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LOW SULPHIDATION AU-AGEPITHERMAL ASSOCIATED MINERALS USING T^2 HOTELLINGS METHOD

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Abstract

The presence of low sulphidation epithermal gold at is a part of the geological process of the Sunda arc, Indonesia. This process encourages the formation of mineralized zones very closely with rock fractures in the Honje Formation and Cipacar Formation. This study describes the role of associated minerals (Ag, Cu, Pb, Zn and As) in Au-Ag Mineralization using the T2 Hotellings method. To obtain field data, namely surface mapping, this study analysed rock sampling for the petrographic test of 17 samples, and drill assay data with drilling depth between 50-450 meters. Meanwhile, the lithological zones were studied by BRAN, VNBR and VEIN and the multivariate normality test showed that the data were multivariate normally distributed between gold (Au) content and associated mineral content. The Multivariate Analysis of Variance average comparison test shows that there is a significant difference between the main mineral content and associated minerals in the lithology of BRAN, VEIN, and VNBR rocks. Minerals Ag, Cu, Pb, Zn and As are significant to Au, although not all lithological zones are significant because the values of the deterministic coefficient are different. Ag in each zone is significant for Au while for Zn and As in each zone is insignificant. Based on the arithmetic regression model on VNBR (Breccia Vein) with a small significance value, it shows that Ag, Cu and Pb influence changes in the grade value of Au. The implication of this research is to provide convenience for metal mineral exploration activities in predicting the role of associated minerals (associated minerals) on the main mineral content, especially for Low Sulphidation epithermal gold (Au).

Keywords: Arsenic, Associated minerals, Epithermal low sulphidation, Gold grade, T2 hotellings.|

1. Introduction

Busur Sunda, which translates to Sunda arc, is a complex geological process which has been widely studied; one of the products of the activity is hydrothermal deposit, a system generating such an epithermal as gold (Au). Gold as low sulphidation sediments made of volcanic rocks on the site of this study has also attracted researchers' attention. The volcanic rocks consist of Miocene basaltic andesite from the Honje formation, breached by the diorite to the andesite embankment, and covered by Cibaliung tuff, and equipped with intrusive diorite closely related to breccia diatreme [1]. Another interesting fact of the site is the presence of mineralization zone restricted by unconformity between Honje and Cipacar Formations. This leads to a question whether there is any grade similarity between the gold produced and its associated minerals as the consequence of the metal sediments. This condition is worth investigating as it might affect the exploration activities to execute, particularly ones related to the data sample and data analysis processes.

Geological studies on hydrothermal deposit exploration, particularly on epithermal low suphidation had been previously conducted carried out. A geochemical analysis on ore sediments, particularly those of gold, commonly focused on structure and formation of the ore [2]. In addition, the model of ore genesis and exploration depends on the analysis of various elements as well as ore formation (p, T, f (O_2), f (S_2), etc.); and its concentration process using geochemical method and mineral analysis employing petrography and microphotograph testing [2]. Characteristic identification of mineralogy and geochemistry of hydrothermal alteration, especially low sulphidation, can be performed by investigating geochemical indicators based on drilling hole logging, petrology, SWIR (PIMA), XRD to find out the source rocks, surficial area, and deposit [3]. Hydrothermal differences are based on mineralogy and geochemistry with various physics-chemical condition during the sedimentation of gold-silver implementing phase relationship among such minerals as sulphide, telluride, and selenide on the sediment [4]. A study on ore mineralogy and hydrothermal considered geological conditions, liquid inclusion, stabile isotope, and age extraction taking into account the sediment ore minerals such as electrum, naumannit, sulphate mineral Ag-Se-Te, chalcopyrite, pyrite, sphalerite and galena [5]. Mineralization is determined by gold complex paragenesis closely related to Cu-Fe-Zn-As and intrusion. A collection of ore including pyrite, chalcopyrite, sphalerite, pyrrhotite, arsenopyrite, and gold has decreased in quantity [6]. This sedimentary study is carried out using petrographic analysis using an optical microscope supported by semi-quantitative analysis (EDS) and backscatter image (BSE) scanned using an electron - SEM microscope, and microprobe processed with a software focusing on the chemical aspects of hydrothermal minerals and their variations presented as an element map (for arsenopyrite, for instance) [7]. Structural aspects on gold ore sediments are important controllers [8, 9]. A classical approach was selected with time restriction of mineralization particularly on gold bearing vein sediments [8]. Such studies have been so far focusing on decomposition of local circumstances of mineralization controller structure formation [10, 11].

