Use of Earthquake Recordings on Geophones for Basin Imaging: Bighorn Arch Seismic Experiment, Wyoming

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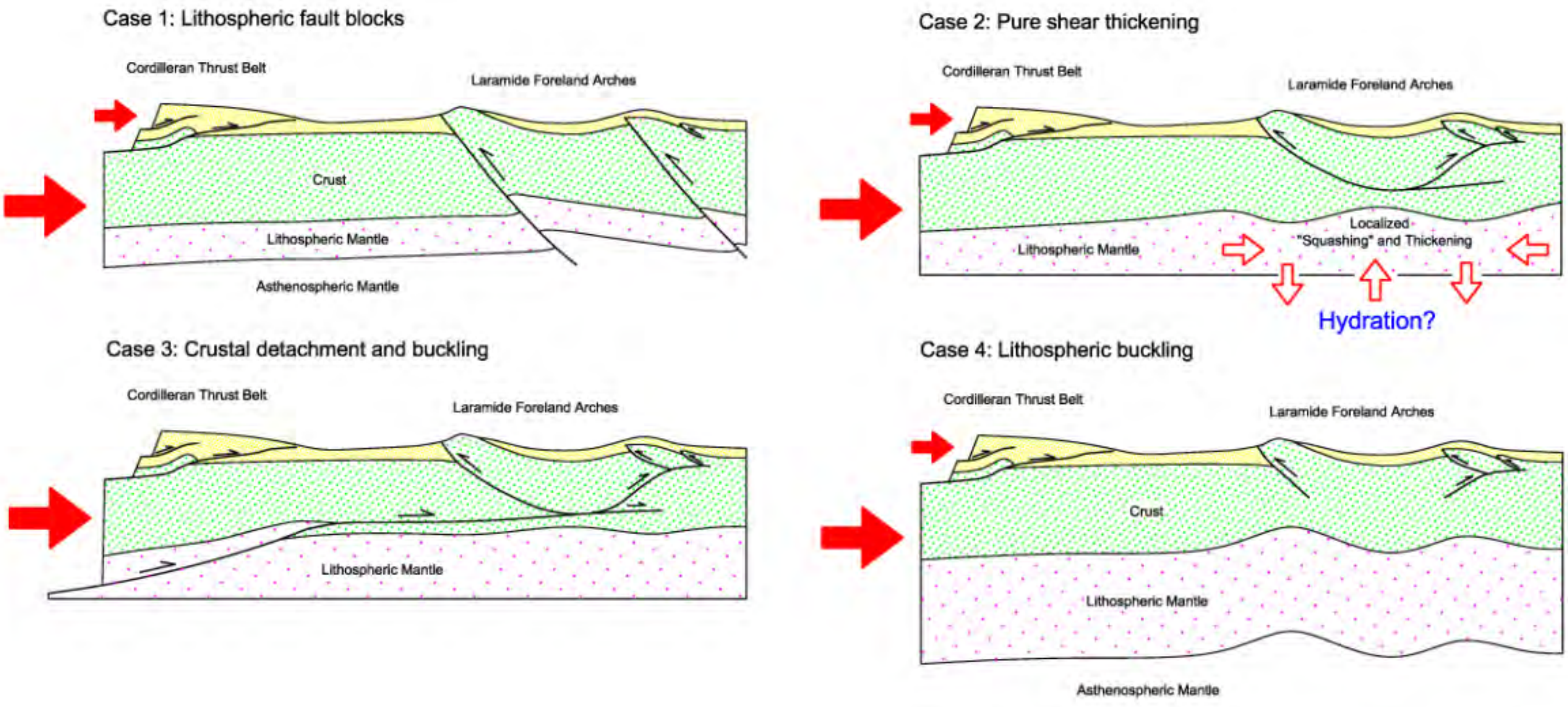
Bighorn Project Pis: Kate Miller (TAMU), Eric Erslev (Wyoming), Steve Harder (UTEP), Megan Anderson and Chris Siddoway (Colorado College), Anne Sheehan (Colorado)

Thanks to the students and collaborators who have contributed to this work, including several in the audience (Zhaohui Yang, Josh Stachnik, Justin Ball)

Active Uses of Passive Seismic Data GSH/IRIS Houston June 3, 2014

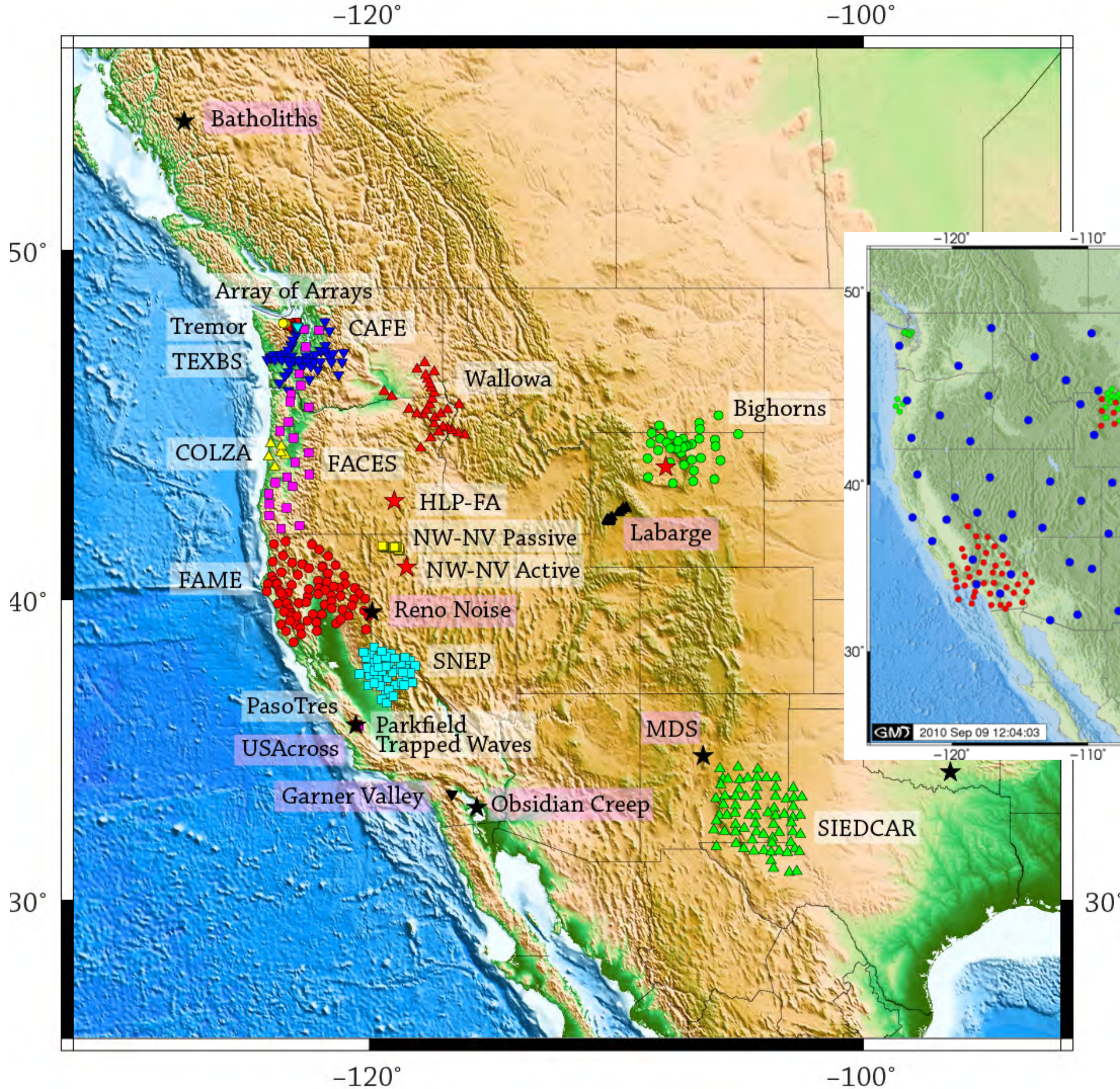
Bighorn Project Goal: Use structural geology and seismology to test competing models for lithospheric-scale structure of Laramide Arches

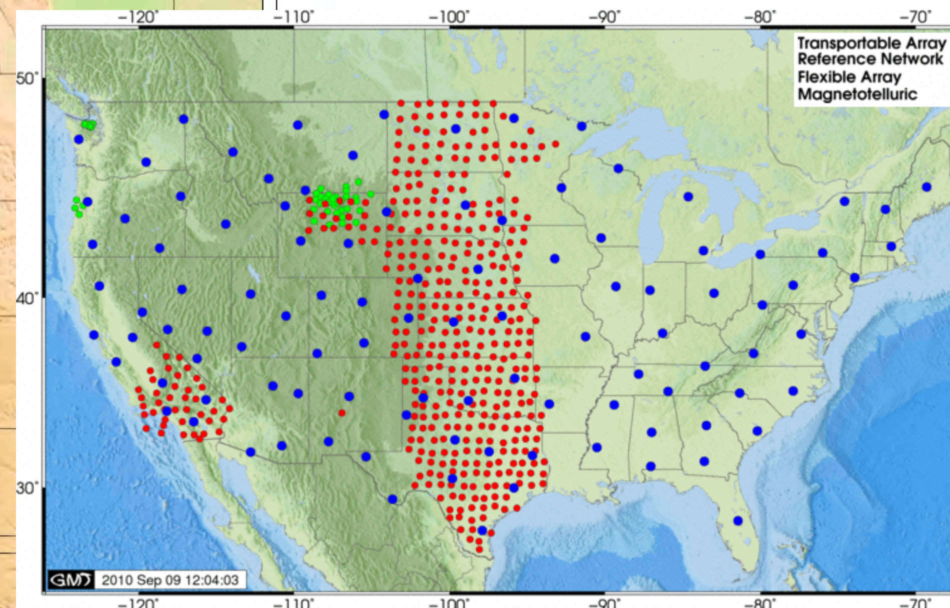


Collaborative with Texas A&M (Kate Miller, L. Worthington), U Wyoming (E. Erslev), UTEP (Steve Harder), Colorado College (M. Anderson, C. Siddoway)

