3- Integrated Stratigraphy of the Miocene Sequence, Miocene from Japan
(WG leader Masaki Takahashi: e-mail: masaki@gsj.go.jp)

Integrated stratigraphy of the Miocene marine sequence in the Tanagura area,
Northeast Japan

Masaki Takahashi
Integrated bio- and chronostratigraphy Research Group, Institute of Geoscience, AIST site C-7.
1-1-1 Higashi, Tsukuba, Ibaraki 305-8567, Japan; msk.takahashi@aist.go.jp

Yukio Yanagisawa
Integrated bio- and chronostratigraphy Research Group, Institute of Geoscience, AIST site C-7.
1-1-1 Higashi, Tsukuba, Ibaraki 305-8567, Japan; y.yanagisawa@aist.go.jp

Hiroki Hayashi
Institute of Geology and Paleontology, Tohoku University.
Aoba, Aramaki, Aoba-ku, Sendai , Japan; rin@mail.cc.tohoku.ac.jp

Hideki Iwano
Kyoto Fission-Track Co.Ltd.: 44-4 Minami-Tajincho, Kita-ku, Kyoto 603-8832, Japan; kyoto-ft@mb.neweb.ne.jp

Toshinori Okada
Hiruzen Institute for Geology and Chronology; 161-1 Sai, Okayama 703-8242, Japan; hiruzen@orange.ocn.ne.jp

Summary

Integrated stratigraphic study along the Miocene marine sequence in the Tanagura area, Northeast Japan, is briefly introduced.

Radiometric ages were recently determined on two volcanioclastic rocks (Kt-1 and Kt-7) interbedded in the lowest and uppermost part of the Miocene Kubota Formation in the Tanagura area. Obtained K-Ar age (10,6 ±0,2 Ma) and fission track age (10,7 ±0,2 Ma) of the Kt-1 Tuff show good agreement with each other, which suggests that these ages represent the eruption age of the Kt-1 pyroclastics. The fission track age of the Kt-7 pumice tuff was determined on 100 zircon grains (10,6 ±0,3 Ma), which coincides with the radiometric ages of the Kt-1 Tuff.

High sediment accumulation rate (25,5 cm/1000 a or 255 m/Ma) is suggested based on K-Ar and fission track geochronology. Previously established microfossil biostratigraphy are well consistent with the geochronology.

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

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 a geologic time scale based on Cande & Kent (1995)'s GPTS, although Baksi (1993), Wei (1995) and Takahashi & 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 interbed datable volcanioclastic layers in Japan, which is a good opportunity for constructing a time scale (Takahashi & Oda, 1997).

---next page---

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).

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 Kubota Formation yields microfossils dominantly. Aita (1988) and Takeshi & Aita (1991) investigated the planktonic foraminiferal and radiolarian biostratigraphy of the formation, respectively. Shimamoto et al. (1998) also reported biostratigraphic study results of planktonic foraminifera, calcareous nannofossil and radiolarians. 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 volcaniclastic layers in the Kubota Formation, as reported by Shimamoto et al. (1998), in which we dated two volcaniclastic layers (Kt-1 and Kt-7). In this paper, we show brief introduction of the geology, litho- and biostratigraphy and K-Ar and fission track ages obtained. The stratigraphic relations between some important microfossil biohorizons and radiometric ages of two pyroclastic rocks are also discussed.

2. Geology and stratigraphy

The Tanagura area is situated on the southern part of Northeast Japan (Fig. 1), where the 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 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. 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, which indicates a shallow sedimentary environment. Benthic foraminifers 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 volcaniclastic layers dominate the Kubota Formation, which conformably covers the Akasaka Formation. Shimamoto et al. (1998) reported the biostratigraphy of the planktonic foraminifera, calcareous nannofossil and radiolarians. They concluded that most of the Kubota Formation was correlative to zone N.16 of the planktonic foraminiferal zone of Blow (1969) or CN6 to CN7 of calcareous nannofossil zones of Okada & Bukry (1980).

Recently Hayashi et al. (2000) re-investigated the planktonic foraminiferal biostratigraphy, and recognized a key species of Neoglobobquadrina 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 coelitus, whose FO defines the base of CN6, and Catinaster calyculus, whose FO defines the base of CN7, were also reported (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 was correlative to the Lychnocanium magnaconruta Zone of Motoyama & Maruyama (1998).

Diatom biostratigraphy of the Kubota Formation was recently established by 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 & Aki (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 correlate to the T. yabei Zone (NPD 5C).
3. Radiometric ages

More than twenty volcaniclastic tuff layers are interbedded in the Kubota Formation, although only the Kt-1 Tuff contains sufficient minerals for conventional K-Ar dating. The Kt-1 Tuff is biotite-rich coarse-grained tuff as shown in Fig. 2. Takahashi et al. (2001) 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 analytical procedure as suggested by Itaya et al. (1991). The results are listed in Table 1 and the weighted-mean age with 1σ uncertainty is also calculated.

<table>
<thead>
<tr>
<th>Sample (mineral)</th>
<th>Potassium (wt. %)</th>
<th>Radiogenic argon 40 (10^18 ccSTP/g)</th>
<th>K-Ar age (Ma)</th>
<th>Non Radiogenic Ar (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kt-1 (biotite)</td>
<td>4.567±0.091</td>
<td>189.7±2.4</td>
<td>10.67±0.25</td>
<td>19.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>185.5±2.4</td>
<td>10.44±0.25</td>
<td>20.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>weighted mean</td>
<td>10.56±0.18</td>
<td></td>
</tr>
</tbody>
</table>

Table 2  Fission track data of zircons from the Kt-1 and Kt-7 Tufts in the Kubota Formation.

