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RESEARCH ARTICLE

Mineralogy and Geochemistry of Gold Ore Low Sulfidation - Epithermal at Lamuntet, Brang Rea, West Sumbawa District, West Nusa Tenggara Province

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Abstract

There are two Artisanal Small scale Gold Mining (ASGM) location in Lamuntet, Brang Rea Subdistrict, West Nusa Tenggara Regency, namely Nglampar and Song location. Nglampar and Song location are included in the low sulfidation epithermal gold deposit system. The research purposes to analyze mineralogy and geochemistry of gold vein deposits and determine system of low sulfidation gold ore in Nglampar, Lamuntet Village. The methods used to determine the mineralogy of gold vein deposits are petrography, mineragraphy and X-ray diffractometer (XRD) analysis, while geochemical analysis using Scanning Electron Microscope (SEM) with Energy Dispersive X-Ray Spectroscopy (EDS), Fire Assay (FA) and Atomic Absorption Spectrophotometry (AAS). The results showed that the minerals contained were quartz (Qz), sericite (Ser), Chalcedon (Chc), chlorite (Chl), pyrite (Py), sphalerite (Sph), galena (Gn) , gold (Au), chalcopyrite (Cp), argentite (Ag), arsenopyrite (Apy), Azurit (Az), Malakit (Mal) and bornite (Bn). Abundant mineral availability such as sphalerite, galena, chalcopyrite and arsenopyrite are characterized by high levels of Zn, Pb, Cu and As the metal in vein deposits. This can be seen on the chemical content of ore in gold vein deposits ie Au 0.1 ppm -27.8 ppm, Ag 3 ppm-185 ppm, Pb 101 ppm - 35,800 ppm, Zn 73 ppm-60,200 ppm, Cu 26 ppm - 1,740 ppm, and As 150 ppm - 6,530 ppm. Based on the results of SEM-EDS analysis shows that the type of gold mineral is the electrum because of the content of Ag> 20%. Based on those characteristics of the mineralogy and geochemistry in this study showed that low sulfidation gold ore in this area is categorized as polymetallic gold-silver system.

Keywords: geochemical, gold ore, LS-epithermal, Lamuntet, mineralogy, West Nusa Tenggara

1. Introduction

Gold is an important natural resource in Indonesia and many of it is done by small scale community called ASGM (UNEP, 2013). There are two ASGM in Lamuntet namely Nglampar and Song location. Both sites are included in the low sulfidation epithermal gold deposit (anonymous, 2015) . Previous research only stated that gold deposits in the area are low sulfidation gold deposits, while low sulfidation gold deposits style are based on variations in ore minerals, gangue minerals and wall rock mineralogy divided into several systems (Corbett, 2002). The purpose of this research is to analyze mineralogy and geochemistry of gold vein deposits and determine system of low sulfidation gold ore in Nglampar, Lamuntet Village.

The ASGM of Nglampar is located administratively in Lamuntet Village, Brang Rea Subdistrict, West Sumbawa Regency, West Nusa Tenggara Province, . the coordinate of research location at 08037'0 "S - 08052'0" S and 116048'02 "E- 116058 ' 0 "E. (Fig. 1).

This mineralogical and geochemical study was conducted as subsequent research on the effect of epithermal gold deposits on gold processing using borax as a substitute for mercury.

2. The Geology of Sumbawa

The Nusa Tenggara archipelago is located in the eastern part of Indonesia and the western part of the Banda arc. The Sumbawa island is at the tectonic active centre of Indonesia. East-west direction which is the meeting point of the three main plates of the Sunda-Banda magmatic arc, namely Indo-Australia, Eurasia, and the Pacific plates. (Hamilton, 1979). The interaction of the three plates forms a complex tectonic especially in the Eastern Indonesia plate boundary (Hamilton, 1979). The Nusa Tenggara archipelago formed the subduction of the Indo-Australian plate beneath the Sunda-Banda arc in the tertiary period, where these bearings formed a volcanic arc on the interior of the Nusa Tenggara (Hamilton, 1979).

