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# Episodic fault permeability in the SW Atlantic passive margin revealed by in situ U-Pb dating of antitaxial calcite veins

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Fluids govern chemical transport and mechanical weakening in the lithosphere, yet the ability of intraplate faults to sustain transient permeability over geological timescales remains unresolved. This uncertainty is particularly acute along passive margins, where low-strain settings commonly preserve limited direct records of fracture-controlled fluid flow and element mobility. Resolving the temporal behaviour of such systems is therefore critical for understanding fluid redistribution in stabilized continental lithosphere. Here we integrate in situ carbonate U-Pb geochronology, cathodoluminescence (CL) petrography, and stable isotope data ($\delta^{13}C$-$\delta^{18}O$) to reconstruct the evolution of a fault-hosted calcite vein in the Permian Irati Formation, Paraná Basin (SW Atlantic margin). Petrographic and CL observations reveal well-developed antitaxial fibrous calcite with curved fibres and micron-scale growth banding consistent with incremental fracture opening and sealing. U-Pb analyses define discrete crystallization pulses at ~75 Ma, ~40 Ma, and ~18 Ma, demonstrating repeated Cenozoic reactivation of inherited basement-controlled structures. Systematic CL banding and rimward enrichment in U and $\delta^{13}C$ are consistent with Rayleigh-type progressive element redistribution within a chemically evolving, hydrodynamically restricted fluid reservoir during vein growth. The integrated textural, geochemical, and geochronological dataset supports diffusion-dominated reactive transport in which fracture opening was episodic and rapidly sealed, limiting sustained advective flushing while promoting incremental chemical evolution of trapped fluids. These results indicate that intraplate faults along the SW Atlantic margin experienced episodically renewed permeability over >50 Myr, highlighting the capacity of passive-margin fault systems to repeatedly localize fluid flow despite predominantly restricted hydrodynamic conditions during individual growth events. Our findings demonstrate how carbonate petrochronology can directly resolve the coupling between fluid chemistry, fracture dynamics, and long-term lithospheric evolution in passive-margin settings.

Figure 1. Geological and structural framework of the studied veins hosted in the Irati Formation within the Jiboia Structure (Paraná Basin), showing major faults and sample location along the Tietê Lineament. This intracontinental setting records deformation associated with SW Atlantic passive-margin reactivation during the Cenozoic.

Figure 2. Cathodoluminescence and petrographic characterization of the PAMf-3 vein. (a) CL image showing banded growth; (b) interpreted age domains; (c) sheared fibre microstructure; (d–f) Tera–Wasserburg plots defining U-Pb ages of individual growth domains.

Figure 1

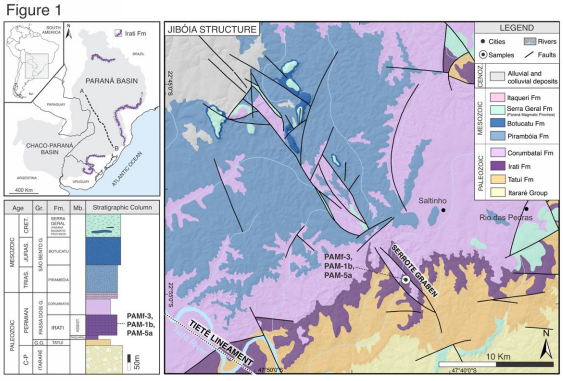


Figure 2

