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インドネシアジャワ島中央部に発達する縞状トラバーチンの生命地球化学
Biogeochemistry of laminated travertines in Central Java, Indonesia

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Travertines are calcite or aragonite precipitates from hot-spring water containing a sufficient amount of calcium and carbon dioxide. Most of travertines show sub-mm order laminations that were formed by daily microbial activities. Two previous studies have suggested different processes in terms of responsible microbe for lamina formation; cyanobacteria that can grow and trap detritus on the travertine surface in the daytime and heterotrophic bacteria that can quickly degrade organic matter from cyanobacteria on the travertine surface in the daytime. The former model was consistent to some calcite travertines (e.g. Takashima and Kano, 2008) and an aragonite precipitates on microbial mat (Okumura et al. 2010), while the latter model was confined to one aragonite travertine (Okumura et al. 2011). Here, we study a huge travertine mound in Indonesia to consider the applicability of these processes for the diverse laminated texture of the travertines.

Pancuran Pitu is one of the hot springs that occur around Mt. Slamet, an active stratovolcano in Central Java, Indonesia. Here, a huge travertine mound was formed along the water passage flowing on the mountain surface, which is 180 m long, 60 m wide and 70 m relative elevation. The water temperature was 51^{o}C at the vent, 45 to 35^{o}C at the mid stream, and decreased to 29^{o}C at the downstream. pH increased from 6.2 to 8.3, and Ca^{2+} concentration decreased toward the downstream (273 to 100 ppm) with respect to CO_2-degassing and $CaCO_3$ precipitation. The other chemical components were constant throughout the water passage. The mineralogy of the travertines was mainly aragonite throughout the mound, which likely reflects high Mg/Ca molar ratio (1.6 to 3.8) in water. Three types of travertine were observed in the mound; (1) brown hard travertine at the upper stream, (2) light yellow friable travertine with green microbial mats at the midstream, and (3) light yellow crystalline hard travertine at the downstream cascade. All types of travertines have sub-mm order lamination, however irregularity in the lamina thickness was recognized only in the brown hard travertine formed near the vent where the water had the highest temperature and iron concentration. The lamination of the brown travertine was unlikely formed by the daily cycle. Light yellow crystalline travertine was formed only under high flow condition as in the cascade, while friable travertine with green microbial mat was formed under low flow condition. The microbial abundance in the friable mat increased with decreased water flow and temperature. Observation using fluorescence microscope revealed that distribution of phototrophs along the lamination was only recognized in the friable travertine with microbial mat, but not in the other types of travertines, in which some other microbes were responsible for the lamination.

The difference in depositional conditions, such as temperature and water flow, resulted in different types of laminations that were likely formed by different microbial processes. Understanding such variations provide some useful information for interpretation of the ancient stromatolites.

References

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