Global review of induced and triggered earthquakes

Miles P. Wilson

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British Seismology Meeting

5th–7th April 2017

Contents

Disclaimer

Years	Education
2011-2014	B.Sc. (Hons.) Geophysics with Geology (Durham University, UK)
2014-2015	M.Sc. (Distinction) Petroleum Geoscience (Heriot-Watt University, UK)
2015-2016	Research Assistant (ReFINE and Professor Gillian Foulger)
2016-	Ph.D. Applied hydrogeological modelling (Durham University, UK)

- **Not a seismologist**
- ‘Big picture science’

Terminology

- *'Induced'* vs. *'Triggered'* earthquakes

- *Induced*

Released energy predominantly of anthropogenic origin

- *Triggered*

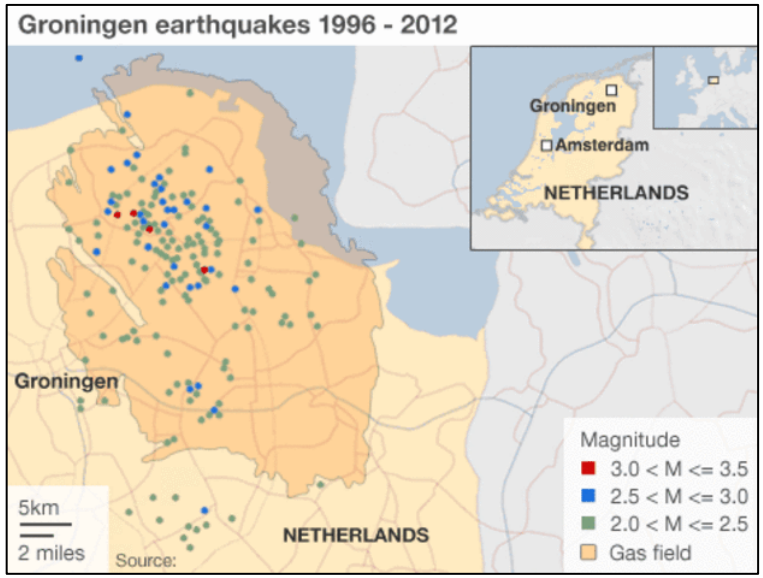
Released energy predominantly of natural origin

Induced – Anthropogenic influence

Study background

NAM

- Groningen gas field, The Netherlands
  - Production from 1963
  - 2.8 tcm gas in place
  - ~50% natural gas production in the Netherlands
- Induced earthquakes
  - Maximum observed magnitude M_L 3.4 (16/08/2012)
- Update the 2013 database



http://www.bbc.co.uk/news/world-europe-22542982


Marine and Petroleum Geology 45 (2013) 171–185

Contents lists available at SciVerse ScienceDirect

Marine and Petroleum Geology

journal homepage: www.elsevier.com/locate/marpetgeo

ELSEVIER

Review article

Induced seismicity and hydraulic fracturing for the recovery of hydrocarbons

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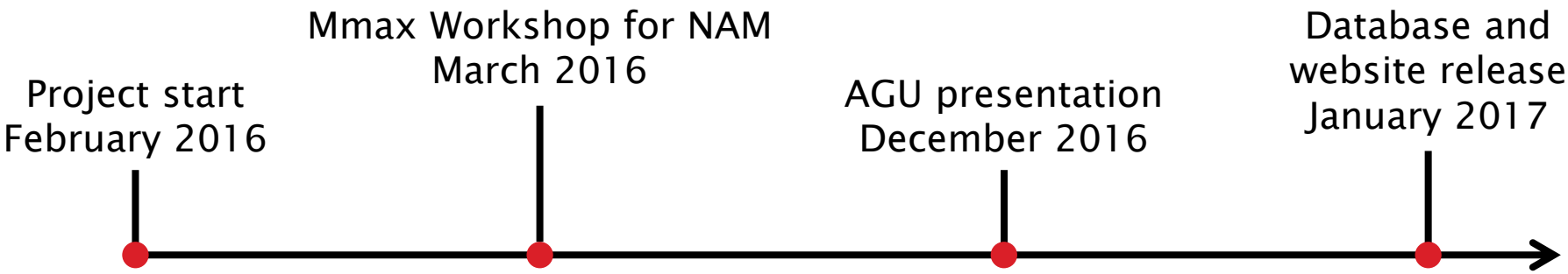
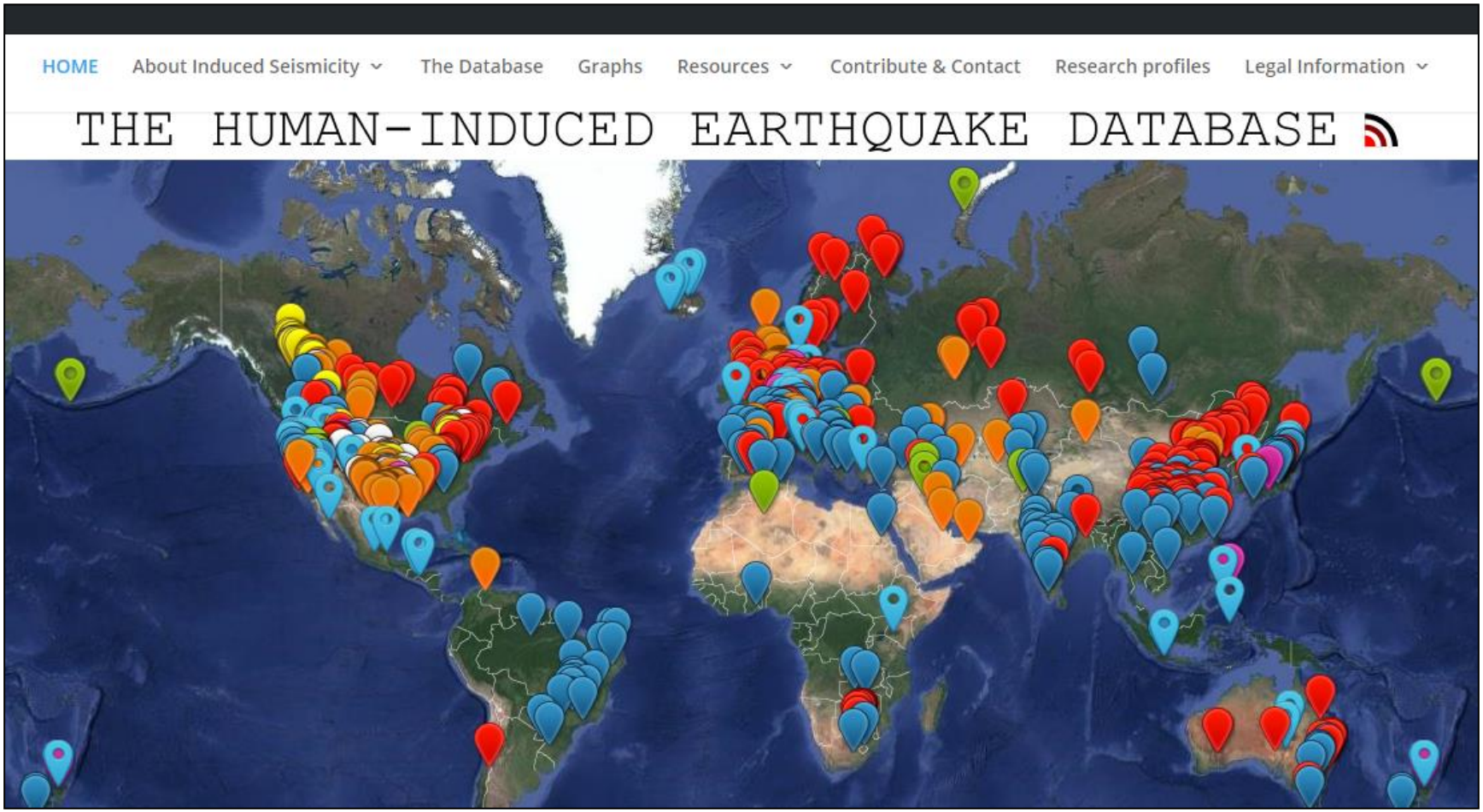
ReFINE
RESEARCHING FRACKING

