P and S Travel Time Tomography Using a Dense Array of Portable Seismographs and Earthquake Sources in Central Oklahoma

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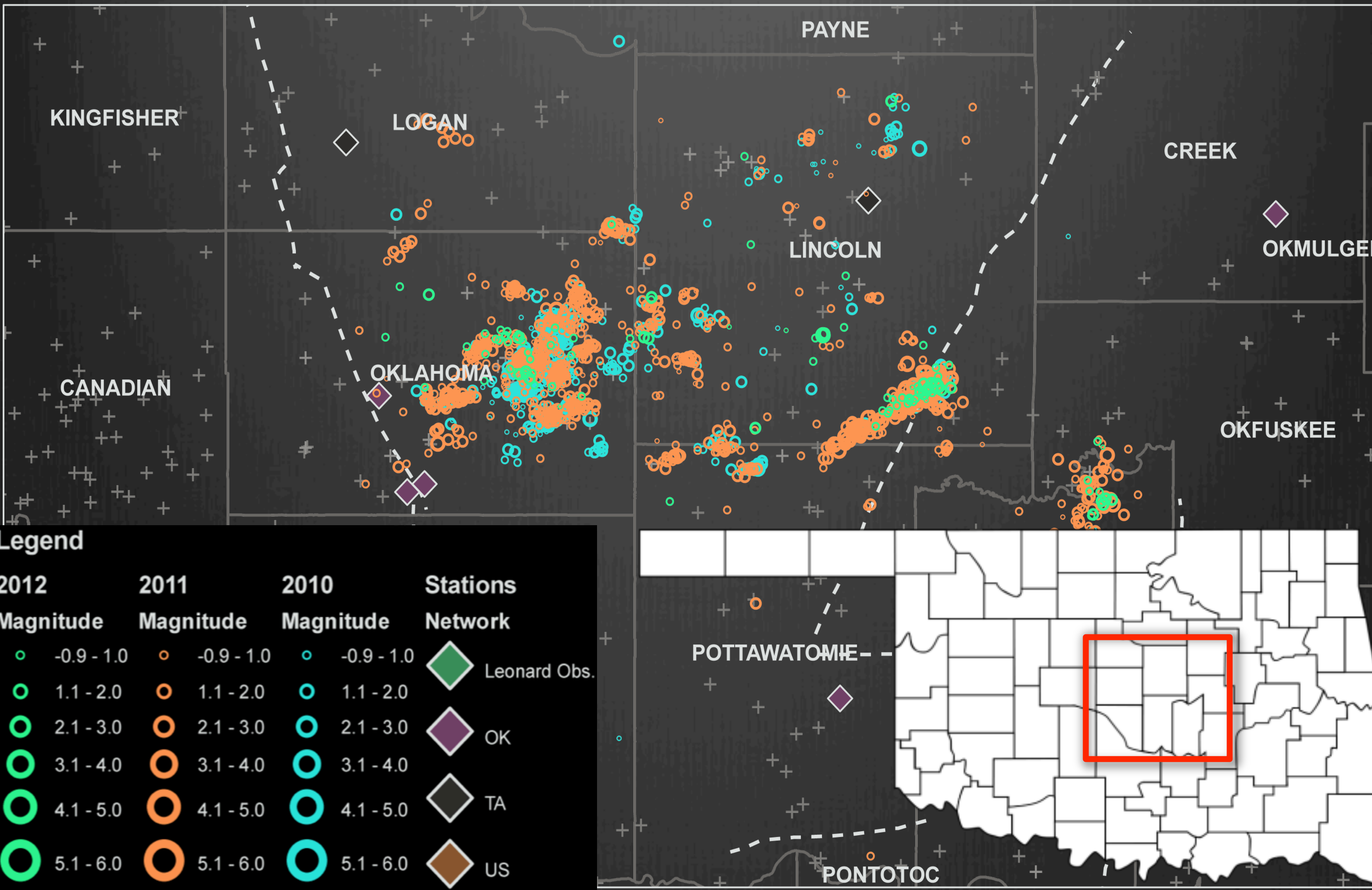
2010-2012 Oklahoma Seismicity

