

Experimental investigation on mechanical properties and permeability evolution of red sandstone after heat treatments

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Key words: Heat treatment, Red sandstone, Triaxial compression test, Mechanical property, Permeability

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Introduction and problem description

Thermal treatment in rocks produces cracks and alters the crack networks because of the different thermal expansion coefficients of grain minerals. Therefore it leads to changes in the mechanical and petrophysical properties of rocks.

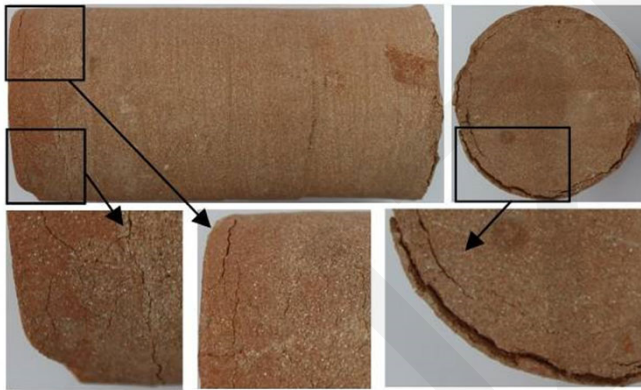
We observed that previous studies mainly focused on the rock mechanics properties after being subject to high temperature (strength and deformation parameters). Although the relationship between permeability and mechanical properties of rocks is of great importance, our knowledge is restricted in terms of how these quantities relate to rocks that have been previously subjected to high temperatures.

This work focuses on the evolution of permeability (gas) due to deformation occurring in sandstone samples previously subjected to thermal treatment.

Experimental procedures

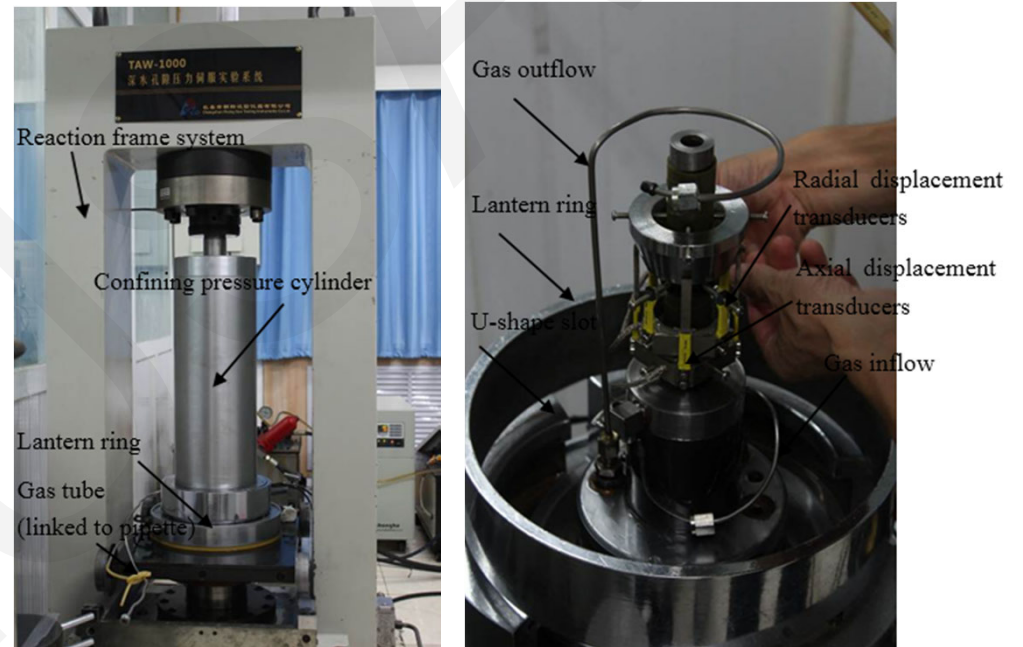


(a) The available samples (20, 200, 400, and 600 °C)



(b) The unavailable samples (800 °C)

Fig. 2 Sandstone samples after heat treatment



(a) Sample assembly

(b) Testing system

Fig. 3 TAW-1000 electro-hydraulic servo controlled testing system and sample assembly

