Elucidation of the Mechanism of Deep-seated Catastrophic Landslides Utilizing Drone Airborne Electromagnetic Survey Technology

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1. Introduction

During typhoon No. 12 (Typhoon Talas) on August 25, 2011, total rainfall in Japan's Kii Peninsula exceeded 1 000 mm over a wide area, and caused deep-seated catastrophic landslides (DCL) with a landslide area of 1 ha or more at 72 locations in the Kii Peninsula.

Research on the mechanism of DCL was carried out from various angles, including topography, geology, hydrology, etc., from immediately after the disaster. In particular, from past research, there is a possibility that fault crushing belts crossing a slope may either induce infiltration of the surrounding groundwater or dam up groundwater. This paper introduces efforts to elucidate the collapse mechanism of a DCL (**Photo-1**) in the Kumano region of Tanabe City, Wakayama Prefecture by utilizing drone airborne electromagnetic surveying.

2. Outline of Kumano region and content of survey

The Kumano region, which is the object of this research, lies in the upper basin of the Kumanogawa River in the Hikigawa river system. Sedimentary rocks are widely distributed in the area. **Photo-1** shows the condition of the Kumano region 1 day after the disaster. Note that the solid yellow line is the survey line of the drone survey, and the dotted white lines show the locations of fault crushing belts determined from the results of a geological reconnaissance and electrical survey. The scale of the DCL is 440 m in width, 250 m in height and 480 m in length, and the volume of the collapsed sediment is approximately 5.26 million m^3. In this study, the resistivity distribution at depths of approximately 0 to 200 m below ground was measured by a drone airborne electromagnetic survey 3 days after typhoon No. 14 (Typhoon Chan-Hom) in October 2020 and during the dry season in the early part of December of the same year in order to investigate the effect of the fault crushing belts on the behavior of the groundwater during heavy rain.

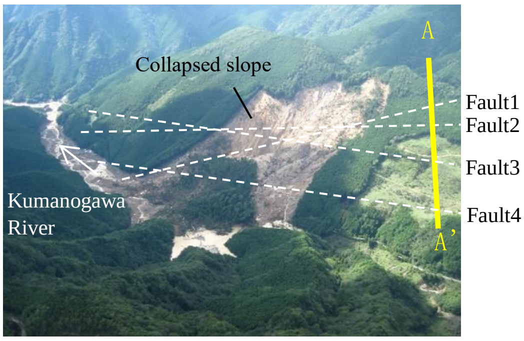

Photo-1 Condition of Kumano region 1 day after disaster (photographed on Sept. 5, 2011)

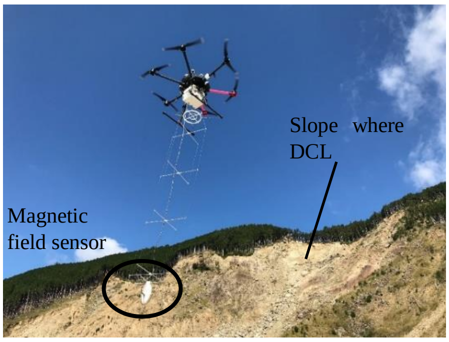

Photo-2 Condition of drone airborne electromagnetic

3. Characteristics of resistivity distribution in vicinity of fault crushing belts by drone airborne electromagnetic survey

Photo-2 shows the condition of the drone airborne electromagnetic survey. A magnetic field is generated by passing a current through a cable laid on the ground surface, and the underground vertical component of the field is measured by a magnetic field sensor suspended from the drone.

First, an airborne electromagnetic survey was conducted by a helicopter on November 28, 2012 to grasp the general geology and distribution of groundwater and spring water. This survey was carried out 2 days after total rainfall of 98.5 mm (at the Japan Meteorological Agency's Nishikawa observation point) due to the passage of a weather front. **Fig.-1** shows the resistivity distribution at approximately 0 to 10 m below ground. As above, the yellow solid line represents the survey line of the electrical survey and drone survey, and the white dotted lines show the locations of fault crushing belts. Low resistivity was detected from the middle to the bottom part of the collapsed slope. The groundwater level is considered to be located at a position shallower than about 10 m below ground in the results of groundwater level observation of the same area during the dry season, and it is thought that this low resistivity zone was formed by groundwater and spring water.

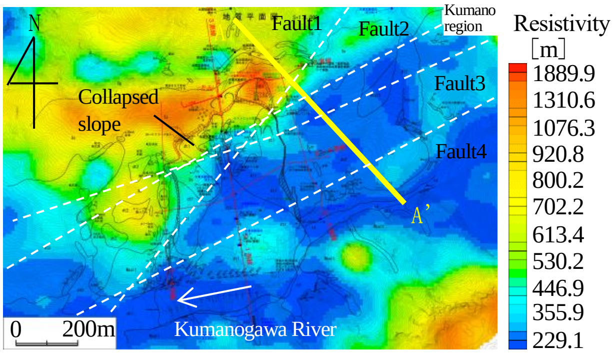

Fig.-1 Result of airborne electromagnetic survey (approx. 0 to 10 m below ground)

Next, **Fig.-2** shows the results of an electrical survey (survey line A-A’ in **Photo-1** and **Fig.-1**) during the period November 25-27, 2020. The electrical survey was carried out by the two-electrode method using an electrode spacing of 10 m and a survey depth of 200 m. This survey measured resistivity during the dry season, as there have been almost no rainfall for 4 days at the start of the measurements. Locations where resistivity varied greatly were considered to be faults, and 4 such locations were found.

