Linking our understanding of induced seismicity to other Net-Zero technologies

James Verdon

James.Verdon@bristol.ac.uk

Bristol University Microseismicity Projects
BUMPS

www1.gly.bris.ac.uk/BUMPS/

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Unconventional Hydrocarbons in the UK Energy System

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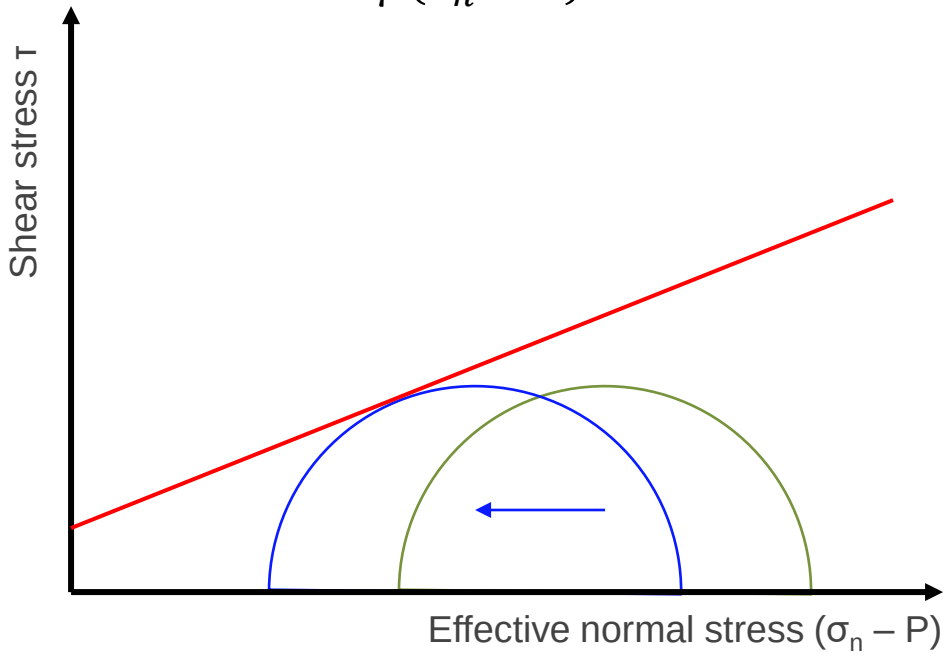
Why does induced seismicity occur?

- Fluid injection increases pore pressure, reducing the effective stress.
- This moves faults towards their failure envelope, allowing slip, resulting in induced seismicity.
- For large events, the majority of the energy released is stored tectonic energy
- Induced seismicity can also be triggered by subsidence associated with fluid production

$$\tau > \mu(\sigma_n - P) + C$$



Why does induced seismicity occur?

Induced seismicity therefore will require the following:

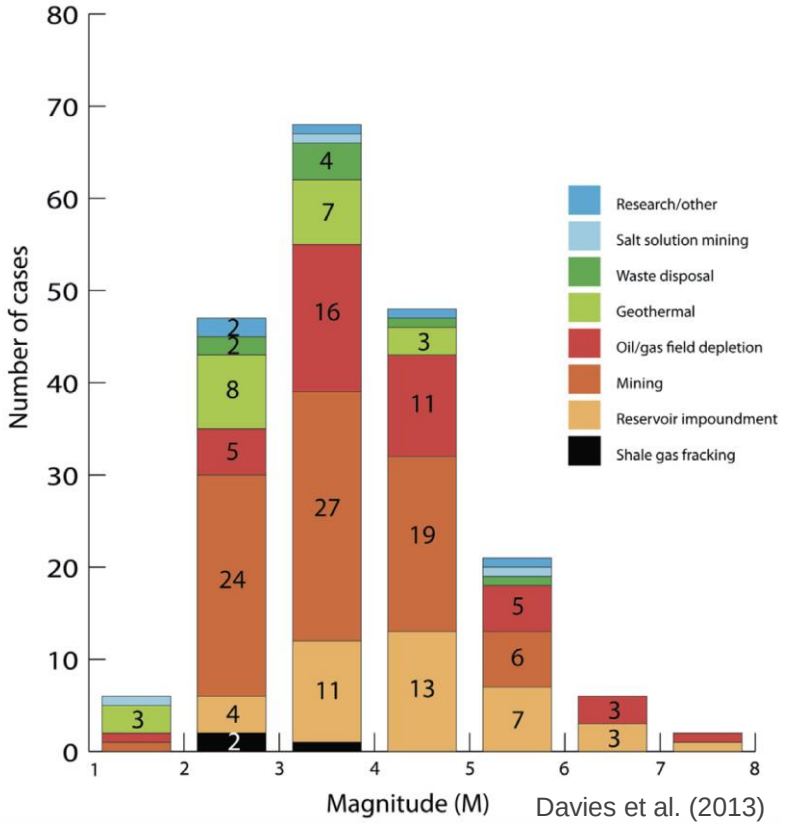
- A pre-existing fault must be present that is near to its critical stress conditions
- A subsurface perturbation that affects the *in situ* stress state on the fault, moving it towards failure
- The fault must have frictional properties such that slip is accommodated by rapid, brittle rupture (as opposed to slow-slip).

