Research on a method of estimating the potential depth of slope failure using the Airborne Electromagnetic Survey

*shuji seto[1], teruyoshi takahara[1], atsuhiko kinoshita[1], hideaki mizuno[1], katsushi kawato[2], minoru okumura[2], ryota kageura[2]

1.Public Works Research Institute, 2.Nippon Engineering Consultants Co., Ltd.

At Ontake volcano in 1984 and Kurikoma volcano in 2008, areas of the volcanoes collapsed and large-scale sediment disasters occurred. These events were unrelated to volcanic eruption. We conducted case studies using airborne electromagnetic surveys to investigate slopes likely to induce landslides on such volcanoes.
Airborne electromagnetic surveys are effective for rapidly investigating wide-ranging extreme environments that persons cannot enter. The surveys were conducted by a helicopter carrying survey instruments; this method of non-contact investigation acquires resistivity data by electromagnetic induction. The surveys were conducted on 15 active volcanoes where volcanic events could have serious social implications. These case studies extracted data showing only areas likely to be at risk of collapse. This is the first time that such data on slopes likely to induce landslides and on estimated collapse depths have been obtained. It remains necessary to find a method of extracting precise data on slopes likely to induce landslides on each volcano.
Firstly, we categorized the properties of the collapsed slopes as cap rock type, extended collapse type, or landslide type on the basis of collapse case and paid attention to the slope of the cap rock type and defined the collapse range based mainly on the topography and geological properties.
Secondly, we analyzed the resistivity structures of collapse cases with a differential filter and found that collapse occurred at a depth at which resistivity suddenly changes. In other volcanoes, we could estimate collapse depth by extracting areas where resistivity suddenly changes.
Several cases, including Hokkaido Komagatake, Asama volcano, and Ontake volcano, will be introduced in this presentation.

Keywords: Airborne Electromagnetic Survey, resistivity, volcano, collapse depth, differential filter

Study on the depth information of resistivity using frequency-domain airborne electromagnetic survey

*minoru okumura[1], Ryota KAGEURA[1], Katsushi KAWATO[1], Teruyoshi TAKAHARA[2], Shuji SETO[2], Atsuhiko KINOSHITA[2]

1.NIPPON ENGINEERING CONSULTANTS CO.,LTD., 2.Public Works Research Institute

Airborne electromagnetic survey is a method to investigate the electrical resistivity distribution of the subsurface from the air using electromagnetic induction. And this method can be subdivided into the time domain type and frequency domain type.
Frequency domain type is a system using several combinations of the transmitter coil and receiver coil. And the survey is towing a sensor that contains the coils by the aircraft. In general, the depth of investigation of the frequency domain type is less than the time domain type. However, near-surface resolution of the frequency domain type is better.
The procedure of cross-sectional analysis of the frequency domain type shown below. First, create an apparent resistivity map for each frequency using the measured data. The next is to calculate the plot depth of apparent resistivity for each frequency. This depth is a function of frequency and apparent resistivity. Inversion has been studied in order to obtain accurate depth information. However, case study using a numerical model are many, but almost no study from the perspective of disaster prevention work.
This study is a report of the cross-sectional analysis using the actual data of airborne electromagnetic survey of the frequency domain type. We compared the apparent resistivity cross-section and the one-dimensional inverted cross section on the basis of the actual geological and groundwater information.
First, we were collected survey data of wide area slopes, including a large-scale collapse and landslides in the distribution areas of accretionary complex and volcanics. And, we were classified depth information of the apparent resistivity in a large-scale collapse of slopes and landslide slope. As a result, large-scale collapsed slopes and landslide slope(including the slope of the neighborhood) can be classified into two types. Type(1) is upper layer is high resistivity, and lower layer is low resistivity, and resistivity contrast between two layers is large. Type(2) is upper layer is low resistivity, and lower layer is high resistivity, and resistivity contrast between two layers is small. Focusing on moving scale of soil, we have found that there are many type(1) slopes near the large-scale collapsed.
So, we create the apparent resistivity cross section by Sengpiel(2000) using the actual measurement data at the type(1), and we applied a one-dimensional inversion to it. Next, we compared the each cross section and geological information and groundwater by the drill hole, and understand the accuracy of the resistivity distribution in the depth direction. As a result, the depth of the layer boundary of type(1) was almost the same in the apparent resistivity cross-section and the one-dimensional inversion analysis. From this, there is no accuracy problems in using the apparent resistivity cross section by Sengpiel(2000) in the preliminary investigation of the large-scale collapse of the type(1) slope.
On the other hand, the resistivity contrast of apparent resistivity cross-section of the type(2) is usually small. Therefore, quantitative analysis may be difficult.
The next, in order to increase the accuracy of depth information of resistivity cross-section of the type(2), we're intend to apply the one-dimensional inversion. Also, we want to continue the study using real data in disaster prevention work because there is almost no example of application of two-dimensional and three-dimensional inversion in the frequency domain airborne electromagnetic

