INDONESIAN JOURNAL ON GEOSCIENCE
Geological Agency
Ministry of Energy and Mineral Resources

Journal homepage: http://ijog.geologi.esdm.go.id
ISSN 2355-9314, e-ISSN 2355-9306

Geochemical Compositions and Magnetic Susceptibility of Soils from Different Origins: A Case Study in South Lampung, Indonesia

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Manuscript received: November, 5, 2018; revised: April, 11, 2019;
approved: February, 7, 2020; available online: September, 7, 2020

Abstract - The study of rock weathering into soil is very important in geophysics. The geochemical and magnetic characteristics of soil were investigated in South Lampung using magnetic susceptibility and X-ray Fluorescence (XRF) measurements to identify the rock origin of the soil. The samples consisted of three soil types, those are granite soil, tuff soil in front of ITERA (Institut Teknologi Sumatra, South Lampung), and tuff soil inside ITERA. The tuffs (in front of and inside ITERA) and granite were taken in and around ITERA. The result showed that granite had the highest magnetic susceptibility value, while tuff soil in front of ITERA had the highest FeO content. Each sample can be distinguished by magnetic susceptibility and FeO content to prove that it can be used as a tool to distinguish the rock origin of soil.

Keywords: soil, geochemical, susceptibility, magnetic, tuff, Lampung

How to cite this article:
Santoso, N.A., Iqbal, M., and Kadja, G.T.M., 2020. Geochemical Compositions and Magnetic Susceptibility of Soils from Different Origins: A Case Study in South Lampung, Indonesia. *Indonesian Journal on Geoscience*, 7 (3), p.267-272. DOI: 10.17014/ijog.7.3.267-272

Introduction

Background

In geophysics, soil is a natural material that is very interesting to be studied. Soil is the result of rock weathering. So far, geochemical method is often used to study the soil. For example, Di Figlia *et al.* (2007) examined the chemical weathering of volcanic rocks on Pantelleria Island, Italy, with the result that the chemical characteristics of the solution and the mobility of soil elements were controlled by source elements and rock-water interactions. In addition to the geochemical method, rock magnetism method is also often used to study the soil. However magnetic susceptibility method is used as a preliminary study measurement.

Safiuddin *et al.* (2011) investigated laterite soil as an indicator of the pedogenic process with magnetic susceptibility. However, they only investigated laterite soil, without a research related to tuff and granite soil.

The aim of this study is to obtain geochemical and magnetic characteristics of soil originated from tuff and granite. The geochemical characteristics were obtained from the composition of oxide minerals in the soil, while the magnetic characteristics were the result of the value of soil magnetic susceptibility.

Geological Settings

Based on the Tanjung Karang Sumatra Geological Map with the scale of 1:250,000 (Mangga *et al*., 1993), the studied area covers several rock formations/units (from old to young), those are Sidodadi Quartzite (Pzgk), Way Galih Schist (Pzgs), Sulan Granodiorite (Kgds), Tarahan Formation (Tpot), Lampung Formation (QTl), and Young Volcanic Deposits (Qhvp). The geologic map of studied area with the sampling locations can be seen in Figure 1.

Based on Mangga *et al.* (1993), Lampung Formation (QTI) deposited in a fluvial-terrestrial environment has Pliocene-Pleistocene age. The formation is composed of rhyolite-dacite tuff, pumice tuff, and pumice sandstone. Tuff has the volcanic ash grain size with the composition of fractured rhyolite-dacite, volcanoclastic, with white to brownish colours. Pumiceous, yellowish-grey to greyish-white, medium- to coarse-grained, poorly sorted, is composed of pumice and rock fragments. Pumiceous sandstone, yellowish-white, fine- to medium-grained, poorly sorted, subrounded, partly contains pumice, cross-bedded, mainly composed of dacitic fragments.

Methods and Materials

Methods

To see the geochemical and magnetic changes in weathering of the original rock into soil, the geochemical composition test and the measurement of magnetic susceptibility were carried out on the samples. Magnetic susceptibility measurement was conducted by using a Bartington MS2B with a dual-frequency sensor (470 Hz and 4700 Hz) in the Laboratory of Characterization and Modeling of Physical Properties of Rocks, Basic Science Centre of A (BSCA), Institut Teknologi Bandung (ITB). Meanwhile, the geochemical analysis was carried out to analyze the chemical composition of the soil using Orbis X-Ray Fluorescence (XRF) spectrometer at the Research Centre for Nanosciences and Nanotechnology (RCNN), ITB.

