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

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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.

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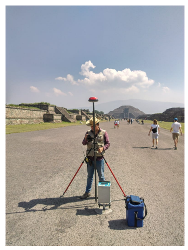
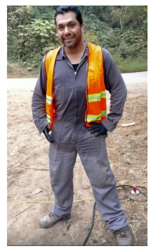
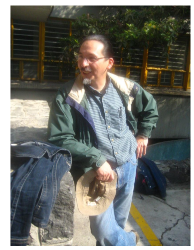


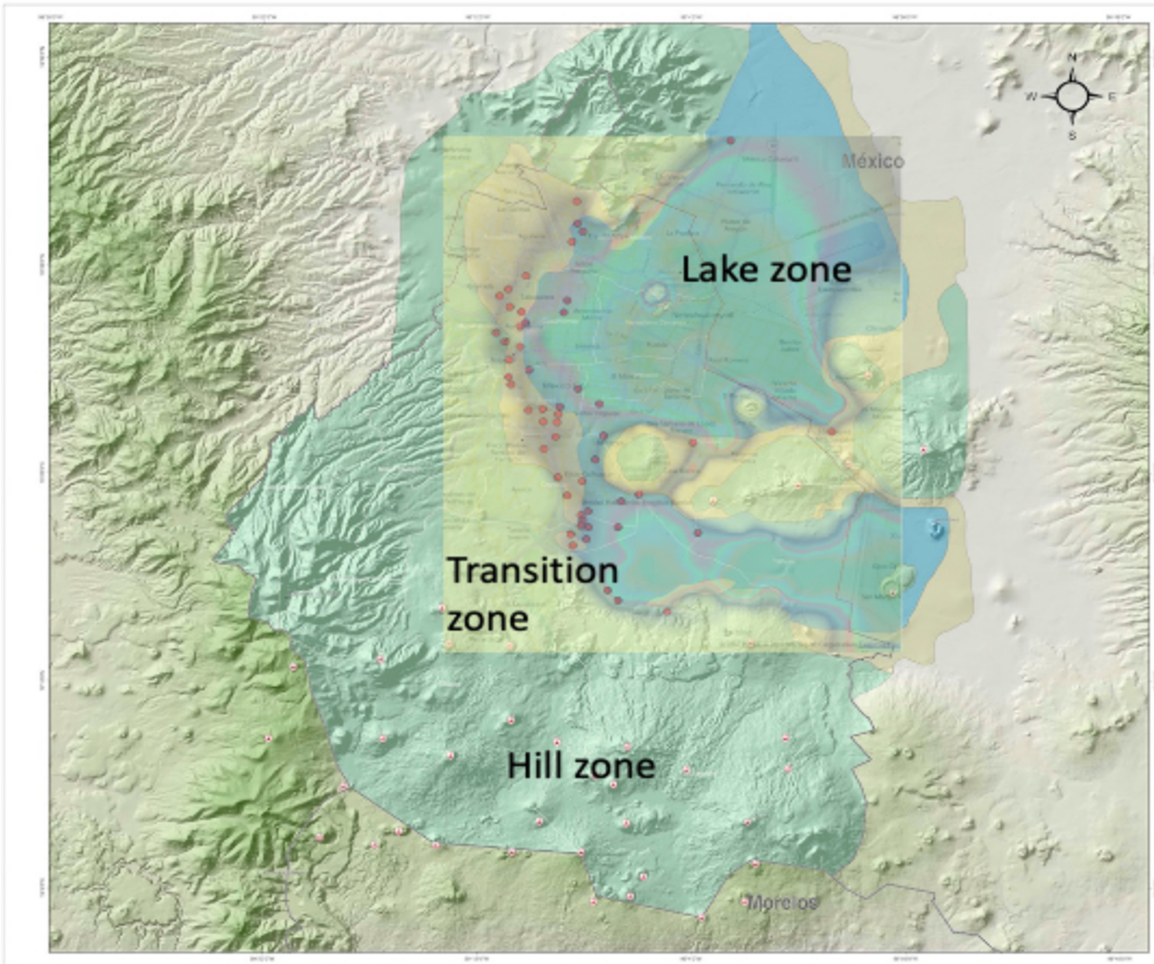




PRESENTED AT:

1. MOTIVATION AND AIM

During September earthquake 19, 2017 (Mw 7.1), many of the damaged buildings in Mexico city were located along a strip that includes the transition and the lake zone



It was a near epicenter (150 Km) that produced spectral accelerations at low periods (0.2-1.5 s). Most of the affected buildings had 3 to 7 levels.

