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Magnetic Susceptibility of nanoparticles in the Lubuk Basung Region

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Abstract: Nanoparticles is particles that have size very small, generally in range from 1 to 100 nanometers. Nanoparticles have one uniqueness with exists characteristic superparamagnetic. Characteristic superparamagnetic is properties the material has magnetization tall if given external magnetic field, however when No There is external magnetic field mark the average magnetization is zero. On size certain, nanoparticles can show transition from superparamagnetic to ferromagnetic or antiferromagnetic. Influence size grain and structure crystal to characteristic magnetic is one method in determine susceptibility. Susceptibility magnetic is defining constant big small a material to magnetized. Study This aim to the analyze mark susceptibility magnetic from nanoparticles rock floating in the area Lubuk Basung. Method used is method magnetism rock with tool Bartington Magnetic Susceptibility Meter Type B. Research results shows in the area Lubuk Basung LBS 23-02 and LBS 23-03 are available concentration content high Fe element and concentration content element Ti more low. Magnetic susceptibility in the area Lubuk Basung have characteristic antiferromagnetic magnetism, and has type grain almost no There is details superparamagnetic and also has mixture superparamagnetic and granular rough or details superparamagnetic <0.05 μm equivalent with <50 nm. So that depicted that size nanoparticles contained in the sample rock floating LBS 23-02 and LBS 23-03 have size nanoparticles below 50 nanometers with characteristic antiferromagnetic magnetism.

Keywords: Nanoparticles; Magnetic Susceptibility; Pumice; Rock Magnets; Magnetic Mineral

1. Introduction

Nanoparticles is particles that have size very small, generally in range from 1 to 100 nanometers. Nanometers (nm) are unit long in System Unit International (SI) which is 1 nanometer equivalent with One billion meters or 10^{-9} meters. Size This very small so that nanoparticles own characteristic different physics and chemistry compared to with more particles big [1] . Because of

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its enormous size small, nanoparticles magnetic own wide very surface big relatively to the volume, which makes they own characteristic unique physical and chemical properties. Nanoparticles have one uniqueness with exists characteristic superparamagnetic. Characteristic superparamagnetic is properties the material has magnetization tall if given external magnetic field , however when no There is external magnetic field mark the average magnetization is zero [2] . On size certain , nanoparticles can show transition from superparamagnetic to ferromagnetic or antiferromagnetic [3] .

Very big size small This give nanoparticles characteristic different unique from material in size macroscopic. A number of characteristic typical nanoparticles covers improvement reactivity chemistry, ability to the penetrate membrane cells, and changes characteristic optical, thermal, as well as magnetism. Nanoparticles magnetic is particle nanoscale which has characteristic magnetic. Particle This often made from materials such as iron oxide Fe_3O_4 (magnetite), cobalt, or nickel, which has characteristic ferromagnetic or superparamagnetism on the nanoscale. Magnetic nanoparticles consist of from various differentiated types based on characteristic the magnetic that is Magnetite (Fe_3O_4) and Maghemite (γ-Fe_2O_3) [4] . Magnetite (Fe_3O_4) is one type nanoparticles the most common magnetic used. Magnetite own characteristic superparamagnetic at the nanoscale , which makes it very effective in application medical such as MRI and therapy hyperthermia [2] . Similar with magnetite, maghemite also have characteristic superparamagnetic. The difference lies in the structure crystals and content the oxygen. Maghemite often used in application similar with magnetite. Influence size grain and structure crystal to characteristic magnetic is one method in determine susceptibility [5] .

Susceptibility magnetic is defining constant big small a material For magnetized [6] . Susceptibility magnetic represent material inclination to become inner magnetic material influence external magnetic field [7] . Measurement susceptibility can also for identify carrier minerals Fe in a sample different types of minerals , as well identify the processes of formation and movement of these minerals [8] . In a number of case, nanoparticles can own susceptibility more magnetic tall compared to with bulk material because size small possible more many atoms on the surface, which can interact more strong with magnetic field.

Intensity external magnetic field If given to someone material, then material the will give called response with magnetization [9] . If magnetization $(\vec{M})$obtained in a material parallel and in the same direction as the external magnetic field $(\vec{H})$, then the proportionality constant is the magnetic susceptibility per unit mass (χ) and is related through the following equation:

$$\vec{M} = \chi\vec{H} \tag{1}$$

Measurement susceptibility magnetic can done almost everything material. Susceptibility magnetic measured at a range Medan magnetic certain will give connection magnetization with Medan the. Connection This can give linear relationship or not linear depending on size Medan magnetic used. Susceptibility magnetic can measured with use method magnetism rocks [10] .

