

# Integrated Active-Passive Source Seismic Exploration

*The best of both worlds...*

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Sisprobe SAS



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# Outline

- Industrial Seismic Reflection Instrumentation
- Active Source Reflection Exploration
- Incorporating Passive Data into Active Source Reflection Exploration
- Passive Imaging and Other Data Products
- Sweetwater Data Set
- Where to from here

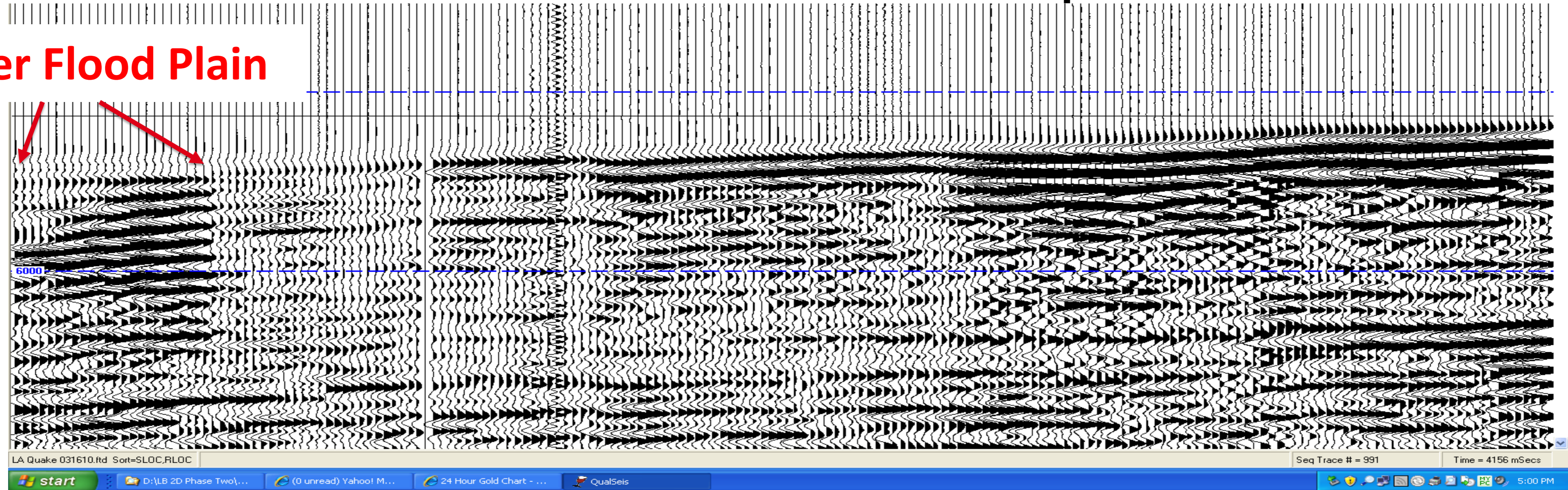
# Nodes - Evolution in Reflection Seismic Recording



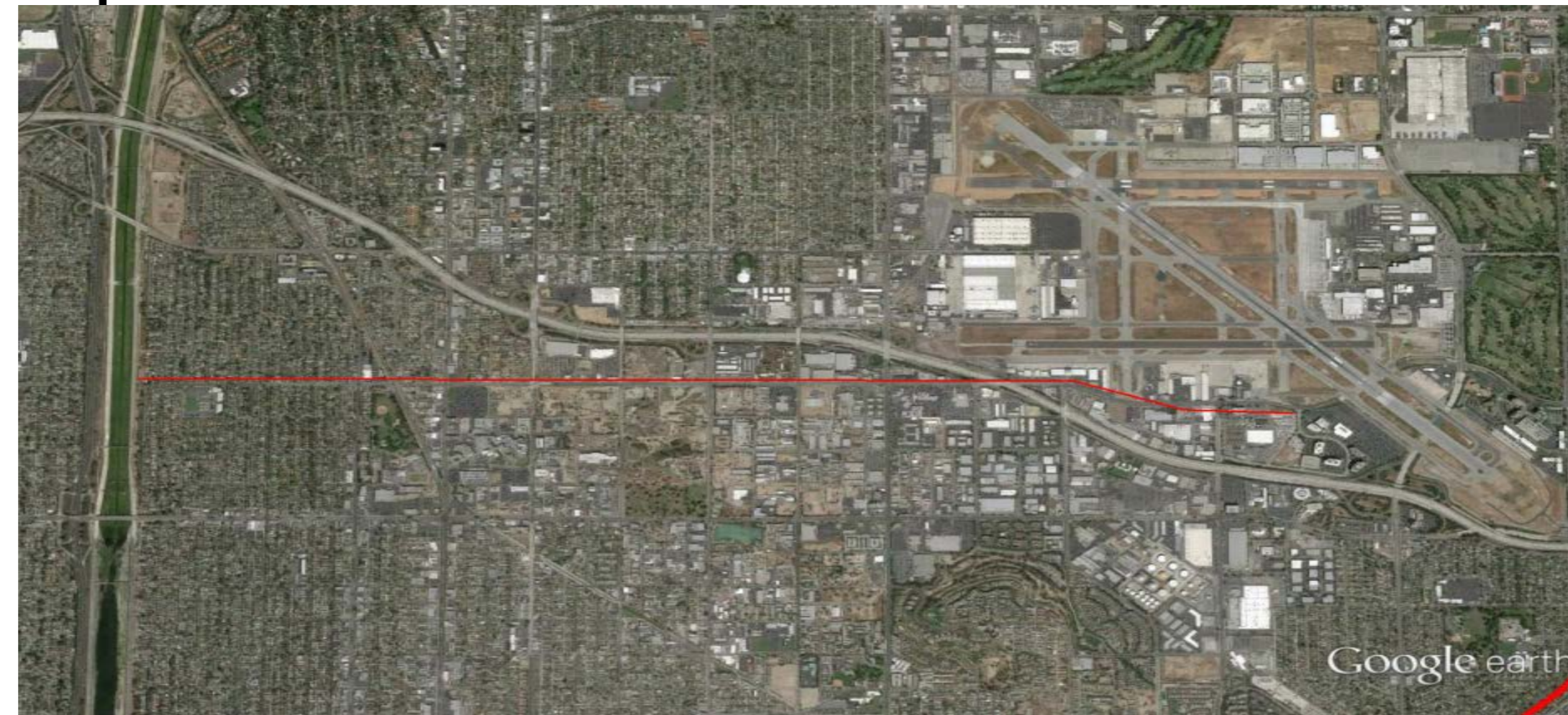
- Cabled to Cable-less
- Lower Cost/More Reliable
- Continuous vs. Segmented\*
- Better HSE footprint
- 30-40 day recording
- First nodes deployed in 2008 +/-
- Nodal instruments now >50% of channels used
- Continuous data not always saved, but industry now realizing it should be saved

# M2.5 Pt. Fermin Earthquake

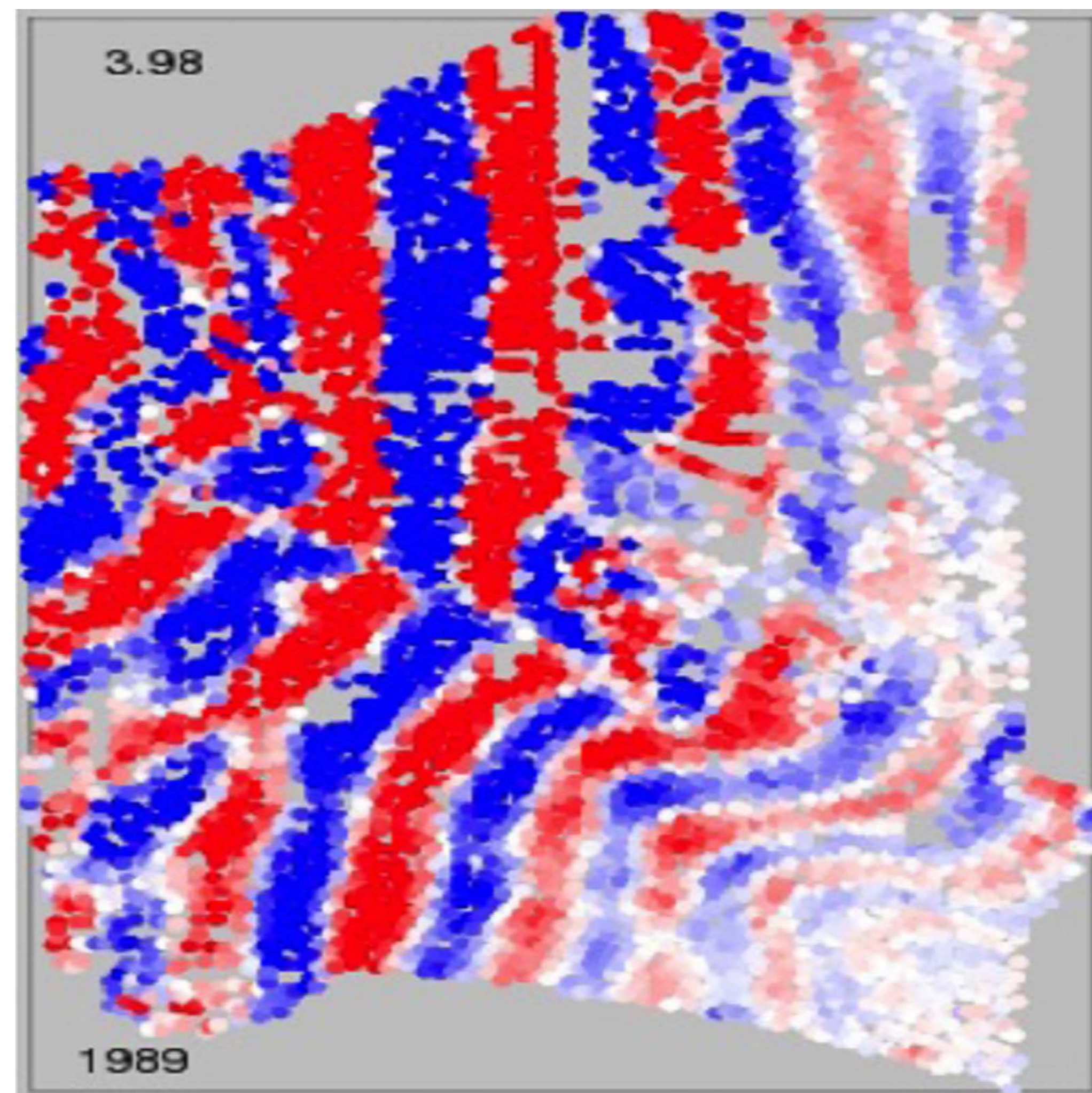
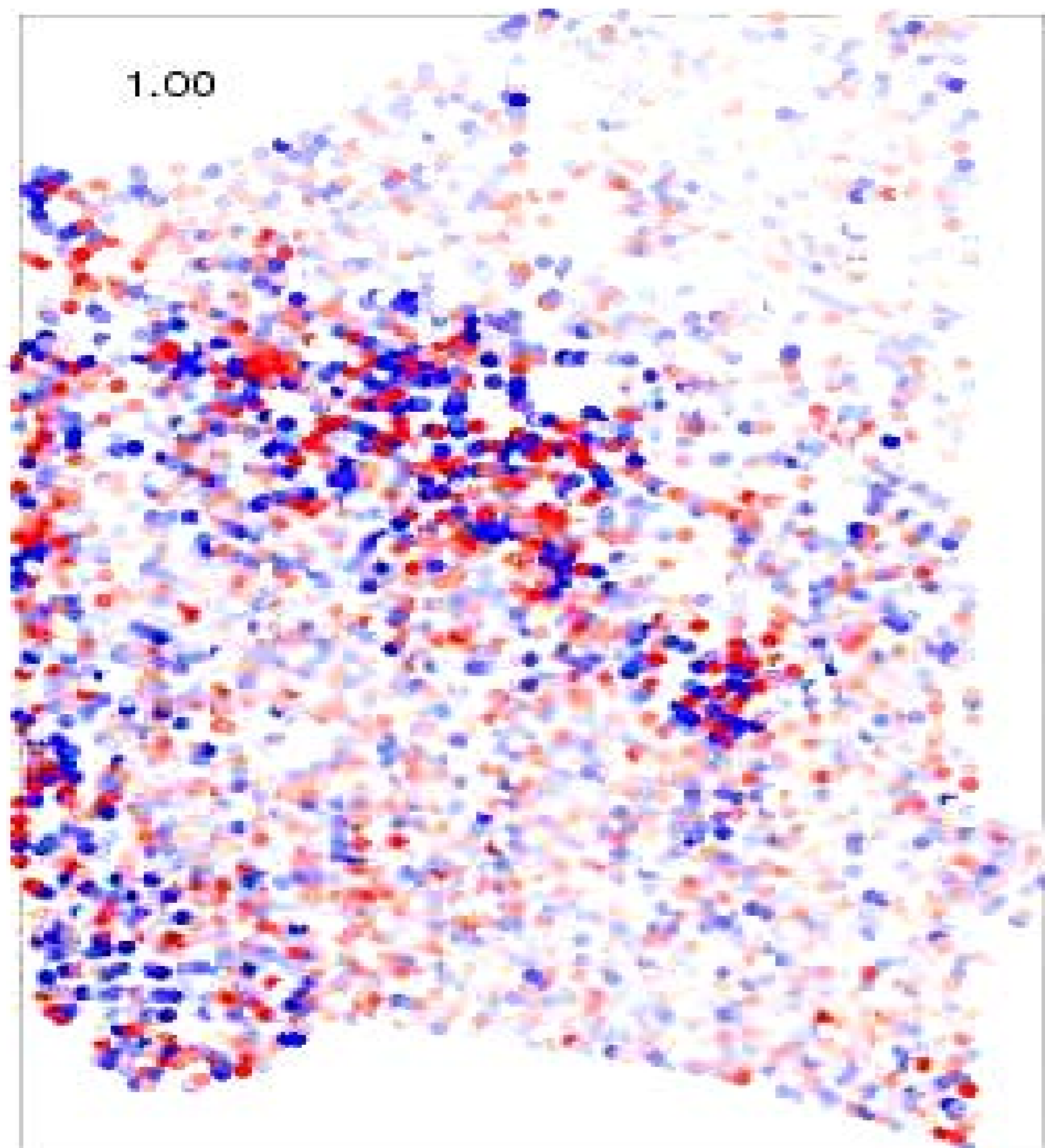
LA River Flood Plain



