Ground Roll Attenuation of Seismic Data through Model-Based Inversion: A Synthetic Study

Shaik Nasif Ahmed[1], Alok Routa[2], and Nimisha Vedanti[3]

[1]Academy of Scientific and Innovative Research, India
[2]Schlumberger
[3]CSIR-National Geophysical Research Institute, India

February 1, 2023

Presenting Author: nasif.ngri20j@acsir.res.in

Abstract

Ground roll is the most common coherent noise observed in the land seismic data, mainly characterized by low frequency and low velocities. In this study, we are demonstrating the application of a model-based surface wave attenuation technique for the efficient removal of ground roll from 2D seismic data. The method employs inversion and adaptive subtraction filtering of surface waves. A 1D viscoelastic model is characterized by considering layer thickness, P & Sv wave velocities, density, and P & Sv wave quality factors (Qp & Qs) for each layer, to compute a synthetic seismogram. A linear Radon transform is used to generate dispersion spectra of input shot gather and synthetic shot gather generated from the model. The misfit between the dispersion spectra of input shot gather and synthetic shot gather is given by an objective function 'J',$J(m) = \,||s-o||_2$, where 's' is the dispersion spectrum of the synthetic data generated by the model, 'o' is the dispersion spectrum of the shot gather and $||.||_2$is the L2-norm of the difference between 's' and 'o'. The main focus is to minimize the objective function J. The local minima always seems to be the bottleneck for most of the non-linear inversion problems. To overcome this constraint, we implemented the Genetic Algorithm (GA) method in the surface-wave inversion process using the tool available in a commercial software. GA is a derivative-free search approach towards global minima, for the solution of the inversion problem. Once an optimized model is achieved from GA, synthetic data is generated and is adaptively subtracted from the shot gather. As the 1D model obtained cannot represent any lateral variations of physical parameters in the earth, adaptive subtraction and GA are implemented several times to mitigate this limitation.

The proposed technique is applied to process a 2D shot gather data (Fig. 1-a) accessed from the SEG wiki Open data set collection of oz Yilmaz-40 shots. In this data, ground roll is masking the reflection events in the shot gather. After implementation of the proposed technique, it is observed that the ground roll is efficiently attenuated and reflections became more prominent by restoring the actual amplitudes, as shown in Fig. (1-b). The dispersion spectrum of both shot gathers is shown in Fig. 1 (c-d), it is observed that the ground roll present in the low-frequency zone (0-15 Hz) is attenuated. The results of the study suggest that the proposed method is quite efficient for surface wave attenuation.

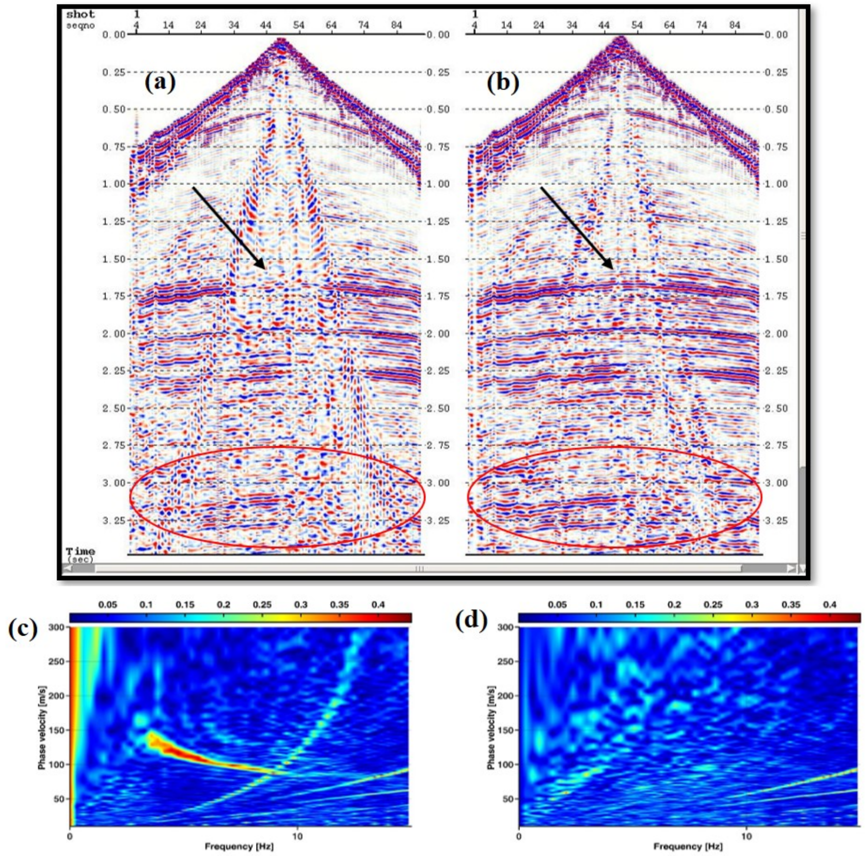


Figure 1. (a) shows a synthetic shot gather(oz25) with interference of ground rolls, (b) shot gather after ground roll attenuation, (c) shows the respective dispersion spectrum of shot gather ‘a’, (d) dispersion spectrum of shot gather ‘b’. It is seen that reflection events appear more prominently after the ground roll attenuation.

Ground Roll Attenuation of Seismic Data through Model-Based Inversion: A Synthetic study

OSPA

Shaik Nasif Ahmed *[1,2], Alok Kumar Routa [1], Nimisha Vedanti [1,2]

1 CSIR-National Geophysical Research Institute, Hyderabad-500007, India
2 Academy of Scientific and Innovative Research (AcSIR), Ghaziabad-201002, India

12th December 2022
AGU FALL MEETING

SCIENCE LEADS THE FUTURE

GROUND ROLL

- *Low frequency*
- *High amplitude*
- *Low velocities*

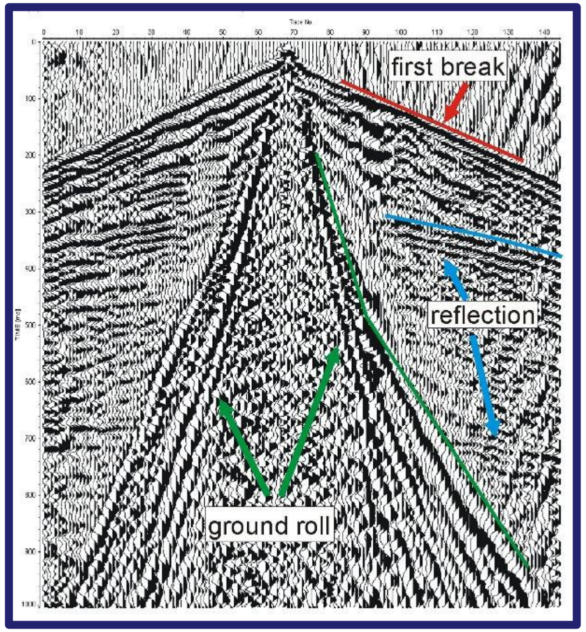


Figure1. Different events observed in seismic data (http://www.geofact.de/?page_id=1809&language=en)

