An overview of the use of laser ultrasonics to estimate the elastic properties of solid materials

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From Cargese and FIFA 2002....

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Pos	Team [V·T·E]	Pld	W	D	L	GF	GA	GD	Pts	Qualification
1	Denmark	3	2	1	0	5	2	+3	**7**	Advance to knockout stage
2	Senegal	3	1	2	0	5	4	+1	**5**	
3	Uruguay	3	0	2	1	4	5	−1	**2**	
4	France	3	0	1	2	0	3	−3	**1**	

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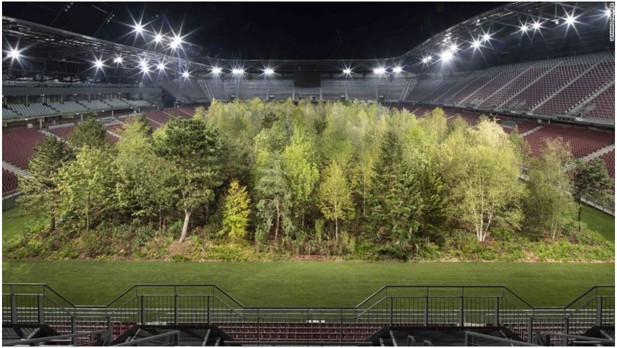
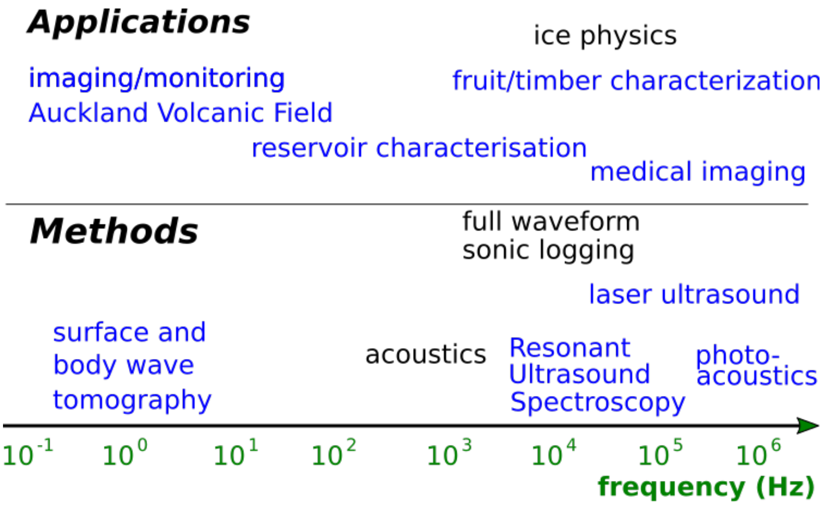


(Klauss Littmann, 2019)

Waves and applications



Resonance on ice (with contacting transducers)