Local earthquake recorded on 180 nodes on a 2D array



# Earthquake Recorded on Long Beach 3D Array (5400 stations)

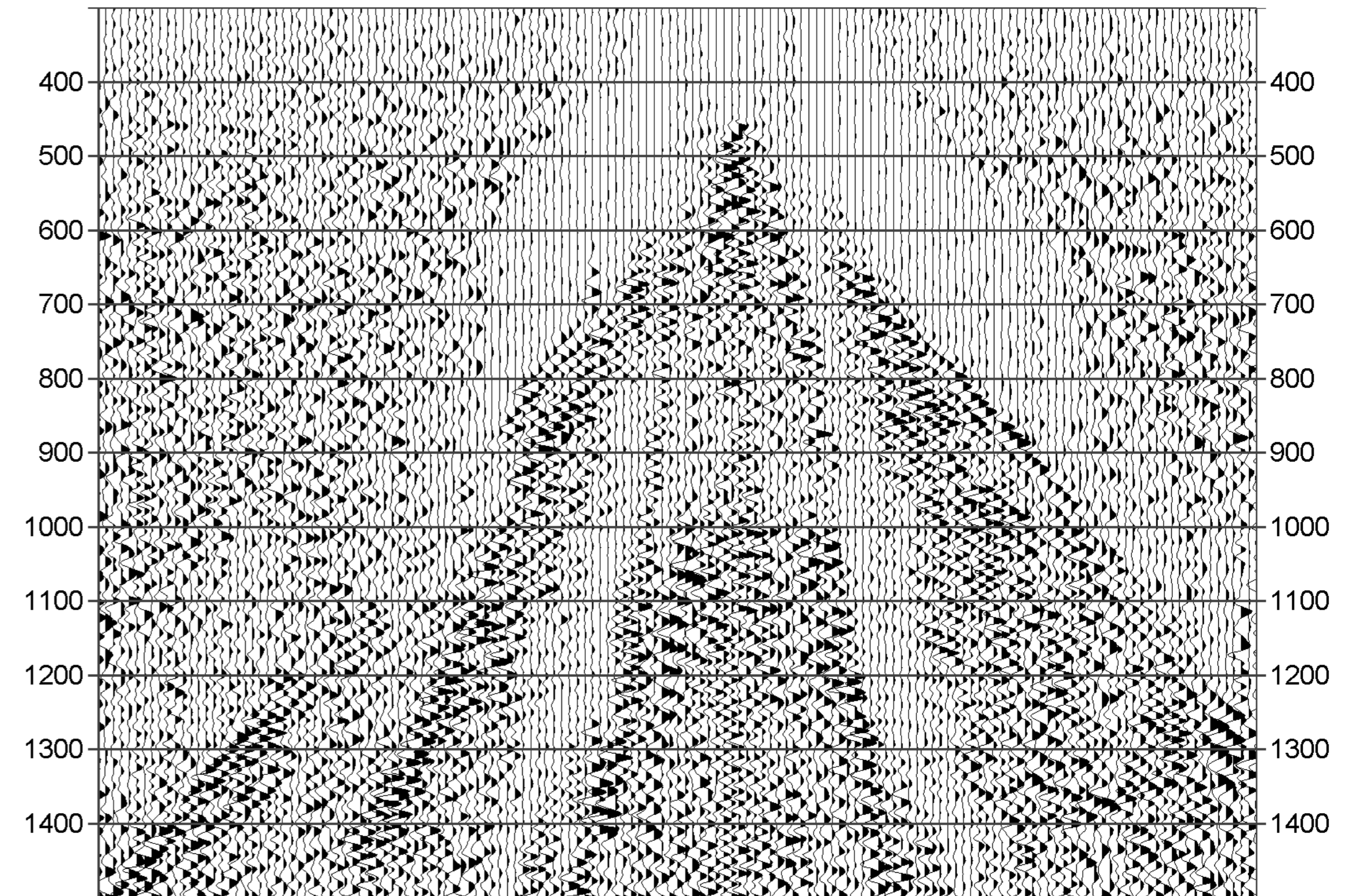
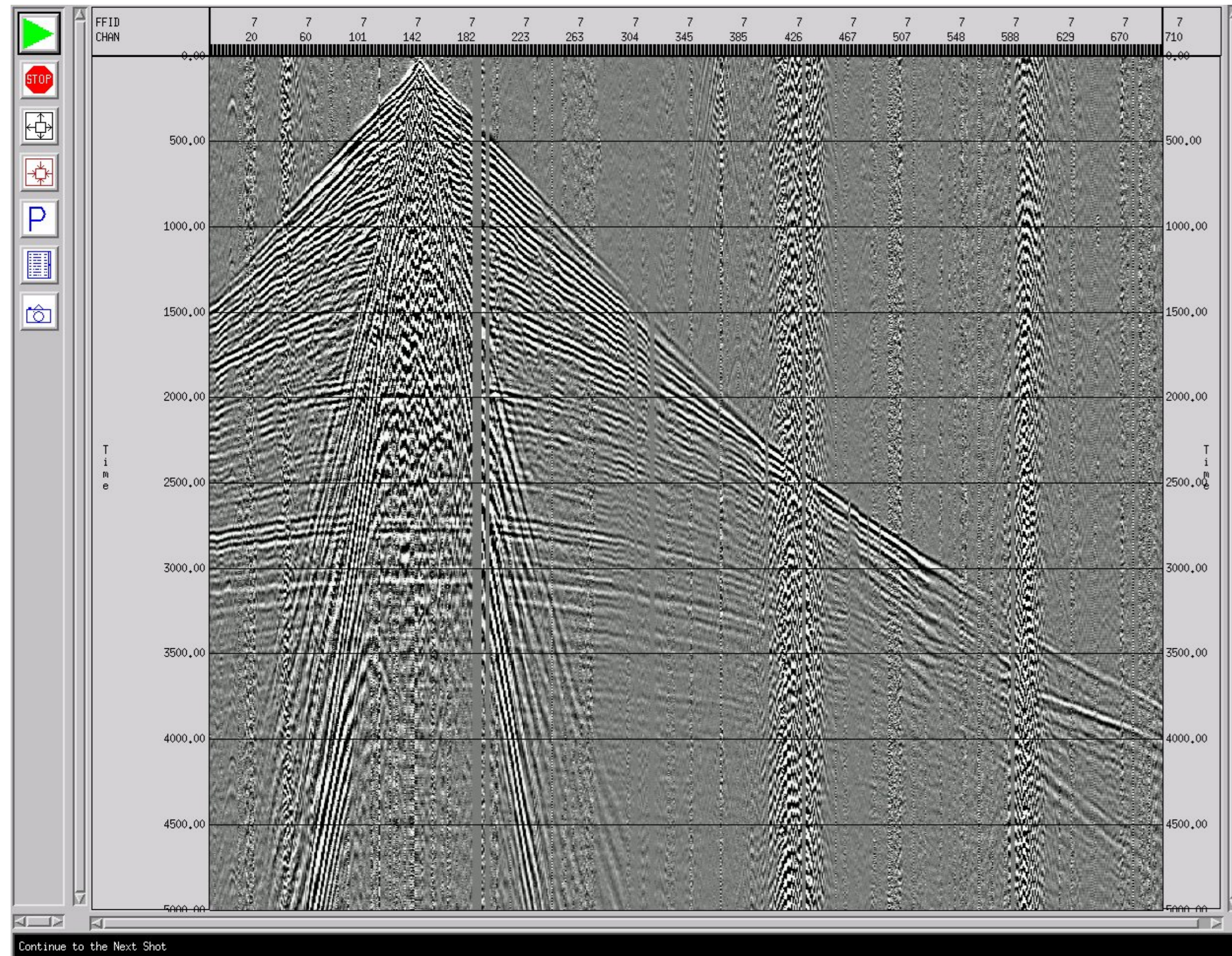


# Active Source Seismology

## Shot Gathers

U.S. Gulf Coast

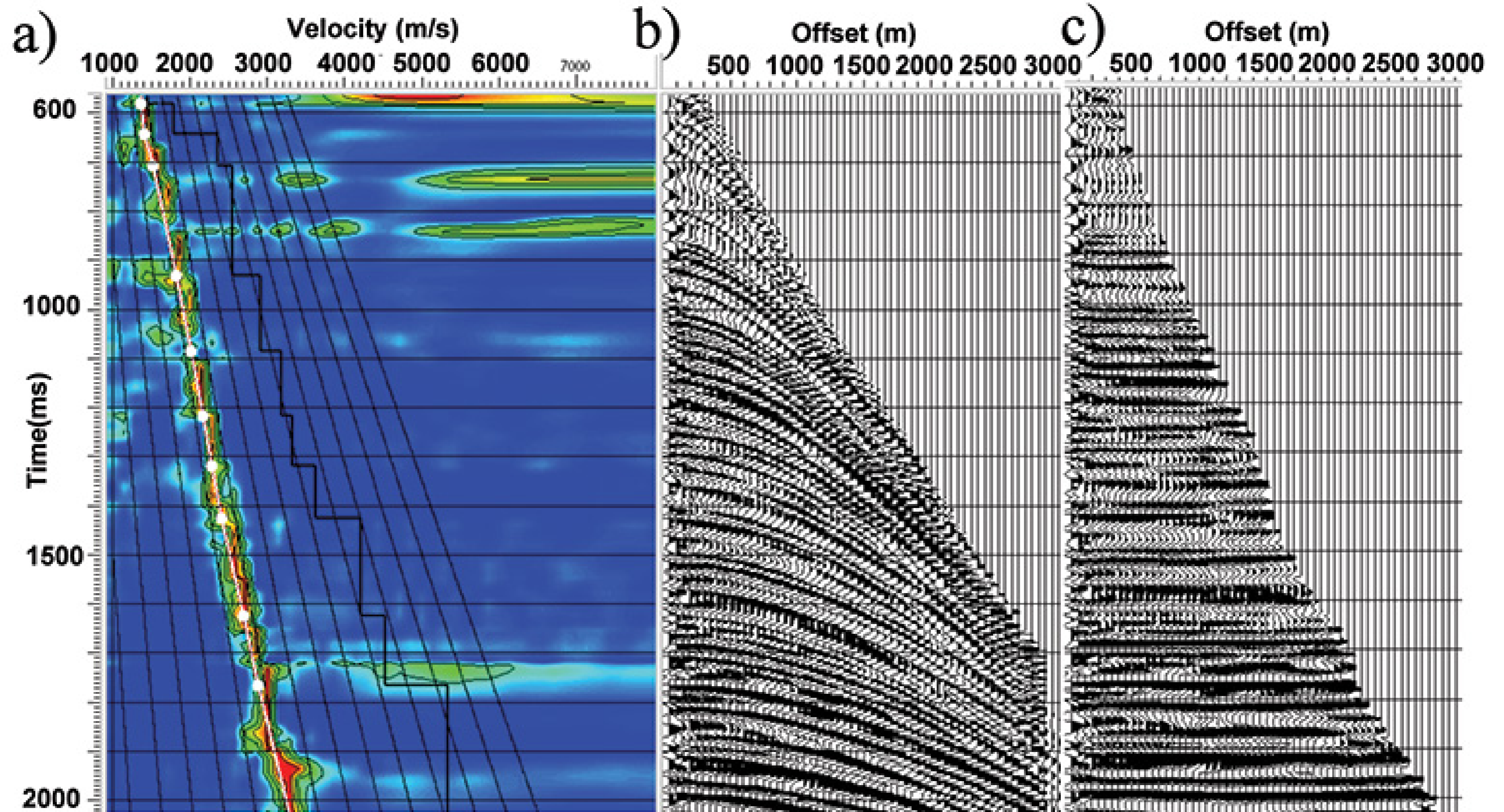
Long Beach



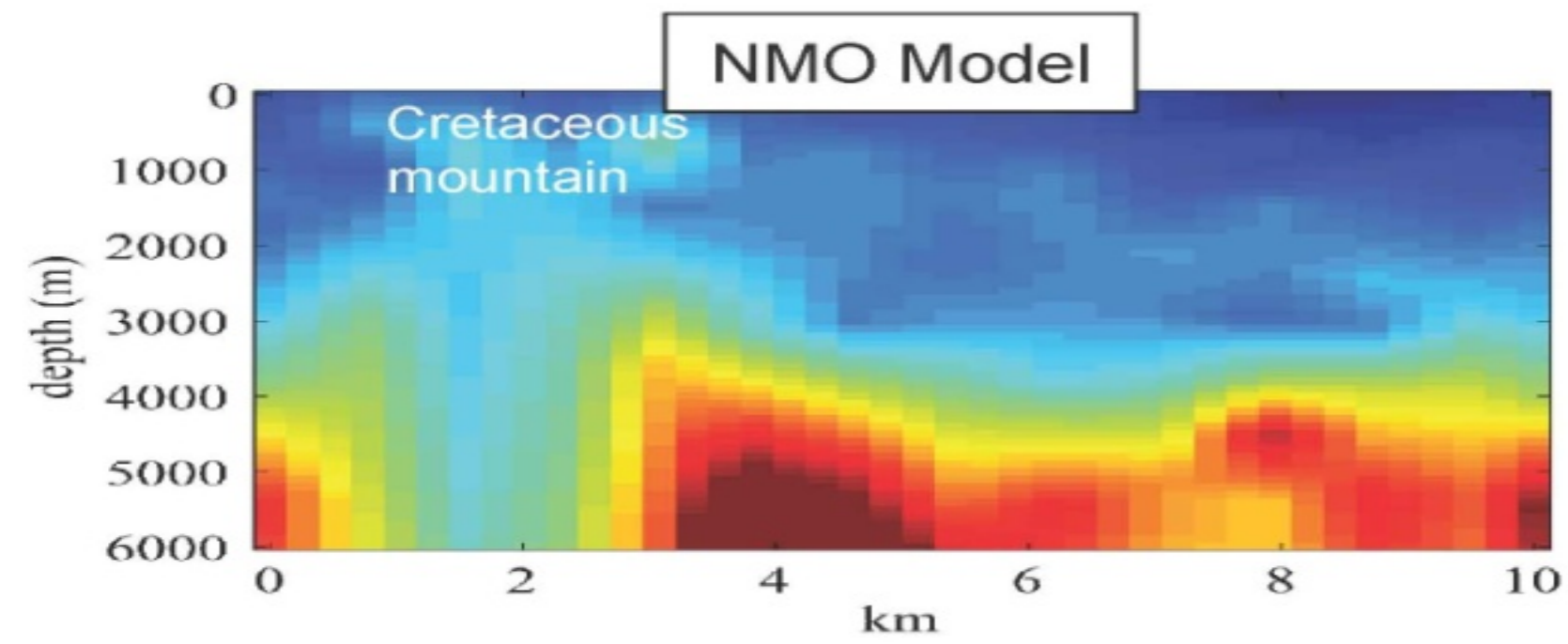
High resolution raw data, but need a simple velocity field to retain resolution in stack.

# Active Source Seismology

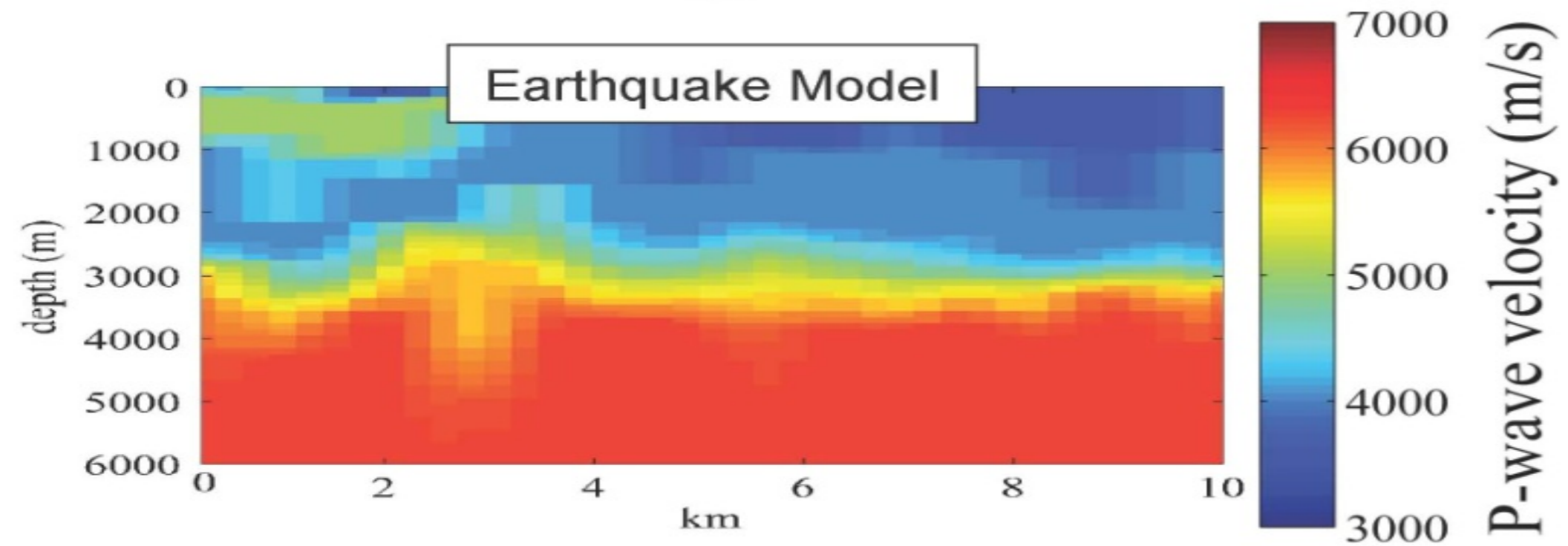
## Normal Move-Out (NMO) Velocity Analysis