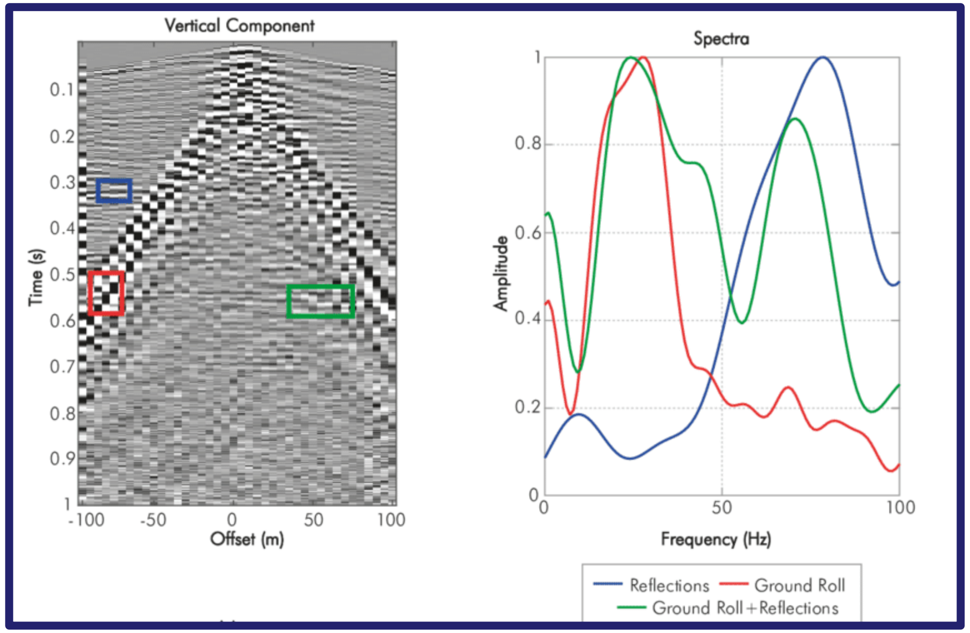


Image Courtesy: Galvis et al. (2016)

SCIENCE LEADS THE FUTURE

GROUND ROLL ATTENUATION

Modeling

Thickness
Density
Vp
Vs
Qp
Qs

Synthetic Ground Roll

Adaptive Subtraction

Inversion

Genetic Algorithm

Optimal Earth model (GR)

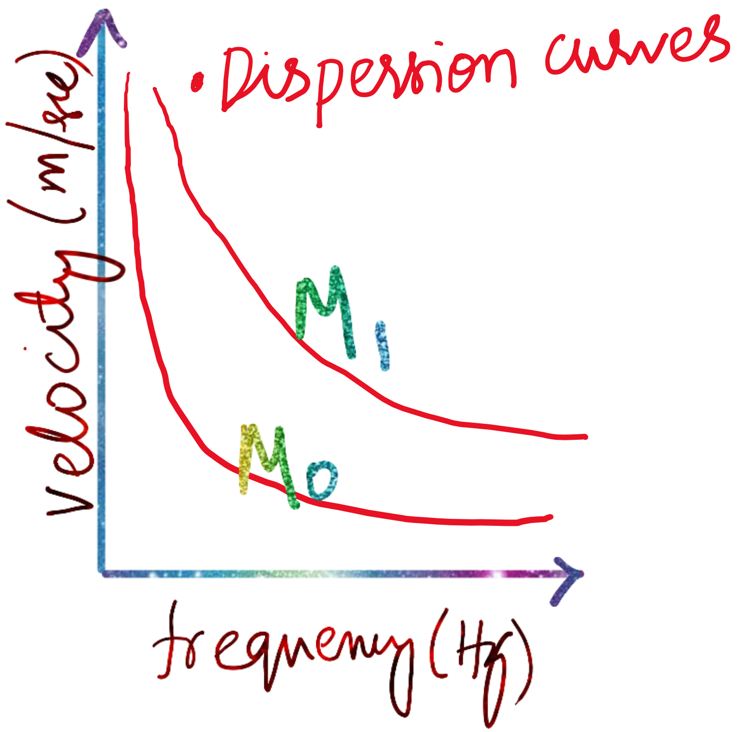
GROUND ROLL ATTENUATION

- Model ⟶ Synthetic Ground Roll
- Dispersion spectrum through Linear Radon Transformation

$$u(p,\tau) = \int_{-\infty}^{+\infty} d(x, t = \tau + px)\,dx$$

$\boldsymbol{d(x,t)}$ is the Shot Gather

u (p,τ)is the slant-stack transform with horizontal slowness (or ray parameter) p and intercept time τ.



Mis-fit

$$J(m) = \sqrt{\sum_{i=1}^{n_f}\sum_{j=1}^{n_v}\frac{(s_{ij} - o_{ij})^2}{n_f n_v}}$$

- S is the dispersion spectrum of the synthetic data generated from the model
- O is the dispersion spectrum of shot gather
- n_f, n_v are the number of sampling points along the frequency and Phase Velocity axis

