Quantifying the Impact of Depletion on Coal Strength

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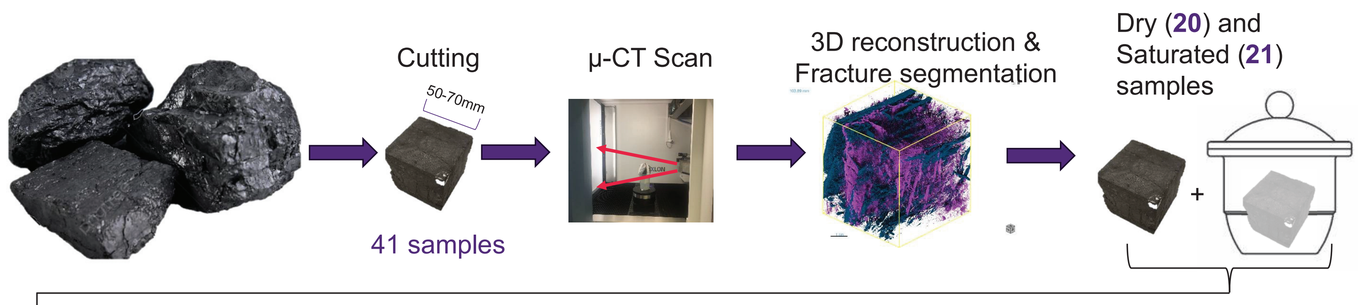
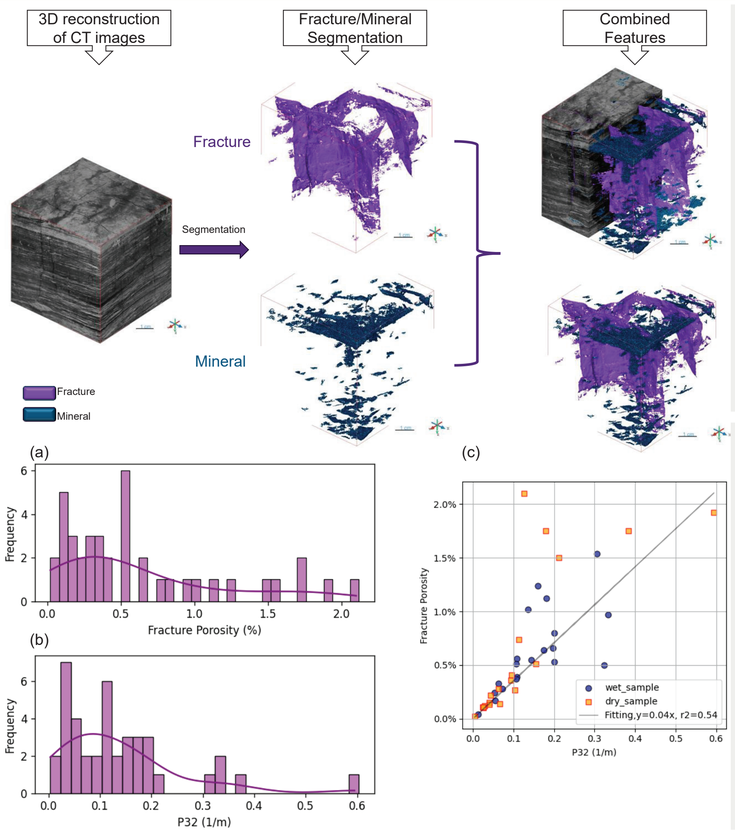
Introduction

- Understanding how coal mechanical properties respond to dewatering and gas depletion is essential for predicting borehole stability and optimizing infill well design in coal seam gas (CSG) operations.
- However, the full extent of these effects on coal strength remains underexplored. This study investigates these impacts using a multi-method approach, including micro-CT imaging, sonic testing, and mechanical testing with acoustic emission (AE) monitoring.
- By examining fracture porosity, dynamic and static mechanical properties under dry and wet conditions, the study provides new insights into coal's structural and mechanical behaviour.
- These findings contribute to refining geomechanical models for CSG developments, aiding in safer and more efficient reservoir management.

