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# Near-surface Seismic Acquisition in the Resende Basin - Comparison between 4.5 Hz and 14 Hz Geophones

**Roberto Miyamoto Pessoa (GISIS/UFF), Marco Cetale (GISIS/UFF), Guilherme Lenz (GISIS/UFF), Felipe Timóteo (GISIS/UFF), Alexandre Motta Borges.**

# Near-surface Seismic Acquisition in the Resende Basin - Comparison between 4.5 Hz and 14 Hz Geophones



## Abstract Summary

One of the challenges in land seismic surveys is the suppression of noise produced by the environment and also by internal and external interference from the instrument, noise that may be present until the final processing of the seismic data due to the natural sensitivity of the geophones and their cutoff frequencies. In this seismic survey, we acquired two 2D seismic lines to compare the performance of vertical geophones with natural frequencies of 4.5 Hz and 14 Hz under identical conditions. The seismograms analyses, amplitude spectrum and FK in the quality control of the raw data indicates and suggests better data resolution for shallow targets when using geophones with a higher natural cutoff frequency.

## Introduction

Near-surface onshore seismic acquisition is important tool in geological characterization, hydrocarbon exploration, geotechnical investitagtion, and enviromental related applicaton such as monitoring onshore carbon capture and storage (CCS).

However, land data acquired at shallow depths are highly susceptible to environmental and instrumental noise, making sensor selection an important aspect of seismic survey design.

Geophones are essential components in the seismic acquisition systems, they transform the mechanical energy of ground particle vibration into broad bandwidth electric signals which have sufficient signal-to-noise ratio.Their natural frequency defines the lower limit of recording bandwidth,and thus influences the investigation depth, vertical resolution, and sensitivity to low-frequency noise. Despite their widespread use, few studies have directly compared geophones with different natural frequencies in identical field conditions according to Li et al. (2009) .

As part of the geophysical and geological structural research project on the Continental Rift of Southeastern Brazil (CRSB), we carried out a 2D near-surface seismic survey in the Resende Basin by the Seismic Imaging and Inversion Group (GISIS) team at the Universidade Federal Fluminense (UFF). In this work, we present a comparative analysis of two commonly used geophone types, comparing their performance under identical acquisition conditions and focusing on differences in signal fidelity, resolution, and signal-to-noise ratio.

## Methodology

To evaluate the influence of geophone natural frequency on near-surface seismic data, we acquired two seismic lines (Figure 1) in the Resende Basin under identical acquisition conditions. In this comparison, the vertical geophones have natural frequencies of 4.5 Hz and 14 Hz (Figure 1(c)). A fixed-spread, shot roll-along acquisition scheme was adopted, in which 72 vertical geophones were planted at 8-meter intervals and remained fixed while the source was activated sequentially at each receiver station. A total of 89 shot points were registered. The Table 1 summarizes the main survey parameters.

The seismic source used was a Propelled Energy Generator (PEG-40), which drops a 40 kg weight onto a metal plate to generate impulsive energy, Figure 1(b). We stack five shots in each source position to create a seismogram and enhance the signal-to-noise ratio. The system recorded with a sampling interval of 250 $\mu$s and a recording time of 1.6 seconds per shot. Data quality control was performed in real-time, shot by shot. The team monitored the seismograms for signal integrity, environmental and instrumental noise, proper sensor coupling, tilt, and electrical contact.

Table 1: Main survey parameters.

| | | | |
|---|---|---|---|
| Active geophones | 72 | Source type | PEG 40 |
| Sampling rate | 250 µs | Stacking per shot | 5 |
| Number of shots | 89 | Geophone 1 | 4,5 Hz |
| Station interval | 8 m | Geophone 2 | 14 Hz |
| Shot interval | 8 m | Seismograph | GEODE |
| Recording time | 1,6 s | Spread type | Roll-along |

