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Shallow structure of the Pitanga Dome, through seismological methods, preliminary results.

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Abstract

Urban seismology is an emerging field of research, with both seismological and engineering objectives. Studies focus on shallow Earth structures, with shallow depth, and their importance in mineral exploration and seismic damage assessment. New low-cost autonomous sensors allow short-term deployments to investigate these structures. This study aims to characterize the geological structure of the Pitanga Dome region, using seismological methods such as Environmental Noise Tomography and spatial autocorrelation. The network of short-period stations will help to estimate ground motions in the area. The work also reviews previous studies on the subject, highlighting the applicability of HVSR methods.

Introduction

Urban seismology has become a recent field of research, for both seismological purposes, such as obtaining better microzonation maps in highly populated areas, and for engineering purposes, such as monitoring traffic or surveying historic buildings. The study of Earth's structures in seismology is still restricted to the depths, with estimates considered "shallow" limited to the upper crust and/or Moho (Fianco et al., 2019, Pavão et al. 2013, França & Assumpção, 2004) and with few estimates of "superficial" depths, for example 200 to 3000 m. Getting to know the shallow structures is important in mineral exploration and also in terms of comprehending seismic damage. For example, sedimentary layers amplify the effect of noise, concentrating and "trapping" energy. To determine seismic amplification due to basins, it is important to use accurate information about the structure in ground motion estimates. Seismic source studies with a dense station network would provide the highest resolution. Currently, with new low-cost, autonomous sensors (known as nodes), short-term deployments in accessible environments present an innovative way to image Earth's shallow structures. With the aim of better understanding the shallow structure of a partially known region that still has questions to be answered, we therefore chose the Pitanga Dome region for the study, which is delimited by a structural high (Dourado et al. 2013),along with other structural features located in the geomorphological unit called Peripheral Depression. A network consisting of approximately 12 short-period seismometers was installed to record for approximately 1 hour and 3 more to record for approximately 2 months, in addition to 2 refraction seismic surveys along the dome region. This study aims to characterize the local geological structure and its impact through the application of seismological and seismic methods, including the Horizontal to Vertical Spectral Ratio, Refraction Seismic, in addition to other methods where possible.

Method and/or Theory

The H/V spectral ratio technique is an experimental technique for evaluating some sedimentary soil characteristics. Due to its low cost for survey and analysis, the H/V technique has been frequently adopted in seismic microzonation investigations. Although the H/V technique alone is not enough to characterize the complexity of site effects and, in particular, the absolute values of seismic amplification, the method has proven useful for estimating the fundamental period of sedimentary soils and has been used for various purposes, such as studies of sedimentary basins, faults, cavities and finally to estimate the fundamental frequency of buildings. Recordings and analyses must be carried out with caution. The main recommended application of the H/V technique in microzonation studies is to map the fundamental period of the site and help constrain the geological and geotechnical models used for numerical calculations. Additionally, this technique is also useful in calibrating site response studies at specific locations. More details of the technique can be found in Yuncha (2000). Using these techniques, it is expected that the structural model for the Pitanga Dome will be obtained and complemented with crustal and upper mantle estimates, thus establishing important information for both tectonic knowledge and mineral exploration. Another line of questioning about intracratonic basins is to know the potential of these basins, as an energy channel for a rupture, for example. We also use the Seismic refraction methods that it emerged in the first decades of the 20th century and began to be used in shallower studies, especially in the area of Engineering geophysics, and in studies of deeper crustal geophysics. With theoretical principles apparently more complex than those of reflection, refraction offers a simpler interpretation of seismograms based on the easier identification of the first arrival of the refracted wave. There are several techniques for interpreting shallow refraction seismic, which consider the first arrivals of waves as a principle. Examples of these techniques include Delay Time, developed by Gardner in 1939, the Hales technique in 1958, the Plus-Minus technique in 1959, and the GRM (Generalized Reciprocal Method), introduced by Palmer in 1980. More recently, tomographic techniques have been developed for shallow refraction seismic, also considering the propagation time of refractions. Usually, the use of these techniques involves the creation of an initial velocity model, where an algorithm that uses ray tracing iteratively calculates the times of the refracted waves, comparing them with the data observed in the field and repeating the process until the difference is adequate for the studies.

Results

H/V curves were made for the 12 seismometers, which recorded for one hour, in addition to the 3 temporary seismographic stations, as shown in the map in Figure 1. In the case of the stations, 1 hour with the least noise was selected for each station, from the approximate 2 months of recordings. In addition, 2 points were chosen to carry out refraction seismic surveys.

