New insights into fracture mechanics of sedimentary rocks using neutron tomography and mechanical tests

A Syed+, G Manoharan+, DL Jacobson*, JM LaManna*, DS Hussey*, E Baltic*, Y Tanino+

+School of Engineering, University of Aberdeen, UK;

*National Institute of Standards and Technology, Gaithersburg, MD, USA.

1. Background and problem

Sedimentary rocks are one of the most common materials encountered in various engineering applications. Engineering structures are designed on the basis of the strength and mechanical properties (Elastic Modulus) measured in the laboratory by subjecting a cm scale rock sample to a known stress field. The mechanical behaviour of the rock is a result of the microscopic processes such as initiation and propagation of cracks within the rock.

The aim of this work was to investigate the microscopic process in rock under varying stress field. This was achieved by acquiring direct images of cylindrical rock specimen under specified loading conditions.

2. Macroscopic behaviour

- Kirby sandstone from Edwards Plateau, US with 17% porosity was used.
- Sample: $D = 1$ in $L = 2.5$ in.
- Imaging conditions of interest (Red dots) were: a) no load, b) stress within elastic limit and c) maximum compressible stress.

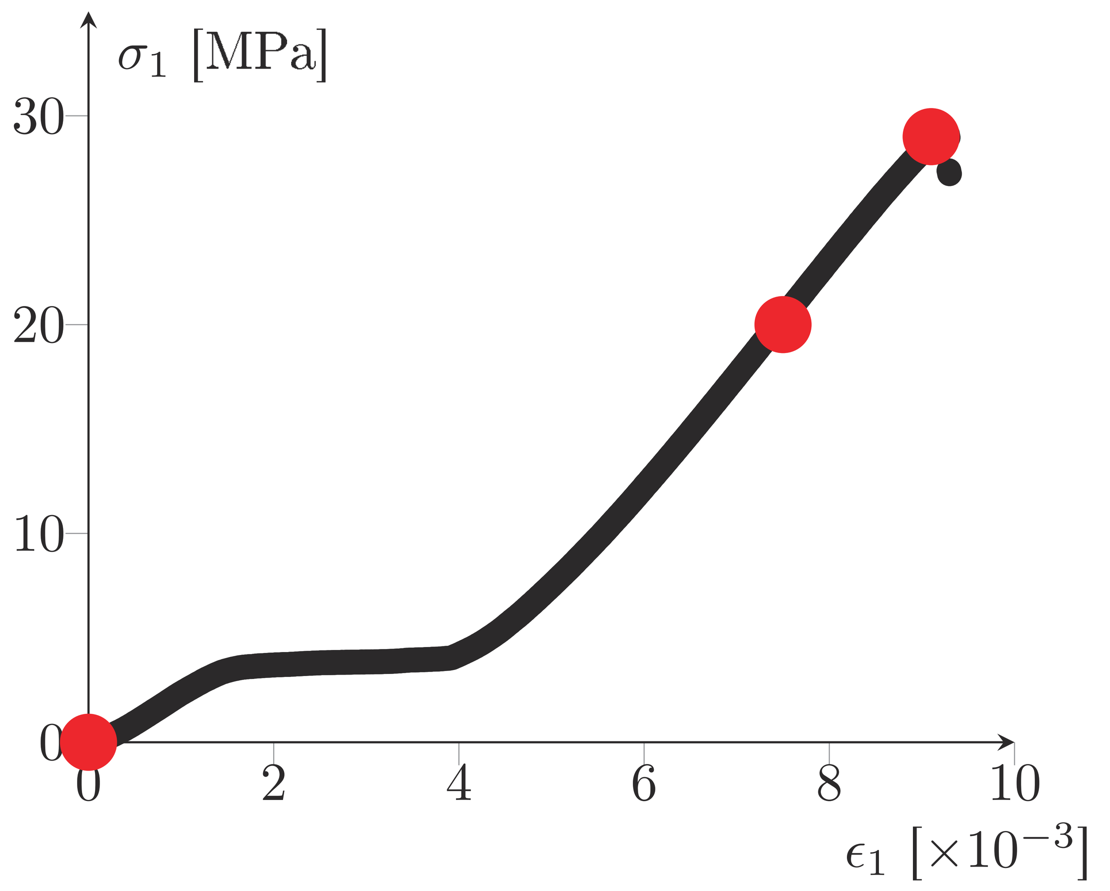

Figure 1: Variation of longitudinal stress with strain measured in the laboratory.

