Field testing of multicomponent DAS sensing

Kevin Hall, Kris Innanen, and Don Lawton

CREWES Sponsors Meeting, Online,
December 2020

NSERC CRSNG
UNIVERSITY OF CALGARY
FACULTY OF SCIENCE
Department of Geoscience

Motivation and Plan

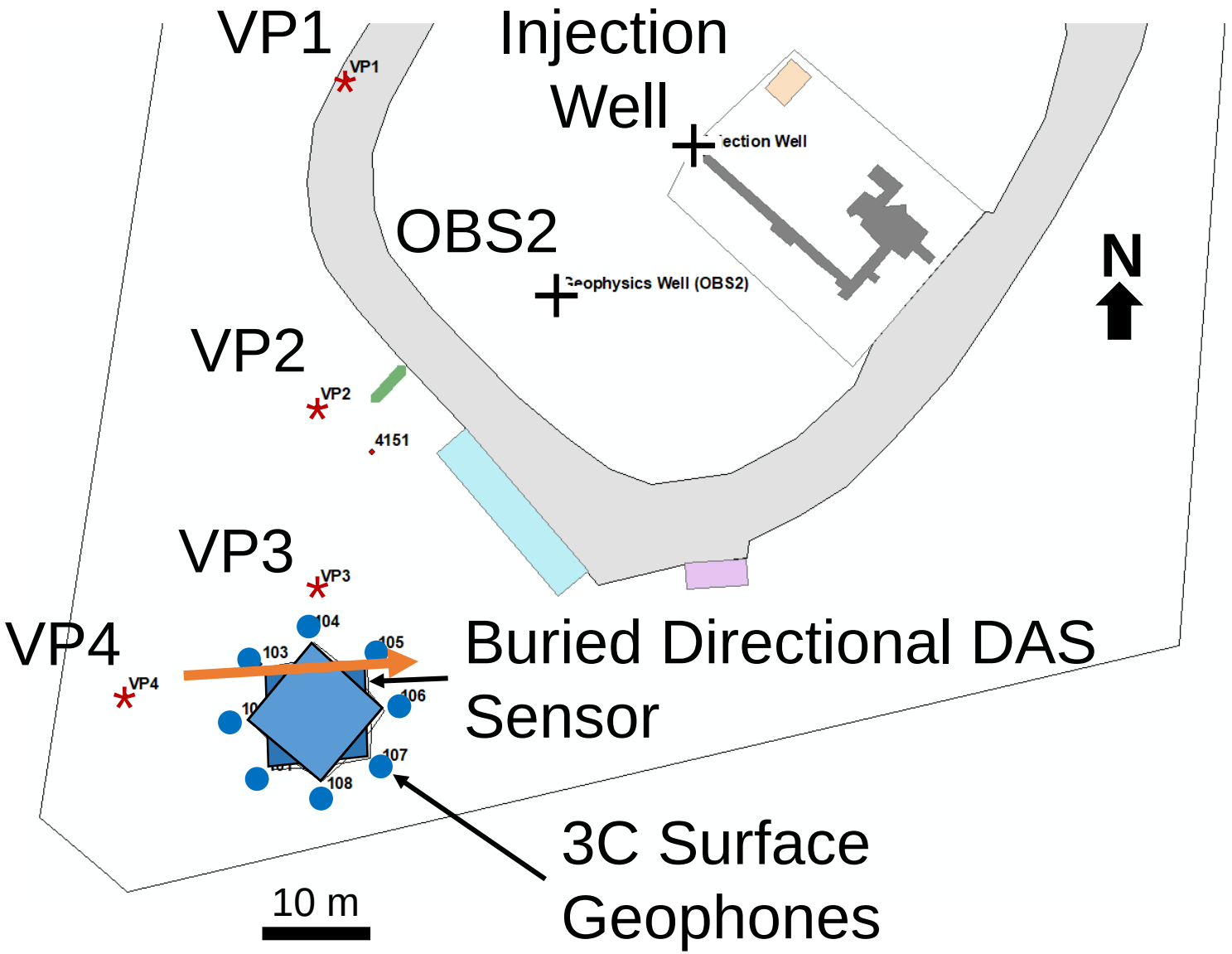
Motivation

- Fibre data:
  - Locally 1C, parallel to the axis of the fibre
  - Strain-rate measurement depends on gauge length
- Geophone data:
  - Can be 3C
  - Does not measure strain-rate

