



Available online at <http://journal.walisongo.ac.id/index.php/jnsmr>

## Characterization of Magnetic Properties of the Coastal Sand Deposits in South Beach of Manokwari, West Papua

Sangaji Hasmi Maharani Ipa<sup>1</sup>, Siti Hadjar Kubangun<sup>2</sup>, Satria Bijaksana<sup>3</sup>, Darharta Dahrin<sup>3</sup>, and Innaa Uswatun Hasanah<sup>1</sup>

<sup>1</sup>Faculty of Mathematics and Natural Sciences, Universitas Papua, Indonesia

<sup>2</sup>Faculty of Agriculture, Universitas Papua, Indonesia

<sup>3</sup>Faculty of Mining and Petroleum Engineering, Institut Teknologi Bandung, Indonesia

### Abstracts

Corresponding author:  
ajiipa2012@gmail.com  
Received: 17 September 2018,  
Revised : 20 Oktober 2018,  
Accepted: 27 November 2018

Coastal sand deposits containing iron particles (magnetic) can be regarded as iron sand and it generally has color from gray to shiny black yet while it is mixed with other minerals, the mineral will have a certain color combination. Coastal sand in the South of Manokwari Regency, West Papua especially in Wosi Beach, Arfai Beach, and Maruni Beach has a different color of the grain according to the source rocks and the sedimentation process. To characterize the magnetic properties of the three coastal sand deposits, several experimentations were done through measurements of the density, magnetic degree, magnetic susceptibility, and also SEM (Scanning Electron Microscopy) and EDS (Energy Dispersive X-Ray Spectroscopy) tests. The coastal sand deposition has a density ranging from 2.50–5.00 g·cm<sup>-3</sup> with the magnetic degree between 0.28–36.29 % and its magnetic susceptibility ranged 80.9×10<sup>-8</sup>–7447.7×10<sup>-8</sup> m<sup>3</sup>·kg<sup>-1</sup>. The coastal sand from Arfai Beach has a magnetic susceptibility between the coastal sand from Wosi and Maruni Beach with the highest value reaching 5135.4 × 10<sup>-8</sup> m<sup>3</sup>·kg<sup>-1</sup>. This is also supported by SEM and EDS data. The percentage of iron element mass (Fe) of the identified magnetic grain distribution in Wosi Beach sand is 6.71–33.90%, Arfai Beach sand is 11.35 – 38.45% and Maruni beach sand is 15.84–44.41%. ©2018 JNSMR UIN Walisongo. All rights reserved.

**Keywords:** characterization, magnetic properties, coastal sand deposits, south beach of Manokwari, West Papua

## 1. Introduction

Iron sand is sand deposits containing iron particles (magnetic), located along the coastal area [1]. Iron sand deposits are usually derived from volcanic rocks are andesitic and basaltic that undergoes physical and chemical changes in the form of weathering (temperature, pressure, and chemical reaction), eroded and transported to the coast through the river flow. Along the coast, the waves and currents of the sea will wash and separate the minerals contained in the iron sand based on the difference in density. Minerals that have a lighter density will be brought back by the sea currents into the ocean while the minerals that have the larger amount of density will be deposited along the coast. Deposition of iron sand is generally easier to occur on sloping coastal area compared to steep one.

Iron sand in Indonesia is scattered along the Indian Ocean, from the west of Sumatra Island to Bali Island, Lombok and the surrounding areas [2]. In addition, the iron sand deposits can also be found in Sulawesi Island, Maluku Islands, and Papua Island. This cannot be separated from the position of the Indonesian Archipelago passed by the Volcanic Belt Line [3] also Indonesia is the region that has the largest amount of volcanoes in the world and they are still active [4]. Iron sand sedimentary is generally gray to shiny black and is unattached because it is not compacted. Nevertheless, it has been mixed with sediment and/or other minerals from rivers and beaches causing the combination of color with white, green, or brown. Iron sand is also very fine-grained, which ranges from 75-150 microns, has a density of 2-5 g·cm<sup>-3</sup> and magnetic degree (MD) from 6.40-27.16 % [5].