This study is supported with results of surficial mapping to clearly identify the existence and distribution of the sediments and rock sampling from every rock, particularly ones from the Honje and Cipara Formations. This aims to perform petrographic testing and Assay data analysis of the drill log on 40 drilling sites to understand under-the-surface distribution and characteristics. To fill in the research gap in the field of gold mineralization, this study used T^2 Hotellings statistical method equipped with Multivariate normality testing. A MANOVA test was also administered to break down associated minerals (Ag, Cu, Pb, Zn, and As) influencing the grade of the gold (Au), and a Correlational Regression Analysis was selected to find out the relationship among each rock lithology in order that exploration activities are eased up and element selection with either positive or negative role was optimum. Nevertheless, this study has limitations; one of which is the absence of petrographic analysis.

2. Materials and Methods

Research site in this study is a gold mining area in Banten, Indonesia (568463, 564mE-572463,565mE and 9251763.565mN-9255763.565mN (UTM 48S)), located approximately 197 km from Jakarta, and is reachable by four-wheeled vehicles for around 4 hours on a paved road. In terms of topography and geomorphology, the site is generally undulating and hilly with the height ranging from 30 to 300 m above the sea. Higher hills are located on the western part of the site namely Honje mountain (approximately 620 meters away), which is part of Ujung Kulon national park. In the meantime, the site slope and its surroundings are about 10-25%. The site is on a low undulating and moderate hilly which are controlled by the alteration type. The moderate hilly area consists of altered smectite-illite rocks.

In terms of physiographical aspect, the research site belongs to the vault and mountains of West Java central depression zone (Fig. 1). This zone is a mountainous area controlled by the lithology of sedimentary and igneous rocks. This zone morphology is also influenced by geological structure such as fold, fault, and joint. The zone also comes with its complexity of condition as it is affected by Banten Block tectonic activities [12]. The site boundary stretches out from the south to the north, ranging from Pelabuhan Ratu to Jakarta Bay. Initially, Java and Sumatera islands were united until they were separated on the Mio-Pliosen era [13]. Java island had an anti-clockwise rotation yet Sumatera island had a clockwise rotation leading to widened Sunda strait to the south, imitating a triangle zone [14]. Geologically, both Java and Sumatera islands had such similarities as the existence of north-south segmented basements in Banten and Lampung, Horst-Graben systems located in Ujung Kulon High-Ujung Kulon Low-Honje High-West Malingping Low, and an active Sumatran horizontal fault in a form of dextral and a horizontal dextral. Ujung Kulon (located in Pelabuhan Ratu Southwest offshore) has a step-over position over the Sumatran fault and Ujung Kulon. Javanese volcanism on the Paleogene is divided into two phases namely (1) last Eocene-first Oligocene producing a magmatic arc on a relatively more south part; and (2) Oligocene - Pliocene producing a magmatic arc in the central part of Java island as what we can see nowadays [15]. This Paleogene and Neogene volcanism is marked by the formation existence of Jatibarang (Paleogene) and Merawu (Neogene). A Pliocene-quarter volcanism phase is indicated by a shift of a transgressive cycle into a regressive cycle and finally into a Neogene Fig. 1(a).

The most recent data show the presence of volcanic rocks aged in early Neogene in south Sumatera namely Kikim and Lahat formations [16-18] and in south Java beach which is Jatibarang formation [18]. The presence of these early Neogenean rocks in Java and Sumatera have successfully shown sustainable magmatic arcs. Jatibarang formation is known to be 29.0 Jtl [18]. There has not been measurement on either Kikim or Lahat formations; however, both are stratigraphically under Talangkar formation coming from the Oligocene era.

Early Neogene volcanic rocks were initially discovered in south Java. Their outcrop can be viewed in West Java (Jampang formation), Central Java (Old Andesite formation), and East Java (Besole formation). The Jampang formation is approximately 17.9 to 32.3 million years old [18] and is considered to be equal to the Old Andesite formation who is at the same age of Oligo-Miocene. The sustainability of early Neogene volcanic rocks in the north Java has not been precisely known. Magmatic arcs represented by such formations as Kikim, Lahat, and Jatibarang were related to the existence of mélange in Luk Ujo (Central Java) and Ciletuh (West Java). In the meantime, Neogene magmatic activities starting in the north on calcium shifts to the south after going through "dormancy" on Eo-Oligocene. This magmatic arc shift is in relation to Sumba micro-continent docking (Sumba, East Java, Paternosphere) Fig. 1(c.).

Based on research site geological section scheme (Fig. 2), this zone is also influenced by such geological structure as fold, fault, and joint, particularly in the gold mineralization areas in the Honje and Cipacar formations consisting of Neogene sediments strongly folded and igneous rock breakthrough. This area is relatively stable since Neogene era. There are strong structural differences among Banten Block, in which is it dominated by north-south direction while in Java, it is dominated by west-east direction structure.

