Experimental Study on Mode I Fracture Characteristics of Heated Flossenbürger Granite with Different Cooling Methods Using DIC and AE

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Motivation

- The mode-I fracture evolution of granite across fine temperature increments within the low-to-moderate thermal range and its sensitivity to cooling path require systematic clarification.
- The thermally induced evolution of the fracture process zone (FPZ) size and its impact on Mode-I fracture parameters of brittle granite need to be accurately quantified.

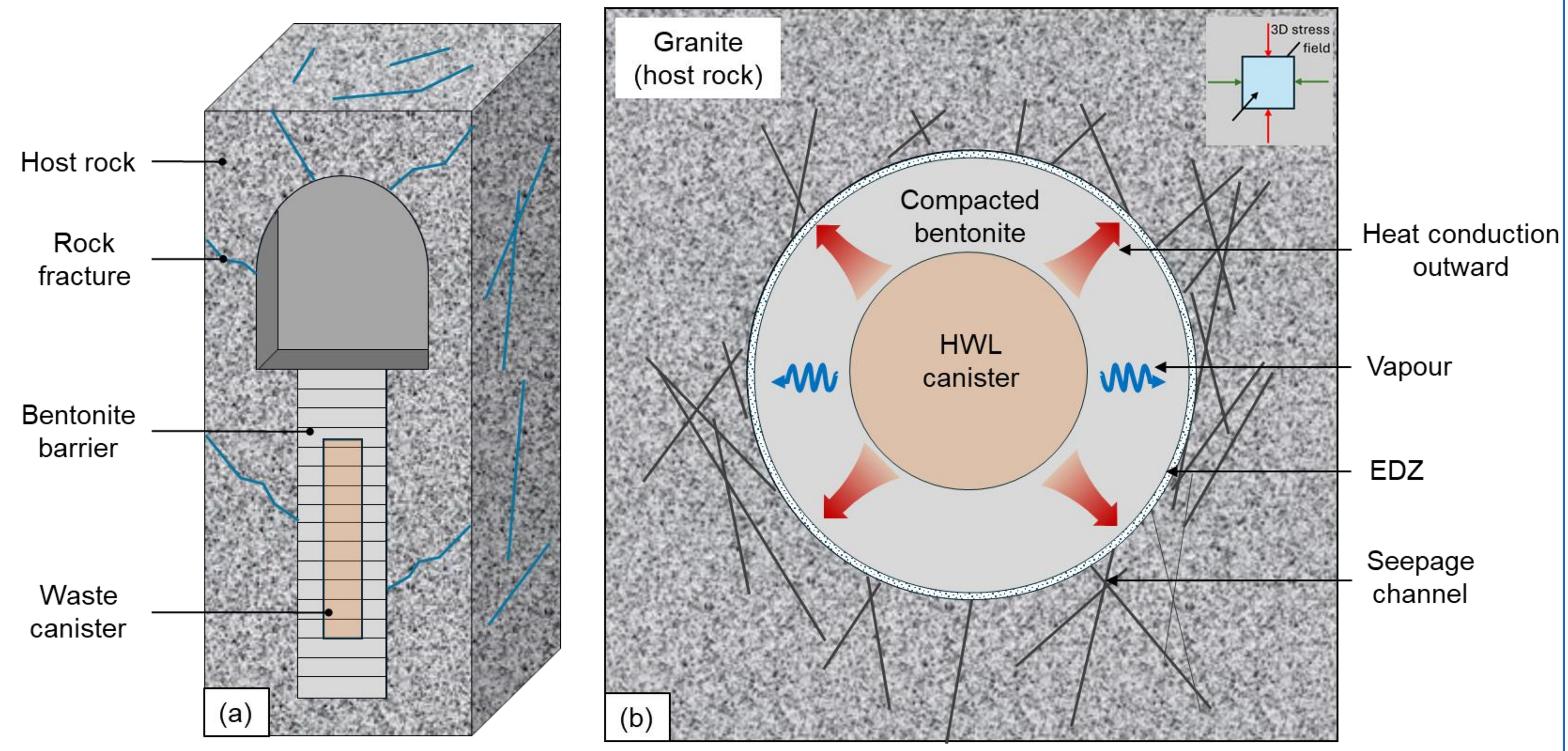

Fig.1. (a) Schematic of the HLW repository in granite; (b) full encapsulation in a tunnel.

