Implications of a large hydrothermal reservoir beneath Taal Volcano (Philippines) as revealed by magnetotelluric observations

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1. Introduction

Taal Volcano (N14°00.1', E120°59.1') is one of the most active volcanoes in the Philippines (Fig. 1). The first recorded eruption was in 1573. Since then it has erupted 33 times resulting in thousands of casualties and large damages to property. In 1995, it was declared as one of the 15 Decade Volcanoes. Beginning in the early 1990s it has experienced several phases of abnormal activity, including seismic swarms, episodes of ground deformation, ground fissuring and hydrothermal activities, which continues up to the present. However, it has been noted that past historical eruptions of Taal Volcano may be divided into 2 distinct cycles, depending on the location of the eruption center, can either be at the Main Crater or at the flanks. Between 1572-1645, eruptions occurred at the Main Crater, in 1707 to 1731, they occurred at the flanks. In 1749, eruptions moved back to the Main Crater until 1911. During the 1965 and until the end of the 1977 eruptions, eruptive activity once again shifted to the flanks.

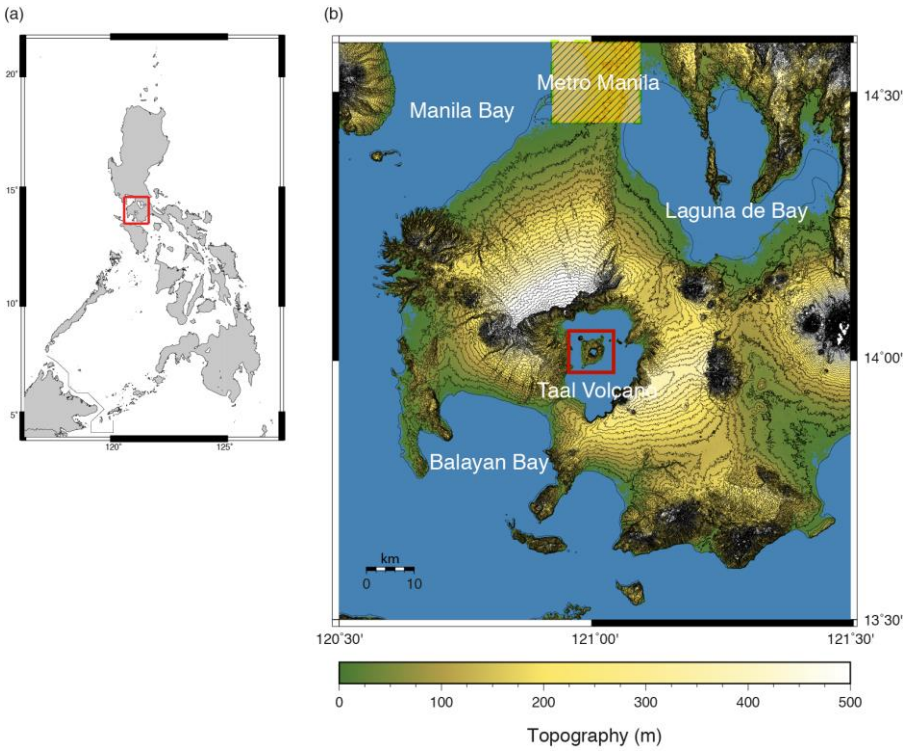

Fig. 1. Location map showing Philippines (a) and Taal Volcano (b).

2. Data and Methodology

As part of the PHIVOLCS-JICA-SATREPS Project magnetotelluric and audio-magnetotelluric surveys were conducted on Volcano Island in March 2011 and March 2012. The AMT soundings were taken at 15 stations while both MT and AMT soundings at 19 stations for a total of 34 stations. Electromagnetic data were collected using 2 Phoenix Geophysics MTU-5 receivers (Fig. 2). The AMT observations (frequencies between 0.01-10,000Hz) were made for a minimum of three (3) hours at each station, while WMT observations (between 0.001-1,000Hz) were made overnight (minimum of 12 hours).