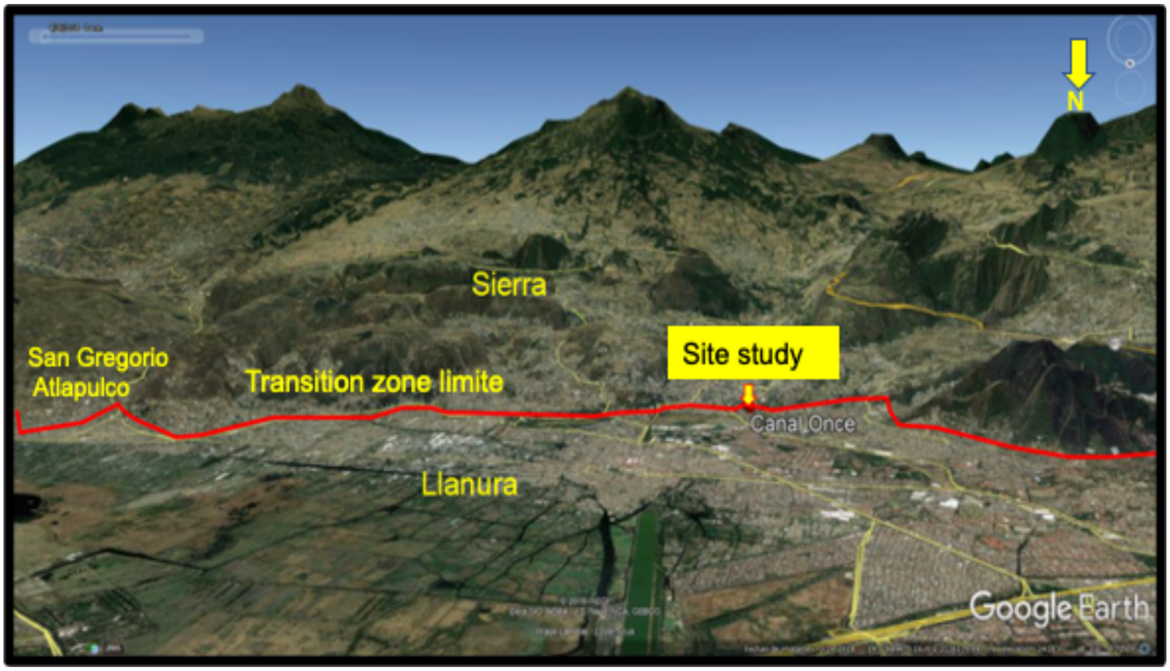
In many of the affected areas, there are no buildings. For example, in the town of San Gregorio Atlapulco, Xochimilco, some homes were damaged, and others were not. So, an important factor seems to be the complex geology of the subsoil.

Aim

Explore the subsoil of a housing unit in the transition zone to identify variations in subsoil properties that influence the seismic site response

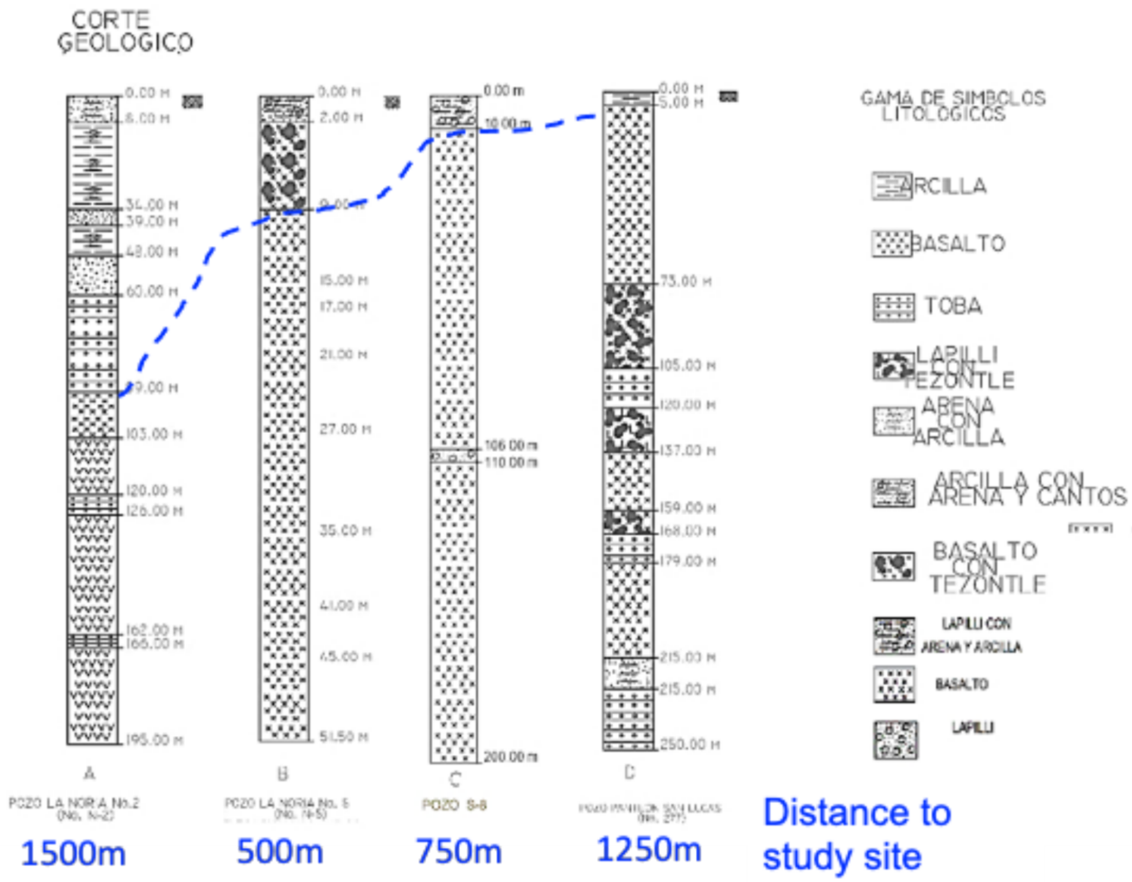
2. SITE STUDY AND PROBLEMATIC

The study area is located in the southern part of Mexico City. The most prominent feature is the so-called Chichinautzin mountain range, from which a large number of drains feed the aquifer of the zone. Geotechnically, the site is located in the transition zone, where site periods are close to 1 s.



