# THE CONSTRUCTION OF EARTHQUAKE DAMAGE DATA ARCHIVES FOR EARTHQUAKE DISASTER MITIGATION

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**ABSTRACT:**

The October 23rd, 2004, Mid Niigata prefecture earthquake attacked the Chuetsu area in central Japan, causing serious damage to major traffic arteries located in a mountainous region of tertiary sedimentary rocks. This earthquake occurred in an active folding area that is mainly in northeastern Japan from the north edge of Fossa Magna. It is thought that these damages indicate typical damage in active folding area. Therefore, for mitigation of the earthquake damage in active folding area, we collected data related to the earthquake damage and constructed earthquake damage data archives. The archived data are as follows, (1) Landform data by aerial photographs and LIDAR, (2) Ground data include boring data and microtremor data, (3) Strong ground motion records, (4) Research outcome and (5) Technical and investigation reports of rehabilitation and reconstruction. The data archives are going to be open to the public on the web. It is hoped that data archives will contribute to mitigation of the future earthquake damage in the active folding area.

**KEYWORDS:** active folding, data archives, 2004 Mid Niigata Earthquake, landform change, disaster mitigation

## 1. INTRODUCTION

The 2004 Mid Niigata prefecture earthquake of JMA magnitude (Hereafter called Mj) 6.8 struck the Chuetsu area in central Japan at 17:56 JST on October 23rd, 2004. (Hereafter called Chuetsu earthquake). The hypocenter was located at 37°17.5'N, 138°52.0'E, at a depth of 13 km. The maximum acceleration of more than 1,500 $cm/s^2$ was recorded at Ojiya K-NET station, which is about 10km west of the epicenter. The characteristic of this earthquake was that many intense aftershocks occurred in succession. Following the main-shock, 3 intense after-shocks occurred at 18:12, 18:34 and 19:45. Magnitudes of these aftershocks were Mj6.0, Mj6.5 and Mj5.7 respectively. JMA scale seismic intensity more than $6^-$ was observed by every aftershock. Continuously intense aftershocks damaged significant social infrastructures such as the roads, railroads, and lifelines such as electric power supply and water supply facilities. Furthermore, 3,791 landslides occurred in the near source area, were interpretated from an aerial photograph. Some of these landslides blocked a river.

Thus the Chuetsu earthquake induced serious damage, but similar earthquake damages have occurred in Japan in the past. In the Akita-Senboku earthquake, which occurred at March 15th, 1914, a lot of landslides and slope failures can be seen in old photographs of the damage. In the Zenkoji earthquake, which occurred at May 8th, 1847, a great failure of the Mt. Iwakura was recorded in an ancient document. Such damage closely resembles the Myouken landslide of the right bank of Shinano River.

These valuable data may have been transmitted only as a document or dictation. Unfortunately valuable experiences have not been utilized for earthquake disaster mitigation of the later generation. There are many reasons why valuable experiences of earthquake disaster are not utilized for disaster mitigation of later generation. It is thought that the biggest reason is that all data including earthquake damage, seismic record, site condition and reconstruction are not archived comprehensively.

As mentioned above, The Chuetsu earthquake occurred in an active folding area, extending from the north edge of the Fossa Magna to the Eastern Japan. So the damage of Chuetsu earthquake can be treated as damage typical to earthquake that may occur in an active folding area. Therefore it was thought as a contribution to future earthquake disaster mitigation that it would be useful to collect a lot of data concerning the Chuetsu earthquake and make a data archive before a traces of the damage were lost.