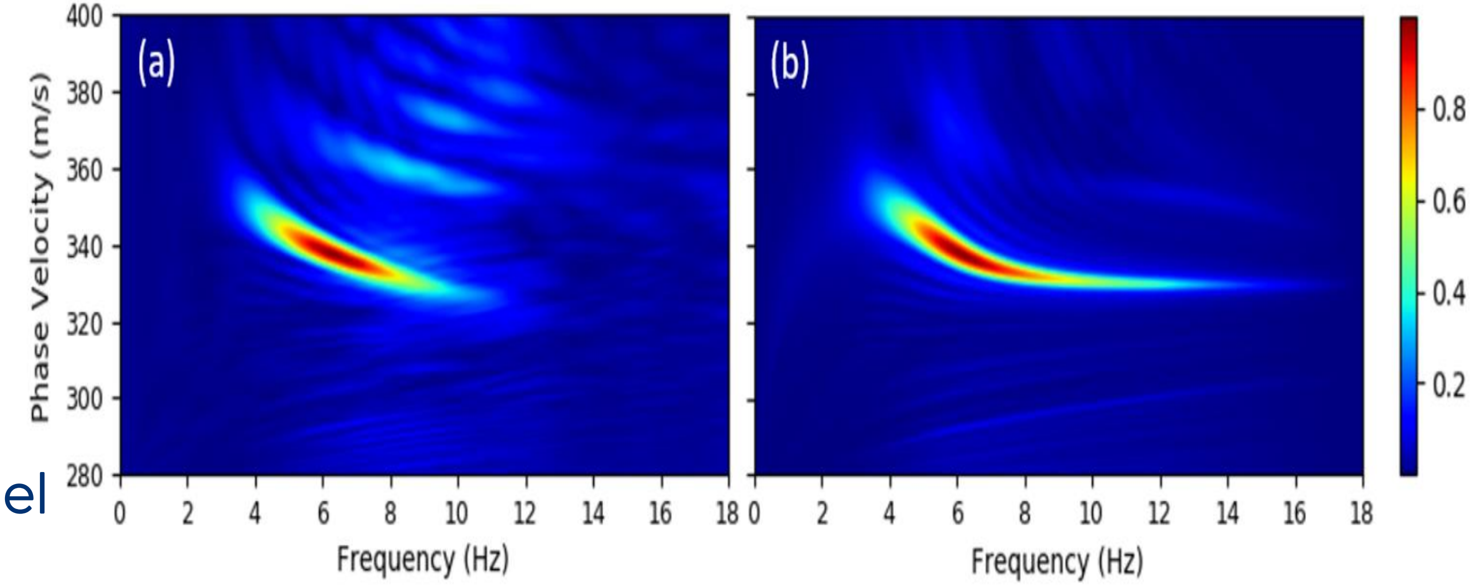
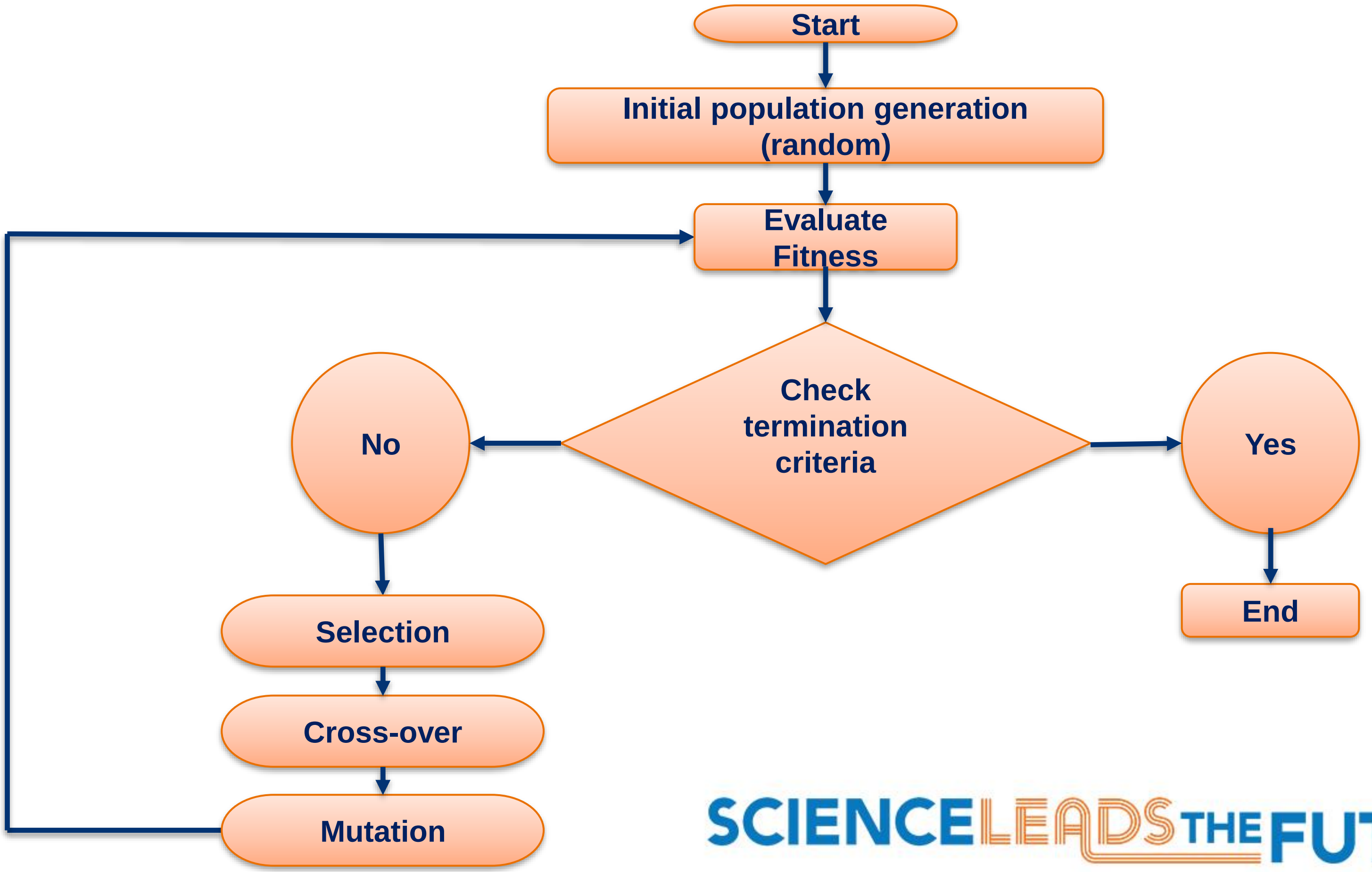


Figure 2.0 Dispersion spectra obtained from seismic(a) and synthetic (b) data. Image Courtesy: Jianyong Bai and Orhan Yilmaz (2020, SEG International Exposition and 90th Annual Meeting)

INVERSION: optimization problem

- Minimize J(m)
- Non-Linear Problem
  Multiple Local
  Minima
- Genetic Algorithm
- Linearized
  optimization
- Multi-Scale
  technique

Genetic Algorithm workflow



OZ-25 Dataset: A case study

Typical dataset for GR attenuation study:

1. Large Amount of GR
2. Primary reflections are covered by coherent GR
3. Variable amplitude of reflections in the whole gather

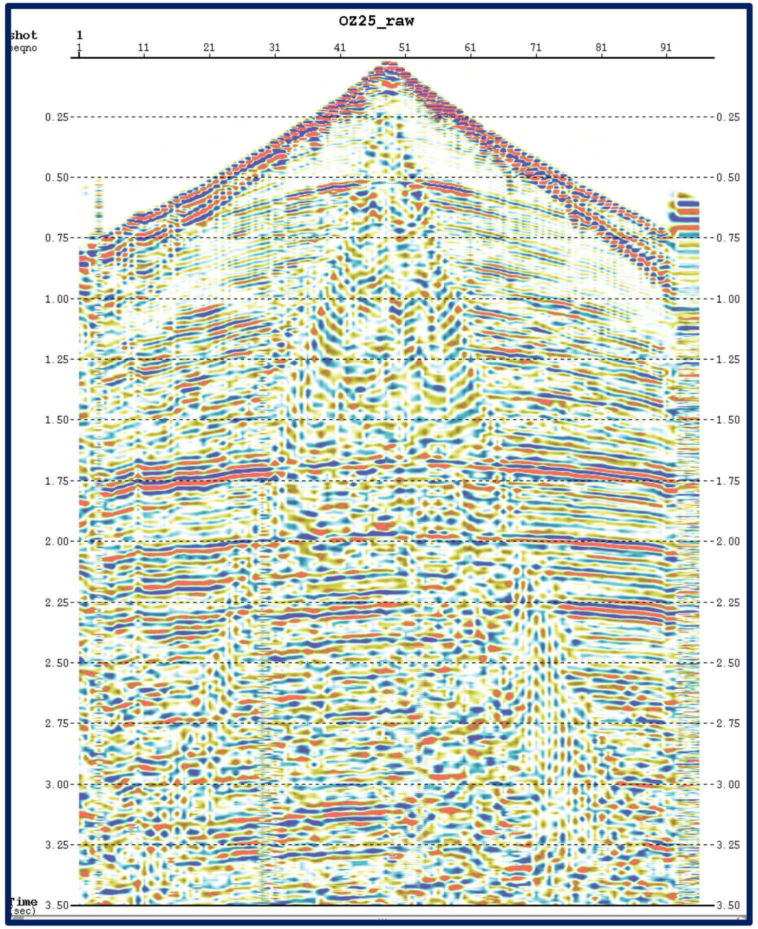


Figure 3.0:Raw OZ-25 field data (SEG Open data)

