From Deep Seismic to Microseismic:
A convergence of disciplines

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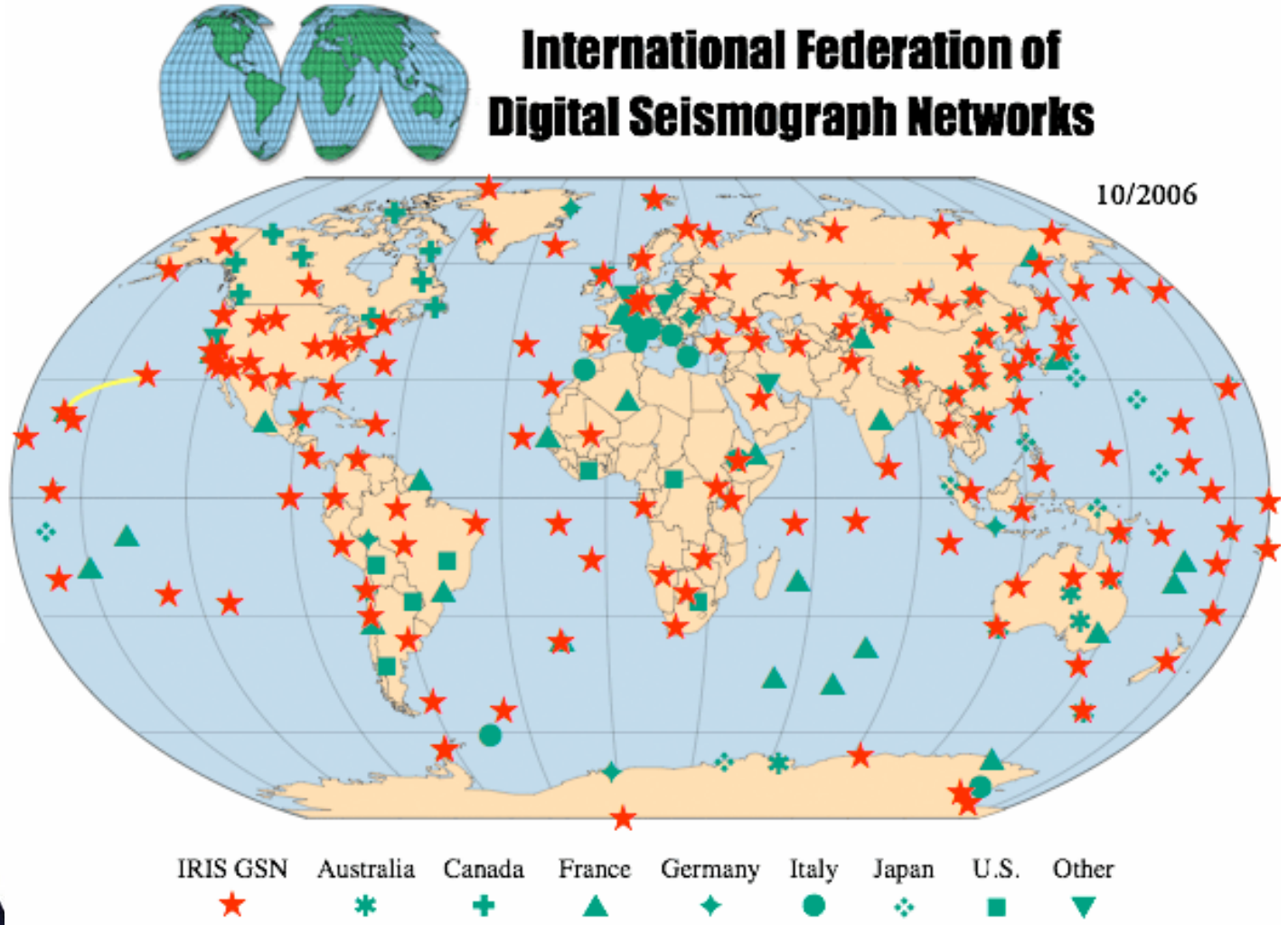
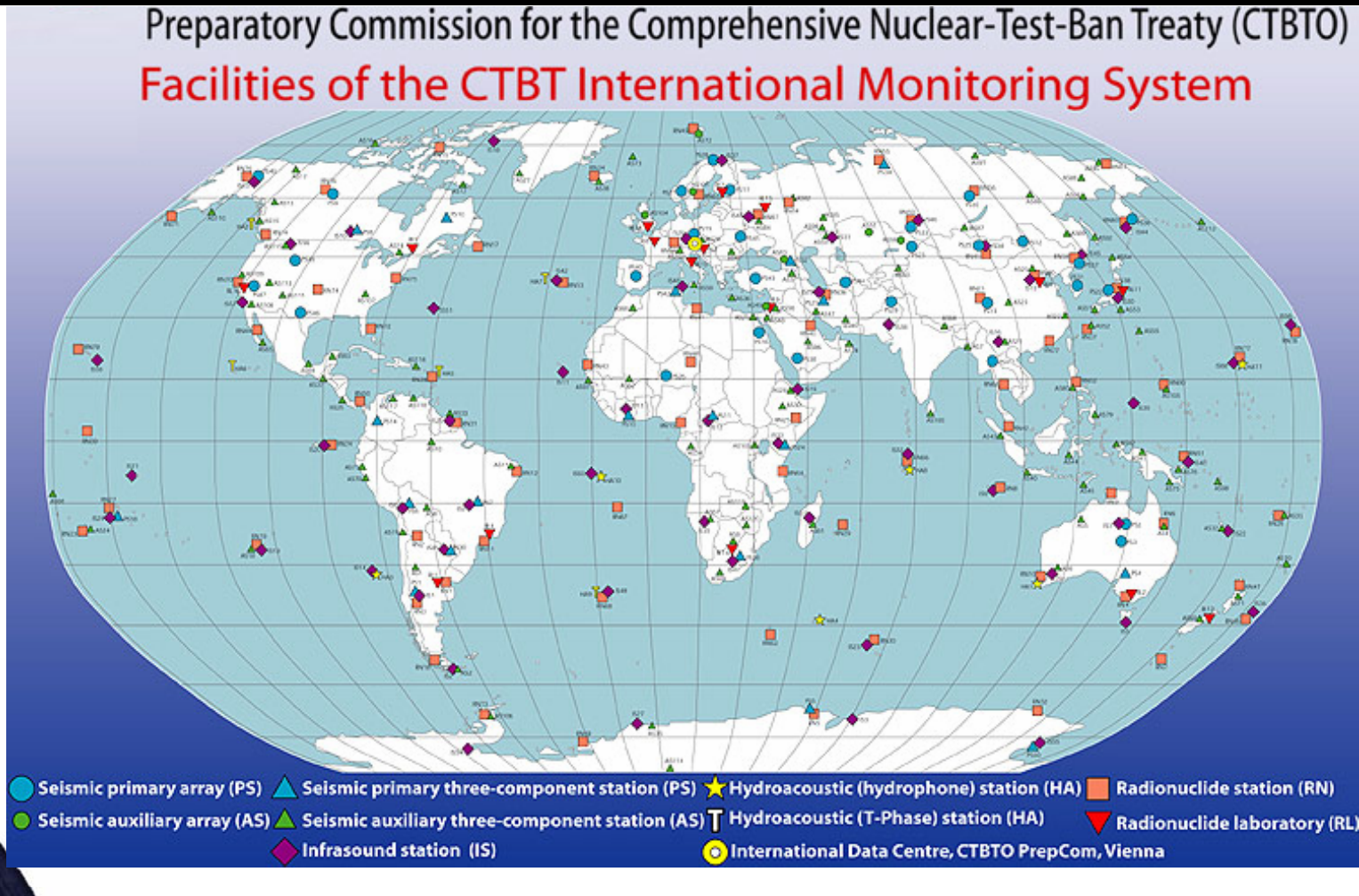
Talk Outline

