Analysis of Mine Call Factor at Meli Gold Mine (Ezana):

Implementing an Ore Reconciliation System considering key performance indicators

By

Tesfaye Medhane

Advisor:
Professor Solomon Tadesse (AAU)

A Thesis submitted to the school of Graduate Studies of Addis Ababa University, in Partial Fulfillment of the Requirements for the Degree of Master of Science in Resource Geology (Mining Geology)

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Addis Ababa University
College of Natural and Computational Science
School of Earth Sciences

June 2020
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Examining Committee Approvals

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Declaration of Originality

I declare and certify that the work contained in this thesis is my own unaided work. This work has not been submitted before for another degree or examination to any other institution or University.

The data and information used in this research were obtained from Ezana Mining Development and information regarded as confidential has been excluded.

____________________________ __________________

Tesfaye Medhane Woldegebriel Date

____________________________ __________________

Professor Solomon Tadesse Date

To all members of my family

To my wife Eleni Negash, my son Yeab and mu daughter Elhanan

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Nomenclature and list of Definitions

In addition to the definitions contained hereinafter, unless the context otherwise requires, the following terms and physical quantities have the meanings set forth below.

Unit	Description / Definition
Ag	Silver
ANS	Arabian-Nubian Shield
asl	above sea level
Au	Gold
BCM	Bulk cubic meters (bulk density)
CIL	Carbon-in-leach
CIP	Carbon-in-Pulp
cm	centimeter
Cu	Copper
DDH	Diamond drill hole
DTM	Digital terrain model
EMD / Ezana	Ezana Mining Development PLC
g/cm^3	Density, grams per cubic centimeter
g/t	a metal grade; grams per tonne
g/t Au	Gold Grade (grams of gold per tonne of rock)
Km	kilometer equal to 1,000 meters
KPI	Key performance indicator
LCM	Loos cubic meter (loos density)
m	Meter
mA	Million years ago
MCF	mine call factor
MoMP	Ministry of Mines & Petroleum
MTD	Month to Date
Oz	troy ounces, equivalent to 31.1034 grams
Pb	Lead
ppb	parts per billion
ppm	parts per million
QA/QC	Quality Assurance/Quality Control. QA describes the laboratory methods used to ensure the quality of the operations. QC describes the operational techniques used by the laboratory to fulfill quality requirements.
ROM	Run of Mine
SG	Specific Gravity
SOP	standard operating procedures
t	metric tonne equivalent to 1,000 kilograms
TD	To date (From start to Date)
tpd	tonnes per day
TTD	Total to Date
UTM	Universal Transverse Mercator
VHMS	volcanic-hosted massive sulfide
VMS	Volcanogenic massive sulfide
YTD	Year to Date
Zn	means Zinc

List of Definitions

Terms	Definition
Artisanal mining	A rudimentary method of collecting oxidized material from which gold is extracted. See also orpailleur below
Assaying	Laboratory analysis to determine the amount of precious metal. Fire assaying is the relatively most accurate method in a quantitative determination of the amount of metal present in the original sample. This method is being used at Meli to determine the grade of gold.

Bulk density (tonnage factor)	It is defined as 'mass per unit volume'. Specific gravity is one of the standard measurements studied from drill core samples. Speaking of large rock masses, within the rock mass there is void space, cavities, open fractures, porosity, etc., that reduces its overall density; would the specific gravity gives too high values if used to calculate the tonnes. Therefore, bulk density or tonnage factor should be estimated and used in resource/reserve calculations.
Country (Wall) Rock	A rock found adjacent to the ore and its host, or the rock encompassing or traversed by a mineral deposit.
Cutoff Grade	It can be divided as analytical cutoff, geological cutoff, economic cutoff, monetary cutoff. Economic cutoff grade means the lowest grade of mineralized material that qualifies as ore. Analytical cutoff means the lowest grade accepted to be processed or estimated. Cutoff grades are normally expressed in g/t (grams per metric tons) or Oz/t (ounces per short ton) for precious metals.
Feed	A feed is an Ore that is hauled to the concentration plant for enrichment.
Lode	either a single vein or a system of related roughly parallel vein
Mineral	Naturally occurring element or inorganic substance having a definite chemical composition and crystalline structure.
Mineral Deposit	A general name for a delineated and quantifiable natural mineral enrichment possibly of economic value.
Mineral resource	An accumulation, occurrences, or showings in such form and quantity that economic extraction of a mineral or substance from the deposit may be currently or potentially feasible. Practically classified as measured, indicated, inferred mineral resources.
Ore (mineral) reserve	Part of a mineral resource on which additional satisfactory technical and economic studies have been carried out to demonstrate that it can justify mining under specified conditions. Practically categorized as proved, probable ore reserve. It includes planned dilution and ore loss.
Ore Loss	Part of an orebody that is not recovered during a mining process. Expressed in a percentage, usually, the term ore recovery used to define the ore loss.
Orpailleur	means a traditional local miner using rudimentary means to collect oxidized surface/sub-surface material from which gold is extracted
Prospection	The second phase of strategic exploration (after reconnaissance) for target identification. The objective is the discovery of a prospect that will be the target for further exploration
Reconnaissance	The first phase of exploration strategy to identify mineralized areas, after target selection, in previously unexplored regions.
Recovery	It can be termed as mining recovery, concentration recovery, metallurgical recovery, etc. it is the percentage of valuable minerals or metal obtained from ore at different stages of mining and processing.
Stockwork	Despite lode, it is a mass of intersecting veins.
Vein	Somewhat narrow tabular mineralized structure deposited due to late magmatic-hydrothermal fluid or circulating groundwater.

Preface

Every mining project is established based on a geologic unit, known as a mineral deposit (an ore). The main aim of the mine geologist is to evaluating known ore bodies and finding more ore to keep the mine running. The responsibilities also include defining an ore relate to geologic factors in the design, planning, and operation of a mine; to characteristics of the ore that is handled in the mineral processing plant.

In integrating the mining with the environment, social concerns, and effectively managing systems (like proper reconciliation system outlined in this study); Geology and Mining are two essential components for economic growth and sustainable development of a country.

As a major contributor to the economy, responsible gold mining companies also have ethical and commercial incentives to improve the health and education of the communities that they operate in. They can significantly invest in programs that have important benefits for the local community. The programs include but not limited to social responsibility programs (schools, colleges, health centers, etc.), building infrastructures (power, water, road, etc.), and Community development programs (education, entrepreneurship, agriculture, healthcare, etc.), and build local supply chains (encouraging entrepreneurship and helping existing local businesses grow).

Naturally, the study area is very promising as part of the ANS, where the first gold mining started in human history which also hosts the VMS deposit that yields multiple metals from single ore like Au, Cu, and Zn. Although the ANS of northern Ethiopia is less explored than those in Sudan and Egypt, we can take a lesson from their studies due to the confirmed geology and deposit similarities to that of Bisha, in Eritrea. As all previous studies, the latest ongoing modern study by Sun Peak company (The same team that study and discover the Bisha and Asmera deposits) forms a Joint Venture with Ezana Mining, confirmed the potential of the study area showing a VMS trend over 10km long. The Large EM and gravity geophysical anomalies located under gossans and on-trend – are similar signatures to both Bisha and Emba Derho Deposits.

In addition, the gold processing activity requires a significant amount of water that can make the region attractive since the country is known as the water tower of Africa. The area's resource potential, coupled with the enthusiasm and dedication of the hardworking community to achieving success, the author believes that the mining will significantly benefit the company and the economy.

Acknowledgments

Thank you, God, for the almighty!

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First, I thank my advisor, Prof. Solomon Tadesse, I've always admired at his unique ability to creatively think outside the box and help to solve and untie problems. I'm indebted to him for the infinite personal support and encouragement throughout the difficult Journey since the source and access of the project area to this date.

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I wish to thank, Mr. Tesfaye Gebre (a metallurgist at EMD), for the incredible help he has given me, and most of all, for his friendship and the brotherhood we have formed during my stay on the mine site.

I wish to thank the enormous generosity of Meli Gold Mine of Ezana (EMD) in supporting the greater part of my stay at Mines. I am deeply indebted to the best leader Mr. Tsegaye Bahta, the general manager of the Meli mine. I am very grateful to Mr. Atakility Araya; this thesis would not be possible without his support.

I wish to thank my best friend, and a brother, Eskeadmas Yinesu, who provided precious advice and support. I thank my friend, Anteneh Tesfaye, for being so incredibly supportive and for having always sacrificed so much for me. Thank you!

Abstract

The study area is located in the promising geological region, the ANS, where the first gold mining started in human history which also hosts the VMS deposit that yields multiple metals from single ore like Au, Cu, and Zn. Mining helps for sustainable development, however, involves high levels of complexity and uncertainty which require huge capital investment and risk.

The most profitable way to exploit a mineral deposit requires continuous evaluation and planning. One practical method is to compare what was planned and what is achieved using MCF. It is the ratio, expressed as a percentage, of the gold called for to the gold accounted for.

If everything went well, the comparison of what the mine delivered to the plant and what the plant received and processed must be as close as possible equal or an MCF of approximately 100%, a situation that is impossible in practice, hence an MCF of 85% was considered reasonable for shortfalls as per different practices in different mining operation. Using additional data and study, this case study will help to draw a national standard in the MCF acceptable values.

The design capacity of the plant is 35 tonnes per hour. Considering the designed plant schedule, the crusher has a capacity of 12,500 tonnes per month crushing. The actual total crushed tonne is 175,742, with an average of 5,325 tonnes per month. Considering the crusher plant design capacity plan, the achievement is 42.6%. The total reconciled total mined and hauled ore were 281,246 tonnes with an average monthly of 8,523 tonnes, indicating that the shortfall is not due to ore supply; instead, it linked to the process plant related to various factors, mainly frequent and extended shutdown of the mill due to many reasons which are not the scope of this research.

With the assumption of a metal recovery of 90.6%, the assumed metal recovered is 25,565 ounces which contributes to an MCF of 85.9%. Though the operation is within the acceptable range of MCF values, it requires studying and addressing the shortfalls. The MCF suggests that gold losses averaged at 14.1%, which implies a 14.1% of the expected revenue was not realized and this translates into negative financial underperformance.

Total ore reserve is estimated at 515,837t@4.81 Au g/t contained 79,748.38 Oz of gold; with the design 92% recovery, the expected gold recovered is 73,368.51 Oz. As at March 2020, the mine extracted 55% (281,246t) of the reserve mass, indicating a 45% (234,591t) tonnes still remain on the ground. The plant processed 62.5% of the tonnes hauled from ROM stockpile, which is only 34% of the total reserve in terms of tonnes.

1

Chapter I: Introduction

Author Picture: Excavator loading an Ore at Meli Open Pt Mining. March, 2020

1.1. Background of the study

Mining operations in general involve high levels of complexity and uncertainty which require huge capital investment and risk. Every mine has unique characteristics. The variance can be due to the natural characteristics of the ore or due to the operational parameters of the extraction method. To be best profitable in mining, it requires continuous evaluation and planning over a time period using updated planning and production data. Unfortunately, almost all operations share the same problem, the discrepancy between what is planned and what is achieved (Muncher Ricketts, 2016).

Thus, for efficient mining, it is necessary to compare the actual production recovered with the desired plan. These two estimations must be as close to each other as possible; or equated to approximately 100 percent, a situation that is impossible in practice (M. N. M. Tetteh, 2014).

The Mine Call Factor is the ratio, expressed as a percentage, of the gold called for from all sources to the gold recovered plus residues in the metallurgical plant (M. Tetteh et al.). An efficiency of 100 percent would equate to complete success, but a figure of at least 85 percent would be considered acceptable. Unfortunately, the Mine Call Factor (MCF) on many mines is below acceptable norms (De Jager, 1997).

1.2. Some important definitions

For the purpose of this research, the following, somewhat modified, definition will be used:

1.2.1 The meaning of ore

Ore is an aggregate of one or more metalliferous minerals, which can be mined, processed, and sold at a profit (Abzalov, 2016). In economic geology, there is a difference between Ore deposit (Orebody) and mineral deposit. An orebody is that part of a mineral deposit that can be mined and marketed at a profit under contemporary technological, economic and legal conditions. Economic conditions and technology are constantly changing, as are the laws, taxation, and restrictive policies of governments. All of these factors dictate whether a deposit of a specific mineral is or is not an orebody (Lacy, 1998).

1.2.2 Waste and Gangue Minerals

Within a given mineral deposit ore minerals are normally associated with other minerals which are less valuable or lack value (Lacy, 1998). These are termed *Gangue Minerals*. The rock which does not contain an adequate percentage of ore minerals to be economically valuable as a source of these minerals is called *Waste*. Waste, like ore, is an economic rather than a geologic term, and changing technology, economic, or political conditions may change waste to an ore, or back again, many times (Lacy, 1998).

1.2.3 Exploration and Exploration Information

Exploration: The search for a mineral deposit (prospecting) and the subsequent investigation of any deposit found until an orebody if such exists, has been established. Exploration information: Information (Figure 1) that results from activities designed to locate economic deposits and to establish the size, composition, shape, and grade of these deposits. Exploration methods include geological, geochemical, and geophysical surveys, drill holes, trial pits, and surface underground openings. (Hustrulid et al., 2013). Term: deposit, mineralization, ore, resource, reserve, etc.

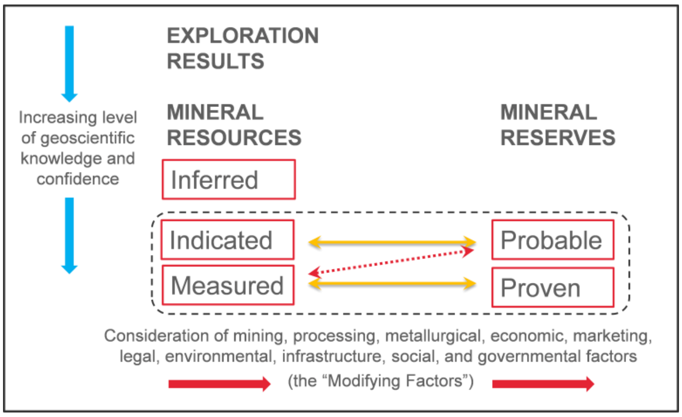


Figure 1: Relationship of exploration information (SME, 1992)

1.2.4 Mining Cycle or Mine-development phases

The mine development can be summarized in four phases (Figure 2). In response to the demand, financial resources are applied in an exploration phase resulting in the discovery and delineation of deposits. These deposits are thoroughly evaluated regarding their economic attractiveness. The conclusion of this phase will be the preparation of a feasibility report. Based on this, the decision will be made as to whether or not to proceed. If the decision is 'yes', then the development of the mine and concentrating facilities is undertaken. The Development phase consists of two stages. The design and construction stage includes design, procurement, and construction activities. This is called the implementation, investment, or design and construction phase. Then, there is the production or operational phase during which the mineral is mined and processed (Hustrulid et al., 2013). The Extraction or production phase also has two stages (Lee, 1984); the startup stage and operation stages. Finally, there is a mine closure and reclamation phase.

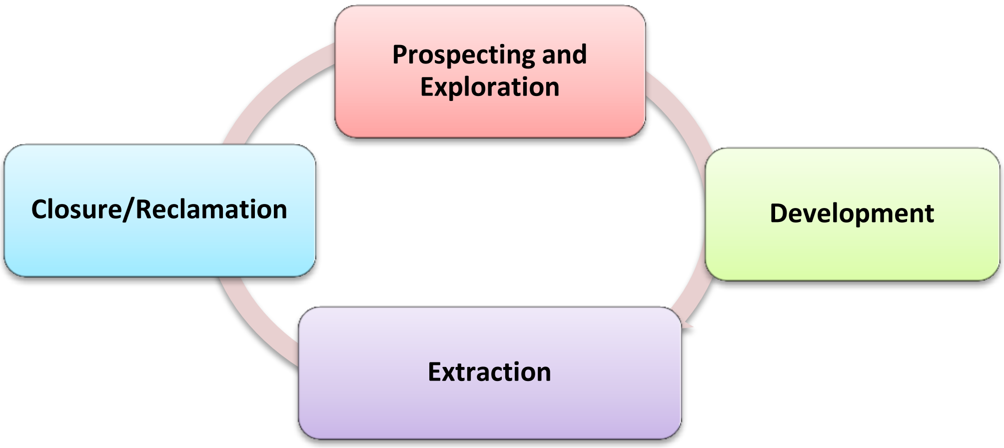


Figure 2: the Life Cycle of a Mine

Table 1: General Time and Cost breakdown of a mining cycle
A breakdown on time requirements for various exploration and development stages was proposed by Allen, 1956 as described in (Lacy, 1998)

Stage	Cost	Time
Reconnaissance	- 1 unit	1-20 years
Examination and evaluation	- 5 units	½ - 3 years
Mine development	30 units	2 - 5 years
Plant construction	80 units	2 - 3 years
Initiating production	7 units	1 - 6 months

According to the largest gold information database, the life of mine has been classified as follows: (World_Gold_Council, 2020)

I. **Gold Mine Exploration**: (1 - 10 years)

As the Gold mine exploration is challenging and complex, it demands significant time, financial resources, and expertise in various professional disciplines. It is mainly characterized by a very low probability of a discovery leading to a mine being developed, with less than 0.1% of prospected sites that will lead to a productive mine. At this stage, the basic facts about the local geology and potentially viable deposit are established.

II. **Gold Mine Development: 1 - 5 years**

This second stage involves the planning and construction of the mine and associated infrastructure. Depending on the location and applicable laws, mining companies must obtain appropriate permits and licenses before they can begin construction. Construction may not be limited to the mine itself, but also construct local infrastructure and amenities to support both logistical and operational needs, as well as employee and community welfare.

III. **Gold Mining Operation: 10 - 30 years**

This stage represents the productive life of a mine, where the ore is extracted and processed into gold. During its life, a number of factors – such as the price of gold or input costs – will affect which areas of an orebody are deemed profitable (economic) to mine. In times of higher prices, mining low-grade ore will become profitable as the higher price offsets the increased cost of extracting and milling greater volumes. When the price is lower or costs rise, it might only prove profitable to extract and process higher-grade ores. Mine plans are regularly re-assessed as market conditions change and new technical information comes to light (World_Gold_Council, 2020).

IV. **Gold Mine Decommissioning: 1 - 5 years**

After a mine has ended operations, possibly because the ore body is exhausted or the remaining deposit becomes unprofitable (uneconomic) to mine, work then focuses on its decommissioning, dismantling, and rehabilitation of the land in which it was situated. As Gold mine closure is a complex undertaking, it will require the operating company to monitor the mine site long after the mine has been closed usually for a period of five to ten years or more. Over this time, the land will be rehabilitated – cleansed and revegetated – and the mining company will work to ensure the gold mine reclamation and return to long-term environmental stability are successful (World_Gold_Council, 2020).

1.2.5 Mining and Milling

For the purpose of this paper, mine and mill are defined as follows:

Mining is a process of digging into the Earth to extract the Ore or other naturally occurring geologic material that is of economic interest to the miner, using them either on the surface or underground, includes ore movement (handling, loading, and hauling) to the run-of-mine (ROM) material pad.

Milling is the process of crushing, grinding and treating raw material from the mine to extract a saleable product. It also involves the processes of loading and transporting of broken ore to the mill via front end loaders (FEL) or conveyor belts in the plant.

1.2.6 Key performance indicators (KPIs)

KPIs are vital management tools. Key performance indicators (KPIs) are the vital navigation tool used by the mining companies to understand whether their operation is on a successful achievement or whether it is swinging off the planned target and budget. The right set of indicators will shine a light on performance and highlight areas that need attention. Without having and analyzing the right KPIs mining operators are sailing blindly.

KPIs have to measure what matters. For KPIs to be the critical navigation instruments that help you understand whether the operation is on the right track or not, we have first to define the strategy and then closely link our KPIs to that. KPI development has to start with the strategy and objectives the business is aiming to achieve. There are generally three reasons why performance measures: to learn and improve, to report, to demonstrate compliance, and to control and monitor.

Example KPIs for the Mining Industry includes but not limited to: Average bucket weight, Average fuel use per machine, Average loading time, Cash operating costs per tonnes/ounces, Cycle distance, Cycle time, Dilution of ore, Dump time, Efficiency of metallurgical recovery, Incident rate (accidents, etc.) per x hours, Percent (metal, etc.) in ore, Production cost per unit, Production rate-bank cubic meter (BCM)/ hour (cubic meters of material moved per hour), Tons of ore feed, Tons per hour, Tons per load, Unit variable costs, Utilization, Waste per ton, Waste volume, etc.

For the purpose of this report, the set of KPIs would be tonnage, ore grade, metal content, stripping ratio, truck factor, loader factor, specific density (SG), and mining and processing operating manuals and procedures. These KPI's data are available and sufficient to analyze the mine call factors, and further to justify future studies.

1.3. About Gold

Gold is an element with symbol Au and atomic number 79 ($_{79}Au$), which means there are 79 protons in the nucleus of every atom (World_Gold_Council, 2020). In a pure form, it is a bright, slightly reddish yellow, dense, soft, malleable, and ductile metal. Gold usually occurs as a native form, found as nuggets or grains in host rocks, in veins, and in alluvial deposits. (https://www.gold.org/about-gold)

Gold is a precious metal. It has emotional, cultural, and financial value and different people across the globe buy gold for different reasons, often influenced by a range of national socio-cultural factors, local market conditions, and wider macro-economic drivers. (https://www.gold.org/about-gold)

The use of gold as money has a long history, but gold relinquished this role after the outbreak of the Second World War. Throughout history, gold has been treasured for its natural beauty and radiance. For this reason, many cultures are using gold as jewelry. Though yellow gold is the most popular color, also gold is available in a diverse palette.

Other uses of gold include in new Innovative uses (the internet, protect the astronauts and equipment from radiation and heat, for use in catalytic converters, and gold's unique properties play a role in the production of a range of chemicals we all use on a day to day basis), in Medicine, in Environment, Engineering and aerospace, and in New technologies. (https://www.gold.org/about-gold)

Gold's properties define gold as the material of choice to guarantee the reliability of performance. Gold's unique properties and versatility make the metal indispensable in engineering and electronics, and its application as a nanomaterial is offering new solutions to a range of global health and environmental challenges (World_Gold_Council, 2020). These unique properties of gold include: Conducts electricity, resistant to corrosion, exceptionally malleable and ductile, Catalytic properties and Biocompatible.

The boiling point of gold is 2,808 degrees centigrade. Gold melts at 1,064 degrees centigrade. Around 187,200 tonnes of gold has been mined since the beginning of civilization (World_Gold_Council, 2020).

1.3.1 About gold jewelry Color

Yellow gold jewelry is still the most popular color, but today gold is available in a diverse palette. The process of alloying—mixing other metals with pure 24-carat gold—gives malleable gold more durability, but can also be used to change its color (World_Gold_Council, 2020).

White gold is created through alloying pure gold with white metals such as palladium or silver. In addition, it is usually plated with rhodium to create a harder surface with a brighter shine. White gold has become the overwhelming choice for wedding bands in the US. The inclusion of copper results in the soft pink complexion of rose gold while the more unusual color such as blue and purple can be obtained from the addition of patinas or oxides on the alloy surface. Black gold for example derives its color from cobalt oxide. (World_Gold_Council, 2020)

1.3.2 Gold Carat

The weight of gold is measured in troy ounces (1 troy ounce = 31.1034768 grams), however, its purity is measured in 'carats'. 'Caratage' is the measurement of purity of gold alloyed with other metals. 24 carat is pure gold with no other metals. See Table 2.

The minimum caratage for an item to be called gold varies by country. In the US, 10 carat is the legal minimum accepted standard of gold caratage, 14 carats being the most popular. In France, the UK, Austria, Portugal, and Ireland, 9 carat is the lowest caratage permitted to be called gold. In Denmark and Greece, 8 carat is the legal minimum standard. (World_Gold_Council, 2020)

1.3.3 Gold Fineness

Fineness is another way of expressing the precious metal content of gold jewelry and represents the purity in parts per thousand. When stamped on the jewelry, usually this is stated without the decimal point.

Table 2 shows some examples of the composition of various caratages of gold.

Table 2: About Gold jewelry characters (World_Gold_Council, 2020)

	Caratage	Gold(Au)	Silver (Ag)	Copper (Cu)	Zinc (Zn)	Palladium (Pd)
Yellow Gold	9k	37.5%	42.50%	20%		
Yellow Gold	10k	41.70%	52%	6.30%		
Yellow Gold	14k	58.30%	30%	11.70%		
Yellow Gold	18k	75%	15%	10%		
Yellow Gold	22k	91.70%	5%	2%	1.30%	
White Gold	9k	37.5%	62.5%			

White Gold	10k	41.7%	47.4%		0.9%	10%
White Gold	14k	58.30%	32.20%			9.50%
White Gold	18k	75%				25% (or Pt)
White Gold	22k	N/A	N/A	N/A	N/A	N/A
Rose Gold	9k	37.5%	20%	42.5%		
Rose Gold	10k	41.70%	20%	38.3%		
Rose Gold	14k	58.30%	9.2%	32.5%		
Rose Gold	18k	75%	9.2%	22.2%		
Rose Gold	22k	91.7%		8.40%		

It means the fineness of 14 carats should be 583 (14/24 = .583333). Similarly, 24 carat should be 1.0 (24/24 = 1.00). However, in practice, there is likely to be a very slight impurity in any gold, and it can only be refined to a fineness level of 999.9 parts per thousand, this is stated as 999.9.

1.4. Overview of Ezana Mining

The study is being conducted at Meli Gold Mine owned by Ezana Mining Development PLC. Currently, the mining is ongoing on the Gossan (Figure 4). The basement rock is in the southern part of the Arabian-Nubian Shield, which is characterized by the presence of Precambrian low-grade metamorphic rocks (Bheemalingeswara et al., 2012).

The deposit has a hematite/goethite gossan cap on the surface that ranges in vertical thickness up to 30 m, and extends in strike length about 100m, having about 2t of gold (Bheemalingeswara et al., 2012).

The diamond drilling program has confirmed about 20-30m thick VMS deposit presence beneath the gossan, however, the company plan is only to mine the gossan currently (Samuel-Abraham et al., 2015).

Figure 3 Author photo of Trenched gossan at Meli for grade control

Figure 4: Author's photo on the main Gossan of Meli (Nov 2019)

Grade control sampling is done using trenches across the ore body on the gossan (Figure 3). The depth of the trench is 1.5m, the results will be extrapolated for a 3 m mining bench or bolck.

1.4.1 Location and Accessibility

The Project is located in the Northwest Tigray State of northern Ethiopia, about 1150 km NNW of the capital Addis Ababa, and can be accessed via air from Addis Ababa to Shire (also known as Inda-Selassie), followed by road South westward about 72 km from the Shire to the project area. The project area can be accessed from the Shire via a paved highway Southwestern direction along the Gondar highway until to Indabaguna (20km), followed to western direction by all-weather gravel road to Edaga-Hibret (26Km) and turn to the south on rough road access in rugged topography to the mine project site (26Km). It also can be accessed through Hitsats-Edaga-Hibret which is longer by 14 Km than the above route.

In addition to the Shire, Axum (A tourist city, 132 Km from Meli) and Mekele (A capital city of Tigray, 382 Km from Meli) have international standard airports.

Table 3: Location and UTM Co-Ordinates of Meli Gold Mine

Administration Location		Meli Prospect UTM co-ordinates
Country	Ethiopia	**0397061mE and 1544113mN**
Region	Tigray Regional National State	**0397231mE and 1542620mN**
Zone	North-Western Tigray	**0393591mE and 1543713mN**
Wereda	Asgede-Tsimbila, Limat Tabiya	**0393804mE and 1542716mN**
Locality	Near Meli Village	

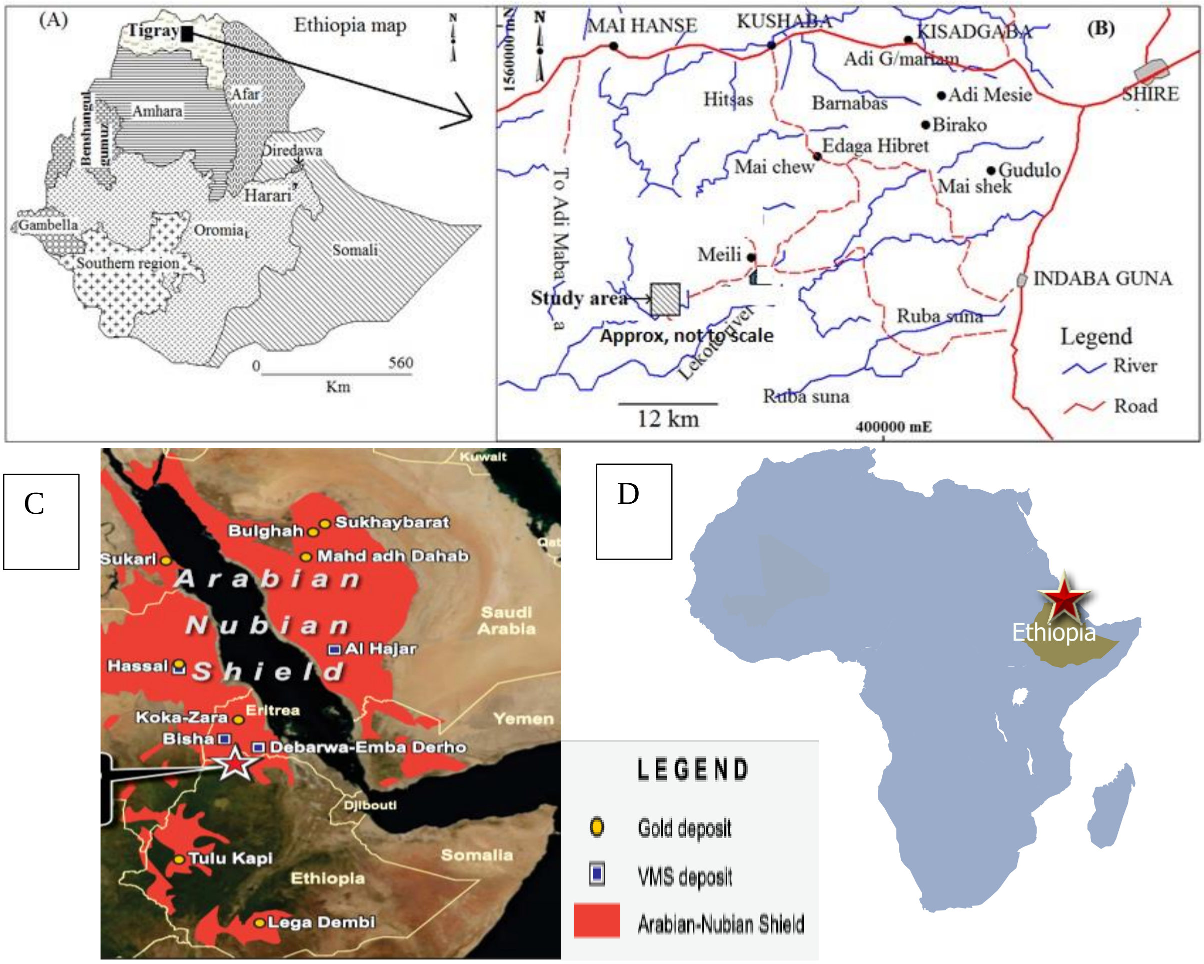


Figure 5 Location Map of the study area, modified after(Mickiale et al., 2017)
The figure indicates (A): Ethiopian Map, (B): Western Tigray, (C): ANS location, and (D): Africa

Figure 6: Boulders at Meli Gold Mining (Picture by author)

1.4.2 Physiography

The Physiography of Meli Gold Mine locality is characterized by gentle, undulating, and dissected topography at its eastern part and rugged hilly relief at its central and western part. Both the first and second-order streams flow to the south to Lekhote River which is one of the major tributaries of the Tekeze River. The area has abrupt relief of altitude ranging between 1127m and 1315m above sea level.