Japan Society of Civil Engineers became the core organization and carried out a research and development project "Earthquake damage in active-folding areas: creation of a comprehensive data archive and suggestions for its application to remedial measures for civil-infrastructure systems" in cooperation with five research organizations. (Hereafter called the active folding project) This paper introduces the earthquake damage data archives, which are one of the results of the research and development project. Figure 1 shows location of target zone of this research and epicenter of 2004 Mid Niigata prefecture earthquake and aftershocks

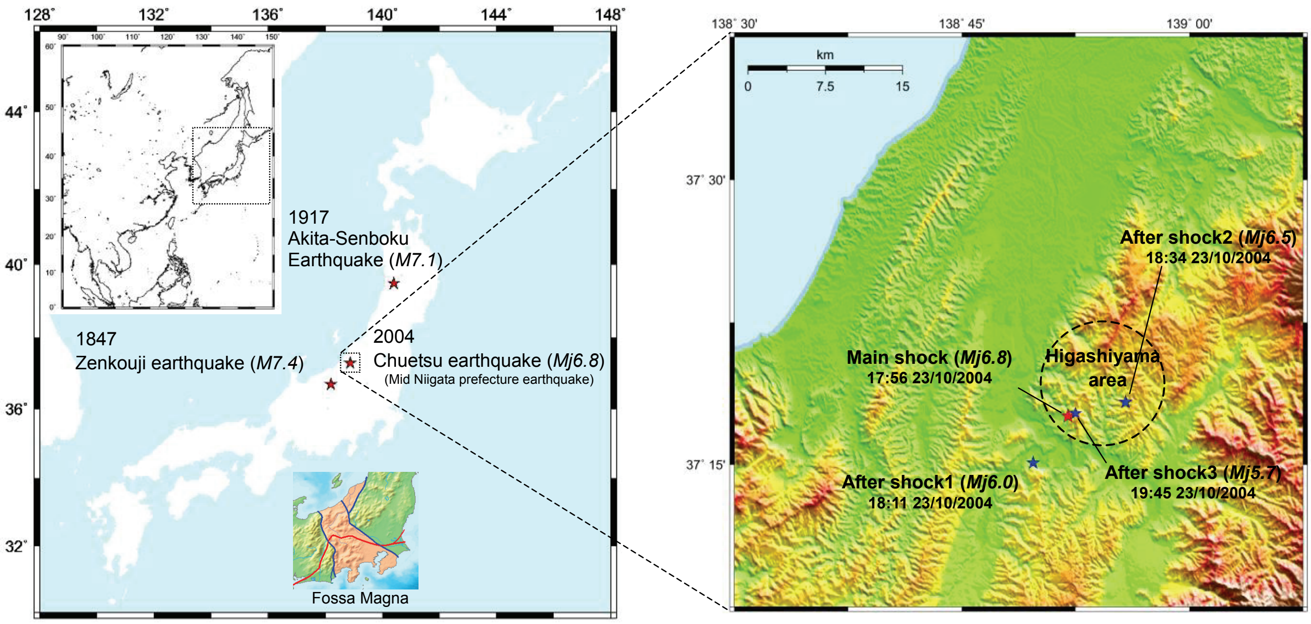



Figure 1. Location of target zone of this research and epicenter of 2004 Mid Niigata prefecture earthquake and aftershocks

## 2. OUTLINE OF THE ACTIVE FOLDING PROJECT

The active folding project was performed as a research and development support program of Ministry of Education, Culture, Sports, Science and Technology for three years from 2005. Research representative is Kazuo KONAGAI who is one of the co-authors in this paper. In this project, we have created a data archive of detailed examples of actual damages with thorough scientific analysis against earthquake damage of active folding area. One of the goals of the project is to make public the data archives with remedial suggestions common to all the earthquake damages in active folding areas.

In the active folding area, thickly accumulated neritic sediment has been folded extensively and focal mechanisms are often complex. In addition to large number of aftershocks, its focal areas vary widely. It is difficult to clarify the connection between the actual damage and the cause, e.g. if it is from the main shock or continuous aftershocks. The erosion of the damaged landform progress rapidly and the deformation extends over a long period of time. Consequently it is inevitable that the remedial measures should be taken for a prolonged period.

It is necessary not only to define spatial distribution of seismic intensity and damages but also to observe and quantify many phenomena on a temporal axis. This project implements research studies listed below for aforementioned subjects.

