

Fluid Inclusion Study of The Tumpangpitu High Sulfidation Epithermal Gold Deposit In Banyuwangi District, East Java, Indonesia

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Abstract

The Tumpangpitu high sulfidation (HS) epithermal gold deposit is located in the south coast of East Java, Banyuwangi District, East Java Province, Indonesia. This area lies within the central portion of the Cenozoic Sunda-Banda magmatic arc which trends southeast from northern Sumatra to west Java then eastward through east Java, Bali, Lombok, Sumbawa and terminating at Banda sea. The geology of the Tumpangpitu is predominantly occupied by Late Oligocene to Middle Miocene low-K calc-alkaline to alkaline andesitic volcanic rocks and interbedded with volcanoclastic rock sequences, which are associated with low-K intermediate intrusions. The mineralization style at the Tumpangpitu area is composed of a high-sulfidation (HS) epithermal gold-copper system which is typically associated with concealed gold-rich porphyry copper system. The HS epithermal mineralization is hosted by volcanic and volcanoclastic rocks in this research area. The mineralization domains are divided into Zone A, Zone B and Zone C which are situated along NW-SE-trending silica ledges zones. The HS epithermal mineralization is texturally occurs as vuggy replacements mineralization as well as stockworks, disseminated forms, fractures and veins. Fluid inclusion study was conducted for 6 quartz vein samples which petrographically entrapped fluid inclusions. Homogenization temperature (Th) and melting temperature (Tm) can microthermometrically be determined by fluid inclusion analysis. The average homogenization temperature (Th) of the fluid inclusions gives 180°C to 342°C and melting temperature are from -0.1 °C to -1.4°C. Tm corresponds to the salinities ranging from 0.1 to 4.5 wt% NaCl equivalent. The paleodepth of ore formation can be estimated from the salinity of fluid. Since the deposit was not formed at boiling condition, the minimum paleodepth of ore (quartz) samples taken from both shallow level (53.35 m) and deep level (135.15 m) is determined at 650m and 1,220 m, respectively. The microthermometric data point out that the Tumpangpitu deposit formed at moderate temperature and low salinity by magmatic fluid mixing and dilution by meteoric water during the hydrothermal fluid evolution. On the basis of the fluid inclusion microthermometric data and its other key characteristics, the Tumpangpitu gold mineralization shares some similarities compared to other typical HS-epithermal gold deposits worldwide although it also shares few differences.

Keywords: Fluid inclusion study, high sulfidation epithermal gold deposit, Tumpangpitu, East Java, Indonesia

1. Introduction

The Tumpangpitu deposit is located in Sumberagung village, Banyuwangi Regency, on the south-eastern coast of the Java Island, East Java Province, Indonesia. It lies about 205 kilometers southeast of Surabaya (the capital of East Java), 60 kilometers southwest of the regional center of Banyuwangi and 120 km due west of Denpasar in Bali. This research area is within-existing infrastructure, with the presence of an active world-class operating mine at Batu Hijau on Sumbawa and copper-gold smelter at Gresik East Java. It is defined as high-sulfidation (HS) epithermal Cu-Au-Ag mineralization with a concealed porphyry Cu-Au mineralization underneath (Marilyono et al., 2014).

Microthermometric results from the fluid inclusion study can be used to estimate the formation temperature of the deposit and the salinity of the hydrothermal fluid. The aim of this fluid inclusion study is to understand the physico-chemical characteristics of the hydrothermal fluids which responsible for the formation of the Tumpangpitu HS epithermal gold deposit.

2. Research Methods

Fluid inclusion study is very important method to know the conditions of the hydrothermal fluids and their origin. We conducted the fluid inclusion study at the Mineral Resource lab, Department of Earth Resource Engineering, Kyushu University, Japan. For the fluid inclusion study, the four selected quartz vein samples were taken from the drill core samples crossing the Tumpangpitu

deposit at the depth of 57.55 meter and the two samples are taken from the depth of 135.15 meter respectively of the drill hole no 12-003. Firstly, we made the double polished thin-section of the thickness between 50 to 100 μm to study the fluid inclusion petrography. Over 130 fluid inclusions were measured to get the microthermometric data by using Linkam THMSG600 stage. We noted the shapes, the sizes, the phases of fluid inclusion, homogenization temperature, melting temperature of the fluids based on the standard citation of [Roedder, 1984](#) and [Bodnar et al., 1985](#). We can determine the salinity of fluid inclusion from the last ice melting temperature (T_m) by using the equation of [Bodnar et al., 1983](#) and [Bodnar and Vityk, 1994](#):

$$\text{Sal.} = 0.00 + 1.78 (T_m) - 0.0442 (T_m)^2 + 0.000557 (T_m)^3$$

where: Sal. = Salinity (wt%NaCl equivalent), T_m = ice melting temperature ($^{\circ}\text{C}$).

