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VEIN TYPES, VEIN TEXTURES AND QUARTZ TEXTURES OF THE GOLD-QUARTZ VEINS IN THE TAUNG NI GOLD PROSPECT AREA, MADAYA TOWNSHIP, MANDALAY REGION, MYANMAR*

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Abstract

Taung Ni area is situated in Madaya Township, Mandalay Region, Myanmar. The mineralization style of the study area is the vein type deposit hosted by quartzite jointed and brecciated interbedded with phyllite. Two main types of quartz veins were observed within the Taung Ni gold-bearing quartz veins system: primary gold-bearing sulphide quartz veins and secondary auriferous deformed / remobilized quartz veins. The quartz veins have generally segmented structure with typically brecciated and laminated/banded textures. Mineralogically quartz dominates in all the mineralized veins and a variety of textures, such as massive quartz, comb quartz, mosaic textures quartz, sheared quartz, and mechanical breakdown of quartz are present. Three generations of quartz based on morphology have been identified: the coarse-grained quartz (first quartz generation), fine-grained to ribbon quartz due to recrystallization (second quartz generation), and sheared and comb structure quartz (third quartz generation). The distinct alteration processes are silicification, chloritization, sericitization, pyritization and hematization. Gold- bearing sulphide quartz veins show a stockwork structure with chalcopyrite filled fractures. Gold occurs as inclusions in chalcopyrite and hematite. Auriferous deformed/remobilized quartz veins show the crushed and fractured characteristics with hematite filled fractures. The hematite quartz bands offer the best potential for significant gold concentration. Fluid inclusion data indicated that the gold-bearing mineralized quartz veins were developed within mesothermal environment. On the basic of those discovered genetic characteristics, quartz veins and textures of quartz, the Taung Ni gold prospect is a orogenic (mesothermal) gold type.

Keywords –Vein types, vein textures, quartz textures, quartz generations, Orogenic (Mesothermal) gold, Taung Ni area**.**

Introduction

Taung Ni area is situated in Madaya Township, Mandalay Region, Myanmar. It is located approximately 35 km northwest of Pyin-Oo-Lwin and about 37 km NE of Mandalay. It lies between Mogok Metamorphic Belt (MMB) (Searle et al., 1964) in the east and the Sagaing Fault (Win Swe, 2013) in the west. The area occupies the western marginal zone of Shan Plateau and to the east of the Central Myanmar Basin. Location map of the study area is shown in Figure.1.

Methods of Study

This study consists of two main stages, field investigations and laboratory work. During the field work, more than fifty (50) rock samples containing of ore and quartz vein materials were collected from Taung Ni gold prospect area. These samples were prepared as thin sections, and polished sections to conduct several types of analysis. Thin sections were examined petrographically to study textural relationships. Mineralization vein textures were carefully noted during the field observation, but some were interpreted from thin sections by optical microscopy using transmitted light. Alternatively, polished sections of ores were studied using reflected light under ore microscope to identify ore mineral assemblages. Furthermore, some of the ore minerals were confirmed by scanning electron microscopy with energy-dispersive X-ray (SEM-EDX). All

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laboratory methods were performed at the Department of Geology, University of Yangon, Myanmar and Defence Services Science and Technology Research Centre, Pyin Oo Lwin, Myanmar.

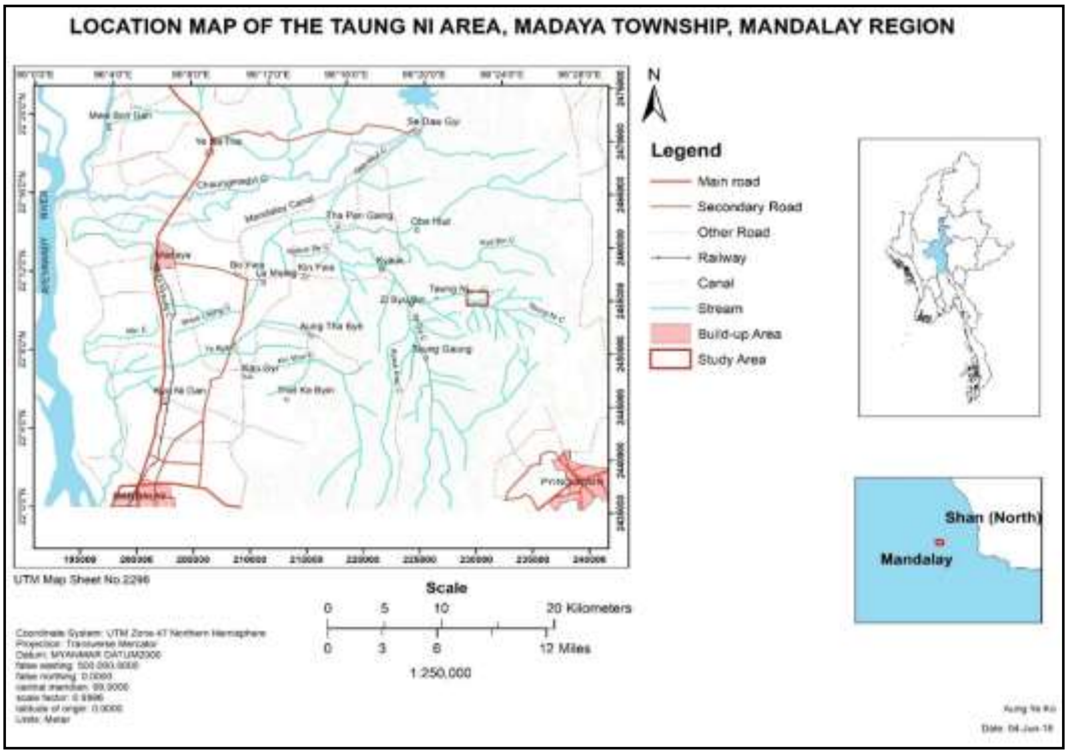

Figure 1 Location Map of the Study Area, Madaya Township, Mandalay Region

Geological Background

With increased knowledge in plate tectonics, it is now generally accepted that Myanmar is geologically built up of two main parts, the Eastern Part or Shan-Thai Block (Bunopas et al., 1983) or Sibumasu Terrane (Metcalfe, 1984) (Kachin Highlands, Shan Plateau, Tenasserim Ranges, East Himalayan Syntaxis, Mogok Metamorphic Belt, etc.) and the Western Part or Burma Platelet or Burma Microplate (Curray et al., 1979) or West Burma (Searle et al.,) with its accretionary prism of Indo-Burman Ranges or Western Ranges (Naga and Chin Hills and Arakan Yoma). Sagaing Fault, a major right lateral strike-slip fault of 1500 km length (Win Swe, 2013 and Soe Thura Tun et al., 2017) geotectonically separates these two parts along the middle. Both parts belong to the larger Asian Plate. India Plate is subducting beneath Burma Microplate, and thus, in the Andaman Sea, forms an east-dipping curvilinear oblique subduction zone that continues onshore along the Western margin of the Indo-Burman Ranges.

The study area, falling in the Shan -Thai Block, lies on the eastern margin of Mogok Metamorphic Belt (MMB), between the Sagaing Fault in the west and the Shan Scarp Fault in the east (Figure 2. a). The MMB consists of Metamorphosed Sedimentary sequences of Precambrian to Carboniferous age. Basement sediments are intruded by Jurassic to Tertiary granitoids (Searle et al., 2007). Regional stratigraphy of the study area and its environs are shown in Figure 2. b. Stratigraphic rock units include Mogok Group, Chaungmagyi Group, Molohein Group, Pindaya Group, Mibayataung Group and Upper Plateau Limestone Group (Maung Thein, 2014).

