International Journal of Nonferrous Metallurgy, 2024, 11, 33-48
https://www.scirp.org/journal/ijnm
ISSN Online: 2168-2062
ISSN Print: 2168-2054

Mineralogical Assessment of Ashashire Gold Ore to Investigate Its Beneficiation Potential by Flotation Method, in Benishangul Gumuz, Western Ethiopia

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How to cite this paper: Zeweli, K.H., Kabeta, M. and Tadesse, B. (2024) Mineralogical Assessment of Ashashire Gold Ore to Investigate Its Beneficiation Potential by Flotation Method, in Benishangul Gumuz, Western Ethiopia. *International Journal of Nonferrous Metallurgy*, **11**, 33-48.
https://doi.org/10.4236/ijnm.2024.113003

Received: June 12, 2024
Accepted: July 28, 2024
Published: July 31, 2024

Abstract

As a technique of separation, flotation is seen to be especially significant to the economy of the industrialized world. Many common metals are tough and costly to extract since the high-grade ores that basic physical and mechanical processes could handle have long since run out. This study was conducted to assess the mineral composition of the Ashashire gold ore deposit and investigate its potential for flotation-based-beneficiation in the Benishangul Gumuz Region, Western Ethiopia. The Ministry of Mines provided the resources for a research study and experimental study including representative sample collection and preparation, mineralogical characterization and analysis of the associated elements, data interpretation, and analysis. Mineralogical analysis was undertaken using Inductively Coupled Plasma (ICP), Quantitative Evaluation of Material by Scanning Electron Microscope (QEMSCAN), and X-ray fluorescence (XRF). Through the utilization of these rigorous methodologies and advanced analytical techniques, valuable insights were gained into the distribution, mineral composition, and characteristics of gold ore in the Ashashire area. The goal of the mineralogical testing assessment was to determine the type of gold ore deposit, the nature and mode of occurrence of the gold-bearing minerals, the identification and quantification of the gangue minerals present in the entire ore, and the possibility of beneficiation by flotation techniques. For the XRF analysis, fourteen samples were taken, and the major and trace elements were analyzed to know their percentage. The sample's investigation revealed that the main gangue mineral was quartz, with minor gangue minerals including ankerite-dolomite, albite, chlorite, muscovite, pyrite, calcite, paragonite, rutile, magnetite, and others. Every experimental mineralogical examination conducted by organizations and individuals in Ashashire ore mineralogy produces comparable results. The Ashashire gold ore deposit is not effective in investigating the beneficiation potential using the flotation method. It is not economically feasible to concentrate Ashashire gold ore for the assessed gangue minerals using the flotation method due to the large losses and chemical reagent consumption caused by the associated gangues within the deposit.

Keywords

Flotation, Beneficiation, Gangue, Ore, Mineralogy, Concentrate

1. Introduction

Valuable minerals and undesirable gangue minerals typically grow together and require the right basic separation techniques for subsequent processing and use of such minerals. Gold has a long mining history, which makes it the noblest metal, and it has many things for many people. Gold is a rare noble metal with a complex geochemistry that is challenging to extract from its ores. It is a unique metal used in many industries for different applications such as remarkable beauty in jewelry, electronics, other human innovations, and coinage metal with a lengthy and fascinating history for numismatists [1]. Gold mining has continued to be a key source of income and economic support in several countries in recent years. The main source of gold is primary gold ore deposits, and for all types of such ore deposits, complex technological processing processes have been formed or created. Following the depletion of high-grade sources, recently, gold is being produced from low-quality refractory gold ores [2]. The complexity of refractory ores necessitates an upgrading in the theoretical and practical knowledge that underpins efficient, profitable, and commercial gold extraction processes. Due to increasing mineralogy complexity and lower grade of ore resources, the technology needed to progress swiftly in the efficient processing of ore minerals. Because different mineral particles have different tendencies to cling to air bubbles, flotation has been widely employed as a flexible and simple process to separate and purify important minerals [3].

Flotation is viewed as a process of separation that is particularly important to the industrialized world's economy. The flotation process is one method of gold recovery that is frequently used in the mineral mining industry. Flotation separation is a versatile technique for concentrating and recovery of low-grade ores, particulates, by-products, metal values, and valuable minerals (such as gold) from arsenic-rich auriferous pyrite concentrates, for example, sheds light on the economics of recycling while also contributing to wastewater treatment and environmental technology [4]. It was a very effective preferred method used in the improving and processing of gold ore containing low-grade sulfide gangues and refractory ore to concentrate gold.

In ancient Greece, Herodotus wrote about a technique of separating gold particles from sand using fatty substances, and later, Arabs used resins to selectively extract azurite from gangue [5]. With the development of column flotation technology, it may be possible to produce high-grade concentrate from low-grade gold ore fines and slimes. Different scholars will investigate the most efficient way to use novel flotation agents to separate gold from gold-bearing minerals like sulfide ores [6].

The different terms for diverse types of flotation processes, due to the range of (air or gas) bubble-generating techniques that are accessible, including ion, precipitates, adsorbing colloid, froth, foam, sorptive, and biosorptive flotation, dispersed air flotation, electrolytic flotation, dissolved air flotation (termed Dissolved air flotation (DAF)) was investigated at various scales. Electrolytic flotation and dissolved air flotation usually require preceding flocculation, and the aggregation of tiny particles may increase capturing effectiveness particles' effects on bubble surfaces were extensively discussed in recently published studies [7] [8]. Due to the low density of the air-mineral aggregates, hydrophobic mineral particles quickly attach to air bubbles and rise to the top of the flotation pulp. In contrast, hydrophilic mineral particles, in the absence of bubble attachment, remain suspended or settle out in the flotation pulp [5].

