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Ore-Forming Fluids of Orogenic Gold Deposit In Tamilouw-Haya, Seram Island, Indonesia

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Abstract - The Tamilouw-Haya orogenic gold deposit is located in the southern arm of Seram Island, Indonesia, occupying Tehoru Metamorphic Complex. Gold mineralization is predominantly in the form of veins, stockwork, and breccia, although minor dissemination is slightly appeared in the rock float samples. Ore-mineral assemblages are dominated by native gold, pyrite, chalcopyrite, sphalerite, tetrahedrite-tennantite (sulfosalt), galena, pyrrhotite, marcasite, realgar, kalininite, and arsenopyrite. Covellite, hematite, goethite, and malachite appear as supergene minerals. High-grade gold ores in this area are generally found in quartz-carbonate veins with the main alteration processes involving silicification, carbonatization, and sericitic. The P-T history of the mineralization was revealed by fluid inclusions, and this study implies the depth of ore deposit and its evolution during mineralization. The primary fluid inclusions from three different types of quartz/quartz-carbonate veins in Tamilouw-Haya crystallized at the homogenization temperature (Th) of 240 °C to 340 °C, with a fluid salinity from 3.87 to 0.70 wt. % NaCl equivalent, and melting temperature (Tm) of -0.4 to -2.3 °C. The ore-forming fluids consist mainly of two-phase (VCO_2+LH_2O) liquid-rich aqueous inclusions, characterized by low to rich CO_2, low salinity, and moderate temperature. There are three vein types as the ore-bearing fluids with precious metals and anomalous high basemetal contents. Quartz type 1- veins (V_1); concordant veins, formed at a temperature of 240-307 °C with an average salinity of 1.8 wt. % NaCl equivalent. Quartz type 2- veins (V_2) tend to cut the rock foliation which are formed at temperature range from 293-336 °C with the average salinity that shows a value of 2.4 wt. % NaCl equivalent. Meanwhile, type 3 quartz-carbonate veins (V_3) are formed at the temperature range of 240-340 °C and the average salinity of 2.72 wt. % NaCl equivalent. These quartz-carbonate veins cut the wall-rock foliation, which is identified as the late stage and associated with ore deposition in Tamilouw-Haya. The gold deposit in Tamilouw-Haya is formed at a depth of about 5.5-9 km of paleo-surface, and the pressure between 1.7-2.4 Kbar in epizonal to mesozonal zones.

Keywords: Tamilouw-Haya, orogenic gold, fluid inclusion, microthermometry, ore-forming fluids

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Introduction

Background

Recently, gold exploration actvities in Indonesia are not only focused along volcanic belts, but are also starting to shift along metamorphic terrains. Some large and medium scale gold deposits such as Awak Mas mesother-mal (Querubin and Walters, 2011), Poboya LS-epithermal (Wajdi *et al*., 2011), Bombana (Idrus and Prihatmoko, 2011), Buru (Idrus *et al*., 2013), and Mendoke-Rumbia (Hasria, 2018) orogenic gold deposits and many gold mineralizing occurrences have been successively discovered in Indonesia. The ore-forming fluids of these deposits were mainly composed of CO_2-NaCl-H_2O type, characterized by rich - CO_2, low to moderate salinity, and moderate temperature as the indication of orogenic gold deposit fluid composition (Gebre-Mariam *et al*., 1995; Groves *et al*., 1998; Goldfard *et al*., 2001).

Tamilouw-Haya is located within Tehoru Metamorphic Complex, Seram Island, Indonesia. Geologically, Tamilouw-Haya is predominantly occupied by metapelitic rocks (intercalated of metasandstone - metasiltstone), slate, phyllite, and locally is overlain by coral limestone and recent alluvial deposit. The extent of the researched area is 10,146.31 Ha (Figure 1). Primary gold mineralization is hosted by slate and metapelitic rocks, controlled by NE-SW and NNE-SSW trending structures. Concordant and discordant veins (V_1-V_3) are associated with gold mineralization, although minor disseminations are slightly appeared in several rock float samples.

Tamilouw-Haya is one of the very abundant primary and secondary gold deposits within Tehoru Metamorphic Complex. In Haya, the gold grade achieved 2.4 g/t, Cu 0.02 %, Pb 1.07%, and Zn 5.5% (Anonymous, 2015). There are six main prospects of gold mineralization in Tamilouw-Haya area namely Wae Lata, Wae Nama, Wae Satu, Wae Yala, Wae Namasula, and Way Wayaudara. Franklin *et al*. (2013) and some government agencies have conducted some preliminary researches on prospect of Seram gold deposits, but they are very restricted. In general, this is the first research in Tamilouw-Haya, and there is no previous detailed study that was focused specifically on the primary gold mineralization. High-grade gold ores in this area are generally found in quartz-carbonate veins with the main alteration processes involving silicification, carbonatization, and sericitization. The ore mineral assemblages within these veins are dominated by native gold, chalcopyrite, pyrite, sphalerite, galena, pyrrhotite, minor sulfosalts (tetrahedrite-tennantite), marcasite, arsenopyrite, realgar, and kaolinite. In this paper, the Tamilouw-Haya gold deposit was studied on the characteristics of fluid inclusions to ascertain temperature formation (trapping), on the type of deposit, and on the evolution of hydrothermal fluids.

Geological Frameworks

Seram Island is located along the northern part of the Outer Banda Arc, eastern Indonesia. It was

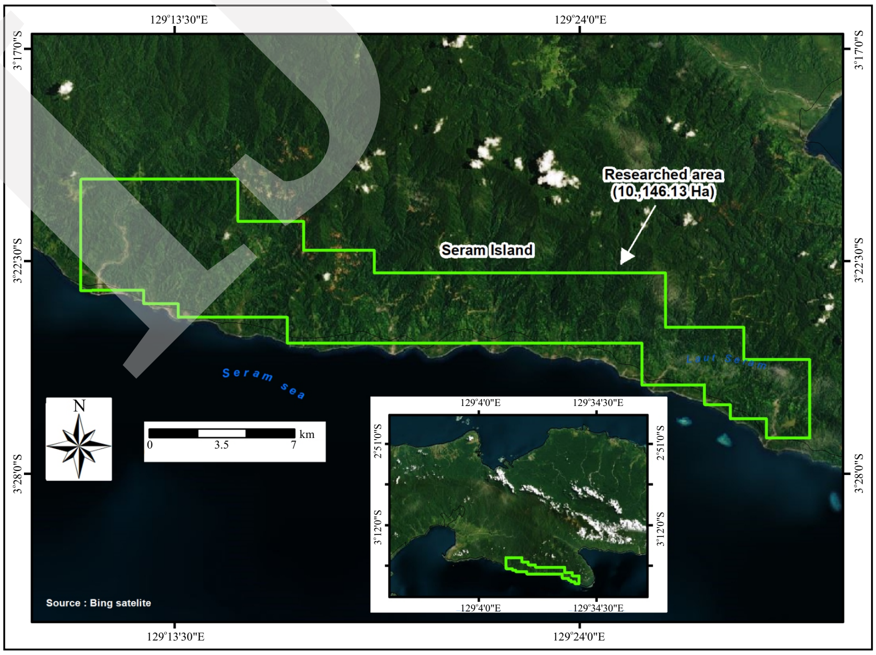


Figure 1. Location map of Tamilouw-Haya area (marked by green lines). Black quadrangle (bottom) indicates Seram Island.