- Modern global seismology & portable array deployments
  - Current and planned projects around the world
  - Three-component instrumentation
  - Techniques for imaging and data analysis
- Microseismic monitoring studies
- Possible interdisciplinary links

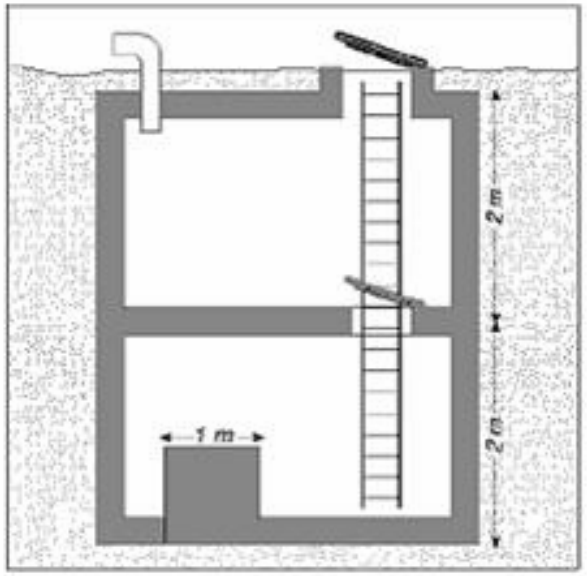
Global Seismic Network



CTBT international monitoring systems



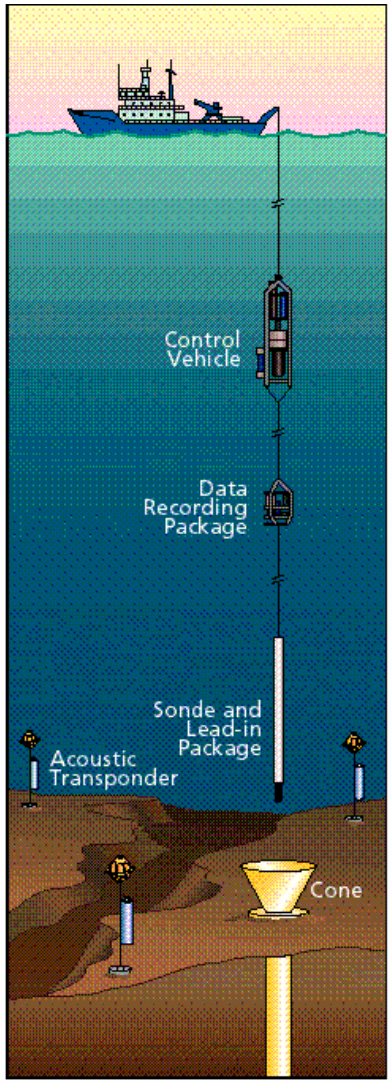
Broadband seismometers



A seismic vault

A state-of-the-art three-component broadband seismometer (Streckeisen STS-1) under vacuum cover.

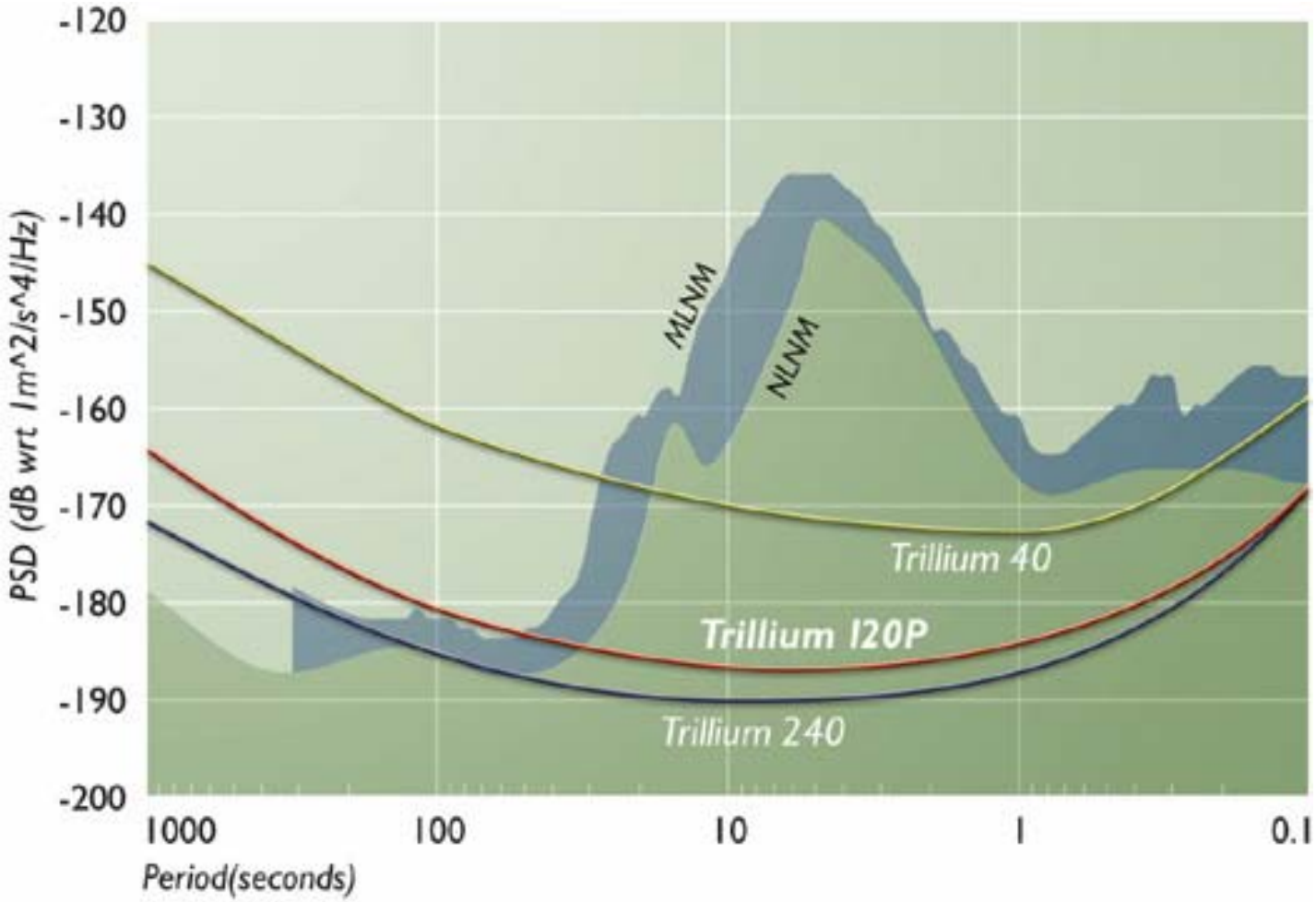
Ocean Seismic Network Pilot Experiment (1998)



