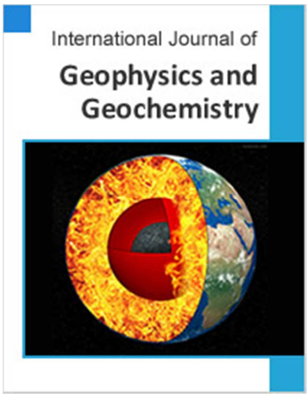
International Journal of Geophysics and Geochemistry
2017; 4(4): 30-38
http://www.aascit.org/journal/ijgg
ISSN: 2381-1099 (Print); ISSN: 2381-1102 (Online)

American Association for Science and Technology



Fluid Inclusion Studies of Marble Hosted Quartz Veins at Onzon Area, Mandalay Region, Central Myanmar

Aung Tay Zar[1, 2], **I. Wayan Warmada**[1], **Lucas Donny Setijadji**[1], **Koichiro Watanabe**[3]

[1]Department of Geological Engineering, Faculty of Engineering, Gadjah Mada University, Yogyakarta, Indonesia
[2]Geology Department, Pyay University, Pyay, Myanmar
[3]Department of Earth Resources Engineering, Faculty of Engineering, Kyushu University, Fukuoka, Japan

Email address
aungtayzar99@gmail.com (A. T. Zar)
[*]Corresponding author

Citation
Aung Tay Zar, I. Wayan Warmada, Lucas Donny Setijadji, Koichiro Watanabe. Fluid Inclusion Studies of Marble Hosted Quartz Veins at Onzon Area, Mandalay Region, Central Myanmar. *International Journal of Geophysics and Geochemistry.* Vol. 4, No. 4, 2017, pp. 30-38.

Keywords
Mogok Metamorphic Belt, Fluid Boiling and Mixing, Epithermal Environment

Received: July 10, 2017
Accepted: July 30, 2017
Published: September 20, 2017

Abstract
Onzon area is located in Thabeikkyin Township, Mandaly Region, Central Myanmar. This area is a part of well-known Mogok Metamorphic Belt. Mogok Metamorphic Belt is complex tectonic region, so gold deposits can be formed at all stages of orogenic evolution. Mineralization is mostly hosted in marble units of Mogok Metamorphic Belt and frequently in gneiss unit. Mineralization veins occur as fracture filling and disseminated in nature where generally observed in fracture and shear zones. Fluid inclusions from quartz veins are studied in order to know the physiochemical conditions of hydrothermal fluids under which they are trapped. Petrographically, most of fluid inclusions show negative crystal shapes and also rounded, elongate and irregular shapes where liquid rich two phase inclusions are dominant. Microthermometric measurements of fluid inclusions were conducted for primary liquid rich fluid inclusions by using a Linkam THMSG600 combined heating and freezing stage. Temperature of homogenization (*Th*) and final melting of ice (*Tm*) were measured by heating and freezing experiment for two type of veins. The value of (*Th*) range from 159°C to 315°C where ice melting temperature (*Tm*) are -0.5°C to -8.9°C respectively. Salinity ranges are from 0.88 to 12.51 wt% NaCl equivlent. Fluid inclusion petrography and microthermometric measurement data show that fluid boiling and mixing were important processes during mineralization and hydrothermal evolution. Data combination of fluid inclusion petrography, microthermometric measurements and paleo-depth as well as any other evidences of vein textures and hydrothermal alteration type from Onzon area are indicated that forming in under shallow level epithermal environment.

1. Introduction

Onzon area is a one of gold field from Mandalay Region, Central Myanmar "Figure 1". It is also part of Mogok Metamorphic Belt. In this area, small scale local gold rush and abundant artisanal working were started last thirty years ago. Gold and base metal mineralizations are mainly hosted in marble unit and also frequently observed in gneiss unit. Generally, gold deposits along Mogok Metamorphic Belt are assumed that orogenic-type gold deposits [1] but it would belong epithermal and locally skarn mineralization. According to structural and lithological controls, mineralization related hydrothermal alteration is developed around fracture filling hydrothermal conduits in marble unit but not pervasive in wide area coverage. Generally, hydrothermal alteration is overlapped with regional metamorphism. Most common hydrothermal alterations in research area are silicic alteration (quartz ± adularia ± calcite ± illite), sericite-illite alteration (sericite ± illite ± quartz± calcite ± chlorite) and propylitic alteration (calcite ± epidote ± chlorite ± actinolite ± illite ± smectite) [2]. Mineralization veins are observed in silicic alteration zone where gold are associated with pyrite, sphalerite, galena, chalcopyrite, marcasite and arsenopyrite. There are variety textures of quartz-carbonate ± adularia veins such as massive vein, banded, bladed calcite, lattice, cockade, comb and some vuggy. The main focus of this paper writing is fluid inclusion studies of quartz veins from Onzon area regard to characteristics of hydrothermal fluids during mineralization.

