1:25,000-scale Active Fault Map in Urban Areas published by GSI

Junko IWAHASHI

Abstract

This paper introduces the "Active Fault Map in Urban Areas", a series of 1:25,000 scale maps showing detailed locations of active faults in urban areas published by the Geospatial Information Authority of Japan (GSI). The 1995 South Hyogo Prefecture Earthquake in the local district of Kobe prompted GSI to obtain more information about inland active faults and to develop Active Fault Maps. Since then, GSI has continued to publish these maps, with 147 maps published as of 2010. The maps describe active faults, active flexures, active folds, and terrain classifications at a scale of 1:25,000. Since 2006, scanned map images and GIS data were also published on the Japanese GSI website. GSI will encourage further improvement of the Active Fault Map in Urban Areas.

1. Introduction

On January 17, 1995, a magnitude 7.3 earthquake caused by an active fault occurred in the nearby district of Kobe, in a city that is representative of the Kansai region and home to more than two million people. More than 6,000 people were killed in this disaster, which was subsequently named "the Great Hanshin-Awaji Earthquake." Prior to that, there was a widespread belief that the Kansai region was safe from large earthquakes. This belief had been influenced by people's focus on ocean-trench earthquakes. Although disasters caused by inland active faults had continued throughout history (e. g., the 1981 Noubi Earthquake, the 1927 Kita-tango Earthquake, and the 1948 Fukui Earthquake), the term "large earthquake" conveyed an image of an ocean-trench earthquake, such as the 1923 Great Kanto Earthquake, which hit the Tokyo metropolitan area and killed more than 100,000 people, the two large tsunamis caused by the Sanriku Earthquakes (1896 and 1933), and the expected Tokai Earthquake. People were shocked that such a large disaster could occur even in modern times. However, the main earthquake disasters in Japan during the 2000s were caused by inland active faults (e.g., the 2003 Mid Niigata Prefecture Earthquake and the 2008 Iwate-Miyagi Nairiku Earthquake).

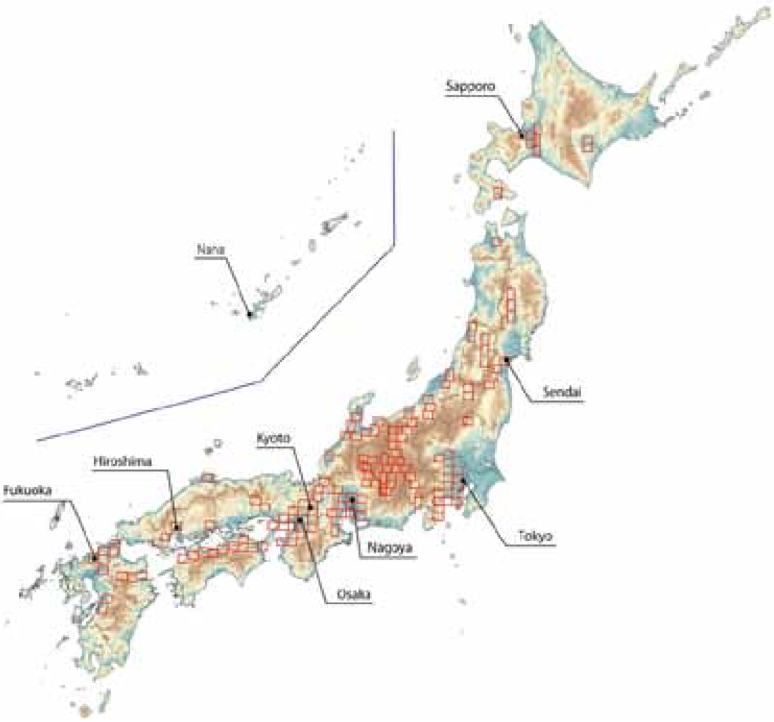

Fig. 1 The coverage of the Active Fault Map in Urban Areas in 2010.

After the Great Hanshin-Awaji Earthquake, interest in the large-scale investigation of urban active faults rapidly gained momentum. GSI received a supplementary budget from the Japanese government in 1995, and in 1996 GSI published 45 active fault maps covering the three major metropolitan areas (Tokyo, Osaka, and Nagoya) and ordinance-designated cities (Masaharu et al., 1997). Since then, GSI has attempted to publish 3 to 11 Active Fault Maps annually in spite of severe economic conditions (Fig. 1). In response to new findings, revised maps covering certain areas have been published since 2006. This paper describes the Active Fault Map in Urban Areas, published by GSI.