WHOI

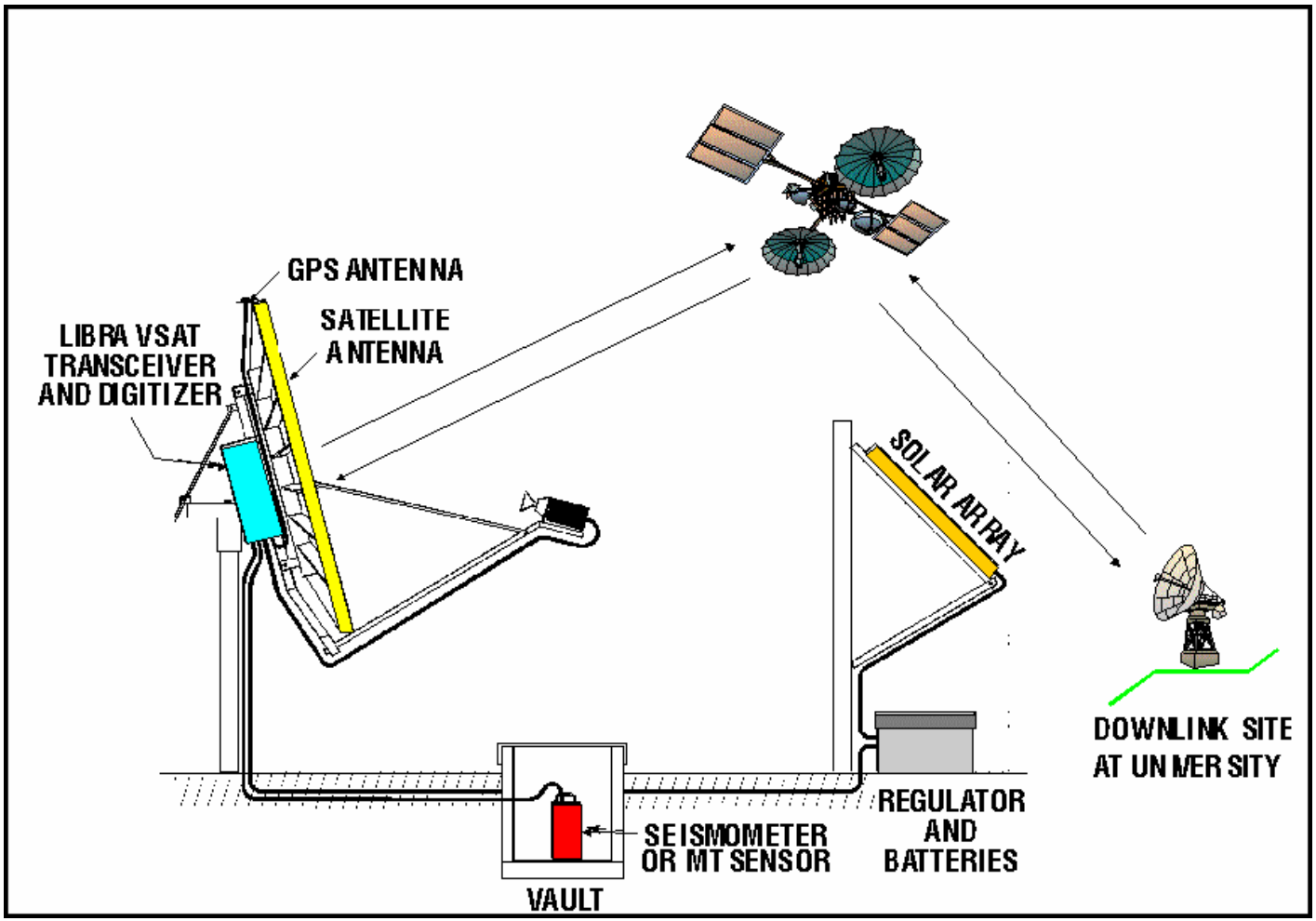
Noise characteristics

Peak noise at 4-6 s is caused by world's oceans



The Canadian POLARIS Project

POLARIS is the only national program using VSAT telemetry



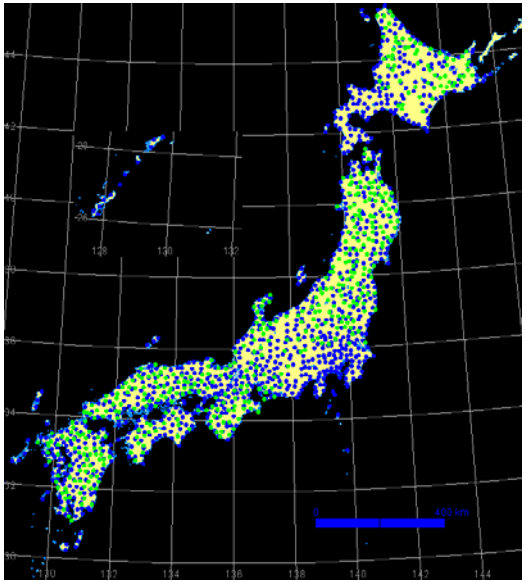
Eaton et al., 2005
www.polarisnet.ca

The Canadian POLARIS Project

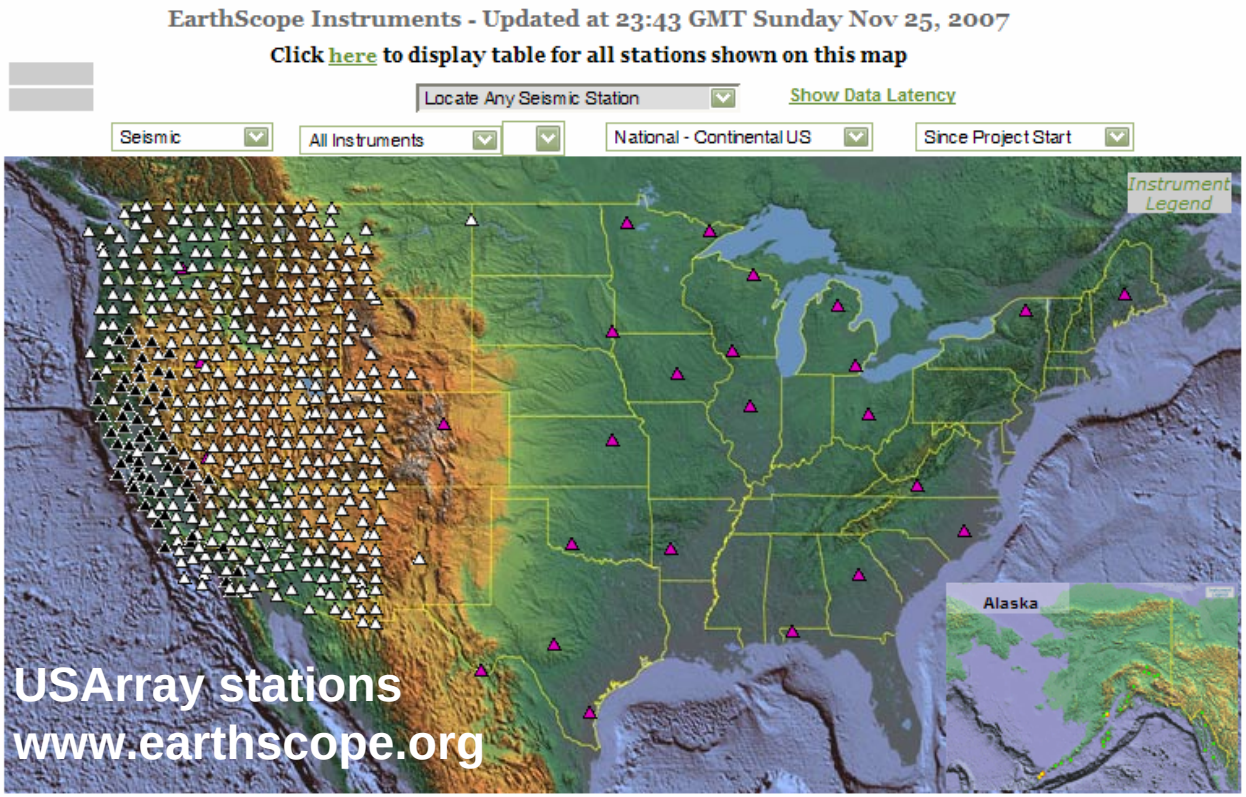
POLARIS station **SILO**

