University of BRISTOL

British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

Induced Seismicity at Thoresby Colliery, UK

Antony Butcher, James Verdon, Richard Luckett, Brian Baptie & J-Michael Kendall

bristol.ac.uk

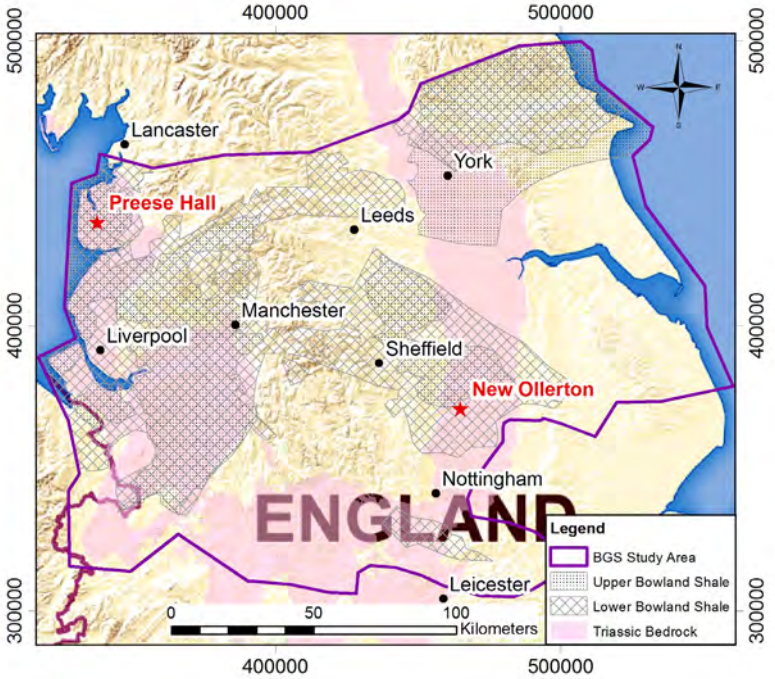
Objectives and Motivation

Setting:

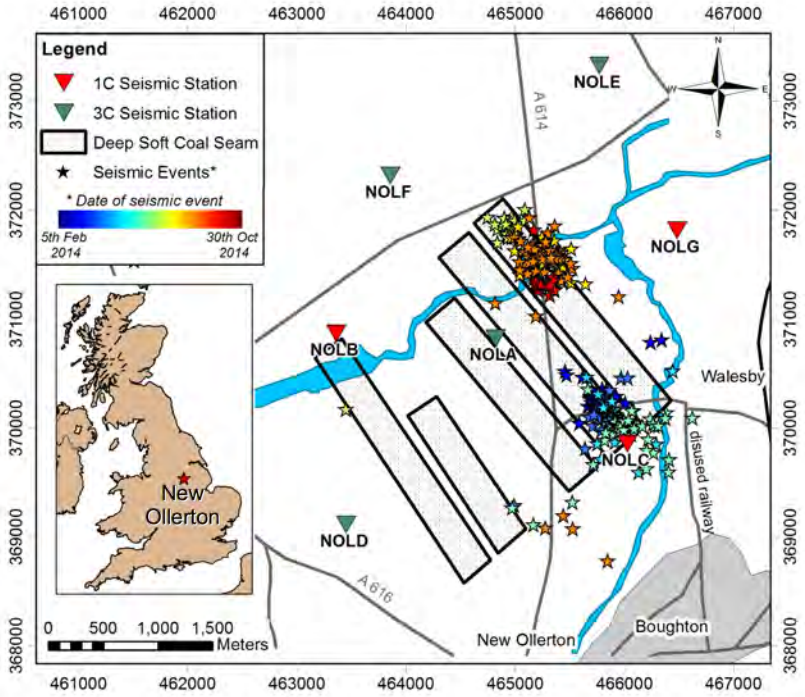
- Seismicity believed to be induced by coal mining in Nottinghamshire
- Monitored with a local network of broadband seismometers

Aims:

- Locate events with respect to mining panels: are events being triggered by mining?
- Understand effects for estimating low magnitudes at short hypocentral distances.

