Tephrochronology of Late Quaternary Strath Terraces and Their Implications to Neotectonic Movements in the Shitada and Tochio Regions of the Niigata Basin, Central Japan

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Late Quaternary strath terraces younger than 50 ka were investigated in the Shitada (Ikarashi River) and Tochio (Kariyada River) regions, central eastern margin of the Niigata Basin, in order to clarify their chronology and implications to neotectonic movements. The terraces were classified based on geomorphologic configuration and tephro-stratigraphic relation between marker tephra horizons and the terraces. Six tephra horizons (ST 1–ST 6) were found in the loam and black soil, which overlie terrace deposits. ST 4 is correlated with the widespread tephra As-K (13 ka), ST 5 with AT (25 ka) and ST 6 with Dkp (50 ka). The terraces are in chronologic order Sh-D, Sh-C, Sh-B, Sh-A₃, Sh-A₂ and Sh-A₁ terraces for the Shitada region and To-D, To-C, To-B, To-A₄, To-A₃, To-A₂ and To-A₁ terraces for the Tochio region.

The presence of strath terraces since the post-glacial transgression indicates that intermittent local and/or regional uplift initiated terrace development. Same aged terraces had different relative heights from the present riverbed across NNE–SSW and NW–SE trending active faults. These discontinuities cannot be simply explained by tilting due to active folding. We propose that the NNE–SSW and NW–SE trending fault systems have been active as the result of block segmentation, which characterize the uplift movement of the Shitada and Tochio regions since 50 ka.

Key words : tephrochronology, neotectonic movement, uplift, strath terrace, active faults, block segmentation

I. Introduction

Late Pleistocene to Holocene inland fluvial terraces are distributed in many areas of the Niigata Basin, including the Shitada and Tochio regions (Fig. 1). Previous studies (Naito, 1975 ; Coll. Res. Gr. on the Geol. of the Shitada Hills, 1976 ; Coll. Res. Gr. on the Kariyada River, 1977 ; Suzuki, 1993. *etc.*) on these terraces were mainly terrace description from a geomorphologic point of view without much emphasis on the chronology of terraces. In the last decade, late Pleistocene to Holocene tephrochronology

in the Japanese Islands has progressed using widespread tephra layers and marker tephra horizons (Machida, 1991, 1999 ; Machida and Arai, 1992. *etc.*). Recently, many detailed studies have clarified the frame of late Pleistocene to Holocene tephro-stratigraphy in the Niigata Basin (Niigata Volcanic Ash Res. Gr., 1981, 1995 ; Watanabe *et al.*, 1994 a, b, ; Watanabe and Niigata Volcanic Ash Res. Gr., 1999).

Several studies on fluvial terraces in Japan mainly discussed about tectonic deformation, explained by tilting due to active folding and/or constant rate of uplift (Naito, 1975 ; Ota and

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Fig. 1 Locality of the study area

Compiled after Geological map of Niigata Prefecture 1:200,000 (1988) and Research Group of Active Faults (1991).

Suzuki, 1979; Kumahara, 1998; *etc.*). However, recent studies (Takahama and Neotec. Res. Gr. of the Niigata Shinano River Region, 1999; Yasui and Neotec. Res. Gr. of the Niigata Shinano River Region, 1999) explained terrace development due to block uplift movement. Similarly, Choi *et al.* (1999) and Kafle *et al.* (1999; *etc.*) discussed about the tectonic controls in the development of terraces. Yoshiyama and Yanagida (1995) calculated uplift rates based on the relationship between fill terraces and equilibrium of river profiles.

This study tephro-chronologically investigated strath terraces younger than 50 ka that are distributed along the Ikarashi River (Shitada region) and Kariyada River (Tochio region). Based on chronologic correlations of the terraces we aim to clarify the neotectonic movements of the Shitada and Tochio regions since 50 ka.

