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Characterization Study of Iron Sand and Silica Deposits Based on Mineralogical-Geochemical Data

Muhammad Idris Juradir[1*], Sitti Ratmi Nurhawaisyah[2], Hasbi Bakri[3], Alam Budiman Thamsi[4], Ahmad Fauzan Haryono[5]

[1-4] Department of Mining Engineering, Faculty of Industrial Technology, Universitas Muslim Indonesia, Indonesia
[5] Department of Mining Engineering, Faculty of Science and Technology, Syarif Hidayatullah State Islamic University, Indonesia
Correspondence e-mail: muhidris.juradi@umi.ac.id

ABSTRACTS

Iron sand and silica sand are strategic commodities for raw materials in the metal, cement, glass, and functional materials industries. However, the quality and economic viability of deposits are largely determined by mineral composition and elemental content. Variations in mineralogical-geochemical characteristics that are not well mapped often lead to inaccuracies in determining quality, beneficiation routes, and industrial utilization directions. Therefore, preliminary characterization is necessary to ensure the most appropriate processing potential and recommendations. This study aims to identify the main minerals carrying Fe and SiO_2 and determine the geochemical composition of both deposits. The research was conducted by taking representative samples at several locations, such as the Jenne Berang River, Burungintia River, and Tanjung Bayang Beach, followed by preparation (drying, sieving, fraction separation). Next, mineralogical and chemical characterization was carried out using X-Ray Diffraction (XRD) and X-Ray Fluorescence (XRF) to determine the mineral and chemical composition. Samples from Tanjung Bayang Beach showed the presence of several main crystalline phases dominated by iron oxides such as Magnetite with a content of 31.5% and Maghemite with 30.4%. In addition, a Quartz phase of 24.7% was identified, representing the dominant gangue mineral in the sand fraction. Another minor phase was Hematite with 13.4%. These samples are iron sand with magnetic iron oxide as the main component. Geochemical analysis of the iron sand samples found Fe_2O_3 at a level of 54.7%, SiO2 at 36.8%, 2.7%, and CaO at 2.3%. The sample from the Jenne Berang River is dominated by the aluminosilicate phase in the form of Albite (plagioclase feldspar, Na-rich) with a fraction of around 84.1%, while the minor phase identified is Fe_3O_4 (magnetite/iron oxide) at around 15.9%. This sample is silica sand with aluminosilicate as its main component. Geochemical analysis of silica sand samples from the Jenne Berang River showed SiO_2 content of 40.3%, Fe_2O_3 18.7%, Al_2O_3 30.7%, and CaO 4.50%. The sample from the Burungintia River is dominated by the Albite phase ($NaAlSi_3O_8$; feldspar/aluminosilicate) with a fraction of approximately 90.2%, while the minor phase detected is Fe_3O_4 (magnetite/iron oxide) at approximately 9.8%. The sample is silica sand with aluminosilicate as the main component. Geochemical analysis of silica sand samples from the Burungintia River showed SiO_2 content of 45.5%, Fe_2O_3 11.6%, Al_2O_3 33.0%, and CaO 4.0%.

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INTRODUCTION

Indonesia is a country rich in natural resources, one of which is iron sand and silica sand. Iron sand is a mining material that contains iron-bearing minerals such as magnetite Fe_3O_4, hematite Fe_2O_3, and ilmenite $FeTiO_3$. These minerals are formed through the weathering of igneous rocks such as basalt, andesite, or ultramafic rocks, which are then carried by water flows to coastal or river areas and undergo sedimentation. (Budiman et al., 2019). These deposits are usually found along the coast, especially in the southern coastal regions of Java, parts of Sumatra, Sulawesi, and Papua. The potential of iron sand in Indonesia is quite large and has strategic value because it is an important raw material in the steel and metal industries (Suprapto, 2014).

Silica sand is a mineral resource with high economic value, mainly due to its silica (SiO_2) content, which is used in various industries such as glass, ceramics, cement, electronics, and chemical industries. However, in its natural form, silica sand often contains various impurities, such as iron (Fe) minerals, clay, and other minerals, which can reduce the SiO_2 content and quality for industrial applications (Suryanat et al., 2025).

The need for data-based mineral downstreaming (quality-based mining) and increasingly intensive coastal resource management. In Indonesia, iron sand generally takes the form of deposits of sand with magnetic minerals (magnetite–titanomagnetite–ilmenite) which have been widely used for low value-added applications, even though variations in grain size, mineralogy, and chemical composition can be used as a basis for mining selection, beneficiation, and source determination.