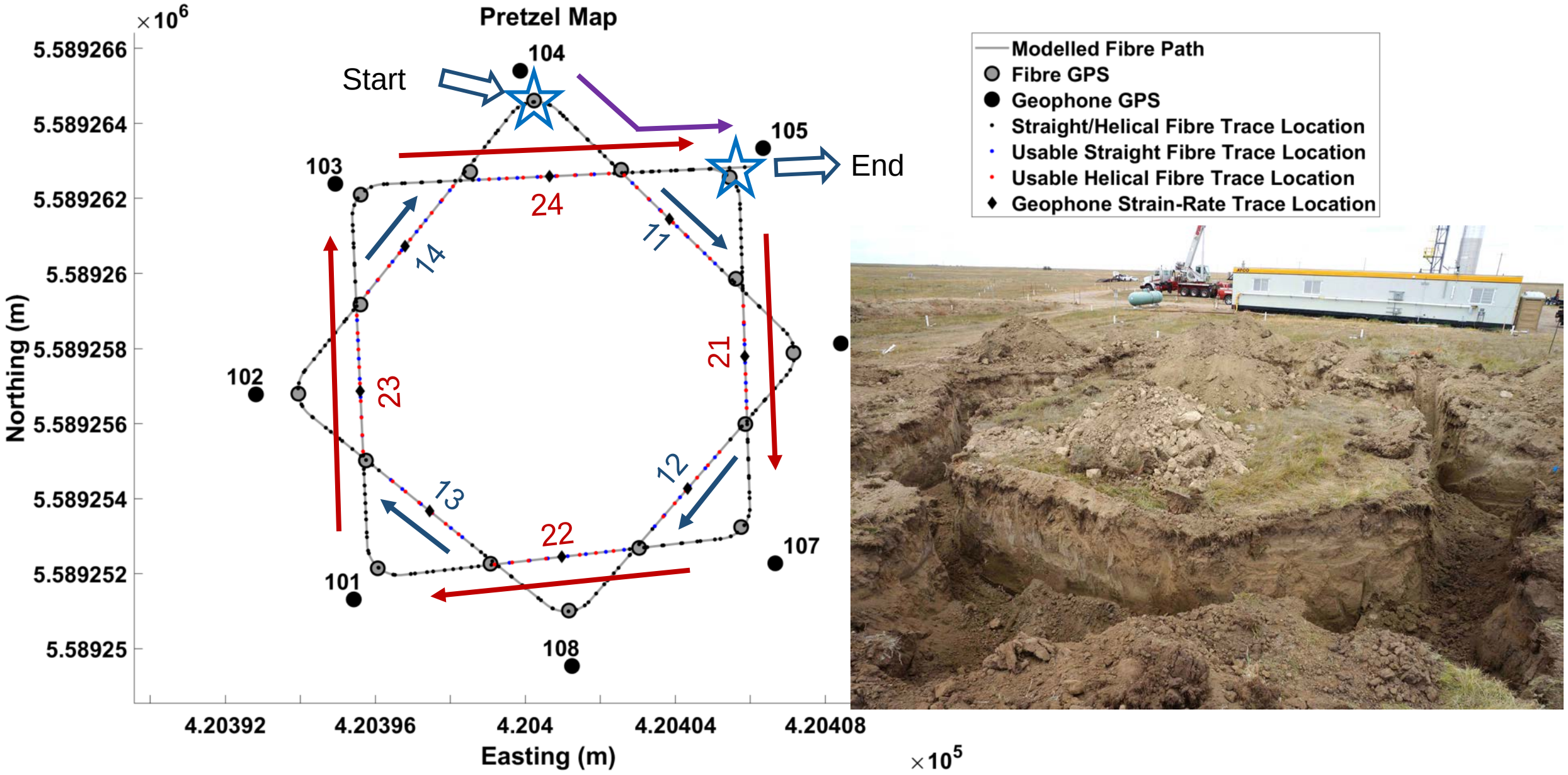
Plan

- Build a directional DAS sensor
- Estimate strain-rate (or strain) tensors from fibre data
- Estimate strain-rate (or strain) tensors from geophone data
- Compare

Field Geometry: Experimental Buried Directional DAS Sensor (DDS)



Field Geometry: DDS Fibre Path Detail



Method: Tensor Estimation

$$\begin{bmatrix} e_{EE} \\ e_{EN} \\ e_{NN} \end{bmatrix} = (L^T L + \alpha I)^{-1} L^T \begin{bmatrix} e_1 \\ \vdots \\ e_8 \end{bmatrix}$$

Eight directional strain-rate (or strain) constant time trace samples, one per side of the DDS

The Answer

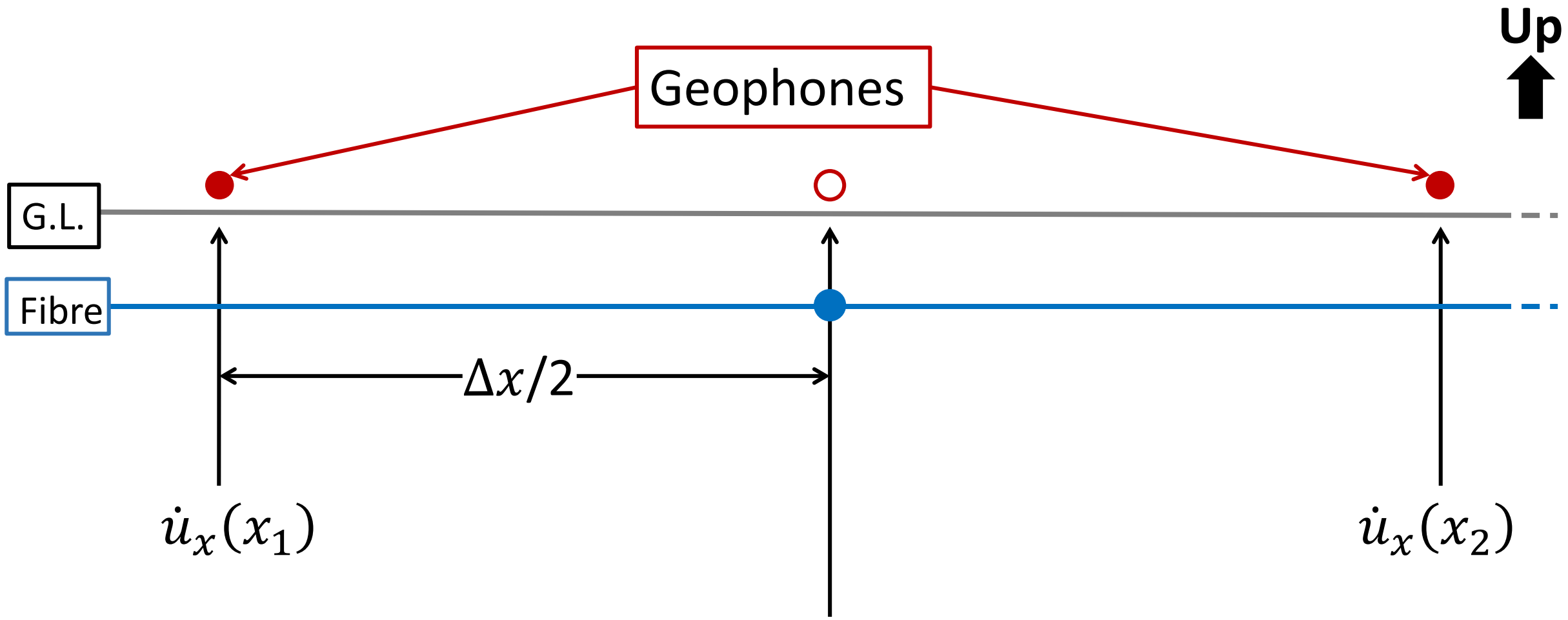
$$L = \begin{bmatrix} \lambda_{EE}^1 & 2\lambda_{EN}^1 & \lambda_{NN}^1 \\ \vdots & \vdots & \vdots \\ \lambda_{EE}^8 & 2\lambda_{EN}^8 & \lambda_{NN}^8 \end{bmatrix}$$

