



Stimulation of hydraulic permeability of fractured granite for enhanced geothermal system using mud acid



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Overview:

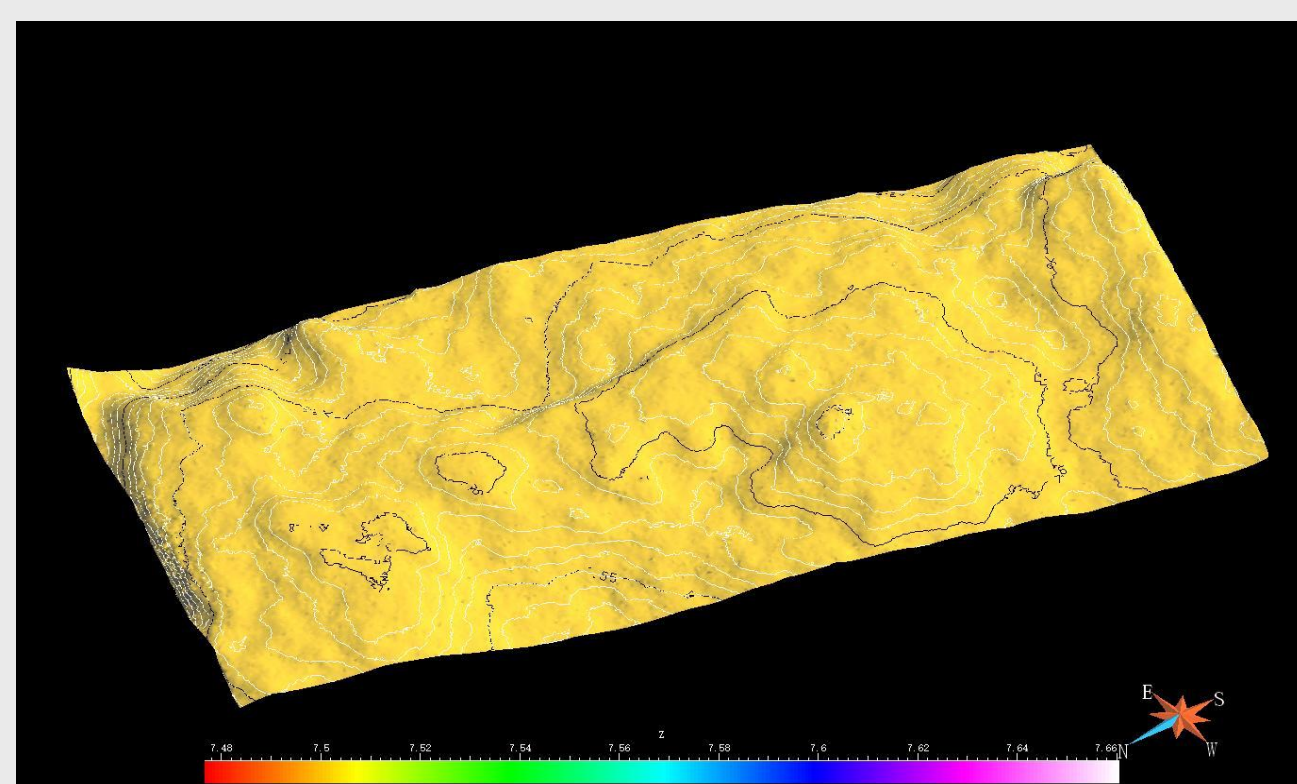
- A large-scale hot-dry-rock (HDR) geothermal field is confirmed in Gonghe basin of Qinghai province, China.
- The geothermal energy in HDR is generally exploited by enhanced geothermal system in which fracture networks is created by hydraulic fracturing.
- However, the created fractures can often closed due to very high geostress, resulting in extremely low hydraulic permeability.
- Stimulation strategies need to be conducted to improve the hydraulic properties in order to achieve a effective geothermal productivity.

