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Hydrothermal Gold Mineralization and Some Features of Ore Mineral at the Onzon-Kanbani Area, Central Myanmar

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ABSTRACT

The Onzon-Kanbani area is a western flank of the Mogok Metamorphic Belt where a gold mineralization is hosted as auriferous quartz-vein with epithermal low-sulfidation style. Mineralization is closely associated with NE-SW trending fractures or a shear zone probably related to the dextral movement of the Sagaing Fault system. Mineralization related hydrothermal alteration is developed as narrow zones along the hydrothermal conduit as silicic alteration, sericite-illite alteration, and propylitic alteration. Dominant alteration minerals are quartz, ±adularia, sericite, chlorite, actinolite, epidote, illite, and smectite. The quartz dominant and base metal quartz-carbonate mineralized veins are characterized by open-space fracture filling of sharp-walled as well as minor amounts of disseminating nature in marble. Gold occurs as free grains or locked within pyrite, sphalerite, galena, and gangue minerals, e.g., quartz. In place, large electrum gold grains are associated with sphalerite and pyrite in the gold-bearing quartz vein whereas fine-grained inclusions or blebs of native gold are observed in pyrite and sphalerite as disseminated specks. Gold and base metal mineralization were mostly deposited in Stage I 'mineralization stage'. In place, 'Stage II' is a barren stage where quartz or calcite veins are barren possessing very minor amounts of pyrite. In the last stage, 'Stage III', some of supergene minerals of hematite, goethite, and chalcocite were formed from primary sulfides through oxidation. Mineralogically, the correlation of gold (Au) with silver (Ag) and copper (Cu) is positive. Nonetheless, gold (Au) versus other ore minerals of lead (Pb), zinc (Zn), tin (Sn) and antimony (Sb) displays negative correlations. The grades of gold and other ore minerals reduce from mineralized veins to outer alteration zones.

Keywords : *Hydrothermal alteration, Mogok Metamorphic Belt, Sagaing Fault, Electrum, Native gold*

1. Introduction

The Onzon-Kanbani gold deposit is one of the primary gold deposits from central Myanmar. It is located in Thabeikkyin Township, Madalay Region. Small-scale local gold mines and abundant artisanal works in this area started thirty years ago. This area is a part of the Mogok Metamorphic Belt [1] which is one of the distinct geological and metallogenic provinces in Myanmar. This belt was formed either by collision in the late Mesozoic [2] or through the strike-slip movement in the Early Triassic [3]. Generally, gold deposits along the Mogok Metamorphic Belt are considered as mesothermal 'orogenic gold' [4] but they belong to epithermal to mesothermal and locally skarn mineralization types. Gold mineralization in Onzon-Kanbani is limited to fracture and shear zones. Currently, gold mineralization is mainly excavated from marble-hosted quartz veins. Quartz veins were the target of gold mining, and locally, stream-sediment prospecting led to the discovery of gold anomalies. The present work have revealed information about structural control on mineralization's vein system, characteristics of ore minerals, mineral paragenesis, geochemistry of ore minerals and their distribution in hydrothermally altered zones. This study will provide detailed structural and mineralogical data of mineralization that formed in the hydrothermal system of the Onzon-Kanbani area.

2. Geologic Setting

Most of Myanmar geological units were formed during the Mesozoic to Cenozoic tectonic processes of subduction, collision, and accretion by a series of plates that rifted off from Gondwana in the south., There are three plates in this region; India, West Burma and Sibumasu (Shan-Thai Block), that have chiseled the landform of Myanmar during the stage of closing the Tethys Ocean (Fig. 1). The early Paleo-Tethys [5, 6] involved the collision of Sibumasu with Indochina terrane. Sibumasu is an acceptable term like a contiguous continental block west of the Paleo-Tethys sutures. In the closure of Neo-Tethys [6], the northward motion of India plate has resulted in the formation of the Himalayan orogeny at 50 Ma [7, 8] within which Indo-Burma ranges in western Myanmar [9, 10]. Currently, India continues moving northwards 35mm per year [11]. The eastern margin of India plate slides obliquely and splits into two components in Myanmar [12]. The first one is an east-directed plate convergence uplifting the Indo-Burma ranges. The second component performs as a strike-slip motion, whereby India moves northward relative to others. On the other hand, the second component between the Indo-Burma ranges and Sibumasu can assume to be part of the West Burma microplate. The West Burma plate must have arrived in its current location relative to other continental blocks of the region by a strike-slip tectonic [3, 5]. Therefore, it is believed that the West Burma microplate amalgamated with Sibumasu either by collision in the late

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Mesozoic [2] or by the strike-slip movement in the Early Triassic [3]. The West Burma plate and Sibumasu are separated by the 'Sagaing fault', a major active right-lateral strike-slip fault in central Myanmar. The Sagaing Fault links two very different, but equally active tectonic domains: the Andaman Sea spreading center in the south and the eastern Himalayan syntaxis in the north [13, 14]. Within Myanmar, the Sibumasu terrane can be split into two distinct geological provinces: the Shan Plateau in the east, and the Mogok Belt in the west [15]. The Mogok Belt is one of the geological and metallogenic provinces in Myanmar [15] and is believed to be part of the southern continuation of Himalaya [1] at the western margin of the Shan-Thai block (Sibumasu). Moreover, the Mogok Metamorphic Belt in Myanmar forms the boundary between Sibumasu and West Burma and is interpreted as the major transcurrent shear zone [16]. This belt has potentially linked the metamorphic and magmatic belts at the southern margin of the Lhasa and Karakoram terranes in Tibet and Pakistan [17] that directly faced the India collision [18]. The Mogok Belt can be subdivided into the Mogok Metamorphic Belt [1] in the west and the Slate Belt [4] in the east. Along the Mogok Metamorphic Belt, phlogopite- and diopside-bearing marbles are principally outcropping with occasional pelite and pasmmite outcrops (Paleozoic to Mesozoic). Moreover, a variety of plutonic rocks such as I-type biotite granite and S-type two-mica granites of Cretaceous-Paleogene age [15, 18, 19] are intruded into metamorphic rocks of the Mogok Metamorphic Belt. East of this belt, the Shan Plateau is topographically high and is composed of carbonate and continental sedimentary rocks (Paleozoic to Mesozoic). However, in the western part, the Mogok Metamorphic Belt is juxtaposed with Central Lowland that is filled by the Eocene to Plio-Quaternary sediments.

