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Experimental study of creep deformation of glauberite salt rock under compression and dissolution coupling effect

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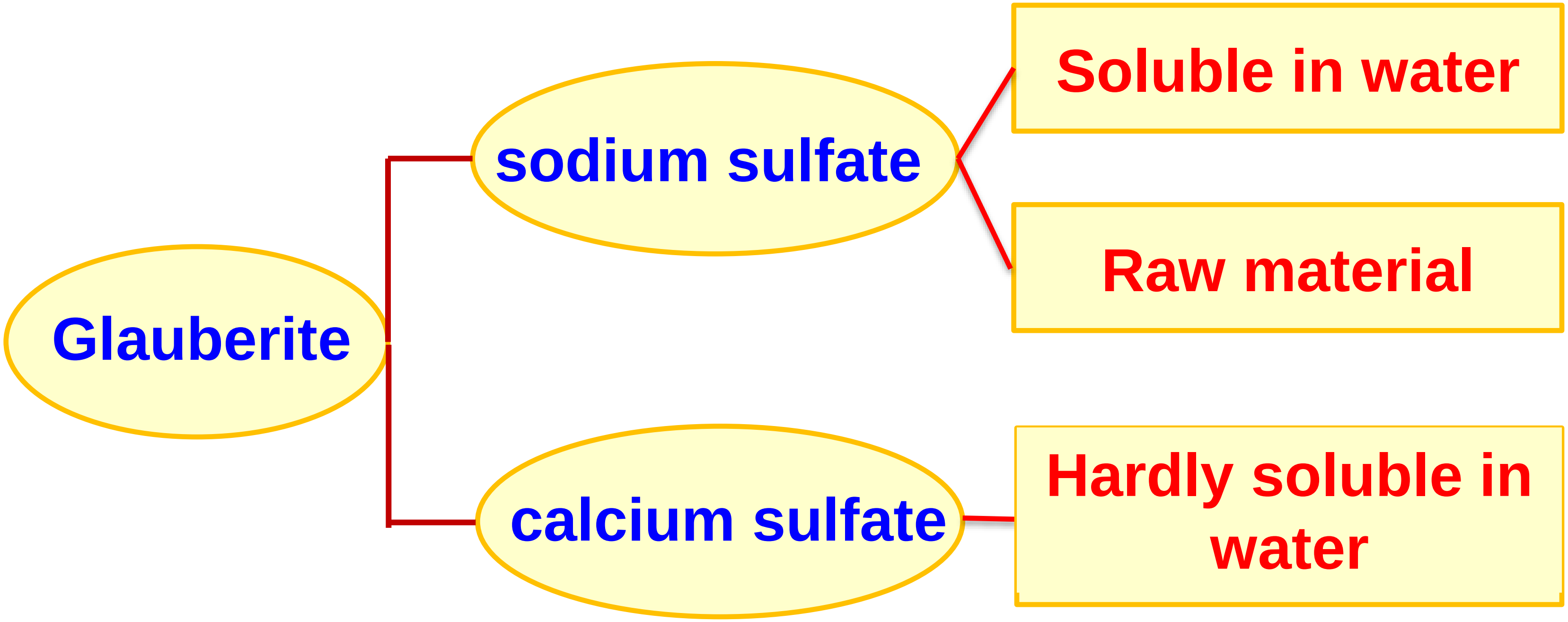
Report Outline

- Introduction
- Experiment and methods
- Results
- Discussion
- Conclusions

1.Introduction

- **Glauberite mainly consists of sodium sulfate and calcium sulfate, i.e., $Na_2Ca(SO_4)_2$, in an anhydrous state.**



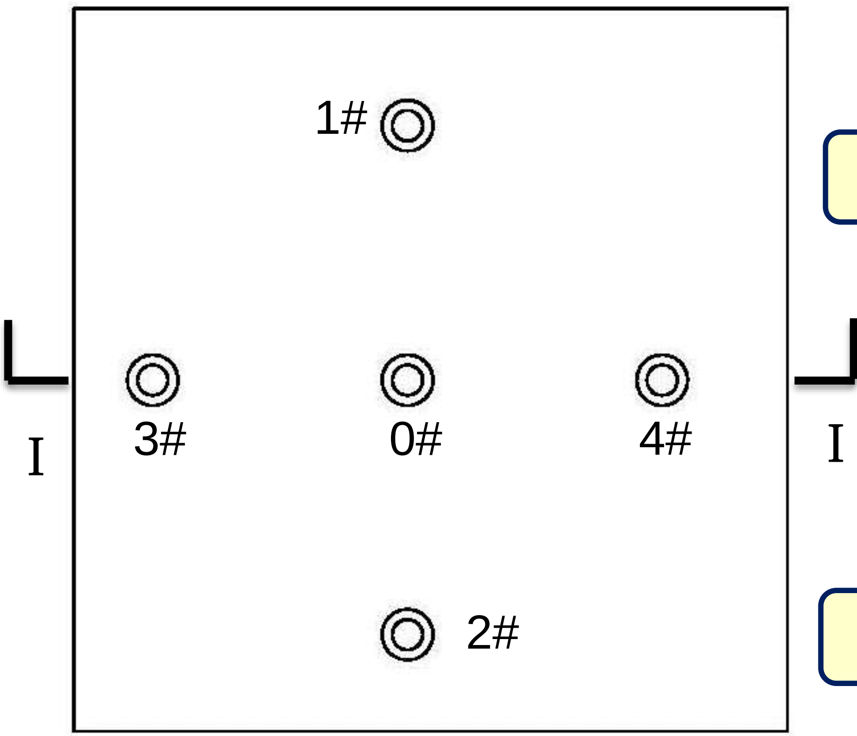
1.Introduction

China is rich in glauberite deposits, which could be alternative resource after glauber salt deposit being exhausted.