Iron sand will have a high economic value if managed properly because it contains major magnetic minerals such as magnetite (Fe<sub>3</sub>O<sub>4</sub>), hematite ( $\alpha$ -Fe<sub>3</sub>O<sub>4</sub>), titanomagnetite or ilmenite (FeTiO<sub>3</sub>) and maghemite ( $\gamma$ -Fe<sub>3</sub>O<sub>4</sub>). In addition to the major magnetic minerals, there are usually

additional minerals such as silica, quartz, calcite, plagioclase, orthoclase, and rutile (TiO<sub>2</sub>). Iron sand containing iron oxide is utilized in the industrial world because it can produce steel [6], dye [7][8], catalyst [9], magnetic recording media [10], ferrite magnets [11] and manufacture of inductor cores [12]. The titanium found in iron sand can also be used commercially as a sponge in the manufacture of military aircraft or even as dental implants in medicine. Another important element of metal contained in the iron sand is vanadium (V<sub>2</sub>O<sub>5</sub>) which is used as metal detectors on the use of X-rays, material structures and alloy elements in readings. The inventory and exploration activities of iron sands in Indonesia by the Geological Resource Center, Geological Agency has been conducted since 1971 spread over the islands of Sumatra, Java, Nusa Tenggara, Sulawesi and the Islands of Maluku [5]. The efforts to find the new potential of iron sands in the territory of Indonesia continue to be done, especially in areas that do not have complete data that informs about the potential and amount of reserves. One of them is in Manokwari Regency, West Papua Province.

The coastal areas in Manokwari Regency have variations of sand color ranging from gray sandy to blackish (potentially iron sand) and white sand. In the South of Manokwari itself, there are more sandy-white beaches until glistening blackish. In order to know the potential or absence of coastal sand deposits in the location, this research is conducted to characterize its magnetic properties through several measurements and testing at the Laboratory.

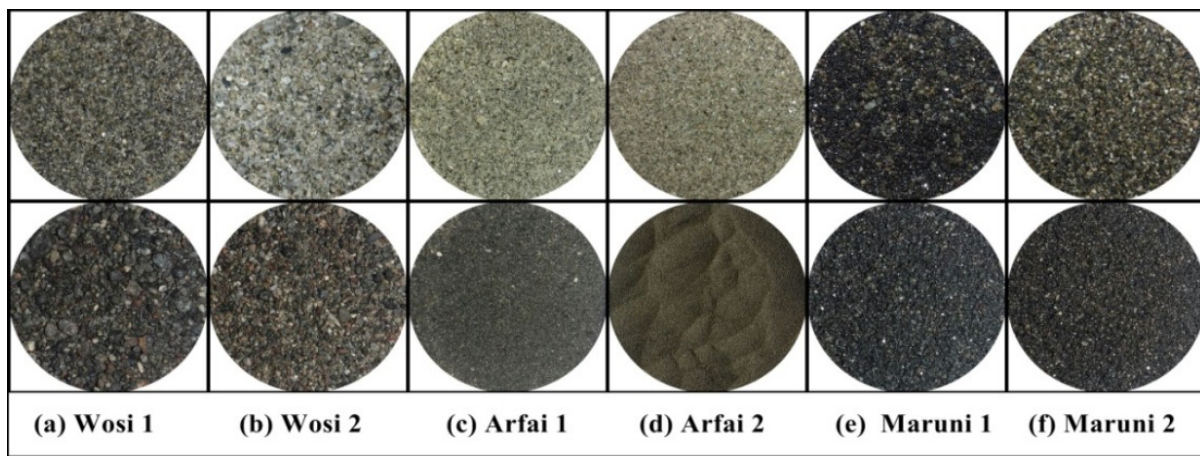
## 2. Experiments Procedure

This research uses sand beach samples taken from the South of Manokwari Regency precisely at Wosi Beach, Arfai Beach, and Maruni Beach. These sand beach samples are then washed with aquades or aquabides and dried under the sun or using an oven at 105°C for 4-24 hours. The physical appearance of the sample is shown in Figure

1. The characterization of the magnetic properties of the coastal sand deposits was done by the analysis of density ( $\rho$ ), magnetic degree (MD), magnetic susceptibility ( $\chi$ ) and also SEM (Scanning Electron Microscopy) and EDS (Energy Dispersive X-Ray Spectroscopy) tests.

