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Mineralization Study of Volcanic Rocks in Colo Volcano Tojo Una-Una Central Celebes

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ABSTRACT

Colo Volcano is an active volcano located on Una-Una Island, Tojo Una-Una Regency, Central Sulawesi Province. Volcanism and magmatism of Mount Colo are still in progress, and this has certainly triggered mineralization in volcanic rocks which is interesting for study. This research aims to reveal the mineralization characteristics of volcanic rocks in the study area. This research was conducted through investigative methods in the form of field observations and laboratory through petrographic and rock chemistry (X-Ray Diffraction analysis) to reveal the presence of alteration minerals as a characteristic of mineralization. The results of this study indicate that the volcanic rocks present are tuff and volcanic breccia in the form of pyroclastic deposits associated with alluvial material and andesite rocks. Identification of alteration minerals through the XRD test shows the presence of hydrothermal alteration minerals with a forming temperature of <300 ° C such as Quartz, Calcite, Clinochlore, Albite, Dickite, Andesine, and K-Feldspar which are classified into Argillic and Propylitic alteration types.

Keyword: *colo volcano; mineralization; hydrothermal alteration; volcanic rocks.*

SARI

Gunung Colo merupakan gunung api aktif yang berada di Pulau Una-Una Kabupaten Tojo Una-Una Provinsi Sulawesi Tengah. Vulkanisme maupun magmatisme Gunung Colo masih berproses, dan hal ini tentunya memicu mineralisasi pada batuan gunungapi yang menarik untuk dilakukan studi. Penelitian ini bertujuan untuk mengungkap karakteristik mineralisasi pada batuan gunungapi di daerah studi.

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Hasil dari penelitian ini menunjukkan bahwa batuan vulkanik yang hadir berupa tufa dan brekasi vulkanik dalam bentuk endapan piroklastik yang berasosiasi dengan material aluvial serta batuan andesit. Identifikasi mineral alterasi melalui uji XRD menunjukkan kehadiran mineral-mineral alterasi hidrotermal dengan suhu pembentukan < 300°C seperti *Quartz* yang umum hadir, *Calcite, Clinochlore, Albite, Dickite, Andesine*, dan *K-Feldspar* yang tergolong kedalam tipe alterasi Argilik dan Propilitik..

Kata kunci: gunung colo; mineralisasi; alterasi hidrotermal; batuan vulkanik.

INTRODUCTION

This volcano is a solitary volcano, separate from a series of Indonesian volcanic routes that stretch from the northern tip of Sumatra - Java - Nusa Tenggara - Molucca and North Sulawesi in Tomini Bay (Chaniago et al., 2004); likewise, Katili and Sudrajat (1989) do not connect between the Quaternary volcanic arc in the North Arm of Sulawesi and the Colo Volcano in Tomini Bay. Hamilton (1979) explained that this volcano from Una-Una Island was formed over the deep Benioff line.

The activity of Colo volcano shows that both volcanism and magmatism are still in progress, which has certainly triggered mineralization in the rocks around the volcanic activity. Based on that, an investigative study is needed to provide information and guidance to reveal mineralization in rocks in the Colo volcano area of Una-Una Island.

Previous research tracing results found that several previous researchers had studied studies related to Mount Colo focused on tectonic settings (Broom-Fendley S, et al., 2011) and the petrographic approach of mineral alteration that occurred in colo volcano (Amin, et al., 2017). This study examines mineralization in rocks using a petrographic approach and rock chemistry analysis to continue existing research. These methods are used to provide information about the presence of alteration minerals as a feature of mineralization.

RESEARCH METHODS

The research method was carried out in two stages of the investigation, starting with a survey of geological conditions then followed by a test analysis of rock samples in the laboratory. The following are the stages of research that has been carried out in the study area.

Geological Survey

A geological survey was conducted to determine the surface geological conditions around Colo volcano. The method used in this activity is through surface geological observations on some rock outcrops found in the field, then recording the outcrops description, taking representative samples and the coordinates of the observation points. Information on geological conditions in the study area is focused on reviewing geological aspects in the form of geomorphology, lithology and structures in the study area.