Results

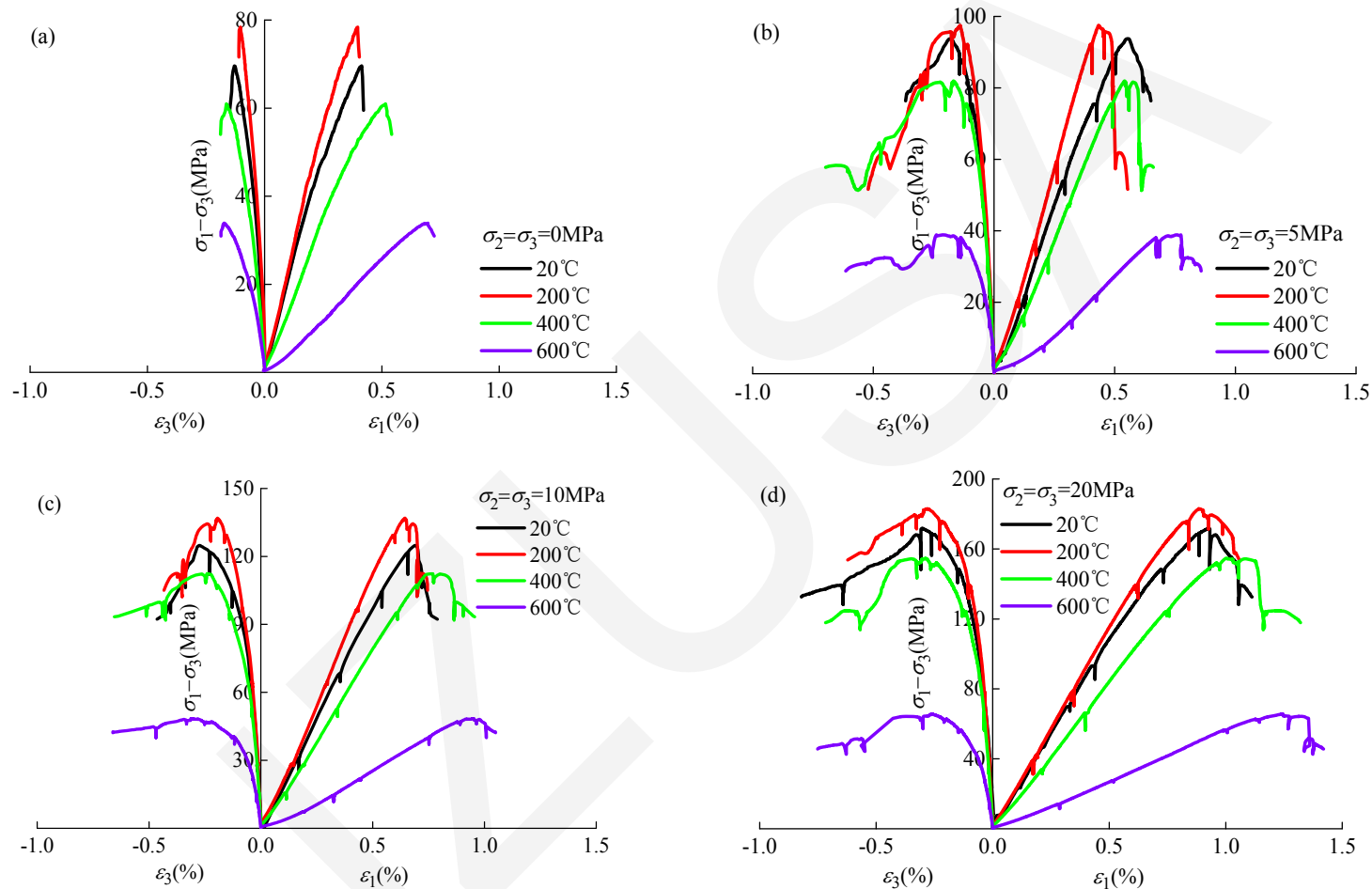


Fig. 4 Stress-strain relationship curves with different confining pressures after heat treatment (ε_1 : axial strain, ε_3 : radial strain), $P_c=0$ MPa (a), $P_c=5$ MPa (b), $P_c=10$ MPa (c) and $P_c=20$ MPa (d)