Fig.-3 (a) shows the resistivity distribution diagram (survey line A-A’ in **Photo-1** and **Fig.-1**) obtained by the drone airborne electromagnetic survey on December 2, 2020, and **(b)** shows the longitudinal (vertical) section distribution diagram obtained by dividing the resistivity value on October 13, 2020, 3 days after the end of rain caused by typhoon No. 14 in October 2020, by the resistivity values in (a). From Fig.-3 (a), it can be understood that a high resistivity zones exist on the A side from fault 1 and on the A’ side from fault 2. These zones are thought to contain a large number of voids as a result of crushing. From (b), the groundwater has infiltrated into the crushed zone on the A side of fault 1, and movement of that groundwater has stopped in the vicinity of fault 1. Thus, fault 1 is estimated to be a type of fault that dams up groundwater. Between faults 1 and 2, the altitude becomes higher as the light-blue zone moves toward the A’ side, and it is thought that the groundwater flows downward toward the Hyakkendani valley in this area. Between faults 1 and 3, it is thought that the groundwater flows down from near the ridge toward the A’ side at a depth of around 80 m underground. Based on the facts that fault 2 contains many cracks and the width of the light-blue zone also becomes wider around fault 2, fault 2 is considered to be a type that induces infiltration of groundwater from the surrounding area. Around fault 3, the width of the light-blue zone becomes smaller as it approaches fault 4, and the light-blue zone disappears near fault 4. Therefore, it is considered that faults 3 and 4 are faults of a type that dams up the groundwater, in the same way as fault 1.

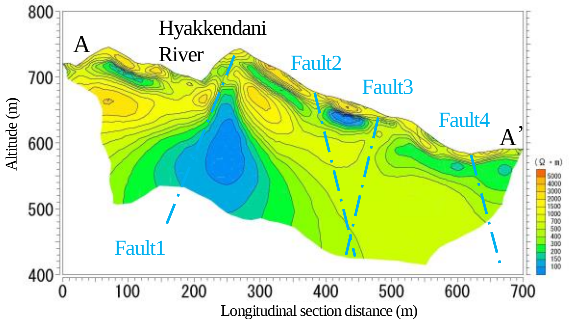

Fig.-2 Result of electrical survey at A-A’ survey line in Photo-1 and Fig.-1

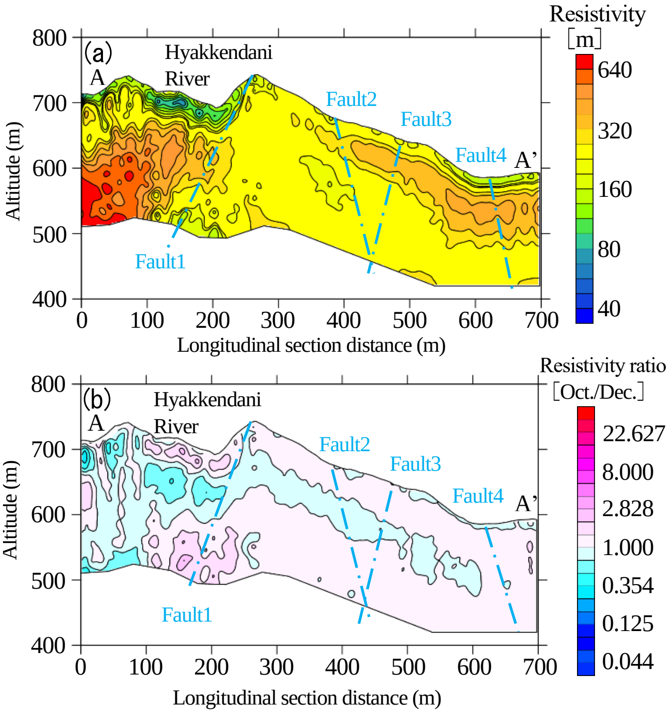

Fig.-3 (a) Longitudinal distribution of resistivity in dry season (Dec. 12, 2020) by drone survey at A-A’ survey line in Photo-1 and Fig.-2, (b) Longitudinal distribution of value obtained by dividing resistivity value 3 days after the end of rain (total rainfall: 217 mm) caused by typhoon No. 14 of 2020 by the resistivity values in (a) at same survey line

4. Conclusion

In this study, the mechanism of deep-seated catastrophic landslides in the Kumano region was investigated from the results of an airborne electromagnetic survey by a drone, and it was suggested that fault crushing belts had a large effect during the disaster. Based on the results of this research, we plan to establish a risk assessment technique for deep-seated catastrophic landslides.

☞For more information:

Kinoshita et al. (2021): Elucidation of mechanism of deep-seated catastrophic landslides by drone airborne electromagnetic survey in Kumano region where DCLs occurred during typhoon No. 12 in 2011, Abstracts of the FY 2021 Annual Conference of the Japan Society of Erosion Control Engineering (in Japanese)