History of Debris Production and River-beds Rising in Kyoto District - A historical interaction between environmental changes and society-

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Series of ruins around the Kyoto basin indicate that massive developments in mountaneos region continued in long time form ancient ages. Verifiing chronological sequaence of landslide deposits and flood sediments by using AMS carbon dating, we could regognize the relationship between historical process of debris production and developments in mountaineous region. Plenty of historical records in Kyoto could be expected to fill chronological gap of landslide deposits. Here, we will describe the chronology of debris production and historical process of river-beds rising as the reslts of relationship between human activities and excess river sediments concentration.

Key words: History, landslides, Kyoto, rising river beds

1. INTRODUCTION

The present is a result of the past. This principle is true in the field of sediment disaster. Excess supply of sediments from mountainous slope by landslide caused debris disaster in alluvial complex between fan and low land. Landslide deposits and flood sediments including river floor deposits could provide specific records on the historical process of sediment disaster between mountain and low land. However we did not understand the details of this process because of insufficient chronological information of these sediments. Therefore we try to regognize the relationship between historical process of debris production and developments in mountainous region using intensive AMS carbon dating on sediments collected around Kyoto basin.

2. MOUNTAIN DEVELOPMENTS AND LANDSLIDES

2.1 Sampling localities

Fig.1 shows distribution of sampling localities of landslide deposits, fan, and river sediments for dating around Kyoto basin. Dating samples of slope deposits were collected from sites A, B, and C in **Fig. 1** in mountain regions. Historical river flood deposits found in archaeological sites were collected form sites D and E, and fan deposits were found in archaeological site of localities F and G in **Fig.1**. Samples collected from sites H, I, and J are sediments of raised-bed rivers, that are historical Tenjo-gawa in southern Kyoto district.

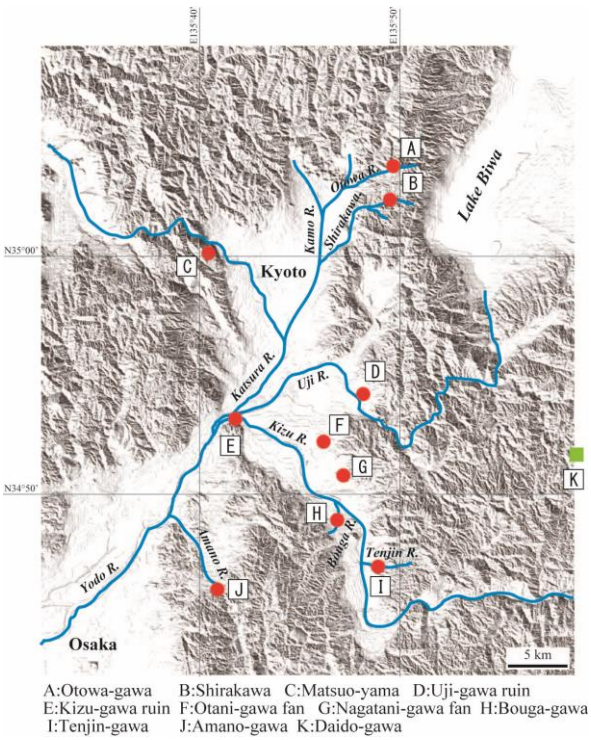

Fig.1 Distribution of sampling sites for dating around Kyoto basin

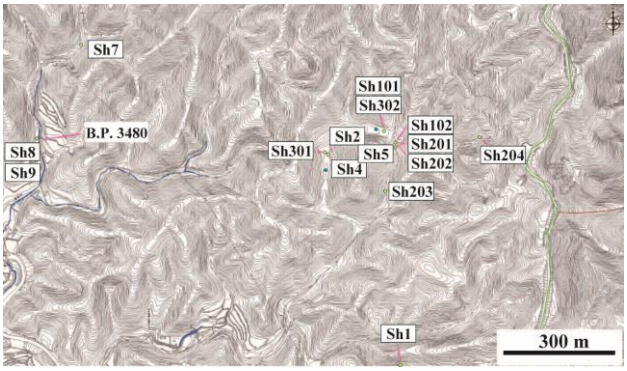

Fig.2 Detailed distribution map of sampling localities for dating around Site B in the upper river basin of the Shira-kawa

Fig.2 shows distribution of sampling localities around Site B in **Fig.1**.