Studies in Aceh show that magnetic susceptibility and grain size distribution correlate with Fe content and can be used for selective exploration and deposit origin studies, while also confirming the heterogeneity of iron sand characteristics between geographically close but geologically different locations (Satria et al., 2021).

Research on deposits around Mount Tambora has even expanded this approach by combining grain size, magnetic susceptibility, X-Ray Diffraction (XRD), X-Ray Fluorescence (XRF), and ICP-OES (including rare earth metals) to distinguish the characteristics of iron sand from volcanic product zones and indicate the potential of certain economic elements (Birrul et al., 2024; Bakri et a., 2023).

On the other hand, silica deposits (quartz sand) are strategic raw materials for the glass, ceramics, filter, and advanced materials (e.g., SiC) industries, but their quality is highly determined by the purity of SiO_2 and the content of impurities (Fe_2O_3, TiO_2, Al_2O_3, CaO, etc.) and their mineralogical characteristics. Studies of beach sand in Sulawesi and Sumatra show that processing (e.g., alkali fusion and purification) can improve silica quality and reveal differences in SiO_2 content and quartz phases through X-Ray Diffraction (XRD) - X-Ray Fluorescence (XRF) - Fourier Transform Infrared (FTIR) (Xia., 2019). Studies on silica characterization in other regions also emphasize the importance of integrating physical, mineralogical, and geochemical analyses to assess suitability for industrial specifications (Wuletaw et al., 2024)

Many iron sand studies focus on magnetic parameters and primary Fe, while LTJ evaluation, carrier mineral associations, and direct implications for separation schemes and industrial quality limits are often not comprehensively mapped (Mounteney et al., 2018). Conversely, silica studies often emphasize SiO_2 purity, but have not always linked geochemical variations to mineralogical controls, grain size fractionation, and enrichment/contamination mechanisms in coastal deposition systems (Wibowo, 2019).

Other literature also confirms that a multi-proxy approach (mineralogy + geochemistry) provides stronger diagnostics for sediment provenance and quality assessment than a single indicator; for example, heavy mineral concentrate geochemistry using Inductively Coupled Plasma – Atomic Emission Spectrometry (ICP-AES) can accelerate screening and strengthen interpretation when combined with mineralogy data (Joshi et al., 2021). In the context of mineral raw materials, the integration of X-Ray Diffraction (XRD) and multi element-element profiles (including minor/trace elements) has also been proven effective in distinguishing ore quality and type and assessing its suitability for use (Wasim et al., 2020).

Thus, this study aims to characterize iron and silica sands in an integrated manner based on mineralogical-geochemical data (X-Ray Diffraction and X -Ray Fluorescence) and to fill important gaps such as producing a deposit quality map based on parameters that can be followed up for the processing, clarifying the geological control and provenance of the distribution of Fe–Ti-bearing minerals and quartz, and providing a database for determining the most rational downstream route (Fe–Ti concentrate, magnetic material, or industrial silica) according to market specifications.

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METHODS

The research samples tested came from three different locations, namely the Jenne Berang River, the Burungintia River, and Tanjung Bayang Beach. This research began with preparatory activities to prepare samples that met the standards for characterization, including drying 5 kg of samples (each) in an oven at a temperature of 100oC for 24 hours, then grinding them with a ball mill for 30-40 minutes, followed by sieving to obtain a size of -200 mesh (-74 microns).

The next process was mineralogical analysis to determine the mineral/compound composition in the samples, conducted using X-Ray Diffraction (XRD) applied to powdered samples using a Bruker D8 advance XRD instrument at a 2 theta angle range of 10°-90°. Qualitative XRD analysis uses the Rietveld Correction method, processed through Bruker Diffrac Suite Search/Match software integrated with the ICDD PDF-4 database.The next stage was geochemical analysis, which aimed to determine the element/metal content in the sample using X-Ray Fluorescence (XRF) with a Bruker S8 Tiger model, which involved exposing 5 grams of sample prepared in pellet form to X-rays. Subsequently, data processing and analysis of the characterization results were carried out, followed by data interpretation to draw conclusions as the final process of this series of studies. The flowchart of this study can be seen in Figure 1.

