# RTM of a distributed acoustic sensing VSP at the CaMI Field Research Station, Newell County, Alberta, Canada

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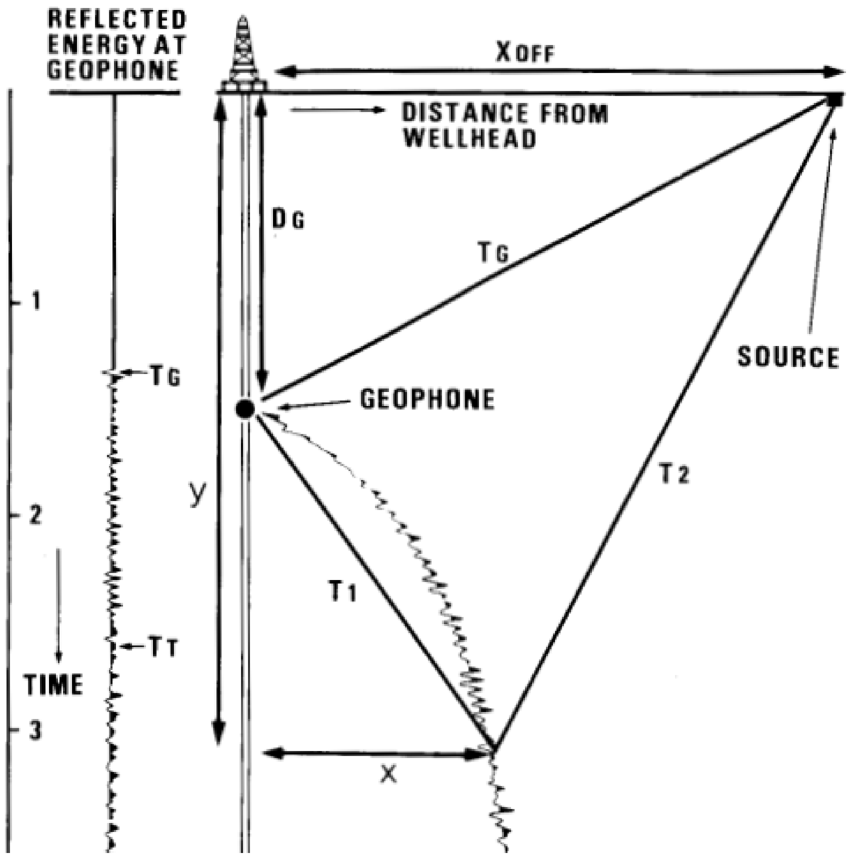
# Motivation

VSP-CDP transform




(Dillon, 1984)

VSP-CDP transform is a single-channel process.

Only reflections from horizontal and near-horizontal interfaces are correctly handled.

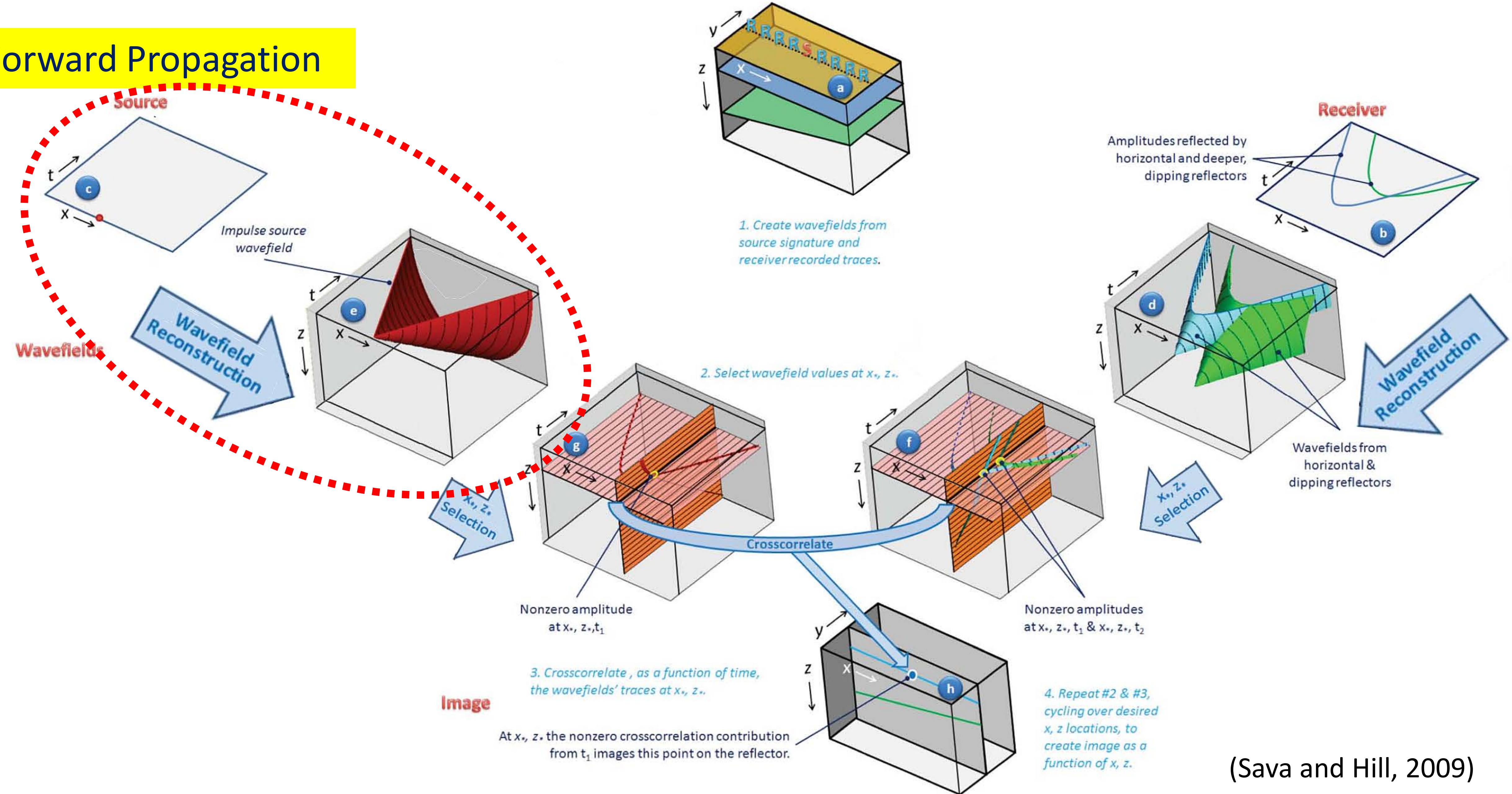
Although CaMI-FRS site has horizontal interfaces, we want to be able to handle more complex structures.

# Agenda

1. Finite difference scheme.
2. RTM Imaging condition.
3. Transformation between fibre response and geophone response.
4. Synthetic modelling and migration experiment.
5. Real data migration.

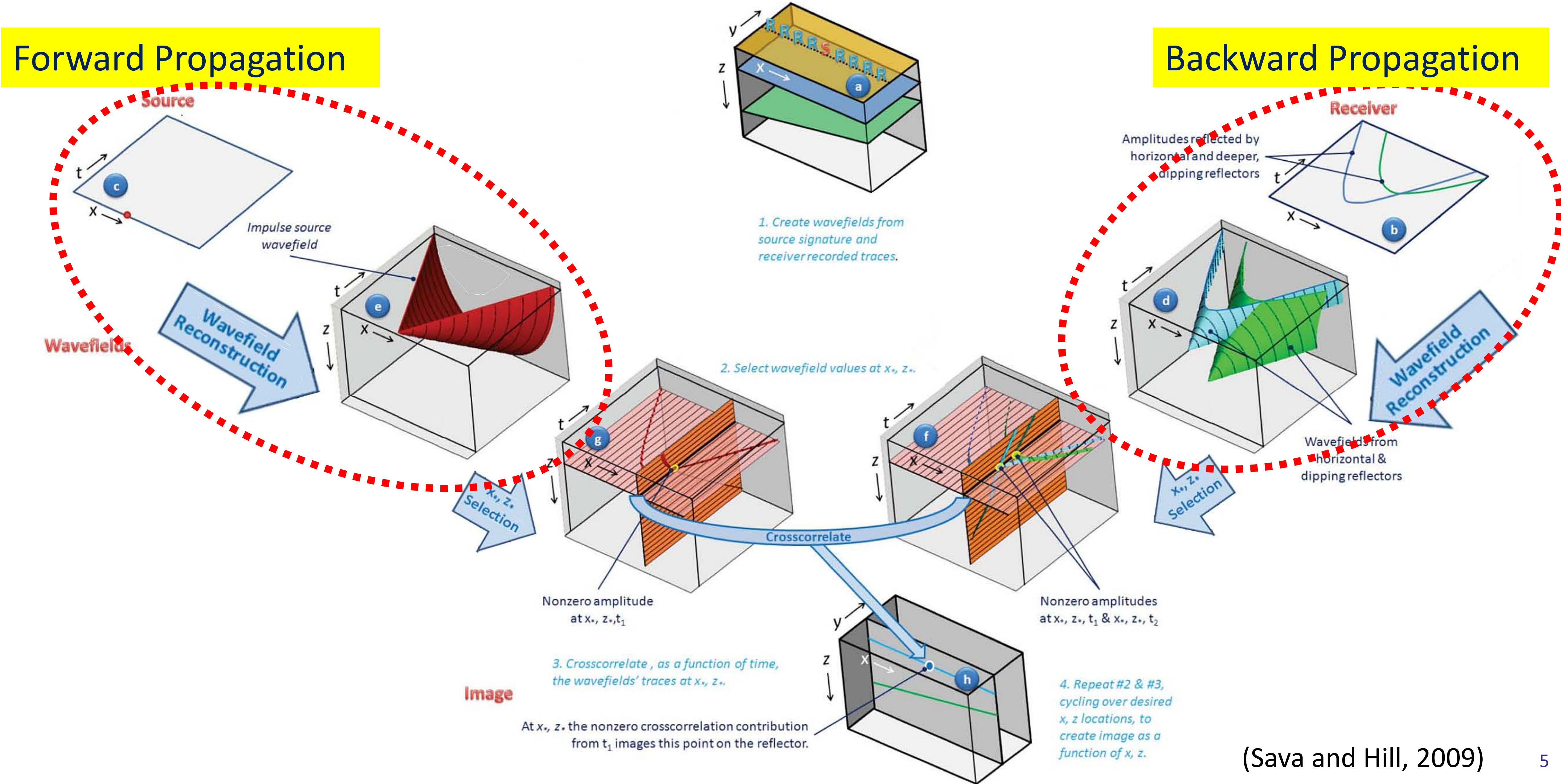
# Reverse time migration (RTM)