The damages observed were sinking, Soil deformation, cracking, cobblestone damage, broken windows, and fracture of walls

The lithology is conformed of lake clays, clays with sands and boulders, basalts with tezontle, stuffs, and lapilli. In general, there is a significant irregularity in the distribution of subsurface materials over short distances. The figure shows the depth at which basalt can be found in the study area.


CORTE GEOLOGICO
0.00 M
6.00 M
34.00 M
39.00 M
48.00 M
60.00 M
103.00 M
120.00 M
126.00 M
162.00 M
166.00 M
195.00 M
2.00 M
15.00 M
17.00 M
21.00 M
27.00 M
35.00 M
41.00 M
45.00 M
51.50 M
0.00 m
10.00 m
106.00 m
110.00 m
200.00 m
5.00 M
73.00 M
105.00 M
120.00 M
137.00 M
159.00 M
168.00 M
179.00 M
215.00 M
250.00 M
A
B
C
D
POZO LA NORIA No.2
POZO LA NORIA No. 5
POZO S-8
1500m
500m
750m
1250m
Distance to study site
GAMA DE SIMBOLOS LITOLOGICOS
ARCILLA
BASALTO
TOBA
LAPILLI CON TEZONTLE
ARENA CON ARCILLA
ARCILLA CON ARENA Y CANTOS
BASALTO CON TEZONTLE
LAPILLI CON ARENA Y ARCILLA
BASALTO
LAPILLI

3. EXPERIMENTS. 2D IMAGES OF ERT AND SNI

Experiments

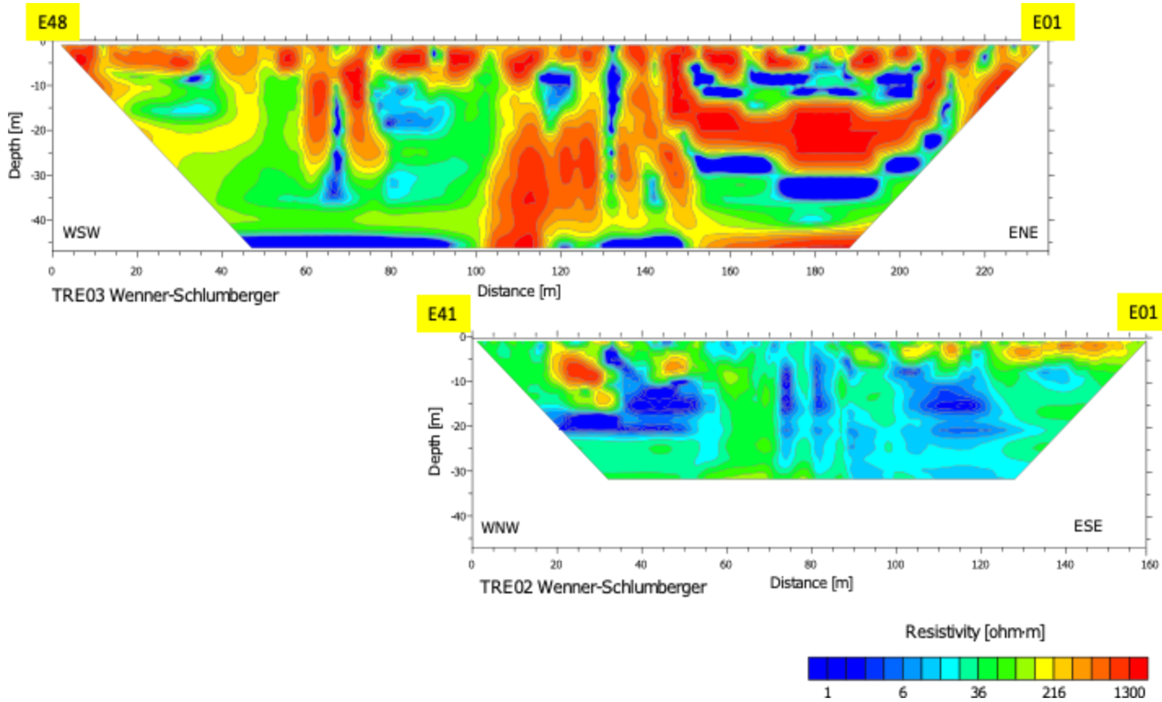
ERT
Resistivimeter
Iris Syscal pro with 48 channels
495 Quadripoles
Wenner-Schlumberger Method

