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Morphological Characteristics and Elemental Composition of Magnetic Minerals from the Volcanic Activity of Lake Maninjau Sediments

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Abstract

Lake Maninjau has formed by the eruption of the Maninjau volcano, which spewed volcanic material to various places. This volcanic material contains various mineral-forming elements, one of which are magnetic minerals that accumulate in lake sediments. This research aims to determine the morphological characteristics and composition of magnetic mineral elements from volcanic activity in the sediments of Lake Maninjau, Agam Regency, Indonesia. Characteristics of morphological and composition of magnetic mineral elements originating from volcanic activity can describe volcanic eruptions in the past. So, this research is very important for paleo-eruption studies because it can be used as supporting information to determine the distribution of volcanic ash from a volcanic eruption in the past based on the magnetic properties of the material. The sample was selected from the core MAN 18-41B site 12 with a depth of 35 - 36 cm because it has a high magnetic susceptibility value. Morphological images of lake sediment magnetic minerals were viewed using a SEM instrument and EDS detector that shows the composition of the elements that arrange magnetic minerals. In general, the analysis of morphological images shows that the magnetic mineral grains in the Maninjau lake sediments are irregular and porous. This indicates that the magnetic minerals originate from volcanic activity. The image produced by Back Scattered Electron (BSE) has a difference in brightness on the surface of the magnetic grains, which indicates that the bright surface contains high Fe elements and the dark surface contains high Si. The spectrum generated by EDS shows that the dominant elements present in magnetic minerals in lake sediments are Fe, Ti and Si. Based on the morphology and elemental composition, it is indicated that the minerals contained in the sediments of Lake Maninjau come from volcanic activity.

Keywords: Magnetic Minerals, Morphology, Maninjau

Introduction

Lake Maninjau is a caldera lake formed by the eruption of the ancient Maninjau volcano, which spewed various volcanic materials [1]. Volcanic material has the main elements in the form of Si, Al, and Ca and contains metal elements in the form of Fe, Pb and Ti. [2]. Elements contained in volcanic materials such as Fe are elements that form magnetic minerals [3]. Volcanic material that originating from the eruption process undergoes a process of deposition and transportation to various places with the help of wind and water [4]. One possible location for volcanic material deposition is lake sediments.

Sediment is a fraction of minerals or organic materials that undergo transportation from various sources and are deposited by the medium [5]. Volcanic lake sediments are formed from caldera collapse material that accumulates at the bottom of the lake [6]. Lake sediments contain a variety of minerals that vary depending on the source of the mineral. Minerals in lake sediments can come from river flows that flow into lakes, dust depositions from the atmosphere (volcanic ash), and minerals formed through the authigenic process [5]. One of the minerals contained in the lake sediment is magnetic minerals.

Minerals are organic solids that occur naturally and through chemical reactions [7]. Magnetic minerals have diamagnetic, paramagnetic and ferromagnetic properties [8]. The presence of magnetic minerals can be known using the Method of Rock Magnetism. For example, the abundance of magnetic minerals can be determined using magnetic susceptibility measurements. The magnetic susceptibility value of the rocks in Lake Maninjau was analyzed in 2020 and it was found that the rocks in the lake have a high magnetic susceptibility value [9].

The purpose of this research is to identify the source of magnetic minerals in the sediments of Lake Maninjau, Agam Regency by looking at morphological images and their elemental composition. Mineral morphology is an image of the outer form of a mineral. Morphological forms can provide information about the source of magnetic minerals derived because magnetic minerals have different properties, types, and morphology depending on the source [10]. This can be seen in **Figure 1**.

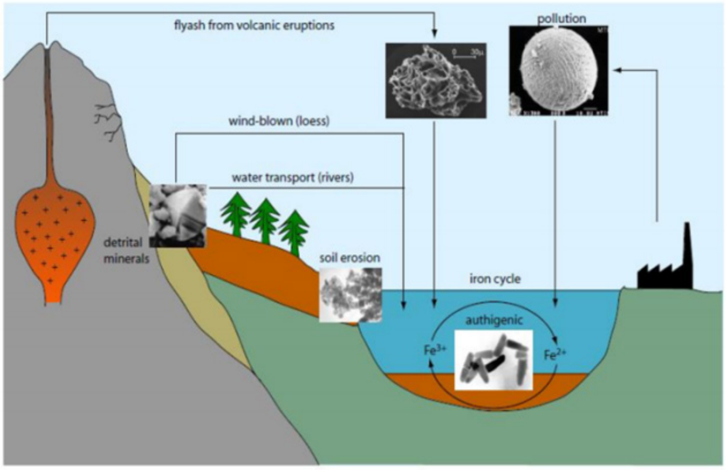


Figure 1 Magnetic mineral morphology in lake environment [11].