USArray Flexible Array (FA) Experiments

Focused Regional Experiments

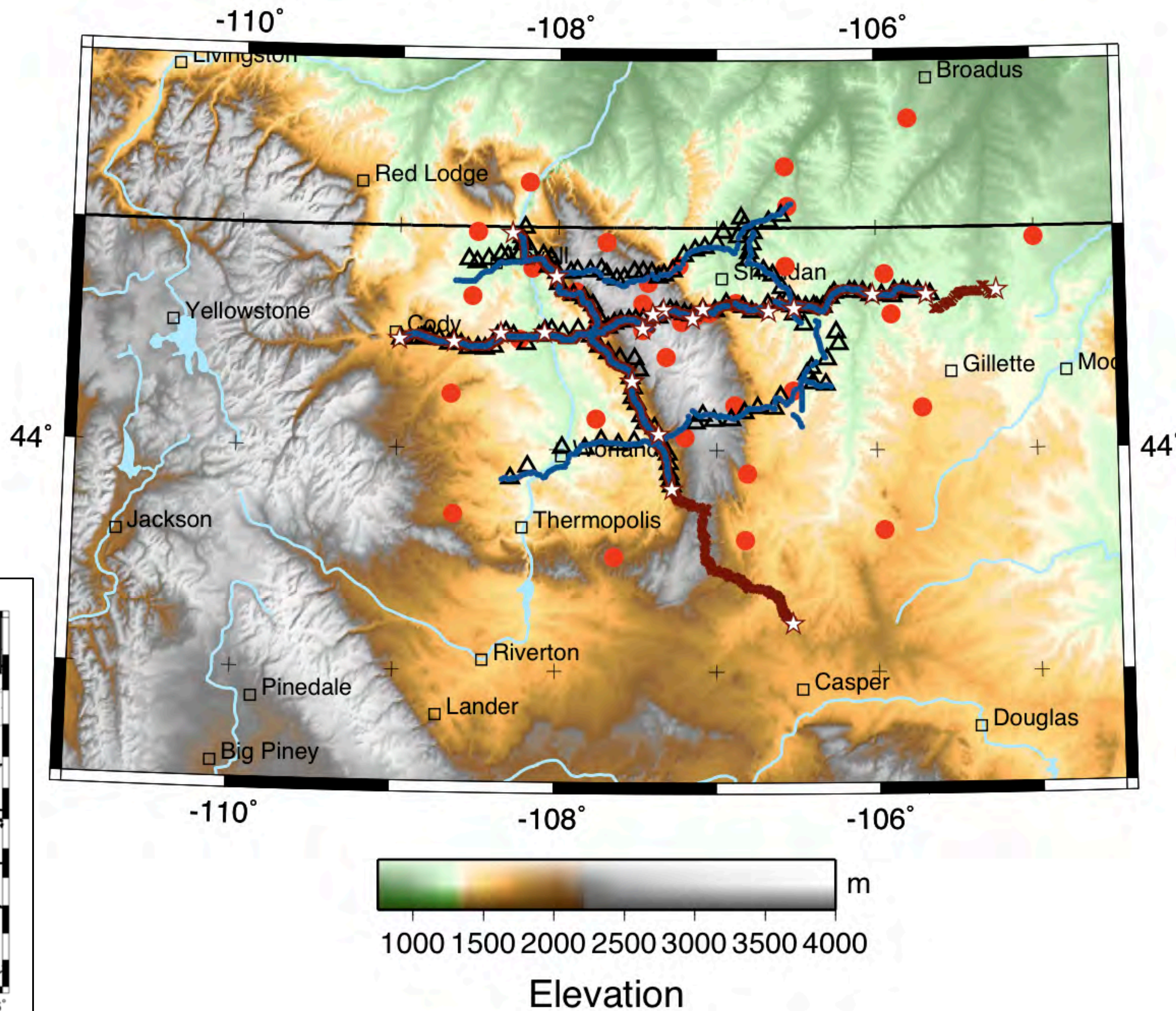


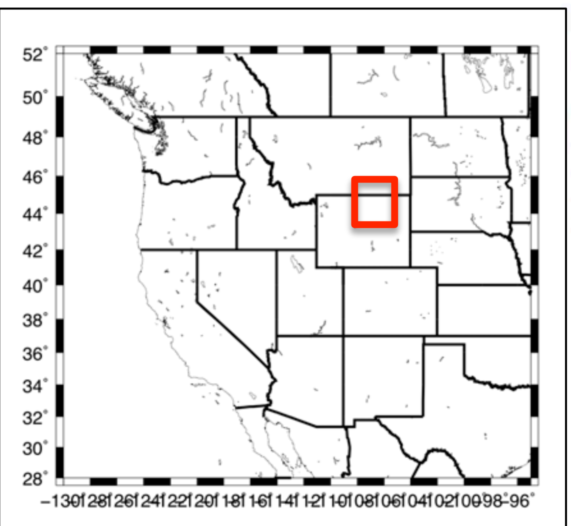


Bighorn Arch Seismic Experiment (BASE)

A USArray flexible array deployment

CU, UTEP, TAMU, U Wyo, CC





Bighorn Arch Seismic Experiment (BASE)

A USArray flexible array deployment

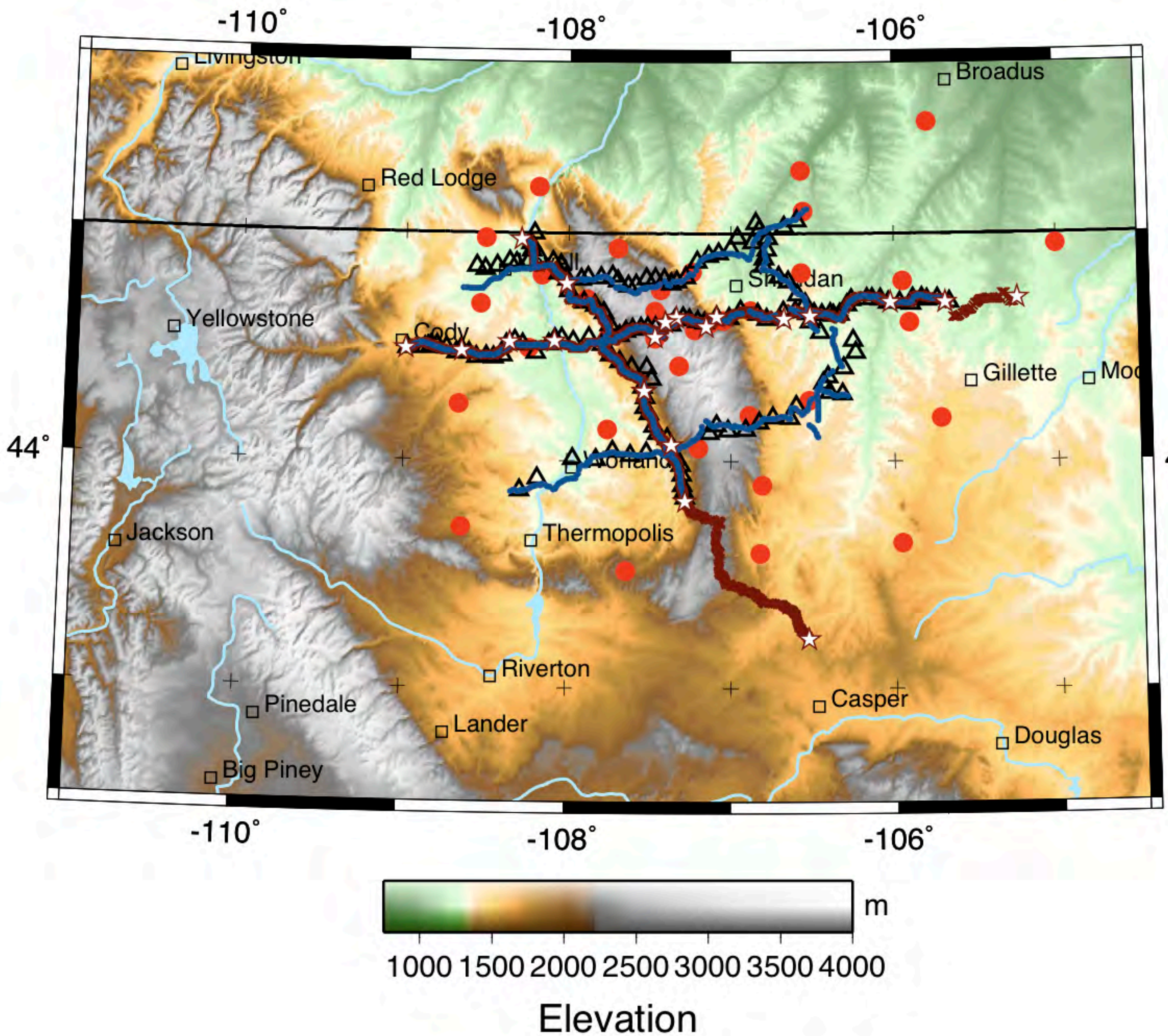
CU, UTEP, TAMU, U Wyo, CC

39 broadband seismometers, 15 months

172 intermediate period, 6 months

850 geophones, 2 weeks continuous passive recording

Active source experiment, 1800 geophones + above, 24 shots



Data Management for Passive Geophone "Texan" Experiment

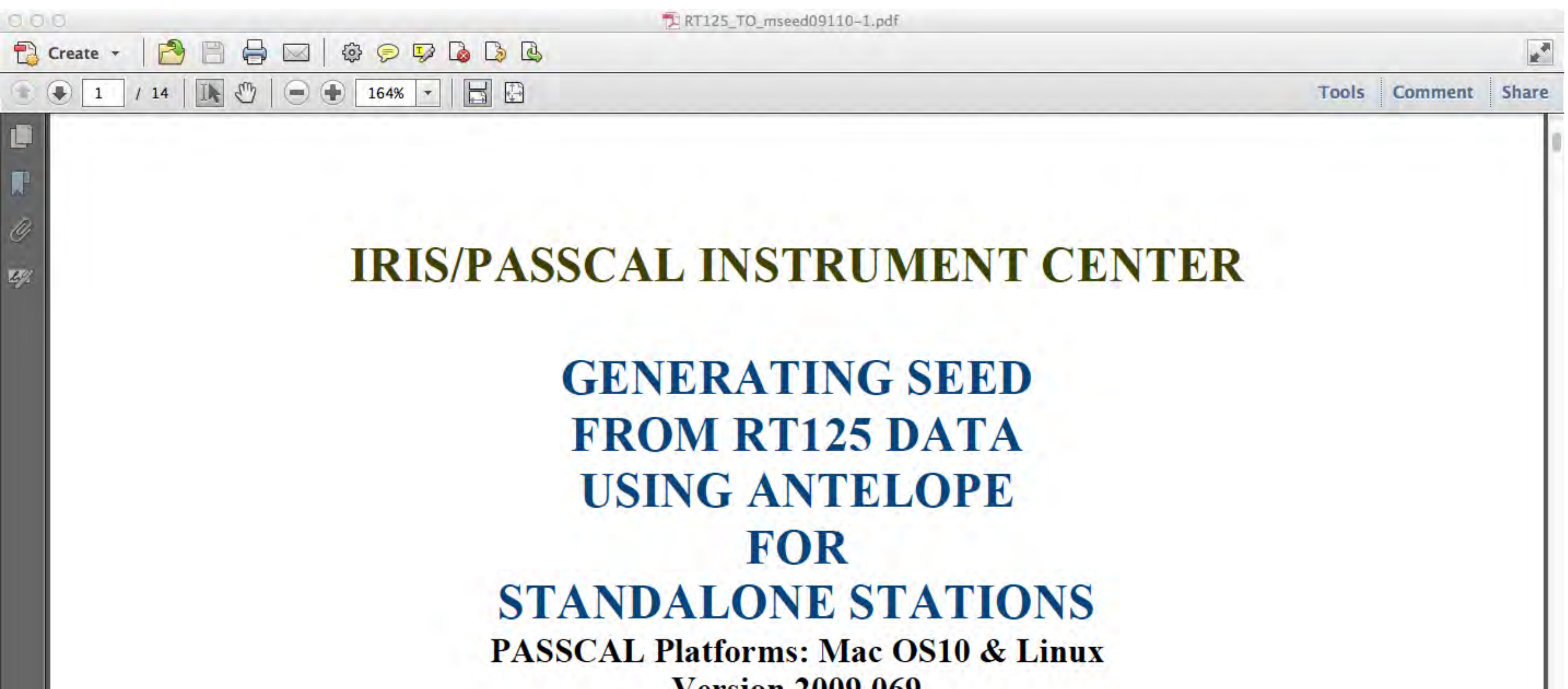
Data Management for Bighorn Passive Texan Experiment

