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K-Ar age study on the Cenomanian/Turonian boundary of the Yezo Supergroup, Hokkaido, Japan, with special reference to OAE-2 and biostratigraphic correlation#

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Abstract

Dated were, with K-Ar method, biotite separates from the eight acidic tuff beds from the Cenomanian/Turonian boundary sections along the Hakkinzawa River and the Takinosawa Forestry Road, Oyubari area and the Obirashibe River, Obira area, which are correlated with the Pueblo section, Colorado, US Western Interior by ammonoid, inoceramid and planktic foraminiferal biostratigraphy, OAE-2 black mudstone bed and $\delta^{13}C$ spike in high resolution. The tuff beds give the ages from 104.1 ± 2.3Ma to 87.7 ± 1.9Ma, extending mostly from the Upper Cenomanian *Euomphaloceras septemseriatum* zone(ammonoid), *Birostrina nipponica* zone(inocerami) or *Rotalipora cushmani* zone(planktic foraminifer) to the Lower Turonian *Fagesia thevestensis* zone(ammonoid) or *Inoceramus kamuy* zone(inocerami).

Key words:K-Ar age, biotite, Cenomanian/Turonian stage boundary, OAE-2, $\delta^{13}C$, Yezo Supergroup, Hokkaido, Japan

INTRODUCTION

International correlation between the Japanese Cretaceous System and the European standard sections by using ammonoids and inoceramid bivalves has been much progressed by Matsumoto and his coworkers(e.g., Matsumoto, 1942, 1943, 1954, 1959, 1977; Toshimitsu et al., 1995) in the last half of this century. In addition, the research of the global chemical key-marker, the $\delta^{13}C$-spike at the C/T boundary, in these years refined the correlation (Hirano, 1995; Hasegawa, 1995).

During the time, radiometric dating of the Japanese Cretaceous System has been carried out by some authors (e.g., Shibata and Miyata, 1978; Shibata, 1992; Shibata & Uchiumi, 1995), but the results are not yet sufficient if compared with the recent progress of biostratigraphic and chemostratigraphic works on the Cretaceous correlation.

In this paper, we attempted to obtain K-Ar ages of biotites from the acidic tuff beds in the sections of the Hakkinzawa River and the Takinosawa Forestry Road, Oyubari area and the Obirashibe River, Obira area, which have the high biostratigraphic resolution in the Middle Yezo Group, Yezo Supergroup distributed in Hokkaido (Fig. 1).

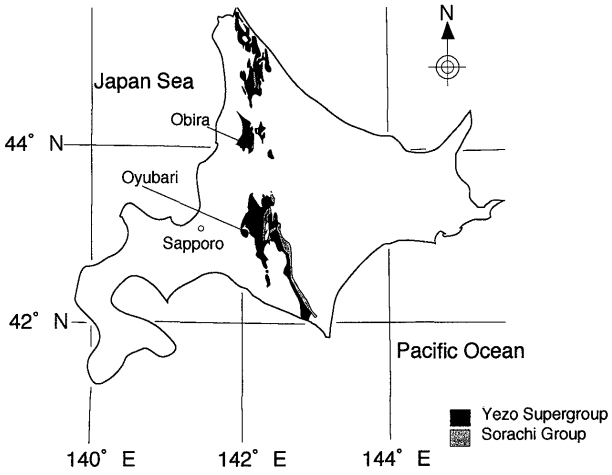

Fig. 1. Map showing the distribution of the Cretaceous Yezo Supergroup and the sampling areas in Hokkaido, Japan.

GEOLOGIC OUTLINE AND STRATIGRAPHIC SETTING

The Yezo Supergroup deposited in the Cretaceous Yezo Forearc basin is longitudinally distributed in north to south direction in central Hokkaido, being divided into the Lower, Middle and Upper Yezo Groups and the Hakobuchi Group in

Read at the 99th Annual Meeting of G. S. J. at Kumamoto(1992).

