The Sequence of River Terrace Development in the Last 20,000 Years in the Ou Backbone Range, Northeastern Japan

Masayuki TOYOSHIMA

1 Introduction

Filltop terraces of the age around 20,000 yr B.P. are reported (*e.g.* Okada and Nakamura 1972 ; Machida and Arai 1979 ; Yanagida 1979 ; Toyoshima 1981) in various areas of Central and Northeastern Japan. These are considered to be of climatic origin. This will be confirmed by the data that the downcutting preceded by valley-filling is initiated synchronously with the turning of trend of climatic change.

This paper reveals the age when the downcutting stage replaced the valley-filling one and examines the evolution of a series of river terraces after the valley-filling in the Ou Backbone Range. It will lead to the reconstruction of fluvial-morphogenetic change under the varying climate of the age which follows the Last-Glacial maximum.

2 Outline of climatic change in latest Pleistocene and Holocene times in Central and Northeastern Japan

Previous studies of paleoclimate show the general trend of increasing temperature for the last about 20,000 years (Flint 1971). The climatic conditions of the age around 20,000 yr B.P. were the coldest in the last 30,000 years for many sites.

Based on pollen-analytical studies in Japan, the periods in which the estimated coldest conditions exist at the respective locations of the sample are reviewed in Table 1. The Table indicates that temperature begins to increase in the time around 20,000 yr B.P.

The mass balance examination of a cirque glacier in the Northern Japanese Alps, Central Japan, leads to the estimation that the winter precipitation attains a minimum in the time of 20,000-18,000 yr B.P. (Ono 1984).

The climatic change mentioned above probably induced some fluvial-process change, which is expected to be recorded in river-terrace form and deposits.

3 Study area

This paper investigates the river terraces in the Onigase, the Naruse, and the Yokote River basins situated in the central part of the Ou Backbone Range (Fig. 2).

THE SCIENCE REPORTS OF TOHOKU UNIVERSITY, 7TH SERIES (GEOGRAPHY)
Vol. 34 No. 2, December 1984

Table 1 The period in which the estimated coldest condition exists

	Location of the pollen sample (Altitude, m a.s.l.)		^{14}C age (yr B.P.)	Reference
1	Ishikari Lowland	(5-100)	12,000 - 25,000	Igarashi and Kumano, 1981
2	Yamagata Basin			Matsuoka *et al.*, 1984
	Nariyasu	(95)	15,000 - 26,000	
	Imazuka	(102)	20,000 - 29,000	
	Zinbashinden	(103)	17,000->30,000	
3	Kawadoi	(274-280)	19,000 - 26,500	Nakayama and Miyagi, 1984
4	Hoshojiri Moor	(530)	12,000 - 21,000-?	Kawamura, 1979 Miyagi *et al.*, 1981
5	Saru-uchi	(460-470)	?-17,000 - 23,000	Yoshida *et al.*, 1981
6	Ozegahara Moor	(1400)	19,400 - 24,500	Sakaguchi, 1978
7	Lake Nojiri	(650-680)	16,300 - 25,600	Kumai *et al.*, 1981
8	Matsumoto Basin, Kiso Valley and the western foot of Yatsugatake Volcano	(820-1360)	?-16,000 - 23,000-?	Sakai, 1981
9	Lake Mikata	(0)	17,000 - 18,000 20,000 - 23,000	Yasuda, 1982

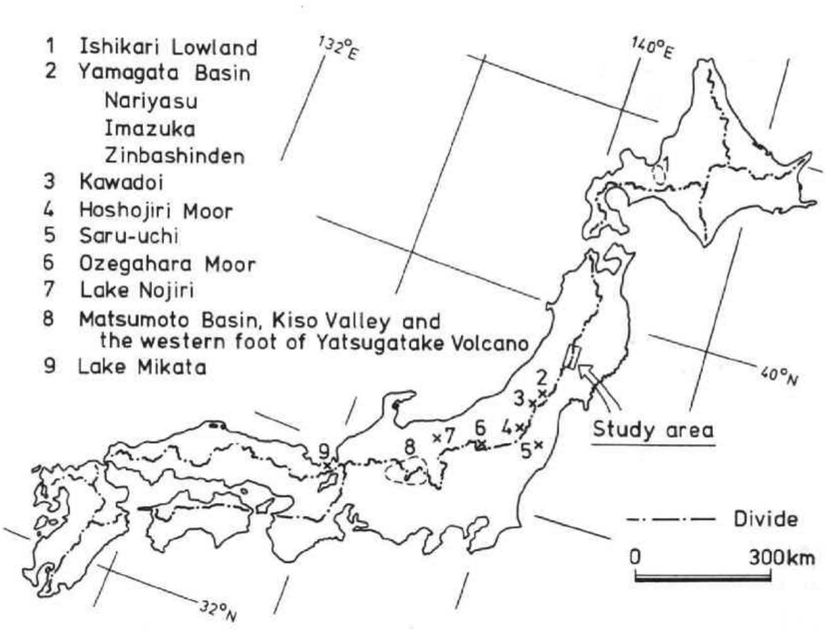

Fig. 1 The location of the pollen sample and the study area

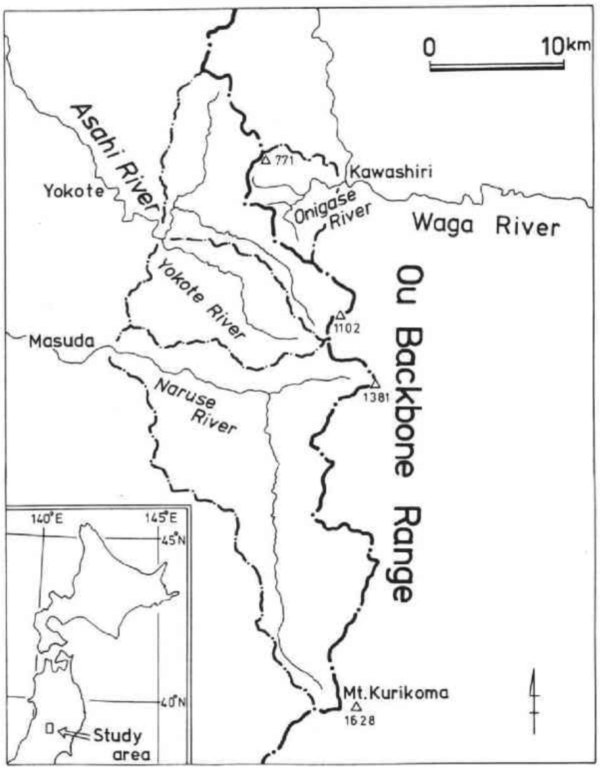

Fig. 2 The Onigase, the Yokote, and the Naruse River basins in the central part of the Ou Backbone Range

These drainage basins have well-developed river terraces of Late Pleistocene age (Nakagawa *et al.* 1971), in comparison with the other areas in the Ou Backbone Range. The Onigase River is a branch of the Waga River which flows in the Kitakami Basin. Both the Yokote and the Naruse join the Omono River in the Yokote Basin. The both basins are intermontane depressions.

