INSTRIKE - Induced Seismicity Risk Estimation in Geothermal Operations

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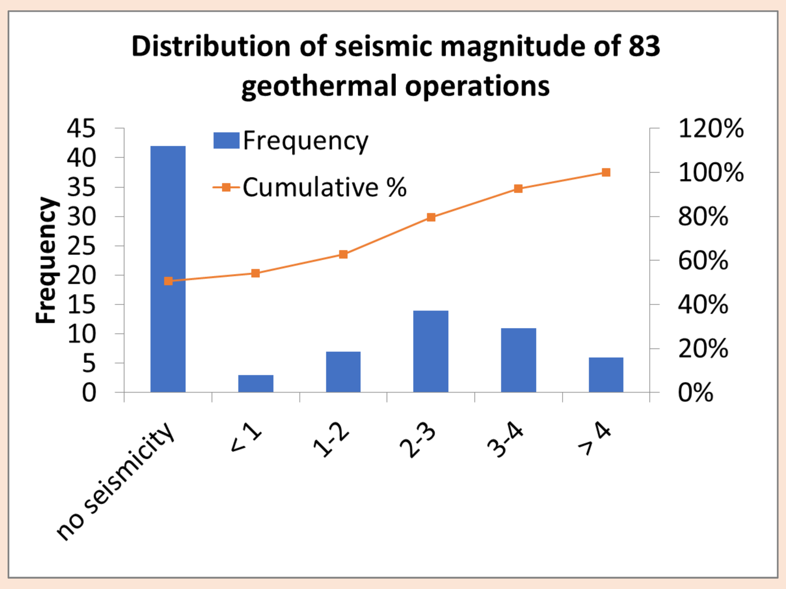
Background

Currently, more than 350 deep geothermal operations are set up worldwide. Though in general a safe, renewable, and reliable source of energy, one drawback might be induced seismicity.

Induced seismicity might occur when faults or bedding planes in the subsurface are activated due to subsurface interventions. This is separate from natural seismicity which often occurs in various geodynamic settings. Since geothermal plants can sometimes be used most efficiently in the vicinity of densely populated cities, an assessment of the risk of induced seismicity has become important.



