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Research Article

Characterization of Ore and Gangue Mineralogy at the Ashashire Gold Deposit, Benishangul-Gumuz Region, Western Ethiopia

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Abstract

This research presents a comprehensive mineralogical characterization of the Ashashire gold deposit in western Ethiopia to inform processing strategies. We analyzed six representative core samples using fire assay with atomic absorption spectroscopy (AAS), inductively coupled plasma (ICP), and quantitative evaluation of minerals by scanning electron microscopy (QEMSCAN). The gold content varied from 1.47 g/t to 5.27 g/t, with a mean value of 2.54 g/t. The results indicate that gold primarily occurs as native gold and gold-telluride, closely associated with tellurium, and is predominantly occurs as free particles or in association with gangue minerals such as quartz and pyrite. Pyrite (2.1-6.73 wt%) is the dominant sulfide mineral, with only trace chalcopyrite detected. The gangue assemblage is dominated by quartz (10.3-42.3 wt%), ankerite-dolomite (9.1-27.6 wt.%), muscovite (8.0-22.6 wt%), chlorite (0.2-17.4 wt%), and albite (5.6-33.7 wt%). Gold grain size distribution reveals 19.2% coarse particles (>60 µm), 27.6% in the 20-40 µm range, and 3.8% very fine particles (<2 µm). The presence of tellurium and gold-tellurides indicates a refractory gold component requiring specialized processing. We recommend an integrated flowsheet that combines gravity separation, flotation, pressure oxidation, and cyanidation (CIL/CIP) to optimize gold recovery. These findings provide a foundation for developing efficient and sustainable processing strategies tailored to the deposit's unique characteristics.

Keywords

Gold, Mineralogy, Ashashire, Gangue, Processing, Tellurium

1. Introduction

Gold has played a significant role in human history, contributing to artistic expression, cultural heritage, and economic development [1]. Gold has been prized by humans for its lustrous colour and its resistance to tarnishing, so it was used for special decorative ornaments and jewellery [2]. Gold was likely the first metal utilized by humans, as it occurs naturally in placer deposits and can be recovered without complex separation techniques [3]. The mineralogical form of gold in ore deposits dictates the extraction methods required for its recovery [4].

Gold ores are broadly classified into two categories based

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on their amenability to extraction: free-milling and refractory ores [5, 6]. Free-milling ores are characterized by gold recoveries exceeding 90% using conventional cyanide leaching, whereas refractory ores require pretreatment processes to achieve acceptable recoveries [7, 8]. Refractory behavior arises from various mineralogical factors, including gold encapsulation in sulfide minerals, the presence of gold-tellurides, or carbonaceous matter that interferes with leaching [5-8]. Beyond this primary classification, gold occurrence can be categorized as microscopic (visible), submicroscopic (invisible), or surface-bound, each presenting distinct processing challenges [9-14].

Comprehensive mineralogical characterization is essential for developing effective gold processing strategies. Key parameters include the mineralogical features of gold-bearing and gangue minerals, grain size distribution, mineral coatings, and the presence of refractory gold phases [11, 13]. A range of analytical techniques, from conventional fire assay and optical microscopy to advanced methods such as electron microscopy (SEM) and laser ablation ICP mass spectrometry, are employed to address the inherent complexity of gold ores [5, 6].

The Ashashire gold deposit is located in Kurmuk Woreda, Benishangul-Gumuz Regional State, Western Ethiopia, lies within the Neoproterozoic Asosa Greenstone Belt (Figure 1). This region, including the Ashashire area, is known for its significant occurrences of primary gold and base metals, as documented by the Geological Survey of Ethiopia, Golden Star Resources Limited (GSR), the Metal Mining Agency of Japan (MMAJ), and Benzu Gold Mining Ethiopia (BGME) [15-18]. These studies have generated extensive geological, geochemical, structural, and geophysical data through analyses of stream sediments, surface samples, and borehole samples. However, the primary focus of most exploration companies in the region has been on assessing the grade and tonnage of deposits to determine their economic viability. While this approach is important, it has often overlooked the critical need to analyse the mineralogical features of the ore and its associated gangue. Understanding these aspects is essential for developing effective processing methods, which can significantly enhance gold recovery and ensure the efficient utilization of resources.

As the Ashashire deposit approaches the production stage, understanding the mineralogical features of the ore and gangue becomes critical for process design. Yet no comprehensive mineralogical study has been conducted specifically to inform processing strategies for this deposit. This study addresses this gap by providing detailed mineralogical characterization of the Ashashire gold deposit, with emphasis on implications for gold recovery. By characterizing both the ore and gangue mineralogy, this research seeks to contribute to the development of a tailored and robust processing strategy that aligns with the unique characteristics of the deposit. The results of this study are expected to play a crucial role in improving the efficiency of gold recovery at Ashashire while also offering valuable insights into mineralogical complexities that can be applied to similar deposits.