Geological map, scale 1 : 200,000 (Ōzawa 1964), demonstrates that the study area is mostly underlain by folded Neogene Tertiary sedimentary rocks, *i.e.* sandstone, mudstone, black mudstone, hard shale, and tuff, except for the source areas of the rivers, where andesite, dacite and rhyolite are exposed. Moreover, the Lower Pleistocene Yoshizawa Formation which is older than the terrace deposits is distributed in the upper reaches of the Onigase River basin.

The highest altitudes of the respective drainage basins are 771 m a.s.l. for the Onigase, 1,115 m a.s.l. for the Yokote, and 1,560 m a.s.l. for the Naruse. Ono (1984), on the basis of the occurrence of glaciated landforms of the Last Glacial age in the high mountains such as the Japan Alps and the Hidaka Range, estimates that the Last Glacial snowline is higher than about 1,700 m a.s.l. at the latitude (38°55′-39°20′N) of the area discussed in this paper. Therefore the study area was apparently free from glaciation even under the coldest climatic condition of about 20,000 yr B.P.

4 Description of river terraces

4.1. The Onigase River basin

The river terraces along the Onigase River, and along the Waga River, are classified as the Togeyama Higher terrace, the Togeyama Lower terrace, the Oarasawa terrace, the Odaino terrace, and the Kotsunagizawa terrace, in chronological order. The distribution of these terraces is shown in Fig. 3.

Nakagawa *et al.* (1971), including both the Odaino terrace and the Kotsunagizawa terrace in the Kawashiri terrace, suggests that the Kawashiri terrace is of Late Pleistocene age. This paper details especially the Odaino terrace and the Kotsunagizawa terrace as below.

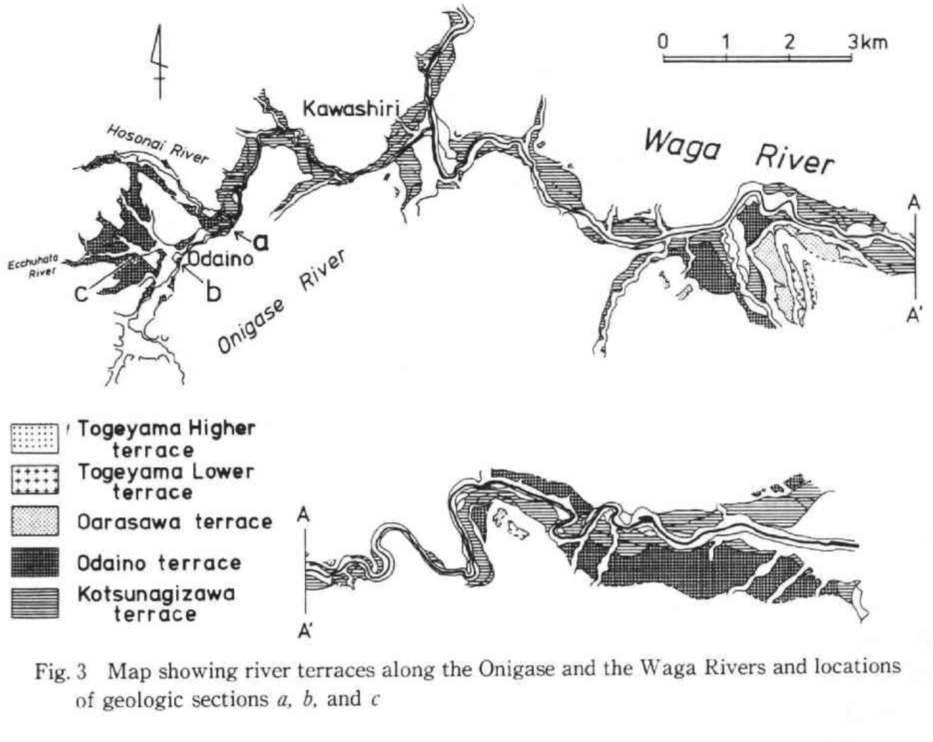

Fig. 3 Map showing river terraces along the Onigase and the Waga Rivers and locations of geologic sections *a*, *b*, and *c*

a) The Odaino terrace

The Odaino terrace is distributed along the tributaries which flow almost conse-

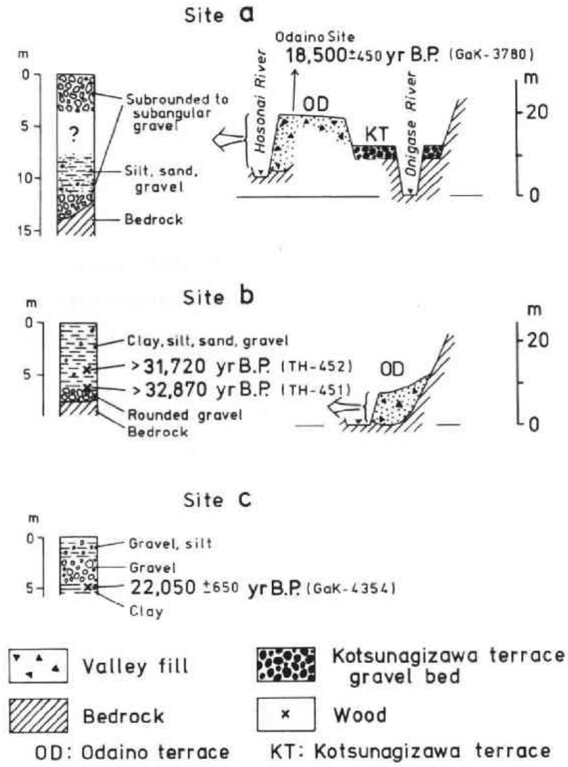

Fig. 4 Geologic sections at sites *a*, *b*, and *c* in the Onigase River basin

quently from the main divide to the Onigase River. The relative height between the terrace surface and the present river floor decreases upstream. This terrace has a feature of dissected alluvial fan sloping about 25 m per km along the Ecchuhata River.

The terrace is underlain by valley fill which varies its thickness and facies with sites (Fig. 4). At site *a*, the valley fill is 14 m thick and consists of poorly sorted and poorly bedded gravel bed, intercalating lenses of fine-grained material (silt, sand, and granule), with a sandy to clayey matrix. Gravel is subrounded to subangular and less than 20 cm in diameter. At Odaino Prehistoric Site situated on the Odaino terrace, a clay bed 20 to 35 cm thick overlies the valley fill and contains scattered charcoals which are dated as 18,500 ± 450 yr B.P. (GaK-3,780) (Odaino Site Research Group 1973).