SCIENCE LEADS THE FUTURE

OZ-25 Dataset: A case study

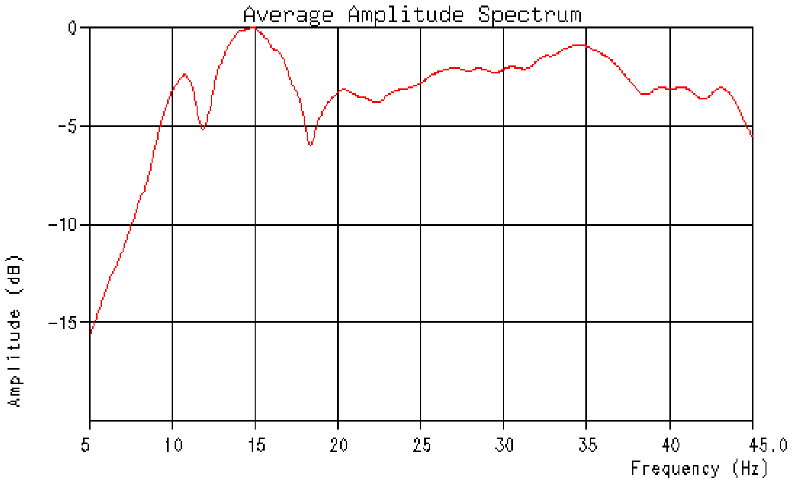


Fig. 4.0: Plot suggesting low-frequency dominancy(GR)

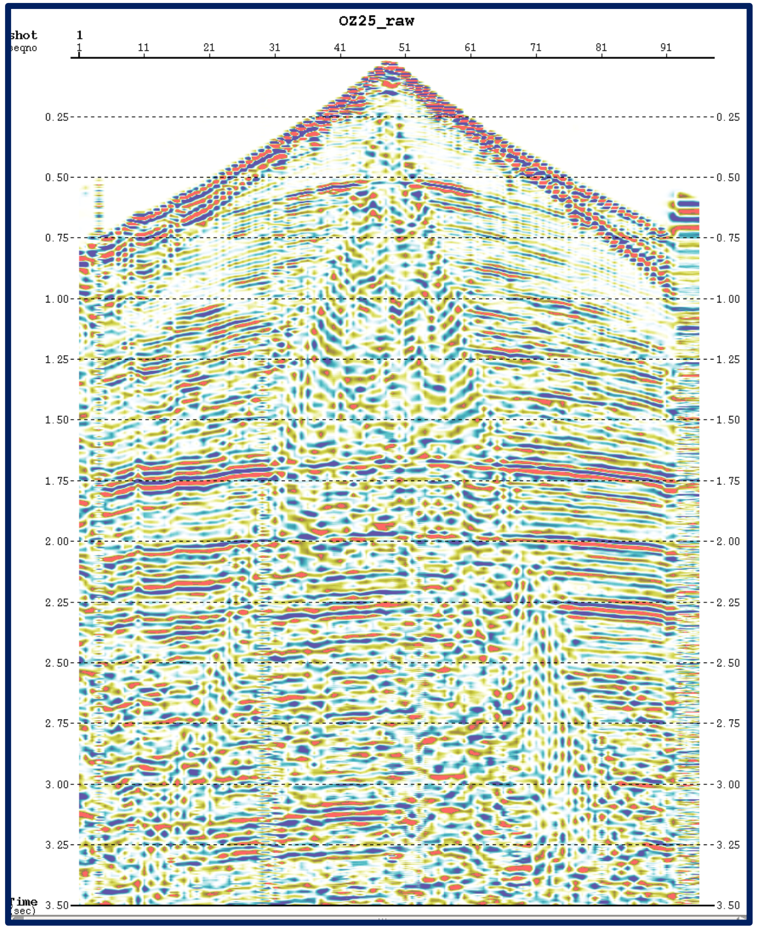
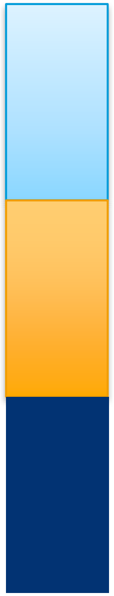


Figure 3.0:Raw OZ-25 field data (SEG Open data)

Model:
Fmax: 15 Hz



Vmin=10m/s , Vmax =200m/s
Hmin =3m, Hmax = 1000m

Vmin=100m/s , Vmax =250m/s
Hmin =3m, Hmax = 200m

Vmin=100m/s , Vmax =300m/s
Hmin =3m, Hmax = infinite

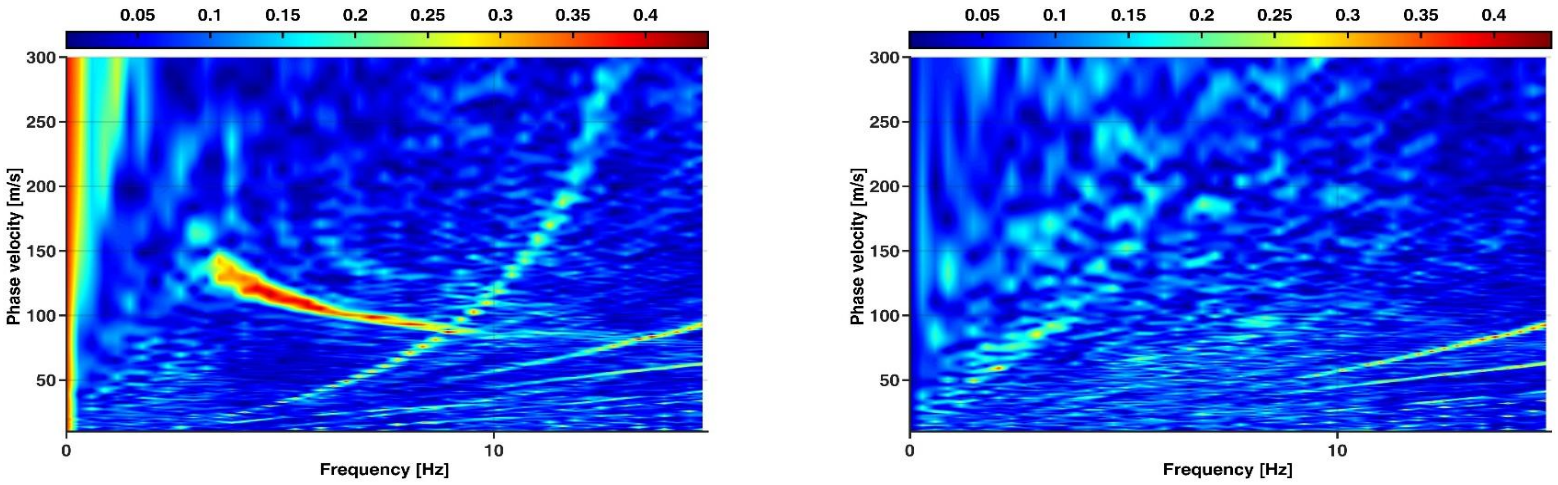


Fig. 5.0: *Dispersion Spectra of the raw Shot gather(left), Dispersion spectra after adaptive subtraction (right)*

