GEOPHYSICAL SUBSOIL CHARACTERIZATION OF A HOUSING UNIT SHAKEN BY THE EARTHQUAKE OF SEPTEMBER 19, 2017 (MW 7.1)

Martín Cárdenas-Soto[1,1], Jesús Sánchez-González[2,2], Jose Antonio Martinez-Gonzalez[1,1], Gerardo Cifuentes-Nava[2,2], and David Escobedo Zenil[2,2]

[1]National Autonomous University of Mexico, Geophysical Engineering
[2]National Autonomous University of Mexico

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Abstract

September 19, 2017 earthquake considerably affected the southern area of Mexico City; specically, in the transition zone, some local subsidence problems were accentuated. This site is associated with a high geological hazard due to faults, cracks, subsidence, landslides, and collapses. The lesson learned from this earthquake showed that much remains to be known, and detailed characterization is needed to dene vulnerable sites that allow for reduction seismic-geological risk. This study used various geophysical methods to explore the subsoil of a housing unit south of Mexico City. The houses began having structural damage on the site, and the surface of the land presented cracks since the year 2012, problems that were magnied after the earthquake. We apply electrical tomography, seismic noise interferometry, and H/V methods. The results show the properties of the subsoil vary drastically both in the lateral direction and in-depth. In particular, it highlights the presence of a discontinuity that divides the area into two different structures. Our interpretations show that the observed damages are due to a series of conjugated events that accentuate differential subsidence: irregularity in subsoil structure and properties, local overexploitation of groundwater, and dynamic amplication effects that accelerate relative displacements during seismic motions.

Detecting Underground Mines by Seismic Noise Autocorrelation and Geophysical Methods

Cárdenas-Soto M., J. Sánchez-González, J. Martínez-González, G. Cifuentes-Nava and D. Escobedo-Zenil
School of Engineering, UNAM - Earth Sciences Engineering Division - Geophysical Department

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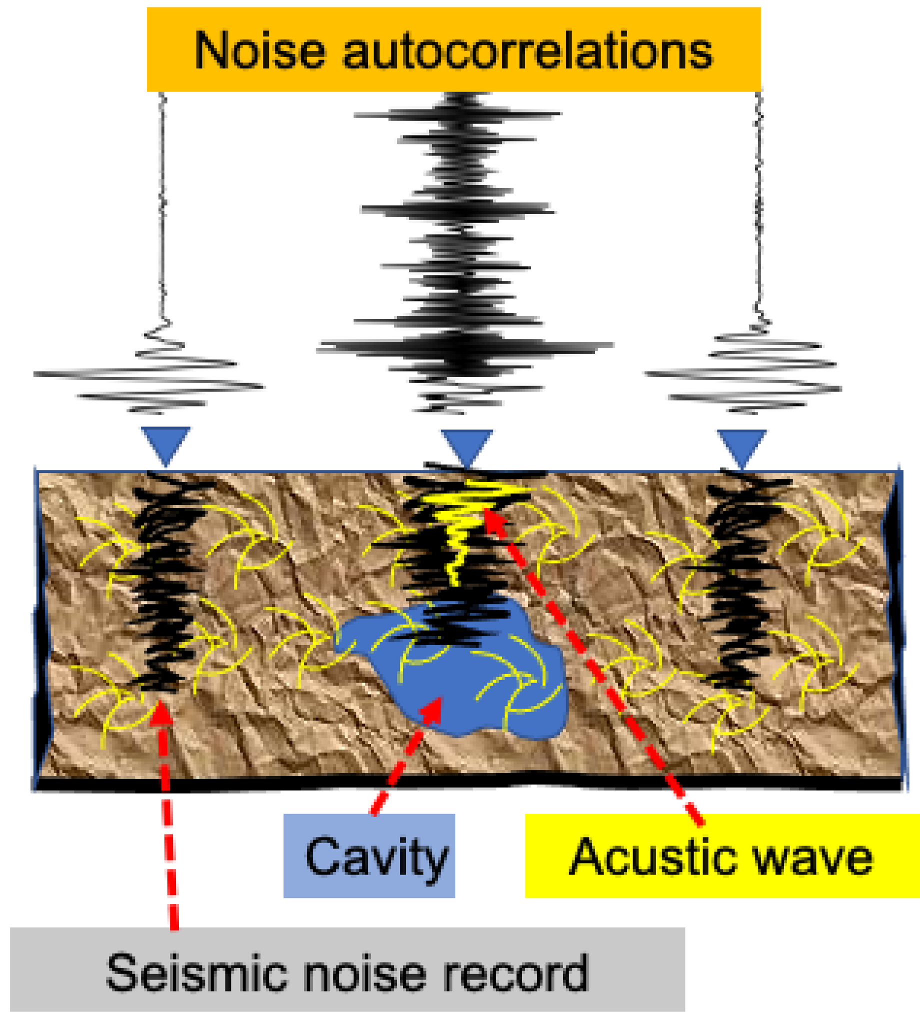
Problem Definition