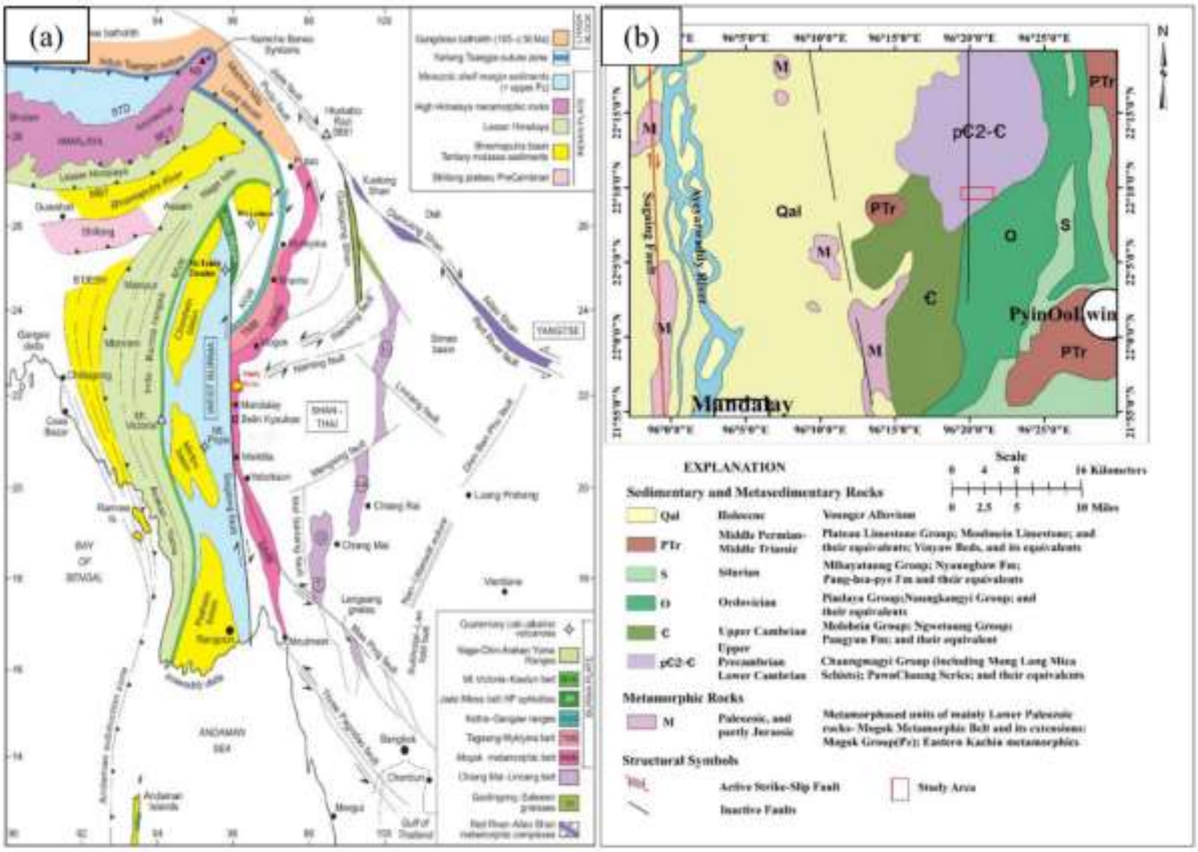

Figure 2 (a) Geological map of Myanmar and surrounding areas showing major structures, faults and Terrane boundaries (Searle et al., 2007). Study area is located within the Mogok Metamorphic Belt (MMB), marked by a star, (b) Regional geological map of the study area and its environs (Maung Thein, 2014).

Geology of Study Area

The geology of the Taung Ni area is quite simple. There is only one stratigraphic rock unit in this area. It is Late Precambrian to Early Cambrian age of Chaungmagyi Group, consisting of **Mauk Kaw Quartzite and Kin Sandy Phyllite** (Khin Maung Swe, 1973) (Figure 3**)**. From microscopic study and XRD results, quartzite and phyllite were found to be composed of low-grade metamorphic minerals such as albite, quartz, chlorite, sericite, epidote, muscovite, actinolite, and biotite. Opaque minerals were often found as disseminations especially observed in phyllite with foliations resulting from the sub-parallel to parallel orientation of minerals such as chlorite or micas due to strong pressure conditions of metamorphism. This rock type has been evidently formed by low grade regional metamorphism. The common occurrence of chlorite and sericite suggest the low pressure and low temperature. Thus, this rock type belongs to the greenschist facies (Aung Ye Ko et al.,2019a).

From field observation, major anticlinal structure was found near the gold deposit which is an asymmetrical anticline of E-W dipping. The east dip with 60° is steeper than that of the west, 42°. Based on measurement of joint sets (N=69) in the field, it shows trends of NNE - SSW, ENE - WSW and NE-SW. The prominent joint set is NE-SW. Fault criteria (slickensides) were usually formed on quartzite. A main foliation that dips steeply towards SE and NW, a stretching lineation that plunges gently NE and SW and a top-to-SW sense of ductile shearing were obseарved. Mineralized vein systems formed on the crest of anticline and synclines. These mineralized veins were complex and found in shear zones, indicating structural control (Aung Ye Ko, 2020).

