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The Content of Magnetic Material in Black Sand of Yeh Gangga Beach

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Abstract

Yeh Gangga Beach is one of the black sand beaches in the Tabanan district. The abundant black sand on this beach stretches along the shoreline with varying grain sizes. This black sand characterizes the specific surface composition as iron sand deposits with high magnetic mineral content. The very high need and use of magnetic minerals in various fields prompt a study of the magnetic mineral content in the black sand of Yeh Gangga beach.The magnetic material content was determined by the extraction method which was expressed in terms of mass fraction. The grain size distribution was determined by the sieve method using a sieve shaker consisting of six mesh numbers, namely 30, 100, 170, 200, 270, and 325.The density of magnetic materials was determined by the principle of mass and volume ratio. The magnetic susceptibility was tested by using a Bartington MS2B susceptibility meter. Meanwhile, the characterization of the elements and their oxides used non-magnetic methods, namely the X-Ray Fluorescence test.The research results show that the magnetic material fraction of Yeh Gangga black sand reach 84.84% with 58.39% of the grains having sizes in the range rentang $150 \leq r < 90 \mu m$. The magnetic susceptibility value is 28.26 10- 6 m3/kg with an Fe element content of 85.15% . The hematite (Fe_2O_3) content reaches 81.69%. This magnetic material has a density of 1914.43 kg/m3. It was concluded that the black sand of Yeh Gangga is dominated by magnetic material which is ferrimagnetic..

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INTRODUCTION

The sand with a dark gray color that tends to be black along the shoreline of Nyeh Gangga indicates a specific surface composition as iron sand deposits. These surface deposits are concentrated mechanically through the separation of natural heavy types of heavy minerals from light minerals by water or air media. The properties and behavior of minerals are collected in a deposit (Jensen & Bateman, 1981). The resulting andesitic-basaltic rock deposits/sediments contain the element iron (Fe). Based on the rock origin, the breakdown process, transportation media, process and place of deposition, it is possible that there will be differences in the mineral content of iron sand between beaches in Indonesia.

The character of iron deposits can be in the form of stand-alone deposits but are often found in association with other metallic minerals. Most iron is present in various types of iron oxide, namely the minerals magnetite (Fe_3O_4), hematite (Fe_2O_3), ilmenite ($FeTiO_3$/$FeO.TiO_2$), limonite ($FeO(OH){\cdot}nH_2O$), and siderite ($FeCO_3$). The iron oxide content that is often found in iron sand is magnetite, titanomagnetite, ilmenite, hematite, and maghemite. There are other follower minerals such as rutile (TiO_2), ilmenite, shene, silica (SiO_2), alumina, and others (Setiady et al., 2020; Purnawan et al., 2018; Vistarani et al., 2019; Begum et al., 2019; Moustafa, 2023; Abdel-Karim et al., 2017). Beside the high Fe content in iron sand, there are also elements C, Na, Mg, Si, P, S, K, Ca, Ti, V, Cr, Mn (Khwaja et al., 2015). It is not uncommon for the minerals in black sand to also contain rare earth magnets such as Yb, Eu, Nd, Sm, Pr and even the radioactive element Th which can be applied in making high energy magnets (Peristeridou et al., 2022). Agustina's research (2021) found the magnetic content of rare earth metals Yb, Eu and radioactive elements Th and U in the black sand of Puya beach, West Kalimantan.

The main mineral content in iron sand is magnetite and hematite. Sand containing the mineral magnetite is characterized by magnetite mineral grains bonding with other magnetite mineral grains to form chain bonds. The mineral grains have an isometric crystal system so that this material tends to be round and rounded up. Magnetite mineral is a mineral with the highest iron content (72.4%). Meanwhile, the mineral hematite is one of the most abundant minerals on the earth's surface and in the earth's crust. This mineral has a trigonal crystal system with a color range from red to brown and grayish black. Pure hematite has a composition of 70% iron and 30% oxygen and is attracted by magnets.

The magnetic properties of a material are indicated by its response to a magnetic field. The magnetic parameter used in the rock magnetism method is magnetic susceptibility. Magnetic susceptibility is a comparison factor between magnetization (M) and external magnetic field (H). The magnetic susceptibility value can be used to determine the properties of magnetic minerals which are often related to the percentage of iron contained in them (Dearing, 1999). Their response to strong external magnetic fields makes magnetite and hematite minerals very useful for research and magnetism-based industries, including electronics engineering, automotive, permanent magnet manufacturing, the steel industry, computing, and household appliances.

