A multi-physics database of injection-induced seismicity in geo-energy projects
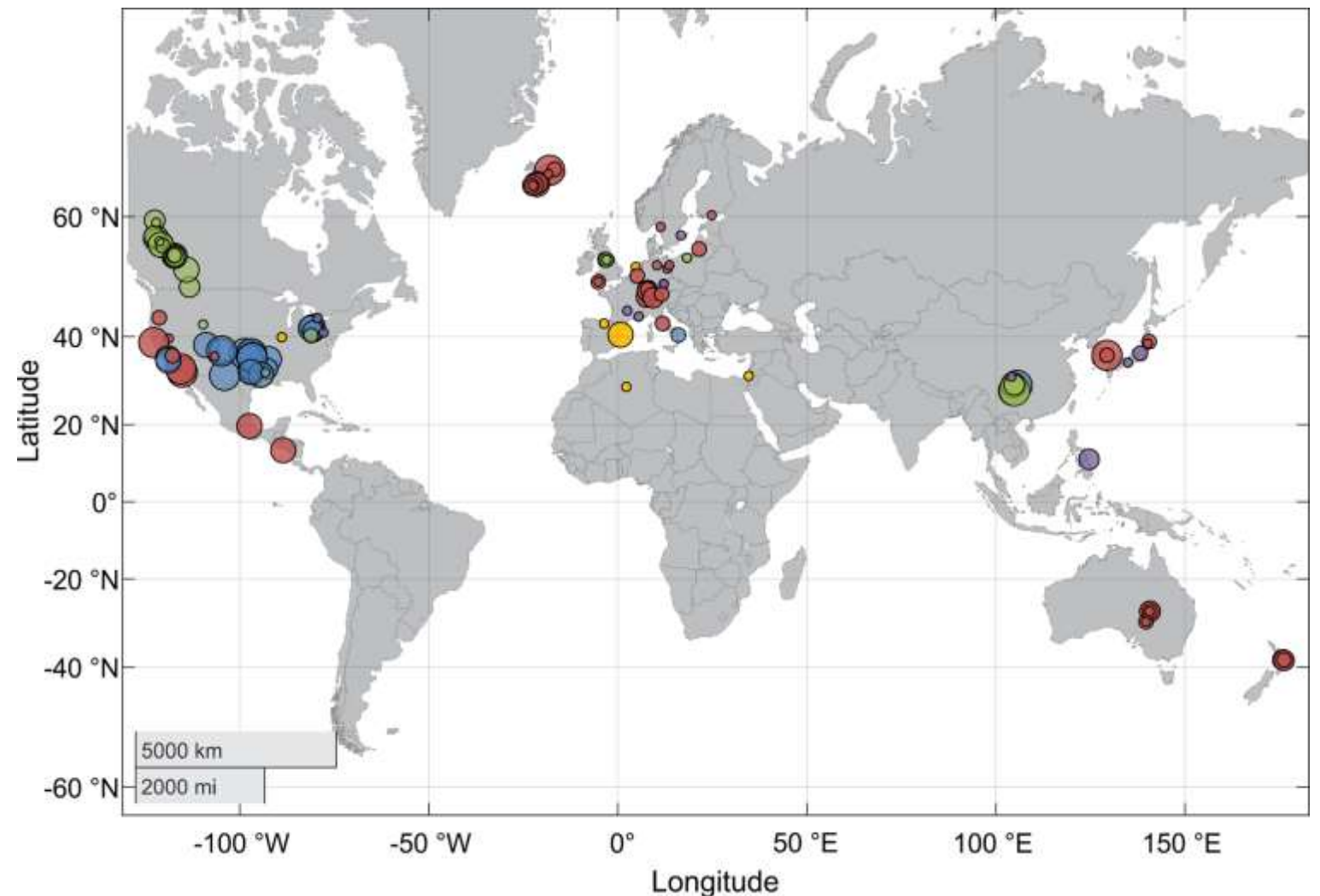
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CSIC
CONSEJO SUPERIOR DE INVESTIGACIONES CIENTÍFICAS

