ALTERATION AND MINERALIZATION STUDIES IN THE JEBLOGAN AREA, KARANGTENGAH, WONOGIRI, CENTRAL JAVA

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Abstract — The research area is located in Jeblogan, Karangtengah, Wonogiri, Central Java. This study aims to investigate the hydrothermal alteration and mineralization. Geological structures present in the research area include faults and fractures. These faults are well-developed trending NE-SW, NW-SE, and N-S as pathways for fluid ascent to the surface, thereby influencing alteration patterns. Mineral alteration assemblages in the research area, based on petrographic, mineragraphy, and XRD analysis, result from hydrothermal processes and include mineral assemblage zones such as Quartz ± Silica ± Pyrite, Alunite + Pyrophyllite ± Zunyite ± Quartz ± Hematite, Illite + Halloysite ± Smectite ± Kaolinite ± Quartz, and Chlorite + Calcite + Epidote ± Pyrite. Mineralization found in the research area includes Chalcopyrite, Sphalerite, Pyrite, Chalcocite, and Galena. Based on the characteristic parameters of the deposit type and laboratory analysis, the deposit type at the research location is low-sulfidation epithermal deposit and intermediate-sulfidation deposit.

Keywords: Hydrothermal Alteration, Karangtengah, Mineralization, Wonogiri.

I. INTRODUCTION

The southeastern part of Wonogiri Regency is predominantly composed of Tertiary volcanic rocks, classified into Mandalika Formation, Arjosari Formation, and Semilir Formation [1]. Typically, primary minerals formed from volcanic origins are associated with rocks that have undergone hydrothermal alteration, intrusions within the central volcanic facies, and are associated with subvolcanic intrusions [2].

Tectonic activity in the area has evolved three times during the Early Miocene, Middle Miocene, and Pliocene-Pleistocene periods [3]. One of the potential hydrothermal deposits can be found in Karangtengah Subdistrict, Wonogiri Regency. The presence of indications of mineral deposits possibly due to intrusive rocks penetrating volcanic rocks and well-developed geological structures in the study area has the potential for hydrothermal alteration and valuable ore mineralization. This background motivated the author to conduct research in this area.

II. METHODS

The goal of study is to investigate hydrothermal alteration and mineralization. It involves utilizing existing data and conducting field observations such as lithology identification and structural geology measurments, followed by rock sampling for laboratory analyses such as Petrography, Mineragraphy, and XRD. The results of field observation delineates lithostratigraphic units, identifies geological structures like fractures and faults with the results in the form of a geological map. The geological map are use as the basis for making alteratin map, characterizes alteration zones based on petrographic and XRD analyses. Mineralization findings including valuable ore minerals, and determines the deposit type through characteristic data assessment. The conclusion is to determine the deposit type based on several researchers. This explanation is outlined in the flow chart below (**Fig. 1**).

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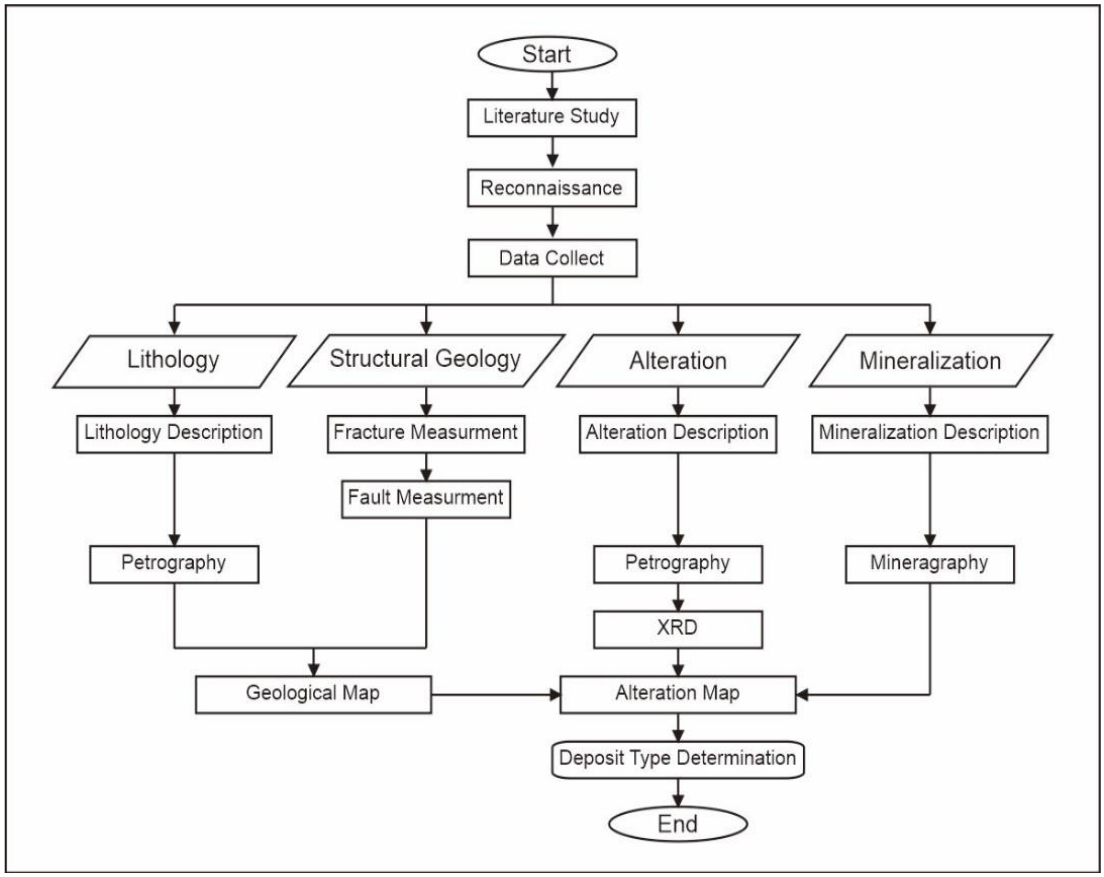

Figure 1. Flowchart of the study

III. RESULTS AND DISCUSSION

A. Stratigraphy

The stratigraphic classification in the study area uses the naming of lithostratigraphic units with an unofficial naming system [4], which names rock units based on observable physical lithological characteristics in the field, considering lithological type and uniformity and the stratigraphic position relative to underlying and overlying units.