At site *b*, the valley fill is composed of a 6.2 m thick sand to clay bed containing pebbles and granules, and 1.3 m thick basal rounded boulder and cobble bed. The radiocarbon ages of the woods buried to a depth of 4.5 m and 6.2 m in the valley fill are older than 31,720 yr B.P. (TH-452) and older than 32,870 yr B.P. (TH-451), respectively

(Fig. 4). Besides, at site *c*, the wood buried to a depth of 4.8 m in the valley fill is dated as 22,050±650 yr B.P. (GaK-4,354) (Yonechi's unpublished data).

b) The Kotsunagizawa terrace

The Kotsunagizawa terrace stands 6 m below the Odaino terrace and 12 m above the river level at site *a*. It is continuously traceable along the Onigase River only downstream from site *a*. The mean slope of the terrace surface along the Onigase River is about 6 m per km.

The terrace is underlain by a 2 to 4 m thick veneer of cobble and boulder (Fig. 4). It is named the Kotsunagizawa terrace gravel bed in this paper. No terraces except for untraceable minor ones are present below the Kotsunagizawa terrace.

c) The longitudinal profiles of the Odaino and the Kotsunagizawa terraces

The longitudinal profiles of the Odaino and the Kotsunagizawa terraces are shown in Fig. 5(A). The gradient of the river channel is shown in Figure 5(B). These figures

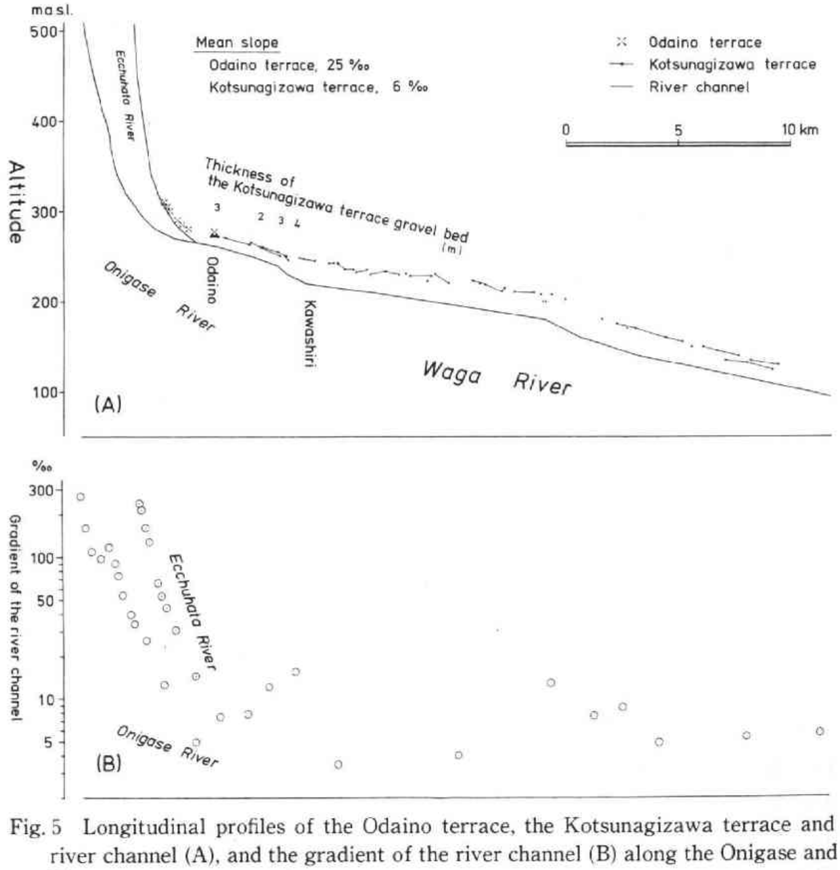

Fig. 5 Longitudinal profiles of the Odaino terrace, the Kotsunagizawa terrace and the river channel (A), and the gradient of the river channel (B) along the Onigase and the Waga

show that the Kotsunagizawa terrace is formed along only the reach where a river gradient is less than 20 m per km. Along the reach where the gradient is steeper than the above value, only the Odaino terrace is present.

4.2. The Naruse River basin

The river terraces in the Naruse River basin are classified as the Yoshino terrace, the Tagonai terrace, the Kakkyo terrace, and the Tsubakidai terrace in chronological order. The distribution of these terraces is shown in Fig. 6.

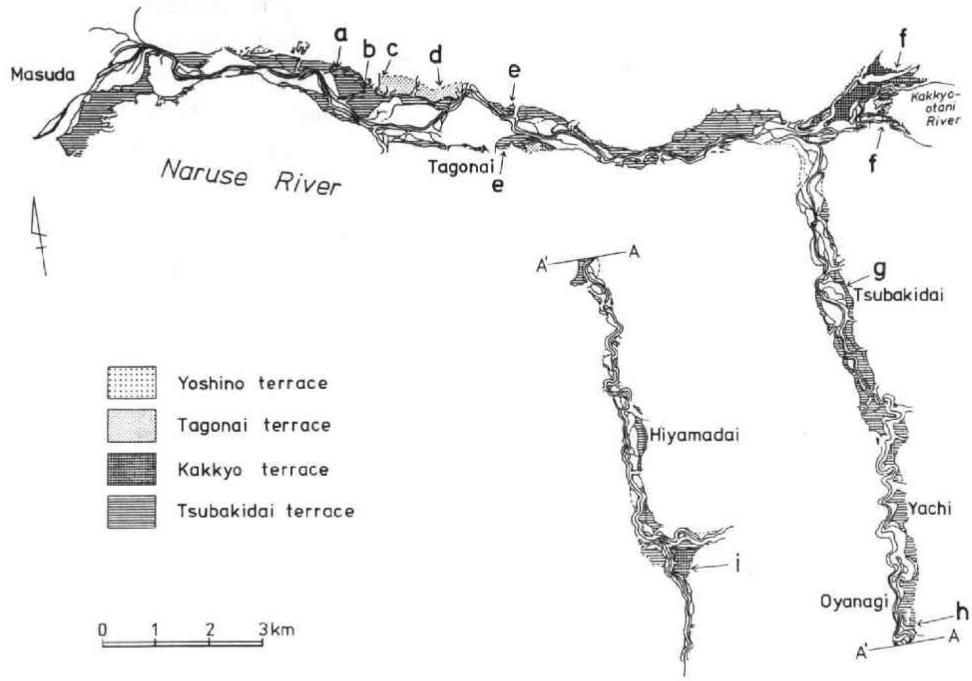

Fig. 6 Map showing river terraces in the Naruse River basin and locations of geologic sections *a–i*