Active	Group2	Group3	Group4	Mini-active
1769	843	842	845	1187

6346 uniquely defined station parameters for a time period of about 17 days

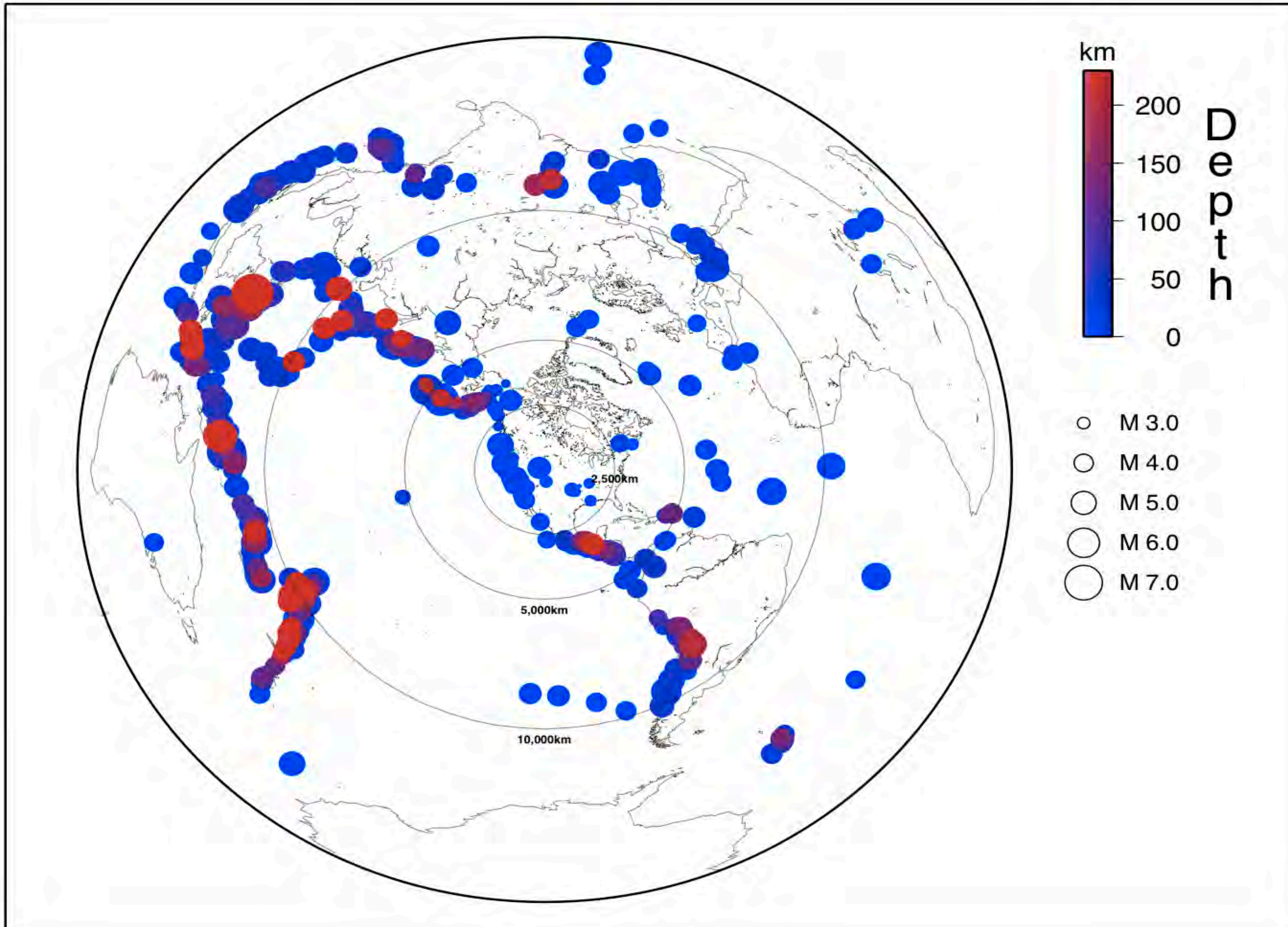
Batch file – describes which Texans were at which station and when

Cut file – file of cut times (on/off with buffer for each station). Have to keep track of which Texan at each site, and each Texan installed and removed

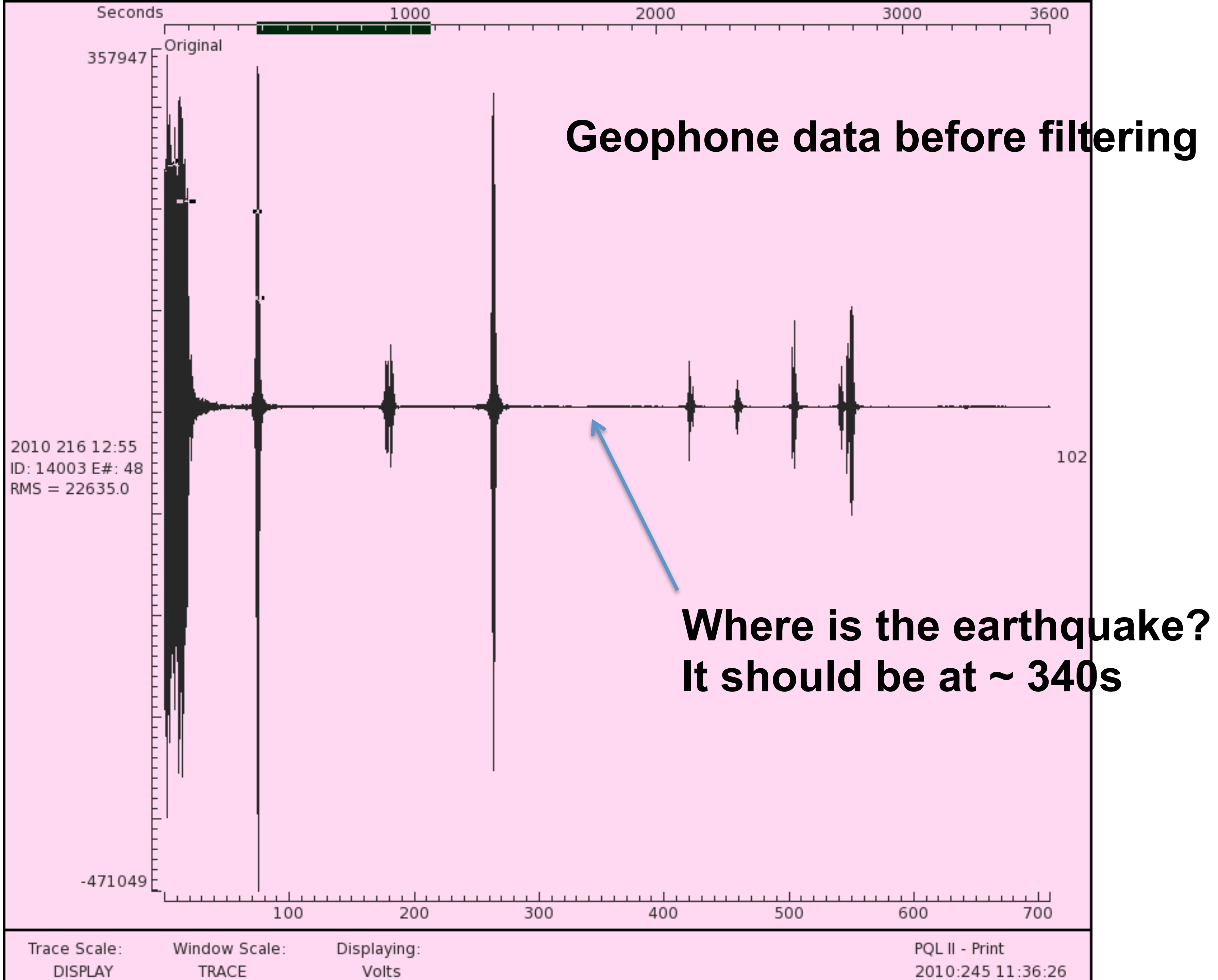


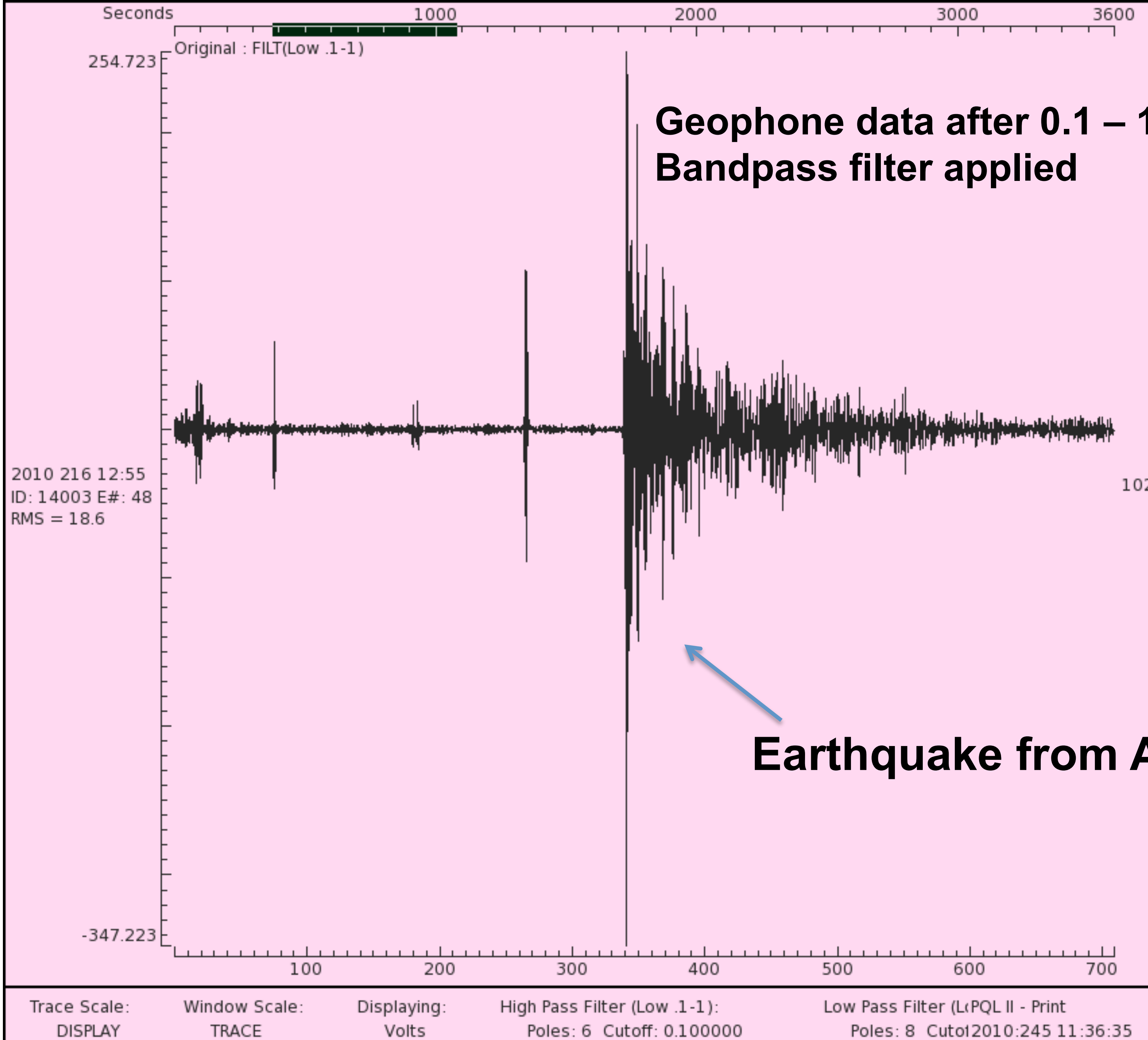
Can arrays of high frequency geophones be used for recording distant earthquakes? **YES**