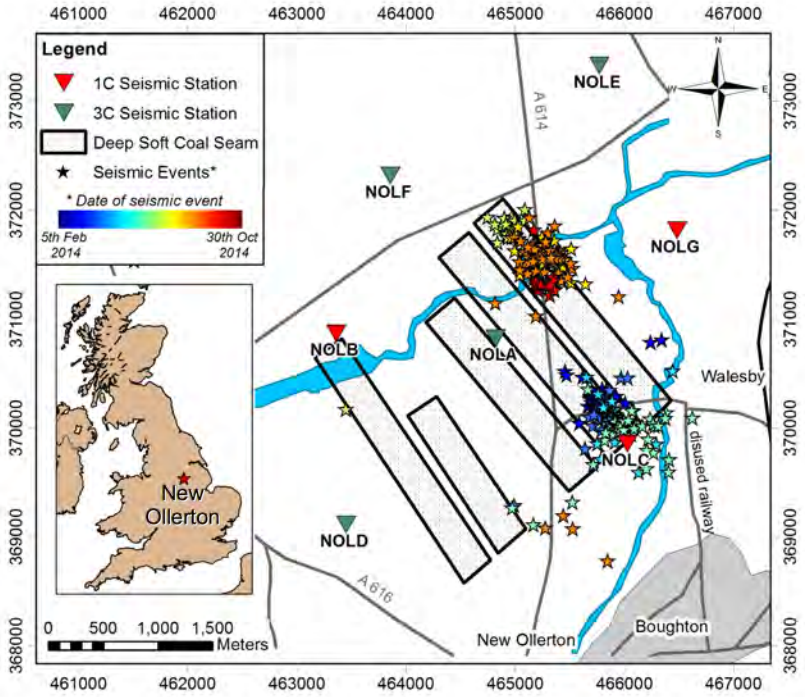


Thoresby Colliery, New Ollerton, UK

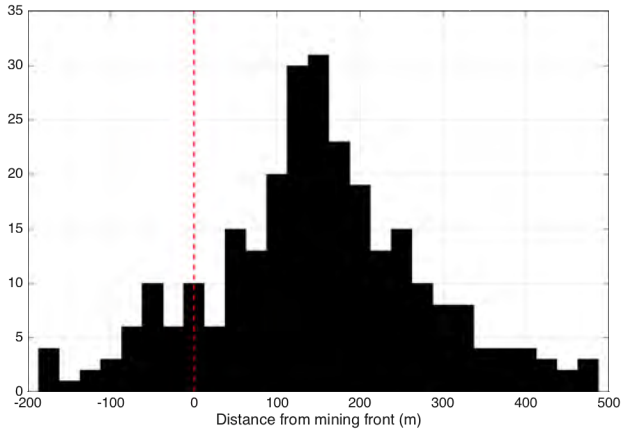


- 305 events recorded during Feb to Oct 2014;
- Largest event had a magnitude of M_L = 1.7 or M_W=1.9;
- Positions track the mining faces of seams;
- Occur at or below the depth of mining;
- Located ahead of the mining front;