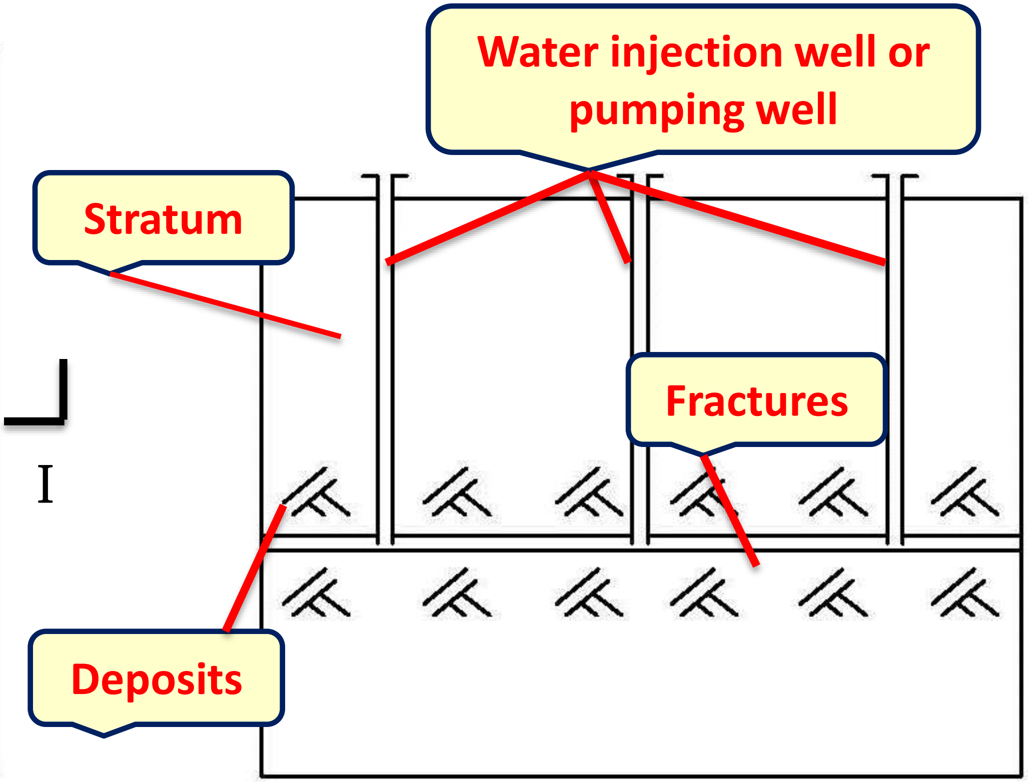
Distribution diagram of mirabilite resources in China

1.Introduction

Solution mining of glauberite salt rock on the surface (Pengshan, Sichuan Province)

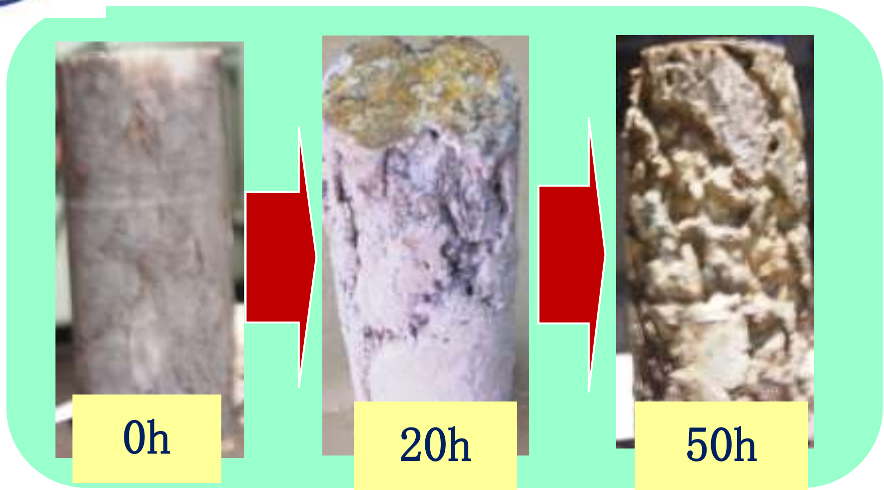


Drilling network diagram

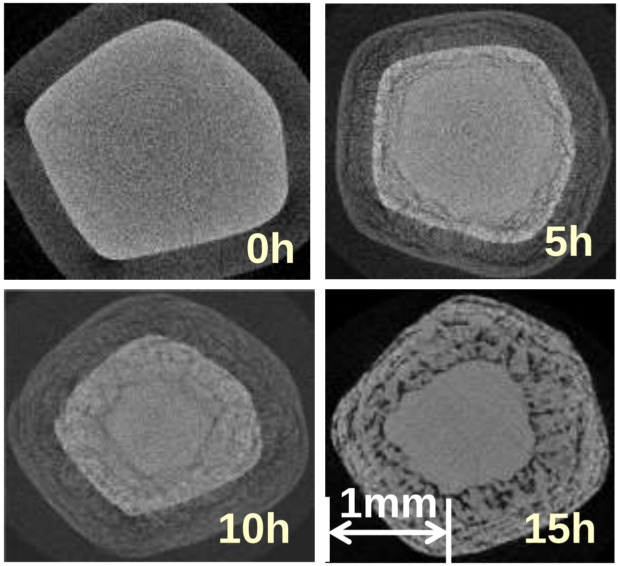


Ⅰ - Ⅰ profile chart

- Solution mining is a long-term process that takes several years to decades. This is a creep problem.
- The ore bodies are subjected to mineral dissolution and dynamic effective stresses.