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Laboratory Data Analysis

In this research, the laboratory analysis using sample analysis methods in the form of petrography and X-ray diffractometer. The petrographic analysis is performed on rocks to identify minerals in thin incisions under the microscope to determine rock names that refer to rock classifications. X-ray diffractometer (XRD) analysis is needed to determine the types of minerals that are difficult to identify with a microscope (petrography), especially for clay minerals to identify alteration minerals. The X-ray diffraction pattern obtained contains information on intensity, diffraction angle (2θ) and diffraction peak value (Å) which were analyzed qualitatively by referring to the X-ray diffraction pattern list book (Table of Key Lines in X-ray Powder Diffraction Patterns of Minerals) in Clays and Associated Rocks, by Chen (1977).

RESULTS AND DISCUSSION

Geological Condition

The geomorphological study conducted by Amin, et al (2017) shows that the geomorphological unit of Una-Una Island consists of four parts. In the middle part is a caldera hill unit which is a pyroclastic deposit from Colo volcano, followed by hills unit from the Colo lava flow, pyroclastics flow hill unit, and Colo lava flow valley unit. Observations in the field show that Una-Una Island, which morphologically consists of a collection of hills and valleys, is the result of volcanic products. The perfect cone morphology as characteristic of volcanoes is invisible. The morphological formation of the hills and valleys was formed by the remnants of the eruption from the Colo Volcano in 1983. The youngest volcanic products are around the caldera lake, bordered by hills to the West and South. The caldera's morphology from Colo Volcano shows the direction of the opening to the North of Una-Una Island.

Volcanostaratigraphic study by Mulyana et al. (2004) shows that there were at least six times the eruptive activity of Colo volcano. Various volcanic products from Colo volcano, both in the form of lava and pyroclastic material are illustrated in the geological map of Mount Colo, as in Figure 1. The volcanic rock from Colo volcano has a rock color variation from gray to light gray. Pyroclastic Bombs are dominated by plagioclase, k-feldspar, hornblende, and biotite with a glass matrix. The composition similar to lava has a porphyritic texture. It is dominated by plagioclase, k-feldspar, hornblende, biotite and mica as phenocrysts with ground mass consisting of glass and plagioclase microlites (Sandjaja, et al., 2018). The volcanic structure that can be found is a caldera structure, where a relatively rounded crater-like morphology is found as a result of the volcanic eruption of Colo in 1983. There is also a volcanic lake that fills the caldera from the eruption of Colo .

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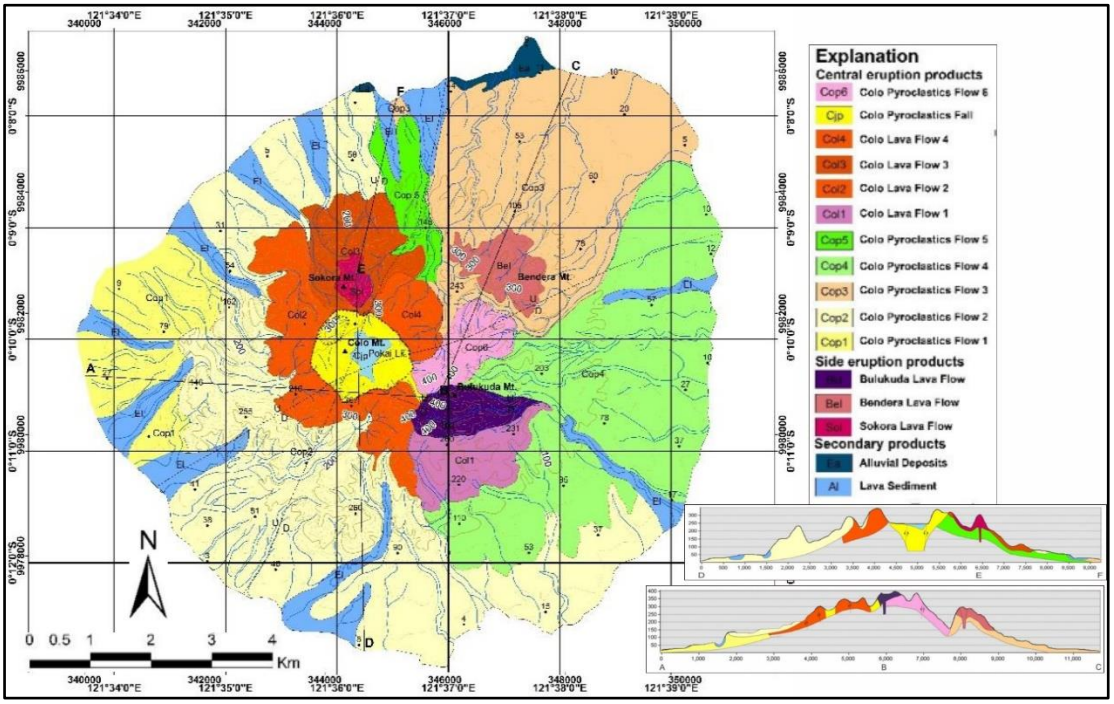

