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SITE INVESTIGATION WITH COMBINED METHODS IN A FAULTED AREA IN MANAGUA, NICARAGUA - A PRE-STUDY

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INTRODUCTION

Geophysical methods are increasingly being applied to geotechnical investigations, as they can identify material properties and material boundaries, as well as variations in space and time of relatively large volumes of soil. Another advantage is that many of these methods are non-intrusive. The combination of several methods and the verification of their results by sampling and correlating with geotechnical methods are advisable in order to improve the reliability of geophysical investigations. In this case we used the following geophysical methods; combined resistivity and time domain induced polarisation (IP) two-dimensional imaging (CVES), seismic refraction plus multi-channel analysis of surface waves (MASW).

The geophysical results are compared to a geologically documented trench, which had been dug 5m south of the geophysical line with a N65°W orientation. The trench intercepted an active fault zone. The geological study determined that the intercepted fault zone corresponds to the Escuela Fault System, one of a many of the complex faulting system within the so-called Managua Graben.

GEOLOGICAL SETTING

The study site is located within the Rubén Darío Campus of UNAN-Managua, in an open area close to a major road.

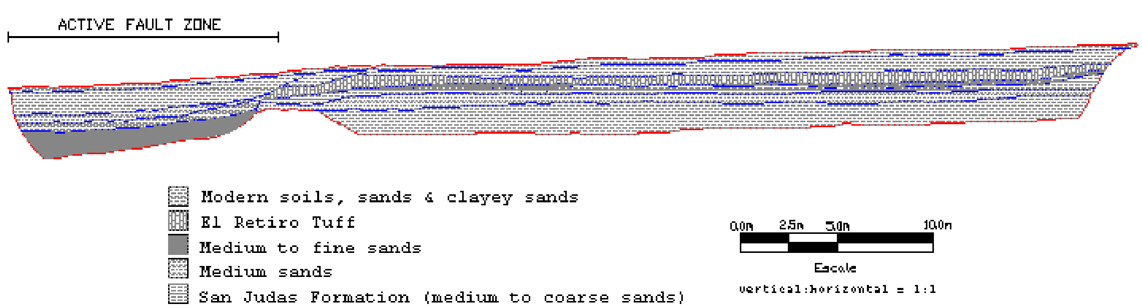

Figure 1. Geologically documented trench (modified from Martínez, 2001).

The materials underlying the Managua city area comprise products within Las Sierras Group. There, some ignimbrites, pyroclastic waves and falls associated to regional explosions from basins formed between the Late Tertiary and the Quaternary can be observed. Overlaying this group, sequences of pyroclastic materials constitute the Las Nubes Group and the Managua Group, as documented by Hradecký et al. (1997).

In the Managua area's soils, products from ancient volcanic activity can be found, e.g. the Masaya, Apoyeque, Motastepe within the Miraflores - Nejapa alignment, as well as others outside of that alignment such as Chico Pelón and Tiscapa. The presence of many fossil soils suggests the existence of periods of inactivity between volcanic or tectonic events, which allowed the development of the various soil types (Hradecký et al., 1997).

The test site is characterized by a volcano-sedimentary sequence. These soils date from the Holocene and comprise modern soils, fossil soils, tuff, basaltic sands of black colour, and fines (Figure 1).

GEOELECTRICAL PROFILING

Three profiles over the same line were performed. An ABEM Lund Imaging System multi-electrode system with four electrode cables was used for the data acquisition (Dahlin 1996). The electrode spacing was 1 m in all cases, for high resolution of the near surface. The results presented here were measured as combined resistivity and time domain IP with gradient electrode configuration (Dahlin and Zhou 2002). The data was inverted using Res2dinv, and the resulting L_1-norm (robust) inverted sections are shown in Figure 2 (Loke et al. 2001). The NW end of the line (station 0m) is the common start point for all geophysical methods used, regardless of the layout extent of each.