previously located in the collision zone between Australian Continent and Banda Subduction Zone, where the Northwest Australian Margin moved towards the Banda Subduction Zone. The northwest shelf of Australia itself was generated due to the break-up of Gondwanaland during Jurassic (Powell, 1976; Veevers, 1982). Tamilouw-Haya is generally characterized by a low plain to moderate-rugged hilly topography with elevations in the range of 3 to 675 m above sea level, separated by several big rivers. Slope gradients are steeper to the western part of the area; a half of them belongs to Tamilouw. The river flow pattern is straight to meander, and at the downstream part it is covered by alluvial deposit. In the south to the coastal plain, Quaternary limestone is locally scattered in Tamilouw and Yalahatan (Figure 2).

Stratigraphically, the researched area is composed of Tehoru Metamorphic Complex consisting of metapelitic/metasediment origin, slate, and phyllite with numerous lenses of carbon. The age of these LP-LT metamorphic rocks are Permian (Audley-Charles *et al*., 1979; Tjokosapoetro *et al*., 1993). In general, the LP-LT metamorphic rock foliation and metapelitic rocks strike N72°E -N135°E and dips 25-48^0 to SSW. The metamor-

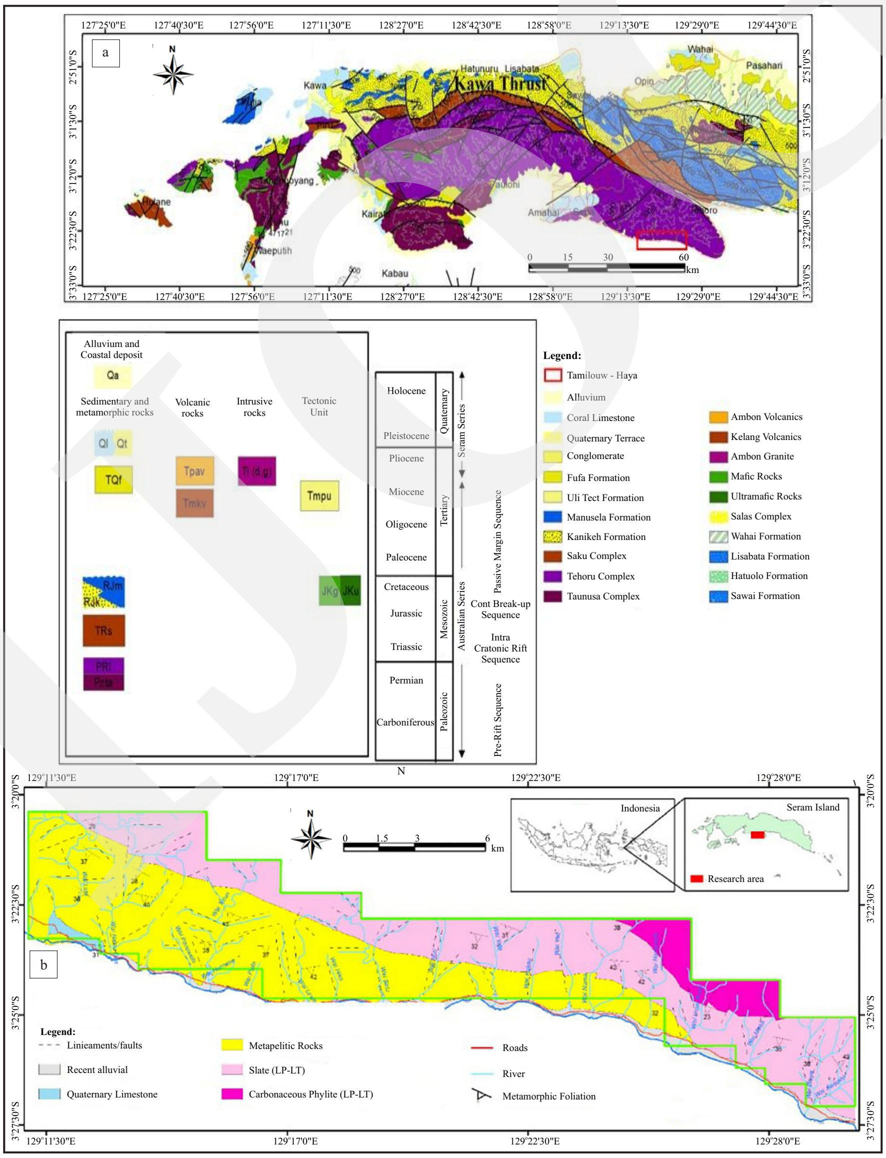


Figure 2. Geological map of Seram adapted from Tjokrosapoetro *et al*. (1993). a). Simplified Tamilouw-Haya geological map.

phic grade generally increases from the southern to the northern part of the researched area. The metapelitic rocks are widespread in the studied area dominated by alternating fine-grained metasandstone and metasiltstone. To the north, the metasandstone thickness increases 75 cm, while the thickness of metasiltstone reaches 12 -15 cm. Tjokrosapoetro *et al*. (1993) mentioned that metapelitic rocks in Tamilouw-Haya as part of the Tehoru Metamorphic Complex consisted of quartz, muscovite, clay, iron oxide, and sulfides. Locally, tectonic setting of Tamilouw-Haya has been influenced by regional compression of Seram Island itself. Despite the tectonic setting of Seram is still subject to debate, at least there have been two tectonic compressions and two continental breaks-up that were related to Seram Island**.** The first continental break-up was followed by tectonic compression that occurred in Paleozoic. Subsequent contraction of the earth crust places high-grade metamorphic rocks such as granulite near the surface, and the upper mantle is uplifted to the surface to form ultramafic rocks. Hence, erosion occurred to further expose of these metamorphic rocks and followed by thermal subsidence as the deposition of Australian series. The second continental break-up and sea floor spreading occurred in Middle Jurassic, and it might correspond to the absence of sedimentation interval in the Australian series. The last orogenic compression or deformation occurred in Late Miocene-Pliocene, and this event is very critical for the geological evolution of Seram (Audley-Charles *et al*., 1979; Kemp and Mogg, 1992; Tjokosapoetro *et al*., 1993; Setyawan *et al*., 2000**)**. Therefore, the ore mineralization process in Tamilouw-Haya is controlled by NE-S and NNE-SSW trending structures as the implication of this last compression event.

