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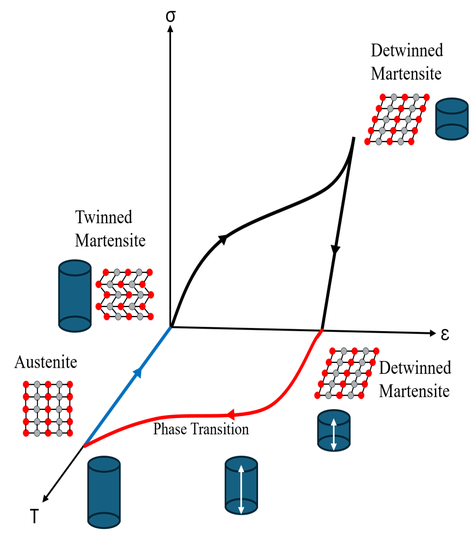
NiTi vs. NiTiHf Shape Memory Alloys: A Comparative Study on Stress-Induced Fracture Control for Geothermal Borehole Near Field Pre-conditioning

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INTRODUCTION

Hydraulic stimulation (single- and multi-stage) is the most commonly used method for enhancing deep geothermal reservoir permeability. However, it lacks control over the fracture initiation direction around a borehole. Moreover, in multi-stage stimulations, the stress shadowing effect can alter the fracture initiation direction at each stage. In this research, we introduce a **borehole pre-conditioning method** using a **Shape Memory Alloy (SMA)-**based **mechanical actuator** to:



- control fracture initiation around a borehole.

What is SMA?

metal that can "remember" its original shape. When it's deformed, it can return to that original shape when heated.

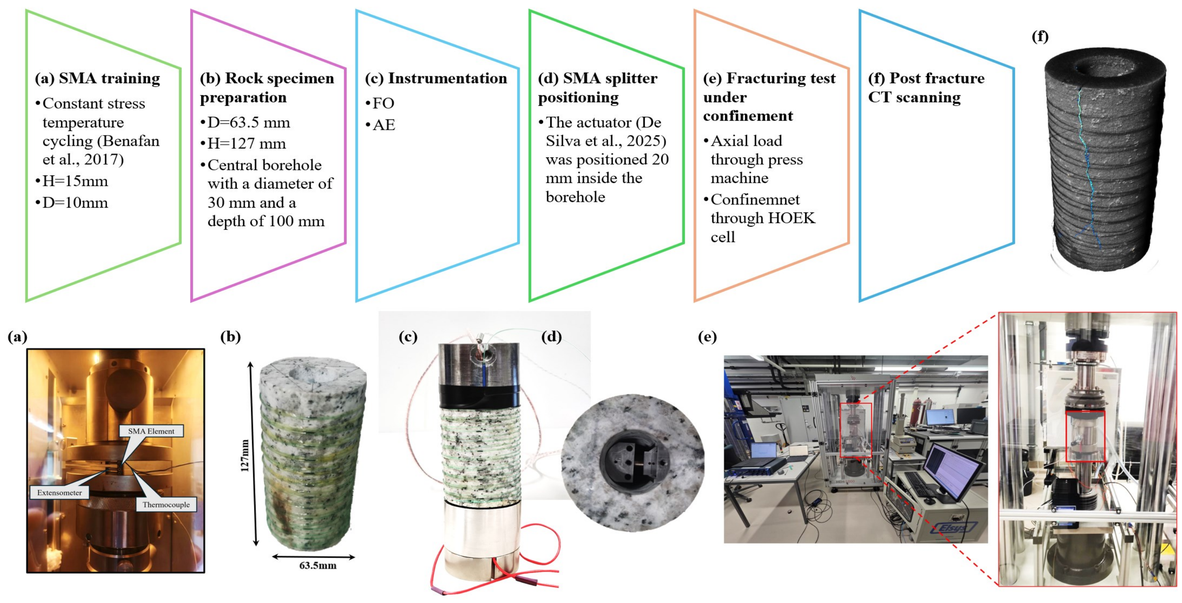
- In this study, we developed and tested in-house NiTi- and NiTiHf-based SMA actuators, chosen for their superior corrosion resistance and high energy density.
- Laboratory fracturing tests were performed on Rotondo Granite specimens from the Bedretto Lab to evaluate the performance of each SMA.