Matrix of terms relating e_i to the output tensor calculated from directional unit vectors

$$\lambda_{AB}^i = (\hat{t}_i \cdot \hat{t}_{AB})(\hat{t}_i \cdot \hat{t}_{AB})$$

$$\hat{t}_N = \begin{bmatrix} 0 \\ 1 \end{bmatrix},\ \hat{t}_E = \begin{bmatrix} 1 \\ 0 \end{bmatrix},\ \hat{t}_1 = \begin{bmatrix} t_1^1 \\ t_1^2 \end{bmatrix},\ \hat{t}_2 = \begin{bmatrix} t_2^1 \\ t_2^2 \end{bmatrix}, \ldots, \hat{t}_8 = \begin{bmatrix} t_8^1 \\ t_8^2 \end{bmatrix}$$

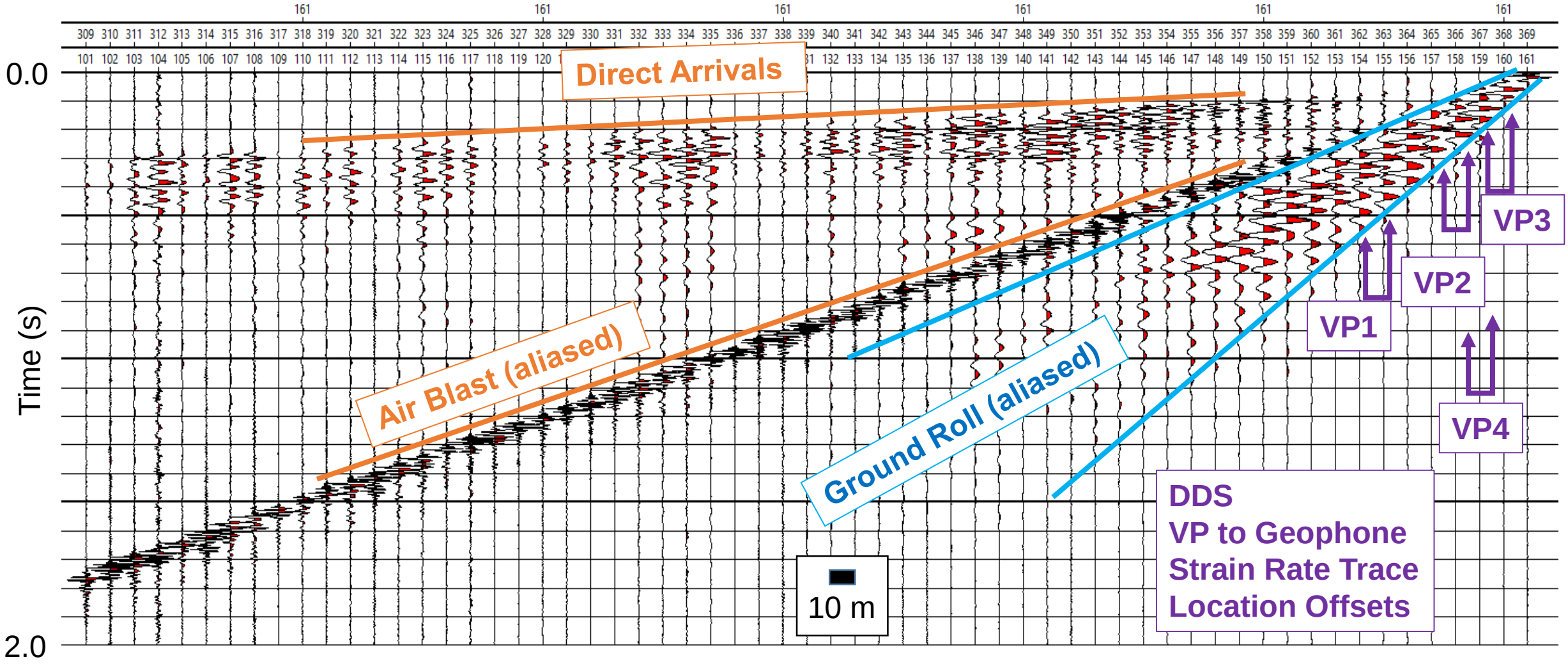
Method: Geophone trace conversion to strain-rate



