Hunting for microseismic reflections using multiplets

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STANFORD
EXPLORATION PROJECT

Outline

- Research objective
- About the dataset
- Strategy and method
- Finding reflections
- Future work

Research Objective

- To use microseismic reflections for imaging the subsurface
- Immediate goal
  - Identify reflections and stack event windows to
    - decrease data size
    - enhance S/N ratio and boost reflections

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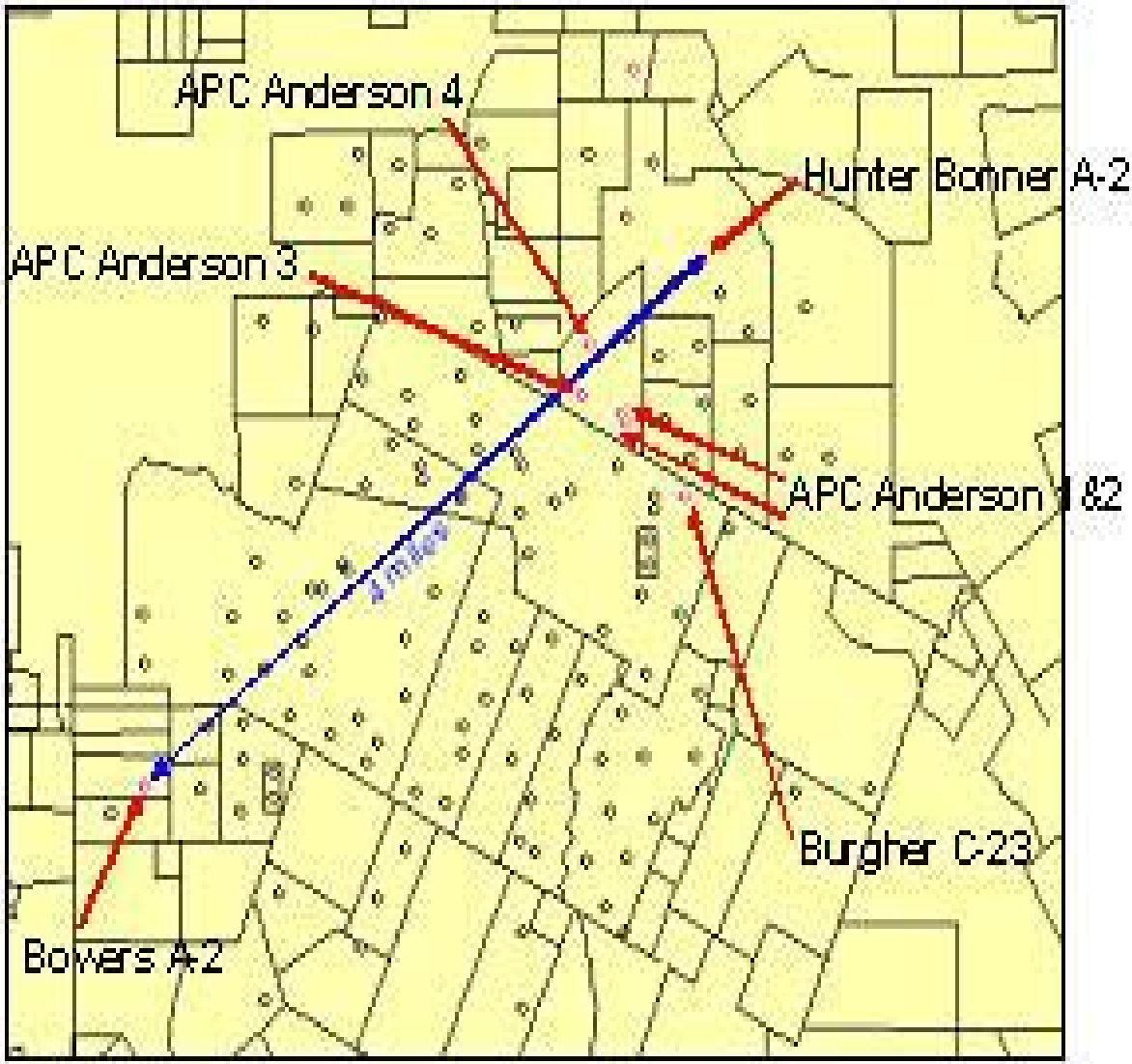
The Bossier Play Wells

- Dowdy Ranch Field, Texas
- Natural Gas field since the 1970's.
- Five sand units: Taylor, Shelly, Moore, **Bonner, and York**
- APC Anderson#2 as hydrofracture treatment well and APC Anderson #1 as a monitoring well (twelve 3 component geophones)



Sharma et al. 2004

What we have

- Recordings with no fracturing treatment (background)
- Recordings from the fracturing treatments in the York and Bonner sands
- A spreadsheet of picked and located events in each (York and Bonner)
- A sonic log from monitoring well

Events used in this work are from the Bonner sand

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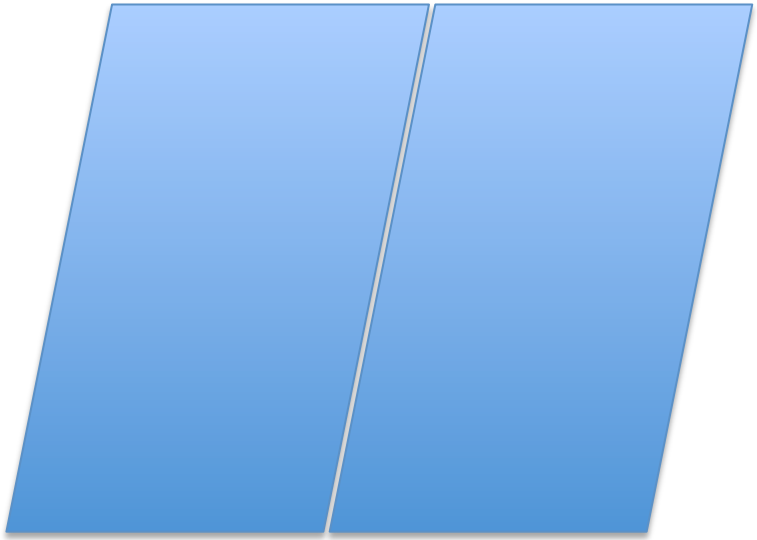
Key assumption

Several microseisms can arise from the **same or proximate subsurface locations** and produce **nearly identical** seismograms.

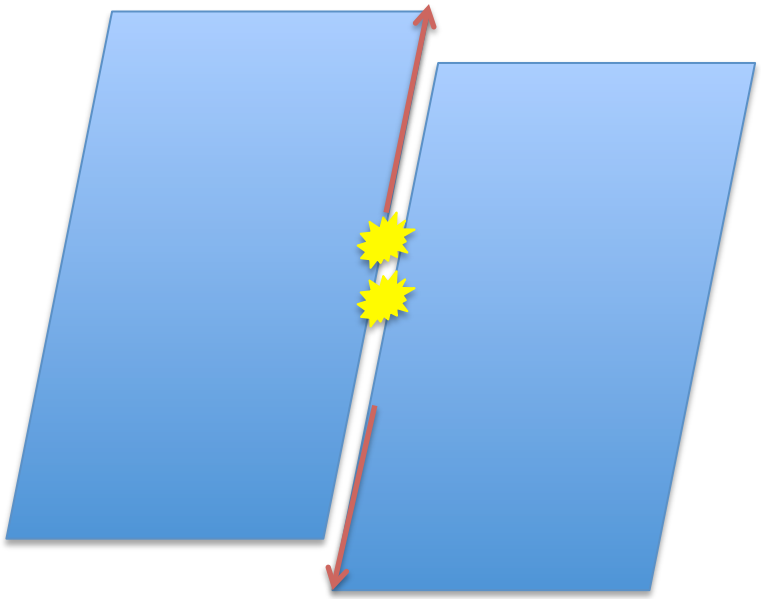
Justification

Most hydraulic fracture microseisms have been observed to have the same source mechanism: **reactivated slippages on faults**.