2. Map standard

Fig. 2 shows current contents as well as an example of the GSI's Active Fault Maps. Although terrain classification legends have varied in different periods and regions, the standards for active faults have been consistent from the beginning. Active faults are defined as repeated activities in intervals of roughly thousands to tens of thousands of years. The Active Fault Map, researchers' names, legend and comments, references, and production method are printed on a sheet. Map titles and legends include English translations. The underlying topographic maps of the active fault maps are 1:25,000 scale topographic maps created by GSI. The active fault maps include approximately 20 to 23 km (EW) by 18 km (NS) in landscape sheets, and 17 to 19 km (EW) by 26 km (NS) in portrait sheets. Paper size is 788 mm by 1091 mm.

3. Survey method

The Active Fault Maps published by GSI were mainly compiled by studying and interpreting aerial photographs while referring to results from previous research and surveys. The main photographs used were 1:20,000 monochrome and 1:10,000 color aerial photographs taken by GSI, as well as older photographs (mainly photographs taken by the U. S. Army in the 1940s) that reflect natural topography before artificial change. The survey results were drawn on terrain classifications in 1:25,000-scale topographic maps. Fig. 3 shows an example image of interpretation using aerial photographs.

GSI has established a committee for these active fault maps. Certification of active faults is confirmed by the head of the committee's research and ideas for each map. Furthermore, to maintain equilibrium between the interpretations of different researchers in identifying faults, several researchers work together and cross-check to reach a consensus before the results are transferred to 1:25,000 topographic maps with terrain classifications such as terraces. Table 1 shows the committee members who assisted with the Active Fault Maps published in 2010.

4. Comparison with other nationwide active fault maps

Nationwide active fault maps have been provided in some countries by governments or research groups. Active fault certification standards, map scales, and publication media vary. Table 2 shows Japan's pioneering active fault maps, as well as foreign active fault maps that display detailed fault specifications or are easy to access via the map database. There are many other nationwide active fault maps aside from those listed in Table 2, including projects in China (Chinese Working Group of the Project 206, 1989), Turkey (Saroglu et al., 1992), and Pakistan (Nakata et al., 1991).

Most of the active fault certification standards are age-dependent. Moreover, certainties and descriptions of faults are often included as additional information. The database of USGS, which is influenced by the global fault map of ILP (Trifonov and Machette, 1993), is unique in the sense that its authors certified active faults according to the magnitudes of predicted earthquakes and focused their descriptions of fault activity on matters such as slip rates.

In Japan, while active fault certification standards are age-dependent, broader activities over more than 10,000 years are included. The adopted standard and fault specifications of the GSI's Active Fault Map in Urban Areas and the Digital Active Fault Map of Japan (Nakata and Imaizumi, 2002) are the same, because the majority of experts who produced the Digital Active Map are also members of the committee behind the Active Fault Map in Urban Areas who assist with GSI projects (Table 1). These maps characterize active faults by repeated activities in intervals of roughly thousands to tens of thousands of years. At present, the Digital Active Fault Map of Japan is the largest scaled active fault map covering the whole of Japan including mountainous areas.

