Cartographical Research on Volcanic Hazards

Mamoru KOARAI, Katuyoshi SUZUKI, Minoru HOSHINO,
Hiroko MIZUKOSHI, Keiichi YUMOTO and Masaharu TSUZAWA
Geographical Survey Institute, Ministry of Construction
1 Kitasato, Tsukuba-City, Ibaraki-Prefecture, Japan

Abstract

Geographical Survey Institute (GSI) has been studying on volcanic hazards using geomorphological and cartographical method. GSI surveyed Bandai Volcano as a model to investigate debris avalanche in volcanic areas. In this research, GSI produced "1:25,000 Geomorphological Map of Bandai Volcano", and the Former Digital Terrain Model of Bandai Volcano just before the 1888 Collapse.

1. Introduction

There are over 200 volcanoes in Japan. Based on the recommendation by the Geodesy Council, the governmental institutions have been doing observation and research on over 80 active volcanoes. The Geographical Survey Institute (GSI) has responsibility for geodesic surveys and compilation of "Volcanic Base Maps" and "Land Condition Maps of Volcano".

Debris avalanche is one of the most catastrophic types of volcanic disasters, such as the activity of Mt. St. Helens in 1980. The candidates for debris avalanche deposits were studied using topographic maps 1:25,000 scale. Thus, 71 deposits from 52 volcanoes have been identified as debris avalanche deposits (Ui et al. :1986).

The 1888 activity of Bandai Volcano, located in the southern part of northeast Japan, caused a typical debris avalanche. On July 15th 1888, Mt. Bandai exploded with subsequent intensive destruction of mountain body. One third of the body disappeared, and a lot of hummocks and lakes (Lake Hibara, Onogawa, Akimoto, Sohara, and Goshiki-numa) were created in the northern foot of the volcano (Figure 1).

As a model investigation of debris avalanche, GSI and other governmental institutions have studied Bandai Volcano since 1990. This project has been supported by "special coordination funds from Science and Technology Agency." In this project, We did geomorphological investigation using technology for land condition survey and digital cartography.

2. Geomorphological maps of Bandai Volcano

2.1 Outline of topography and geology of Bandai Volcano

Bandai Volcano is one of the Quaternary volcanoes. All the eruptive rocks of Bandai is pyroxene andesite.

Bandai Volcano consists of four peaks, Mt. Oh-bandai (1818.6m), Mt. Kusigamine (1636m) located on northeast part, Mt. Akahani-yama (1430m) located on south east part and Mt. Maru-yama (1359m) located on northwest part.

Bandai Volcano caused many debris avalanche in its geological history. At least, five collapse calderas can be identified geomorphologically, collapse caldera formed in 1888 on north side 5, Numanodaira crater on east side 3, Biwazawa collapse on east side 4 and two collapse calderas (large is 1, small is 2) on southwest side (Figure 2). And debris avalanche deposit and hummocks can be recognized on the lower reaches of the collapse caldera (Moriya :1988; Mimura :1988).

2.2 Landform classification on the north side of Bandai volcano

The research for landform classification consists of aerial photo interpretation, field survey, topographical analysis using a Digital Terrain Model (DTM) and topographic measurement of hummocks using total station on land area and side scan sonar survey on lake area. We compiled "1:15,000 geomorphological map Bandai Volcano - the 1888 collapse and debris avalanche -", in

1992.

In this map, the landform created by the collapse in 1888 is classified into inter deposit area, avalanche valley area, transformed area, and debris avalanche deposit area.

There are specific landforms which are not recognized in other area, such as avalanche valley, transformed hummocks, linear fissure and scarp like landslide.

2.3 Geomorphic History

We have studied on other debris avalanche deposit since 1993, especially Okinashima Debris Avalanche deposit (from collapse caldera 1) in the south foot of Bandai Volcano. Table 1 is Bandai Volcano's geomorphic history based on the result using geomorphological analysis and tephrochronology.

According to aerial photo interpretation, two debris avalanche deposit areas are confirmed in the south foot of Bandai Volcano. New Okinashima Debris Avalanche deposit area (from collapse caldera 2) covered the valley plains inner Okinashima Debris Avalanche deposit area. Okinashima Debris Avalanche occurred after the spouting of Hayama 2nd Pumice from Bandai Volcano, and before the spouting of Hayama 1st Pumice from Bandai Volcano. And, New Okinashima Debris Avalanche (Zunashi Debris Avalanche?) occurred after the spouting of Hayama 1st Pumice, and before the spouting of Aira Tn Volcanic Ash (AT) from Aira caldera in southern Kyushyu Island.