Figure 1. Geological of Colo Volcano (modified from Amin, et al., 2017 and Mulyana, et al., 2004)

Volcanic Rocks of The Study Area

The distribution of volcanic rocks in the study area is quite complex. Mulyana, et al. (2004) and Sendjaja, et al, (2018) stated that volcanic rocks on Una-Una Island are dominated by pyroclastic deposits, both falls and flows and at several points in the field, volcanic breccias and andesite which is an extrusive product from Colo volcano.

The pyroclastic sedimentary rock units associated with alluvial deposits with a composition of volcanic material are found along the river basin on Una-Una Island. Appearances in the field indicate that these deposits are composed of volcanic material with sediment sizes varying from gravel-sand to clay. The thickness of the sediment deposits as a volcanic product reaches 12 - 15 meters above the ground. The layers show records of depositional mechanisms (volcanostratigraphy), where at the bottom are fluvially deposited pyroclastic lava deposits, followed by pyroclastic surge and pyroclastic flow deposits, which are quite thick. There are also outcrops of volcanic breccia in some rock contacts with manifestations (hot springs) indicating alteration of mineralization.

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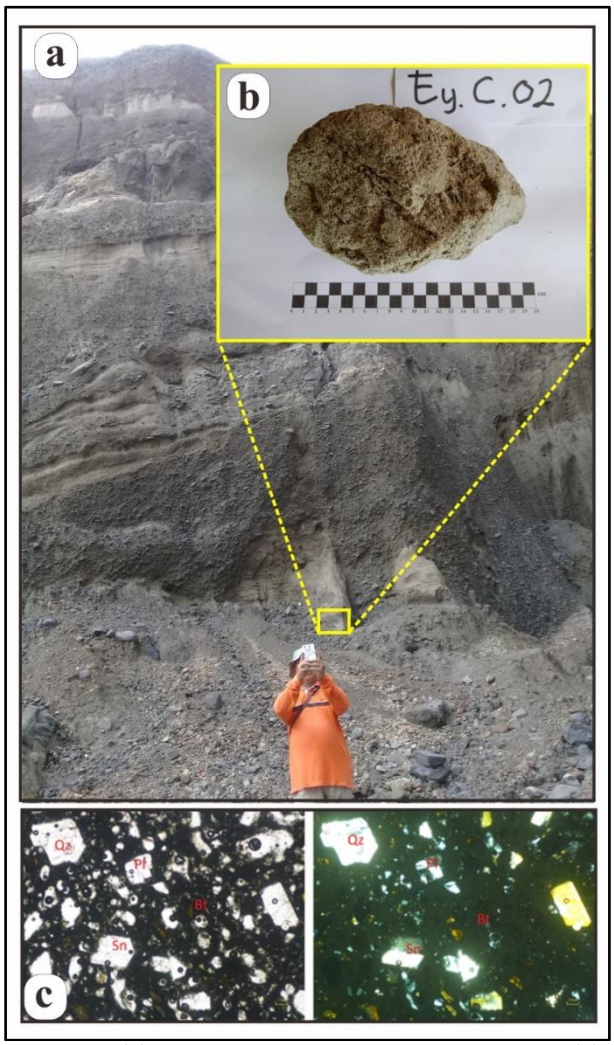

Figure 2. Tuff outcrop appearance; (a). The tuff outcrop found in Ambu, (b). Tuff sample, and (c). Tuff petrographic section

Pyroclastic rocks that were also found in the study area were tuffs. The appearance of these rocks in the field is gray to yellowish, some were found exposed in the form of boulders around the fluvial area towards the colo volcano center (Figure 2). This rock has a grain size of ≤ 1 mm, it does not show gradations in grain size with a relatively lightweight. At several places where there are geothermal manifestations (hot springs and geysers), the tuff appears to be weathered and slightly altered. The results of petrographic analysis show that the rock samples have a massive structure, composed of quartz, plagioclase, k-feldspar-opaque minerals and groundmass with a mineral size of 0.1-0.5 mm.