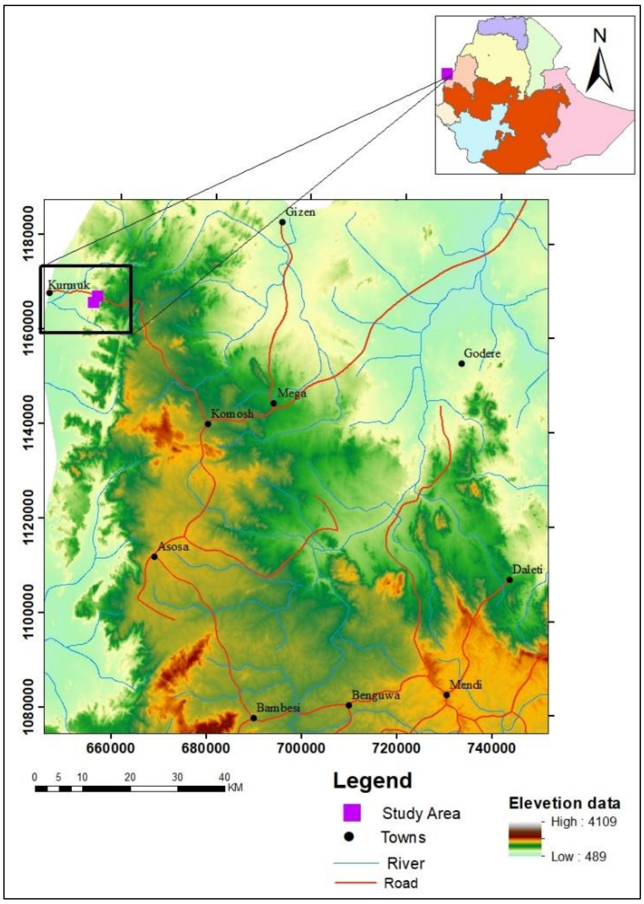


Figure 1. *Location map of the study area.*

2. Materials and Methods

2.1. Materials and Equipment

Samples and data were sourced from the Ministry of Mines of Ethiopia. Analytical instrumentation included Fire Assay with Atomic Absorption Spectroscopy (AAS) for gold quantification (detection limit: 0.01 ppm), ICP for elemental analysis, and QEMSCAN for mineralogical evaluation. ArcGIS, Microsoft Excel, and Word were used for spatial analysis, data processing, and documentation.

2.2. Methodology

2.2.1. Sample Collection and Preparation

Six representative core samples were collected from the mineralized zone. Sample preparation was conducted at the ALS laboratory in Addis Ababa, where they were crushed to -3 mm, riffle-split to obtain 1 kg sub-samples, and pulverized to 75 µm using an LM2 pulveriser, ensuring uniformity for analysis.

2.2.2. Analytical Techniques

(i). Chemical Analysis

Chemical analyses were conducted at ALS Johannesburg laboratory. Fire Assay with AAS was used for gold quantification with a detection limit of 0.01 ppm. ICP was used for comprehensive multi-elemental analysis to determine associated elements and their concentrations (Table 2).

(ii). Mineralogical Analysis

The remaining sub-samples were ground to 75 μm (P80) and analyzed using QEMSCAN. This technique provided quantitative mineralogical composition (Table 4), identification of gold-bearing minerals and their associations (Figure 4), and grain size distribution of gold (Table 5). These data were used to develop processing strategies for the deposit. Figure 2 provides a visual representation of the overall workflow from sample collection to analysis.

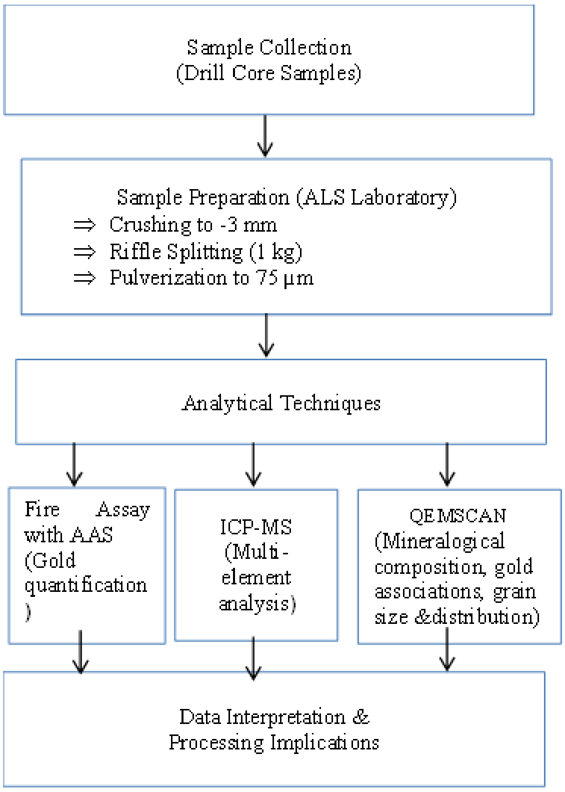


Figure 2. *Flow diagram for the mineralogical characterization of the Ashashire deposit.*

3. Results and Discussion

3.1. Results

3.1.1. Gold Grade and Variability

The gold concentration of six representative samples was quantified using fire assay with Atomic Absorption Spectroscopy (AAS). Each sample was assayed in triplicate, and average values were calculated. Results (Table 1) show gold content ranging between 1.47 g/t and 5.27 g/t, with an average of 2.54 g/t (Figure 3). Sample AS6 exhibited the highest variability (2.65 to 5.27 g/t), indicating the presence of coarse gold particles, which can significantly affect processing efficiency.

