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

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Located in the island of Luzon and 60 km south of the capital city of Manila, Taal Volcano is one of the most active volcanoes in the Philippines. The first recorded eruption was in 1573 and since then it has erupted a total of 33 times, with the last eruption in 1977. These eruptions resulted in thousands of casualties and considerable damage to property. In 1995 it was declared one of the '1990s decade volcano' by IAVCEI. Although the volcano remained fairly quiescent after the 1977 eruption, at the beginning of the 1990s it began to exhibit several phases of abnormal activities, such as episodes of seismic swarms, ground deformation and fissuring, and hydrothermal activities, all of which continues to the present. Examining past eruptions of Taal Volcano however, it has been observed that these can be divided into 2 distinct cycles, depending on the location of the eruption: eruptions centered at the Main Crater (1572-1645 and 1749-1911); and eruptions occurring at the flanks (1707-1731; 1965-1977).

We conducted (as part of the PHIVOLCS-JICA-SATREPS Project), magnetotelluric and audio-magnetotelluric surveys on Volcano Island, in March 2011 and March 2012. The objective of this survey was to create a resistivity model of the hydrothermal system beneath the volcano. Initial (2-D) inversion modeling revealed a prominent and large zone of relatively high resistivity between 1 to 4 kilometers beneath the volcano and almost directly beneath the Main Crater and surrounded by zones of relatively low resistivity. The anomalous zone of high resistivity is hypothesized to be a large hydrothermal reservoir filled with volcanic fluids in a gaseous phase. Three-dimensional forward modeling reveals the size of the reservoir to be as large as 3 km in diameter and between 1 km to 4 km in depth. This reservoir appears to be overlain by an impermeable cap, which exhibits a lower resistivity signature compared to the hydrothermal reservoir. Past eruptive activities of Taal Volcano (which are characterized by repeated changes in eruption sites, i.e. alternating between the Main Crater and the flanks and separated by long repose times), could be related to the presence of such a large hydrothermal. During the cycle of Main Crater eruptions, this hydrothermal reservoir is depleted, whereas during a cycle of flank eruptions this reservoir is replenished with hydrothermal fluids. In particular, the 1911 January 30 eruption showed an anomalous feature similar to a gas explosion, which can be attributed to the large hydrothermal reservoir collapsing catastrophically.

Keywords: hydrothermal reservoir, phreatic eruption, magnetotellurics, Taal Volcano