Methods and Materials

This research used fieldwork, geological and mineralization mapping methods, combined with microthermometry of fluid inclusion. The geological and mineralization mapping was carried out in two months to collect rock samples, for geological, mineralization, and alteration prospecting in Tamilouw-Haya area.

At least six selected samples of ore-bearing veins from three different types (V_1-V_3) are collected from the field for fluid inclusion study. The analysis was performed with double-side polished preparations in Laboratory of Geomin-Aneka Tambang in Jakarta, while the heating and freezing stage was assembled using the Linkam THMSG 600 microscope. Veins, in general, contain at least three types of quartz/quartz-carbonate to represent ore mineralization types in Tamilouw-Haya. The first vein type (V_1) is represented by sample TMW-LT.18, the second vein type (V_2) is represented by HY-WNM.05, and the last is the third vein type (V_3) accumulated into four samples *i.e*. TMW-LT.01, TMW-WS.06, HY-WNM.07, HY-WYU.02. The five samples contain measureable fluid inclusions, and only one sample (TMW-LT.01) is too small for observation.

The preparation of sample for observation is made on the double polished thin-section with the thickness average in the range between 100 to 150 μm. In the study of fluid inclusion petrography and microthermometry, the shapes, sizes, phases of fluid inclusion, homogenization temperature (T_h), and melting temperature (T_m) are based on the standard citation of Roedder (1984) and Shepherd *et al*. (1985). The determination of fluid inclusion salinity (Equation 1) is calculated by using the equations of Bodnar (1993) and Bodnar and Vityk (1994) from ice melting temperature (T_m) which is as follow:

$$Sal = 0.00 + 1.78 (T_m) - 0.012 (T_m)^2 + 0.000557 (T_m)^3 \quad (1)$$

Results and Analysis

Quartz and Host Rock

Primary ore mineralization in Tamilouw-Haya is hosted by slate and metapelitic rocks of Tehoru Metamorphic Complex. There are three vein types as the ore-bearing fluids with precious metals and polymetalic sulfide contents. Concordant vein, namely type 1 quartz vein (V_1), is characterized by massive shape, sheeted, segmented, the average thickness is < 2 to 7 cm, that tends to be parallel to the foliation of metamorphic rocks, and weak mineralized to barren (Figure 3a). This vein is associated with pyrite and chalcopyrite. Discordant veins are separated into two vein types. Type 2 quartz vein (V_2) is cross to the foliation, massive, weak mineralized to barren, associated with silicification with the thickness of