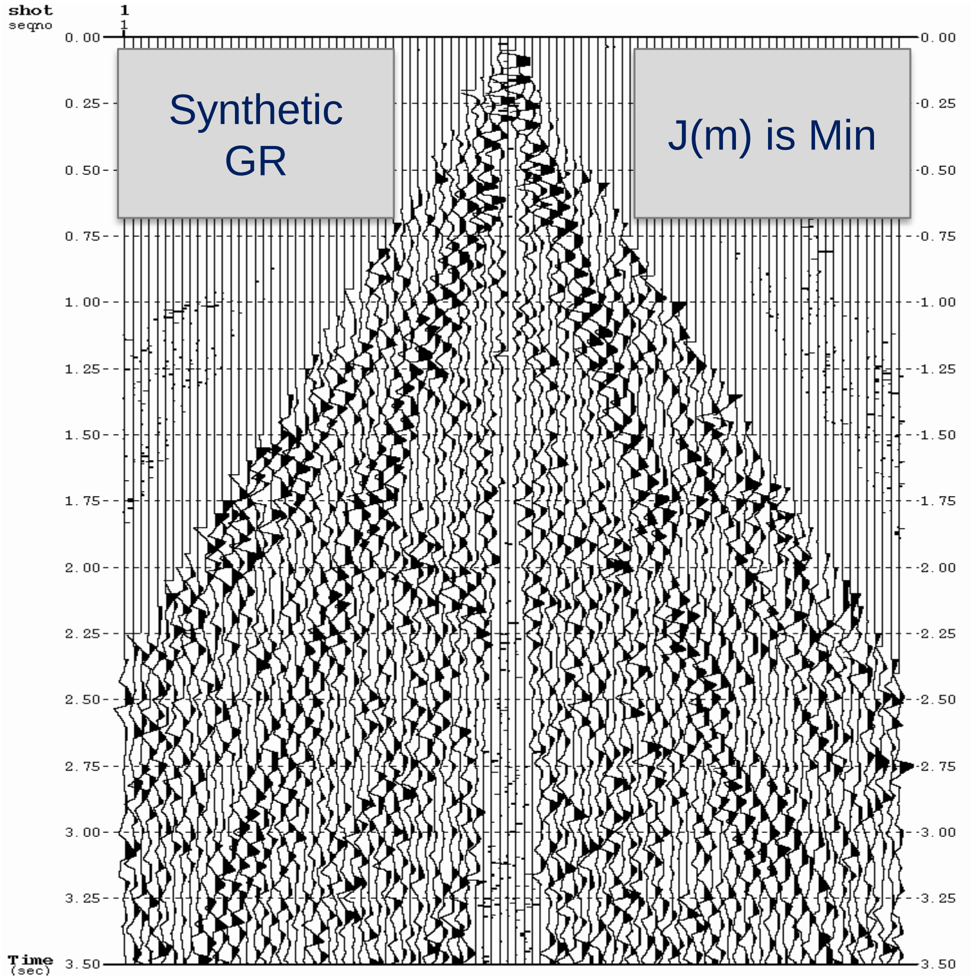
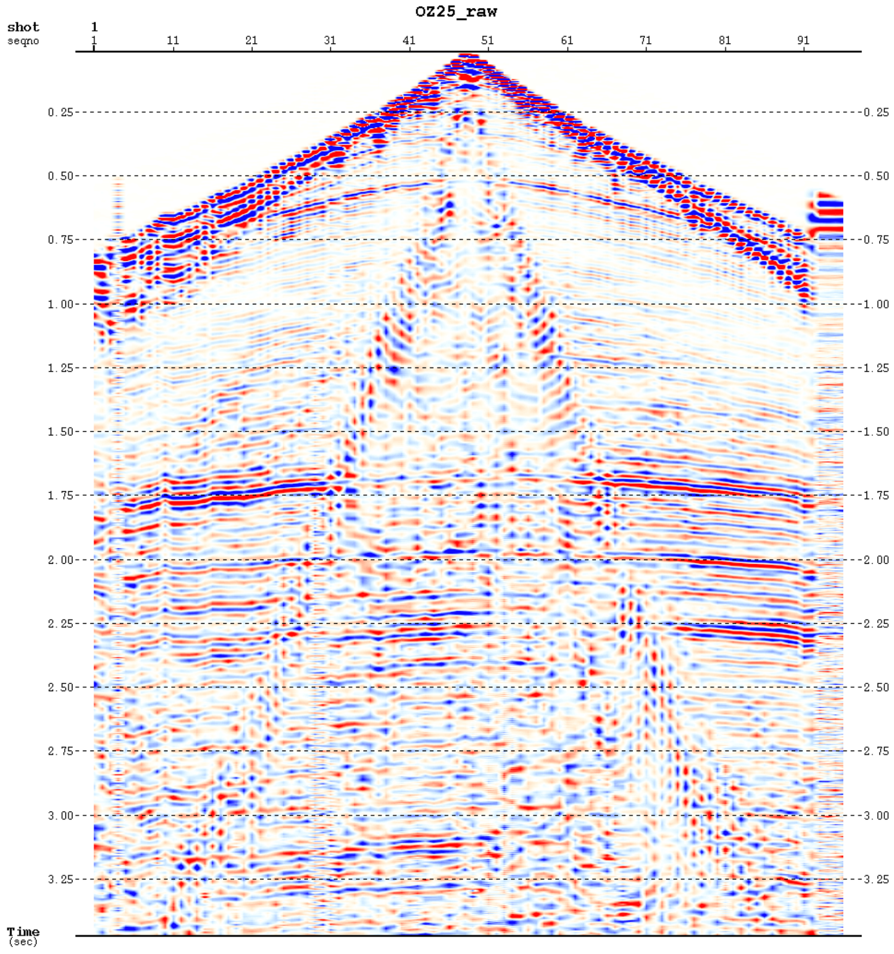
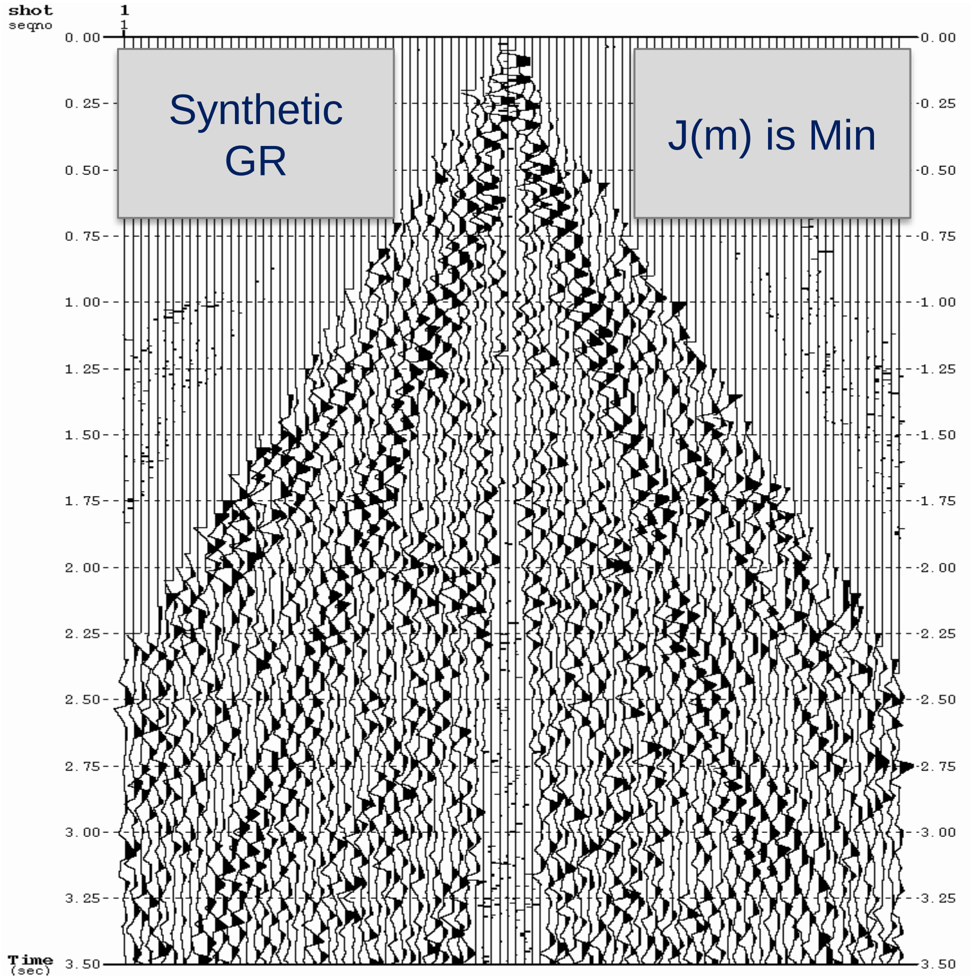