Earthquakes: A rich source of seismic energy



3 weeks of global seismicity

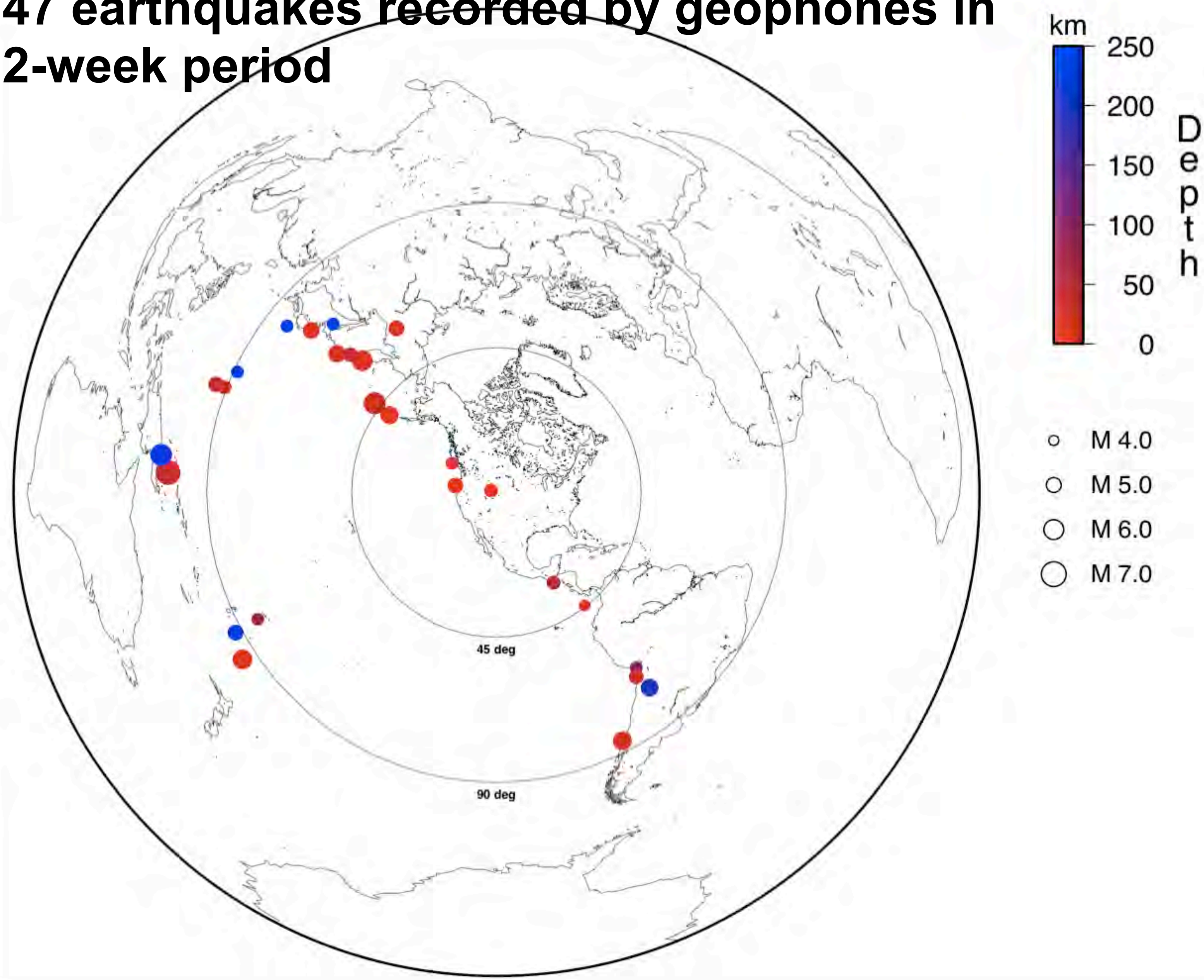

Seconds
1000
2000
3000
3600
Original
357947
-471049
Geophone data before filtering
2010 216 12:55
ID: 14003 E#: 48
RMS = 22635.0
102
Where is the earthquake?
It should be at ~ 340s
100
200
300
400
500
600
700
Trace Scale:
DISPLAY
Window Scale:
TRACE
Displaying:
Volts
PQL II - Print
2010:245 11:36:26



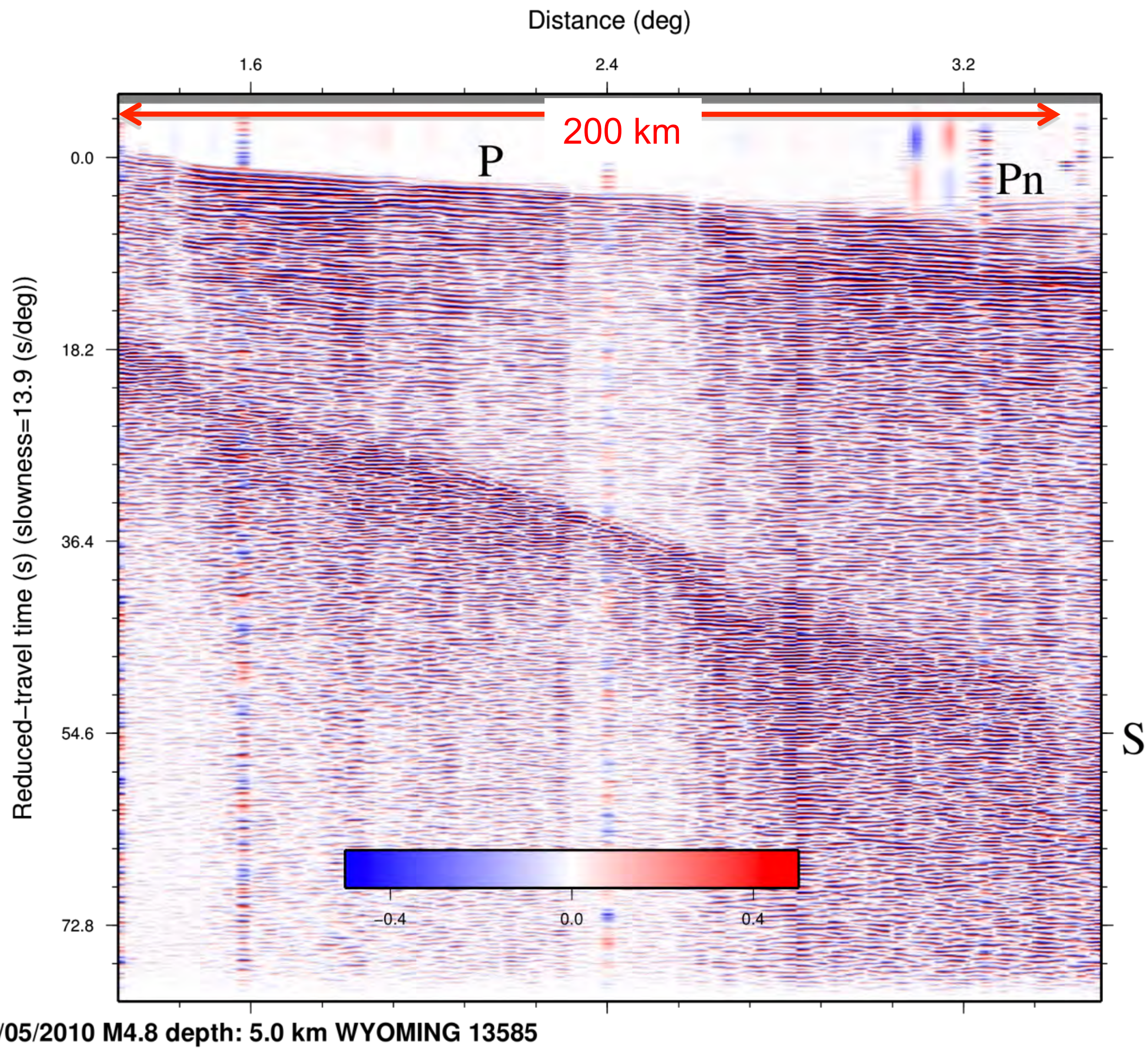
Geophone data after 0.1 – 1 Hz Bandpass filter applied

Earthquake from Alaska

47 earthquakes recorded by geophones in 2-week period



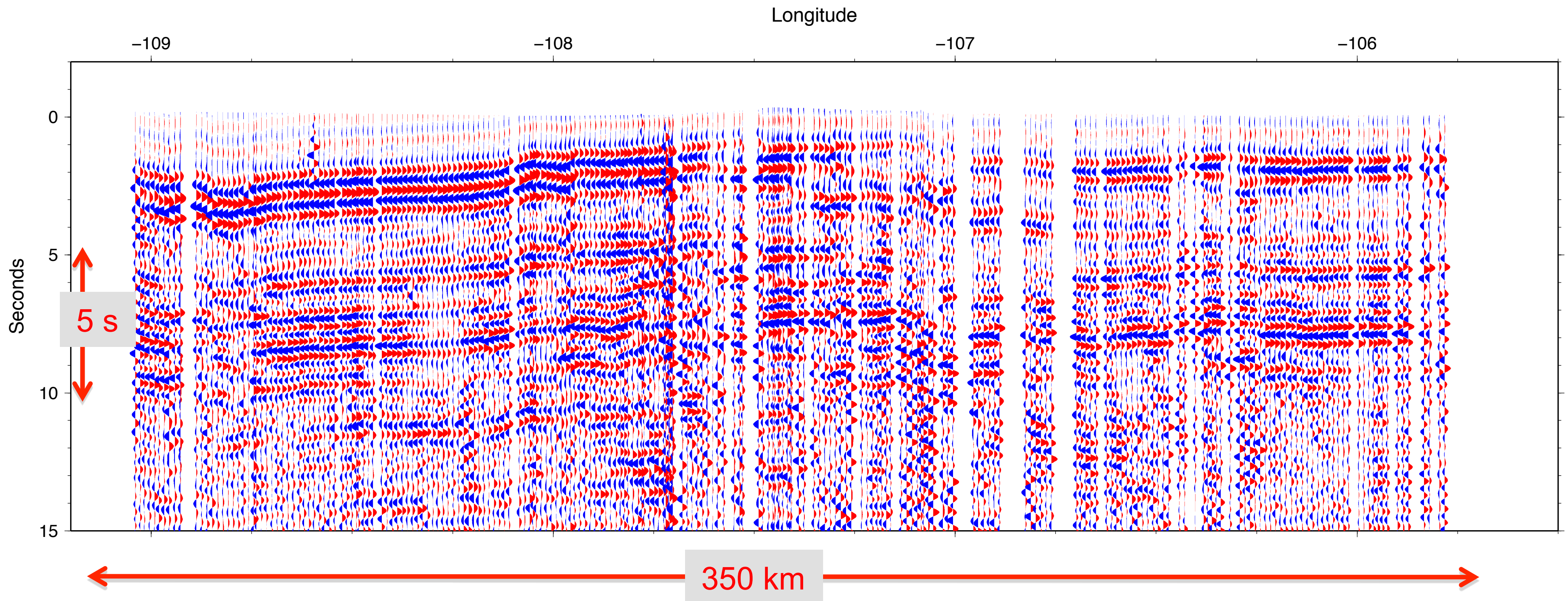
Regional earthquakes recorded on geophones



