Time-lapse refraction analysis monitoring shallow gas migration

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Objective

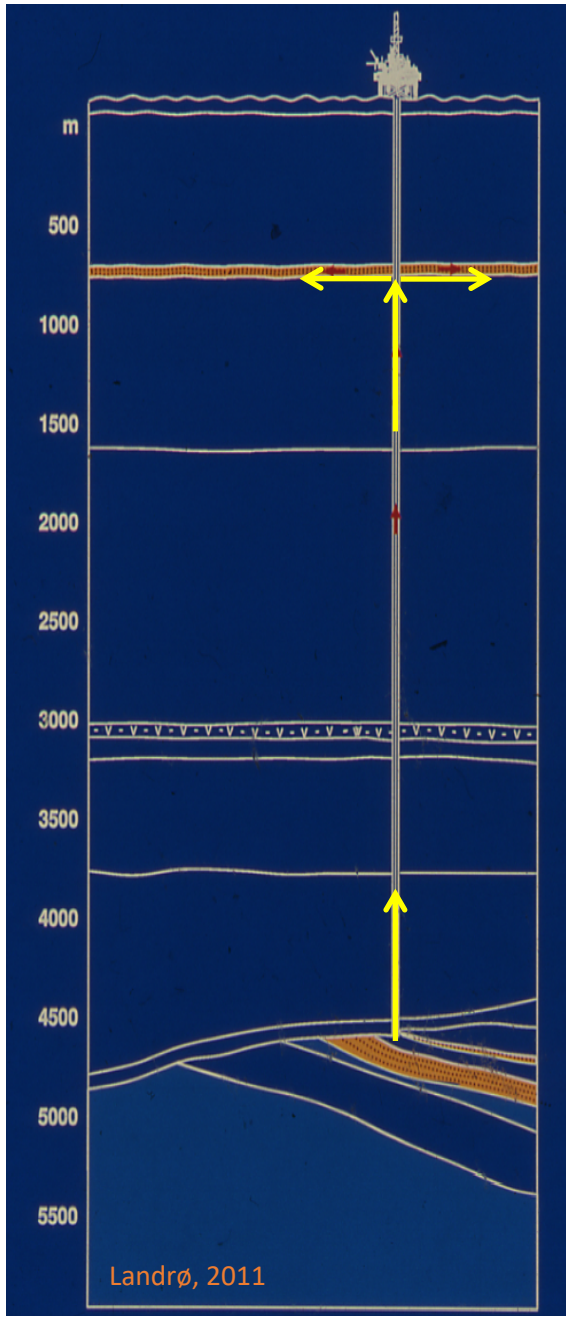
- Perform a 4D refraction time-shift analysis to detect and monitor gas anomalies as shallow as possible

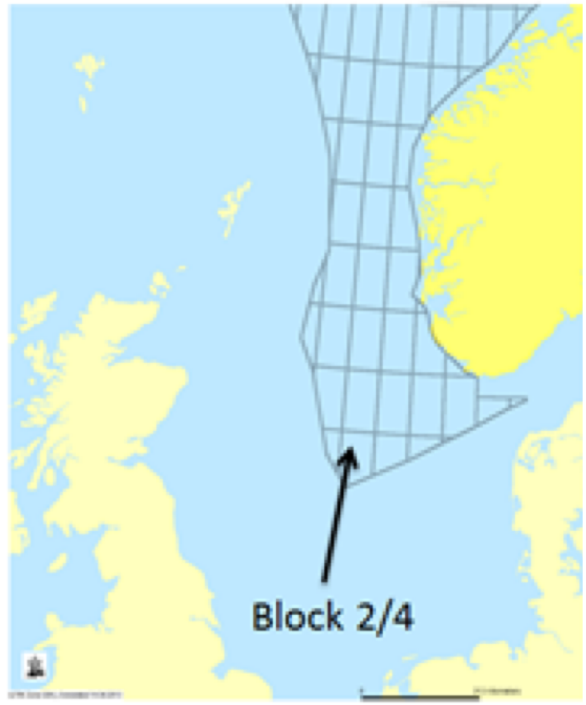
- Motivation:
  - Monitor fluid migration from an underground blowout.
  - Shallow gas can be a geohazard for crew, installations and the environment.
  - Carbon capture and storage scenarios.

