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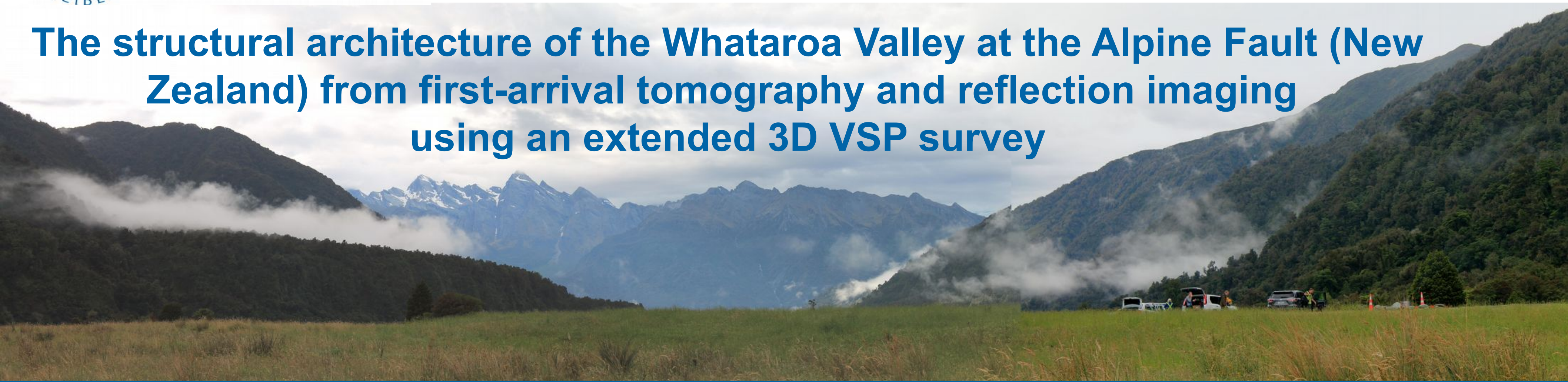
The structural architecture of the Whataroa Valley at the Alpine Fault (New Zealand) from first-arrival tomography and reflection imaging using an extended 3D VSP survey



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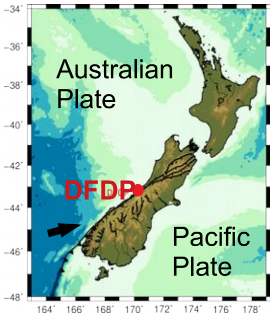
Overview

Motivation

- The Alpine Fault in New Zealand is a major plate boundary that is late in its earthquake cycle.
- The ICDP drilling DFDP project analyses the fault zone at depth.



Main Goals – Seismic data handling

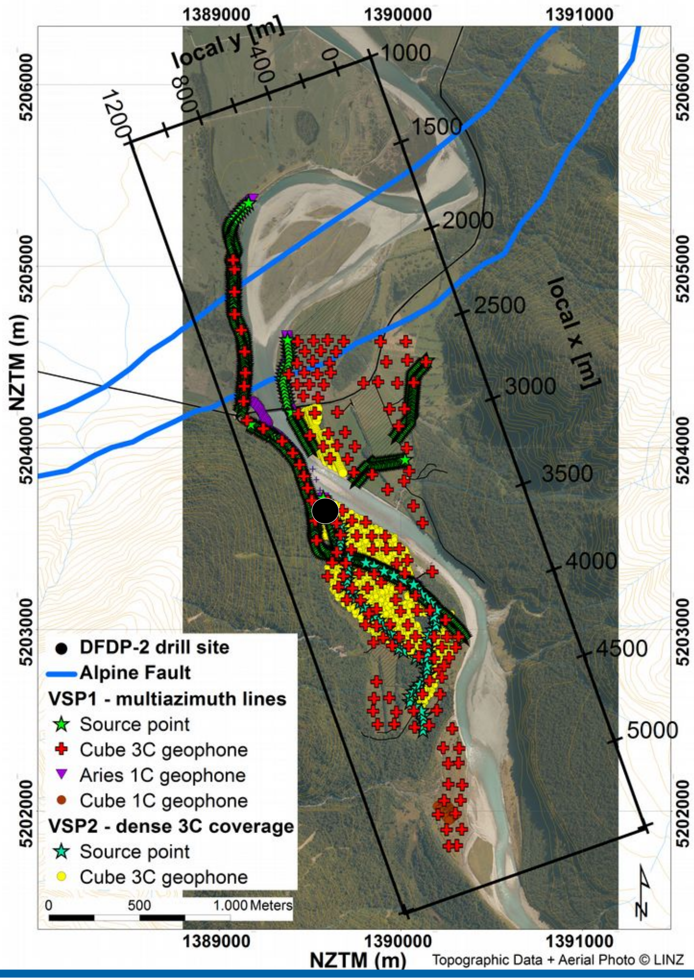
- Detailed P-wave velocity model in 3D
- Detailed 3D seismic images (in progress for various subsets of the data set)
- Compare conventional and fibre-optic recordings in the borehole (in progress)