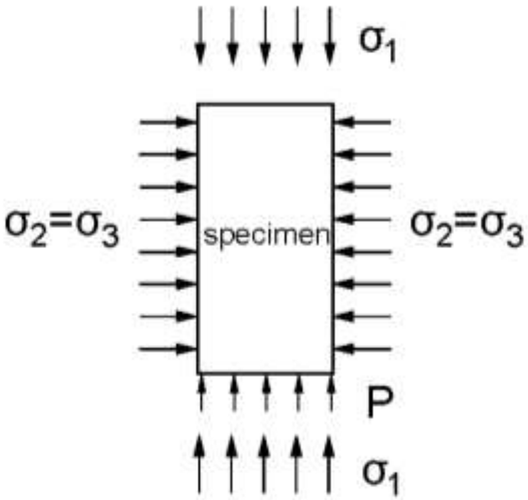
(*Transp. Porous Med, 2008,74(2):185-199)*



The results of micro computed tomography during the dissolution of glauberite

- **The in-situ solution mining process involves dissolution and erosion transforming glauberite salt rock from a dense rock into a porous medium.**
- **Glauberite creep deformation involves triaxial compression and dissolution coupled effect.**

2.Experiment and methods



The glauberite specimens(ϕ50×100mm) before and after testing

Tri-axial rock mechanics testing machine with multifunction

- The axial stress and circular confining pressure were 5.0 and 4.0 MPa, respectively.
- The infiltration pressures of fresh water of the specimens 1, 2, and 3 are 3.0, 2.0 and 1.0 MPa, respectively.

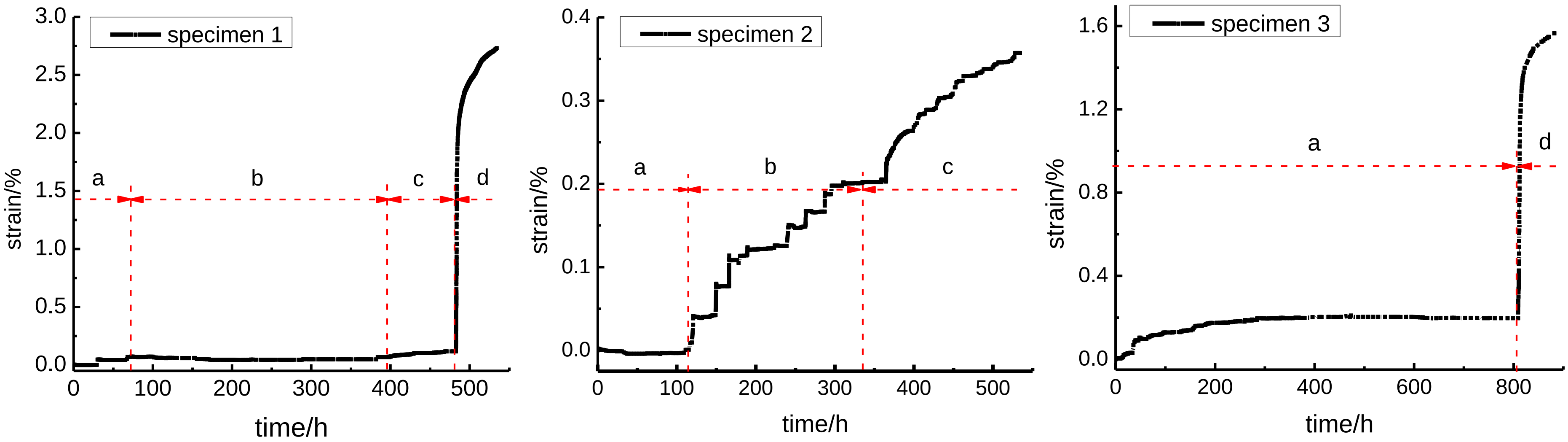
Experiment process

1. The creep stage of hydraulic connection (CSHC)
2. The creep stage with pore water pressure (CSPWP)
3. The creep stage after drainage (CSAD)
4. The creep stage under an axial pressure of 20 MPa (CSAP)

This process was divided into four stages to simulate processes of solution mining. It's expected to provide a reference for analyzing cavern stability and surface subsidence in solution mining.