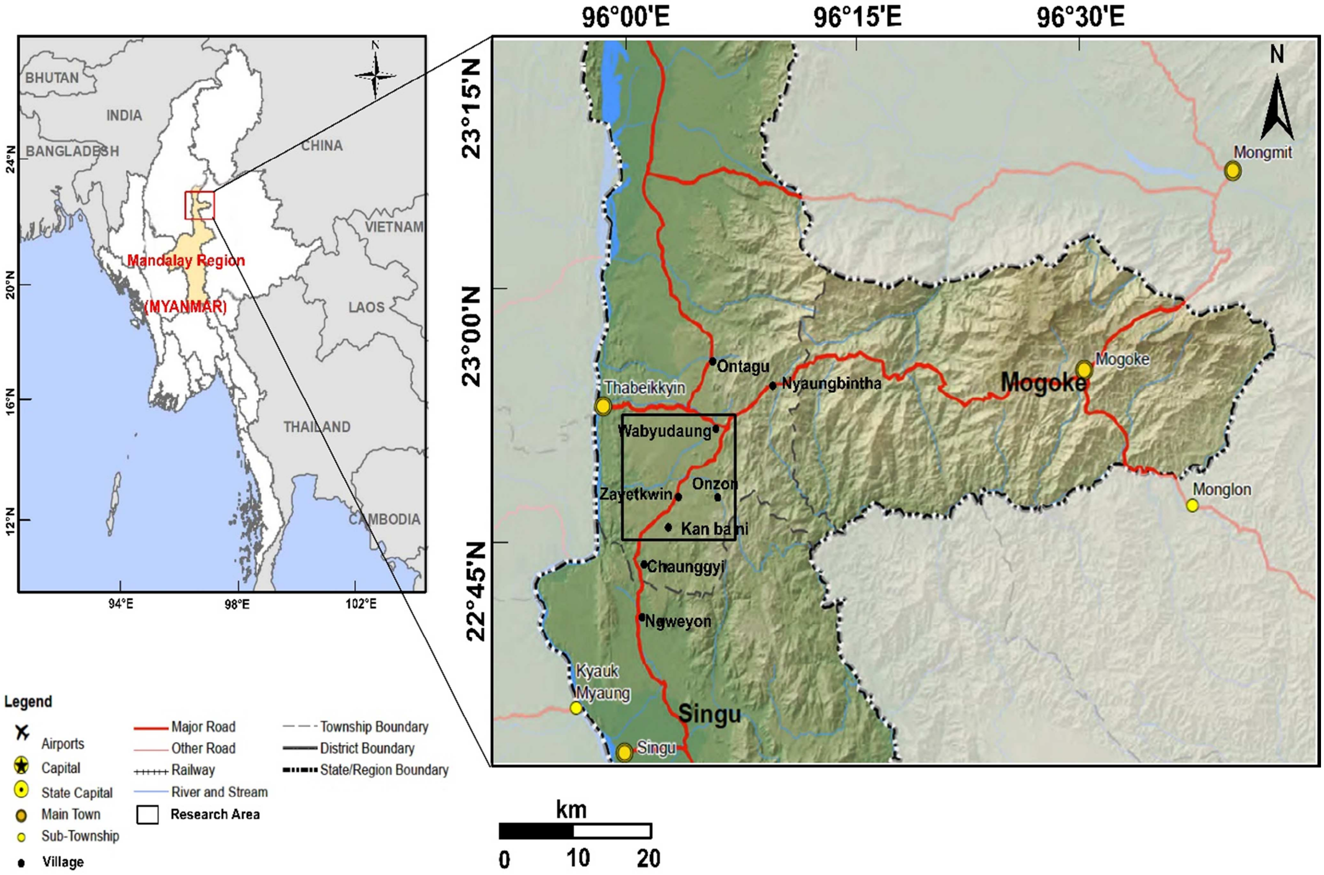


Figure 1. Location map of Onzon area, Mandalay Region, Central Myanmar (Source: base map, stream and elevation are taken from MIMU and SRTM 90m).

2. Geologic Setting

Myanmar is tectonically complex region and composed with micro plates such as Sinbumasu, West Burma and India. Along a tectonic history is built by repeatedly occurring subduction, accretion and collision events. These events chiseled the geological landform and metallogenic provinces in Myanmar. Traditionally, the territory of Myanmar is subdivided into (1) the India plate to the west, (2) Burma microplate (West Burma) in central part and (3) Shan-Thai block (Sibumasu) 'east of the Sagaing fault' "Figure 2". Mogok Metamorphic Belt is one of the distinct geological and metallogenic province in Myanmar and located between Central low-land (West Burma) and Shan-Thai block (Sibumasu). It is believed that southern continuation of Himalaya [3] and formed by either collision [4] or strike-slip movement [5]. In this place, well-known right lateral strike-slip fault, Sagaing fault [6] is served as western boundary. Alternatively, structural configuration of this area is closely related to this fault. Mogok Metamorphic Belt is composed of Paleozoic to Mesozoic meta-carbonate rocks and metapelite where variety of Cretaceous-Palaeogene plutonic igneous rocks [4], [7], [8] are intruded to older rocks. East of this belt, Shan Plateau is a topographic high, with average elevation of about 1000m and mainly composed of a series of Ordovician-Triassic carbonate rocks and continental sedimentary rocks (Jurassic?). The western margin of Mogok Metamorphic Belt is juxtaposed with Central low-land which is filled by Eocene to Plio-Quaternary sediments.