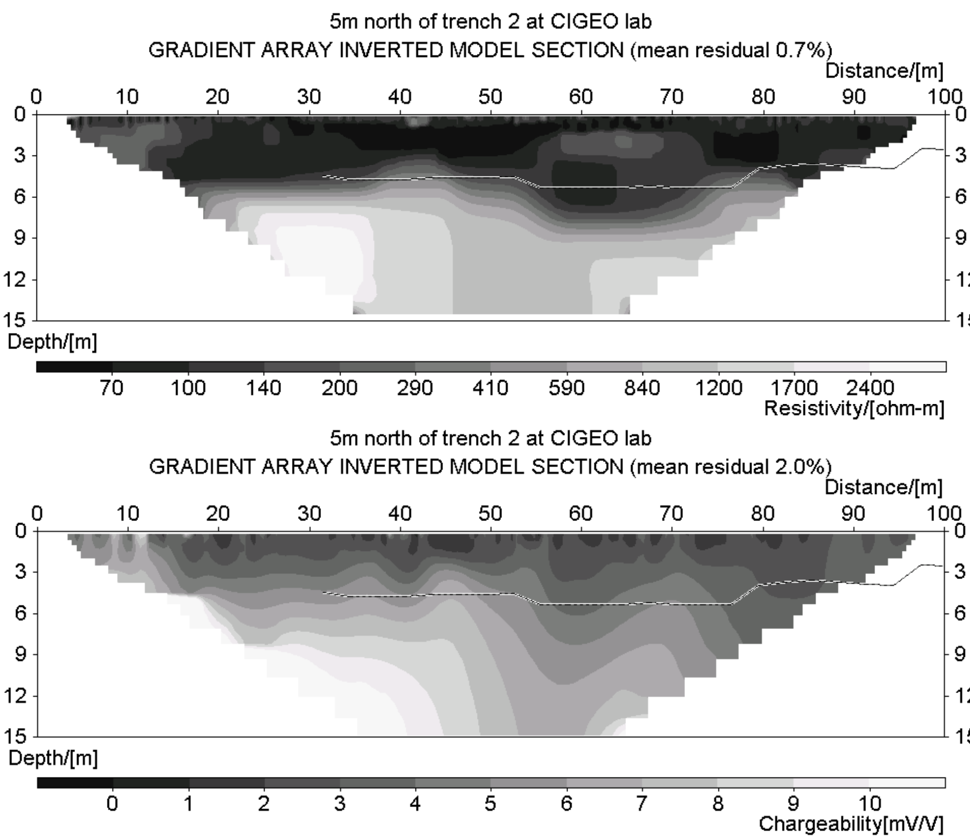

Figure 2. Inverted geoelectrical sections with depth to refractor from seismic survey marked: resistivity (top) and induced polarisation (bottom).

The inverted resistivity section shows a layered structure, with an upper layer of approximately 4-6 metres depth with lower resistivity underlain by a high resistive layer. At the start of the line the top layer has a distinctly different character, obviously due to the documented fault zone. The depth of the upper layer varies, with increased thickness at 55-75 m along the line, possibly caused by another faulted zone (beyond the trench). The resistivity of the bottom layer varies, maybe also as a result of faulting. The IP section largely shows the same picture as the resistivity, but more smoothed, with low chargeability in the top and higher at depth. The anomalous character of the fault zone at the start of the line is also clearly visible in the IP section.

SEISMIC REFRACTION

Two seismic methods were applied, seismic refraction and the multi-channel analysis of surface waves (MASW) method. These tests were performed exactly over the same line where resistivity profiling was carried out. A 24-channel Geode seismograph with 4.5 Hz geophones was used. For seismic refraction, geophones were placed with a separation of 3 metres between each receiver, and a 12 lb (5.44 kg) hammer source with a 25 cm metal plate was used at five shot positions (2 offset shots, 2 end-of-line shots and one middle-of-line shot) evenly spaced every 33 metres.

The results show a 2-layer profile, with P-wave velocities (Vp) of the first layer averaging 377 m/s. The second layer (refractor) has an average Vp of 590 m/s at depths between 2.5 and 5.3 metres. These results can be compared with the resistivity profiles for a segment starting at station 31.5m (Figure 2). Because there is a fence almost at the beginning of the investigation line, it was not possible to place the geophones closer to the station 0m and have the direct offset shot as well, needed to use the delay method in the interpretation. The depth to the refractor follows the shape of the depth to the high resistive bottom layer, but the dip at 55-75m is shallower (figure 2). Hence it seems that the refractor and high resistivity bottom layer are showing the same geological feature, and the discrepancy in depth may be caused by underestimation by the resistivity method due to equivalence or that there is an additional layer with low resistivity but high velocity at 55-75m.

