

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

Anne Sheehan

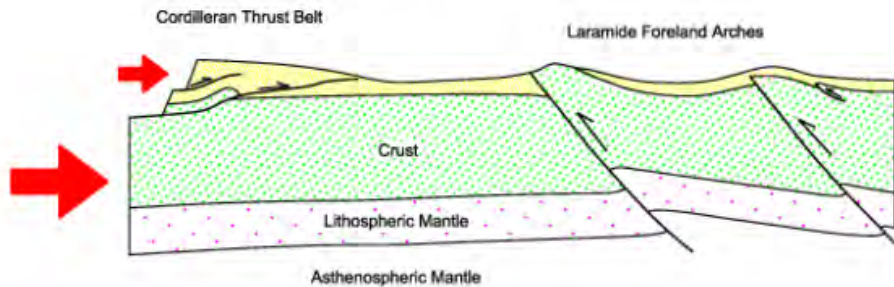
University of Colorado

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

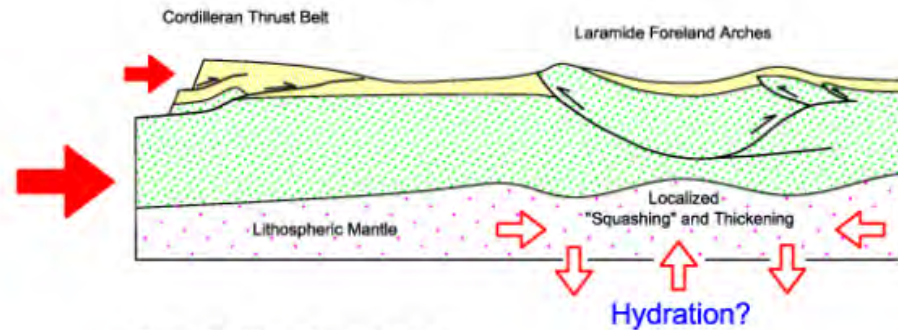
Thanks to the students and collaborators who have contributed to this work, including several in the audience (Zhaohui Yang, Josh Stachnik, Justin Ball)