Density and magnetic susceptibility measurement were undertaken originally or it had not been magnetically separated (Figure 1 above, 1200x1200 dimensions) as well as on the samples that had been

magnetically separated (Figure 1 below, 440x440 dimensions). The magnetic separation process is the process of separating the magnetic grains of the sand from the non-magnetic grains by using magnetic spinbar repeatedly. The magnetic grain mass distribution from the separation is used for the measurement of density, magnetic susceptibility and in determining the magnetic degree (MD) of sand. These sand samples are also used in SEM and EDS testing.



**Figure 1.** The physical appearance of the sand before (above) and after (below) the separation

### 3. Result and Discussion

#### *Density ( $\rho$ )*

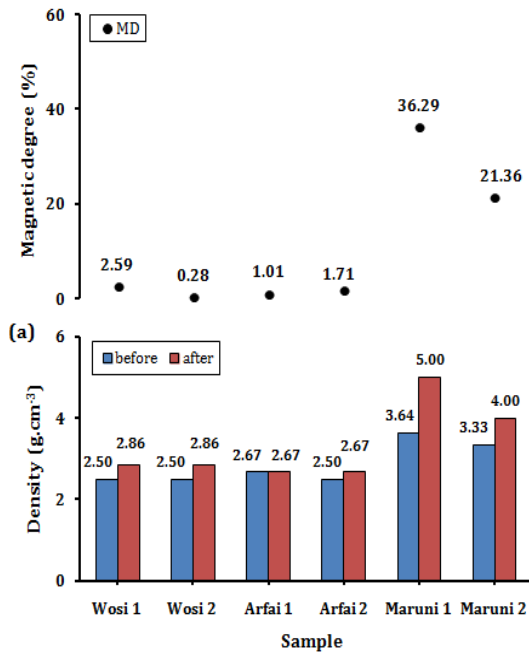
Figure 2a shows the density distribution of coastal sand by using submersion method [13] both before and after the magnetic separation. The density measurements were conducted at the Physics Laboratory in the Faculty of Mathematics and Natural Sciences, Papua University and Soil Physics Laboratory in the Faculty of Agriculture, Papua University. The density of the sands before the separation (blue) varies between 2.50–3.64 g·cm<sup>-3</sup> with the lowest density is from Wosi 1 Beach and Wosi 2 Beach and also Arfai 2 Beach while the highest density is from Maruni 1 Beach. Then, the density for the sands those have been magnetically separated (red) is between 2.67–5.00 g·cm<sup>-3</sup>, with the lowest

density is from Arfai 1 Beach and Arfai 2 Beach, while the highest density is from Maruni 1 Beach.

The density of Arfai 1 Beach does not change both before and after separation. On the other hand, the density of the sand from Arfai 2 Beach slightly rises. This is due to the absence of significant or even minor changes to the comparison of mass and volume parameters at the determination of density. But then, there are other factors that influence the density of sands such as mineral content, grain shape and grain size [13][14].

Based on the results of this study, it is said that the sand density will be higher after the separation between magnetic particles and non-magnetic particles. This indicates that the mineral content of the sand particles also has an impact on the high-low density of

the sands. It means that the concentration of magnetic minerals is directly proportional to its density. However, in some conditions, it may not have happened. Figure 1 (below) shows the size of the sand particles as a result of magnetic separation. It can be seen that the size of the sands from Arfai 1 Beach and Arfai 2 Beach is comparatively finer than other samples, and those samples have a lower value of the sand density than the samples from Wosi 1 Beach and Wosi 2 Beach, which is coarse relatively. In addition, the grain size of the sands from Maruni Beach is in between the sands of Arfai and Wosi Beaches, which has the highest amount of the sand density.



**Figure 2.** Distributions of (a) density and (b) magnetic degree

*Magnetic Degree (MD)*

The results of the magnetic degree from the beaches of Wosi, Arfai, and Maruni are shown in Figure 2b. The values of magnetic degree vary from 0.28–36.29 % with the lowest and highest value respectively from Wosi 2 Beach and Maruni 1 Beach. The value of the magnetic degree is influenced by the mass concentrate, which is obtained from the magnetic separation process. If mass

concentrate is high then it will increase the value of the magnetic degree and vice versa.