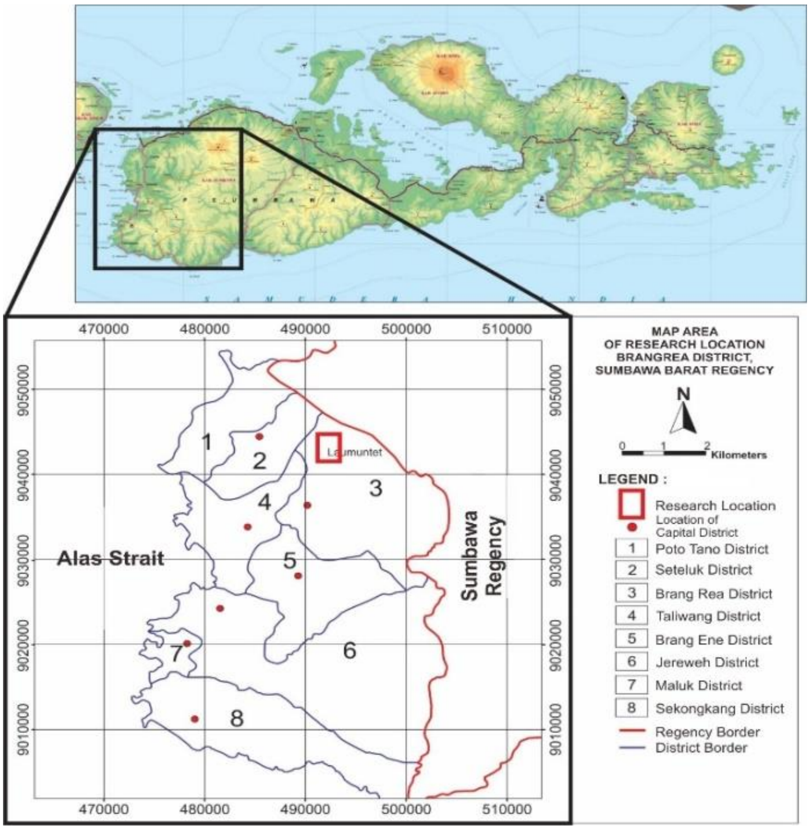


Fig. 1. Map of location research in Lamuntet, scale 1:425.000 (Bakosurtanal, 2002).

The Sumbawa island lies in the arch of Banda islands, which is a continuation of the Solo zone (Van Bemmelen, 1949). The East-West-oriented arc is a collision between the Indo-Pacific plate and the continental edge of the Australian plate (Hamilton, 1979).

Taliwang gold mineralization is formed in the temperature range ≥ 2200C to 1500C which is part of the epithermal mineralization system spread from the upper super large crustiform-colloform to the lower calidic cesedonic calm at a depth range between 250-150 m below the paleosurface (Herman , 2007).

Generally, Lamuntet blocks are dominated by chlorite-calcite-magnetite alterations formed on volcanic andesite rocks, whereas rock samples at the Nglampar site exhibit pyrite-sphalerite-galena ± chalcopyrite mineralization. Quartz veins carrying high oxidized Au-Ag-Cu mineralization are hematite-limonite. The main quartz veins are commonly north-eastern with an estimated zone length of 400 m and have a width of 1-2 meters. Quartz vein texture consists of comb composed by coarse euhedral, vuggy and sugary / sacharoidal / fine grained crystalline quartz crystalline quartz (nd, 2015).

3. Research Methods

The ASGM of Lamuntet Village is located in the north of Brang Rea Subdistrict, reachable by flight from Praya International Airport in Central Lombok Regency, and then drive four-wheeled vehicles to the east approximately 1.5 hours to Kayangan Harbor in East Lombok. Next take the ferry boat about 2 hours to Poto Tano in West Sumbawa. From Poto Tano to Lamuntet village, approximately 1.5 hours away by four-wheeled vehicles, while to reach ASGM site in the Ngampar mountains from Lamuntet village walk as far as 5.8 km for about 2 hours.

Analytical methods used for mineralogy are petrography, mineragraphy and XRD analysis, while for analyzing mineral geochemistry using SEM-EDS analysis, FA and AAS.

The petrographic analysis was carried out on a thin section that aims to determine the type of mineral as much as 30 samples. Mineragraphy analysis was done on polished section to know the type of metal mineral amounted to 30 samples. XRD analysis was done on bulk samples to confirm the type of minerals found from petrographic analysis, as much as 5 samples.

SEM-EDS analysis was done on polished section to know gold mineral type in the sample as much as 5 sample, and FA and AAS to know the content of metal element as much as 15 sample.

4. Result and Discussion

4.1. Petrography analysis

Petrography and mineragraphy analysis using a microscope with the brand Euromax.

The results of petrographic analysis conducted on 30 samples stated that the types of minerals encountered in thin section were quartz (Qz), sericite (Ser), Chalcedon (Chc), chlorite (Chl), Pyrite (Py) and opaque minerals (Opq). In megascopic minerals can be seen in Fig. 2.

The presence of comb-textured quartz veins is composed by a coarse-grained euhedral crystalline, sugar-like (sugary). Ghost-bladed textured quartz consists of a thin sheet of quartz anhedral crystals formed as a replacement for other minerals (usually calcite), and during its precipitation is affected by impurities (Allen, 1996) .

The alteration of sediment is phyllic and texture encountered ie gradation crystals, gradation-veinlet crystals, comb and vuggy cavities.

Several thin section analyses are shown in Fig. 3. On a Plane Polarized Light (PPL) the gray-thin section of the grey rock and the Crossed Polarized Light (XPL) shows a light grey color; texture of rocks with minerals size <0.1-4 mm, subhedral-anhedral crystals; Mineral compositions were prepared by quartz (35-60%), sericite (5-25%), Chalcedon (5-10%), mineral oxide (5-15%), pyrite (5-20%), and opaque minerals (10-20%). The percentage of mineral availability, the size of each mineral, the type of alteration and texture contained in the deposit can be seen in Table 1.

The gangue minerals are dominated by quartz which is equal to 35-60%, while pyrite amounts to 5-20%. The quartz is a gangue mineral that exists in almost all low sulfidation gold deposit systems, only in some having relatively large values. This is because it occurs at the final stage of paragenetic, especially in the high crust level, the entry of meteoric water into the ore environment results in a large addition of quartz (Corbett. 2013).