Rock magnetism is one of the geophysical methods that investigates the magnetic properties of a material. All materials have magnetic properties, but the magnetism of a material differs from one to another [11]. The rock magnetism method is a method that measures the magnetic susceptibility of rocks to determine how much the rock responds to a magnetic field, thereby providing information about the general magnetic mineral content of the rock [12]. This method has a relatively high accuracy in measurement [13]. The rock magnetism method is used to identify rock types and magnetic mineral content. Differences in magnetic susceptibility can provide clues to the mineralogical composition of rocks.

Indonesia has abundant natural magnetic material potential, one of which is pumice. Pumice is a natural magnetic material formed due to volcanic activity. The distribution of pumice in Indonesia is spread across several islands, one of which is Sumatra [14]. On Sumatra Island, especially in West Sumatra with volcanic activity areas, such as the eruption of Mount Maninjau Purba, pumice is produced during an eruption [15]. Pumice is formed from rapidly cooling lava and contains trapped gas bubbles, giving it a light and porous nature. The presence of pumice provides benefits for local industries, such as agriculture, construction, and skin care, because pumice can be used as a natural material that has various functions. Pumice can be used to remove water contaminants if coated with nanoparticles such as metal oxides.

Metal oxides are formed when metals react with oxygen, an example of a metal oxide is iron oxide. Iron is the most abundant metal in nature as the most abundant element forming the earth, which is approximately 4.7-5% in the earth's crust. Most iron is found in rocks and soil as iron oxide, such as magnetite iron oxide (Fe_3O_4), hematite (Fe_2O_3), limonet (Fe_2O_3 H_2O) and siderite (Fe_2CO_3) [16]. In life, iron is a metal that is often used, because it is widely available in all corners of the world and its processing is relatively cheap and easy and its properties are easily modified. Pumice and obsidian contain titanomagnetite minerals, with no evidence of prolonged crystallization at high oxygen levels on the earth's surface [17]. Ti-magnetite is greatly influenced by factors such as melt composition and temperature. Iron oxide in pumice forms nano triggered by oxides in the magma chamber [18]. To be able to determine the magnetic susceptibility of pumice nanoparticles, the method used is the rock magnetism method.

This research is important because examining the magnetic susceptibility of pumice nanoparticles can provide information about the mineral composition and formation process of the rock. Pumice is a type of rock formed from volcanic eruptions, has high porosity, and usually contains certain minerals that can be magnetic. In the Lubuk Basung area, which is part of West Sumatra, this study can provide insight into the geological history and volcanic activity that has occurred in the area. Magnetic susceptibility can be used to detect the presence of magnetic minerals, such as magnetite or hematite, which may be contained in pumice. This research makes it possible to find out whether pumice in the area contains valuable minerals or other natural resources that can be explored further.

2. Materials and Method

The research was conducted in several stages starting from the sampling stage, sample preparation, measurement, data processing, and data analysis. Retrieval sample carried out in the area Lubuk Basung, Agam, West Sumatra (Fig 1). Lubuk Basung located at coordinates S 02.9450 ° E 100.046°. Lubuk Basung is the capital city Regency Religion in West Sumatra Province, Indonesia. Condition geology in Lubuk Basung influenced by its existence in the Bukit Barisan area which is network mountains that stretch along Sumatra Island. Lubuk Basung region located near with the fault zone big, like Sumatran Fault, which is one the most active fault in the world. This matter cause area This prone to to activity seismic, incl earthquake earth. Lubuk Basung area consists from various type rocks, incl rock volcanic, sedimentary, and metamorphic. Rock volcanic in this region originate from activity volcanic mountains fiery in Sumatra, like Mountain Marapi and Mt Singgalang. This region own hilly topography with a number of steep valley. Condition This often cause happen erosion and landslides, especially during the season Rain. Although No is at right in the volcanic zone active, Lubuk Basung located No Far from a number of mountain Active volcano in West Sumatra. This make it potential affected by activity volcanic, like eruption or lava flow.

