A study on caldera lake-groundwater system based on a multiple isotope approach

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Lake Masyu (212 m deep; 19.6 km^2 in area; water surface at 352 m a.m.s.l.), eastern Hokkaido, Japan, is a seepage caldera lake with no surface outflow and inflow. The caldera lake-groundwater system was investigated to elucidate the effect of lake-water seepage from Lake Masyu on the hydrology and hydrogeochemistry of Masyu volcano and its adjacent areas. Previous studies on the lake indicated that, on the basis of a conventional water balance method, there is a large amount of seepage of some 65,000 km^3/day to the surrounding volcanic aquifers.
The analyses of ^2H, ^{18}O,^{13}C, ^3He and water chemistry for samples from rivers, springs, and bores in 2009 and 2010 are reevaluated in detail to quantify the lake-water contribution to river and spring discharges and to the downgradient groundwater field. The water samples from Leke Masyu are markedly enriched in heavy isotopes and fall on a line with a slope of 5.0 in the δD vs.$δ^{18}O$ diagram, which is characteristic of open-water bodies subject to evaporation. The lake water is also enriched in carbon isotope and in the range between 4 and 5‰ $δ^{13}C$. The mixing proportion of lake water was calculated on the basis of δD and $δ^{18}O$ by applying a simple two end-member mixing model. As a result, the lake-water contribution proved to be significant for the huge springs on the southeastern flank (Nishibetsu-Gawa Headwater Springs) and those on the southwestern flank (Biruwa Springs), consisting of 30% of their discharges. Taking into account their total daily discharge of 140,000m^3 measured in July 2009, some 65% of the lake-water seepage from Lake Masyu, that is 42,000 m^3/day, is estimated to concentrate in these springs. In contrast, the Kaminoko-Ike Spring on the northern flank with a discharge of some 15,000m^3/day, water of which has long been considered to be of Lake Masyu origin, isotopically showed no evidence of lake water. It is also the case in the other medium-sized springs located on the northern and eastern flanks. The analyses of stable carbon isotope, high isotopic values of -9 to -7‰ $δ^{13}C$ for Nishibetsu-Gawa Headwater Springs and of -9 to -8‰ $δ^{13}C$ for Biruwa Springs, and a low value of -21‰ $δ^{13}C$ for Kaminoko-Ike Spring, are consistent with these estimates. It is also the case with ^3He: Nishibetsu-Gawa Headwater Springs and Biruwa Springs had a high content of ^3He of magmatic origin, whereas there was no ^3He of magmatic origin in Kaminoko-Ike Spring. Rivers that originate in the flanks of Masyu volcano showed little or no isotopic evidence of lake water. An overall estimate, therefore, is that approximately 23,000 m^3/day of seepage from Lake Masyu is still unaccounted for. The hydraulic connection of volcanic aquifers to Lake Masyu is likely to account for this. The isotopic analyses show some hot springs and groundwaters from the 100-350m deep bores in the southern and southwestern flanks contain substantial proportions of lake water, indicating seepage water from Lake Masyu plays an important role in forming hydrothermal and groundwater system. A schematic diagram for the caldera lake-groundwater system in and around Masyu volcano is depicted on the basis of these data.

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