Results

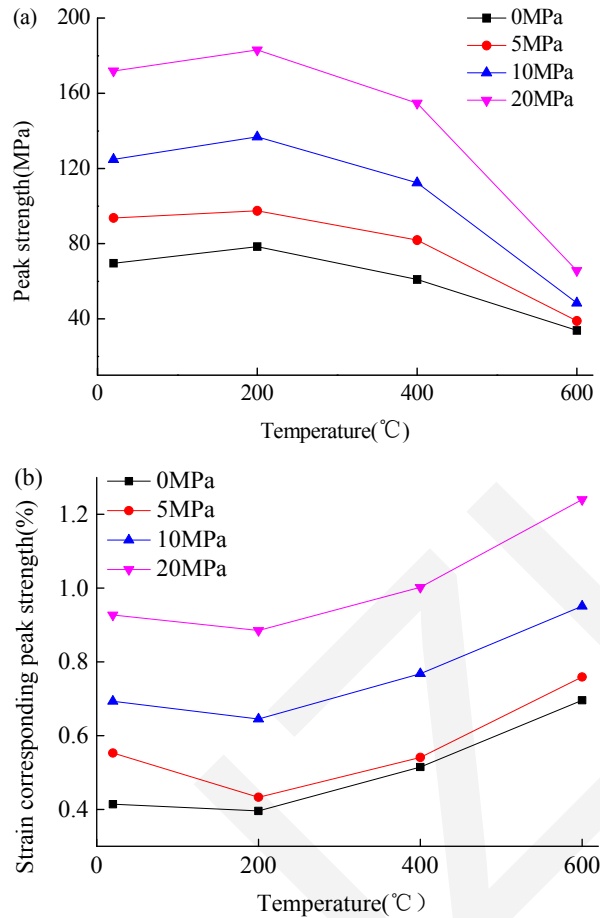


Fig.5 Peak strength (a) and corresponding strain (b) of sandstone samples under different confining pressures after heat treatment

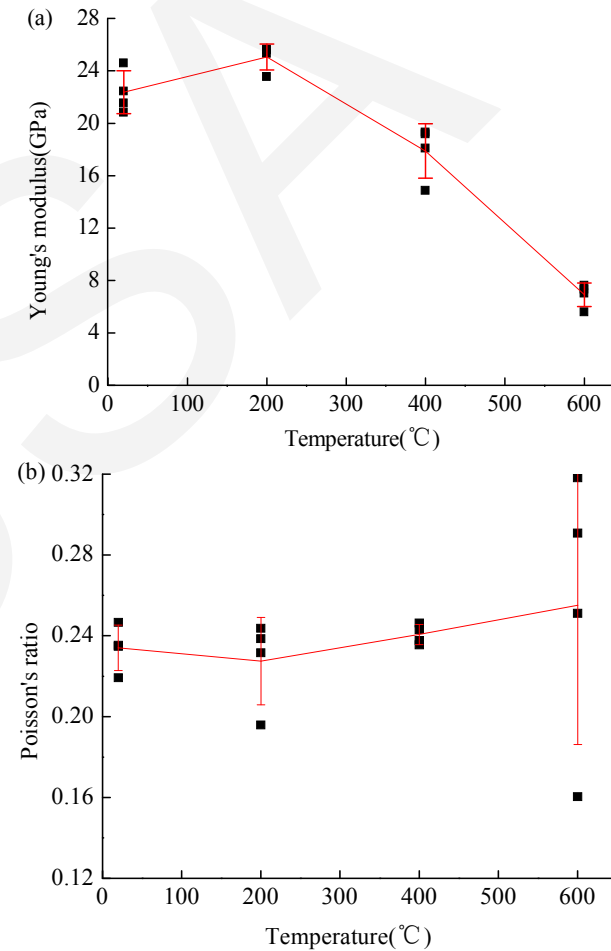


Fig. 6 Young's modulus (a) and Poisson's ratio (b) after heat treatment at different temperatures