The Yoshino terrace stands about 50 m above the river level, and is underlain by a 2 m thick veneer of gravel. The Tagonai terrace stands 40 to 50 m above the river level. It is underlain by valley fill which is more than 6 m thick at site *d*, about 10 m thick at site *c*, and about 30 m thick at site *f*. This paper details especially the Kakkyo terrace and the Tsubakidai terrace.

a) The Kakkyo terrace

The Kakkyo terrace is distributed only in the vicinity of the Kakkyo-otani River and at site *i*. The Kakkyo-otani River flows consequently from the main divide to the Naruse River. The mean slope of this terrace surface is 53 m per km along the

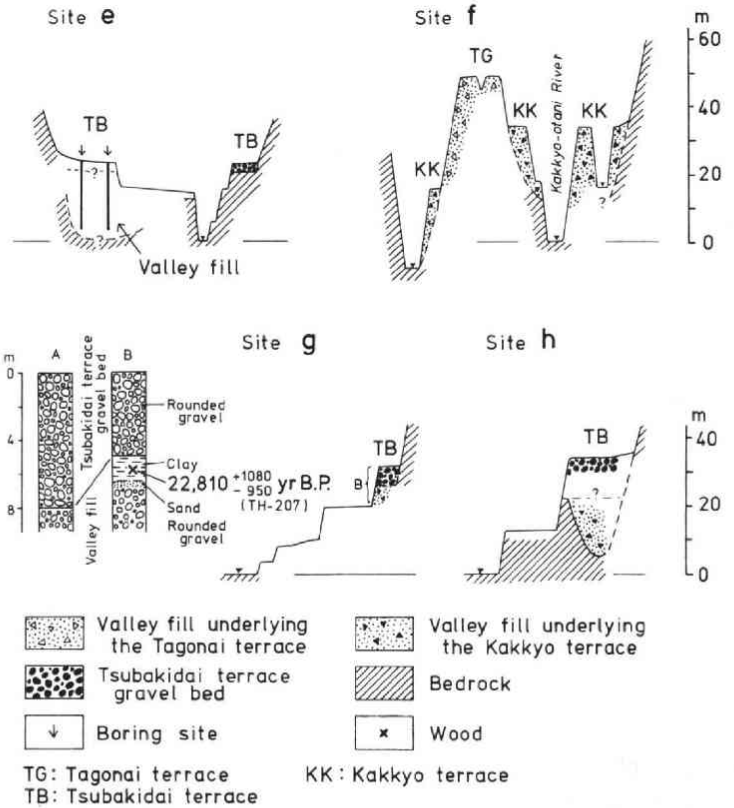

Fig. 7 Geologic sections at sites *e*, *f*, *g*, and *h* in the Naruse River basin

Kakkyo-otani River.

At site *f*, the Kakkyo terrace stands about 35 m above the river level, and is underlain by younger valley fill about 25 m thick (Fig. 7). This valley fill is distinguishable from the older one underlying the Tagonai terrace, because the latter is more weathered. The younger valley fill is made up largely of poorly sorted and poorly bedded gravel bed and contains intercalated lenses of fine-grained material. The gravel is mainly subrounded cobble or boulder.

At site *i*, the valley fill is 12 m thick and made up mostly of subangular pebbles and cobbles. At site *g*, the valley fill is overlain by a veneer of gravel (5 m in thickness) underlying the Tsubakidai terrace as detailed below.

At site *h*, the base of the valley fill or the buried valley bottom is 5 m above the river level. The bore-hole records at site *e* reveal that the buried valley bottom is at the almost same level as the river channel or below it (Fig. 7).

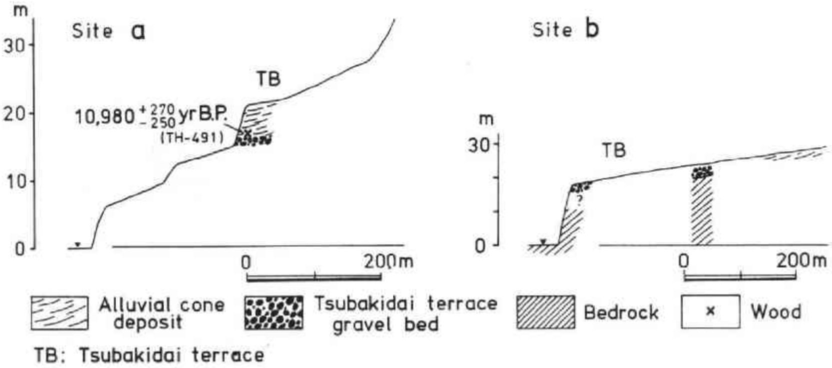

Fig. 8 Geologic sections at sites *a* and *b* in the Naruse River basin

b) The Tsubakidai terrace

The Tsubakidai terrace is continuously traceable along the Naruse River, except for the reaches where landslide has deformed the terrace feature. The mean slope of the terrace along the Naruse River is about 12 m per km.

The terrace is underlain by a veneer of gravel ranging in thickness from 2 to 8 m. The veneer, named the Tsubakidai terrace gravel bed in this paper, overlies the above-mentioned valley fill (Fig. 7, *g*) and bedrock (Fig. 8, *b*).

At site *g*, the Tsubakidai terrace gravel bed is 5 m thick rounded gravels and the underlying valley fill is composed of clay bed (0.8 m thick) containing angular to subangular gravel, sand bed (0.2 m thick), and rounded gravel bed in descending order (Fig. 7, *g*(B)). The radiocarbon age of the wood buried in the clay bed is $22{,}810^{+1080}_{-950}$ yr B.P. (TH-207). At the outcrop (A), 30 m downstream from the outcrop (B) on the same terrace scarp, the Tsubakidai terrace gravel bed is 8 m thick and is directly underlain by the rounded gravel bed, a member of valley fill, and the clay bed mentioned above is missing. This stratigraphic evidence suggests that the Tsubakidai terrace gravel bed is slightly unconformably underlain by the valley fill at site *g*. There is an apparent difference in facies between the Tsubakidai terrace gravel bed and the underlying valley fill. The latter is characterized by a higher content of sitly matrix and smaller reddish brown or black gravel (mainly 10 to 20 cm in diameter) coated with iron or manganese. The former attains a maximum diameter of 50 cm and is accompanied by a matrix of sandy material.

The alluvial cone deposit frequently overlies the Tsubakidai terrace gravel bed. The radiocarbon age of the wood buried in the alluvial cone deposit at site *a* is 10,980 $^{+270}_{-250}$ yr B.P. (TH-491) (Fig. 8, a).

