Sediment Dynamics of a High Gradient Stream in the Oi River Basin of Japan[1]

Hideji Maita[2]

Abstract: This paper discusses the effects of the valley width for discontinuities of sediment transport in natural stream channels.

The results may be summarized as follows: 1)In torrential rivers, deposition or erosion depend mostly on the sediment supply, not on the magnitude of the flow discharge. 2)Wide valley floors of streams are depositional spaces where the excess sediment from the upper stream area is temporarily deposited. In the erosional process that follows, the sediment runs off down stream in a way that can be explained by an exponential process.

Numerous researches in the area of sediment control work in mountainous areas have been carried out. However, our understanding of the effect of discontinuities in the history of sediment transport is still insufficient. In order to gain a fuller understanding, it is first necessary to examine the morphology of streams in their natural state without sediment control structures. With this in mind we selected the Higashigochi basin of a small tributary of the Oi river as our study area. During 1982 the basin was subjected to a period of intense rainfall of more than 900mm. This released abundant sediment, about 150,000m^3 in the observed reach. As a result the morphology of the stream changed. Taking this opportunity, we were able to study and come to a greater understanding of the dynamics of sediment transport. This paper analyzes a series of changes in the morphology of a high gradient gravel-bed stream that resulted from nine floods.

STUDY AREA

Topography and Geology

The Higashigochi river basin, with a drainage area of about 28 km^2, is a small tributary of the Oi river system emptying into the Pacific side of Honshu Island. A 2406 meter peak, located at the north corner of the basin is the highest point,

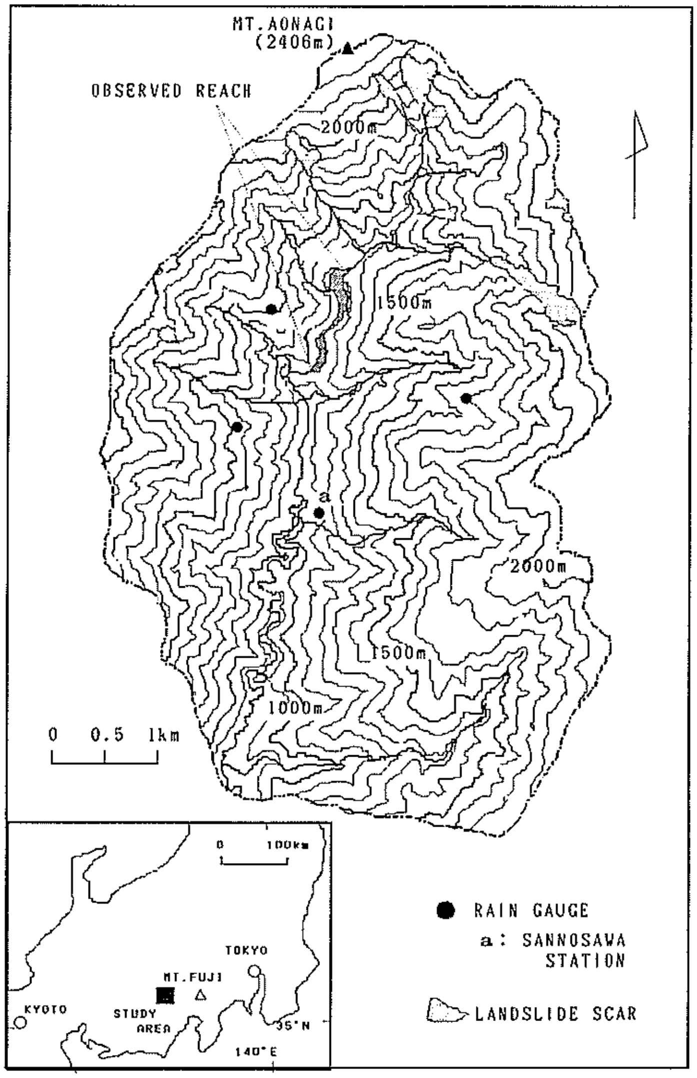

Figure 1--The study area.

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while the elevation of the confluence with the main river, about 770 meters, is the lowest point in the study area. This gives a relief of about 1640 meters over a linear distance of 7.5 km. Reflecting this high relief, slopes are in general very steep with an average of about 38° (Fig. 1).

The bedrock is mainly composed of shale and sandstone from the Cretaceous period. The rock is generally fractured because the basin is situated in the high, uplifting zone of the Japanese Southern Alps.

As a result of these topographical and geological conditions, the ratio of landslide scars to the area of the basin is 2.9 percent and this figure reaches 7.6 percent in the upper basin.

Stream Channel Shape

The longitudinal profile of the Higashigochi river is shown in Figure 2. This figure shows that the stream is steep and the profile can be divided into three parts in terms of its gradient. The lower part, with a gradient of about 1/30, the middle part with a gradient of about 1/20 and the upper section the gradient of which is more than 1/10. The observed reach was located in the upper section. As to the planar shape of the stream, the meander and the variation of channel width is remarkable.

Climate

According to the climatic records at the Sannosawa station (Fig. 1), the average rainfall between the months of April and November from 1970 to 1981 was about 2,500 mm. Consequently, the mean annual precipitation may reach about 3,000 mm, but it is very variable.

The mean annual temperature is 9.8°C, with the highest temperature occurring in August and the lowest in January. Temperature records of daily maxima and minima suggest that freeze/thaw processes are normally active from the latter half of November to the first half of April (Fig. 3).

Vegetation

Vegetation is predominantly deciduous below the 1,500-1,800 meter zone and conifers dominate at higher elevations. Below the 1,500-1,800 meter zone, Japanese cedar (Chryptomeria japonica D. Don), Japanese cypress (Chamaecyparis obutusa S. et Z.) and Japanese larch (Larix leptolepis Gordon) have been planted.

