, which defines the CN5b/CN6 boundary and is estimated at 11.3-10.9 Ma (Berggren *et al.*, 1995), was recognized at the middle level between the Kt-3 and Kt-4 tuff layers, about 30 m above the Kt-1. The FO of *Catinaster calyculus* defines the base of CN7 and is estimated at 10.7 Ma (Berggren *et al.*, 1995). This biohorizon was reported at the upper part of the Kubota Formation. The last occurrence (LO) of *Coccolithus miopelagicus* (estimated at 11.0-10.8 Ma) is located at the uppermost part of the Kubota Formation, about 10 m below the Kt-7 pyroclastics (10.6 ± 0.3 Ma). Thus the estimated ages of each biohorizon almost coincide with the radiometric ages of the Kt-1 and Kt-7 tuff layers. These chronostratigraphic ages as well as biostratigraphic age-estimations strongly suggest that 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.). Thus we can estimate a high sedimentation rate (>25.5 cm/1000 yr.) based on the radiometric ages of two tuff layers when we adopt 1σ error for each age.

5. Conclusion

The fission track dating was applied for the Kt-7 Tuff, interbedded in the uppermost part of the Miocene Kubota Formation in the eastern Tanagura area, Northeast Japan. The fission track age of the Kt-7 pumice tuff (10.6 ± 0.3 Ma; 1σ error) shows almost same age to the K-Ar and fission track ages of the Kt-1 Tuff, interbedded in the lowest part of the

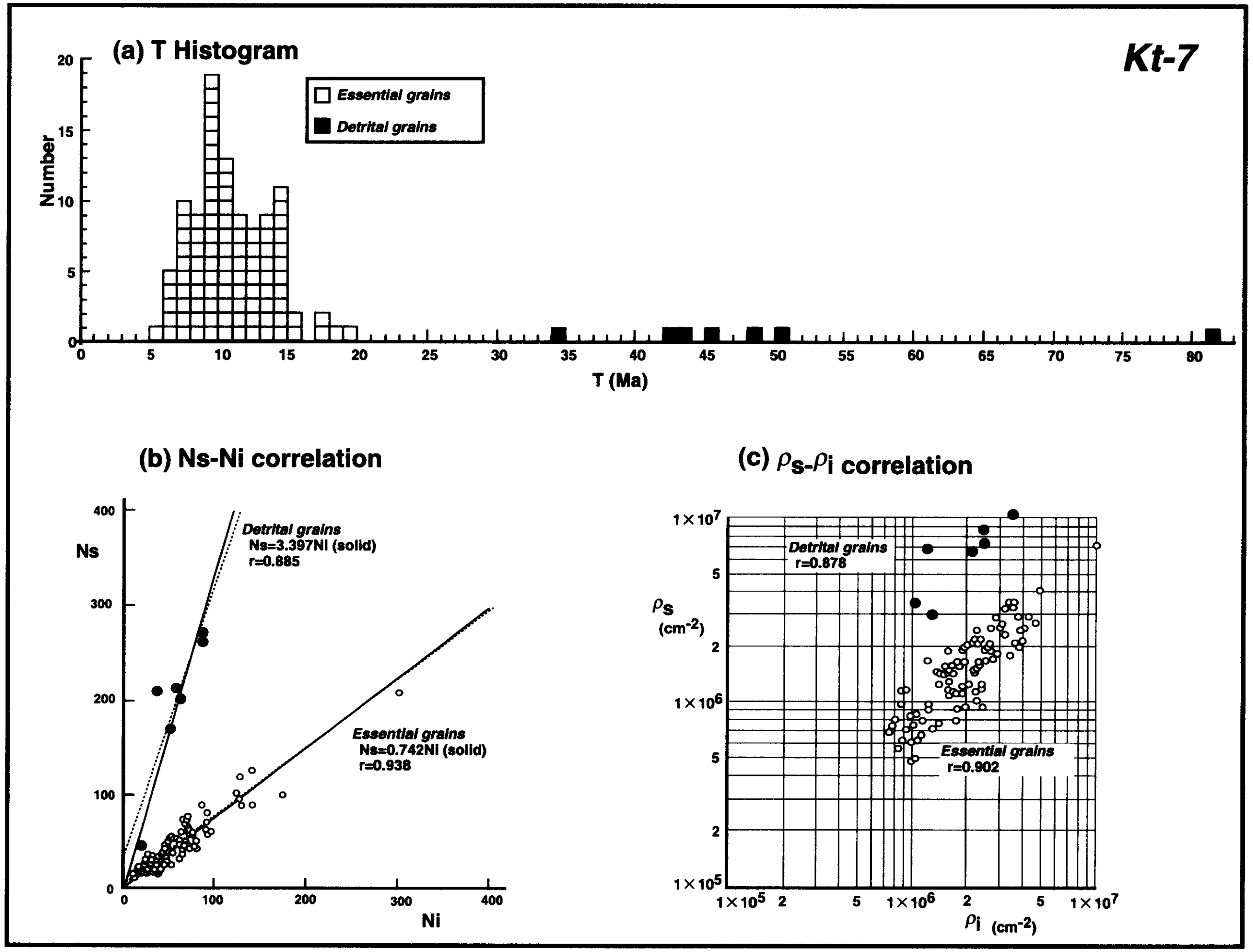

Fig. 4 Grain-by-grain plots of fission track data for zircon from the Kt-7 Tuff using the external detector method applied to the internal surface (ED1). (a) Histograms of grain-age, (b) correlation of spontaneous track counts (*Ns*) and induced track counts (*Ni*), and (c) correlation of spontaneous track density (ρs) and induced track density (ρi) are given. Statistical values of correlation coefficient (r) is also indicated. The grain-age distribution and linearity of Ns/Ni and $\rho s/\rho i$ correlation demonstrate that the Kt-7 Tuff zircon has a single age population after exclusion of seven contaminated detrital (older) grains.

