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A new approach to triggering mechanism of volcano landslides based on zeta potential and surface free energy balance

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ABSTRACT

The layers of Almagre (iron-rich deposits) from Tenerife Island are the result of thermal metamorphism of soils in contact with lava flow (1073–1273 K). These layers of small thickness relative to the basaltic wash, are interesting for geotechnical study, because the stability of the deposits is determined by the weakest element, in this case Almagre, which acts as a sliding plane. The flow of maritime air over the hillsides of the volcanic islands increases the content of cations in ashes deposits. This modifies the superficial properties of material that composes the substratum. This modification affects the retention of water and the cohesion of material making up the deposit. The results show that the presence of sodium and magnesium increased the hydrophobicity of the material, which had a weak water retention capacity and strong cohesion at basic pH. When there is iron in solution, repulsion between the particles is greater than one obtained with other studied electrolytes. Hence, the deposit is less stable, and Almagre under saturated water conditions constitutes an ideal layer for landslides.

1. Introduction

Large volcanic landslides are a common phenomenon in the Canary Islands; >20 huge volcanic landslides were detected during the last decades around this archipelago (Hürlimann et al., 2004). Recent studies show that there are two main causes of these landslides: structural axes and residual soils.

The objective of this work is to improve the insights into the causes of large volcanic landslides focusing mainly on the existence of these residual soils.

The Island of Tenerife in the Canary Islands of Spain (Fig. 1) has been studied by the international scientific community. This is indicated by a multitude of articles published in recent years related to the consequences of a potential slide of hillsides (e.g., tsunami, loss of life, economic losses (Broothaerts et al., 2012; BASU and DE, 2003). These studies analyzed the topography, extent of present vegetation, and geotechnical parameters of the area (Crozier and Glade, 2005), and calculated hillside safety factors via simulations (Zhou et al., 2003) based on different models of the area.

Our study is based on the layer of eruptive material known as "Almagre," selected for its unique geologic history (Ancochea et al., 1990–1999) and characteristic geotechnical contacts with the low and top layers. This materials consists of layers (a few millimeters to meters in thickness) of iron oxides, either magnetite (Fe_3O_4) or hematite (Fe_2O_3), alternating with bands (iron-poor) of eruptive materials (Katsuta et al., 2012). As to its origin, there is no clear consensus (Perkins, 2009). Several models have been proposed to explain its genesis: deposition in environmental lacustrine, hydrothermal, evaporite, meteorization … which assumes the planes of typical slides in Tenerife (Martí, 1997; Hürlimann et al., 2004)". The Almagres is widespread residual soils, which were detected at many sites in the Tenerife. Studies on residual soils showed that their geotechnical properties depend on many factors including the type of parent rock, climate, time, etc., and strongly differ from sedimentary soils (Blight, 1997). The stratigraphic data indicate that residual soils above ash fall deposits have a very limited extent and those formed on lava flows have only a very small thickness. In contrast, the soils formed on phonolitic pyroclastic deposits have generally a wide extent and a thickness of several decimeters. Weathering processes changed such pyroclastic deposits, produced by explosive eruptions of phonolitic magmas, into residual soils characterized by their red color. Later the residual soil was covered by a lava flow, further modifying the soil by thermal processes. Thus, the residual soils are characterized by their double cementation: firstly by the lithification processes during the deposition of the hot pyroclastic material and secondly by the thermal alteration from the lava flow covering the soil layer (Hürlimann et al., 2004).We characterize interfacial properties of Almagre and their modification in association with the presence of various electrolytes (Na-Mg-Fe) and different pH values.

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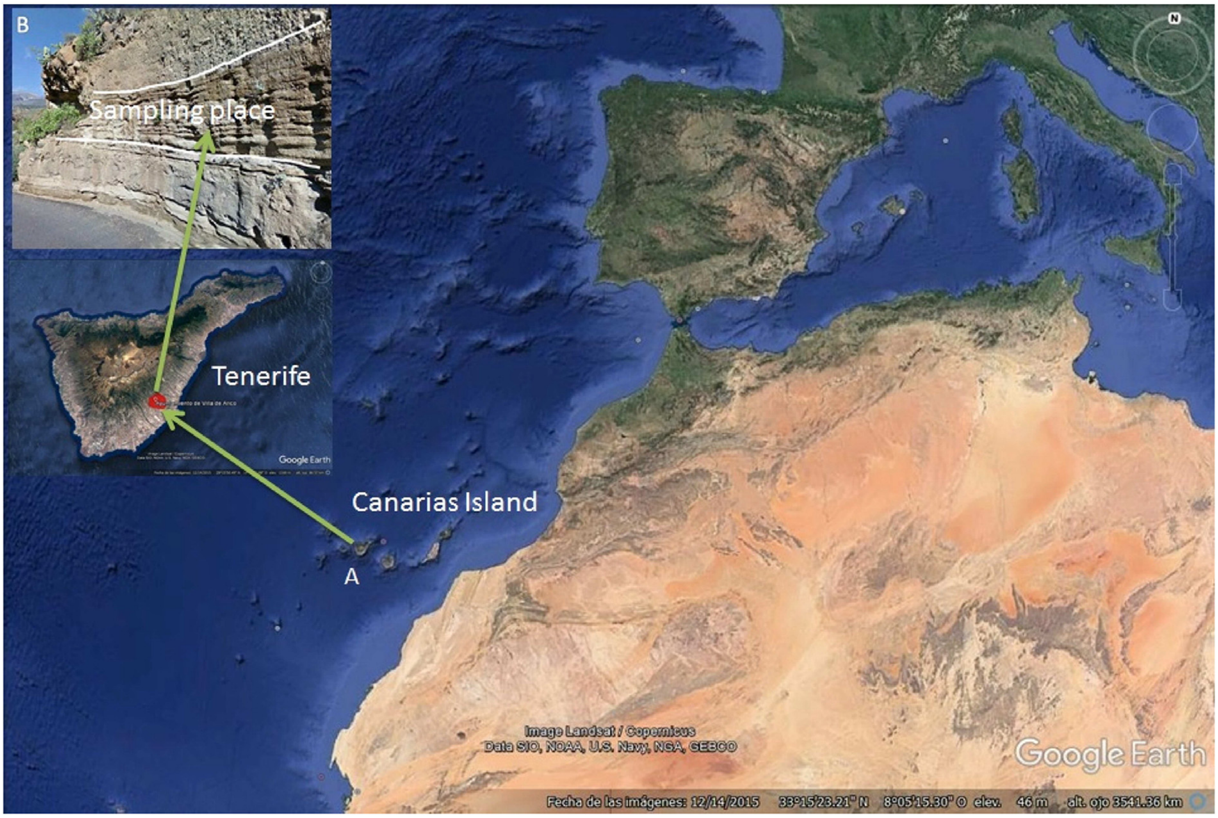