Chemical technology has evolved from the idea of unit operations with the help of succeeding the concepts to create a unified field of separation processes [9]. Recent research endeavors primarily emphasize the role of physical chemistry, such as zeta-potential measurements, contact angle, etc., in flotation by describing some key flotation characteristics [10]. The design and manufacturing of chemicals used in flotation have advanced dramatically, and there are numerous new ideas and techniques that we may use to our advantage [11].

Still, there is a lack of fundamental knowledge and understanding regarding the interactions between the primary and secondary mineral phases that are unique to refractory ore, solution chemistry, and the particle-solution interfacial species, particle interactions, and chemical or electrochemical reactions that underlie the mechanisms and kinetics of the improved gold extraction (by cyanide leaching) from complex low-grade ores [12]. Additionally, it is still unclear how these factors will interact during the alkaline cyanide leaching process, whether they will work together to produce fast kinetics and high gold recovery, or whether they will work against one another (e.g., low leach rate, passivation/encapsulation, poor gold recovery, and high reagent consumption).

The main objective of the previous works on the Ashashire Gold ore deposit was to locate areas of interest that deserve further exploration to get an economic placer and primary gold deposits, and all the works do not ascertain the genesis and Para genesis of Ashashire primary gold prospect area. No one studied the mineralogical analysis for beneficiation purposes.

The main objective of the mineralogical testing assessment on the Ashashire gold ore deposit was to determine the type of gold ore deposit, the nature and mode of occurrence of the gold-bearing minerals composition, the identification and quantification of the gangue minerals present in the entire ore, and the possibility of beneficiation by flotation techniques.

Inductively Coupled Plasma (ICP), Quantitative Evaluation of Material by Scanning Electron Microscope (QEMSCAN), and X-ray fluorescence (XRF) were used in the mineralogical analysis. Greenschist to amphibolite facies metamorphic minerals, including chlorite, carbonate, sericite, and quartz, make up the majority of the host rock of the Ashashire gold deposit; pyrite, pyrrhotite, magnetite, sphalerite, chalcopyrite, galena, and gold are found in the ore petrography analysis.

The results of every experimental mineralogical evaluation of the Ashashire ore mineralogy are comparable, and most gangue minerals are likely to have an impact on gold flotation methods. The size of the gold particles, the gangue, and the mineralogy of the ore all have a significant impact on the flotation technique selection for Ashashire gold concentrate.

The flotation technique is not a cost-effective way to concentrate the Ashashire gold for the reported gangue minerals. Because more chemical reagents will be consumed by such gangues. Consequently, the type of the ore deposit, the mineralogy of the ore, and the distribution of gold in the ore all play a significant role in the mineralogical evaluation of the Ashashire gold deposit to explore its flotational beneficiation potential.

2. Methods and Materials

The Ministry of Mines provided all the resources used for this research study, and the sample collection strategy was used by corporate policies that were taken from papers and modified to meet the research's unique objectives and protect the privacy of the data. The information gathered from the laboratory data was examined and interpreted to derive important insights and conclusions. Data from earlier research, including both published and unpublished articles, was gathered and examined.

2.1. Sample Collection and Preparation

Six representative samples were selected from the mineralized zone of the core section for mineralogical characterization. The mineralogical examination was undertaken using Inductively Coupled Plasma (ICP), Quantitative Evaluation of Material by Scanning Electron Microscope (QEMSCAN), and X-ray fluorescence (XRF).

The sample preparation from the six different individual samples for the analyses was undertaken at the ALS sample preparation facility in Addis Ababa, where they were individually crushed to 100% less than 1.3mm through a Boyd jaw crusher. Then, the nominal 80% passing 75 μm crushed individual sample was composited to generate a 2 kg subsample using a riffle splitter for the mineralogical analysis and 200 g was submitted for head fire assay analysis [13] [14].

2.2. Analytical Techniques

The analysis involved a range of analytical techniques. XRF analysis provided crucial mineralogical identification, while AAS analysis played a pivotal role in quantifying major and trace elements. Through the utilization of these rigorous methodologies and advanced analytical techniques, valuable insights were gained into the distribution, mineral composition, and characteristics of gold ore in the Ashashire area. The comprehensive results obtained from this study can serve as a guide for future beneficiation and development activities at the mining site, aiding in informed decision-making and maximizing the potential of this valuable mineral resource [13] [14].

3. Results and Discussion

3.1. Ore-Analysis

The key to comprehending element concentrations and the existence of other related elements is ore analysis. Without a doubt, each mineral or rock's economic value may be determined by chemical analysis (**Table 1**).

Pyrite is the most abundant sulfide mineral in the study area. It is also the second most abundant opaque mineral, next to magnetite. Most often, the veins of pyrite are crystallized following the direction of gangue minerals. (**Figure 1(c)**). In several cases, it has also been observed that the pyrite grains enclose inclusions of gangue minerals, giving the minerals a poikilio-blastic texture which implies the gangue is older than the pyrite (**Figure 1(a)**).

Table 1. Samples investigated by ore-microscope and their description [15].

Sample no	Mineral	Modal (%)	Texture	Textural Descriptions/Notes
ASDD0002-05	Pyrite	20	Idio-Xenoblastic	**Spotted and Veinlet texture:** Veins of pyrite crystallized across the section following the direction of gangue minerals. Inclusions of gangue minerals enclosed on grains of pyrite are poikilio-blasts. Microfractures filled by gangue minerals are seen on the grains of pyrite. One fine gold grain masked under gangue is visible in the section. Minor grains of pyrite lie like spots on the gangue minerals.
	Gangue	80	-	
ASDD0002-10	Pyrite	35	Idio-Xenoblastic	**Veinlet texture:** Veins of pyrite crystallized across the section following the direction of gangue minerals. Inclusions of gangue minerals enclosed on grains of pyrite are poikilio-blasts. One fine grain of gold is also visible on pyrite grains.
	Chalcopyrite	Trace	Xenoblastic	
	Gold	1 grain	Idioblastic	
	Gangue	65	-	
ASDD0002-19	Pyrite	27	Idio-Xenoblastic	**Porphyroblast and Veinlet texture:** Veins of pyrite and chalcopyrite crystallized across the section following the direction of gangue minerals. Large crystals of pyrite with inclusions of gangue minerals enclosed on grains of pyrite as poikilio-blasts are porphyroblasts on the section.
	Chalcopyrite	8	Xenoblastic	
	Gangue	65	-	