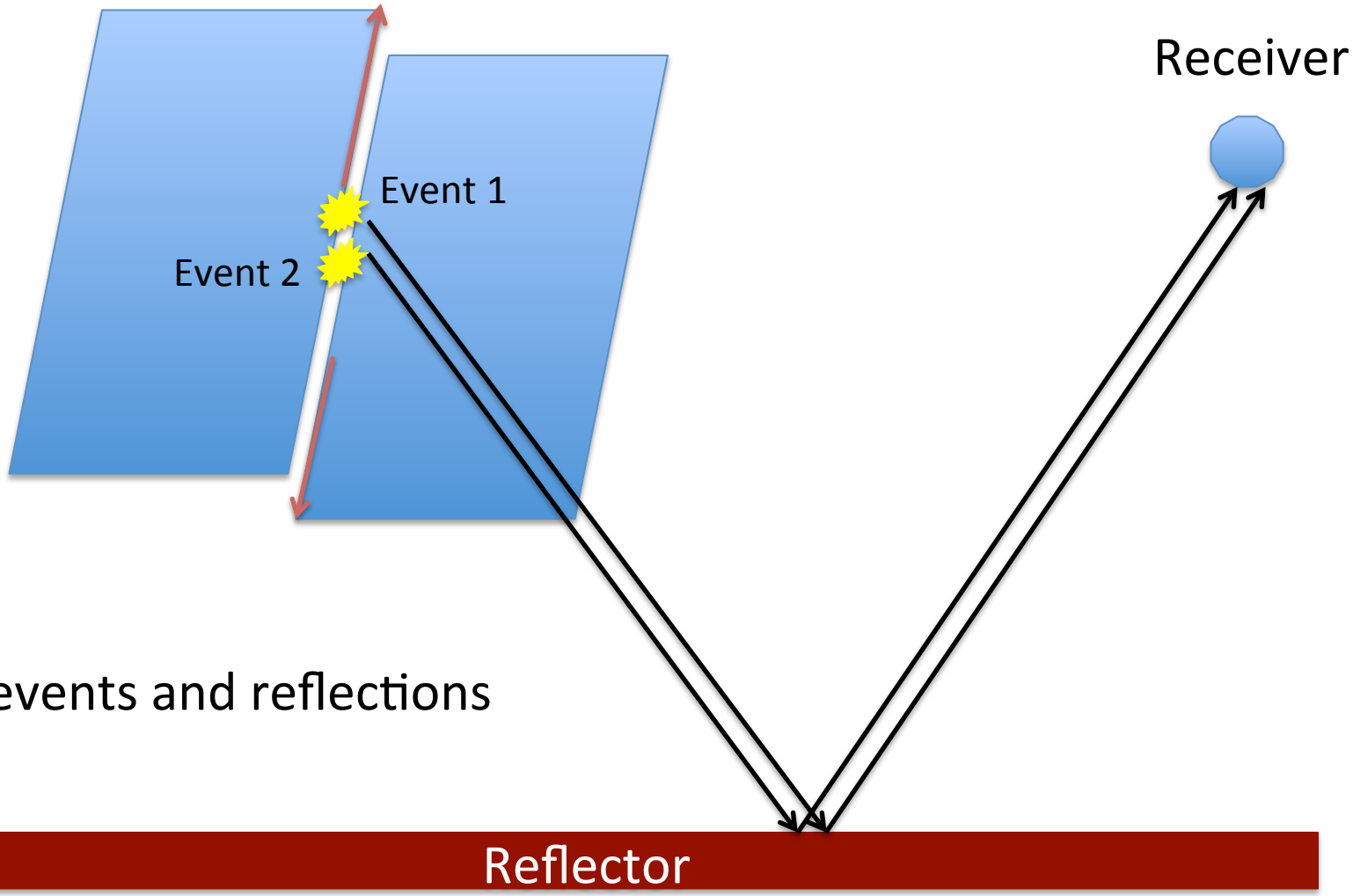
Key assumption



Key assumption



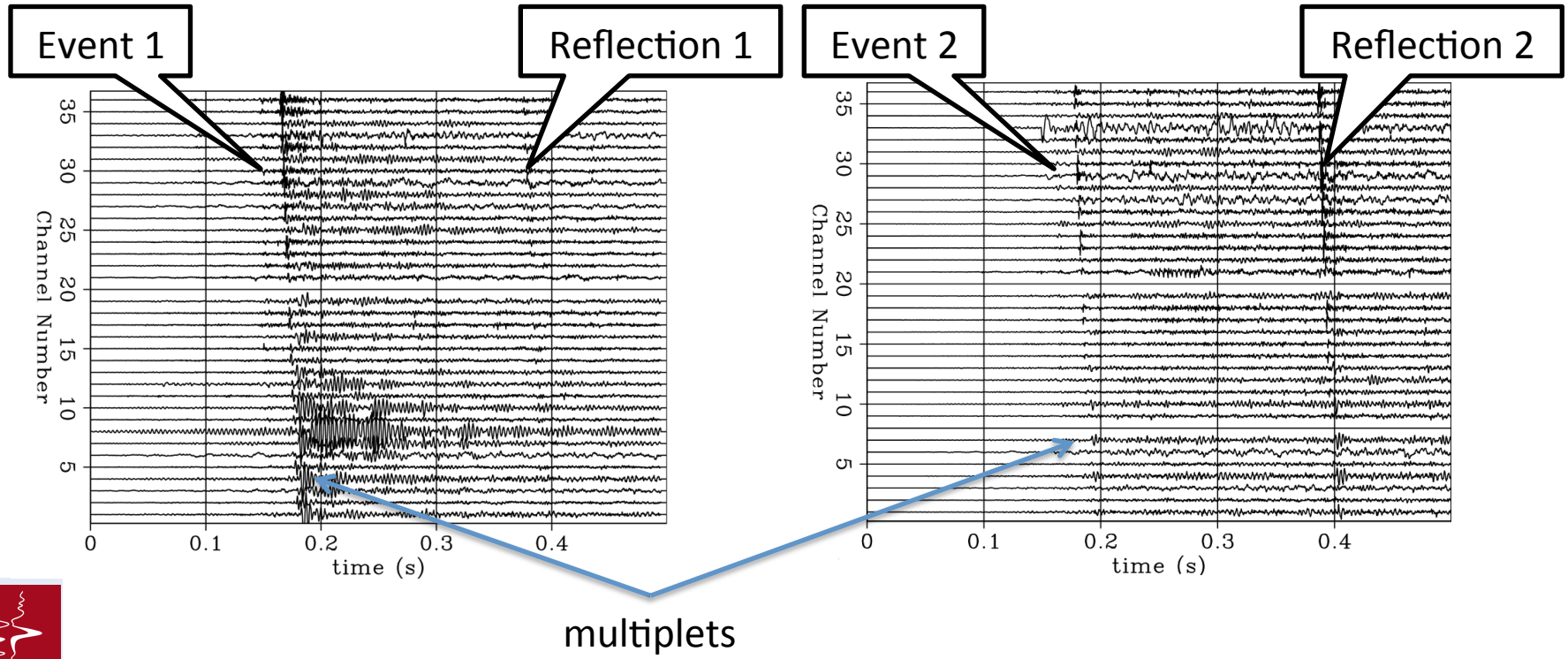
Key assumption



Identical events and reflections

Key assumption

Close events have nearly identical seismograms



Strategy

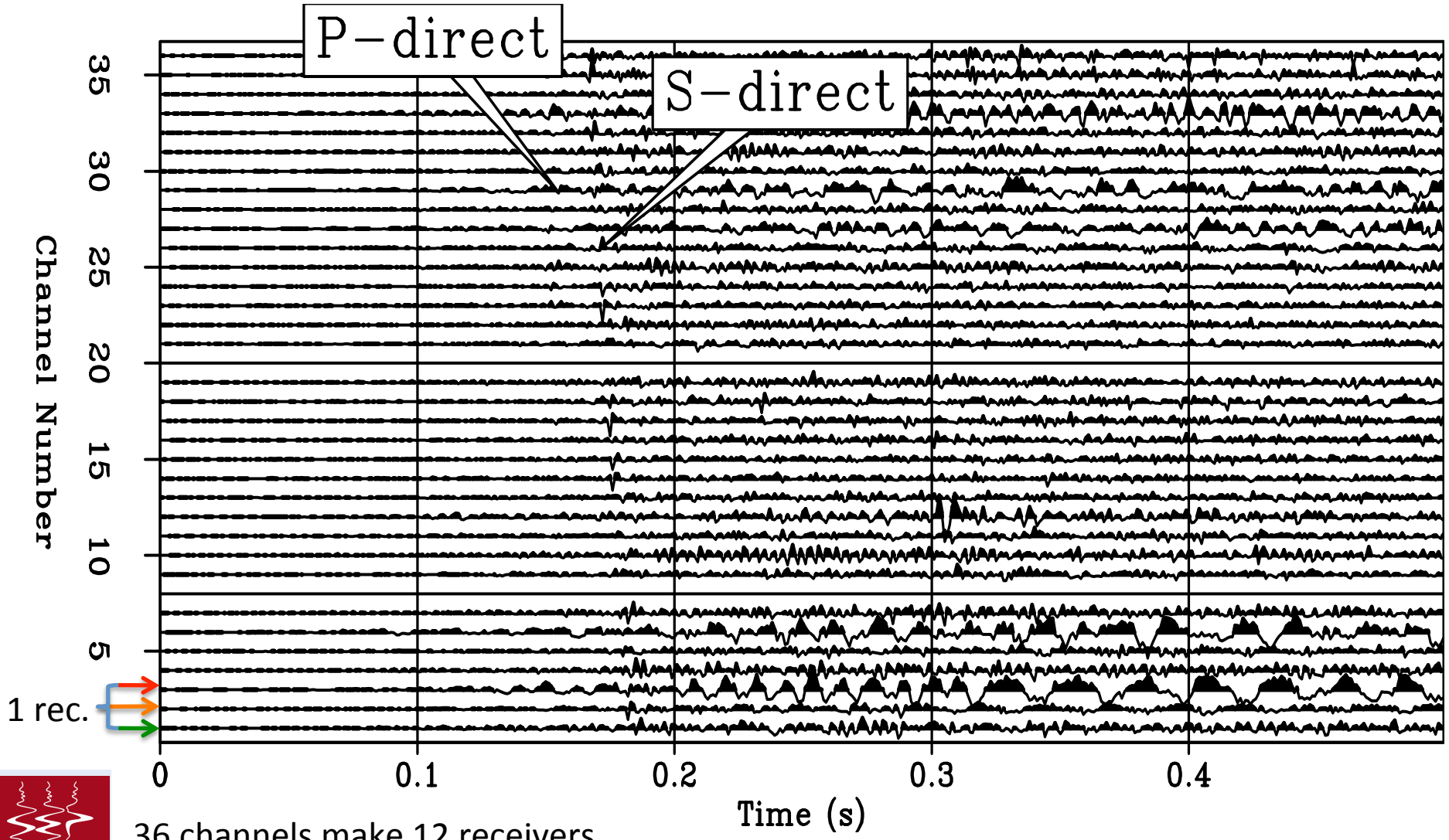
- Identify and align multiplets (replicas) of waveforms
- Stack to increase S/N ratio and possibly see reflections

Method

Adapted from earthquake seismology

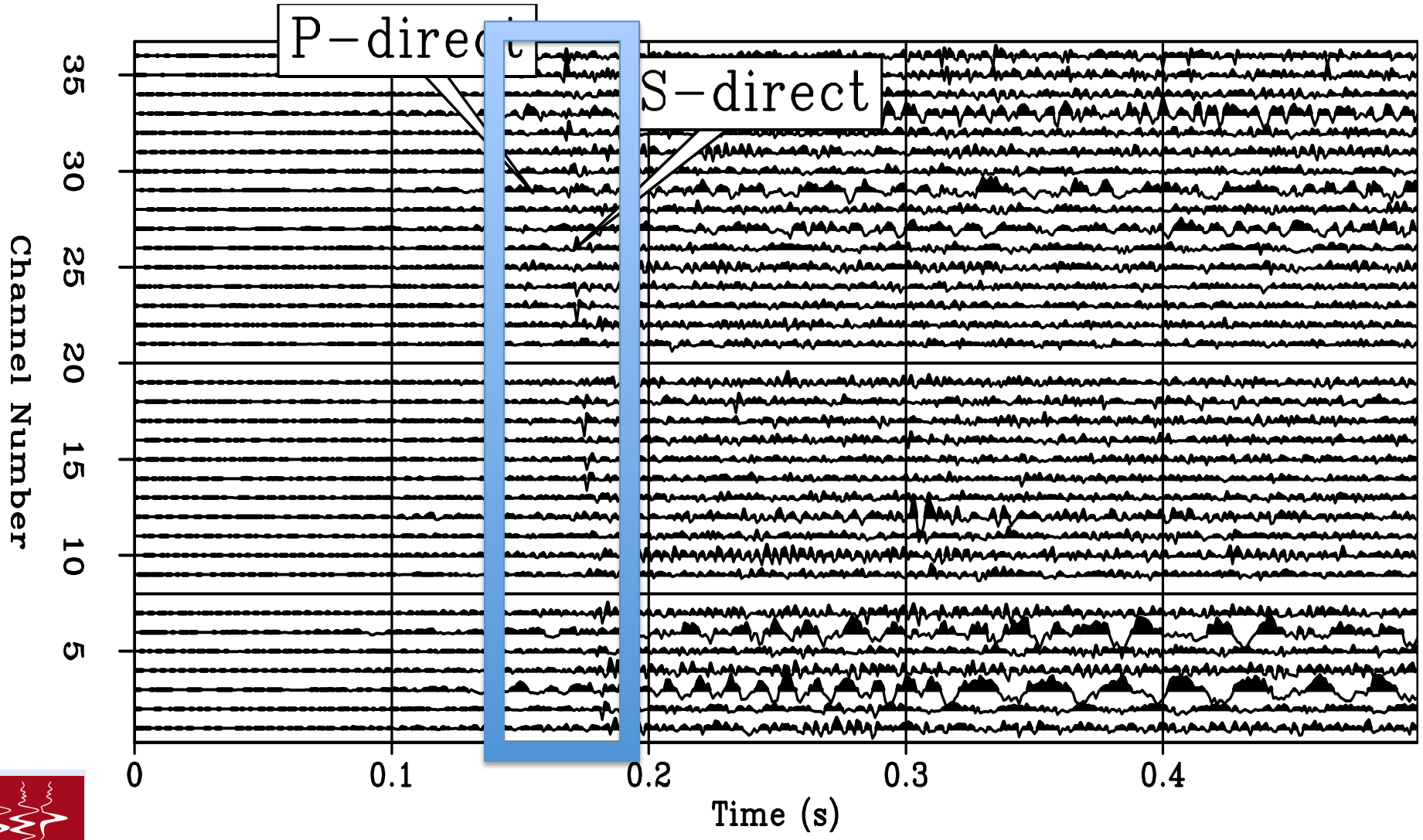
1. Select master event
2. Find replicas using cross-correlations
3. Stack the cross-correlations
4. Find peak locations
5. Align the multiplets
6. Stack

