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Epithermal Gold-Silver Deposits in Western Java, Indonesia: Gold-Silver Selenide-Telluride Mineralization

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Abstract - The gold-silver ores of western Java reflect a major metallogenic event during the Miocene-Pliocene and Pliocene ages. Mineralogically, the deposits can be divided into two types *i.e.* Se- and Te-type deposits with some different characteristic features. The objective of the present research is to summarize the mineralogical and geochemical characteristics of Se- and Te-type epithermal mineralization in western Java. Ore and alteration mineral assemblage, fluid inclusions, and radiogenic isotope studies were undertaken in some deposits in western Java combined with literature studies from previous authors. Ore mineralogy of some deposits from western Java such as Pongkor, Cibaliung, Cikidang, Cisungsang, Cirotan, Arinem, and Cineam shows slightly different characteristics as those are divided into Se- and Te-types deposits. The ore mineralogy of the westernmost of west Java region such as Pongkor, Cibaliung, Cikidang, Cisungsang, and Cirotan is characterized by the dominance of silver-arsenic-antimony sulfosalt with silver selenides and rarely tellurides over the argentite, while to the eastern part of West Java such as Arinem and Cineam deposits are dominated by silver-gold tellurides. The average formation temperatures measured from fluid inclusions of quartz associated with ore are in the range of 170 – 220°C with average salinity of less than 1 wt% $NaCl_{equiv.}$ for Se-type and 190 – 270°C with average salinity of ~2 wt% $NaCl_{equiv.}$ for Te-type.

Keywords: epithermal gold-silver deposit, fluid inclusions, selenides, Se-type, tellurides, Te-type, western Java

INTRODUCTION

Western Java hosts several gold deposits and all of the mineralizations follows the Sunda-Banda magmatic arc, which is the longest magmatic arc in Indonesia (Figure 1). The ore deposits of western Java reflect a major metallogenic event during the Miocene-Pliocene. Mineralogically, the deposits can be divided into two types, those are Se-type and Te-type with some different characteristic features. Telluride and selenide minerals in many epi- and mesothermal deposits are often associated with gold and silver that have an important role worldwide. The principal characteristics of the Te- and Se- minerals in epithermal deposit were described by Sillitoe and Hedenquist (2003).

The Se-type of western Java mineralization mostly lies within and on the flanks of the Bayah Dome and is represented by Pongkor, Cikidang, Cisungsang, Cirotan, and Cibaliung deposits, while the Te-type is located more eastern and represented by Arinem and Cineam deposits (Figure 2). Studies of ore mineralogy and geochemistry were carried out within the epithermal ore deposits of western Java by previous authors such as Pongkor (Basuki *et al.*, 1994; Marcoux and Milesi, 1994; Sukarna *et al.*, 1994; Milesi *et al.*, 1999; Sukarna, 1999; Warmada *et al.*, 2003; Syafrizal *et al.*, 2005; Syafrizal *et al.*, 2007; Warmada *et al.*, 2007), Cikidang (Rosana and Matsueda, 2002), Cibaliung (Sudana and Santosa, 1992; Marcoux and Milesi, 1994; Marjoribanks, 2000; Angeles *et al.*, 2002; Harijoko *et al.*, 2004;

