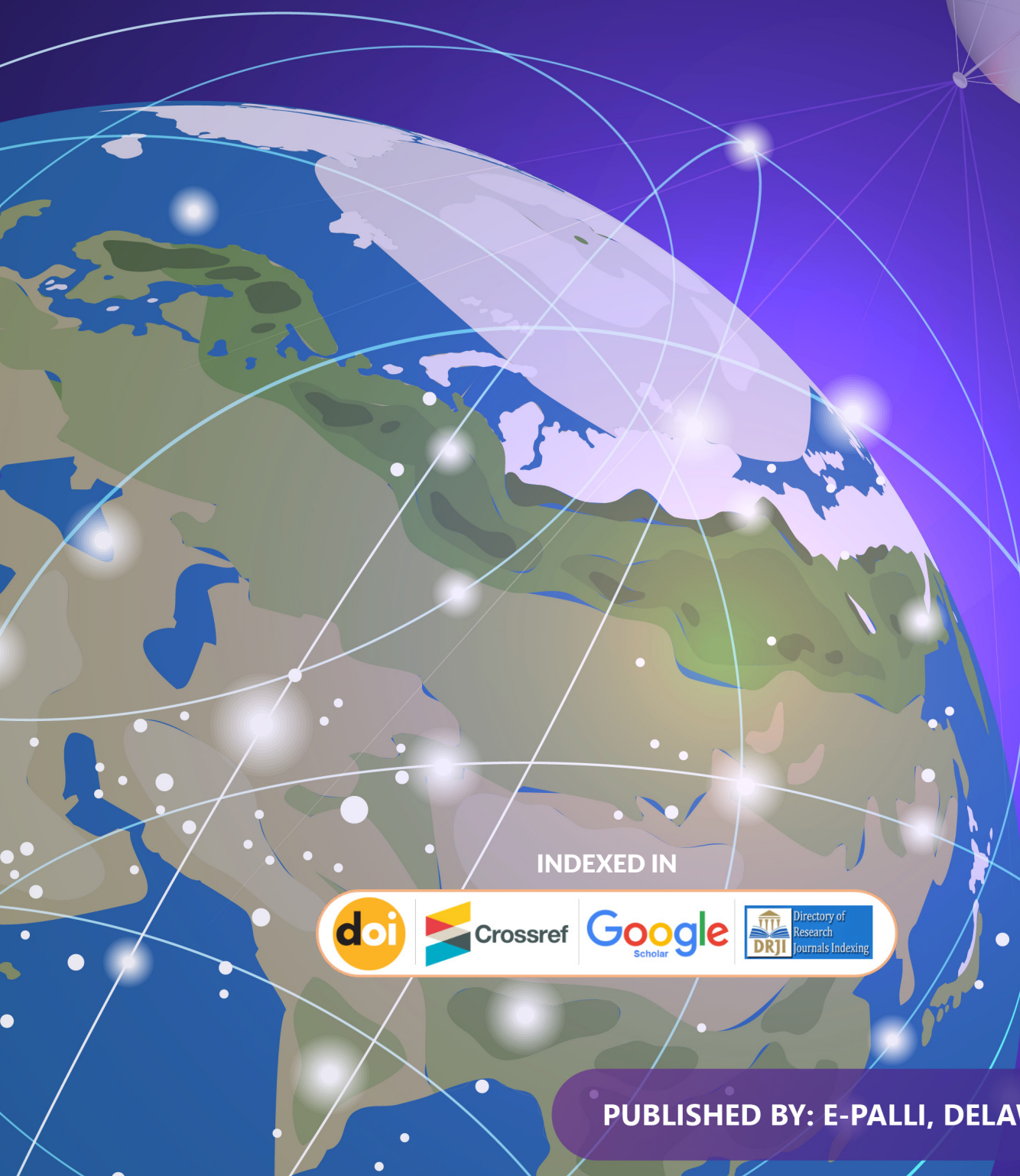
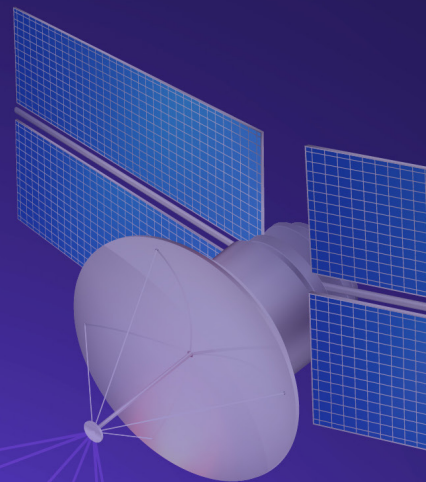




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## Geochemical and Petrological Survey in Northern Ethiopia Basement Rocks for Investigation of Gold and Base Metal Mineralization in Finarwa Area and Its Surrounding Southeast Zone of Tigray, Ethiopia.

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### ABSTRACT

The study is accompanied in northern Ethiopian basement rocks, Finarwa area and its surrounding areas, south eastern Tigray. The objective of the study is to amendment field geology, mineralogy, and geochemical characteristics to deliberate about the gold and base metal mineral potential investigations. From the field observations the geology of the area haven been described and mapped based on mineral composition, texture, structure and colour of both fresh and weather rocks. The ore mineral under microscope are commonly base metal sulphides pyrrhotite, Chalcopyrite, pentlandite occurring in variable proportions. Galena, chalcopyrite, pyrite and gold mineral are hosted in quartz vein. The base metal sulfides occur as disseminated, vein filling and replacement. Geochemical analyses result from inductively coupled plasma mass spectrometry (ICP-MS) and atomic absorption spectrometry (AAS) indicates the threshold of geochemical anomalies is directly related to the identification of mineralization information. From samples stream sediment samples and the soil samples indicated that the most promising mineralization occur in the prospect area are gold(Au), copper (Cu) and zinc (Zn). This is also supported by the abundance of chalcopyrite and sphalerite in some highly altered samples. The stream sediment geochemical survey data shows relatively higher values for zinc compared to Pb and Cu. The moderate concentration of the base metals in some of the samples indicates availability base metal mineralization in the study area requiring further investigation. In addition the sulphide concentrations in the research area are related to different stages of mineralization and are controlled both by structures and lithology. They are well established in the slate-phyllite and metavolcanics along the shear zones and faults as disseminated and vein filling. The rock and soil geochemistry shows significant concentration of gold with maximum value of 0.33ppm and 0.97 ppm in the south western part of the study area.

### INTRODUCTION

Rocks and minerals around us are used to develop new technologies and are used in our everyday lives. Our use of rocks and minerals includes as building material, cosmetics, cars, roads, and appliances. In order maintain a healthy lifestyle and strengthen the body, humans need to consume minerals daily. Ethiopia is one of the African countries with considerable mineral resource potential and is endowed with substantial amounts of metallic and non-metallic resources and has a long history of exploration (e.g. Assefa, 1985 and Tadesse et al., 2003). Low to high grade Precambrian rocks of southern, western, northern and eastern Ethiopia have huge potential for base metal, precious and rare metal mineralization (Tadesse et al., 2003). However, the mining activities have not reached to the expected levels and at the time Ethiopia is gaining marginal economic benefits from these resources. One of the reasons for less input from the mineral sector seems to be the lack of basic geological information and skills, related to mineral exploration and sustainable conducive environment for foreign and local investment but since the last decades or so the situation is fast changing in the country in favor of mineral exploration inviting many exploration companies in the mining industry. Modern minerals exploration started in 1968 with the establishment of Ethiopian Geological survey which is

engaged in basic geological surveying of the country. Mineral exploration as introduced in the country during the 1960s when the United Nations Development program (UNDP) executed a mineral survey in western and southern Ethiopia. The Economic Minerals Exploration Department was organized in 1984, with the establishment of the Ethiopian Institute of Geological surveys (EIGS), later it was reorganized as the Mineral Exploration and Evaluation Core Process (MEECP) in July 2009. The aim of this unit is to conduct detail and follow up explorations and evaluate the economic mineral as well as the hydrocarbon potential of the country and assess the viability of these recourses for further development, ultimately contributing to the socio-economic progress. During the past here or four decades various occurrences of precious, metallic, industrial and hydrocarbon resources have been identified.