Observed reach

The observed reach extended about 1 km, where the stream, coming through the V-shaped narrow valley first meets a wide floor of about 40 to 130 meters. Then the stream again enters a narrow valley section at the end of the observed reach (Fig. 4). The gradient of the stream bed in the observed reach ranges from 1/8 to 1/15.

Because no modification of the channel of the reach by sediment control structures had been undertaken, we were able to examine the morphology of the channel in its natural state.

METHOD

In this research we regarded the actual stream channel itself as the place for the field experiments. As a result, various measurements

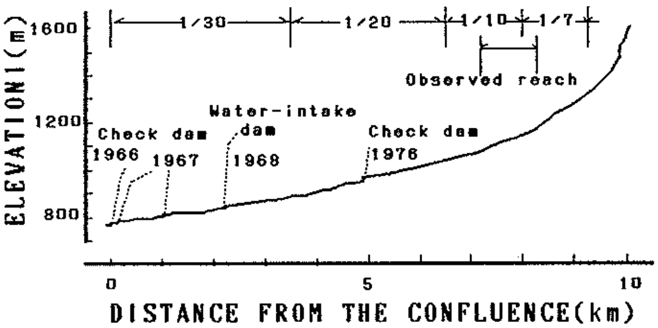

Figure 2--The longitudinal profile of the Higashigochi river.

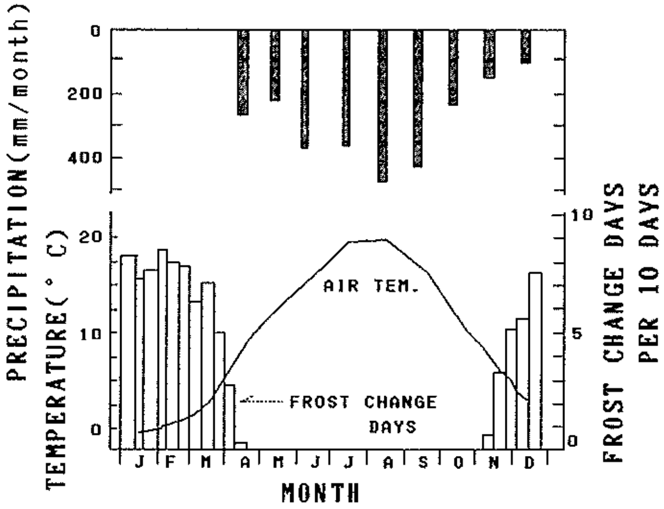

Figure 3--The climate of the study area.

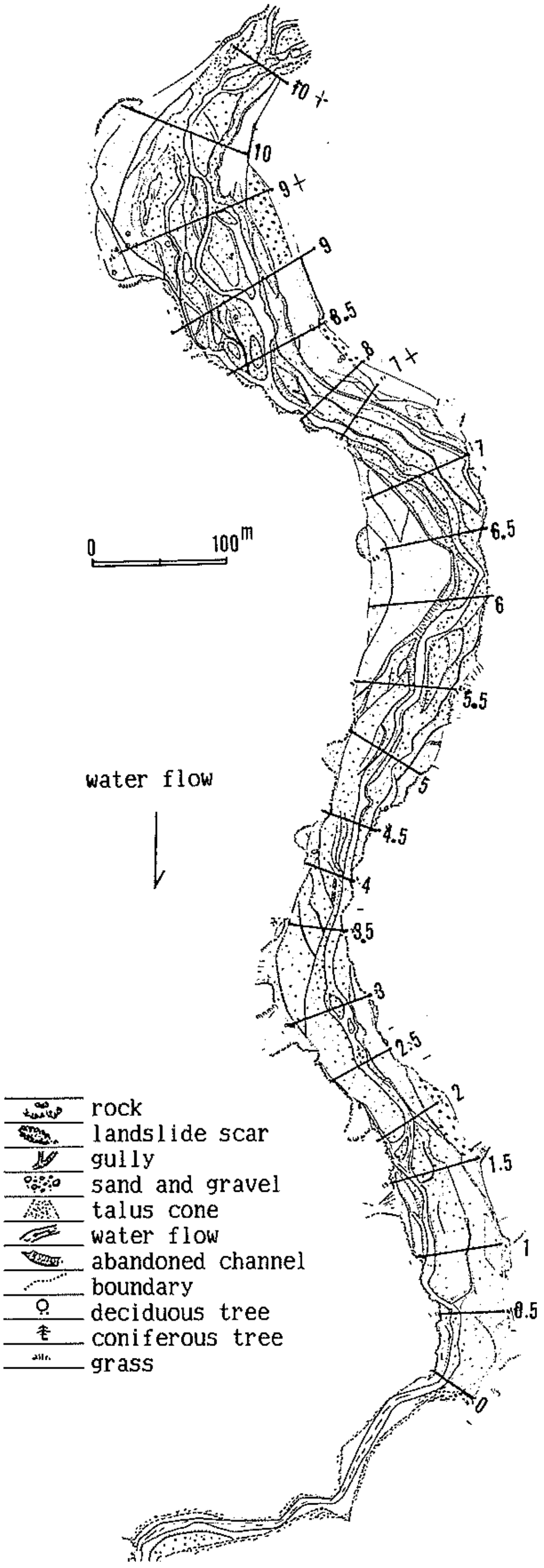

Figure 4--The observed reach after the 8209 flood and the location of the cross sections

were carried out in the study area. In order to record a sequence of changes in the channel morphology of the observed reach, whenever a river bed fluctuation occurred over the period 1979 to 1985, the leveling of 22 cross sections of the observed reach at intervals of about 50 meters was carried out(Fig. 4). Plane surveying was mostly carried out at the same time. The vertical and horizontal distribution of the grain size of the stream bed was investigated after the river bed fluctuations in September 1980 and September 1982. In order to measure the volume of the deposits on the bedrock of the observed reach, seismic prospecting was carried out after the river bed fluctuation in August 1981.

