Distribution of Magnetic Susceptibility of Natural Iron Sand in the Sarmi Coast Area

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Abstract. Iron sand, a raw source of magnetic materials, is known to exist in a particular area in Indonesia. However, researchers mostly focused on the iron sand source from the western coast of Sumatera and the southern coast of Java while the northern coast of Papua had not been yet identified. In this study, iron sand samples were collected from the coastal area of Sarmi located on the northern coast of the Papua Province between these geographic positions 1°47'52.30"S - 138°40'27.60"E and 1°57'57.50"S - 138°57'7.60"E. The results show that samples from Tor River estuary had the highest mass-specific magnetic susceptibility values, varying approximately from 3000 to 4000 \times 10^{-8} \text{ m}^3/\text{kg}. Contrarily, samples from the Verkame area had a much lower mass-specific magnetic susceptibility, varying approximately from 200 to 600 \times 10^{-8} \text{ m}^3/\text{kg} unexpectedly. The mineral and magnetic structure confirms the presence of iron oxide minerals in iron sands from the Tor River estuary.

1. Introduction

Indonesia has long been well known to be rich in mineral resources. Significant deposits of tin, copper, bauxite, nickel, gold, silver, uranium, granite, coal, manganese, natural asphalt and also iron sands have already been discovered over several decades [1]. Specifically, iron sand resources reach up to 160 million tons in Indonesia [2]. It’s scattered across the coast and rivers, starting from the island of Sumatra and ending on the island of Papua. Iron sands’ significant existence encouraged scientist to conduct research concerning this material, in order to find more valuable industrial capabilities than just simply as building material which has a low economic value [3]. It has been reported that iron sand contains iron oxides such as magnetite (Fe_3O_4), maghemite (\(\gamma\)-Fe_2O_3) and hematite (\(\alpha\)-Fe_2O_3) [4], which are considered raw materials in a number of industrial applications. Some important physical properties such as high saturation magnetization, high Curie temperature, high coercivity, chemical stability, and corrosion resistance lead to a wide application of these materials [5-6].

Several researchers have studied and utilized Indonesian iron sand. Iron sand from the southern Coast of Yogyakarta was found to be potential raw ceramic magnet materials [7], while materials obtained from Dlodo beach, Tulungagung, East Java were successfully synthesized as red and yellow color pigments [8]. Moreover, study on iron oxide nanoparticles synthesis based on iron sand was more focused on in order to achieve higher performance of materials [9-10]. Regrettably, researchers mostly focused on the iron sand source from the western coast of Sumatera and the southern coast of Java while the northern coast of Papua had not yet been identified.

Sarmi is one of the latest regencies in the Papua Province, established in 2003 with an area of 35.587 km². The name stands for the names of the largest tribes in the area, namely Sobey, Armati,
Rumbuai, Manirem, and Isirawa. In 2013, the Geological Agency of Indonesia and the Ministry of Energy and Mineral Resources released information on strategic minerals balance in the Sarmi Regency that 600 million tons of iron sand was presumed deposited in certain areas, specifically at Verkame (Pantai Barat District), Dabe-Nengke (Tor Atas District), and Wiru (Bonggo District) [11]. However, any physical properties of these materials had not yet been reported. In this paper, we reported a preliminary study of magnetic and mineral properties of natural iron sand in the Sarmi coast area, to identify the magnetic susceptibility, mineral composition and crystal structure of the iron sand. The results of this study are expected to provide information for Sarmi Regency Governments to create policy and provide researchers to conduct in-depth study of materials.

2. Experimental Methods
Data provided by the Geological Agency of Indonesia [11] exhibits that the potential presence of iron sand in the Sarmi coast is located in (a) Verkame and (b) Dabe-Nengke and (c) Wiru, as shown in figure 1. However, our preliminary survey in the determination of the study area was concentrated on the substantial presence of iron sand and easy access to the location. Accordingly, we limited the study area to geographic positions of 1°47'52.30"S - 138°40'27.60"E and 1°57'57.50"S - 138°57'7.60"E. Samples were collected from 20 survey points.

![Figure 1. Location map of the Sarmi coast showing Verkame (a), Dabe-Nengke (b) and (c) Wiru.](image)

Collected samples were soaked and washed with distilled water to remove the sea water content subsequently with natural drying for 3 days. The mass-specific magnetic susceptibility values were measured using a MS2B Susceptibility Meter, to study the magnetic properties. The mineral compositions were calculated by Scan Quant X (SQX) software using Rigaku ZSX Primus II WDXRF spectrometer, while the X-Ray Diffraction patterns were collected using Shimadzu 7000 X-Ray Diffractometer with CuKα radiation in the 2theta range of 20 to 70 degrees. Both experiments were conducted in order to study the mineral and structural properties of the samples.

