Characteristics of surface hydrothermal alteration around Gunung Pancar area, West Java, Indonesia

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Abstract. Hydrothermal alteration is an interaction between rock and hydrothermal fluid by means changing the mineralogical composition of the rock. This process is controlled by permeability, chemical composition, temperature, pressure, and duration of the hydrothermal alteration. Gunung Pancar, located in West Java, is considered an outflow for Gunung Gede Geothermal System. Typical geothermal surface manifestations found around Gunung Pancar are hot springs, warm ground and surface alteration. Basic geological mapping was conducted followed by water and altered rock sampling. Petrographic and diffraction methods are completed to confirm altered protolith. Water analyses were conducted to determine water type and origin. Alteration zonation is then inferred based on the water type, intensity of alteration and then cross referenced with indication of structural geological features. Zonation reveals that the intensity of alteration gets weaker as it moves away from the apparent faults. The result suggested that the permeability of the host rock affects thermal fluid movement around Gunung Pancar and subsequently the local geothermal conceptual model.

Keywords: Gunung Pancar, geothermal, hydrothermal alteration, fluid movement

1. Introduction

Hydrothermal alteration is the response of mineralogical, textural and chemical of rocks to a changing thermal and chemical environment in the presence of hot water, steam and or gas [1]. Mapping alteration mineral assemblage at the surface (figure 1) can help locate the most possible zone for geothermal exploration (i.e. the highest temperature, pressure or permeable zone) [2, 3]. This research aims to determine geochemical characteristics of Gunung Pancar based on fluid samples and surface alteration zonation. Gunung Pancar is located in Sentul, West Java (1-hour drive from City of Depok) (figure 2). This research was conducted in 1 x 2 km² area surrounding Gunung Pancar. Most notable features around Gunung Pancar are the pine forest and warm spring for bathing.
2. Geological overview
Three formations were identified in the research area (figure 3) [4]. Jatiluhur Formation interfingering stratigraphic relationship with Klapanunggal Formation, consisting of marl, shale, and sandstone. In the younger strata, andesite rock formation at middle Miocene consisting of minerals such as oligoclasts-andesine, augite, hypersthene, and hornblende is deposited [4].

3. Methodology
12 rock samples with varying degree of alterations were collected together with 5 thermal water samples from around the area of Gunung Pancar (figure 4). Nine thin section specimens were analysed using petrographic microscopy at Petrography Laboratory, Universitas Indonesia. Seven rock samples were analysed with X-Ray Diffraction methods in Research Center for Nanosciences and Nanotechnology, Institut Teknologi Bandung. Five thermal water samples were analysed with convention geothermal fluid analysis, but only three of the water samples were analysed using isotope analysis at Pusat Sumber Daya Geologi, Bandung.
4. Results and discussion
Slickenside was observed at N20E/77, indicating normal fault and that controlled the presence thermal manifestations. Lithology that was found in the area includes rock outcrops such as Andesitic intrusion with moderate intensity alteration and recent and fossil travertine deposits at proximity to the thermal manifestation. Thermal features include hot pool, warm ground at the surrounding area of the hot pool, seepage of warm water in the nearby pipelines and altered outcrops with different alteration intensities.
4.1. Thermal fluid characteristics
Four (out of five) fluid samples are sulphate water and one samples chloride-sulphate water type. Acidic thermal water occurs most likely due to shallow steam condensate as a result from near surface oxidation of H₂S gas (producing SO₄ species) [5]. The source of fluid is most likely to be meteoric; where the concentration of D and ¹⁸O are near the Meteoric Trend Line (figure 5b).

4.2. Alteration characteristics

4.2.1 Travertine deposit and high intensity alteration. Fresh travertine deposits were found in the proximity of Kawah Merah; fossil travertines were spread in a downward terrace originating from Kawah Merah (figure 6a). Both fossil & recent travertine deposit reacts with HCl confirming the carbonate content of the deposits. Thin section confirms the presence of calcite and abundance of clay mineral indicating high intensity alteration from the travertine deposit (PCR 533 B) (figure 6b). Diffraction analysis also confirms the presence of calcite and dickite, inferring the role of CaCO₃ dissolution within the geothermal system (figure 7).

