Geomorphological and geological characteristics of deep-seated gravitational slope deformation in the Kamikochi area, central Japan

Satoru KOJIMA[(1)], Yoshiyuki HASEGAWA[(1, 4)], Naoya IWAMOTO[(1, 5)] , Keitaro KOMURA[(2)] and Hidehisa NAGATA[(3)]

(1) Department of Civil Engineering, Gifu University, Japan
E-mail: skojima@gifu-u.ac.jp
(2) Department of Earth Sciences, Chiba University, Japan, (3) Fusuido Co. Ltd., Japan,
Present address: (4) Dai Nippon Construction, Japan, (5) Sanyu Consultants Inc., Japan

Abstract

Geomorphic features related to the deep-seated gravitational slope deformations (DSGSDs) such as double and multiple ridges and uphill-facing scarps are ubiquitous on the Nagakabe Ridge in the Kamikochi area, Northern Japan Alps. We carried out hand-auger drilling at two linear-depressions between double ridges on the Nagakabe Ridge, and got nine cores about 80 to 160 cm long. The lithology of the nine cores are more or less similar, and the sediments are composed of carbonaceous black mud, dark or light gray mud, and yellowish brown silt, from top to bottom. Refractive index analyses on bubble type volcanic glasses included in the sediments near the gray mud horizons suggest that they are derived from the Kikai Akahoya tephra erupted about 7.3 ka about 1,000 km southwest from this area. The sediment accumulation rate is calculated as about 0.1 mm/year on the basis of this age. The formation of these DSGSDs might be related to the climate change from the dry and cold condition in the Last Glacial Maximum to the wet and humid climate in the post-glacial period about 10 ka.

Keywords: deep-seated gravitational slope deformation, landslide, Kamikochi, Japan

1. Introduction

Recent development of LiDAR (Light Detection and Ranging or Laser Imaging Detection and Ranging) technique makes it possible to map the landform in detail, and the topography of mountains which is difficult to access because of poor road network system or thick vegetations can be visualized clearly and be analyzed precisely. By using the LiDAR maps, many deep-seated gravitational slope deformations (DSGSDs; Crosta et al., 2013) have been recognized in mountain ranges of Japan (e.g., Kojima et al., 2015). The study of DSGSDs is very important, because they are considered to be precursors of deep-seated catastrophic landslides (e.g., Chigira et al., 2013). The geologic characteristics and development history of the DSGSDs, however, are poorly understood in Japan, except a few pioneering works (e.g., Mokudai and Chigira, 2004). This study aims at revealing the geomorphological and geological characteristics of the DSGSDs on the Nagakabe Ridge in the Kamikochi area, central Japan (Fig. 1), following our similar researches in the Etsumi Mountain Range, central Japan, and the Mt. Tsuenomine area, Kii Peninsula (Kojima et al., 2015).

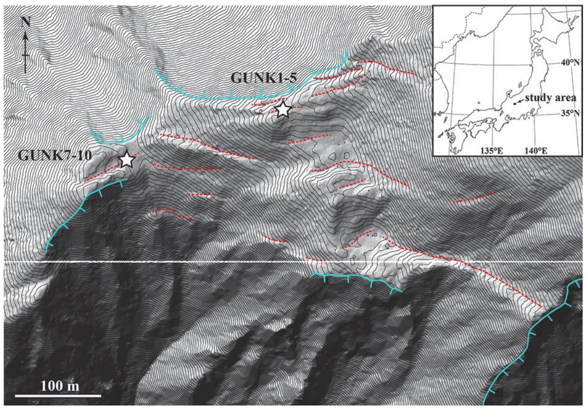

Fig. 1 Topographic map and index map (inset) of the Nagakabe Ridge in Kamikochi area, central Japan. Red dotted line: linear depression, blue line with hatched line: landslide scarp, star: hand-auger drilling site. The topographic map is prepared on the basis of the DEM data provided by the Matsumoto Sabo Office, Hokuriku Regional Development Bureau, Ministry of Land, Infrastructure, Transport and Tourism, Japan, and the contour interval is 2 m.

2. Geomorphological and geological setting

The study area in the southern part of the Northern Japan Alps is about 2,000 m above sea level, and is located about 500 m below the tree line of this area.

Rocks in and around the study area consist mostly of sandstone and mudstone with minor amounts of chert; they are constituents of the Mino terrane composed of Jurassic accretionary complexes (Harayama, 1990). The bedding planes of the rocks are trending NE-SW parallel to the direction of the Nagakabe Ridge, and are dipping to NW about 40-60°. Many small-scale landslides occur on the steeper SE-facing slopes of the ridge, whereas DSGSDs are common on the NW-facing slopes. Many double and multiple ridges and uphill-facing scarps, which are considered to be the DSGSDs, are present along the Nagakabe Ridge (Fig. 1).