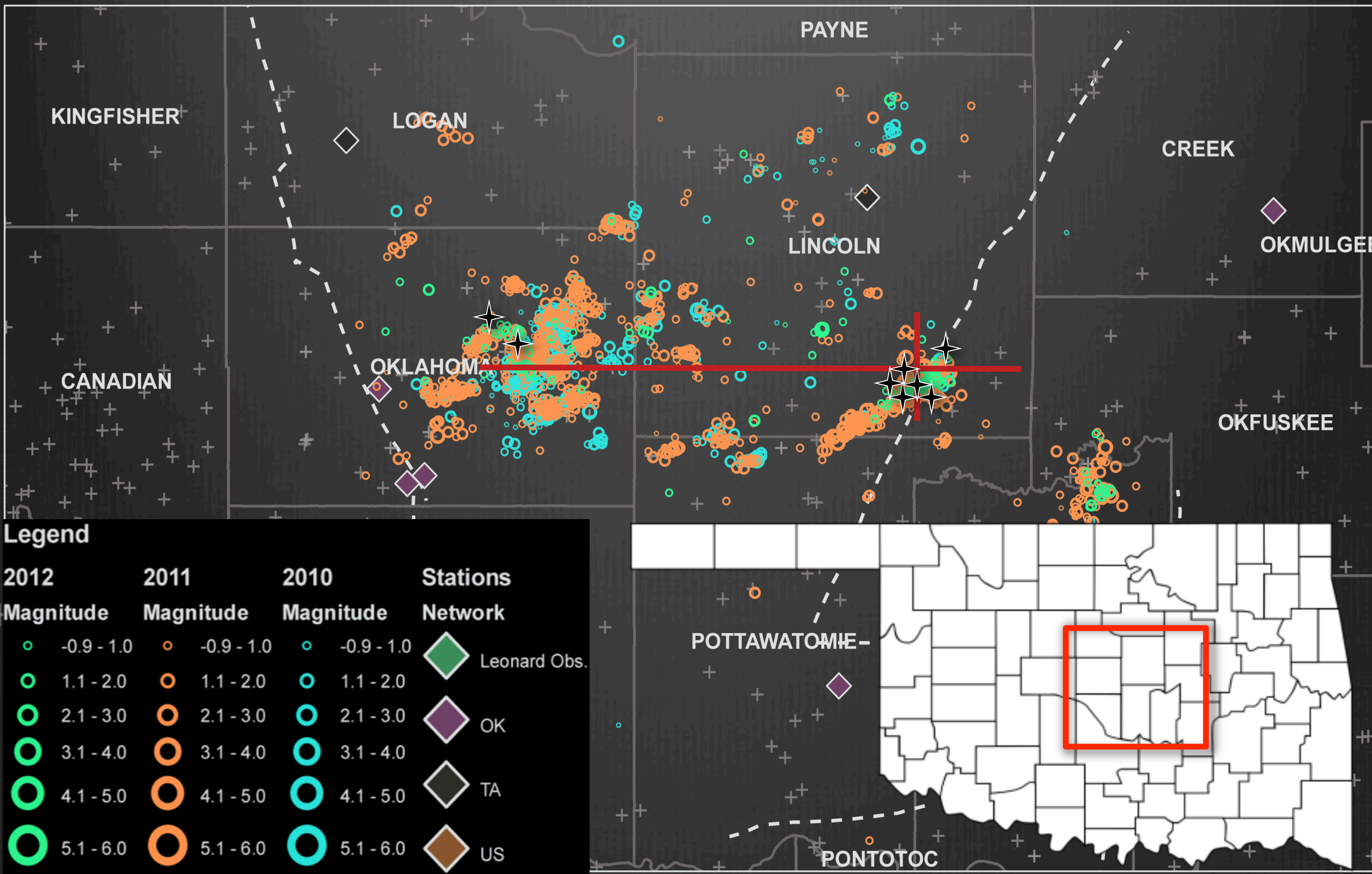


Survey Design

Take advantage of a unique opportunity to record a reversed refraction profile using well-located earthquakes as sources

- 123 TEXAN recorders with 4.5Hz vertical geophones spanned a 68km E-W line between Jones and Prague.
  - 0.55 km average spacing
- 33 TEXAN recorders with 4.5Hz vertical geophones spanned a N-S line through Prague.
  - 0.4 km average spacing
- Recorded continually during 4 nights to minimize cultural noise.
- 2 earthquakes were recorded from the Jones swarm and 6 from the Prague sequence
  - Magnitudes 1 and 2

