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Insights into basalt seismic attenuation in the Paraná basin from synthetic seismic experiments

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Summary

Seismic data on regions with thick basalt layers (Serra Geral Gp) at Paraná Basin clearly show severe high-frequency attenuation at reflections from sub-basalt interfaces. This work aims to analyze the basalt attenuation using 1D velocity models from Paraná Basin well logs. Synthetic seismogram spectral analysis demonstrates that the peg-leg attenuative mechanism harms the high-frequency energy of sub-basalt events.

Introduction

Volcanic rocks from the Serra Geral Gp at Paraná Basin are stratified, with sub-horizontal vesicular low-velocity zones parallel to massive basalt thicker layers. The strong impedance contrast inside Serra Geral can cause a severe attenuation of high frequencies, harming sub-basalt imaging. As discussed by Maresh *et al.* (2006) and Ziolkowski & Fokkema (1986), basalt layering can provoke several peg-leg multiples that engulf part of the downgoing wavefield, removing the high-frequency energy of the signal.

Ziolkowski *et al*. (2003) show in their study of the basalt north of Shetland that scattering can be significantly reduced for frequencies below 30 Hz. Their numerical experiments using different frequencies demonstrate that reflections of sub-basalt events are more visible when low frequency is employed. De Souza (1982) also showed that basalt is almost transparent for frequencies below 40 Hz in his study of the Paraná Basin.

This study aims to investigate and analyze how the basalt layering harms the frequency energy content of sub-basalt reflection, using Paraná Basin well logs to build realistic 1D velocity models. Here, we analyze the peg-leg multiple attenuation mechanism in the sub-basalt events.

Method

To evaluate the basalt attenuation due to the stratification layers, we follow the strategy based on the work of Maresh *et al* (2006), which is described as:

- The compressional wave velocity model is built from Paraná Basin sonic logs. We use Gardner's relation for the density, $\rho = 0.33V_p^{0.25}$.
- Set both source and receiver at the model surface.
- Solve wave propagation and calculate the synthetic seismograms. As we are only interested in the reflection of sub-basalt layers, we isolate those events by taking the difference between two synthetic seismograms: one calculated by considering the whole well log model, and the other by considering only the basalt layers. The acoustic wave equation is solved using a staggered-grid finite difference scheme with second- and fourth-order approximations of time and space derivatives, respectively.
- After calculating the synthetic seismogram, we perform its spectral analysis, including a comparison with the source spectra.

Examples

For the spectral analysis of the basalt attenuation, we select sonic logs from the following wells: 1-BB-1-PR, 2-CS-1-PR, 1-GP-1-PR, and 1-PH-1-PR (ANP/REATE, 2021). Figure 1 shows (a) V_P from sonic logs and (b) their geographical position. We also indicate in (a) the main reflector as the basalt bottom, which is the interface between Serra Geral basalts and Botucatu Fm sandstones. We adopted a vertical sampling of 2.5 m to ensure a good representation of the layered basalt in the velocity models. We used a minimum-phase Orsmby wavelet with frequency band = {2, 8, 72, 96 Hz} as source.

