# Mineralogical and Chemical Characterization of Gidan Waya Tin Ore: Implications for Efficient Beneficiation and Tin Extraction Methods

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## ABSTRACT

This study investigates the characterization and beneficiation of Gidan Waya tin ore, focusing on its mineralogical and chemical composition to optimize gravity concentration processing. X-ray fluorescence (XRF) analysis revealed that tin (Sn) is the dominant element in the ore, accounting for 37.85%, followed by silicon (Si) at 11.18%, and iron (Fe) at 4.72%. Other elements such as niobium (Nb), titanium (Ti), and calcium (Ca) were also detected in smaller quantities. Mineralogical analysis through X-ray diffraction (XRD) confirmed that cassiterite ($SnO_2$) is the most abundant mineral phase, comprising 71% of the sample, with quartz ($SiO_2$) and archerite ($NH_4$) also present. The findings highlight the significance of removing gangue minerals, particularly quartz, to enhance the recovery of tin. The results suggest that Gidan Waya tin ore contains valuable trace elements and impurities that can influence the beneficiation process, underscoring the need for a tailored approach to processing. This study provides vital information for developing efficient and sustainable tin extraction methods, which could contribute to improved resource utilization and economic growth in Nigeria's mining sector.

**Keywords:** Tin ore characterization, Gidan Waya, X-ray fluorescence (XRF), Gravity concentration, X-ray diffraction (XRD)

## INTRODUCTION

Tin (Sn), primarily extracted from cassiterite ($SnO_2$), is one of the most important non-ferrous metals in the world, with widespread industrial applications, including the production of alloys, tin plating, and the manufacturing of electronic components (Burt, 2019). The demand for tin is expected to continue increasing, especially for use in the rapidly growing electronics and energy sectors (Burt, 2020). Given its economic importance, the efficient extraction and beneficiation of tin ore have become critical to ensuring a sustainable supply of this valuable metal for various industries. Traditional methods of tin ore processing, such as crushing, grinding, and gravity concentration, remain widely used, with gravity concentration standing out due to its cost-effectiveness, simplicity, and environmental benefits compared to chemical-based methods (Ding, 2018). Gravity concentration relies on the differences in specific gravity between the tin-bearing minerals and gangue materials, making it particularly effective in processing coarse-grained tin ores and removing unwanted impurities such as quartz, feldspar, and mica (Falcon, 2021).

The Gidan Waya tin ore deposit in Nigeria, however, has not been well-characterized, leading to significant gaps in understanding its mineral and chemical composition. The lack of detailed information on the ore's composition makes it challenging for miners, researchers, and investors to assess the ore's quality and select the appropriate extraction and beneficiation techniques. This knowledge gap not only hinders optimal ore processing but also increases the risk of resource wastage, higher costs, and environmental harm (Jeon, 2018).

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Despite the considerable importance of gravity concentration in the mining sector, challenges such as achieving high recovery rates while maintaining a high-grade concentrate persist, particularly with low-grade ores and fine tin particles (Falcon, 2022). Optimizing the beneficiation process for Gidan Waya tin ore will therefore improve recovery rates, reduce processing costs, and minimize environmental impacts, which are essential in meeting the growing demand for tin in industrial applications.

The purpose of this research is to address this knowledge gap by characterizing the elemental and mineralogical composition of Gidan Waya tin ore. By doing so, the study aims to provide a foundation for identifying the most effective processing methods for this specific ore type. This information will aid in the development of more efficient beneficiation techniques, contributing to the economic growth of Nigeria's mining sector and enhancing sustainable practices in mineral processing.

Global studies on tin ore beneficiation, particularly through gravity concentration, have been extensive, there is limited research on the characterization and processing of Gidan Waya tin ore. The absence of detailed studies on the ore's composition and processing challenges leaves a gap in understanding how to best exploit this valuable resource for industrial use (Akinola et al., 2022; Alabi et al., 2024). This research will fill this gap by providing specific data on Gidan Waya tin ore's composition and optimal beneficiation techniques, which are critical for developing sustainable mining practices and enhancing tin recovery.

