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Hydrothermal Alteration, Ore Mineralization, and Fluid Inclusion Characteristics of Tarra Prospect, Awak Mas Deposit, Luwu Area, South Sulawesi, Indonesia.

N S Putri [1,*], M Mawaleda[2], A Jaya[2], I Setiawan[3]

[1]Department of Mining Engineering, Amamapare Polytechnic, Jalan C Heatubun, Kwamki, Mimika Baru, Mimika 99971
[2]Department of Geological Engineering, Hasanuddin University, Jalan Poros Malino Km. 6, Gowa, Makassar 92171
[3]Research Center for Geotechnology, LIPI, Bandung, Jawa Barat 40135
e-mai: nilamputri23@yahoo.com

ABSTRACT

Tarra area is one of the Awak Mas gold prospect in Sulawesi, Indonesia. Geographically and geologically, this area is located in the central part of West Sulawesi, and occupies the southern part of the Latimojong Complex. Host rock of gold mineralization in this area, known is the Meta-Sedimentary rock, which is a member of the Latimodjong Formation. The research carried out includes geological surveys by taking rock outcrop samples, as well as taking samples from the drilling cores in the Company's Coreset. A total of 28 rock samples were petrographic analysis, 19 samples were carried out by mineragraphic analysis, and 4 samples were analyzed for fluid inclusion. The results of the study show that in the Tarra area there are two types of alteration, namely (1) the phillic type alteration which is characterized by the presence of the quartz-sericite-opaque minerals assemblage, and (2) the propylitic type which is characterized by the presence of quartz-chlorite-epidote. Meanwhile, the results of the mineralization analysis show that there is sulfide mineralization, which consists of pyrite, chalcopyrite, and covellite, and the oxide minerals consist of hematite, and goethite. This study, has known that ore mineralization accompanies the formation of quartz veins. The results of the analysis of fluid inclusions trapped in the quartz vein show that there are two fluid phases, namely double phase (liquid-rich), L + V where L > 50% as a primary inclusion and mono-phase where L = 100% with a quartz vein temperature around 260°C - 320°C, low salinity, minimum forming depth of 1050 meters under the paleo-surface. Based on the homogenization temperature (Th) of the fluid inclusion above, it should be interpreted that sulfide ore deposits in the Tarra Area are included in the type of Mesothermal deposits.

Keywords: mineralization; hydrothermal fluid; awak mas

1. Introduction

The research site of Tarra is one of the Awak Mas projects, which developed by PT. Masmindo Dwi Area. The Tarra area is located in South Sulawesi Province, Indonesia, on the south side of the Latimojong Complex (Figure 1). The Latimojong Complex comprises the Low-grade Metamorphic Latimojong Formation, an Upper Cretaceous Turbiditic Flysch Sequence with intercalations of Andesitic Volcanic and Limestone, and Highgrade Metamorphic basement rocks, including Blueschists and other Schist types, Serpentines and Metadolerite, showing in places highly contorted foliation [1]. The lithologies of the Awak Mas from the oldest to the youngest are successively occupied by Latimojong Formation (Kls), Lamasi Volcanic Formation (Tolv), and felsic intrusive rock (Tmpi) [2]. The basement rocks belong to a Mid-Cretaceous dismembered accretion zone that extended from Central Sulawesi and through to the Bantimala Complex in the Southern part of Sulawesi [3]. The Awak Mas area is a predominant lithological unit is a thick sedimentary package that has been subjected to a low-grade, greenschist facies metamorphism [4]. The rocks are generally light to dark grayish-green, foliated, typically fine-grained, with protoliths ranging from metaclaystone, metasiltstones to metafine grained sandstones [5].

Several studies conduct in the area of Awak Mas namely [6]. Mostly research examines the characteristics of mineralization and alterations in Rante Domain, [1] researching the mineral deposits of Sulawesi, [5] researching the geology and mineralization of Awak Mas, [7] researching gold mineralization at the prospect of Salu Bulo, and [8] researching on the geology and geochemistry of gold mineralization in Salu Bulo's prospect. This study obtained more codified information about the hydrothermal process that formed the Tarra sulfide deposits.