3. Geological Setting

3.1 Regional Geology

This area lies within the central portion of the Cenozoic Sunda-Banda magmatic arc which trends southeast from northern Sumatra to west Java then eastward through east Java, Bali, Lombok, Sumbawa and terminated at Banda sea. The Eastern Sunda Arc is located along the tectonically active zone that marks the convergence of three major plates: Eurasian, Indo-Australian, and Pacific plates (Fig. 1). The western segment of the arc (West to East Java) developed on thick continental crust on the southern margin of Sundaland, whereas the eastern segment (East Java to Sumbawa) was constructed on a thinner island arc crust bounded by Australian continent crust

further east (Sumba and Timor) ([Maryono et al., 2014](#)). The Eastern Sunda Arc is located along the tectonically active zone that marks the convergence of three major plates: Eurasian, Indo-Australian, and Pacific plates (Fig. 1). The western segment of the arc (West to East Java) developed on thick continental crust on the southern margin of Sundaland, whereas the eastern segment (East Java to Sumbawa) was constructed on a thinner island arc crust bounded by Australian continent crust further east (Sumba and Timor) ([Maryono et al., 2014](#)).

The geology of Eastern Sunda arc is mainly composed of island arc-type volcano sedimentary successions of Oligocene to Quaternary age and igneous rocks of Paleocene-Eocene age ([Hellman, 2011](#)). In east Java the Upper Miocene volcanic units are represented by Wuni Formation which is widespread at Blitar and Lumajang area (Fig.2). Late Oligocene to Middle Miocene magmatic rocks are widespread and continuously distribution along the whole belt. The volcanoclastic rocks of Late Miocene to Pliocene age are more abundant than the older volcanic rocks in the southern margin of the belt and Low-K calc-alkaline to weakly alkaline andesitic volcanic and interbedded volcanoclastic rocks, associated low-K intermediate intrusions and minor shallow water marine sedimentary rocks extend from Java to Bali, Lombok and Sumbawa ([Macpherson and Hall, 1999](#)).

In the Sunda plate, the metallic occurrences are abundant and these are associated with subduction-related volcanic centers. There are six categories of Cu-Au deposits within the arcs: porphyry copper-gold, high sulphidation epithermal, low sulphidation epithermal, gold-silver-barite-base metal, skarn, and sediment-hosted mineralization ([Carliile and Mitchell, 1994](#)).