Table 1. *Gold assay results for representative core samples.*

Sample ID	Lithology	Au Assay 1 (g/t)	Au Assay 2 (g/t)	Au Assay 3 (g/t)	Average (Au g/t)
AS1	Granite	2.25	2.26	2.24	2.25

Sample ID	Lithology	Au Assay 1 (g/t)	Au Assay 2 (g/t)	Au Assay 3 (g/t)	Average (Au g/t)
AS2	Granite	1.62	1.92	1.84	1.79
AS3	Pelite	1.47	1.92	1.75	1.71
AS4	Pelite	2.33	2.03	2.22	2.19
AS5	Mafic	4.07	3.64	3.53	3.75
AS6	Mafic	2.65	2.82	5.27	3.58
Average					2.54

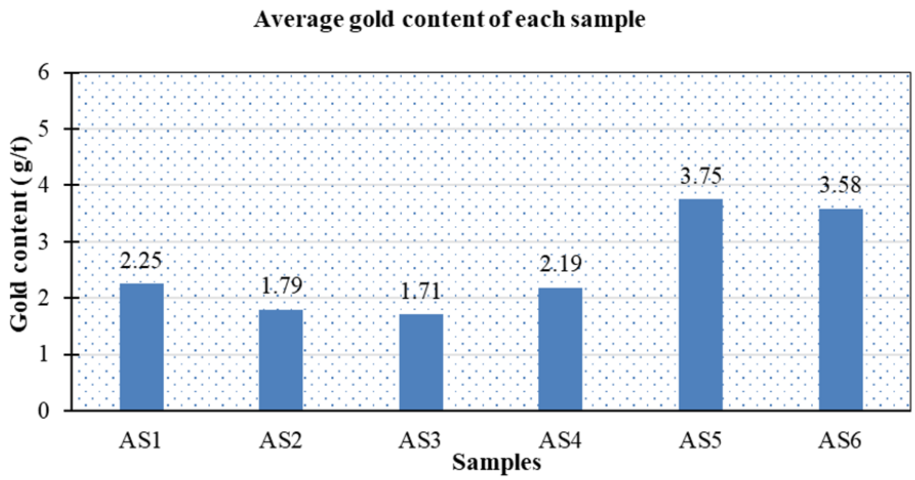


Figure 3*. Average gold concentration for representative core samples.*

The significant variability in gold content, particularly in sample AS6, suggests the presence of coarse gold particles. Such particles pose challenges for conventional cyanide leaching due to their slower dissolution rates and potential for incomplete recovery [7]. Gravity separation is recommended as a pre-concentration step to address this issue. Techniques such as shaking tables, jigging, or centrifugal concentrators exploit density differences between gold and gangue minerals to isolate the coarse gold fraction. Implementing gravity separation before leaching reduces the volume of material requiring further processing, lowering operational costs and improving economic feasibility [18, 19].

3.1.2. Elemental Composition

ICP analysis revealed the geochemical characteristics of the deposit (Table 2). Silver (Ag) levels were low (0.3-2.1 ppm). Tellurium (Te) was detected in all samples (1.2-3.4 ppm), suggesting the presence of telluride minerals. Organic carbon was below detection limit (<0.03%) in most samples, indicating minimal risk of preg-robbing. Sulfide sulfur ranged from 0.52% to 3.02%, indicating variable sulfide mineral content. Copper (52-260 ppm) and zinc (34-118 ppm) concentrations were relatively elevated. Mercury was detected in three samples at 0.5 ppm, while arsenic remained below 10 ppm in all samples.

Table 2*. Multi-element concentrations in core samples.*

Element	Unit	AS1	AS2	AS3	AS4	AS5	AS6
Ag	ppm	0.3	0.3	0.6	0.6	2.1	0.6
Te	ppm	2.4	2.4	1.2	1.8	3.4	1.6
C Organic	%	0.03	<0.03	<0.03	<0.03	<0.03	<0.03
S sulphide	%	1.02	0.52	0.98	2.28	2.1	3.02
Cu	ppm	74	52	260	214	258	120

Element	Unit	AS1	AS2	AS3	AS4	AS5	AS6
Zn	ppm	62	34	108	118	104	92
Hg	ppm	0	0	0	0.5	0.5	0.5
Ni	ppm	20	20	50	45	45	45
Pb	ppm	3	5	10	15	20	2.5
As	ppm	<10	<10	<10	<10	<10	<10

The ICP results indicate that silver (Ag) levels are relatively low; varying between 0.3 ppm and 2.1 ppm, indicating that the deposit is not strongly enriched in silver. The presence of tellurium in all samples is particularly significant, as gold-tellurides are refractory to conventional cyanidation and necessitate specialized extraction techniques such as pressure oxidation or roasting [5, 6]. The low organic carbon content (<0.03%) eliminates concerns about carbonaceous interference with cyanidation [19]. The variable sulfide sulfur content (0.52-3.02%) indicates the occurrence of sulfide minerals, including pyrite and arsenopyrite, which can consume cyanide and oxygen during leaching [19]. Elevated copper and zinc concentrations suggest potential base metal sulfide mineralization, which may require selective flotation for effective gold recovery [5]. The low arsenic levels (<10 ppm) are favorable, as arsenic compounds pose environmental and health risks during processing [20].