(1) Comprehensive research and study regarding design of the data archives.
    Aggregating the earthquake record and the ground data, tracing the detailed ground deformation from before to after the earthquake, and collecting the detailed records of measures.
(2) Study of strong ground motion in active-folding areas
    Detailed estimation of ground motion with a source process model which is obtained from the earthquake data, gravity survey, and microtremor measurement.

(3) Study of geology and geohazards in active-folding areas
Implementation of research studies listed below. The expected results include inputs to infrastructure system design, together with ground motion data.
1) Extraction of geological and geotechnical data
2) Geohazard analysis.

(4) Improvement of earthquake resistance of infrastructure systems in active-folding areas
Implementation of research studies, listed below, regarding typical characteristics of ground motion and ground displacement in active-folding areas obtained by subject 2 and 3：
1) Seismic response and aseismic reinforcement of bridges with spans/viaduct systems in areas of the complex topography and geology.
2) Seismic resistance of concrete structures under the influence of both its aging degradation and incidental facilities.
3) Improvement of disaster mitigation for tunnel systems in active-folding areas.
4) Life-line system research.

(5) Finding similarities in damages and suggesting remedial measures.
Accumulation of necessary knowledge in terms of disaster mitigation considering that deformation of the damaged landforms, which are also landslide-prone areas, extends over a long period of time, and that most of the active-folding areas in Japan overlaps the heavy snowfall areas.

Figure 2 shows research system of active folding project.

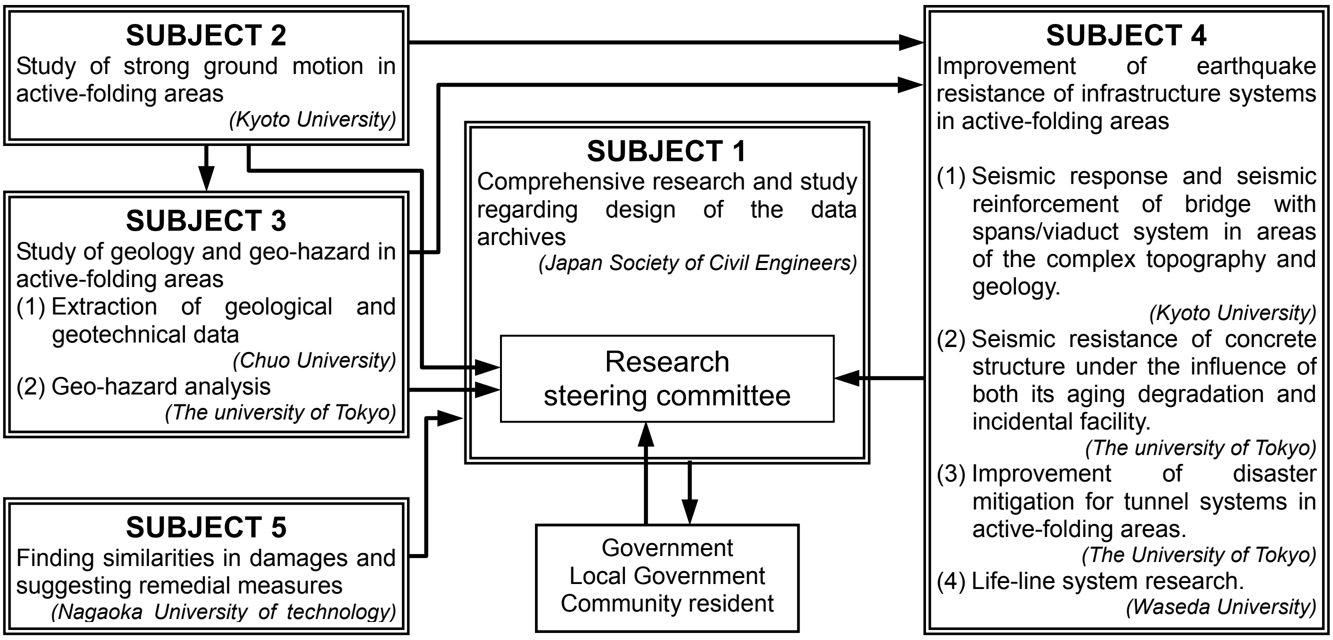



Figure 2. Research system of active folding project: “Earthquake damage in active-folding areas: creation of a comprehensive data archive and suggestions for its application to remedial measures for civil-infrastructure systems”, Special Coordination Funds for Promoting Science and Technology, Ministry of Education, Culture, Sports, Science and Technology (2005-2007).