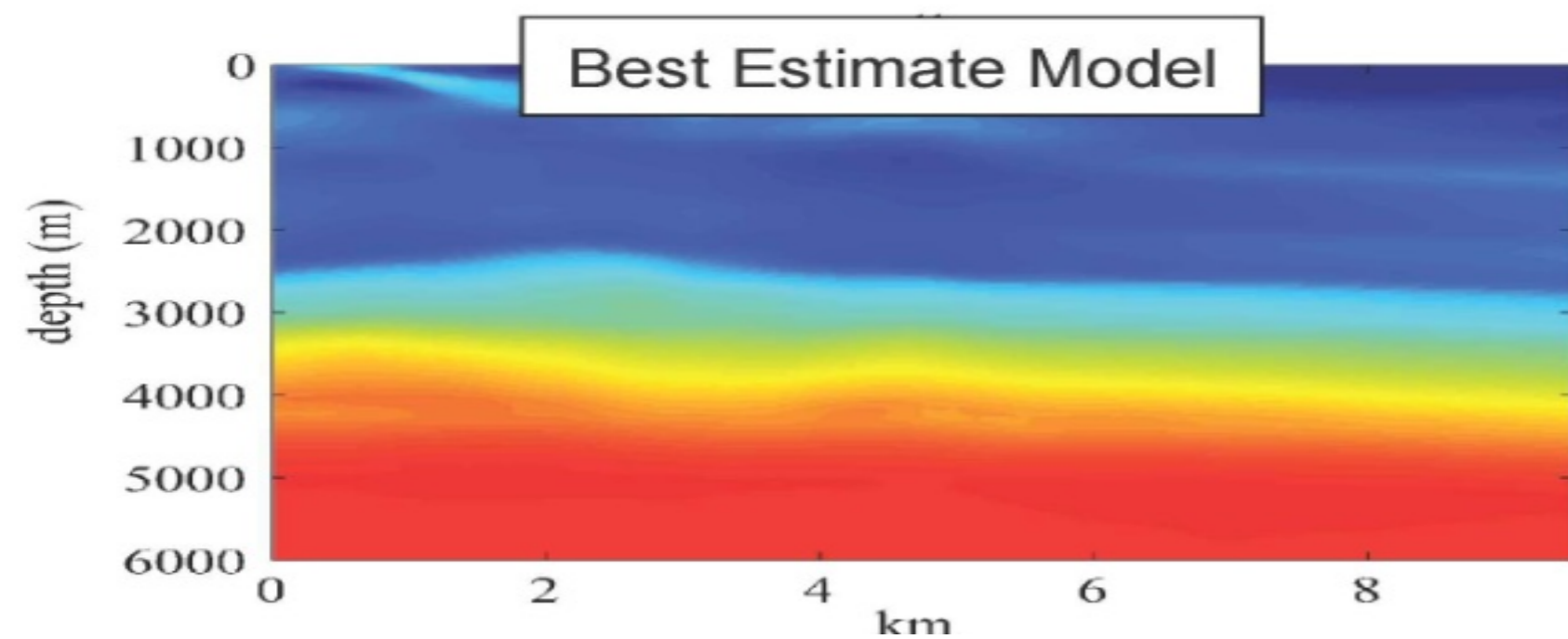
# Velocity, Velocity, Velocity



from NMO analysis



from travel-time tomography & receiver function

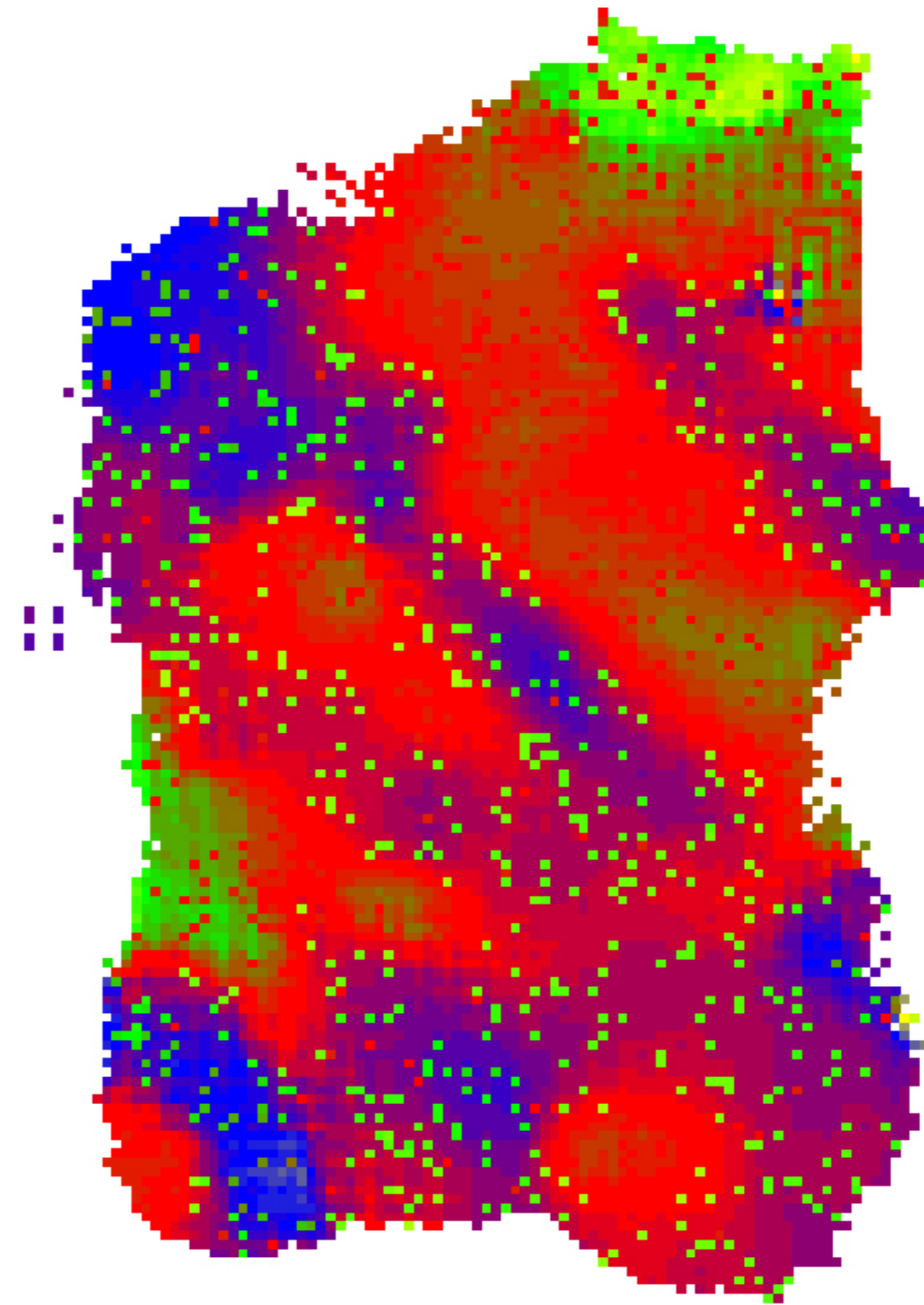
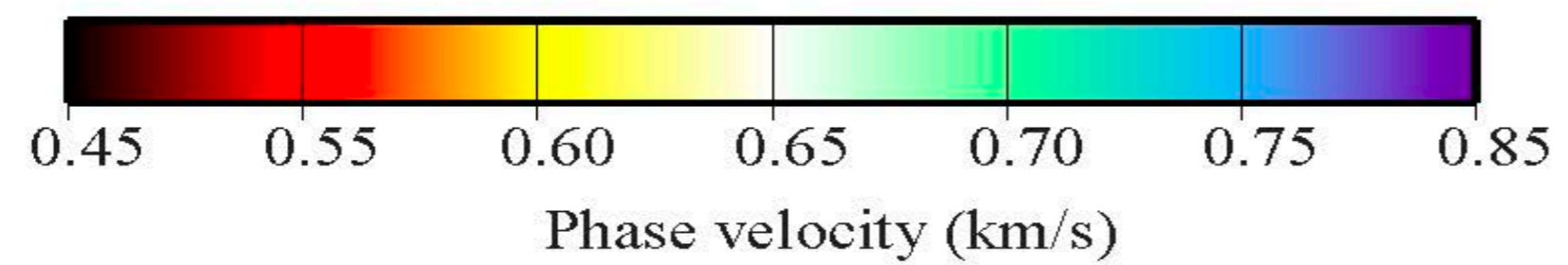
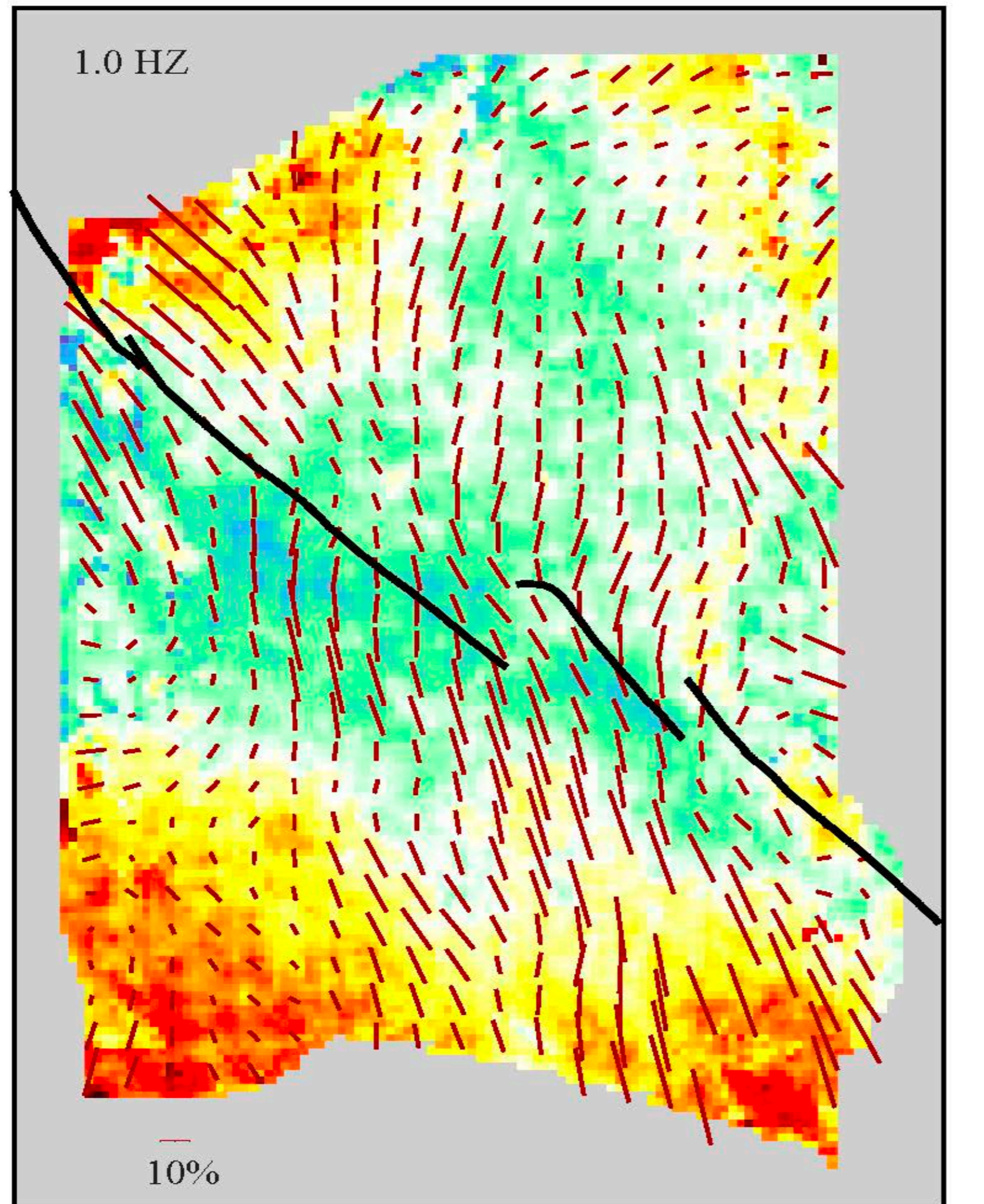


from well control

from Saltzer et al, 2011 SEG Expanded Abstract



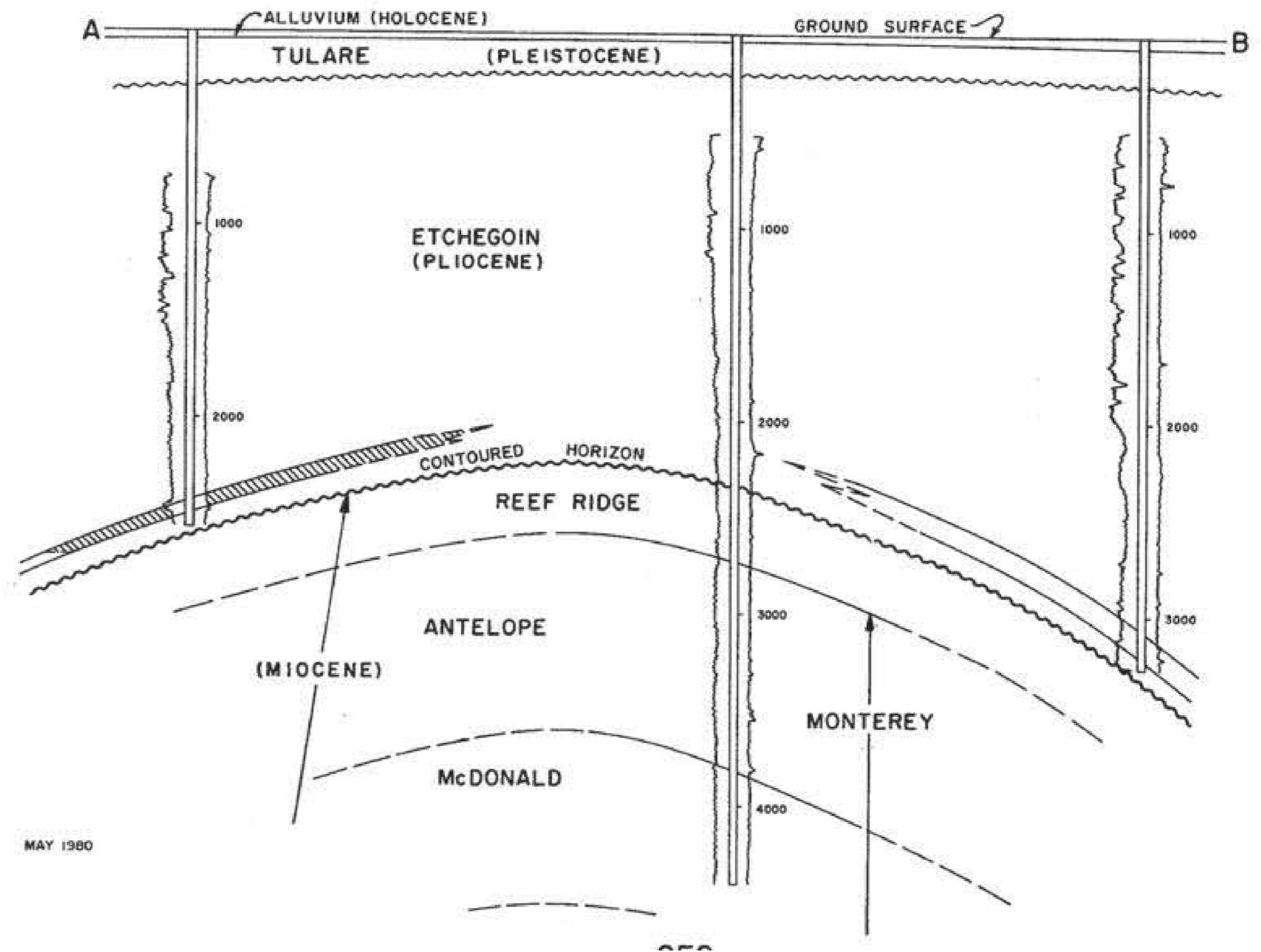
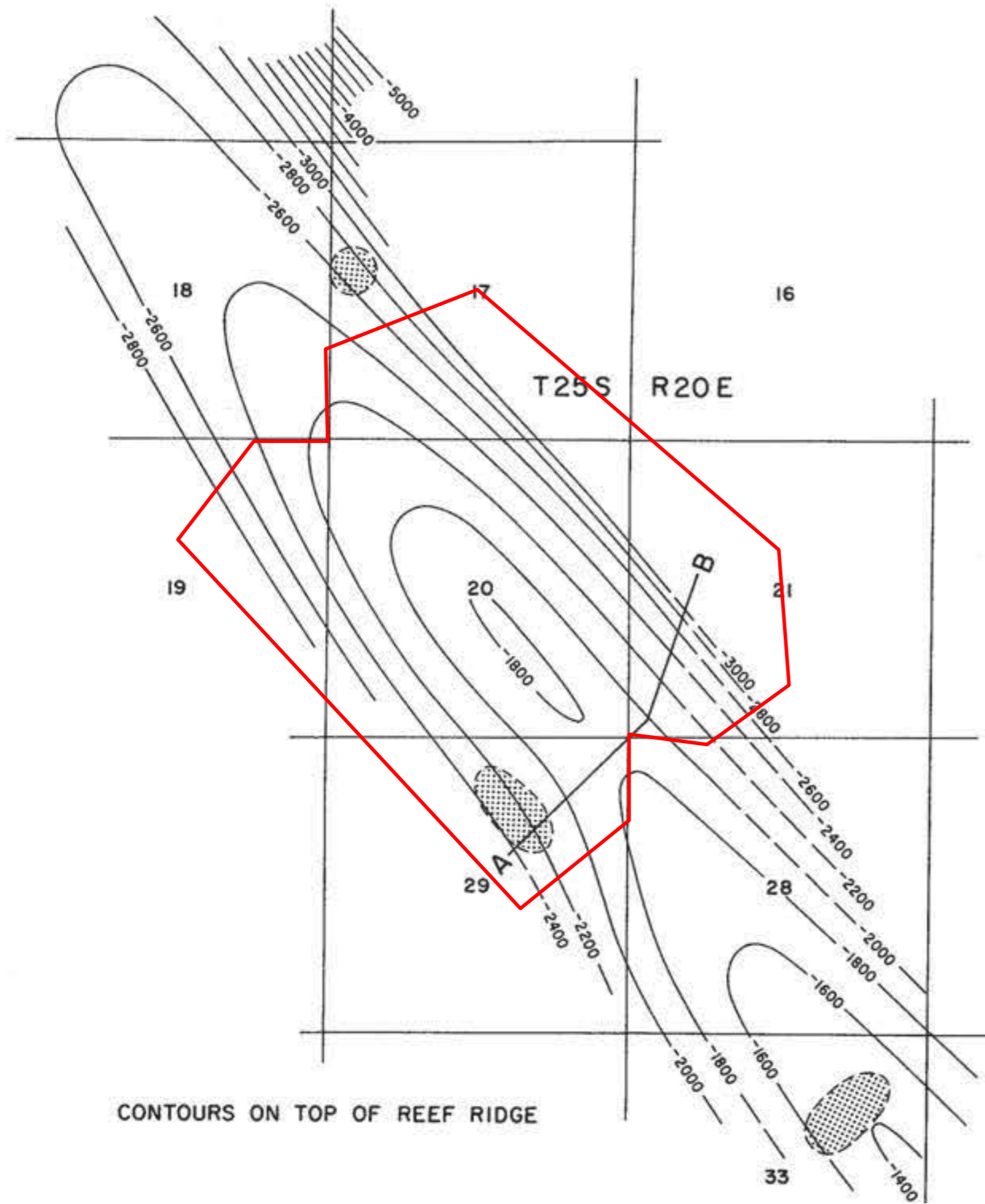
# Anisotropic Velocity Variations



