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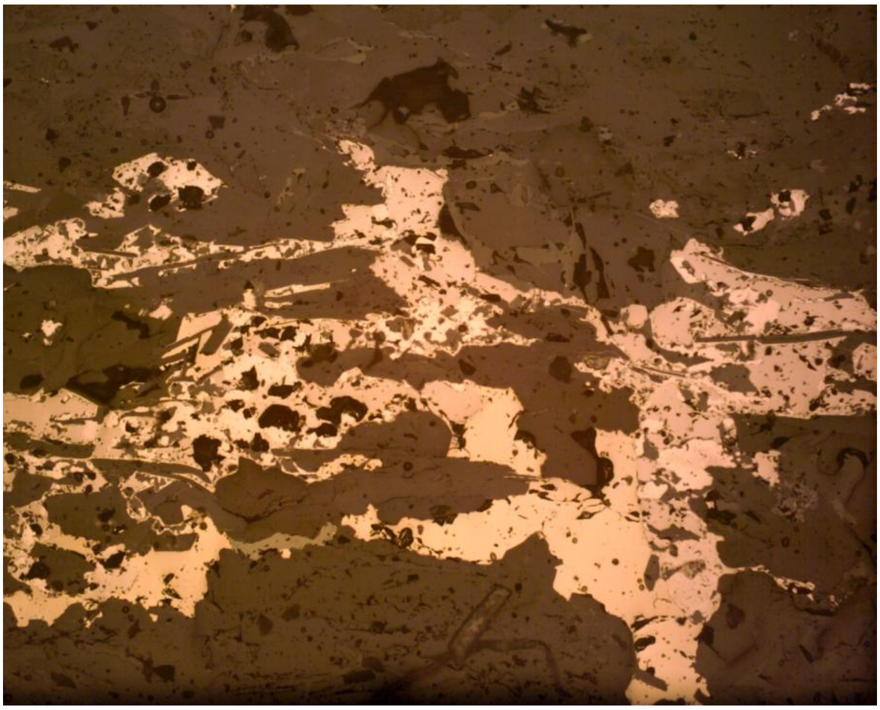
SCHOOL OF GRADUATE STUDIES SCHOOL OF

EARTH SCIENCES

GEOLOGY AND GENESIS OF SHEAR-ZONE-HOSTED GOLD-BASE METALS MINERALIZATION IN MAY HIBEY IN TIGRAY, NORTHERN ETHIOPIA



By Ashenafi Araya

A Thesis submitted to the School of* Earth Sciences *of Addis Ababa University In Partial Fulfillment of the Requirements for the Degree of Master of Science in Mineral Exploration

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Abstract

Gold-base metal deposit at the May Hibey in northern Tigray occur within the Greenstone Belt, consists of gold intergrown with quartz and/or sulphide mineral and iron oxides in deformed and structurally complicated rocks. The gold-base metal mineralization in the area is hosted almost exclusively within a series of disconnected bands and lenses of quartz veins. These units which are hosted by sequences of metasedimentary and metavolcanic rocks including sericite quartz schist, chlorite mica schist, gossaniferous quartzite, quartz feldspathic schists, quartz porphyry and basic volcanic. Two types of ores have been observed in the field: Primary ore and oxidized ore. Mineralogicaly, the primary ore is marked by gold and sulphides (pyrite, pyrrhotite, galena, sphalerite, pyrrhotite). The oxidized ore is dominated by gold and oxides (hematite, ilmenite, limonite and goethite) facies.

The main alteration processes is represented by silicification, seritization, chloritization, epidotization and sulphidation. Sulphidation involved pyrite, pyrrhotite, galena, sphalerite and chalcopyrite.

The ore bodies occur in the form of veins, vein-lets, intervening silicified rocks, stringers and stockworks.

The mineralization is defined by a complex paragenesis of gold in association with Cu-Pb-Zn- Fe-sulphides and iron oxide minerals.

Field geological observations and laboratory analyses shows that: (1) interbanding of ores of contrasted composition within the greenstone belts, (2) presence of cross-cuttings veins, (3) variation of ore mineralization with variation in meta-volcanic-sedimentary facies, (4) metamorphism of both the ores and the host rocks, (5) intense brittle-ductile shearing along the ore zone, and (6) wall rock alteration:

Suggest that gold and base metals mineralization were deposited by reaction of hydrothermal fluids with iron oxides and sulphides in the host during deformation and metamorphism.

Three recent discoveries of VMS-type Cu-Zn-Pb-Au-Ag at Terer, Terakimiti, Adi Bladie in northern Tigray, along with the May Hibey Au and base-metals discovery, indicate good potential for base and precious metal resources in northern Tigray region.

Keywords: Meta-sedimentary rocks, Primary ore, Sulphide minerals, Oxidized ore, ore minerals, Orebody, VMS

ACRONYMS

ADK	Aplitic dyke
BIMV	Basic to intermediate metavolcanic
BMV	Basic metavolcanic
FMV	Felsic metavolcanic
GS	Graphitic schist
IMV	Intermediate metavolcanic
MDK	Mafic dyke
QFS	Quartz Feldspar schist
QP	Quartz porphyry
QV	Quartz vein
QZT	Quartzite
TC	Talc chlorite schist
VMS	Vocanogenic massive sulphide

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1. Introduction

The need for natural resources in the development of a country is an undisputable issue. The resources are available either on the surface or subsurface of the Earth. Search for these resources whether mineral or water thus mainly targets the Earth's crust. The resources are the result of a particular or combination of geological processes and occur in a suitable geological condition. A variety of exploration methods such as geological, geochemical and geophysical either single or in combination are employed in search of these resources, keeping in view the geology of the area and type of resource. The basement or Precambrian terrains which are invariably metamorphosed, tectonically disturbed and affected by intrusive plutons are some of the potential targets for a variety of mineral deposits e.g. base metal sulphides, native gold, skarn, greisen, pegmatite etc). Use of metallogenic/ deposit genetic models has become an important step in outlining prospective areas regionally in the search of mineral resources. A preliminary investigation related to Paragenesis provides the information whether to undertake a detailed survey or not.

1.1 Location of the Study area

The May Hibey block is located in the Tigray National Regional State of Northern Ethiopia approximately at 50km southwest Shire which in turn found at about 294km from Mekelle city, Capital of the region. Mekelle is 783 km far from Addis

The Meli village, where the camp is currently situated, could be accessed from Shire town along a dry gravel paved road taking about two hours drive. The specific detail area is then located about 7km from Meli to the northwest and is generally accessible through dry weathered roads constructed by Ezana Mining Development (EMD).The study area is 2 km^2. The study area is considered to be moderately rugged with elevations ranging from 1050m-1300m.

Table 1: Geographic coordinates of the area

Corner Point	Easting	Northing
A	387500	1545800
B	389500	1545800
C	389500	1546800
D	387500	1546800

Location Map of the study area

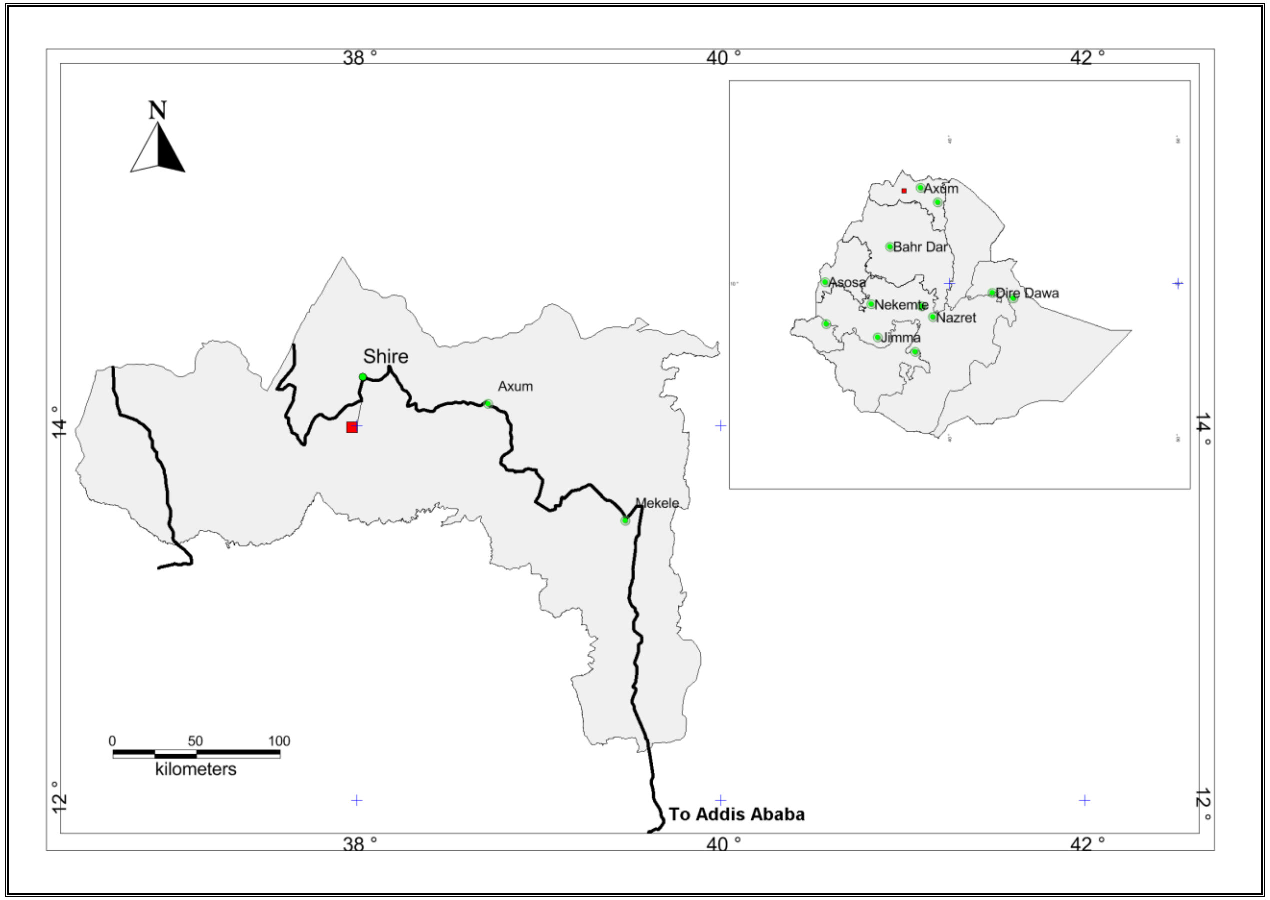


Figure 1 : Location of Map of the Study area

1.2 Topography, Elevation, Vegetation

The project area is located in an area of a relief ranging from 1,050 to 1,300 meters in elevation above sea level. Ground cover consists of various types of short grasses and small brush near drainages in the low terrain, to barren rock and brush at higher altitudes and steeper slopes. During the growing season much of the land is covered by short grass and maize.

1.3 Climate

The project area 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 with average rainfall of 800-1000 mm per annum. Mean daily temperatures range from a high of 32.5°C in March to a minimum of 13°C in January (EurGeol Dr. S. M. Archibald, 2011, NI 43-101 Technical Report). Most of the region is devoid of vegetation, with minor areas of shrub brush and trees most commonly located along tributaries and main drainages.

1.4 Physiography

The country consists predominately of a high central plateau and mountain region that ranges from 1050 to 1300 m in elevation above sea level, and tapers to lower elevation westward and southwestward.

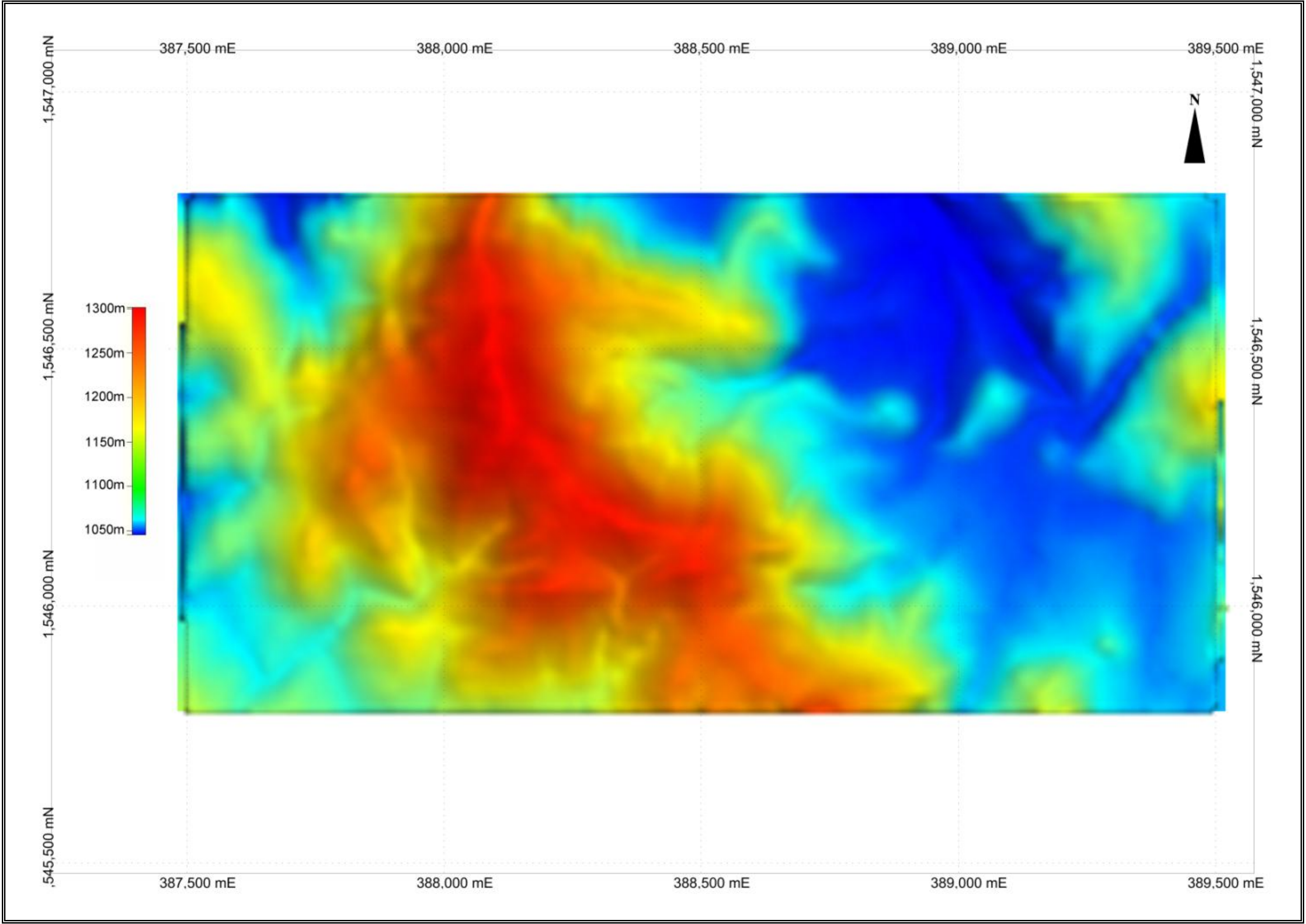


Figure 2: Physiography map of the study area

1.5 Objective of the Project

1.5.1 General Objective

- To study genesis of the hydrothermal deposition of ore minerals in May Hibey in Northern Ethiopia

1.5.2 Specific Objective

- Geological Mapping of the area
- deciphering the detailed geologic history of ore deposits and metamorphic events
- To study mineralization of the area
- To establish the relationship between lithologies and surface mineralization in the area
- To conduct detail quartz veins and vein lets inventory in the area
- To know equilibrium assemblage of mineral phases

1.6 Research Methodology and materials

1.6.1 Methodology

Traditional geological mapping method was generally applied to map the detail geology of the area. The methods followed to achieve the above objectives are comprised of different steps. Because the area is covered by Meta sediments and Meta volcanic rocks, most of the units were found elongated having the same trend of about NW-SE. Therefore, after classifying the detail area in to four quadrants (NE, SE, SW and NW), the first step was carried out on detail foliation trend mapping (Appendix A) in each and every lithological unit in closely spaced manner. Some structural information was then drawn from the foliation trend inventory of the area as discussed in the later sections of the report. Secondly, base map with 1:1000 scale was prepared and traverses were designed from north to south in each quadrant to potentially access the contacts of adjacent lithologies. The contacts between adjacent lithologies are then collected in few distance intervals by GPS which later transferred to the base map at field. Classification of lithological units was achieved by considering various criteria like compositional abundances, alteration minerals/features and surface silicification.

Detail quartz veins and vein lets inventory was carried out in the area. The larger quartz veins are mapped with their actual size and shape while the vein lets are inventoried by taking the GPS position of their end points. The soil analysis result of the area was entered in to GIS, processed and finally converted in to grid maps.

20 drill core samples were selected and sent to the Caglari (Italy) laboratory for preparation of polished section. Then the results were analyzed and interpreted using electron microscope and do the paragenesis of minerals. 10 drill core samples also were sent to Caglari laboratory (Italy) to identify the lithologic minerals.

At last, all these collected data layers were organized and processed by using Geographic Information System from which different interpretations, synthesis and conclusions could be drawn. The software that has been used for the interpretation are ArcGIS 9.3, MapInfo/Discover 12, 3DEM, Global Mapper11 and Micromine2011

1.6.2 Material used for the work

- Geological compass
- GPS
- Hand lens
- Geological hammer
- Measuring tape
- Sample bag
- Topomap
- GIS Software (ArcGIS 9.3, MapInfo/Discover, 3DEM, Global Mapper11 and Micromine2011)

2 Literature Review

2.1 EXPLORATION HISTORY

In 1970 and 1972, exploration activities (regional mineral prospecting works including soil sampling and rock sampling with detailed geological and geochemical surveys) in northern Ethiopia were carried out by the Ministry of Mines. Further exploration works did not take place from 1974 to 1993 due to the civil war. Work during 1994-95 included regional and follow-up geological and geochemical surveys in most areas, and detailed exploration that included geological mapping, trenching and geophysical survey in selected areas.

Ezana Mining plc (a local exploration company) subsequently conducted intensive exploration. This included stream sediment, soil and rock chip sampling from regional to detailed-scale work in Terer, Mai Hanse and other areas in 1996-1998.

Most exploration work was suspended from 1999 until 2001 during the border conflict with Eritrea. In 2001, Ezana started reverse-circulation (RC) drilling at Terer, based on encouraging prospecting results. The RC drilling operation intersected VMS and disseminated sulphide mineralisation that produced geochemical and geophysical anomalies within the felsic meta-volcanic rocks.

In 2004, an airborne electromagnetic geophysical survey (at a scale of 1:50,000) was conducted in the 341km^2 area, and outlined several magnetic anomalies. However, further exploration not done for VMS Cu-Zn-Au-Ag orebodies. Since March 2007, Beijing Donia Resources has established three JV companies with Ezana for conducting exploration in northern Ethiopia. This has included extensive exploration activities (incorporat- ing high-resolution QB image purchasing and interpretation), different scales of geological mapping, stream sediment sampling and irregular soil sampling, geophysical surveys of ground magnetic, IP and TEM, and trenching and test diamond drilling.

2.2 Gold and base metals in the Northern greenstone belt

MINERAL resource development is playing a key role in the development of the Ethiopian economy. In the past six years, the average growth in Ethiopian GDP has exceeded 10%.

To maintain this development, the government requires further exploration and development of the country’s resources. This Horn of Africa nation, which contains deposits of gold, silver, copper, platinum, potash and tantalum, exported US$281 million of gold in the fiscal year to July 7, 2010 (according to Gebre Egziabher Mekonen, head of Mineral Operations Department at the Ministry of Mines). Two companies are at the centre of these efforts: Ethiopian-born Saudi billionaire Sheikh Mohammed al-Amoudi's MIDROC Gold Mine plc; and Perth- based Nyota Minerals Ltd. Both companies plan large-scale operations, and investment in the country's mining industry has surged from less than US$100 million in 2003 to an accumulated US$1.3 billion in 2010. Mining has become the second-largest industry for inward investment after agriculture. There is "great potential" for discovering base metals (associated with gold and silver) in northern Ethiopia, according to Beijing Donia Resources Co, and its local partner, Ezana Mining plc. (Gebre Egziabher et al 2006)

2.3 METALLOGENETIC SETTING

Regionally, the northern Ethiopia area is part of Neo-Proterozoic (0.85-0.50Ga) Arabian-Nubian Shield, being composed of granitoid-greenstone belt terranes and crustal gneissic terranes. These lie on either side of Red Sea, and also underlie parts of Egypt, Sudan, Eritrea, Saudi Arabia, Yemen and Jordan.

The terranes represent the northern sector of the East African Orogen, with crustal rocks of similar age extending to southern Madagascar. The green schists represent normal volcanic sedimentary sequences in the Ethiopia. Currently, there are at least 60 VMS-type deposits presents in the Arabian-Nubian shield, excluding the newly discovered volcanogenic massive sulphide (VMS) deposits in northern Ethiopia. (EurGeol Dr. S. M. Archibald, 2011)

The Nubian Shield was divided into five tectonic terranes in northern Tigray (from west to east: the blocks of Shiraro, Adi Hageray, Adi Nebried, Chila and Adwa). They are characterised by distinct cycles of magmatic activities separated by ophiolite belts analogous to the situation in Arabia. VMS mineralisaition and orebodies were recently found in the Adi Nebried Block, where the metallogenic tectonic settings is very similar to those of Debarwa Cu-Zn deposits in Asmara VMS-type metallogenic zones, and is the SW extension part of the Asmara zone.

2.4 VMS DISCOVERIES

At least three VMS-type Cu-Zn-Au-Ag deposits have been discovered in the northern Ethiopia area. This indicates, according to Beijing Donia, "much potential for base and precious metals resources in this region". Terer Cu-Zn-Au-Ag deposit Located 57km northeast of Shire in northern Tigray (near the border between Ethiopia and Eritrea), the deposit consists of two VMS orebodies: Adi Ekele and Mai Argab. A pre-feasibility study is ongoing but the estimated total resource of equivalent copper (Cu+Zn+Au+Ag) is about 100,000t. Terakimti Cu-Zn-Au-Ag deposit Located 29km northeast of Shire in northern Tigray, on the western side of the Terer deposit, the Terakimti VMS mineralisation is parallel to the Terer zone. The surface trenching has indicated there is about 3t of gossan gold, and test drilling has confirmed that the primary VMS zone is 800m along strike length, with an average thickness of 12m and the dip extends to 150m. Further drilling has been planned after the ground gravity and TM surveys are completed to enlarge the base and precious metals resources in Terakimti area.Adi Bladie Cu deposit Located 25km northwest of Shire in northern Tigray, this is the SW extension of the Terakimti VMS mineralisation. The test diamond drilling has confirmed that the VMS copper orebody is more than 300m long along strike, with an average thickness of 8m and 1.8% Cu grade. The on-going exploration is to enlarge the metal resource of Adi Bladie deposit.

Precambrian metamorphic and associated intrusive igneous rocks make up 25% of the country's landmass, which are exposed in the northern, western, southern and eastern parts of the country. They are dominantly north-trending linear belts of low-grade metavolcano-sedimentary rocks and mafic-ultramafic rocks, sandwiched between medium- to high-grade gneisses and migmatites. They occupy the interface between the Mozambique Belt (MB) in the south and the Arabian-Nubian Shield (ANS) to the north. Stern (1994) coined the term East African Orogen (EAO) to encompass both the MB and ANS. EAO represent a plate tectonic cycle spanning a time-period of 350 Ma, beginning by about 900 Ma with rifting and continental break-up and ending by about 550 Ma subsequent to a continent-to- continent convergence between East and West Gondwana (Vail, 1985; Berhe, 1990; Abdelsalam and Stern, 1996;).