3.1.3. Elemental Correlations

The correlation between gold (Au) and associated elements in the Ashashire deposit provides insights into its mineralogical characteristics and processing potential. Statistical analysis (Pearson correlation) was conducted using IBM SPSS Statistics (version 20) on ICP and AAS gold data. Table 3 presents these correlation coefficients, reveal varying degrees of linear relationships, ranging from strong positive to negligible correlations. Scatter diagrams (Figure 4) visually represent these relationships.

Table 3. *Pearson correlation coefficients between gold and associated elements.*

Element	Unit	Au	Ag	Te	C Organic	S sulphide	Cu	Zn	Hg	Ni	Pb	As
Au	ppm	1.00	0.54	0.59	-0.03	0.39	0.72	0.40	0.18	0.55	0.19	0.38
Ag	ppm	0.54	1.00	0.53	-0.06	0.01	0.15	0.36	0.12	0.31	0.13	0.11
Te	ppm	0.59	0.53	1.00	-0.07	0.14	0.51	0.26	0.11	0.44	0.17	0.09
C Organic	%	-0.03	-0.06	-0.07	1.00	0.01	-0.07	-0.08	-0.01	-0.10	-0.09	-0.05
S sulphide	%	0.39	0.01	0.14	0.01	1.00	0.14	0.32	0.08	0.13	0.23	0.07
Cu	ppm	0.72	0.15	0.51	-0.07	0.14	1.00	0.64	0.31	0.57	0.33	0.25
Zn	ppm	0.40	0.36	0.26	-0.08	0.32	0.64	1.00	0.16	0.46	0.26	0.17
Hg	ppm	0.18	0.12	0.11	-0.01	0.08	0.31	0.16	1.00	0.28	-0.04	0.11
Ni	ppm	0.55	0.31	0.44	-0.10	0.13	0.57	0.46	0.28	1.00	0.39	0.23
Pb	ppm	0.19	0.13	0.17	-0.09	0.23	0.33	0.26	-0.04	0.39	1.00	0.15
As	ppm	0.38	0.11	0.09	-0.05	0.07	0.25	0.17	0.11	0.23	0.15	1.00

A strong positive correlation is observed between gold and copper (r = 0.72), along with moderate positive correlations with tellurium (r = 0.59), silver (r = 0.54), zinc (r = 0.40), and nickel (r = 0.55). In contrast, correlations with organic carbon (r = -0.03), sulfide sulfur (r = 0.39), and arsenic (r = 0.38) range from negligible to weak.

A strong Au-Cu correlation suggests copper-bearing minerals (e.g., chalcopyrite) are associated with gold mineralization. The moderate Au-Te correlation indicates the presence of gold-tellurides (e.g., calaverite, sylvanite), which are refractory to cyanidation and necessitate advanced processing methods, including pressure oxidation or roasting [5]. The weak Au-S correlation (0.39) suggests sulfide minerals are not the dominant gold hosts, consistent with QEMSCAN findings showing gold predominantly as liberated grains or associated with gangue minerals. The negligible Au-organic carbon correlation (-0.03) confirms that carbonaceous interference with cyanidation is unlikely [19].