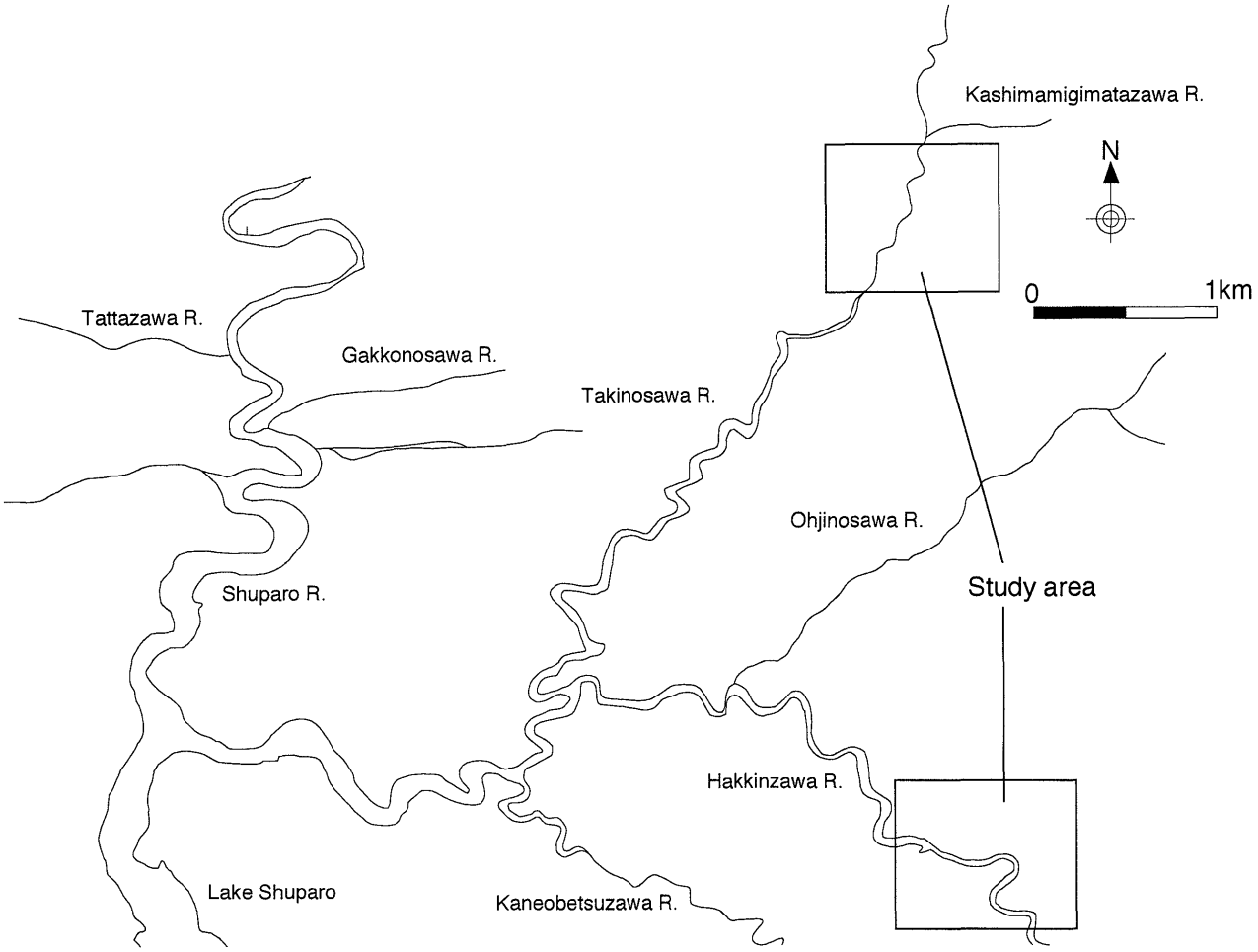

Fig. 2. Index map showing the Hakkinzawa River and the Takinosawa River, Oyubari area, central Hokkaido, Japan. Takinosawa Forestry Road is in parallel with the Takinosawa River.

ascending order(Okada, 1982). The basal part of the Lower Yezo Group is correlated with the Barremian by the recent radiolarian biostratigraphy(Mitsugi and Hirano, 1997), and the uppermost Hakobuchi Group has been with Maastrichtian(e.g., Toshimitsu et al., 1995).

The Cenomanian/Turonian stage boundary is in the middle of the Middle Yezo Group which is characterized by abundant ammonoids and inoceramid bivalves, resulting in high biostratigraphic resolution(e.g., Hirano et al., 1992; Toshimitsu et al., 1995). Volcanism seems to have been active in the period from the Cenomanian/Turonian boundary to about 200m younger level in thickness, because thick acidic tuff beds intervene in the section.

In the Hakkinzawa section of Oyubari area(Fig. 2), positive spikes of $\delta^{13}C$ of OAE-2 were detected by Hasegawa (1995). The basal Turonian indices, *Inoceramus kamuy* Matsumoto & Asai(1996), *Mytiloides* aff. *sackensis* and *Puzosia orientalis* were reported from the level just above the younger positive spike of $\delta^{13}C$ (Toshimitsu et al., 1995). In addition, the international Lower Turonian index *Pseudaspidoceras flexuosus* occurred at the 12.5m younger level in thickness from the younger positive spike (Hirano et al., 1992; Hirano, 1995). The analyzed K-Ar ages were obtained for the acidic tuff beds in the *P. flexuosus* zone about 100m younger level than the second spike and in the *Euomphaloceras septemseriatum* zone about 50m older level than the second spike.

In the Takinosawa Forestry Road section of Oyubari area(Fig. 2), the age was obtained for the acidic tuff bed 2m above the black mudstone of OAE-2.

In Obira area, $\delta^{13}C$ spike was detected below the locally dominant tuffaceous beds in the section of the Kanajirizawa River (Fig. 3; Hasegawa and Saito, 1993). The first occurrence datum plane of the regional basal Turonian index, *I. kamuy* is confirmed just below the tuffaceous beds

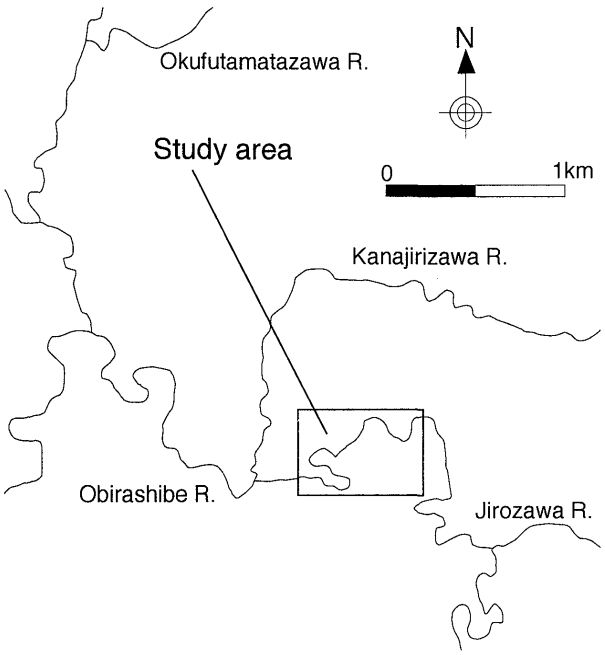

Fig. 3. Index map showing the Obirashibe River, Obira area, Hokkaido, Japan.

in the Obirashibe River. The ages were obtained for acidic tuff beds in the levels between the Upper Cenomanian *Birostrina nipponica* zone and the basal Turonian *I. kamuy* zone.

