

ADDIS ABABA UNIVERSITY
ADDIS ABABA INSTITUTE OF TECHNOLOGY
CENTER FOR ETHIO-MINES DEVELOPMENT

Master of Engineering in Mineral Processing



Mineralogical assessment of Ashashire gold ore to investigate its beneficiation potential by flotation method, in Benshangul Gumuz western Ethiopia.

By

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A project submitted to the center for Ethio-mines development, Addis Ababa University Institute of Technology in the partial fulfillment of the requirements for the Degree of Master of Engineering in Mineral Processing.

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June, 2023

Addis Ababa, Ethiopia

DECLARATION

I, the undersigned, hereby declare that the project entitled with “*Mineralogical assessment of Ashashire gold ore to investigate its beneficiation potential by Flotation method, in Benshangul Gumuz western Ethiopia*” has been carried out by me under the supervision of Bogale Tadesse (PhD) and Kaleb Gebreyes (MSc), center for Ethio-mines development, Addis Ababa University Institute of Technology in the year 2023 as a part of Master program in Mineral Processing. I further declare that this project has not been submitted, presented to any university or institution for the award of any degree or diploma program and all sources of materials used for the project are appropriately cited and fully acknowledged.

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ACKNOWLEDGEMENT

I want to start by thanking the All-Powerful God. The Ethiopian Ministry of Mines and the Addis Ababa University Institute of Technology, in particular the Ethio-mines Center, deserve the utmost gratitude for having planned and carried out the project Mineral Engineering program.

My profound gratitude is extended to my advisor Doctor Bogale Tadesse (PhD) from Curtin University Western Australia for his restless skillful assistance with crucial aspects of my project work. I will also give my sweet thanks to my co-advisor Mr. Kaleb Gebreyes from the Mineral Industry Development Institute who has supported and assisted me in every possible way practically with important ideas throughout the completion of this project work.

Words may not suffice to express my gratitude for all my families specially my wife w/ro Meseret Kiros, my father Ato Haile Zeweli and my brother Weldegebriel Haile for being constant source of strength in every aspect of my life, kind-hearted treatment, understanding, love and endless support up to this day.

Also, I would like to express my gratitude to Mr. Kiros Alemayehu, the Minister Office secretary head and Dr. Sofia Mohamed, the Director for Mineral licensing and administration for providing and allowing me to access the necessary data.

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ABBREVIATIONS/ACRONYMS

A.D	Anno Domini
Ag	Silver
Au	Gold
AUD	Australian dollar
B.C	Before Christ
Cm	Centimetre
DAF	Dissolved Air Flotation
Kg	Kilogram
MIBC	Methyl isobutyl carbinol
NE	North East
µm	Micrometre
USA	United States of America
wt %	Weight Percentage
PGM	Platinum group minerals
AAS	Atomic absorption spectroscopy
QEMSCAN	Quantitative Evaluation of Material by Scanning Electron Microscope
XRD	X-Ray Diffraction
rpm	Rotation per minute
SEM	scanning electron microscope
AS	Ashashire
ICP-OES	Inductively Coupled Plasma Optical Emission Spectroscopy
LILE	Large Ion Lithophile Elements
HFSE	High Field Strength Elements
REEs	Rare Earth Elements
NE-SW	North East to South West
CIL	Carbon In Leach
EMDC	Ethiopian Mineral Development Corporation
RLM	Reflected Light Microscope
EGI	Ethiopian Geological Institute
MMAJ	Metal Mining Agency of Japan
PLC	Private limited company
UNDP	United Nation Development Program
EAO	East African Orogeny
BIF	Banded iron formation

ABSTRACT

Primary and placer gold deposits are found in the Ashashire area, which is an orogenic gold prospect area. These resources are a source of income for both companies and artisanal gold miners. It is located in the Western Greenstone belt of the Precambrian volcano-sedimentary belt, at Kurmuk Woreda, in the western Ethiopian region of Benshangul Gumuz. The region is near to the Sudanese border and is referred to as Ashashire informally. Gold is the most valuable commodity in the world. Due to the significant study that experts from all around the world have done on the history of gold, namely its birth. Ethiopia is a developing country, but it has not yet reached its full potential. Some claims and exploratory activities claim that Ethiopia is rich in precious metals, including gold, which are processed using incredibly archaic methods in many different regions of the country. As a result, the main objective of this research project is to investigate the mineral makeup of Ashashire gold ore in order to assess its potential for flotation-based beneficiation. The geochemistry was validated by both inductively coupled plasma mass spectrometry and fire assay. The petrographic analysis includes a description of the host rock and ore deposit. The host rock mostly consists of chlorite, carbonate, sericite, and quartz, with minor amounts of greenschist to amphibolite facies metamorphic minerals. Pyrite, pyrrhotite, magnetite, sphalerite, chalcopyrite, galena, and gold are found in the ore after petrographic investigation. According to ore microscopic and geochemical study, gold mineralization has strong spatial connections with alteration traits as carbonitization, silicification, sulfidation, and sericitization. The concentration of gold increases with host rocks that have been sericitized, carbonitized, silicified, and sulfurized. According to the ore geochemical data, the gold deposit contains up to 10.3ppm and is contained in chlorite-sericite-carbonate schist in carbonate-quartz veins. This gold deposit's target region is the Ashashire region. It is possible that gold is precipitated from hydrothermal solutions due to the intense wall rock alteration and the strong relationship between carbonate-quartz veins and gold. Every experimental mineralogical examination conducted by organizations and individuals in Ashashire ore mineralogy produces comparable results. It is not economically feasible to concentrate Ashashire gold for the reported gangue minerals using the flotation method. Due to the possibility of large recovery losses and increased chemical reagent consumption from such gangues. Then, prospective approaches for recovering gold from the Ashashire gold deposit include combining processing technologies like gravity separation, flotation processes, and leaching.

1. INTRODUCTION

1.1. General background and Justification

Flotation is viewed as being particularly important to the industrialized world's economy as a process of separation. The high-grade ores that could be handled by simple physical and mechanical methods have long since run out, making it extremely difficult and expensive to extract many common metals and inorganic basic materials. Herodotus, an ancient Greek historian, is claimed to have been the first to have written about a technique for separating gold particles from sand using fatty substances in the fifth century B.C. (V.A. Glembotskii, et al., 1972). Later, in the 15th century A.D., the Arabs used resins to selectively extract azurite from gangue. In the past, these were thought to be the beginnings of floating.

The flotation process is one method for recovering gold that is frequently used in the industry. It is a preferred method for improving low-sulphide and refractory ore for additional gold recovery processing, and it is a very effective approach to concentrate gold. Flotation is a versatile technique for concentrating low grade ores and particulates. It has recently been used in the processing of low grade gold ore containing sulphide gangues. With the development of column flotation technology, it may be possible to produce high grade concentrate from low grade gold ore fines and slimes. The most efficient way to use novel flotation agents to separate gold-bearing minerals from sulphide ores will be investigated (A. Vidyadhar and R. Singh, 2007).

Due to the increasingly complex mineralogy and lower grade of many modern ore resources, technology needs to progress swiftly in order to process these minerals efficiently. The terms for different diverse types of flotation processes, including ion, precipitates, adsorbing colloid, froth, foam, sorptive, and biosorptive flotation, are also investigated at various scales. Dispersed air flotation, electrolytic flotation, and dissolved air flotation should all be included in the aforementioned list (termed DAF) due to the range of (air or gas) bubble generating techniques that are accessible. The latter usually requires preceding flocculation, as was extensively discussed in a recent study (2017) (E.A. Deliyanni et al.). The aggregation of tiny particles may increase the effectiveness of their capture. A summary of particles' effects on bubble surfaces was published (G. Bournival, et.al., 2015). Chemical technology has evolved from the idea of unit operations over time and with the help of succeeding concepts to create a unified field of separation processes (E.N. Peleka and K.A. Matis,

2011). Recent descriptions of some key flotation research endeavors, with a primary emphasis on the role of physical chemistry in flotation, include zeta-potential measurements, contact angle, etc. (G.Z. Kyzas, 2015). 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 (D.R. Nagaraj and R.S. Farinato, 2016).

By using flotation separation, by-products, metal values, and minerals can be recovered. The recovery of usable valuable minerals (such as gold) from arsenic-rich auriferous pyrite concentrates, for example, shed light on the economics of recycling while also contributing to wastewater treatment and environmental technology (G.Z. Kyzas and K.A. Matis 2016).

Additionally, it was discovered that under carefully monitored flotation conditions, it was able to selectively separate pyrite from arsenopyrite in an auriferous bulk flotation concentrate that was stocked in the mine area.

Gold has a long history and is many things to many people, making it the most noble metal. It is a rare metal with a complex geochemistry that a geochemist finds challenging to extract from the earth and its ores. It is a metal of remarkable beauty that will stay forever for a goldsmith and jeweler. It is a metal with unique qualities that can be employed in electronics and several other human innovations, according to industrial artists. It is a coinage metal with a lengthy and fascinating history for numismatists (Robert W. Boyle, 1987).

Gold has been crucial to the economic development of several nations, including Australia, South Africa, the United States, China, Canada, and Ghana, due to its highly desired qualities and unique uses. This significance has existed since the dawn of civilization (Webber, K., 2012). Australian gold accounts for 16% of the world's 56,700 t of gold, or AUD\$ 542.48 billion, according to a recent estimate of the world's gold mining reserves (Statista. 2016), with an average gold price of AUD\$ 1690/oz. When gold prices are predicted to hit historic highs (AUD\$ 2670/oz) in 2020, the 16% gold deposit will be worth about AUD\$ 857.05 billion more.

By environmentally friendly mining their gold reserves, several poor countries (like Ghana), blessed with gold riches, have greatly reduced poverty. Gold mining has continued to be a key source of income and economic support in recent years.

Following the depletion of the majority of high grade sources, more gold is being produced from low quality, refractory gold ores (Adams, M.D., 2016). The complexity of these refractory ores is growing, necessitating an upgrade in the theoretical and practical knowledge that underpins efficient, profitable,

commercial gold extraction processes.

There is still 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 (Oraby, E.A. et al., 2017). 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).

1.2. Statement of the problem

In the world of commerce, gold (Au) is used to symbolize wealth and prosperity. Due to its low concentration and dispersion distribution in gold bearing ores, its determination is an intricate and critical process. Operators aim for a concentrate with a high rate of gold recovery during the gold concentration process. However, because the grade of the concentrate is inversely related to gold recovery, it is imperative to learn how to generate a high-quality concentrate using the appropriate recovery techniques (Michael Silva, 1986).