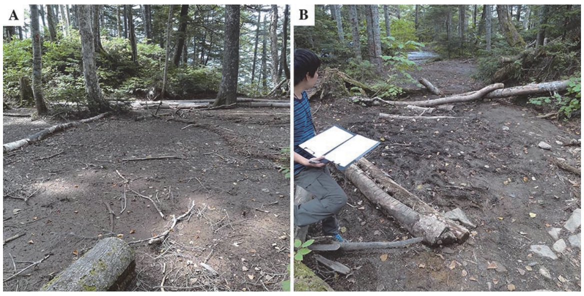

Fig. 2 Photographs showing the flat surfaces of the drilling sites. A: drilling site of GUNK-7 to 10, B: drilling site of GUNK-1 to 5.

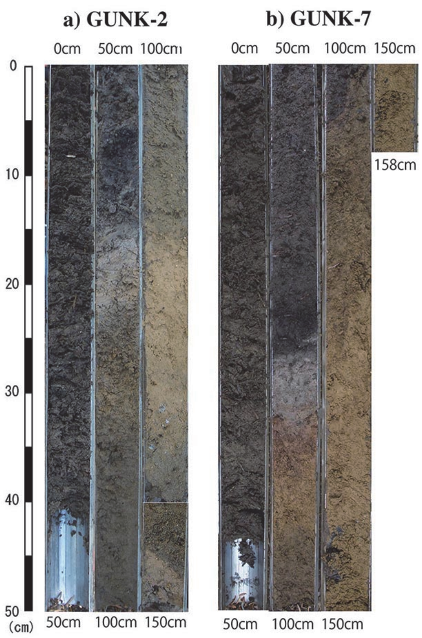

Fig. 3 Photographs of the two examples of cores, GUNK-2 and GUNK-7, drilled on the Nagakabe Ridge, Kamikochi area, central Japan.

3. Lithology of sediments accumulated in the ridge-top depressions

Two sites are selected for detail studies (Figs. 1 and 2), and hand-auger drilling was carried out at these sites. We obtained nine cores, GUNK-1 to 5 and GUNK-7 to 10, from these two sites, respectively (Fig. 1). Length of the cores ranges from 80 to 160 cm.

The lithology of the sediments is more or less similar through the nine cores; black carbonaceous mud is the topmost sediments, dark or light gray mud at the middle, and yellowish brown silt at the bottom (Figs. 3 and 4). The carbonaceous mud includes rich plant fragments derived from the surrounding forests. The deposition of the gray mud without plant remains suggests an environmental change at this horizon of these sites. The silt formations occasionally including granule- to pebble-size clasts of volcanic and sedimentary rocks at their lower horizons are interpreted to be loam or aeolian deposits.

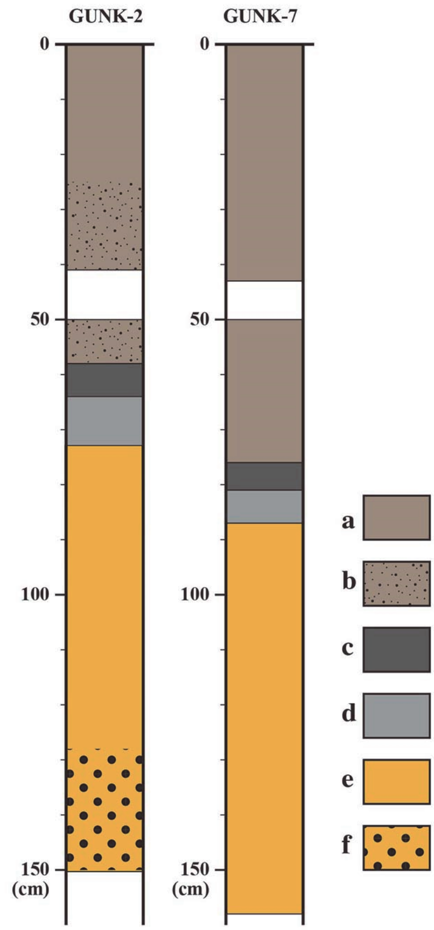

Fig. 4 Geologic columnar sections of the representative cores drilled on the Nagakabe Ridge, Kamikochi area, central Japan. a: carbonaceous mud, b: carbonaceous mud with sand grains, c: dark gray mud, d: light gray mud, e: silt, f: silt with granule- or pebble-sized clasts.