A 1-dimensional model was derived using OCCAM 1-D inversion. It generates the smoothest possible 1-D model and only deviating from the simplest model so that it fits the data up to a prescribed tolerance. This results in quick convergence of the solution. A 2-dimensional model was then made using Ogawa and Uchida (1996) inversion of the impedances by performing a linearized, least squares inversion, where an initial model is modified iteratively while simultaneously applying a smoothness constraint until a small misfit is achieved. Further 3-D forward modeling was then made using Fomenko and Mogi's (2002) code. This method utilizes a finite-difference staggered grid of non-uniformly sized rectangles, giving highly accurate results even with irregular grids. The use of irregular grids allows fast calculations because small cells can be limited to those near conductivity breaks.

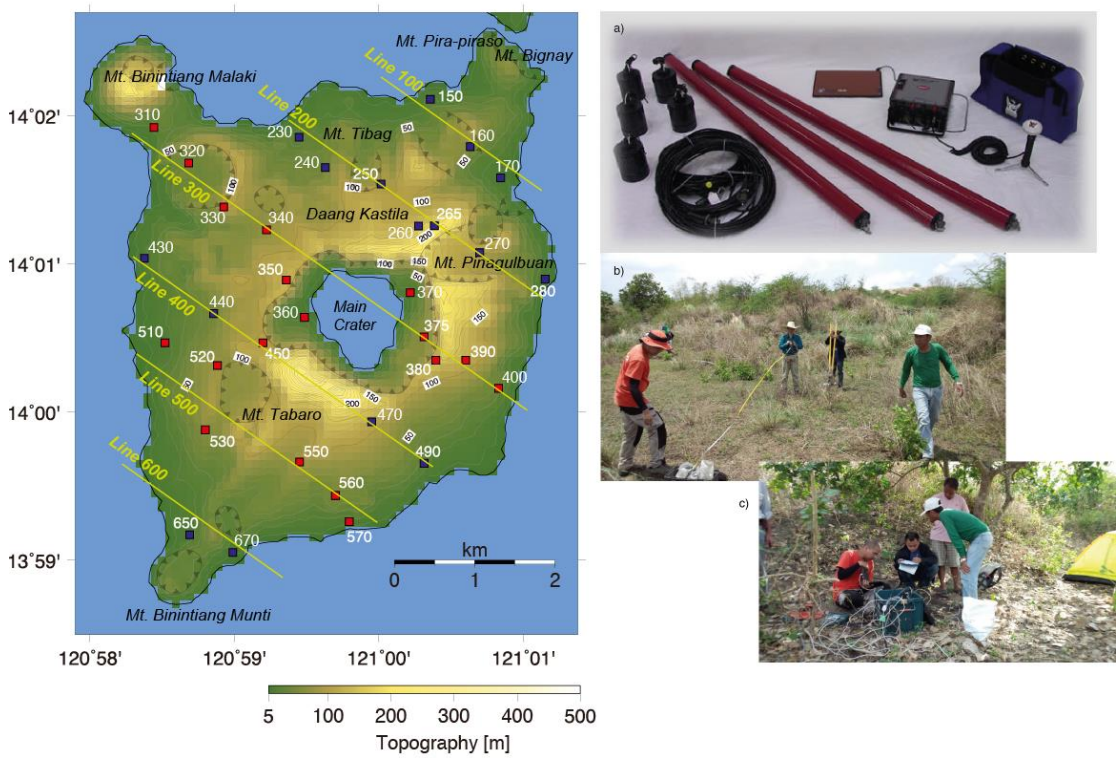

Fig. 2. Map of Taal Volcano showing MT stations occupied in 2011 (red squares) and 2012 (blue squares), sample picture of Phoenix Geophysics MTU-5 receiver and coils (a) and fieldwork photos (b and c).