The same with carbonates as gangue minerals, it will decrease due to different depositional environments (Corbett, 2002). Low sulfidation gold ore style divided into the arc-low sulfidation gold ore and the rift-low sulfidation gold ore, based on derivation of magmatic source rock and circulating meteoric geothermal waters (Corbett, 2002).

Epithermal gold deposits are formed at shallow depths in the hydrothermal system associated with magma and generally occur in volcanic arcs (Cooke and Simmons, 2000).

The arc-low sulfidation devided into quartz-sulphide gold ± copper, polymetallic gold-silver, carbonate base-metal gold and epithermal quartz gold-silver. Those classification are not only based on distance from magmatic source rock (Corbett and Leach, 1998) but also varying of ore, gangue mineral and wall rock mineralogies (Corbett, 2002).

The rift-low sulfidation comprises adularia-sericite epithermal gold, which formed circulating meteoric geothermal waters (Corbett, 2002).

Mineragraphy analysis results show that the metallic minerals seen in the polished section are sphalerite (Sph), galena (Gn), Pyrite (py), electrum (El), gold (Au), chalcopyrite (Cp), argentite (Ag), arsenopyrite (Apy), Azurit (Az), Malakit (Mal) and bornite (Bn). The appearance of these minerals is shown in Fig. 4.

The texture of the ore seen from the polished section is the texture of the exsolution on the inclusion of Au, El, the replace texture of Py-Cp, Sph-Ag, Py-Sph, Cp-Gn, Cp-Apy.

The size of minerals, the percentage of ore mineral and the texture of the ore can be seen in Table 2.

Vein is dominated by sphalerite, galena, pyrite and acanthite, while chalcopyrite is only about 1%, It indicates that epithermal deposits are included in polymetallic gold. Polymetallic gold-silver is transition between quartz-sulphide gold±copper and carbonate base-metal gold but it is different (Corbett, 2002).

Galena and sphalerite abundance is reflected in the geochemical results of ore which can be seen in Fig. 9, and mineragraphy gold ore in Fig. 4. The highest grades of Pb and Zn were 35800 ppm and 60200 ppm respectively, Pb and Zn indicate galena and sphalerite minerals.

Sphalerite and galena are common in low epithermal gold ore, while pyrite is abundant (White and Hedenquist, 1995).

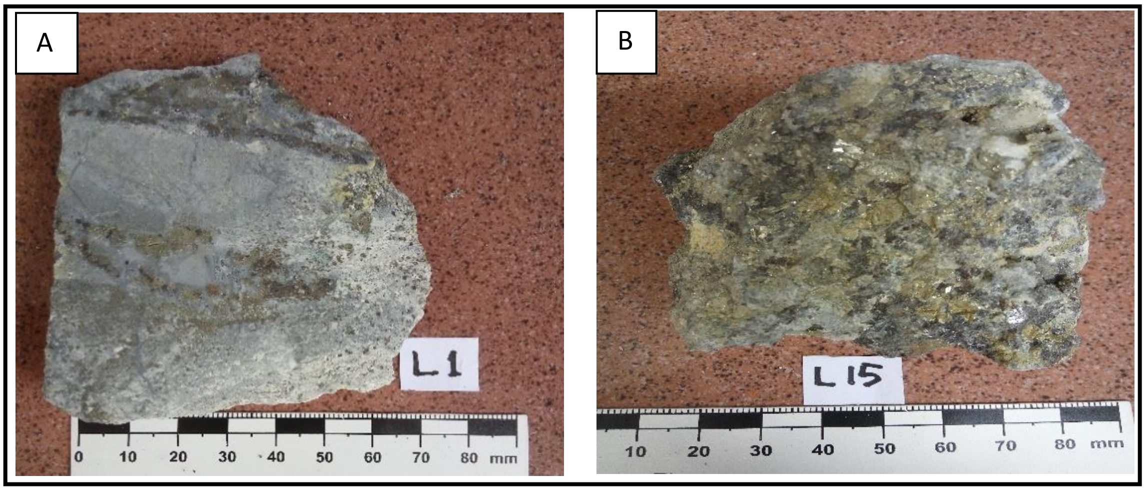


Fig. 2. The appearance of vein texture. (A). Comb texture, (B) Ghost-bladed texture.

Table 1. Characteristics of Epithermal Deposit in Lamuntet

Mineral	Percentage of Mineral (%)	Size of Mineral (mm)	Vein texture	Type of Alteration
Quartz (Qz)	35 -60	0,2 – 1,5	Gradation crystall,	phillic
Sericite (Ser)	5 -25	<0,1	gradation crystall-	
Chlorite (Chl)	5- 25	<0,1 – 1,5	veinlet, comb dan	
Chalcedon (Chc)	5- 10	-	vuggy cavities.	
Pyrite (Py)	5- 20	<0,5		
Opaque mineral (Opq)	10 – 20	0,5 - 3		
Oxide mineral (Oxd)	5 – 15	– 4		