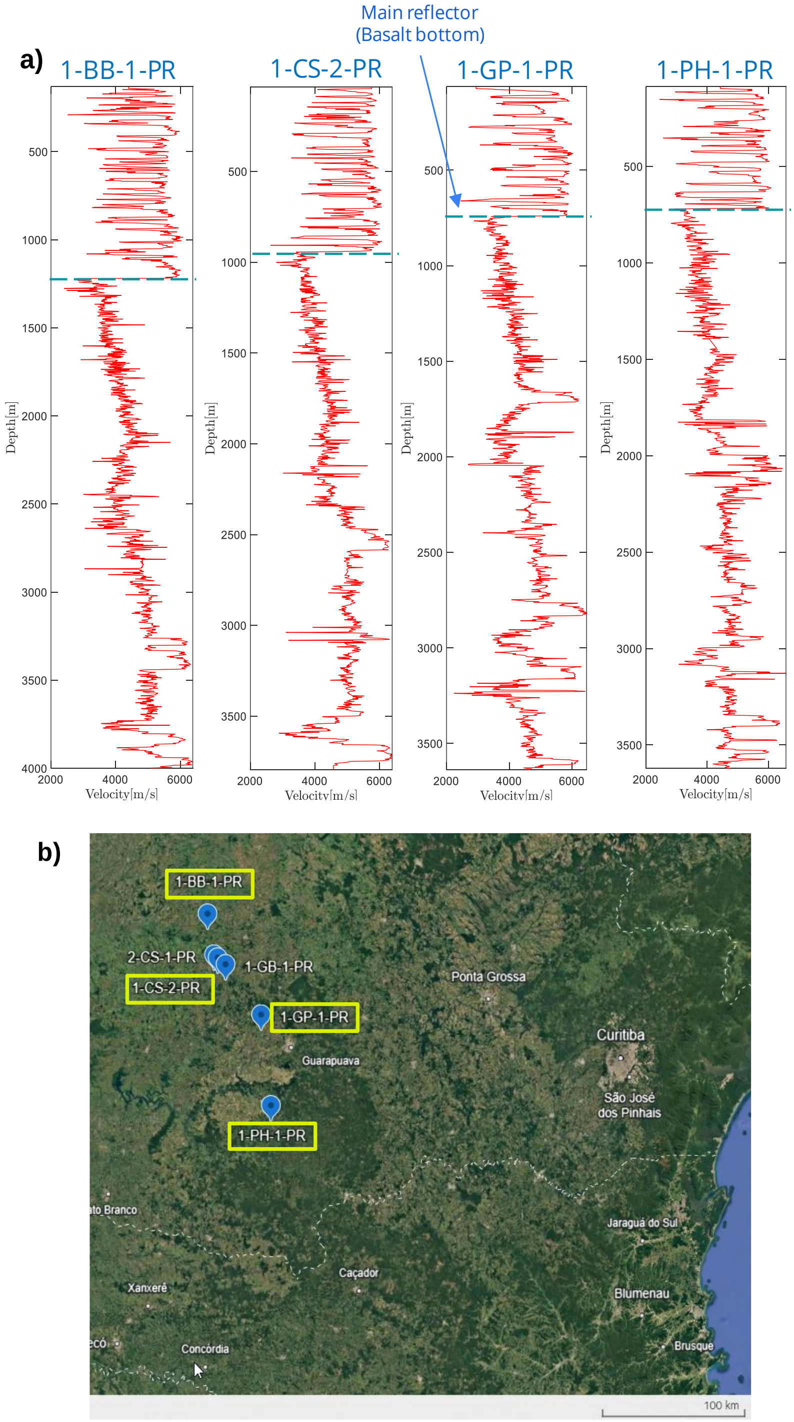

Figure 1: (a) Velocity models built from sonic log. The dashed line indicates the main reflector (basalt bottom) of interest. (edited from ANP/REATE, 2021) (b) Geographical location of the analyzed wells.

Figure 2 shows synthetic traces considering seismic events from the whole well log 1-BB-1-PR extension (in red) and sub-basalt events only (in blue).

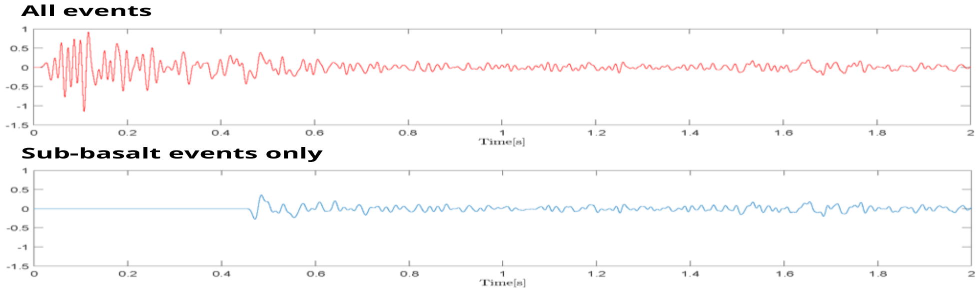

Figure 2: Synthetic seismic traces for well 1-BB-1-PR (see Figure 1). In red, seismic events from the whole well log; in blue, sub-basalt events only.

Results

Figure 3 depicts the spectrum of the whole seismic trace (see Figure 2), and sub-basalt events only for all wells. A comparison of sub-basalt events (in blue) and whole trace events (in red) shows that the high-frequency energy is associated with stratified basalt events. The entire trace spectrum is similar to the source spectra. On the other hand, sub-basalt events concentrate their frequency content at low frequencies (8-30 Hz). This indicates how the basalt stratification and its peg-leg multiples harm the high-frequency content of the sub-basalt events. We can see that the model related to well-log 1-PH-1-PR is the most harmful due to the multiple attenuative mechanisms.