K-AR AGE DETERMINATION OF ACIDIC TUFFS

Samples studied for this project were acidic tuffs collected from the three sections for the C/T boundaries. The samples were crushed with a mortar and then sieved. Biotites were separated from 100-150 mesh size fractions of the washed and dried samples with isodynamic separator.

Analyses of potassium and argon in biotite separates and calculations of ages and errors were carried out by using the method described by Nagao et al. (1984) and Itaya et al. (1991). Potassium was analysed by flame photometry using a 2000ppm Cs buffer and has an analytical error of under 2% at 2 σ confidence level. Argon was analysed on a 15cm radius sector type mass spectrometer with a single collector system using an isotopic dilution method and an argon 38 spike (Itaya et al., 1991). Multiple runs of a standard (JG-1 biotite, 91Ma) indicate the error of argon analysis is about 1% at 2 σ confidence level. The decay constants for ^{40}Ar and ^{40}Ca, and ^{40}K content in potassium used in the age calculation are from Steiger and Jager (1977) and are 0.581×10^{-10}/yr, 4.962×10^{-10}/yr and 0.000167, respectively.

The K-Ar ages obtained are shown in Table 1 and the results are compared with exact geographic indication, stratigraphic level and biostratigraphic control below.

Oyubari area

YS70079: 95.5 ± 2.1Ma (Table 1). A white acidic tuff bed which varies from 15cm to 30cm in thickness, from the exposure at the junction of the Hakkinzawa River and the branch(Fig. 4; Y5234 in Hirano et al., 1977, fig. 2; Y070079 in Hirano et al., 1989, fig. 9). The stratigraphic level is in the upper part of the Member M8 of the Middle Yezo Group (Fig. 5; Tsuchida and Hirano, 1995). It is also in the Middle and Upper Cenomanian *Inoceramus pennatulus* zone in inoceramid biostratigraphy, middle Upper Cenomanian *Euomphaloceras septemseriatum* zone in ammonoid biostratigraphy and middle Upper Cenomanian *Rotalipora cushmani* zone in foraminiferal biostratigraphy (Hasegawa, 1995; Hirano, 1995).

YS70073: 87.7 ± 1.9Ma (Table 1). A 25 cm thick white acidic tuff bed, in the Member M9 of the Middle Yezo Group (Tsuchida and Hirano, 1995), which is about 100m above the younger δ^{13}C spike of OAE-2. It is about 20m distant upstream from the locality of abundant *Mytiloides labiatus* on the right bank of the Hakkinzawa River(Figs.

Table 1. Analytical results of eight acidic tuff beds in and around the Cenomanian/Turonian boundary from the sections of the Hakkinzawa River and Takinosawa Forestry Road, Oyubari and the Obirashibe River, Obira area, Hokkaido.

Sample Name	Route	K (wt%)	Rad. 40Ar (10E-8ccSTP/g)	K-Ar Age (Ma)	Non Rad. Ar (%)
YT100037	Takinosawa Riv.	4.304 ± 0.086	1555.8 ± 18.4	90.8 ± 2.1	17.6
YS70073	Hakkinzawa Riv.	3.536 ± 0.071	1232.9 ± 12.4	87.7 ± 1.9	3.4
YS70079	Hakkinzawa Riv.	3.285 ± 0.066	1250.5 ± 14.2	95.5 ± 2.1	15.3
OT6052	Obirashibe Riv.	3.116 ± 0.062	1140.0 ± 12.1	91.9 ± 2.0	7.8
OT6040	Obirashibe Riv.	3.150 ± 0.063	1109.2 ± 11.4	88.6 ± 1.9	4.3
OT6044	Obirashibe Riv.	4.472 ± 0.089	1656.2 ± 16.9	93.0 ± 2.0	4.5
OT6045A	Obirashibe Riv.	4.198 ± 0.084	1533.7 ± 15.4	91.8 ± 2.0	3.0
OT6053	Obirashibe Riv.	3.288 ± 0.066	1366.9 ± 14.3	104.1 ± 2.3	4.7

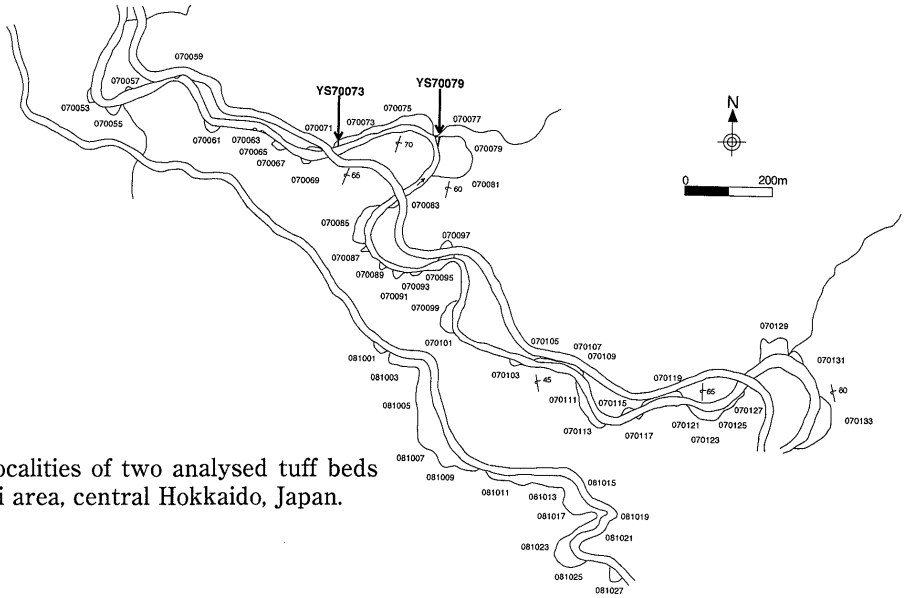

Fig. 4. Route map showing the localities of two analysed tuff beds in the Hakkinzawa River, Oyubari area, central Hokkaido, Japan.