II. Geologic setting

The Ikarashi River and Kariyada River flows northwestward from the Echigo Mountains,

cutting through the uplifting tectonic block of the Shitada-Higashiyama Hills (Fig. 1). This block unit is approximately 40 km long and 15 km wide as indicated by NW-SE and NNE-SSW trending topographic lineaments. The Shitada-Higashiyama Hills consist of folded Tertiary (Miocene to Plio-Pleistocene) sedimentary and volcanic rocks of the Niigata Basin (Tateishi, 1988, *etc.*). The folding, are characterized by NNE-SSW trending anticlinal and synclinal axes and active folding has been reported in the Shitada region by Naito (1975) and Coll. Res. Gr. on the Geol. of the Shitada Hills (1976). Many NNE-SSW trending fault systems, which are the same trend as the Shibata-Koide Tectonic Line are also present. The Shibata-Koide Tectonic Line, which is the eastern margin of the Niigata Basin became active in the Pliocene (Takahama, 1985) and is presently active in some areas but not in others (Kato and Yamazaki, 1979), perhaps indicating a segmented nature.

Fig. 2 Standard tephrostratigraphy of loam and its characteristics at locality T2 (refer to Fig. 8)

III. Tephro-stratigraphy (methods and correlations)

A standard tephro-stratigraphy of the loam and black soil was first established for this study at an outcrop at locality T2 (Fig. 2). The loam and black soil which is approximately one meter thick was classified into four units ; A (black soil, 5 YR 2.5/1), B (dark brown loam, 10 YR 4/3), C (strong brown loam, 7.5 YR 5/6) and D (yellowish-red loam, 5 YR 4/6) units based on Munsell's soil color chart. The colored layers possibly indicate the different tephra zones. However, it is difficult to clearly distinguish the tephra horizons in the field, therefore samples of loam and black soil were taken at 5cm intervals. Each sample was washed and sieved (63μm and 125μm) for microscopic observation. The basal part of the loam (unit D) included a mixture of numerous hornblende and orthopyroxene (flat type) overlain by a zone having bubble wall shards (unit C), which is overlain by a zone having fiber/pumice type (unit B) and further having bubble wall shard glasses (unit A). Volcanic glasses (15–20 glass shards for each sample) and flat type orthopyroxene (10–15 grains for each sample) were picked for chemical composition analysis (EPMA) using the JXA-8600 type X-ray micro-analyzer (Niigata University). The conditions for analyses were : voltage acceleration=15KV, sample current=1.3×10⁻⁸A, beam diameter=5μm and ZAF correction.

The EPMA analysis results indicated the pre-

Fig. 3 Chemical composition of volcanic glasses of ST1-ST5 (TiO₂-MgO)
S* and T* are sample localities (refer to Figs. 6, 7 and 8).

sence of six (ST 1–ST 6) tephra horizons at the type locality (loc. T2). Volcanic glasses from As-K (taken from an outcrop at Agatsumagun district, Gunma Prefecture as pointed out by Takemoto, 1996), AT (taken from an outcrop at Hiruzenbara district, north Okayama Prefecture as pointed out by Hiruzenbara Collaborative Research Group, 1973) and orthopyroxenes of Dkp (taken from an outcrop east of Lake Daisen as pointed out by Machida, 1996) tephtras were analyzed together with this study's samples and the chemical compositions (Figs. 3 and 4) showed that ST 4 (included in

unit B) correlated with the widespread tephra of As-K (approx. 13 ka, Arai, 1962), ST 5 (included in unit C) with AT (approx. 25 ka, Machida and Arai, 1976) and ST 6 (included in unit D) with Dkp (approx. 50 ka, Machida and Arai, 1979). ST 1, ST 2 and ST 3 could not be correlated with widespread marker horizons. However, archeological remains from the Jomon-Banki period (approx. 3 ka) have been discovered in the Sh-A₁ and Sh-A₃ terraces (Shitada Educational Committee, 1994) as described below. Therefore the ST 1, ST 2 and ST 3 tephra (included in unit A) are considered

Fig. 4 Chemical composition of orthopyroxenes of T2, S29 (refer to Figs. 6, 7 and 8) and Dkp

to have fallen approximately between 3 ka and 13 ka.

IV. Classification of the strath terraces

The terraces were subdivided in chronologic order Sh-D, Sh-C, Sh-B, Group Sh-A (Sh-A₃, Sh-A₂ and Sh-A₁) terraces for the Shitada region and To-D, To-C, To-B, Group To-A (To-A₄, To-A₃, To-A₂ and To-A₁) terraces for the Tochio region (Fig. 5), based on geomorphic configuration and tephro-stratigraphic relation between the marker tephra layers and the terraces (Fig. 6). We used 1 : 2,500, 1 : 5,000 and 1 : 10,000 topographic maps as well as using a hand level to measure the relative height of the terraces.