Forward Propagation



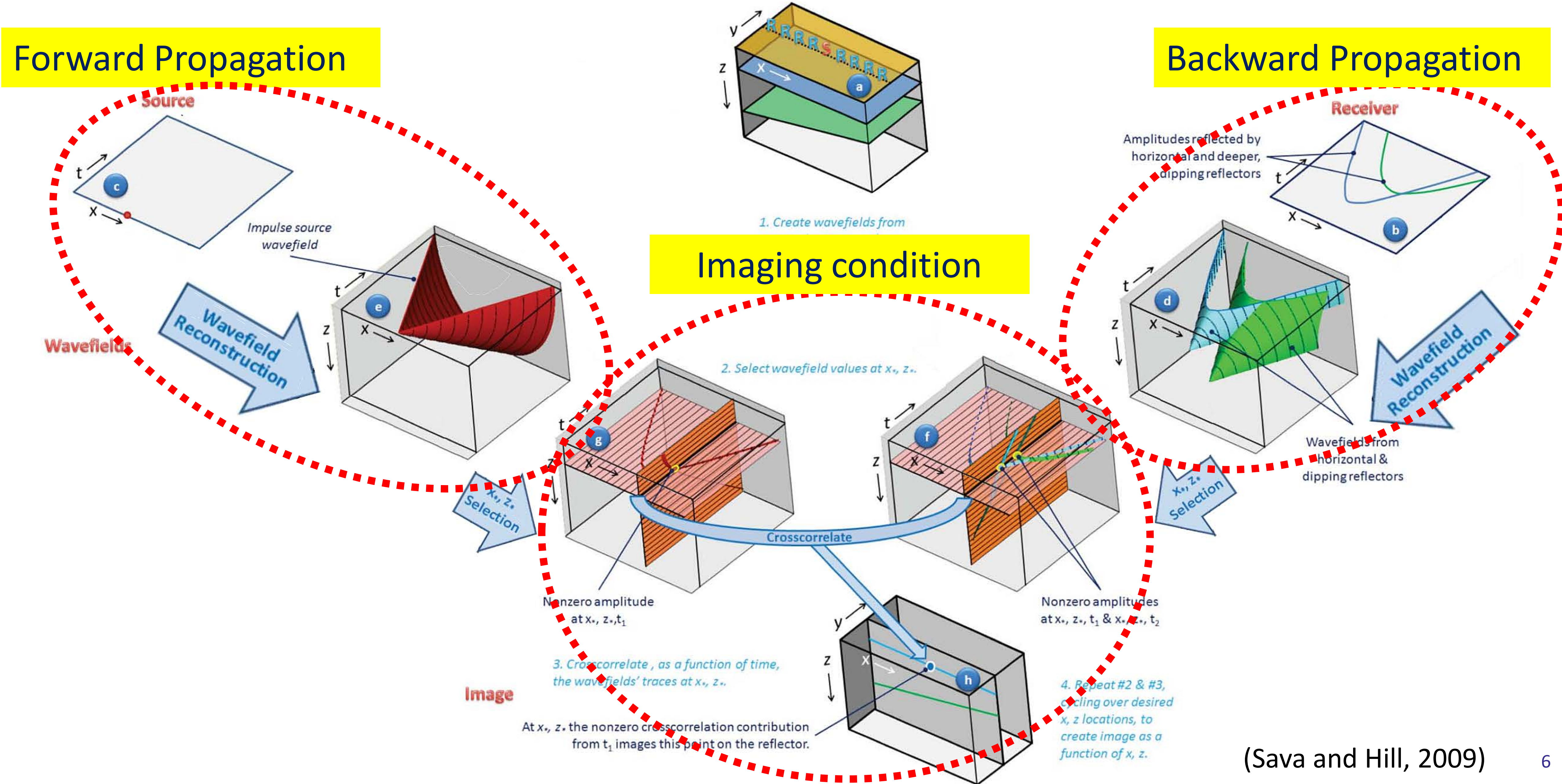

(Sava and Hill, 2009)

# Reverse time migration (RTM)



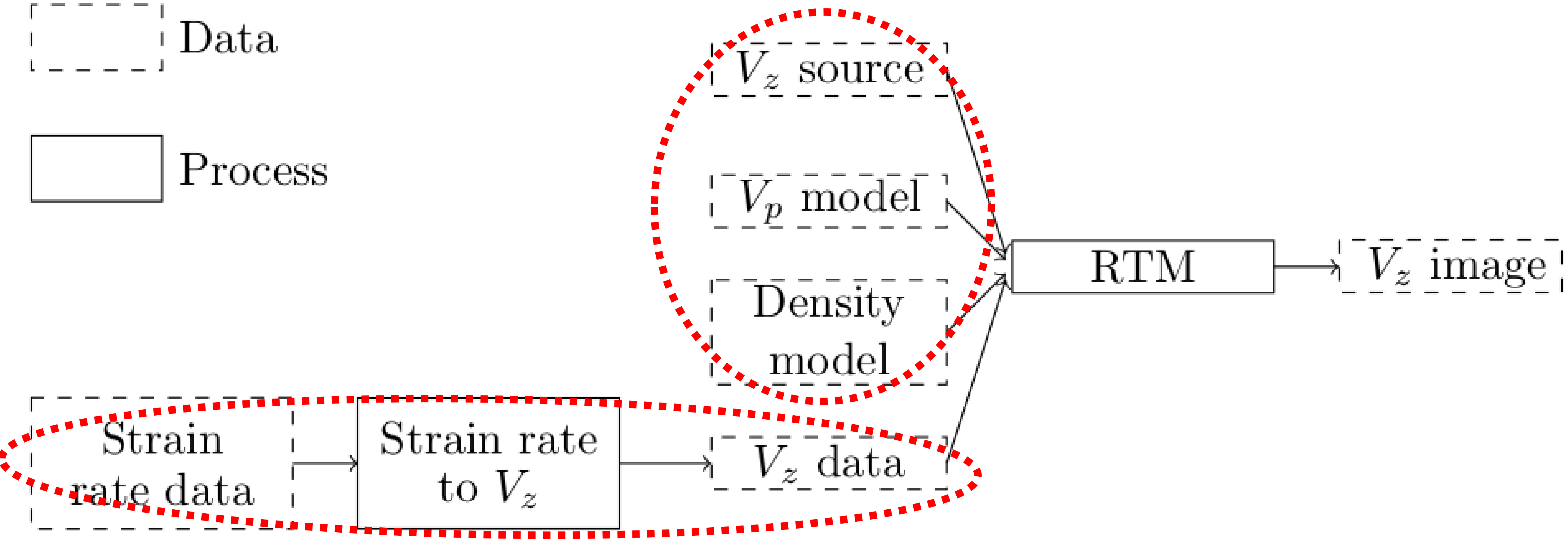

(Sava and Hill, 2009)

# Reverse time migration (RTM)




(Sava and Hill, 2009)

# RTM workflow

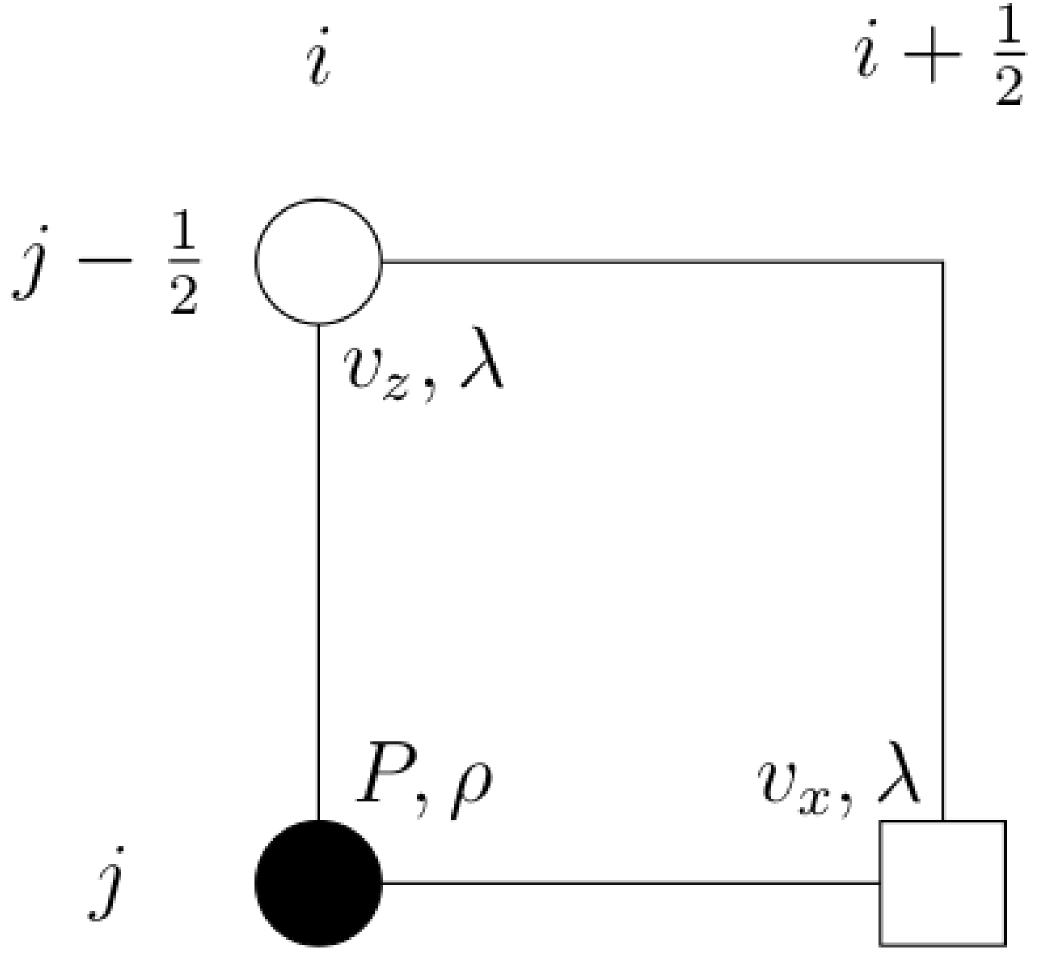


# 1. Acoustic FD

$$\frac{\partial P}{\partial t} = \lambda \left( \frac{\partial v_x}{\partial x} + \frac{\partial v_z}{\partial z} \right) + s$$

$$\frac{\partial v_x}{\partial t} = \frac{1}{\rho}\frac{\partial P}{\partial x}$$

$$\frac{\partial v_z}{\partial t} = \frac{1}{\rho}\frac{\partial P}{\partial z}$$




P pressure

$v_z$ is vertical particle-velocity.

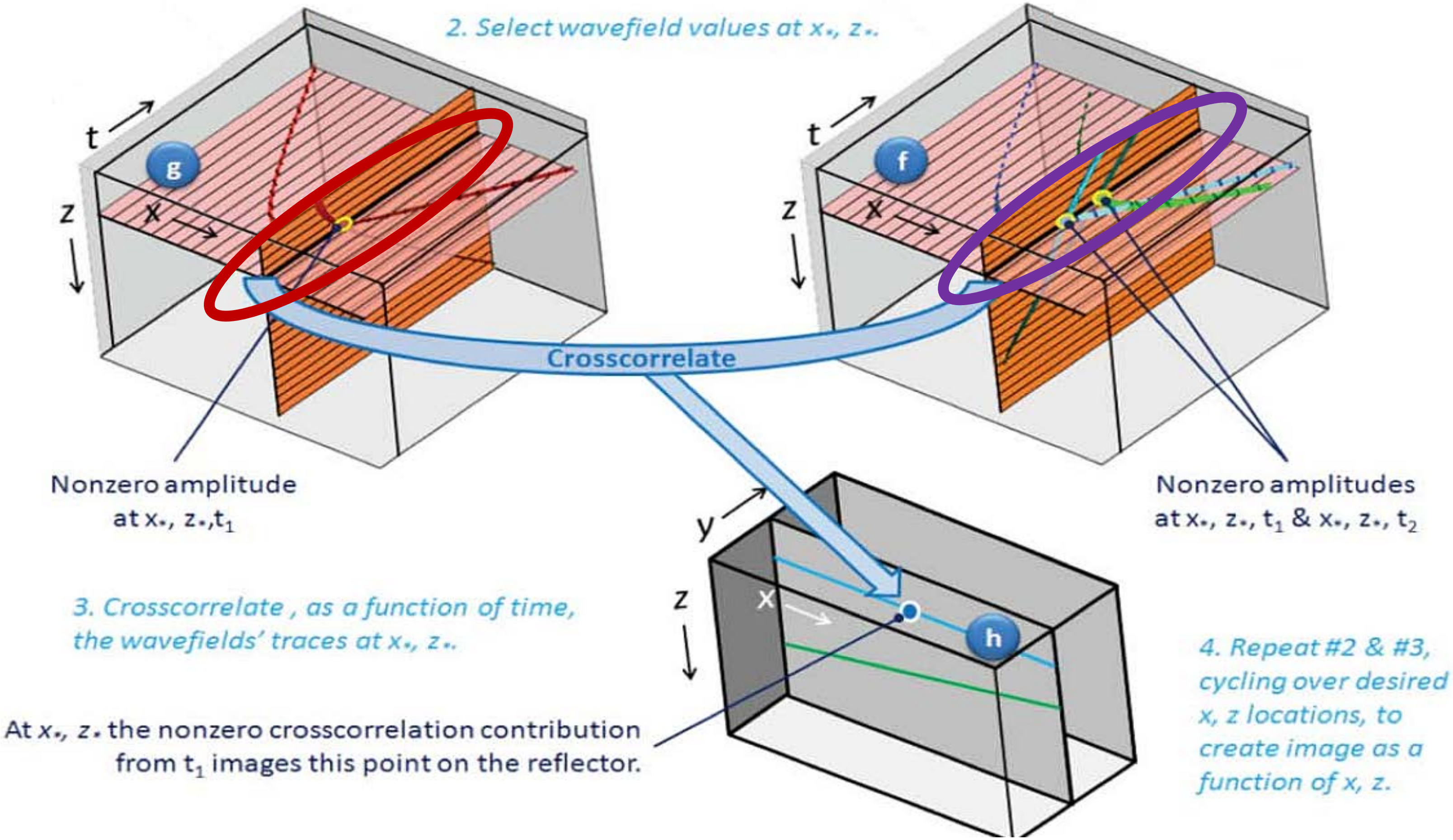
$v_x$ is horizontal particle-velocity.