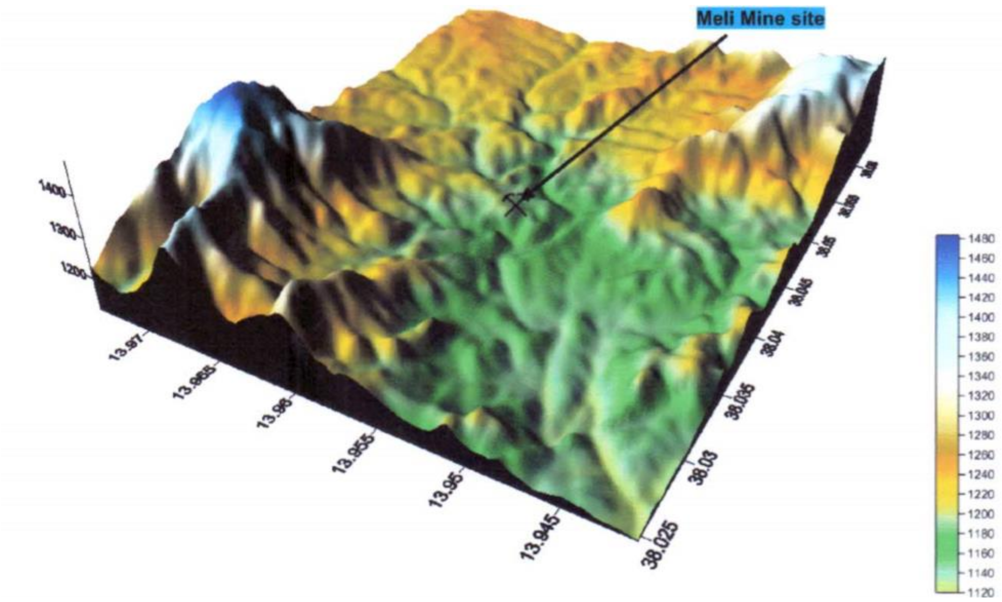


Figure 7: Digital Elevation Model of Meli Gold Mine(Ezana_Private_Report)

1.4.3 Vegetation and Climate

Most of the region is devoid of vegetation, with some parts consists of various types of short grasses and small trees commonly located near drainages and steeper slopes. The project region is characterized by a temperate to hot climate and has both dry and wet seasons. The rainy season extends from mid-June to mid-September, and expected high temperature in March and a minimum in January.

Table 4: Meli Gold Mine Weather summary (Ezana_Private_Report)

Altitude	1200 m
Atmospheric Pressure	840 mbar
Min. Temperature	5 ^{0}C
Max. Temperature	45 ^{0}C
Annual Average Rainfall	900 mm
Relative Humidity – Average	46 %
Wind speed - Maximum	25 m/s

Figure 8 Picture taken from Meli camp view (vegetation by EMD)

Figure 9: Author Picture showing Meli Gold Area land covers (March 2020)

2

Chapter II: Research Defining & Methodology

Author Picture: Truck hauling an Ore from Pit to Rom Stockpile

2.1 Problem Statement

The estimated in situ gold is usually disagreed from what is finally produced at the process plant. There are several reasons which contribute to this variance. Until proper data analysis from different measurement points taken that can lead to variance, it would become difficult to establish where the actual causes are and solve or minimize the problem. From site visit, the author learned there is a discrepancy between what is the mine called for and what is received or processed. The preliminary assessment of the process leads to the presence of the problem.

The problem can arise from issues such as inaccurate grade control results, movements during mining, poor mining supervision, crushing cycle, inaccurate weightometer readings and recoveries, poor assay strategy, and residue estimation. Metal losses can be reduced to the minimum if there is an understanding of the problem and compliance to implement protocols, which serve as standard operating procedures (SOP).

2.2 Significance of the research

Using mine to mill reconciliation process, or using mine call factors, first, it helps to examine what happened to the ore tonnage and grade that is not reflected further along the production process. Then, it defines how much of the product was lost in the extraction system or gives an indication of how accurate the estimate turned out to be compared to the quantity of metal recovered plus residue (Ana Carolina Chieregati et al., 2009).

The comparisons of what the mine delivered and what the process received must be as close as possible equal or an MCF of approximately 100%, a situation that is impossible in practice, hence an MCF of 85% was considered reasonable for shortfalls. The tonnes and grade variances are separately examined together along with the total metal content.

The factors then used for adjustment for Shortfalls and excesses of tonnage and grade discrepancies also enable us to use correct densities (especially LCM) and accurate truck or bucket factor measurements for calculating tonnages of ore loaded (Storrar, 1981).

The understanding of MCF generally helps for improving the quality of ore mined and fed to the mill for the mine to operate efficiently. The significance of the MCF includes:

- to know the relationship between ore mined and delivered for processing
- to measure the performance of the operation against the plan,
- to confirm grade and tonnage estimation accuracy,
- to ensure the valuation of mineral assets is accurate, and provide production key performance indicators,
- helps to a better understanding of the ore for better estimation and ore mark-ups both one the plan and on the ground, thus maximum mining and process recovery,
- reduce or minimize ore loss and dilution,
- for better planning and scheduling

As indicated in the number of literature and standing facts, well-managed Gold mining is a major economic driver for many countries across the world. In addition to its bringing foreign direct investment, foreign exchange and tax revenues to countries, it is a major contributor to the creation of direct as well as indirect employment and business opportunities for local people.

2.3 Research key questions to be answered

What is the impact of mine call factor problem on Ezana open-pit gold mine?

In order to meet the objectives of this study, the following questions are posed:

(1) What is the reporting relationship between ore mined and delivered for processing?

(2) Where do Ore measurements originate and end in mining and process networks?

(3) What criteria do they use to measure and adjust ore tonnes and grade on process flowsheets?

(4) How is Ore measurement and reconciliation conducted on a routine basis?

(5) What (which) is the best practice for ore reconciliation for the project?

2.4 Research objectives

2.4.1 General objectives

The main goal of this study is to analyze the mine call factor and to subsequently understand the source of the problems within the mining and process flow network in the objective of improving the quality of ore mined and fed to the mill.

Then, by clarifying the research theory and methods, the thesis will present the empirical results of the investigation, the main conclusions, and recommendations.

Finally, the result can be taken as a case study together with the theoretical approaches, which will help to develop a protocol or SOP in regards to mineral and metal accounting practices, with a further study which can be a national standard.

2.4.2 Specific Objectives

The metal accounting protocol was developed on tonnage measurement, QAQC methods, and analysis as well as mine to mill reconciliation with a focus on the mining department.

Further study to cover up to the plant and processing sections of the mine to unite the mining and processing units into a single system (perhaps called operation) will be a positive step towards dissolving the historic mine to mill boundary. The objectives of the research include:

- To investigate the MCF and prepare the actual reconciliation table, which is a key for future optimization of all the key parts of an operation, leading to the best possible utilization of the resources.
- To understand the relationship between ore planned, mined, delivered for processing and output
- To develop an ore flow chart from the pit to the crusher,
- Development of guidelines for data collection, data analysis, and reporting
- To develop an integrated database (Using Microsoft office) to unite the mining and processing data into a single system to generate a key performance indicator (KPI)
- Establish ore reconciliation system using MS-Excel;
- Analyze variances over time and space and investigate causes of those variances;
- To develop mitigation measures can be put in place to minimize variances at those points which should lead to minimizing overall mine call factor variance,
- Creating a Mine Site Reconciliation procedures, which is a guide to reconciliation that allows others to understand the practices used at Ezana mine site and details who is accountable for the reconciliation system

- Improvement of Ore accounting from deposit to process through the implementation of an integrated reconciliation system.

2.5 Assumptions

The assumptions used in this research study are: -

- The MCF is only affected by the possible cause of losses highlighted hereafter
- As not available to get actual gold bullion data, it is estimated from available 8-month processing recovery and the ores data delivered to the plant.
- The MCF can be reliably used to indicate areas where the gold loss occurs, at Meli Gold Mine

2.6 Anticipated results / Outcome

The expected outcomes are to identify which area has the highest variance and to minimize the overall effect of mine call factor.

The mine's current quality control protocol will further be expanded to reflect current practices. The mine to mill reconciliation analysis compares production estimates from various sources (resource/reserve model, grade control model, truck tally, stockpile, and plant received/feed) in the period from operation started to February 2020. The anticipated result will be:

- reduced ore loss and dilution
- better reconciliation between mill and mine
- an improved grade control system
- greater consistency in the interpretation of ore outlines; and
- ultimately will improve mine profitability and productivity

2.7 Methodological approach

The research will use an approach combining both quantitative and qualitative techniques:

- Quantitative: analysis and interpretation of data from the mining.
- Qualitative: interviews and literature reviews.

2.8 Data collection and analysis methodology

After conducting a site visit to obtain a better understanding of ore flow and method of operation, the author will gather both forecasted and actual data. The data will be coded, sorted, and cataloging in either way or a combination of the following categories:

- Spatial: geographic area (bench, or ore zone);
- Temporal: by time period (monthly, quarterly, yearly); and
- Physical: by the process

The data includes:

- ➢ Existing standard operating procedures for measuring volume, tonnage, relative density, grades, method of evaluation, grade control procedures, sampling, and Assaying.
- ➢ Month-end survey measurements (monthly mine advance survey and tally)
- ➢ Tonnage and grade from the long-range model, short-range model, and grade control model for the period. This data can be generated by overlain the mine advance survey on the models for capturing tonnage and grade produced for the period.
- ➢ Month-end tonnage and grade from mining production.
- ➢ Month-end inventory of stockpile tonnes and grade,
- ➢ Crusher feed on the mine and/or stockpile
- ➢ Mill feed/mill received/processed Tonnage and grade, usually known as head grades and tons. Processing grades from assay results reported from direct sampling, as opposed to back-calculated from tailings grades and adjusted recoveries. Back calculated head tonnage and grades should not be used for model optimization (Rossi et al., 2014).

The specific method and data analysis approach is described in chapter 5 of this report.

Using the data and information from design and production, we can produce Mine call factors, sometimes known as mine Call Factors (MCF), as defined and proposed by (Parker, 2012; Rossi et al., 2014) and are further outlined by many scholars including (Amoako et al., 2015; Bester et al., 2016; A. C. Chieregati et al., 2019; Nielson, 2018)

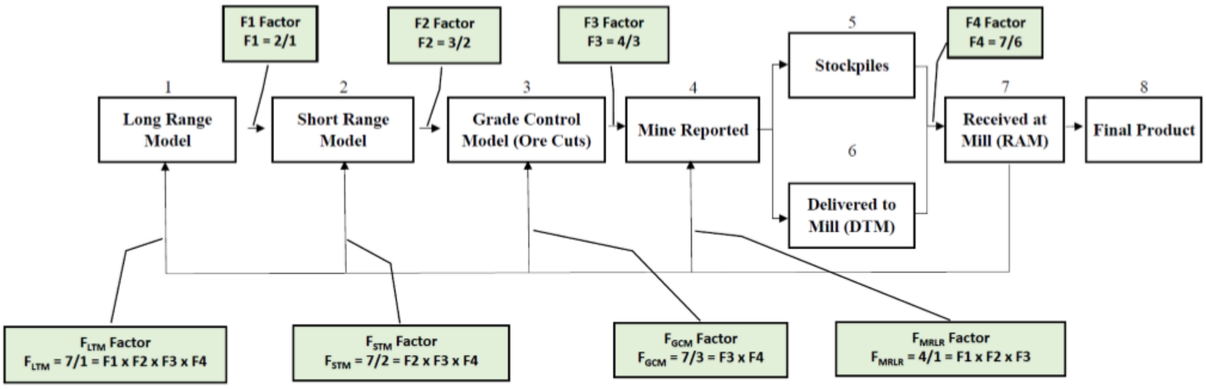


Figure 10 relationship of each factor along the mine value chain(Nielson, 2018)

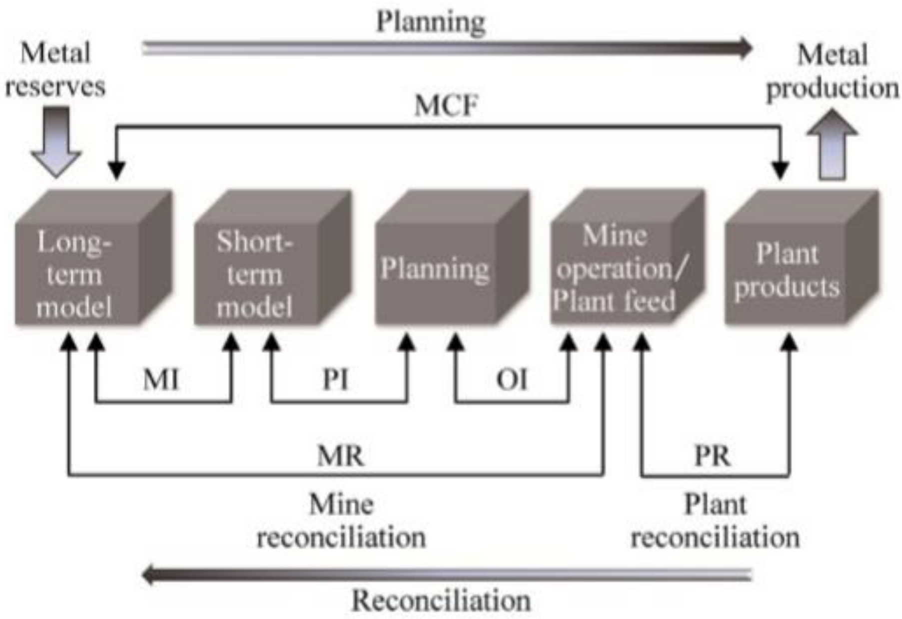


Figure 11: Reconciliation model adapted from (A. C. Chieregati et al., 2019)

Practical experience and theory of reconciliation provide different techniques approaches based on the type of operation and data availability. These techniques of reconciliation include Depletion by mining; Reconciliation of resources with grade control; reconciliations between ore reserves, grade control and production; and the use of reconciliation factors (mine call factors).

2.9 Monitoring reconciled data using Statistical Process Control (SPC)

In practice, the factors calculated and mentioned above can be used to create a series of run charts representing a line graph plotted over a period of time (Parker, 2012). Having a consistent MCF of one represents an unbiased forecast from the block model and in practice is unrealistic. Variation is likely to occur within the reconciliation system and ideally should vary around a factor of one.

a) Run charts

Run charts provide an efficient tool that can be used in ore reconciliation to identify early trends in the data. However, run charts are limited in their ability to alert the analyst of process stability and the need for adjustment.

b) Control charts

To better analyze the capability of each predictive model, a set of control charts can be produced. These charts are similar to a run chart, but use the process mean and control limits to help identify if a system is stable.

$$MR_i = |x_i - x_{i-1}|$$

Equation 1

Where MR_i is the moving range value derived from two successive observations, x_i, and x_{i-1}. The criteria for the Individual Control chart are defined as follows:

$$Upper\ Control\ Limit\ (UCL) = \bar{x} + 3 \times \frac{\overline{MR}}{d_2}$$

Equation 2

$$Center\ line = \bar{x}$$

Equation 3

$$Lower\ Control\ Limit\ (LCL) = \bar{x} - 3 \times \frac{\overline{MR}}{d_2}$$

Equation 4

Where $\overline{MR}$ represents the mean of the moving range values and d_2 is the un-biasing constant. Because the observations of the moving range are always n = 2 for an individual chart the value for d_2=1.128 (Montgomery, 2009 & Rigdon et al., 1994). A value of 3 is used to calculate the control limits representing an estimate of three standard deviations away from the sample mean. For tighter control, this value can be changed to 2 or even 1 standard deviation (Rigdon et al., 1994).

3

Chapter III: Literature Review

3.1 Historical Geology background

Gold has been valued since the earlier period to the current day, and have an influential role in human history quite the other metals. Egypt was the primary gold-producing country in the earlier period, since around 2,133 B.C in Coptos town, the current Quft on the eastern side of the River Nile (Habashi, 2016). Within the old Egyptian language, the word Nubia signifies “gold”. They established underground mining of vein gold in 1300 BC in Nubia, and there have been quite 100 mines within the area, producing Nubian gold (Adams, 2005). The regional geological formation called Arabian-Nubian Shield (ANS), where the study area also located.

Besides different types of deposits, the area is well characterized by volcanogenic massive sulfide ore deposits (VMS, also referred to as volcanic-hosted massive sulfide (VHMS) deposit, are a sort of metal sulfide ore deposit, mainly copper-zinc which are related to and created by volcanic related hydrothermal activities in submarine environments. The ANS host various metallic resources (precious, rare, base, and ferrous Ferro-alloy metals). Gold-bearing massive Sulphide ore deposits containing Cu, Zn, and Au related to gossans are well-known within various Neoproterozoic meta-volcano-sedimentary belts of the Arabian Nubian Shield (Solomon-Tadesse et al., 2003).

3.2 Mining in Ethiopia

Ethiopia has most of the essential elements required for fulfillment as a mining nation, with a vast range of undeveloped minerals and other natural resources (Figure 14 and Figure 15). Mining is not unaccustomed to Ethiopia; the country incorporates a gold mining history spanning quite three millennia (Assefa_Kumssa, 2019).

Figure 12: 5th-century gold coin of King Ebana, Aksumite currency ("Aksumite currency," 2020)

Driven by emeralds, opals, and sapphire it's a fast-growing gemstone mining industry. The bulk discovered within the last 10 years, including the recent, famous, and high-value Tigray sapphires (Assefa_Kumssa, 2019).

Table 5: Ethiopia's mineral production ((Assefa_Kumssa, 2019)

Indicator	2015/16	2016/17	2017/18
Annual mineral revenue (in million birr)	176.69	164.79	161.6
Number of investors licensed on mineral exploration and production	56	61	7
Revenue generated from mineral investment (million birr)	176.79	164.47	161.6
Export earnings generated from gold, tantalum, and other gemstones (million USD) (ASM and Companies)	309.1	231.25	133.56
Gold production (kg)	4,387.49	3,449.03	2,643.93
Limestone (tonnes)	4,120,288.40	4,335,085.34	10,896,331.82
Gypsum (tonnes)	80,555.60	85,236.00	253,165.11

Gold is one in every of Ethiopia's main export commodities generating revenue and has been mined starting precedent days, primarily as alluvial or free gold as orpailleur. Currently, considering modern and enormous scale mining, Ethiopia has two operating gold mines, Lega Dembi (in southern Ethiopia owned and operated by Midroc Gold) and Meli Gold Mine (in the northern part of the country owned and operated by Ezana Mining Development).

According to information from MoMP of Ethiopia, Currently, there are over 50 companies undertaking exploration and mining (or under advanced development stage) (with 2 started operations). Some advanced-stage projects are described in Figure 13.

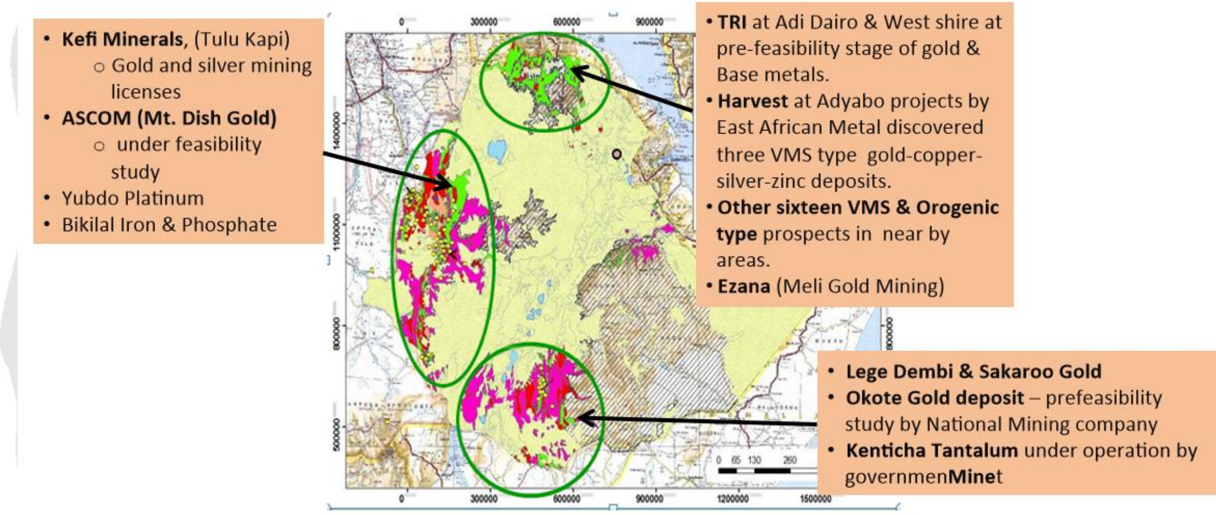


Figure 13: Mining and advanced exploration projects of Ethiopia (Assefa_Kumssa, 2019)

The government of Ethiopian introduced an awfully competitive legal and monetary regime that attracted many local and international companies to involve in mineral operations ranging from exploration to mining activities. The mining laws have been revised many times to make them more competitive and to form a more conducive environment to invest in the mining sector. 1) Making it easier for investors to access information on Ethiopia's mineral potential, 2) licensing regime is becoming increasingly transparent (Figure 16), 3) development of quality geo-data to de-risk and thus reduce the cost of investment. And 4) having developed with the assistance of the Canadian government for a stable legal framework and are committed to transparency and accountability within the extractive sector. Many foreign and local companies are granted reconnaissance, exploration, and mining licenses including for gold and base metals. Table 5 shows the recent mineral production data in Ethiopia.

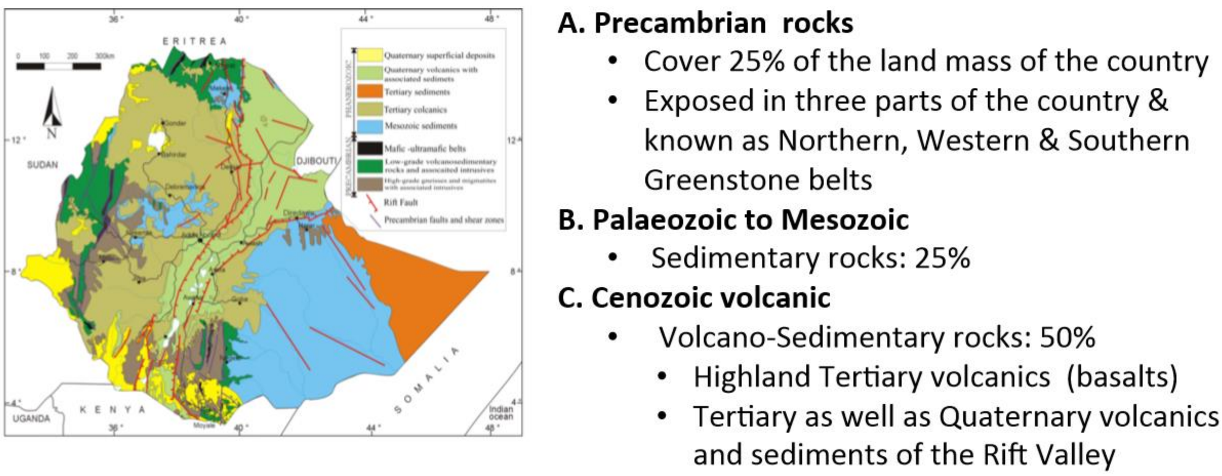


Figure 14: Geology and mineral potential of Ethiopia (Assefa_Kumssa, 2019)

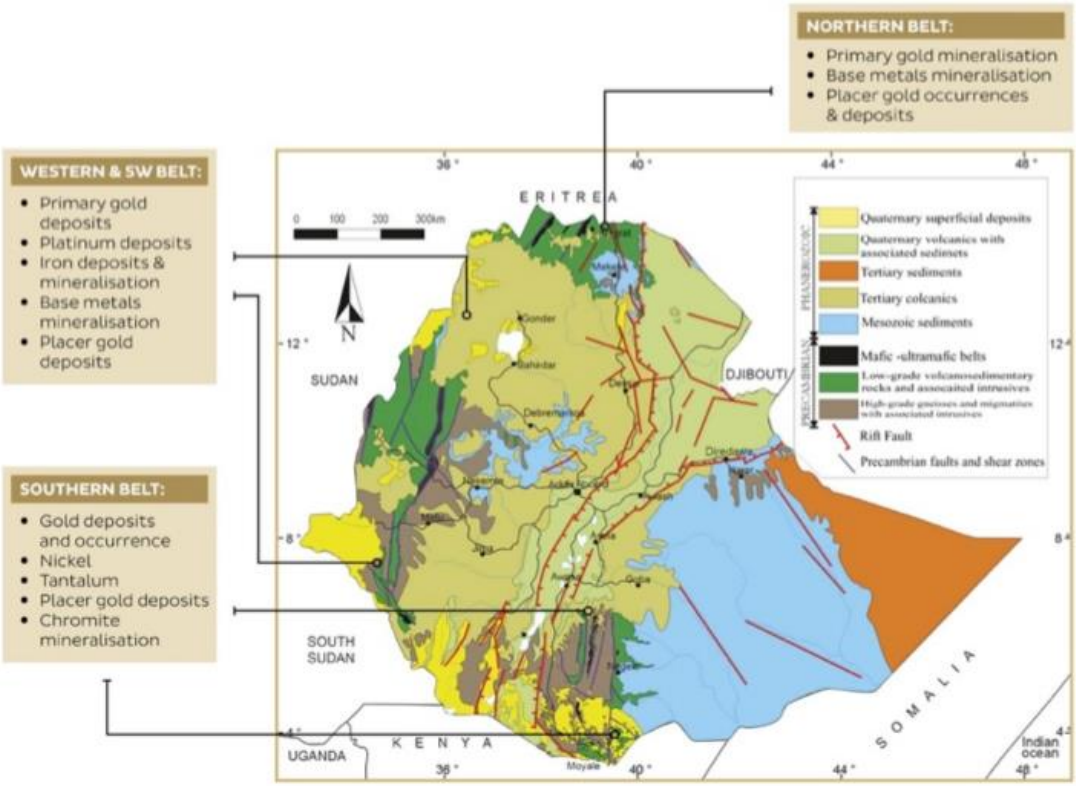


Figure 15: Metallic mineral potential of Ethiopia (Assefa_Kumssa, 2019)

3.2.1 Licensing Regimes of Ethiopia

1. Reconnaissance license: issued for an 18 month period, non-renewable and non-exclusive.

2. Exploration license: issued for a maximum of 10 years (3 years initial renewable, renewed twice for a period not exceeding one year each) and exclusive. Further extension of renewal could also be allowed for a maximum of 5 years.

3. Retention license: for a maximum of 6 years (3 years initial & renewable for an additional 3 years) and provides exclusive rights. Granted upon conditions related to the discovery of mineral deposits and the existence of adverse conditions related to the market or processing technology.

Four varieties of mining license are available

a) Large scale: is issued for 20 years initial, renewable for 10 years and exclusive;

b) Small scale: is issued for 10 years initial, renewable for five years and exclusive;

c) Artisanal Mining: is issued for two years, exclusive and non-renewable; and

d) Special Small Scale: the license is issued to upgrade Artisanal mining licensees to use machinery & equipment. It is issued for 10 years initial, renewable for five years, and exclusive.

Figure 16: Ethiopia's Mining License application procedures (Assefa_Kumssa, 2019)

3.3 Arabian-Nubian-Shield (ANS)

The Arabian–Nubian Shield encompasses a well-documented history of ancient gold and copper mining. It's a predominantly Neoproterozoic crustal block that hosts a range of mineral deposit types, including orogenic gold deposits (e.g. Lega Dembi, Tulu Kapi); and volcanogenic massive sulfide (VMS)–oxide gold deposits (Figure 17).

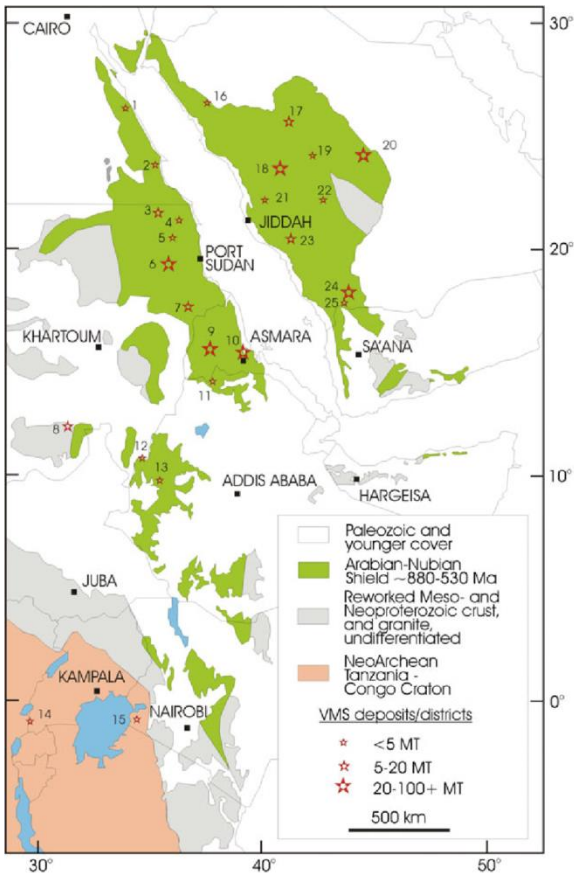


Figure 17: Arabian–Nubian shield map with Location of VMS deposit(Barrie, 2016)
Ethiopia: 11: Tarakimti, 12 Abetselo, Azale, and Akendayu; 13 Tulu Boli and Wankey

Nubian Shield: The *0.85–0.55 Ga Nubian Shield (>3 x 10^6 km^2) underlies parts of Egypt, Sudan, Eritrea, Ethiopia, Somaliland, and Kenya. It comprises gneissic, granitic, and volcano-sedimentary rocks west of the Red-Sea, which constitutes the western half the Arabian-Nubian

Shield that was divided by the opening of the Red Sea within the early Miocene. In broad terms, the Nubian Shield comprises a series of lithotectonic blocks and/or accreted arc terranes that broadly young from west to east, which was intruded and sutured by younger, calc-alkalic to mildly alkaline, granitoid plutons from 600–525 Ma during the Pan-African orogeny (Barrie, 2016). Thanks to the periodically arid or tropical environment, many of the VMS deposits within the Nubian Shield are subjected to near-surface oxidation and supergene enrichment, with the result that gold and copper are relatively enriched at shallow depths, thus making them favorable targets for exploration from an economic standpoint (Barrie, 2016).

The Arabian-Nubian Shield (ANS) is an exposure of mostly Neoproterozoic aged crystalline rocks on the sides of the Red-Sea, found in Israel, Palestine, Jordan, Egypt, Sudan, Eritrea, Ethiopia, Yemen, and Somalia. The ANS is that the northern ½ of a known collision zone called the East African Orogeny. This collision zone was formed when East and West Gondwana collided to create the supercontinent Gondwana during the Neoproterozoic time. The East African orogeny extends southward to the Mozambique Belt and is a subset of the Pan-African orogeny. The assembly of Gondwana coincided with the breakup of Rodinia, closure of the Mozambique Ocean, and growth of the shield at 870 Ma (Johnson et al., 2003).

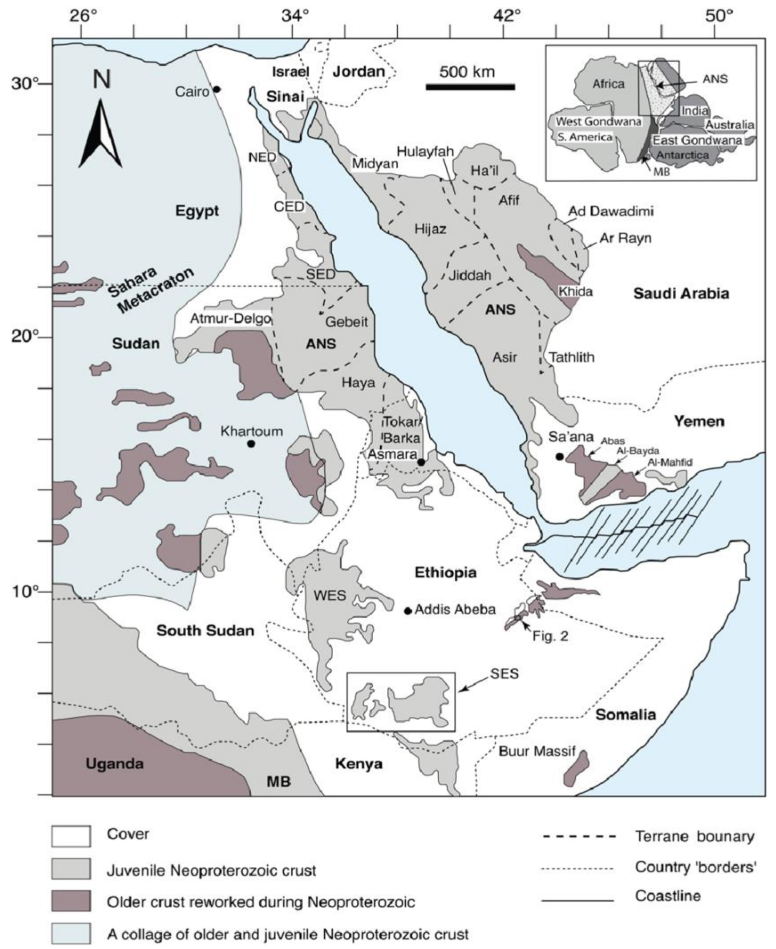


Figure 18: Simplified geological map of the Arabian–Nubian Shield (Yeshanew et al., 2017)
Inset shows the situation of the Arabian–Nubian Shield (ANS) and Mozambique Belt (MB) within the East African Orogeny. WES: Western Ethiopian Shield; SES: Southern Ethiopian Shield; NED: Northern Eastern Desert; CED: Central Eastern Desert; SED: Southern Eastern Desert.