Study background



- Literature review, predominantly peer-reviewed studies
- Report all suggested cases (not our opinion)

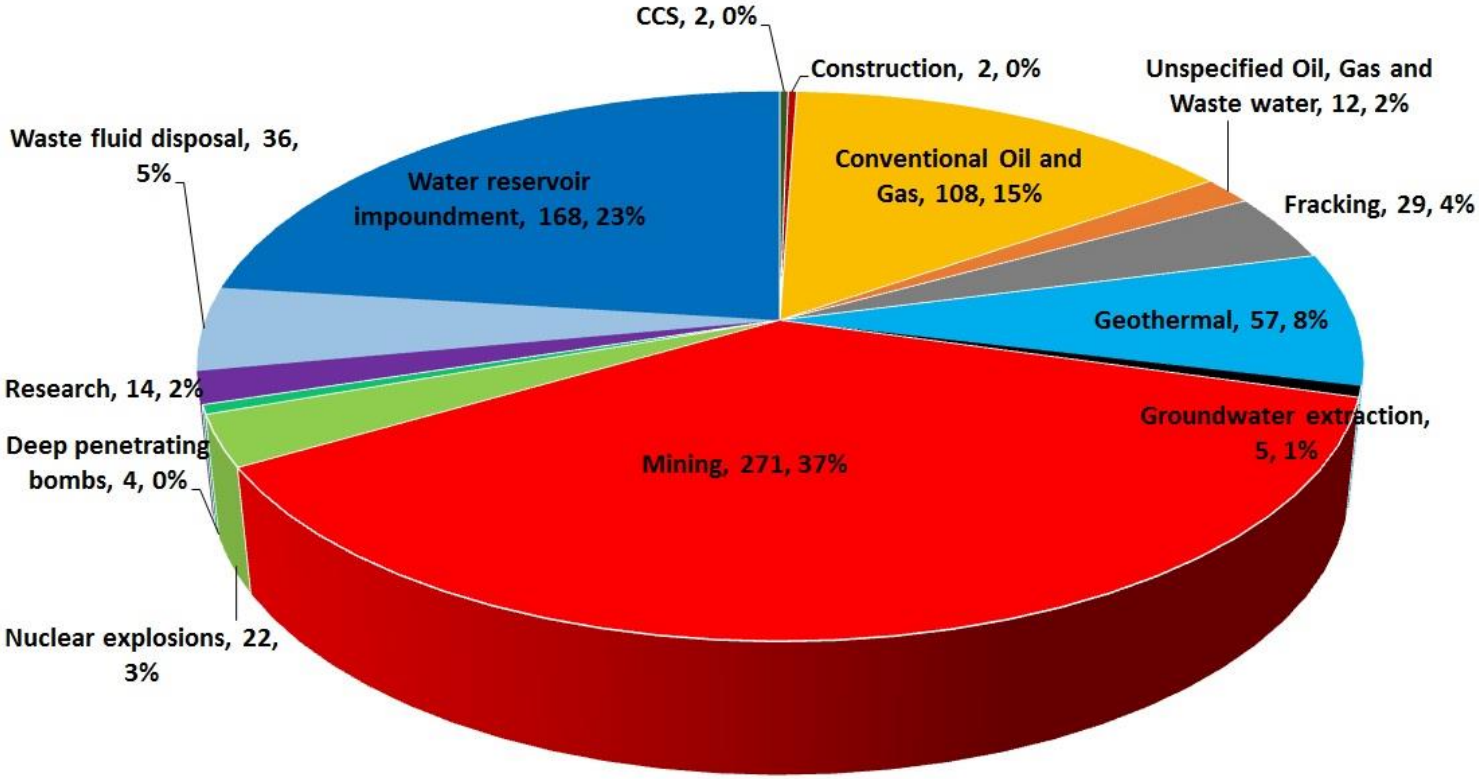
HiQuake overview



www.inducedearthquakes.org