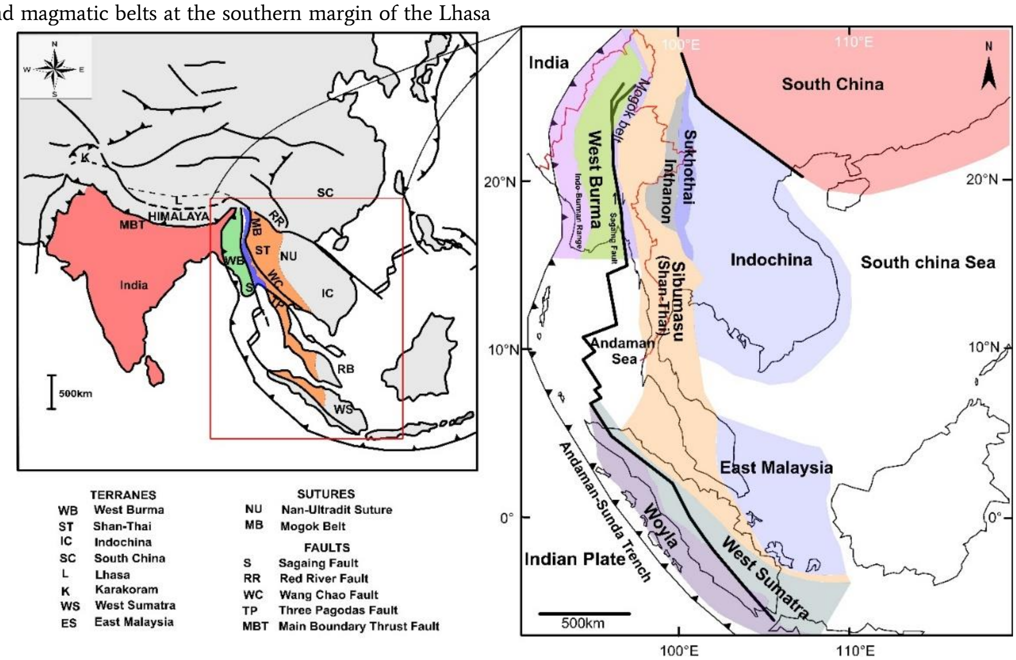


Fig. 1. Regional geological setting of Myanmar (Modified after Barley et al. [18]).

3. Methodology

Both field observation and laboratory studies were carried out for this study. Some of the field data are very useful for diagnosing the features of the hydrothermal system as well as the structural controls on the mineralization. In fact, laboratory analyses are also the essential parts to discuss more detail and understand more about the system's evolution. Over thirty polish-thin and polished ore specimens were prepared and the mineralogical study was conducted using both a petrographic microscope and an ore microscope. X-ray diffraction (XRD) analysis were also conducted on altered rock samples to identify the alteration mineral assemblages. Major- and trace-elements analyses of ore and altered rocks were carried out by X-ray fluorescence spectrometry (XRF) as well. Some of the altered samples and ore were analyzed using the Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES) and Inductively Coupled Plasma Mass Spectrometry (ICP-MS) to know the concentration of Au and Ag. Moreover, some of the polished ore specimens were studied using the scanning electron microscopy attached with energy dispersive X-ray (SEM-EDX) to confirm and know specific type of a mineral composition (semi-quantitative elemental composition). All of these laboratory works were conducted in the Department of Earth Resources Engineering, Mineral Resources Lab, Kyushu University, Japan.

4. Geology of the Onzon-Kanbani Area

The basement rocks exposed in the Onzon-Kanbani area are metamorphic rocks of the Mogok Metamorphic Belt and subordinate of plutonic igneous rocks. These metamorphic and igneous rock units have different surfical coverage (Fig. 2). The majority of metamorphic rocks include a variety of marbles, calc-silicate rock, and gneiss. Depending on mineral content, marble is classified as phlogopite marble, diopside marble and pure white marble where diopside calc-silicate rock is interbedded with diopside marble and occurred along the margin of igneous intrusion. Gneiss unit observed unconformably underlain by marble. It includes biotite gneiss and minor garnet-biotite gneiss. Petrographic study of calcareous (variety of marbles) and pelitic (gneiss) rocks indicate that calcite, diopside, phlogopite, actinolite, epidote, chlorite, quartz, biotite, and garnet are the common minerals in the assemblage. Based on index minerals, this assemblage is considered as a low to medium grade temperature (greenschist to amphibolite facies) of the metamorphic condition [20, 21]. These metamorphic rocks such as a variety of marbles, calc-silicate rock, and gneiss are widely distributed in eastern and western parts. The age of the protolith of metamorphic rock was originally considered Precambrian [22], but Permian fossils in the marble near Kyaukse [23] indicate that the Carboniferous to Triassic age is more likely. There are two dominant types of plutonic igneous rocks in the Onzon-Kanbani area. Igneous units generally covered the middle part of the research area. Younger granite and syenite igneous rocks intrude the older metamorphic rocks. The 'I-type' biotite granite also called 'Kabaing granite' is a main igneous intrusion of the research area, whereas the 'S-type' syenite and leucogranite are observed as small intrusive bodies. In place, magmatism of leucogranite and syenite melts emplaced in the Eocene time during the regional metamorphism and then Kabaing granite intruded in the Miocene after regional metamorphism [18] by faulting or overthrusting.

