THE FORMATION AND OUTBURST FLOODING OF THE LARGEST LANDSLIDE DAM ON THE YATSUGATAKE VOLCANO IN JAPAN

Kimio Inoue[1], Toshio Mori[1] and Takahisa Mizuyama[2]

INTRODUCTION

The authors researched the formation and outburst flooding of the landslide dam in histrical age and reported in Interpraevent 9th, 10th and 11th. And we published two books related with the formation and outburst flood of landslide dams in Japan (Tabata et al., 2002 and Mizuyama et al., 2011). The Yatsugatake Volcano, in the Nagano Prefecture, Central Japan, had been violently shaken by an earthquake on August 22, 887 (September 30, Ninna era, Japanese calender), which caused a large-scale collapse. The massive collapse of debris flowed down along the Otsuki River in the form of a large-scale debris avalanche and blocked the Chikuma River channel, upstream of the Shinano River, forming a gigantic landslide dam in the upper reaches. During the ruins of the 9th Century in the area from Sakudaira to the Nagano Basins along the Chikuma River, Ninnna flood sand covered ancient rice paddies and houses.

RECORDS IN HISTORICAL MATERIALS

Records of this disaster are mentioned in many historical materials. To summarize these historical materials, records from the 887 disasters caused by the earthquake and from the 888 flood disasters. In other words, these materials can be interpreted to show that, on August 22, 887, in addition to the disaster caused by the violent earthquake (great ocean-trench earthquake) that hit most of the main Japanese islands, a massive collapse occurred in the Yatsugatake Volcano, which blocked the Chikuma River and resulted in the formation of a huge landslide dam. Subsequently on June 20, 888, or 303 days later, the landslide dam collapsed, causing a heavy flood which washed away both houses and castles in six districts of the Nagano Prefecture and caused numerous human fatalities.

SCALE OF LANDSLIDE DAMS AND THE EXTENT OF FAILURE FLOODS

Kawachi (1983) presumed that the sector collapse of the eastern flank of the Yatsugatake Volcano resulted in the formation of a horseshoe-shaped caldera of 2.25 km in north-south length, 3.5 km in east-west length and 350 m in maximum relative height and estimated that the sediment from the Otsuki River Debris Avalanche amounted to 350 million m^3. However, the volume of the horseshoe-shaped caldera is estimated to be over one billion m^3 and the authors have decided that this landform is a result of repeated debris avalanches as large as that which occurred 887, along with volcanic activities such as phreatic explosions.

Based on the interpretation of a 1/25000 topographic map and aerial photos, the altitude of the river bed at the point of the river channel blockade is 1000 m above sea level, debris avalanche sediment exist along Otsuki River and there are many mudflow hill landforms and lakes including Lake Matsubara on the debris avalanche. Based on the conditions of extrusive landforms such as mudflow hills near Lake Matsubara, the inundation height is estimated to be 130 m. Tracing the contour at this altitude results in the inundation area and volume of approximately 13.5 km^2 and 580 million m^3 respectively, which means that one of the largest landslide dams in Japan had been formed at this site.

This landslide dam had an extremely large inundation volume and did not become full immediately. The landslide dam formed along the Chikuma River and gradually collected water for about ten

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months. Eventually, the dam had become filled 303 days later during torrential rainfall in the rainy season. It then failed suddenly, causing a secondary debris avalanche. The water collected behind the landslide dam turned into massive flood waves that flowed down the Chikuma River over 100 km to the lower reaches which resulted in flooding and the deposit of the Ninna Flood sand. If the landslide dam had been filled in 303 days (26.1 million seconds), the average rate of inflow from the upper reaches of the Chikuma River would be calculated as 22.2 m^3/s (the catchment area upstream: 353 km^2).

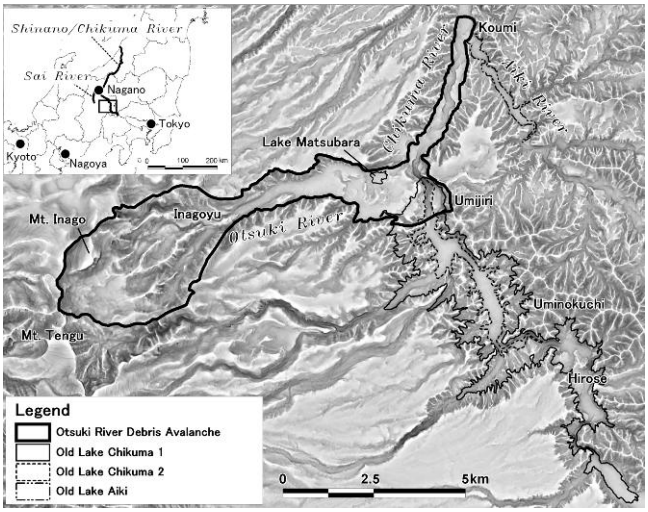

Fig.1 Relief map of the Yatsugatake Volcano, the debris avalanche and the landslide dams