All the terrace deposits unconformably overlie Pliocene and Miocene series and include rounded to sub-rounded gravels ranging from 5–40 cm, showing occasional imbrications parallel to the present rivers. The gravels, which originated from the Miocene basement, are composed of andesite and tuff and the matrix is coarse sand. The gravels are overlain by coarse to very fine sand followed by a gra-

Geological age	Tephra horizon	Fluvial Terraces						
		Shitada				Tochio		
		This study	Naito (1975)	Coll. Res. Gr. on the Geol. of Shitada Hills (1976)	Suzuki (1993)	This study	Naito (1975)	Coll. Res. Gr. on the Kariyada River (1977)
Quaternary	Holocene	ST1-ST3 (3-13ka)	Group Sh-A	Sh-A ₁	Low ground			
				Sh-A ₂				
				Sh-A ₃	Ig-VI	Hanabuchi Terrace	IX	
		ST4 (As-K, 13ka)						
	Middle to Late Pleistocene	ST5 (AT, 25ka)	Sh-B					
		ST6 (Dkp, 50ka)	Sh-C	Ig-V	Tanabire Terrace	VIII	To-B	
			Sh-D	Ig-IV	Sasaoka Terrace	VII VI	To-C	Kr-IV
			older terraces (undivided)	Ig-III	Chikusan Shikenjo Terrace	V	older terraces (undivided)	Kr-III
				Ig-II	Oohainanbu Terrace	IV		Kr-II
				Ig-I		III		
				Oodaira		I		

Fig. 5 Stratigraphic table and comparison with previous works of the terraces in the Shitada and Tochio regions

Fig. 6 Vertical columns of the terraces showing the occurrence of tephra layers
Localities are shown in Figs. 7 and 8.

dational zone comprising sandy loam, which are covered by loam and black soil.

The gradational zone of sandy loam is considered to be the deposits at the initial stage of terrace emergence. Therefore, the tephra layer

included in the sandy loam indicates the approximate age of the terrace emergence.

1. Ikarashi River (Shitada region)

The terraces are distributed on both banks of the Ikarashi River from the Meishita through

Fig. 7 Terrace distribution map (A) longitudinal profile (B) cross sections along the Ikarashi River, Shitada region (C)

S* - locality of vertical columns (refer to Fig. 6).

to the Hara district (Fig. 7-A). The correlations between this and previous studies are shown in Figure 5 and the vertical columns are shown in Figure 6.

Group Sh-A

Sh-A₁ Terrace : This is the lowest terrace distributed on either side of the Ikarashi River

from the Meishita to Hara districts, relatively 3–5 m higher than the present riverbed (Fig. 7-B). The terrace gravels and sand are 30 cm + thick and are overlain by 15–30 cm thick very fine black sand. Archeological remains from the Jomon-Banki period (3 ka) were discovered on this terrace surface (Shitada Educational

Committee, 1994; Fig. 7-A).

Sh-A₂ Terrace: This terrace is only distributed in the Meishita district on both banks of the Ikarashi River, relatively 13 m higher than the present riverbed (Fig. 7-B). The terrace gravels and sand are 120 cm thick, which unconformably overlie the basement and are overlain by 20 cm thick very fine black sand, including the ST 1–ST 3 tephra (Fig. 6).

Sh-A₃ Terrace: This terrace is distributed along the right bank of the Ikarashi River in the Morimachi district and on both banks in the Meishita district, relatively 10–13 m higher in the Morimachi district and 16–18 m in the Meishita district than the present riverbed (Fig. 7-B). The terrace gravels and sand are 50–90 cm thick, which unconformably overlie the basement and are overlain by 10–60 cm thick very fine black sand, including the ST 1–ST 3 tephras (Fig. 6). Archeological remains from the Jomon-Banki period (3ka) were discovered on this terrace surface (Shitada Educational Committee, 1994, Fig. 7-A).

Sh-B Terrace: This terrace is distributed on both banks of the Ikarashi River in the Shimoppara district and on the left bank in the Yagimae district, relatively 9–10 m higher on the left bank and 18–20 m higher on the right bank than the present riverbed (Fig. 7-B). The terrace gravels and sand are 40–80 cm thick, which unconformably overlie the basement and are overlain by 20 cm thick loam (unit B) and 15 cm thick black soil (unit A), where the ST 4 tephra (As-K, 13 ka) is included in the sandy loam (Fig. 6).