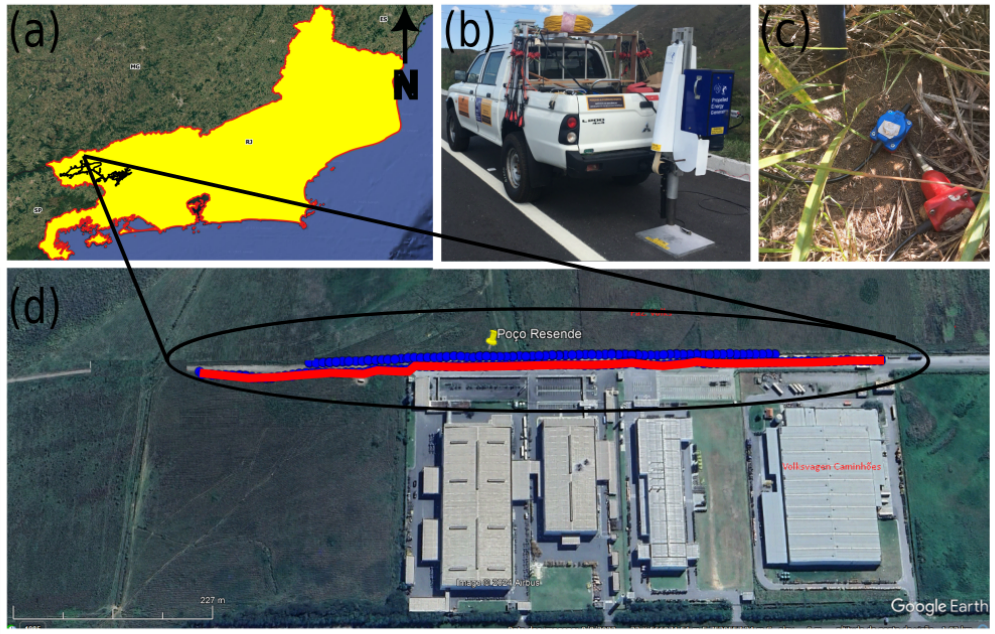


Figure 1: Seismic acquisition survey. (a) Map of Rio de Janeiro State, southeastern Brazil, highlighting the Resende Basin. (b) Accelerated drop-weight source system. (c) Geophones with natural frequencies of 4.5 Hz and 14 Hz. (d) Source (red line) and receiver (blue dots) positions over the road.

## Results

The comparison between the raw shot gathers is presented in Figures 2(a)-(d), where the seismograms using end-on spread are depicted in Figures 2(a) and (b) while the seismograms slip spread are presented in Figure (2(c) and (d)). The seismograms with a natural frequency of 4.5 Hz (Figure (2(a) and (c))) exhibit more ambient noise than the seismogram with a natural frequency of 14 Hz (Figure (2(b) and (d))).