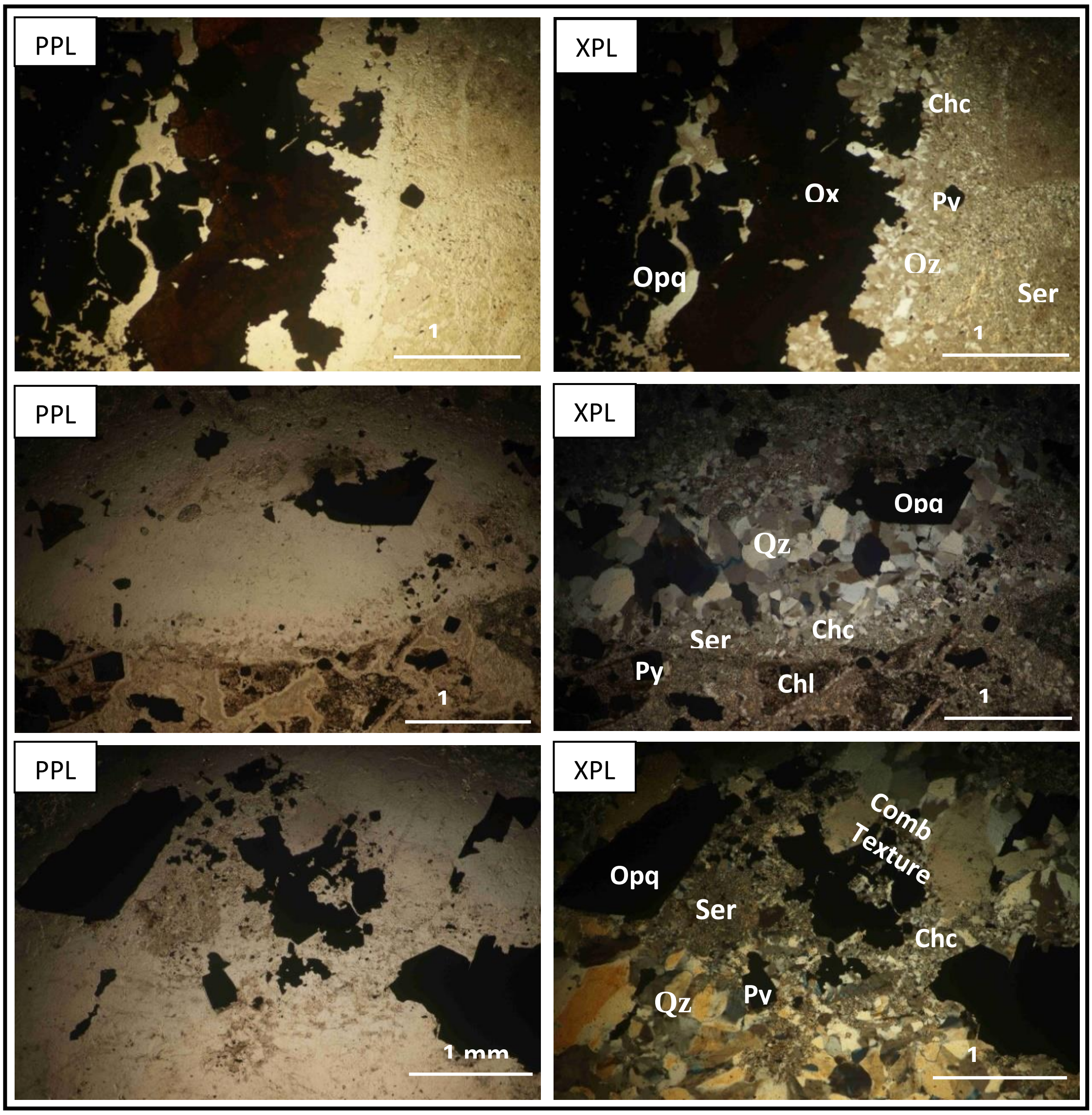


Fig. 3. The appearance of quartz, sericite, pyrite, chalcedon, chlorit and opaque mineral (PPL is Parallel Polarized Light, XPL is Crossed Polarized Light).

Xrd analysis using a tool with Rigaku Multiflex 2 kW brand, with emitting x-ray using Cu metal target, emitting voltage ie 32 kV, 20 mA current and 0.64 kW power.

XRD analysis results in some samples showed there were minerals dominated by quartz, pyrite, calcite, sericite, pyroxene, hornblende and plagioclase. Similarly, it is observed in a thin section that the minerals present in rocks are quartz (Qz), sericite (Ser), chlorite (Chl) and Pyrite (Py). The results of XRD analysis can be seen in Fig. 5.

All of the minerals present in site indicated that there was a match between the observed results in thin section and XRD test results that the existing mineralized associations were predominantly dominated by quartz (Qz), sericite (Ser), calcite (Cal), chlorite (Chl) and pyrite (Py).

4.2. XRD Analysis

Quartz (Qz), sericite (Ser), calcite (Cal), chlorite (Chl) and pyrite (Py) are the dominant gangue mineral in polymetallic gold-silver (Corbett, 2002), which can be seen in Fig.3.

Formation of polymetallic vein occurs in the basement rock associated with the formation of carbonate base-metal gold which is a mixture of magmatic sources and bicarbonate water which then comes out as subvolcanic intrusion (Corbett, 2002).