Sh-C Terrace: This terrace is distributed on the left bank of the Ikarashi River in the Sasaoka, Shimoppara and Meishita districts, relatively 14–15 m higher in the Sasaoka and Shimoppara districts and 25 m in the Meishita district than the present riverbed (Fig. 7-B). The terrace gravels and sand are 80 cm thick, which unconformably overlie the basement and are overlain by 35 cm thick loam (units C and B) and 25 cm thick black soil (unit A), where the ST 5 tephra (AT, 25 ka) is included in the sandy loam (Fig. 6).

Sh-D Terrace: This terrace is distributed on both banks of the Ikarashi River in the Hara, Iida, Sasaoka, Shimoppara and Yagimae dis-

tricts. The approximate relative height of the terrace from the present riverbed decreases downstream from 22 m in the Yagimae district to 9 m in the Sasaoka district (Fig. 7-B). Between the Yagimae and Sasaoka districts the Shimoppara Fault (Naito, 1975) vertically displaces this terrace by approximately 1.5 m (Fig. 7-B). The relative height of the terrace increases downstream towards the Hara district to 19 m. The terrace gravels of the Sh-D Terrace in the Hara district consist of Miocene basement rocks, same as the other terraces along the Ikarashi River. Also, pebble imbrication indicates that the Ikarashi River, not the branch Odaira River, formed the Sh-D Terrace in the Hara district. Between the Sasaoka and Hara districts the Machiyashiki Fault (Suzuki, 1993) also vertically displaces the terrace by 2–3 m (Fig. 7-B). In the Iida district, it is relatively 21 m higher than the present riverbed and decreases downstream to 16 m (Fig. 7-B). The terrace gravels and sand are 50–100 cm thick, which unconformably overlie the basement and are overlain by 75 cm thick loam (units D, C and B) and 30 cm thick black soil (unit A), where the ST 6 tephra (Dkp, 50 ka) is included in the sandy loam (Fig. 6).

2. Kariyada River (Tochio region)

The terraces are distributed on both banks of the Kariyada River and a part of the Shiotani River from the Koutokuji to Akedo and Hitozura districts (Fig. 8-A). The correlations between this and previous studies are shown in Figure 5 and the vertical columns are shown in Figure 6.

Group To-A

To-A₁ Terrace: This is the lowest terrace distributed on either side of the Kariyada River and Shiotani River from Koutokuji to Akedo and Hitozura districts, relatively 3–5 m higher than the present riverbed (Fig. 8-B). The terrace gravels and sand are 100 cm+ thick and are overlain by 15–30 cm thick very fine black sand.

To-A₂ Terrace: This terrace is only distributed in the Hara district on the right bank of the Kariyada River, relatively 9 m higher than the present riverbed (Fig. 8-B). The terrace gravels and sand are 50 cm+ thick, which unconformably overlie the basement and are

Fig. 8 Terrace distribution map (A) longitudinal profile (B) cross sections along the Kariyada River, Tochio region (C)

T* - locality of vertical columns (refer to Fig. 6).

overlain by 90 cm thick very fine black sand, including the ST1–ST3 tephra (Fig. 6).

To-A₃ Terrace: This terrace is only distributed in the Hara district of the Kariyada River, relatively 14 m higher than the present riverbed (Fig. 8-B). The terrace gravels and sand are 140 cm thick, which unconformably overlie the basement and are overlain by 80 cm thick black soil (unit A), including the ST1–ST3 tephra (Fig. 6).

To-A₄ Terrace: This terrace is distributed on both banks of the Kariyada River in the Akiba, Hara and Akedo districts, relatively 25 m higher in the Akiba, 20 m in the Hara and 13 m higher in the Akedo districts than the present riverbed (Fig. 8-B). The terrace gravels and

sand are 50–180 cm thick, which unconformably overlie the basement and are overlain by 60–70 cm thick black soil (unit A), including the ST1–ST3 tephra (Fig. 6).