Research objectives:

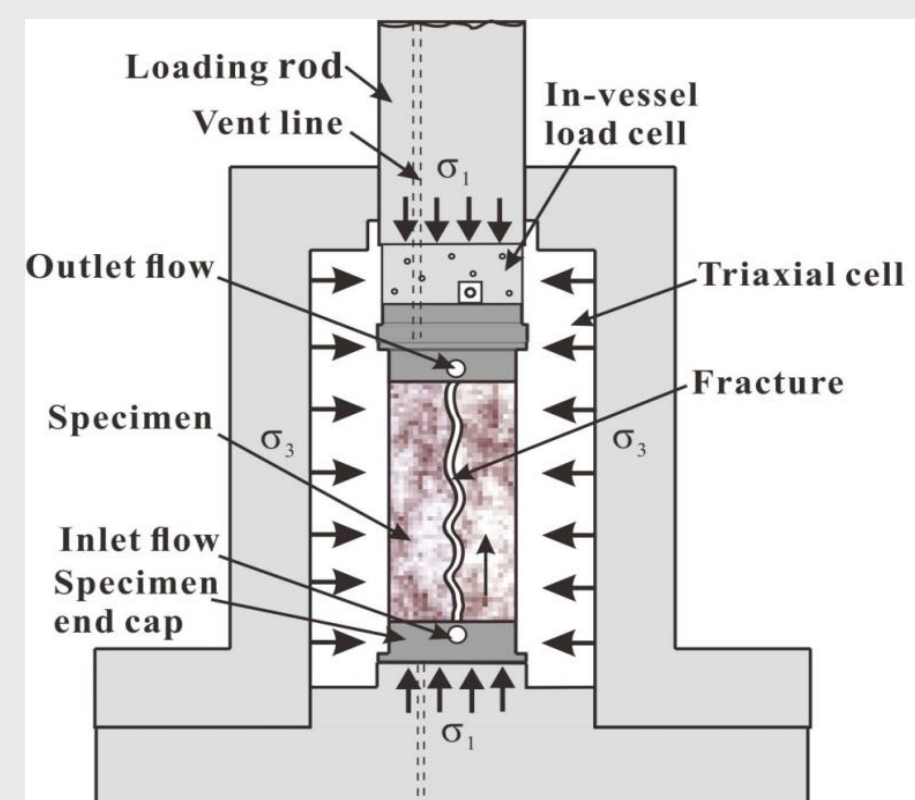
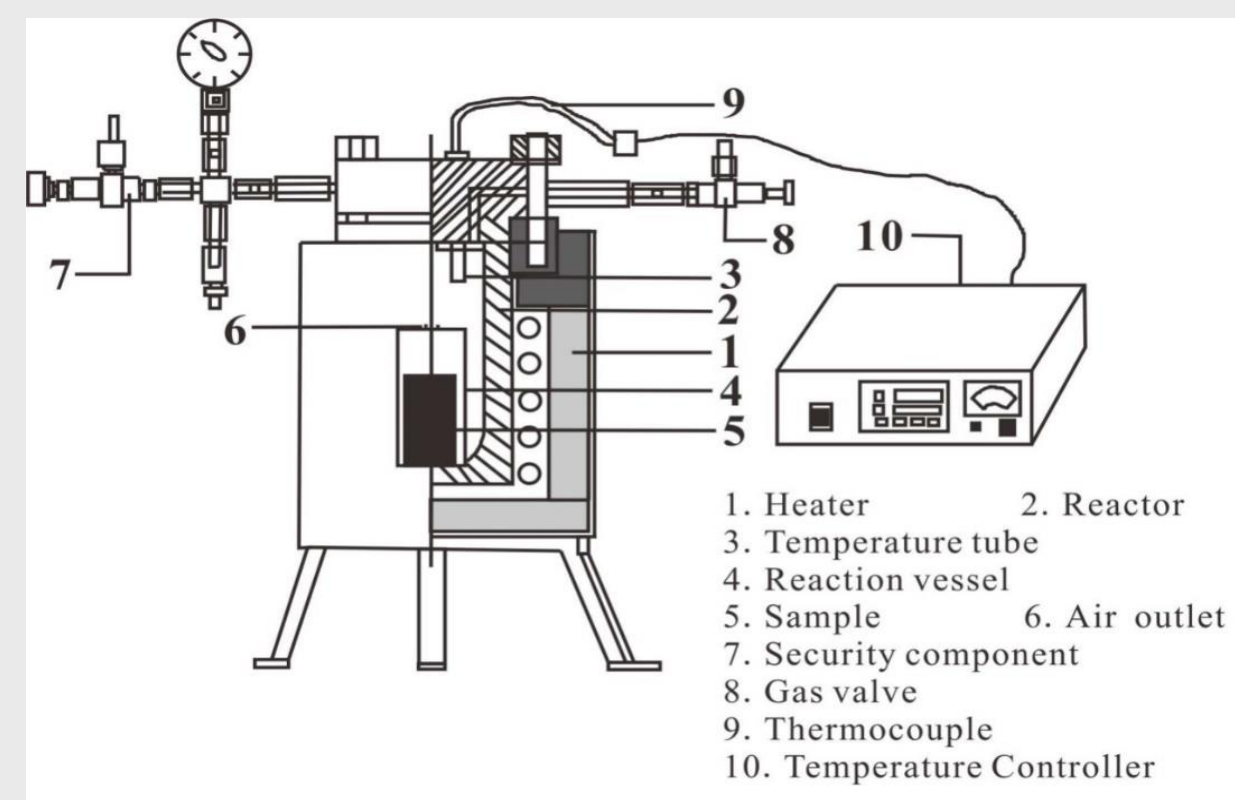
- Stimulation of hydraulic permeability of fractured granite using mud acid with different mixtures ratios.
- Optimization of chemical agent types, reaction temperature and time for instructing a practical application of EGS projects.
- Investigation of the mechanisms for the chemical reaction.
- Exam of the dissolution and precipitations.