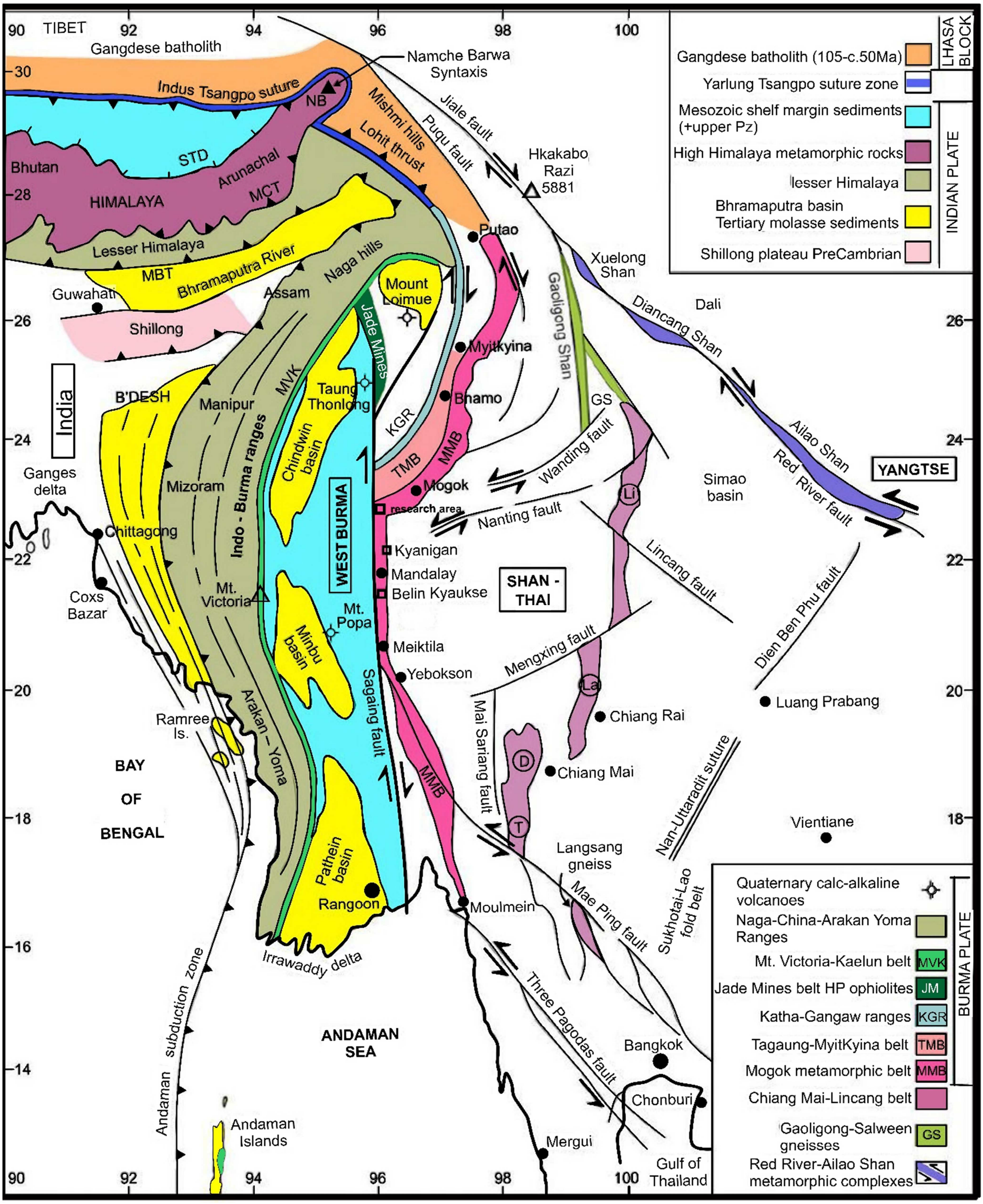


Figure 2. Regional geological and geologic setting map of Myanmar [9].

3. Deposit Geology

The area is occupied by metamorphic rocks of Mogok Metamorphic Belt such as variety of marbles, calc-silicate rock and gneiss "Figure 3". In this place, younger calcic-metamorphic rocks (Upper Paleozoic to Mesozoic) are unconformably overlaid by older gneiss unit (Lower Paleozoic). These metamorphic rocks are intruded by late phase plutonic rocks of leucogranite, syenite and biotite granite. The emplacements of syenite and leucogranite (S-type) were taken place between 35 to 23 Ma after initial collision between India and Eurasia (at 65 to 55 Ma) [7] but the main intrusion of biotite granite and also called 'Kabaing granite' (I-type) was emplaced in 15.8 Ma or late Miocene [10] by process of faulting and overthrusting. Mineralization veins are predominantly hosted in marble unit and also frequently observed in gneiss unit with width up to 3 meters. The well-known N-S trending Sagaing fault served as western margin of research area. Interpretative NE-SW trending faults from research area which are relatively parallel to the foliation of metamorphic rocks.

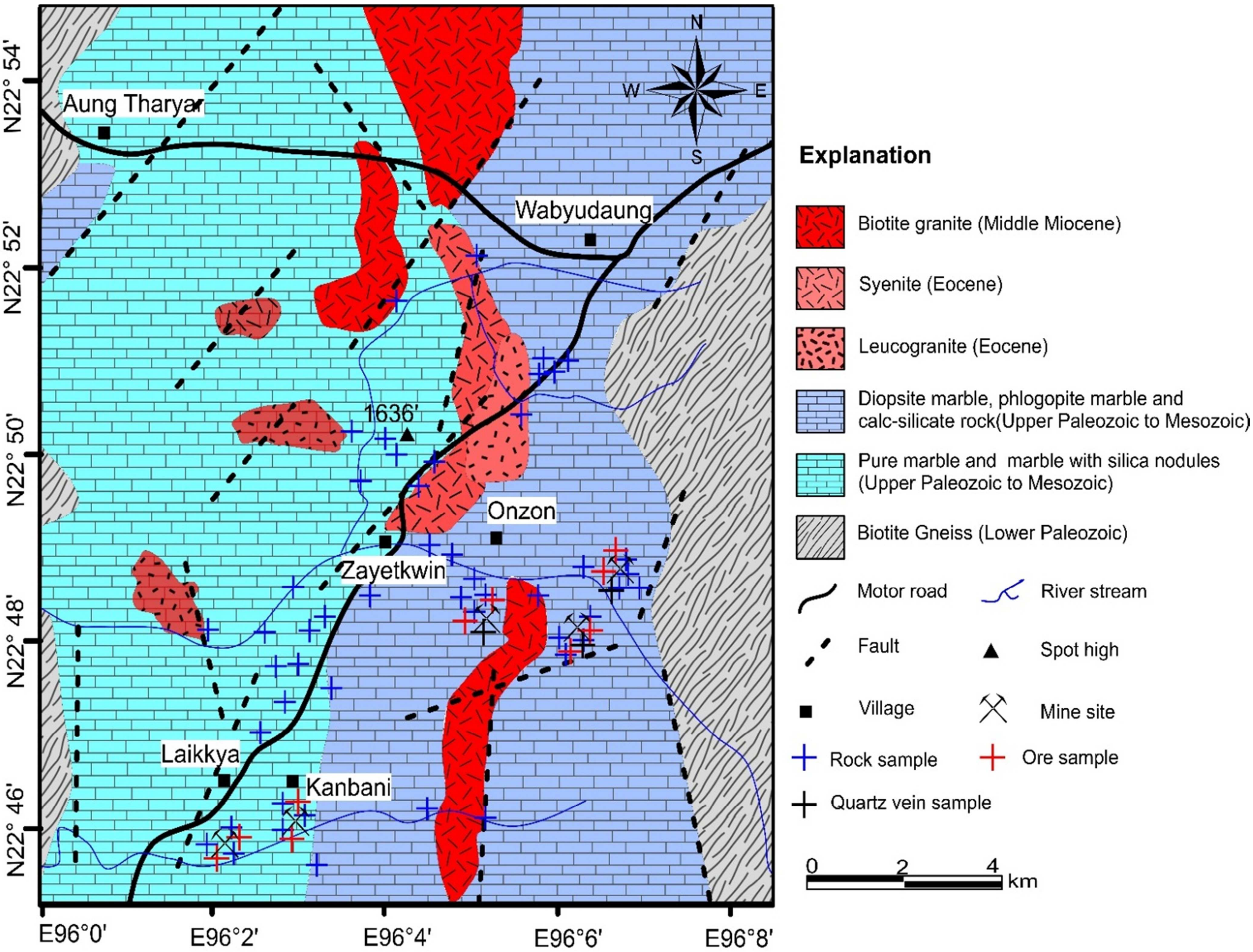


Figure 3. *Simplify geological map of Onzon area with sample locations modified after Thein et al. [11].*

4. Mineralization Veins

In research area, gold mineralization is observed as fracture filling veins but sometime disseminated nature are also found. At least two types of mineralization veins are identified such as gold bearing quartz veins and banded quart-carbonate veins with base metal "Figure 4". Both of veins are closely associated with gold and base metal mineralization. Their vein trends are generally followed the regional structural trend, mostly NE-SW in direction. Many local gold worksites are working on the narrow mineralization zones. Gold bearing quartz veins are mostly observed in Onzon (east of research area), where massive and banded natures are common characteristics. Sometime, visible gold or gold nuggets (electrum) are observed which are associated with gangue mineral quartz as well as base metal pyrite and sphalerite. In this place, base metal quart-carbonate veins are observed in entire area, basically banded vein in nature and a variety of vein texture are also observed such as crustiform, bladed, lattice, comb and cockade. Remarkable amount of base metal sulphides are identified in this vein, sometime observed as carbonate base metal sulphide vein. Gold are occurred as fine grained native gold in sulphides. The common ore mineral in research area are native gold, electrum, pyrite, galena, sphalerite, chalcopyrite and arsenopyrite.