Methods

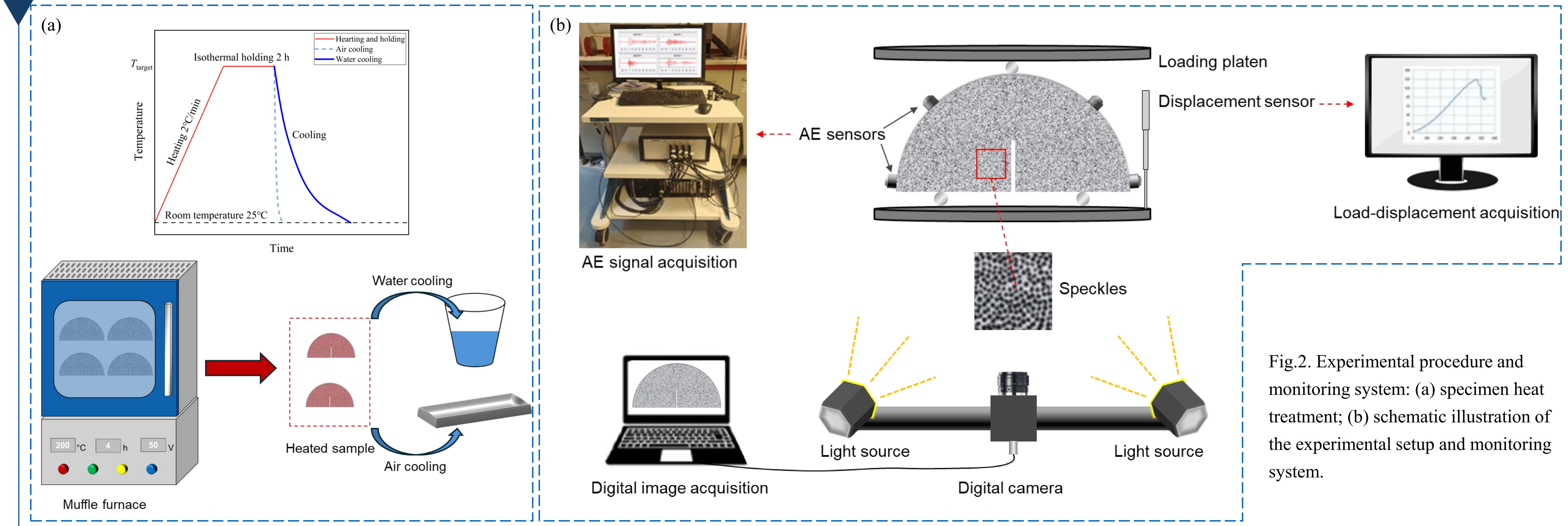

Fig.2. Experimental procedure and monitoring system: (a) specimen heat treatment; (b) schematic illustration of the experimental setup and monitoring system.