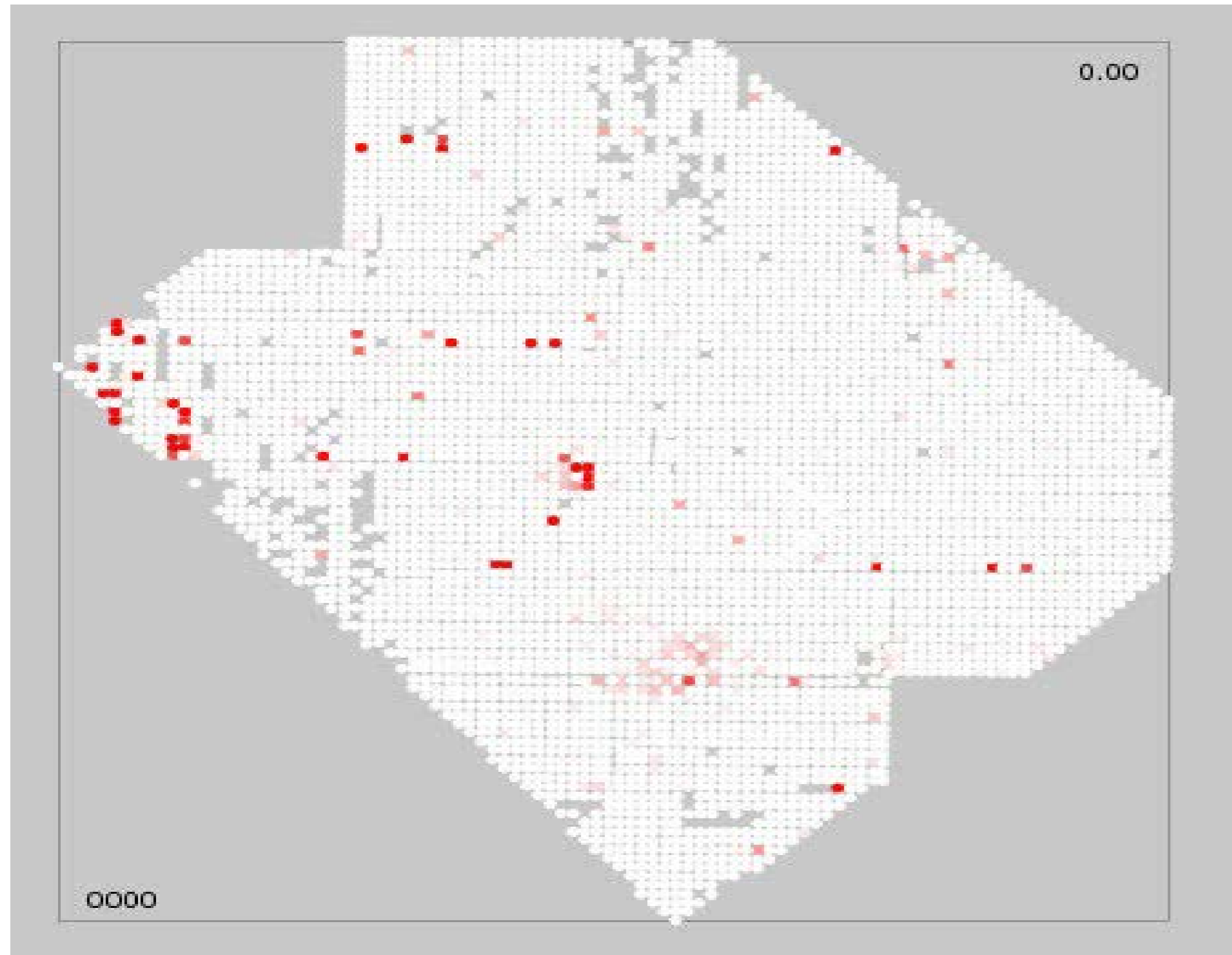
Azimuth coded by color

# Weathering Statics - Almond Crest 3D

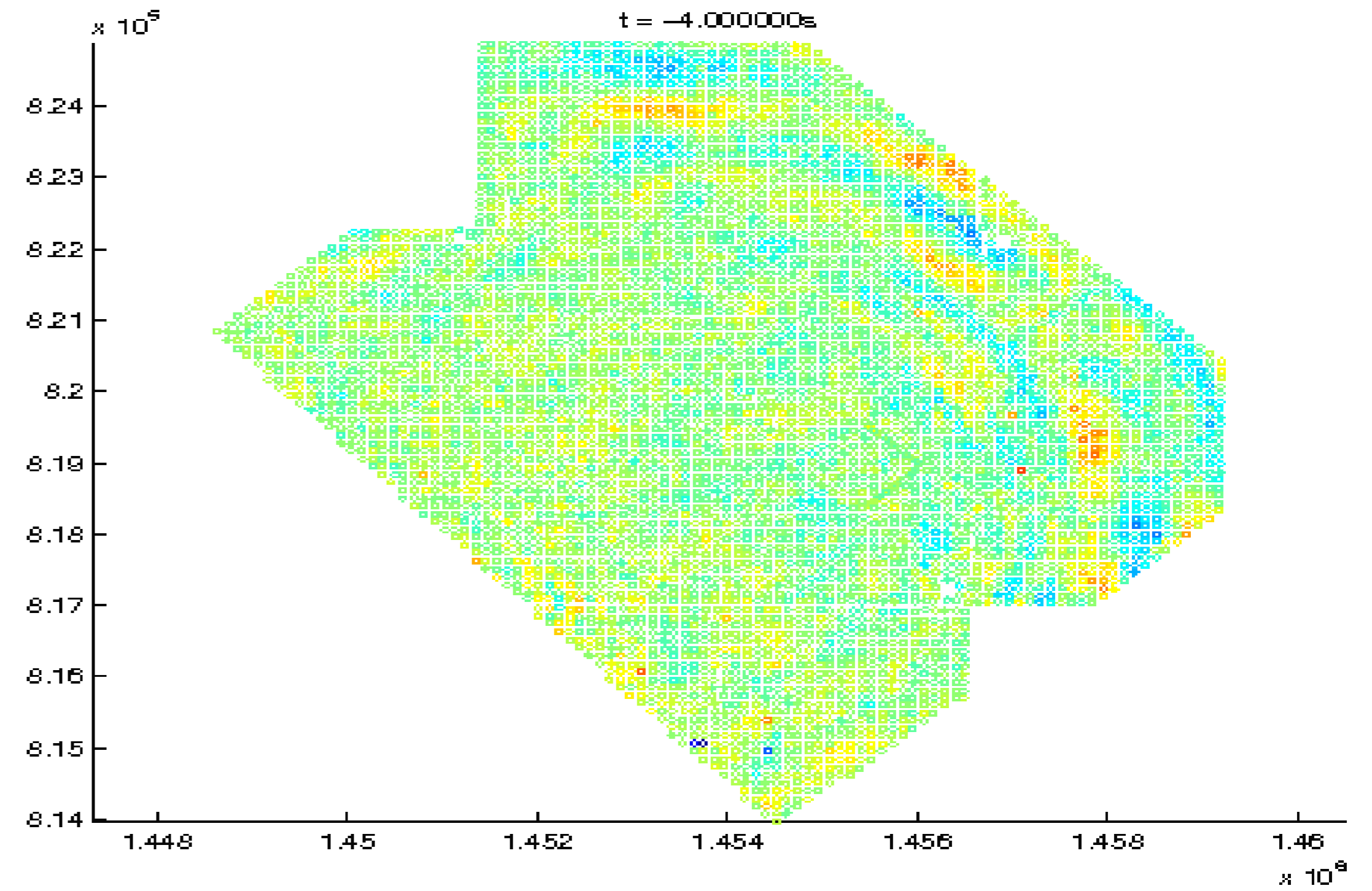
NORTHWEST LOST HILLS OIL FIELD



# Almond Crest 3D



Shot hole dynamite: 2.2# at 20'

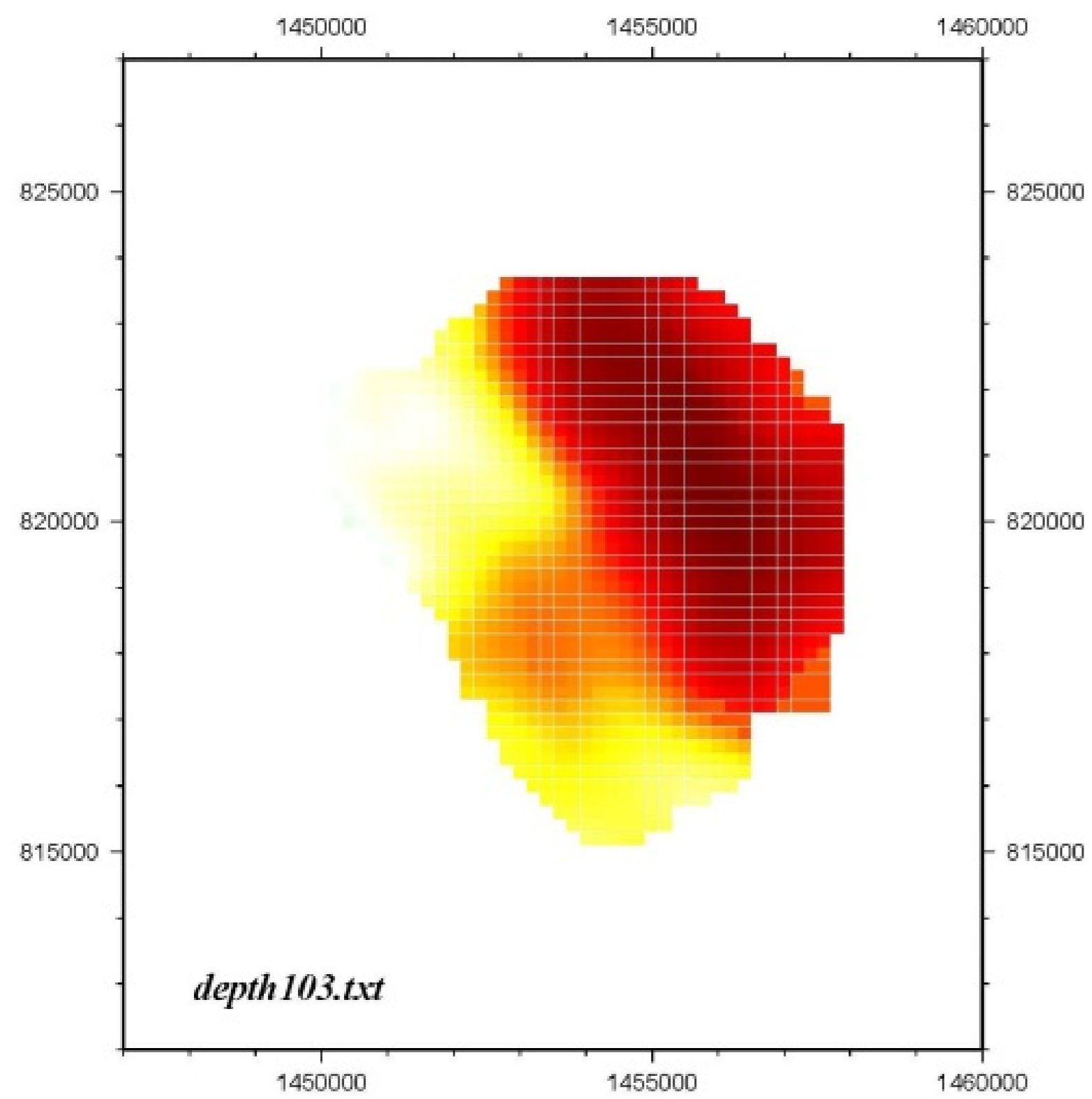


Virtual source from ambient noise cross-correlation

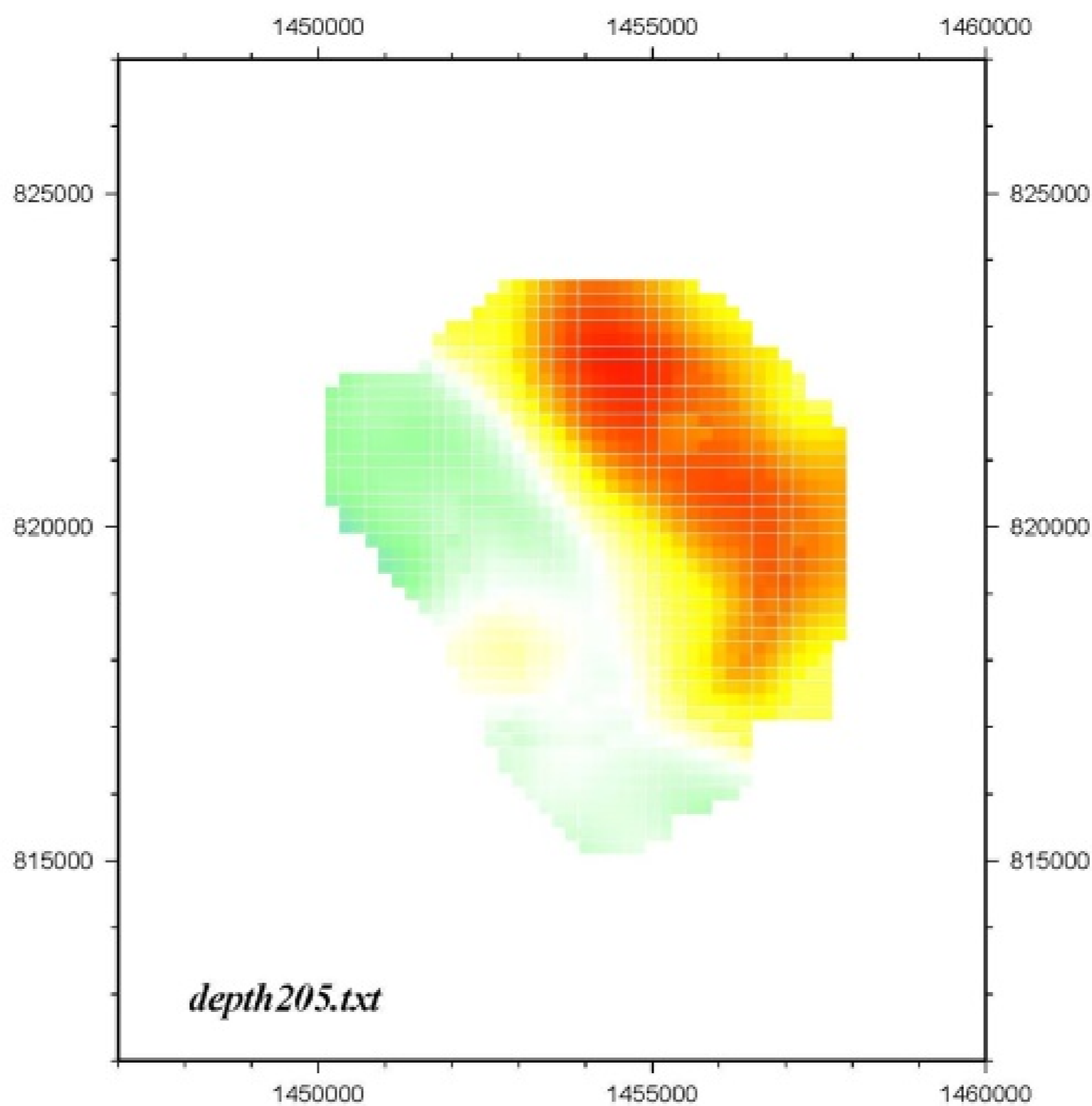
# Almond Crest 3D

## ANSWT Velocity Model

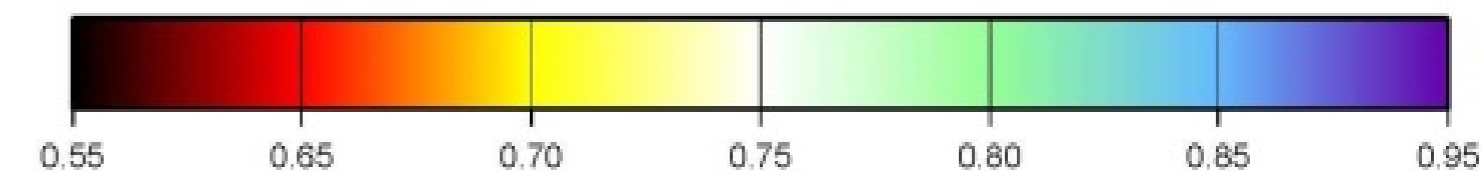
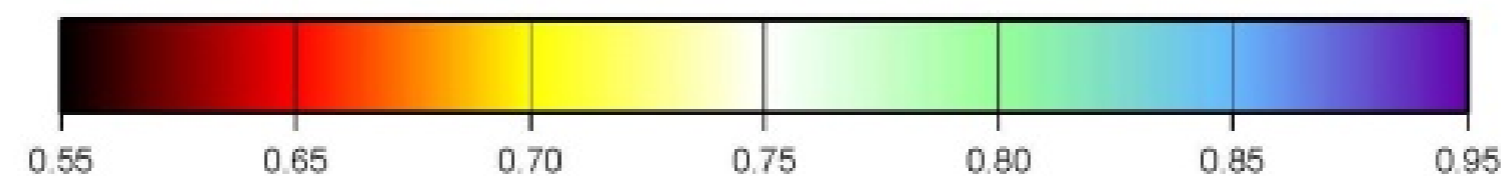
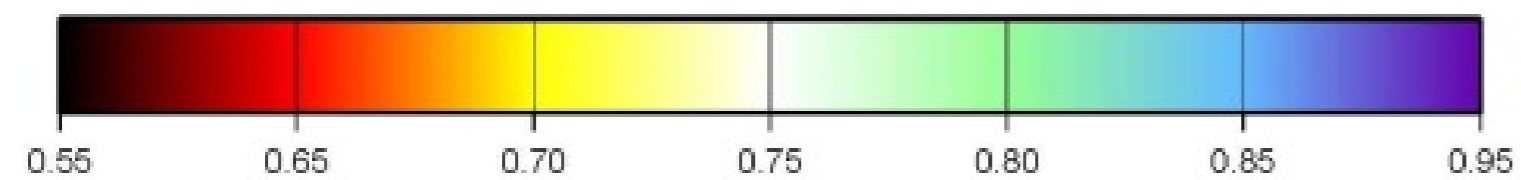
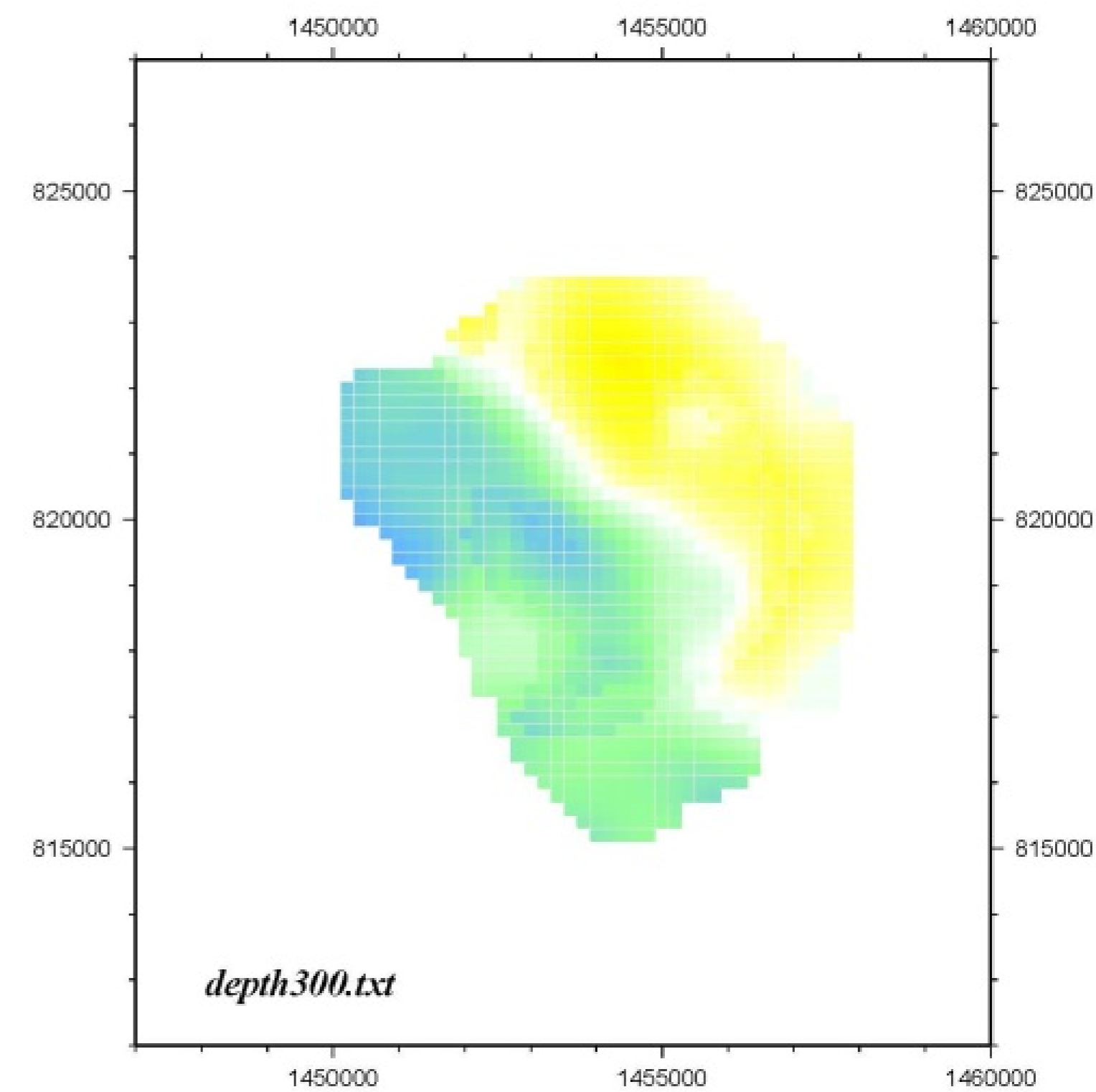
**~330'**