4.3. Chemical of Gold Analysis

Microscopic observations of samples on polishing section indicate that the gold minerals are very small (10-60 μm) and these are categorized as very fine grain size of gold (Grayson, 2007). It is also stated on the results of SEM-EDS analysis (Figs. 6 and 7). From result of SEM-EDS then done calculation and got atomic ratio (atomic ratio) in sample that percentage of atom from Ag> 20% hence gold mineral type Lamuntet area is electrum (Table 3). According to Harris (1990), if the content of Ag more than 40% then the type of gold mineral called aurian silver.

The dominant of galena and sphalerite is the basis for the presence of silver ore. Low metal grade, even though it can be mined, occur increased in a dilatation structure. The dilatant structure is caused by repeated mineralization (Corbeet, 2002).

4.4. Geochemical Ore Analysis

Geochemical analysis of ore aims to determine the chemical element content of ore in the sample that is using FA and AAS. Elements that are analyzed are elements of minerals contained from the analysis mineragraphy that Au, Ag, Pb, Zn, As, Cu and Hg. The results of the analysis can be seen in Fig. 5 and 9.

The geochemical composition of the ore-forming fluid will determine the mineral assemblages (Zhu et.al.,2011).

Fig.5 shows the highest Au content found in the L1 and L15 samples of 27.8 ppm and 26.1 ppm respectively. While the highest levels of Ag were found in L1, L5 and L15 samples which were 115 ppm, 185 ppm and 121 ppm, respectively.

Figure 9 shows that vein samples in Lamuntet have high grades of Pb, Zn, Cu and As. The highest level of Pb was found in L1 which was 35,800 ppm. This Pb metal indicates that samples contain abundant galena minerals. This can be seen also in the mineragraphy analysis that many visible galena minerals (Gn) in the sample.

Similarly, the presence of Zn metal, especially with the highest content of 60,200 ppm in L1 samples indicates that the sphalerite (Sph) mineral concentration in the sample is quite abundant.

Table 2. Characteristic of ore mineral epithermal

Mineral	Percentage of mineral (%)	Size of ore (mm)	Ore texture
Sphalerite (Sph)	8 – 15	0,05 – 2	Exsolution texture in inclusion Au, El, replace texture Py-Cp, Sph-Ag, Py-Sph, Cp-Gn, Cp-Apy
Galena (Gn)	5 – 15	0,1 – 2,5	
Pyrite (Py)	9 -25	0,1 – 2	
Gold (Au)	<1 - 1	<0,1	
Chalcopyrite (Cp)	3 – 6	0,01 – 0,5	
Argentite (Ag)	5 – 25	0,1 – 1	
Bornite (Bn)	3 - 5	0,5 – 1,5	
Arsenopirite (Apy)	4 - 5	0,1 – 1	
Azurit (Az)	3 - 5	0,5 – 1	
Malakit (Mal)	3 - 5	0,1 – 0,5	

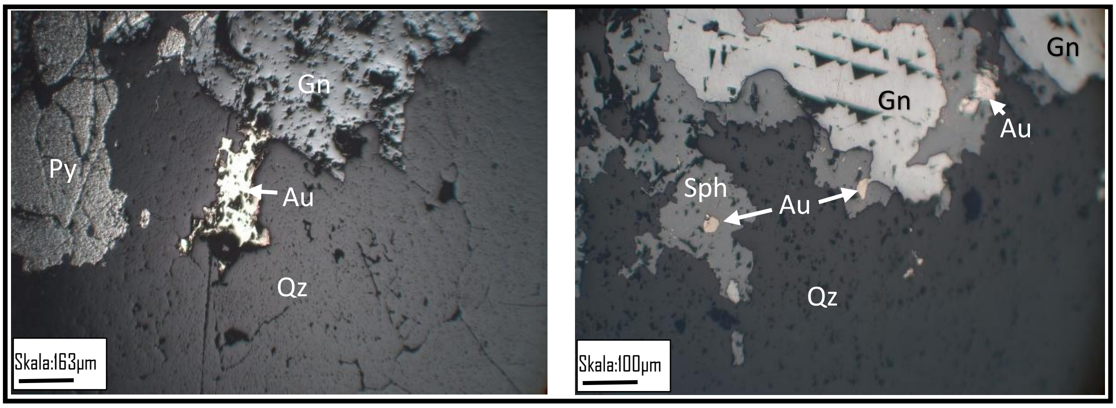


Fig. 4. The appearance of sphalerite (Sph), pyrite (Py), galena (Gn), quartz (Qz) and gold (Au) in polished section

Table 3. Weight of Au and Ag into sample.

Mineral			Weight wt%	Atom Mass	Element mole	Atomic Ratio	Atomic (%)	Mineral
L1		Au	56,28	196,97	0,29	0,41	41	Electrum
		Ag	43,72	107,87	0,41	0,59	59	
L5(1)		Au	57	196,97	0,29	0,42	42	Electrum
		Ag	43	107,87	0,40	0,58	58	
L14(1)		Au	34,9	196,97	0,18	0,23	23	Electrum
		Ag	65,1	107,87	0,60	0,77	77	
L15(1)	1	Au	53,88	196,97	0,27	0,39	39	Electrum
		Ag	44,48	107,87	0,43	0,61	61	
	2	Au	55,52	196,97	0,28	0,41	41	Electrum
		Ag	46,12	107,87	0,41	0,59	59	
	3	Au	57,39	196,97	0,29	0,42	42	Electrum
		Ag	42,61	107,87	0,40	0,58	58	
L15 (4)	1	Au	48,85	196,97	0,25	0,34	34	Electrum
		Ag	51,15	107,87	0,47	0,66	66	
	2	Au	48,5	196,97	0,50	0,34	34	Electrum
		Ag	51,5	107,87	0,48	0,66	66	
	3	Au	46,63	196,97	0,24	0,32	32	Electrum
		Ag	53,37	107,87	0,49	0,68	68	
	4	Au	40,95	196,97	0,21	0,28	28	Electrum
		Ag	59,05	107,87	0,55	0,72	72	