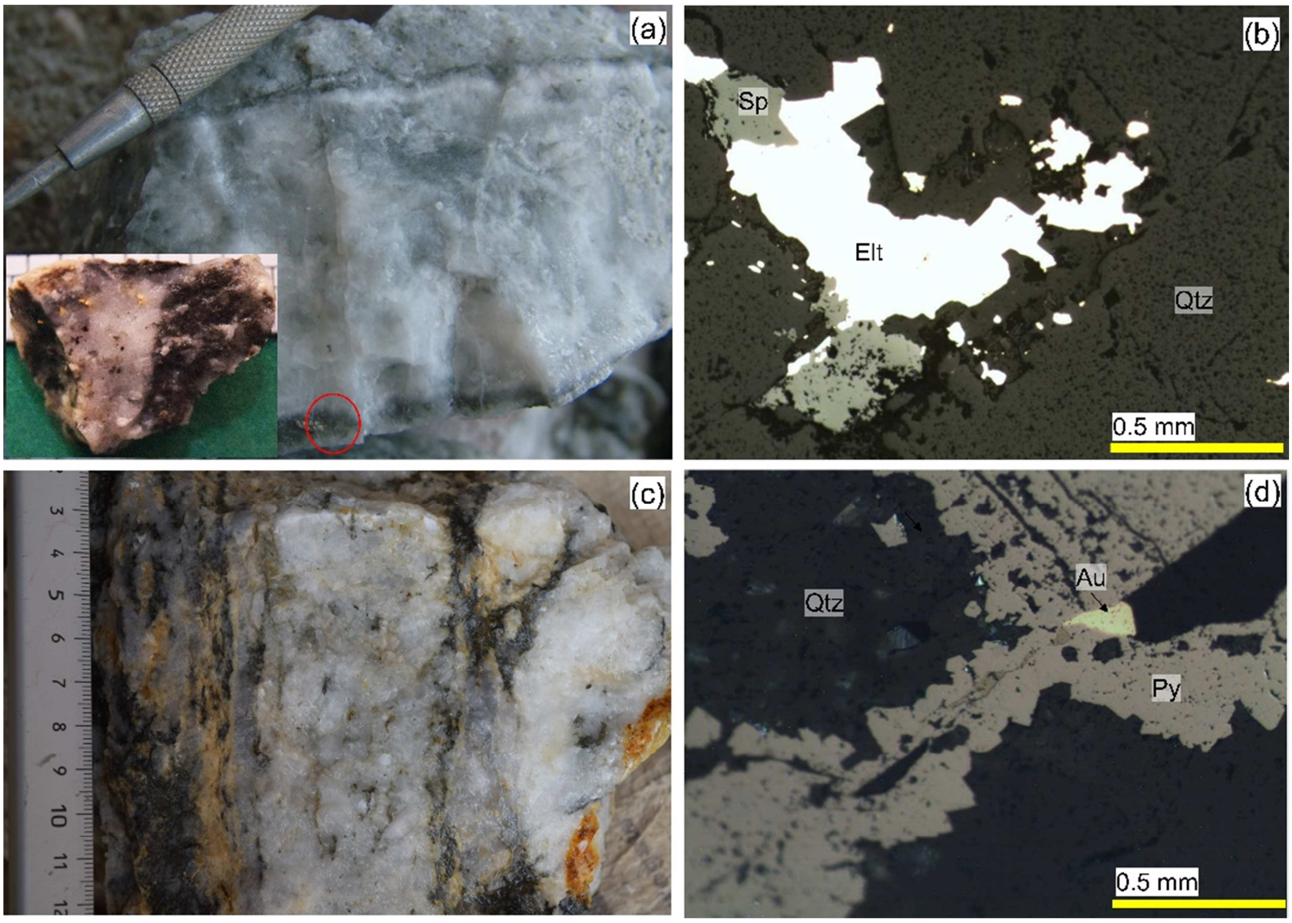


Figure 4. *Photos show (a & b) gold bearing quartz vein with visible gold grain and its photomicrograph and (c & d) banded base metal quartz-carbonate ± adularia vein and its photomicrograph (Qtz= quartz, Py= pyrite, Sp= sphalerite, Elt= electrum and Au= native gold).*

5. Research Methods

Different types of hydrothermal quartz vein samples were collected from research area to conduct fluid inclusion studies. Sample collection was based to representative samples that are associated with gold and base metal mineralization as well as clear quartz samples which easy to find and interpret fluid inclusions under microscope. Double polished quartz wafers were prepared for these quartz veins where the thickness of wafers varied between 150 and 300µm. Firstly, these quartz wafers were conducted by transmitted light microscope to study fluid inclusion petrography where shapes, sizes, nature of occurrences and phases within fluid inclusions were noted based on standard citations of Roedder and Bodnar et al. [12], [13]. Microthermometric measurements were done using Linkam THMSG600 combined heating and freezing stage with a temperature range of -196 to +600°C and attached to Nikon petrographic microscope with Axiovision software where temperature reproducibility is ±0.1°C. Believable primary fluid inclusions were selected for measurement. Totally 102 fluid inclusions are measured for homogenization temperature (*Th*) and last ice melting temperature (*Tm*). Salinity of these fluid inclusions was determined from last ice melting temperature by using Bodnar's equation. All of laboratory analysis were made in Department of Earth Resource Engineering, Mineral Resource lab, Kyushu University, Japan.

