The Role of GIS in Volcano Disaster Prevention

by

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ABSTRACT

In 2000, there were two major volcanic eruptions in Japan-- the eruption of Mt. Usu in Hokkaido on March 31, which ended a dormant period of 23 years; and the eruption of Mt. Oyama in Miyake Island on July 8. The Geographical Survey Institute compiled GIS data on these two events on CD-R and distributed it to relevant disaster prevention organizations, municipalities and others who could use the information. A free download site has also been established on the Geographical Survey Institute's home page to provide information to as many general users as possible.These GIS data contain thematic information from base maps such as 1:25,000 topographic maps, public facilities, GPS observation point information, landform classifications from volcanic land condition maps, and landform change information derived from aerial photographs, among other sources. Free software enables users to display the data in overlay format, search information, and easily understand various types of data. Additionally, more highly integrated GIS software can help municipal organizations combine our data with theirs to establish observation systems for drafting public evacuation plans and learning more about volcanic activity.

KEY WORDS:
GIS in volcano Disaster Prevention
Disaster Prevention – Info Sharing
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1. INTRODUCTION

The crater of Mt. Usu is in close proximity with residential areas. However, using volcano information obtained before the eruption, hazard maps, etc., about 10,000 local residents were successfully evacuated without injury or loss of life. At Mt. Oyama in Miyake Island as well, the intensive observations by disaster prevention organizations and scientific investigations, and timely provision of pertinent information to local residents played a significant role in the successful, injury-free evacuation there. Presently, all of the residents of Miyake Island, who have been evacuated for several months now, still have not been able to return to the island due to concerns about emissions of poison gas from the volcano.

In the meantime, national and local governments and the Coordinating Committee for Prediction of Volcanic Eruption have been exchanging and evaluating information and considering measures to take. At the same time, these organizations have been using the Internet and mass media to provide the public with as much information as possible. For our part, we at the Geographical Survey Institute have been

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undertaking many relevant activities, such as making observations using various geodesic methods such as GPS, distance and angle observations, leveling surveys, etc., taking aerial photos and interpreting them to determine topographical changes, and providing basic information through maps and similar media. At the same time, we have opened two new pages at our web site: the "Mt. Usu Page" and the "Miyake and Kouzu Islands Page" to provide people in Japan with information on these important matters.
(URL http://www.gsi.go.jp/)
Most of the information in these disaster prevention activities has been geographic information. But while many proposals have been made for the utilization of GIS, there is almost no place in Japan where it has been used at an actual disaster site. The Geographical Survey Institute has a wealth of information needed to formulate volcano disaster prevention policy. To effectively utilize this information for disaster prevention and restoration activities, it is necessary to compile volcano data for GIS and establish a system that can provide this information quickly.

In March 1998, the Geographical Survey Institute began monitoring earthquakes in the Mt. Iwate area which had been signaling the volcano's reawakening. During this first use of volcano data for GIS, we looked at specific ways to compile and provide pertinent data. Then we compiled a CD-R version of "GIS Data for Disaster Prevention at Mt. Iwate" that included data from related organizations. This was distributed to relevant organizations in early November. The next year, a disaster prevention map was added to the information, data from observation organizations were corrected, etc., and compiled into a new CD-R called "GIS Data for Disaster Prevention at Mt. Iwate", which was not only distributed to relevant organizations, but also made available to the general public via the Internet.
Furthermore, since the eruption of Mt. Usu in March 2000 and the reawakening of volcanic activity on Miyake Island in June 2000, we have been using our experiences with Mt. Iwate to put our data in a manual format that can be provided even more quickly.

This paper describes "GIS Data for Mt. Usu," and discusses methods for its provision and use.

2. CONDITION OF GIS FOR PREVENTING VOLCANO DISASTERS

Our experiences with Mt. Usu have given us the following ideas regarding the areas in which this type of GIS can be used.
(1) Technical organizations such as the Coordinating Committee for Prediction of Volcanic Eruption investigate all the data provided by other organizations to determine current conditions and make predictions for the future.
(2) Organizations such as disaster prevention headquarters at the site examine all the materials provided by other organizations to formulate measures to establish evacuation sites, treat disaster victims, reduce the amount of damage, provide emergency relief and help with restoration.
(3) Instruction, safety confirmations, etc., should be provided to residents by police, fire fighters, self-defense forces (national guard), etc., for emergency evacuations, rescuing victims, and allowing evacuees to return home to retrieve necessary items.
(4) Information should be provided to local residents, the news media, and the Japanese people.