2.2 Archaeological sites in the Higashi-yama

The eastern mountains of Kyoto basin are called "Higashi-yama". These mountains consist of Triassic to Jurassic sedimentary rocks intruded by Cretaceous granite [*Kimura et al.*, 1998]. This low-mountain area has been traditionally where farmland meets the forest, and important trail between Kyoto basin and the Lake Biwa region. The sediments deposited by the river passing through Granite area consists well sorted sands of light color, so the river debouching form this area called "Shira-kawa" that means the "white river". The light colored sands collected form the Shira-kawa has been used in traditional Japanese gardens in Kyoto.

Fig.3 Cross section of artificial pit that is filled by burned soil and charcoal aggregation (Sh2 and Sh4 in **Fig.2**)

An archaeological site was discovered in the upper river basin of the Shira-kawa (Sh2 and 4 in **Fig.2**). As shown in **Fig.3**, we perceived a square shaped pit, in depth and width about 1.2 m. The inside of the pit was filled by burned soil with abundant charcoals. The results of dating on this burned soil and charcoals, cal. AD 677-782 and cal. AD 762-873, indicate that the developments in this region started 7th to 9th century. In ancient ages, logging forest was difficult by common people because of religious taboo. Development of mountain area was progressed by large temple and shrine. The age of the burned soil in this archaeological site indicate just before age that is Enryakuji temple, the largest temple in Kyoto, was founded in 8th to 9th century.

2.3 Buried black Soils

In the upper river basin of the Shira-kawa, humid black soil layers were buried by landslide deposits in several horizons (ages). Valleys with flat valley floor that were filled by the repeated landslides are shown in **Fig.2**, i.e. the valley from Sh2 to Sh203. In this valley, the buried soil layer about 20 cm in thickness covers directory weathered granite (saprolite) as shown in **Fig. 4**. This buried black soil layer is confirmed as lowest horizon in this area, and dated from cal. AD 753±22 (774-891) at base (Sh202 in **Fig. 2**) to cal. AD 956±23 (990-1150) at top of the soil (Sh201 in **Fig. 2**).

Fig.4 Outcrop in a valley by gully erosion (Sh5 in **Fig.2**). The black soil layer at the middle part is covered by landslide deposits

It means that accumulation of humid soil started at approximately the same time with the beginning of development as shown in archaeological site of Sh2 and Sh4 in **Fig.2** and **Fig.3**, and it continued about 200 years until 10th-12th century. After that, this area covered by yellowish medium sands indicating slope instability around mountain area. Considering thickness of the soil layer and its dark color, the organized mountain-burning process was planned and conducted extensively in this area.