Sampling and testing:

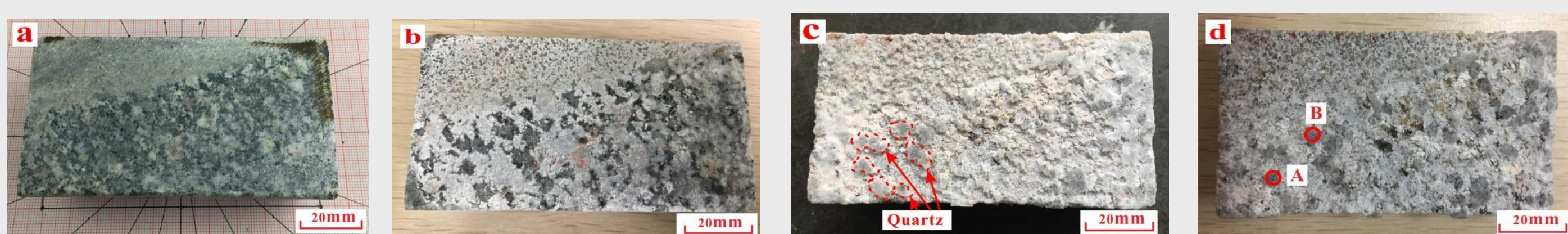
- Cutting the granite sample to cylindrically shaped with size of 50 mm diameter and 100 m length.
- Creating artificial fractures by using Mechanic Testing System (MTS).



- Put the samples under a container and inject chemical agents (mud acid) into the fracture
- Load the samples at the hydraulic devices for hydraulic testing