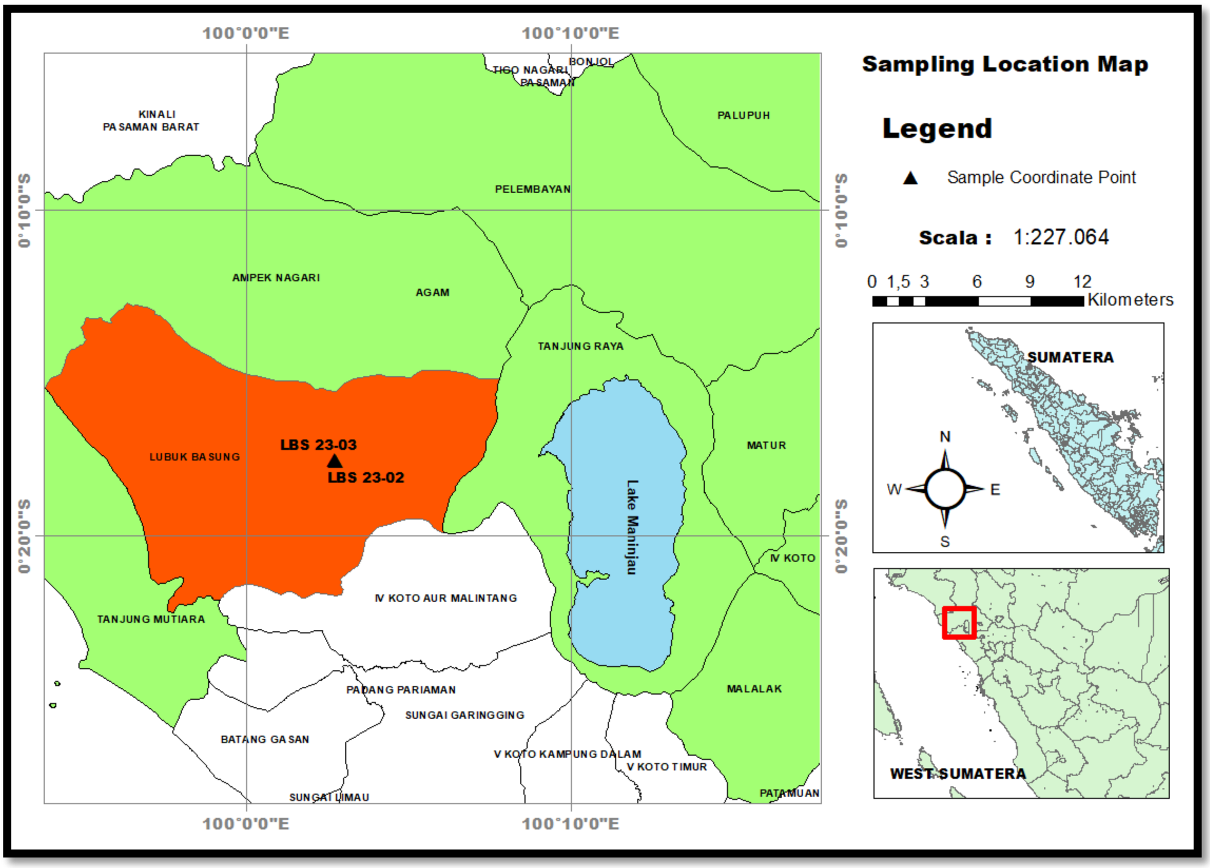

Figure 1. Sampling Location Map

Before analyzed, samples form rock buoyant made with method smoothed and inserted to in a 10 ml holder, as well measured its mass. Samples that have been weighed use balance sheet Ohaus measured its vulnerability use tool Bartington Magnetic Susceptibility Meter Sensor Type B (MS2B) [19] . This tool has two different frequencies, low frequency (470 Hz) and high frequency (4700 Hz). Frequency-dependent magnetic susceptibility can indicate the presence of superparamagnetic minerals in the sample [20] . From the measurement results with different frequencies, with equation (2) the frequency-dependent susceptibility (χ_{fd}) (%). The highest frequency-dependent susceptibility value with a percentage of more than 14%. If it is more than 14% then the data has been contaminated. For know and get frequency dependent susceptibility (χ_{fd}) (%) then, can used equation 2

$$\%\chi_{fd} = \frac{\chi lf - \chi hf}{\chi lf} \times 100\% \quad \% \qquad (2)$$

Where χ_{lf} is the susceptibility of the mass to the frequency low and χhf is mass susceptibility at high frequencies. χ_{fd} interpreted as the minimum of the narrower frequency range that is interpreted For reflect existence SP (superparamagnetic) particles [21] . In rocks and soil, ferromagnetic minerals generally originate from family iron -titanium oxide, sulfide iron, and hydroxide iron. By general, increasingly tall ferromagnetic mineral content in a rocks, then the more tall susceptibility the magnetic. On the contrary, increasingly diamagnetic mineral content will the more decrease susceptibility the magnetic. This matter can seen in % $\chi_{fd}$where the higher the valueχ_{fd} so existence particle superparamagnetic the more high, so content ferromagnetic will the more low. On the contrary if mark χ_{fd} the more low so the presence of superparamagnetic particles is low and the ferromagnetic content is high. Information about existence grain superparamagnetic This can obtained through measurement susceptibility magnetic on two different frequencies, p This caused characteristic sensitive superparamagnetic (SP) grains to change frequency. Difference susceptibility magnetic in difference frequency known with the frequency dependent susceptibility parameter (χ_{fd}).

