Goldschmidt 2026 Abstract
https://doi.org/10.46427/gold2026.34316

Preservation of primary carbonate isotopic compositions in tectonically and hydrothermally active regions: Insights from the Linzhou Basin, southern Tibetan Plateau

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In carbonate successions, the occurrence of dike intrusions and calcite veins reflects episodes of thermal heating and fluid-rock interactions, both of which have the potential to modify the original isotopic compositions of depositional carbonates. However, the magnitude of such alteration and the conditions under which primary isotopic signals may be preserved require quantitative evaluation.

To address this issue, I employed one-dimensional thermal conduction modeling to investigate the spatial and temporal temperature evolution of hosting carbonate rocks under two end-member scenarios: 1) instantaneous high-temperature (1100 °C) heating associated with dike intrusion, and 2) sustained low-temperature (170 °C) heating representing long-lived fault-related thermal fluid flow. The model results, integrated with petrographic observation, isotopic data, and fluid-rock modeling, were used for screening carbonate diagenesis in the Linzhou Basin of southern Tibet, which demonstrates contrasting diagenetic histories among different stratigraphic units.

The middle Cretaceous Takena marine carbonates and Upper Cretaceous Shexing lacustrine carbonates experienced an initial stage of shallow burial water-buffered recrystallization, followed by a second stage of deeper burial rock-buffered recrystallization. Both stages occurred during latest Cretaceous regional upper-crustal shortening/thickening and resulted in complete resetting of primary isotopic signatures.

In contrast, lacustrine and pedogenic carbonates of the early Eocene Nianbo Formation record two discrete thermal events. The first, at ~54–50 Ma, was associated with dike intrusions and reached peak temperatures of ~300 °C in wall rocks. The second occurred during the early Neogene and reflects fault-related thermal fluid flow, with peak temperatures of 130–170 °C in wall rocks. Although both thermal events caused carbonate recrystallization and solid-state bond reordering, their effects were spatially restricted. Isotopic resetting is limited to sub-meter to meter-scale zones adjacent to dike intrusions or along focused fluid-flow pathways. Carbonates outside these localized thermal aureoles experienced minimal alteration and retain syn-depositional isotopic compositions. The calculated paleoelevations exceeding 4 km for the Gangdese Arc at ~55 Ma support the existence of a high southern Tibetan Plateau during the early stage of India-Asia collision.

Overall, this study demonstrates that even in tectonically and hydrothermally active regions, primary isotopic signals can still be preserved beyond localized thermal perturbations.