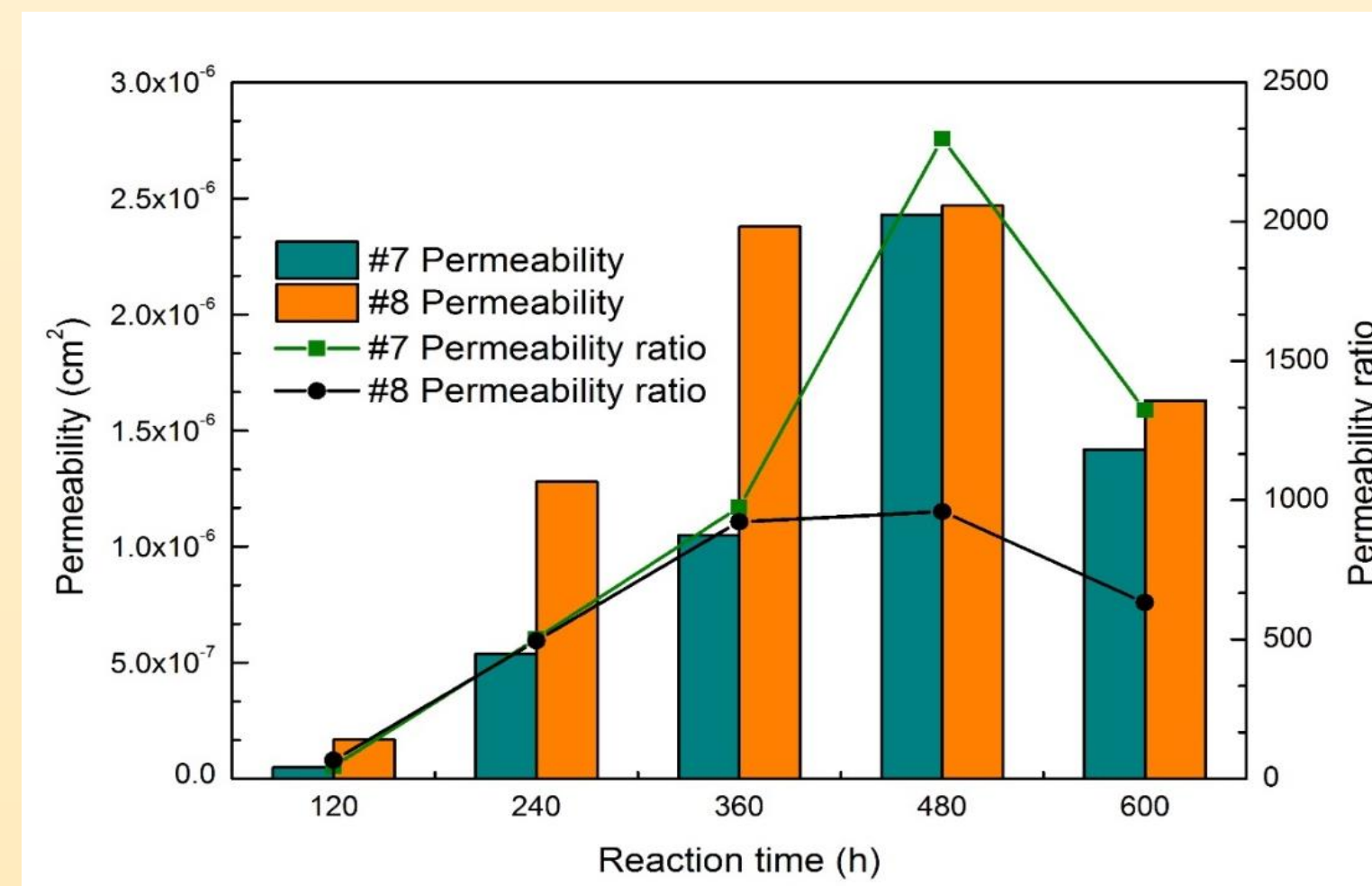
- The morphological changes of the fracture's surface is analyzed before and after the chemical reaction.
- Fluid is collected for the analysis of the dissolution and precipitation of the granite are identified using Energy Dispersive X-Ray Spectroscopy (EDX)
- Roughness change in surface



(a) Flat surface, (b) Starts the dissolution and precipitation, (c) Surface becomes rough, (d) Roughness of surface decreases to lower level with the stimulation going.

