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Living Ophiolites: Dynamic Carbon Cycling and Catalytic Abiotic Gas Generation on 10^4-Year Timescales

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The generation and migration of hydrogen and methane in serpentinizing environments have fundamental implications for deep carbon cycling, the origin of life, and emerging carbon-free energy resources. Here we present an integrated geochemical study of gas emissions from the Bulqizë chromite mine in Albania, where underground access to depths exceeding 1000 m enables direct investigation of one of Earth's most intense natural hydrogen systems (~200 tonnes H_2/year- Truche et al., 2024, 2025).

Through comprehensive analysis of bulk and clumped isotopes, noble gases, molecular compositions, and structural controls, we report the first occurrence of radiocarbon-bearing methane (3.76 ±0.06 pMC; ~26 ka) in any ophiolite globally. Although no direct liquid water discharge was observed, pervasive salt efflorescence and moisture along draining fractures testify to active gas and fluid seepage from depth. Methane clumped isotopes indicate disequilibrium with H_2 and suggest formation from a single hydrogen source, with a microbial origin probability below 10%. High $\delta^{13}C$-CH_4 values (−12.3‰), complete isotopic reversal in C_2–C_4 alkanes, and volatile organic compound signatures further support predominantly abiotic synthesis. Noble gas and nitrogen isotopes reveal mixing between atmospheric (80–85%) and crustal (15–20%) components, confirming an open system with active recharge.

Strikingly, gas emissions are structurally controlled and occur exclusively along a major fault zone intersecting the chromitite ore body. Fe-Ni alloys and platinum group elements in chromitite appear to catalyze CO_2 reduction to methane at temperatures well below those required for uncatalyzed abiotic synthesis, sustaining extraordinary gas fluxes unexplained by conventional models.

Our findings transform understanding of ophiolitic gas systems from fossil reservoirs to dynamic features cycling carbon on 10^4-year timescales. Chromitite emerges as a key catalyst and exploration target throughout the global ophiolite belt, establishing ophiolites as active participants in the contemporary carbon cycle and offering a new paradigm for natural hydrogen generation.

Truche, L., et al. (2024). A deep reservoir for hydrogen drives intense degassing in the Bulqizë ophiolite. *Science*, *383*(6683), 618-621.

Truche, L. et al. (2025). A dynamic H_2 system with multi-source methane in chromitite-rich ophiolitic settings. *GCA,* 409, 281-307.