The ANS hosts a spread of mineral deposit styles, including volcanic-hosted massive sulfide (VMS) or orogenic gold deposits. Significant deposits within the Arabian-Nubian Shield include:

- Bisha Mine in Eritrea – VMS
- Asmara Project in Eritrea – VMS /gold
- Block 14 in Sudan – VMS
- Sukari Deposit in Egypt – Gold
- Jabal Sayid in the kingdom of Saudi Arabia – VMS
- Lega Dembi in Ethiopia

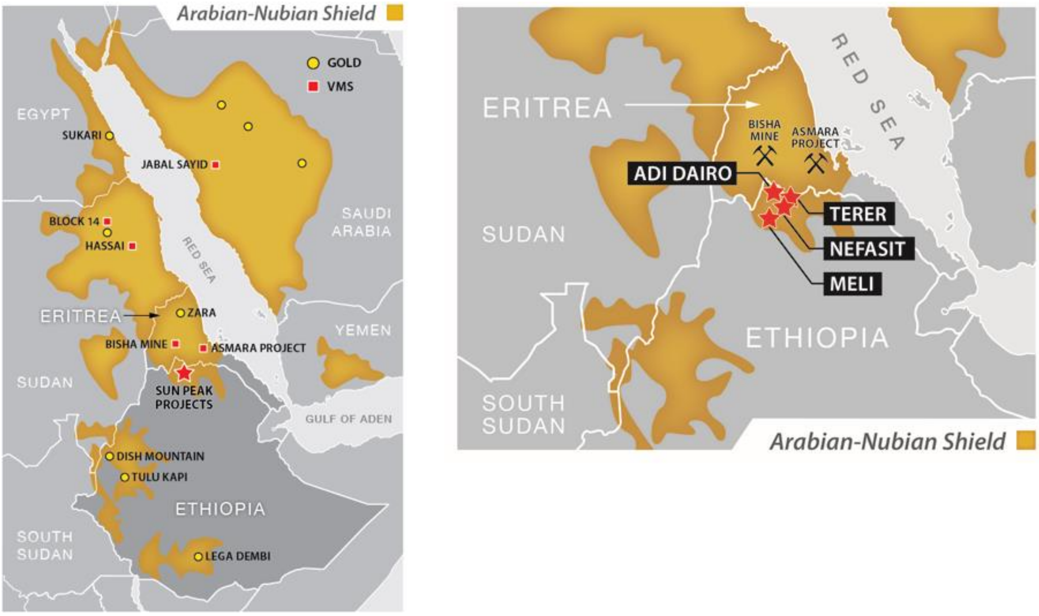


Figure 19: Simplified ANS Map with Sun Peak projects (Including Meli) source: Sun Peak website (www.sunpeak.com)

3.4 Geological Setting and mineralization

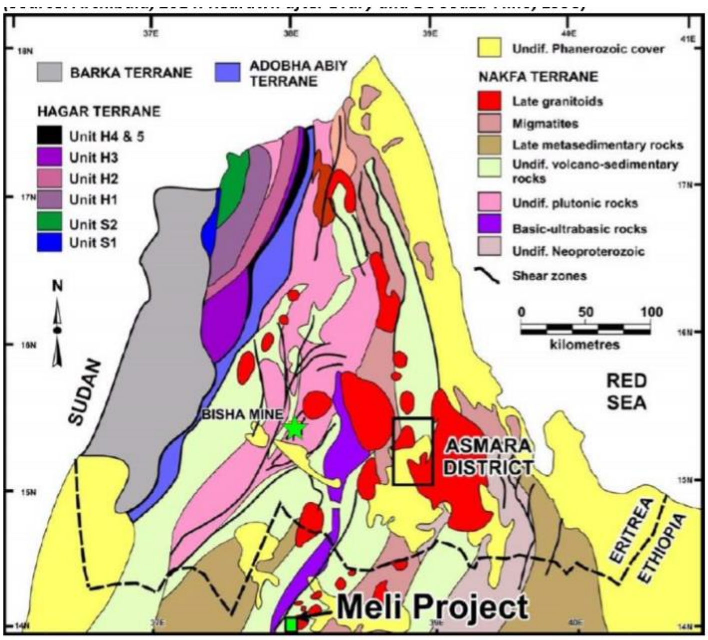


Figure 20: Meli geological setting with respect to Sun Peak projects in Ethiopia & Eritrea Source: (SunPeak-Metals, 2020)

The Project area is found within the Pan African, Neo-Proterozoic, Arabian-Nubian Shield. This belt of rocks comprises a composite set of granitoid greenstone terranes located in NE Africa and extends through Eritrea, Egypt, Sudan, Ethiopia, and western Saudi Arabia.

The regional geology of the northern Ethiopian originated normally from Precambrian and specifically Neoproterozoic and forms the southern a part of the Arabian Nubian Shield (ANS). Geology of northern Ethiopia is dominated by low-grade rocks belonging to ANS whereas the southern part is additionally represented by the high-grade rocks Mozambican belt additionally to the rocks of ANS (Asfawossen-Asrat et al., 2001; Kazmin, 1971). The geological history and setting of the region are quite understandable that accretionary tectonics followed by metamorphism, intrusions, deposition, and uplifting become the most events that controlled the structural evolution of the region. Structurally characterized by the presence of a series of anticlines and synclines, widespread shear zones trending NE-SW with sinistral slip movement and thrusting with NW vergence to bear with Zager mafic/ultramafic intrusive (Tarekegn-Tadesse et al., 1999).

The structures and colors developed within the gossan indicate the pre-existing sulfide mineralogy. Per (Bheemalingeswara et al., 2012), Presence gold related to visible gold, together with silver and base metals related to gossan and quartz veins suggests that both massive sulfide mineralization and hydrothermal quartz veins as sources for gold. Base metals, gold, and silver concentrations, their mobility patterns, and host rock association indicate the presence of massive sulfide mineralization subsurface and compares well with the VMS type mineralization -related gossans reported within Ethiopia et al in ANS (Bheemalingeswara et al., 2012).

3.5 Local Geology and structures

The project area is found within the southern part of the Nakfa Terrane which has been further subdivided into a variety of tectonically and stratigraphically distinct blocks within one in all which, the Adi Nebrid block, the bulk of mineral occurrences are located in Figure 21. It consists of a northeasterly striking, steeply dipping, a low-grade sequence of basic to intermediate flows, pyroclastics, minor rhyolite, and various sediments of Neoproterozoic age. A variety of granitoid intrusive complexes cut the layered rocks and have locally deformed the enclosing layered rocks. This block cuts through the area of the Meli property which is primarily underlain by Tsaliet Group metavolcanic and meta-volcaniclastic rocks.

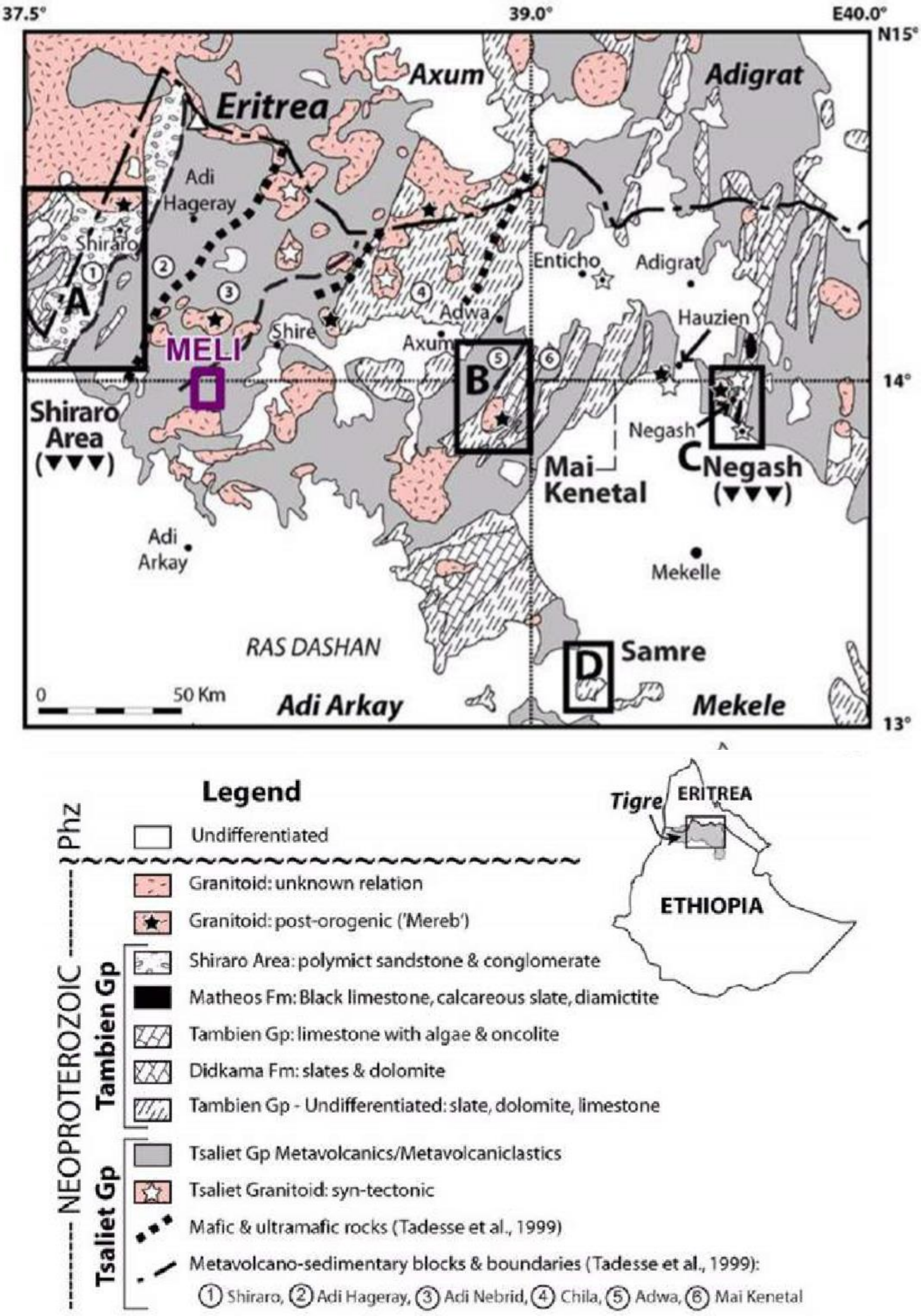


Figure 21: Geology of the Meli region
(source: Miller et al., 2011) as indicated on (SunPeak-Metals, 2020)

The study area consists of metavolcanic, metavolcaniclastics, and metasediments of Neoproterozoic age and intruded by syn- and post-tectonic granitoid and has experienced polyphase deformations. The rocks belong to the Tsaliet Group (Samuel-Abraham et al., 2015).

The area exhibits various types of alterations dominated by chlorination, also found ferrugenization, epidotization, sericitization, silicification, and carbonization are found in the study area (Samuel-Abraham et al., 2015). Gossan development is another visible feature in the area indicating the alteration of sulfide minerals due to oxidation. Previous studies and field survey indicates the presence of sulfide mineral assemblage, pyrite, chalcopyrite, sphalerite, and galena, respectively ordered as per their abundance rank.

EMD has conducted preliminary regional geological mapping (encompassed the study area) at a scale of 1:50,000 over 600 square kilometers. The Precambrian rocks of the area comprise of felsic to mafic meta-volcanic, meta-volcaniclastics, and detrital and chemically precipitated metasedimentary rocks and chaotically intermixed linear belts of mafic-ultramafic rocks. The whole sequence is intruded by the syn and post -tectonic granitoid. They are unconformably overlain by a thin veneer of Phanerozoic sedimentary rocks and intruded by younger intrusive of (Quaternary) anorthositic plugs. The rocks have undergone intense tectonic activity and associated poly-phase deformations (EMD, 2009).

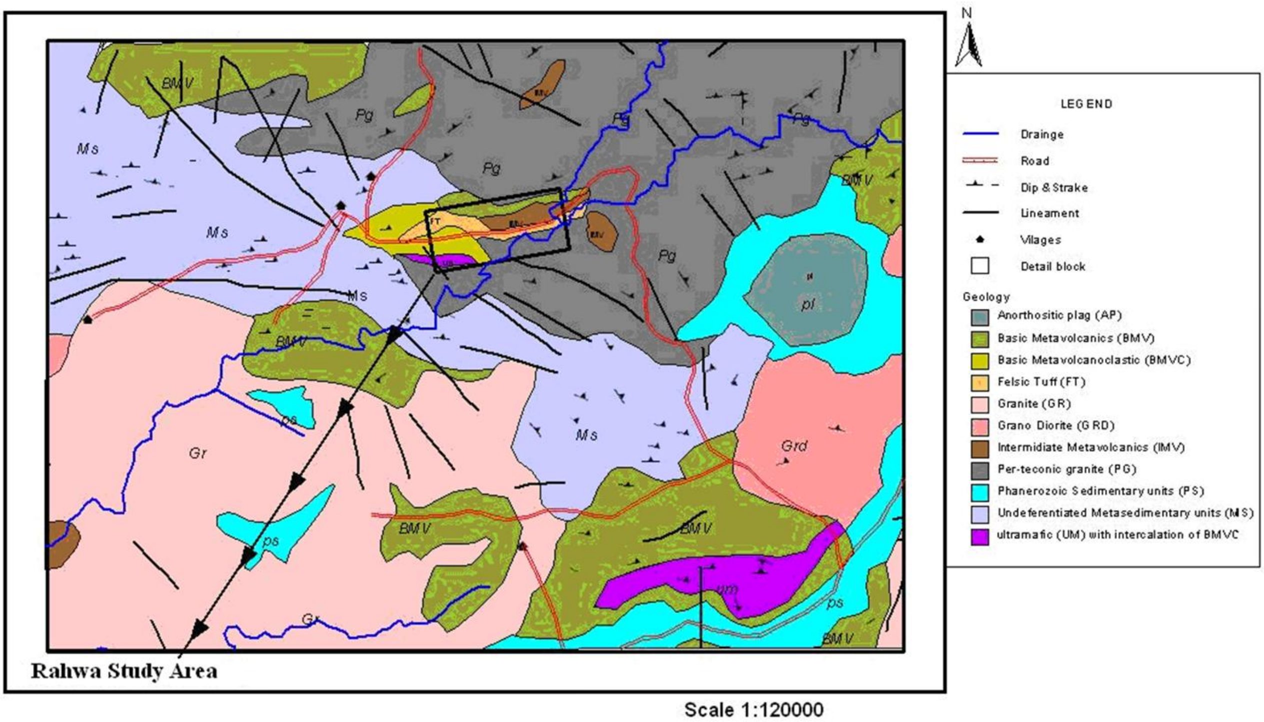


Figure 22: Prospecting geological map of Rahwa (after (EMD, 2009))

3.5.1 The lithology of the study area

The diversity of lithologies within the Adi Nebrid block is a function of the collapsed backarc basin geological setting of the area. This setting is postulated due to the presence of cycles of mafic and felsic volcanic and volcanoclastic rocks, syn-volcanic intrusions, and the occurrence of deep and shallow water sediments (Archibald et al., 2014). The area underwent significant deformation during the destruction of the back-arc basin resulting in the development of isoclinal and recumbent folds as well as thrusts and shear faults. A period of crustal thickening followed, resulting in the emplacement of late orogenic granitic bodies (SunPeak-Metals, 2020).

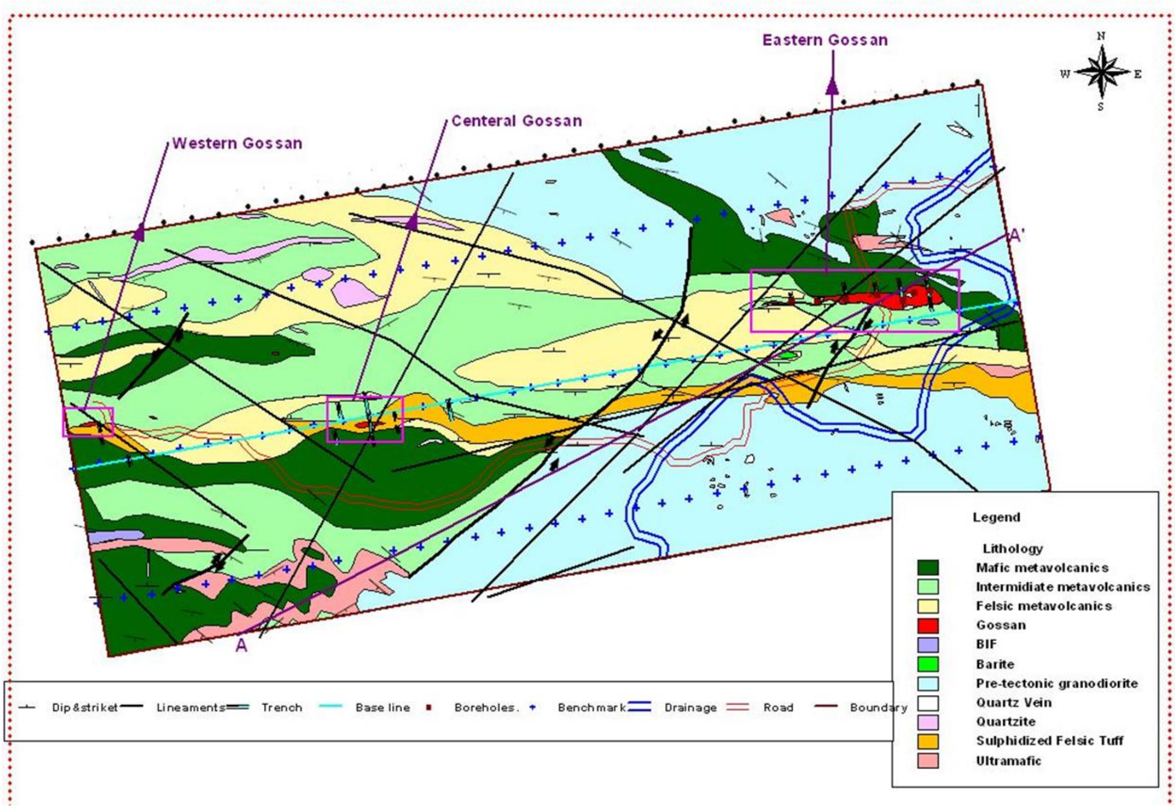


Figure 23: Geological map of the study area (Ezana_Private_Report)

(1) Mafic Metavolcanic Rocks

This unit is found in contact with the felsic and intermediate metavolcanic and exposed as attenuated, dispersed, and roof pendants or thrust nappe within the syn-tectonic granodiorite outcrop pattern. These exposures form subdued to rugged ridges. The general foliation of the rocks is E-W and dipping moderately to sub-vertical due south. Petrographic analysis of thin section by EMD shows 40% chlorite, 30% quartz, 20% calcite, and 10% opaque. The rock shows fine-grained texture and well developed Schistosity (EMD, 2009).

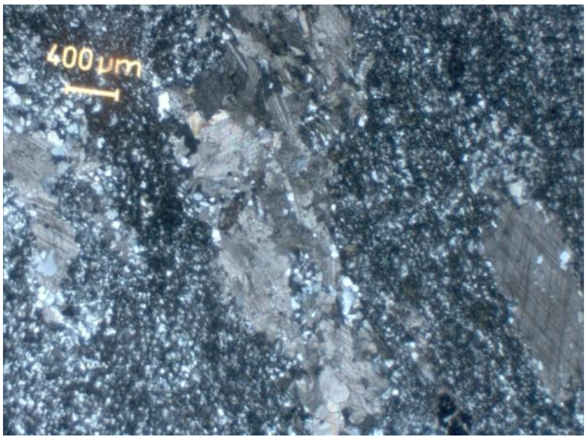


Figure 24: Photomicrograph of mafic metavolcanic rock, Rahwa area (X25) (EMD, 2009)

(2) Intermediate metavolcanic rocks

These rocks are found in contact with the felsic and mafic tuff and ultramafic rocks and form moderate to rugged topographic relief in the north and south. The rock is grayish-green and exhibits massive to strongly foliated fabric and fine to medium-grained texture, the massive variety appears as blocks. The rocks are composed of quartz and mafic minerals. Petrographic analysis by EMD indicates the presence of quartz (55%), chlorite (30%), mafic minerals (10%), and opaque (pyrite) (5%). The rock shows porphyroblastic texture displayed by the coarse-grained mafic minerals in the groundmass of quartz and chlorite (EMD, 2009).

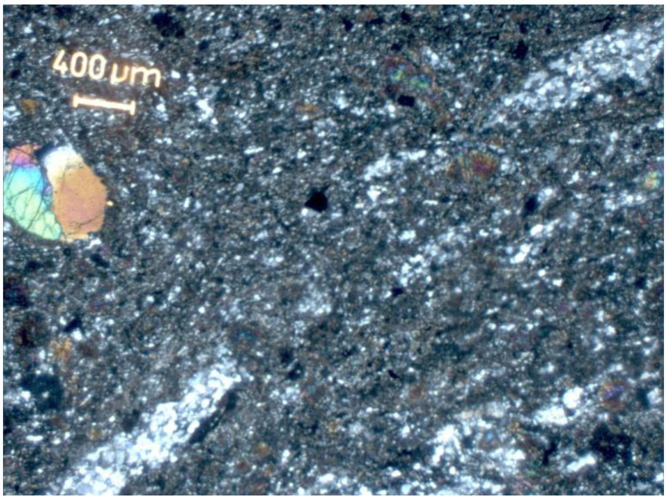


Figure 25: Photomicrograph of intermediate meta-volcanic, Rahwa area (X25) (EMD, 2009)

(3) Felsic metavolcanic rocks

This rock exhibits orange-brown color when weathered and buff, white or pale grey when fresh and composed of quartz eyes mantled in the fine-grained matrix of quartz, feldspar, and sericite. At places, particularly close to the gossans the felsic tuff becomes chloritic and imparts a green hue color to the rock. The strongly deformed and locally crenulated part shows variegated colors of reddish-brown, white grey, and dark brown. Towards the gossan the content and size of the quartz eyes decreases due to intensive shearing and physical break down. The development of kaolinization is prominent in the rock. The rock is intensely traversed by later quartz veins (EMD, 2009).

Petrographic examination of the rock by EMD revealed that of quartz (65%), calcite

(15%), chlorites (10%), and 10% opaque (pyrite). It shows well-developed Schistosity produced by the fine-grained quartz, calcite, and chlorite and anastomosed around the euhedral quartz porphyroblast (EMD, 2009).

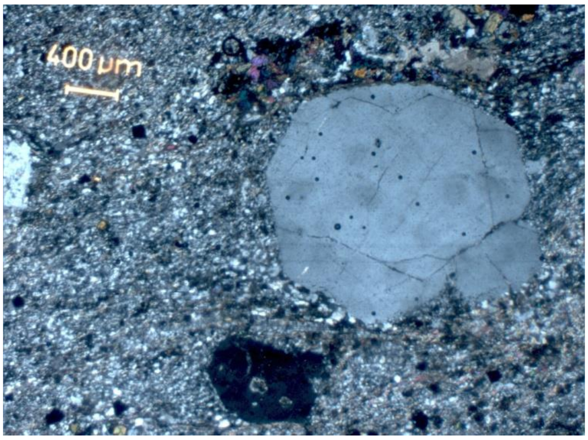


Figure 26: Photomicrograph of felsic metavolcanic rock, Rahwa area (EMD, 2009)

(4) Quartzite

Outcrops of this rock are found in the northwestern part of the study area and extend discontinuously along the east-west direction and form elevated hills. The rock displays variegated colors such as white, light to deep purple, yellow, and light to dark grey and is ferruginized. It is in association with felsic tuff and intermediate metavolcanic. It is concordant, brecciated, and relatively thick (1-2 meters), with pinch and swell (mesoscale boudinage) outcrop pattern throughout the strike of the eastern gossan. Quartzite seems to be syn-depositional together with the BIF which predominantly contains iron minerals like magnetite (EMD, 2009).

(5) Ultramafic intrusive

This unit is exposed in the southeastern part of the research area and consists of talc, pyroxenes, serpentine, and chlorite. It shows well-developed Schistosity represented by talc and talc-chlorite. Minor pods of Serpentinite and pyroxenite are present within the rock. Morphologically, it forms chains of small bodies occupying tops and saddle topographic relief. The talc schist is light grey to creamy and weakly to well-developed foliation and forms blocks and at places, it contains manganese stainings. The talc-chlorite schist is light green to green with well-developed foliation. The talc-bearing rock frequently impregnated with coarse pyrite cubes. Disseminated pyramidal magnetite crystals are seldom noted in the talc-chlorite schist. Mafic metavolcanic rock is engulfed by the ultramafic rock and show ramp folds. Foliation trends vary from NE, E-W, and NW and dip sub-vertically S and SE and show grooved surfaces. Regionally, the ultramafic rock occurs as a marker zone demarcating the metavolcanic and metasediments. The ultramafic and associated rocks are part of a thrust nappe. Ultramafic bodies are exposed in the northeastern part of Rahwa (at the Central Steep Zone of Adi-Nereid Block) (Tadesse, 1990) and also at the southwest of Rahwa. Spatially and litho-structurally, the Rahwa ultramafic rocks are possibly the southwestern continuation of the Central Steep Zone (Meda Kemtse Ultramafic Melange) of Adi-Nebrid Block

(6) Syn-pre tectonic granodiorite

It is exposed in the eastern part of Rahwa, encompassing the meta-volcanic rocks and forms moderate topographic relief to the south and subdued ground to the north. At places, the metavolcanic and ultramafic are found as xenoliths and roof pendants in the intrusive rock. The granodiorite is deformed and its contact with the adjoining metavolcanic is structural. It shows grayish color with medium-grained eyes of quartz, massive to weakly foliated and composed of quartz, feldspar, biotite, and minor amphibole. Hence the unit is deformed and contains quartz phenocrysts, it is confusing with the crystal tuff (Quartz tuff), especially on the weathered surface. Petrographic examination, as reported in the (EMD, 2009) report, shows that the quartz phenocrysts developed by recrystallization at margins, which indicates the contact metamorphism. This unit is designated as syn-tectonic intrusive in the northeastern part of the mapped area (Terer) and considered as a heat engine for mineralization (Ezana_Private_Report). Several concordant and discordant veins and veinlets of quartz and dikes are seen in this unit.

Petrographic examination of the rock (Figure 27) reveals the presence of quartz (55%), feldspar (15%), sericite (15%), chlorite (5%), ferromagnesian minerals (5%) and opaque (5%). The quartz and feldspar minerals are coarse and equigranular. Quartz shows wavy extinction. Alteration of feldspars has resulted in the development of sericite. On the other hand, chlorite could be derived from the alteration of ferromagnesian minerals and alignment indicates deformation and metamorphism (EMD, 2009).

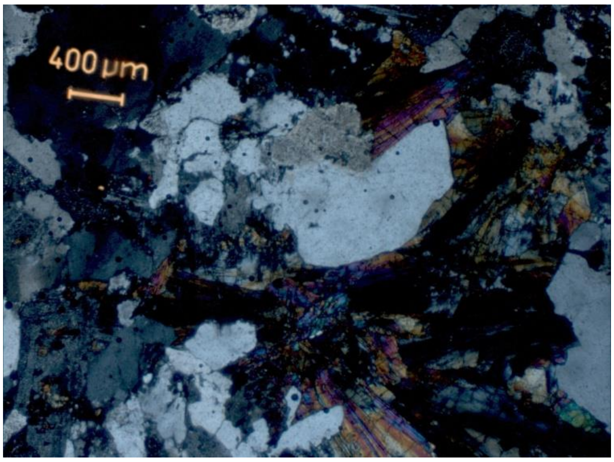


Figure 27: Photomicrograph of granodiorite, Rahwa area (X25)(EMD, 2009)

3.5.2 Metamorphism

Previous researchers have reported that the Precambrian rocks of the ANS are metamorphosed to low-grade Greenschist facies. Tarekegn (1999) has outlined regional and contact metamorphism within the metavolcanic-sedimentary rocks of the Axum Sheet.

The metamorphic mineral assemblage of the rocks within the study area provides local information, but it may well be a clue for the regional metamorphic grade. From the limited petrographic analysis and field examinations, the Precambrian rocks of the research area contain the subsequent metamorphic index mineral assemblage;

- the mafic and intermediate metavolcanic rocks contain calcite - actinolite- epidote- chlorite- quartz;
- the felsic metavolcanic rocks show sericite-quartz;
- the ultramafic rocks are typified by chlorite- talc- tremolite-actinolite; and
- The Pre-tectonic granodiorite has quartz-sericite.

The metamorphism process has governed the planar fabric of the rocks, and these are represented by slaty, phyletic, and schistose textures. Besides these features, primary sedimentary layering was also noted within the andesitic tuff. The planar fabrics of the mafic to felsic rocks wrap around the quartz and also the quartz is neither appeared as an overgrowth nor consumed, thus it’s representing a growth during explosive volcanism. Therefore, the metamorphic index mineral assemblages and therefore the planar fabrics encountered within the Precambrian rocks of the Rahwa area indicate low-grade greenschist metamorphism. The established low-grade of metamorphism of the Rahwa area complemented with the adjacent areas are analogous to the metamorphic grade of the ANS” (Ezana_Private_Report).

3.5.3 Alterations

While conducting a mineral exploration, alterations are important guidance mainly for VMS deposits and associated gossan, as their footprint is far larger than the associated mineralization. Alterations may develop from hydrothermal fluids, meteoric water, and metamorphic processes. A classic alteration pipe in VMS deposits encompasses a sericite-chlorite-quartz-pyrite rich margin and a quartz-chlorite-sulfide rich core (Galley et al, 1999). Alterations may be identified by field examination, petrographic and light microscope, and laboratory analysis. The subsequent (Figure 28) alterations were illustrated within the Rahwa research area using petrographic analysis and field examinations (Ezana_Private_Report).