Materials

Six samples were taken around ITERA consisting of granite (GN), granite soil (GNS), tuff in front of ITERA (TDI), tuff soil in front of ITERA (TDIS), tuff inside ITERA (TFI), and tuff soil inside ITERA (TFIS). GN and GNS were taken

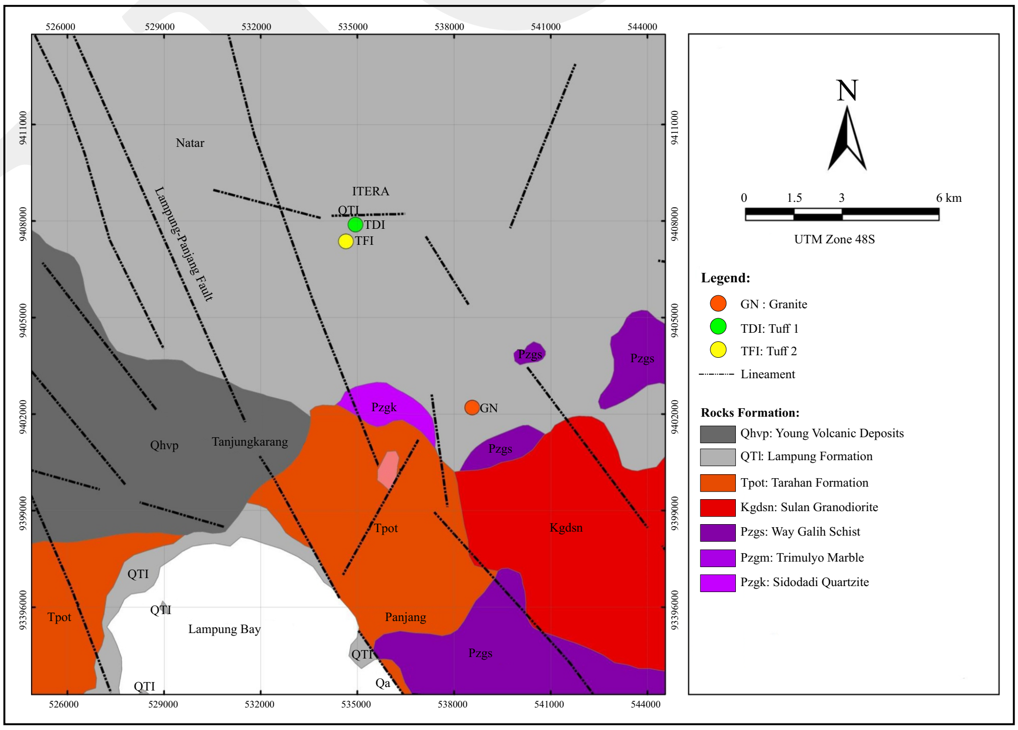

Figure 1. Geologic map of Tanjung Karang with the sampling locations (Mangga *et al*., 1993).

at Lematang Toll Gate, Tanjung Bintang. The coordinates of each sampling site can be seen in Table 1. The samples were taken in the middle part of outcrop using scopes and hammers. The outcrops of the sample are shown in Figure 2.

Table 1. Coordinates of Each Sampling Site

No	Sample	Coordinate (Zone 48S)	
		Long (East)	Lat (South)
1	GN, GNS	105° 20’ 53.07”	5° 24’ 29.67”
2	TDI, TDIS	105° 18’ 55.37”	5° 21’ 24.39”
3	TFI, TFIS	105° 18’ 45.76”	5° 21’ 41.53”

Before carrying out the measurement of magnetic susceptibility the samples had been prepared in the Laboratory of Characterization and Modeling of Physical Properties of Rocks, Basic Science Centre of A (BSCA), ITB. The samples were inserted into a holder with diameter of 22.54 cm and 2.2 cm high. After being inserted into a holder, the samples were weighed. Each sample was divided into three holders for measuring the magnetic susceptibility. Each holder was measured five times to get the average. Then, the average results of each holder were averaged again to get the accurate value of magnetic susceptibility of each sample. Samples for geochemical analysis were prepared in the Research Centre for Nanosciences and Nanotechnology (RCNN), ITB. Samples were prepared in dry powder before XRF analysis.