Mt. Inagodake remains at the head of the caldera as a massive moving rock body of about 1000 m in long axis, 700 m in short axis, 200 m in height and 140 million m^3 in estimated volume. This moving rock mass may have been formed at the time of the mountain body collapse in 887. It may also be the case that the moving rock mass had existed earlier and that the mountain body collapse may have occurred on a large scale that included that part of the rock mass. This moving rock mass contains a wind cave and is almost completely separated from the bedrock. The moving rock mass carrying Mt. Inagodake, which still exists, may collapse significantly due to future earthquakes, torrential rainfalls or post-volcanic activity, which may cause a new debris avalanche to block the channel of the Chikuma River and form a landslide dam.

Looking at the situation from this perspective, the condition of the movement of the rock body near Mt. Inagodake should be monitored by displacement observation via GPS, etc.

Conclusion

A considerable amount of literature has been published in relation to the Yatsugatake Volcano Otsuki River Debris Avalanche and Ninna Flood and there have been many discussions that include the 887 and 888 theories. As explained above, the phenomena mentioned in literature can be explained by a theory that the large-scale landslide dam of 130 m in height (with an inundation volume of 580 million m^3) that was formed took as long as 303 days to be filled before it could fail. The failure caused a secondary debris avalanche, which blocked the Aiki River near Koumi and formed Old Lake Aiki (that remained for over 600 years). Although Old Lake Chikuma 1 collapsed, Old Lake Chikuma 2 of 50 m in height remained for 123 years. Various place-names that still exist in the upper reaches of the Chikuma River could be construed as records of these landslide dam phenomena.

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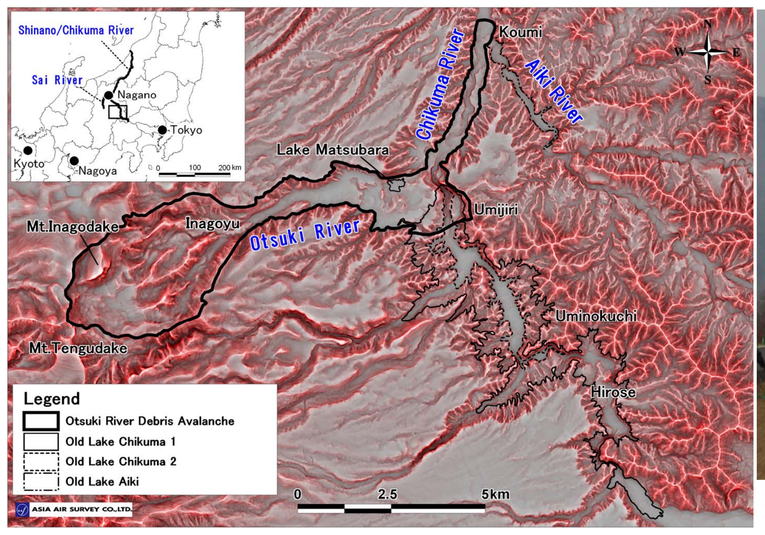

Figure 1 Relief map of the Yatsugatake Volcano, the debris avalanche and the landslide dams

Photo 1 Terrain after large-scale sector collapse of Kita Yatsugatake at Shinkai on the Otsuki River Debris Avalanche (photo by Inoue)