Magnetic minerals derived from pollution are usually round, while magnetic minerals derived from volcanic eruptions tend to be irregular and porous [11]. In addition, the authigenic process in the lake environment also produces elongated magnetic minerals [11]. The size of the grain can provide information about the domain type of magnetic minerals. Magnetic mineral domain types are divided into 3 [11] Single Domains (SD) measuring less than 0.1 µm, Multidomains (MD) measuring more than 10 µm and Pseudosingle Domains (PSD) measuring 0.1 to 20 µm [12].

The morphological shape and elemental composition of a sample can be seen using the Scanning Electron Microscopy (SEM). SEM is an instrument used to characterize the surface of a nanomaterial in the form of the surface of the material [13]. The material that can be characterised by SEM is a conductor material because it can interact with electrons [14]. SEM can also observe the elemental composition of a specimen using an Energy Dispersive Spectrometer (EDS). The dominant composition of elements in a specimen is seen from the peaks of the elements displayed in the form of a spectrum.

Materials and methods

The sampling was conducted by Hamdi *et al.* in 2018 at Lake Maninjau, Agam Regency, West Sumatra (**Figure 2**).

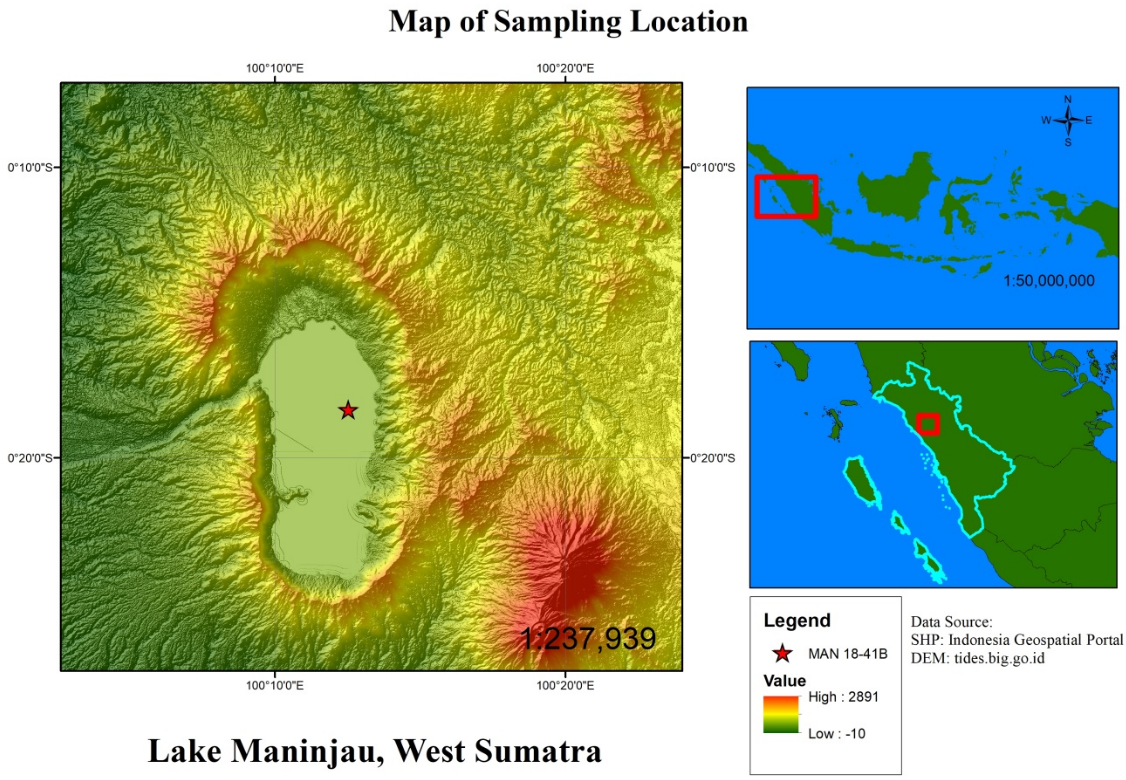


Figure 2 Map of sampling location.