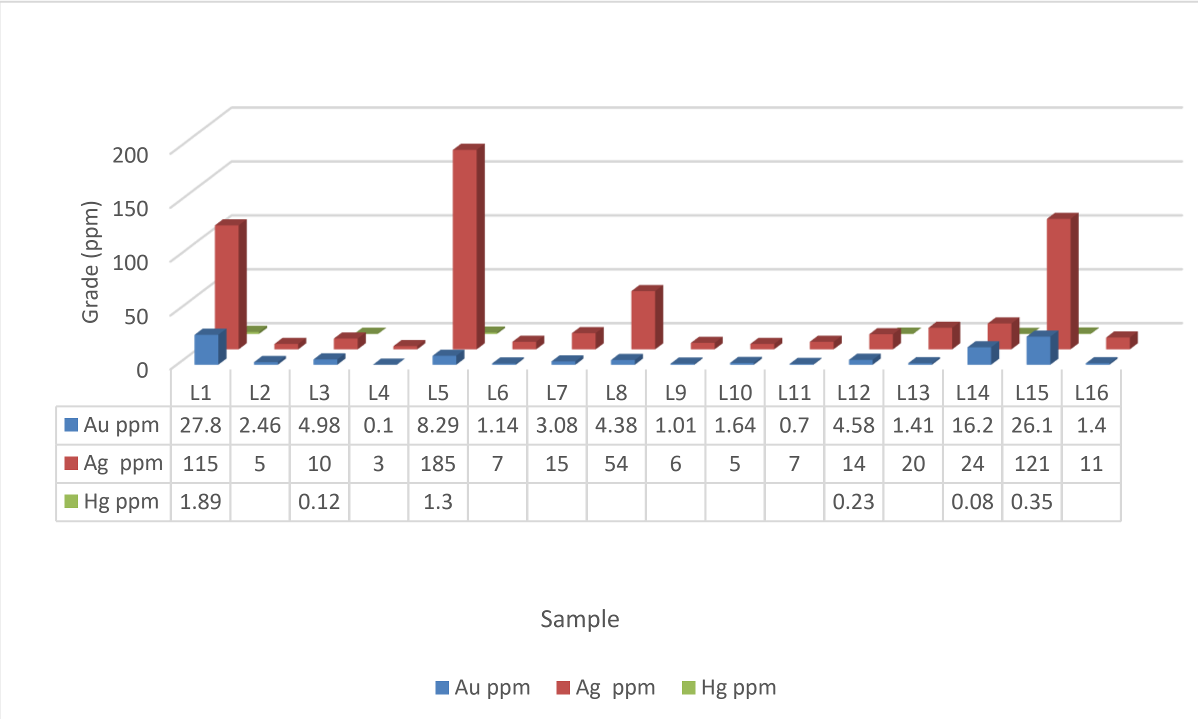


Fig. 5. Grade of Au, Ag and Hg in Lamuntet Vein