Results

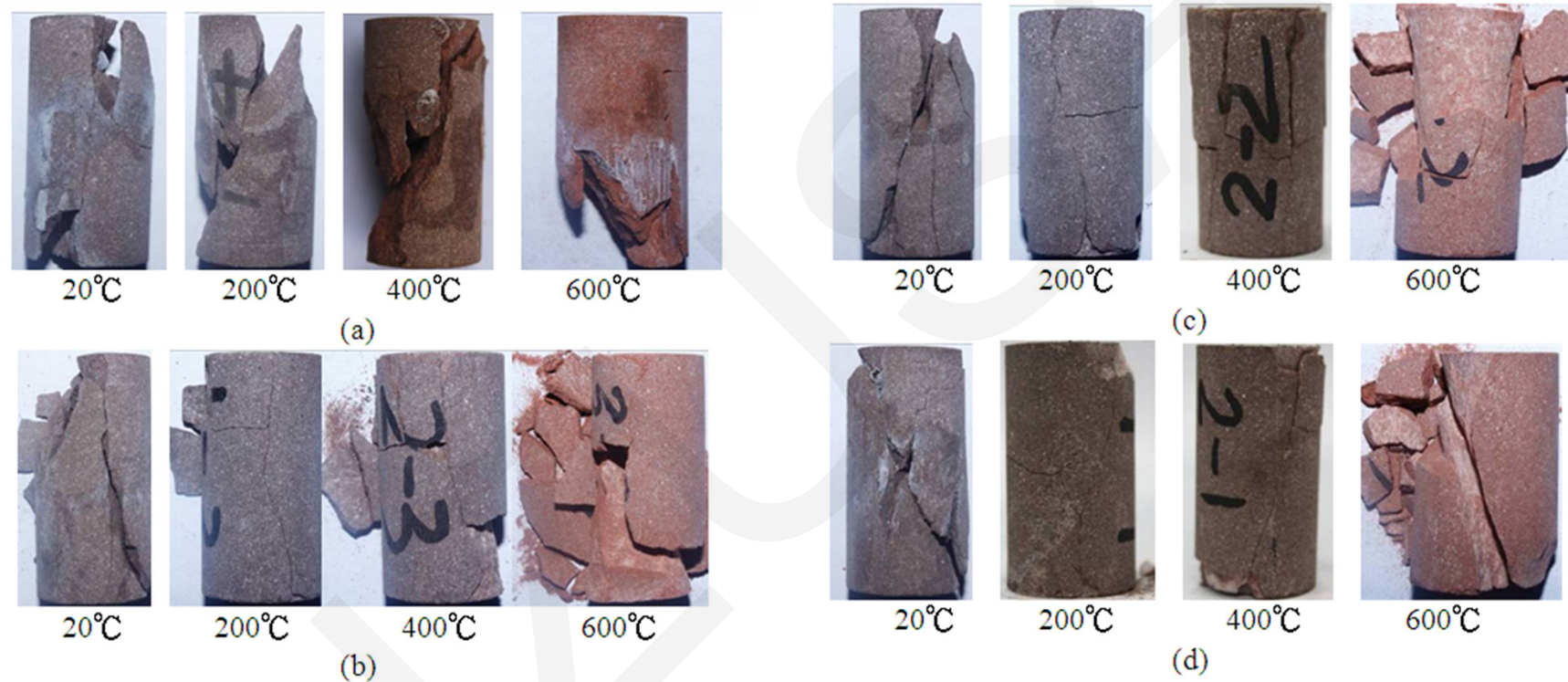


Fig. 7 Fracture patterns of sandstone samples after compression tests, $P_c=0$ MPa (a), $P_c=5$ MPa (b), $P_c=10$ MPa (c) and $P_c=20$ MPa (d)