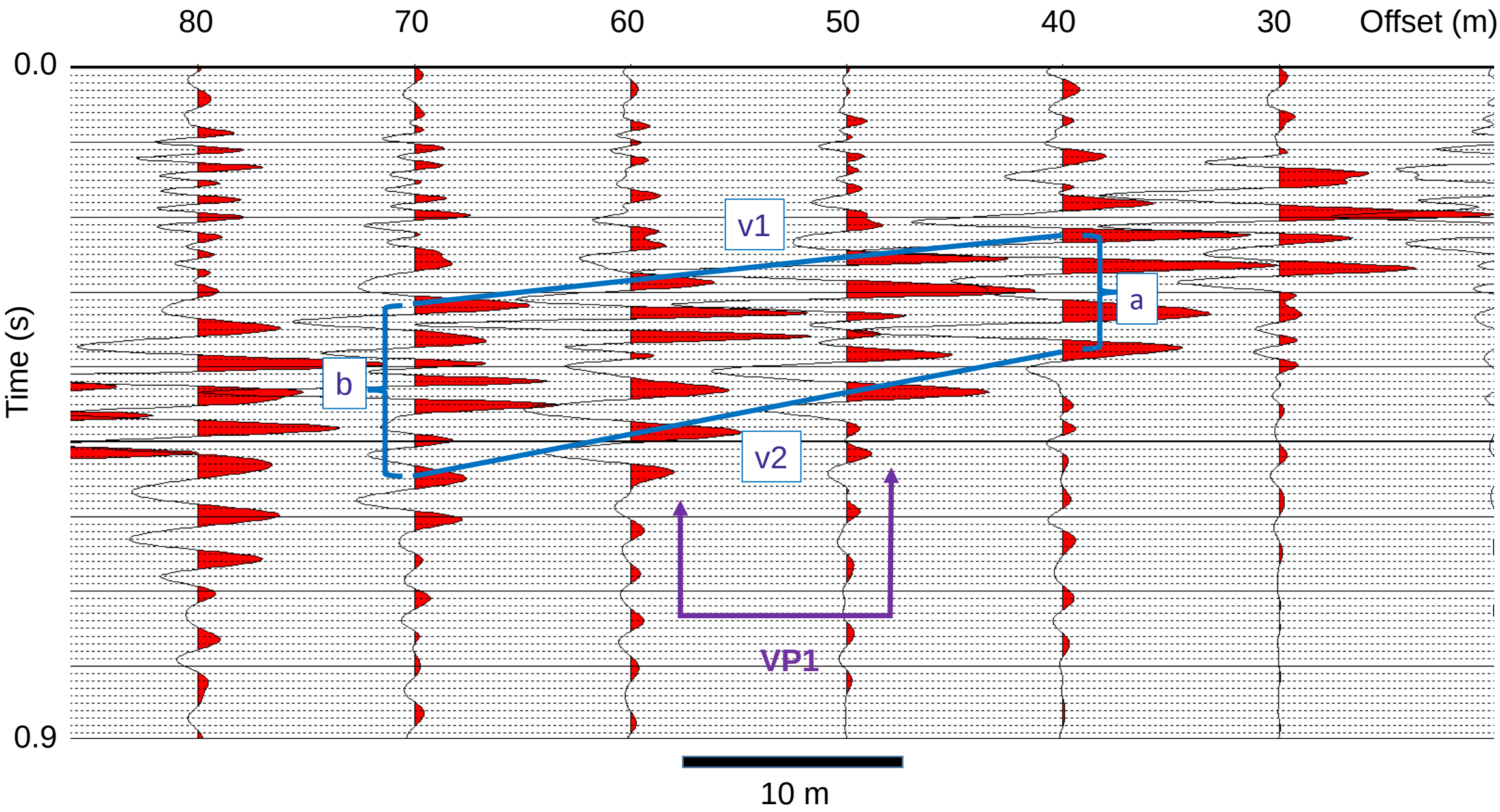
$$\dot{\epsilon}_{xx}(\Delta x/2) = \frac{\partial \dot{u}_x}{\partial x} \approx \frac{\dot{u}_x(x_2) - \dot{u}_x(x_1)}{\Delta x}$$

Data Expectations: Overview

May 2017, VP 13161 (Trench line), 3C Geophones, inline component, No Filters or AGC