Figure 6.0: Synthetic GR generated from optimized Earth Model

Raw Data





GR Attenuated Data

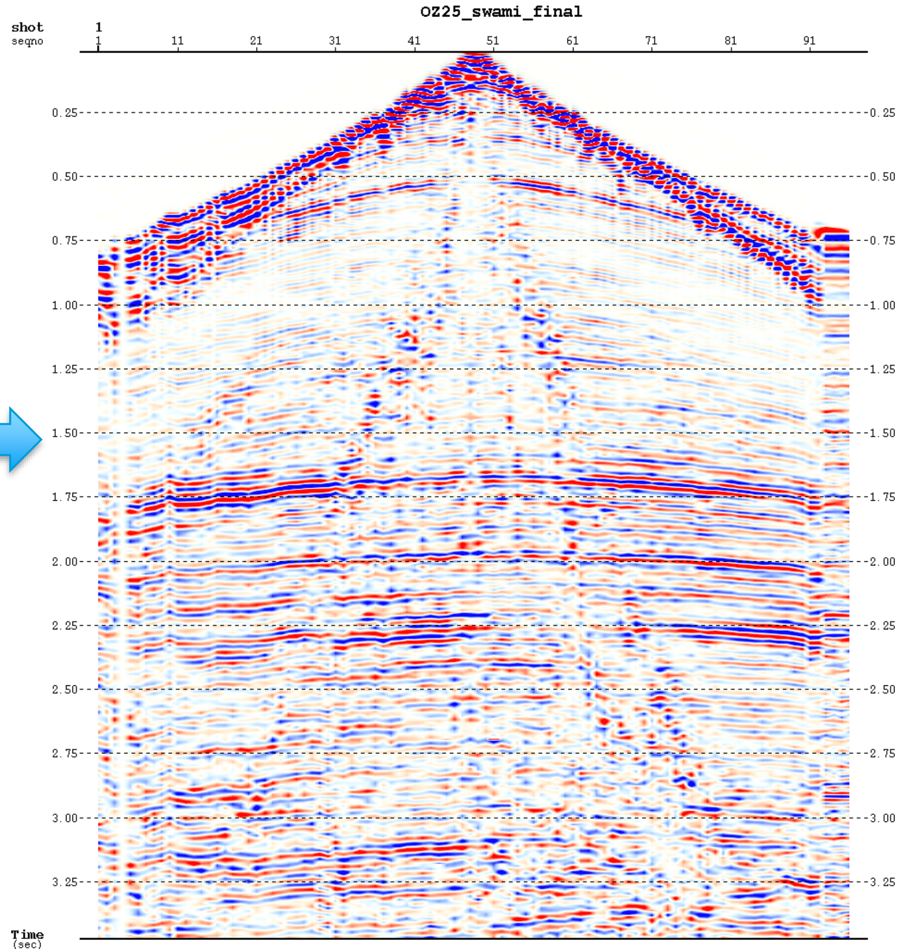
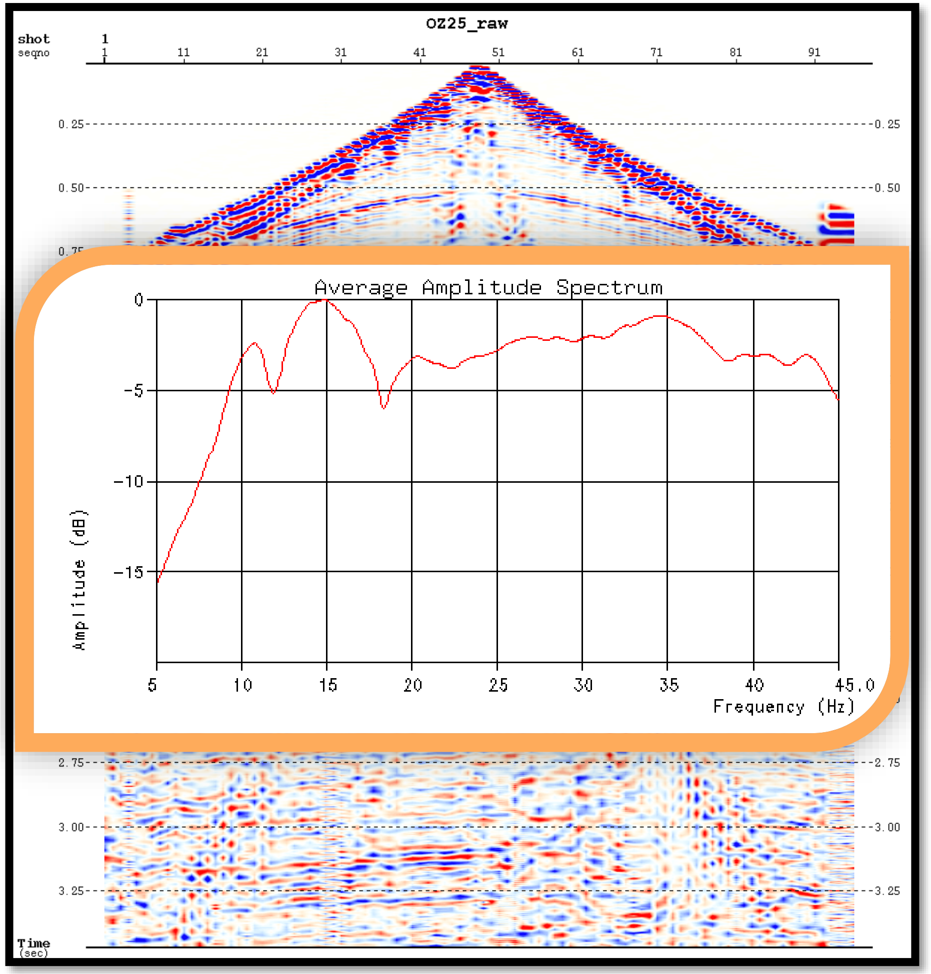
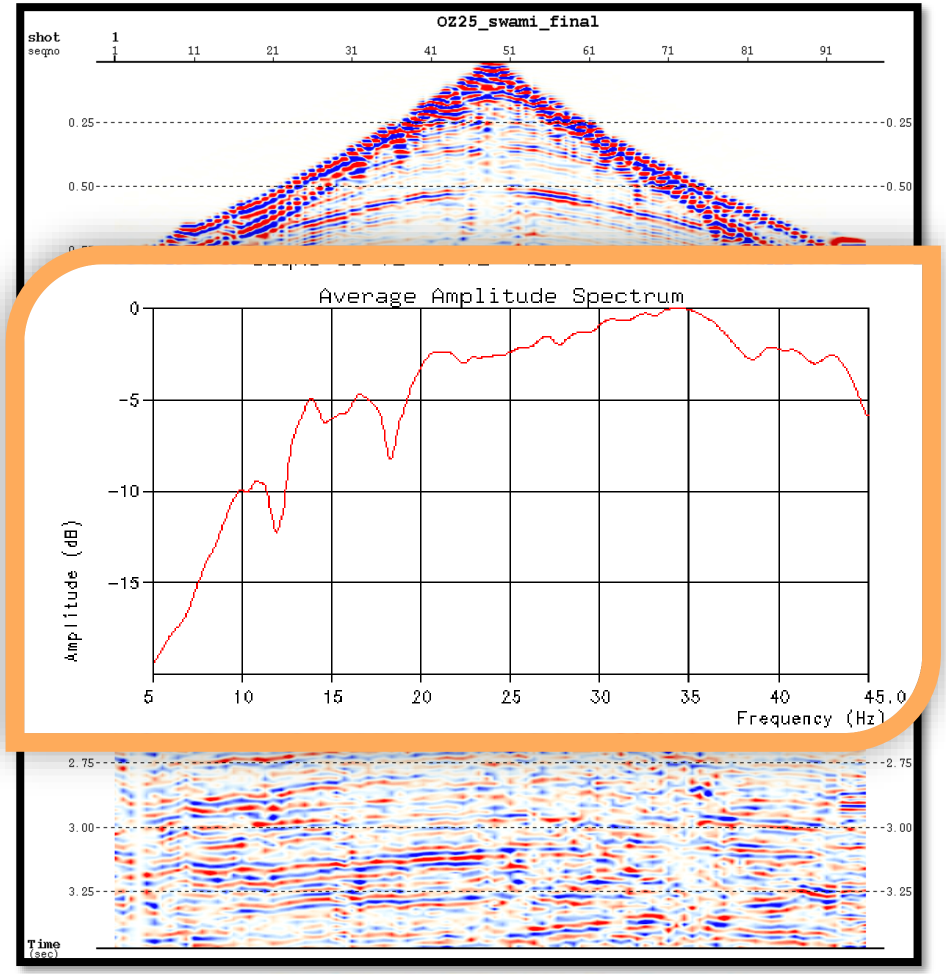