3.Results

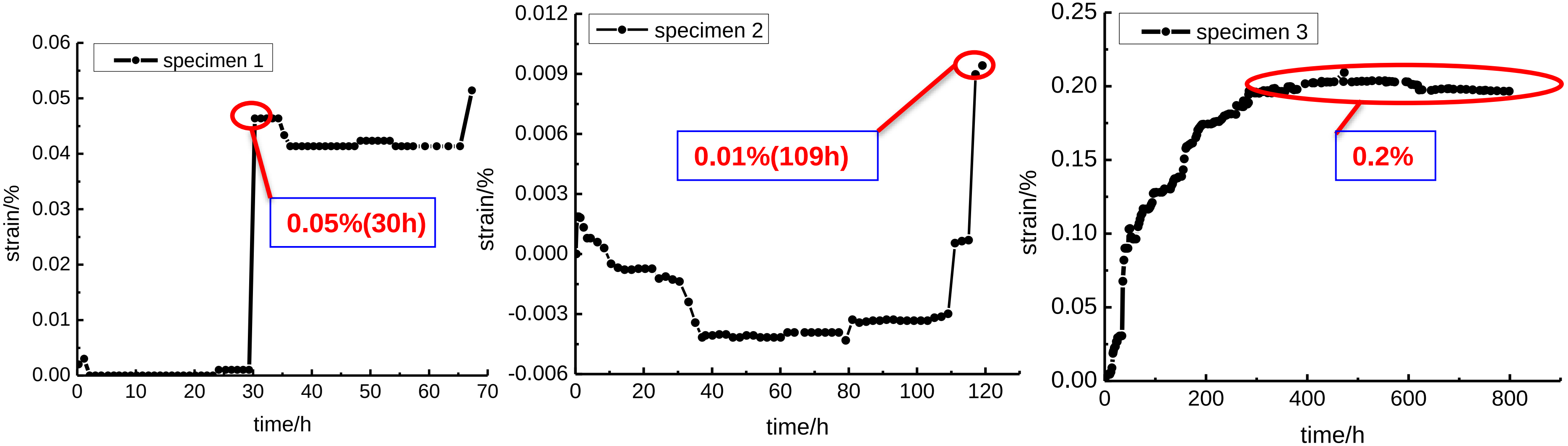
3.1 Deformation during loading



Creep curves of specimens 1, 2, and 3 during the entire loading process

The letters represent different stages in the creep experiments: "a" represents CSHC; "b" represents CSPWP; "c" represents CSAD; and "d" represents CSAP.

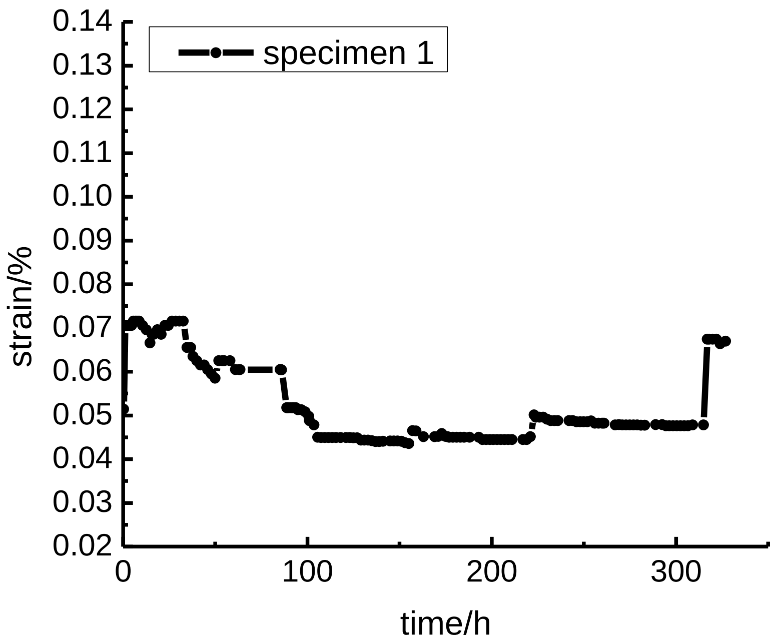
3.2 Deformation during CSHC

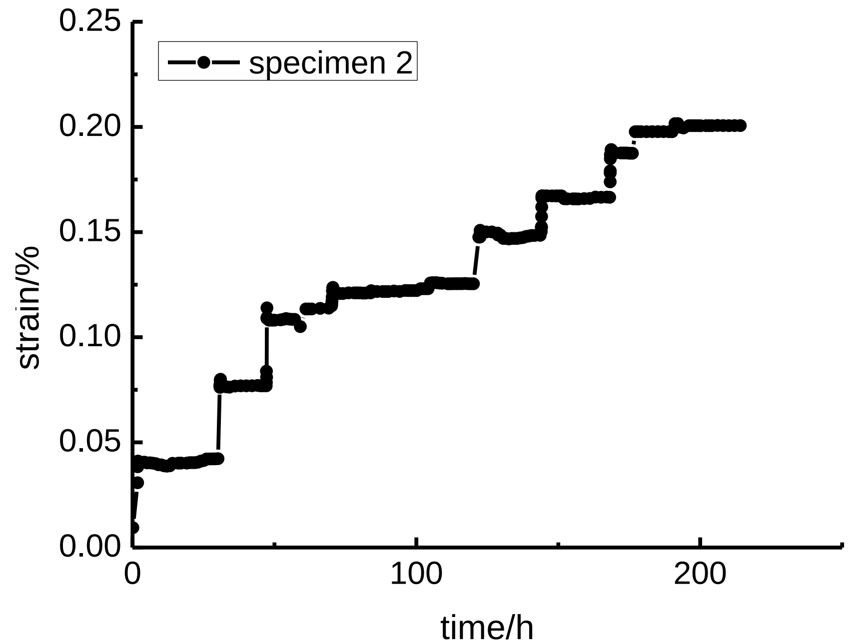


Strains of specimen 1, 2, 3 over time under infiltration pressure of 3, 2, 1 MPa, respectively.