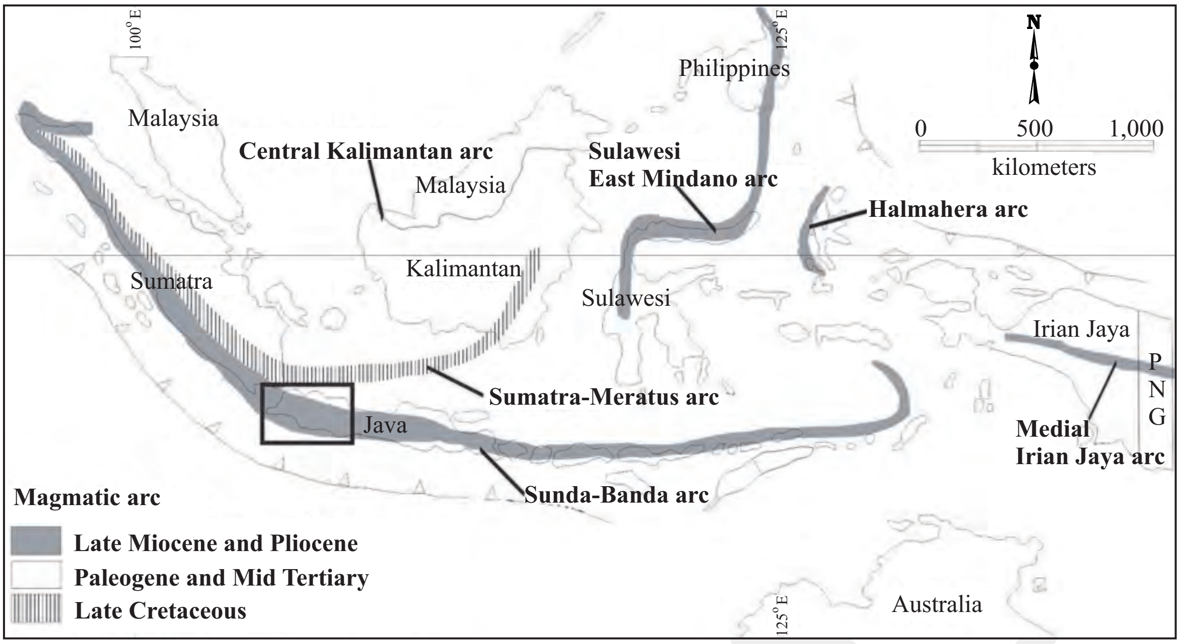

Figure 1. Distribution of the magmatic arc within the Indonesia archipelago from Late Cretaceous to Pliocene (modified after Carlile and Mitchell, 1994). The location of the studied area is bounded by a rectangle.

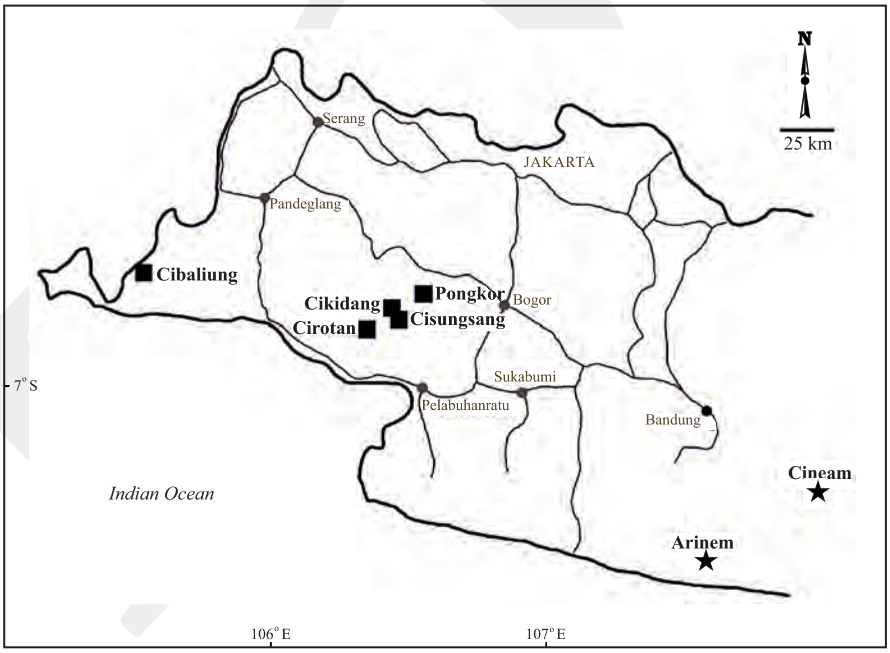

Figure 2. Location and distribution of the Se- (■) and Te- (★) type epithermal Au-Ag deposits in the western Java, Indonesia.

Harijoko *et al.,* 2007), Cisungsang (Rosana *et al.,* 2006), Cirotan (Milesi et *al.,* 1993; Marcoux *et al.,* 1993), Arinem (Yuningsih *et al*., 2012), and Cineam (Widi and Matsueda, 1998).

Most of the Se- and Te-type deposits in western Java are in the form of vein. However, the Cisungsang deposit forms the massive sulfide with some vein association. Vein size of the Se- and Te-types are various from several meters to more than 5,000 m in length and from a few centimeters up to 5 m in width. The gold mineralization ages within this area for the Se-type are mostly of Pliocene and Pleistocene with the range from 2.4 to 1.7 Ma and Late Miocene (11.18 Ma) for Cibaliung deposit. K-Ar age dating of Te-type indicates the mineralization ages are around 9.9 ~ 8.5 Ma or Late Miocene, respectively.

The principal objective of this research is to summarize the mineralogical and geochemical characteristics of Se- and Te-type epithermal mineralization in western Java. Ore and alteration mineral assemblage, fluid inclusions, and radiogenic isotope studies were undertaken in some deposits in western Java combined with literature study from previous authors.

METHODS

Thin-, polished- and doubly polished sections of samples from western Java deposits were analyzed using transmitted- and reflected-light microscopes. Additional samples of altered host rocks were investigated by X-ray diffraction using standard treatment methods for clay mineral identification. Geochemical analyses for major, minor, and trace elements of ores were conducted by ICP at Acme Analytical Laboratories (Vancouver) Ltd., British Columbia, Canada.