λ Lamé parameter

ρ density

s source term

# 2. RTM normalized imaging condition




$$I(x,z) = \frac{\int_0^T v_z(x,z)\hat{v}_z(x,z)dt}{\int_0^T v_z(x,z)^2 dt},$$

(Sava and Hill, 2009)

# 3. **Daley** strain rate to vertical particle-velocity transformation

Strain rate is the usual DAS measurement:

$$f = \frac{\partial \epsilon_z}{\partial t}$$

**Daley**:

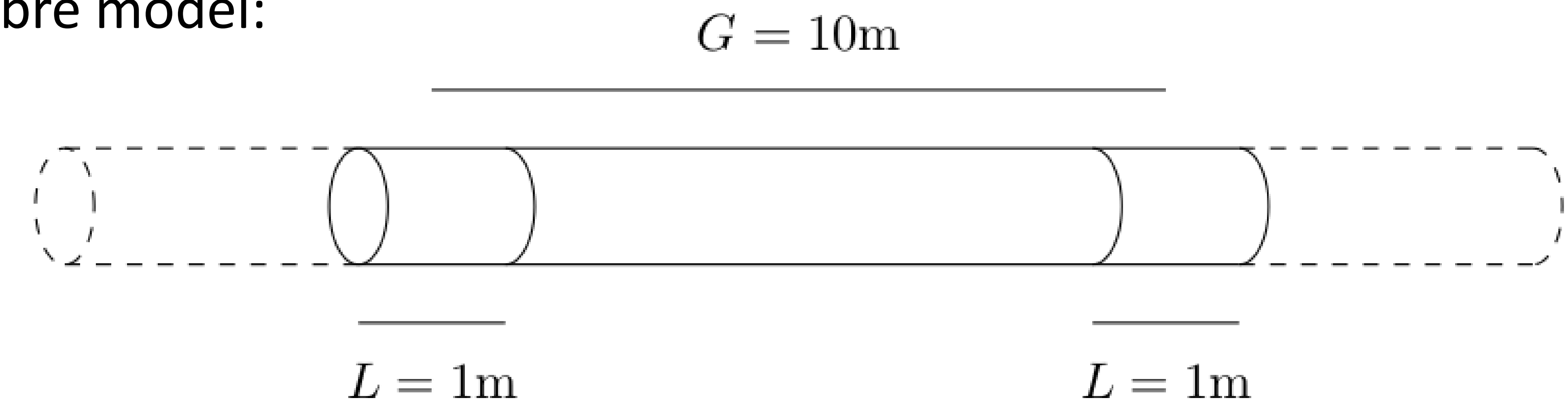
$$v_z(z) \;=\; -c(z)\int f(z)dt,$$

c(z) is apparent wave velocity measured in the well.
c(z) ≈ 3500m/s using the source closest to the well.

(Daley et Al., 2016)

# 3. **Bóna** strain rate to vertical particle-velocity transformation

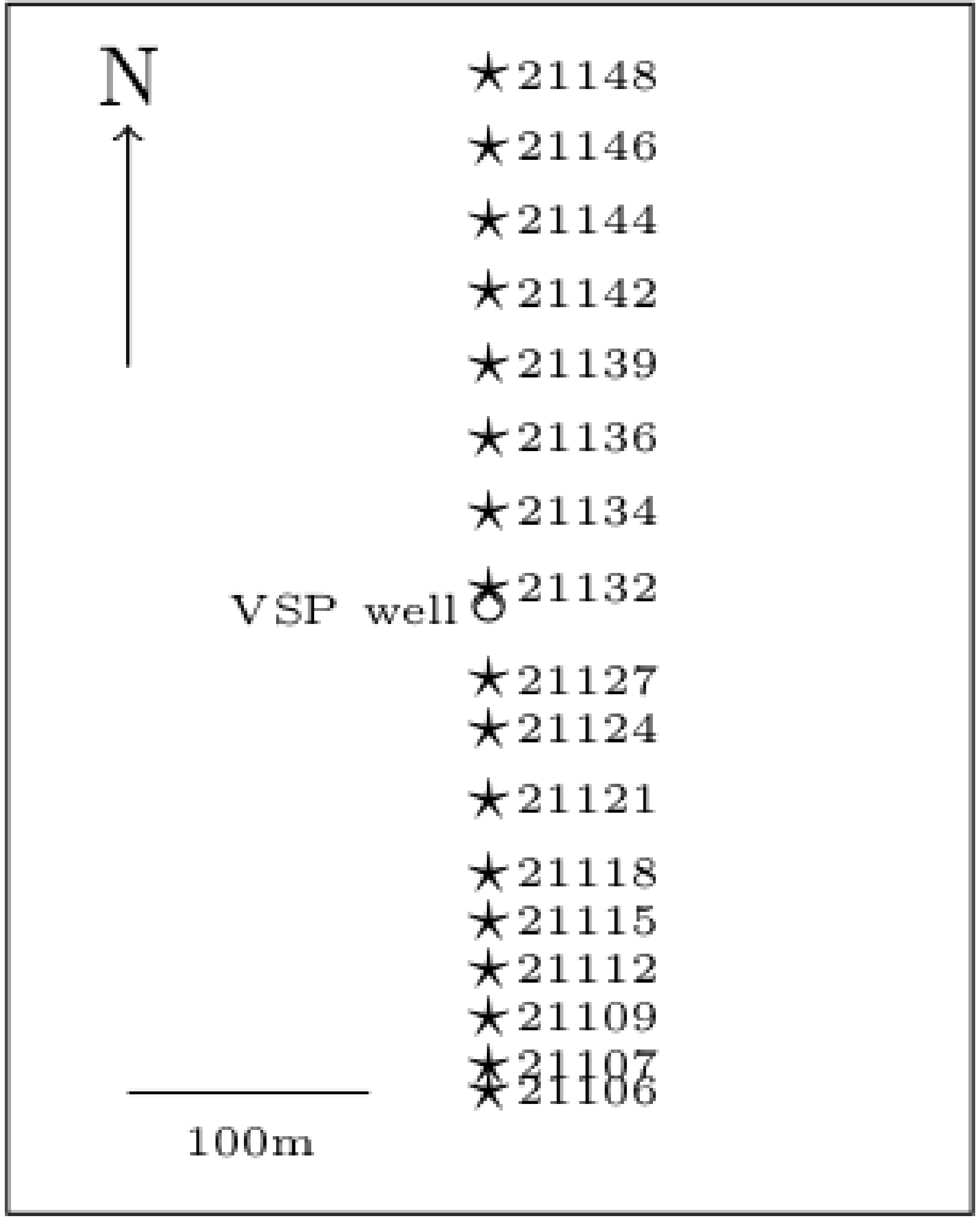
DAS Fibre model:

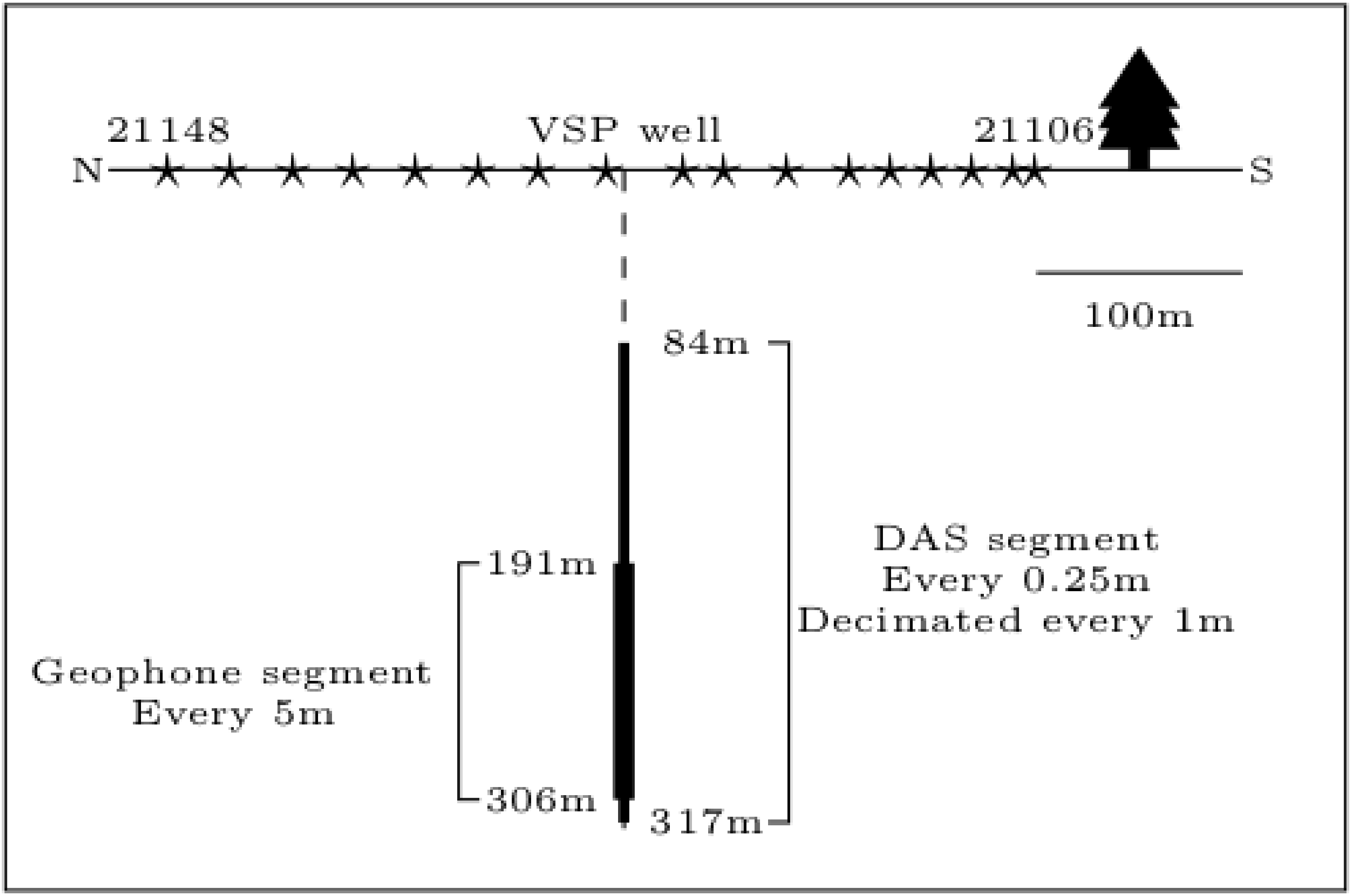



**Bóna:** $$v_z(k_z) = f(k_z)\frac{-ik_z}{\left(1-e^{ik_zL}\right)\left(1-e^{ik_zG}\right)+\gamma},$$

(Bona et Al., 2017)