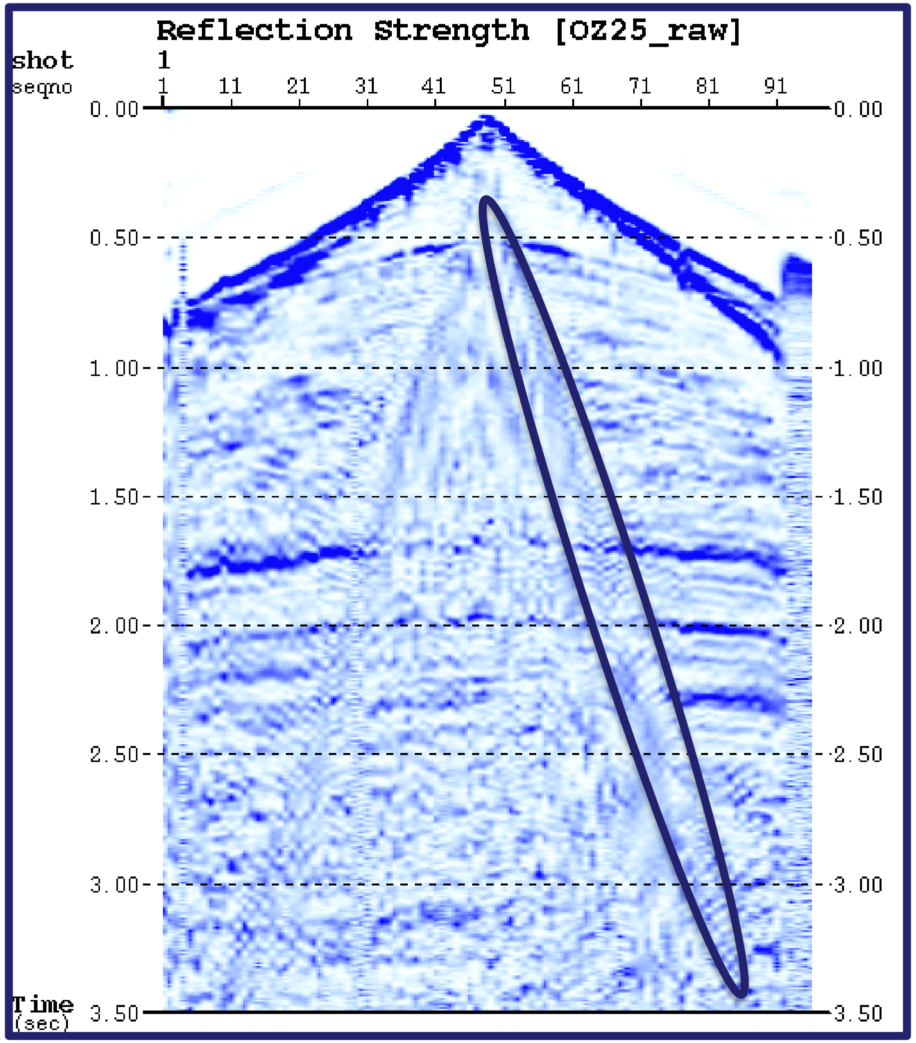
Figure 6.0: Synthetic GR generated from optimized Earth Model