survey.

Keywords: frequency-domain airborne EM, resistivity section, inversion

A case study of aerial time domain helicopter EM survey

*Ryoji Hirata[1], Youichi Yuuki[1], Om Pradan[1]

1.OYO corporation

Aerial source (Tx) and receiver (Rx) time domain electromagnetic (EM) survey systems have been developed and used in many countries from the past. Recently, some survey companies are carrying out airborne time domain EM survey in Japan by bringing a whole system from overseas. Meanwhile, grounded Electrical Source Airborne Transient EM (GREATEM) system has been in operation in Japan since about 10 years.
Last year, aerial Tx and Rx Time domain EM system (P-THEM) was introduced in Japan for the first time. In this report, we introduce the case study and result of the survey carried out with the new P-THEM system.

Keywords: time domain EM, airborne survey

Influence of ground clearance on airborne gravity gradiometry survey

*Sho Aibe[1], Atsushi Shirota[1], Akihiko Chiba[1], Hiroshi Yamaguchi[2], Masato Fukuda[3]

1.Sumiko Resources Exploration & Development Co., Ltd., 2.Fugro Japan Co., Ltd., 3.Japan Oil, Gas and Metals National Corporation

In geophysical surveys, increase in the distance between the sensors and the survey targets generally causes deterioration of resolution. Higher altitude above the ground level leads to degraded resolution in airborne surveys. While low-level flight is desirable for high resolution measurements, the ground clearance in actual surveys can increase to avoid rugged terrains, tall trees and high-rise structures including power lines. While the influence of higher clearance can be estimated by upward-continuing the gravity data to the flight surface, only a few case studies based on actual surveys are found.

Japan Oil, Gas and Metals National Corporation has been conducting airborne gravity gradiometer (AGG) surveys at the nominal terrain clearance of 120 m in the geothermal potential evaluation projects by using heliborne geophysical methods. We collected AGG data by varying the ground altitude at 120 m, 250 m, 500 m and 750m for the purpose of directly evaluating the influence of flight height on the vertical gravity gradient component (GDD) and vertical gravity (gD).

In the survey results, we observed a significant loss in the resolution of GDD due to the increased flight height, compared with that of gD. We plan to compare the measured results at each altitude with the calculated values by upward continuation of GDD and gD at 120m.

Keywords: Airbornne Gravity Gradiometry, Vertical gravity gradient, Flight height

3D magnetization structure of Aogashima Volcano by aero-, sea-surface and deep-sea magnetic vector surveys

Jun matsuo[1], Nobuhiro Isezaki[2], *Keizo Sayanagi[2]

1.OYO International Corporation, 2.Institute of Oceanic Research and Development, Tokai University

