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## Patterns of variation magnetic properties and chemical elements of soil profile in landslide area of South East Sulawesi Indonesia

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**Abstract.** Applications of the magnetic properties of rock continue to be developed because of its ability to integrate the understanding of the variation patterns of minerals and chemical elements in the process of soil formation and also their influence due to external factors. The primary objective of this study is to know how the trends of variations of the magnetic properties and chemical elements on soil profile in landslide area, and how the association between the element as well as the association between chemical elements and magnetic properties. Eleven soil profiles are the focus for the study of magnetic properties (parameter of magnetic susceptibility) and their elemental content (i.e., using the X-Ray Fluorescence, XRF). From the soil profiles studied, one hundred and twenty-four samples were taken and analyzed for their magnetic properties and elemental content. The results of this finding show that the trend of variation in magnetic susceptibility and chemical elements in soils differs from the normal soils and soils affected by human activity. The linear correlation between  $\chi_{LF}$  and  $\chi_{FD}$  values indicates that the soil profile in this study is a natural soil profile even though it has undergone changes due to landslides.

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## 1. Introduction

Recently, the application of the magnetic properties has developed to integrate understanding of the many natural process, started from pollution and contaminants [1,2], reconstruction of the palaeoclimatic [3], estimation of the soil age [4], up to the identification of the Tsunami sediment [5]. Information of the magnetic properties are also developed for the practical purposes start from the evaluating the soil degradation based on the iron component observed by the magnetic properties [6, 7], up to for the soil development [8, 9] and investigation of the fabric of ultrafine magnetic particles [10]. Even though have been developed in several aspect, the association between the variation of the magnetic properties and the distribution of the chemical elements are not fully understood up to this day.

In many study, it has been known that the presence of the superparamagnetic (SP) grains in soil and their distributions in space related with the pedogenic history [11] that controlled by the climate, and their development is also often associated with the economical-valued chemical elements such as Ni, Co and Mn [11,9] at limonite and saprolite layers.

Understanding variations of magnetic properties and distribution of chemical elements in soil profile are a crucial part since they are related with the pedogenic and lithogenic processes. Improving the understanding of variation both of them, therefore, will provide information useful for soil management and expand our ability to model the processes involved in soil development. One potentially important pattern of variation in soil profile that is not yet well understood is how the distribution of the chemical elements correlated with their magnetic patterns of variation. The magnetic properties analysis from laterite soil and landslide soil in southeast Sulawesi was carried out based on magnetic susceptibility values. The information about magnetic properties of soil from landslide potential area in South Konawe and the laterite soil in Wantulasi area give us certainly to determine whether the magnetic susceptibility and frequency dependent susceptibility can be used as a proxy in landslide hazard.

## 2. Methods

### 2.1 Site Description and Sampling Method

Wantulasi area soils is a laterite soil located on the southeast Sulawesi Indonesia. This soils are generally derived from the Soil Samples were obtained in September 2013 from three sites were taken thirty nine sample with the sampling range in each profile are about 15 cm upward measured. From All the thirty nine sample were studied their magnetic properties, eighteen samples were selected from the third of profiles (i.e., each profile consists of six samples) for the chemical elements analysis using the X the magnetic properties eighteen from an area near Wantulasi that is located. Of the three profiles studied, one hundred and six samples were taken and analyzed for their magnetic properties and elemental content.

The landslide profile is located on Wolasi, South Konawe district southeast Sulawesi where 20 samples are taken from top slide profile, 20 samples from middle slide profile and 10 samples from bottom of slide with ranged 5 cm upward. Of the three profiles studied, 50 samples observed magnetic properties and elements content.

### 2.2 Magnetic Properties Measurement

In this work, two method of the measurement of the magnetic properties (i.e., magnetic susceptibility in both frequency, 470 Hz and 4700 Hz using a Bartington MS2 Susceptibility meter, and the measurement of the anhysteretic remanent magnetization (ARM). All the samples were measured in both of frequency taken from ten different profile performed by ITB Palaeomagnetic Laboratory on

whole sample using the Bartingrong MS2B asumtions . The second method, measurement of *ARM* (Anhysteretic Remanent Magnetization) was conducted on selected samples by exposing the samples under a peak alternating magnetic field of 80 mT with a constant field of 0.05 mT. *ARM* was given to the samples following demagnetization by AF (alternating field) demagnetizer in a Molspin AF Demagnetizer (Molspin Ltd., Newcastle upon Tyne, United Kingdom).