Rainfall was measured by several rain gauges placed around the basin (Fig. 1) and the flood discharge was calculated by a storage function run-off model below (Maita et al. 1984).

$$Sl=KQ^{P},\quad P=0.6,\quad K=8.6A^{0.14},\quad Tl=2.5A^{0.14}re^{-0.4}$$

Here, Sl is the hypothetical storage depth of rainwater over a basin considering the time lag Tl between rainfall excess re and flood discharge Q, and A is the area of a basin.

SHAPE CHANGES OF THE STREAM CHANNEL

Threshold Rainfall

Nine river bed fluctuations were confirmed in the observed reach from 1979 to 1985. Table 1 shows the largest values recorded for the continuous rainfall and hourly rainfall measured at several precipitation stations. It also shows the maximum calculated peak discharge at the end of the observed reach for each of the rainfall events and when a river bed fluctuation occurred.

Table 1--The magnitude of rainfall and discharge for each flood.

flood name	continuous rainfall (mm)	max. hourly rainfall (mm/h)	peak discharge (m³/s)
7910	260.0	31.5	32.8
8009	229.5	37.0	14.8
8108	289.0	29.0	25.9
8208	933.0	69.5	96.9
8209	564.0	34.5	54.5
8305	296.0	29.0	26.4
8308	851.0	40.5	74.4
8309	330.0	33.0	34.7
8506	411.5	38.0	54.5

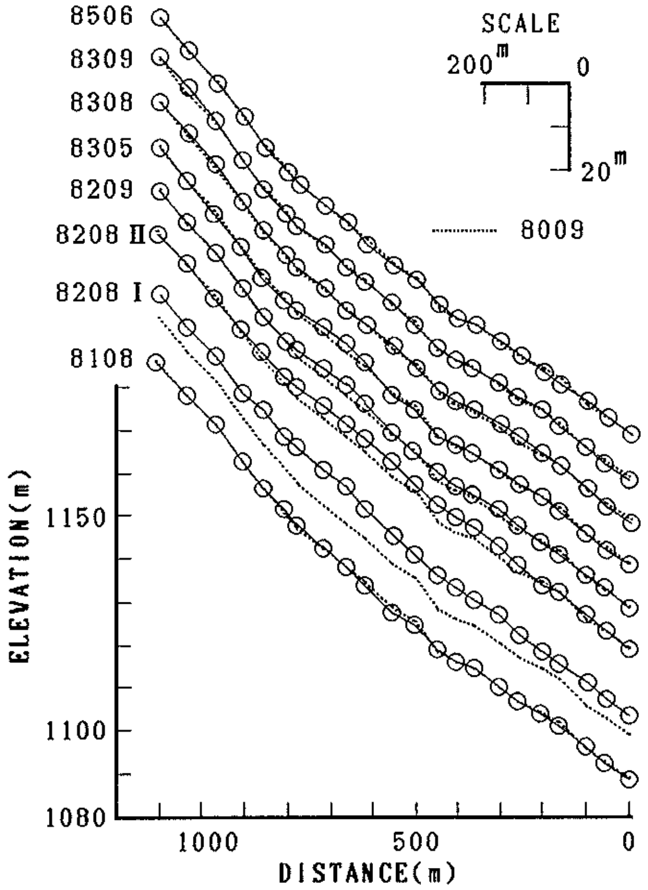

Figure 5--The changes in the lowest longitudinal stream bed profile in the observed reach.

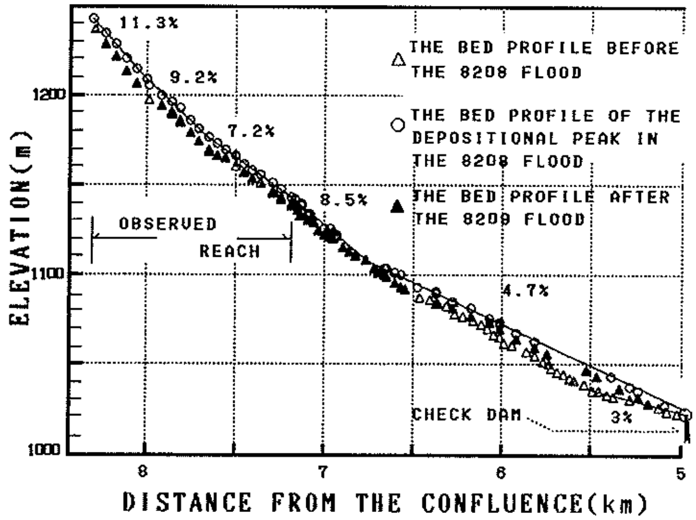

Figure 6--The changes in the longitudinal bed profile of the 3.3 km of stream between a check dam and the observed reach before and after the 8208 flood.

From the figures in Table 1, it seems that a continuous rainfall level of about 200 mm or a maximum hourly rainfall of about 30 mm is the threshold rainfall for a river bed fluctuation in the Higashigochi river basin. Such figures occurred about once every 1.3 to 1.5 years.

Changes of Channel Shape

Figure 5 shows the lowest longitudinal stream bed profile in the observed reach. The profile, formed by the 8208 flood (the flood in August 1982), is divided into two stages. One, shown as 8208I in Figure 5, is the bed profile of the depositional peak. The other, shown as 8208Ⅱ ,is the profile after the recession flow of the 8208 flood partially eroded the buried bed. Because of the clarity of the profile changes, each profile is compared to the profile after the 8009 flood (the flood in September 1980). Other floods were named in this manner.

Figure 6 shows the longitudinal stream bed profile of the approximately 3.3 km of stream between a check dam and the observed reach before and after the 8208 flood. As shown in Figure 4 and 5, the large deposition of the 8208 flood was caused by a continuous rainfall of 933 mm and an hourly rainfall of 69.5 mm (a recurrence interval of more than 30 years), which Typhoon no. 10 produced between August 1 and 3, 1982 (Fig. 7). This event raised the stream bed from 3 meters to 8 meters. Subsequently, rapid erosion ensured that the bed profile regained its former shape very rapidly. As shown in Figure 6, the check dam had no influence on the deposition in the observed reach caused by the 8208 flood. Besides it was noted that there was almost no drift wood debris in the observed reach in spite of such a large flood.

