K-Ar ages of the Shogunzawa and Okuda Tuff beds in the Miocene marine sequence in the Iwadono Hills, central Japan

Masaki Takahashi*, Yukio Yanagisawa* and
Toshinori Okada**

(Received June 26, 2003; accepted November 7, 2003)

Abstract: K-Ar ages were determined for the Shogunzawa and Okuda Tuff beds in the Miocene marine sequence in the Iwadono Hills, Saitama Prefecture, central Japan. The K-Ar ages on Shogunzawa biotite (11.99 ± 0.27 Ma and 12.01 ± 0.27 Ma; 1σ error) are well consistent with a ^{40}Ar - ^{39}Ar age of the correlative tuff (Kitamura Tuff bed: 11.79 ± 0.08 Ma; 2σ error) in the Tomioka area. The K-Ar ages were obtained from the Okuda hornblende as 10.90 ± 0.30 Ma and 10.85 ± 0.28 Ma. Combining with microfossil biostratigraphy, the sediment accumulation rate of the Miocene marine sequence in the Iwadono Hills is suggested to have increased at around 12.5 Ma.

Key words: Miocene, K-Ar age, integrated stratigraphy, Iwadono Hills, central Japan.

1. Introduction

Radiometric dating of interbedded volcanoclastic layers in the fossiliferous marine sequence should give important constraints for establishing an integrated geologic time scale, because high-resolution biostratigraphy indicates not a numerical age but only a relative stratigraphic (chronologic) position. As the Japanese islands have been typical volcanic arcs since the Miocene, some marine successions are suitable for integration of biostratigraphy with chronology based on radiometric dating. The Miocene marine sequence in the Iwadono Hills, central Japan, interbeds some volcanoclastic layers within the fossiliferous sediments. We present newly obtained

K-Ar ages of the Shogunzawa and Okuda Tuff beds in the Shogunzawa Formation, middle part of the sequence. The sediment accumulation rate for the Miocene marine sequence in the Iwadono Hills is discussed based on integrated stratigraphy.

2. Geology and Stratigraphy

The Iwadono Hills is located at the eastern margin of the Kanto Mountains, central Japan. About 900m-thick marine sediments are distributed, which are divided into five formations as follows; Godo, Negishi, Shogunzawa, Hatoyama and Imajuku Formations in ascending order (Fig. 1; Kurihara *et al.*, 2003). This sequence overlies the Lower and lowest Middle Miocene marine sediments of the Kamikarako Formation unconformably, and may in be fault contact with pre-Neogene Sanbagawa metamorphic rocks at western end. The Plio-Pleistocene conglomerate of the Mononiyama Formation covers these formations horizontally.

*産業技術総合研究所 地球科学情報研究部門複合年代層序研究グループ Integrated Bio- and Chronostratigraphy Group, Institute of Geoscience, GSJ/AIST

**(株)森山地質年代学研究所 Hiruzen Institute for Geology & Chronology

Fig. 1 Geological map and stratigraphy of the Iwadono Hills, central Japan (partly modified from Kurihara *et al.*, 2003). The sample locations for K-Ar dating are also indicated

The Godo Formation consists of conglomerate and very coarse- to medium-grained sandstone. The Negishi Formation is composed of densely-bioturbated massive silty fine- to medium-grained sandstone with three volcanoclastic layers (I-0, I-1 and I-3). Scattered glauconite grains are often observed in the Negishi Formation. The Shogunzawa Formation, conformably covering the Negishi Formation, is

composed of dark gray diatomaceous massive siltstone and sandy siltstone with six volcanoclastic layers. The rhythmic alternating beds of siltstone and medium-grained sandstone characterize the Hatoyama Formation. The Imajuku Formation consists of medium-grained massive sandstone and tuffaceous fine-grained sandstone.

These Miocene strata show southward in-

Fig. 2 Outcrop photographs of the Shogunzawa and Okuda Tuff beds. Sample horizons are on the detailed columnar sections of each tuff bed.

clined basin form with one broad anticline and two synclines. A few number of faults are observed, but each key tuff bed is traceable throughout the area (Kurihara *et al.*, 2003).