Measurement of magnetic anomaly vectors is absolutely essential to obtain a magnetization structure of the magnetized body. We have developed a new magnetometer for measurement of the vector magnetic field, called High Precision Magnetic survey System (HPMS), which can be used in various situations, for instance, in the air, on the sea surface and in the deep-sea. We have applied the HPMS as Heliborne Three Component Magnetometer (HTCM), Deep-tow Three Component Magnetometer (DTCM) and Shipboard Three Component Magnetometer (STCM) for airborne surveys (2006 and 2009) and marine magnetic surveys (2014) over and around the volcanic island, Aogashima. A helicopter of Nakanihon air service and Tokai University Vessel 'Bousei-Maru' were used for the HTCM surveys and for the STCM and DTCM surveys, respectively. The Aogashima Island is an active volcanic island included in the Izu-Ogasawara volcanic arc. The objectives of this study were to obtain magnetic anomaly vectors on Aogashima volcano by aero-, sea surface and deep-sea magnetic surveys, and to clarify 3 dimensional spaced 3 component magnetization structure of the volcano.

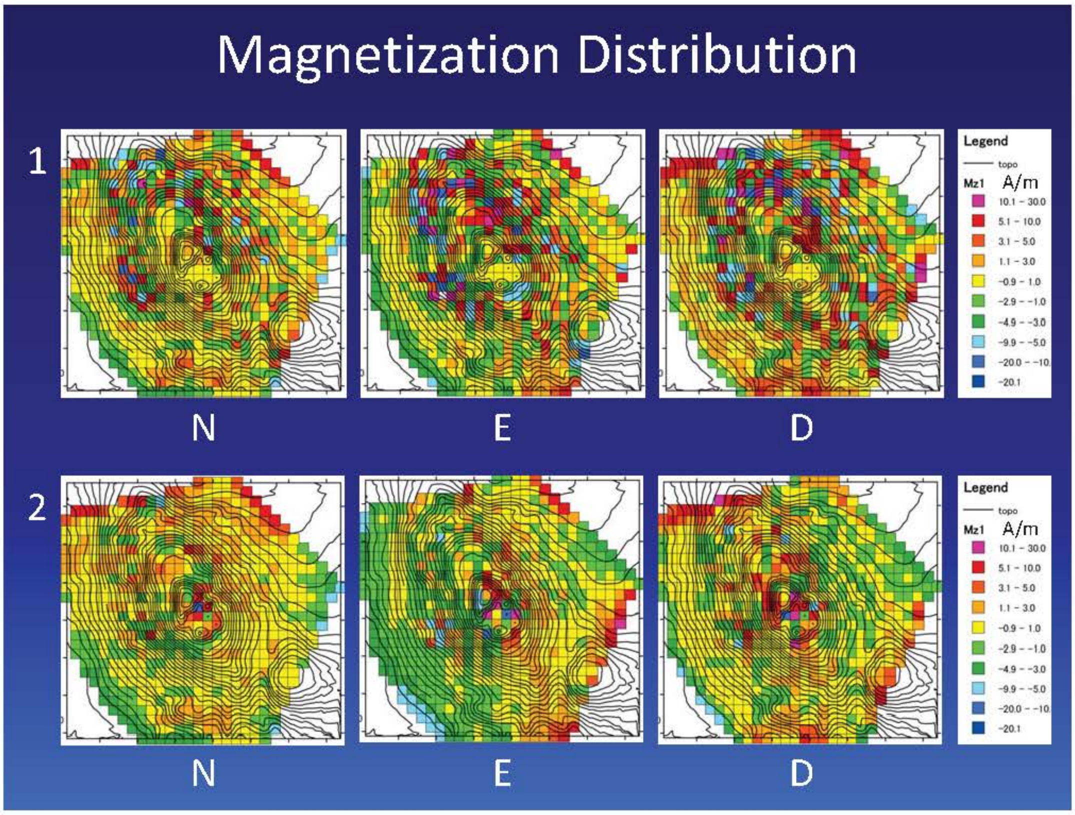
In the HTCM surveys, a towing frame mounted with the HPMS, GPS and wireless LAN devices was towed using a fiber rope below the helicopter. In the DTCM survey, the towing frame mounted with the HPMS, acoustic positioning (SSBL) and acoustic communication devices was towed near the sea bottom using a wire rope. In the STCM survey, the towing frame mounted with the HPMS and GPS devices was fixed on the after-deck of the ship. Three components of the observed geomagnetic field, F = (Hh, Hs, Hv), and gyro data (yaw, pitch, roll) are sampled in 10Hz. SSBL positions are fixed every 10 seconds. F, the vector in ship's coordinate (heading, starboard, vertical) is rotated to the vector in Earth's coordinate (X, Y, Z: north, east, vertical down) using the gyro data. From the rotated vector (X, Y, Z), the IGRF field is subtracted to get three components of a magnetic anomaly (dX, dY, dZ).