The compositions of ore minerals were determined using a JEOL 733 electron microprobe analyzer at Hokkaido University. Standards used were natural chalcopyrite, InP, MnS, CdS, FeAsS, Sb_2S_3, PbS, SnS, HgS, ZnS, and elemental Se, Au, Ag, Te. The probe was operating at 20kV voltage and the beam current of 10nA was focused to 1-10 µm diameters with peak counting for 20s. The X-ray lines measured were As, Se, Te, Cd, Ag, Bi, and Sb (Lα), S, Cu, Zn, Fe, and Mn (Kα), and Pb, Au, and Hg (Mα). The data were corrected by ZAF correction.

Doubly polished thin sections were prepared on 200 µm thickness for fluid inclusion study on quartz, sphalerite, and calcite minerals. Microthermometric analysis was performed on a Linkam THMSG 600 system attached to a Nikon transmitted-light microscope. Heating rate was maintained near 2°C min^{-1} for measurement of homogenization temperature (Th_{total}) and 0.5°C min^{-1} for measurement of ice melting temperature (T_m). Precision was 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 was 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), hydrocarbons (CH_4, C_2H_6), and solid phases in fluid inclusions was identified by Raman spectroscopic analyses on limited samples.

RESULTS AND ANALYSES

Ore Mineralogy

The dominant opaque minerals from the Se-type deposits are Se- and Se-bearing silver minerals (aguilarite, naumannite, argentite, polybasite, and pyrargyrite), electrum, and tetrahedrite with various amounts of sulfide minerals of sphalerite, galena, chalcopyrite, arsenopyrite, and pyrite. Other ore minerals are found in a trace amount. Some rare minerals of Bi- and Sn-bearing minerals such as lillianite and canfieldite occur in Se-type deposit of Cirotan (Milesi *et al.*, 1993). The Te-type is characterized by the occurrence of hessite, petzite, stutzite, tetradymite, altaite, and tennantite-tetrahedrite, with a high amount of sulfide minerals of sphalerite, galena, chalcopyrite, and pyrite with occurrences of arsenopyrite. Some photomicrographs of the ore minerals associated in the Se- and Te-type deposits are presented in Figure 3.

Rare telluride minerals of hessite and altaite were reported from the Se-type deposit (Harijoko *et al*., 2007), but until now there are no selenide minerals observed in the Te-type deposits of Arinem, except for the Te-type deposit of Cineam which contains trace of Se-bearing minerals of pyrargyrite-proustite. The occurrences of the ore minerals from the two types of deposits are sum-

