# Hydrogeophysical characterization of intrusive bodies in the tropics: Upper Estibaná sub-catchment case study

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## 1. Introduction

In tropical areas, outcropping intrusive bodies can become very weathered, which increases their hydrogeological potential. Shallow weathered intrusive layers, known as regolith, have very low yields, nevertheless identifying the location and extent of these layers is crucial for securing water availability in rural, water-scarce areas. The Estibaná sub-catchment is a rural, seasonally dry area, located in South-Central Panama (Figure 1). Electrical resistivity tomography (ERT) and transient electro-magnetic sounding (TEM) techniques were used to identify the stratigraphy and to explore the hydrogeophysical properties of the intrusive bodies from the Faldar site, located in the upper Estibaná sub-catchment.

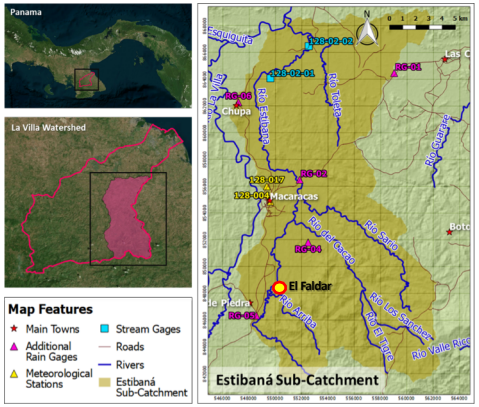



**Figure 1. Study area location within Panama.**

## 2. Geological Context

The types of rocks that are present in the study area are: The basalts and andesites of the Playa Venado formation located in the southeast, the agglomerates and tuffs of the Pese formation which cover the majority of the sub-catchment, the limestones of the Changuinola-Ocu formation located at the north, and the sandstones of the Macaracas formation located in the center of the study area. El Faldar is located in between the Macaracas plain and the foothills that underwent morpho-structural changes due to local faults generally oriented North-South.

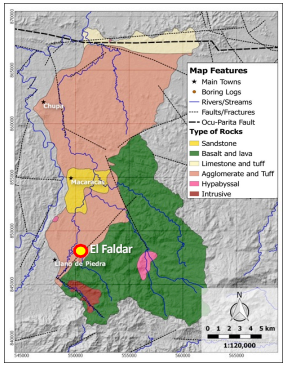



**Figure 2. Geology of the Estibaná sub-catchment.**

## 3. Materials and Methods

Three electrical resistivity (ERTs) profiles of 235 m long and three electromagnetic sounding (TEMs) of 50 m x 50 m loop were performed at the El Faldar site (Figure 3).

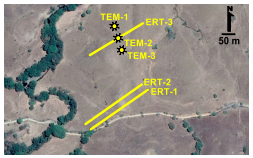
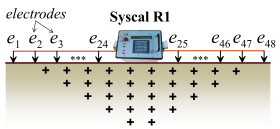



**Figure 3. Electrical profile distribution and electromagnetic sounding positions.**

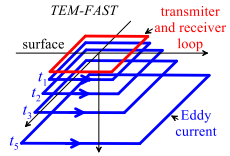
### 4.1 ERT Methodology




Wenner-Schlumberger array, $a$ = 5 m, $N_{electrodes}$ = 48, $N_{levels}$ = 23, $N_{data}$ = 529

The inversion routine used was the smoothness constrained least-squares inversion with an L2-norm implemented by a quasi-Newton optimization technique (Loke and Barker 1996).

### 4.2 TEM Methodology




**TEM-FAST:** I = 50 m, stack = 5, i = 4A

For the TEM soundings, the transient response E(t) was transformed into apparent electrical resistivity values through an asymptotic equation (Barsukov et al. 2005). Then the values were inverted using the modified Levenberg-Marquardt method (Barsukov et al. 2007).

## 4. Results and Discussion

### 4.1 Electrical Resistivity Tomography Results

The inverted profiles show surface horizon of low electrical resistivity (< 3 Ω.m) in the Southwest-Northeast direction. This electrical anomaly is associated with a weathered intrusive body which is a preferential flow path for groundwater recharge (Figure 4).

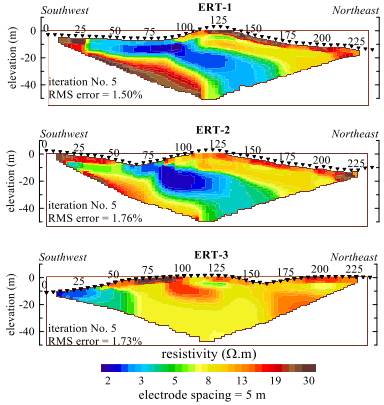



**Figure 4. Inverted profiles of the apparent electrical resistivity data set.**

### 4.2 Transient Electromagnetic Sounding Results

The results from the TEM soundings reveal the existence of 2 distinct horizons: A first layer of low electrical resistivity, followed by a high resistivity one, possibly an impermeable layer.

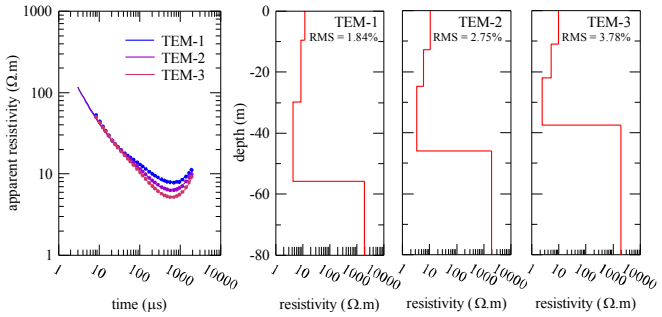



**Figure 5. Graphics of TEM datasets and 1D models.**

## 5. El Faldar Geologic Cross-Section

In the dynamics of movements and ascents, the Macaracas plain lagged behind the mountainous volcanic formations of the periphery and allowed the development of a geological structure associated with sedimentary volcanic formations in which shales, volcanic agglomerates and basalts predominate. In this section there is a fractured and meteorized body of sandy texture characterized as intrusive granodioritic and on which lies a sedimentary sequence with a slight dip to the east (10º) (Figure 6). This type of rock in this location suggests possibility of surface water diversion and infiltration into underground sectors outside the Estibaná riverbed.

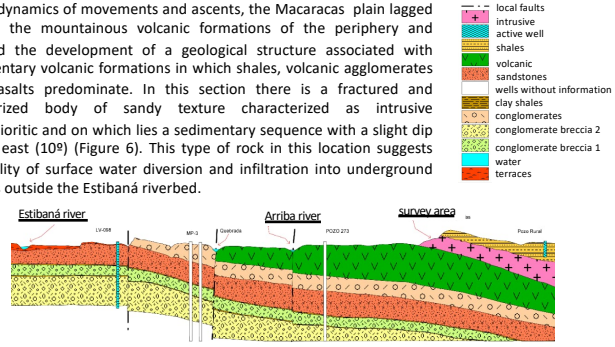



**Figure 6. Geological cross-section of the El Faldar site, Estibaná sub-catchment.**

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