Since ancient times, different minerals have been separated via gravity separation according to their densities (Falconer Andrew, 1970). Gold gravity separation is the oldest gold extraction process and the extraction of gold using gravity separation process have low recovery rate of gold.

Gravity separation is frequently an efficient method for separating bigger gold particles from the other gangue minerals. However, the effectiveness of gravity separators decreases sharply for finer particle sizes, which are often less than 75 microns (Martinez G. et al., 2021). This technique must be combined with other processes, such as flotation and cyanidation.

The vein gold separation effect will be enhanced if other gold extraction processes are used with the gold gravity separation method, which is generally not suitable for vein gold ore extraction.

The flotation method has long been one of the most effective techniques to process gold-bearing ores since gold is a mineral that readily floats. Basic gold deposits usually contain both gold and sulphide minerals. Both of these minerals may easily float on water and produce stable mineralized foams.

They make excellent carriers for minerals containing gold.

The flotation method is widely used to process gold-bearing sulphide ore with high floatability because it can maximize the enrichment of gold into the sulphide mineral concentrate and the cost of the gold extraction process is low.

This study aims to gain access to the mineralogy of the Ashashire gold deposit in order to examine a suitable flotation approach, which is a widely utilized method and the typical method used to recover gold particles. This would close the gaps between widely used methods for recovering fine gold particles, such as gravitational separation and other traditional gold separation techniques, and frequently used flotation separation techniques. The main goal of this study is to investigate the potential for flotation techniques to beneficiate the Ashashire gold ore deposit by doing a mineralogical examination.

1.3. Location and Accessibility of the study area

Benshangul-Gumuz National Regional State, in western Ethiopia, is where the project's research area is located. It is about 750 kilometres from Addis Ababa, the nation's capital, and 90 km northwest of Asosa, the area's administrative centre. Asosa can be reached from Addis Ababa in 55 minutes with Ethiopian Airlines' daily flights. The 767 aircraft can land on the all-weather tarmac runway.

The main route of travel from Asosa to the Project is a 100 km asphalt road that passes via Homosha, the communities of Agubela and Kutaworke, and Kurmuk, which is 20 km southwest of the Project at a border crossing with Sudan. The intended infrastructure is located about 5 km to the west of the border between Ethiopia and Sudan.

The study region is situated between latitudes 1140000 and 1180000 North and longitudes 640000 and 680000 East. The main road between Addis Ababa and Assosa, Addis Ababa-Ambo-Nekemte-Gimbi-Mandi-Assosa, connects to it. The location is roughly 45 km southwest of Assosa Town, and the only all-weather dirt road leads there ([Abebe Bedassa, 2014](#)).

1.4. Physiography of Ashashire

The elevation range of the study region is around 700 to 1200 metres above sea level. The geographic center of Ashashire is roughly in latitude 36N, or UTM zone. The area consists of harsh valleys, high mountains, and flat to steep slopes ([Source: Kurmuk mining PLC feasibility study, 2021](#)).

1.5. Climatic Conditions of the project study area

The region has a dry to semi-dry climate. The dry season's highest temperature ranges between 40°C and 45°C and lasts from the end of October until the middle of May. From the middle of May until the middle of October, there is a rainy season with maximum rainfall of up to 240 mm and average temperatures between 25 and 37 degrees Celsius.

1.6. Population and land use in the project study area

There are hardly any people living in the study area and its surroundings. The area is populated by Mao, Como, and Berta people, who speak Maogna, Comogna, and Bertegna, respectively, as their mother tongues. Most Berta people, along with a small number of Como and Mao people, speak Arabic and adhere to Islam. The area's scattered villages and settlements have been incorporated into a single settlement with the aid of the local government. The main commercial hub of the area is Asosa Town, which is also home to an airport, lodging options, dining establishments, a hospital, and other healthcare facilities.

Only a small section of the area is used for farming by the local inhabitants. The capacity to hunt, breed cattle, nurture bees, pan for placer gold, and cultivate land with irrigation and rain feed are all necessary for the inhabitants to exist. The main crops farmed in the area include sorghum, maize, groundnuts, cotton, tobacco, oilseeds, and a variety of fruits like mango, papaya, and lemon. Though this varies occasionally, the wet seasons are when malaria infestations are most likely.

1.7. Previous Works

The Ashashire gold and sulphide mineralization is dominated by Precambrian meta-sediments and metavolcanics of the greenschist facies, according to (GSR, 1997 and GSE, 1995). Cenozoic basaltic sheeted dykes and sills, as well as syn- to post-tectonic intrusions of basic to acidic chemistry, have all encroached on these areas.

(Fontana, 1945) has located and appraised greenstone bands in western Ethiopia. Huntington Geology and Geophysical Ltd. and the UNDP worked together on a photo geological mapping project in 1967. The EIGS-UNDP Joint Mission also conducted airborne radiometric and magnetic studies for the aim of mineral prospecting (UNDP, 1972).

The aforementioned academics and institutions have used diamond drilling, grab and pit sampling, stream sediment, soil, and regional mapping to define and test the area of interest and mineral occurrences.

To characterize the mineral occurrences and geology of the target areas, the Metal Mining Agency of Japan (MMAJ, 1974) also carried out two phases of exploration between 1973 and 1974. These phases comprised photo geological reconnaissance surveys at sizes of 1:50,000 to 1:60,000, geochemical prospecting from stream silt, pan concentration, and soil samples.

The reconnaissance survey covers the regions of Assosa-Kurmuk-Gizen, Mendi-Tobo, and Gorrdana-Billa. Of the 10,000km² overall survey areas, 8000km² are in the Assosa-Kurmuk-Gizen region, which includes the Ashashire, Kurmuk mining PLC license area.

Ahmed M. asserts that in addition to reinterpreting past research from the years 1980 to 1982, EIGS launched a Programme of stream sediment, soil, and rock sampling in 1982. For this, regions of interest for additional research were identified using geological mapping, geophysics, soil, rock, and drill core samples. The EIGS followed up on their initial survey between 1982 and 1983 in order to complete the soil grids and spot anomalies in the Dul region, encompassing the Dul Mountain, Azale, and Ashashire. These regional surveys included rock samples from altered or mineralized outcrops as well as soil samples from numerous precise 100m by 500m grids.

The EIGS began the Dul Gold Exploration Project in 1994 in attempt to define, evaluate, and develop the gold occurrence at Dul Mountain and related occurrences nearby. This project includes 736.8 metres of diamond drilling, 960 metres of trenching, 446 metres of pitting, and geophysical investigation (Masresha J., et al., 1995).

The 1800km² Dul and Menghe license zones were the subject of an exclusive exploration permit granted to Golden Star Resources Limited Ethiopia Company (GSR) in 1995. Over the course of the three years that they researched these licenses, they dug diamond drill holes at Dul Mountain, Menghe Ridge at Azale, and seven trenches at Ashashire. Drilling did not mimic what would happen on the surface. GSR started a campaign to designate four new goals through stream sediment collection as a result of their repeated failures to pursue prior targets (GSR, 1997). Finally, due to the precipitous drop in gold prices, they renounced their exploration licenses in Ethiopia in 1998.

According to studies by (Masresha, 1999), gold has been discovered to be associated with pyrite, chalcopyrite, pyrrhotite, scheelite, monazite, magnetite, and siderite in the Mount Dul region, a southwestern extension of the Ashashire potential.

In Ashashire According to a 2015 Aurigin assessment, the main mineralization is open-ended along the trend and down dip. The company feels that the Ashashire potential is still the best and top priority target of the western Ethiopia project after collecting soil and core samples, geochemically analyzing a range of trenches and drill holes, and evaluating the existing project. However, the aforementioned papers do not reveal the origin or paragenesis of Ashashire's main gold prospect area.

The primary goal of the earlier exploratory work in the area was to identify areas of interest that merited more investigation in order to obtain an economically viable placer and primary gold deposits.

1.8. Objectives of the study

1.8.1. General Objective

The general objective of this project is the mineralogical assessment of Ashashire gold ore deposit to investigate its beneficiation potential by flotation technique.

1.8.2. Specific Objectives

- Mineralogical assessment of the Ashashire gold ore deposit.
- Investigating the beneficiation potential of Ashashire gold by flotation technique

1.9. Significance of the project study

The goal of this project study is to demonstrate that flotation is a technically and economically viable method for recovering low grade gold sulphide ores by evaluating the beneficiation potential of the Ashashire gold ore deposit through mineralogical investigation. The recovery of gold concentrate is negatively impacted by the employment of gravity-based technologies in gold processing, as was already mentioned.

However, by using flotation separation processes, small- or large-scale gold processing businesses can recover the gold successfully. This research will also be essential for tackling mineralogy-related issues that affect flotation gold extraction techniques. The mineral processing industry would greatly benefit from learning how to recover gold from its deposit without losing more gold to tailings.

Because it may boost the enrichment of gold into the sulphide mineral concentrate and has a cheap cost, the flotation method is frequently used to process gold-bearing sulphide ore with high floatability.

If the mineralogical assessment is finished, it will be easy to develop a desirable approach for upgrading low-sulphide and refractory ore for additional gold recovery treatment technology. It also offers a method for concentrating and isolating an ore's key elements in order to produce a grade of mineral concentrate fit for use as a raw material in effective hydro- or pyrometallurgical processes.

In order to effectively develop resources for associated gold mines, this project will extensively evaluate the Ashashire gold deposit's flotation-based beneficiation potential.

The project's results will be useful to businesses who want to process gold using flotation techniques, academic communities interested in gold flotation technique research, researchers, and those dedicated to studying mineral processing. These parties will help the gold processing sector and increase stakeholders' or decision-makers' knowledge bases.

1.10. Scope of the study

The scope of this project was more precisely focused on review of the mineralogical evaluation of the Ashashire gold ore deposit in order to look into its potential for beneficiation utilizing by using flotation technology.

2. LITERATURE REVIEW

The flotation method of mineral processing entails altering the surfaces of the ore particles such that, depending on whether the water is hydrophobic or hydrophilic, it either repels or attracts it. Large-scale flotation technology was created in the early 20th century to recover extremely fine mineral particles that had previously been lost in gravity concentration facilities. The preferred technique today for separating many minerals from their ores is flotation (Sajjad M. and Otsuki A., 2022).