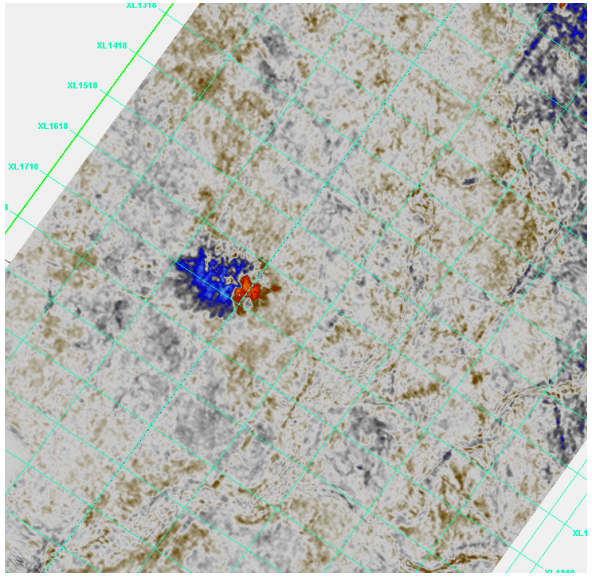
Introduction

- Block 2/4
- Blowout in well 2/4-14

  January 1989
- Repeated seismic 1988 – 2009

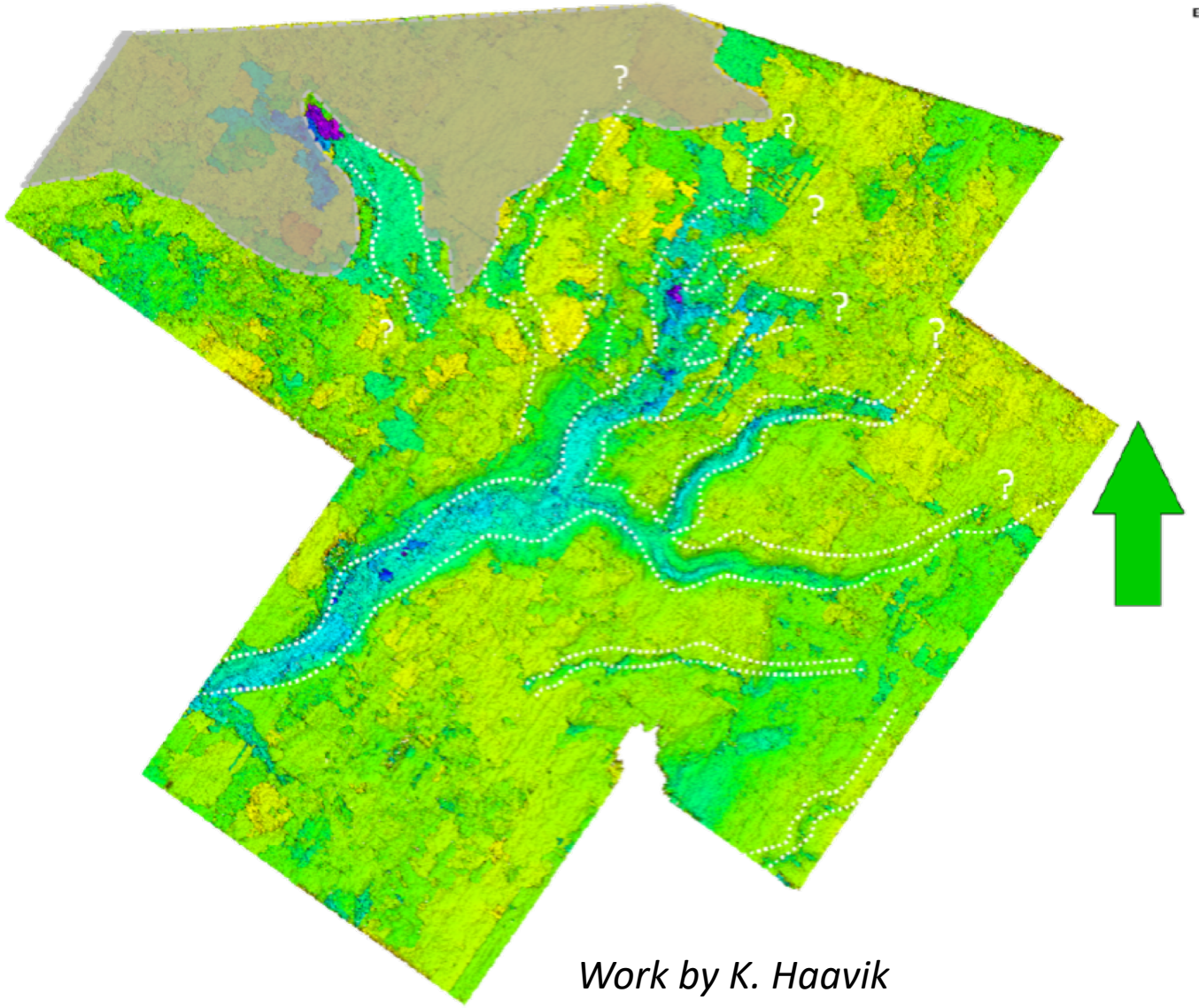






Tunnel valleys

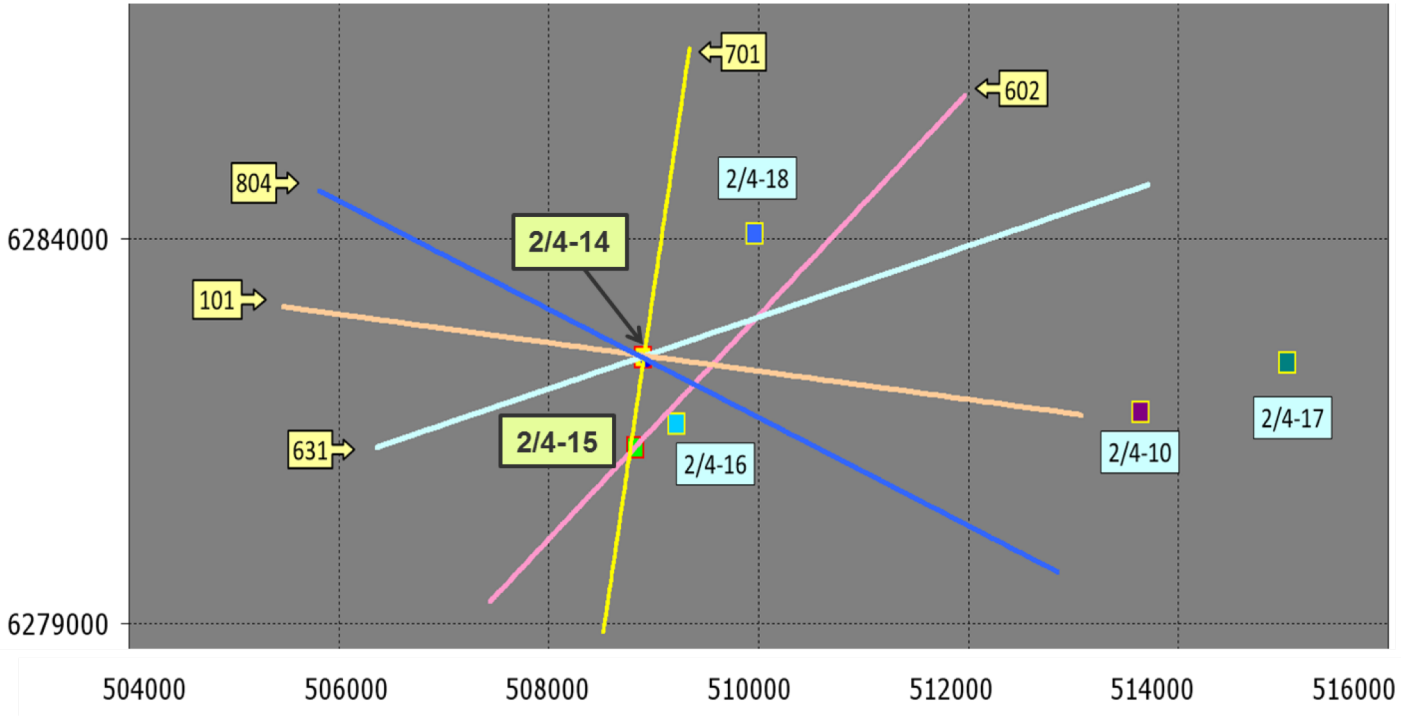
- Interpreted tunnel valleys in the area
- Porous and permeable infill
- Might store large volumes of gas and serve as transport routes