Result and Discussions

In geophysics, weathering of rocks into soil is interesting to be studied. Can weathering of rocks be identified geochemically and magnetically? To answer this question, it is necessary to conduct soil and magnetic geochemical tests on the samples. The geochemical test were carried out on weathered tuff. The samples used were TDI-TDIS and TFI-TFIS. Based on field observation, all tuffs were white. After weathering, the tuffs turned into red and grey soils. What chemical composition causing the variation in soil colour? Based on the

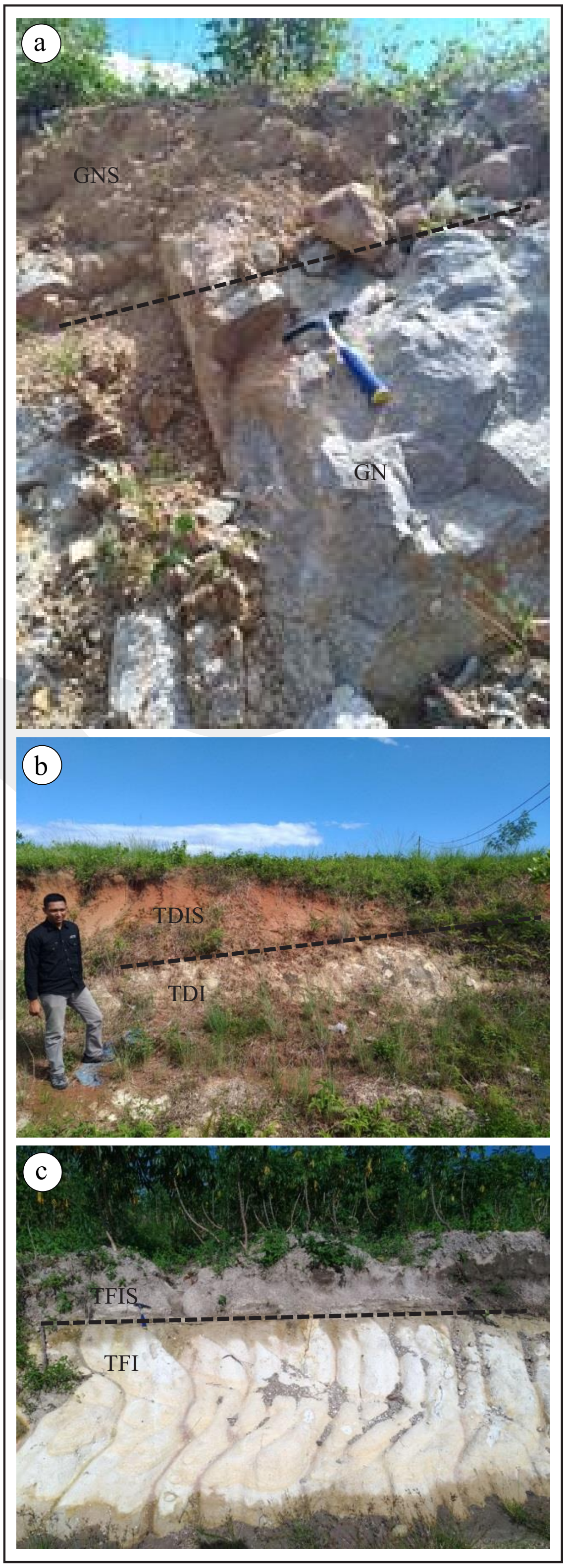

Figure 2. Field photographs showing the sequence of the outcrops: a) GNS-GN, b) TDIS-TDI, c) TFIS-TFI.

Natural Resource Conservation Service - Soils, United State Department of Agriculture (2019), the cause of the red colour of the soil was the Fe minerals. Figure 3 presents the percentages of Fe minerals obtained after the geochemical test in the sample. It can be seen in the percentage that Fe minerals in the TDIS is the highest. This proves that the red TDIS is caused by the increase in Fe minerals after weathering of the TDI.

If the Fe minerals caused the red colour soil, then what is the cause of the grey colour? Is it the quartz mineral (SiO_2) or other minerals? Figure 4 presents the percentages of oxide minerals that cause grey soil. Figure 4 shows that Al_2O_3 mineral increases after weathering on TFI occurred. The dominance of this Al_2O_3 mineral contributes to the grey colour soil. In addition, based on observation in the field, this grey soil indicates that the TFI area formed in the anaerobic environment caused by rain water that settled on a waterproof layer for a long time (Lynn and Pearson, 2000).

Based on the geochemical test results (Table 2), plotted in the diagram of Le Maitre *et al.*

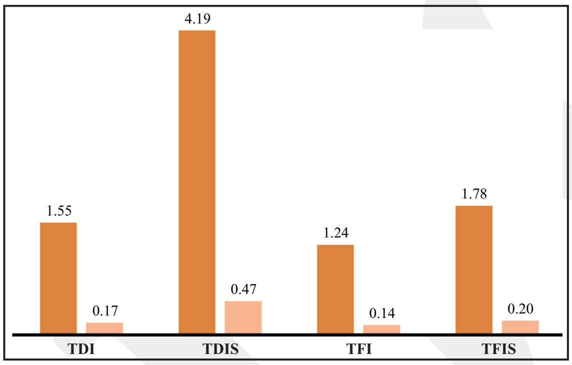

Figure 3. Percentage of Fe minerals based on XRF in sample (weight in %). FeO (orange) and Fe_2O_3 (pink).