Sutton Inlier, Northern Ontario

New international initiatives



Japan's K-net



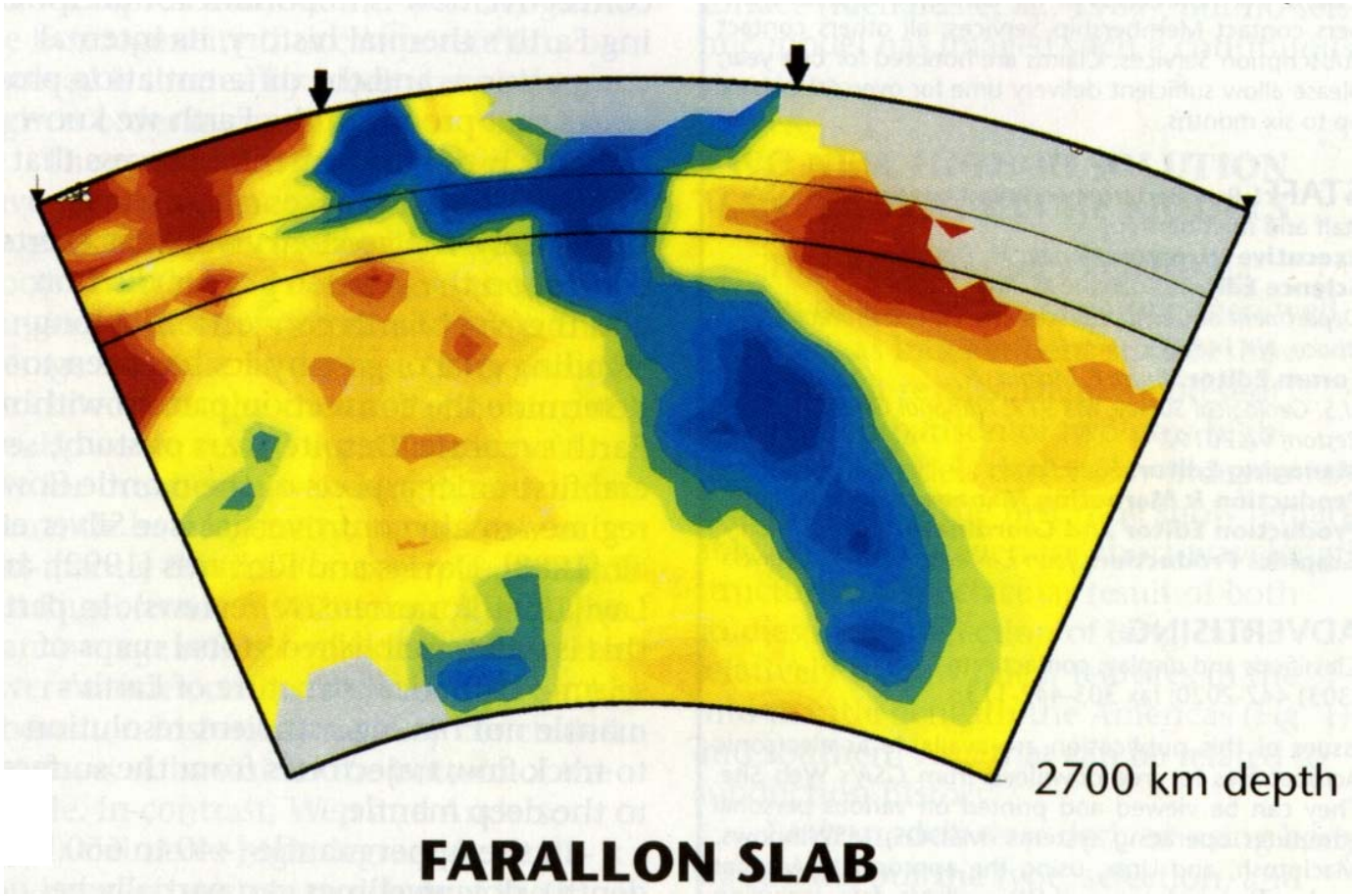
USArray is a giant 3-D seismic survey of the continental U.S. over a 10-year period

Earthscope is the largest NSF funded project in U.S. history

Global seismic tomography

Image of S-wave velocity perturbation (blue fast, red slow).

Latitude of southern U.S.