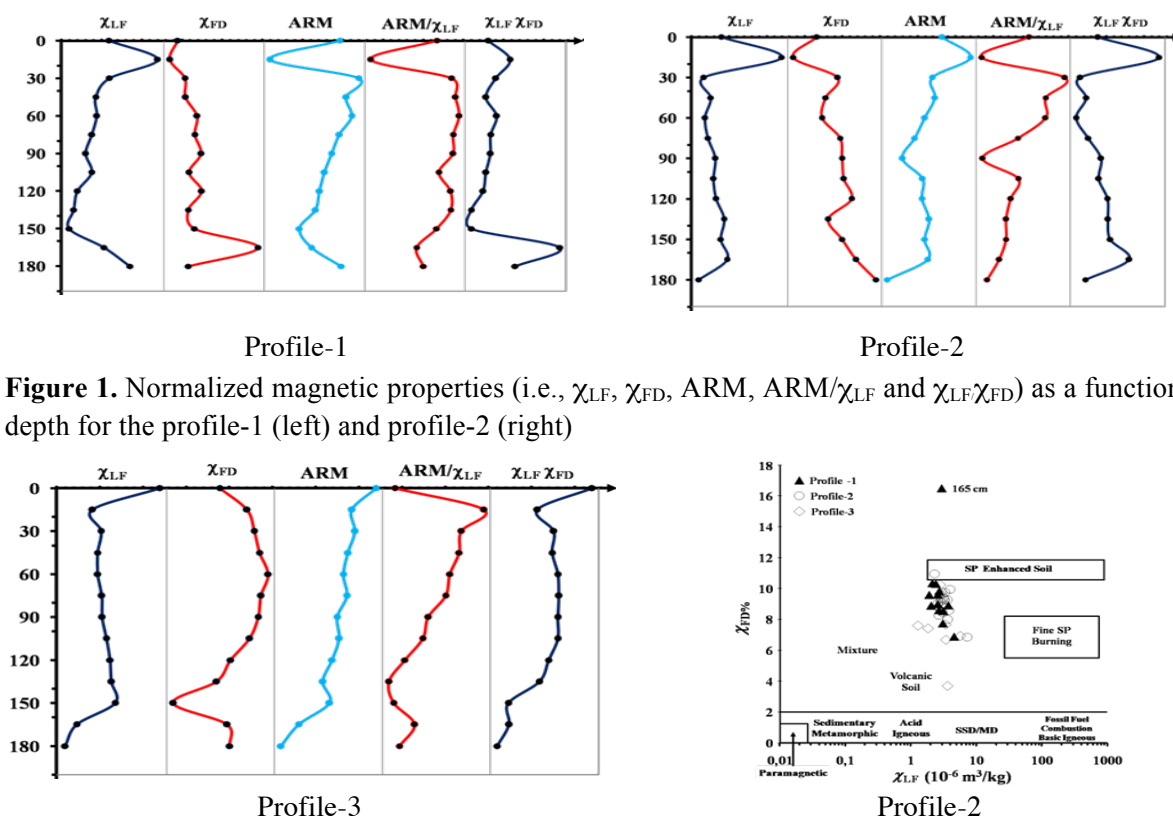
### 2.3 Chemical Analysis

Elemental analysis was performed by Kendari Assay Laboratory (PT IOL Indonesia) on whole soil samples (<2-mm) and on sand, silt and clay size (200 Mesh) fractioned samples using x-ray fluorescence (XRF) Spectrometry, Advant “Xp” type reported as percent weight of major elements as oxides. Percent weight of major elements as oxides was determined based on comparison with a certified standard reference material (SY-4, Canadian Certified Reference material Project) and organic carbon was estimated based on weight loss on ignition at 1010°C.