The need for magnetite (Fe_3O_4) and hematite (Fe_2O_3) has increased from year to year for industrial development in modern life. Local iron sand minerals hematite (Fe_2O_3) and magnetite (Fe_3O_4) have potential as industrial raw materials based on magnetic properties, electrode materials, magnetic cores, and iron nugget briquettes which have been researched by Agusu et al. (2019) and Zulhan et al. (2022).

Therefore, efforts are being made to obtain local iron sand in order to ensure the availability of magnetic minerals. The distribution of iron sand in various areas has been identified, including at Loji and Ciletuh Sukabumi beaches (Setiady et al., 2020), North Pringgabaya village, East Lombok (Safitri et al., 2020), Samas beach Bantul (Sismanto et al., 2017), Bubujung Tasikmalaya beach (Suwahyadi et al., 2021), Betaf Sarmi beach, Papua (Haryati et al., 2019), and iron sand in Sumbawa district (Nugraha et al., 2021).

The black sand of several southern beaches on the island of Bali is thought to be iron sand with a high iron mineral content. Research by Rachmawati et al. (2023) found that the black sand of Nyanyi beach in Tabanan district contains iron elements reaching 89.41% and is classified as a soft magnetic material which is antiferromagnetic. However, the local community uses black sand as a material for carvings for buildings, gates or places of worship. Supposedly, this local iron sand could have high economic value. Still in one district, there is Yeh Gangga beach with different physical sand characteristics. In order to explore the magnetic mineral potential of iron sand on Yeh Gangga beach, research is deemed necessary. By disclosing the magnetic material content, it is hoped that unique minerals will be discovered that will be beneficial for the development of science and industry as well as research interests.

This research describes the magnetic mineral content of black sand on one of the southern beaches of the island of Bali, namely Yeh Gangga beach. The aim of this research is to describe 1) the magnetic material characteristics of the black sand of Yeh Gangga beach based on the magnetic material fraction of magnetic minerals, grain size and density, 2) the magnetic mineral content, and 3) the magnetic susceptibility value.

METHOD

Black sand samples were taken at three different locations on the beach surface randomly. Natural separation techniques were used to separate iron sand from impurities. Magnetic and non-magnetic minerals were separated by extraction method using a permanent magnet 10 times. The grain size of the magnetic mineral samples was filtered by using a sieve shaker machine. The mesh was stacked with the small number 50 at the top, followed by numbers 100, 170, 200, 270, and 325. The density of the iron sand sample is determined using the principle of mass and volume ratio. Characterization to determine the elements and oxides contained in the sample used a non-magnetic method, namely the X-Ray Fluorescence (XRF) test. The element concentration was determined based on the wavelength of individual material components from the fluorescent emissions produced by the sample when irradiated with X-rays (Brouwer, 2010). The magnetic susceptibility test was chosen to determine the response of the magnetic material contained. Magnetic susceptibility testing used a Bartington MS2B susceptibility meter. The device sensor displayed the magnetic susceptibility volume value which was then calculated to obtain the magnetic susceptibility value by dividing it by the sample volume, namely $\chi = \kappa/\rho$. The magnetic susceptibility test was carried out with a low frequency of 0.46 Hz (Sarmast et al., 2017). All data were analyzed quantitatively and expressed in mass percentages.

RESULTS AND DISCUSSION

The iron sand sample in Figure 1 is black sand from Yeh Gangga beach which has a dark gray sand color that tends to be black and shiny. This black sand is attracted by permanent magnets. Magnetic and non-magnetic materials resulting from the extraction of 450 grams of black sand samples are presented in Table 1. The magnetic material fraction in the black sand sample from Yeh Gangga beach reach 84.84% with a mass varying from 372.42 – 399.55 grams. This value is much higher than the amount of non-magnetic material. These results show the abundance of magnetic material in the black sand of Yeh Gangga. However, this value is lower than the magnetic mineral fraction of iron sand samples at Nyanyi beach studied by Rachmawati et al. (2023). Physically, black sand samples appear smooth, dark gray, tend to be black and shiny. This color indicates the presence of Fe elements in the iron oxide, namely magnetite or hematite. According to Cornell, R. M., & Schwertmann, U. (2003), hematite has a varying luster appearance from submetallic to metallic. Hematite's color ranges from red to brown and black to silver grey. Meanwhile, magnetite is a black, opaque sediment, varying in luster from submetallic to metallic.