Motivations: Mexico City is a densely populated city. Its western area is topographically abrupt, and the geological risk is increased because the subsoil structure is composed of vulcano-sedimentary materials, which were exploited economically in the mid-twentieth century, leaving a series of underground mines.

Goal: Use ambient seismic noise to capture the resonance produced by discontinuities in the subsoil. In special, we propose a fast and versatile method that detects the presence of abandoned mines and whose results can be compared with other geophysical methods.

Hypothesis

Main idea: We hypothesize that the seismic noise propagating between the surface and the cavity roof can generate a stationary acoustic wave (Fedin et al, 2020). Hence, the autocorrelation of noise can extract the response in reflection (Claerbout, 1968).



Data Acquisition

We collected electrical resistivity and seismic noise data in L-shaped arrays.

- An Iris instrument resistivimeter model Syscal Pro 48 Switch programmed in Wenner-Schlumberger mode was used in the ERT2D study.
- Ambient noise at 250 Hz sampling ratio was acquired using a Geometrix Geode seismograph with 24 - 4.5 Hz vertical geophones. The seismic record traces were increased by interpolating pairs of records to obtain 47 register points.
- Georadar data were acquired on one side of the array due to parked cars. ProEx System MALA GPR was used with a 100 MHz antenna.
- ERT data inversion was carried out using EarthImager2D software. GPR data processing was realized using GeoScanners GPRSoft software.

Results

ERT2D and GPR:

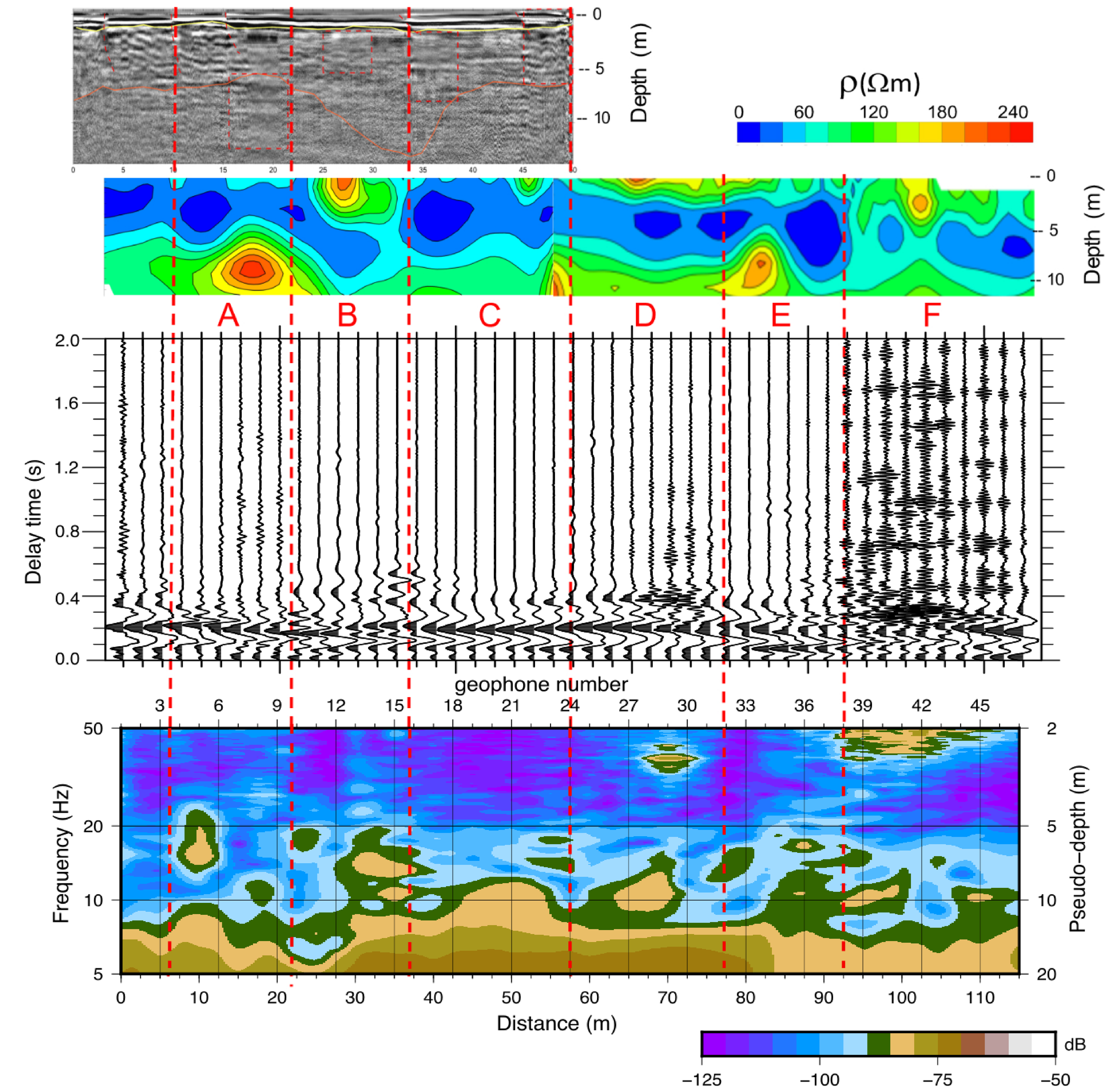
In the figure, we can see high resistivities close to the ground surface (zones B and F) that correspond to the presence of mines. At depths greater than 7 m, the resistive maxima in zones A and E are likely to represent a cavity. Throughout the section, there is a horizon of saturated materials. We can observe loss and distortion of the signal on the radargram due to a lack of lateral stratified continuity or high saturated materials.

Seismic Noise Autocorrelations:

We normalized the noise records (one-bit and spectral whitening), carried out autocorrelations every 8 s over 30 minutes, and calculated the Power Density Spectra (PDS). We observe the main correlation pulse (around 2 s) is almost constant except in that zones where superficial high resistivities values are present. Cavity presence could be associated in zones where the main pulse is distorted (zones A, B, E), or coda autocorrelation waveforms exhibit high-frequency vibrations (zones D, F).

The PDS image, as a function of the distance vs. frequency or pseudo-depth ($z=Vp/2f$; $Vp=400$ m/s obtained from refraction study), show C zone has fewer subsoil discontinuities; only high attenuation values (-125 dB) at frequencies higher than 20 Hz could be related to saturated materials. In zones B and F, the resonances at 15 and 45 Hz correspond to the cavity (high resistivities) observed in the ERT2D section.

The frequency of 10 Hz divides two zones. PDS values near -85 dB and below 10 Hz describe a lateral irregularity related to the high resistivities below 8 m depth. So, for frequencies higher than 10 Hz, the PDS values could correspond to subsoil alterations produced by anthropogenic activities.



Conclusions and Future Work

The seismic noise autocorrelations capture the resonance produced by an acoustic wave trapped between the roof cavity and the free ground surface. Direct and coda waves are altered by the presence of the cavity, the subsoil resonance, and saturated materials. The cavity effect appears for frequencies larger than 10 Hz. Pipes and drains systems also could be detected in frequencies more significant than 40 Hz. An L array also could be used to apply Ambient Noise Tomography (ANT, Cárdenas et al., 2020) to imaging the problematic zone and compare it with ER3D results. We are working on that.

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