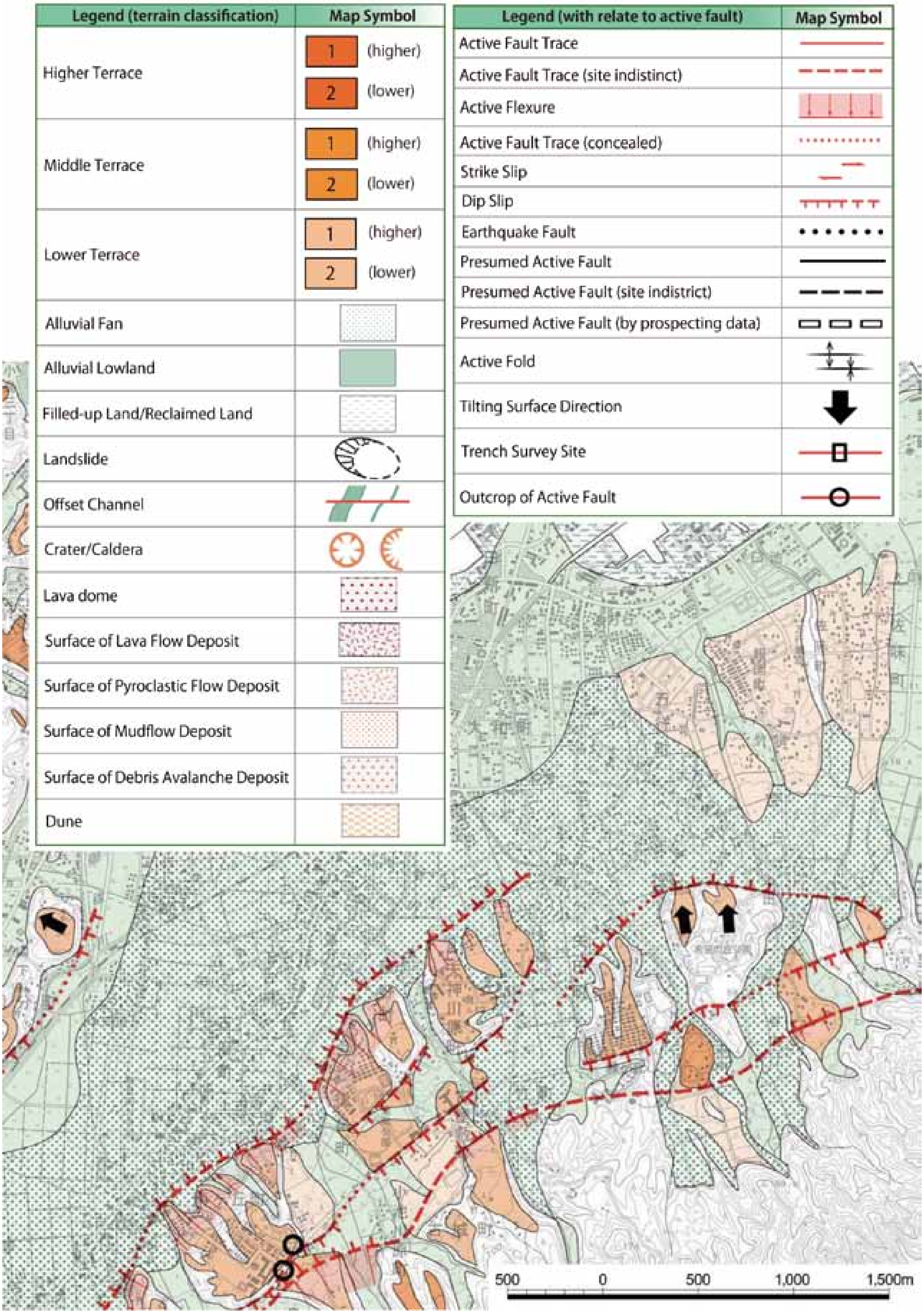

Fig. 2 Contents and an example of the Active Fault Map in Urban Areas. The example shows a clipped image of "Ochigata" published in 2010.