No terraces except for untraceable minor ones are present below the Tsubakidai

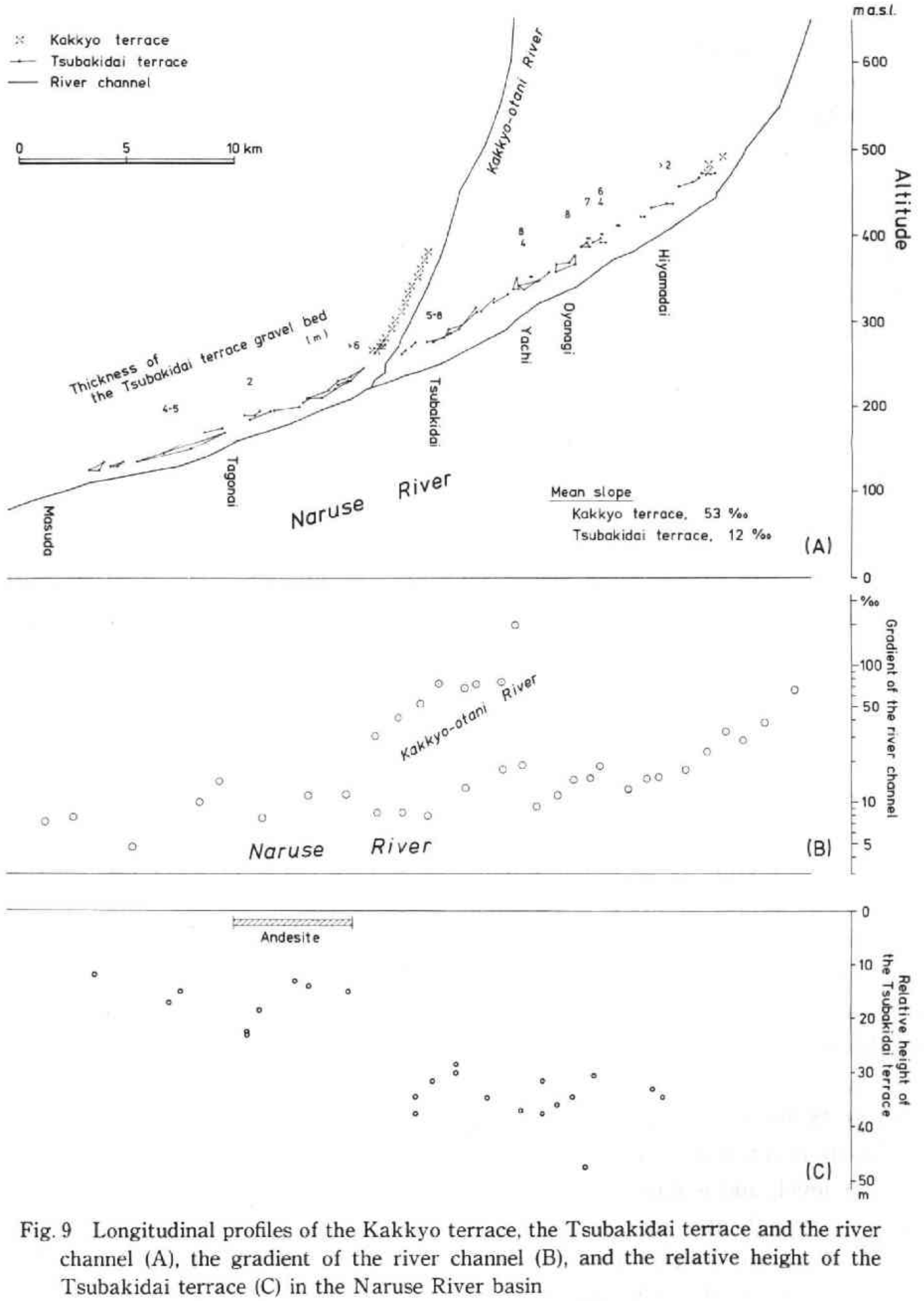

Fig. 9 Longitudinal profiles of the Kakkyo terrace, the Tsubakidai terrace and the river channel (A), the gradient of the river channel (B), and the relative height of the Tsubakidai terrace (C) in the Naruse River basin

terrace.

c) The longitudinal profiles of the Kakkyo and the Tsubakidai terraces

The Longitudinal profiles of the Kakkyo and the Tsubakidai terraces are shown in Fig. 9(A). The gradient of the river channel is shown in Fig. 9(B).

These figures show that the Tsubakidai terrace is formed along only the reach where a river gradient is less than 40 to 30 m per km. Along the reach where the gradient is much steeper, only the Kakkyo terrace is present.

Besides, it is apparent that the longitudinal profile of the Tsubakidai terrace is less concave than that of the river channel. This results in that the relative height of the Tsubakidai terrace attains its maximum in the middle reach. The relative height of the Tsubakidai terrace was measured by levelling as shown in Fig. 9(C). The maximum relative height, attaining about 40 m, is recorded in the section between Tsubakidai and Hiyamadai. Additionally, the smaller value of the relative height in the section between Tagonai and Tsubakidai is ascribed to the partial exposure of the more resistant rock, andesite, on the river bed.

4.3. The Yokote River basin

The river terraces along the Yokote and the Asahi Rivers are classified as the Yokotezawa terrace, the Iwase terrace, the Itaizawa terrace, the Mitsumata terrace, and the Nango rerrace, in chronological order. The distribution of terraces is shown in Fig. 10.

a) The Mitsumata terrace

The Mitsumata terrace is distributed only in the upper part of the Yokote River basin, and stands about 14 m above the river level near its downstream end. This terrace has a feature of dissected alluvial fan sloping about 48 m per km.

The Mitsumata terrace is underlain by about 15 m or more thick valley fill, whose base is inferred to be at the almost same level as the river channel at site *a* (Fig. 11). The valley fill is poorly sorted and poorly bedded gravel bed which is composed of subrounded to subangular cobble and boulder with a matrix of silty material and contains many intercalated lenses of sand and silt.

Peaty material buried at 4.5 m below the Mitsumata terrace surface at site *f* is dated as $23{,}200^{+1100}_{-900}$ yr B.P. (GaK-3,188) (Okada and Nakamura 1972).