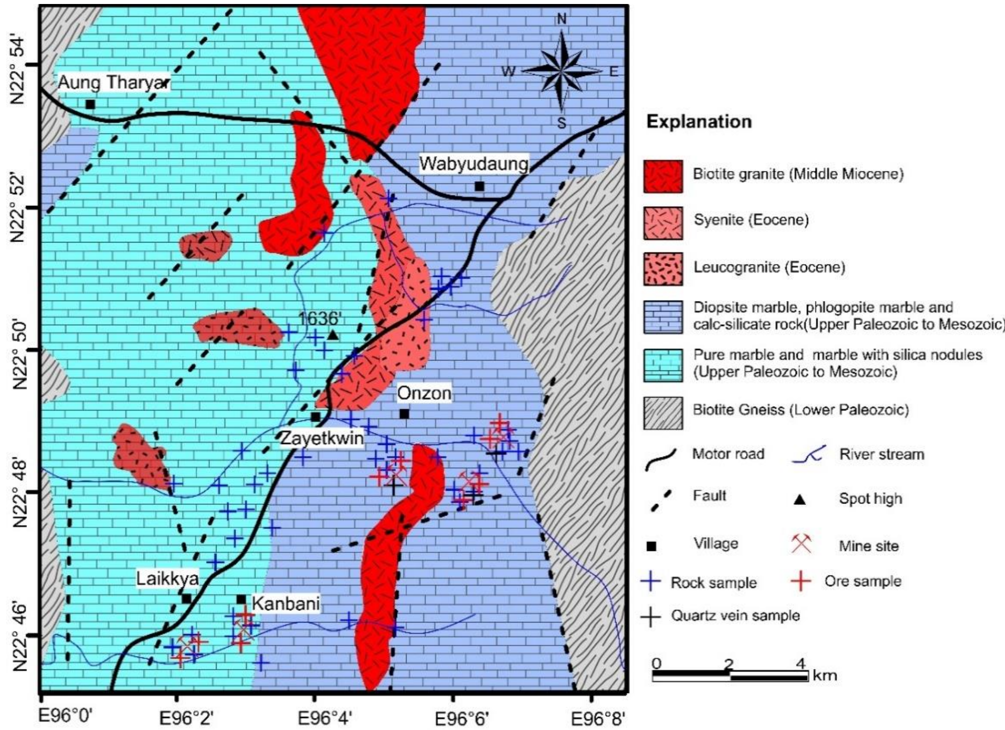


Fig. 2. Simplify geological map of the Onzon-Kanbani area with sample location (Modified after Thein et al. [24]).

5. Structure

The Onzon-Kanbani area is located near the major Sagaing Fault in Myanmar. The Sagaing Fault [25] is still active, deep-seated, N-S extending, right-lateral strike-slip fault, which stretches over 1000 km across the country (Fig. 1). This fault lies 10 km west of the Onzon-Kanbani area. Based on field observation and interpretation of landsat images, there are numerous faults trending two major directions, NW-SE and NE-SW where NE-SW is more common (Fig. 3). These trends represent a system of conjugate faults during a compressional stress where the stress direction comes from an NW direction (acting by an NW-SE direction). Basically, conjugate faults can observe along the major strike-slip faults. It is compatible with a structural joint rose diagram of the research area which displays three prominent joint sets of NNW-SSE, NNE-SSW and N-S directions where NNE-SSW joints roughly coincide with the strike of foliation in regional metamorphic rocks (Fig. 3). The general trend of foliation in metamorphic rocks as well as the fracture and shear zones follow the regional fault direction (NE-SW direction). Therefore, regional geological structures of the research area might be directly related to the Sagaing Fault system. In place, these fracture and shear zones are the host of auriferous quartz veins (Fig. 4). The trends of mineralized veins of the research area also showed NW, NE and N directions with a steep slope, where the mean trends of veins follows the regional structural controls.

6. Mineralization and hydrothermal alteration

Marble is commonly characterized by the presence of gold and base metal veins mineralized with various widths 0.5 to nearly 3 meters. Moreover, mineralization is occasionally observed in gneiss. Mineralized veins are more of fracture filling veins, but minor replacement or disseminated mineralization are also found in marble (Fig. 5). Basically, mineralized veins are characterized by open-space filling nature of sharp-walled veins. These veins occupied the fracture and shear zones with N, NE, NW trending directions and steep slopes. Many local gold worksites are operating in narrow mineralization zones. There are two types of gold vein mineralization in Onzon-Kanbani area; gold-bearing quartz vein and base metal quartz-carbonate vein. Gold-bearing quartz veins are mostly observed in the shallow level of local underground mine (~30m-50m) where vein mineralizations are mainly composed of quartz, calcite, ±adularia, and minor sulfide minerals. 'Adularia' is an occasional component in vein mineralization and associated with coarse-grained quartz. It is formed as subhedral to euhedral crystal form with a rhombic shape. The deeper portion of vein system is mostly rich in base metal sulfides (pyrite, galena, and sphalerite) where veins are deposited as base metal quartz-carbonate veins (~90m-160m). . Varieties of quartz vein textures occur in mineralized quartz veins. Some have shown boiling characters of epithermal mineralization such as crustiform banding, lattice, bladed, chalcedony quartz, comb, and cockade.

Mineralization related to hydrothermal alteration is developed around mineralized veins which is observed along the fracture or shear zones. There are three alteration zones from proximal to distal hydrothermal conduit such as silicic, sericite-illite and propylitic alteration [26] (Fig. 6). In fact, alteration halos occur as narrow zones which overlap the regional metamorphism of the research area. Generally, the inner silicic zone core is imprinted to vein mineralization, but the groundmass is strongly silicified whereas adularia and chlorite are also found, frequently. Sericite-illite alteration occurs as a narrow zone along the silicic alteration where sericite occurs as fine grains like widespread dustings. The outer propylitic alteration is characterized by the presence of calcite, chlorite, epidote, and actinolite. Propylitic alteration covers a wide area but it is believed that some part of the propylitic alteration is not related to the ore-forming hydrothermal system [27]. It might have overlapped the system through regional metamorphism.