6. Result and Discussion

6.1. Fluid Inclusion Petrography

A total of 7 quartz vein samples from two different veins were prepared for fluid inclusion studies. Firstly, quartz wafers of quartz dominant vein samples and quartz-carbonate vein samples were studied under transmitted light microscope to identify fluid inclusion petrography. This study includes observing of shapes, sizes, mode of occurrences and types of fluid inclusions. Most of fluid inclusions show negative crystal shapes, rounded, elongate and irregular shapes where their sizes range from 5 to 50 µm and most inclusions are above 10 µm in size. These fluid inclusions are observed in growth zones, small clusters and as dispersed arrays. Generally, primary fluid inclusions are dominant but secondary fluid inclusions that trapped along fractures are also observed with lineament arrays. There are three types of fluid inclusions are identified based on their phase relation (1) Two-phase liquid-rich inclusions with constant liquid-to-vapor ratios, (2) Two-phase liquid and vapor containing coexisting liquid-rich and vapor-rich inclusions with a broad range in liquid to vapor ratios, and (3) Two-phase vapor-rich inclusion "Figure 5". Rarely, three-phase (solid + liquid + vapor) fluid inclusions are observed in quartz vein sample. Liquid-vapor characteristics of fluid inclusions are commonly applied to assess whether or not boiling has occurred within the hydrothermal system. Two-phase fluid inclusions with constant ration of liquid and vapor are showed that consistent conditions of temperature and pressure (non-boiling condition) in hydrothermal system. Otherwise, two-phase fluid inclusions with coexisting liquid-rich and vapor-rich inclusions in samples are indicated that inclusions are trapped in boiling or immiscible fluid system [13] "Figure 5c". Primary fluid with necking-down are also observed in samples. Necking-down is a typical dissolution precipitation process, which finally leads to negative crystal shape.

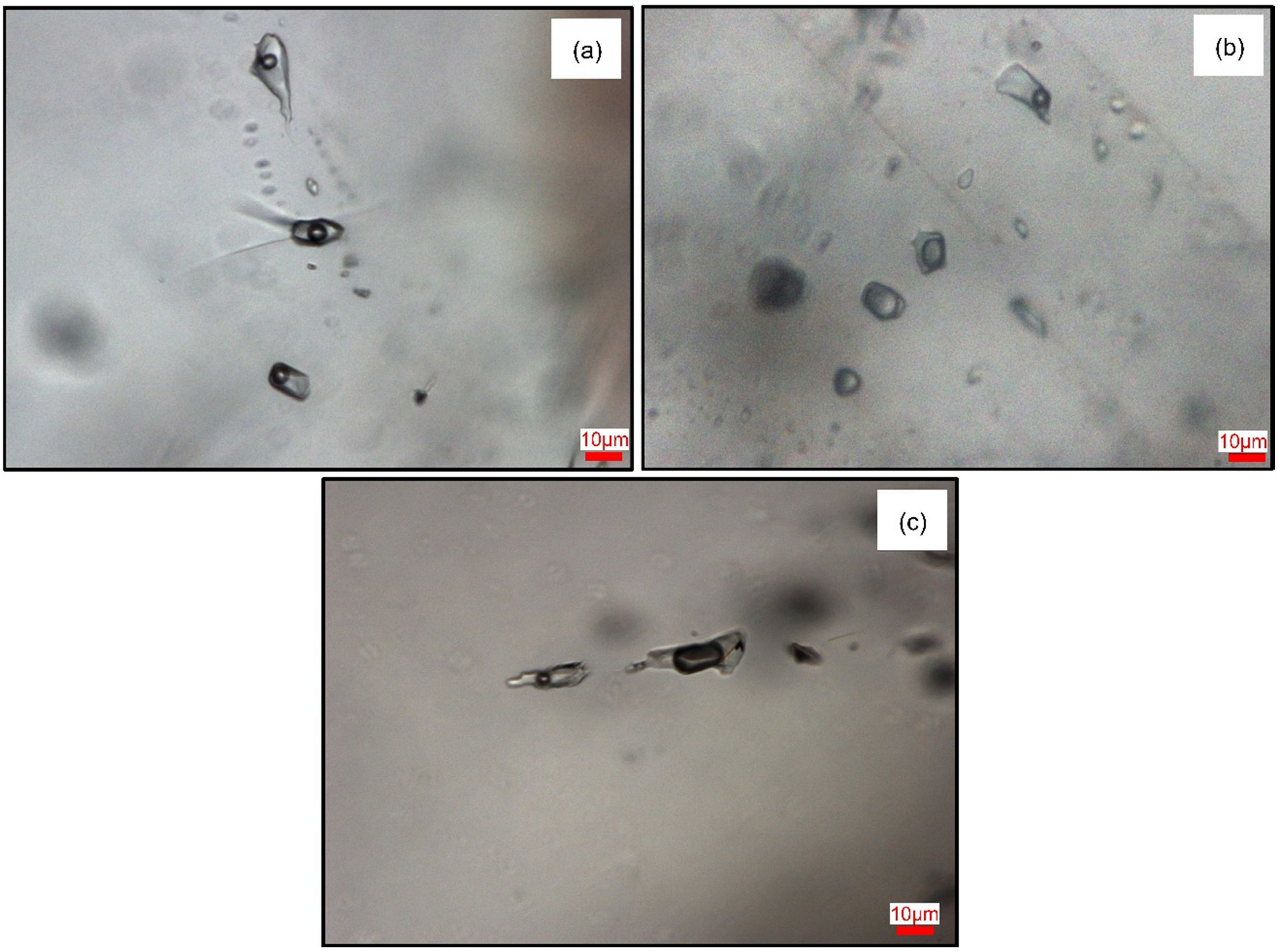


Figure 5. *Photomicrographs show (a) containing liquid-rich inclusions with consistent liquid-to-vapor ratio 'non-boiling', (b) coexisting liquid-rich and vapor-rich fluid inclusions 'boiling nature', and (c) necking-down in fluid inclusions 'dissolution precipitation'.*