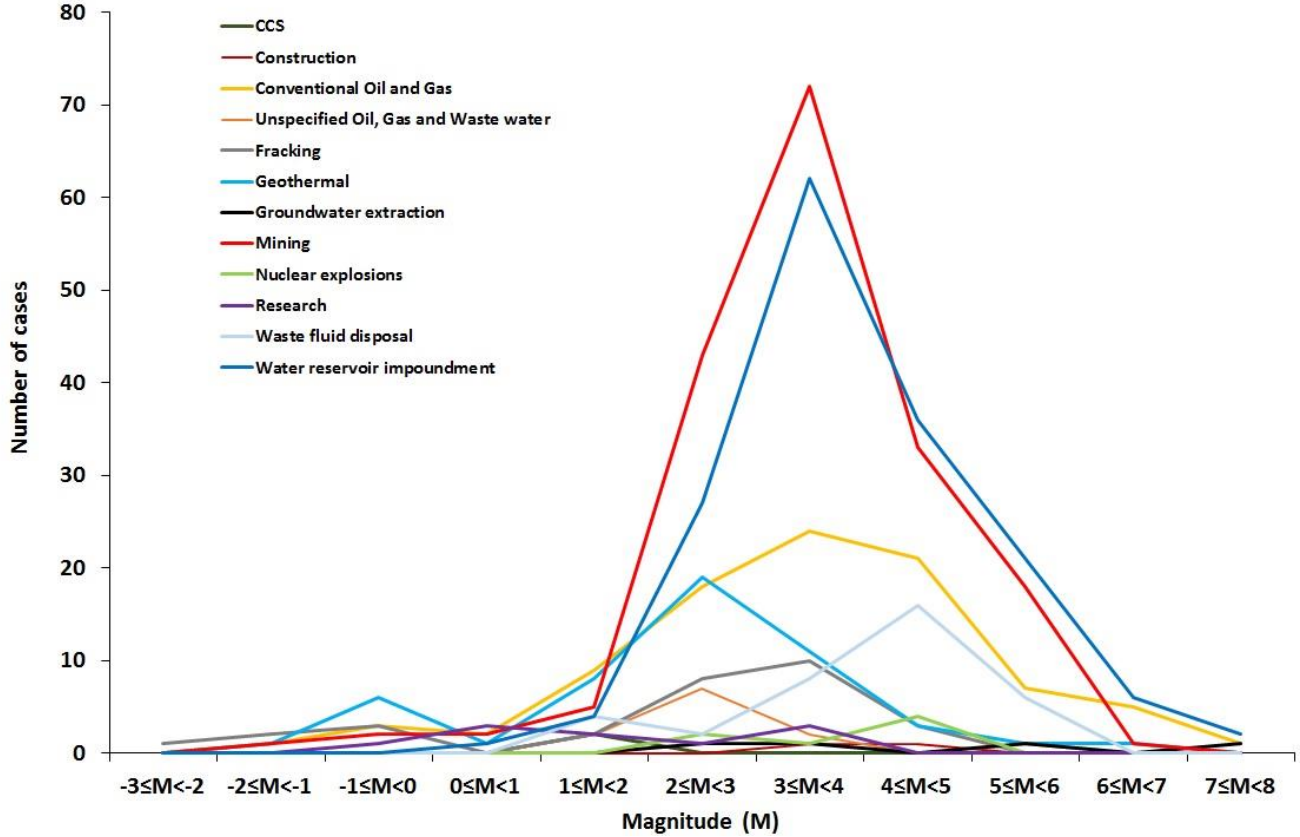
Project types

- 730 projects with reported induced seismicity

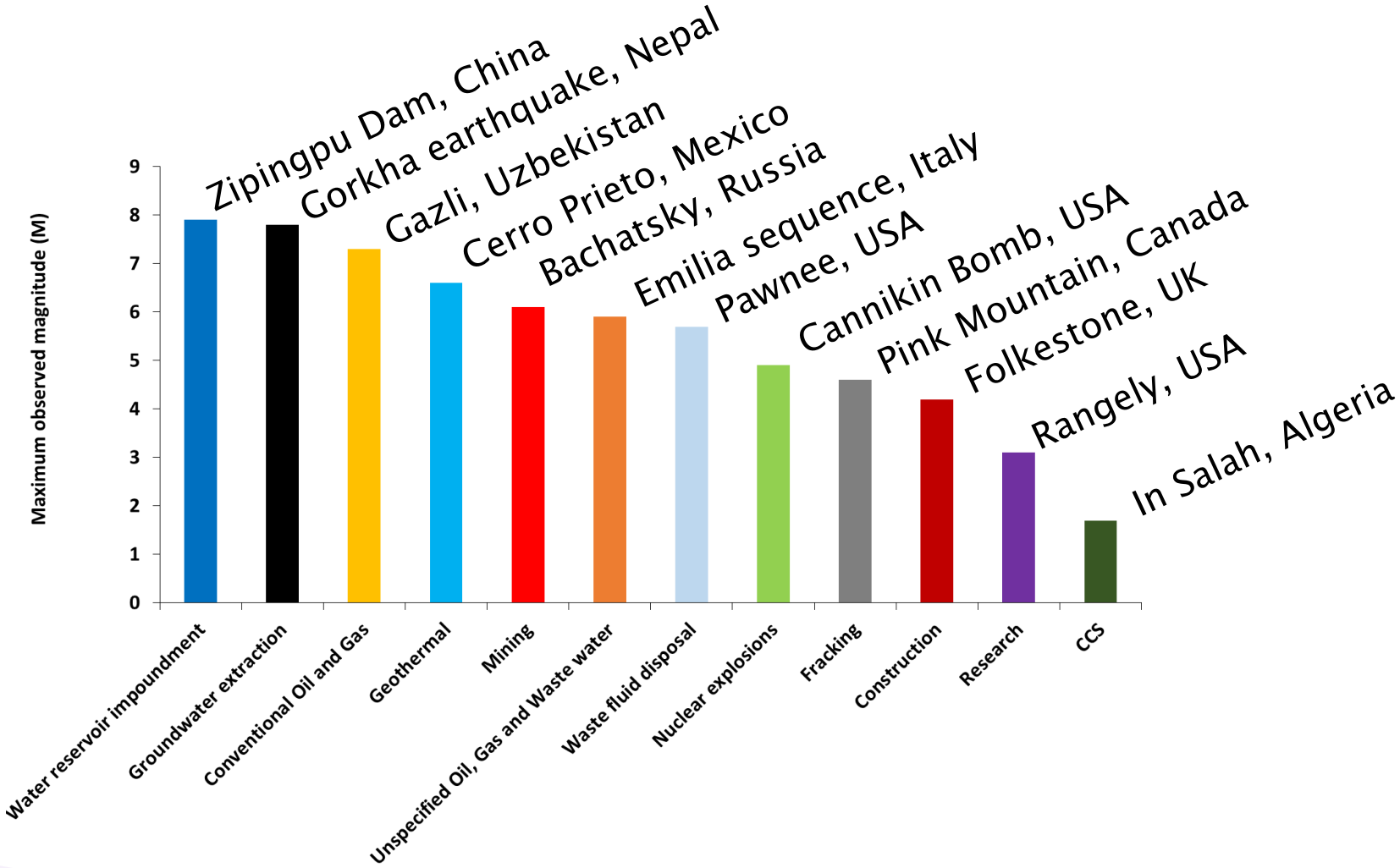


Mmax range

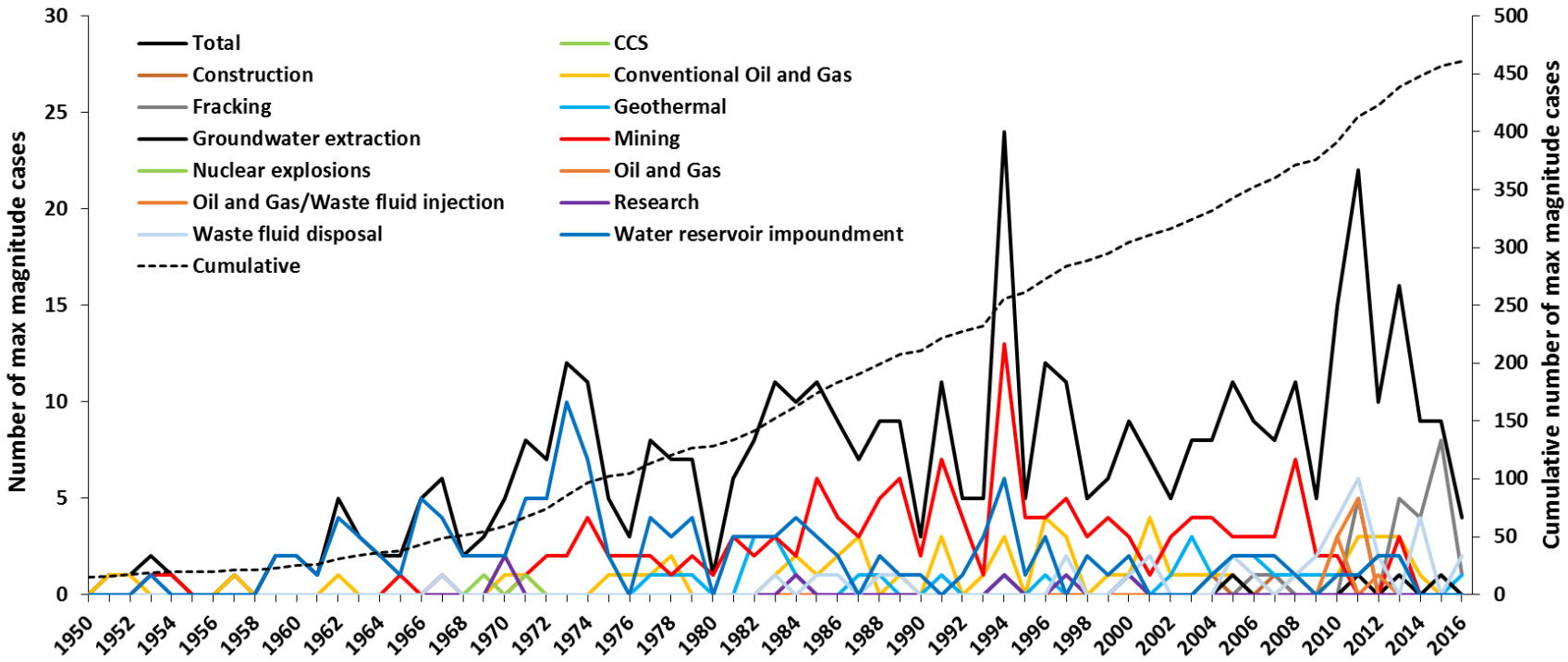
- Most commonly reported Mmax value $3 \leq M < 4$