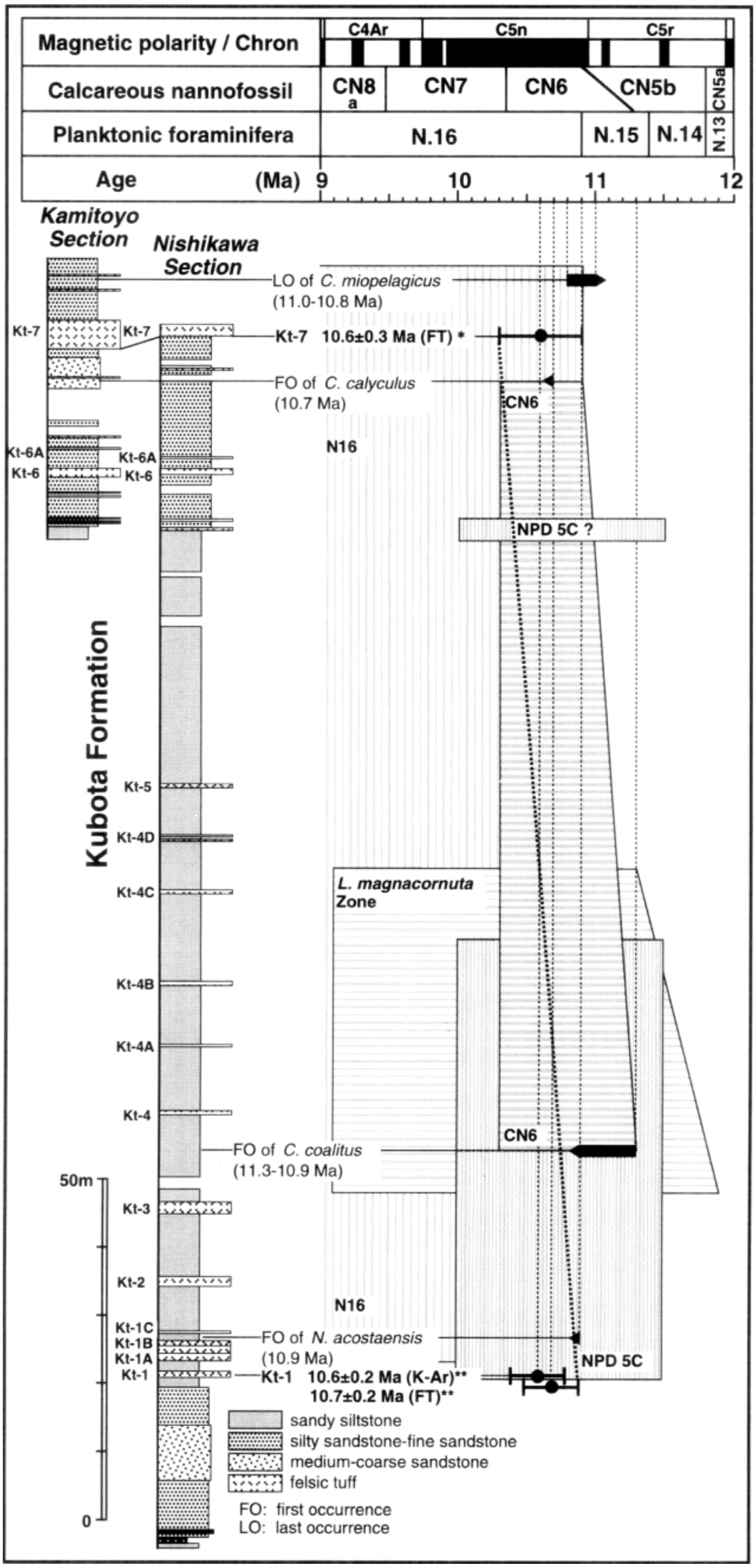

Fig. 5 Stratigraphic relationship between the dated tuff and biostratigraphic zones (included some important biohorizons). The integrated stratigraphic analysis revealed the high sedimentation rate of the Miocene marine sequence of the Kubota Formation.

Kubota Formation. These radiometric ages show good agreement with the previously established calcareous and siliceous microfossil biostratigraphy, and suggest a high sedimentation rate of the Kubota Formation.

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福島県東棚倉地域に分布する中新世海成層に挟在する Kt-7 凝灰岩のフィッションントラック年代

高橋雅紀・岩野英樹・柳沢幸夫・林　広樹

要　旨

福島県東棚倉地域に分布する中新世海成層の久保田層最上部に挟在する軽石質凝灰岩(Kt-1)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，10.6±0.3 Ma (1σ error)の年代値を得た．得られた年代値は，久保田層最下部で Kt-7 凝灰岩のおよそ 200 m 下位に挟在する Kt-1 凝灰岩の K-Ar およびフィッショントラック年代に誤差範囲で一致する．これらの放射年代値は既存の浮遊性微化石層序に基づく年代と調和的であることから，それぞれの火砕流堆積物の噴出年代を示すと判断される．久保田層における複合年代層序学的結果は，久保田層の堆積速度が非常に大きかったことを示している．