Master Event Window

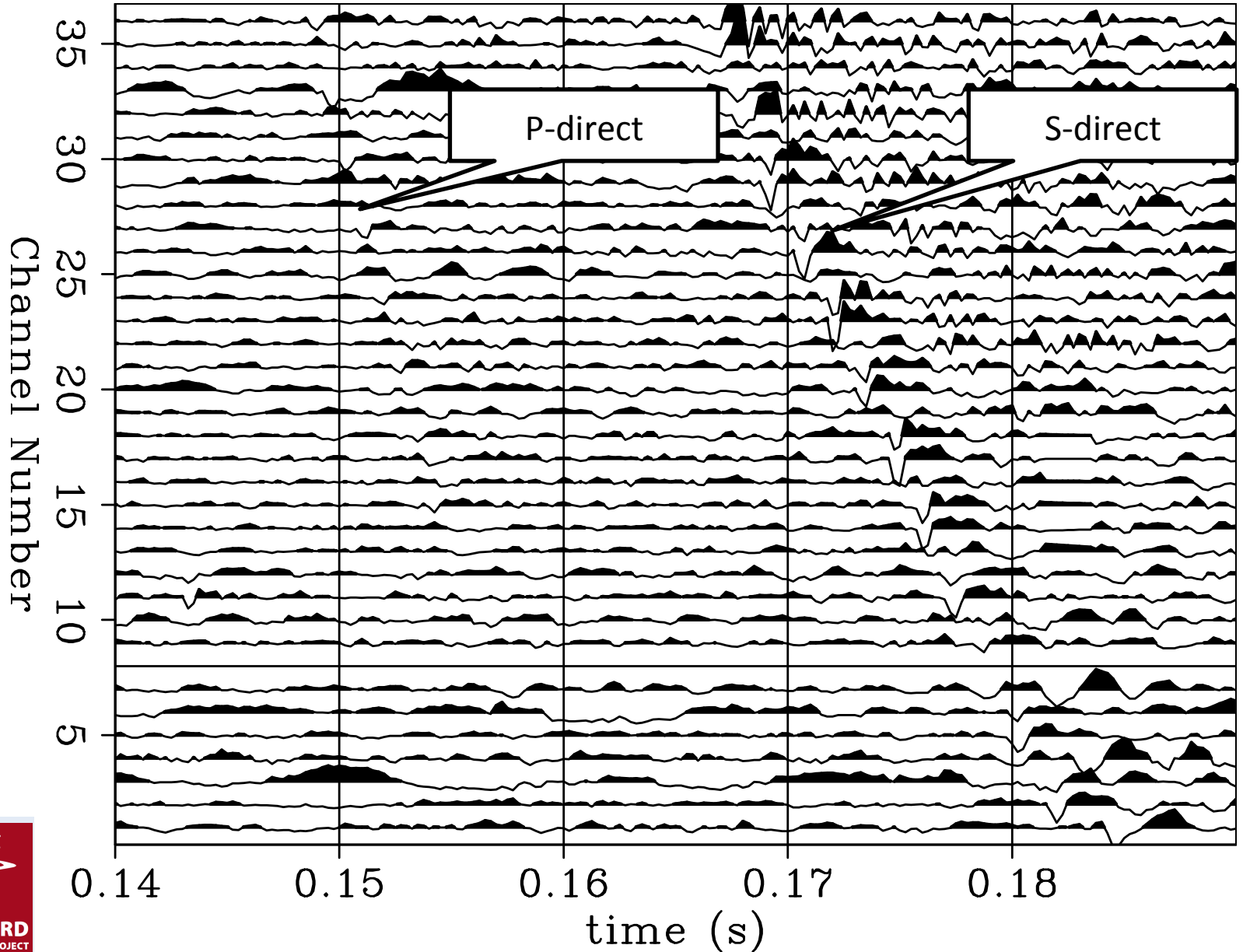


36 channels make 12 receivers

Master Event Window

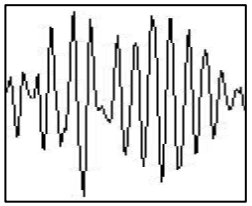


Master Waveform



Running window cross correlation

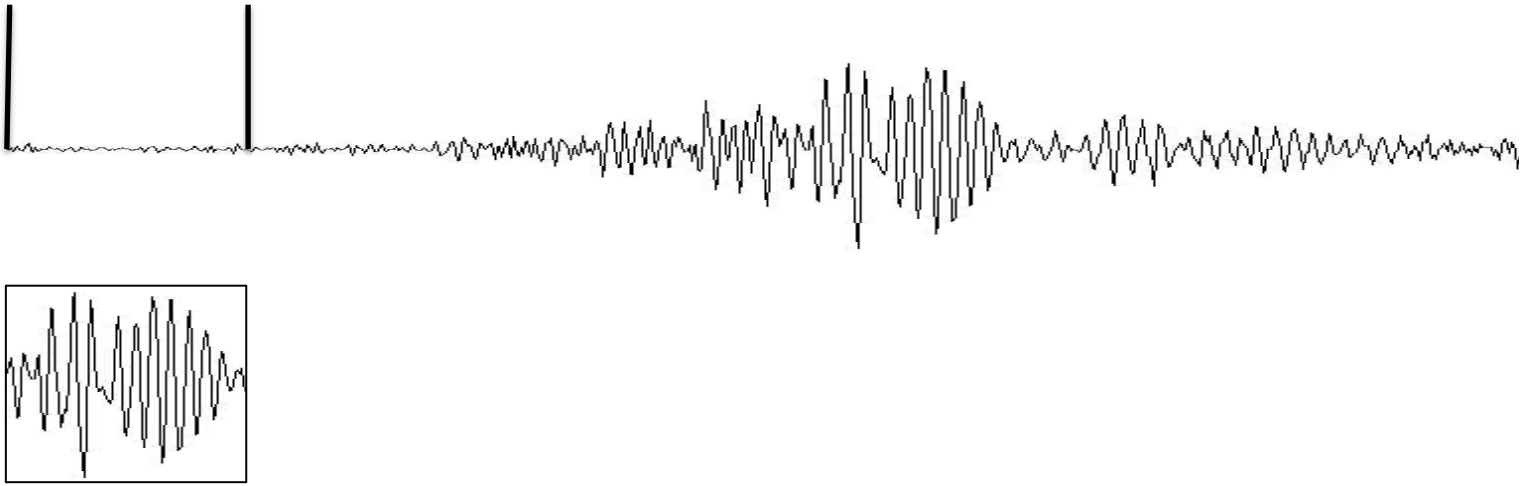
Event Window



Master waveform

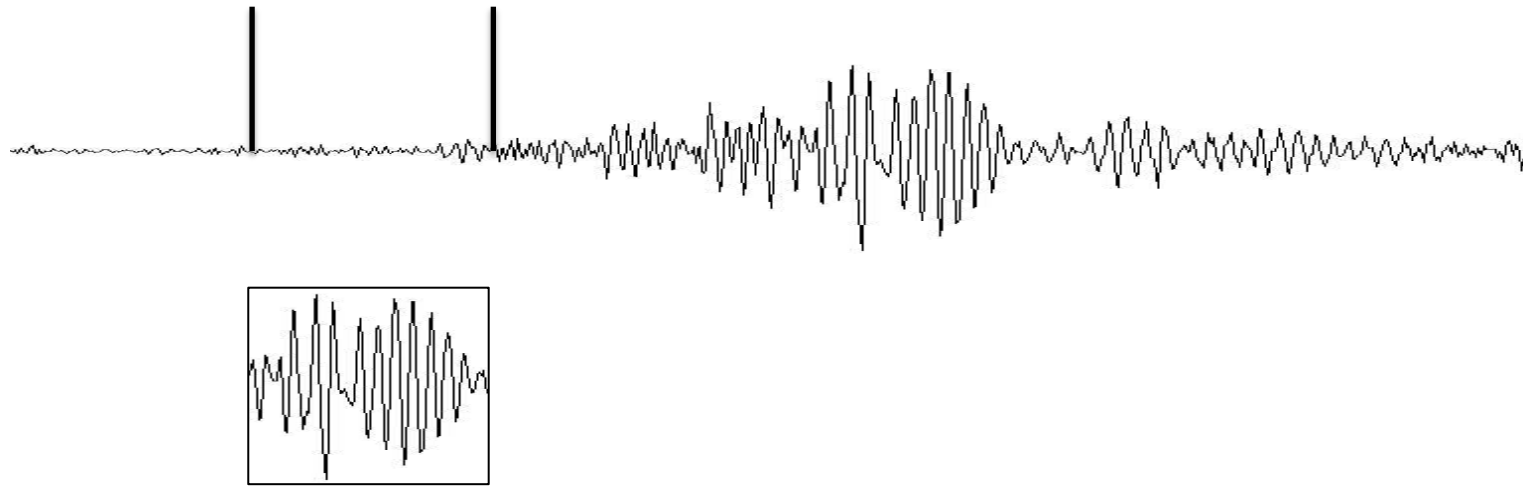
Showing only one trace for simplicity

