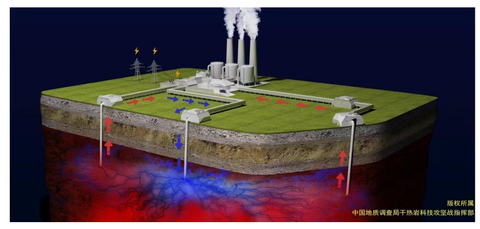
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Geostress Characteristics And Fault Slip Tendency Of Hot Dry Rock Reservoir In Gonghe Basin, Northwest China

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INTRODUCTION

Enhanced Geothermal Systems (EGS) are an effective method for developing hot dry rock geothermal resources, which involves injecting high-pressure fluid into the reservoir to create fracture networks, thereby enhancing reservoir permeability. However, high-pressure fluid injection can induce fault activation and instability, leading to seismicity (Tester et al., 2006; Ellsworth, 2013).

The in-situ stress state of a reservoir provides fundamental data for assessing induced seismicity risks in hot dry rock (HDR) development, directly determining the initial stability of pre-existing faults and indirectly influencing the perturbation effects of injection-induced fault instability (Feng et al., 2022). In practice, constraints such as testing conditions often limit extensive in-situ stress measurements. Furthermore, numerical simulations of 3D stress fields frequently yield inaccurate results due to an insufficient consideration of influencing factors and parameters; for instance, improperly accounting for the Poisson effect can introduce initial displacements that are challenging to eliminate (Wang et al., 2008).

Based on geological data from the study area, this study employs numerical simulation and focal mechanism solution inversion to characterize the in-situ stress field distribution in the Gonghe GR2 geothermal well. Using the Mohr-Coulomb failure criterion and Byerlee's law, combined with the classical hydrological model (Hsieh and Bredehoeft, 1981), this study provides a concise analysis and discussion on the activity of fractures near the geothermal well.

METHODS

Based on regional geological tectonic evolution, focal mechanism solution inversion, and in-situ stress measurement data, this study analyzed the characteristics of the regional strfield in the Gonghe Basin. Combined with the reservoir structure and lithological characteristics of the geothermal wells at the Gonghe EGS site, a three-dimensional model was established. Ut orthotropic elastic constitutive relations, three-dimensional in-situ stress data of the geothermal wells were obtained through finite element numerical simulation.

A probabilistic analysis method for fault slip instability, based on the Mohr-Coulomb criterion, is used to evaluate induced by water injection in HDR development (Zoback and Gorelick, 2012; Ellsworth, 2013). The Mohr-Coulomb failure criterion is given by Equation (1):

$$\begin{cases} \tau_s \gg \mu(\sigma_n - P_f) \\ P_f = P_0 + \Delta P \end{cases} \quad (1)$$

The relationship between the pore water pressure increase induced by fluid injection and injection parameters can be expressed by Equation (2) (Hsieh and Bredehoeft, 1981), referred to as the Hsieh-Bredehoeft hydrogeological model in subsequent analysis:

$$\begin{cases} T\left(\frac{\partial^2 \Delta h}{\partial x^2} + \frac{\partial^2 \Delta h}{\partial y^2}\right) \gg S\frac{\partial \Delta h}{\partial t} - Q(t)\delta(x)\delta(y) \\ \Delta P = r\Delta h \end{cases} \quad (2)$$

Where Δh is the pressure head increment induced by injection, *T* is the transmissivity of the reservoir, S is the storage coefficient of the reservoir, (x, y) is the location of the injection well, *Q*(t) is the injection rate, t is the injection time, and r is the unit weight of the fluid.

RESULTS

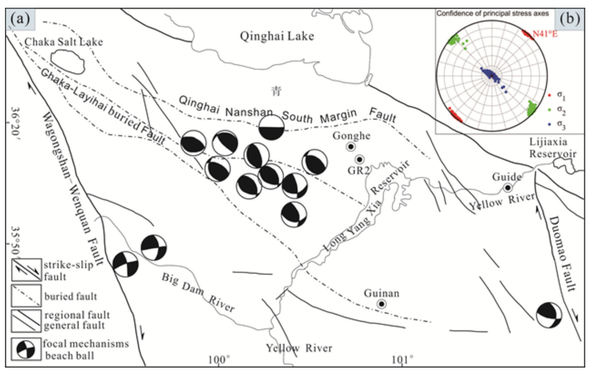


Figure 1. Seismic source dstribution map of gonghe Basin (a) and the focal mechanism synthesis solution(b)