Table 1. Interpretation of values χ_{fd}

χ_{FD}	Persentase	Information
Low χ_{fd}%	< 2 %	There are almost no Sp grains
Medium χ_{fd}%	2- 10%	A mixture of SP and coarse granules, or SP granules <0.05 µm
High χ_{fd}%	10-14%	Almost all SP items
Very high χ_{fd}%	> 14%	Incorrect measurements, anisotropy, weak samples or contamination

(Source: [20])

Table 3 shows four divisions, each categorized into low, medium, high, and very high levels. Frequency-dependent susceptibility values with a percentage below two percent without superparamagnetic grains. Superparamagnetic grains are magnetic nanoparticles contained in ferrimagnetic or ferromagnetic. The highest frequency-dependent susceptibility value with a percentage of more than 14%. The relationship between magnetic susceptibility values with magnetic properties and types of magnetic minerals can be seen in Table 1.

Table 2. Magnetic Susceptibility of Various Minerals

Magnetic Minerals			
Mineral Type	**Properties of Magnetism**	**Magnetic Susceptibility**	
		Volume (x 10^{-6} SI)	**Mass (x 10^{-8} SI)**
Magnetite (Fe_3O_4)	Ferrimagnetic	1.000.000 – 5.700.000	20.000 - 110.000
Hematite (αFe_2O_3)	Antiferromagnetic	500 - 40.000	10 – 760

Maghemite (γFe_2O_3)	Ferrimagnetic	2.000.000 - 2.500.000	40.000 - 50.000
lemenite ($FeTiO_3$)	Antiferromagnetic	2.200 - 3.800.000	46 - 80.000
Pyrite (FeS_2)	Ferrimagnetic	35 - 5.000	1 – 100
Pyrhotite (Fe_7S_8)	Ferrimagnetic	3.200.000	69.000
Geothite ($\alpha FeOOH$)	Antiferromagnetic	1.100 - 12.000	26 – 280
Non Magnetic Minerals			
Quartz (SiO_2)	Diamagnetic	13 – 17	0,5 - 0,6
Calcite ($CaCO_3$)	Diamagnetic	7,5 – 39	0,3 - 1,4
Halite (NaCl)	Diamagnetic	10 – 16	0,48 - 0,75
Galena (PbS)	Diamagnetic	33	0,44

(Source:[11])

When in bulk form, magnetite has high magnetic susceptibility due to its ferromagnetic nature. However, as a nanoparticle, magnetite can exhibit superparamagnetic properties, which changes the way the material responds to a magnetic field. Hematite in bulk form usually exhibits antiferromagnetic properties, but as a nanoparticle, it can exhibit increased magnetic susceptibility due to changes in its magnetic structure.

The size and shape of nanoparticles can affect magnetic susceptibility. Smaller nanoparticles tend to have higher susceptibility due to stronger quantization effects. The shape of nanoparticles can also affect the internal magnetic field distribution, which in turn affects susceptibility. The size of a material at the nanoscale affects the magnetic properties of that material. Magnetic susceptibility is a measure of how strongly a material can be magnetized in an external magnetic field. Minerals in bulk form have a certain magnetic susceptibility that is unique to each type of mineral. However, when these minerals are reduced to nanoparticle size, their magnetic susceptibility can change significantly. This change is caused by the effect of particle size on the crystal structure and magnetic domains of the mineral.

When ferromagnetic or ferrimagnetic minerals are reduced to nanometer size, the particles can become superparamagnetic. In this state, the nanoparticles exhibit magnetic properties only under an external magnetic field and have no residual magnetization when the field is removed. This is different from ferromagnetism on a bulk scale, where the material can retain magnetization even after the magnetic field is removed.

3. Results and Discussion

Results data measurement content elements contained in the sample rock floating in the area Lubuk Basung there is mark content Fe and Ti elements can seen in Figure 2.