Running window cross correlation



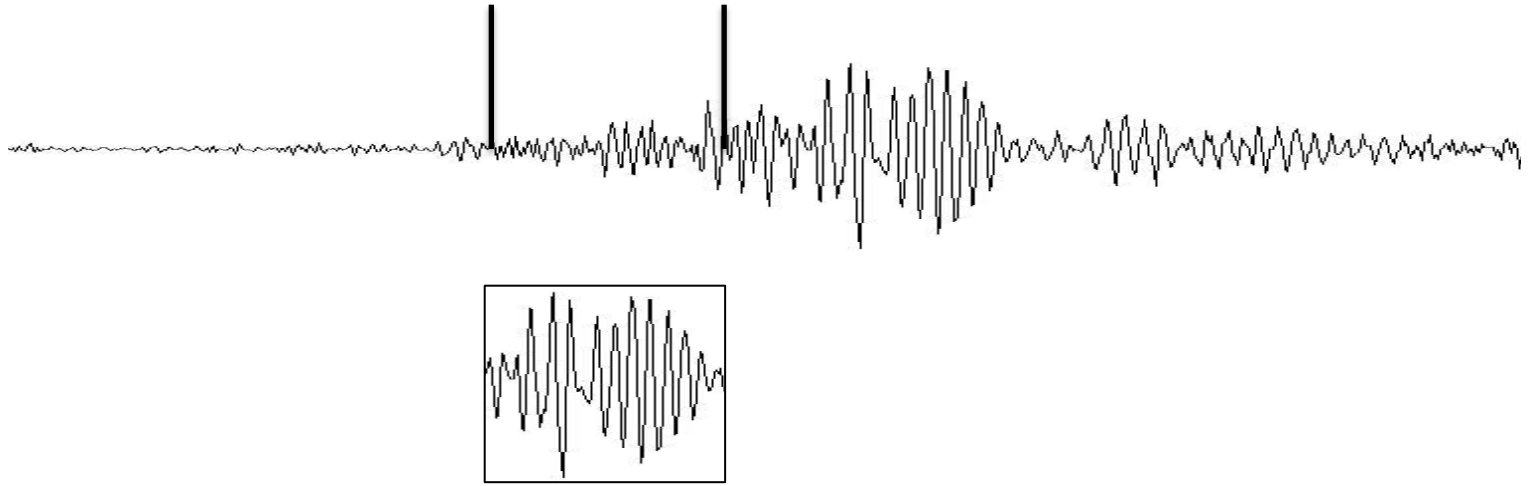
Cross-correlation result

Running window cross correlation



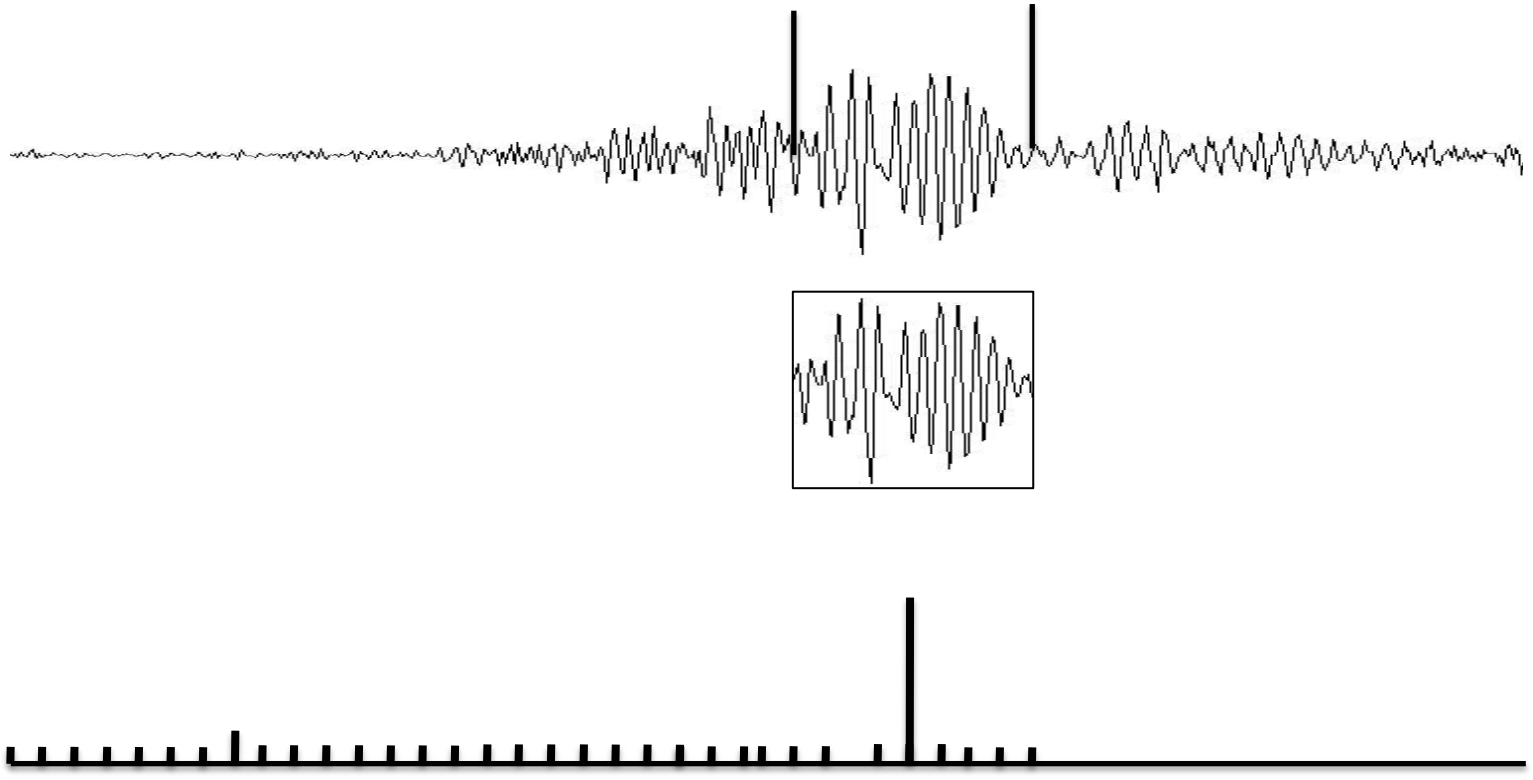
Cross-correlation result

Running window cross correlation



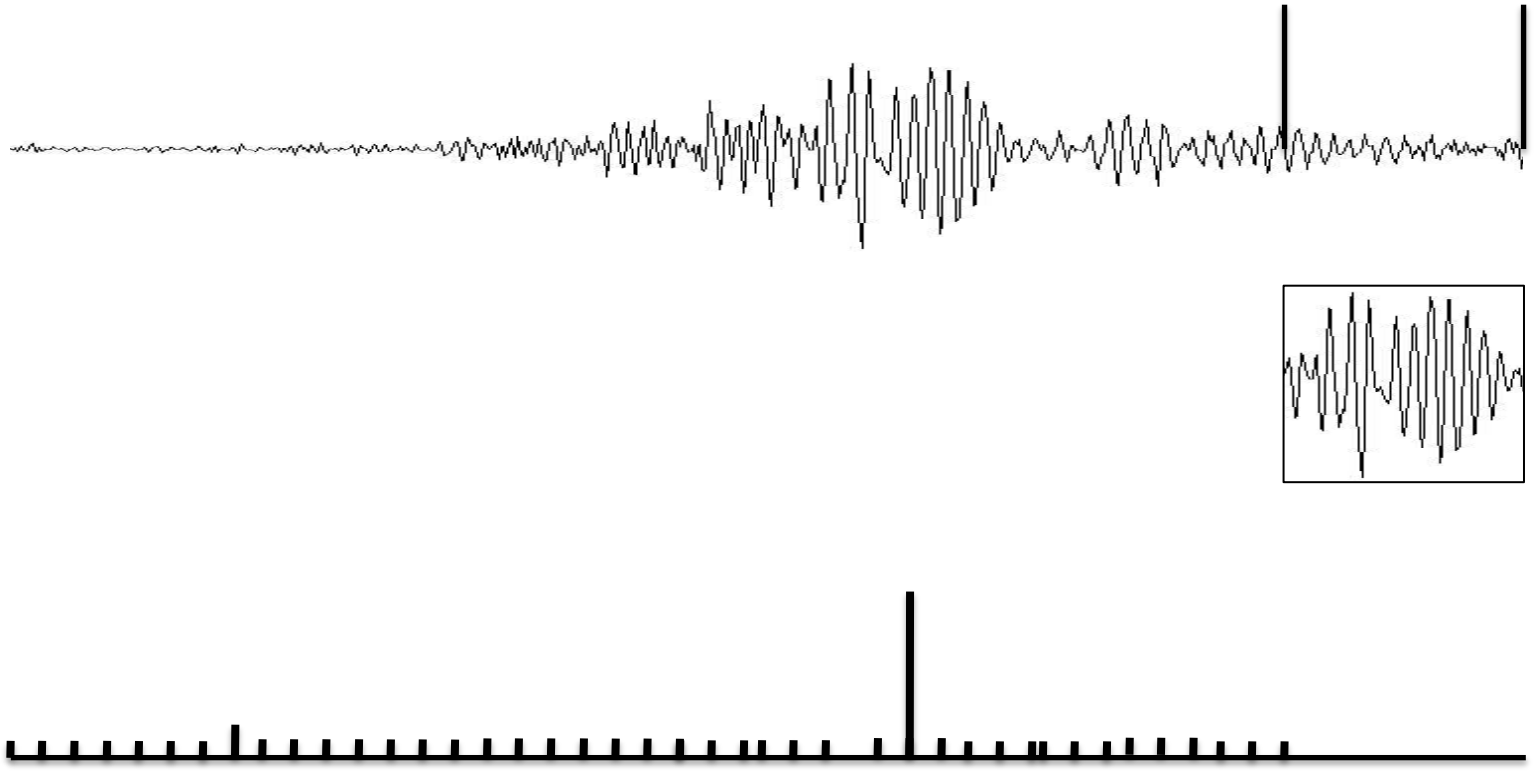
Cross-correlation result

Running window cross correlation