3. Neutron imaging

Figure 2: Triaxial test cell to house the sample along with pressure gauge and loading jack.

- Rock sample was placed in the cell and longitudinal stress corresponding to the red dots in Figure 1.
- 2-D radiograms of the sample were acquired at 0.4° intervals.

4. Sinograms

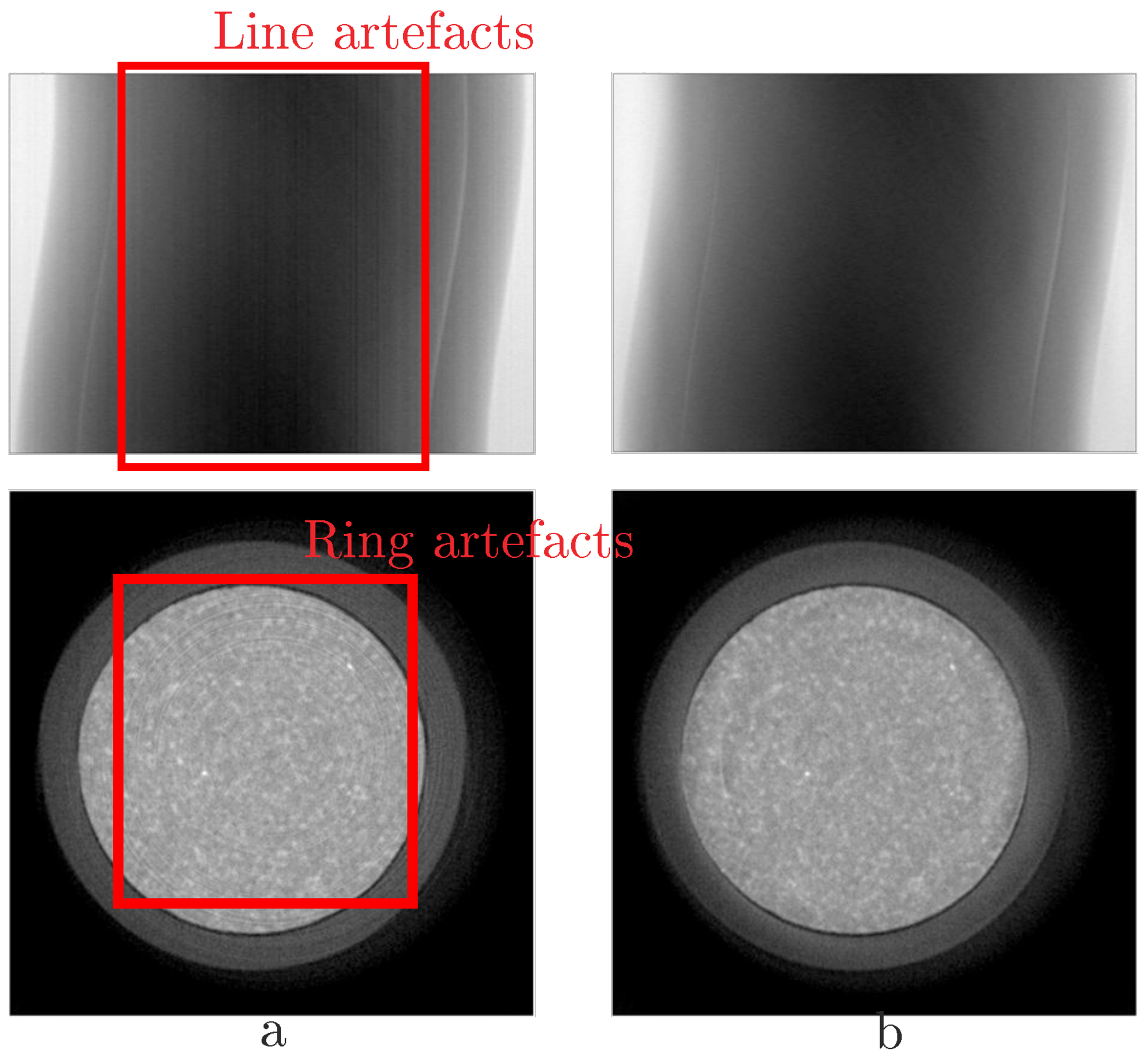

Figure 3: Reconstructed sinograms a) without filter b) with combined wavelet Fourier filtering.

- Sinograms constructed from 2-D radiograms exhibited line and ring artefacts.