SNI
2 Geode seismometers
48 channels
Vertical geophones
60 min of seismic noise

Several H/V measures

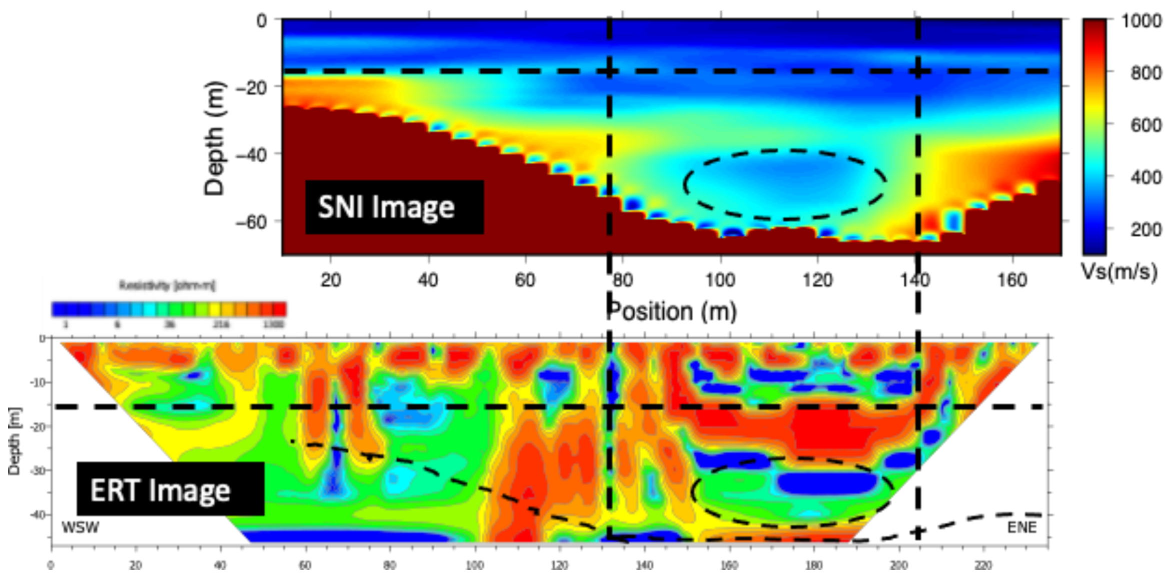
Electric Resistivity Tomography (ERT)

The site exhibits significant variations in resistivity in the horizontal and vertical directions. Some areas are very saturated due to natural runoff and leaks in the water system



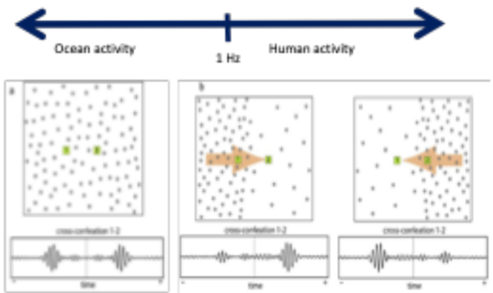
ERT vs SNI results

We compare the images obtained by the two methods. SNI can not resolve in the first 20 m depth, where ERT shows resistive materials. SNI exhibits an irregular substratum, while ERT indicates a vertical discontinuity to the middle of the profile. A remarkable similarity of the vertical distribution of properties is observed at the center of both studies.



4. SEISMIC NOISE INTERFEROMETRY (SNI)

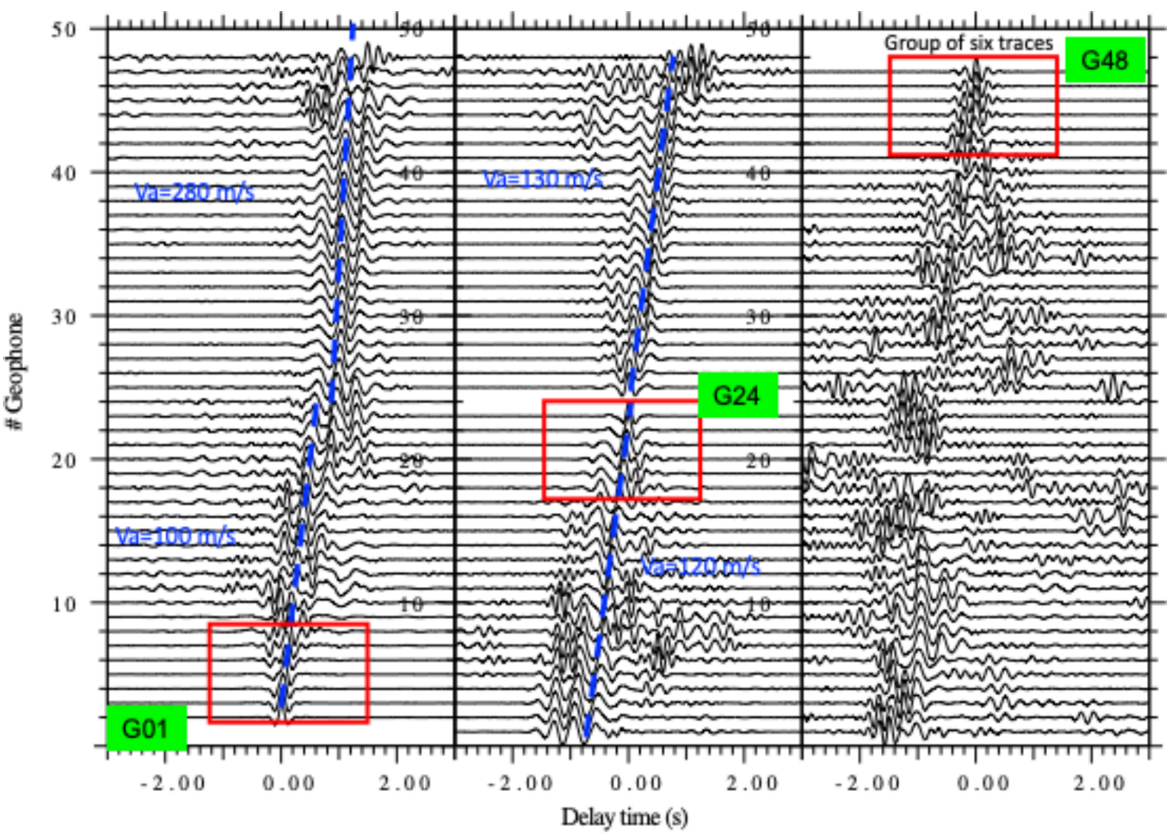
Cross-correlations, Line 3. Source virtual sections