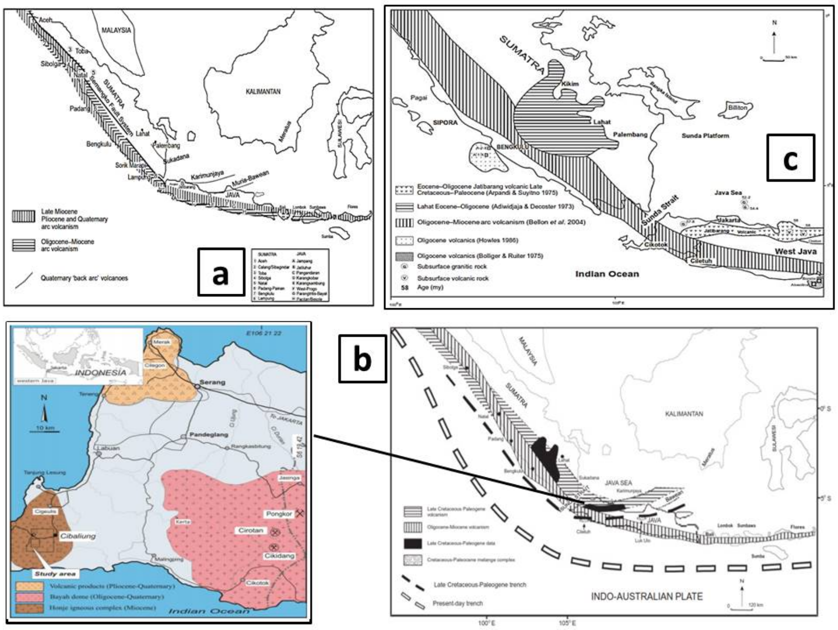

Fig. 1. (a) Oligo-Miocence and Piocence-Quarter magmatic arcs, (b) Distribution of Early Neogene volcanic rocks based on surface and below the surface data and (c) Changes of magmatic arcs in Java and Sumatera [18].

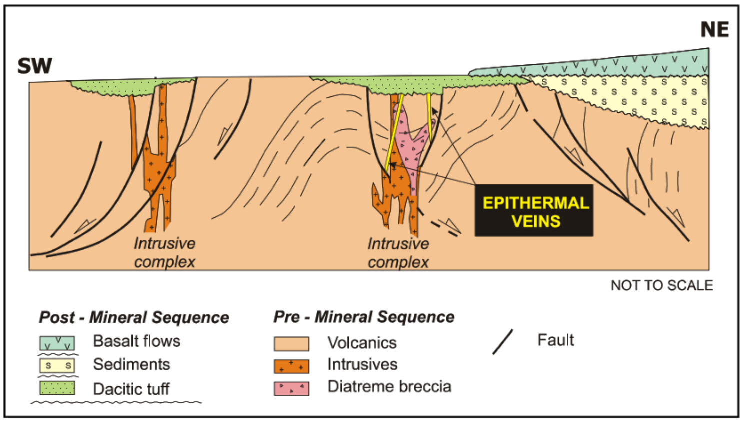

Fig. 2. Research site geological section scheme [19].

Stratigraphy from the older to the younger on the research site is categorized into four rock units [12], such as Honje lava unit (Late Miocene/ 11.4 mya), Honje breccia unit (Late Mioece), tufa unit (Early Pliocene/ 4.9 mya), and alluvial sediment (Holocene - Resen). On the research site, there are two predominant big formations namely Honje Formation, which contains lithology of volcanic breccia, tufa, lava, andesite-basal, and scraped wood. This formation is approximately Late Miocene based on some of the rock units mixed with Bojongmanik Formation. The thickness of Honje formation is around 500-600 meters. In the meantime, the formation distribution scatters in Honje mountain, Tilu mountain, and Citeurep area; this area is breached by andesite-basalt rocks [12] and Cipacar Formation which consists of tuff, pumice, tuff sandstone, tuff clay stone, breccia tuff, and marl. These types of rocks are commonly layered well, and their thickness is about 250 meters, crushed by Bojong Formation and younger rock units. Foraminifera fossils within this formation show that they are relatively Pliocene (N19-N21). In this formation, there also molluscs fossils, shells, and extractods. Their deposition site is shallow land-sea area [12].

Cibaliung source rocks are ordered from changing to not changing rocks. The changing ones are a part of Honje formation yet the not chancing ones are related to Cibaliung tuff [20]. This formation is found alongside Ciletuk river in the Southwest lowland of Cibaliung mining area. According to Marjoribank (2000), Honje volcanic units comprise the lava streams of basaltic andesite and volcanic breccia with sporadic interlude tuff sediment. The volcanic stream is strong while the volcanic breccia is the automatic and hyaloclastite breccia stream. Some spark plugs and embankments of sub-volcanic andesite infiltrate to the Honje formation around Cibitung. In the meantime, the intrusive rocks are commonly porphyritic-aphanitic with dominant plagioclase and pyroxene phenocryst (Fig. 3).