2.4 1/25,000 Geomorphological Map of Bandai Volcano

We also compiled in 1995 "1/25,000 Geomorphological Map of Bandai Volcano (Figure 3)" based on this geomorphic history. This map covers all the areas of Bandai Volcano including all debris avalanche deposit area.

In this map, the landform formed by volcanic activity is classified into Rim of crater or caldera, Lava dome, Depositional landforms in the collapse caldera, Youngest volcanic body (Young Oh-Bandai Lava Flow, Bokodai Lava Flow etc.), Young volcanic body (Old Oh-Bandai Lava Flow), Old volcanic body (Kushigamine Lava Flow, Akahaniyama Lava Flow etc.) and Sarashina Pumice Flow Deposit.

The landform formed by the rockslides and debris flows is classified into Collapse caldera wall, Hummocks transformed area, Avalanche valley, Linear fissure, Hummocks, Debris avalanche deposit (1888 Ko-Bandai, Suriagehara, Biwazawa, Zunashi and Okinashima), Debris flow deposit in 1938 and Mudflow deposit of the 1954 Yugetayama collapse.

The landform formed by fluvial activity and others is classified into Young alluvial fan at volcanic foot, Old alluvial fan at volcanic foot, Alluvial fan at adjacent areas, Koyagawa Mudflow, Fluvial landforms, Terraces and Landslides.

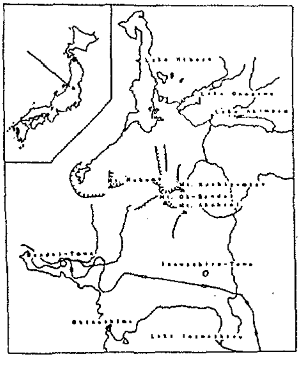

Figure 1 Location of Bandai Volcano

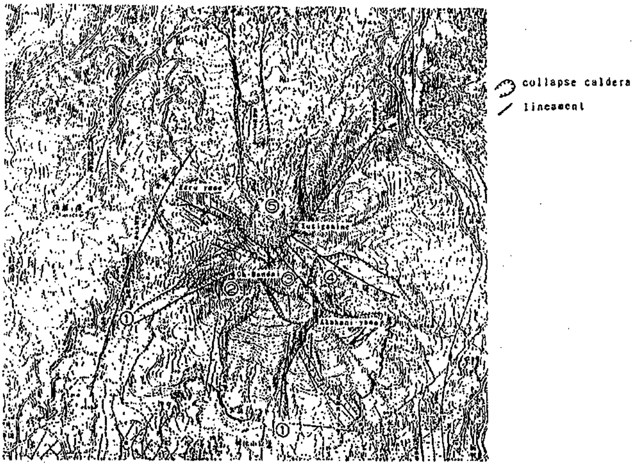

Figure 2 Collapse caldera on the peak of Bandai Volcano

Table 1 Geomorphic history of Bandai Volcano

Age	Tephra	Geomorphic History of Bandai Volcano
A.D. 1954		Collapse of Yugeta-yama
A.D. 1888		Collapse of Ko-Bandai ⑤
A.D. 806		Collapse of north side ?
2.4ka		Collapse of Biwa-zawa ④.
5ka	Numazawa Numazawako Tephra (Nm-NM)	
		Collapse of Numanodaira ③
		Nagamine mud flow from Koyagawa-River
13~14ka	Asama Futatukuchi Tephra (As-FtA)	
		Formation of Oh-Bandai
25ka	Aira Tanzawa Tephra (AT)	
		Young Oh-Bandai lava flow
		New Okina-shima debris avalanche ②
		Old Oh-Bandai lava flow
30~46ka	< Hayama Pumice 1 (HP1) >	Spouting of HP1 (Sarashina pumice flow)
50~52ka	Daisen Kurayoshi Tephra (DKP)	
50~55ka	Numazawa Kanayama Tephra (Nm-KN)	
66~77ka	Akagi Okkai Tephra (Ag-OK)	
		Okina-shima debris avalanche ①
72~83ka	< Hayama Pumice 2 (HP2) >	Spouting of HP2
74~86ka	Ontake Nagawa Tephra (On-NG)	
86~90ka	Aso 4 Tephra (Aso-4)	
		Oshizawa debris avalanche from Nekoma Volcano
	Numazawa Shibahara Tephra (Nm-SB)	
		Akahani lava flow and Xushigamine lava flow