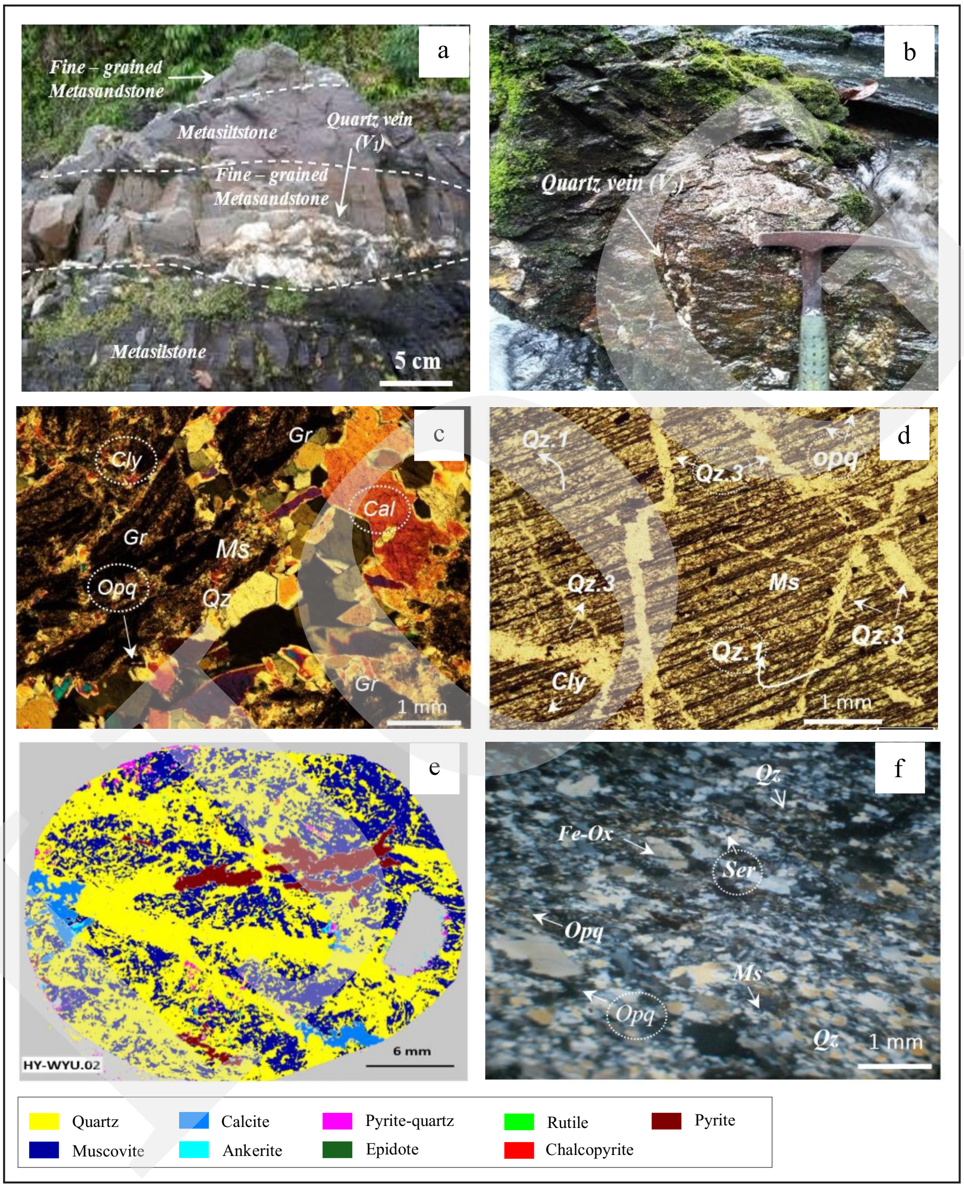


Figure 3. Field photographs, photomicrographs, and Micro XRF results of three alteration types occurred in Tamilouw-Haya area. a). Intercalated of fine-grained metasandstone and metasiltstone outcrop. The average thickness is < 2 – 7 cm with segmented quartz vein (V1). b). Type 2 Quartz veins (V2) cut the rock foliation with the thickness of < 2 cm. c). Cross polarized light photomicrograph of carbonatization alteration (HY-WYU.02) showing minerals of calcite (Cal), quartz (Qz), opaque minerals (opq), mica/muscovite (Ms), clay (cly), and graphite (gr). d). Parallel polarization photomicrograph of silicification (HY-WNM.07.3) showing vein minerals of quartz 1 (Qz.1) parallel to foliation, opaque mineral (opq), clay (cly), muscovite (Ms), and type 3 quartz veins that cut foliation (Qz.3). e). Cross polarized light photomicrograph results of quartz-muscovite meta-sandstone sample at the sample code of TMW-LT.18B showing alignment of quartz (Qz) as groundmass of the crystal, muscovite (Ms), altered sericite (Ser) which fills the fracture, iron oxide (Fe-Ox), and opaque minerals (Opq). f). Micro XRF analysis of carbonatization alteration in sample HY-WYU 02 showing mineral composition of quartz, muscovite, ankerite, calcite, pyrite, epidote, rutile, and chalcopyrite.

Table 1. Characteristics of Quartz Vein/Quartz-Carbonate Vein Type in Tamilouw-Haya

Quartz veins	Veins relation to the hostrock	Texture and thickness	Alteration types	Ore mineral assemblages
V_1	Concordant	Massive, sheeted, segmented, < 2 – 7 cm	Sericitization	Ccp, Py
V_2	Discordant	Massive, < 2 cm	Silicification	<Au, Py, Ccp, Sp, Apy
V_3	Discordant	Massive, brecciated, stockwork, boudin-like texture, segmented, 2 – 5 cm	Silicification, carbonatization	Au, Py, Ccp,Sp,Gn,Po, Ttr, Tnt, Mrc, APy, Cnb, Klt, Rg.

< 2 cm. The ore mineral assemblages are pyrite, chalcopyrite, sphalerite, arsenopyrite, and minor gold (Figure 3b).

The last, the so-called "mineralized vein" (V_3), is composed of quartz-carbonate, segmented, deformed, cross to the foliation of metamorphic/metapelitic rocks, and characterized by stockwork - breccia vein textures. The average thickness of these veins were 2-5 cm. The ore mineral assemblages embedded in these veins are pyrite, gold, chalcopyrite, sphalerite, galena, pyrrhotite, arsenopyrite, cinnabar, kalininite, realgar, marcasite, and minor sulfosalts (tetrahedrite and tennantite). The characteristics of quartz veins/quartz-carbonate vein type in Tamilouw-Haya are shown in Table 1.

The characteristics of primary ore mineralization in Tamilouw-Haya are generally found in quartz/quartz-carbonate veins associated with carbonatization, silicification and sericitic alteration types. Carbonatization alteration is characterized by the presence of carbonate minerals (calcite-ankerite) associated with quartz, opaque, and pyrite (Figure 3c). It is generally formed in the vein or breccia zone which is a shear zone, breciated, segmented, and discontinue. Low to strong altered, selective to pervasive alteration, and precipitation of calcite is associated with fluctuations in CO_2 concentration with pH close to neutral.

The silicification is characterized by the presence of quartz veins that cut and parallel to rock foliation (concordant and discordant veins). Generally, quartz is present and associated with calcite, sulfide (pyrite), and clays (Figure 3d). The alteration is formed in veins/veinlets, stockwork, and breccia zones associated with carbonates, and vary in different intensities (pervasive).

Sericitic alteration is characterized by the presence of quartz, sericite, and opaque minerals (Figure 3e). It is generally formed in metapellitic host rock. V_1 - V_2 veins are associated with this alteration type. Selectively pervasive sericite replaces muscovite and acid plagioclase. Gold and polymetallic sulfide mineralization at the researched area is predominantly in the form of veins, stockwork, and breccia, although minor dissemination is slightly appeared in rock float samples. In addition, ore mineralization is obviously shown by micro-XRF image in Figure 3f showing the presence of chalcopyrite and pyrite.

Ore Mineralization

Carbonatization and silicification are most closely related to high-grade gold mineralization in Tamilouw-Haya. It is associated with intense alteration within stockwork and breccia vein textures (V_3) (Figure 4). Calcite is the most carbonate mineral in the researched area and accompanied by ankerite and siderite. The brecciated vein textures are abundant, and mainly formed during the late stage of mineralization. It contains clasts of altered host rocks (monomitic clast/fragment of slate) with angular to subrounded shape of various sizes.

The brecciated vein host rock is an association of quartz, calcite, minor graphite, and sulfide minerals (Figures 4a and 4b). This mineral assemblage is an alteration product of clasts and matrix of breccia which is similar to the alteration mineral assemblage observed in type 3 vein (V_3). Alteration halo occurred on a millimetre to centimetre scale along the veins, and it is thicker in presumably metasandstone host rocks.

In Tamilouw-Haya, mineralization is characterized by native gold, pyrite, chalcopyrite, ga-