Continued

ASDD0002-20	Pyrite	22	Idio-Xenoblastic	**Veinlet texture:** Veins of pyrite crystallized across the section following the direction of gangue minerals. Inclusions of gangue minerals enclosed on grains of pyrite are poikilio-blasts.
	Gangue	78	-	
ASDD0002-23	Pyrite	30	Idio-Xenoblastic	**Replacement and Veinlet texture:** Veins of pyrite and chalcopyrite crystallized across the section following the direction of gangue minerals. Inclusions of gangue minerals enclosed on grains of pyrite are poikilio-blasts. Some grains of pyrite are replaced by chalcopyrite and vice-versa.
	Chalcopyrite	12	Xenoblastic	
	Gangue	58	-	
ASRCD0009-02	Pyrite	15	Idio-Xenoblastic	**Veinlet texture:** Veins of pyrite crystallized across the section following the direction of gangue minerals. Veins of gangue minerals are cutting the surface of pyrite grains and micro-fractures filled by gangue minerals are also seen over it.
	Gangue	85	-	
ASRCD0009-05	Pyrite	25	Idio-Xenoblastic	Veins of pyrite crystallized across the section following the direction of gangue minerals. Inclusions of gangue minerals enclosed on grains of pyrite are poikilio-blasts. Veins of gangue minerals are cutting some parts of pyrite grains, and micro-fractures filled by gangue minerals are also seen over it.
	Gangue	75	-	
ASRCD0009-07	Pyrite	2	Hypidio-Xenoblastic	**Spotted and Veinlet texture:** Minor Veins of pyrite crystallized across the section following the direction of gangue minerals. Some grains of pyrite lie like spots in only a very small part of the gangue minerals.
	Gangue	98		

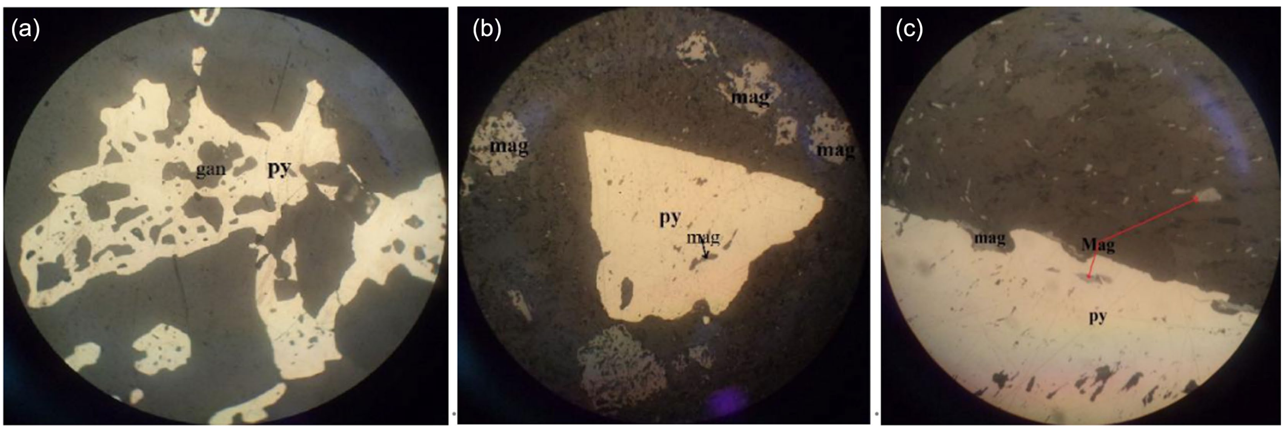

Figure 1. Photomicrographs of the various ore minerals show the distribution and texture of pyrite and its relationship with other minerals [15]. (a) Photomicrographs of Sample ASDD0002-21, magnification 100 x. Mineral composition: pyrite 15%, and gangue 85%. Textural Descriptions/Notes: Spotted and Veinlet texture The pyrite vein crystallized across the section following the direction of gangue minerals. Inclusions of gangue minerals enclosed in pyrite grains give it a poikilio-blastic texture. Some grains of pyrite lie like spots on the gangue minerals. (b) Sample ASDD0002-17, magnification 100 x. displays the distribution and the relationship of magnetite and pyrite. Mineral composition: magnetite 25%, pyrite 5%, hematite 5% and gangue 65%. Textural Descriptions: Most magnetite has well-defined cubic/idoblastic texture but at times they are also found with no defined outline/shape, i.e., xenoblastic texture. In addition, magnetite was found to be an inclusion in the idioblastic pyrite. That can suggest magnetite is older than pyrite; it may also mean that pyrite is formed at the expense of magnetite by taking Fe from it. (c) Sample ASDD0002-17 (same sample as B), but the picture is taken in a different view and Magnification (200x).

