NEAR SURFACE GEOSCIENCE'21 CONFERENCE & EXHIBITION

Abstract # 88

Geophysical characterization of near-surface formations in the La Villa River catchment (Los Santos, Panama)

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Context

The assessment of the hydrogeological dynamics of the La Villa watershed located in the Azuero Peninsula (Figure 1), in the Central Pacific region of Panama, is an important element in the water resource management of this region which is part of the Dry Arc region. The Dry Arc region, compared to the rest of Panama, receives half rainfall while most of the economic activity is based on agriculture.

Only recently, this region has been the subject of a hydrogeological study (Castrellón, 2016 and 2018) to roughly assess the water flows between the groundwater reservoirs and the hydrographic network. This work has allowed to establish additional structural constraints to define a first conceptual and numerical models concerning the regional structure and connectivity of the La Villa watershed aquifer system. At this scale, hydrogeological modelling is hampered by 1) the low number of hydrological and hydrogeological observations (piezometers, flow measurements), 2) the low resolution provided by satellite data for the spatialization of the surface information, and 3) the absence of spatialized data to describe the internal variability of the subsurface.

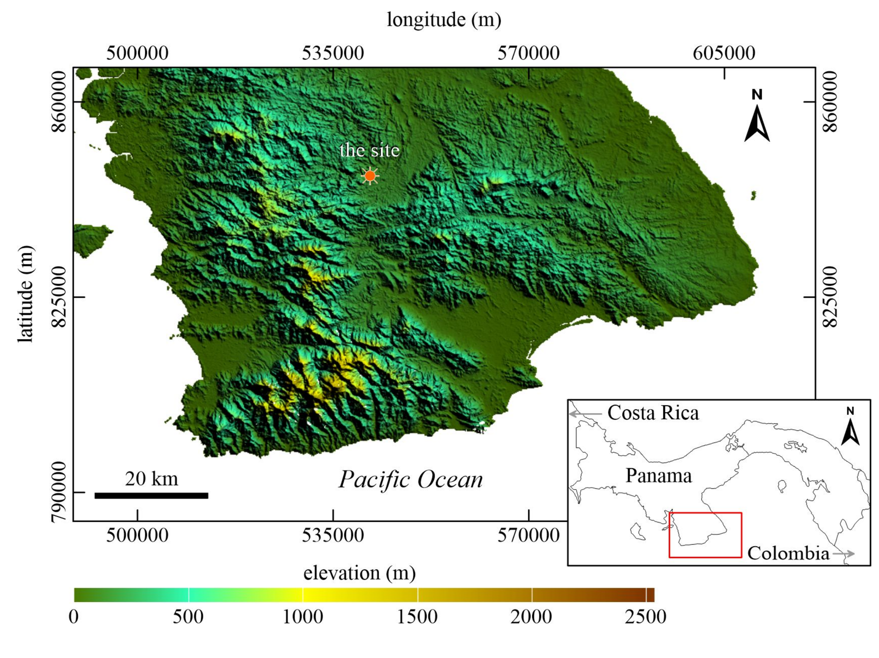

Figure 1: General topography of the region and location of the study area.