Numerous gold and base metal occurrences that have been reported in several locations throughout Late Proterozoic low-grade metamorphic belts of southern, southwestern, western, eastern, and northern Ethiopia (Tadesse, et al, 1996, Tadesse,et al, 2003). Gold is the dominant mineral commodity in Ethiopia and the artisanal miners occurs mainly in the form of secondary placer deposits. Primary gold is currently mined at the Lega Dembi area in southern Ethiopia, which has a resource of ~60 t Au

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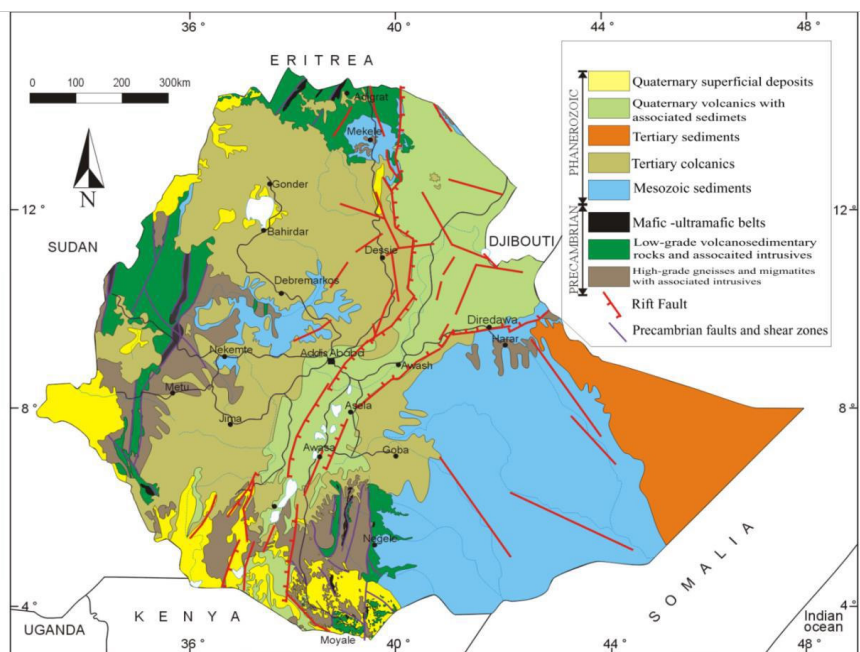
with an average 6 g/t of Au (Tadesse et al. 2003) that hosted in Neoproterozoic greenstone rocks and shear-zone. Currently, some projects have reached an advanced exploration stage in western and northern Ethiopia and are entering a pre-mining phase, possibly in a couple of years to become the next mines. Although Ethiopia is still underexplored for gold, and other metallic and industrial mineral deposits, notable exploration activities have been carried out both by the Geological Survey of Ethiopia and private companies.

Mineral resources of Ethiopia have not yet well explored and exploited, and hence its contribution to the overall economy or GDP is low. However, as reported by the World Bank Group (2014), its contribution to the foreign exchange earnings reached about 10% of which the artisan mining takes the lion's share of over 65%. The artisan mining also significantly contributes to the employment of at least 1.26 million people and supports

the livelihood of over 7.5 million populations.

In the study area exploration activities have been unsuccessful in identifying surface and subsurface extensions of mineralization, largely due to a poor understanding on the type of lithology, structural controls, genesis and occurrences of mineralization.

Underpinning Artisanal gold mining in Finarwa area is the broader issue that structural adjustment and market liberalisation has 'induced significant unemployment which has forced many people into illegal artisanal mining to supplement their incomes'. So this study is carried out to identify the host rock, type of alteration, structural analysis, and geochemical anomaly and to recommend site of mineralization to conduct feasibility study in the study area as well as correlating the anomaly with the standard and correlating with similar deposits in other parts of Tigray.



**Figure 1.1:** Map of distribution low grade volcano-sedimentary sequences in Ethiopia (after Mengesha et al., 1996, Gebresilassie, 2009 & cited from Haftu., 2015).

### Description of the study area

The study area is located in the northern Ethiopia, in south Eastern zone of Tigray along the Samre -Soqeta road town (Amhara region) which is about 90km from Mekelle capital city of Tigray(Figure 1.2).

It can be reached by the gravel road extended from Mekelle - Samre – Finarwa or by asphaltic road from Mekelle-Abi-Adi then gravel road from Abi-Adi to Yechilay- Finarwa which continue into Amhara region. The study area covers an area of 36 km<sup>2</sup> and is bounded between UTM coordinates 0501000m to 0507000m East and 1448000m to 1442000m North. Regionally, the area is lying within Samre topo sheet map and is entirely covered by low grade metamorphic rocks of Precambrian age.

### Problem statement

The importance of developing a mineral exploration

and mining with -free and reliable work plan has long been recognized by the mining companies. However, numerous mineral exploration projects are still plagued by delays and cost overruns, which can frequently be traced to ineffective identification and treatment of mineralized zones. First, when a exploration is not properly identified during scheduling, subsequent conflicts in the field are inevitable. Today's projects are becoming more and more technically complex and logistically challenging, which exposes exploration operations to even more complex exploration activities.

Currently, there is no viable explanation for the existence of the potential metallic mineral resources except the gold which mined by local miners by panning. . Determining the source(s) for the minerals (s) is a problem that has not been solved. A powerful tool that has not been utilized by any workers is a detailed study of mineral chemistry in the



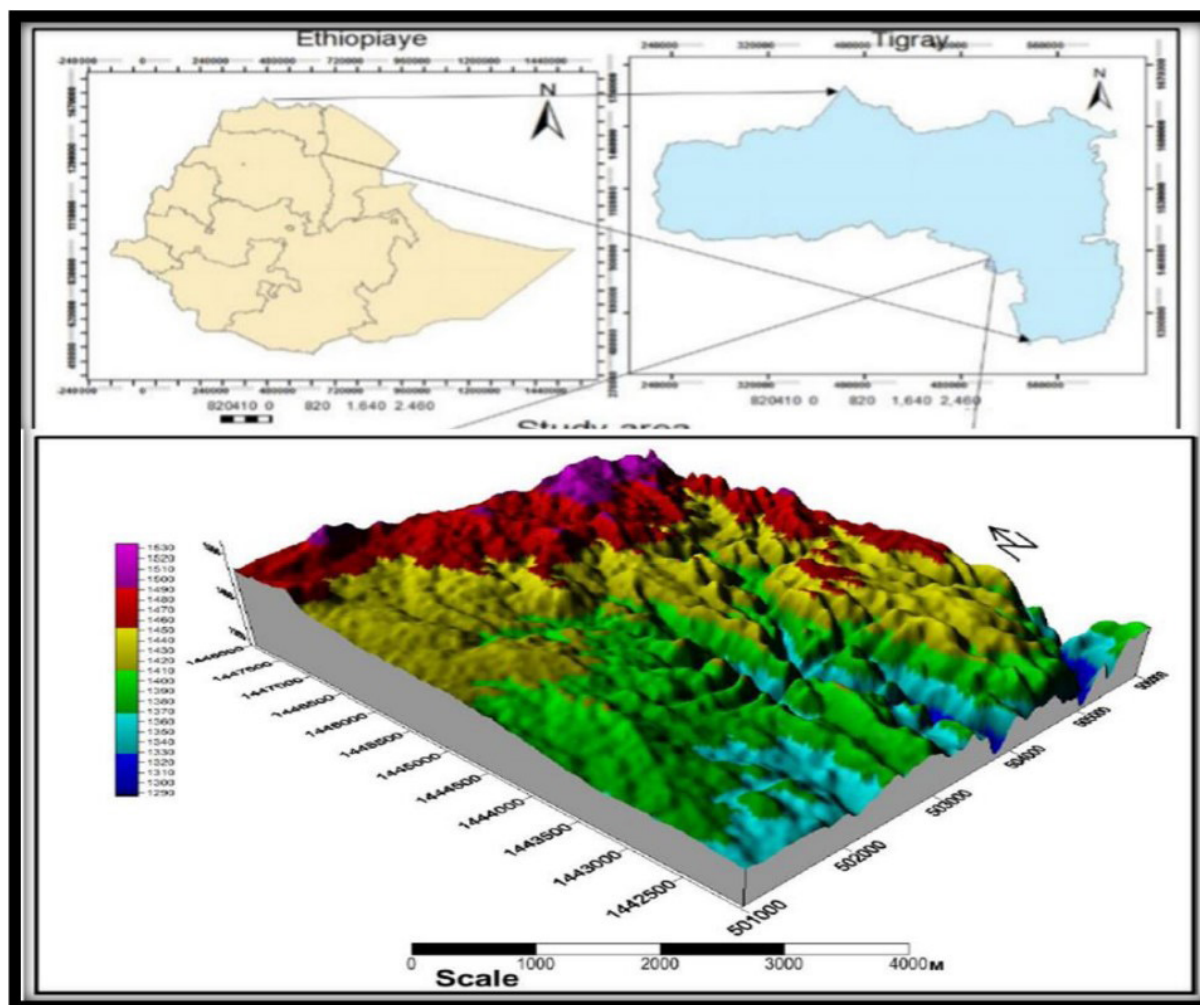


Figure1. 2: Location map of the study area

metamorphic rocks of the Finarwa area. Consequently, I propose to seal the glaring gap in the understanding of the genesis of the mineralization and the controlling factors for the mineral distribution by conducting a quantitative study of the mineral assemblages of the study area.