Iman R. Kivi

GEoREST Team

GEoREST Workshop on Induced Seismicity
Palma (Mallorca), Spain
11-13 March 2024

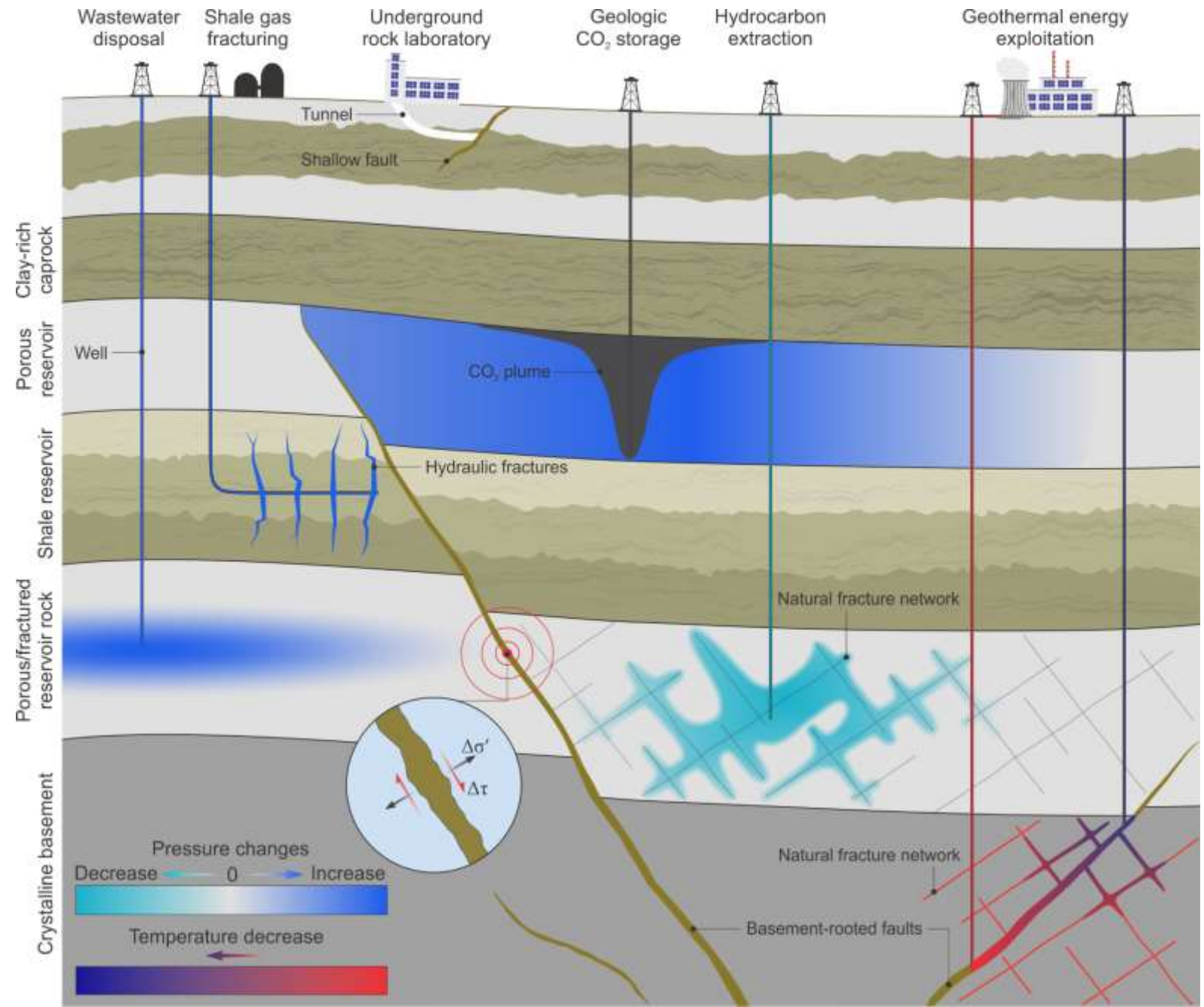# Induced seismicity has posed challenges in different geoenergy applications