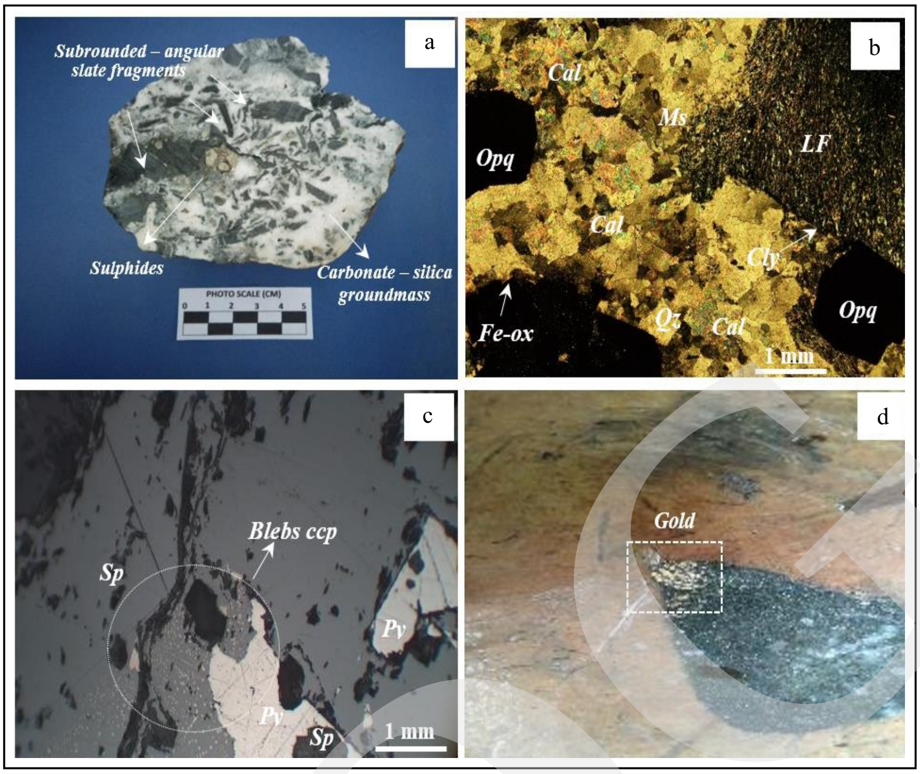


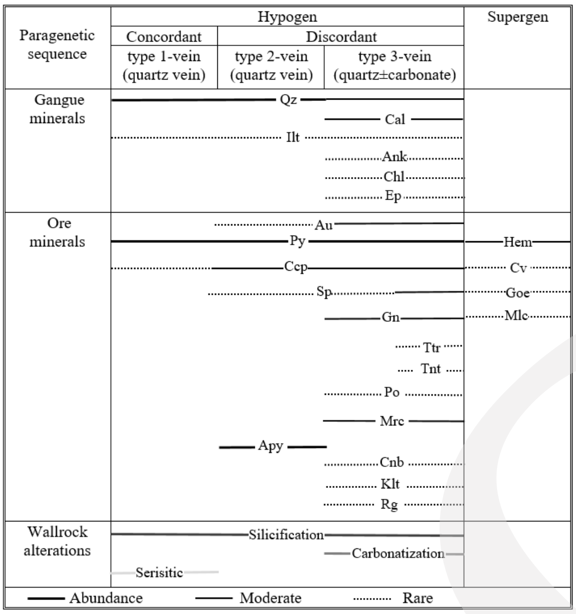
Figure 4. a). Brecciated slate, monomic breccia sample taken from TMW-LT.01. It shows lithic fragment of slate embedded in the carbonate-silica groundmass. b). Photomicrograph of brecciated slate showing hydrothermally altered host rock consisting of lithic fragment (LF), calcite (Cal), quartz (Qz), clay (Cly), muscovite (Ms), graphite (Gr), and opaque minerals (Opq). c). Chalcopyrite (Ccp) and sphalerite (Sp) exsolution-texture, sphalerite replaces pyrite (Py), and disseminated texture of subhedral pyrite (Py) within quartz gangue. d). Secondary gold grains with varying sizes ranging from 0.1–0.5mm, euhedral–subhedral in Wae Yala River.

lena, sphalerite, cinnabar, and iron oxide (Figures 4c-d). Quartz-carbonate veins are generally bright to milky coloured, massive, with a thin thickness of between 0.5-2 cm which is parallel and predominantly cuts rock foliation. The supergene process and the influence of water circulation that occurs in primary gold deposits at or near surface caused decomposition of primary gold which then forms secondary deposits in Tamilouw-Haya. The secondary gold size varies from 0.1-0.5 mm, euhedral to subhedral. The ore-mineral assemblages in the researched area are dominated by native gold (Au), chalcopyrite ($CuFeS_2$), pyrite (FeS_2), sphalerite (ZnS), galena (PbS), pyrrhotite (FeS_x), minor sulfosalts (tetrahydrite-Tennantite), marcasite (FeS_2), arsenopyrite (FeAsS), covellite (CuS), hematite (Fe_2O_3), goethite (FeO(OH)), and malachite ($(Cu_2CO_3(OH)_2$. Paragenetic stage of mineralized veins in Tamilouw-Haya is shown in Table 2.

Petrography of Fluid Inclusion

Shepherd *et al.* (1985) classified fluid inclusions into monophase (liquid or vapour), two-phases (liquid + vapour or vapour + liquid), and multiphases. Most of fluid inclusions in Tamilouw-Haya contain two phases (liquid+vapour) liquid-rich fluids. In general, the size of fluid inclusion in Tamilouw-Haya ranges from 4.52 -56.18 μm. Fluid inclusion analysis was only carried out on primary fluid inclusions. The fluid inclusions in the Tamilouw-Haya also have a predominantly slightly elongated, rounded or circle form (Figures 5a-e) and minor necking in a slightly long tabular inclusion form (Figure 5f). Fluid inclusions show a fairly distribution of vapour (CO_2) composition, even though its contents are not abundant or relatively small. Fluid inclusions do not show boiling conditions which are characterized by the phase separation between the liquid and vapour through the contribution of metamorphic and meteoric