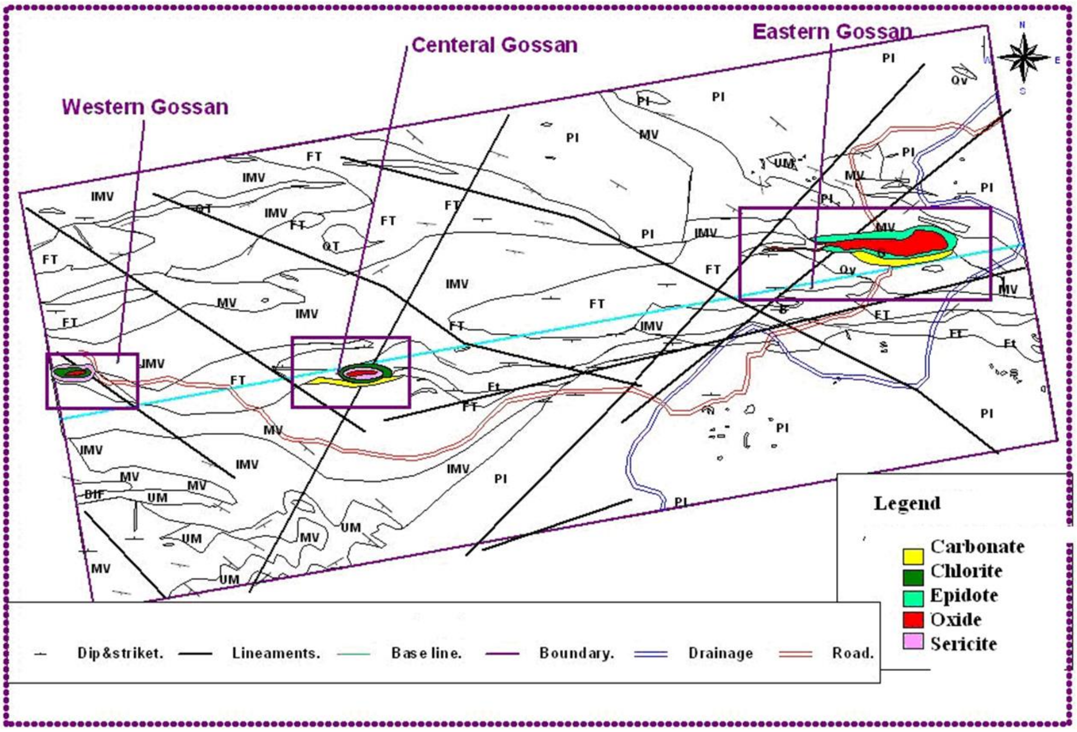


Figure 28: Alteration zones within the study area

a) Oxidation

Oxidation could be a general terminology used for the concentration of iron by means of chemical processes. Per Blanchard et al., (1958) as described in (Ezana_Private_Report), the oxidation processes of rocks and minerals resulted within the following products:

Gossan: defined as a cellular accumulation of limonitic material derived from the leaching of sulfide-bearing veins and VMS deposits.

Capping: the leached and limonite-stained upper portion of disseminated sulfide ore bodies, especially porphyry copper deposits.

Ironstone: used for hematitic ore that's applied to weathered outcrops containing a considerable amount of limonitic material.

In the eastern, central, and western parts of the study area, oxidation has given various yellowish, reddish-brown, deep reddish-brown, black and lightweight reddish colors, and structures. The assorted colors and cellular box-work structures are generated from oxidation or leaching of iron-bearing massive sulfide minerals and vein-type iron-bearing minerals (Moon, 2006; Blanchard et al. 1958), thus the oxidation within the eastern, central and western parts of the study area are designated as gossan. Within the southeastern part of the study area oxidation is represented by reddish-brown and reddish color blobs and stains, and according to Blanchard et al., (1958) these are considered as capping. This is often validated further by the presence of disseminated pyrite related to the alteration zones.

The gossans of the study area are developed by the interaction of meteoric water and VMS and superimposed iron-bearing quartz veins and this was evidenced by the presence of stable minerals containing gold, silver, lead, and therefore the signatures of the colors and box-work structures. Borehole drilling and geophysical survey have defined the zone of oxidation to an average depth of 30 meters within the eastern gossan and up to 75 meters within the central and western gossans. Therefore, gossan is among the key indicators for VMS or sulfide vein-type deposits.

b) Chloritization

Chlorite alteration is noted within the strongly foliated, sulphidized felsic metavolcanic exposed near the contact with the central and western gossans, and within the strongly deformed mafic and intermediate metavolcanic. In thin section, the basaltic rock contains abundant quartz, chlorite, and calcite, but void of plagioclase, that is thanks to the breakdown of plagioclase to quartz and chlorite. The alteration is the reaction product of pure Fe-Si-Ca rich hydrothermal fluid and the host rock and common in chlorite-quartz rich core alteration in VMS deposits (Galley et al. 1999). Within the bore-holes and trenches, the felsic metavolcanic consists of chlorite and disseminated sulfides and this assemblage is typical of footwall chlorite alteration in VMS deposits.

c) Epidotization

It is encountered within the massive to faintly foliated mafic and intermediate metavolcanic occurring near the eastern gossan. Within the mafic and intermediate metavolcanic rocks the epidote appears as clast and stringer; while adjacent to the gossan it’s intensively concentrated and more massive.

d) Sericitization and Kaolinization

This alteration is pervasively depicted within the strongly deformed and commonly sulphidized felsic metavolcanic. The prominent sericite alteration is noted at the contact of the central and western gossan. Kaolinization is intimately associated with sericitization and localized at the central part of the sericite zone. The kaolinization might be a progressive alteration product of sericite. Sericite is one of the common alterations in VMS deposits.

e) Silicification

In outcrops at places, silicification is noted to the northeast of the eastern gossan at Lekhote River, containing abundant fine pyrite. This supports the alterations observed within the thin section and typical of chlorite-quartz-sulfide (pyrite) rich alteration pipe in VMS deposits.

f) Carbonization

Calcite is observed in thin sections and drill chips (bore-hole 2). Within the thin section (Plate 1), the calcite appears as aggregates, fracture filling, and laths within the grain boundary. Calcite is usually found with Zn-Pb-Cu VMS deposits associated with sericite-chlorite-quartz-pyrite alterations resulted from low-temperature hydrothermal fluids (Galley, et al. 1999).

On the basis of the above mentioned different types of alterations, field examination, and limited petrographic analysis the study area shows the presence of chlorite-quartz-sulfide and sericite-chlorite-quartz-pyrite alteration pipes, which are intimately associated with VMS deposits. Therefore, these alterations supplemented by the co-existence of an oxidized zone could be indicative of the possibility of attaining VMS deposits in the research area and the gossan is developed from the oxidation of VMS.

3.6 Mineralization

Mineralization on the Meli property is primarily observed as surficial iron oxide minerals (goethite, limonite) hosting gold and minor base metals. Beneath the higher developed and more massive gossans, during a number of the deeper diamond drill holes, precious and base metals-rich VMS-style massive and semi-massive sulfide mineralization has been intersected. The surficial gossan material is mostly chocolate to red in color, locally varying to yellow (Photo 7-2). Vuggy and box work textures are locally created by leaching of sulfide minerals, and disseminated, layered or laminated, wavy and grooved hydrated silica (chert/jasper) has also been noted within the gossan. Milky, glassy, iron-stained and brecciated veins and veinlets of quartz also occur, and are commonly concordant with the gossans. Ghosts of weathered sulfide minerals might also be observed as disseminations and fine stringers within the typically strongly foliated serialized and kaolinized felsic metavolcanic rocks which commonly occur adjacent to the gossans. Borehole drilling and geophysical surveys have defined the zones of strong oxidation beneath the gossans as occurring to a mean depth of 30 meters within the Eastern gossan and, at a depth of possibly up to 75 meters within the Central and Western gossans.

3.7 Tectonic setting and Ore Genesis

According to the research by Mulugeta Alene et al (2000) on the Neoproterozoic Rocks of Northern Ethiopia (Arabian-Nubian Shield), the Metavolcanic and plutonic rocks indicated to be orogenic magmatism developed in an exceedingly volcanic arc setting, and are similar models to evolution of the Arabian-Nubian Shield Sudan, Egypt and Saudi Arabia (Mulugeta-Alene et al., 2000).

Tadesse (1997) conducted geological studies over the realm covered by the Axum map sheet on to the north of the Meli concession. He suggested that the shear zones between the blocks bear evidence of early pervasive shortening, which was progressively followed by late sinistral strike-slip movements. Such structural sequences also are common within the accreted terranes of Arabian-Nubian Shield (ANS) and are per field mapping, indicating that the realm encompasses a characteristic of an intra-oceanic island arc tectonic setting.

VMS may be a variety of metal sulfide ore deposits of mainly Cu-Zn-Pb and is related to and created by volcanic associated hydrothermal events in sub-marine environments. They're a predominantly layered accumulation of sulfide minerals that precipitate from hydrothermal fluids on or below the seafloor in an exceedingly big selection of ancient and modern geological settings (Barrie et al., 2007).

According to Abraham et al, Ore minerals present are pyrite, chalcopyrite, sphalerite, and galena and secondary minerals like chalcocite/covellite and goethite/limonite; with the dominant mineralization of chalcopyrite and sphalerite minerals; leading the ore of rich in Cu and Zn. The ore body is present at the contact between metavolcanic rocks of mafic and intermediate compositions. Gossan developed on the ore body being auriferous makes this layer economically viable. The mineralization is additionally metamorphosed and based on nature, host rock composition is categorized as Cu-Zn (+Au)-rich, bimodal VMS mineralization, and produced in an island arc tectonic setting (Samuel-Abraham et al., 2015).

3.8 Mine-Call Factor (MCF)

According to the definition by Storrar (Storrar, 1981), MCF is a ratio, expressed as a percentage, which the precise product accounted for in recovery plus residue bears to the corresponding product called for by the mine's measuring methods. The formula is mathematically expressed as:

$$MCF = \frac{product\ accounted\ for\ within\ the\ recovery, plus\ residues}{product\ called\ for\ by\ mine's\ measuring\ \&\ evaluation\ methods} \times 100\%$$

Equation 5

Mine call factor is an adjustment derived from comparing the tonnes and grade of gold actually mined from part of a deposit and also the original ore reserve projections. (Rudenno, 2012)

The Mine Call Factor accounting method isn't standard on all the mines, but it's still the sole criterion for determining the general mining efficiency. It is now and then adapted to the needs of a specific mine (De Jager, 1997).

According to L. Xingwana (Xingwana, 2016), the mine survey department is accounted for measuring and recording ore and waste mined as per indicated parameters of the deposit. All tonnages from different sources, including stockpiles, are added together and compared with the actual tonnage received at the plant. The difference is understood as tonnage discrepancy and is indicated by the MCF.

As the theory of MCF defined by Storrar (Storrar, 1981), if a mine's evaluation method is ideal, and sampling, assaying, and tonnage measurements within the mine and plant are flawless and there aren't any losses anywhere, then the MCF should be adequate to 100%. MCF can, therefore, be viewed as a measure of the efficiency of all the processes within the mine value chain.

3.9 Ore loss and ore Dilution

Ore loss refers to any unrecoverable economic ore left inside a pit (scattered, like boulders, in place as a ramp, or not properly mined at the boundaries, misplaced during trenching for sampling), or to any valuable ore not recovered by the mineral processing system. Ore losses also arise when valuable material is misclassified as waste and sent to the waste dumps (Engmann et al., 2013).

Dilution may occur as a result of low-grade or waste product mixing with ore during the operation and being sent for processing, thus reducing the ore value (Ana Carolina Chieregati et al., 2009) or any waste matter within a mining block (Yilmaz, 2011). Dilution is quantified as the ratio of the tonnage of waste mined and sent to the mill to the total tonnage of ore plus waste that's milled (Wang et al., 2011). It's always expressed as a percentage:

Equation 6

$$\text{Dilution} = \frac{\text{Waste tonnes}}{\text{Ore plus waste tonnes}} \times 100\%$$

3.10 Reconciliation Principles

Ore reconciliation primarily focuses on comparing actual production data to modeled estimates that are wont to forecast future production. The first objective of a reconciliation program in a producing mine is to properly account for all ore and other material mined (Rossi et al., 2014).

One of the objectives of ore reserve estimation is to make a sound estimate of the tonnage and grade. This is often hard to be true in practice. Errors will occur, and these are associated with inaccurate orebody knowledge at the time of ore reserve estimation and to the assumptions made on the accuracy with which ore is chosen from the waste within the ore control process. It's generally accepted during a precious metals mine, annual reconciliation between mine and mill would be ±10%. A tiny low negative error can cause a mine to miss its cash flow targets. Errors may end in incorrect decisions, and should even end in premature mine closure (Parker, 2012).

The two main sources of error:

a. inaccuracy in estimation of resources and/or ore reserves (long-range model)

b. Inefficiency within the mining process to segregate ore and waste as planned (short-range model) by the ore control staff.

According to parker, (Parker, 2012), to know and avoid sources of error, it's useful to assemble independent reconciliation data both for tonnes and grade at various stages of the mining process and analyze it in terms of ratios, called factors.

$$F_1 = \frac{short\ range\ model\ depletions}{long\ range\ model\ depletions}\ ;\ F_2 = \frac{received\ at\ mill}{delivered\ to\ mill}$$

Equation 7

$$F_3 = F_1 \times F_2 = \frac{short\ range\ model\ depletions}{long\ range\ model\ depletions} \times \frac{received\ at\ mill}{delivered\ to\ mill}$$

Equation 8

The long-range model is built using geological interpretations supported exploration and/or delineation drill holes. The short-range model is usually constructed using samples from closely spaced drill holes and/or mapping information. This information is employed to delineate ore and waste in mineable shapes. A high factor value indicates conservatism within the denominator; conversely, a low factor value indicates optimism in the denominator.

4

Chapter IV: Ore flow at Meli Gold Mine

4.1 Property Description and Ownership

The study area is comprised by east to northeast-trending belts of weakly metamorphosed Neoproterozoic rocks comprised mainly of mafic to felsic flows and pyroclastic rocks, as well as volcaniclastic and sedimentary rocks; this same belt of rocks hosts significant VMS mineral deposits in the Asmara area of Eritrea, about 200 km NNE of the Property (SunPeak-Metals, 2020).

Prospecting and follow-up Geochemical exploration work by Ezana Mining Development (EMD) in 2006 located gold-enriched gossan zones in the southcentral part of the Property that has been named the Eastern, Central and Western zones, which are dispersed over a length of about 3.5 km. Percussion and diamond drilling of more than 95 holes from 2008 to 2012 focused on defining a Goldrich zone within the oxide cap that extends to depths of 25 to 30 m. Analyses of surface channel samples and drill chip sample (a total of sixteen holes) from the Eastern Gossan zone were used by Ezana in 2009 to make a preliminary, non-compliant estimate, indicating that the mineralized oxide cap may contain about 4 tons of gold with an average grade of 4.0 g/t Au using a 0.3 g/t Au cut-off (EMD, 2009).

From few holes drilled to depth indicate that the underlying sulfide zone dips about 55° to the south, continues at least 100 m down dip, and intersects VMS-style massive sulfide mineralization that contains gold and base metal mineralization. A number returned very significant intercepts, including 4.2% Cu, 0.7% Zn, 1.5 g/t Au, 37.1 g/t Ag over 17.4 m (hole RH-DH-01, 28.65-46.05

m) and 2.4% Cu, 1.0% Zn, 2.6 g/t Au, 37.8 g/t Ag over 15.1 m (hole RH-DH-49, 65.0-80.1 m). This zone is open to expansion at depth and along strike (SunPeak-Metals, 2020).

In 2013 Ezana applied for and was granted, a mining license by the Ethiopian Ministry of Mines. Ezana undertook mine planning and feasibility studies and followed-up in 2016 with the construction of a carbon-in-pulp extraction plant adjacent to the Eastern Meli gossan zone. Open cut extraction of the gossan cap commenced in 2017 (over the three Meli gossan zones) and the mill has operated intermittently since that time.

Meli Gold Mine, Ethiopia's second modern gold mine, is owned by Ezana Mining Development PLC, the latter is a subsidiary of the Endowment Fund for the Rehabilitation of Tigray (EFFORT). Ezana Mining Development PLC (EMD) is an endogenous company engaged in gold, base metals and industrial minerals exploration and development in Ethiopia. Meli Mine is located in Meli prospect (3.5 km^2) that is presently under production and the advanced exploration stage is part of the Rahwa concession covering an area of 800km^2 under prospecting.

The Location, Accessibility, Topography, Vegetation, and Climate of the area are described in Chapter 1 of this report.

Figure 29: Meli Gold Mine employees Camp

4.2 Deposit Geology and Mineralization

The general geological setting and regional geology described in the literature review section of this report.

The geology of Meli open pit is characterized by chaotically intermixed ultramafic with mafic, intermediate and felsic flows and explosives, gossan, and related volcanogenic massive sulfide (VMS) mineralization.

The economic gold deposit occurs in auriferous gossan of the area.

The Arabian-Nubian shield hosts numerous volcanogenic massive sulfide (VMS) deposits. Studies from deposits discovered in the ANS of Sudan and Saudi Arabia indicated that all deposits are marked by significant surface gossans (Archibald, 2011).

Significant researchers and further detailed studies by various companies indicated that the ANS is the potential to host economic quantities of gold found in epithermal, oxide, and primary massive sulfide mineralization.

The most common alteration associated with the VMS mineralization is sericitization, chloritization, and locally kaolinitization. Primary base metal mineralization of interest includes predominately chalcopyrite and sphalerite, associated with massive pyrite. This mineralization also contains notable Au, Ag, and Pb. Clearly defined oxide and supergene zones of mineralization are also present. The ore deposit is similar to the primary massive sulfide deposit of Bisha VMS deposit, western Nakfa terrane of Eritrea (Bheemalingeswara and Atakilty, 2012), which is one of the known VMS deposit being mined by NEVSUN, a Canadian mining company.

Ezana Mining also identified Orogenic lode gold mineralization at Maihibay, located approximately 7 km east of the Meli deposit. Gold mineralization is associated with quartz veins along a shear zone and also occurs as free gold associated with sulfides in mainly quartz veins.

A site visit observation together with literature review indicates the presence of well-developed, about 30m thick auriferous gossan represented by limonite, goethite, and hematite overlying the massive sulfide mineralization. It displays variegated reddish-brown, dark red, yellowish, and light reddish colors (Bheemalingeswara et al., 2012).

4.3 Gossans

Gossan is a term from mineral economics. The gossan might also be called an iron cap. This denotes a concretion of iron hydroxides formed on top of sulfide vein, where it reaches the surface. It’s formed during the supergene sulfide ore enrichment when softly acidic surface water percolates through the ore (mineral) deposit. Many sulfide ores are oxidized during this process and brought into the solution.

Gossan is developed by the method of chemical weathering. Topography, climate, inherent minerals, and environment are the determining factors in chemical weathering. In relating these factors the relative position of the present-day natural environment of weathering can be established in terms of EH and PH. The varied colors observed in gossan are thanks to various factors like mineralogy, grain size, aggregation, and moisture content.

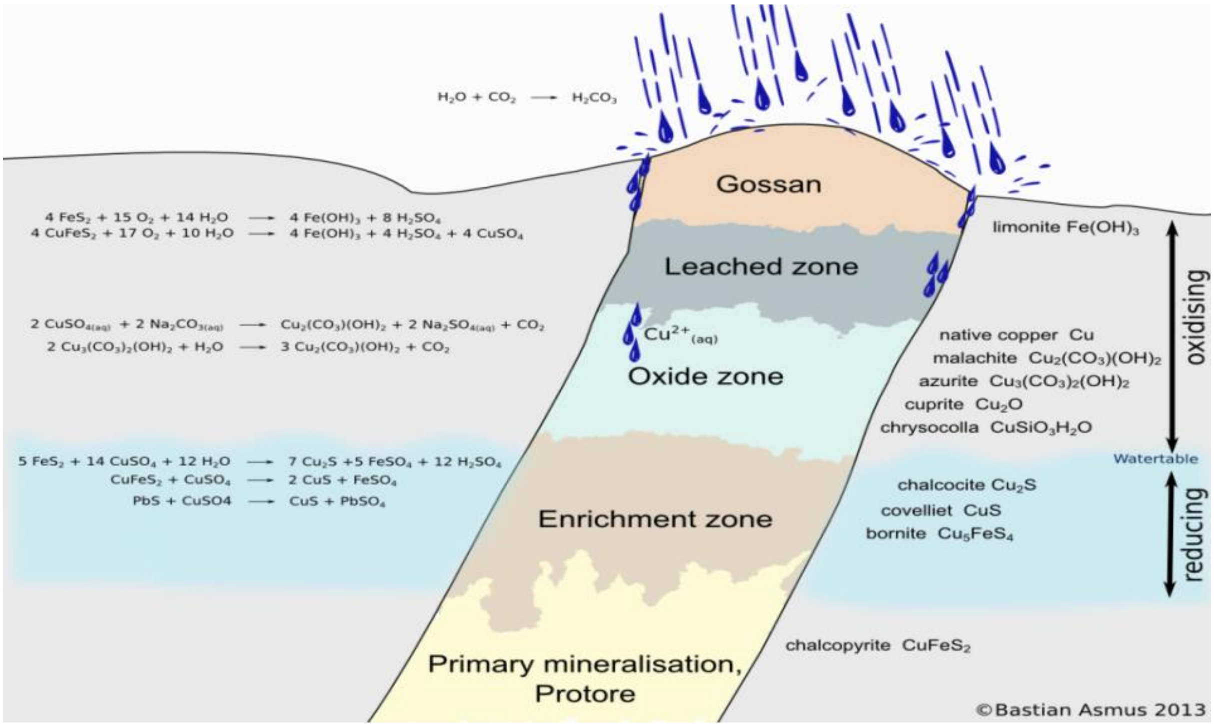


Figure 30 Schematic view of a sulfide vein, modified after (Evans, 2009).
The schematic view of a sulfide vein, and can see the oxidation zone, consisting of the gossan, the leached zone, and the oxidized zone. The reducing zone consists of the enrichment zone and the area of primary mineralization modified by Bastian Asmus in 2013 after (Evans, 2009) published on the website: http://en.archaeometallurgie.de/gossan-iron-cap/

4.3.1 Oxide Gold Zone development of ANS:

Most of the VMS–oxide gold deposits of the Nubian shield are classic examples of metallic enrichment in supergene and oxide zones above VMS deposits in weathered terrane (Barrie, 2016).

Significant enrichments of copper occur within the supergene sulfide zone, and of Pb, Au, and Ag within the kaolinite-quartz-sulfate and oxide zones, compared to the primary massive sulfide. Near the oxidized upper part of the water table, Cu^{2+} reacts with Sulphur or hydrogen sulfide to form covellite (CuS) or chalcocite (Cu_2S), depending on the abundance of Cu and the redox potential. If there is excess copper under more oxidizing conditions, chalcocite predominates, as covellite takes on extra Cu^{2+}. Various kinds of literature including from Bisha deposit, chalcocite generally forms above covellite under slightly oxidized circumstances. Pyrite has a dual role in that it acts as a host for Cu deposition as its Fe ions are replaced by Cu ions, and its relatively high solubility in oxidizing environments frees sulfur to groundwater, which lowers the groundwater pH and leads to chalcopyrite dissolution. Supergene processes may have been operative over very long time periods, as warm arid/tropical conditions in these areas have existed for millions of years, evidenced by the presence of thick laterites and saprolitic soils below mid-Oligocene flood basalts. Zinc sulfide is significantly more soluble than lead and copper sulfides in the oxidized, low-pH ground-water environment and is more likely to be removed from the deposit area by groundwater transport unless sequestered by carbonate to form smithsonite. Gold enrichment in the hematite-goethite gossan of the study area is common in weathered and oxidized ore deposits. In this environment, gold enrichment is believed to form by weathering, where the gold is derived from the decomposition of auriferous sulfides (pyrite in particular), by a combination of chemical, residual, and mechanical processes. Hence, the post-Miocene uplift and rapid deflation in the region creates the opportunity to develop significantly enriched gold and copper oxide (and supergene copper) profiles above primary the VMS sulfide deposits. Gold and silver can be transported as either chloride or aqueous sulfur complexes at low temperatures under oxidizing; low-pH conditions and precipitated as native metals with iron oxides. Low-pH conditions are indicated by the occurrence of a jarosite and goethite assemblage, which is stable only at pH 1–2.5 under oxidizing conditions, provided that potassium and sulfur are present (works of Alpers and Brimhall 1989), as indicated by (Barrie, 2016)

Figure 31: Gold-enriched oxide gossan at main Meli gossan mining (Author picture)

4.3.2 Meli Gossan

The gossan in the Rahwa area is found as a discontinuous outcrop pattern along a strike length of 3.5 kilometers and these are spatially classified as Eastern, Central, and Western Gossan zones. The central and western gossans appear as narrow lensoidal bodies; hence a relatively adequate data is available for the eastern gossan that has significant size. The gossans are represented by hematite, goethite, and limonite.

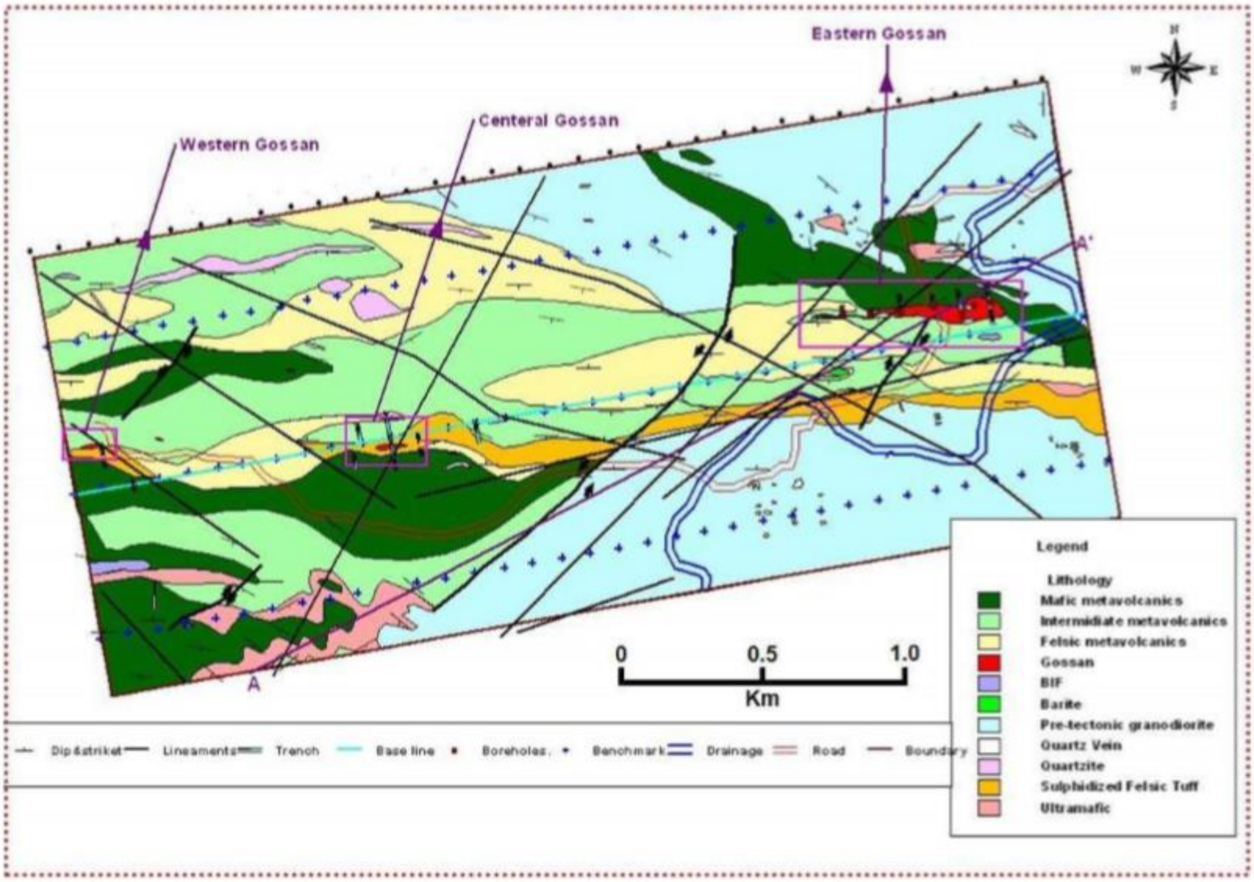


Figure 32: Geology of Meli Gossan zones,
Eastern, Central, and Western Gossan zones (Ezana_Private_Report)

A. Eastern Gossan

This gossan outcrop generally forms flat topography with small undulated hills and saddles. The gossan is extended for 650 meters along strike and 80 meters width in (Figure 32). The gossan displays variegated and vivid colors of reddish-brown, yellowish, jet black, and light reddish which appear as layers, tints, blobs, and dissemination. Black and brown pebbles, cobbles, and sands are mantled in the hydrated and siliceous/jasperoid iron oxide gossan and exhibit both conglomeratic and brecciated textures. Disseminated, as well as layered/laminated, wavy, and grooved hydrated silica (chert/jasper) are also noted, where the concentration increases in the yellowish gossan. (Ezana_Private_Report)

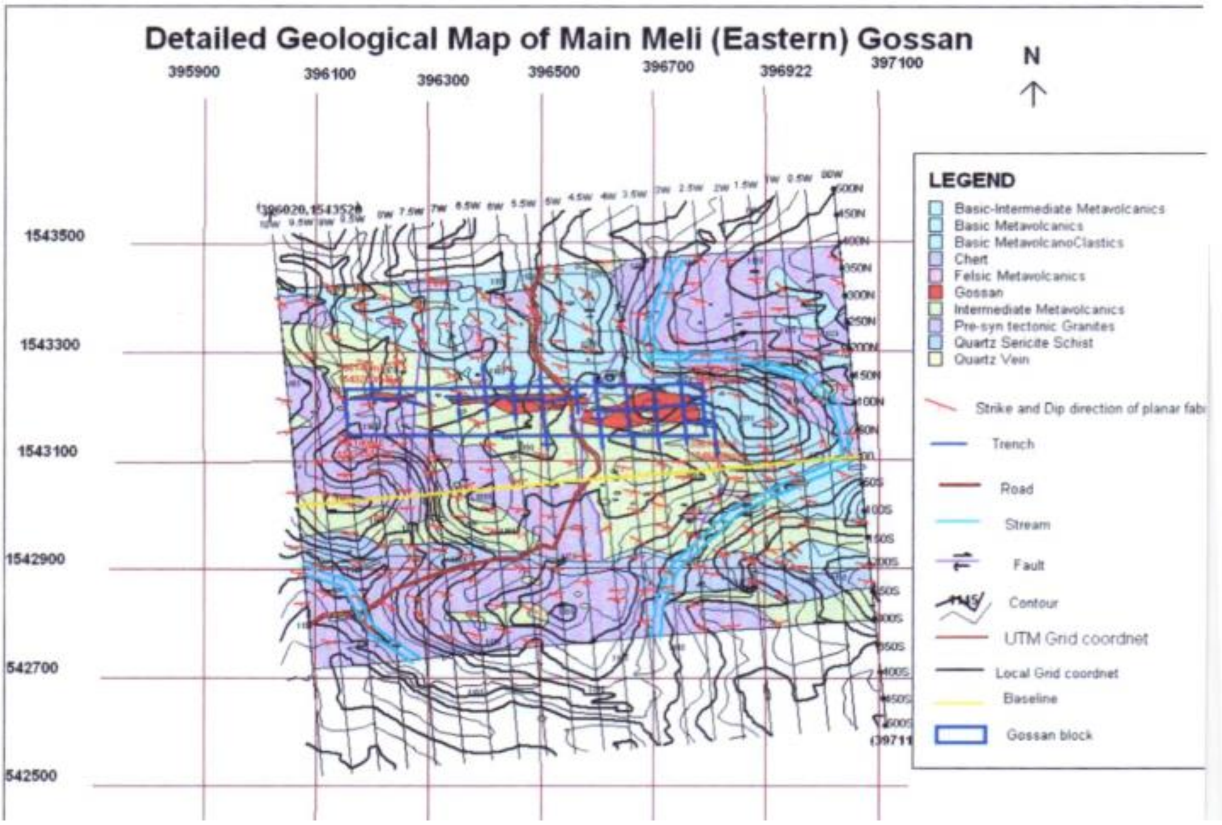


Figure 33: Geological map of main Meli (Eastern) Gossan

B. Central Gossan

This gossan is exposed in the central part of the Rahwa area forms relatively elevated topographic relief. It has a strike length of 100 meters with a thickness that varies from 1 meter to 5 meters. The gossan is concomitantly and concordantly hosted in felsic metavolcanic with abundant quartz and ghosts of sulfides and it is encompassed by intermediate to mafic metavolcanic to the south and north, respectively. The gossan displays deep reddish-brown and reddish colors. The lithological association and structural set-up are almost similar to the Western Gossan; however other distinct features of gossan are absent. Therefore, this gossan could be relatively depleted in precious and base metal mineralization. (Ezana private report)

C. Western Gossan

This gossan crops out in the western part of the study area form peneplain and subdued topographic relief. It has a strike length of 100 meters and the thickness varies from 1 meter to 6 meters. The gossan is concomitantly and concordantly hosted in felsic metavolcanic rock with abundant quartz and ghosts of sulfides and these units are encompassed by intermediate to mafic Metavolcanic to the south and north, respectively. (Ezana private report)

4.4 Production history and exploration works

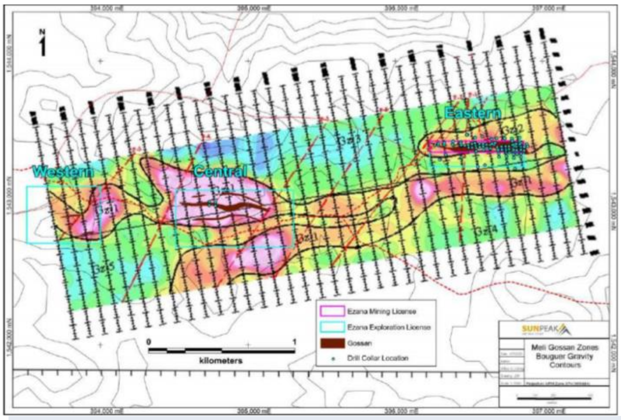
Before commencing mining production, the project area has seen extensive historic various exploration works, including stream sediment, soil and rock chip sampling, geological mapping, geophysical surveys, trenching, RC (reverse-circulation) and diamond drilling.

