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Environmental conditions for dolomite formation in the late Miocene Lake Bira revealed by Mg and Sr isotopes

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$d^{26}Mg$ values and $^{87}Sr/^{86}Sr$ ratios are used as tracers of calcite and dolomite formation in the late Miocene Lake Bira. Mg and Sr isotope ratios were analyzed in freshwaters and brines that currently feed the Sea of Galilee (the modern remnant of Lake Bira) and in limestones and dolostones comprising the Bira Formation. $d^{26}Mg$ and $^{87}Sr/^{86}Sr$ ratios of the Sea of Galilee waters (~0.89‰, ~0.7075) are consistent with the mixing of mainly carbonate and basaltic waters with subsurface Ca-chloride brines (e.g., Tiberias Spa). The $d^{26}Mg$ values in the limestones and dolostone of the Bira Formation range from ~ -1.0 to ~ -3.5‰. and -2.8 to -1.8 ‰, respectively. The $d^{26}Mg$ values in Lake Bira waters at that time were between ~-2 ‰ to ~1 ‰, as calculated from the fractionation factors between water and either calcite or dolomite (-2 ‰ and -0.75 ‰, respectively). Isotope mixing calculations suggest that waters with positive $d^{26}Mg$ values (estimated as ~1.2 ‰) were added to the lake. We suggest that these waters were Ca-chloride brines that were formed in the late Miocene Jordan Valley by interaction between evaporated seawater and the local limestones. These brines deposited the contemporaneous thick sequences of salt (halite) and gypsum in the Jordan Valley to the east of the lake. Dolomitization of the limestones increased the $d^{26}Mg$ of the brines during their re-circulation through the surrounding aquifers due to Rayleigh fractionation, The dolomitization process was accompanied by the production of a Ca-chloride solution.

Limestone formation required enhanced freshwater input; a process accompanied by increasing hydrological head that induced an enhanced inflow of the Ca-chloride brine with high $d^{26}Mg$ to the lake. Dolomite formation was associated with the weakening of the hydrological head, and diminishing flow of the brine to the lake.

The formation of dolomites in the lacustrine environment of Lake Bira and the contemporaneous deposition of gypsum in the nearby Jordan Valley provides a model for dolomitization in marginal environments (e.g., lagoons and subkhas), where the Mg is exchanging with Ca during the dolomitization process and the excess Ca taking the sulfate to form gypsum.