To-B Terrace: This terrace is distributed on both banks of the Kariyada River in the Hara, Akiba and Akedo districts, relatively 38 m higher in the Akiba, 29 m in the Hara and 20 m in the Akedo districts than the present riverbed (Fig. 8-B). The terrace gravels and sand are 80–120 cm thick, which unconformably overlie the basement and are overlain by 40 cm thick loam (unit B) and 20 cm thick black soil (unit A), where the ST4 tephra (As-K, 13 ka) is included in the sandy loam (Fig. 6).

To-C Terrace: This terrace is distributed in

the Akiba, Hara, Akedo and Hitozura district, relatively 52 m higher in the Akiba, 47 m in the Hara, 37 m in the Akedo and 18 m in the Hitozura districts than the present riverbed (Fig. 8-B). The terrace gravels and sand are 120–240 cm thick, which unconformably overlie the basement and are overlain by 50–60 cm thick loam (units C and B) and 20 cm thick black soil (unit A) where the ST 5 tephra (AT, 25 ka) is included just above the sandy loam (Fig. 6). The longitudinal distribution of this terrace, which continues towards the Hitozura district, indicates the paleo-channel of the Kariyada River (Fig. 8-A). After the emergence of this terrace, the Kariyada River changed its channel to the present course.

To-D Terrace : This terrace is distributed in the Koutokuji and Tochikura districts along the right bank of the Kariyada River, relatively 62 m higher in the Koutokuji and 55 m in the Tochikura districts than the present riverbed (Fig. 8-B). The terrace gravels and sand are 50–90 cm thick, which unconformably overlie the basement and are overlain by 100 cm thick loam (units D, C and B) and 30 cm thick black soil (unit A), where the ST 6 tephra (Dkp, 50 ka) is included 20 cm above the sandy loam (Fig. 6).

V. Discussions

1. Significance of the strath terraces

We recognized that the terrace deposits are relatively thin (less than a few meters) and unconformably overlie the basement (Fig. 6). Furthermore, the basement crops out along the present rivers indicating that they are all strath (rock or erosion) terraces. Therefore, in spite of the so-called post-glacial transgression, the strath terraces continued to develop along the Ikarashi and Kariyada Rivers, indicating continuous river degradation regardless of the sea level rise.

These facts clearly indicate that sea level change did not have any influence in the process of forming these terraces. Once the rivers had degraded to reach local equilibrium, it could not erode vertically anymore hence they began to erode laterally widening the riverbed. Then intermittently, local and/or regional uplift rejuvenated the degradation of the rivers forming the terrace scarp and the emergence of

the terrace surface (possibly earthquake induced). Shanley and McCabe (1994) explained that fluvial responses to base level and climate change in the inland areas are a complex phenomenon. They stated that uplift initiated adjustments of the channel, which resulted in cycles of aggradation, planation and degradation.

Similarly, in the Shitada and Tochio regions, regardless of whether small-scale climatic changes occurred or not, the effect of tectonic uplift was the primary factor initiating terrace development. Therefore, the relative height of the terrace from the present riverbed at a certain point indicates the vertical amount of erosion, which nearly equals the amount of uplift. Yoshiyama and Yanagida (1995) discussed about calculating the uplift rate from fill terraces however, their method cannot be applied to the strath terraces of this study.

2. Discontinuous rates of uplift inferred from terrace deformation

Based on the above viewpoint, we recognized that the same aged terrace had different relative heights from the present riverbed along the same river, indicating differential rates of local uplift. The boundaries separating the different uplift rates were active faults.

Shitada :

NNE–SSW trending discontinuities

1) Sumon River : In the upper reaches of the Ikarashi River in the Meishita district, the Sh-C Terrace is relatively 25 m and the Sh-A₃ Terrace is 16–18 m higher than the present riverbed (Fig. 7-B). However, in the Yagimae district, the Sh-C Terrace is relatively 14–15 m and the Sh-A₃ Terrace is 10–13 m higher than the present riverbed (Fig. 7-B). The discontinuity of the relative heights, as shown in figure 7-B, is marked by the NNE–SSW trending lineament where the Sumon River flows (Fig. 7-A). This topographic lineament is probably an active fault with the higher rate of uplift in the Meishita district compared to the Yagimae district. The NNE–SSW trending Sumon River according to Suzuki (1993) is considered to be a part of the Shibata–Koide Tectonic Line.