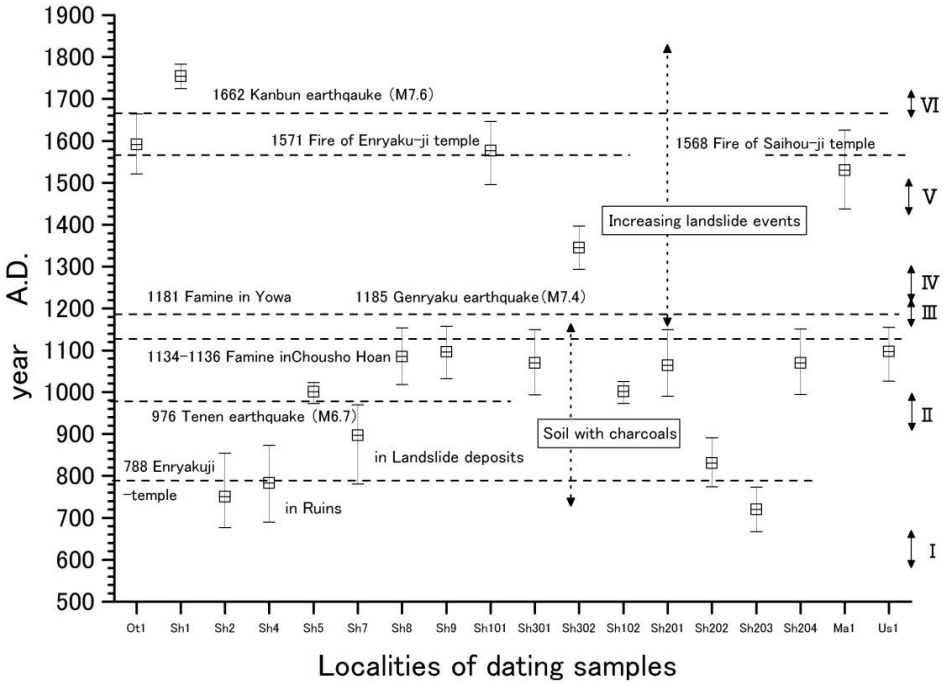

Fig.5 Corpus of dating results of landslide deposits, valley filling deposits, and buried soils in mountain region around Kyoto basin (A, B, and C in **Fig.1**). Ot1 sample was collected in A, Ma1 in B. Others were collected in B as shown in **Fig. 2.** The ages of buried soils directly covered by landslide deposits (e.g. Sh8) will indicate the ages of just before landslide events. The ages of soils covering landslide deposits, and valley filling deposits (e.g. Sh1) will indicate the ages after the events. Based on these considerations, "I-VI" indicates landslide events detected by results of dating of these sediments.

Table 1 Description of dating samples in **Fig.5**

Loc.	Sites	Sampling materials	Sampling part
Ot1	A	Valley filling deposits (1m thick)	middle
Sh1	B	Flood deposits/Valley filling (50cm thick)	middle
Sh2	B	Charcoals and soils in artificial ditch	lower
Sh4	B	Organic soils outside of the ditch of Sh2	whole
Sh5	B	Buried soils (20 cm thick) covered by landslide deposits (1.5m thick)	middle
Sh7	B	Charcoals and humid soils in landslide deposits /stratified flood deposits (1m thick)	lower
Sh8	B	Buried soils (10 cm thick) covered by landslide deposits (at least 2m thick)	middle
Sh9	B	Buried soils (10 cm thick, 0.5m beneath Sh8) covered by landslide deposits (at least 2m thick)	middle
Sh101	B	Buried soils (10 cm thick) covered by flood deposits (at least 0.7m thick)	upper
Sh302	B	Buried soils (20 cm thick,0.7m beneath Sh101) covered by landslide deposits	upper
Sh301	B	Buried soils (15 cm thick) covered by landslide and flood deposits (at least 2.5m thick)	middle
Sh102	B	Buried soils (15 cm thick) covered by landslide deposits (at least 0.8m thick)	middle
Sh201	B	Buried soils (20 cm thick, 0.6m beneath Sh102) covered by landslide deposits	upper
Sh202	B	Buried soils (20 cm thick, 0.6m beneath Sh102) covered by landslide deposits	lower
Sh203	B	Charcoals and humid soils with artificial disturbance covering slope deposits (2.5m thick)	lower
Sh204	B	Buried soils (15 cm thick) covered by landslide deposits (at least 1.0m thick)	middle
Ma1	C	Landslide deposits with charcoals (at least 2.0m thick)	lower

***Shaded pairs collected in same outcrops but in different horizons**

2.4 Landslide deposits at the 1185 earthquake

Corpus of dating results is shown in **Fig.5** and **Table 1**. **Fig.6** show road cutting slope that is Sh8 and Sh9 in **Fig.2**. Here, landslide mass slid down from the steep slope of left hand side, and covered on the humid soil layer at the top of weathered granite. Based on the results of dating on the buried top soil, this landslide event occurred just after cal. AD 1020±23 (1032-1158). As shown in **Fig. 5**, landslide events that would occur in 12th century were widely discovered in the upper river basin of the Shira-kawa (i.e. Sh204).