According to Tampubolon et al in 2014, the magnetic degree of iron sand is from the range of 6.40–27.16%. The magnetic degree of the sands from Maruni 2 Beach has 21.36% and Maruni 1 Beach has more than 27.16%, which is 36.29%. It gives the information of the potential indicator but it is recommended to have further analysis of iron content that has at least 63% Fe along the coastal area.

*Magnetic Susceptibility ( $\chi$ )*

Table 1 represents a comparison of the magnetic susceptibility values of sand beach between before and after the magnetic separation. Magnetic susceptibility measurement uses a unit of Bartington MS2 Magnetic Susceptibility Meter and Multisus II program at the Magnetism Rocks Laboratory in ITB. From the three beaches, the magnetic susceptibility of the sand from Wosi Beach has the lowest value and the highest value is from Maruni beach in both conditions. Before separated, the value of magnetic susceptibility of samples from Wosi Beach ranged  $80.9 \times 10^{-8} - 142.6 \times 10^{-8} \text{ m}^3 \cdot \text{kg}^{-1}$  and increased after separation to  $500.5 \times 10^{-8} - 1717.6 \times 10^{-8} \text{ m}^3 \cdot \text{kg}^{-1}$ . It is similar to the samples from Arfai and Maruni beaches. Samples from Arfai Beach ranged  $636.9 \times 10^{-8} - 755.4 \times 10^{-8} \text{ m}^3 \cdot \text{kg}^{-1}$  and increased after separation to  $1613.9 \times 10^{-8} - 5135.4 \times 10^{-8} \text{ m}^3 \cdot \text{kg}^{-1}$ . Whereas on Maruni Beach, sample ranged  $2173.5 \times 10^{-8} - 3106.6 \times 10^{-8} \text{ m}^3 \cdot \text{kg}^{-1}$  and increased after separation to  $6360.6 \times 10^{-8} - 7447.7 \times 10^{-8} \text{ m}^3 \cdot \text{kg}^{-1}$ . Directly proportional to the increase of density of the sand samples before and after separation, magnetic susceptibility values also increased significantly. The amount of impurity minerals that are still mixed with sand samples greatly influence the magnetic susceptibility value. Samples that have been magnetically separated, will have a magnetic mineral distribution more than the sand samples that have not been separated. Thus, the magnetic susceptibility value will also rise.

### *Analysis of SEM and EDS*

The results of photomineralogy and identification of elements in sand samples from Wosi Beach, Arfai Beach, and Maruni Beach are respectively shown in Figure 3, Figure 4, and Table 2. Measurements of the sample from Wosi 1, Arfai 1, and Maruni 1 Beach uses a single unit of SEM-EDS type JEOL-JSM-6510LV at Hydrogeology dan Geochemistry Laboratory in ITB Bandung. Furthermore, the sand samples of Wosi 2, Arfai 2, and Maruni 2 Beach were tested using a type of JEOL-JED-2200 series at the TEKMIRA Laboratory in Bandung.

As shown in Figures 3 and 4, the grain shape and grain size of the samples from each area are not homogeneous. The grain shape tends to round up a sharp angle and the grain size from fine to coarse. The farther the distance of the source from the location of sedimentation, the size will be finer and vice versa. The angular grains are also one of the merits indicating that the displacement is not far from the source rocks, besides other physical and chemical factors.

Table 2 represents the percentage of the identified elements mass of each sample. Samples from Wosi 1 Beach, Arfai 1 Beach, and Maruni 1 Beach are identified having the high number of C element, due to the presence of carbon tape used to attach the sample so that the value is the total. Element O is the dominant element of the three samples and when is combined with other elements such as Fe, Si, Ti, Mg, Ca, Al, Na or C, it can form several compounds such as FeO, Fe<sub>2</sub>O<sub>3</sub>, Fe<sub>3</sub>O<sub>4</sub>, SiO<sub>2</sub>, TiO<sub>2</sub>, Al<sub>2</sub>O<sub>3</sub> or other oxide compounds. The highest content of Fe element from the samples reached 15.84% was found in Maruni 1 Beach followed by Arfai 1 Beach of 11.35% and the lowest was 6.71% in Wosi 1 Beach.