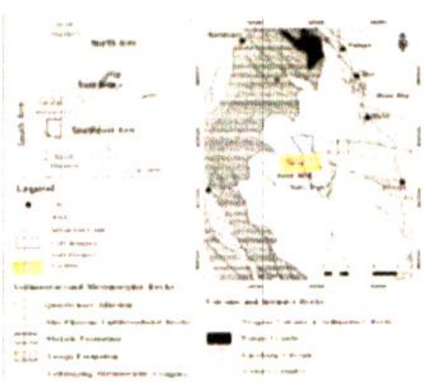

Figure 1. Regional geology map of the Awak Mas gold deposit modified after [9].

2. Methods

This preliminary study was carried out through several approaches, namely literature study, fieldwork, and rock sampling. Consists of 4 outcrop samples taken from 4 observation points (Figure 2: red points) and 24 drill core samples representing from 5 drill points (Figure 2: green points), namely TRD111, TRD122, TRD133, TRD144, TRD155 (Figure 3).

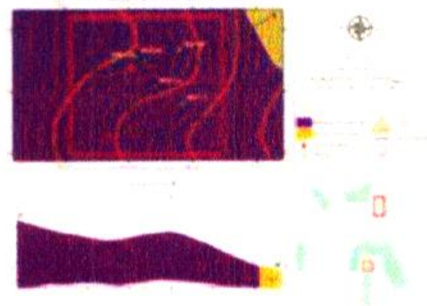

Figure 2. The sampling locality and geological map of the Tarra area, modified after [2].

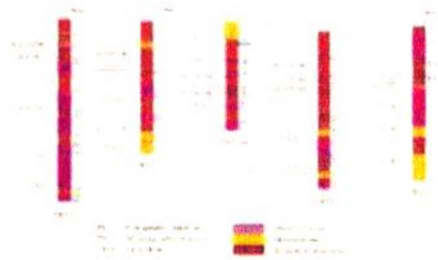

Figure 3. Drill hole cross-section and sampling point. PA (petrography analyzed), PM (mineragraphic analyzed), TRD (drill hole).

Laboratory analysis includes: 1) petrographic analysis (thin section); Samples were prepared into thin section of 28 selected samples with 3 outcrop samples and 25 drilling core samples. Sample preparation was done by "Obsidian Geo-Laboratory Services", Bandung. Furthermore, a petrographic analysis was carried out using a Nikon-type polarization microscope with a 50x magnification at the Mineral Optics Laboratory, Department of Geological Engineering, Hasanuddin University; 2) mineragraphic analysis (polish section); The sample was prepared by 19 selected samples with details of 3 outcrop samples and 16 samples from the drilling core. The preparation of polishing section is also carried out at "Obsidian

Geo-Laboratory Services", Bandung. Then the analysis was carried out using a Nikon-type ore microscope with magnifications of 50x, 100x, and 200x at the Optical Mineral Laboratory, Department of Geological Engineering, Hasanuddin University. 3) Fluid inclusion analysis (double polished section). Three samples of quartz vein were prepared consisting of 2 drilling core samples and 1 outcrop sample. Samples were prepared and Microthermometric Analysis was performed using LINKAM THMS 600 to measure freezing and heating temperatures. The entire analysis was carried out at the Geotechnology Research Center, Lembaga Ilmu Pengetahuan Indonesia (LIPI), Bandung.

3. Results and Discussion

A. Alteration and Mineralization

The total of 28 thin section samples have been analyzed by Polarization Microscope. The analysis shows that the main lithology units consist of metaclaystone, metasiltstone, and hematitic mudstone. Following is a brief breakdown of the results of the petrography analysis of the 28 samples have been analysed (table 1).

Table 1. Summary of Petrographic Analysis

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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There are two types of alterations in the Tarra area. 1) The phyllic type is characterized by the presence of quartz-sericite-opaque minerals (Figure 4a, 4b); 2). The prophylitic type characterized by the presence of quartz–chlorite-opaque minerals (Figure 4c), and quartz–epidote (Figure 4d).