4. Clast composition and age of the sediments

4.1 Composition of the sediments

In order to estimate the age and depositional environment of the sediments, composition of clastic grains between 62 and 200 micrometers in diameter (250 and 100 mesh) was analyzed by using the polarizing optical microscope. The grains include volcanic glass, crystal grains, plant fragments, charcoal, and unknown grains (Figs. 5 and 6). The plant fragments are rich in the upper horizons, and it is consistent with the lithology of the sediments. The volcanic glasses are of three kinds: bubble, pumice-fibrous, and pumice-sponge types. The drilling sites are within 15 km from the volcanoes, such as Mt. Yakedake and Akandana active during the last 30,000 years (Harayama, 1990; Oikawa, 2002).

4.2 Origin of the volcanic glass

Local small volcanic eruptions usually eject pumice type volcanic glasses, whereas extremely large volcanic eruptions typically disperse bubble type glasses over a wide area (Machida and Arai, 2003). Tephras derived from such large eruptions have been well identified mainly on the basis of the refractive index of the bubble type volcanic glasses and provide key evidence on the age of the Quaternary sediments in Japan (Machida and Arai, 2003). The refractive index of the bubble type volcanic glasses extracted from their peak horizons (62-72 cm in depth of GUNK-2 and 87-92 cm of GUNK-7) were concentrated between 1.508 and 1.516 (Fig. 7), and coincide with that of Kikai Akahoya tephra (K-Ah) erupted about 6.3 ka (7.3 cal ka) about 1,000 km southwest of the study area (Machida and Arai, 2003).

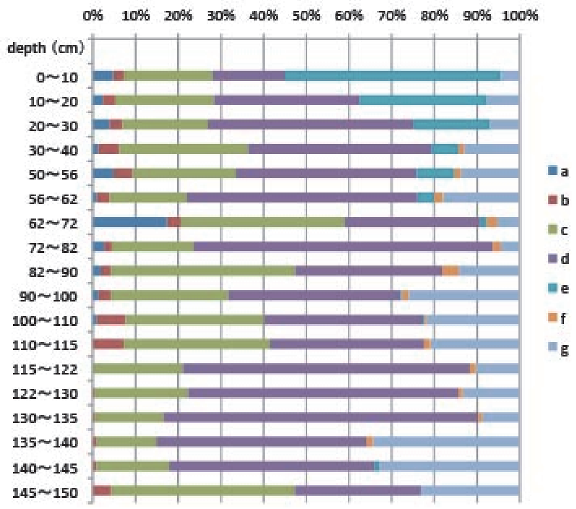

Fig. 5 Composition of grains between 62 and 200 micrometers in diameter in the sediments accumulated in the linear depression, GUNK-2, on the Nagakabe Ridge, Kamikochi area, central Japan. Randomly extracted 200 grains were counted for each horizon. a-c: volcanic glass a: bubble type, b: pumice-fibrous type, c: pumice-sponge type, d: crystal grain, e: plant fragment, f: charcoal, g: unknown.

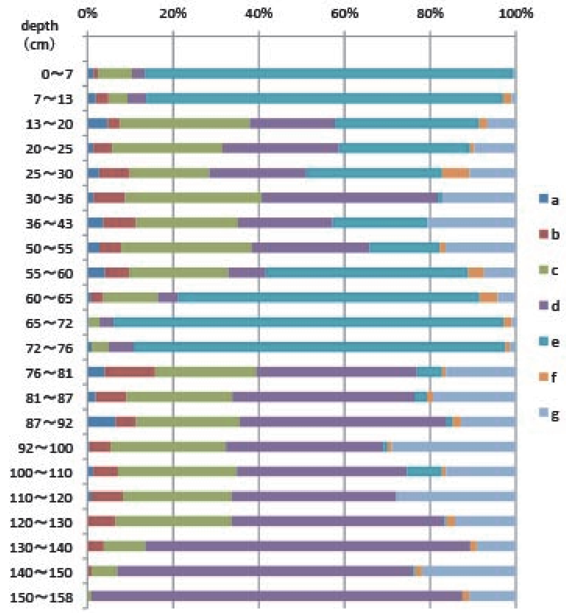

Fig. 6 Composition of grains between 62 and 200 micrometers in diameter in the sediments accumulated in the linear depression, GUNK-7, on the Nagakabe Ridge, Kamikochi area, central Japan. See Fig. 5 for explanation of the abbreviations.