- **The level of infiltration pressure affects the degree of the hydraulic connection of glauberite salt rock.**
- **Hydraulic connection time for specimen 1, 2 were 67h, 120h, respectively. Specimen 3 was not connected in 800h.**

3.3 Deformation during CSPWP

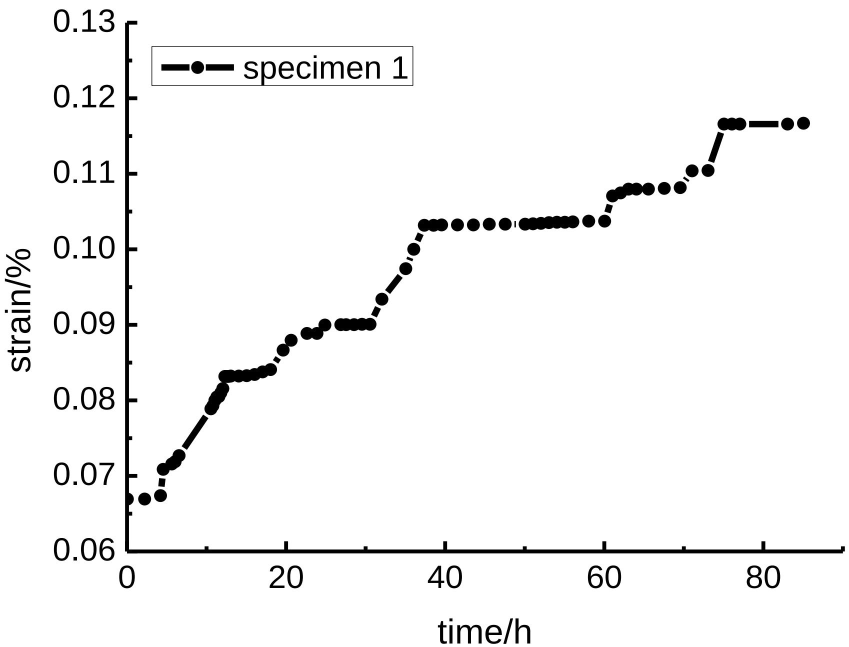


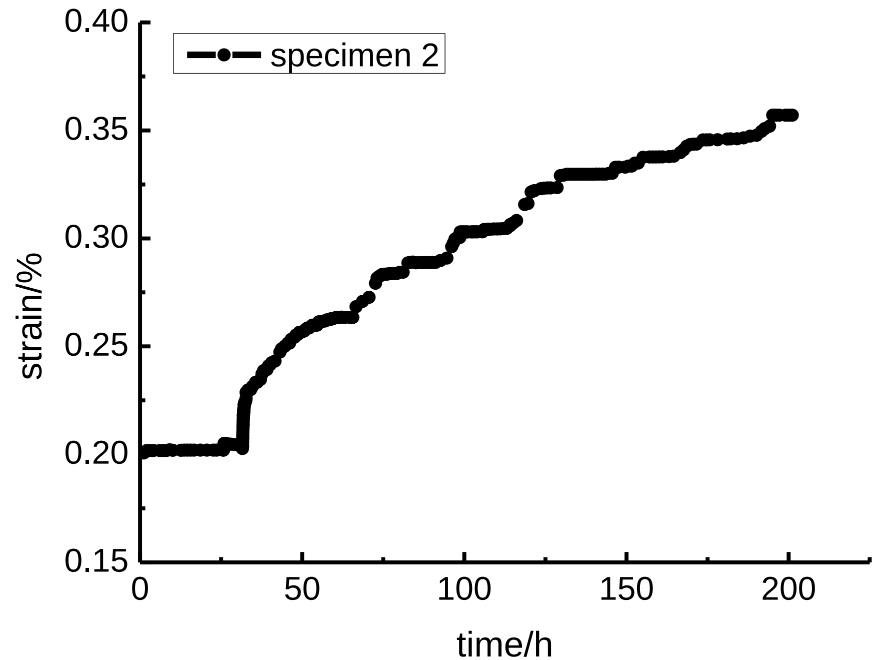


Strains of specimens 1 and 2 over time at CSPWP

- **The axial strain of specimen 1 remained at approximately 0.05% (330h). For specimen 2, the axial strain increased from 0.01% to 0.2% (214 h).**
- **The deformations of the two specimens are determined by the axial effective stress on the solid skeleton as well as the dissolution and softening effects.**