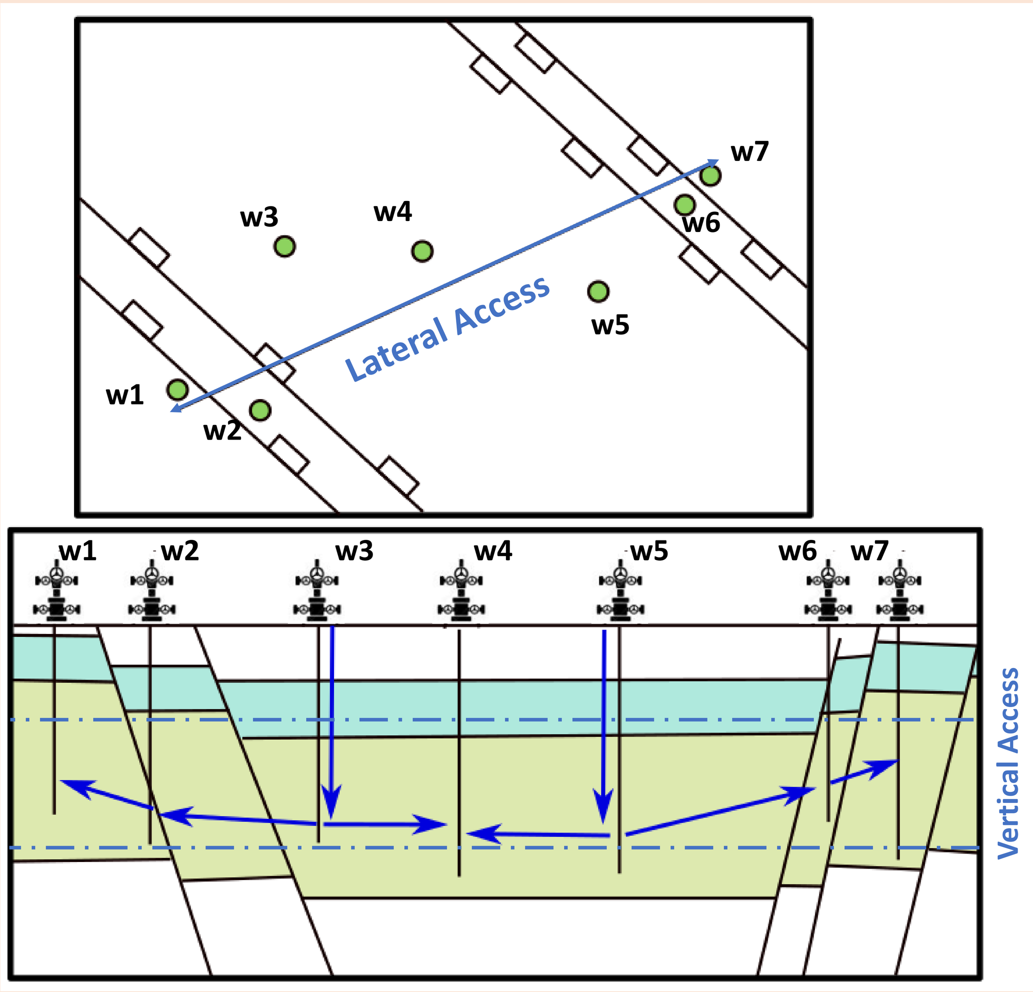
Data Collection

- Published papers, PhD thesis, conferences, reports, etc.
- Public databases (Buijze's database, world stress map, USGS earthquake catalog, global seismic hazard map, NLOG, HIKE European fault database, etc.)
- Researchers who wrote papers on specific geothermal fields and willing to contribute to our study
- Operators willing to share their experience
- Previous Partner experience

Risk parameters

Parameters influencing the failure mechanisms are first identified and described in detail. In the next step, field and operation data are reviewed to develop direct or indirect information about these parameters. If it was indirect information, it will be used in a further step to estimate the parameters (e.g. miniFrac data to determine minimum horizontal stress).

Sample parameters collected to determine **Zone of impact**: lateral and vertical reservoir access:



Sorting is performed into parameters that are hard or impossible to be changed compared to the ones that can influenced, and importance of parameters: (A) must have; (B) nice to have; (C) lowest priority:

Geothermal reservoir system factors

- Type of reservoir (A)
- Reservoir zone porosity / permeability (A)
- Rock strength and strength ratio (A)
- Rock stiffness (A)
- Field heterogeneity (A)
- Overburden thickness (A)
- Depth to basement (A)
- Natural seismicity depth (A)
- Reservoir faults (B)
- Bounding Fault Existence and Contact Area (A)
- Fault(s) permeability (C)

Mechanical State Risk Factors

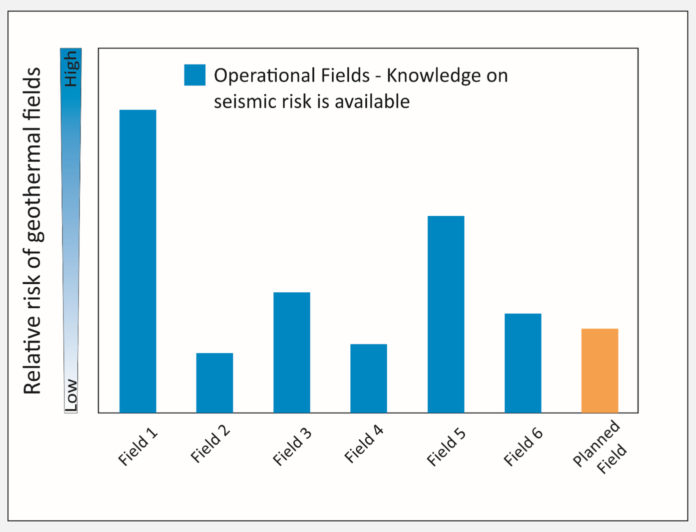
- Stress regime (A)
- Effective Stress ratio (A)
- Critically stressed faults (A)
- PP gradient & PP/effective Shmin stress ratio (B)