# DAS VSP acquisition



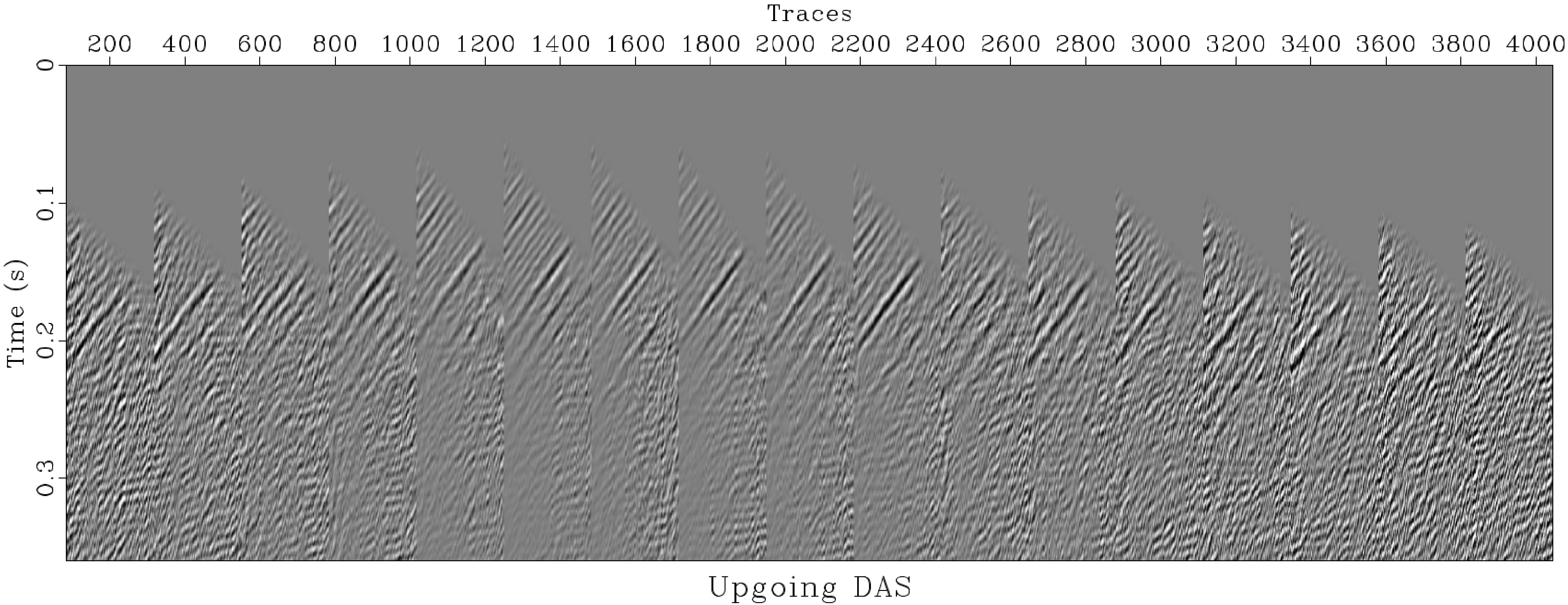




17 shot gathers.

Source was IVI EnviroVibe with linear sweep 10-150Hz.

338m DAS fibre and 24 3-C geophones in the well.

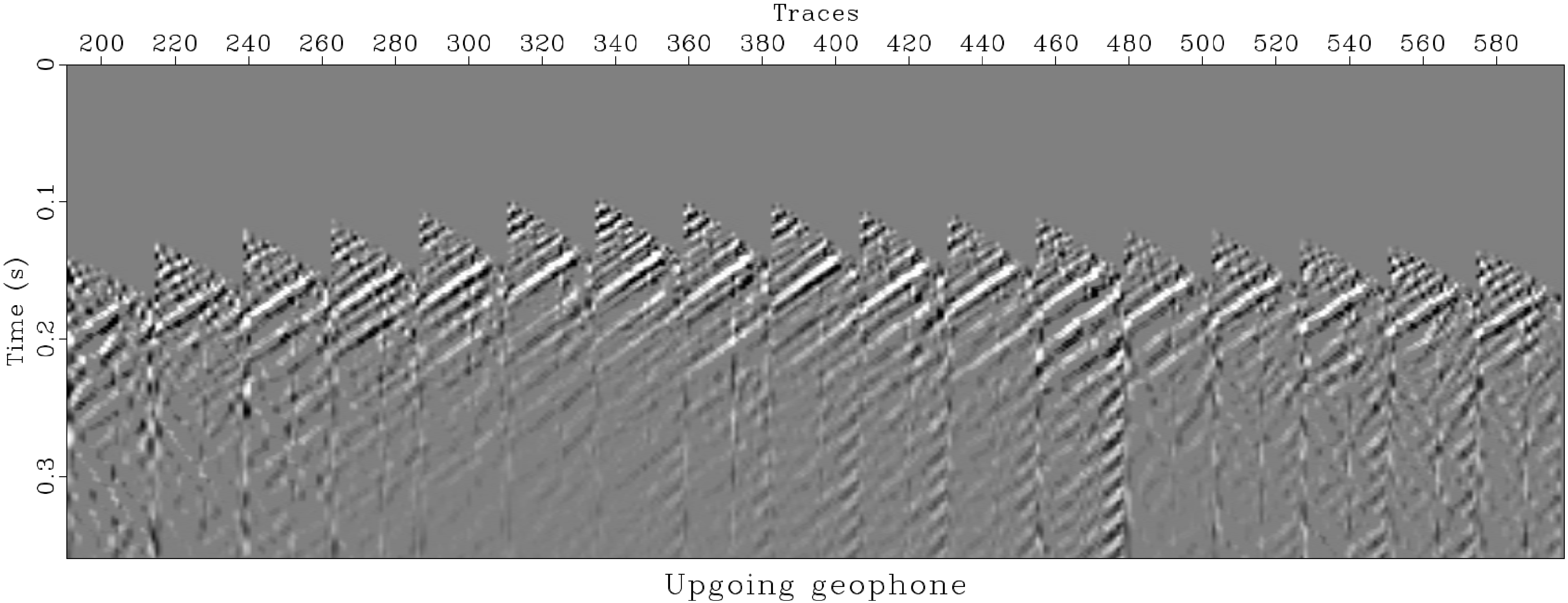
# DAS VSP data




- Geometry and first break picking.
- Wavefield separation.
- Gain for spherical spreading and transmission loss.
- Deconvolution of upgoing wavefield.

(Gordon, 2019)

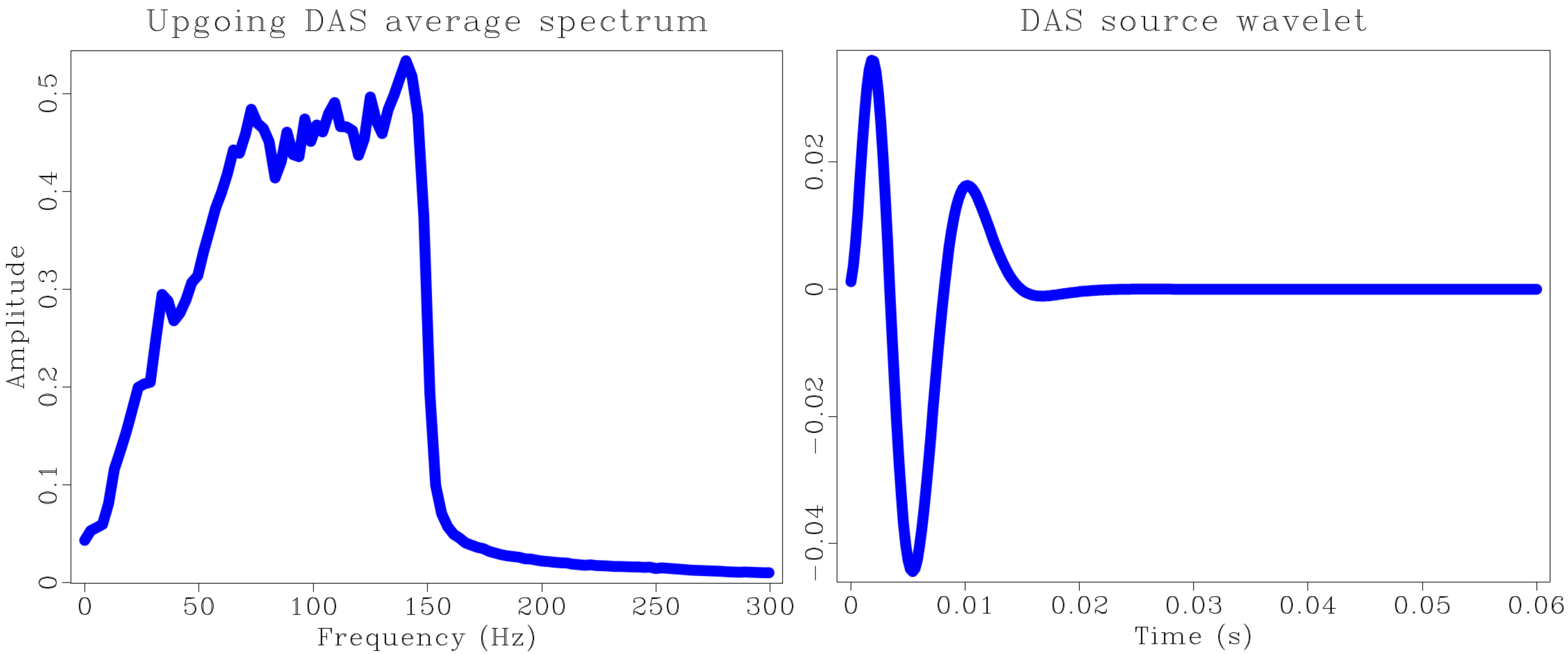
# Geophone VSP data



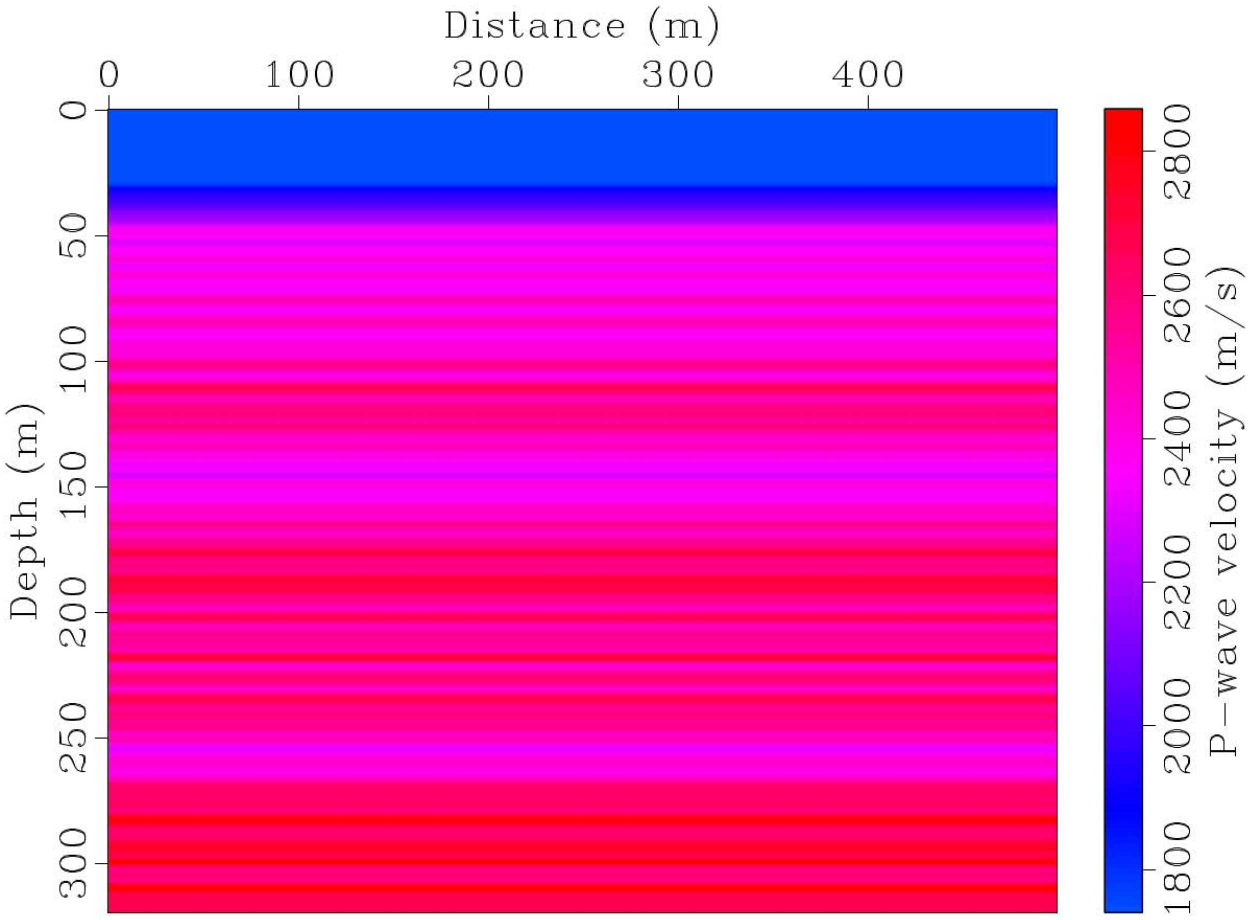

- Geometry and first break picking.
- Wavefield separation.
- Gain for spherical spreading and transmission loss.
- Deconvolution of upgoing wavefield.