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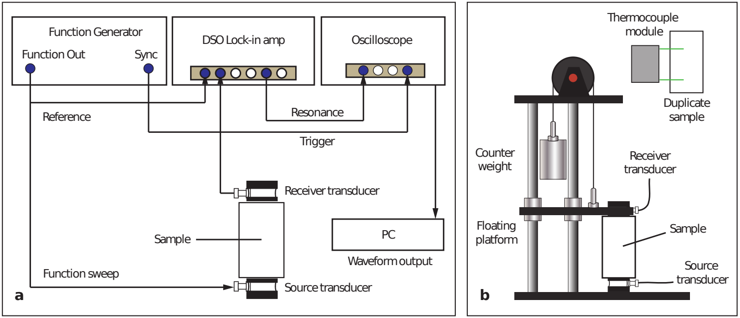
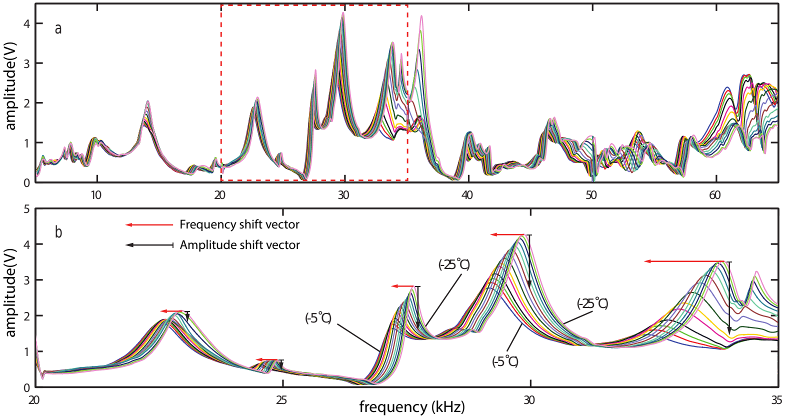
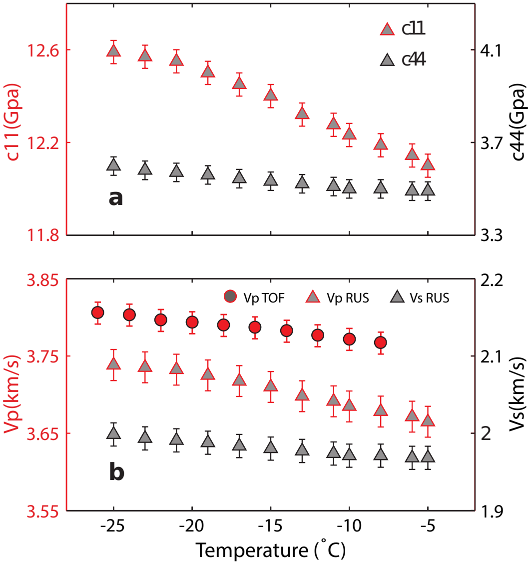


Detecting small changes in (man-made poly-crystalline) ice

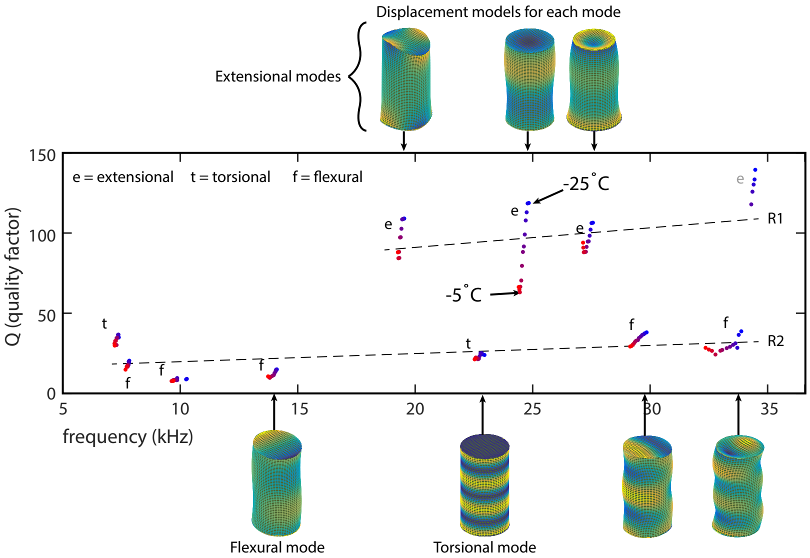


Vaughan et al. (The Cryosphere, 2016)

Elastic constants of ice



Attenuation in ice



Monitoring the temperature in ice

- From -20 to -5 Celsius, we see *partial melt* in the pores
- This partial melt:
  - has an effect on the elastic parameters, particularly c_{11} (v_p),
  - an even bigger effect on *attenuation* (mostly Q_p)
- The quality factor Q is notoriously hard to estimate with seismic data, but has real potential for monitoring (fluids)