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

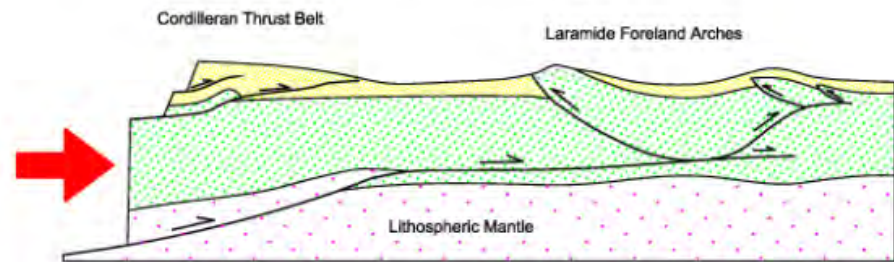
Case 1: Lithospheric fault blocks



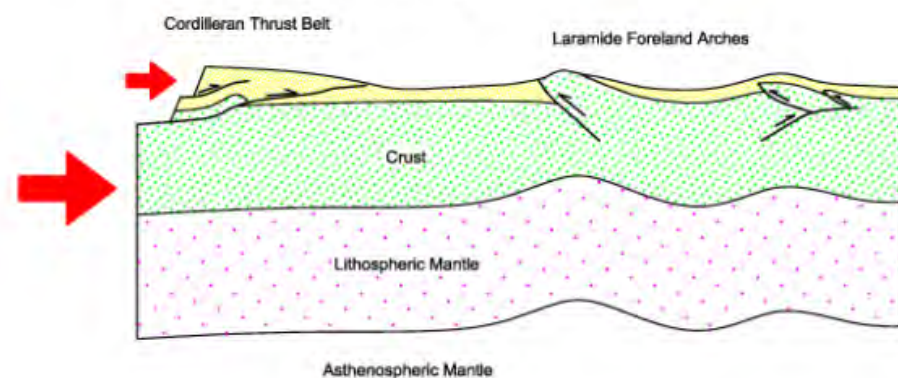
Case 2: Pure shear thickening



Case 3: Crustal detachment and buckling



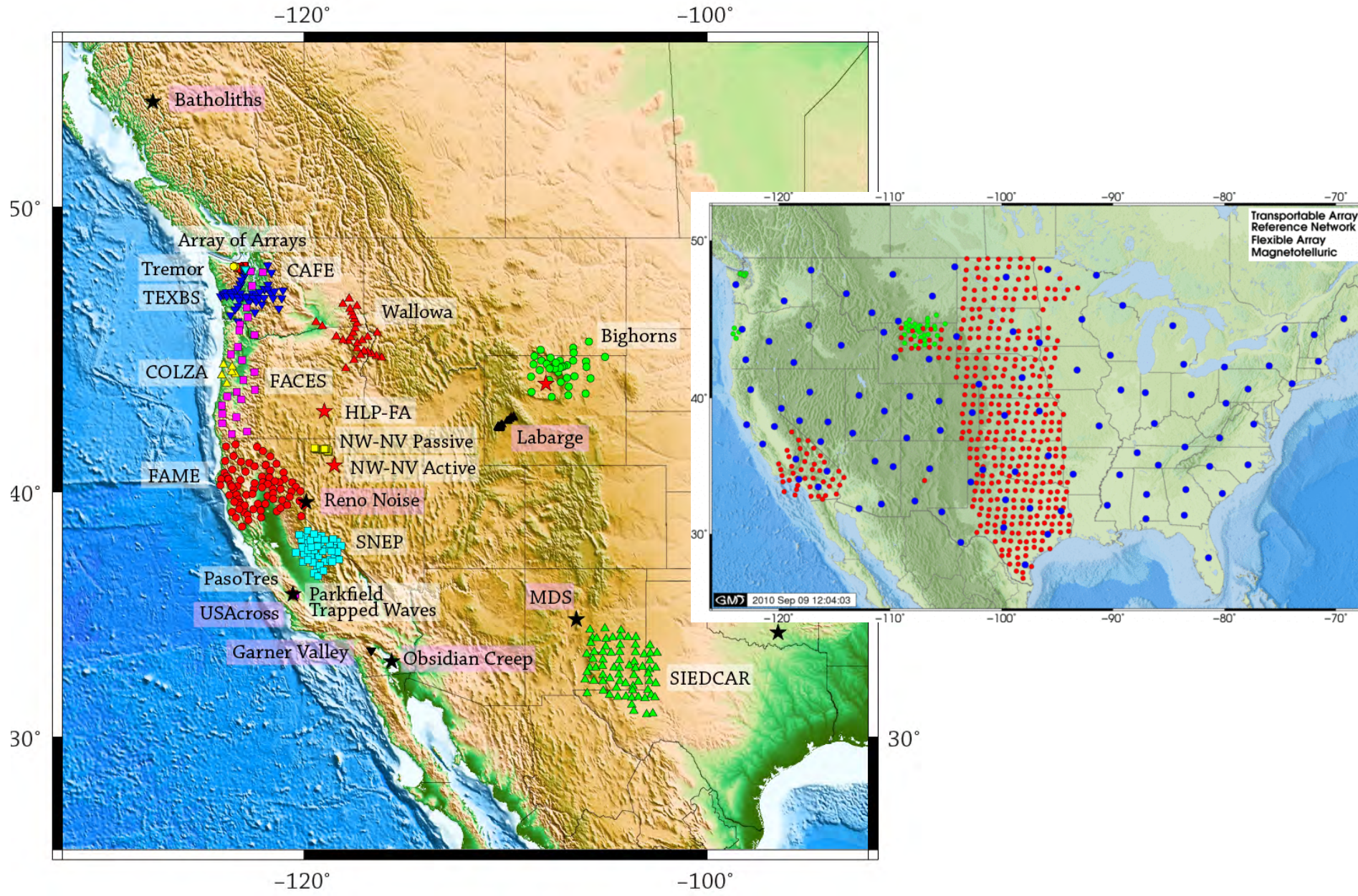
Case 4: Lithospheric buckling



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

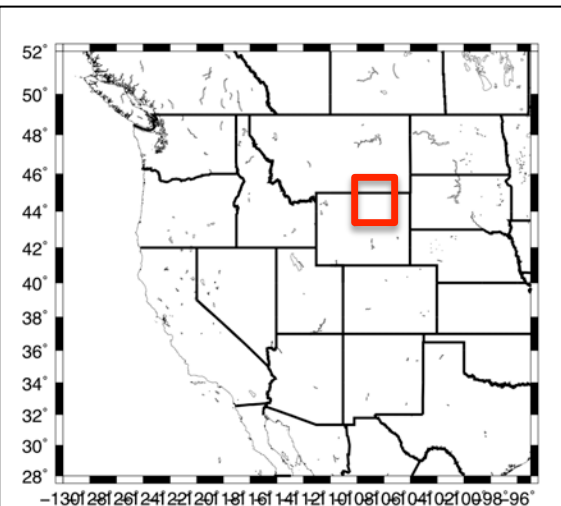
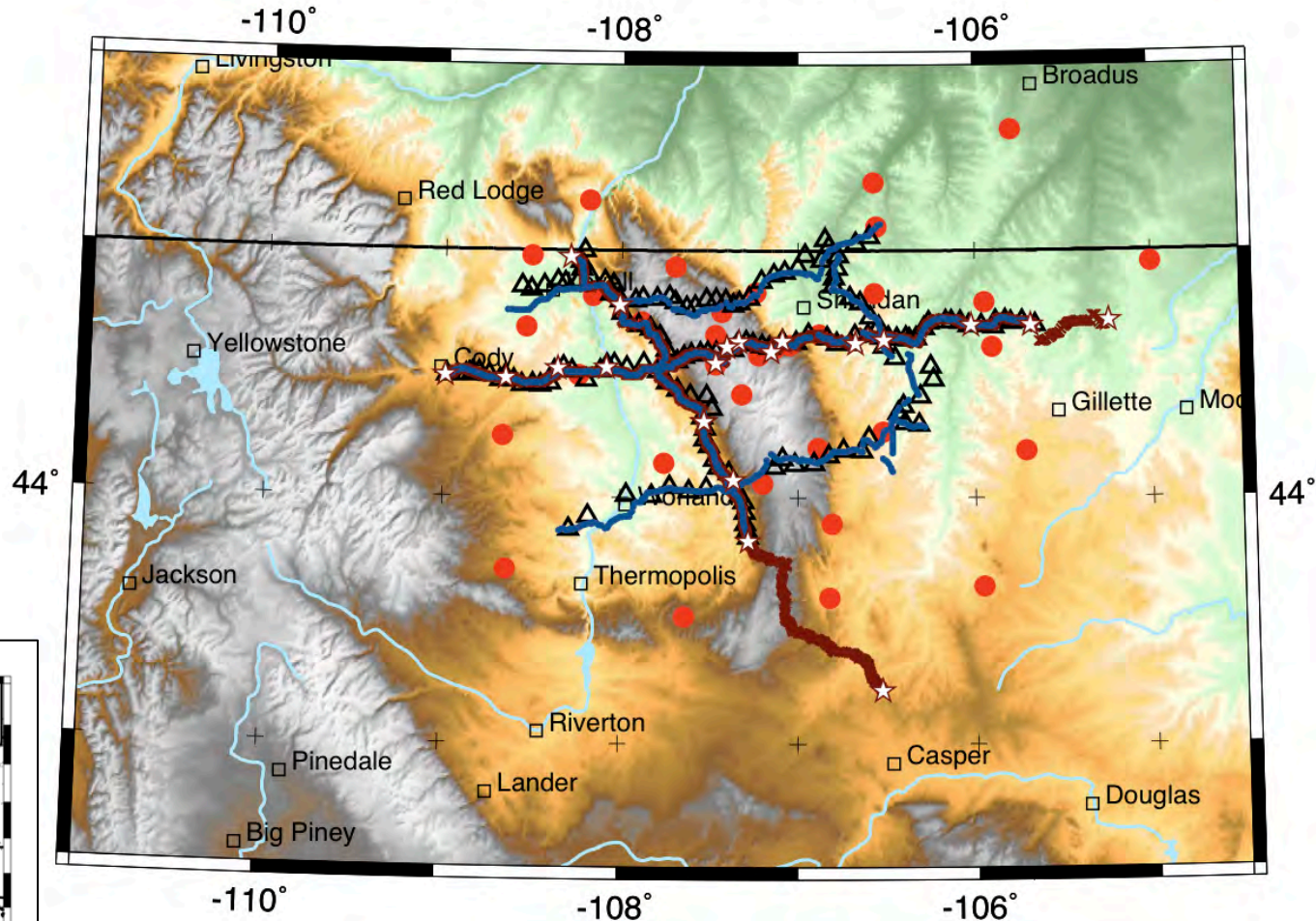
## Focused Regional Experiments



# 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

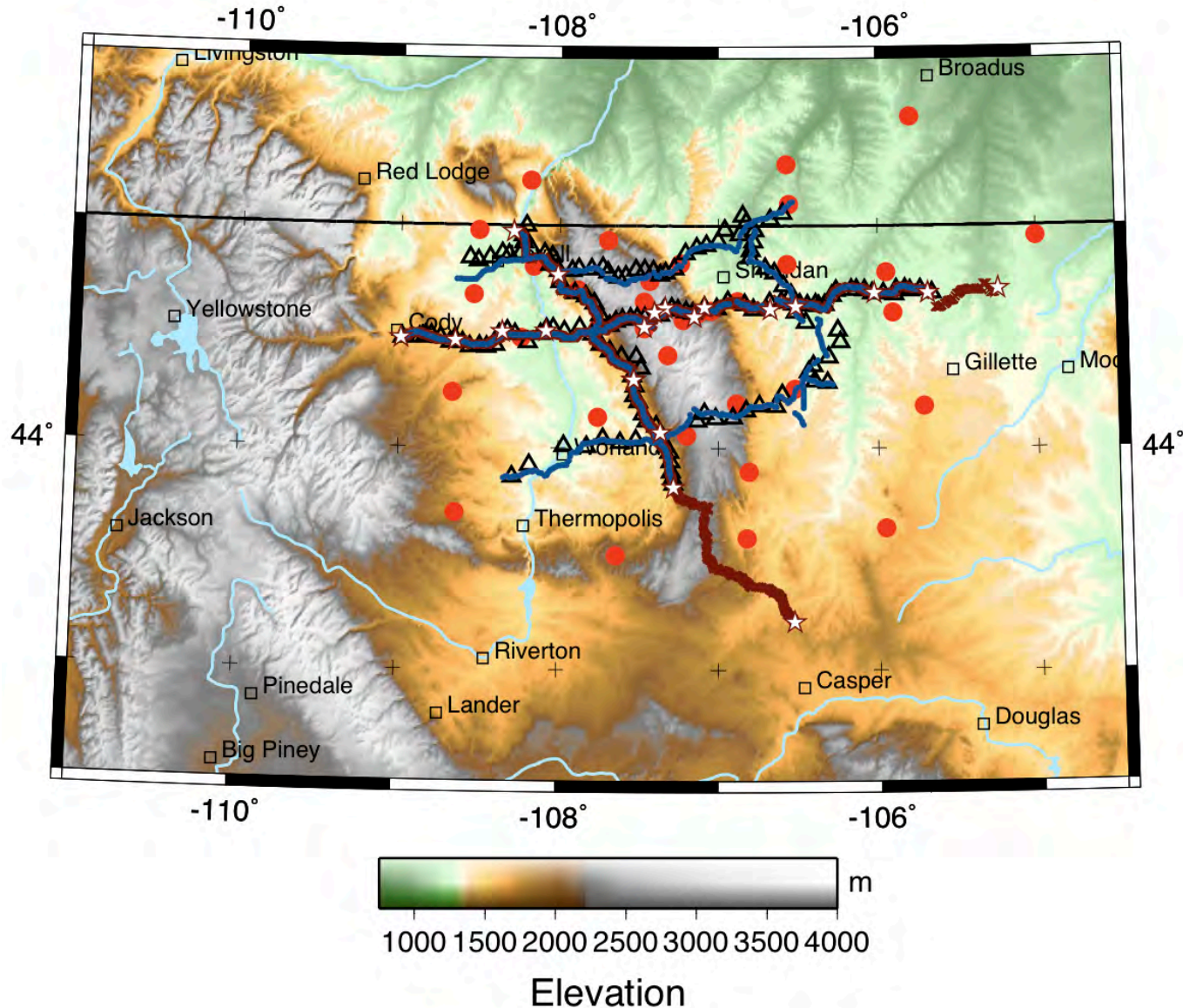
CU, UTEP, TAMU, U Wyo, CC

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



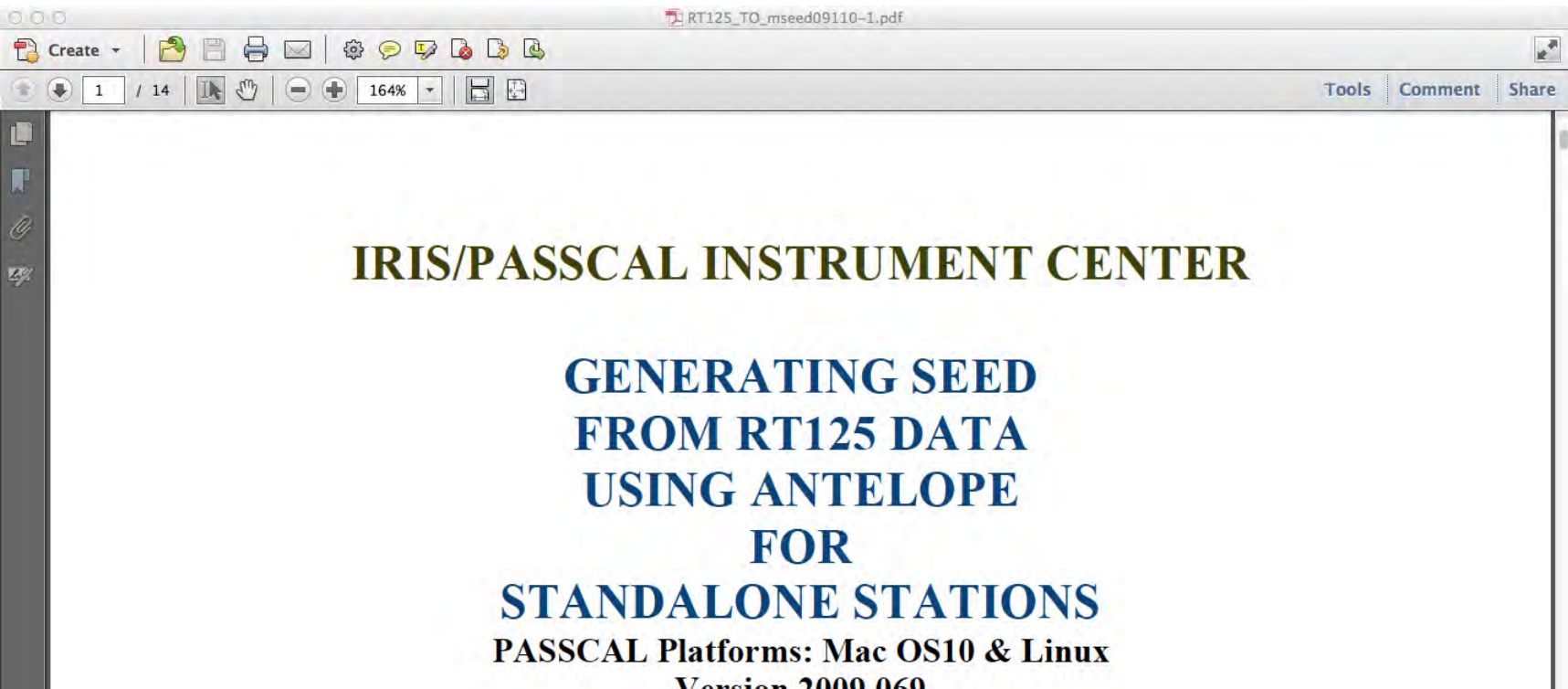
# Data Management for Bighorn Passive Texan Experiment