Figure 5. Characteristics of thermal waters in Gunung Pancar area based on (a) Cl-SO₄-HCO₃ ternary diagram, and (b) isotope analysis. Red circles indicate the clustering of water analysis data.

Figure 6. Field observation of (a) fossil travertine deposits, (b) fresh travertine deposits, (c) and (d) its optical mineral analysis, thin section analysis. Cal indicating calcite (PPL), Cly indicating clay mineral (XPL).
4.2.2 Intermediate intensity alteration. Most intermediate intensity alterations are distributed to the west of surface manifestation. Thin section confirms the presence of clay minerals, quartz and groundmass (figure 8a). Groundmass indicates that the rock has not fully altered yet. Protolith minerals such as muscovite and feldspars and clay minerals such as chlorite, kaolinite, and illite are present (figure 9).

4.2.3 Low intensity alteration. Thin section shows the presence of groundmass; indicating that the rocks have low intensity alteration (figure 10a). Diffraction analysis confirms the presence of muscovite and feldspar which is likely to indicate the protolith (unaltered) rock (figure 11). Chlorite and Illite are clay minerals, as alteration products from the protolith. Quartz can act as protolith or altered product (secondary quartz).

Alteration is supported by lithology physical properties (i.e. porosity and permeability) [3]. Around Gunung Pancar, surface alteration is enforced by secondary permeability induced from the normal and strike slip fault. Normal fault creates open spaces to promote fluid circulation in the surface [3]. Based on the alteration intensity, topography plays an important part to the direction of fluid movement.

![XRD Analysis of the travertine deposit (sample PCR 533 B); ca indicating calcite and dc indicating dickite.](image)

**Figure 7.** XRD Analysis of the travertine deposit (sample PCR 533 B); ca indicating calcite and dc indicating dickite.

![Optical mineral analysis and observation of moderately altered rock, (a) PPL, (b) XPL and Gms indicating groundmass (c) and (d) Qz indicating quartz Cly indicating clay minerals.](image)

**Figure 8.** Optical mineral analysis and observation of moderately altered rock, (a) PPL, (b) XPL and Gms indicating groundmass (c) and (d) Qz indicating quartz Cly indicating clay minerals.
Figure 9. XRD analysis of the moderately altered rock (sample PCR 364 and PCR 537); c indicating chlorite, k indicating kaolinite, i indicating illite, m indicating muscovite and f indicating feldspar.

Figure 10. Optical mineral analysis and Observation of low intensity altered rock (a) PPL, (b) XPL and (c) Gms indicating groundmass, Qz indicating quartz and Cly indicating clay minerals.

Figure 11. XRD Analysis of the low intensity altered rock (sample PCR 370); c indicating chlorite, q indicating quartz, i indicating illite, m indicating muscovite and f indicating feldspar.
Figure 12. Alteration zonation map

Thermal fluid tends to move towards the lower topography (trending NW and NE) as suppose to the south. Surface alteration intensity decreases as it moves farther away from the manifestation and Gunung Pancar. (figure 12). Travertine deposit is distributed at the proximity of the intersection of the faults. Kaolinite (product of argillic alteration) shows near surface oxidation due to weak acidic – neutral fluid circulating in the surrounded lithology. Illite and dickite are part of kaolinite group and are more widely spread to the north-west direction possibly along the fissure of Kawah Putih. Limestone lithology (Tmj) may have interfered with the equilibrium of thermal fluid causing CaCO₃ dissolution and depositing travertine. Feldspar alteration to kaolinite is the result of potassium ion mobility due to water-rock interaction and the release of protons from the rock [1].

5. Conclusion
Geochemical characteristics–geothermal fluid type of Gunung Pancar controls the type of clay mineral distributed on the surface around Gunung Pancar area; mostly chloride-sulphate water associated with argillic alteration (e.g. kaolinite, dickite). The distribution of alteration intensity and clay minerals were successfully determined. The intensity of alteration decreases as it moves northward the direction to the lower topography.

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