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風化基岩流域における複数の手法を用いた地下水流動の推定
Estimation of bedrock groundwater movements using multiple investigation methods at a weathered granite mountain, Japan

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Introduction

Previous studies have noted that bedrock groundwater is one of the important factors influencing stream discharge and streamwater chemistry. However, most previous studies were conducted not by direct measurement of bedrock groundwater but by using indirect methods, such as solute tracers and water budget analysis. Thus, the movement and flow path of bedrock groundwater remain incompletely understood based on direct measurements of bedrock groundwater. To better understand the dynamics of bedrock groundwater, we evaluated the flow path of bedrock groundwater based on groundwater table movement, water chemistry of bedrock groundwater and elution experiment of bedrock using dense borehole wells at a small catchment in a mountainous area.

Methods

The study was performed at the Fudoji Experimental Watershed located in the Tanakami Mountains in the southeastern part of Shiga Prefecture, central Japan. Precipitation was monitored using tipping-bucket rain gauges, and discharges were observed at eight small catchments, ranging in area from 0.1 to 2.3 ha. Seven small catchments (subcatchments) were included in the largest catchment (2.3 ha), within which we installed 61 borehole wells. The water table of bedrock groundwater was then observed at these borehole wells. Rainwater, streamwater from the small catchments and bedrock groundwater from the borehole wells were sampled, and the concentrations of major ions and SiO_2 as well as the water stable-isotope ratios $d^{18}O$ and dD were measured in the Graduate School of Agriculture, Kyoto University. The elution experiment of bedrock obtained by borehole excavation was conducted to evaluate the elute potential of rock itself. The elution water was analyzed by chemical analysis as described above.

Results and Discussion

The results of the analysis of the groundwater table of bedrock groundwater indicated that there were several fluctuating characteristics and that these characteristics of groundwater table change had locality. At the area having higher altitude in the ridge, the bedrock groundwater-table changes were gradual but the ranges of fluctuation were larger than those of the lower wells. At the lower-altitude points, although the bedrock groundwater table responded rapidly, the ranges of fluctuation of the groundwater table were small relative to those of the higher points. Some areas responded only to peak rainfall over a short time. Based on the groundwater flux analysis, bedrock groundwater moves across the surface divide. A catchment inflowed by a neighboring catchment showed a high specific discharge.

The relationships among chemistries derived from the chemical weathering of bedrock indicated that although the weathering processes were similar in the catchment, the weathering level varied among the borehole wells. The chemistries of bedrock groundwater at each catchment and of streamwater at each catchment showed large variability. The results of elution experiment and chemical variability of bedrock groundwater suggested that the concentrations of Na^+ were high when the bedrock depth was shallow and the degree of hardness of bedrock was low. In addition, the concentrations of Ca^{2+} were high as the bedrock depth deep and the hardness degree of bedrock was high. The concentrations of Na^+ and Ca^{2+} with local characteristics may be explained by specific flow path and different flow paths of bedrock groundwater across the surface divide. Our study indicated that groundwater movements assumed by the groundwater table were different with those estimated by chemical characteristics, suggesting that complex processes of groundwater flow path and chemical dynamics occur in the weathered bedrock.

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