FLUID INCLUSION CHARACTERISTICS OF AURIFEROUS ARINEM AND BANTARHUNI QUARTZ VEINS, ARINEM, WEST JAVA, INDONESIA

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Abstract

A microthermometric study of fluid inclusions were carried out on the samples from the epithermal gold-silver-base metal mineralization of Arinem and Bantarhuni veins of Arinem deposit from different levels, stages and minerals types (quartz, sphalerite and calcite) to understand the characteristics of the fluid inclusions trapped, and to determine the physical and chemical environments of ore mineral deposition. The results of primary fluid inclusions measurement of stages I and II of main ore mineralization revealed that Arinem and Bantarhuni quartz veins are in the average range of 194.0°–267.3°C, and sphalerite samples are 194.1°–241.2°C. The measurement indicates a general decrease of temperature with decreasing depth and an increasing paragenetic time. The evidence of boiling was measured from substage IA of the Arinem vein with the filling temperatures of these inclusions range from 216.8°–247.3°C. Under such condition, with an average fluid density of 0.861 g/cm^3 and a pressure of about 21.7 bars, the paleo-depth would have about 235 meters. Fluid inclusions assemblages from main stages I and II from all levels commonly show a narrow range in Tm values (0.18–4.43 wt.% NaCl$_{equiv.}$). This is also marked in fluid inclusions assemblages from late stage (stage III) of barren quartz (0.35–3.87 wt.% NaCl$_{equiv.}$). Raman spectroscopic analyses of CO_2, N_2, H_2S and CH_4 on selected fluid inclusions of the Arinem vein samples, shows no volatile components other than H_2O.

Keywords: Arinem, Bantarhuni, fluid inclusion, microthermometry, quartz, salinity.

Sari

Studi mikrotermometri inklusi fluida dilakukan terhadap sampel dari mineralisasi emas-perak-logam dasar tipe epitermal Arinem dari level, stage dan mineral yang berbeda (kuarsa, sfalerit, dan kalsit) dari urat Arinem dan Bantarhuni, Jawa Barat, Indonesia. Tujuan dari penelitian ini adalah untuk mengetahui karakteristik dari inklusi fluida yang terjebak dalam mineral, yang berguna dalam pengenalan lingkungan fisik dan kimia dari deposit Arinem. Studi terhadap inklusi fluida primer dari stage I dan II mineralisasi bijih utama urat Arinem dan Bantarhuni menunjukkan temperatur homegenisasi rata-rata berkisar antara 194.0°–267.3°C untuk inklusi fluid dari sampel kuarsa dan 194.1°–241.2°C untuk sampel sfalerit. Berdasarkan hasil pengukuran temperatur homogenisasi menunjukkan penurunan temperatur dengan berkurangnya kedalaman dan meningkatnya paragenesa mineral. Indikasi boiling terukur pada sampel kuarsa dari substage IA urat Arinem dengan temperatur berkisar antara 216.8°–247.3°C. Pada kondisi seperti ini, nilai densitas adalah sekitar 0.861 g/cm^3 dengan tekanan 21.7 bars, dan paleo-depth adalah sekitar 235 meter. Himpunan inklusi fluida dari stage I dan II dari level yang berbeda umumnya menunjukkan kisaran nilai temperatur melting yang kecil (0.18–4.43 wt.% NaCl$_{equiv}$). Hal yang sama juga terjadi pada himpunan inklusi fluida dari stage terakhir (stage III) dari sampel kuarsa barren (0.35–3.87 wt.% NaCl$_{equiv}$). Analisis Raman spektroskopis terhadap CO_2, N_2, H_2S dan CH_4 dari beberapa sampel inklusi fluida urat Arinem tidak mendeteksi adanya komponen volatil lain selain H_2O.

Kata kunci: Arinem, Bantarhuni, inklusi fluida, mikrotermometri, kuarsa, salinitas.

Introduction

The information of any aspect related to the deposition of ore-grade mineralization may be very helpful in exploration. Fluid inclusion analyses can provide very useful information and may be used as an exploration guide in the search for mineralized systems. These analyses can be very accurate

indicators of the physical and chemical environments of mineral deposition in the hydrothermal system (Roedder, 1984). The trapped fluid in an inclusion preserves a record of the composition, temperature and pressure of the mineralizing environment.

The aims of this fluid inclusions study are to understand the characteristics of the fluid inclusions trapped, and to determine the physical and chemical environments of ore mineral deposition. This study

may be useful to recognize the thermal gradient along the veins within the Arinem area vertically and horizontally, and the possible boiling of hydrothermal fluids in the epithermal system through fluid inclusion analyses which may indicate conducive conditions to ore deposition.