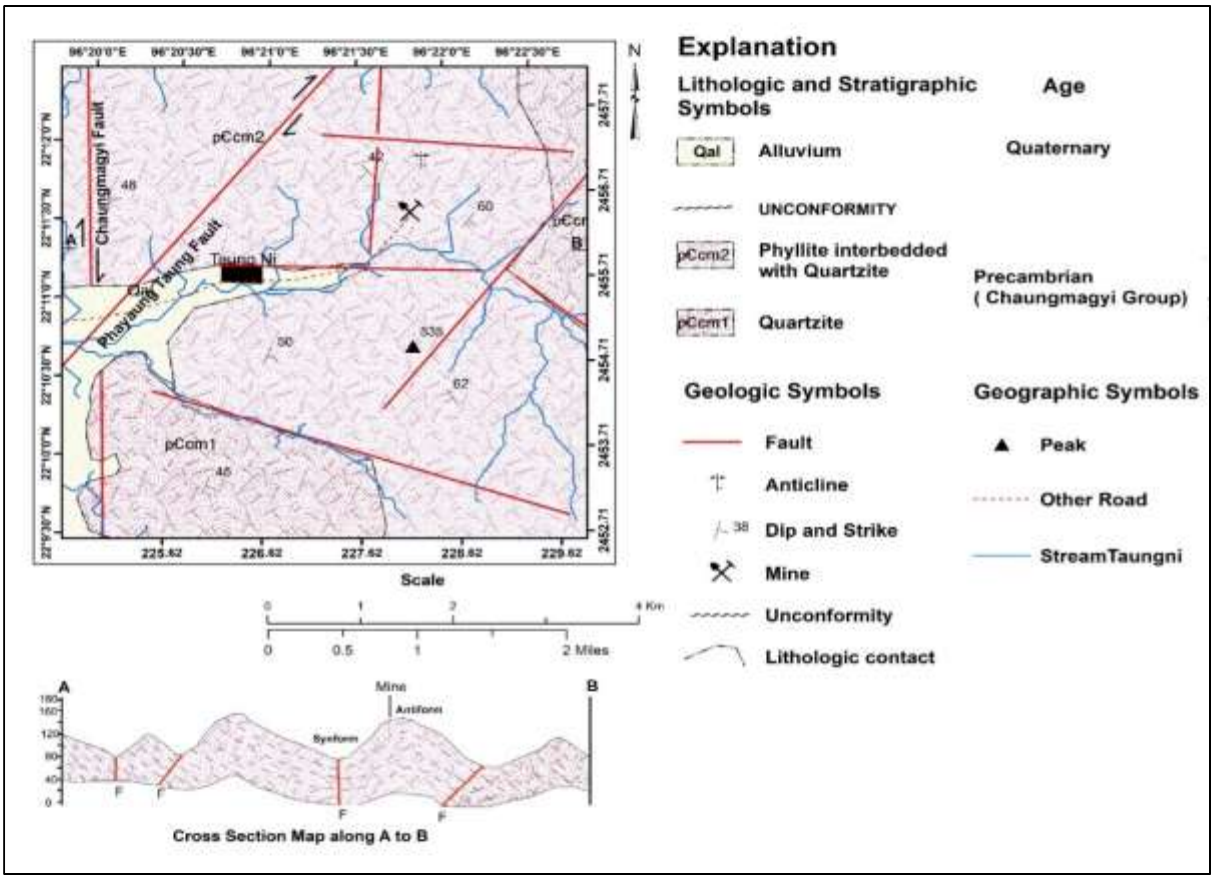

Figure 3 Geological Map of the Taung Ni Area, Madaya Township, Mandalay Region

Vein Types

The mineralization style of the study area is the vein type deposit hosted by deformed, jointed and brecciated quartzite interbedded with phyllite. The gold mineralization is associated with quartz veins occurring along the fractures of the host rock. Regionally, Taung Ni gold mineralization lies within the shear zone between Sagaing Fault and Shan Scarp Fault. The main controlling factor is the regional structure that nearly trends NE-SW and possibly formed by the activity of Phayaung Taung Fault causing the deformation like, shearing, brecciation favourable for mineralization. The gold-bearing quartz veins/ veinlets filled NE-SW and E-W structure lineaments of dilational fault zone. In the field, gold-bearing mineralized veins were observed mostly brecciated and crushed. The deposit profile suggests that the gold mineralization is most possibly related to orogeny because strong compressional and transpressional (shear) environment (Groves et al., 1998) were clearly developed indicating the strong structural control.

Two main types of quartz veins were observed within the Taung Ni gold-bearing quartz veins system: primary gold-bearing sulphide quartz veins and secondary auriferous deformed/ remobilized quartz veins. Gold-bearing sulphide quartz veins were more abundant than auriferous deformed/remobilized quartz veins in the gold prospect. Veins occurs mostly as veinlets and stringers, and stockwork veins (Figure 4. a & b).

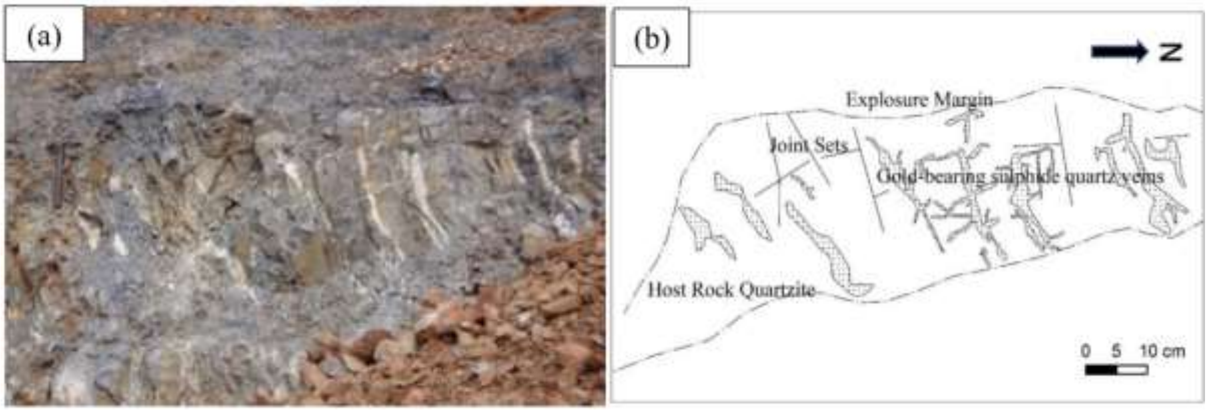

Figure 4 (a) & (b) Stockwork vein system of sulphide quartz veins hosted in quartzite

The thickness of primary gold-bearing sulphide quartz veins range from 1 to 10 cm. Veins are hosted in quartzite. Mostly, veins are steep dipping and vein direction range NNE-SSW/60°-75°vertical within host rocks (Figure 5. a & b). Secondary auriferous deformed / remobilized quartz veins are commonly developed near the E-W post-mineralization structures and they are much brecciated, deformed in oxidized zone (Figure 6. a & b). The thickness of veins is from 0.5cm to 4cm. Visible gold associated with secondarily formed hematite, Fe- hydroxides are rich in deformed quartz veins filling in micro fractures and at the crest of the vein and brecciated quartzite zone.

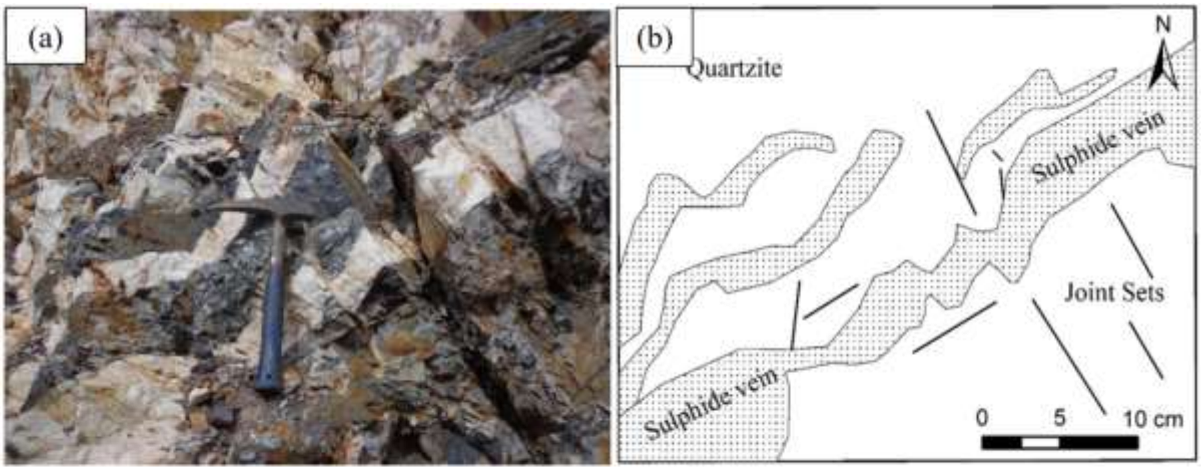

Figure 5 (a) & (b) Individual vein system of sulphide quartz veins hosted in quartzite