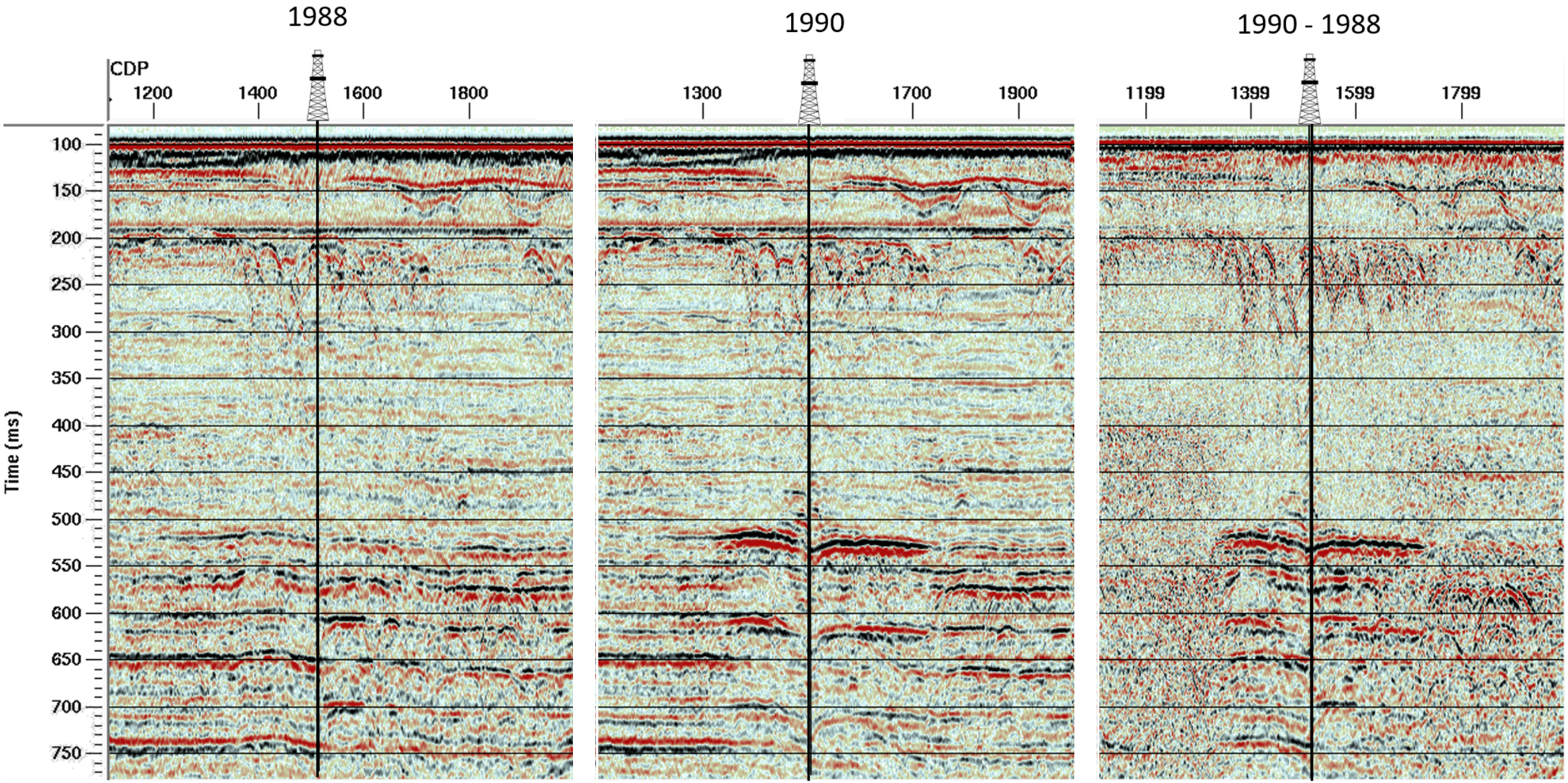


Work by K. Haavik

Provided data

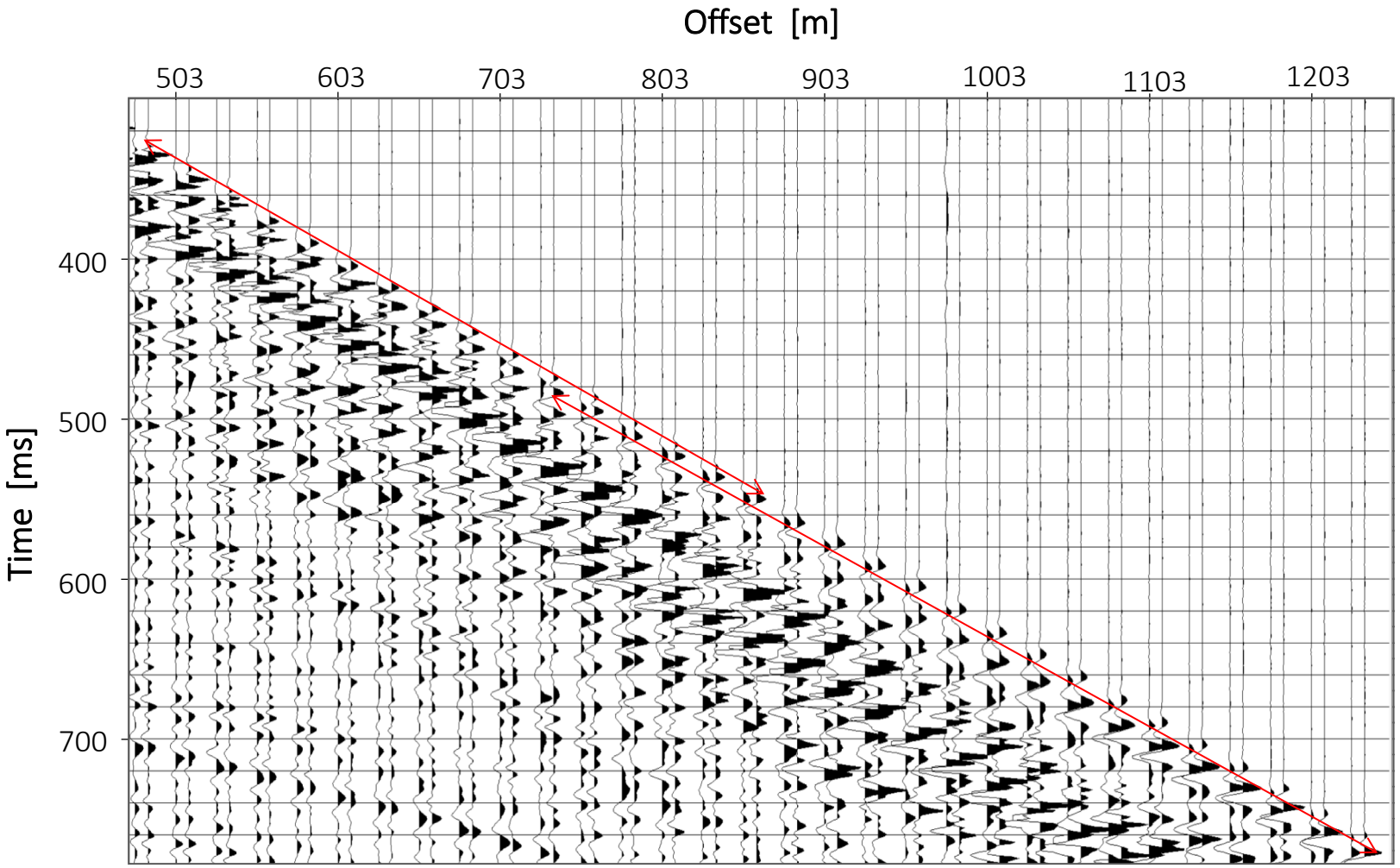
- Line 804, intersecting well 2/4 – 14
- Acquired in 1988, 1990, 2009
- Repeatability – good opportunities for 4D analysis