Site description

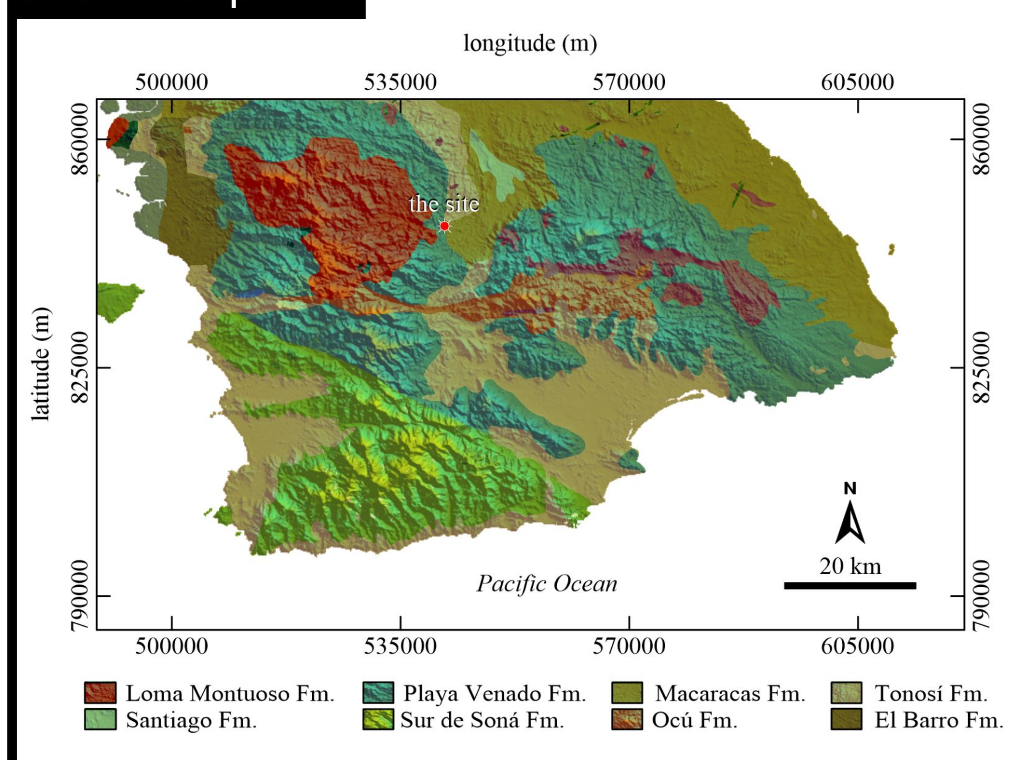

Figure 2: Main geological formations of the region.

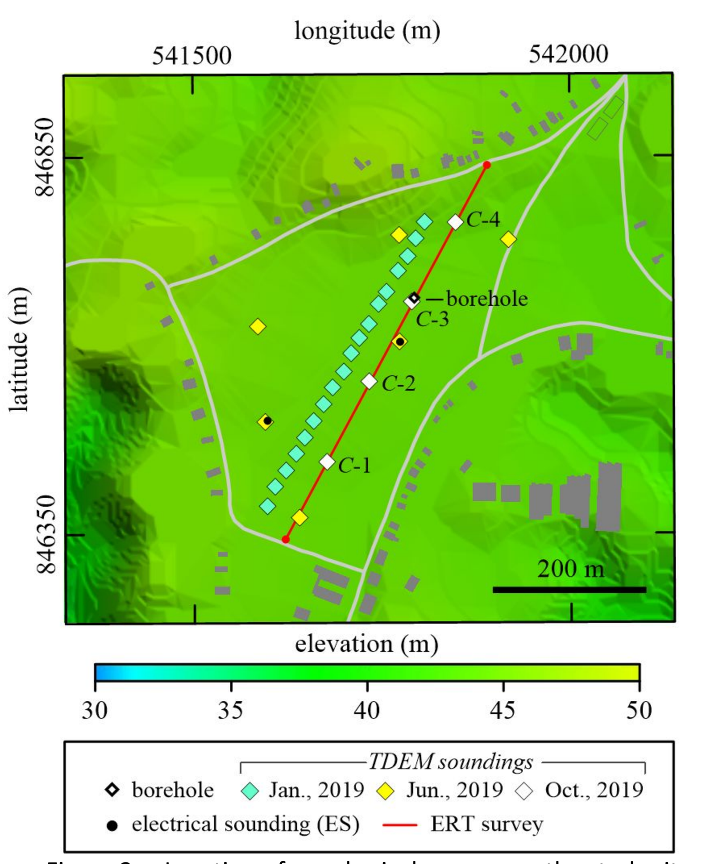

Figure 3: Location of geophysical surveys on the study site.

The site is located 10 km southwest of Macaracas. The terrain is sparsely vegetated due to poor soil conditions. Along the electrical resistivity tomography survey line (reference profile), the topography is sub-horizontal with a slope of less than 1%.