(Snieder, Phys. Rev. E, ***69****, 2004)*

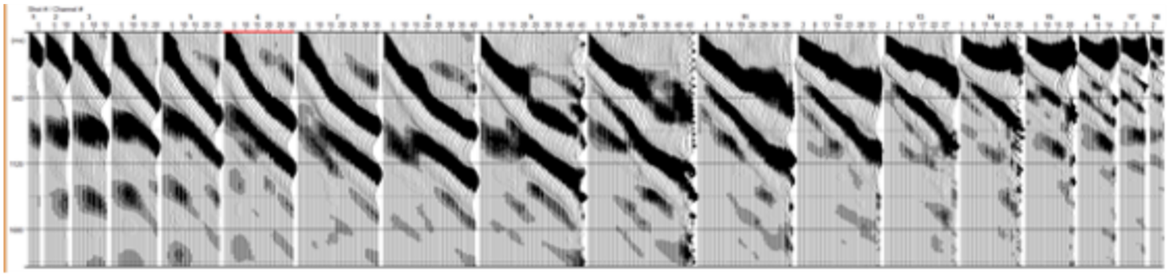
We carry out seismic noise-correlations between all pairs of receivers. The wave trains emerge with amplitude remarkable in time delays less than 2 s. The pulses have a high signal to noise ratio and emerge consistently either in the anti-causal or causal side.

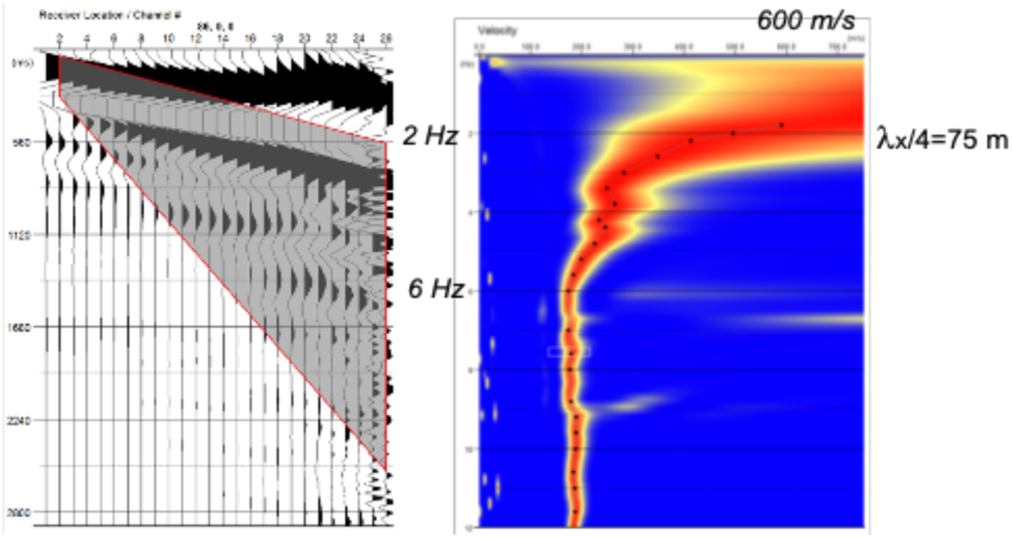
We observe sudden changes in velocity, and the correlation is lost in some receivers. After the virtual source position, the continuity of the correlation pulse can be followed in the first six receivers.