2) Shimoppara and Machiyashiki Faults : Between the Yagimae–Shimoppara and Hara districts, the Sh-D Terrace is displaced by the

NNE–SSW trending, Shimoppara and Machiyashiki Faults (Fig. 7-B). In the Yagimae–Shimoppara districts, the Sh-D Terrace is relatively 22 m higher than the present riverbed (Fig. 7-B). The relative height decreases to 9 m near the Odaira River in the Sasaoka district and from the Sasaoka district increases downstream to 19 m (Fig. 7-B) in the Hara district. This deformation was previously explained by active folding where the Odaira River district was considered to be the synclinal axis (Naito, 1975; Coll. Res. Gr. on the Geol. of Shitada Hills, 1976). The Shimoppara Fault vertically displaces the Sh-D Terrace by 1.5 m where the down throw side is upstream (Fig. 7-B). The older terrace is also displaced by approximately 10 m, indicating accumulative displacement of the fault. Suzuki (1993) studied the Shimoppara Fault in detail and concluded that it was active after 28 ka. The Sh-D Terrace is displaced but the Sh-B Terrace is not displaced. Therefore, this fault is thought to have been inactive during the Holocene.

The Machiyashiki Fault (Suzuki, 1993) also vertically displaces the Sh-D Terrace by 2–3 m where the down throw side is upstream (Fig. 7-B). This fault does not deform the younger Sh-A₁ Terrace, therefore it is considered to have been inactive during the Holocene. The segmentation of the Sh-D terrace due to the Shimoppara and Machiyashiki Faults cannot be simply explained by tilting, due to active folding. Suzuki (1993) also suggested that the linear fault line and the fault scarp of the Machiyashiki Fault could not be explained by active folding.

NW–SE trending discontinuity

Ikarashi River: The relative heights of the Sh-A Group terraces in the Meishita district on both banks of the Ikarashi River are respectively the same (Fig. 7-C, cross section A–A'), indicating a uniform uplift rate for the Meishita district. However, on the right bank of the Ikarashi River, in the Morimachi district, the Sh-A₃ Terrace is relatively 10–13 m higher than the present riverbed and on the opposite bank, in the Yagimae district, the Sh-B Terrace is relatively 9–10 m higher than the present riverbed (Fig. 7-C, cross section B–B'). The younger Sh-A₃ Terrace on the right bank is

relatively 2–3 m higher than the Sh-B Terrace on the left bank. These two districts are separated by a NW–SE trending lineament where the Ikarashi River flows (Fig. 7-A). The Sh-B and Sh-A₃ terraces are not tilted therefore tilting cannot explain the above phenomenon. Instead, the NW–SE trending lineament, possibly an active fault, is the boundary with the higher rate of uplift in the Morimachi district compared to the Yagimae district. Also, the Sh-B Terrace on the right bank in the Morimachi district is relatively 19 m higher than the present riverbed however, on the left bank in the Shimoppara district is 9 m, indicating a 10 m difference (Fig. 7-C, cross section C–C'). Furthermore, on the right bank in the Iida district, the Sh-D Terrace is relatively 21 m higher than the present riverbed, which decreases downstream to 16 m (Fig. 7-B). However, on the left bank, in the Sasaoka district, the Sh-D Terrace is relatively 9 m higher than the present riverbed, which increases downstream to 19 m (Fig. 7-B). There is a maximum difference of 16 m in the relative height of the Sh-D Terrace (Fig. 7-C, cross section D–D'), where the Iida district is higher compared to the Sasaoka district.

The higher rate of uplift on the right bank, indicated by the difference in relative height of the same aged terrace, is not due to tilting. The data clearly shows that the uplift movements along the Ikarashi River are independent to one another. The different uplift movement is possibly segmented by a NW–SE trending concealed fault, located somewhere along the Ikarashi River.

Tochio:

NNE–SSW trending discontinuity

Kariyada River: The Kariyada River, between the Hara and Sakae–Akedo districts flows in a NNE–SSW direction (Fig. 8-A). On the right bank in the Hara district, the To-B Terrace is relatively 27 m higher than the present riverbed, however in the Sakae–Akedo districts, is 20 m (Fig. 8-C, cross section B–B'). This displacement is not due to tilting of the terrace instead it is marked by a NNE–SSW trending lineament, possibly an active fault, which runs between the Hara and Sakae–Akedo districts (Fig. 8-C, cross section B–B').