Thoresby Colliery, New Ollerton, UK

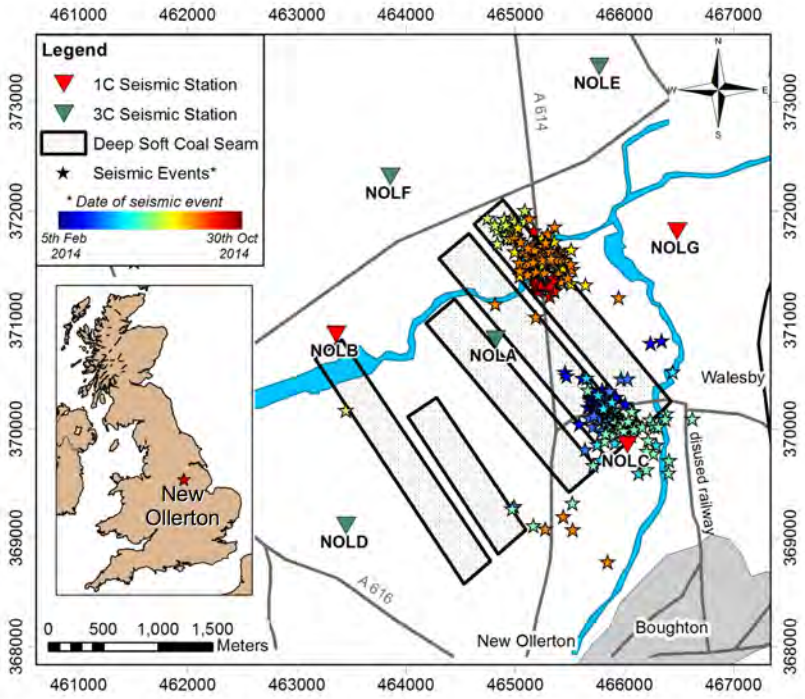


- 305 events recorded during Feb to Oct 2014;
- Largest event had a magnitude of M_L = 1.7 or M_W=1.9;
- Positions track the mining faces of seams;
- Occur at or below the depth of mining;
- Located ahead of the mining front;



bristol.ac.uk

Thoresby Colliery, New Ollerton, UK

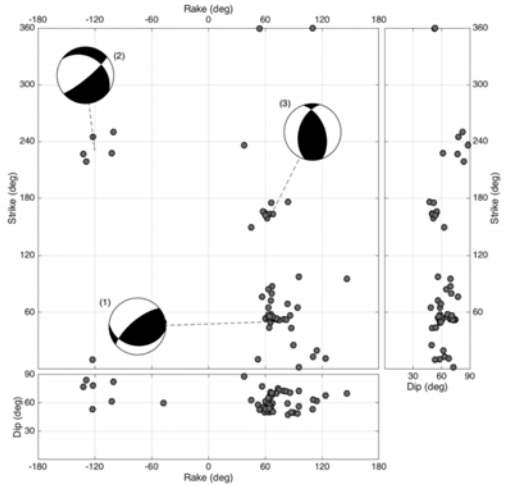


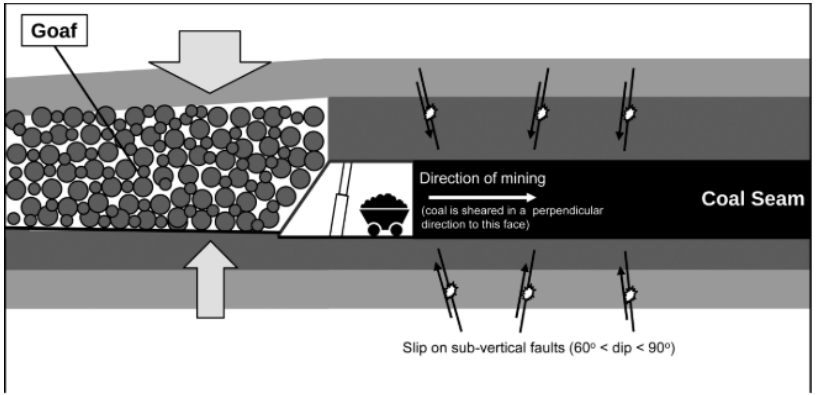
Mining-induced seismicity in the Nottinghamshire Coalfield

I. Bishop,[1]† P. Styles[1] & M. Allen[2]

Source Mechanisms

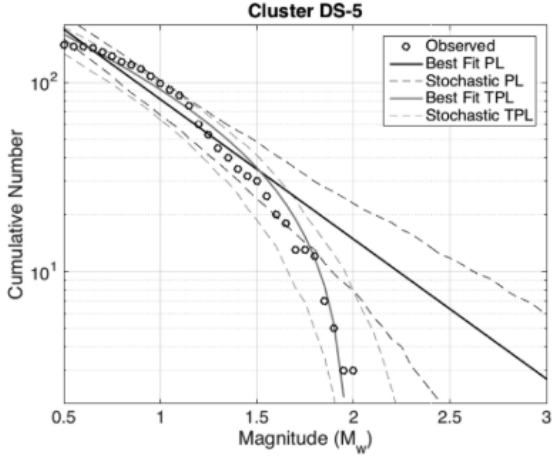
- P-wave polarities and relative amplitudes inverted for double-couple focal mechanisms.
- We compute source mechanisms for 173 events where P-wave polarities can be clearly identified.
- Source mechanisms are dip-slip motion along near-vertical planes;
- Slip planes consistent with the geometry of the mining activities;