The initial reconnaissance exploration in the Meli concession area was recorded by Ezana (EMD), starting about the year 2006 on their 800 km² Rahwa prospecting license. Ezana conducted stream sediment and rock chip sampling and geological mapping which led to the discovery of the current open-pit mines (three precious metal-rich gossans) that lie within a zone that has an overall strike length of 3.5 km (called Meli gossan zones – Pit A, B, and C) Figure 32.

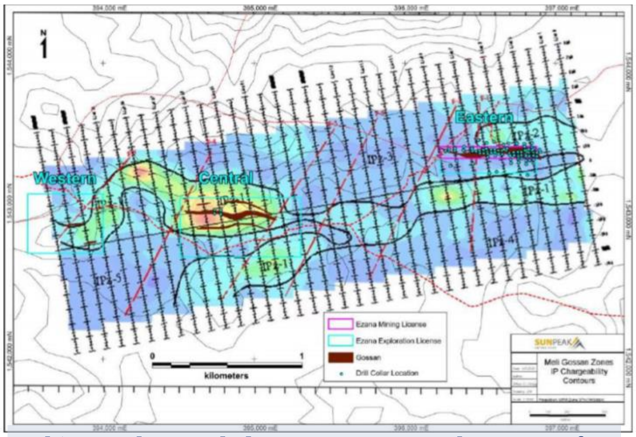
In 2007 Ezana converted its prospecting license to an exploration license and conducted a detailed exploration of the Meli concession comprised of dense stream sediment and rock chip sampling. Broad trends of anomalous geochemistry were defined by stream sediment sample results, particularly by Zn and Ag values, with local coincident Au and Cu. The anomalous areas appear to be aligned with the stratigraphy and are perhaps associated with VMS-mineralized horizons (SunPeak-Metals, 2020).

The company did a follow-up exploration using the geochemical and geophysical survey; however, the discovery of significant mineralization in the Meli gossans area diverted its exploration attention, leaving the majority of the extensive targets and focus on the gossan.

In the same year as the geochemical works, in 2007, the company acquired external contractors for the integrated detailed geophysical survey that including magnetic, gravity, and Induced Polarization (IP)/resistivity surveys over a 1.5 X 3.5 Km area that encompassed the three gold-bearing Meli gossan zones. The 35 NNW-trending survey lines were each 1,500 m in length and spaced 100 m apart (Figure 34).



a) Gravity contours in the area of Meli gossan zones (warmer colours represent higher density)



b) IP Chargeability contours in the area of Meli gossan zones (warmer colours represent higher chargeability)

c) Gravity contPriority geophysical targets in the area of Meli gossan zones ours

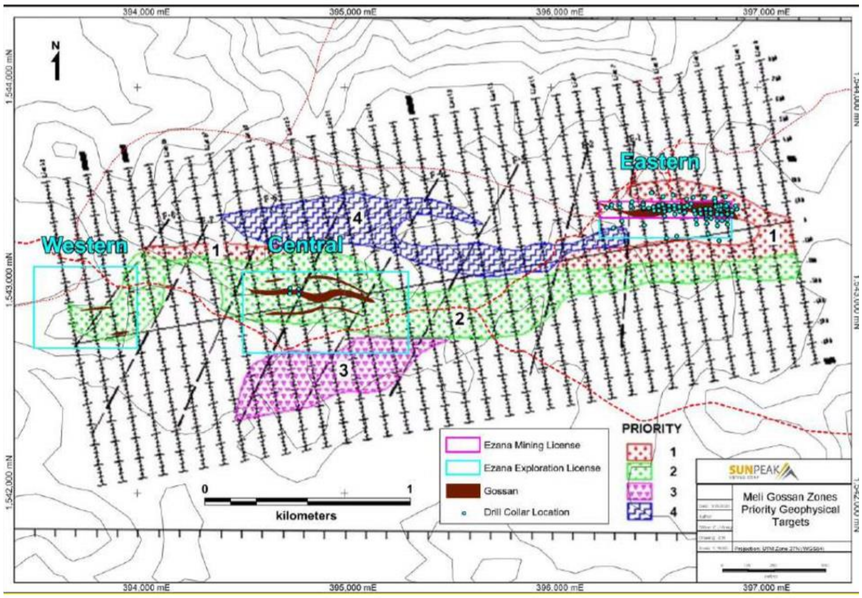


Figure 34: Geophysical Survey at Meli Gossan
a) Gravity b) IP Chargeability c) Priority target (Source: Lul Earth Sciences, 2007 as indicated on (SunPeak-Metals, 2020))

Ezana began drilling targets in the Meli gossan area in 2008. As can be seen on Figure 34 C, drilling to date has been concentrated almost exclusively on the Eastern gossan zone, drilled 7 shallow vertical holes, totaling 269 m, with a water well percussion drill on the Eastern Meli gossan, with an intent to test the down-dip continuity of mineralization. In 2009, a reverse circulation (RC) drill was contracted to complete 9 boreholes on the Eastern gossan; they had an aggregate depth of 429m. These holes were oriented at an azimuth of 350^0 and inclined at -55^0. Percussion holes have prefix RVH and RC holes have prefix RHRC. As can be seen in Table 6, some of the holes returned some very significant gold grades, such as 16.76 g/t Au over 20 m in hole RVH-04 and 39.51 g/t Au over 12 m in hole RVH-07. The 2008 holes were primarily drilled to test the gold-enriched oxide zone, which was found to extend to about 30 m depth, but some holes also encountered sulfide minerals near or below that depth. For example, in RHRC-01A, massive sulfide was encountered between 25 and 30m. In RHRC-08, massive sulfide was encountered between 31 and 42m and between 47 and 54m, and the hole bottomed in massive sulfide due to drilling problems. Samples from this hole returned gold values ranging from 0.2 to 3 g/t Au, with one 1 m sample returning a high of 11.4 g/t Au; copper averaged 0.5% over 33 m and zinc averaged 0.67% over 22 m. (SunPeak-Metals, 2020)

Table 6: Assay intervals for percussion and RC DH in Eastern Meli gossan (SunPeak-Metals, 2020)

Hole ID	Depth (m)	Au(g/t)/m	Ag (g/t)/m	Cu (%)/m	Zn (%)/m
RVH-01	31	**5.48/28m**	4.11/27m	0.14/7m	0.02/7m
RVH-02	94	3.15/8m	4.05/19m, 8.2/16m	0.19/10m, 0.19/11m	0.15/10m
RVH-03	40			0.27/19m	0.027/20m
RVH-04	40	**16.76/20m**	3.7/20m	0.1/19m	0.03/5m
RVH-05	22		2.8/10m	0.3/4m,0.15/1m, 0.17/1m	0.06/18m
RVH-06	22	0.6/5m	3/2m	0.12/1m	0.03/16m
RVH-07	24	**39.5/12m, 16.3/2m**	23.4/12m, 18/2m	0.14/4m	
RHRC-01	50	3.92/18m	8.1/30m incl. 11.3/18m	0.2/35m	0.1/5m
RHRC-01A	33	3.42//18m	15.6/21m incl. 42.2/6m	0.15/4m, 0.16/8m, 0.9/5m incl. **1.89/2m**	
RHRC-02	50	**9.89/28m**	19.9/27m	0.16/13m	0.06/18m
RHRC-03	35	**7.1/11m**	5.1/28m	0.2/6m	0.12/5m
RHRC-04	30	1.17/2m	3/9m	0.33/10m	0.04/10m
RHRC-05	45	6.5/7m, 4.8/3m, 0.54/3m	2.5/8m	0.12/4m, 0.14/5m, 0.15/2m	0.03/6m
RHRC-06	62	1.56/2m	3/3m	0.22/12m, 0.17/7m	0.03/25m
RHRC-07	28	0.61/1m	5.8/1m	0.17/1m	0.03/5m
RHRC-08	54	0.43/26m	12.8/15m, incl. 18/9m, 13.5/8m incl. 18/5m	0.22/12m, **0.5/33m** incl. 1.3/1m, 1.97/3m, 2/1m	**0.67/22m**, incl. 1.2/4m, 1.9/1m

In 2009, the channel samples, along with analyses from the 16 Eastern gossan zone drill holes, were used by Ezana to make a preliminary, non-compliant resource estimate suggesting that the mineralized oxide cap may contain as much as 4 tons (3600 kg) of gold with an average grade of 4.0 g/t Au, calculated using a 0.3 g/t Au cut-off (Ezana private company report).

Following from these recommendations made in December 2008 by Andrew Philips from ACA Howe International in the period between 2009 and 2012, Ezana drilled more than 80 diamond drill holes in the Eastern Meli gossan, with the main objective of testing the potential of the oxide cap, called the gossan.

Even though only a few of the holes were drilled into the deeper parts of the underlying sulfide-bearing zone. Of the holes drilled into the sulphide zone, a number returned very significant intercepts, including 4.2% Cu, 0.7% Zn, 1.5 g/t Au, 37.1 g/t Ag over 17.4 m (hole RH-DH-01, 28.65-46.05 m) and 2.4% Cu, 1.0% Zn, 2.6 g/t Au, 37.8 g/t Ag over 15.1 m (hole RH-DH-49, 65.0-80.1 m) (Figure 35). True thicknesses of the mineralized intervals are approximately 90-95% of the drilled lengths. An example of the grades encountered across the width of one of the significant mineralized intercepts is shown in Table 7. It tabulates all the assays for the VMS-style mineralization in drill hole RH-DH-01, and it shows that the sulfide zone yields consistent strong copper and zinc grades throughout, and that zinc appears to increase in grade downhole. It also shows that lead values coincide with those of zinc, but are of lower tenor, returning less than 0.3% Pb, on average.

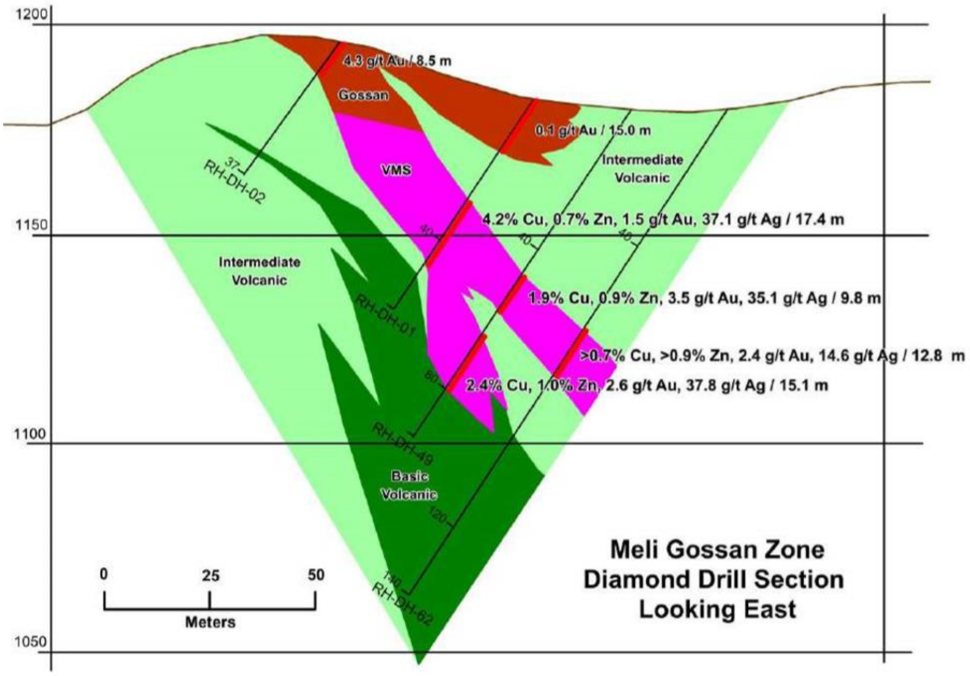


Figure 35: Eastern Meli gossan zone drill section looking east
(source: Ezana private company report as indicated on (SunPeak-Metals, 2020))

Table 7: Eastern Meli gossan for selected drill intercepts (SunPeak-Metals, 2020)
Diamond drill hole RH-DH-01 (source: Ezana private company report)

Hole ID	Depth From (m)	Depth To (m)	Length	Lithology	Au_ppm	Ag_ppm	Cu_ppm	Zn_ppm	Pb_ppm
RH-DH-01	28.65	29.80	1.15	VMS	1.27	**43.20**	**56220**	7630	680
RH-DH-01	29.80	30.80	1.00	VMS	1.21	33.20	**39400**	2005	141
RH-DH-01	30.80	31.80	1.00	VMS	**1.78**	**40.00**	**34640**	1520	340
RH-DH-01	31.80	32.80	1.00	VMS	1.41	**36.70**	**44200**	3514	280
RH-DH-01	32.80	33.80	1.00	VMS	**3.35**	**38.90**	**44160**	2411	360
RH-DH-01	33.80	34.80	1.00	VMS	**1.63**	**44.10**	**76320**	7160	1440
RH-DH-01	34.80	35.80	1.00	VMS	**2.41**	**49.50**	**59860**	7850	3860
RH-DH-01	35.80	36.80	1.00	VMS	0.86	23.80	**35100**	2176	1440
RH-DH-01	36.80	37.80	1.00	VMS	1.09	**38.60**	**37960**	3295	540
RH-DH-01	37.80	38.80	1.00	VMS	1.47	**42.40**	**25240**	4205	260
RH-DH-01	38.80	39.80	1.00	VMS	**2.41**	22.70	**32960**	5750	3386
RH-DH-01	39.80	40.80	1.00	VMS	0.24	**47.50**	**32400**	5130	1440
RH-DH-01	40.80	41.80	1.00	VMS	1.42	32.00	**27900**	**20060**	2765
RH-DH-01	41.80	42.80	1.00	VMS	0.33	31.80	**64860**	7030	1180
RH-DH-01	42.80	43.80	1.00	VMS	**1.82**	**42.50**	**37700**	**11960**	2900
RH-DH-01	43.80	44.80	1.00	VMS	**2.55**	**40.50**	**30200**	**23100**	2343
RH-DH-01	44.80	46.05	1.25	VMS	0.72	25.20	**34960**	5090	480
Average: 28.65 m to 46.05 m = 1.5 g/t Au, 37.1 g/t Ag, 4.2% Cu, 0.7% Zn over 17.4 m									

In 2013 Ezana applied for and was granted, a mining license. Ezana undertook mine planning and feasibility studies and followed-up in 2016 with the construction of a CIL plant adjacent to the Eastern Meli gossan zone. Open cut extraction of the gossan cap commenced in 2017 and the mill has operated intermittently since that time.

In 2017 Ezana signed a joint venture agreement with Sun Peak Metals Corporation, Canada, to form Axum Metals Share Company (Axum). Axum undertook compilation and reinterpretation of all the previous exploration data and initiated the construction of an ArcGIS/MapInfo GIS spatial database. From the compiled and re-interpreted maps in the GIS database, as well as from geological field visits, the work by Axum suggested that at least two types of mineral deposits might occur in the Meli concession area, as follows:

I. VMS-style mineralization defined by oxide gossans underlain by sulphidic zones,
II. Orogenic gold vein mineralization hosted by shear zones and outlined by altered host rocks and geochemical anomalies.

In 2019 Axum applied for and was granted, the Meli exploration license, which surrounds the area of Ezana's small mining license area and Ezana's two small exploration licenses covering the Central and Western gossan zones.

The Axum team has already identified primary targets for further exploration and the results of that exploration between 2019 and the present day. The Sun Peak Metals team (now with Axum) has previously applied the use of modern advanced exploration techniques successfully at both Bisha and the Asmara Project, located nearby in Eritrea.

Sun Peak Metals Corp is a Canadian junior mining company, and the team has worked in the region for over 15 years with both Nevsun Resources on the Bisha Project and Sunridge Gold on the Asmara Project. Over the last couple of years, Sun Peak has been conducting exploration, applying the same exploration techniques the team used successfully during the discovery of both Bisha and the deposits on the Asmara Projects. This includes an airborne VTEM survey completed in October 2019 and detailed ground gravity surveys over several high priority targets. Drilling began in February 2020. For the year 2020, Axum has proposed a comprehensive work program totaling more than US$1.1 million. This includes at least 4,000 meters of diamond drilling to test the well-defined Eastern Meli massive sulfide zone to depth, as well as testing of property-wide targets via ground-based geophysical, geochemical, and geological surveys. (SunPeak-Metals, 2020)

4.5 Mining Operations at Meli

The mining operations are conducted using conventional open pit mining methods, but only involve the two standard units of operation namely loading and hauling. As the mining is on the oxidized material, it is a free dig; meaning doesn't involve drilling and blasting. During this study, mining was conducted by the company itself.

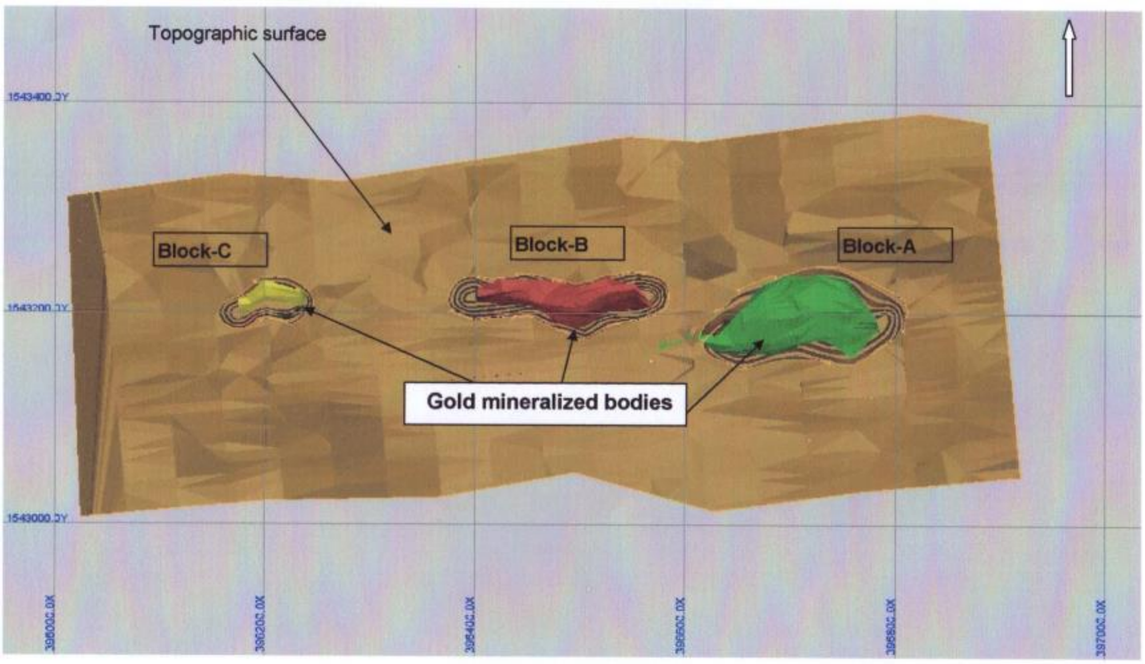


Figure 36: Plan view of Meli OP design layout (Ezana_Private_Report)

The current Mineral Reserve estimate for the Project was developed by Midroc Gold. Mining of the Mineral Reserves at the Project is by open pit mining methods level by level using medium-sized excavator and 16 cubic meter capacity tipper trucks, on all three locations.

- Pit A: also called Block A, had initial level 1199m asl and designed to reach 1160m asl represents a total mass of tonnage of 364,838 with a diluted grade of 4.96 Au g/t. the total waste in this ore body is 123,799t.
- Pit B: also called Block B. the top initial level was 1196m asl with a total ore mass of 136,658 tonnes at a diluted grade of 4.9 g/t. The total amount of waste estimated at 139,310t.
- Pit C: the third pit on the western part which contains 14,300 tonnes with 4.81 g/t. Waste tonne indicated in this body is 51,266t.

The load and haul from these pts are carried using an excavator and tipper trucks as a haul truck. The material is mined and dumped to the run of mine stockpile located near the crusher and later re-handled using the front end loader to feed to the crusher.

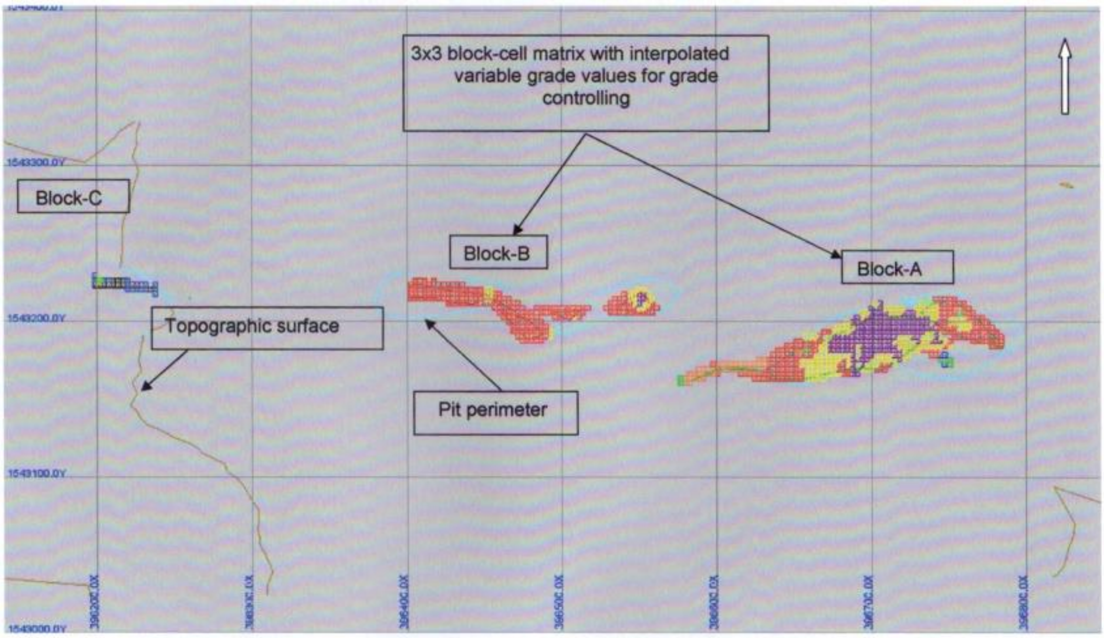


Figure 37: Level plan 1175 showing mining block (Ezana Private Report)

It is usually necessary to blend different ore types to maintain the grade of the mill feed, and it is necessary to load and haul fragmented and boulder ore separately, boulders will be left separately until the excavator changes its bucket with rock breaker in a different day.

4.6 Processing Plant

The processing plant designed for Meli Gold Mine has the capacity to process 35 tonnes per hour at a grade of Au 4.37g/. The metallurgical plant for the Meli Gold plant is a standard Milling & CIL circuit. CIL stands for Carbon In Leach, where the leached or dissolved gold is adsorbed on activated carbon while at the same time, and in the same tank the leaching reaction still takes place.

The designed considered 3 shifts of 8 hours each in a day, 365 days a year, and 91.3% availability. All the Milling, thickening, and CIL have the planned operating hours of 8,000 Hr. /Yr. and operational throughput of 35dry t/hr. with a design throughput (max.) of 40t/hr.

The plant includes:

- Two-stage Crushing. The first stage crushing is carried out by jaw crusher which has the Operational throughput capacity of 85t/hr. designed to 3,000 hr. /Yr. planned operating hours. The Second stage crushing is carried by Cone Crusher, which has the same planned operating hours of 3,000hr/Yr. with the capacity of operational throughput of 50t/hr. The rage is between ROM Feed F100 with approximately 500mm and ROM Feed F21is 1mm
- Intermediate stockpile. At a crushing feed rate of 85t/hr., the stockpile live capacity approximated at 1,000 tonnes and a total capacity of 2,000 tonnes.
- Followed by one ball mill (grinding). The milling rate is 35 dry t/hr. ore, and has 3.5m inside shell diameter and 5.5m grinding length. The mill product p80 is 74micro meter. Design cyclone overflow slurry is 35% solid by mass, and Mill discharge slurry is 60% solid by mass.
- Thickener to increase the solid content in the pulp from the mill and to gain back some amount of water. Thickener diameter is 10m with a feed tonnage capacity of 35t/hr.
- The CIL plant
- Carbon elution/electrowinning in a Zadra circuit, Dore smelting, and carbon regeneration
- Detox plant to neutralize/destroy the cyanide in the residue prior to discharge the tailing storage

Figure 38: Ezana Processing plant (Picture by Author)

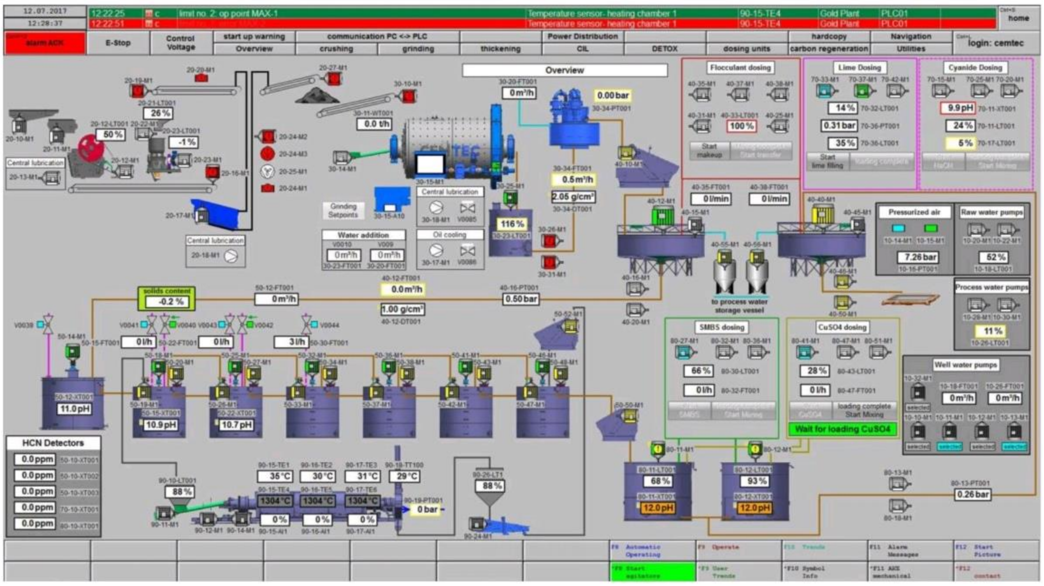


Figure 39: Overview of the Meli process plant (Ezana_Private_Report)

4.6.1 The mechanism for Gold Adsorption

As a noble metal, Gold prefers to exist in its natural state as gold metal. Naturally noble metals are unreactive. Cyanide is one of the few chemicals that will react with gold. In metallurgical applications, the metal being recovered is generally present in ore in low grades thus must be "concentrated up" to an extent where it may be smelted into a bar. Activated carbon is an adsorbent that increases the concentration of gold in the solution phase. For example – An ore containing 3 g/t is leached, mixed with carbon, which leads to 3 000 g/t, a concentration up of 1 000 times. During the elution process, the gold is removed from the carbon. This is diluted to 300 g/t gold in a clear solution; concentrating being up 100 times from the original head grade.

"Activated Carbon" is a generic term for a family of highly porous carbonaceous materials that cannot be defined by a structural formula, or by chemical analysis. In other words, a piece of carbon with millions of tiny interlocking holes (called pores) is called activated carbon. Under a microscope, activated carbon looks like a sponge (Ezana private manual).

Initially, the gold is leached using cyanide with lime and oxygen, etc. The dissolution of gold from the ore results in the gold present in water as the gold cyanide ion approximated as follows:

$$Au + 2CN^{-} \rightarrow Au(CN)^{-}_{2}$$

Gold + Cyanide → Gold cyanide ion.

The gold cyanide ion in water prefers to be a neutral species and thus the negative charge will be countered by any positive ion such as Ca^{2+}, Mg^{2+}, H^{+}, Na^{+}, K^{+}, etc.

For calcium, the gold cyanide ion joins with calcium to form a calcium gold cyanide ion pair:

$$2Au(CN^{-})^{-}_{2} + Ca^{2+} \leftrightarrow Ca(Au(CN^{-}_{2})_{2} \text{ (ion pair)}$$

The ion pair is a neutral species and will be adsorbed by activated carbon by physical adoption depending on factors including Mixing efficiency, Pulp density, the Particle size of carbon, Temperature, Cyanide concentration, pH, Contact time, Type of activated carbon, etc.

Elution is a reverse of adsorption by changing certain external factors. Inversely changing key factors that favor adsorption will reverse the adsorption mechanism. In order to elute gold off the carbon, the calcium gold cyanide ion pairs must be changed into a form that the activated carbon will reject, i.e. the adsorption processes are reversed.

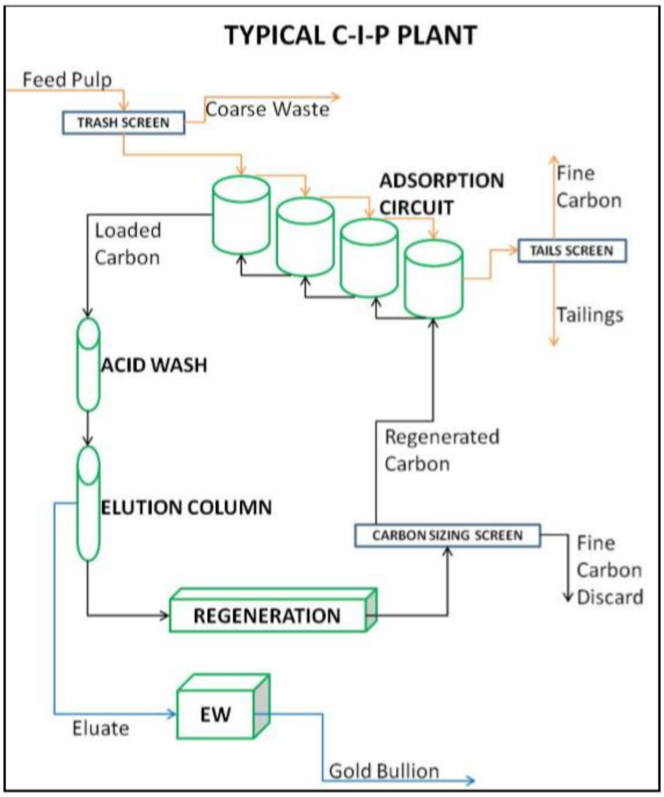


Figure 40: Typical CIL Plant demonstrates Meli processing (Ezana private Report)

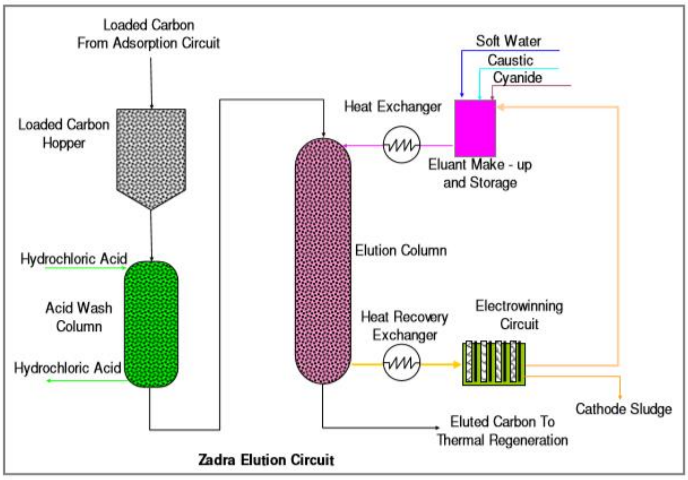


Figure 41: Typical Zadra Elution Circuit (Ezana Private Report)

4.6.2 Sampling in the processing plant

Sampling in the plant is done using a hammer sampler on the mill feed conveyor belt to determine the head grade. After the eight-hour shift, the sample is split, using a riffle to obtain a representative sample. A sample for each shift is submitted to the mine site assay laboratory for analysis and a duplicate is retained for reference purposes

4.6.3 Process Ore flow chart

The process started by first stage crushing, which is carried out by jaw crusher which has the Operational throughput capacity of 85 t/hr.; and followed by Second stage crushing that carried by Cone Crusher that has a capacity of operational throughput of 50 t/hr. The resultant size range is between ROM Feed F100 with approximately 500mm and ROM Feed F21is 1mm. Ore crushed is then piled at the intermediate stockpile. At a crushing feed rate of 85 t/hr., the stockpile live capacity approximated at 1,000 tonnes and a total capacity of 2,000 tonnes.