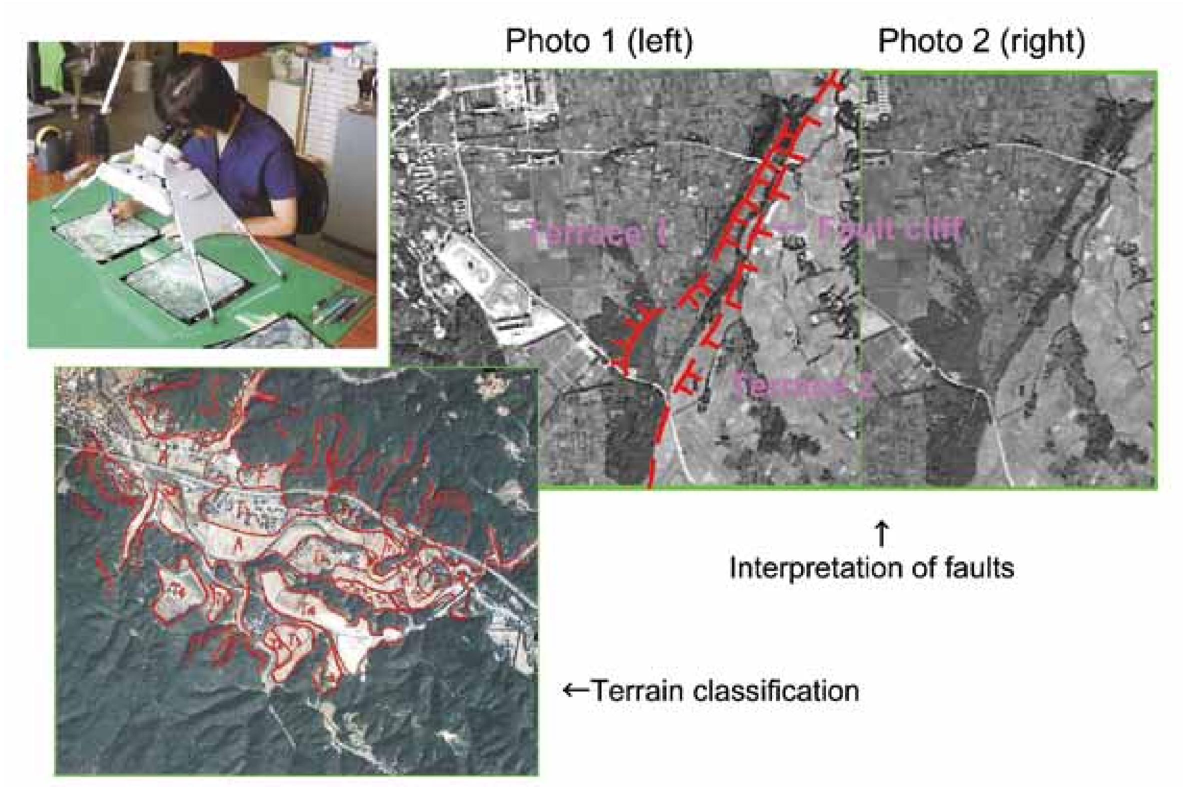

Fig. 3 Examples of interpretation using aerial photographs.

Table 1 Committee members who helped with the Active Fault Maps published in 2010

Noboru Chida (Oita University)	Hideaki Goto (Hiroshima University)
Kazuomi Hirakawa (Hokkaido University)	Daisuke Hirouchi (Shinshu University)
Toshifumi Imaizumi (Tohoku University)	Heihachiro Kaneda (Chiba University)
Yasuhiro Kumahara (Gunma University)	Yasutaka Ikeda (Tokyo University)
Tatsuya Ishiyama (Tohoku University)	Takahiro Miyauchi (Chiba University)
Takashi Nakata (Hiroshima University)	Atsumasa Okada (Ritsumeikan University)
Hiroshi Sawa (Turuoka National College of Technology)	Nobuhiko Sugito (Nagoya University)
Yasuhiro Suzuki (Nagoya University)	Masami Tougou (Housei University)
Hiroyuki Tsutsumi (Kyoto University)	Hiroshi Yagi (Yamagata University)

Table 2 Examples of nationwide databases and fault maps around the world

Country/region	Organization/author	Name of map/database	Map scale	Adopted standards	Fault specifications	Data formats
Eurasia and the Americas	International Lithosphere Program (ILP) II-2	World Map of Major Active Faults	1:5,000,000	Holocene (<10,000 years) and late Pleistocene (the past 100,000 - 130,000 years)	Slip rate, age of last fault activity, sense of displacement and reliability of fault identification, young folds and other features	Paper map, computer data base
New Zealand	GNS Science	New Zealand Active Faults Database	1:100,000	Evidence of having moved at least once in the past 100,000 years	Sense of fault, recurrence interval, last event, slip rate, single event displacement	Web GIS
United States	USGS	Quaternary Fault and Fold Database of the United States	NaN	Source of earthquakes M > 6, Quaternary	Geologic setting, fault orientation, fault type, sense of movement, slip rate, recurrence interval, the time of the most recent surface-faulting event	Web GIS, kmz, shapefile
Iran	National Geoscience Database of Iran	Fault Map of Iran	NaN	Enormous rupture or recent (<10,000 years) activity	Fault activity (active or not active during the past 10,000 years)	Web GIS
Taiwan	Lin, C. H. et al., 2000	The Active Fault Map of Taiwan	1:500,000	Recent (<100,000 years B.P.) activity or clear offsets	First category: (1) activated in the Holocene; (2) offset the manmade structures; (3) related to recent large earthquake (i.e. earthquake fault); (4) offset the recent alluvium; or (5) shows the creeping phenomena as proposed by present geodetic method. Second category: (1) activated within 100,000 years B.P.; or (2) offset the terrace deposits.	Paper map
Japan	The Research Group for Active Faults of Japan, 1991	Active Faults in Japan	1:200,000	Quaternary activity	Certainty of fault and fault type	Paper map
Japan	Nakata, T., Imaizumi, T. eds., 2002	Digital Active Fault Map of Japan	1:25,000	Repeated activities in intervals of roughly thousands to tens of thousands of years that have left their mark on the landform during the past hundreds of thousands of years	Certainty of fault and fault type, trench point, sense of movement	Shapefile, paper map