The high-grade gneisses and migmatites are referred to as Lower Complex is part of the Mozambique Orogenic Belt and generally consist of amphibolites facies (locally granulite facies) orthogenesis, paragneisses, migmatites, granulite and amphibolite with bands of marble. The low-grade volcano-sedimentary rocks with associated mafic to felsic intrusives, which is referred to as Upper Complex, on the other hand, belongs to the Pan-African Arabian-Nubian Shield. These lithotectonic terranes are juxtaposed along north-south sheared thrust contacts, which are marked by mafic-ultramafic rocks (arc-like ophiolite sequences), that are overprinted by post accretionary structures including north-trending shortening zones and major northwest-trending sinistral and minor northeast-trending dextral strike-slip faults. Most ages obtain from the Precambrian rocks of Ethiopia range between 900 and 500 Ma with exception of older Archean and Mesoproterozoic ages obtained from some of the rock units in southern and eastern part of the country.

The Precambrian rocks have received attention in the current exploration activity for base and precious metals. The belts of mafic-ultramafic rocks and major shear zones bounding the two contrasting stratigraphic complexes are potential targets for gold, base metals, nickel, platinum and other mineralization.

The northern Ethiopian Precambrian rocks are characterized by the occurrence of low-grade volcanic, volcano-sedimentary, mafic and ultramafic rocks of ophiolitic character, and plutonic rocks of typical Arabian-Nubian Shield assemblage. The tectonics of the Precambrian of northern Ethiopia is characterized by thrust and fold belt type tectonics with a predominant northwest directed sense of displacement. Felsic plutonism of syntectonic, late- and post-tectonic granitoid range in age from 800 to 600 Ma is common in Precambrian of northern Ethiopia (Tadesse, 1998; Tadesse et al., 1999; Asrat et al., 2001).

Beyth, 1972; Kazmin, 1972 and Mengesha et al., 1996 have grouped the Precambrian rocks of northern Ethiopia into: - (i) Tsaliet Group, (ii) Tambien Group, (iii) Didikama Formation, and (iv) Shiraro Formation (Table 3.). However, geological mapping and regional compilation of the Axum sheet by the GSE (Tadesse, 1997) showed that part of what was considered as the Tsaliet Group, which consists of widespread low-grade metavolcano-sedimentary rocks are divided into four tectono-stratigraphic blocks (Adi Hageray, Adi Nebrid, Chila, and Adwa; Table 2). These tectono-stratigraphic blocks are separated by mafic-ultramafic belts and characterized by the occurrence of lithological units having different structural, metamorphic and magmatic history.

Integration of geochemical data with field, lithological and structural studies demonstrate the occurrence of east to west accreted intra-oceanic arc sequences within the Precambrian of northern Ethiopia, which are probably formed in a supra subduction zone tectonic setting, and were conflated by accretion and superimposed strike-slip deformation (Tadesse, et al., 1999).

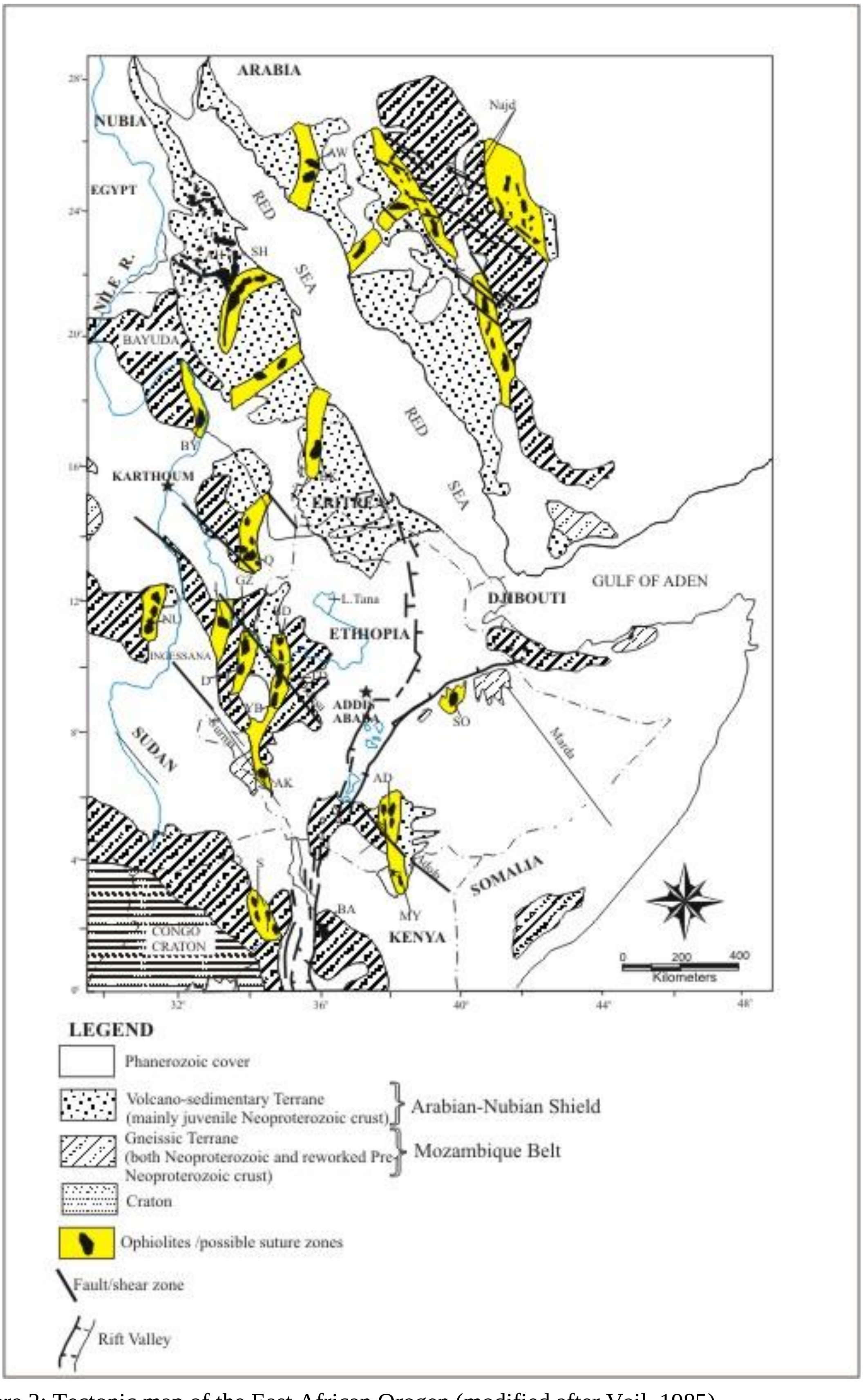


Figure 3: Tectonic map of the East African Orogen (modified after Vail, 1985).

Ophiolites: AD, Adola; AK, Akobo; AH, Allaqi-Heini; AW, Jebel al Wask; BA, Baragoi; BD, Baruda; BK, Barka; BU, Bir Umq; BY, Bayuda; D, Dul; G, Gebel Gerf; GZ, Gizen; I, Ingessana; MY, Moyale; NU, Nubia; Q, Qala al Nahal; S, Sekerr; SH, Sol Hamed; SO, Soka; TD, Tulu Dimtu; YB, Yubdo.

Table 2: Litho-stratigraphy of the Precambrian of northern Ethiopia

<table>
<tr><th colspan="3">Kazmin, 1973; Mengesha et al., 1996 and references therein</th><th colspan="2">Tarekegn (1997)</th></tr>
<tr><td rowspan="7">Late Proterozoic Rocks</td><td rowspan="4">Tsaliet Group</td><td rowspan="4">Metavolcanics ranging in composition from basalts to dacites and rhyolites and associated metasediments</td><td>Adi Hageray Block</td><td>Metasediments including undifferentiated, water-lain tuffaceous metasediments, greywacke, conglomerate, slate, impure marble and calcareous siltstone. It unconformably underlies the Shiraro block and to the east bounded by Zager mafic-ultramafic belt with the Adi Nebrid block</td></tr>
<tr><td>Adi Nebrid Block</td><td>A thick, broadly southeast-dipping but locally upright folded sequence of basic to intermediate Metavolcanics, pyroclastics and associated immature volcanoclastic metasediments</td></tr>
<tr><td>Chila Block</td><td>This block is bounded to the west by the central steep zone with Adi Nebrid and to the east by Daro Tekli mafic-ultramafic belt with Adwa blocks. It is composed of fine grained metasedimentary rocks including phyllite, pelitic schist and recrystallized chert. Lenses of graphite schist are common</td></tr>
<tr><td>Adwa Block</td><td>Comprises a NW-dipping succession of porphyritic basalt and basaltic andesites, agglomerates, graded bedded and cross laminated greywacke associated with water-lain tuffaceous phyllite, conglomerate, minor chert and calcareous schists. Rhyolitic and dacitic layers are also present but are insignificant in volume. It unconformably overlies by Tambien Group</td></tr>
<tr><td>Tambien Group</td><td>Slate and limestone with interbedded phyllite. It is divided into Arequa Formation (lower unit) consists of Werei Slate, Assem Limestone and Tsedia Slate, from bottom to top, and Mai Kental Limestone (upper unit) consists of black, massive, fine grained limestone partly algal and oolitic</td><td rowspan="2">Mai Kental Block</td><td rowspan="2">Consists of black, massive, fine grained limestone partly algal and oolitic alternating with gray, black or variegated slates</td></tr>
<tr><td>Didikama Formation</td><td>Dolomite alternating with gray, black or variegated slates</td></tr>
<tr><td>Shiraro Formation</td><td>Sandstone and conglomerate consisting of slate, phyllite and granite clasts. It overlies all the above lithologies on angular unconformity</td><td>Shiraro Block</td><td>Dominated by weakly metamorphosed and deformed, post-accretionary sandstone and conglomerate</td></tr>
</table>

2.5.1 Geology of the study area

The study area lies on the northern Ethiopia particularly of Axum sheet has subdivided in to six tectonostratigraphic sequences among which the Adi Nebrid block become an interest of discussion. The study area is spatially located within the Adi Nebrid stratigraphic block of the Axum sheet (Figure 5) which in turn is located within the Nakfa tectonostratigraphic sequence of the Eritrean basement. Therefore, it is important to closely look in to the lithological and structural settings of this block (Adi Nebrid block) for it could extend to further south and mirror the geology of study area. According to (Tadesse et al., 1999) and Howe (2009 &2011) the Adi Nebrid block has lithologicaly comprised of thick southeast dipping basic to intermediate metavolcanics, pyroclastic rocks and immature volcanoclastic sediments. The volcanoclastic rocks of the Adi Nebrid block are intruded by a series of post and pre tectonic granites, dykes, basic/ultrabasic intrusive and quartz veins.

2.6 Structures of northern Ethiopia with reference to ANS

The general geological history and geological setting of the region has been summarized in the above section. It is quite understandable that accretionary tectonics followed by metamorphism, intrusions, deposition and uplifting has become the main event which controlled the structural evolution of the region. Moreover, previous studies on lithostructural synthesis using modern image interpretation techniques conducted on the Eritrean basement had revealed the presence of unique structural corridors, the Bisha structural trend and the Debarwa structural trend. Most of the VMS and gold occurrence areas in Eritrea have been greatly controlled by these structural trends mainly of the Debarwa structural trend. The Debarwa structural trend has become the prime interest of this section for its direct consequence to the geology of northern Ethiopian especially of the Axum sheet. This structural trend (Debarwa) has started from the Nakfa terrane of the Eritrean basement and propagates further down to the corresponding Adi Nebrid block of the Axum sheet Howe (2009). In addition, the Adi Nebrid block has structurally characterized by the presence of series of anticlines and synclines, wide spread shear zone trending NE-SW with sinistral slip movement and thrusting with NW vergence in contact with Zager basic/ultrabasic intrusive (Tadesse et al.,1999). Generally, deformation in the region is presumed to be complex/polyphase with five phases of deformation and several post deformation granitic intrusive (Howe, 2009 &2011).

2.6.1 Structures of the May Hibey Block

The satellite image interpretation by Howe (2011) has divided the May Hibey block in the three lithostructural domains. The study has also mapped faults, fractures and foliations in the area and concluded that the May Hibey block is situated to the east of the Debarwa structural trend. However, the study also suggested the presence of Debarwa structural trend in the May Hibey block due to the reason that Debarwa structural trend is not a single structure rather composite structure. In addition, the present report gave more emphasis on structures mapped on the Adi Nebrid block of the Axum sheet. The May Hibey block is situated on the eastern limb of a relatively longer anticlinal structure with axis trending NE-SW. This structure is lithologicaly covered by Meta-agglomerates, intermediate metavolcanics sericite-quartz-feldsphatic schist which agreed with most of the lithologies mapped in May Hibey. The Maychew area, northern extension of May Hibey block, and even further north to Enda Bernabas block are all situated to the eastern side of this anticlinal structure.

3. Local Geology

3.1 Lithological Units of the detail area

3.1.1 Graphitic Quartzite (Gqtz)

Lenses of graphitic quartzites are exposed in the central parts of the mapped area. It is mostly found outcropped at ridges and hill sides and composed of mainly of quartz and other accessory iron minerals (gossaniferous) like hematite and magnetite forming thin reddish and dark layers respectively. The rock is generally heavy and has dark weathered and reddish-white fresh color. The location/placement of all the lenses of graphitic quartzites is presumed to be controlled by faults with strike slip components as seen in (Figure 4).

3.1.2 Basic Meta Volcanics (BV1, BV2, BV3)

The basic Meta volcanic unit in the area is subdivided and mapped in to three different units (BV1, BV2 and BV3) due to varied accessory minerals and alteration effects. Mineralogicaly, they all are composed entirely of chlorite, muscovite and some dark minerals like biotite. The basic Meta volcanic (BV1) is exclusively rich in accessory mineral, magnetite, which is rarely/not seen in other basic volcanic units and hence mapped as a separate unit. The basic Meta volcanic (BV2) is differentiated due to its alteration effects seen within and at its contacts with adjacent units. The unit generally looked backed, burnt and altered especially at its contacts having dark color. This unit seems affected by normal faulting followed by strike slip movements. The basic Meta volcanic (BV3) differs from the rest for its surface silicification. Numerous very thin quartz stringers are clearly seen on the surface of the rock and fractures oriented at NE are found mostly filled with relatively thicker quartz veins. Hence, the units are mapped separately as seen in (Figure 4).

3.1.3 Sericite quartz schist (Sqsc)

The unit has relatively larger coverage in the central part of the mapped area and found trending in NW-SE direction. It is composed mainly of quartz and sericite and found hosting most of the quartz veins and vein lets occurrence of the mapped area. The fresh rock is massive, welded and jointed with whitish fresh and unconsolidated, foliated reddish weathered color. Currently local miners are densely mining this unit since it has intruded by gold hosting veins of various thicknesses trending in N-S and NNE directions. The unit also seemed affected along its strike by faulting with strike slip component as seen in (Figure 4).

3.1.4 Quartz feldspathic schist

The unit is found trending the same with sericite quartz schist and mostly mapped at the ridge slopes in the area. It is composed mostly of feldspar and quartz with whitish fresh and whitish-reddish weathered (kaolinized) color. The unit is also found intimately mixed with other units like chlorite schist and mica schist, mapped in the area. The fresh rock is massive and highly jointed forming cliffs in the area and hosted many vein lets as shown (Figure 4).

3.1.5. Graphitic schist (Gsc)

The unit is mapped in the southern half of the area and never found in the northeastern part of the mapped area. It is highly foliated graphite with well developed schistocity and mostly found in gradational contact with sericite quartz schist and quartzite. It is very massive, jointed and darkish when fresh and very friable grayish when weathered. The mapped unit is trending at NW-SE direction similar with sericite quartz schist but there is no much quartz veins and vein lets intruding this unit. In contrast, most of the veins running through sericite quartz schist are seen terminating at the contact with graphite schist. The unit has seemed to be displaced by faulting with strike slip component as seen on the map in (Figure 4).

It is highly foliated with well developed fractures and undulating/wavy nature, reflecting thrusting in the area.

3.1.6. Chlorite mica schist (Chl-Msc)

Two lenses of chlorite mica schist, seemed structurally controlled, are mapped in the central part of the detail area. It is composed mainly of mica and chlorite and found in contact with sericte quartz schist and graphitic schist. It has less foliated greenish fresh and reddish weathered colors. The unit hosted less quartz veins and less local miners are seen mining at this unit as compared to sericite quartz schist.

3.1.7. Intermediate Meta volcanic (Imv)

The unit is mapped in the northeastern corner of the detail area and found in contact with quartz feldspathic schist and basic Meta volcanic (Bv1). It is mainly composed of muscovite mica, chlorite, quartz and some plagioclase minerals. It is light to dark greenish grey, fine to medium grained and moderately foliated.

3.1.8. Quartz porphyry (Qp and CQp)

Quartz porphyry in the area is subdivided and mapped in to two different units: quartz porphyry (Qp) and coarser quartz porphyry (CQp). Compositionally, both of them are composed mainly of quartz with feldspathic groundmass. Quartz porphyry (Qp) is mapped in the northern end, central and thin layers in the western part of the detail area. It consists of rounded to sub rounded clasts of blue quartz eyes with size ranging from 1-10mm. In contrast, the coarser quartz porphyry (CQp) is found in the northeastern part in contact with basic Meta volcanic and quartz feldspathic schist. In some places the weathered CQp are seen forming kaolinized domes intruded by quartz veins of varied directions. In CQp the quartz eyes are rotated, deformed and coarser in size ranging from few mm to 3cm. The quartz clasts are stretched and elongated along the foliation plane and showed developed tails as shear sense indicators like beta and delta structures with mostly showing dextral shear sense.

3.1.9. Porphyritic intermediate Meta volcaniclast (QImvc)

It is mapped in the northeastern and northwestern parts of the detail area and found exposed mostly at river cut exposures. The unit is intermediate Meta volcaniclast (as described above) with clasts of quartz seen on the groundmass. The quartz clasts are rounded to sub rounded in shape and size ranging from 1-5mm.

3.1.10. Quartzite (Qzt)

The unit is found in the southern and southwestern parts and never mapped in the northern part of the mapped area. It is mostly composed of quartz and some feldspar minerals and generally massive, less foliated and fine to medium grained.

3.1.11. Mixed schist (Msc)

The unit is named mixed schist because it is an intimate mixture of different schists including chlorite schist, mica schist, sericite quartz schist and quartz feldspathic schist. It is generally weathered, friable, fine grained and varied colors like white, red, grey etc.

3.1.12. Intrusive

It is composed mainly of quartz and feldspar with minor biotite and muscovite. The unit is mapped in the northwestern corner of the detail area.

3.1.13. Basic dykes

Basic dykes are mapped in the southern part of the area. They are found detached along the strike direction and have thickness of about a meter and orientation ranging from 090^{0-}-140^{0}

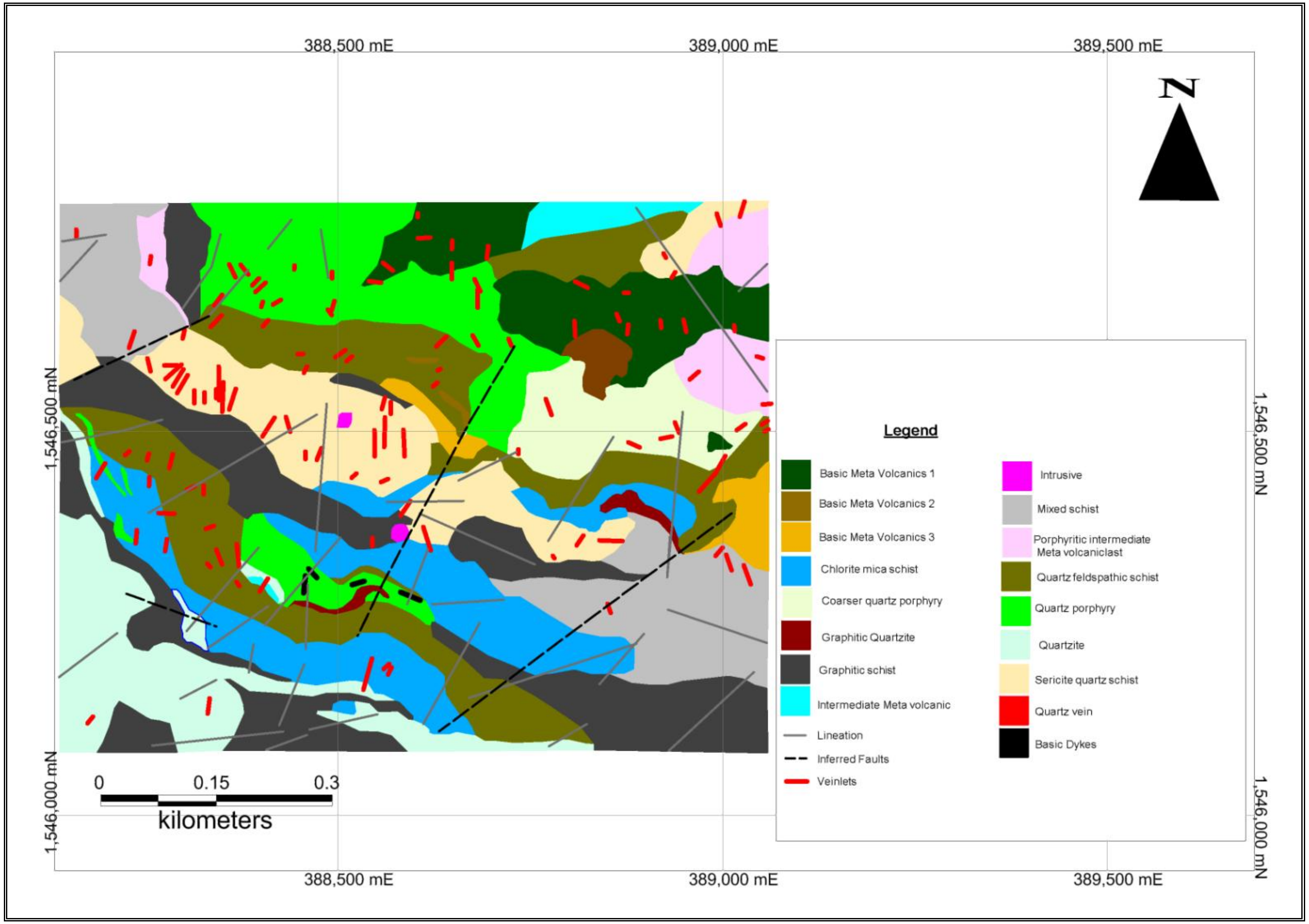
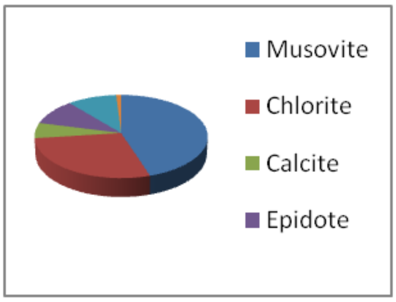


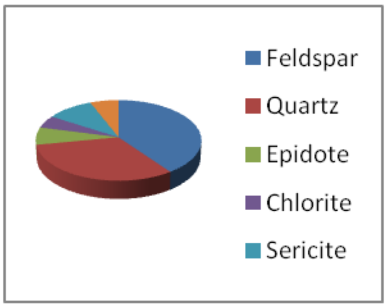
Figure 4: Detail Lithological map of the study area