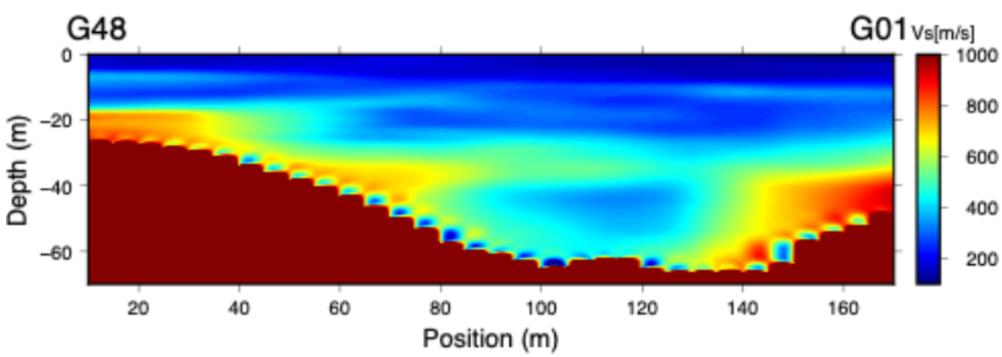
CMPCC analysis

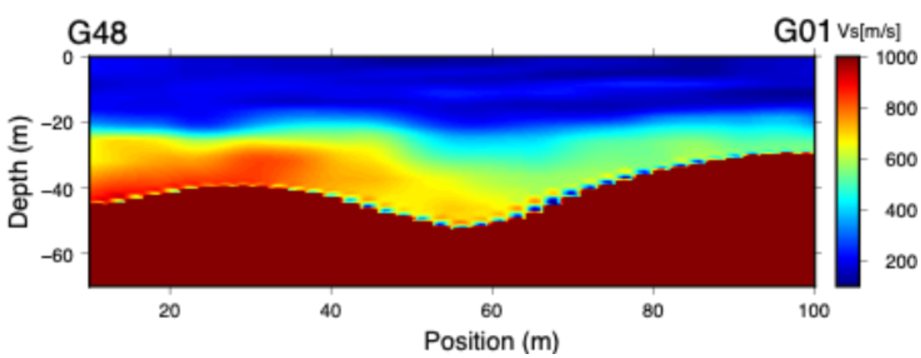
We produce 1D Vs profiles by using the Common Mid-Point cross-correlation technique (CMPCC). Phase velocity dispersion curves were extracted from each CMP gather, grouping the traces to obtain phase continuity among traces but limiting each gather's distances to 20 m (binsize 5) to detail correctly lateral heterogeneity.





2D Vs sections were built from the interpolation of the 1D Vs profiles. In the first 20 m depth, the dispersion curves do not define the structure; they only indicate a layer with average velocities at 150 m/s. The CMPCC analysis allows defining the Vs lateral variation.