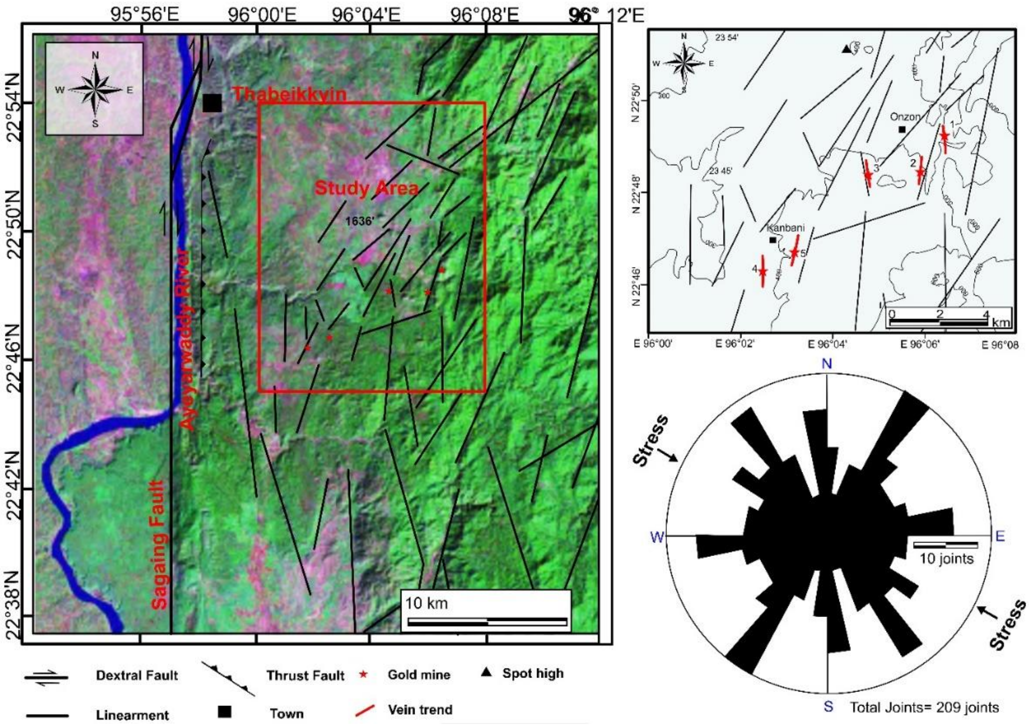


Fig .3. Landsat structural lineament map with gold vein trend and structural joint rose diagram of the Onzon-Kanbani area (Based on structural and geological map of Thein et al. [9]).

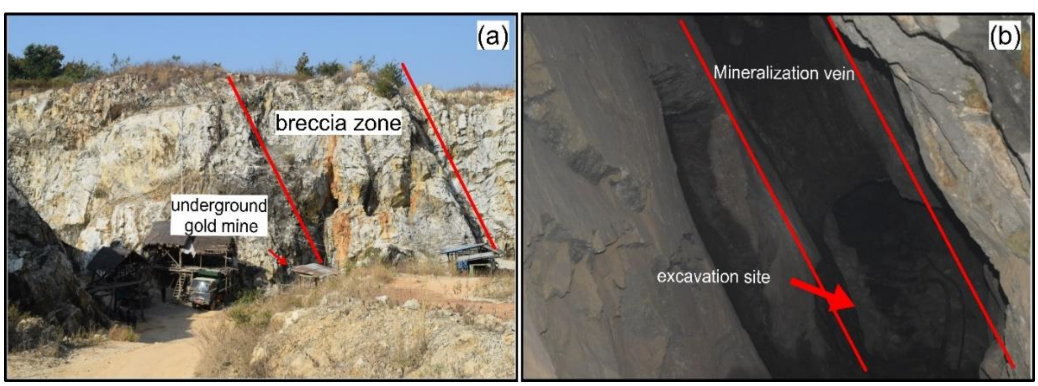


Fig. 4. (a) Goldmine from the breccia zone, and **(b)** excavation site of fracture filling vein mineralization.

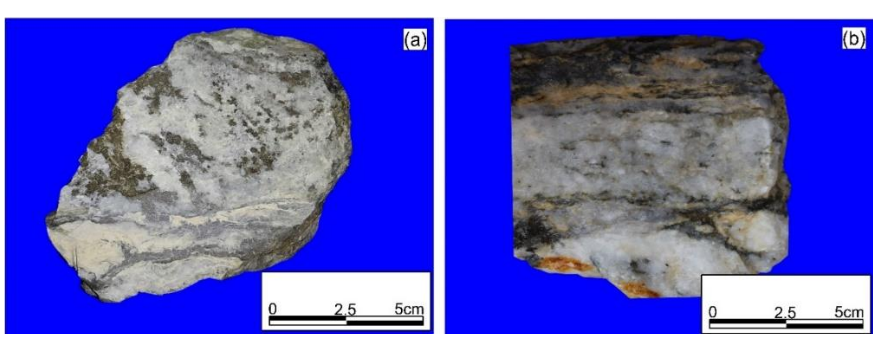


Fig. 5. (a) Fissure filling vein nature plus disseminated mineralization in base metal quartz-carbonate vein, and **(b)** banded nature of gold-bearing quartz vein.