Also, the To-A₄ Terrace in the Hara district is relatively 20 m higher than the present riverbed, however in the Sakae-Akedo districts is 13 m (Fig. 8-B). The presence of To-A₂ and To-A₃ only in the Hara district (Fig. 8-C, cross section A-A') may indicate that the NNE-SSW trending active fault that displaces the To-B Terrace separates the higher rate of uplift in the Hara district compared to the Sakae-Akedo districts.

3. Implications to block segmentation

The above descriptions show that the same aged terrace was discontinuous across NNE-SSW and NW-SE trending active faults, indicating differential local uplift rates as a result of block segmentation. The Shitada and Tochio regions which lies within the Shitada-Higashiyama Hills uplift block unit is considered to be segmented into smaller block units, being separated by these active faults.

As mentioned earlier, NNE-SSW trending fault systems (dominant trend in the Niigata Basin) can be recognized in the Shitada and Tochio regions (Fig. 1) including those of this study (Figs. 7-A and 8-A). These fault systems are the same trend as the Shibata-Koide Tectonic Line, which has been active since the Pliocene (Takahama, 1985) and also marks the eastern margin of the Niigata Basin. However, the NW-SE trending fault along the Ikarashi River (Fig. 7-A) is a trend that was dominant in the Early to Middle Miocene (Suzuki *et al.*, 1974). Although further investigations are required, the block segmentation in the Shitada and Tochio regions is probably due to neotectonic movements caused by late Quaternary regional stress fields inducing movements of older basement structures.

VI. Conclusion

This study tephro-chronologically investigated late Quaternary strath terraces younger than 50 ka and discussed about their implications to neotectonic movements in the Shitada and Tochio regions, based on chronologic correlations of the terraces.

Six tephra horizons (ST 1-ST 6) were discovered in the loam and black soil, which overlie terrace deposits. ST 1, ST 2 and ST 3 can be correlated to approximately 3-13 ka based on

the relationship with archaeological remains. ST 4 is correlated with widespread tephra As-K (13 ka), ST 5 with AT (25 ka) and ST 6 with Dkp (50 ka) on the basis of heavy mineral assemblage and chemical composition of glass shards. Based on the geomorphologic configuration between terraces and marker tephra, a new geomorpho-stratigraphy of the terraces younger than 50 ka was established.

In spite of the post-glacial transgression, strath terraces continued to develop along the Ikarashi and Kariyada Rivers indicating that tectonic uplift was the primary factor initiating terrace development. However, same aged terraces were discontinuous across NNE-SSW and NW-SE trending active faults as a result of block segmentation, characterizing the uplift movement of the Shitada and Tochio regions since 50 ka.

Further investigations are required in order to clarify : geometry and mechanisms for the block segmentation, which local and/or regional block movement initiated terrace development and to understand these local phenomena within the regional tectonic frame.

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更新世末～完新世河成段丘のテフロクロロジーと ネオテクトニクス

—新潟堆積盆地東縁部下田・栃尾地域の事例—

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(要 旨)

新潟盆地東縁部の下田(五十嵐川)・栃尾(刈谷田川)地域に分布する5万年より若い侵食段丘を調査し、段丘の編年およびテクトニックな運動を明らかにした。これらの地域のロームおよび黒土から、6つのテフラ層準(ST1～ST6)をみいだした。このうちST4は広域テフラAs-K(13ka)に、ST5とST6はそれぞれAT(25ka)とDkp(50ka)に対比できる。各地域の段丘は、地形的特徴と火山灰層序に基づき、下田地域では年代順にSh-D、Sh-C、Sh-B、Sh-A₃、Sh-A₂、Sh-A₁に、栃尾地域ではTo-D、To-C、To-B、To-A₄、To-A₃、To-A₂、To-A₁に区分できる。

これらのうち、最終氷期以降の侵食段丘は、各地域を含む間欠的な隆起運動によって形成された。同年代に対比された段丘の現河床からの比高の差異は、有意な変位を示し、NNE-SSWおよびNW-SE方向の活断層の運動を示唆している。この比高の差異は、活褶曲による変動や単純な一方向への傾動運動によるものではないと考えられる。これらの特徴から、下田・栃尾地域の5万年以降の隆起運動は一様ではなく、NNE-SSWおよびNW-SE方向に発達した活断層に伴うと推定され、複数のセグメントに区分できることを示している。

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