Results

Acoustic emission response

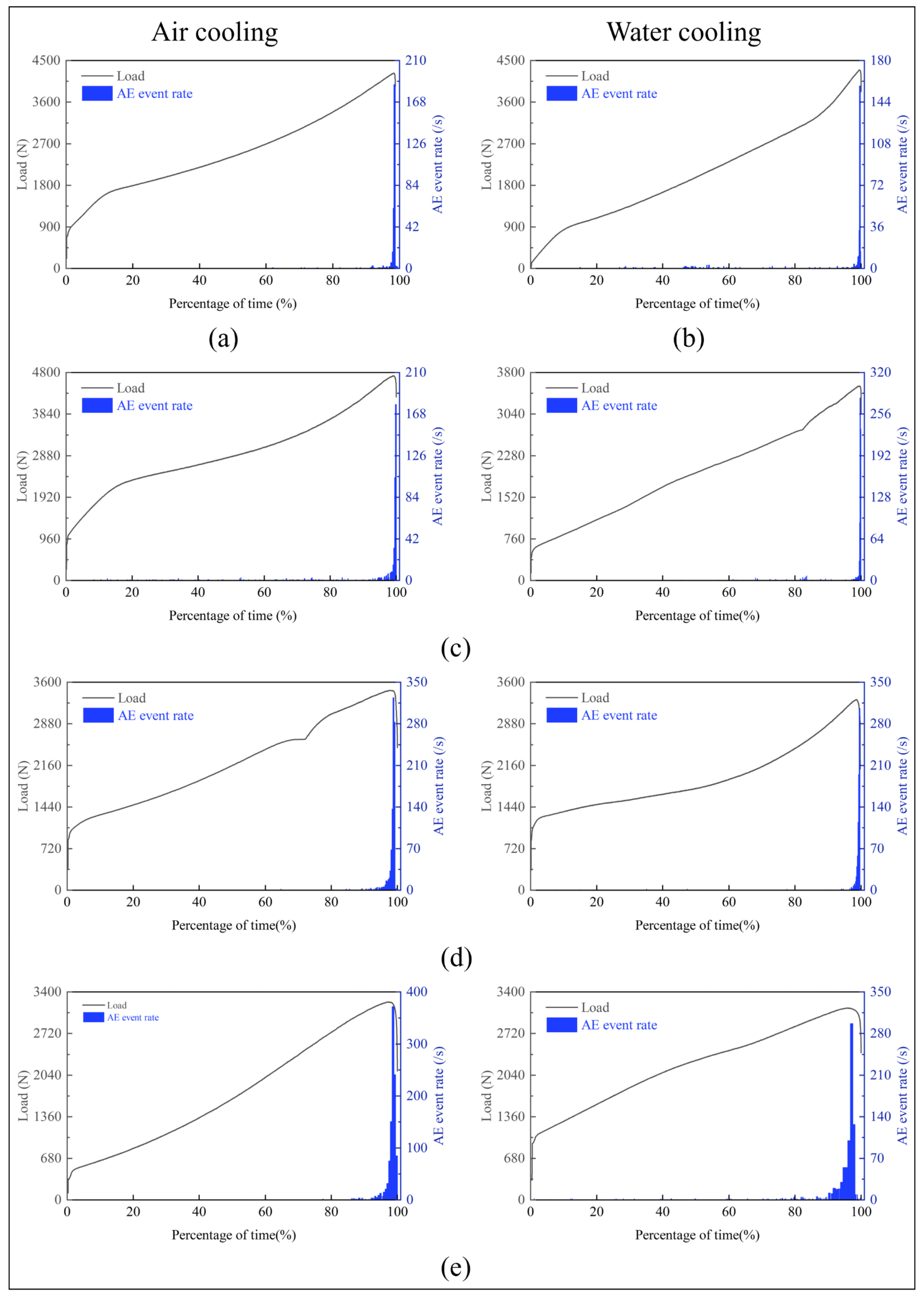

Fig.3. Acoustic emission (AE) event responses for granite samples exposed to different temperatures: (a) 25°C; (b) 100°C; (c) 150°C; (d) 250°C; (e) 350°C.