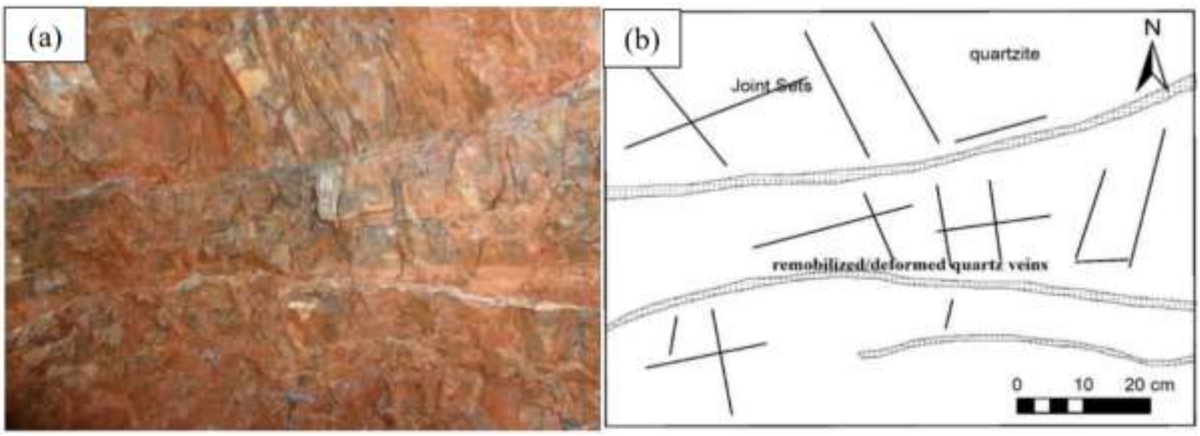

Figure 6 (a) & (b) Individual vein system of deformed /remobilized quartz veins hosted in quartzite

Vein Textures

Most of the hydrothermal veins are formed from silica-bearing fluids that originated from (1) igneous intrusions; (2) deep convection of meteoric fluids; (3) metamorphic devolatilization; (4) mantle-derived fluids (Jia et al., 2000). Quartz veins are commonly found in low-grade metamorphic rocks, typically within or above the brittle-ductile crustal stress field, forming around 2-3 kbar and 200-350°C. Hydrothermal veins can be syn-tectonic to post-tectonic (Bons, 2001). The texture has been grouped into three major classes (primary, recrystallization, and replacement) to aid interpretation of their origin and environment of formation. Primary growth textures represent initial open-space vein fill. Recrystallization textures reflect the transformation of amorphous silica or chalcedony to quartz. Replacement textures represent partial or complete pseudomorphs of other minerals by silica minerals within veins.

In the study area, the primary gold-bearing sulphide quartz veins are commonly segmented with massive, brecciated and laminated/banded textures (Figure 7. a, b, c & d). They are composed predominantly of reddish-brown to milky whitish quartz. Auriferous deformed/remobilized quartz veins developed in brecciated and oxidized zone. Vein internal texture is dissimilar to primary veins and composed crystals were of irregular form, containing much micro-fracture/ crack in which filled by secondary oxidized minerals. The mineralized veins are composed of old rose to milky white quartz. Most quartz veins show the crushed and fractured characteristics (Figure 8. a, b, c & d).

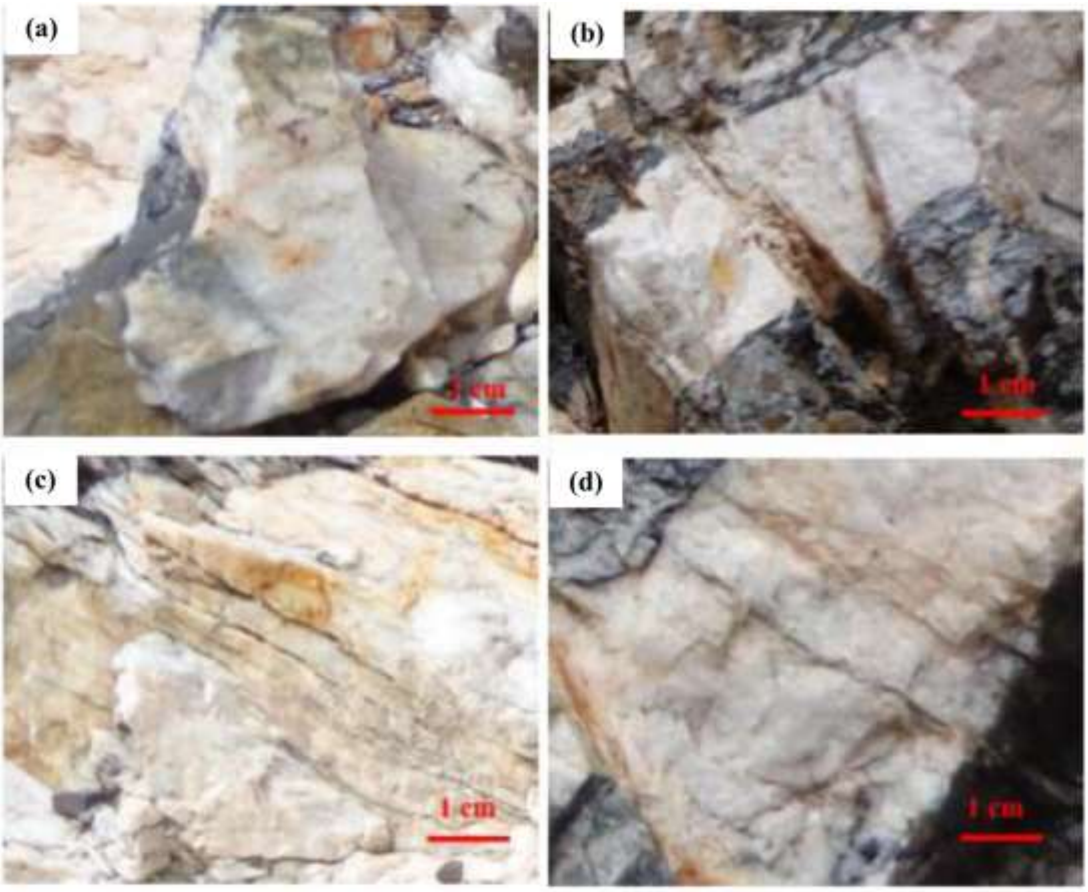

Figure 7 (a) & (b) Massive quartz veins (c) Laminated quartz vein, and (d) Banded quartz veins