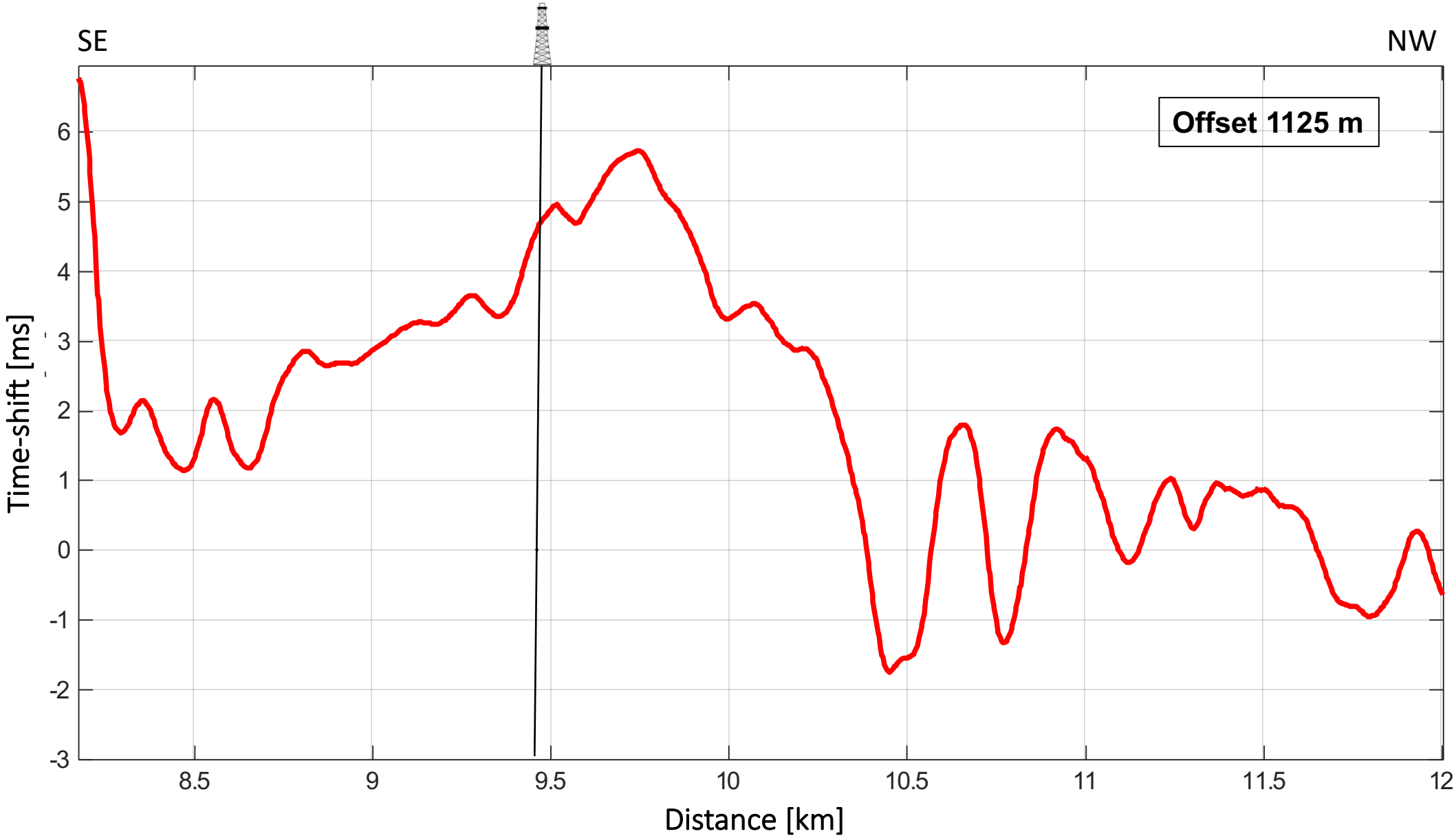

1988
1990
1990 - 1988
CDP
1200
1400
1600
1800
1300
1700
1900
1199
1399
1599
1799
Time (ms)
100
150
200
250
300
350
400
450
500
550
600
650
700
750