## 3. Results

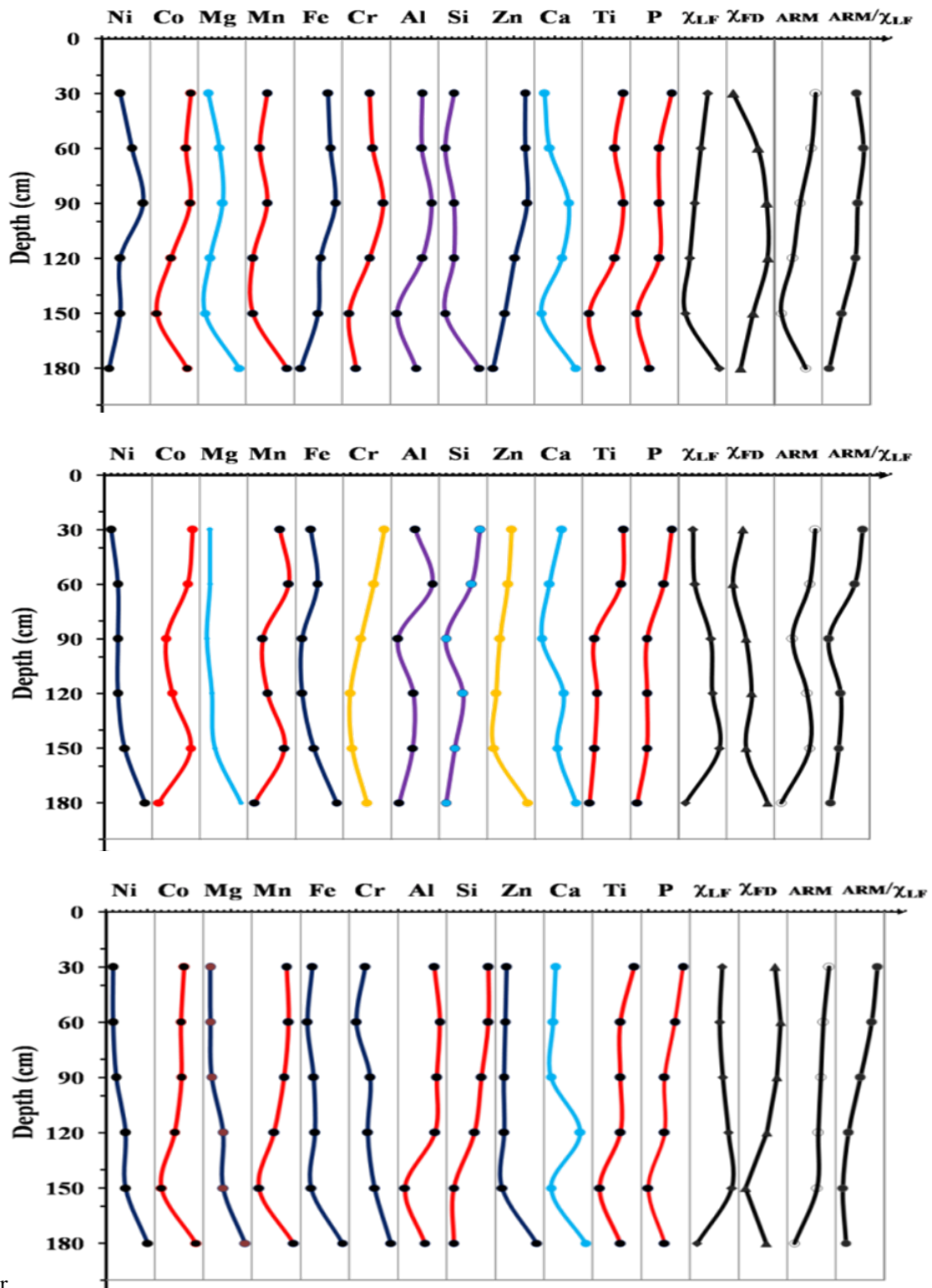
### 3.1 The variation of the magnetic properties

The patterns of variation of the magnetic properties in all the three soil profile were performed in the figure.1, (i.e., profile-1, profile-2 and profile-3, respectively) and figure 2. As shown in that figure, the trends of variaton for the magnetic susceptibility in all profile increase upward that express the enrichment of the magnetic mineral. The incresing trend is upward, therefore, also indicate a prolong pedogenic proceeses



**Figure 1.** Normalized magnetic properties (i.e.,  $\chi_{LF}$ ,  $\chi_{FD}$ , ARM, ARM/ $\chi_{LF}$  and  $\chi_{LF}\chi_{FD}$ ) as a function of depth for the profile-1 (left) and profile-2 (right)