In **Figure 2** it appears that the sample was taken at 0°18'20.20' S and 100°12'31.36" E. The samples were taken using a drill equipped with a 0.5 m long sample container. Lake sediment samples are placed into PVC pipes with both ends closed. Then the sample preparation process is carried out. The preparation process includes a sub-sampling process in the form of splitting a PVC pipe, which divides the sample into 2 parts as shown in **Figure 3**, and then the sample is taken every 2 cm for the extraction process.

Figure 3 Sample in PVC pipe that has been split into 2 parts.

The sediment sample that has been selected is a sample that has a high magnetic susceptibility value. Magnetic susceptibility was measured with the MS2E sensor at EOS Laboratory, Nanyang Technological University, Singapore in January 2020. The highest magnetic susceptibility values were found at a depth of 350 - 360 mm. The high value of magnetic susceptibility indicates an abundance of magnetic minerals.

Furthermore, the extraction process is carried out on the sample using a magnetic rod to obtain a powder sample. The samples were cleaned using an ultrasonic cleaner such as **Figure 4** and dried in the oven for an hour.

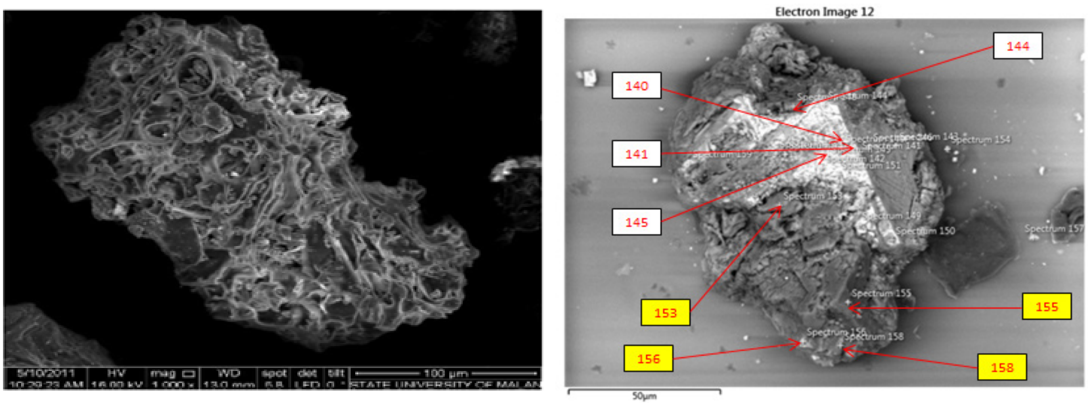
Figure 4 Ultrasonic cleaner.

Then the sample is inserted into a mold table consisting of 12 holes and inserted into the Scanning Electron Microscopy (SEM) for measurement. The type of SEM used is the JSM-7800F model.

SEM JSM-7800F features Electron Backscattered (BSE), and Energy Dispersive Spectrometer (EDS). BSE displays an image based on the difference in atomic numbers, the higher the atomic number the brighter the image is displayed. EDS displays a spectrum that is accompanied by a percentage of the weight of a mineral-forming element derived from sample interactions with X-rays. So it can be known the composition of the forming elements of minerals found in the measured samples.

Results and discussion

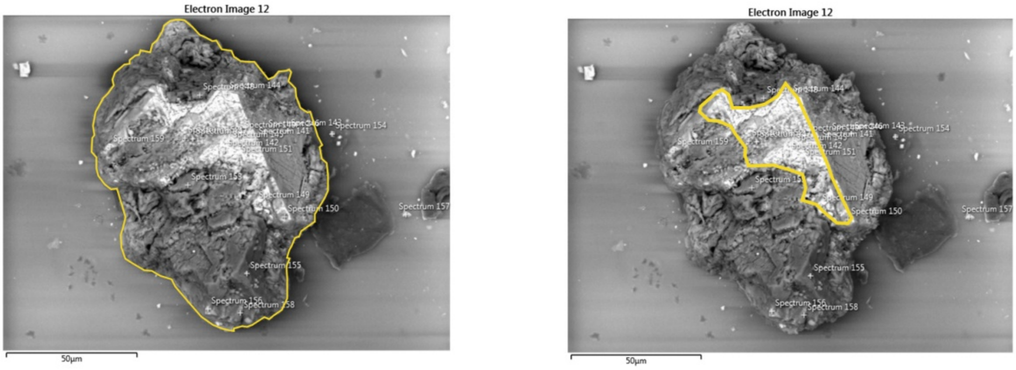
The result obtained from the measurement of SEM against Maninjau lake sediment samples is in the form of morphology and elemental composition. The sample that was the focus in this study was MAN 18-41B Site 12. Measurements of MAN 18-41B Site 12 lake sediment can be seen in **Figure 5**.