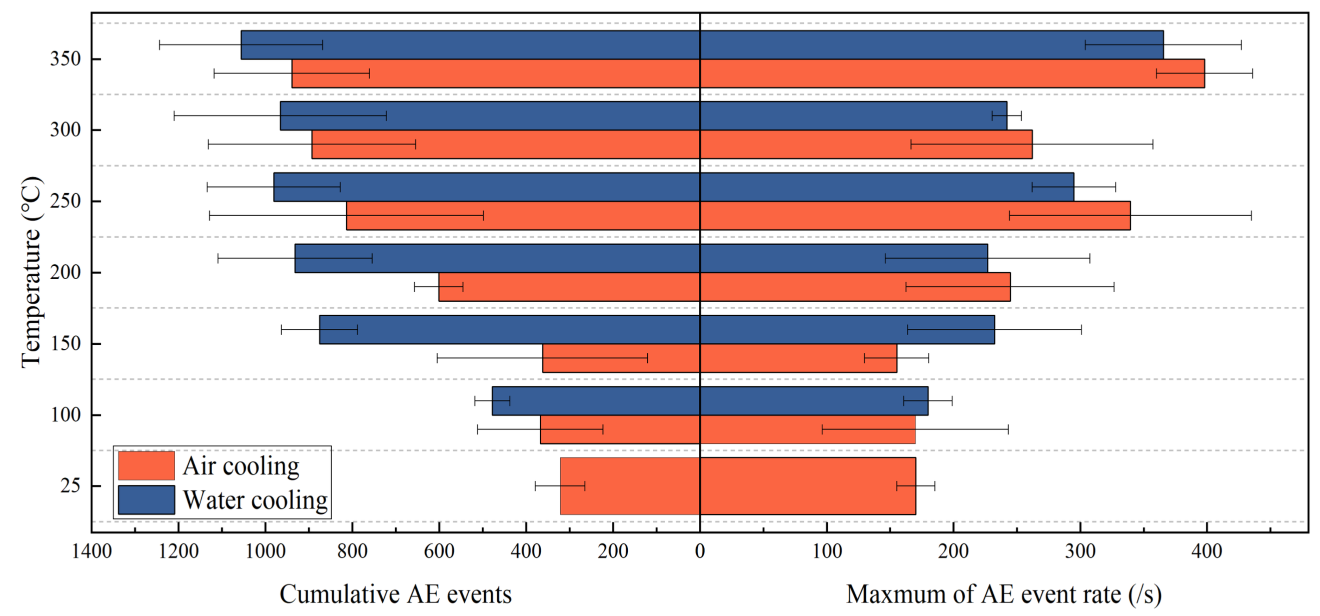

Fig.4. Variations of the cumulative AE events and the maximum of AE event rate of fully-developed FPZ with different temperatures.

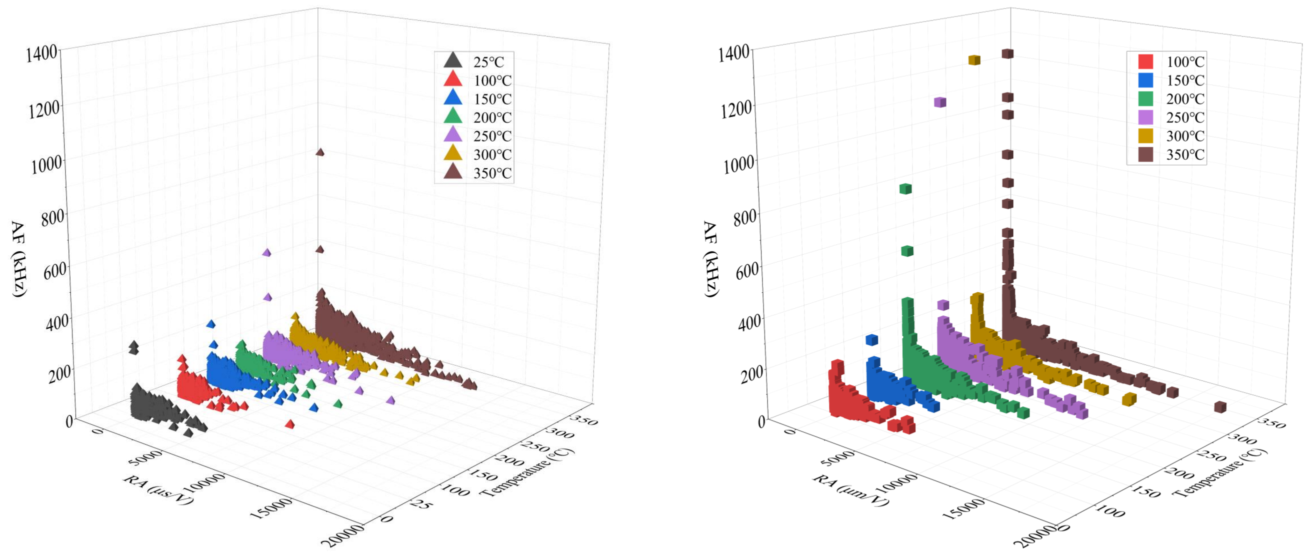

Fig.5. Distribution of the rise angle (RA) and the average frequency (AF) of granite samples under different temperatures and cooling methods: (a) air cooling; (b) water cooling.