- Hence the occurrence and prevalence of induced seismicity will depend on **geological factors** (the in situ structural geology, local stress conditions) and **operational factors** (the size and nature of the stress perturbation)

Induced seismicity and energy technologies

Induced seismicity has occurred in association with most forms of subsurface injection:

- Hydraulic fracturing: e.g., Lancashire, Duvernay shale (Canada)
- Geothermal: e.g., Basel, St. Gallen, Cooper Basin
- CCS: (e.g., In Salah, Decatur)
- Waste-water disposal: e.g., Oklahoma, Rubiales (Colombia)
- Natural gas storage: e.g., CASTOR (Spain)

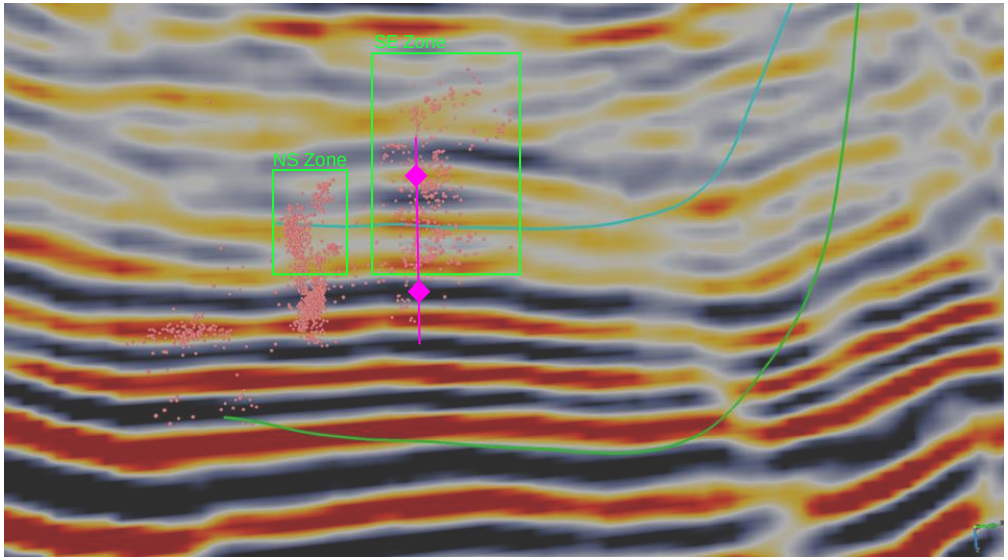


Davies et al. (2013)

Managing Induced Seismicity?

By effective site selection?

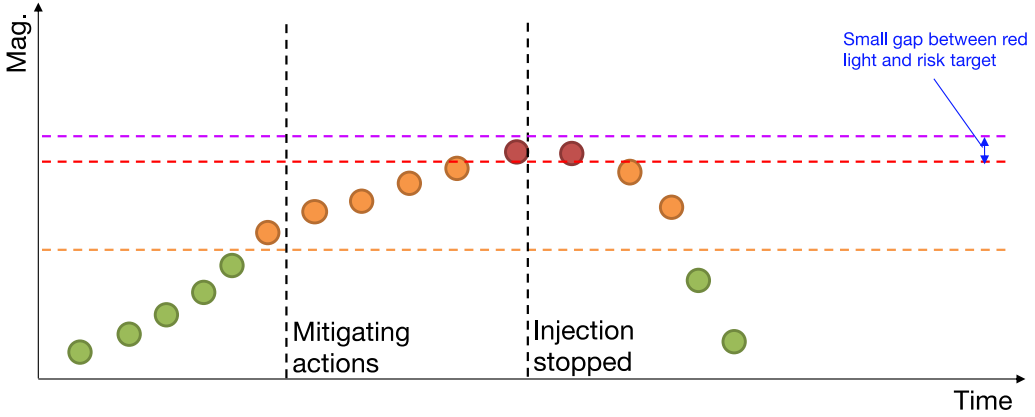
- If we can find sites with no pre-existing faults present, induced seismicity can be avoided.
- However, faults can be challenging to identify even where good-quality geophysical imaging is available
- In some areas, faults are ubiquitous and cannot be avoided easily