3.4 Deformation during CSAD

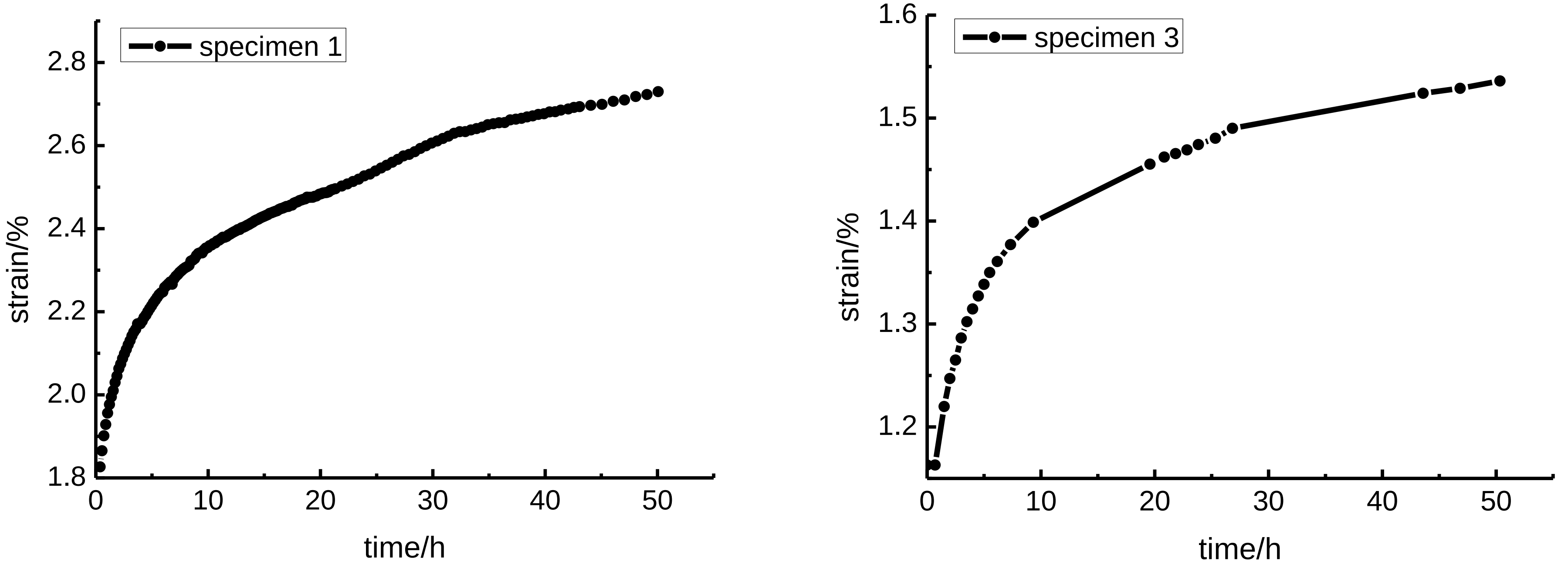




Strains of specimen 1 and 2 over time at CSAD

- **The creep strain of specimen 1 increased from 0.07% to 0.12% in 85h (0.05%); the creep strain of specimen 2 increased from 0.20% to 0.36% in 214h (0.16%).**
- **The deformations of the two specimens indicate creep characteristics.**

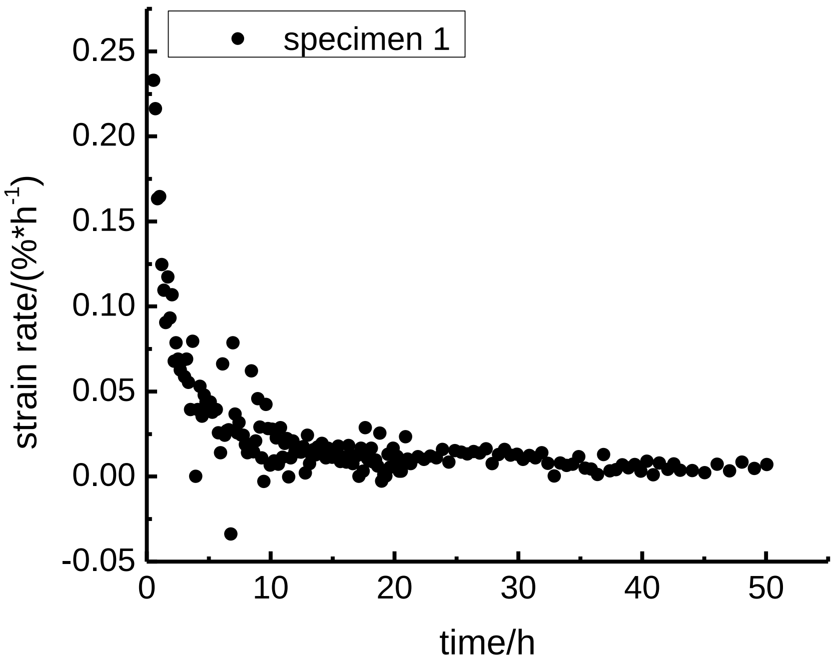
3.5 Deformation during CSAP

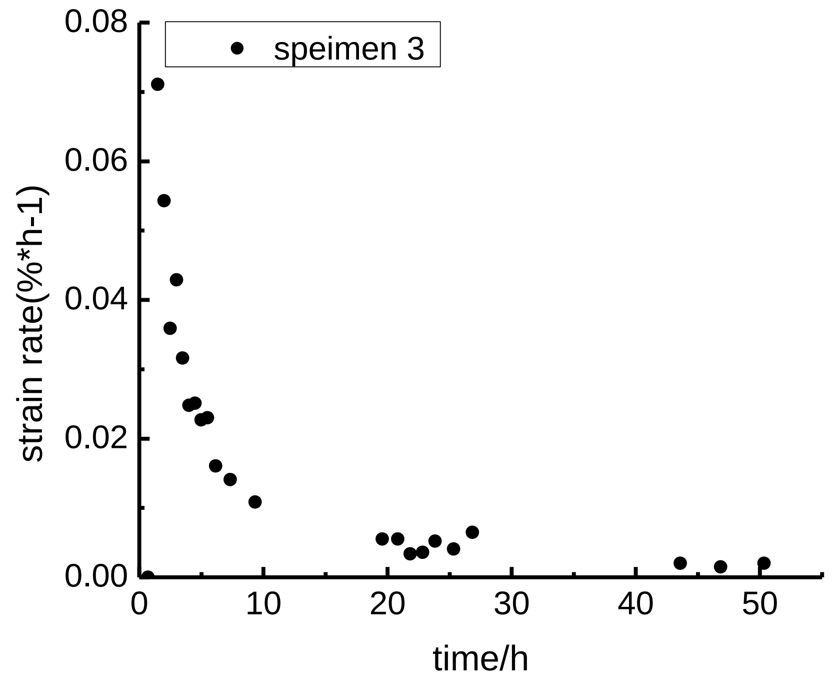


Strains of specimens 1 and 3 over time at CSAP

- **For specimen 1, creep strain increment was 0.90%(1.83%-2.73%), while for specimen 3, the creep strain increment was o.38%(1.16%-1.54%).**
- **These results further demonstrate the different infiltration pressure loading histories of specimens 1 and 3.**