1. Arjosari breccia-tuff Unit

This unit occupies an area of 65%, spreading to the south and northwest of the research area. This unit has undergone alteration almost entirely. Field appearances of this rock unit include intercalations of Tuff Breccia, Polymictic Breccia, Tuff, with interbeds of Lava, Conglomerate, Shale, Sandy Marl, and Marl Limestone with intercalations of volcanic breccia and limestone breccia. Dominantly, the lithology of this rock unit has been significantly altered.

Arjosari breccia-tuff Unit is the oldest unit in the study area and has a stratigraphic relationship of interfingering with Mandalika lava-andesite Unit. The contact between the tuff breccia and lava is observed in the field. The stratigraphic relationship with Mandalika lava-andesite Unit is shown by the morphology, where the lava is positioned at a higher topographic level than the Arjosari breccia-tuff Unit.

2. Mandalika lava-andesite Unit

Mandalika lava-andesite Unit in the study area covers 13% of the area, mainly located in the northern part of the research area. This unit has undergone significant alteration and is associated with thrust fault landforms.The lithological characteristics of Mandalika lava-andesite Unit consist of andesitic lava with altered breccia interspersed throughout the study area.

Stratigraphic relationships in Mandalika lava-andesite Unit are demonstrated by the higher topography of the lava compared to Arjosari breccia-tuff Unit. Geological profiles and cross-sections parallel to the strike indicate interfingering relationships between Arjosari breccia-tuff Unit. Meanwhile, with the Dacite Lithodeme and Andesite Lithodeme, it shows cross-cutting relationships.

3. Rohtawu lava-andesite Unit

Rohtawu lava-andesite Unit in the study area covers 12% of the area, located in the northeastern part of the research area. This unit has undergone significant alteration and is associated with lava dome landforms, which are elevated due to resistant rocks.The lithological characteristics of Rohtawu lava-andesite Unit consist of andesitic lava with well-developed joint and foliation structures that have been moderately altered (see **Fig. 2**).

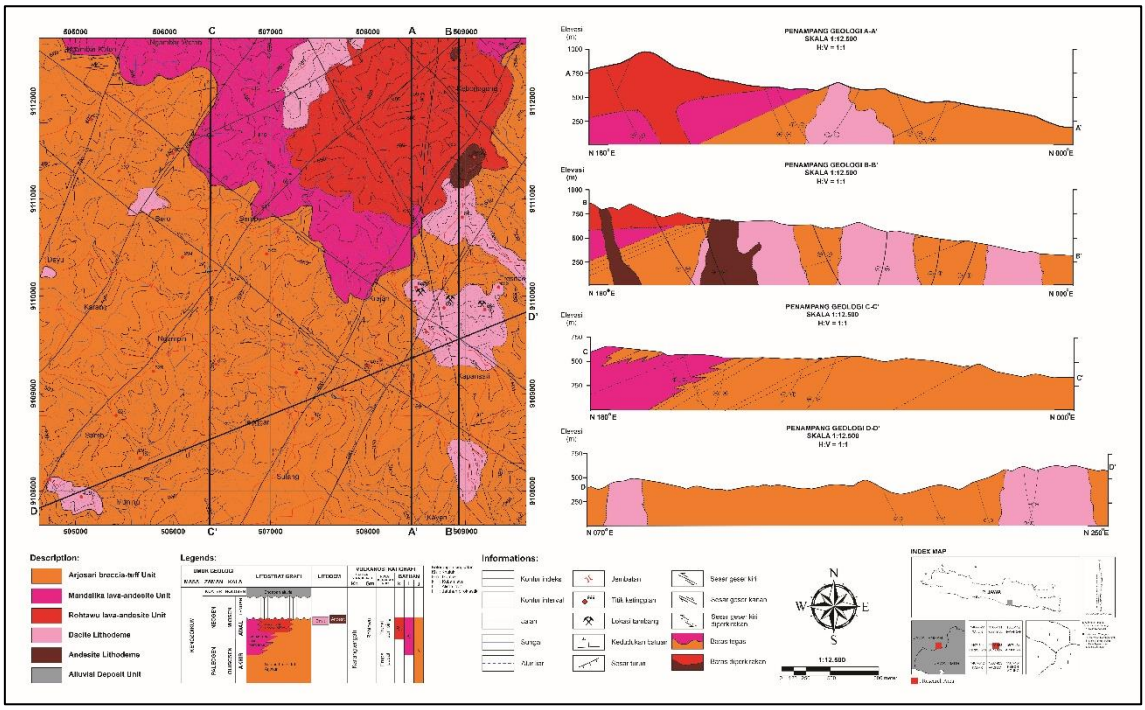

Figure 2. Geological Map of the Research Area.

Rohtawu lava-andesite Unit flow is a lateral eruption from the ancient Karangtengah volcano, cutting through Arjosari breccia-tuff Unit and Mandalika lava-andesite Unit before overlying them and intruding into Dacite Lithodeme and Andesite Lithodeme with cross-cutting relationships.