Non-contacting ultrasound with lasers

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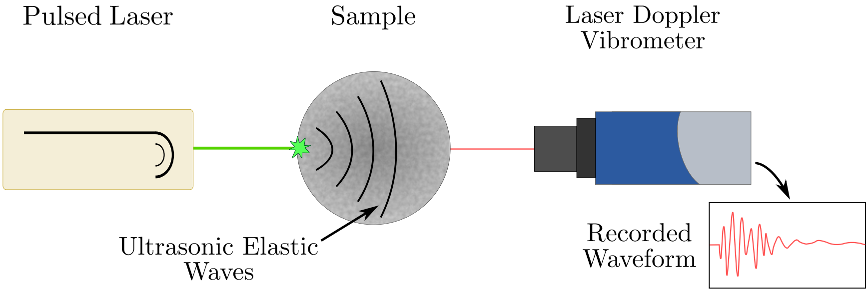
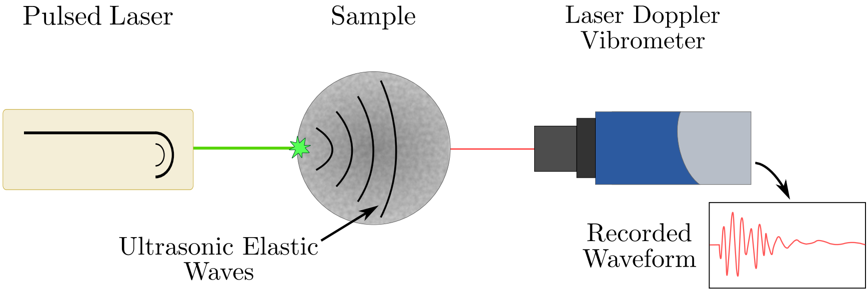
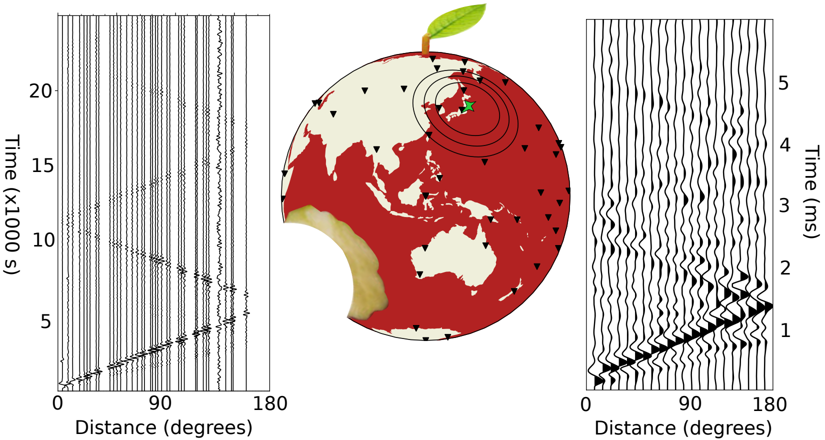


Non-contacting ultrasound with lasers



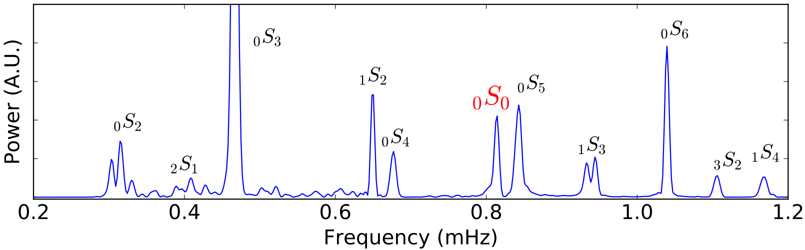
Rotation and translation under computer control for source, receiver, and the sample