**~660'**

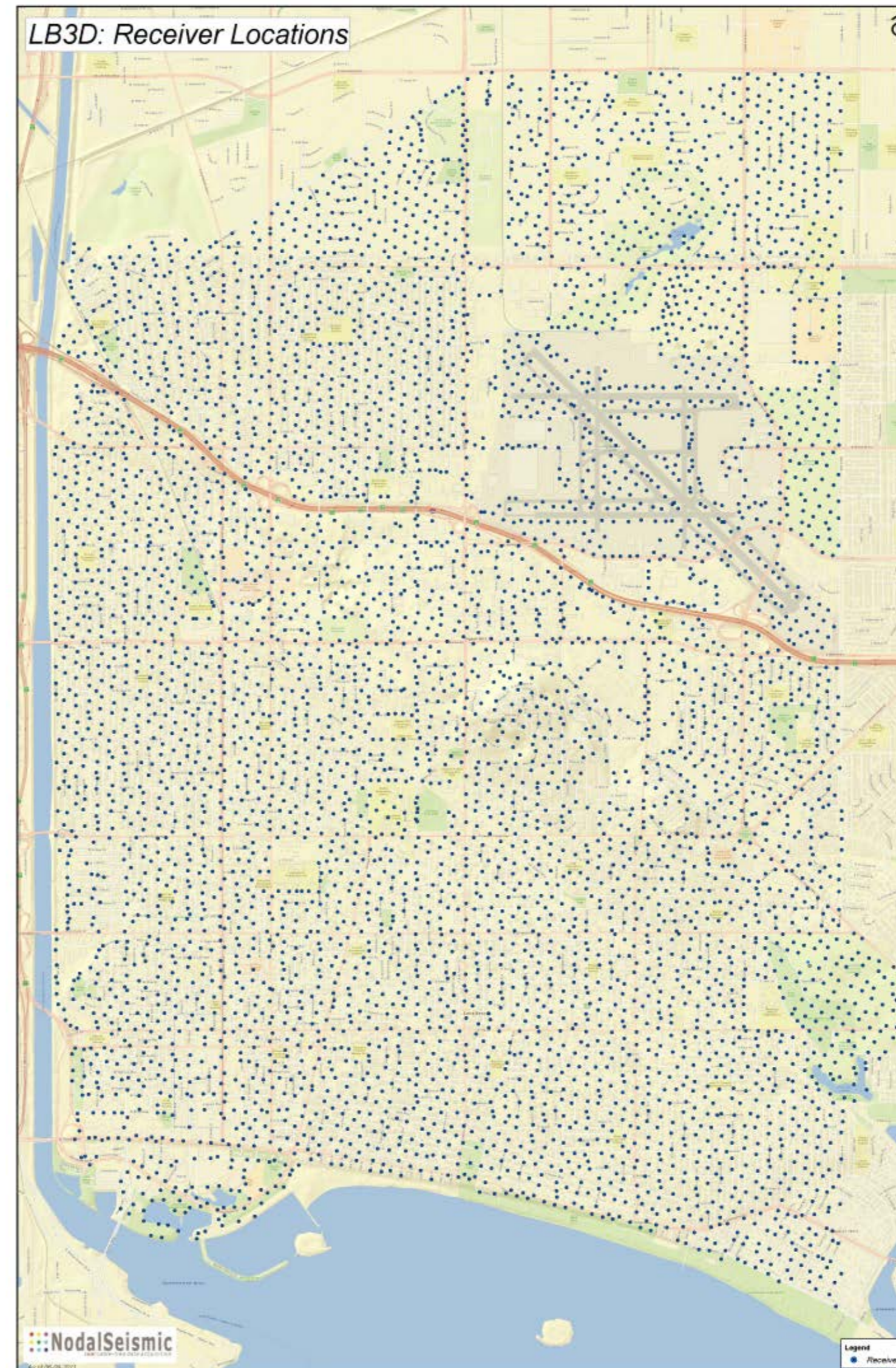
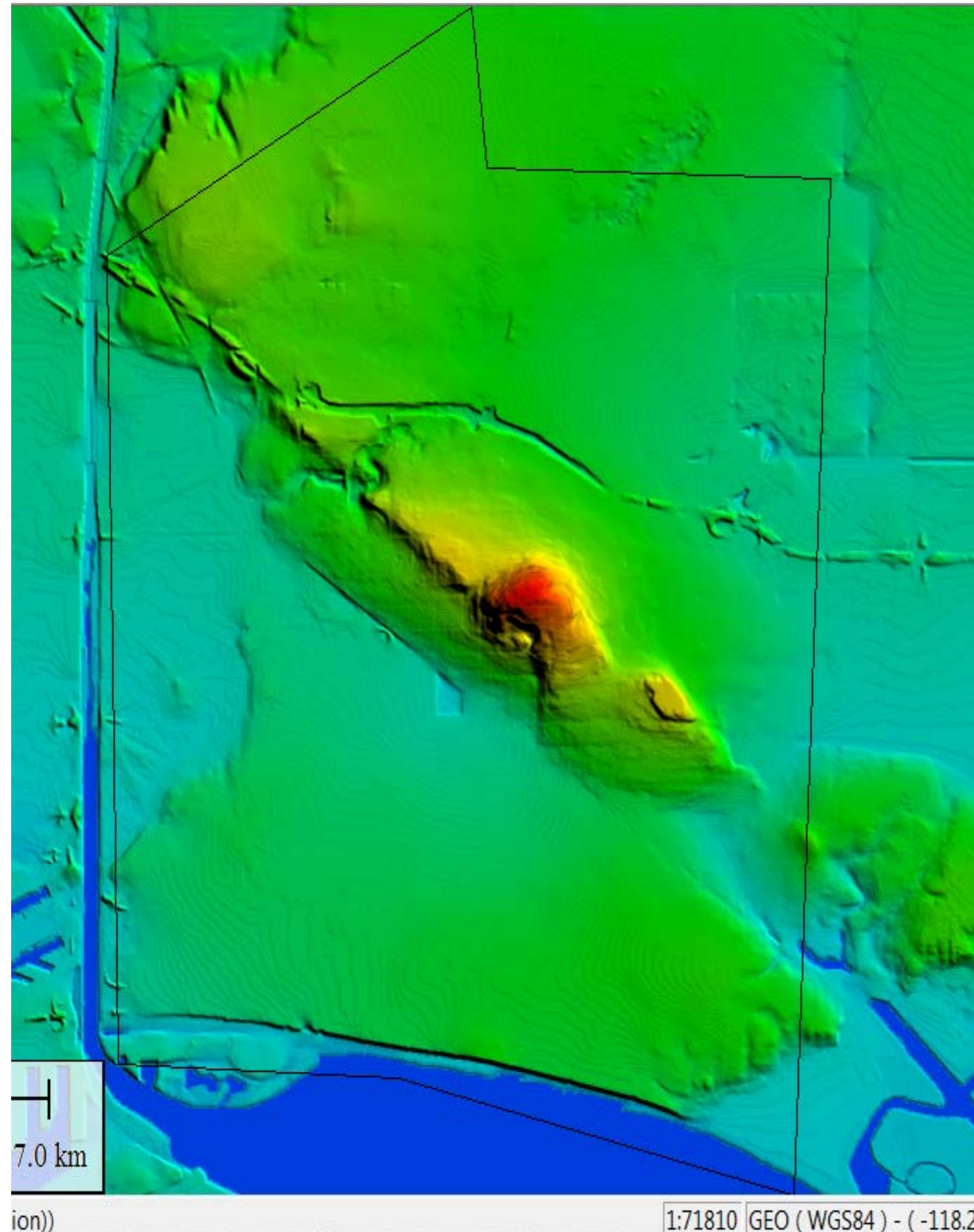


**~990'**



# Long Beach 3D Example

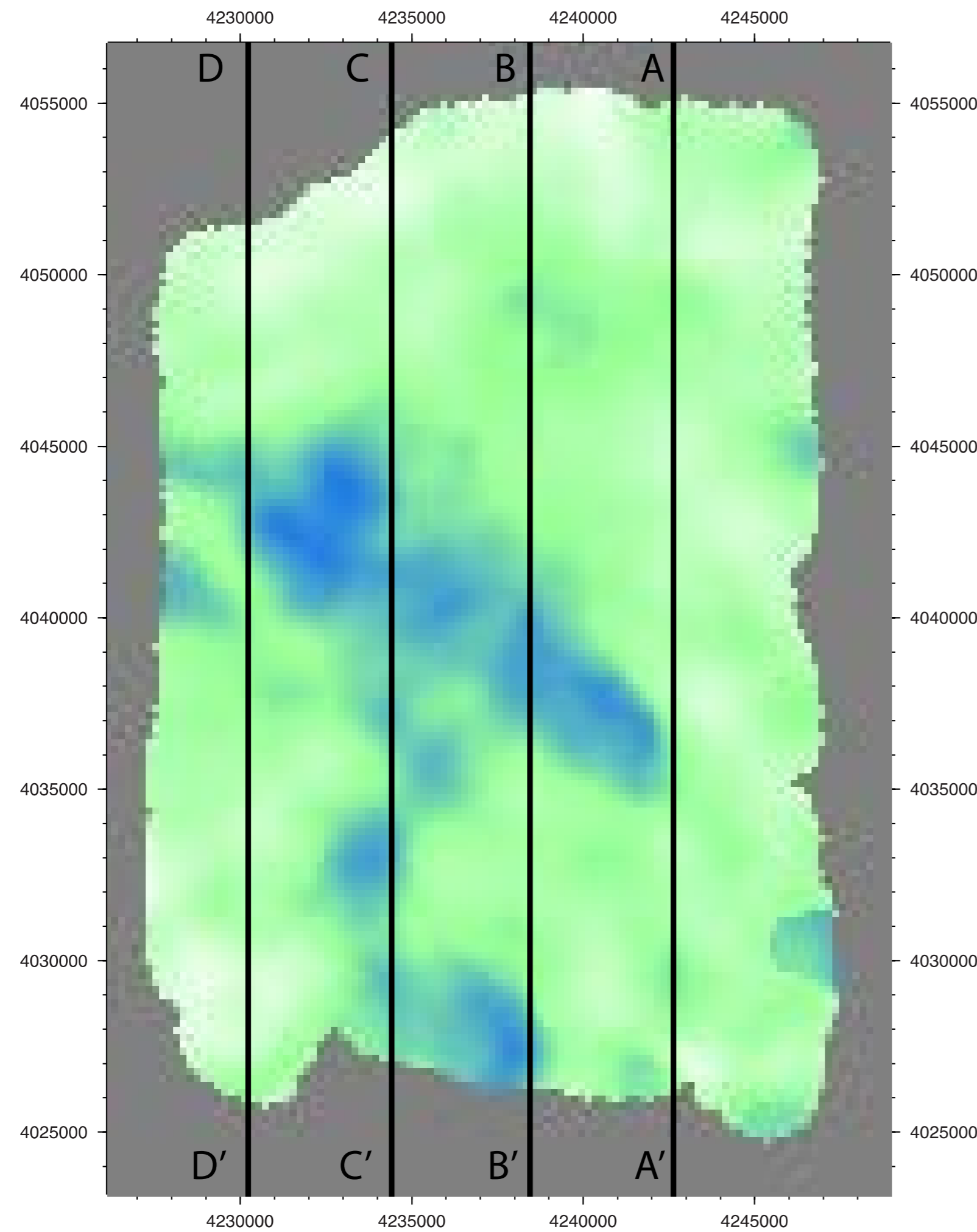
## Survey Statistics



- ~60 sq. km
- Active Source (Vibroseis)
- Urban survey
- 5400 receivers/nodes (static)
- Receiver spacing 100m inline & 100m X-line (uniform array)
- 10 Hz CT-30 geophone (vertical)
- 3 Hz low cut filter
- 6 months of continuous data
- ~150 Tbytes of data

# Long Beach 3D Example

ANSWT Velocity Model ( $V_s$ )



A'

B'

C'

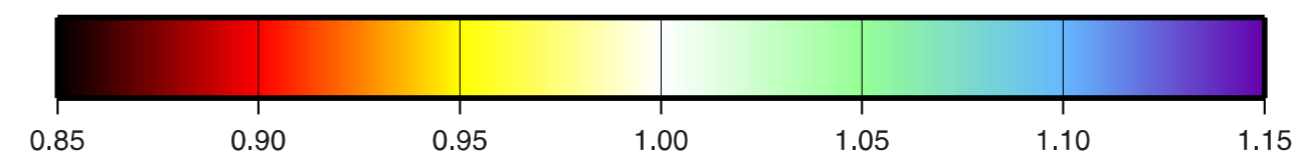
D'

A

B

C

D



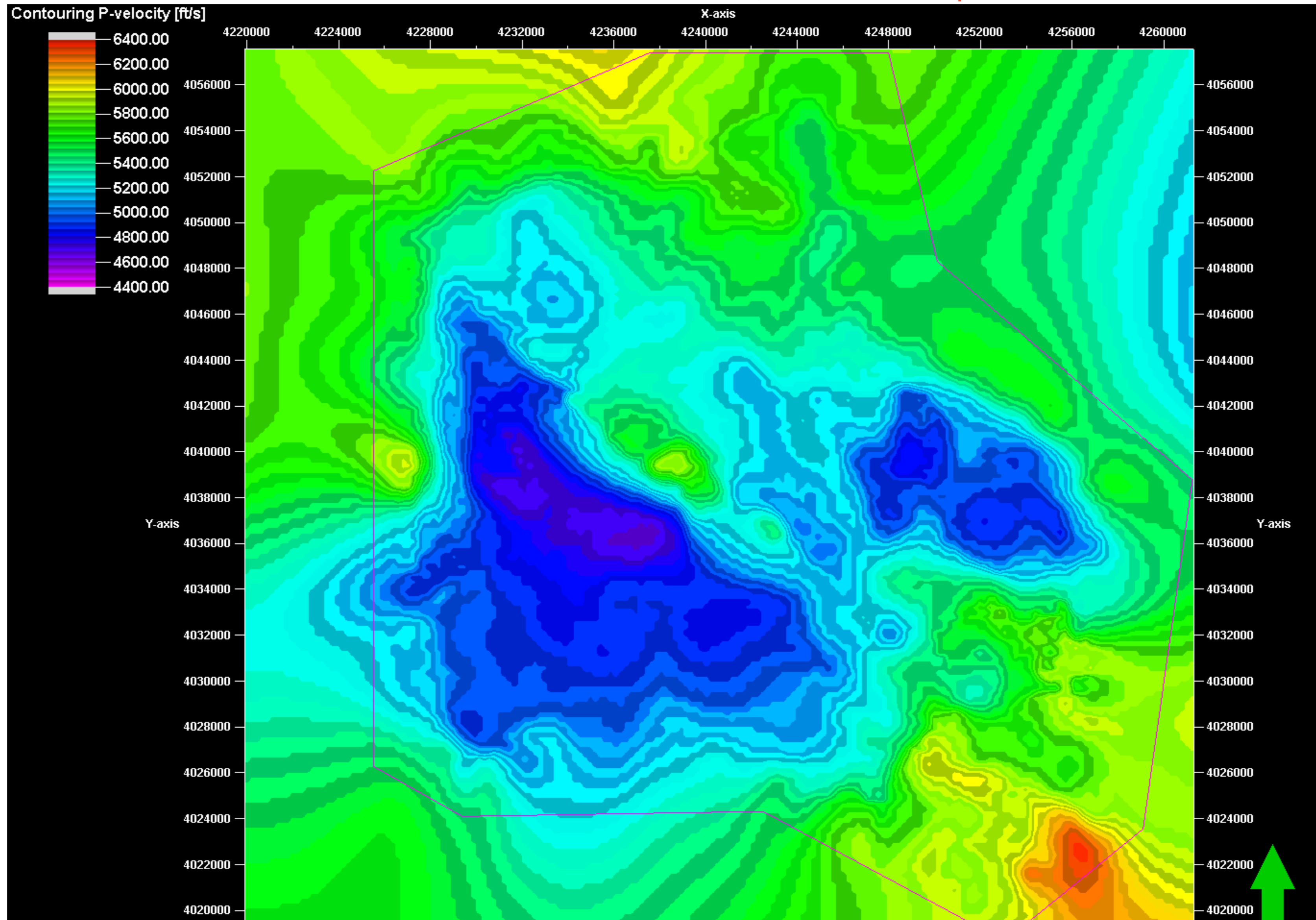
Relative  $V_s$

$V_s$  (km/sec)