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

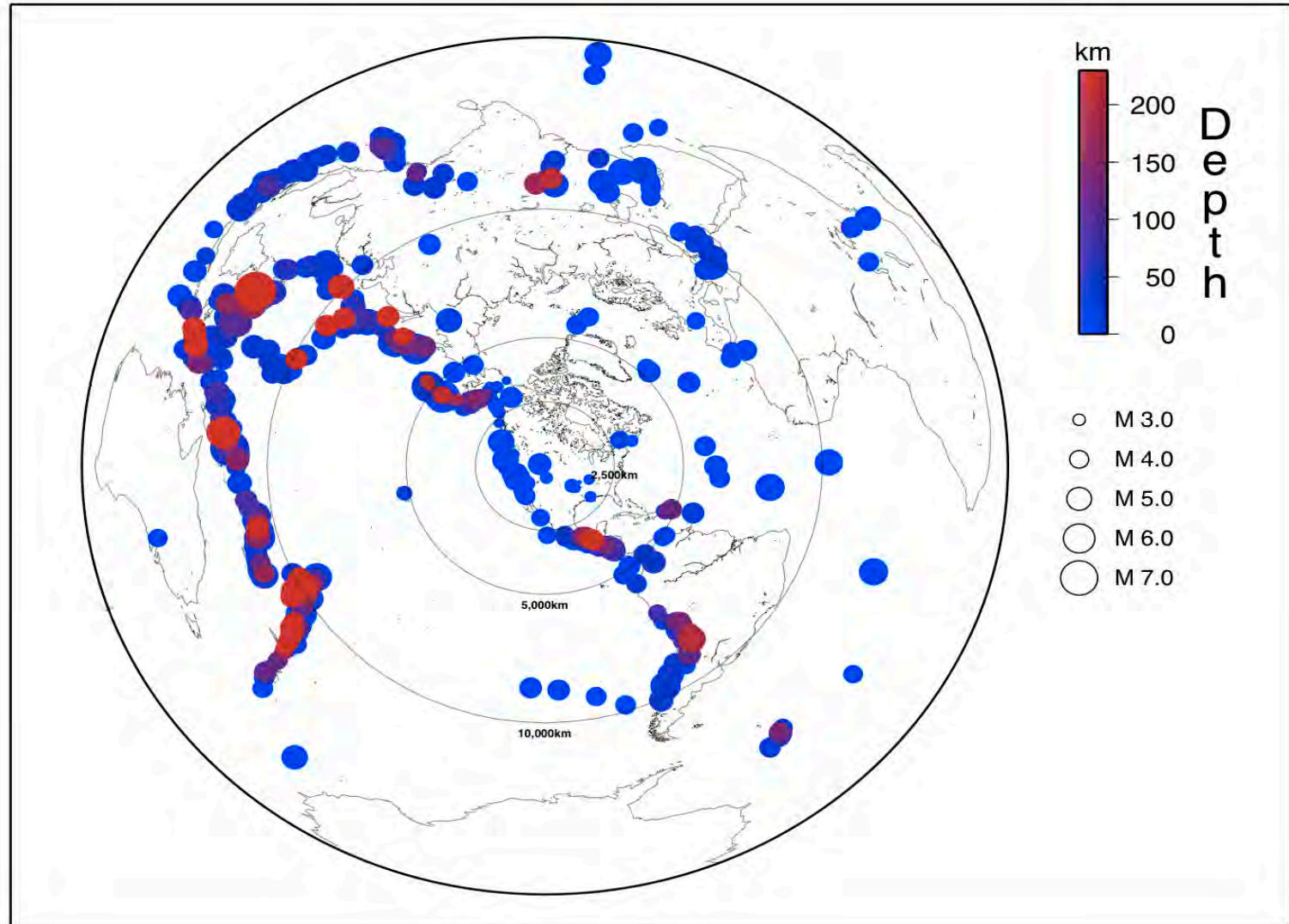


Can arrays of high frequency geophones be used for recording distant earthquakes? **YES**





# Earthquakes: A rich source of seismic energy



3 weeks of global seismicity

Seconds 1000 2000 3000 3600

357947

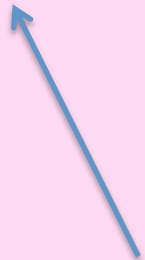
Original

**Geophone data before filtering**

2010 216 12:55  
ID: 14003 E#: 48  
RMS = 22635.0

102

-471049



**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

Seconds 1000 2000 3000 3600

254.723

Original : FILT(Low .1-1)

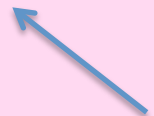
**Geophone data after 0.1 – 1 Hz  
Bandpass filter applied**

2010 216 12:55  
ID: 14003 E#: 48  
RMS = 18.6

102

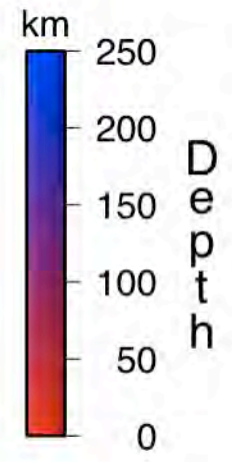
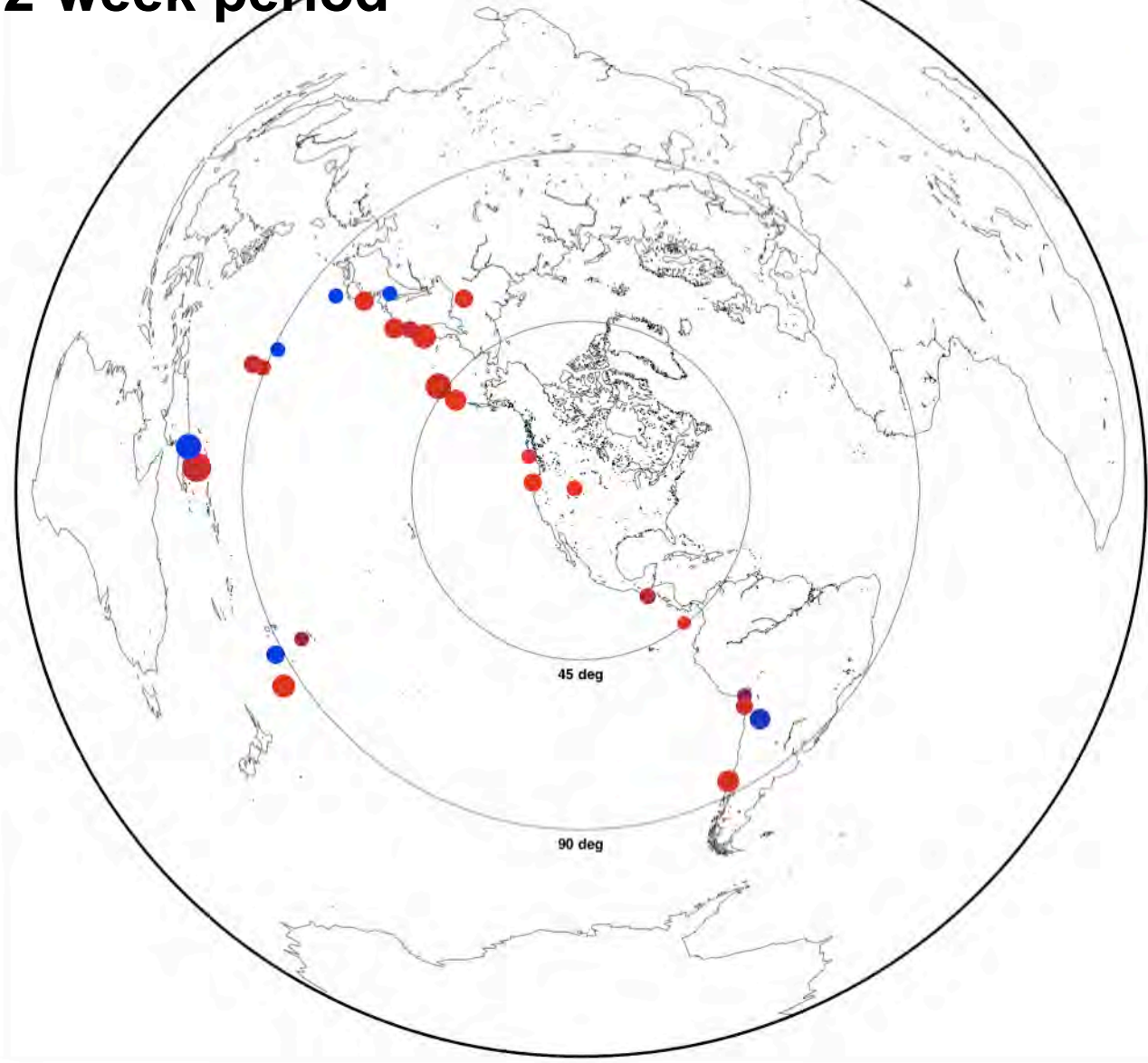
-347.223