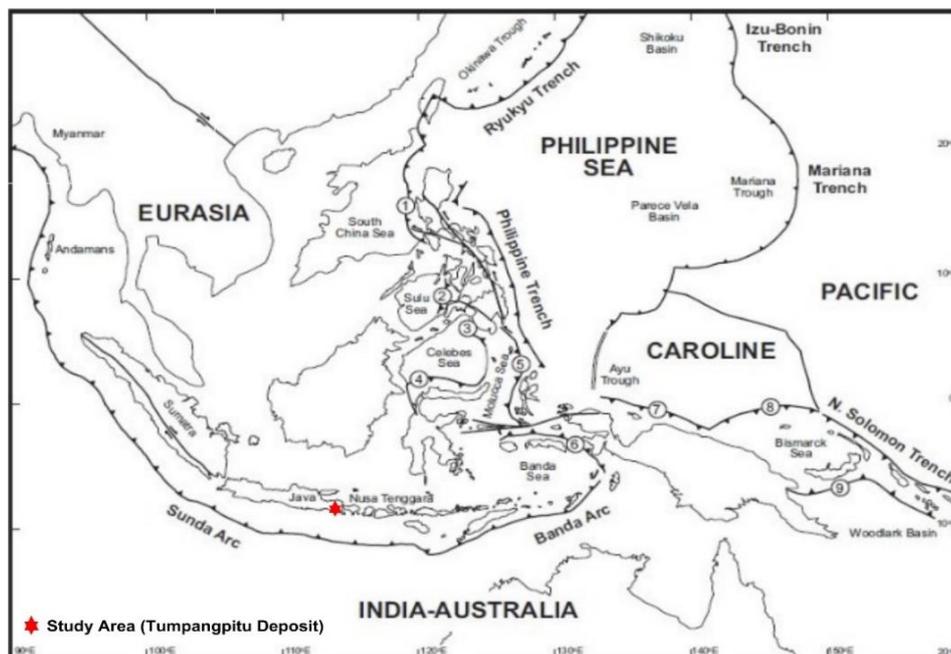


Fig. 1. Map of SE Asia highlighting major tectonic plates and plate boundaries ([Mapcherson and Hall, 1999](#))

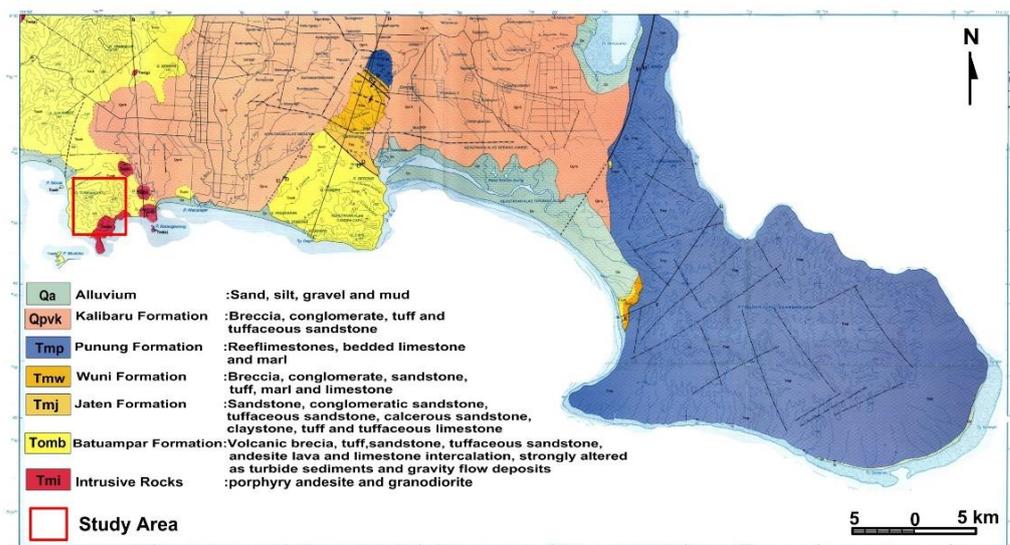


Fig. 2. Regional geological map of the southeast corner of Java and the red rectangle is prospect area (Achdan and Bachri, 1993)

3.2 Deposit Geology

The Tumpangpitu area is predominantly occupied by Late Oligocene to Middle Miocene low-K calc-alkaline to alkaline andesitic volcanic and interbedded volcanoclastic rock sequence, associated with low-K intermediate intrusions and minor shallow water marine sedimentary rocks (Harrison, 2012). In the shallow of the Tumpangpitu is dominated by epithermal environment and in the deeper portion is characterized by porphyry system. Fig 3 is geological map of Tumpangpitu area. In this research, we emphasized only in epithermal environment. The typical rock types of this area are diorite, volcanic breccia, diatreme breccia, hydrothermal breccia and andesitic lava and breccia.

4. Ore Mineralization

The mineralization at Tumpangpitu is composed of an Au-rich porphyry Cu-Au-Mo system associated with high-sulfidation epithermal Cu-Au-Ag system (Hellman, 2011). The HS epithermal mineralization is hosted by volcanic and volcanoclastic rocks in the research which especially covering 3 domains of mineralization consisting of Zone A, Zone B and Zone C. The three domains are extended along NW-SE trending silica ledge zones (Fig. 4). The mineralization generally occurs hosted by lapilli tuffs and vuggy replacements mineralization as well as stockworks, disseminated forms, arrays of sulfide fractures and veins, containing pyrite +/- enargite +/- tetrahedrite-tennantite +/- chalcocite +/- bornite that occur widely within the more silica-rich portions of the silica ledges (Fig 5, 6, 7,8). Mineralization generally occurs as vug filling or massive replacement within silica ledge zone. The dissemination mineralization found in the advanced argillic altered rock. In open space or

fractures, veinlets and some micro-veinlets mineralization can be found in the research area. In open space or fractures, veinlets and some micro-veinlets mineralization can be found in the research area (Fig. 5). Gold mineralization is mainly associated with pyrite and enargite mineral and it can be found in massive/ vuggy silica zone, advanced argillic alteration zone and some are in silicic core.

