# Relationship between magnetic susceptibility and elemental composition of Guano from Solek Cave, West Sumatera

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**Abstract.** We measured the magnetic properties and geochemistry of guano on a vertical profile from Solek Cave in West Sumatera. The aim of study was to evaluate whether there was a relation between magnetic susceptibility and the elemental composition of guano. Samples were collected at depth every 5 cm a depth of 230 cm where bedrock was reached. Magnetic susceptibility was measured by using susceptibility meter type Bartington MS2B and the element composition of guano samples was measured by X-Ray Fluoroscence (XRF). Percentage frequency dependence magnetic susceptibility was calculated from the percentage ratio of $\chi_{LF} - \chi_{HF}$. The results showed that the magnetic susceptibility varied between 86.8 x $10^{-8}$ $m^3/kg$ to 2204.2 x $10^{-8}$ $m^3/kg$. The results of the frequency dependence magnetic susceptibility indicates that the samples were dominated by multi domain magnetic grains. Additionally, guano samples were found to contain several elements such as Mg, Al, Si, Ca, K, P, Fe and Ti. In We find that there is weak correlation between magnetic susceptibility and elemental composition, particularly Fe and Ti. It indirectly shows the presence of authigenic minerals.

## 1. Introduction

Clastic sediments formed mechanically which can come from within the cave and materials transported in cave from outside [1]. Guano is one of clastic sediments in the cave and derived from rest of the process of disgestion (feces) of bats and birds [1,2]. Bat guano is mostly composed of organic material such as Chitin ($C_{18}H_{26}N_2O_{10}$) [2,3]. Chitin substances derived from insects that have not been digested in the body of the bat then deposited on the cave floor. However after guano deposits accumulate over long time periods, the organic material has decrease and mixed with other materials such as clay, quartz and phosphate minerals [4,5]. Besides that heavy metals can be also found in guano deposits [6,7].

Guano can be used as a good proxy to reveal past environmental changes such as tropical condition, vegetation, winter condition and anthropogenic influence [6,7,8,9,10]. Environmental changes stored in guano deposits can be seen and analyzed from material content such as magnetic minerals [9]. Although the presence and abundance of magnetic minerals in sediments is very small, but has a great influence and might serve as proxy indicators for environmental changes [11]. The magnetic minerals transport into the natural archives in two main ways such as transported by wind, water or because of the biological and chemical process [12].

The magnetic properties can be measured by using environmental magnetism method [12]. Besides that environmental magnetism had been widely used to detect magnetic mineral that provide natural archive of environmental process in suspended or deposited sediments of lakes [13,14], rivers [15,16,17], marines [18,19], soils [20,21] and cave deposits [7,22,23]. Magnetic susceptibility is a parameter that can explain how much magnetic minerals contained in the sample [24]. Magnetic susceptibility is described as the ratio of total magnetization induced to the intensity of the magnetic field generating magnetization [12,25]. Measurement of magnetic properties using magnetic susceptibility parameter is considered effective, fast, non-destructive and affordable [25,26].

Magnetic susceptibility ($\chi$) is not only influenced by abundance of iron-bearing ferrimagnetic and anti-ferromagnetic minerals, but also due to presence of diamagnetic and paramagnetic minerals such as carbonates quartz and clays [27]. The presence of magnetic minerals also explain whether it might come from biogenic, authigenic or detrital input [12,28]. In this study, we measured magnetic susceptibility ($\chi$) and geochemistry of guano samples. Furthermore, we evaluate there was a relation between magnetic susceptibility and elemental composition of guano.

## 2. Methods

Sampling was conducted from one site of Solek Cave in West Sumatera Province. The site is located in Solek Cave ($0^0$ 16' S, $100^0$ 43' E). The samples were collected vertically at depth every 5 cm a depth of 230 cm where bedrock was reached. A total of 46 guano samples were put into polyethylene bags then taken to Geophysics Laboratory in State University of Padang. In the laboratory, samples were opened from polyethylene bags and placed into tightly secured cylindrical plastic holder.