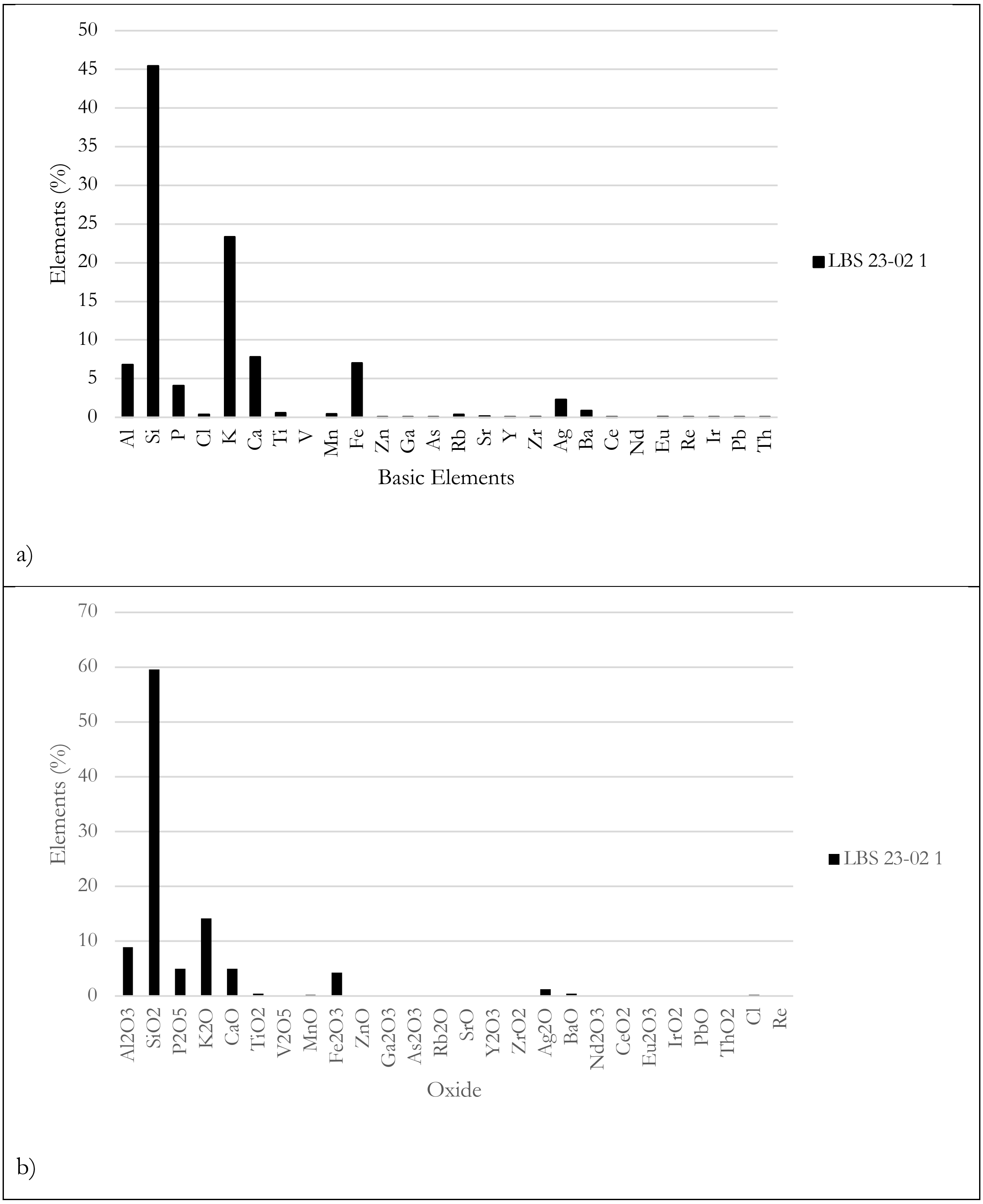

Figure 2. Histogram of XRF measurements on LBS samples 02-23-1 (a) Content element base rock, (b) Content Oxides in rocks

Sample LBS 23-02-1 has content element forming the magnetic minerals Fe and Ti (Fig 2). Content the Fe element is 7.029% and the content oxide Fe_2O_3 as much as 4.303%. Whereas content element Ti as much as 0.614% and content TiO_2 oxide as much as 0.451%. Apart from that, there are other elements in the pumice stone.