One of the problems with (1) and (2) is that different organizations prepare different maps to depict observation data, making it difficult to directly overlay information for interpretation. Therefore, there would be much merit for these organizations to do something as simple as use the same base map. Furthermore, if the main information from the various organizations could be provided as numerical data based on common base maps, this information could be overlaid on GIS to enable more rapid and accurate investigation.

In addition, regarding aspect (3), members of support units might not always be familiar with the local geography, so it might take time to provide guidance for residents and make the necessary confirmations.

Finally, regarding aspect (4), if the base maps for the transmitted information are conflicting, this will cause unnecessary confusion with residents and others.

Most of these problem points should be resolved to some extent by the use of GIS that is based on common map data. Here, we have aimed to develop GIS by conceptualizing (1) and (2).

In this case, the conditions we considered for deriving disaster-prevention GIS were as follows:
(1) There are multiple organizations that both receive and transmit information, and they have different experiences with GIS. Therefore, GIS application should be made as universal and simple as possible.
(2) A framework should be created and managed to provide new data on a daily basis.
(3) The GIS should be able to 1) incorporate provided data without modification, 2) display choices and overlays, 3) enlarge and reduce visual attributes, 4) set up colors and 5) move data, among other functions.
(4) In order to improve compatibility of analyses using more integrated GIS software, the geographic data format should be as universal as possible.

3. DESCRIPTION OF "GIS DATA FOR MT. Usu"

(1) Description of data

"GIS Data for Mt. Usu" can be roughly divided into base map data and thematic information. Base maps include 1:200,000 scale regional maps, and 1:25,000 and 1:5,000 scale topographic maps. Thematic information consists of information on public facilities, geographic names, results of triangulation and benchmark calculations, and diagrams showing land conditions around volcanoes. There is also information collected from the Usu eruption, which includes GPS observation positioning information, vertical fluctuation derived from leveling surveys, leveling observation route map, principal point positioning information from color aerial photographs, information on land deformation, and diagrams showing changes caused by ground upheaval. The following is an explanation of information gathered during times of emergency.

GPS observation positioning information is composed of the electronic control point of the Geographical Survey Institute (continuous observation point) and the data from the temporary GPS observation points that were set up after the eruption. It also contains attribute data that has been added from receivers (Trimble or Ashtec) data on observation initiation, etc.

The vertical fluctuation derived from leveling surveys consists of leveling results obtained before the eruption of Usu, and after the eruption (May and June), which were used to create relative fluctuation data (pre-eruption and May observations, pre-eruption and June observations).

The leveling observation route map is based on data obtained from leveling survey after the eruption (May and June).

Principal point positioning information was derived from a series of color aerial photographs taken by the Geographical Survey Institute after the eruption of Usu. These photos come with attribute information such as course and photo numbers.

Land deformation information is compiled by topographic interpretation made from the above color aerial photos. It comprises data on craters, pyroclastic mounds, faults, fissures, areas of mud deposition, and time-series data (7 periods) for areas of notable ground upheaval.

Upheaval maps contain information provided by the Public Works Research Institute. These maps depict differences in digital elevation models (DEMs) for two periods (3/31 and 4/26) around the NW base of Usu that were created with an aerial laser measurement system.

(2) Formats of software, data, etc.

Some organizations do not have GIS software, while others have versions that have little or no compatibility with other versions. Therefore, to