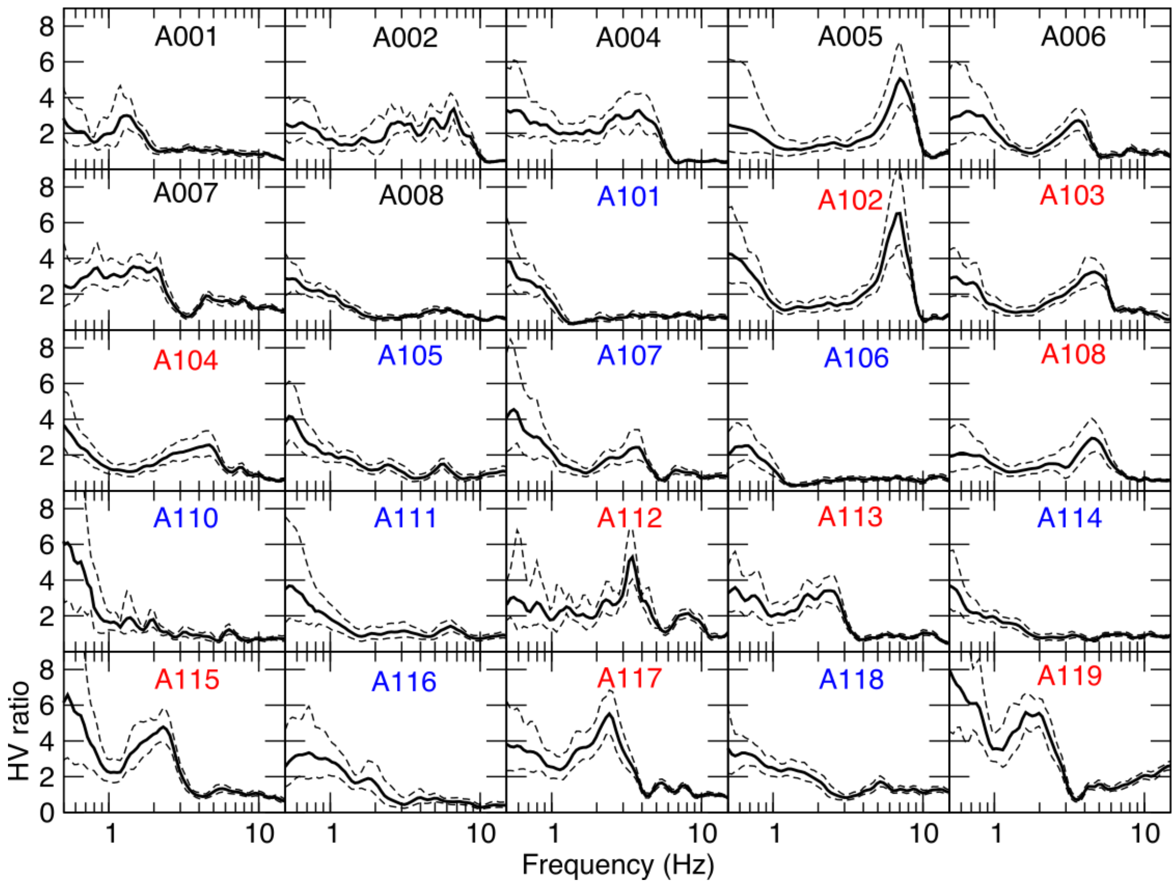




5. SITE RESPONSE. HVSR

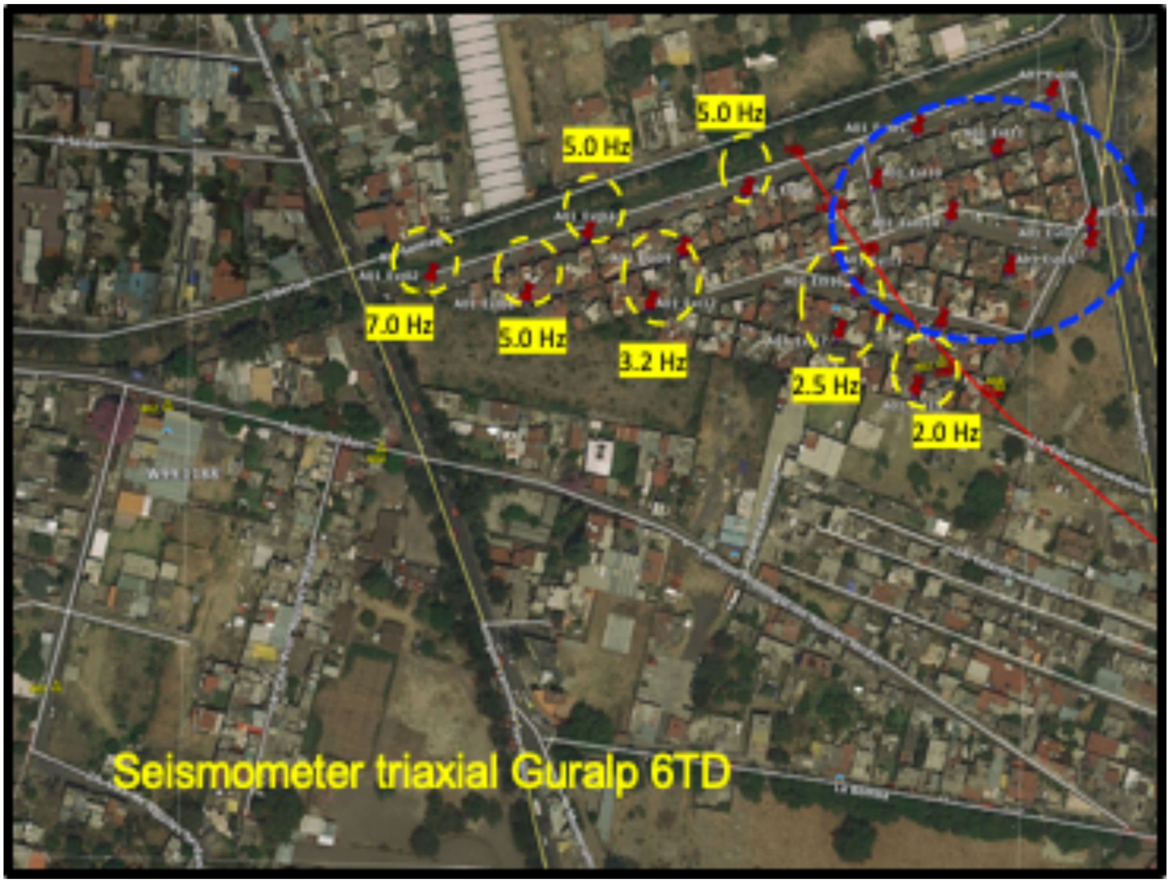
H/V spectral ratios

We explored the possible presence of soft materials and the substratum depth using 25 measurements of 30 min of seismic noise to apply the HVSR method. We observe weak impedance contrast, but it was enough to indicate the seismic response of a soil layer in the frequency range of 2 and 7 Hz.



The soil frequencies are only present on the West side of the study area (yellow circles). Whereas on the East Side, the spectral ratios are flat (stations inside a blue circle).