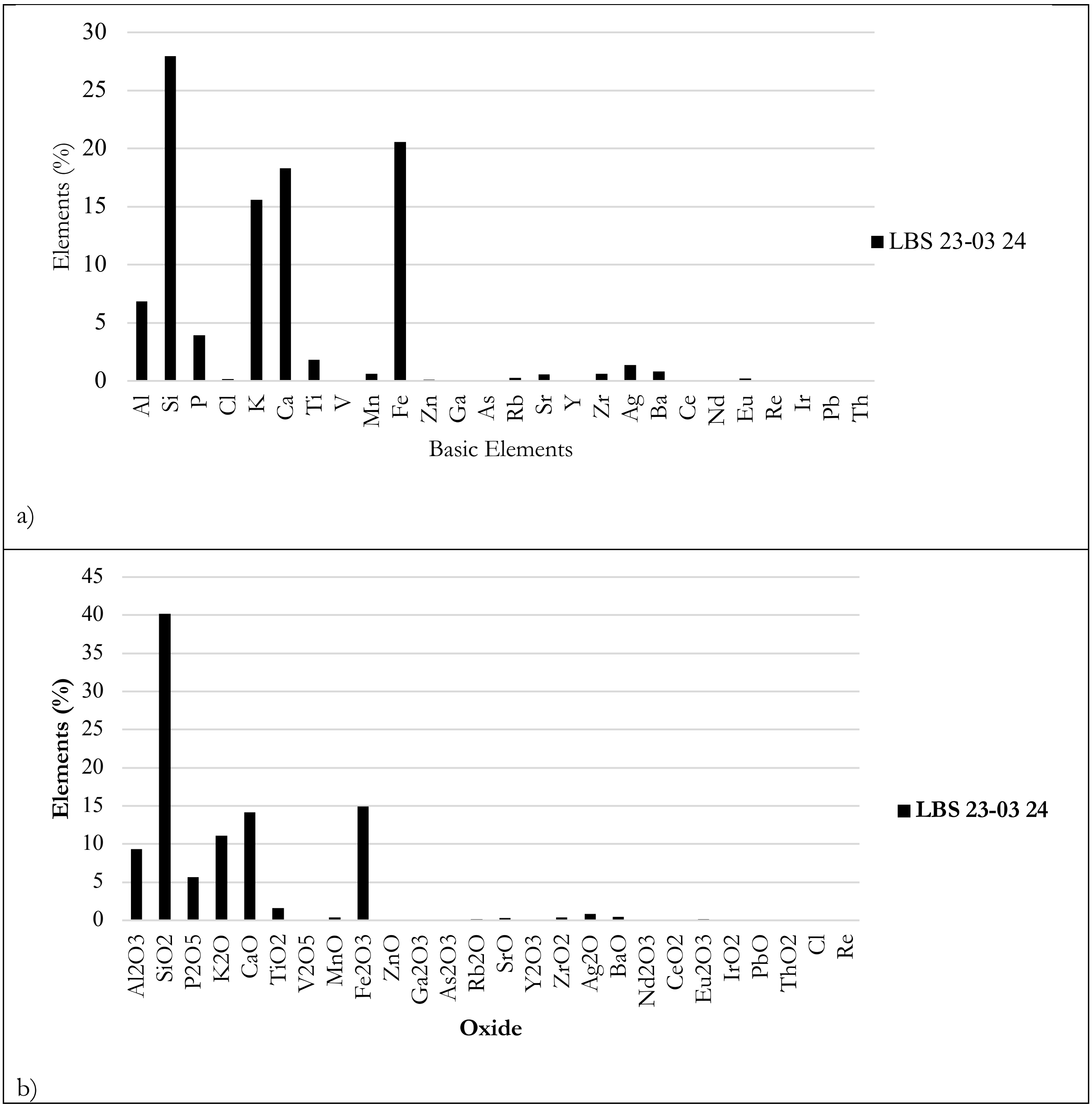

Figure 3. Histogram of XRF measurements on LBS samples 03-23-24 (a) Content element base rock, (b) Content Oxides in rocks

Sample 03-23-24 has content element forming the magnetic minerals Fe and Ti (Fig 3). Content Fe elements contain 20.579 % content oxide Fe_2O_3 as much as 14.917%. Whereas content element Ti own content as much as 1.837% and content TiO_2 oxide as much 1.614 %. Apart from that, there are other elements in the pumice stone.

Based on mark content element of Fe and Ti as well as mark Fe_2O_3 oxide and TiO_2 oxide then can known that magnetic minerals of Fe is hematite with formula chemistry αFe_2O_3 and elements Ti is the mineral Iemenite with formula $FeTiO_3$ chemistry.