By Fan-Chi Lin

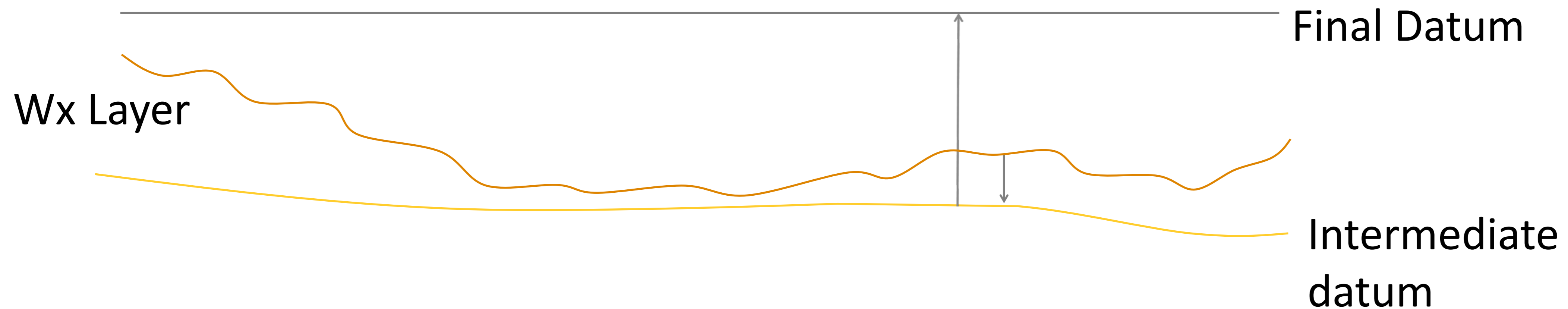
# Long Beach 3D Example

## Depth Slice of 3D Velocity Model ( $V_P$ )



## Weathering Statics Derivation

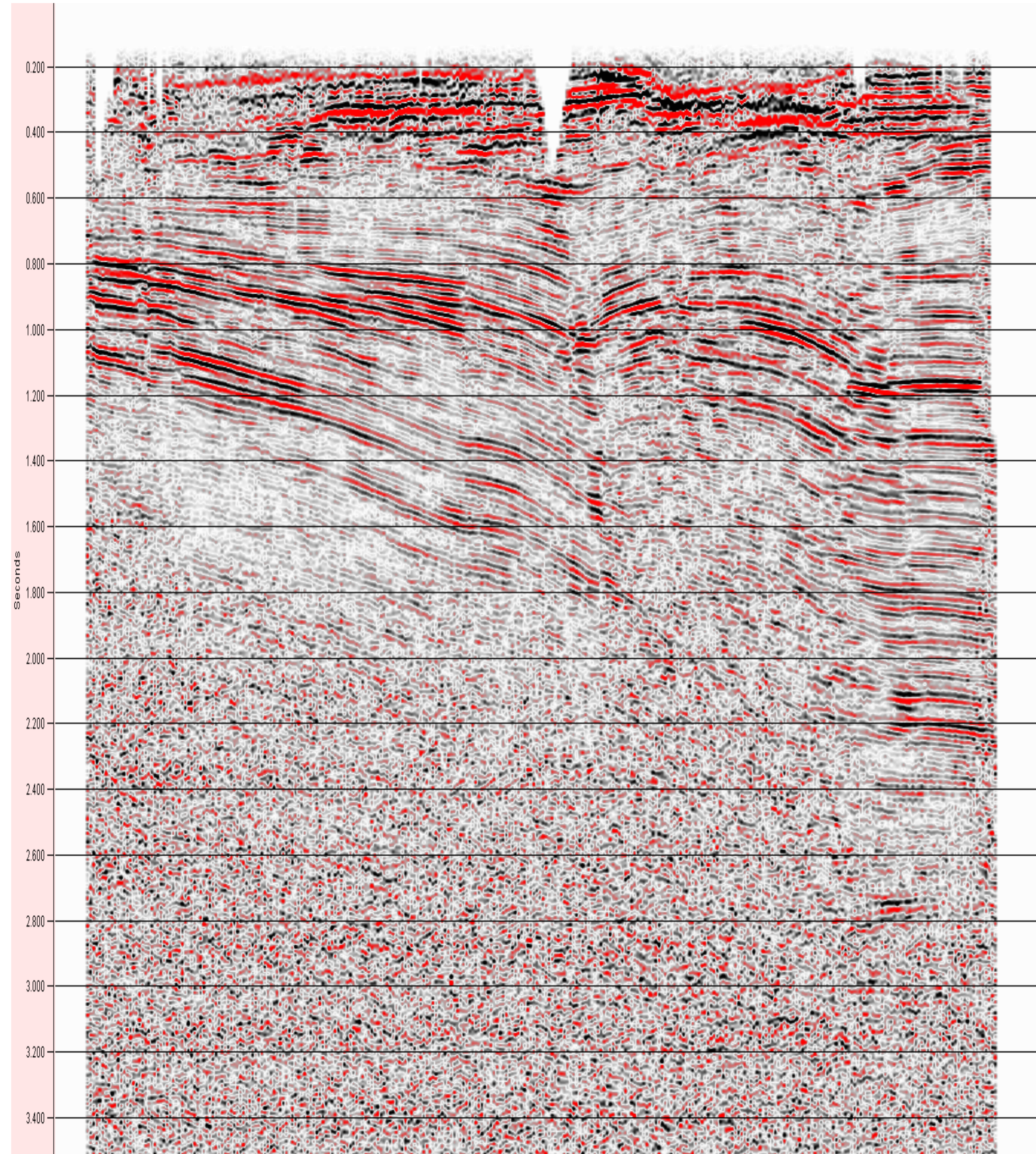
- Calculate time shifts from topography down to intermediate datum through P-velocity model and then to final datum using replacement velocity