Table 1 GIS Data for Mt. Usu

Base map data	Map images (raster)	Four 1:200,000 regional maps	Muroran, Tomakomai, Iwanai, Sapporo
		Seven 1:25,000 topographic maps	Date, Mareppu, Abuta, Soubetsu, Toyoura, Touya, Nakatouya
	Principal data (vector)	Four 1:200,000 regional maps	Muroran, Tomakomai, Iwanai, Sapporo
		Seven 1:25,000 topographic maps	Date, Mareppu, Abuta, Soubetsu, Toyoura, Touya, Nakatouya
		Four 1:5,000 topographic maps	XI-PF-30/31, 31/32, 40/41, 41/42
Thematic information	Position reference information	Public facilities, geographic names	National organizations, local public bodies, schools, fire stations, hospitals, polices, post offices, geographic names
	Observation-related information	Control point results, GPS observation points, aerial photos, leveling route maps, etc.	Triangulation results, benchmark results, GPS observation point information, principal point positioning information from aerial photographs, leveling route maps, etc.
	Landform classification	Volcano land condition map “Mt. Usu”	Caldera wall, atrio, lava dome, cryptodome, scoria cone, etc.
	Landform change information	Results of photo analyses	Crater, fault/fissure, significant upheaval area, mud accumulation area, etc.
	Upheaval level information	Upheaval level change map	Differences in DEMs for two periods around the NW base of Usu

promote the greatest commonality with the least effort, we considered using free ArcExplorer software (ESRI, Inc., USA) and providing a relatively versatile data format. As a result, we decided to use image data in Tiff format, and vector data in ESRI Shape File format.

ArcExplorer can display all types of data selections, enlarge and reduce images, display attributes and search conditions, among other functions. To set symbols, colors, etc., for display with ArcExplorer, we considered potential standard displays and created project files (.aep). Double-clicking these project files (.aep) allows the user to call up standardized displays of the above data. We have also prepared files in (.apr) format for organizations that have ArcView software.

(3) Coordinate system

The formulation of volcano disaster prevention policies requires not only data from Geographical Survey Institute, but also the collection and integration of vast amount of data from related organizations in order to understand current conditions. Therefore, we considered a coordinate system that could be used with many types of information to make the creation of databases more efficient and facilitate the compilation of unique data from each organization. For this purpose, we have prepared two types of coordinate systems: BL (geographical coordinates) and XY (plane rectangular coordinates). Data can be overlaid only in files based on the same coordinate system. Since image data (raster data) from 1:200,000 regional maps and 1:25,000 topographic maps are converted into either BL or XY coordinates, they are different from published image data.

4. PROVISION OF "GIS DATA FOR Mt. Usu"

(1) CD-R format

We began compiling a database for GIS in May, finished it in mid-June, and distributed it in CD-R format to relevant organizations. These CD-Rs contain project files, data files, a set-up program for ArcExplorer, chart files for GIS data, a demonstration files, and a ReadMe file. Each CD-R is housed in a case that has simple directions for use on the back of the cover sheet.

We decided to prepare "GIS Data for Miyake Island, etc." at the end of August and held a press conference on September 8 to announce its release. This software was distributed to the same organizations that had received the Usu software.

(2) Access via the Internet

Because new information is being obtained every day, and this information should be released in a timely manner to help with the formulation of disaster policy, we created a site to provide access to base maps and theme maps through the Geographical Survey Institute's home page. This site was opened in September.

Fortunately, the activity of the Usu volcano has been gradually diminishing, and more and more residents are being allowed back to their homes, so we were never able to provide real-time information on a practical basis. However, we conducted some experiments to prepare for a similar disaster that may occur sometime in the future.

We also set up a user registration corner for organizations related to eruptions and disaster prevention so that those registered organizations can receive up-to-date information by e-mail.

5. THE USE OF "GIS DATA FOR Mt. USU"

(1) Display

Base maps can be displayed in different scales. In the case of paper maps, different sets of maps have to be used for different scales, but GIS software allows users the covered area to be easily converted to the required scale on the computer screen display. This makes it easier to understand conditions at the scene of a disaster.

"GIS Data for Mt. Usu" include image and vector data from 1:200,000 scale regional maps, and 1:25,000 topographic maps, as well as vector data from 1:5,000 topographic maps. These maps have some compatibility issues depending on the scale display on the screen. By using the function for setting the minimum and maximum scales of ArcExplorer, small-scale display of an entire image can be 1:200,000 vector data; but, as the image is enlarged, scale is automatically converted to 1:200,000 raster data, 1:25,000 vector data, 1:25,000 raster data, and 1:5,000 vector data, in that order.

In addition, for blocked out data such as land classification data, land deformation information, etc., from volcano land condition maps, the programs makes half-tone displays so that raster images of the base map can be seen.