Data Expectations: Ground Roll

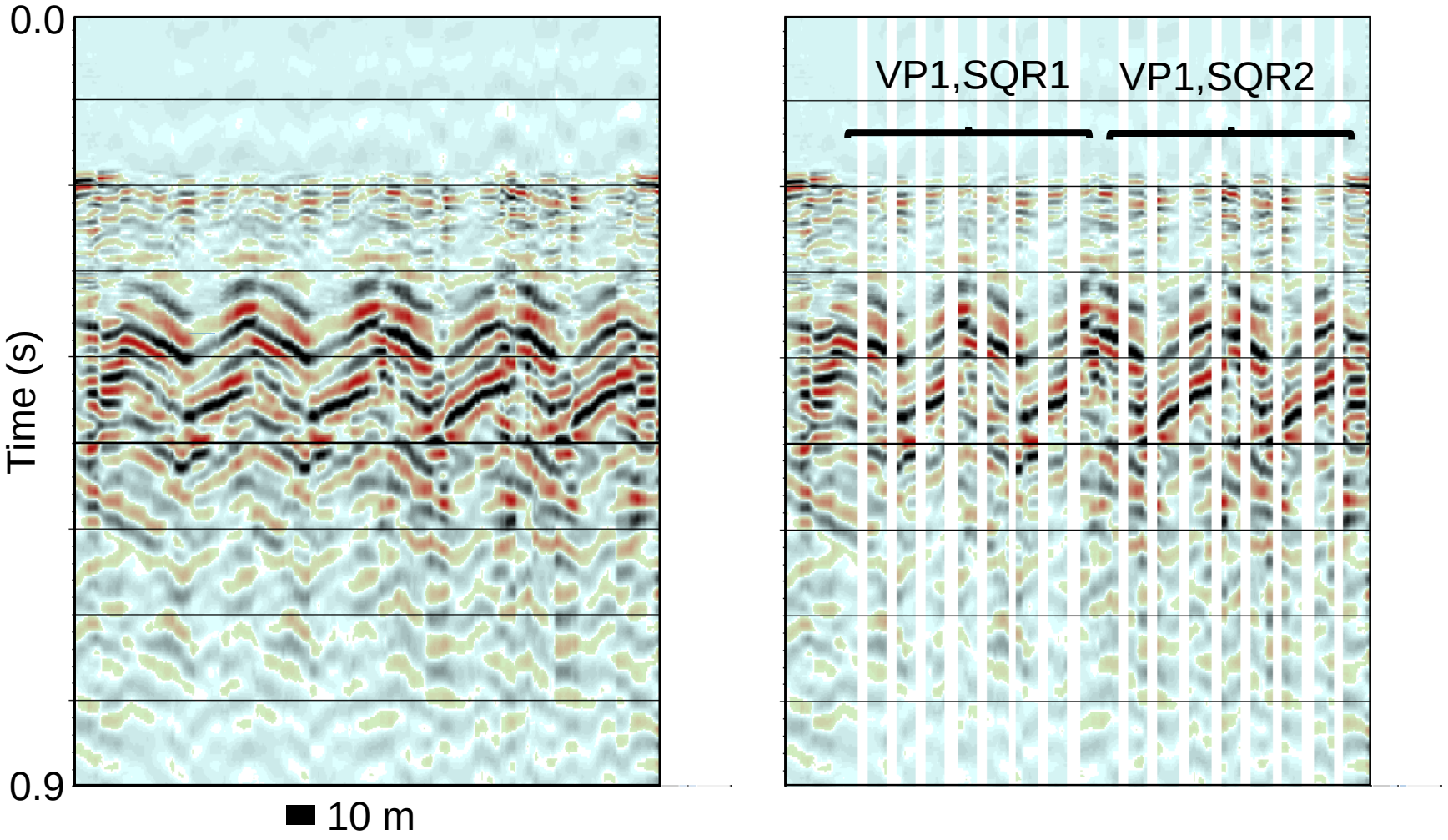


Data Preparation: Line Segment Gathers (LSG)

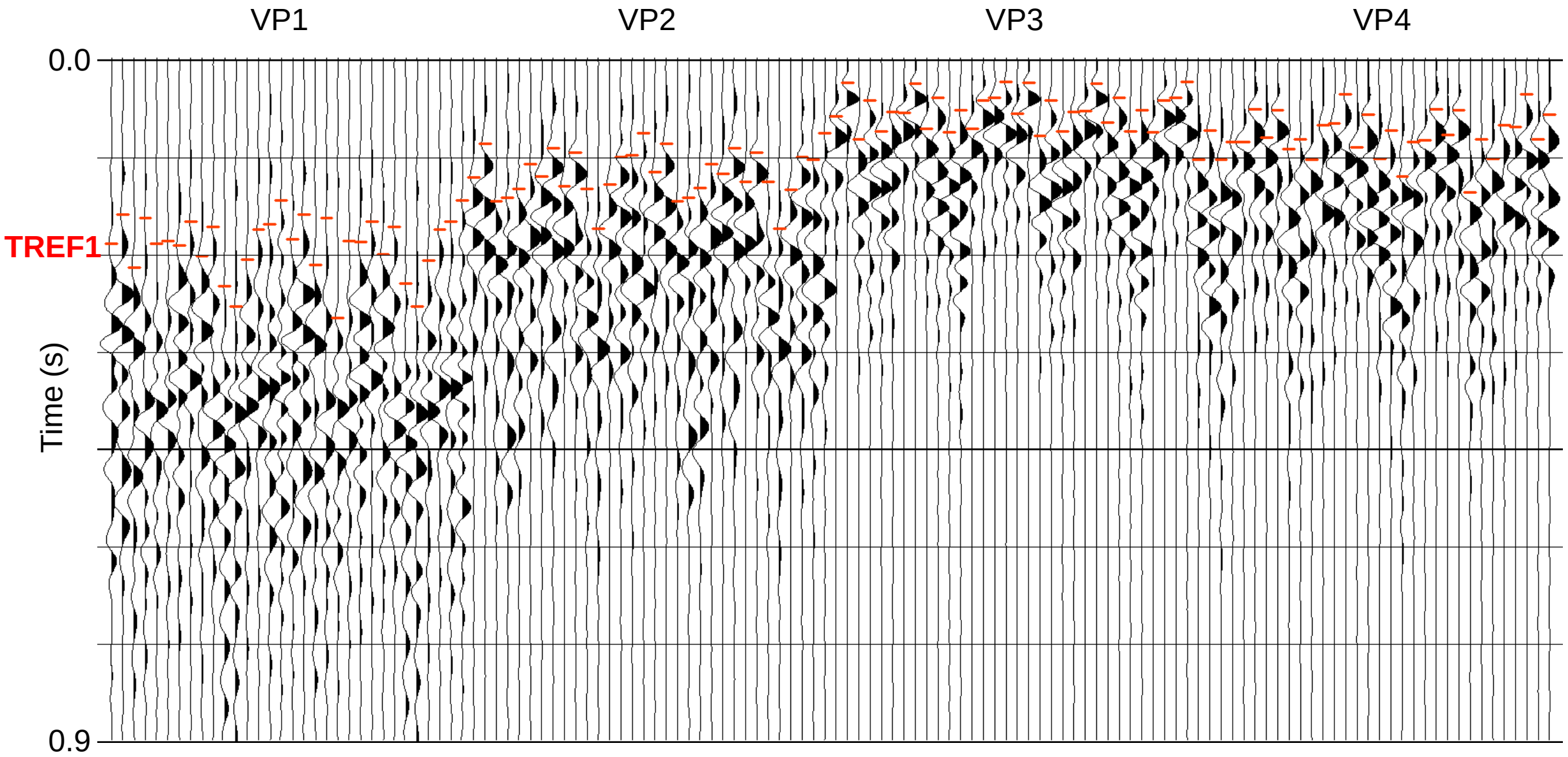
a) Straight fibre (Strain-rate), AGC, no filters