Fig.6 Outcrop of landslide deposits (Sh8 and Sh9 in **Fig.2**).

In the eastern mountain of Kyoto, the Higashi-yama district, the Genryaku earthquake (M7.4) in 1185 should be a noteworthy event as its serious damages between Kyoto basin and Lake Biwa district. This earthquake is a well-known as a practical and vivid description of the disaster by Kamo-no-choumei in his great essay "An Account of My Hut". After the 1185 earthquake, frequency of landslide was increased as shown in **Fig. 5**.

2.5 Forest destruction shown in the events

As shown in **Fig. 5**, four landslide events were found from the 1185 event to the end of 17th century, while only two landslides events were detected before 12th century during 600 years from 7th century. Although the series of developments from 7th century destroyed forest cover in mountainous slopes around Kyoto basin, the serious damages in mountainous slopes by the 1185 earthquake was an accelerating trigger of deforestation and landslides in this region.

Based on old paintings on scenery of Kyoto, bare mountains was common landscape of eastern mountains, "the Higashi-yama", at least in 18th century. The sample Ot1 was collected the upper river basin of the Otowa-gawa that runs beside the Shugakuin detached palace founded in 17th century. Pollen analysis reveals that *Pinus* and *Diploxylon* (i.e. *Pinus densiflora*) are dominant in this sample. It means that destruction of original forest proceeded until 16th century, and pine trees distributed widely in the mountain. Abundant micronized charcoals are also found in the sample Ot1. It suggests large fire event around the upper river basin of the Otowa-gawa. The Enryakuji-temple located near by the site A including Ot1 sampling point was attacked and burned out by troops of Nobunaga in 1571.

As the results of the forest destruction, river sediments increased and caused to make raised-bed rivers in the alluvial fan around the basin after 14th century.

3. THE AGES OF TENJO-GAWA

3.1 What is the Tenjo-gawa

Fig.7 is a famous historical painting, the ukiyoe, in Edo era (19th century). The travelers could go across the Kusatsu River by walking because that the river has very little water flow. The roof of houses was painted behind travelers at almost same level. It means the ground level of village was so lower than the level of the river bed. These rivers of higher river bed (floor) than the ground level of surroundings are called "Tenjo-gawa". It means "the river on the roof" in Japanese.

Fig.7 "Ukiyoe" of rivers of higher river bed in early 19th century. (by Hiroshige Andou)

Fig.8 shows the tunnel of modern age passing just below the river in **Fig.7**. The river runs from right hand side to left above the level of road. Like this scenery between river and villages, the Tenjo-gawa, are common in western part of Japan because that the Tenjo-gawa was formed artificially during historical urban developments. The western part of

Japan, the Kinki district, was the region having highest density both of population and the Tenjo-gawa before the construction of Edo (Tokyo).

Fig.8 Present Kusatsu River and tunnel under the river of **Fig.7**

Two conditions were needed to form the Tenjo-gawa. When the river channel was artificially fixed, and supply of sediments overloaded by forest destruction in upper river basin, the river bed started to be rising, and finally the river bed should be so higher than the roof of houses. Thus Tenjo-gawa is typical artificial landforms which became necessary the environmental changes in the upstream mountain region of rivers such as slope instability by landslides.

3.2 The Tenjo-gawa in southern Kyoto basin

As shown in **Fig. 9**, the Kizu River and its tributaries forms typical raised bed river system in the Minami-Yamashiro district. Landslides in mountainous slope surrounding the basin supplied huge amount of sediments to the river system. As a result of rapid rising river bed including mainstream (the Kizu River), catastrophic floods were recorded in 1590, 1712, and 1802 in this district. In 17th century, the government repeatedly declared to prohibit soil loss from mountains and promoted afforestation programs in the whole upper river basin in this district.