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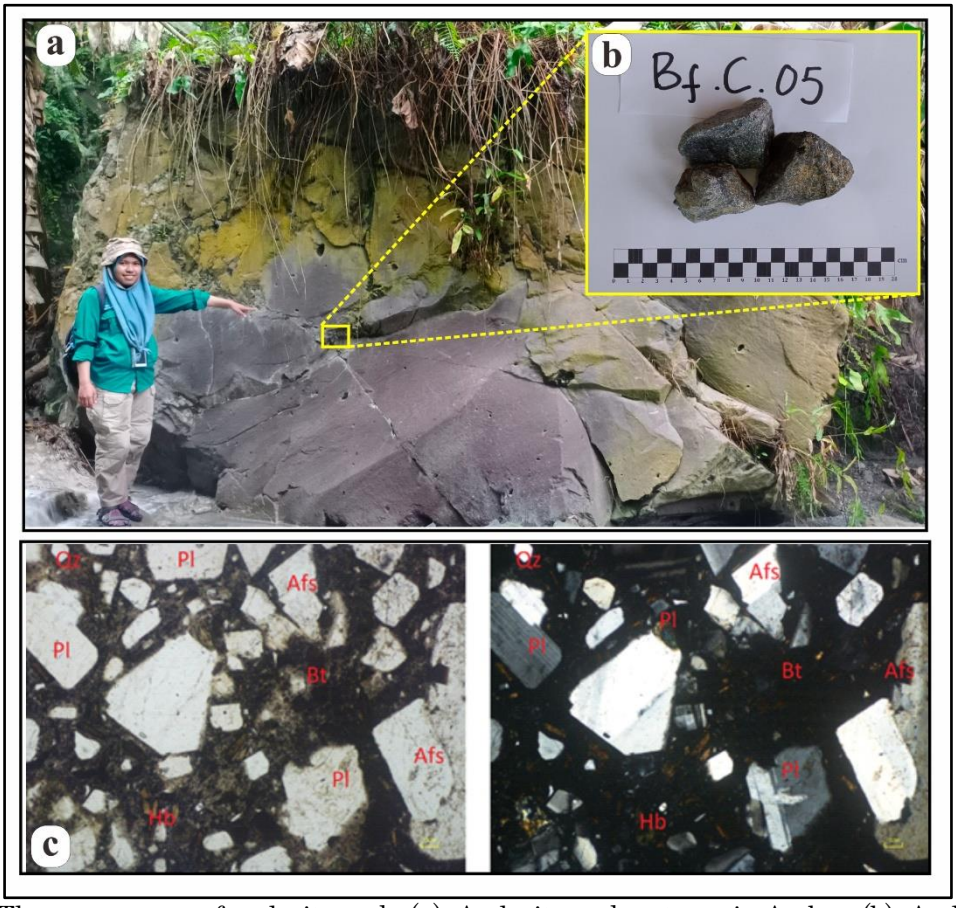

Figure 3. The appearance of andesite rock; (a). Andesite rock outcrop in Ambu , (b). Andesite rock samples, and (c). Andesite petrographic section.

Other volcanic rocks found at Colo Volcano are Andesite rocks. These rocks are interpreted as extrusive products from Colo volcano, which is a massive mass found in the area around the center of Colo volcano (Figure 3). With the intermediate composition, the appearance of andesite under a massive structure microscope has undergone a secondary change of about 20%, porphyritic rock texture composed of 75% phenocryst and 15% groundmass. Phenocrysts measuring 0.2 - 1.6 mm consist of plagioclase, hornblende, k-feldspar, quartz, biotite and opaque minerals. The groundmass is dominated by volcanic glass and granular pyroxene. Secondary minerals consist of mineral oxide spread over the groundmass to form fine black grains and fractures in individual minerals.