Figure 8 shows the changes in the cross sectional channel profiles in the observed reach. The black shaded parts of the diagram represent deposition. Erosion is shown by the unshaded area between the lines describing the cross section. The large deposition almost flattened the bed in the observed reach. After the flood, incision of the stream bed meant that these profiles nearly recovered their former shape. The recovery was more rapid in the narrow part of the valley than in the wide part.

Figure 9 shows the changes in the planar shape of the stream bed in the observed reach. The large deposition not only caused large changes in the planar shape but also the location of the thalwegs. The erosional process of the stream bed meant that the shape of the bed returned to its former shape and the thalwegs returned to their former positions.

Thus, large depositions have a marked effect on the stream bed but these changes are not permanent and the erosional process causes the channel shape to revert to its former one.

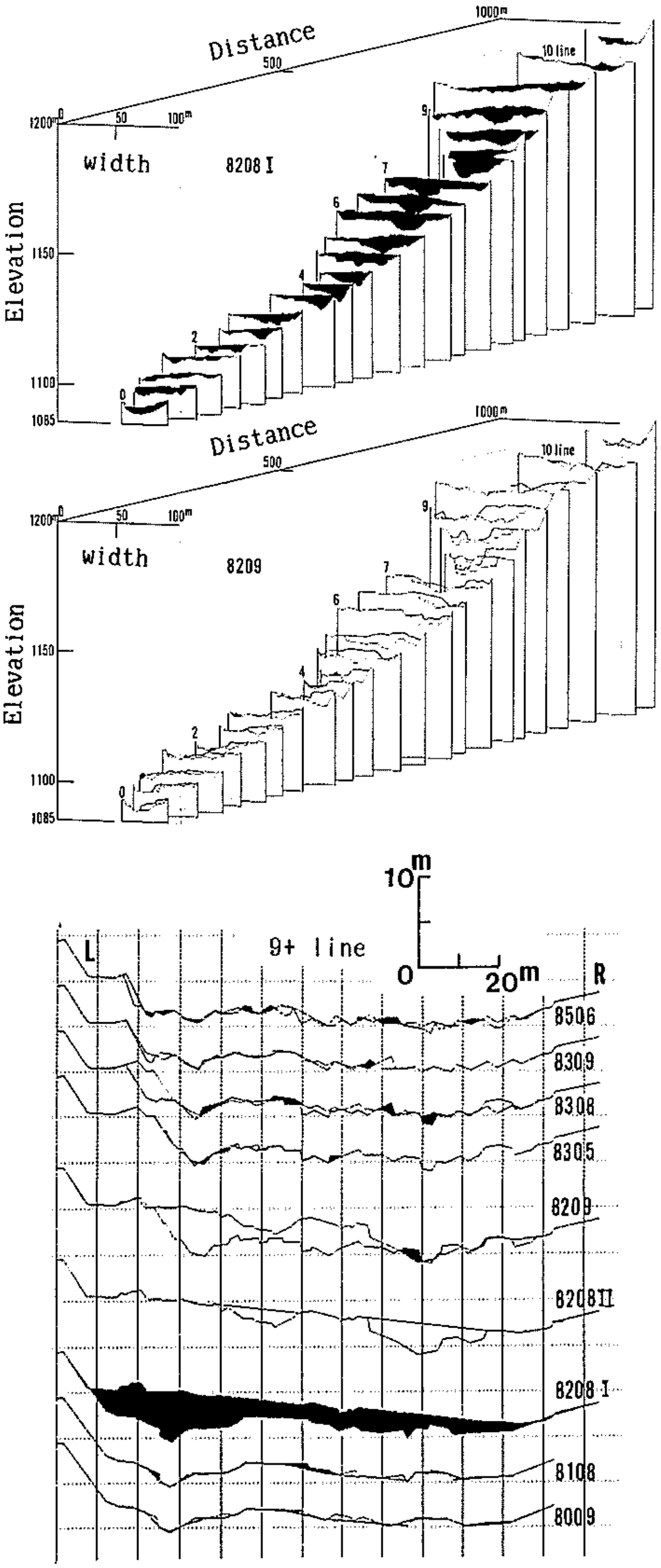

Figure 8--Some examples of the changes in the cross sectional profiles in the observed reach.