The Shogunzawa Tuff bed is interbedded in the middle part of the Shogunzawa Formation. This volcanoclastic layer is composed of partly laminated fine- to medium-grained tuff in its lower part, and undulated very fine-grained tuff in the upper part (Fig. 2). The Okuda Tuff bed is interbedded in the upper part of the Shogunzawa Formation. More than 10m-thick Okuda Tuff bed is characterized by pisolite layers in the lowest part (Fig. 2).

About 3 kg tuff samples for K-Ar dating were collected from the biotite-rich coarse-grained pumiceous portion of the lowest part of both the Shogunzawa and Okuda Tuff beds (Fig. 2).

3. K-Ar age

The samples were crushed and sieved into the mesh size fractions 48-80 (177-297 μ m). After ultrasonic rinsing, the magnetic fraction of the samples were separated using an isodynamic separator. Fresh biotite fractions were purified from the Shogunzawa Tuff bed using the heavy liquid technique. In contrast, as biotite of the Okuda Tuff bed is extremely altered, we purified hornblende for K-Ar dating of the Okuda Tuff.

Quantitative analysis of argon and potassium was performed using the analytical procedure as suggested by Itaya *et al.* (1991), at the

Hiruzen Institute for Geology & Chronology. The results are listed in Table 1 and weighted-mean ages are also calculated.

4. Discussion

We obtained K-Ar ages of the Shogunzawa Tuff bed as 11.99 ± 0.27 Ma and 12.01 ± 0.27 Ma that show no significant difference in age. Therefore, we calculated a weighted-mean age as 12.0 ± 0.2 Ma (Table 1).

Fission track age of 12.7 ± 0.8 Ma was determined on zircon of the Shogunzawa Tuff bed (Kasuya, 1987), which shows somewhat older than the K-Ar biotite age obtained. However, this fission track age is regarded as invalid at present, because the zeta calibration was not adopted in Kasuya (1987).

Takahashi and Hayashi (1991a) measured zircon crystal morphology and suggested that the Shogunzawa Tuff bed can be correlated with the Kitamura Tuff bed in the Tomioka area, about 50km northwest of the Iwadono Hills. The $^{40}\text{Ar}-^{39}\text{Ar}$ age was precisely determined on Kitamura biotite as 11.79 ± 0.08 Ma (Odin *et al.*, 1995), which coincides with the K-Ar age of the Shogunzawa Tuff bed (12.0 ± 0.2 Ma).

In addition, the Shogunzawa Tuff bed is also correlative with the Am-4 Tuff bed in the Boso Peninsula and with the Og1 Tuff bed in the Karasuyama area based on the zircon crystal morphology (Takahashi and Hayashi, 1991a, b). The K-Ar hornblende age of the Am-4 Tuff bed (11.7 ± 0.2 Ma; Takahashi *et al.*, 1999) co-

Table 1 K-Ar ages of the Shogunzawa and Okuda Tuff beds in the Iwadono Hills, central Japan. K-Ar age was calculated with the following decay constants (Steiger and Jäger, 1977). $\lambda_e = 0.581 \times 10^{-10}$ /year, $\lambda_\beta = 4.962 \times 10^{-10}$ /year.

Sample (mineral)	Potassium (wt. %)	Radiogenic argon 40 ($10^{-8}\text{cm}^3\text{STP/g}$)	K-Ar age (Ma)	Non Radiogenic Ar (%)
Shogunzawa Tuff bed (biotite)	6.841 ± 0.137	319.4 ± 3.3	11.99 ± 0.27	3.5
		319.9 ± 3.3	12.01 ± 0.27	3.9
		weighted mean	12.0 ± 0.2	
Okuda Tuff bed (hornblende)	0.531 ± 0.011	22.53 ± 0.43	10.90 ± 0.30	3.5
		22.42 ± 0.38	10.85 ± 0.28	3.9
		weighted mean	10.9 ± 0.2	

(error : $\pm 1\sigma$)

Fig. 3 Sediment accumulation curve for the lower part of Miocene marine sequence in the Iwadono Hills.

incides with that of the Shogunzawa Tuff within the standard deviation. The K-Ar (11.8 ± 0.2 Ma; Takahashi *et al.*, 1999) and fission track ages (11.6 ± 0.4 Ma; Takahashi and Iwano, 2000) of the Og1 Tuff bed show good agreement with the K-Ar age of the Shogunzawa Tuff. Moreover, recently determined ^{40}Ar - ^{39}Ar age on Og1 hornblende (11.99 ± 0.18 Ma; Odin *et al.*, 2001) indicates a same age with the K-Ar age of the Shogunzawa Tuff bed (12.0 ± 0.2 Ma). Thus the obtained K-Ar age of the Shogunzawa Tuff bed is much the same with the radiometric ages of correlative tuff beds widely distributed in central Japan, which confirms the reliability of these radiometric ages and therefore the obtained ages represent a timing of Shogunzawa pyroclastics eruption.

