

Constraining Dead Sea Rift Evolution Through U-Pb Dating of Cave Calcites: Insights from Israeli Hypogenic Caves

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Speleogenesis dating presents a scientific challenge as it involves the absence of material rather than deposition. Dating options include analyzing speleogenesis by-product minerals or dating sediments deposited within cavities near their formation time, thereby establishing chronological constraints for cavity formation. In hypogenic caves, these constraints can be established by dating phreatic calcite deposited while caves were below the water table. This study dates hypogenic caves along central and southern Israel to determine the karst time frame. Dating of old vadose speleothems provided the timing of cave emergence from groundwater, which is significant for determining the chronology and rate of vertical movement along the western margins of the Dead Sea Rift (DSR).

We employed Laser Ablation (LA) U-Pb chronology of phreatic and vadose cave calcite to determine speleogenesis timing and vertical tectonic stages. Samples were collected from sites at similar altitudes across a ~150-kilometer north-south transect along the western DSR margin. In-situ LA U-Pb chronology of calcite, combined with calcite $\delta^{18}\text{O}$ values ranging from -16‰ to -9‰ and D-excess values of 9-29 in $\delta^{18}\text{O}$ - δD analyses of calcite fluid inclusions (FI), reveals meteoric water infiltration into the aquifer, marking the timing of sea regression and onset of meteoric water infiltration.

Vertical tectonics commenced in the region during the early Miocene, causing initial cave uplift above the water table and deposition of first vadose speleothems around 20 Ma. The average uplift rate of the western DSR margin was approximately 26 m per million years, increasing to 120 m per million years from 6 Ma to present. This change appears related to a shift of several degrees in the previously parallel sinistral strike-slip movement of the Dead Sea Transform, introducing an extensional component and causing pull-apart basin development.

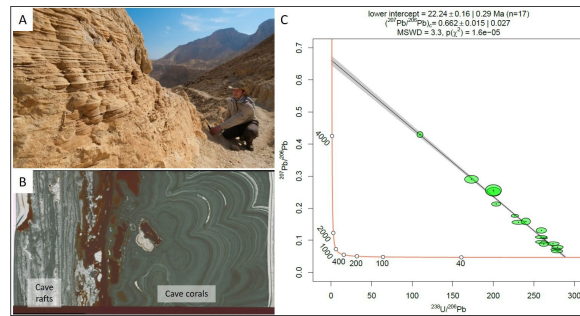


Figure title: A – Outcrop of phreatic calcite in the Arugot Canyon side showing the marks of groundwater levels. Preliminary results of this calcite show an age of ~300 ka, similar to phreatic calcite at the same altitude on the opposite side of the canyon. B – Thin section of phreatic calcite (cave rafts, left) and vadose calcite (cave corals, right) from a site near the water divide on the Dead Sea Rift's western side. The cave rafts show ages of 24.5 ± 0.5 Ma to 22.0 ± 0.2 Ma, while cave corals show younger ages of 9.3 ± 0.5 Ma to 5.4 ± 0.2 Ma. C – U-Pb dating isochron on Terra Wasserburg diagram. Results of one of the analysis done on the cave rafts presented in B left side.