## 3. EARTHQUAKE DAMAGE DATA ARCHIVES (*EDDA*)

The areas considered for data collection to make the earthquake damage data archives (Hereafter called *EDDA*) are the Chuetsu area, the Akita-Senboku area (Hereafter called Daisen area) and the Nagano area. These areas are located in the active folding area. The Daisen area and the Nagano area are included in the source area of the Akita Senboku earthquake and the Zenkouji earthquake respectively.

The main collected data are five kinds of the following. (1) Landform data, (2) Ground data, (3) Strong ground motion data, (4) Research outcome, (5) Technical and investigation reports of rehabilitation and reconstruction. In the Daisen area and the Nagano area, only Landform data were collected. The collecting data of the *EDDA* are shown in table 1. The summary of (1) Landform data, (2) Ground data and (3) Strong ground motion data are shown as follows.

### *3.1 Landform (Topographic) data*

In Chausu-yama in Nagano City, the crack that was caused by the landslide that occurred by the Zenkouji earthquake had begun to spread from about 1884 after 37 years later from earthquake. Furthermore, a sliding soil mass had begun to move downward in 1911. Thus, the ground tends to move after an earthquake continuously in the active folding area. Therefore we carried out aerial laser measurement for candidate areas and made a DEM (Digital Elevation Model). Initially, DSM (Digital Surface Model) was made by the aerial laser measurement. The DSM is information including a building and vegetation. DEM made by removing the information such as a building and the vegetation from DSM. In the Chuetsu area, we got 6 time-section data include before earthquake for the purpose of evaluating ground deformation after the earthquake. The DEM before earthquake was made based on an aerial photograph taken in 1975. Influence on landform change by the earthquake is clarified by comparing these DEM mutually.

### *3.2 Ground data*

Ground data consist of boring data and microtremor data. Regarding boring data, we collected every data that include past investigation reports. The analog data was digitized on this occasion. The microtremor data were measured during the active folding project. For users to be able to use the microtremor data depending on their own research purpose, the original time history data are published.

### *3.3 Strong Ground motion data*

A lot of strong ground motion records were observed in the Chuetsu earthquake. But a strong ground motion characteristic of source region was not clarified because there were few seismometers installed in this area. The active folding project evaluated the strong ground motion characteristics of the source area by numerical analysis. In the earthquake damage archives, these calculation results were published.