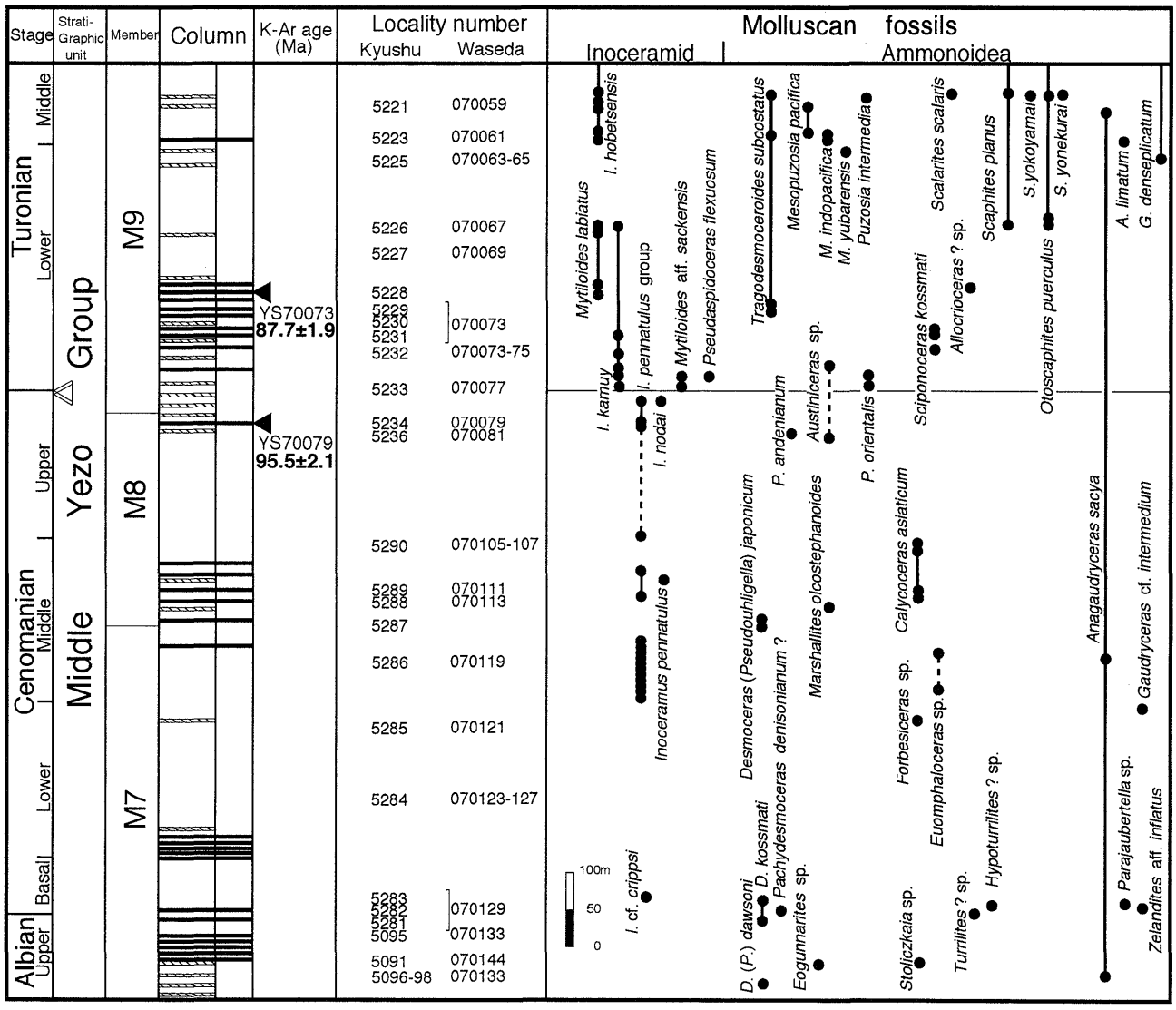

Fig. 5. Columnar section of the Hakkinzawa River with analysed K-Ar ages(two solid triangles) and molluscan range charts. Two triangles: $\delta^{13}C$ spikes after Hasegawa(1995) and Hirano(1995). The Cenomanian/Turonian boundary is defined by the younger $\delta^{13}C$ spike which is completely concordant with the biostratigraphic boundary definition.

4, 5; Y5229 in Hirano et al., 1977, fig. 2; Y070073 in Hirano et al., 1989, fig. 9). There are some thick white tuff beds on the bank between the exposures of this sample and the black mudstone bed of OAE-2, but no fresh biotite was separated from them. The tuff is lain in the Lower Turonian *Inoceramus kamuy* zone (Toshimitsu et al., 1995; Matsumoto and Asai, 1996) and lower Lower Turonian *Pseudaspidoceras flexuosus* zone (Hirano, 1995).

YT100037: 90.8 ± 2.1Ma (Table 1). A 30cm white acidic tuff bed of the Member M9 of the Middle Yezo Group (Tsuchida and Hirano, 1995) in the exposure of the Takinosawa Forestry Road along the Takinosawa River (Fig. 6; Y6016 in Hirano et al., 1977, fig. 4; Y100037 in Hirano et al., 1989, fig. 14). It is about 20m distant upstream from the valley between two contiguous exposures, Y100035 and Y100037. There is the OAE-2 black mudstone bed 2m below the tuff bed, which is in the lower part of the Lower Turonian *I. kamuy* zone (Fig. 7). In ammonoid biostratigraphy, this level would be in the undiscovered *Watinoceras devonense* zone below the *P. flexuosus* zone by correlation with the Hakkinzawa River section.