3.2 Petrographic Microscopy

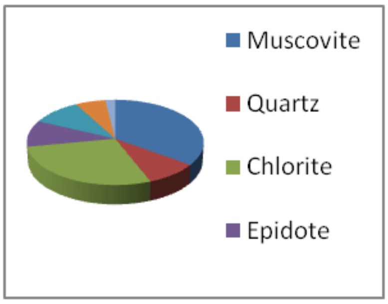
10 drill core samples were sent to the Caglari (Italy) lab to identify the lithogic minerals. The main lithlogy units are Chlorite -Miscovite Schist, Sericite - Quartz Schist, Quartz-Chlorite -*Muscovite* Schist, Quartz -*Feldspar* Schist, Chlorite-Biotite-Muscovite Schist, Chlorite-Biotite-Quartz –Sericite- Schist, Talc Schist and Quartzite. See also Annex C for the tables of thin section samples. (See also Annex C for modal percentage distribution)



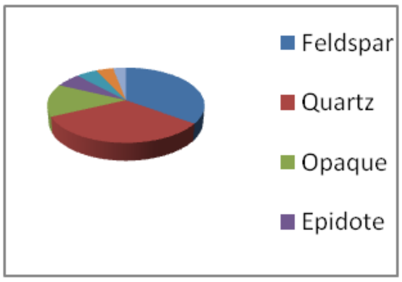
A) Chlorite -Miscovite Schist



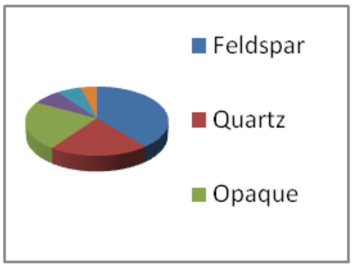
B) Sericite - Quartz Schist



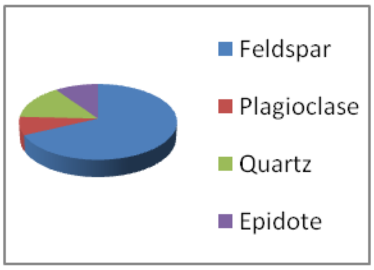
C) Quartz-Chlorite -*Muscovite* Schist



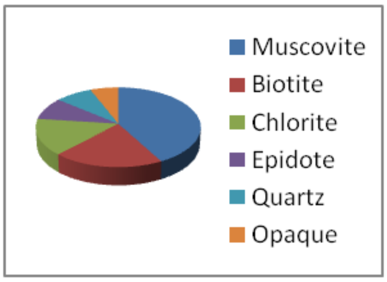
D) Quartz -*Feldspar* Schist



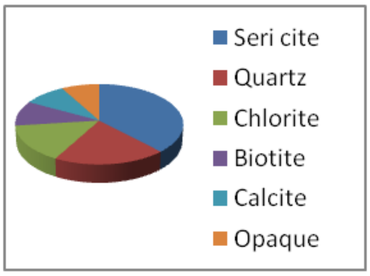
E) Quartz-Feldspar Schist



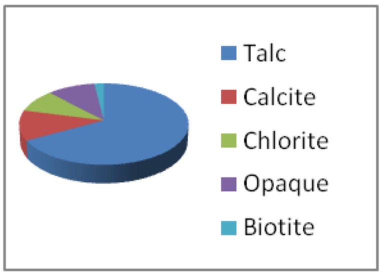
F) Quartz-Feldspar Schist



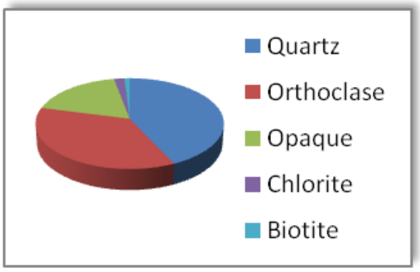
G) Chlorite-Biotite-Muscovite Schist



H) Chlorite-Biotite- Quartz –Sericite- Schist



I) Talc Schist



J) Quartzite

Figure 5: Thin Section Analysis

3.3 Structures of the study area

3.3.1. Foliation, shearing and thrusting

Structural study of the area was started by mapping the foliation trace of the whole area in a very closely spaced manner. As a result two prominent ranges of foliation trends have observed through the area. These are foliations striking 040^0-080^0 and 080^0-120^0 among which the former foliation trend constitutes the majority of the foliation in the area and found sandwiching the later foliation trend. This study has therefore noticed the presence of narrow shear zone with dextral sense of movement trending NW-SE. The Veins and quartz porphyry with rotated quartz crystals were also local observations depicting the presence of shearing in the area as shown in (Figure 8a &8b).

Even though clear exposures were not observed there are some indicators showing the presence of thrusting in the area. For example, in the western part of the area lithologies are found repeatedly stacked together having wavy or undulating nature that could be explained in terms of thrusting. In addition some shear joints with sense of thrusting (according to Anderson's fault principle) were seen in the area (Figure 9).

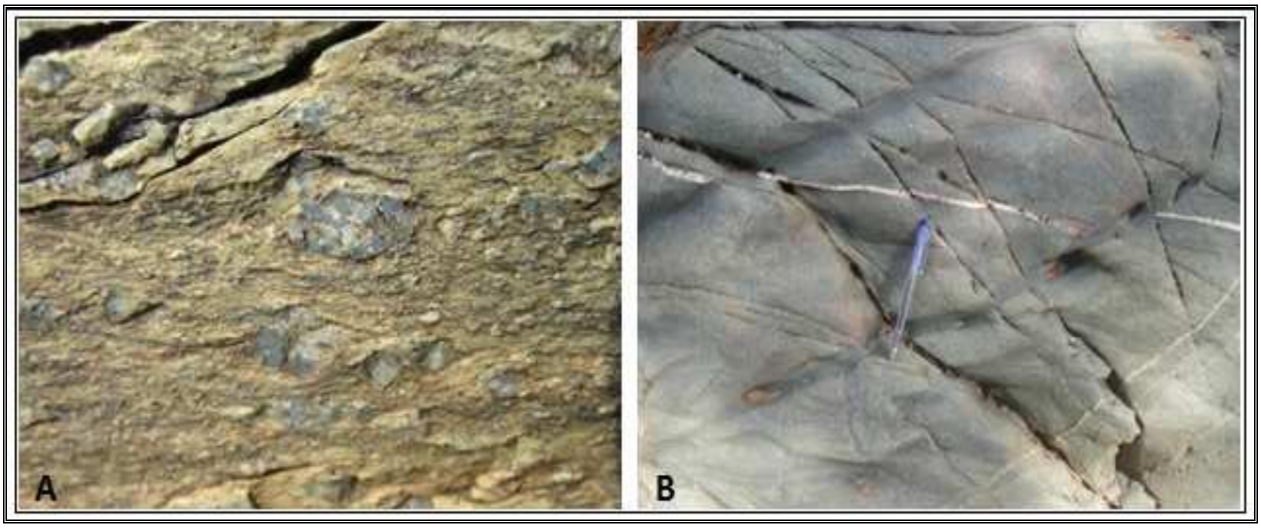


Figure 6: A) Sheared quartz veins with tails and B) Thin quartz veins displaced by narrow shear zones

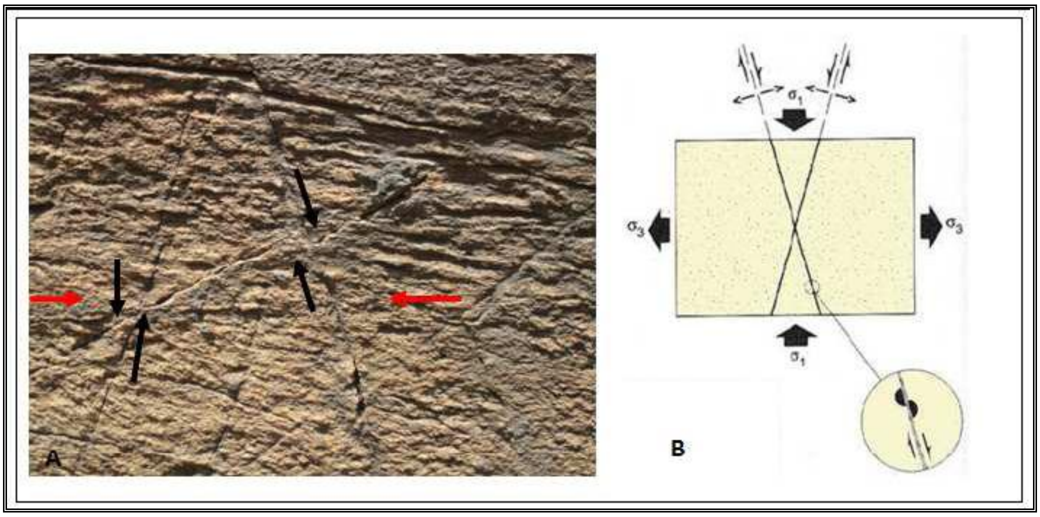


Figure 7: A) Shear joints with sense of thrusting B) Anderson's fault model

The study area has made ground truthing and found that most of what was called faults correspond to ridges, valleys, rivers, creeks and hence digitized and adopted as lineaments rather than faults in this study. Furthermore, movements with strike slip component were also seen manifested on veins, fractures and basic dykes found in the area. Lineation and budin structures also observed in the field which are indicators of shear zone. Generally the structural situation of the area was presented in (Figure 10) below.

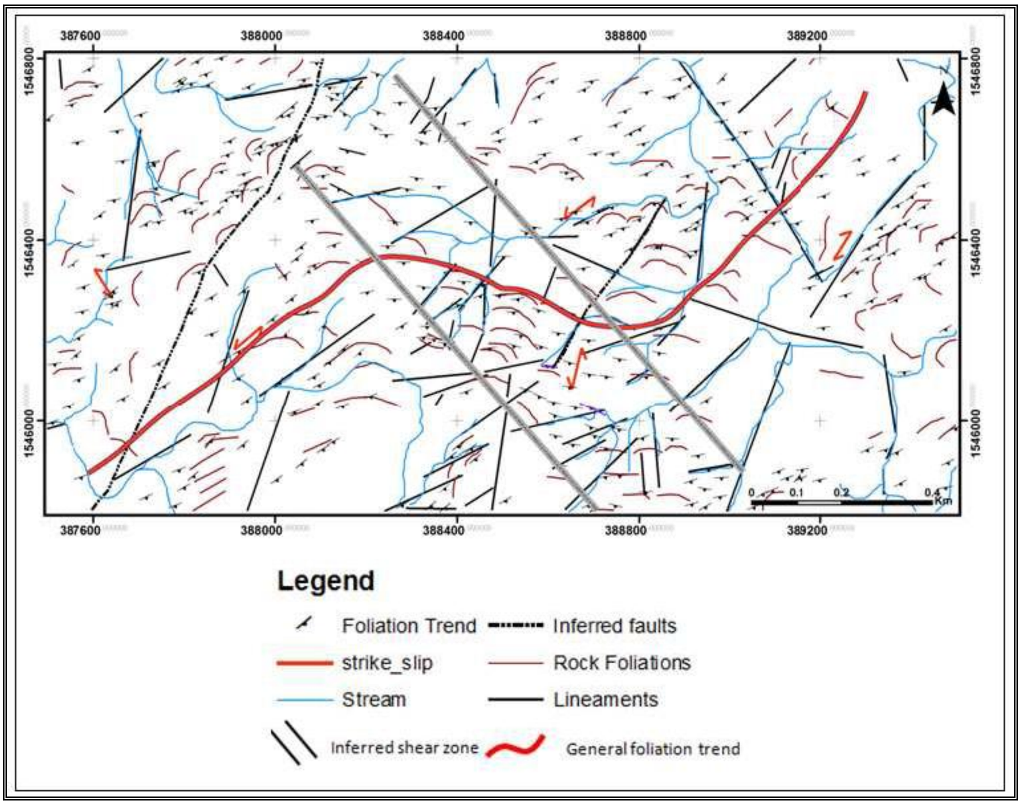


Figure 8: Structural map of the study area

3.3.2. Fractures and Joints

Fractures are also common structural features in the area with varied thickness and strike length. Some of the lithologies affected by fractures include; sericite quartz schist, quartz feldsphatic schist and quartz porphyry. Fractures are also characterized by the presence or absence of infilling with quartz veins. Most fractures with longer strike length and wider thickness are mainly filled with quartz veins of barren mineralization except fractures. The Azimuthal distribution of the inventoried fractures (Figure 10) has indicated two prominent fracture orientations namely; 010^0-020^0 and 310^0-320^0 but there are also N-S striking fractures as well. Fractures trending E-W are seemed to older as compared to others.

3.3.3. Quartz veins

Quartz veins and veinlets of the area are exhaustively collected with various parameters including strike/dip, thickness, strike length and associated mineralization. Accordingly, the collected quartz veins are grouped into three categories based on their exposed thickness. These are veins with thickness less than 0.3cm, 0.3cm-1m and greater than 1meter. Those with thickness greater than 1meter are indicated on the map with their actual size and shape whereas those less than a meter (vein lets) are represented by lines. The azimuthal distribution (Figure 10) has showed the presence of prominent trends including 000^0-020^0, 030^0-040^0, 310^0 -320^0 and some with along the foliation and E-W directions. As clearly seen from the azimuthal distributions of both veins and fractures there exist good agreement especially at N-S, NNE and NW trends implying that most of these veins were conduited through the pre-existing relatively younger fractures. Field observations on vein cross-cuttings have showed that veins trending ENE (075^0) and E-W are relatively older as compared to veins tending at NNE (025^0) and NNW (320^0) directions.

Some of the lithologic units hosting the quartz veins and vein lets include: sericite quartz schist, chlorite mica schist, gossaniferous quartzite, quartz feldspathic schist, quartz porphyry and basic volcanic.

Generally, field observations showed that veins trending at N-S and NNE directions are presumed to be mineralized as compared to others like E-W and NW trending veins. Quartz veins with thickness greater than a meter (Figure 10) are not generally mineralized and not seen being mined by local miners in the area, the reason for this is the quartz vein which is greater than a meter and thin vein and vein lets are not the same generation. In contrast, very thin veins and veinlets are currently being mined by local miners and their distribution seemed controlled by lithologies with most favored by sericite quartz schist, chlorite mica schist, basic volcanic (Bv3) and quartzite as seen in the detail geological map of the study area. (Figure 4)

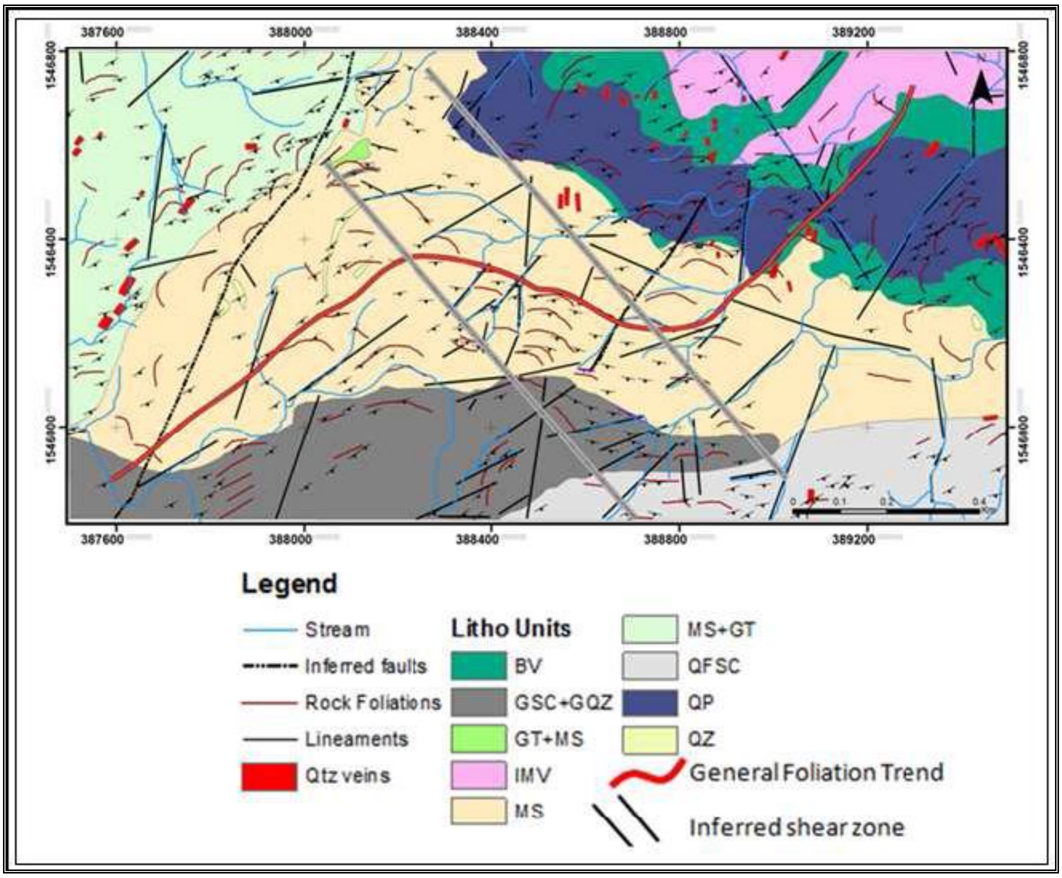


Figure 9: Distribution of quartz veins thicker than a meter over the lithologies

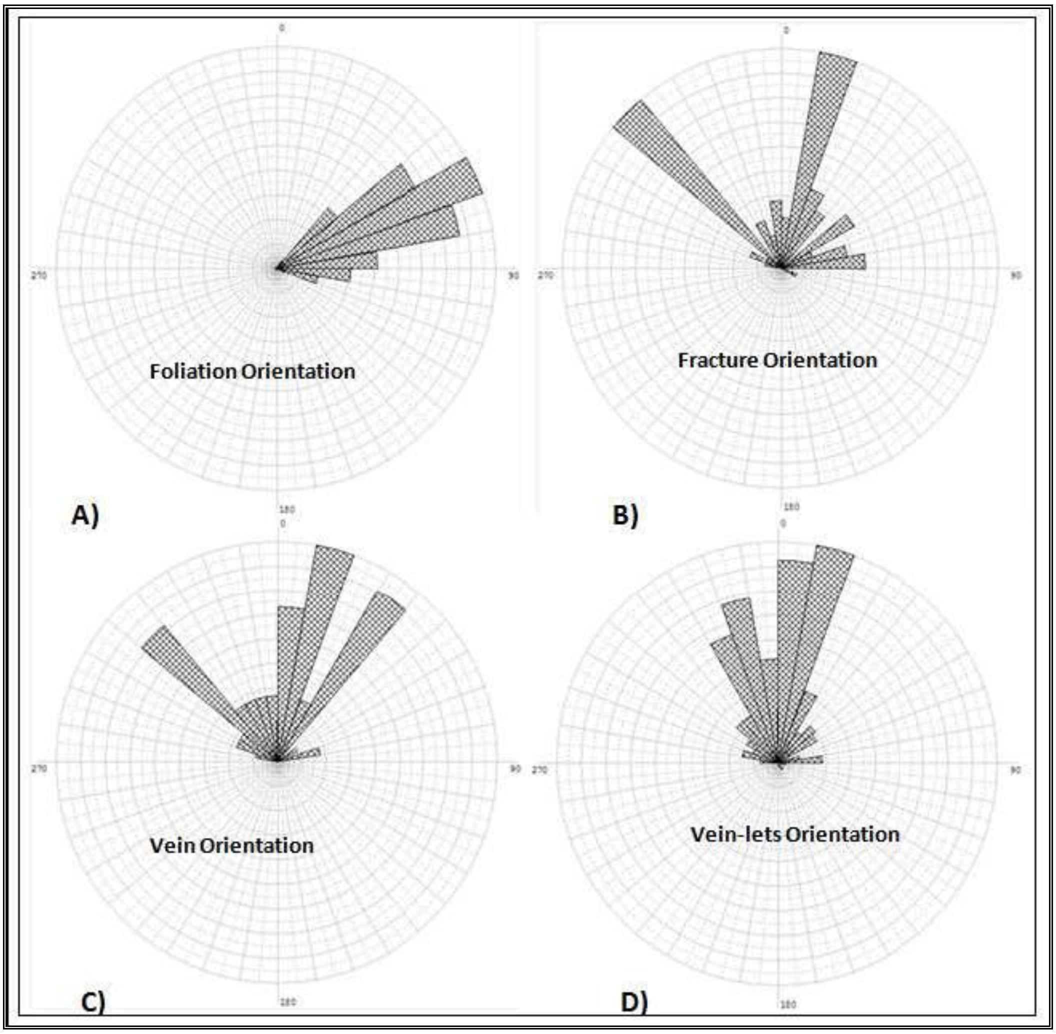


Figure 10: Azimuthal distribution of A) Foliation orientation B) Fracture orientation C) Quartz vein orientation D) Veinlets orientation

The above figure showed that good agreement exists between fracture and vein orientations at some specific directions like 010^0-020^0 and 040^0-050^0. Most of the vein lets are trending at N-NNE and N-NNW among which the former is mostly associated with gold mineralization and seen being densely mined by the local miners in the area. Majority of the vein lets inventoried was taken from the sericite quartz schist where trenching and drillings are currently on going.

4. Inter-relationship between lithologies and mineralization

4.1. Gold

Grid soil sampling of 200m by 25m was collected from B horizon and was carried in the area and analyzed for elements including Au, Pb, Cu, Zn, Co and Ni. The tershold value of the area was calculated using statistical method using the mean of the population and using 2SD. (i.e above 2SD is anomalous). The analyzed geochemical data of each element was then gridded (changed in to raster maps) to apply overlays for further interpretations. Bi-directional gridding method is presumed to be appropriate to grid the data collected along straight lines or nearly parallel lines. Hence this gridding method was applied to grid the geochemical data acquired in the area. The grid map for the area is shown in (Figure 11). The western parts showed less gold concentration while the central, northern and northeastern parts showed relatively elevated gold anomaly. High gold anomalous areas are covered by Meta sediments and Meta volcanic rocks with relatively highest anomalies observed in Meta sediments. The map has also showed the strong gold anomaly of the area lying almost within the narrow shear zone identified from foliation analysis trending NW-SE.

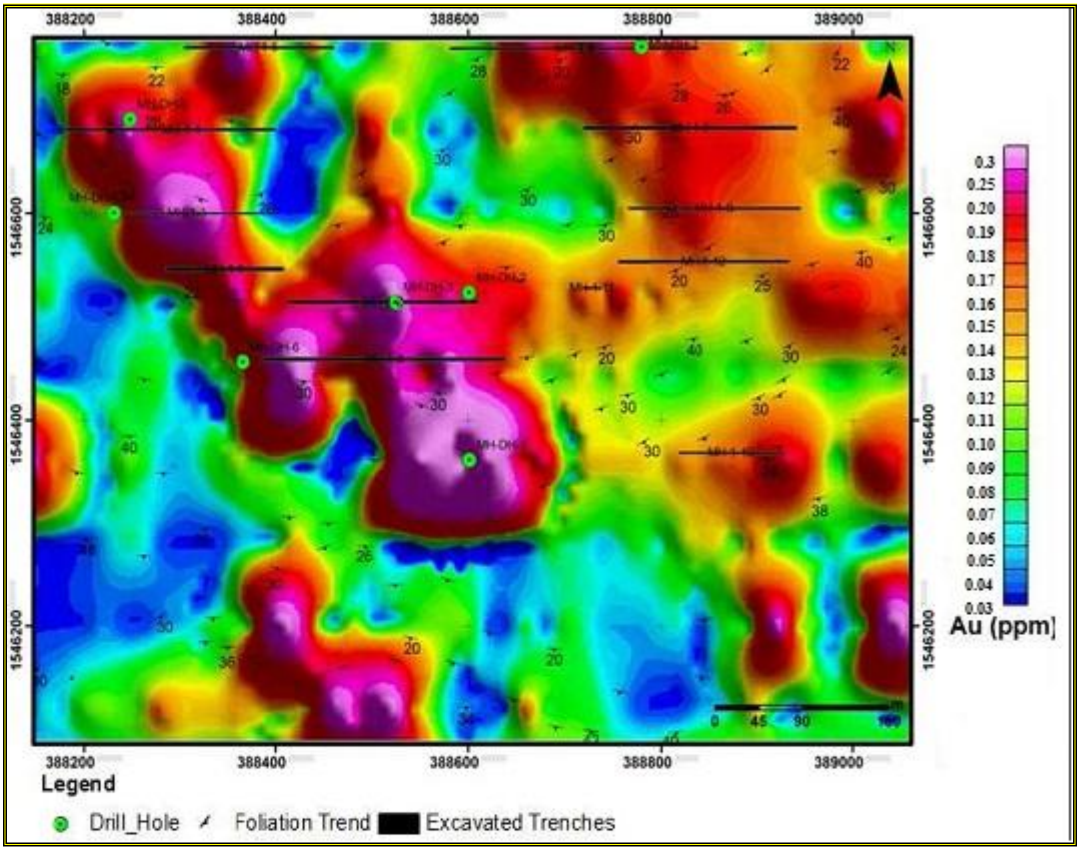


Figure 11: Au anomaly distribution map of the study area

The strong anomaly trending NW-SE is clearly seen bounded by low gold anomaly areas. The gold anomaly was then overlaid with the mapped lithological map of the area to see the relationship between them as shown in (Figure 12). The various mapped lithologies have showed different corresponding gold anomaly. Accordingly, the highest gold (Au>0.2) anomaly area trending NW-SE that lay within the narrow shear zone is mainly covered by sericite quartz schist. Mica chlorite schist, intrusive and graphitic quartzites are the lithologies which are partially covered by this high anomaly zone. In addition some spots of highest anomaly areas are covered by lithologies like graphitic schist, and mixture of graphitic schist and sericite quartz schist as shown in (Figure 12).