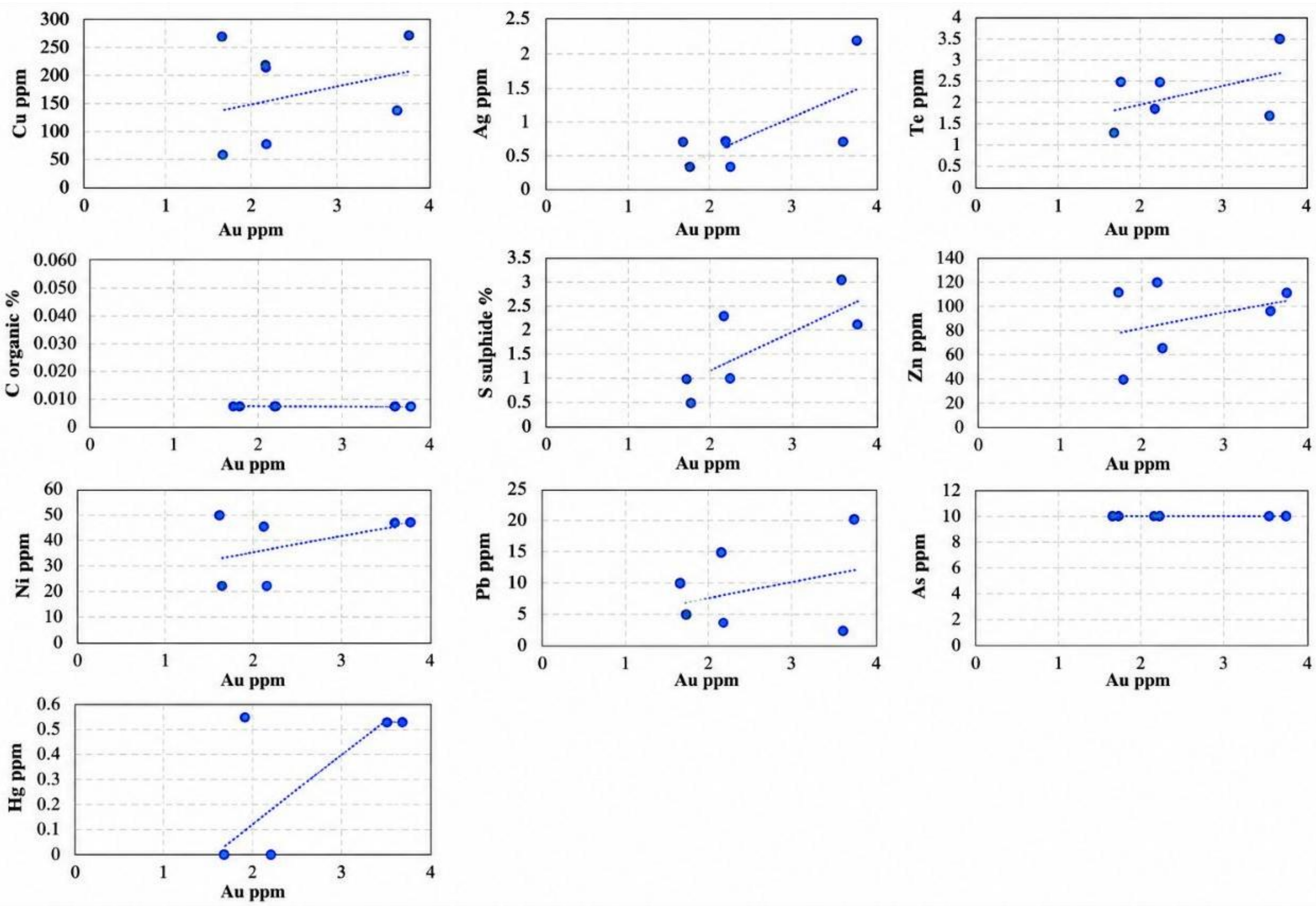


Figure 4. *Scatter plots of gold versus associated elements.*

The scatter plots (Figure 4) visually confirm the correlation patterns observed in Table 3. Gold concentrations range from 1.71 to 3.75 ppm, with positive trends evident for Ag, Cu, and Te. These relationships suggest the presence of metal-bearing minerals such as chalcopyrite, silver sulfides, or tellurides (e.g., calaverite, sylvanite), which influence gold deposition and recovery [5].

The Au-Cu, Au-Zn, and Au-Pb associations indicate potential sulfide-related mineralization. Such mineralization can complicate processing through complex metallurgical interactions and may increase environmental risks via acid rock drainage generation, requiring careful management [21].

Low organic carbon and arsenic concentrations are favorable, reducing the likelihood of preg-robbing during cyanidation and minimizing arsenic-related environmental and health concerns [20].

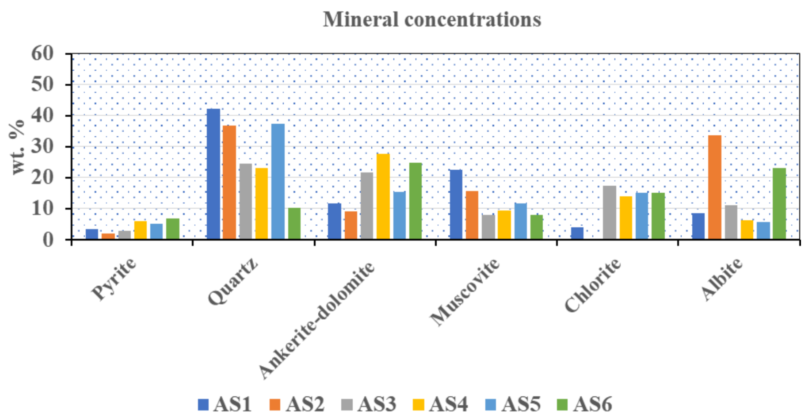
While correlation analysis provides a foundational understanding of the deposit's mineralogy, comprehensive mineralogical and geochemical analyses along with metallurgical testing (cyanidation, flotation, gravity separation) are necessary to optimize gold recovery and address environmental challenges.

3.1.4. Mineralogical Composition

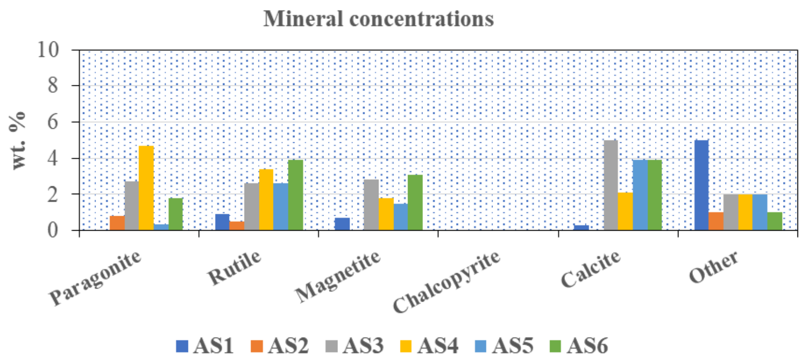
QEMSCAN analysis revealed the mineralogical composition of the samples (Table 4; Figure 5). Dominant minerals include quartz (10.3-42.3%), ankerite-dolomite (9.1-27.6%), muscovite (8.0-22.6%), chlorite (0.2-17.4%), albite (5.6-33.7%), and pyrite (1.9-6.73%). Minor minerals include rutile (0.5-3.9%), magnetite (0.01-3.1%), calcite (0.3-5.0%), and paragonite (0.35-4.7%). Chalcopyrite was present only in trace amounts.