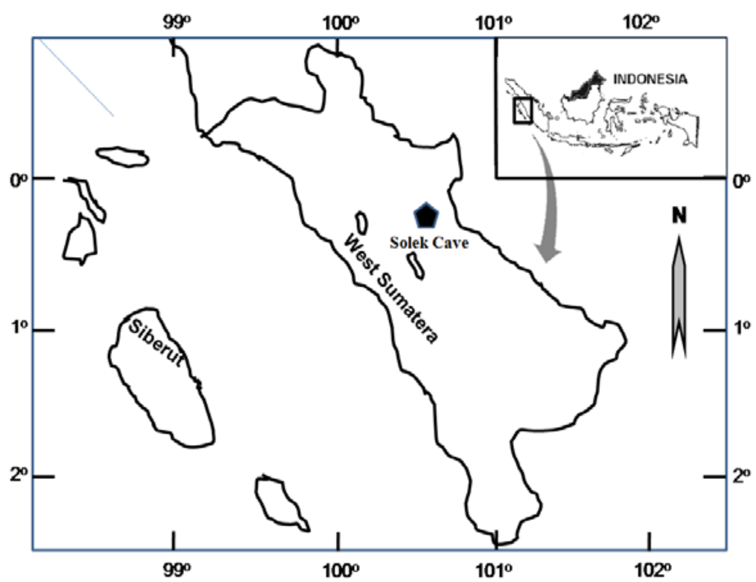


**Figure 1.** Location of sampling site

Magnetic susceptibility measurements were performed by using Bartington MS2B instrument at two different frequencies, 0.47 kHz for low frequency magnetic susceptibility ($\chi_{LF}$) and 4.7 kHz for high frequency magnetic susceptibility ($\chi_{HF}$) with the 1.0 sensitivity setting. Each sample was measured three times to obtain average value with an air reading before and after each series for drift correction. Frequency dependent susceptibility $\chi_{FDS}$ could be obtained from percentage ratio $\chi_{LF} - \chi_{HF}$. This parameter can detect superparamagnetic influence (Dearing, 1999). Meanwhile, selected guano samples were examined by using X-Ray Fluorescence (XRF) to obtain elemental composition of guano samples. The selected samples represent the lowest to the highest magnetic susceptibility value. XRF measurements were condcucted by using PANalitical type Epsilon 3 at Chemical Laboratory in State University of Padang. The results of magnetic susceptibility values are plotted against each depth and elemental composition in order to see the relationship.

## 3. Results

Figure 2 shows three graphs of magnetic susceptibility values in low frequency ($\chi_{LF}$), high frequency ($\chi_{HF}$) and frequency dependent susceptibility ($\chi_{FDS}$) of guano samples from Solek cave. The low frequency magnetic susceptibility values ($\chi_{LF}$) varied between 86.8 x $10^{-8}$ $m^3$/kg to 2204.2 x $10^{-8}$ $m^3$/kg with an average of 641.98 x $10^{-8}$ $m^3$/kg. The high frequency magnetic susceptibility values ($\chi_{HF}$) have values ranging from 85.5 x $10^{-8}$ $m^3$/kg to 2200.5 x $10^{-8}$ $m^3$/kg with an average of 637.85 x $10^{-8}$ $m^3$/kg. Peak values of magnetic susceptibility were found at a depths of 10 cm, 120 cm, 150 cm, 160 cm and 195 cm with values above 1000 x $10^{-8}$ $m^3$/kg. Figure 3 shows the graph of $\chi_{HF}$ against $\chi_{lF}$. The graph shows a linier relationship between two parameters with good correlation coefficient ($R^2$ = 1). The $\chi_{HF}$ obtained is not much different compared to $\chi_{LF}$. Guano samples from Solek Cave have a fairly large magnetic susceptibility values and its values fluctuate at each depth.