A microthermometric study was carried out on the samples from the epithermal gold-silver-base metal mineralization of Arinem deposit located at Western Java, Indonesia (Fig. 1). The Arinem deposit comprises three groups of mineralized quartz veins, *i.e.*, the Arinem, Bantarhuni, and Halimun veins (Antam, 1993) and the focus for this study is on the samples from Arinem and Bantarhuni veins. Reflected and transmitted light microscopes of polished and double polished thin sections and some electron microprobe studies of the Arinem and Bantarhuni veins are obtained. Together with crosscutting relationships between minerals and secondary structural studies, it shows that vein filled reflects three temporal mineralizing stages.
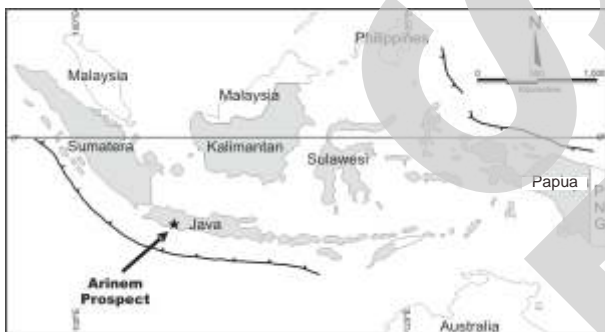

Figure 1. Map of the Indonesia region indicates the location of the Arinem prospect showing by black arrow.

The three stages of mineralization are stage I (substage IA, IB, IC, and ID), stage II (substage IIA, IIB, and IIC) and stage III (substage IIIA and IIIB). The stages I and II are ore-rich, whilst stage III is barren (Yuningsih *et al.*, 2011 in press). Those three distinct stages (vein-forming events) of hypogene mineralization were followed by a supergene stage. The Arinem deposit has a typical polymetallic association, ore minerals are mainly composed of sulfide minerals of sphalerite, galena, chalcopyrite and pyrite with some minor and trace minerals of arsenopyrite, marcasite, pyrrhotite, bornite, and argentite. The Te-bearing mineral of hessite, stutzite, petzite, tetradymite and altaite also observed. Other trace minerals are electrum, hematite and sulfosalt minerals of enargite, tennantite and tetrahedrite. The secondary minerals included covellite, chalcosite, Mn oxides and goethite-limonite.

Microthermometric Measurement and Results

Double polished thin sections were prepared on 200 μm thickness for the fluid measurements. Apart of quartz at stage III most of the quartz samples were selected for fluid inclusions that were associated with deposition of sulfides±gold±silver. The horizontal extent of sample localities for fluid inclusion measurements of the Arinem vein is more than 1.2 km and the vertical interval is approximately 240 m, and for the Bantarhuni vein is more than 2 km and vertically is about 265 m. Microthermometric measurement was performed on a Linkam THMSG 600 system attached to a Nikon transmitted-light microscope.

Heating rates were maintained near 2°C/min for measurement of homogenization temperature (Th_{total}) and 0.5°C/min for measurement of ice melting temperature (Tm). Precision is calculated as ±0.1°C in the temperature range of the observed phase changes. Accuracy between -60 and -10°C is estimated in the order of ±0.2°C, whereas between -10 and +30°C and above +200°C is placed at ±0.5 and ±2°C, respectively. Instrumental calibration was done using synthetic pure H_2O (0°C), dodecamethylene glycol (82.0°C), benzanilide (163.0°C), sodium nitrate (306.8°C), n-tridecane (-5.5°C), n-dodecane (-9.6°C), chlorobezene (-45.6°C), and chloroform (-63.4°C) inclusion standards.

Salinity estimations were determined from the last melting temperatures of ice, utilizing the equation by Bodnar (1993). The possibility of the presence of volatile species (CO_2, N_2, H_2S, CH_4) and solid phases in fluid inclusions were identified by Raman spectroscopic analyses on limited samples of the Arinem vein. Analyses were conducted using a JY Horiba T64000 Raman microprobe equipped with an electronically cooled charge-coupled device (CCD) detector, using 514.57 nm (green) Ar-ion laser excitation at Fukuoka University.

A total of 595 primary fluid inclusions were examined in 13 samples (11 quartz, 1 sphalerite, and 1 calcite) from different levels of the Arinem vein in order to document the ranges of fluid compositions and temperatures during the three stages of mineralization and to investigate their variations in time and space. In addition the 326 primary fluid inclusions were also obtained from 8 quartz and 4 sphalerite samples of the Bantarhuni vein (next to Arinem vein) for comparison.

Microthermometric measurements were performed on as many samples as possible, chosen at random, but fewer ice-melting data were obtained than homogenization data due to the small size of the some inclusions. Only those inclusions which homogenized into the liquid phase could be measured; the behavior of vapor-rich inclusions could not be monitored because of their opaque appearance. The inclusions contain no daughter minerals and readily homogenize to the liquid phase upon heating.