The percentage of mass is found in the sample of Wosi 2, Arfai 2 and Maruni 2, Fe and O are dominant. As well as in the

samples from Wosi 1, Arfai 1 and Maruni 1, the highest Fe content is also discovered in the sample from Maruni Beach followed by Arfai Beach and Wosi Beach. The mass percentage of Fe element in the samples from Maruni 2 Beach is 44.41%, Arfai 2 Beach is 38.45%, and Wosi 2 Beach reaches 33.90%. Other identified elements associated in the samples are Na, Mg, Al, Si, Ca, Cr and Ti.

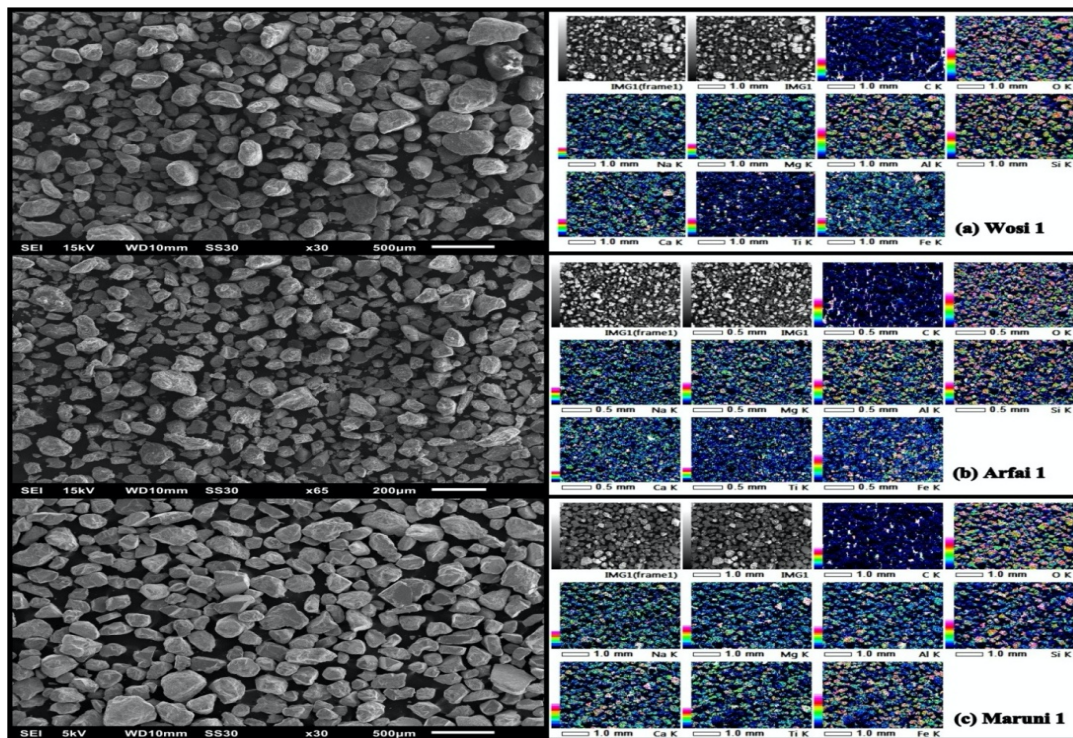
The composition of Fe element in the sample will affect the magnetism properties. When the Fe content is high in the sample, the magnetic susceptibility value will also be high. This statement has been proved by the results obtained from this study that samples from Maruni 1 Beach, Arfai 1 Beach, and Wosi 1 Beach. The same order also is applied on the samples from Maruni 2 Beach, Arfai 2 Beach, and Wosi 2 Beach.

The percentage of Fe element that tends to be lower in the sample from Beach 1 than Beach 2 is due to the existence of percentage of element C in its quantitative analysis. The sample from Beach 1 takes into account the mass percentage of element C while the sample from Beach 2 does not take into account the mass percentage of element C. However, it still shows the comparison between the samples. Samples from Maruni Beach has the highest Fe content, then the samples from Arfai Beach and the lowest is the sample from Wosi Beach.