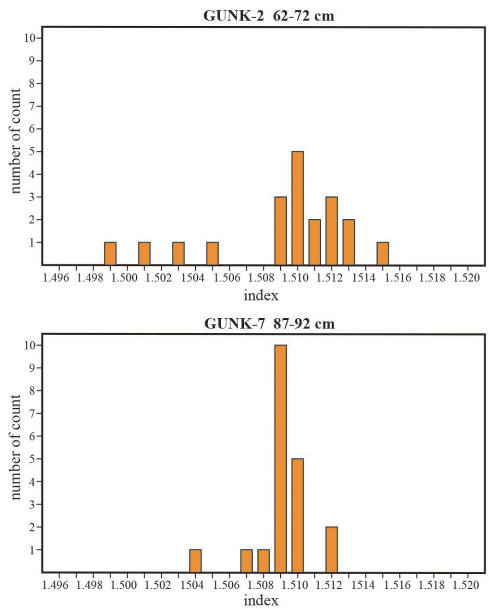

Fig. 7 Refractive index of bubble type volcanic glasses in the sediments accumulated in the linear depressions, GUNK-2 (62-72 cm in depth) and GUNK-7 (87-92 cm in depth), on the Nagakabe Ridge, Kamikochi area, central Japan.

5. Discussion

Sedimentary environmental change and/or climate change, from the poor to rich vegetation environment, can be estimated at the horizons of gray mud. Although the tree line is about 500 m higher in elevation than the drilling sites now, it must be lower than the sites before the age of gray mud horizon. Peak concentration of volcanic glasses of bubble type and their refractive index suggest that the change occurred around 7.3 cal ka. After the Last Glacial Maximum about 25-20 ka, the climate was becoming warmer, milder, and wet. The sedimentary environmental change detected in the drill cores treated in this study might be related to this global climate change.

Sediment accumulation rate of the carbonaceous mud (and gray mud) calculated by using the age of the K-Ah tephra is about 0.1 mm/year. If we could extend the rate to the bottom of the sediments, the DSGSDs are estimated to have formed about 15 ka. This might be also related to the climate change after the Last Glacial Maximum.

6. Conclusions

The sediment cores drilled by hand-auger equipments at the linear depressions on the Nagakabe Ridge in the Kamikochi area, central Japan, are 80-160 cm in length, and are composed of carbonaceous black mud, dark-light gray mud, and brown silt, from top to bottom. Refractive index analyses on bubble type volcanic glasses included near the gray mud horizons suggest that they are derived from the Kikai Akahoya tephra erupted about 7.3 cal ka. The sediment accumulation rate is calculated to be about 0.1 mm/year on the basis of this age. The formation of these DSGSDs might be related to the climate change between the Last Glacial Maximum and the present-day warm and humid condition.

Acknowledgements

The authors thank to the Agency for Cultural Affairs of Japan, the Ministry of the Environment Government of Japan, and the Ministry of Agriculture, Forestry and Fisheries of Japan for the permission of sample collection by the hand-auger drilling. The DEM data were provided by the Matsumoto Sabo Office, Hokuriku Regional Development Bureau, Ministry of Land, Infrastructure, Transport and Tourism, Japan. The measurements of refractive index of the volcanic glasses were performed at the Department of Earth Sciences, Chiba University under the guidance by Associate Professor Heitaro Kaneda. Part of this study was financially supported by Grants-in-Aid for Scientific Research, Japan Society for the Promotion of Science, 23540531 and 26400487.

References

Chigira, M., Tsou, C.Y., Matsushi, Y., Hiraishi, N. and Matsuzawa, M. (2013): Topographic precursors and geological structures of deep-seated catastrophic landslides caused by Typhoon Talas. Geomorphology, Vol. 201, pp. 479-493.

Crosta, G.B., Frattini, P. and Agliardi, F. (2013): Deep seated gravitational slope deformations in the European Alps. Tectonophysics, Vol. 605, pp. 13-33.

Harayama, S. (1990): Geology of the Kamikochi district. With geologicla sheet map at 1:50,000, Geologial Survey of Japan, 175pp. [JE]

Kojima, S., Kaneda, H., Nagata, H., Niwa, R., Iwamoto, N., Kayamoto, K. and Ohtani, T. (2015): Development history of landslide-related sagging geomorphology in orogenic belts: examples in central Japan. In: Lollino, G., Giordan, D., Crosta, G.B., Corominas, J., Azzam, R., Wasowski, J. and Sciarra, N. (eds.) Engineering Geology for Society and Territory, Vol. 2, pp. 553-558, Springer, Heidelberg.

Machida, H. and Arai, F. (2003): Atlas of Tephra in and around Japan, [revised edition]. University of Tokyo Press, 336pp. [J]

Mokudai, K. and Chigira, M. (2004): Geomorphic features and processes of gravitational mountain deformation in the area from Mt. Yambushi to Oya-Kuzure, central Japan. Geographical Review of Japan. Vol. 77, No. 2, pp. 55-76. [JE]

Oikawa, T. (2002): Geology, volcanic history and eruptive style of the Yakedake Volcano Group, central Japan. Journal of Geological Society of Japan, Vol. 108, pp. 615-632. [JE]

[J]: in Japanese

[JE]: in Japanese with Englishi abstract