The heating and freezing measurements were conducted on primary fluid inclusions trapped. The primary inclusion was large enough to study, aqueous, mostly consisting of two phases (liquid-L and vapor-V) at room temperature. Type L-V inclusions being dominant in most inclusions (avg. >70 vol.%). However, the vapor bubble occupies up to ~90 vol.% of some inclusions. L-V inclusions occur in clear and smoky quartz, sphalerite and in medium- and coarse-crystalline calcite. Although some of the fluid inclusions were necked down (formation process of several smaller inclusions that have the same total volume as the original single inclusion but a smaller total amount of surface energy, Roedder 1984), the ones used in the microthermometric study ranged from 5 to 40 μm in length and were classified according to the nomenclature of Roedder (1984).

Three types of fluid inclusion are recognized those are (I) two-phase primary - pseudo-secondary liquid-rich fluid inclusion; (II) two-phase primary - pseudo-secondary vapor-rich fluid inclusion; and (III) two-phase secondary fluid inclusion. The inclusions were considered primary or pseudo-secondary, as they were formed isolated within the crystals, in planar arrays outlining growth zones, or in healed fractures that terminated against growth zones, respectively. Inclusions in quartz and sphalerite that occur in planes of healed fractures that do not terminate against growth zones were considered secondary; commonly these fractures cut across crystal boundaries. Secondary fluid inclusions, <20 μm in length, occur along healed fractures that cut across crystal boundaries whereas pseudo-secondary fluid inclusions, which are less abundant than primary or secondary inclusions, formed only along healed fractures within crystals (Figs. 2 and 3).

The results of measurements from primary fluid inclusions in quartz from different levels of the Arinem vein indicate that homogenization temperatures at stage I is in range of 176.6°–325.1°C, stage II is 156.9°–311.8°C and stage III is 165.1°–236.1°C. A measurement from sphalerite and calcite from substages IIA and IIIB give a result of 152.7°–218.0°C and 140.4°–217.1°C, respectively. The quartz samples of Bantarhuni veins were indicated the fluid inclusion homogenization temperatures at stage I is in range of 206.6°–344.3°C, stage II is 202.0°–306.5°C and stage III is 168.4°–275.6°C. The sphalerite from stage I and II give a result of 202.2°–255.8°C and 189.2°–266.4°C. The results of heating and freezing studies of fluid inclusions for Arinem and Bantarhuni veins are presented in Tables 1 and 2. The data listed in Tables 1 and 2 are considered to be representative samples of the fluid at least during short-time intervals of Arinem and Bantarhuni veins.
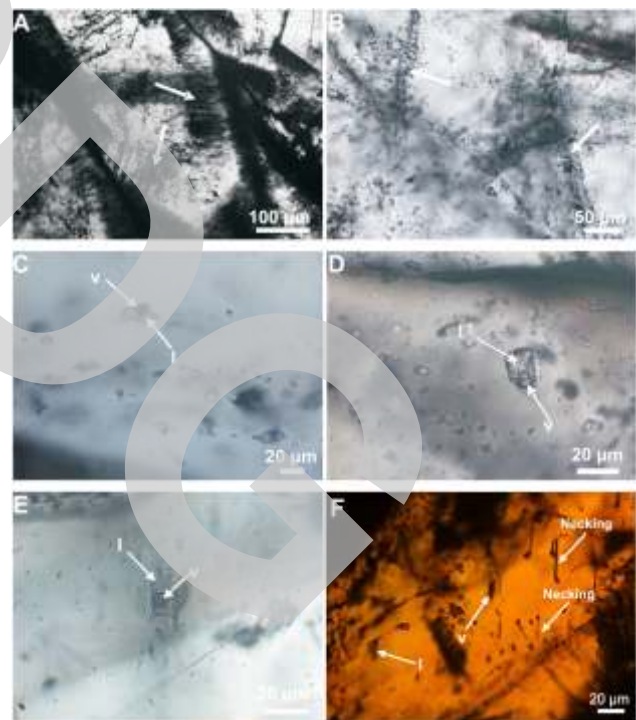