Based on the results of this study, the iron content (Fe) identified in coastal sand samples with the range of 6.71 until 44.41%. This study is a preliminary study to identify and characterize the magnetic properties of coastal sand samples located in the South of Manokwari Regency, West Papua. Therefore, it is needed further testing and analysis to determine the distribution patterns of Fe content along the coast that have the potential to be done as a support in the calculation of potential and reserves.

**Table 1.** Magnetic susceptibility of ( $\chi$ ) the sand sample before and after magnetic separation

Sample	Before Separation		After Separation	
	Range $\chi$ ( $\times 10^{-8} \text{ m}^3 \text{ kg}^{-1}$ )	Mean $\chi$ ( $\times 10^{-8} \text{ m}^3 \text{ kg}^{-1}$ )	Range $\chi$ ( $\times 10^{-8} \text{ m}^3 \text{ kg}^{-1}$ )	Mean $\chi$ ( $\times 10^{-8} \text{ m}^3 \text{ kg}^{-1}$ )
Wosi 1a	80.9 – 81.8	81.5 ± 0.4	616.2 – 623.9	619.8 ± 2.5
Wosi 1b	107.6 – 108.9	108.4 ± 0.5	500.5 – 503.0	501.7 ± 0.9
Wosi 1c	114.3 – 116.1	114.9 ± 0.7	522.9 – 524.9	523.8 ± 0.8
Wosi 2a	86.8 – 89.2	87.8 ± 0.8	1608.9 – 1612.4	1611.1 ± 1.2
Wosi 2b	130.0 – 132.4	131.4 ± 0.8	1711.9 – 1717.6	1714.5 ± 2.1
Wosi 2c	141.3 – 142.6	142.1 ± 0.5	1352.9 – 1356.0	1354.4 ± 1.0
Arfai 1a	697.6 – 699.3	698.3 ± 0.6	1756.1 – 1761.2	1758.7 ± 1.7
Arfai 1b	753.7 – 755.4	754.5 ± 0.6	1613.9 – 1617.2	1615.3 ± 1.2
Arfai 1c	688.5 – 691.9	689.8 ± 1.2	1748.2 – 1752.1	1750.4 ± 1.6
Arfai 2a	636.9 – 642.0	638.9 ± 1.7	3657.3 – 3666.4	3660.6 ± 3.7
Arfai 2b	655.7 – 659.2	657.4 ± 1.3	3818.0 – 3836.3	3827.6 ± 6.7
Arfai 2c	654.9 – 657.9	656.9 ± 1.1	5125.6 – 5135.4	5130.9 ± 3.4
Maruni 1a	2173.5 – 2188.0	2180.1 ± 4.9	6845.6 – 6849.7	6847.0 ± 1.4
Maruni 1b	3101.9 – 3106.6	3104.8 ± 1.6	7437.8 – 7447.7	7442.7 ± 3.6
Maruni 1c	2895.5 – 2899.6	2897.7 ± 1.7	7220.9 – 7227.8	7224.1 ± 2.9
Maruni 2a			6489.6 – 6508.4	6497.3 ± 6.2
Maruni 2b			6360.6 – 6372.6	6366.8 ± 3.9
Maruni 2c			6897.6 – 6918.0	6911.6 ± 7.4