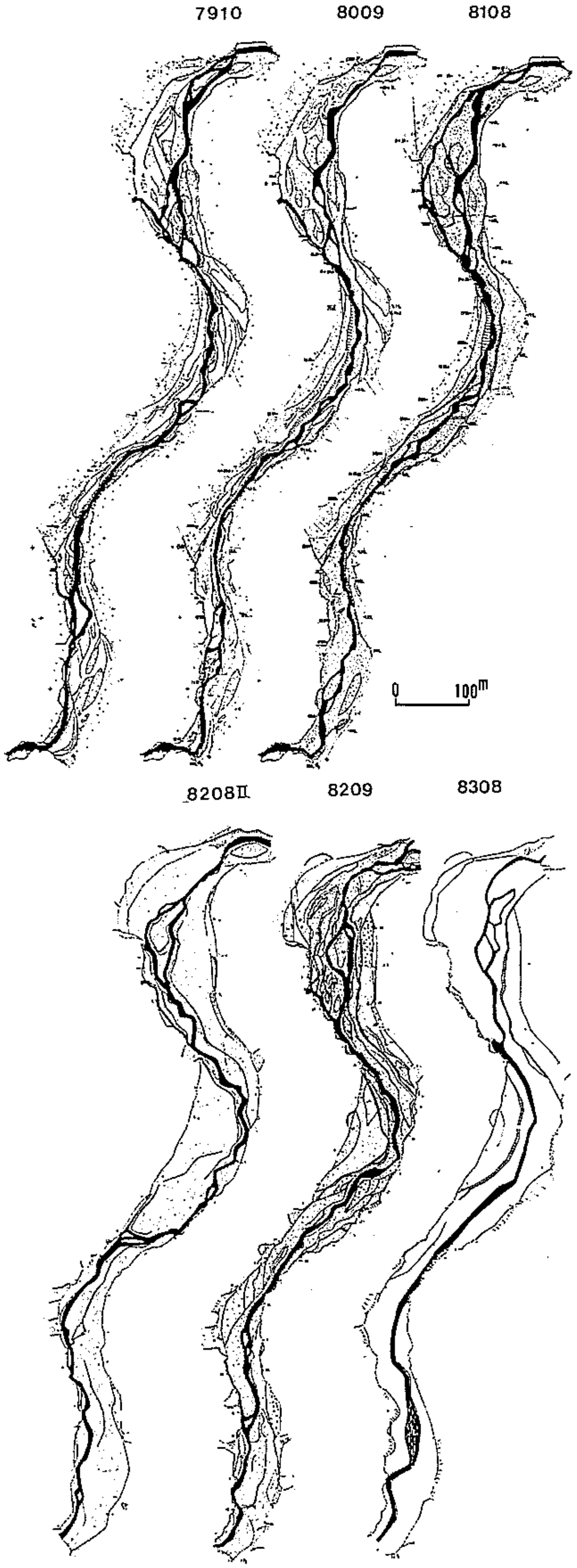

Figure 9--The changes in the planar shape of the stream bed in the observed reach. The black shaded parts of the diagrams represent the low water flows.

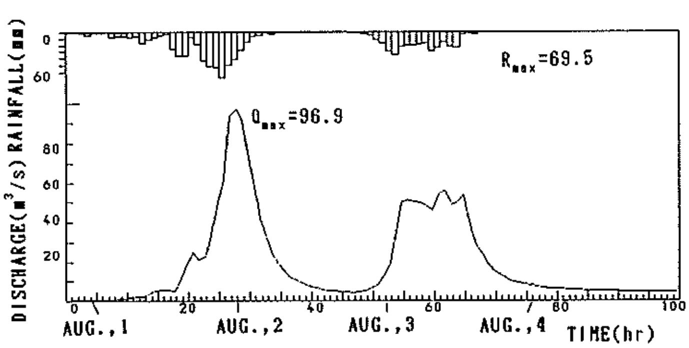

Figure 7--The observed hyetograph in the study area and the calculated hydrograph at the end of the observed reach in the 8208 flood.

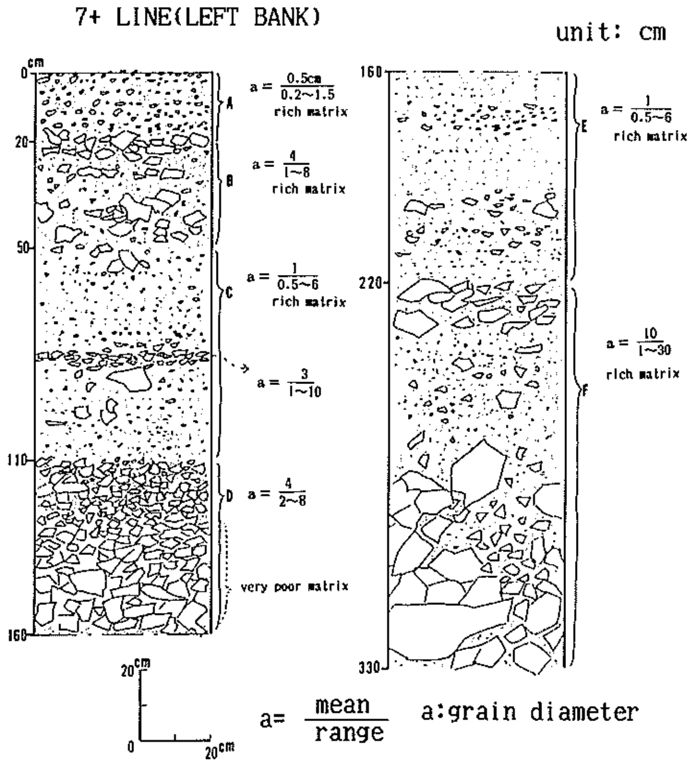

Figure 10--The structure of the deposit formed by the 8208 flood at 7+ line.

Structure of Deposits Formed by the 8208 Flood

Figure 10 shows the structure of the deposit formed by the 8208 flood at 7+ line shown in Figure 4. Although the deposition was formed by one flood there are several parts with laminar structures. As Iseya et al.(1990) described, it is thought that this structure was formed when a shallow and high velocity flow transported heterogeneous sediment, raising the bed at a high rate. Because of the large deposition, the grain size of the stream bed became smaller. On the other hand, erosion caused the grain size to become larger as the smaller sediment was removed from the stream bed.

QUANTITATIVE CHANGES OF RIVER BED FLUCTUATION

Changes of the Volume of Deposit

Figure 11 shows the changes of the volume of the deposits on the bedrock in the observed reach. This was found by using the volume of the river bed fluctuation and cross sectional bedrock profiles measured by seismic prospecting in October 1981. The volume of the river bed fluctuation can be obtained by the following steps. First, as shown in Figure 12, the volume of the river bed fluctuation of the segment is calculated by the equation below.

$$V=((E11+E12+\ldots)+(D11+D12+\ldots)+(E21+E22+\ldots)+(D21+D22+\ldots))L/2$$

Here, V is the volume of the river bed fluctuation of the segment, L is the distance between two adjacent cross sections, E11,E12,..etc, and D11,D12,..etc, are the areas surrounded by the two cross sectional profiles before and after a flood at the A1 cross section. E11,E12,..etc, represents the area eroded and is negative, D11,D12,..etc, represents the deposited area and is positive. E21,E22,..etc, and D21,D22,..etc, represent the same variables measured at the A2 cross section. The volume of the river bed fluctuation of the observed reach can be obtained by taking the sum of the volumes of each segment. Thus, the overall volume may be positive or negative in sign.