Figure 2. Photomicrograph of fluid inclusions trapped in quartz, calcite and sphalerite crystals at Arinem vein. (A) Zoned crystal, dark outer rims rich in primary fluid inclusions, from L300m; (B) secondary fluid inclusions along fracture of quartz, from L300m; (C) cluster of primary two phase liquid-rich fluid inclusions in quartz, from L300m; (D) isolated large primary liquid-rich fluid inclusion in quartz, from L265m; (E) two phase liquid-rich primary fluid inclusion in calcite, from L265m; (F) co-existing two phase liquid-rich and vapor-rich primary fluid inclusions in sphalerite and the appearance of the necking, from L265m.
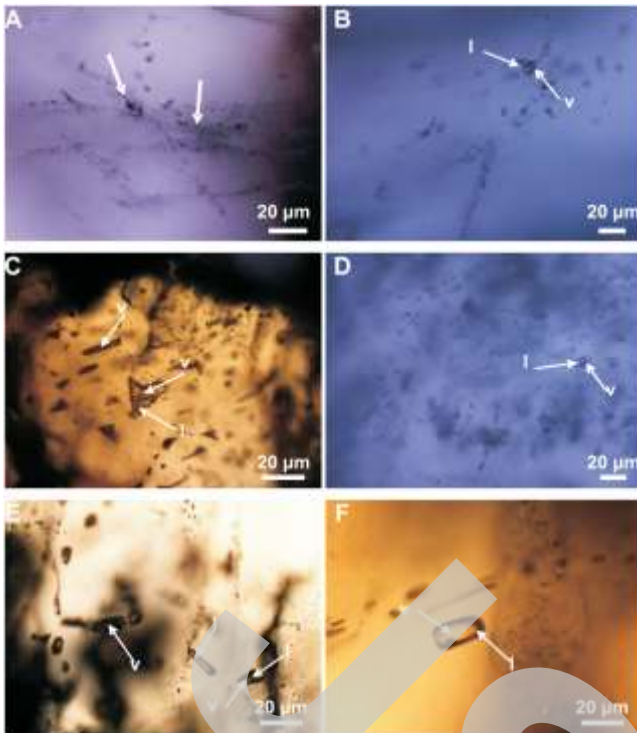
Figure 3. Photomicrograph of fluid inclusions trapped in quartz and sphalerite crystals at Bantarhuni vein. (A) Fine grains of secondary fluid inclusion along fracture of quartz, from L275m; (B) primary vapor-rich fluid inclusion of quartz, from L275m; (C) co-existing primary two phase liquid-rich and vapor fluid inclusions in sphalerite, from L155m; (D) cluster primary liquid-rich fluid inclusion in quartz, from L155m, (E) two phase vapor-rich primary fluid inclusion in sphalerite coexisting with vapor and liquid fluid inclusions, from L140m; (F) two phase primary vapor-rich fluid inclusion in sphalerite, from L140m.

Table 1. Thermometric data for fluid inclusions in Arinem vein.

Vein Stage	Level (m)	Mineral	$N\,T_h$ [1]	T_h range (°C)	T_h mean (°C)	$N\,T_m$ [2]	T_m range (°C)	T_m mean (°C)	NaCl range (wt %)	NaCl mean (wt %)
IIIB	265	Quartz	22	165.1 - 236.1	194.0	13	(-0.2) - (-1.7)	-0.9	0.35 - 2.90	1.57
	265	Calcite	12	140.4 - 217.1	187.3	9	(-0.7) - (-2.3)	-1.5	1.22 - 3.87	2.57
IIC	265	Quartz	62	170.9 - 259.6	203.6	21	(-0.1) - (-1.5)	-1	0.18 - 2.57	1.74
	200	Quartz	64	178.9 - 307.9	247.5	36	(-0.1) - (-2.6)	-1.4	0.18 - 4.34	2.41
IIB	300	Quartz	60	175.5 - 289.0	212.8	-	-	-	-	-
IIA	440	Quartz	43	156.9 - 311.8	216.4	26	(-0.1) - (-2.1)	-1.1	0.18 - 3.55	1.91
	300	Quartz	29	177.0 - 302.0	230.4	-	-	-	-	-
	265	Sphalerite	22	152.7 - 218.0	194.1	17	(-1.0) - (-2.2)	-1.5	1.74 - 3.71	2.57
IB	265	Quartz	75	176.6 - 299.0	232.6	24	(-0.4) - (-2.5)	-1.6	0.71 - 4.18	2.74
	200	Quartz	46	166.9 - 303.9	259.9	17	(-1.0) - (-2.5)	-1.6	1.74 - 4.18	2.74
IA	440	Quartz	12	178.6 - 282.5	218.9	8	(-0.5) - (-2.4)	-1.5	0.67 - 4.03	2.57
	300	Quartz	88	180.5 - 319.6	236.4	-	-	-	-	-
	200	Quartz	60	183.9 - 325.1	267.3	20	(-0.6) - (-2.5)	-1.6	1.05 - 4.18	2.74

[1] Number of inclusion measured for T_h
[2] Number of inclusion measured for T_m

Table 2. Thermometric data for fluid inclusions in Bantarhuni vein.