The present study determine the host lithologies, extent and associated geochemical features of the metallic mineralization in addition to that children who are also participating in practical mining which leads them to achieve poor academic performance in school will be solved by putting criteria measurements .

## METHODOLOGY

Twenty two stream sediment and nineteen soil analysed using inductively-coupled plasma mass spectrometry (ICP-MS) in addition to this six stream sediment samples have been analysed using atomic absorption spectrometry (AAS) for cross checking and, nine mineralized rock samples were collected for analysing gold and base metal mineralization using ICP MS and six mineralized rock samples were collected and prepared for polished section. The samples analyzed using AAS have detection limit of 0.002ppm and most samples remain above detection limit shows positive anomaly for both gold and base metal occurrence.

The research works have been followed by three main phases during the study. The first is pre-field work consists of collection of relevant published and unpublished literatures from institutes; Bureaus, universities and internet were conducted. In addition field work planning, base map preparation and interpret enhanced thematic Images, looking different geological and geochemical.

The second phase is field work which includes lithological description and collection of rock, stream sediment, gravel, sand and soil samples placid from representative populations. Each sample location would be recorded with GPS(Geographic Positioning system) plastic flagging tape and a small aluminium tag or plastic pin-marker showing the sample number.

Analyses of the soil and stream sediment samples taken enable the observation of patterns and concentrations in the distribution of metals in the soil and stream sediment which would potentially indicate enriched rock underneath. Inspected field characteristics, mineralogical and geochemical composition of gold bearing quartz veins and soils and used to establish prospectivity prediction models that indicate ranking of areas with potential gold mineralization.

Collected samples transport for preparation of thin sections and chemical analysis. Thin sections (both

polished and unpolished) prepared for studying the mineralogical, textural and alteration behaviour of the rocks using polarizing and reflecting microscopes. The bulk and grab samples crushed by jaw crusher and pulverized to -200 mesh sizes by the tungsten carbide ball mill. The representative portions of these samples will obtain by passing individual sample through splitter. The representative powdered samples stored in the glass bottles and were heated at 110°C overnight and then the bottles stored in the desiccator for further processing.

### Methods to determine the threshold of geochemical anomalies

There are many kinds of methods for determining the threshold of geochemical anomalies: the statistical method, direct graphical method, geochemical section method, martensitic distance method, single element calculation, cumulative frequency method, local singularity analysis, exploration data analysis method, etc. In this study soils, stream sediments and rocks geochemical analysis result data are treated and processed using conventional statistical method (simple statistics) such as mean, range, coefficient of variation, standard deviation and threshold value and compared with general background concentrations. Exploration data analysis

method is used to process the gold and base metal data and determine the abnormal thresholds.

In exploration geochemistry, values of the threshold [mean  $\pm$  2 standard deviation (Std)] were originally used to identify about 2.5% of upper (or lower) extreme values and act as the threshold for further inspection of large data sets (Hawkes and Webb, 1962). The method requires that the geochemical data follow normal distribution. Some extreme values in the geochemical data derived from the data distribution or a second (mineralization) distribution could influence the results of this method, i.e., 5%, 10%, 20%, or even 50% of the data could be identified as extreme values.

### Geology of the study area

The development of the Ethiopian basement is directly or indirectly related with the Arabian Nubian shield (ANS) and the Mozambique Orogenic Belt (MOB) both of which are related to the formation of the East African Orogene (EAO). The formations of northern Ethiopia provide that the geology of the region is the southern extension of the Arabian Nubian Shield (Tadesse et al., 1999; Tadesse, 1996 and 1997; Abdelsalam and Stern, 1996). The Arabian Nubian Shield extends from Jordan and southern Israel in the north to Eritrea and Ethiopia

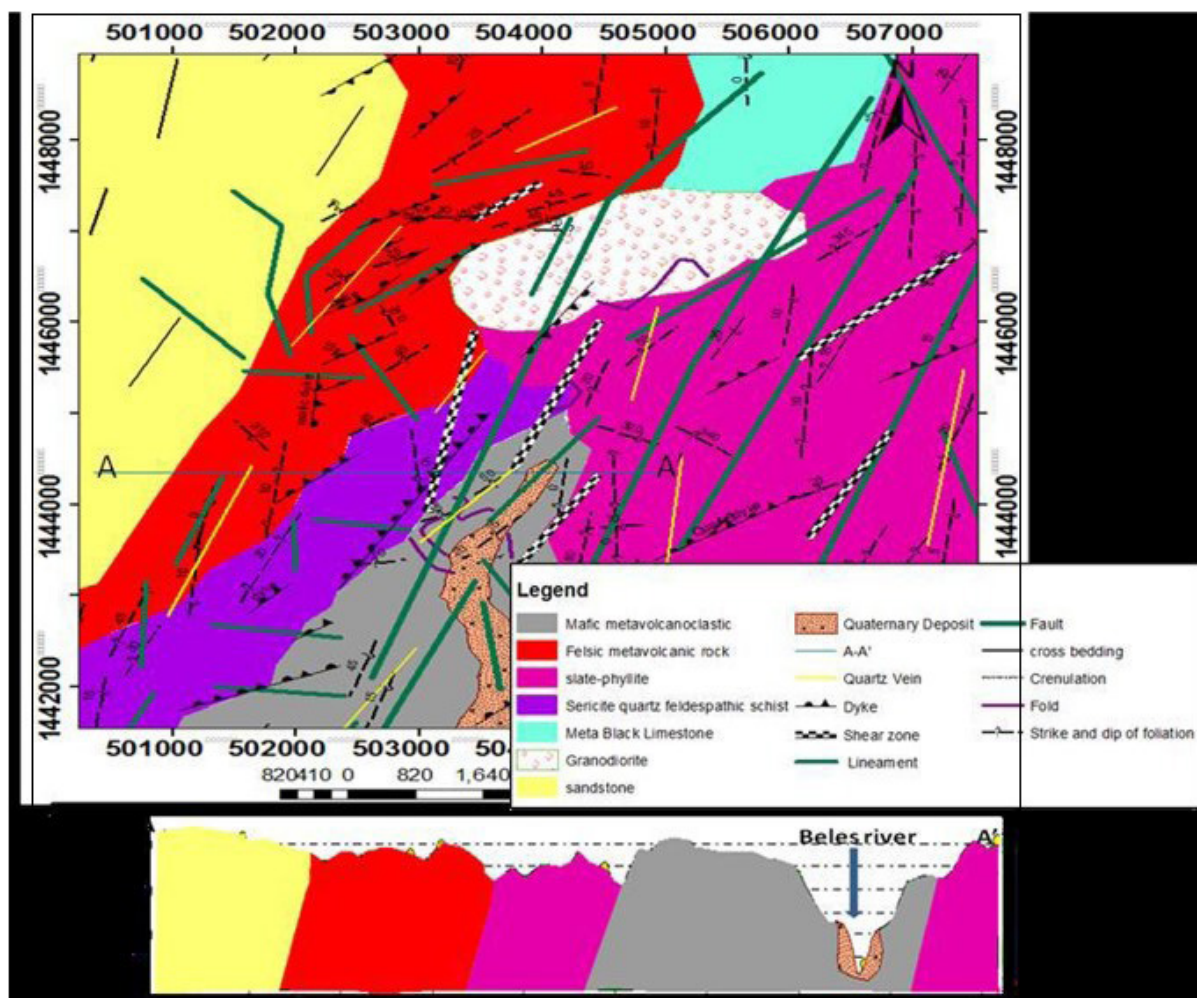


Figure 1.3: Geological map of the study area



in the south and Egypt in the west to Arabia and Oman in the east (Blasband et al., 2000; Archibald et al., 2014). Most of the Precambrian volcano-sedimentary sequences and associated intrusions have been subjected to several orogenic episodes during the Pan African Orogeny, which is the cause for the formation of the Arabian–Nubian Shield terranes (Tadesse et al, 2003). The

Arabian-Nubian shield hosts numerous VMS deposits, orogenic lode gold deposits and placer deposits practiced by artisanal workers (Barrie et al., 2007). The ANS hosts numerous gold deposits in several districts found within the entire shield most notably in Saudi Arabia, Sudan, Ethiopia and Eritrea (Barrie et al., 2007; Barrie and Hannington, 1999).