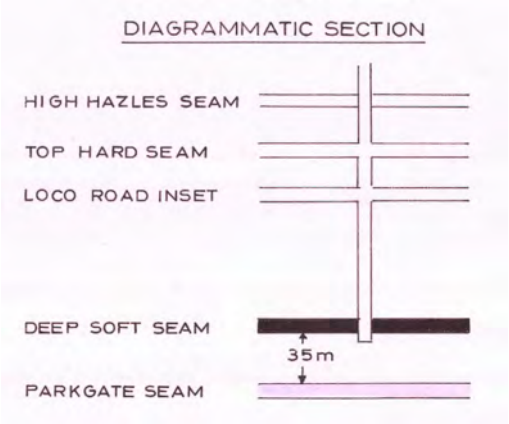




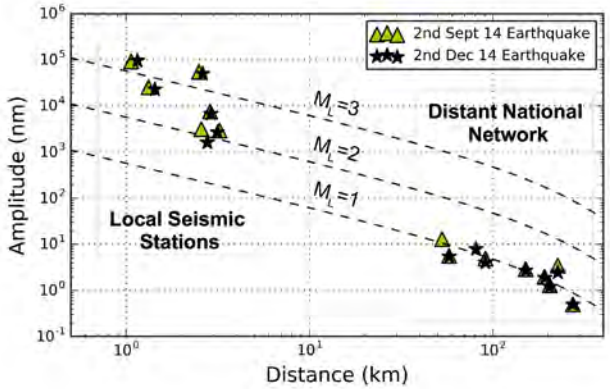
Magnitude Distribution

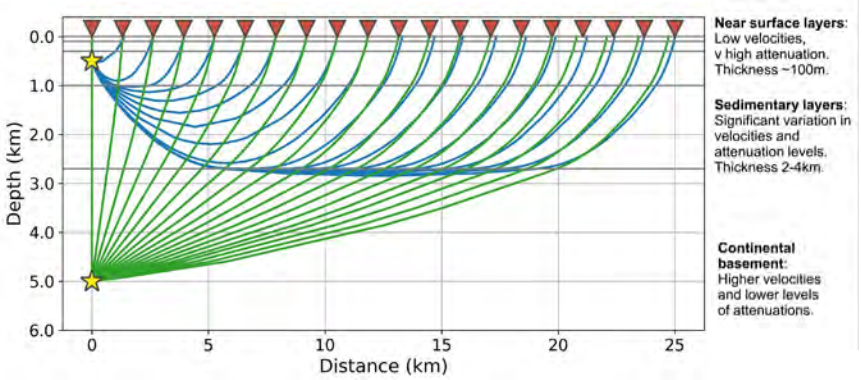
- Event population does not follow G-R power-law relationship;
- Requires a truncated power law distribution, with a maximum rupture radius of ~ 40m;
- Might be explained by the presence of overlying and underlying Top Hard and Parkgate Seams, which has already been mined.





Local Magnitudes

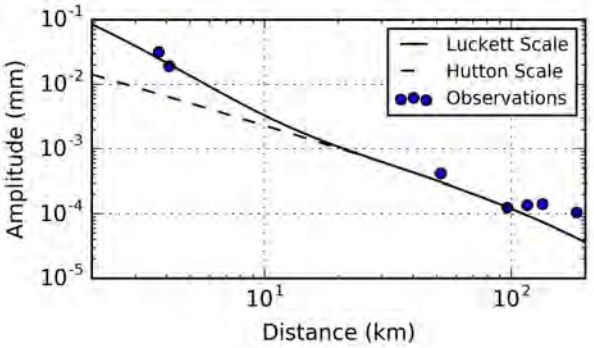


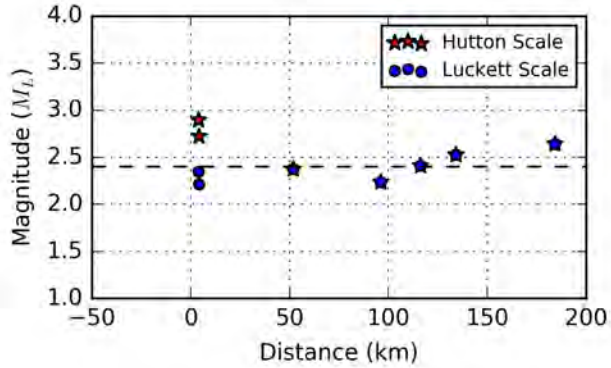


- M_L UK: Current BGS M_L scale - based on Hutton & Boore (1987) scale from S California.
- M_L NOL: Inverted directly from data over a 1-5km distance range using New Ollerton Dataset.
- M_L LUC: Uses M_L UK scale and fits an exponential function to correct for short distances.