It is difficult to make generalizations about the flotation of gold ores due to its vast range of applications. Most problems with gold ore flotation have nothing to do with metallic gold floating. Physical restrictions including the shape and size of the gold particles and the stability of the foam significantly affect how much gold is recovered during flotation. When floated with other sulphide minerals, the amount of sulphide bubble loading may function as a barrier to the attachment of free gold, reducing flotation performance. Most minerals must be covered with a water-repellent material in order to make them float.

A thin layer of chemicals or oils can be applied to finely crushed mineral particles to keep them dry and help them adhere to air bubbles. A pulp of ore, water, and suitable chemicals is churned up to coat the mineral particles; these chemicals adhere to the surfaces of the mineral particles and make them hydrophobic. Unwet particles are brought to the pulp's top surface by air bubbles, where they adhere to them and become part of the froth, which can then be skimmed off. Unwanted minerals that naturally resist soaking can be treated to make their surfaces moist and sink (Pryor, E. J., and E. J. Pryor, 1965).

The ability to change the floatability of minerals enables many hitherto difficult separations that are now commonplace in modern mills. Flotation can be used to concentrate the minerals gold, copper, lead, and zinc, which typically coexist with one another in their ores. Several complex ore combinations that were previously of little value have become significant sources of various metals by utilizing the flotation process.

The primary sources of inorganic materials and essential components in many biological and technological applications, such as drug and gene delivery, pharmaceuticals and cosmetics, electronics, catalysis, and water treatment, come from minerals, which are non-renewable natural resources (Ying Y. et. al., 2017).

Although the term "mineral" is not precisely defined, it is generally understood to refer to naturally occurring crystalline solids having very well-known chemical compositions (Cleaves II HJ et al., 2012).

They make up the Earth's crust and are primarily in compound form, though they can also be in elemental form. The majority of the Earth's crust are made of silicate, alumino-silicate and carbonate minerals (e.g., quartz, feldspar, mica, kaolinite, talc, limestone); while other important mineral classes comprise native elements (e.g., native gold, graphite, diamond), sulphides (e.g., molybdenite, sphalerite, galena), oxides (e.g., hematite, malachite, rutile), phosphates (e.g., apatite, monazite), and so on. The primary source of many inorganic materials, such as metals and alloys, ceramics, glasses, chemicals, and other substances that are not naturally organic, is ore. The Earth's crust is filled with increased grades of economic minerals that can be used (Kumari Neeraj and Chandra Mohan, 2021).

2.1. Flotation reagents

As opposed to this, unwanted gangue minerals and valuable minerals frequently coexist and grow together, needing separation for further processing and usage. The versatile and straightforward method of flotation has been widely used to separate and purify key minerals. This is due to the fact that various mineral particles have varying propensities to adhere to air bubbles. Due to the air-mineral aggregates' low density, hydrophobic mineral particles readily connect to air bubbles and climb to the top of the flotation pulp, but hydrophilic mineral particles either remain suspended or settle out in the flotation pulp in the absence of bubble attachment (A. Vidyadhar and R. Singh, 2007).

In flotation, a variety of inorganic and organic chemicals (surfactants) are used to alter the properties of surfaces. According to their purpose, flotation reagents can be loosely divided into the following categories: collectors, frothers, depressants, activators, and regulators. In addition to surfactants, there are a few inorganic substances present. These are either utilized as depressants (soluble silicates and sulphides and organic polymeric compounds), activators (metal ions), or pH regulators (lime, soda ash, sulphuric acid, caustic soda, etc.) (A. Vidyadhar and R. Singh, 2007).

The amount of gold that can be collected from gold-bearing ores depends on the deposit's properties, the ore's mineralogy, and the distribution of gold within the ore. Collectors like xanthates and hydroxamates can chemically bind the specific metal sites of sulphide or non-sulphide minerals to increase the hydrophobicity of mineral surfaces.

This makes their hydrocarbon tails visible. The target minerals may absorb the depressants and become hydrophilic as a result.

Activators, depressants, modifiers, and, most crucially, flotation collectors can be used in the flotation technique to alter the surfaces of mineral particles. Flotation collectors carefully adsorb on precious minerals' particle surfaces to boost their hydrophobicity. Because of this, priceless minerals may stick to air bubbles, which lead to the eventual addition of aggregates of bubble-particles to the flotation concentrate (Nagaraj and Farinato, 2016).

Froth flotation frequently leads to the homo and hetero aggregation of mineral particles in addition to the bubble-mineral attachment and chemical reagent adsorption on mineral surfaces. In the end, surface interactions between air bubbles, mineral particles, and chemical reagents in aquatic environments dictate the value recovery and selectivity of froth flotation separation (Wang J. et.al., 2015).

Following froth flotation, concentrates and tailings are produced, which are then processed using dewatering techniques for water recycling and tailings disposal. Coagulants or flocculants are used to help with the solid or liquid separation throughout these processes. While flocculants can bind a large number of mineral particles together during the dewatering process, both coagulants and flocculants, which depend on the surface contacts between mineral particles in the presence of these reagents, can lessen the attraction between mineral particles.

In order to develop more efficient industrial processes and chemical additives that will enhance the performance of solid-solid and solid-water separation, it is essential to have a thorough understanding of the mechanisms underlying mineral-mineral, bubble-mineral, and mineral-reagent interactions in complex aqueous media. A variety of state-of-the-art analytical techniques have been employed to date to evaluate the surface properties and interaction mechanisms of mineral particles with and without the adsorption of chemical reagents in flotation processes (Wang J. et.al.,2021).

As a result, flotation collectors are essential for recovering valuable minerals. Due to the increasing depletion of high grade and simple to process ores, the mineral industry has a tremendous challenge in the successful processing of refractory, low grade, and widely dispersed ore resources. It is well known that using a flotation collector with a unique architecture might greatly improve selective flotation during flotation separation (Nagaraj and Farinato, 2016).

Because minor changes in the molecular structures of flotation collectors have the potential to significantly alter the strength and selectivity of collector adsorption, structure-activity relationships are extremely important and can be a key strategy for the rational design of flotation collectors (Liu et al., 2017; Yang et al., 2017).

The majority of these studies focus on how a collector's functional groups affect how well minerals are separated by flotation. However, little is understood about the effects of non-polar groups (such as different alkyl xanthates) on mineral flotation (Wang, 2016; Liu et al., 2017).

Most importantly, the size and form of a non-polar group may have an impact on flotation collectors' capacity to make mineral surfaces sufficiently hydrophobic to encourage float (Wang, 2016). By incorporating a branched hydrocarbon group into standard xanthates collectors, it is possible to significantly increase both their ability to collect xanthates and their selectivity. For instance, 1,2-dimethylpropyl xanthates outperforms linear alkyl chain xanthates collectors in flotation for the gold and copper deposits (Lu and Wang, 2017). It is important to emphasize that 1,2-dimethylpropyl xanthate is often employed in industrial scale facilities.

It is important to realize that many other processes, such as smelting, cyanidation, and gravity concentration, are necessary in addition to flotation in order to recover gold from a particular ore. Despite the fact that there are many different crushing and grinding circuits in use, they are not covered here. This article will not go into detail regarding the many types and sizes of flotation machines used in the processing of gold ore because they can all be operated to produce an acceptable result. The treatment of low-sulphide (5% S) refractory gold ores such copper-gold ores and stibnite-gold ores is being concentrated on, with a particular emphasis on the role of flotation in the overall flowsheet. Gold tellurides and tiny gold in pyrite or arsenopyrite are both present in these ores (Yan and Hariyasa, 1997).

2.2. Natural and Liberated Gold Flotation

By preserving the surfaces of the free gold particles as free of organic species as feasible and by eliminating any clinging slime particles, experience has shown that free gold particles can be selectively retrieved against pyrite. This can be done with little to no pH regulators, just a small number of collectors and a proper frother to stabilize the froth, and perhaps a tiny bit of dispersant.

Alkoxy or phenoxy carbonyl alkyl thionocarbamates, dialkyl or diaryl monothiophosphates and monothiophosphinates, glyoxalidine, and aminothiophenols were among the collectors that were found to increase the selectivity for gold versus pyrite (Marabini et al., 1991).

According to research by (Nagaraj et al., 1991), Monothiophosphorous acids have the ability to selectively float gold from base-metal sulphides.

At the laboratory scale, the selective flotation of gold from pyrite with PAX has been proven using hydrogen peroxide as an oxidizing agent (Monte et al., 1997). The addition of hydrogen peroxide alone made the surfaces of both gold and pyrite hydrophobic. The gold surface became somewhat hydrophobic after the addition of xanthate, while pyrite remained hydrophilic at pH levels greater than or equal to 10.

Sulphide ores with free gold are frequently treated on flotation plants as though the gold were part of a vast or intricate sulphide mineral matrix. This results in the addition of collector and activator at high dose levels. Due to the development of dixanthogen on both the gold and sulphide surfaces in this application, xanthate adsorption on both sulphides and gold makes selective flotation somewhat challenging (Gardner and Woods, 1977).

2.3. Gold and Gold-Bearing Mineral Flotation

Primary gold deposits are the principal source of gold, and elaborate technological processing procedures have been established for all kinds of ores from such deposits. Following metallurgical redistribution, flotation schemes are the most frequently used method for processing oxidized and gold-bearing sulphide ores, according to the examination of published works (Fedotov P. K. et.al. 2019).

The technological procedures outlined above each have benefits and drawbacks. Because of the numerous variables that affect the process' effectiveness, flotation stands out among them. The recovery size prior to flotation is one of the key variables (Kuptcova A. V. et al., 2019). The degree of pulp aeration, flotation time, medium pH, conditioning, pulp density, and many other factors are also impacted by the reagent mode (Mynarczykowska A. et al. 2015).

Gold from the Ashashire is refractory because some of it is found as tellurides, while other gold is finely dispersed or in solid solution with pyrite. Many researchers looked into the idea of selectively flotation the tellurides from pyrite and treating each product individually to improve gold recovery and recover tellurium as a by-product when flotation was first introduced.

According to (Smith A.M., 1963), tellurides can be floated before sulphides before the collector is added for sulphide flotation. During laboratory experiments, only frother (Aerofroth 65) and copper sulphate were added as reagents. Smith noted that the results at the plant scale were comparable to those in the laboratory testing and suggested that a further cleaning stage might yet be able to raise the quality of the telluride concentrate.

(Smith L.I., 1963) provided evidence to corroborate the facts above. He discovered via experimentation that no collector was needed because the telluride could be floated away as the pulp left the grinding area. A slightly acidic media favored telluride flotation more than an alkaline medium in the flotation of pyrite prior to the addition of xanthate and copper sulphate, according to the results of additional laboratory studies.

