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Fault Zone Resistivity Structure and Monitoring at the Taiwan Chelungpu Drilling Project from AMT data

C.-w. Chiang (1), M. J. Unsworth (2), C.-s. Chen (1), C.-c. Chen (1), A.-t. Lin (1), and H.-l. Hsu (1)

(1) Inst. of Geophysics, National Central Unversity, Taiwan (R.O.C.)(93642006@cc.ncu.edu.tw), (2) Department of Physics, University of Alberta, Edmonton, Canada

The Chi-Chi earthquake occurred on September 21st, 1999 in the Western Foothills of central Taiwan. This Mw=7.6 earthquake produced a 90 km long surface rupture and caused severe damage across Taiwan. The coseismic displacement on the Chelungpu fault was one of the largest ever observed. The Taiwan Chelungpu drilling project (TCDP) began in 2003 and resulted in a 2,000 m well that recovered cores from the fault zone at A-hole and finished in 2005 with two boreholes (A-hole and B-hole) being completed. The Chelungpu fault that caused the Chi-Chi earthquake was observed in the core at a depth of 1,111 m (FAZ1111). Another fault zone (Sanyi Fault - FAZ1710) was observed at depths of 1,500∼1,710 m.

Since the electrical resistivity of rocks is sensitive to the presence of fluids, geophysical methods that remotely sense sub-surface resistivity, such as Magnetotellurics (MT), can be a powerful tool in investigating the fluid distribution in the shallow crust. The effectiveness of MT in imaging fault zones has been demonstrated by studies of the San Andreas Fault zone in California, the U.S. and elsewhere. In magnetotellurics, the depth of exploration increases as the signal frequency decreases. Thus for imaging shallow fault zone structure at the TCDP site, the higher frequency audio-magnetotelluric (AMT) method is the most suitable. In this paper, AMT data collected at the TCDP site from 2004 to 2006 are presented. Spatial and temporal variations are described and interpreted in terms of the tectonic setting.

Audio-magnetotelluric (AMT) measurements were used to investigate electrical resistivity structure at the TCDP site from 2004∼2006. These data show a geoelectric strike direction of N15ºE to N30ºE. Inversion and forward modeling of the AMT data were used to generate a 1-D resistivity model that has a prominent low resistivity zone (< 10 ohm-m) between depths of 1,100 and 1,500 m. When combined with porosity measurements, the AMT measurements imply that the ground water has a resistivity of 0.55 ohm-m at the depth of the fault zone.

Time variations in the measured AMT data were observed from 2004∼2005 with maximum changes of 43% in apparent resistivity and 18° in phase. The change in apparent resistivity is greatest in the 1,000∼100 Hz frequency band. These frequencies are sensitive to the resistivity structure of the upper 500 m of the hanging wall of the Chelungpu Fault. The decrease in resistivity over time appears to be robust and could be caused by an increase in porosity and a re-distribution of the groundwater.