## 4. APPLICATION OF *EDDA* FOR EARTHQUAKE DISASTER MITIGATION

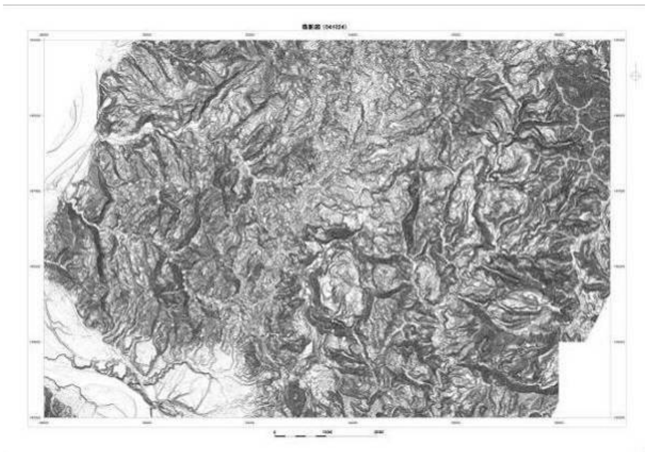
As previously mentioned, the main damage in the Chuetsu earthquake was geotechnical damage like landslides. Furthermore, the active folding area have characteristic such as that the ground tend to continuously move after an earthquake. We evaluated landform change after earthquake in the Chuetsu area using DEM data.
Figure 3(a) shows elevation data in the Chuetsu area as a shaded image. Left side is before earthquake and right side is after earthquake. Figure 3(b) shows difference between the DEMs for before and after the earthquake. Differential data means landform change due to the Chuetsu earthquake and other landform changes taking place between 1975 and 2004 October 23.
A yellow zone can be seen on the left-lower corner at differential map. So differential map means that this area lifted up by an earthquake and elevation change is more than 1m.
The DEM data are effective for the evaluation of the landform change. We attempted more detailed evaluation with DEM for landslide disaster at the Takezawa area. A large-scale landslide occurred in two places. Figure 4 shows the influence of earthquake on the landform change. Large landform change is confirmed in two places. The left side is the Dainichi-yama area and right side is the Higashi-Takezawa area. The landform change is seen also in the other areas.
Figure 5 shows the influence of thaw and avalanche on the landform change. The landform change around the Dainichi-yama where a large landslide occurred is hardly seen. In the Higashi-Takezawa area, we can see the influence of river block.

Table 1 Main Collected data of earthquake damage data archives

| Area | Kind of data | Classification of data | Content | |
|---|---|---|---|---|
| Chuetsu | Landform (Topographic) | DEM (Digital elevation model) | Higashiyama area / 6 time sections include before earthquake | |
| | | | 1975 | Before earthquake |
| | | | *24th,Oct. 2004* | *After mainshock* |
| | | | 28th,Oct. 2004 | After aftershock |
| | | | *May 2005* | *First thaw after earthquake* |
| | | | 12th,Aug. 2006 | One year later |
| | | | 16th,May, 2007 | Two year later |
| | | | Uono River / 2 time sections include before earthquake | |
| | | | 1975 | Before earthquake |
| | | | 28th,Oct. 2004 | After aftershock |
| | | | Takamachi area / 1 time section after earthquake | |
| | | Ortho Image | Higashiyama area / 4 time sections include before earthquake | |
| | | | 1975 | Before earthquake |
| | | | 28th,Oct. 2004 | After aftershock |
| | | | 12th,Aug. 2006 | One year later |
| | | | 16th,May, 2007 | Two year later |
| | | Differential Image | Higashiyama area / 8 time sections | |
| | | | 1975 - 24th, Oct. 2004 | |
| | | | 1975 - 28th, Oct. 2004 | |
| | | | 24th, Oct.2004 - 28th, Oct. 2004 | |
| | | | 28th, Oct.2004 - May 2005 | |
| | | | 28th, Oct.2004 - 12th, Aug. 2006 | |
| | | | May 2005 - 12th, Aug. 2006 | |
| | | | May 2005 - 16th, May 2007 | |
| | | | 12th, Aug. 2006 - 16th, May 2007 | |
| | | Shaded Image | Higashiyama area<br>6 time section same as DEM<br>Uono River<br>2 time section same as DEM | |
| | | Contour Image | Higashiyama area / 4 time sections same as Ortho image<br>Uono River / 2 time sections same as DEM | |
| | Ground | Boring | Soil profile and SPT-N value | |
| | | Report | 2 typical slope disaster sites (in Japanese)<br>Higashi-Takezawa and Yokowatashi | |
| | | Microtremor | 3 components microtermor data | |
| | Strong Ground motion | Engineering base motion | Ground motion on the engineering base by 3D-FDM | |
| | | Maximum ground motion distribution | Maximum ground motion distribution found by space interpolation from engineering base motion | |
| | Research Outcome | Railway(Shinkansen) | Study on Shinkansen Derailment (in Japanese) | |
| | | Lifeline | Study on lifeline damage in Ojiya city | |
| | | Slope disaster | Slop disaster data base | |
| | Report | Government | Reconstruction and rehabilitation | |
| | | Local government | Reconstruction and rehabilitation | |
| Nagano | Landform (Topographic) | DEM (Digital elevation model) | Nagano area / 1 time section | |
| | | | 15th, May 2006 | For future reference data |
| | | Ortho Image | Nagano area / 1 time section same as DEM | |
| | | Shaded Image | Nagano area / 1 time section same as DEM | |
| | | Contour Image | Nagano area / 1 time section same as DEM | |
| | | Aerial photograph | Nagano area / 1 time section (24th, Nov. 2006) | |
| Daisen | Landform (Topographic) | DEM (Digital elevation model) | Daisen area / 1 time section | |
| | | | 12th, May 2006 | For future reference data |
| | | Ortho Image | Daisen area / 1 time section same as DEM | |
| | | Shaded Image | Daisen area / 1 time section same as DEM | |
| | | Contour Image | Daisen area / 1 time section same as DEM | |