Unstable

$$CFS = \tau - \mu\sigma'_n$$

0

Stable

Δp — Injection/extraction pressure changes

$\Delta\sigma_n$ — THM loading/unloading

$\Delta\tau$ — THM loading/unloading tectonic shearing

$\Delta\mu$ — Friction weakening

**Kivi et al. (2023). Earth Sys. Sci. Data**

Multiphysics data plays a key role in different fields of studying induced seismicity

Probabilistic modeling

Physics-based modeling

Analytical/empirical scaling models

Cumulative injected fluid volume (McGarr, 2014; Galis et al., 2017)

State of stress (Li et al., 2021)

Total number of induced earthquakes (van der Elst et al., 2016)

Size of the stimulated rock volume (Shapiro et al., 2011)

Time elapsed from the start of injection (Shapiro et al., 2021)

Injection pressure (Zang et al., 2014)

Injection rate (Weingarten et al., 2015; Alghannam and Juanes, 2021)
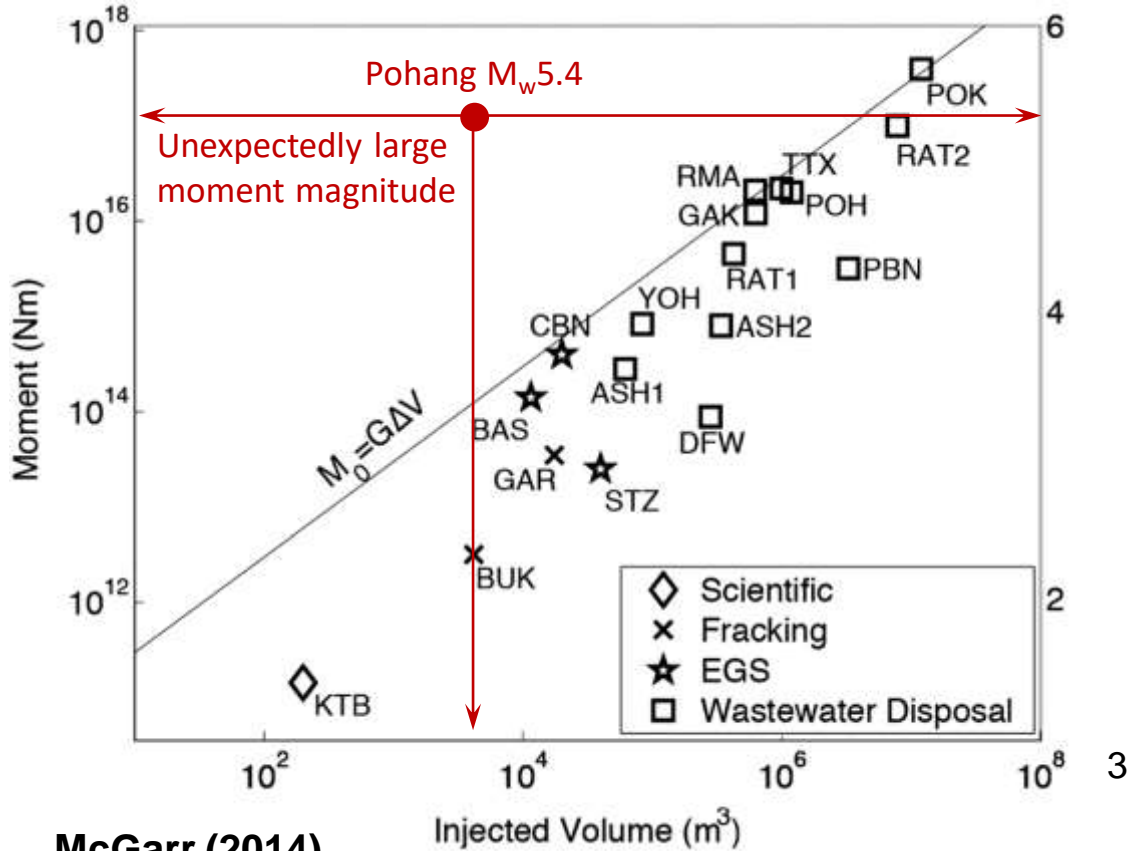
McGarr (2014)