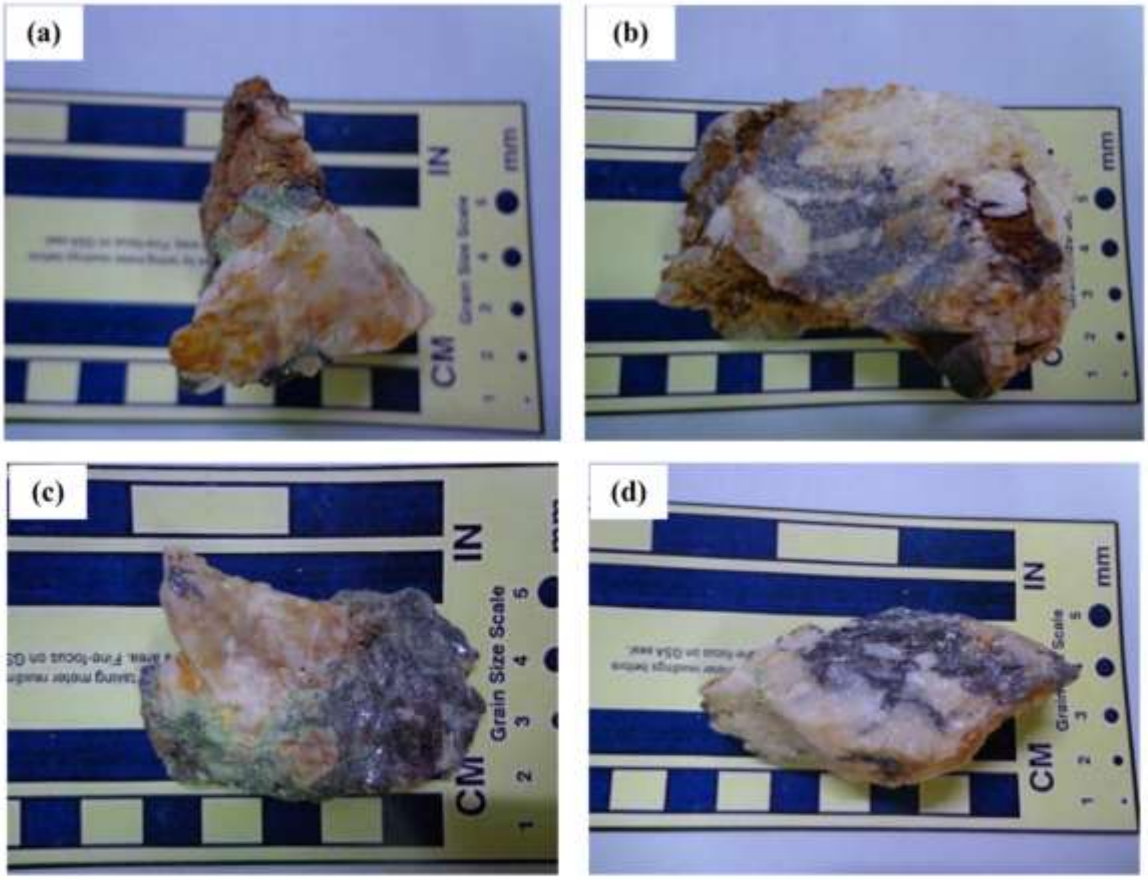

Figure 8 (a), (b), (c) & (d) Brecciated and oxidized quartz veins

Quartz Textures and Alteration Mineralogy

Quartz textures are excellent indicators of the nature and intensity of deformation prevailing during vein formation (Jébrak,1992, Vearncombe,1993 and Bouchot et al,1994). Mineralogically, quartz dominates in all the mineralized veins and commonly displays multiple growth stages and a variety of textures, such as comb quartz, recrystallized quartz (mosaic texture quartz), crushed and fractured characteristics of quartz (sheared quartz) and mechanical breakdown of quartz (Figure 9, 10 and 11). Quartz grains boundary are closely interlocked with irregular margins probably due to recrystallization and pressure effect. All quartz grains show wavy extinction and size equality is very poor. Little amounts of sericite are found along the marginal granulation and fractures of quartz grains. The mechanical fractures and marginal granulations are also common. All these fractures indicate the pre or syn-tectonic crystallization of quartz veins (Bons, 2001). Sheared and comb structure quartz indicate the formation of veins accompanied by intense stress and shearing (Folk,1974).

In the mineralized quartz veins, three generations of quartz based on morphology have been identified (Fig. 12). They include coarse-grained quartz with deformed grain boundaries (Qtz1, Fig. 12 a& b), incipient recrystallized quartz (Qtz2) defined by small polygonal quartz grains, sub-grains occupying inter-grain planes mainly parallel to the grain boundaries and vein margins (Figure 12 a, b, c, d & e) and deformed-elongated (stretched) quartz ribbons (Qtz3 Fig. 12 c, d, e & f). The quartz crystals display undulate extinction. The coarse-grained quartz regarded as the first generation and fine-grained to ribbon quartz due to recrystallization (second generation) resulting from multiple episodes of deformation and fluid circulation (Kurz et al., 2000, Oliver, 2001 and White, 2001).

Sheared and comb structure quartz (third generation) indicate the formation of veins accompanied by intense stress and shearing (Folk,1974).

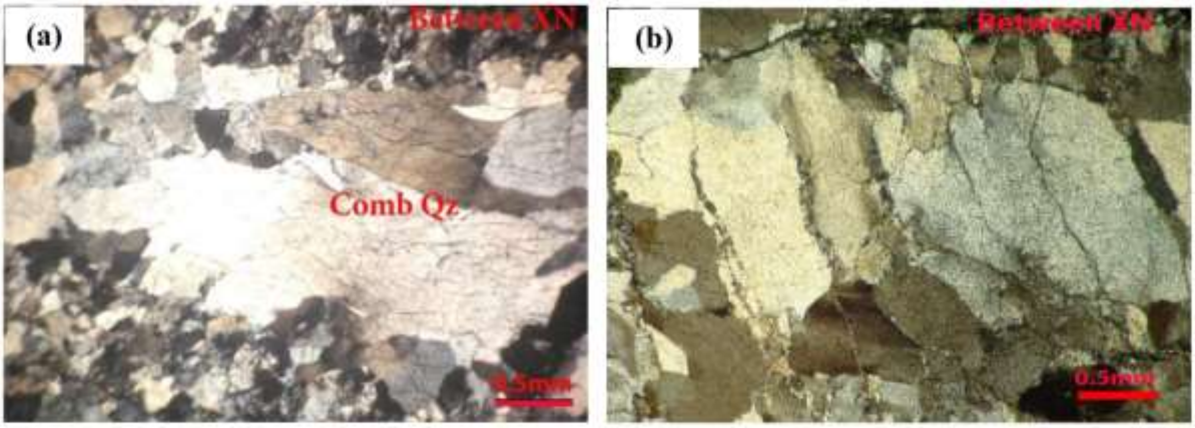

Figure 9 (a) & (b) Comb texture of quartz in quartz vein (Thin-section) (Between XN)

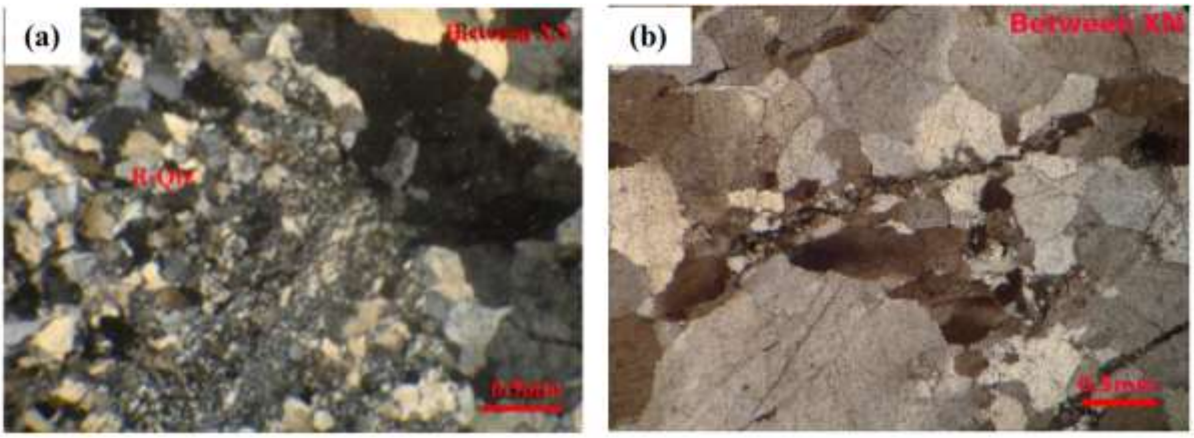

Figure 10 (a) & (b) Recrystallized quartz (R-Qtz) (Mosaic texture) in quartz vein (Thin-section) (Between XN)