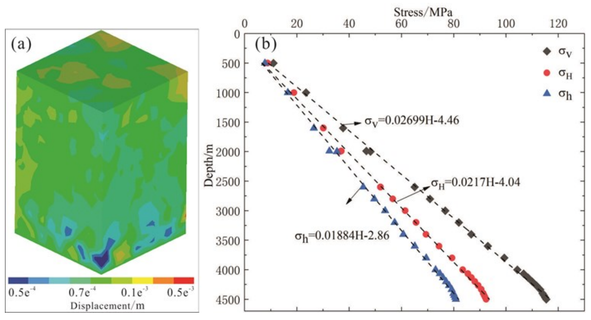


Figure 2. Seismic source distribution map of gonghe Basin (a) and the focal mechanism synthesis solution(b)

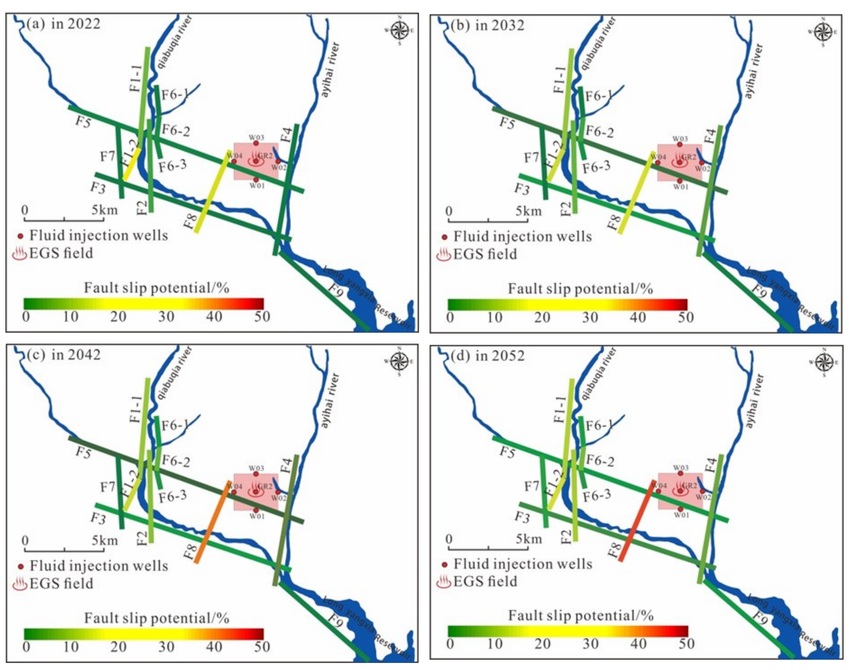


Figure 3. FSP for near-field faults induced by geothermal well injection ,(a) 2022,(b) 2032,(c) 2042,(d) 2042

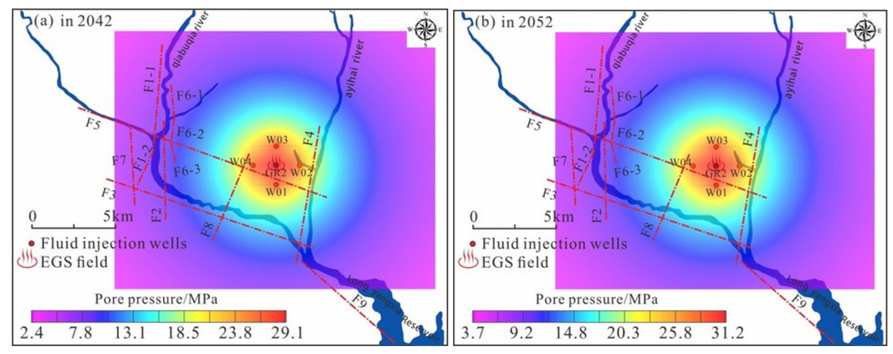


Figure 4. The result of excess pore water pressure caused by geothermal well water injection

Table 1. Probability of fault slip potential on the faults near the Gonghe EGS field.

