Goldschmidt 2026 Abstract
https://doi.org/10.46427/gold2026.35663

Estimating the radiolytic-driven habitability and economic potential of the continental crust

OLIVER WARR[1], PETER HIGGINS[2,3] AND BARBARA SHERWOOD LOLLAR[3,4]

[1]University of Ottawa
[2]Harvard University
[3]University of Toronto
[4]Institut de Physique du Globe de Paris, Université Paris Cité

Natural decay of radioelements such as U, Th and K in the crust produce economic elements (e.g. helium) and drive radiolytic production of geochemical components such as hydrogen (H_2) and sulfate (SO_4^2) which can support chemosynthetic life in the Earth's continental crust (1-2). Habitability models based on these processes have become a common feature of planetary and astrobiological mission planning on other planets and moons in the solar system (3). However, no study has attempted to estimate the total autotrophic chemolithotrophic biomass that radiolysis might potentially support on our home planet, or incorporate the physico-chemical parameters controlling helium production.

This study addresses this gap by applying a Monte Carlo-based approach which incorporates geochemical and geological parameters to evaluate crustal habitability and helium resource production (4). This approach demonstrates that radiolysis may support as much as 10^5-10^6 cells/L of in situ sulfate reducers in crustal fluids – comparable to biomass ranges observed in the deep biosphere (5). These results indicate that in hydrogeologically isolated settings, radiolysis might be a primary bio-sustaining process and may be capable of supporting a global biosphere over geological timescales without photosynthetic primary production, with direct implications for the search for life on other rocky worlds.

Radiogenic ^{4}He (and ^{40}Ar) are co-produced with H_2 during radiolysis, and are key economic resources required to meet society's pressing needs for the green energy transition. The Monte Carlo approach can identify areas and regions with localized high source rock potential for these resources. They can therefore be applied as a key exploration tool alongside evaluating migration rates and trapping efficiency. Overall, the approach can evaluate the expected potential for a region to generate an economic-grade reservoir of ^{4}He, and the timescales needed to get that, information which is urgently needed to develop successful exploration strategies to meet future societal needs.

[1]Lin, L-H, et al. Geochemistry, Geophys. Geosystems 6, 7 (2005).

[2]Li, L., et al. Nat. Commun. 7, 13252 (2016).

[3]An Astrobiology Strategy for the Search for Life in the Universe. (2019).

[4]Warr, O. *et al*. Front. Earth Sci. 11, 387 (2023).

[5]Templeton, A & Caro, T. AREPS, 51, 493–519 (2023).