The La Villa watershed has an area of 1 284 m² and is mainly drained by the La Villa River and constrained by two adjoining sub-watersheds of Parita (northwest) and Guarare (southeast). The geology of the region (Azuero Peninsula) is essentially characterized by a volcanic context and a topography made of hills culminating at less than 1000 m (Cerro Cacaranado). At least 8 geological formations (Figure 2) are represented (Castrellón, 2016). The site is located at the intersection of the Macaracas formation (sedimentary formation, sandstone and tuff from Oligocene), Tonosi formation (sedimentary sandstone, shale and tuff from Eocene) and Playa Venado (volcanic andesite, tuff and basalt from Eocene/Oligocene). The climate is tropical with an average rainfall of over 1000 mm. However, it does not exceed 60 mm/month during 7 months (Souifer, 2010). The geophysical assessment of the site was carried out using several methods: Time Domain ElectroMagnetic and Electrical soundings (TDEM and VES), Time Domain Reflectometry (TDR) measurements, Electrical Resistivity Tomography (ERT) and passive seismic soundings.

Passive seismic results

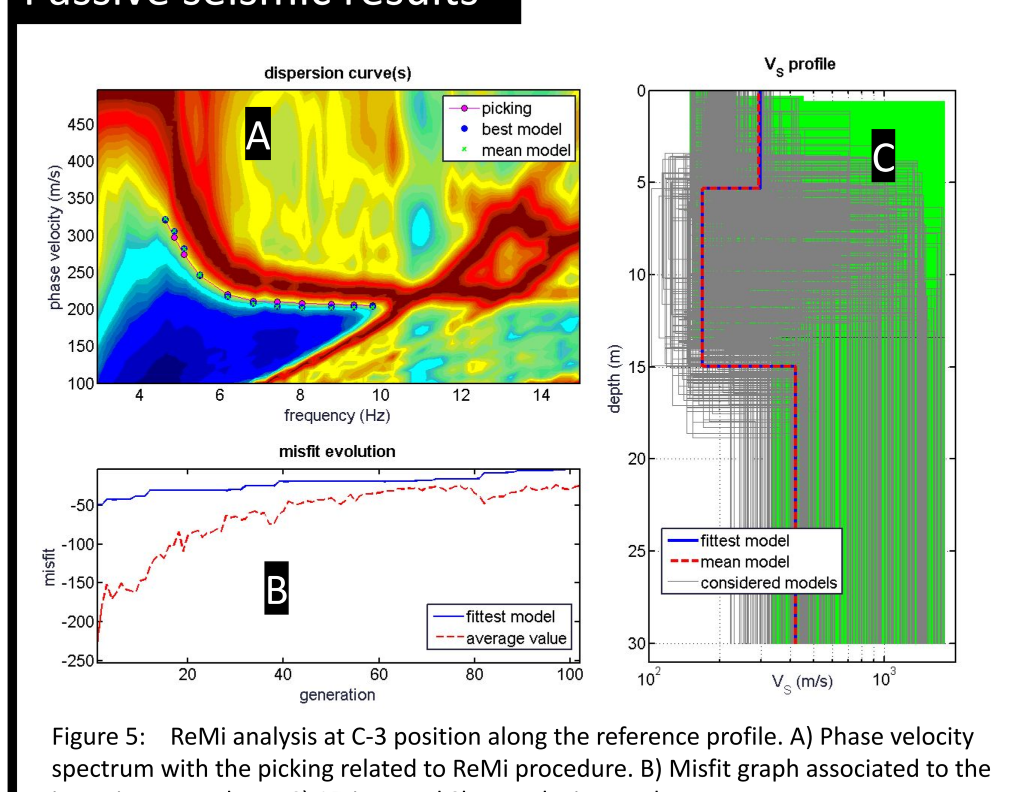

Figure 5: ReMi analysis at C-3 position along the reference profile. A) Phase velocity spectrum with the picking related to ReMi procedure. B) Misfit graph associated to the inversion procedure. C) 1D inverted Shear velocity results.