General description of Cilabiung mineralization site is shown in an igneous rock site namely Honje Formation linked to Kubah Bayah by Plio-Plistocene. Honje Formation itself is Late Miocene dominated by igneous rocks composed of basaltic to andesitic as well as volcanic breccia intercalated with sedimentary rocks. This formation is then crushed by Cibaliung Formation dominated by tuff composed of dacitic (Fig. 4) [4, 21].

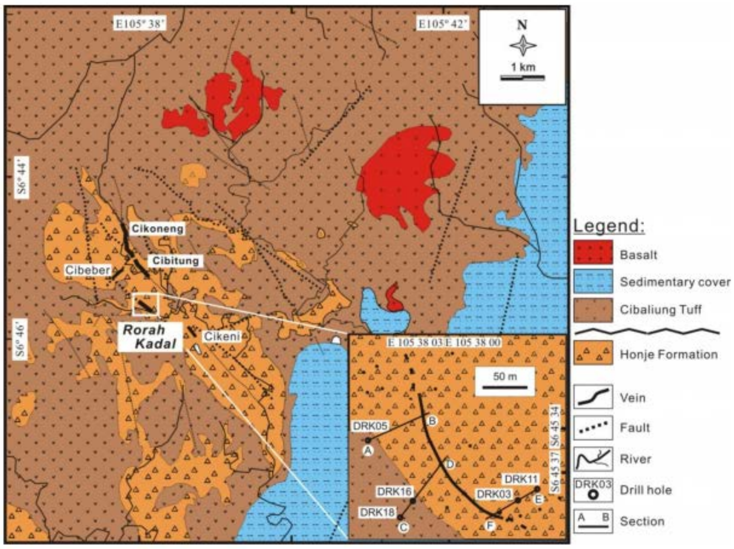

Fig. 3. Geological map of the site showing Rorah Kadal veins, Cikoneng, and Cibitung [1].

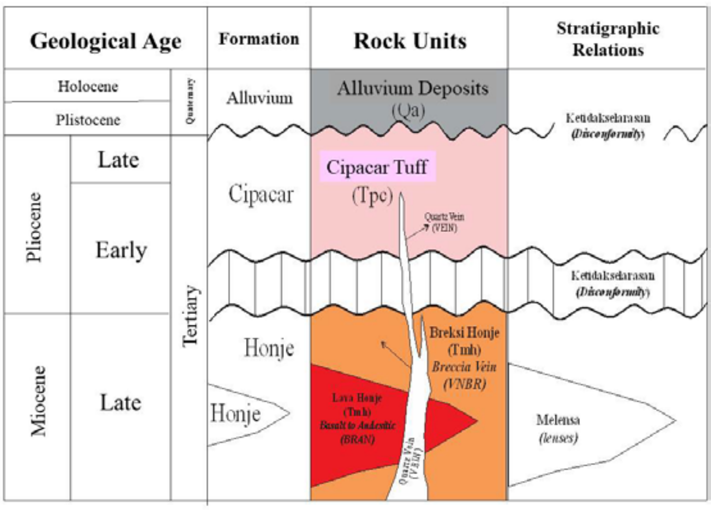

Fig. 4. Rock stratigraphy column on research site [21].

Several veins are found on the mineralization site namely Cibitung vein and Cikoneng vein identifiable through quartz-cerisite and adularia. The alteration zoning is differentiated by silicic (dominant quartz), propilic (chlorite, epidote, carbonate, and quartz) and argillic (illite and smectite). The main metal minerals are electrum, pyrite, chalcopyrite, sphalerite, and galena and the other minerals are tetrahedrite, argentite, polybasite and bornite, as well as hessite and stromeyet in small amounts. Based on the regional structure of West Java, it can be concluded that the research site structural pattern is NW-SE direction since it is the main and earliest structure. This structure is a tensile force serving as mineralization controller main geological structure. This is proven by the existence of vein quartz with around 30 m thickness directed N-W and N-NW [12]. The prospect of gold in Cibaliung is located on the W—NW direction with the width at 3.5 km and length at 6 km. The N-NW directions having rich gold deposit relatively upright quartz vein system are the north CIkoneng and south Cibitung which is 400 m away. The body with rich gold deposit has the width around 1-10 m, length around 140-200 m, and depth around 300 m and even deeper. In Cikoneng-Cibitung, this type of body is dilatational jogs and sigmoid bends which are formed by fractured intersections of such directions as W-NW, N-NW, and N-NE. Gold and silver ore in Cikoneng-Cibitung is formed in several phases of quartz vein namely low sulfidation adularia-sericite within the epithermal system.