Main Goals – Interpretation

- Understand structures previously obscured in 2D seismic data → 3D effect
- Understand glacial valley structures of the Whataora Valley (particularly the shape of the basement)
- Image Alpine Fault structures and relate to local tectonics (in progress)

Data Set

A combined surface and borehole seismic data set was recorded in 2016 with diverse seismic equipment within the Whataroa Valley where the DFDP-2B borehole is located.



Survey equipment and setup

- Source: vibrator
- Receivers in the borehole
  - 3C borehole tool (< 400 m)
  - hDVS (DAS-type; fibre-optic cable < 893 m)
- Receivers at the surface
  - 412 x 1C geophones (▼)
  - 160 x 3C geophones (✚▼)

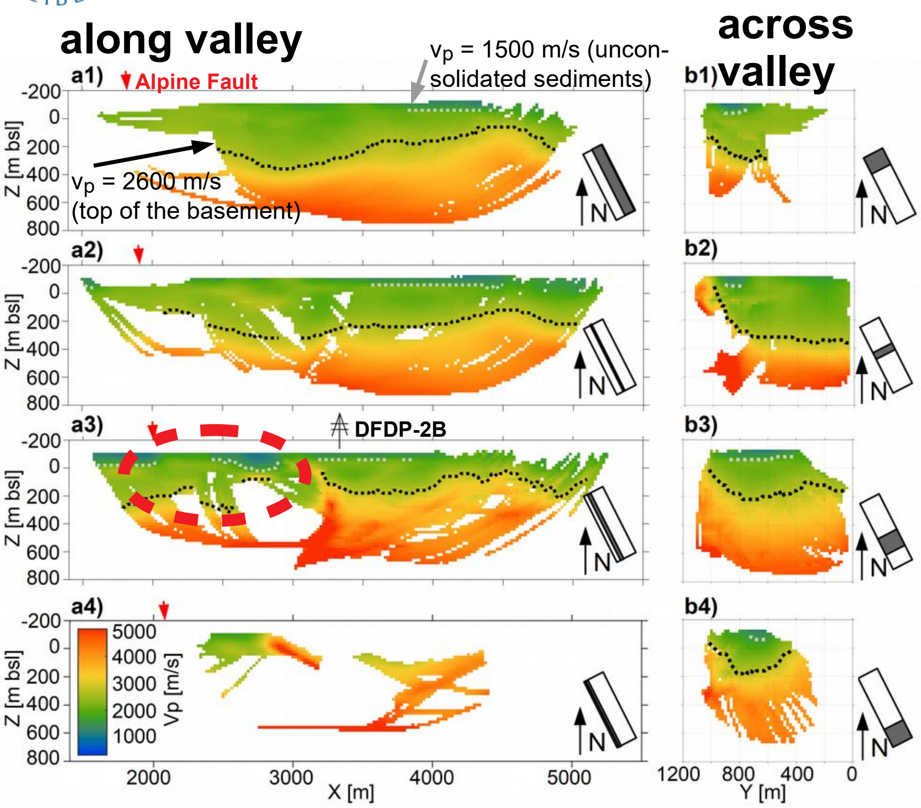
Experiments

- Zero-Offset VSP (●)
- VSP1: multiazimuth source lines sparse 3C coverage (✚ ★)
- VSP2: dense 3C coverage 71 source locations (▼ ★)

