

PROCEEDINGS

Temperature-Dependent Hydraulic Fracturing and Reaction-Induced Crack Growth in Peridotite for Activated Natural Hydrogen Generation

Yunzhi Yue¹, Jiacheng Dai^{2*}, Chi Xu¹, Zhijie Ding², Zongying Wang², and Shouceng Tian²

¹National Key Laboratory of Petroleum Resources and Engineering, China University of Petroleum (Beijing), Changping, Beijing, 102249, China

²Karamay Branch of National Key Laboratory of Petroleum Resources and Engineering, Karamay Campus, China University of Petroleum (Beijing), Karamay, Xinjiang, 834000, China

*Corresponding Author: Jiacheng Dai. Email: daijc@cupk.edu.cn

ABSTRACT

Serpentinization of peridotite is an important geological process for natural hydrogen generation, but its efficiency is restricted by the low permeability of ultramafic rocks and the limited connectivity of natural fractures. Water must access reactive mineral surfaces, while generated hydrogen also requires connected pathways for migration and release. Therefore, hydraulic fracturing may activate tight peridotite by creating initial conductive fractures before subsequent water–rock reactions. In this study, true triaxial hydraulic fracturing experiments and a two-dimensional reaction-induced expansion model were combined to investigate fracture activation and post-fracturing crack evolution in peridotite. Cubic peridotite specimens with a central borehole were hydraulically fractured using water at 25 °C and 80 °C to compare the effects of temperature on pressure response, breakdown behavior, fracture geometry, and initial flow-channel formation. In the numerical model, the hydraulically generated conductive fracture was treated as the dominant seepage pathway, while reaction-induced volume expansion around reactive zones and pore-pressure accumulation associated with hydrogen generation were introduced to analyze secondary crack initiation and propagation. Three post-fracturing scenarios were compared: reaction expansion in intact peridotite, reaction expansion affected by a hydraulically induced conductive fracture, and reaction expansion coupled with gas-pressure accumulation. The results show that water-based hydraulic fracturing can activate tight peridotite under both temperature conditions, and temperature variation changes the pressurization process, breakdown response, and fracture propagation pattern. The generated hydraulic fractures provide access pathways for water invasion and create favorable structural conditions for subsequent reaction-induced alteration. Meanwhile, reaction expansion in intact peridotite mainly produces localized radial cracks around reactive zones, which are difficult to connect into an effective fracture network. When a hydraulically induced conductive fracture is present, secondary cracks tend to deflect toward and connect with the main fracture, indicating that the initial hydraulic fracture can guide later reaction-induced crack growth. Additional gas-pressure accumulation enhances local tensile stress and damage zones, thereby improving crack connectivity and potential flow capacity. Overall, temperature-dependent hydraulic fracturing controls the initial fracture framework, while reaction-induced expansion and gas pressure further promote post-fracturing crack growth. Their coupling may increase reactive surface area, improve fluid migration pathways, and support artificial activation of natural hydrogen generation in ultramafic rocks.

KEYWORDS

Peridotite; natural hydrogen; hydraulic fracturing; reaction-induced expansion

Acknowledgement: The authors would like to thank the laboratory staff and colleagues for their assistance with sample preparation and hydraulic fracturing experiments.



Copyright © 2026 The Author(s). Published by Tech Science Press.

This work is licensed under a Creative Commons Attribution 4.0 International License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Funding Statement: This work was supported by the 2025 Postdoctoral Innovative Talent Support Program, “Study on the Mechanism of Spontaneous Fracturing and Permeability Enhancement in Peridotite Induced by Hydrogen-Generating Reactions” (Grant No. BX20250029), the Youth Science Fund of the Natural Science Foundation of Xinjiang Uygur Autonomous Region, “Natural Hydrogen Generation and Migration Mechanisms in Peridotite under Spontaneous Fracturing” (Grant No. 2025D01B202), and the Xinjiang Science and Technology Frontier Talent Support Program, “Research on Natural Hydrogen Accumulation Mechanisms and Key Technologies for Exploration and Development” (Grant No. XJRC-2025-KJ-KJQY-003).

Conflicts of Interest: The authors declare no conflicts of interest to report regarding the present study.