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Roles of clay layers in rainfall-runoff processes in a serpentinite headwater catchment

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Rainfall-runoff processes in a headwater catchment have been typically explained by water flow in permeable soil layers (comprised of organic soil layers and mineral soil layers produced by weathering of bedrock) overlying less permeable layers (i.e., bedrock). In a catchment where mineral soils are characterized by clayey materials (e.g., mudstone, slate, and serpentine catchment), it is possible that mineral soil layers function substantially as less permeable layers because of a low permeability of clayey materials. However, roles of clay layers in rainfall-runoff processes in such a headwater catchment are not fully understood. In this study, we conducted detailed hydrological, hydrochemical, and thermal observations in a serpentinite headwater catchment (2.12 ha) in Hokkaido, Northern Japan, where mineral soil layers consisting of thick clay layers (thickness: approximately 1.5 m) produced by weathering of the serpentinite bedrock underlies organic soil layers (thickness: approximately 0.4 m). Saturated hydraulic conductivity (Ks) and water retention curve of these two layers were also measured in a laboratory. The observation results demonstrated that groundwater was formed perennially in the organic soil layers and clay layers. The groundwater level within the organic soil layers and specific discharge of the catchment showed rapid and flashy change in response to rainfall. In contrast, the groundwater level within the clay layers showed slow and small change. Temperature of the groundwater and stream water suggested that water from the depth of the organic soil layers contributed to streamflow. The electric conductivity (EC) of the groundwater in the clay layers was very high, ranging from 321 to 380 μS cm^{-1}. On the other hand, the EC of soil water (unsaturated water stored in the organic soil layers) was relatively low, ranging from 98 to 214 μS cm^{-1}. Hydrograph separation using EC showed that contribution of water emerging from the clay layers to the total streamflow ranged from 31 to 76% in low to high flow periods. Temporal variation in the total head, measured using tensiometers installed at four depths at the ridge of the catchment, indicated that in wet periods when the groundwater level in the organic soil layers was high, water flow from the organic soil layers to the clay layers occurred, whereas, in dry periods, water flow from the clay layers into the organic soil layers occurred. The laboratory measurements showed that the organic soil layers had high Ks (10^{-2} cm s^{-1}) and low water-holding capacity, whereas the clay layers had low Ks (10^{-4} cm s^{-1}) and high water-holding capacity. It can be concluded from these results that clay layers play two roles: (1) forming perched groundwater table and lateral flow on the clay layers (the role of less permeable layers) and (2) supplying water into the organic soil layers in the dry periods (the role of water supplier).