4. Dacite Lithodeme

Dacite lithodeme in the study area covers 6% of the area, located in the central-northern part of the research area. This unit has undergone significant alteration and is associated with lava dome landforms. The lithological characteristics of Dacite lithodeme consist of dacitic lava with well-developed joint and foliation structures that have been moderately altered.

In the stratigraphic relationship, Dacite Lithodeme intrudes into Arjosari breccia-tuff Unit, Mandalika lava-andesite Unit, and Rohtawu lava-andesite Unit with cross-cutting relationships. Additionally, it is overlain by the Andesite Lithodeme, showing the topographic characteristics of Dacite Lithodeme being lower than Andesite Lithodeme.

5. Andesite Lithodeme

Andesite lithodeme in the study area covers 4% of the area, located in the northern part of the research area. This unit has undergone significant alteration and is associated with lava dome landforms. The lithological characteristics of Andesite Lithodeme consist of andesitic lava with well-developed joint and foliation structures that have been moderately altered. Stratigraphic relationships of Andesite lithodeme indicate intrusions into Dacite lithodeme and Rohtawu Lava-Andesite unit with cross-cutting relationships.

6. Alluvial Deposit Unit

The alluvial deposit unit covers an area of approximately 1% and is distributed along the rivers in the research area. In the field, this rock unit consists of loose material and alluvial deposits ranging from clay to boulders resulting from the breakdown of pre-existing rocks in the vicinity that have unconsolidated and

have been transported due to fluvial processes. The stratigraphic relationship of the alluvial deposit unit with the unit below it (older unit) is not in sync.

B. Geological Structure

1. Fractures

Alteration and weathering processes that have occurred extensively in the research area make it difficult to observe tectonic fractures in the field. Tectonic fractures with ideal conditions for data collection are typically found in lava and breccia units within the Mandalika andesite-lava Unit.

2. Faults

Alteration and weathering processes that have occurred extensively in the research area make it difficult to observe tectonic fractures in the field. Tectonic fractures with ideal conditions for data collection are typically found in lava and breccia units within the Mandalika andesite-lava Unit Based on stereographic analysis, the rock units in the research area are intersected by left strike-slip faults, right strike-slip faults, and normal faults. The right strike-slip faults with a southeast to northwest orientation are controlled by the stress patterns from the Middle Miocene Era, while the left strike-slip faults with a southwest to northeast orientation are controlled by stress patterns from the Pliocene – Pleistocene Era.

Among the two structural patterns in the research area, the structural pattern resulting from the stress in the Middle Miocene era plays a role in the alteration and mineralization events in the research area. This is evidenced by the presence of vein mineralization and alteration patterns that follow the geological structural patterns produced by the ancient stress during that era, which is southeast to northwest.

C. Alteration

The presence of dacite intrusion and andesite intrusion is believed to have influenced the alteration of rocks in the research area. However, not all intrusion and hydrothermal alteration processes result in valuable ore mineral deposits. The latest intrusion, which is the andesite intrusion, has led to hydrothermal alteration and mineralization. This is based on the development of geological structural patterns associated with the rise of this intrusion, which contains valuable ore minerals, as well as alteration and mineralization occurring in two previous intrusion bodies.

1. Quartz + Silica ± Pyrite (Silicic)

This type of alteration is characterized by the abundance of silica minerals (SiO_2) such as quartz. In the research area, this alteration is prevalent in the southwestern, northwestern, and southeastern parts, covering approximately 20% of the total research area. This type of alteration is often associated with rocks in contact with intrusions, geological structure lines (faults and fractures), or around mineralization vein zones. In this alteration, the original rock texture of andesite lava and dacite intrusion is almost entirely transformed (80-90% secondary minerals), with the original texture of the parent rock no longer visible (see **Fig. 3**).

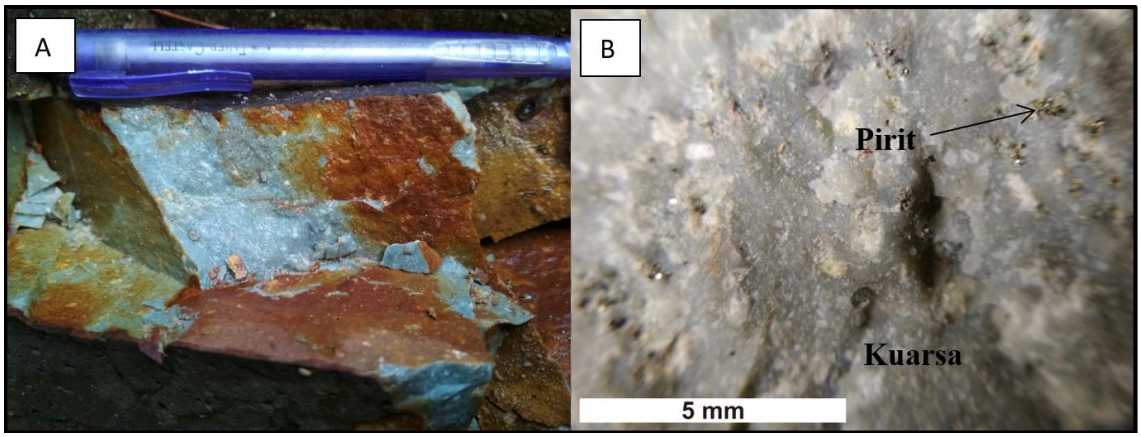

Figure 3. Appearance of Quartz and Pyrite Minerals

2. Alunite + Pyrophyllite ± Quartz ± Zunyite ± Kaolinite ± Hematite (Advanced Argillic)

Advanced argillic alteration in the research area is found in small areas in the northwest, southwest, northeast, and central parts of the eastern section, covering 10% of the total alteration area. Advanced argillic alteration occurs in dacite, tuff, and andesite lava rocks and is characterized by the presence of

minerals such as pyrophyllite, alunite, quartz, zunyite, and kaolinite. The presence of minerals like pyrophyllite and zunyite **(Figs. 4** and **5)** is a key indicator that the hydrothermal fluids were acidic and high-temperature [5], [6].

