3D geological modelling using geological / geotechnical and AEM data

Jacques Deparis, Benoit Vittecoq, Timothée Jaouen, Frédéric Lacquement, José Perrin, Guillaume Martelet

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Geophysics in Elephant Country

3D GEOLOGICAL MODELLING USING GEOLOGICAL AND EAM DATA

J. DEPARIS[1], B. VITTECOQ[1], T. JAOUEN[1], F. LACQUEMENT[1], J. PERRIN[1], G. MARTELET[1].

[1] UMR 7327, BRGM, CNRS, UNIVERSITE D'ORLEANS, F-45060 ORLEANS, FRANCE

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Understanding the hydrogeological functioning of volcanic island is essential for an adapted management of water resource and for a better supply to population, particularly in those who have seen their population increase in years. Nevertheless, geological, hydrological or hydrogeological data are often very scarce, and appropriate approach have to be found in order to improve the hydrogeological functioning of these islands.

Groundwater resource is closely correlated with the permeability of rocks, and, in basaltic volcanic islands, permeability is usually considered to be negatively correlated with age formations. Younger lavas have higher permeability than older one's often highly weathered (Custodio et al., 1988). Existing hydrogeological models of basaltic volcanic islands describe large-scale systems at the volcano or island scale, and two end models have been described. The Hawaiian model (Meinzer, 1930) considers a low-lying basal aquifer linked to inland dike-impounded and perched aquifers overlying impervious layers and/or confined by dykes (Tabasaki and Mink, 1983). The Canary Islands model (Custodio, 1975; Custodio et al., 1988) considers a continuous and isotropic basal aquifer, and a decrease of hydraulic conductivity with the age of the volcanic rocks. Nevertheless, those models are consistent with Young Island (< 5 Ma) and seem not fully appropriate for older island such as Mayotte Island.

Mayotte Island is a small French overseas territory of the Comoros archipelago in the Indian Ocean. Its population has quickly increased during the last decades and has been multiplied by four in less than 30 years. The island is now very densely populated with more than 500 inhabitants per square kilometer. Water needs are thus substantial. Surface water resource is very strongly solicited, and too dry seasons can lead to critical situations. Nevertheless, its hydrogeological functioning is not well known, and understanding the hydrogeological functioning of the island is thus essential for an adapted management of groundwater resources and to make appropriate drilling campaigns.

In 2010, an helborne SkyTEM survey on the whole island has been performed. The transmitter loop is composed of four 284 m² loops that transmit a low moment with a single turn and a high moment with four turns of the loop. The current generated by the low moment is 11 A, giving a moment of about 3100 Am² and a turn off time of 10 microseconds. That generated by the high moment is 108 A, giving a moment of about 123,000 Am² and a turn off time of 38 microseconds. The first sampling gate is centred about 6.5 microseconds for the low moment and the last window of the high moment is 8 ms.

A linear 3000 km of SkyTEM TDEM data was acquired in a month. The average flight line spacing was 200 metres, with local spacings of 400 metres or 100 metres. The average speed of the helicopter was 18 m/s (65 km/h) with an average ground clearance of the transmitter loop being 48 metres. The TDEM decay curves were filtered using Workbench software with 1D modelling of the curves based on the Ward and Hohmann (1988) solutions. Data inversion was done with em1Dinv software (Auken et al, 2004) using a 20-layer model with fixed depths and a spatial constraint between the model resistivities of nearby soundings (Viezzoli et al, 2008). This model was preferred to a stratified-type inversion because the development of the weathering profile is not conducive to the presence of a sharp contrast between the bodies.

The aim of the research presented in this paper is to show the calibration of 3D resistivity mapping realized on another and older volcanic island, with boreholes data in a test site in the South of Mayotte Island, and how the highlighted paleo-valley structure enhance understanding the hydrogeological functioning of the South of Mayotte Island.

To establish the 3D model, we used correlation between borehole, geological map and 3D resistivity grids. Comparison between TDEM data, borehole and pumping tests data have provided new evidence about the hydrogeological scheme of the island, which seems different from the two previously mentioned. This study is focused in the South of the and includes two watersheds. The surface of the Kani-Kéli watershed, the west one, is about 4.9 km², and the surface of the Mronabeja watershed, the est one, is about 4.4 km². Four boreholes have been made in the past Simplified and interpreted geological logs show that two boreholes are drilled in weathered lavas, whereas the two others encountered about 30 m of weathered lavas overlying unweathered and superposed fresh fissured lava flows, with a confined aquifer in the fresh lava.

3D geological model of this area is made with GeoModeller ® software. Two kinds of data are used: polygons extracted from the provisional geological map using ArcMap and TDEM data. One model was produced with TDEM sounding (i.e. without resistivity interpolatation).

3D modeling of different geological formations can delineate structures with a hydrogeological interest. Indeed, in healthy fractured lavas, characterized by variable resistivity of 30 to 100 Ω.m, are considered as potential reservoirs of groundwater in these formations modeled structures thus correspond to aquifer sector Choungui South.

The results show that helicopter borne TDEM is particularly adapted for this volcanic island, with low resistivities soils outcropping. Data computation also allows to image geological structure in 3D and boreholes comparison allows attributing geological identification for the main ranges of resistivity data. Productive boreholes, in the axis of a resistive body, and unproductive boreholes outside, allow confirming the implication of paleo-valley as major constraint for groundwater flows and the necessity to enhance existing conceptual model. The South of Mayotte Island is thus proposed as an end member of basaltic models. These results are very hopeful, and we are now looking for similar structure in order to drill new boreholes, to confirm the replicability of this aquifer structure, and to provide water to population. method.

Cited Literature

Auken, E. and Christiansen, A. V., 2004, Layered and laterally constrained 2D inversion of resistivity data: Geophysics, 69, 752-761.

Custodio E., 1975, Hydrogeologia de las rocas volcanicas, 3rd UNESCO-ESA-IHA Symposium on Groundwater, p. 23-69.

Custodio E., Lopez Garcia L., Amigo E., 1988, Simulation par modèle mathématique de l'île volcanique de Ténériffe (Canaries, Espagne). Hydrogéologie, p. 153-167.

Meinzer, O.E., 1930, Ground water in the Hawaiian Islands in Geology and water resources of the Kau District, Hawaii: U.S. Geological Survey Water-Supply Paper 616, p. 1-28.

Tabasaki K.J., Mink J.F., 1983, Volcano feeder dikes impound large reservoirs of groundwater in the Hawaiian islands, International conference on groundwater and man. Australian Water Resources Council, Canberra, ACT, Australia, Sydney, p. 309-318.

Viezzoli, A., Christiansen, A. V., Auken, E., and Sørensen, K. I., 2008, Quasi-3D modeling of airborne TEM data by Spatially Constrained Inversion: Geophysics, 73, F105-F113. pdf

Ward S.H., Hohmann G.W, 1988, Electromagnetic theory for geophysical applications: Electromagnetic Methods in Applied Geophysics 1, 130–311.