Method

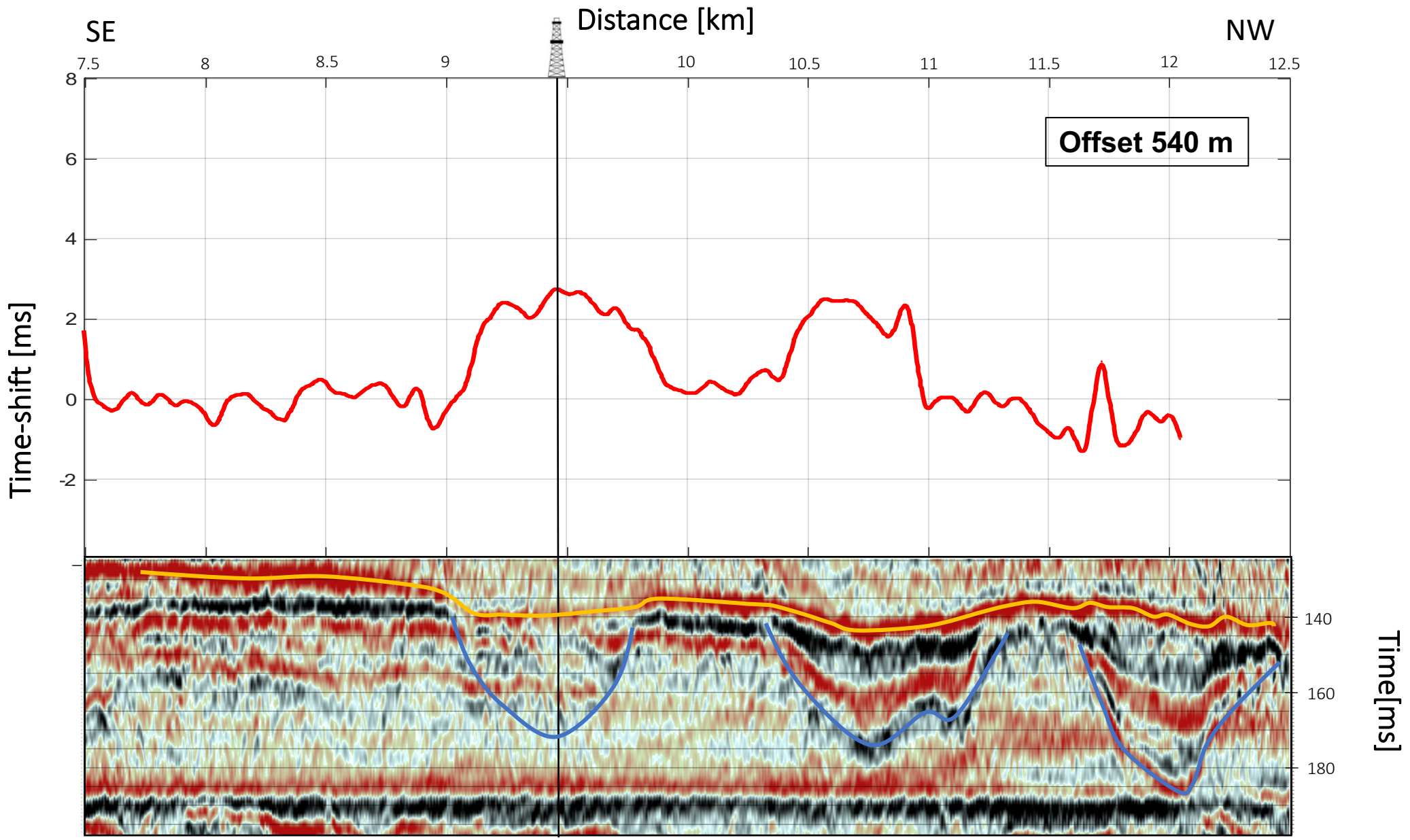
- Identify refractions
- Alternate datasets
- Cross-correlation
- Extract time-shift values



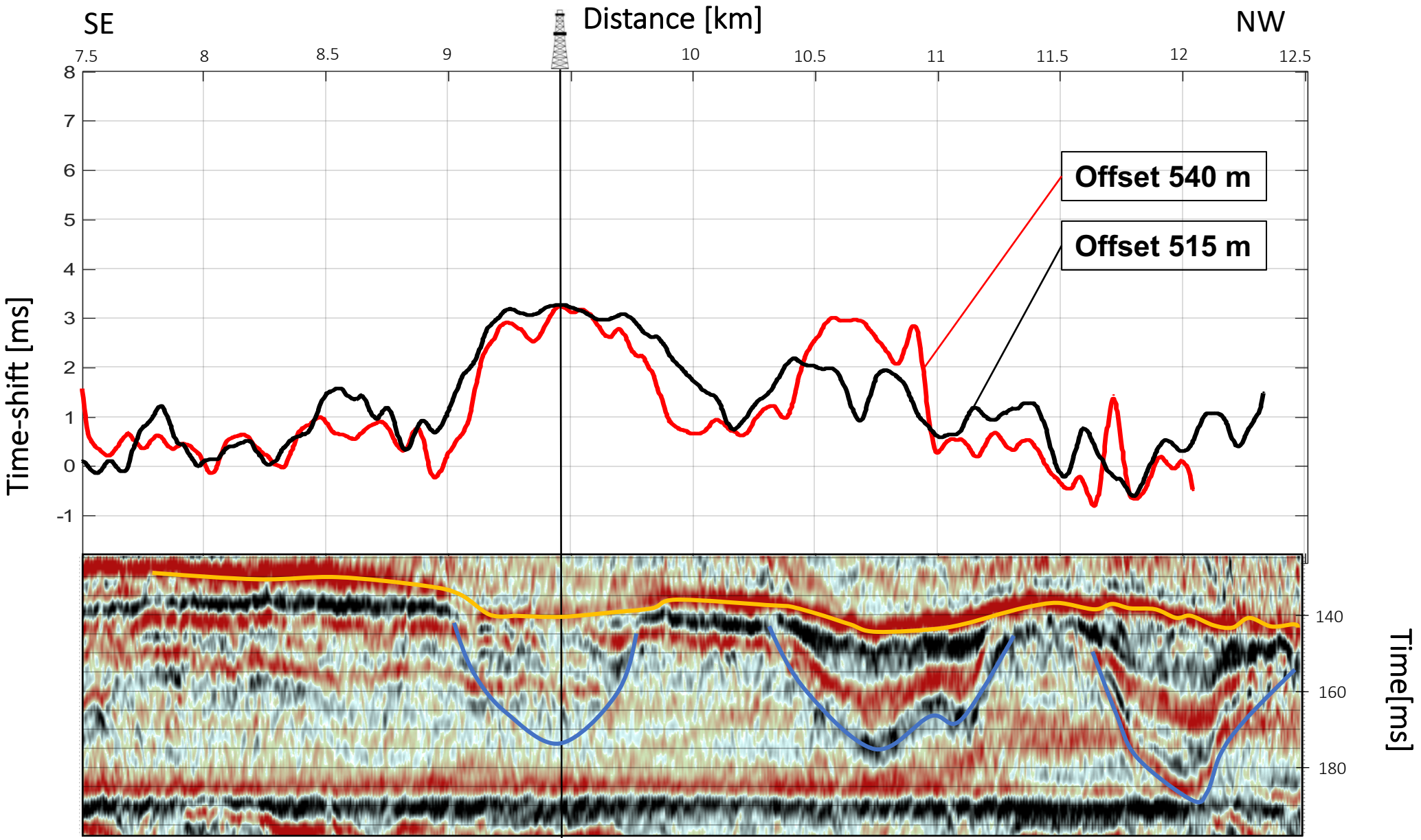
1988 – 1990: Significant anomaly, 1.5 km