Table 4. *QEMSCAN mineralogical analysis of representative samples (wt%).*

Mineral	AS1	AS2	AS3	AS4	AS5	AS6
Pyrite	3.5	2.1	3	5.9	5.1	6.73
Quartz	42.3	36.7	24.5	23.2	37.3	10.3
Ankerite-dolomite	11.7	9.1	21.7	27.6	15.4	24.9
Muscovite	22.6	15.8	8	9.4	11.6	8
Chlorite	4.1	0.2	17.4	13.9	15.2	15
Albite	8.6	33.7	11	6.2	5.6	23
Paragonite	trace	0.8	2.7	4.7	0.35	1.8
Rutile	0.9	0.5	2.6	3.4	2.6	3.9
Magnetite	0.7	trace	2.8	1.8	1.5	3.1
Chalcopyrite	trace	trace	trace	trace	Trace	trace
Calcite	0.3	trace	5	2.1	3.9	3.9
Others	<5	<1	<2	<2	<2	<1



(a)



(b)

Figure 5. *(a) Principal mineral abundances, and (b) secondary mineral abundances in all samples.*

The gangue mineralogy of the Ashashire deposit is characterized by pyrite as the dominant sulfide mineral, comprising 2-6.7% by weight across all samples, while chalcopyrite was present only in trace amounts. The non-sulphide gangue minerals, which constitute the majority of the deposit, include quartz, ankerite-dolomite, muscovite, chlorite, and albite.

Other minerals, such as paragonite, rutile, magnetite, and calcite, were present in lower quantities. The variability in gangue mineral abundance across the samples suggests potential differences in mineralogical composition within the deposit, which could influence processing strategies.

3.1.5. Gold Mineralogy and Grain Size Distribution

The QEMSCAN analysis of the Ashashire Gold deposit identified two primary gold forms: native gold and gold-telluride. Native gold was the dominant form, while gold-telluride occurred in minor amounts. Gold predominantly occurs as liberated grains or in association with gangue minerals, notably quartz and pyrite, frequently along grain boundaries. A smaller proportion of gold was detected as inclusions within pyrite or as small grains located in fractures. Scanning electron microscope backscattered electron (BSE) images of representative gold grains (Figure 6) further confirm the variability in grain size and mineral associations.