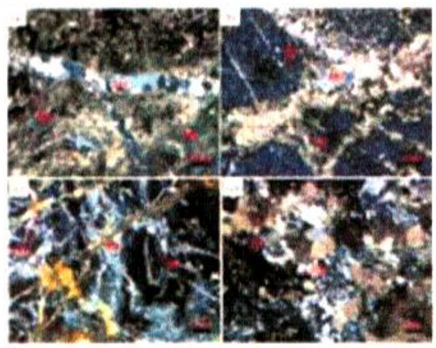

Figure 4. Microphotograph of thin section, X Nicol: (a) Sample Code: TRD155(45:60) and (b) Sample code: TRD133(97:07) shows Quartz (Qtz), Sericite (Ser), Opaque Mineral (Op): representing Phyllic Alteration Type; (c) Sample Code: TRD111:7025) and (d) Sample Code: TRD155(105:40) shows Quartz (Qtz), Chlorite (Chl), Edidote (Ep), Opaque Mineral (Op): Reflects Propylitic Alteration Type.

Quartz minerals present with a form of veins that intersect or align with the direction of the rock. Sericite minerals present with spreads and some are associated with quartz veins. Chlorite Minerals present associated with quartz in the form of veins. Epidote Minerals present very rarely with very small size. Generally, the percentage of hydrothermal alteration on each samples in the research area is variated, moderate (approximately 30-50% altered) to strong altered up to 90%.

The total of 19 samples of polish section heve been analyzed were indicates that ore mineralization is characterized by sulfide mineral and oxide mineral. The sulfide minerals consist of pyrite, chalcopyrite, and covellite. Oxide minerals consist of hematite and goethite. Based on ore mineral textures, we obtained two major textures namely replacement and open-space filling. The replacement texture showed pyrite was replaced by chalcopyrite and pyrite border replaced by covellite (Figure 5b), pyrite have been oxidized to become hematite mineral as secondary mineralization process (Figure 5c). The open space filling texture shows pyrite filling the quartz vein (Figure 5a), and goethite filling the quartz vein as well as a secondary process (Figure 5d). Considering these two textures, it can be concluded that the ore paragenesis formed in this area is pyrite and chalcorprite as early stage sufide mineralization. Furthermore, covellite, hematite and goetite are supergene enrichments.

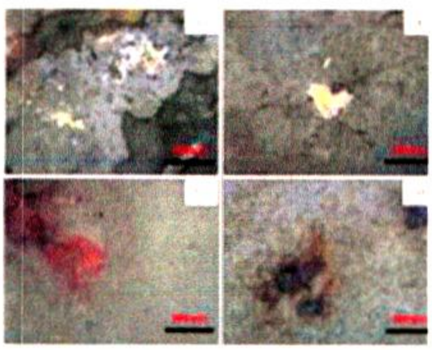

Figure 5. Microphotograph of polish section shows the ore mineralization namely pirite (Py), chalcopyrite (Cep), covellite (Cv), hematite (Hem), goethite (Goe). (a) Sample Code: TRD122(19:20): pyrite and chalcopyrite in quartz vein; (b) Sample Code: TRD133(51:50): covellite inclusion on pyrite; (c) Sample Code: TRD111(70:25): hematite by oxidation of sulfide minerals; (d) Sample Code: TRD155(66:85): goethite by hydration of hematite minerals.

3.2 Fluid Inclusion

Based on fluid inclusion analyzed, 2 type inclusions are present in the samples including primary and secondary inclusions [10]. Petrographic study indicates that fluid inclusions in quartz vein types consist of 2 phases namely 1) double phase (liquid-rich), L + V where L > 50% as a primary inclusion (Figure 6a, 6b) and 2) monophase where L = 100% (Figure 6c, 6d).