(Gordon, 2019)

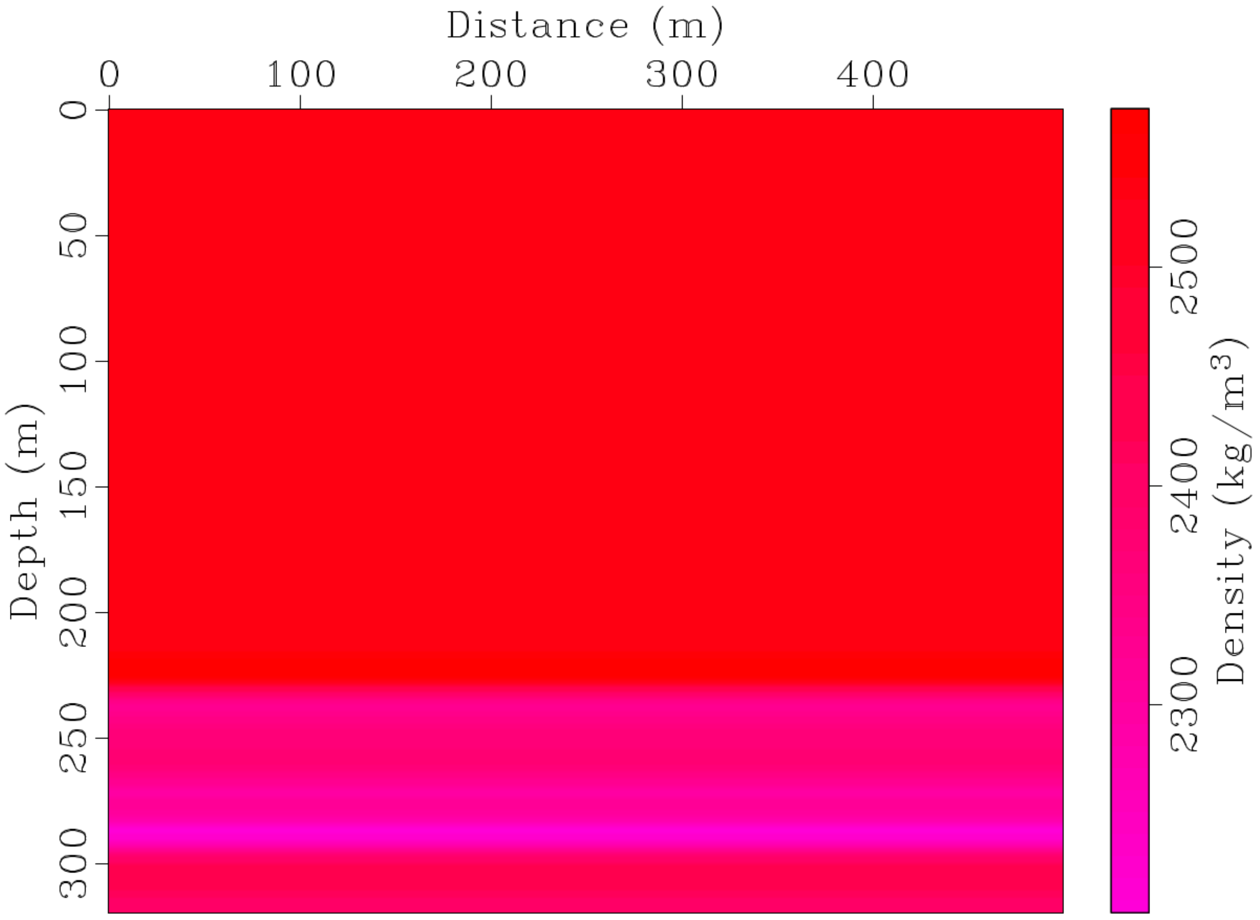
# Vz source wavelet



# P-wave velocity and density model



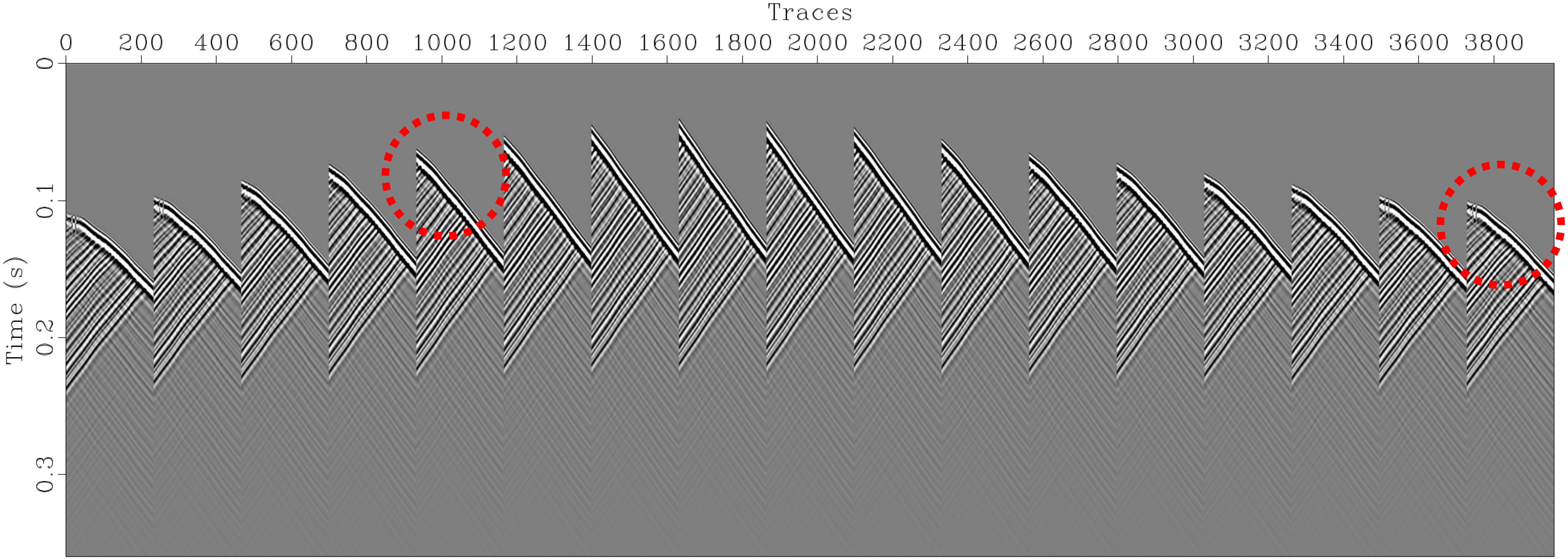

P−wave velocity model




Density model

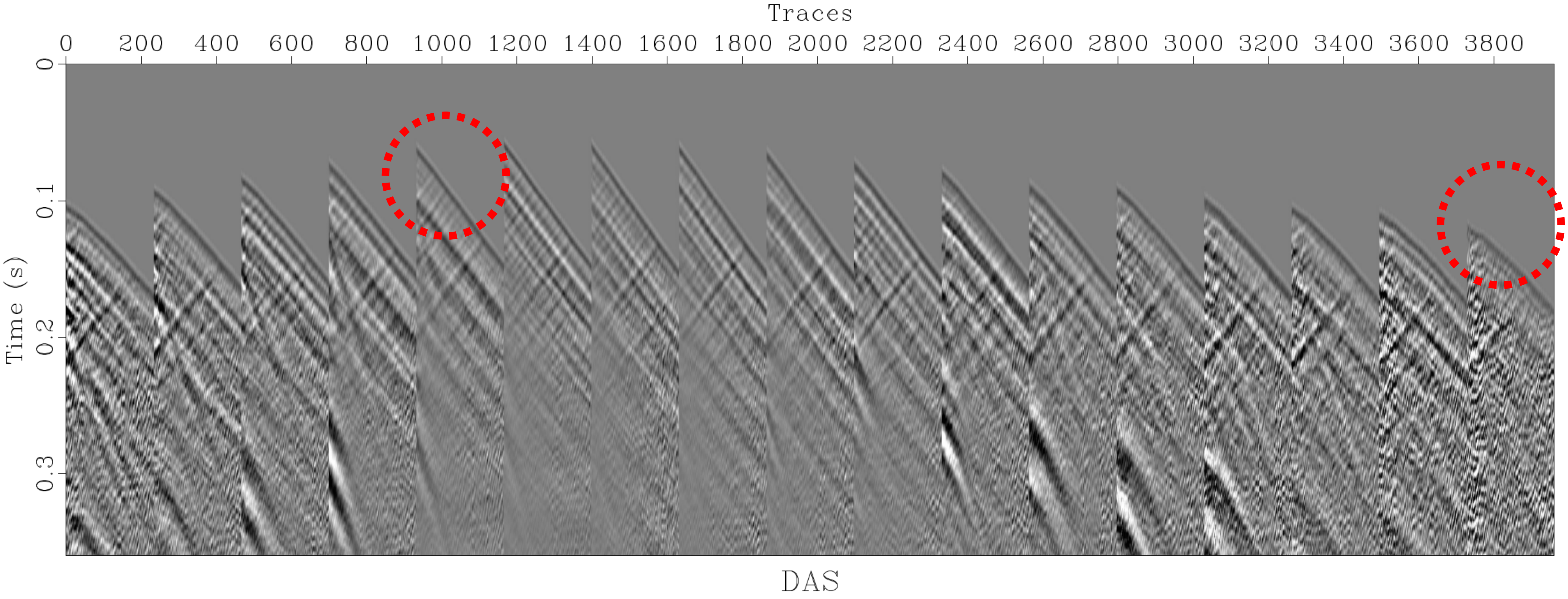
$$\lambda = \rho V_p^2$$

# Synthetic DAS

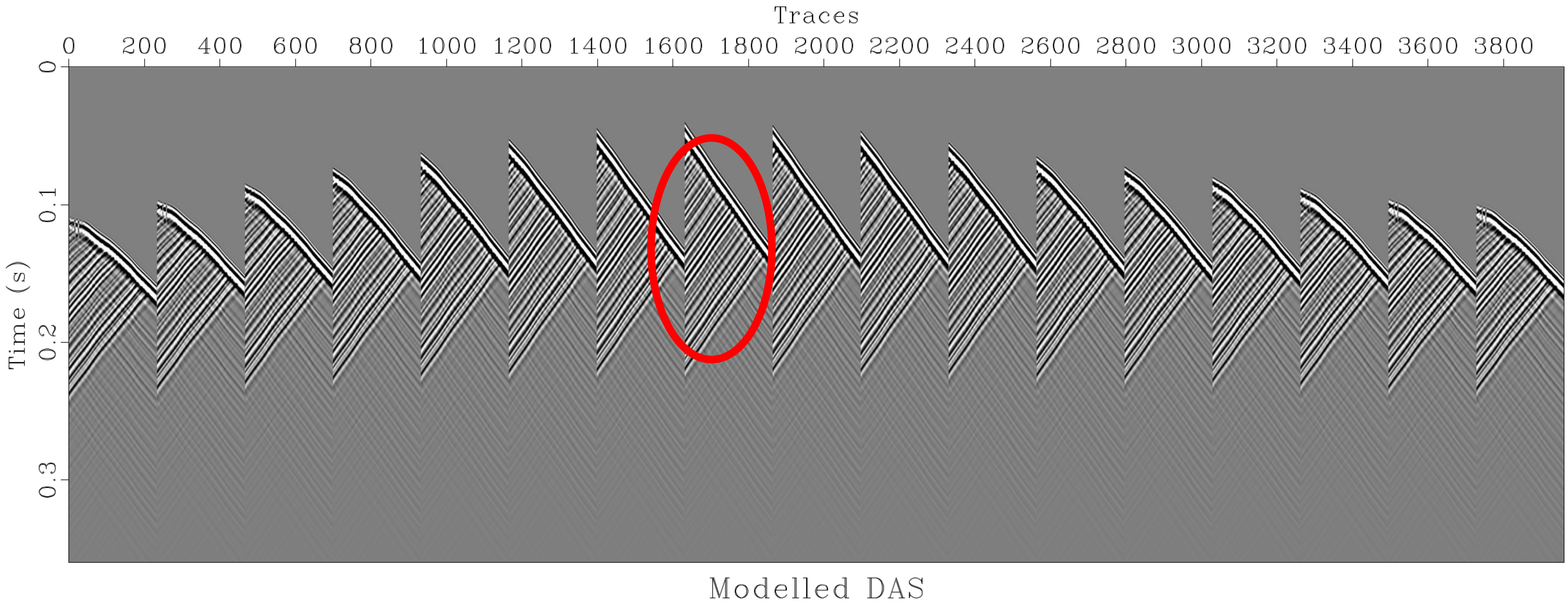



Modelled DAS

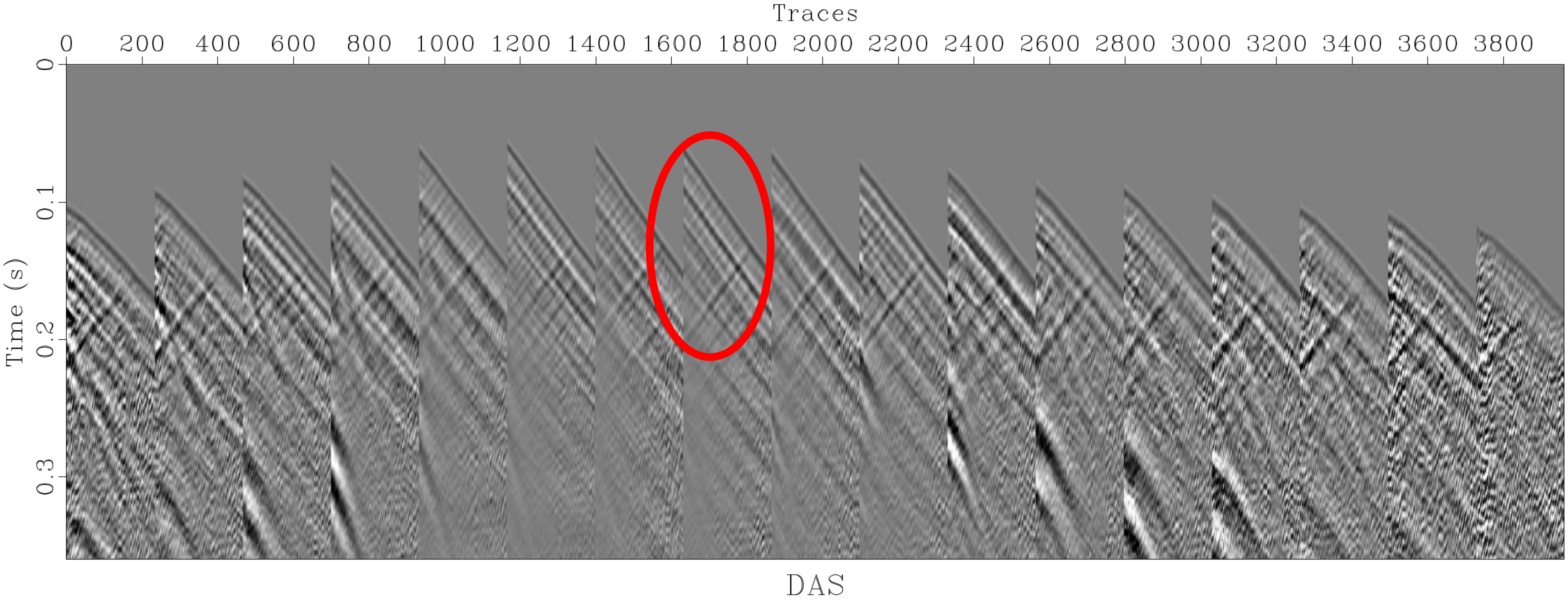
# Real DAS


Traces