Table 2. Paragenetic Stage of Mineralized Veins in Tamilouw-Haya



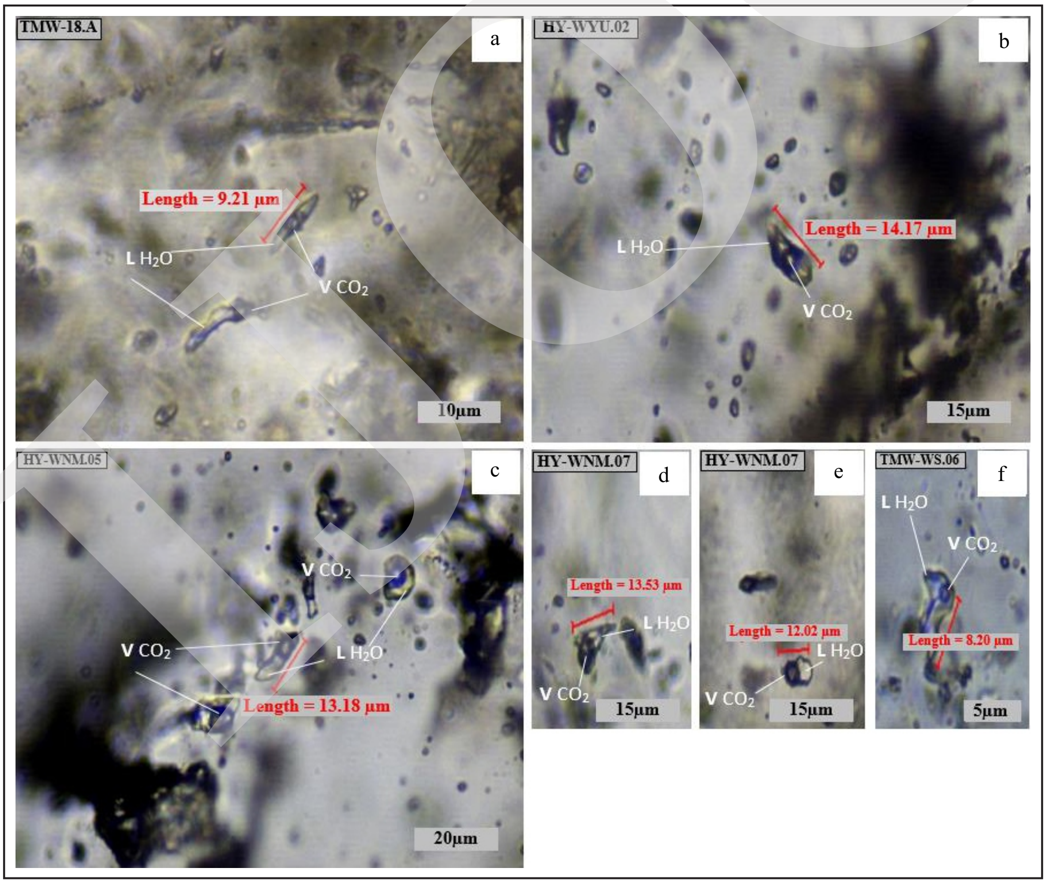


Figure 5. Photomicrographs of two phase (LH_2O+VCO_2) liquid-rich fluid inclusion morphology assemblages in Tamilouw-Haya: a). Fluid inclusion in elongated tabular form with VCO_2 is centred and uncentered (Tmw-18A or V_1); b). Slightly long tabular and circle inclusion form, V/(V+L) > 50% from sample Hy-Wyu.02 and Hy-Wnm.05 (V_2 and V_3); c). A slightly circle form with the size of 13.18 µm from sample HY-WNM05; d). A circle form with the size of 13.53 µm; e). A circle form with size 12.02 µm from sample HY-WNM07; f). Necking in a slightly long tabular inclusion form (Tmw-WS.06 or V_3).

fluids that form quartz/quartz- carbonate veins indicated by the presence of H_2O-CO_2.

Microthermometry of Fluid Inclusion

The calculation of microthermometry is based on the results of the fluid inclusion analysis. It resulted in the homogenization temperature range (T_h) and salinity which are as follows: the type 1 quartz vein (V_1) which is parallel to the foliation varies from 240 - 307 °C with the salinity of 0.7 - 2.9 wt. % NaCl equivalent, type 2 quartz-vein (V_2) that cuts the foliation plane shows the homogenization temperature (T_h) ranging from 293 - 336 °C with the salinity of 1.74 - 3.06 wt. % NaCl equivalent, and quartz-carbonate vein is classified as type 3 vein ranging from 240 - 340 °C with the salinity of 0.88 - 3.87 wt. % NaCl equivalent (Table 3).

The data of Table 3 show that three types of veins (V_1 - V_3) have almost the same characteristics of T_m, T_h, and salinity values indicating those are trapped and formed in a moderate temperature and low salinity formation. Based on the data of microthermometry and calculation of salinity measurements from the Table 3 below, it is entered into the histogram curve with the aim to obtain the range of high frequency homogenization and salinity temperatures (peak) from each type of veins in the studied area.

Discussion

Two main styles of gold mineralization vein characteristics are typified by concordant and discordant veins in Tamilouw-Haya. Discordant veins are generally associated with silicification and carbonatization alteration, and tends to contain high grades of gold mineralization. In particular, Goldfarb *et al*. (2005) stated that in low-grade metamorphic rocks which are generally brittle deformation, the ore texture is similar to epithermal deposits at the epizonal zone of orogenic gold deposit. For instance, it can be seen in the gold deposits at Yilgarn Craton-Wiluna (Gebre-Mariam *et al*., 1995) and the Fimiston ore deposit, Golden Mile (Bateman and Hageman, 2004) showing open space filling including the typical texture of comb, cockade, crustiform, colloform, and chalcedony veins.

However, it is notable that Tamilouw-Haya deposit contains significance base metal, and it may still open for another argument that this type of deposit is associated/overprinted with other deposit types. In addition, the ex-decomposition texture called "chalcopyrite disease" or chalcopyrite blebs in sphalerite in several samples of Tamilouw-Haya also reflects a typical of epithermal system (Barton and Bethke, 1987; Dana *et al*., 2021). In this case, an advanced further research is needed to understand the types of these deposits in Seram Island.

Gold is associated with quartz veins/quartz-carbonate vein type, which is also commonly observed in many orogenic gold deposits such as Yilgarn Craton-Wiluna (Gebre-Mariam *et al*., 1995), Fimiston ore deposit, Golden Mile (Bateman and Hageman, 2004) and Fairview gold mine, South Afriva (Altigani, 2021). Petrographic analysis of fluid inclusions in the veins indicates that the distribution of vapour (CO_2) composition in Tamilouw-Haya are relatively low or not abundant This is probably due to the position of

Table 3. Fluid Inclusion Microthermometry Analysis Results for Tamilouw-Haya Deposit

Sample code	Vein Types	n	T_h (°C)		T_m (°C)		Salinity (wt% Nacl eq.)	
			Th range	Th mean	Tm range	Tm mean	Sal.range	Sal. Mean
TMW-LT.18	V_1	15	240-307	270.3	-0.4 - -1.7	-0.81	0.70-2.90	1.40
HY-WNM.05	V_2	15	293-336	311.5	-1.0 - -1.8	-1.40	1.74-3.06	2.40
HY-WNM.07	V_3	15	298-340	300.2	-0.9 - -2.3	-1.36	1.57-3.87	2.48
HY-WYU.02	V_3	15	296-332	313.8	-0.9 - -2.0	-1.45	1.57-3.39	2.49
TMW-WS.06	V_3	15	240-270	253.1	-0.5 - -0.9	-0.67	0.88-1.57	1.18

n= number of measurements Th= Temperature of Homogenization
V_1 – V_3= Vein types Tm= Temperature of Melting

gold and polymetallic sulfide deposits occupying the epizonal zone or close to the surface, and the distribution of vapour (CO_2) composition tends to be released to the surface through the rock fractures during mineralization process. Similarly, this fact is also observed in Bombana (Idrus *et al*., 2013), and Awak Mas (Ernowo *et al*., 2019). This is consistent with the concept of the orogenic gold deposit model according to Gebre-Mariam *et al.* (1995) and Groves *et al.* (1998). In addition to all described above, the gold precipitation mechanism in Tamilouw-Haya is probably controlled by the bisulfide (HS^-) complex system. Gammons and Williams-Jones (1997) stated that at a system temperature of <350 °C, gold solubility was controlled by bisulphide ion (HS-) with $AuHS^o$ dominating at relatively low pH, while Au $(HS)_2^-$ at a higher pH. Based on the homogenization temperature of fluid inclusion in Tamilouw-Haya at a temperature of 240-340 °C, the bisulfide complex (HS^-) is considered as the main ligand for gold deposition in Tamilouw-Haya deposit.