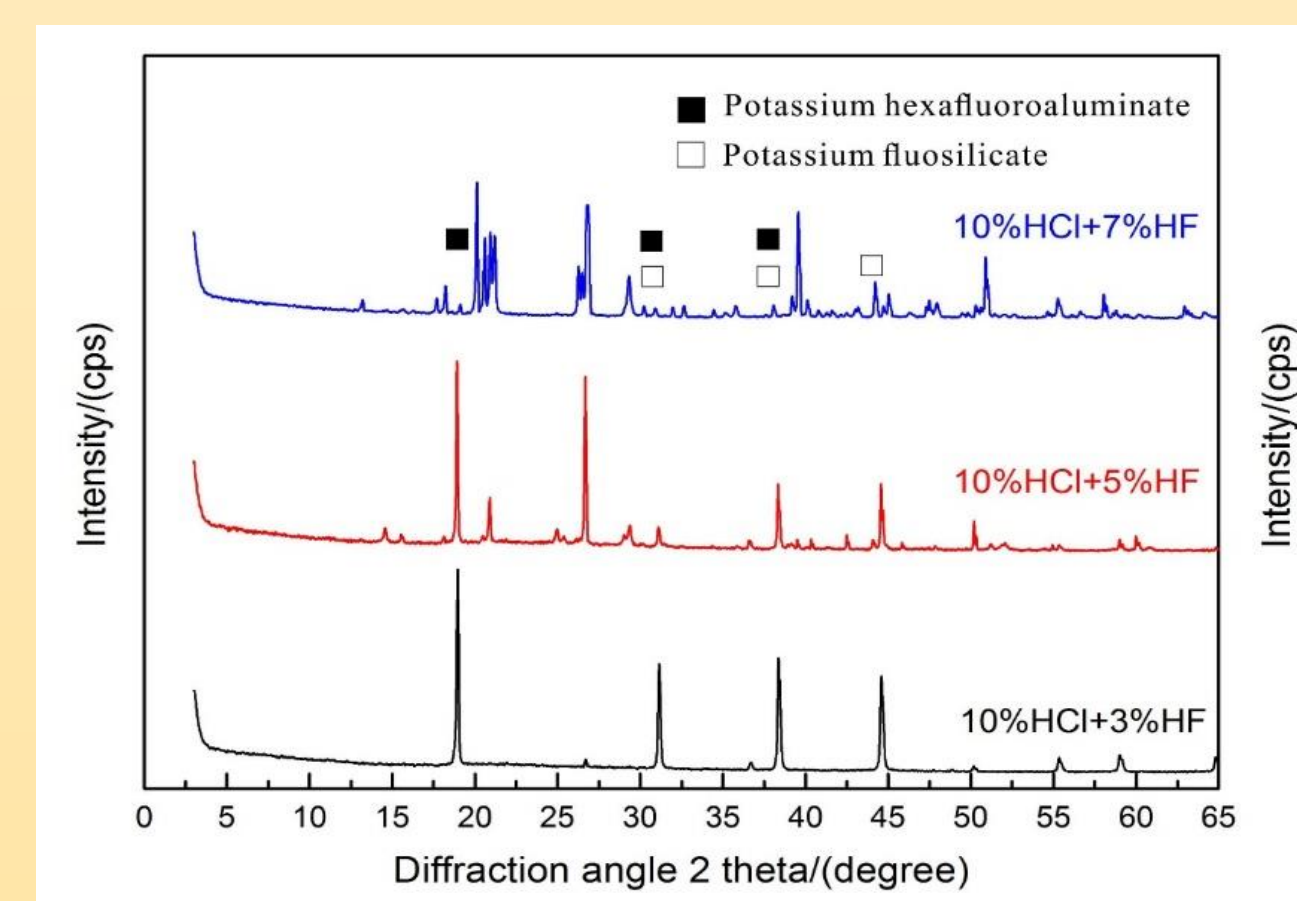
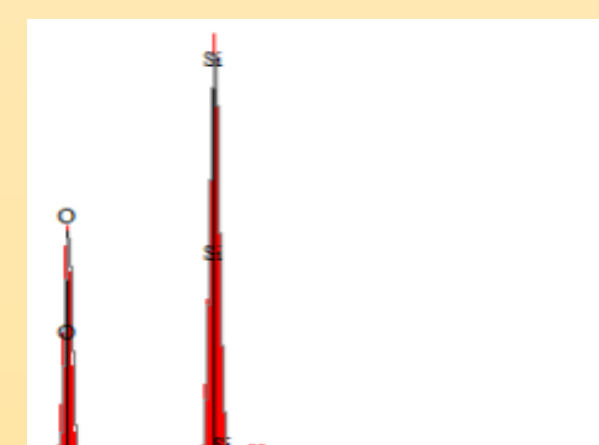
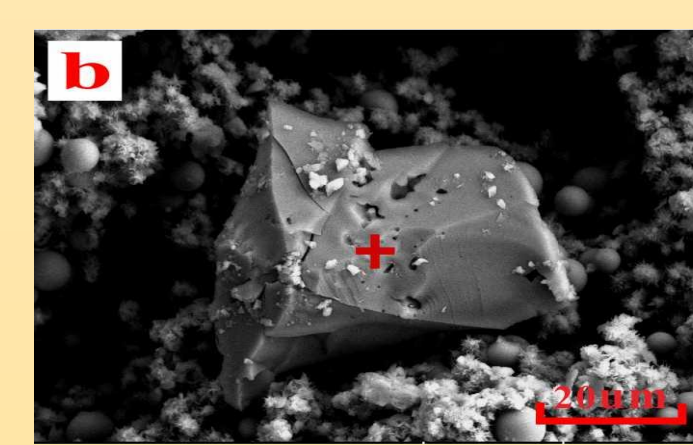