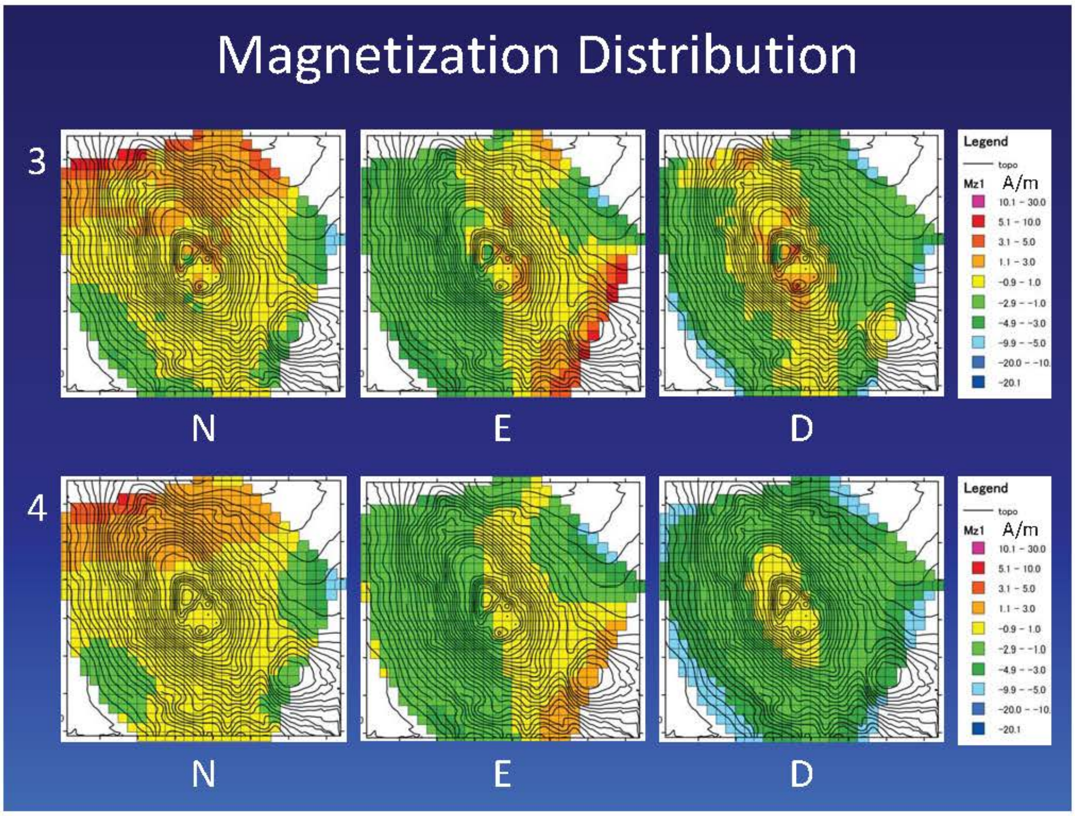
3D spaced 3 component magnetizations of the Aogashima volcano are analyzed by solving the linear least square equation for the obtained magnetic anomaly vectors. We tried 4 layer block model which consists of blocks with width of 500m, depth of 500m, and thickness of 250 m, 500 m, 750 m and 1000 m. The total number of the blocks is 2,492. The upper surface of Layer 1 approximates topographic surface. 25,536 data of three components of magnetic anomalies were inputted, and 7,476 data of three components of magnetization of 3D magnetized body were obtained by magnetization inversion with least square method using a dumping factor.