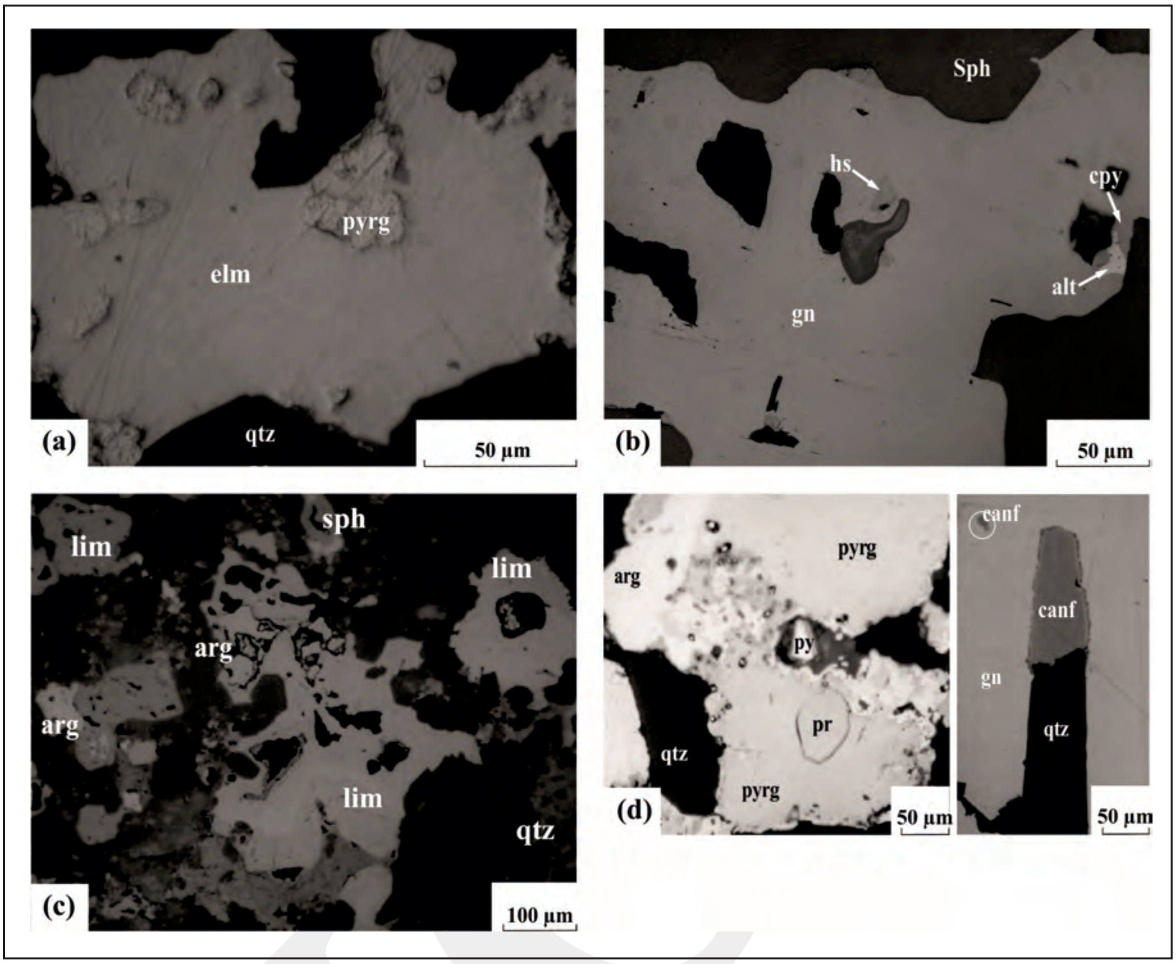

Figure 3. Reflected-light photomicrographs of the ore mineral association from some deposits at the western Java. (a) Pongkor; (b) Arinem; (c) Cikidang; (d) Cisungsang. Abv.: alt=altaite, arg=argentite, canf=canfieldite, cpy=chalcopyrite, elm=electrum, gn=galena, hs=hessite, lim=limonite, pr=proustite, py=pyrite, pyrg=pyrargyrite, qtz=quartz, sph=sphalerite.

marized in Table 1 along with other characteristics of those deposits.

Ore Geochemistry

The FeS content of sphalerite from the Te-type is generally similar to those of the Se-type mostly in the range of 0.1-2.4 mol% (Se-type) and 0.5~2.0 mol% (Te-type, rare are up to 8.5 mol%). However, the FeS content of sphalerite from massive deposit of the Cisungsang (Se-type) is higher, ranging from 13.6-19.6 mol%, and from Cirotan is between 0.5 and 26.0 mol% (Milesi *et al*., 1993). Cadmium content in sphalerite of Se-type is in the range of 0.1-2.0 mol% and in Te-type of Arinem around 0.1-1.0 mol%.

The Ag content of electrum from the Se-type is higher than that from the Te-type, ranging between 22-68 wt% and 14-40 wt%. Some ore minerals from Se-type contain selenium such as in galena which is up to 1.5 wt%, in acanthite-aguilarite up to 13.5 wt%, and in polybasite up to 3.6 wt% (with Te content up to 5.5 wt%). Tellurium content in proustite is in trace amount and in uytenbogaardtite is up to 0.8 wt%. Ore minerals of the Te-type deposit of Arinem contain selenium such as in galena which is up to 1.9 wt%, in tetradymite 0.1-2.1 wt%, and up to 1.4 wt% in petzite.

Geochemical analyses on the bulk vein samples inferred Mn are higher in the Se-type, but low in the Te-type. Bi and Hg are lower in the Se-type compared to the Te-type deposit. The comparison of the geochemical composition between the Te- and Se-type deposits represented by the Arinem and Pongkor deposits is show in the Table 2.

Table 1. Summary of Mineralogic, Age and Geochemical Characteristics of the Se- and Te-Types of Western Java Ore Deposits