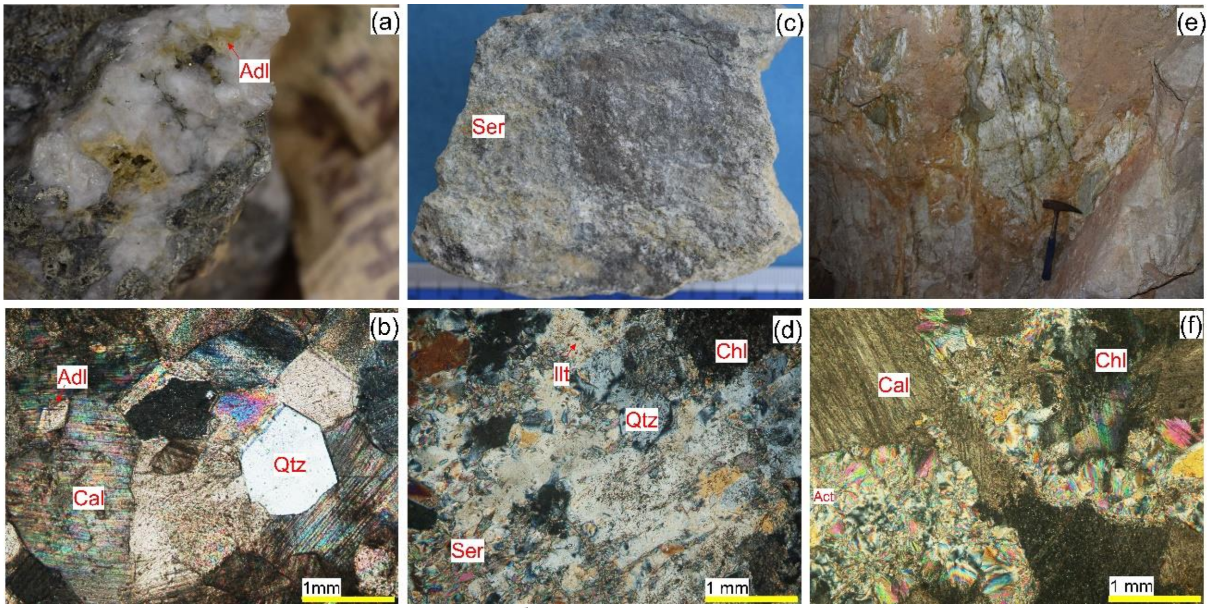


Fig. 6. hand specimens and photomicrographs of each altered zone **(a, b)** silicic alteration zone with cavity filling adularia and its rhombic shape crystal under the microscope, **(c, d)** widespread fine grained sericite in sericite-illite alteration zone, and **(e, f)** propylitic alteration zone and its photomicrograph. (Qtz=quartz, Cal=calcite, Adl=adularia, Ser=sericite, Ilt=illite, Chl=chlorite, Act=actinolite).

7. Ore mineralogy

Ore and gangue mineral assemblages identified in the Onzon-Kanbani area are of the low- sulfidation epithermal deposits and includ quartz, calcite, adularia, sericite, pyrite, galena, sphalerite, chalcopyrite and marcasite that are associated with illite and smectite clays. Ore mineralogy of the Onzon-Kanbani area is relatively simple, in which gold and base metal are mostly observed in fracture veins, fissure filling, and partially are disseminated in marble. Hypogene ore minerals in mineralized veins are pyrite, galena, sphalerite, chalcopyrite, marcasite and minor native gold, electrum, and arsenopyrite. However, primary pyrite and chalcopyrite are partially or completely altered to supergene minerals of goethite, hematite, and chalcocite. This shows an oxidizing condition of primary sulfides by circulated meteoric water.

Pyrite [FeS_2] Pyrite commonly occurs as the primary sulfide as well as the alteration mineral over the entire period of mineralization. Indeed, pyrite is the most common sulfide of the mineralization. Generally, it is observed as large to fine euhedral grains. In the mineralization, pyrite is associated with gangue quartz, sphalerite, galena, and chalcopyrite. Large-grained pyrite is commonly cemented by quartz gangue and other sulfides such as sphalerite and galena. Early formed pyrite cubes occur as relic crystals in anhedral chalcopyrite and sphalerite grains (Fig. 7). Late phase fine-grained pyrite is observed as fissure filling or breccia cemented materials. In some place, vein mineralization is composed with fined-grained massive pyrite cemented by coarse-grained sulfides and other hydrothermal gangue minerals. This indicates overprinting of hydrothermal ore fluid on the syngenetic massive pyrite.

Sphalerite [ZnS] Sphalerite is a common mineral in the mineralization as subhedral to anhedral grains. Most sphalerites show yellowish brown-gray color and are associated with pyrite. Sometimes, is the grains are observed as fracture filling or replacement to euhedral large grain pyrite. Generally, sphalerite at high sulfur activity has a honey yellow to light brown color with their low FeS [28]. Moreover, the FeS mol% content of sphalerite coexisting with pyrite or pyrrhotite should range from 0.2 to 1% [29]. This low Fe sphalerite must have formed at higher crustal levels in a cooler condition. Small grains of chalcopyrite are frequently found in sphalerite grains (Fig. 7). This is resulted either by epitaxial growth during sphalerite formation or replacement of copper-rich fluid reacting with sphalerite after the formation. Normally, gold in the Onzon-Kanbani deposit is closely associated and largely inter-grows sphalerite. In some places, sphalerites also intergrow galena.

Galena [PbS] Galena occurs as anhedral form associated with sphalerite, pyrite, and chalcopyrite. It shows a white to light gray color. Its perfect cleavage is usually visible and frequently shows triangular pits (Fig. 7). Curved cleavage pits indicates post-depositional deformation. Sometimes, galena encloses earlier-formed sphalerite. Some of galena grains are texturally associated with gold specks. Basically, gold is associated with sphalerite, galena, pyrite, and chalcopyrite.

Chalcopyrite [CuS] Chalcopyrite is also one of the common sulfide minerals but has a minor amount in the Onzon-Kanbani mineralization. Chalcopyrite occurs as a late mineral in fracture filling as well as entrapped in sphalerite (Fig. 7). It shows bright yellow color under the ore microscope and associates with pyrite, sphalerite, galena, and gold. There are two different forms of chalcopyrite. Most grains are anhedral in shape and found in fracture and grains boundaries of gangue quartz and pyrite. Another kind is observed as exsolved grains in sphalerite (chalcopyrite disease). Chalcopyrite is closely associated with native gold and is occurred as fracture filling.