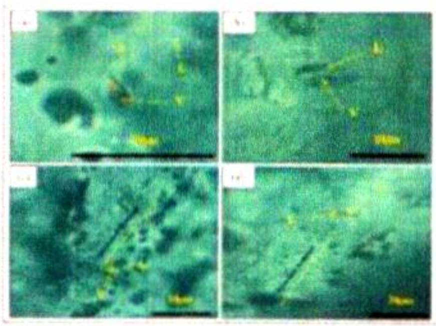

Figure 6. Microphotograph of double polish thin section in cross-polarized light show the fluid inclusions with liquid (L) and vapour (V). (a, b) the primary fluid inclusion consist of liquid and vapour; (c, d) the secondary fluid inclusion. Generally consist of liquid 100% and some of inclusions consist of liquid and vapour.

Figure 7. The relationship between homogenization temperatures (*Th*) with salinity in quartz vein samples of Rante Awak Mas is plotted on the Th *vs* salinity chart [10]

The results of microthermometry measurements, the range of homogenization temperature (*Th*) starting from 260°C to 330°C with an average of 290.5°C. The parallel foliation vein formed at a temperature ranging from 260°C to 330°C, data on microthermometry measurements of OC4 samples are presented in the form of a histogram (Figure 8a, 8b). The across foliation vein formed at the temperature range from 265°C to 313°C, data on microthermometry measurements of TRD122 samples are presented in the form of a histogram (Figure 8c, 8d). The brecciated vein formed at a temperature range from 270°C to 325°C, data on microthermometry measurements of TRD144 samples are presented in the form of a histogram (Figure 8e, 8f). All the quartz veins formed at low salinity range from 0,71 wt% NaCl equivalent to 1,60 wt.% NaCl equivalent.

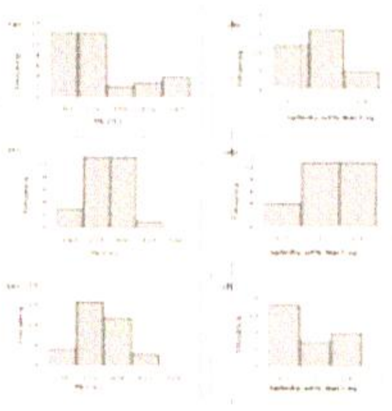

Figure 8. Histogram of microthermometric measurements indicating the frequency of homogenization temperature and salinity. (a) frecuency of homogenization temperature of OC4 sample, (b) frecuency salinity (wt% NaCl *eq*) of OC4 sample, (c) frecuency of homogenization temperature of TRD122 sample, (d) frecuency salinity (wt% NaCl *eq*) of TRD122 sample, (e) frecuency of homogenization temperature of TRD144 sample, (f) frecuency salinity (wt% NaCl *eq*) of TRD144 sample. *Th* vs salinity diagram space due to various fluid inclusion evolution processes and precipitation mechanism [11] in figure 7, the evolution of fluid inclusion formed by the process of mixing with the fluid that has contrasting drainage (isothermal mixing with fluids of contrasting salinity). Generally, fluid with low salinity in the form of groundwater fluid or meteoric fluid. Based on boiling – point curve [12], the vein formed at depth minimum at 1050m below paleowater table. The classification of hydrothermal deposits based on the temperature of deposits formation according to [13], can be interpreted that the Tarra deposits are included in the type of mesothermal deposit.

4. Conclusion

The results of the laboratory analysis from this study can be concluded as follows: (1) There are two types of alteration in the Tarra area is (a) The phyllic alteration type, characterized by the presence of the mineral assemblage of quartz-sericite-opaque minerals, and (b) The propylitic alteration type, characterized by the presence of quartz-chlorite-epidote minerals. (2) Ore mineralization occurs in two stages, namely sulfide mineralization to produce chalcopyrite and pyrite, as well as oxide mineralization and secondary enrichment to produce covellite, hematite and goethite. (3) The results of the fluid inclusion analysis showed that fluid inclusion formed in 2 phases namely double phases (liquid-rich), L + V where L > 50% as a primary inclusion and monophase where L = 100% with the quartz vein temperature around 260°C – 320°C, low salinity, minimum forming depth of 1050 meters under the paleo-surface. (4) From the temperature homogeneity data in the fluid inclusion analysis above, it can be interpreted that the sulfide ore mineralization that occurs in the Tarra Area is a Mesothermal Type Ore Deposit.

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