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Comparative limnological study of three Japanese stratified lakes to assess the necessary condition of manganese geochemical focusing

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In lake sediments, manganese (Mn) enrichment is often observed at greater depths within the same lake basin (e.g., Schaller et al., 1996; Scholtysik et al., 2021). It has been suggested that this is caused by the “geochemical focusing”, i.e. horizontal diffusion of Mn leached from reducing sediments and oxidation of MnO_2 is the main cause of enrichment (Schaller et al., 1996). In this study, we made a comparative limnological approach of Japanese monomictic lakes having similar nutrient levels but different maximum depths to test the factors controlling the progress of this focusing process. The sediment core samples and porewater were collected from multiple depths of the lakes, Lake Kizaki (KZK, 29 m), Lake Nakatsuna (NKT, 13 m), and Lake Nojiri (NJR, 38 m), then measure chemical form of Mn and Fe by XAFS and SEM. From October to November 2021, the anoxic water mass was prevailed in the deepest zone of all three lakes. The sediments in three lakes showed different trend of depth-Mn/Fe (mg/g) relationship: decreasing Mn/Fe toward deeper zone in Lake Kizaki (22.0 m : 13.8, 25.0 m :11.3, 28.6 m : 7.4), constant Mn/Fe in NKT (9.7 m : 7.5, 12.0 m : 6.3, 14.0 m : 6.3), and increasing Mn/Fe toward deeper zone in NJR (25.5 m : 26.4, 35.5 m : 46.9, 37.0 m : 187.5). Lowest mean Mn/Fe in NKT is likely attributed to the preferential removal of Mn through river flow due to the small difference of depth between anoxic water mass and epilimnion. Notable differences between KZK and NJR was the presence of $MnCO_3$ in sediment, i.e., contribution of $MnCO_3$ in deepest zone of NJR was up to 38%. This indicated that fixation of Mn as secondary mineral which is stable under reducing condition is necessary to record Mn accumulation in deep zone of the lake. Porewater chemistry of NJR indicated supersaturation of $MnCO_3$, due to higher pH than the other lakes. Overall, lake depth affects interbasin difference of Mn/Fe, while condition which $MnCO_3$ formed is important factor to control intrabasin variability of Mn/Fe.