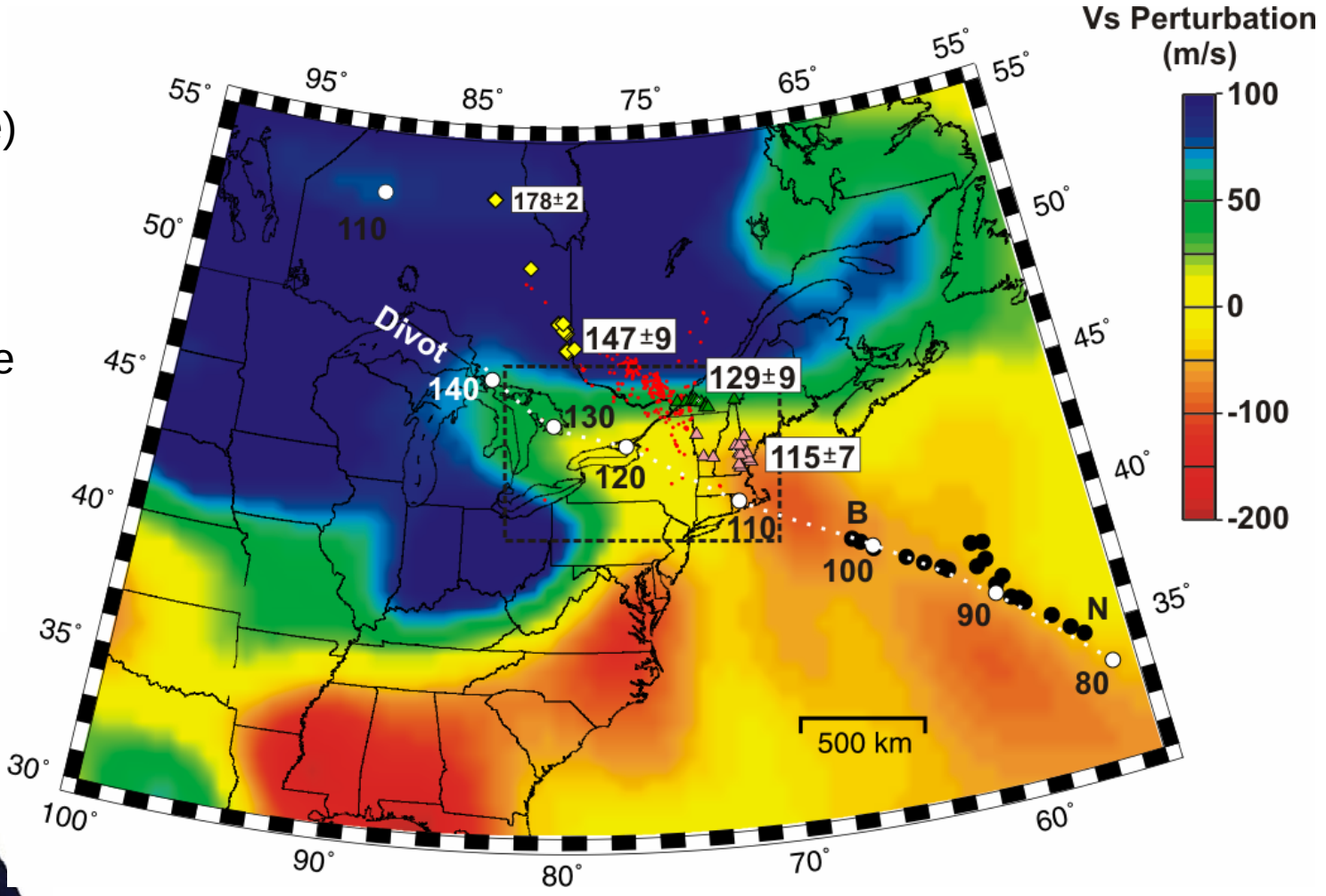


Grand et al., 1997

Surface-wave tomography

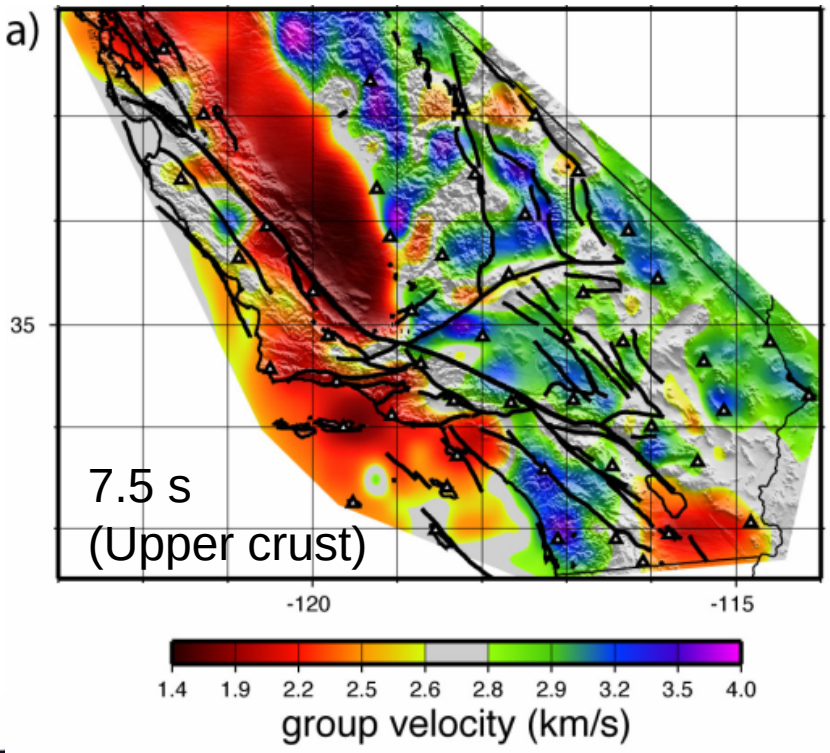
Fast region (blue) represents mantle root beneath NA

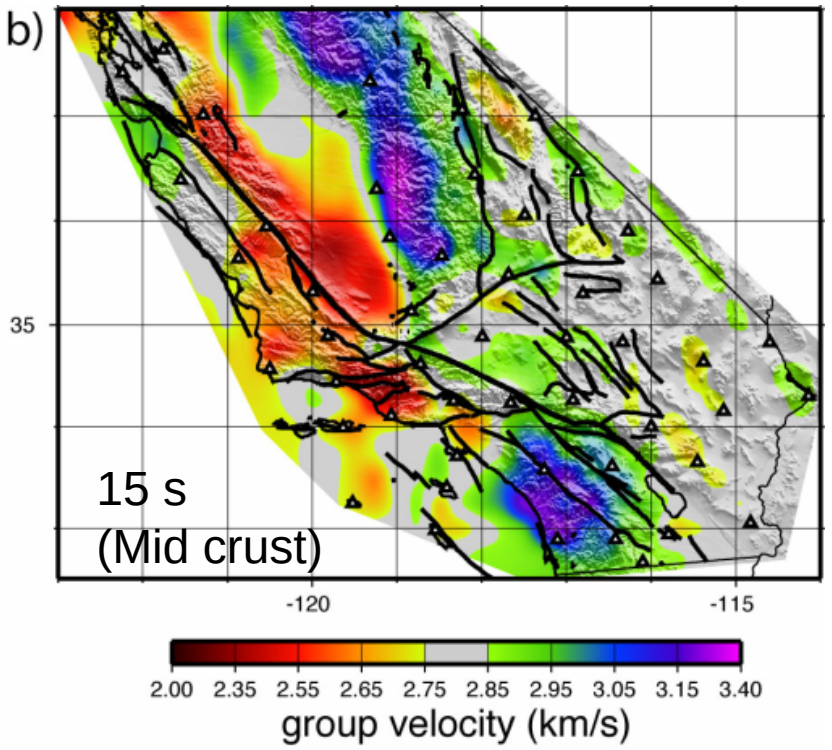
Divot may be due to hotspot track



Eaton and Frederiksen, Nature, 2007

Ambient noise tomography





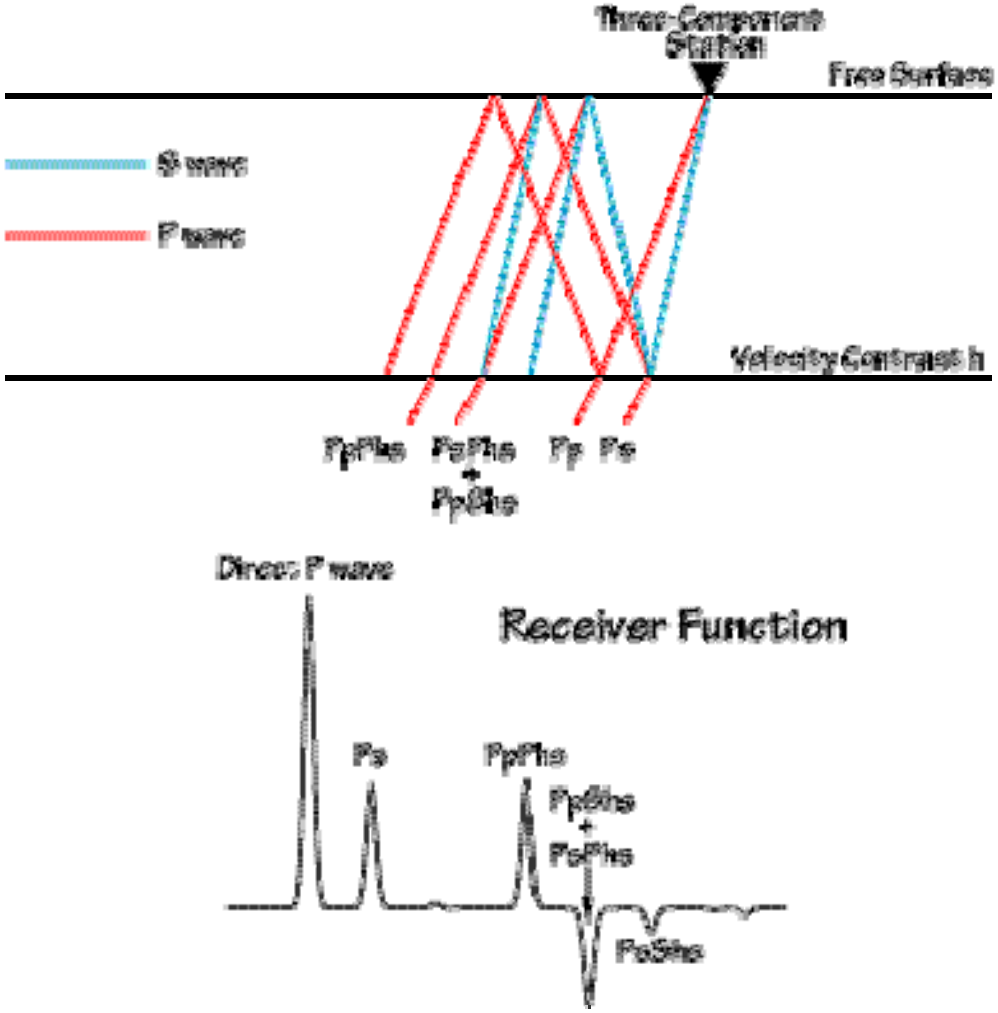
Rayleigh group speed maps constructed by cross-correlating one month of ambient noise between Californian USArray stations**.** Black solid lines show known active faults. Triangles show locations of USArray stations used.