## MATERIAL AND METHODS

Ore samples were collected from three alluvial sites along a stream channel in Gidan Waya, Kaduna State, Nigeria (7.0994°N, 10.7685°E), an area known for tin-bearing granitic and pegmatitic formations. Sampling focused on stream sediments where visible cassiterite grains were present, using shovels and head pans. The samples were immediately sealed in clean polythene bags to preserve their natural condition and prevent contamination. In the laboratory, the samples were air-dried, crushed using a jaw crusher, and ground in a ball mill to achieve uniform particle size, followed by conning and quartering to homogenize the sample.

Mineralogical analysis was performed using X-ray Diffraction (XRD), which identified cassiterite ($SnO_2$) as the dominant tin-bearing mineral, with quartz, feldspar, and mica as the primary gangue minerals. XRD was selected for its precision in determining crystalline phases, essential for understanding the mineral liberation required for efficient gravity separation. For chemical analysis, X-ray Fluorescence (XRF) was used. The representative ore sample was crushed, pulverized, and pressed into a pellet for analysis. The pellet was then subjected to XRF, where primary X-rays caused the sample's atoms to emit secondary fluorescent X-rays. These emitted rays were analyzed to determine the elemental composition of the ore, providing accurate data on major and minor oxides such as $SnO_2$, $SiO_2$, $Al_2O_3$, and $Fe_2O_3$. This comprehensive analysis helped guide the selection of the most appropriate beneficiation method for the Gidan Waya tin ore.

## RESULT

Table 1: Chemical Composition of Gidan Waya Iron Ore (XRF Analysis)

| Oxide Component | Chemical Formula | Composition (%) |
|---|---|---|
| Tin | Sn | 37.85% |
| Silicon | Si | 11.18% |
| Aluminum | Al | 3.81% |
| Iron | Fe | 4.72% |
| Niobium | Nb | 1.18% |
| Titanium | Ti | 3.25% |

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| | | |
|---|---|---|
| Calcium | Ca | 2.00% |
| Chlorine | Cl | 0..43% |
| Tantalum | Ta | 0.82% |

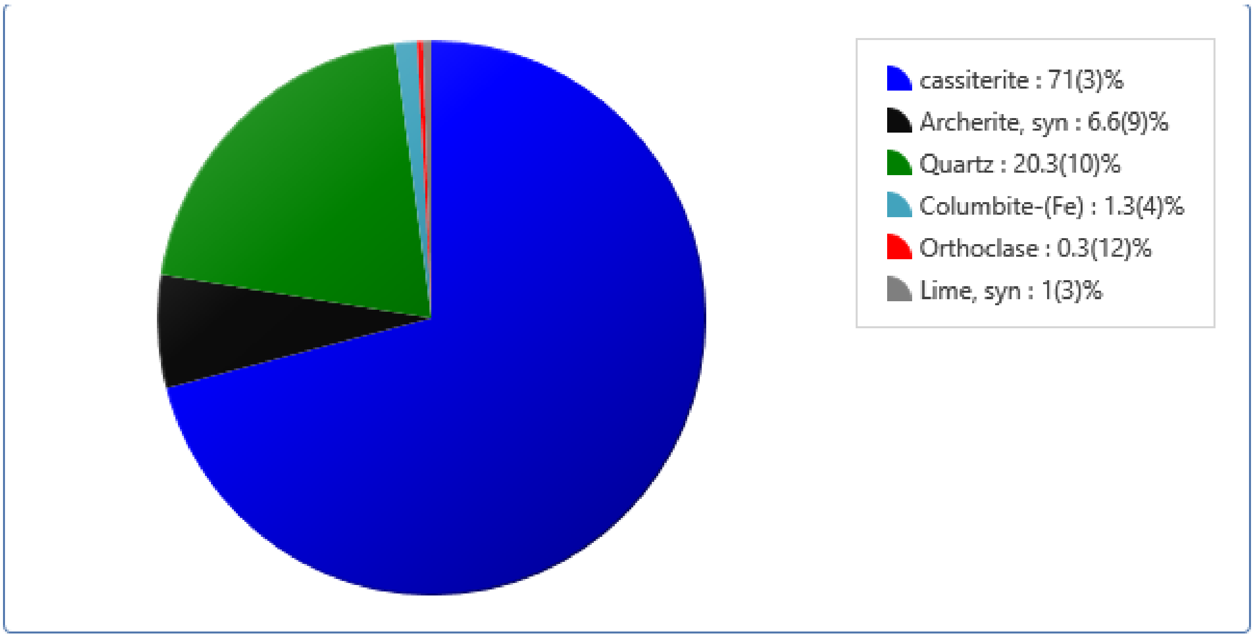


Figure 4.1: XRD Analysis Result

Table 2: Mineralogical Analysis of Gidan Waya Tin Ore (XRD Analysis)