The Neoproterozoic basement rocks exposed in the study area includes metasediments, meta volcanics /clasts and younger Granitoids. The metasediment and metavolcanic rocks, except for the younger granitoids have been tectonized, sheared, altered and in some places show sulphide mineralization. They are crosscut by various types of disseminated sulphide-bearing dykes and veins.

The Neoproterozoic basement rocks are the oldest rocks exposed in the study area. The basement rocks of the region indicate that the metavolcanic rocks form the oldest, followed by phyllite, slate, and carbonate and the associated post-tectonic plutonic units (Miller et al., 2003; Beyth, 1972), granodioritic composition (Alene et al., 2000; Garland, 1980) and sedimentary cover rocks. Therefore, the order of the rocks from oldest to the youngest is metavolcanic, slate-phyllite, carbonate, granitoids and sandstone. On the basis of mineral association and their textures observed from hand spacemen petrographical studies, the rocks in the study area are named as metavolcanic/clastic, slate-phyllite, meta-black limestone and granitoids. The presence of chlorite, muscovite and biotite, development of foliation and presence of primary compositional banding of minerals in the metamorphic rocks indicates the rocks in the study area have experienced low grade metamorphism. Furthermore, the development of crenulation cleavage at places is observed due to the localized effects of quartz

intrusion or intensive shearing but only in phyllite. On the other hand depending on the distribution (random) and orientation of the minerals in the intrusive rocks shows that this rock is post tectonic granitoids.

Among the two dominant types of metamorphic rocks (meta-volcanic and phyllite), metavolcanics are dominated by fine grained mineral matrix with few coarse quartz, plagioclase and mineral clasts and rock fragments than slate-phyllite rock. The clasts vary from dominant quartz, plagioclase to mafic mineral and rock fragments and show rounded sub-rounded and irregular shapes. Similarly, phyllite is characterized by fine grained mineral matrix and with well-developed foliation and crenulations and boudinage as well as primary compositional banding of minerals.

#### Felsic Metavolcanic

The felsic metavolcanics in the study area display a variegated color which ranges from brownish to reddish in color and are fine grained and shining appearance due to presence of fine grained sericite minerals. The rock is intensively fractured and intruded by quartz veins having different orientation and thicknesses ranging from 5 to 20 cm . It is highly affected by hydrothermal alterations forming different quartz veins.

#### Mafic-Metavolcanoclastic Rock

This unit is composed of intercalation of mafic-metavolcaniclastic which is exposed at the south eastern part of the study area. The dominant rock unit is mafic metavolcaniclastic with less foliated phyllite rock while the metavolcanoclastic is nearly none to slightly foliated with a general strike direction of N-S. The fresh and weathered color of the metavolcanic rock in the area is green brownish and dark gray respectively. The clasts have rounded to sub rounded and elongated shape. The rounded clast suggests that the rock does not undergone intensive deformation.

#### Slate-Phyllite and Graphitic schists

The slate phyllite and graphitic schist intercalation



Figure 1.4: Felsic metavolcanic with quartz vein

rocks in the study area are derived from sedimentary, volcanoclastic and mafic flows. They are variegated in color which range from gray, black and reddish colors with dominantly dark grey and black colored. The unit is fine grained texture, slightly foliated, composed of graphite, micas (sericite), and minor amount of fine grained chlorite, feldspar and quartz.

This unit is the dominant lithology in study area and covers around 55 % of the area and is highly foliated trending N-S to NE-NW. The degree of the orientation of the foliations frequently shifts due to the intruding intrusive bodies within the slate-phyllite rock. Veinlet and Quartz veins several meters thick aligned parallel to the foliation direction and frequently shifting orientation



**Figure 1.5:** Slate phyllite graphic schist

is observed. The presence of muscovite in the contact between the slate phyllite and granite in the central part of the study area gives the unit shiny appearance and affected by sericite alteration due to shearing movements.

### Quartz Veins

These are formed when hydrothermal solution percolates through fractures. Quartz veins are the common in filling secondary material and distributed in the terrain particularly along shear zones and the contact between phyllite and dyke. Based on their cross-cutting relationship it is possible to determine the history and time of emplacement of the quartz veins. Their size ranges from vein let a few centimeter thickens (1cm) up to reef size (50 meter) thick. The vein is dominantly wide spread in the western part in filling weak zones parallal and perpendicular to the foliation orientation.

The thickness of the veins are variable, it ranges from about few cms upto 50m. The overall orientation of these veins and veinlet's lies in N40°-80°W, N15°-30°E, E-W and N-S strike and dipping vertically to sub-vertically to the northern, western, northern and western parts respectively.

The quartz veins in the study area are characterized by pure quartz vein (white color), smoky quartz vein and yellowish color. Most of the veins are highly brecciated and silicified cutting the phyllite/slate intercalation; at place there is quartz reefs and fragments of quartz veins cover a wide area as quartz float.

### Alterations

Alterations of minerals are very commonly associated with the intensive hydrothermal related activities which results in oxidation, kaolinization, silicification, ferruginization and sericitization.

**Table 1:** Quartz vein strike direction

NO	Quartz vein	Thickens (cm)	Location (UTM)		Elevation
			Northing	Easting	
1	660	5	1542720	540468	2107
2	850	3.5	1542720	540468	2107
3	100	5	1542929	541824	2087
4	650	10	1542929	541824	2087
5	50	3	1542929	541824	2087
6	3400	50	1543001	541199	2081
7	3500	53	1545447	538462	2023
8	750	60	1545447	538462	2023
9	50	6	1545899	541148	1996
10	800	10	1545899	541148	1996

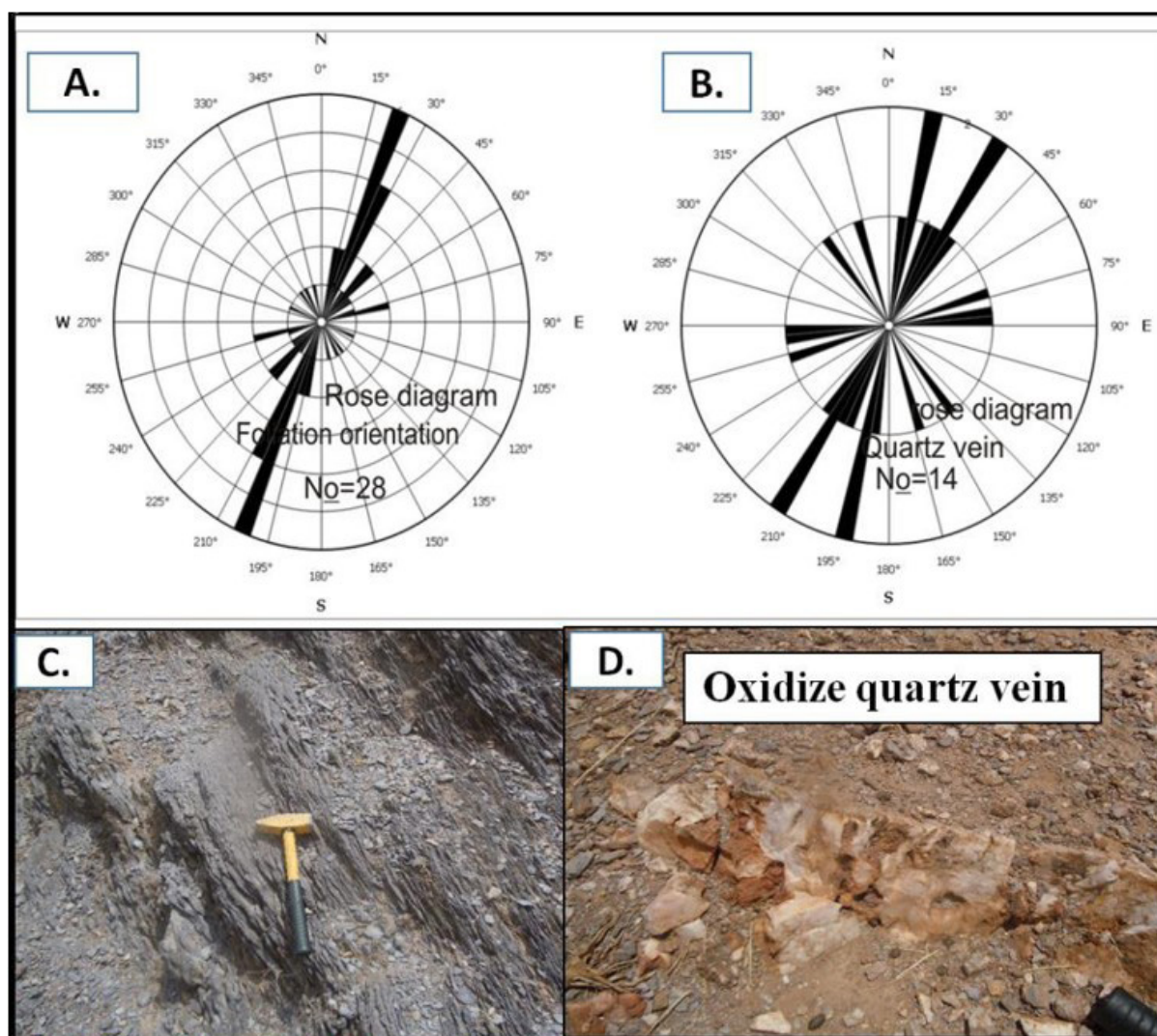
Oxidation type alteration is common with in the western and central part of the study area in quartz veins both in the felsic metavolcanic rock and slate phyllite rock. Oxidation has been furnished various colors of yellow, reddish brown, deep reddish brown, black and light reddish. The various colors have been generated from oxidation or leaching of iron bearing minerals and vein type iron bearing minerals. Pyrite crystals associated with this rock are also common but the sulphide dissolves to the air to react with oxygen. This reaction represents the chemistry of pyrite weathering to form ferrous iron and sulfides.  $2\text{FeS}_2(\text{Pyrite}) + 7\text{O}_2(\text{Oxygen}) + 2\text{H}_2\text{O}(\text{water}) = 2\text{Fe}(\text{Ferrous Iron})$

