Clarifying Geological Structure of Deep Catastrophic Landslide Using Airborne Electromagnetic Survey

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Abstract

The airborne electromagnetic (AEM) survey is useful to estimate the resistivity structure of the underground by measuring electromagnetic inductions for a short period. In this study, we target the deep catastrophic landslides (DCL) which had been triggered by Iwate-Miyagi Inland Earthquake in 2008 at the mountain slopes of Mt. Kurikoma. The fluidized materials ran down and attacked a small spa hotel and resulted in a lot of loss of human life. In considering mitigation measures, it is important to predict the slope where the DCL occurs. In this study, we aimed to estimate DCLs risk of slopes. First, we conducted a field survey; we confirmed the distribution of geological conditions and collapse section. Soft altered tuff breccia has spread on the whole slopes of the survey area, and is covered by andesite cap rock at the upper part of slopes. It was estimated DCL has occurred at the boundary of andesite and altered tuff breccia. Secondly, we conducted AEM survey over a wide range including the landslide. While the specific resistivity of the uncollapsed zone is 400Ω-m or more, that of collapsed zone is 100-200Ω-m below and shows low resistivity value. Lastly, as a result of the comparison between the results of the field survey and that of the AEM survey, a spatial distribution of specific resistivity almost correspond to the underground geologic settings, such as andesite cap rock. By the distribution of high-resistivity zone, andesite and collapsed andesite layer could be estimated. In this survey area, the collapse occurs in the andesite cap rock, the high-resistivity zone is equivalent to the slope at risk of DCLs. In conclusion, in order to evaluate a risk of DCL, it is necessary to take into account underground information. The AEM survey can be one of the practical methods applicable for the evaluation of a risk of DCL.

Keywords: deep catastrophic landslide, airborne electromagnetic survey, resistivity,

1. Introduction

Prediction of deep catastrophic landslide-prone (DCL-prone) slope is critical to make mitigation measures. In order to evaluate a risk of DCL, it is necessary to know underground information. About the extracting method of the DCLs risk of slopes, many studies have been accomplished until now (Sasahara et al., 2014; Chigira et al., 2012; Yokoyama et al.; 2012). These studies were based on an analysis technique that focuses on the topography of the ground surface. There are few studies focused on the subsurface structure which has influenced outbreak of the DCL.

In this study, the authors target DCLs which had been triggered by Iwate-Miyagi Inland Earthquake in 2008 in mountain slopes of Mt. Kurikoma, which is an active volcano in the north-eastern Japan. Field survey was conducted in and around the DCLs where the airborne electromagnetic survey, hereinafter called AEM survey, was also executed. In order to evaluate applicability of the AEM survey, the authors compare the results of the field survey with that of the AEM survey in this report.

2. Location

Survey area is the headwaters of the Dozou of the left hand tributary of Sanhazama river of Kitakami River system. DCLs were induced in the headwaters slope by the Iwate-Miyagi Inland Earthquake on June 14th, 2008. The fluidized materials ran down and attacked a small spa hotel "Komanoyu Onsen" and resulted in a lot of loss of human life (Fig.1).