Conclusions

The high-frequency content of sub-basalt events in synthetic data built from Paraná Basin sonic logs is very harmed by the peg-leg multiples of the layered basalt. This partly clarifies the high- and low-frequency observed in the basalt and sub-basalt events, respectively, found in real data. Additionally, the spectral analysis demonstrates that the frequency content of the sub-basalt events starts to decay around 30 Hz.

Acknowledgments

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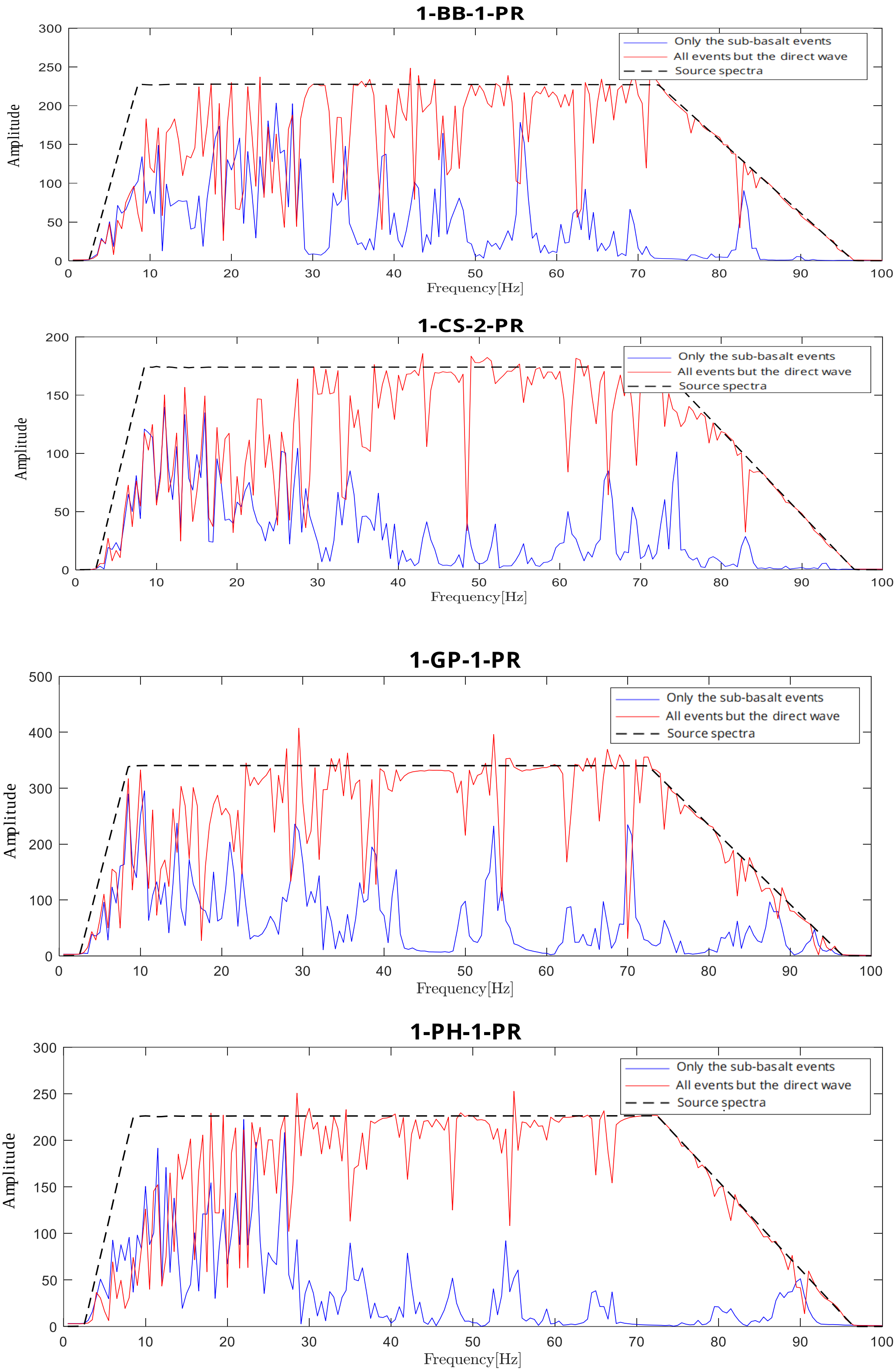

Figure 3: Amplitude spectra of reflection events from the models in Figure 1. Strong amplitude decrease occurs around 30 Hz for sub-basalt (blue line), indicating that all energy is related to intra-basalt events (reflections and internal multiples, red line) above this frequency.