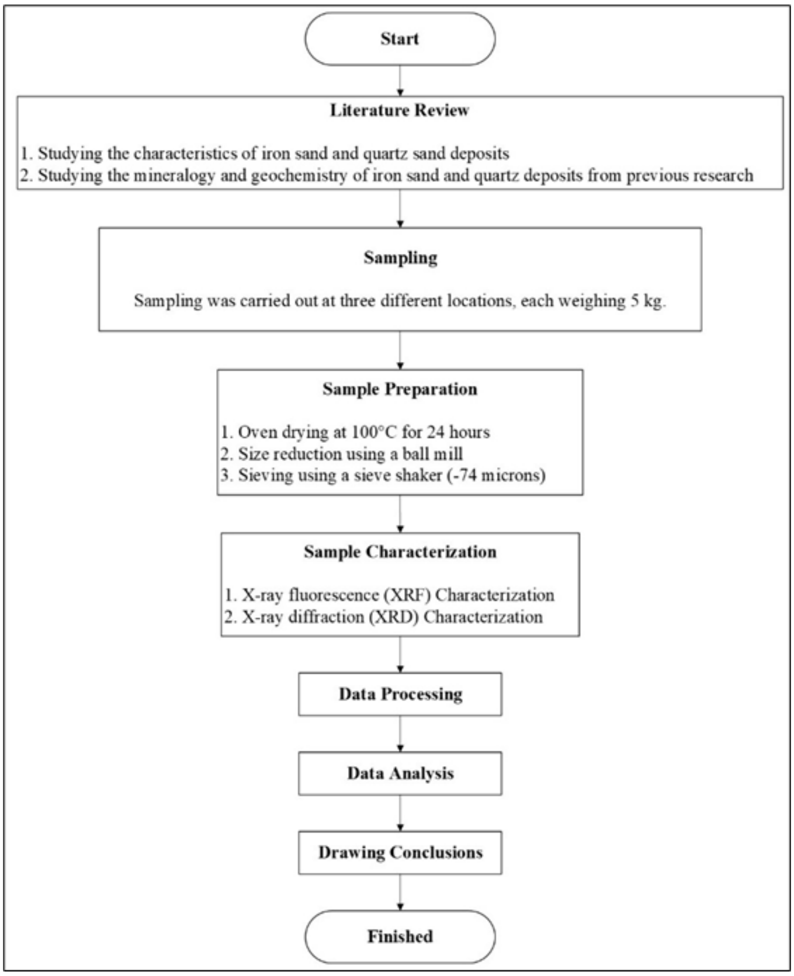

Figure 1. Research flow chart

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RESULTS AND DISCUSSION

X-Ray Diffraction (XRD) Analysis of the Tanjung Bayang Beach Sample

The results of the analysis (XRD) of the iron sand sample (Figure 2) show the presence of several main crystalline phases dominated by iron oxides. The diffraction pattern displays the highest intensity peak at around 2θ ~35–36°, which is characteristic of the iron oxide spinel phase, especially magnetite/maghemite. Pattern matching and semi-quantitative quantification results indicate that the sample consists of ~31.5% Fe_3O_4 (magnetite) and ~30.4% maghemite (γ-Fe_2O_3), bringing the total spinel phase to ~61.9%. In addition, a quartz (SiO_2) phase of ~24.7% was identified, representing the dominant gangue mineral in the sand fraction. Another minor phase is hematite (α-Fe_2O_3) of ~13.4%.