b) Straight fibre (Strain-rate), Traces to discard, AGC, no filters

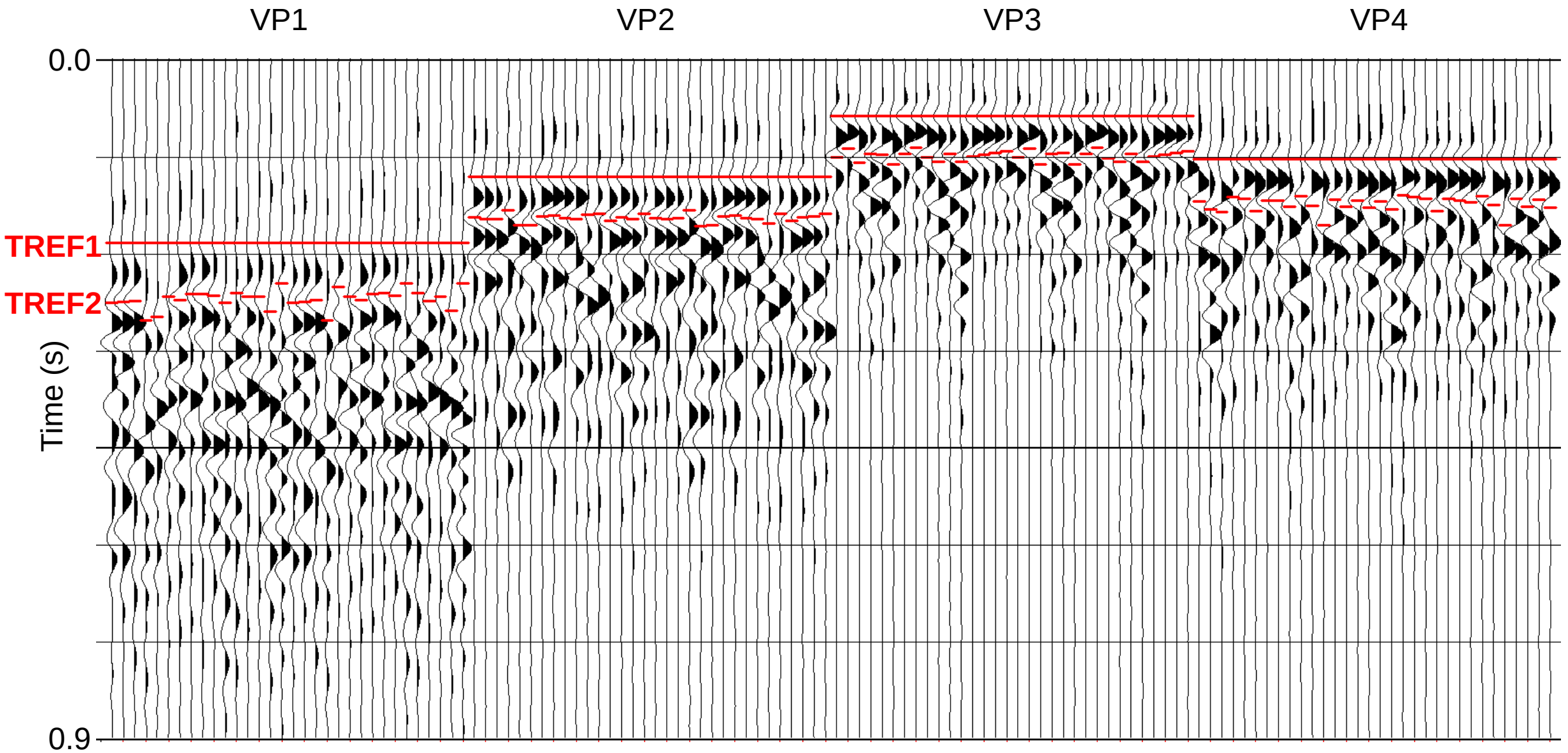
c) Straight fibre (Strain-rate), Traces to keep (LSG), AGC, no filters