Figure 1. Black color of iron sand

Table 1. Mass fraction of magnetic material samples

Sample	Mass fraction of material			
	magnetic (gram)	%	nonmagnetic (gram)	%
YG 1	372.42	82.76	77.58	17.24
YG 2	399.55	88.78	50.45	11.21
YG 3	373.31	82.96	76.69	17.04

The density of the black sand magnetic material sample from Yeh Gangga beach of 1914.43 kg/m^3 with the grain size distribution is presented in Table 2.

Table 2. Grain size distribution of magnetic material samples

Size	%			$\bar{x}$
	YG1	YG2	YG3	
$r \geq 600\ \mu m$	0.00	0.00	0.00	0.00
$150 \leq r < 600 \mu m$	34.32	45.36	33.75	37.81
$90 \leq r < 150 \mu m$	63.71	51.31	60.14	58.39
$75 \leq r < 90 \mu m$	1.97	2.37	4.91	3.08
$53 \leq r < 75 \mu m$	0.00	0.96	1.20	0.72
$45 \leq r < 53 \mu m$	0.00	0.00	0.00	0.00
$r < 45 \mu m$	0.00	0.00	0.00	0.00

The grain size of Yeh Gangga black sand magnetic material samples is dominantly in the range 150≤r<90μm. As many as 58.39% of the black sand magnetic material samples from this beach are in this size range. A small portion, 0.72%, of these black sand grains are 53≤r<75 μm in size. No samples were found with grains smaller than 53 μm. Based on the grain size distribution, it shows that the magnetic material sample can be classified as black sand with a fine grain size (0.06 – 0.2 mm).

The results of black sand samples screening using the electron scattering method show that the intensity of x-rays emitted by electrons of the Fe element transitioning from the K shell is higher than that of the Eu and Mn elements at the same energy, namely 6.05 keV. The intensity is 2250 cps/22 μA. The spectra of elements contained in the black sand of Yeh Gangga beach are presented in Figure 2.

There are 14 element contents in the magnetic material samples in Yeh Gangga black sand, namely Si, Al, P, Ca, Ti, V, Cr, Mn, Fe, Zn, Br, Eu, Re and Bi, which are presented in Table 3. Table 3 shows that the Fe element content in black sand samples is most dominant compared to the content of other elements. The Fe element in the black sand sample from Yeh Gangga beach reaches 85.15%. The large percentage of Fe elements indicates the abundance of magnetic minerals in the black sand samples from Yeh Gangga beach. The dark gray color of the sand tends to black, indicating a high Fe content. The blacker the color of the sand, the stronger its magnetic properties (Mufit et al., 2013). Meanwhile, the gloss effect of black sand samples can be caused by the presence of the Ti element. When the magnetic value (Fe) increases, the Ti element also increases. The XRF results also show the presence of follower elements with a content of ≤ 1.70%, namely the elements Zn, P, Br, Bi, Ca, Si which are diamagnetic. This black sand sample also contains rare earth metal elements, namely 0.65% Eu, which are paramagnetic. The magnetic properties of the sample black sand are contributed not only from the Fe element, but also from the elements Ti, V, Cr, Mn, Re, Al which are paramagnetic and Cr which is antiferromagnetic. The magnetic mineral content in the black sand samples of Yeh Gangga beach is presented in Table 4.