Passive seismic data have been acquired at four positions along the reference profile using a Geometrics Daqlink instrument. The results of inversion for a three-layered model is showed Figure 5C. Each line of acquisition is composed of 16 z-geophones (4.5 Hz) with a spacing of 10 m. The time sampling is 2 ms and the record length was 32 seconds. Twenty records per location have been acquired and stacked to obtain a mean seismogram. The ReMi method has been tested using winMASW® from Eliosoft.

Discussions and conclusions

This preliminary work illustrates the first geophysical survey on the La Mesa plateau located at the south of Macaracas, in the La Villa watershed. Along a reference profile on which a borehole was drilled, TDEM, ERT, VES, TDR and Passive seismic geophysical investigations were used to image the variability of the laterite formation over a thickness of nearly 60 m, and particularly the saturated zone (aquitard ?) that have been identified by drilling. The TDEM allowed to distinguish the alteration profile of the lateritic formation, with an upper resistive (> 1000 Ω m) layer followed by the saturated zone (between 10 and 100 Ω m) and then a clayey formation (< 10 Ω m) resulting from the alteration of the basaltic parent rock and the leaching due to the climatic conditions in tropical context. Due to its very high near-surface resolution, the VES identified the transition linked to the increase of water content. In contrast, the ERT was not able to image the water table located at around 6 m at the C-3 position because of the 5 m spacing. The ReMi sounding showed a second layer corresponding to a decrease of Vs which seems coherent with the observed water table. These results nicely illustrate the interest of geophysical investigations for hydrogeological modelling, as it can provide additional structural constraints through the characterization of the superficial formations, and functional constraints through the localization of the water table level.

Next steps to assess the hydrogeological dynamics consist in assessing joint/cross inversion of TDEM/Passive seismic (and future active seismic acquisitions)/ERT and the construction of a nearby piezometer to gather direct hydrogeological information.