Digital image correlation fracture process

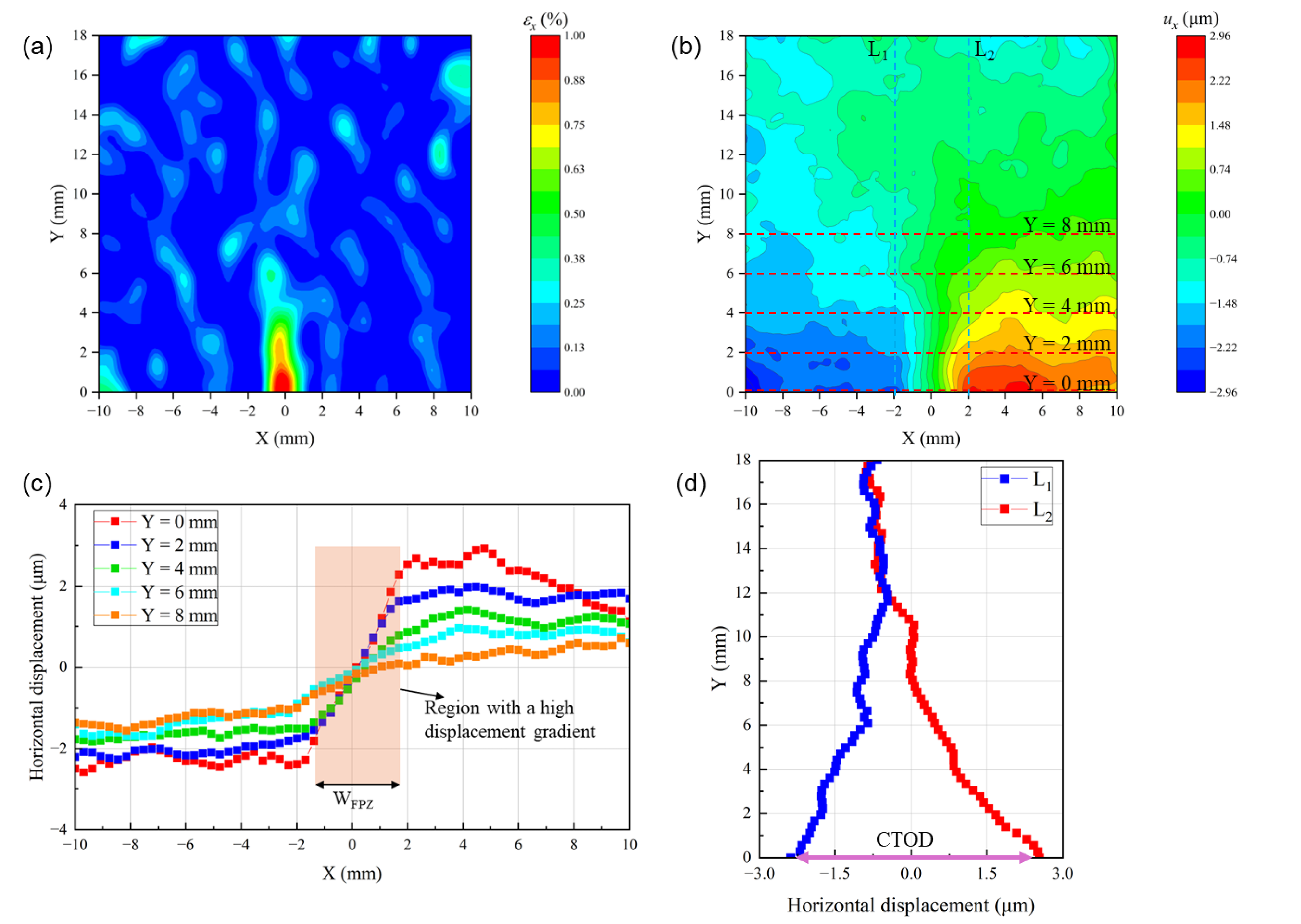

Fig.6. Determination of the FPZ size and CTOD: (a) horizontal displacement contour; (b) horizontal strain contour; (c) horizontal displacement profiles; (d) horizontal displacement profiles.

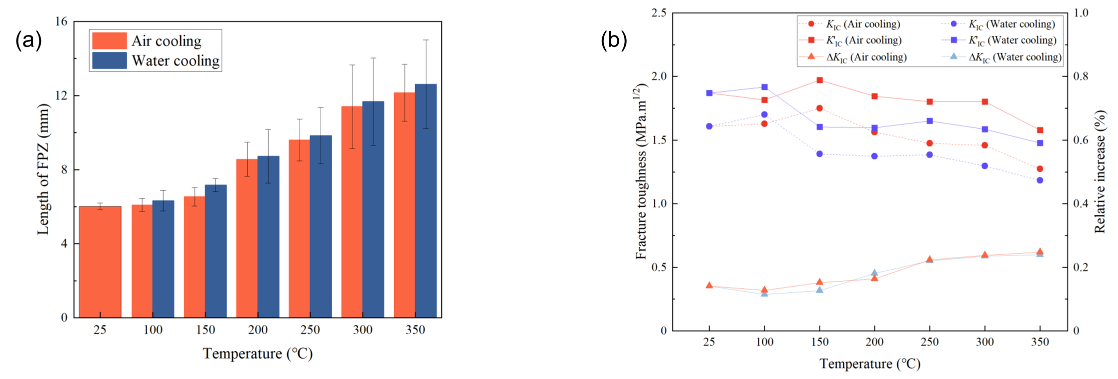

Fig.7. (a)Variation of the FPZ length; (b) Comparison of fracture toughness values calculated with and without consideration of FPZ.