Shapiro et al., Science, 2005

Receiver-function analysis

Receiver functions are obtained by deconvolving a radial seismogram using the vertical component

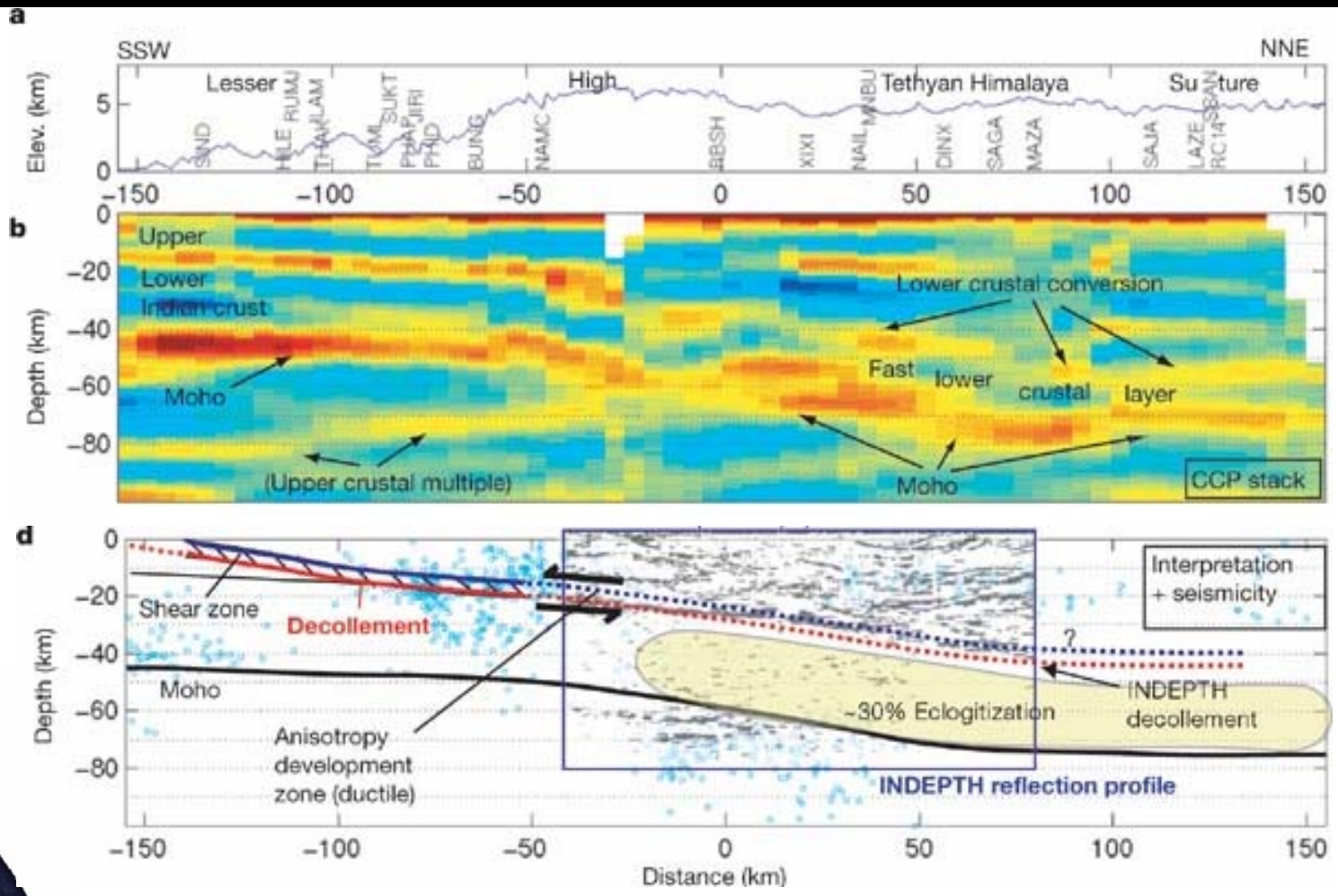
Deconvolved trace shows mode-converted arrivals “free” of source-side scattering



http://eqseis.geosc.psu.edu/~cammon/HTML/RftnDocs/rftn01.html

Receiver-function analysis

Receiver function profile from Himalaya

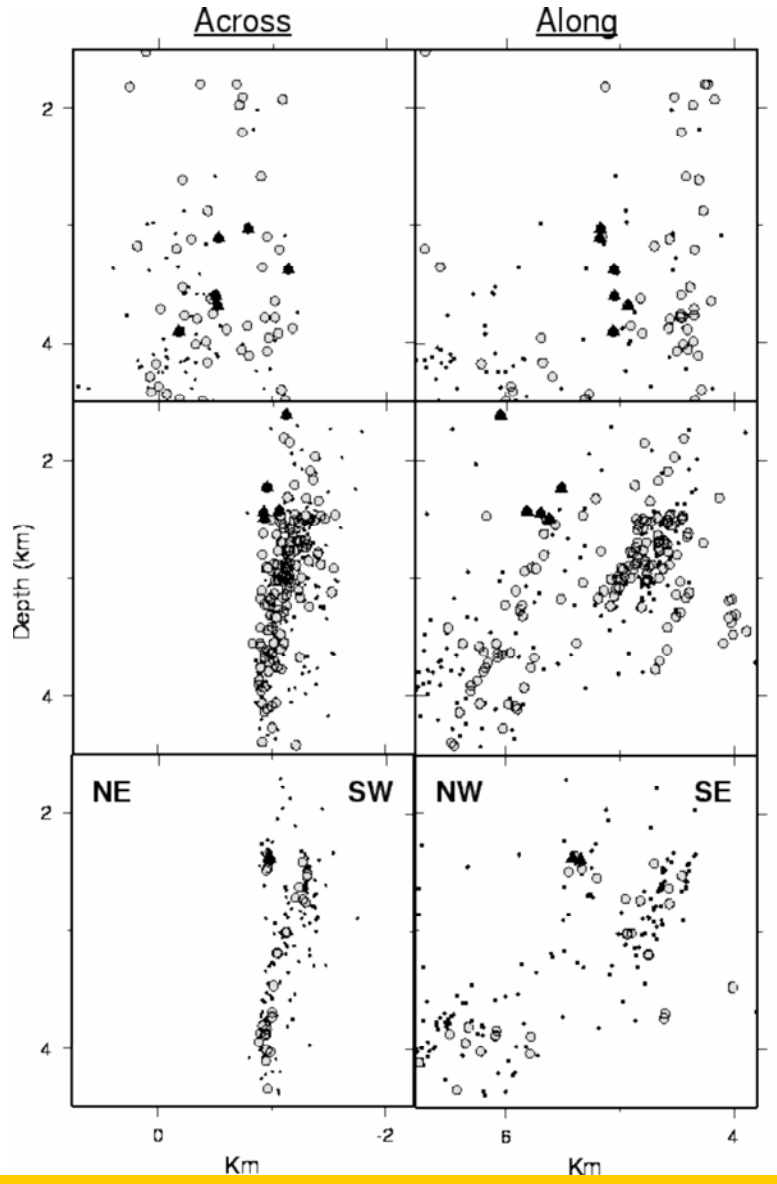


Schulte-Pelkum et al., Nature, 2005.