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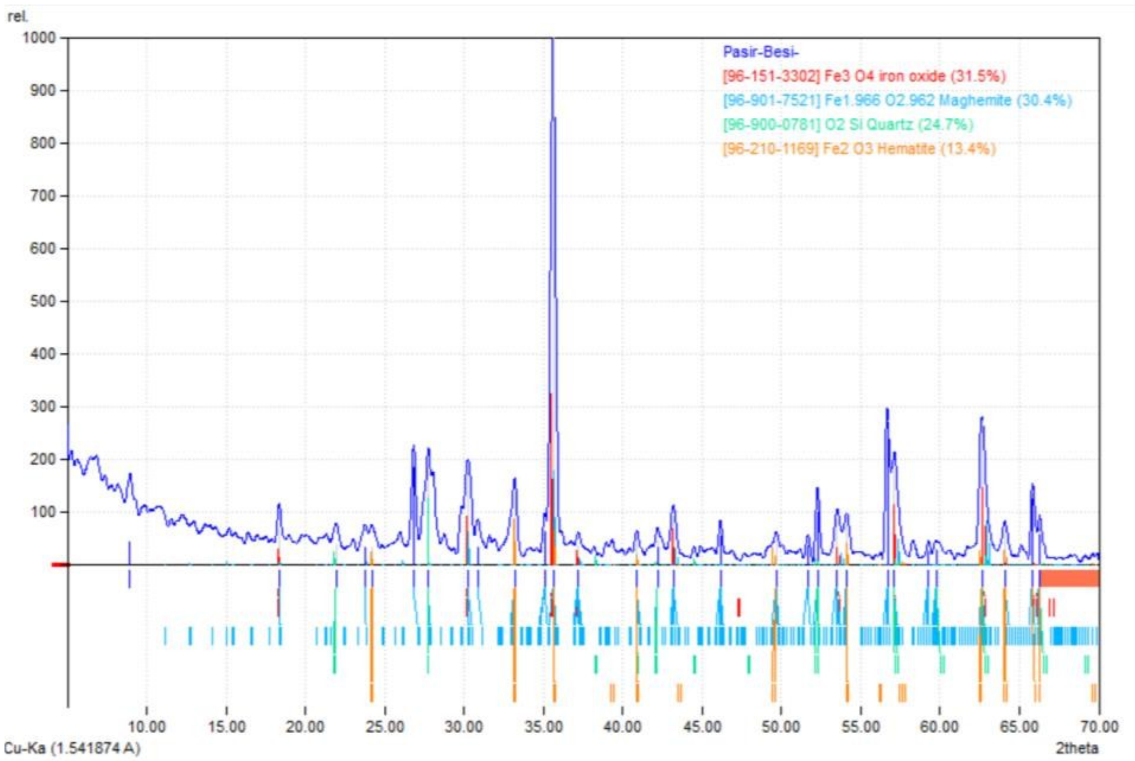

Figure 2. XRD analysis diffractogram of the Tanjung Bayang Beach sample

The presence of magnetite and maghemite is indicated by the appearance of characteristic peaks in the range of 2θ ~30°, ~35°, ~43°, ~57°, and ~62–63°, which are generally associated with plane reflections in spinel structures. The prominent quartz peak at around 2θ ~26.6° confirms the relatively significant contribution of silica in the sample. Meanwhile, the detection of hematite indicates the presence of partial oxidation of iron minerals or the presence of natural hematite phases in the source material. Overall, the XRD results (Table 1) confirm that the iron sand sample has a high iron oxide content with a predominance of the spinel phase, but still contains a significant fraction of silicate (quartz), so that further processing (e.g., magnetic separation) has the potential to increase the iron-bearing mineral content (Bakri et al., 2025; Juradi et al., 2021a).

Table 1. Results of XRD analysis of samples from Tanjung Bayang Beach

Minerals	Chemical Composition	Grade (%)
Magnetite	Fe_3O_4	31.5
Maghemite	Fe_2O_3	30.4
Quartz	SiO2	24.7
Hematite	Fe_2O_3	13.4

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X-Ray Diffraction (XRD) Analysis of Jenne Berang River Samples

The analysis results of silica sand samples (Figure 3) show diffraction patterns dominated by the aluminosilicate phase. Phase identification through pattern matching shows that the main mineral component of the sample is albite (Al–Na aluminosilicate feldspar) with a fraction of approximately 84.1%, while the minor phase detected is Fe_3O_4 (magnetite/iron oxide) at 15.9%. The dominance of albite is indicated by the numerous dense and intense diffraction peaks in the 2θ ~20–35° range, which is a common characteristic of feldspar minerals (Thamsi et al., 2024).