| **Identified Mineral Phases** | **Chemical Formula** | **Relative Abundance (%)** |
|---|---|---|
| Cassiterite | $SnO_2$ | 71% |
| Archerite | $NH_4$ | 6.6% |
| Quartz | $SiO_2$ | 20.3% |
| Columbite | Fe | 1.3% |
| Orthoclase | $KAlSi_3O_8$ | 0.3% |
| Lime | CaO | 1% |

## DISCUSSION

The chemical composition of Gidan Waya tin ore, as determined through X-ray fluorescence (XRF) analysis, shows that tin (Sn) is the dominant component, accounting for 37.85% of the ore. Silicon (Si) follows at 11.18%, which is consistent with the presence of quartz, a common gangue mineral. Aluminum (Al) is present at 3.81%, and iron (Fe) at 4.72%, indicating the presence of iron-bearing minerals in the ore. Other elements detected in smaller quantities include niobium (Nb) at 1.18%, titanium (Ti) at 3.25%, calcium (Ca) at 2.00%, chlorine (Cl) at 0.43%, and tantalum (Ta) at 0.82%. These findings suggest that, in addition to cassiterite ($SnO_2$), the ore contains significant amounts of other valuable elements such as titanium and niobium, as well as impurities like chlorine and calcium, which could influence the beneficiation process.

Mineralogical analysis through X-ray diffraction (XRD) identified several key mineral phases in the ore. Cassiterite ($SnO_2$) was the most abundant, comprising 71% of the sample, confirming that the primary source of tin is cassiterite. Other minerals present include archerite ($NH_4$) at 6.6%, quartz ($SiO_2$) at 20.3%, and columbite

(Fe) at 1.3%. The presence of quartz suggests that gangue removal will be a significant part of the beneficiation process. Additionally, trace amounts of orthoclase ($KAlSi_3O_8$) and lime (CaO) were detected at 0.3% and 1%, respectively. These findings highlight the mineralogical characteristics of Gidan Waya tin ore and provide valuable insights into the ore's composition, which will guide the selection of the most effective beneficiation methods for efficient tin extraction. The data also underscores the importance of separating cassiterite from gangue minerals like quartz to improve the quality of the final concentrate.

## REFERENCES

1. Akinola, A., Obams, A., & Ifeanyi, A. (2022). Determination of minerals of cassiterite tailings and its recycling potential using empirical method at Plateau State, Nigeria. *International Journal of Advances in Scientific Research and Engineering*. Retrieved from ResearchGate
2. Alabi, O. O., Olatunde, B. J., Ebenezer, A. O., & Elizabeth, G. Y. (2024). Investigating the gravity beneficiation consequences on Farin Lamba cassiterite towards tin oxide production. *Saudi Journal of Engineering and Technology*. Retrieved from saudijournals.com
3. Burt, R. (2019). *Tin mineralogy and beneficiation* (industry overview).
4. Burt, R. (2020). *Advanced methods for tin extraction and processing*.
5. Tin Ore Beneficiation Methods, Processes and Challenges (2024). *Xinhai Mining Industry Overview*. Retrieved from xinhaimining.com
6. Tin Ore Gravity Separation: Influencing Factors, Advantages & Disadvantages (2025). *JXSC Machine*. Retrieved from jxscmachine.com
7. Ding, H. (2018). *Beneficiation of tin ores by gravity concentration techniques*. *Minerals Engineering*, 114, 1-9. https://doi.org/10.1016/j.mineng.2017.12.001
8. Falcon, P. J. (2021). *Gravity separation methods in mineral processing: Challenges and advancements*. *Journal of Mining Science and Technology*, 45(3), 289-305. https://doi.org/10.1007/s11041-020-00433-x
9. Jeon, H. (2018). *Optimization of tin ore beneficiation for sustainable mining and processing*. *Journal of Sustainable Mining*, 18(2), 76-89. https://doi.org/10.1016/j.jsm.2017.10.003