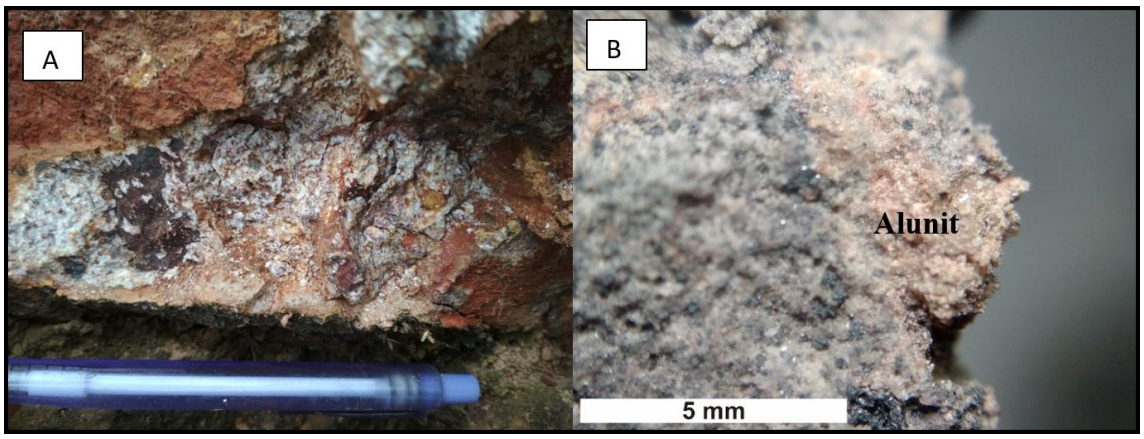

Figure 4. Appearance of Quartz, Clay and Alunite Minerals

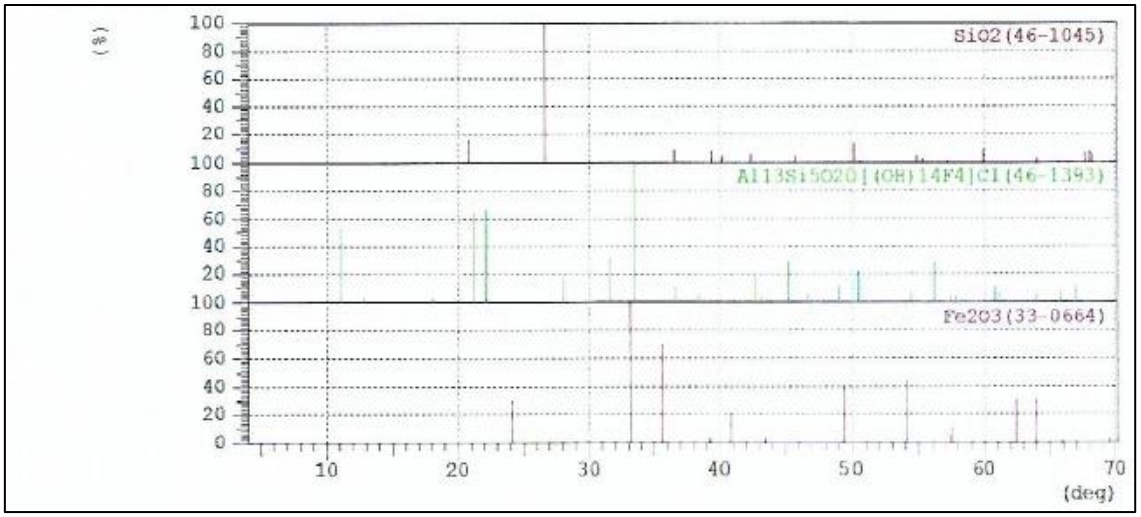

Figure 5. XRD analysis shows Quartz, Zunyite, and Hematite

3. Illite + Halloysite ± Smectite ± Kaolinite ± Quartz (Argillic)

Argillic alteration in the research area covers a wide area, approximately 45%, and transforms the rock units in the research area. This alteration type typically presents highly weathered and soft conditions in the field, making petrographic analysis difficult. Therefore, X-Ray Diffraction (XRD) analysis is used to determine the mineral alteration assemblages. Based on field megascopic descriptions and available samples, the identified mineral assemblages in this alteration are illite, halloysite, smectite, kaolinite, and quartz **(Figs. 6** and **7)**, consistent with the clay mineral alteration assemblages [5].