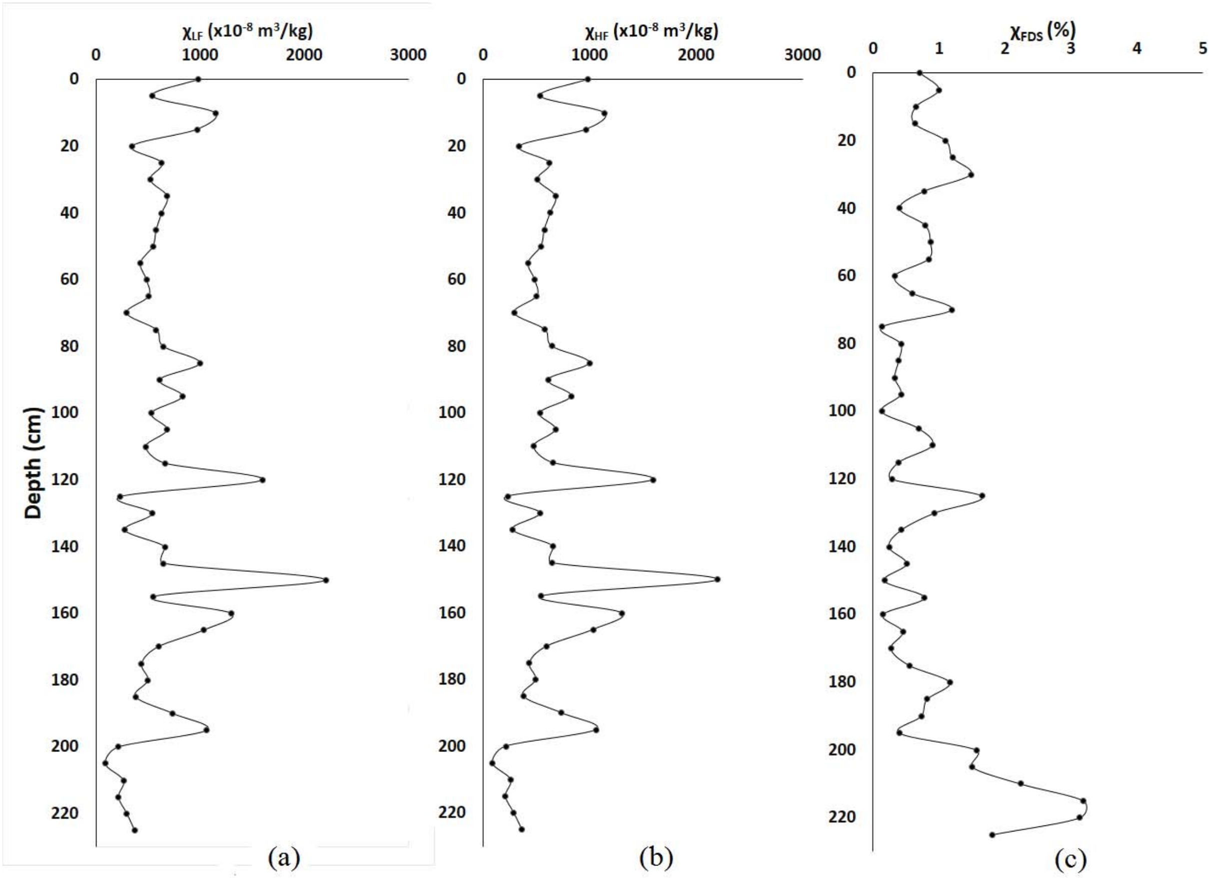


**Figure 2.** Magnetic susceptibility in low frequency (a) high frequency (b) and frequency dependent susceptibility (c).

The results of percentage frequency dependent susceptibility ($\chi_{FDS}$%) has varying values at each depth. The calculated $\chi_{FDS}$ values were obtained between 0.13 % to 3.19 % with an average 0.85%. Figure 4 shows relationship between $\chi_{LF}$ and $\chi_{FDS}$ with weak correlation ($R^2$ =.0.41). These results show that all almost samples contained Multi Domain (MD) grains. Only three samples were found contained mixture Single Domain (SD) and Superparamagnetic (SP) grains at depth of 95 cm, 100 cm and 105 cm. The $\chi_{FDS}$% values which are smallest or closer to zero (<2%) have MD grains. Meanwhile $\chi_{FDS}$% values between 2-10 % indicate mixture SD and SP grains [25].