Data collection was carried out by 1) literature survey towards mining industry desk evaluation report; 2) Surface geological mapping; 3) Petrographic test of rocks; and 4) Data analysis of drill and Assay test results. This study also employed geological remapping to obtain details on Honje and Cipacar Formations with 60 mapping station spots spreading out at Ciletuk river and Mangkualam-Padasuka villages (Fig. 5). The geological remapping processes comprise description of rocks, analysis and measurement of the fault and measurement of RWD from the surface rock outcrops. The description of the rock outcrops is based on a sample of 10 to 15-cm rock chunks. To find out their mineral, this study administers a laboratory analysis to 17 samples of thin incision of rocks through a petrography test. Some information obtained from the geological remapping are (1) position of the rocks, veins, or charcoal: (2) distribution, direction, and shapes of the surface; (3) variation, position, contact, and lithological units (stratigraphy or formation; (4) geological structure influencing the site's geological condition; and (5) other supporting information such and geomorphological, geotechnical, and hydrological conditions.

Fig. 5. Outcrops of andesite rock ST-4.1.

In addition to the sample, the data used in this study are the drilling data from the mining industry exploration activities with the depth varies from 50 to 450 meters on 40 drilling spots. The data are acquired from PT Cibaliung Sumberdaya. The distance among the drilling spots also varies from 50 to 150 meters. To collect more data, this study also re-analyses the drilling lithological logs for the rock distribution as take the sampling of a certain depth with the mineralization direction guidance. The Assay data obtained are 40 analysis drilling spots with a variety of the main minerals which is gold (Au) and such associative minerals as silver (Ag), copper (Cu), lead (Pb), zinc (Zn), arsenic (As), mercury (Hg), antimony (Sb) and titanium (Ti). The data are then statistically analysed as an attempt to get clear description of the data validation and verification in order to have accurate conclusions. The quantitative data analyses consist of 1) data coding; 2) data entering; 3) data cleaning; 4) dta output; and 5) data analysis. In the meantime, the statistical computation employed in this study is T2 Hotellings test.

3. Results and Discussion

3.1. Results

The main objective of this study is to analyse the roles of associated minerals (Ag, Cu, Pb, Zn, and As) and their influences on the gold (Au) from rock lithological zones on Au-Ag mineralization using T^2 Hotellings test analysis method. Prior to the test, this study employed a multivariate normality test to identify the variation description of the associated mineral grade. In addition, a correlational regression test is also carried out to obtain information about the relation of each rock lithological zone mathematically in determining the sedimentary grade of the variables. The influence of the associated minerals is explained on the T^2 Hottelings testing as the method elaborates differentiating variables among the associated minerals. The exploration activities on the research site show that the rock lithology is divided into six types of namely andesite (ANDS), basalt to andesite breccia hyaloclastite, flow, expiclastite (BRAN), porphyritic andesite (PAND), quartz vein (VEIN), breccia vein (VNBR), basalt dike (DBSL). This study, however, focuses on analysing three lithological types including BRAN, VEIN, and VNBR based on the relative presence of the associated mineral grade distribution. The laboratory analysis results to the sediments, either those of the main minerals or those of the associated minerals revealed the existence of five associated minerals comprising silver (Ag), copper (Cu), galena (pb), zinc (Zn), and arsenic (As). To identify the distribution of the minerals' grade, this study investigates the sample of drilling log data on a certain depth selected by the mineralization zones containing gold and other minerals.

Table 1 shows data of associated mineral grade value of each relatively high gold sediment-carrying rock lithology. The score of multivariate normality testing shows that the distribution score of the associated minerals is relatively even as it is indicated by the score of R of each rock lithology >0.9. This indicates that there is a relation among the minerals. It is also shown in Table 1 that mean comparison testing of each rock lithology is needed to acquire accurate description of which mineral has the best potential and is correlated with either the main or associated minerals. Each lithology shows whether there is difference of gold grade (Au) as the main mineral to later identify whether there are similarities and differences of lithological differences or whether there are other influential factors.

Table 1. Rock lithology, grade, and multivariate normality test results.

Mineralization zone	Testing sample depth (m)	Grade (ppm)						R Score	Conclusion
		Au	Ag	Cu	Pb	Zn	As		
BRAN	81.50-506.00	0.00-1.25	0.00-24.00	0.00-57.00	0.00-16.00	0.00-96.00	0.00-98.00	0.932	There is Relation
VNBR	47.33-473.15	0.01-98.25	0.50-1.130	0.00-2.570	0.00-1.120	0.00-1.600	0.00-132.0	0.974	There is Relation
VEIN	106.50-409.10	0.01-41.83	0.50-1.210	0.00-200.0	0.00-397.0	0.00-547.0	0.00-27.00	0.976	There is Relation

Multivariate analysis of variance (MANOVA) test with level of significance (α) at 5% is administered to identify the difference of mineral grades (Au, Ag, Cu, Pb, Zn, and As) on such mineralization zones as breccia to andesite (BRAN), quartz vein (VEIN), and breccia vein (VNBR). Of all the associated minerals, one playing the most important role has not been identified. Therefore, a T^2 Hostelling test is conducted (Table 2).