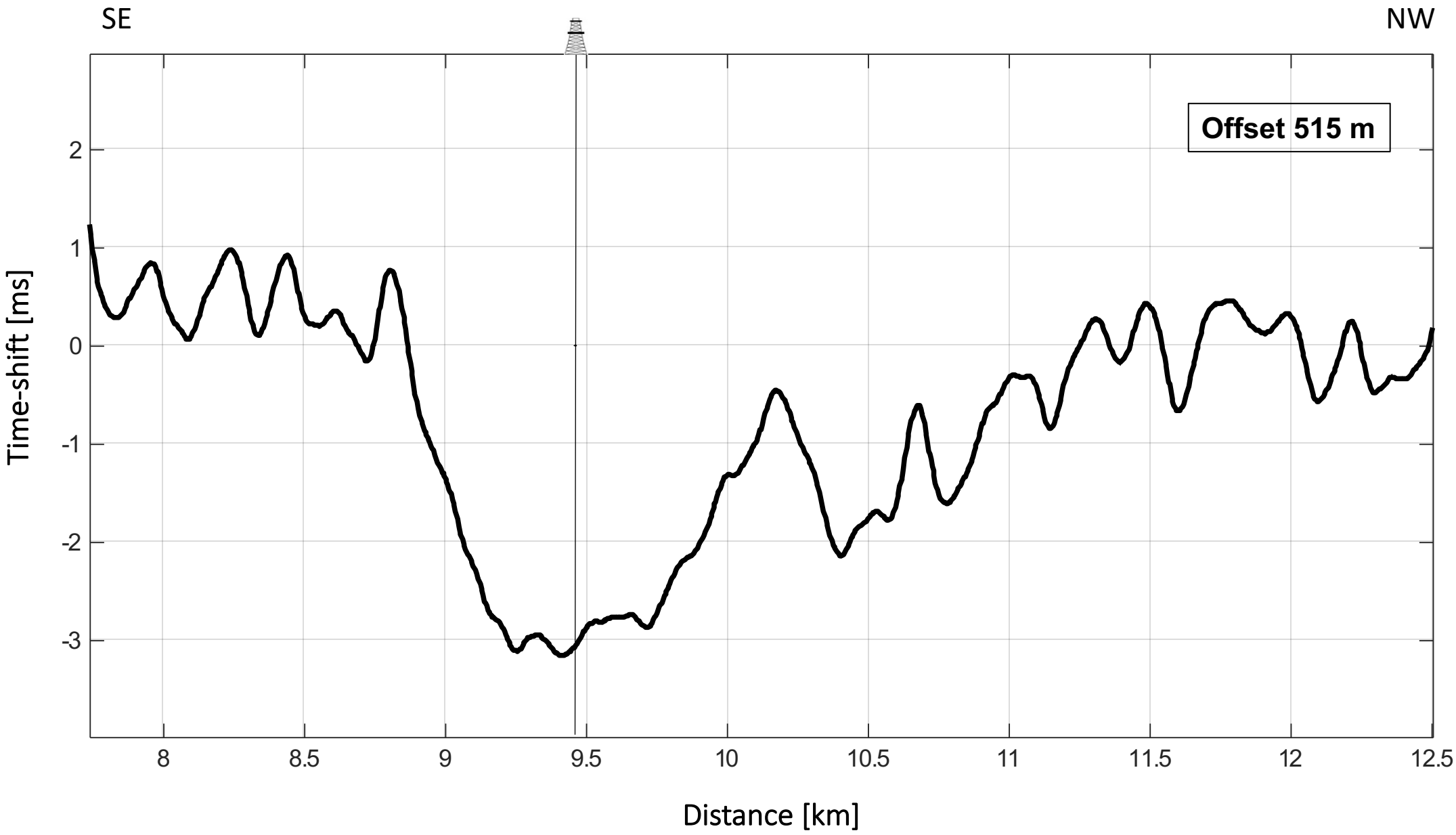
1988 – 1990: two anomalies, good correlation with tunnel valleys