100 200 300 400 500 600 700



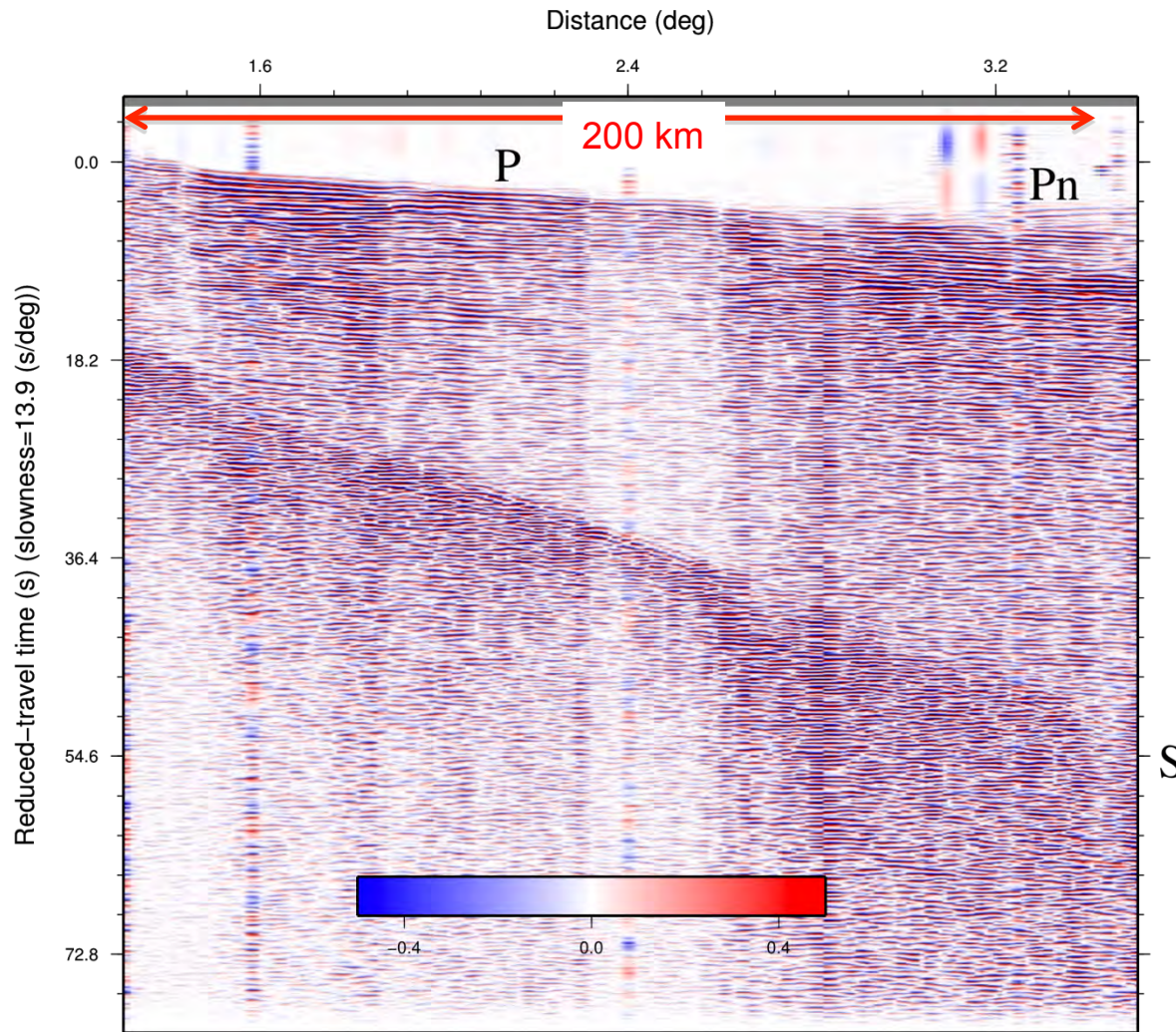
**Earthquake from Alaska**

# 47 earthquakes recorded by geophones in 2-week period



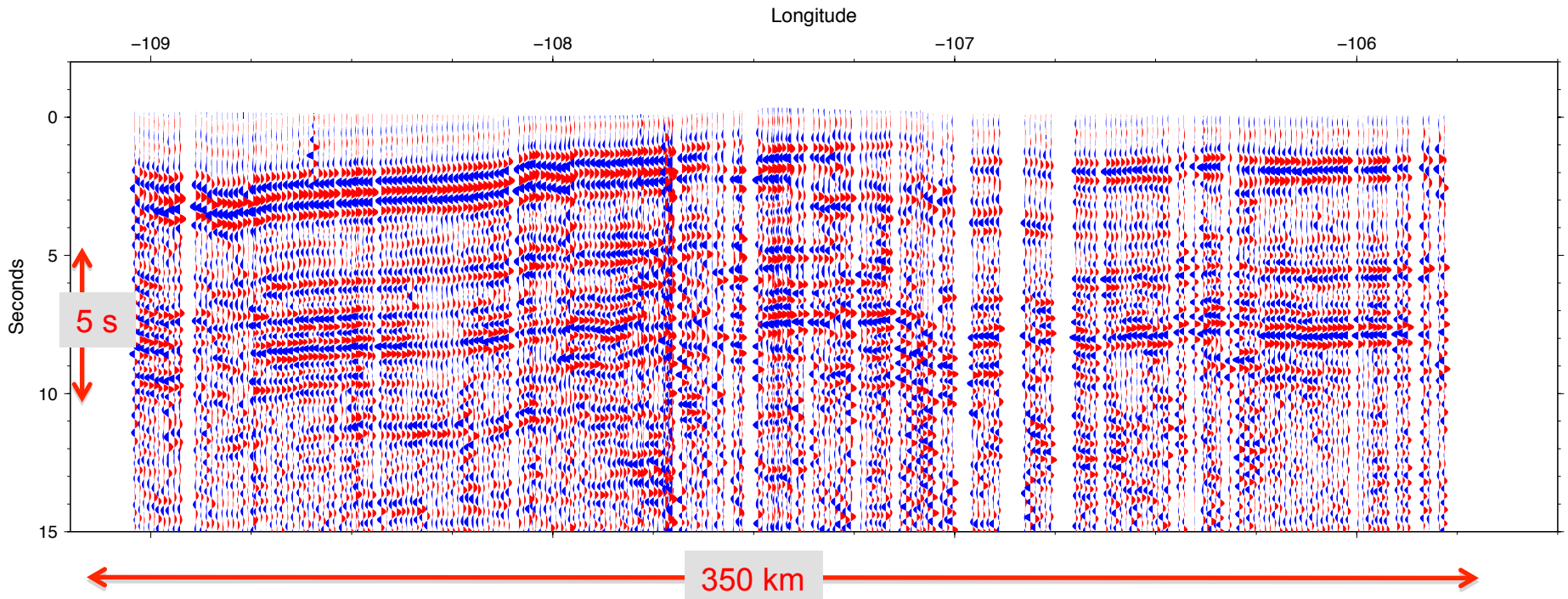
- M 4.0
- M 5.0
- M 6.0
- M 7.0

# Regional earthquakes recorded on geophones



**Magnitude 4.8 Jackson Hole earthquake**  
recorded on Wyoming Bighorn Project geophones

# Recording of a teleseism on geophones

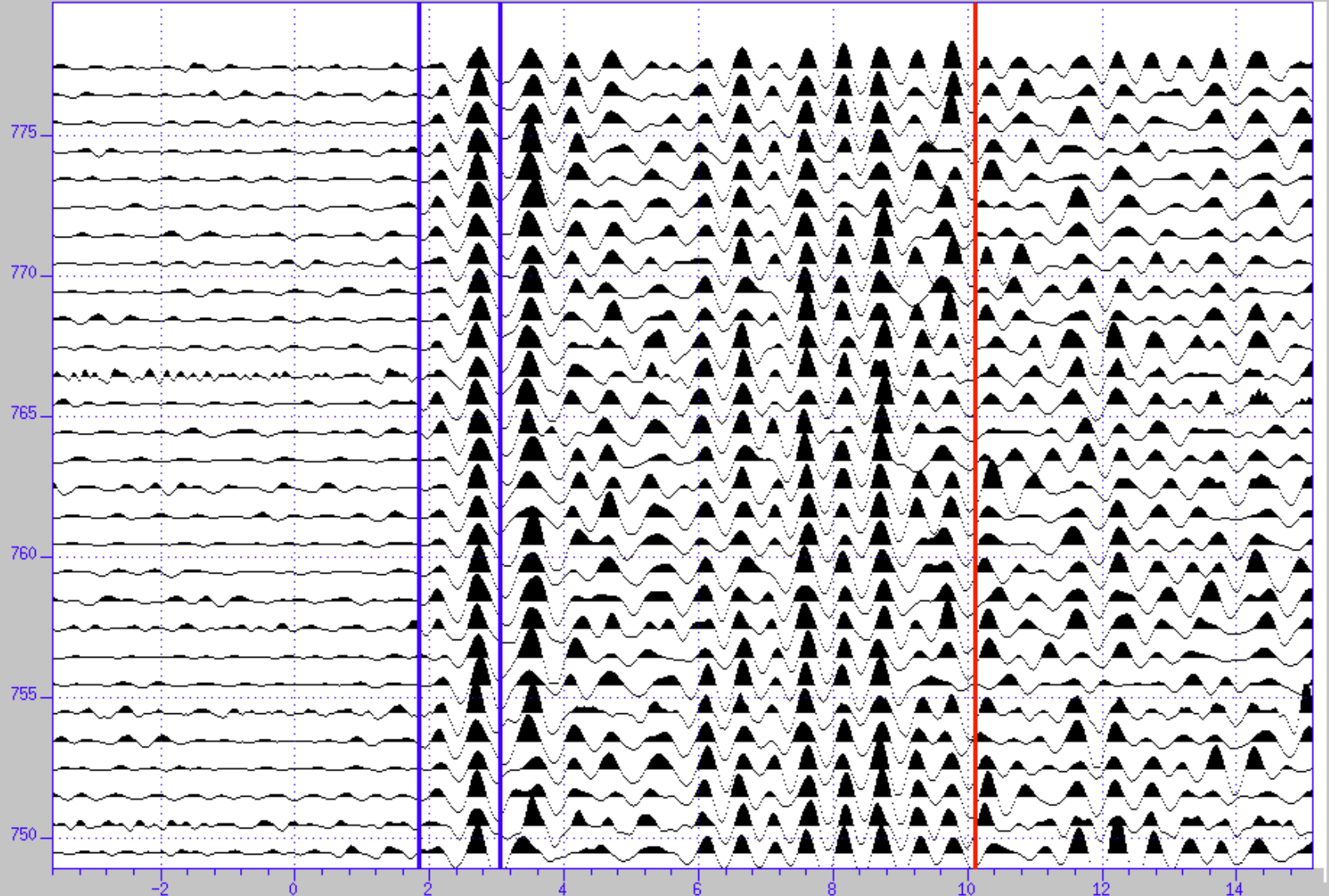


- Example above – magnitude 5 earthquake from Alaska
- No processing besides 1-2 Hz filter
- A rich source of energy for structural studies