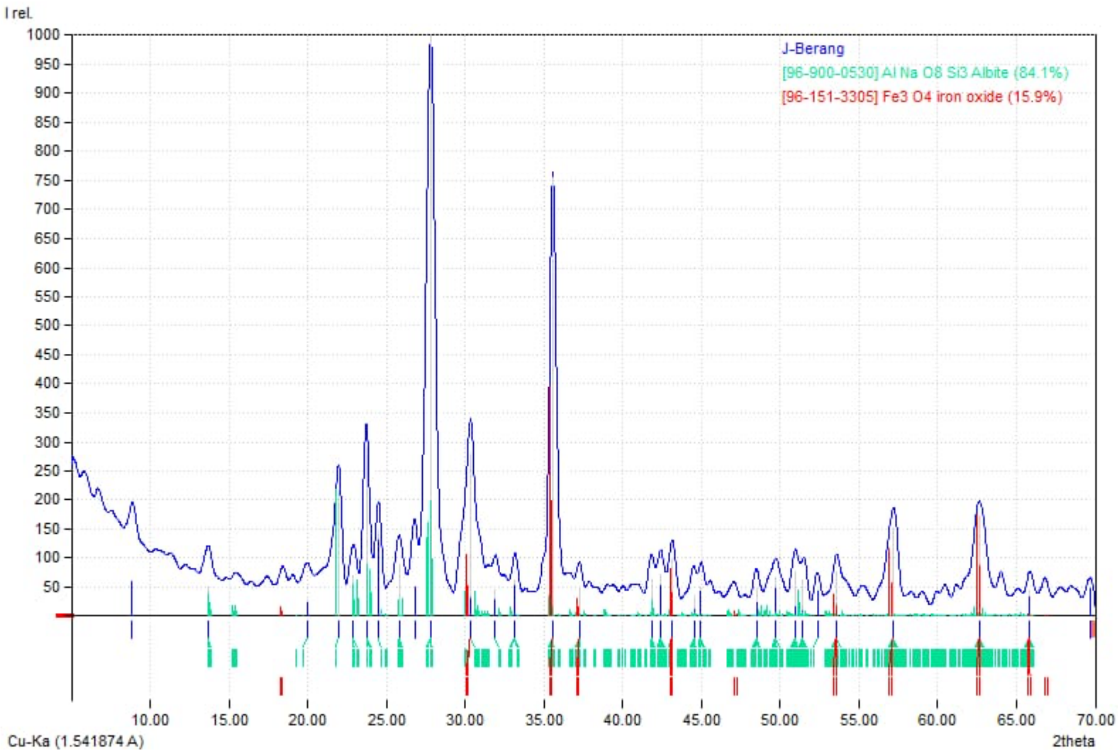

Figure 3. XRD analysis diffractogram of the Jenne Berang River

The presence of magnetite is confirmed by the appearance of characteristic spinel iron oxide peaks in the range of 2θ ~35–36° and supporting peaks in the higher angle range, although some peaks overlap with albite reflections. Overall, the XRD results (Table 2) confirm that the sample is predominantly feldspar (albite) with magnetite iron oxide as a minor component, so that its mineralogical composition is more representative of a silicate matrix than an iron oxide concentrate.

Table 2. Results of XRD analysis of samples from the Jenne Berang River

Minerals	Chemical Composition	Grade (%)
Albite(Al)	$AlNaO_8Si_3$	84.1
Magnetite	Fe_3O_4	15.9

X-Ray Diffraction (XRD) Analysis of Burungintia River Samples

The results of the analysis (XRD) of silica sand samples (Figure 4) show that the main crystalline phase composing the material is albite ($NaAlSi_3O_8$). Pattern matching and semi-quantitative quantification indicate an albite fraction of ~90.2%, while the minor phase identified is Fe_3O_4 (magnetite/iron oxide) at ~9.8%. The dominance of albite is reflected in the appearance of many dense and sharp diffraction peaks in the 2θ ~20–35° range, which is characteristic of feldspar minerals.