The gold anomaly (0.1-0.2) is mainly covered by the basic and intermediate Meta volcanic rock mapped in the area. This range of gold anomaly is also covered at some areas by the lenses of graphitic quartzite mapped in the area. The distribution of quartz veins and veinlets seemed consistent with the anomaly distribution of the area. In such a way that, high quartz veins and veinlets concentration found at the sericite quartz schist showed highest gold anomaly followed by the meta volcanic rocks containing the next high concentration of quartz veins and vein let distribution and hence showed higher gold anomaly. However, there are lithologies with relatively denser quartz veins and vein let concentrations but reflecting low gold anomaly. Some of these lithologies include feldspathic sericite quartz schist (FSqsc), quartz feldspathic schist (Qfsc), quartz porphyry (Qp) and coarser quartz porphyry (CQp) as shown in the map (Figure 12).

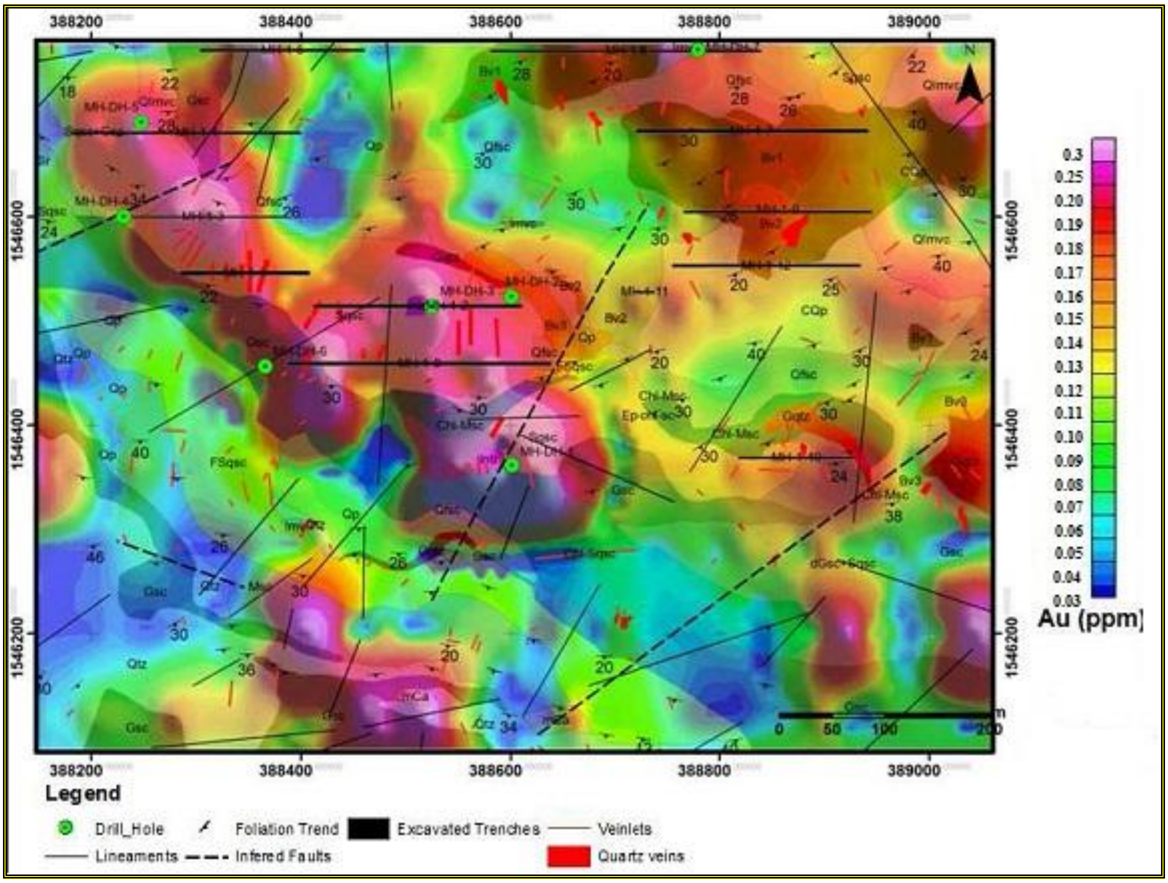


Figure 12: lithological map overlaid on gold anomaly map

4.2. Base metals

Grids for base meals (Cu, Pb and Zn) were analyzed and their relationship with the surface mapped lithologies is outlined. The grids of these elements generally showed the same distribution trend throughout the area. A very prominent zone (area under the dashed black lines) as shown in (Figure 13) is found exhibiting high anomaly for the three elements especially for Cu and Pb trending NW-SE. This zone is covered by mainly sericite quartz schist and graphitic quartzite with minor chlorite mica schist and graphitic schist. In addition to this anomaly zone, Cu and Zn have showed other anomalies at the NE and NW corners of the area covered by meta volcanic to the NE and quartzite and graphitic schist to the NW corner. The anomaly distribution of Pb didn't exhibit any anomaly at the corners of the mapped area other than the prominent zone running NW-SE. anomaly maps lithology overlaid on base metals of the study area are presented in appendix B.

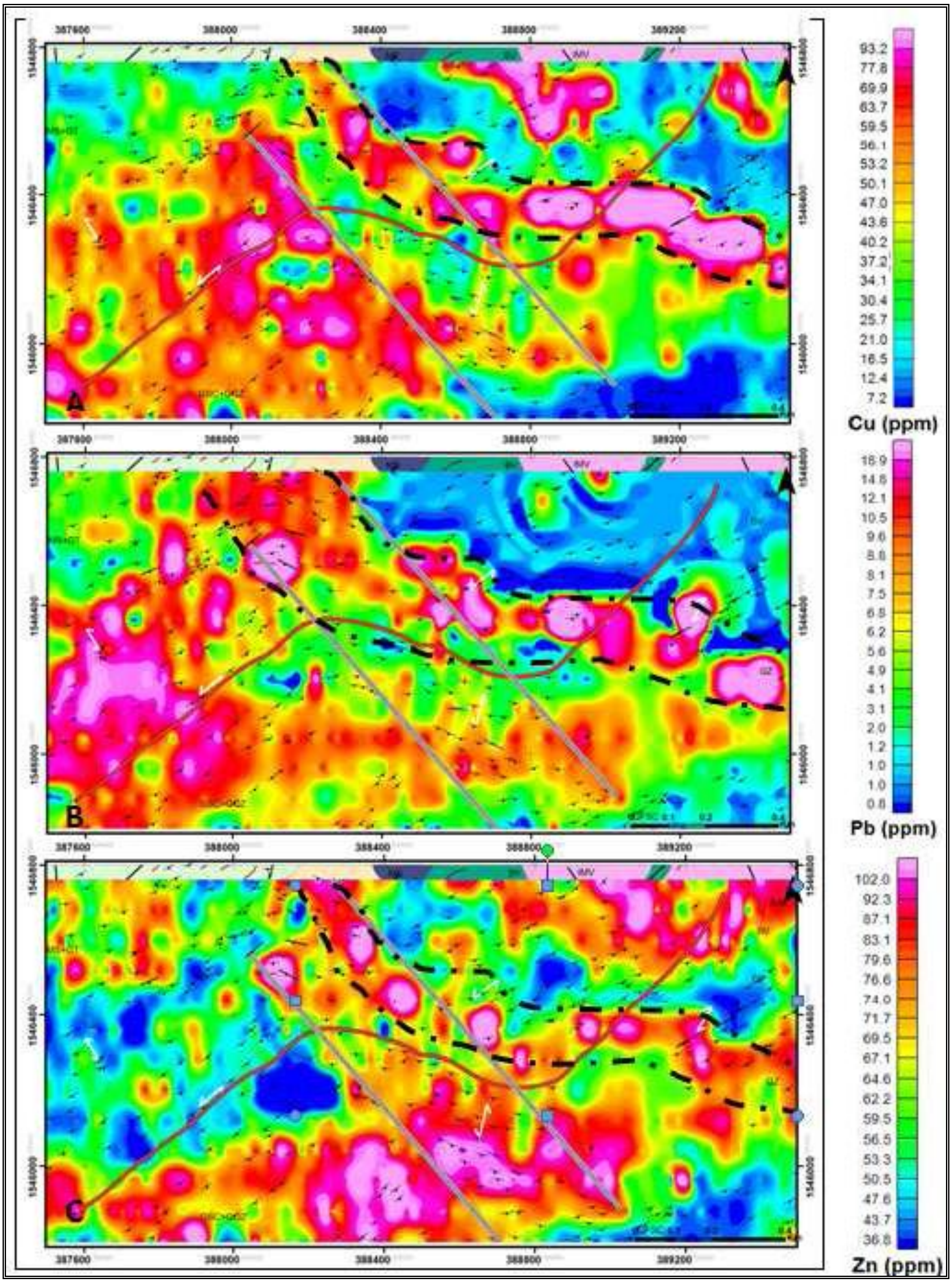


Figure 13: The anomaly distribution map for base metals A) Cu B) Pb and C) Zn

4.3. Drill hole Data

32 drill holes are drilled based on the soil anomaly. Accordingly, the highest gold (Au>0.2) anomaly area trending NW-SE that lay within the narrow shear zone is mainly covered by sericite quartz schist, Mica chlorite schist, intrusive and graphitic quartzites are the lithologies which are partially covered by this high anomaly zone. In addition some spots of highest anomaly areas are covered by lithologies like graphitic schist, and mixture of graphitic schist and sericite quartz schist. See Annex D for Drill hole colars.

4.3.1 Mineralization

Mineralization is intimately linked to alteration, forming from the same hydrothermal fluids. Mineralization occurs when conditions have allowed mineral precipitation in economic concentrations, beyond the initial alteration 'footprint'.

From visual significant intersect and assay result it is shown that the mineralization of Mai Hibey is related to Quartz vein, vein lets and quartz vein stringers. The host rocks are sericite quartz schist, Mica chlorite schist, intrusive and graphitic quartzites, graphitic schist, and

4.3.2 Alteration

Alteration is the evidence of hydrothermal fluids passing through rocks, altering primary rock-forming minerals. Alteration and mineralization are intimately linked, forming from the same hydrothermal fluids, with alteration being the precursor to mineralization, but mineralization may or may not develop, depending if physio-chemical conditions are favorable or not for economic mineral precipitation. Recognition of alteration then is critical as an initial vector to potential mineralization.

Hydrothermal alteration has developed in the form of sericitization, silicification, carbonitization, and chloritization and minor epidotization. Most of the gold and disseminated sulfide mineralization is associated with carbonitization, sericitization and silicification. Alteration minerals include carbonate (predominantly ankerite), muscovite, chlorite, albite, pyrite, Chalcopyrite, Sphalerite, Pyrrhotite, hematite, Illmenite, quartz and rare epidote.

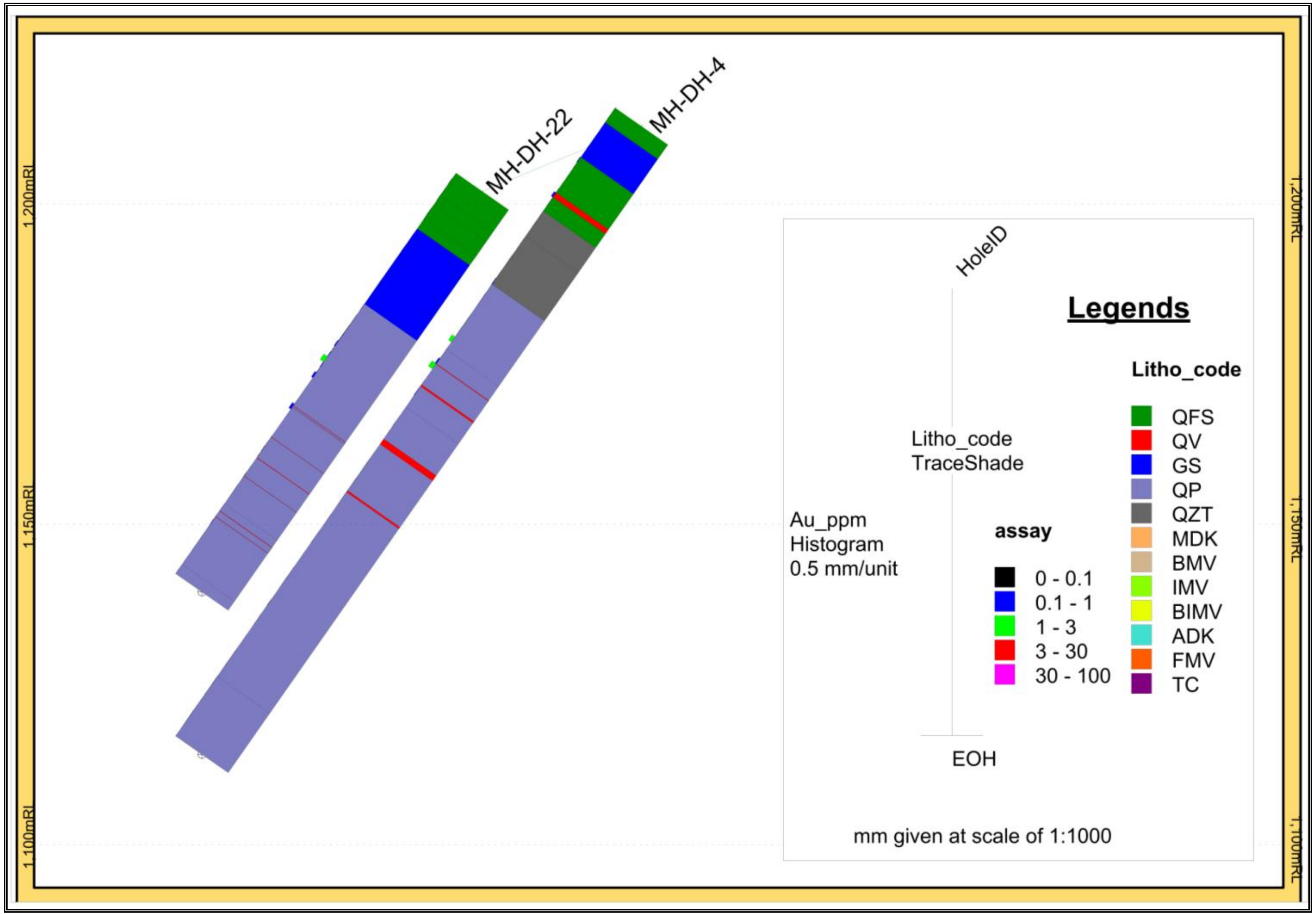


Figure 14: Section_1 shows downhole lithlogy vs Assay result of MH-DH-22 and MH-DH-4

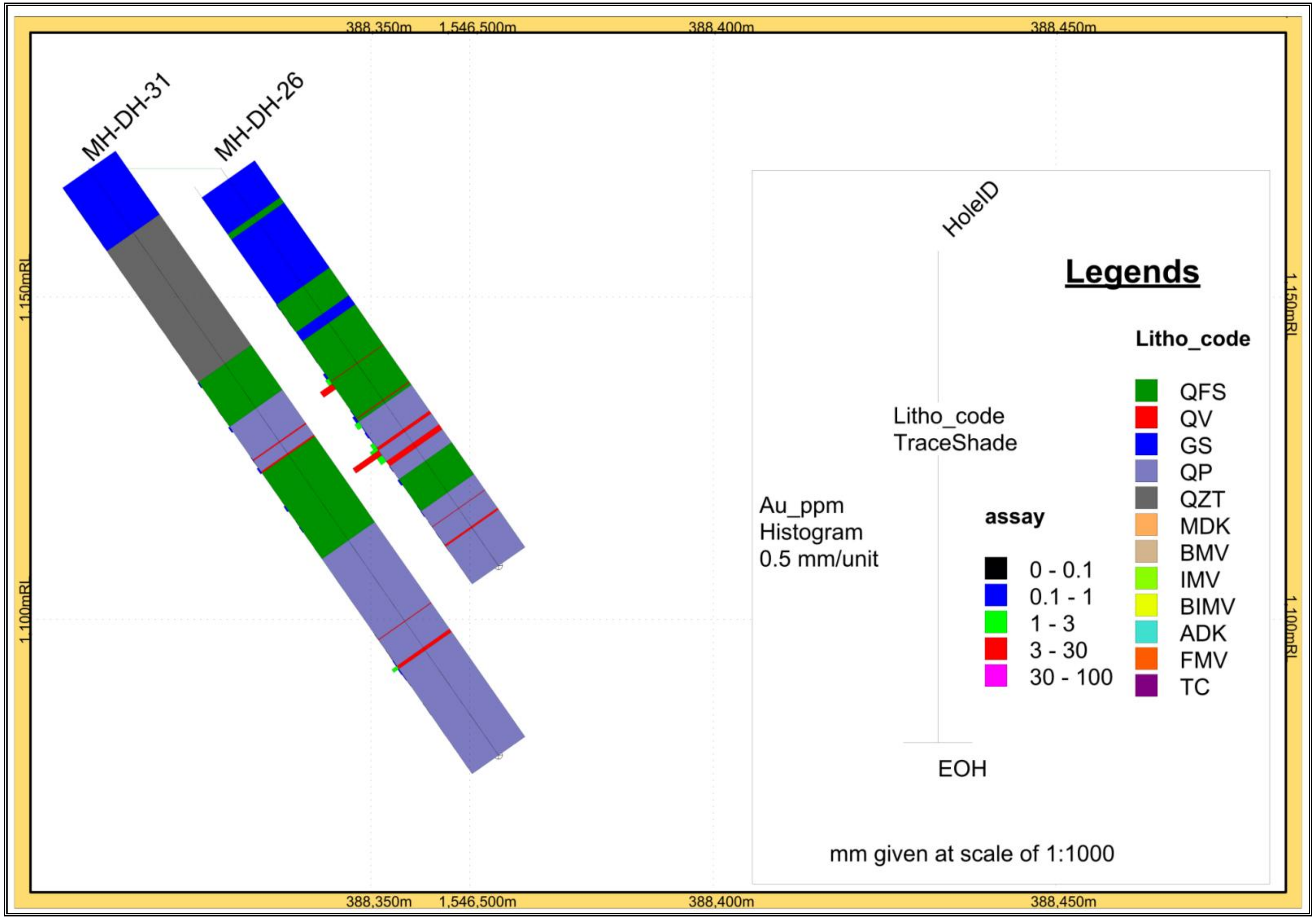


Figure 15: Section_2 shows downhole lithlogy vs Assay result of MH-DH-26 and MH-DH-31

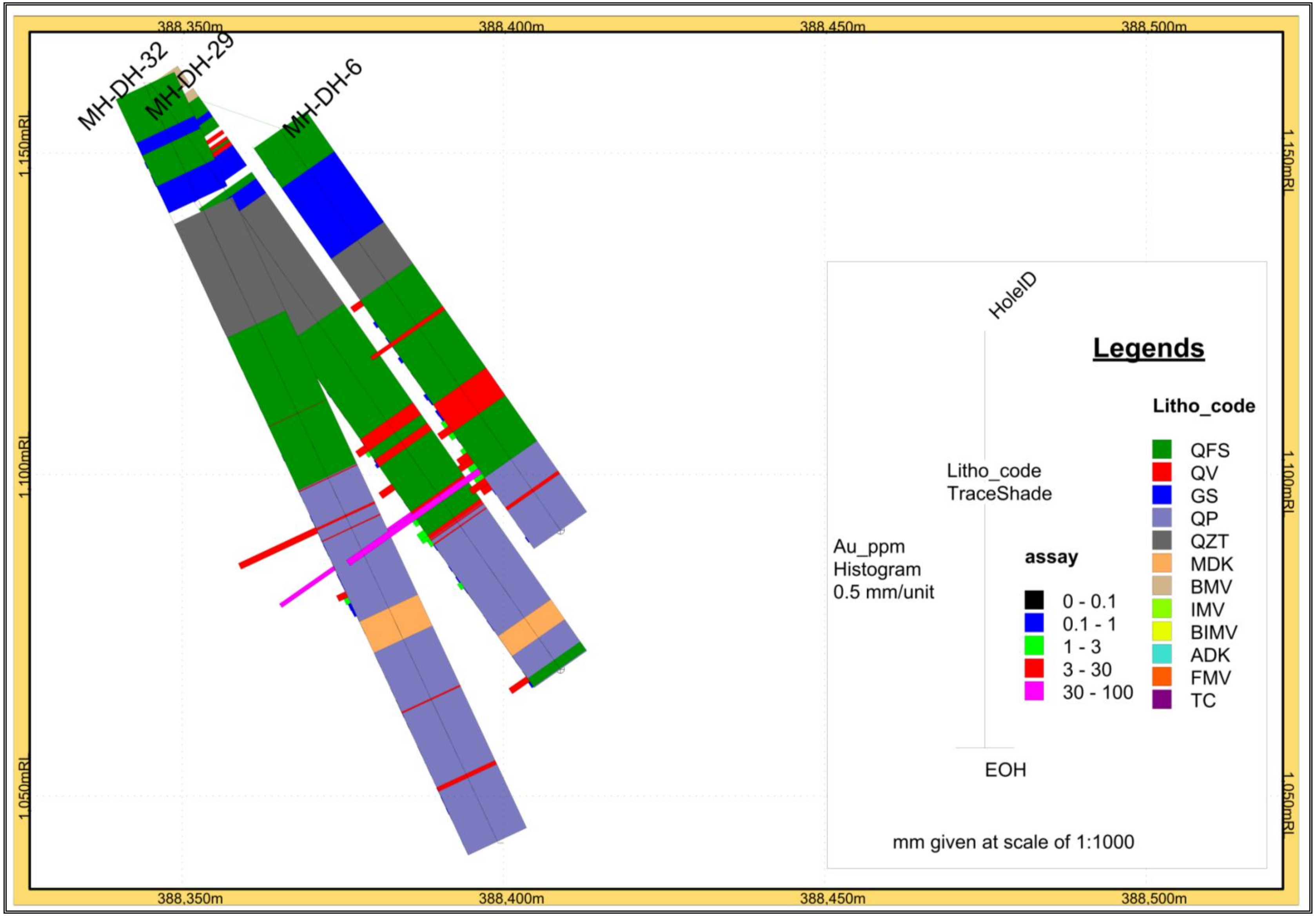


Figure 16: Section_3 shows downhole lithlogy vs Assay result of MH-DH-6, MH-DH-29 and MH-DH-32