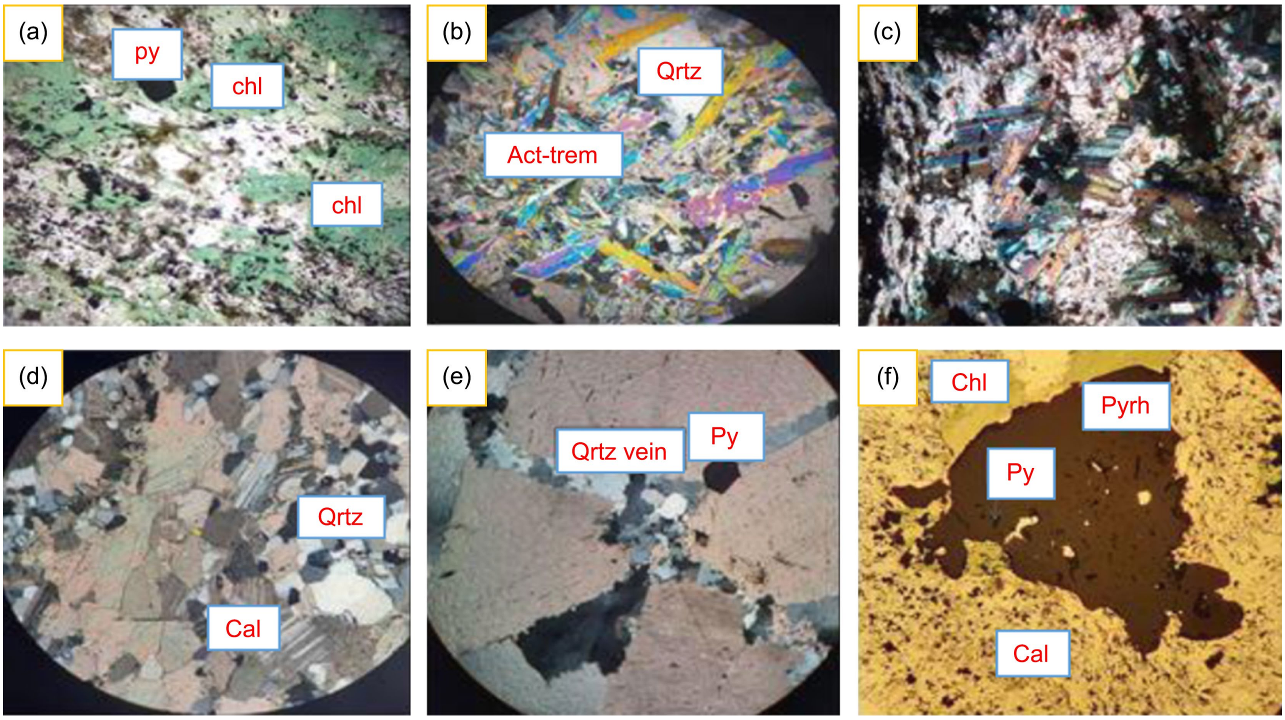

Figure 2. Petrography of host rocks (a). chlorite schist (b). actinolite-tremolite schist (c). porphyroblast textured and polysynthetic twinning in chlorite schist (d). quartz-carbonate vein with some pyrite minerals in mafic schist (e). radiated quartz intergrowth in a vein form on carbonate dominate schist rocks (f). pyrite-pyrrhotite ore mineral poikilitic/sieve textured replacement on proximal carbonate-chlorite altered host rock (10X) [16].

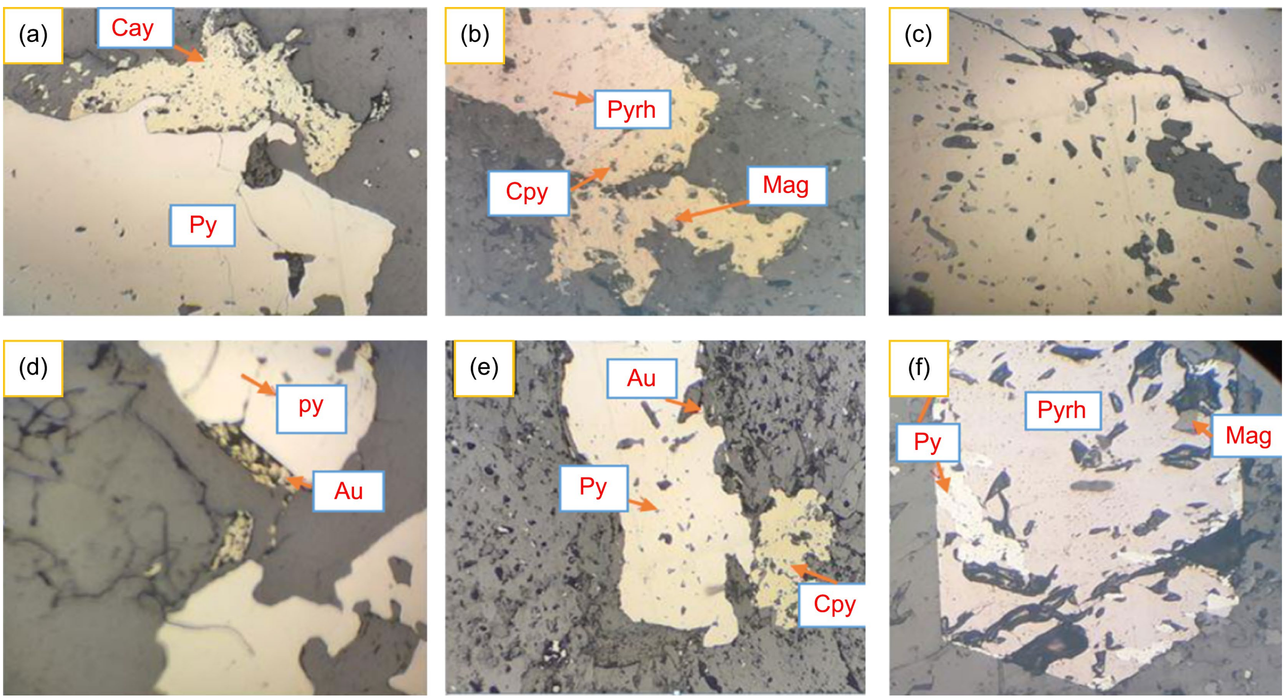

Figure 3. Petrography of ore body (a). Pyrite and chalcopyrite replacement and Au replacement on chlorite-carbonate schist rocks, (b). Pyrrhotite, chalcopyrite, and magnetite replacement in host rocks, (c). magnetite filling in fractures and hematite (d). gold and pyrite filling on fractures and replacements on quartz and calcite veins (e). pyrite and chalcopyrite replacement f) pyrite replacement or exsolution on pyrrhotite with magnification power (10X) [16].