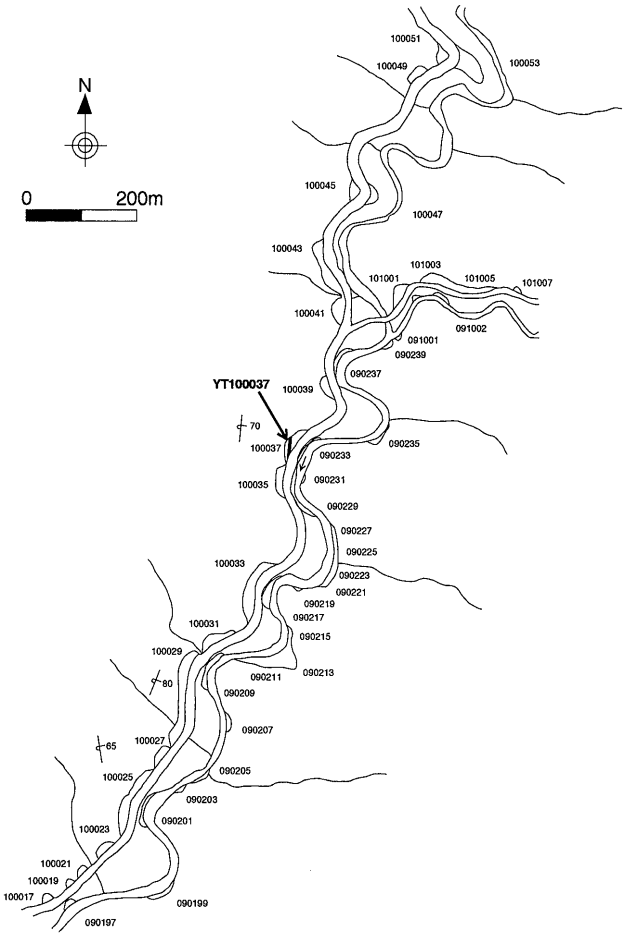

Fig. 6. Route map showing the localities of analysed tuff bed in the Takinosawa Forestry Road along the Takinosawa River, Oyubari area, central Hokkaido, Japan.

Obira area

OT6053: 104.1 ± 2.3Ma (Table 1). This sample comes from the 30cm white acidic tuff bed in the large exposure of the left bank of the Obirashibe River(Fig. 8; R5243 in Tanabe et al., 1977; T6053 in Sekine et al., 1985 and Asai and Hirano, 1990). It is in the Member Mh of the Middle Yezo Group (Tanabe et al., 1977; Sekine et al., 1985; Asai & Hirano, 1990) and biostratigraphically in the Upper Cenomanian *Birostrina nipponica* zone and the Cenomanian *Desmoceras japonicum* zone.

OT6052: 91.9 ± 2.0Ma (Table 1). A 180cm white acidic tuff bed in the left bank to the river bottom of the Obirashibe River (Fig. 8; R5242 in Tanabe et al., 1977; T6052 in Sekine et al., 1985 and Asai and Hirano, 1990). It is in the Member Mh of the Middle Yezo Group and in the Upper Cenomanian *B. nipponica* zone (Fig. 9).

OT6044: 93.0 ± 2.0Ma (Table 1). The sample comes from a 350cm white acidic tuff, which exposes repeatedly for three times in the meandering area of the Obirashibe River (Fig. 8; R5224 in Tanabe et al., 1977; T6044 in Sekine et al., 1985 and Asai and Hirano, 1990), and the level is in the Member Mj of the Middle Yezo Group. It is biostratigraphically in the Lower Turonian *I. kamuy* zone, being separated 117m thick from the first occurrence of the index species(T6048')(Fig. 9). As *Fagesia* sp. is reported from T6047' and *Pseudaspidoceras* sp. from T6038(Tanabe et al., 1977), this level situates in *Fagesia thevestensis* zone to *Pseudaspidoceras flexuosus* zone in ammonoid biostratigraphy. Thus, this sample is the closest to the Cenomanian/Turonian boundary in the Obirashibe River section.

OT6045A: 91.8 ± 2.0Ma (Table 1). This is a 35cm thick white acidic tuff bed just above the tuffaceous bed (Fig. 8; R5225 in Tanabe et al., 1977; T6045 in Sekine et al., 1985, Asai & Hirano, 1990). It is in the Member Mj of the Middle Yezo Group and in the Lower Turonian *I. kamuy* zone. *Pseudaspidoceras* sp. was obtained from T6038, just above this bed (Fig. 9).

OT6040: 88.6 ± 1.9Ma (Table 1). This is from the 150cm white acidic tuff bed in the apparent lower level, in the Obirashibe River (Figs. 8, 9; R5216 in Tanabe et al., 1977; T6040 in Sekine et