Mineralization

The volcanic activity of the Colo volcano creates a hydrothermal-magmatic system, where the transfer of heat energy occurs either conductively or by convection, which then triggers hydrothermal alteration in the volcanic rocks of the Colo volcano. The hydrothermal alteration in the study area was exposed in certain areas, where there was contact with volcanic activity manifestations. The XRD analysis results on altered volcanic rock show that in general, there are two types of alteration, namely propylitic alteration and argillic alteration. Propylitic alteration is characterized by the presence of

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albite, chlorite (clinochlorite), albit and carbonate minerals (calcite) accompanied by generally present quartz. Argilic alteration is characterized by the presence of altered quartz minerals, accompanied by the presence of Dickite minerals, silica in the form of Feldspar (Andesine and K-Feldspar).

In Evans (1993) it is revealed that propylitic alteration is characterized by the presence of chlorite, epidote, albite and carbonate (calcite, dolomite, and ankerite), this is slightly different from the alteration that occurred in the study area where Epidote not identified. This alteration is formed at neutral to alkaline pH (Corbett and Leach, 1997). this alteration is not widespread in the study area, even in areas outside of the center of Colo volcano. Based on macroscopic observation and XRD analysis, the present propylitic alteration was characterized by quite low secondary minerals (Figure 4). The secondary minerals are in the form of chlorite and a little calcite mineral. The influence of alteration in rocks acts on individual minerals selectively. The presence of secondary minerals in the form of chlorite or calcite is interpreted to only change the matrix in the form of volcanic glass. It is interpreted that this occurs because the interaction of hydrothermal fluids is less reactive with the body of rock or because of limited contact.

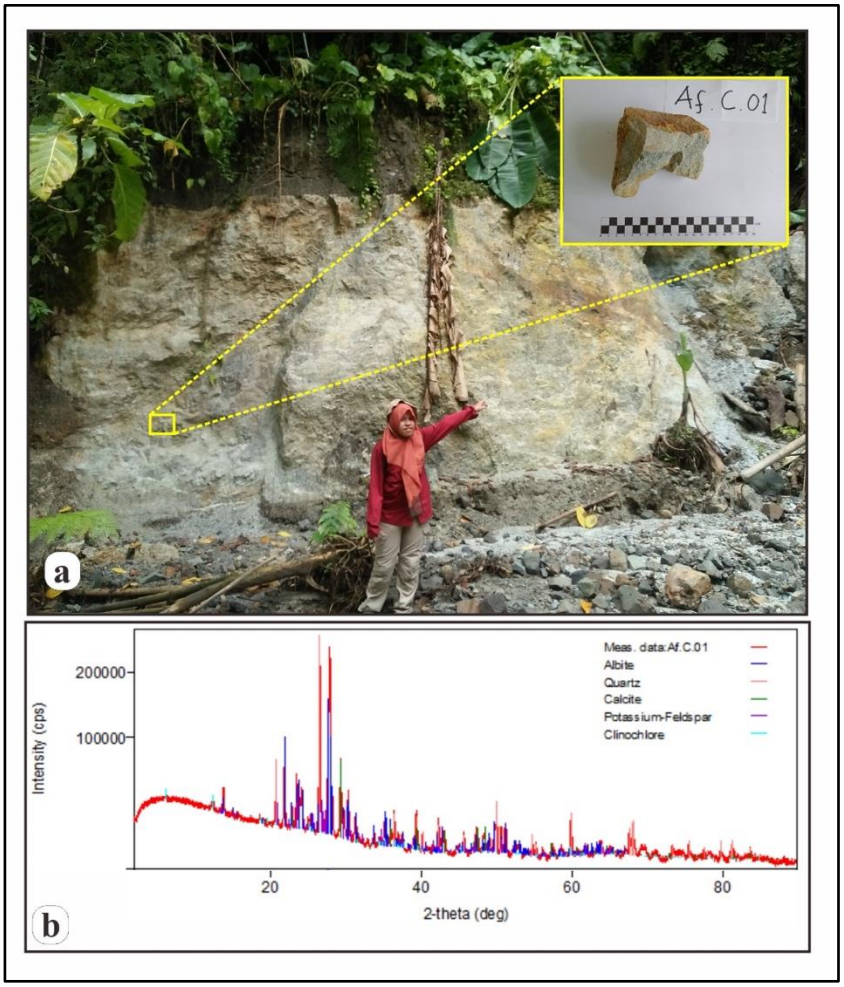

Figure 4. Propylitic alteration zone appearance; (a). The rock outcrops in propylitic alteration are yellowish gray in color, (b). The results of the XRD analysis of the sample Af.C.01.