Maximum Mmax's for different project types



Induced earthquakes through time



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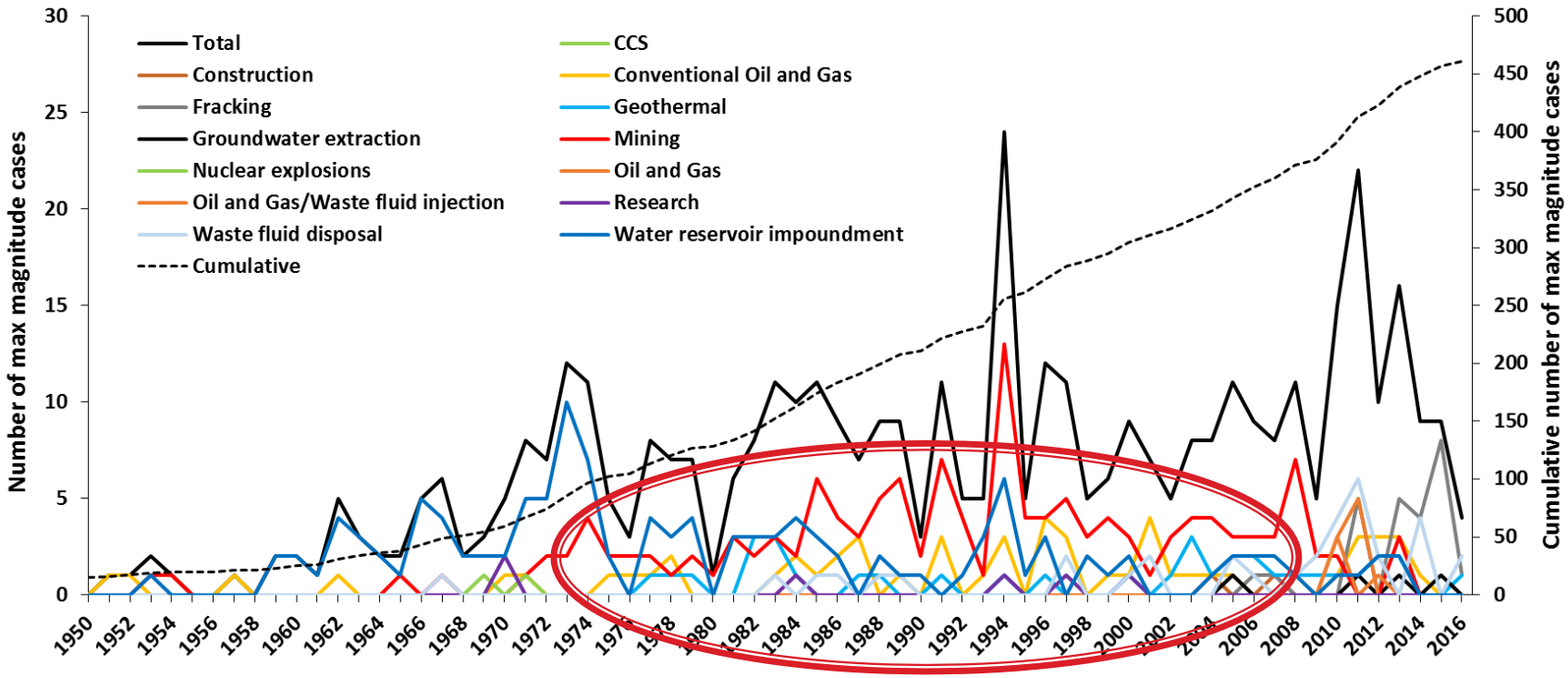
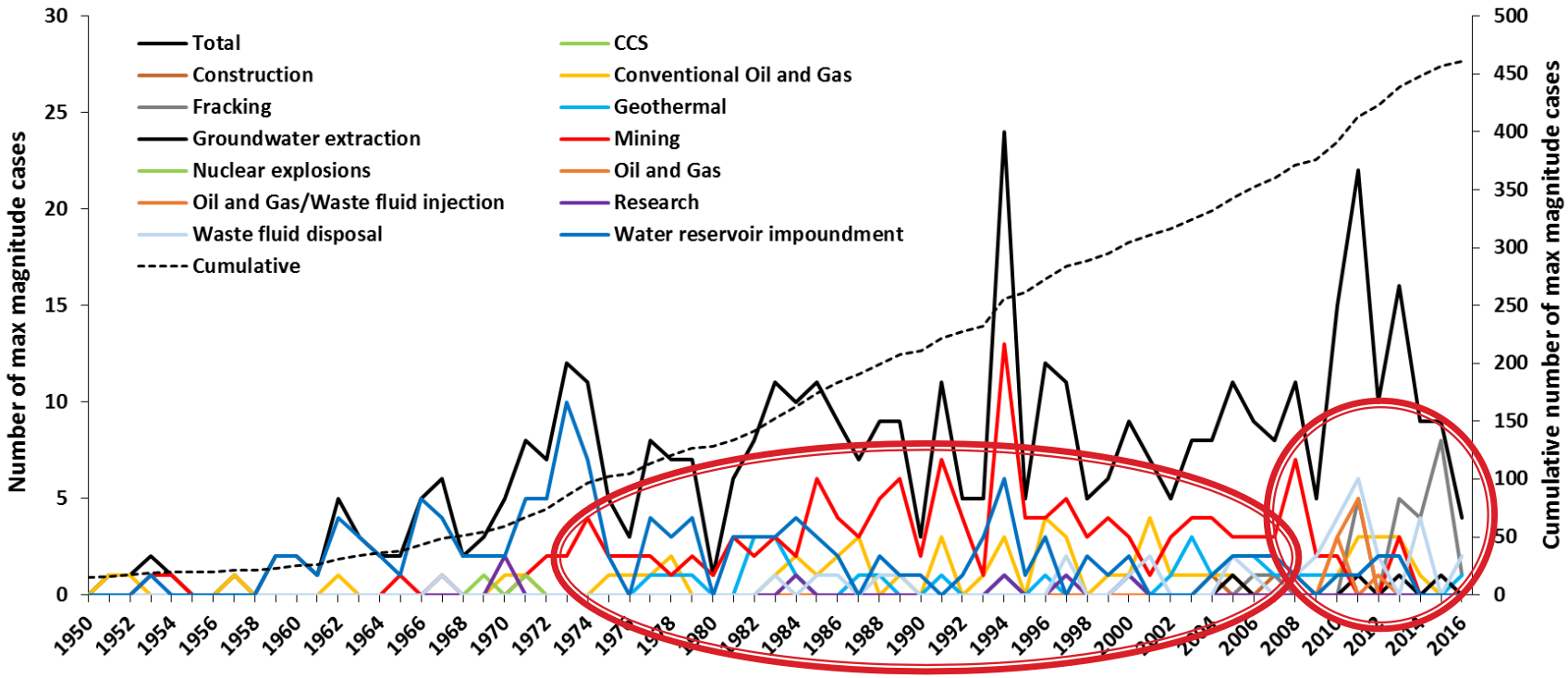
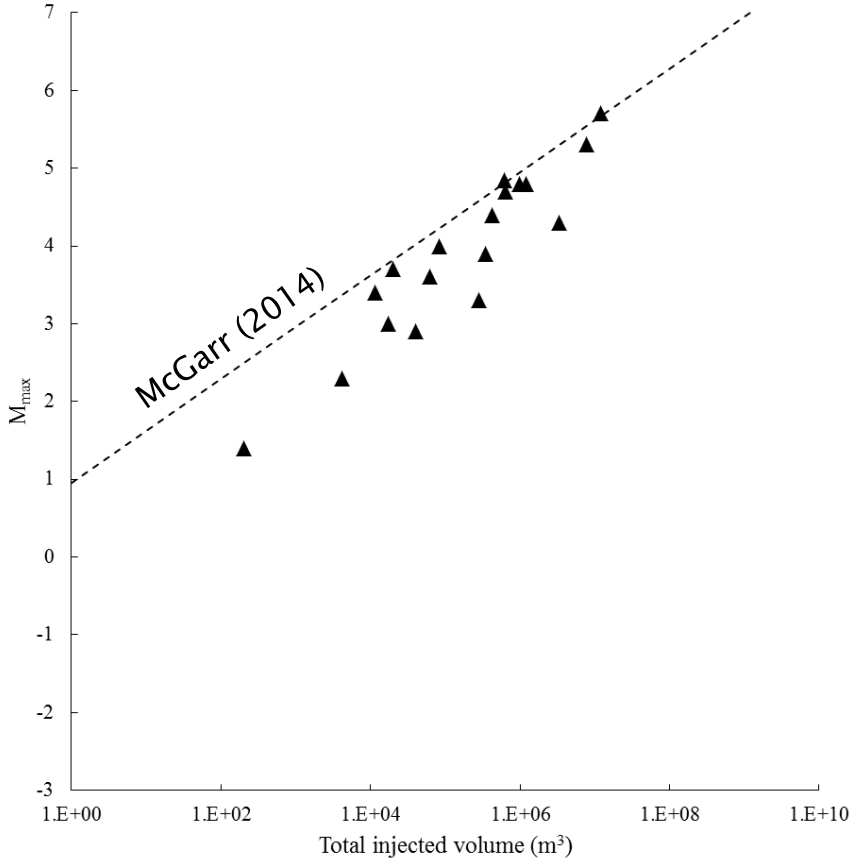
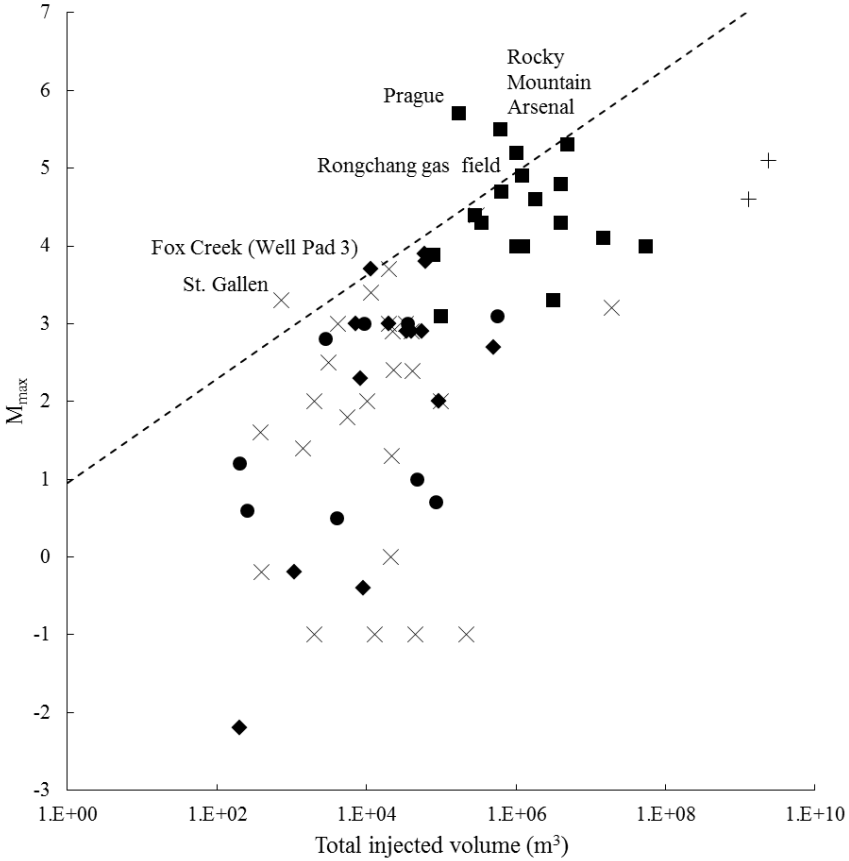