The Active Fault Map in Urban Areas includes new insight gained from the pioneering active fault maps.

The long-term evaluation of active faults in Japan has been examined by the Headquarters for Earthquake Research Promotion of the Ministry of Education, Culture, Sports, Science and Technology (http://www.jishin.go.jp/main/index-e.html).

5. Application

Local governments are the leading users of the GSI's Active Fault Maps. They use the maps mainly for their regional disaster prevention planning and the planning of public infrastructures such as water projects and disposal centers. Nishinomiya City in Hyogo Prefecture uses the maps as a basis for its building code. Local governments have made many investigations based on trenching and boring since the publication of the Active Fault Maps. Among private corporations, leading users include the real estate and nuclear power industries. A large amount of scientific research has also utilized the maps; e. g., research into tectonic geomorphology and simulations of seismic ground motions (Hirata et al., 2005; Thompson et al., 2010).

The Active Fault Maps enable users to understand the positional relationship between large buildings and active faults thanks to their relatively detailed map scale (1:25,000). The Active Fault Maps also show terrain classifications that were formed in the late Quaternary (e. g. terraces, alluvial lowlands, and landslides). Therefore, users can also learn about ground conditions and large landslides around active faults.

6. Future direction

GSI plans to continue publishing several Active Fault Maps annually. There is no plan to change the map legend; however, the methods of publication and investigation are expected to develop with the times. Internet browsing of the Active Fault Map in Urban Areas commenced in June 2006, with the Active Fault Maps published on the Japanese GSI website using map browsing systems. One of these systems utilizes a user-friendly approach that displays scanned tile images of the maps (see http://www1.gsi.go.jp/geowww/themap/fm/index.html for the clickable index map). Another is on a platform called "The Digital Japan," which is a web-based GIS system developed by GSI. This displays free digital maps created by GSI and includes an overlay function, easy drawing functions, and a gazetteer query function. As of 2010, The Digital Japan is available in Japanese and is mostly used by local Japanese governments for their transmission of thematic maps. Approximately 80% of the questions we receive are now taken from Internet users, and the migration from paper maps to Internet-based maps looks likely to accelerate. However, there is a difference between the needs of private users who want to check faults around their houses and public users who want to examine broad areas for their research or city planning: the latter probably require paper maps.

A special version of GSI's 1:25,000-scale Active Fault Map was published in 2009, after the Iwate-Miyagi Nairiku Earthquake struck in 2008 (Geographical Survey Institute, 2009; "Geographical Survey Institute" is GSI's previous English name). The aim of the map was to record the damaged state of terrain and to assist users with reconstruction. In addition to aerial photographs, GSI and the researchers who investigated the map also used airborne laser scanner (LiDAR) data for the survey of terrain. This included terrain interpretation by 1 m contours from LiDAR DEM, surveys of tectonic movement by the differential data of pre- and post-event DEMs, and the investigation of terrain changes using multi-temporal LiDAR DEMs (Fig. 4). LiDAR technology has spread rapidly among developed countries over the past decade. Nearly 70% of the land of Japan is covered by forests while urban areas are largely covered by overcrowded buildings, hence the texture of topographies in Japan appear to be finer than those of continents. However, LiDAR is able to survey fine topography beneath forests and can enable its users to ascertain urban topographies with buildings removed. For these reasons, LiDAR is in high demand in Japan. Furthermore, development can be seen in the surveying and archiving of LiDAR DEMs. After appropriate image processing, LiDAR DEM images provide accurate