Magnitude 4.8 Jackson Hole earthquake recorded on Wyoming Bighorn Project geophones

J. Stachnik

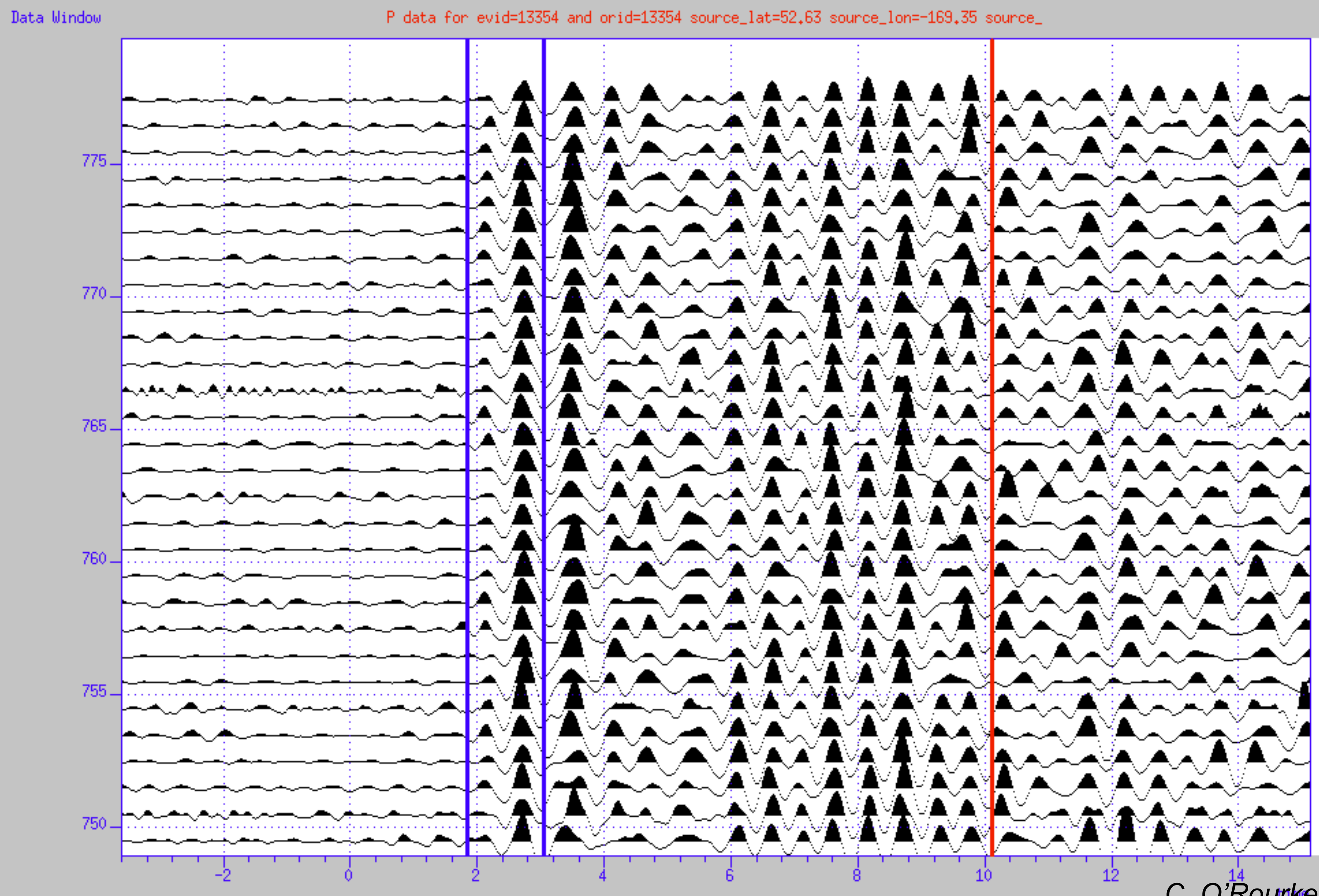
Recording of a teleseism on geophones



- Example above – magnitude 5 earthquake from Alaska
- No processing besides 1-2 Hz filter
- A rich source of energy for structural studies

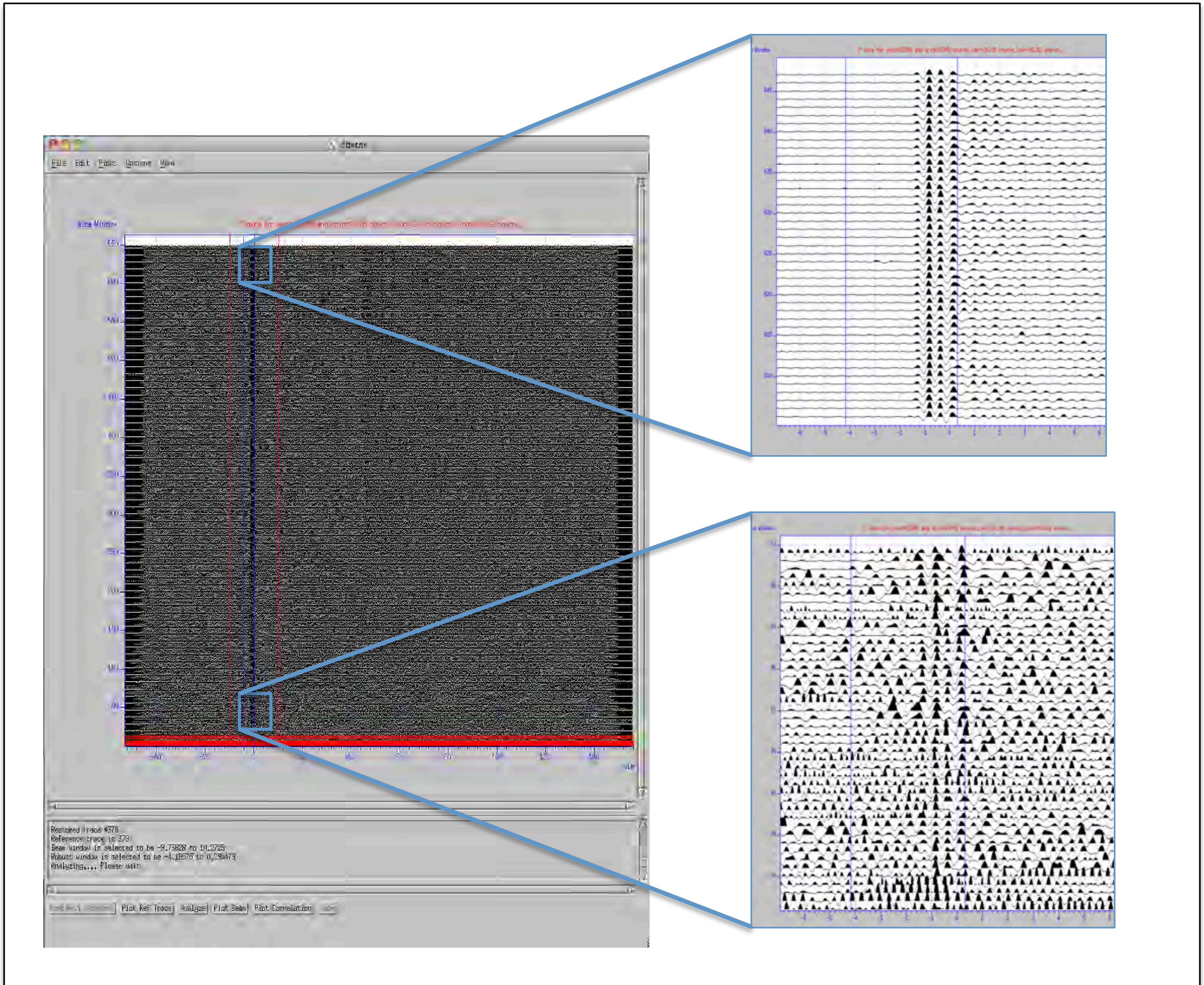
C. O'Rourke

Teleseismic P wave travel time picking using waveform crosscorrelation with geophone data