Waves in two (approximate) spheres



Physics Today, October 2017

The modes of a sphere



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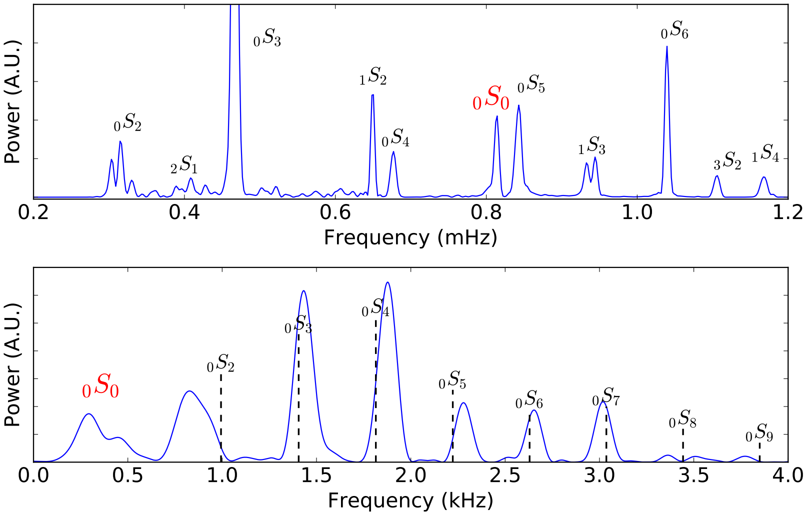
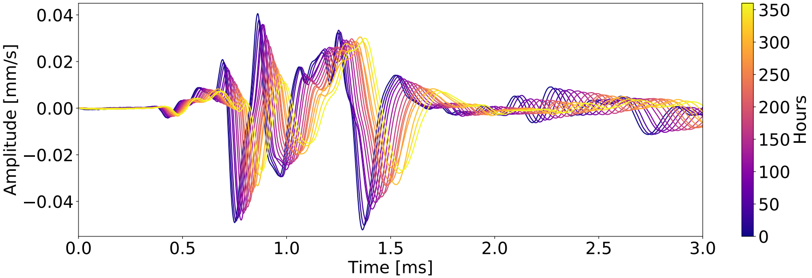
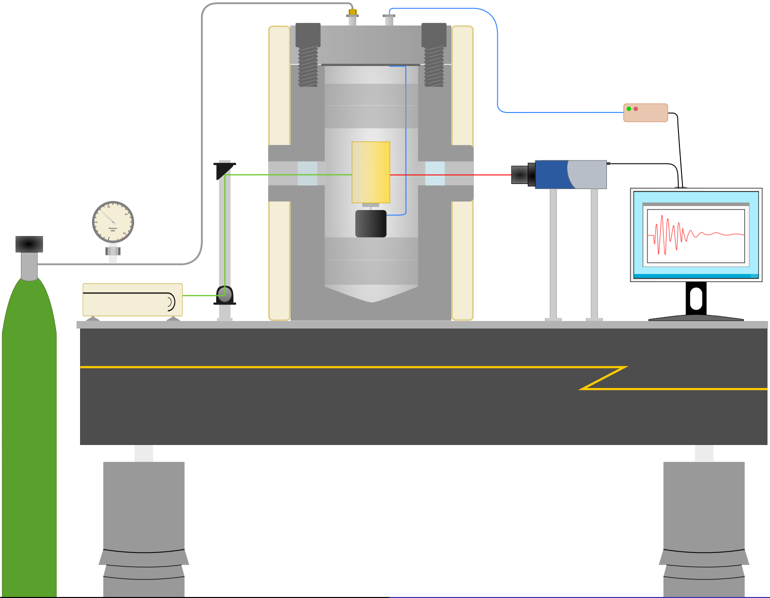


