Chemical and Geochemical Characterization of the Evolution of Soils of Krakatau Islands

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Abstract

The Krakatau volcano erupted in 1883 and created a unique ecosystem where the surrounding islands were completely sterilised. While volcanic activity and plant succession have been extensively studied in the Krakatau islands, the soils received less attention. As the age of the parent material is known precisely, and the islands are isolated, soils of Krakatau islands could provide insights on the first stages of weathering in tropical volcanic regions. This study aims to characterize soils from the Krakatau islands. In 2015, ten sampling sites were selected from Mt. Anak Krakatau, Rakata, Panjang, and Sebesi islands, all making part of the Krakatau island complex. Field morphology was observed from representative profiles on each island. Soil samples were collected and analysed for physical and chemical properties. The geochemical analysis was carried out using the X-ray fluorescence (XRF). Linear discriminant analysis was used to separate materials from the four islands based on their chemical and geochemical concentrations. While the four islands were nearby and influenced by the 1883 eruption of Mt. Krakatau, the analysis showed that the chemical and geochemical characteristics of volcanic ash for each island are distinct. Discriminant analysis of chemical and geochemical properties differentiated soils of Anak Krakatau as the youngest ones, and soils of Sebesi are the most developed ones. The following sequence of the soil weathering degree was established: Sebesi > Rakata > Panjang > Anak Krakatau.

Keywords: Volcanic soils; andosols; geochemistry; discriminant analysis; tephra; Indonesia

INTRODUCTION

The late Mt. Krakatau erupted in May-August 1883 and had sterilised all soil and vegetation in the islands. Much has been investigated on the vegetation and volcanic activities of Krakatau (R. J. Whittaker, Bush, & Richards, 1989); however, the soils of Krakatau are less studied. As the age of the parent material is known precisely, and the area is less influenced by human activities, examining soils of Krakatau could provide an insight into the first stages of weathering and pedogenesis in tropical volcanic regions. The study of volcanic materials and their weathering products can inform us on the nutrient supply, and impacts on existing soils (Alloway, Andreastuti, Setiawan, Miksic, & Hua, 2017; Anda, 2016; Dian Fiantis, Ginting, Nelson, & Minasny, 2019). Understanding the triggers and controls of soil formation will lead to better sustainable use and made us aware of the fragility of soil formation and avoid degradation.

2. MATERIALS AND METHODS

Soil sampling and analysis

During a survey conducted in April 2015 ten representative soil profiles were selected: 1 soil profile on Mt. Anak Krakatau (elevation 60 m a.s.l), 2 soil profiles on Rakata (elevation 2 and 50 m a.s.l), 2 soil profiles on Panjang (elevation 2 and 48 m a.s.l) and 5 soil profiles on Sebesi islands (elevation 66, 156, 250, 356, and 455 m a.s.l). The location of the samplings is given in Figure 1. As the Anak Krakatau, Rakata, and Panjang islands do not have roads and a national park, sampling was done in the best possible manner to select a typical representative soil in the area. At Anak Krakatau, loose materials covered the entire island, and thus only 1 profile was be excavated. At Rakata and Panjang islands, the soils are loose sandy materials, and thus one profile near the coast and one at a higher elevation were excavated. Sebesi island is more developed with vegetation, and therefore the sampling locations represent a transect of elevation.

The soil morphological features were observed from soil profiles in the field, and soils were sampled by collecting approximately 3 kg from each soil horizon and transferred into polyethylene plastic bags for analyses. Undisturbed soil samples were obtained using a standard ring sampler with a known volume to determine soil bulk density. The samples were then brought to the laboratory, air-dried, ground homogenously, and sieved to a size fraction smaller than 2 mm.

The particle sizes of ash and soil samples were determined by sieving and pipette method (Staff, 1996). Silt- and clay-sized fractions were measured after sedimentation, according to Stokes law. Soil pH was measured in H_2O and 1 M KCl at a solution ratio of 1:5 after 30 min of equilibration. The Walkley and Black wet oxidation method was used to determine organic C content, and total N was determined by the Kjeldahl method (Tan, 2005). The available phosphate anion was analyzed colorimetrically using a visible-light spectrophotometer (Tan, 2005). P retention was determined following the method described by Blakemore, Searle, and Daly (1987). Exchangeable cations and cation exchange capacity (CEC) were determined by 1 N NH_4OAc, pH 7.0, extraction; the leachate was used to determine the exchangeable base cations, which were measured by atomic absorption spectrophotometry (AAS). Saturation of individual base cations was calculated by dividing the content of individual exchangeable cations by the effective CEC and expressed as a percentage (Anda, 2012). Extraction with acid ammonium oxalate for the dissolution of non-crystalline materials and metal-organic complexes was carried out as outlined by Van Reeuwijk (2002). Contents of acid-ammonium oxalate-extractable Si, Al, and Fe (Si_o, Al_o, and Fe_o) were measured by AAS.