Operations Risk Factors

- Zone of impact (A)
- ΔT relative to initial temperature (A)
- ΔP relative to initial pressure (A)
- Distance of producers & injectors to closest faults (A)
- Injection volume and production volume (B)
- Type of operation (A)

Next Steps

- Finalize data collection and QC and harmonization of data.
- Apply methods such as cluster analysis, random forest, contingency table analysis, Optimization methods, neural network and/or Discriminant function analysis.
- Ideally, identify one method that provides a good correlation between the parameters of an operation and the (non) observed seismicity during the operation.



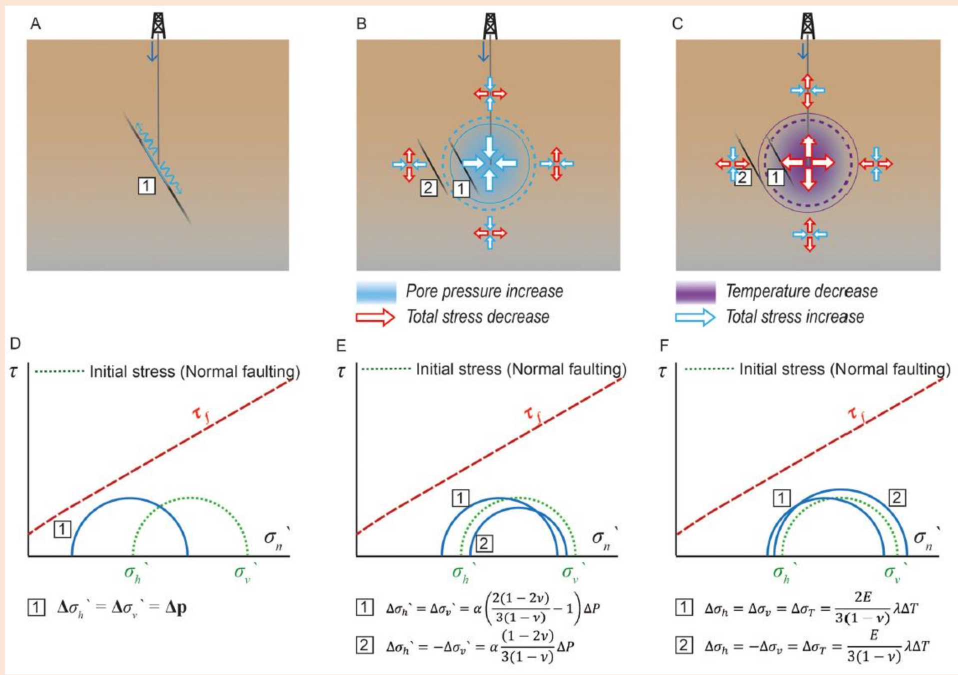
Method

The InStRikE project aims to develop a smart planning tool for assessing induced seismicity risk in planned geothermal activities.

Risk mechanisms are identified and risk parameters influencing those are collected for various geothermal operations.

Analysis of risk parameter combinations in correlation with observed seismicity (or not) during operations is performed. The approach is based on advanced statistical analyses (including the application of machine learning) of various parameters of existing geothermal operations and the resulting seismicity observed in the field.