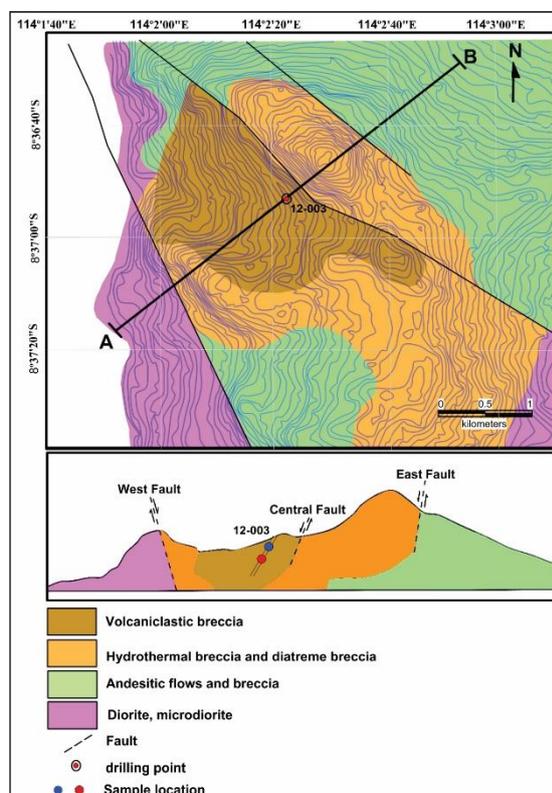


Fig. 3. Geological Map with drill point of the Tumpangpitu deposit, Banyuwangi Regency, East Java and cross section of the area along A-B (Source from BSI Company).

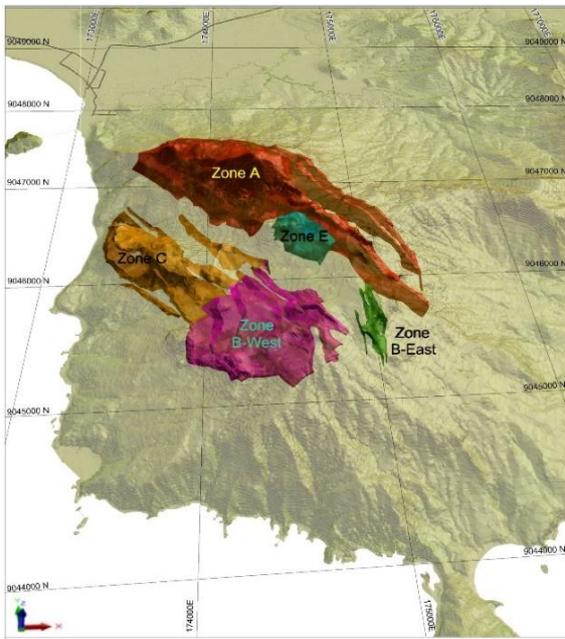


Fig. 4. 3D view for Tumpangpitu domains: Zone A- mineralized zones dip moderately to the southwest. Zone B- mineralized zones strike north-south and dip steeply to the east. Zone C- mineralized zones dip moderately to the northeast. Zone E- mineralized zones dip moderately to north-south (Source from BSI Company).



Fig. 5. Ore textures: (a) vuggy quartz (b) massive sulfide (pyrite) vein texture and (c) small sulfide veinlet intercalated with clay.