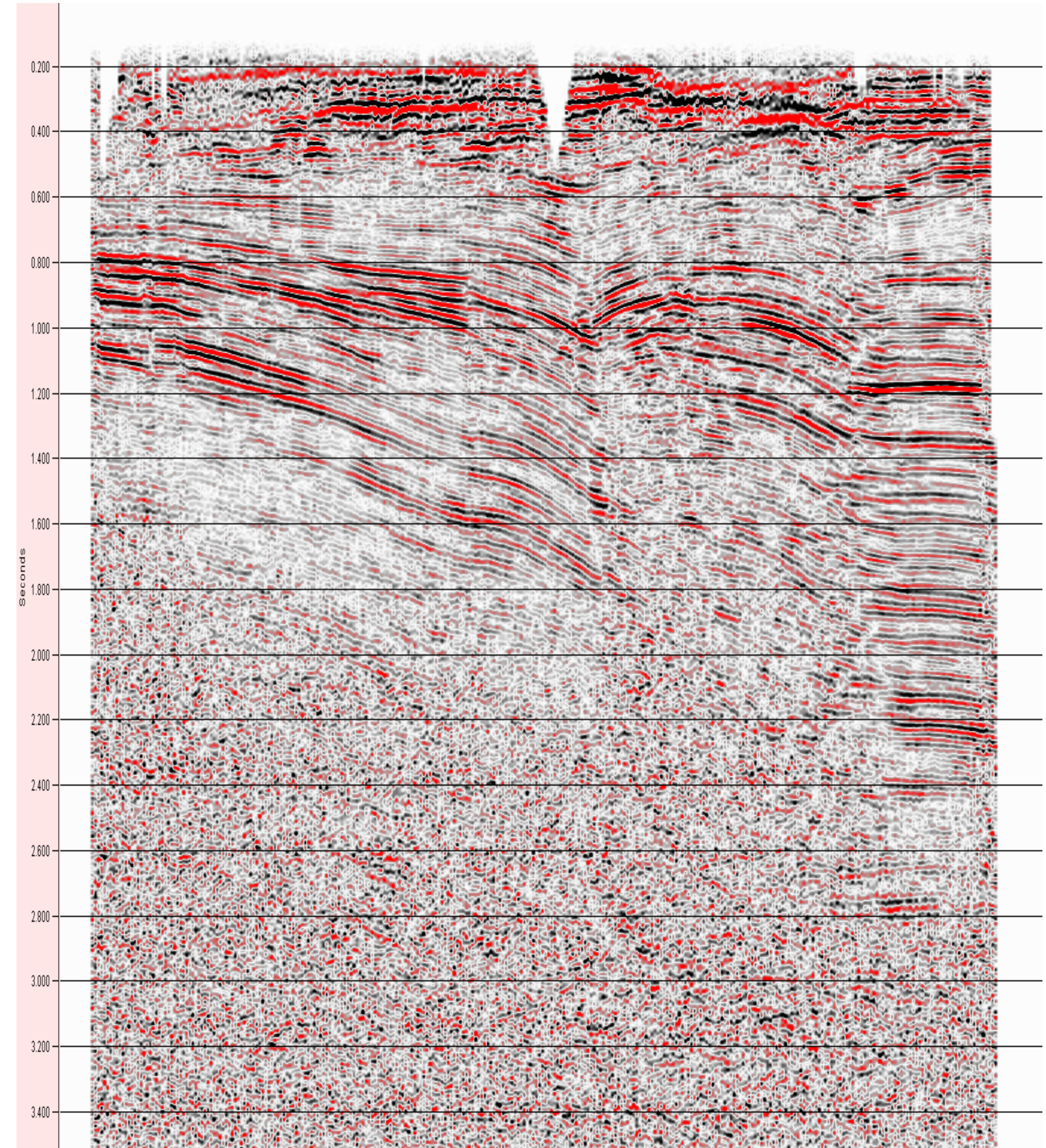


# Long Beach 3D Example

Without Statics

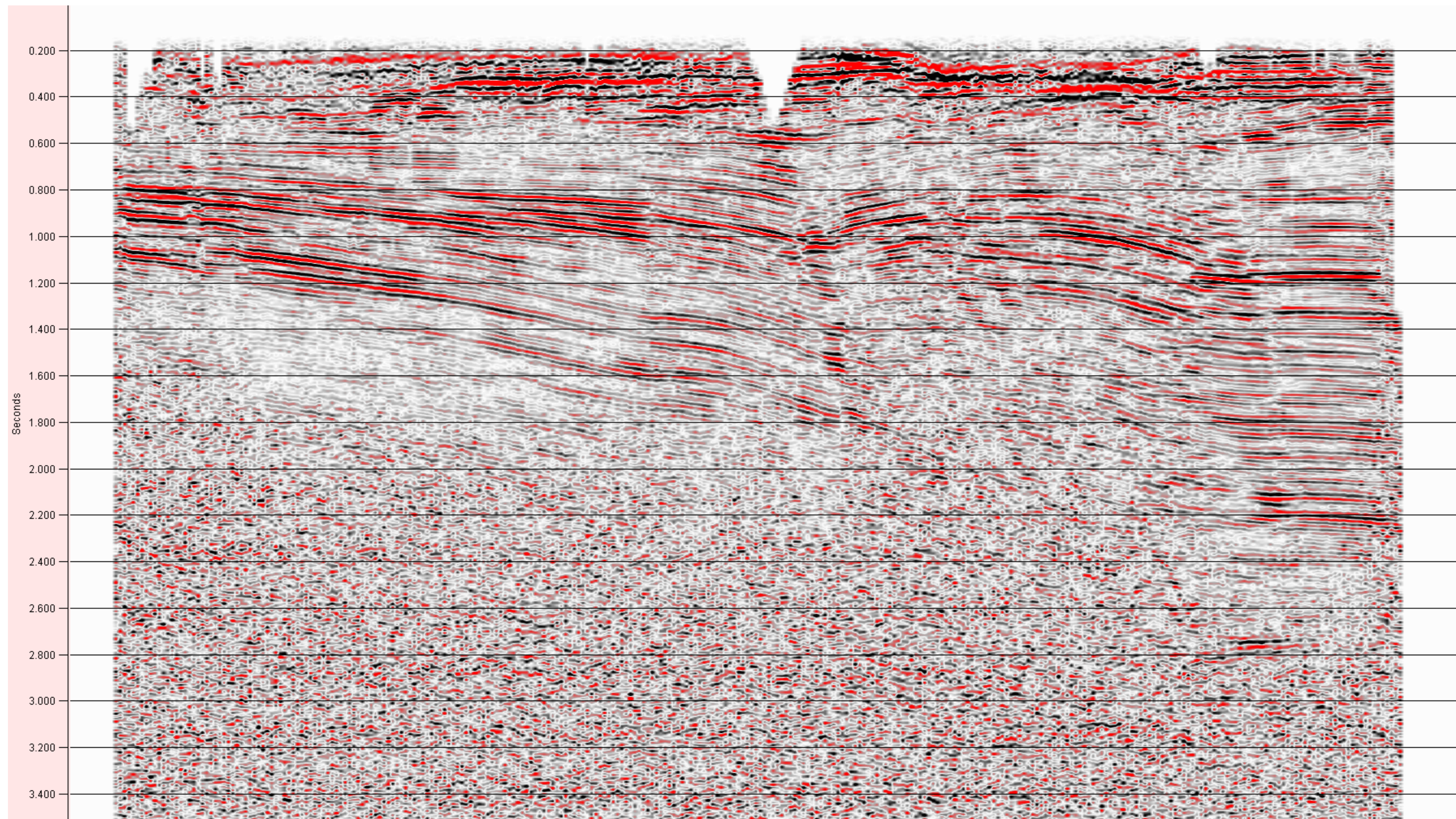


With Statics



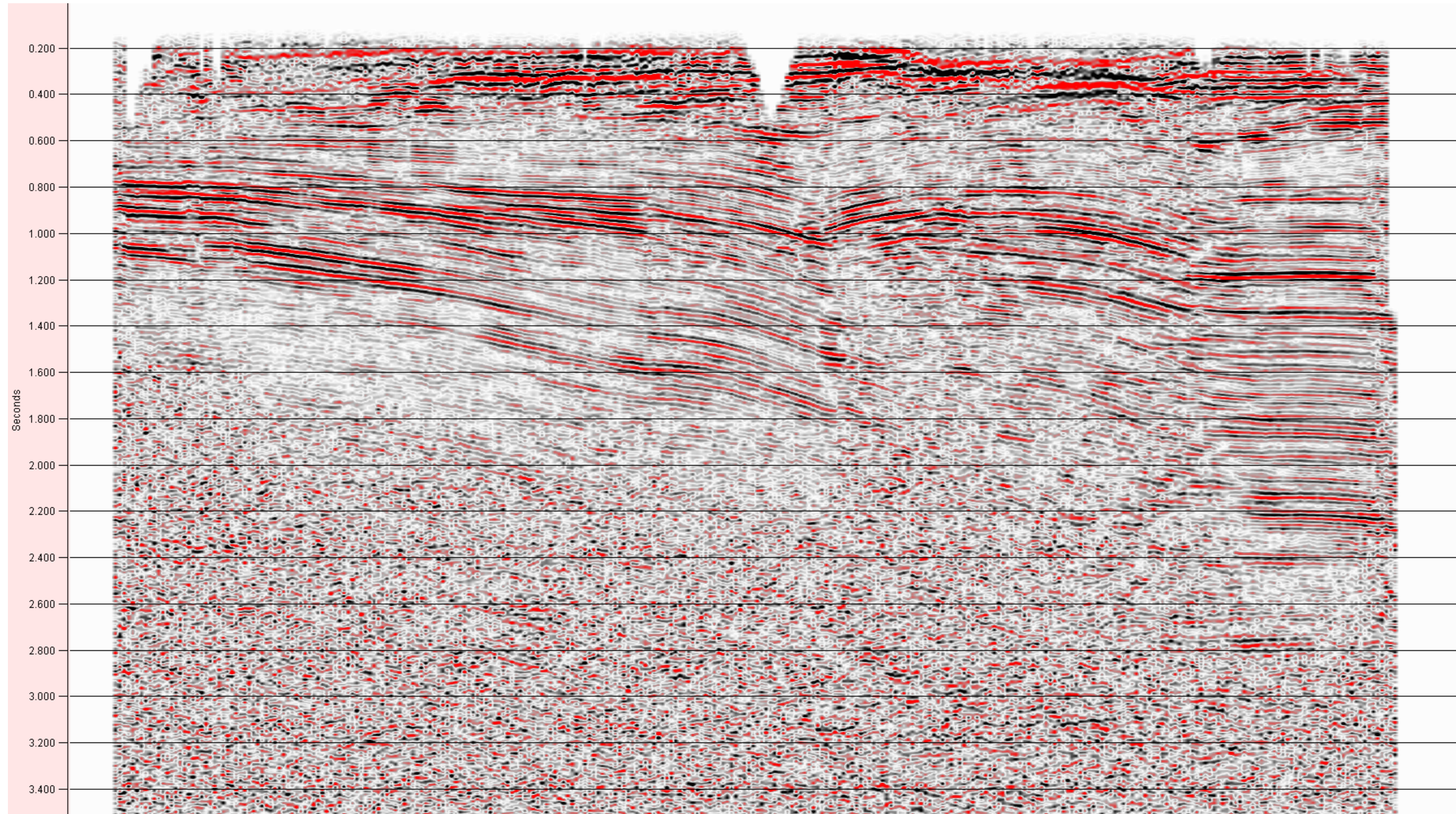
# Long Beach 3D Example

Elevation Statics Only



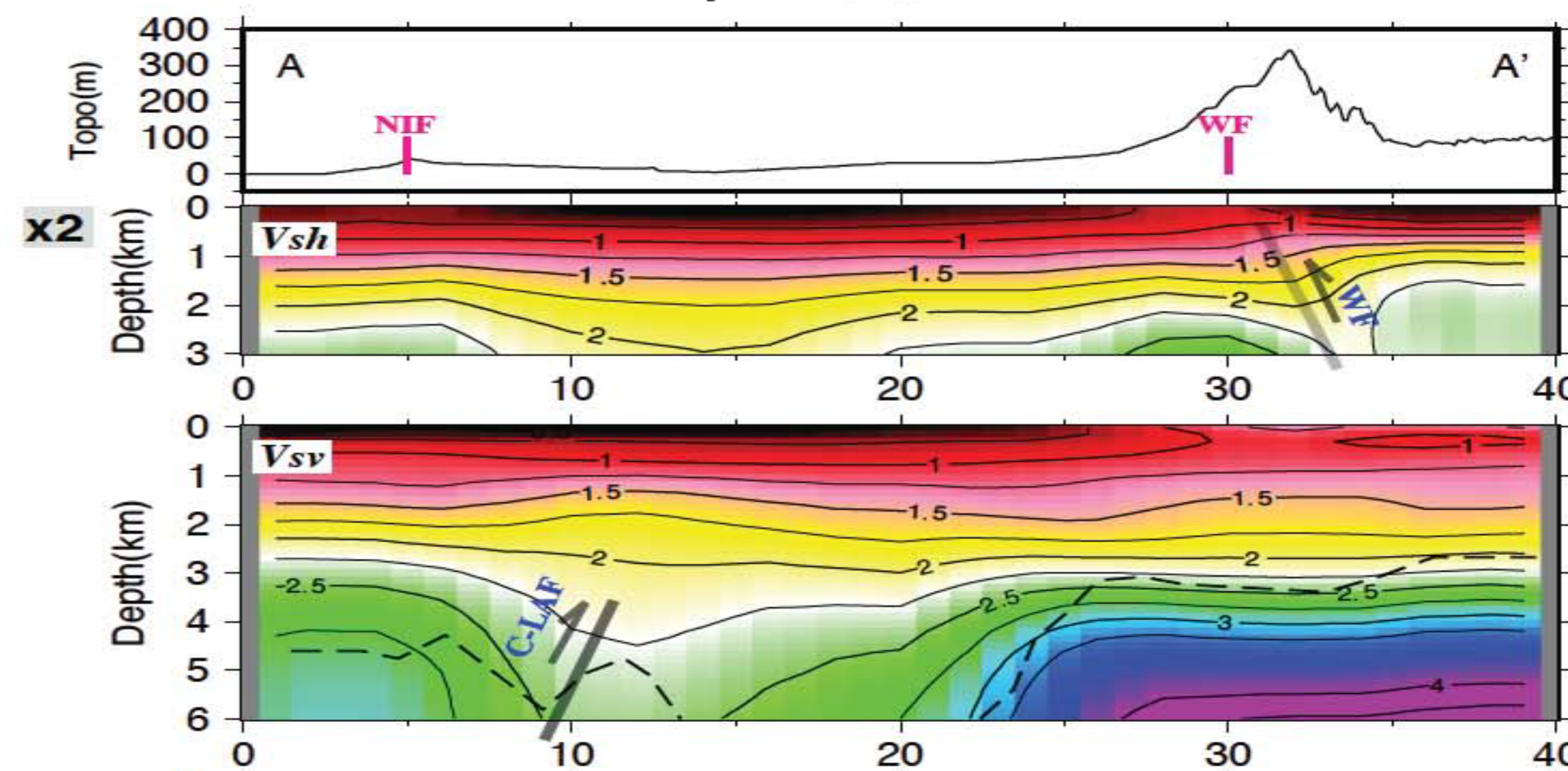
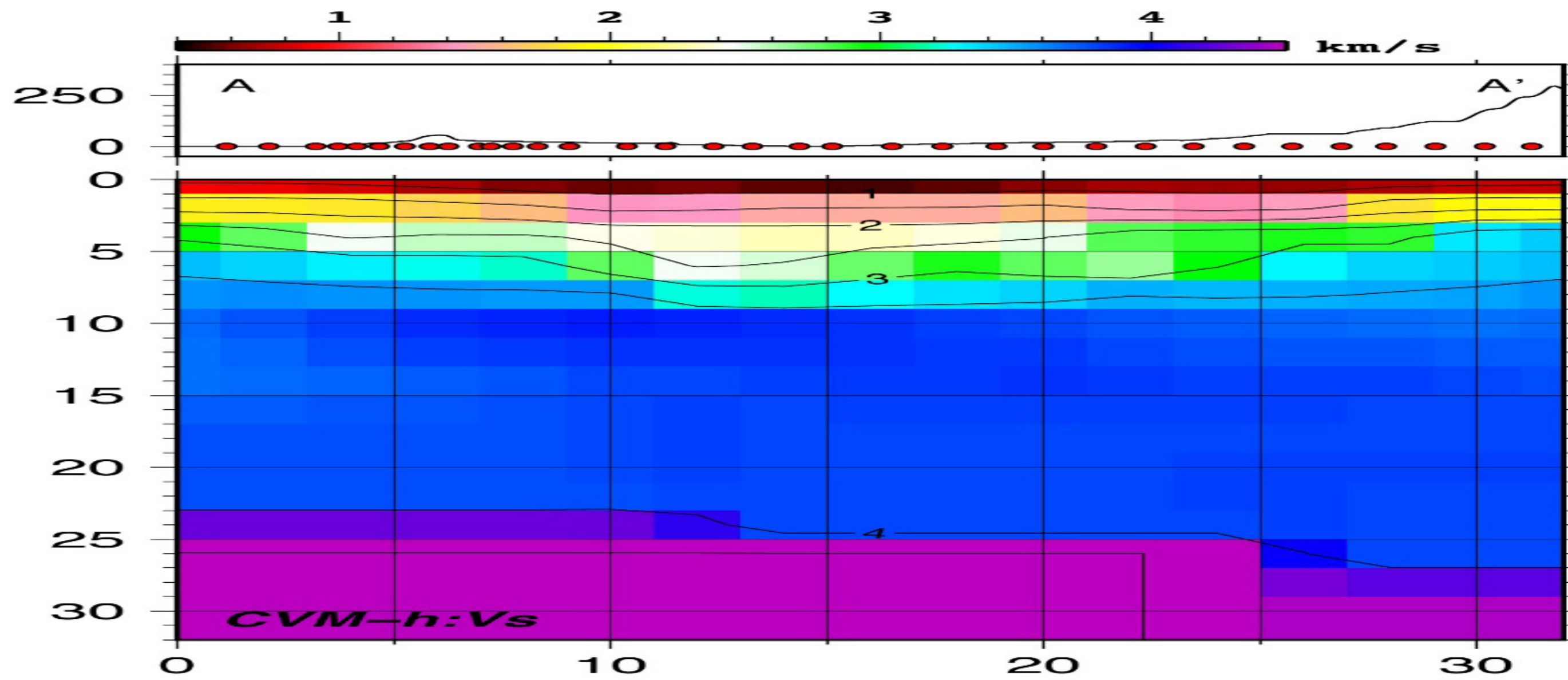
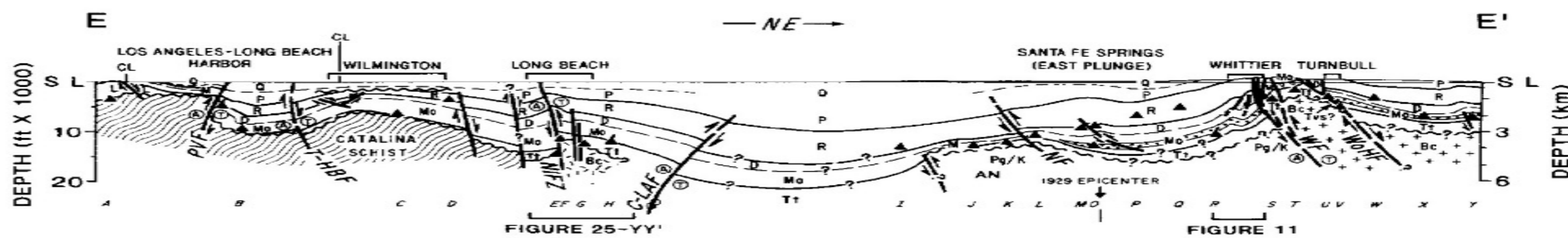
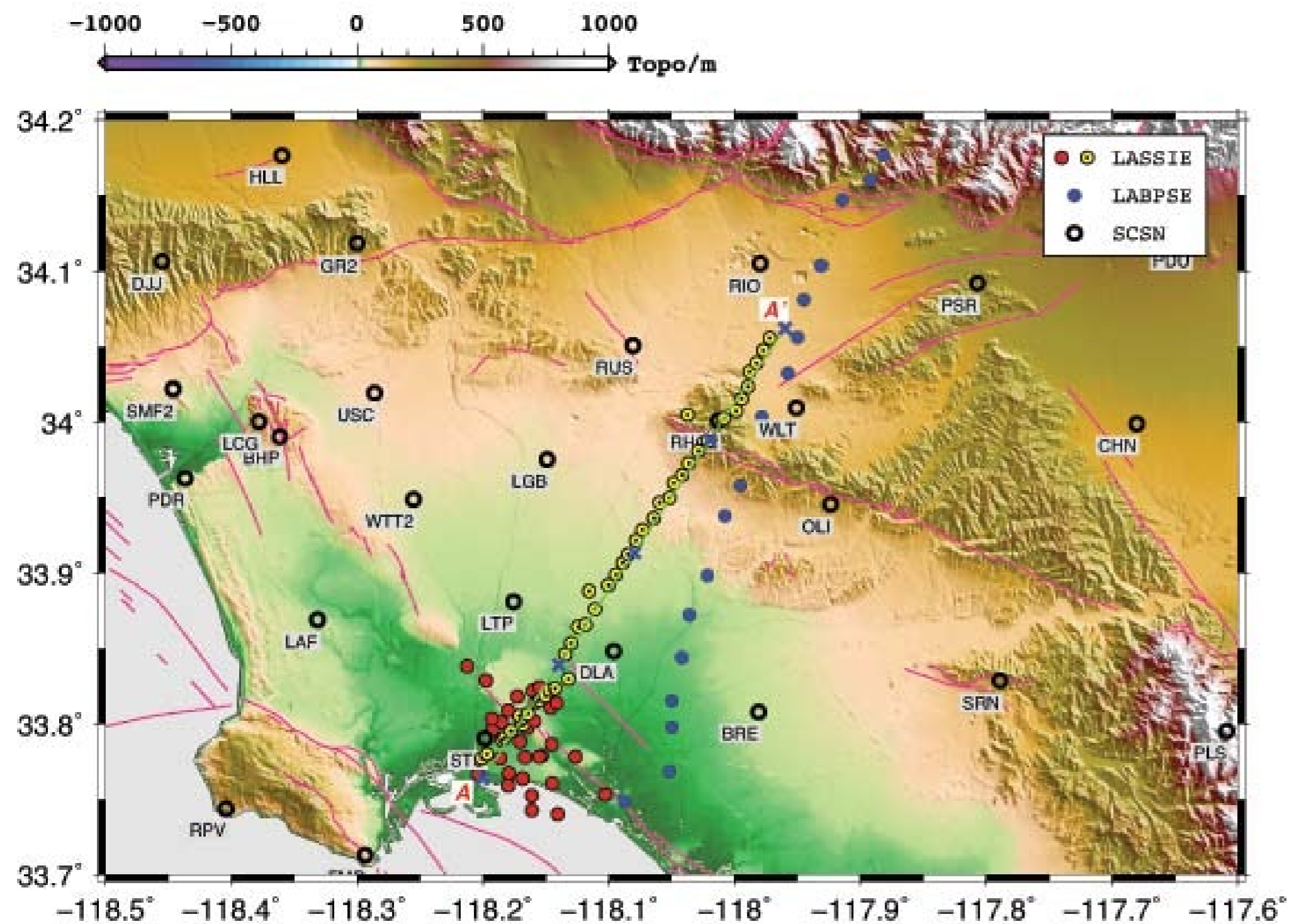
# Long Beach 3D Example