It will need a variety of methods, including a literature study, data collecting, processing, analysis, and interpretation, to accomplish the goals of this project.

Due to their rarity and somewhat distinctive characteristics (high specific gravity, brightness, and average atomic number), gold minerals are relatively simple to pre-concentrate for examination and identification using optical and electron microscopes. It is crucial to keep in mind the various forms of gold, measure each one separately, and ensure that the constraints of the measuring method or equipment do not compromise results, or at least be aware of that potential, when doing quantitative gold department examinations.

Because of its simplicity, rapidity, requirement for specialized instrumentation, and relative affordability, diagnostic leaching (Tumily et al., 1987; Lorenzen, 1995), the first approach for thorough gold disposition studies, was enthusiastically welcomed by industry and metallurgical laboratories. It consists of a sequence of progressively more aggressive acid-digestion phases separated by a series of cyanidation steps. As a result, it divides a gold assay into gold that is water-soluble, exposed to cyanide, and gold that is bound up in carbonates, sulphides, and silicates.

The related gold minerals' size distribution and whether a particular target grind exists for liberation are further aspects of characterization. Surface impurities that impeded the recovery of free gold in floatable size classes are also identified. The matching of a secondary collector to the rejected gold grain composition is a relatively modern technique to aid in the exploration of methods to increase the recovery of free gold (Chryssoulis et al., 2003a).

3. METHODOLOGY

The following methods, activities, and procedures are carried out in order to accomplish the aforementioned goals. In order to identify the project problem or gap in the study field, data have been gathered and a thorough evaluation of the literature has been performed. The historical data survey and collection includes primary and secondary data (from historical bore holes), geochemical analysis, published and unpublished articles, reports, journals from advisors, senior students, websites, and organizations like the Ministry of Mines, the Ethiopian Geological Institute (EGI), and Kurmuk Mining PLC. It also includes reports from advisors, senior students, and journals from journals. These data include mineralization theories and the outcomes of geochemical testing.

4. MINERALIZATION OF ASHASHIRE ORE BODY

4.1. Mineralogy

Mostly sulphide and oxide minerals, such as pyrite (Py), pyrrhotite (Pyrh), chalcopyrite (Cpy), galena (Gn), magnetite (Mag), hematite (Hem), and a trace quantity of sphalerite (Sph), make up the ore mineralogy.

With varying proportions of muscovite, chlorite, and actinolite-tremolite, quartz and carbonates (calcite and dolomite) make up the majority of the gangue minerals in the greenstone-hosted quartz-carbonate vein deposits in Ashashire.

Precious metal gold (Au) is typically linked to sulphide and oxide minerals. It has a vivid yellow color and is the youngest relative among the minerals that cohabit. It can be found in native form in veins and fractures as well as dissemination and inclusions in sulphides like pyrite and pyrrhotite.

Galena (PbS) galena (PbS) is an isotropic mineral with high reflectivity and three precisely positioned cleavages that are visible as triangle pits. Galena is frequently linked with hydrothermal minerals such quartz, sphalerite, pyrite, chalcopyrite, carbonates (dolomite, and calcite), and others. It is mainly associated with quartz-calcite veins and shear zones. The mineralization, which is primarily found in calcite-quartz veins and mafic (chlorite) schist, is often controlled by structural considerations.

The other sulphide mineral that is frequently observed in hand specimens and at the microscopic level, in addition to pyrrhotite, is pyrite (FeS₂). It might be difficult to distinguish between pyrite and pyrrhotite in hand specimens. But it is easy to recognize them according to their petrographic characteristics. Pyrite is yellowish white to brilliant white, in contrast to pyrrhotite pinkish brown to brown with tarnished surfaces. It is easily identifiable under a microscope due to its yellowish white to bright white colour, idiomorphic texture, isotropic nature, and high reflectivity nature in comparison to chalcopyrite.

It appears as inclusion, dissemination, exsolution, and replacement in host rocks and is regarded to be the earliest and later mineral for precipitation. In the hand specimen, it has a metallic luster and a greenish-black stripe against gold.

Pyrite is connected to the hydrothermal minerals chalcopyrite, sphalerite, galena, and pyrrhotite. From the initial stages of crystallization to the final phases, pyrite has a diverse genetic makeup. It occasionally replaces pyrrhotite and contains gold ([Sewagegn Yenesew, 2020](#)).

Mineralization, including pyritization, often takes the form of vein and fracture filling in host rocks such

muscovite-chlorite-carbonate schist and chlorite schists.

Chalcopyrite: is a mineral that has the chemical formula (CuFS_2) and is referred to in this study as Cpy. Low reflectivity compared to pyrite, brassy yellow color. Additionally, it exhibits bluish to purplish to greenish tarnish on worn-out surfaces in contrast to pyrrhotite and pyrite. It is far more challenging to identify chalcopyrite, a pale yellowish mineral, from gold. Gold is less frequent than other metal and often has a very bright colour (Sewagegn Yenezew, 2020).

Chemically, **hematite** is represented as (Fe_2O_3), and in this work, it is referred to as (Hem). The primary distinguishing characteristics of hematite are a botryoidal appearance and a blood crimson internal reflection. These deposits are found in massive masses in Precambrian rocks, which are siliceous sedimentary rocks that have undergone regional metamorphism and are rich in iron. These rocks have residual accumulations of hematite and goethite that have formed due to natural processes leaching the accompanying silica. It can be found in some iron-oxide-Cu-Au deposits as well as contact metamorphic deposits as a significant phase. In a range of mineralizing settings, it can also be found as an alteration mineral (Marshall et al., 2004).

Magnetite is abbreviated as (mag), and in hand specimens, it mostly exhibits a grey to brown color with a brownish tint, a strong magnetic field, and a dull metallic luster. By being generally browner and slightly brighter than sphalerite, magnetite is distinguished from hematite, which is significantly darker and devoid of a bluish-white hue. It is mainly associated with a range of minerals and has a low concentration, especially ilmenite, hematite, pyrrhotite, pyrite, chalcopyrite, sphalerite, and galena. In Ashashire, magnetite is found as lamination dissemination with sulphides in shears and veins as well as in oxidized zone skarn deposits. Within alteration haloes, magnetite can also be found as veins or disseminations.

Pyrrhotite: Pyrrhotite is referred to as (Pyrh) in this paper. The most prevalent ore mineral, pyrrhotite, is distinguished by its light yellow to pinkish brown colour and is associated with the majority of sulphide minerals. It can be identified by the tarnished impact that oxygen exposure has had on its crystal surface. This material seems granular or even enormous in some situations (Sewagegn Yenezew, 2020).

It has a chemical composition. $\text{Fe} (1-x) \text{S}$, where $X=0-0.02$ and Ni and Co are occasionally present to create the chemical formula $(\text{Fe}, \text{Ni}, \text{Co}) 1-x\text{S}$. Pyrrhotite is remarkable because, as indicated by its peculiar chemical formula, it maintains a fluctuating iron content. The lack of iron in its chemical structure, which is also the cause of its magnetic characteristics, results in variability.

4.2. Alterations studied in Ashashire

Gold and sulphide deposits show significant lateral zonation of alteration stages from proximal to distal assemblages on scales of centimeters to metres. The width of the alteration zones as well as their mineralogical assemblages is frequently influenced by the crustal level and surrounding rock type. Sercitization or, less frequently, the development of biotite, K-feldspar, or fuchsite (a chromium-rich variation of the mineral muscovite) is the outcomes of alkali metasomatism. Mafic minerals have a high chloritization rate. Dolomite and calcite are examples of carbonates. Pyrite and pyrrhotite are sulphides.

Either infiltration through fractures or diffusion between grain boundaries causes the change. Chloritization, sulfidation, silicification, oxidation, and carbonitization are further significant changes. In banded iron formation (BIF) and Fe-rich mafic host rocks, as well as close to quartz and calcite veins, sulfidation, primarily pyritization, is high. According to (Grove et al., 1998), considerable amounts of CO₂, S, K, H₂O, SiO₂, Na, and LILE are added to wall rock alteration in greenschist facies rocks.

According to (Evans M., 1987), the host rock's type, content, texture, structure, porosity, and permeability are all elements that affect how the host rock is altered. Effectiveness of alteration and mineralization is further influenced by hydrothermal fluid properties, such as temperature, pressure, pH, and Eh.

Eats and Vanderhor (1998) assert that the kind of host rock and metamorphic grade determine the sort and extent of modifications in Archean greenstone-hosted deposits. For instance, low grade mafic rocks commonly exhibit chlorite-epidote-carbonate alteration far from the mineralization and carbonitization-sercitization-chloritization-and-sulfidation (pyrite-pyrrhotite) alteration nearby. Biotite has additionally occasionally been seen. In ultramafic host rocks, highly magnetic minerals including talc, serpentine, and actinolite-tremolite minerals can be found.

By using a field, laboratory, or petrographic investigation, it is possible to find gold and base metal deposits as well as to identify unique alteration types with varying intensities. The wall rock alteration is the consequence of various processes involving rock-forming minerals that occur as heated aqueous fluids flow along fractures and grain boundaries (Sewagegn Yenesew, 2020).

A rock's weak spots, such as fractures, fissures, cleavage planes, and other surfaces of weakness, are commonly followed by alteration. For instance, after foliations, mica schists display parallel patterns.

The most common and often observed alterations include chloritization, silicification, sericitization, sulfidization, oxidation, and carbonitization, according to the pertinent considerations below.

A. Chloritization

Chloritization is the most frequent and efficient type of alteration that contributes to the byproducts of hydrothermal activity in the region (fig. 1). A hint is provided by the formation of the mineral hydrothermal chlorite. It occurs more commonly in mafic rocks than in meta-sedimentary and intrusive rocks. Mafic and ultramafic minerals like pyroxene and amphibole are replaced by chlorite minerals. According to a field survey and petrographic investigation of the mafic metavolcanic rocks, secondary chlorites have even formed on the surfaces where the main minerals collide. The region is exposed to low to medium retrograde metamorphism and is composed of the greenschist to amphibolite facies, according to the occurrence of chlorine mineral in metamorphic terrain.