Scale	Name	M_L Scale
Hutton & Boore (1987)	M_L UK	$M_L = log(A) + 1.11log(r) + 0.00189r - 2.09$
Butcher et al. (2017)	M_L NOL	$\leq 17km$: $M_L = log(A) + 1.17log(r) + 0.0514r - 3.0$ $> 17km$: $M_L = log(A) + 1.11log(r) + 0.00189r - 2.09$
Luckett et al. (2019)	M_L LUC	$M_L = log(A) + 1.11log(r) + 0.00189r - 2.09 - 1.16e^{-0.2r}$

Newdigate: M_L=2.4 – 18/07/2018

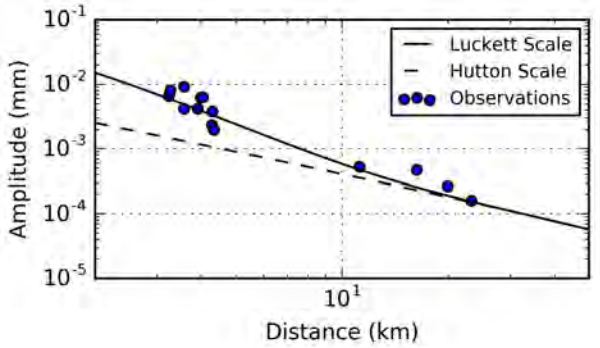


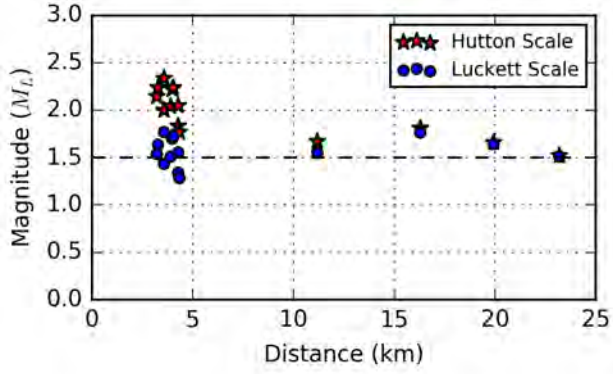


Amplitude plotted with different scales, with a divergence observed at distances <15km.

Station magnitudes calculated using both Hutton and Luckett M_L scales.

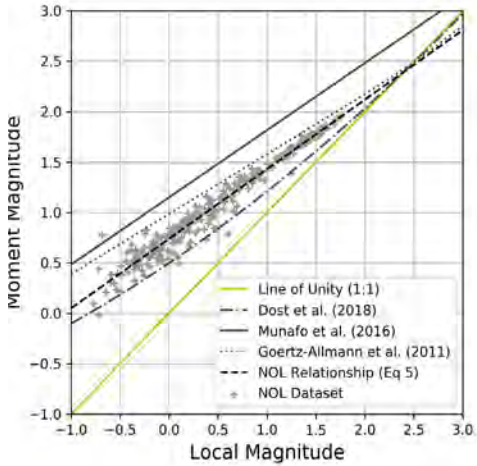
Preston New Road: M_L=1.5 – 11/12/2018

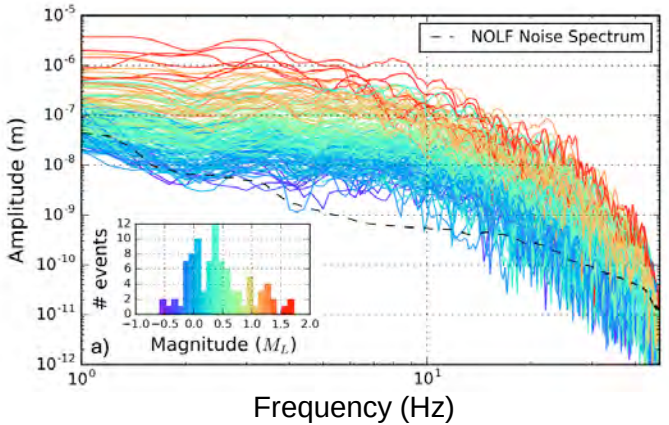




Moment Magnitudes

- Diverge between M_L and M_W which is consistent with datasets from different locations;
- Empirical relationship is $M_W = 0.69M_L + 0.74$;
- Difference caused by a constant corner frequency imposed by a decay of high frequency energy;
- Normal Brune source model inappropriate for these events.