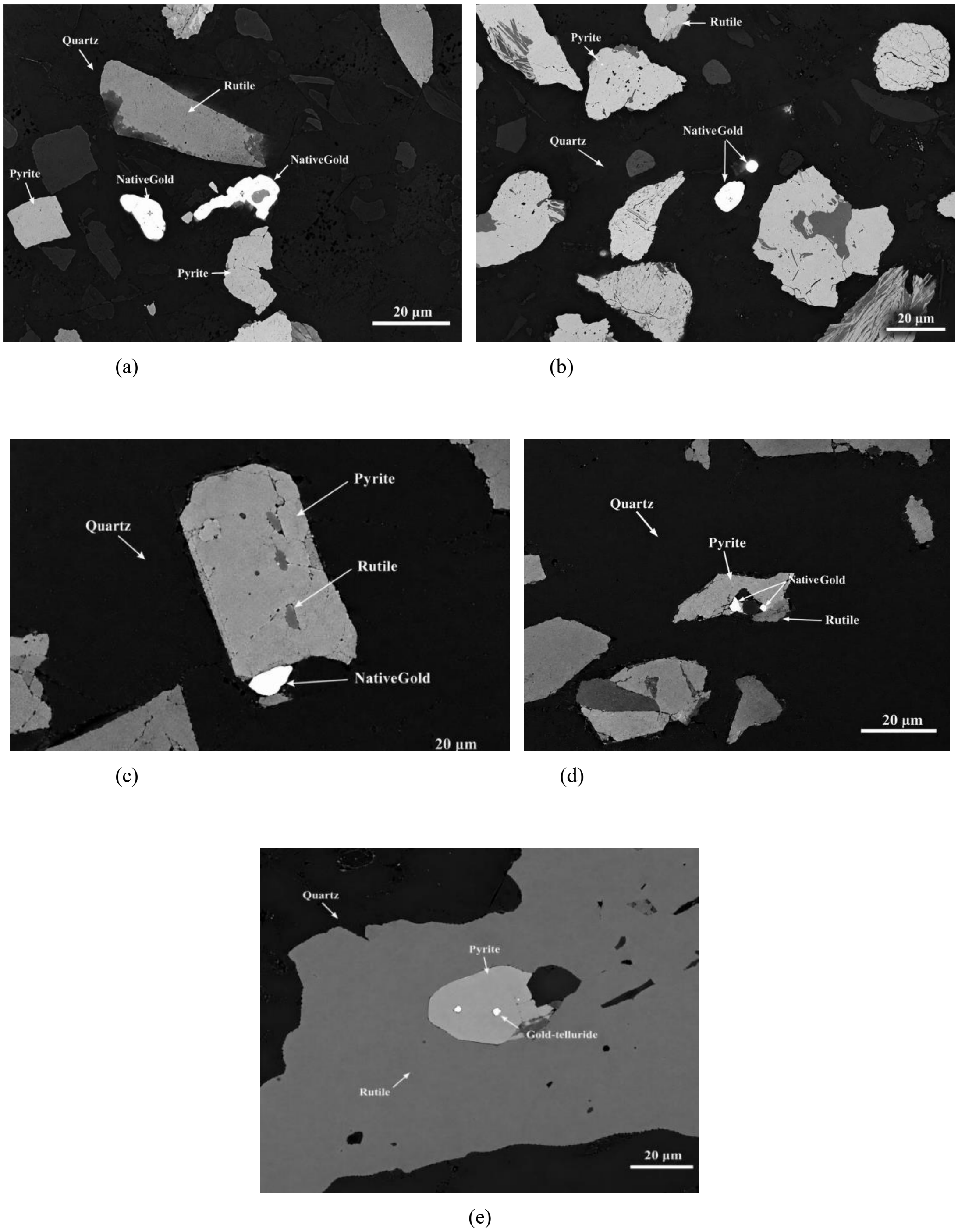


Figure 6. *Backscattered electron (BSE) images of representative gold grains: (a, b) Liberated native gold; (c) Native gold with pyrite along grain boundaries; (d) Native gold associated with pyrite and quartz; (e) Pyrite with gold-telluride inclusions (possibly calaverite, $AuTe_2$).*

In total, 352 gold grains were identified, ranging from very fine (<2 µm) to coarse (>60 µm) in size. The grain size distribution, summarized in Table 5, shows that gold is fairly evenly distributed across intermediate size ranges. The highest proportions of gold grains fall within the 20-40 µm (27.6%) and 40-60 µm (26%) size intervals. Coarser grains (>60 µm) account for 19.2% of the total, while very fine-grained gold (<2 µm) represents only 3.8%. The 2-20 µm range comprises 23.4% of the gold grains.

Table 5. *Gold grain size distribution.*

Grain size range (µm)	Proportion (%)
< 2	3.8
2 -20	23.4
20 -40	27.6
40 -60	26
> 60	19.2
Total	100

3.2. Discussion

3.2.1. Processing Implications

Mineral processing comprises two main operations: liberation of valuable minerals through comminution, and subsequent separation based on differences in physical properties [22-24]. Ore mineralogy influences grinding requirements, feasible concentrate grades, and separation difficulty [25]. Varying mineralogical compositions may require multiple concentration stages to produce an optimal concentrate. Ore texture impacts liberation efficiency and the accessibility of valuable minerals during concentration; fine-grained minerals may require ultra-fine grinding, introducing challenges such as increased impurities and decreased concentrate grades [23].

Based on the ease of gold recovery, ores are divided into free-milling and refractory types [7]. Free-milling ores allow gold liberation through conventional methods (grinding, gravity separation, flotation, and cyanidation). Refractory ores require additional steps (roasting, pressure oxidation, and bioleaching) to liberate gold trapped in the mineral matrix. The Ashashire deposit is predominantly free-milling, with gold occurring along grain boundaries or within gold-bearing gangue minerals. However, minor gold-telluride phases, identified through QEM-SCAN analysis, indicate a small refractory gold fraction.

(i). Effect of Ore Texture

SEM analysis reveals that most gold occurs along micro-fractures and grain boundaries, facilitating liberation at coarse particle sizes. However, a portion occurs as inclusions within pyrite and quartz, and as very fine particles (<2 µm). Liberating these fractions requires ultra-fine grinding, which increases processing costs, accelerates equipment wear, and may reduce concentrate grades [23]. Fine grinding can also produce slimes that impede downstream operations (flotation, thickening) [24]. Coarse gold particles are better recovered via gravity separation, while fine particles may require flotation or leaching [7]. Balancing liberation efficiency with the adverse effects of ultra-fine grinding is critical for processing strategy development.

(ii). Effect of Gold Mineralogy

Native gold, readily leachable by cyanide, dominates the deposit. However, gold-tellurides present a refractory component due to slow leaching kinetics [6]. Refractory gold minerals form strong chemical bonds, making them less accessible to conventional cyanidation. Strategies to enhance recovery include raising leach solution pH to 12-12.5, which improves telluride solubility [5], although excessive pH adjustment can lead to the precipitation of secondary minerals or the generation of cyanide-consuming compounds. Alternative methods oxidation, roasting, or pressure leaching can break down refractory minerals and improve accessibility to leaching solutions.

(iii). Effect of Gangue Minerals

Gangue minerals significantly influence processing efficiency [26]. The gangue mineralogy, determined by QEM-SCAN, is dominated by quartz, ankerite-dolomite, muscovite, chlorite, and albite, with pyrite as the main sulfide and minor rutile, magnetite, calcite, and paragonite. Sulfide minerals (pyrite, chalcopyrite) consume oxygen and cyanide during leaching, though the relatively low pyrite content (2.1-6.73%) suggests minimal impact [19]. Carbonate minerals (ankerite-dolomite, calcite) increase pH and consume cyanide, forming less-soluble metal-cyanide complexes [19]. The high abundance of ankerite-dolomite indicates pH adjustment or neutralization may be necessary. Quartz contributes to ore hardness and abrasiveness, increasing equipment wear; wear-resistant materials and optimized grinding circuits may be required [19]. Clay minerals, notably muscovite and chlorite, possess large surface areas that can adsorb gold from solution; agglomeration or pre-leaching may be necessary to address this challenge [26]. Understanding specific gangue minerals and their impacts is essential for optimizing recovery rates and minimizing operational challenges [5].

