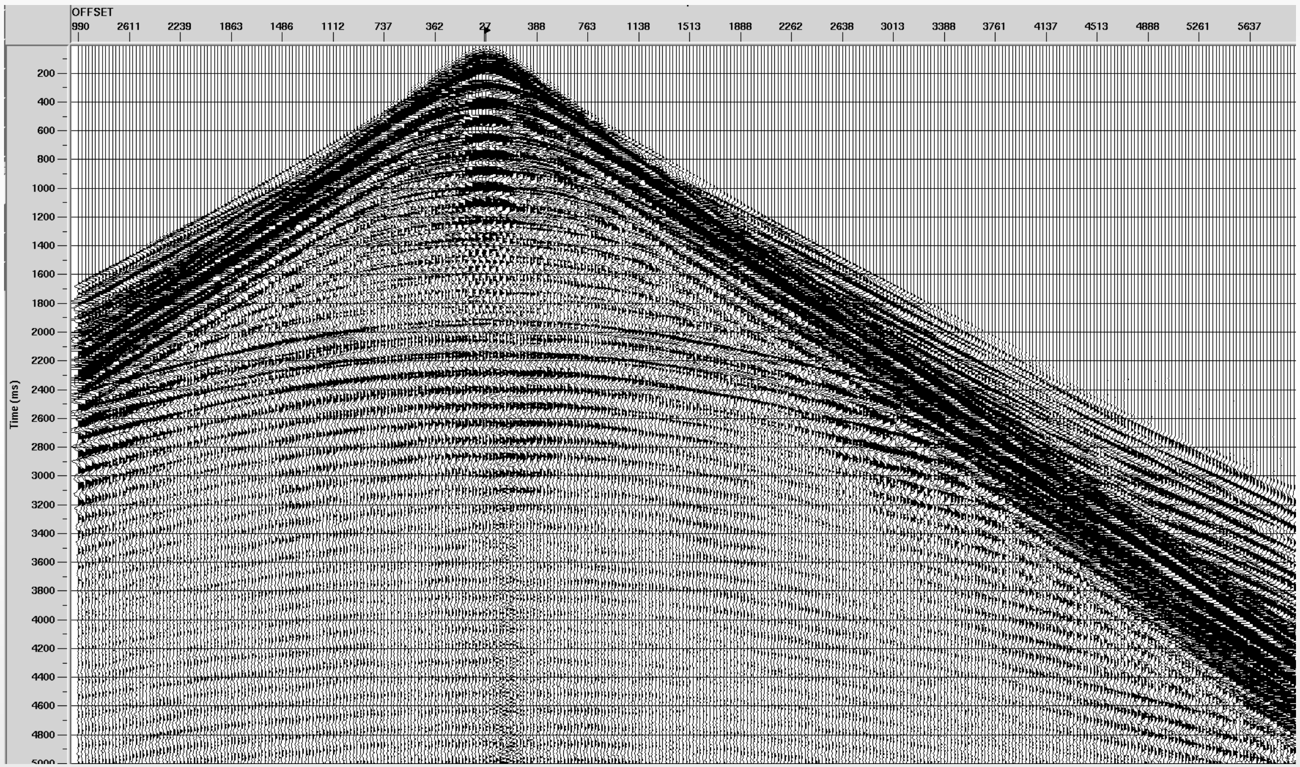
4 D refraction analysis – status and future applications



NTNU
Norwegian University of
Science and Technology

M. Landrø, NTNU

References

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- Hilbich, **2010**, Time-lapse refraction seismic tomography for the detection of ground ice degradation, The Cryosphere, 4, 243-259.
- Zadeh, Landrø and Barkved, **2011**, Long-offset time-lapse seismic: Tested on the Valhall LoFS data, Geophysics, 76, O1-O13.
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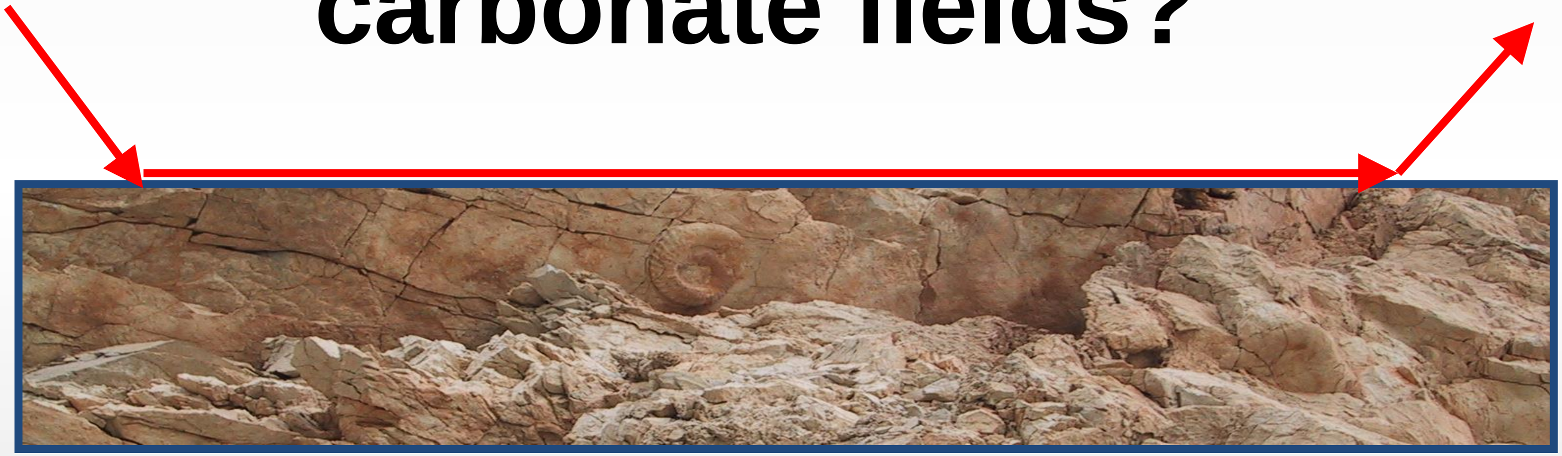
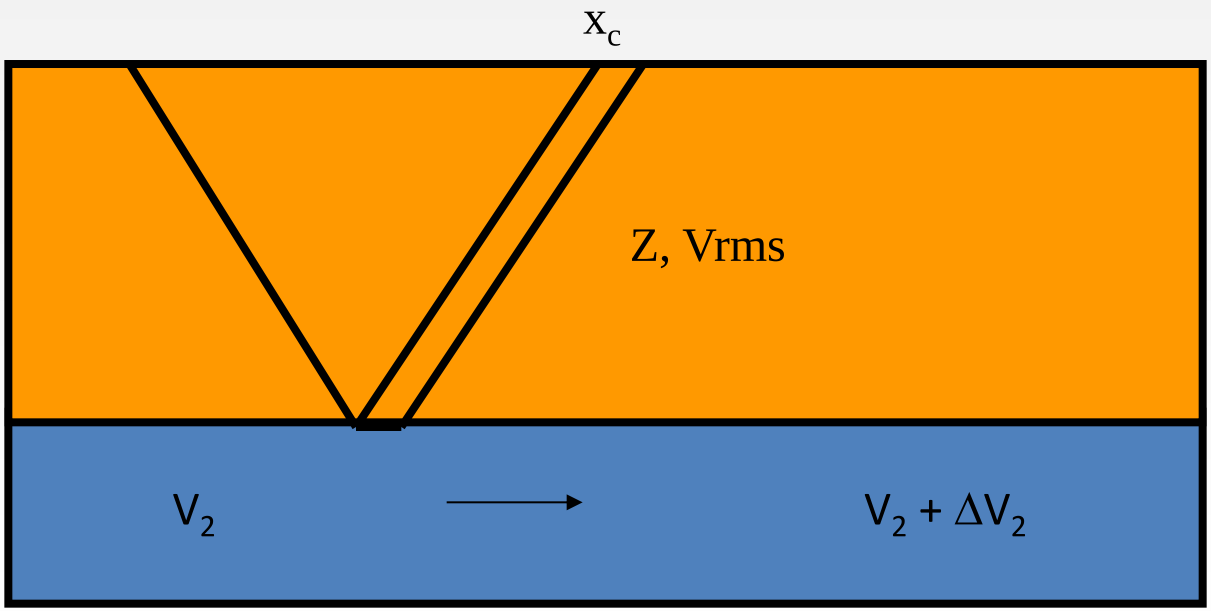
Time lapse refraction seismic – a tool for monitoring carbonate fields?



by

M. Landrø (NTNU) , A. K. Nguyen, (SINTEF) and H. Mehdizadeh, (NTNU)

SEG, 2004



$$x_C = \frac{2z}{\sqrt{\frac{v_2^2}{v_{RMS}^2} - 1}}$$

$$x'_C = \frac{2z}{\sqrt{\frac{(v_2 + \Delta v_2)^2}{v_{RMS}^2} - 1}}$$

Simple relation between critical offset shift and velocity change

Change in critical offset due to a velocity change in the reservoir layer:

$$\Delta x_c \approx -\frac{\Delta v_2}{v_{RMS}} \frac{v_2}{v_{RMS}} \frac{2z}{\left(\frac{v_2^2}{v_{RMS}^2} - 1\right)^{\frac{3}{2}}}$$

Typical values:

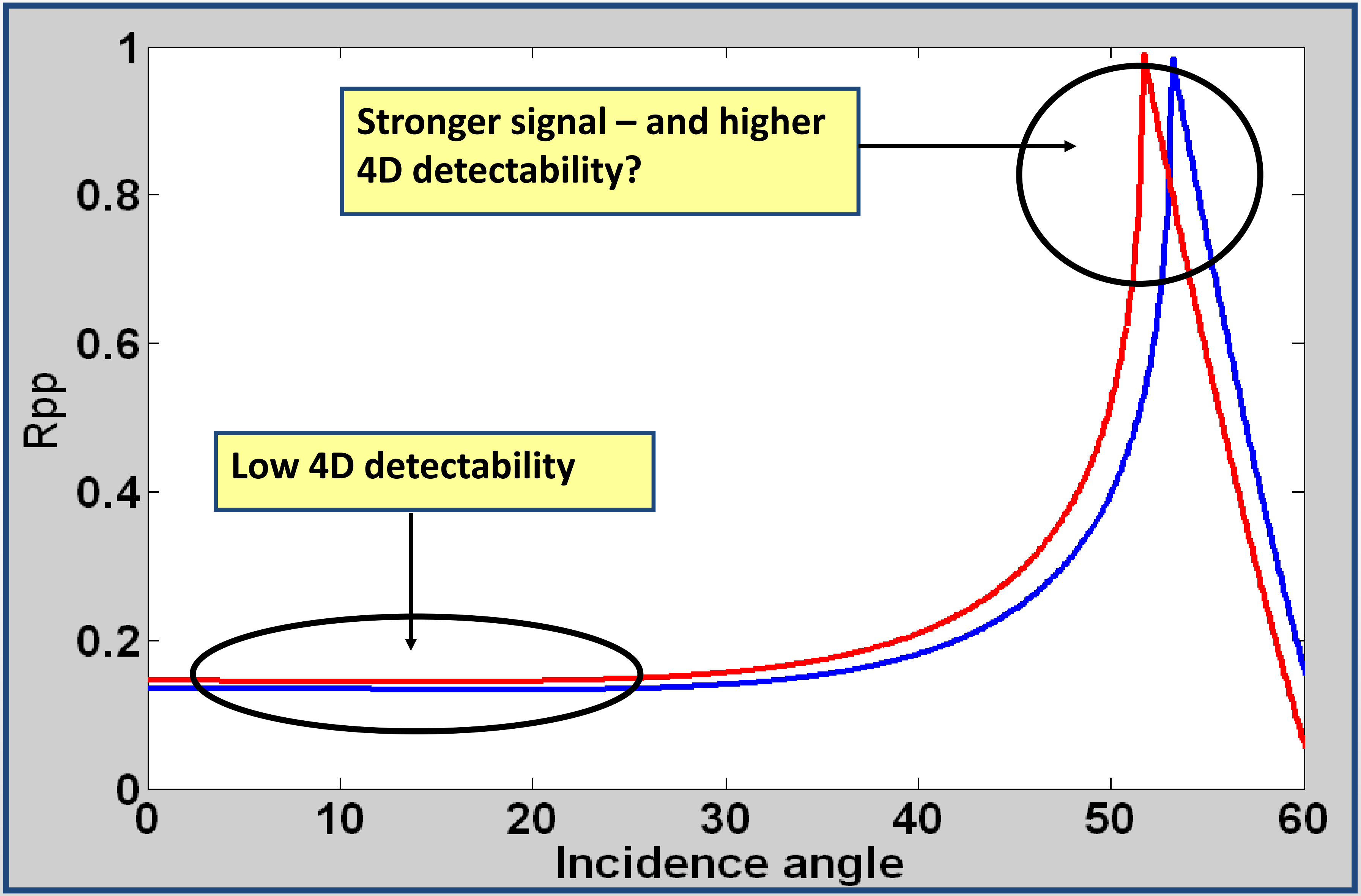
2000 m depth
V_2 = 2500 m/s
V_{RMS} = 1800 m/s

→

$$\Delta x_c \approx -3.4 \Delta v_2$$

A 50 m/s velocity change => a shift of 170 m

For small velocity changes the reflectivity changes at normal offsets are small – but the shift in critical angle is more pronounced...



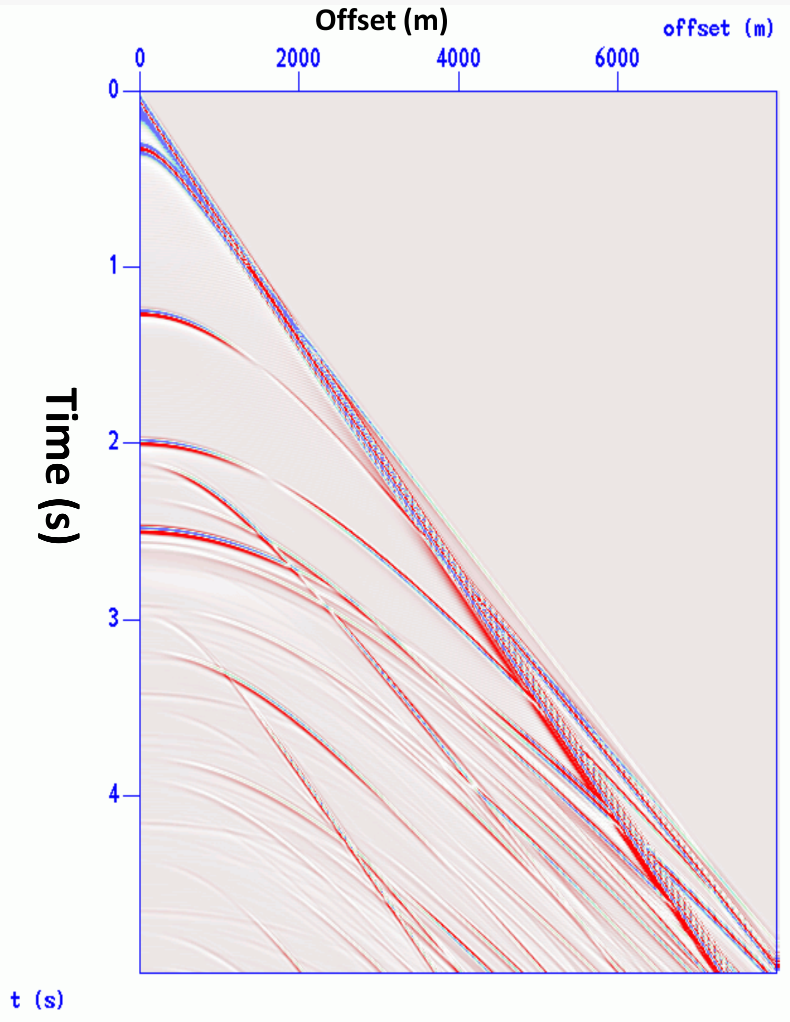
The synthetic model:

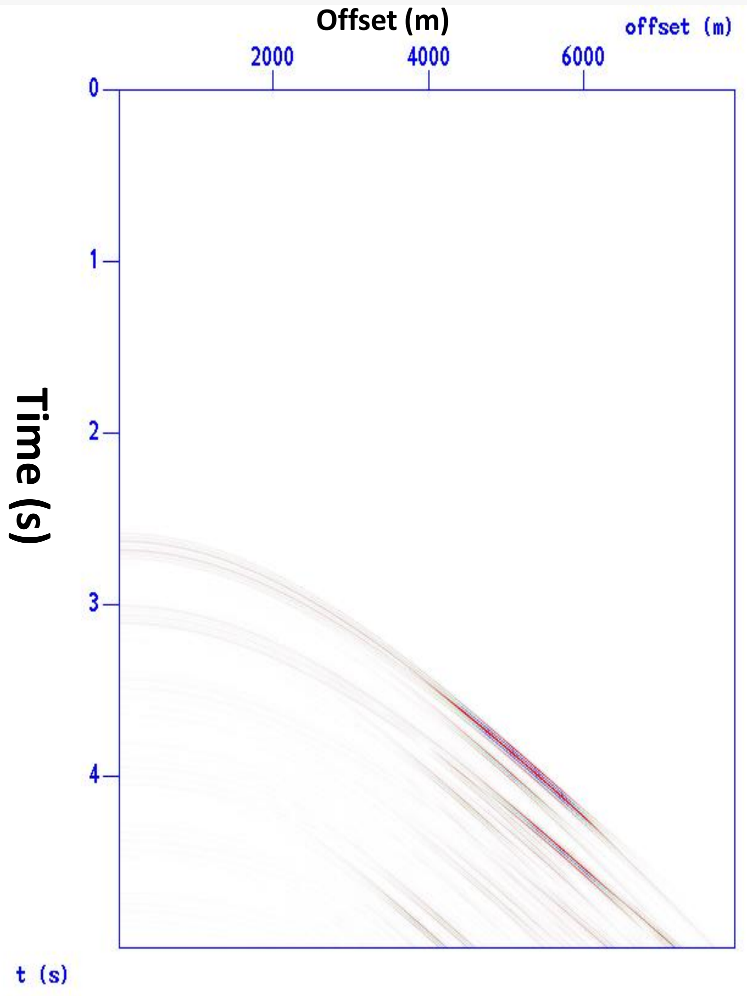
	Thick-ness (m)	Vp(m/s)	Vs(m/s)	Density (kg/m3)
Water	210	1480	0	1000
Layer 1	800	1700	600	1500
Layer 2	700	1900	1000	1700
Layer 3	500	2000	1400	2000
Reservoir	100	2500 (base) 2550 (model 1) 2600 (model 2)	1800	2200
Half plane	Infinity	2300	1600	2300