## RESULT AND DISCUSSION

### Artisanal miners and placer deposits

Surface exposures of gold Mineralization in the area in alluvial(stream sediment) and elluvial(soil) placer deposits are extensively panned at Finarwa area and it's surrounding during rainy season and carrying water from far distances in the intermittent rivers and at any time in the Perennial Rivers. This is the direct implication for the occurrence





**Figure 1.6:** Rose diagrams showing: - A) Foliation orientation B) Quartz vein orientation

of gold in the study area which is hosted within the shear zone affected by hydrothermal activity.

Weathering processes produces samples (soils and stream sediments) that return records on local hidden mineralization or on the potential existence of major or minor mineralization in a wide region. The residual soil is the geochemical sample that is often used to detect the location of hidden mineralization. Migration of groundwater provided chemical response at the surface. This process produces elemental dispersion pattern. Most of these dispersed elements (e.g., Cu, Ag, Zn, Cd, As, Bi, Pb, Sb, Hg, W, Mo, and Se) are useful indicators or pathfinders for the presence of gold.

In Finarwa artisanal gold mining has become an increasingly widespread economic activity of the local people undertaken by socially differentiated groups with a wide range of education levels and economic backgrounds incorporating a wide variety of 'labour intensive activities without mechanisation.

The local people economic activities participation in both farming and mining locate way of life into the classification 'mining farmers' versus 'farming miners' which drawing attention to large-scale population

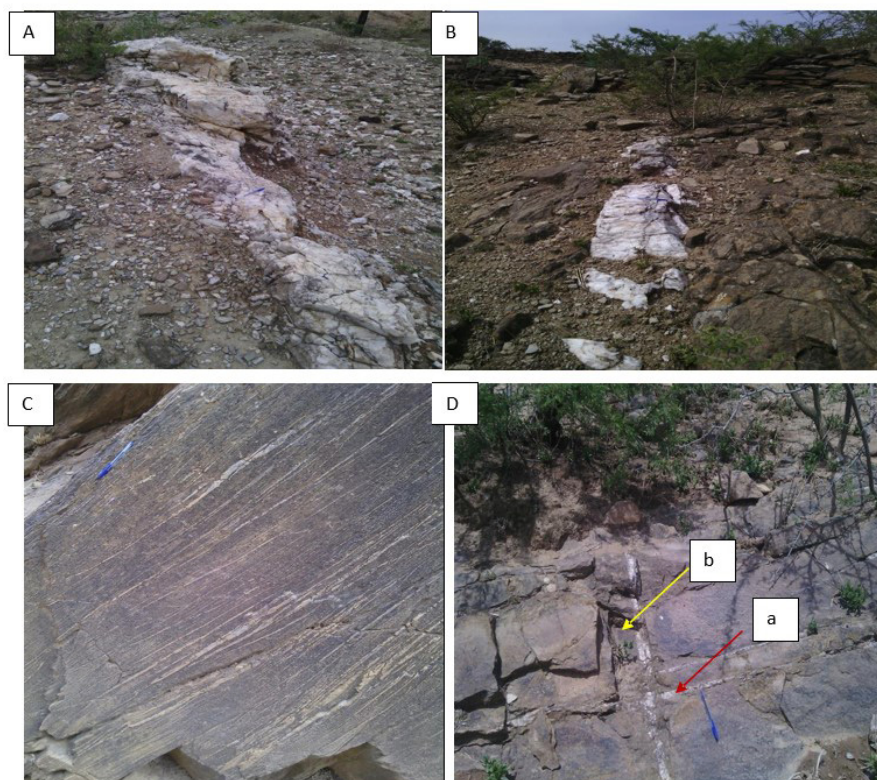
displacement and economic transition has reconfigured, but not eliminated co-existing importance of both sectors in the same regions.

Mining and farming have often co-existed alongside many other informal income generation strategies with past work noting that livelihood struggles have been shaped by a myriad of political and historical forces that underpin unemployment crises. Gold is artisanally mined from eluvial deposits within Finarwa area and its district but mine site selection and mining operations are done without any understanding of mode of occurrence, compositional characteristics and extent of gold mineralisation.

Foundation of the Artisanal gold mining in Finarwa area is the broader issue that require structural adjustment and market liberalisation has 'induced significant unemployment which has forced many people into illegal artisanal mining to supplement their incomes'. According to the reports from the governmental offices the number of populations involving in the traditional gold mining in Finarwa and its surrounding Abergele district exceeds 10,000 peoples.

In the fieldwork in Finarwa area, artisanal miners





**Figure 1.7:** Reef greater than 50cm thickness, (C); vein let (1cm thick), (D); Cross cutting relationship between vein a and b (vein b is younger than vein a).



**Figure 1.8:** source from government Investment and Industry Development office panning of gold from stream sediment in Finarwa surrounding area(Abergel district)

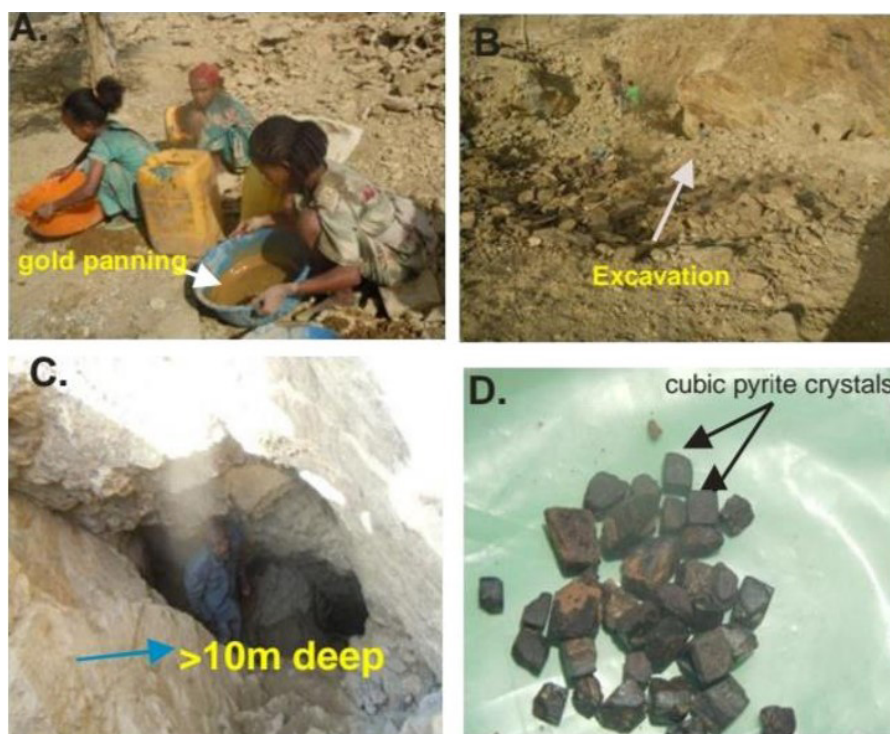
operate in groups, locally known as Mahber, which generally comprise people who share relationship ties, are extended family members, or friends who have known each from their place of origin or those who have worked together at different mine sites over a long period of time. Some the groups(Mahberat) are made up of wage labourers employed by a sponsor. Although the groups predominantly comprise male members (due to heavy manual work involved), women are also involved in groups either as sponsors who hire labour or as gold buyers or dealers who buy gold for resale locally or to

gold smuggling syndicates. Women can also act as co-managers of a group (Mahber) with their friends. Eluvial gold occurs within the low grade slate phyllitic rock and metavolcanic rock in some locations called minor gold fields and has been recovered by artisanal miners through excavation of several pits of various dimensions and depths. The soil rich in gold was panned and washed and lighter fractions were removed until heavy minerals with gold grains remained. The gold grains were separated from the heavy mineral concentrates manually. Residual weathering of rocks that underlain the study

area resulted into soil formation and this is reflected in its mineralogy. Weathering facilitated the dispersion of the geological materials containing primary gold mineralization. The major mineralogical constituent in all

the soil samples examined is quartz. There is no distinct pattern in the mineralogical composition of the minor and trace constituents.