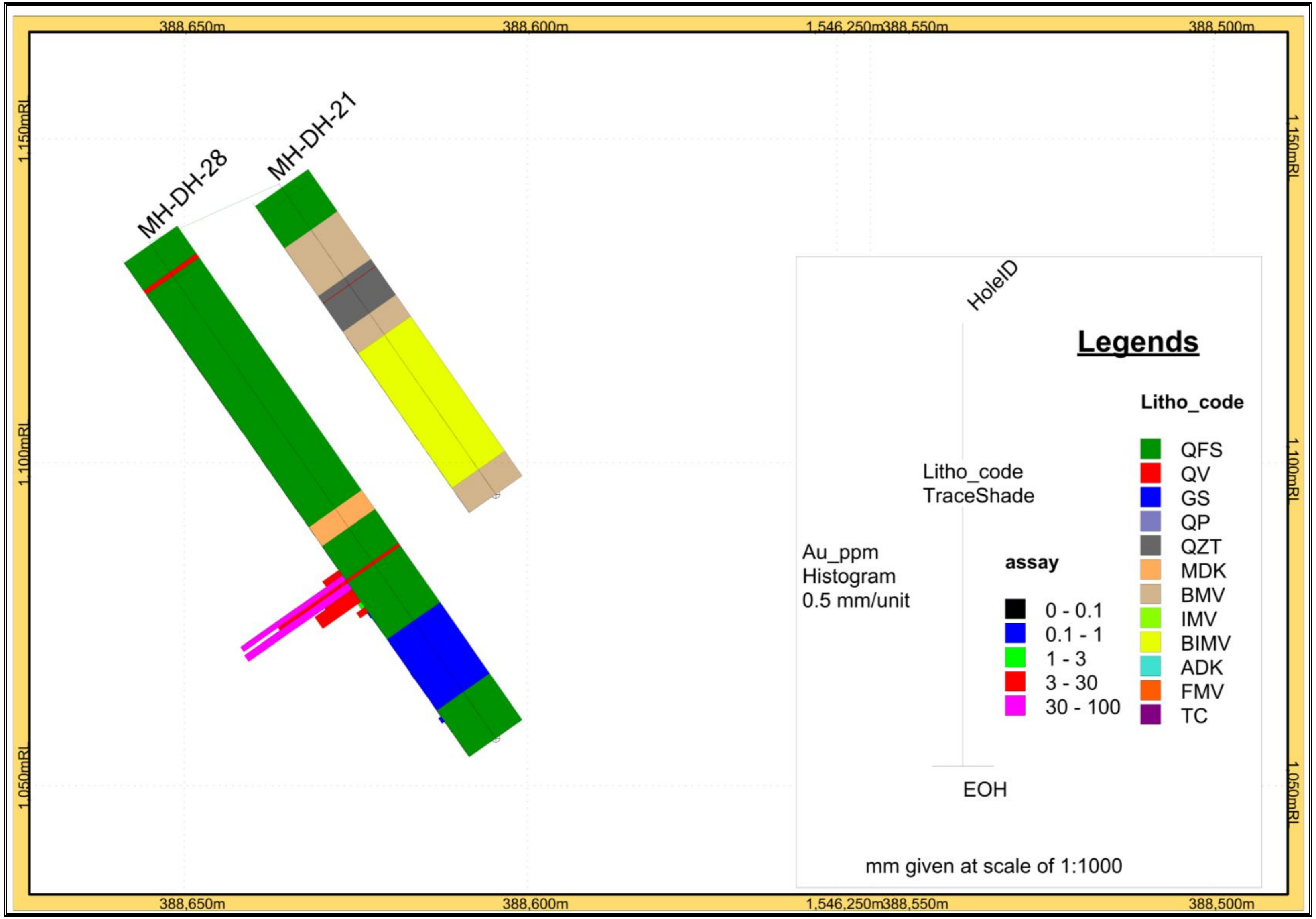


Figure 17: Section_4 shows downhole lithlogy vs Assay result of MH-DH-28 and MH-DH-21

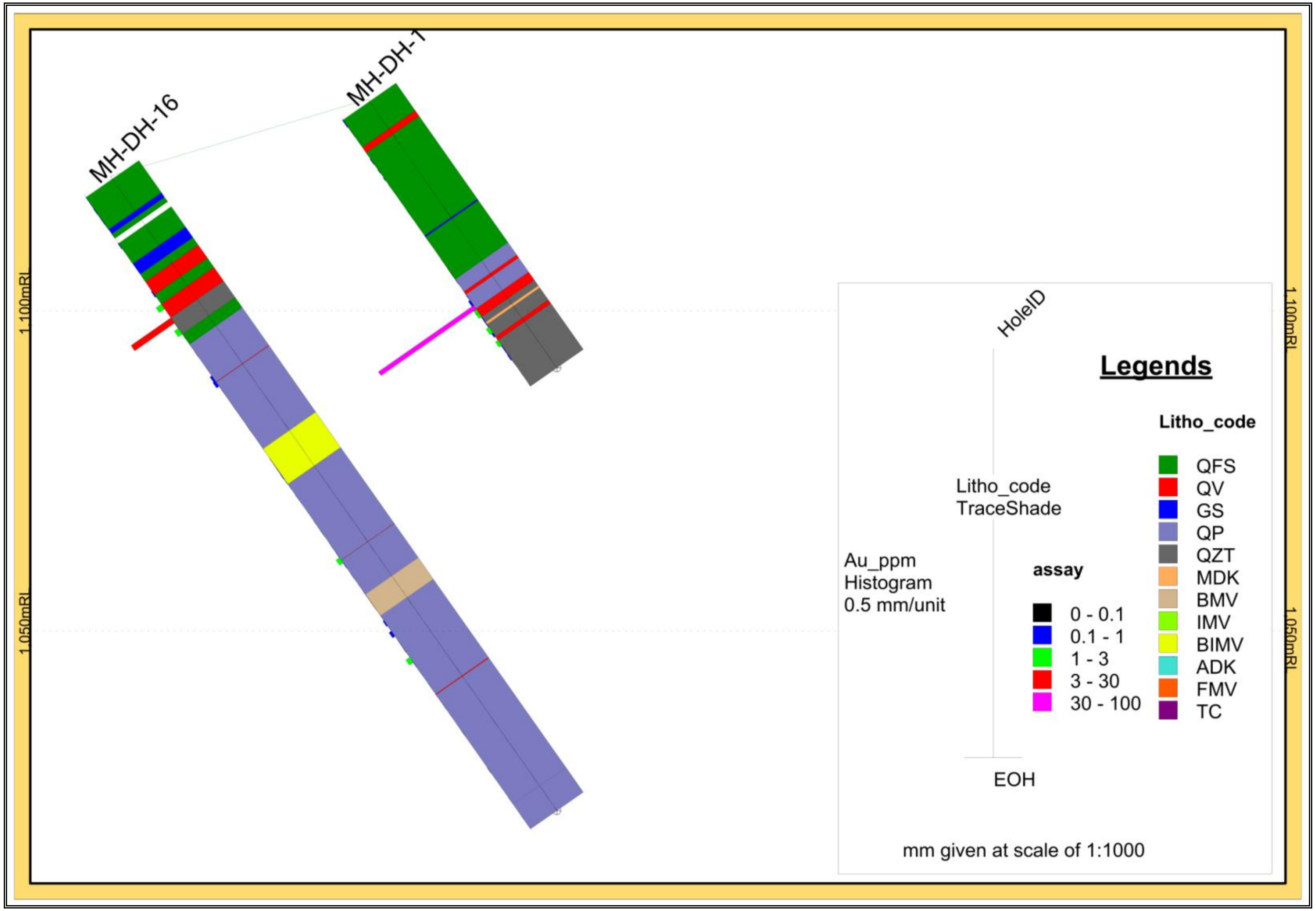


Figure 18: Section_5 shows downhole lithlogy vs Assay result of MH-DH-22 and MH-DH-4

5. Discussion

The Gold-base metals occurrence at the May Hibey is a shear-zone--hosted meneralization in deformed and structurally complicated meta-volcanic and metasediments within Greenstone Belt northern Tigray. The gold-base metals mineralization is hosted almost exclusively within a series of disconnected bands and lenses of quartz dominantly by a sequence of rocks including sericite quartz schist, chlorite mica schist, gossaniferous quartzite, quartz feldspathic schists, quartz porphyry and basic volcanic. Gold-base metals mineralization involved localized deformation and cleavage formation, fine grained Fe oxides veining, followed by later stage quartz veining and replacement with sulphidation of included wall rock fragments comprising the earlier iron oxide veins.

The position of the ore bodies within the host rocks, together with the setting of other known occurrences in northern Ethiopian Greenstone Belt, indicates shear zone-hosted gold-base metals mineralization character of the May Hibey mineralization.

Field observations at the May Hibey indicate that the major alteration processes is marked by silicification, seritization, chloritization, oxidation, epidotization and sulphidation, varying both laterally and vertically. Sulphidation involved pyrite, pyrrhotite, galena, sphalerite and chalcopyrite.

A common feature of chalcopyrite is the presence of star shaped sphalerite exsolutions. This types of exsolutions give an important information about the stage of temperature undergone during the mineralization processes, which can be identified in the interval 250 – 300 °C (Ramdohr, 1980; Boyle, 1987).

Gold is absent in these conditions, generally forming with galena and chalcopyrite at latest stage following metamorphism and during a period of spaced to penetrative cleavage development at a temperature 200° C. Gold occurs as sub-micron in and around the edges of galena and as free gold, implying that the low temperature environment was favourable condition for gold-base metals precipitation. The presence of gold as an inclusion in galena, together with absence of gold in unmineralized wall rocks with pyrrhotite clearly supports a temporal association of gold and galena.

Based on different textural features of the ore minerals and gangue, as well as intergrowth relationships, the paragenetic sequences have been divided into three paragenetic stages: paragenesis one is characterized by the presence of pyrrhotite, chalcopyrite, and sphalerite. The sulphide minerals mainly occur in the wall rocks and are inherited as relicts in auriferous veins. In paragenesis two, pyrite replaces pyrrhotite along grain boundaries (see photo 1). Finger-like protrusion of pyrite in pyrrhotite is common. Paragenesis three represents Au, galena, arsenopyrite, pyrite, and chalcopyrite. These minerals are confined to brecciated, milky, laminated or banded quartz veins and vein-lets and iron-rich carbonates. Gold occur as an inclusion in galena and pyrite.

Field observations testify that in most cases, primary sedimentary textures and structures have been well preserved indicating that the host rocks for the mineralization was derived from protolith of originally sedimentary and mostly clastic materials. Subsequent deformation of the gold-base metals enriched meta-volcanic-sedimentary led to the local remobilization and re-concentration of gold-base metals in highly deformed zones. In other words, the gold was originally precipitated at above-normal concentrations in the host material, but, was concentrated up to ore grade with deformation of the meta-volcanic-sediments.

The gold-base metals mineralization at May Hibey is hosted almost exclusively within a series of disconnected bands and lenses of quartz vein. It consists of gold intergrown with quartz and/or sulphide minerals and iron oxides in deformed and structurally complicated meta-volcanic and metasedimentary rocks. These units are hosted by a sequence of rocks including sericite quartz schist, chlorite mica schist, gossaniferous quartzite, quartz feldspathic schists, quartz porphyry and basic volcanics. The auriferous quartz occur in the form of veins, vein-lets, stringers, intervening silicified rocks, quartz breccia and stockworks that propagated along mesoscale ductile to brittle-ductile shear zones. The ore is largely concentrated in quartz occurring in the form of veins, veinlets, and stringers. Gold and sulphides also occur in selvages of altered wall rocks. The pods and asymmetrical sigmoidal veins are discontinuous, parallel to the lithological layering throughout the ore zone. Most quartz veins dip to the west, strike parallel to the shear zone and main foliation. However, some veins are discordant to the shear zone and are folded within the main foliation parallel to the axial attitude. Although gold and base metals are concentrated within the shear zone, the grade is higher in the portion dominated by quartz vein, and stringers. Breccia and stockworks zones consist of abundant randomly oriented quartz veinlets and brecciated quartz veins, cemented by quartz and sulphides. Gold and associated sulphides are disseminated in breccias clasts and inter-vein materials.

Based on differences in mineral paragenesis and lithology of their host rocks, the ore body at the May Hibey can be subdivided into two bodies: Primary ore and oxidized ore. Minerallogically, the primary ore is marked by sulphide (pyrite, pyrrhotite, galena, sphalerite, pyrrhotite). The oxidized ore is dominated by oxide (hematite, limonite and goethite) facies. Magnetite occurs as disseminated to massive bands of subhedral to euhedral grains. Hematite occurs in the form of finely crystalline laminae, or as laths. Quartz, in the form of cross-cutting veins, is also a common alteration mineral and most typically, the gold is inergrown with sulphides mainly, galena and chalcopyrite in the quartz, with fragments of iron oxides. In the ore body, white grey silica is common in the form of either a secondary mineral replacing the host rock or as quartz vein.

Therefore, the intimate associations between gold-base metal mineralization, metasedimentary meta-volcanic successions, brittle-ductile shear zones, lithological contrast within the shear belt is, therefore similar to most of the shear-zone hosted gold-base metals mineralization like those described by Robert and Brown (1986) for Sigma mine in Canada and Andrews et al. (1986) for Abitibi greenstone belt in Canada.

Geological field observation and ore microscopy analyses on 20 rock samples collected from bore holes indicate a mineral association consisting of gold accompanied by sulphides and iron oxides in variable abundance, with quartz, and silicates as gangue minerals.

Gold, pyrite, galena, pyrrhotite, sphalerite, and galena; oxides (magnetite, hematite goethite and ilmenite) were observed both in the field and from laboratory analyses:.

Based on different textural features of the ore minerals and gangue, as well as intergrowth relationships, the paragenetic sequences have been divided into three paragenetic stages: paragenesis one is characterized by the presence of pyrrhotite, and sphalerite. The sulphide minerals mainly occur in the wall rocks and are inherited as relicts in auriferous veins. In paragenesis two, pyrite replaces pyrrhotite along grain boundaries. Finger-like protrusion of pyrite in pyrrhotite is common. Paragenesis three represents Au, galena, chalcopyrite, and pyrite. These minerals are confined to brecciated, milky, laminated or banded quartz veins and vein-lets with iron-oxides.

The following are descriptions of the ore mineral associations observed from field work and laboratory investigations:

Gold- occurs either as isolated particles finely dispersed in quartz with galena, chalcopyrite, and pyrite (photo MH-TS-20-04). Gold is frequently associated with galena and with chaccopyrite and pyrite. Gold, also occur associated with galena (photo MH-PS-5-03-01). Gold have been also observed as an isolated element in quartz (photo MH-TS-20-04). Gold inclusion in galena is very common exhibiting mutual grain boundaries. “Bleb structures”, which occasionally curvature (indicating the effect of mild deformation), are pronounced. These structures result from contemporaneous filling of open space by both gold and galena, in which gold occurs as blebs attached to cavity wall.

Pyrite – is the most abundant sulphide minerals, possibly occurring in several generations. It occurs as disseminated, crystals and/or vein accompanied with other sulphides mainly with chalcopyrite. Large crystals of pyrite (crystal habit anhedral) with gold and chalcopyrite as an inclusion in pyrite (photo MH-PS-5-03-01_ Photo 2). Pyrite also occurs with thin strips of hematite with inclusion of ilmenite (MH-TS-25-05_Photo1). In section, MH-PS-20-02, abundant presence of pyrite subhedral crystals with chalcopyrite (photo MH-PS-20-02_10X) and pyrhotite have been observed (photo MH-PS-20-02_photo1_20X). Sometimes pyrite occurs in euhedral crystal (cubes) (photo MH-TS-11-01_Photo2_10X)

Dissemination of minute elements of pyrite, mostly euhedral occur with probable rutile (photo MH-PS-11-03_10X). Pyrite occurs both as open-space filling and replacement of pre-existing iron oxides. Typical grains are anhedral where they occupy fractures, fissures, vesicles in quartz.

Pyrrhotite – is also common sulphide minerals in the lithotypes outside the mineralization and may have been derived through metamorphism of pyrite. Pyrrhotite occurs as massive, large grains, or tabular crystals isolated or as a group with other sulphide minerals such as pyrite, chalcopyrite and sphalerite in quartz and quartz breccia. Strongely anisotropic mineral, average brightness, probably pyrrhotite (pink color) with chalcopyrite as an inclusion in pyrrhotite crystal has been observed (Photo MH-TS-21-02, 10X). An element of, monoclinic pyrrhotite with large elements of pyrite with chalcopyrite (photo MH-TS-5-04), and pyrrhotite (pink in photo) as inclusion in pyrite have been observed (photo MH-TS-5-04_photo1).

A monoclinic element of pyrrhotite, brighter than the more common pyrrhotite so far observed (photo MH-TS-5-02_10X).

Galena – occur as isolated, massive, large grains and or in association with other sulphides mainly chalcopyrite, sphalerite and pyrite, in quartz breccias (photo MH-PS-5-03-01_ photo 2). Individual grains are invariably associated with chalcopyrite, and sphalerite and pyrite in fractures, vesicles and other openings.

Sphalerite – is relatively rare occurring as isolated minerals or associated with chalcopyrite, pyrite and galena in quartz. Sphalerite in the ores is generally granular, being only locally interstitial. Lamellar twining is common. It exhibits several generations, the highest temperature phase shown by star shaped exsolutions in chalcopyrite. Sphalerite, (gray in center photo) occurs as an inclusion in chalcopyrite (photo MH-TS-1-01_20X). Sphalerite, (gray bottom center) occur with disseminated pyrite, concordant with the texture of the rock and chalcopyrite and pyrrhotite (pink) (photo MH-TS-5-02_10X).

The mineral commonly occurs as open space filling in association with galena and chalcopyrite. Textural relations among these three minerals are paragenetically ambiguous, although the sphalerite most typically surrounds and appears to engulf interlocking aggregates of chalcopyrite and galena.

Chalcopyrite – occur as isolated massive, large grains or in association with sulphide minerals dominantly pyrite, and sphalerite in quartz. Gold is absent in these conditions, generally forming within galena and pyrite at the latest stage (200 °C) (Ramdohr, 1980; Boyle, 1987). Contact relations with pyrite are generally trasgressive, with chalcopyrite veining and rimming pyrite grains in vesicles, or surrounding a number of pyrite subhedral in fissures.

1. Section MH-TS-25-05: (low) presence of oxides and some small crystals of pyrite and chalcopyrite, sometimes included in pyrite (photo MH-TS-25-05, 20X). Hematite (thin strips) inside of the ilmenite (MH-TS-25-05_photo1, 20X) and wrecked pyrite crystal.

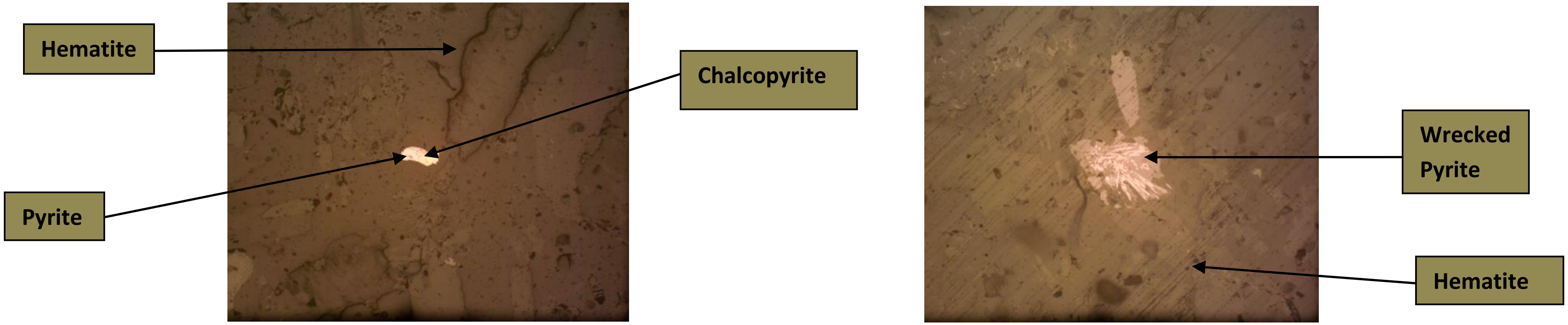


Figure 19: Polished section MH-TS-05 showing Pyrite, Chalcopyrite, and Hematite

2. Photo MH-PS-5-03-01_ Photo 1, 10X; photo MH-PS-5-03-01_ Photo 2: presence of a element composed of gold in contact with galena and gold as free grain.

Figure 20: Polished section MH-PS-03-01 showing Gold, Galena and Iron Oxide

3. Section (MH)-TS-11-09: Big crystals of pyrite, generally anhedral, with inclusion of chalcopyrite crystals (photo MH-TS-11-09_10X.tif: with chalcopyrite in contact), which show, in X Nicols, weakly anisotropic. Chalcopyrite (photo MH-TS-11-09_10X_Photo1) with a small anhedral pyrite crystal in contact.

