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Weathering profile of non-welded ignimbrite and the water infiltration behavior within it in relation to the generation of shallow landslides

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Abstract

The mechanism underlying rain-induced shallow landslides of non-welded ignimbrite is found to be a special type of weathering profile and the behavior of water infiltrating through that profile, according to our study of Ito ignimbrite in southern Kyushu, Japan. Rhyolitic volcanic glass, the primary component of ignimbrite, is first hydrated and dissolved, forming halloysite. Halloysite near ground surface is then transported through the ignimbrite by infiltrating water and becomes clogged in interstices to form clay bands. Suction monitoring across a weathering profile indicated that downward infiltration of water is disrupted once by a zone of less-permeable clay bands and again at the weathering front. This disruption at the front is caused by a capillary barrier effect caused by the structure where finer, weathered material overlies coarser, fresh material. This results in a well-defined weathering front, particularly beneath a slope where water flux is parallel to the front, whereas the front is transitional beneath a ridge top where the front is nearly horizontal and the water flux is normal to the front. Infiltrating water from rain increases the weight of weathered material and decreases the suction within the material, which is the final trigger of a shallow landslide of non-welded ignimbrite; long-term weathering, which proceeds on the order of years, provides slide material.

Keywords: Ignimbrite; Weathering; Landslide; Soil moisture

1. Introduction

The weathering of rocks has been studied in various scientific fields, such as geology, engineering geology, mineralogy, soil science, and geomorphology. But the relationship between the weathering and the occurrence of landslides has not been well understood. This is because the previous studies focused on partial elementary processes rather than on sequential and interconnected weathering processes. Consequently, weathering profiles are not well characterized or understood, while soil profiles, which

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form the upper part of weathering profiles, have been studied in many countries. Although recent studies advanced the understanding of water–rock interaction, which is the most important process for the formation of a weathering profile, they focused mostly on chemical reactions rather than the characterization or interpretation of weathering profiles. Some researchers have made geochemical models of reaction and advection (Phillips, 1991; Lichtner et al., 1996; Lasaga, 1998), but those models are still conceptual and have not fully explained weathering profiles in nature. The characterization of weathering profiles used to be performed by geotechnical or engineering geological researchers (Moye, 1955; Ruxton and Berry, 1957; Geological Society, 1995) because they have to know the profiles to evaluate the geometrical distribution of mechanical properties of rocks as foundations. Weathering profiles have been studied for the following: granite (Moye, 1955; Ruxton and Berry, 1957; Chigira, 2001), marine sedimentary rocks (Chigira, 1990; Chigira and Sone, 1991; Chigira and Oyama, 1999; Hachinohe et al., 1999; Oyama and Chigira, 1999), vapor-phase crystallized ignimbrite (Chigira et al., 2002), and non-welded ignimbrite (Shimokawa et al., 1989; Yokota and Iwamatsu, 1999; Kawano and Tomita, 1999). These studies showed that each rock type has specific weathering profiles, which can be explained by geological processes. This geological characterization and interpretation of weathering profiles must be performed much further to establish a methodology of extending very limited data obtained by drilling, geophysical prospecting, or monitoring to a wider area on the basis of generality of geological processes.

Pyroclastic flow deposits (i.e., ignimbrite), one of the most common pyroclastics in tectonically active regions (Cas and Wright, 1996), have been prone to landslides during heavy rainfalls. For example, Shirasu, which is a local name of typical non-welded and unconsolidated ignimbrite in Kagoshima and is described in this paper, has been involved in shallow landslides on many occasions, resulting in numerous casualties (Fig. 1, Yokota and Iwamatsu, 1999; Yokoyama, 1999); this situation is generally expected in ignimbrite areas in humid regions. Shirasu weathers so quickly that, after a landslide strips off the surface weathered layer, weathering recommences and quickly provides material for the next landslide (Shimokawa et al., 1989; Yokota and Iwamatsu, 1999). The migration of a weathering

Fig. 1. Landscape in Kagoshima Prefecture, showing the shallow landslides of 1993 (photo by Kokusai Koku Photo).