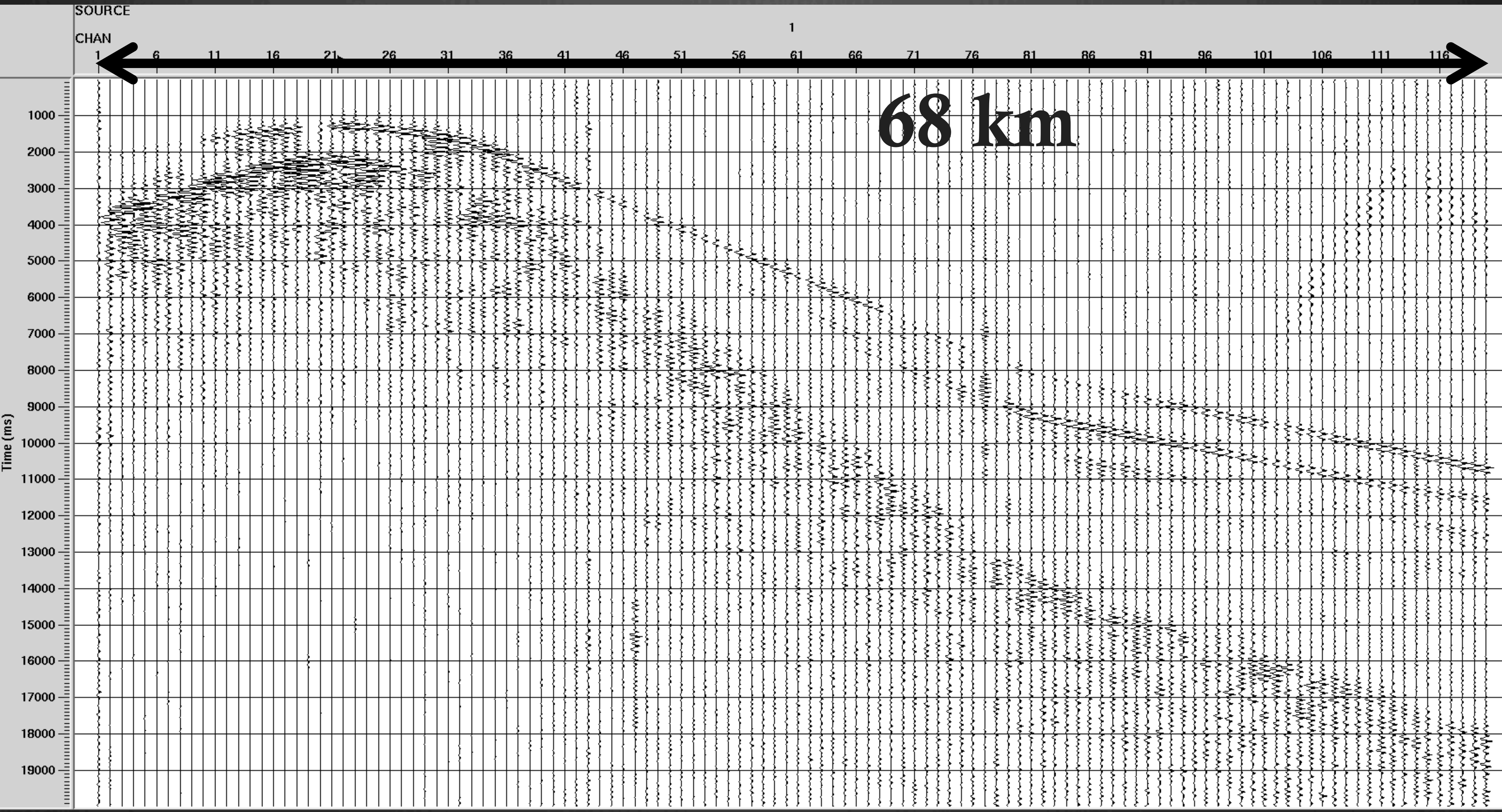
Survey Design



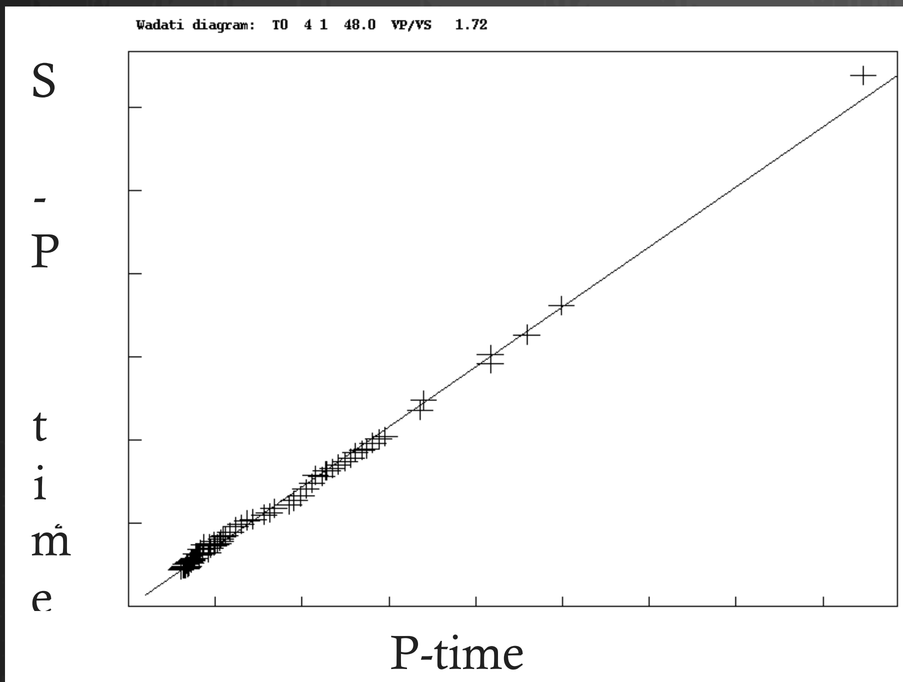
Source Locations

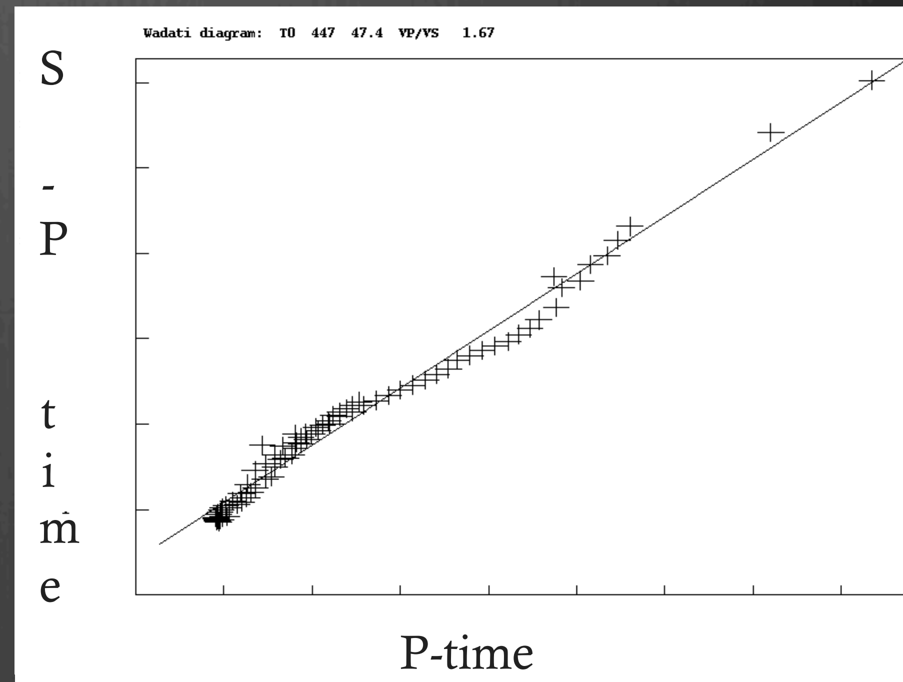
- Origin times first determined with OGS regional seismic network with Seisan
- First breaks were picked with Landmark's ProMAX software
  - Receiver geometry allowed for visual correlation of phases
  - Used coherence, bandpass, AGC, trace muting, trace scaling
- S and P travel times from ProMAX were added to the regional station phase arrival times to further refine source locations and origin times with Seisan
- Average spacial uncertainty:
  - 0.4km vertical
  - 0.3km horizontal
- Average temporal error: 0.12 seconds