At site *d*, a terrace underlain by valley fill more than 10 m thick stands 18 m above the river level, and is named the Itaizawa terrace in this paper. Nakagawa *et al.*'s (1971) report indicates that the Itaizawa terrace is correlative with the Mitsumata terrace mentioned above. The author's opinion is that the Itaizawa terrace is that of the preceding period. It is based upon the following variation in relative height of each terrace. The relative height of the Itaizawa terrace is 18 to 20 m. If the

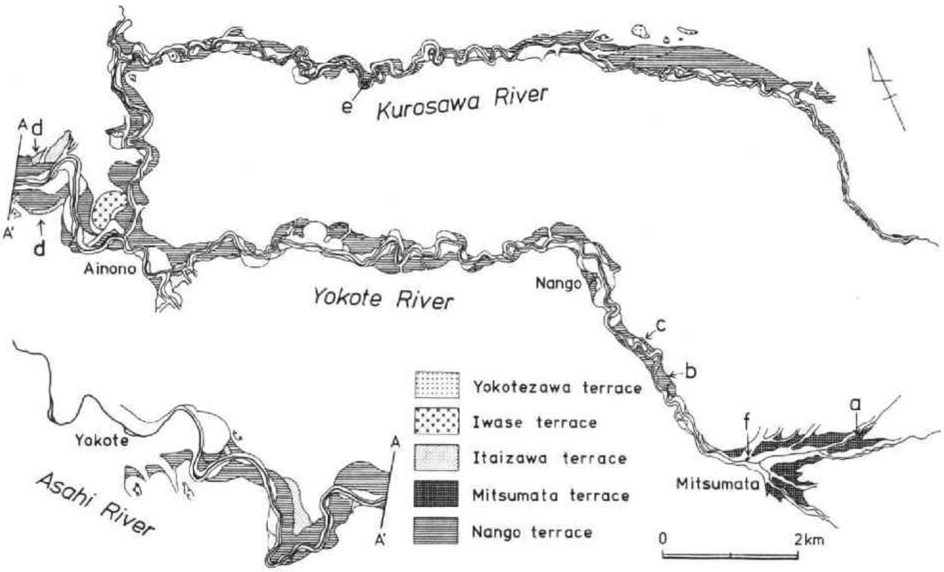

Fig. 10 Map showing river terraces along the Yokote, the Kurosawa, and the Asahi Rivers and locations of geologic sections *a–e*

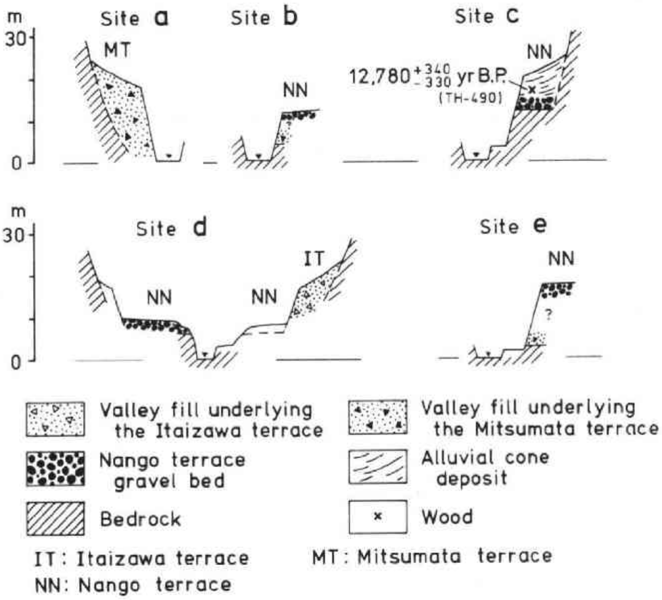

Fig. 11 Geologic sections at sites *a–e* along the Yokote and the Kurosawa Rivers

Itaizawa terrace is tentatively correlated with the Mitsumata terrace (its relative height, 14 m) as indicated in Nakagawa *et al.* (1971), then the relative height of the terrace increases in the downstream direction as a result. This variation in relative height in the downstream direction is not detected in the other terraces. The Yokotezawa terrace and the Iwase terrace above the Itaizawa terrace show longitudinally uniform relative heights of about 55 m and about 25 m, respectively. The Nango terrace below the Itaizawa terrace shows slightly decreasing relative height in the downsteram direction, as detailed below. It is unlikely that only the Itaizawa ~Mitsumata terrace shows the increasing relative height downstream.

b) The Nango terrace

The Nango terrace is continuously traceable downstream from Mitsumata. The mean slope of the terrace surface along the Yokote River and the Asahi River is about 9 m per km. The terrace is underlain by a veneer of gravel, named the Nango terrace gravel bed, ranging in thickness from 2 to 5 m.

At site *c* and *d*, the Nango terrace gravel bed overlies bedrock (Fig. 11). At site *b* and *e*, the Nango terrace gravel bed overlies valley fill (Fig. 11) which is distinguishable from the former. The Nango terrace gravel bed consists mainly of rounded boulders and cobbles. By contrast, the valley fill is composed of sandy to silty material containing rounded gravel.

The radiocarbon age of the wood buried in the alluvial cone deposit which overlies the Nango terrace gravel bed at site *c* is $12{,}780^{+340}_{-330}$ yr B.P. (TH-490).

No terraces except for untraceable minor terraces are present below the Nango terrace along the Yokote River.

c) The longitudinal profiles of the Mitsumata and the Nango terraces

The longitudinal profiles of the Mitsumata and the Nango terraces along the Yokote-Asahi River are shown in Fig. 12(A). The gradient of the river channel is shown in Figure 12(B).

These figures show that the Nango terrace is formed only along the reach where a river gradient is less than 30 or 20 m per km. Along the reach where the gradient is steeper than above value, only the Mitsumata terrace is present.

The relative height of the Nango terrace is measured by levelling as shown in Fig. 12(C). It attains a maximum of about 18 m near Nango, and decreases both upstream and downstream from Nango. It proves the less concavity of the Nango terrace profile than that of the present river profile.