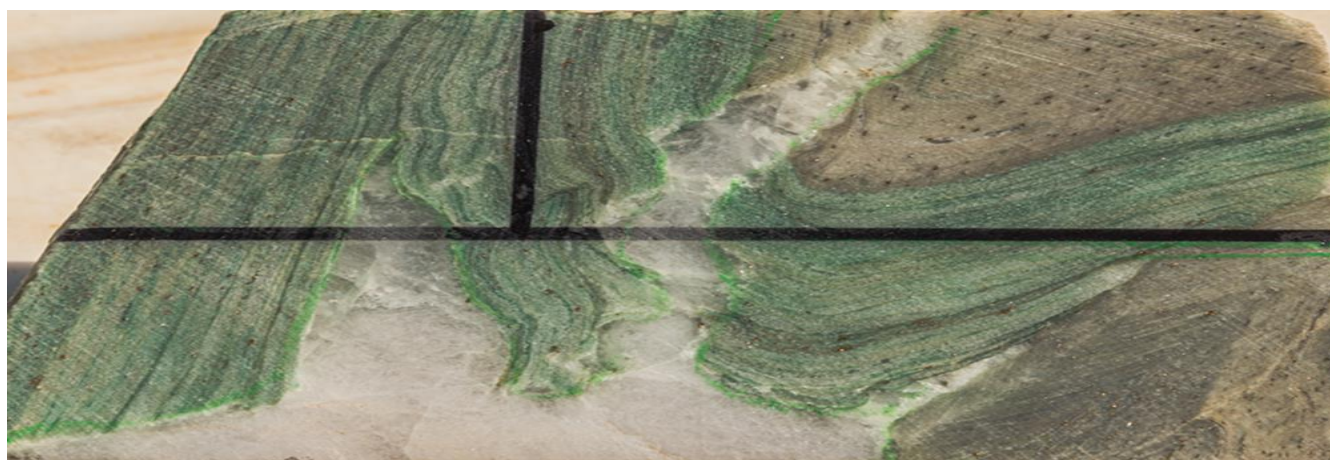


Figure 1: Chloritization alteration

(Source: Kurmuk mining PLC Exploration report, 2021).

B. Silicification

Silicification is a type of alteration that most frequently occurs around veins, with veins typically following weak zones, according to a petrographic analysis backed by field data using a drill and outcrop samples (fig. 2). Usually, secondary quartz is found to signify this alteration. Meta-mafic volcanic rocks and meta-sedimentary rocks both still have this substantial, sparsely distributed alteration. The degree and intensity of alteration varies from one type of rock to another depending on the host rock's proximity to the veins and how distal it is from the host rock.

The degree of this alteration, which can range from low to high levels of silicification, metamorphism grade, and depth, has been experienced by almost all rocks.



Figure 2: Silicification

(Source: Kurmuk mining PLC Exploration report, 2021)

C. Sericitization

Sericitization is a rather rare type of alteration seen in Ashashire, and it is mostly found in granite in association with mafic meta-volcanics and meta-sedimentary rocks. It can be thought of as a very finely divided fibrous material that occasionally encloses hexagonal subdural minerals and is sandwiched between grains of harder minerals like quartz. The plagioclase grains in intrusion are the main examples of this feature. Additionally, it frequently forms inside alkali feldspars or at the grain boundaries of plagioclases when feldspars act as a replacement unit. The creation of fine-grained sericite mineral is a common way to show it.

D. Sulfidization

Sulfidation is the most frequent and pervasive alteration type found in drill samples of mafic meta-volcanics, meta-sediments, and meta-granite. Its absence from rocks on the surface suggests that it was swiftly oxidized and gone due to its high oxidation susceptibility. In samples taken from test boreholes with quartz veins, pyritization is a characteristic and frequent sulphide alteration (Sewagegn Yenesew, 2020).

E. Carbonitization

Carbonitization is indicated by the minerals calcite and dolomite (Figures 3 and 4). Both metasedimentary and metavolcanic rocks frequently display this. Calcite alteration can be found by applying diluted hydrochloric acid. It fizzes in an obvious way. The use of strong acid distinguishes dolomitization alteration from calcitization. While using weak acid, it is challenging to get it to fizz.

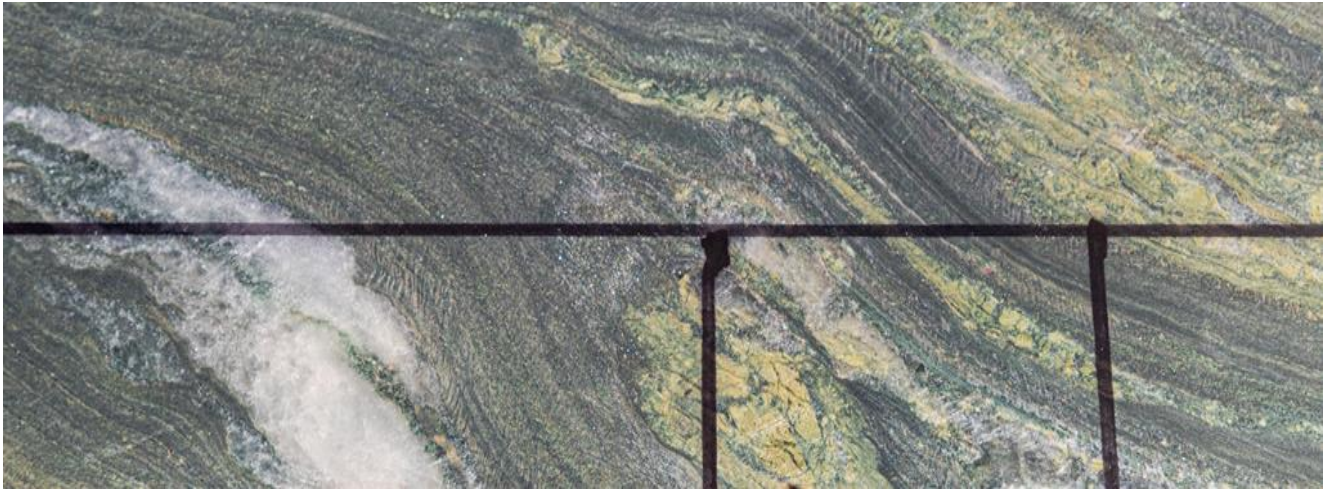


Figure 3: carbonized mafic schists

(Source: Kurmuk mining PLC Exploration report, 2021)

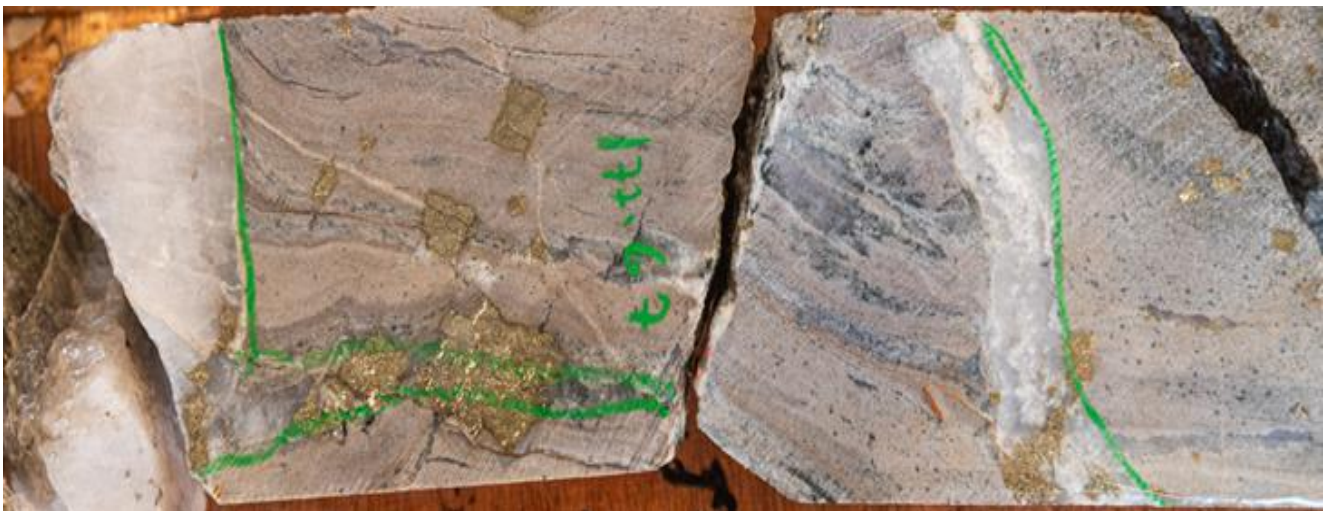


Figure 4: Cross cutting linear quartz-carbonate \pm pyrite veins that are coarse grained and altered selvages along favorable layers (chrome rich meta-sediments or mafic) that may pass into alteration

(Source: Kurmuk mining PLC Exploration report, 2021)

5. GEOCHEMISTRY

5.1. Major, trace and REE element analysis

The main and trace element data of fourteen samples, [Tables 1 and 2](#), representing various lithologies with varied degrees of alteration, are examined using variation diagrams, spider diagrams, and classification diagrams.

Table 1: Major oxides data from XRF analysis

Major oxides in percentage (%)										
Sample number	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	MnO	MgO	CaO	Na ₂ O	K ₂ O	TiO ₂	P ₂ O ₅
Calcite-muscovite schist	34	17.57	8.49	0.23	7.56	11.95	3.85	2.16	1.36	0.03
Muscovite- calcite schist	48.54	14.17	11.67	0.12	4.14	6.09	2	2.55	0.99	0.03
Muscovite- calcite schist	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
Muscovite- calcite schist	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

(Source: Abebe Bedassa, 2014).

Table 2: Data from XRF study of trace elements

Sample number	Trace elements in part per million (ppm)										
	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

(Source: Abebe Bedassa, 2014)

According to Sewagegn Yenesew, 2020 the major elements geochemistry of Ashashire deposit were also explained here below. Table 3 lists the major and minor element oxide percentage compositions for the Ashashire region. According to the Harker diagram in fig. 9, the host rock exhibits significant compositional differences. SiO₂ ranges from 40.3 to 66.3%, Al₂O₃ ranges from 9.5 to 15.75%, Fe₂O₃ ranges from 2.37 to 16.45%, CaO ranges from 2.4 to 12.25%, MgO ranges from 1.24 to 7.56%, K₂O ranges from 0.02 to 2.61%, Na₂O ranges from 0.003 to 0.113%, TiO₂ ranges from 0.19 to 1.94%, MnO ranges from 0.03 to 0.21%, and P₂O₅ ranges from 0.01 to 0.18% with 3.5 to 18% loss on ignition.

The greater loss on ignition value suggests that the rock component has a large number of volatile elements (Sewagegn Yenesew, 2020).

Geochemical data clearly demonstrates a positive association with SiO_2 versus K_2O and Na_2O and a negative correlation with Al_2O_3 , CaO , MgO , and Fe_2O_3 in the majority of metavolcanic and intrusive rocks.