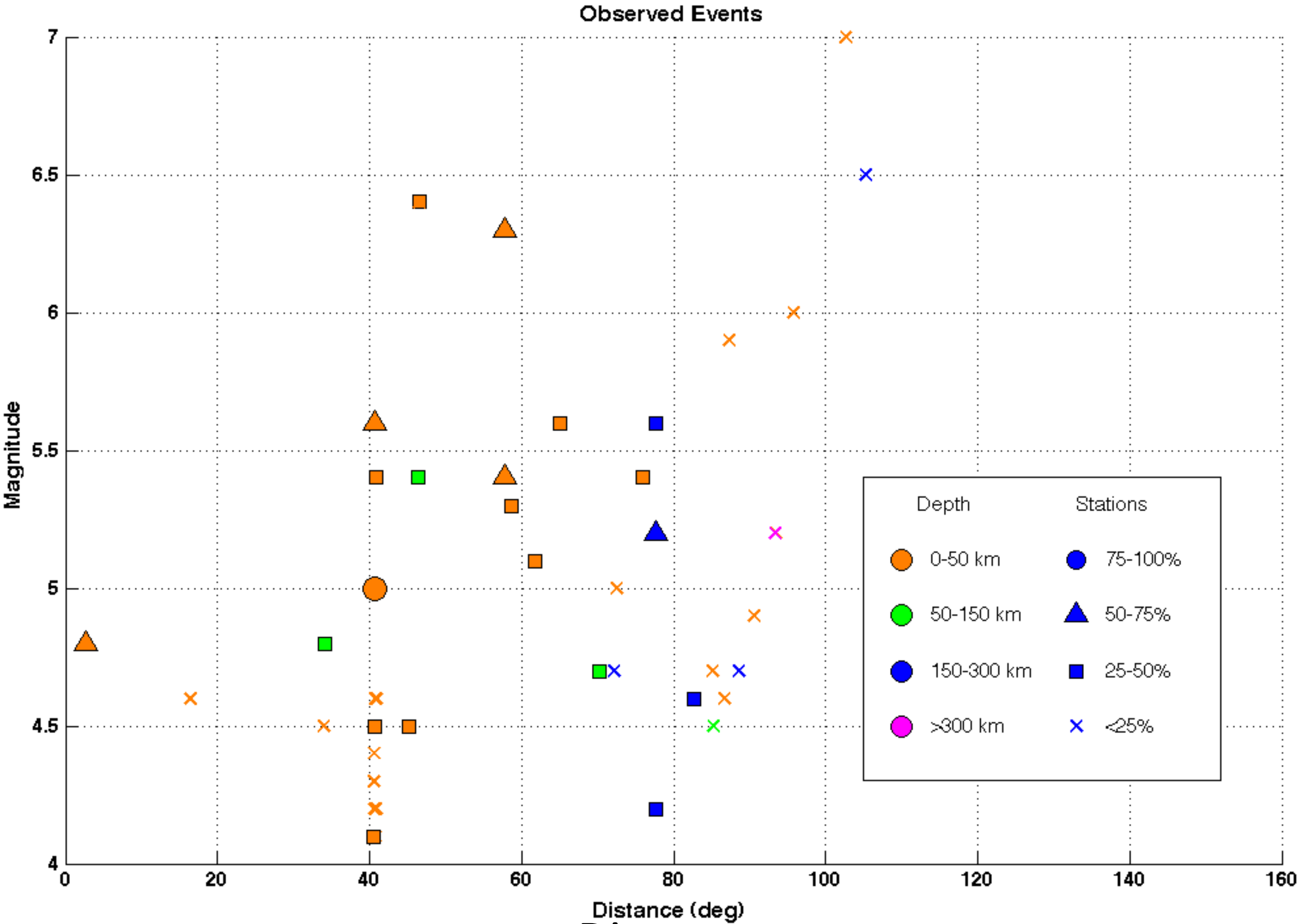
C. O'Rourke

Teleseismic P wave travel time picking



C. O'Rourke

Magnitude-Distance distribution of earthquakes recorded on geophones



Magnitude

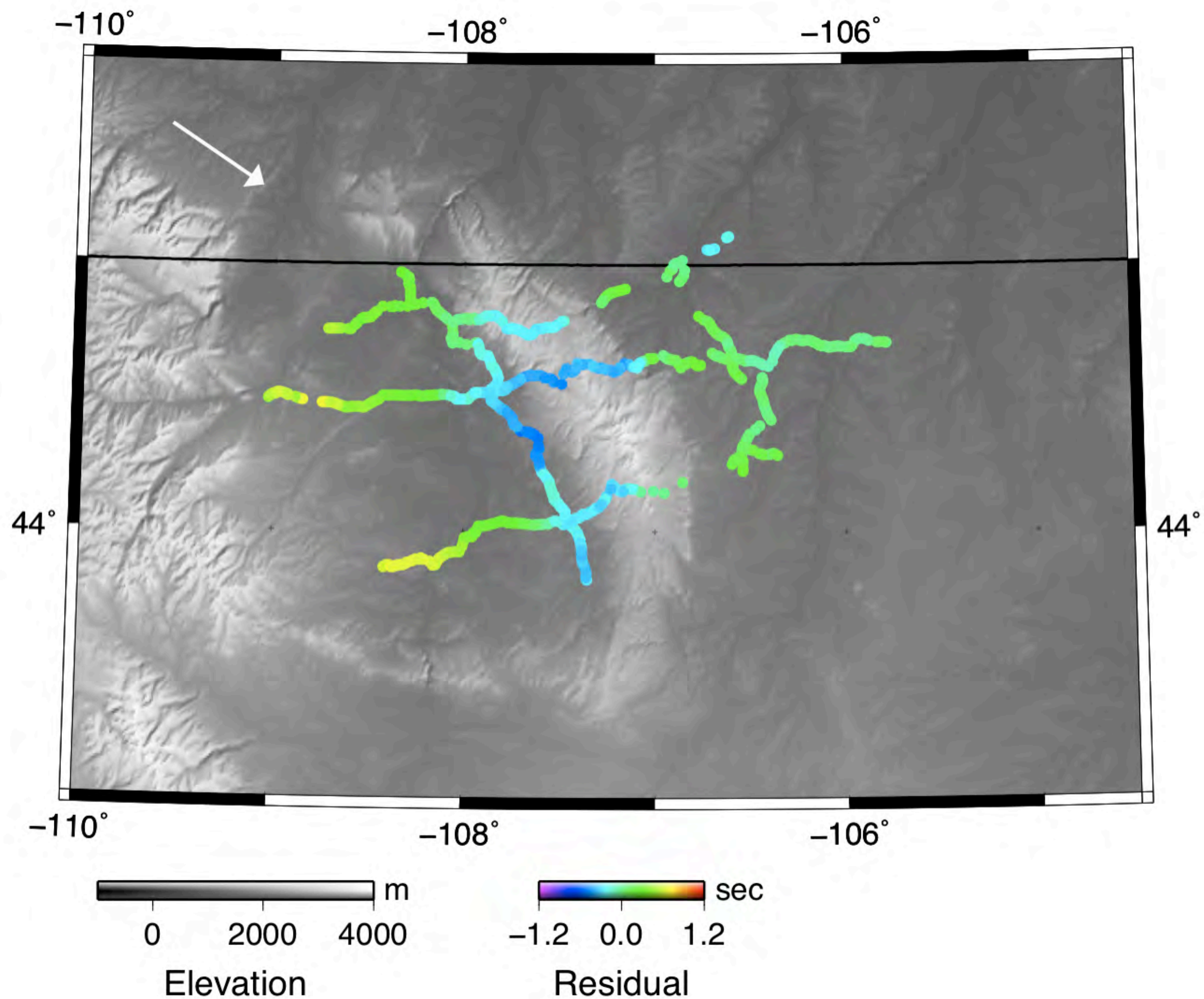
Distance

Calculating residual times for teleseismic P-wave arrivals

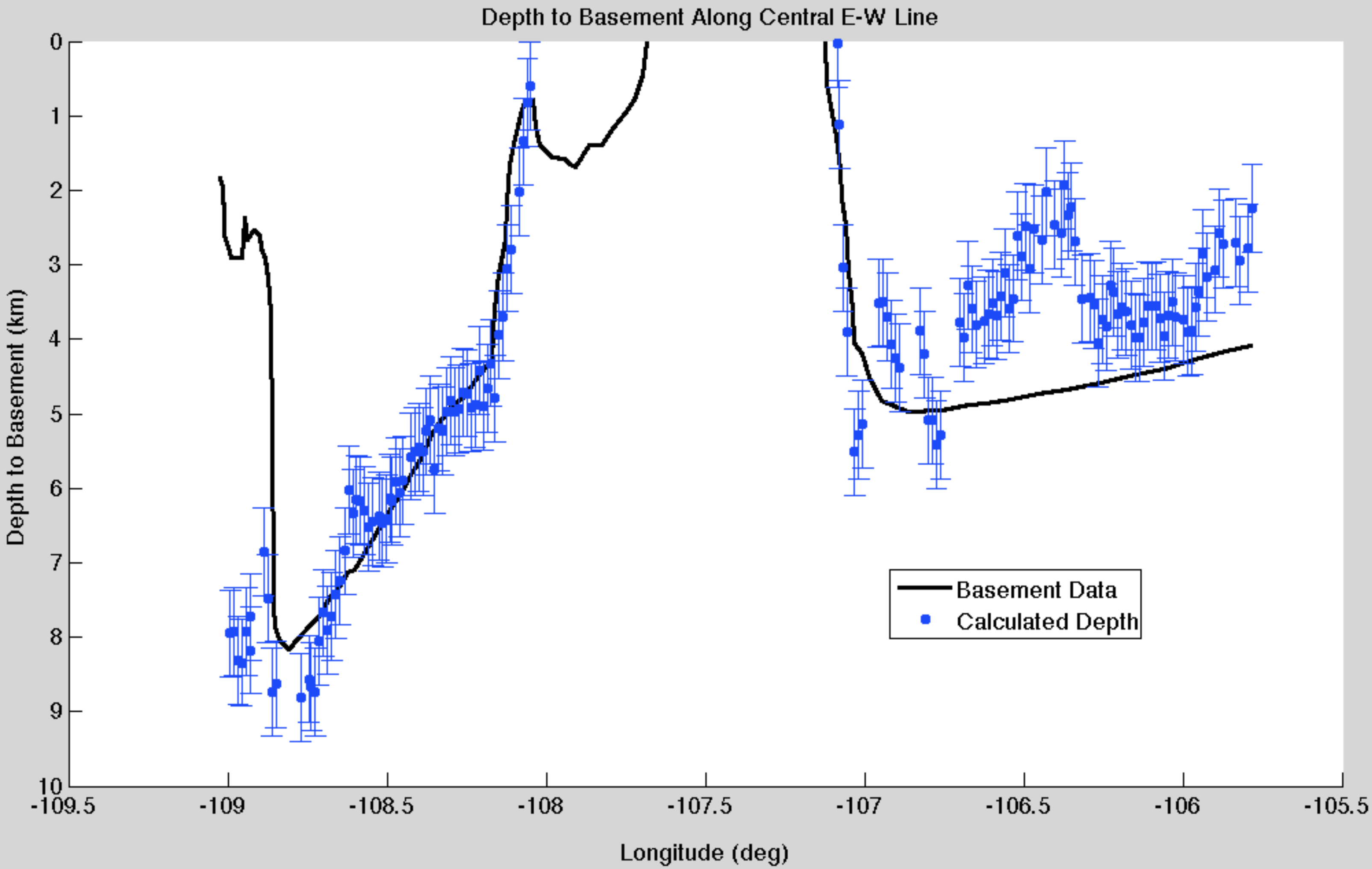
• Remove the predicted event-station travel time

• Remove travel times from elevation, using approximate velocity values for the surface geology