Elevation plus ANSWT-derived Statics



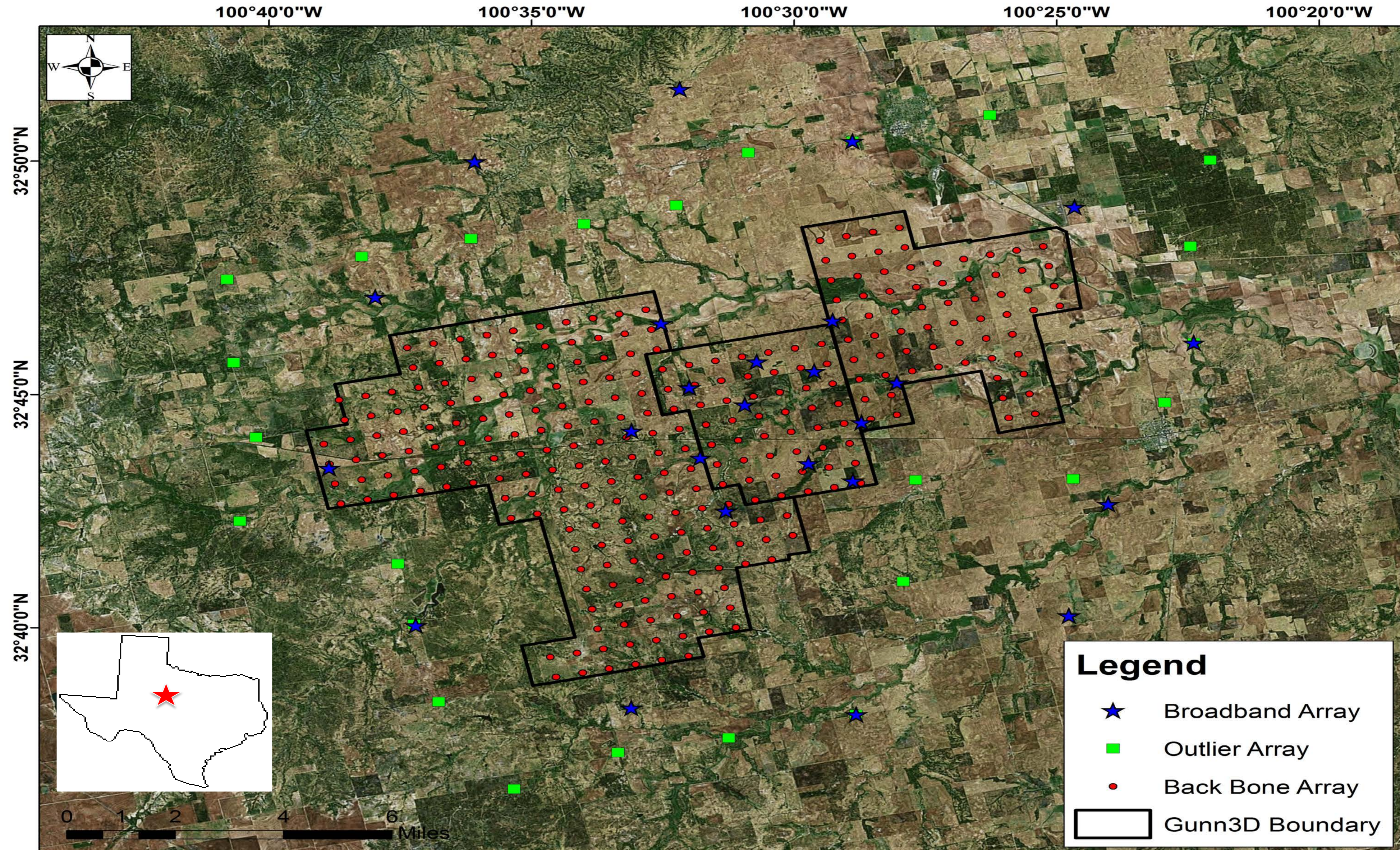
# LASSIE Experiment

## ANSWT Imaging

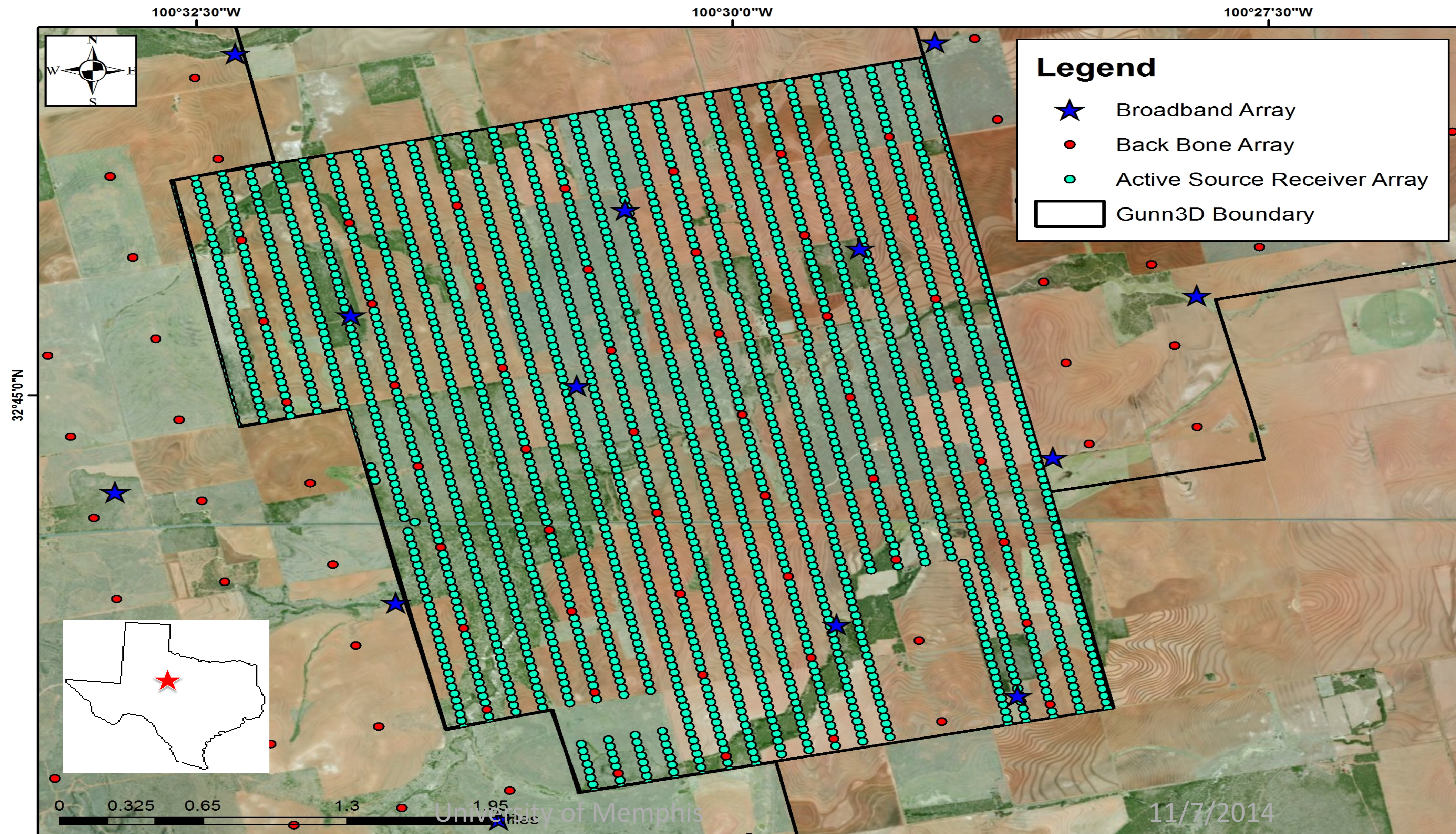


Ma and Clayton, 2016

# Sweetwater 3D Seismic Array



# Sweetwater 3D Seismic Array



25 broadband stations

5 Polar Trillium 120PHQs (From NSF equipment at PIC)

21 Trillium Compact Postholes from Nanometrics

Centaur digitizers from Nanometrics

25 Polar quick deploy enclosures

2639 ZLand nodes

6" height - 5" diameter - 4.8lbs

Single component vertical geophone

10 Hz natural frequency

2 week battery life

GPS for timing

24 bit analog to digital converter

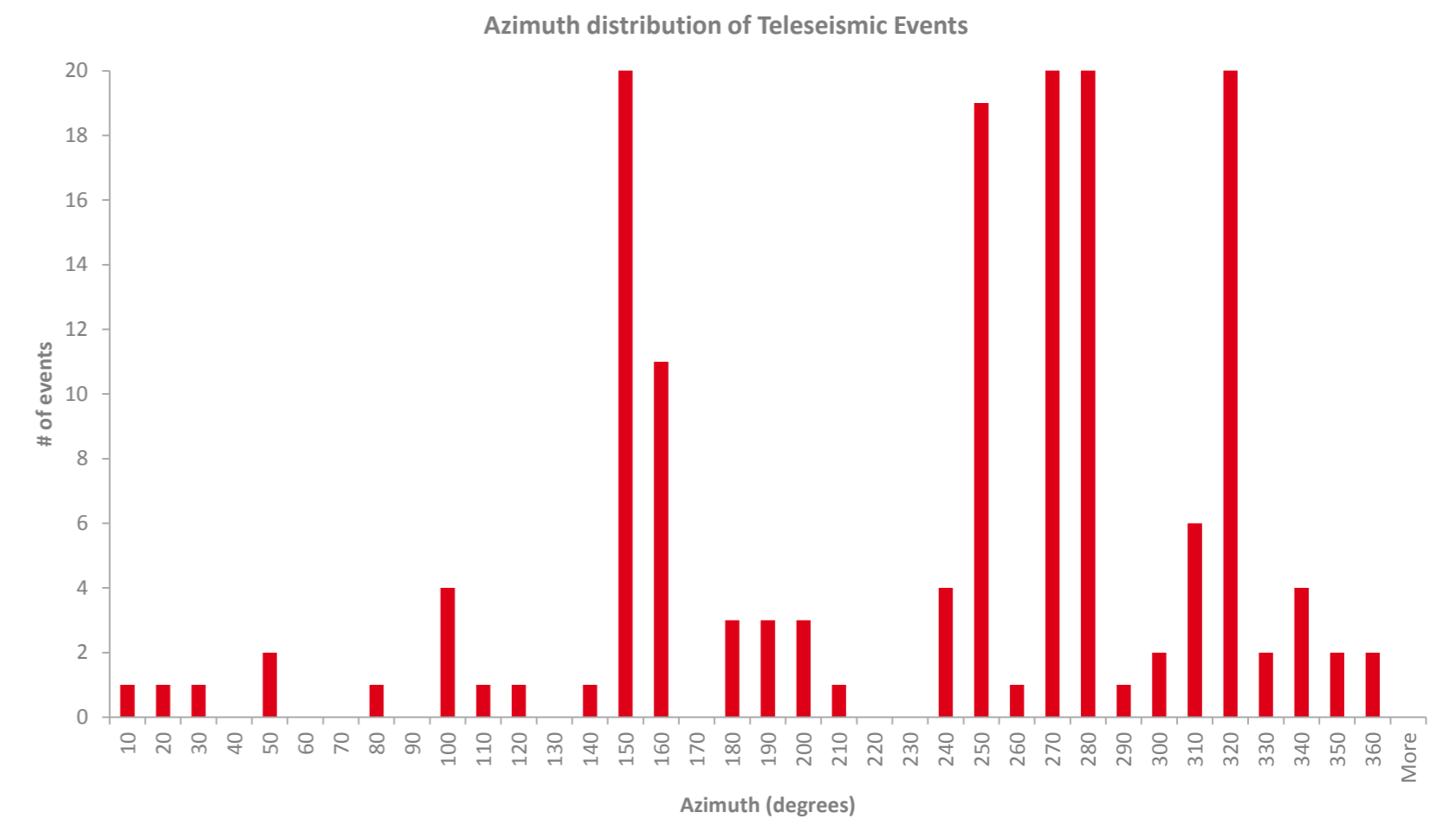
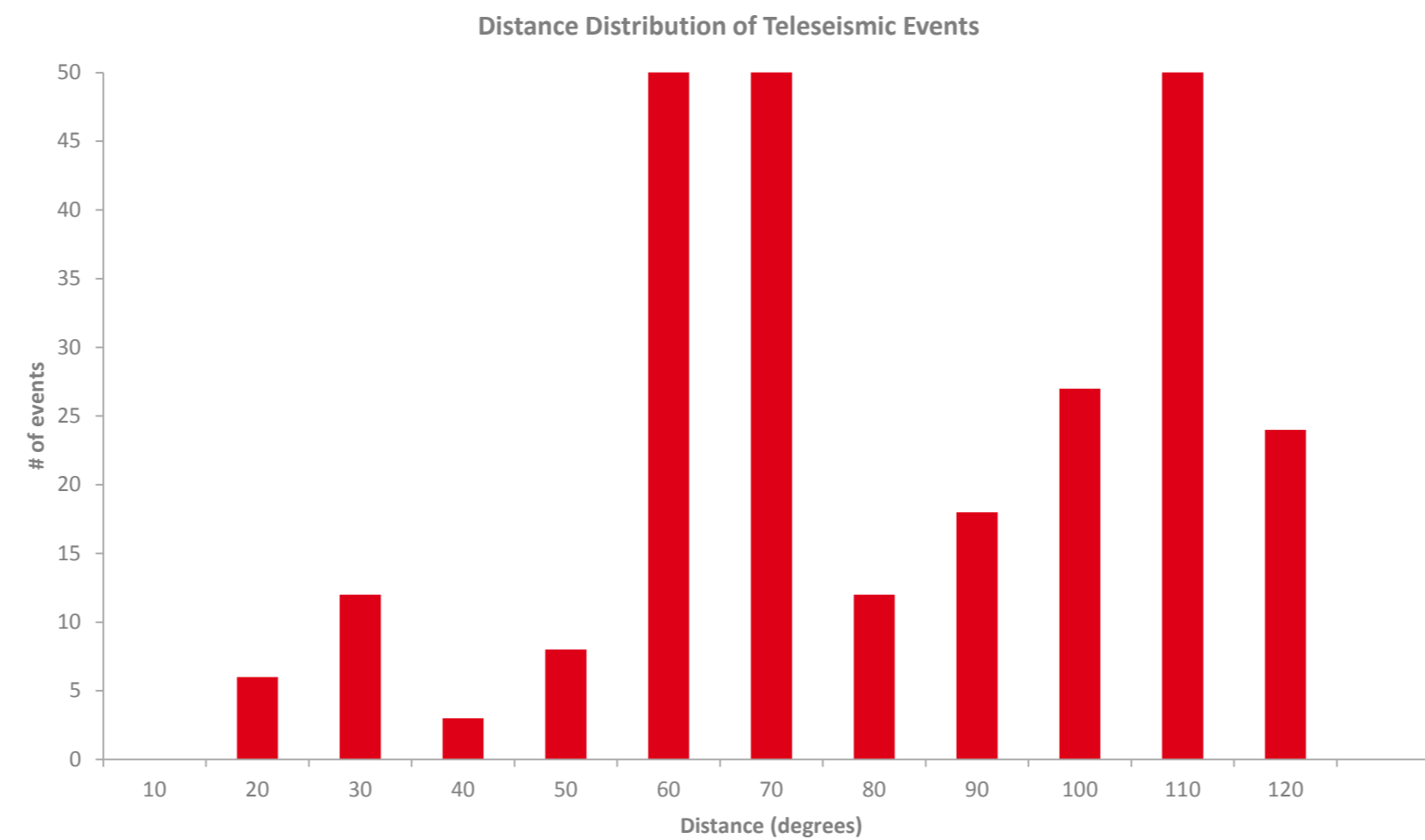


# Sweetwater 3D Sources



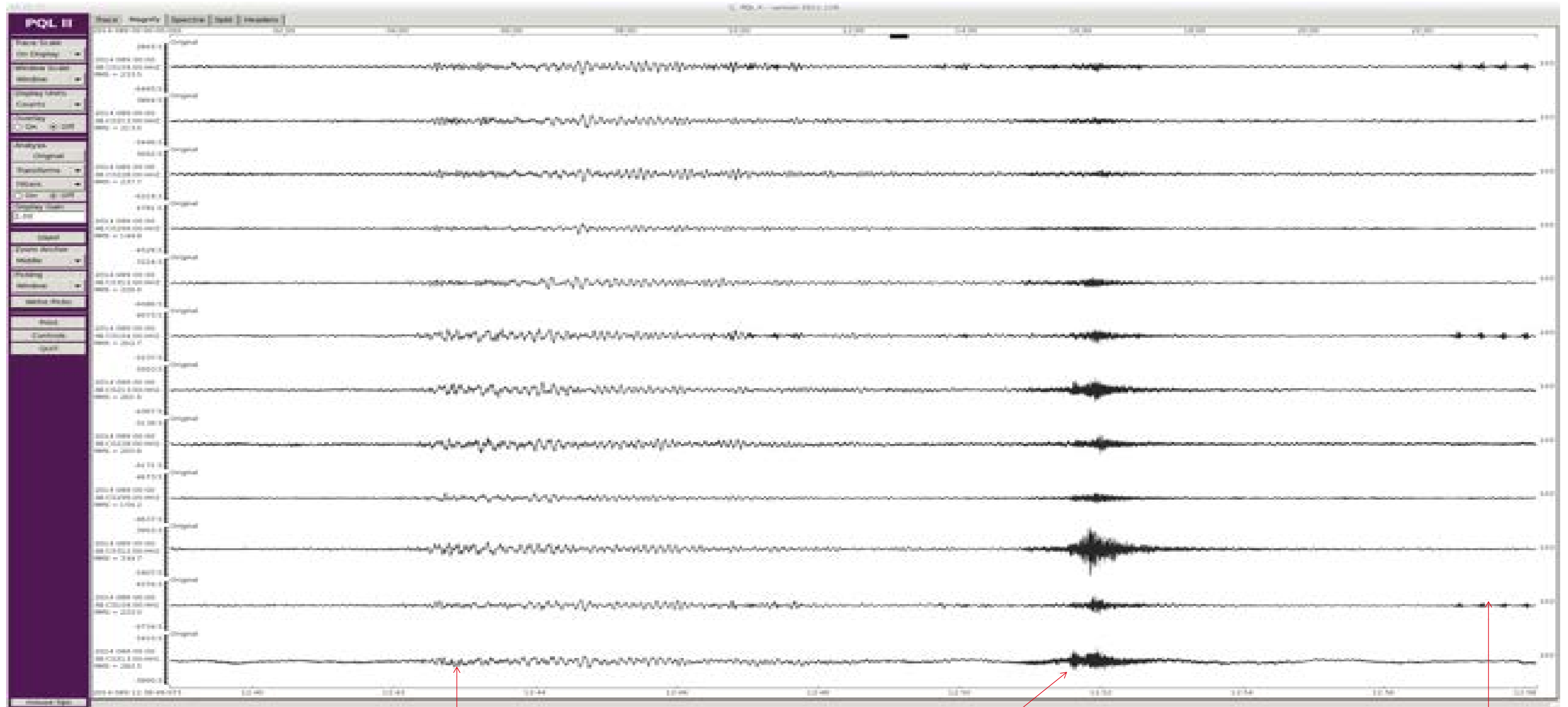
- Vibroseis sweep
- Teleseismic Earthquakes
- Regional Earthquakes
- Microseismic Earthquakes?
- Injection wells
- Oil Pump Jacks
- Large wind farms
- Fracking wells
- Roads
- Farm machinery

Teleseismic EQs	
M>8	1
M>7	6
M>6	27
M>5	267





# 3 Events on Sweetwater Broadband Array

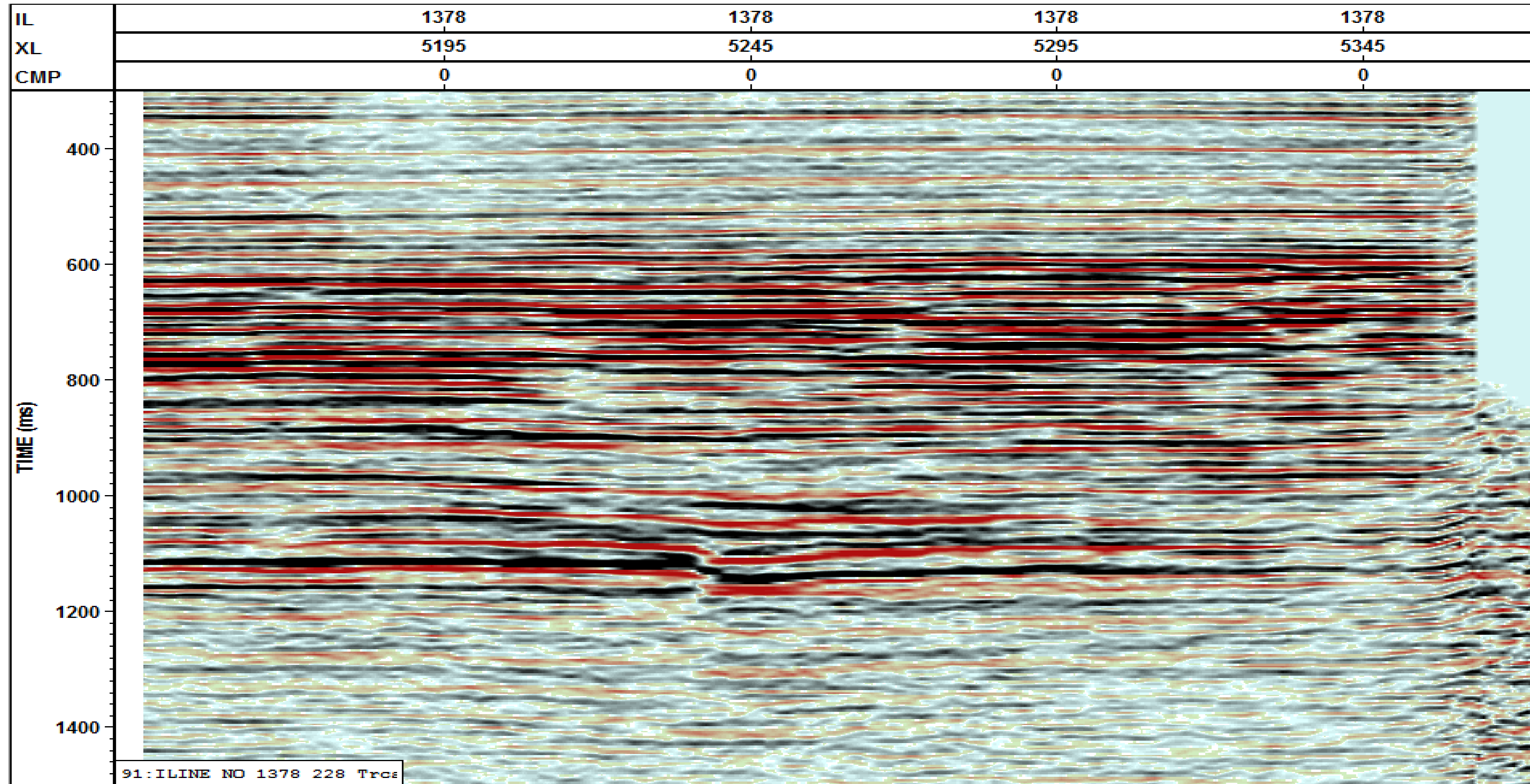


M4.8 in Yellowstone

EQ in Oklahoma

Vibroseis (4 sweeps)

# SWEETWATER 3D PSTM



# Summary

- Evolution to nodal active source instruments enables new opportunities
- Improve active source imaging (velocity model)
- More information about the subsurface
- Growing untapped data
- Need for infrastructure (people, methods, software, etc.) to exploit data
- If not La Jolla, consider Grenoble...