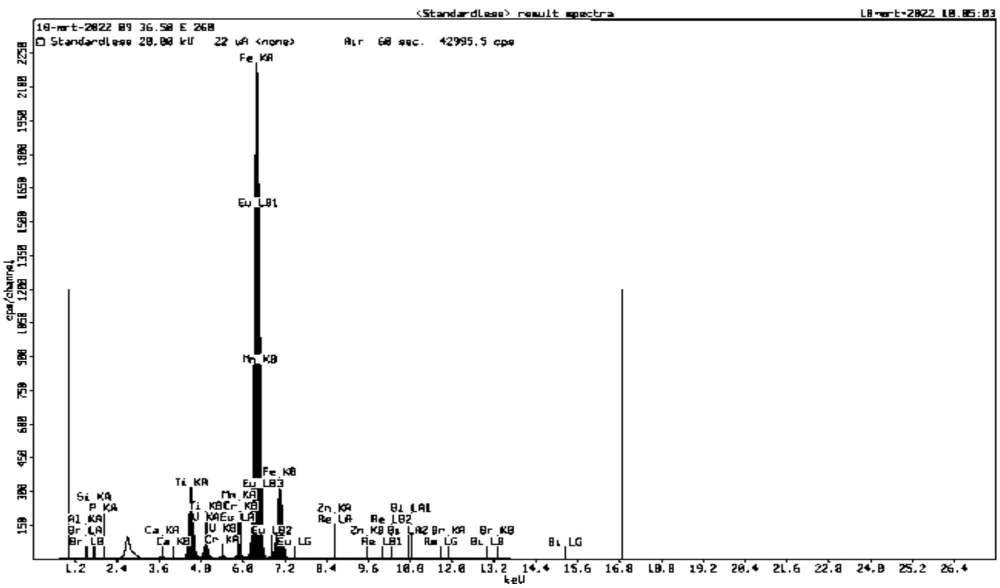

Figure 2. Spectra of a sample of Yeh Gangga black sand magnetic material

Table 3. Element content in magnetic material samples

Element	Amount (%)
Si	1.70
Al	1.00
P	0.30
Ca	0.52
Ti	7.66
V	0.61
Cr	0.10
Mn	0.54
Fe	85.15
Zn	0.10
Br	0.29
Eu	0.65
Re	0.20
Bi	0.85

Table 4. The content of mineral in magnetic material samples

Oxida	Amount (%)
SiO_2	2.70
Al_2O_3	2.00
P_2O_5	0.52
CaO	0.54
TiO_2	9.41
V_2O_6	0.64
Cr_2O_3	0.12
MnO	0.44
Fe_2O_3	81.69
ZnO	0.07
Br	0.29
Eu_2O_3	0.69
Re_2O_7	0.2
Bi_2O_3	0.69

The mineral that is dominant or has the highest percentage in the black sand samples from Yeh Gangga beach is hematite (Fe_2O_3). This mineral amounts to 81.69%. Apart from hematite, there are other minerals as follower minerals carried during the deposition process. These associated minerals are present in relatively small amounts. Minerals ZnO, P_2O_5, Br, Bi_2O_3, CaO, SiO_2 are diamagnetic. Meanwhile, the minerals Al_2O_3, TiO_2, V_2O_6, Cr_2O_3, MnO, Eu_2O_3, and Re_2O_7 also contribute to the magnetic properties of the black sand samples. The rutile mineral in the black sand sample is quite high, reaching 9.41 %. The Ti content in rutile has great potential for high technology applications.

Table 5. Magnetic susceptibility of samples

Samples	Susceptibility	
	κ_{lf} (10^{-5})	χ_{lf} ($10^{-6}m^3/kg$)
YG1	5338.5	27.886
YG2	5632.1	29.419
YG3	5257.4	27.462

Table 5 shows the fluctuating magnetic susceptibility values at the three sampling locations. The high magnetic susceptibility value of the sample indicates a high magnetic mineral content. The magnetic behavior of a mineral is controlled by the particular atoms that make up the lattice and the lattice structure. In some minerals, the same atoms give rise to different magnetic states because they can form alternative lattice structures. Minerals that show a strong magnetic response tend to contain iron (Fe) atoms in their lattice. This result is in accordance with the XRF characterization results presented in Tables 3 and 4. The magnetic susceptibility value at low frequencies shows that the black sand sample is dominated by magnetic material that is ferrimagnetic. The ferrimagnetic properties of magnetic material samples are also indicated by positive magnetic susceptibility values.

CONCLUSION

The black sand of Yeh Gangga beach has a magnetic material fraction of 84.84%, with 58.39% of the grains having a size in the range $90 \leq r < 150$ μm. This magnetic material has a density of 1914.43 kg/m^3 with a magnetic susceptibility value of 28.26 10-6 m^3/kg. The magnetic mineral content is dominated by the mineral hematite (Fe_2O_3) reaching 81.69 % with an Fe content of 85.15%. Another finding in this research is that this black sand contains rare earth metal elements, namely 0.65% Eu, which is paramagnetic, and a Ti content of 7.66% in the rutile phase. The mineral content of hematite (Fe_2O_3) found in the black sand of Yeh Gangga beach can contribute directly to use of making color pigments made from magnetic minerals and magnetic nanoparticles. Meanwhile, the general contribution of the results of this research are : 1) the development of knowledge and technology of iron sand magnetic minerals, 2) the development of iron sand magnetic nanoparticles, 3) the development of applications of iron sand magnetic minerals in various fields of modern life, 4) regional policies related to the management and processing of iron sand , 5) policy on the development of environmentally friendly iron sand mining technology. The potential presence of iron sand along the Yeh Gangga beach could provide capital for regional development on the island of Bali..

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