The figure shows three components of magnetization of each layer. Thin contour lines show the topography. The Aogashima Island is located at the center of each map. The shallower layers have complicated magnetization distribution, especially in Layer 1. There are larger magnetization to the north of the island as seen in Layers 1 and 2. The deeper layers such as Layers 3 and 4 have smooth magnetization distribution comparing with Layers 1 and 2. Layers 3 and 4 show the following characteristic distributions: relatively large positive north component of magnetization to the north of the island, contours of east component of that elongated along the ridge, and small downward component of that along the ridge in Layer 3 and under the island in Layer 4.

In conclusion, we have developed the versatile and useful equipment corresponding to a multiplatform that can survey the vector magnetic fields in the air, on the sea surface and in the deep-sea. That enables us to calculate the 3 dimensional and 3 components magnetization. The HPMS should make a contribution for more detailed and reliable magnetic geophysical surveys.

Keywords: three components of geomagnetic anomaly, magnetization vector, 3D magnetization structure, vector magnetometer for multi-platform, Shipboard Three Component Magnetometer (STCM), Deep-tow Three Component Magnetometer (DTCM)


Magnetization Distribution
1
Legend
topo
Mz1 A/m
10.1 - 30.0
5.1 - 10.0
3.1 - 5.0
1.1 - 3.0
-0.9 - 1.0
-2.9 - -1.0
-4.9 - -3.0
-9.9 - -5.0
-20.0 - -10.
-20.1
N
E
D
2
Legend
topo
Mz1 A/m
10.1 - 30.0
5.1 - 10.0
3.1 - 5.0
1.1 - 3.0
-0.9 - 1.0
-2.9 - -1.0
-4.9 - -3.0
-9.9 - -5.0
-20.0 - -10.
-20.1
N
E
D


Magnetization Distribution
3
Legend
topo
Mz1 A/m
10.1 - 30.0
5.1 - 10.0
3.1 - 5.0
1.1 - 3.0
-0.9 - 1.0
-2.9 - -1.0
-4.9 - -3.0
-9.9 - -5.0
-20.0 - -10.
-20.1
N
E
D
4
Legend
topo
Mz1 A/m
10.1 - 30.0
5.1 - 10.0
3.1 - 5.0
1.1 - 3.0
-0.9 - 1.0
-2.9 - -1.0
-4.9 - -3.0
-9.9 - -5.0
-20.0 - -10.
-20.1
N
E
D

Repeated aeromagnetic surveys at Kuchi-erabu-jima volcano by using unmanned helicopter

*Takao Koyama[1], Takayuki Kaneko[1], Takao Ohminato[1], Atsushi Watanabe[1], Wataru Kanda[2]

1.Earthquake Research Institute, University of Tokyo, 2.Tokyo Institute of Technology

Kuchi-erabu-jima island is an active volcanic island in Kyushu, and some volcanic events happened in the last century. Very recently, a phreatic eruption occurred on Aug. 23rd 2014, and a phreatomagmatic explosion followed it on May 29th 2015. At the latter eruption, a pyroclastic flow attacked a village, and all the residents in the island have evacuated out of the island. The eruptive activity never happens after a tiny Vulcanian eruption on 18th June 2015.
We conducted repeated aeromagnetic surveys in April and September 2015 by using unmanned helicopter. The altitude of the flight was kept to about 100 m above the ground and geomagnetic total intensity data at an almost whole area above the volcanoes were obtained. A total measurement length of flight was about 60 km.
The first survey in April 2015 revealed that the average magnetization is so small as about 1.8 A/m, which is typical value for andesite. Also the crater areas show very low magnetization, while surrounding areas of the crater have relatively strong magnetization as much as 3 A/m. The second survey in September detected small changes of the geomagnetic field. It reveals that the demagnetization in the crater and the magnetization around the crater. It may indicate that the magmatic products erupted out of the crater and showed the demagnetized features, while some ashes and pyroclastic flow remain at the volcanic surface around the crater and got some magnetization.

Keywords: aeromagnetic survey, unmanned helicopter, volcano