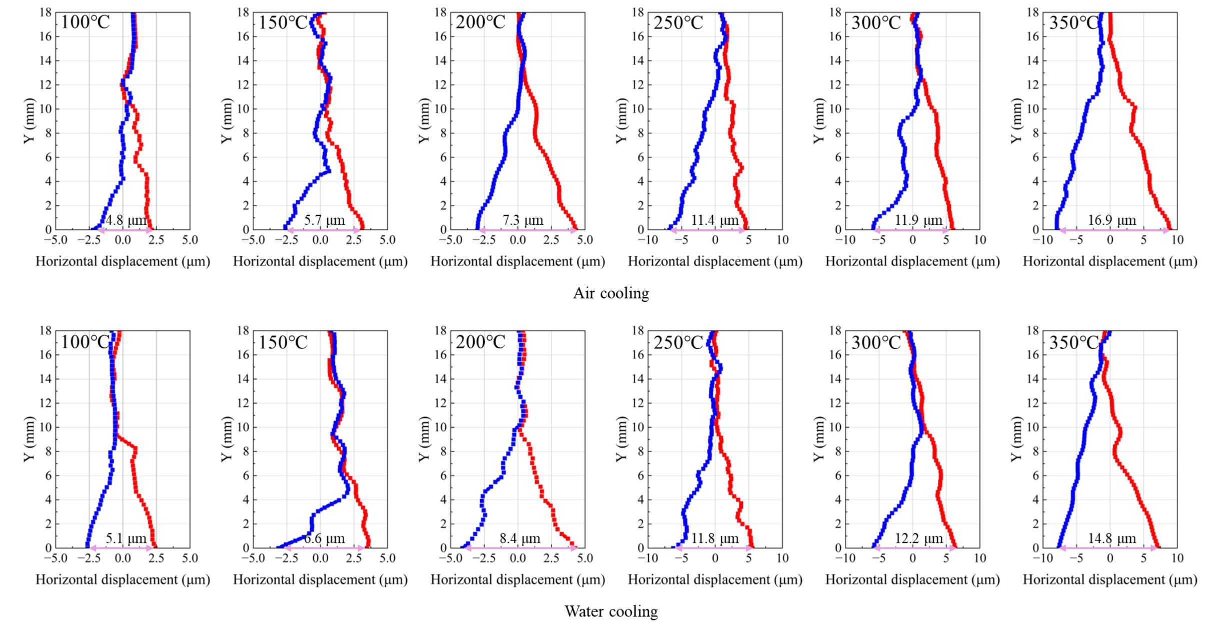

Fig.8. Crack tip opening displacement (CTOD) of granite specimens subjected to different temperatures and cooling methods.

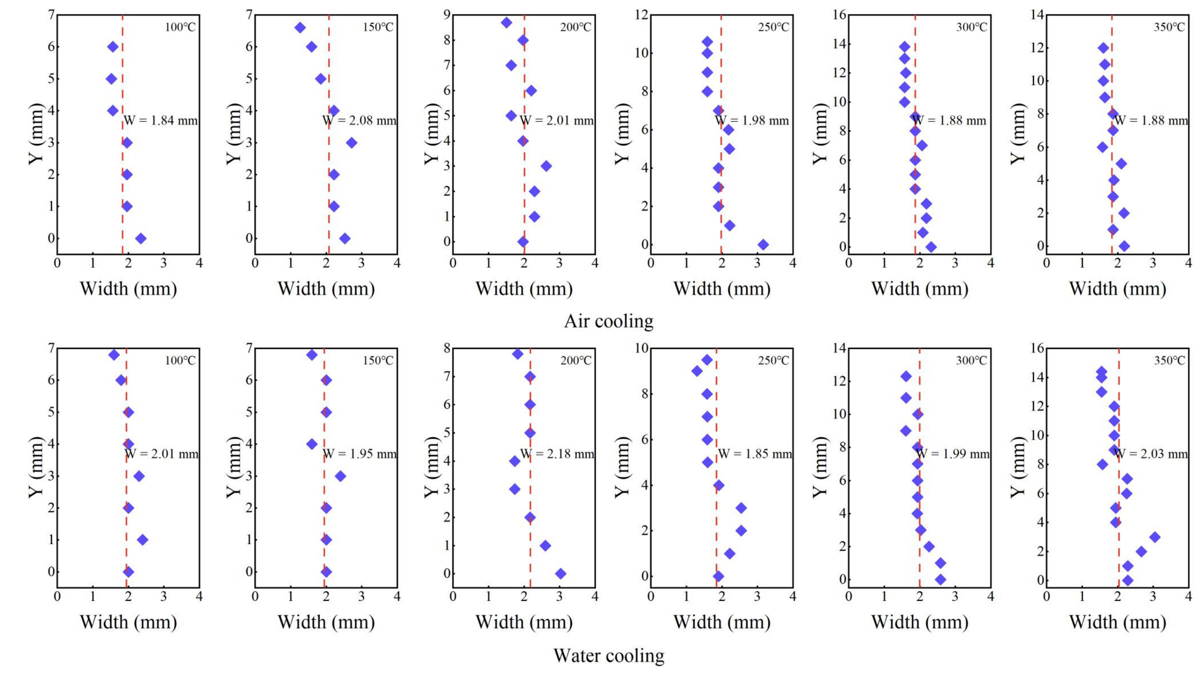

Fig.9. The measured FPZ width along the FPZ of granite specimens subjected to different temperatures and cooling methods.

Conclusion

- Thermal treatment significantly affects granite fracture behavior, with the effect of temperature outweighing that of the cooling path.
- Elevated temperatures induce more microcracks during the development of FPZ.
- FPZ length and CTOD increase with thermal treatment temperature, particularly under water cooling, whereas apparent fracture toughness decreases. The FPZ-corrected effective fracture toughness is more than 20% higher than the uncorrected fracture toughness.