(2) Examples of landform classification and displays of the crater in the present study

Figure 1 is an overlay map showing volcano land conditions, the crater and area of upheaval as 1:25,000 map images. Volcano land conditions are used to show past lava dome. We can clearly see that the most recent area of activity was at the western edge of this area, away from the hard lava dome.

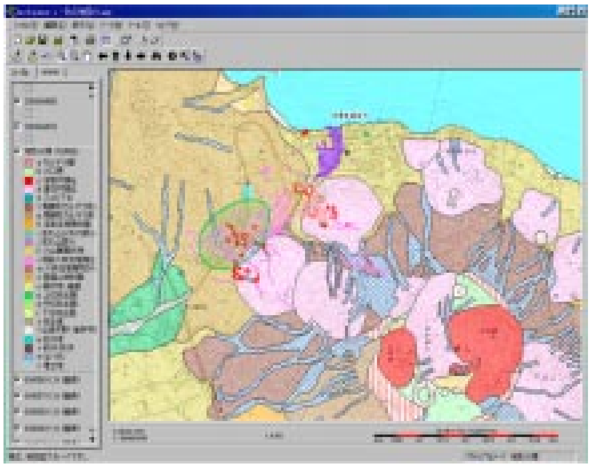

Fig.1

(3) Example of interpreted land deformation

Figure 2 shows the geological attributes interpreted from aerial photographs taken on April 3, 2000. Information on the crater, faults, fissures, area of conspicuous upheaval, are overlaid as 1:25,000 map images to allow more suitable investigations to be made. Furthermore, overlaying this information with data from other organizations should increase the effectiveness of interpretations in general.

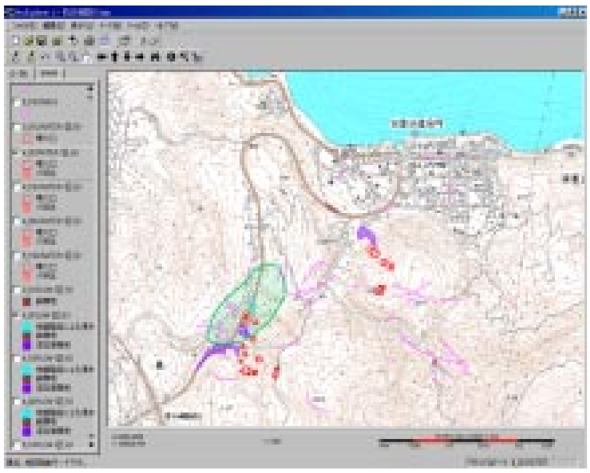

Fig. 2

(4) Example of displaying positions of public facilities

Figure 3 is an example of public facilities data overlaid on a 1:200,000 map image. By overlaying this image with information on designated evacuation areas, road restrictions, etc., it can be used to consider evacuation measures and provide information to residents.

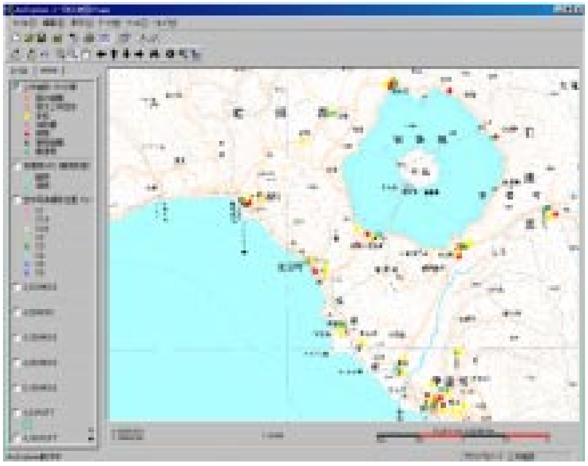

Fig.3

(5) Example of attribute display

Figure 4 is an image of detailed public facility attributes that was created using the individual attribute display function of ArcExplorer. By managing attribute data that authorities should be aware of, such as the number of families in evacuation shelters, number of patients in hospitals, etc., these data can be displayed on GIS to improve the efficiency of emergency response.