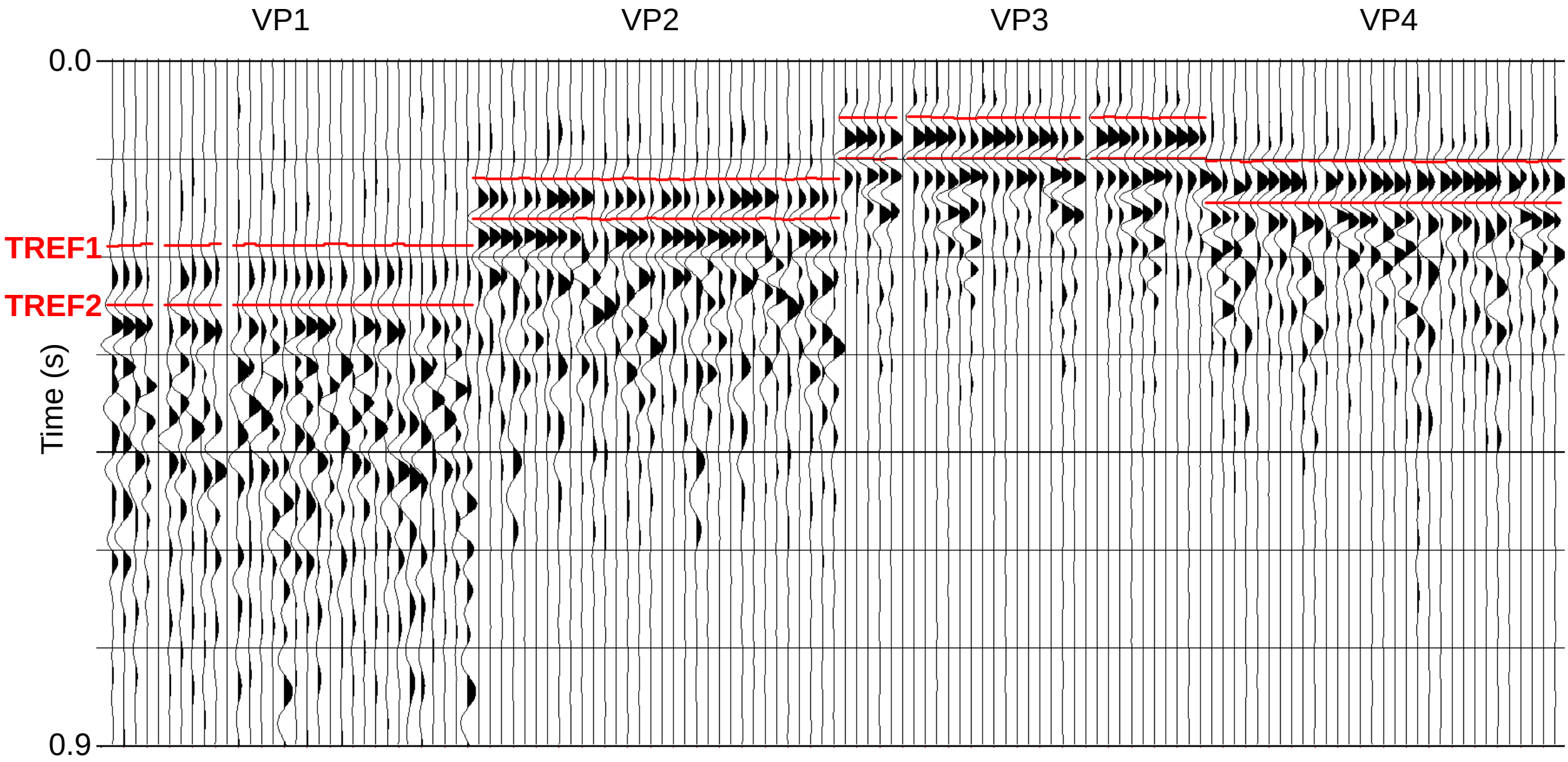
Data Preparation: Vertically Stacked LSG



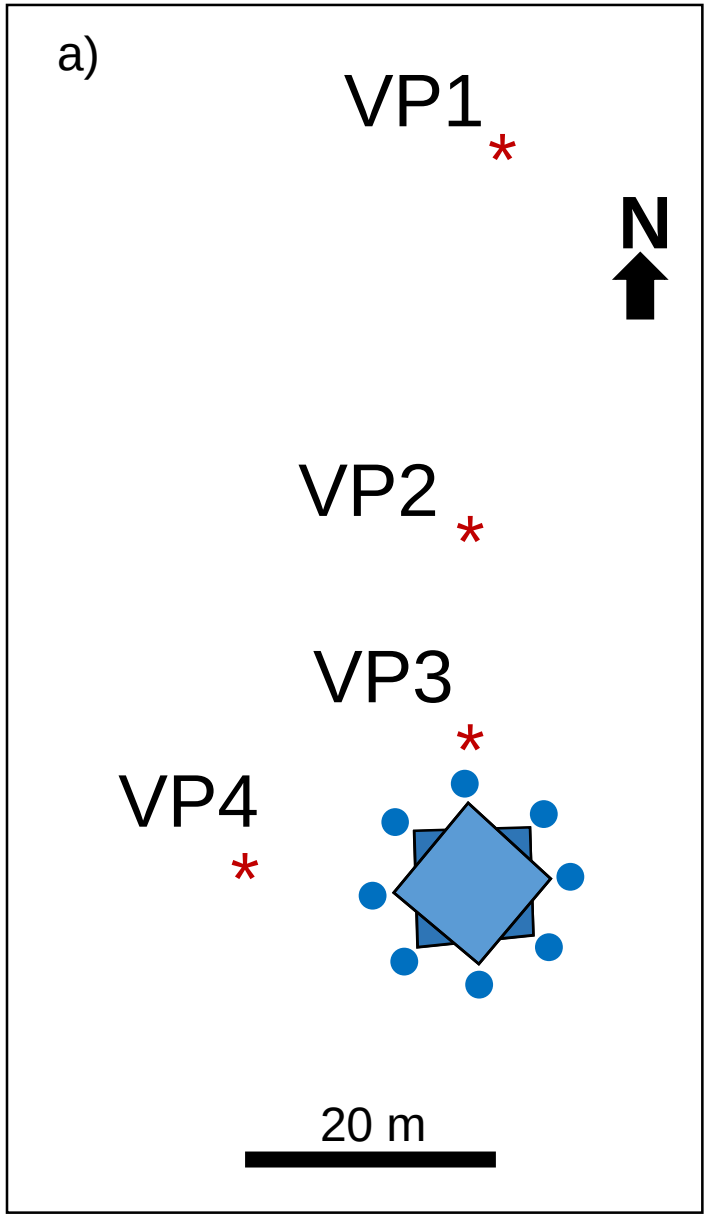
Data Preparation: Aligned Vertically Stacked LSG