As for the Okuda Tuff bed, we obtained K-Ar age of 10.90 ± 0.30 Ma and 10.85 ± 0.28 Ma (Table 1). The fission track age of the Okuda Tuff bed (11.9 ± 0.8 Ma; Kasuya, 1987)

also suggests somewhat older than the K-Ar age as well as the case of Shogunzawa Tuff bed. Additional fission track dating is required for solving this discrepancy between K-Ar and fission track ages of the Shogunzawa and Okuda Tuff beds.

K-Ar ages of tuff beds in the Iwadono Hills are first obtained through this work. Combining with microfossil biostratigraphy, we discuss the sediment accumulation history of the Miocene marine sequence in the Iwadono Hills (Fig. 3).

The last occurrence (LO) of calcareous nanofossil *Sphenolithus heteromorphus*, determining the CN 4/CN 5 a boundary (13.6 Ma) is recognized in the Negishi Formation (Kurihara *et al.*, 2003). Diatom biostratigraphy (Kurihara *et al.*, 2003) also suggests that the upper part of the Negishi Formation through the lowest part of the Shogunzawa Formation was deposited between the first occurrence (FO)

of *Denticulopsis praedimorpha* var *minor* (12.7 Ma) and the LO of *Crucidentacula nicobarica* (12.3 Ma; Yanagisawa and Akiba, 1998; Watanabe and Yanagisawa, 2003). Therefore, a low sediment accumulation rate of $<1.7\text{--}3.3$ cm/1,000 yr. is suggested for the Negishi Formation, because only 15–30 m thick coquinaceous sandstone of the Negishi Formation has deposited during more than 0.9 m.y. (13.6–12.7 Ma) interval.

In contrast, high sedimentation rate is suggested for the Shogunzawa Formation. Mean sedimentation rate of $29\text{--}67$ cm/1,000 yr. is calculated for the lower half of the Shogunzawa Formation (ca. 200 m/0.7–0.3 m.y.). Between the Shogunzawa and Okuda Tuff beds, sedimentation rate is calculated as 6.4 cm/1,000 yr. (ca. 70 m/1.1 m.y.). This decreasing sedimentation rate in the upper part of the Shogunzawa Formation may suggest the geologic response of the marine regression from the Shogunzawa siltstone to Hatoyama and Imajuku regressive sequence.

5. Conclusion

K–Ar ages were determined for the Shogunzawa and Okuda Tuff beds in the Miocene marine sequence in the Iwadono Hills, central Japan. The K–Ar ages were obtained from Shogunzawa biotite as 11.99 ± 0.27 Ma and 12.01 ± 0.27 Ma. K–Ar ages of 10.90 ± 0.30 Ma and 10.85 ± 0.28 Ma were determined for Okuda hornblende. Integrated stratigraphy of K–Ar geochronology and microfossil biostratigraphy revealed that sediment accumulation rate of the Miocene marine sequence in the Iwadono Hills has increased at around 12.5 Ma.

Acknowledgments

We are grateful to Dr. Y. Kurihara of the National Science Museum for his constructive discussion on geology and stratigraphy of the Iwadono Hills. We also thank two anonymous reviewers for their critical reading of the manuscript, and constructive suggestions and advice. This work is contribution to the Special

Project for Earthquake Disaster Mitigation in Urban Areas by the Ministry of Education, Culture, Sports, Science and Technology, Japan.