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Argillic alteration is generally found in the rock contact zone with the manifestation of volcanic-hydrothermal activity. Megascopic observations in the field show the presence of Quartz and Chlorite minerals. The argillic outcrops in the field are characterized by whitish gray to brownish-yellow rocks indicating the presence of clay minerals (Figure 5). XRD analysis results show the presence of common quartz minerals accompanied by Dickite and Feldspar minerals (Andesine and K-Feldspar) with the presence of chlorite (Clinochlore) in samples Af.C.03 and Af.C.04 which are volcanic breccia rock with fragments of andesite rock. Besides, the results of petrographic tests for rocks near Ambu by Amin, et al (2017) reveal indications of Pyrite mineralization as a change from Smectite.

Figure 5. Argilic alteration zone appearance is whitish gray to brownish-yellow; (a and b) Outcrops near Sakora, (c). Outcrop on the Urundaka river, and (d). An outcrop near Ambu.

Based on the results of mineralogical tests using XRD analysis for altered volcanic rock samples of Colo volcano, the temperature in the geothermal system can be interpreted. This condition refers to the general relationship between temperature and mineralogy of aluminasilicate mineral alteration (Reyes, 1990; Wohletz, et al. 1992; Hedenquest, et al., 2000). In general, the temperature range of mineralization by hydrothermal alteration in the study area can be determined using the scheme in Figure 6. Based on the interpretation of the temperature range of mineralization formation from alteration minerals and identification of Pyrite minerals by Amin. et al., (2017) in the study area, it can be interpreted that the conditions of the geothermal system allow the formation of an epithermal type of hydrothermal ore deposit. Epithermal type ore mineralization is formed at shallow depths (1-

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2 km from the surface) and relatively low temperatures (<300° C) which is also associated with volcanic-geothermal activity (Lindgren, 1933; Hedenquist and Lowenstern, 1994).

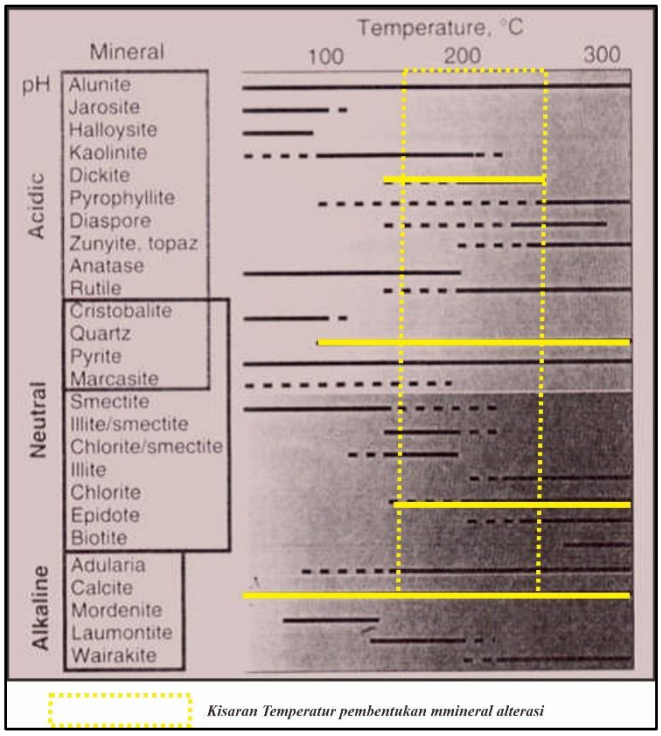

Figure 6. Mineralization Temperature Range Based on Alteration Minerals (modified from Hedenquist et al., 2000).

CONCLUSIONS

Referring to the results of research through analysis and studies related to mineralization of volcanic rocks on Colo volcano, Una-Una Island, the following concludes.

1. The volcanic rocks present on Colo volcano Una-Una Island are dominated by pyroclastic rocks such as tuff and volcanic breccias, which are mostly deposited as pyroclastic deposits associated with alluvial deposits by the fluviation process, and there are also extrusive volcanic rocks in the form of Andesite rocks.
2. Identification of alteration minerals in the study area through XRD analysis of altered volcanic rock shows the presence of hydrothermal alteration minerals with a formation temperature of <300 ° C such as the commonly present Quartz, Calcite, Clinochlore, Albite, Dickite, Andesine, and K-Feldspar which belong to the Argillic and Propylitic alteration types.

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