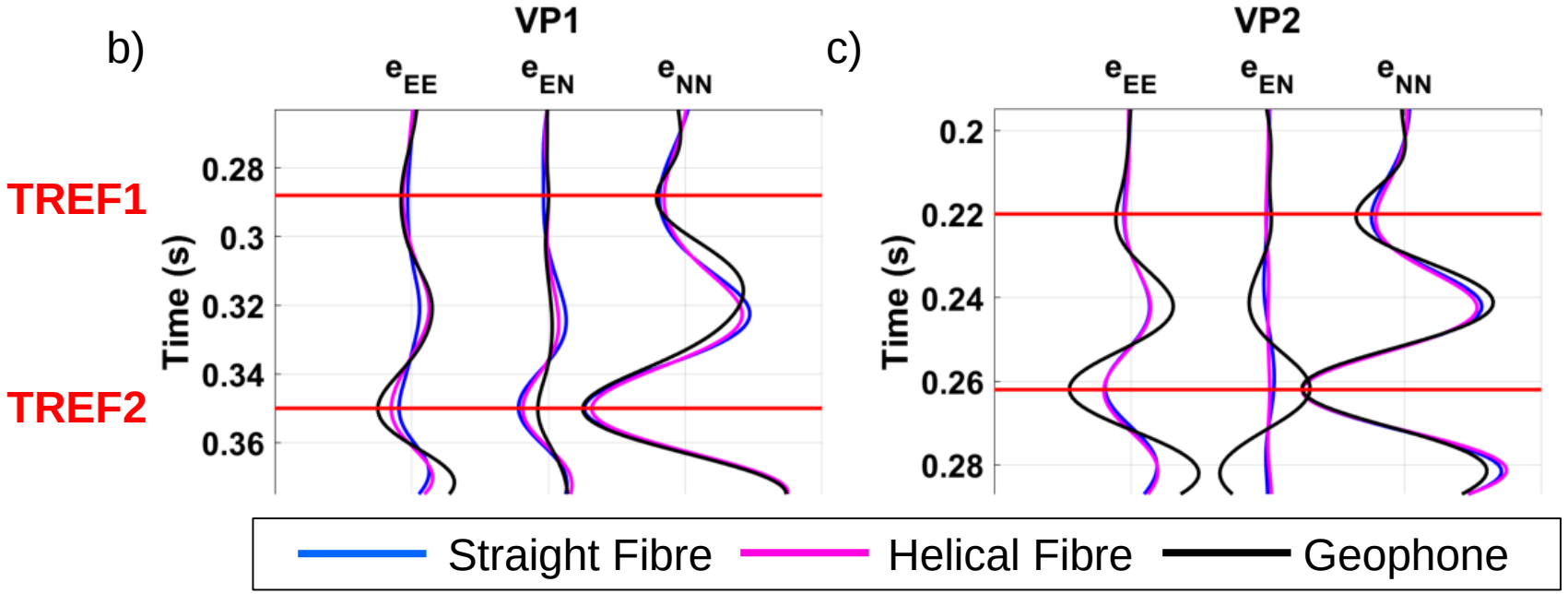


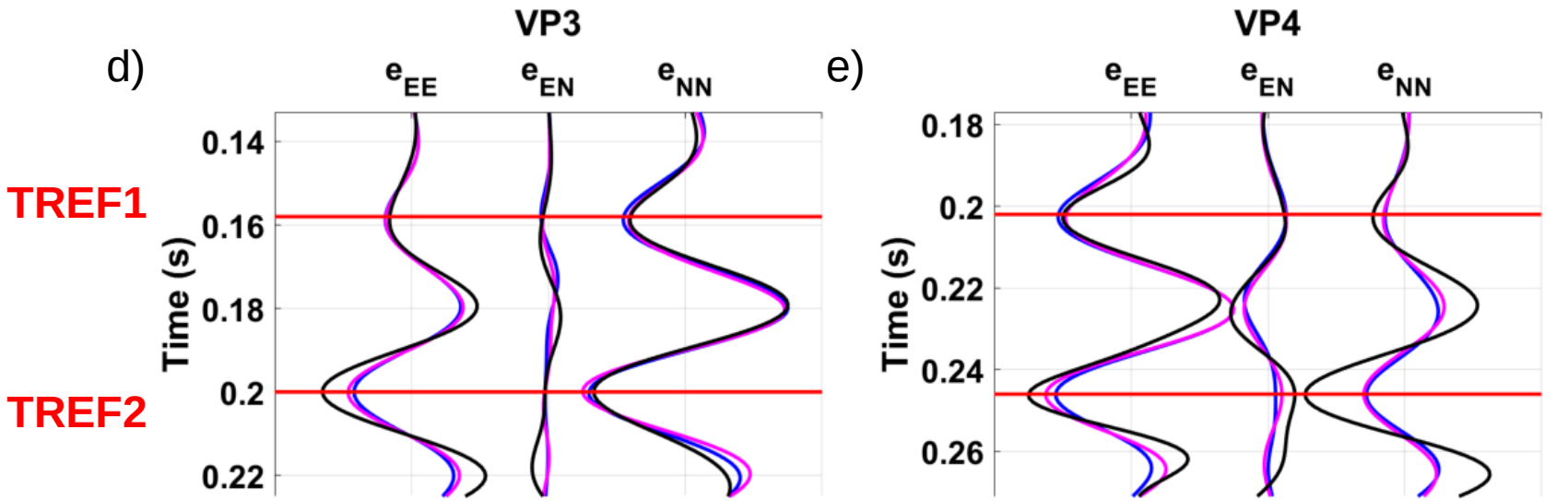
Data Preparation: Aligned and Stretched Vertically Stacked LSG



Results: Strain-Rate Tensors







Discussion and Future Work

Discussion

- Estimated strain-rate time-series-tensors
  - No significant differences fibre cable types
  - Geophone results are similar

Future Work

- Ground Roll Usage
  - Smaller DDS and smaller gauge lengths
- Shear Reflections
  - Need to remove ground-roll (and air blast) OR
  - Use larger VP to DDS offsets

Acknowledgements

- Halliburton (Field Acquisition)
- Schlumberger (Vista software)
- MathWorks (Matlab software)

- CREWES sponsors
- CaMI.FRS JPI subscribers

- NSERC through the grant CRDPJ 461179-13, CRDPJ 543578-19, and in part by an NSERC-DG