Apple-watching for 15 days



Postharvest Biology and Technology, 2016

Laser Ultrasound, controlling pressure and temperature



The Alpine Fault, New Zealand

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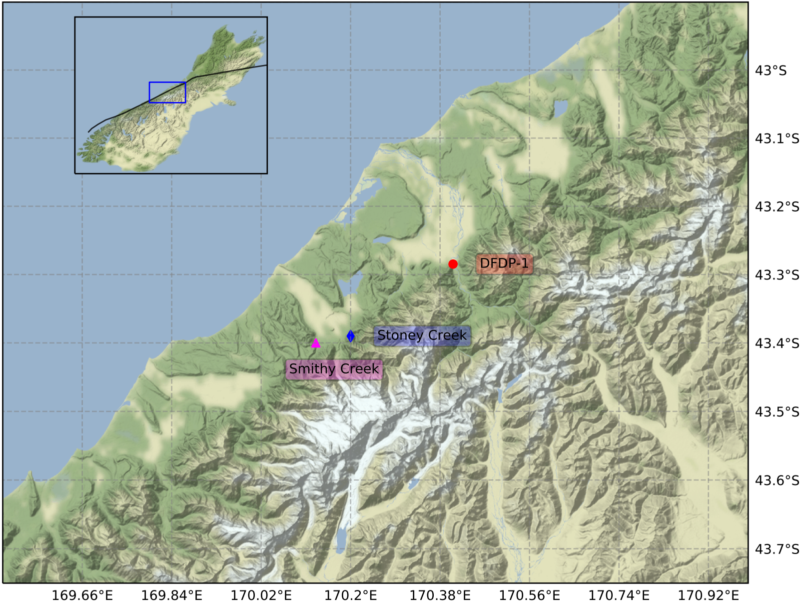
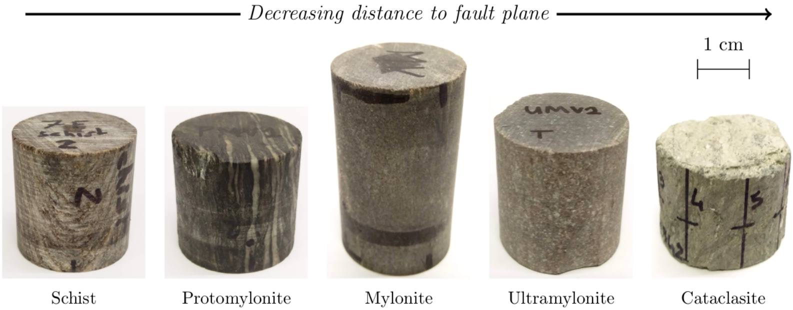
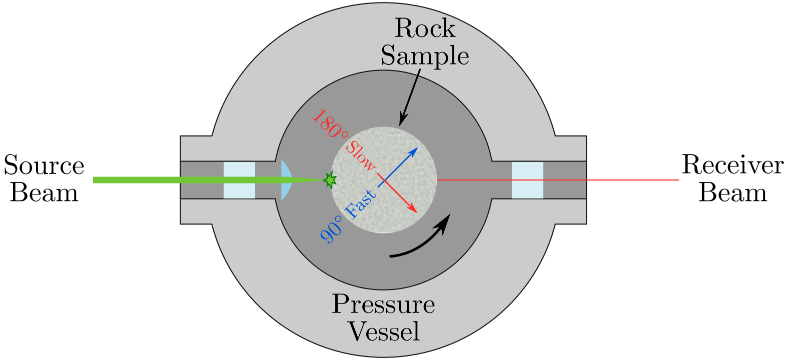