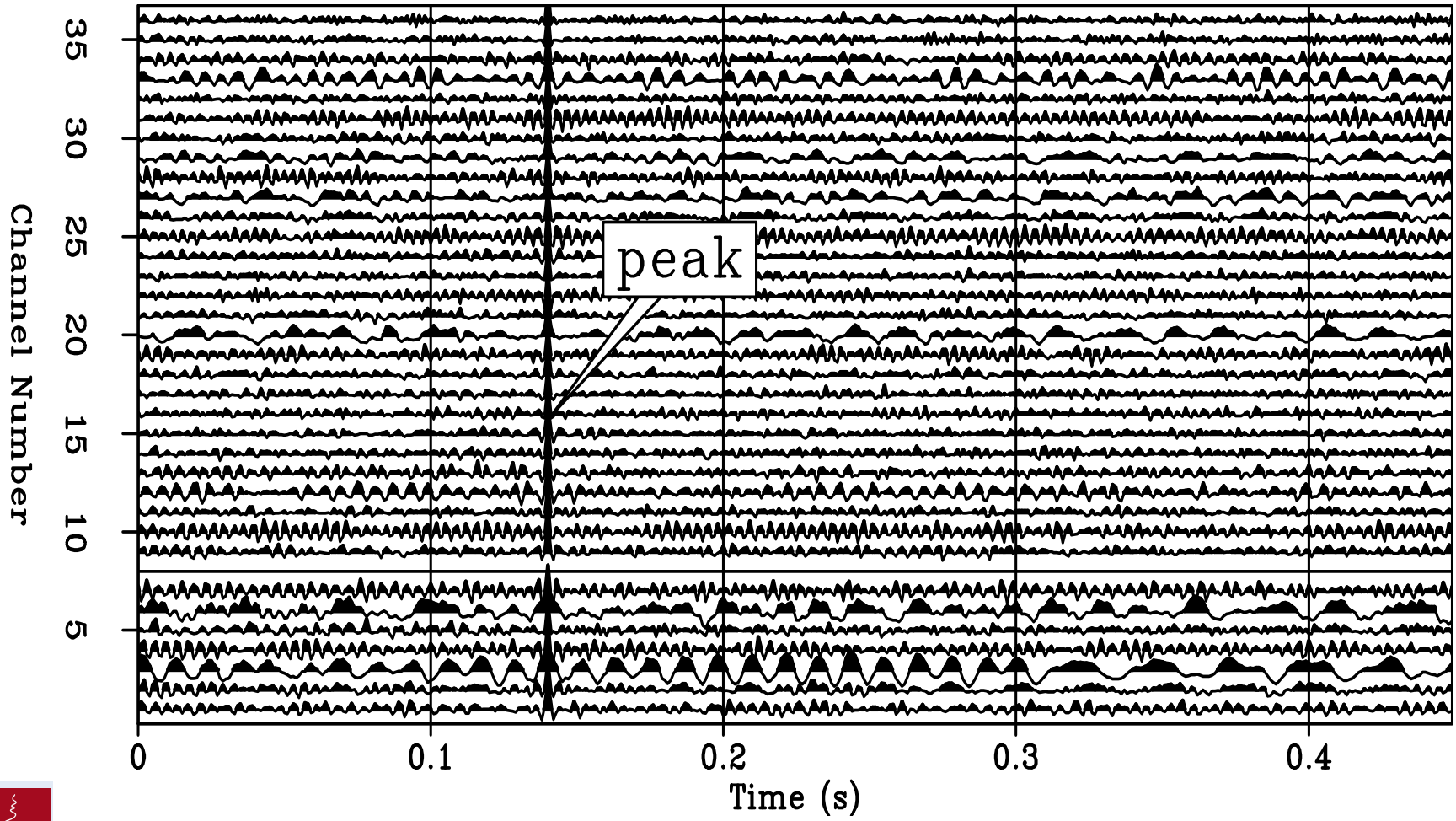
Cross-correlation result

Running window cross correlation

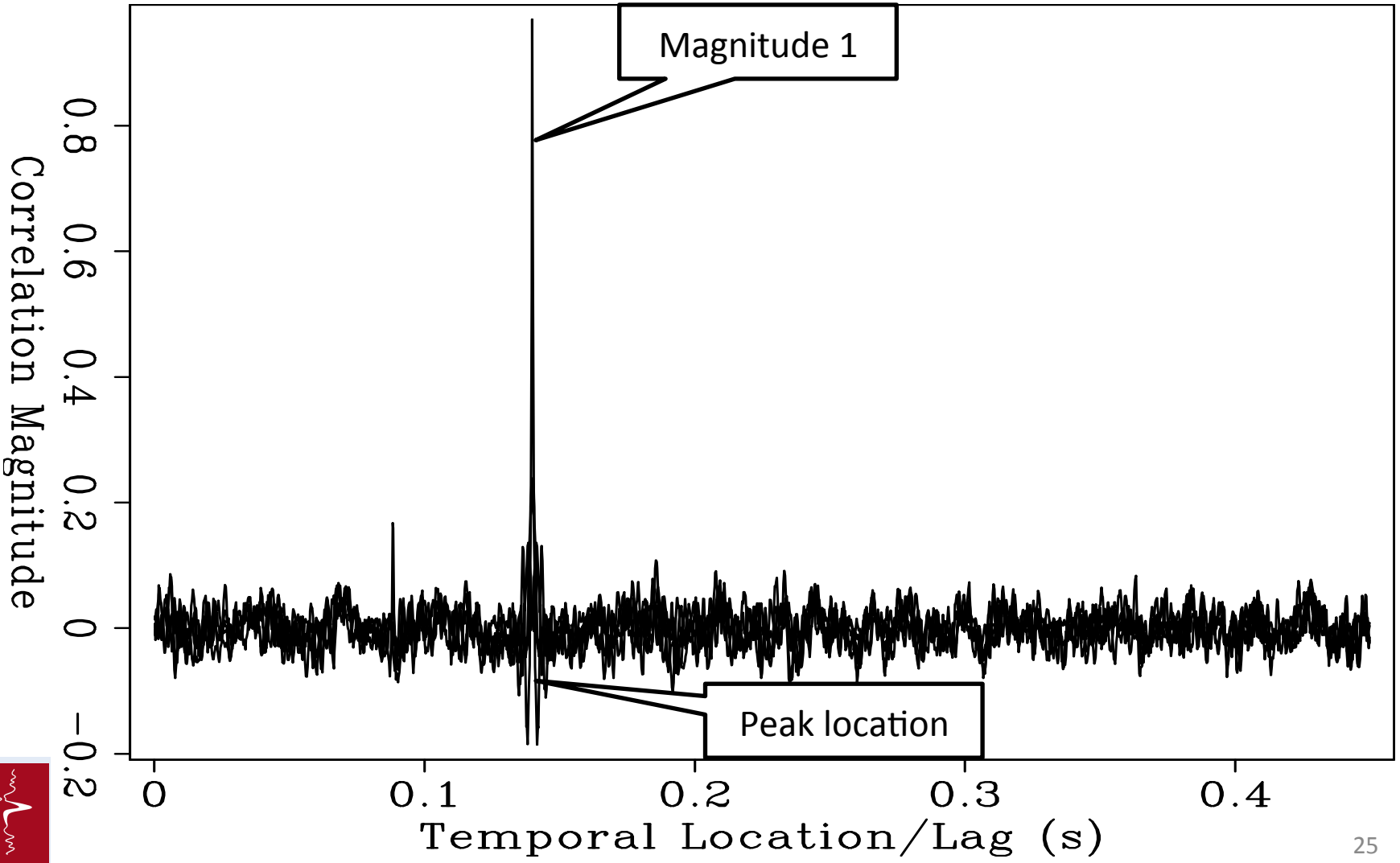


Cross-correlation result

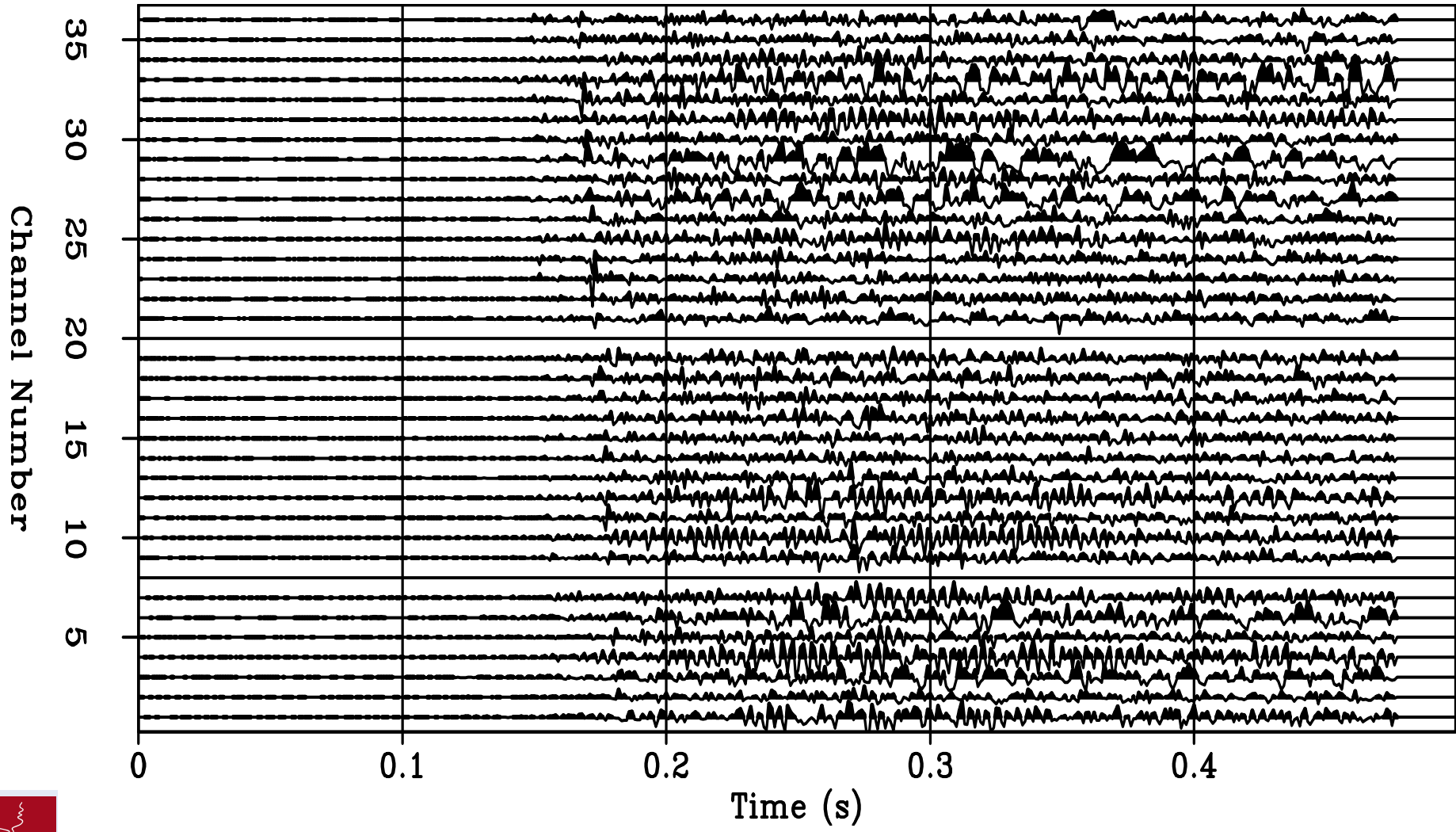
Cross-correlation result



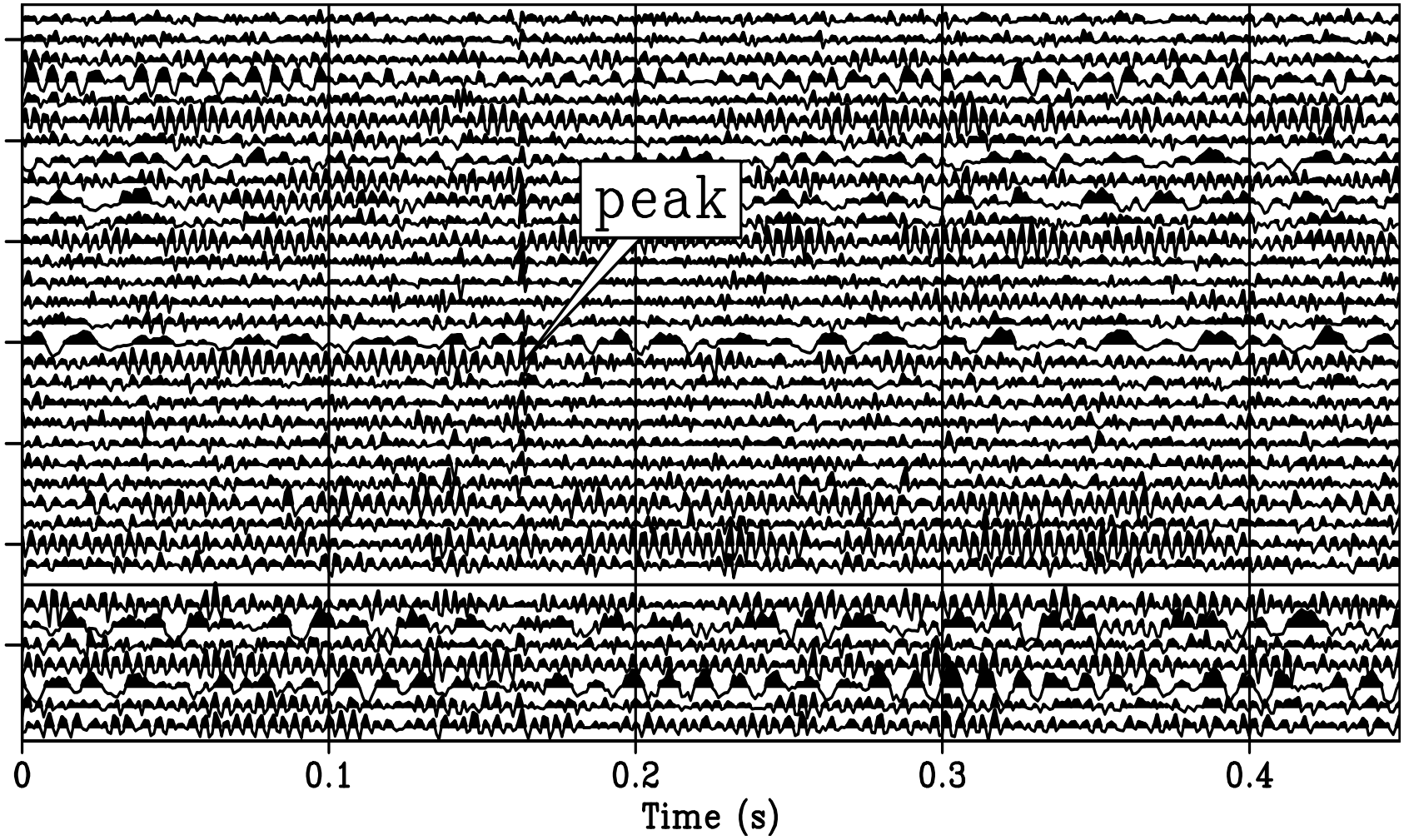
Stacked cross-correlation



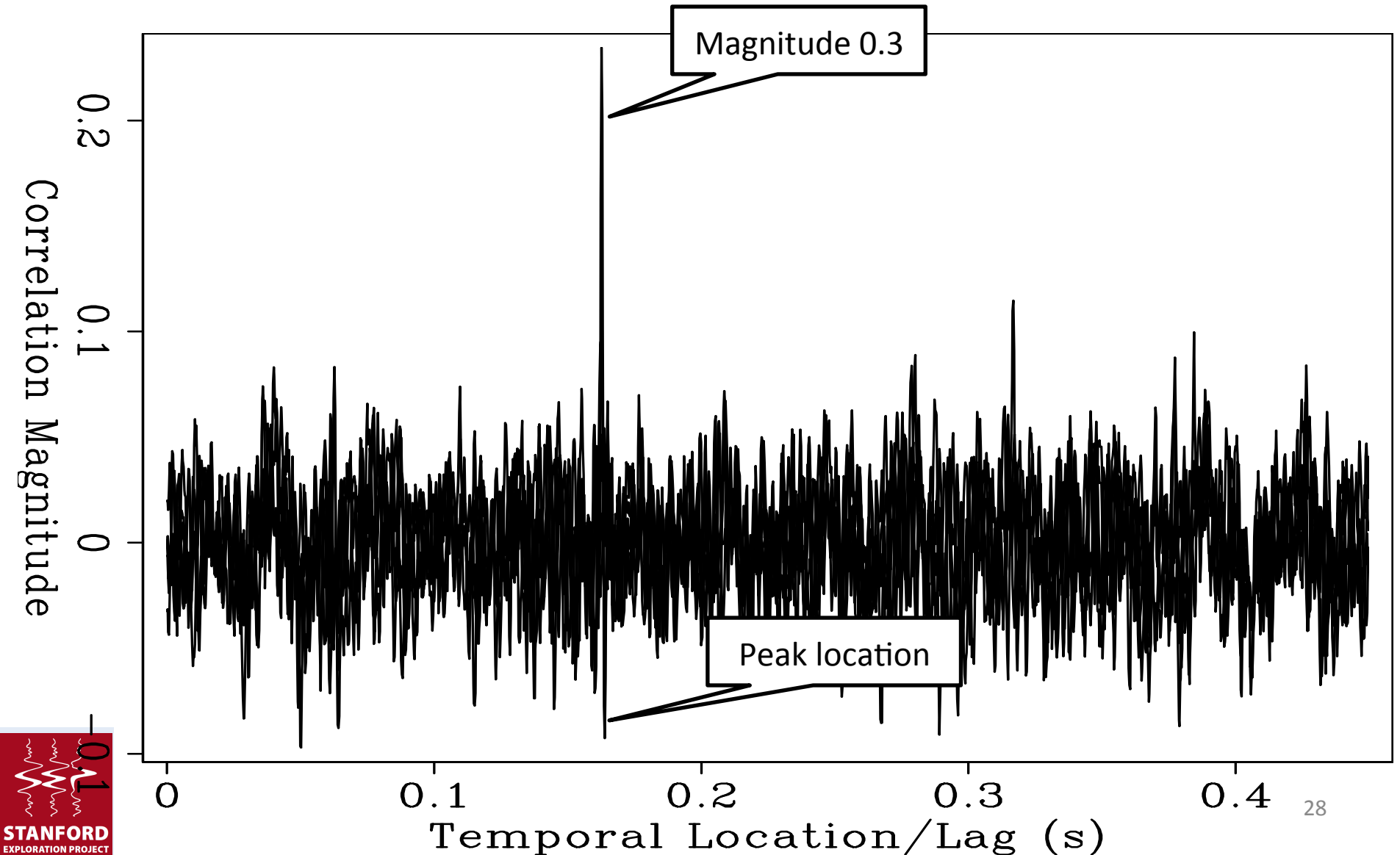
Event window (not master)