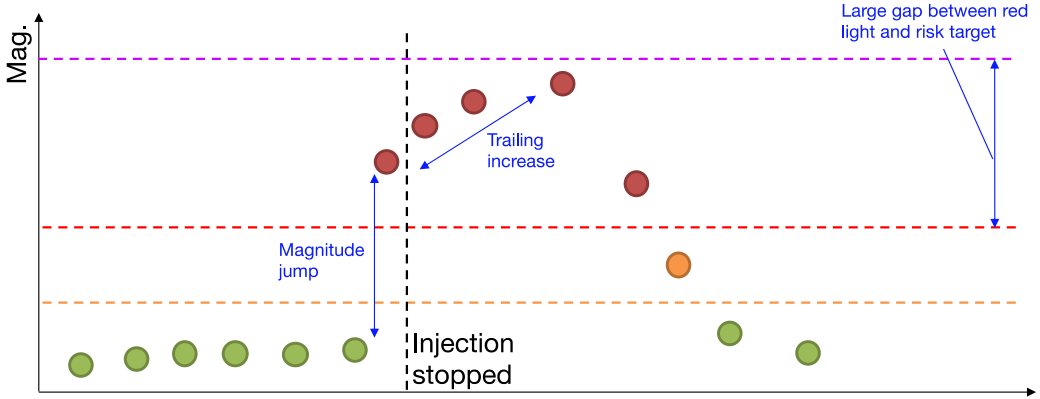
Managing Induced Seismicity?

Traffic Light Schemes

- Modify or stop injection when certain magnitude thresholds are reached
- Most widely-used induced seismicity mitigation approach



- Red light must be set below the level that is to be avoided – but how much below (magnitude jumps and trailing events)?

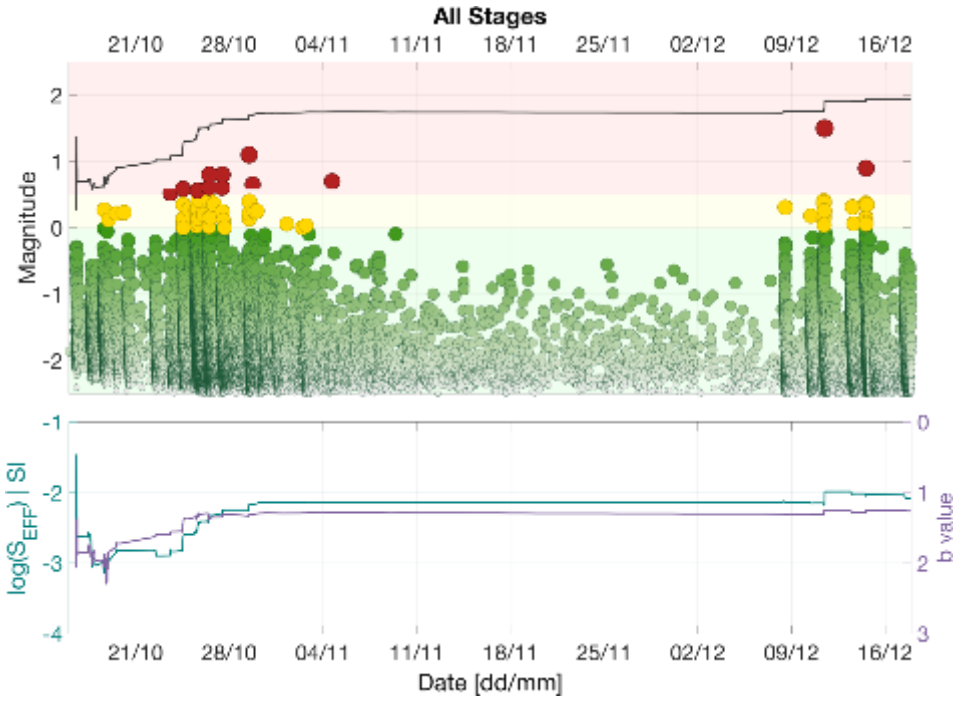


Managing Induced Seismicity?

Forecasting models

- Model M_{MAX} based on observed microseismicity, using forecasts to guide decision-making

- Range of models now in circulation – further work needed to judge their effectiveness



Induced Seismicity and Net Zero Technologies

Some Big Questions:

- **Will induced seismicity occur?** If it involves injection of fluids into the deep subsurface, there is a risk of triggering induced seismicity…
- **Can we avoid IS through judicious site selection?** At present, our ability to effectively image faults in the subsurface prevents us from using site selection to avoid IS.
- **Traffic-light schemes?** Currently the risk mitigation method of choice, but what thresholds to use as the red light?

Induced Seismicity and Net Zero Technologies

Future directions:

- Can forecasting models be used to guide IS risk-management?
- What are the physical processes that take place during fault reactivation?
- What factors control M_{MAX}?
- Can we adapt operations to reduce/prevent IS?
- What levels of monitoring are required?
- Improving resilience rather than reducing hazard?
- What observations are we failing to make?

Thanks!

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