METHODS

Actuator:

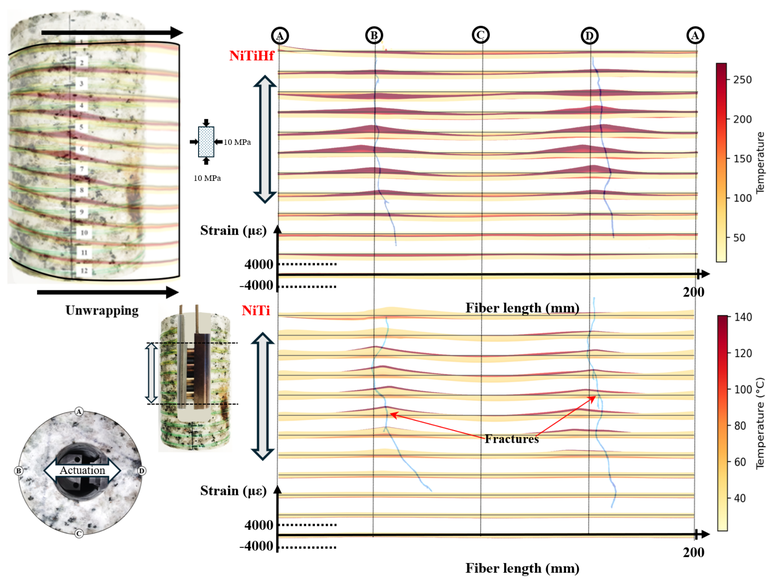


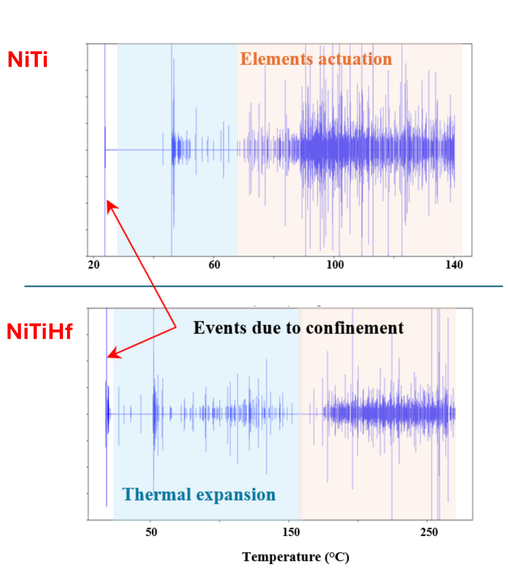
Fracturing experiment:

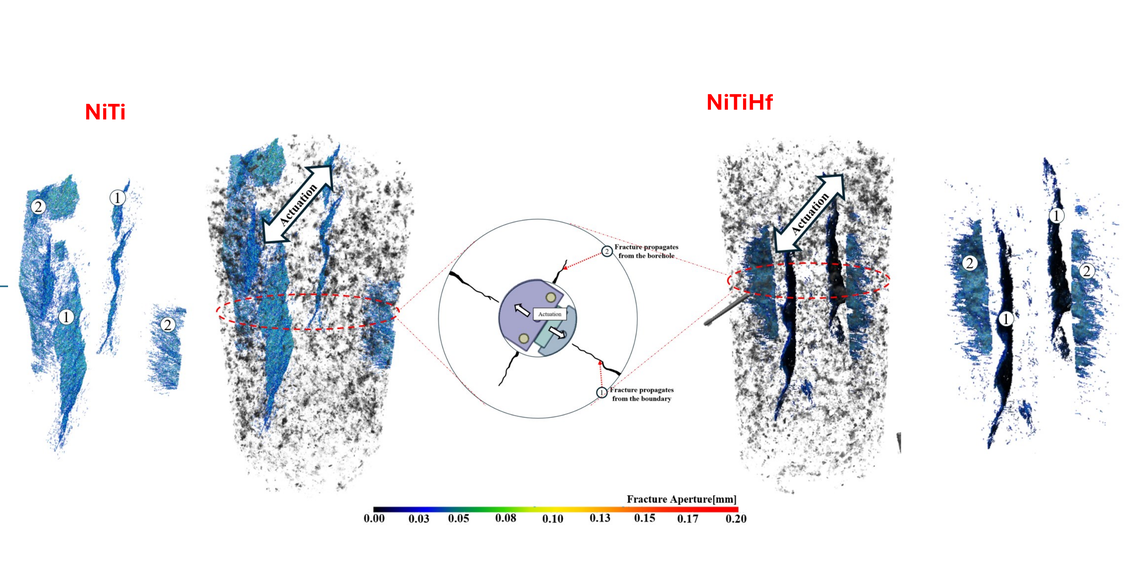


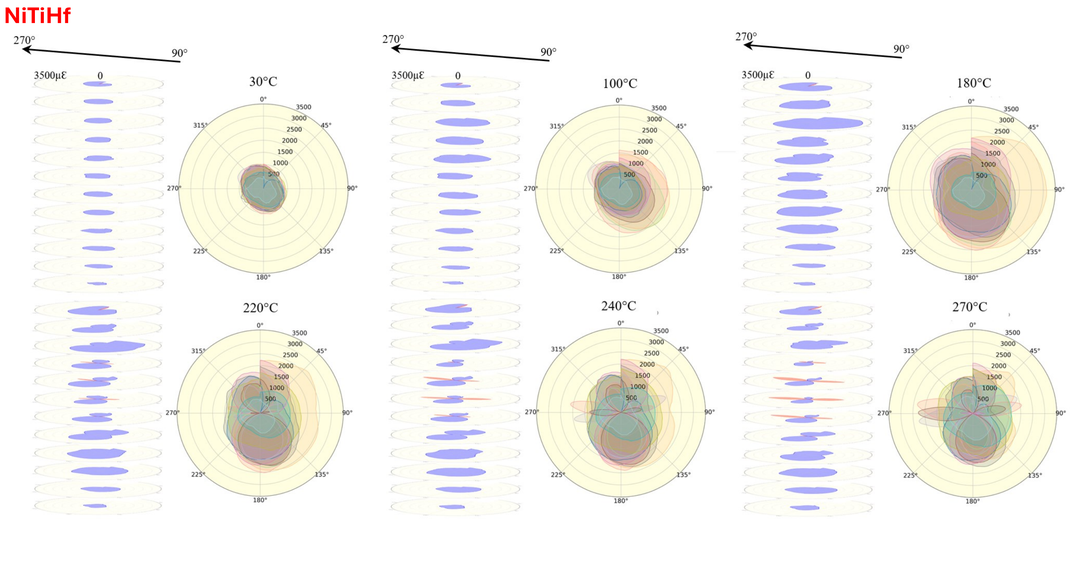
RESULTS

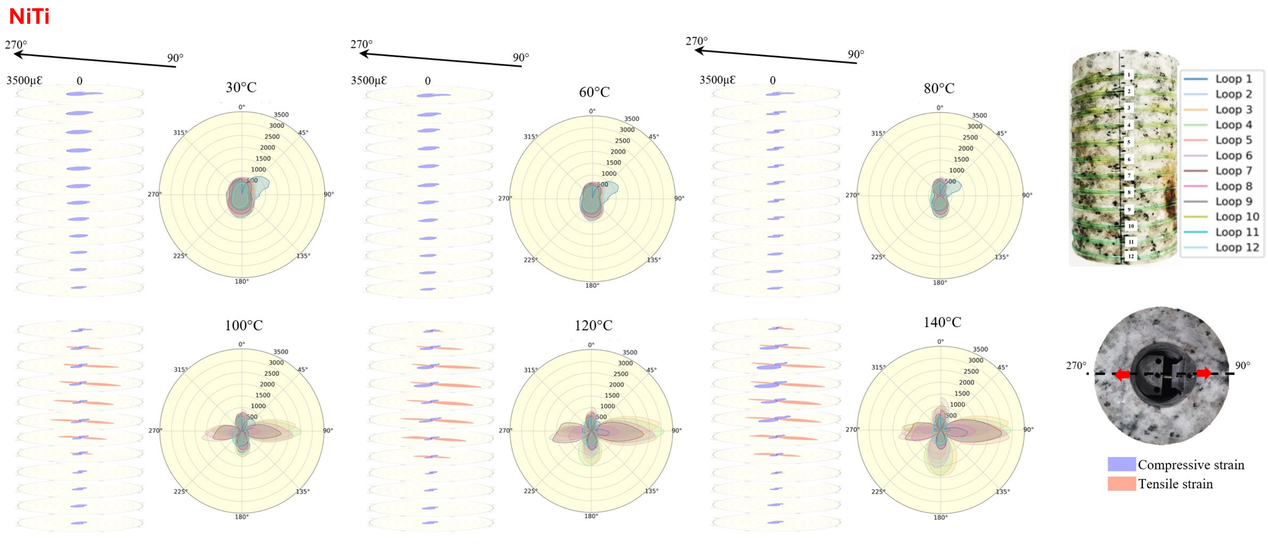
The trained NiTiHf and NiTi SMA exhibits 1.4% and 1.6% actuation strains, respectively. When actuated under constant strain, NiTiHf can generate an average of 715 MPa (at 240°C) stress while NiTi can generate an average of 540MPa (at 140°C).











DISCUSSION

- Due to its higher actuation temperature of 180°C, NiTiHf presents a significant advantage over NiTi (80°C) in geothermal reservoir environments.
- The average magnitude of AE events in NiTi is approximately 0.017 V, whereas in NiTiHf it is around 0.014 V. This suggests a much higher degree of fracturing in NiTi, which is further supported by the segmented CT images.
- Due to its higher actuation strain, NiTi produced longer fractures extending from the borehole compared to NiTiHf. In the axial direction, the NiTi elements generated two fractures measuring 92.68 mm and 77.28 mm, whereas the NiTiHf elements produced fractures of 53.15 mm and 61.83 mm. Radially, NiTi achieved fracture lengths of 16.36 mm and 11.62 mm, while NiTiHf resulted in shorter radial fractures of 12.70 mm and 9.26 mm.
- In both cases, fractures initiated from the borehole and propagated perpendicular to the actuator's actuation direction.
- NiTi generated a maximum tensile hoop strain exceeding 3000 με, compared to approximately 2500 με for NiTiHf.

CONCLUSION

The 10 MPa confined tests demonstrate that both SMAs can effectively precondition the near‑borehole region and induce fractures oriented perpendicular to the actuator's direction of actuation. The results indicate that NiTi is more suitable for low‑temperature rock environments, whereas NiTiHf performs better under high‑temperature preconditioning conditions. Additionally, this simple thermally triggered actuator offers a practical advantage: **it can precondition the borehole without requiring complex mechanical systems and can be reused multiple times.**

Acknowledgements

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REFERENCES

- De Silva, V. R. S., Aaron, J., Kong, X. Z., & Madonna, C. (2025). Unlocking the potential of shape memory alloys for near-borehole fracture stimulation: Numerical and experimental insights for underground energy extraction. Journal of Cleaner Production, 520, 146111. https://doi.org/10.1016/J.JCLEPRO.2025.146111.
- Benafan, O., Noebe, R. D., & Halsmer, T. J. (2016). Static rock splitters based on high temperature shape memory alloys for planetary explorations. Acta Astronautica, 118, 137–157. https://doi.org/10.1016/j.actaastro.2015.10.009.