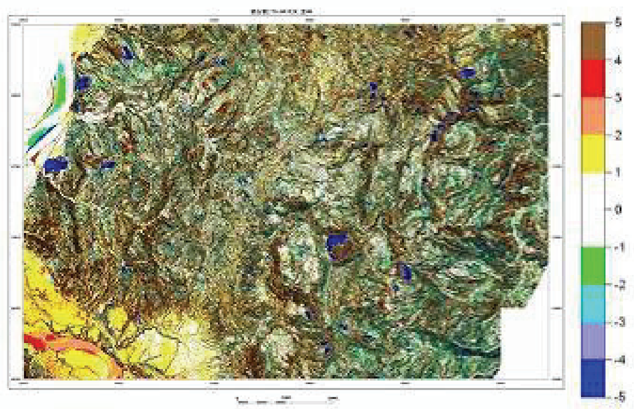
(The italic type shows data that is not yet open to the public)

Before earthquake (1975)



After earthquake (24th ,Oct. 2004)

(a)Elevation data (Shaded image)



(b) Differential data that subtract after earthquake from before earthquake

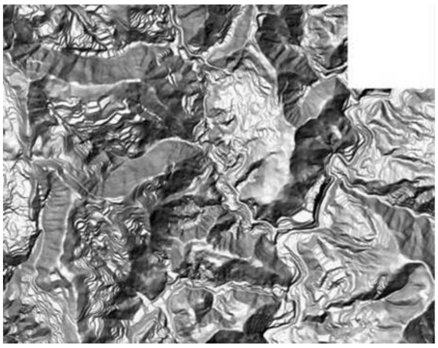
Figure 3. Landform data (DEM) made by aerial photograph and aerial leaser measurement and differential data: Differential data means landform change due to earthquake.

## 5. CONCLUSION

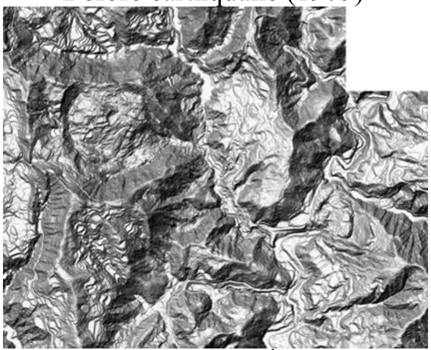
We have attempted to create an earthquake damage data archives for earthquake disaster mitigation in active folding area in Japan. The collected data are (1) Landform data, (2) Ground data, (3) Strong ground motion data, (4) Research outcome and (5) Technical and investigation reports of rehabilitation and reconstruction. In the future, we try to collect more data and add it to the archives.
The earthquake damage data archive shows it in the following web sites.
***http://active-folding.iis.u-tokyo.ac.jp/archives/en/***

