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Crack Dynamics Propagation in the Fractured Geothermal Reservoir Under Thermo-Hydro-Mechanical-Chemical Coupling

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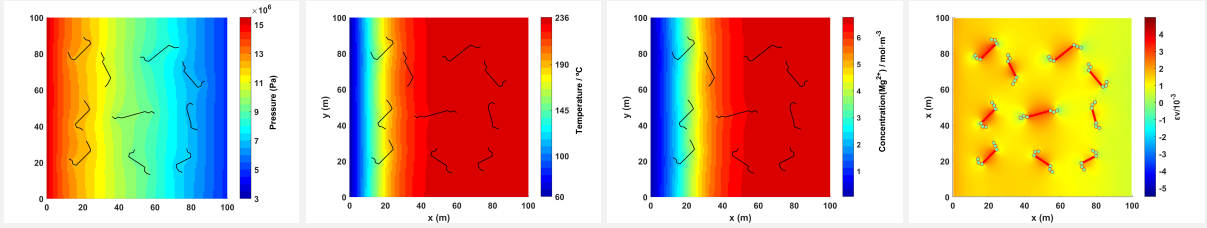
ABSTRACT

As climate change accelerates due to fossil fuel use, geothermal energy emerges as an indispensable renewable solution 1. Hot dry rock (HDR) reservoirs, accounting for more than 90% of total geothermal resources 2, have gained wide attention worldwide for their abundant reserves, wide distribution, and carbon-free, stable, and efficient supply characteristics 3. While HDR geothermal energy offers significant potential, its development faces challenges, including the complex interaction between fluid flow, heat transfer, reactive solute transport, and the rock's mechanical processes, referred to as the THMC coupling process 4. Cracks, ubiquitous in HDR geothermal reservoirs, exhibit complex behaviors, complicating the assessment, prediction, and control of these features during geothermal energy extraction 5. Despite recent advances in modeling THMC coupling processes, a comprehensive approach to accurately representing the morphological changes of cracks in HDR geothermal reservoirs under THMC conditions is still lacking, especially at the reservoir field scale. To overcome this scientific challenge, this work extends the THMC coupling model by Han et al. 6 to incorporate crack dynamics propagation. This approach utilizes a coupled XFEM-EDFM scheme, which employs a separate crack mesh embedded within a background rock matrix mesh. Then, a domain-integral method (J integral) is applied to compute the equivalent stress intensity factor (SIF) criterion, which is subsequently used to govern both the onset and dynamics of crack propagation. The distribution fields of pressure, temperature, concentration, and crack growth after 1000 days of heat extraction in the HDR reservoir are illustrated in Figure 1. The results demonstrate that variations in pressure, temperature, and reactive solute transportation significantly contribute to crack growth in the reservoir during long-term heat extraction. This model can be utilized to analyze crack dynamics propagation under THMC coupling conditions and to assess the impact of interactions between THMC processes and crack propagation on heat extraction in deep geothermal systems.



(a) Pressure (b) Temperature (c) Concentration (d) Bulk strain

Figure 1. Multi-field distribution in an HDR reservoir after 1000 days of heat extraction

KEYWORDS

Fractured reservoir; hot dry rock; thermo-hydro-chemical-mechanical coupling; embedded discrete fracture model; fracture dynamics propagation

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