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
3200
3400
3600
3800
Time (s)
0
0.1
0.2
0.3
DAS

# Synthetic DAS



# Real DAS


Traces
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2200
2400
2600
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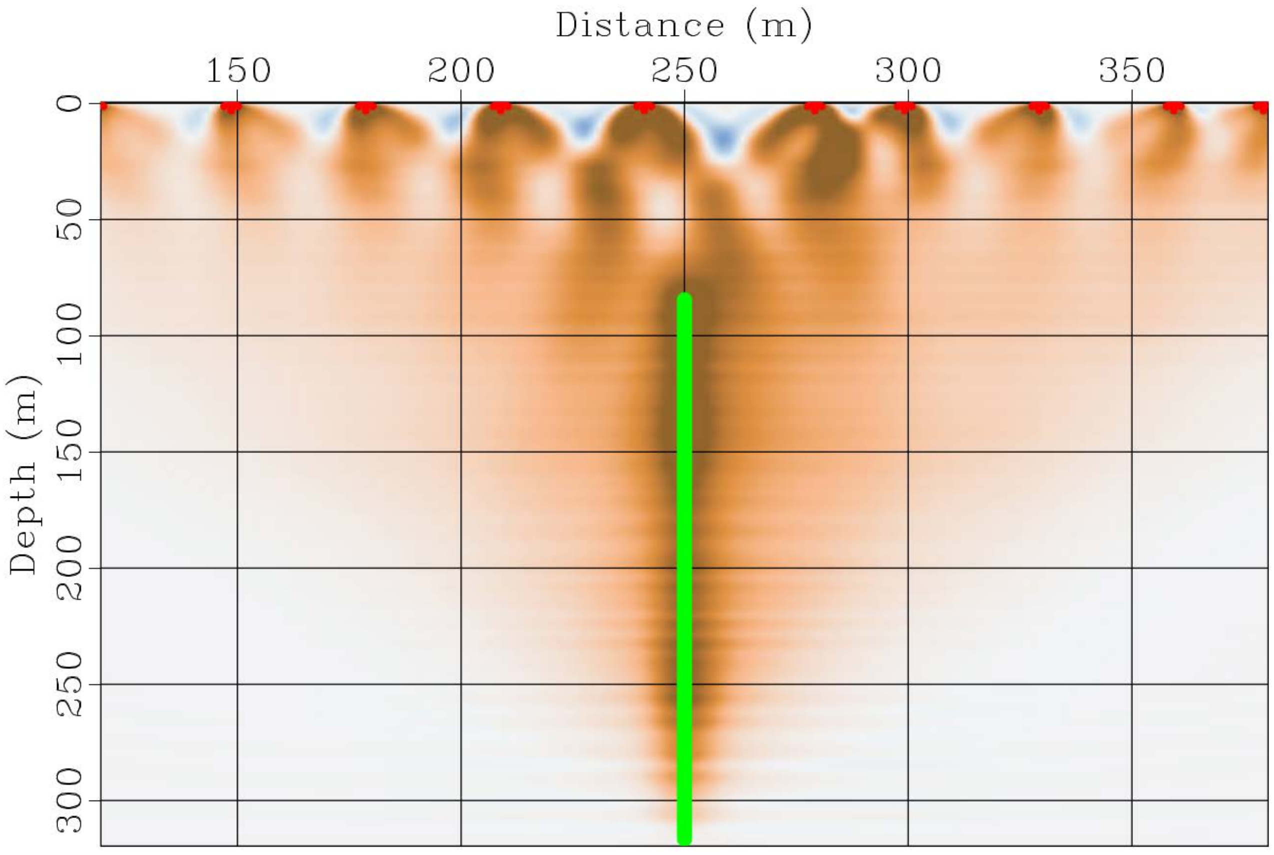
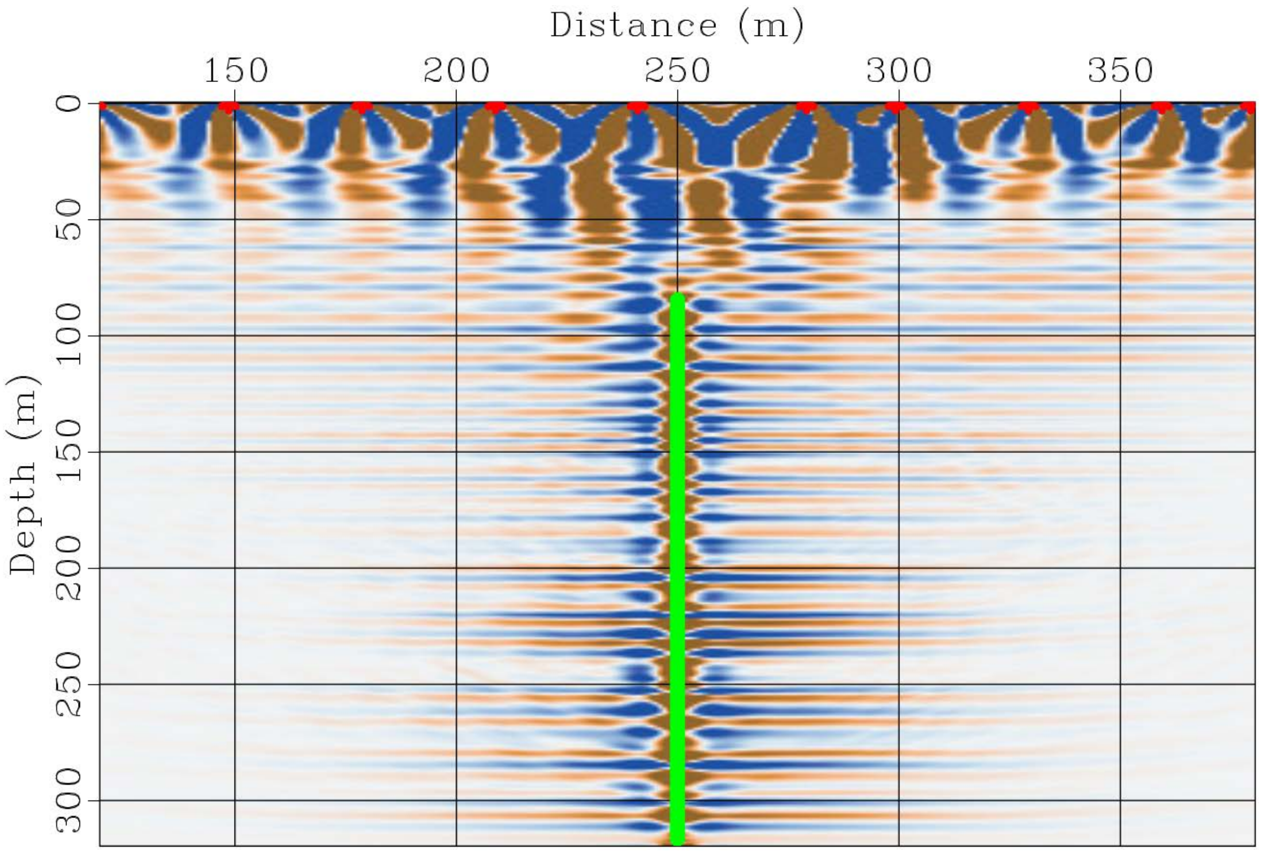
3200
3400
3600
3800
Time (s)
0
0.1
0.2
0.3
DAS