Results

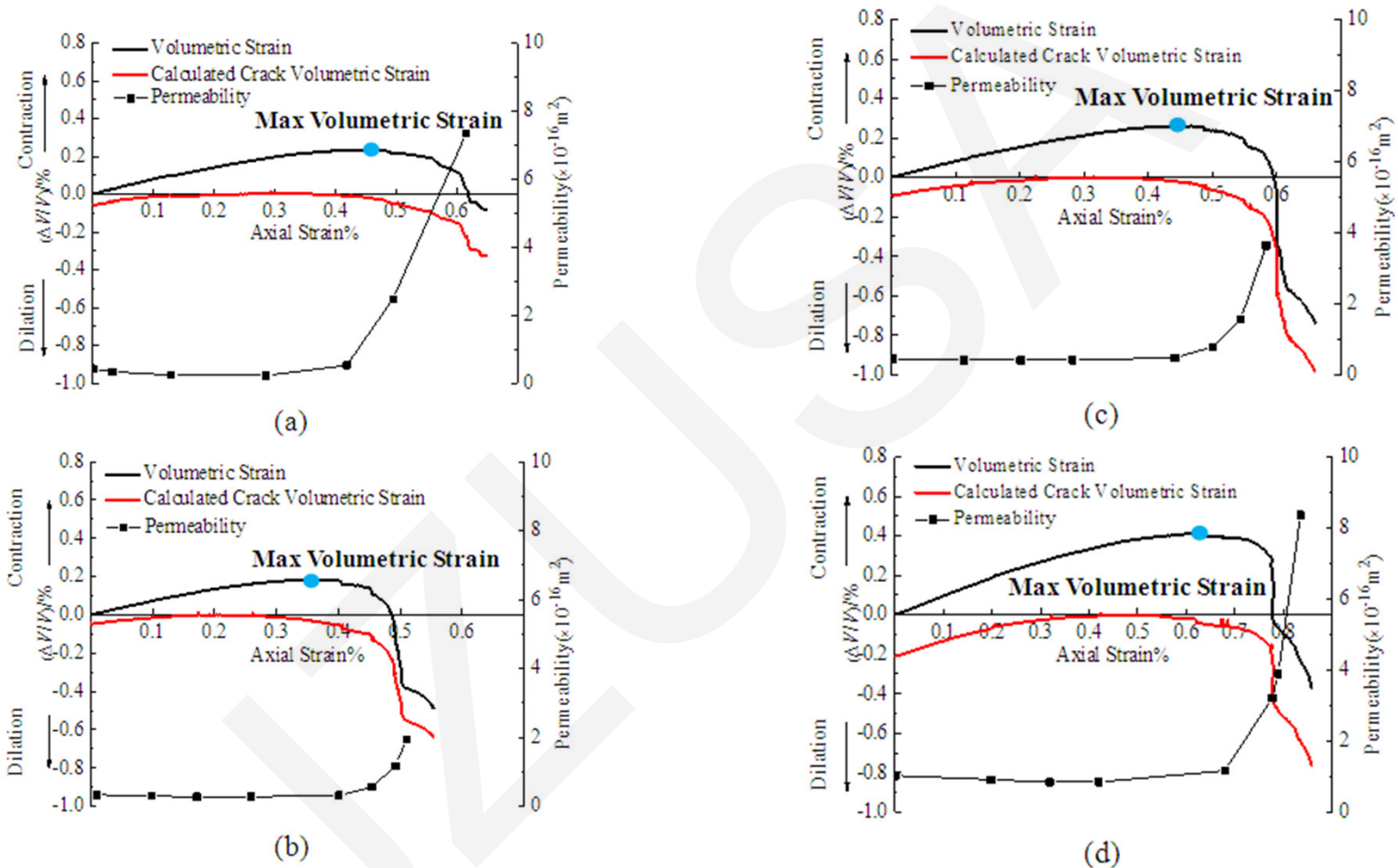


Fig. 8 Strain-volumetric and permeability curves of sandstone after heat treatment under 5 MPa confining pressure, 20°C (a), 200°C (b), 400°C (c) and 600°C (d).

