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Natural hydrogen generation preserved for >300 Myr in podiform chromitite damage zones of supra-subduction-zone ophiolites

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Natural hydrogen (H_2) exploration increasingly targets ophiolitic terranes, yet a key paradox remains: how do ultramafic complexes hundreds of millions of years old still sustain substantial H_2 fluxes? Here we show that, in supra-subduction-zone (SSZ) ophiolites, podiform chromitites and their damage zones can maintain both catalytic surfaces and fluid pathways that keep serpentinization and H_2 generation active at near-ambient temperature over geological timescales.

We compare two chromitite-bearing SSZ ophiolites separated by ~200 Myr: the Paleozoic Kempirsay massif (Ural Mountains, Kazakhstan; 250–400 Ma) and the Jurassic Bulqizë ophiolite (Albania; 160–165 Ma). Despite this age contrast, both systems display a consistent geochemical signature: H_2-rich gas seeps (>80–90 vol% H_2) with nearly identical hydrogen isotope compositions (δD = −743 to −766‰ VSMOW), spatially restricted to podiform chromitite bodies. At Kempirsay, Soviet experimental work, largely overlooked in the Western literature, indicates H_2 production from Fe-bearing minerals at 17–24°C. At Bulqizë, new radiocarbon data on associated methane (3.76 ± 0.06 pMC; apparent age ~26 kyr) demonstrate renewal of the CH_4–H_2 inventory on 10^4-year timescales, ruling out release of ancient fossil gas.

We propose a coupled catalytic–hydraulic model. Mechanically stiff chromitite inclusions concentrate fracturing in the surrounding peridotite–serpentinite matrix, sustaining permeability for meteoric-water infiltration and gas migration. Fresh dunite and harzburgite surrounding chromitite ore bodies supply the Fe^{2+} required for H_2 generation, while spinel/chromite surfaces, magnetite, and PGE phases catalyze water reduction and Fischer-Tropsch-type reactions generating the observed CH_4. In SSZ ophiolites, serpentinized, permeable corridors can periodically reconnect thick panels of weakly hydrated, chromitite-bearing harzburgite–dunite to meteoric fluids via reactivated fault networks, preserving large volumes of reactive peridotite for hundreds of millions of years.

Together, these results identify chromitite-bearing SSZ ophiolites as long-lived, low-temperature H_2 systems and highlight podiform chromitite damage zones as priority targets for natural hydrogen exploration worldwide (Fig. 1).

References: Truche et al., 2024 (Science); Truche et al., 2025; Devirtz et al., 1992; Lidin et al., 1982; Mayhew et al., 2013.

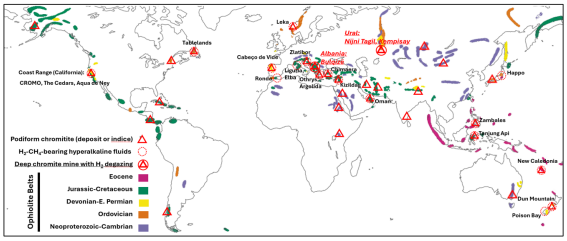

Figure 1. Global distribution of chromitite-bearing SSZ ophiolites with H_2–CH_4-rich fluids, modified after Vaughan & Scarrow (2003). From Donzé & Truche, submitted to Geochemical Perspectives Letters, 2026.