We have tried to make the database readily accessible and understandable

Global physics-based database of injection-induced seismicity

Iman R. Kivi ✉, Auregan Boyet, Haiqing Wu, Linus Walter, Sara Hanson-Hedgecock, Francesco Parisio, and Victor Vilarrasa
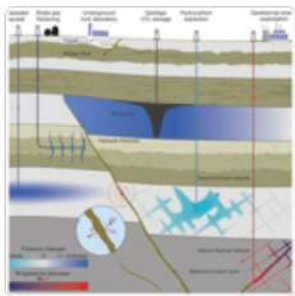
🔓 **[Dataset] Global physics-based database of injection-induced seismicity**

Kivi, Iman Rahimzadeh CSIC (iD) 👤; Boyet, Auregan CSIC (iD); Wu, Haiqing; Walter, Linus CSIC (iD); Hanson-Hedgecock, Sara CSIC; Parisio, Francesco CSIC (iD); Vilarrasa, Víctor CSIC (iD) 👤

Files in This Item:

File	Description	Size	Format	
GEoREST_database_bibliography_v20.11.2022.docx	Dataset	93,5 kB	Microsoft Word XML	View/Open
GEoREST_database_dictionary_v20.11.2022.docx	Dataset	23,31 kB	Microsoft Word XML	View/Open
GEoREST_induced_seismicity_database_v20.11.2022.csv	Dataset	105,09 kB	Unknown	View/Open
GEoREST_induced_seismicity_database_v20.11.2022.xlsx	Dataset	2,49 MB	Microsoft Excel XML	View/Open
GEoREST_database_Readme.txt	readme	9,51 kB	Text	View/Open

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The database covers a wide range of multiphysical parameters relevant to induced siesmicity

158	Events
71	Variables
~ 7000	Data entries
> 500	References

Database variables

General project information
- Case number
- Country
- Location
- Latitude (°)
- Longitude (°)
- Project type
- Sub-class

Host rock properties
- Formation name
- Stratigraphy
- Fracture density (count/m)
- Density (kg/m³)
- Porosity (-)
- Permeability (m²)
- Young's modulus (GPa)
- Poisson's ratio (-)
- Bulk modulus (GPa)
- Shear modulus (GPa)
- Biot coefficient (-)
- Friction angle (°)
- Cohesion (MPa)
- UCS (MPa)
- Tensile strength, T_0 (MPa)
- Thermal Conductivity (W/mK)
- Thermal expansion coefficient (1/K)

Site characteristics
- Depth of basement (m)
- Stress
- Overburden stress, σ_v (MPa)
- Min. horizontal stress, σ_h (MPa)
- Max. horizontal stress, σ_H (MPa)
- Max. horizontal stress direction (°)
- Pore pressure (MPa)
- Temperature (°C)

Fault properties
- Strike (°)
- Dip (°)
- Dip direction (°)
- Fault name
- Fault type
- Thickness (m)
- Core thickness (m)
- Distance from injection (m)
- Intersection depth (m)
- Density (kg/m³)
- Porosity (-)
- Permeability (m²)
- Normal Stiffness (GPa/m)
- Shear stiffness (GPa/m)
- Dilation angle (°)
- Young's modulus (GPa)
- Poisson's ratio (-)
- Friction angle (°)

Injection data
- Depth of injection (m)
- Injection type
- Injection start date
- Fluid type
- Injection temperature (°C)
- Max. Injection rate (m³/s)
- Injected volume (m³)
- Net injection volume (m³)
- Max. wellhead pressure (MPa)
- Max. bottomhole pressure (MPa)

Induced seismicity information
- Seismicity onset
- Time between injection and first seismicity (d)
- Number of events
- Depth of seismicity (m)
- G-R law parameters, before injection
- G-R law parameters, during injection
- G-R law parameters, after injection

Seismicity information for M_{max}
- M_{max}
- Type of M_{max}
- Depth of M_{max} (m)
- Distance from injection (m)
- Date of M_{max}

Complementary remarks

References

Distribution of project types in the database does not necessarily point to their seismogenic nature but data accessibility

The database is mainly built upon HiQuake

We do not judge whether or not earthquakes were induced/triggered

Data availability on a publicly accessible scientific basis

Excluded cases that lack basic information like moment magnitude, injection information or host rock properties.