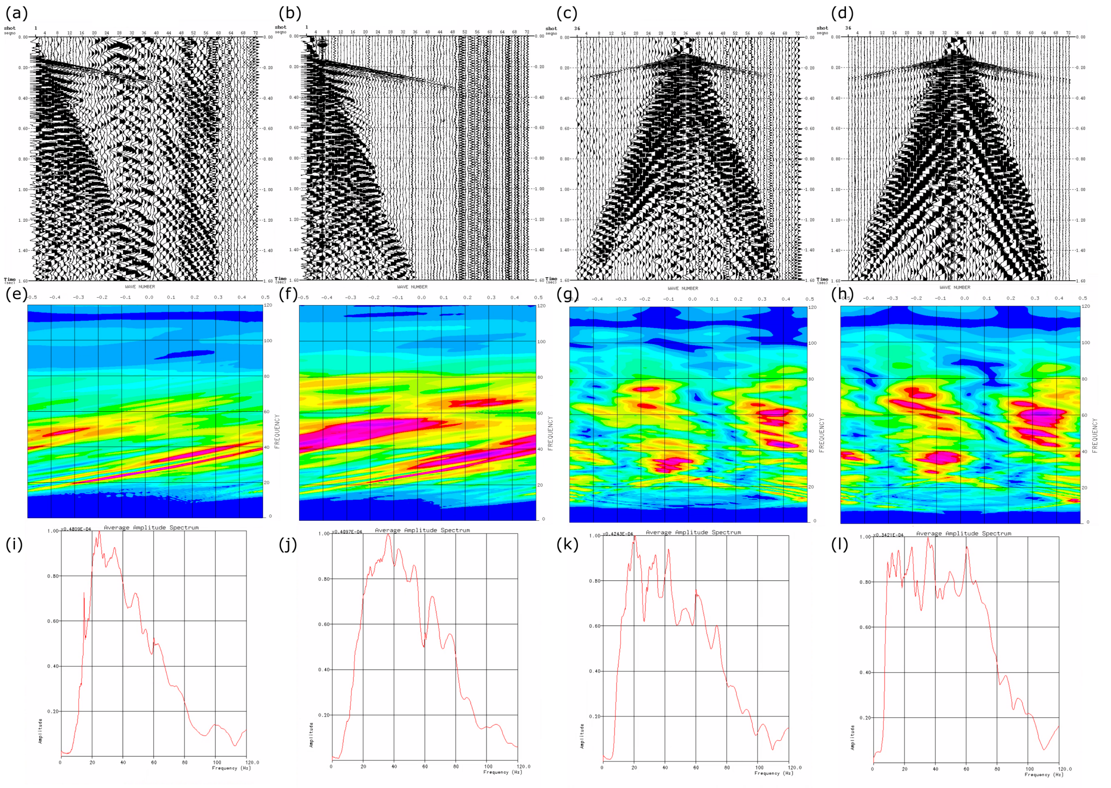


Figure 2: Comparison of seismic data acquired with end-on and slip spreads using geophones with natural frequencies of 4.5 Hz (a,c,e,g,i,k) and 15 Hz (b,d,f,h,j,l) . (a–d) Time-domain seismograms. (e–h) Seismograms in the frequency–wavenumber (F–K) domain. (i–l) Amplitude spectra.

Analysis of the seismic data in the F–K domain (Figures 2(e) and (g)) reveals the presence of aliasing effects caused by the ground roll in the end-on spread, which are also present, though less pronounced, in the slip spread data. Geophones with a natural frequency of 14 Hz exhibited higher amplitude energy distributed across the F–K domain than those with a 4.5 Hz natural frequency. Besides that, the amplitude spectra (Figures 2(i) and (l)) indicate that lower frequencies are more attenuated in the seismograms recorded with the 14 Hz geophones, which helps reduce the contribution of high-amplitude noise.

In the brute stack comparison (Figure 3), generated using a constant velocity model and without any seismic processing, only shallow reflectors are visible. Besides that, the ambient noise dominates the brute stacks. However, the section acquired with 4.5 Hz geophones reveals deeper events, particularly on the left side of the seismic section. Subsequent seismic processing tests indicate that the 14 Hz geophones produce a higher-quality stacked section, as they are less affected by low-frequency noise. These results helped to improve quality control in the field, minimizing noise analysis and time spend when checking the seismograms, contributing to the dynamics of the survey.

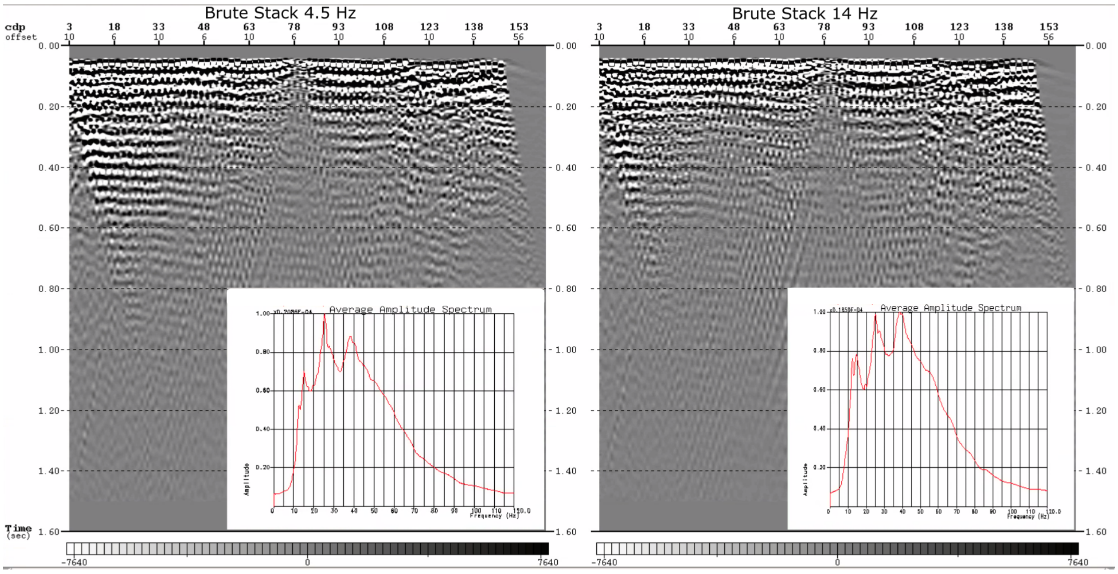


Figure 3: *Brute stack* and Spectral Analysis . In left side 4.5 Hz and in right side 14 Hz.

## Conclusions

The choice between 4.5 Hz and 14 Hz geophones should consider the study objective, geological environment, and source frequency range. For sources like the one used in this survey, with a frequency range from 10 to 250 Hz, combining the 14 Hz geophones offers better resolution for surveys of relatively shallow targets,making them suitable for research in shallow onshore basins. On the other hand, 4.5 Hz geophones may provide better resolution for registering low-amplitude signals and improving the signal-to-noise ratio in deeper targets. For future work, comparisons and analyses with higher cut-off frequency geophones and tests with different seismic line geometries.

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## References

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