Vein Stage	Level (m)	Mineral	$N\,T_h$ [1]	T_h range (°C)	T_h mean (°C)	$N\,T_m$ [2]	T_m range (°C)	T_m mean (°C)	NaCl range (wt %)	NaCl mean (wt %)
IIIB	275	Amethyst	17	191.8 - 275.6	211.4	12	(-0.2) - (-1.6)	-0.9	0.35 - 2.73	1.57
	275	Quartz	31	168.4 - 250.8	217.1	13	(-0.5) - (-1.7)	-1.2	0.87 - 2.90	2.07
IIC	155	Sphalerite	4	189.2 - 250.1	223.7	21	(-0.5) - (-1.5)	-1.0	0.87 - 2.57	1.74
	140	Sphalerite	18	218.0 - 266.4	235.2	10	(-0.8) - (-2.0)	-1.5	1.39 - 3.39	2.57
	140	Quartz	43	202.0 - 304.3	248.6	25	(-0.9) - (-2.2)	-1.5	1.57 - 3.71	2.57
IIA	155	Quartz	45	210.7 - 306.5	252.8	21	(-0.9) - (-1.9)	-1.4	1.57 - 3.23	2.41
	155	Sphalerite	18	210.4 - 275.4	241.2	10	(-0.8) - (-2.0)	-1.5	1.39 - 3.39	2.57
IC	140	Quartz	55	215.5 - 344.3	257.5	27	(-0.6) - (-2.5)	-1.6	1.05 - 4.18	2.73
IB	140	Quartz	15	221.6 - 291.5	256.4	9	(-1.1) - (-1.9)	-1.5	1.91 - 3.23	2.57
	140	Sphalerite	17	202.2 - 255.8	233.5	9	(-1.1) - (-2.3)	-1.6	1.91 - 3.87	2.74
	10	Quartz	33	206.6 - 309.5	261.5	17	(-1.0) - (-2.3)	-1.6	1.74 - 3.87	2.74
IA	275	Quartz	30	215.3 - 327.1	267.3	19	(-0.5) - (-2.2)	-1.4	0.87 - 3.71	2.41

[1] Number of inclusion measured for T_h
[2] Number of inclusion measured for T_m

Vapor-rich inclusions are present in some samples but usually constitute only a minor proportion of the total fluid inclusion populations. They mostly tend to occur in distinct planes and do not appear to occur in direct association with the liquid-rich inclusions. Rare heterogeneous trapping is indicated in one quartz sample of substage IA Arinem vein. This quartz sample from substage IA mineralization which shows evidence of boiling contains both gas-rich and liquid-rich inclusions along the same growth band. The filling temperatures of these two types of inclusions range from 216.8 to 247.3°C.

Freezing studies are best and most readily used to measure the salinity of fluid inclusions because the lowering of the freezing point of pure water is directly proportional to the amount of salt in solution. This is achieved by measuring the final ice melting temperature on reheating the frozen inclusion (Shepherd *et al.*, 1985). Fluid inclusion melting temperatures and calculated salinities from Arinem and Bantarhuni veins are summarized in Tables 1 and 2. Salinities have been calculated using formulas based on the freezing point depression experimental data of Hall *et al.* (1988) and Bodnar (1993) :

wt.% NaCl $= (-1.78 \times Tm) - (0.0442 \times Tm^2) - (0.000557 \times Tm^3)$

Where Tm = final ice melting temperature

The salinities of fluid inclusions in Arinem vein revealed from quartz, sphalerite and calcite determined by freezing point measurements are less than 4.34 wt.% $NaCl_{equiv}$. The ice melting temperatures range from -2.6° to (-0.1)°C, with distribution of apparent salinity in all stages and levels of mineralization vein body. The fluid inclusions freezing study of Bantarhuni vein shows a salinity < 4.18 wt.% $NaCl_{equiv}$. with the ice melting temperature range from -2.5° to (-0.2)°C.

During freezing of inclusions, no unusual solid phases such as CO2 hydrate were observed from both veins. Fluid inclusion assemblages from main stages I and II from all levels commonly show a narrow range in Tm values (0.18 to 4.43 wt.% $NaCl_{equiv.}$). This is also marked in fluid inclusion assemblages from late stage (stage III) of barren quartz (0.35 to 3.87 wt.% $NaCl_{equiv.}$). Temperatures fall within the range of -2.6° to –0.2°C, indicating that inclusion fluids are slightly dilute. Raman spectroscopic analyses of CO_2, N_2, H_2S and CH_4, performed on selected fluid inclusions from Arinem vein detected no volatile component other than H_2O.

Discussion

The T_h average from fluid inclusions in quartz assemblages indicate that the main-stage of Arinem and Bantarhuni veins were deposited in the range of 194.0 – 267.3°C and 211.4 – 267.3°C, with a general decrease of temperature with decreasing depth and increasing paragenetic time (Tables 1 & 2; Fig. 4). However, one quartz sample from substage IA of Arinem vein shows evidence of boiling, with the presence of gas-rich and liquid-rich inclusions along the same growth band. The filling temperatures of these two types of inclusions range from 216.8–247.3°C. These data were interpreted to indicate that actual boiling took place at 216.8°C with higher filling temperatures resulting from the trapping of various liquid : vapor proportions.

In order to estimate the true temperature of mineralization from filling temperatures of fluid inclusions, the pressure on the fluid must be known. No pressure correction is needed for inclusions trapped while the fluids were boiling. The presence of vapor-rich inclusions in this sample indicates that P-T conditions probably were close to the liquid-vapor, two-phase (boiling) curve. This conclusion is supported by the presence of bladed texture of quartz after calcite (Yuningsih *et al.*, 2011 in press).