EM et DC Results

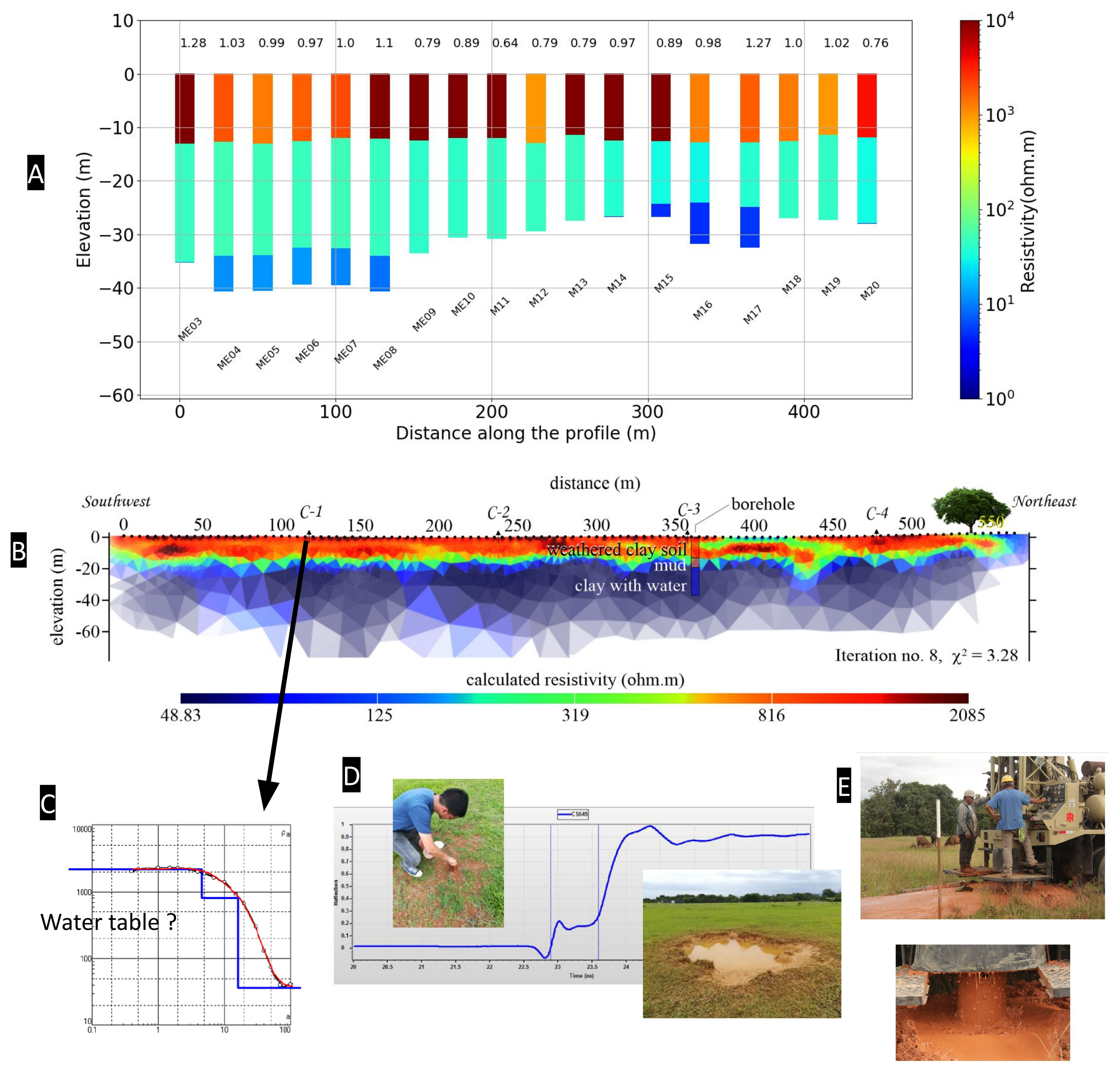

Figure 4: A) TDEM inversion results along the reference profile. B) ERT inverted section along the reference profile. C) A VES sounding at the C-1 position along the ERT survey line (reference profile). D) Photo of the site with a raw TDR signal measured on a sample near the C-3 position along the ERI profile. E) Photo of the drilling machine used to the calibration geological log.

The geophysical investigations took place in January, June and October 2019. In the present study, a TDEM configuration (Figure 4A) with a coincident 25 m × 25 m square loop and a 1-A step current was used (Temfast from AEMR). The TDEM inversion was performed using Py_TDEM_1D (Schamper et al., 2018). Between 0 and 230 m along the reference profile, a three-layer model explained the data while after 230 m a two-layer model has been defined (the deepest 3rd layer is at the limit of the sensitivity; the 1D models have been blanked below an estimated depth of investigation). The contrast between the clay rich and the leached subsurface horizon (including the saturated part) at around 25-30 m depth is clearly defined.

Soil samples tested by X-Ray diffractometer indicated a quasi-absence of clay, and a high proportion of metals and silica (iron hydroxide, aluminum and quartz). A borehole (Figure 4E) located at 365 m along the ERT survey line revealed a leached red laterite formation at the surface, a water table at 6 m and a clay formation around 19 m depth.

Time domain reflectometry (TDR) measurements (CS645 sensors from Campbell Scientific) were performed (Figure 4D) to estimate the high frequency relative dielectric permittivity (~16) and confirm the soil DC resistivity obtained by ERT (Figure 4B) and VES (Figure 4C). The VES located at C-1 was inverted with IP2WIN® and confirm an intermediate horizon most likely due to the presence of a water table. The ERT survey line was 560 m long (Wenner-Schlumberger setup) with an electrode spacing of 5 m. The electrical resistivity measurements were performed with a Syscal- Pro (Iris Instruments). The ERT pseudo-section was inverted using BERT free software package. The results illustrate the electrical resistivity variations due to tropical lateritic formations: starting with a horizon rich in iron oxide and poor in clay content, then an intermediate saturated formation, followed by the clayey formation.

Acknowledgement

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