**Figure 2.** Normalized magnetic susceptibility as function of depth (i.e.,  $\chi_{LF}$ ,  $\chi_{FD}$ , ARM, ARM/ $\chi_{LF}$  and  $\chi_{LF}\chi_{FD}$ ) with respect to depth for the profile-3 (left), and Scattergram of  $\chi_{FD}\%$  versus  $\chi_{LF}$  on the three laterite profile at which the box and labels are founded from Dearing (1999) (right)



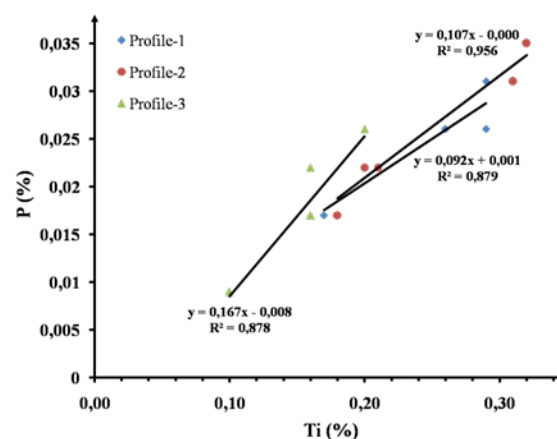
**Figure 3.** The Comparison of Variations of the chemical Elements and the magnetic properties (susceptibility) with respect to depth for the profile-1, Profile-2 and profile-2top to down, respectively, for selected samples

### 3.2 The distribution of the chemical elements and magnet properties

Analysis of the chemical element by XRF method identified fifteen element presented in Wantulasi soil in which the soil profile contains Ni, Co, Cu, Mn, Si, Mg, Fe, Zn, Al, Cr, Ca, T, P and S (figure 3). Fe is most abundant ranging from 14 - 18 %, follow by Si, Al, Ni, Co, Cu, Mn, Si, Mg, Zn, Al, Cr, Ca, T, P and S with less than 0,03%. The percentage of Si, which has been clearly performed, ranging from 2-8 %, consistent with analysis in other soils. Not clear or significant trends are observed in the comparison of the chemical element between the two profile. Among the various forms of chemical element found in soil profile, the existances of elements of Nickel (Ni), iron (Fe), Cobalt (Co) are of particular important for the application of the magnetic properties, since they have a highly magnetic susceptibility [12] and are economically valuable and worth.

### 3.3 Correlation between the magnetic properties and chemical elements

Although assignment of the association between the variation of the magnetic properties and the chemical-elements distribution can be unreliable, we suggest that the observed pattern between the two, can be related to the weathering history of the soils. The results of this comparative characterization demonstrate some distinct differences between the magnetic characteristic and chemical elements in soil profile. The observed differences are consistent with the hyphotesis that the high-Fe soil has experienced more intense weathering resulting from either the higher Fe concentration or the lower magnetic properties or both. Further work is needed to expalin the observed difference between the high-Fe and control soil and to identify specific mechanisms by which altered weathering conditions determine weathering rates. A high correlation was found (Figure 4) between the magnetic susceptibility and the Fe content of the frequency dependent susceptibility. This indicate that Fe, as well as Ni, Co and Mn, are elements that have high correlation in laterite soil.