2% and 4% velocity increase for TL model 1 and 2

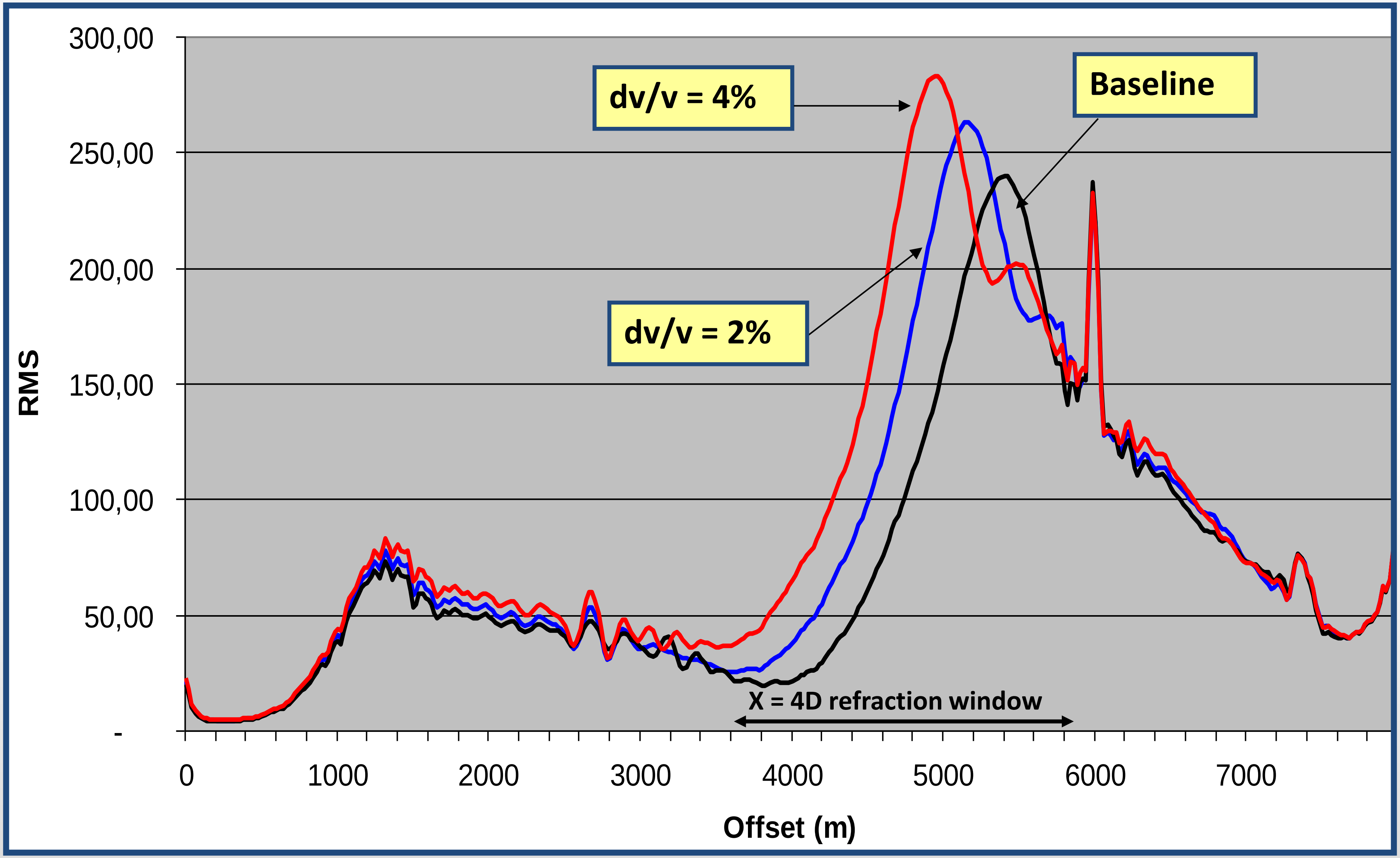
Baseline and difference data

(Finite difference modeling)

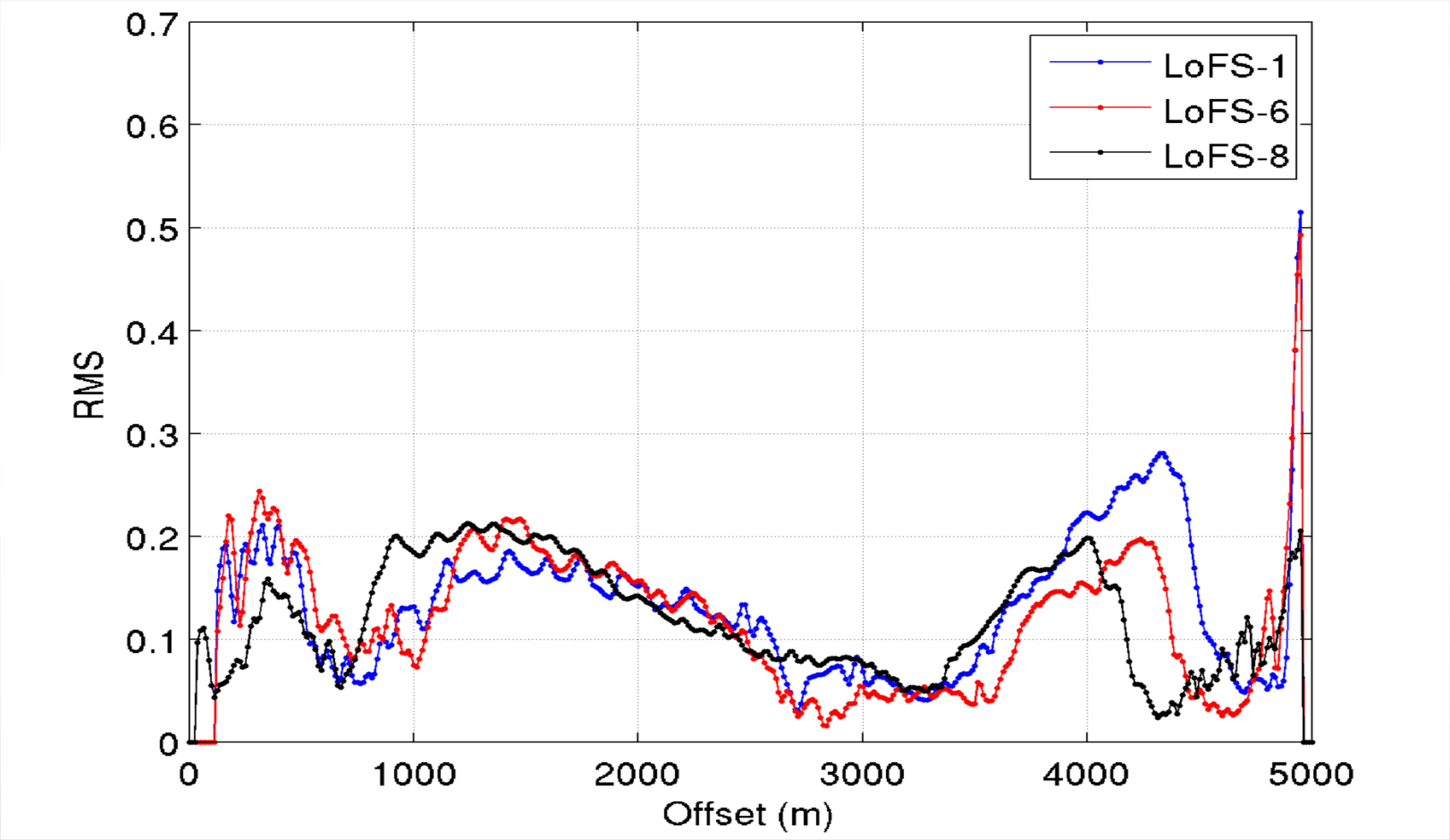




RMS (whole trace) versus offset for base and the two monitor surveys – clear shift and amplitude increase observed