Results

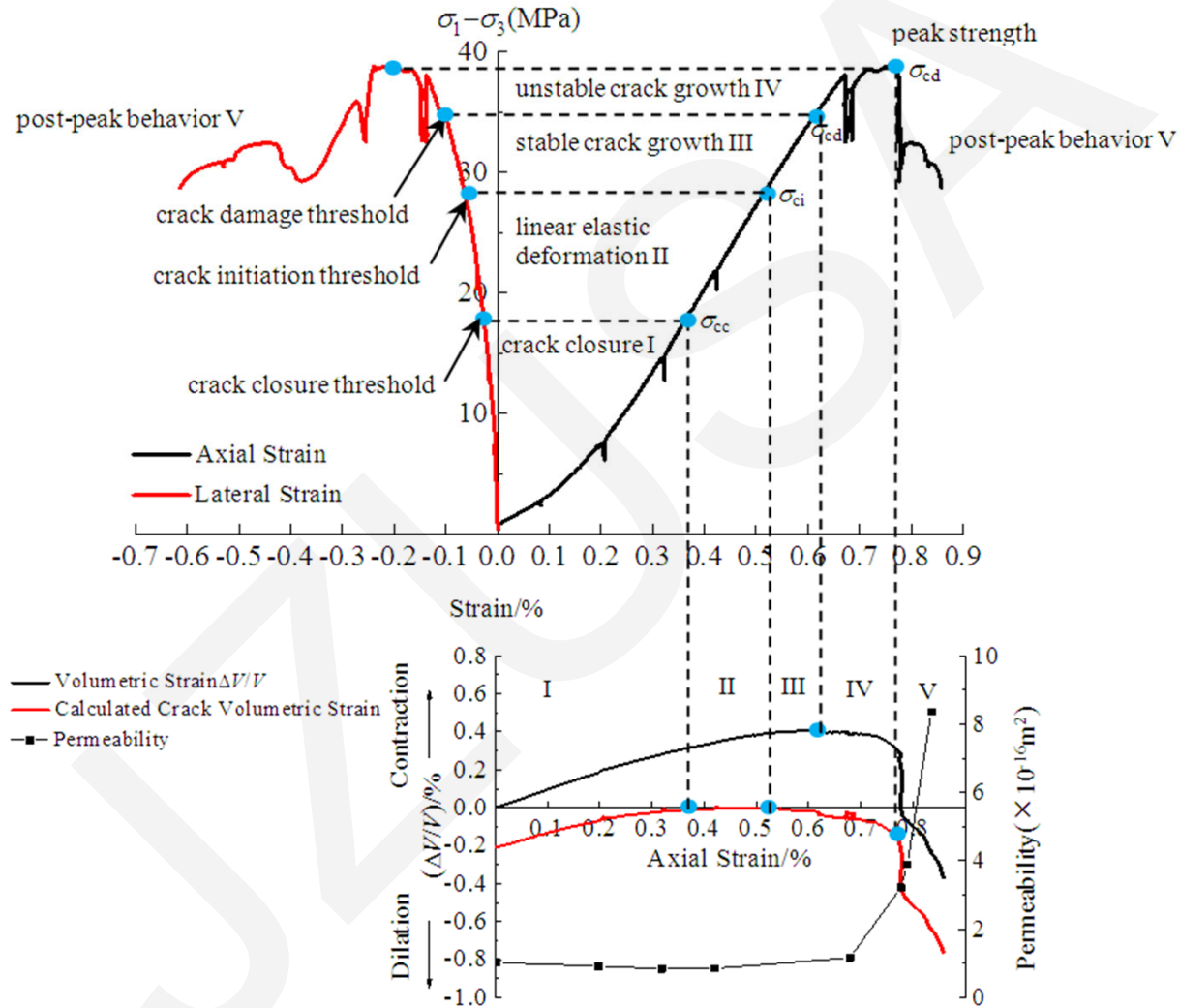


Fig. 9 Stress-strain relationship and permeability evolution after heat treatment

Conclusions

1. At the temperature of 20-200°C, the primary pore and cracks gradually closed, which improved the density degree and caused the strength and elastic modulus to increase and permeability to decrease. From 200 to 600°C, the degradation effects of the temperature on sandstone became evident, the strength and elastic modulus decreased, and the strain corresponding to the peak stress and initial permeability increased significantly.
2. With the increase of the confining pressure, the degree of internal crack closure in the sandstone increased, which resulted in the reduction of the initial permeability; in addition, larger internal cracks occurred with the severely degraded sandstone samples, which had a greater effect on the closure with the increase of the confining pressure, and the initial permeability decreased more significantly.
3. Gas permeability of sandstone in a complete stress-strain process varied with the evolution of cracks in the samples. In general, the permeability decreased in the initial loading stage due to the crack closure, after which it remained stable in the elastic deformation stage, then gradually increased in the crack growth stage. Prior to the peak strength, the permeability was enhanced sharply by about one or two orders of magnitude.