This would imply that mafic magma and felsic magma typically fractionate. Mafic meta-volcanic rocks have high Al_2O_3 concentrations (9.5 to 15.75 w %), low MgO concentrations (1.24 to 7.56 w %), and extremely low percentages of Cr, Mn, Ba, P, and Sr oxides (Table 3).

Table 3: Whole rock major and minor geochemical data in wt% of Ashashire, Western Ethiopia

Sample Type	S. ID	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	Na ₂ O	K ₂ O	Cr ₂ O ₃	TiO ₂	MnO	P ₂ O ₅	SrO	BaO	Total	LOI
Intercalation	CH06	49.7	11.25	9.04	8.87	3.86	1.76	0.74	0.011	0.77	0.17	0.05	0.02	0.01	96.15	9.9
Quartz veined-chlorite schist	CH04	65.9	6.65	7.06	5.59	2.82	1.01	0.32	0.01	0.83	0.11	0.05	0.02	bdl	98.38	8.01
Quartz-calcite vein	CH07	66.3	15	2.37	2.4	1.24	4.63	1.56	0.006	0.19	0.03	0.07	0.05	0.05	98.03	4.13
Meta-ultramafic	CH08	44.3	9.55	6.75	11.35	7.56	0.16	2.61	0.113	0.19	0.13	0.01	0.05	0.04	101	18.19
Meta-ultramafic	CH03	40.3	13.3	15.45	8.5	5.64	2.2	0.2	0.019	1.59	0.19	0.11	0.02	bdl	100.87	13.35
Chlorite- schist	CH10	53.5	15.05	12.3	3.88	4.32	5.85	0.13	0.003	0.7	0.17	0.14	0.01	bdl	99.51	3.46
Meta-Pelite +granite	CH02	55.9	15.75	5.97	5.72	2.71	3.85	1.83	0.006	0.67	0.1	0.18	0.04	0.04	101.77	9
Mafic tuff	CH01	42	11.6	14.45	8.95	4.8	3.14	0.04	0.013	1.94	0.21	0.16	0.02	bdl	96.23	8.91
Chlorite-quartz schist + granite	CH09	61.7	15.5	3.13	4.1	2.46	5.5	1.35	0.014	0.29	0.05	0.16	0.06	0.06	101.03	6.66
Mafic schist	CH05	45	13.25	16.45	12.25	5.23	0.94	0.02	0.018	1.68	0.21	0.13	0.01	bdl	101.48	6.29

The highest concentrations of MgO, K₂O, and Cr₂O₃ are found in Sample CH08, which was taken from sericite-epidote-chlorite schist distal to a calcite-quartz vein and has significant chloritization and epidotization alteration. The lowest concentrations are found in Na₂O, Al₂O₃, TiO₂, and P₂O₅ (Sewagegn Yenesew, 2020).

SiO₂ is compared to major and minor element oxides including Al₂O₃, Na₂O, K₂O, P₂O₅, CaO, MgO, Fe₂O₃, and TiO₂. Al₂O₃, Na₂O, K₂O, and P₂O₅ show positive trends in silica, whereas CaO, MgO, Fe₂O₃, and TiO₂ show negative trends. The negative correlation between K₂O and SiO₂ indicates that the K-bearing minerals (feldspars, muscovite, and biotite) must have crystallized and precipitated from the hydrothermal solution. Al₂O₃, K₂O, Na₂O, TiO₂, and P₂O scatter points are the result of these oxides' significant mobility during alteration and metamorphism (Sewagegn Yenesew, 2020); however they typically exhibit a positive trend.

5.1.1. Trace and REE Geochemistry

The large ion lithophile elements (LILE) Ba, Cs, Th, K, and Sr are enriched in the research area's geology, while Eu is deficient in all samples, according to the multi-element variation diagram. The compatibility and incompatibility of the elements in the hydrothermal solution and magma is implied by the depletion and enrichment.

The fractionation of plagioclase-rich magma in the magma fractionation series causes the Eu depletion whereas the low degree partial melting of LILE-bearing crustal materials causes the enrichment of LILE. Additionally, the flat trend in HFSE suggests that garnet Peridotite mantle is not the source of the magma, but rather spinel Peridotite mantle. They exhibit some ups and downs in a multi element variation diagram if they are derived from garnet Peridotite mantle ([Sewagegn Yenesew, 2020](#)).

The majority of rare earth elements (REEs), with the exception of Eu, which can also have Eu^{2+} , exhibit comparable geochemical features in petro genetic studies of igneous rocks. As a result, their geographic distribution indicates specific petro genetic processes ([Wilson M., 1997](#)). The multielement diagram in Figure 10's spikes, downs, and flat pattern displays a very high ratio of the rock's composition to that of chondrite, which may indicate that the rock was formed by only a minor amount of partial melting.

If there was a high degree of partial melting, light REEs should have shown a lower value and ratio due to their compatibility with low REEs as compared to high REEs. Since Ashashire metabasalt is enriched in large ion lithophile elements (LILE), its trace element and REE geochemistry displays a zigzag (spike and down) pattern on a chondrite normalized diagram. It also exhibits a nearly constant (flat) trend in high field strength elements (HFSE), a pronounced negative anomaly in Eu, and a spike in K as a result of the melting of K-bearing minerals. According to ([Sifeta et al., 2005](#)), this pattern is typical of island arc basalts.

Strong positive spikes at Ba, K, and Sr, as well as a trough at Ta, are indicated by the multielement spider diagram in fig. 10's discussion of the elemental geochemistry of the entire rock. According to ([Wilson M. et al., 2013](#)), these properties are thought to be typical of island-arc magmatism.

Regardless of whether they are from the tholeiitic, calc-alkaline, or shoshonitic magma series, the island arc basalts differ from basaltic magma generated at mid-oceanic ridge and oceanic island in having unique spikes at Sr, K, and Ba (Wilson M., 1997). This further supports the idea that the Ashashire metabasalt may reflect island arc magmatism.

5.2. Ore Geochemistry

After precious and base metal examinations, ten drill samples from the lithologies of metavolcanic, metavolcanoclastics, and metasedimentary are shown in Table 4 below. The majority of these samples were taken from shear zones and calcite-quartz veins. Zinc concentrations range from 18 to 157 ppm with a mean of 91, lead concentrations from 0.7 to 3.8 ppm with a mean of 2.07 ppm, and copper concentrations range from 21.5 to 274 ppm with a mean of 143.4. With a mean value of 0.673, silver levels vary from 0.01 to 1.83 ppm. Co concentrations range from 6 to 57.8 ppm on average, while arsenic concentrations range from 0.2 to 31.6 ppm on average. Gold values range from up to 8.38 ppm with an average value of 2.41 ppm, and Ni values range from 9.4 to 88 with a mean of 64.6 ppm. The seven selected trenches' assay results that were examined by GSR show that Ashashire gold accounts for an average grade of roughly 2.58g/t (Sewagegn Yenesew, 2020).

Typically, less than 10% of the vein volume is made up of muscovite, sericite, epidote, amphibole, native gold, pyrrhotite, and chalcopyrite. The veins are primarily made up of quartz, carbonate, pyrite, and chlorite. The ore's gold content ranges from 1.5:1 to 9.6:1, and although having relatively low concentrations of base metals, it contains large amounts of molybdenum (Mo) and arsenic (As). Bi has an immediate affinity for Au. But there is a connection between Co, Cu, Pb, Zn, and other elements. Gold-mineralized veins with Au > 0.5 ppm are most frequently found in quartz-carbonate veins, where they are severely damaged.

The spatial association of Co and Ni with gold may be caused by the interaction between the mineralizing fluid and the wall rock. Titanite and titanomagnetite may have both crystallized during the early fractionation stage of the magma series, as seen by the falling trend of TiO₂ in comparison to SiO₂.

Table 4: Concentration of precious and base metals in ppm at Ashashire, Western Ethiopia

Fire Assay (Au-AA25) and IC-PMS (ME-MS41) Method for Precious and base metal assay result in ppm															
Hole ID	Rock Type	Sample ID	Au1	Au2	Ag	Au2/Ag	Cu	Pb	As	Co	Cr	Mo	Ni	Sn	Zn
ASDD001	Banded and weathered chert.	CH20	0.07	bdl	0.04	Bdl	56.5	0.9	1	16.5		0.23	32.4	nd	53
ASDD001	Oxidized surface material	CH19	2.38	0.98	1.57	0.6242	232	1.7	6.2	48.9	57	0.82	71.9	0.2	133
ASDD010	Surface oxidized material	CH18	0.1	0.02	0.01	2	199	0.9	1.8	55.5	94	0.14	64.7	0.2	123
ASRCD009	Granite with recrystallized quartz vein	CH17	8.81	0.06	0.04	1.5	24.7	0.7	0.2	6	3	0.12	9.4	nd	18
ASRCD009	Brecciated chlorite-sericite-carbonate schist	CH16	10.3	8.38	1	8.38	56.6	2.4	1	25.7	7	0.28	30.6	nd	56
ASRCD009	Chlorite-sericite schist	CH15	2.99	1.59	0.46	3.45652	245	1.7	1.2	42.3	41	0.65	52.8	nd	98
ASDD010	Granite intrusive with quartz-calcite vein	CH14	2.72	1.87	0.98	1.90816	274	3.5	7.9	73.2	59	0.25	88.6	nd	157
ASDD002	muscovite-chlorite schist	CH13	6.76	2.4	0.25	9.6	21.5	3.8	3.6	35.6	41	0.84	161.5	nd	55
ASDD002	Mafic schist	CH12	2.49	2.04	0.55	3.70909	92.6	2.3	31.6	50.4	17	0.28	59.8	nd	72
ASDD002	Carbonate-chlorite schist	CH11	5.04	4.36	1.83	2.38251	232	2.8	12	57.8	50	0.08	73.9	nd	141

(Source: Sewagegn Yenesew, 2020).

Table 4 shows the results of the fire assay method and ICP-MS for measuring precious and base metal concentrations. Where Au1 represents the fire assay gold concentration and Au2 the ICP-MS gold concentration. Where --nd-- not defined.

Whereas CH11 denotes a carbonate-chlorite schist, CH12 (mafic schist) denotes an amphibole-chlorite-carbonate-hosted calcite-quartz vein, CH13 denotes a sheared muscovite-chlorite schist that hosts a quartz-calcite vein, CH14 represents sheared granite intrusive with quartz-calcite vein, Chlorite-sericite-carbonate (mafic) schist is represented by CH15, sheared granite with recrystallized quartz vein by CH16, sheared granite with brecciated chlorite-sericite-carbonate schist by CH17, weathered and brecciated surface oxidized material by CH18, highly oxidized surface material by CH19, and highly banded and weathered chert by CH20.