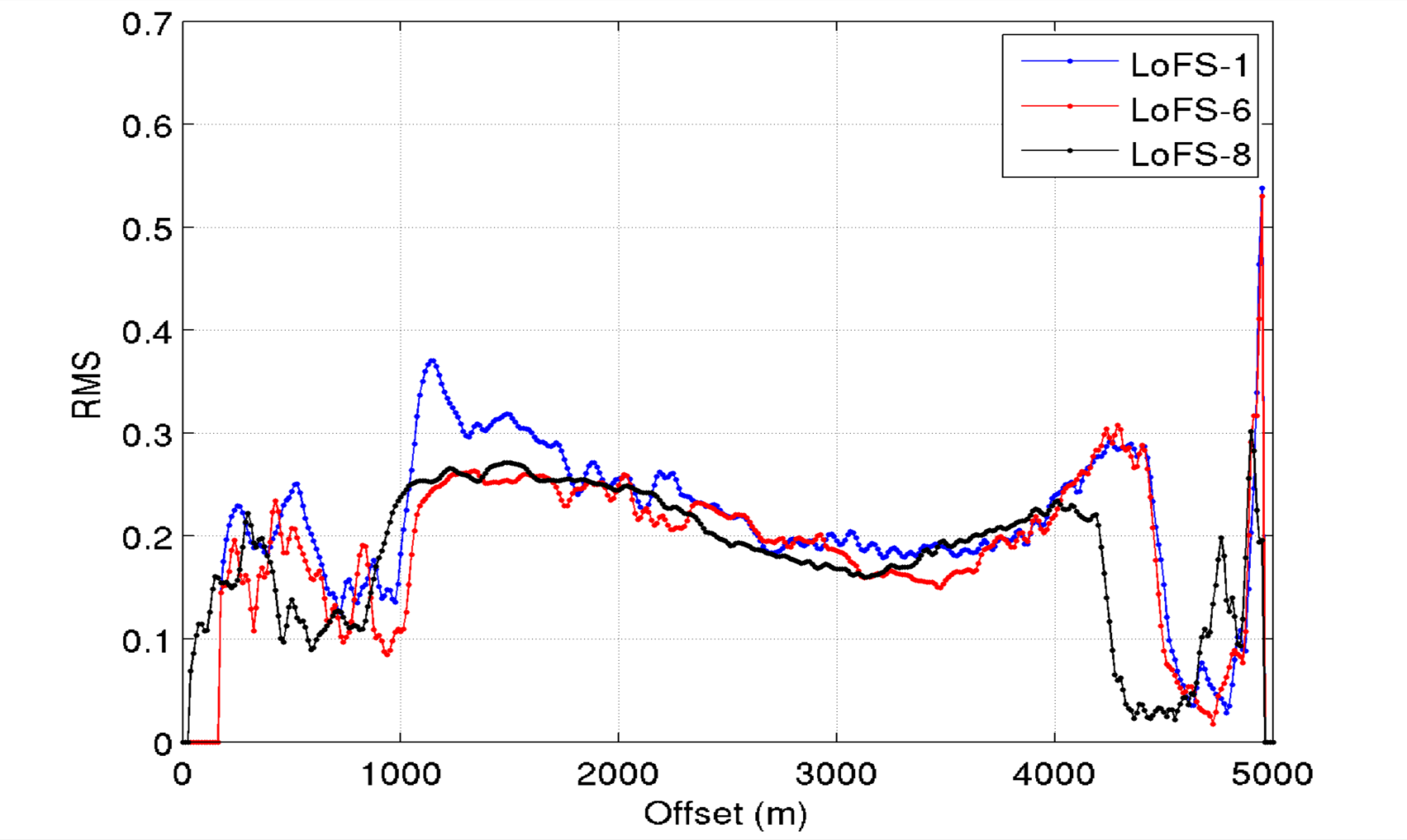


Valhall LoFS-data – Example 1



Systematic decrease in X_M from LOFS-1 to LOFS-8

Valhall LoFS-data – Example 2

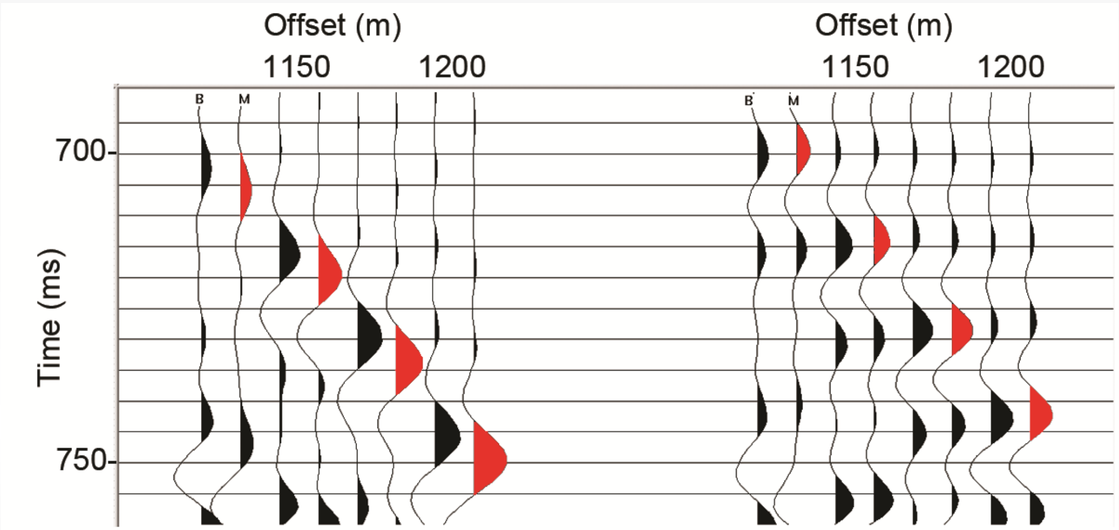


No change from LOFS-1 to LOFS-6, followed by a significant change

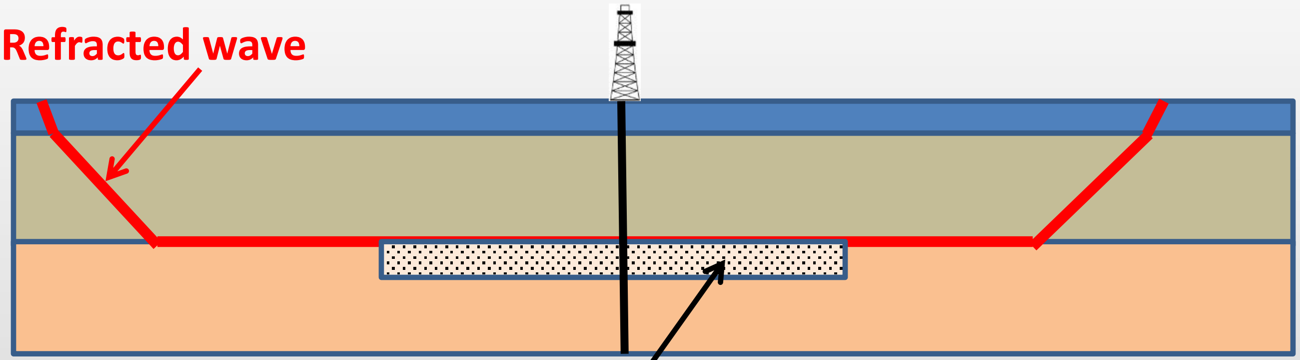
4 D refraction timeshift analysis

Close to well

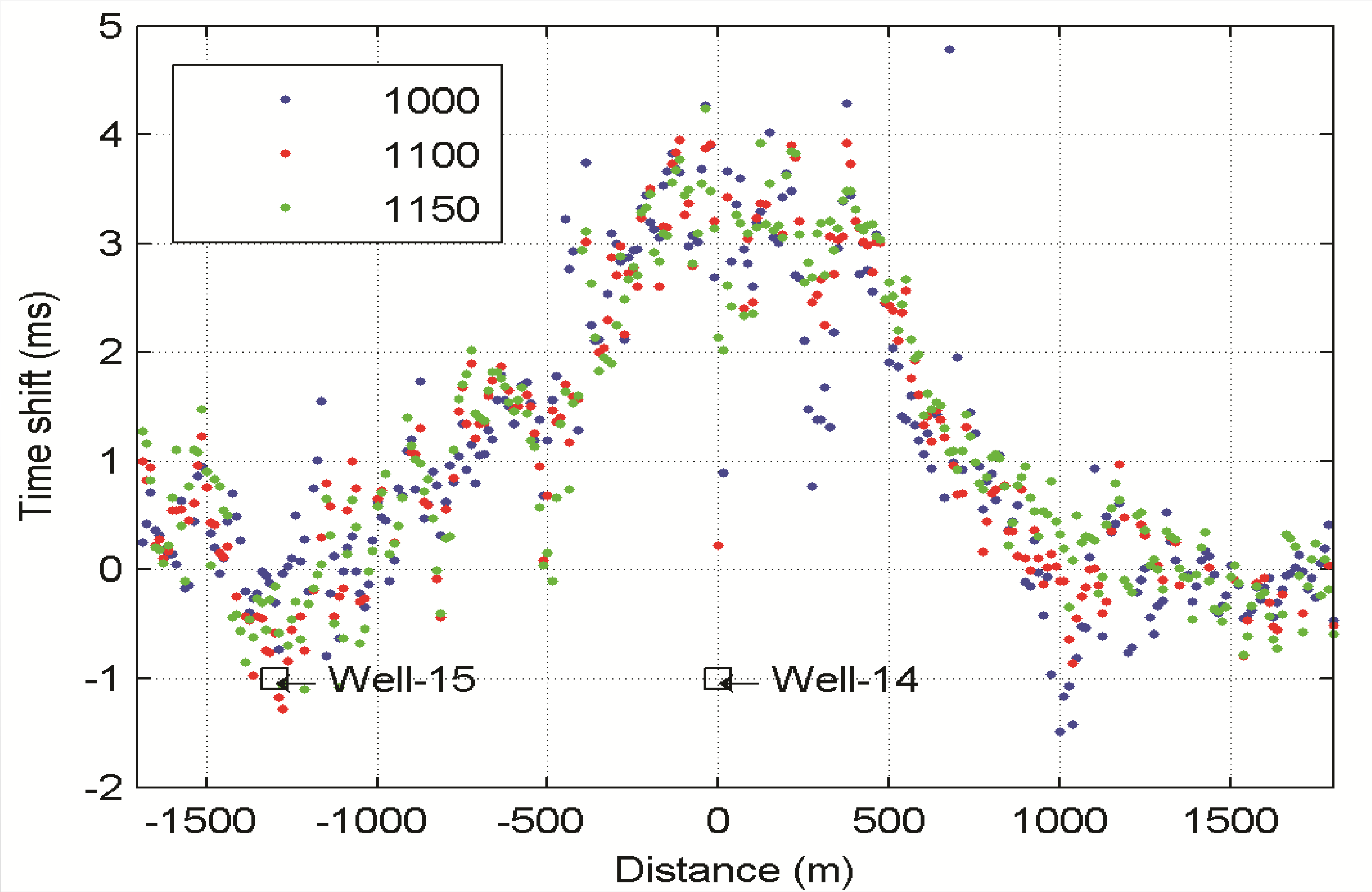