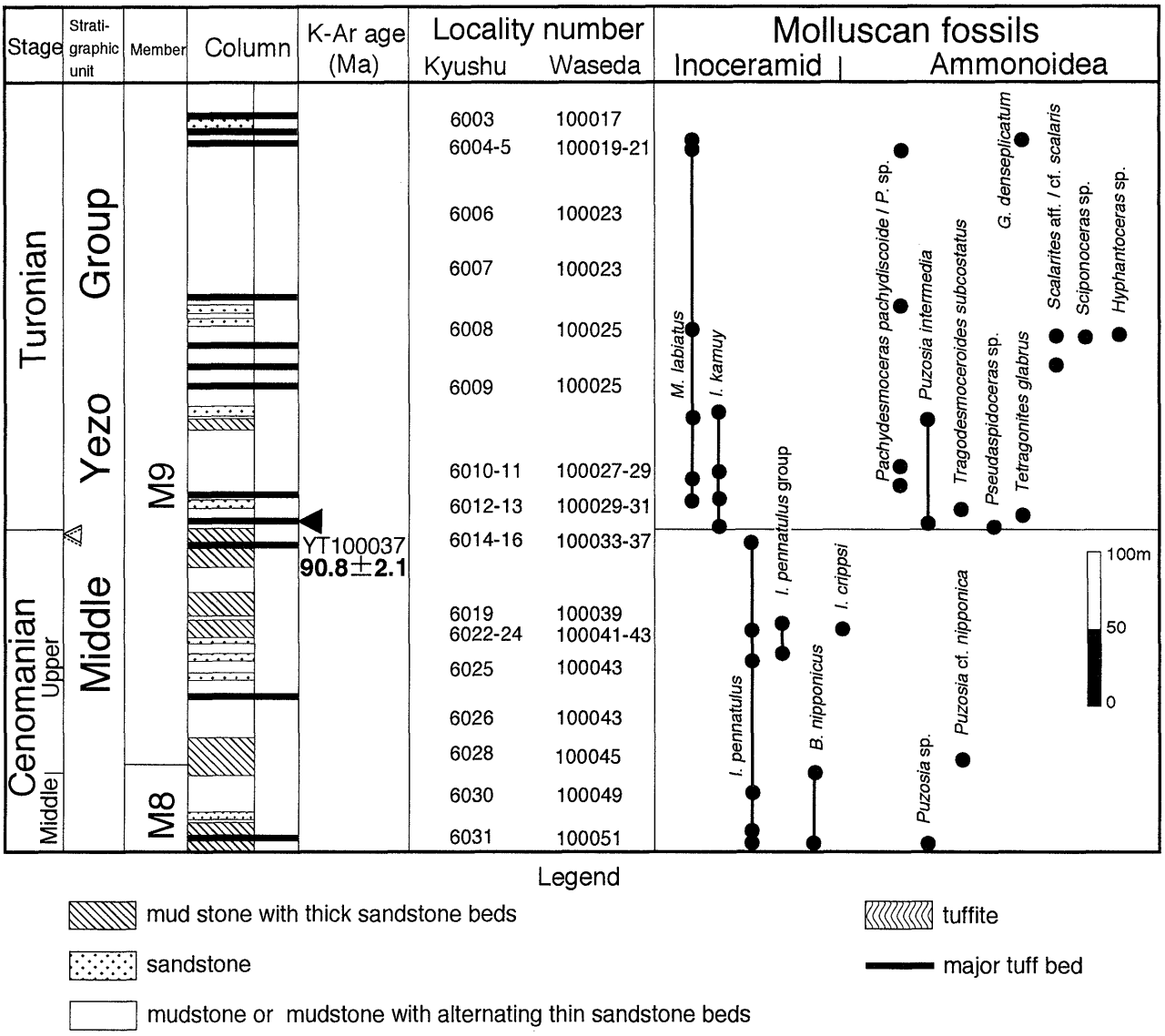

Fig. 7. Columnar section of the Takinosawa Forestry Road with analysed K-Ar age(a solid triangle) and molluscan range charts. The Cenomanian/Turonian boundary is defined just above the black mudstone of OAE-2, which is completely concordant with the biostratigraphic boundary definition.

al., 1985, Asai and Hirano, 1990). The level is biostratigraphically in the same *I. kamuy* zone as in OT6044 and OT6045A, and lithostratigraphically correlated with the unexposed level between OT6044 and OT6045A.

CONSIDERATION

The radiometric age for the Cenomanian/Turonian boundary has hitherto been reported by many authors, with various materials (glaucony or biotite) and methods(K/Ar or Ar/Ar) : 93.5 and 93.3Ma in the Middle Yezo Group by Shibata and Miyata (1978), 91Ma by Cowie and Bassett (1989), 90.4Ma by Harland et al.(1990), 98.0Ma in the Middle Yezo Group by Shibata(1992), 93.3Ma by Obradovich(1991), 93.46 ± 0.38Ma by Kowalis et al.(1992) and 93.1 ± 0.3Ma by Kowalis et al.(1995). McArthur et al. (1994) reported the radiometric ages based on Obradovich (1994) for each ammonite zone, noting 93.4Ma for the base of the Basal Turonian *Watinoceras devonense* zone. McArthur et al.(1994) published their results with an expert ammonite biostratigrapher, W. J. Kennedy, after the OAE-2 was clarified by $\delta^{13}C$ spike in the US Western Interior. As has been known, the Cenomanian/Turonian boundary is defined by ammonite biostratigraphy with reference to the chemical key-marker-bed, $\delta^{13}C$ spike, and therefore we compare our K-Ar age results with those of McArthur et al.(1994).