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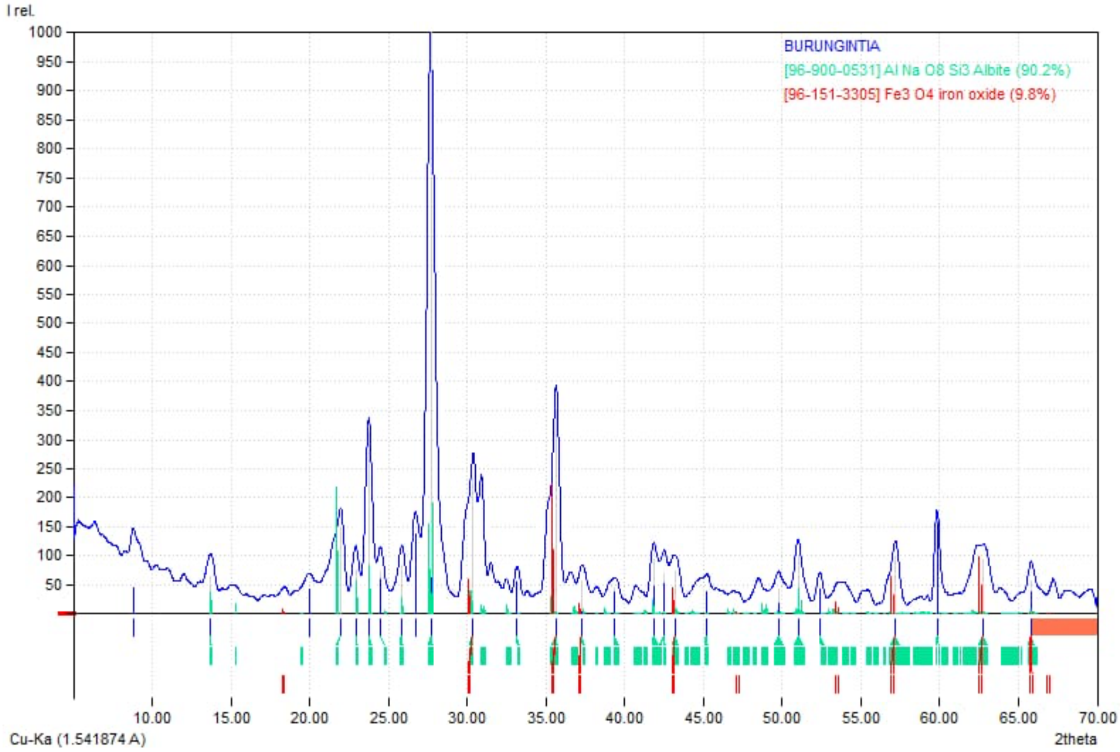

Figure 4. XRD analysis diffractogram of Burungintia river samples

Meanwhile, the presence of magnetite is confirmed by the appearance of characteristic spinel iron oxide reflections at around 2θ ~35–36° and several supporting peaks at higher angles, although some reflections overlap with albite peaks. Overall, the XRD results (Table 3) confirm that the sample is an aluminosilicate-rich material (feldspar) with magnetite as a minor component.

Table 3. Results of XRD analysis of Burungintia river samples

Minerals	Chemical Composition	Grade (%)
Albite(Al)	$AlNaO_8Si_3$	90.2
Magnetite	Fe_3O_4	9.8

X-Ray Fluorescence (XRF) Analysis of Tanjung Bayang Beach Samples

The results of X-ray fluorescence (XRF) analysis in Table 4 show that the samples are dominated by Fe_2O_3 at 54.7%, followed by SiO_2 at 36.8%. The high Fe_2O_3 content indicates iron oxide-rich material, with an estimated Fe content equivalent to approximately 38.3% Fe. On the other hand, the relatively high SiO_2 content confirms the presence of silicate phases as the main gangue component, which has the potential to reduce the effective iron content and increase the need for purification processing (Joshi et al., 2021; juradi et al., 2021b).

Table 4. XRF (X-Ray Fluorescence) of Tanjung Bayang Beach

Oxide Element	Grade (%)
Fe_2O_3	54.7
SiO_2	36.8
Al_2O_3	2.7
CaO	2.3

Minor oxides detected include Al_2O_3 (2.7%) and CaO (2.3%), which are likely related to the contribution of aluminosilicate minerals and small amounts of calcium phases. Overall, the XRF composition classifies the sample as a Fe_2O_3-rich material but still containing significant silica, so a

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beneficiation process (e.g., separation/reduction of the silicate fraction) may be necessary to improve product quality (Bakri et al., 2024; Juradi et al., 2023).

X-Ray Fluorescence (XRF) Analysis of Jenne Berang River Samples

The results of X-ray fluorescence (XRF) analysis of the samples (Table 5) show that the main oxide composition is dominated by SiO_2 at 40.3% and Al_2O_3 at 30.7%, which cumulatively reach around 71.0%. These findings indicate that the samples have strong aluminosilicate characteristics and are likely composed primarily of silicate/aluminosilicate minerals.