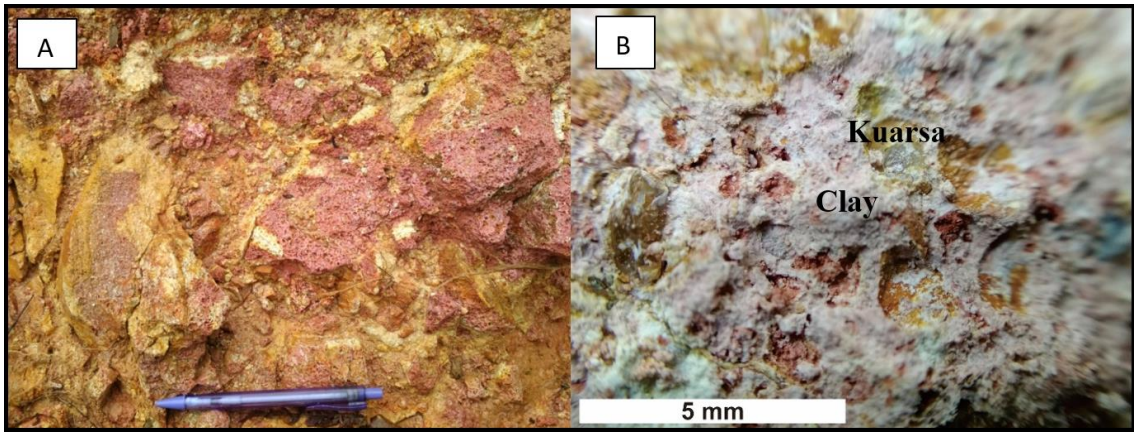

Figure 6. Appearance of Clay Minerals

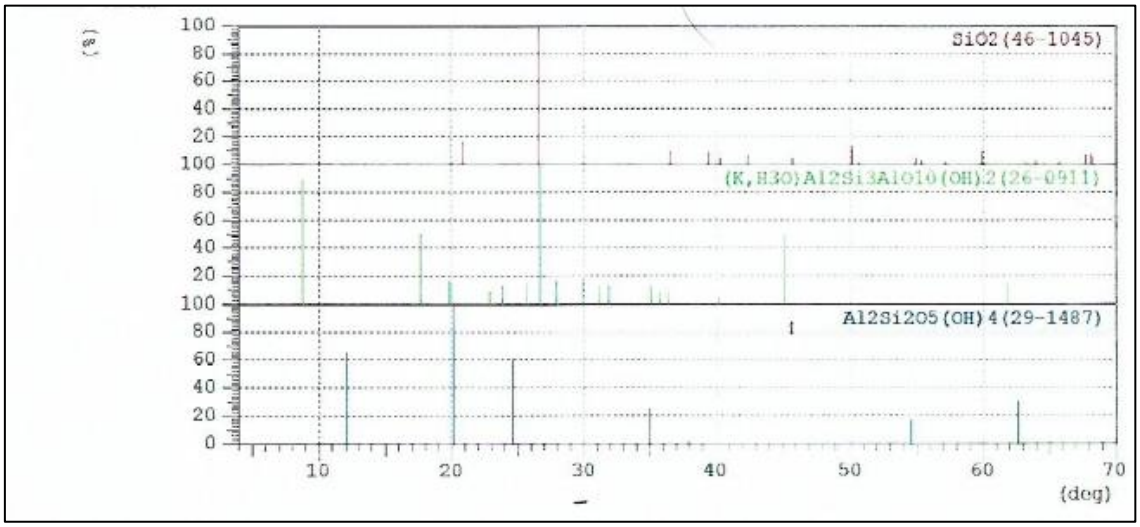

Figure 7. XRD analysis shows Quartz, Illite and Halloysite

4. Chlorite + Calcite + Epidote ± Pyrite (Propylitic)

The distinctive feature of propylitic alteration is its greenish color, which is easily recognizable. In the research area, this alteration type occupies the largest area, approximately 25% of the total research area. Based on megascopic descriptions and petrographic analysis, propylitic alteration in the research area consists of alteration minerals such as chlorite, calcite, epidote, and pyrite as the primary alteration minerals (see **Fig. 8** and **9**).