**Figure 3.** Photomineralogy of sand samples from (a) Wosi 1, (b) Arfai 1 dan (c) Maruni 1

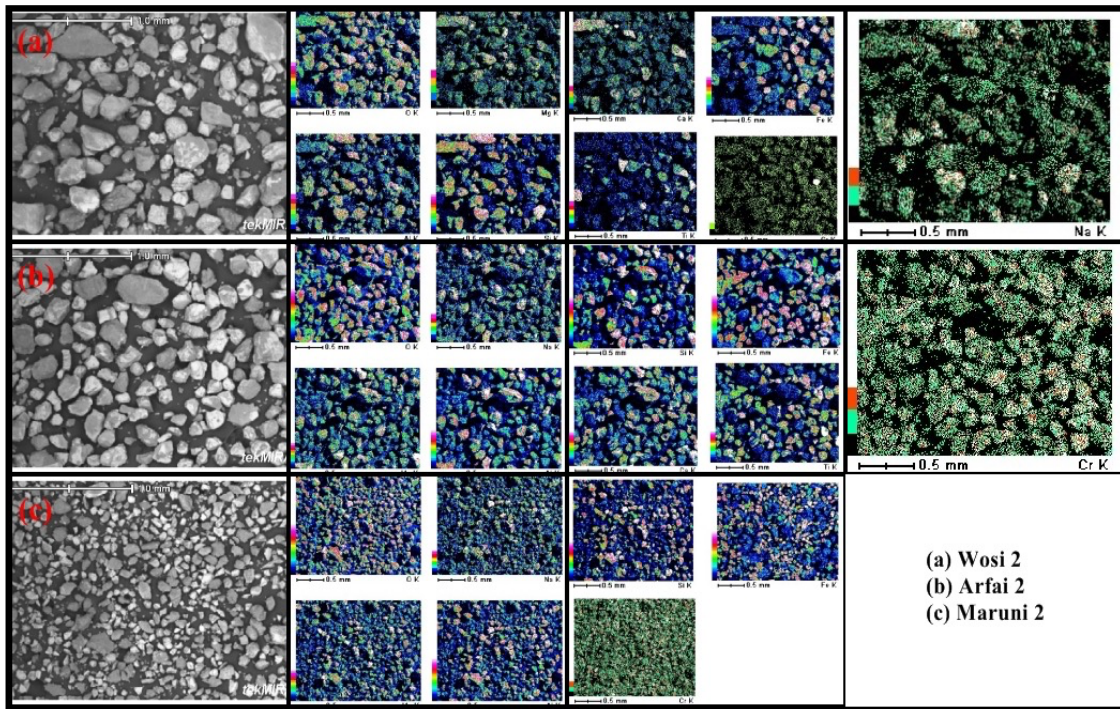


Figure 4. Photomineralogy of sand samples from (a) Wosi 2, (b) Arfai 2 dan (c) Maruni 2

Table 2. The presentage of element mass

Sample	% Mass									
	C	O	Na	Mg	Al	Si	Ca	Cr	Ti	Fe
Wosi 1	27.41	41.81	1.68	2.35	4.83	12.13	1.41	*	1.68	6.71
Arfai 1	26.81	40.70	1.06	2.92	4.69	10.04	1.18	*	1.25	11.35
Maruni 1	21.24	41.50	0.91	2.06	3.44	8.21	2.59	*	4.19	15.84
<i>JED-2300 analysis station</i>										
Wosi 2	*	35.62	1.66	3.01	6.40	11.67	2.82	0.28	4.66	33.90
Arfai 2	*	33.48	1.29	2.18	4.74	8.94	4.03	0.14	6.74	38.45
Maruni 2	*	33.51	1.38	3.29	6.38	10.87	-	0.15	-	44.41
<i>RDCMCT-JED-2200 series</i>										

#### 4. Conclusion

Regarding the results of this study, the sand samples from Maruni Beach have density ranged 3.33–5.00 g·cm<sup>-3</sup> with the magnetic degree of 21.36–36.29% and the highest magnetic susceptibility reaches 7447.7×10<sup>-8</sup> m<sup>3</sup>·kg<sup>-1</sup>. The sand samples of Arfai Beach have density ranged

2.50–2.67 g·cm<sup>-3</sup> with magnetic degree of 1.01–1.72% and the highest magnetic susceptibility reaches 5135.4×10<sup>-8</sup> m<sup>3</sup>·kg<sup>-1</sup>. While the Wosi Beach sand sample has density ranged 2.50–2.86 g·cm<sup>-3</sup> with magnetic degree of 0.28–2.59% and the highest magnetic susceptibility reaches 1717.6×10<sup>-8</sup> m<sup>3</sup>·kg<sup>-1</sup>.

The presence of Fe element in each sand sample varies with the highest percentage to the lowest in a row is the sand of Maruni Beach, Arfai Beach and Wosi Beach. This is in mutual accord to the high magnetic susceptibility value of Maruni beach sand and followed by Arfai Beach while the lowest is the sand of the beach Wosi.