Table 2. Comparison test of BRAN-VEIN lithological zones.

Zone	T^2 *Hotellings*	C^2	Remarks
BRAN and VEIN	83.14436	16.04749	H_0 rejected
BRAN and VNBR	47.22805	16.04749	H_0 rejected
VEIN and VNBR	12.88669	16.04749	H_0 accepted

Table 2 shows that in terms of comparison of each rock lithological zone, there is a significant difference of mineral grades (Au, Ag, Cu, Pb, Zn, dan As) on the BRAN and VEIN zones. The mineral is classified to have significant difference is the simultaneous confidence interval level score is 0. It is shown in Fig. 6 that the simultaneous confidence interval score of As is not 0, while that of Au, Ag, Cu, Pb, and Zn is 0. The difference is obtained from the As mineral grade. In addition, it can be concluded that for BRAN-VNBR rock lithology (see Fig. 6), there is a significant difference of mineral grade between Au and Ag, Cu, Pb, An, and As indicated by the score of simultaneous confidence interval test which is 0. Meanwhile, there is no significant difference of mineral grade between Au and Ag, Cu, Pb, Zn, and As on the VEIN-VNBR lithological zone as the results of the T^2 Hotelling is $12.8867 < C^2$ (16.0475).

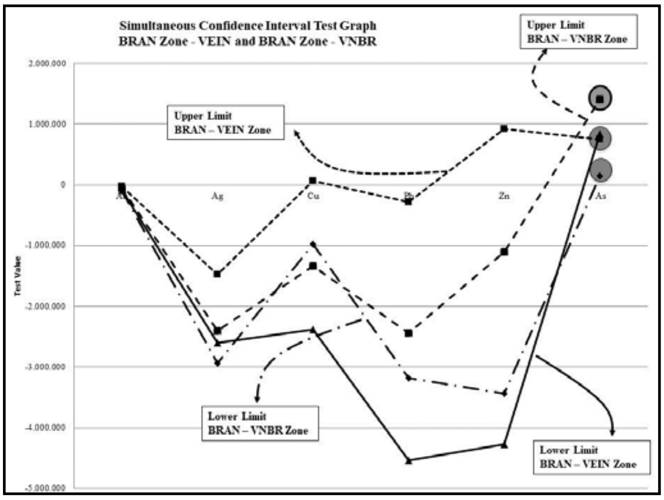

Fig. 6. Simultaneous confidence interval test graph on the zones of BRAN-VNBR and BRAN-BEIN.

The result of T^2 Hotellings is also supported by that of the correlational regression test aiming to identify the influence of each associated mineral (Ag, Cu, Pb, and As) towards that of gold (Au). A correlational regression is valued based on the determinant, indicating how much each associated mineral influences the data analysis, including the correlational coefficient of each associated mineral.

Graph correlation regression test results of such lithological zones as BRAN, VEIN and VNBR can be seen in Fig. 7.

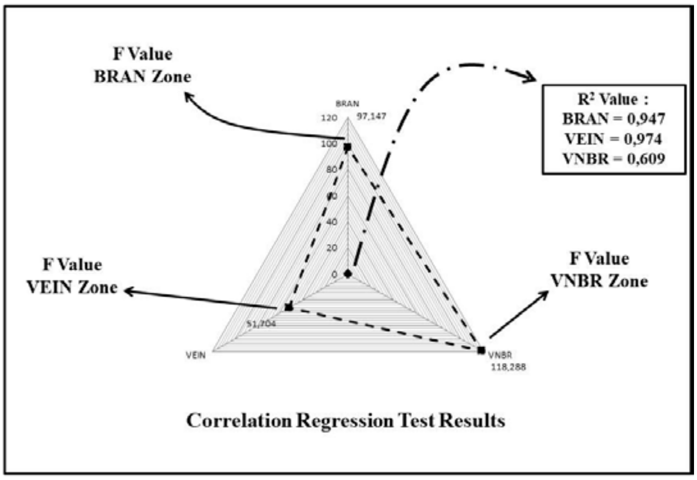

Fig. 7. Graph correlation regression test results of such lithological zones as BRAN, VEIN and VNBR.

The results of ANOVA presented by a linear equation describing the influence of each associated mineral to Gold (Au) as follows.