References

- Berggren, W. A., Kent, D. V., Swisher, C. C. III and Aubry, M.-P., 1995: A revised Cenozoic geochronology and chronostratigraphy. *in* Berggren, W. A., *et al.*, eds., *Geochronology, time scales and global stratigraphic correlation*, SEPM Special Pub., **54**, 129–212.
- Itaya, T., Nagao, K., Inoue, K., Honjou, Y., Okada, T. and Ogata, A., 1991: Argon isotope analysis by a newly developed mass spectrometric system for K–Ar dating. *Mineral. Jour.*, **15**, 203–221.
- Kasuya, M., 1987: Comparative study of Miocene fission-track chronology and magneto-biochronology. *Sci. Rept. Tohoku Univ., 2nd ser. (Geol.)*, **58**, 93–106.
- Kurihara, Y., Horiuchi, S. and Yanagisawa, Y., 2003: Lithostratigraphy and integrated diatom and calcareous nannofossil biostratigraphy of the Miocene sequence in the Iwadono Hills area, Saitama Prefecture, central Japan. *Jour. Geol. Soc. Japan*, **109**, 215–233.
- Odin, G. S., Takahashi, M. and Cosca, M., 1995: $^{40}\text{Ar}/^{39}\text{Ar}$ geochronology of biostratigraphically controlled Miocene tuffs from central Japan, comparison with Italy and age of the Serravallian-Tortonian boundary. *Chem. Geol. (Isot. Geosci. Sec.)*, **125**, 105–117.
- Odin, G. S., Takahashi, M. and Cosca, M., 2001: $^{40}\text{Ar}/^{39}\text{Ar}$ geochronology of Middle Miocene calcareous nannofossil biohorizons in Central Japan. *Chem. Geol. (Isot. Geosci. Sec.)*, **171**, 239–252.
- Okada, H. and Bukry, D., 1980: Supplementary modification and introduction of code numbers to the low-latitude coccolith biostratigraphic zonation (Bukry, 1973, 1975). *Mar. Micropaleontol.*, **5**, 321–325.
- Steiger, R. H. and Jäger, E., 1977: Subcommission on geochronology: convention on the use of decay constants in geo- and cosmochronology. *Earth Planet. Sci. Lett.*, **36**, 359–362.
- Takahashi, M. and Hayashi, M., 1991a: Classification and correlation of Miocene tuffs in the Kanto area using zircon crystal morphology. *Jour. Geol. Soc. Japan*, **97**, 451–459.
- Takahashi, M. and Hayashi, M., 1991b: Zircon crystal morphology of the Miocene tuff in the Kamogawa area, Boso Peninsula, central Japan. *Jour. Japan. Assoc. Petrol. Technol.*, **56**, 477–481.

- Takahashi, M. and Iwano, H., 2000: Fission track age of the Og1 Tuff in the Miocene marine sequence of the Arakawa Group in the Karasuyama area, central Japan. *Bull. Geol. Surv. Japan*, **51**, 477-484.
- Takahashi, M., Mita, I. and Okada, T., 1999: K-Ar age of the Am-4 Tuff related to the CN 5 a/CN 5 b boundary on the Miocene marine sequence in the Boso Peninsula, central Japan. *Jour. Japan. Petrol. Technol.*, **64**, 382-387.
- Watanabe, M. and Yanagisawa, Y., 2003: High resolution Oligocene and Neogene diatom biostratigraphy in the Middle-to-high latitude North Pacific. —reexamined diatom biochronology at Leg 145 Site 887C—. *110th Annual Meet., Geol. Soc. Japan*, abstract, 232.
- Yanagisawa, Y. and Akiba, F., 1998: Refined Neogene diatom biostratigraphy for the northwest Pacific around Japan, with an introduction of code numbers for selected diatom biohorizons. *Jour. Geol. Soc. Japan*, **104**, 395-414.

要 旨

岩殿丘陵の海成中新統に挟在する將軍沢および奥田凝灰岩の K-Ar 年代

高橋 雅紀・柳沢 幸夫・岡田 利典

埼玉県岩殿丘陵に分布する中新世海成層に挟在する2層の珪長質火砕流堆積物について K-Ar 年代を測定し、將軍沢凝灰岩（黒雲母）については 11.99 ± 0.27 Ma（誤差 $\pm 1\sigma$ ）および 12.01 ± 0.27 Ma の、一方、奥田凝灰岩（角閃石）については 10.90 ± 0.30 Ma および 10.85 ± 0.2 Ma の年代値を得た。既報の各種浮遊性微化石生層準の見積もり年代とともに、岩殿丘陵の中新統の年代層序を総括した。さらに、堆積速度曲線を作成した結果、中期中新世初期の海進直後は非常に遅い堆積速度が示されるが、およそ 12.5 Ma に珪藻質シルト岩が堆積をはじめると、堆積速度は飛躍的に増大したことが明らかとなった。