Precise hypocentre determination

San-Andreas fault (Parkfield segment)

More precise hypocentre locations achieved by cross-correlation (XC) and double-difference (DD) algorithms



NCSN

HRSN

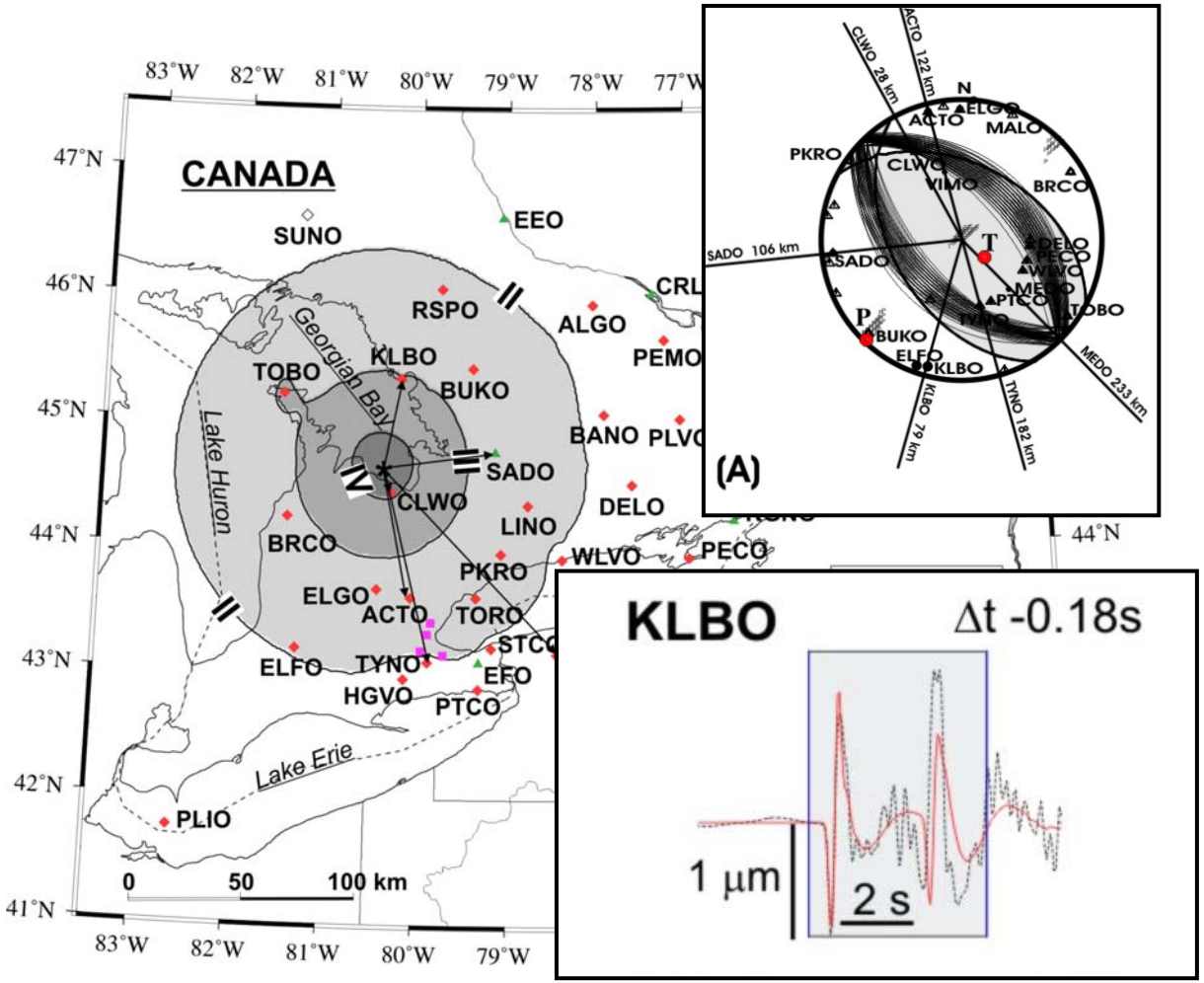
HRSN-DD+XC

McEvilly et al., 2001

Moment Tensor Inversion

Small earthquake in Georgian Bay, Ontario (October, 2005)

Waveform fitting (inversion) used to obtain accurate focal mechanism

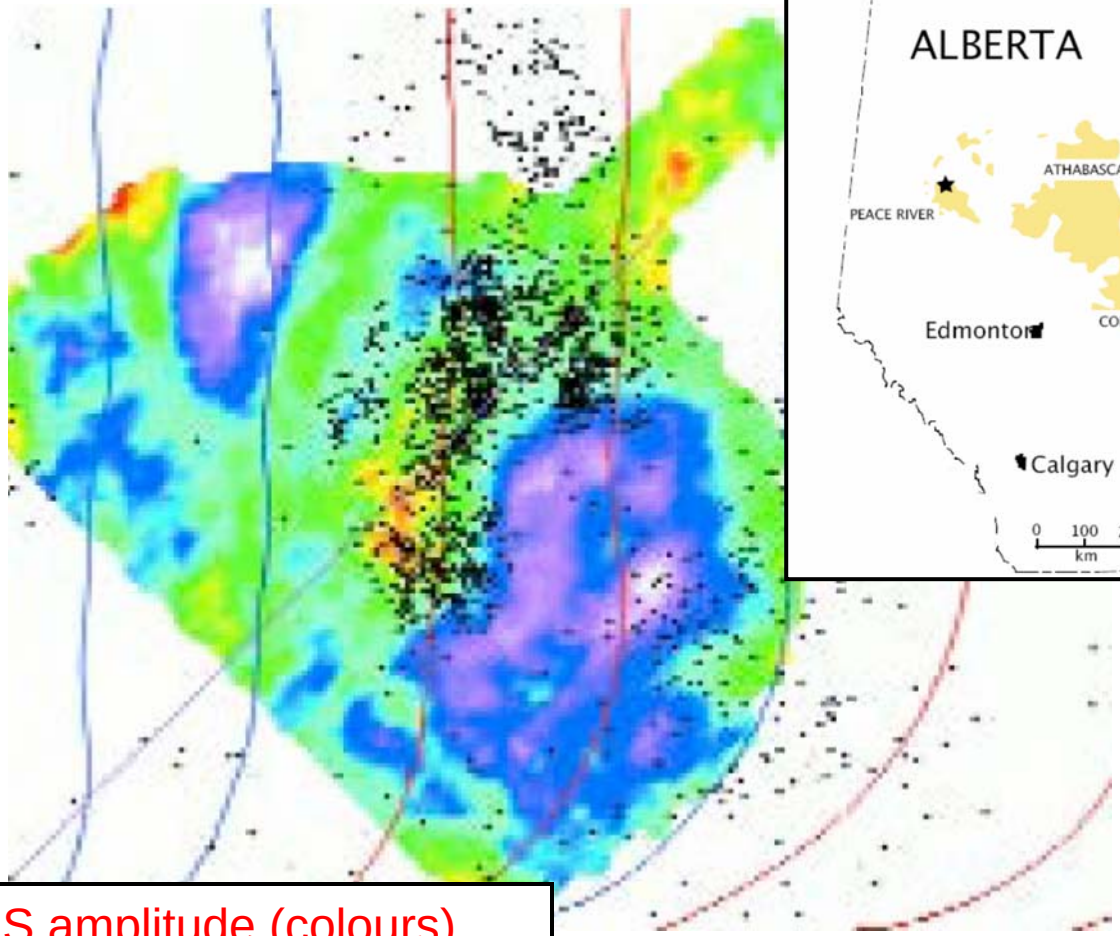


Dineva et al., BSSA, 2007

Microseismic reservoir monitoring

Monitoring of in-situ heavy oil enhanced production, Peace River

Microseismicity shows that steam causes fracturing, preferentially in higher-permeablity zones (***not what was expected***)



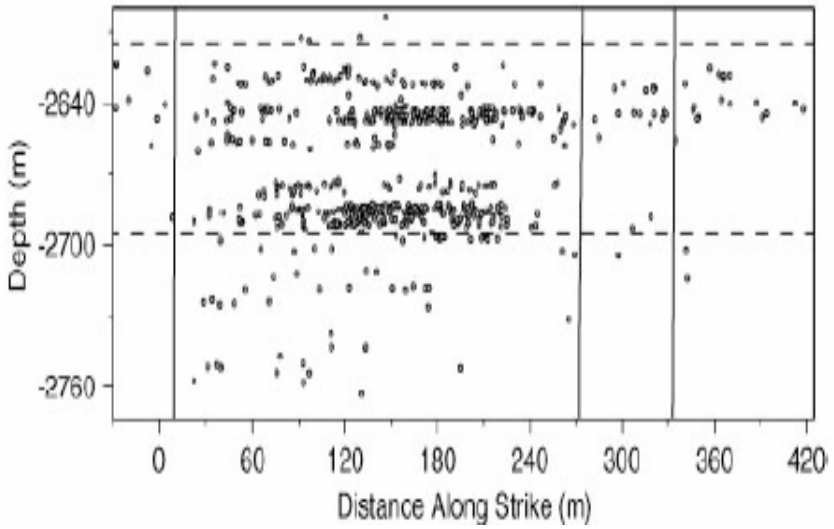
3-D RMS amplitude (colours) and microseismic activity (dots)