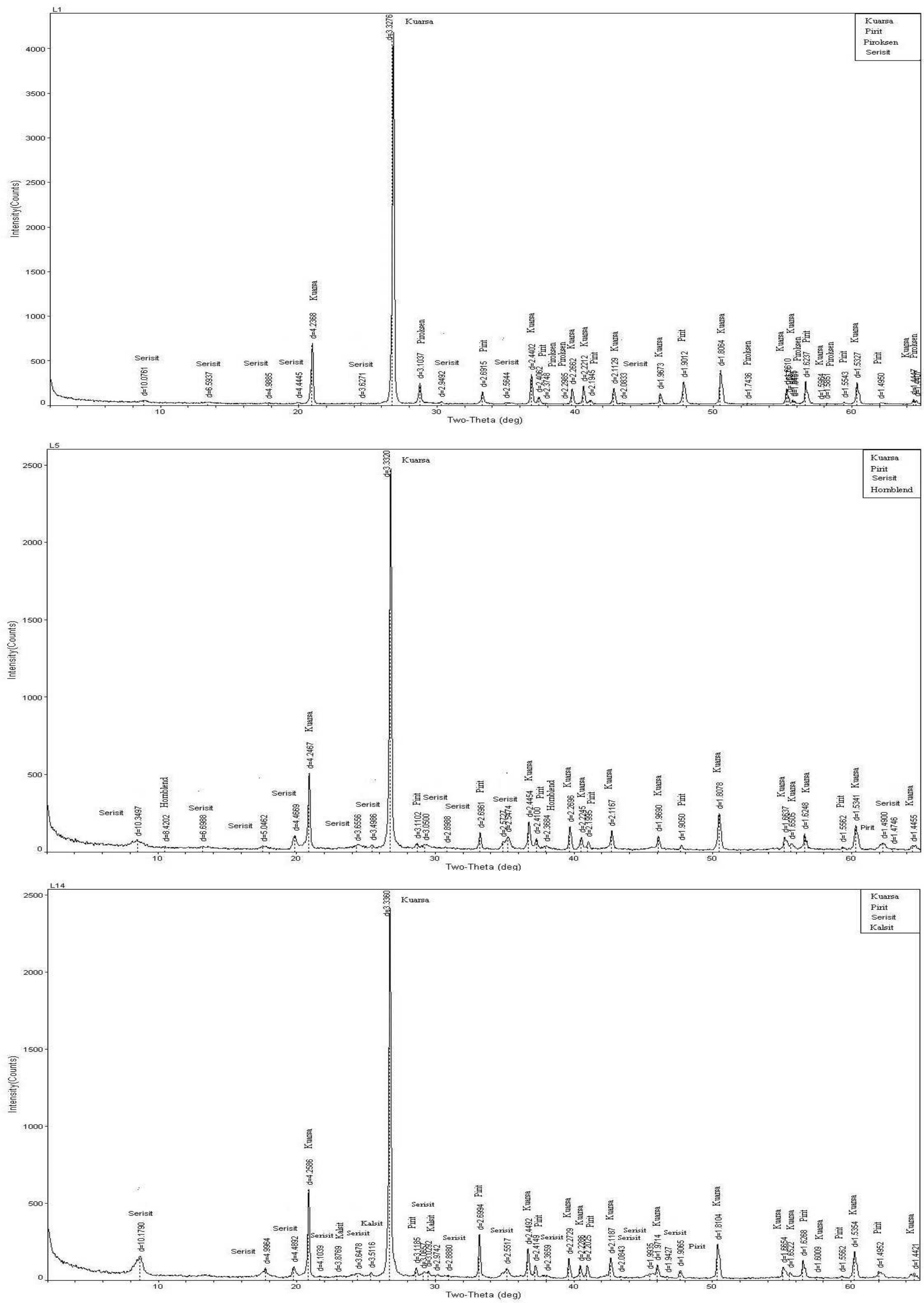
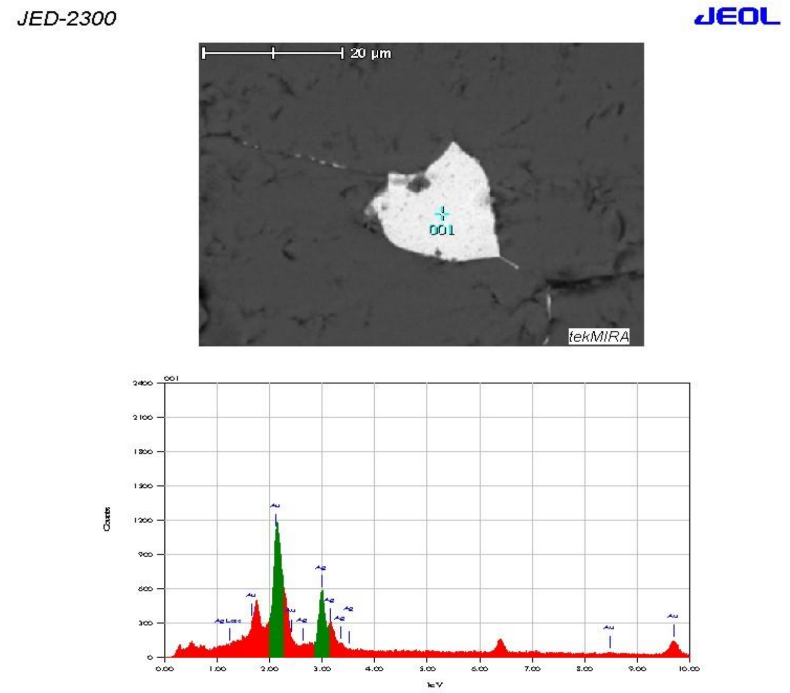
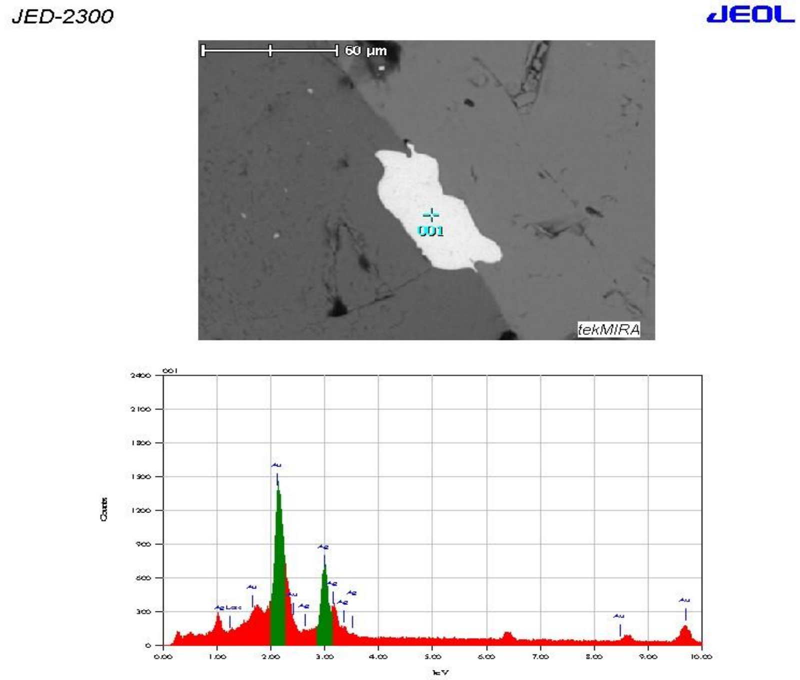