Failure mechanisms



From Buijze et al., 2019

We consider two main **failure mechanisms** that can lead to induced seismicity:

- fault reactivation
- bedding plane slip

These failure mechanisms are a result of one or more of the following **causes**:

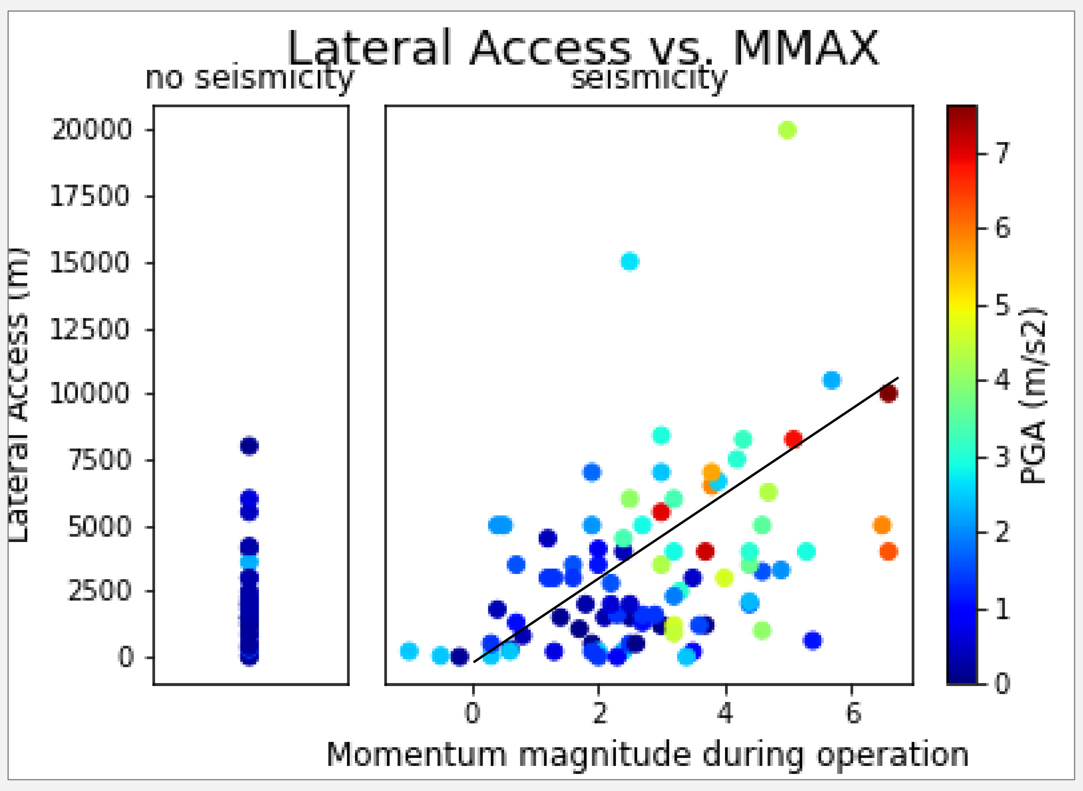
- Pore pressure change
- Poro-elastic induced stresses
- Thermo-elastic volume induced stresses
- Mass change
- Localized shear (in the overburden or at the top/bottom of the reservoir)