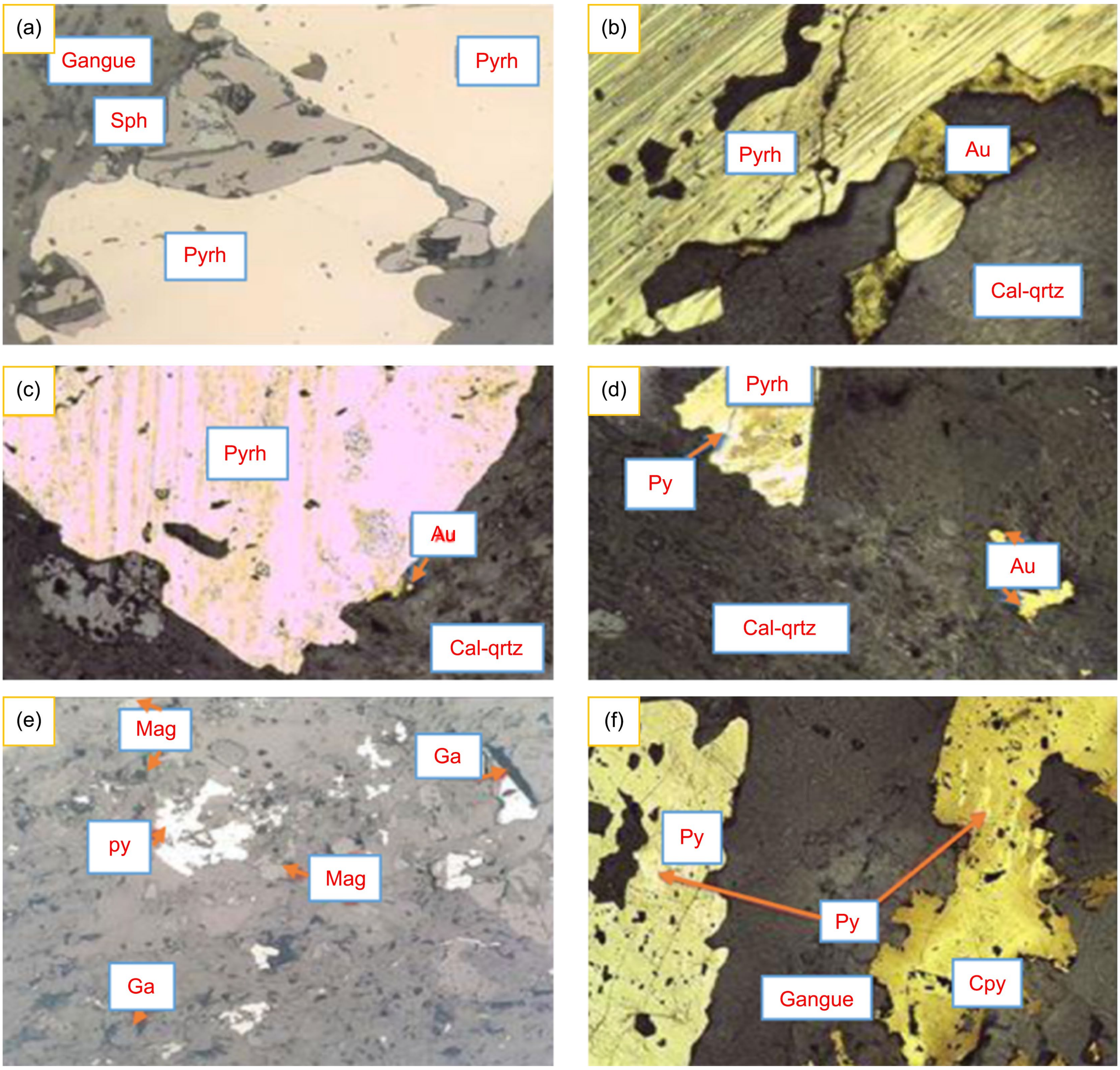

Figure 4. Paragenetic series and textures of ore minerals (a). sphalerite and pyrrhotite with nearly straight (sharp) boundary (co-genetic), (b, (c). grains of gold have a cuspate shape means younger than pyrrhotite both replacing the host rock (d). exsolution of pyrite from pyrrhotite and gold disseminated over the host rock (e). magnetite, galena, and pyrite replacing the host rock without common boundary (nearly equal precipitation) (f). exsolution/replacement of pyrite from pyrrhotite and chalcopyrite (10X) [16].

3.1.1. ICP Analysis

The content of elements associated with gold in the Ore samples was determined by the Inductively Coupled Plasma ("ICP") method. The result of the selected elemental analysis carried out on the Ashashire deposit using ICP is shown in the following table [13] [14].

3.1.2. QEMSCAN Analysis

The remaining sub-samples were ground to a P80 of 75 μm and then submitted for mineralogical analysis by quantitative evaluation of minerals by scanning electron microscopy (QEMSCAN). The purpose of the mineralogy testing was to identify the nature and mode of occurrence of the gold-bearing minerals, to identify the type of gold ore, to identify and quantify gangue minerals present in an ore, etc. (**Figures 2-4**) [13] [14].

Through the analysis by QEMSCAN, the percentage composition of the composite sample minerals present in the studied deposits is given in **Table 2**. The main gangue minerals are quartz, Ankerite-dolomite, Muscovite, Chlorite, Albite, and pyrite, as shown in **Figure 5**. Other minerals with minor presence are rutile, magnetite, calcite, and Paragonite, as shown in **Figure 6** (**Table 3**).

Table 2. Selected elemental assays of core samples using ICP.