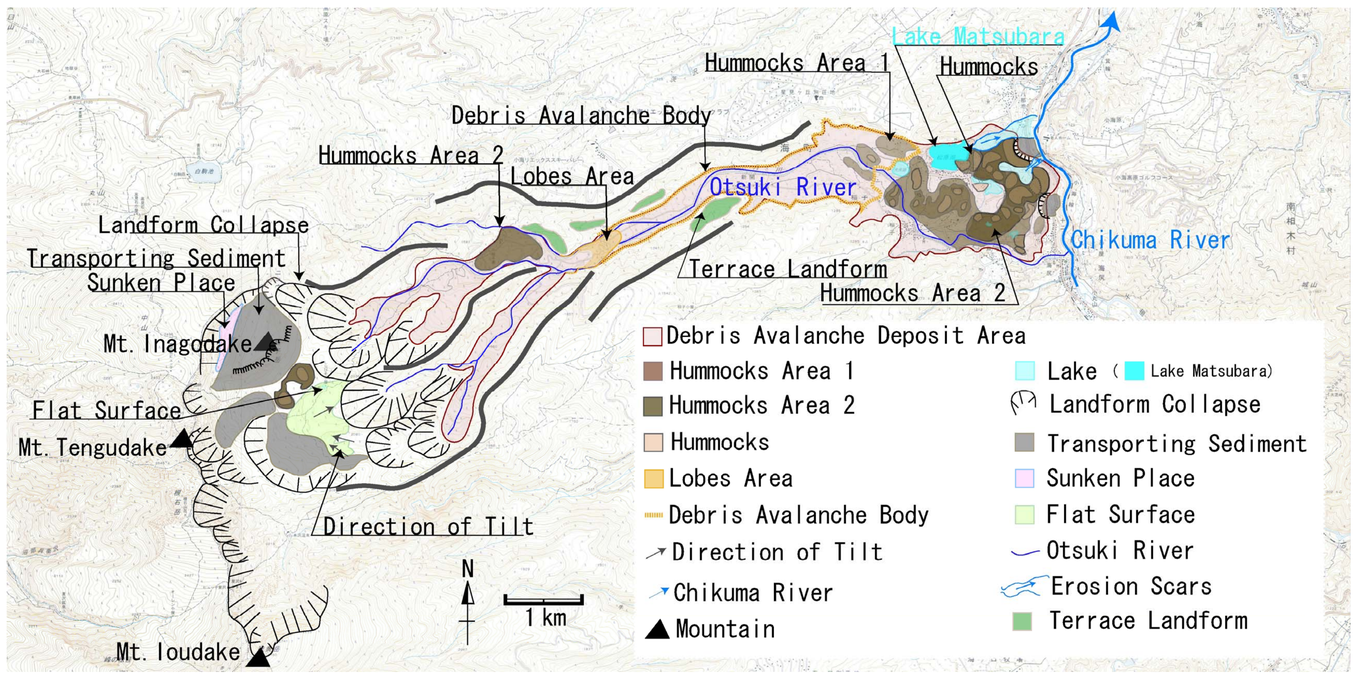

Figure 2 Landform classification map of the Otsuki River basin (Matchida et al.2009., Inoue et al. 2011)

Table 1 Radiocarbon date of sediment from the Otsuki River Debris Avalanche (Inoue et al., 2010)

Surveyer	C14 Age	Cristian Age	Measurement No.
Yatsugatake Survey G.	2120± 90B.P.	B.C.170	Gak-10119
Shagawa（1984）	1840±190B.P.	A.D.110	Gak-11847
Kawachi（1983）	1780±110B.P.	A.D.170	Gak-9488
Kawachi（1983）	950± 90B.P.	A.D.1000	Gak-10299
Okuda（2000a）	1187± 76B.P.	A.D.849±83B.P	Nagoya Univ.
Okuda（2000b）	1224± 41B.P.	A.D.812±57B.P	Nagoya Univ.

Table 2 Ruins covered with Ninna Flood sand (Inoue et al., 2010)

No	Ruins Name	Addres	Latitude	Longitude
1	Shinonoi Ruins Group	Nagano City Shinonoi Shiozaki	N36°33′	E138°07′
2	Ishikawa Jori Ruins	Nagano City Shinonoi Shiozaki	N36°33′	E138°06′
3	Shiozaki Ruins Group.	Nagano City Shinonoi Shiozaki	N36°34′	E138°08′
4	Yashiro Ruins Group	Chikuma City Amenomiya	N36°32′	E138°09′
5	Koshoku Ruins Group	Chikuma City Yashiro	N36°31′	E138°09′
6	Chikaraishi Jori Ruins	Chikuma City Chikaraishi	N36°28′	E138°10′
7	Kamigomyo Jori Ruins	Sakaki Town Kamigomyo	N36°27′	E138°10′
8	Aokishita Ruins	Sakaki Town Minamijo	N36°26′	E138°11′
9	Sunahara Ruins	Saku City Shionata Shinada	N36°16′	E138°25′
10	Atobe Mamada Ruins	Saku City Atobe Mamada	N36°14′	E138°28′