Gold [Au] Gold occurs as free grains or locked within pyrite, sphalerite, galena, and gangue minerals such as quartz. In ore microscopic studies, gold shows a bright yellow color, resistance to tarnish, metallic luster, hackly fracture and very high density. Depending on the Ag content, the color of electrum is slightly different. As the Ag content increases, the color becomes whitish yellow. Based on their atomic percent of Au, there are two types of gold grains: 'native gold (>80 % Au) and electrum (<80 % Au)'. They are observed as large grain electrum gold and small disseminated specks of native gold. SEM-EDX analyses of thirty-eight gold grains showed that electrum gold has a Au atomic ratio of 66-80 % and their size ranges between 100-200 μm whereas native gold has a Au ratio of 80-87 % and a 25-100 μm range of size (Fig. 8). Electrum is mostly observed as large grains in gold-bearing quartz veins but native gold is observed as fine grains in base metal quartz-carbonate veins and carbonate base metal sulfide veins. Visible electrum gold in the quartz gangue is frequently observed and associated with sphalerite and pyrite (Fig. 7e). On the other hand, native gold is mostly associated with base-metals such as pyrite, sphalerite, and galena (Fig. 7f). The Au ratio (%) of native gold and electrum from the Onzon-Kanbani gold deposit is summarized in Fig. 9.

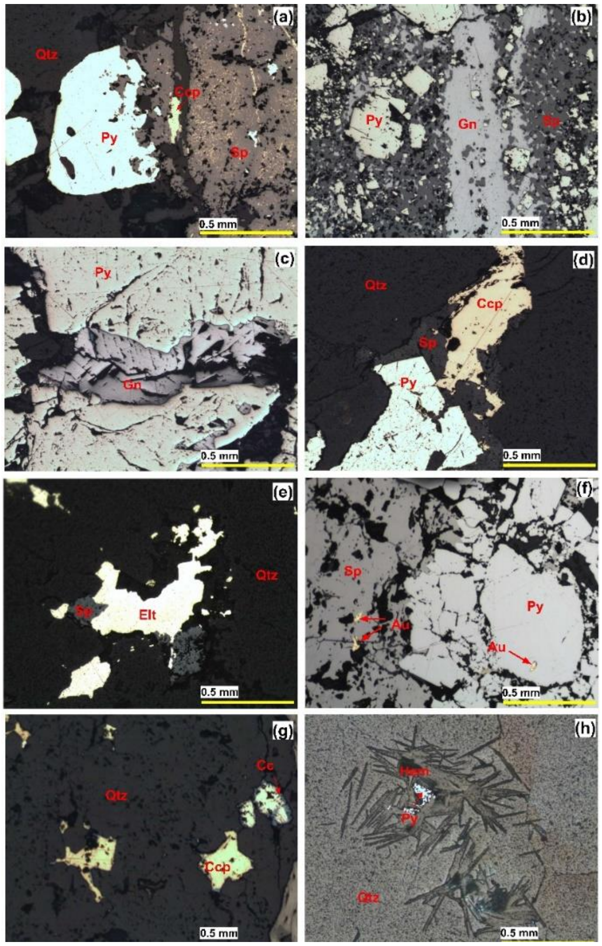


Fig. 7 (a) Euhedral pyrite's fractures replaced by sphalerite and chalcopyrite; **(b-d)** base metal pyrite, sphalerite and galena in mineralized vein; **(e)** small native gold grains in pyrite and sphalerite; **(f)** large electrum grain in mineralization quartz vein; **(g)** chalcopyrite partly altered secondary sulfide chalcocite; and **(h)** pyrite and specular hematite (Qtz-quartz, Py-pyrite, Sp-sphalerite, Gn-galena, Ccp-chalcopyrite, Cc-chalcocite, Hem-hematite, Elt-electrum and Au-native gold).

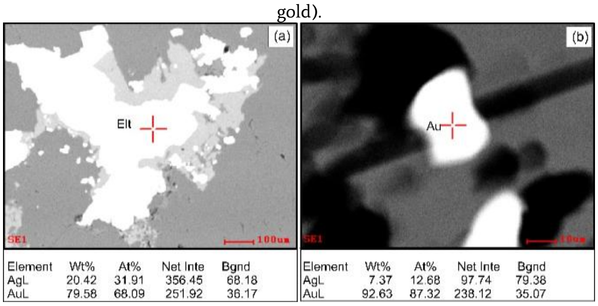


Fig. 8 (a) Elemental composition of electrum grain in gold-bearing quartz vein and **(b)** elemental composition of native gold in the base metal quartz-carbonate veins under SEM-EDX.

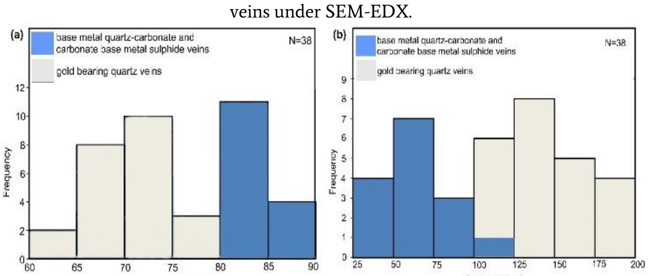


Fig. 9 (a) Frequency histogram for Au ratio (%) of electrum and native gold from the Onzon-Kanbani Gold deposit, and **(b)** Frequency histogram for electrum and native gold grain size from the Onzon-Kanbani gold deposit.

