

Infrared spectroscopy characteristics of mount Sinabung volcanic materials, North Sumatra, Indonesia

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Abstract. Infrared spectroscopy has the capability to determine the mineralogical composition of geologic materials. Its reflectance spectra contain diagnostic spectral absorption feature characteristics that can be used for analyzing the mineral chemistry and chemical composition of volcanic material samples. In this research, we analyze the infrared spectral shapes and properties of volcanic materials at specific wavelength ranges in order to identify compositional information of the samples. We used volcanic material samples such as ash and rocks (tuffs) collected from Sinabung volcano, North Sumatra, Indonesia. Reflectance spectra of the samples were characterized using infrared spectroscopic method. Variation in depth of spectral absorption features and reflectance values of ash and rock samples related to grain size, chemical and mineralogical composition, and surface roughness of the samples. The spectroscopic characteristics showed that these volcanic samples exhibit a strong Al-OH absorption feature centered at ~2200 nm. It indicates that the samples contain predominantly clay or other phyllosilicate minerals. Reflectance spectroscopy can be used to extract compositional information of mineralogy in volcanic material samples.

1. Introduction

Mount Sinabung, a stratovolcano located in North Sumatra, Indonesia, has erupted for several time in the last few years [1,2]. The current Sinabung volcano eruption (19 February 2018) produced a huge gray ash column into the air and spread over a large area as observed by weather radar [3]. The volcanic ash resulted from these eruptions have affected various problems on human health, economic development, and physical properties of environment at the surrounding area of the mountain. The ash contain various materials and minerals which are dominated by a high concentration of silica and alumina [4,5]. There are various analytical methods have been applied to determine chemical and mineralogical composition volcanic materials [5-7]. However, these conventional approaches are costly and impracticality for sample preparation and field measurement. Infrared spectroscopy technique offers a non-destructive approach, relatively easy sample preparation, and can be utilized practically for field and laboratory measurement [8-10]. Therefore, in this study we analyze mineralogical composition of volcanic material samples based on spectroscopic characteristics of infrared reflectance spectra.

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Infrared laboratory spectroscopy has been employed for analyzing compositional information of raw materials [8-14]. Reflectance spectra of minerals or rocks in the infrared wavelength region have diagnostic absorption features. The spectral features are controlled by vibrational processes of hydroxyl (OH), water (H₂O), carbonate (CO₃), sulfate (SO₄) and typical cationic transitional vibrations present in phyllosilicates (e.g., Al-OH, Mg-OH, and Fe-OH bearing clay, mica and serpentine) [10-12]. Hence, these absorption feature characteristics can be used to distinguish mineral chemistry and composition in rock or geologic samples. The presence of clay and other phyllosilicate minerals in the samples is determined by vibrational absorption features around 2200 nm and 2300 nm due to the combination of the OH stretch with the Al-OH and Mg-OH bending modes, respectively [11,12]. The new generation development of infrared spectrometry with the highest spectroscopic resolution could enable to analyze the abundance and composition of naturally mixed minerals in volcanic material samples.

2. Materials and methods

2.1. Volcanic material samples

The volcanic material samples were obtained from the surrounding area of Mount Sinabung, North Sumatra, Indonesia (Figure 1). Two types of volcanic samples, such as ash and rocks (tuffs) (Figure 2), were collected during fieldwork from 23 to 25 February 2018, which is few days after Sinabung volcano eruption on 19 February 2018 [3]. Ash samples were acquired from two different locations: (1) a coffee garden area of Payung village (Ash1, 98.378E, 3.126N; Figure 1) and (2) an abandoned residential area of Kinepen village (Ash2, 98.381E, 3.091N; Figures 1 and 2a). Rock samples (tuffs) were taken from an outcrop area of Kabanjahe subdistrict (Rocks, 98.483E, 3.109N; Figures 1 and 2b).

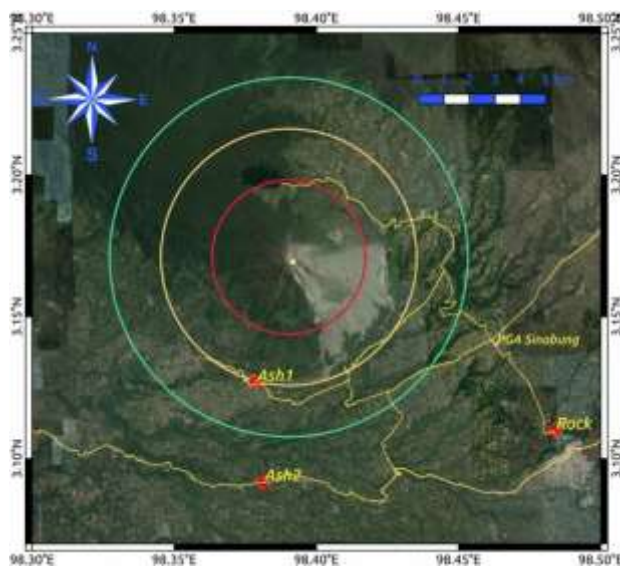


Figure 1. Location map of study area around Mount Sinabung, North Sumatra, Indonesia. Google earth image illustrates the affected area after the volcano eruption on 19 February 2018, the danger zone (line circle) and site of volcanic samples collection (red dot). ©2018 Google.