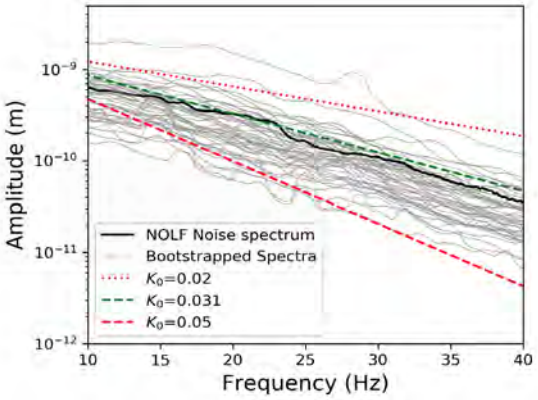


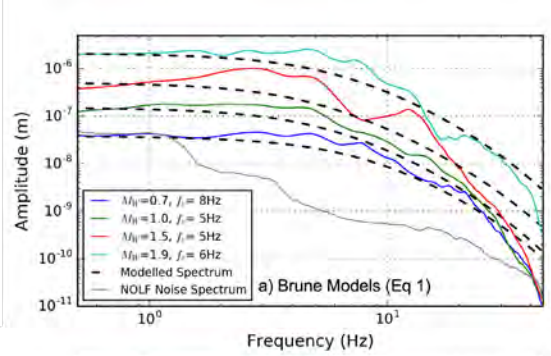


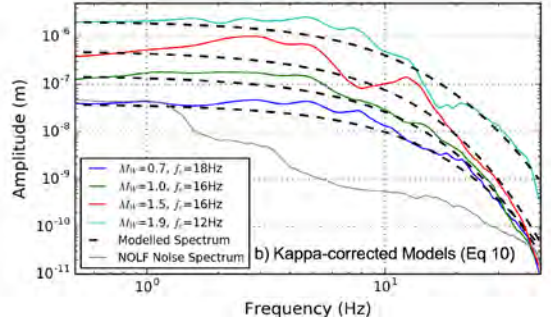
Moment Magnitudes

- Diverge between M_L and M_W which is consistent with datasets from different locations;
- Empirical relationship is $M_W = 0.69M_L + 0.74$;
- Difference caused by a constant corner frequency imposed by a decay of high frequency energy;
- Normal Brune source model inappropriate for these events.

$$\Omega(f) = \frac{\Omega_0 e^{-(\pi f d/vQ)}}{[1 + (f/f_c)^2]} e^{(-\pi f \kappa_0)}$$