After crushing, it is followed by one ball mill (grinding). The milling rate is 35 dry t/hr. ore, and has 3.5m inside shell diameter and 5.5m grinding length. The mill product p80 is 74micro meter. Design cyclone overflow slurry is 35% solid by mass, and Mill discharge slurry is 60% solid by mass.

The next stage is thickening using thickeners. Thickener’s use is to increase the solid content in the pulp from the mill and to gain back some amount of water. Thickener diameter is 10m wide with a feed tonnage capacity of 35t/hr.

The process plant is a CIL plant, followed by Carbon elution/electrowinning in a Zadra circuit, Dore smelting, and carbon regeneration. The process ends with the Detox plant to neutralize/destroy the cyanide in the residue prior to discharge of the tailings storage.

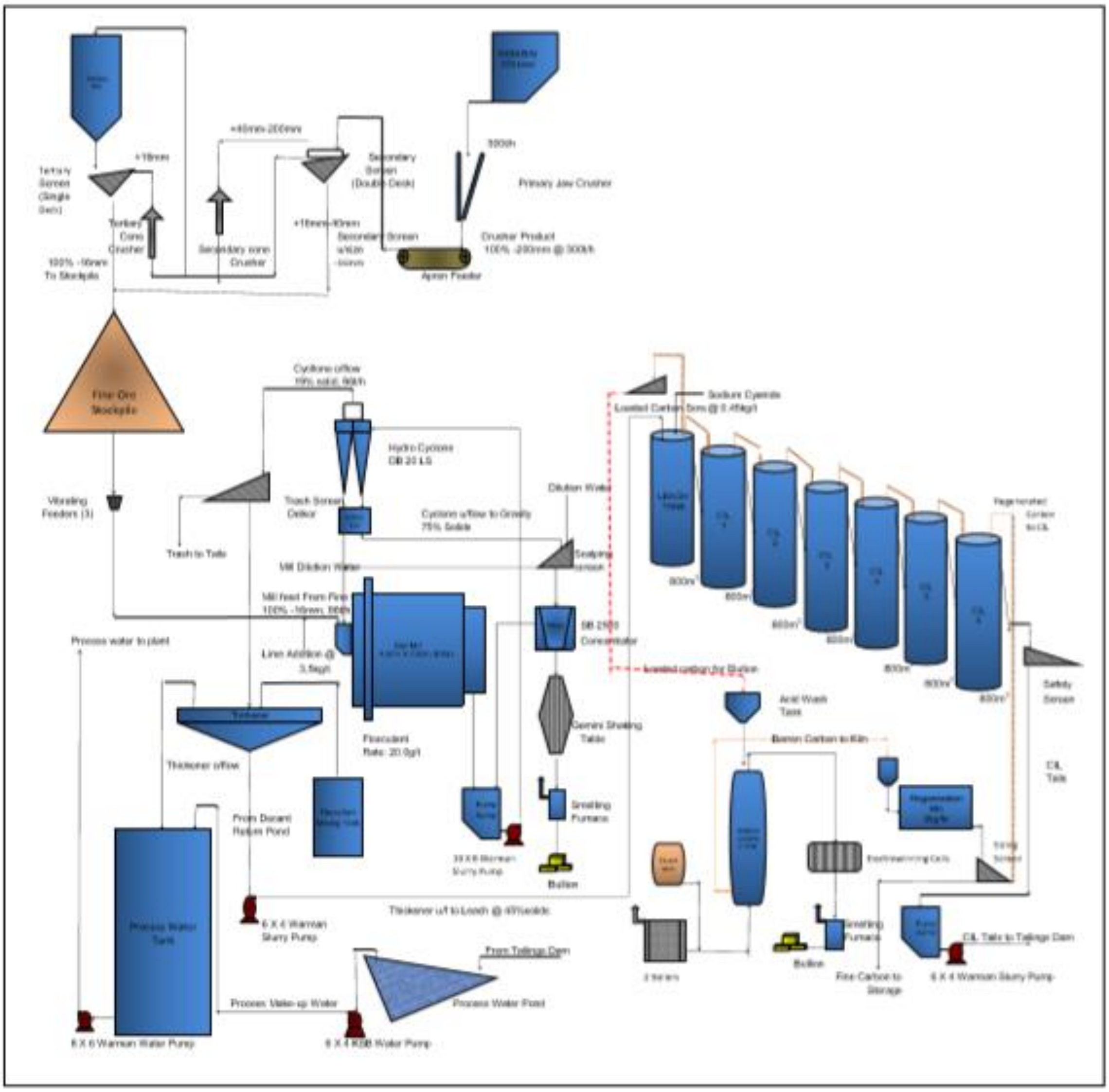


Figure 42: Process Ore flow chart (Ezana_Private_Report)

5

Chapter V: Data Analysis and Data Presentation

5.1 Data analysis and generate factors

Recent actual production data from July 2019 to February 2020 (Table 8) shows the mining section mined and hauled 125,110t of ore to the ROM stockpile. The mining data indicates 71,012t to be delivered to the crusher team; the crusher team data shows as 74,420t to be received from the mining which has a 3,408t difference (4.6%). In the same period, the process section measures 75,859t processed, which is a 1,439t variance with the crusher team and 4.847t with the mining team. The production profile during the same period shows the existence discrepancy along the mining path, meaning the problem of variance between the planned and what is achieved, which requires the need for MCF analysis.

Table 8: Ore production profile (Jul-19 to Feb-2020)

Month	Mined and Hauled			Delivered to Crusher (Mine)			Crushed (Process)			Processed at Mill			
	Tonnes (t)	Grade (g/t)	Contained Gold (Oz)	Tonnes (t)	Grade (g/t)	Contained Gold (Oz)	Tonnes Crushed (t)	Grade (g/t)	Contained Gold (Oz)	Ore Feed (t)	Head Grade (g/t)	Gold Recovery (%)	Recovered Gold (Oz)
Jul-19	17,680.8	3.12	1,775.6	4,736.5	6.16	938.4	4,536.5	6.16	898.7	7,444	4.12	86.5%	852.5
Aug-19	2,162.4	4.60	320.0	7,299.5	4.51	1,059.6	7,671.1	4.51	1,113.5	5143.1	4.31	90.7%	646.5
Sep-19	1,017.6	5.20	170.2	10,103.2	4.07	1,321.6	10,081.9	4.07	1,318.8	6052.1	5.05	91.1%	894.8
Oct-19	3,180.0	3.13	320.0	11,767.0	4.53	1,713.3	14,133.5	5.08	2,308.2	20,131	5.52	91.6%	3271.1
Nov-19	36,040.0	4.60	5,333.5	5,976.4	6.53	1,255.0	2,441.7	7.77	609.7	2329.2	7.55	92.5%	522.8
Dec-19	36,252.0	4.60	5,364.9	3,000.0	4.90	472.3	5,432.3	6.21	1,085.1	5074.2	6.65	91.7%	995.1
Jan-20	7,801.6	4.61	1,156.6	13,235.2	4.63	1,970.6	15,296.7	4.56	2,240.2	14,772	5.40	90.6%	2322.4
Feb-20	20,976.0	4.65	3,138.5	14,894.4	5.82	2,786.7	14,826.5	3.18	1,514.6	14914	4.67	90.3%	2023.0
Total	125,110.4	4.37	17,579.3	71,012.1	5.04	11,517.6	74,420.2	4.63	11,088.9	75,859	5.21	90.6%	11,528.2

5.1.1 Resource and Reserve

Table 9 and Table 10 illustrates the Ore resource and reserve on the Eastern gossan for Meli Gold mine. The data summarizes the key ore information for all the three pits (pit-A, Pit-B, and Pit-C) detailed based on the mining level of 3m.

Table 9: Meli Ore block data before and after dilution (modified after (Ezana_Private_Report)

Body-A Ore tonnage

Level	In Situ Ore Volume (m3)	In Situ Ore tonnage (t)	Grade (g/t)	Diluted Ore Volume (m3(	Diluted Ore tonnage (t)	Diluted grade (g/t)	Gold Content (g)	Waste after dilution (t)
1199	1,995.00	5,187.00	7.51	1,995.00	5,187.00	7.51	38,954.37	640.00
1196	6,800.00	17,670.00	6.21	7,662.00	19,921.20	5.51	109,809.64	3,336.00
1193	12,400.00	32,230.00	6.01	13,451.00	34,971.30	5.54	193,814.44	4,110.00
1190	15,490.00	40,270.00	6.15	17,984.00	46,757.10	5.29	247,521.10	2,813.00
1187	17,100.00	44,460.00	5.61	18,369.00	47,759.40	5.22	249,302.64	10,036.00
1184	17,420.00	45,290.00	5.14	19,025.00	49,463.70	4.70	232,655.38	10,676.00
1181	15,640.00	40,670.00	5.1	18,054.00	46,940.00	4.42	207,395.69	20,050.00
1178	12,630.00	32,830.00	5.33	15,080.00	39,206.70	4.46	174,837.01	11,624.00
1175	9,740.00	25,320.00	5.5	11,285.00	29,339.70	4.75	139,292.41	13,688.00
1172	7,330.00	19,070.00	5.73	8,481.30	22,051.40	4.95	109,165.07	12,703.00
1169	4,450.00	11,570.00	5.48	5,314.80	13,818.50	4.59	63,432.75	12,998.00
1166	1,880.00	4,900.00	4.9	2,464.80	6,408.48	3.74	23,996.23	10,900.00
1163	580.00	1,510.00	4.72	890.10	2,314.26	3.08	7,131.09	8,303.00
1160	110.00	280.00	4.81	269.07	699.58	1.94	1,357.01	1,921.00
TOTAL	123,565.00	321,257.00	5.60	140,325.07	364,838.33	4.93	1,798,664.83	123,798.00

Body-B Ore tonnage

Level	In Situ Ore Volume (m3)	In Situ Ore tonnage (t)	Grade (g/t)	Diluted Ore Volume (m3(	Diluted Ore tonnage (t)	Diluted grade (g/t)	Gold Content (g)	Waste after dilution (t)
1199	1,842.90	4,791.54	6.22	2,085.30	5,421.78	5.50	29,803.37	1,376.00
1196	3,160.00	8,230.00	7.57	3,801.90	9,884.94	6.30	62,306.95	7,292.00
1193	4,410.00	11,480.00	7.63	5,439.00	14,141.00	6.02	85,107.80	8,428.00
1190	5,610.00	14,580.00	6.57	7,041.00	18,306.60	5.23	95,721.02	12,698.00
1187	6,010.00	15,620.00	6.12	7,984.50	20,759.70	4.60	95,555.44	11,054.00
1184	5,860.00	15,240.00	5.99	7,546.50	19,620.90	4.65	91,311.40	12,161.00
1181	4,900.00	12,740.00	6.91	6,333.00	16,466.00	5.35	88,021.50	14,909.00
1178	3,920.00	10,180.00	6.3	4,906.50	12,756.90	5.03	64,207.21	18,759.00
1175	2,430.00	6,310.00	5.44	3,174.00	8,252.40	4.16	34,324.56	17,079.00
1172	1,770.00	3,050.00	4.11	1,809.90	4,705.74	2.66	12,533.00	13,855.00
1169	690.00	1,810.00	3.09	1,086.12	2,823.91	1.98	5,585.88	12,015.00
1166	430.00	1,120.00	2.84	668.34	1,737.68	1.83	3,171.67	5,537.00
1163	250.00	640.00	2.05	397.80	1,034.28	1.28	1,321.00	2,631.00
1160	120.00	310.00	1.84	210.21	546.55	1.04	570.92	1,017.00
1157	200.00	60.00	1.8	77.04	200.00	0.52	104.31	497.55
TOTAL	41,602.90	106,161.54	6.33	52,561.11	136,658.38	4.90	669,646.03	139,308.55

Body-C Ore tonnage

Level	In Situ Ore Volume (m3)	In Situ Ore tonnage (t)	Grade (g/t)	Diluted Ore Volume (m3(	Diluted Ore tonnage (t)	Diluted grade (g/t)	Gold Content (g)	Waste after dilution (t)
1199								
1196								
1193								
1190								
1187								
1184								
1181								
1178								
1175	200.00	40.00	1.98	*200.00*	*40.00*	*1.98*	86.12	0.00
1172	780.00	2,020.00	1.17	728.26	1,893.49	1.25	2,364.61	5,706.00
1169	1,090.00	2,830.00	1.11	1,426.50	3,708.90	0.84	3,133.10	7,017.00
1166	1,080.00	2,830.00	1.09	1,465.30	3,809.91	0.80	3,066.70	9,767.00
1163	620.00	1,620.00	1.16	1,074.00	2,792.60	0.68	1,889.47	9,746.00
1160	350.00	910.00	1.23	540.67	1,405.75	0.79	1,112.63	9,708.00
1157	150.00	390.00	1.26	265.33	689.87	0.71	490.37	9,321.00
TOTAL	4,270.00	10,640.00	1.14	5,700.06	14,340.52	0.85	12,143.00	51,265.00

Table 10: Summary of Meli Resources (Ezana private report)

Pit	In Situ Ore Volume (m3)	In Situ Ore tonnage (t)	Grade (g/t)	Diluted Ore Volume (m3(	Diluted Ore tonnage (t)	Diluted grade (g/t)	Gold Content (g)	Waste after dilution (t)
Pit-A	123,565.00	321,257.00	5.600122861	140,325.07	364,838.33	4.93	1,798,664.83	123,798.00
Pit-B	41,602.90	106,161.54	6.331510251	52,561.11	136,658.38	4.90	669,646.03	139,308.55
Pit-C	4,270.00	10,640.00	1.142716165	5,700.06	14,340.52	0.85	12,143.00	51,265.00
TOTAL	169,437.90	438,058.54	5.67	198,586.24	515,837.23	4.81	2,480,453.85	314,371.55

Pit	Contained Gold (Kg)	Contained Au Ounces (Oz)	Planned Recovery (%)	Gold to be Recovered (Kg)	Gold to be Recovered (Oz)	Total Pit tonnes(Ore +waste)	Stripping ratio (W:O)	Waste after dilution (t)
Pit-A	1,798.66	57,828.37	92%	1,654.77	53,202.10	488,636.33	0.34	11,054.00
Pit-B	669.65	21,529.60	92%	616.07	19,807.24	275,966.93	1.02	0.00
Pit-C	12.14	390.41	92%	11.17	359.17	65,605.52	3.57	314,371.55
TOTAL	2,480.45	79,748.38	92%	2,282.02	73,368.51	830,208.78	0.61	325,425.55

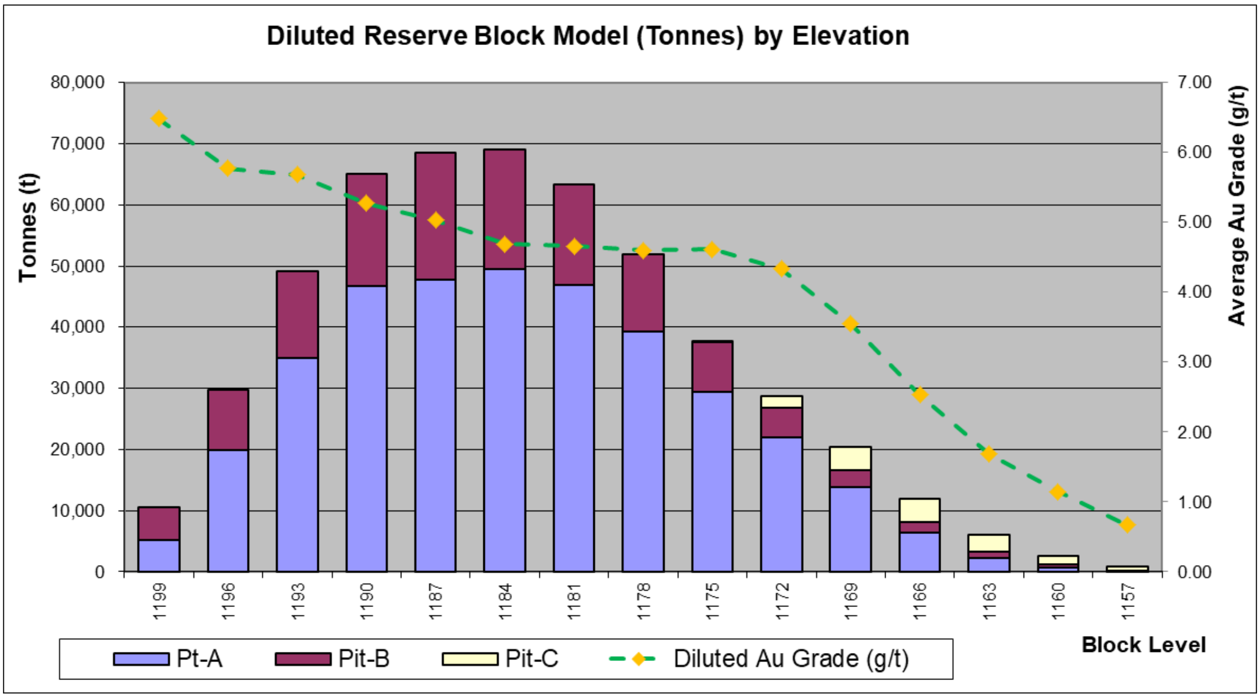


Figure 43: Graph showing the Diluted Ore Reserve quantity (tonnes & Grade)

5.1.2 Production trend of Meli

Figure 44 shows the historical production trend in tonnes from July 2017 to February 2020. Ore crushed and processed tonnes peaked at 15,297 tonnes in January 2020 and following at 14,827 tonnes in the following month February 2020. During the period from the mine started just before July 2017 to February 2020, the crusher process 175,742t@5 g/t averaged at 5,325 tonnes per month with a generally upward trend. The processing figure has a slight difference from the mining reported figure of 172t@5.15 g/t.

The production for each period was variable with a general upward trend.

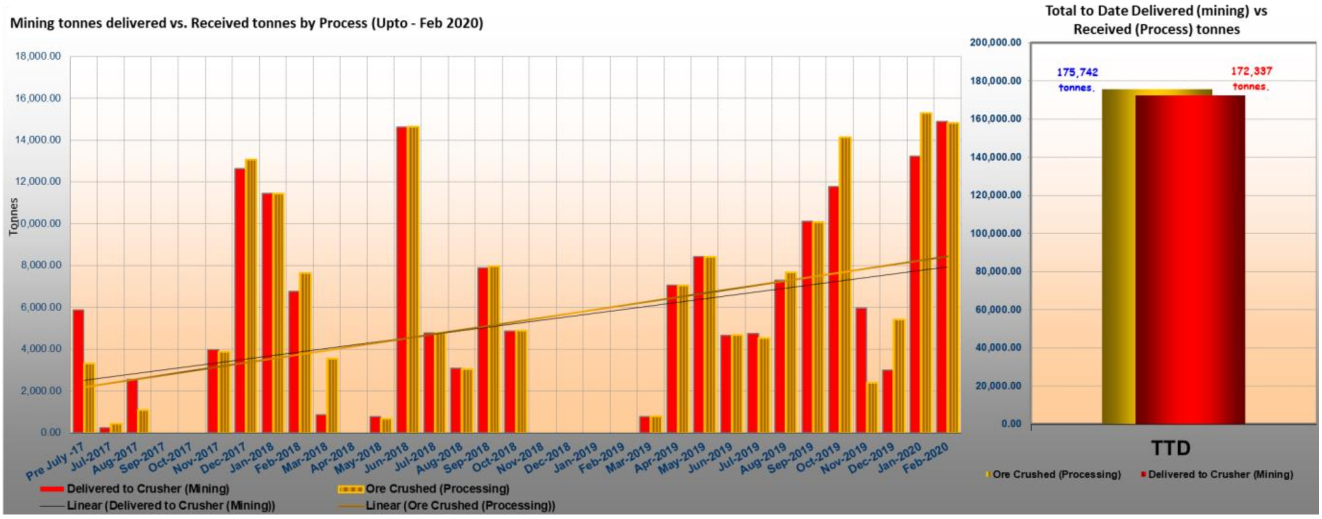


Figure 44: Mining tonnes delivered vs. Received tonnes by Process (Up to - Feb 2020)

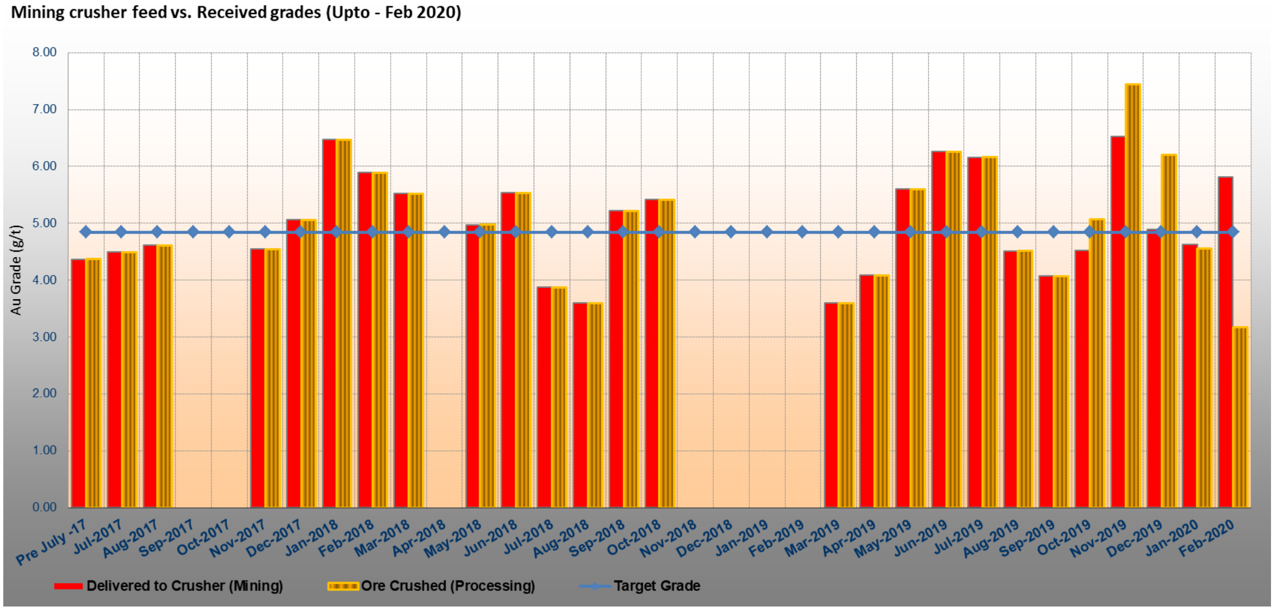


Figure 45: Mining Grades delivered vs. Received grades by Process (Up to - Feb 2020)

5.1.3 Analysis of Ore production

The summary of ore flow analysis for the mining and processing as of 2017 are analyzed to determine tonnage or grade loss.

Table 11: Mining Ore depleted for 8 months period July 2019 to February 2020

Month	Mined Level	Resource Depleted Tonnes (t)	Grade (g/t)	Contained Gold (Oz)
Jul-19	1190 A&B)	3,265	5.26	552
	1187B	14,416	4.60	2,133
Aug-19	1187B	2,162	4.60	320
Sep-19	1190 B	975	5.23	164
	1187B	42	4.60	6
Oct-19	1187B	2,162	4.60	320
Nov-19	1187B	36,040	4.60	5,333
Dec-19	1187B	36,252	4.60	5,365
Jan-20	1187B	6,530	4.60	966
	1184B	1,272	4.65	190
Feb-20	1184B	9,231	4.65	1,381
	1187A	11,745	4.70	1,776
	Total	124,092.8	4.64	18,508

Table 12: Ore mined and processed from July 2019 to February 2020

Month	Mined and Hauled			Delivered to Crusher (Mine)			Crushed (Process)			Processed at Mill			
	Tonnes (t)	Grade (g/t)	Contained Gold (Oz)	Tonnes (t)	Grade (g/t)	Contained Gold (Oz)	Tonnes Crushed (t)	Grade (g/t)	Contained Gold (Oz)	Ore Feed (t)	Head Grade (g/t)	Gold Recovery (%)	Recovered Gold (Oz)
Jul-19	17,680.8	3.12	1,775.6	4,736.5	6.16	938.4	4,536.5	6.16	898.7	7,444	4.12	86.5%	852.5
Aug-19	2,162.4	4.60	320.0	7,299.5	4.51	1,059.6	7,671.1	4.51	1,113.5	5143.1	4.31	90.7%	646.5
Sep-19	1,017.6	5.20	170.2	10,103.2	4.07	1,321.6	10,081.9	4.07	1,318.8	6052.1	5.05	91.1%	894.8
Oct-19	3,180.0	3.13	320.0	11,767.0	4.53	1,713.3	14,133.5	5.08	2,308.2	20,131	5.52	91.6%	3271.1
Nov-19	36,040.0	4.60	5,333.5	5,976.4	6.53	1,255.0	2,441.7	7.77	609.7	2329.2	7.55	92.5%	522.8
Dec-19	36,252.0	4.60	5,364.9	3,000.0	4.90	472.3	5,432.3	6.21	1,085.1	5074.2	6.65	91.7%	995.1
Jan-20	7,801.6	4.61	1,156.6	13,235.2	4.63	1,970.6	15,296.7	4.56	2,240.2	14,772	5.40	90.6%	2322.4
Feb-20	20,976.0	4.65	3,138.5	14,894.4	5.82	2,786.7	14,826.5	3.18	1,514.6	14914	4.67	90.3%	2023.0
Total	125,110.4	4.37	17,579.3	71,012.1	5.04	11,517.6	74,420.2	4.63	11,088.9	75,859	5.21	90.6%	11,528.2

Table 13Reserve Depletion from July 2017 to February 2020

Bench (Combined)	Reserve Depleted (In-situ Ore Block Cut)			Diluted Ore Block Depleted (Mine Planning)		
	Tonnes (t)	Grade (g/t)	Oz	Tonnes (t)	Grade (g/t)	Oz
1199	9,979	6.89	2,211	10,609	6.48	2,211
1196	25900	6.64	5,531	29806.14	5.77	5,534
1193	43,710	6.44	9,044	49,112	5.68	8,968
1190	54,850	6.26	11,042	65,064	5.28	11,036
1187	60080	5.74	11,093	68519.1	5.03	11,087
1184	60,530	5.35	10,419	69,085	4.69	10,416
1181						
1178						
1175	40	1.98	3	40	1.98	3
1172	2,020	1.17	76	1,893	1.25	76
Total	257,109	5.98	49,418.11	294,128	5.22	49,329.25

Table 14: Ore flow from July 2017 to Feb 2020

Mined and Hauled (Mine Reported)			Delivered to Crusher			ROM Stockpile			Received at Mill (Crushed)		
Tonnes (t)	**Grade (g/t)**	**Oz**	**Tonnes (t)**	**Grade (g/t)**	**Oz**	**Tonnes (t)**	**Grade (g/t)**	**Oz**	**Tonnes (t)**	**Grade (g/t)**	**Oz**
281,246	5.22	47,169	172,337	5.15	28,544	108,562	5.34	18,625	175,742	5.00	28,228

Table 15: Reconciliation matrix for Meli Gold Mine (July 2017 to Feb 2020)
Note: A model indicator (MI), the Planning indicator (PI), Operation indicator (OI), Mine Reconciliation (MR), Plant Reconciliation (PR)

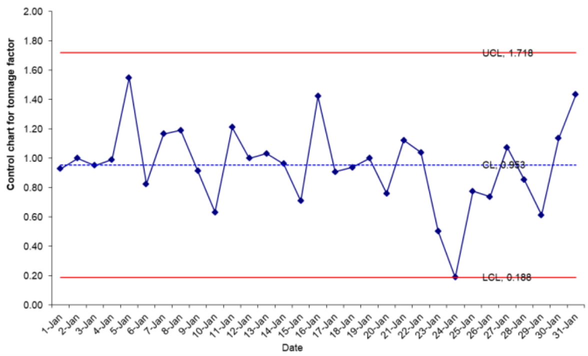
		Reserve (Depleted)			**Mine**			**Plant**	
Variable	**Metal**	Insitu (Long term	Diluted (Short term)		Mined	Crusher Feed		Stock	Plant feed
Mass (t)	Tonnes (t)	257,109	294,128		281,246	172,337		108,562	175,742
Grade	Au (g/t)	5.98	5.22		5.22	5.15		5.34	5.00
Contained metal	Au (Oz)	49,418	49,329		47,169	28,544		18,625	28,228
Reconciliation Indicators (%)		MR	MI		PI	OI			PR
		57%	100%		96%	61%			99%
Estimated produced metal (Au Oz)		25,565							
Plant recovery (%) - extrapolated		90.6%							
MCF (%)	85.9%								

5.1.4 Ore delivered (Mining) vs Ore Crushed (Process)

The plant's capacity is to process 35 tonnes per hour, within 24 hours; the plan is to deliver 840 tonnes, and 25,200t per month. Until February 2020, there are 26 months where production data recorded. There were a significant number of planned as well as unplanned shutdowns of the crusher due to many reasons.