- Artefacts were removed by using combined wavelet-Fourier filtering [1].

5. 3-D tomograms

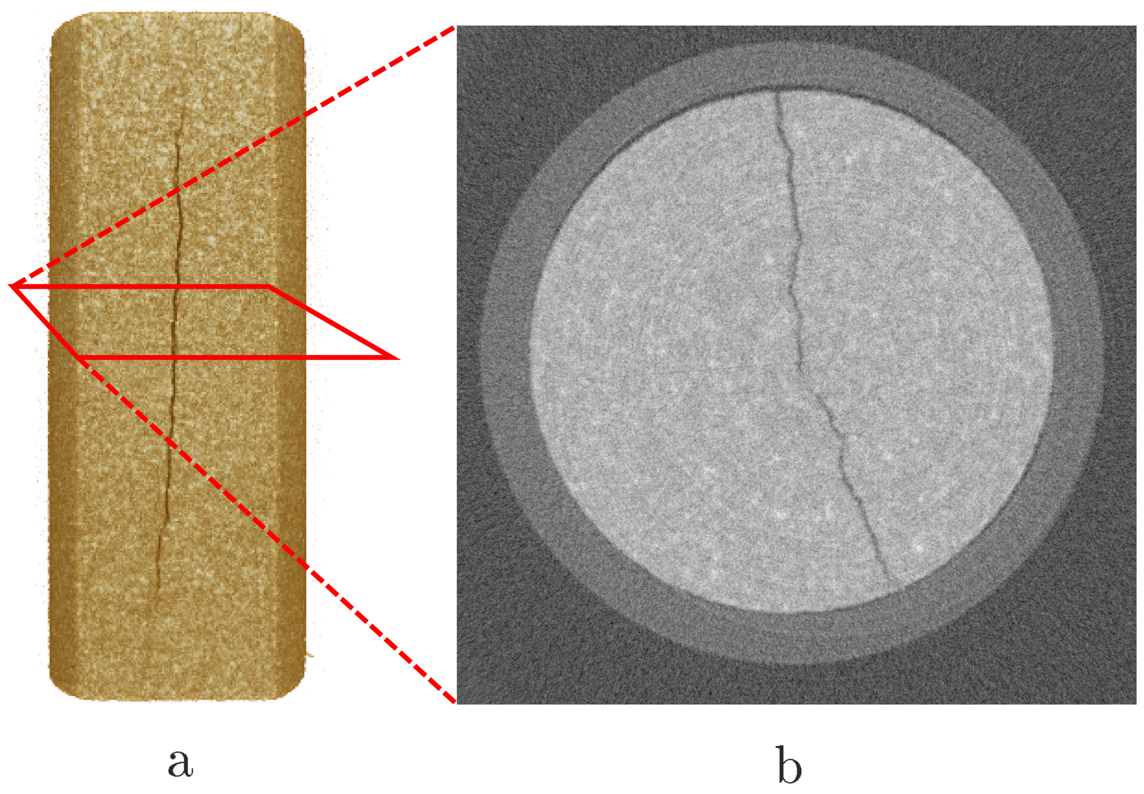

Figure 4: Reconstructed a) 3-D tomogram and b) a view of cross section of the rock.

- Single continuous crack was observed in the sample at load $\sigma_1 = 21$ MPa and spanned 88% of the length.
- The aperture and length of the crack marginally increased further with increase in σ_1, whilst the sample exhibited linear elasticity.

