Mineralogy of travertine deposit in Ciseeng geothermal field, Parung, West Java, Indonesia

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Abstract. Travertine deposits are carbonate rocks consists mainly of calcium carbonate minerals, supersaturated from bicarbonate-rich water. Both recent and fossil travertine deposits are found in Ciseeng geothermal field, West Java. The travertine deposits are distributed around three distinctive areas Tirta Sayaga, Mount Panjang and Mount Peyek. This study aims to determine minerals found in travertine deposits in Ciseeng geothermal field. Mineralogical analysis can determine the evolution of hydrology system and local climate change. Principal methods of analysis consists of petrographic and diffraction methods. Analysis results indicate similar mineral composition of calcite and microcrystalline carbonate (micrite) between recent and fossil travertine deposit with more diverse texture in fossil travertine due to the evolution of water composition affecting deposition and diagenesis process. The absence of aragonite indicates a low-temperature geothermal system.

Keywords: Travertine, mineralogy, geothermal, Ciseeng

1. Introduction
Travertine deposits are a chemically-precipitated limestone with the tendency to be localised around points of spring emergence and are precipitated as result by CO₂ transfer from or to groundwater which leads to CaCO₃ supersaturation [1, 2]. Travertine deposits originated from highly concentrated bicarbonate springs due to reaction between dissolved CO₂ and a carbonate rock and may indicate low temperature system [2, 3]. Fossil travertine are more difficult to be identified as their morphologies may have been modified by weathering, erosion or diagenesis [2]. A comparison between the textural characteristics of fossil and recent travertine, allows to infer possible diagenetic products [4].

The aim of this research is to determine the mineralogy of fossil and recent travertine deposit in Ciseeng using petrographic, diffraction and fluorescence method. Microscopic identification of travertine is the most prominent to understand the formation, mineralogical history, diagenesis and understanding the difference in travertine physical characteristics [2]. Furthermore, the mineralogy and composition of travertine deposit obtained from diffraction and fluorescence method can help better understanding the state & evolution of Ciseeng hydrological composition.
2. Geological overview
Ciseeng geothermal field is located in Parung, West Java, Indonesia (figure 1). Indonesia’s Ministry of Energy and Mineral Resources [5] reported that there is a low temperature fluids circulating in Ciseeng. Geological mapping [6] outline that there is a regional structure trending in the NS direction that may control the presence of thermal manifestations. There are three active thermal manifestations of warm pool and extensive travertine deposit (both fossil and recent deposit) in Tirta Sayaga, Mount Panjang and Mount Peyek. Based on geochemical analysis for the thermal water, Ciseeng thermal fluids are very saline water with high concentration of chloride, calcium and bicarbonate concentration [6].

The stratigraphic sequence in the studied area, as illustrated in the simplified geological map in figure 2, comprises a wide range of rock units including Quaternary Alluvial (Qa), Quaternary Andesite of Sudamanik Volcano (Qvas), Quaternary Alluvial Fan (Qav), Tertiary Pliocene Serpong Formation (Tpss), and Tertiary Miocene Bojong Manik Formation (Tmb). Qa consists of clay, silt, sand, gravel, pebble, and boulder; Qvas consists of hornblende-pyroxene andesite, porphyritic; Qav consists of bedded fine tuff, sandy tuff, interbedded with conglomeratic tuff; Tpss consists of alternating conglomerate, sandstone, siltstone, claystone with plant material, pumice conglomerate, and pumice tuff; Tmb consist of alternating sandstone and claystone with limestone intercalation [7]. The carbonate from limestone lithology of Tmb is most likely to react with thermal water and lead to precipitation of travertine deposits on the surface.

Figure 1. Research location (a) map of West Java, Banten and DKI Jakarta, (b) location of Ciseeng geothermal field and the three manifestations.

Figure 2. Simplified geological map of the studied area [7].
3. Method

20 samples of travertine deposits were collected from around Ciseeng geothermal field, Parung, West Java. Three manifestations in Tirta Sayaga, Mount Panjang and Mount Peyek shows notably travertine deposits in different morphologies such as fissure ridges terraced slopes and mound respectively [8]. The travertine deposits were categorised as fossil or recent deposits based on its occurrence in the field. The samples were then selected for further mineralogical analysis of petrographic, X-Ray Diffraction and X-ray Fluorescence. Petrographic analysis was held in Geological Science Study Program, Universitas Indonesia using petrographic microscopy Leica DM750P to analyse the texture and mineralogy [4]. Diffraction method is used to analyse mineral composition of the samples while elemental analysis used to determine major and trace element [9, 10]. Diffraction and Elemental analysis was completed in UPP IPD FMIPA Universitas Indonesia using PAN Analytical X’Pert Pro (CuKα 1.54 Å).