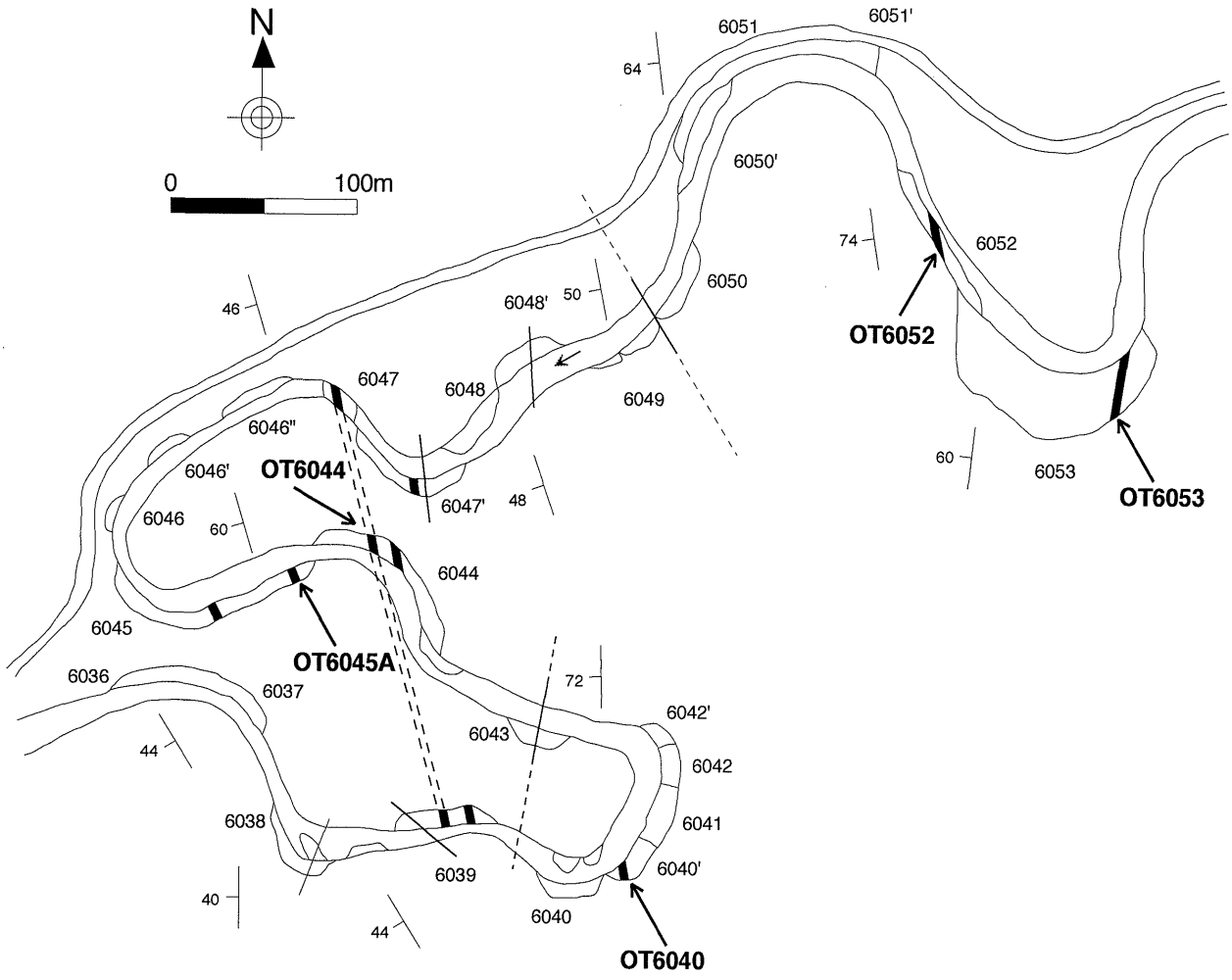

Fig. 8. Route map showing the localities of analysed tuff beds in the Obirashibe River, Obira area, Hokkaido, Japan.

The Hakkinzawa section has high biostratigraphic control by many biostratigraphic studies of ammonoids, inoceramids and foraminifers (e.g., Hirano et al., 1977; Hirano, 1995; Hasegawa, 1995), as well as the $\delta\,^{13}C$ spike (Hasegawa, 1995). The two samples dated are somewhat distant from the level of the $\delta\,^{13}C$ spike, because the tuff beds close to the level was not sufficient in preservation of fresh biotite.

The age of YS70079 in the *Euomphaloceras septemseriatum* zone, 95.5 ± 2.1Ma is very concordant with 93.7Ma of the base of the equivalent *Sciponoceras gracile* zone by McArthur et al.(1994). The age of YS70073 in the *P. flexuosus* zone, 87.7 ± 1.9Ma, is also concordant with 93.0Ma of the base of *Watinoceras coloradoense* zone by McArthur et al.(1994). It follows that the Cenomanian/Turonian boundary is in the range between 87.7 ± 1.9Ma and 95.5 ± 2.1Ma in this section.

The Takinosawa Forestry Road section has also high biostratigraphic control and the black mudstone bed of the OAE-2 as in the Hakkinzawa. The tuff bed (YT100037) just above the black mudstone bed of the OAE-2 is 90.8 ± 2.1Ma in age, being very concordant with 93.4Ma of the base of *W. devonense* zone of McArthur et al.(1994).

The Obirashibe River section has been biostratigraphically studied well (e.g., Tanabe et al., 1977; Sekine et al., 1985; Asai and Hirano, 1990). The $\delta\,^{13}C$ spike is detected in the Kanajirizawa section close to this section. *Pseudaspidoceras* sp. was obtained at T6038 which is a little higher than OT6044, giving 93.0 ± 2.0Ma. The level of OT6044 is clearly in *Inoceramus kamuy* zone in inoceramid biostratigraphy and is also in *Fagesia thevestensis* - *Mammites* aff. *nodosoides* zone of ammonite biostratigraphy. Its age is very concordant with 92.4Ma of the base of the *Mammites nodosoides* zone by McArthur et al.(1994).