First Breaks



Wadati Plots



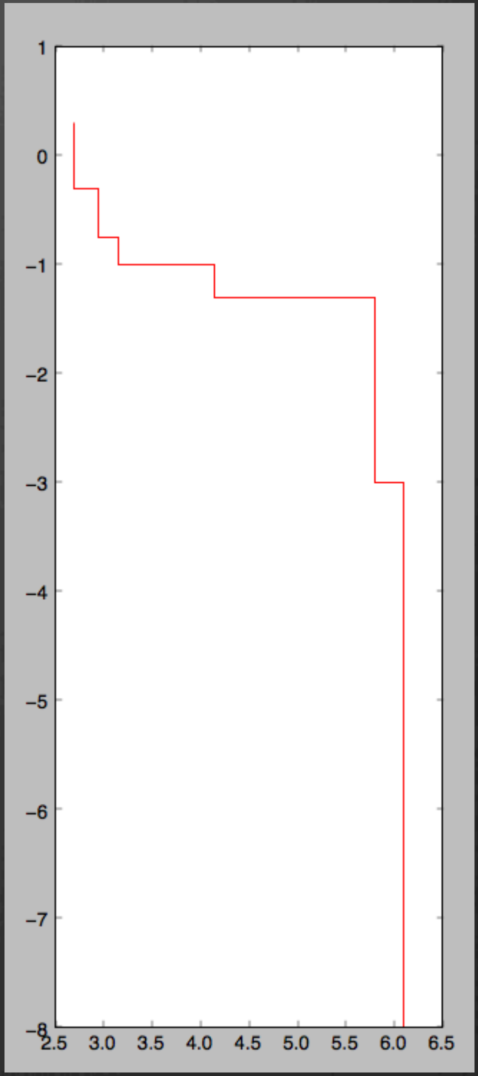


- Jones (West) Earthquake
- Vp/Vs = 1.72

- Prague (East) Earthquake
- Vp/Vs = 1.67

Initial Model

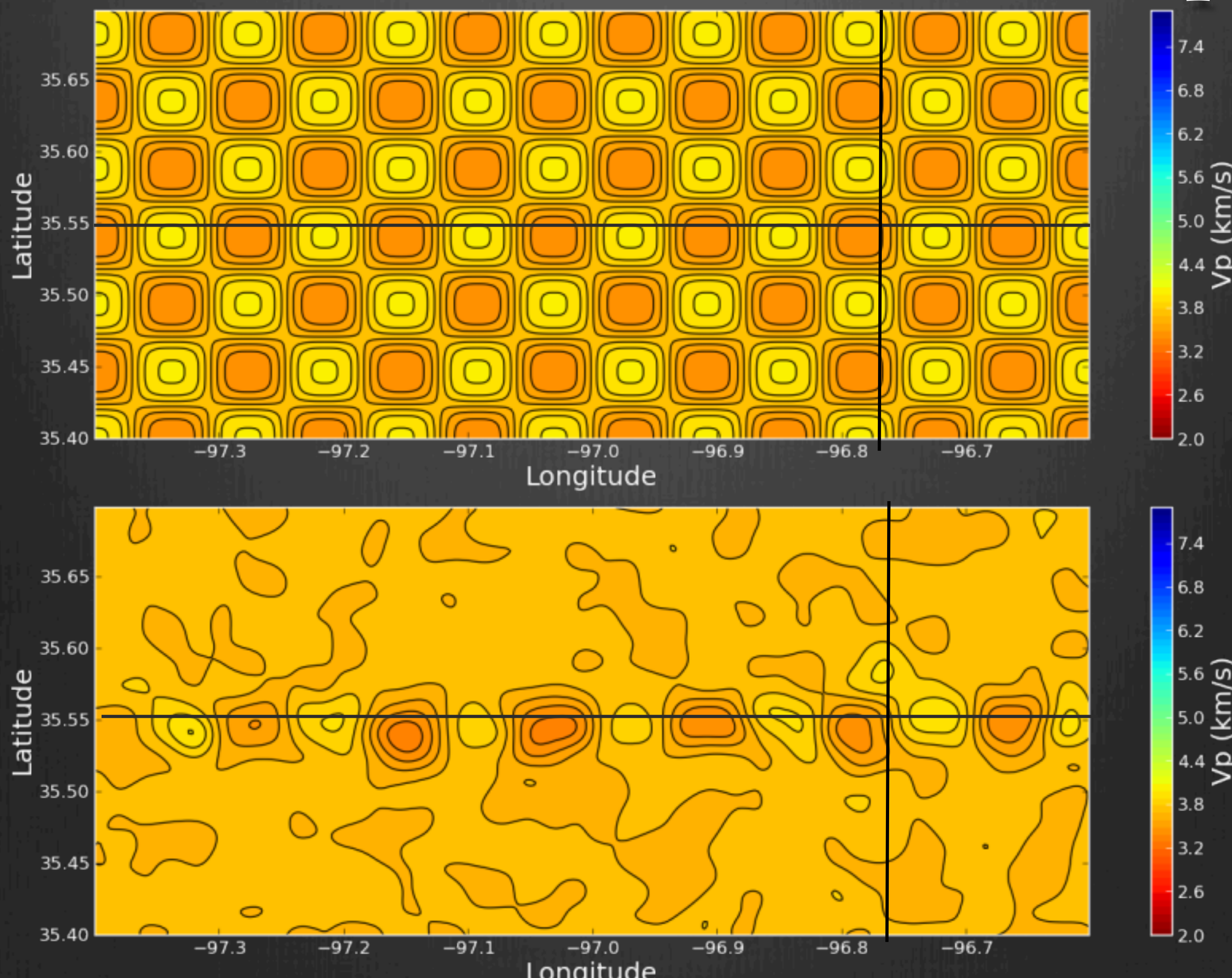
- Depth to Basement (Luza and Lawson, 1981):
  - Jones: 2.75km
  - Prague: 1.8km
- Sonic logs show a high velocity (~5.5km/s) sedimentary package above basement at 1.5km deep in Prague
- Initial velocity model from Toth et al (2012)
  - Joint velocity and hypocenter inversion (VELEST) constrained by sonic logs and double-difference relocation (HypoDD)