Based on Figure 2 and Figure 3 samples rock floating in the area Lubuk Basung own mark content high Fe elements. High Fe element value own impact direct to size and nature nanoparticles magnetic, like nanoparticles hematite (Fe_2O_3) or magnetite (Fe_3O_4) [4] . whereas mark content element Ti less compared to Fe element. Ti often used for modify characteristic magnetic from

nanoparticles Fe_2O_3 or Fe_3O_4. With content Low Ti, nanoparticles possible show characteristic more magnetic strong because domination.
Hematite mineral own characteristic magnetism antiferromagnetic and magnetic minerals have characteristic antiferromagnetic and ferrimagnetic magnetism. Abundance of magnetic minerals can seen from frequency low (χ_{lf}) and high frequency (χ_{hf}) found in the sample rock floating in the area Lubuk Basung as shown in Table 3.

Table 3. Susceptibility Values Magnetic Rock Floating in the area Lubuk Basung

No	Sample Name	χ_{lf} ($\times 10^{-8}$ m ^{3}/kg)		χ_{fd} (%)	
		Range	Average	Range	Average
1.	LBS 23-02	6.5-163.3	33.9302	0-5.71	2.096551
2.	LBS 03-23	41.9-626.4	341,046	0-2.43	0.8704

On rocks buoyant Lubuk Basung 23-02 which has mark χ_{lf} the highest is LBS 23-02-9 (163.3×10^{-8} m ^{3}/kg) and the value χ_{lf} the smallest is owned by the LBS 23-02-1 sample (6.5×10^{-8} m ^{3}/kg) with an average of 33.93023×10^{-8} m ^{3}/kg, while mark χ_{fd}.The largest (%) is owned by the LBS 23-02-38 sample (5.71%) and χ_{fd} the smallest (%) is LBS 23-02-2, LBS 23-02-4, LBS 23-02-15, LBS 23 -02-39 (0%) with an average of 2.096512%.

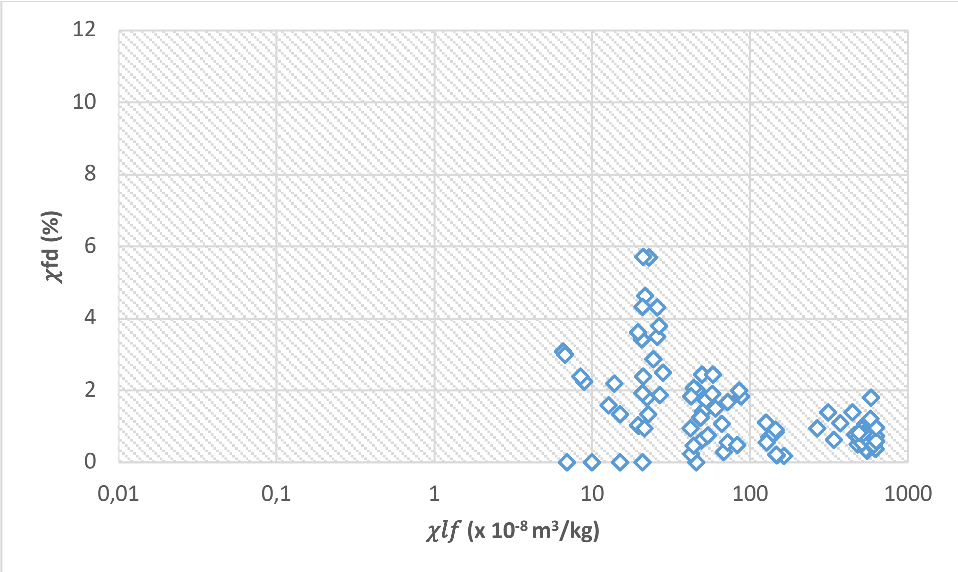

Figure 4. Relationship plot mark χ_{lf} and χ_{fd}(%) on the sample

On rocks buoyant Lubuk Basung 23-03 which has mark χ_{lf} the highest is LBS 23-03-22 ($626.4\times10^{-8}m^3/kg$) and the value χ_{lf} the smallest was owned by the LBS 23-03-40 sample ($41.9\times10^{-8}m^3/kg$) with an average of $341.046\times10^{-8}m^3/kg$, while mark χ_{fd} the largest (%) was owned by the LBS 23-03-33 sample (2.43%) and χ_{fd} the smallest (%) was LBS 23-03-39 (0%) with an average of 0.8796%. In context rock buoyant, which is type rock volcanic, susceptibility the magnetic usually different. Differences in each sample caused by differences characteristic magnetism sample. Susceptibility high magnetic show relative ferromagnetic mineral content little and porosity tall in rock buoyant, meanwhile susceptibility low magnetic show that sample tend nature diamagnetic[13]

. Connection between χ_{lf} and χ_{fd} (%) on samples pumice of Lubuk Basung 23-03 got it seen in the graph (Fig 4).