Gold and sulphide ore minerals were recognized in



**Figure 1.9:** Showing Recovery of gold by local people A. panning for gold B. artisanal miners C. deep hole excavation of gold following quartz vein within felsic metavolcanic rock

the study area as attained the field work, soil, rock and stream sediment analysis results and ore petrography. The district has a high potential for shear-zone related gold mineralization as the traditional mining in the area are following quartz veins and ore petrography showing ore minerals concentrated in quartz veins. Quartz vein controlled gold gathering is also exercised by the local people in the study area by deep hole excavation(>10m) following quartz vein within the felsic metavolcanic rock in southeastern part of the study area. Occurrence of gold is observed in the surface samples as tiny micron grains associated with sericitization alterations in excavated holes in area as most of the local peoples concentrate in winter season. The Au-bearing quartz veins are generally more deformed and associated with hydrothermally altered sericite-chlorite schist.

Gold bearing quartz veins crosscut metapelites (slate, phyllite with schist) and intensively weathered granite in the study area indicating epigenetic styles of mineralization. These veins vary considerably in thickness and often exhibit significant vertical and longitudinal continuity. Vein contacts are generally sharp and steeply dipping. Primary gold in the area predominantly occurs in quartz veins, stringers that associated with second generation quartz vein and second phase of deformation within the basement rocks specially quartz veins within metavolcanic rock.

### Ore Petrography

Gold and sulphide ore minerals were recognized in the field (Megascopic) and in microscopic study (petrography). Most of the minerals that are recognized in the field occurred on and near quartz veins especially around the shear zone. Hydrothermal alteration related sulphide mineralizations are observed from ore petrography study of the rocks collected from the research area. Ore forming sulphide minerals including pyrite, chalcopyrite and galena. They are recognized in metavolcanic clastics, metavolcanic and quartz dikes. The mineral pyrite is occurs as both disseminated and vein filling type.

**FNCR 4:-**The section contains both gold and pyrite minerals. The samples were taken from the slate-phyllite rock unit intensively affected by hydrothermal veins. The gold and pyrite minerals in the unit occur as vein type of mineralization. Pyrite is medium grained and euhedral (as cubic outlines) to subhedral in shape.

**FNCR 6:-**The section contains pyrite, chalcopyrite, opaque minerals which occurs within the metavolcanic rock unit. The pyrite mineral in the unit occurs as vein type of mineralization, which is characterized by fracturing, medium grained and subhedral in shape.

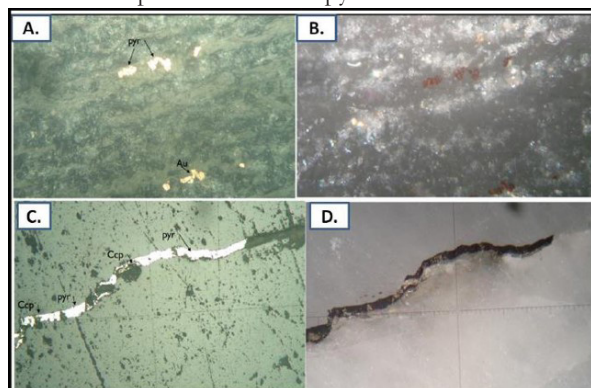
**FNCR 7:-**This section is composed of only pyrite mineral occurring within the quartz rich rock unit which is moderately oxidized. The pyrite mineral occurs as coarse grained size and euhedral grain shape.

**FNCR 10:-**It is mainly composed of pyrite and galena

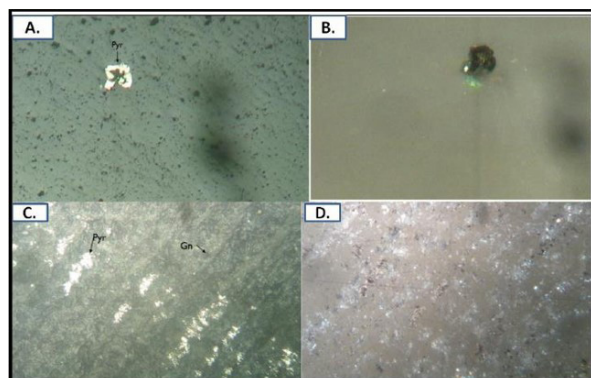


ore minerals within the felsic metavolcanic rock unit. Pyrite occurs as disseminated type of mineralization and medium to coarse grained size in a large amount. Galena occurs as replacement style of mineralization, medium grained size in a small amount within the pyrite veins.

From the ore microscope observation it is concluded that the gold, pyrite, chalcopyrite and galena minerals in Finarwa area are associated with quartz veins found within both meta-sediments and meta-volcanic rocks. Since the area is highly affected by post tectonic shearing in some samples disseminated pyrite is observed.



**Figure 1.10:** Ore Microscope where Au=gold, Gn=Galena, pyr=pyrite, Ccp=chalcopyrite, opq=opaque minerals



**Figure 1.11:** Ore Microscope where Au=gold, Gn=Galena, pyr=pyrite, Ccp=chalcopyrite, opq=opaque minerals

### Geochemical Survey

Geochemical background and threshold are two essential concepts in mineral exploration and geochemistry. Background is defined as 'the normal abundance of an element in barren earth material or normal crustal abundance of material naturally'. The standard crustal abundance value for Au 0.0035 ppm, Co 29 ppm, Cu 68 ppm, Pb 13 ppm, Ag 0.075 ppm and Zn 76 ppm (Fortescue, 1992, Parker 1967). Geochemical value which is not same as the background is threshold anomaly that can be positive or negative. The threshold value calculated from the mean and median plus two standard deviations (Rose et al. 1979).

Geochemical data are treated and processed using simple statistics such as mean, range, coefficient of variation, standard deviation and threshold value and compared with general background concentrations. Geochemical

concentration values for nine elements (Au, Ag, Pb, Zn, Cu, Mo, W, As and Sb). A total of

nine rock, nineteen soil and twenty two stream sediment samples discussed in this study were taken at a low density of about 1 sample per 1km<sup>2</sup> from the areas. The statistical properties of the concentrations of these nine elements are summarized in Table 1, Table 2 and Table 3 indicating non normal data distributions.

### Rock geochemistry result

The geochemical data analysis of the mineralized rock samples shows tremendous anomaly for gold and copper concentration. The result shows presence of some anomaly for gold and copper concentration which is hosted in the shear zone altered metamorphic rocks. The oxidized quartz vein within the low grade rocks shows gold and copper mineralization.

From the rock geochemical analysis result the maximum navigated result value for gold is 0.33 ppm which is obtained from the analysed samples taken from quartz vein. The rock geochemical analysis result for gold content ranges from 0.02 to 0.33 ppm with a mean value of 0.086 ppm and two standard deviation value of 0.198214, the threshold value calculated from mean plus two standard deviation for gold is 0.2849 and the standard crustal abundance for gold which is 0.003 ppm (Fortescue 1992) therefore the area have good potential for gold mineralization.

From the rock geochemical analysis for Ag content ranges from 0.02 to 3.4 ppm with a mean value of 1.513 ppm, two standard deviation values of 2.19381 and the calculated threshold value is 3.7071, the result from the rock geochemical analysis for Pb range from 2 to 79 ppm with mean values of 17.33 ppm, two standard deviation values of 46.891 and the calculated threshold value is 64.25 and the result from the rock geochemical analysis for Cu ranges from 27 to 240 ppm with mean value of 90.11 ppm, two standard deviation values of 137.405 and the calculated threshold value is 227.52, the result from the rock geochemical analysis for Zn value ranges from 6 to 170 ppm with mean 57.55 ppm, two standard deviation values of 97.228 and the calculated threshold value is 154.78.

The result from the rock geochemical analysis for Ni content range from 3 to 80 ppm with mean 18.33 ppm, two standard deviation values of 47.506 and the calculated threshold value is 65.837. and for Co value ranges from 2 to 11 ppm with mean 7.55 ppm, two standard deviation values of 5.086 and the calculated threshold value is 12.642 respectively. Gold, Copper, zinc and lead show that geochemical data analyses result the area with sufficient mineral resources because of the mineralized core samples have higher threshold value for gold, lead copper and zinc value.