It is interesting to note that the vapor-rich end members of the boiling system were not observed in primary fluid inclusions of bladed quartz. This may be because of too small fluid inclusion occured in bladed quartz samples so it was missed during the investigation or as a consequence of the shallow ore environment (open system), in which the vapor phase moves much more rapidly and is correspondingly much less likely to become trapped.

Though there is a strong correlation between fluid inclusions temperature and relative levels within the system but the fluid inclusions temperature versus salinity plots show that there is no obvious correlation between temperatures of homogenization and fluid salinity (Figs. 5 and 6). In contrast with some of other studies (e.g., Hayba *et al.*, 1997), there is no clear linear relationship between fluid inclusion T_h and salinity values, a feature which is usually assumed to be indicative of boiling or fluid mixing processes. The nearly linear relationship between homogenization temperatures and salinities of fluid inclusions from stages I through III of Arinem and Bantarhuni veins indicate a history of progressive decrease of average temperature with increasing paragenetic time.
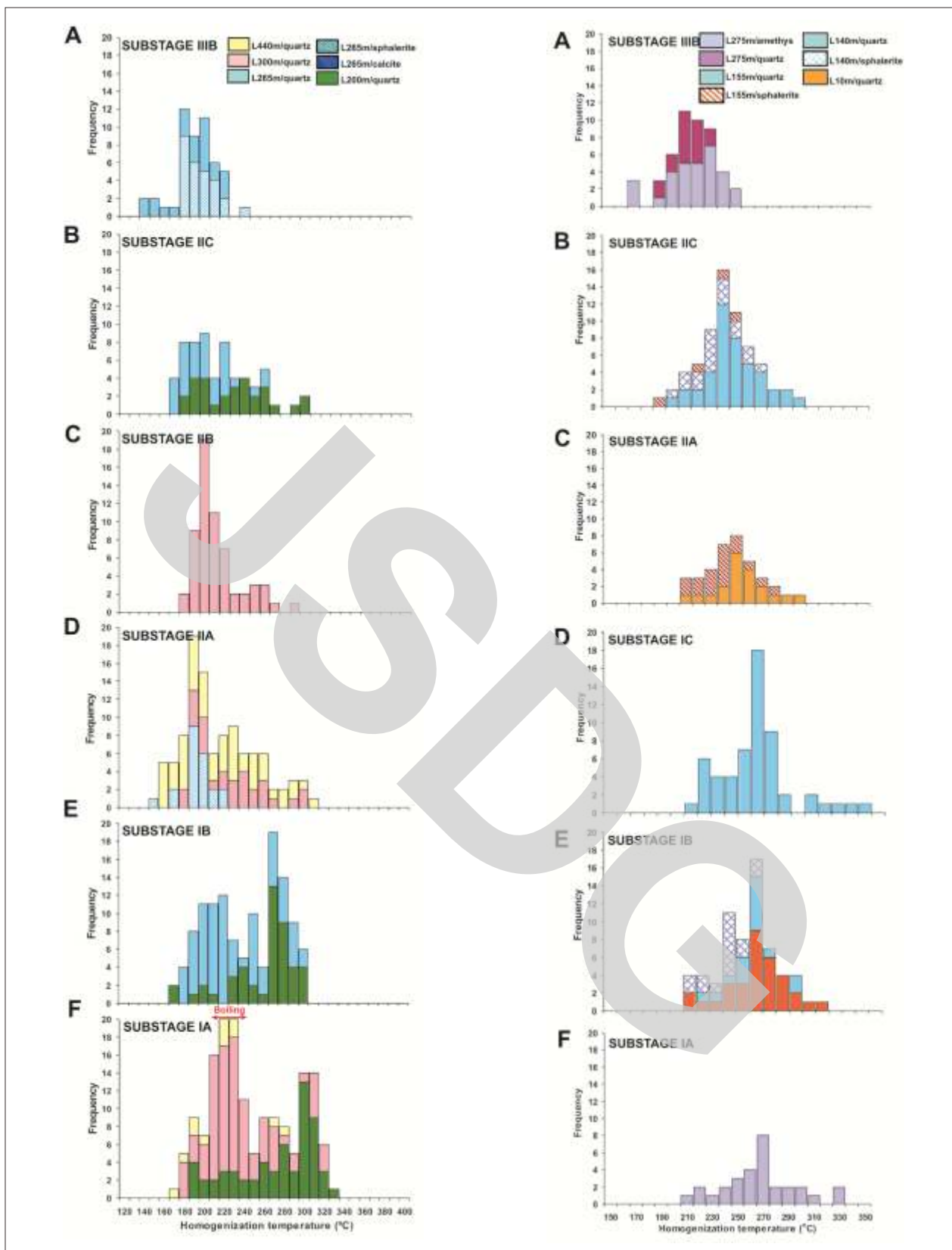
Figure 4.   Left : Fluid inclusions homogenization temperatures range of every stage of Arinem vein, (A) barren quartz of substage IIIB; (B-D) stage II of substages IIC-IIA; (E-F) stage I of substages IB & IA. Right : fluid inclusions homogenization temperatures range of every stage of Bantarhuni vein, (A) barren quartz-amethyst of substage IIIB; (B-C) substages IIC and IIA; (D-E-F) substages IC, IB and IA. Show the slightly decreasing of Th from early stage of substage IA (F) to last stage of substage IIIB (A).
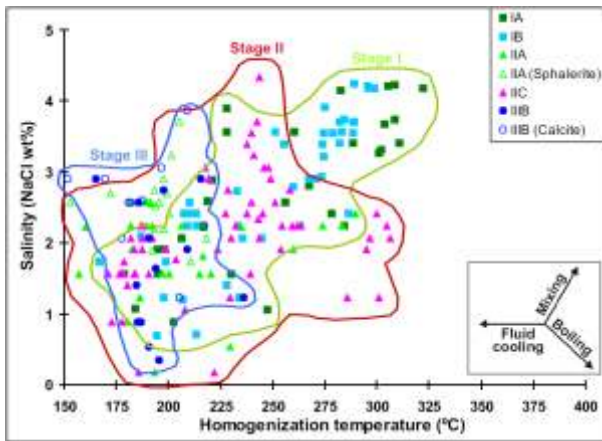
Figure 5. Temperature of homogenization (T_h, °C) against salinity (wt.% $NaCl_{equiv.}$) plot for fluid inclusions in samples of quartz, sphalerite and calcite from different stages of the Arinem vein.