In this part, ore-forming fluid characteristics are discussed that may lead to the formation temperature, salinity, and its evolution, and finally to define the ore deposit type for this gold mineralization as well.

Formation Temperature, Salinity, and Evolution of Hydrothermal Fluids

Fluid inclusion microthermometry can be used to calculate the formation temperature (trapping) and salinity of the responsible hydrothermal fluid for ore-forming formation. The formation temperature (trapping) was calculated based on the graph of histogram (peak) of the homogenization temperature (T_h), while the salinity of the formation was determined based on the graph/curve histogram (peak) of the fluid salinity (Table 4 and Figure 6).

Based on graph of histogram analysis in Tamilouw-Haya, it can be concluded that homogenization temperature (T_h) of quartz-carbonate veins (type 3) which are "the minerali-zed zone" were higher than type 1 quartz veins and type 2

Table 4. Estimated Formation Temperature (trapping) and Salinity in Tamilouw-Haya from Three Different Vein Types

Sample code	Vein types	Formation temperature (°C); Estimated from histrogram (peak) of homogenization temperature	Salinity (wt. % NaCl equivalent); Estimated from histrogram (peak) of salinity
TMW-LT-18	V_1	260-270°C	0.8-1.0
HY-WNM.05	V_2	300-310°C	2.2-2.4
HY-WNM.07, HY-WYU.02, TMW-WS.06	V_3	320-330°C	2.4-2.6

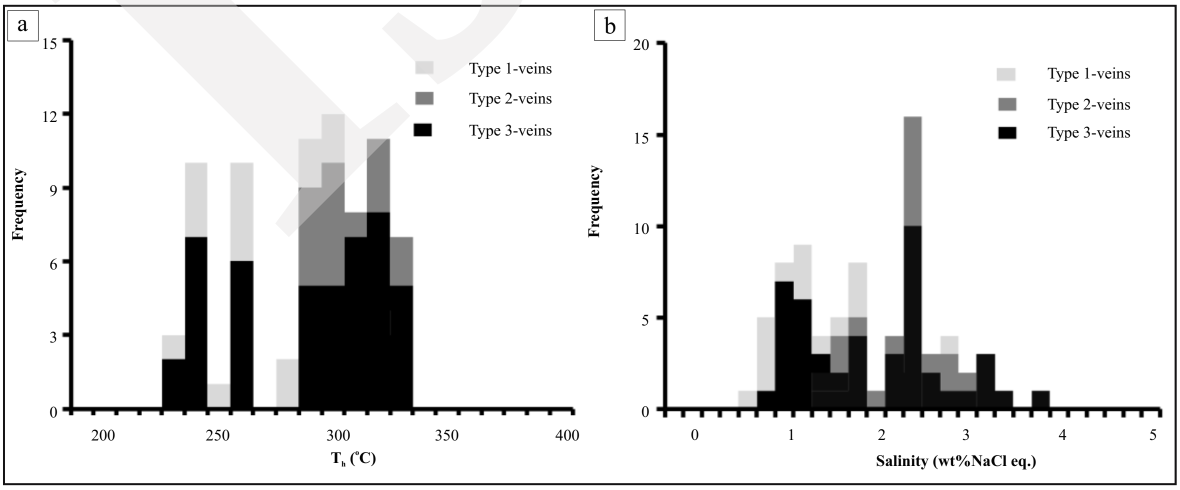


Figure 6. Histograms of: a). accumulated homogenization temperature (T_h) and b). Salinity of the quartz-carbonate veins were used for fluid inclusion analysis in Tamilouw-Haya.

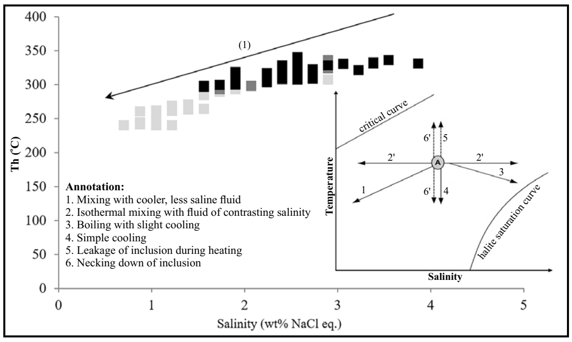


Figure 7. Diagram of salinity vs homogenization temperature (T_h) related to fluid evolution in Tamilouw-Haya based on Shepherd *et al*. (1995) annotation/classification.

quartz veins, homogenized at 320-330 °C with the salinity range of 2.4-2.6 wt. % NaCl equivalent.

Furthermore, the analysis of the hydrothermal fluid evolution in Tamilouw-Haya was carried out by plotting salinity range vs homogenization temperature (T_h). These results are correlated against homogenization temperature vs salinity trend diagram based on Shepherd *et al.* (1985) classification to measure its fluid evolution processes. Figure 7 shows that the homogenization temperature (T_h) vs salinity in Tamilouw-Haya is gradually declined - trend due to its differences in temperature and fluid salinity which tends to be decreasing. Fluid evolution in Tamilouw-Haya tends to show a mixing with cooler, less saline fluids (Shepherd *et al*., 1995) where the source of this fluid have moderate temperature and low salinity formation. Determining the depth and pressure of the formation (trapping) of orogenic gold deposits is based on boiling or immiscible conditions of fluid inclusions (Brown and Hagemann, 1995). However, the indication of fluid inclusion boiling in Tamilouw-Haya was not observed. Thus, determination of the depth of formation temperature was carried out by correlating the temperature (T_h) obtained with the formation (trapping) temperature of the orogenic deposit according to Groves (1993); Gebre-Mariam *et al.* (1995); Goldfarb and Groves (2001).

Based on the correlation between the formation temperature (trapping) continuum model of orogenic gold deposits, it is indicated that the gold deposit in Tamilouw-Haya is formed at a depth of about 5.5 - 8.5 km of paleosurface and the pressure between 1.7- 2.4 Kbar in the epizonal to mesozonal zones (Figure 8).