8. Mineral paragenesis

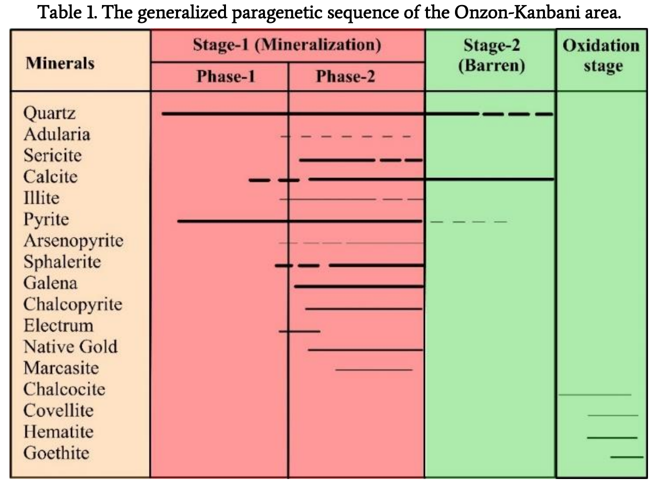
Considering vein structures, ore and gangue mineral textures, and alteration characteristics, the paragenetic sequence of mineralization was determined for theOnzon-Kanbani area as three stages 1) mineralization stage, 2) barren stage, and 3) oxidation stage (Table 1).

Stage I In the mineralization stage, the first early phase formed quartz, pyrite, and minor calcite minerals are observed far from the late phase sulfides and quartz core vein. Besides, early formed pyrite and quartz minerals show euhedral crystal forms whereas anhedral sphalerite is younger than quartz and pyrite in order of deposition. Some of anhedral sphalerites are replaced along the boundary by later formed galena grains. Moreover, disseminated chalcopyrite rods and small grains occur in sphalerite as an exsolution texture. It means chalcopyrite is overgrowth during sphalerite formation or replace it after formation. Gold is mostly observed in quartz as gangue mineral as well as in pyrite, sphalerite, galena and chalcopyrite groundmass as disseminated specks. In parts, electrum gold is the first deposition product followed by the first forming quartz, pyrite, and sphalerite. Later, native gold is deposited as fine-grained native gold with base metal sulfides such as pyrite, sphalerite, galena, and chalcopyrite. Actually, quartz, calcite, and pyrite are present in small to large quantities over the entire period of mineralization. Sericite and a minor amount of adularia are found with quartz in mineralized veins as well.

Stage II The veins that formed after the mineralization stage are barren calcitic or silicic veins. This stage is called the post-ore stage. Indeed, a large amount of medium-grained mosaic quartz and calcite are the common minerals in this stage with a very minor amount of pyrite. Chalcedony and amorphous silica locally occur along the fractures and apparently indicate rapid deposition during the alteration process.

Stage III Oxidation stage was started after the mineralization by circulated meteoric water at the structurally weak zones of mineralization. In fact, supergene minerals of hematite, goethite, and chalcocite were partially or completely transformed from primary sulfides by an oxidation reaction. The by-product of iron oxide staining the silicic zone often shows a yellow or rusty color. Sometimes, it exists even in very deep levels of the deposit. Oxidation intensity is too high in shallow level of mineralized veins where most of the primary minerals are changed to oxidized forms but are highly enriched in gold.

Table 1. The generalized paragenetic sequence of the Onzon-Kanbani area.



9. Ore chemistry

Sixteen ore and altered rock samples were analyzed by XRF, ICP-AES, and ICP-MS to clarify the geochemical characteristics of ore minerals. Based on geochemical analyses, scattergrams of gold (Au) versus silver (Ag), copper (Cu), lead (Pb), zinc (Zn), tin (Sn) and antimony (Sb) were plotted to understand their correlation (Fig. 10) in the mineralization process. The relationship of gold (Au) and silver (Ag) is positive where their grades are not very different. In parts, copper

(Cu) also displays a positive correlation but it is not distinct. For gold (Au) versus zinc (Zn) and lead (Pb), they have negative correlations. However, gold (Au) vs. tin (Sn) and antimony (Sb) show poor negative correlations. Although localized visible gold is found, the average values of gold (Au) from the Onzon-Kabani area is not too high. Nevertheless, analysis of selected ore samples from the mineralization zone displays average contents of 77ppm Au and 9ppm Ag (Table 2).

Moreover, the gold and base metal distribution of altered zones were also interpreted based on chemical analyses of altered rocks. The gold and base metal contents of altered zones are shown in Table 3. Generally, the distribution of gold (Au) and sulfide minerals of zinc (Zn), lead (Pb) and copper (Cu) show negative slopes in the field (Fig. 11) from proximal (silicic alteration) to distal (propylitic alteration). In fact, gold and base metal are significantly depleted in the propylitization process rather than the silicification and sericitization porcesses. It means that the vein mineralization is more dominant than the disseminated mineralization. In the silicification zone, mineral assemblages and textural relationships suggest the precipitation of ore minerals from a supersaturated hydrothermal solution. Therefore, the hydrothermal solution was diluted to outer zones of alteration. Alternatively, the gold and base metal concentrations are reduced toward the outer alteration zones, as well.

Table 2. Ore chemistry of some selected ore samples.

Sample	Au (ppm) ICPMS	Ag (ppm) ICPMS	Cu (ppm) XRF	Pb (ppm) XRF	Zn (ppm) XRF	Sn (ppm) XRF	Sb (ppm) XRF
GK-2	5	12	98	70	138	10	32
GF-7	186	76	626	67	20	15	28
GF-11	73	8	1192	10	8	12	18
GS-1C	2	9	169	639	211	16	21
GF-1VB	14	8	3002	45	122	12	11
GM-6	144	32	1306	37	53	13	7
GM-5	58	16	6261	745	486	12	9
GF-8	189	73	2224	58	25	8	13
GF-1A	30	6	7056	55	67	1	5