Element	Unit	AS1	AS2	AS3	AS4	AS5	AS6
Ag	ppm	0.3	0.3	0.6	0.6	2.1	0.6
As	ppm	<10	<10	<10	<10	<10	<10
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 sulfide	%	1.02	0.52	0.98	2.28	2.1	3.02
Cu	ppm	74	52	260	214	258	120
Zn	ppm	62	34	108	118	104	92
Hg	ppm	0.3	0.3	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	1	1	1	0.5	0.5	0.5

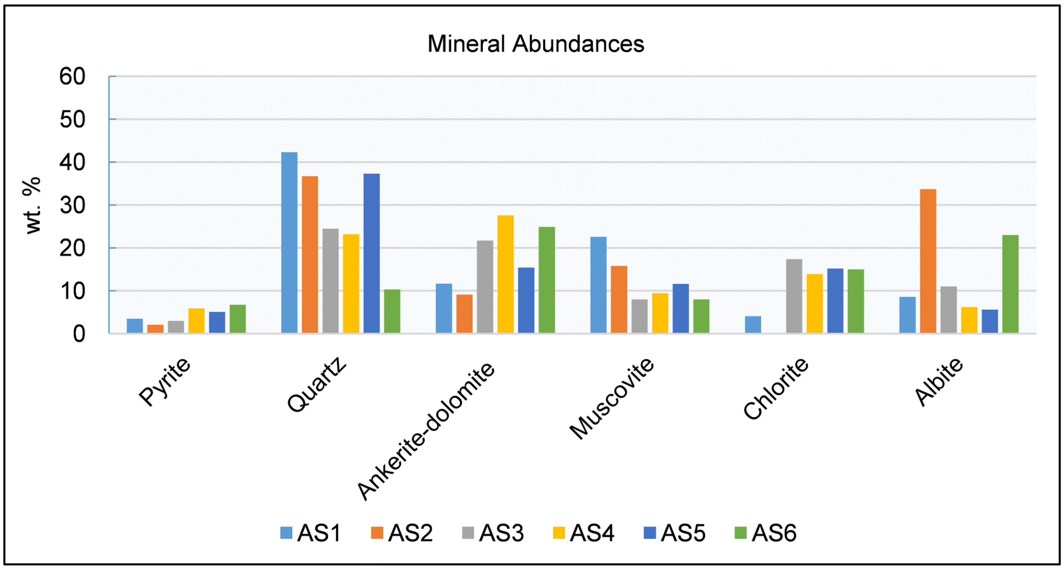

Figure 5. Mineral abundances for principal components for all Ashashire samples.

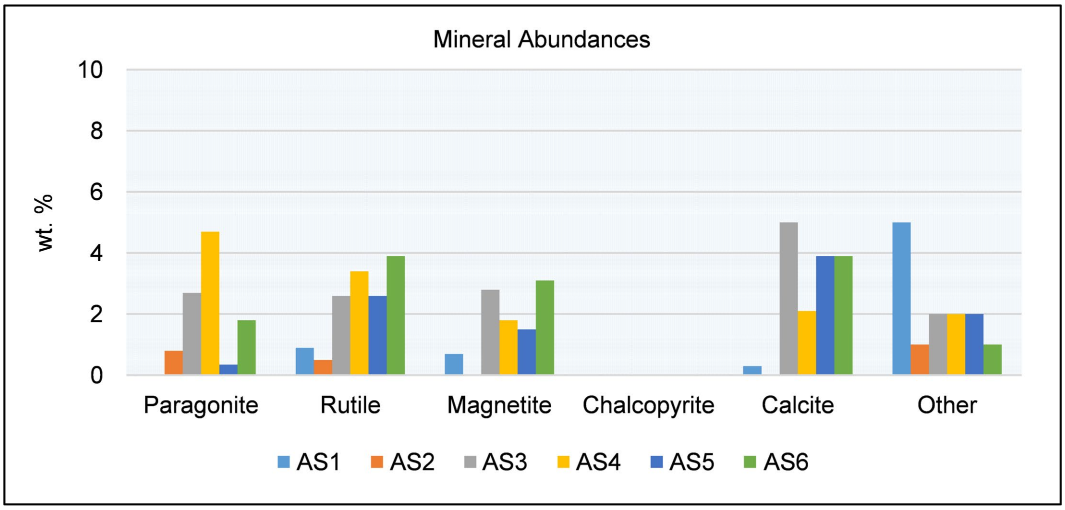

Figure 6. Mineral abundance for secondary components for all samples.

Table 3. Mineralogical composition of Ashashire Sample (AS) gold deposits (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

The average percentage abundance of metal minerals and gangue minerals are 4.388% Pyrites, 1.65% Magnetite, 2.32% Rutile, 29.05% Quartz, 14.68% Albite, 12.6% Muscovite, 2.342% Paragonite, 13.46% Chlorite, 18.4 % Ankerite-Dolomite, 2.53% Calcite with trace Chalcopyrite [13] [14].

The major and minor element oxide percentage compositions of the Ashashire area were done by different researchers. The host rock shows significant variations in the composition of different minerals and gauges. Among these SiO_2 ranges from 40.3% to 66.3%, Al_2O_3 ranges from 9.5% to 15.75%, Fe_2O_3 ranges from 2.37% to 16.45%, CaO ranges from 2.4% to 12.25%, MgO ranges from 1.24% to 7.56%,

Na_2O ranges from 0.16% to 5.85%, K_2O ranges from 0.02% to 2.61%, Cr_2O_3 ranges from 0.003% to 0.113%, TiO_2 ranges from 0.19% to 1.94%, MnO ranges from 0.03% to 0.21%, and P_2O_5 ranges from 0.01% to 0.18% [16].

The field and laboratory or petrographic investigation shows different alteration types with various intensities. Gold and base metal mineralization are identified. Wall rock alteration includes many processes by which rock-forming minerals are altered due to reactions accompanying the flow of heated aqueous fluids along fractures and grain boundaries [16].

