The relationship of volcanic facies and temperature range derived from the associated clay mineral in Gunung Endut, Banten

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Abstract. Gunung Endut located in Lebak, Banten is one of the prospected areas of geothermal energy resource on the island of Java, Indonesia. The presence of clay mineral in the surface can help to determine the hydrothermal fluid temperature circulating in Gunung Endut. Based on the collected samples, petrography analysis revealed the presence of clay minerals while diffraction method confirmed the presence of dickite, montmorillonite, kaolinite, pyrophyllite, chlorite, diasporre and illite. There are three different temperature range from each volcanic facies. It is predicted that clay minerals at their temperature range in Gunung Endut are formed based on the type of rocks and the topography of the research area.

Keywords: Clay mineral, petrography, XRD, volcanic facies, Gunung Endut

1. Introduction

Gunung Endut located in Lebak Region, Banten Province is one of many areas in Java which has manifestations [1]. The existence of manifestations indicates that there is hydrothermal fluid circulating within the area [2]. There are four volcanic facies that affected the zonation of the area based on rock lithology (table 1) [3].

Our research area (figure 1) consisted of two volcanic formations Qpv (Formasi Gunung Api Endut) and Tpg (Formasi Genteng) respectively [4]. Qpv (Gunung Api Endut Formation) consists of volcanic breccia, lava and pyroclastic-tuff. Tpg (Genteng Formation) consists of pumice tuff, tuffaceous sandstones, conglomerate breccia, marl, and silicified wood. Permeability properties may afflict the hydrothermal fluid circulation within the geothermal area [5]. Pyroclastic rocks have higher permeability compared to igneous rock [6].

Clay minerals are a product from the activities of hydrothermal fluid [7]. X-ray Diffraction (XRD) method can be used to determine its intensity of such clay minerals [7]. In principle, the XRD method identifies specific minerals by analyzing the structural surface where each mineral exhibits a unique structural surface [7].
Table 1. Volcanic facies [3]

| Volcanic facies | Lithology                                      |
|-----------------|------------------------------------------------|
| Central         | Siliceous dome, Vent breccia, Agglomerate, Intrusive |
| Proximal        | Lava, Tuff breccia, Lapilli tuff                |
| Medial          | Lahar, Tuff                                     |
| Distal          | Lacustrine siltstone, Conglomerates, Interbedded sandstone and tuff |

Figure 1. (a) Research area location and (b) Gunung Endut geological map [4].

There are two types of clay mineral based on fluid type which is neutral fluid and acidic fluid types [8]. Clay minerals existence in the surface can be associated with a certain temperature range where the clays were formed [8].

2. Methodology
Rock samples were taken during geological mapping in Gunung Endut, Banten. Ten samples were acquired to be analyzed with petrography analysis and XRD methods from petrological identification. Petrological identification was performed to identify the protolith of samples which can be used to predict the faces. Petrography analysis was conducted to confirm the presence of mineral alteration within the samples in microscopic scale. XRD method was used to identify the type of clay mineral. XRD analysis’ device that being used was Bruker D8 Advance with angle 0.0205°. The result of
petrography and XRD clay mineral identification was combined to create a zonation model. Temperature range gained by Reyes [8] alteration table (figure 2).

3. Results and discussion

Ten samples acquired from the petrological identification shows different facies within the samples where it was identified as a volcanic product in the forms of pyroclastic and igneous rock (table 2). Petrological identification showed samples have proximal until medial facies while distal facies lithology showed by geological mapping that being conducted. Facies determination was also derived from dominant lithology in a geological regional map based on Sujatmiko and S.Santosa [4].

Petrography analysis confirms both protolith and altered clay minerals (table 3). Two methods of observation using Cross Nichol and Parallel Nichol were completed. Most samples exhibit yellow-orange mineral, an indication of clay mineral in its feldspar protolith.

Diffraction analysis shows clay mineral existence from ten samples. Three dominant minerals alteration are gained: Dickite, Montmorillonite, and Kaolinite. Quartz, montmorillonite, kaolinite, and dickite existence can confirm the fluid temperature range based on Reyes (figure 3) [8].

Data interpretation shows the highest temperature zonation within the range 120–280 °C, range 180–260 °C zonation, and range 180–280 °C zonation. Temperature zonation gained by using clay mineral association based on Reyes (figure 4) [8].