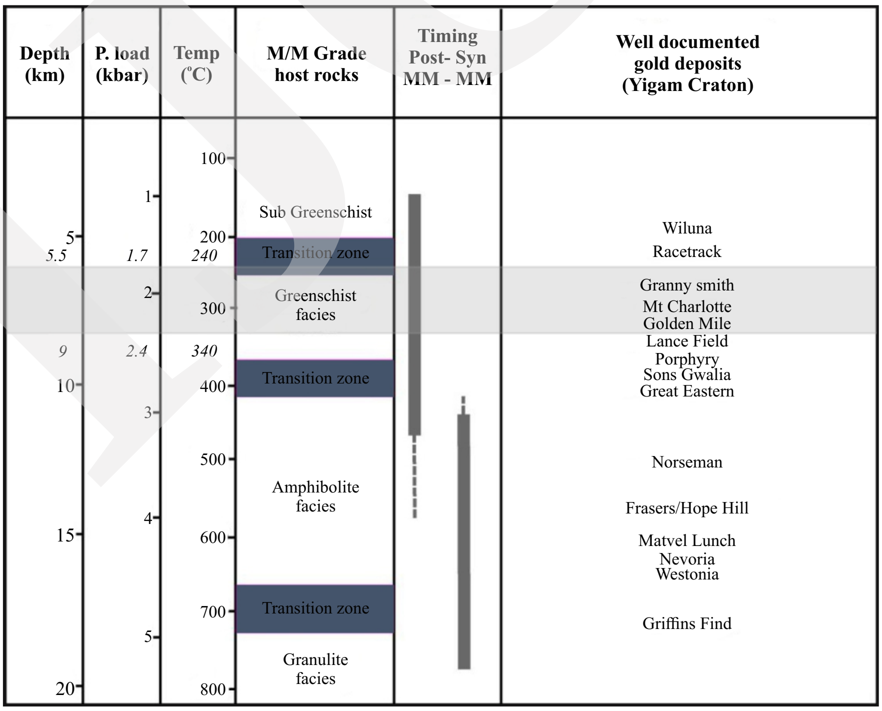


Figure 8. Plot of the Tamilouw-Haya gold deposit formation (trapping). Pressure load, temperature, and timing of mineralization are obtained from orogenic gold deposit continuum model of Western Australia (modified after Groves, 1993; Gebre-Mariam *et al*.,1995; Goldfarb and Groves, 2001).

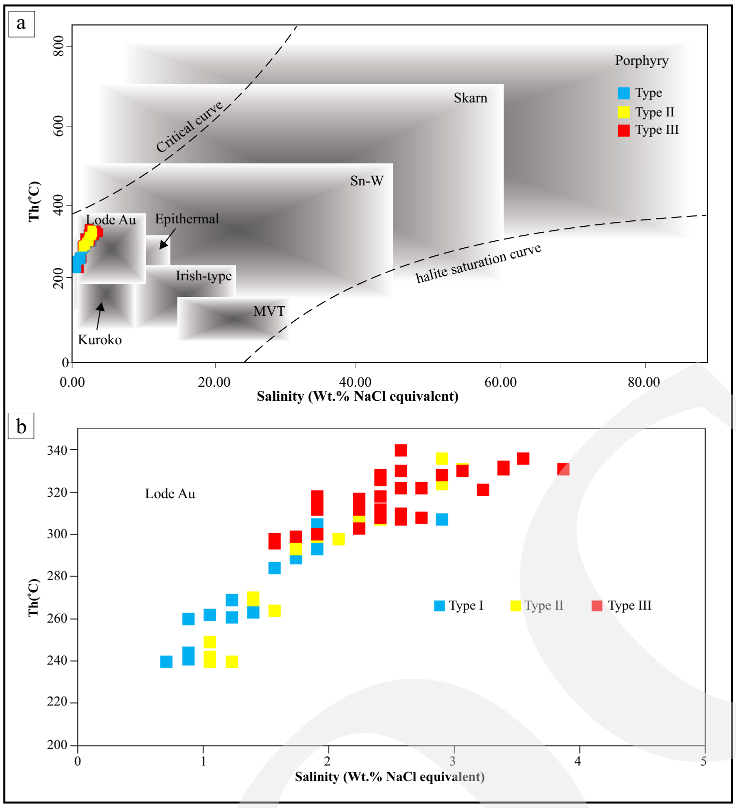


Figure 9. a). Classification of ore deposits based on temperature homogenization range (Th) and b). salinity of fluid inclusions based on Wilkinson (2001), Tamilouw-Haya gold deposit type falls to lode Au or orogenic gold deposit range.

Deposit Type

The classification of ore deposit on the basis of temperature homogenization range (T_h) and salinity of fluid inclusions from different deposit types is well classified by Wilkinson (2001). The deposit type in the studied area is obviously determined by plotting the ranges of homogenization temperature and salinity of fluid inclusions which are 240 to 340 °C and 0.70 - 3.87 wt. % NaCl equivalent, respectively. Thus, the deposit type in the studied area is in the range of lode Au or orogenic gold deposit (Figure 9).

In addition, there are some arguments to support this gold deposit which may support the orogenic deposit style which are as follows :

1). The host rock of mineralization is metamorphic rocks (slate and metapelitic domain), and has been altered to silisification, carbonatization, and serisitization (Groves *et al*., 1993; Thompson and Thompson, 1996).

2). The structure and mineralization style are veins that associated with breccias and stockworks, dissemination and replacement that may occur in the epizonal - mesozonal zone of orogenic gold deposit (Hageman and Cassidy, 2000). The NE-SW and NNE-SSW trending geologic structure as ore-trapped mechanism is influenced by last compression that occurred in Late Miocene to Pliocene.

3). The depth and pressure of this deposit achieved 5.5-8.5 km, that are unable to compare with epithermal system which tends to be formed under a low pressure as deep as 2 km with the pressure of 0.5 kbar (White and Hedenquist, 1995; Corbett and Leach, 1998; Cooke and Simmons, 2000; Gemmell and Simmons, 2007).

4). Characteristically, the ore-forming fluids are medium temperature and low salinity with a distinctive composition of metamorphic fluid (CO_2) in the quartz/quartz-carbonate secretion as diagnostic features of orogenic gold type. It is also notable that the typical of epithermal textures are absent or rarely to be found in the researched area. In this case, it can be concluded that the mineralization formation processes in Tamilouw-Haya were orogenic deposit style involving metamorphism and mineralization.

Conclusions

Fluid inclusion data from Tamilouw-Haya gold deposit revealed that concordant veins or type 1 quartz veins (V_1) were formed at a temperature of 240-307 °C with an average salinity of 1.8 wt. % NaCl equivalent. Whilst discordant veins consisting of type 2 quartz veins (V_2) were formed at the temperature ranging from 293-336 °C, with average salinity of 2.4 wt. % NaCl equivalent. Quartz-carbonate veins (V_3) developed in the temperature range of 240-340 °C and the average salinity of 2.72 wt. % NaCl equivalent. Based on the correlation between the formation temperature (trapping) to the depth of ore-forming temperature of gold deposits, it is indicated that the gold deposit in Tamilouw-Haya was formed at a depth of about 5.5 - 8.5 km of paleosurface and the pressure between 1.7-2.4 Kbar in the epizonal to mesozonal zones.

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