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Hidden fluxes of deep energy sources at convergent margins

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The availability of energy sources is a primary requirement for habitable environments. While surface life thrives on photosynthesis, microbial communities in dark and extreme regions of Earth are nourished by deep geologic volatiles stemming from fluid-rock interactions, such as abiotic CH_4 and H_2. Substantial volumes of these volatiles can be stored inside pressurized fluid inclusions (FIs) in crustal and mantle rocks. Their release in near-subsurface environments has been shown to generate fluxes capable to sustain microbial life in hydrothermal systems[1]. Despite the widespread documentation of CH_4-H_2-rich FIs in diverse crustal and mantle rocks exhumed from great depths, the role of FI release deeper in the lithosphere remains unexplored, notwithstanding its potential to support a vast and significantly deeper biosphere.

We combined FI petrographic-spectroscopic characterization with bulk CH_4 concentration and isotopic measurement from 102 crustal, mantle, and metasomatic rock samples exhumed from subduction zones over the Phanerozoic. These rocks recorded multiple events of CH_4-H_2 "catch and release" during FI entrapment in minerals and their successive release via metamorphic or metasomatic mineral reactions (e.g. serpentinization of ultramafic rocks and retrogression of metamafic rocks). During exhumation, this mechanism transferred 10^{-4} – 10^{-1} m^3_{STP} of CH_4 and 10^{-5} – 10^{-2} m^3_{STP} of H_2 per m^3 of rock from deep subduction zones to shallower, potentially life-supporting environments.

These CH_4 storage-release potentials align with values reported for shallower crustal and mantle rocks at mid-ocean ridges[1]. Therefore, when rates of mineral transformation and FI release in deep rocks equate those of shallow hydrothermal systems[2], the resulting CH_4-H_2 fluxes in the deep Earth could be comparable to those fuelling near-subsurface microbial communities. Major lithospheric discontinuities – most notably the slab-mantle interface[3] and crustal shear zones[4,5] – act as preferential pathways for the focused and protracted[3] migration of deep CH_4-H_2, delivering critical energy sources from the deep Earth toward habitable environments.

References

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