Divided into 5 categories based on the geoenergy applications

Multiple cases for different phases of a project

Injection operations	Number of cases	Percentage (%)
Hydraulic fracturing	54	34.6
Geologic gas storage	7	4.4
Geothermal energy	58	36.5
Research	15	9.4
Wastewater disposal	24	15.1
Total	158	100
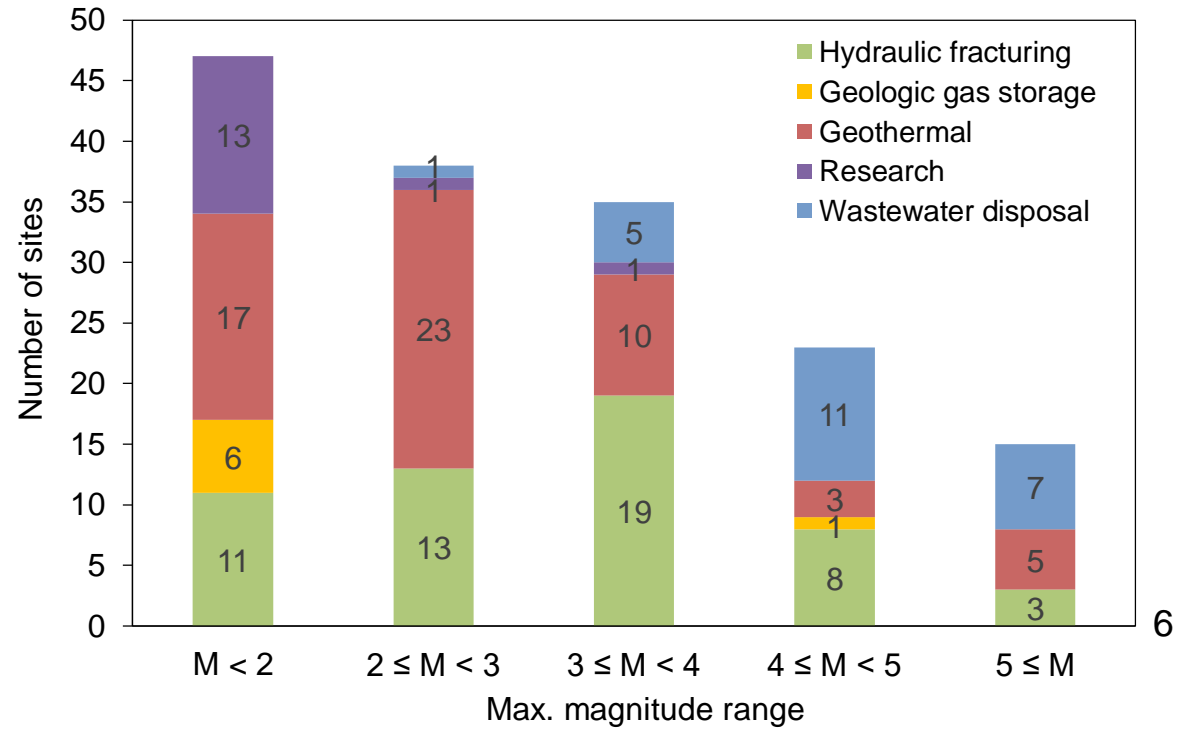
Neither the frequency nor the type of induced earthquakes is uniformly distributed worldwide