• Remove the mean value from each station



Basin depths estimated using teleseismic travel time residuals



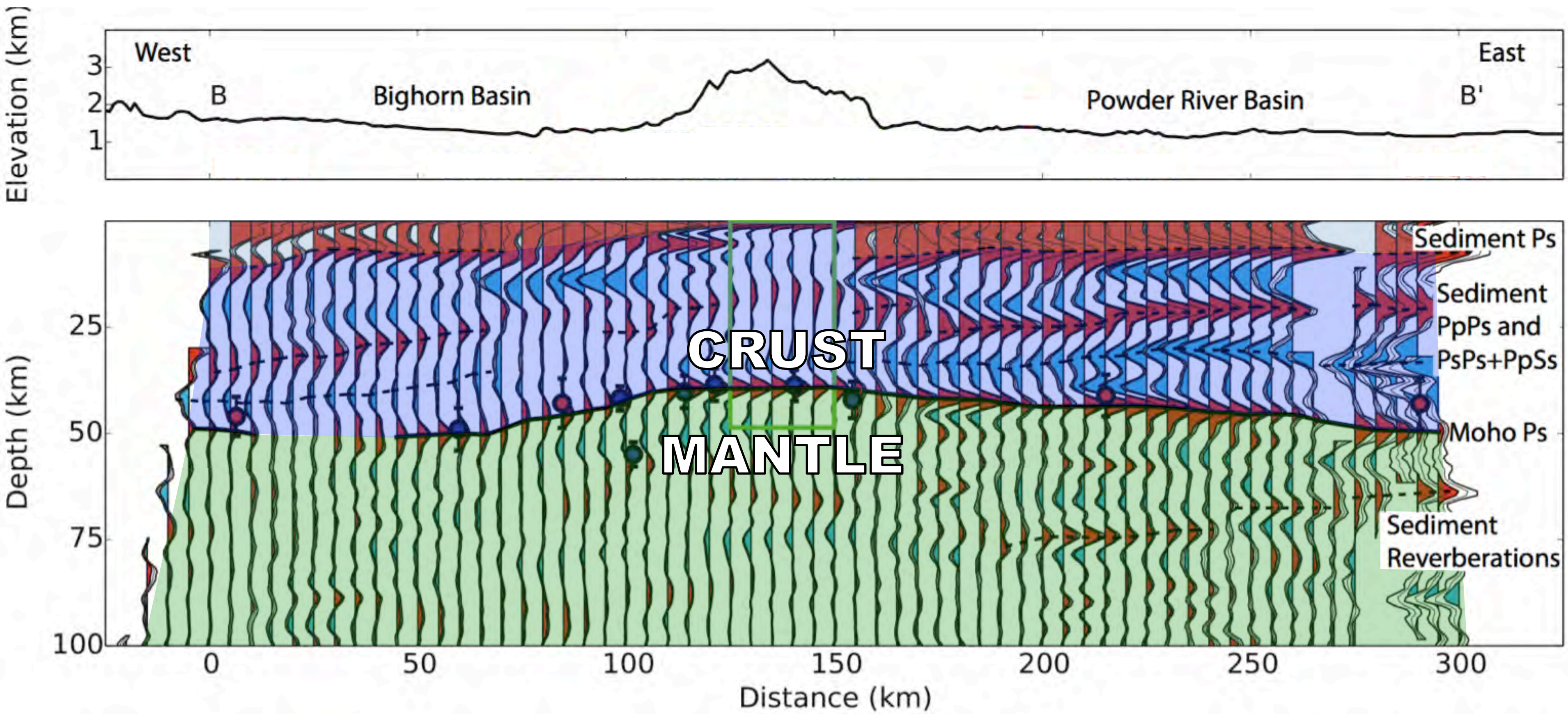
O'Rourke et al., EPSL, 2014

Teleseismic Receiver Function Image

Constructed by deconvolving vertical component seismogram from radial

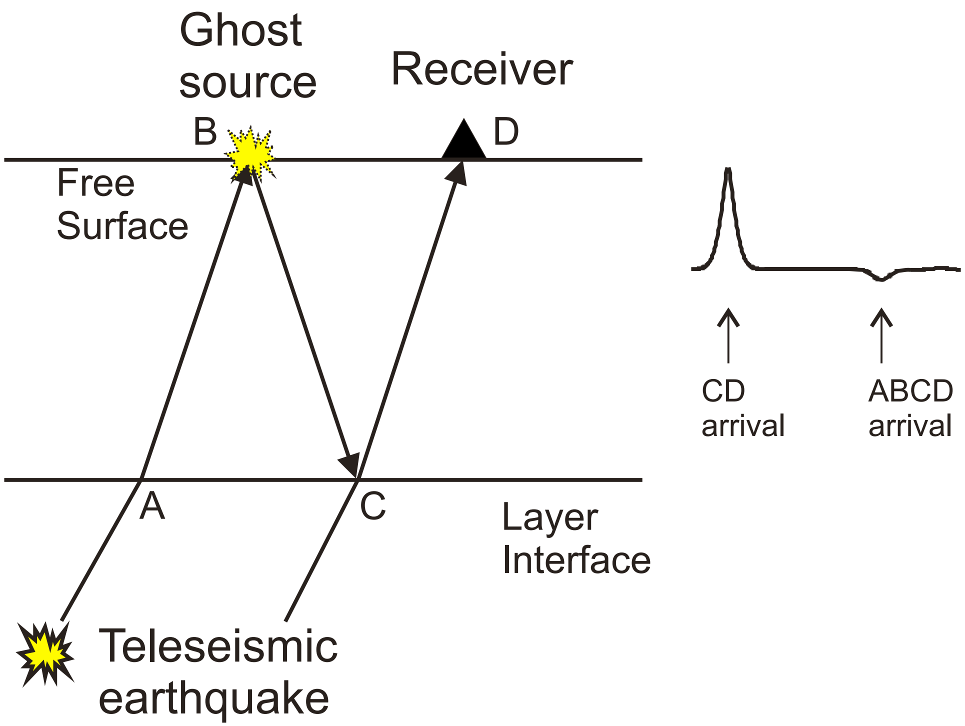
Requires 3C seismogram

What to do if only have single component geophone?

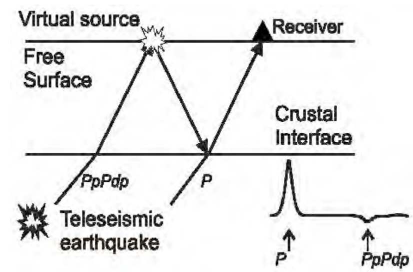


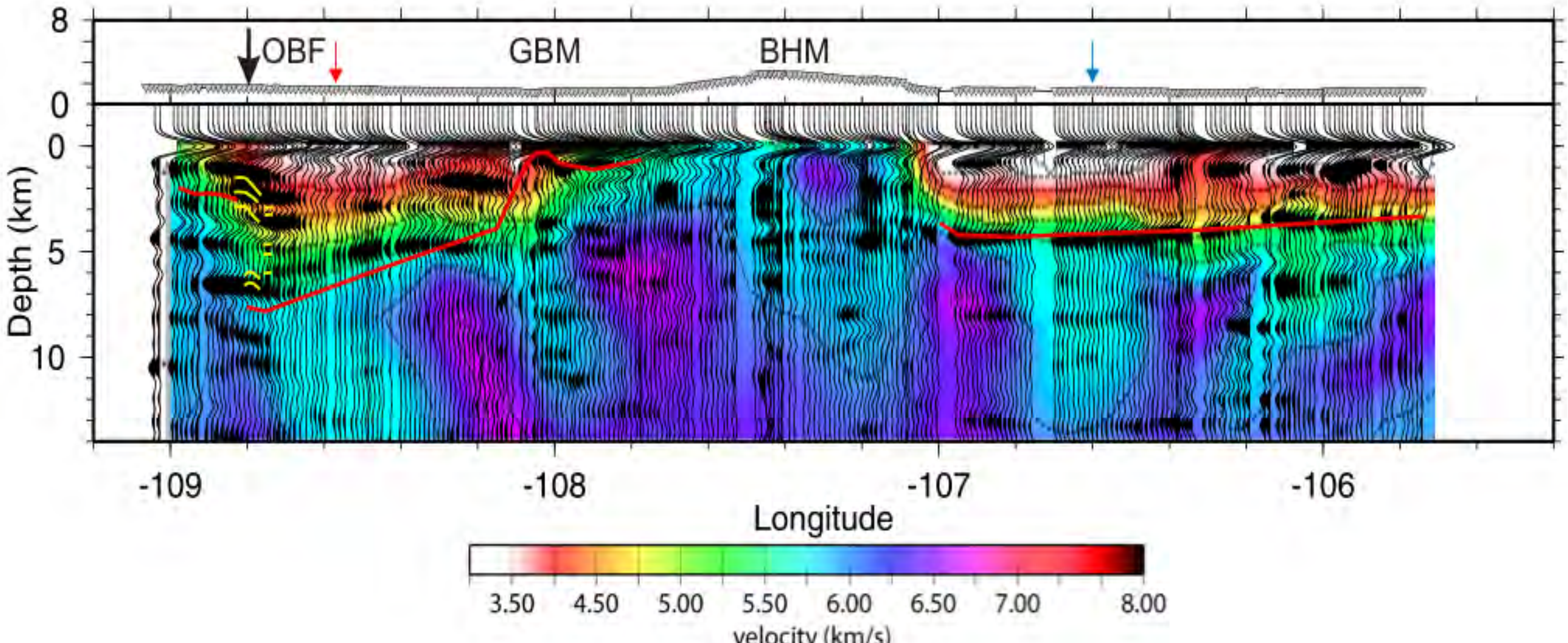
Yeck et al., in review, 2014

Teleseismic P wave reverberations as a 'virtual source'



Teleseismic P wave reverberations as a 'virtual source'



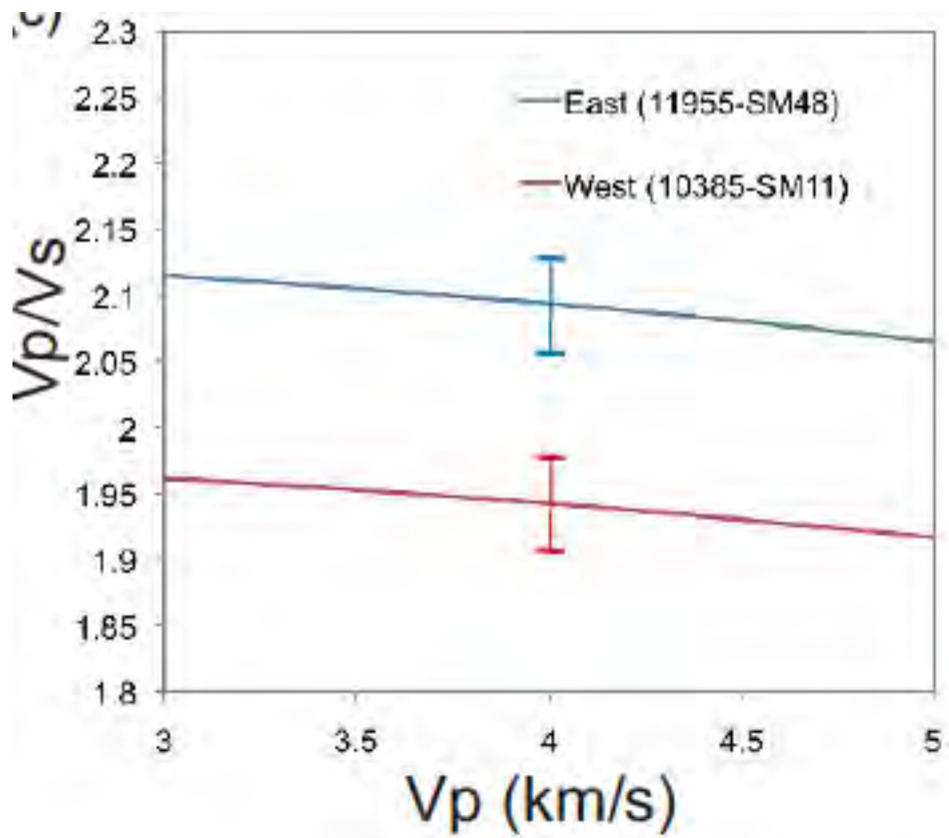


- Wiggles – teleseismic P reverberations
- Color – active source tomography (Worthington and Miller)
- Red line – basin thickness from industry data