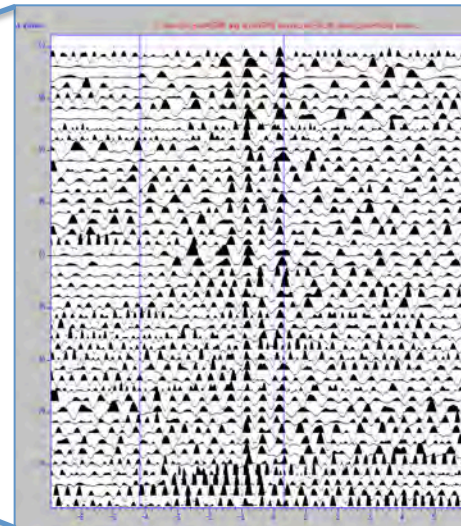
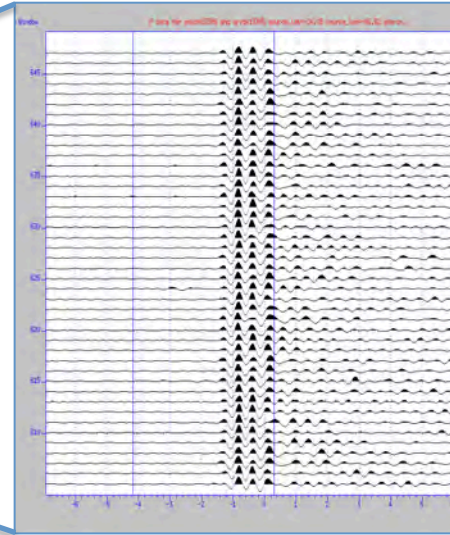
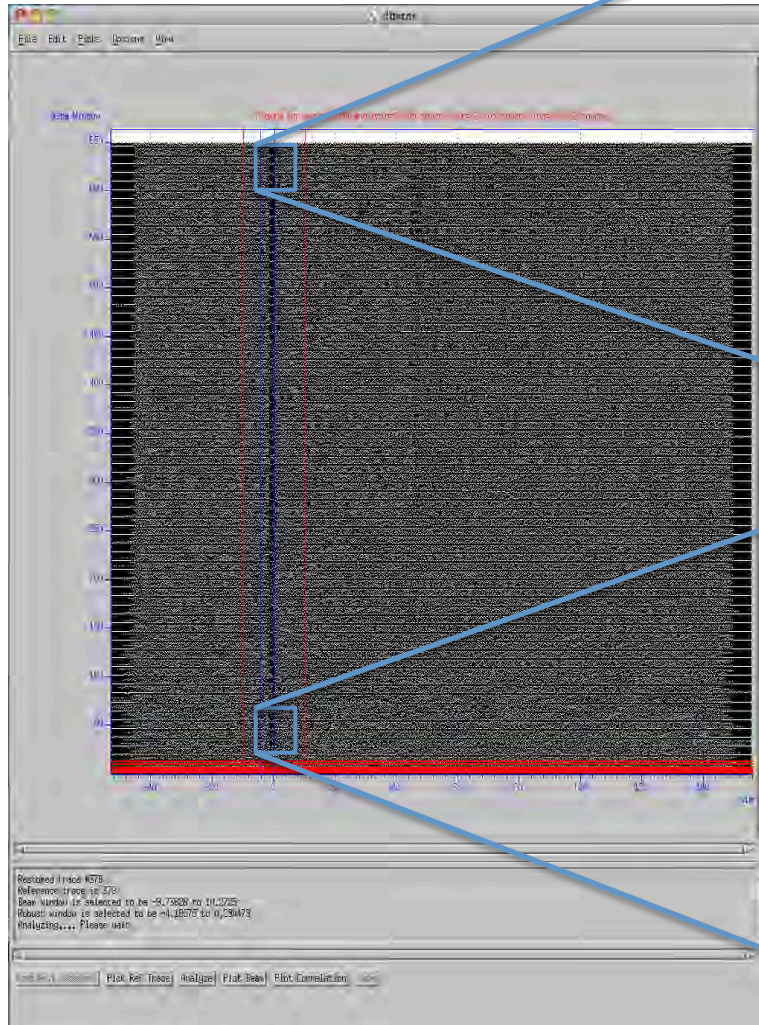
# Teleseismic P wave travel time picking using waveform crosscorrelation with geophone data

Data Window

P data for evid=13354 and orid=13354 source\_lat=52.63 source\_lon=-169.35 source\_