Preliminary results

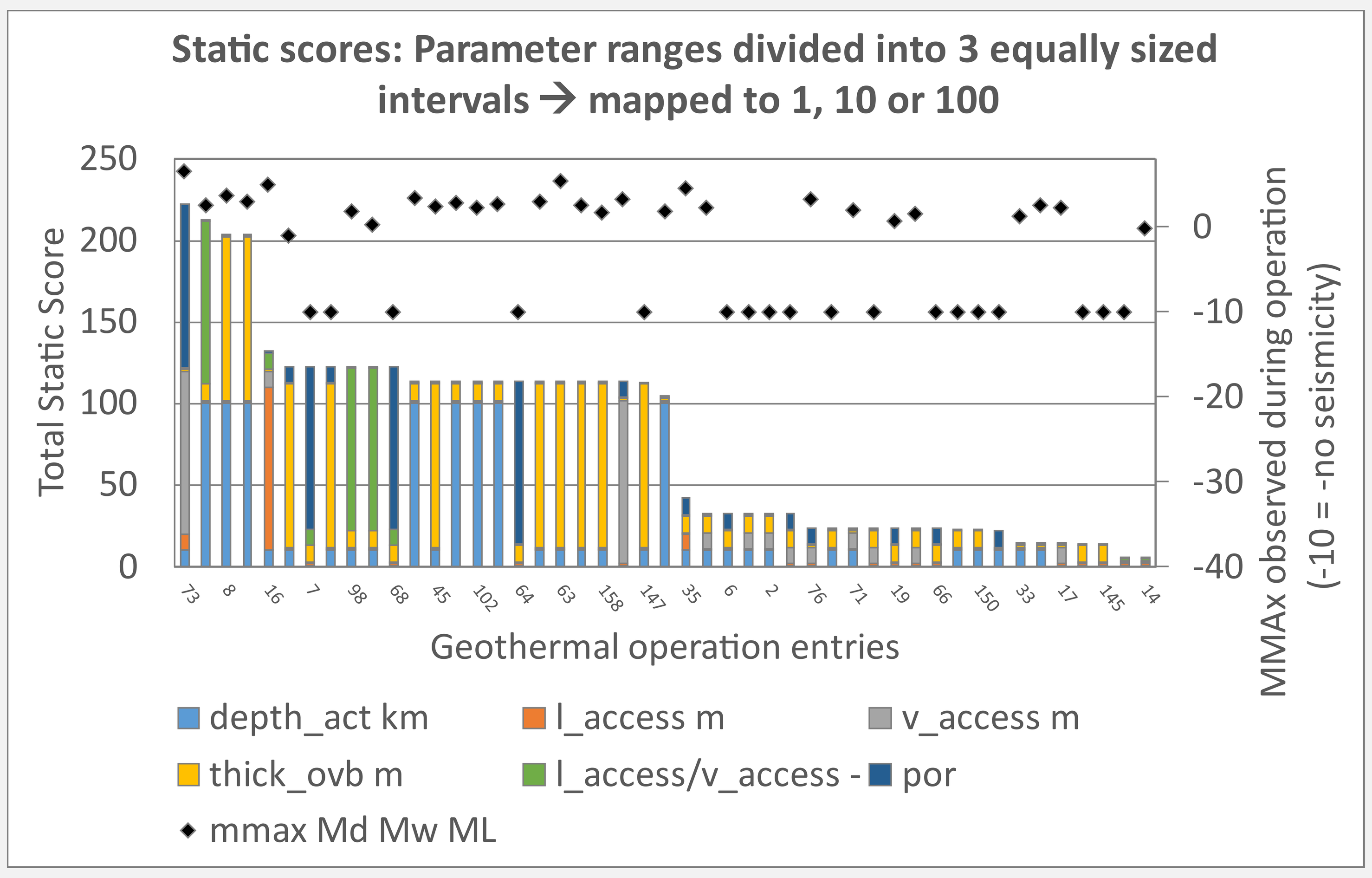
Visualizing risk parameters versus observed seismicity during operation:

→Helps to determine outliers

→QC of input data



Apply static risk parameter weighing factors:



→Only view operations seen with no seismicity and high Total Static Score.

→Match seismicity clusters or magnitude of seismicity?

→Confirms that more advanced analysis is required → See Next Steps.

References

1. Buijze, Loes, et al. "Review of induced seismicity in geothermal systems worldwide and implications for geothermal systems in the Netherlands." Netherlands Journal of Geosciences 98 (2019).
2. Moeck, Inga, et al.. "Slip tendency analysis, fault reactivation potential and induced seismicity in a deep geothermal reservoir." Journal of Structural Geology 31.10 (2009): 1174-1182.

Projectpartners:

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