Away from well



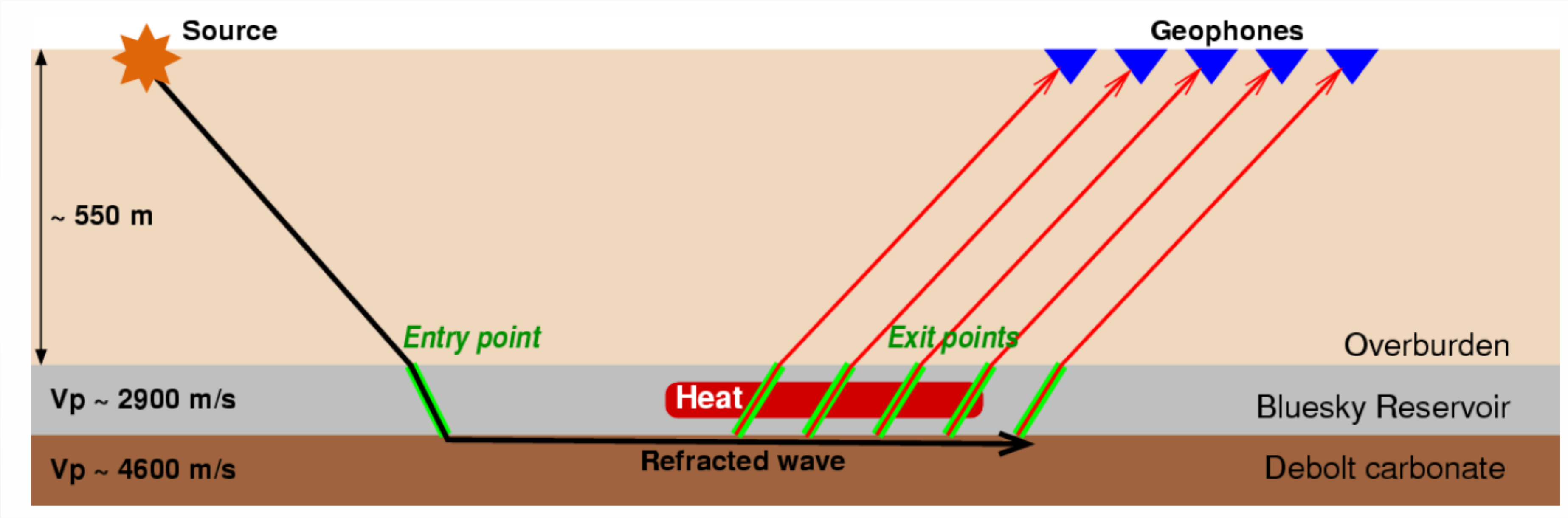
Field data



4 D refraction timeshift analysis

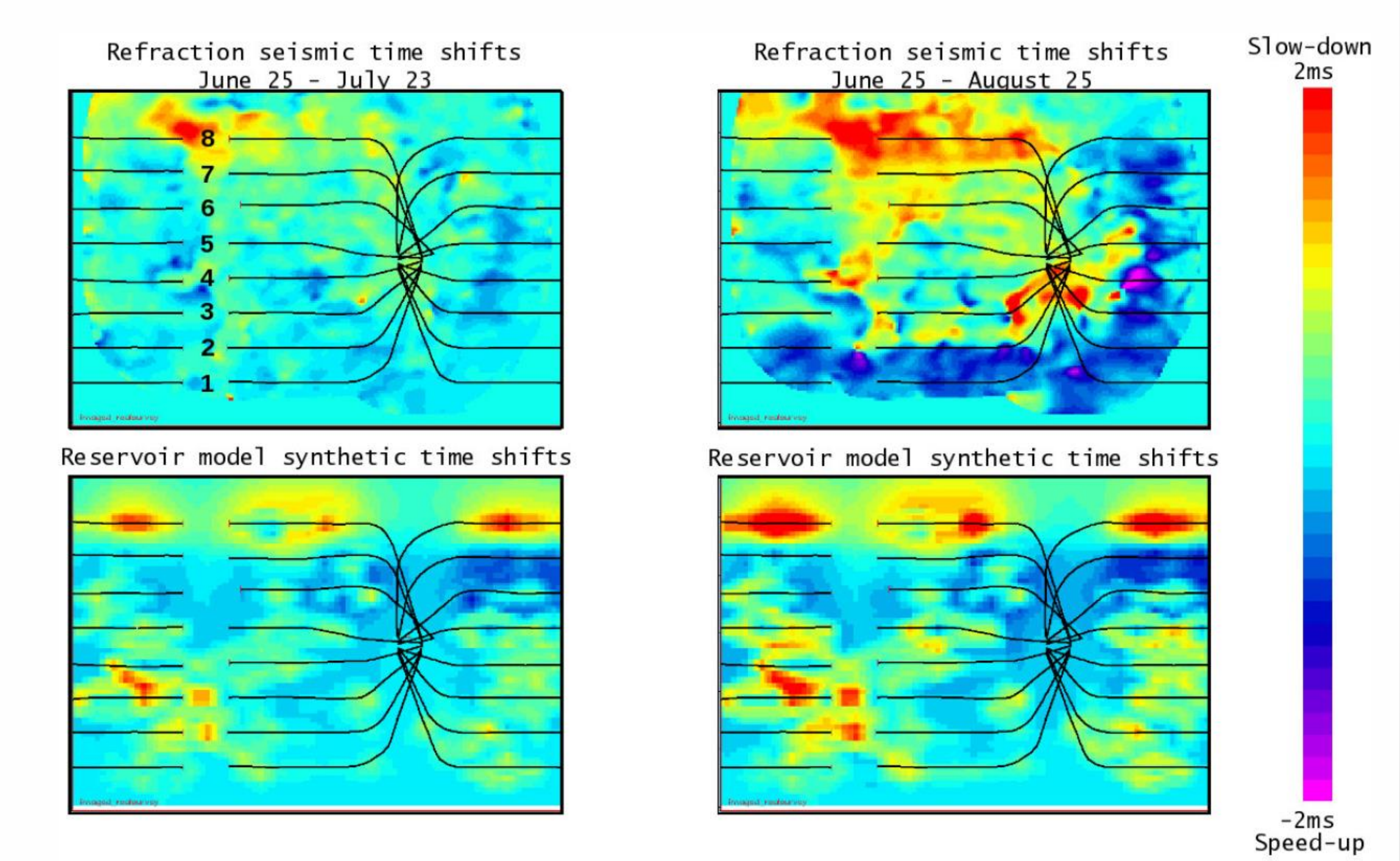


4D refraction examles: Peace River heavy oil field, Alberta



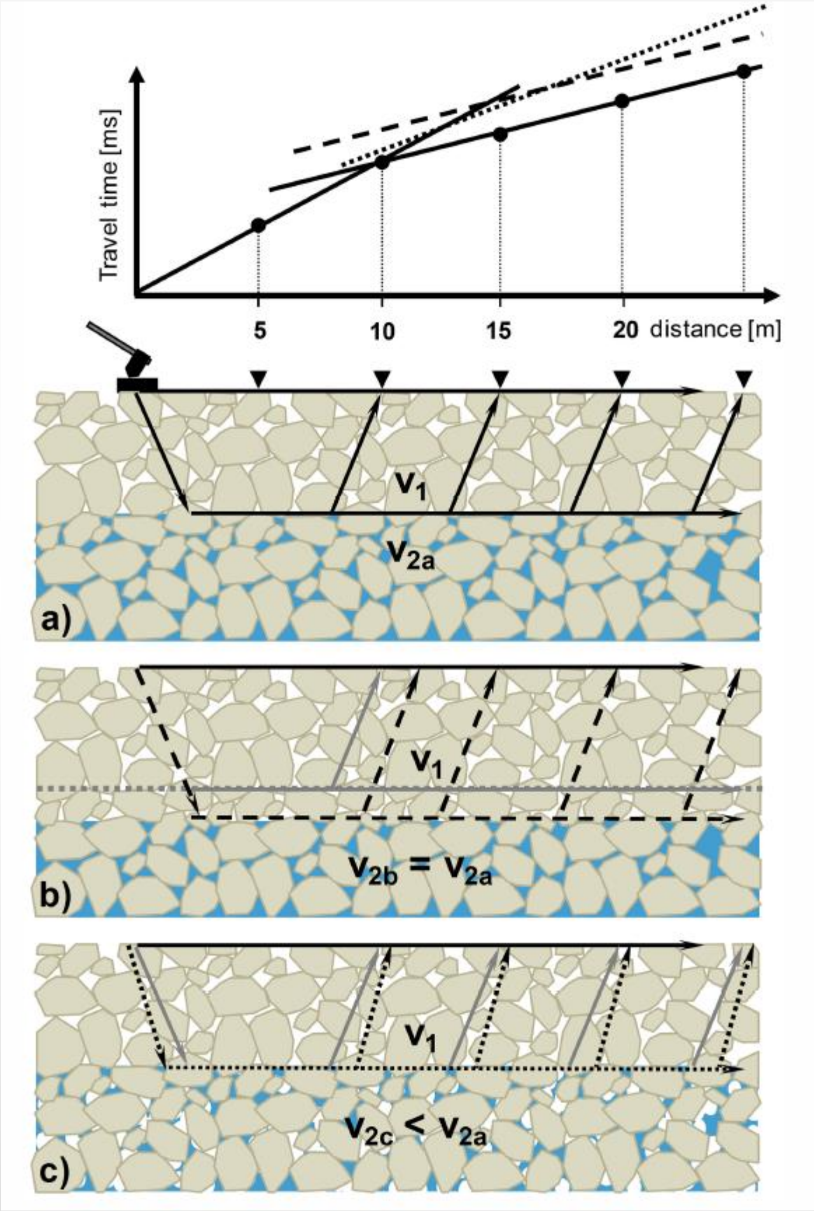
Hansteen et al., SEG, 2010

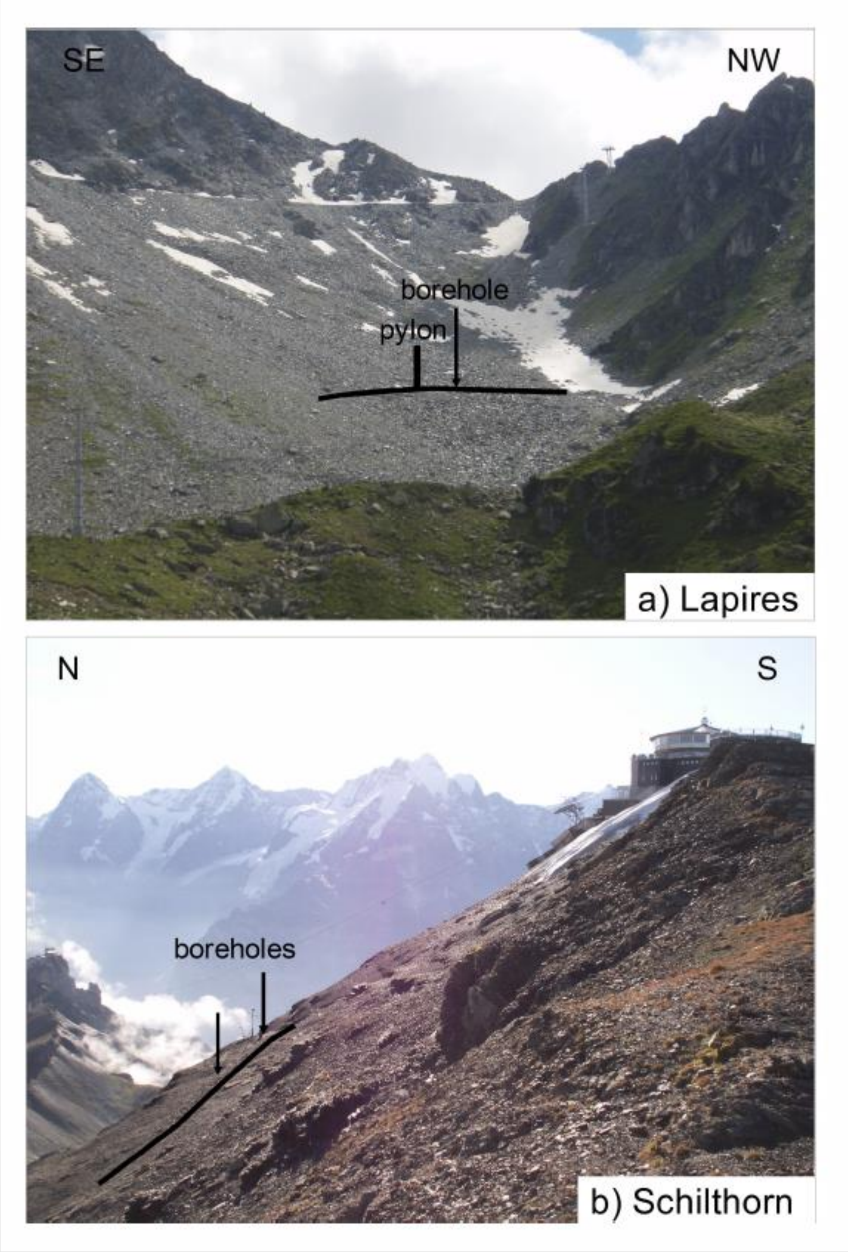
4D refraction examle: Peace River heavy oil field, Alberta