5.3. Gold and Sulfide Mineralization

The morphology of the minerals governs the structural regulation of the Ashashire gold deposit. Understanding the structural status of the examined region is crucial in order to comprehend the mineralization pattern of an ore deposit. It gives directions on the origin, movement, interaction with regional rock, and formation of deposits of the mineralizing fluid. According to a thorough field observation from boreholes and outcrop samples, the mineralization of Ashashire's gold and sulphide deposits is strongly influenced by micro to macro NNE-SSW trending, with 60 to 700 dipping geological structures located between virtually NNE-SSW trending shear zones.

The petrographic observation lends more credence to the concept that these structures are in charge of overseeing all aspects of ore production, including transportation and storage. The hydrothermal fluid's path determines the morphology of the mineralization. The hydrothermal gold and sulphide mineralization is preserved with shear hosted carbonized mafic schist typically chlorite-calcite, sericite, actinolite, tremolite, and muscovite, as evidenced by the metamorphic hydrothermal mineral assemblage in host rock following the carbonate - quartz veins and shearing ([Sewagegn Yenesew, 2020](#)).

In some chlorite veins as well as calcite-quartz veins, the gold is present within quartz or close to pyrite or pyrrhotite sulphide minerals. In veins of metal sulphides like pyrite, pyrrhotite, and calcite-quartz that are themselves surrounded by hydrothermally active distal alteration minerals like epidote, chlorite, and quartz, gold naturally appears as inclusions or disseminates.

Geochemical studies show that base metal and gold sulphides are frequently present in concentrations of less than 0.3% Cu. Base metals are plentiful and there is little economic concentration in Ashashire. A gold-only deposit with a low concentration of base metals replaces the deposit's previous status as a base metal and gold sulphide deposit.

Brecciation and fracturing, as well as related ferginized zones, are associated with gold-sulfide mineralization in the vicinity of sulfidized, carbonized, and chloritized alteration zones hosted in shear zones and linked quartz veins. Mineralized veins are frequently shear-hosted or chlorite-carbonate-quartz-dominated structurally controlled veins in Ashashire orogenic gold and sulphide prospects. ([Sewagegn Yenesew, 2020](#)).

Additionally, the host rocks have very little actinolite or tremolite, which are typical amphibolite facies minerals, and very little (less than 10%) sulphide minerals. The related minerals show a variety of textures, including interlocking granular textures in pyrite, magnetite, and pyrrhotite grains and euhedral quartz grains in the majority of cases. This suggests that the granular texture is the result of grains recrystallizing during metamorphism ([Sewagegn Yenesew, 2020](#)).

Gold is discovered as inclusions in chlorite-sericite-carbonate rocks of carbonate-quartz veins, sulphide minerals, notably pyrite and pyrrhotite, and in the nearby most heavily altered wall rock. Sulphide minerals are typically found in alteration haloes and ore. The primary sulphide found in most ores is pyrrhotite, which frequently coexists with pyrite and oxides (magnetite). Rarely do connected mineral assemblages include base metal-containing sulphides like galena, sphalerite, and chalcopyrite.

The majority of field and lab studies have demonstrated that carbonate-quartz veins rich in gold are characterized by visible mineralization of pyrite + pyrrhotite + magnetite, chalcopyrite, sphalerite, galena, and hematite. Pyrite and pyrrhotite are distributed differently throughout the mineralized veins, with pyrrhotite being the most prevalent ore mineral and constituting between 40 and 60 percent of all sulphide phases in the ore mineral assemblages. It is frequently found in association with pyrite, sphalerite, chalcopyrite, and magnetite.

The minerals pyrite and pyrrhotite are particularly susceptible to weathering and rapidly oxidized or tarnished. Disseminated sulphides are frequently found in association with combinations of chlorite, sericite, muscovite, and carbonates in the mineralized quartz veins. In the western greenstone belts, three forms of gold mineralization have been observed, according to a 2013 research by [Benzu Gold Mining Ethiopia](#).

Mineralization in the region has been linked to:

1. Syenite intrusions,
2. Skarn gold, and
3. Fault-shear hosted gold mineralizations in meta-sediments.

The findings of the field and laboratory investigation show that the majority of the quartz-calcite vein rims on shear zones in the schist rocks consisting of chlorite and carbonate were where the gold mineralization in the Ashashire region was concentrated.

Some granite samples subjected to geochemistry analysis show that intrusive rocks are also associated with gold mineralization. The average grade of Ashashire gold in the seven selected trenches, as determined by GSR's analysis of assay data, is 2.58g/t. While the assay results for the Benu Gold Mining fire reached 64ppm. In the fire assay geochemical findings documented for this investigation, the gold content varies from 0.02 to 10.3 parts per million (ppm) and, on average, reaches 4.17 ppm. The sample (CH20) that is made up of silicified rock has the lowest concentration, whereas the sample (CH16), which is mostly made up of quartz veins and is composed of chlorite, sericite, and carbonate rocks, has the highest anomaly of gold. It was also connected to meta-sedimentary rocks with crenulation and potassic alteration, particularly fuchsite alteration. According to inductively coupled plasma mass spectrometry (ICPMS), the same sample's (CH20) and (CH16) Au concentrations are below the detection limit (0.02ppm) and 8.38ppm, respectively. Pyrite and pyrrhotite contain inclusions of it.

The range between 0.624 and 9.6 is typically the range when the Au/Ag ratio is constantly >1. There is neither enrichment nor depletion of Ca, Fe, Mn, or Mg. Utilizing alteration mineral assemblages, alteration indices based on CO₂ and K, and pathfinder elements rich in the deposits, it is possible to identify exploration sites and vectors to ore in bedrock ([Juhani et al., 2011](#)).

The Ashashire area and its surroundings are filled with old mining pits. Most western Ethiopians engage in artisanal gold mining, particularly the Kurmuk Woreda communities who follow the river courses. This shows that placer gold is frequently sourced from orogenic lode gold deposits. The vast circum-Pacific placer fields in the California foothills belt, the Russian Far East, and central Victoria are only a few of the significant placer locations ([Goldfarb et al., 1998](#)).

6. RESULTS AND DISCUSSION

6.1. Results

To ascertain its potential for flotation-based beneficiation, the detailed mineralogical evaluation of the Ashashire gold ore deposit was investigated from a variety of published and unpublished literatures. The percentage compositions of the major and minor element oxides for the Ashashire region are shown in [Table 3](#). According to Harker diagram, the host rock shows significant compositional variations. SiO₂ ranges in concentration from 40.3 to 66.3%, Al₂O₃ from 9.5 to 15.75%, Fe₂O₃ from 2.37 to 16.45%, CaO from 2.4 to 12.25%, MgO from 1.24 to 7.56%, K₂O from 0.02 to 2.61%, Na₂O from 0.003 to 0.113%, TiO₂ from 0.19 to 1.94%, and MnO from 0. The higher loss on ignition value implies that there are many volatile components in the rock component. ([Sewagegn Yenesew, 2020](#)).

In most metavolcanic and intrusive rocks, geochemical data clearly shows a positive correlation with SiO₂ versus K₂O and Na₂O and a negative correlation with Al₂O₃, CaO, MgO, and Fe₂O₃ (fig. 9).

This would suggest that felsic and mafic magmas frequently fractionate. High Al₂O₃ concentrations (9.5 to 15.75 w %), low MgO concentrations (1.24 to 7.56 w %), and incredibly low levels of Cr, Mn, Ba, P, and Sr oxides define mafic meta-volcanics ([Table 3](#)).

Quartz and sulphides were present as inclusions while gold was developing within grain boundaries. More than 60% of the ore is made up of aluminum and silicon oxides. Due to the presence of sulphide sulphur (0.35%), the ore can be attributed to weak sulfuric acid. The inductively coupled plasma optical emission spectroscopy (ICP-OES) investigation found that the ore contained few dangerous pollutants. While the arsenic (As) content ranges from 0.5 to 1 ppm, the antimony value is quite low.

The percentage composition of the six individual sample minerals contained in the examined deposits, as determined by the quantitative assessment of minerals by scanning electron microscopy (QEMSCAN) and X-ray diffraction (XRD), is presented in [Table 5](#). According to [Fig. 5](#), the primary gangue minerals are quartz, ankerite-dolomite, muscovite, chlorite, albite, and pyrite. As depicted in [Fig. 6](#), other minerals with a small presence include rutile, magnetite, calcite, and paragonite.

Table 5: Mineralogical composition of gold deposits (wt. %) for the six individual samples

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

(Source: Kurmuk mining PLC feasibility study, 2021)