Connection between χ_{lf} and χ_{fd} *(%)* on samples rock buoyant from Lubuk Basung 23-03 got it seen on the graph below (Fig 2). every sample own mark χ_{fd}*(%)* are different every the sample with range 0%-5.71%, meanwhile mark χ_{lf} also varies with a range of $6.5 \times 10^{-8} m^3/kg$ to $626.4 \times 10^{-8} m^3/kg$. Based on susceptibility data magnetic field obtained (Table 3) and the plot in (Fig 4), can be classified characteristic magnetism and type details superparamagnetic in each sample, so can used for analyze characteristics details superparamagnetic magnetic minerals in every sample (Table 4). Big small highly magnetic granules influence properties of magnetic minerals [22]. Magnetic grains are matter most importantly in the magnetic domain because both of them show mark susceptibility the same magnetic from measurement frequency high and low [23] .

Table 4. Characteristics of magnetic minerals sample

Sample Name	**Susceptibility Value Magnetic**		**Characteristic magnetism**	**Type grain**
	χ_{lf} ($10^{-8} m^3/kg$)	**χ_{fd}(%)**		
LBS 23-02	6.5 – 163.5	0 – 2.43	Antiferromagnetic	Almost No own SP granules and Mixture of SP and granules rough, or SP granules < 0.05 μm
LBS 03-23	41.9 – 626.4	0 – 5.71	Antiferromagnetic	Almost No own SP granules and Mixture of SP and granules rough, or SP granules < 0.05 μm

Based on Table 4, can seen characteristics of magnetic minerals each sample. Characteristic magnetism rock floating in the area Lubuk Basung sample LBS 23-02 is characteristic antiferromagnetic, with range mark χ_{lf} that is $6.5 \times 10^{-8} m^3/kg$–$163.5 \times 10^{-8} m^3/kg$ with type grain almost No There is details superparamagnetic and also has mixture superparamagnetic and granular rough or details superparamagnetic < 0.05 μm with range mark χ_{fd}*(%)* from 0%–2.43 %. Characteristic magnetism rock floating in the area Lubuk Basung sample LBS 23-03 is characteristic antiferromagnetic, with range mark χ_{lf} $41.9 \times 10^{-8} m^3/kg$– $626.4 \times 10^{-8} m^3/kg$ with type grain almost No There is details superparamagnetic and also has mixture superparamagnetic and granular rough or details superparamagnetic < 0.05 μm with mark χ_{fd}(%) 0%– 5.71%. So it is concluded that the second pumice sample has superparamagnetic grains < 0.05 μm according to the International Standard Unit which is equivalent to < 50 nm.

Based on Table 3 and Table 4 it can be grouped that a type of magnetic mineral sample rock floating in the area Lubuk Basung are hematite (αFe_2O_3) and lemenite ($FeTiO_3$) with characteristic magnetism antiferromagnetic. These results describe that sample rock floating in Lubuk Basung show exists oxidant iron. Presence oxide iron superparamagnetic (>50-80 nm) in rocks buoyant shown with mark χ_{fd}*(%)* is high [21] . Details superparamagnetic is nanoparticles contained magnetic in ferrimagnetic or ferromagnetic. So that depicted that size nanoparticles contained in the sample rock floating LBS 23-02 and LBS 23-03 have size nanoparticles below 50 nanometers with characteristic antiferromagnetic magnetism.

4. Conclusion

Based on results XRF measurements and results magnetic susceptibility of stones floating in the area Lubuk Very rude varies. From XRF measurements in the area Lubuk Basung LBS 23-02 and LBS 23-03 are available concentration content high Fe element and concentration content element Ti less. Magnetic susceptibility in the area Lubuk Basung have characteristic antiferromagnetic magnetism, and has type grain almost no there is details superparamagnetic and also has mixture superparamagnetic and granular rough or details superparamagnetic < 0.05 µm equivalent with <50 nanometers. So that depicted that size nanoparticles contained in the sample rock floating LBS 23-02 and LBS 23-03 have size nanoparticles below 50 nanometers with characteristic antiferromagnetic magnetism.

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