# 4. Synthetic data RTM (inverse crime)

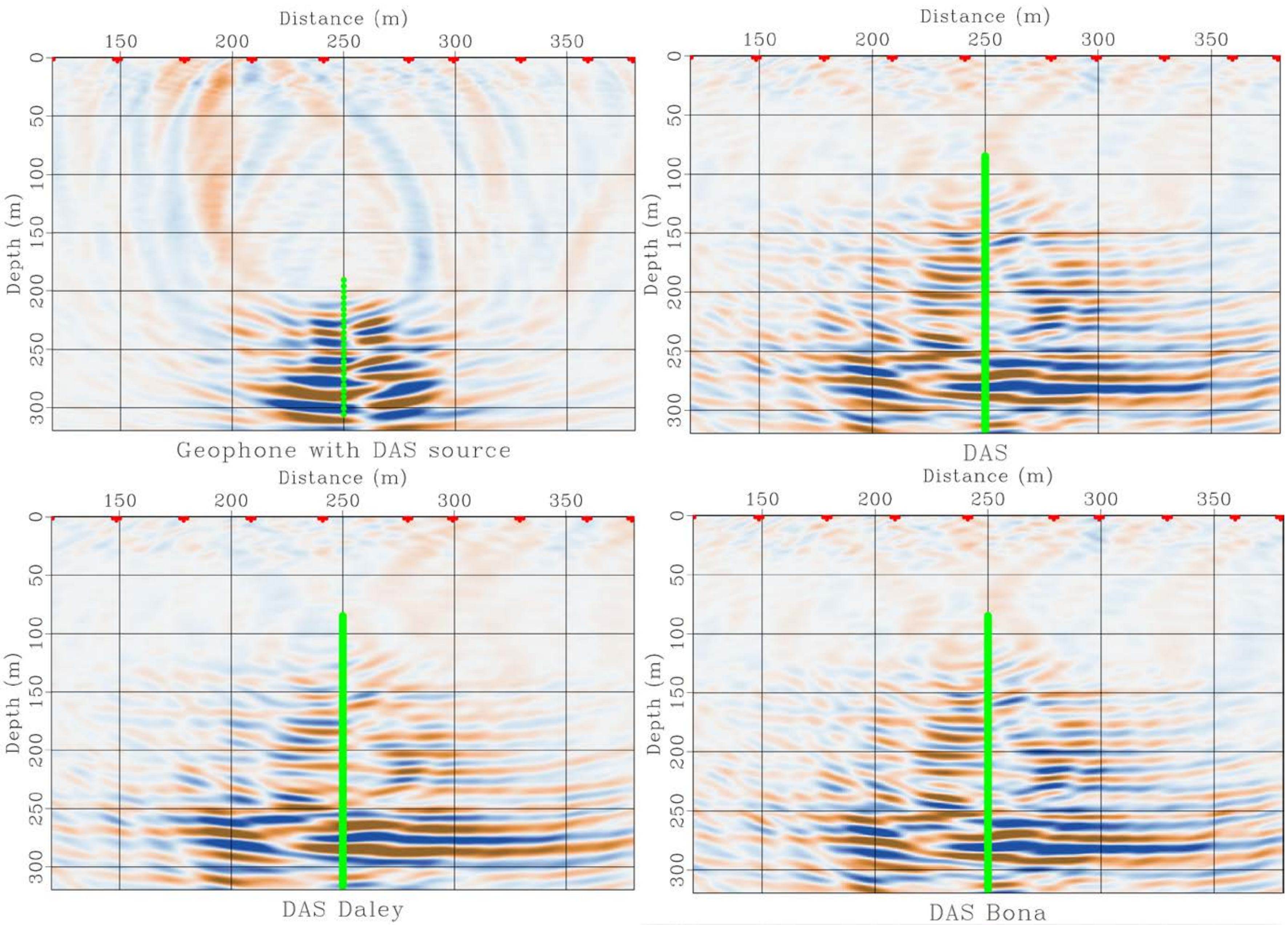



Synthetic VSP DAS

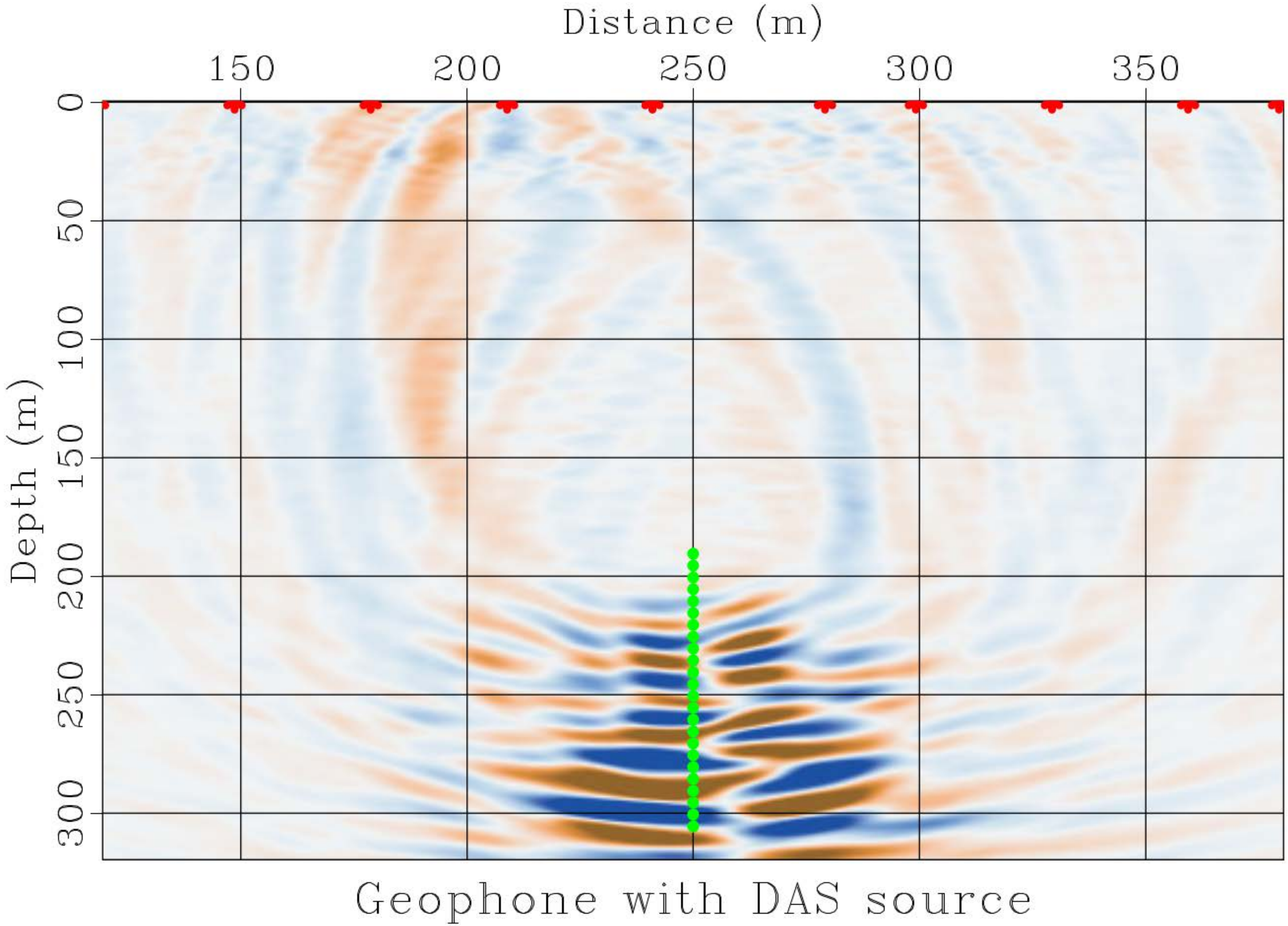



Synthetic VSP DAS with Laplacian

# 5. Real data RTM without Laplacian (NL)

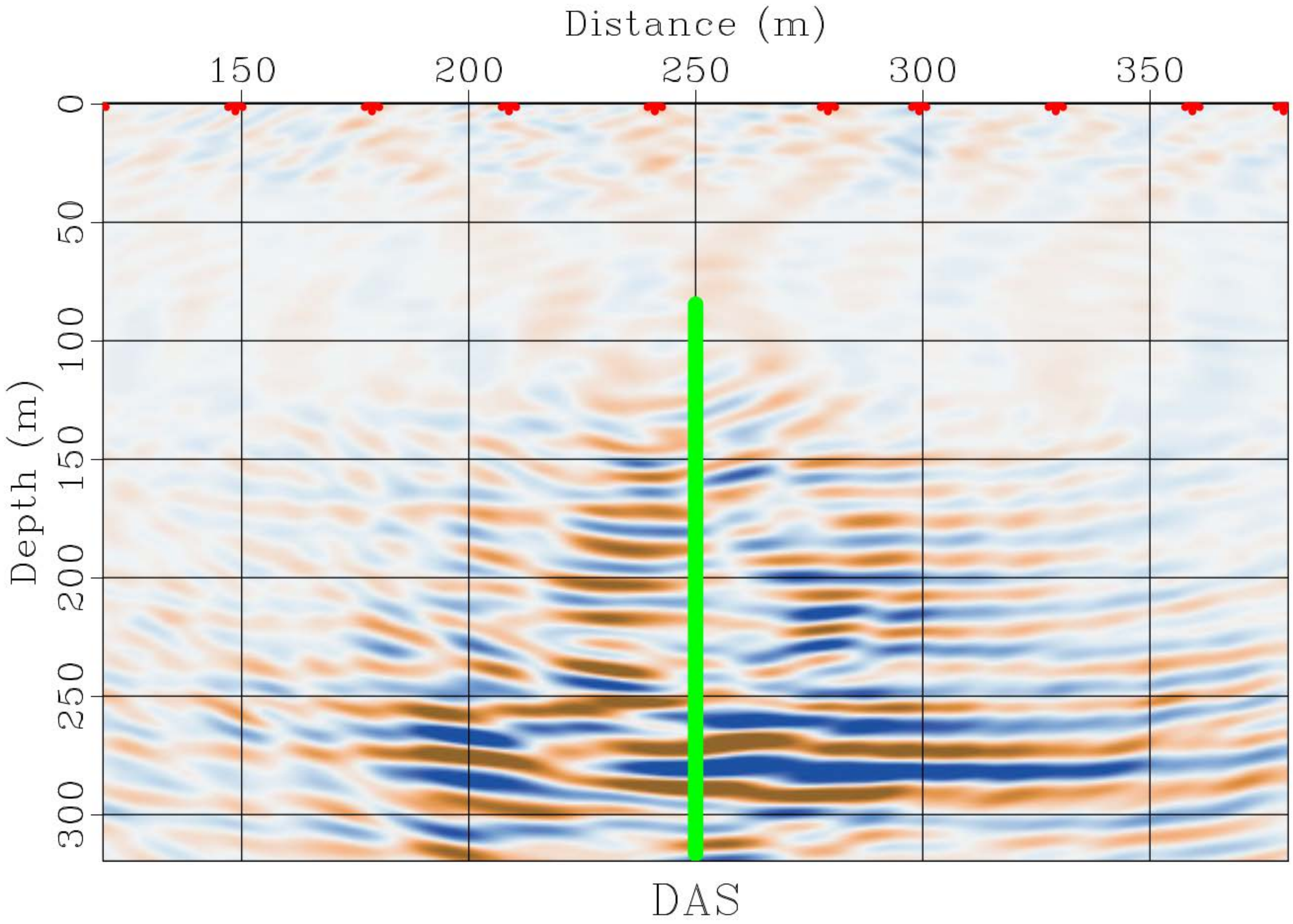


# 5. Geophone RTM



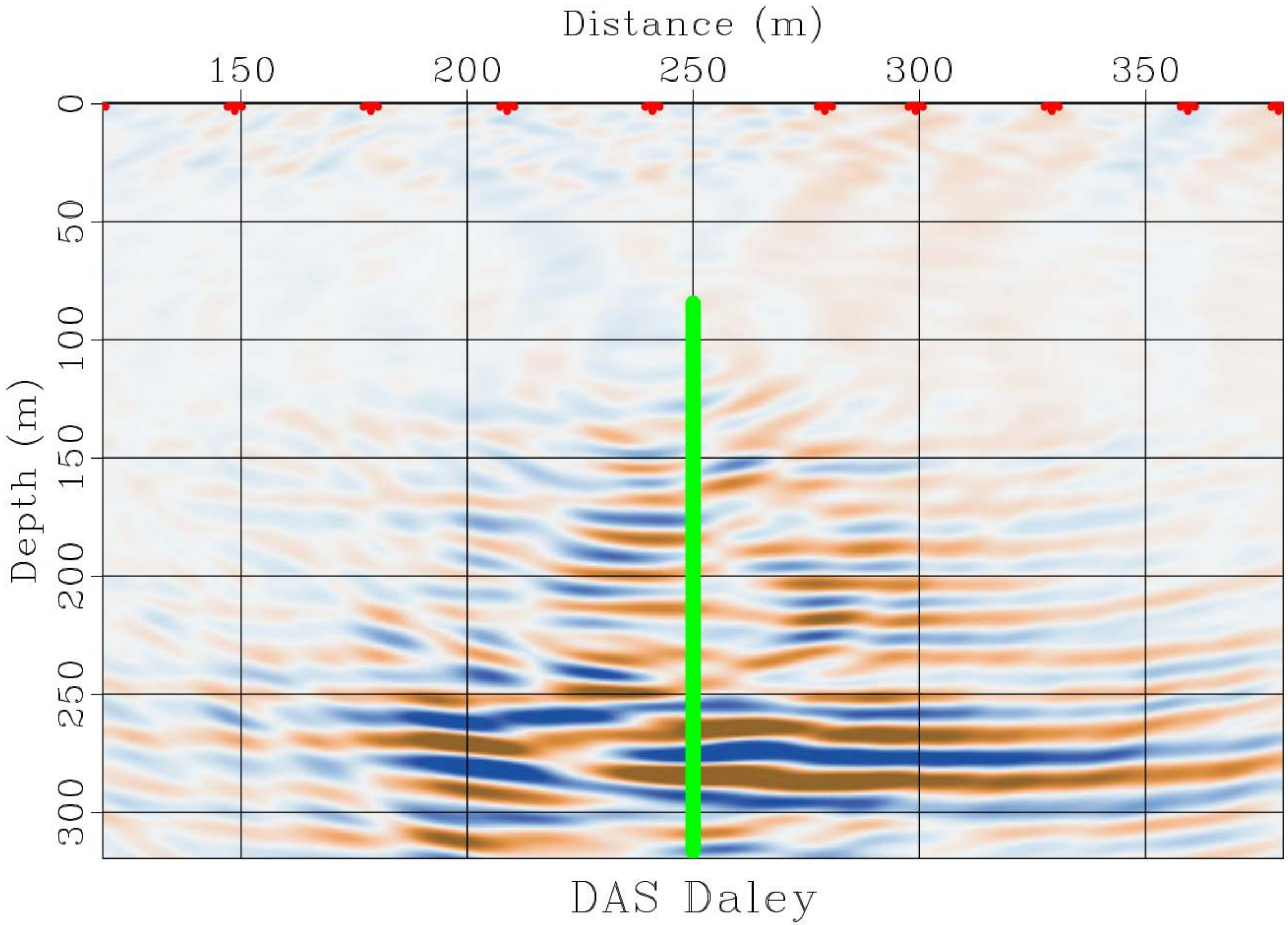

*NL

# 5. Untransformed strain rate RTM



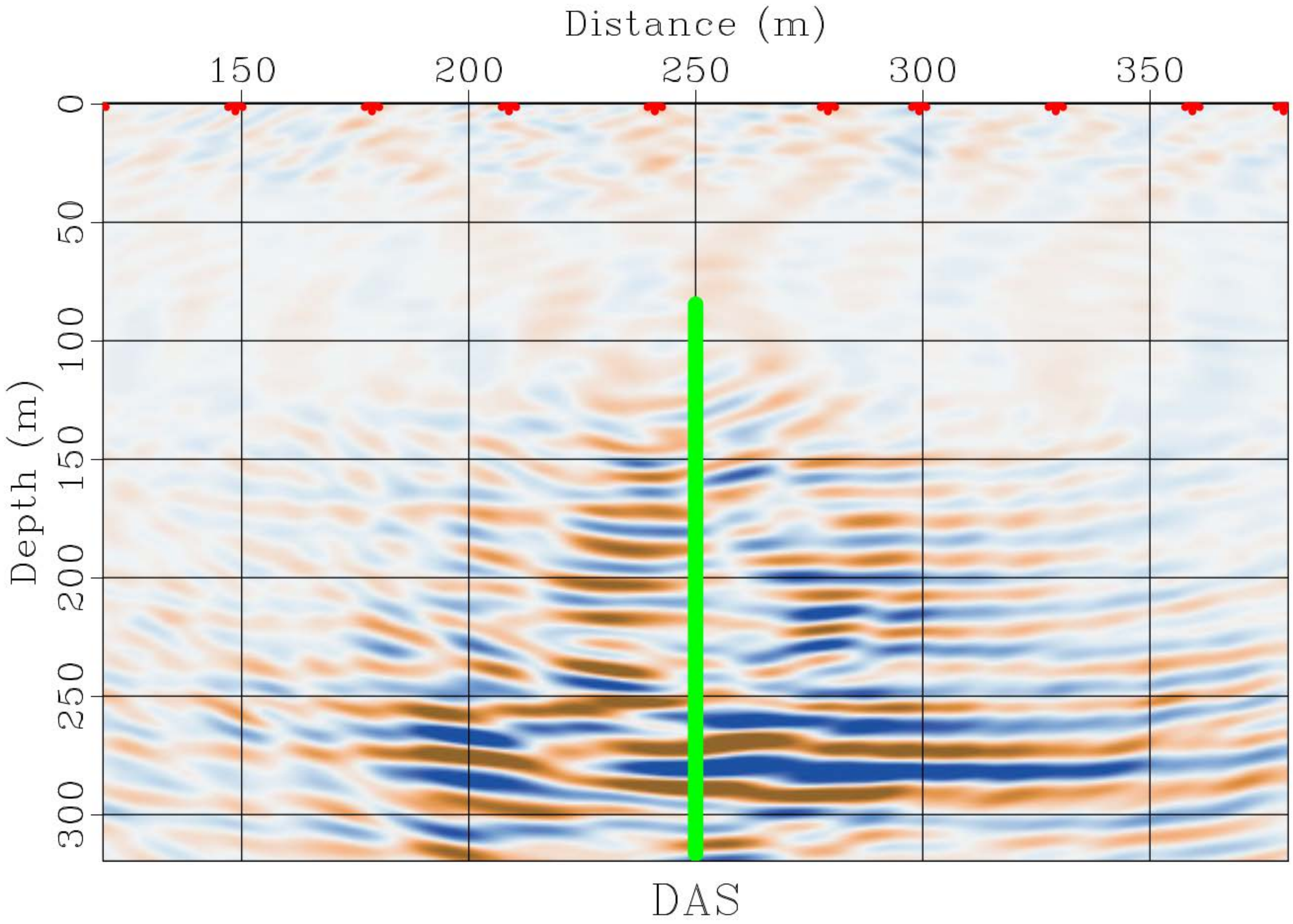

*NL

# 5. DAS RTM transformed with Daley technique



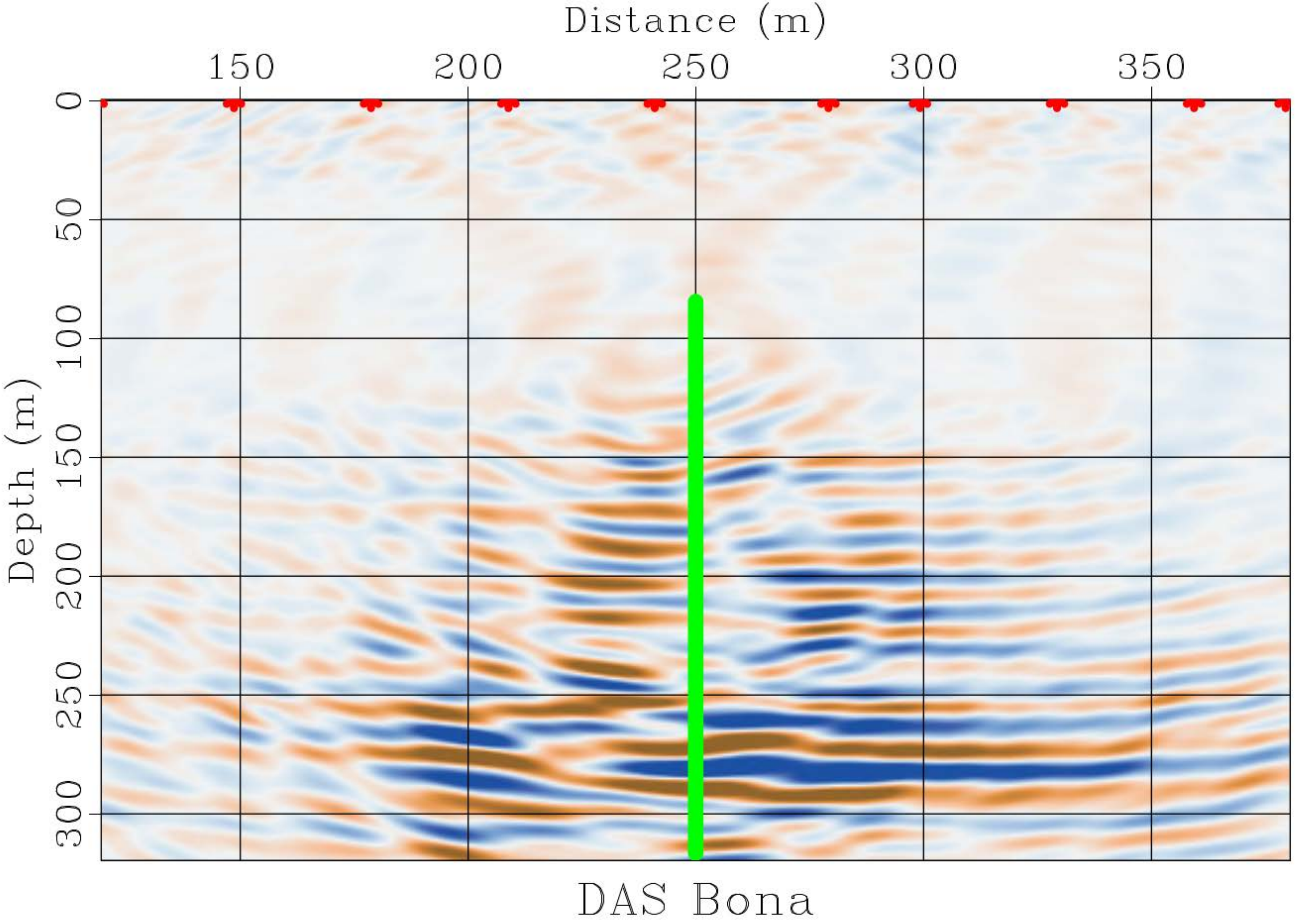

*NL

# 5. Untransformed strain rate RTM




*NL

# 5. DAS RTM transformed with Bóna technique




*NL

# Summary

- The RTM of the walkaway VSP DAS data from the CaMI Field Research Station is possible with the current data quality.

- This RTM have similar quality than the RTM from geophone data so we hope it could be used to perform monitoring at this facility.

- There were no apparent differences between the three RTM approaches we tested but we think a more detailed analysis is still needed.

- The Laplacian operator, widely used to eliminate low frequency noise caused by the RTM algorithms, was not needed when real VSP data were migrated.

# Acknowledgements

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REPSOL

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