BRAIN Y = 0.438 + 0.096 Ag - 0.011 Cu + 0.002 Pb + 0.001 Zn + 0.003 As, ones with significant influence are Ag, R^2 = 94.7% (1)

VEIN Y= 0.862 + 0.037 Ag + 0.007 Cu - 0.032 Pb + 0.018 Zn + 0.126 As, ones with significant influence are Ag and Pb, R^2 = 97.4% (2)

VNBR Y= 3.320 + 0.060 Ag + 0.009 Cu - 0.022 Pb + 0.004 Zn - 0.026 As, ones with constant significance are Ag, Cu, and Pb, R^2 = 60.9% (3)

The equations conclude that such minerals as Ag, Cu, Pb, An, and As significantly influence Au. However, the influence in not of every zone as they have difference determinant coefficient scores. For instance, Ag is significantly influential towards Au and Az and As are both not influential on every zone. All the three models show that the best regression is on VNBR (breccia vein). Referring to the significance score and variation of the associated mineral with influence, this study found that the grade of AU on the VNBR zone ha the most various improvement as it is affected by three associated minerals namely Ag, Cu, and Pb with the following model.

VNBR Y= 3.006 + 0.069 Ag + 0.009 Cu - 0.016 Pb (4)

3.2. Discussion

This study discusses the roles and influence of associated minerals to the grade of Au on AU-Ag low sulphidation mineralization zone. Moreover, this study presents a new analysis in measuring the associated minerals for primary gold sediment exploration, which is able to analyse the level of Au grade. The existence of the mineralization zone is closely related to the rock fracture caused by tectonic activities. The area is close to Cimandiri fault on the Northeast of sinistral strike - slip fault and Ujung Kulon fault, extension of dextral fault - Sumatera fault slip [5, 22]. The gold mining primary rocks consists of andesite [23]. A petro-graphical analysis of the sample is dominated by plagioclase, pyroxene, small hornblende. Silicification and chloride occur as a changed mineral [23]. The porphyritic texture is dominated by microcrystalline basic mass as much as 40% with several changes. The fracture is then filled by silica minerals.

The influence of fracture filled with silica minerals gives a description related to the mineralogy characteristics of the studied area, one of which is mineralogy and geochemistry of hydrothermal alternation related to the low and middle sulphidation as well as gold-silver epithermal sediments [3]. Hydrothermal fluid leading to the formation of Cibaliung deposit is interpreted as pH neutral. The temperature of the sediment formation ranges from 170 to 220 ° C either in shallow or deep area [5]. The origin of hydrothermal fluid is interpreted as dominant meteoric water passing the rocks' walls with high ratio of water-rock based on the isotope of oxygen and hydrogen [5].

Mineralization/ alteration of vein sediments associated with basic metal sediments is characterized by the mineral formation zonation both on high and low temperature. The veins located on the proximal area are rich with copper and metal ratio rather than sulphur. Gold-bearing mineral is also associated with the sulfide sediments which have been oxidized. The sediments are closely related to the Volta or metal reactivity order, in which the metals on the left are able to reduce ones on the right in terms of their substances.

The difference of mineralization zones also includes that of source rocks, which contain difference minerals. Each mineral has its own characteristics; gold, for instance, is a metal commodity with high value which can stand alone or be associated with other metal and non-metal minerals. The mineralization is determined by gold complex para-genesis related to Cu-Fe-Zn-As and also intrusion [6]. There are a number of ores such as pyrite, chalcopyrite, sphalerite, pyrrhotite, arsenopyrite, and gold which are put in order based on their mineralization abundance [6]. Quartz as an indicator of a metal mineral is closely related to Au metal mineral. Fractured rocks give easier access to the quartz to fill in. with the help of other factors such as ore-carrying fluid, enrichment on the quartz veins will be formed. In another case, As, Fe, and A1 are generally mobilized on a rainy season. Arsenic is adsorbed or related to Fe and A1 (hyrd) oxide on the sediments. Fractions Fe and A1 (hyrd) oxide adsorbed by the crystalline are the main fractions of As controlling seasonal mobility. The total concentration of A1, Fe, and As are commonly higher on a dry season [24].

The As-Au correlation has been drawing huge attention as gold solubility increases with the As concentration within the alkali fluid [2]. The main gold-bearing minerals are pyrite and arsecopyrite consisting of As of the Carlin golden sediment. Since the gold mineral and As-bearing correlate positively, As is considered to have an important role on Au concentration [2]. Gold tends to be concentrated on the liquid vapor phase on high temperature and pressure. The association of Au-As and Au-Sb is commonly found on gold deposit. Original antimony/ arsenic of original gold complication can actually be deposit from hydrothermal fluid with low sulphur fugacity. On that area, arsenic is strongly associated by Fe and A1 oxide [25]. Specific minerals widely distributed within ore-gangue explain concentration anomalies of Au, Ag, and U detected on the north Apennine sulphide sediment sample [26]. Gold, uraninite, and minor sulphide AG (argentite) are metal bearers on Fe-Cu ores, while Ag anomaly marked on sulphide corchia Zn-Fe ores are recorded by freibergite and minor Ag2S [26].