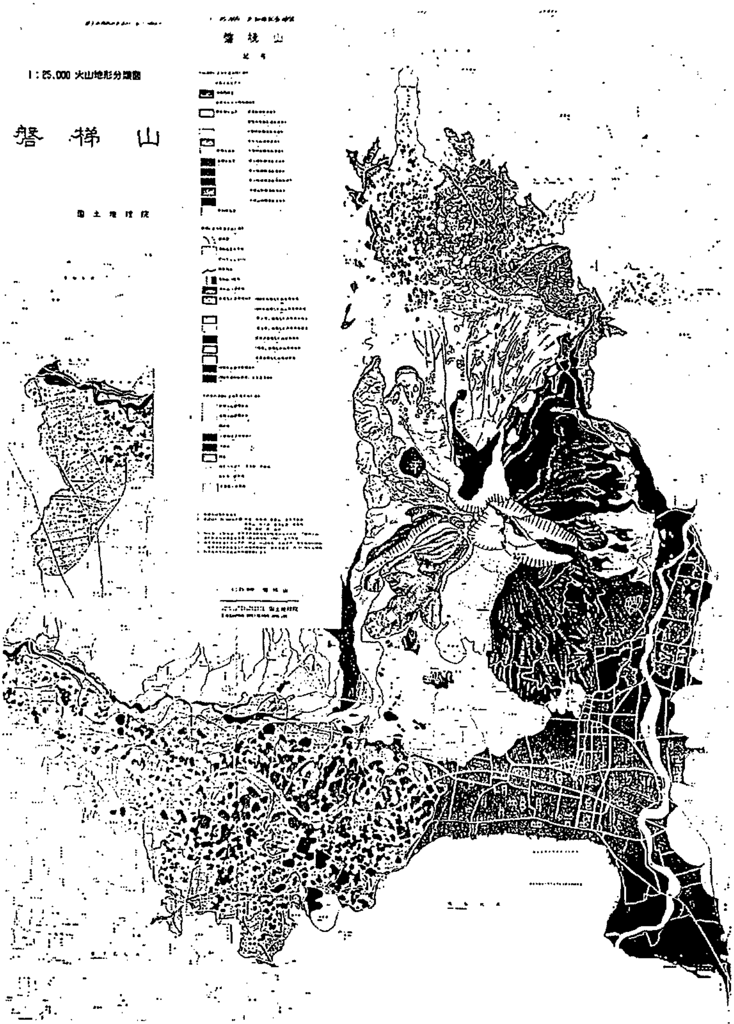

Figure 3 Geomorphological map of Bandai Volcano

3. Former Terrain Model of Bandai Volcano just before the 1888 Collapse restored from olden map.

3.1 The 1888 landform formation process

Much research had done about the 1888 debris avalanche of Bandai Volcano. Nakamura (1978) explained that avalanche valley was formed by the shaving due to rushing avalanche, based on the assumption that a violent steam-blast collapse destroyed the peak of Ko-Bandai just after the first collapse. However, Yonechi (1987) explained "multiple collapse hypothesis" of the 1888 collapse of Bandai Volcano, using olden sketch and olden photo. This hypothesis claims that disaster consisted of at least two collapses, large scale destruction in the first stage which occurred on the mountainside, and the gigantic collapse of the peak of Ko-Bandai in the second stage.

In this research, we studied on the mechanism of the 1888 Bandai Volcano collapse, noticed avalanche valley, concentrated hummocks in main deposit area, linear arrangement of deformed hummocks in transformed area, linear fissure in east side slope of avalanche valley and so on. We considered a new landform formation process of the 1888 Bandai Volcano collapse based on multiple collapse hypothesis.

1st Explosion of volcanic body, First collapse
2nd Occurrence of debris avalanche,
Formation of hummocks and avalanche valley
3rd Suspension of collapse
4th Collapse of the Ko-Bandai like landslide,
Formation of linear fissure and transformed area

However, there are many problems with this hypothesis, such as the existence of Ko-Bandai in the suspension of collapse, the formation mechanism of the avalanche valley, deformed hummocks in transformed area, and so on.