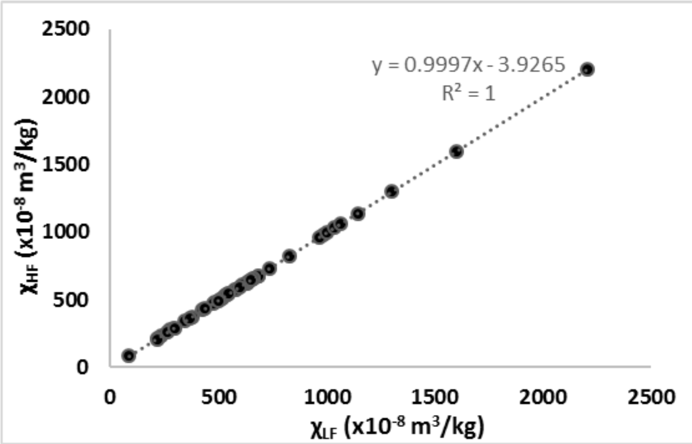


**Figure 3.** Relationship between the $\chi_{LF}$ and $\chi_{HF}$.

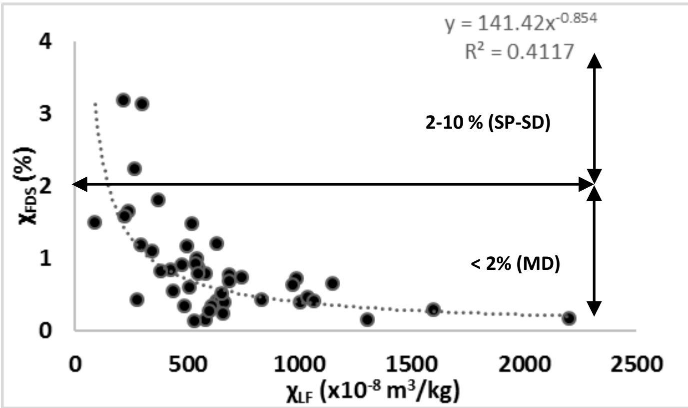


**Figure 4.** Relationship between $\chi_{LF}$ and $\chi_{FDS}$.

**Table 1.** XRF results showing elemental composition.

| Sampel | Elemental Composition (%) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Depth (cm) | Fe | Ti | Mg | Al | Si | P | K | Ca |
| 0-5 | 13.813 | 1.898 | 1.134 | 26.217 | 45.973 | 3.244 | 2.358 | 3.39 |
| 35-40 | 13.514 | 1.357 | 2.868 | 28.381 | 47.96 | 1.573 | 1.936 | 0.843 |
| 150-155 | 10.91 | 1.093 | 0.995 | 32.748 | 50.169 | 0.468 | 0.859 | 0.85 |
| 155-160 | 17.419 | 1.725 | 5.852 | 24.78 | 43.963 | 1.265 | 1.199 | 1.514 |
| 205-210 | 10.448 | 1.406 | 2.48 | 31.404 | 48.44 | 0.796 | 1.131 | 0.807 |

The analyses of selected guano samples have revealed the presence and concentration of elemental composition (Table 1). Other elemental composition were not listed because their values showed relatively little variation. The results of XRF shows presence of element such as Fe which are part of ferromagnetic elements, paramagnetic (Ti, Mg, Al, K and Ca) and diamagnetic (Si and P). High concentration of Al and Si were found respectively with the average percentage of 28.7 % and 47.3 %. The average percentage of Fe for guano samples is 13.22 %, while average percentage of Ti is 1.49 %. The other elements (Mg, P, K and Ca) have the average percentage values respectively are 2.66 %, 1.46 %, 1.49 % and 1.48 %.