3. Results and Conclusion

Modeling reveals a prominent and large zone of relatively high resistivity between 1 to 4 kilometers beneath the volcano almost directly beneath the Main Crater, surrounded by zones of relatively low resistivity (Fig. 3). This anomalous zone of high resistivity is hypothesized to be a large hydrothermal reservoir filled with volcanic fluids. The presence of this large hydrothermal reservoir could be related to past activities of Taal Volcano. In particular we believe that the catastrophic explosion described during the 1911 eruption was the result of the hydrothermal reservoir collapsing. During the cycle of Main Crater eruptions, this hydrothermal reservoir is depleted, while during a cycle of flank eruptions this reservoir is replenished with hydrothermal fluids.

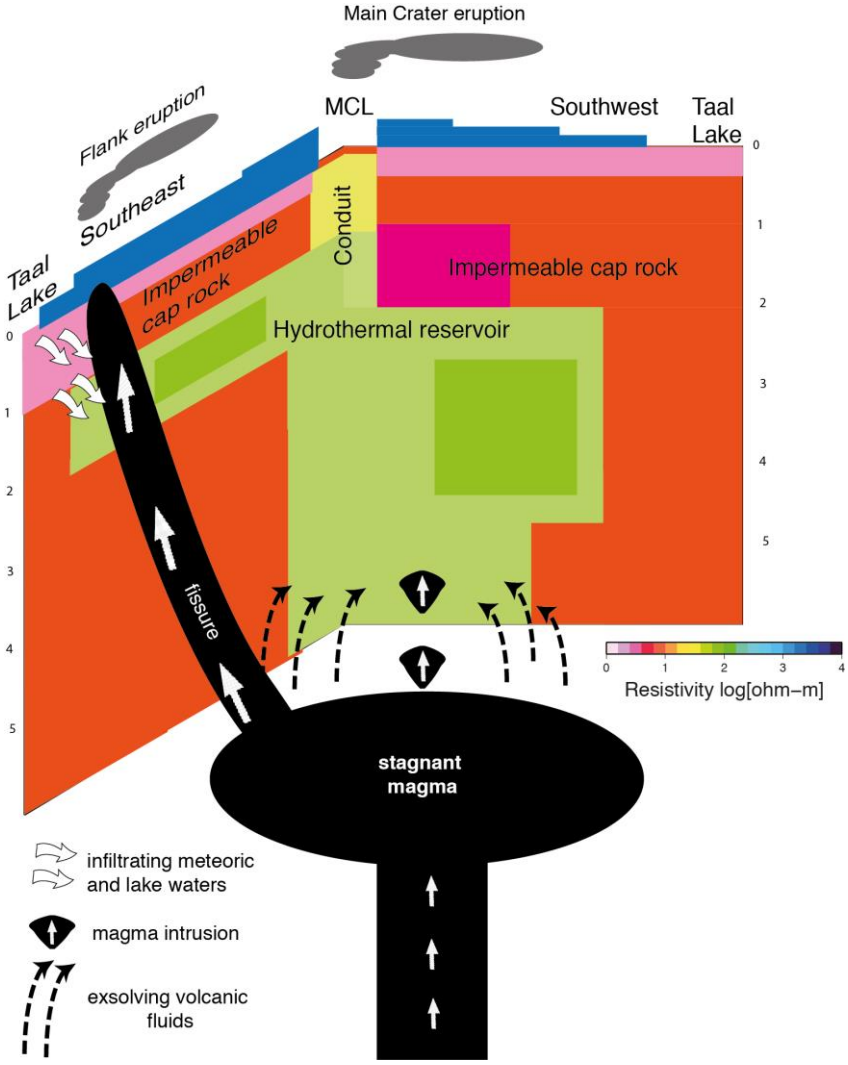

Fig. 3 Schematic diagram of the hydrothermal system beneath Taal Volcano.