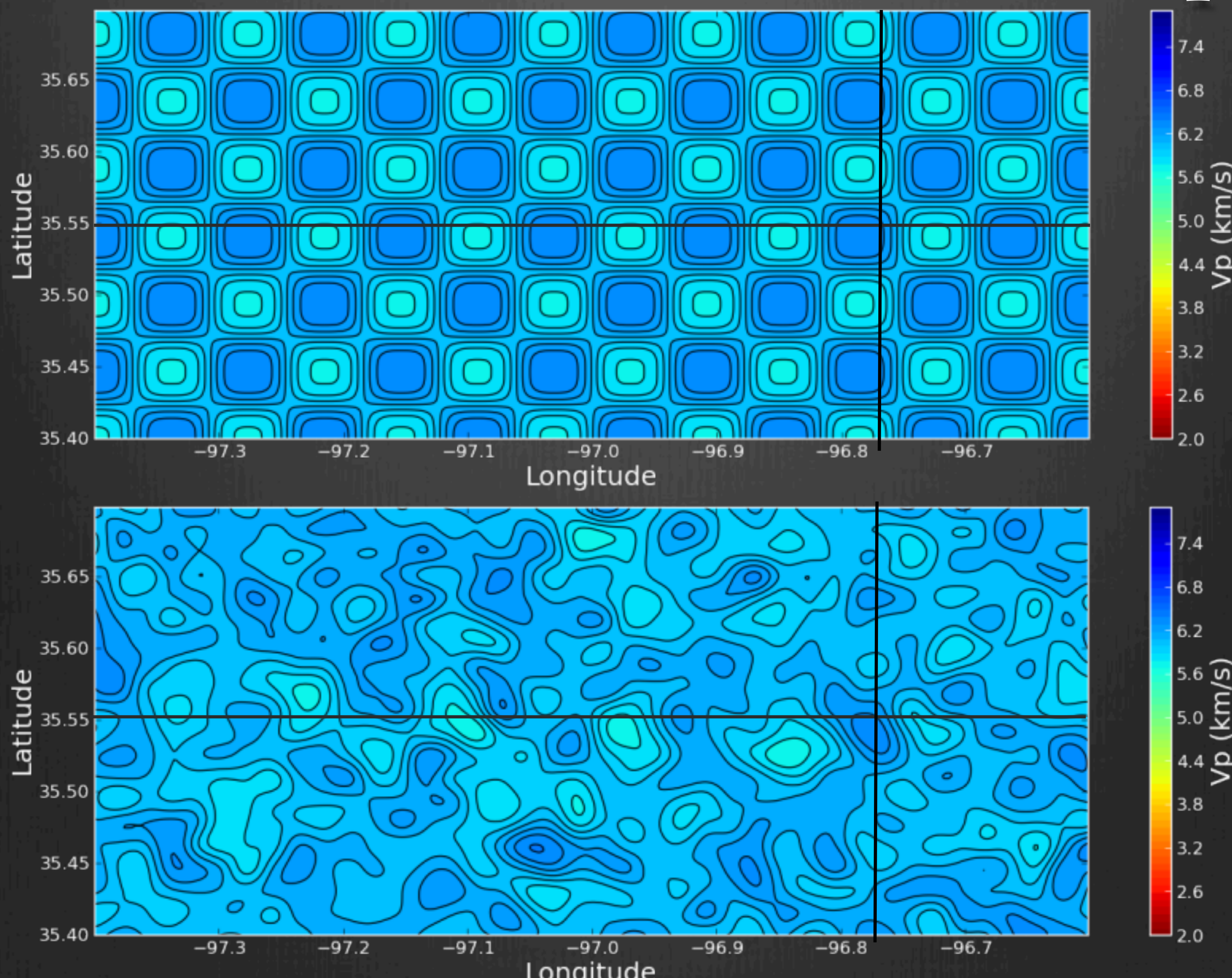
Inversion and Checkerboard Resolution Test

- FMtomo (Ralinson et al, 2006) was used for Checkerboard resolution tests and the forward and reverse modeling
- Checkerboard perturbations
  - 5km spacing in X,Y, and Z
  - Alternating +/- 0.3 km/s
- Checkerboard: Stopped converging after 5 iterations
  - Chi-squared misfit of 35.7 was reduced to 0.035
- Inversion: Stopped converging after 9 iterations
  - Chi-squared misfit of 5115 reduced to 11.93