5 Discussion of the terrace development

5.1. The stage of valley-filling

Two valley fills, being different in age, are observable in the Naruse and the

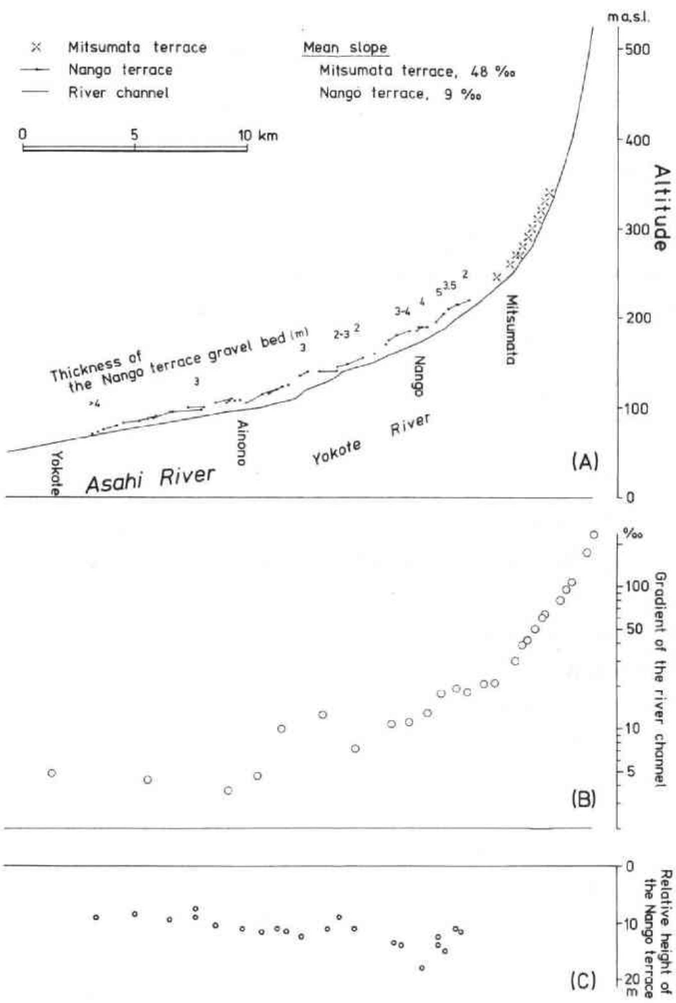

Fig. 12 Longitudinal profiles of the Mitsumata terrace, the Nango terrace and the river channel (A), the gradient of the river channel (B), and the relative height of the Nango terrace (C) in the Yokote River basin

Yokote River basins. The younger valley fill is dated as $22{,}810^{+1080}_{-950}$ yr B.P. and $23{,}200^{+1100}_{-900}$ yr B.P. for the Naruse and the Yokote, respectively. The valley fill in the Onigase River basin is dated as older than about 33,000 yr B.P. at a horizon near its base, and as $22{,}050 \pm 650$ yr B.P. at an upper horizon. From these radiocarbon ages it is concluded that above-mentioned three younger valley fills are of the same age. It means that the filltop terraces, such as the Odaino terrace in the Onigase River basin, the Kakkyo terrace in the Naruse River basin and the Mitsumata terrace in the Yokote River basin, are correlative with one another. The filltop terrace of the age is designated the F terrace.

The radiocarbon ages at a horizon near the base of the valley fill which forms the F terrace reveal that the initiation of valley-filling dates back before 33,000 yr B.P.

5.2. The stage of downcutting

a) The reach with a steeper river gradient

After the formation of the filltop terrace, a channel has been incised without the formation of any terrace in the reach with a steeper river gradient than about 30 m per km. Two radiocarbon ages of the wood in the upper valley fill in the Onigase River basin, 22,050 ± 650 yr B.P., and of the charcoal obtained from Odaino Prehistoric Site situated on the Odaino terrace (filltop terrace), 18,500 ± 450 yr B.P., lead to a hypothesis that the stage of downcutting replaced the stage of valley-filling in the time around 20,000 yr B.P. The following fact supports the hypothesis: the woods which are stratigraphically considered to have been deposited in the stage of downcutting are dated as $10{,}980^{+270}_{-250}$ yr B.P. and $12{,}780^{+340}_{-330}$ yr B.P. for the Naruse River basin and the Yokote River basin, respectively.

b) The reach with a gentler river gradient

In the reach with a gentler river gradient than about 30 m per km, a well-traceable veneer of gravel was laid down to form the Kotsunagizawa terrace, the Tsubakidai terrace and the Nango terrace in the respective basins. They are correlative with one another and are designated the G terrace.

Absence of the F terrace in the reach where the G terrace is developed may indicate that the sedimentation of gravel resulting in the G terrace gravel bed and the concurrent valley-floor widening proceeded at the almost same level as the top of the valley fill.

In the uppermost part of the reach, such as the site *a* in the Onigase River basin, the G terrace gravel bed is laid down in the lower position than the Odaino terrace (filltop terrace). Presumably it results from the difference in the gradient, with which sediments was laid down, between the valley fill and the G terrace gravel bed. The latter has a gentler gradient than the former. The difference in gradient between the two becomes smaller downstream.

The idealized long profiles of the F terrace and the G terrace are shown in Fig. 13(c). In the reach with a gentler river gradient, the incision following the valley-filling was interrupted or delayed by deposition of the veneer of gravel (the G terrace gravel bed) (Fig. 13(a)).

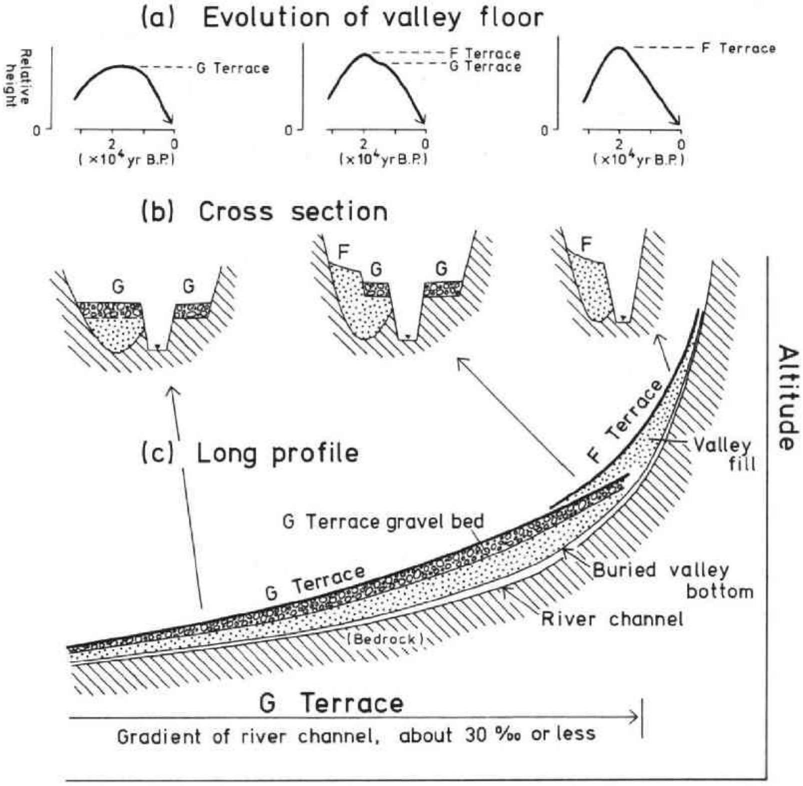

Fig. 13 Idealized evolution of valley floor (a), cross sections (b), and long profiles of the F terrace, the G terrace and the river channel (c)

5.3. The sequence of terrace development

From the following facts it is concluded that the Odaino terrace, the Kakkyo terrace and the Mitsumata terrace in the respective river basins are of climatic origin. The facts are firstly that they are filltop terraces underlain by thick valley fill, and secondly that initiation of the downcutting following valley-filling dates back to around 20,000 yr B.P. The age is simultaneous with the age of climatic change, *i.e.* the beginning of increasing temperature, which may have been associated with increase in rainfall in the presently humid temperate climate zone. As suggested frequently, the valley-filling seems to be attributed to the excess of sediment supply to the channel by some slope processes which are active under the cold climatic condition.