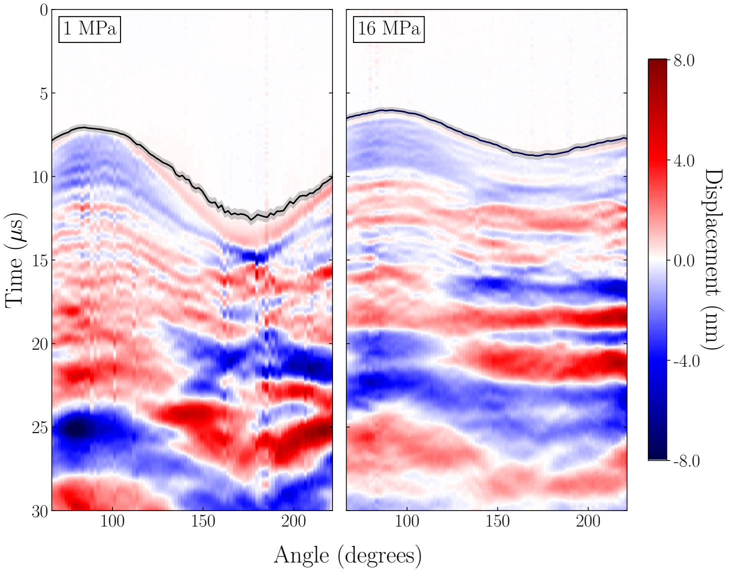
Alpine Fault rocks



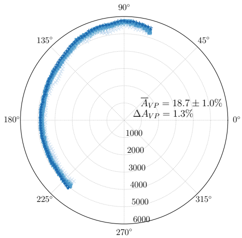
Rotational scan under pressure



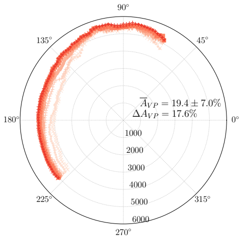
Pressure dependence



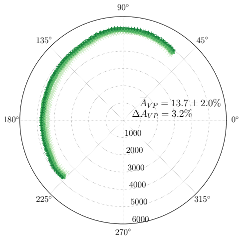
Rose diagrams



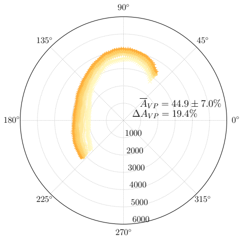
(a) Schist



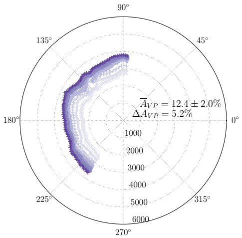
(b) Protomylonite



(c) Mylonite

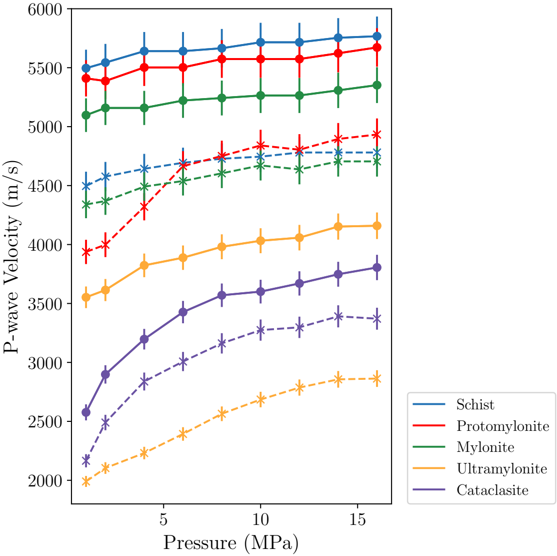


(d) Ultramylonite

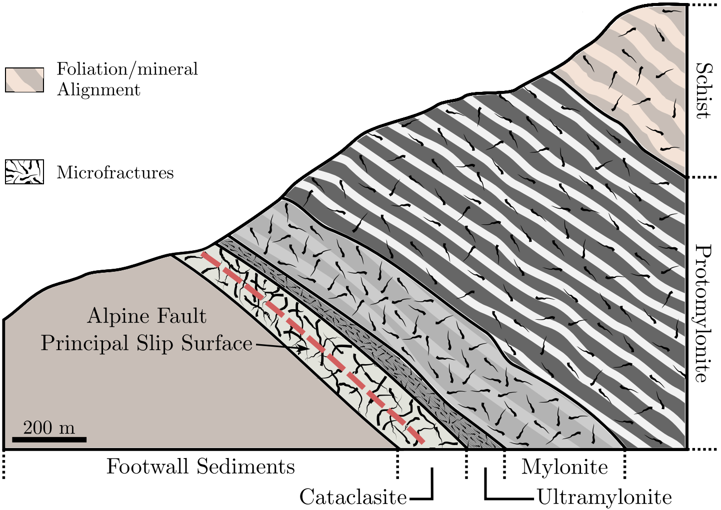


(e) Cataclasite

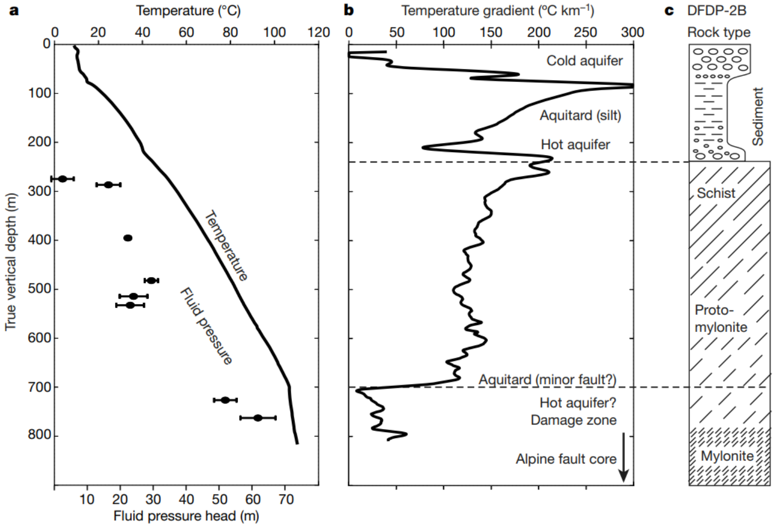
Anisotropy as a function of distance to the Alpine Fault