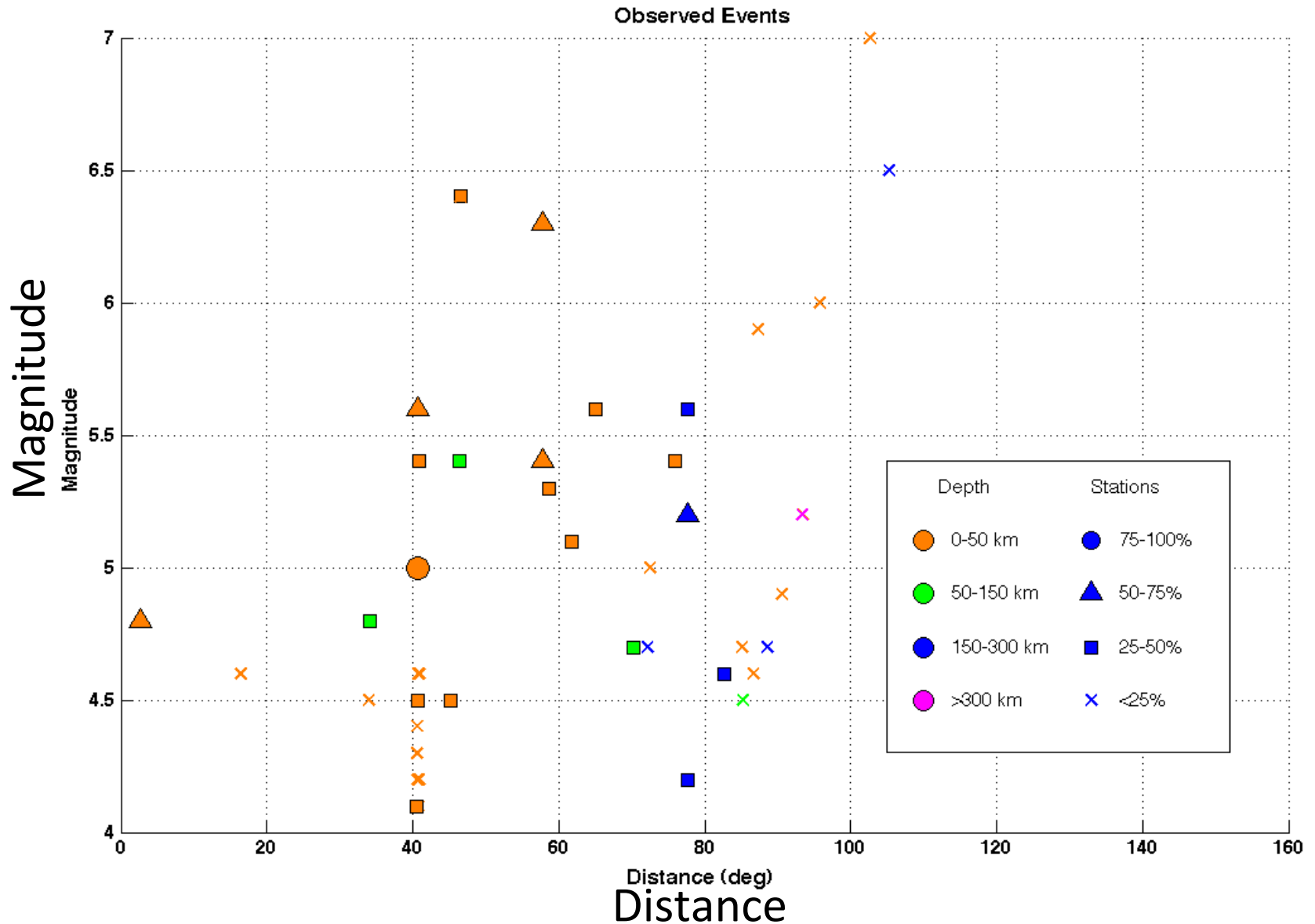


# Teleseismic P wave travel time picking



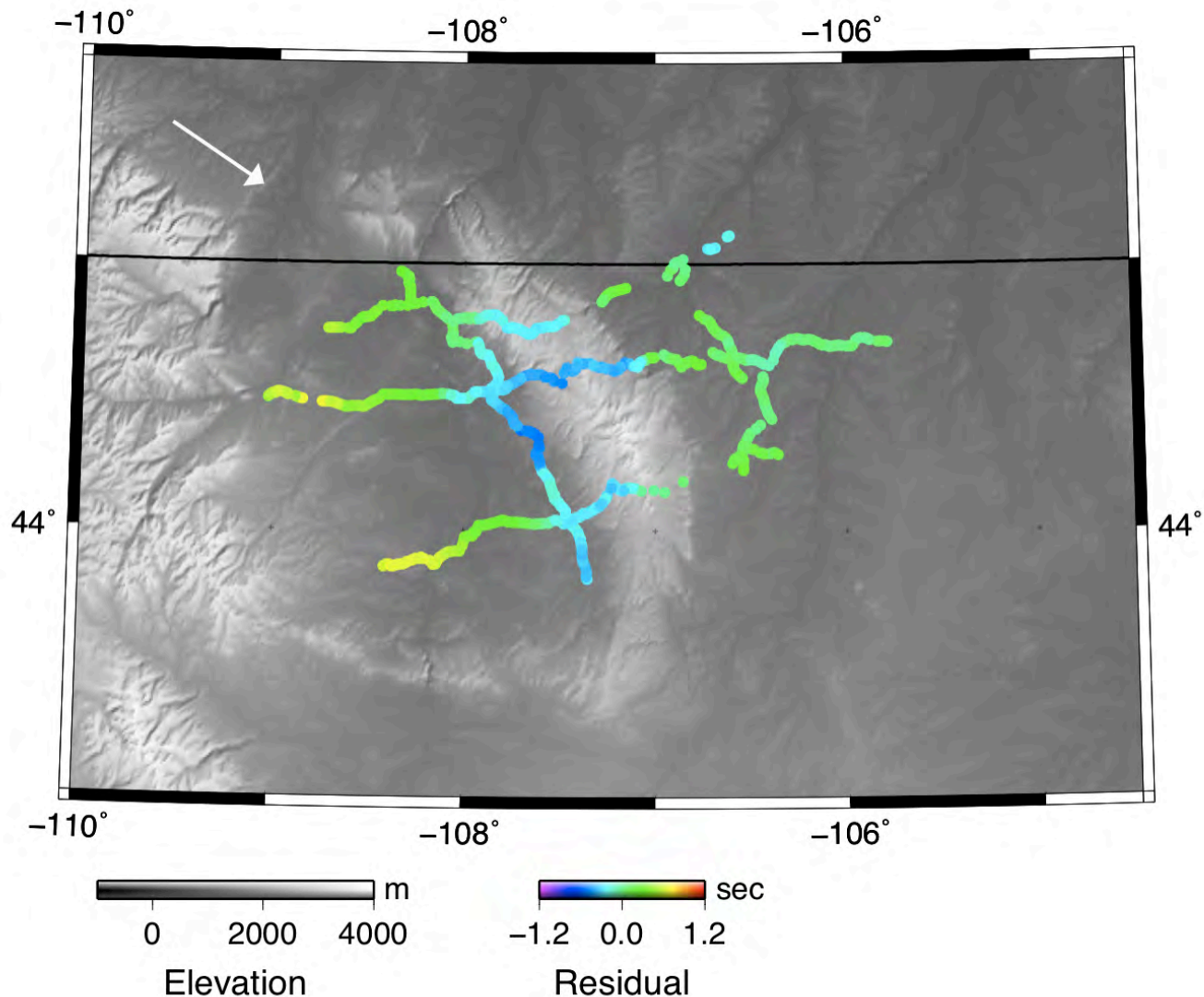


# Magnitude-Distance distribution of earthquakes recorded on geophones

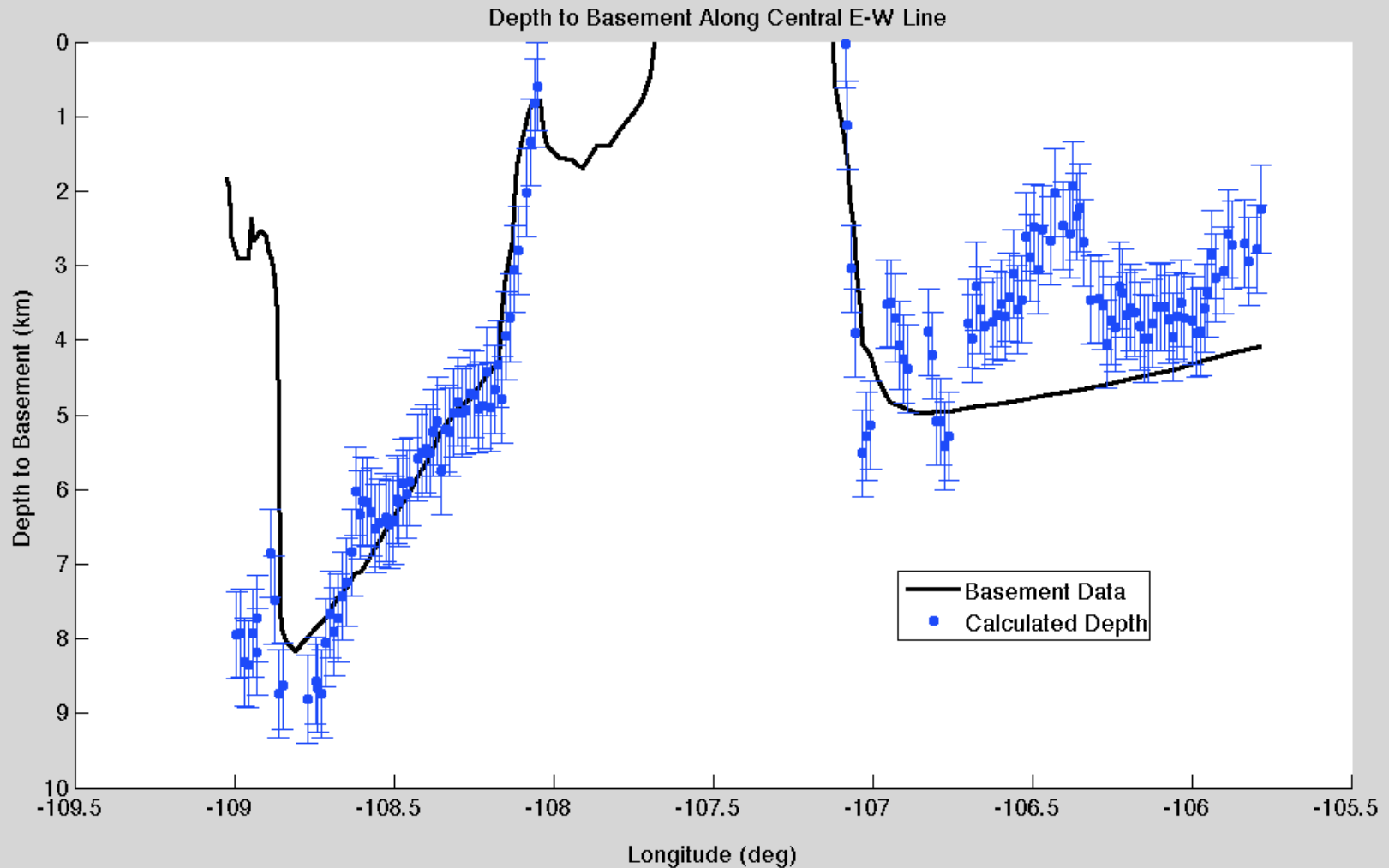


# Calculating residual times for teleseismic P-wave arrivals

- 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

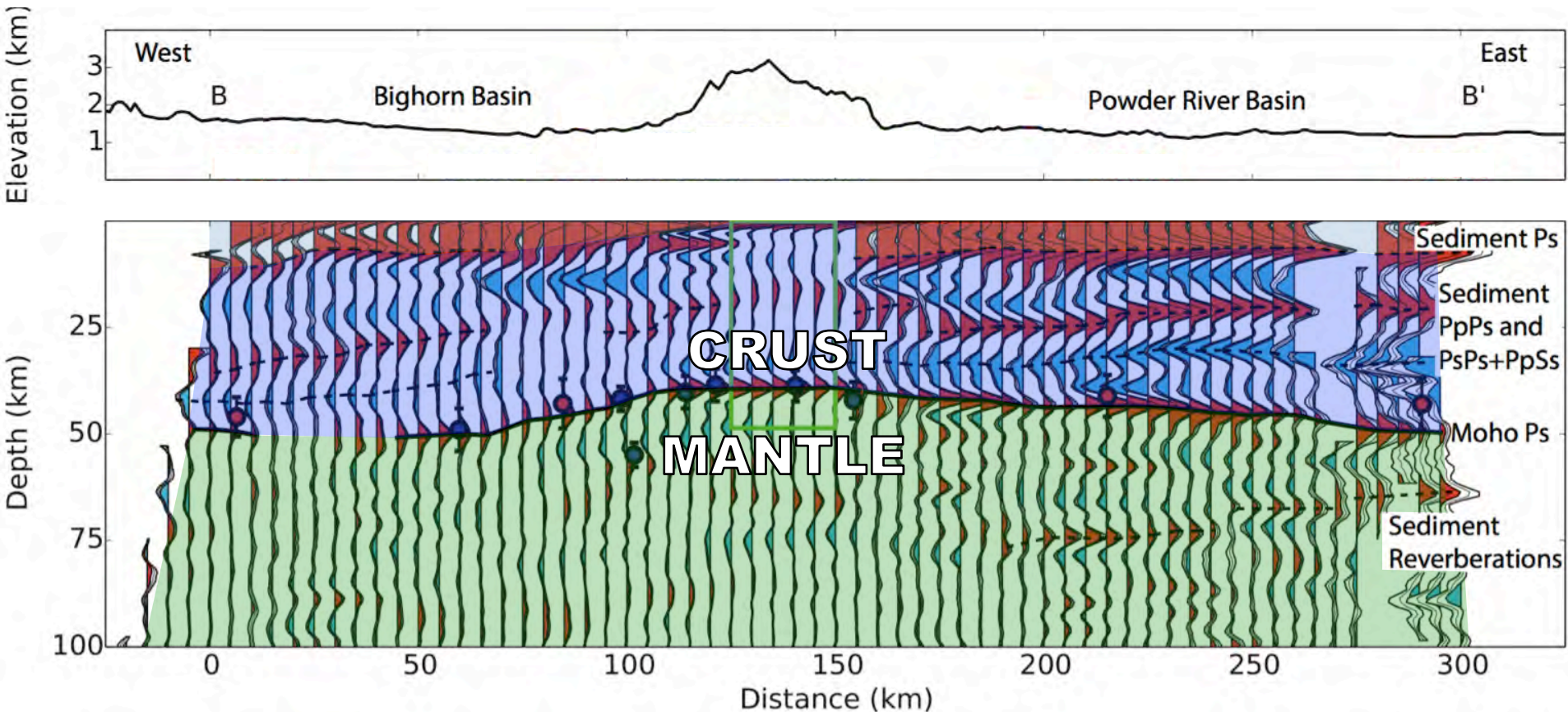


# Teleseismic Receiver Function Image

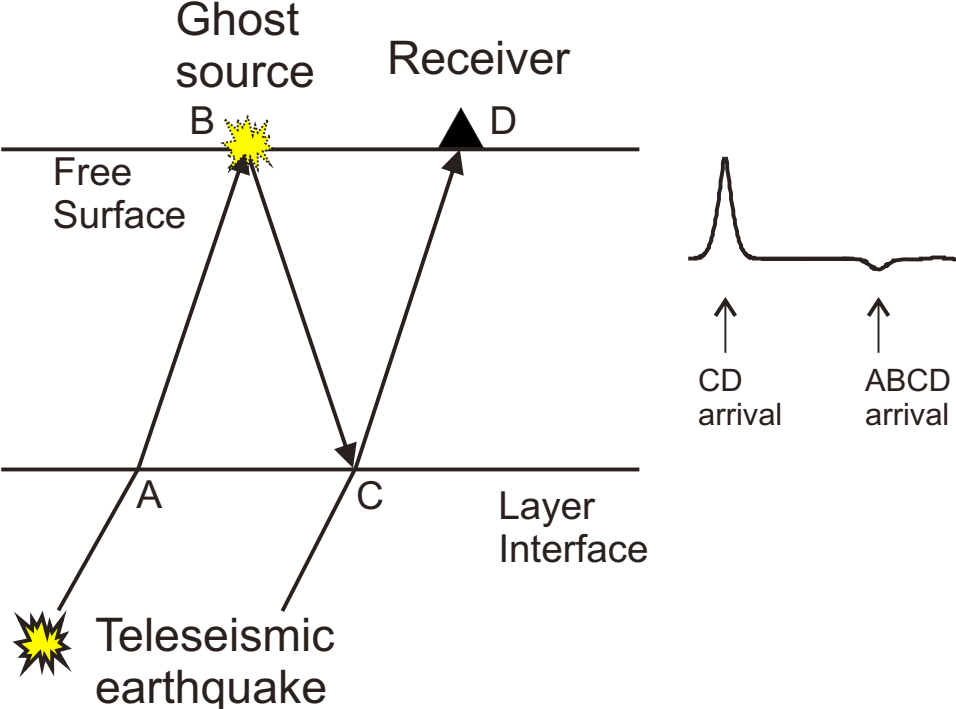