Kivi et al. (2023). Earth Sys. Sci. Data
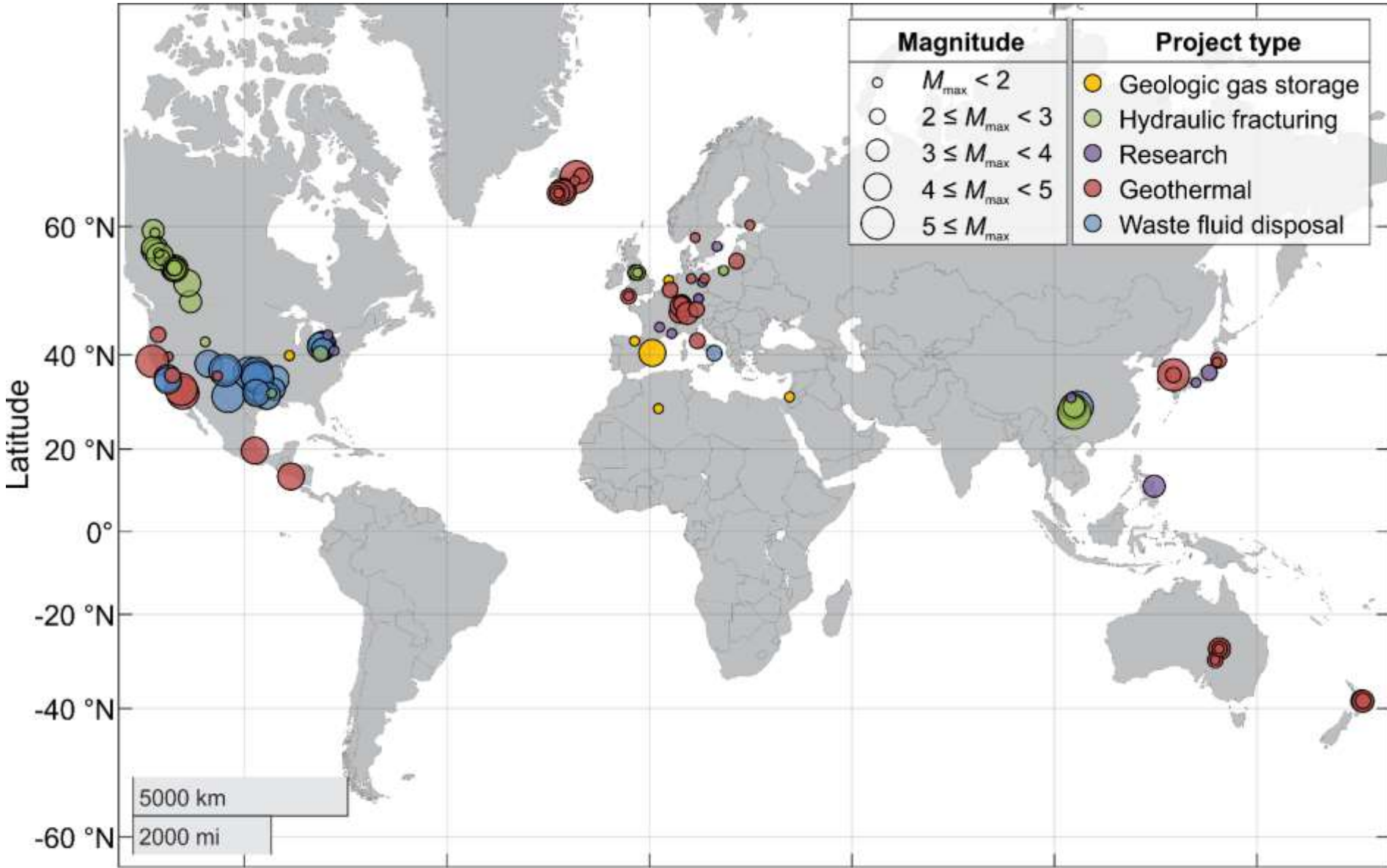
Direct inspection of the collected data unravels some important trends