As can be seen from Figure 11, the volume of the deposits was decreased gradually to about 120,000 m^3 by the process of erosion between 1980 and 1981. But the 8208 flood in 1982 deposited sediment of more than 150,000 m^3 and the total volume of sediment on the bedrock increased to 270,000 m^3. After that, it decreased rapidly to about 130,000 m^3. As the changes between 1982 and 1985 show, the erosional process continued in the observed reach after the 8208 flood despite the fact that there were some large rainfalls in this period. This means that there was little sediment in the upper basin of the observed reach because unstable debris had been mostly swept from the stream beds and the slopes of the upper basin by the heavy rainfall associated with the 8208 flood.

ANALYSIS AND DISCUSSION

Figure 13 shows the relation between the absolute value of the river bed fluctuation in the observed reach and the peak flow discharge. This peak flow discharge was adopted as an index of the magnitude of discharge. As the graph shows, the volume of the river bed fluctuation is not always large in comparison with the increase of flow discharge and it seems probable that the ordering of the floods is an important factor. To attempt to unravel this complicated

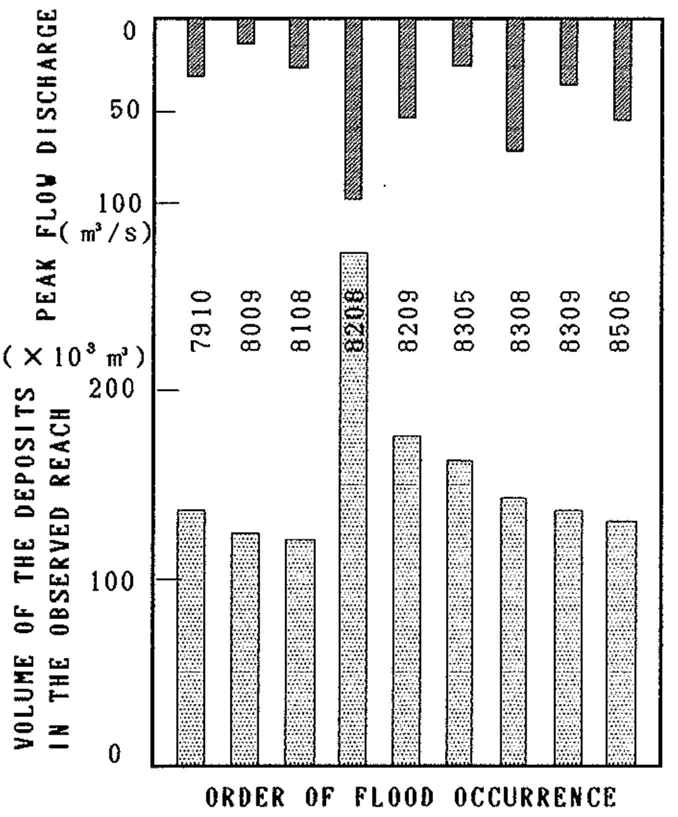

Figure 11--The changes of the volume of the deposits on the bedrock in the observed reach.

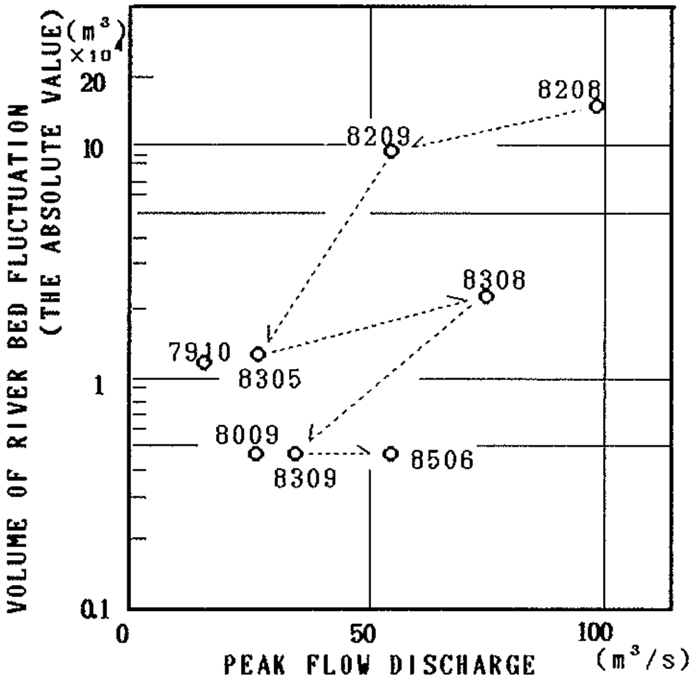

Figure 13--The relation between the absolute value of the river bed fluctuation in the observed reach and the peak flow discharge.

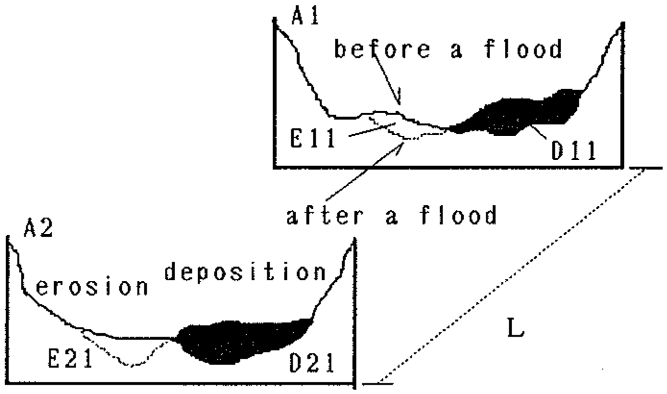

Figure 12--The schematic diagram to obtain the volume of the river bed fluctuation.

relationship, the idea of the specific volume of the river bed fluctuation was introduced. The specific volume was obtained by dividing the volume of the river bed fluctuation by the peak discharge adopted as an index of the flood discharge.