The elemental composition of the samples was determined using a benchtop X-ray fluorescent spectrometer (XRF) PANalytical Epsilon 3, with 120-second readings with three replicates.

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FIGURES

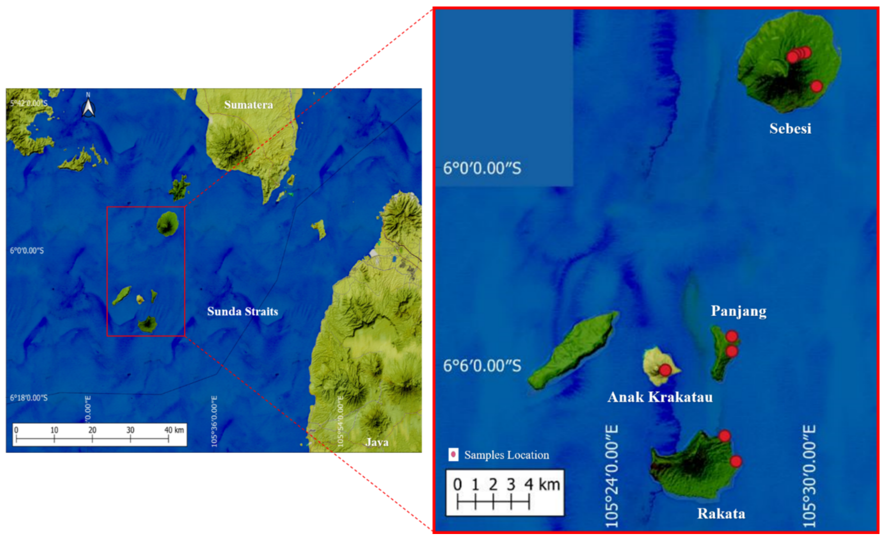

Figure 1. Location of field observations at the Krakatau islands.

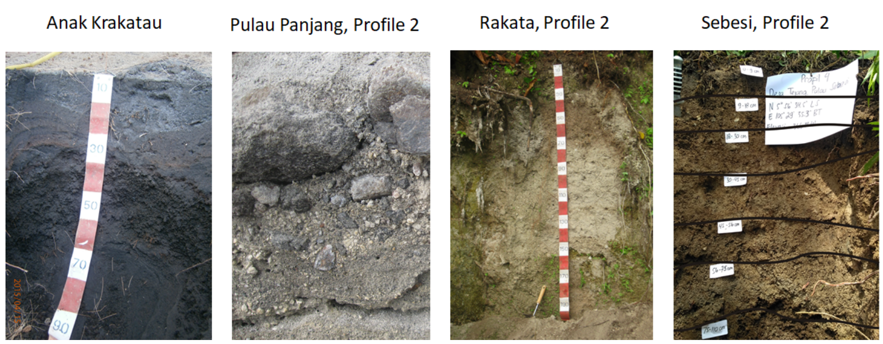

Figure 2. Photographs of soils of Krakatau islands.

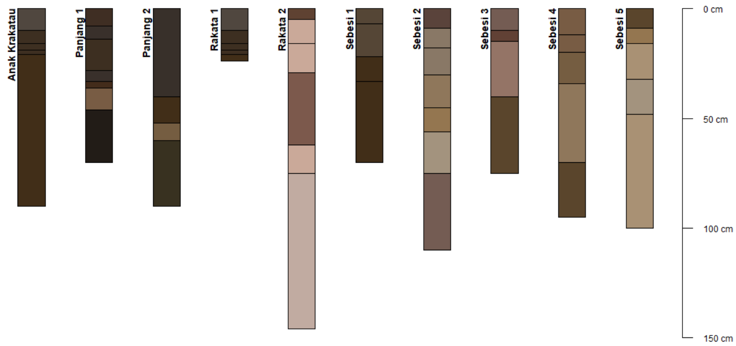

Figure 3. The morphological representation of Krakatau soils.