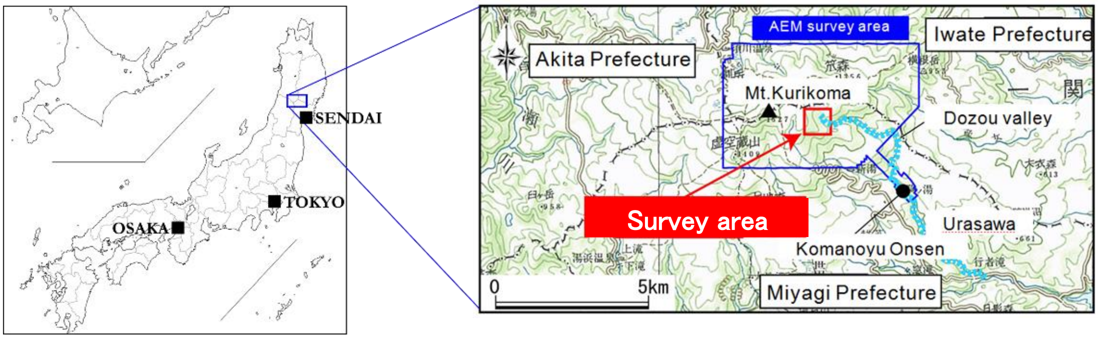

Fig. 1 Location of the survey area

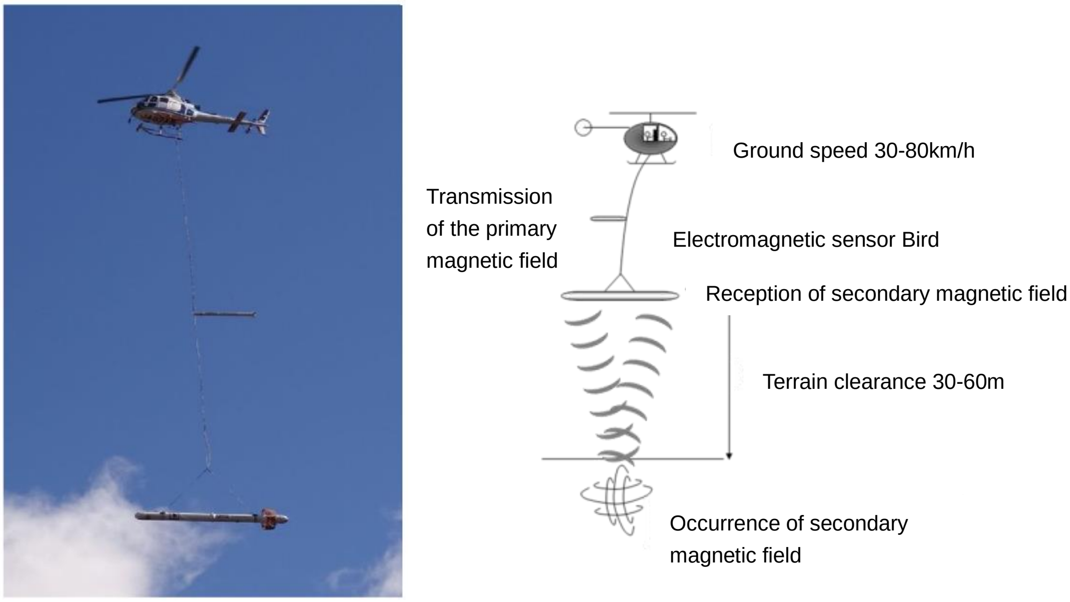

Fig. 2 The schematic view of the airborne electromagnetic survey method

3. Investigative method

3.1 Geological distribution and structure

We performed geological survey to clarify the geological distribution, structures and weathering state of rocks of the entire landslide area. Geological survey was uniformly carried out not only within the landslide but also back slope. We observed the outcrops along the route, and measured the fault direction, weathering conditions and geological structure. The field survey was conducted to measure the resistivity of the outcrop rock using a simple ratio resistivity measuring device.

3.2 AEM survey

AEM survey obtains the ground resistivity of a wide area by measuring the intensity of a secondary magnetic field induced in the ground by a primary magnetic field transmitted at a transmitting coil. Since the lower the frequency of the electromagnetic waves, the deeper they penetrate into the ground, it is possible to survey a wide range of depths by using multiple frequencies simultaneously. Resistivity obtained by airborne electromagnetic survey is a value that varies depending on the type of rock, water saturation, porosity, and clay minerals. Generally, resistivity is high in fresh hard rock, and decreases with the degree of weathering (Archie, 1942; Takakura, 2009).