To study the mechanism of Bandai Volcano's collapse in 1888, we restored its Terrain Model just before the 1888 collapse using olden map.

3.2 Pre-collapse map

Yonechi (1992) introduced a historic map, "Bandaisan no Zu", as the first disaster map by scientific investigation in modern Japan (Figure 4). It shows the former topography of Bandai Volcano and surroundings.

"Bandaisan no Zu," was compiled in 1889 at the scale of 1:50,000 by the Geological Survey of Japan, Ministry of Agriculture and Commerce. Contour interval is 40m. The oldest 1:50,000 topographical map "Bandaisan" produced by the Land Survey Department of Japanese Army, was compiled in 1908. Consequently, "Bandaisan no Zu" is older than "Bandaisan" by nearly 20 years.

3.3 Restoration process

The flow of restoration process is shown in Figure 5.

We digitized "Bandaisan no Zu" with a scanner and and vectorized the result to make digitized contour lines with VTRAK (Informatix Co.). Figure 6 is the output of vectorized contour line data.

Then, we put contour line data of vector in MOSS (Informatix Co.), and made DTM of 25m interval.

Using the DTM, we produced some terrain analysis pictures for geomorphological analysis, such as a bird's-eye views map and an slope classification map (Figure 7).

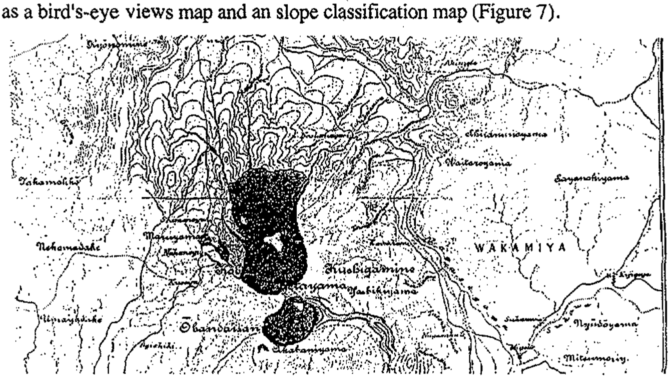

Figure 4 Bandaisan no Zu

BANDAISAN-NO-ZU

↓ reading by scanner

Raster data

↓ vector transformation

Vector data

↓ inseting

D T M

↓ making bird's-eye views, the slope and so on

Terrain analysis pictures

Figure 5 The flow of restoration process

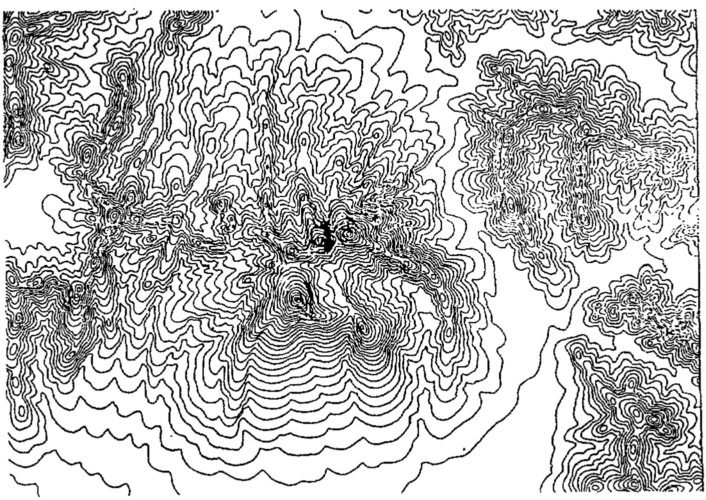

Figure 6 Digitized contour lines

Figure 7 Slope classification map

3-4 Utilization of DTM for Geomorphological Analysis

(a) Topographical measurement of collapsed volume

The DTM of Bandai Volcano just before the 1888 collapse revealed the collapsed part of volcanic body. However, "Bandaisan no Zu" contains considerable distortions for altitude and horizontal positions. We assume that these arose from not only unsophisticated survey technology at that time but also misidentification of mountain peaks by surveyors.

These distortions are inherited to the DTM. We are correcting them in order to calculate volume of the collapse and debris avalanche deposit by comparing it with the present DTM.