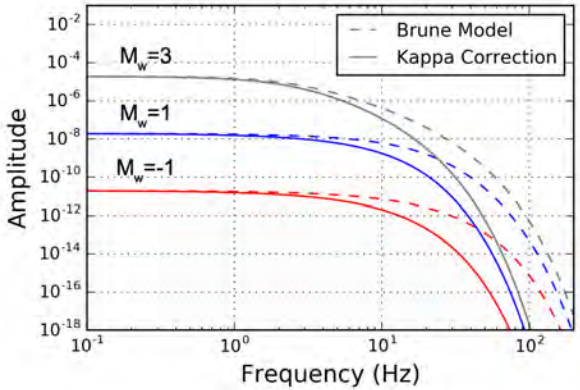




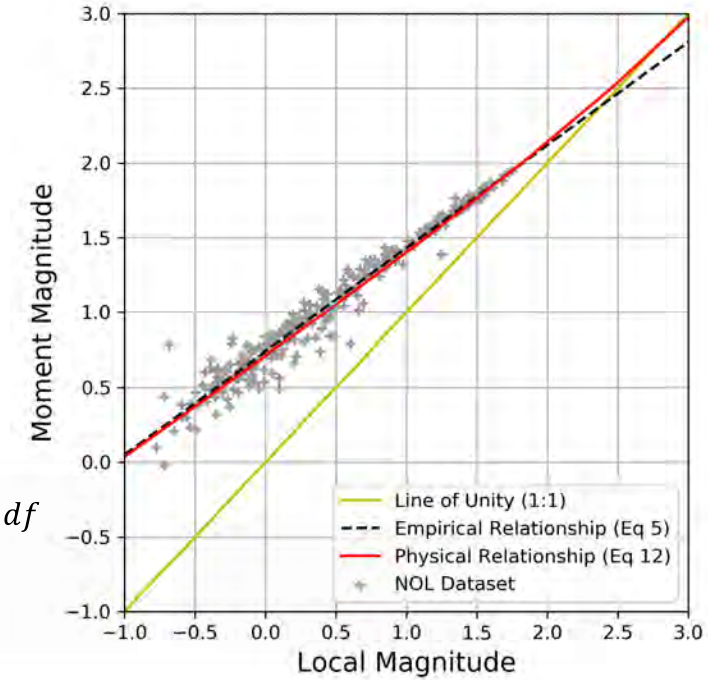


Physics based M_L-M_W relationship

- Empirical relationships require pre-existing datasets to invert relationship;
- M_L-M_W relationship determined by using the integral of the Kappa corrected Brune Model;
- Consistent with the empirical derived relationship.

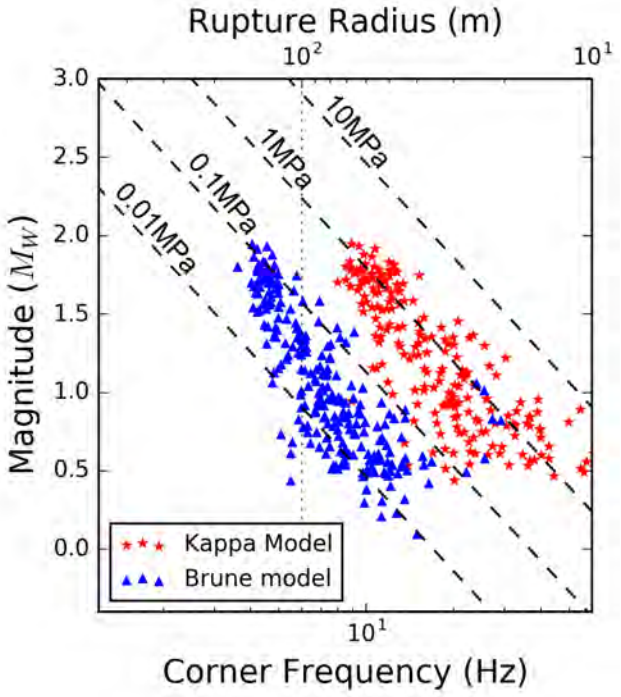


$$\text{Amax} = \int_0^\infty \frac{\Omega_0 e^{-(\pi f d/vQ)}}{[1+(f/f_c)^2]} e^{(-\pi f \kappa_0)} df$$



Corner Frequencies and Source Properties

- Corner frequencies and seismic moment used to calculate rupture radius and stress drops;
- Rupture radius for Kappa-corrected model are consistent with previous findings;
- Stress drop values can be an order of magnitude lower when the loss of high frequency energy is uncorrected.



Conclusions

- Event hypocentres occur ahead of the mining fronts as they propagate to the SE. Events are clearly triggered by mining activities.
- Event magnitudes do not follow expected power-law distribution – possible limit on rupture length created by underlying mined seam.
- Local magnitudes are overestimated at close hypocentral distances, and recently proposed M_L scales have been shown to be valid for PNR and Newdigate.
- Incorrect calculation of source properties if a 1:1 relationship between M_L and M_W is assumed. M_W results in higher estimates of magnitude than M_L due to a preferential decay of high frequencies.
- High frequency energy decay can be modeled using the parameter $K_{0,}$ derived using ambient noise.
- These models can provide a physics based relationship between M_L and M_W.
- Corner frequency estimates are compromised at low magnitudes. Therefore rupture radius and stress drop calculations need to include a correction for K_0 for these type of events.