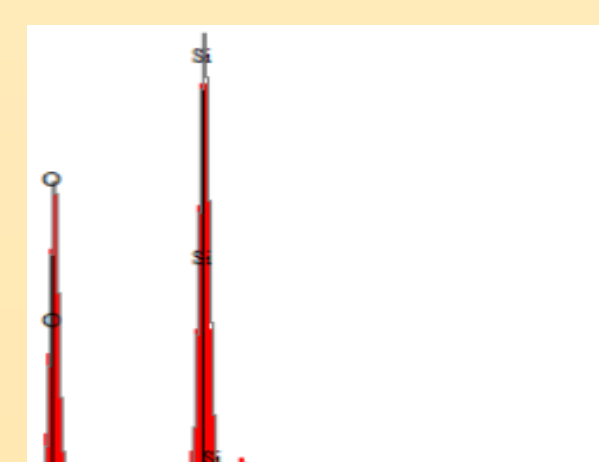
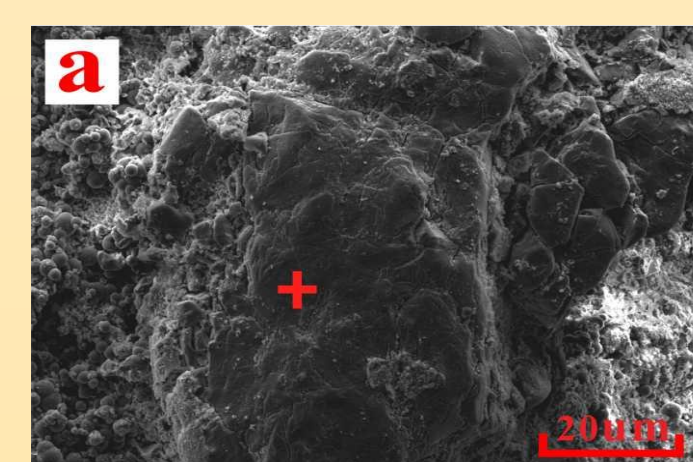
Results and discussion:

Permeability changes



- The hydraulic permeability of the fractures increase to reach a peak value and then decrease due to the morphological changes
- The optimized reaction duration for 480 h is determined for the chemical reaction
- The mud acid consisting of 12% HCl + 5% HF stimulate efficiently with the granite samples

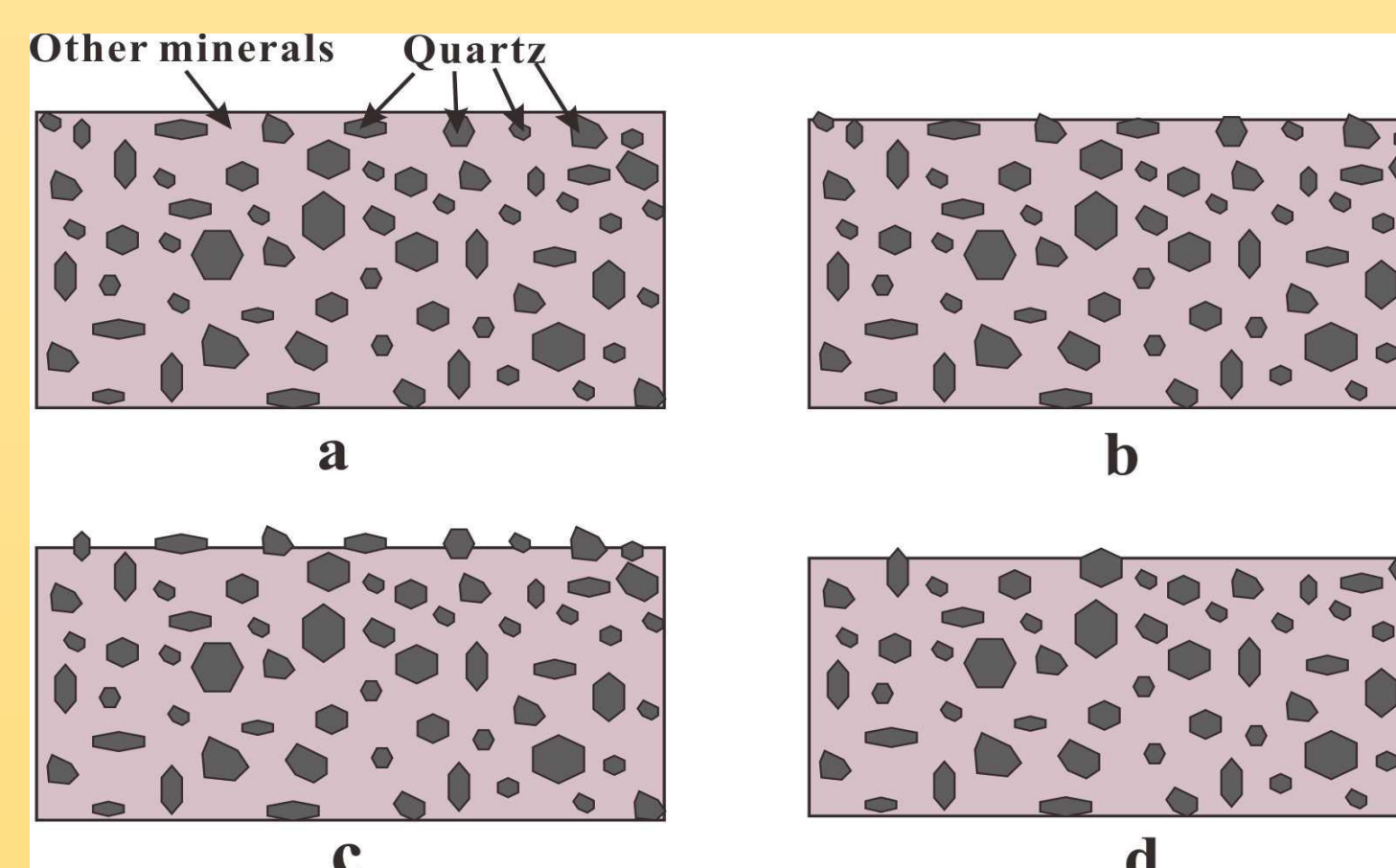
Mineral dissolution and precipitation



Particles on the surface are considered to be quartz according to the EDX (O and Si with ratios very close to 2 : 1)

Potassium fluorosilicate and potassium fluoroaluminate, typical minerals produced via the chemical reactions of HF with feldspar and biotite were identified.

Reaction process



- (a) The sample shows flat plane before chemical reaction.
- (b) The quartz starts to expose because the surrounding minerals are dissolved. In this stage, the hydraulic permeability increase with time as well.
- (c) With the stimulation continues, the quartz particles exposing proceeds. Consequently, the permeability reach a peak value.
- (d) Finally, the quartz particles fall from the samples with the reaction goes.

Major findings:

- Chemical type: The mud acid with a HF concentration of 5% stimulated the hydraulic properties of the fractured granite with highest efficiency.
- Reaction time: The dissolution of quartz is largely influenced by the reaction duration. The best reaction duration is 480 h and the permeability increases by 2297 times.
- Reaction dose: Considering the surface area of the fractures, 6.24-6.25 ml/cm² chemical stimulant per square centimeters (cm²) of the mixture of 10% HF and 5%HCl mud acid is needed to guarantee the effectiveness of chemical stimulation.
- Reaction mechanism: Compared to quartz, feldspar and biotite are more sensitively reacted with mud acid. Hence, the quartz could be used as proppant to support the opening of the fractures.

Acknowledgements:

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