(a) (b)

Figure 5 Morphology of magnetic minerals (a) volcanic ash magnetic mineral morphology [15], (b) morphology of lake sediment magnetic minerals MAN 18-41B Site 12.

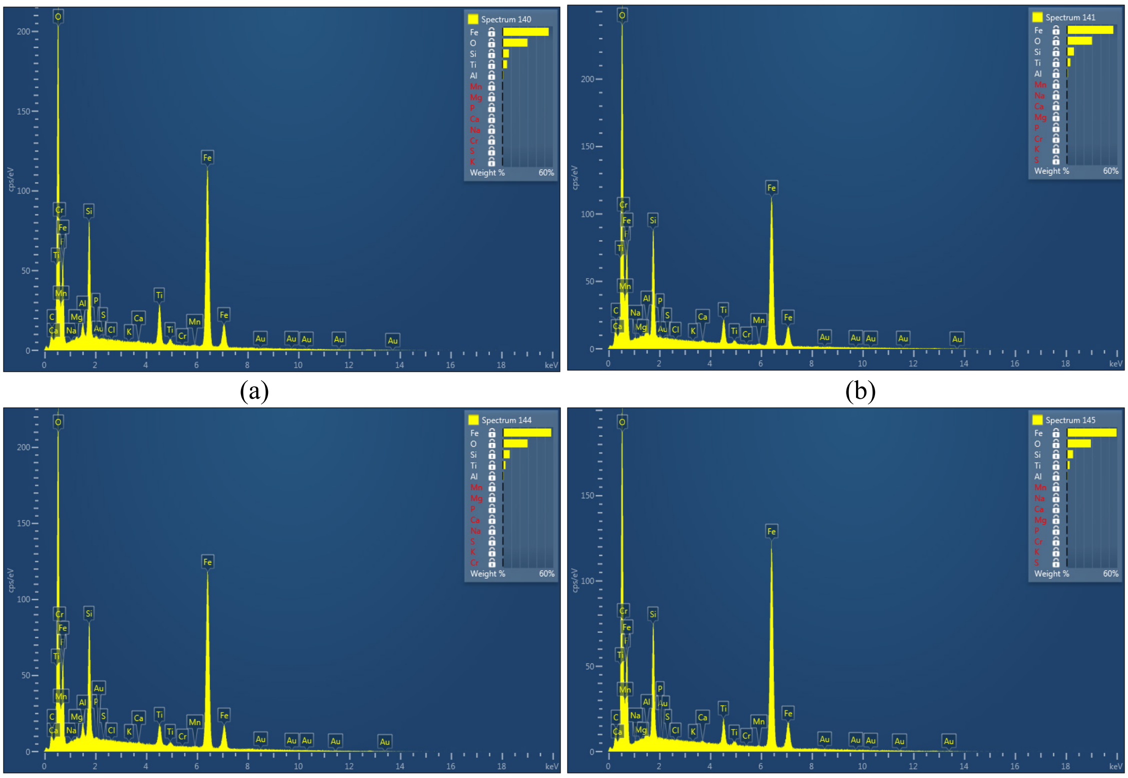
Figure 5 shows that the sample surface is divided into 2 parts, namely a dark surface (such as the spectrum 153, 155, 156, and 158) and a bright surface (such as the spectrum 140, 141, 144, and 145). The brighter the grain surface indicates the high Fe content, otherwise the darker surface indicates the low Fe element content. The resulting image is influenced by the atomic number, where the higher the atomic number of an element the brighter the surface image displayed [16]. Dark colours are more dominant than brighter colours as seen in **Figure 6**. The area is brightly coloured about 15.83 % of the overall area.



(a) (b)

Figure 6 Magnetic mineral grain surface (a) overall area, and (b) magnetic grain surface which has a bright colour.

The magnetic mineral grain size of the MAN 18-41B Site 12 sample, which is 100 µm, indicates that this type of mineral domain is multidomain [16]. To see the composition of the elements contained in this grain is done a spectrum capture on the surface of the sample. In the capture of this grain there are 20 spectrums namely spectrum 140 to 159. The spectrum that has the same colour is indicated to have the same elemental composition. So it takes some spectrum to represent the whole spectrum. To know the elements contained on each spectrum of the grain is taken 8 spectrums representing 2 different areas. The EDS measurement results in the brighter area in the form of spectra are shown in **Figure 7**.