Fig. 6. XRD result



Element	(keV)	mass%	Error%	At%	Compound	mass%	Cation	K
Ag L	2.983	43.72	1.10	58.65				39.9602
Au M	2.121	56.28	1.09	41.35				60.0398
Total		100.00		100.00				



Element	(keV)	mass%	Error%	At%	Compound	mass%	Cation	K
Ag L	2.983	43.00	0.94	57.94				39.1643
Au M	2.121	57.00	0.93	42.06				60.8357
Total		100.00		100.00				

Fig. 7. Spot analysis of gold in L.1 code of polished section (magnification 2.000 x, scale 20 µm).

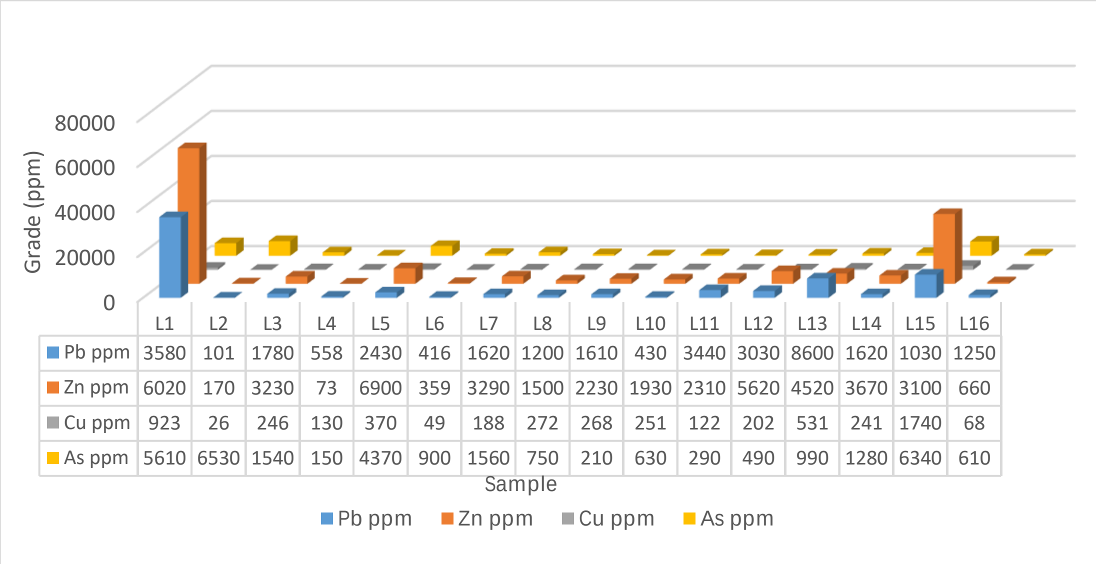


Fig. 9. Grade of Pb, Zn, Cu and As in Lamuntet Vein.

Table 4. Characteristic of ore at Nglampar block in Lamuntet

Characteristic of ore	Nglampar block in Lamuntet
Type of gold	Electrum
Size of gold ore	10-60 micron
Gangue Mineral	Dominated by quartz and pyrite
Association mineral	quartz (Qz), sericite (Ser), chalcedon (Chc), chlorite (Chl), pyrite (Py) opaque mineral (Opq).
Ore	sphalerite (Sph), galena (Gn), pyrite (Py), electrum (El), chalcopyrite (Cp), argentite (Ag), arsenopyrite (Apy), Azurit (Az), malakite (Mal) bornite (Bn).
Element content	Au : 0,1 ppm -27,8 ppm Ag : 3 ppm-185 ppm Cu : 26 ppm - 1.740 ppm Pb : 101 ppm - 35.800 ppm Zn : 73 ppm-60.200 ppm As : 150ppm - 6.530 ppm Hg : 0,08ppm-1,89ppm S : 5,10%-25,3%
Texture	Gradation crystall, gradation crystall-veinlet, comb and vuggy cavities.

Abundance of chalcopyrite and arsenopyrite minerals was also seen from high Cu and As levels of 1,740 ppm in L15, and 6,530 ppm in L2. According to Chryssoulis and Cabri (1990), the presence of As elements can identify submicroscopic gold carrying minerals, arsenopyrite and pyrite. It can also be said that the presence of As is the most commonly used element as the pathfinder element of the existence of gold in geochemical exploration (Boyle, 1965, Webb, 1958). Based on the description of mineralogy and geochemical analysis, the characteristics of gold deposits in Nglampar block Lamuntet can be summarized as in Table 4.

5. Conclusion

Based on those characteristics of the mineralogy and geochemistry in this study showed that low sulfidation gold ore in this area is categorized as polymetallic gold-silver system.

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