Figure 14 shows the specific volume of the river bed fluctuation in the observed reach arranged in the order in which the floods occurred. As this graph shows, a regularity is apparent. The specific volume decreases exponentially in the erosional process following the large deposition of the 8208 flood. As shown in Figure 15, this regularity of the erosional process in the observed reach can be expressed by the following exponential equation.

$$S(t) = -\alpha \exp(-\beta t) \qquad \alpha > 0,\ \beta > 0$$

Here S is the specific volume of the river bed fluctuation per unit distance, t is the occurrent order expressed as 1,2,.. etc, during the erosional process. In the case of the series of events in the observed reach α is 3.3 and β is 0.8.

Valley Floor Width and River Bed Fluctuation

Figure 16 shows the different ways in which the specific volume decreases during the erosional process, depending on the width of the valley . This difference can be expressed in terms of the parameters of the exponential equation above. In the wider parts of the valley in the observed reach (average width 72 meters), α is 3.3 and β is 0.8. In the narrower parts in the observed reach (average width 50 meters), α is 5.0 and β is 1.4. Thus, as the valley becomes wider β decreases. It is believed that β can be used as an index to shown how the valley floor width influences the volume of the river bed fluctuation.

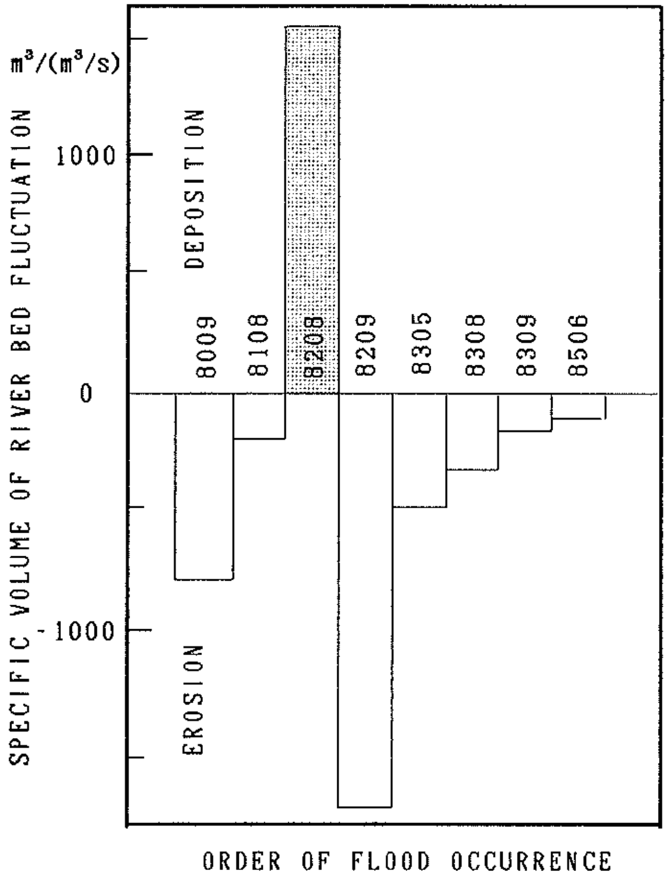

Figure 14--The specific volume of the river bed fluctuation in the observed reach arranged in the order in which the floods occurred.

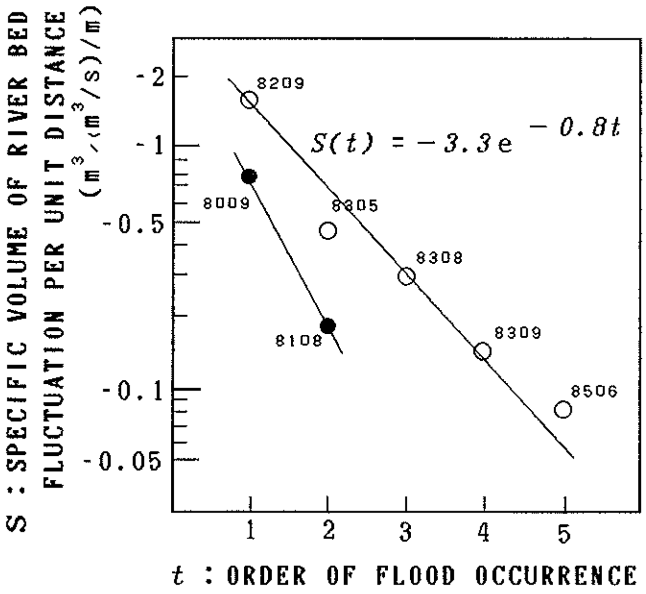

Figure 15--The exponential relation between the specific volume in the observed reach and the order of the flood occurrence during the erosional process.