Table 16: Ore delivered vs Ore Crushed for January 2020 production

	Delivered to Crusher (Mining)						Ore Crushed (Processing)						Factor (%) = Ore Crushed / Ore Delivered					
	Grade(g/t)		Tonnes (t)		old content (O		rade(Au g/t		Tonnes (t)		Gold content (Oz)		Grade Factor		Tonnage Factor		Metal Factor	
Date	Daily	MTD	Daily	MTD	Daily	MTD	Daily	MTD	Daily	MTD	Daily	MTD	Daily	MTD	Daily	MTD	Daily	MTD
1-Jan-20	6.42	6.42	288.0	288	59.4	59	5.96	5.96	421.3	421	81	81	0.93	0.93	1.5	1.5	1.4	1.4
2-Jan-20	0.00	6.42	-	288	0.0	59	5.38	5.76	221.5	643	38.3	119.0	1.00	0.90	1.0	2.2	1.0	2.0
3-Jan-20	6.17	6.40	24.0	312.0	4.8	64	5.86	5.81	640.8	1,283.5	120.7	239.8	0.95	0.91		4.1		3.7
4-Jan-20	6.60	6.49	230.4	542.4	48.9	113	6.53	6.04	592.6	1,876.1	124.4	364.1	0.99	0.93	2.6	3.5	2.5	3.2
5-Jan-20	3.88	5.47	345.6	888.0	43.1	156	6.01	6.03	503.9	2,380.0	97.4	461.5	1.55	1.10	1.5	2.7	2.3	3.0
6-Jan-20	5.85	5.55	230.4	1,118.4	43.3	200	4.82	5.73	794.9	3,174.9	123.1	584.7	0.82	1.03	3.5	2.8	2.8	2.9
7-Jan-20	5.05	5.45	264.0	1,382.4	42.9	242	5.89	5.76	692.1	3,867.0	131.1	715.7	1.17	1.06	2.6	2.8	3.1	3.0
8-Jan-20	3.90	5.22	249.6	1,632.0	31.3	274	4.64	5.59	668.9	4,535.9	99.8	815.6	1.19	1.07	2.7	2.8	3.2	3.0
9-Jan-20	5.04	5.17	619.2	2,251.2	100.3	374	4.60	5.46	683.8	5,219.7	101.2	916.8	0.91	1.06	1.1	2.3	1.0	2.5
10-Jan-20	5.50	5.23	513.6	2,764.8	90.8	465	3.47	5.32	404.3	5,624.0	45.1	961.8	0.63	1.02	0.8	2.0	0.5	2.1
11-Jan-20	3.94	5.15	182.4	2,947.2	23.1	488	4.77	5.30	195.1	5,819.0	29.9	991.8	1.21	1.03	1.1	2.0	1.3	2.0
12-Jan-20	0.00	5.15	-	2,947.2	0.0	488	0.00	5.30	-	5,819.0	-	991.8	1.00	1.03	1.0	2.0	1.0	2.0
13-Jan-20	3.50	4.81	758.4	3,705.6	85.3	573	3.61	5.26	133.6	5,952.6	15.5	1,007.3	1.03	1.09	0.2	1.6	0.2	1.8
14-Jan-20	4.26	4.73	643.2	4,348.8	88.1	661	4.10	5.16	554.3	6,507.0	73.0	1,080.3	0.96	1.09	0.9	1.5	0.8	1.6
15-Jan-20	3.54	4.65	326.4	4,675.2	37.1	699	2.51	5.00	427.4	6,934.4	34.5	1,114.8	0.71	1.08	1.3	1.5	0.9	1.6
16-Jan-20	3.83	4.55	657.6	5,332.8	81.0	779	5.45	5.04	618.1	7,552.5	108.3	1,223.0	1.42	1.11	0.9	1.4	1.3	1.6
17-Jan-20	3.39	4.51	192.0	5,524.8	20.9	800	3.07	4.88	637.6	8,190.1	63.0	1,286.0	0.91	1.08	3.3	1.5	3.0	1.6
18-Jan-20	3.32	4.44	312.0	5,836.8	33.3	834	3.11	4.76	630.7	8,820.8	63.1	1,349.2	0.94	1.07	2.0	1.5	1.9	1.6
19-Jan-20	0.00	4.44	-	5,836.8	0.0	834	4.01	4.71	612.8	9,433.6	79.0	1,428.2	1.00	1.06	1.0	1.6	1.0	1.7
20-Jan-20	5.79	4.59	716.8	6,553.6	133.4	967	4.40	4.70	395.9	9,829.5	56.0	1,484.2	0.76	1.02	0.6	1.5	0.4	1.5
21-Jan-20	5.81	4.66	409.6	6,963.2	76.5	1044	6.52	4.80	584.4	10,413.9	122.5	1,606.6	1.12	1.03	1.4	1.5	1.6	1.5
22-Jan-20	5.13	4.72	1,024.0	7,987.2	168.9	1213	5.33	4.82	437.0	10,850.8	74.9	1,681.5	1.04	1.02	0.4	1.4	0.4	1.4
23-Jan-20	4.30	4.68	768.0	8,755.2	106.2	1319	2.16	4.77	212.7	11,063.5	14.8	1,696.3	0.50	1.02	0.3	1.3	0.1	1.3
24-Jan-20	3.69	4.64	384.0	9,139.2	45.6	1364	0.69	4.67	272.1	11,335.5	6.0	1,702.3	0.19	1.01	0.7	1.2	0.1	1.2
25-Jan-20	5.36	4.66	256.0	9,395.2	44.1	1408	4.15	4.65	393.6	11,729.1	52.5	1,754.8	0.77	1.00	1.5	1.2	1.2	1.2
26-Jan-20	6.42	4.80	768.0	10,163.2	158.5	1567	4.73	4.66	640.1	12,369.2	97.3	1,852.1	0.74	0.97	0.8	1.2	0.6	1.2
27-Jan-20	3.79	4.70	1,024.0	11,187.2	124.8	1692	4.07	4.62	784.3	13,153.5	102.6	1,954.8	1.07	0.98	0.8	1.2	0.8	1.2
28-Jan-20	4.42	4.69	640.0	11,827.2	90.9	1783	3.77	4.59	468.2	13,621.7	56.7	2,011.5	0.85	0.98	0.7	1.2	0.6	1.1
29-Jan-20	4.80	4.69	512.0	12,339.2	79.0	1862	2.94	4.53	575.5	14,197.2	54.3	2,065.8	0.61	0.96	1.1	1.2	0.7	1.1
30-Jan-20	4.60	4.69	384.0	12,723.2	56.8	1918	5.22	4.56	637.7	14,834.9	107.0	2,172.8	1.13	0.97	1.7	1.2	1.9	1.1
31-Jan-20	3.17	4.63	512.0	13,235.2	52.2	1971	4.54	4.56	461.8	15,296.7	67.5	2,240.2	1.43	0.98	0.9	1.2	1.3	1.1
Total	**4.63**	**4.63**	**13,235**	**13,235**	**1,971**	**1,971**	**4.56**	**4.56**	**15,296.7**	**15,296.7**	**2,240.2**	**2,240.2**	**0.98**	**0.98**	**1.2**	**1.2**	**1.1**	**1.1**



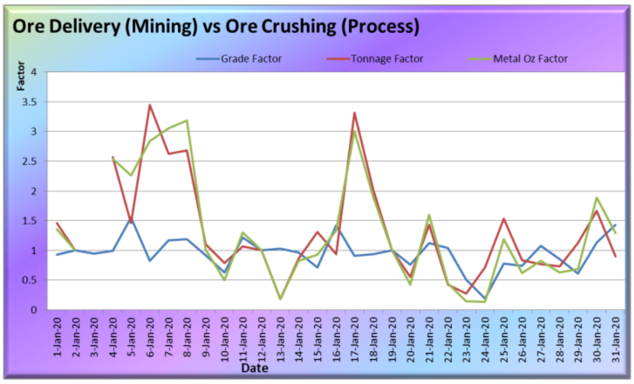


Figure 46: Ore delivered vs Ore Crushed for January 2020 production

From the graph (Figure 46), the metal content is directly related to the tonnes. The grade is lower by 2%, while the tonne is higher by 20%. It can be observed that the 20% tonne increments contribute to the 10% metal content. In general, it is noted from Table 18 that both the grade and tonne contribute almost equally for the metal content.

Table 17: Reconciliation factor for ore Delivered and ore crushed

	Delivered to Crusher (Mining)						Ore Crushed (Processing)						Ore crushed (Process) / Ore delivered					
	Grade(Au g/t)		Tonnes (t)		Gold content (Oz		Grade(Au g/t)		Tonnes (t)		Gold content (Oz)		rade Varian		nnes Varian		etal Varianc	
Month	Month	TTD	Month	TTD	Month	TTD	Month	TTD	Month	TTD	Month	TTD	Month	TTD	Month	TTD	Month	TTD
Sep-2019	4.07	4.07	10,103.2	10,103.2	1,321.6	1,321.6	4.07	4.07	10,081.9	10,081.9	1,318.8	1,318.8	1.00	1.00	1.00	1.00	1.00	1.00
Oct-2019	4.53	4.32	11,767.0	21,870.1	1,713.3	3,034.9	5.08	4.66	14,133.5	24,215.4	2,308.2	3,627.0	1.12	1.08	1.20	1.11	1.35	1.20
Nov-2019	6.53	4.79	5,976.4	27,846.5	1,255.0	4,290.0	7.45	4.91	2,389.9	26,605.4	572.1	4,199.1	1.14	1.02	0.40	0.96	0.46	0.98
Dec-2019	4.90	4.80	3,000.0	30,846.5	472.3	4,762.3	6.21	5.13	5,432.3	32,037.6	1,085.1	5,284.2	1.27	1.07	1.81	1.04	2.30	1.11
Jan-2020	4.63	4.75	13,235.2	44,081.7	1,970.6	6,732.9	4.56	4.94	15,296.7	47,334.3	2,240.2	7,524.5	0.98	1.04	1.16	1.07	1.14	1.12
Feb-2020	5.82	5.02	14,894.4	58,976.1	2,786.7	9,519.7	3.18	4.52	14,826.5	62,160.8	1,514.6	9,039.1	0.55	0.90	1.00	1.05	0.54	0.95
Total	**5.02**	**5.02**	**58,976**	**58,976**	**9,520**	**9,520**	**4.52**	**4.52**	**62,161**	**62,161**	**9,039**	**9,039**	**0.90**	**0.90**	**1.05**	**1.05**	**0.95**	**0.95**

	Delivered to Crusher (Mining)						Ore Crushed (Processing)						Factor = Ore crushed (Process) / Ore delivered (Mining)					
	Grade(Au g/t)		Tonnes (t)		Gold content (Oz)		Grade(Au g/t)		Tonnes (t)		Gold content (Oz)		Grade Variance		Tonnes Variance		Metal Variance	
Month	Month	TTD	Month	TTD	Month	TTD	Month	TTD	Month	TTD	Month	TTD	Month	TTD	Month	TTD	Month	TTD
Jan-2019	0.00	0.00	-	-	0.0	0.0	0.00	0.00	-	-	-	-	1.00	1.00	1.00	1.00	1.00	1.00
Feb-2019	0.00	0.00	-	-	0.0	0.0	0.00	0.00	-	-	-	-	1.00	1.00	1.00	1.00	1.00	1.00
Mar-2019	3.60	3.60	785.9	785.9	91.0	91.0	3.60	3.60	785.9	785.9	91.0	91.0	1.00	1.00	1.00	1.00	1.00	1.00
Apr-2019	4.09	4.04	7,061.4	7,847.3	928.2	1,019.2	4.09	4.04	7,061.4	7,847.3	928.2	1,019.2	1.00	1.00	1.00	1.00	1.00	1.00
May-2019	5.60	4.85	8,411.0	16,258.3	1,514.7	2,533.9	5.60	4.85	8,411.0	16,258.3	1,514.7	2,533.9	1.00	1.00	1.00	1.00	1.00	1.00
Jun-2019	6.27	5.16	4,665.7	20,924.0	940.1	3,474.0	6.27	5.16	4,665.7	20,924.0	940.1	3,474.0	1.00	1.00	1.00	1.00	1.00	1.00
Jul-2019	6.16	5.35	4,736.5	25,660.6	938.4	4,412.3	6.16	5.34	4,536.5	25,460.6	898.7	4,372.7	1.00	1.00	0.96	0.99	0.96	0.99
Aug-2019	4.51	5.16	7,299.5	32,960.0	1,059.6	5,471.9	4.51	5.15	7,671.1	33,131.6	1,113.5	5,486.2	1.00	1.00	1.05	1.01	1.05	1.00
Sep-2019	4.07	4.91	10,103.2	43,063.2	1,321.6	6,793.5	4.07	4.90	10,081.9	43,213.6	1,318.8	6,805.0	1.00	1.00	1.00	1.00	1.00	1.00
Oct-2019	4.53	4.83	11,767.0	54,830.2	1,713.3	8,506.8	5.08	4.94	14,133.5	57,347.1	2,308.2	9,113.3	1.12	1.02	1.20	1.05	1.35	1.07
Nov-2019	6.53	4.99	5,976.4	60,806.5	1,255.0	9,761.9	7.45	5.04	2,389.9	59,737.0	572.1	9,685.3	1.14	1.01	0.40	0.98	0.46	0.99
Dec-2019	4.90	4.99	3,000.0	63,806.5	472.3	10,234.2	6.21	5.14	5,432.3	65,169.3	1,085.1	10,770.4	1.27	1.03	1.81	1.02	2.30	1.05
Jan-2020	4.63	4.93	13,235.2	77,041.7	1,970.6	12,204.8	4.56	5.03	15,296.7	80,466.0	2,240.2	13,010.7	0.98	1.02	1.16	1.04	1.14	1.07
Feb-2020	5.82	5.07	14,894.4	91,936.1	2,786.7	14,991.6	3.18	4.74	14,826.5	95,292.4	1,514.6	14,525.3	0.55	0.93	1.00	1.04	0.54	0.97
Total	**5.07**	**5.07**	**91,936**	**91,936**	**14,992**	**14,992**	**4.74**	**4.74**	**95,292**	**95,292**	**14,525**	**14,525**	**0.93**	**0.93**	**1.04**	**1.04**	**0.97**	**0.97**

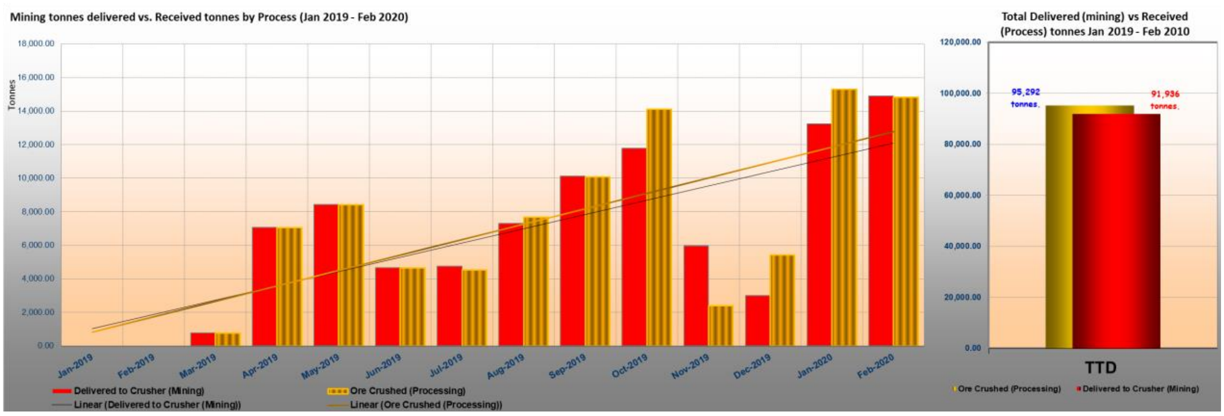


Table 18: Mining Ore delivered to crusher vs. Received Ore by Process (July 2017 to Feb 2020)

	Delivered to Crusher (Mining)						Ore Crushed (Processing)					
	Grade(Au g/t)		Tonnes (t)		Gold content (Oz)		Grade(Au g/t)		Tonnes (t)		Gold content (Oz)	
Month	Month	TTD	Month	TTD	Month	TTD	Month	TTD	Month	TTD	Month	TTD
Pre July -17	4.37	4.37	5,883.5	5883	826.6	826.6	4.37	4.37	3,311.4	3311	465	465
Jul-2017	4.50	4.38	247.8	6131	35.9	862.5	4.50	4.39	439.4	3751	63.6	528.8
Aug-2017	4.62	4.45	2,555.9	8,687.2	379.4	1,241.9	4.62	4.44	1,104.6	4,855.4	164.0	692.8
Sep-2017		4.45	-	8,687.2	0.0	1,241.9		4.44	-	4,855.4	-	692.8
Oct-2017		4.45	-	8,687.2	0.0	1,241.9		4.44	-	4,855.4	-	692.8
Nov-2017	4.55	4.48	3,977.7	12,664.9	582.3	1,824.2	4.55	4.49	3,890.4	8,745.8	569.6	1,262.3
Dec-2017	5.06	4.77	12,650.5	25,315.4	2,057.4	3,881.6	5.06	4.83	13,089.4	21,835.1	2,128.7	3,391.1
Jan-2018	6.48	5.30	11,437.0	36,752.4	2,382.1	6,263.7	6.48	5.40	11,437.0	33,272.1	2,382.1	5,773.2
Feb-2018	5.89	5.39	6,768.5	43,520.8	1,282.3	7,546.0	5.89	5.49	7,659.9	40,932.0	1,451.2	7,224.4
Mar-2018	5.52	5.40	856.7	44,377.5	152.2	7,698.2	5.52	5.49	3,547.1	44,479.1	630.1	7,854.5
Apr-2018		5.40	-	44,377.5	0.0	7,698.2		5.49	-	44,479.1	-	7,854.5
May-2018	4.98	5.39	778.8	45,156.3	124.6	7,822.8	4.98	5.48	678.8	45,157.9	108.6	7,963.0
Jun-2018	5.54	5.43	14,620.2	59,776.5	2,604.8	10,427.6	5.54	5.50	14,641.4	59,799.4	2,608.6	10,571.6
Jul-2018	3.87	5.31	4,764.8	64,541.4	592.9	11,020.5	3.87	5.38	4,764.8	64,564.2	592.9	11,164.5
Aug-2018	3.60	5.23	3,079.8	67,621.2	356.7	11,377.1	3.60	5.30	3,037.3	67,601.5	351.7	11,516.3
Sep-2018	5.22	5.23	7,901.3	75,522.4	1,325.9	12,703.0	5.22	5.29	7,970.0	75,571.5	1,337.4	12,853.7
Oct-2018	5.41	5.24	4,878.1	80,400.6	849.0	13,552.1	5.41	5.30	4,878.1	80,449.6	849.0	13,702.7
Nov-2018		5.23	-	67,621.2	0.0	11,377.1		5.30	-	67,601.5	-	11,516.3
Dec-2018		5.23	-	67,621.2	0.0	11,377.1		5.30	-	67,601.5	-	11,516.3
Jan-2019		5.24	-	80,400.6	0.0	13,552.1		5.30	-	80,449.6	-	13,702.7
Feb-2019		5.24	-	80,400.6	0.0	13,552.1		5.30	-	80,449.6	-	13,702.7
Mar-2019	3.60	5.23	785.9	81,186.4	91.0	13,643.0	3.60	5.28	785.9	81,235.5	91.0	13,793.7
Apr-2019	4.09	5.14	7,061.4	88,247.8	928.2	14,571.2	4.09	5.19	7,061.4	88,296.9	928.2	14,721.9
May-2019	5.60	5.18	8,411.0	96,658.9	1,514.7	16,085.9	5.60	5.22	8,411.0	96,708.0	1,514.7	16,236.6
Jun-2019	6.27	5.23	4,665.7	101,324.6	940.1	17,026.0	6.27	5.27	4,665.7	101,373.7	940.1	17,176.7
Jul-2019	6.16	5.27	4,736.5	106,061.1	938.4	17,964.4	6.16	5.31	4,536.5	105,910.2	898.7	18,075.4
Aug-2019	4.51	5.22	7,299.5	113,360.6	1,059.6	19,024.0	4.51	5.25	7,671.1	113,581.3	1,113.5	19,189.0
Sep-2019	4.07	5.13	10,103.2	123,463.8	1,321.6	20,345.6	4.07	5.16	10,081.9	123,663.2	1,318.8	20,507.8
Oct-2019	4.53	5.07	11,767.0	135,230.7	1,713.3	22,058.9	5.08	5.15	14,133.5	137,796.7	2,308.2	22,816.0
Nov-2019	6.53	5.14	5,976.4	141,207.1	1,255.0	23,313.9	7.45	5.19	2,389.9	140,186.6	572.1	23,388.1
Dec-2019	4.90	5.13	3,000.0	144,207.1	472.3	23,786.2	6.21	5.23	5,432.3	145,618.9	1,085.1	24,473.2
Jan-2020	4.63	5.09	13,235.2	157,442.3	1,970.6	25,756.9	4.56	5.16	15,296.7	160,915.6	2,240.2	26,713.4
Feb-2020	5.82	5.15	14,894.4	172,336.7	2,786.7	28,543.6	3.18	5.00	14,826.5	175,742.1	1,514.6	28,228.0
Total	**5.15**	**5.15**	**172,337**	**172,337**	**28,544**	**28,544**	**5.00**	**5.00**	**175,742**	**175,742**	**28,228**	**28,228**
Reconciliation Factor = Ore Crushed (process)/Ore Delivered (Mining)							**0.97**		**1.02**		**0.99**	

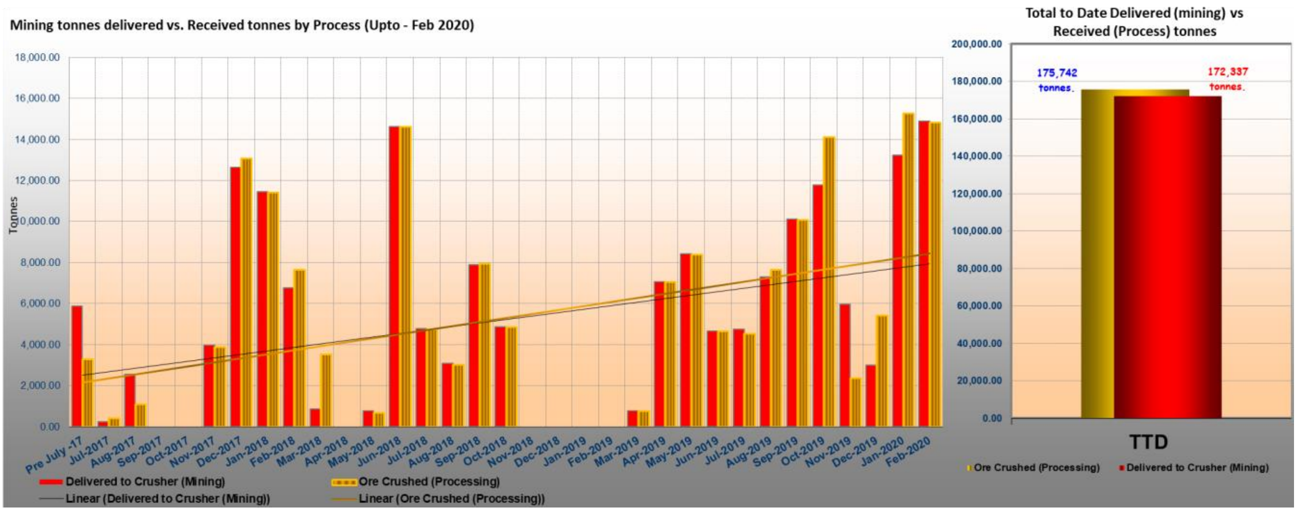


Figure 47: Mining tonnes delivered vs. Received tonnes by Process (Up to - Feb 2020)

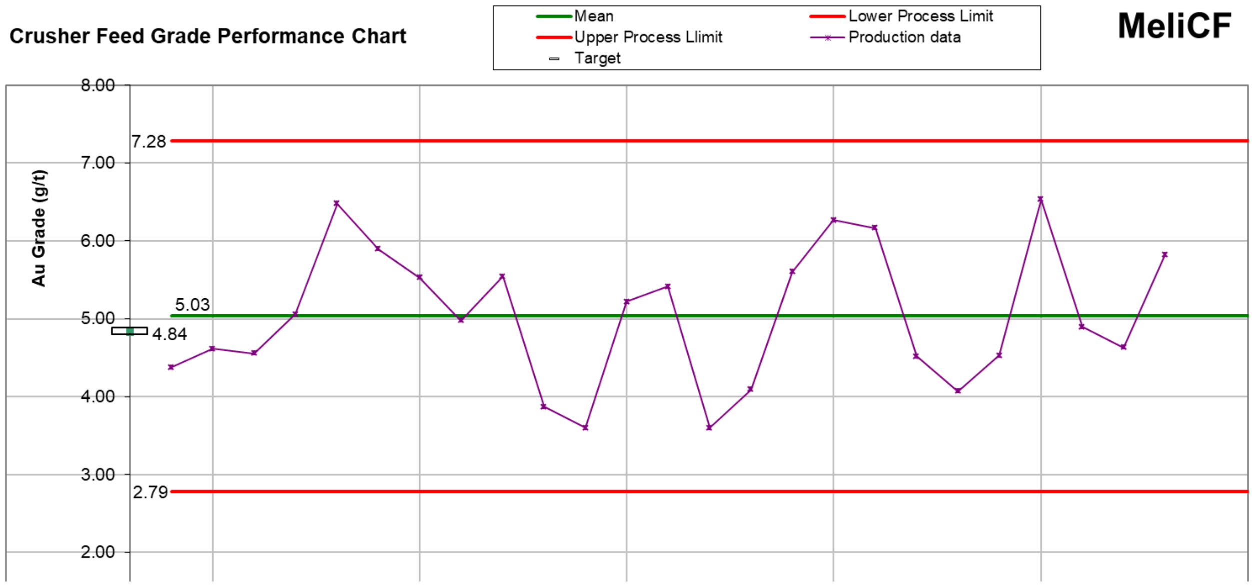


Figure 48: Mining Crusher Feed Grade Performance Chart

Table 19: Descriptive data analysis for Ore delivered (Mining) and Ore Received (Process)

Statistics	***Delivered to Crusher (Mining) FOR Tonnes (t)***	***Crusher (Mining) for Grade (Au g/t)***	***Ore Crushed (Processing) for Tonnes (t)***	***Ore Crushed (Processing) for Grade (Au g/t)***
Mean	6,628.3	5.01	6,759.3	5.01
Standard Error	864.6	0.17	928.1	0.20
Median	5,929.9	4.94	5,155.2	5.02
Mode	#N/A	#N/A	#N/A	#N/A
Standard Deviation	4,408.5	0.86	4,732.6	1.02
Sample Variance	19,434,506	0.74	22,397,835	1.05
Kurtosis	(0.82)	(0.90)	(0.88)	(0.16)
Skewness	0.42	0.16	0.53	0.33
Range	14,646.6	2.93	14,857.3	4.27
Minimum	247.8	3.60	439.4	3.18
Maximum	14,894.4	6.53	15,296.7	7.45
Sum	172,336.7	130.33	175,742.1	130.39
Count	26	26	26	26
Confidence Level(95.0%)	1,780.61	0.3483	1,911.55	0.4133

The skewness value for all areas indicate a fairly symmetrical data distribution

5.1.5 Calculation of Reconciliation Factors

The method of calculating reconciliation factors at Meli using tonnes and grades content of the in-situ ore block model as a long-term model, diluted ore block model as a short-term model, ore cut as grade control model, and also tonnes and grades mined and delivered by the mining and received by the plant as processed by the mine for the given period (monthly for this study). These factors are modified to suit the traditional method of calculating reconciliation factor as:

i. F_1 factor - F_{1t}, $F_{1l,}$ and F_{1f}, - for tonnes, grades and metal content respectively of the long-term model versus the short-term model and are calculated generically as:

$$F_1 = \frac{Diluted\ Ore\ block\ model}{Insitu\ Ore\ block\ model}$$

Equation 9

ii. F_2 factors - F_{2t}, F_{2l}, and F_{2f}, - for tonnes, grades and metal content respectively of the grade-control model versus the short-term model and are calculated as:

$$F_2 = \frac{grade\ control\ Ore\ cut}{Diluted\ Ore\ block\ model}$$

Equation 10

iii. F_3 factors – F_{3t}, F_{3l}, and F_{3f} - tonnes, grades, and metal content respectively, for the monthly mine report versus the grade-control model.

$$F_3 = \frac{Ore\ delivered\ by\ Mine}{Grade\ control\ Ore\ cut}$$

Equation 11

iv. F_4 factors - F_{4t}, F_{4l}, and F_{4f}, - for tonnes, grades, and metal content respectively. For received-at-mill material versus the mine reported. This factor may be calculated generically:

$$F_4 = \frac{Received\ at\ mill}{Mine\ reported}$$

Equation 12

Table 20: Compares of Reconciliation Factors for Meli Mine (total to Date)

F1 Factor= Diluted Ore/Insitu Ore			F2 Factor = Mined Ore /Diluted ore Res			F3 Factor =Delivered to Mill / Mined ore			F4 Factor = Received at Mill / Delivered to Mill		
Tonnes	Grade	Oz	Tonnes	Grade	Oz	Tonnes	Grade	Oz	Tonnes	Grade	Oz
1.14	0.87	1.00	0.96	1.00	0.96	0.61	0.99	0.61	1.02	0.97	0.99

Table 21: Compares of Reconciliation Factors for Meli Mine (July-19 to Feb-20)

	F1 Factor= Diluted Ore/Insitu Ore			F2 Factor = Mined Ore /Diluted ore Res			F3 Factor =Delivered to Mill / Mined ore			F4 Factor = Received at Mill / Delivered to Mill		
Month	Tonnes	Grade	Oz	Tonnes	Grade	Oz	Tonnes	Grade	Oz	Tonnes	Grade	Oz
Jul-19				1.00	0.66	0.66	0.27	1.97	0.53	0.96	1.00	0.96
Aug-19				1.00	1.00	1.00	3.38	0.98	3.31	1.05	1.00	1.05
Sep-19				1.00	1.00	1.00	9.93	0.78	7.76	1.00	1.00	1.00
Oct-19				1.47	0.68	1.00	3.70	1.45	5.35	1.20	1.12	1.35
Nov-19				1.00	1.00	1.00	0.17	1.42	0.24	0.41	1.19	0.49
Dec-19				1.00	1.00	1.00	0.08	1.06	0.09	1.81	1.27	2.30
Jan-20				1.00	1.00	1.00	1.70	1.00	1.70	1.16	0.98	1.14
Feb-20				1.00	0.99	0.99	0.71	1.25	0.89	1.00	0.55	0.54
TOTAL				1.00	0.99	0.99	0.57	1.15	0.66	1.05	0.92	0.96

5.2 Factors to measures the mining operation performance

These four classes of factors serve as the basis for the direct determination of several performance measures.

1. F_{LTM} - One such measure quantifies the accuracy of the long term model (LTM) in terms of tonnes and grades of ore delivered to the mill. That is, it measures how well the reserve block model predicts material delivered to the mill. which is the basis of future cash flows from the operation (Rossi et al., 2014). This factor is calculated as:

$$F_{LTM} = F_1 * F_2 * F_3 * F_4 = \frac{Received\ at\ mill}{Insitu\ Ore\ block\ model}$$

Equation 13

2. F_{STM} – is another performance measurement, quantifies the benefits achieved by, for instance, in-fill drilling, with the assumption that this is the difference between a long-term model (LTM) and a short-term model (STM):

$$F_{STM} = F_2 * F_3 * F_4 = \frac{Received\ at\ mill}{Diluted\ Ore\ block\ model}$$

Equation 14

3. F_{GCM} - Performance for the grade control model versus the material received at the mill is monitored by the F_{GCM} Factor and is calculated as:

$$F_{GCM} = F_3 * F_4 = \frac{Received\ at\ mill}{Grade\ control\ Ore\ cut}$$

Equation 15

F_{GCM} measures the mining operation performance by evaluating any unplanned dilution and ore loss. The F_4 factor indicates of ore loss and dilution in the haulage and stockpiling system.

4. F_{MLRL} measures the performance of the mine reported values versus the long-range model to understand how the predictive models are forecasting production in the mine. The comparison is calculated as:

$$F_{MLRL} = F_1 * F_2 * F_3 = \frac{Received\ at\ mill}{Ore\ delivered\ by\ Mine}$$

Equation 16

Table 22: Factors measuring the mining operation performance (Total to date)

FLTM=Received at mill/Insitu Ore block model			FSTM=Received at mill/Diluted Ore block model			FGCM=Received at mill/Grade control Ore cut			FMLRL=Received at mill/Ore delivered by Mine		
Tonnes	Grade	Oz	Tonnes	Grade	Oz	Tonnes	Grade	Oz	Tonnes	Grade	Oz
0.68	0.84	0.57	0.60	0.96	0.57	0.62	0.96	0.60	1.02	0.97	0.99

Table 23: Factors measuring the mining operation performance (July-19 to Feb-20)

	FLTM=Processed at mill/Insitu Ore block model			FSTM=Processed at mill/Diluted Ore block model			FGCM=Processed at mill/Grade control Ore cut			FMLRL=Processed at mill/Ore delivered by Mine		
Month	Tonnes	Grade	Oz	Tonnes	Grade	Oz	Tonnes	Grade	Oz	Tonnes	Grade	Oz
Jul-19				0.42	0.87	0.32	0.42	1.32	0.48	1.57	0.67	0.91
Aug-19				2.38	0.94	2.02	2.38	0.94	2.02	0.70	0.95	0.61
Sep-19				5.95	0.97	5.26	5.95	0.97	5.26	0.60	1.24	0.68
Oct-19				9.31	1.20	10.22	6.33	1.76	10.22	1.71	1.22	1.91
Nov-19				0.06	1.64	0.10	0.06	1.64	0.10	0.39	1.16	0.42
Dec-19				0.14	1.44	0.19	0.14	1.44	0.19	1.69	1.36	2.11
Jan-20				1.89	1.17	2.01	1.89	1.17	2.01	1.12	1.17	1.18
Feb-20				0.71	1.00	0.64	0.71	1.00	0.64	1.00	0.80	0.73
TOTAL				**0.71**	**1.00**	**0.64**	**0.61**	**1.19**	**0.66**	**1.07**	**1.03**	**1.00**

6

Chapter VI: Analysis of Ore Loss/Gain

6.1 Ore flow balance sheet

The summary of the ore flows analysis for the period 2017 to February 2010 to determine percentage tonnage and grade losses is shown in Table 15. The full ore flow balance sheet is presented in the table below.