Hansteen et al., SEG, 2010

Monitoring ground ice degradation by time-lapse refraction

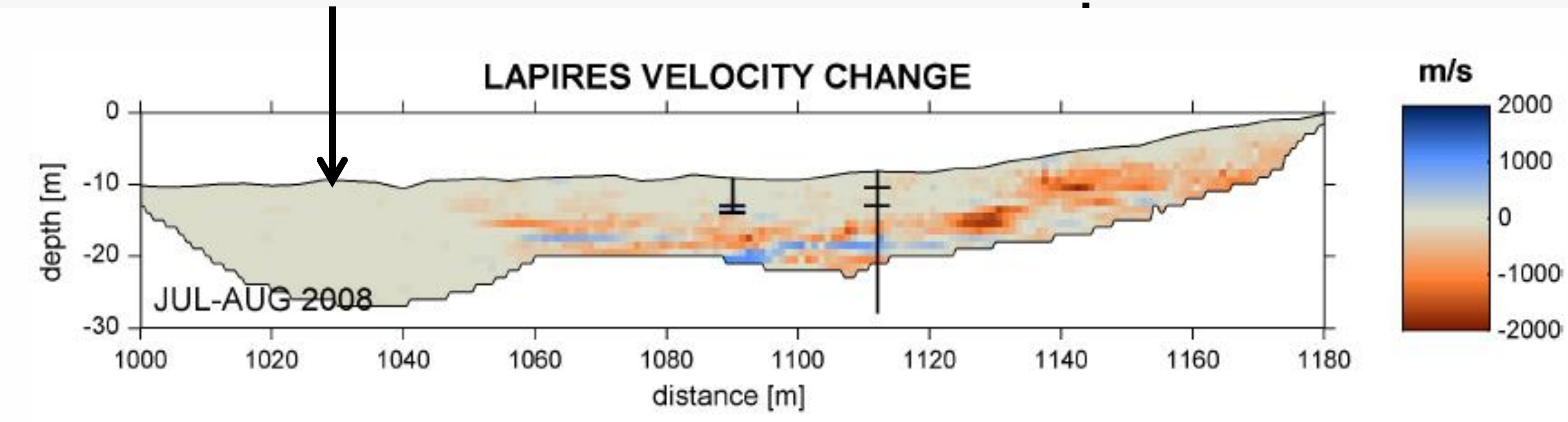




Hilbich, 2010, The Cryosphere

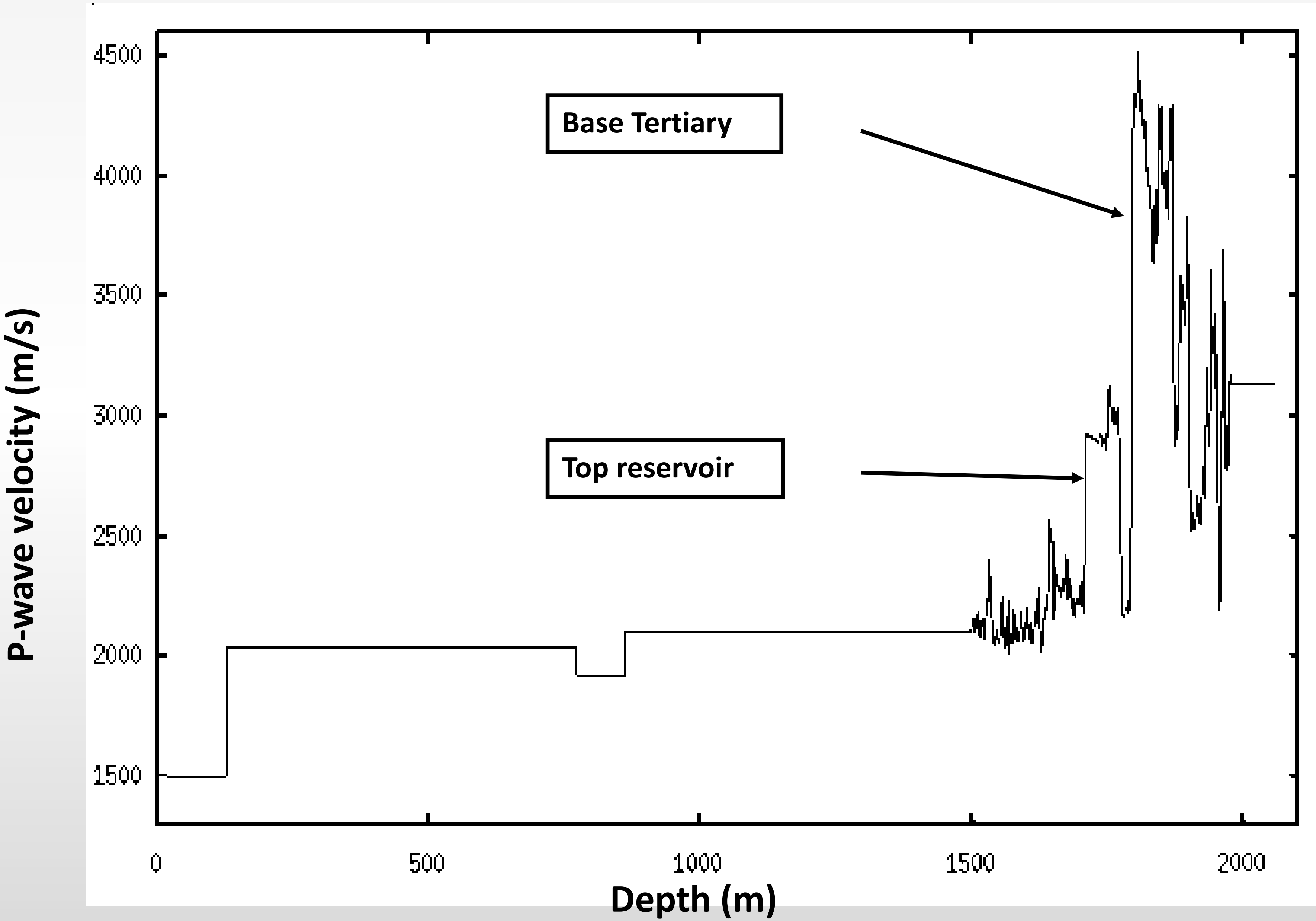
No melting

Melting

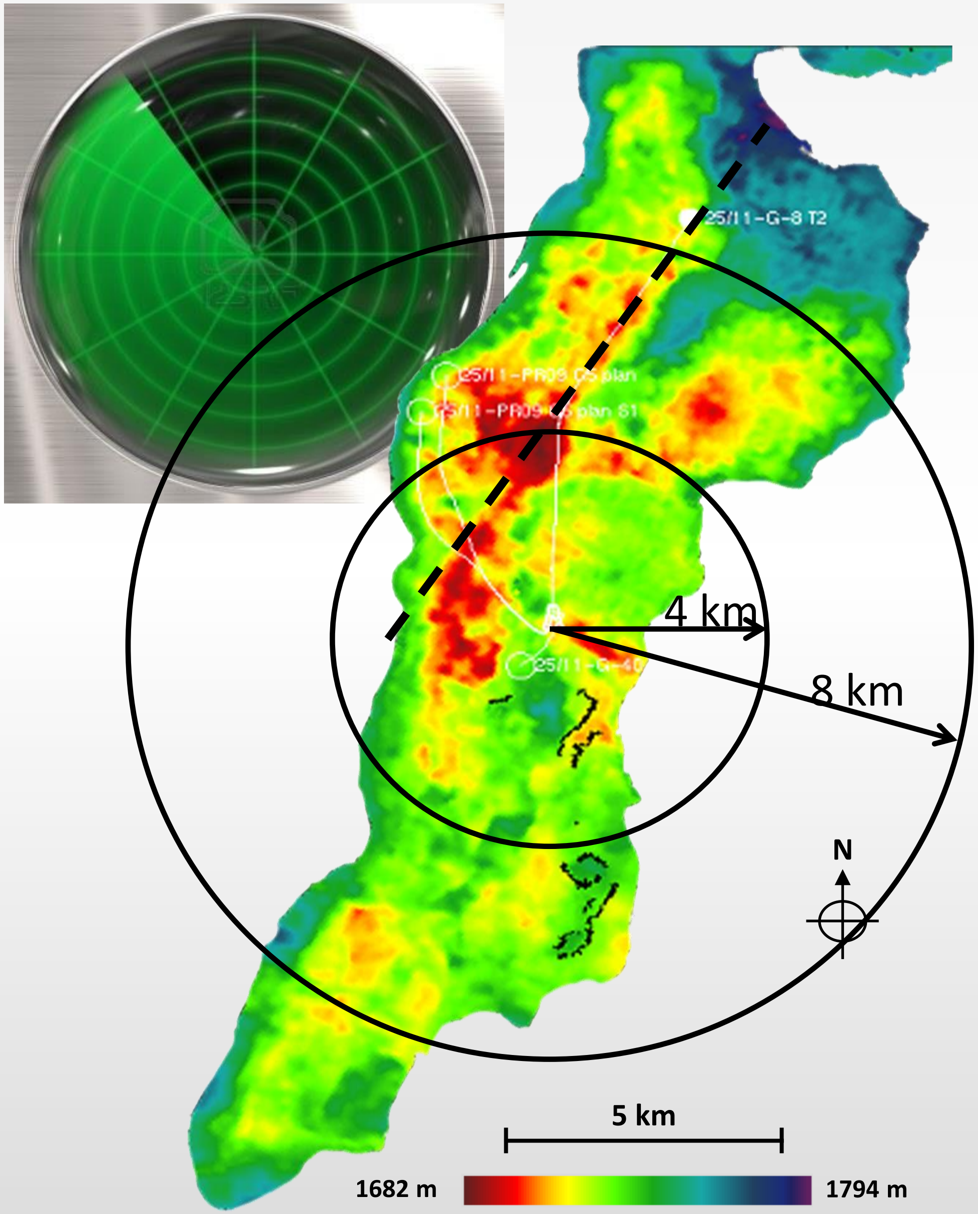


Hilbich, 2010, The Cryosphere

Well log from Grane field



Time lapse refraction radar



Reservoir monitoring:

- **Refractions from top/base reservoir**
- **Rig source fired every day**
- **Measure 4D time shifts and amplitudes**
- **Multiazimuthal analysis**

Leakage detection:

- **Use shallow refraction to detect shallow gas leakage or abnormal pressure build ups**

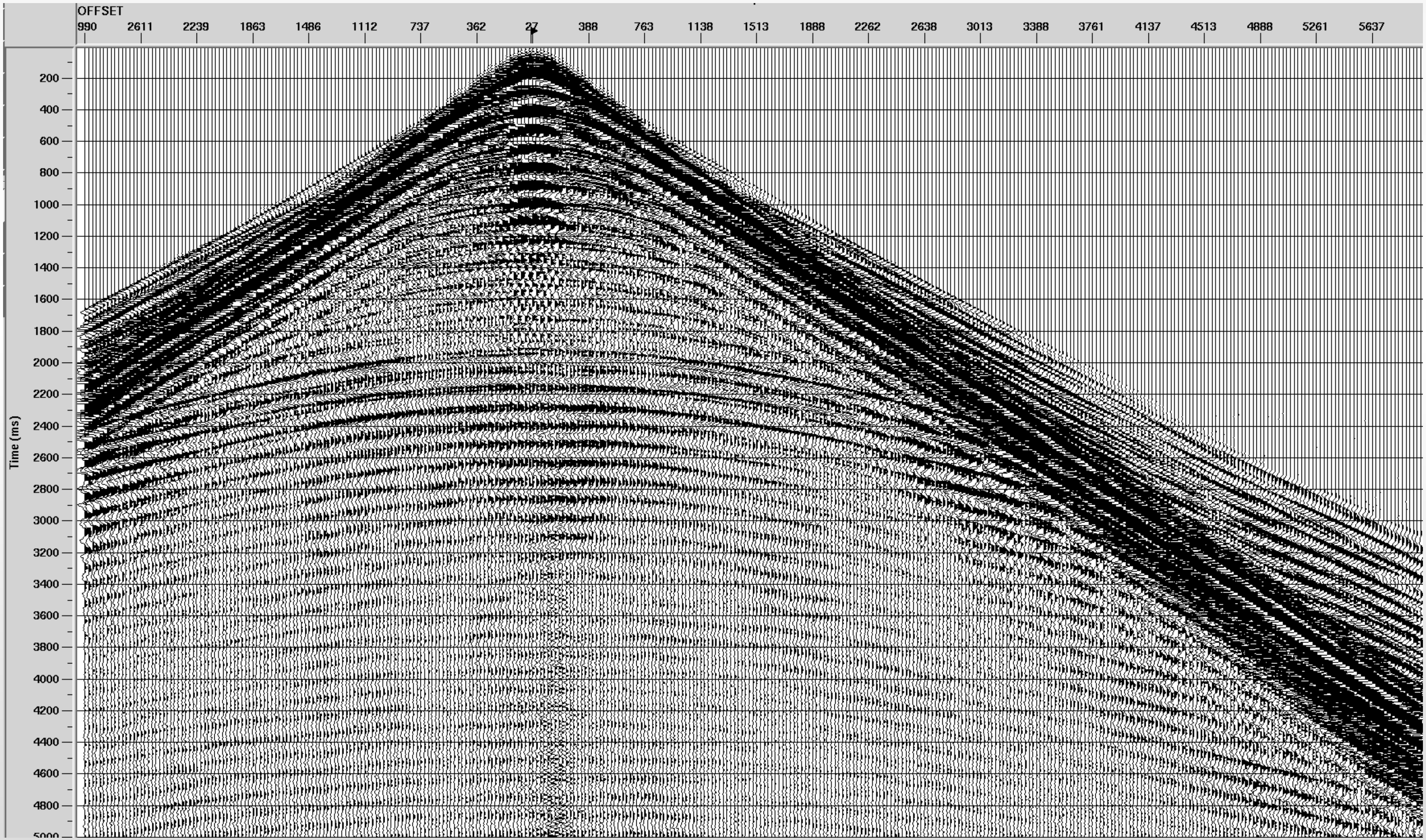
Crustal monitoring:

- **Detect crustal stress changes**
- **Limited to max refraction depths**
- **Conventional 4D for this purpose?**

Method is sensitive to ***velocity*** variations

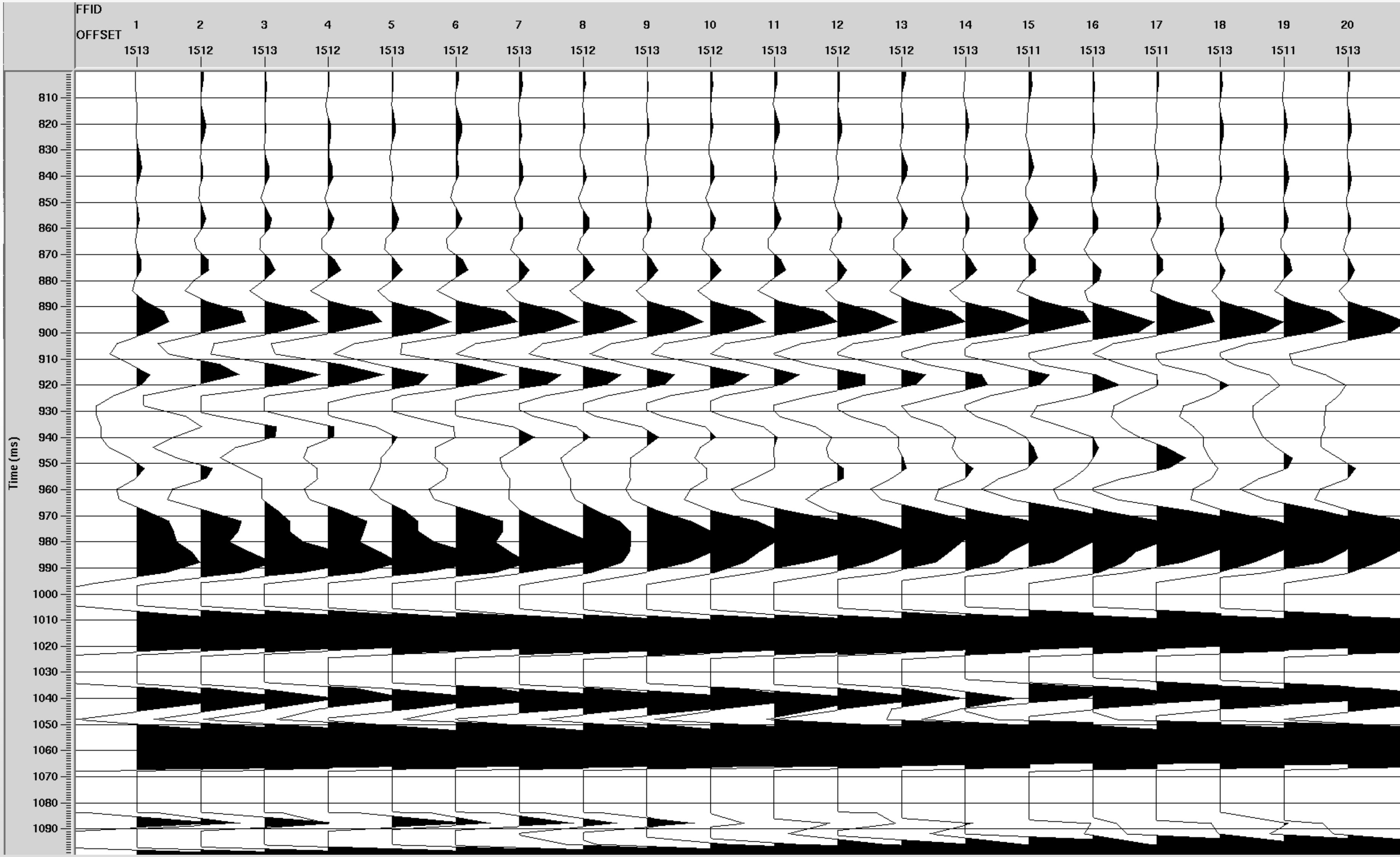
Shot gather – Grane Field, seabed hydrophone data