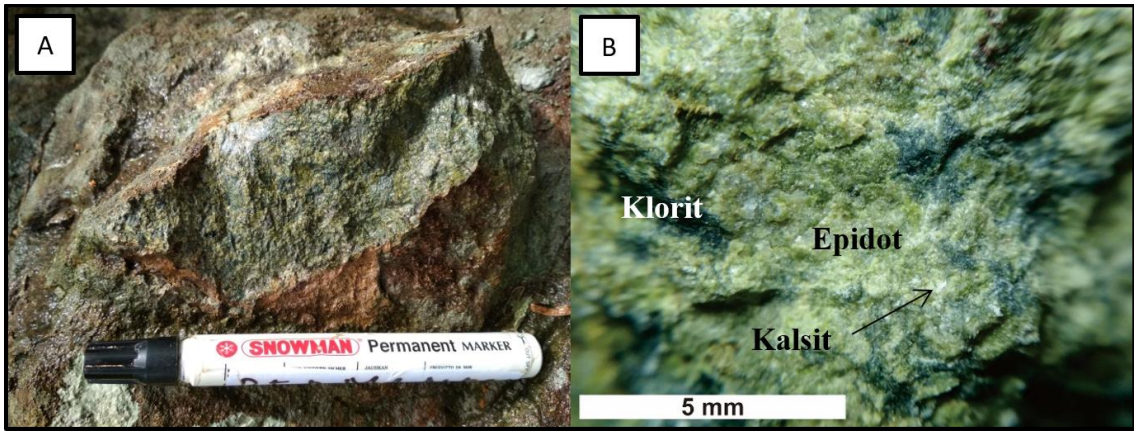

Figure 8. Appearance of Chlorite, Calcite and Epidote Minerals

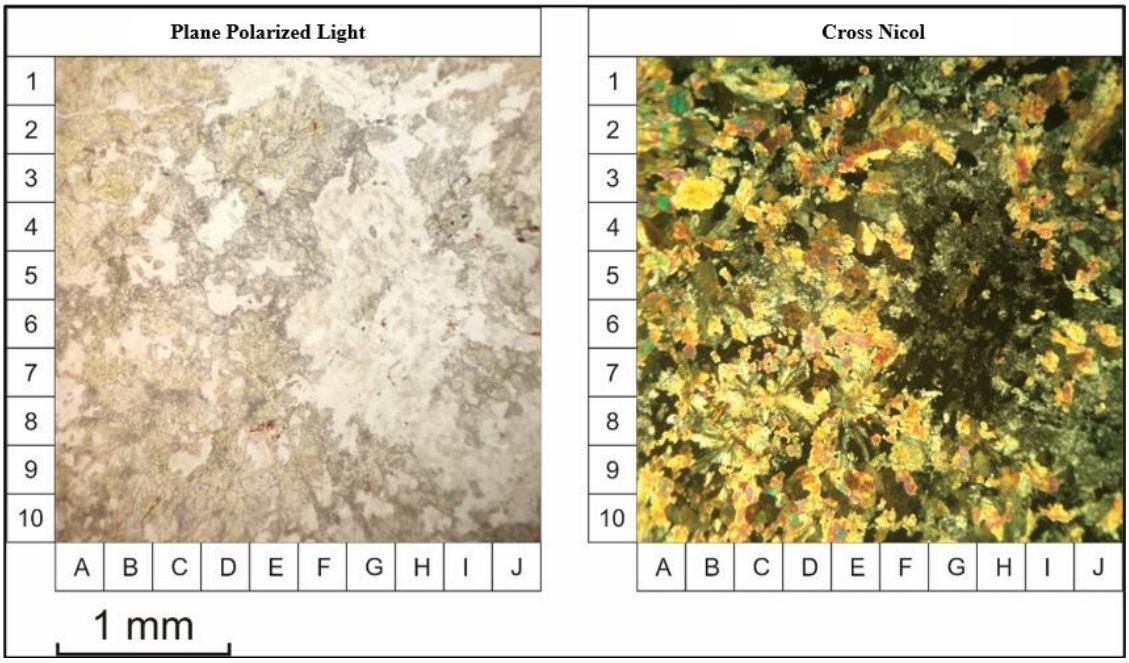

Figure 9. Petrography analysis shows Chlorite (6G), Calcite (4D), Epidote (2C) and Pyrite (4J)

D. Mineralization

The alteration and mineralization processes in the research area occurred during the Early Miocene, coinciding with the intrusion of dacite, which generated hydrothermal fluids. These hydrothermal fluids formed valuable ore mineral deposits in veins trending southeast to northwest. The valuable metal commodities present in the research area are Gold-Copper-Zinc-Lead (Au-Cu-Zn-Pb) in the form of minerals such as chalcopyrite ($CuFeS_2$), pyrite (FeS_2), sphalerite (ZnS), chalcocite (Cu_2S), galena (PbS) and Gold (Au) **(Fig. 10** and **11)**. Valuable metal deposits in the research area are found in mineralization veins, including quartz veins, pressure veins, dissemination, and hydrothermal breccias.

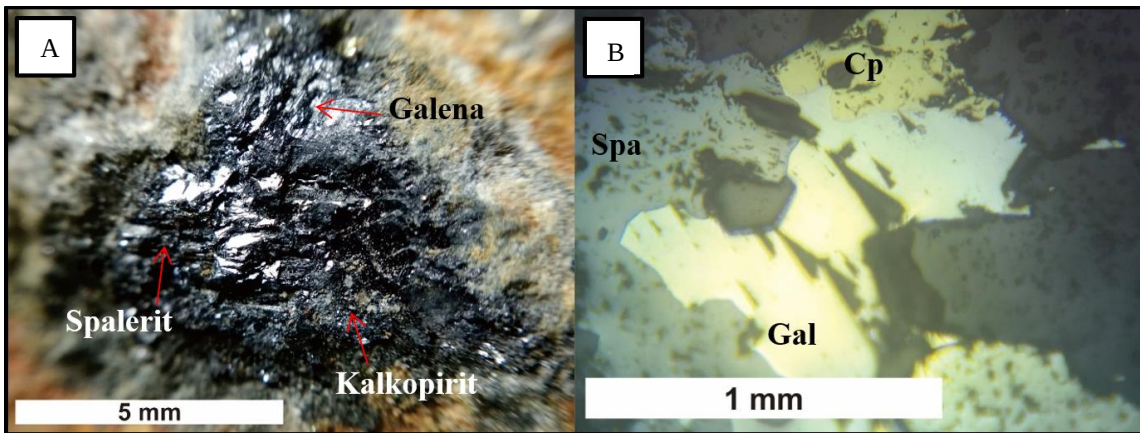

Figure 10. Appearance of Galena, Sphalerite, and Chalcopyrite [7]-[8]