3. Results and Discussion
The mass-specific magnetic susceptibility values from 20 survey points are shown in table 1, while the distribution maps are shown in figure 2. It is shown that samples from the Tor River estuary (survey points #15-16) have the highest mass-specific magnetic susceptibility values varying approximately from 3000 to 4000 x 10⁻⁸ m³/kg. These high magnetic susceptibility values infer high concentration of magnetic minerals that are predominantly magnetite. In contrast, the magnetic susceptibility of samples from the Verkame district area is much lower, except for a few samples (survey points # 1-3) taken from the Verkame River estuary. Such lower magnetic susceptibility might infer a low
concentration of magnetic minerals or the presence of weaker magnetic minerals such as hematite [12].

| Survey Points | Survey Coordinates | Susceptibility (χ) (× 10⁻⁸ m³/kg) |
|---------------|--------------------|----------------------------------|
| 1             | 1°47'52.30"S 138°40'27.60"E | 284.17                           |
| 2             | 1°48'23.10"S 138°41'00.20"E | 661.60                           |
| 3             | 1°48'40.40"S 138°41'22.90"E | 192.75                           |
| 4             | 1°49'35.40"S 138°42'15.90"E | 150.00                           |
| 5             | 1°50'29.96"S 138°43'12.44"E | 98.55                            |
| 6             | 1°51'09.70"S 138°44'52.10"E | 45.97                            |
| 7             | 1°50'47.57"S 138°45'03.69"E | 6.95                             |
| 8             | 1°51'24.20"S 138°44'55.20"E | 79.80                            |
| 9             | 1°51'32.89"S 138°44'46.35"E | 36.05                            |
| 10            | 1°58'07.60"S 138°52'09.40"E | 1330.97                          |
| 11            | 1°58'07.88"S 138°52'09.91"E | 2442.20                          |
| 12            | 1°58'07.80"S 138°52'10.30"E | 2014.63                          |
| 13            | 1°58'08.10"S 138°52'11.10"E | 1520.23                          |
| 14            | 1°58'07.60"S 138°52'39.00"E | 1242.67                          |
| 15            | 1°58'00.40"S 138°52'46.90"E | 3049.63                          |
| 16            | 1°57'31.70"S 138°53'28.80"E | 3879.47                          |
| 17            | 1°57'34.40"S 138°53'29.80"E | 1153.30                          |
| 18            | 1°57'36.09"S 138°54'20.46"E | 544.43                           |
| 19            | 1°57'18.00"S 138°54'19.40"E | 902.03                           |
| 20            | 1°57'57.50"S 138°57'07.60"E | 702.63                           |
Figure 2. Distribution maps of magnetic susceptibility in the Sarmi coast area

To confirm the minerals in the iron sand, we calculated the mineral compositions of samples from (a) Verkame River estuary – point #2 and (b) Tor River estuary – point #16, where the results are shown in table 2. The results revealed that samples from the Tor River estuary contain a significant percentage of iron oxide minerals (16.8 %) compared to the Verkame River estuary (6.48 %) where it dominantly contained silicon oxides (71.3 %).

Table 2. Mineral compositions

| Oxide minerals | Compositions | (a) Verkame - Point #2 | (b) Tor – Point #16 |
|----------------|--------------|------------------------|---------------------|
| Si oxides      | 71.3 %       | 43.9 %                 |                     |
| Fe oxides      | 6.48 %       | 16.8 %                 |                     |
| Al oxides      | 10.9 %       | 8.52 %                 |                     |
| Ca oxides      | 3.54 %       | 17.3 %                 |                     |
| Na oxides      | 1.70 %       | 1.11 %                 |                     |
| Mg oxides      | 0.94 %       | 9.07 %                 |                     |
| Others         | 5.41 %       | 3.30 %                 |                     |

The presence of iron oxide mineral was also confirmed by X-ray diffraction. Figure 3 shows the X-ray diffraction pattern of iron sand samples from (a) Verkame River estuary – point #2 and (b) Tor River estuary – point #16. The major peaks of the sample (b) clearly shows the typical pattern for iron oxide magnetite minerals (Fe₃O₄) according to the Joint Committee on Power Diffraction Standards / JCPDS number 19-629, together with mixed mineral components of Ca(Mg, Fe, Al) (Si, Al) 206
(JCPDS # 41-1483). Subsequently, peaks of the samples (a) were comparable with the typical pattern of silicon oxides (JCPDS # 46-1045) and mineral glasses NaAlSi$_3$O$_8$ (JCPDS # 9-0466).

![X-ray diffraction patterns](image)

**Figure 3.** X-ray diffraction patterns for samples from (a) Verkame River and (b) Tor River estuary.

Higher concentrations of iron found in the estuary area rather than in the river have been observed since long ago [13]. It is notable that the primary sources of estuarine sediments are rivers, offshore and littoral areas, and the shorelines of the estuaries. Sand may have been brought into estuaries from the offshore and littoral material, since sand is the predominant material exposed on ocean beaches [14]. Therefore, the source of iron sand in the Sarmi coast area can be suspected to originate from the Tor River. Study of the existence of iron sand along the Tor River is being conducted.

4. Conclusion
The preliminary study of natural magnetic and mineral properties of iron sand in the Sarmi coast area was successfully conducted. The results revealed that the area with the highest susceptibility was found in the Tor River estuary and indicates that the magnetite minerals (Fe$_3$O$_4$) were high potential deposits. Further study is needed to explore the origin of the iron sand in the Sarmi coast area, in that it may very well be quite unique from other areas in Indonesia.

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