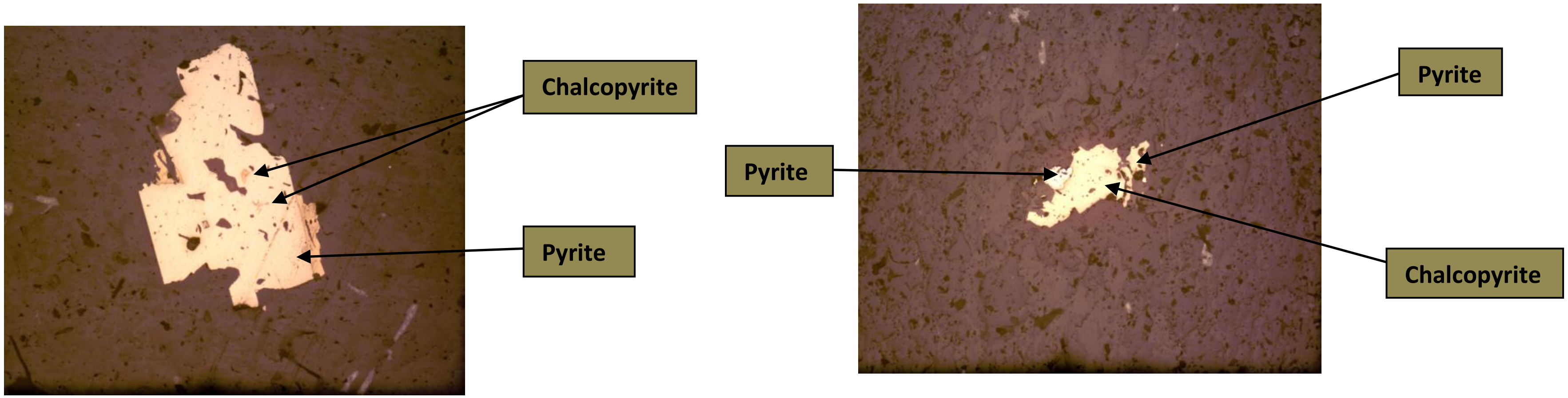


Figure 21 : Polished section MH-TS-11-09 showing Pyrite, Chalcopyrite

4. Section MH-PS-11-03: dissemination of minute elements of pyrite, mostly euhedral with inclusion of rutile in pyrite crystal (photo MH-PS-11-03_10X). Observed small element of chalcopyrite and wrecked pyrite (photo MH-PS-11-03_10X_foto1)

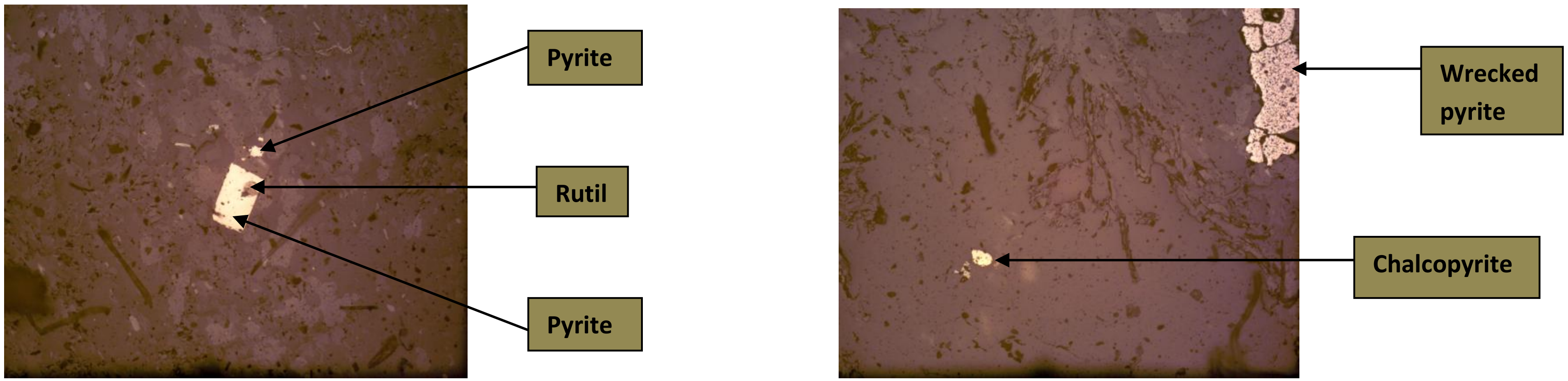


Figure 22: Polished section MH-PS-11-03 showing Pyrite, Chalcopyrite and Rutile

5. Section MH-TS-20-01: dissemination of small crystals of pyrite (sometimes euedral) (photo MH-TS-20-01_2.5X.tif and magnification -> MH-TS-20-01_10X.tif)

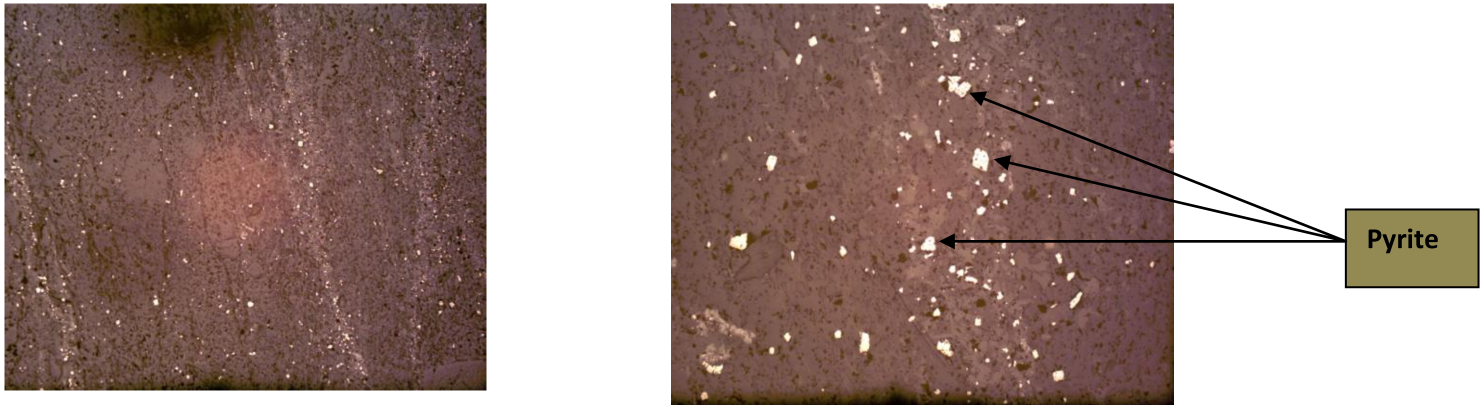


Figure 23: Polished section MH-TS-20-01 showing Pyrite

6. Section MH-PS-5-03: Elements of Pyrite (photo MH-PS-5-03, 10X) and (photo: MH-PS-5-03_Photo2, 20X).

Figure 24: Polished section MH-TS-5-03 showing Pyrite

7. Section MH-TS-11-01: small crystals of chalcopyrite, often included in pyrite crystals (photo MH-TS-11-01_10X); sometimes pyrite occurs in euhedral crystal (cubes) - photo MH-TS-11-01_foto2_10X)

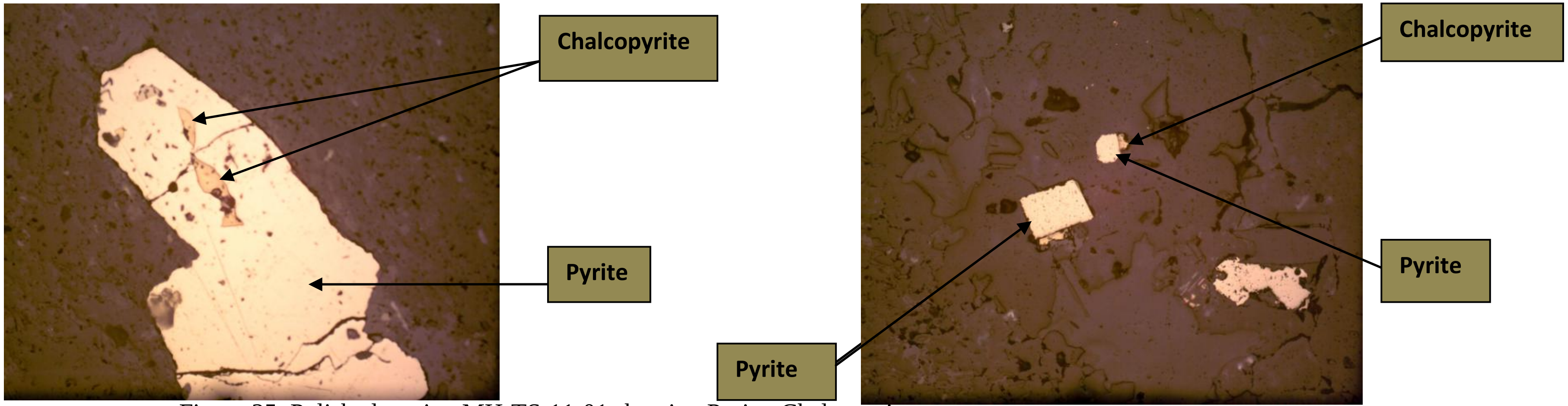


Figure 25: Polished section MH-TS-11-01 showing Pyrite, Chalcopyrite

8. Section MH-PS-20-02: Big crystal of pyrite subhedral within which are included chalcopyrite (photo MH-PS-20-02_10X). Observed some elements of pyrrhotite (photo MH-PS-20-02_photo1_20X)

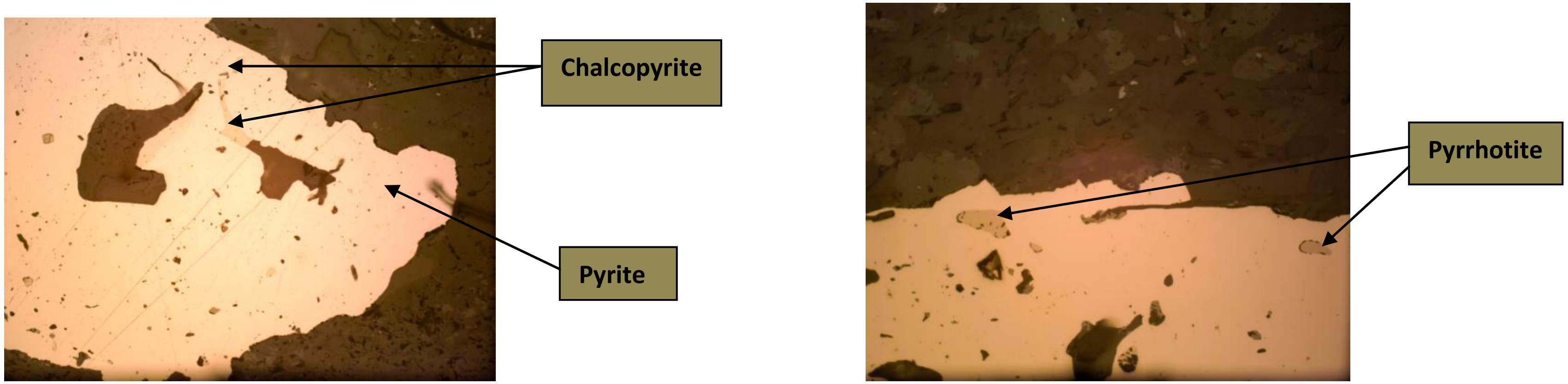


Figure 26 : Polished section MH-TS-11-01 showing Pyrite, Chalcopyrite, Pyrrhotite

9. Section MH-TS-5-04: large elements of pyrite, macroscopic visible, in which are included chalcopyrite elements (photo MH-TS-5-04), and also observed Pyrrhotite (pink in photo) included in pyrite (photo MH-TS-5-04_poto1). Observed an element of pyrrhotite monoclinic.

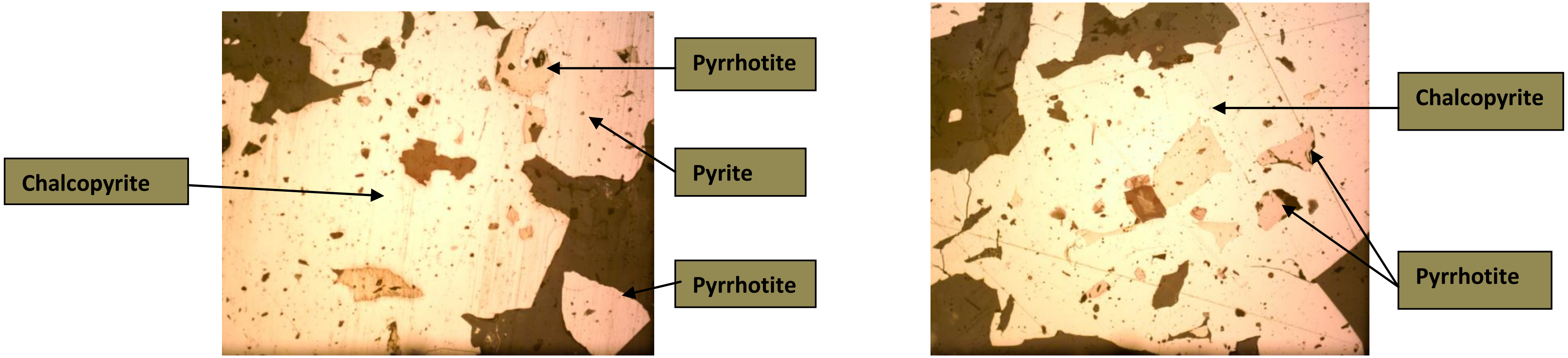


Figure 27 : Polished section MH-TS-5-04 showing Pyrite, Chalcopyrite, Pyrrhotite

10. Section MH-TS-11-05: rare elements of Gold (photo MH-TS-11-05_20X)

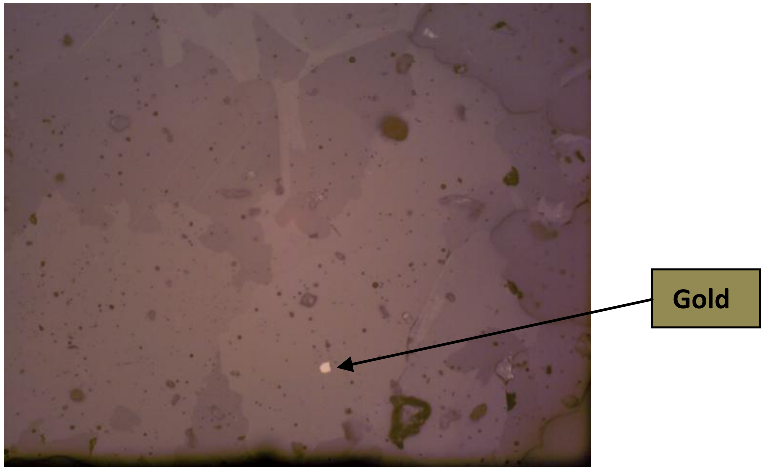


Figure 28: Polished section MH-TS-5-04 showing Gold

11. Section MH-TS-5-02: Wrecked pyrite, concordant with the texture of the rock. Presence of chalcopyrite, pyrrhotite (pink) and an element of sphalerite (gray, bottom center) (photo MH-TS-5-02_10X). Observed an element of pyrrhotite a monoclinic, brighter than the more common pyrrhotite so far observed.

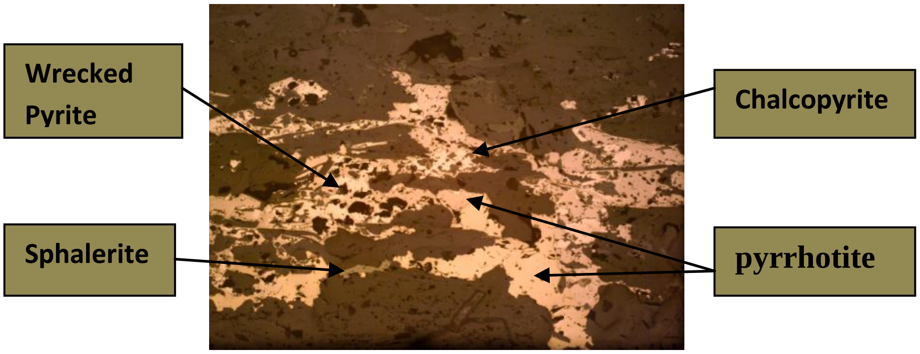


Figure 29: Polished section MH-TS-5-02 showing Pyrite, Chalcopyrite, Pyrrhotite and Sphalerite

12. Section MH-TS-6-09: scarce presence of Wrecked pyrite crystals (Photo MH-TS-6-09_10X)

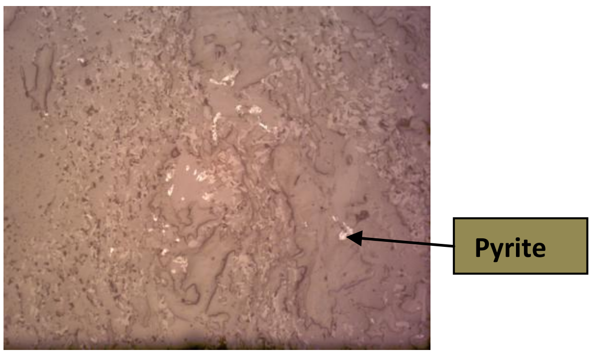


Figure 30: Polished section MH-TS-5-04 showing Pyrite

13. Section MH-TS-1-01: Pyrite, concordant with the texture of the rock. Observed Pyrrhotite with chalcopyrite and Sphalerite included (gray in center photo) (photo MH-TS-1-01_20X).

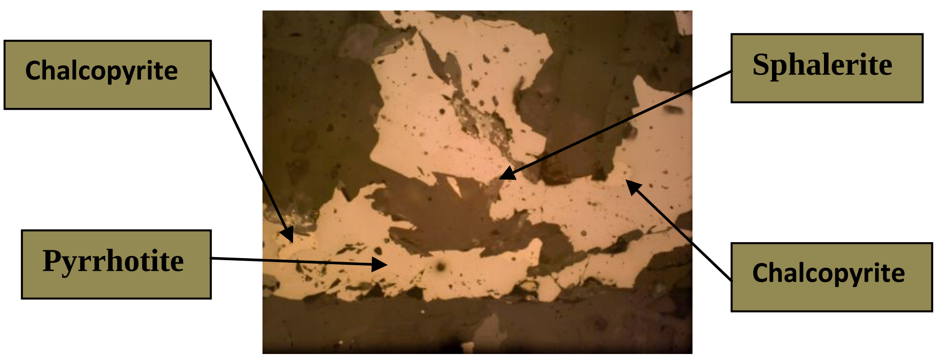


Figure 31: Polished section MH-TS-5-02 showing Chalcopyrite, Pyrrhotite and Sphalerite

14. Section MH-TS-20-04: observed only gold (photo MH-TS-20-04).

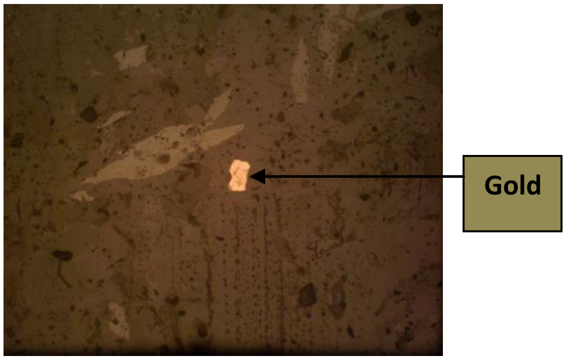


Figure 32: Polished section MH-TS-20-04 showing Gold

15. Section MH-TS-25-04: pyrite and chalcopyrite, in disseminated elements of small - medium dimension (photo MH-TS-25-04_20X).

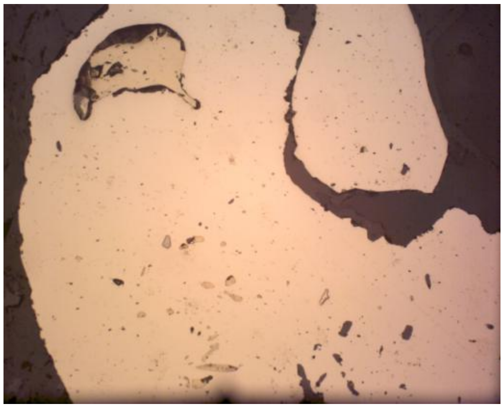


Figure 33: Polished section MH-TS-25-04 showing Pyrite and Chalcopyrite

16. Section MH-TS-21-01: Some element of chalcopyrite and pyrrhotite (photo MH-TS-21-01).

Figure 34 : Polished section MH-TS-21-01 showing Pyrrhotite and Chalcopyrite

17. Section MH-TS-1-03: Wrecked pyrite crystals (photo MH-TS-1-03), of medium size.

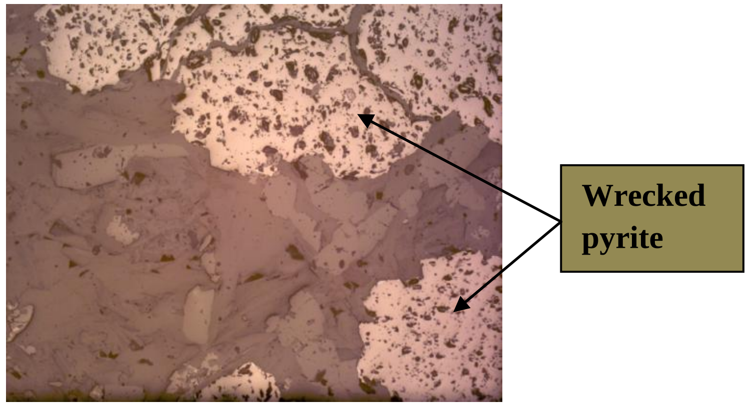


Figure 35: Polished section MH-TS-1-03 showing Pyrite

18. Section MH-TS-1-04: only few elements of chalcopyrite (photo MH-TS-1-04, 20X)

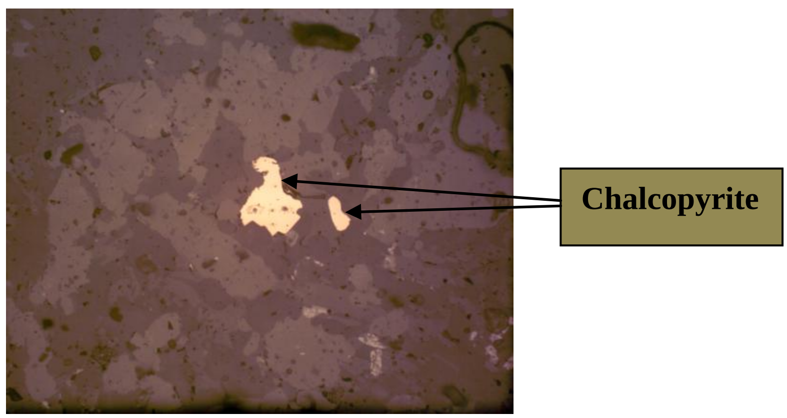


Figure 36: Polished section MH-TS-1-04 showing Chalcopyrite

19. Section MH-TS-25-02: Elements of Wrecked pyrite, especially in crystals wrecks (photo MH-TS-25-02, 10X)

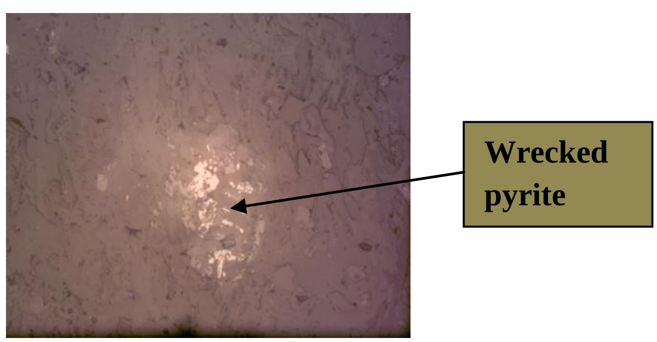


Figure 37: Polished section MH-TS-25-02 showing Pyrite

20. Section MH-TS-21-02: presence of strongly anisotropic mineral, average brightness, probably pyrhotite (pink color). Presence of chalcopyrite, also inside of pyrrhotite crystals (Photo MH-TS-21-02, 10X).

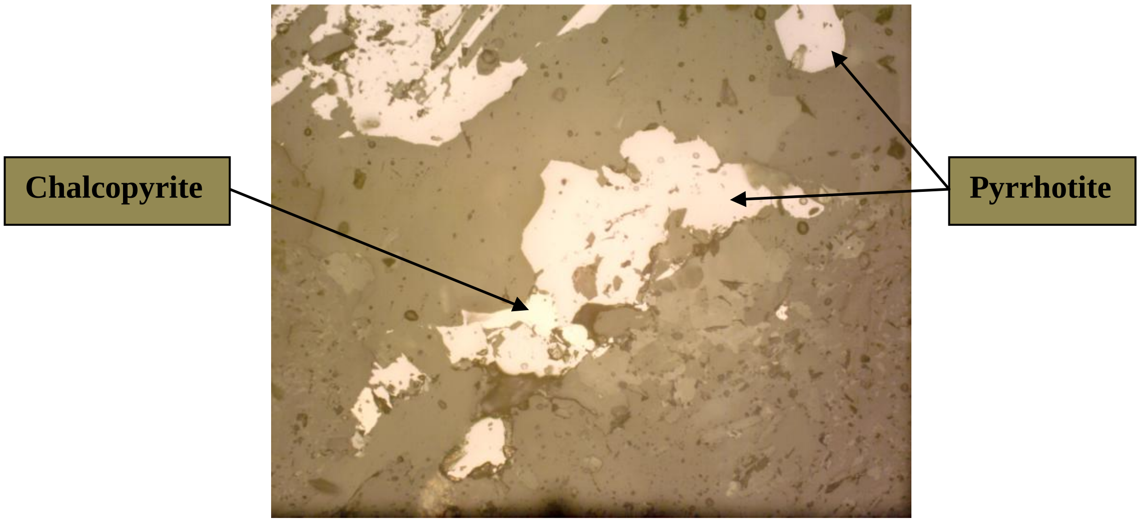


Figure 38: Polished section MH-TS-25-04 showing Pyrrhotite and Chalcopyrite

6. Conclusions and Recommendations

Field geological observations and laboratory analyses indicates that there is an interbanding of ores of contrasted composition within the meta-volcanic-sedimentary; virtual presence of cross-cuttings veins; variation of ore mineralization with variation in metasedimentary facies. Metamorphism of both the ores and the host rocks; presence of intense brittle-ductile shearing along the ore zone; presence of wall rock alteration; suggest that gold mineralization at the area was deposited by reaction of hydrothermal fluids with iron oxides and sulphides in the country rock during deformation and metamorphism, causing precipitation of gold and sulphides.