Induced earthquakes through time



Injection-induced earthquakes

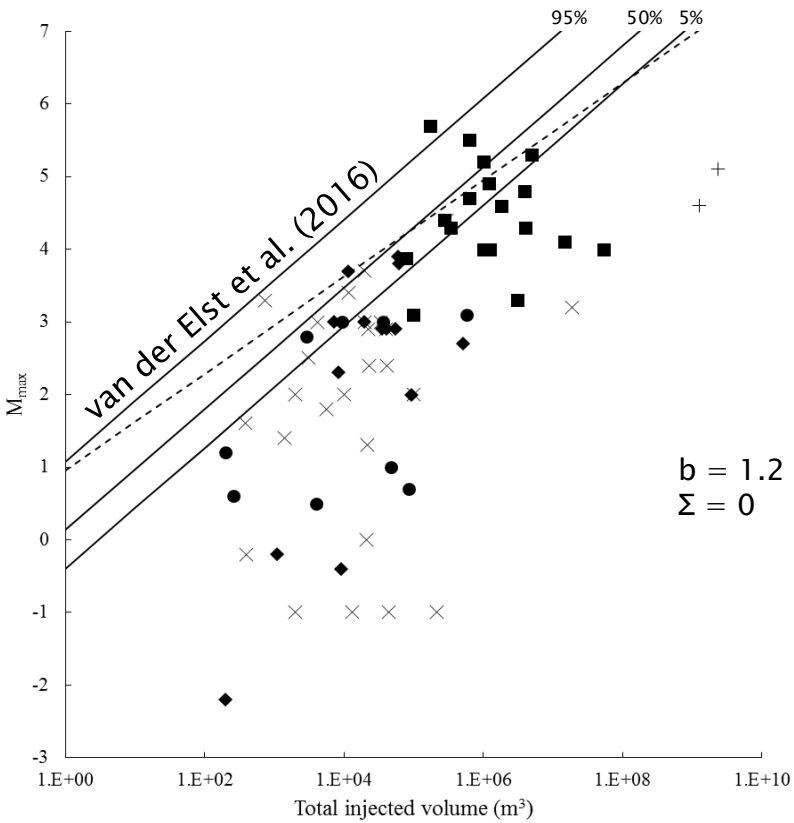


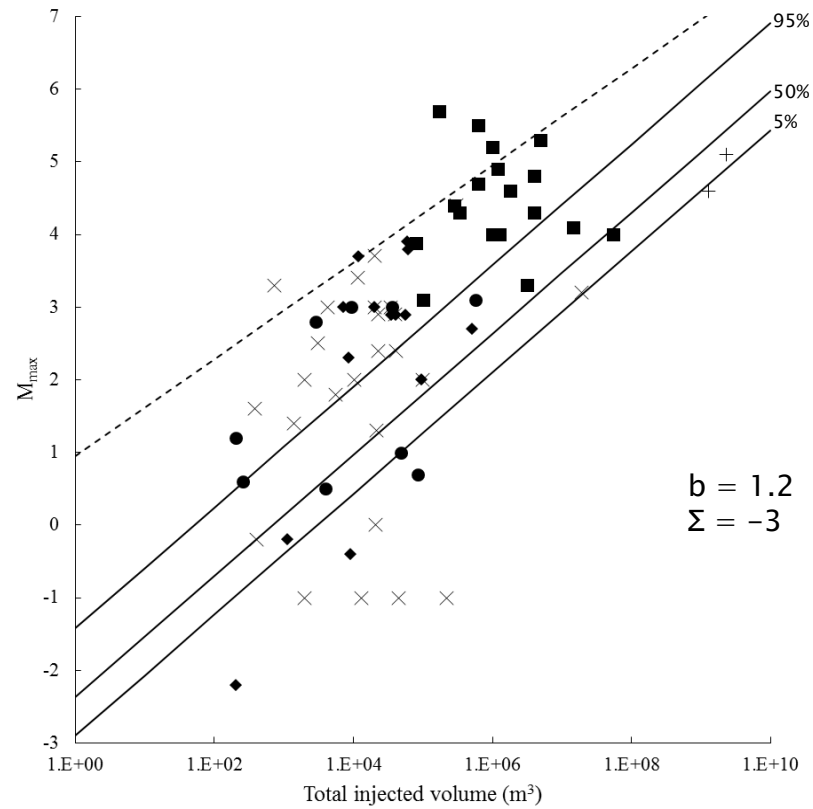


Anthropogenic control on Mmax?