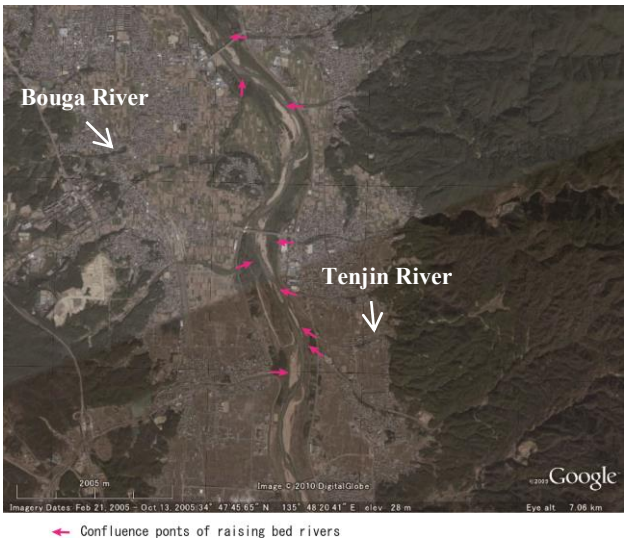

Fig.9 The Kizu River and its tributaries. Red arrows are confluence points of the Tenjo-gawa to the main stream

3.3 The Base of Tenjo-gawa

It was well known that the rising rate of river bed increased in 17th century [*Chiba*, 1973], however, the ages of the base of the Tenjo-gawa, in other word, when river bed start to rise was not clear. **Fig.10** shows that alluvial flood deposits of 10th century are overlaid by the Tenjo-gawa sediments of the Bouga River of 14th century (Site H in **Fig.1**).

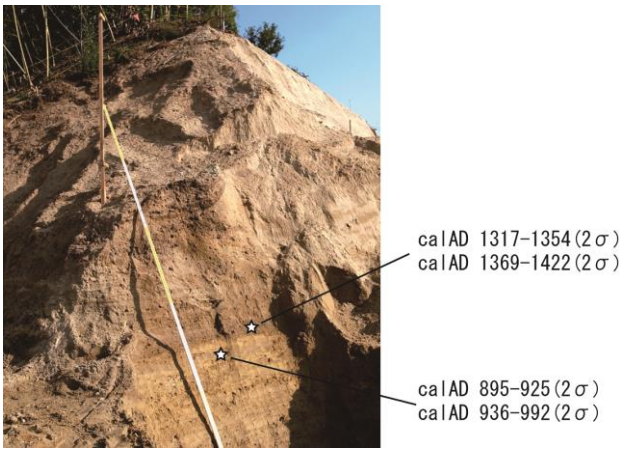

Fig.10 Excavated cross section of Bouga River. The T enjo-gawa sediments (light colored) accumulated on alluvial floods deposits (yellowish colored).

Similar results were known in other rivers. In Site G in **Fig.1**, alluvial fan sediments of the Nagatani River accumulated on flood sediments in 6th to 7th centuries. The age of the top soil of this flood sediment layer is cal. AD 1272±20

(1276-1308). It means that supply of sediments from mountains increased after 13th to 14th centuries. In Site I (Tenjin River), the age of base of the Tenjo-gawa is cal. AD 1380±40 (1300-1430). In Site J (Amano River), the age of base of the Tenjo-gawa is cal. AD 1340±40 (1290-1420). These results revealed that the river bed rising in the southern Kyoto district started from 14th century in accordance with increasing of river load.

3.4 Social factor to make Tenjo-gawa

Archaeological and geological investigations in southern Kyoto region revealed that the rising of river bed started from the 14th century and accelerated the rising rate from the 17th century. The development of upstream mountainous area, deforestation and keeping grass field in long term period, led to increasing landslides and topsoil erosion in the mountainous slope, so that the bare mountains were common scenery around the advanced developed region in Japan during the ages of raised bed rivers from the 14th to the 19th century.

The backgrounds of the beginning of these exhaustive developments in mountainous slope surrounding of urban region are reflected in the social changes going on the 14th century. Social confusion continues to demise of ancient order forced to take the regional social and economic integration and generated the new integrated villages that they interested to increasing food production by cultivation needed to large quantity of grass supplied from surrounding grass (bare) mountains. The classic landscape of raised bed rivers in Japan which started in the mediaeval ages shows the history of interaction between environmental changes and ancient society.