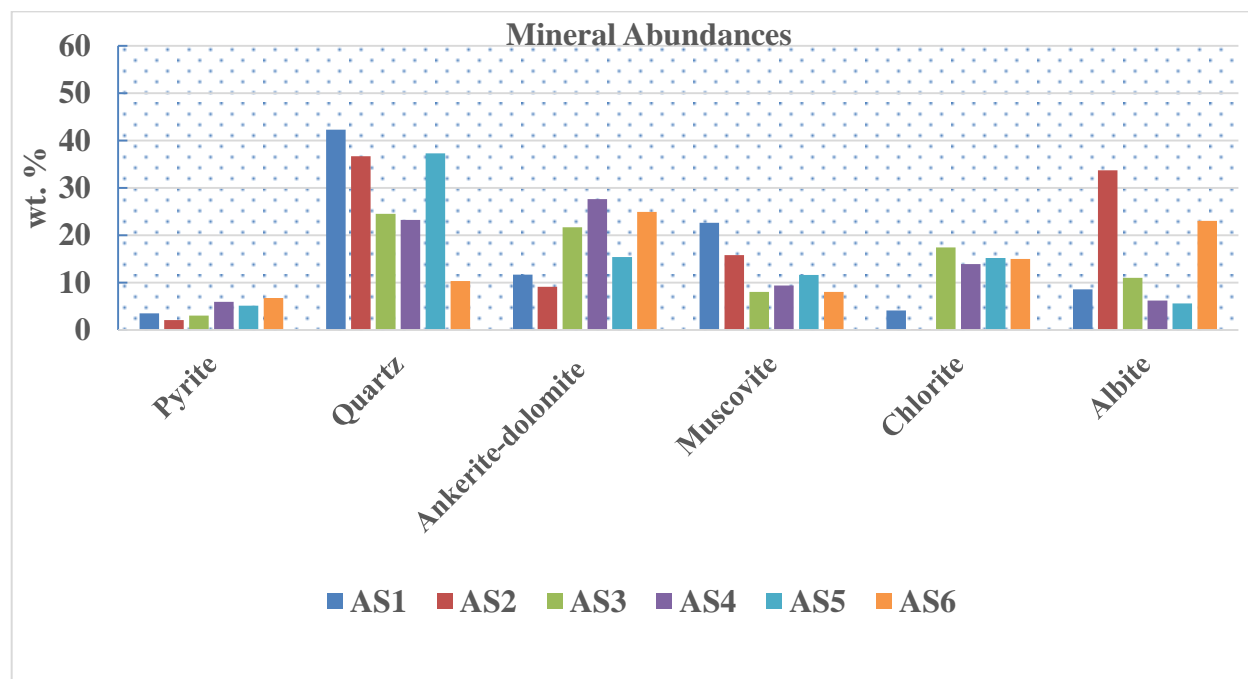


Figure 5: Mineral abundances for all samples' primary components

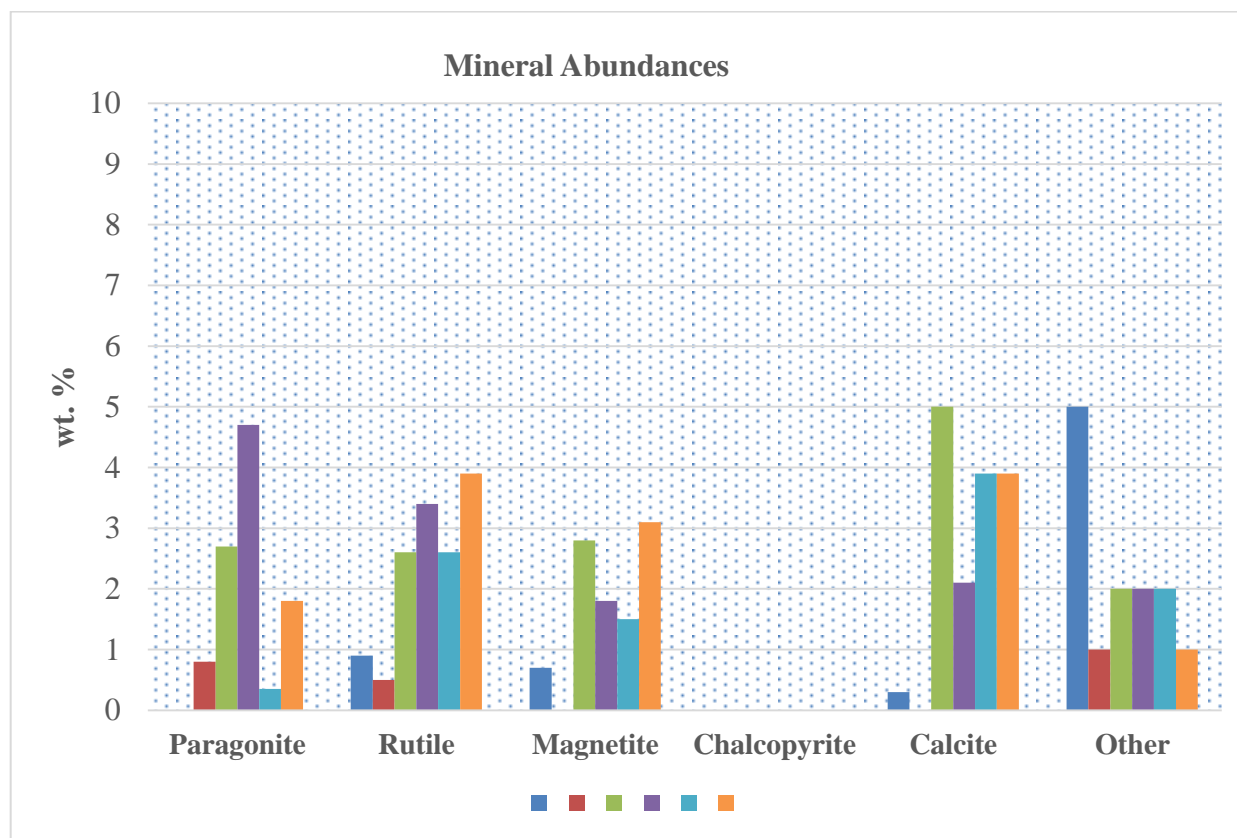


Figure 6: Mineral Abundances for secondary components for all samples

Table 6: Gold Head Assays of the six representative Samples by fire assay with atomic absorption spectroscopy (AAS) finish method

Sample No.	Rock Type	Assay 1 (Au g/t)	Assay 2 (Au g/t)	Assay 3 (Au g/t)	Average (Au g/t)
AS1	Granite	2.25	2.26	2.24	2.25
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
Total average grade					2.54

(Source: Kurmuk mining PLC feasibility study, 2021).

The native gold spans in particle size from 0.01 mm to 10 mm, and frequently exhibits a typical size distribution pattern. The average mean diameters in a given ore are 1 mm for a refractory ore including pyrite and gold tellurides, 5 mm for a typical siliceous ore containing pyrite containing 1%–3% sulphur, or 5 mm for a typical free-milling quartz-pyrite gold ore.

Table 7: Selected elemental assays of core samples by Inductively Coupled Plasma (“ICP”) method

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 sulphide	%	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

(Source: Kurmuk mining PLC feasibility study, 2021)

6.2. Discussion

Inadequate research has been done on the gold and sulphide deposits in Ashashire and the western Assosa margin. However, numerous academics, organizations, and institutions have compiled a sizable number of primary gold occurrences. Among them are the [Metal Mining Agency of Japan \(MMAJ, 1974\)](#), the [EMRDC \(1982\)](#), the [EIGS \(1991\)](#), the [Golden Star Resources Ltd. \(1997\)](#), the [Benzu Gold Mining Ltd. \(2013\)](#), and Kurmuk Mining PLC, which is now working.

On gold prospecting targets, they have performed geological, geochemical, and structural analysis utilizing core drill samples, trench and borehole samples, and stream sediment. These studies' findings supported the existence of high-quality gold.

They did not, however, describe the mineralization and paragenesis processes that gave rise to the minerals. A significant advancement in the scientific understanding of mineral resources was historically made via the study of genesis and paragenesis.

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.

The hydrothermally altered metavolcano-sedimentary rocks often surround the mineralized veins and shear zones at the proximal and distal ends, respectively. The secondary hydrothermal gangue and ore minerals, such as chlorite, calcite, quartz, actinolite-tremolite, and epidote minerals, primarily replace the host rocks. The host rocks were also replaced by minor amounts of ore minerals such as chalcopyrite, galena, pyrite, pyrrhotite, magnetite, hematite, and sphalerite.

While the quantity of Au lodes may be related to accretionary fluid processes, the source of the Au is most likely the abundant mafic-ultramafic greenstone series terrains. Due to the fact that it requires periods of continental development ([Goldfarb et al., 2001](#))

The inclusions of pyrite, magnetite, and pyrrhotite, as well as a little quantity of galena and chalcopyrite of sulphide 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.

They are fracture fillings (pyrite, pyrrhotite, chalcopyrite, galena, sphalerite, and iron oxides) that are located in the contact zone of the host rock units and are connected to some wall-rock modifications. The structural control over the distribution of the principal gold deposits and occurrences (calcite-quartz vein or strongly fractured and sheared zones; ([Moharram et al., 1970](#)) is evident.

In summary, three factors may have contributed to the Ashashire gold precipitation:

1. Hydrothermal fluid losing sulphide (H₂S), and
2. Due to the dissolution of carbonaceous metasedimentary rocks brought on by the contact with acidic hydrothermal fluid, acidification may result in the creation of traps. Additionally, this might alter the fluid chemistry and hydrogen fugacity.
3. As described by ([Ridely, 2013](#)), because of a decrease in the physiochemical conditions of hydrothermal fluid as it flows towards the earth's surface after experiencing deep fissures.

Then, it was discovered that 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.

Finally, the flotation technique is not effective for the Ashashire gold due to the following reasons:

- The main issue with the gangue minerals in the flotation of gold ore is that the amount of dolomite in the final flotation concentrate reduces 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 sulphide 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.
- A phyllosilicate mineral with a platy micaceous texture, muscovite is hydrophilic. The flotation of sulphide 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, this is the case.

It is understood from the practice of flotation of sulphide 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 the majorities of gangue minerals has an impact on gold flotation processes and increase the need for chemical reagents.

7. CONCLUSION AND RECOMMENDATION

7.1. Conclusion

The mineralogy of the ore, the gangue, and the size of the gold particles all has 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. This deposit was created by a variety of geological processes, and the structure of the rocks played a key role in the localization of ore and the flow of fluids.

The petrographic analysis reveals that visible gold grains are occasionally found as inclusions in sulphide 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. The majority of ore and alteration haloes are composed of sulphide 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.

There are several hydrothermal changes that have an impact on the studied region. These changes include sulfidation, carbonitization, silicification, sericitization, and chloritization 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 indicate 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.

7.2. Recommendations

Further in-depth work in geological/lithological description is necessary because the majority of past efforts on gold finding did not fully identify the geology or structural components. Understanding the origin of gold and sulphide minerals during mineral formation, as well as how micro- to macro-level discontinuities impact the area, is vital. In order 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.

Given the discovered gangue minerals, the flotation strategy seems to be an ineffective way to concentrate Ashashire gold. Given that these gangues use more chemical reagents and less sulphide. Then, prospective approaches for recovering gold from the Ashashire gold deposit include combining processing technologies like gravity separation, flotation processes, and leaching.

Significant improvements have been made in the hydrometallurgical methods used to recover gold during the past few decades, including cyanidation (CIL, resin-in-pulp), bio-oxidation, etc. Each of these processes has been well discussed and recorded in the literature. So we can use hydrometallurgical technology to extract the Ashashire gold deposit.

About the flotation properties of the gold present in various ores and the gold-carrying sulphides, however, very little is known. The sparse distribution of distinct gold minerals and their incredibly low concentrations in the ore are one of the primary reasons for the dearth of fundamental study on the flotation of gold-bearing ores. The flotation of gold-bearing ores then needs some basic research. There aren't many places on earth where gold tellurides are found, and there aren't many research on how to treat them. The telluride and silicate floatability difficulties at the Ashashire ore deposit must therefore be further investigated scientifically.

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