<table>
<thead>
<tr>
<th>Sample code</th>
<th>No. of crystals</th>
<th>Spontaneous (Nt)</th>
<th>Induced (Nt)</th>
<th>P(χ2)</th>
<th>Dosimeter (Nd)</th>
<th>r</th>
<th>U-content (ppm)</th>
<th>Age (Ma)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kt-1(ED1)</td>
<td>30</td>
<td>2.40 (3289)</td>
<td>3.09 (4232)</td>
<td>0</td>
<td>7.909 (2430)</td>
<td>0.854</td>
<td>310</td>
<td>10.8±0.3</td>
</tr>
<tr>
<td>Kt-1(ED2)</td>
<td>30</td>
<td>1.56 (1136)</td>
<td>4.33 (3149)</td>
<td>26</td>
<td>7.909 (2430)</td>
<td>0.898</td>
<td>440</td>
<td>10.6±0.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>weighted mean</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10.7±0.2</td>
</tr>
<tr>
<td>Kt-7(ED1)</td>
<td>100</td>
<td>1.59 (4286)</td>
<td>2.14 (5779)</td>
<td>2</td>
<td>8.130 (2498)</td>
<td>0.902</td>
<td>210</td>
<td>10.6±0.3</td>
</tr>
</tbody>
</table>

(1) p 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 2π/4π (ED1) and 1 for 2π/2π (ED2).
(3) Ages were calculated using a dosimeter glass SRM612 and age calibration factors ξ (ED1) = 352±3 (Iwano & Danhara, 1997) and ξ (ED2) = 372±5 (Danhara et al., 1991).
(4) P(χ2) is the probability of obtaining the χ2-value for v degrees of freedom (where v = number of crystals-1).
(5) r is a correlation coefficient between pS and pI.
(6) Samples were irradiated in the TRIGA MARK II nuclear reactor at St. Paul's University (Rikkyo Daigaku), Japan.

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

Only the fission track dating was applied for the Kt-7 pyroclastics, because the tuff does not contain biotite nor sufficient hornblende minerals for K-Ar dating. We measured fission track age of the Kt-7 Tuff on more than 100 zircon grains through ED1 method. The fission track age was calculated from 100 grains, which were regarded as essential based on the careful observation through microscope. The results are listed on Table 2.

4. Discussion

We obtained the K-Ar biotite ages of 10.67 ± 0.25 Ma and 10.44 ± 0.25 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 χ2-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 above and below the observed internal surfaces using age standards with no contamination of detrital grains. Takahashi et al. (2001) concluded that the main reason for the result of the χ2-test is not the contamination of detrital grains but the heterogeneity of uranium contents inside the grain. In fact, the ED2 data passed the χ2-test. Therefore, we adopted a weighted-mean value of 10.7 ± 0.2 Ma for the fission track age of the Kt-1 pyroclastics (Table 2). This age well coincides with the K-Ar age of the same tuff. Consequently, we can conclude that the obtained ages are reliable and indicate the eruption age of the Kt-1 pyroclastics.

Only fission track age was obtained for the Kt-7 pumice tuff layer in the upper part of the Kubota Formation. The fission track age of 10.6 ±0.3 Ma indicates almost equal to both the K-Ar as well as fission track age of the Kt-1 pyroclastics, interbedded about 200 m below the Kt-7 Tuff. Thus the high sediment accumulation rate for the Kubota Formation is suggested by chronostratigraphy based on K-Ar and/or fission track ages.

Recently Hayashi et al. (2000) recognized Neogloboquadria 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) or 11.0 (Montanari et al. 1997, p. 613). 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 nanofossil biostratigraphy, some important biohorizons were recognized by Shimamoto et al. (1998). The FO of Cathinator coalescens, 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 30 m above the Kt-1. The FO of Cathinator calyculus, defining the base of CN7 whose age was estimated as 10.7 Ma (or 11.2 Ma Montanari et al., p. 613), 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, 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 age of the Kt-1 and Kt-7 tuff layers. These chronostratigraphic as well as biostratigraphic age-estimates strongly suggest that about 200-m thick marine sediments of the Kubota Formation may be deposited during a very short time interval (the uncertainty of the radiometric ages: ca. 0.4 Ma), indicating a high sedimentation rate (>25.5 cm/1000 a / 255 m/Ma).

Fig. 3 Stratigraphic relationship between the dated tuffs and biostratigraphic zones (including some important biohorizons). The obtained ages of the Kl-I and Kl-7 Tuffs and the numerical age of each biohorizon, estimated on the basis of the Berggren et al. (1995)'s time scale, are also indicated.

5. Conclusion

K-Ar and/or fission track dating were applied for the Kt-1 and Kt-7 Tufts, interbedded in the lowest part and uppermost part of the Miocene Kubota Formation in the Tanagura area, Northeast Japan.

The K-Ar biotite ages (10.6 ± 0.2 Ma) and fission track ages (10.7 ± 0.2 Ma) of the Kt-1 pyroclastics coincide with each other, suggesting the reliability of the ages obtained. The fission track age of the Kt-7 pumice tuff (10.6 ± 0.3 Ma) is almost equal to the K-Ar and fission track ages of the Kt-1 Tuff.

These radiometric ages show good agreement with the previously established calcareous and siliceous microfossil biostratigraphy.

Acknowledgments

This work has been realized under the aegis of the working group Integrated Stratigraphy of the Miocene Sequence: Miocene from Japan, which is under the auspices of the Subcommission on Geochronology (S.O.G.), International Commission on Stratigraphy of the I.U.G.S. In this context, the long-standing collaboration with Prof. G. S. Odin of the Pierre et Marie Curie University (Paris) has been especially helpful.

References (* in Japanese with English abstract, ** in Japanese)