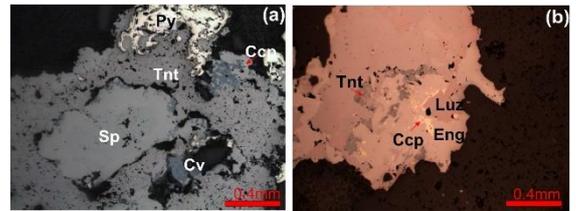


Fig. 6. Photomicrograph showing Intergrowth of pyrite, enargite, luzonite, sphalerite, chalcopyrite, covellite in vugs. (Py=pyrite, Eng=enargite, Luz=luzonite, Tnt=tennantite, Ccp=chalcopyrite, Sp=sphalerite and Cv=covellite)

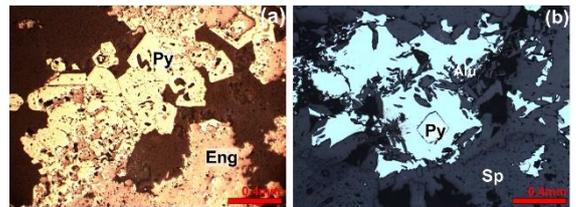


Fig. 7. Photomircograph show (a) euhedral pyrite with cracks along the fracture and (b) euhedral-anhedral pyrite grains within networks of alunite laths (Py=pyrite, Alu=alunite, Eng=enargite and Sp=sphalerite)

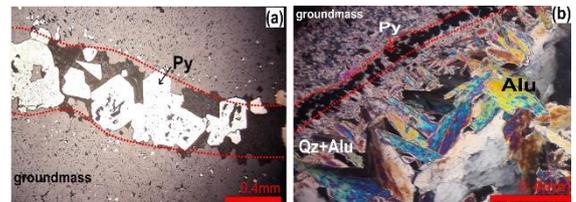


Fig. 8. Photomircographs of (a) pyrite vein with groundmass and (b) quartz and alunite vein with pyrite vein (Py=pyrite, Alu=alunite, Qz= quartz).

5. Fluid Inclusion Study

5.1 Petrography

Abundant primary and secondary fluid inclusions are found in quartz vein samples taken from the deposit. The homogenization temperature and melting temperature were measured only on the primary inclusions. The sizes of fluid inclusion in the quartz phenocrysts generally range from 5 μm to 50 μm . The morphologies of the fluid inclusions are generally spheroidal, elongate, and prismatic forms. Some of representative forms of fluid inclusions described details in Fig. 11. The two-phase (liquid+vapor) fluid inclusion are common. There are two type of fluid inclusions consisting of vapor- rich and liquid-rich inclusions. The vapor dominated inclusions are not common and it contain 5 to 15 percent of total fluid inclusions.



Fig. 10. Photographs of some quartz samples associated with enargite and pyrite mineralization which has inclusions entrapped in quartz.

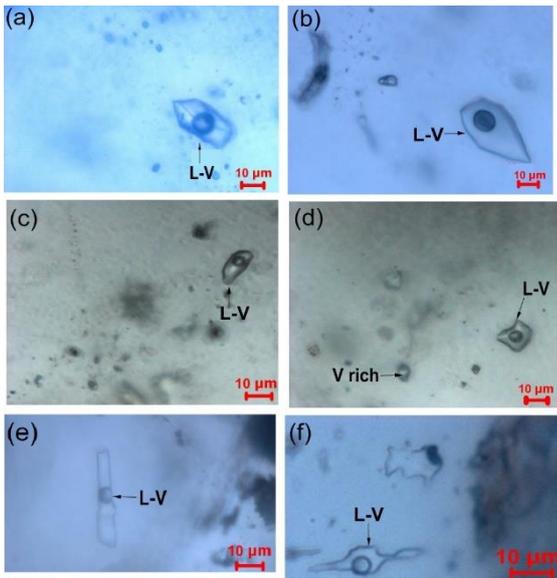


Fig. 11. Photomicrographs of fluid inclusions petrography: (a) the slightly flattened negative crystal form, (b and c) the slightly rounded negative crystal form with secondary filling in microfracture, (d) the fluid inclusion in cubic form, (e) the oblated tubular form and (f) necking in a long tubular inclusion form.

5.2 Microthermometry

Fluid inclusion microthermometric data were collected from the conducting of the temperature of homogenization and melting temperature. We conducted the fluid inclusion analysis from the two different depths (at 57.55 meter and at 135.15 meter). Based on the fluid inclusion data, the homogenization temperature at 57.55 meter is (180 °C -340 °C) and at the depth of 135.15 meter is (230 °C -360 °C) (Fig. 12). The distribution of homogenization temperatures of fluid inclusions (histograms) are shown in Fig 11. According the homogenization temperature of histogram, the formation temperature of shallow depth is 270 °C and the deeper is 310 °C. The measurement of melting temperature of fluid inclusion data is range from -0.1 °C to -1.4 °C.