### Acknowledgment

We would like to thank the Ministry of Research, Technology, and Higher Education of the Republic of Indonesia for the financing Fundamental research Scheme PEKERTI 2017 and also Magnetism Rocks Laboratory in ITB, Hydrogeology and Geochemistry Laboratory in ITB and TEKMIIRA Laboratory for technical assistance.

### References

- [1] Bates, R. L., and Jackson, J. A., "Glossary of Geology, Second Edition", *American Geological Institute Fall Church*, Virginia, 1980.
- [2] Rahmat, N., Suwarti, T., and Samodra, H. "Peta Geologi Indonesia Lembar Surabaya, Edisi Kedua", *Pusat Penelitian dan Pengembangan Geologi*, Bandung, 1998.
- [3] Abidin, H. Z., "GPS Survey for Natural Hazard Mitigation in Indonesia", *Country Report of International Union of Geophysics and Geodesy (Indonesian Committee)*, Sapporo Japan, pp. 22-27, June 30 - July 11, 2003.
- [4] Tjetjep, W. S., and Wirakusumah, D. A., "Activities Related with IAVCEI in Indonesia", *A Country Report from Indonesia, International Union of Geophysics and Geodesy (Indonesian Committee)*, Sapporo, Japan, pp. 52-70, June 30 - July 11, 2003.
- [5] Tampubolon, A., Pardiarto, B., Candra, C., Sutisna, D. T., Dinarsih, D., Widhiyatna, D., Sunuhadi, D. N., Yuningsih, E. T., Franklin, F., Sukmayana, I., Ostman, I., Yudawinata, K., Oktaviani, P., Hilman, P. M., Ulfa, R. M., Rahmawati, R., Wahyuningsih, R., Gunradi, R., Suprpto, S. J and Sukaesih, S. "Pasir Besi di Indonesia; Geologi, Eksplorasi dan Pemanfaatannya", *Pusat Sumber Daya Geologi*, Badan Geologi, Kementerian Energi dan Sumber Daya Mineral, Bandung, 2014.
- [6] Muta'alim, T. L., Purwanto, H., and Subiantoro, "Pembuatan Prereduced Pellet Pasir Besi", *Laporan Penelitian (in house research)*, PPTM, Bandung, 1995.
- [7] Ozel, E., Unluturk, G., and Turan, S., "Production of Brown Pigments for Porcelain Insulator Applications", *Journal of the European Ceramic Society*, vol. 26, pp. 735-740, 2006.
- [8] Elias, M., Chartier, C., Prvot, G., Garay, H., and Vignaud, C., "The Colour of Ochres Explained by Their Composition", *Materials Science and Engineering : B*, vol. 127(1), pp. 70-80, 2006.
- [9] Smit, G., Zmevi, S., and Lzr, K., "Adsorption and Low-Temperature Oxidation of CO Over Iron Oxides", *Journal of Molecular Catalysis A : Chemical*, vol. 252, pp. 103-106, 2006.
- [10] Peng, Y., Park, C., and Laughlin, D. E., "Fe<sub>3</sub>O<sub>4</sub> Thin Film Sputter Deposited from Iron Oxide Targets", *Journal of Applied Physics*, vol. 93(10), pp. 7957-7959, 2003.
- [11] Yulianto, A., "Kajian Sifat Magnetik Pasir Besi dan Optimasi Pengolahannya menjadi Magnet Ferit", *Disertasi*. Institut Teknologi Bandung, Bandung, 2006.
- [12] Yulianto, A., and Aji, M. P., "Fabrikasi MnZn-Ferit dari Bahan Alam Pasir Besi Serta Aplikasinya untuk Core Induktor", *Prosiding Pertemuan Ilmiah XXIV HFI*, pp. 128-13310, April 2010, Semarang, DIY, 2010.
- [13] Agus, F., and Marwanto, S., "Sifat Fisika Tanah dan Metode Analisisnya : Penetapan Berat Jenis Partikel Tanah", *Balai Besar Litbang Sumberdaya Lahan Pertanian*, Badan Penelitian dan Pengembangan Pertanian, Departemen Pertanian, Jakarta, 2006.
- [14] Hardjowigeno, S., "Ilmu Tanah", *Akademika Pressindo*, Jakarta, 2010.