Table 5. Results of XRF analysis of the Jenne Berang River

Oxide Element	Grade (%)
SiO_2	40.3
Al_2O_3	30.7
Fe_2O_3	18.7
CaO	4.5

The Fe_2O_3 content of 18.7% indicates the presence of iron oxide components in medium concentrations, while CaO of 4.5% indicates a minor contribution from calcium-rich phases. Overall, the XRF data confirms that the sample is dominated by a silicate-alumina matrix rather than iron oxide, so that increasing the iron content (if this is the target of the process) requires a beneficiation stage to reduce the silicate/alumina fraction (Juradi et al., 2021b).

X-Ray Fluorescence (XRF) Analysis of Burungintia River Samples

The results of X-ray fluorescence (XRF) analysis of the samples (Table 6) show that the chemical composition is dominated by SiO_2 at 45.5% and Al_2O_3 at 33.0%, with a combined contribution of approximately 78.5%. This dominance of SiO_2–Al_2O_3 indicates a strong aluminosilicate material character, so that the main matrix of the sample is likely composed of silicate/aluminosilicate minerals.

Table 6. Results of XRF Analysis of Sungtai Burungintia

Oxide Element	Grade (%)
SiO_2	45.5
Al_2O_3	33.0
Fe_2O_3	11.6
CaO	4.0

The Fe_2O_3 content of 11.6% indicates the presence of iron oxide in relatively low concentrations, while the CaO content of 4.0% indicates the presence of a minor amount of calcium-rich phases. Overall, the XRF data confirms that the sample is more silicate-alumina in nature than iron-rich material, so if increasing the iron content is the goal of the process, a beneficiation stage is required to reduce the aluminosilicate fraction (Joshi et al., 2024).

CONCLUSION

The results of mineralogical analysis for the three samples, in the sample originating from Tanjung Bayang beach, showed the presence of several main crystalline phases dominated by iron oxides such as Magnetite with a content of 31.5% and Maghemite 30.4%. In addition, a Quartz phase of 24.7% was identified, representing the dominant gangue mineral in the sand fraction. Another minor phase is hematite at 13.4%. This sample is iron sand with magnetic iron oxide as its main component. Geochemical analysis of the iron sand sample found Fe_2O_3 at a level of 54.7%, SiO_2 at 36.8%, 2.7%, and CaO at 2.3%.

The sample from the Jenne Berang River is dominated by the aluminosilicate phase in the form of Albite (plagioclase feldspar, Na-rich) with a fraction of around 84.1%, while the minor phase identified is Fe_3O_4 (magnetite/iron oxide) at around 15.9%. This sample is silica sand with aluminosilicate as its main component. Geochemical analysis of silica sand samples from the Jenne Berang River showed SiO_2 content of 40.3%, Fe_2O_3 18.7%, Al_2O_3 30.7%, and CaO 4.50%.

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The sample from the Burungintia River is dominated by the Albite phase ($NaAlSi_3O_8$; feldspar/aluminosilicate) with a fraction of approximately 90.2%, while the minor phase detected is Fe_3O_4 (magnetite/iron oxide) at approximately 9.8%. The sample is silica sand with aluminosilicate as the main component. Geochemical analysis of silica sand samples from the Burungintia River showed SiO_2 content of 45.5%, Fe_2O_3 11.6%, Al_2O_3 33.0%, and CaO 4.0%.

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REFERENCE

Bakri, S., Abdullah, MA., Juradi, MI., & Nurhawaisyah, SR. (2024). Studi Pemisahan Sio2 pada Pasir Silika Menggunakan Shaking Table. Jurnal Inovasi Pertambangan Dan Lingkungan, 3(2), 85-90. https://doi.org/10.15408/jipl.v3i2.34225.

Bakri, S., Anas, M., Wakila, M. H., & Chalik, C. A. (2023). Geochemical Characterization of Silica Sand in the Sidenreng Rappang Area Based on X-Ray Diffraction Analysis and X-Ray Fluorescence Analysis. *Journal of Geology and Exploration*, 2(1), 1–7. https://doi.org/10.58227/JGE.V2I1.36.

Bakri, S., Mursit, M., Juradi, MI., & Arifin, M. (2025). Benefisiasi Pasir Besi Pantai Karsut Daerah Jeneponto Dengan Metode Konsentrasi Magnetic Separator. *Jurnal Teknologi Sumberdaya Mineral*, 6(1), 13-20. https://doi.org/10.15408/jipl.v3i2.34225.