2.2. Reflectance spectra measurement

Reflectance spectra of four selected volcanic samples (ash1, ash2, rock1 and rock2) were measured using a FieldSpec 4 Hi-Res Spectroradiometer from Analytical Spectral Devices (ASD) Inc., Longmont, Colorado, USA (Figure 3a). The spectrometer acquires the spectra from the visible/near infrared (VNIR) to the shortwave infrared (SWIR) (350–2500 nm) wavelength regions. We used a Spectralon (Labsphere, North Sutton, NH, USA) to calibrate the spectral measurements of each volcanic sample. The reflectance spectra of ash and rock samples were recorded using the ASD contact probe (Figure 3b). The instrument setting and spectral measurement procedure are described in previous studies [8,14]. Five reflectance spectra were acquired to obtain an average reflectance

spectrum from each volcanic sample. We utilized ENVI software package version 4.7 to process the reflectance spectral data.



Figure 2. Volcanic material samples collection from surrounding Mount Sinabung areas: (a) Ash samples were collected at Kinepen village (Photographs: Irwandi, taken on 25 February 2018) and (b) rock (tuff) samples were taken from Kabanjahe subdistric (Photographs: Irwandi, taken on 24 February 2018).

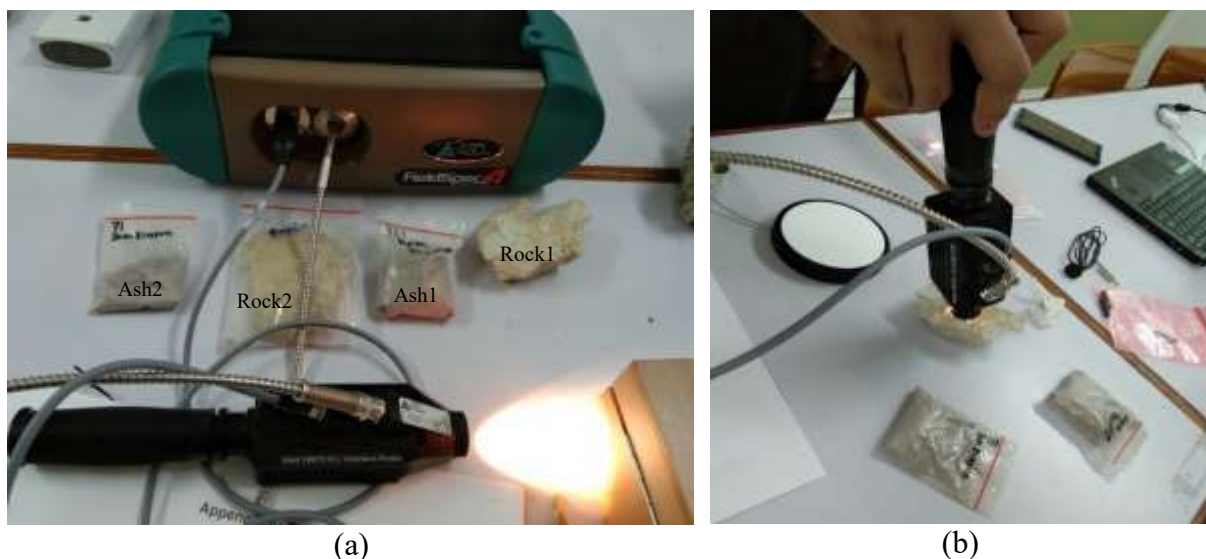


Figure 3. Infrared reflectance spectra measurement, showing (a) a FieldSpec 4 Hi-Res Spectroradiometer and selected volcanic samples (ash1, ash2, rock1 and rock2) and (b) the ASD contact probe acquisition technique (Photographs: Irwandi, taken on 21 February 2019).

2.3. Spectral features characterization

Volcanic samples spectral feature characteristics, such as spectral shape and wavelength position were analyzed from continuum-removed reflectance spectra [15] in order to determine mineralogical composition. The absorption wavelength position is the wavelength at which the maximum absorption or minimum reflectance of an absorption feature occurred [16]. The wavelength position of Al-OH spectral feature in the wavelength range of 2170–2250 nm was processed using Hyperspectral Python (HypPy) software package version 2.6 [17]. The position of absorption band was calculated using a simple quadratic method [18]. These spectroscopic properties were characterized by following a routine procedure as described in Zaini et al. [8,19].