- ■ Waste fluid disposal
- ● Research experiments
- + Geothermal field scale
- × Geothermal exploitation
- ◆ Fracking

Injection-induced earthquakes

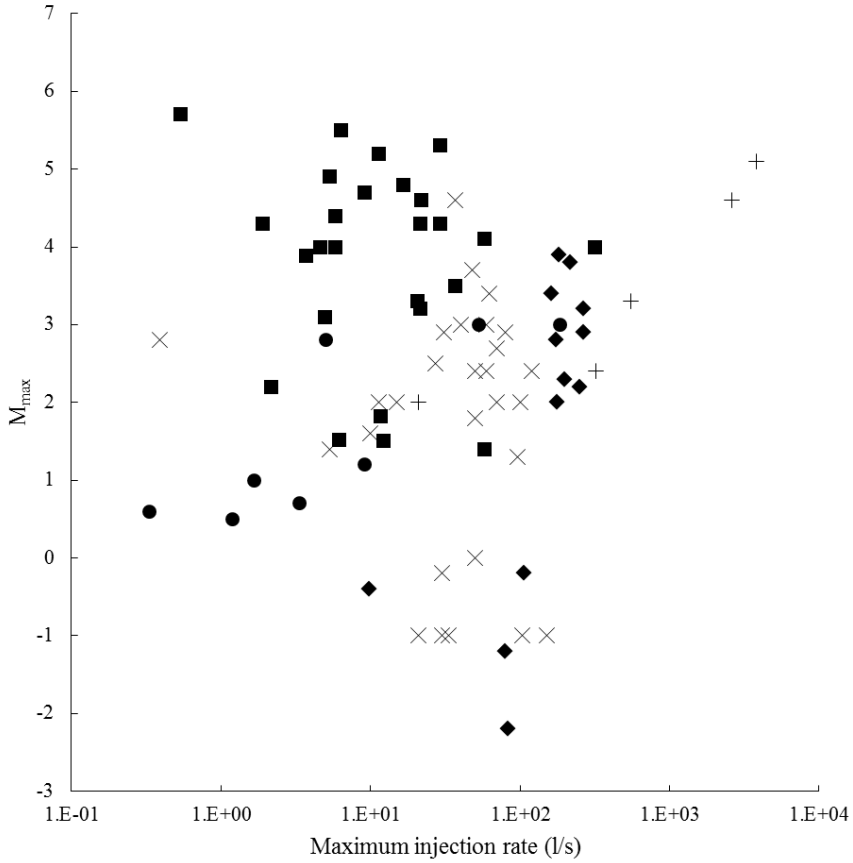


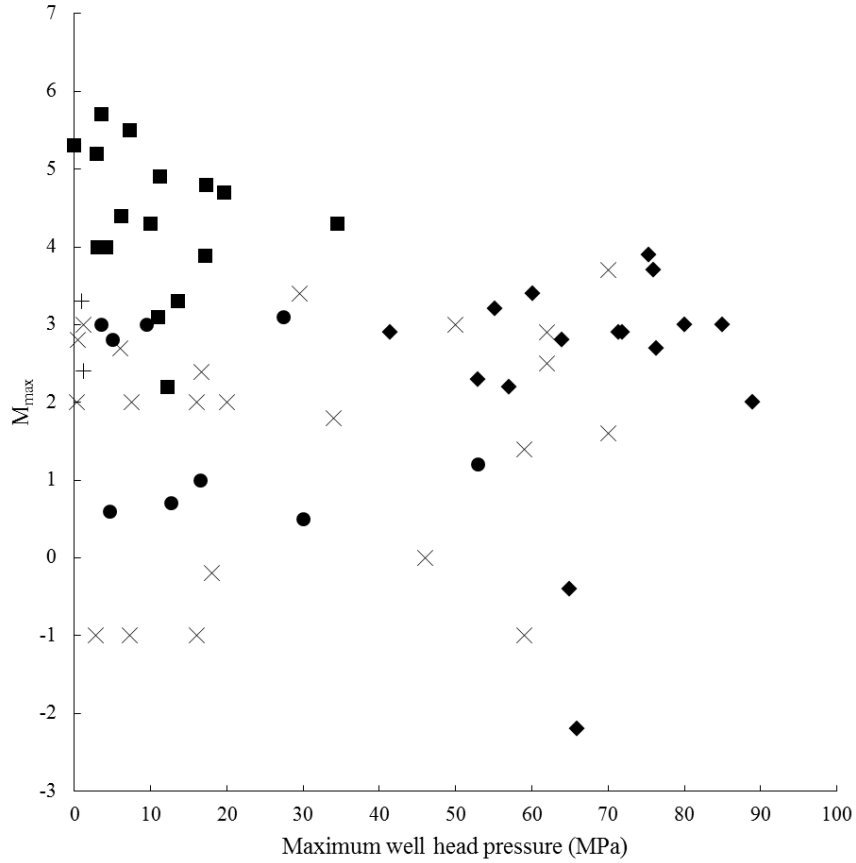


Tectonic control on Mmax?

- Waste fluid disposal
- Research experiments
- Geothermal field scale
- Geothermal exploitation
- Fracking