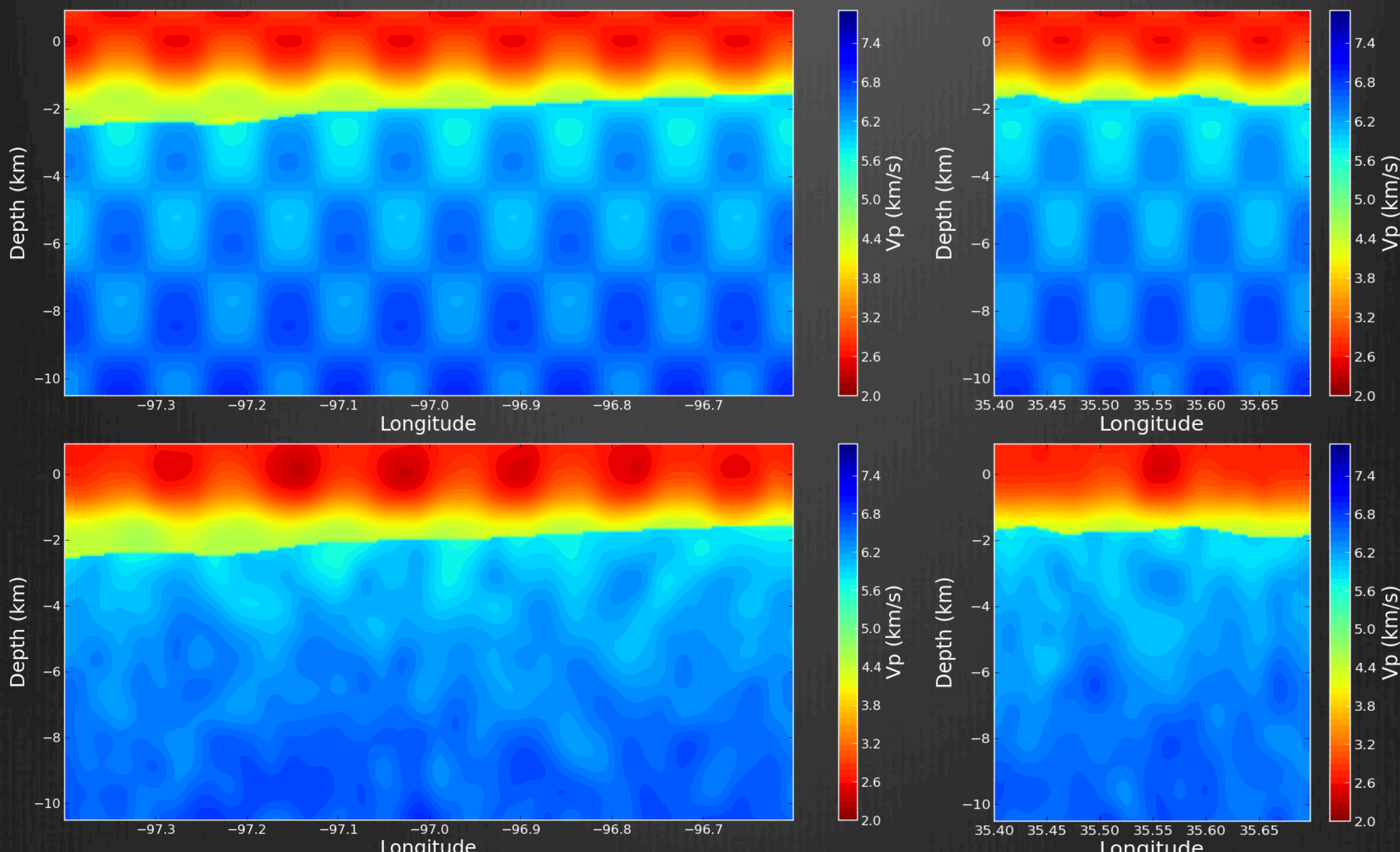
Checkerboard Test – 1km deep



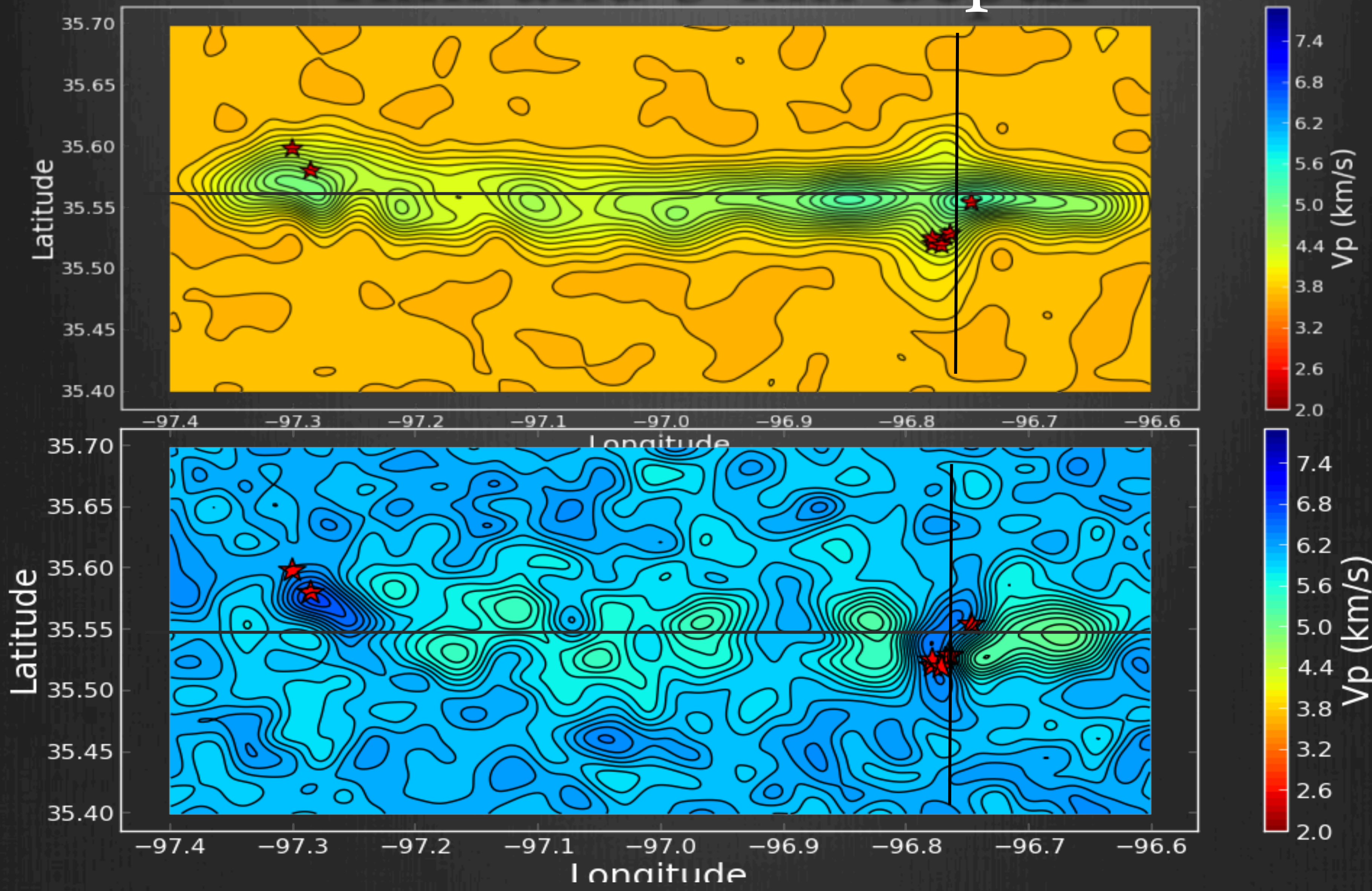
Checkerboard Test – 3km deep