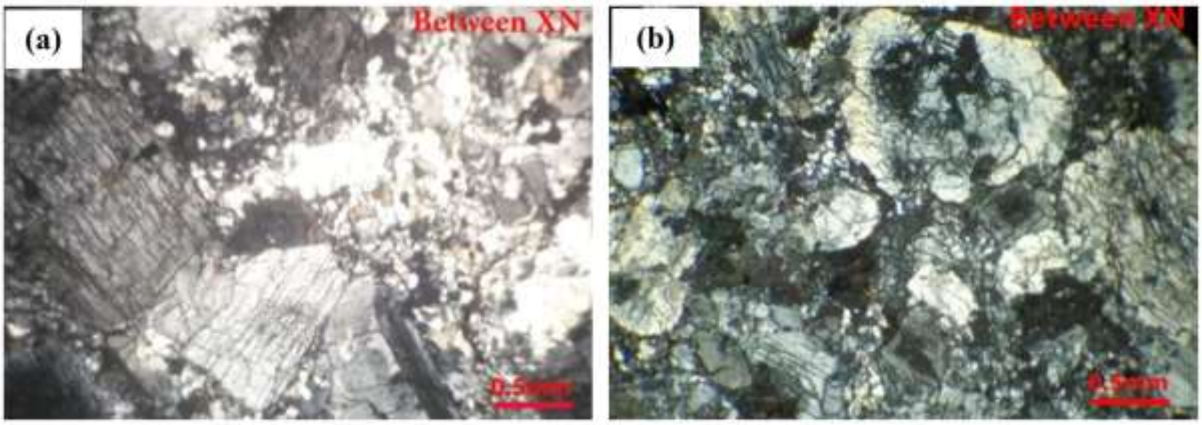

Figure 11 (a) Crushed and fractured characteristics of quartz (Sheared quartz) (b)Mechanical breakdown of quartz grains (Sheared quartz) (Thin-section) (Between XN)

Hydrothermal alteration was restricted to narrow zone around veins overlapping regional metamorphism that occurred in the study area. Sericite is abundant along the contact with the quartzite wallrock. The formation of sericite in the altered wallrock increases the permeability along the shear zone since sericite enhances permeability and facilitates ductile deformation (Kurz et al., 2000, Oliver, 2001 and White, 2001). Generally, the vein related alteration is characterized by silicification, sericitization, chloritization and pyritization and carbonization from inner to outermost zones. Hematization and kaolinitization are found in oxidized/ supergene and strongly brecciated zones of post-mineral structural controlled wallrocks. From the microscopic study and XRD results, three distinct alteration mineral assemblages were formed; quartz + sericite + chlorite ± kaolinite, quartz + sericite + chlorite ± kaolinite ± carbonate and iron oxide + quartz + sericite + chlorite. According to the field observation, microscopic study and XRD results, the distinct alteration processes occurred in the study area are silicification, chloritization, sericitization, pyritization and hematization (Aung Ye Ko, 2020).

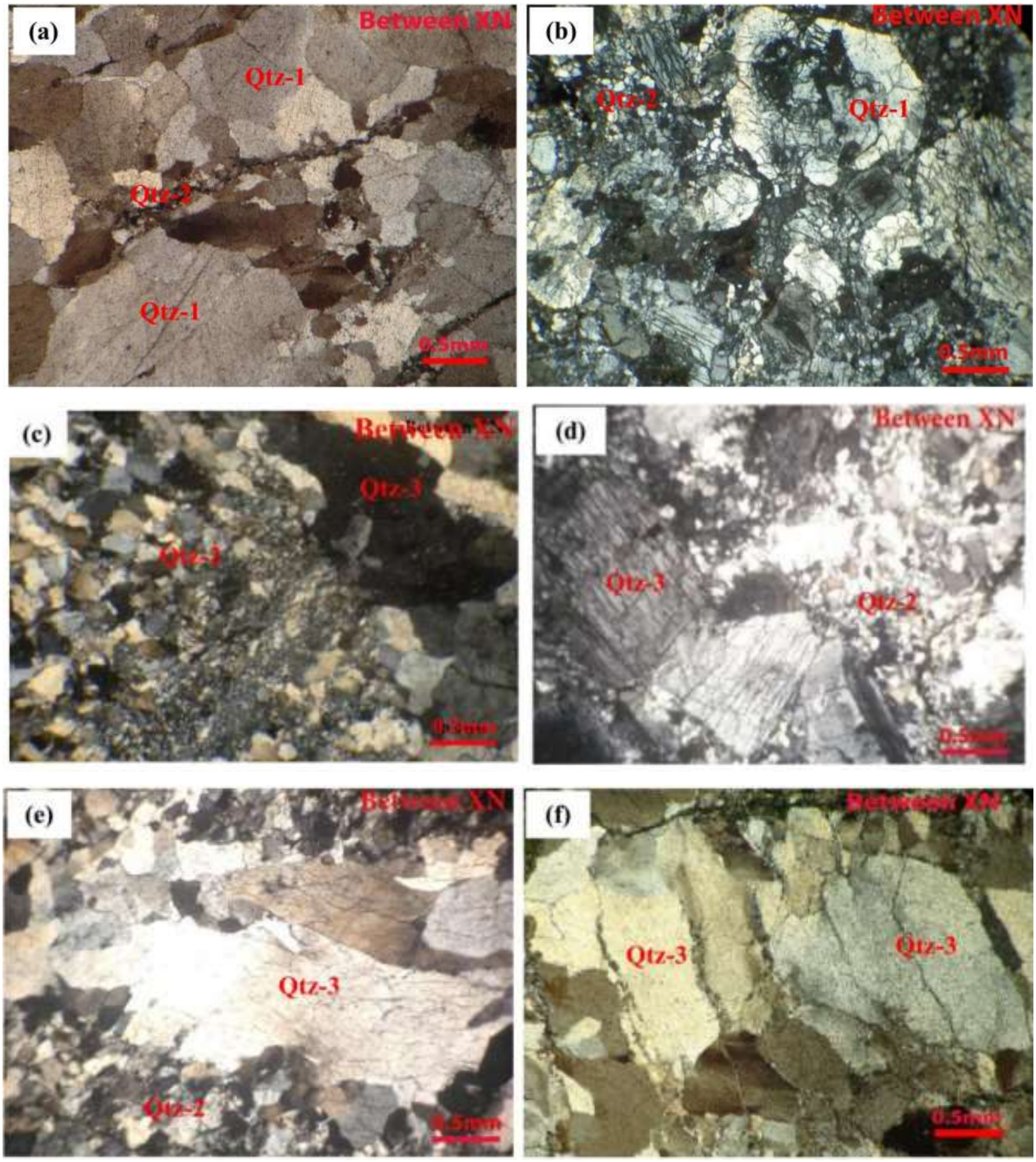

Figure 12 Photomicrograph showing generations of quartz in the mineralized quartz vein in Taung Ni area (Abbreviations: Qtz1=first quartz generation, Qtz2=second quartz generation, Qtz3=third quartz generation).