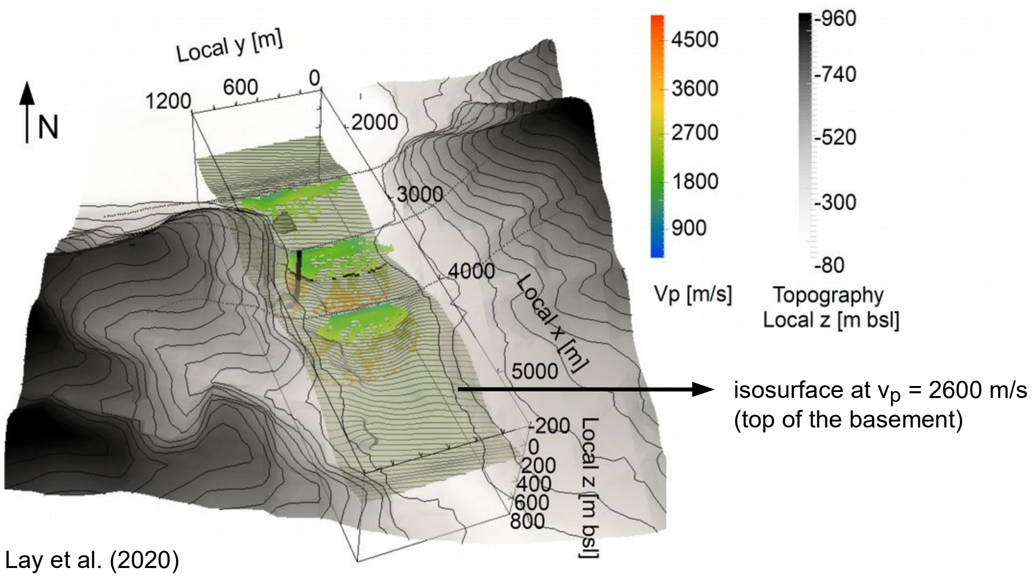
Relevant Publications

Lay et al., 2016
Townend et al., 2016
Constantinou et al., 2016
Lay et al., 2020

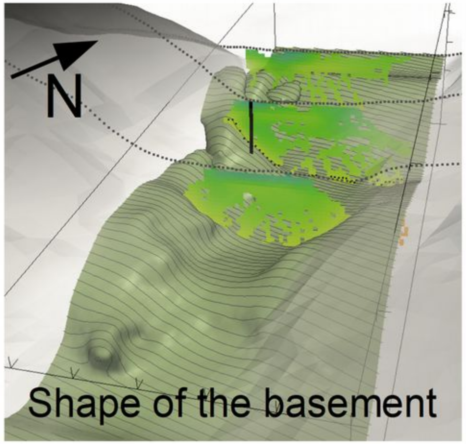
Glacial valley structures from the 3D P-wave velocity model



- 3D P-wave velocity model from first-arrival travel time tomography using surface and borehole recordings
- Sediment layer $v_p \approx 2200 \pm 400$ m/s; 150-460 m thick
- Schist basement $v_p \approx 4200 \pm 500$ m/s



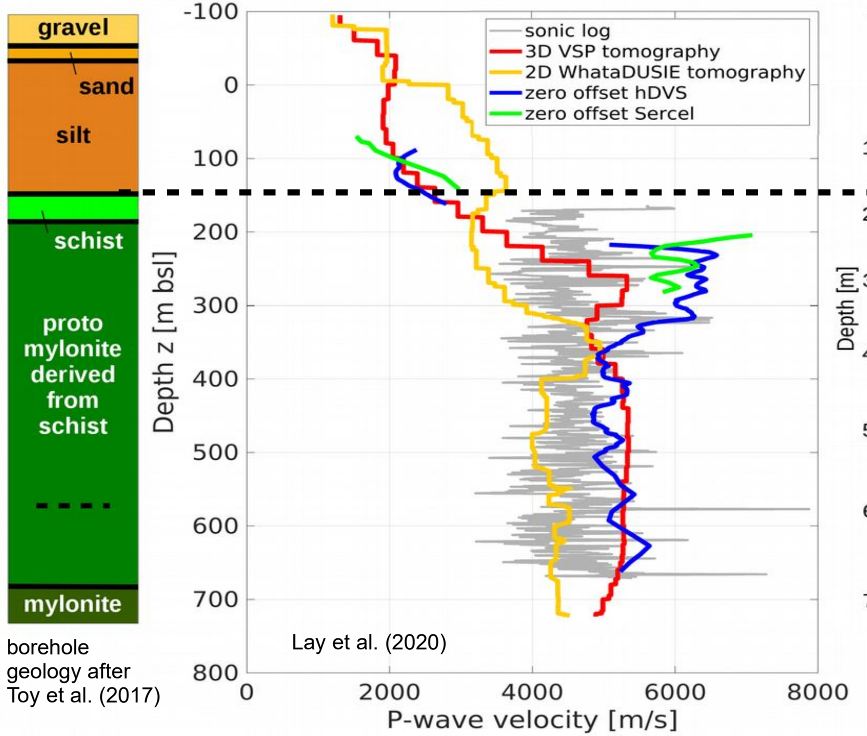
Lay et al. (2020)