(a) (b) (c) (d)

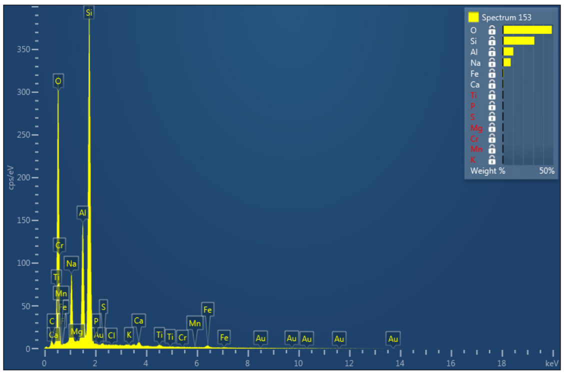
Figure 7 EDS measurement results, (a) spectrum 140, (b) spectrum 141, (c) spectrum 144 and (d) spectrum 145.

In **Figure 7**, it appears that spectrum 145 has the highest content of Fe elements compared to other spectra. The results of the analysis of the composition of the elements on the brightly coloured parts with the EDS of the elements have different weight percentages in 100 % mixed weight and differ in each capture, as seen in **Table 1**.

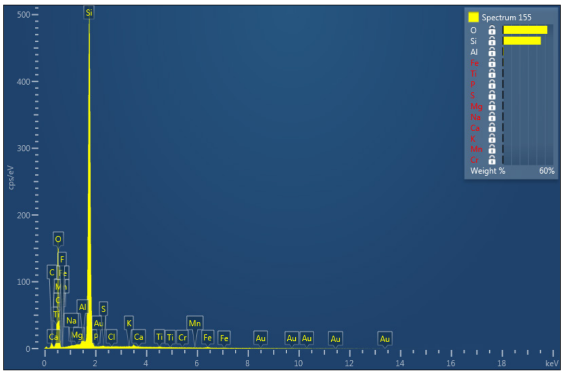
Table 1 Elemental composition of MAN 18-41B Site 12 (I).

Elements	% Weight			
	Spectrum 140	Spectrum 141	Spectrum 144	Spectrum 145
Sodium (Na)	0.12	0.26	0.15	0.25
Magnesium (Mg)	0.36	0.24	0.25	0.16
Aluminium (Al)	1.92	2.32	2.27	1.55
Silica (Si)	16.43	18.07	17.24	15.62
Phospor (P)	0.43	0.28	0.33	0.21
Sulfur (S)	0.08	0.04	0.09	0
Potassium (K)	0	0.07	0.04	0.05
Calcium (CA)	0.2	0.24	0.19	0.22
Titanium (Ti)	9.18	6.73	5.06	5.46
Chromium (Cr)	0.1	0.09	0.04	0.08
Manganese (Mn)	0.36	0.59	0.39	0.38
Iron (Fe)	70.81	71.07	73.96	76.01
Total	100	100	100	100

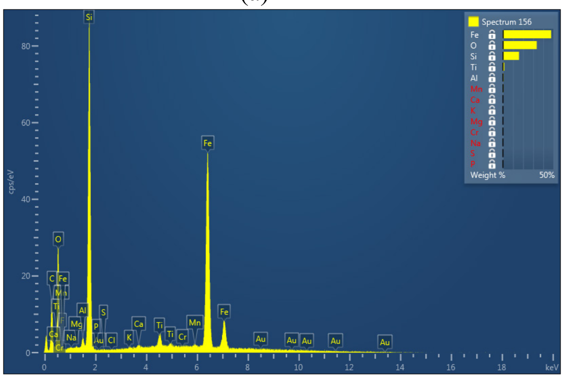
Based on **Table 1**, Fe, Si, and Ti elements are the dominant elements. In brighter magnetic grains there is a high Fe element. On spectrum 145 there is the highest Fe content compared to the other. For spectrums in darker areas can be seen from EDS measurement results such as **Figure 8**.