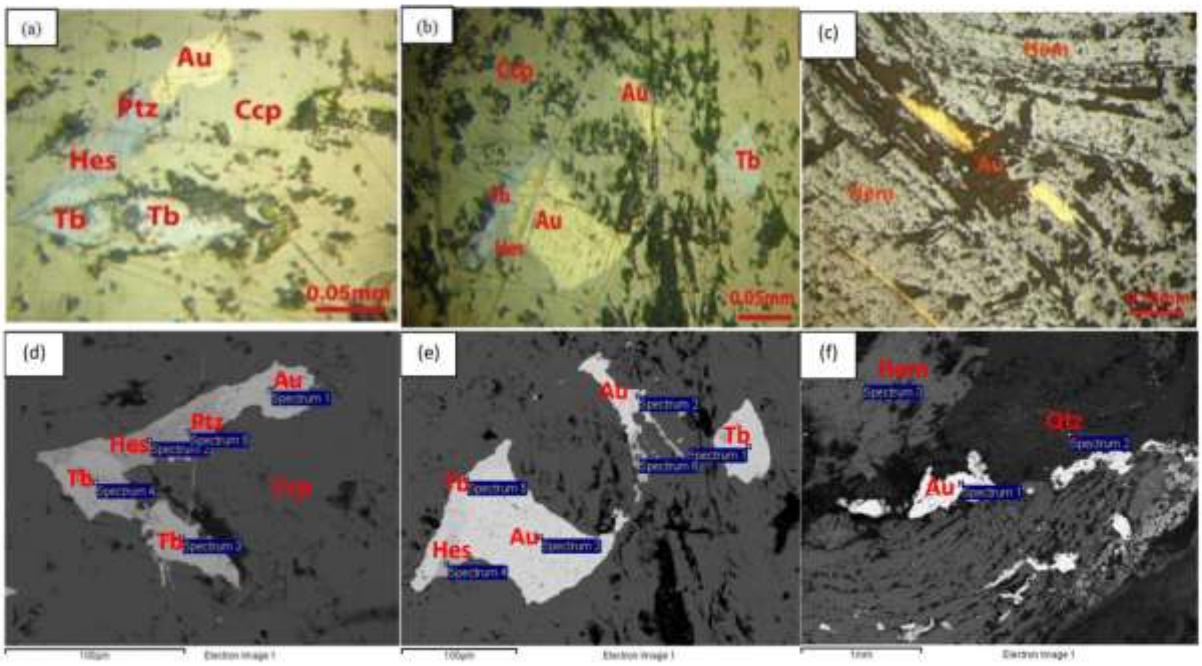

Figure 13 (a), (b) & (c) Gold associated with petzite, hessite, chalcopyrite, tellurobismuthite, hematite and quartz (Polished Section), (d), (e) &(f) Back Scattered images of gold, petzite, hessite, chalcopyrite and tellurobismuthite, hematite and quartz (Au = Gold, Ptz = Petzite, Hes = Hessite, Ccp = Chalcopyrite and Tb= Tellurobismuthite, Hem = Hematite Qtz=quartz).

The gold-bearing sulphide quartz veins mainly contain gold, electrum, petzite, hessite, chalcopyrite, tellurobismuthite and quartz dominated gangue minerals. Gold could be observed in chalcopyrite and closely associated with rare tellurium and bismuth compound minerals. Electrum grains were also found especially in sulphide quartz veins. Electrum grains are associated with gold in chalcopyrite grains and some are in quartz. In secondary veins, native gold occurs either as isolated free grain in the matrix of quartz as well as closely associated with hematite and bismuth. Its grains are strongly related to deformed, remobilized quartz veins in the brecciated zone (Figure 13). They were found together with hematite in micro-fractures of quartz. That indicates supergene origin at least in part for the native gold in Taung Ni gold prospect.

From fluid inclusion data of mineralized quartz veins, it can be deduced that there are two different mineralization phases marked by difference of homogenization temperature and salinity. Fluid inclusion microthermometry data of selected samples is shown in Table.1 Temperature-salinity diagram for various types of ore deposits (Wilkinson, 2001) is shown in Figure 14 (Aung Ye Ko, 2020).

Table 1 Fluid inclusion microthermometry data of selected samples

Sample ID	Host Rock	Host Mineral	Inclusion Type	No. of Inclusion	Homogeni-zation Tem, Range (°C)	Ice Melting Tem (°C)	Salinity (wt% NaCl.)	Remarks
PYT-1	quartzite	quartz	L-V	11	340-403	-1.7 to -2	3.01 to 3.53	Sulphide quartz vein (Early Stage)
PYT-2	quartzite	quartz	L-V	10	320-396	-1.3 to -1.6	2.31 to 2.83	Deformed quartz vein (Later Stage)

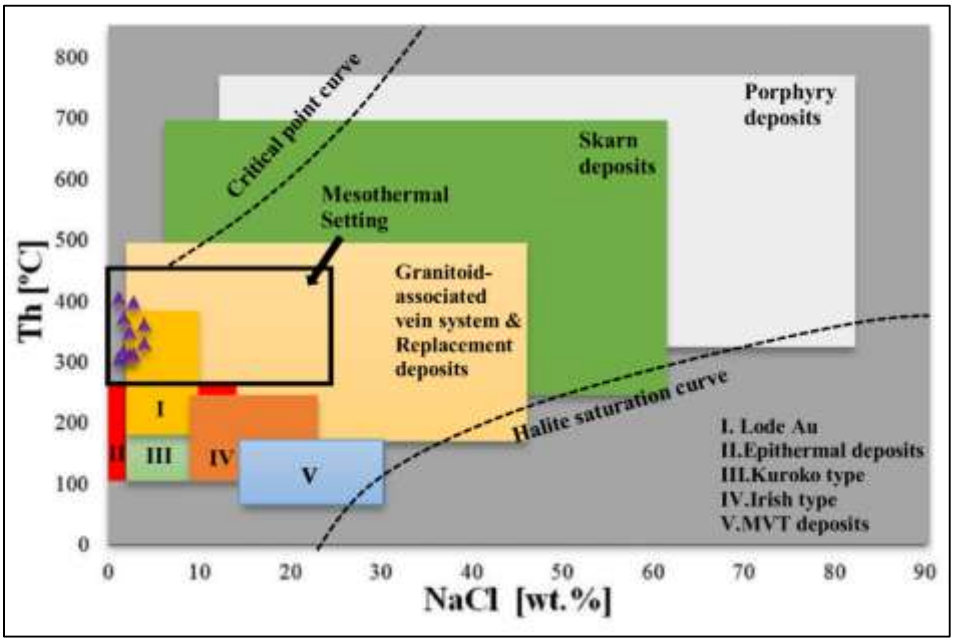

Figure 14 Temperature-salinity diagram for various types of ore deposits (Wilkinson, 2001)

Discussion

The mineralization style of the study area is the vein type deposit hosted by quartzite which is deformed, interbedded with phyllite, jointed and brecciated. Mineralized vein systems formed on the crest of anticlines and synclines. These mineralized veins were complex and found in shear zones, indicating structural control. The gold-bearing quartz veins/ veinlets filled NE-SW and E-W trending dilational fault zone. Gold-bearing mineralized veins are mostly brecciated and crushed. These deformation structures focused and enhanced crustal fluid circulation and mineralization. The deposit profile suggests that the gold mineralization must be related to orogeny because strong compressional and transpressional (shear) environment (Groves et al., 1998) were clearly developed.