Kivi et al. (2023). Earth Sys. Sci. Data
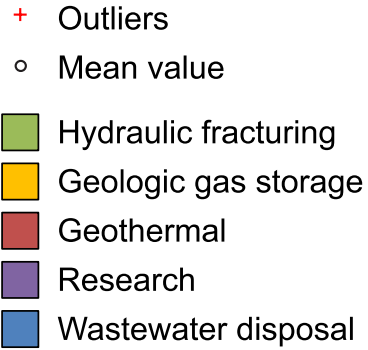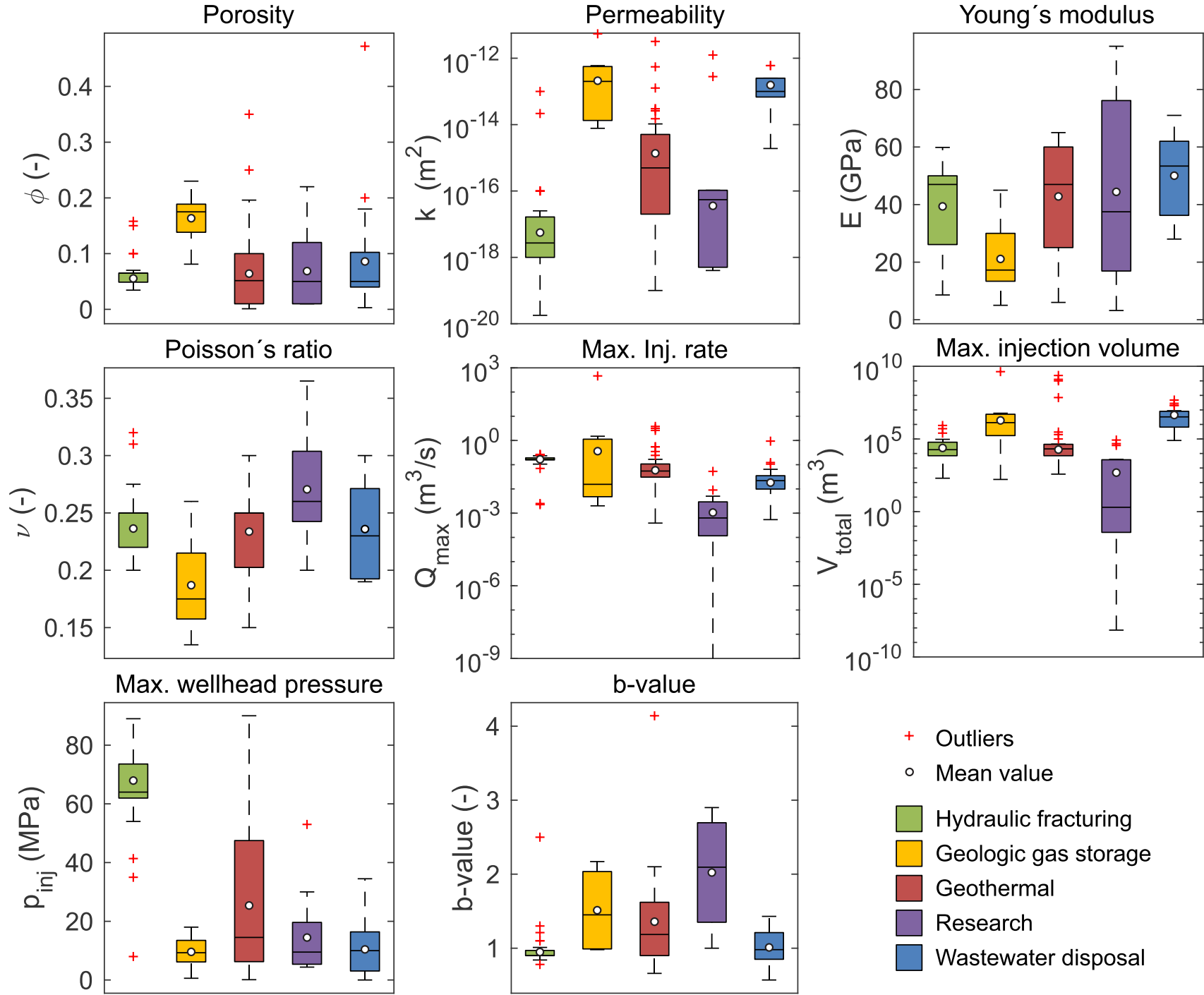
Summary

The database provides an opportunity for
- exploring potential links between operational parameters and induced seismicity
- developing/verifying scaling relationships for constraining maximum possible earthquake magnitude

Understanding and management of induced seismicity can benefit from multidisciplinary collaborations between academia and industry

We will launch an interactive webpage for the database to enable users to contribute to the database

Database will be presented in mixed flat-file and rational structure

Future additions may include incorporation of seismicity catalogues and time series of injection data

Thank you very much for your attention!

www.georest.eu

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