The high concentration of iron is result of ferruginization type of alteration in the study area. The threshold value calculated from the mean and median plus two standard deviations (Rose et al. 1979).

**Table 2:** Rock geochemical analysis

Rock Id	Au	Ag	Cu	Co	Ni	Pb	Zn	Fe
CFN-01	0.09	1.1	90	10	13	79	170	63225
CFN-02	0.02	3.4	240	7	13	32	32	9933
CFN-03	0.02	0.9	29	8	3	5	57	64092
CFN-04	0.02	0.7	27	7	9	4	24	18971
CFN-05	0.05	3.4	170	11	80	7	35	8741
CFN-06	0.33	1	34	7	3	9	64	57497
CFN-07	0.02	0.02	45	2	5	4	6	479
CFN-08	0.18	1.6	69	10	35	14	107	87311
CFN-09	0.05	1.5	107	6	4	2	23	13274
Max	0.33	3.4	240	11	80	79	170	87311
min	0.02	0.02	27	2	3	2	6	479
Mean	0.08667	1.5133	90.111	7.555	18.33	17.33	57.55	35947
2STD	0.198	2.193	137.4	5.086	47.5	46.89	97.22	60059
Threshold	0.284	3.707	227.5	12.64	65.83	64.22	154.7	96006

**Table 3:** showing stream sediment Geochemistry

Sample No.	Au_ppm	Co_ppm	Cu_ppm	Fe_%	Ag_ppm	Ni_ppm	Pb_ppm	Zn_ppm
FNST1	0.04	32.5	26	8.64	<0.1	36	6	95
FNST2	0.04	31.3	74	6.48	<0.1	53	11	91
FNST3	0.06	28.8	69	6.15	<0.1	48	11	85
FNST4	0.04	29.8	61	5.85	<0.1	57	11	74
FNST5	0.08	25.1	57	5.05	<0.1	51	6	64
FNST6	0.05	28.5	59	6.35	0.2	60	10	77
FNST7	0.08	26.5	52	6.15	0.2	46	11	80
FNST8	<0.01	4.6	8	1.12	<0.1	8	6	15
FNST9	0.08	21.4	37	5.13	0.2	41	9	102
FNST10	0.06	27.7	73	6.85	0.1	24	19	114
FNST11	0.01	5.7	11	1.37	<0.1	8	7	20
FNST12	<0.01	3.6	8	1.16	<0.1	8	4	9
FNST13	0.05	3.9	8	1.47	<0.1	10	7	9
FNST14	0.01	4.6	10	1.43	<0.1	11	5	12
FNST15	0.06	10.8	13	2.5	<0.1	10	4	30
FNST16	0.114	37.2	69	6.63	0.1	110	12	94
FNST17	0.97	26.2	45	5.28	0.2	58	11	63
FNST18	0.68	26.2	70	5.71	0.2	36	26	97
FNST19	0.12	43.7	59	4.64	<0.1	22	9	82
FNST20	0.12	19.7	69	5.61	0.2	24	11	88
FNST21	0.03	7.6	13	2.12	0.4	12	6	22
FNST22	0.05	21.9	68	6.21	0.1	25	25	144
Max	0.97	43.7	74	8.64	0.4	110	26	144
Min	0.01	3.6	8	1.12	0.1	8	4	9
Stdv	0.31128	12.932	26.6015	1.94678	0.2494	11.81	7.4054	42.3543
Mean	0.1372	21.2409	43.59	4.631	0.19	34.454	10.318	66.68
Threshold	0.75976	47.1049	96.793	8.52456	0.439	46.264	25.1288	151.389

### Stream Sediment Geochemistry

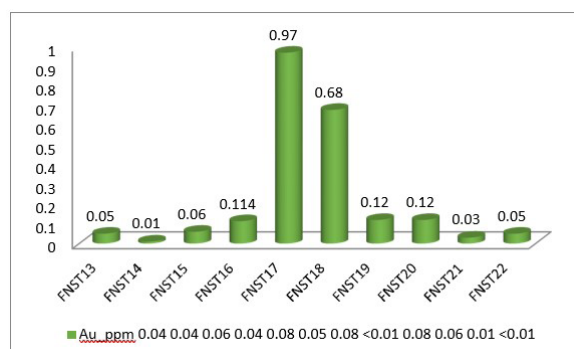
Drainage sediment geochemistry in the study area is used for evaluating the mineral resources over a large area based on the premise that the sediment chemistry and mineralogy reflect the bedrock and surface geology of the drainage catchments area upstream from the sample site (Cannon et al., 2004). Be in assumption about the value for the standard crustal abundance value for Au, 0.0035ppm, Co , 29 ppm Cu, 68ppm Pb, 13ppm Ag, 0.075ppm and Zn, 76 ppm (Fortescue, 1992, Parker 1967).

From the geochemical analysis result the maximum

navigated result value for gold is 0.97 ppm which is obtained from the analysed samples taken from river bank around which intensive artisanal miners pan. Geochemical analysis result displays the value for Au content ranges from 0.01 to 0.97 ppm with a mean value of 0.1372 ppm and two standard deviation value of 2(0.31128), the threshold value calculated from mean plus two standard deviation for gold is 0.7597 and standard crustal abundance for gold which is 0.003 ppm therefore the area shows negative potential for gold mineralization. The result from the geochemical analysis for Ag content range from 0.1 to 0.47 ppm with mean 0.19 ppm, two



standard deviation values of 0.2494 and the calculated threshold value is 0.439 and for Co value ranges from 3.6 to 43.7 ppm with mean 21.24 ppm, two standard deviation values of 2(12.932) and the calculated threshold value is 47.1049 respectively. From the geochemical analysis for Pb range from 4 to 26 ppm with mean values of 10.318 ppm, two standard deviation values of 2(7.4054) and the calculated threshold value is 25.1288 and the result from the geochemical analysis for Cu ranges from 8 to 74 ppm with mean value of 43.59 ppm, two standard deviation values of 2(26.6015) and the calculated threshold value is 96.78, the result from the geochemical analysis for Zn value ranges from 9 to 1744 ppm with mean 66.68



**Figure 1.12:** Histogram for gold concentration from the stream sediment

**Table 4:** Soil Geochemistry

SampleID	Au_ppm	Ag_ppm	Co_ppm	Cu_ppm	Fe_%	Zn_ppm	Ni_ppm	Pb_ppm
FNS1	0.12	0.3	11.7	52	2.96	95	29	9
FNS2	0.28	0.2	32.1	69	6.52	91	88	9
FNS3	0.21	0.2	16	52	3.86	85	37	11
FNS4	0.05	0.3	15.1	53	3.23	74	57	7
FNS5	0.06	0.2	18.1	36	4.01	64	58	9
FNS6	0.11	X	12.3	20	4.22	77	19	18
FNS7	0.16	0.2	26	95	7.92	80	47	10
FNS8	0.6	0.3	22.3	31	5.65	15	21	9
FNS9	0.7	0.1	19.8	68	4.94	102	35	11
FNS10	0.9	X	15.6	36	4.89	114	27	6
FNS11	0.4	0.1	19.4	52	5.26	20	28	18
FNS12	0.11	<0.1	19.6	61	4.66	9	73	8
FNS13	0.55	0.2	16.4	58	4.98	9	25	36
FNS14	0.78	0.1	30.7	89	5.97	12	94	13
FNS15	0.06	<0.1	22.3	115	6.27	30	33	6
FNS16	0.04	0.2	19.9	93	4.83	94	45	17
FNS17	0.02	0.3	16.4	84	4.66	63	18	13
FNS18	0.87	0.3	22.8	85	4.97	97	67	48
FNS19	0.05	<0.1	15.3	108	4.37	82	61	5
Max	0.9	0.3	32.1	115	7.92	114	94	48
Min	0.02	0.1	11.7	20	2.96	9	18	5
FNST22	0.05	21.9	68	6.21	0.1	25	25	144
Max	0.97	43.7	74	8.64	0.4	110	26	144
Min	0.01	3.6	8	1.12	0.1	8	4	9
2(Stdv)	0.6068	0.1484	10.775	52.21	2.28	69.826	45.064	21.08
Mean	0.3194	0.214	19.56	66.15	4.96	63.8	45.36	13.84
Threshold	0.9262	0.3624	30.33	118.36	7.24	133.62	90.424	34.9

ppm, two standard deviation values of 2(42.3543) and the calculated threshold value is 75.69.