The metamorphic hydrothermal minerals such as calcite, chlorite, sericite, actinolite-tremolite, muscovite, epidote, and quartz mineral assemblage in host rock following the carbonate-quartz veins and shearing infers that the hydrothermal gold and sulfide mineralization is preserved with shear hosted carbonized mafic schist commonly chlorite-calcite-quartz veins possibly by diffusion of ore constituents through dehydration of hydrated metavolcanic-sedimentary rocks during greenschist to amphibolite facies regional metamorphism [15].

Inadequate research has been done on the gold and sulfide deposits in Ashashire and the western Assosa margin. However, numerous academic organizations and institutions have compiled a sizable number of primary gold occurrences. On gold prospecting targets, they have performed geological, geochemical, and structural analyses utilizing core drill samples, trench and borehole samples, and stream sediment. These studies' findings supported the existence of high-quality gold.

They describe the mineralization and paragenesis processes that gave rise to minerals. The study of genesis and paragenesis has historically advanced the scientific understanding of mineral resources.

The goal of the mineralogical testing assessment was to determine the type of gold ore deposit, the nature and mode of occurrence of the gold-bearing minerals, the identification and quantification of the gangue minerals present in the entire ore, and the possibility of beneficiation by flotation techniques.

3.1.3. Major, Trace, and Rare Earth Element Analysis

For the XRF analysis, 14 samples were taken, and the major and trace elements were analyzed to determine their percentages. For details, see **Table 4** and **Table 5**.

The inclusions of pyrite, magnetite, and pyrrhotite, as well as a little quantity of galena and chalcopyrite of sulfide minerals, are typically found with pyrite, magnetite, and pyrrhotite in the gold-bearing pyrites, pyrrhotite, and magnetite. The concentration of ore bodies is exceedingly complicated, yet it frequently occurs on weak zones, primarily post-tectonic fractures (calcite-quartz veins), and shear zones.

The gold is found with pyrite-telluride and quartz in the gold-bearing ore obtained from the Ashashire area. The sample's investigation revealed that the main gangue mineral was quartz, with minor gangue minerals including ankerite-dolomite, albite, chlorite, muscovite, pyrite, calcite, paragonite, rutile, magnetite, and others.

Table 4. The percentage of major oxides using XRF analysis [15].

Major oxides in percentage (%)										
Sample number (rock name)	**SiO_2**	**Al_2O_3**	**Fe_2O_3**	**MnO**	**MgO**	**CaO**	**Na_2O**	**K_2O**	**TiO_2**	**P_2O_5**
ASDD0002-23	34	17.57	8.49	0.23	7.56	11.95	3.85	2.16	1.36	0.03
ASDD0002-22	48.54	14.17	11.67	0.12	4.14	6.09	2	2.55	0.99	0.03
ASDD0002-19	48.95	12.65	7.24	0.14	7.19	9.65	1.25	2.73	0.22	0.02
Actinolite-Plagioclase-epidote-schist	66	13.68	4.73	0.25	1.77	3.05	5.14	1.86	0.45	0.07
ASDD0002-19	38.38	17.83	8.82	0.2	6.43	9.33	3.44	2.68	0.92	0.04
Chlorite-Calcite schist	47.22	11.79	14.26	0.36	16.26	1.39	0.37	0.12	0.22	0.04
Muscovite-calcite schist	45.07	15.32	9.89	0.57	17.33	1.02	1.07	1.68	0.46	0.08
Chlorite-Calcite schist	45.76	14.28	12.53	0.53	8.61	6.59	3.95	0.2	1.11	0.11
ASRCD0009-09	65.65	12.6	4.25	0.09	2.79	4.04	1.07	2.31	0.72	0.04
Muscovite-calcite schist	70.6	12.46	4.75	0.06	1.82	1.43	6.77	0.18	0.46	0.07
Actinolite-chlorite schist	44.64	13.17	12.12	0.19	7.06	6.52	1.83	0.70	1.36	0.19
muscovite-calcite schist	38.96	14.72	8.65	0.19	8.11	10.88	2.07	3.56	0.55	0.03
Chlorite-Calcite schist	51.94	13.64	8.45	0.14	9.84	6.53	4.13	1.69	0.68	0.05
Chlorite-Muscovite-schist	52.66	12.01	10.14	0.18	10.12	5.24	5.21	0.88	0.27	0.04

Table 5. XRF study of trace elements [15].

Trace elements in part per million (ppm)											
Sample number (rock name)	**Ba**	**Co**	**Cu**	**Mo**	**Nb**	**Pb**	**Sc**	**Sr**	**Y**	**Zn**	**Zr**
Muscovite-calcite schist	337	16	65	3	5	29	15	461	21	77	91
Calcite-chlorite schist	282	50	85	3	5	28	15	110	20	66	67
Muscovite-calcite schist	344	27	1984	3	5	30	16	445	19	80	57
Muscovite-calcite schist	336	25	45	3	5	30	13	386	18	77	44
Muscovite-calcite schist	274	37	28	3	5	26	13	263	18	41	60
Actinolite-chlorite schist	375	85	414	2	1	35	16	14	19	115	35
Calcite-chlorite schist	306	55	112	1	7	31	17	336	25	95	135
Muscovite-chlorite schist	437	16	133	3	5	35	15	30	20	1212	39
calcite-muscovite schist	453	19	18	3	14	41	11	78	30	89	151
calcite-muscovite schist	436	9	22	3	5	39	11	69	31	69	148
Calcite-chlorite schist	439	111	19	3	5	62	12	2	23	17	2
ASRCD0009-09	459	11	38	3	5	37	12	381	24	53	78
Plagioclase-actinolite-epidote schist	393	37	55	3	6	31	15	204	21	54	52
Calcite-chlorite schist	347	36	47	3	6	32	16	40	19	68	39
Calcite-Muscovite schist	330	21	144	3	5	29	15	811	22	92	134