6. Fracture network

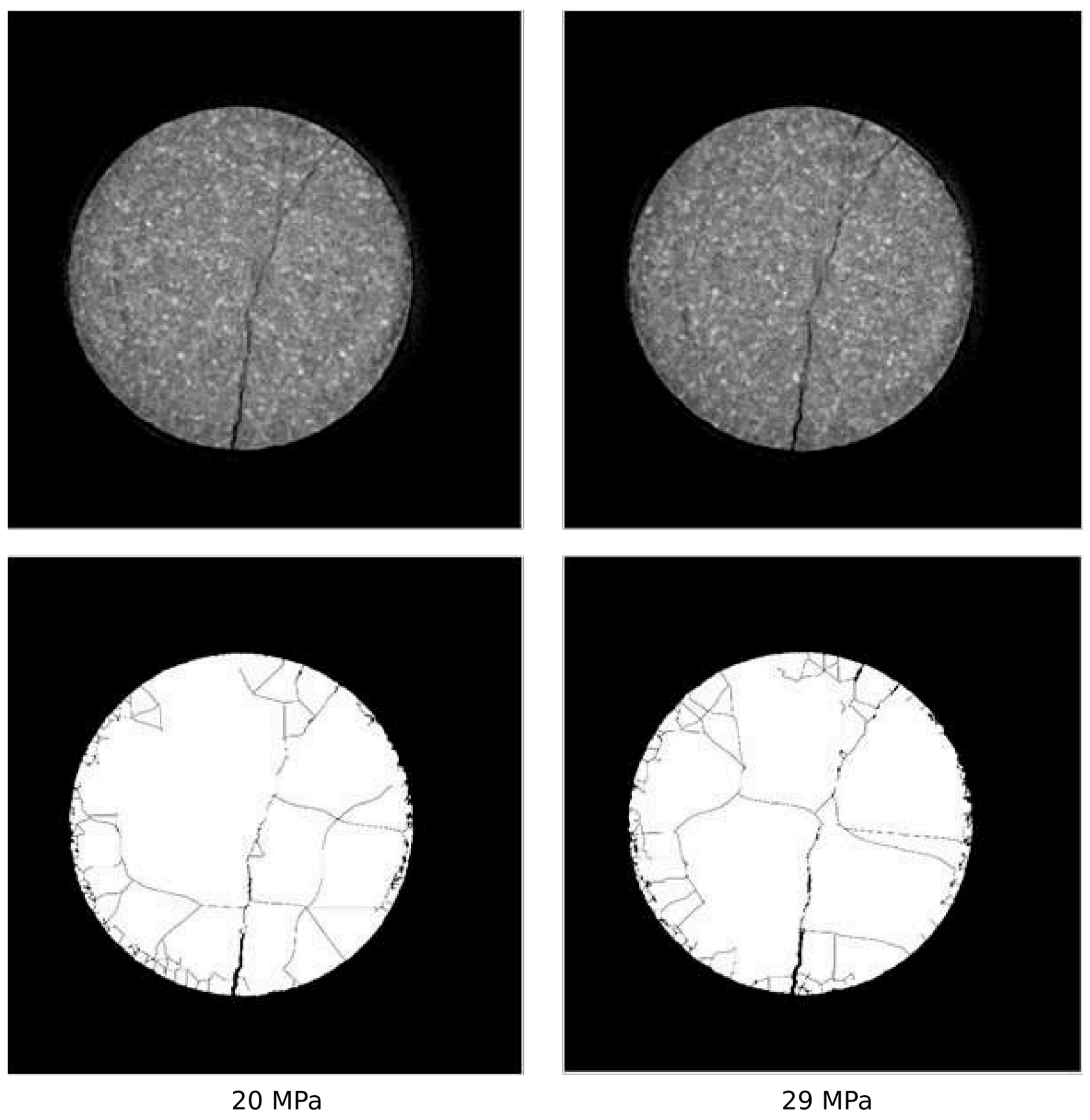

Figure 5: Fracture network from segmented images at (l) 20 MPa and (r)29 MPa.