5.3 Salinity of hydrothermal fluid

By using Bodnar's equation (1993), the salinity of fluid inclusion is calculated from the melting temperature. The salinity value is range from 0.1 to 4.5 wt % NaCl equiv and the average salinity is (0.5 – 2 wt.% NaCl eq.) (Fig. 13). Based on the average homogenization temperature ranges (270 °C and 310 °C) and the averaging salinity is of 1 wt.% NaCl eq. belong to the epithermal system (Wilkinson, 2001). The salinity variations are controlled by fluid mixing. It shows a trend of isothermal mixing (Fig 14). Based on the plotting of these data, the Tumpangpitu area falls in the epithermal deposit. The results for the depths of formation of quartz veins from recent depth of 57.55 m (the red line)

and 135.15 m (the blue line) respectively are shown in Fig 15.

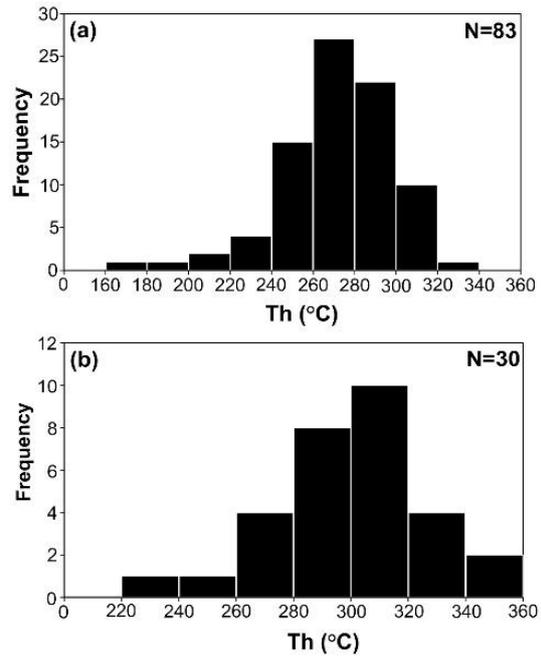


Fig.12. Frequency distribution of homogenization temperatures (Th) of fluid inclusions study at the depth of (a) 57.55 m and (b) 135.15 m.

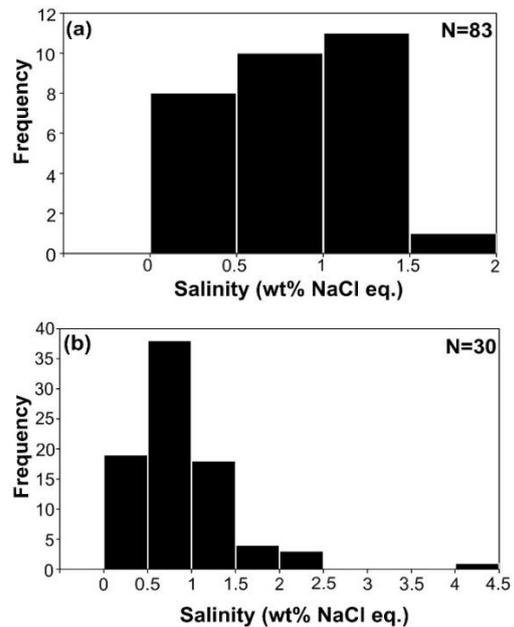


Fig.13. Frequency distribution of salinity (NaCl wt.% eq.) of hydrothermal fluid (a) shallow sample taken at 57.55 m and (b) the deeper sample at 135.15 m.

6. Discussion

Based on the study of the fluid inclusions, the Tumpangpitu was not observed for boiling evidence. It is possibly related with the isothermal fluids mixing and possibly related to surface fluid dilution processes (Fig 14). The formation temperature can be estimated from the fluid

inclusion microthermometric data and the formation depth can be estimated from the boiling point curve of Hass, 1971 (Shepherd et al., 1985). The formation temperature is plot on the temperature axis and the salinity value is plot on the curves of salinity (Fig. 15). According to the plotting data (Fig. 16), the Tumpangpitu area belongs the epithermal environment (cf. Wilkinson, 2001).