## 4. Discussion

Comparing the guano deposits to that from elsewhere [7,9], the magnetic susceptibility values in the Solek Cave (above 100 x $10^{-8}$ $m^3$/kg) were relatively high and could be indicated high concentration of ferrimagnetic in the guano deposits. The observed variability of magnetic susceptibility values was likely due to controlled by climate alteration. Data from geochemical analysis by using XRF, shows relatively high concentration of Al and Si. The presence of Si and P indicate that guano deposits contain quartz and phosphate minerals [4,5]. Solek Cave are mostly composed of several high concentration elements including paramagnetic. The abundance of heavy metals which found in the guano deposits was even very small. The anthropogenic impact could be evaluated according to the heavy metals abundance [16,20]. Thus, it was evident that guano deposits inside the Solek Cave were natural and not affected by anthropogenic influence. Mostly magnetic grains which found in guano deposits were Multi Domain. The presence of consistent fine magnetic grains (e.g. magnetite) could be also caused by climate change [23].

Figure 5 shows relationship between the $\chi_{LF}$ and elemental composition and Table 2 shows the coefficient determination of $\chi_{LF}$ and elemental composition. Mostly there are weak correlations between magnetic susceptibility and elemental composition with low $R^2$ values. Weak corelation $\chi_{LF}$ -Fe and $\chi_{LF}$ -Ti were likely due to the association with authigenic minerals [29]. By looking at the condition in the Solek cave, magnetic minerals are not derived by the detrital source and may come from authigenic.

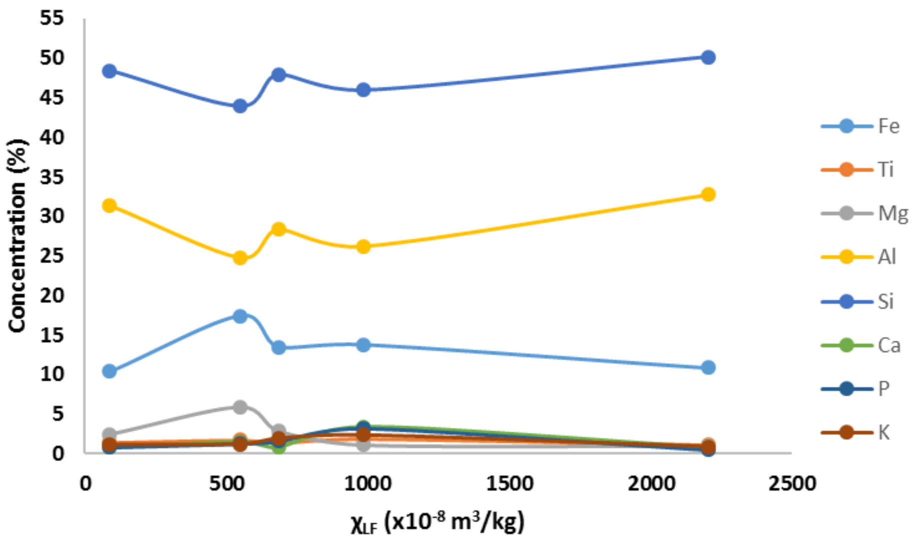


**Figure 5.** Relationship between the $\chi_{LF}$ and elemental composition.

**Table 2.** Relationship between $\chi_{LF}$ - elemental composition and $R^2$ values.

| Elemental Composition | $R^2$ |
|---|---|
| $\chi_{LF}$ - Fe | 0.06 |
| $\chi_{LF}$ - Ti | 0.21 |
| $\chi_{LF}$ - Mg | 0.28 |
| $\chi_{LF}$ - Al | 0.16 |
| $\chi_{LF}$ - Si | 0.23 |
| $\chi_{LF}$ - P | 0.02 |
| $\chi_{LF}$ - K | 0.05 |
| $\chi_{LF}$ - Ca | 0 |

## 5. Conclusion

Magnetic susceptibility variations are not only controlled by the concentration of iron oxide and magnetic grain size but also paramanetic element such as (Ti, Mg, Al, K and Ca). Weak correlation of Fe and Ti against magnetic susceptibility may have been associated with authigenic minerals.

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