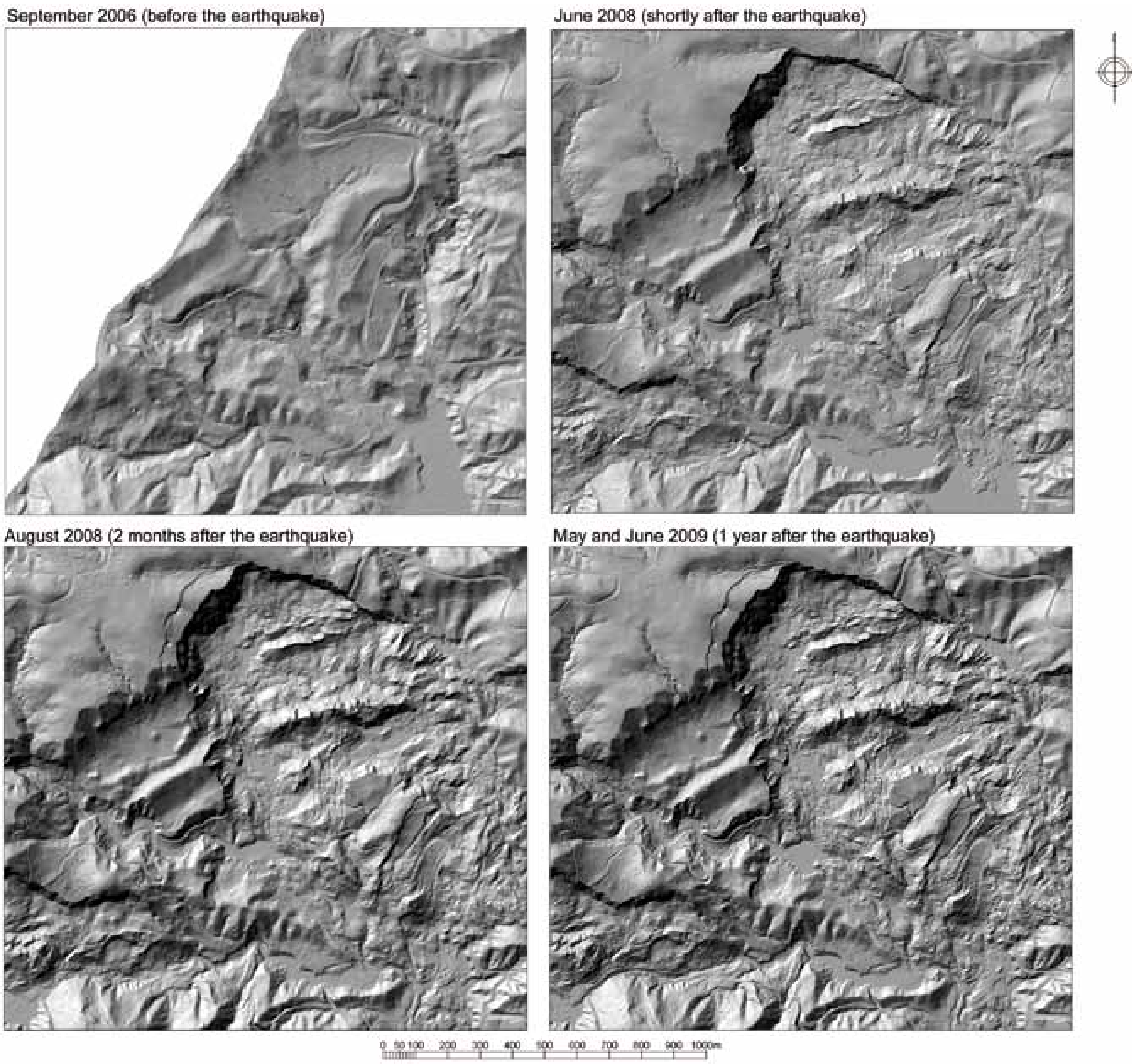

Fig. 4 Multi-temporal shaded-relief images created from LiDAR DEMs in the northern region of the Aratozawa dam (Geographical Survey Institute, 2009).

descriptions of topographic characteristics. The use of LiDAR DEMs for the GSI's Active Fault Maps will continue to expand

7. Conclusion

In Japan, inland active faults often lie in the mountain footslopes of urban neighborhoods. Therefore, information concerning the sites of active faults is very important for seismic hazard assessments. GSI will encourage ongoing improvement of the Active Fault Map in Urban Areas.

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