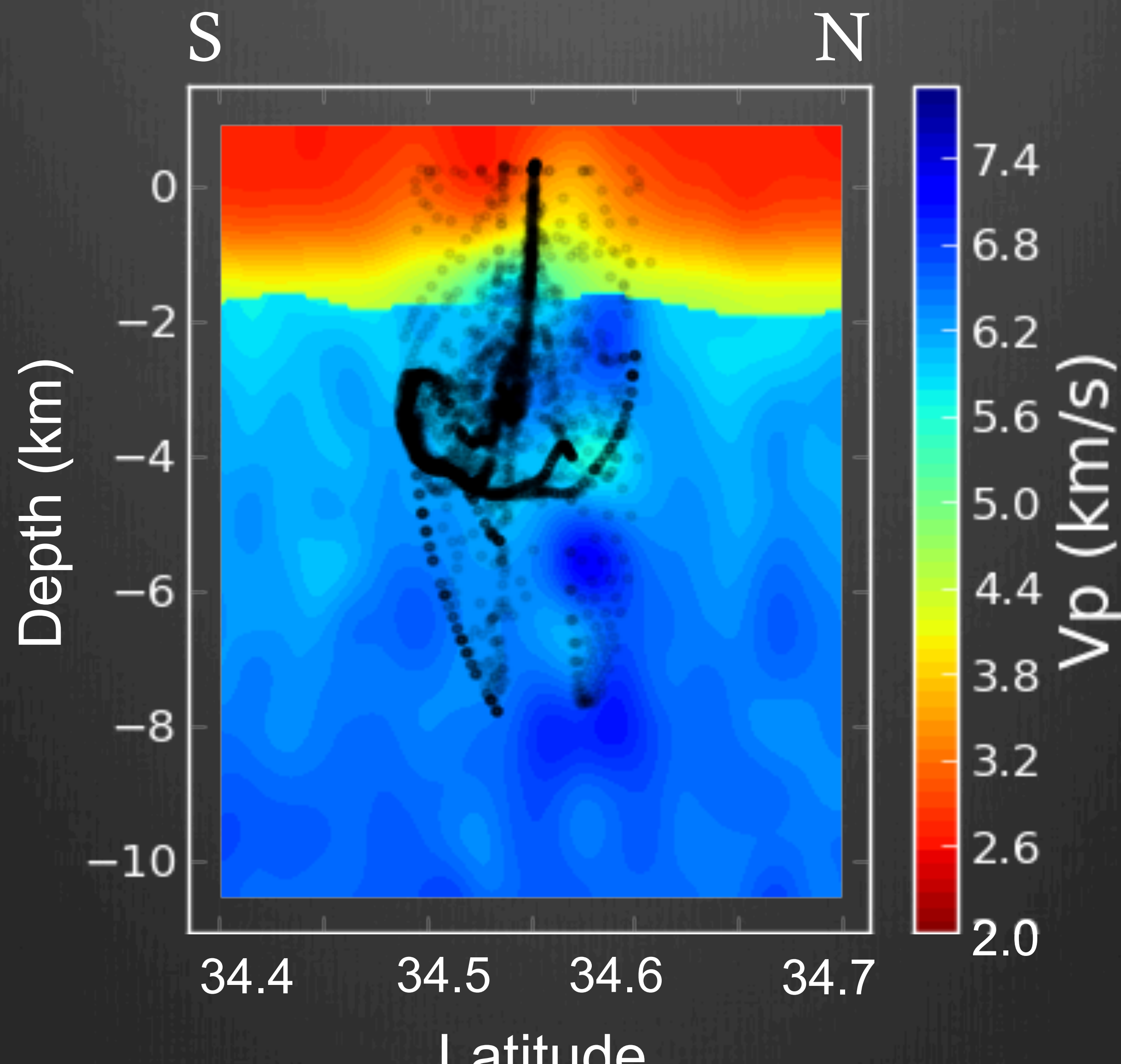
Checkerboard Test



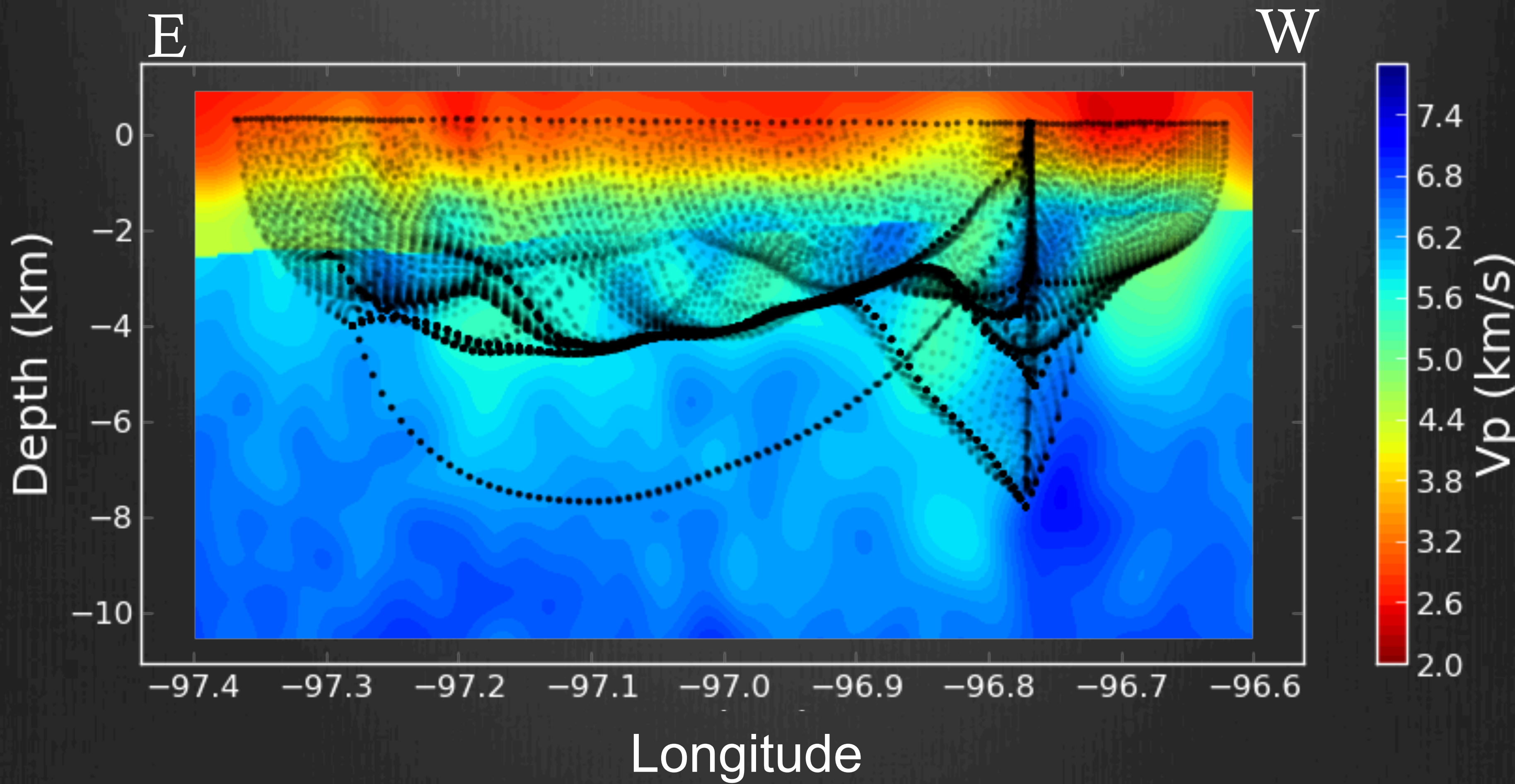
Tomographic Inversion 1km and 3 km depth