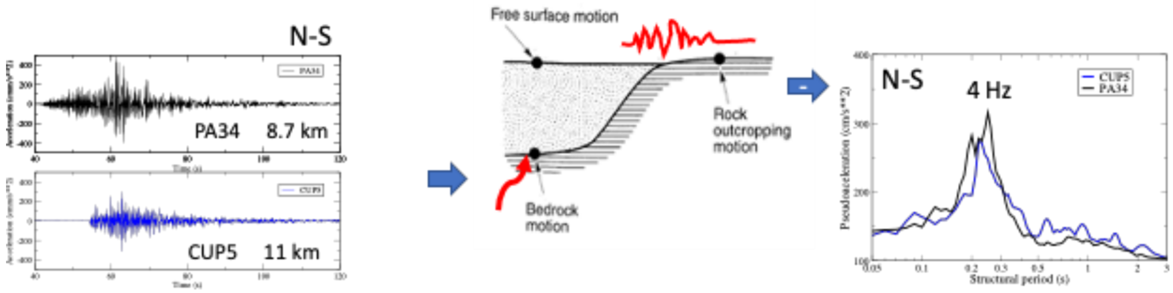
The absence of soil frequencies in the east part may be due to resistive materials close to the surface, which cannot be detected by the dispersion curves.


5.0 Hz
5.0 Hz
7.0 Hz
5.0 Hz
3.2 Hz
2.5 Hz
2.0 Hz
Seismometer triaxial Guralp 6TD

6. MAXIMUM SHAKING AND CONCLUDING REMARKS

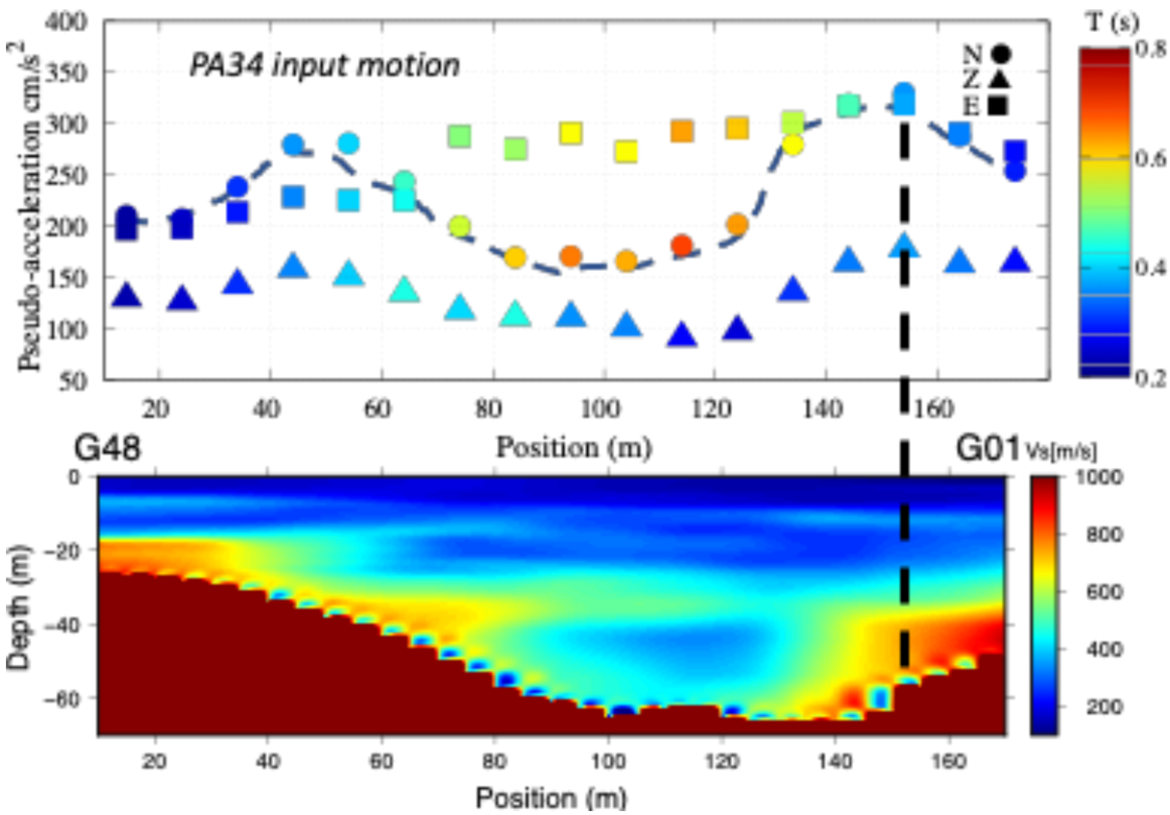
Maximum surface pseudo-accelerations

To estimate surface accelerations, we use the earthquake record 09.19.2017 to simulate the maximum surface response (Haskell method) due to the subsoil's 1D Vs structure.



The response spectra of two close accelerometric stations (PA34 and CUP5) show maximum accelerations near 4 Hz (using the 1D VS model indicated by the vertical dashed line).

A strong effect of soil amplification due to the lateral Vs irregularity, and shallow bedrock, is observed (blue dashed line).In the center of the model, the site periods are increased according to the soft materials' depth.



Conclusions

The results show that the subsoil properties 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.

The observed damages are due to a series of conjugate events that accentuate differential subsidence:

(a) irregularity in the structure and properties of the subsoil,

(b) local overexploitation of groundwater,

(c) seismic and dynamic amplification effects accelerate relative displacements during seismic ground motions.

DISCLOSURES

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Declaration of Conflicting Interest

The authors declare that there is no conflict of interest to disclose.

Data Availability Statement: Data available on request from the authors

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ABSTRACT

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