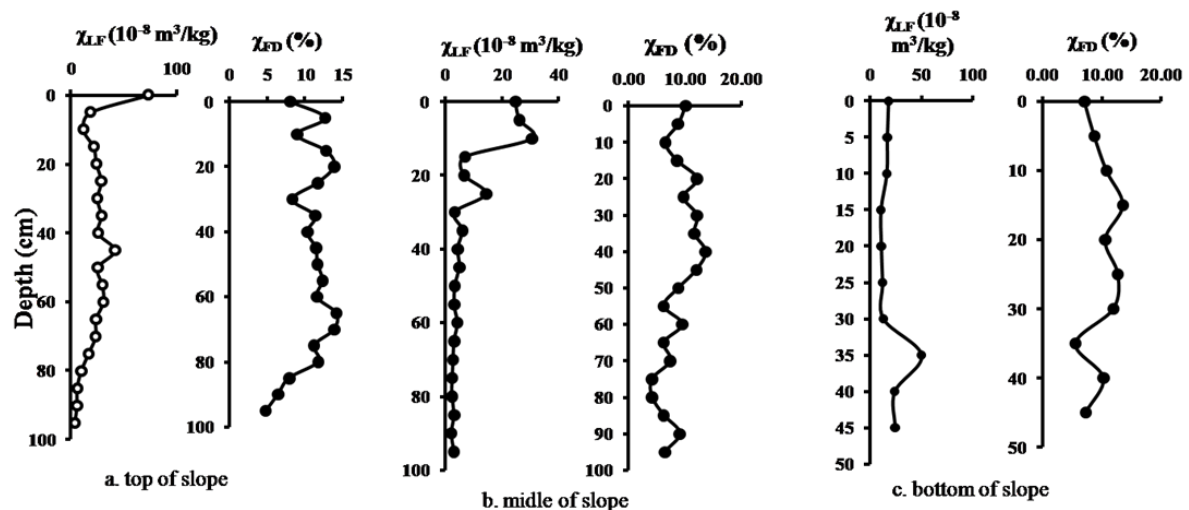
**Figure 4.** Relationship between concentration of Ti and P elements in all the three profile

As shown in above figure, the overall samples does not indicate whether or not magnetic properties correlates directly with the chemical elements. Although several soil samples perform the correlation between the chemical elements, the obtained results are still needed to test with the other methods

### 3.4 The variation of the magnetical properties of landslide soil

The patterns of variation of the magnetic properties of landslide soil on all the three soil profile were performed in the figure.5, (i.e., to, profip of slide, middle of slide and bottom of slide, respectively). In the top of slide  $\chi_{LF}$  value range from  $4,2 \times 10^{-8} \text{ m}^3/\text{kg}$  to  $73,2 \times 10^{-8} \text{ m}^3/\text{kg}$ , middle of slide  $\chi_{LF}$  value ranging from  $3,1 \times 10^{-8} \text{ m}^3/\text{kg}$  to  $24,8 \times 10^{-8} \text{ m}^3/\text{kg}$  and in the bottom of slide  $3,7 \times 10^{-8} \text{ m}^3/\text{kg}$  -  $20,5 \times 10^{-8} \text{ m}^3/\text{kg}$ . Analysis of the chemical element by XRF method identified six element

presented in landslide soil in which the soil profile contains Fe, Al, Mg, P, Si and S, however, they have irregularly pattern in magnetic value in top of slide, middle of slide and bottom of slide. As shown in that figure, the trends variation for the magnetic susceptibility in top and middle profile increase upward that express the enrichment of the magnetic mineral. The increasing trend is upward, herefore, also indicate a prolong pedogenic proces. Whereas, in the bottom of slide the trends of variation for the magnetic susceptibility differ with the others because of erosion processes and the landslide processes in a long time ago.



**Figure 5.** The magnetic properties ( $\chi_{LF}$  and  $\chi_{LF}\chi_{FD}$ ) of landslide soil as a function of depth for top of slide (left) middle of slide and bottom of slide (right)

#### 4. Discussion

Soil erosion causes a severe loss of biodiversity, soil fertility, and plant biomass productivity especially in agricultural activities in South Konawe Distric. The natural fenomena where there are some external factor including climate condition (the rain fall 2726,3 m m/year and the slope of field 300-600 m at sea level) triggering erosion as well as soil attributes such as mechanical composition, organic matter content, and water permeability. An experimental approach to soil erosion estimates is the use of measuring the magnetic properties of soil in landslide area and have the diferent pattern with laterite soil in Wantulasi site.

#### 5. Conclusion

This study provide inform that there exist a good correlations between elements in laterite soil profile at which the good correlation for all profile shown in the Titanium and phospour (P) element. This means that existing of one element in soil profile associated with the a given elements. the trends of variaton for the magnetic susceptibility in laterite soil increase upward that express the enrichment of the magnetic mineral, therefore, also indicate a prolong pedogenic proceeses. This study provides also confirming evidence that the magnetic properties does not directly correlated with all the chemical elements in laterite soil. The identification of the variation magnetic properties on the landslide soil indicated that the magnetic properties pattern as a proxy to evaluate landslide evident for long time ago.

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