Tomographic Inversion

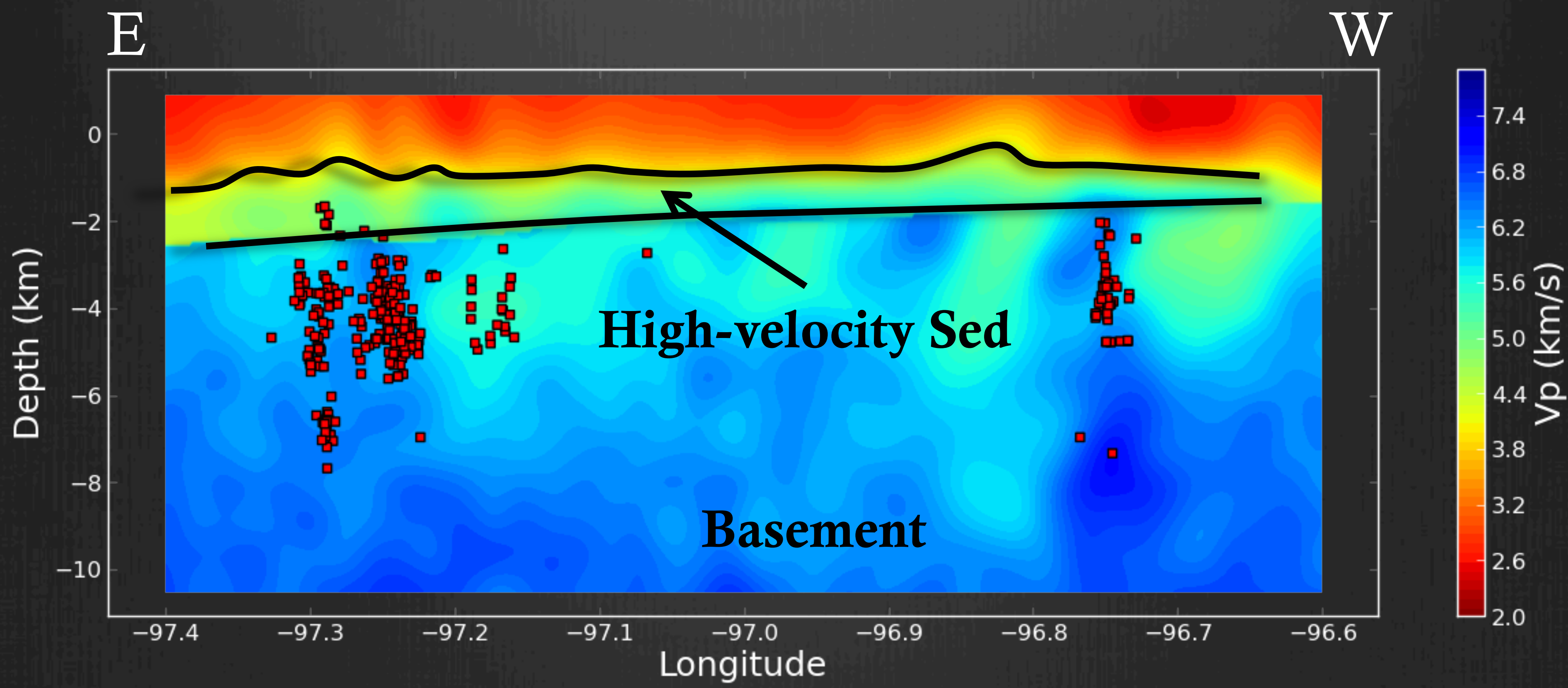


Tomographic Inversion



Conclusions

- High velocity sedimentary layer does not follow basement
- Hypocenter locations are moderately correlated to velocity contrasts



Further Work

- Use inverted hypocenters to adjust travel times and iterate
- In the center of the survey area, Luza and Lawson (1983) report a ~250mT negative magnetic anomaly with no corresponding gravity anomaly.
- Integrate a gravity survey with state aeromag survey to correlate to velocity structure
- Use filtering and trace stacking to enhance deeper reflections
- Shrink checkerboard tiles. Rapid recovery of velocity and interface structure indicate current checkerboard tests probably understate survey resolution