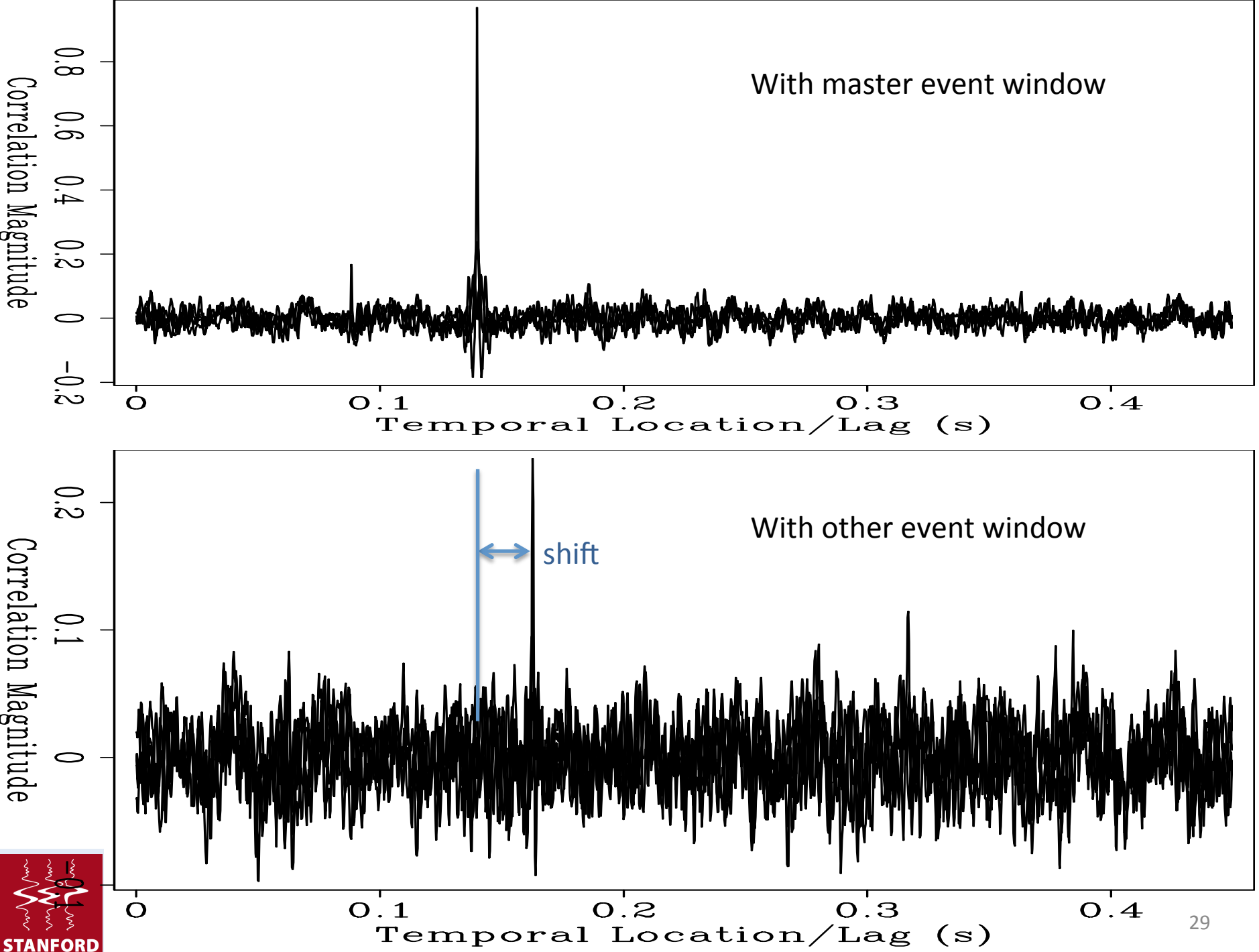


Cross-correlation peak

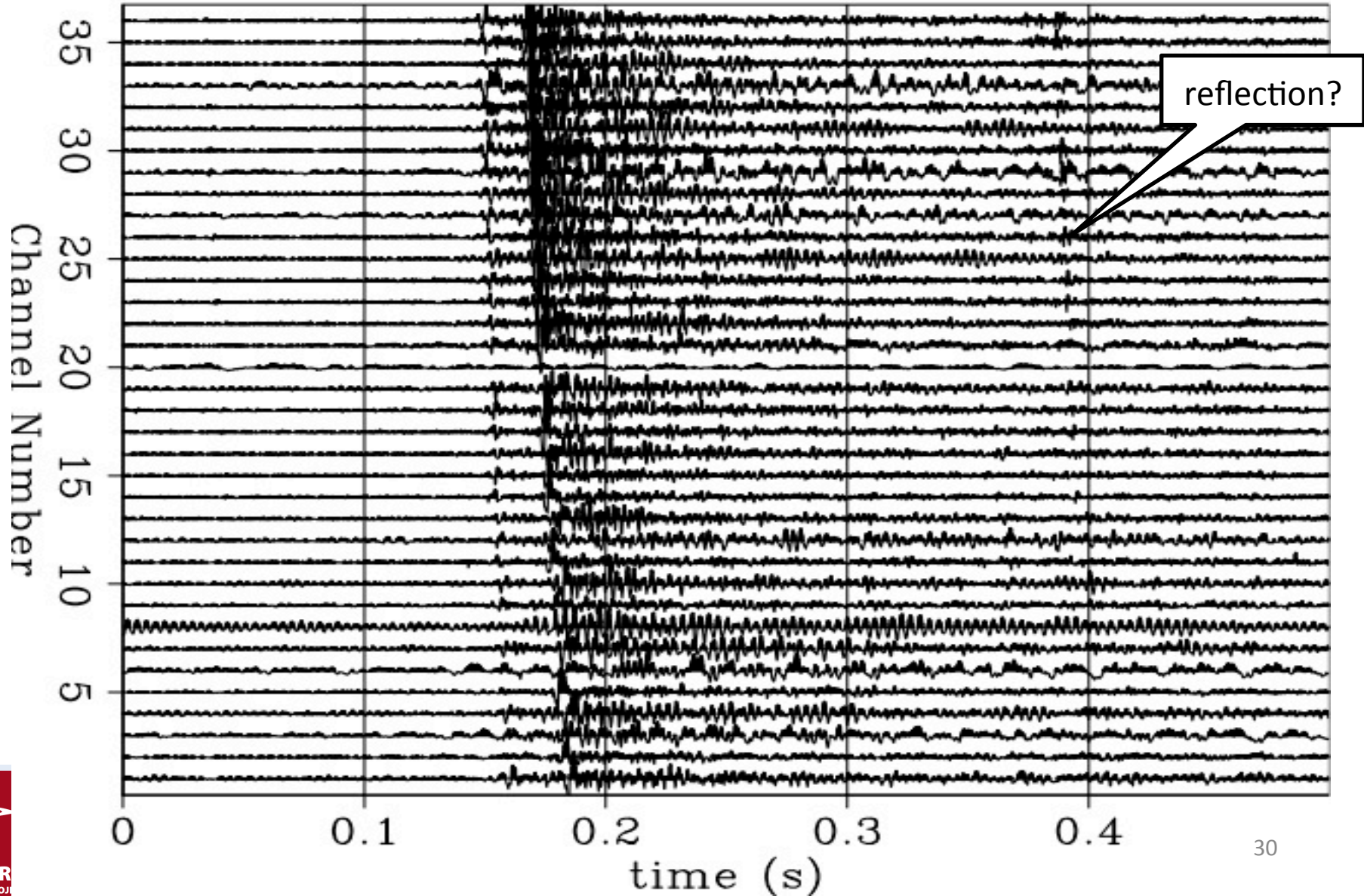


Stacked cross-correlation peak

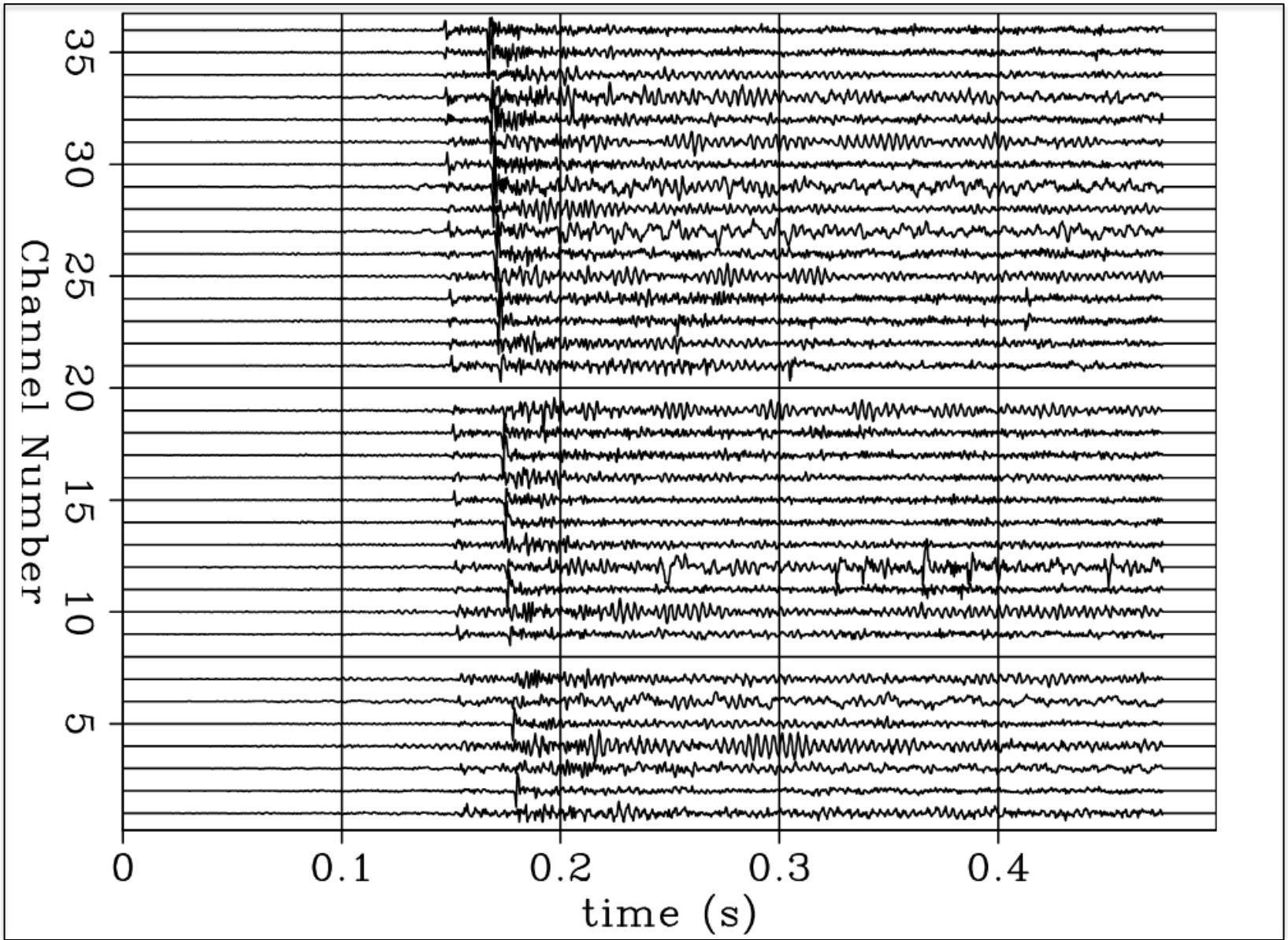



With master event window
Correlation Magnitude
0.8
0.6
0.4
0.2
0
−0.2
0
0.1
0.2
0.3
0.4
Temporal Location/Lag (s)
With other event window
shift
Correlation Magnitude
0.2
0.1
0
−0.1
0
0.1
0.2
0.3
0.4
Temporal Location/Lag (s)