Fig. 1. Location of the island is relative to the Canary Island, and detailed presentation of the study site.

1.1. Geologic history and tectonic context of Tenerife

The geologic history of the Tenerife in Canary Islands began 12 Ma ago. It has been investigated by numerous researchers ((Carracedo et al., 2007–2011), (Longpré et al., 2009)). First it emerged I build acquaintance as "Roque de Conde" (11,6–6.4 Ma), later "Anaga" (8–3.2 Ma) and "Teno" (7.4–4.5 Ma). The geologic characteristics were investigated by Ancochea et al. (1990 & 1999), Churakov and Gimmi (2011), Martí (1997), Soto et al. (1999) and Rošic et al. (2012).

The origin of the volcanism is open to debate. We sampled in the complex called "Edificio de las Cañadas" (or Las Cañadas for short). This complex is in the southeastern part of the island, near the municipality of Guimaras. Nearby is a landslide with a volume of material >120 km^3 and an approximate age of 1 Ma. It is not the only landslide; another in Las Cañadas is dated 180,000 years ago (Masson et al., 2002).

The geologic history of Las Cañadas is marked by explosive-type volcanism, with the emission of pyroclastic clouds. Between the formation of Las Cañadas I and the II was a period of erosion and relative volcanic tranquility.

Almagre is a layer of very unique origin. It formed when materials of eroded or organic soil were buried by lava flows. These deposits are rich in iron. They are principally reddish, caused by alteration of minerals with iron, and show differential erosion in the deposit.

The above causes contact metamorphism in sedimentation of materials in previous periods and subsequent erosion, owing to layers of lava and pyroclastic expelled during this stage that buried the materials studied here. To all this must be added the effect of seawater, which in ordinary conditions contains a wide range of dissolved ions (mainly $Cl^- > Na^+ > Mg^{2+}$). Sea breezes have high moisture content, so rocks not in direct contact with seawater still experience its effects and their initial characteristics are thereby changed.

In many cases, the stratovolcanoes such as Teide Volcano, present steep slopes. Consequently they are susceptible to sudden and catastrophic failure (Bommer, 2002). Thus, earthquake-induced landslides in the Canary Islands constitute significant natural hazards. Mitigation of the landslide hazard there requires thorough understanding of the behavior of these volcanic deposits under static and dynamic conditions. The soil shows a general tendency to form aggregations of clay particles, usually showing different structures and levels of cementation. The cohesion of soils depends on several factors. Rheology properties in aqueous media are influenced by interactions between particles. The control of flocculation phenomena, adsorption, wetting, and rheological properties of dispersion depends on particle interactions (Bailey et al., 2009; Cockell, 2010; Churakov and Gimmi, 2011; Rošic et al., 2012; Kadar et al., 2014; Ontiveros-Ortega et al., 2014, 2016; Plaza et al., 2015; Baumgarten et al., 2012–2013).

Much of the scientific and technological interest in clay minerals derives from their interfacial interactions with colloidal particles (clays and other minerals) in the presence of a liquid, usually water.

Almagre layers are distributed throughout the island of Tenerife Fig. 1 (A). We chose a study area in the southwest part of the island of Tenerife (Mt. Teide), along local road TF-28. Samples were taken in a ravine in the nearby locality of Villa de Arico, see Fig. 1 (B).

2. Methods

2.1. Preparation of samples and description used materials

The samples were prepared before chemical and mineralogical analyses, they were immersed and washed by distilled water and Later they were left to dry at a temperature of 343,15 K over 48 h. Then, particles of diameter >2 mm were removed by sieving. Finally,