Deposit	Ore mineralogy	Host rocks, gangue, and alteration-mineralization age (Ma)	pH, T_h (ºC), Salinity (wt% $NaCl_{equiv.}$)
Se-Type			
Pongkor [1]	*Se- & Te-minerals*: agulilarite, trace hessite. *Sulfosalt*: tetrahedrite, famatinite, PROUSTITE, PEARCEITE-POLYBASITE, antimony-PEARCEITE. *Sulfide & other minerals*: pyrite, chalcopyrite, sphalerite, galena, uytenbogaardtite, chalcocite, stromeyerite, mckinstryite, ACANTHITE, bornite, electrum, Au-Ag alloy,willemite, massicot, manganese oxide, limonite.	*Host rocks*: andesitic breccia, tuff, lapili, andesite intercalated limestone & sandstone (Oligocene-Early Miocene), basement shale and sandstone, host rock overlain by sedimentary rocks of Miocene age, which consist of claystone, limestone, sandstone, and volcanic rocks. *Gangue & alteration*: quartz, calcite, dolomite, kutnohorite, carbonate, rhodochrosite, adularia, montmorilonite, chlorite, illite/smectite, smectite, kaolinite, K-feldspar. *Mineralization age*: 2.05~2.7	*pH*: neutral. T_h: carbonate: 171-249 (205±15) quartz: 180-287 (220±21) spha : 220-320 (258±29) *Salinity*: carbonate: (0.5±0.6) quartz: 0-5.0 (1.0±1.0)
Cikidang [2]	*Se- & Te-minerals*: aguilarite. *Sulfide & other minerals*: pyrite, ARGENTITE, sphalerite, galena, electrum, manganese oxide, limonite.	*Host rocks*: volcanic rock of lapilli tuff & breccia (Early Miocene). *Gangue & alteration*: smectite/chlorite mixed layer mineral, epidote, carbonate, illite, quartz, kaolinite, limonite, montmorilonite, K-feldspar, adularia. *Mineralization age*: 2.4	*pH*: neutral. T_h: quartz: 170-260 (215) *Salinity*: quartz: <3.0
Cibaliung [3]	*Se- & Te-minerals*: aguilarite-naumannite, trace altaite, hessite. *Sulfosalt*: tennantite-tetrahedrite, POLYBASITE. *Sulfide & other minerals*: pyrite, sphalerite, galena, arsenopyrite, marcasite, ARGENTITE-stromeyerite, trace chalcopyrite, bornite, electrum, rare native silver.	*Host rocks*: basaltic andesite volcanics intercalated tuffaceous sediment (Middle-Late Miocene) overlaid unconformably by dacitic tuff, younger sediments & basalt flows. The sedimentary rocks consist of conglomerate, calcareous sandstone, and limestone. *Gangue & alteration*: quartz, adularia, calcite, smectite, illite, mixed layered chlorite-smectite and illite-smectite, kaolinite, epidote, zeolite. *Mineralization age*: 11.18~10.65	*pH*: neutral. T_h: quartz: 160-330 (170-shallow), 170-300 (220-deep) *Salinity*: quartz: <1.0
Cisungsang[4]	*Se- & Te-minerals*: aguilarite. *Sulfosalt*: PYRARGYRITE, PROUSTITE. *Sulfide & other minerals*: sphalerite, galena, arsenopyrite, pyrite, marcasite, pyrrhotite, chalcopyrite, ARGENTITE, greenockite, acanthite, canfieldite, electrum.	*Host rocks*: breccia tuff, limestone (Miocene). *Gangue & alteration*: not well developed, silica, small calcite, rare clay. *Mineralization age*: -	*pH*: neutral. T_h: quartz: 160-300 *Salinity*: quartz: 2.2-3.4
Cirotan [5]	*Se- & Te-minerals*: aguilarite. *Sulfosalt*: tetrahedrite, POLYBASITE, PYRARGYRITE. *Sulfide & other minerals*: pyrite, marcasite, galena, chalcopyrite, pyrrhotite, sphalerite, arsenopyrite, acanthite, greenockite, mackinawite, uytenbogaardtite, covellite, electrum, scheelite, cassiterite, canfieldite, lillianite, wolframite.	*Host rocks*: calc-alkaline rhyolitic-dasitic, quartz microdiorite (Miocene) cutting volcano-sedimentary series. *Gangue & alteration*: chlorite, epidote, quartz, calcite, rare Fe-Ti oxides, illite/smectite, kaolinite, adularia, apatite, rare gypsum, anhydrite. *Mineralization age*: 1.7	*pH*: neutral. T_h: quartz: 180-255 sphalerite: 207-280 *Salinity*: sphalerite : 2.89-7.15 quartz: -

Words in capital: Se- and or Te-bearing mineral. References: [1]Basuki *et al*., 1994; Marcoux and Milesi, 1994; Milesi *et al*., 1999; Sukarna *et al*., 1994; Sukarna, 1999; Syafrizal *et al*., 2005; Syafrizal *et al*., 2007; Warmada *et al*., 2003; Warmada *et al*., 2007; [2] Rosana and Matsueda, 2002; [3]Angeles *et al*., 2002; Harijoko *et al*., 2004; Harijoko *et al*., 2007; Marcoux and Milesi, 1994; Marjoribanks, 2000; Sudana and Santosa, 1992; [4]Rosana *et al*., 2006; [5]Milesi *et al*., 1993; Marcoux *et al.,* 1993; [6]Yuningsih *et al*., 2012; 7Widi and Matsueda, 1998.