Yang et al., GRL, 2012

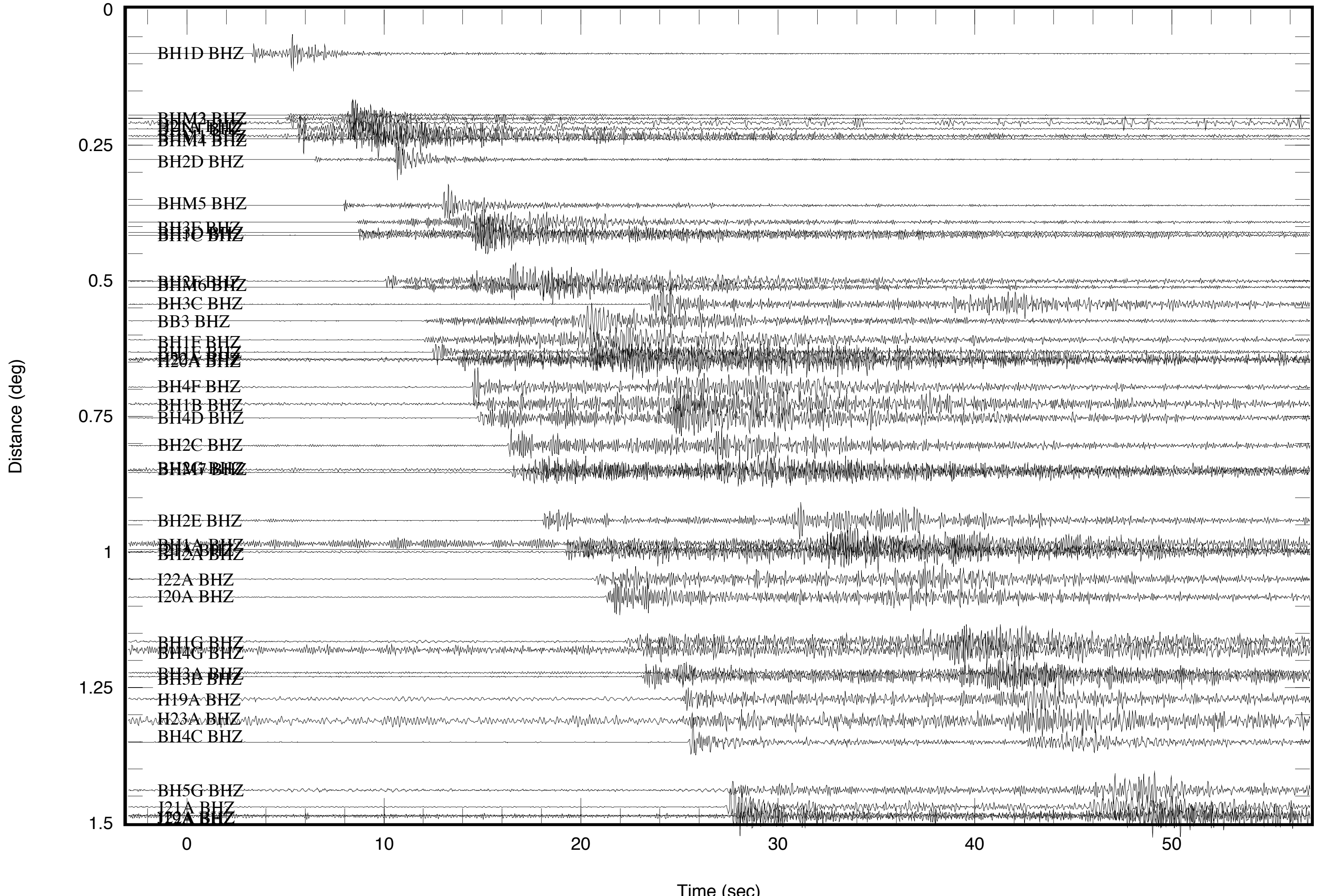
Vp/Vs ratio (join PpPdp and Ps)

- $T_{PpPdp\text{-}Pp} / T_{Ps\text{-}Pp} = f(Vp, Vp/Vs, pp, ps)$, where pp and ps are known ray slowness.
- Varying Vp b/t 3 to 5 km/s
- Sedimentary Vp/Vs → PpPdp is related to sedimentary layer



Yang et al., GRL, 2012

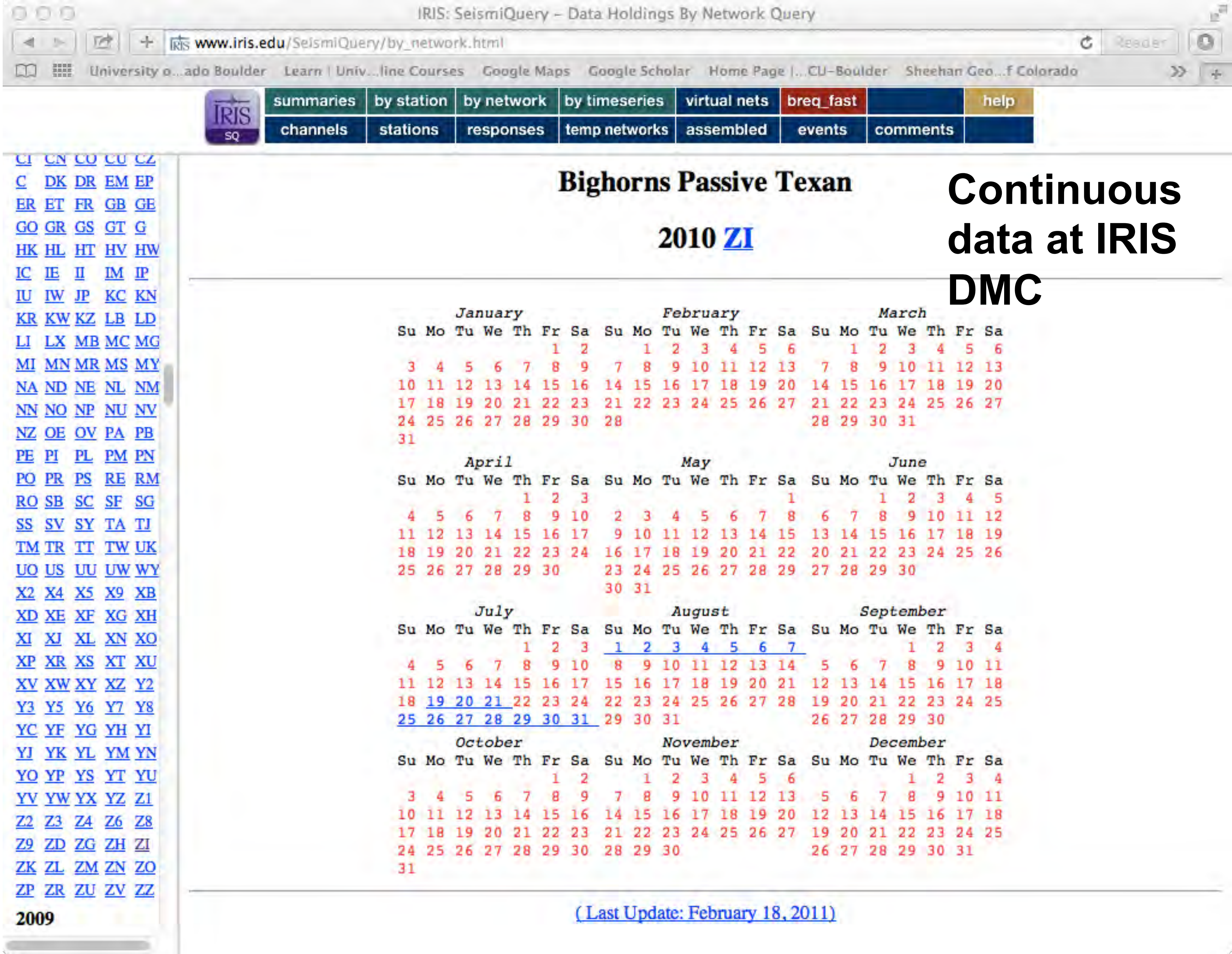
Local earthquake



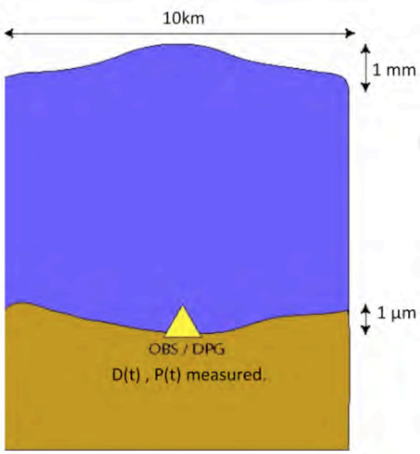
Filter: BW 3 3 10 3

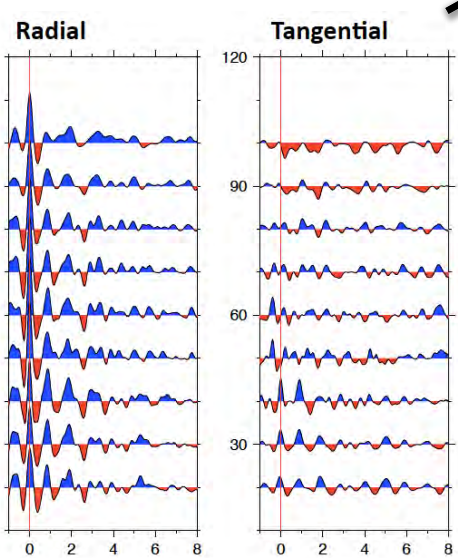
BRTT dbrsec: TA_BBSP_db dbrsec.TA_BBSP_db.1.ps colino Thu May 1 15:20:28 2014

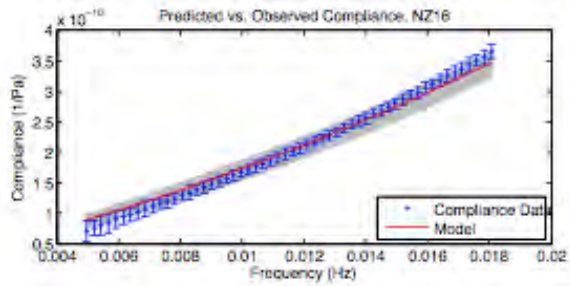
Continuous data at IRIS DMC

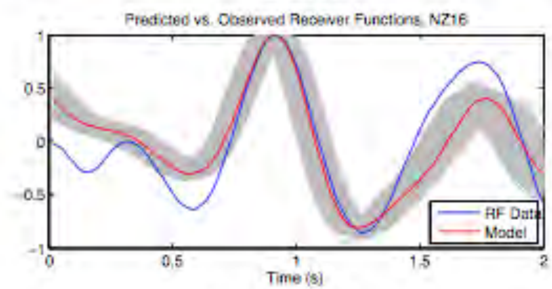


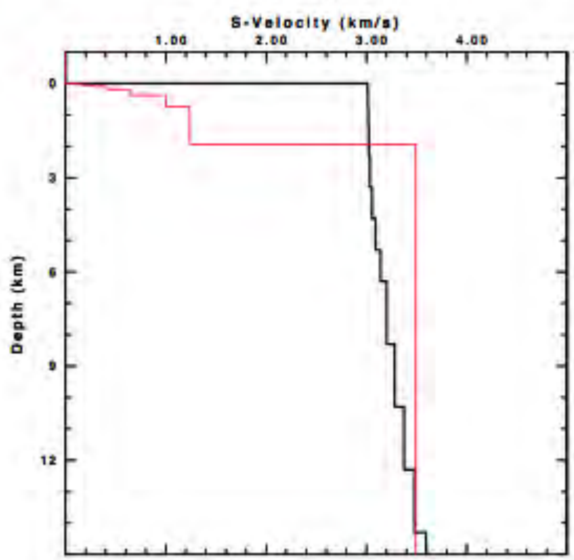
Other efforts by our research group: Seafloor passive source studies utilizing both seismic and pressure recordings











See Justin Ball poster:

Joint inversion of seafloor compliance, receiver functions, and surface wave dispersion

Summary

Passive recordings using 4.5 Hz geophones on Texan recorders provide usable teleseismic waveforms

The high frequency passive recordings are useful for

- Tomography
- P wave virtual source methods
- Local seismicity studies (also background seismicity from USArray and academic project useful for induced seismicity studies, background state of stress)

Planned and ongoing research

- Low fold reflection and compare refraction statics and ambient noise statics (with L. Worthington, UNM)
- Active source interferometry (with S. Haines and Tricon) – with refraction model for static correction, test vs ambient noise statics

Exploration industry can benefit from utilizing passive recording time during or after an active experiment