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Numerical assessment of the potential for future limnic eruptions in Cameroon, based on regular monitoring data

KOZONO, Tomofumi[1*] ; KUSAKABE, Minoru[2] ; YOSHIDA, Yutaka[3] ; NTCHANTCHO, Romaric[4] ; OHBA, Takeshi[5] ; TANYILEKE, Gregory[4] ; HELL, Joseph V.[4]

[1]Science, Tohoku Univ., [2]Science, Univ. of Toyama, [3]Yoshida Cons. Eng. Office, [4]IRGM, [5]Science, Tokai Univ.

A limnic eruption is a gas outburst from a lake, and it can cause a catastrophic disaster in the surrounding area. Lakes Nyos and Monoun in Cameroon, Central Africa, are volcanic crater lakes where limnic eruptions with catastrophic releases of CO_2 gas occurred in 1986 (Nyos) and 1984 (Monoun), claiming close to 1800 lives. To understand the mechanism of the limnic eruptions in these lakes, regular monitoring of the chemical composition of the lake water has been conducted since the limnic eruptions, and it allows us to obtain detailed information about CO_2 profiles in the lakes. In this study, we assessed their eruptive potential at Lakes Nyos and Monoun, on the basis of numerical modeling and the CO_2 profiles obtained by the regular monitoring of the lakes.

The evolution of the CO_2 profiles suggests one particular scenario for producing an eruption: supply of CO_2-undersaturated fluid from the lake bottom that induces upwards growth of the bottom layer, leading eventually to CO_2-saturation at mid-depths of the lake. By using a numerical model for the ascent of a plume of CO_2 bubbles, we investigated whether bubble formation in this scenario leads to a bubble plume reaching the lake surface (i.e., a limnic eruption). We found that under realistic conditions (e.g., a CO_2 profile deduced from the regular monitoring data), a bubble plume generated from mid-depths can reach the lake surface with a CO_2 high flux, which corresponds to a limnic eruption. This indicates that the ascent of the bubble plume caused by the upward growth of the CO_2-undersaturated layer is a possible mechanism for inducing a limnic eruption.

Another important factor that affects the current CO_2 profiles in Lakes Nyos and Monoun is the artificial removal of dissolved CO_2 (“controlled degassing”) using degassing pipes. As CO_2-rich water is withdrawn from the deep layer through a pipe, the pipe flow becomes self-sustaining due to bubble formation and expansion caused by decompression in the rising water column. This leads to the formation of a fountain on the lake surface. The most recent CO_2 profiles obtained by the regular monitoring indicate a drastic decrease in the CO_2 concentration at the bottom of the lake. We developed a numerical model for degassing pipe flow so that we could investigate the effects of changes in CO_2 concentration at the lake bottom on the dynamics of the pipe flow and the degree of degassing. From the model, the quantitative relationship between CO_2 concentration at the lake bottom and fountain height observed on the surface of the lake is established. Our results agree well with the observed heights, indicating that our model is successful in capturing the dynamics of the degassing pipe flow in Lakes Nyos and Monoun.

Keywords: Limnic eruption, Lake Nyos, Lake Monoun, Numerical model, Degassing pipe