Fig. 2 shows the schematic view of the airborne electromagnetic survey method with actual survey situation. With this system, it is possible to explore about 100 to 150 m depth and measure three dimensional resistivity distributions by navigating a helicopter in a lenticular pattern.

In this study, AEM survey was conducted around Mt. Kurikoma in August 2009.

4. Result and Discussion

The geological setting of the survey area is composed of volcanic ejecta of Mt. Kurikoma. Tuff breccia, altered tuff breccia, autobrecciated lava, and andesite are layered and tephra is on the top of the layers (Fig.3). The dimension the DCL was about 400m in length, about 300m in width and about 15 to 20 m in thickness. The volume of the landslide was estimated to be about 890,000 m3.

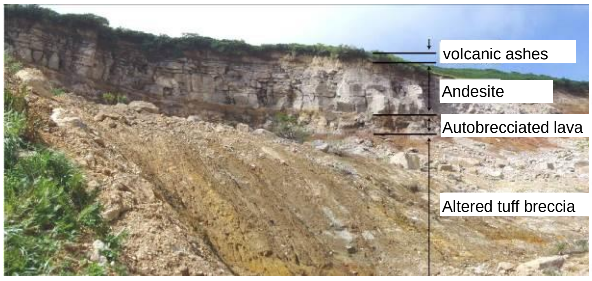

Fig. 3 Circumstances surrounding the collapse scarp of Dozou valley

Table 1 Relationship between geology and resistivity

resistivity	surface deposit	basement geology
400Ω-m >	—	andesite
200Ω-m～400Ω-m	sediment of old landslide	
150Ω-m～200Ω-m	tephra	autobrecciated lava altered tuff brecca tuff brecca
100Ω-m～150Ω-m	collapse landslide	
< 100Ω-m	sediment in progress	

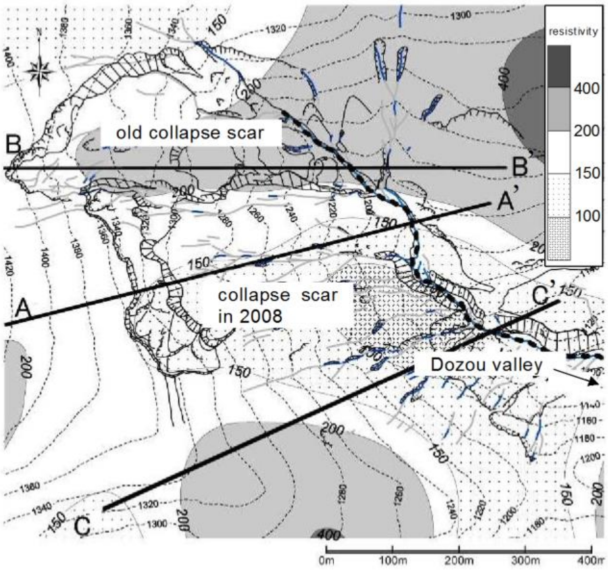

Fig. 4 Spatial distribution of specific resistivity of the shallowest layer of the survey area

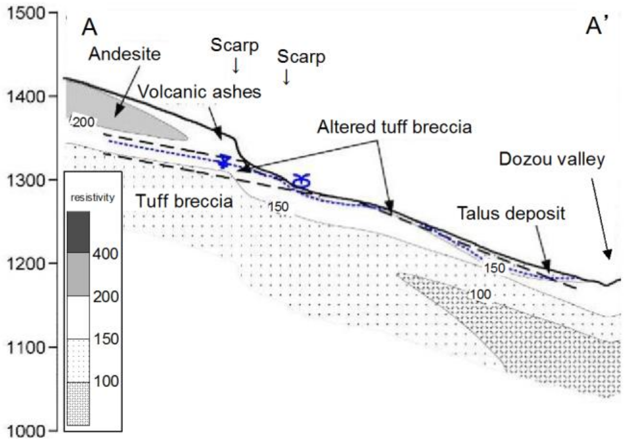

Fig. 5 Cross longitudinal profile of specific resistivity along the section line A-A'