3.2.2. Potential Processing Strategies for the Ashashire Deposit

The mineralogy of the Ashashire deposit characterized by quartz, pyrite, gold-tellurides, and various gangue minerals presents several potential processing routes to optimize gold recovery. The two primary gold types, native gold and gold-telluride, require tailored approaches due to differences in density and refractory nature. An integrated flowsheet combining pre-concentration, selective separation, and leaching techniques is recommended for maximum recovery.

Gravity separation offers a viable route for pre-concentrating native gold and gold-tellurides due to their higher density relative to gangue minerals. The presence of coarse gold particles (19.2% >60 μm, particularly in sample AS6) makes gravity separation a more suitable option than cyanide leaching for recovering these particles [22]. This approach reduces processing costs by removing a significant portion of gold before further treatment.

Flotation selectively separates gold from sulfide minerals. Hydrophobic gold particles adhere to air bubbles and are carried to the surface, while sulfides remain hydrophilic [23]. This pre-treatment enhances the efficiency of subsequent cyanide leaching, a widely used technique for extracting gold from finely ground ores. Cyanide dissolves gold into solution, which is then recovered using activated carbon [5].

Pressure Oxidation is particularly effective for refractory gold, such as gold-tellurides, and sulfide-rich ores. Pressure oxidation, conducted with oxygen and sulfuric acid at elevated temperatures, effectively oxidizes sulfide minerals, improving amenability to cyanide leaching and increasing gold recovery [7].

The Carbon-in-Leach (CIL) and Carbon-in-Pulp (CIP) methods involve the direct adsorption of dissolved gold onto activated carbon during leaching. These techniques are efficient for high-grade gold ores and streamline recovery by simplifying downstream processing [24].

An integrated approach Gravity Separation → Flotation → Pressure Oxidation → Cyanidation (CIL/CIP) balances the deposit's complex mineralogy with optimized processing efficiency, maximizing gold recovery while minimizing costs and environmental impact.

4. Conclusion

This study provides critical insights into the mineralogical features and processing implications of the Ashashire gold deposit. Gold is predominantly present as native gold and gold-tellurides, closely associated with tellurium, and occurs mainly as free particles or in association with gangue minerals, notably quartz and pyrite. The gangue assemblage is dominated by quartz (10.3-42.3%), ankerite-dolomite (9.1-27.6%), muscovite (8.0-22.6%), chlorite (0.2-17.4%), and albite (5.6-33.7%). Pyrite (2.1-6.73%) is the dominant sulfide mineral, with only trace chalcopyrite present.

The occurrence of tellurium and gold-telluride minerals indicates a refractory gold component that necessitates specialized processing techniques beyond conventional cyanide leaching. Additionally, the occurrence of coarse gold particles (19.2% >60 μm), especially in sample AS6, suggests that gravity separation as a viable pre-concentration method for recovering this fraction before further processing.

To optimize gold recovery and address the mineralogical complexity of the deposit, an integrated flowsheet combining gravity separation, flotation, pressure oxidation, and cyanidation (CIL/CIP) is recommended. However, further metallurgical testing including gravity recovery, flotation kinetics, and cyanidation of oxidized products is essential to validate and optimize the proposed processing strategy.

These findings provide a foundation for developing efficient and sustainable processing strategies tailored to the unique characteristics of the Ashashire deposit.

5. Recommendations

To enhance the understanding of the Ashashire gold deposit and improve gold recovery, the following actions are recommended:

First, detailed mineralogical characterization should be enhanced through visual identification during drill-core logging to provide contextual information on mineral distribution, coupled with EPMA analysis of gold grains to precisely characterize the composition of gold-tellurides and their associated elements.

Second, specific metallurgical testing is essential to validate the proposed processing flowsheet. Cyanide leach tests should establish baseline recoveries and optimal leaching parameters. Gravity separation tests are needed to evaluate coarse gold recovery efficiency, particularly given the significant coarse gold fraction in sample AS6. Flotation tests should assess sulfide-gold separation and determine optimal reagent conditions.

These investigations, combined with the mineralogical data presented in this study, will enable the development of a robust, economically viable, and sustainable processing strategy tailored to the unique characteristics of the Ashashire deposit.

Abbreviations

AAS	Atomic Absorption Spectroscopy
ALS	Australia Laboratories Service
ICP	Inductively Coupled Plasma
ppm	Parts Per Million
QEMSCAN	Quantitative Evaluation of Minerals by Scanning Electron Microscopy
SEM	Scanning Electron Microscope
wt%	Weight Percent

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Author Contributions

Getnet Belachew: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Validation, Visualization, Writing – original draft, Writing – review & editing

Yohannes Belachew: Data curation, Formal Analysis, Investigation, Validation, Visualization, Writing – review & editing

Mastewal Tamene: Data curation, Formal Analysis, Investigation, Validation, Visualization, Writing – review & editing

Conflicts of Interest

The authors declare no conflicts of interest.

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