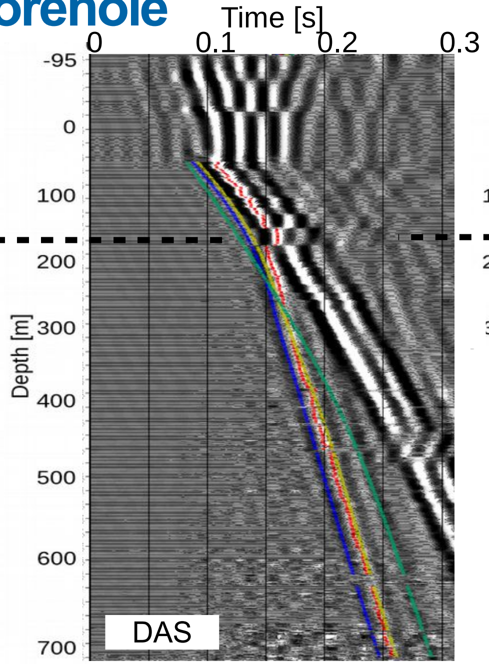


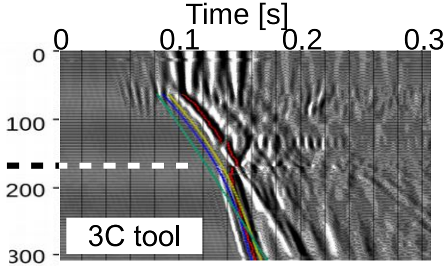
3D structures of old glacial valley

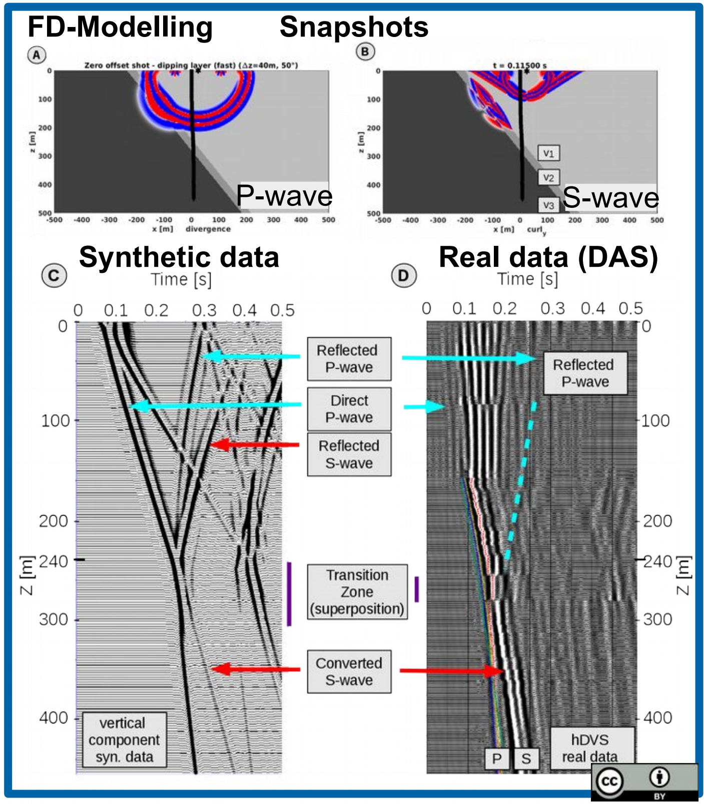
- Sediment layer thicker in the central valley
- Steep western valley flank
- Previous 2D seismic data was influenced by out-of-plane signals
- Basement topography
- Correlation with surface topography and borehole results
- Possibly Alpine Fault related structures

P-wave velocities from the borehole









- Correlation of P-wave velocities with borehole geology
- Consistent P-wave velocities along the borehole
- Good correlation between 3C borehole tool and DAS recording

- 2D FD elastic wavefield modelling of a steep valley flank within the DFDP-2B borehole explains arrivals observed in real data with a reflected upgoing P-wave and a converted downgoing S-wave.

Seismic imaging

- **VSP2**: densely spaced 3C geophones
  - 71 source locations
  - **1916** receiver locations spacing: N → S ~10 m
    W→ E ~20 m
- Reflections from sides clearly recorded in cross-valley profiles (★▬)
- PSDM (Fresnel Volume Migration)
  - fault related structures in single source gathers correlate with expected fault model (★▬ ▬)
  - stack of 71 source gathers, absolute amplitudes for robust stacking (▣▣) illustrate steep valley flanks and basement topography
- Top of the basement correlates well with results from the velocity model