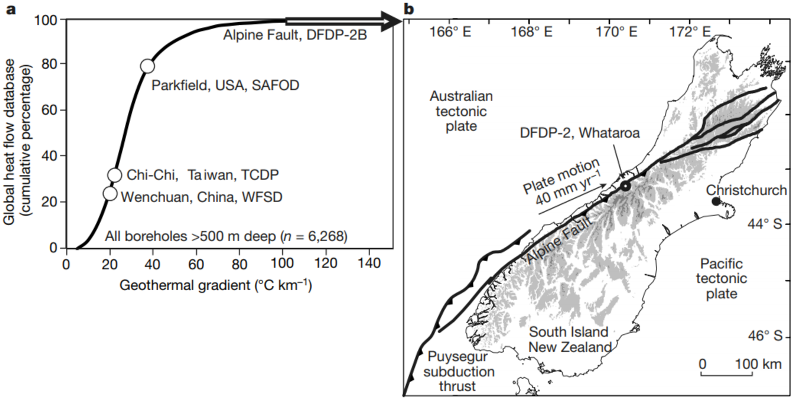
Conceptual cross-section of the Alpine Fault



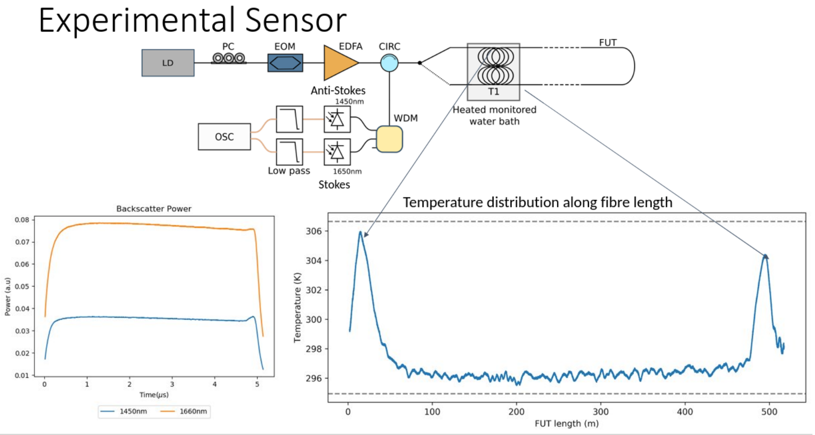
The geothermal gradient of the Alpine Fault



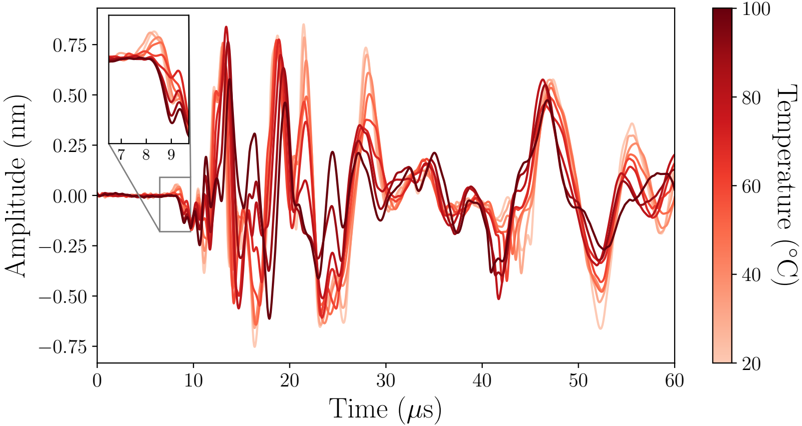
Geothermal gradient in fault zones



Fibre-optic temperature (and strain) sensing



Temperature dependence of elastic wave speed



Implications for the Alpine Fault

- Estimates of $v_p(P, T)$ in Alpine Fault rocks show the importance of fractures and the geothermal gradient.
- Furthermore, this information can be used to
  1. Seismic imaging
  2. Fault strength

Outlook of (laboratory) wave propagation research

- Elastic waves are sensitive probes of the physical properties of many solids:
  - Earth
  - timber
  - fruit
  - ice
  - the human body, others ...

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  With laser ultrasound, we are poised to learn more about how each of these parameters control (seismic waves in and near) faults