6.2. Fluid Inclusion Microthermometry

The common two-phase liquid rich fluid inclusions from different veins were selected to conduct microthemometric measurements. This study has enabled to understand the characteristics of fluid inclusions such as temperature, pressure, density and paleo-depth of their forming. Totally 102 fluid inclusions from 5 samples of quartz veins and 2 samples of quart-carbonate veins were analyzed for homogenization temperature (*Th*) and last ice melting temperature (*Tm*). There are three import reasons why these fluid inclusions were chosen: (1) the inclusions are mostly intimately associated with gold and base metal mineralization, (2) the sizes of fluid inclusions are reliable to measure >5μm which allows for more confident thermometric analysis, and (3) these selected fluid inclusions can believe as primary fluid inclusions. The homogenization temperature (*Th*) of quartz veins range from 168°C to 315°C that are relatively higher than of quartz carbonate veins whereas last ice melting temperature (*Tm*) of quartz veins range from -5.5 to -0.5°C. The salinities of the fluid inclusions were calculated from *Tm* [14] where rage from 0.88 to 8.55 wt.% NaCl equivalent with an average of wt.% NaCl equivalent. In fact, fluid inclusions from quartz-carbonate veins are a bit lower in homogenization temperature range from 159°C to 267°C. The data of last ice melting temperature (*Tm*) that hosted in quartz-carbonate veins tend to be higher ranging from -8.9 to -0.5°C corresponding to relatively high salinity range between 0.88 to 12.51 wt.% NaCl equivalent (average wt.% NaCl). Frequency distributions of *Th* different veins show uni-modal distributions "Figure 6". All of these fluid inclusions from different veins are plotted in *Th* and salinity diagram "Figure 8" whereas they show low *Th* and salinities of epithermal field. Moreover, salinity and *Th* bivariate diagram can deduce fluid physiochemical process during the evolution of extinct hydrothermal system "Figure 7". This diagram showed that wide range variation of fluid inclusion salinities and homogenization temperature on the other hand the trend of increasing salinities with decreasing temperature. The trend of increasing salinity with decrease temperature indicates boiling condition where fluid inclusion density range from 0.7 to 1 g/cm^3. Salinity variation pointed out boiling or effervescence in the system, but significant salinity increases will only take place by continuous boiling in the restricted fractures [15]. Alternatively, fluid mixing also could be happen by adding or mixing with a more or less saline solutions because some fluid inclusions in specific temperatures showed their fluid mixing trends in figure. Generally, the formation temperature of vein refers to first peak of histogram distribution of *Th* under the boiling condition [13]. In this place, formation temperature of research area can assume that 170 to 180°C for quartz vein and 160 to 170°C for quartz carbonate vein respectively. Alternatively, their estimated formation depth are 150m for quartz carbonate vein and 180m for quartz from pale-water table but it is not represented to entire veins. In fact, the formation depth of Onzon quartz veins might be 120-1100 m depth below paleo-water table "Figure 9".

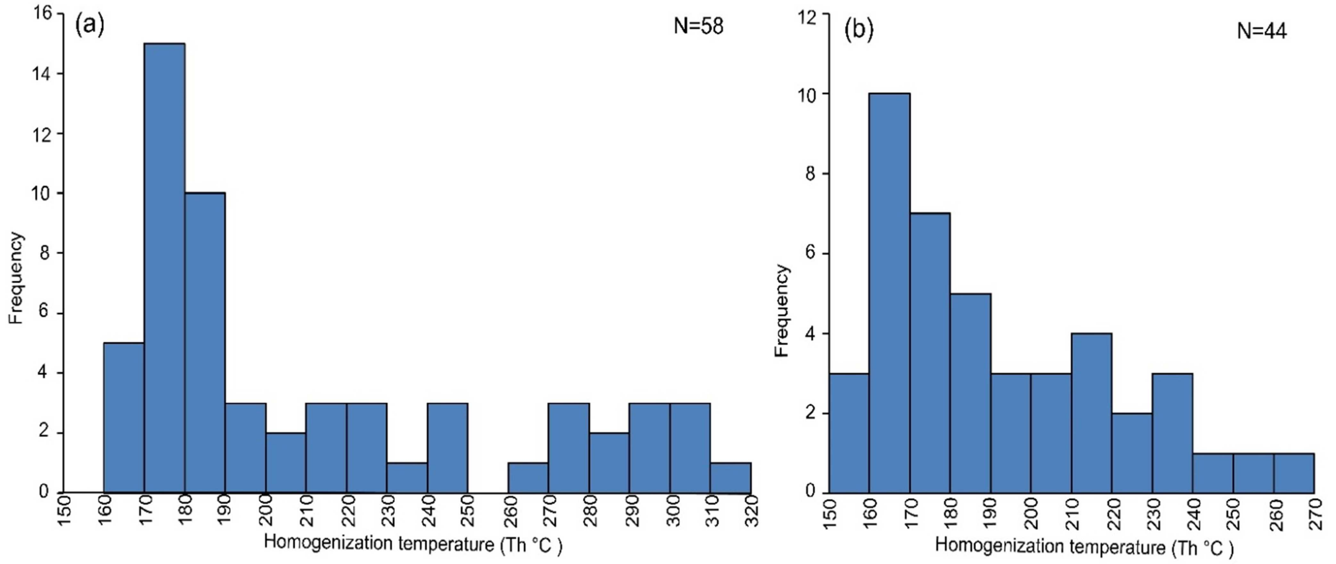


Figure 6. *Histograms show homogenization temperature (Th) of (a) quartz vein fluid inclusion and (b) quartz-carbonate vein (N=number of fluid inclusion).*