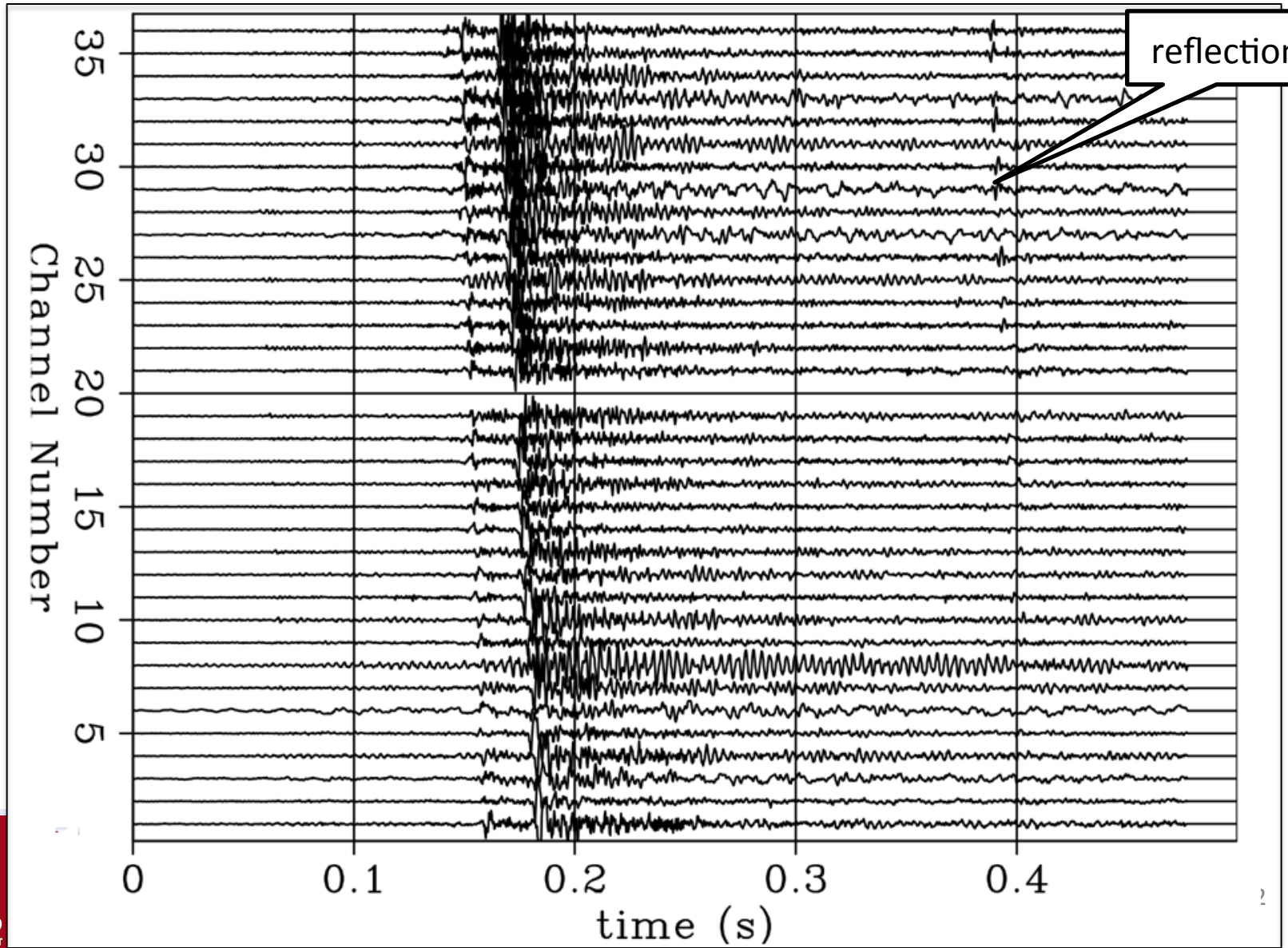
Stack of aligned event windows



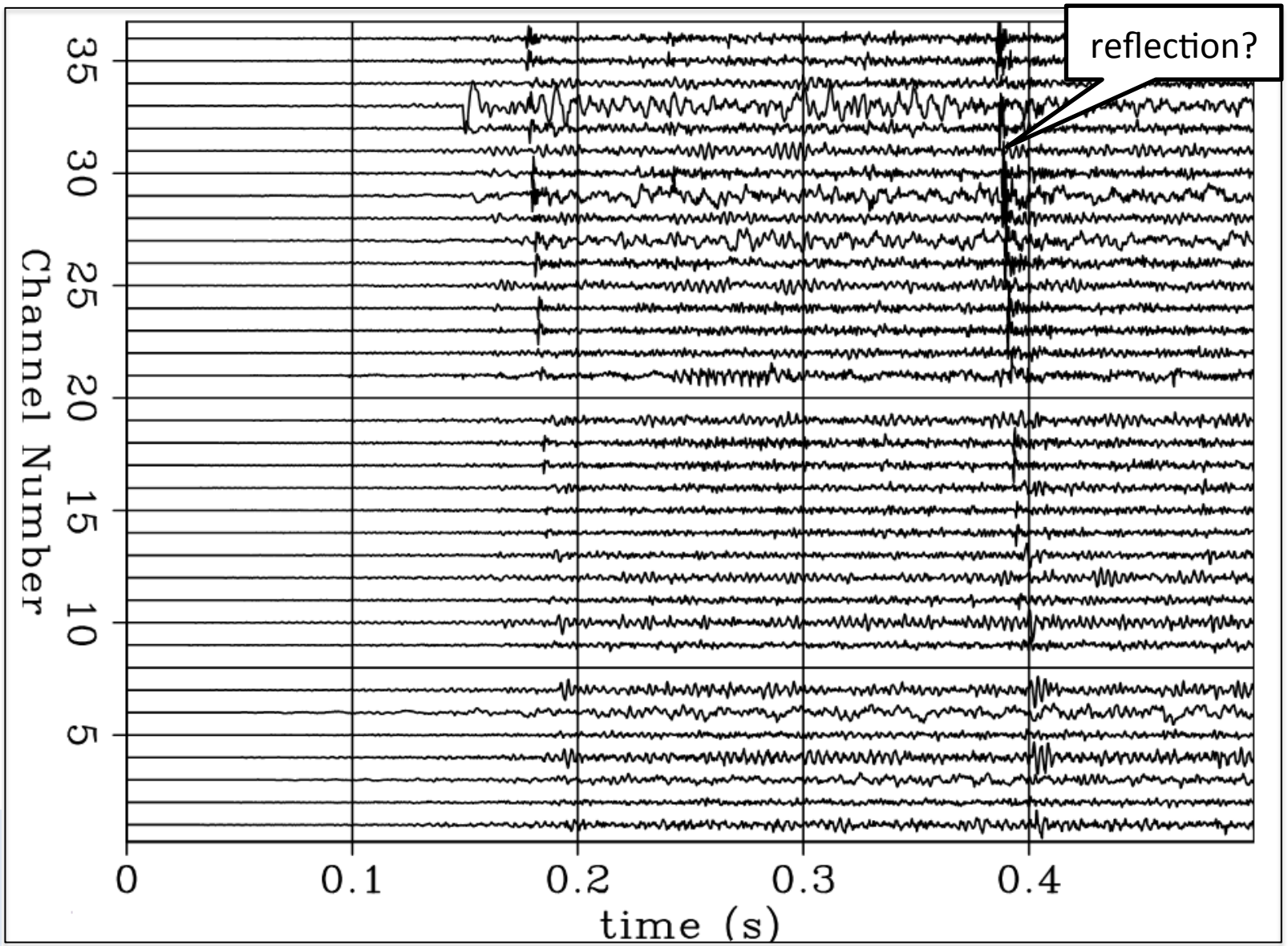
Individual windows



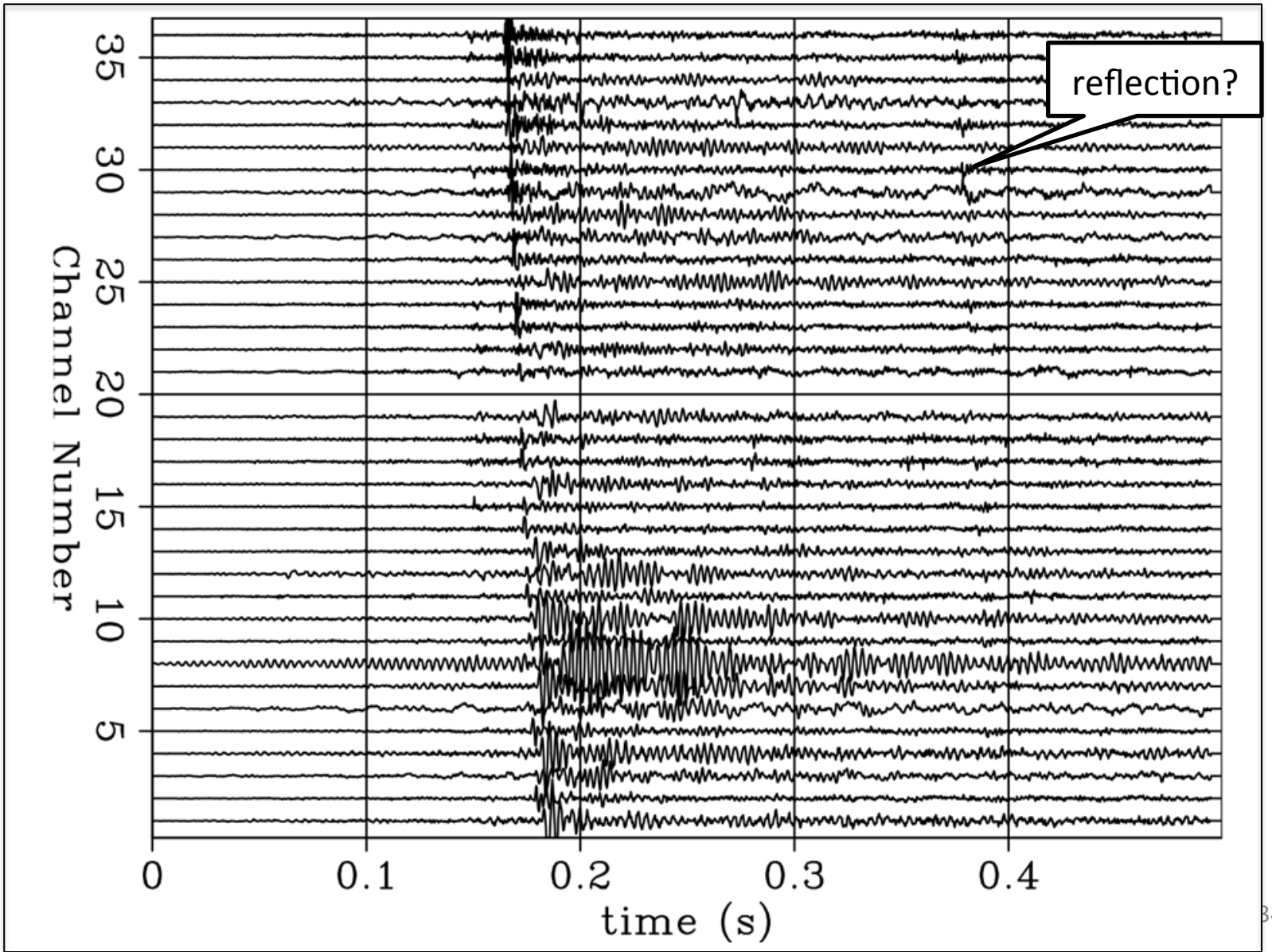
Individual windows



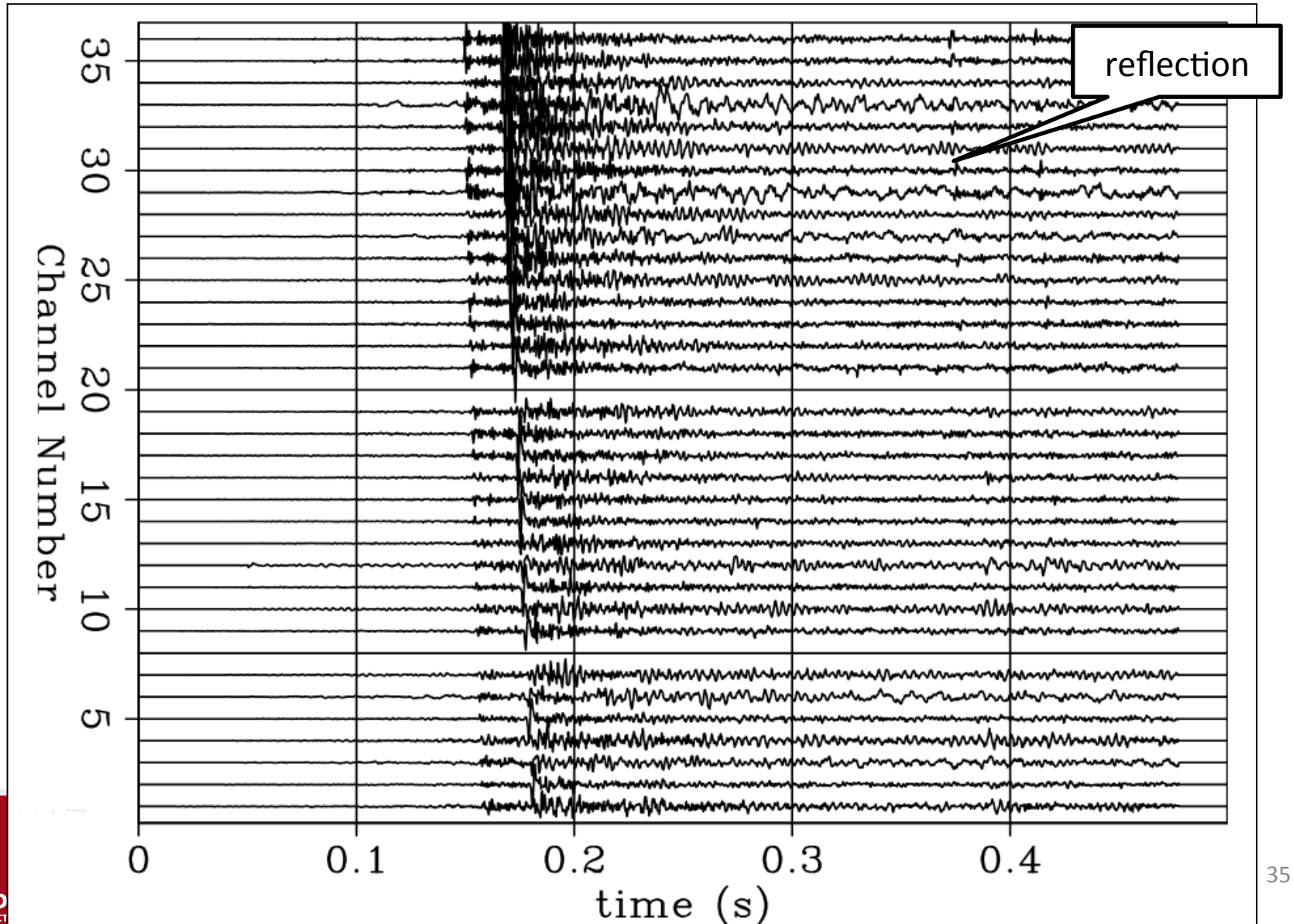
Individual windows



Individual windows



Individual windows



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Conclusions

- We identified and stacked some multiplets and their reflections
- Stacked multiplets and reflections are not as strong on the stack as they appeared on specific individual event windows
- Misalignment issues

Future work

- Dealing with misalignment
  - Use fractional sample shifts
  - Introduce trace-by-trace variable shifts (warping) of multiplets to account for small source location changes
  - Apply warping to reflections as well

Acknowledgements