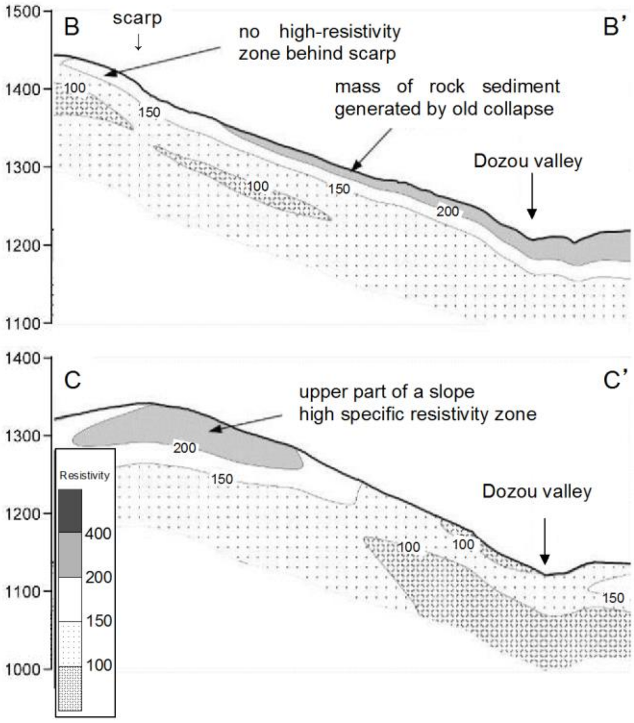

Fig. 6 Cross longitudinal profile of specific resistivity along the section lines B-B' and C-C'

The sliding mass is divided into the two blocks. The first one is the upper block near the head scarp and the second is the lower block which had already run down as a mudflow and hardly remains on the slope. The weakly altered tuff breccia with kaolin clay is exposed on the slope surface lower than the upper block.

Fig. 4 shows spatial distribution of specific resistivity of the shallowest layer of the survey area. Fig. 5 shows cross longitudinal profile of specific resistivity along the section line A-A' in Fig. 4 which is a middle line of the DCL in 2008. Fig. 6 shows the sections B-B' and C-C' where no landslide has occurred so far. As shown in Fig. 4 the field survey infers that the sliding mass of the DCL in 2008 seemed to be composed of the andesite cap rock, and weakly altered tuff breccia.

As shown in cross sectional profile of the A-A' section line, the distribution of the andesite cap rock seems to correspond almost to a higher specific resistivity zone (over 400Ω･m) , that is higher than 200Ω･m while the distribution of the underlying altered tuff breccia is roughly shown as a lower specific resistivity zone. On the other hand, a section line B-B' crosses over an ancient DCL scar. As the cross sectional profile of the section line B-B', no higher specific resistivity zone is found in the upper part of the slope whereas there is a thin layer with higher specific resistivity on the lower part of the slope. It seems to correspond to the fact that there is no andesite cap rock but andesite talus deposits because the cap rock seemed to have collapsed and deposited on the lower part of the slope at the time of the ancient DCL. While the specific resistivity of the uncollapsed zone is 400Ω・m or more, that of collapsed zone is 100-200Ω・m below and shows low resistivity value.

Using simple resistivity measuring instrument, the resistivity of outcrops was measured. The hard andesite lava was high resistivity, altered andesite was low resistivity, and especially spring part is very low. Trends in the local resistivity by resistivity measurement of outcrops were harmonious with the aerial electromagnetic resistivity.

5. Conclusion

As a result of the comparison between the results of the field survey and that of the AEM survey, a spatial distribution of specific resistivity almost correspond to the underground geologic settings, such as andesite cap rock. In order to evaluate a risk of DCL, it is necessary to take into account underground information. The AEM survey can be one of the practical methods applicable for the evaluation of a risk of DCL.

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