## ACKNOWLEDGEMENT

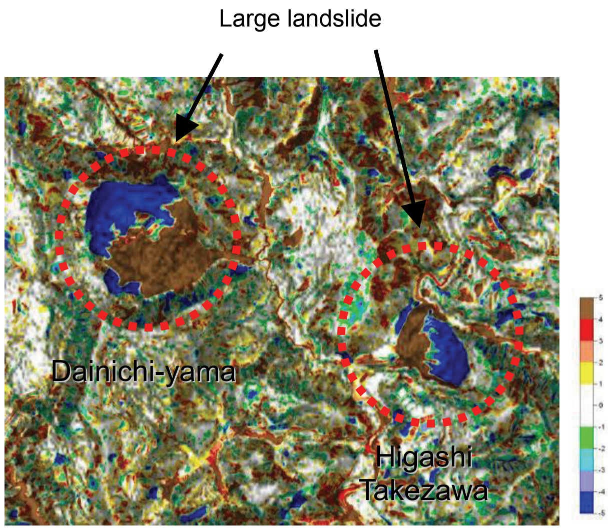
This paper summarizes one of the outcomes of the Research and Development program for Resolving Critical Issues, “Earthquake damage in active-folding areas: creation of a comprehensive data archive and suggestions for its application to remedial measures for civil-infrastructure systems, ”Special Coordination Funds for Promoting Science and Technology, Ministry of Education, Culture, Sports, Science and Technology.
The authors would like to express their sincere thanks to all members of the project steering committee organized under the Japan Society of Civil Engineers as the core of the project. Furthermore, we thank all of organizations, which contributed earthquake damage data. Finally, We would like to express our gratitude to Associate Professor Dr. Jorgen JOHANSSON, The University of Tokyo, for his kind suggestion.



Before earthquake (1975)

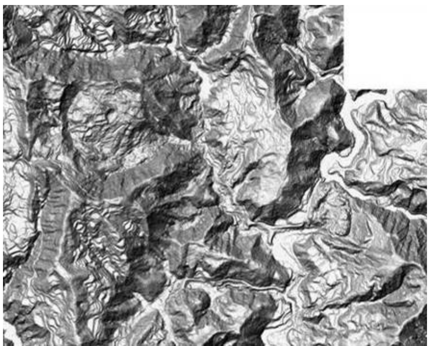


After earthquake / 24th, Oct. 2004

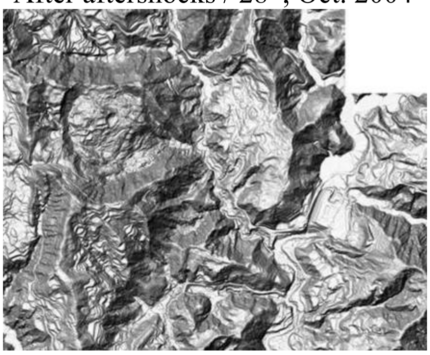



(a) Elevation data (Shaded image) (b) Differential image

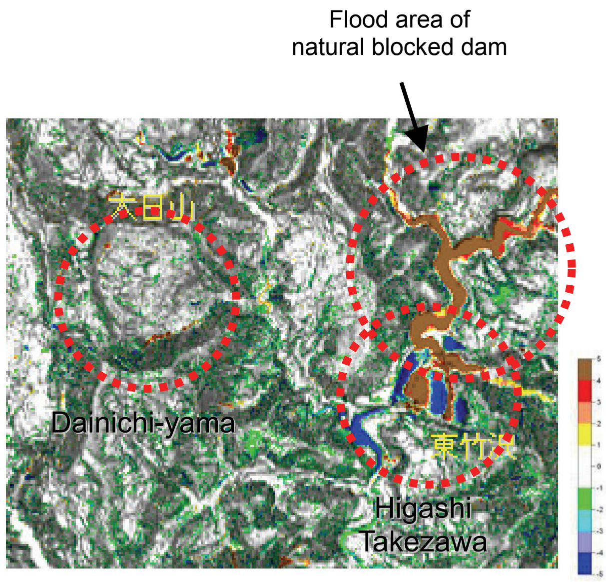
Figure 4. The influence of earthquake on the landform change in the Takezawa area



After aftershocks / 28th, Oct. 2004



First thaw after earthquake / May. 2005




(a)Elevation data (Shaded image) (b)Differential image

Figure 5. The influence of thaw and avalanche on the landform change in the Takezawa area

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