Birrul Waalidain, A., Harwan, H., & Aswadi, M. (2024). Geochemical Characteristics of Iron Sand Deposits in Karsut Beach Area, Jeneponto Regency, South Sulawesi Province. *Journal of Geology and Exploration*, 3(1), 41–47. https://doi.org/10.58227/jge.v3i1.171.

Budiman, A., Handayani, D., & Nurwidyanto, H. (2019). Karakteristik Mineralogi dan Kimia Pasir Besi di Pantai Selatan Kabupaten Kebumen Jawa Tengah. *Jurnal Sumber Daya Geologi*, 29(1), 27–36.

Joshi, K., Banerji, U., Dubey, CP., & Oliveira EP. (2021). Heavy minerals in provenance studies: an overview. *Arabian Journal of Geosciences*. 14:13-30.

Juradi, M. I., Asmiani, N., Anwar, H., Bakri, S., Arifin, M., & Nurhawaisyah, S. R. (2023). Benefisiasi Bijih Mangan Paludda Kabupaten Barru Sulawesi Selatan Menggunakan Magnetic Separator. *Jurnal Pertambangan*, 7(1), 28-32.

Juradi, M. I., Bakri, H., Nurhawaisyah, S. R., Yusuf, F. N., & Bakri, S., Wakila, M. H. (2021b). Peningkatan Kadar Bijih Besi Batubessi Kec. Barru Kab. Barru Dengan Metode Pemisahan Magnetik. *Jurnal Geosapta*, 7(2), 85-89.

Juradi, M. I., Umar, E. P., Nurhawaisyah, S. R., Bakri, S., & Arifin, M. (2021a). Pengaruh Ukuran Partikel Pada Proses Peningkatan Kadar Dan Perolehan Bijih Besi Bontocani Menggunakan Dry Intensity Drum Magnetic Separator. *Jurnal Pertambangan*, 5(4), 153-157.

Mounteney, I., Burton, AK., Farrant, AR., Watts, MJ., Kemp, SJ., & Cook, JM. (2018). Heavy mineral analysis by ICP-AES a tool to aid sediment provenancing. Journal of Geochemical Exploration. 184:1-10.

Satria, B., Masrurah, Z., & Fajar S. (2021). Magnetic susceptibility and grain size distribution as prospective tools for selective exploration and provenance study of iron sand deposits: A case study from Aceh, Indonesia. *Heliyon*. 7(12),80-89.

Suprapto, E. (2014). Karakteristik dan Potensi Pasir Besi di Indonesia. *Jurnal Geologi dan Sumberdaya Mineral*, 24(2), 89-98.

Suryanata, P., Jayatri U., Bijaksana, S, Fajar S., & Harlianti, U. (2025). Magnetic and geochemical studies of iron sand deposits around Tambora Volcano in Sumbawa, Indonesia: A proxy for search high quality iron sand. Rudarsko-geološko-naftni zbornik. *The Mining-Geology-Petroleum Engineering Bulletin*, 40(5),19-30.

Thamsi, A. B., & Jafar, N. (2024). Mineraloid Opal: Karakteristik dan Kandungannya. books.google.com.https://books.google.com/books?hl=en&lr=&id=e0obEQAAQBAJ&oi=fnd&pg=PP1&dq=%22alam+budiman+thamsi%22&ots=Rauz_G6s3l&sig=XaQ1QfolZEhr0h62yapnBljzlIU.

Journal of Geology & Exploration
Vol. 5, No. 1, June 2026: 21 – 29
E-ISSN 2963-2869

Wasim, M., Tariq, A., Shafique, MA., & Qureshi, RN. (2020). Characterization and differentiation of iron ores using X-ray diffractometry, instrumental neutron activation analysis and inductively coupled plasma optical emission spectrometry. *Journal of Radioanalytical and Nuclear Chemistry*, 323:179-187.

Wibowo, A. (2019). Analisis Kandungan Logam Pasir Besi di Sungai Opak. *Jurnal Teknik Mineral*, 11(1), 45-53.

Wuletaw, A., & Mihret, B. (2024). Physicochemical and mineralogical characterization of silica sand from the Lemi region, Blue Nile Basin, central Ethiopia: Evaluating industrial applications and resource potential. *Heliyon*. 14(10),75-84.

Xia, K. (2019). Engineering geology and ground collapse mechanism in the Chengchao Iron-ore Mine in China. *Engineering Geology*, 249, 129–147. https://doi.org/10.1016/j.enggeo.2018.12.028