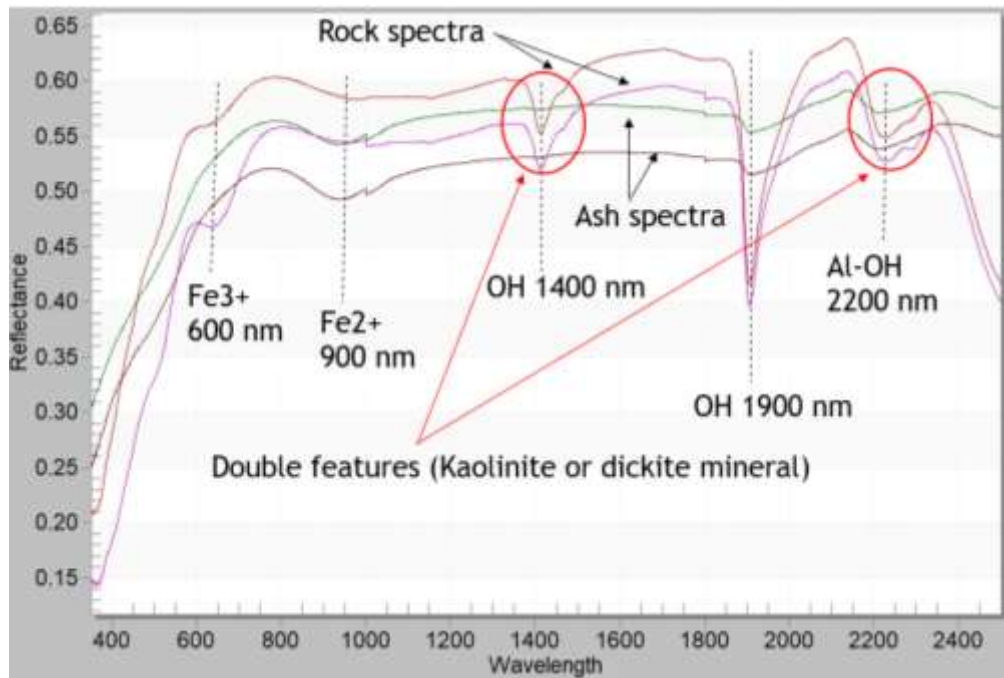


Figure 4. Infrared reflectance spectra of volcanic material samples. Rock reflectance spectra exhibit double features at 1400 nm and 2200 nm which indicate the presence of clay minerals such as kaolinite or dickite in the samples.

3. Results and Discussion

The infrared reflectance spectra of ash and rock samples collected from different locations around Mount Sinabung are shown in Figure 4. The Spectral signatures of the volcanic samples show diagnostic absorption feature characteristics of surface mineralogy. These spectral curves illustrate different reflectance value and depth of absorption features (Figure 4). Ash samples are darker and finer grain size than rock (tuff) samples. The darkness of ash samples are probably due to impurity of opac materials in the samples. Variation in depth of absorption features and reflectance values related to physical and chemical properties of the synthetic and geologic samples including grain size [19], texture [20], as well as chemical and mineralogical composition of the samples [19,21].

The reflectance spectra of ash samples exhibit obviously different shapes of absorption features compared to rock reflectance spectra (Figure 4), particularly spectral features at around 1400 nm and 2200 nm. These features specify that the volcanic samples between ash and rocks contain different mineralogical composition. Fe^{3+} and Fe^{2+} spectral absorption features around 600 nm and 900 nm shown in Figure 4 are influenced by electronic process or unfilled electron shells of Fe transition element [12]. Absorption features at wavelength around 1400 nm and 1900 nm, and 2200 nm attributed to OH vibration and the combination of the OH stretch with the Al-OH bending modes, respectively [11,12]. A prominent absorption feature around 2200 nm indicates the presence of clay or other phyllosilicate minerals in the samples [11,12]. The double features of rock reflectance spectra at wavelength around 1400 nm and 2200 nm designate to clay minerals such as kaolinite or dickite [11,12]. However, these double features do not present in ash reflectance spectra. It specifies that ash samples contain different type of clay or other phyllosilicate minerals compared to the rock samples.

4. Conclusion

Infrared reflectance spectra demonstrate slightly different spectroscopic characteristics of the volcanic samples. Depth of spectral absorption features and reflectance values of ash and rock samples are affected by grain size, chemical and mineralogical composition, and surface roughness of the samples.

The variation of OH and Al-OH absorption feature shapes at wavelength around 1400 nm and 2200 nm, respectively indicates that the samples are composed by a slight difference composition of clay or other phyllosilicate minerals. The infrared spectroscopy is an applicable method for identifying mineral chemistry composition of volcanic materials.

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