Table 1. ....continued

Deposit	**Ore mineralogy**	**Host rocks, gangue, and alteration-mineralization age (Ma)**	**pH, T_h (ºC), Salinity (wt% $NaCl_{equiv.}$)**
Te-Type			
Arinem ^{6}	*Se- & Te-minerals*: hessite, altaite, tetradymite, stutzite, petzite. *Sulfosalt*: enargite, tennantite, tetrahedrite. Sulfide & other minerals: sphalerite, GALENA, chalcopyrite, pyrite, marcasite, arsenopyrite, pyrrhotite, argentite, covellite, chalcocite, electrum, hematite.	*Host rocks*: andesitic tuff, tuff breccias, lava (Oligocene-Middle Miocene) overlain unconformably by a volcanic group composed of andesitic breccias and tuff. *Gangue & alteration*: quartz, calcite, sericite, illite, mixed layered illite-chlorite, chlorite-smectite, kaolinite. *Mineralization age*: 8.8~9.9	*pH*: neutral. T_h: quartz: 157-327 (194-267) sphalerite: 153-275 (194-235) calcite: 140-217 (187) *Salinity*: quartz: 0.2-4.3 (1.6-2.7) sphalerite: 0.9-3.9 (1.7-2.7) calcite: 1.2-3.9 (2.6)
Cineam ^{7}	*Se- & Te-minerals*: hessite, petzite, aguilarite. *Sulfosalt*: tetrahedrite-tennantite, PYRARGYRITE, PROUSTITE. *Sulfide & other minerals*: pyrite, sphalerite, galena, arsenopyrite, chalcopyrite, argentite, realgar, stibnite, orpiment, electrum, iron-oxide.	*Host rocks*: andesitic-dasitic volcanic rocks (Oligocene-Miocene) intruded by diorite, granodiorite, andesite and dacite intrusive. *Gangue & alteration*: quartz, illite, calcite, propylite, argillic, silisification and locally phyrophylite. *Mineralization age*: 8.5~9.6	*pH*: neutral. T_h: quartz: 190-240, up to 350 *Salinity*: quartz: 1.45-2.30, up to 3.7.

Words in capital: Se- and or Te-bearing mineral. References: [1]Basuki *et al*., 1994; Marcoux and Milesi, 1994; Milesi *et al*., 1999; Sukarna *et al*., 1994; Sukarna, 1999; Syafrizal *et al*., 2005; Syafrizal *et al*., 2007; Warmada *et al*., 2003; Warmada *et al*., 2007; [2] Rosana and Matsueda, 2002; [3]Angeles *et al*., 2002; Harijoko *et al*., 2004; Harijoko *et al*., 2007; Marcoux and Milesi, 1994; Marjoribanks, 2000; Sudana and Santosa, 1992; [4]Rosana *et al*., 2006; [5]Milesi *et al*., 1993; Marcoux *et al.*, 1993; [6]Yuningsih *et al*., 2012; 7Widi and Matsueda, 1998.

Table 2. Comparison of Bulk Chemical Analyses of Te-Type (represented by Arinem Deposit) and Se-Type (represented by Pongkor Deposit) Ores

Arinem Deposit											
	Arinem Vein								**Bantarhuni Vein**		
	IA	**IB**	**IIA**	**IIA**	**IIA**	**IIB**	**IIC**	**IIC**	**IIB**	**IIC**	**IIC**
Se	***308***	***30***	***116***	***305***	***190***	***35***	***119***	***>500***	***212***	***>500***	***>500***
Te	***32***	***na****	***156***	***57***	***53***	***14***	***14***	***209***	***na***	***na***	***na***
Pb**	2.85	0.31	0.03	3.66	2.35	1.24	1.32	15.71	0.10	25.27	21.78
Mn	929	696	1,161	3,407	1,161	1,703	309	2,013	>100	1,084	852
Cd	1,287.3	47.2	2.9	112.1	528.7	101.7	885.3	>2,000	19.2	1,964.1	1,160.2
As	13.2	>10,000	13.6	289.9	247.8	3,134.9	1,669.8	4.4	<0.5	<0.5	<0.5
Sb	4.5	71.2	1.2	8.0	6.4	26.0	16.3	11.9	2.8	24.3	15.4
Hg	2.52	0.88	0.23	3.81	4.4	3.32	1.59	4.5	0.06	3.22	1.44
Bi	11.6	0.4	199.5	12.7	18.3	0.2	2.4	24.7	122.1	42.9	6.3

Pongkor Deposit [1]											
	CGH	**CGH**	**CGH**	**CGH**	**CRG**	**CRG**	**GH**	**KC**	**KC**	**KC**	**KC**
Se	***14.5***	***12.0***	***<0.1***	***8.28***	***23.6***	***52.0***	***777***	***181***	***199***	***145***	***44.3***
Te	***<0.1***	***0.5***	***<0.1***	***2.7***	***<0.1***	***<0.1***	***0.9***	***3.1***	***0.2***	***0.2***	***<0.1***
Pb	8	10	18	2,010	770	502	9,200	10,100	438	276	37
Mn	25,553	2,729	963	1,194	1,039	1,738	11,448	5,248	259	747	1,421
Cd	<0.1	<0.1	0.1	3.9	32.1	10.7	107	101	5.3	3.2	0.5
As	10.2	39.2	98.3	62.6	22.9	36.6	185	58.9	46.1	53.7	46.3
Sb	12.4	12.6	14.7	71.8	34.1	8	39.1	125	146	156	83.8
Hg***	45	93	214	158	18	53	95	123	19	69	38
Bi	0.06	0.05	0.14	0.11	0.09	0.09	0.14	0.14	0.1	0.09	0.08

Unit in ppm; * no analyses; ** in percent (%); *** in ppb; [1] Warmada *et al.* (2003).