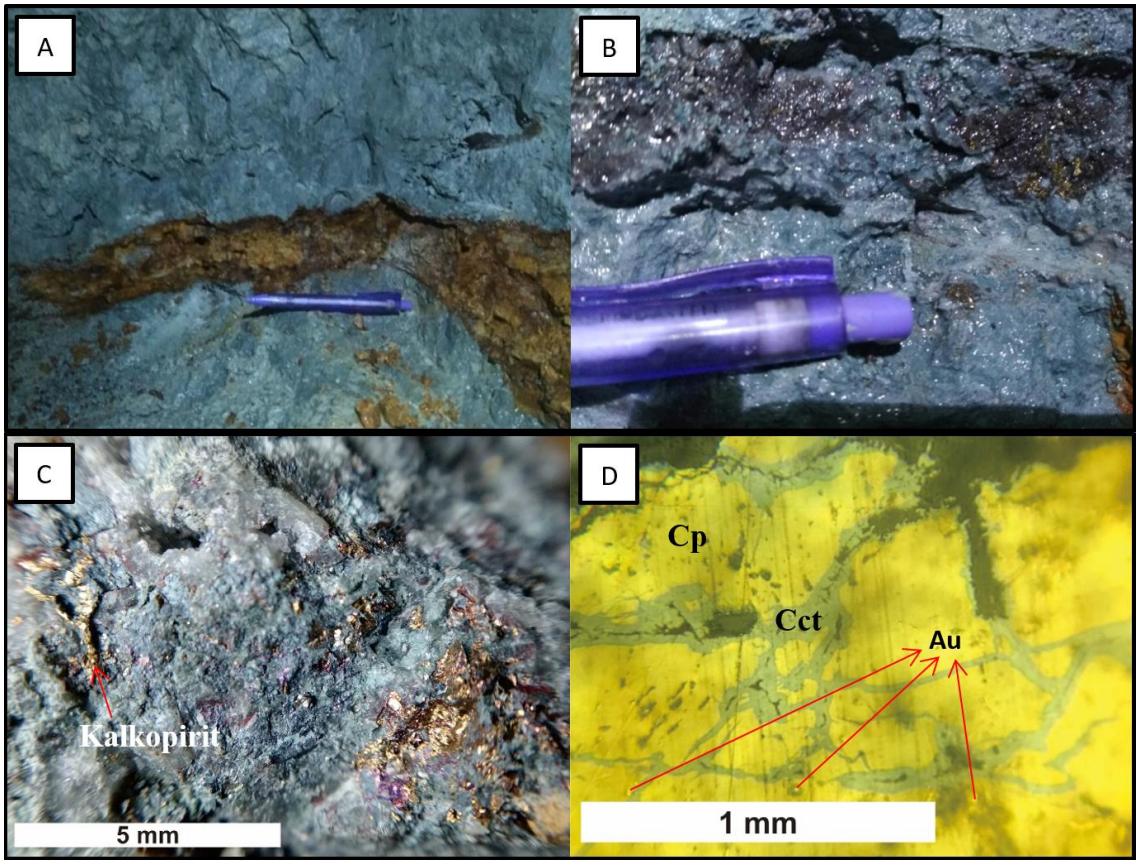

Figure 11. Appearance of Chalcopyrite, Chalcocite and Gold [7]-[8]

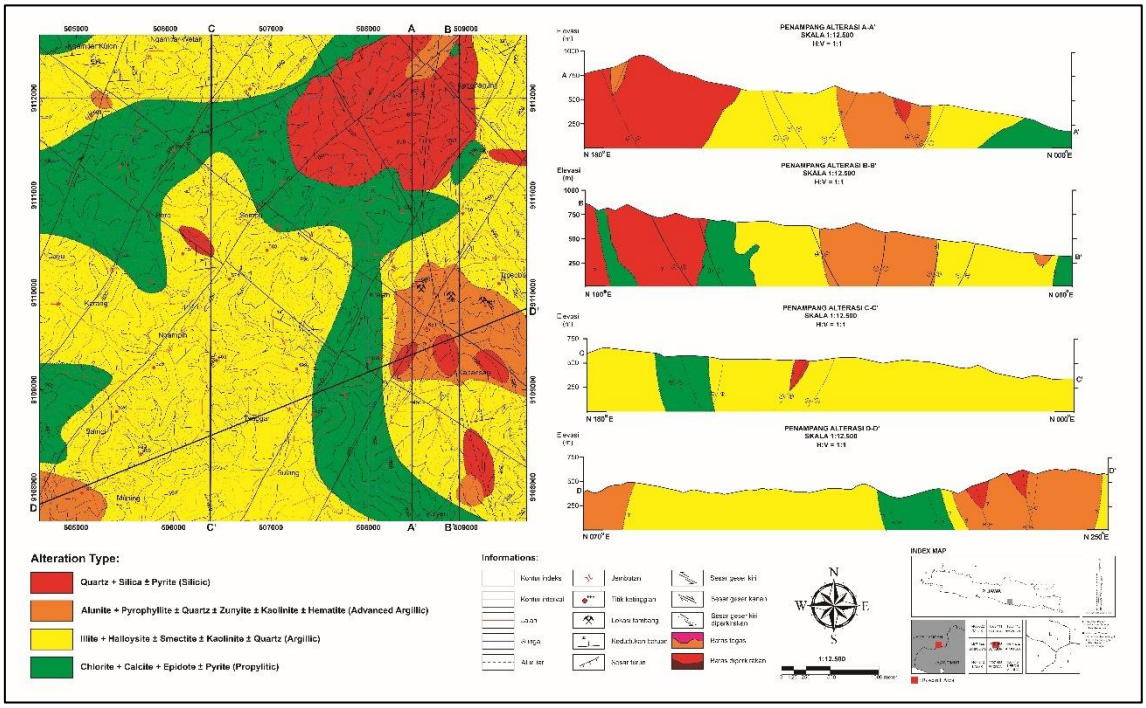

Figure 12. Alteration Map of the Research Area

E. Deposit Type

The alteration and mineralization processes in the research area occurred during the Early Miocene, To determine the characteristics of deposit type in the research area, the author approached key parameters

leading to a specific deposit type, referring to several experts in the field. Determination of alteration type [9] - [15].

Table 1. Determination of deposit type [15]

Characteristics	Deposits in the research area
Tectonic Setting	island arc
Genetic Relationship	calc-alkaline
Igneous Rock	dacite, andesite
Host Rock Type	dome, lava flow, pyroclastic
Base Metals	Pb, Zn, Cu, Au
Au Content	present
Ag/Au	Au
Tonnage and Au Grade	-
Deposit Form	veins, stockwork, hydrothermal breccias, disseminated
Ore Minerals	sphalerite, galena, chalcopyrite, chalcocite, pyrite
Abundance of Ore Minerals	chalcopyrite
Gangue Minerals	quartz, calcite
Mineral Textures	crustiform, vuggy
Proximal Alteration	quartz, alunite, pyrophyllite, zunyite, sericite, halloysite, illite, smectite, kaolinite, epidote, chlorite, calcite
Fluid Inclusions	-
Formation Depth	-
Fluid Characteristics	-