Constructed by deconvolving vertical component seismogram from radial

Requires 3C seismogram

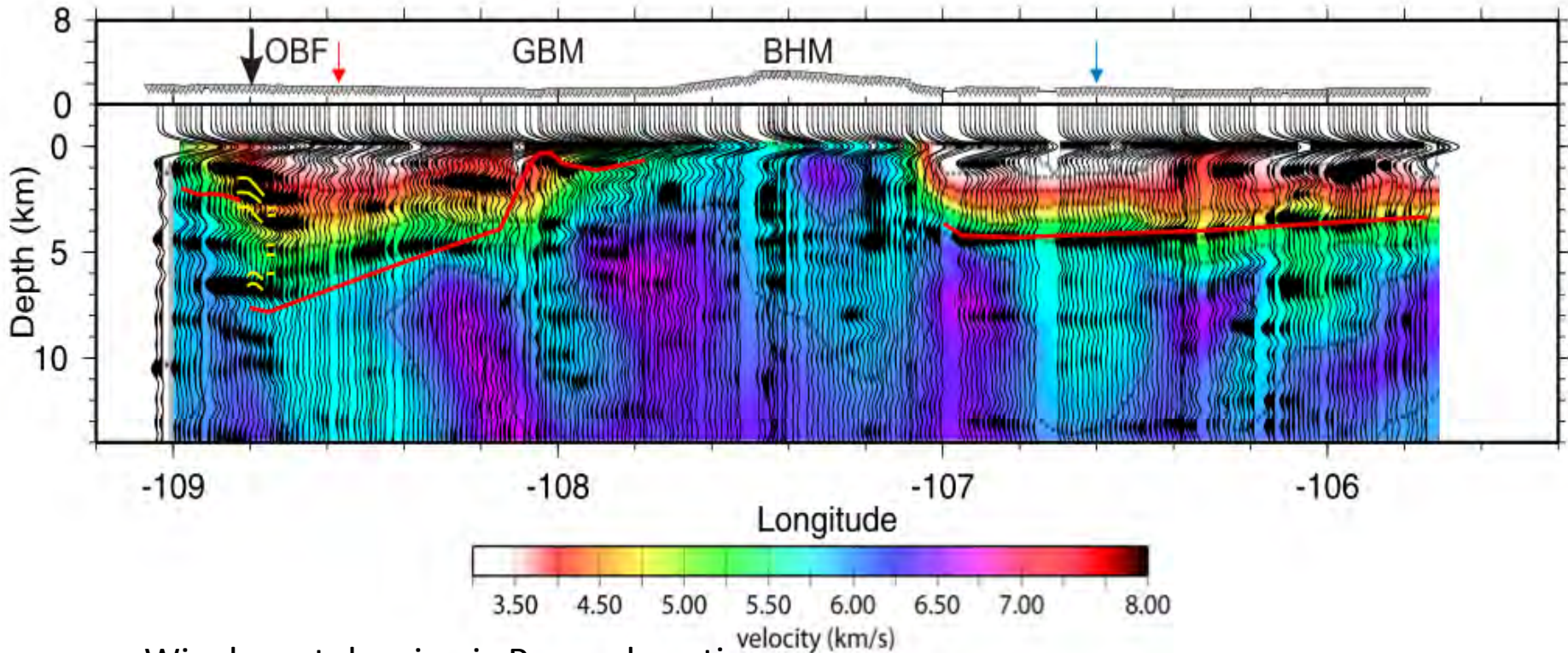
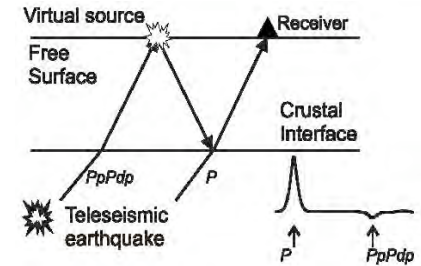
What to do if only have single component geophone?



# Teleseismic P wave reverberations as a 'virtual source'



# Teleseismic P wave reverberations as a ‘virtual source’



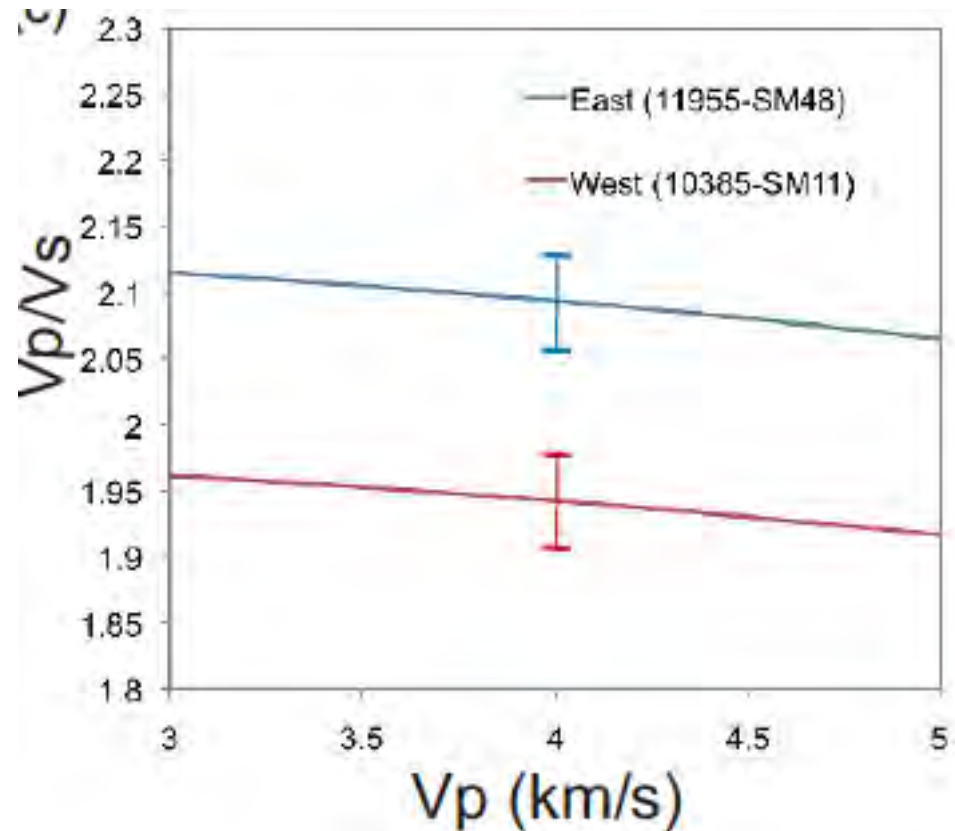
- Wiggles – teleseismic P reverberations
- Color – active source tomography (Worthington and Miller)
- Red line – basin thickness from industry data