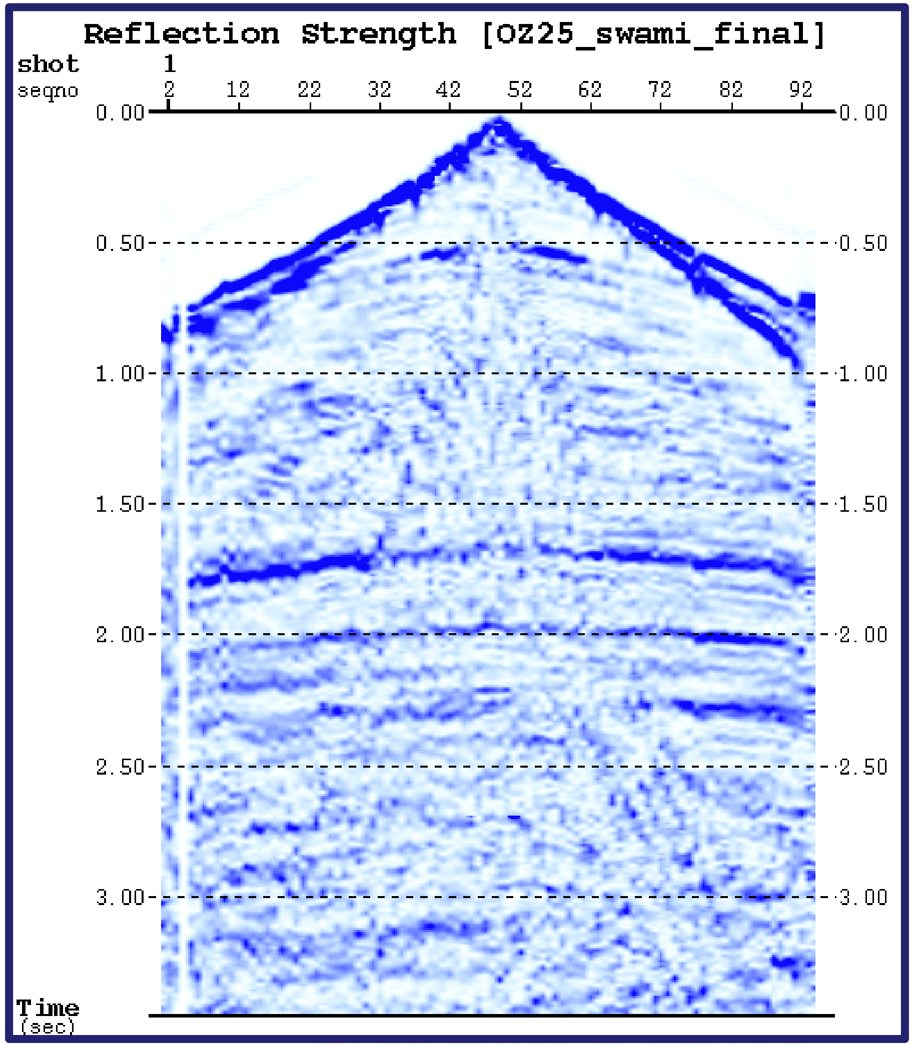
AGU FALL MEETING





SCIENCE LEADS THE FUTURE

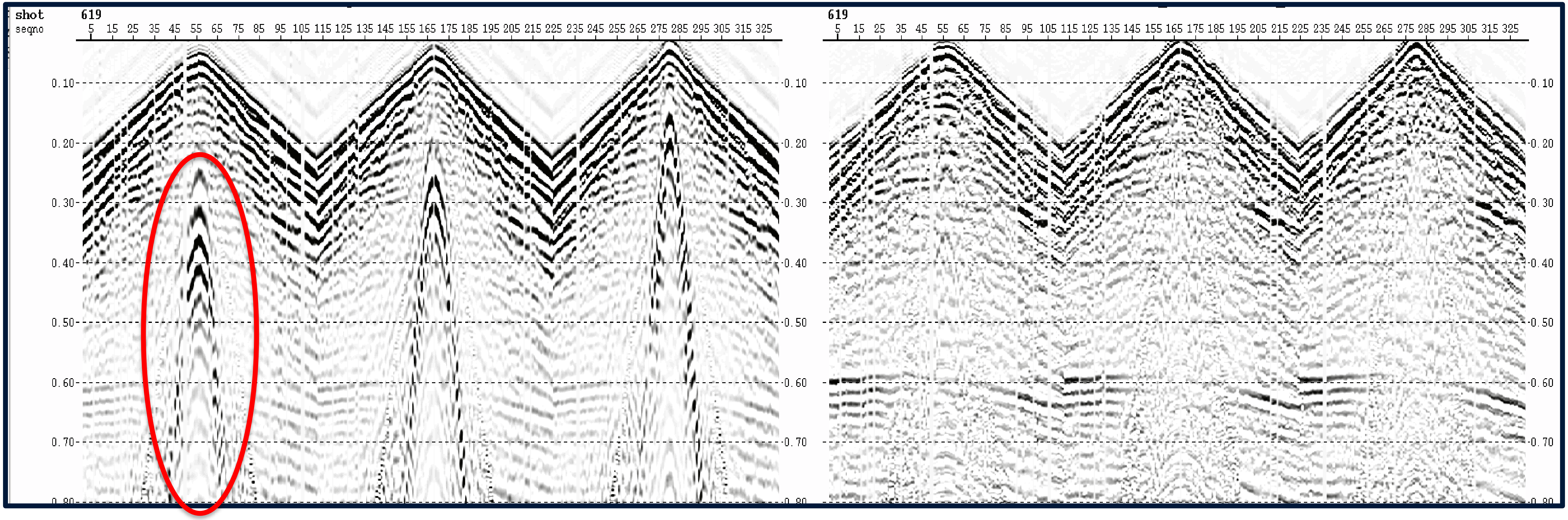




SCIENCE LEADS THE FUTURE

AGU FALL MEETING

3D shot gather of an Indian coal field



SCIENCE LEADS THE FUTURE

References:

- Aki, K. and Richards, P. [1980] *Quantitative Seismology: Theory and Methods*. W. H. Freeman.
- Bai, J. and Yilmaz, O., 2018, June. Model-based surface wave analysis and attenuation. In *80th EAGE Conference and Exhibition 2018* (Vol. 2018, No. 1, pp. 1-5). European Association of Geoscientists & Engineers.
- Chen*, Y., Jiao, S., Gan, S. and Yang, W., 2015. Ground rolls attenuation using bandlimited signal-and-noise orthogonalization-the OZ-25 dataset case study. In *SEG Technical Program Expanded Abstracts 2015* (pp. 4745-4749). Society of Exploration Geophysicists.
- Dou, S. and Ajo-Franklin, J.B., 2014. Full-wavefield inversion of surface waves for mapping embedded low-velocity zones in permafrost. *Geophysics*, *79*(6), pp.EN107-EN124.
- Luo, Y., Xia, J., Miller, R.D., Xu, Y., Liu, J. and Liu, Q., 2008. Rayleigh-wave dispersive energy imaging using a high-resolution linear Radon transform. *Pure and Applied Geophysics*, *165*(5), pp.903-922.
- Nelder, J.A. and Mead, R., 1965. A simplex method for function minimization. *The computer journal*, *7*(4), pp.308-313.
- Niño-Niño, C.A., Agudelo-Zambrano, W.M., Serrano-Luna, J.O., Sierra, D.A. and Sánchez-Galvis, I.J., 2016. SVD polarization filter taking into account the planarity of ground roll energy. *CT&F Ciencia, Tecnología y Futuro*, *6*(3), pp.5-24.
- Whitley, D. [1994] A genetic algorithm tutorial. *Statistics and Computing*, 65–85.
- http://www.geofact.de/?page_id=1809&language=en

AGU
ADVANCING EARTH
AND SPACE SCIENCE

राष्ट्रीय भूभौतिकीय अनुसंधान संस्थान, भारत
NGRI (CSIR) INDIA

DST@ 1971-2021
विज्ञान एवं प्रौद्योगिकी विभाग
DEPARTMENT OF
SCIENCE & TECHNOLOGY

Paradigm®

OSPA

MATLAB®