Injection-induced earthquakes

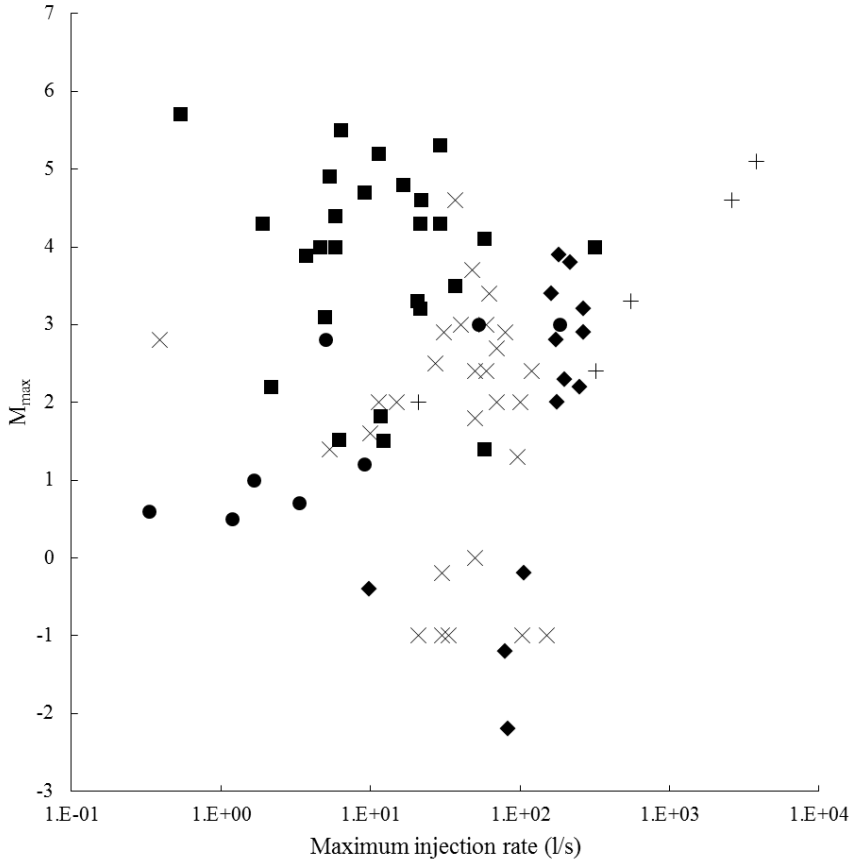


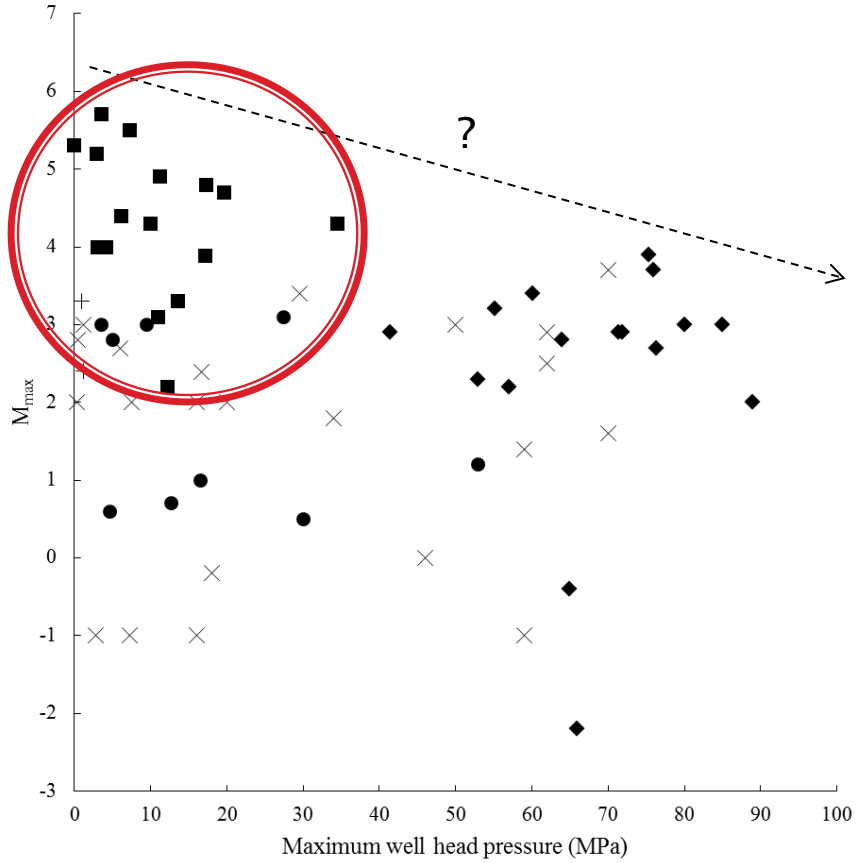


Tectonic or anthropogenic control on Mmax?

- Waste fluid disposal
- Research experiments
- Geothermal field scale
- Geothermal exploitation
- Fracking

Injection-induced earthquakes





Anthropogenic or tectonic control on Mmax?

- Waste fluid disposal
- Research experiments
- Geothermal field scale
- Geothermal exploitation
- Fracking

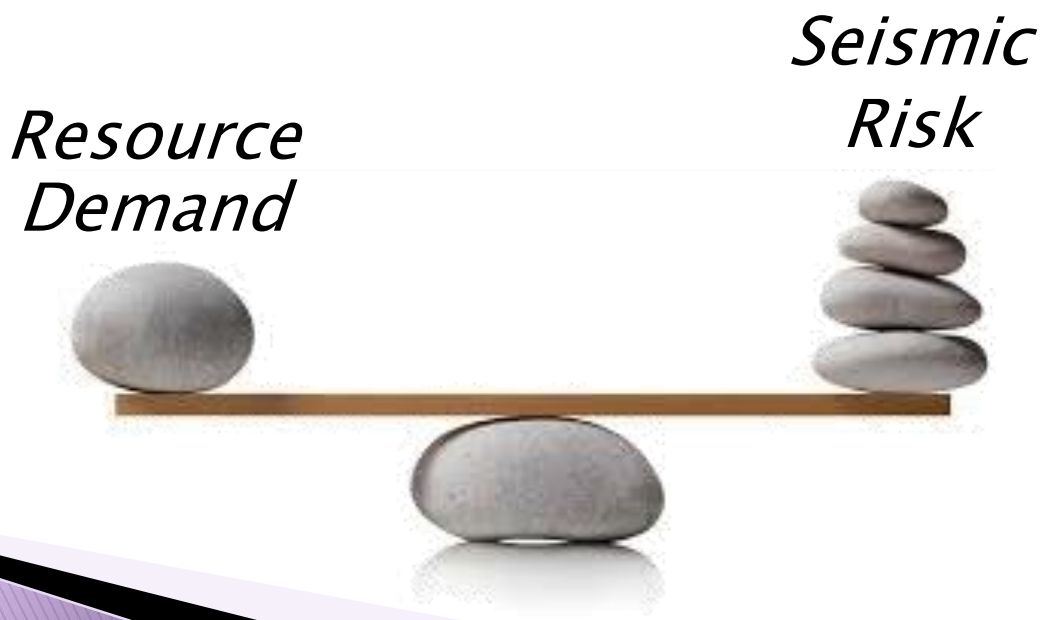
Society and induced earthquakes

- M_L 1.5 smallest felt fracking-induced earthquake (BGS, 2016)
- M_W 4.6 in Canada not felt (Atkinson et al., 2016)

Earthquake magnitudes
(and peak ground accelerations)
require context

Society and induced earthquakes

- We don't want induced earthquakes to be a risk…
- But we all use electricity, metals, plastics, petrol, etc.



Summary

- Induced earthquakes caused by more industrial activities than generally appreciated
- HiQuake contains 730 projects, largest proposed induced earthquake has M_W 7.9
- Recent years have seen an increase in reported injection-induced earthquakes
- Anthropogenic or tectonic control on Mmax still uncertain
- Earthquake magnitudes need consideration in societal context
- Balance needed between resource demand and seismic risk

Thank you

www.inducedearthquakes.org

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References

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McGarr, A. 2014. Maximum magnitude earthquakes induced by fluid injection. *Journal of Geophysical Research: Solid Earth*, 119(2), 1008–1019.

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