From the stream sediment data it is concluded that the gold, zinc and lead shows enriched geochemical data analyses result the area with sufficient mineral resources because of the mineralized core samples have higher threshold value for gold, lead and zinc value. Whereas Co and Cu are depleted because the threshold value below the standard crustal abundance.

It can be seen from the histogram that the distribution of Au and base metal minerals in the study area does not conform to normal distribution. Therefore, it is reasonable to use the uniform abnormal threshold in the study area.

#### Soil Geochemistry result

The threshold for Au is 0.926 ppm and maximum is 0.9

ppm, for Pb threshold is 34 ppm whereas the maximum is 48 ppm, for Cu threshold is 118.3 ppm and maximum value is 115 ppm respectively, for Zn threshold value is 133.6 ppm and maximum value 114ppm respectively, for Ag threshold value is 0.3624 ppm and the threshold value for is 30.33 ppm respectively. Therefore it is concluded that in the study area from the soil data Au, Pb, Zn and Co shows enrichment where as Cu, Ag and Mn are depleted. Geochemical map shows high gold concentration in the streams near to metavolcanic rocks and slate phyllite rocks which are frequently intruded by quartz veins in central and southeastern part of the study area. The quaternary deposits also contain enormous gold concentration locating around the river banks. The gold concentration is low in the streams near to the granodioritic rock and in the limestone.

Cu & Zn concentration is high in the streams flowing through slate phyllitic and granodioritic rock as shown in the geochemical map. But both concentrations of Cu & Zn in streams flowing through felsic metavolcanic rocks ranges from low concentration in northern part of the study to high concentration in the central part of the study area.

Co concentration is very high in the streams flowing through slate phyllite rocks and river banks. But in the stream near to felsic metavolcanic rocks Co ranges from low concentration to high concentration as shown in the geochemical map.

Ni concentration is high in the stream sediment samples

engaged from the mafic metavolcanic rocks with low concentration in the streams of felsic metavolcanic and granodioritic rocks.

Mn concentration is moderate to high in streams flowing through both felsic and mafic metavolcanic rocks. There is low concentration of Mn for quaternary deposits (river area).

Geochemical map data illustrates element concentration ranges designated as high background and low background areas based on the average back ground value and anomalies values. The demarcated geochemical map showing concentration and distribution of gold and base metal for the samples is presented in map as follows:

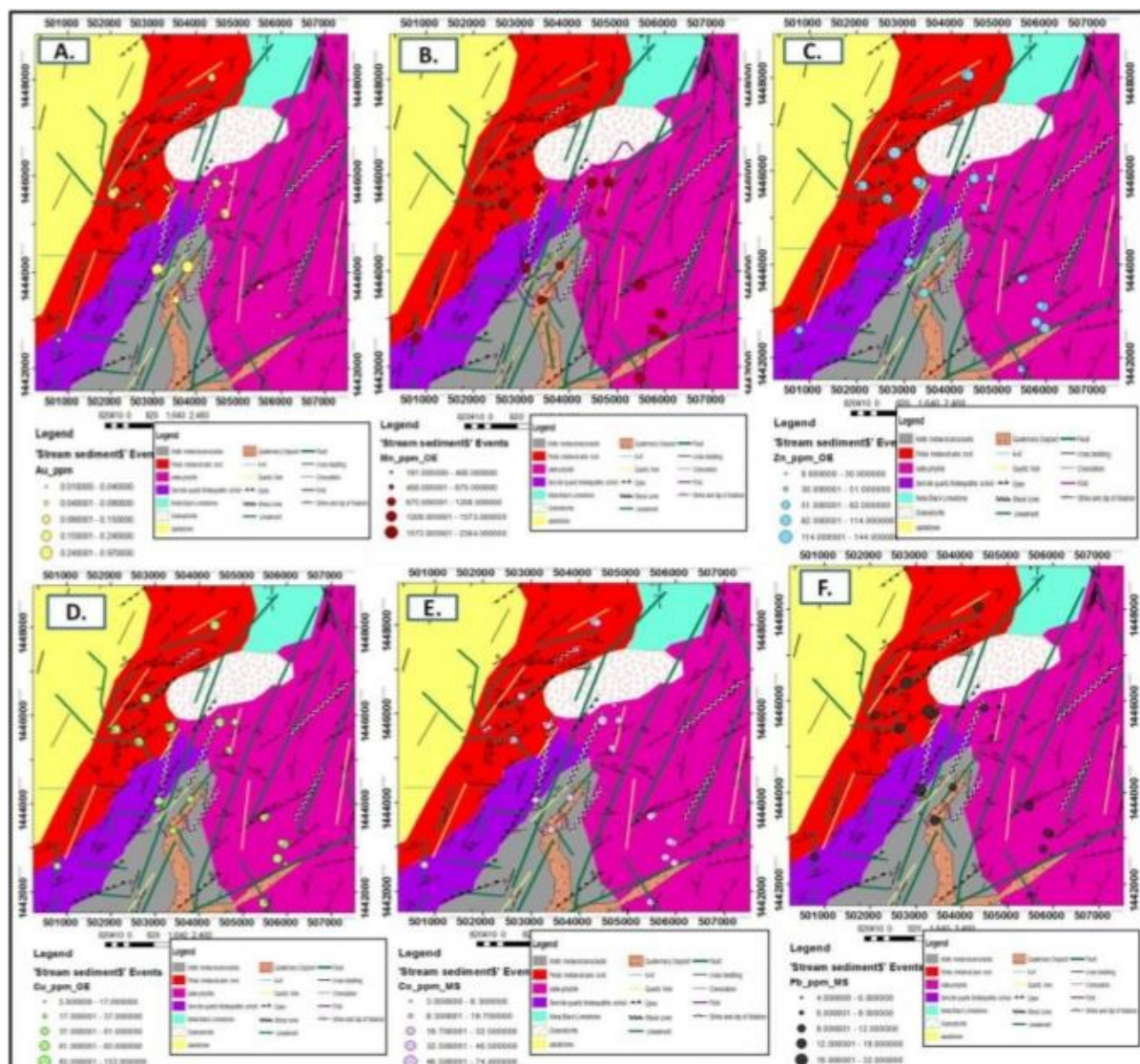


Figure 1.14: Geochemical map A. Au B. Mn C. Zn D. Cu E. Co F. Pb

The potential source rocks in the study area for base metal and gold mineralization is enriched by gold bearing quartz veins and associated sulfides. The association of gold with sulfides and alteration pattern is comparable with other similar deposits. Ore mineralizations recognized from ore petrography, geochemical survey results of stream sediment, and rock samples reveal several indications for the base metal and gold mineralization in the study

area. Though the concentration of the base metals and gold is not as such considerable, this may show that either the mineralization is too low or the high mobility of copper and zinc and high mechanical resistance of lead and gold for transportation may lead to the low concentration of the metals in the stream sediments. Soil geochemical results on the hand show relatively moderate concentration as compared to stream sediment sample



results that reveals low to moderate mineralization had been take place in the study area.

The assay results from sampling campaign and geological mapping indicate that there is high mineralization zone in the area. The most significant mineralization is Cu and Zn mineralization as shown by geochemical analyses result with low Au content in the felsic granitic rock. The copper mineralisation is associated with disseminated pyrite, chalcopyrite and sphalerite both in metasedimentary (sandstone to mudstone) and greenschist host rocks.

The alteration and mineralisation of the sampled rocks indicate that the area has been subjected to hydrothermal alteration. Confidence in the assay results is strengthened by the outcrops (intensity of sulphide-bearing quartz vein) and polished section scale mineralization where significant sulphide mineralization were observed. In addition, widespread alteration zone within the area is also support the promising mineralization occurrence.

## CONCLUSIONS

Geologically the area covered with low grade metamorphic rocks of Arabian Nubian shield type. The dominant lithology units are categorized into Meta volcanic and Meta sedimentary rocks (slate and phyllite) but there are also eminent limestone and sandstone which are intruded by granitic body. The meta volcanic and meta sedimentary rocks are frequently cut by quartz veins with different orientation measurements which the source for hydrothermally originated mineral deposits. on the result, nickel and cobalt are highly anomalous elements indicating the source for the mineralization controlled by different structures such as fractures and joints.

Artisanal miners especially for gold in the study area is regularly practiced by the communities especially in summer or rainy season the number of population increases. There are around 10,000 peoples who live by both farming and mining in the study area which may called as farming miners or mining farmers.

The ore petrography of study indicates presence of pyrite, pyrrhotite, chalcopyrite, galena and gold crystals under microscope. From the geochemical analysis result of rock, stream sediment and soil samples by conventional statics the threshold for gold, copper and zinc is enriched or positive anomaly indicating zone of high mineralization. Whereas cobalt and lead shows depleted mineralization.

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