Host Rocks and Hydrothermal Alteration

In general, the dominant host rocks for both Se- and Te-type deposit are dacitic-basaltic volcanic rocks. The Se-type occurs in volcanic rocks and sometimes some sedimentary rocks intercalated; while Arinem and Cineam deposits of the Te-type formed in volcanic rocks. The gangue mineral of Se- and Te-types is characterized by the presence of large amounts of quartz, followed by carbonate and illite. Some of Mn carbonate (manganoan calcite and rhodocrosite) occurred in Se-type deposit.

The characterizing gangue by the presence of adularia is well developed in some Se-type, while there is no adularia found at the Te-type. Hydrothermal alteration patterns in the Se- and Te-type deposits are similar with the abundance of the propylitic alteration, and are dominated by chlorite, illite, mixed layered illite-smectite and chlorite-smectite. Argillic alteration is characterized by illite, montmorillonite, and some of kaolinite, usually enveloping the vein where the silicification and sericitisation occurred. The association alteration minerals in those deposits indicate the pH is neutral with slightly acid at the late stage of mineralization for some of deposit (such as in Arinem).

Homogenization Temperature and Salinity of Fluid Inclusions

Fluid inclusion data of quartz indicate that the Se- and Te-types formed over temperature ranges between 160 - 330ºC and 160 - 350ºC, on the average (shallower to deeper) of around 170 - 220ºC and 190 - 270ºC, respectively. The salinity of ore fluids for the Se-type is estimated to have been slightly lower than that for ore fluids of the Te-type. The Se-type has the salinity up to 3.4 wt% $NaCl_{equiv.}$ on the average of less than 1 wt% $NaCl_{equiv.}$ except for the Cirotan deposit which is up to 7.15 wt% $NaCl_{equiv.}$ (Milesi *et al.*, 1993) and for Te-type is in the range of 0.2 - 4.3 wt% $NaCl_{equiv.}$ on the average of ~2 wt% $NaCl_{equiv.}$. Formation temperature and salinity estimated from the fluid inclusion homogenization temperature and melting temperature for both types of deposits are summarized in Figure 4.

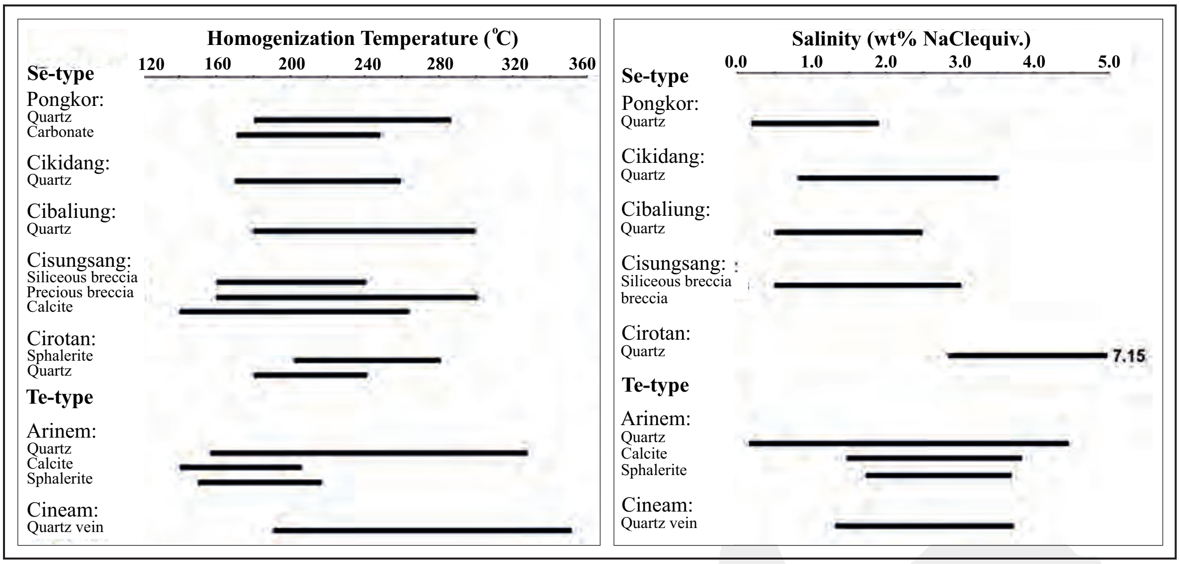

Figure 4. Temperature and salinity ranges of the Se- and Te-type deposits estimated from homogenization and melting temperatures of fluid inclusions.