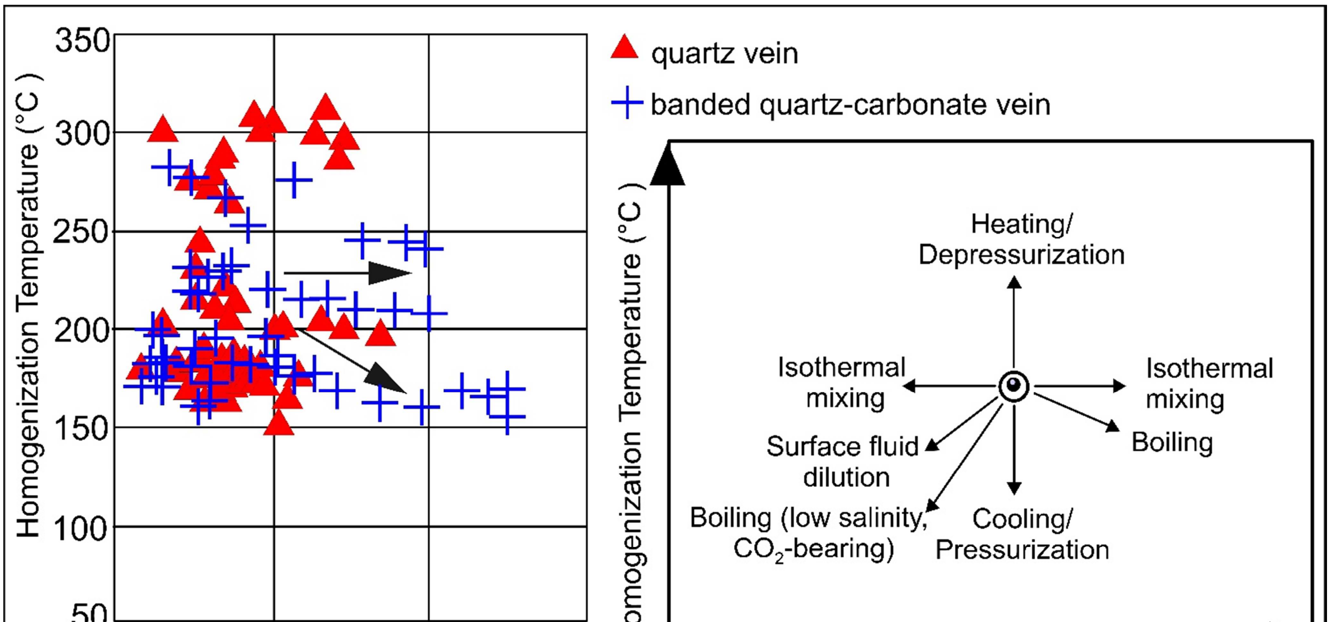


Figure 7. *Temperature of homogenization (Th) vs. salinity of fluid inclusions from two different vein generations at Onzon marble-hosted gold deposit. Schematic model of fluid evolution is adapted from Wilkinson [15].*

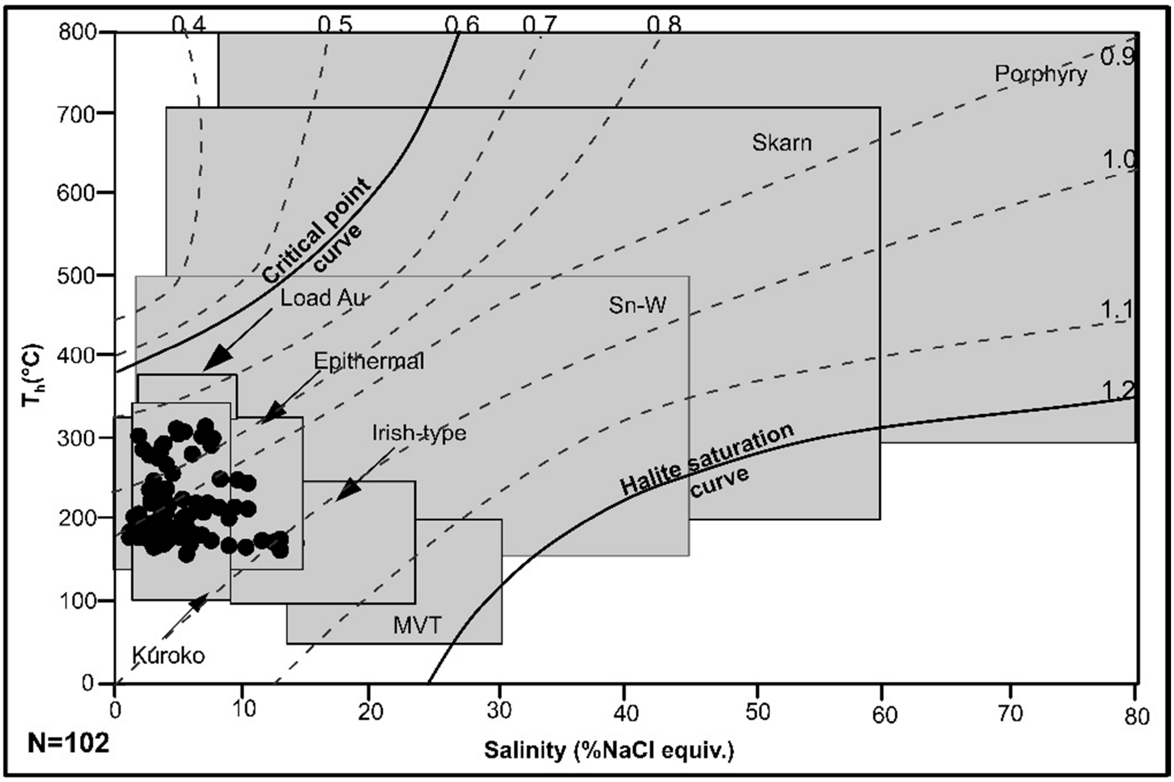


Figure 8. *Th (°C)-salinity diagram illustrating typical range for inclusions from different deposit types and their density range. Note that fields should not be considered definitive and compositions exist outside the ranges [15].*

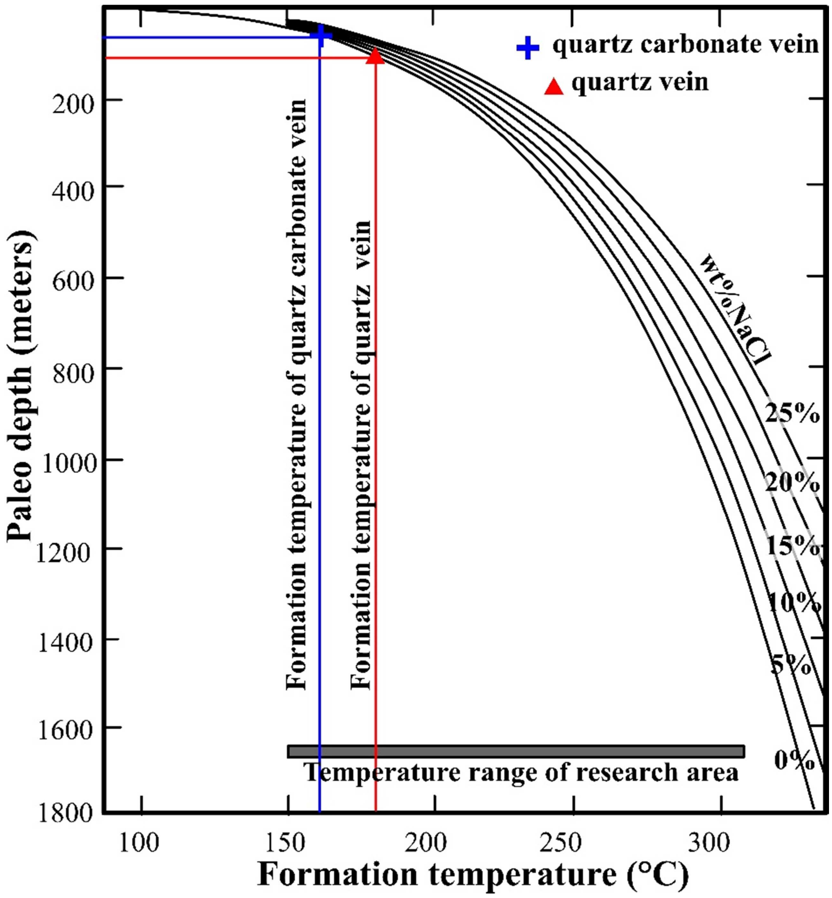


Figure 9. *Diagram shows the formation depth of quartz veins from marble-hosted gold deposit. The curves adopted from Hass [16] where blue colored curve's intervals represent their range observed in system.*