Name	Sement	Strike(°)	Dip(°)	Probability of fault slip potential			
				in 2022	in 2032	in 2042	in 2052
F1	F1-1	3	52	6%	10%	12%	15%
	F1-2	22	52	20%	28%	32%	35%
F2	F2	358	58	3%	8%	10%	14%
F3	F3	288	63	0%	0%	0%	0%
F4	F4	10	80	1%	3%	4%	5%
F5	F5	290	88	0%	0%	0%	0%
F6	F6-1	352	73	0%	1%	2%	2%
	F6-2	4	73	2%	4%	5%	7%
	F6-3	345	73	0%	0%	0%	1%
F7	F7	356	75	0%	1%	1%	2%
F8	F8	24	65	18%	37%	42%	45%
F9	F9	312	70	0%	0%	0%	0%

DISCUSSION

As shown in Figure 4, the maximum excess pore water pressure caused by continuous injection in the deep geothermal well until 2040 and 2050 does not exceed29.1 and 31.2 MPa. Furthermore, the influence range of the pore water pressurebance caused by injection is approximately 5–15 km centered on the injection well, with the maximum excess pore water pressure occurring at the center of the injection well and decreasing radiy outward as the distance from the injection well increases.

The results(Fig 3) indicate that with the continuous injection of fluid, the probability FSP values of the NE, NNE and NWN-striking boundry faults (F1-1, F1-2, F2, Fb7, F8) will gradually increase; furthermore, the magnitude of FSP variation changes with fauland distance from the injection well. For example, the FSP values of F8, the closest to injection wells W03 and W04 (≤6 km) crease from 18% in 2022 to 45% in 2052, and those of F1-2 increase rom 20% in 2022 to 35% in 2052, indicating high activity; however, the FSP values on faults F3,F5 and F9 (NW and NWW strikes) are nearly zero, suggesting additional fault stability for NW and NWW-striking faults.

In practice, factors such as injection pressure, reservoir permeability, temperature changes, and hydration during injection can variably influence fault activation. As large-scale development of hot dry rock geothermal energy has not yet been implemented in the study area, and parameters from deep geothermal well testing are limited, this paper does not discuss the effects of injection pressure or temperature changes on injection-induced fault instability. These aspects will be prioritized in future research.

CONCLUSION

This study analyzed the characteristics of the regional stress field in the Gonghe Basin based on the inversion of focal mechanism solutions, obtained three-dimensional in-situ stress data for the GR2 geothermal well through numerical simulation, and investigated the impact of HDR water injection on fault slip tendency. The main conclusions are as follows:

(1)The simulated in-situ stress distribution agrees with theoretical values, with initial displacements effectively eliminated (below 10^{-3} m), allowing for a reliable prediction of the in-situ stress field characteristics within the well. For the GR2 well in the Gonghe Basin, within the depth range of 500–4500 m, the minimum horizontal principal stress ranges from 7.31 to 81.4 MPa, the maximum horizontal principal stress ranges from 8.4 to 93.16 MPa, and the vertical principal stress ranges from 10.4 to 117.4 MPa. The maximum horizontal principal stress direction in the Gonghe Basin is generally NE-oriented (NE41°).

(2)Within the depth range of 500–4500 m, the three principal stresses generally follow $\sigma_V > \sigma_H > \sigma_h$, indicating that the vertical stress dominates, horizontal tectonic forces are relatively weak, and the stress regime in this area favors normal faulting.

(3)Under an injection rate of 183 m^3/h, the total excess pore water pressure generated by continuous injection over 30 years does not exceed 31.2 MPa. This pressure disturbance is centered on the injection well, with an influence range not exceeding 10 km. The slip tendency for some faults under continuous injection exceeds 35% (reaching up to 45%), indicating a high activation risk that may lead to fault slip instability and induce earthquakes within the field, necessitating precautionary measures.

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REFERENCES < HEADING STYLE>

Ellsworth,L. Injection-induced earthquakes.Science.2013, 341(6142):1225942.
Hsieh,P,A., Bredehoeft,J,D. A reservoir of the Denver earthquakes:A case of induced seismicity[J]. Journal of Geophysical Research.1981, 86(B2): 903-920.
Jing,F., Sheng,Q., Zhang,Y., et al. Research on distribution rule of shallow crustal geostess in China mainland [J]. Chinese Journal of Rock Mechanics and Engineering. 2007, 26(10): 2056-2062.
Kim,K,H., Ree,J,H., Kim,Y., et al. Assessing whether the 2017 Mw5.4 Pohang earthquake in south Korea was an induced event[J].Science. 2018,360(6392):1007-1009.
Lee,K,K., Ellsworth,W,L., Giardini,D., et al. Man-aging injection-induced seismic risks.Science, 2019,364, 730-732.
Zoback,M,D., Gorelick,S,M. Earthquake triggering and large-scale geologic storage of carbon dioxide[J]. Proceedings of the National Academy of Sciences. 2012(26), 109,10164-10168.
Vavryčuk,V. Iterative joint inversion for stress and fault orientations from focal mechanisms[J]. Geophysical Journal International.2014,199:69-77.