Following metamorphim, the host units were subject to further deformation, brittle-ductile shearing and development of open spaces which become filled with late stage Au-base metals mineralization.

Continued brecciation and a further silicification with associated precipitation of gold, sulphides, resulted in mineralization of May Hibey.

The ore mineral paragenesis (Au-Cu-Pb-Zn sulphides and iron oxides) also points to similar origin.

The gold is present in quartz veins or the immediate wall rock, wherein the precipitation reaction occurs. Access to the favourable depositional environment of the host for the hydrothermal fluids was provided by large scale fault and shear systems in a manner similar to that visualized in mesothermal models.

The geometry of the ore body, types and variation of alteration zones, host rock lithologies, base and precious metal associations, and variation of Cu-Zn-Pb ratio imply that the May Hibey mineralization is a shear-zone hosted Au and base metal deposit.

The most frequently gold-base metal bearing ores from the area occur in quartz vein, silicified rocks, stockworks, which are concordant with the NW-SE trending brittle-ductile shear zones and dominantly hosted by metasediments. Therefore, the intimate association of between gold and base metal mineralization, metasedimentary succession, brittle-ductile shear zones, lithological contrast within the shear belt is, therefore similar to most of the shear zone hosted-gold deposit like those described by Robert and Brown, 1986 for Sigma mine, Canada and Andrews et al., 1986 for Abitibi, Quebec.

This new study at the area gives the paragenetics sequence of the minerals in the area and the relationship between lithology and mineralization using sub surface data. Therefore this will help in continuing detail study in the area.

The newly discovered shear-hosted Au-base metal mineralization at May Hibey and the presence of discoveries of VMS-type deposits at Terer Cu-Zn-Au-Ag, Terakimti Cu-Zn-Au-Ag and Adi Bladie Cu deposit and presence of other sulphidic zones and wider alteration zones at Nefasit and Hamlo and Mai Hanse area, and the similarity of all these occurrences with well established mineral district of Arabian-Nubian-Shield (ANS) witness the metallogenic significance of the region, especially for Cu-Zn-Pb-Au and related mineralizations.

Three VMS type Cu-Zn-Au-Ag deposits discovered in the northern Tigray:

- Terer Cu-Zn-Au-Ag deposit located 57km northeast of Shire

- Terakimti Cu-Zn-Au-Ag deposit, located 29km northeast of Shire, on the western side of the Terer deposit,

- Adi Bladie Cu deposit located 25km northwest of Shire, SW extension of the Terakimti VMS mineralization and

- Recent discovery of Au-base metals at May Hibey,

Indicates that much potential for base metals and precious metals resources in this region. Furthermore, In addition to the three VMS deposits above mentioned, there are other VMS mineralisation zones in this region including Nefasit and Hamlo, and gold mineralisation in the Mai Hanse area, justifying, the region seems likely to become the centre of the country's base and precious-metals exploration effort in the future, and will eventually meet the development needs of country.

7. Reference

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8. Appendix

A) Foliation trend inventoried data of the sub- May Hibey block

Northing	Easting	Elevation(m)	structure observed	Strike	dip dir/amount	Lithology Observed	other structure observed
1546738	388067	1239	foliation and sets of fractures	85NE	175/45	Quartz porphry	sets of fractures striking at 20NE, 60NE 80NE
1546750	388064	1239	foliation and sets of fractures	80NE	170/45	Quartz porphry	Fractures strking at 40NW and 60NE
1546787	388091	1233	folliation and sets of fractures	90E	180/45	Quartz porphry	Fractures with N-S strike
1546800	388005	1191	foliation	85NE	175/40	quartz-feldspathic schist	Quartz veins veins along the foliation
1546734	387942	1162	Foliation	65NE	155/46	quartz-feldspathic schist	Quartz veins veins along the foliation
1546798	387882	1142	Foliation	70NE	160/50	quartz-feldspathic schist	
1546791	387830	1124	Foliation	60NE	150/60	quartz-feldspathic schist	The qtz-fsp-schist looks thrusting over the granite??
1546762	387848	1132	foliation and sets of fractures	70NE	160/30	quartz-feldspathic schist	Fractture planes with strike of 20NE, 70NE, 40NW
1546739	387853	1144	Foliation	65NE	155/45	quartz-feldspathic schist	Fractures across the foliation
1546741	387815	1134	foliation and sets of fractures	80NE	170/25	quartz-feldspathic schist	Fractures along strike of N-S and 20NE
1546743	387797	1141	foliation and sets of fractures	50NE	140/30	Quartz porphry	Fractures striking at 60NW and N-S
1546748	387791	1140	foliation and sets of fractures	60NE	150/30	Quartz porphry	Fractures with strikes of 20NE and 40NW
1546727	387787	1135		60NE	150/30	quartz-feldspathic schist	The qtz-fsp-schist looks thrusting over the granite??
1546727	387789	1139	Qtz-vein				Southern, central and northern tips of a qtz vein striking at
1546732	387789	1140	Qtz-vein				10NE and about 3m surface thickness
1546742	387791	1139	Qtz-vein				
1546589	387965	1226	Foliation	70NE	160/30	quartz-feldspathic schist	Contact with quartz porphry seems thrusting over??
1546604	387969	1231	foliation and sets of fractures	50NE	140/30	quartz-feldspathic schist	Dominant fractures striking at 20NE and 70NW
1546607	387993	1238	Foliation	74NE	164/30	quartz-feldspathic schist	Fractures with strikes of 40NE and 90EW
1546616	388025	1254	Foliation	55NE	145/28	Pre-tectonic granite	Fracture striking at 60NW
1546618	388046	1261	Foliation	58NE	148/50	quartz-feldspathic schist	
1546638	388085	1267	Qtz-vein				Southern, central and northern tips of a qtz vein striking N-S
1546643	388086	1271	Qtz-vein				and thickness of about 4m
1546650	388088	1269	Qtz-vein				
1546492	388009	1261	foliation	45NE	135/30	Pre-tectonic granite	
1546569	388052	1260	foliation	50NE	140/20	quartz-feldspathic schist	
1546623	388047	1260	foliation	68NE	158/30	quartz-feldspathic schist	Contact with quartz porphry seems thrusting over??
1546737	388056	1238	foliation	48NE	138/30	Pre-tectonic granite	Fracture striking at 40NW
1546691	388040	1232	foliation	50NE	140/20	Pre-tectonic granite	
1546671	388015	1242	foliation	50NE	140/25	Pre-tectonic granite	dominant fractures striking at 20NE and 40NW
1546672	388031	1248	foliation	64NE	154/28	Pre-tectonic granite	
1546609	388004	1243	foliation	70NE	160/28	Pre-tectonic granite	
1546527	388980	1244	foliation	70NE	160/24	quartz-feldspathic schist	Two sets of fractures at strikes of 40NW and 20NE
1546510	387961	1241	foliation	70NE	160/40	quartz-feldspathic schist	E-W fractures observed
1546486	387893	1206	foliation	60NE	150/24	quartz-feldspathic schist	Fracture at 40NE intruded by quartz vein of thickness about 2m
1546495	387917	1214	foliation	80NE	170/26	quartz-feldspathic schist	
1546504	387906	1214	foliation	75NE	165/40	quartz-feldspathic schist	
1546505	387928	1210	foliation	80NE	170/30	quartz-feldspathic schist	
1546523	387935	1206	foliation	60NE	150/35	quartz-feldspathic schist	Fracture at 40NW
1546543	387931	1197	foliation	75NE	165/24	quartz-feldspathic schist	Fractures developed at 20NE and 40NW
1546615	387901	1169	foliation	65NE	155/40	Pre-tectonic granite	
1546595	387890	1164	Qtz-vein				NE, middle and NW ends of a qtz-vein striking at 60NW with a
1546536	387886	1154	Qtz-vein				thickness of about 1m
1546595	387876	1152	Qtz-vein				
1546585	387896	1179	foliation	70NE	160/40	quartz-feldspathic schist	
1546548	387882	1189	foliation	75NE	165/28	quartz-feldspathic schist	
1546480	387838	1183	foliation	80NE	170/30	quartz-feldspathic schist	
1546462	387802	1172	foliation	70NE	160/25	quartz-feldspathic schist	sets of fractures striking at 30NE, 40Nw
1546488	387772	1142	foliation	65NE	155/30	Pre-tectonic granite	qtz-vein striking at 40NE offseted with sinistral sense

1546563	387735	1119 foliation	60NE	150/40	quartz-feldspathic schist	Fractures at strikes of E-W and 20NE
1546673	387705	1110 foliation	70NE	160/30	quartz-feldspathic schist	
1546461	387877	1242 foliation	50NE	140/30	quartz-feldspathic schist	
1546459	387816	1181 foliation	70NE	160/26	quartz-feldspathic schist	Qtz-vein of about 30cm thick at a strike of 20NW
1546437	387744	1165 foliation	80NE	170/45	Quartz porphry	Qtz-vein of about 1m thick at a strike of 10NE
1546455	387739	1168 Qtz-vein				South-middle and northern end of a qtz-vein
1546466	387746	1166 Qtz-vein				
1546480	387757	1158 Qtz-vein				
1546511	387738	1143 foliation	78NE	168/20	quartz-feldspathic schist	
1546568	387732	1124 foliation	80NE	170/24	quartz-feldspathic schist	
1546614	387711	1105 foliation	80NE	170/24	quartz-feldspathic schist	
1546571	387665	1140 foliation	80NE	170/38	quartz-feldspathic schist	
1546637	387653	1146 foliation	80NE	170/42	quartz-feldspathic schist	
1546485	387646	1148 foliation	80NE	170/36	chl-qtz-fsp-schist	
1546489	387462	1152 Qtz-vein				southern, middle and northern tip of a vein striking at 40NE and
1546494	387651	1150 Qtz-vein				with thickness of about 1m
1546497	387654	1151 Qtz-vein				
1546612	387565	1151 foliation	80NE	170/40	quartz-feldspathic schist	
1546623	387566	1154 Qtz-vein				northern, middle and southern tip of a vein striking at 30NE
1546614	387561	1156 Qtz-vein				
1546585	387588	1159 Qtz-vein				
1546695	387550	1155 Foliation	78NE	168/28	quartz-feldspathic schist	
1546737	387607	1109 Foliation	78NE	168/30	Qtz-fsp-mica-schist	incontact with quartz porphry
1546774	387592	1115 Foliation	60NE	150/30	chl-mica-schist	
1546785	387471	1132 Foliation	70NE	160/20	quartz-feldspathic schist	Fractures developed at 20NE and 40NW strikes
1546760	387454	1128 Foliation	80NE	170/28	Qtz-fsp-mica-schist	
1546790	387392	1111 Foliation	74NE	164/20	Qtz-fsp-mica-schist	
1546715	387397	1131 Foliation	60NE	150/28	Qtz-fsp-mica-schist	fractures striking N-S
1546621	387432	1142 Foliation	70NE	160/32	Qtz-fsp-mica-schist	
1546663	387500	1151 Foliation	50NE	140/32	Qtz-fsp-mica-schist	incontact with quartz porphry striking at 70NE and qtz vein of 20NE
1546610	387526	1161 Qtz-vein				Qtz vein with approximate strike of 10NE
1546600	387517	1161 Qtz-vein				
1546588	387516	1159 Qtz-vein				Qtz vein with an approximate strike of 20NE
1546579	387510	1157 Qtz-vein				
1546327	387833	1212 Foliation	70NE	160/28	Quartzite	
1546271	387861	1216 Foliation	60NE	150/30	Quartzite	
1546238	387817	1215 Foliation	55NE	145/24	Quartzite	Fracture at 20NW
1546190	387861	1198 Foliation	70NE	160/24	Quartzite	Fractures develped at 40NW and 40NE strikes
1546134	387891	1183 Foliation	60NE	150/20	Quartzite	
1546093	387920	1175 Foliation	58NE	148/26	Quartzite	
1546043	387939	1163 Foliation	54NE	144/28	Quartzite	
1546126	387745	1180 Foliation	60NE	150/30	Quartzite	Qtz-veins of about 1m thick striking at 40NE and 60NW
1546076	387757	1169 Foliation	60NE	150/40	Quartzite	Qtz-veins striking at N-S, 40NE, 50NW
1546956	387707	1127 Foliation	50NE	140/36	Quartzite	
1546047	387666	1132 Foliation	65NE	155/46	quartz-feldspathic schist	
1546114	387651	1135 Foliation	50NE	140/40	quartz-feldspathic schist	
1546144	387563	1134 Foliation	54NE	144/28	Quartzite	
1546090	387569	1130 Foliation	70NE	160/30	Quartzite	
1546030	387545	1120 Foliation	65NE	155/30	Quartzite	qtz veins striking 40NE and 40NW, fractures striking 15NW, E-W
1546095	387479	1103 Foliation	80NE	170/30	quartz-feldspathic schist	

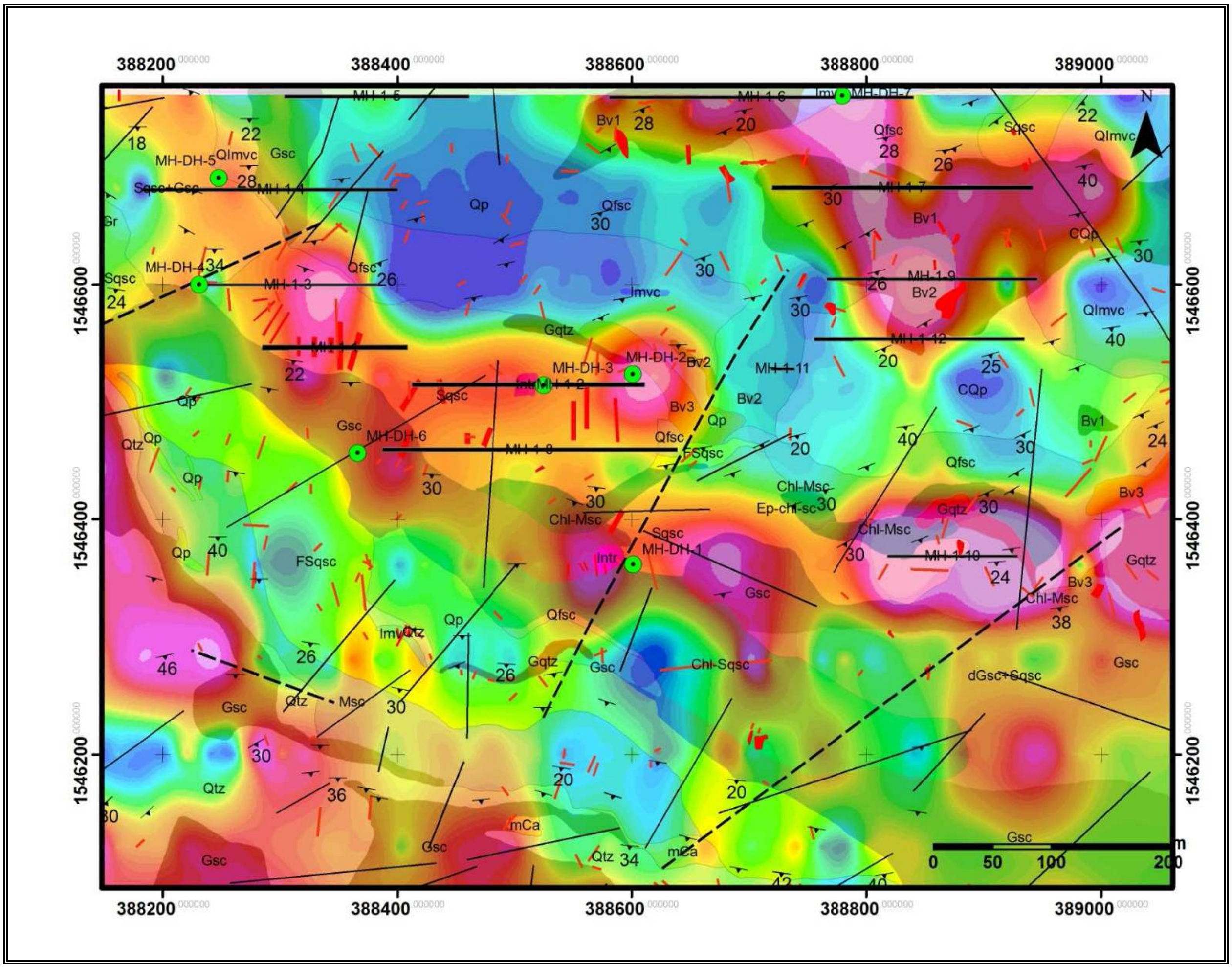
1546124	387513	1118	Foliation	80NE	170/38	quartz-feldspathic schist	
1546182	387569	1127	Foliation	60NE	150/32	Qtz-fsp-mica-schist	
1546212	387570	1117	Qtz-vein				qtz vein of thickness about 2m and striking at 40NW
1546221	387575	1113	Qtz-vein				
1546228	387579	1111	Qtz-vein				
1546344	387555	1139	Foliation	58NE	148/28	quartz-feldspathic schist	
1546433	387717	1153	Foliation	60NE	150/38	Qtz-fsp-mica-schist	
1546452	387616	1145	Foliation	54NE	144/28	quartz-feldspathic schist	
1546377	387621	1142	Qtz-vein				qtz vein of thickness about 2m and striking at 40NE
1546387	387629	1147	Qtz-vein				
1546394	387638	1149	Qtz-vein				
1546364	387622	1147	Foliation	80NE	170/30	quartz-feldspathic schist	
1546312	387625	1146	Qtz-vein				Qtz vein of about 4m thick and striking at 20NE
1546297	387618	1139	Qtz-vein				
1546283	387611	1135	Qtz-vein				
1546294	387580	1133	Foliation	70NE	160/32	quartz-feldspathic schist	
1546251	387609	1120	Qtz-vein				Qtz vein of about 4m thick and striking at 40NE
1546248	387604	1119	Qtz-vein				
1546240	387602	1114	Qtz-vein				
1546239	387576	1110	Foliation	78NE	168/36	quartz-feldspathic schist	
1546257	387642	1126	Foliation	76NE	166/26	quartz-feldspathic schist	
1546284	387645	1131	Foliation	50NE	140/30	Quartz porphry	
1546274	387641	1128	Foliation	60NE	150/26	quartz-feldspathic schist	qtz veins striking 40NE,40NW, 10NW, 30NW, 24NE
1546255	387653	1137	Foliation	50NE	140/26	quartz-feldspathic schist	
1545993	387508	1131	Foliation	70NE	160/28	Graphitic phyllite	
1545872	387574	1138	Foliation	70NE	160/26	Graphitic phyllite	
1545828	387718	1144	Foliation	64NE	154/25	Quartzite	
1545809	387781	1136	Foliation	68NE	158/30	Quartzite	
1546382	388059	1276	Foliation	50NE	140/24	Quartzite	
1546329	388074	1279	Foliation	42NE	132/30	quartz-feldspathic schist	
1546357	388048	1259	Foliation	52NE	142/20	Quartzite	
1546320	388023	1259	Foliation	40NE	130/28	Quartzite	
1546267	388038	1262	Foliation	50NE	140/24	Quartzite	
1546240	388072	1244	Foliation	44NE	134/20	Qtz-chl-schist	
1546208	388107	1236	Foliation	44NE	134/24	Qtz-chl-schist	
1546189	388024	1221	Foliation	46NE	136/28	Quartzite	
1546223	387996	1219	Foliation	50NE	140/28	Quartzite	
1546285	387933	1207	Foliation	50NE	140/24	Quartzite	
1546152	387921	1169	Foliation	60NE	150/26	Quartzite	fractures filled with qtz veyns striking 50NW, 80NE,20NE,60NE
1546083	388011	1155	Foliation	40NE	130/26	Quartzite	
1546096	388087	1193	Foliation	60NE	150/32	Quartzite	
1546077	388098	1193	Foliation	64NE	154/30	Quartzite	
1546128	388120	1211	Foliation	54NE	144/32	Quartzite	
1546157	388152	1232	Foliation	50NE	140/30	Quartzite	
1546149	388187	1256	Foliation	48NE	138/30	Quartzite	
1546053	388211	1255	Foliation	70NE	160/38	Graphitic schist	
1546030	388149	1239	Foliation	65NE	155/34	Graphitic schist	
1546037	388096	1214	Foliation	60NE	150/32	Graphitic schist	
1546016	388043	1188	Foliation	70NE	160/30	Graphitic schist	
1545951	388130	1211	Foliation	60NE	150/38	Graphitic schist	

1545934	388106	1203	Foliation	58NE	48/40	Graphitic schist	
1545902	388060	1181	Foliation	50NE	140/36	Graphitic schist	
1545867	388005	1157	Foliation	54NE	144/34	Graphitic schist	
1545360	387897	1130	Foliation	60NE	150/32	Graphitic schist	
1545943	387931	1163	Foliation	50NE	140/36	Graphitic schist	
1545952	387860	1155	Foliation	50NE	140/28	Graphitic schist	
1545875	387822	1134	Foliation	50NE	140/30	Graphitic schist	
1545850	387801	1135	Foliation	60NE	150/28	Graphitic schist	
1545888	387789	1136	Foliation	70NE	160/30	Graphitic schist	
1545811	388281	1151	Foliation	60NE	150/26	Graphitic schist	
1545809	388344	1160	Foliation	50NE	140/20	Graphitic schist	
1545805	388375	1173	Foliation	50NE	140/40	Graphitic schist	
1545848	388374	1176	Foliation	48NE	138/38	Graphitic schist	
1545918	388389	1177	Foliation	50NE	140/40	Graphitic schist	
1545941	388404	1183	Foliation	50NE	140/36	Graphitic schist	
1545935	388432	1194	Foliation	50NE	140/30	Graphitic schist	
1546538	388106	1291	Foliation	80NE	170/28	Graphitic schist	fractures developed at 10NE and 40NE
1546514	388078	1288	Foliation	78NE	168/40	quartz-feldspathic schist	
1546440	388082	1302	Foliation	80NE	170/38	quartz-feldspathic schist	fractures developed at 60NE and 10NW, E-W
1546433	388086	1301	Qtz-vein				Qtz vein of about 2m thick and strike of 20NE
1546436	388088	1308	Qtz-vein				
1546443	388092	1306	Qtz-vein				
1546386	388130	1303	Foliation	72NE	162/46	Graphitic schist	
1546342	388086	1289	Foliation	70NE	160/44	quartz-feldspathic schist	
1546282	388202	1276	Foliation	78NE	168/46	quartz-feldspathic schist	
1546208	388280	1275	Foliation	60NE	150/30	Quartzite	
1546178	388349	1258	Foliation	90E	180/36	Quartzite	
1546183	388326	1272	Foliation	84NE	174/30	Quartzite	
1546161	388384	1266	Foliation	100E	190/30	Quartzite	
1546063	388421	1244	Foliation	70NE	160/30	Graphitic PHYLLITE	
1545849	389477	1114	Foliation	80NE	170/40	quartz-feldspathic schist	
1545859	389379	1118	Foliation	60NE	150/48	quartz-feldspathic schist	
1545926	389370	1111	Foliation	64NE	154/40	quartz-feldspathic schist	
1545904	389483	1126	Foliation	64NE	154/34	quartz-feldspathic schist	
1545980	389499	1128	Foliation	70NE	160/30	quartz-feldspathic schist	
1546020	389469	1113	Qtz-vein				Qtz vein of about 2m thick and strike of 72NE
1546018	389461	1116	Qtz-vein				
1546018	389452	1114	Qtz-vein				
1546202	389478	1113	Foliation	60NE	150/30	Mica-chl-schist	
1546316	389432	1136	Foliation	60NE	150/28	Mica-chl-schist	
1546293	389177	1094	Foliation	75NE	165/30	Mica-chl-schist	
1546323	389195	1107	Foliation	60NE	150/20	chl-schist	
1546277	389257	1119	Foliation	72NE	162/20	chl-schist	
1546264	389315	1121	Foliation	60NE	150/22	chl-schist	
1546266	389369	1129	Foliation	60NE	150/26	chl-schist	
1546315	389420	1130	Foliation	64NE	154/34	chl-schist	
1546347	389465	1156	Foliation	62NE	152/30	chl-schist	
1546406	389493	1179	Foliation	52NE	142/40	qtz-fsp-chl-schist	

