



# Multi-source multi-receiver microseismic reflection imaging: case study Basel

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# Aim: extract more information from existing microseismic datasets









**Idea:** treat a microseismic event as active seismic source and image recorded reflected waves using techniques adapted from conventional reflection seismics

## Features of microseismic reflection data



- Much more sources than receivers
- Sources are within the area of interest, receivers are far away
- Events have specific radiation patterns and energies
- Low aperture
- Usually low S/N ratio

### **Microseismic Reflection Imaging approach**

- Use only most reliable events
- Detect reflected waves, mute all the rest
- Consider polarization of reflected waves (use directional migration algorithm)

## **Polarity estimation**





$$C_{ij} = \frac{1}{N} \sum_{n=T}^{T+N} u_i(n) u_j(n) \qquad i, j = \{1, 2, 3\}$$
$$(C - \lambda I) p = 0 \qquad \lambda_1 \le \lambda_2 \le \lambda_3$$

 $\vec{p_3}$  – polarization of the P-wave  $\vec{p_1}$  – polarization of the S-wave

Linearity of hodogram (Samson, 1977)

$$R = \frac{(\lambda_1 - \lambda_2)^2 + (\lambda_2 - \lambda_3)^2 + (\lambda_3 - \lambda_1)^2}{2(\lambda_1 + \lambda_2 + \lambda_3)^2}$$

 $C = \frac{\lambda_2^2 + (\lambda_2 - \lambda_1)^2}{2(\lambda_2 + \lambda_1)^2}$ 





















## **Frequency filter optimisation**



#### **Common receiver gather**



#### **Common receiver gather**



#### EGS at Basel: Microseismic monitoring



## EGS at Basel: Microseismic monitoring





## **Microseismic event location**



Kummerow et al. (2011), further improved by Kummerow et al. (2012)



#### **Selected events**



## **Common receiver gather**



## **Common receiver gather**



# Imaging results: 2D



# **Imaging results: 3D**



## **Consistency of the images**



## **Correlation with Vp/Vs estimates**



Kummerow et al. (2012)

#### **Correlation with borehole measurements**









- Microseismic waveforms can be used to get a high resolution reflection image of a stimulated reservoir interior
- The Microseismic Reflection Imaging approach was applied to the Basel EGS data recorded at 3 different borehole instruments, 2.5 – 5 km away from the injection interval
- Images of the data from different sensors are consistent and show structure of reflectors within the stimulated reservoir

#### **Clustered and non-clustered events**



# Interpretation



# Interpretation



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## Interpretation