![Figure 2. Selected clay mineral associated temperature range [8]](image)

| Temperature Range | 50 °C | 100 °C | 150 °C | 200 °C | 250 °C | 300 °C |
|-------------------|-------|-------|-------|-------|-------|-------|
| Quartz            |       |       |       |       |       |       |
| Montmorillonite   |       |       |       |       |       |       |
| Kaolinite         |       |       |       |       |       |       |
| Dickite           |       |       |       |       |       |       |

**Table 2. Gunung Endut petrology identification result**

| No. | Sample code | Protolith     | Volcanic facies |
|-----|-------------|---------------|-----------------|
| 1   | N.87        | Andesite      | Distal          |
| 2   | J9          | Crystalline Tuff | Medial         |
| 3   | V56         | CrystallineTuff | Medial         |
| 4   | St. 01      | Andesite      | Proximal        |
| 5   | R51         | Andesite      | Proximal        |
| 6   | Z 8.3.      | Dasit         | Distal          |
| 7   | Z. 9.8.     | Andesite      | Distal          |
| 8   | Z. 3.1.     | Andesite      | Distal          |
| 9   | N 6.15      | Vitric Tuff   | Medial          |
| 10  | N 6.14      | Crystalline Tuff | Medial     |
### Table 3. Gunung Endut petrography analysis result

| No. | Sample code | Mineral                                      |
|-----|-------------|----------------------------------------------|
| 1   | N.87        | Opaque, Quartz, Feldspar, Plagioclase, Glass, Clay alteration |
| 2   | J9          | Quartz, Feldspar, Glass, Olivine, Clay alteration |
| 3   | V56         | Quartz, Glass, Opaque, Clay alteration       |
| 4   | St. 01      | Quartz, Opaque, Plagioclase, Microcrystalline quartz, Clay alteration |
| 5   | R51         | Quartz, Opaque, Microcrystalline quartz, Clay alteration |
| 6   | Z 8.3       | Quartz, Opaque, Muscovite, Feldspar, Olivine, Clay alteration |
| 7   | Z 9.8       | Quartz, Opaque, Plagioclase, Feldspar, Clay alteration |
| 8   | Z 3.1       | Quartz, Opaque, Feldspar, Microcrystalline quartz, Clay alteration |
| 9   | N 6.15      | Glass, Opaque, Clay alteration               |
| 10  | N 6.14      | Quartz, Rock fragment, Feldspar, Microcrystalline quartz, Clay alteration |

### Figure 3. (a) Montmorillonite dominant, (b) Dickite dominant stacking, (c) Kaolinite dominant

(M: Montmorillonite; Dp: Diaspore; Dk: Dickite; I: Illite; Mk: Muscovite; C: Chlorite; Fs: Feldspar; K: Kaolinite; Pr: Pyropylite; Sp: Sepiolite; Pg: Palygorskite; dan Qz: Quartz).
Based on the zonation distribution of the altered minerals, proximal-medial facies exhibit higher temperature range due to the proximity to the heat source of Gunung Endut. Consequently, distal facies zonation appears to exhibit a lower temperature (figure 5).

Based on figure 4, it appears that there is an anomalous temperature gradation. Fluid temperature appears to fluctuate in the north side of a field area. Near-surface oxidation between shallow hydrothermal fluid and surface-atmosphere on the northern part of the research area triggers the fluctuating acidity of the fluid (figure 5). Zonation 2 (medial facies) marks as the transition area between the proximal and distal facies (figure 6). Zonation 2 exhibits clay minerals as a product of lower temperature hydrothermal fluids.

Moreover, the northern part of the research area mainly consists of the pyroclastic unit. Pyroclastic units appear to have higher permeability properties as aforementioned by Brace [6]. Different lithology unit also drives the formation of various altered minerals.
Figure 6. Relationship within geological lithology with clay mineral alteration, zonation 1 anomaly in the field area and zonation 3 southern area of field area located in Qpv (Gunungapi Endut formation).

4. Conclusion
In conclusion, there are three temperature range zonation in the research area. Fluid temperature ranging from 120–280 °C are distributed in the southern part, 180–260 °C are distributed in the southern part and northern part of a field area, and 180–280 °C in the center the research area. This zonation was made by the existence of Dickite, Kaolinite, Montmorillonite, and Quartz in the data. The higher fluid temperature range is consistent with the proximal facies of Gunung Endut.

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