GeoNetZero CDT

The Centre for Doctoral Training (CDT) in Geoscience and the Low Carbon Energy Transition

Geothermal reservoir characterisation and monitoring from three-component beamforming of ambient seismic noise

Supervision:

Dr Katrin Löer, Dr Amy Gilligan - University of Aberdeen

Project description:

Geothermal energy is recognised as a source of low-carbon heat compatible with meeting net zero emission targets in the UK's future energy mix. Exploration and exploitation of geothermal sites thus play an important role in facing the challenge of decarbonisation. When characterising deep geothermal reservoirs, a crucial parameter is permeability, which is typically provided by faults and fractures in the rock acting as natural propagation paths for induced fluids between the injection and the production boreholes. Exploiting their natural occurrence can reduce the need for creating artificial pathways by hydraulic fracturing.

Over the last two decades, the development of ambient seismic noise methods has provided **new, cheap and ubiquitous tools to image and monitor the subsurface using the Earth's natural background vibrations.** This project will investigate how three-component (3C) beamforming of ambient seismic noise contributes towards the characterisation and monitoring of a geothermal reservoir. 3C beamforming is an array method that provides the means to determine dominant direction of arrival, velocity and polarisation of an ambient seismic noise wavefield. Where noise sources are sufficiently well distributed it can be used to estimate azimuthal anisotropy of surface wave velocities (Riahi et al., 2013), which indicates the **existence of aligned faults and cracks in the near subsurface.** A recent study (Löer et al., 2020) used 3C beamforming to detect the onset of the brittle-ductile transition, an important parameter in modelling of superhot geothermal systems, indicating the maximum possible depths for fractures to exist.

Overall this project will i) help to quantify and interpret 3C beamforming results of ambient noise for fracture characterisation, ii) set out guidelines for optimised station deployment in the field, iii) give estimates of fracture distribution and orientation at depth at existing and potential geothermal sites.

Objectives:

1) Using numerical anisotropic Earth models and **synthetic data sets**, this project will assess the suitability of 3C beamforming to detect anisotropy from ambient noise measurements in different scenarios and determine its sensitivity towards temporal changes of anisotropic properties.
2) Building on the results from numerical analyses, the method will be applied to **real data sets** recorded across operational geothermal sites (for example, United Downs, UK; Los Humeros, Mexico). The student will incorporate recent

advances in beamforming technology to address the issue of apparent anisotropy caused by an uneven distribution of sources or stations. Comparing beamforming results with existing well log data will help calibrate the method.

3) There is the strong possibility for the student to deploy a **new seismic network** at a site of interest, for example at Hill of Fare, near Banchory, Aberdeenshire, advancing an existing geothermal feasibility study. Analysis of this new data set by means of 3C beamforming will provide an estimate of the distribution and orientation of fractures in the target rock.

Training:

The student will acquire a profound understanding of seismic theory and signal processing, develop strong skills in numerical modelling, and gain expertise in data management and acquisition, qualifying for a career in the environmental or energy sector as well as in academia. Further, the CDT Training Academy provides a 20-weeks training programme over the course of the 4-years studentship. All participants will receive technical training in different scientific areas such as geology, geophysics, petroleum and reservoir engineering, sustainable exploration etc.

Further information:

Please contact Katrin Löer (katrin.loer@abdn.ac.uk) to inquire details of the project. Note that **only applications from UK citizens can be considered**. More information about eligibility and the application procedure can be found here.

References:

- Löer, K., Toledo, T., Norini, G., Zhang, X., Curtis, A., & Saenger, E. H. (2020). Imaging the Deep Structures of Los Humeros Geothermal Field, Mexico, Using Three-Component Seismic Noise Beamforming. *Seismological Research Letters*.
- Riahi, N., Bokelmann, G., Sala, P., & Saenger, E. H. (2013). Time-lapse analysis of ambient surface wave anisotropy: A three-component array study above an underground gas storage. *Journal of Geophysical Research: Solid Earth*, *118*(10), 5339-5351.