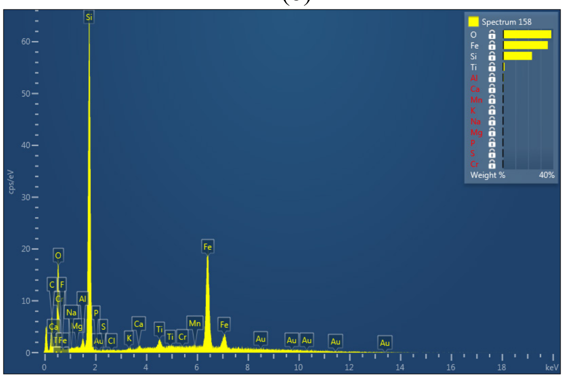
(a)



(b)



(c)



(d)

Figure 8 EDS measurement results, (a) spectrum 153, (b) spectrum 155, (c) spectrum 156, and (d) spectrum 158.

The spectrum of EDS measurement results (**Figure 8**) shows that darker surfaces contain higher Silica (Si) elements than Iron (Fe). On spectrum 155 there is the highest Si content compared to the other. The high silica (Si) content in the dark part indicates that the sample surface has still covered with Quartz. The results of the analysis of the composition of the elements in the dark part with the EDS of the elements have different weight percentages in 100 % mixed weight and differ in each capture, as seen in **Table 2**.

Table 2 Elemental Composition of MAN 18-41B Site 12 (II).

Elements	**% Weight**			
	Spectrum 153	**Spectrum 155**	**Spectrum 156**	**Spectrum 158**
Sodium (Na)	10.36	0.07	0.02	0.15
Magnesium (Mg)	0.05	0.1	0.1	0.16
Aluminium (Al)	19.43	1.91	0.96	1.23
Silica (Si)	66.76	96.44	34.11	49.39
Phospor (P)	0.35	0.19	0	0.09
Sulfur (S)	0.13	0.19	0.04	0.08
Potassium (K)	0	0	0.09	0.2
Calcium (CA)	0.93	0.01	0.25	0.49
Titanium (Ti)	0.68	0.36	2.34	2.15
Chromium (Cr)	0.02	0	0.04	0
Manganese (Mn)	0.01	0	0.55	0.25
Iron (Fe)	1.28	0.73	61.49	45.83
Total	100	100	100	100

The presence and source of magnetic minerals in lake sediments can be predicted through the study of morphology and the composition of the forming elements of the minerals. The morphological form of minerals is seen through SEM measurements, while EDS is used to see the composition of elements found in minerals.

This form of magnetic mineral found in maninjau MAN 18-41B Site 12 lake sediment samples is generally more likely to be irregular and have a grunt on its surface. This indicates that the magnetic minerals in the lake's sediments are derived from volcanic processes [15] that have been eroded, it seems that there is a weathering process on the grains so that it looks retributed on the surface [14]. Similar conditions have also been shown in the morphology of magnetic mineral elements in peatland sediments in Lake Diatas [4]. The size of the magnetic mineral grains contained in the sediment of Lake Maninjau is 100 μm in size so that the minerals contained in the lake sediment samples are included in the multidomain group [17].

BSE results show that the surface shape of the lake sediment samples generally has a dark colour. This indicates that the sample is still covered with impurities. The high elemental content of Fe is indicated by the presence of a bright surface. [16]. The higher the atomic number of an element, the brighter the grain surface of the sample being measured. The dark surface is thought to contain magnetic minerals. This can be seen from the results of spectrum 156 and 158, which are quite high in the elemental Fe content.

The EDS results show that the elements present in the sediment samples of MAN 18-41B site 12 lake have dominant elements of Iron (Fe), Silica (Si), and Titanium (Ti). Some other elements in small amounts are Na, Mg, Al, K, Ca, Cr and Mn. The elements in this lake sediment indicate that this sediment has a high magnetic content as seen from the high Fe content and is still covered by impurities such as Silica (Si). The high content of Fe elements on the bright surface of the grain allows the presence of

Magnetite and Hematite minerals. Whereas in the dark part there is a high Si element indicating the presence of the mineral Quartz. The high content of silica (Si) on the lake Maninjau is consistent with the geological situation dominated by Pumice stone and aggregates [18]. When viewed from the morphological form and elemental composition, the magnetic minerals contained in the Maninjau lake sediments come from volcanic activity.

Conclusions

It can be concluded that the morphological images of the MAN 18-41B Site 12 samples observed by SEM tended to be irregular and porous with a rough grain surface. The EDS results show that the dominant elements are Iron (Fe) and Silica (Si). Based on the morphological images and elemental composition, the magnetic minerals present in the Maninjau lake sediments are indicated to come from volcanic activity.

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