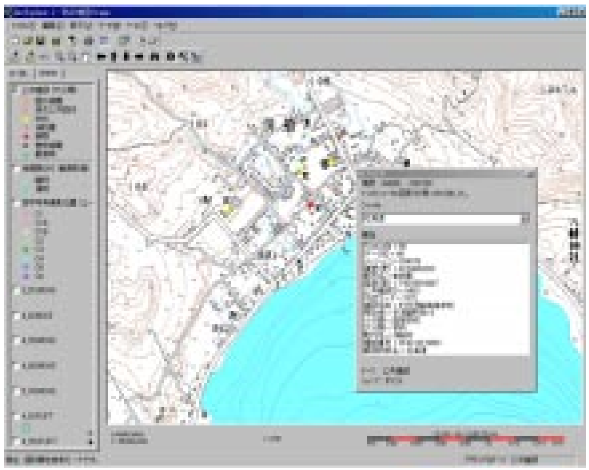

Fig.4

(6) Example of condition search

Figure 5 shows an example of a search of hospitals in Date City that was made using the condition search function of ArcExplorer. The search turned up the Date Red Cross Hospital. We feel that this type of search function can make many kinds of uses possible as soon as attribute data are entered.

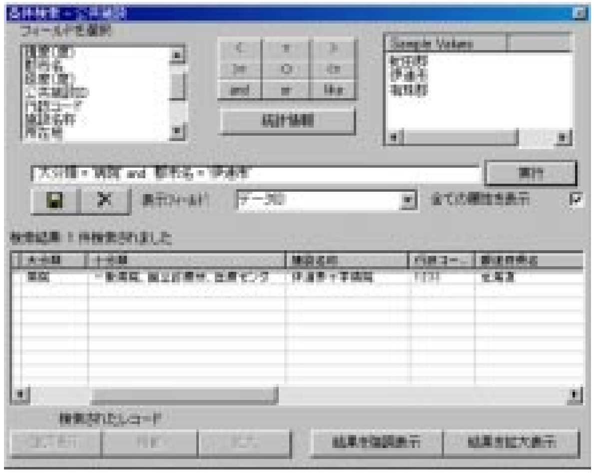

Fig.5

(7) Example of highlighted display of search results

Figure 6 is a display of cryptodome made with the condition search function. Results are highlighted in red on the map.

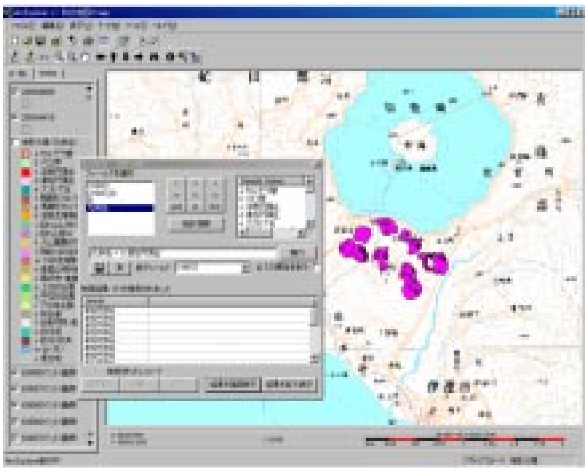

Fig. 6

(8) Use of other types of GIS software

For example, the use of ArcView can link image data from aerial photographs with the principal point information from these photos. This makes it possible to display needed photos from the position from which they were taken.

In addition, it is easy to add or delete figure data. For example, showing polygon information from evacuated areas on the display and integrating it with information on residents would make it easier to grasp information on resident in evacuated areas.

6. CONCLUSION

Because of our conviction that GIS would be effective in analyzing damage caused by volcanic eruptions last year, we compiled a data set called "GIS Data for Mt. Usu". This paper has reported on the contents and merits of GIS utilization. However, in order to use GIS software and data to formulate actual policies to prevent volcano disasters, much remains to be done, including enhancing GIS software functions, standardizing information from disaster prevention headquarters and related organizations, developing new GIS software, pre-processing data for the GIS database, and developing a suitable system for GIS.

We must consider these issues and work toward implementing whatever is feasible.

In recent years, many GIS-related seminars and conferences have been held in various locations to spread the word about this important tool. Local governmental organizations are using GIS to update information from their own topographic maps for urban planning, disaster prevention, and providing information on facilities and historical sites.

Finally, by making various types of information on Japan's land available in electronic media, the Internet can be used to, for example, simulate volcanic eruptions, predict lava flow, and select evacuation sites. Thus this will help authorities to prevent volcano-related disasters.

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