# Vp/Vs ratio (join PpPdp and Ps)

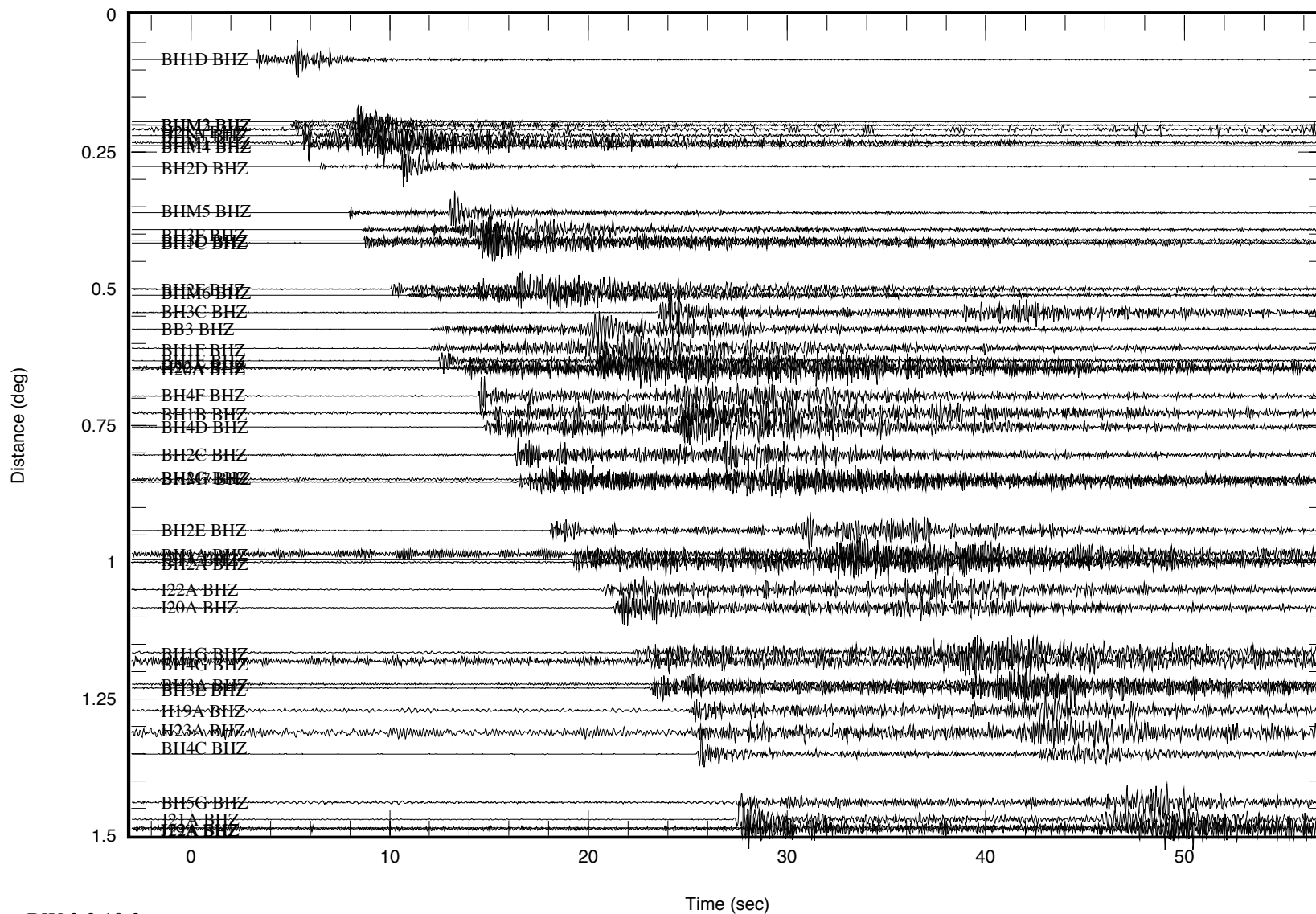
$T_{PpPdp-Pp} / T_{Ps-Pp} =$   
 $f(Vp, Vp/Vs, pp, ps),$   
where pp and ps are  
known ray slowness.

Varying Vp b/t 3 to 5  
km/s

Sedimentary Vp/Vs  $\rightarrow$   
PpPdp is related to  
sedimentary layer



# 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





summaries	by station	by network	by timeseries	virtual nets	breq_fast		help
channels	stations	responses	temp networks	assembled	events	comments	

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- [XI](#) [XJ](#) [XL](#) [XN](#) [XO](#)
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- [YC](#) [YF](#) [YG](#) [YH](#) [YI](#)
- [YJ](#) [YK](#) [YL](#) [YM](#) [YN](#)
- [YO](#) [YP](#) [YS](#) [YT](#) [YU](#)
- [YV](#) [YW](#) [YX](#) [YZ](#) [Z1](#)
- [Z2](#) [Z3](#) [Z4](#) [Z6](#) [Z8](#)
- [Z9](#) [ZD](#) [ZG](#) [ZH](#) [ZI](#)
- [ZK](#) [ZL](#) [ZM](#) [ZN](#) [ZO](#)
- [ZP](#) [ZR](#) [ZU](#) [ZV](#) [ZZ](#)

## Bighorns Passive Texan

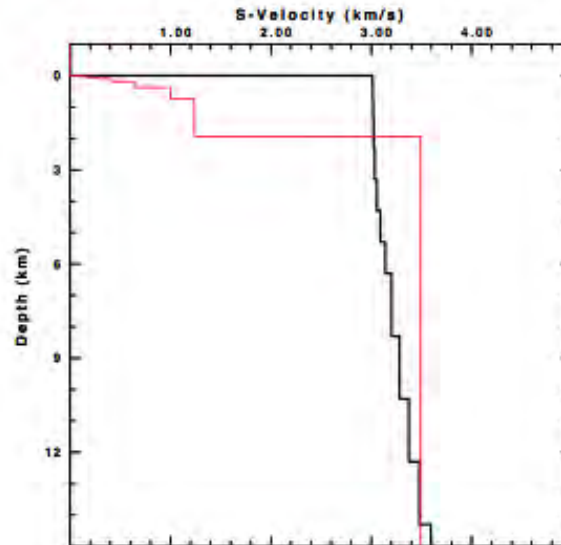
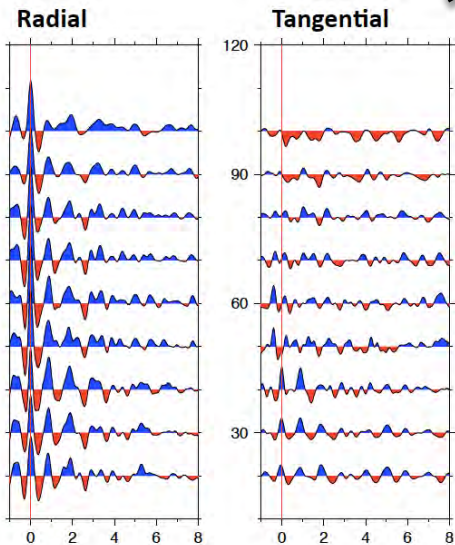
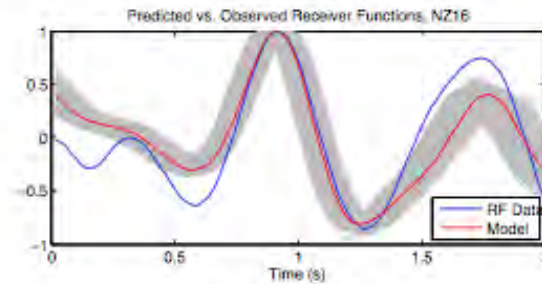
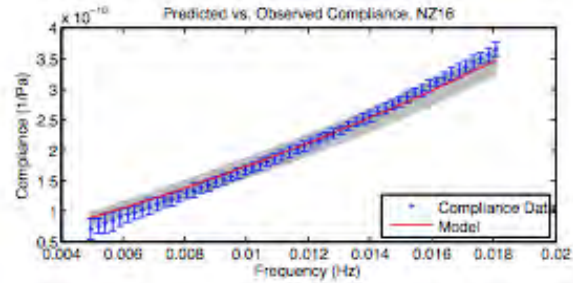
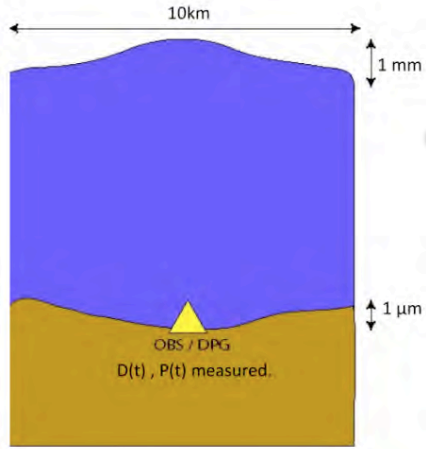
2010 [ZI](#)

# Continuous data at IRIS DMC

<i>January</i>							<i>February</i>							<i>March</i>								
Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa		
					1	2	1	2	3	4	5	6	1	2	3	4	5	6				
3	4	5	6	7	8	9	7	8	9	10	11	12	13	7	8	9	10	11	12	13		
10	11	12	13	14	15	16	14	15	16	17	18	19	20	14	15	16	17	18	19	20		
17	18	19	20	21	22	23	21	22	23	24	25	26	27	21	22	23	24	25	26	27		
24	25	26	27	28	29	30	28							28	29	30	31					
31																						
<i>April</i>							<i>May</i>							<i>June</i>								
Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa		
				1	2	3						1	1	2	3	4	5					
4	5	6	7	8	9	10	2	3	4	5	6	7	8	6	7	8	9	10	11	12		
11	12	13	14	15	16	17	9	10	11	12	13	14	15	13	14	15	16	17	18	19		
18	19	20	21	22	23	24	16	17	18	19	20	21	22	20	21	22	23	24	25	26		
25	26	27	28	29	30		23	24	25	26	27	28	29	27	28	29	30					
							30	31														
<i>July</i>							<i>August</i>							<i>September</i>								
Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa		
				1	2	3	1	2	3	4	5	6	7				1	2	3	4		
4	5	6	7	8	9	10	8	9	10	11	12	13	14	5	6	7	8	9	10	11		
11	12	13	14	15	16	17	15	16	17	18	19	20	21	12	13	14	15	16	17	18		
18	19	20	21	22	23	24	22	23	24	25	26	27	28	19	20	21	22	23	24	25		
25	26	27	28	29	30	31	29	30	31					26	27	28	29	30				
<i>October</i>							<i>November</i>							<i>December</i>								
Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa		
					1	2				1	2	3	4	5	6				1	2	3	4
3	4	5	6	7	8	9	7	8	9	10	11	12	13	5	6	7	8	9	10	11		
10	11	12	13	14	15	16	14	15	16	17	18	19	20	12	13	14	15	16	17	18		
17	18	19	20	21	22	23	21	22	23	24	25	26	27	19	20	21	22	23	24	25		
24	25	26	27	28	29	30	28	29	30					26	27	28	29	30	31			
31																						

(Last Update: February 18, 2011)

# 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