Experimental Procedures



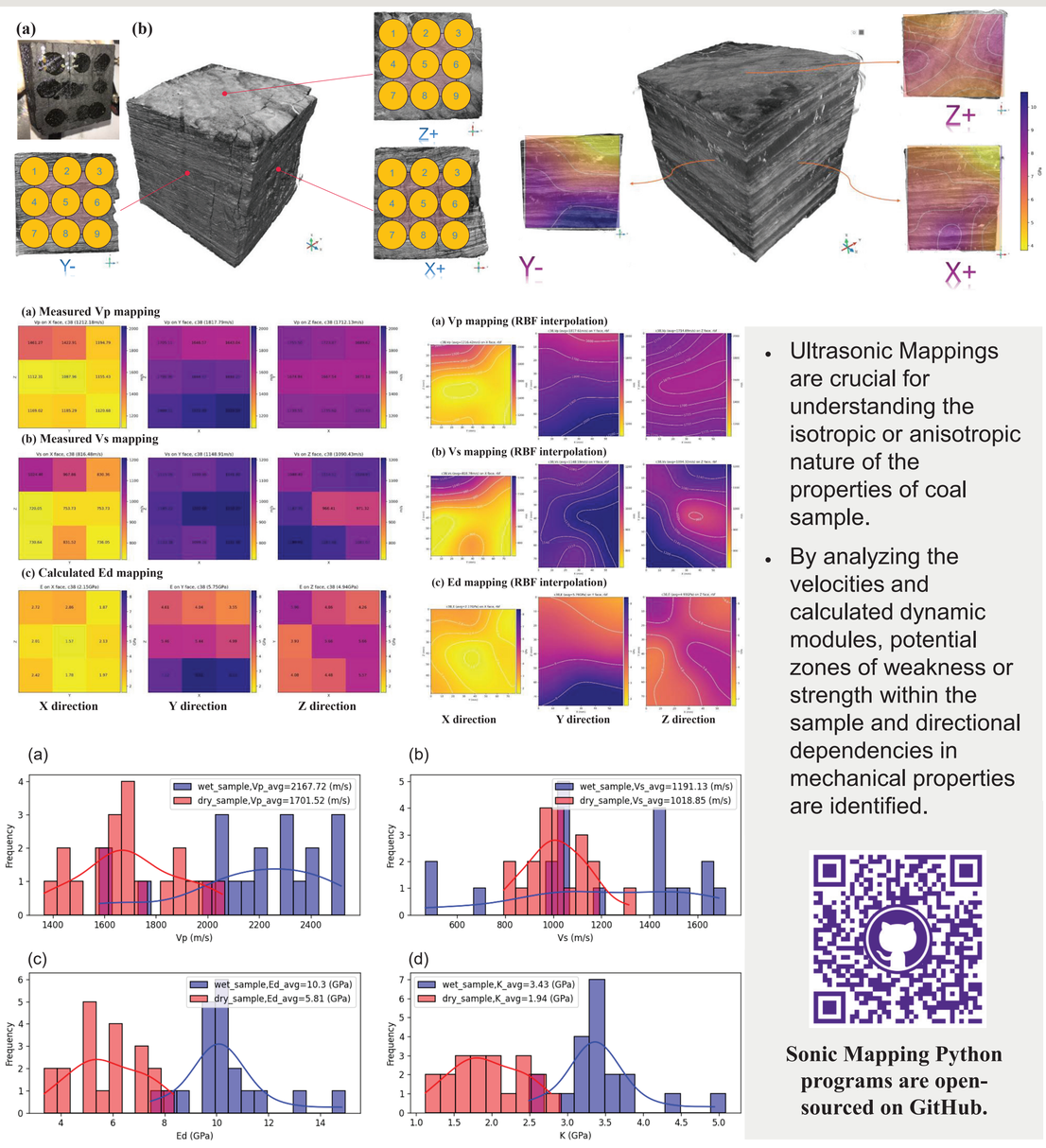
Result: CT imaging and Ultrasonic imaging



- High-resolution 3D coal model was reconstructed by using 3,500 projections (40–45 GB per sample) measured via YXLON CT machine at UQ Centre of Advanced Imaging.
- The image segmentation technique is applied to distinguish fractures, minerals, and the coal matrix for detailed microstructural analysis.

- **Fracture Porosity:** The volume fraction of fractures within the coal matrix, offering a measure of the void space available for fluid flow or gas storage.
- **Fracture Intensity (P32):** The total surface area of fractures (A_t) per unit volume (V_u), indicating the density and distribution of the fracture network within the sample as $P32 = \frac{A_t}{V_u}$.