(b) Consideration of recent mass movements

Mt. Yugeta, the neighboring peak to Mt. Ko-Bandai, remained from the 1888 collapse and collapsed in 1954.

Fig.8 shows the picture of restoration model of former terrain from Aizu-Wakamatsu region (a), compared with the olden photo taken from Aizu-Wakamatsu region just after collapse (b), and DTM produced from aerial photo taken by US military in 1948, before Mt. Yugeta-yama collapsed in 1954.

Yonechi (1987) recognizes the left peak of olden photo is Mt. Ko-Bandai, and proposes multiple collapse hypothesis, which Mt. Ko-Bandai peak remained just after collapse. However, under comparison of these three pictures, it is appropriate to consider the left peak of the olden photo as Mt. Yugeta-yama.

(c) Pre-1888 collapse of northern side of Bandai Volcano

On contour map and inclination classification figure of former terrain model, steep slopes are concentrated near the summits of Mt. Ko-Bandai and Mt. Oh-Bandai, in the vicinity of Biwazawa, and the west side of Mt. Yugeta-yama.

To the west of Mt. Yugeta-yama, the existence of two semi-circular steep slopes is confirmed; they look like two collapse walls standing side by side. Below them, a linear valley remains, which may be the sweeping route of a debris avalanche which originated from the semi-circular collapse.

Yonechi and Takeda (1994) presume that the olden collapse wall existed near Kaminoyu Hot Spring where located in the west side of Mt. Yugeta-yama by the description of olden geological report (Nishiyama,1887). This suggests that the west semi-circular steep slope among the reconstructed north slope of Mt. Bandai is the collapse pointed out by Yonechi and Takeda (1994). On the other hand, Tanaka et.al. (1994) reported the radio carbon age of the sample taken from highest part of wall by the 1888 collapse, which suggests the collapse in AD 806.

It is therefore highly probable that the volcanic activity of AD 806 was a steam explosion near Kaminoyu Hot Spring.

4. Conclusion

In this research, we compiled "Geomorphological Map of Bandai Volcano", and restored the Former Digital Terrain Model of Bandai Volcano just before the 1888 Collapse. These are useful for geomorphological consideration of the collapse characteristics of Bandai Volcano, especially the process of the 1888 Collapse.

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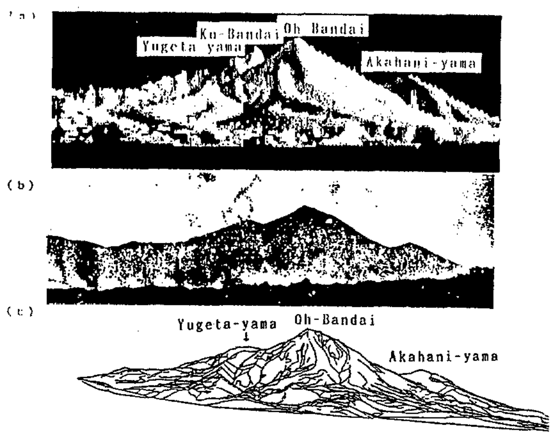

Figure 8 DTM and olden photo from Aizu-Wakamatsu region

Figure 1. A report of Mt.Ko-bandai collapse

Figure 2. The Pre-collapse Map [Der Bandaisan]
-The German version of [Bandaisan no zu]

Figure 3. The flow of restoration process

Figure 4. The output of contour line
Figure 5. A:The bird's-eye view from the Tsuruga Castle in the Aizu region before Mt.Ko-bandai collapse
Figure 6. B:The bird's-eye view from the Tsuruga Castle in the Aizu region at the present time
Figure 7. C:The bird's-eye view from north of Mt.bandai before Mt.Ko-bandai collapse
Figure 8. D:The photograph from the Aizu region,in 15,7,1888
Figure 9. E:The photograph from castle tower of the Tsuruga castle in 3,6,1994
Figure 10. The slope classification
Figure 11. The distortion of Pre-collapse Map

The location of the top of a mountain in Pre-collapse Map

The location of the same one in the represent map

The arrow from the top of a mountain in Pre-collapse Map to the same one in the present map

The distance between two tops of mountains in the Pre-collapse Map is longer than it in the represent map

The distance between two tops of mountains in the Pre-collapse Map is shorter than it in the represent map The distance between two tops of mountains in the Pre-collapse Map is the same of it in the represent map

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