Faults and shear zones are major fluid conduits in crustal basement (Kerrich, 1986 and (Knipe, 1993). Breccias are a common product in the highest, most fluid-saturated part of crustal fault zones where the potential for dilation strain increases the range of breccias formation processes (Woodcock et al., 2008). Brecciation is an excellent precursor to mineralization, as circulating hydrothermal fluids will readily interact with the fractured rocks. Enhanced permeability created in breccia zones provides pathways for crustal fluids that are sometimes metal- or hydrocarbon-rich (Woodcock et al., 2008). Thus, breccias are associated with numerous types of ore deposits both in surface and subsurface environments (Jebrak, 1997).

Gold mineralization in Taung Ni shear zone system is associated with brecciated quartz veins in steeply dipping brittle-ductile shear zones. Here brecciation is enhanced by transgranular fracturing. The quartz veins breccias show a characteristic stockwork structure with a network of discontinuous and closely spaced fractures that host mineralization. As such, the breccias act as a matrix for hydrothermal deposits. Gold-bearing quartz veins are commonly segmented, occasionally brecciated and laminated and has massive texture. In fact, gold- bearing quartz veins in the prospect area exhibit orogenic/mesothermal gold type (Groves et al., 2003).

By field evidence and fluid inclusion, it has been found that data, later stage veins were formed at around 1 km depth and early-stage mineralization were developed at 3km below the paleo water table. As indicated by mineralization with different depth conditions, it can be assumed that the MMB was uplifted between (Late Oligocene–Early Miocene, 26 and 21 Ma, Li et al., 2013 and Late Eocene–Early Miocene, 31-24 Ma, Searle et al., 2017) due to sustained subduction and collision. There was an uplift deformation occurring before later phase mineralized veins system. In view of geological conditions, fluid inclusion data, host rock mineralogy and ore mineral assemblages, gold-bearing mineralized quartz veins were found to be developed under mesothermal conditions. Figure 15 depicts interpretation mineralized system based on field evidence and fluid inclusion data.

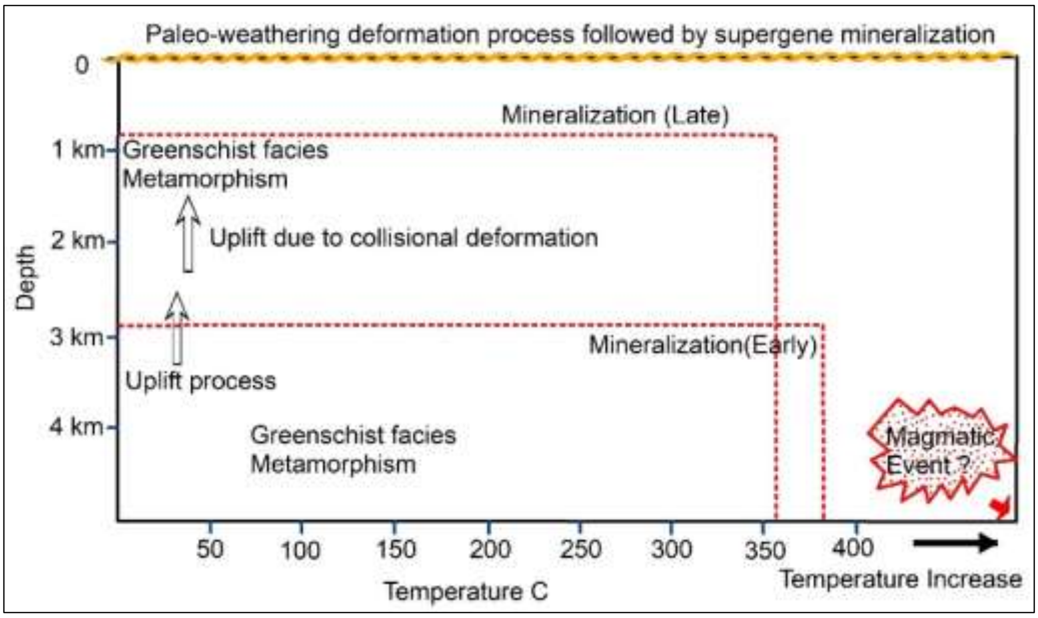

Figure 15 Schematic diagram of mineralization depth based on field evidence and fluid inclusion data showing possible two mineralization events (late mineralization developed during uplift due to collisional deformation) (Adapted from Win Phyo, 2017)

Mineralogically, quartz dominates in all the mineralized veins commonly displaying multiple growth stages and a variety of textures. Especially, primary growth texture such as massive quartz and comb quartz, and recrystallized texture such as mosaic texture quartz are found in all the quartz veins. Sheared quartz, and mechanical breakdown of quartz also dominate in all the mineralized veins. Sheared and comb structure quartz indicate the formation of veins accompanied by intense stress and shearing (*Folk*, 1974).

By morphology, three generations of quartz have been identified. They include coarse-grained quartz with deformed grain boundaries (Qtz1), incipient recrystallized quartz (Qtz2) defined by small polygonal quartz grains and sub-grains occupying inter-grain planes mainly parallel to the grain boundaries and vein margins and deformed-elongated (stretched) quartz ribbons (Qtz3). The coarse-grained quartz regarded as the first generation and fine-grained to ribbon quartz due to recrystallization (second generation) resulting from multiple episodes of deformation and fluid circulation (Kurz et al., 2000, Oliver, 2001 and White, 2001). Sheared and comb structure quartz (third generation) indicate the formation of veins accompanied by intense stress and shearing (*Folk*, 1974).

The distinct alteration processes are silicification, chloritization, sericitization, pyritization and hematization. Sericite is abundant at the contact with the quartzite wallrock. The formation of sericite in the altered wallrock increases the permeability along the shear zone since sericite enhances permeability and facilitates ductile deformation (Kurz et al., 2000, Oliver, 2001 and White, 2001).

Gold- bearing sulphide quartz veins show a stockwork structure with chalcopyrite filled fractures. Gold occurs as inclusions in chalcopyrite and hematite. Auriferous deformed /remobilized quartz veins show the crushed and fractured characteristics with hematite filled fractures. Hydrothermal hematite quartz bands offer the best potential for significant gold concentration Suh et al. (Suh et al., 2006). It is true at Taung Ni gold prospect.

Conclusions

Taung Ni vein system is structurally controlled by a dominant NE-SW trending shear zone and gold mineralization is most possibly related to orogeny. Quartz vein textures exhibit criteria of mesothermal (orogenic) gold type. All of quartz textures are indicative of orogenic gold mineralization. The generations of quartz also imply that the gold prospect is orogenic gold type. Fluid inclusion data indicated that the gold-bearing mineralized quartz veins were developed under mesothermal environment. According to the deposit profile, and the characteristics of the vein type, vein textures, and quartz textures, Taung Ni gold prospect is orogenic gold mineralization formed under mesothermal conditions.

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