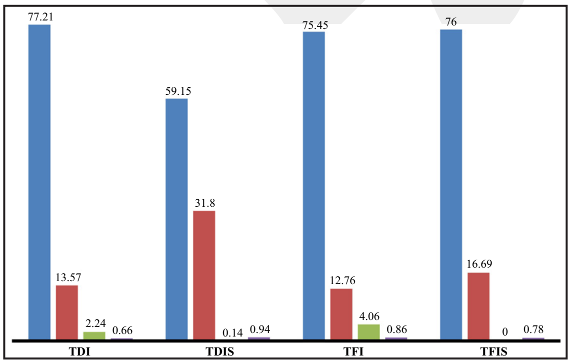

Figure 4. Percentages of minerals that give grey colour to the soil. SiO_2 (Blue), Al_2O_3 (red), K_2O (green), and MgO (purple).

Table 2. List of the Average Magnetic Susceptibility and Percentages of FeO based on Sample Data

Samples	Average χ_{LF} ($\times 10^{-8}$ m^3/kg)	FeO (%)
GN	37.17	0.15
GNS	50	1.24
TDI	4.8	1.55
TDIS	23.17	4.19
TFI	31.17	1.24
TVIS	9.37	1.78

(1989), TDI and TFI are rhyolitic tuffs (Figure 5a). Whereas, GN is a granitic rock based on direct observation and syenite on the basis of the geochemical test plotted in the diagram of Cox *et al*. (1979) (Figure 5b). If tuffs derived from rocks of the same origin, but after weathering have different soil results, they could be distinguished geochemically. Likewise, if granite and rhyolitic tuff originated from the same magma, both could still be distinguished geochemically. Are there other parameters that can identify this besides geochemistry? The authors have tried to use magnetic susceptibility to distinguish samples.

Measurement of magnetic susceptibility was used to see the abundance of magnetic minerals in the samples. Based on Table 2, the samples can be distinguished by the value of magnetic susceptibility after weathering process the soil. The values of the GN to GNS and TDI to TDIS magnetic susceptibility increase. In contrast, the value of the TFI to TFIS decreases. Why does the magnetic susceptibility value of TFI-TFIS decrease? The geochemical data needed to be associated with the value of magnetic susceptibility. The geochemical data needed to be the geochemistry of FeO minerals in each sample, because the value of magnetic susceptibility is related to magnetic minerals (Dearing, 1999). The relationship between magnetic susceptibility and FeO minerals can be seen in Figure 6. GNS has the highest magnetic susceptibility value, while TDI has the lowest magnetic susceptibility value. In Figure 6, tuffs and igneous rocks from the same magmatic origin show different