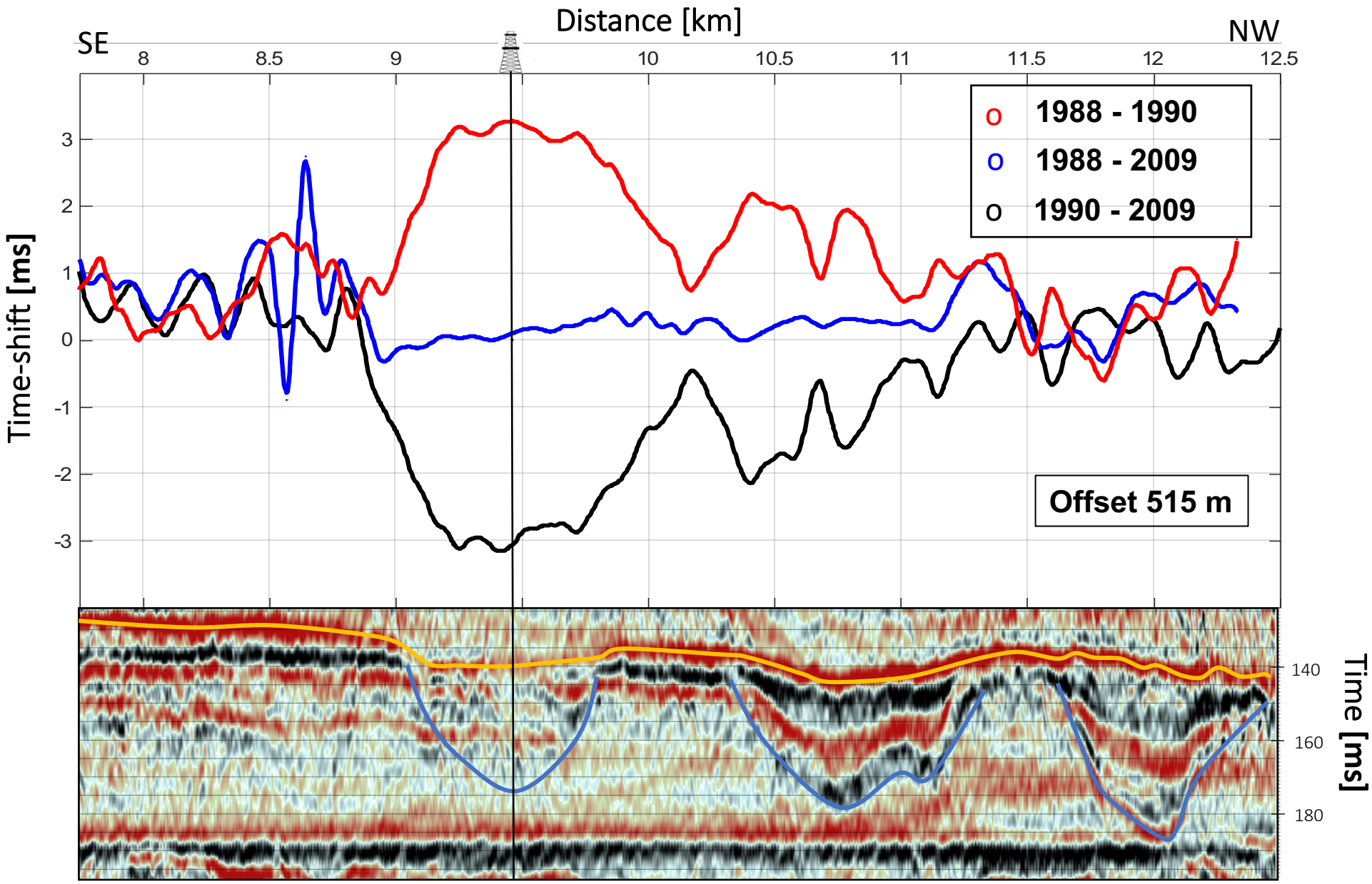
Differences due to variations in time-gates and offsets