Water depth: 128 m

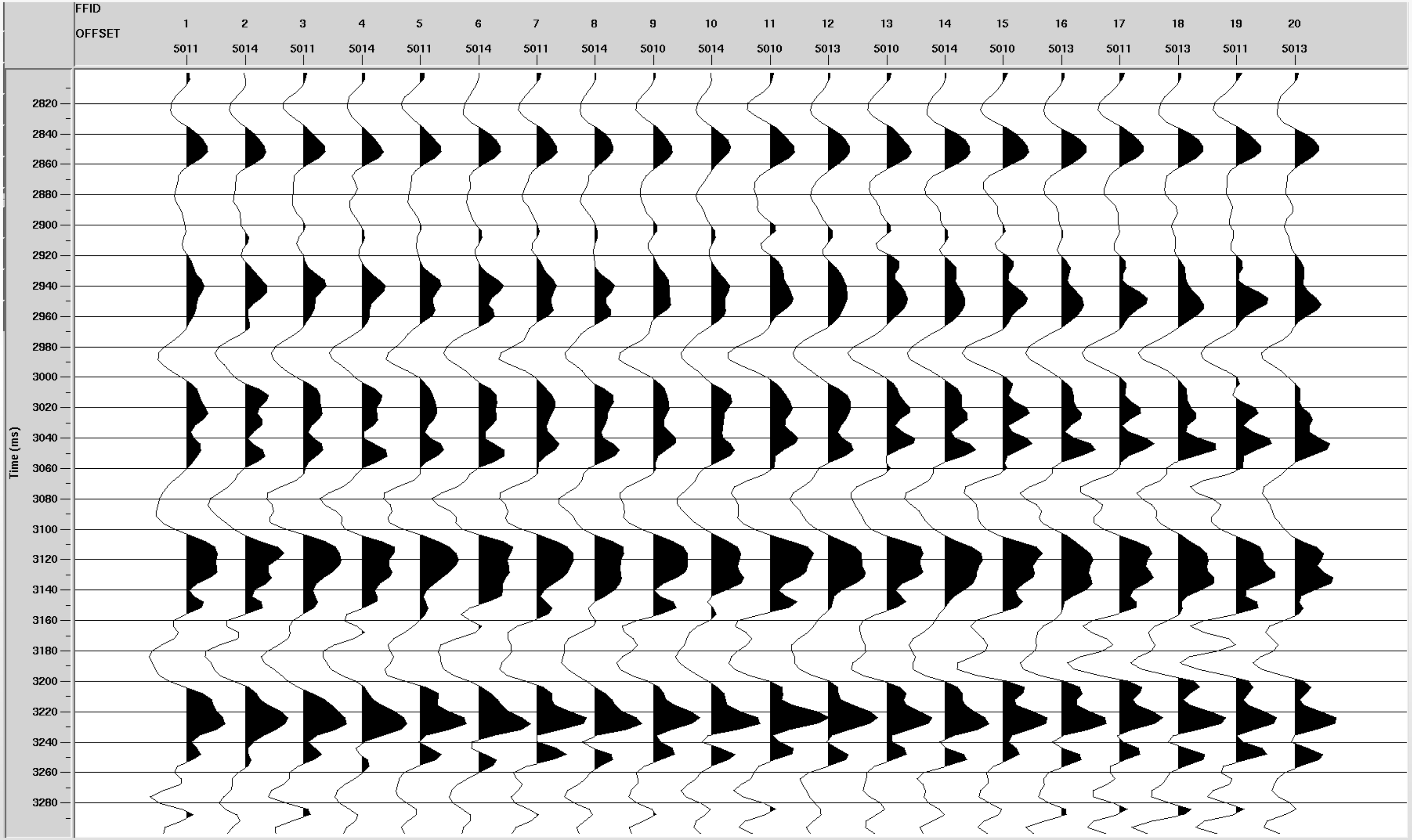


Grane: Shallow refraction – lateral variation

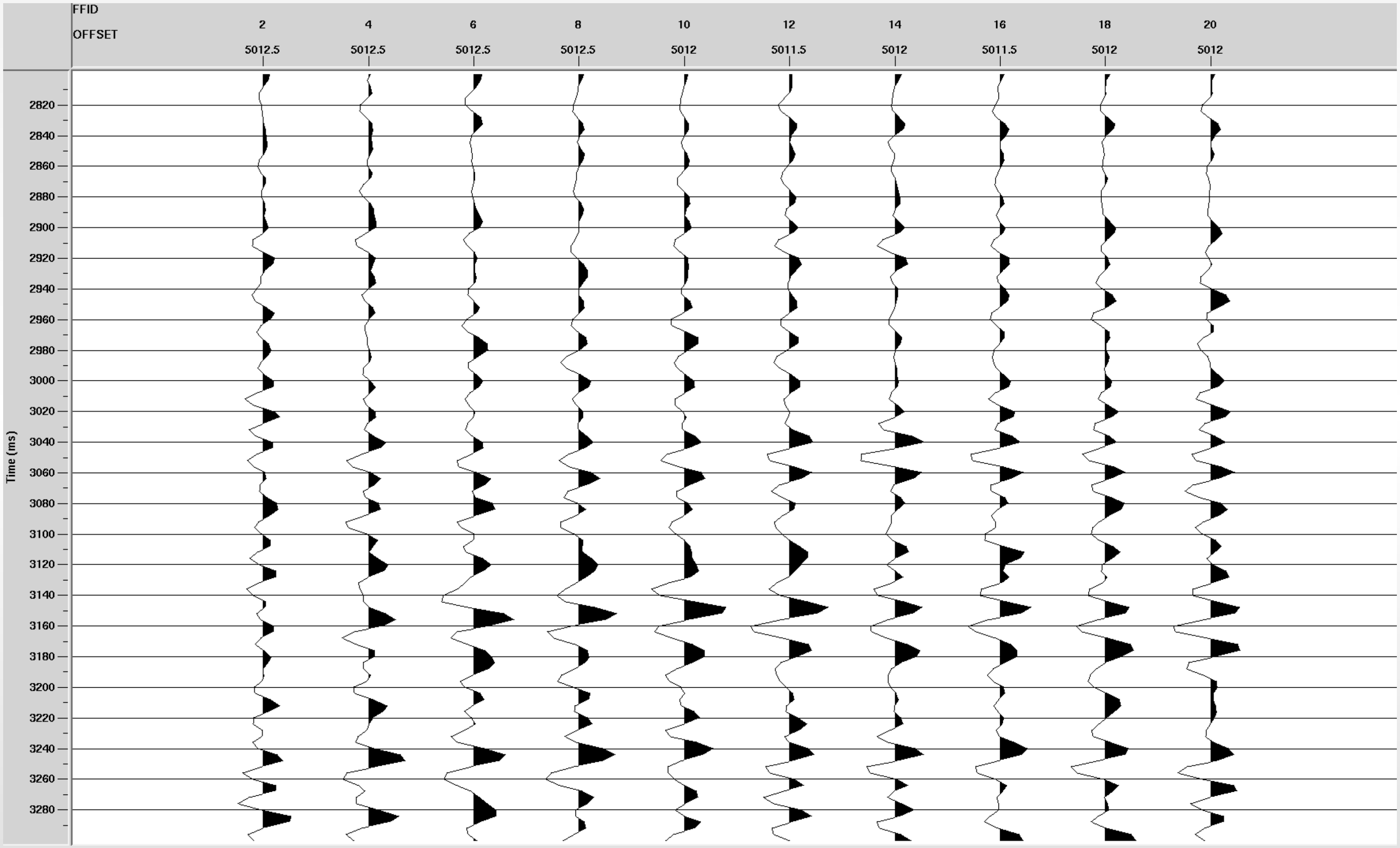
Approximately 25 m between each CDP-position



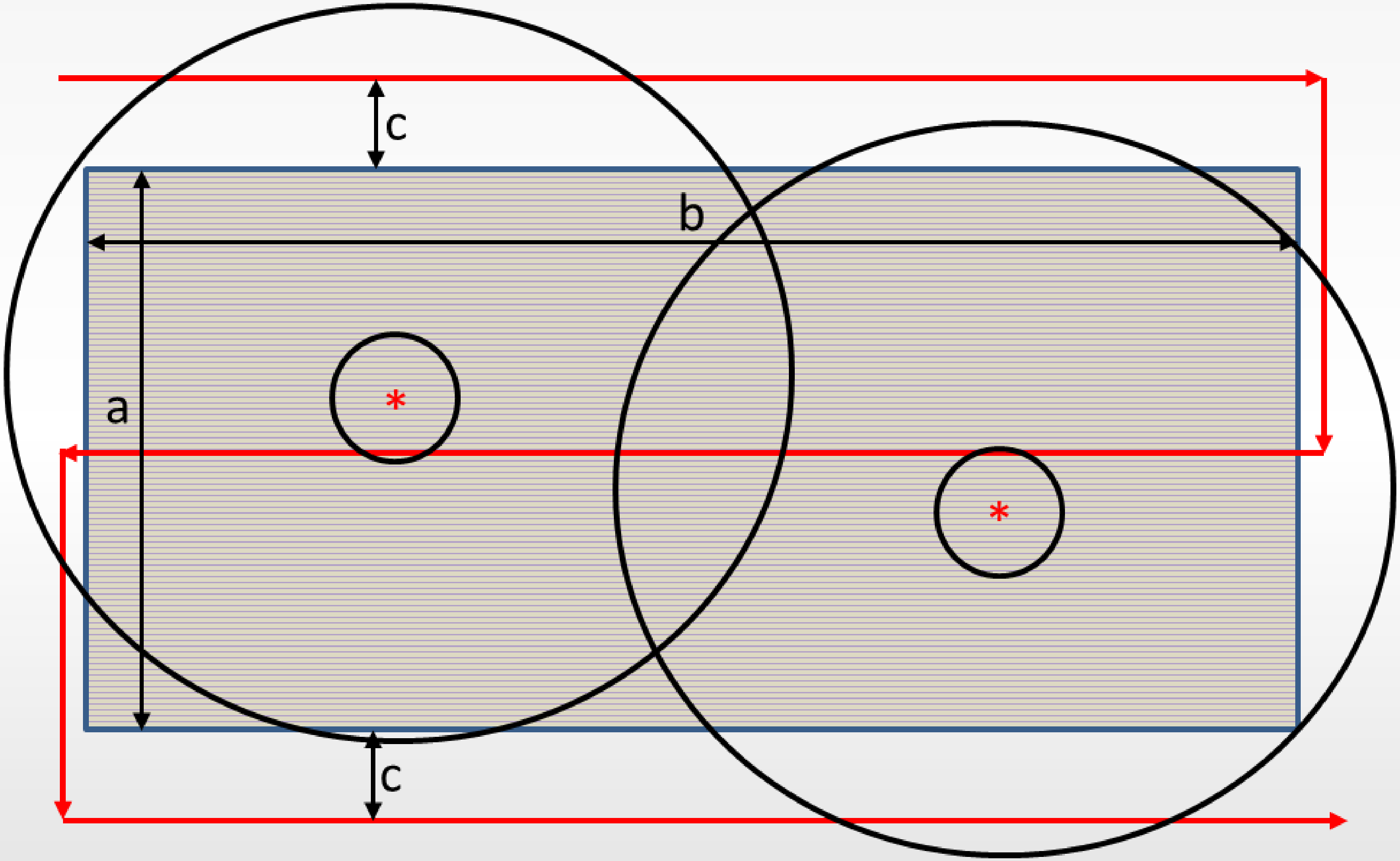
Grane – refracted signals at 5000 m offset, 20 adjacent shots separated by 25 m



Difference between adjacent pairs – shifted by 25 m NRMS = 33 %



Permanent arrays: Source at platform or sparse shooting



Example: a=8 km, b = 24 km and c=1 km => 9 hours shooting

Summary

- 4-5 examples of succesful use of refracted events for 4D analysis
- Clean velocity change estimation
- Complementary to traditional 4D analysis
- Both amplitude and traveltime information useful
- More noise at ultra-long offsets
- Permanent arrays makes it possible to design a time lapse refraction radar – monitoring daily changes