3.5 Deformation during CSAP





Strain rate of specimens 1 and 3 over time at CSAP

- **Average creep rate of specimen 3 was $1.78\times10^{-4}h^{-1}$, which is 71% of that of specimen 1($2.5\times10^{-4}h^{-1}$).**
- **Creep mechanical characteristics of glauberite are significantly affected by the infiltration pressure loading history.**

4.Discussion

4.1 Creep failure mechanism analysis

The glauberite specimens after test

- For specimens 1 and 2, the fracture planes were in the axial direction, while no visible cracks were observed on the surface of specimen 3.
- The failure characteristics at the bottom of the specimen are more obvious with larger infiltration pressure.

4.2 Constitutive model and parameter identification

The generalized Kelvin model is used to fit the strain curves of the different stages for glauberite salt rock. The strain formula under the compression effect can be obtained according to Wang Z. Y as follows:

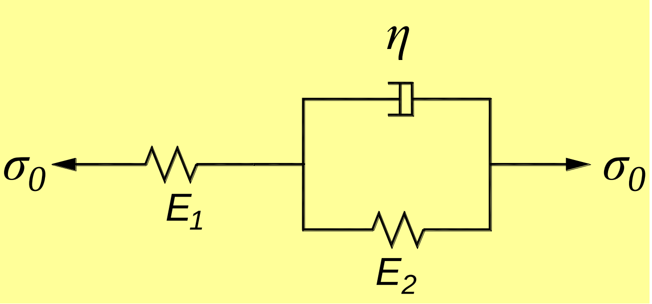
$$\varepsilon(t)=\cancel{\frac{1}{9K}(\sigma_1+2\sigma_3)+\frac{\sigma_1-\sigma_3}{3G_1}}+\frac{\sigma_1-\sigma_3}{3G_2}\left(1-\exp\left(-\frac{G_2}{\eta_2}t\right)\right)$$

Where K-----Elastic bulk modulus

G_1—Elastic shear modulus

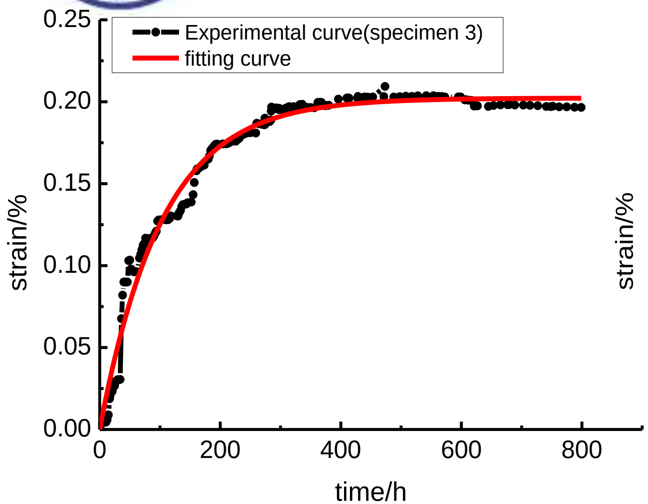
G_2--- Viscoelastic shear modulus

η_2---- Viscoelastic coefficient

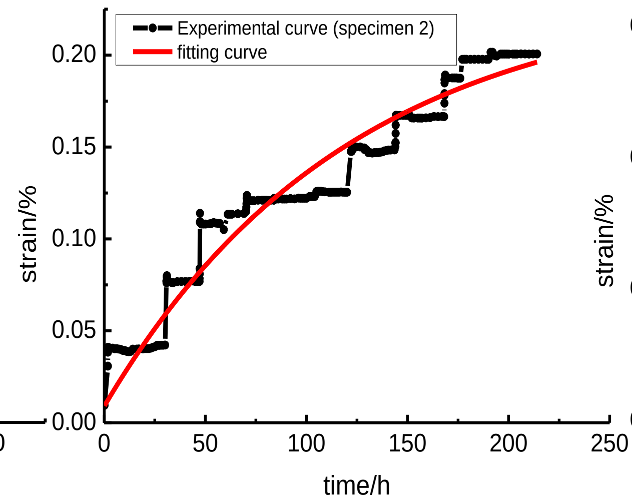


Generalized Kelvin model

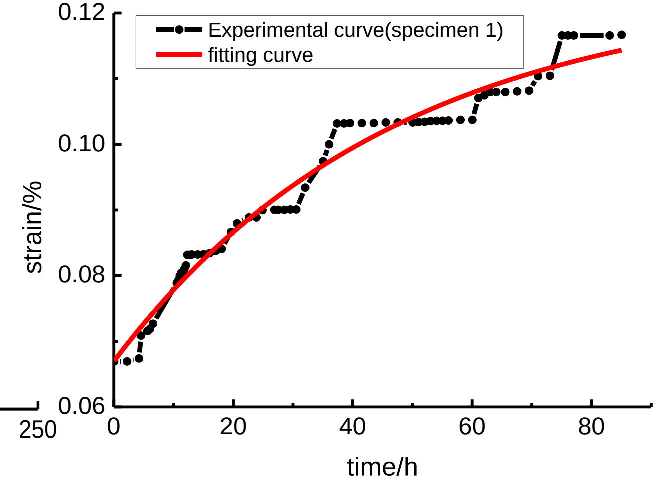
$$\varepsilon_1(t)=\frac{\sigma_1-\sigma_3}{3G_2}\left(1-\exp\left(-\frac{G_2}{\eta_2}t\right)\right)$$