- We thank Pinnacle, a Halliburton company, and the United States Department of Energy for providing the dataset.

Thank you!

Questions?

Comments?

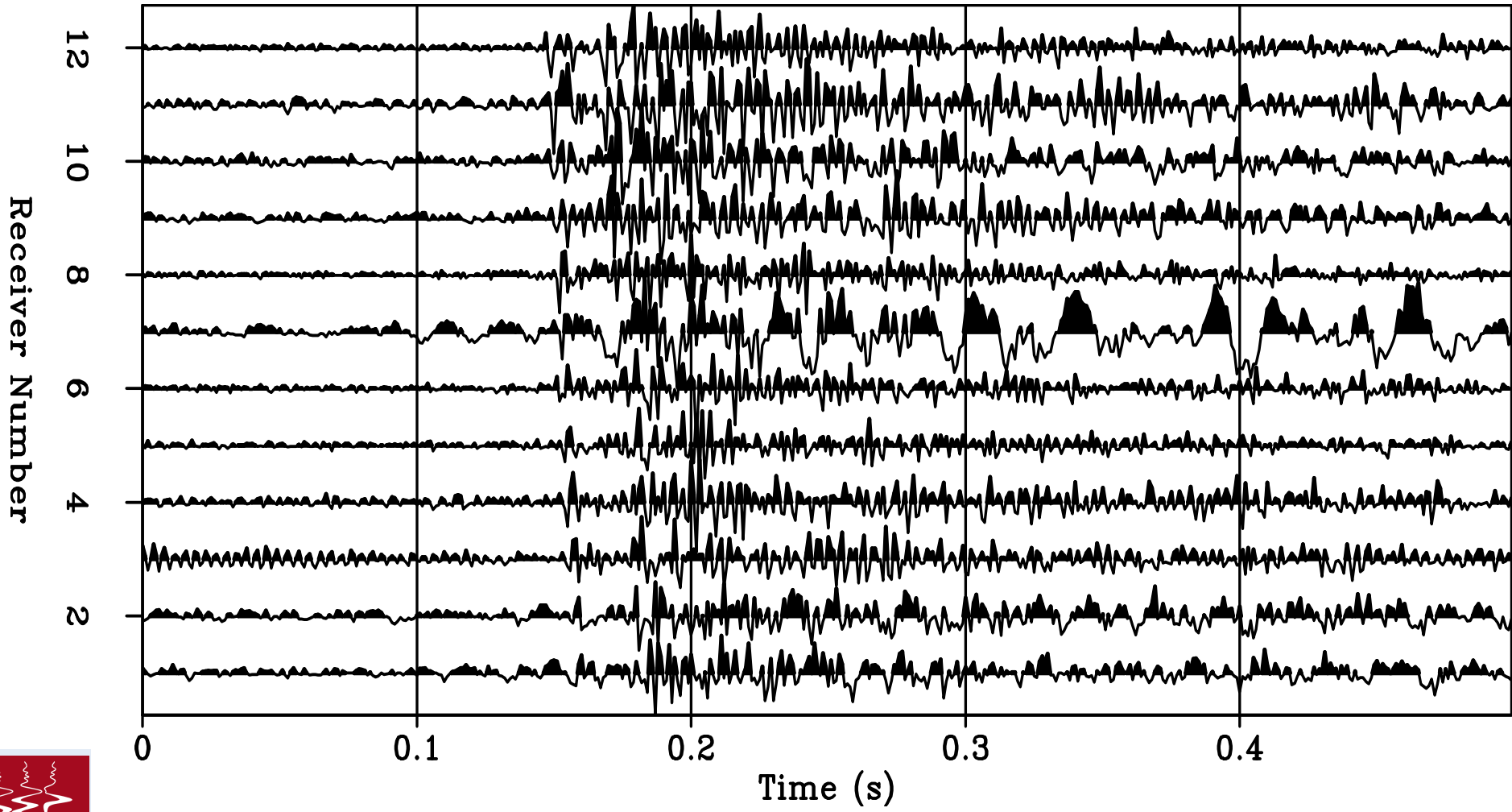
Summary

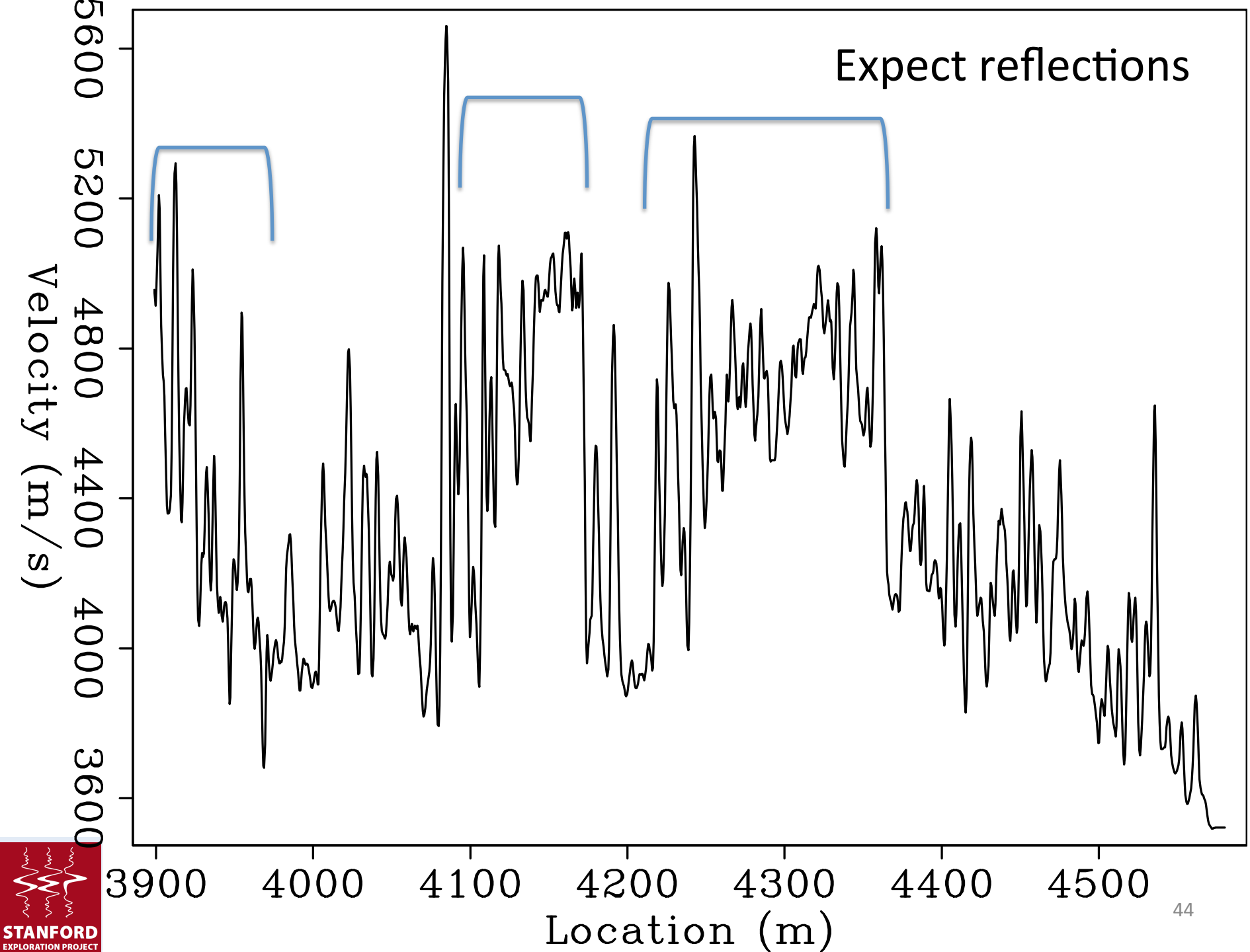
- Our ultimate goal is to use microseismic reflections to image the subsurface
- We have successfully identified and stacked multiplets and their reflections
- We still need to work on some alignment problems to further enhance S/N ratio and boost reflections

References

Sharma, M. M., P. B. Gadde, R. Sullivan, R. Sigal, R. Fielder, D. Copeland, L. Griffin, and L. Weijers, 2008, Slick water and hybrid fracs in the Bossier: Some lessons learnt: SPE Annual Technical Conference and Exhibition, Houston, TX, USA, 89876–MS.

P-direction projection of stacked event windows




Expect reflections
Velocity (m/s)
5600
5200
4800
4400
4000
3600
3900
4000
4100
4200
4300
4400
4500
Location (m)