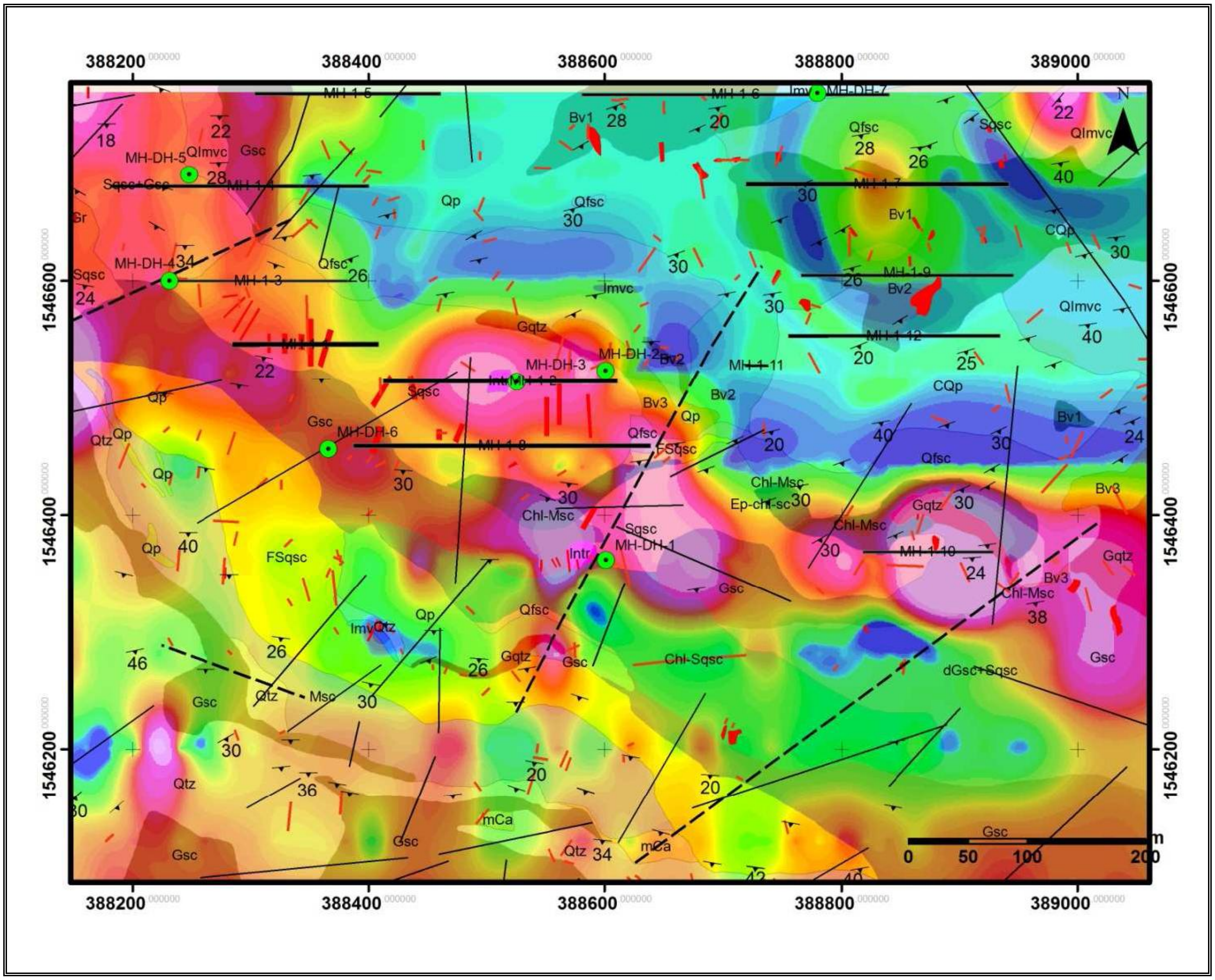
1546391	389468	1165	Foliation	66NE	156/30	chl-qtz-fsp-schist	
1546327	389282	1110	Foliation	80NE	170/40	qtz-fsp-chl-schist	
1546357	389305	1128	Foliation	60NE	150/30	qtz-fsp-chl-schist	
1546358	389331	1130	Foliation	62NE	152/30	chl-qtz-fsp-schist	
1546370	389364	1128	Foliation	60NE	150/28	chl-qtz-fsp-schist	
1546388	389327	1121	Foliation	50NE	140/26	chl-qtz-fsp-schist	
1546409	389351	1122	Foliation	64NE	154/38	chl-qtz-fsp-schist	
1546434	389388	1135	Foliation	56NE	146/30	chl-qtz-fsp-schist	
1546427	389412	1140	Foliation	70NE	160/48	chl-schist	
1546471	389429	1152	Foliation	58NE	148/30	chl-qtz-fsp-schist	
1546518	389428	1135	Foliation	70NE	160/24	chl-qtz-fsp-schist	
1546494	389403	1136	Foliation	52NE	142/28	chl-qtz-fsp-schist	
1546473	389372	1125	Foliation	62NE	152/24	chl-qtz-fsp-schist	
1546425	389336	1113	Foliation	62NE	152/30	chl-schist	
1546380	389309	1107	Foliation	60NE	150/20	chl-schist	
1546494	389209	1122	Foliation	70NE	160/36	qtz-fsp-schist	
1546544	389296	1126	Foliation	72NE	162/32	qtz-fsp-schist	
1546576	389364	1127	Foliation	62NE	152/38	chl-qtz-fsp-schist	
1546597	389344	1130	Qtz-vein				Qtz vein of about 4m thick and striking at 20NE
1546588	389339	1128	Qtz-vein				
1546579	389333	1125	Qtz-vein				
1546575	389287	1129	Foliation	66NE	156/24	chl-qtz-fsp-schist	
1546539	389203	1117	Foliation	78NE	168/30	Qtz-fsp-mica-schist	
1546591	389166	1097	Foliation	70NE	160/28	chl-schist	
1546691	389229	1130	Foliation	52NE	142/28	chl-qtz-fsp-schist	
1546809	389032	1082	Foliation				qtz vein of about 8m thick and strike of 12NE
1546801	389027	1081	Qtz-vein				
1546781	389020	1074	Qtz-vein				
1546753	388889	1059	Foliation	70NE	160/34	qtz-fsp-schist	
1546737	388911	1053	Foliation	54NE	144/24	qtz-fsp-schist	
1546699	388986	1058	Foliation	80NE	170/50	chl-schist	
1546658	388980	1056	Foliation	78NE	168/30	Mica-chl-schist	
1546635	389033	1060	Foliation	84NE	174/30	Mica-chl-schist	
1546620	389006	1066	Foliation	76NE	166/40	Mica-chl-schist	
1546561	389009	1073	Foliation	82N	172/40	chl-schist	
1546574	389038	1037	Foliation	80NE	170/30	chl-schist	
1546555	389069	1069	Foliation	80NE	170/35	chl-schist	
1546432	389989	1071	Foliation	72NE	162/30	chl-schist	
1546487	389035	1038	Foliation	66NE	156/32	chl-qtz-fsp-schist	
1546508	389076	1078	Foliation	70NE	160/26	chl-qtz-fsp-schist	
1546478	389047	1097	Foliation	66NE	156/24	chl-qtz-fsp-schist	Qtz vein of strike 44NW
1546446	389037	1092	Foliation	58NE	148/26	chl-qtz-fsp-schist	
1546461	389079	1105	Foliation	80NE	170/34	qtz-fsp-schist	
1546460	389122	1102	Foliation	64NE	154/20	chl-qtz-fsp-schist	
1546435	389096	1118	Foliation	80NE	170/25	chl-qtz-fsp-schist	
1546434	389147	1103	Foliation	74NE	164/20	chl-qtz-fsp-schist	Qtz vein of N-S strike
1546337	389002	1103	Foliation				QTZ vein of about 6m thick and striking at 10NE

1546443	388801	1094	Foliation	70NE	160/30	Quartz-porphry	
1546477	388834	1068	Foliation	80NE	170/40	Quartz-porphry	
1546475	388890	1085	Foliation	70NE	160/30	Quartz-porphry	
1546423	388925	1097	Foliation	60NE	150/20	qtz-fsp-schist	
1546438	388929	1082	Foliation	60NE	150/30	qtz-fsp-schist	
1546470	388934	1085	Foliation	65NE	158/24	Quartz-porphry	
1546549	388958	1068	Foliation	74NE	164/24	chl-schist	
1546538	388906	1074	Foliation	74NE	164/25	Quartz-porphry	
1546565	388851	1078	Foliation	60NE	150/20	chl-schist	
1546714	388875	1057	Foliation	68NE	158/24	qtz-fsp-schist	
1546753	388985	1047	Foliation	40NE	130/22	chl-schist	
1546491	388931	1074	Qtz-vein				QTZ VEIN OF ABOUT 2M THICK STRIKING 10NW
1546499	388931	1070	Qtz-vein				
1546631	388875	1070	Qtz-vein				Qtz vein of about 2m thick striking 10NW
1546643	388877	1071	Qtz-vein				
1546651	388875	1064	Qtz-vein				
1546410	388738	1117	Foliation	70NE	160/38	chl-schist	
1546378	388783	1119	Foliation	60NE	150/30	chl-schist	
1546423	388765	1120	Foliation	80NE	170/30	Quartz porphry	
1546437	388686	1110	Foliation	70NE	160/24	Quartz porphry	
1546462	388711	1099	Foliation	65NE	155/22	Quartz porphry	
1546469	388741	1112	Foliation	76NE	166/20	Quartz porphry	
1546543	388815	1085	Foliation	68NE	158/20	Quartz porphry	
1546574	388772	1094	Qtz-vein				qtz vein of about 2m thick and striking at 16NE
1546576	388776	1090	Qtz-vein				
1546609	388809	1070	Foliation	75NE	165/26	Quartz porphry	
1546587	388742	1088	Foliation	80NE	170/30	Quartz porphry	
1546587	388703	1092	Foliation	78NE	168/28	Quartz porphry	
1546621	388661	1096	Foliation	70NE	160/30	Quartz porphry	
1546650	388748	1099	Foliation	68NE	158/20	chl-schist	
1546631	388782	1086	Foliation	62NE	152/38	chl-schist	
1546617	388810	1095	Qtz-vein				QTZ vein of about 4m thick striking to 40NW
1546629	388816	1086	Qtz-vein				
1546642	388802	1088	Foliation	60NE	150/28	chl-mica-schist	
1546681	388769	1140	Foliation	70NE	160/30	chl-mica-schist	
1546746	388696	1114	Foliation	80NE	170/20	chl-mica-schist	
1546723	388817	1139	Foliation	80NE	170/28	Quartz porphry	
1546712	388867	1148	Foliation	84NE	174/26	Quartz porphry	
1546594	388159	1137	Foliation	100E	190/24	Quartz porphry	
1546719	388137	1218	Foliation	90E	180/24	qtz-fsp-schist	
1546733	388120	1205	Foliation	92E	182/20	qtz-fsp-schist	
1546749	388146	1187	Foliation	94E	184/20	Graphitic quartzite	
1546732	388178	1182	Foliation	90E	180/18	Quartz porphry	fractures observed striking to 20NW and 30NE
1546762	388224	1156	Foliation	110E	200/20	Graphitic quartzite	
1546739	388274	1168	Foliation	90E	180/22	qtz-fsp-schist	
1546659	388573	1142	Foliation	76NE	166/30	Quartz porphry	
1546714	388581	1137	Foliation	60NE	150/36	chl-schist	
1546747	388609	1136	Foliation	70NE	160/28	chl-schist	
1546728	388679	1127	Foliation	66NE	156/30	chl-schist	

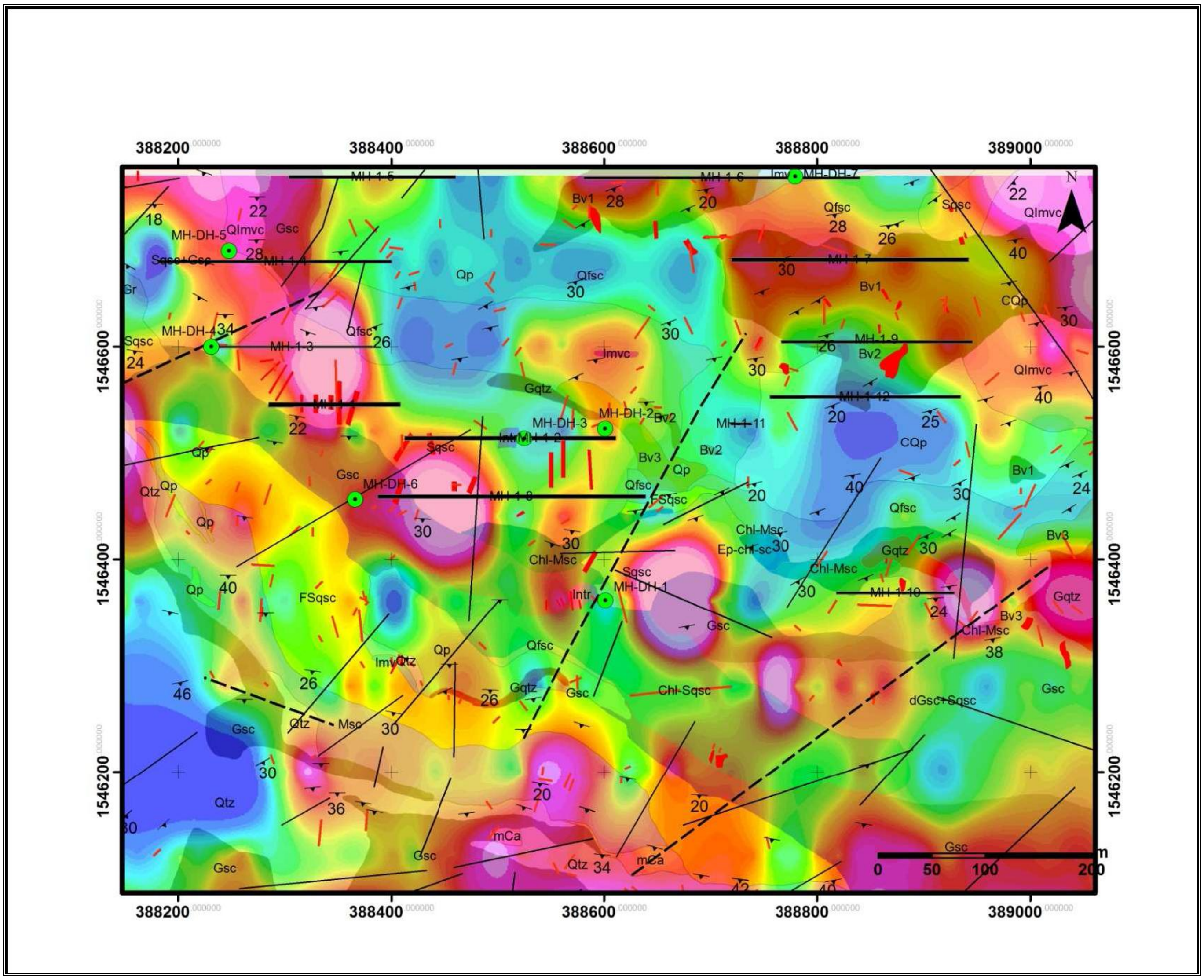
B) The soil anomaly grid maps for base metals (Cu, Pb and Zn) overlaid on the mapped lithological units, bore holes and trenches of the detail area



Cu anomaly map overlaid on mapped lithologies, foliations, lineaments and others



Pb anomaly map overlaid on lithologies and structures bore holes and trenches



Zn-anomaly map overlaid on lithologies, structures, bore holes and trenches locations

C) Thin Section Analyisis

Sample No. 1	Sample type: Rock	
Rock Name: **Chlorite -Miscovite Schist**	**Type of Analysis:** Thin section preparation & petrographic analysis.	
Hand specimen description:		

Abr.	**Mineral**	**Mode %**	**Texture**
	Musovite	45	Xenoblastic
	Chlorite	28	Fibrous
	Calcite	6	Xenoblastic- Hypidioblastic
	Epidote	10	Xenoblastic
	Opaque	10	Xenoblastic- Hypidioblastic
	Plagioclase	1	Xenoblastic
	Biotite	Trace	Flaky

Sample No. 2	Sample type: Rock	
Rock Name: **Seri cite - Quartz Schist**	**Type of Analysis:** Thin section preparation & petrographic analysis.	
Hand specimen description:		

Abr.	**Mineral**	**Mode %**	**Texture**
	Feldspar	40	Xenoblastic
	Quartz	32	Xenoblastic
	Epidote	7	Xenoblastic
	Chlorite	5	Fibrous
	Sericite	10	Fine
	Calcite	6	Xenoblastic
	Opaque	Trace	Xenoblastic

Sample No. 3	Sample type: Rock	
Rock Name: **Quartz-Chlorite -*Muscovite* Schist**	**Type of Analysis:** Thin section preparation & petrographic analysis.	
Hand specimen description:		

Abr.	**Mineral**	**Mode %**	**Texture**
	Muscovite	35	Xenoblastic
	Quartz	9	Xenoblastic
	Chlorite	28	Fibrous
	Epidote	10	Xenoblastic
	Opaque	10	Xenoblastic
	Biotite	6	flaky
	Plagioclase	2	Xenoblastic
	Calcite	Trace	Xenoblastic

Sample No. 4		Sample type: Rock	
Rock Name: **Quartz -*Feldspar* Schist**		**Type of Analysis:** Thin section preparation & petrographic analysis.	
Hand specimen description:			

Abr.	**Mineral**	**Mode %**	**Texture**
	Feldspar	35	Xenoblastic
	Quartz	33	Xenoblastic- Hypidioblastic
	Opaque	14	Xenoblastic
	Epidote	6	Xenoblastic
	Sphene	5	Xenoblastic
	Calcite	4	Xenoblastic
	Plagioclase	3	Xenoblastic
	Muscovite	Trace	Flaky

Sample No. 5	Sample type: Rock	
Rock Name: **Quartz-Feldspar Schist**	**Type of Analysis:** Thin section preparation & petrographic analysis.	
Hand specimen description:		

Abr.	**Mineral**	**Mode %**	**Texture**
	Feldspar	39	Xenoblastic
	Quartz	21	Xenoblastic
	Opaque	23	Xenoblastic- Hypidioblastic
	Epidote	7	Xenoblastic
	Sphene	6	Xenoblastic
	Plagioclase	4	Xenoblastic
	Biotite	Trace	Flaky

Sample No. 6	Sample type: Rock	
Rock Name: **Quartz-Feldspar Schist**	**Type of Analysis:** Thin section preparation & petrographic analysis.	
Hand specimen description:		

Abr.	**Mineral**	**Mode %**	**Texture**
	Feldspar	70	Xenoblastic- Hypidioblastic
	Plagioclase	8	Xenoblastic
	Quartz	15	Xenoblastic
	Epidote	10	Xenoblastic
	Chlorite	Trace	Fibrous
	Biotite	Trace	Flaky

Sample No. 7	Sample type: Rock	
Rock Name: **Chlorite-Biotite-Muscovite Schist (Metavolcanics)**	**Type of Analysis:** Thin section preparation & petrographic analysis.	
Hand specimen description:		

Abr.	**Mineral**	**Mode %**	**Texture**
	Muscovite	42	Xenoblastic- Hypidioblastic
	Biotite	20	Flaky
	Chlorite	15	Fibrous
	Epidote	9	Xenoblastic
	Quartz	8	Xenoblastic
	Opaque	6	Xenoblastic
	Calcite	Trace	Xenoblastic

Sample No. 8	Sample type: Rock	
Rock Name: **Chlorite-Biotite- Quartz –Seri cite-Schist**	**Type of Analysis:** Thin section preparation & petrographic analysis.	
Hand specimen description:		

Abr.	**Mineral**	**Mode %**	**Texture**
	Seri cite	38	fine
	Quartz	20	Xenoblastic
	Chlorite	15	Fibrous
	Biotite	10	Flaky
	Calcite	9	Xenoblastic
	Opaque	8	Xenoblastic

Sample No. 9	Sample type: Rock	
Rock Name: **Talc Schist**	**Type of Analysis:** Thin section preparation & petrographic analysis.	
Hand specimen description:		

Abr.	**Mineral**	**Mode %**	**Texture**
	Talc	67	fibrous
	Calcite	12	Xenoblastic
	Chlorite	9	fibrous
	Opaque	10	Xenoblastic
	Biotite	2	Xenoblastic

Sample No. 10	Sample type: Rock	
Rock Name: **Quartzite**	**Type of Analysis:** Thin section preparation & petrographic analysis.	
Hand specimen description:		

Abr.	**Mineral**	**Mode %**	**Texture**
	Quartz	43	Hypidioblastic-Xenoblastic
	Orthoclase	36	Hypidioblastic-Xenoblastic
	Opaque	18	*Idioblastic*-Xenoblastic
	Chlorite	2	Fibrous
	Biotite	1	Flaky
	Calcite	Trace	Xenoblastic

D) Drill hole Collar

HoleID	Easting	Northing	RL	Azimuth	Dip	Total Depth
MH-DH-1	388600	1546360	1133	270	55	150.1
MH-DH-2	388600	1546520	1153.65	270	55	154.5
MH-DH-3	388524	1546503	1150	270	55	150.45
MH-DH-4	388230	1546600	1212.353	90	55	150
MH-DH-5	388246	1546687	1186.5	90	55	150.55
MH-DH-6	388365	1546456	1154	90	55	146.3
MH-DH-7	388775	1546760	1072.5	270	55	125.1
MH-DH-8	388810	1546600	1075	90	55	120
MH-DH-9	388454	1546120	1246	90	55	150.25
MH-DH-10	388537	1546330	1148	70	55	160.8
MH-DH-11	388765	1547232	1035	320	55	148.7
MH-DH-12	388368	1546401	1161	90	55	150.25
MH-DH-13	388776	1547218	1034	320	55	119.5
MH-DH-14	388382	1546649	1159	90	55	80
MH-DH-15	388293	1546521	1182	70	55	100
MH-DH-16	388640	1546360	1121	270	55	140.1
MH-DH-17	388303	1546641	1182	290	55	80.15
MH-DH-18	388260	1546564	1187	70	55	100
MH-DH-19	388690	1546082	1148	250	55	94.5
MH-DH-20	388575	1546489	1136	70	55	120.2
MH-DH-21	388636	1546280	1143	250	55	160
MH-DH-22	388255	1546601	1202	55	55	102.4
MH-DH-23	388403	1546503	1161	90	55	119.75
MH-DH-24	388602	1546401	1126	250	55	141.6
MH-DH-25	388485	1546450	1122	270	55	120.5
MH-DH-26	388328	1546487	1170	70	55	120.5
MH-DH-27	388643	1546240	1149	250	55	212
MH-DH-28	388655	1546287	1134	250	55	201.1
MH-DH-29	388345	1546456	1161	90	55	130.25
MH-DH-30	388274	1546514	1182	70	55	140
MH-DH-31	388309	1546479	1170	70	55	130.4
MH-DH-32	388344	1546456	1161	90	65	130.25