***Figure 1**: Map of all points where the HVSR was calculated and where all the seismic surveys were carried out. The 12 blue dots are the locations where measurements were taken for approximately 1 hour, the red dots represent the locations where temporary seismographic stations were installed for approximately 2 months and the green dots represent the locations where seismic tests were carried out.*

The curves were generated using the Geopsy software and the resonance frequency and amplitude values of the respective curve were returned from it. The values obtained are shown in the Figure 2.

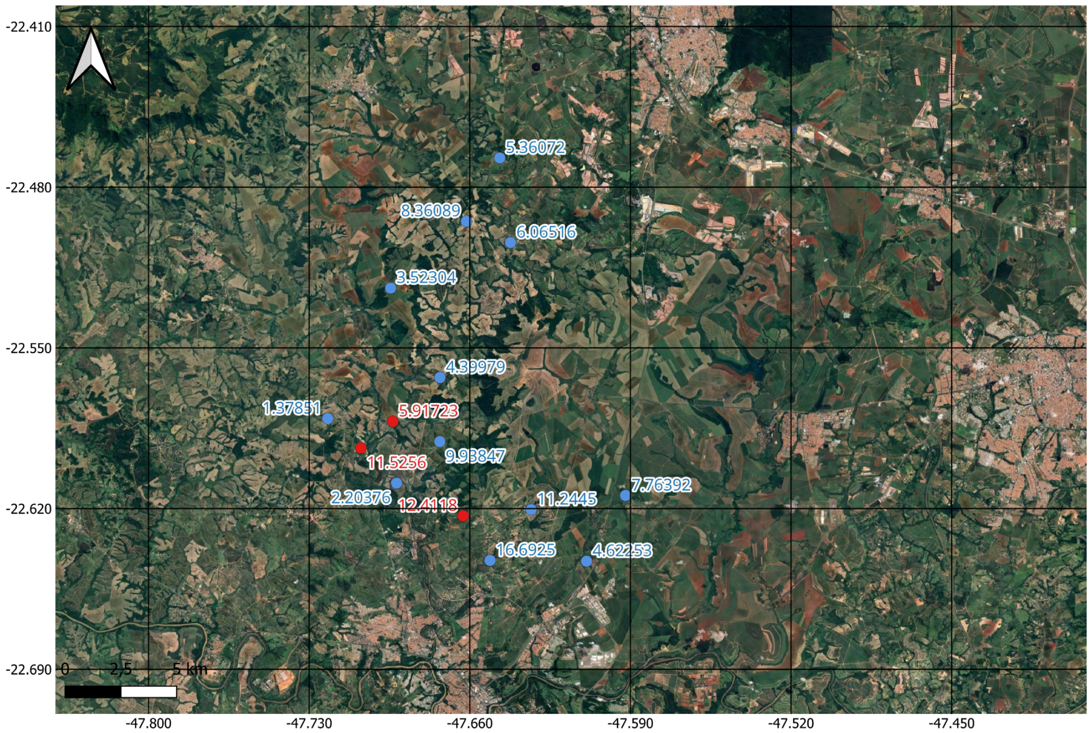

Figure 2: *Map of the values obtained for the resonance frequency for all the places where the HVSR surveys were carried out. The blue dots are the locations where measurements were taken for approximately 1 hour and the red dots represent the locations where temporary seismographic stations were installed for approximately 2 months and the green dots represent the locations.*

A refraction seismic interpretation was made at place “S1” on the map in Figure 2. In it, the propagation velocity of the first layer was found to be approximately 368 m/s, with a thickness of 1.30 m. For the second layer, the velocity found was approximately 719 m/s and its thickness varied between 3.39 and 5.51 meters, due to the irregularity of the interface below. The third layer had a velocity that varied between approximately 1522 to 1923 m/s with a thickness that varied between 5.4 to 13.3, also due to an irregular interface below. And below it there is a fourth layer with a propagation velocity of approximately 5327 m/s.

The interpretation was also made at point “S2” on the map in Figure 1. In it, the propagation velocity of the first layer was found to be approximately 588 m/s, with a thickness of 1.73 m. For the second layer, a propagation velocity of approximately 1722 m/s and a thickness ranging from 1.30 to 7.38 meters were found, with a tendency to thin in the higher coordinates. Below this interface, a third layer was found with a propagation velocity of approximately 2959 m/s.

Conclusions

The H/V survey shows a predominance of shallow structures, assuming an S wave velocity of 850 m/s, the maximum thickness obtained is about 150 m. The refraction seismic role was to link the first layers in the dome and presented results consistent with the results obtained by H/V. The eastern part of the dome is thicker than the other part. Next steps will be the inversion of the linked H/V, when possible at seismic velocities

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