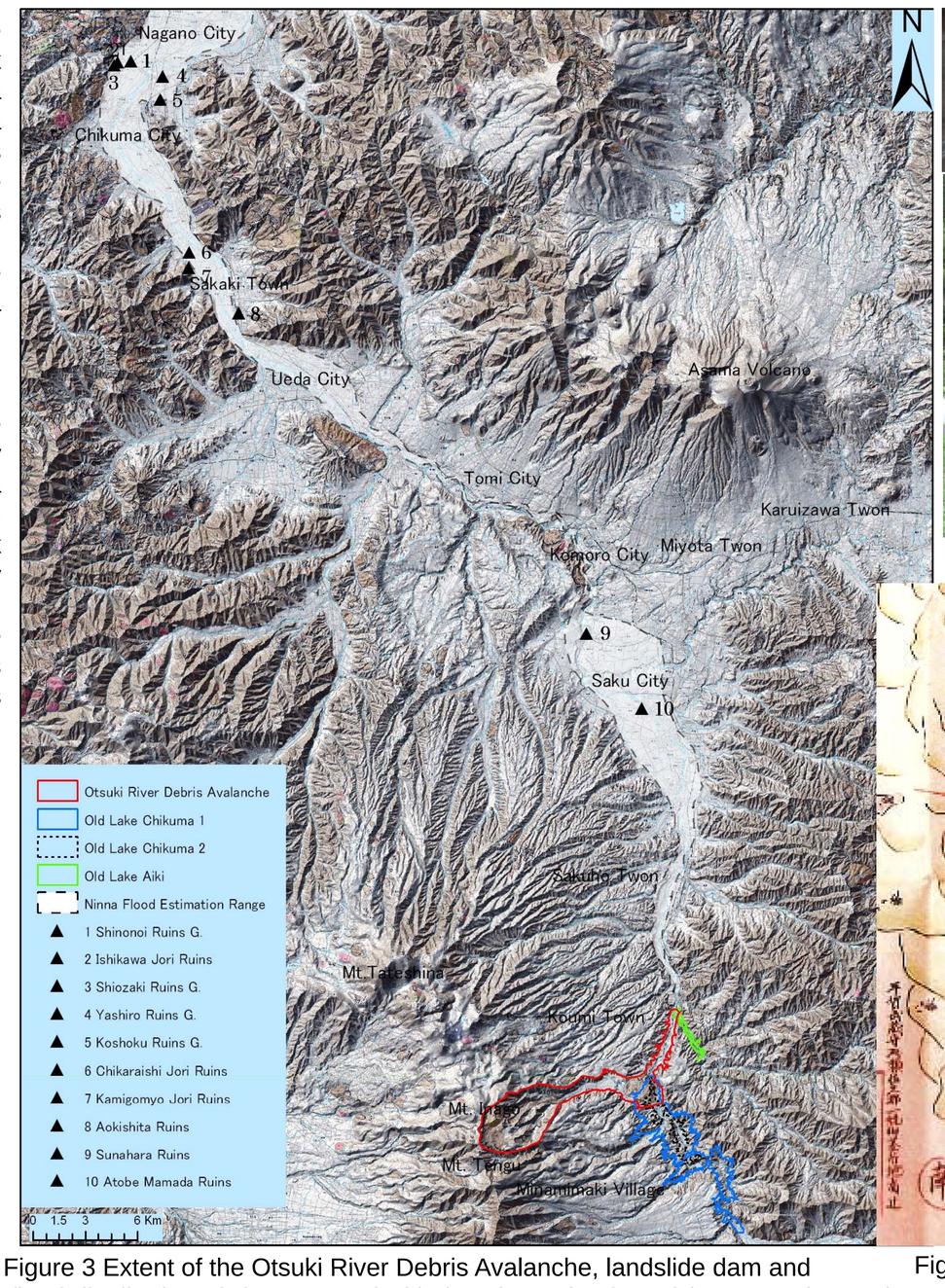

Figure 3 Extent of the Otsuki River Debris Avalanche, landslide dam and flood-distribution of sites covered with the Ninna Flood sand (Inoue et al., 2011)

Photo 2 Minato Shrine (means port shrine)

Figure 4 Southern part of Saku in Kurumisawa Map (owned by Ryukichi Kurumisawa)