The fact shows that mineralization of Au-Ag-U is limited on stratiform and strataboud ores and is not found on subsea floor stockwork veins. In terms of arsenic geochemistry, arsenic contains minerals such as orpiment (As_2S_3), realgar (AsS) and arsenopyrite (FeAsS) on earth. It is identified that arsenic shows strong affinity with sulfur and iron. As a matter of fact, sulfofil affinity benefits hydrothermal transformation from arsenic sulphide sediments to (As_2S_3) or realgar (AsS) [27]. Ore-shoots marked by the improvement of Au grade including IS and LS can actually develop on a structural intersection in which the ore fluid can climb up along normal fracture and mix with sulphide acid fluid. These results are in line with those of the previous works. However, the previous works did not use the T^2 Hottelings method to analyse the low sulphidation gold mineral sediments investigating the roles of associated minerals affecting the grade of Au. As / (As + S) (atomic) vs Au (ppm) pyrite diagram from a granitoid sample, southwest New Brunswick can be seen in Fig. 8.

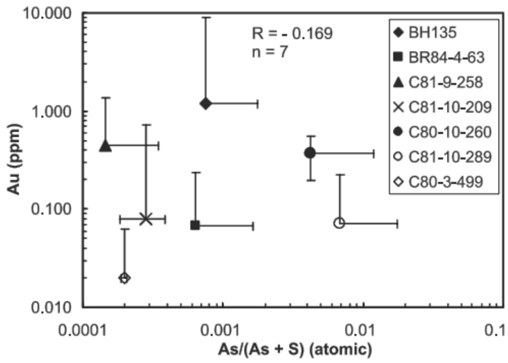

Fig. 8. As / (As + S) (atomic) vs Au (ppm) pyrite diagram from a granitoid sample, Southwest New Brunswick. The bar is one standard deviation for the vertical and horizontal axes. The LOD for Au is 0.02 ppm [28].

The As-Au correlation has attracted great attention. Experimental work shows that gold solubility increases with As concentration in alkaline liquids [29]. The main gold-bearing minerals are pyrite and arsenopyrite which contain As in Carlin-type gold deposits. Because the minerals gold and Asbearing (pyrite and arsenopyrite) are positively correlated, As is considered to play an important role in Au concentration. Gold tends to be concentrated in the vapor phase of liquids at high temperatures and pressures. Au-As and Au-Sb associations are commonly found in gold deposits. Native antimony and / or arsenic and native gold deposits can precipitate from hydrothermal fluids of low sulphur fugacity. In addition to Au, we have considered Arsenic as an important factor to detect gold because As - Au correlation has drawn great attention. Because they have similar complexes which means that by breaking down As complex, Au is released and As itself remains as well, native gold would be increased by increasing As and in fact, they are proportional; so arsenic could be an extremely significant sign of Au [30].

4. Conclusions

A study on the analysis of the effect of presence and presence of mineral associations in the environment of low-sulphidation Au-Ag epithermal deposits has been conducted. Having used the Multivariate statistical analysis method of Analysis of Variance (MANOVA), Analysis of Variance (ANOVA), Correlation Regression and Analysis of T^2 Hotels, this study concluded that (1) the multivariate normality test shows that the data distribution of the associated mineral content is relatively normal, and it is concluded that there is a relationship between each associated mineral, indicating that the gold content data and the associated mineral content have a positive relationship; (2) the three rock lithology zones show a significant difference among the associated minerals (Au, Ag, Cu, Pb, Zn, and As) in the rock lithology of BRAN, VEIN, and VNBR; (3) BRAN-VNBR rock lithology has a significant difference between the mineral content of Au and that of the associated minerals (Ag, Cu, Pb, Zn, and As), the difference between the lithological zones of these rocks is derived from the mineral content of As. For the VEIN-VNBR lithological zone there is no significant difference between the mineral content of Au and that of the associated minerals (Ag, Cu, Pb, Zn, and As).

For BRAN-VEIN lithology, there are significant differences between the associated minerals (Au, Ag, Cu, Pb, Zn, and As) in the BRAN and VEIN zones. This difference is obtained from the mineral As content and (4) VNBR lithology zone (Breccia Vein) by correlation regression is the best zone to have significance and variation of mineral associations which influence Au content, which is influenced by 3 associated minerals, namely Ag, Cu and Pb.

Nomenclatures

ANOVA	Analysis of Variance
BRAN	Basalt to andesite breccia hyaloclastite, flow, expiclastite
BSE	Backscatter image
EDS	Semi-quantitative analysis
MANOVA	Multivariate of Analysis Variance
PIMA	Portable Infrared Mineral Analyser
SEM	Scanned using an electron microscope
SWIR	Short Wave Infrared Reflectance
T2 Hotellings	Multivariate probability distribution that is tightly related to the F-distribution and is most notable for arising as the distribution of a set of sample statistics that are natural generalizations of the statistics underlying the Student's t-distribution.
VEIN	Quartz Vein
VNBR	Breccia Vein
XRD	X-Ray Diffraction

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