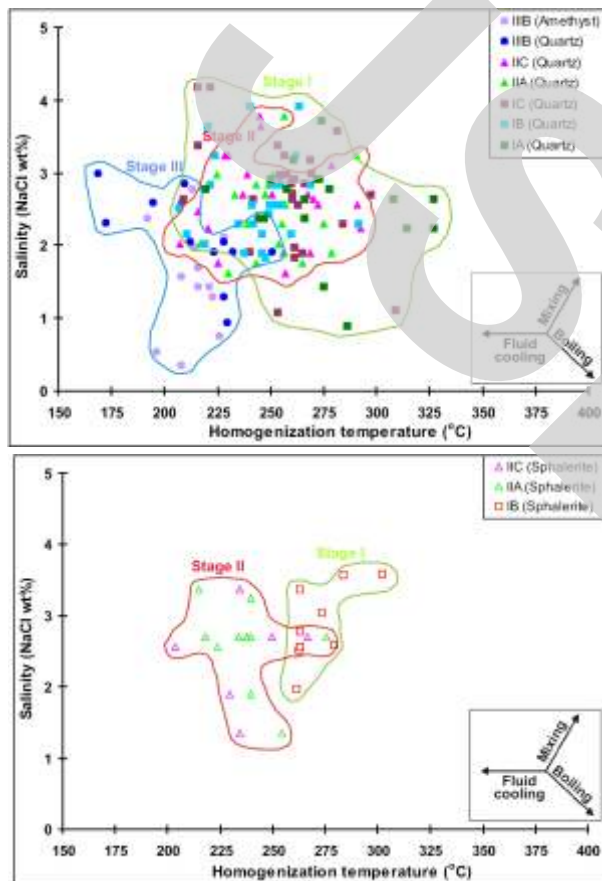Figure 6. Temperature of homogenization (T_h, °C) against salinity (wt.% $NaCl_{equiv.}$) plot for fluid inclusions in samples of quartz (left) and sphalerite (right) from different stages of the Bantarhuni vein.

From the temperature-pressure-salinity data on salt solutions summarized by Haas (1971) it is obtained a fluid pressure of 21.7 bars of 2 wt.% $NaCl_{equiv.}$ fluid at 216.8°C for sample with boiling of substage IA of the Arinem vein. The open vuggy character of

substage IA vein material (Yuningsih *et al.*, 2011 in press) suggests that the ore fluids probably circulated freely to the surface and that pressure during substage IA crystallization was essentially hydrostatic. Under such conditions, with an average fluid density of 0.861 g/cm3 and a pressure of about 21.7 bars, the paleo-depth would have about 235 meters (Fig. 7).

By making similar assumptions for the others fluid inclusions data of every substages and level of the Arinem and Bantarhuni veins, due to wide vertical distribution of the average temperature range (around 203°–267°C), equates the paleo-depth estimating of 160–590 m for the stages I and II of mineralization.

Fluid inclusions from the gold-silver portion of the stages I and II paragenesis indicate a systematic decrease of average temperature from 267° to 203°C. Continued cooling resulted in deposition of substage IIA-C mineralization and ultimately in barren stage III quartz. Post quartz and calcite stages III represents the final cooling of a hydrothermal system which had been repeatedly inundated by progressively cooler waters. They reflect a further decline of average temperature of 194°C (quartz) and 187°C (calcite).