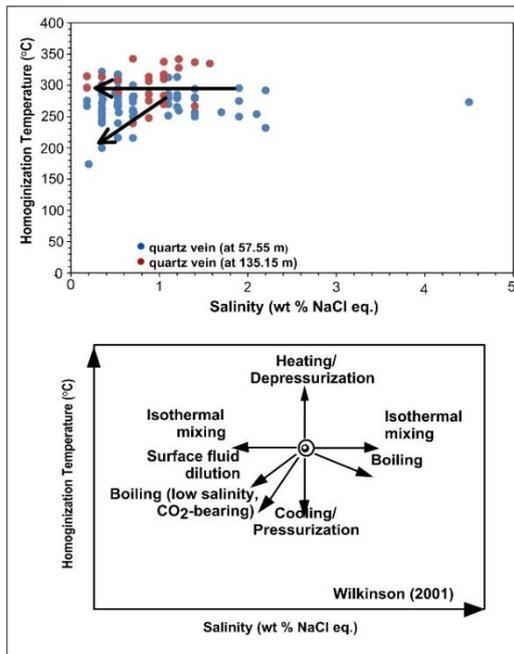


Fig. 14. Salinity (wt.% NaCl eq.) versus homogenization temperatures (Th, °C) for fluid inclusions of the Tumpangpitu deposit.

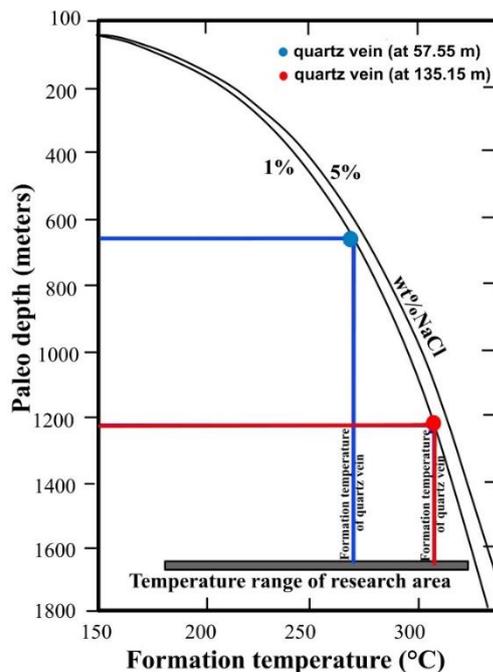


Fig.15. The formation depth of quartz vein samples from the shallow samples (57.55 m blue line) and deep samples (135.15 m; red line).

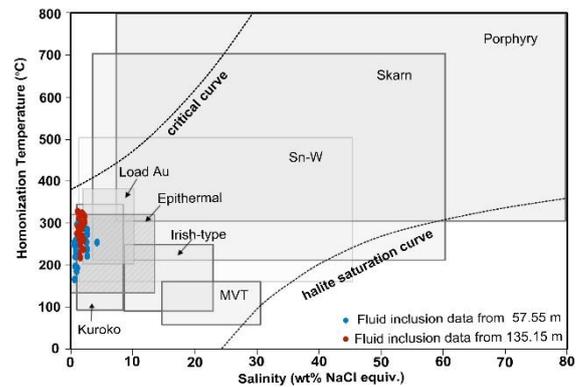


Fig 16. Salinity vs Th illustrating typical ranges for inclusions from different types of deposits (Wilkinson, 2001). The fluid inclusions from the Tumpangpitu area fall in the epithermal field.

7. Conclusion

In the Tumpangpitu research area, the mineralization is hosted by volcanic and volcanoclastic rocks and it occurred as vuggy replacements mineralization as well as stockworks, disseminated forms, fractures and veins. By assuming the temperature of homogenization is identical to the formation temperature, the Tumpangpitu HS epithermal gold deposit was formed at temperature between 270°C and 310°C. The average melting temperature is -0.3 °C and -0.7°C corresponding to the salinity of hydrothermal fluid of 0.5 to 2 wt% NaCl equivalent. The paleo-depth of both shallow and deep samples taken are about 650m and 1220m, respectively (Fig 15).

The microthermometric data suggest that the Tumpangpitu deposit formed at moderate temperature and low salinity by magmatic fluid mixing and dilution by meteoric water during the hydrothermal fluid evolution. Although the Tumpangpitu HS epithermal gold deposit exhibits few differences in characteristics, but in general it hares some similarities compared to other typical HS-epithermal gold deposits worldwide.

8. Acknowledgements

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