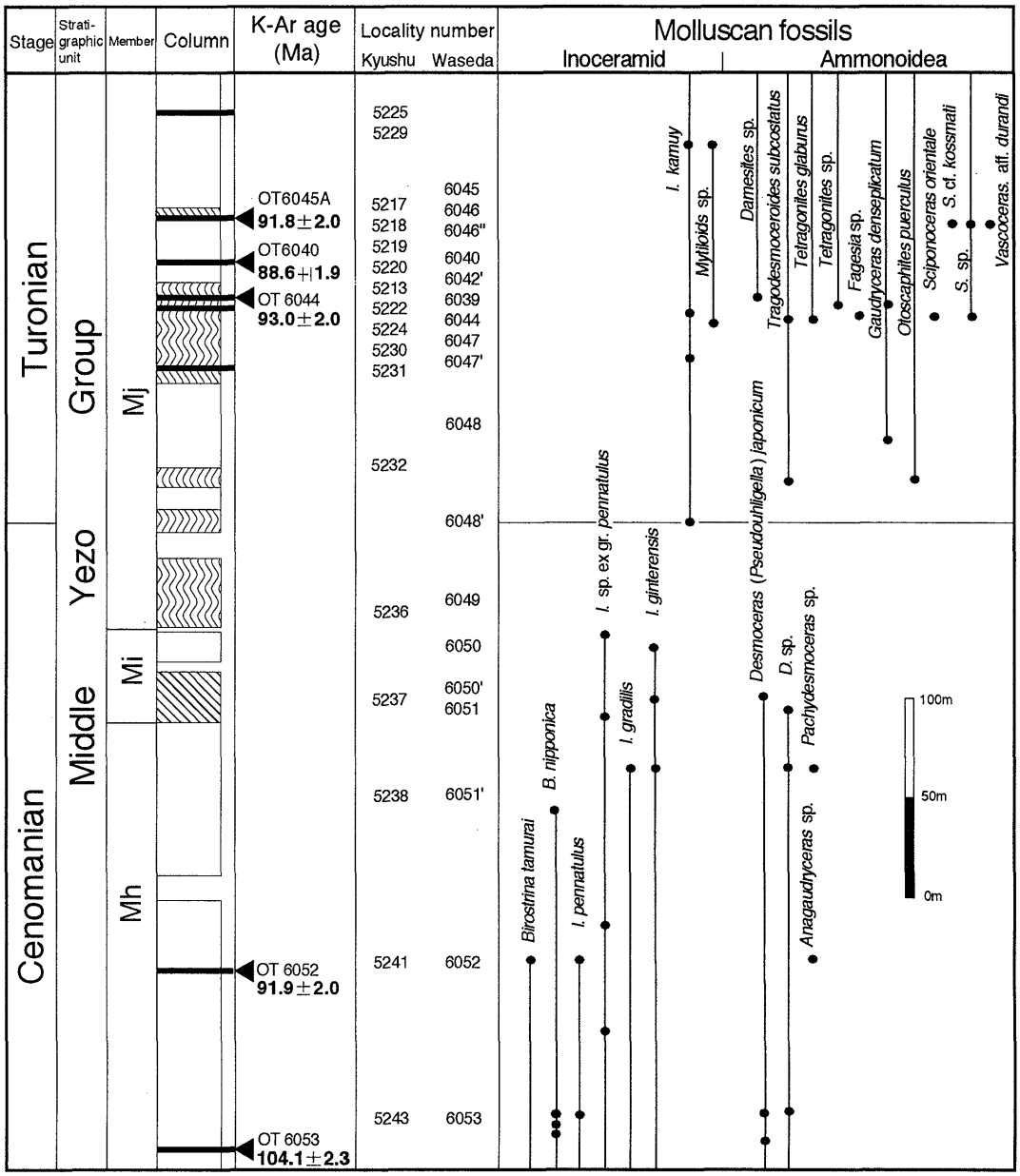

Fig. 9. Columnar section of the Obirashibe River with analysed K-Ar ages(five solid triangles) and molluscan range charts. The Cenomanian/Turonian boundary is defined by the molluscan range charts.

The age, 91.8 ± 2.0Ma of OT6045A is also very concordant with McArthur et al.(1994). The ages obtained in this section fairly harmoniously change from 104.1 ± 2.3Ma through 93.0 ± 2.0Ma to 91.8 ± 2.0Ma with the stratigraphic position. This section may be the best candidate for the reference section of radiometric age if the series of tuff beds will be dated with other methods.

CONCLUSIONS

We dated biotite separates from acidic tuff beds in the Cenomanian/Turonian stage boundary sections of the Middle Yezo Group and the obtained K-Ar ages are comparably concordant with the hitherto published ages: 95.5 ± 2.1Ma from the Upper Cenomanian *Euomphaloceras septemseriatum* zone, and 87.7 ± 1.9Ma from the Lower Turonian *Pseudaspidoceras flexuosus* zone of the Hakkinzawa section, 90.8 ± 2.1Ma from the Lower Turonian *Inoceramus kamuy* zone of the Takinosawa Forestry Road section, being correlated with *Watinoceras devonense* zone of Pueblo section, and in the Obirashibe River section, 104.1 ± 2.3Ma and 91.9 ± 2.0Ma in the Upper Cenomanian *B. nipponica* zone, and 93.0 ± 2.0Ma, 88.6 ± 1.9Ma and 91.8 ± 2.0Ma in the *Fagesia thevestensis* -

Mammites aff. *nodosoides* zone.

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（要　旨）

Hirano, H., Koizumi, M., Matsuki, H. and Itaya, T., 1997, K-Ar age study on the Cenomanian/Turonian boundary of the Yezo Supergroup, Hokkaido, Japan, with special reference to OAE2 and biostratigraphic correlation. *Mem. Geol. Soc. Japan*, No. 48, 132-141.（平野弘道・小泉雅一・松木裕人・板谷徹丸，1997，蝦夷累層群のセノマニアン・チューロニアン階境界付近の凝灰岩のK-Ar年代－特にOAE2及び化石層序学的対比との関連について．地質学論集，No. 48, 132-141）

アンモナイト類，イノセラムス類，浮遊性有孔虫類化石層序およびOAE-2黒色泥岩層，$\delta^{13}C$スパイクによりセノマニアン・チューロニアン階境界が北米西部内陸のコロラド州Puebloのセクションと高い精度で対比されている北海道の蝦夷累層群の大夕張地方の白金沢セクションと滝の澤林道セクション，小平地方の小平藁川セクションの酸性凝灰岩中の黒雲母を用いてK-Ar放射年代を求めた．これらの酸性凝灰岩は主として上部セノマニアンの *Euomphaloceras septemseriatum* 帯，*Birostrina nipponica* 帯，または *Rotalipora cushmani* 帯から下部チューロニアン階の *Inoceramus kamuy* 帯または *Fagesia thevestensis* 帯にわたり，8枚の凝灰岩層から得られた年代は104.1±2.3Maから87.7±1.9Maの範囲である．