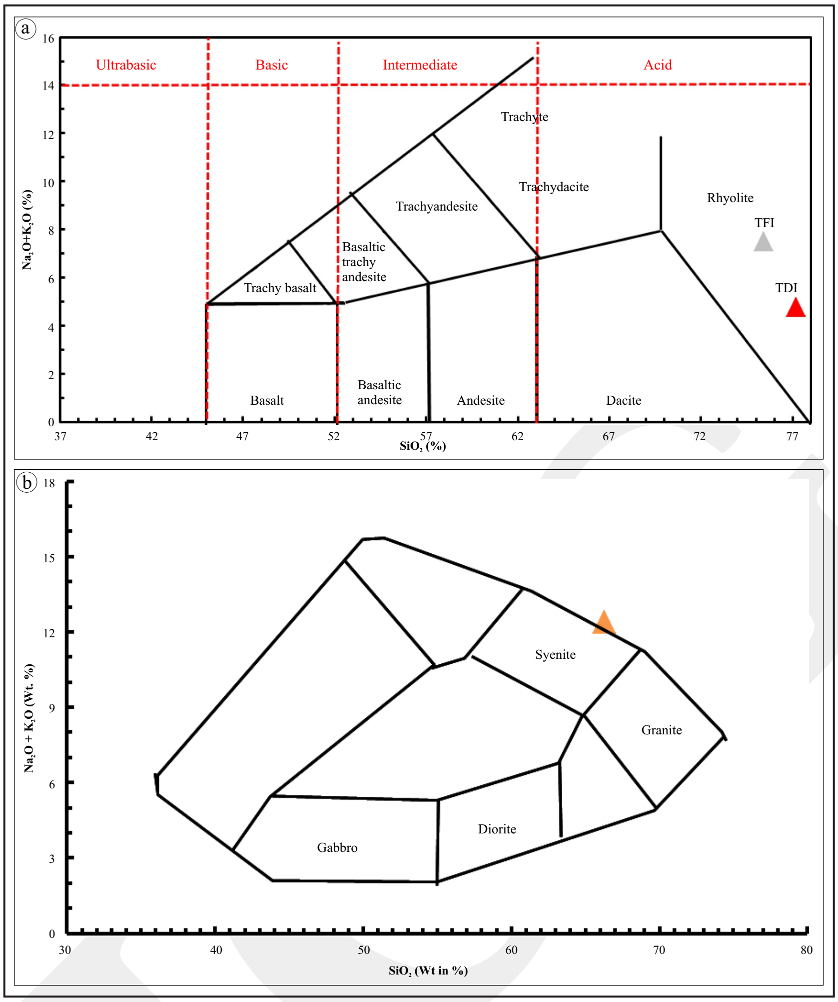

Figure 5. a) Plot of TFI and TDI in the diagram of Le Maitre *et al*. (1989); b) Plot of GN in the diagram of Cox *et al.* (1979).

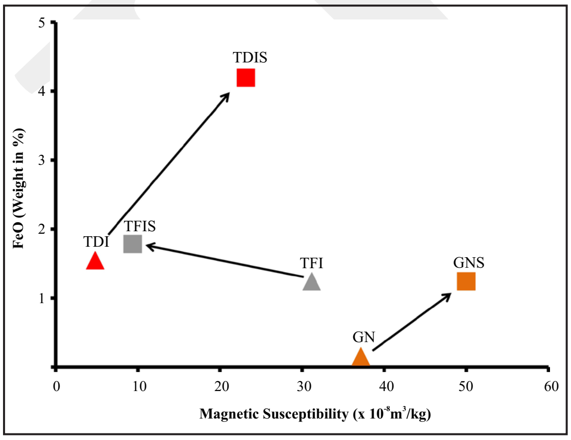

Figure 6. Values of magnetic susceptibility versus FeO mineral contents based on sample data.

weathering results with different variations in the value of magnetic susceptibility. Soil with the highest FeO content does not contain the highest magnetic susceptibility value, while the soil with the lowest FeO content has the highest magnetic susceptibility value. This raises the presumption that the concentration of FeO minerals do not affect the value of magnetic susceptibility. The most influential factor is the type of magnetic minerals in the sample. The type of magnetic minerals formed can be identified from the colour of the soil. The colour of the soil indicates the type of minerals that formed in the soil.

Based on the soil colour, the FeO minerals formed in the sample are likely hematite, goethite, and glauconite. Based on Natural Resource Conservation Service - Soils, United State Department of Agriculture (2019), FeO minerals formed in the GNS is goethite (brown), in TDIS is hematite (red), and in TFIS is glauconite (grey). The cause of the strangeness decreasing the value of magnetic susceptibility in TFI is due to the FeO minerals turning into glauconite. This is supported by the presence of an anaerobic environment in the TFI area where FeO minerals were reduced to colourless (Lynn and Pearson, 2000).

According to Safiuddin *et al.* (2011), the magnetic susceptibility value of laterite soils was higher than the soils originating from weathered tuff and granite. The magnetic susceptibility of laterite soils is around 3,000 x $10^{-8}m^3/kg$, meanwhile soils from weathered tuff and granite rock are around 28 x $10^{-8}m^3/kg$. Laterite soils have high magnetic susceptibility values, because they are derived from weathered ultrabasic and basaltic rocks. The results of this comparison strengthen the study of Santoso *et al.* (2019) on the soil around Mount Bromo, which concluded that differences in the origin of rock affected the value of magnetic susceptibility.

Conclusions

Based on the results of the discussion, the geochemical composition and magnetic susceptibility values prove that they could be used as a tool to distinguish the origin rock of soil. The combination of geochemistry, magnetic susceptibility, and soil colour is a good combination in interpreting the soil parent rocks. The results of this study are very useful for further geophysical research in studying soil.

Acknowledgement

The authors appreciate the HIBAH MANDIRI ITERA with a research contract number 134d/IT9.C1/PP/2018, as well as Virgian Rahmanda as a field assistant. Furthermore, the authors would also thank Prof. Satria Bijaksana for the opportunity given to the process of measuring magnetic susceptibility at the Laboratory of Characterization and Modeling of Physical Properties of Rock, ITB.

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