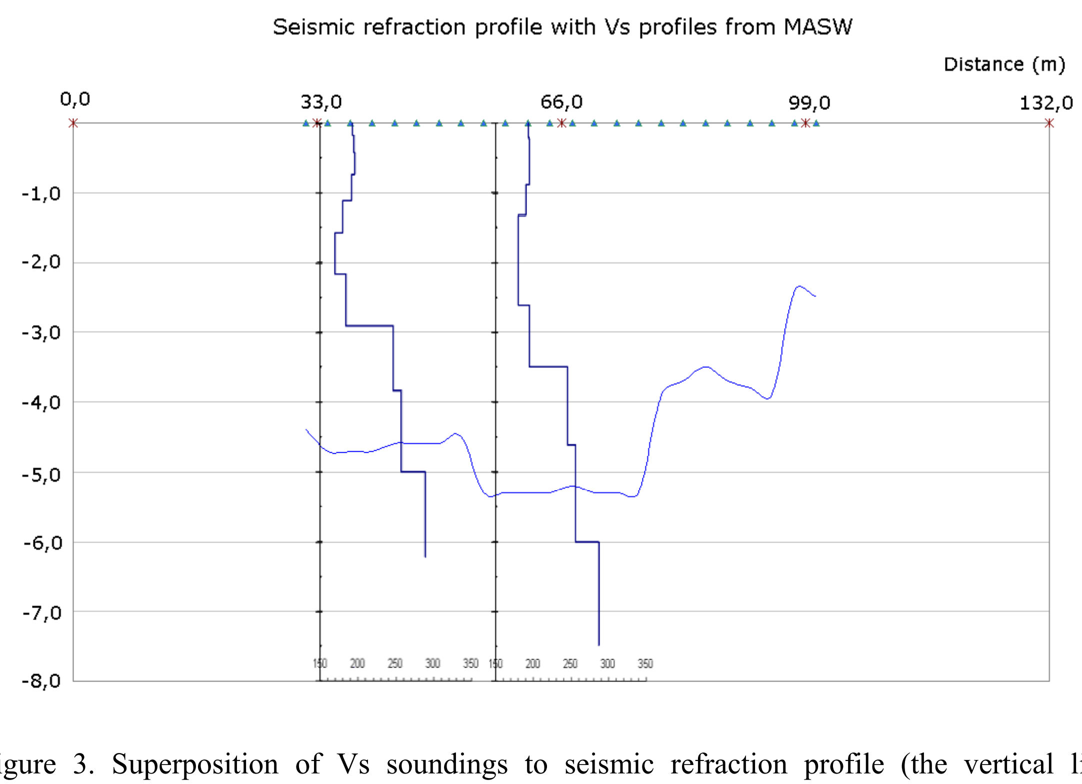

Figure 3. Superposition of Vs soundings to seismic refraction profile (the vertical line indicates the place the Vs model is attributed to).

MULTICHANNEL ANALYSIS OF SURFACE WAVES

For MASW, a 20 lb (9.07 kg) sledgehammer on a 25 cm diameter metal plate was used as the source. The resolution of dispersion analysis for MASW increases with a higher number of used channels. With the walk away method, which consists on incrementing the distance of the seismic source to the geophone spread fixed in the same location, a record can be constructed with more traces than the number of channels available. Four records were taken, two at each side of the geophone spread, and the corresponding walk away records were constructed. Even when the road adjacent to the study site has a moderate to heavy traffic that introduced noise to the record, the method demonstrated to be insensitive to that kind of interference.

The resulting velocity model for every record is a vertical profile of shear wave velocity, corresponding to the central point of active receivers. It is apparent that the refractor stratum, identified with the seismic refraction method, corresponds to the layers with shear wave velocities of 255 - 257 m/s obtained from the MASW analysis (Figure 3).

CONCLUSIONS

This study shows that the tested non-destructive geophysical techniques can be consistently combined as to make an assessment of the geological, engineering geological and geotechnical setting for a given site. The geoelectrical imaging provides a continuous 2D model with a better overview and more detail than the seismic methods, while the latter give the engineers a direct measurement of geotechnical properties. The results suggest geoelectrical imaging be used at an early stage to give an overview, and the plans for how and where to apply seismic methods to be based on these results. Finally a drilling and sampling programme can be designed on basis of the combined geophysical results.

A “roll-along” acquisition procedure for the MASW method could be used to create a bi-dimensional profile crossing the entire fault zone would help to identify and locate the fault, and also would provide measurements of Vs within the fault zone as well as at both sides, for seismic microzonation purposes.

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