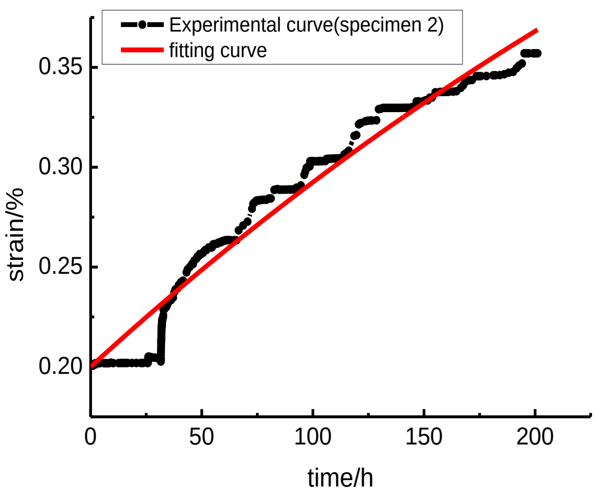
Creep strain of specimen 3 over time at CSHC



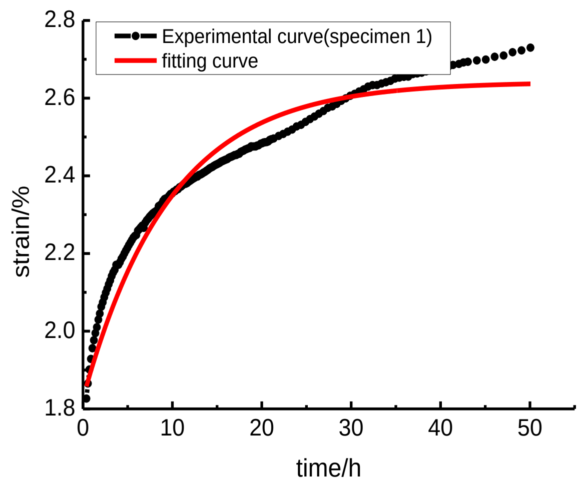
Creep strain of specimen 2 over time at CSPWP



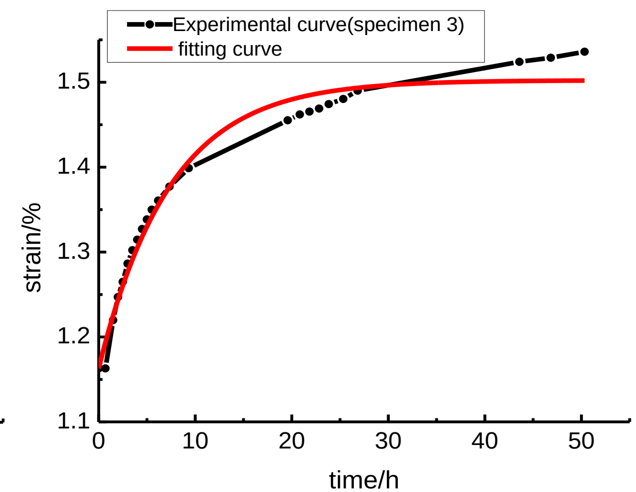
Creep strain of specimen 1 over time at CSAD



Creep strain of specimen 2 over time at CSAD



Creep strain of specimen 1 over time at CSAP



Creep strain of specimen 3 over time at CSAP

Parameters of the generalized Kelvin model

creep stage	specimen number	G_2/MPa	$\eta_2/(\mathrm{MPa \cdot h^{-1}})$	correlation coefficient/R^2
a	3	1.64	170.54	0.98
b	2	1.48	178.53	0.94
c	1	5.89	275.47	0.97
	2	0.65	326.60	0.95
d	1	6.54	63.78	0.94
	3	15.71	115.92	0.98

- **The results show that the correlation coefficients of the two results are greater than 0.94, illustrating good fit.**

4.3 Creep deformation mechanism of glauberite

Creep characteristic under infiltration pressure

Dissolution of minerals

Pervasion action

Deformation of solid skeleton

Influencing factor

- Effective stress
- Duration of pressure infiltration

5.Conclusions

- During CSHC, the hydraulic connection time shortens with increasing infiltration pressure.
- During CSHC and CSPWP, it’s mainly the effective stress and the degree of weakening that determine the creep deformation of glauberite salt rock.
- At CSAD, the loading history of the previous stage impacts the creep deformation.

- **At CSAP, the weakening of mechanical properties of the solid skeleton dominates the creep deformation of glauberite salt rock.**
- **The fracture surface caused by dissolution and erosion effects expands along the axial direction of the specimen.**
- **The generalized Kelvin model can be used to describe the creep deformation of glauberite salt rock under the coupled effects of compression and infiltration pressure.**

Thanks!