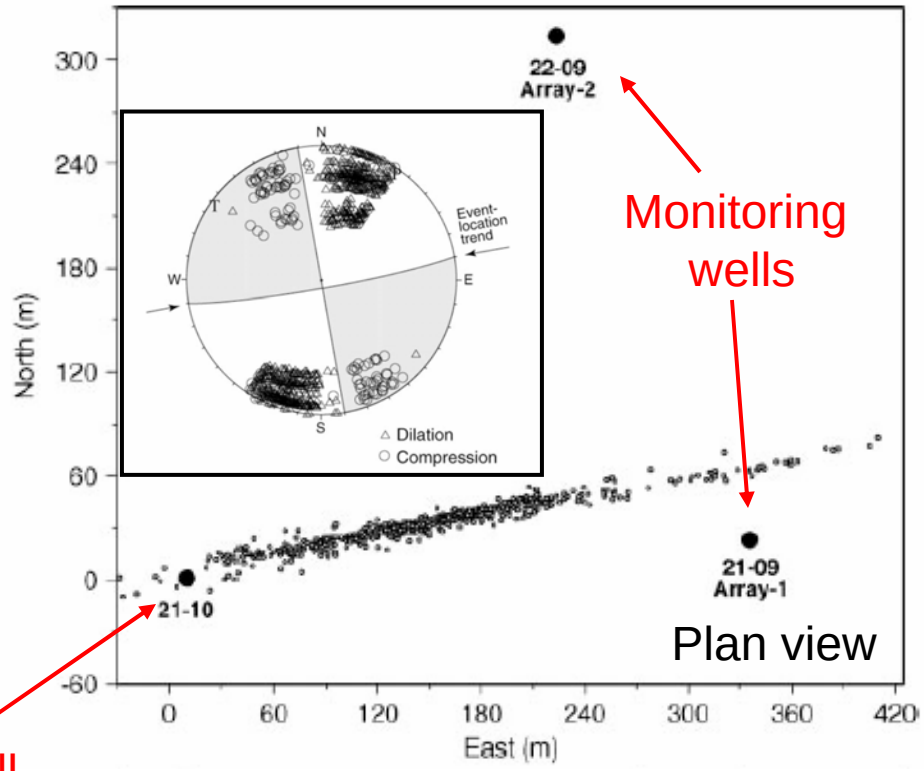
McGillivray, 2005

Horizontal well cyclic steam stimulation (CSS)

Microseismic monitoring of hydraulic stimulation

Cross section

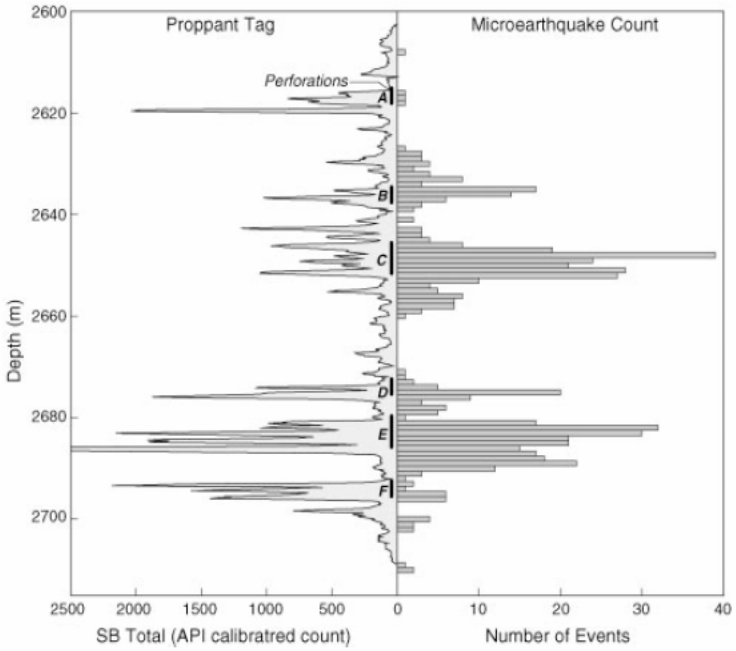


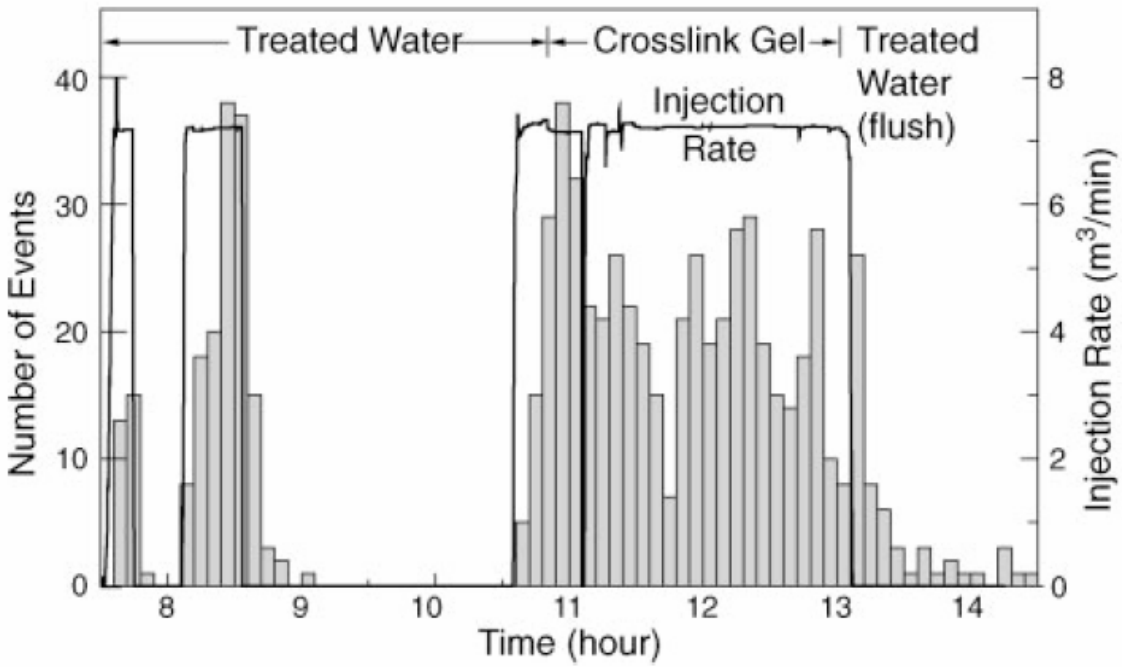


- Hydraulic fracture stimulation, Carthage Cotton Valley, east Texas
- Existing fractures experience strike-slip reactivation within regional stress field

Rutledge and Phillips, 2003

Microseismic monitoring of hydraulic stimulation





- Carefully re-located microseismic events correlate with perforation zones and injection rate
- *Little or no hydraulic communication between discrete perforation intervals, came as a surprise*

Rutledge and Phillips, 2003

Potential Cross-linkages between disciplines

Exploration Seismic

Microseismic monitoring

Surface-wave tomography

Migration, Inversion, Deconvolution

Fracture processes

Global seismology

Precise hypocentre Methods (HypoDD), Moment-tensor inversion