4. Results and discussion

4.1. Petrographic analysis

Petrographic analysis of travertine deposit in Ciseeng confirms the presence of calcite. Besides calcite, microcrystalline carbonate or micrite were observed in all travertine samples (figure 3). Based on its appearance, fossil travertine deposit shows a more diverse texture compared to recent travertine deposit. It is possible that fossil travertine has undergone series of transformation within its mineralogical order as the deposit come in contact with atmospheric condition.

Recent travertine deposit shows a lamination between calcite crystals and micrite. On the other hand, fossil travertine deposit shows different crystal shapes and morphologies. This suggest that fossil travertine had undergone diagenesis process to allow the crystal to re-arrange and being incorporated with other minerals such as mineral clays, traces minerals of corundum or quartz. Moreover, fossil travertine may also have had its Ca²⁺ ion substituted with a similar radii ion when constantly exposed to thermal waters [2].

4.2. Diffraction analysis

Eight travertine samples (both fossil and recent) were analysed using diffraction method (figure 4). Based on the diffractogram, all samples exhibit similar mineralogical composition of calcite, clay minerals (dickite) and traces of corundum. Calcite is the apparent dominating minerals as supposed to aragonite (a polymorph of CaCO₃). Calcite has a simple mineral structure of trigonal crystal [2] and is more stable thermodynamically compared to aragonite [11]. The intensity of clay mineral is very low in all travertine deposits. Clay mineral appears to be in the form of dickite. Dickite can be found together in the kaolinite-serpentine group [12] and indicating weak acidic thermal water [12]. Traces of corundum are also present, possibly detrital origin due to its resistance to weathering [13].

4.3. Elemental analysis

Elemental analysis was conducted with X-Ray Fluorescence analysis. The results were obtained as percentage weight of each elements and element oxides. Six samples of selected fossil and recent travertine deposits undergone elemental analysis (figure 5). All sample confirms that the majority elements comprise in the travertine deposit are Ca-oxide. All samples also confirm the presence of Al-oxide, Fe-oxide and Ti-oxide confirming the presence of clay minerals (dickite) and traces of corundum. Si-oxide is only present in travertine deposit at Tirta Sayaga (0.89–0.923%). Fe-oxide percentage in travertine deposit increase as the salinity of the water is high [3].

Sr-oxide percentage stood out among other trace elements ranging from 1.7–3.1 %. Sr-oxide percentage is more abundant in recent deposit possibly due to the recent of Sr leaching from the surrounding host rock into the fluid circulating which eventually precipitated in the travertine deposit. Sr is a common element from the dissolution of marine limestones [14] suggesting that the lithology
units in Ciseeng geothermal field may be comprised from marine sedimentary rocks. Sr-oxide is prominent as it can help determine the age using Sr isotope dating [2] and predicting the age of the geothermal system [14].

The absence of aragonite crystal in all travertine deposits from Ciseeng may infer the process of CO2 loss in the subsurface. Calcite usually forms as the dominant carbonate however when CO2 loss occurs very fast, aragonite may form instead of calcite [15]. At a normal condition, CO2 is lost from the solution on contact with an atmospheric condition whose CO2 concentration is lower than sub-surface solution [2]. CO2 loss may occur promptly when subsurface boiling occurs at higher temperature geothermal system. These findings suggest that Ciseeng geothermal field lies within the low-intermediate temperature geothermal system.

Figure 3. Thin section photomicrograph of fossil travertine (a, c, e) and recent travertine (b, d, f) deposits in Tirta Sayaga, Mount Panjang and Mount Peyek which comprised of calcite (c) and micrite (m).
Figure 4. Diffraction analysis for travertine deposit.
Figure 5. Results of elemental analysis of 6 selected samples, (a) Calcium oxide percentage graph, (b) Strontium oxide percentage graph, and (c) Trace element percentage graph.

5. Conclusion
The mineralogy of travertine (both fossil and recent) deposit in Ciseeng geothermal field consists of mainly calcite with micrite and traces of oxides. Fossil travertine deposit show a more diverse texture compared to recent travertine due to diagenesis process caused by evolution of water composition and reaction between fossil travertine deposit and atmospheric condition. Sr-oxide percentage is comparatively high to other trace elements. The abundance of calcite minerals instead of aragonite leads to the indicator of low-temperature geothermal system.

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