It is of particular interest that the sedimentation of veneer of gravel and the concurrent valley-floor widening after the valley-filling resulted in the formation of a fillstrath or a strath terrace (the G terrace) in the reach with gentler river gradient than about 30 m per km. Previous studies has confirmed no stable condition of climate, crustal movement and sealevel in the period between 20,000 yr B.P. and 10,000 yr B.P. when the G terrace was formed. The problem of the G terrace formation after valley-filling required further studies from the viewpoint of both external events and complex response of a drainage basin to them as conceptualized by Schumm (1977).

6 Conclusion

The latest-valleyfilling stage was replaced by the stage of downcutting at the age around 20,000 yr B.P. and a filltop terrace (F terrace) was formed in the study area situated in the central part of the Ou Backbone Range. The age of the change in fluvial processes, about 20,000 yr B.P., is simultaneous with the age of climatic change suggested in previous pollen analytical studies. It indicates the filltop terrace of about 20,000 yr B.P. to be of climatic origin.

In the stage of downcutting after the valley-filling, a veneer of gravel was laid down to form a well-traceable terrace (G terrace), such as the Kotsunagizawa terrace, the Tsubakidai terrace and the Nango terrace in the respective river basins. The causality of this terrace formation after valley-filling should be remarked and further studies from a wider viewpoint are necessary.

Acknolwedgement

The author wishes to thank Dr. T. Tamura of Tohoku University for critical reading of the manuscript. The author is much indebted to Dr. F. Yonechi of Tohoku University for providing the unpublished data of ^{14}C age and for many helpfull suggestions, and to Dr. K. Omoto of Tohoku University for guidance with the experiments of radiocarbon measurement.

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

Flint, R.F. (1971): *Glacial and Quaternary Geology.* John Wiley & Sons, Inc. N.Y., 892p

Igarashi, Y. and S. Kumano (1981): Vegetational Changes during the Last Glacial Age in Hokkaido.** *Daiyonkikenkyu (The Quaternary Research),* **20** 129-141

Kawamura, T. (1979): Palynological Studies of Bog Deposits in Tohoku District —— Special Reference to the Distribution of *Cryptomeria japonica* ——.** *ibid.,* **18** 79-88

Kumai, H., S. Akahane, and The Nojiri-ko Excavation Research Group (1981): Last Glacial Paleoenvironment around Lake Nojiri, Central Japan.** *ibid.* **20** 175-189

Machida, H. and F. Arai, (1979): Daisen Kurayoshi Pumice: Stratigraphy, Chronology, Distribution and Implication to Late Pleistocene Events in Central Japan.** *Chigaku-zasshi (Journal of Geography),* **88** 313-330

Matsuoka, I., J. Akutsu, K. Manabe, and S. Takeuchi (1984): Quaternary deposits of the Yamagata Basin, Northeast Honshu, Japan —— Time-stratigraphic classification and sedimentary environment of the deposits ——. *Jour, Geol. Soc. Japan,* **90** 531-549**

Miyagi, T., K. Hibino, T. Kawamura and K. Nakagami (1981): Hillslope Development under Changing Environment since 20,000 Years B.P. in Northeast Japan. *Sci. Repts. Tohoku Univ., 7th Ser. (Geogr.),* **31** 1-14

Nakagawa, H., T. Ishida, S. Oike, S. Onodera, O. Nanasaki and T. Matsuyama (1971): Terraces along the Asahi and Waga Rivers, Northeastern Honshu, Japan.** *Tohoku Univ., Inst. Geol. Pal., Contr.*, **71** 47-59

Nakayama, T. and T. Miyagi, (1984): Hillslope Development and Sediment Yield under Changing Environment since 46,000 Years B.P. in the Kawadoi Basin, Northeast Japan.** *Ann. Tohoku Geogr. Assoc.*, **36** 25-38

Odaino Site Research Group (1973): Odaino Iseki no ^{14}C nendai.* *Chikyu-kagaku,* **27** 148-149

Okada, A. and K. Nakamura (1972): Ou sanmyaku nai, Akita-ken Hiraka-gun Sannai-mura Mitsumata ni okeru taiseki dankyu no keisei nendai.* *Chikyu-kagaku,* **26** 263-264

Ono, Y. (1984): Last Glacial Paleoclimate Reconstructed from Glacial and Periglacial Landforms in Japan *Geogr. Rev. of Japan,* **57** Ser. B, 87-100

Ōzawa, A. (1964): *Geological map, Scale 1 : 200,000, Shinjo.* Geol. Surv. Japan.

Sakaguchi, Y. (1978): Climatic Changes in Central Japan since 38,400 yBP —— Viewed from Palynological Study on Ozegahara Deposits ——. *Bull. Dept. Geogr. Univ. Tokyo,* **10** 1-10

Sakai, J. (1981): Climatic Changes during the Late Pleistocene in Central Japan.** *Daiyonki-kenkyu (The Quaternary Research),* **20** 165-173

Schumm, S.A. (1977): *The fluvial System.* Wiley, 338p

Toyoshima, M. (1981): A Geohistorical Study of Fluvial Land form through the Last 30,000 Years at the Eastern Fringe of the Yamagata Basin, Japan. *Sci. Repts. Tohoku Univ., 7th Ser. (Geogr.),* **31** 15-28

Yanagida, M. (1979): The Geomorphic Development of the Middle Course of the Agano River.** *Geogr. Rev. of Japan,* **52** 689-705

Yasuda, Y. (1982): Pollen Analytical Study of the Sediment from the Lake Mikata in Fukui Prefecture, Central Japan —— Especially on the Fluctuation of precipitation since the Last Glacial Age on the Side of Sea of Japan ——.** *Daiyonki-kenkyu (The Quaternary Research),* **21** 255-271

Yoshida, T., S. Ito, M. Shirase, T. Horiuchi, K. Manabe, K. Suzuki, S. Takeuchi, T. Nonaka, Y. Nirei, and N. Nirei (1981): Quaternary Strata and Plant Fossil Assemblages in the Central Abukuma Mountains, with Special Reference to Changes of Vegetation in the Southern Tohoku District during the Last Glacial Age.** *ibid,* **20** 143-163