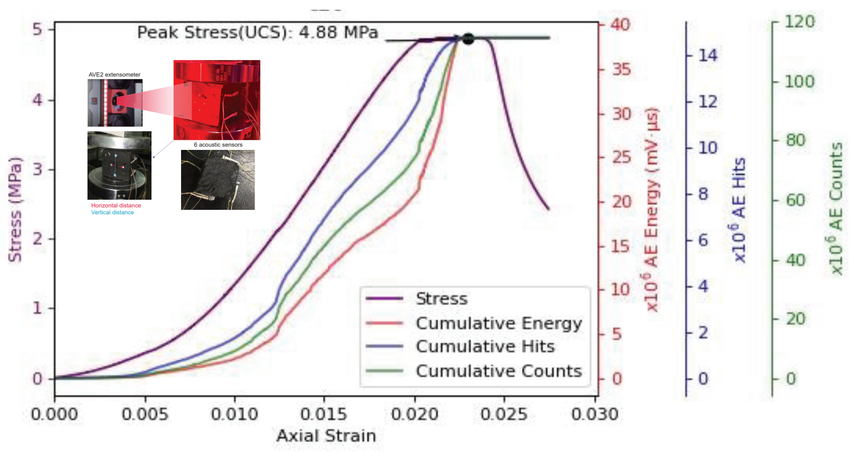
- Side-by-side comparison of the digital coal with dynamic Young's modulus mapping in both 3D and 2D of each direction.
- Ultrasonic mapping captures the presence of a high-density mineral located at the top area of the sample, which correlates with lighter colors observed in the CT scan images.

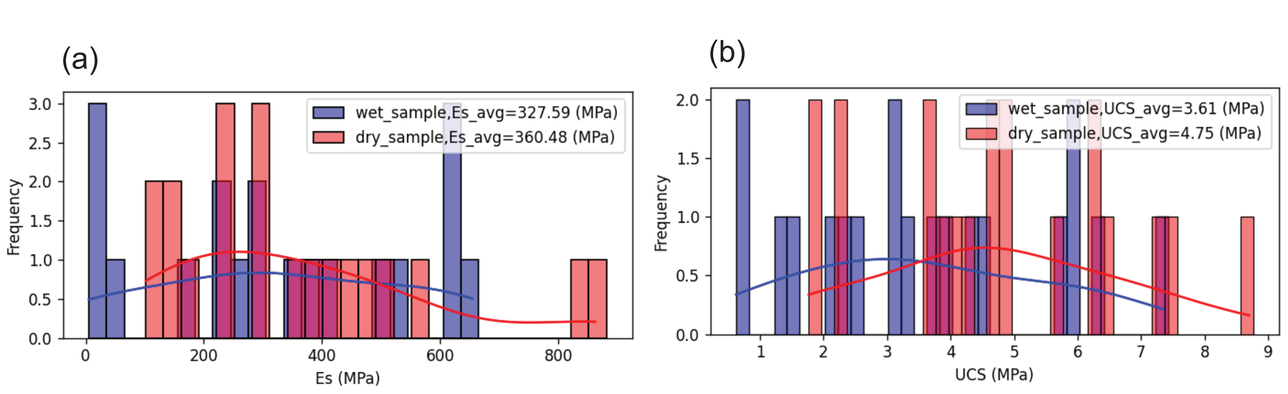


- Ultrasonic Mappings are crucial for understanding the isotropic or anisotropic nature of the properties of coal sample.
- By analyzing the velocities and calculated dynamic modules, potential zones of weakness or strength within the sample and directional dependencies in mechanical properties are identified.

Sonic Mapping Python programs are open-sourced on GitHub.

Results: Unconfined Compressive Strength (UCS) & Young's Modulus (E_s)





Conclusions

1. Wet coal exhibit higher Vp and dynamic Young's modulus (Ed), indicating that water saturation significantly influences sonic properties.
2. Dry coal display a 10% higher Young's modulus and a 31% greater UCS, demonstrating that dewatering strengthens coal but may also promote embrittlement.
3. Dry coal exhibit 104% more AE hits and 340% higher AE energy, suggesting more abrupt fractures and reduced damping effects of water, whereas wet samples show lower AE activity, reflecting suppressed microcrack propagation.
4. These findings provide a foundation for improved geomechanical models, contributing to better borehole stability predictions and optimized infill well designs in coal seam gas (CSG) developments.

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