The co-existence of moderate-salinity inclusions with low-salinity inclusions can be explained as the result of extensive boiling and vaporization of low-salinity fluid, but it can also result from mixing of two fluids of different salinity. Although the V/(L+V) ratio of the fluid inclusions is generally low, trends in Figs. 5 and 6 suggest that cooling of fluids occurred during quartz and calcite precipitation.

The decreasing of PCO_2 on boiling, as carbon dioxide is lost to the steam phase, increases the pH of the solution and leads to supersaturation and precipitation of calcite. Reduced fluids leached gold as they circulated through the volcanic rocks, carrying it in the form of bisulfide complexes. Interaction of these aqueous-carbonic fluids with the country rocks probably caused hydrothermal alteration and also precipitated sulfides in the alteration zones.
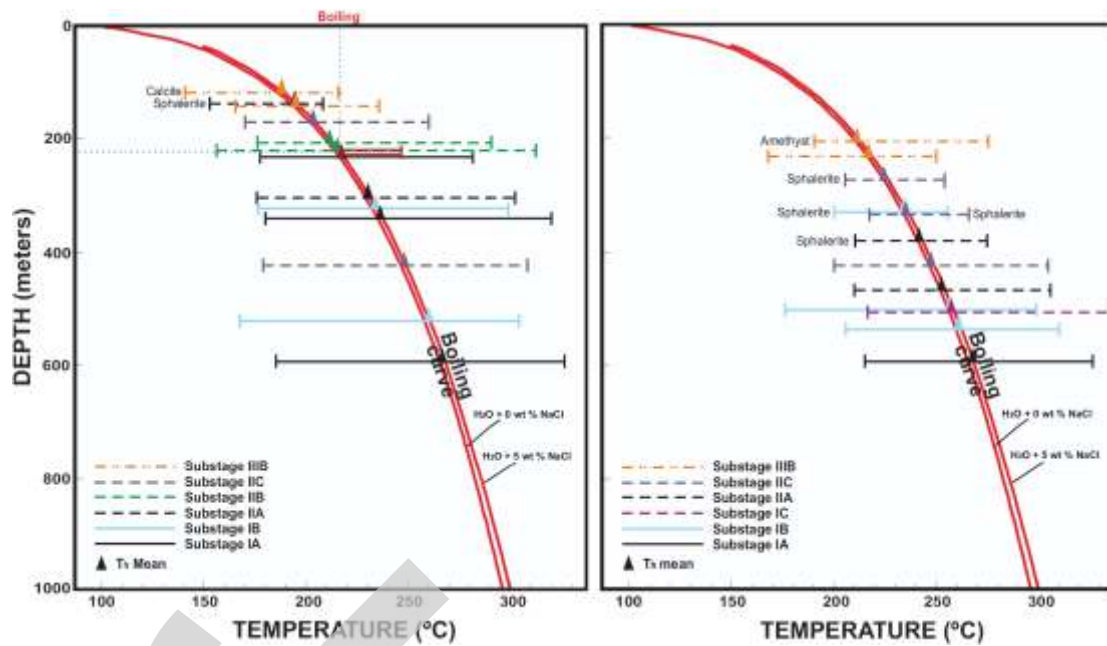
Fig. 7.   Range and mean of fluid inclusions homogenization temperatures (T_h) versus depth for different stage and level of Arinem (left) and Bantarhuni (right) veins. Possible boiling point with depth curves for water within 0 and 5 wt.% NaCl$_{equiv.}$ (Haas, 1971) are positioned to fit the mean T_h values. Dashed line showing evidence for trapping of a boiling fluid occurred in substage IA of Arinem vein.

Conclusions

It has not been demonstrated that these were the fluids which also precipitated the precious metals in the Arinem deposit. Most of the fluid inclusion samples analyzed were selected from their sulfides±gold±silver association, this has indicated that the gold-silver-base metal minerals at Arinem was probably formed from those same fluids. The broadly characteristics of the fluids obtained from the fluid inclusion from quartz are not too high salinity (<4.34 wt.% NaCl$_{equiv.}$) and moderate temperatures (average between 194.0°?267.3°C). Such fluids are very similar to those advocated for numerous precious and basemetal vein deposits associated with shallow, calc-alkaline, igneous rocks (Roedder, 1984, Hayba *et al.*, 1985).

The co-existence of fluid-rich and vapor-rich inclusions indicates the trapping of a boiling fluid, and thus the system is interpreted to be under hydrostatic pressure, meaning that homogenization temperatures may be considered reasonable approximation to hydrothermal fluid trapping temperatures. The wide range in homogenization temperatures reflects the great vertical extent of sample points within the vein system.

The fluid inclusion study would a very helpful tool in the continuing exploration program at Arinem. The information gleaned from this study has greatly facilitated the overall interpretation of the Arinem paleo-hydrology and vein paragenesis. These factors, along with the increased knowledge of the physico-chemical conditions of vein deposition, will act as an exploration guide during further exploration work along the Arinem vein system.

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