DISCUSSIONS

Mineralogically, sulfide minerals are abundant in the Te-type and varied in the Se-type from trace (*e.g.* Pongkor) to abundant (*e.g.* Cirotan). This phenomenon is contradictory with the Se- and Te-types in Japan *where* sulfide minerals, except for pyrite and marcasite are very poor in amount for the Te-type, but sulfide minerals such as argentite, sphalerite and galena are abundant in the Se-type (Shikazono *et al.*, 1990).

The Se- and Te-type deposits in western Java are characterized by the temperature generally of <300°C, on the average of less than 220°C for Se-type and less than 270°C for Te-type. These also show a general decrease of temperature with decreasing depth and increasing paragenetic time. The salinity is low (frequently <4 wt% $NaCl_{equiv.}$) and the fluids probably are meteoric in origin with some sources being mixed with the magmatic origin.

The characteristics of Se-type deposits worldwide shows that electrum and selenide minerals have been deposited from fluid with temperature ranging around 150 - 210ºC (Matsuhisa *et al.*, 1985; Izawa *et al.*, 1990; So *et al.*, 1995) as indicated by fluid inclusions with low salinity (0.4 - 1.6 wt% $NaCl_{equiv.}$). The fluids are meteoric in origin (Matsuhisa *et al.*, 1985; So *et al.*, 1995) although magmatic solutions may have mixed with meteoric water such as in Hishikari (Matsuhisa and Aoki, 1994).

Otherwise, the temperatures of telluride deposition were less than 354ºC (melting point of hypogene sylvanite) in general and usually are below 250ºC with salinities in the range of <1 to 6 wt% $NaCl_{equiv.}$ (Kelly and Goddard, 1969; Saunders and May, 1986; Ahmad *et al.*, 1987). Textural evidence shows that tellurium mineral was formed after sulfide mineral and this concludes that magmatic sulfur was put to the fluid first then followed by input of tellurium. Some sulfide minerals also sometimes contain tellurium concentration due to minor substitution of Te for S. Sindeeva (1964) cites tellurium will presumably be concentrated in sulfide or oxide melts or in an aqueous phase evolved from crystallizing magmas due to the apparent rejection of tellurium by silicate minerals.

Shikazono *et al.* (1990) reported that Te-type deposits in Japan occurred at a higher level than Se mineralization in the same mining district. Aoki (1988) investigated the Osorezan hot springs and at the very shallow levels he found Au-Te minerals (*e.g.* krennerite, coloradoite) but no Se minerals have been identified. In the western Java mineralization, some Te mineralizations are associated with the Se-type deposits (Pongkor and

Cibaliung), though Se minerals are uncommon to coexist with the Te-type deposit. Comparison with other Se- and Te-types in Japan pointed the physicochemical conditions of the Arinem and Cineam deposits exhibited mineral assemblages might be deposited closer to the heat source and shallower than those of the western most deposits (Pongkor, Cikidang, Cibaliung, Cisungsang, and Cirotan).

Geochemical analysis of Se and Te elements from both Se-type of Pongkor and Te-type of Arinem deposits show the content of Te is higher at the vein samples of Te-type Arinem deposit, but the difference of Se content from both types of deposits is not too significant (Table 2). Otherwise, the petrographic investigation shows the occurrence of Se-mineral at Pongkor, but not at Te-types of Arinem and it is rare in Cineam deposits. Thus, it is concluded that there are other factors besides the host rock types, and the distance from the heat source controlled the formation of the Se- and Te-minerals among the Se- and Te-type deposits.

CONCLUSIONS

The ore mineralogy of the Te-type deposits of western Java was characterized by the abundance of sulfide minerals with minor Te-minerals of hessite, petzite, stutzite, tetradymite, and altaite, while the Se-type has various amounts of sulfide minerals with the occurrence of minor Se-minerals of aguilarite and naumannite, and Se-bearing minerals of argentite, polybasite, and pyrargyrite. Other minerals were found as minor or trace in both types of deposits.

The mineralogic data indicate that the Se- and Te-type deposits in western Java are characterized by the presence of a large amount of quartz and carbonates, with accessories of illite, chlorite, and smectite. Adularia is present at the Se-type but not in the Te-type, and generally the propylitic and argillic alteration zonation of the Se- and Te-types is similar. Formation temperatures of the Te-type are generally higher than those for the Se-type.

The comparison with the Se- and Te-types occurred in Japan pointed to the conclusion that the Te-mineralization probably occurred closer to the volcanic centre and at a higher level of the geothermal system than the Se-mineralization. It is also concluded that there might be other factors controlled the formation of the Se- and Te-minerals within those deposits.

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