10. Conclusion

Gold mineralization at the Onzon-Kanbani is related to an NE trending fracture and shear zone, in which the vein mineralization occurs as fracture filling in marble. The vein system is closely associated to regional structural lineaments that represent a system of a conjugate fault during acting as a compressional stress. The mineralization is related to the Sagaing Fault system. Generally, in this area, the mineralized veins are composed of quartz, calcite, adularia, and sulfide minerals. In some parts, quartz core gold-bearing quartz veins are observed in the shallow level of the vein system but the base metal quartz-carbonate veins occur in deeper parts. In fact, the base metal content gradually increases to the deeper part of the vein system. Actually, the gold mineralization occurs in both vein types. In case of gold-bearing quartz veins, electrum gold is observed as large grains (100-200 μm) associated with quartz gangue, sphalerite, and pyrite. On the other habd, native gold is found in base metal quartz-carbonate veins as fine-grained sparks (25-100 μm) within pyrite, galena, and sphalerite. Moreover, the mineralization related hydrothermal alterations are developed as narrow zones along vein mineralization. These alteration processes, from proximal to distal of the hydrothermal conduit, are silicification, sericitization, and propylitization. The style of alterations indicates that the intensity of hydrothermal alteration decreases to outer halos of alteration. Furthermore, the mineralogical study has revealed three mineral paragenetic stages in the mineralization. At the early stage of main mineralization, electrum and native gold are deposited with pyrite, sphalerite, galena, and chalcopyrite. Afterward, mineralized veins are barren as quartz or calcite veins with a very minor amount of pyrite. In the last stage, supergene ore minerals of hematite, goethite, and chalcocite are formed by oxidizing of primary sulfides. Indeed, gold and other ore minerals are high content in ore samples where gold is positively correlated with silver and copper. However, base metals such as 'zinc and lead' show negative correlations with gold whereas antimony and tin show poor negative correlations. According to mineral content, silicic and sericite-illite alteration zones are high in ore mineral concentration than the propylitic alteration zone. The ore mineral content of alteration zones gradually reduce toward the outer zone.

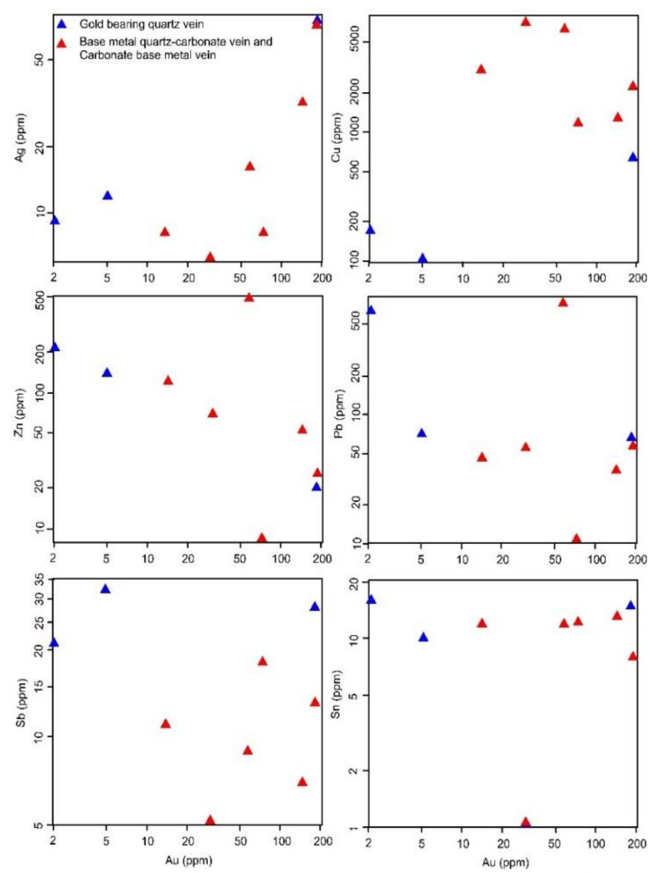


Fig .10. Scattergrams of gold (Au) versus silver (Ag), copper (Cu), lead (Pb), zinc (Zn), antimony (Sb) and tin (Sn).

Table 3. Ore minerals content of each altered zone.

	Silicic Alteration		Sericite alteration			Propylitic	
Sample ID	**GM-8**	**GM-9**	**GK-3**	**GK-5**	**CHL1**	**GS1**	**GM11**
Cu (XRF)	18	12	92	10	9	11	4
Zn (XRF)	8	6	535	68	67	33	18
Pb (XRF)	18	10	210	14	4	1	n.d
Au (ICP-AES)	5.5	4.26	n.d	3.25	3.91	1.41	3.2

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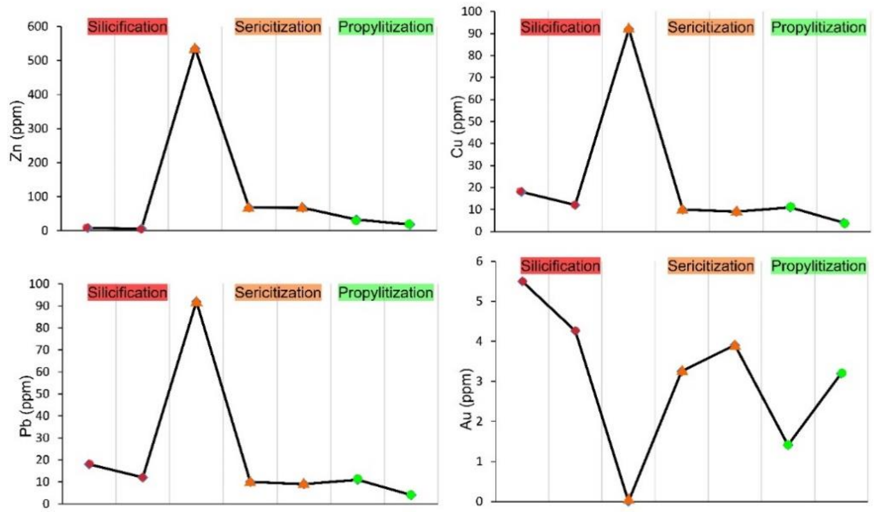

Fig. 11. Diagrams showing the variation of Zn, Pb, Cu and Au contents in each altered zone.

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