4. DISASTERS IN MODERN TIMES

Deforestation in mountainous slope during WW2 to take woods for fuel was one of major causes of serious flood disaster in 1953. As shown in **Fig.11**, shallow landslides on bare slopes were induced by heavy rainfall. It was considered to be similar scenery in the medieval ages in this district.

In August 2012, the front advanced southward from Japan Sea to western Japan. Kyoto district was ravaged by torrential rain fall for warm humid air influx during 13th to 14th August. Amount of rainfall per hour in southern Kyoto district reached 90 mm, total rainfall from the beginning was over 300 mm. 36 houses were destructed, and over 2600 houses were flooded by over flow of small rivers in the urban areas of Kyoto, Joyo and Uji cities [*Uji City*, 2014].

Fig.11 Photograph of newspaper reported about the 1953 disaster

Especially, washout of the Midajiro river caused severe floods in recent rapid urbanized residential regin in Uji, Kyoto (**Fig.12**). The Midajiro river is a typical Tenjo-gawa with rised river bed higher than few meters form the residential level of grounds. This river has flooded in 1967, and made serious damages to farmland of 7 ha. However, this district was urbanized during 1970's after this flood, and residents were not informed about the flood event of the river. We can recognise the typical relationship between the high risk river and new coming residents around the river here. Thus, Tenjo-gawa has been a high risk river form still in ther modern times.

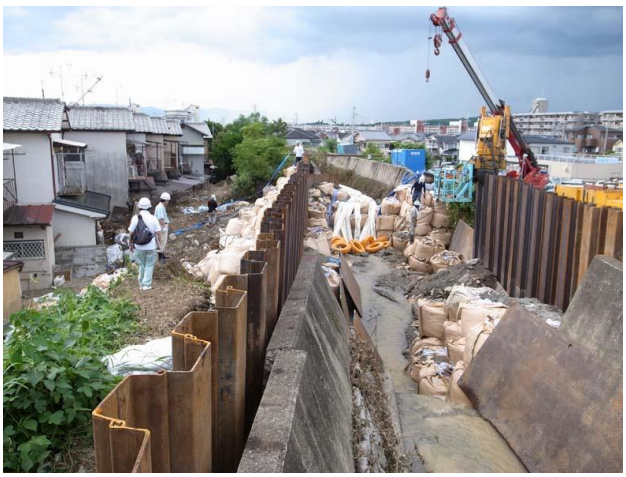

Fig.12 Flood of Midajiro river in 2012

5. CONCLUSIONS

The brief history of sediment discharges in mountain slopes around Kyoto basin was described. In the upper river basin, humid black soil layers

were buried by landslide deposits in several horizons (ages). The Mountain developments started 7th to 9th century, and landslide deposits that would be induced by the 1185 earthquake were widely discovered in the eastern mountains of Kyoto basin. As the results of the forest destruction, rising-river bed started from 14th century in accordance with increasing of river load by massive sliding in mountainous slopes.

Tenjo-gawa, raised-bed river, is formed as the historical results of over discharges, and artificial fixing of river channels after 14th century. The rising rate of river bed increased in 17th century in accordance with the progress of deforestation.

Recent disasters, floods in 1953 and floods in 2012, Tenjo-gawa has been a high risk river form still in ther modern times. Thus, the history of mountainous slopes around Kyoto represents a typical example of the relationship between artificial changes of mountain environment and society. History made every day.

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REFERENCES

Chiba, T. (1973): Culture in bared mountain, Gakuseisha, Tokyo, 233 p. (in Japanese)

Kimura, K., Yoshioka, T., Imoto, N., Tanaka, S., Musashino, M. and Takahashi, Y. (1998): Geology of the Kyoto-Tohokubu District. With Geological Sheet Map at 1:50,000, Geol. Surv. Japan, 89 p. (in Japanese with English abstract 5p.).

Uji City (2014): The flood disaster in southern Kyoto district, Aug. 13-14,2012, Uji City office, 78 p. (in Japanese).