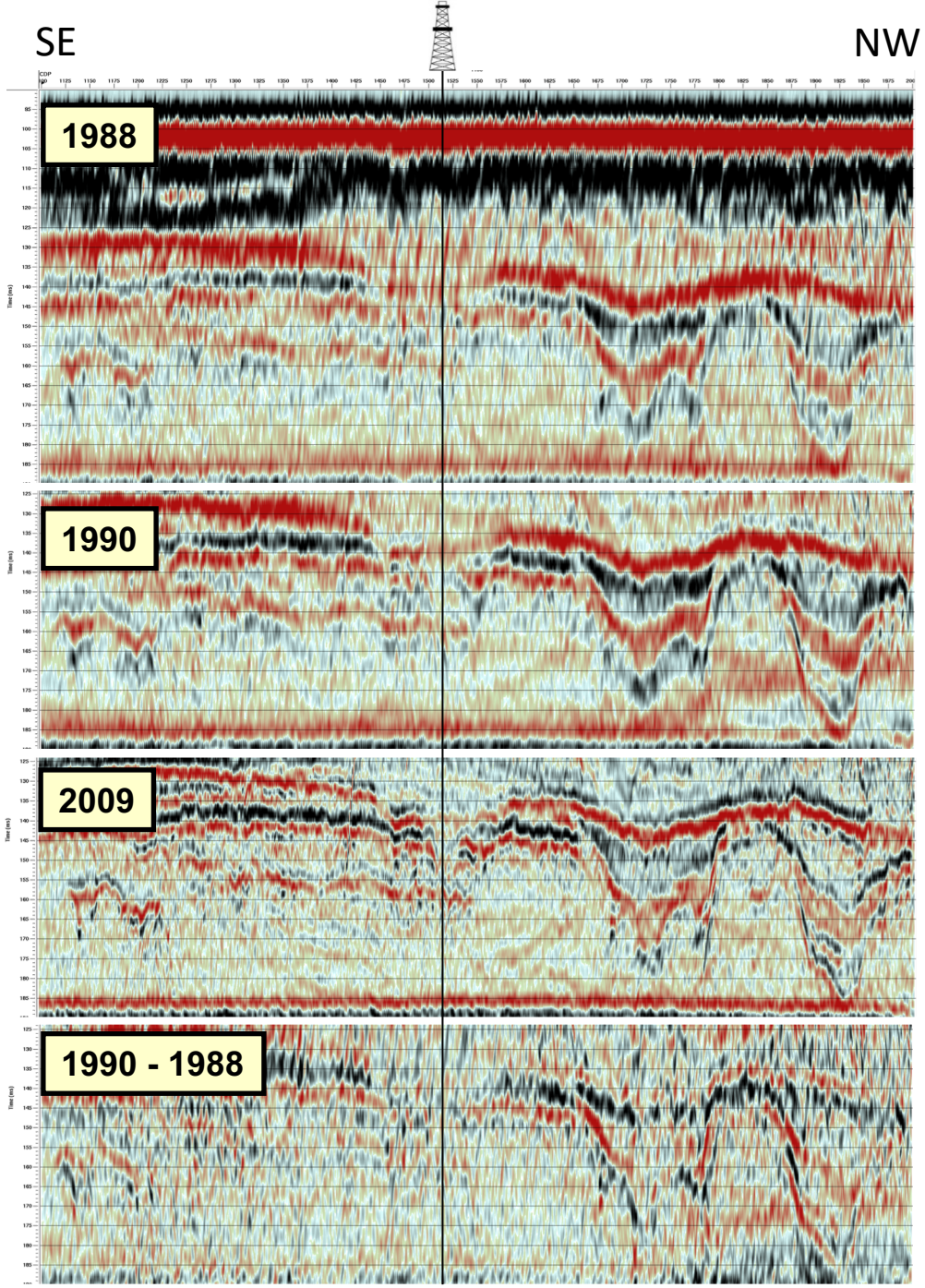


1990 – 2009: Negative anomalies indicating less gas



1988 – 1990 – 2009: Gas migrated out of tunnel valley

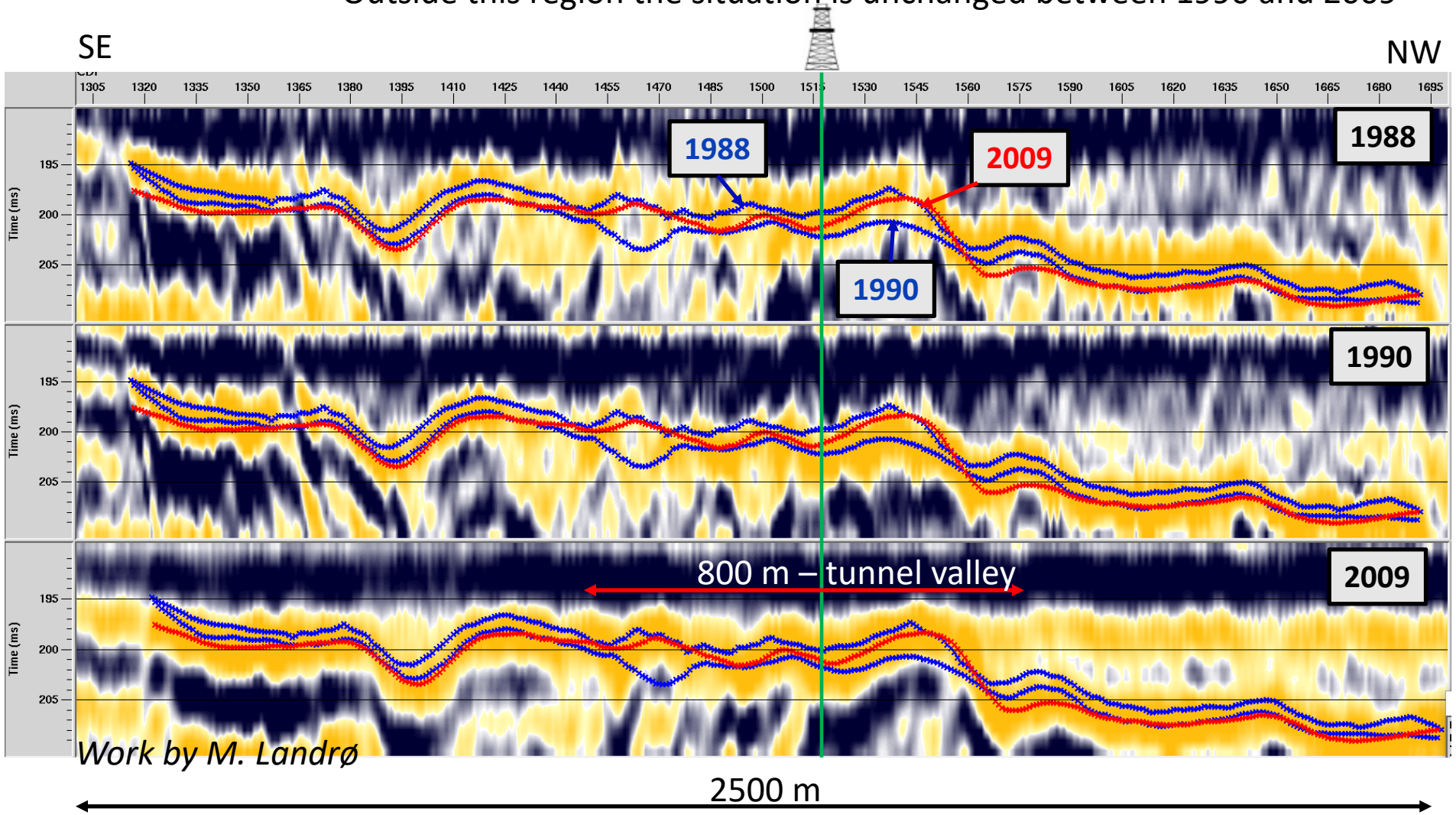




- Tunnel valleys may be difficult to image due to inhomogeneous and chaotic infill.
- The horizontal refracted waves enables us to detect velocity changes in the seismic data that may not be visible on reflection seismic.

Line 804 – shallow timeshifts – indications of leakage patterns

- Alignment of seabed reflection to 100 ms
- Near to the well: significant increase in timeshift between 88 and 90 – followed by a reduction back to pre-blowout values again – 800 m width
- Outside this region the situation is unchanged between 1990 and 2009



Summary

- The tunnel valleys act as storage volumes and transport routes for the blowout gas
- 4D refraction seismic using horizontal waves detects variations that may not be visible on conventional reflection seismic
- Uncertainties and limitations
  - Quality of data
  - Geometry
  - Repeatability issues