Table 24: Meli Ore production summary (As of February 2020)

		Upto Current Level			All Levels		
	SOURCE	TD Ore tonnes (t)	TD Grade (g/t)	TD Mining Ounces (Oz)	Ore tonnes (t)	Grade (g/t)	Mining Ounces (Oz)
Ore Reserve	Pit A - Reserve	204,060	5.25	34,467	364,838	4.93	57,828
	Pit B - Reserve	88,135	5.22	14,783	136,658	4.90	21,530
	Pit C - Reserve	1,933	1.26	79	14,341	0.85	390
	Total Reserve	**294,128**	**5.22**	**49,329**	**515,837**	**4.81**	**79,748**
Mined (Depleted)	Pit A - Mined	192,340	5.25	32,488	192,340	5.25	32,488
	Pit B - Mined	88,135	5.22	14,783	88,135	5.22	14,783
	Pit C - Mined	771	1.26	31	771	1.26	31
	Total Mined	**281,246**	**5.23**	**47,302**	**281,246**	**5.23**	**47,302**
Remained (Available)	Pit A - Remained	11,719	5.25	1,980	172,498	4.57	25,340
	Pit B - Remained	0	5.22	0	48,523	4.32	6,746
	Pit C - Remained	1,163	1.26	47	13,570	0.82	359
	Total Remained	**12,882**	**4.89**	**2,027**	**234,591**	**4.30**	**32,446**

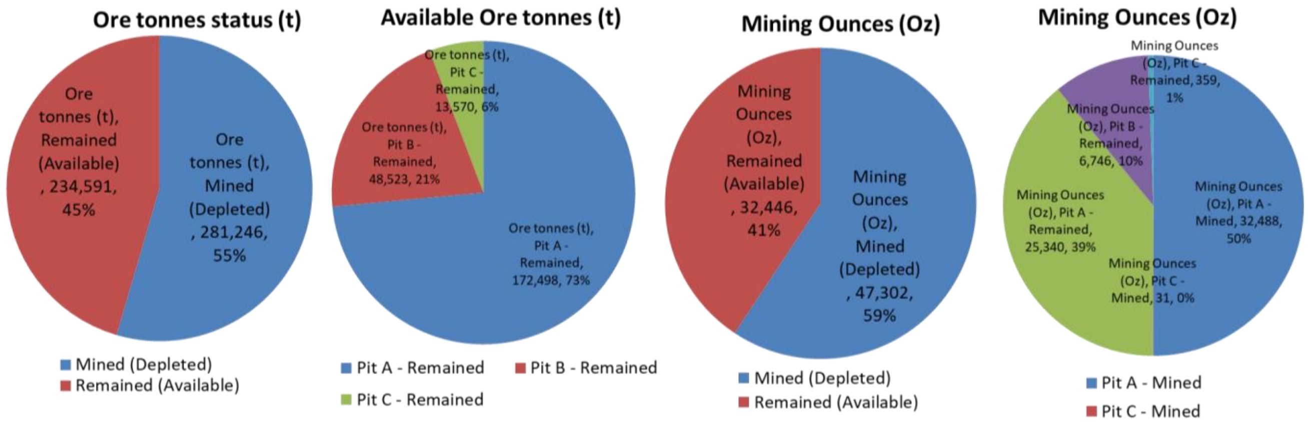


Figure 49: Chart showing Reserve ore available and depletion

The following are the highlighted points from the ore flow analysis:

- The total ore cut in the period from the mine started around July 2017 to February 2020 is 281,246t @ 5.22 g/t Au containing 47,169 Oz. According to the mining report, 172,337t

@5.15 g/t Au is delivered to the plant, and 108,562t@estimated 5.34 g/t (18,625 oz.) stockpiled on ROM pad.

- The total ore processed (crushed) during this period is 175,742t @5.00 g/t Au, contained metal of 28,228 Oz. actual total recovered metal data is not available, thus assumed what is crushed is what is produced with the assumption of 90% recovery as estimated from the available 8-month actual recovery data.

6.2 Source of tonnage/grade gain/loss

a. Inaccurate weightometer measurement

Inaccurate weightometer measurements have tended to vary the tonnes crushed at Meli as the milled tonnes are the base to reconcile the tonnes. Reliable tonnage measurement is a credible and standard practical application in gold mines. During the site work, it was noticed the weightometer was not functional and the team was using a belt cut method to measure the tonnes for mill feed. Weightometer must be maintained and calibrated regularly using approved techniques and standard procedures. Apart from defining the actual tonnage, a weightometer is a critical instrument to check the efficiency of the metallurgy section which has a key impact on the MCF. However, there is a strong correlation between what the mining delivers to the crusher from the ROM pad with that of the process reported figures. The mining estimated figures are underestimated than that of the process measured tonnes. This suggests the weightometer down is not to mask the inefficiencies of the metallurgy department. Weightometer is a vital measurement method to define the performance of the mine, it is a key to maintain it and put in place maintenance schedule and calibration procedures, and require getting current calibration certificate.

b. Boulders

The mining is a free dig using an excavator. When boulders encounter (Figure 6 & Figure 50), it will be placed aside for the future after it is broken using a rock breaker. There a possibility that this ore is misclassified in the ore blocks mining.

Figure 50: Boulders waiting for the rock-breaker (Author Picture)

c. *Specific gravity*

Specific gravity (SG) of 2.6t/m3 (at some times 2.65) was used at Meli mining. This appears to be overstated for the gossan or oxide material. As stated in chapter Vii, the recommendation section specifies the discrepancy between truck tally and reconciled ore tonnes.

d. *Unplanned dilution*

Meli Mine mineralization comprises gossan-hosted ore characterized by a nugget effect and sandy texture. The mineralized zones are easily identifiable and distinguishable from the barren zone. However, ore/waste delineation poses a challenge because of the high wall slide due to the un-cohesive and sandy nature of the ore and host material. It is possible ore lost to the waste body and ore dilution due to the addition of waste to the ore body during mining activity. It is also possible undefined material may fall to the open trench.

e. *Grade control Sampling*

Grade control sampling is done via trenching. In contrast to RC/DD drilling, trenching requires the removal of significant ore material to open a ditch for sampling. It is noticed a 1.5m deep and about 1m wide trench across the ore body. Though the material is placed adjacent to the trench but highly susceptible to dilution during grade control activity, weather (Rain/wind), and during machinery movements during mining preparation. This dilution leads to the gold called for is higher than the gold accounted.

7

Chapter VII: Conclusion and Recommendations

7.1 Discussion and Conclusions

	Crusher 1 (Jaw)	Crusher 2 (CONE)	Unit
Operating Days per Year	365	365	Days/year
Operating Shift Length	8	8	Hours
Operating Shifts/Day	1	1	Shifts
Operating Hours/Day	10	10	Hours/day
Start-up & Shutdown Delays	1.50	1.50	Hours/day
Planned Maintenance Delays	4.50	4.50	Hours/week
Planned Operating Hours	3000	3000	Hours/year
Availability	91.3	91.3	%
Available Hours	75	75	Hours/week
Available Hours	7 956	7 956	Hours/year
Design Throughput (max.)	100		Tons/hour
Operational Throughput	85	50	Tons/hour

The design capacity of the plant is 35 tonnes per hour. The crusher has operational throughout 50 tonnes per hour for the Cone crusher. Assuming the planned operating hour of 3,000 Hours/year (250 h/month), had a planned capacity of 12,500 tonnes per month crushing. However, the average monthly crushing is 5,325 tonnes per month. Considering the crusher plant design capacity plan, the achievement is 42.6%. Theoretically, there was a tonnage loss of 57.4%, implying that 57.4% of the expected revenue was not realized.

The reconciled total mined and hauled ore was 281,246 tonnes with an average monthly of 8,523 tonnes. Considering the plant capacity of 35t/h, the crushed tonnes could be at least 8,750t per month. This implies that the shortfall is not due to ore supply; instead, it linked to the process plant which could be due to other many reasons which are not the scope of this research.

With the assumption of metal recovery of 90.6%, the assumed metal recovered is 25,565 ounces which contributes to an MCF of 85.9% (Table 15). Though the MCF of below 100%, in general, the operation is within the acceptable range of MCF values. This suggests that gold losses averaged at 14.1%. Implies 14.9% of the expected revenue was not realized and this translates into negative financial underperformance.

The reserve ore estimated to be 515,837t@4.81 Au g/t contained 79,748.38 Oz of gold. If the plan goes well, with the design 92% recovery, the expected gold to be recovered is 73,368.51 Oz.

With 35 t/hr. processing capacity, the expected planned monthly tonnage is 25,200t. The total reserve under consideration for the mine is 515,837t (Table 10). It could have been completed within 22.5 months with 90% efficiency. However, after 26 months, 45%, 234,591t (Figure 49) of the reserve still remained on the ground. The plant only processed 55% (281,246t) of the original reserve extracted.

Three scenarios for when to complete the active reserve:

- If continuing with a previous monthly rate of 6.628 t (Table 19), it will take about 39 months (with a 10% contingency time), which is May 2023.
- If continuing with the current rate of 14,894t per month, it will take 17 months with a 10% additional contingency time, which is July 2021.
- If it goes with the design plan of 24,500t, it will take 10.5 months, which is expected around January 2011.

The above scenario holds true for the current reserve, however, the company is undergoing active exploration works to add and maximize the resource and the reserve which extends LOM.

7.2 Recommendations

1. Truck factor vs tonnage factor (SG usage)

According to the ore characteristics study data from Meli operating manual section 2.3 (below Table 26), the bulk density is 1600kg/m3, and however, the mining and grade control is using the specific gravity 2600 as a tonnage factor. The definition, in section, for bulk density:

Bulk density (tonnage factor)	It is defined as 'mass per unit volume'. Specific gravity is one of the standard measurements studied from drill core samples. Speaking of large rock masses, within the rock mass there is void space, cavities, open fractures, porosity, etc., that reduces its overall density; would the specific gravity gives too high values if used to calculate the tonnes. Therefore, bulk density or tonnage factor should be estimated and used in resource/reserve calculations.

Thus, the tonnage factor needs to adjust to reflect the definition and the ore characteristics. Use the bulk density 1.6 (BCM) for the load and haul tonnage calculations, and also for the crusher feed. The actual data analysis on-site also indicates the overestimation of tonnes and indicates the use of 1.69 (see Table 25).

Perhaps, it is recommended to use a truck factor, which is a multiple of density and volume. And importantly, the truck factor should be dynamic depending on the season. Thus, recommended using a monthly updated truck factor as an example indicated in Table 25.

Table 25: Truck factor Analysis (by Author)
Negative variance values removed, as it indicates not all ore depleted yet

Truck Factor Report

							Truck Factor (used)			**Actual**
		Bench	Truck Count calculated tonnes (t)	Reconciled survey tonnes (t)	Variance	# of Truck Counts	Truck Volume (used)	SG Used	Truck Factor (tonnes/load)	Truck factor for the month (t/L)
Pit A	1199	Pit A-1199	6,853	5,187	24%	165	16.00	2.60	41.60	31.48
	1193	Pit A-1193	53,806	34,971	35%	1,293	16.00	2.60	41.60	27.04
	1190	Pit A-1190	72,250	46,757	35%	1,737	16.00	2.60	41.60	26.92
	1187	Pit A-1187	42,782	36,040	16%	1,028	16.00	2.60	41.60	35.04
Pit B	1196	Pit B-1196	11,266	9,885	12%	271	16.00	2.60	41.60	36.50
	1193	Pit B-1193	23,235	14,141	39%	559	16.00	2.60	41.60	25.32
	1190	Pit B-1190	44,096	18,307	58%	1,060	16.00	2.60	41.60	17.27
Pit C	1172	Pit C-1172	1,484	728	51%	36	16.00	2.60	41.60	20.41
		TOTAL	**255,771**	**166,016**	**35%**	**6,148**	**16.00**			27.50

Weighted Average Truck Factor (t/L)	**27.00**	
Proposed Truck Factor (Next Month)	**27.00**	Thus, volume 16 and SG for next Month will be 1.69

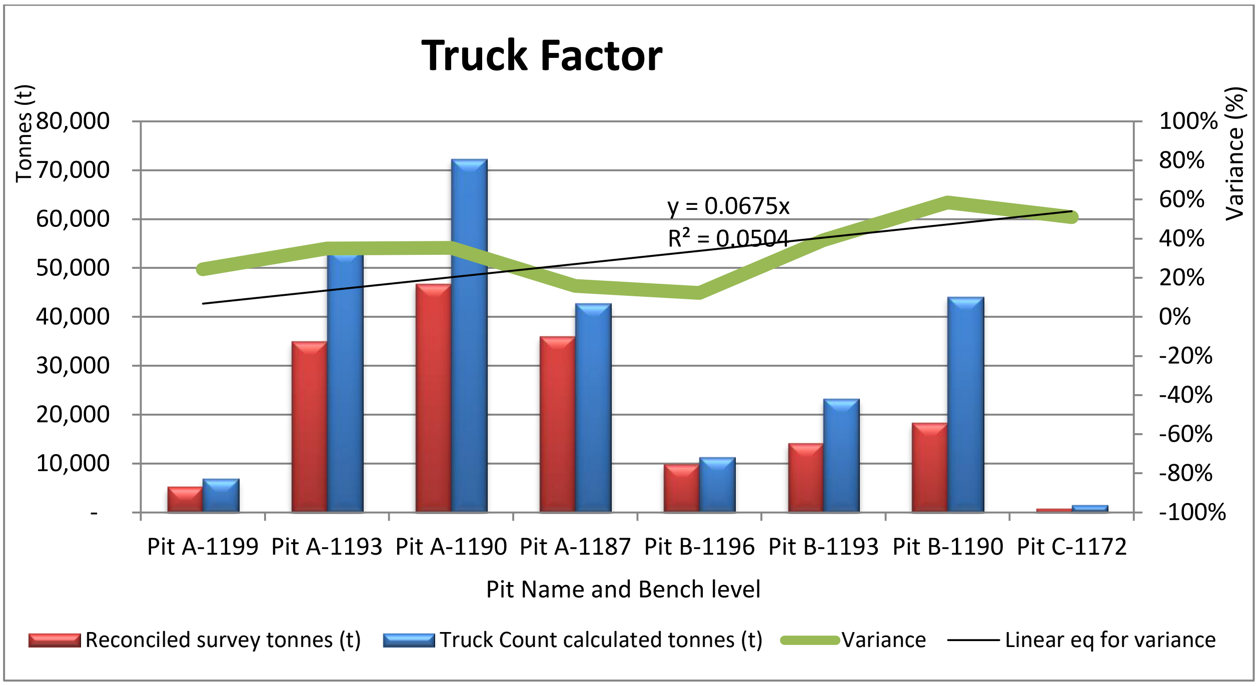


Table 26: Ore characteristics as per metallurgy test

2.3 ORE CHARACTERISTICS / FEED MATERIAL SPECIFICATION (AS PER METALLURG. TEST WORK)

Ore composition:		
Au	4.37	g/t
Ag	6.40	g/t
SiO_2	52.80	%
Fe_2O_3	27.40	%
Al_2O_3	4.81	%
Cu	0.17	%
Pb	0.13	%
CaO	0.23	%
MgO	0.12	%
Bulk density	1 600	kg/m³
Specific gravity ore	2 650	kg/m³
Angle of repose	40	°
Feed moisture	3	%
Measured Bond Work Index	12.40	kWh/t
Assumed Bond Work Index	17.00	kWh/t

Source: Ezana private current Operating manual

2. Crusher feed Loader factor

As the recent six-month data indicated in Table 17, the mining ore delivery tonnage is underestimated by 5% (Ore processed/Ore delivered = 1.05) as to the process tonnes. The current SG being used is 1.6, and then need to change it to 1.69 until further analysis. It is also recommended to use a monthly moving variable factor based on a dry and wet season.

3. Mill feed grade blending

The plant design is to process a grade of 4.37 g/t (as indicated on ore characteristics study Table 26) or 4.84 g/t (as per the mining reserve model Table 10). However, the actual feed grade is averaged at 5.15 g/t (as per delivered grade to the plant by mining, Table 14) and 5.00 g/t (as per plant received grade, Table 14). It is expected to have a lower recovery if feed more than the design or planned grade. In mining practice, the higher the feed grade, results in the higher the tails grade which contributes to the lower recovery percentage. The last 8-month actual head grade average is 5.21g/t (Table 12). Thus, it’s recommended to blend the high-grade ore with low-grade ore not to exceed the plant feed grade more than the planned (as per diluted ore reserve model) or plant design grade (as per metallurgy ore characteristics test).

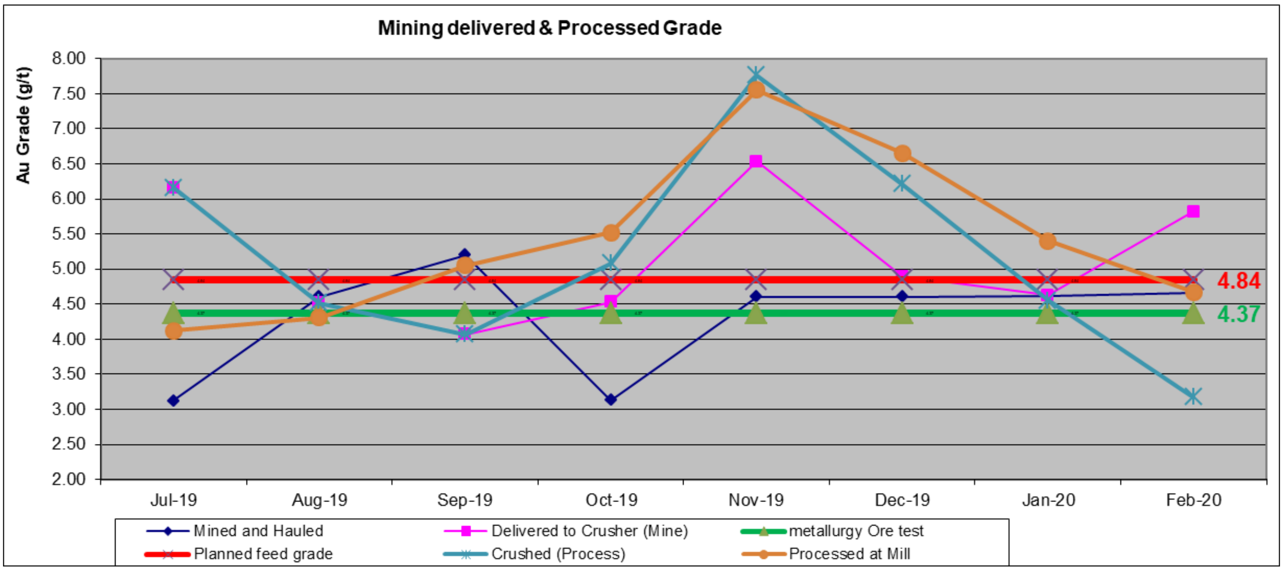


Figure 51: Monthly grade for mining, crushing and head grade

Moreover, it is much better to keep the high-grade stockpile for future blending as the grade is getting low as we go deep into the mining blocks. See below Figure 52

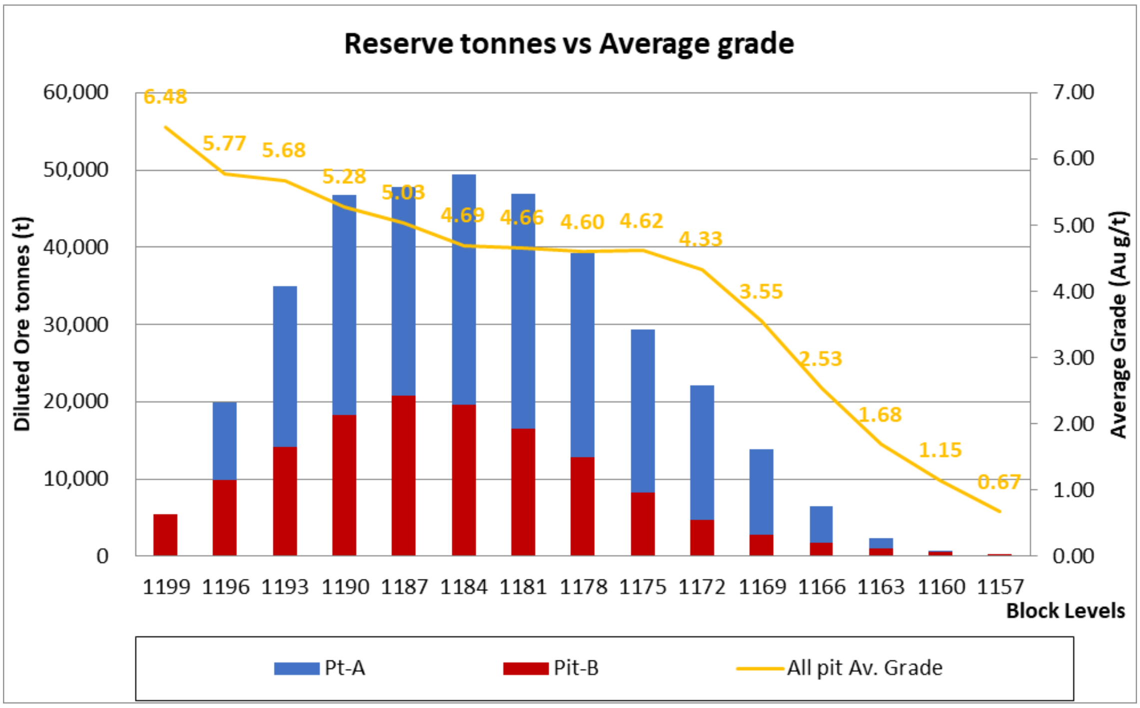


Figure 52: A graph showing reserve ore by elevation

4. Implementing Ore reconciliation system

Truck counts

Truck counts are carried out by bench supervisors. At the end of the month discrepancies between truck-count tonnages and ore-block tonnages can be significant. Toe and plain poor bench elevation maintenance by the mining team can produce significant variation, thus need proper elevation maintenance at the end of month survey.

Truck counts are used to acquiring the first estimate of ore delivered from the mine to the ROM pad. Final reconciliation of delivered tons should be based on milled tons and the ROM pad stockpile balance, provided that the process used calibrated weightometer and the ROM pad is leveled and properly stockpiled which is surveyed as per EOM inventory protocols.

Ore reserves balancing

There are currently 2 ore reserve models.

- Based on the in-situ exploration resource estimation, before dilution.
- Based on the level of ore tonnes and grade after dilution. The official reserves are still based on this model.

For the monthly report, Grade Control reserves are compared against both reserves. Ore reserve depletions are calculated by using string outlines over mined-out areas. Depletions do not allow for bench floors deviating from the design. The process can easily be performed on SURPAC software as the design and model were created using the same program.

Stockpiles and mill

Final reconciliation is against the balance of grade control reserves, against the balance of ore milled and the ROM pad ore stockpile balance.

Delivered from mine ore grade is the balance between milled grades and depleted from or added to stockpile grade. The stockpile grade is calculated as follows: ore delivered from the mill is added to the stockpiles at GC grades. At the end of the day, a new average grade is calculated. The next day ore is depleted at this average grade. In this way the chance that ore stockpiles grades will get out of hand is limited. If this nevertheless appears to have happened, an end of month change to the stockpile grade can be considered.

Ore Mining Records

All ore handling is recorded in the folder “ore production tallies” with a new file for every month. A separate balance needs to maintain in the folder, which summarizes truck counts per block per day with truck counts from boulders marked as a separate entity.

Reconciliations are maintained in the folder ”monthly reports” with a spreadsheet for every month, detailing blocks mined, and comparison with exploration and UC reserves. Year to date and production to date figures with regards to depleted reserves and actuals are maintained in various worksheets. The author created a template to be modified and used by the mine teams.

Bench (Combined)	Reserve Depleted (In-situ Ore Block Cut)			Diluted Ore Block Depleted (Mine Planning)		
	Tonnes (t)	Grade (g/t)	Oz	Tonnes (t)	Grade (g/t)	Oz
1199	9,979	6.89	2,211	10,609	6.48	2,211
1196	25900	6.64	5,531	29806	5.77	5,534
1193	43,710	6.44	9,044	49,112	5.68	8,968
1190	54,850	6.26	11,042	65,064	5.28	11,036
1187	60080	5.74	11,093	68519	5.03	11,087
1184	60,530	5.35	10,419	69,085	4.69	10,416
1181						
1178						
1175	40	1.98	3	40	1.98	3
1172	2,020	1.17	76	1,893	1.25	76
Total	257,109	5.98	49,418.11	294,128	5.22	49,329.25

Date	Mine Reported (Hauled)			Delivered to Mill			Received at Mill			Processed at Mill		
	Tonnes (t)	Grade (g/t)	Oz	Tonnes (t)	Grade (g/t)	Oz	Tonnes (t)	Grade (g/t)	Oz	Tonnes (t)	Grade (g/t)	Oz
1-Jan-20												
02-Jan-20												
03-Jan-20												
04-Jan-20												

To date	Mined and Hauled (Mine Reported)			Delivered to Crusher			ROM Stockpile			Received at Mill (Crushed)			Processed at Mill (Estimated at 90% recovery)		
	Tonnes (t)	Grade (g/t)	Oz	Tonnes (t)	Grade (g/t)	Oz	Tonnes (t)	Grade (g/t)	Oz	Tonnes (t)	Grade (g/t)	Oz	Tonnes (t)	Grade (g/t)	Oz
	281,246	5.22	47,169	172,337	5.15	28,544	108,562	5.34	18,625	175,742	5.00	28,228			

5. Improving the Grade Control Systems

For sampling, it is advisable to use RC drilling to delineate the ore boundary. Comparatively, Rip-line using dozer will be cost-effective and less dilution method than trenching. Preferably, advised to use both trenching and rip line alternatively and replace once you get confidence in the method. It is recommended to implement the following Quality Control procedures.

I. Quality Control procedures

Rip Line Procedures

1) Ensure an appropriate PPE is worn before you start with the process
2) Delineate your strike and dip directions.
3) Make a reference point across the strike of your orebody, and continue at regular intervals.
4) Ensure that the bulldozer to be used for ripping has a well fitted single ripper.
5) Dozer should stand with direction towards the footwall
6) Make sure you are 10 meters away from dozer during the ripping process
7) It should use a blade to clear the surface until a clean surface is obtained
8) Ripping should be done after procedure 5 in a straight line
9) Collect samples at a 1-meter interval

Pit Sampling Procedures

1) Ensure an appropriate PPE is worn before you start with the process
2) Ensure the samples to be collected are free from contamination
3) Mark out sample intervals with a measuring tape
4) Collect samples into a clean plastic bag

5) Assign sample ticket to each bag and after, write the sample numbers on the bag.
6) Clip each of these sample bags after procedure 5
7) Care should be taken in handling the bagged sample.
8) Assign a dispatch note to the samples
9) Send all samples to the laboratory on-site for analysis

Ore Mining Procedures

At Meli mine, Paper plots of the ore blocks showing ore block numbers are issued to the bench supervisor, who is in charge of directing the excavator around the ore zones. Also common practice at site, the bench supervisors mark the number of trucks on a log sheet which is a standard and recommended mining procedure. However, it is better to improve the quality by introducing measures as Provide a radio to the bench supervisor, and they radio the ROM pad that truck X has left with ore type Y. When the truck arrives at the ROM, the truck number and time of arrival are reported on a log sheet. Tallies from the ROM and pit are compared the next morning.

Ore is preferentially mined during daylight hours. Low-grade ore can be mined during the night shift provided there is proper lighting. Waste and subgrade material can be mined 24 hours a day. Ore zones can be protected by no dig lines –white flagging tape- to avoid that they are mined or approached too closely –this is especially important for night shift hours.

The following summarized procedure recommended during mining:

1) Ensure an appropriate PPE is worn before you start with the process
2) Stand at least 10 to 12 meters away from the digger.
3) Ensure personal visual contact with the digger
4) Avoid standing at the blind side of the digger.
5) Communicate with the digger at regular times to ensure the best ore material is mined and sent to the ROM pad.
6) Before an ore material is mined, communicate to the ROM pad supervisor the ore material type to be mined and the trucks to carry the ore material
7) Geo-technician must tally the amount of ore material mine at a particular time and record the start and finish time.

II. Improve grade estimation techniques

Cut-offs for string and Ore Block Outline Creation

No iron rule exists that is applicable to all circumstances. The general aim is to create more or less regular continuous ore zones within a cut-off at 0.2 g/t. The cut-off can drop to 0.1 g/t or even lower if this is required to maintain continuity or to maintain minimum widths of 3 meters. It is also recommended to include a below-cut-off sample if a high-grade sample (>10 g/t) would otherwise be right at the contact. This is to avoid the possibility that some high-grade ore will be lost during mining.

Minimum widths for ore blocks have been set at +0.5 m to the width of the excavator bucket and lesser widths should be avoided. The creation of thinner zones may actually lead to the loss of the thin economic band. Similarly, waste zones less than +0.5 m to the width of the excavator bucket should be avoided as much as possible. Ore blocks should have mineable shapes. Outlines must be created such, that mining sharply to the tapes will not cause loss of ore. At high-grade contacts, it can, therefore, be prudent to include 0.2 to 0.3 meters of waste in the design of the ore blocks. This has to be judged from place to place –i.e. depending on the location of the high-grade samples that caused this high-grade contact.

Ore Marking

Ore blocks should be pegged and taped-out by the survey department using color tape corresponding to ore types. Where required, the base of an ore block is indicated by white tape. The current stick pegged has the potential to cause ore loss and dilution. Instead, if the colored peg is not available, it is possible to use while lime (or locally called “nora”) to mark-out the ore outline by the survey team.

Replace the polygonal method

Currently, mining is using a polygon method for estimation. The mine should avoid using the polygonal method which may overestimate the grade and need to adopt a more suitable geostatistical method for grade control estimation. The recent development of the computerization of the geological database helps to facilitate geological modeling. Example a software SURPAC

6. Introduce updated morning Toolbox talk-topics

It is a common and recommended culture to adapt morning production meetings also called toolbox talk just before the operation starts preferably at the pit. Starting with the safety talk and previous day production performance, the team can have a brief discussion on the day plan and cons and pros to achieve a plan. The session helps to elevate the work morale and performance.

7. Update and implement all required SOP’s

As the company, it is expected to have as many as possible standard operating procedures. In addition to the recommended grade control procedures listed in this section above, the following SOP’s will further enhance the performance of the mine:

- ✓ Mining Dozer Operations Procedure
- ✓ Mining Driving In Mining Areas Procedure
- ✓ Mining Dump truck Operations hauling Procedure
- ✓ Mining Dump Truck Tipping Procedure
- ✓ Mining General Safety Pit Rules Procedures
- ✓ Mining Operating an Excavator Operations Procedure
- ✓ Mining Pit and Waste Dump Inspections Procedure
- ✓ Mining ROM Pad Loading and Feeding Procedures
- ✓ Mining ore spotting procedures

8. Further research

An implementing all-in-one reconciliation system requires all raw data archived using quality control at every stage. The total mill processing data in this paper was excluded from the analysis and the estimated from crusher feed ore is used for mill processing data to define the MCF. A proper sampling method at the processing plant is now in place and reliable data is recorded. Thus, future work for the project using the complete mill data will be providing a full mine-through-mill reconciliation solution adapted for the company use.

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In addition to the reference cited and listed next page of this report, materials from (Beyglou, 2016), (Chanderman, 2017), (A. Chieregati et al., 2011), (Craig et al., 2014), (International, 2007), (Worash-Getaneh et al., 2015), (Yohannes-Yihdego et al., 2018) have supported the author.

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