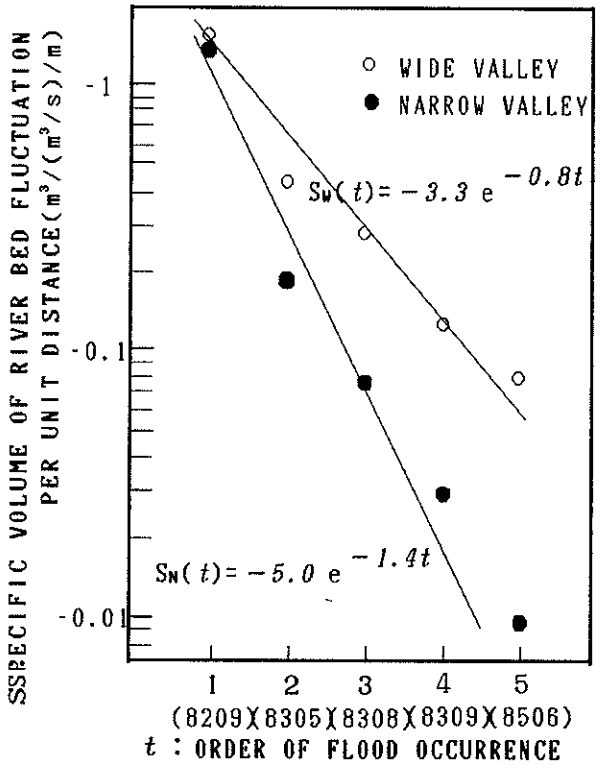

Figure 16--The different ways in which the specific volume decreases during the erosional process, depending on the width of the valley.

CONCLUSION

The magnitudes of the flow discharge and the river bed fluctuation did not exhibit a one to one correspondence. We were able to find a regularity in the quantitative changes by arranging the river bed fluctuations in the order of the occurrence of the floods. This implies that the history of sediment transport plays an important role. That is to say, when little unstable debris remains in the upper reaches and slopes of the basin, a trend towards the erosion of the river bed continues even if a larger flood occurs. Thus, in torrential streams in headwater regions, deposition or erosion depend mostly on the sediment supply, not on the magnitude of the flow discharge.

The valley floor width is closely related to the dynamics of sediment transport. In the erosional process, the specific volume of the river bed fluctuation decreases rapidly in narrow valley floors, but only decreases slowly in wide floors. On the other hand, in the depositional process, the wider the valley floors are, the more sediment from the upper reach they can retain. Therefore, the wide valley floors of a stream are depositional spaces where the excess sediment from the upper stream area is temporarily deposited. In the erosional process that follows, sediment runs off down stream in a way that can be explained by an exponential process. In other words, wide valley floors represent spaces that retard sediment transport.

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Snow-Cover Condition in Japan and Damage of the Sugi (*Cryptomeria Japonica* D. Don)[1]

Hideaki Taira[2]

Abstract: Japan is one of the most snowiest regions in the world. Particularly the mountainous area of Honshu (the main island), along the Japan Sea has heavy snow in winter. In some places, snow piles up more than four meters and the ground is coverd with snow about one hundred and forty days a year. The sugi tree is widely planted in snowy regions, and snow-pressure damages, such as basal bending, occure in juvenile stands, and after that crown snow-damage, such as stem breakage, happen in younger stands about 10～30 years-old. Basal bending is formed by the difference in recovery rate between the upper part and the lower part of the stem during growing season. Root damage occurs when the stem is prostrated, and the compression wood is formed in the process of the reelection of the fallen stem. Crown snow-damage happens during the condition of comparative warm air temparatures ranged from three degrees below zero to three degrees above zero. The strength of the stem against crown snow-damage depends on the diameter of the tree, tree taper, constunt μ for the root, and the modulus of elasticity. Pulling up the fallen stem, and controlling the tree density are important in preventing these snow damage.

Introduction: It is said that Japan is the snowiest region in the world. The Japan sea area of Honshu has a lot of snow every year. Though the snow protects plants from severe coldness in winter and is an important source of water, it also is the cause of damages such as basal bending and stem breakage. The sugi is an important spicese for reforestation in Japan and the total area of sugi reforestation exceeds 4.15 million ha., making it about 48 percent of the total artifical forest in Japan. The sugi is widely planted in snowy regions, but suffer many kinds of snow damages every year. Basal bending, stem breakage, stem bending and uprooting are recognized problems in the sugi reforestation, and these snow damages are classified in to two types; one is snow-pressure damage which occurs in younger aged trees untill they are about ten-years-old and the other is crown snow-damages which occur in trees over ten years old. But the types of snow damage depends on the snow-cover condition. The author will talk about the relationship between the snow-cover condition in Japan and the type of snow damage, the mechanism of main snow damage and its control.

THE SNOW COVER CONDITION IN JAPAN AND SNOW DAMAGE

The mean annual maximun snow depth of Japan is shown in Fig-1. A high percentage of snowy areas are distributed along the Japan Sea, and in some areas, snow depth exceedes four meters. In contrast there is only about 10～50 centimeters in the area along the Pacific Ocean, and the mountainous area of Shikoku and Kyushu island, and most areas of Shikoku, Kyushu and the southern part of the main island have less than 10 centimeters.

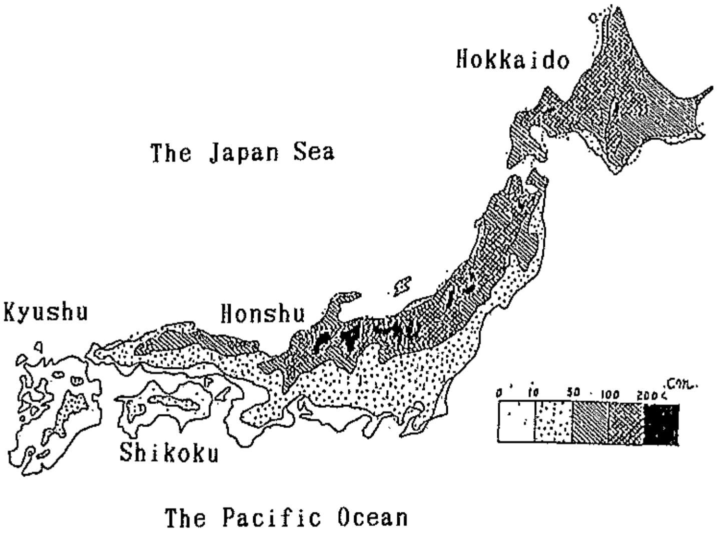

Fig.－1. Distribution map of annual maxmun snow depth