Based on the data obtained from the research, the research area fits the characteristics of a Low-Sulfidation Epithermal Deposit Type. This conclusion is based on the tectonic setting of an island arc, the presence of dacite and andesite igneous rocks, the type of host rock (dome, lava flow, pyroclastic), the presence of base metals such as Pb, Zn, Cu, Au, the form of the deposit (veins, stockwork, hydrothermal breccias, disseminated), and the minerals present, including sphalerite, chalcopyrite, galena, chalcocite, and pyrite. Gangue minerals include calcite and quartz, with textures described as crustiform and vuggy. The proximal alteration includes minerals like quartz, alunite, pyrophyllite, zunyite, sericite, halloysite, illite, smectite, kaolinite, epidote, chlorite, and calcite. Additionally, the research area includes areas crossed by faults indicative of a Medium-Sulfidation Hydrothermal Deposit Type, based on the occurrence of minerals such as galena, sphalerite, pyrophyllite, alunite, and zunyite in the faults zone.

IV. CONCLUSION

The lithology in the research area consists of six rock units, in descending order of age: Arjosari breccia-tuff Unit (Late Oligocene-Early Miocene), Mandalika andesite-lava Unit (Late Oligocene-Early Miocene), Rohtawu andesite-lava Unit (Early Miocene), Dacite Intrusion (Early Miocene), Andesite Intrusion (Middle Miocene), and Alluvial Deposits (Holocene-Recent).

The geological structures present in the research area include faults and fractures, with the main controlling fault being a strike-slip fault with a NW-SE orientation. The research area is divided into four alteration zones: Quartz ± Silica ± Pyrite (Silicic), Alunite + Pyrophyllite ± Zunyite ± Quartz ± Hematite (Advanced Argillic), Illite + Halloysite ± Smectite ± Kaolinite ± Quartz (Argillic), and Chlorite + Calcite + Epidote ± Pyrite (Propylitic).

The alteration type in the research area has parameters that match specific deposit types: Tectonic Setting of an island arc; Igneous Rocks dacite and andesite; Host Rock Type dome, lava flow, pyroclastic; Base Metals Au, Zn, Pb, Cu; Deposit Form veins, stockwork, hydrothermal breccias, disseminated; Ore Minerals sphalerite, galena, chalcopyrite, chalcocite, pyrite; Gangue Minerals quartz, calcite; Mineral Texture crustiform, vuggy; Proximal Alteration quartz, alunite, pyrophyllite, zunyite, sericite, halloysite, illite, smectite, kaolinite, epidote, chlorite, calcite; Therefore, the research area is concluded to belong to the Low-Sulfidation Epithermal Deposit Type, with some areas crossed by faults indicative of the Medium-Sulfidation Hydrothermal Deposit Type.

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REFERENCES

[1] H. Samodra, S. Gafoer, dan S. Tjokrosapoetro, *Geologi Lembar Pacitan*, Bandung, Indonesia: Pusat Penelitian dan Pengembangan Geologi, 1992.
[2] R. Abdissalam, S. Bronto, A. Harijoko, dan A. Hendratno, "Identifikasi gunung api purba Karangtengah di Pegunungan Selatan, Wonogiri, Jawa Tengah," *Jurnal Geologi Indonesia*, vol. 4, pp. 235-267, 2009.
[3] C. Abdullah, N. Magetsari, dan H. Purwanto, "Analisa dinamik tegasan purba pada satuan batuan paleogen-neogen di Daerah Pacitan dan Sekitarnya, Provinsi Jawa Timur ditinjau dari studi minor dan kekar tektonik," Prosiding ITB Sains dan Teknologi. 35A (2), pp. 111-127. Bandung: Institut Teknologi Bandung, 2003.
[4] *Sandi Stratigrafi Indonesia*, Komisi Sandi Stratigrafi Indonesia, Jakarta: Ikatan Ahli Geologi Indonesia, 1996.
[5] J. Lowell and J. Guilbert, "Lateral and vertikal alteration-mineralization zoning in phorpyry ore deposits," *Economic Geology*, vol. 65, pp. 373-408, 1970.
[6] J. Hedenquist and N. White, "Epithermal Gold Deposits: Style, Characteristic, and Exploration," *Society of Economic Geology Newsletter*, vol. 23, pp. 1-13, 1995.
[7] J. Craig, and D. Vaughan, *Ore Microscopy and Ore Petrography*, Canada: Jhon Wiley and Sons, Inc. 1994.
[8] D. Marshall, C. D. Anglin, and M. Hamid, *Ore Mineral Atlas*, Newfoundland, Geological Association of Canada – Mineral Deposits Division, 2004.
[9] R. H. Sillitoe, "Styles of High-Sulphidation Gold, Silver and Copper Mineralisation in Porphyry and Epithermal Environments," Pacrim'99, Bali Indonesia, 1999.
[10] R. H. Sillitoe, "Porphyry Copper Systems," Society of Economic Geologists, Inc, 2010.
[11] R. H. Sillitoe, "Epithermal Paleosurface," *Mineralium Deposita, International Jurnal of Geology, Mineralogy and Geochemistry of Mineral Deposit*, pp. 767-793, 2015.
[12] R. H. Silitoe and W. Hedenquist, "Linkages between volcanotectonic settings, ore-fluid compositions, and epithermal precious deposits," *Society of Econoc Geologists*, 2003.
[13] G. Corbett, and T. M. Leach, "Southwest pacific rim gold-copper system: structure, alteration, mineralization," Colorado, USA: Society of Economic Geologist, Inc, 1998.
[14] J. Hedenquist and B. Haughton, "Epithermal gold mineralisation and its volcanic environment," Sydney: The Foundation, 1987.
[15] J. B. Gemmell, "Low and intermediate sulfidation epithermal deposits," Center of Ore Deposit Research. University of Tasmania, 2004.