7. Conclusion

Based on fluid inclusion petrography and microthermometric measurements, quartz veins of Onzon area are characterized by low homogenization temperature (*Th*) and salinity. Most of primary fluid inclusions are trapped in quartz crystal of growing zones as small clusters and dispersed arrays where liquid-rich two phase fluid inclusions are dominant. In fluid petrography, coexisting of liquid-rich and vapor-rich fluid inclusions are observed as indicator of boiling that happened in hydrothermal system of research area. Typical dissolution precipitation character of necking-down fluid inclusions are also observed. In microthermometric measurement, the *Th* value of quartz veins are a little bit higher than quartz-carbonate vein but salinity value of both quartz veins are not too differences. The occurrence of wide range variation in fluid inclusion salinities and homogenization temperature indicates boiling condition as well as mixing with more or less saline solutions. Moreover, fluid inclusions *Th* and salinity diagram of research area showed that the territory of epithermal system. Additionally, the estimated formation temperature of quartz vein and quartz-carbonated vein are 180°C and 170°C and also their estimated formation depths are not higher than 200m under paleo-water table. All of these available data from fluid inclusion petrography and microthermometric measurement, it can be concluded that hydrothermal system of Onzon area were probably developed at shallow level, low temperature and low salinity epithermal setting.

Acknowledgements

The authors would like to deeply acknowledge AUN/SEED-Net (JICA) program for financial supporting to carry out this research work as worry free. Moreover, we would like to thank all of local companies and staffs from there because they helped our team during field trip as well as their critical discussions in out of field trip. Personally, we would want to express our gratitude to Mr. Naing Win and Mr. Win Phyo for their constructive suggestion and debate.

References

[1] A. H. G. Mitchell, N. Htay, C. Asua, L. Deiparine, A. Khine, and S. Po, "Geological Setting of Gold Districts in Myanmar," *PACRIM Semin. AusIMM, Bali, Indones. Oct.*, 1999.

[2] A. T. Zar, I. W. Warmada, L. D. Setijadji, K. Yonezu, and K. Watanabe, "Ore and Alteration Mineralogy of Onzon-Kanbani Gold Deposit, Thabeikkyin Township, Mandalay Region, Myanmar: Implication for Deposit Genesis," in *International Symposium on Earth Science and Technology 2016*, 2016, pp. 262-267.

[3] D. L. Searle and B. T. Haq, "The Mogok Belt of Burma and Its Relationship to the Himalayan Orogeny," *Proc. Int. Geol. Congr.*, vol. 22, pp. 132-161, 1964.

[4] A. H. G. Mitchell, "Guides to metal provinces in the Central Himalaya collision belt; the value of regional stratigraphic correlations and tectonic analogies," *Mem. Geol. Soc. China*, vol. 3, pp. 167-194, 1979.

[5] I. Metcalfe, "Late Palaeozoic and Mesozoic tectonic and palaeogeographical evolution of SE Asia," *Geol. Soc. London, Spec. Publ.*, vol. 315, no. 1, pp. 7-23, 2009.

[6] W. Swe, "A Strike-slip faulting in central belt of Burma [abstr.]," *Reg. Conf. Geol. SE Asia, Kuala Lumpur. Annex. Geol. Soc. Malaysia Newsl.*, vol. 34, p. 59, 1972.

[7] M. E. Barley, A. L. Pickard, K. Zaw, P. Rak, and M. G. Doyle, "Jurassic to Miocene magmatism and metamorphism in the Mogok metamorphic belt and the India-Eurasia collision in Myanmar," *Tectonics*, vol. 22, no. 3, p. n/a-n/a, 2003.

[8] A. H. G. Mitchell, S.-L. Chung, T. Oo, T.-H. Lin, and C.-H. Hung, "Zircon U–Pb ages in Myanmar: Magmatic–metamorphic events and the closure of a neo-Tethys ocean?," *J. Asian Earth Sci.*, vol. 56, pp. 1-23, Aug. 2012.

[9] M. P. Searle, S. R. Noble, J. M. Cottle, D. J. Waters, A. H. G. Mitchell, T. Hlaing, and M. S. A. Horstwood, "Tectonic evolution of the Mogok metamorphic belt, Burma (Myanmar) constrained by U-Th-Pb dating of metamorphic and magmatic rocks," vol. 26, 2007.

[10] G. Bertrand, C. Rangin, H. Maluski, and H. Bellon, "Diachronous cooling along the Mogok Metamorphic Belt (Shan Scarp, Myanmar): the trace of the northward migration of Diachronous cooling along the Mogok Metamorphic Belt," *J. Asian Earth Sci.*, no. June 2017, pp. 649-659, 2001.

[11] M. L. Thein, O. Myint, S. Kyi, and H. N. Win, "Geology and stratigraphy of the metamorphosed early Paleozoic rocks of the Mogok – Thabeikkyin – Singu - Madaya Areas," Yangon, 1990.

[12] E. Roedder, "Fluid Inclusions," *Mineral. Soc. Am. Rev. Mineral.*, vol. 12, no. Reviews in Mineralogy, p. 644, 1984.

[13] R. J. Bodnar, C. W. Burnham, and S. M. Sterner, "Synthetic fluid inclusions in natural quartz. III. Determination of phase equilibrium properties in the system H_2O-NaCl to 1000?C and 1500 bars," *Geochim. Cosmochim. Acta*, vol. 49, no. 9, pp. 1861-1873, Sep. 1985.

[14] R. J. Bodnar, "Revised equation and table for determining the freezing point depression of H," vol. 57, no. 1988, pp. 683-684, 1993.

[15] J. J. Wilkinson, "Fluid inclusions in hydrothermal ore deposits," *Lithos*, vol. 55, pp. 229-272, 2001.

[16] J. L. Hass, "The Effect of Salinity on the Maximum Thermal Gradient of a Hydrothermal System at Hydrostatic Pressure," *Econ. Geol.*, vol. 66, pp. 940-946, 1971.