7. 3D fracture

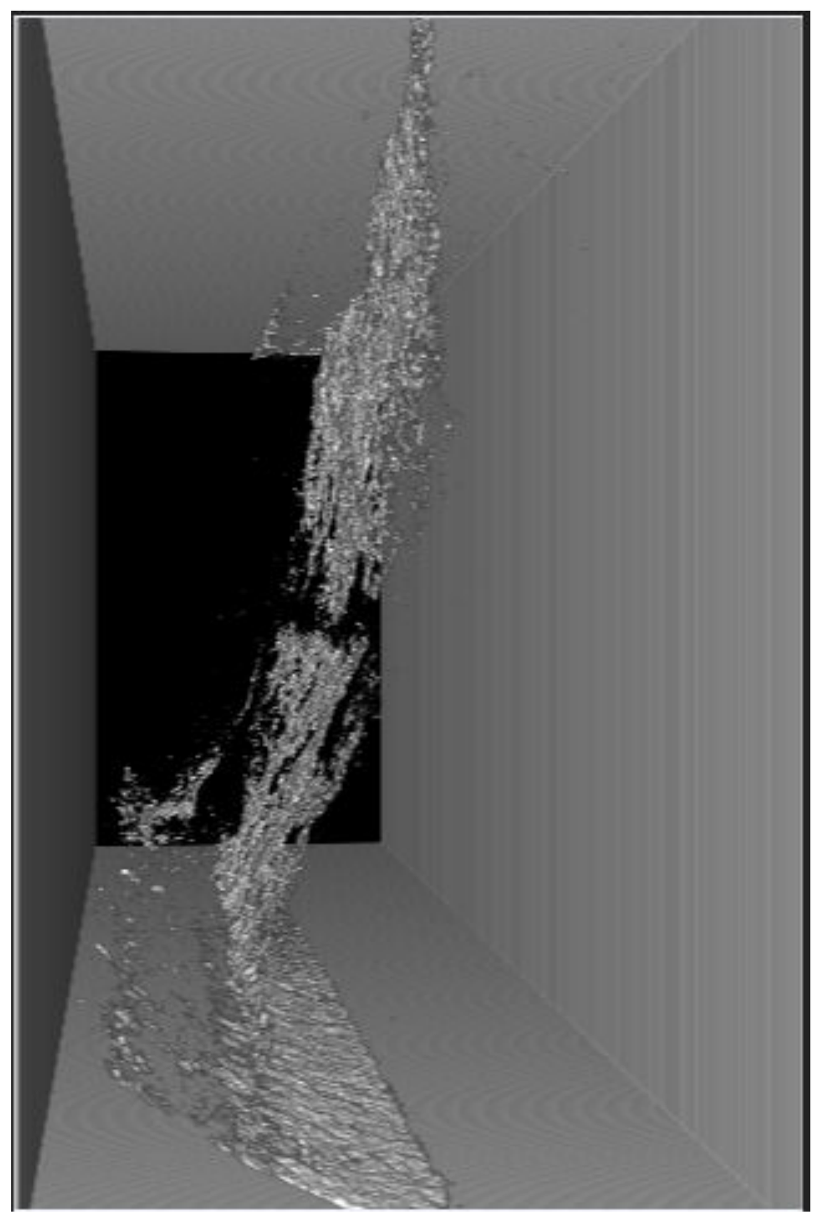

Figure 6: 3D image of fracture extracted from segmentation of 3D tomograms using TILT [2].

7. Conclusions

- Neutron imaging has been successfully used to observe the process of crack initiation and propagation of rocks under stress, to complement the macroscopic behaviour observed in the laboratory.
- Sliced neutron tomograms depicted two fractures but segmentation of the images revealed a network of fractures encompassing the two main fractures.
- Nucleation of other cracks noted with an increase in σ_1 to 29 MPa.

Acknowledgements

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References

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[2] Deng, H., Fitts, J.P. and Peters, C.A., 2016, *Computational Geoscience*, **20**, 231-244.