Then, the Ashashire gold ore deposit is not effective in investigating the beneficiation potential using the flotation method. I have put scientific reasons as follows:

- The main issue with the gangue minerals in the flotation of gold ore is that the amount of dolomite in the final flotation concentrate will reduce the purity of the gold.
- Pyrite particles are known to dramatically alter pulp chemistry and negatively impact flotation performance due to their altered texture. The highest intrinsic gold value may be found in the pyrite's framboidal structure. However, issues with the floatability of fine-grained, altered pyrite particles may result in considerable amounts of gold loss to tailing.
- Selective separation was challenging because the flotation rates and recoveries of the telluride minerals were similar. Gold ore of the Telluride variety is challenging to dissolve in the cyanide solution.
- Selective separation was challenging because the flotation rates and recoveries of the telluride minerals were similar. Gold ore of the Telluride variety is challenging to dissolve in the cyanide solution.
- A phyllosilicate mineral with a platy micaceous texture, muscovite is hydrophilic. The flotation of sulfide minerals can be adversely affected by the presence of micas and clays. For instance, the presence of muscovite is linked to an increase in pulp viscosity, the development of slime coatings, and a high recovery of muscovite in the final gold concentrate, which has an impact on subsequent steps.
- Silicate minerals including quartz, muscovite, chlorite, and amphiboles can cause considerable recovery losses in gold ores. Due to trapped gold particles in the silicates and low hydrophobicity levels in the sulfide-silicate mineral complexes.

It is understood from the practice of flotation of sulfide minerals that the induction of an acidic environment frequently activates flotation while also reducing concentrate yield. The results of all experimental mineralogical analyses of the Ashashire ore mineralogy are generally consistent, and most gangue minerals hurt gold flotation processes and increase the need for chemical reagents.

4. Conclusions

Understanding the origin of gold and sulfide minerals during mineral formation, as well as how micro to macro-level discontinuities impact the area, is vital. To analyze the Ashashire gold deposit's potential for flotation beneficiation, it is important to consider the kind of ore deposit, the mineralogy of the ore, and the distribution of gold within the ore.

The mineralogy of the ore, the gangue, and the size of the gold particles all have a significant impact on the flotation process selection for gold concentrate. There is no one universal method for flotation of the gold-bearing minerals, thus the process is tailored to the characteristics of the ore. Each ore requires a different flow sheet and reagent scheme. It is also implied by the alterations, mineralogical, and textural evidence that the Ashashire orogenic gold ores were formed from intricate hydrothermal solutions.

The petrographic analysis done by different individuals and organizations reveals that visible gold grains are occasionally found as inclusions in sulfide minerals, primarily in pyrite and pyrrhotite, as well as in chlorite-carbonate-quartz veins that develop in (chlorite-sericite-carbonate) schist in carbonate-quartz veins that are close to strongly altered wall rocks. Most ore and alteration haloes are composed of sulfide minerals, which frequently account for close to 10% of the total rock composition.

Pyrrhotite typically outnumbers pyrite and other oxides (such as magnetite and hematite) in most ores. There are sporadic assemblages of metallic minerals, such as galena, hematite, chalcopyrite, and sphalerite. Several hydrothermal changes have an impact on the studied region. These changes include sulfidation, carbonization, silicification, sericitization, and chlorination because of the development of quartz, sericite, and chlorite, as well as pyrite and pyrrhotite, calcite, and dolomite.

Pyrite, pyrrhotite, chalcopyrite, galena, sphalerite, magnetite, and a trace amount of hematite make up the major ore mineralogy. The morphology, texture, and grain boundary relationship of these minerals indicates that the oxide minerals (magnetite, hematite, and occasionally pyrite) formed at an early stage of crystallization, followed by the formation of pyrite, gold, pyrrhotite, and sphalerite galena, and finally the crystallization of pyrite.

It is not economically feasible to concentrate Ashashire gold ore for the assessed gangue minerals using the flotation method due to the presence of the associated gangues' that leads to large recovery losses and increased chemical reagent consumptions. Then, prospective approaches for recovering gold from the Ashashire gold deposit include combining processing technologies like gravity separation, flotation processes, and leaching.

5. Recommendations

Further in-depth work in geological description is necessary because most past efforts on gold finding did not fully identify the geology or structural components. Significant improvements have been made in the hydrometallurgical methods used to recover gold during the past few decades, including cyanidation (carbon in leach), bio-oxidation, etc. So, we can use hydrometallurgical technology to extract the Ashashire gold deposit.

The flotation properties of the gold present in Ashashire ores and the gold-carrying sulfides are known very little. The sparse distribution of distinct gold minerals and their incredibly low concentrations in the ore is one of the primary reasons for the dearth of fundamental studies on the flotation of gold-bearing ores. The flotation of gold-bearing ores then needs some basic and detailed scientific research.

There aren't many places on Earth where gold tellurides are found, and there isn't much research on how to treat them. The telluride and silicate floatability difficulties at the Ashashire ore deposit must therefore be further investigated scientifically.

Acknowledgements

I expressed my gratitude to Associate Professor Bogale Tadesse (PhD) for his valuable assistance and to my coauthors, Kaleb Gebreyes, and Misganu Kabeta, for their valuable contributions to this study. The personnel from the Ethiopian Ministry of Mines Dr. Sofia Abdulkadir, and Mr. Kiros Alemayehu are also appreciated for their legal help in allowing me to use confidential data from the Ministry Archives. Finally, I would like to thank my family, who participated in this study.

Authors' Contributions

Kiross Haile Zeweli: The corresponding author prepared a research proposal and developed the design of the research review. All authors reviewed and approved the manuscript for submission.

Availability of Data

The datasets used or analyzed during the current study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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