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GPR investigation of the near-surface geology in a geothermal river valley using contemporary data decomposition techniques with forward simulation modeling

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ABSTRACT

Although geophysical studies on the geothermal field are in favor of deep structures, the shallow investigations are needed for understanding the local hydrological regime and assessing environmental compliance when setting up a geothermal power plant. We demonstrate the possibility of investigating the shallow structure of a complex site of the geothermal valley located at Chingshui, northeast Taiwan by using the ground penetrating radar (GPR) with advanced data processing techniques. Taking the challenging topography into account, the low frequency (50 MHz) unshielded bistatic GPR antennas were transported above the ground to prevent from submerging in water and avoid the surface obstacles. Two newly developed data processing techniques, the multidimensional ensemble empirical mode decomposition (MDEEMD) and multivariate empirical mode decomposition (MEMD), with the Hilbert-Huang spectrogram analysis were applied to the data. For each survey line, an initial subsurface layer model was generated by referring to the processed field data, and the finalized subsurface layer model accompanying the synthetic GPR profile were obtained with the aid of the finite difference time domain (FDTD) numerical simulation modeling. The results of this study suggest that the undulation reflections shown in each survey line are folding structures extending from the cliff edge, and that no evidence of fault traces near the surface is found. Apart from the geological findings, we believe that the field technique in conjunction with the proposed data processing method can overcome the topographic difficulties of the geothermal field and may provide better subsurface image of an area with poor GPR reflection quality.
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1. Introduction

Chingshui is a small mountain village located in the metamorphic terrains of northeast Taiwan where numerous non-volcanic thermal springs are found. It has long been proposed that geothermal reservoirs could be developed in the area (Chiang et al., 1979) because Chingshui is within an active seismic zone of the Taiwan mountain belt which was formed by the collision of the Philippine Sea plate and the Eurasian plate around the rim of western Pacific marginal basins (Jolivet et al., 1989). Starting from early 1970s, a series of geological, geochemical, and geophysical surveys along with the initial design of the geothermal power generator have been conducted in the Chihgshui area (Lee, 1994; Su, 1978) by Industrial Technology Research Institute (ITRI) and Chinese Petroleum Company (CPC) for researching and developing the geothermal industry in Taiwan (Lee, 1994; Mao and Chan, 2006). Most of the geophysical investigations in the Chingshui area focused on the deep structure of geothermal reservoirs. For example, magnetic, magnetotelluric, gravity (Lee, 1994) and seismic (Lin and Yeh, 2001) surveys have been carried out for that purpose. Before conducting the deep exploration, some shallower structure surveys like resistivity (Cheng and Lee, 1977) and electromagnetic (Chiang and Liu, 1983) had been attempted as well for understanding geothermal fluids distribution. The first experimental geothermal power generator of 1.5 MW was established in this area in 1976. Five years later, the second geothermal power generator of 3 MW was commissioned; therefore, a total of 4.5 MW power generation capacity in the Chingshui geothermal power plant was installed by 1981 (Mao and Chan, 2006). Although the tectonic setting of Taiwan and geothermal outcrops found in the locality of Chingshui indicate that this area has the potential to generate sustainable electric power, the Chingshui geothermal power project was terminated in 1993 due to the rapid decline in geothermal well productivity caused by technical difficulties. The reasons were

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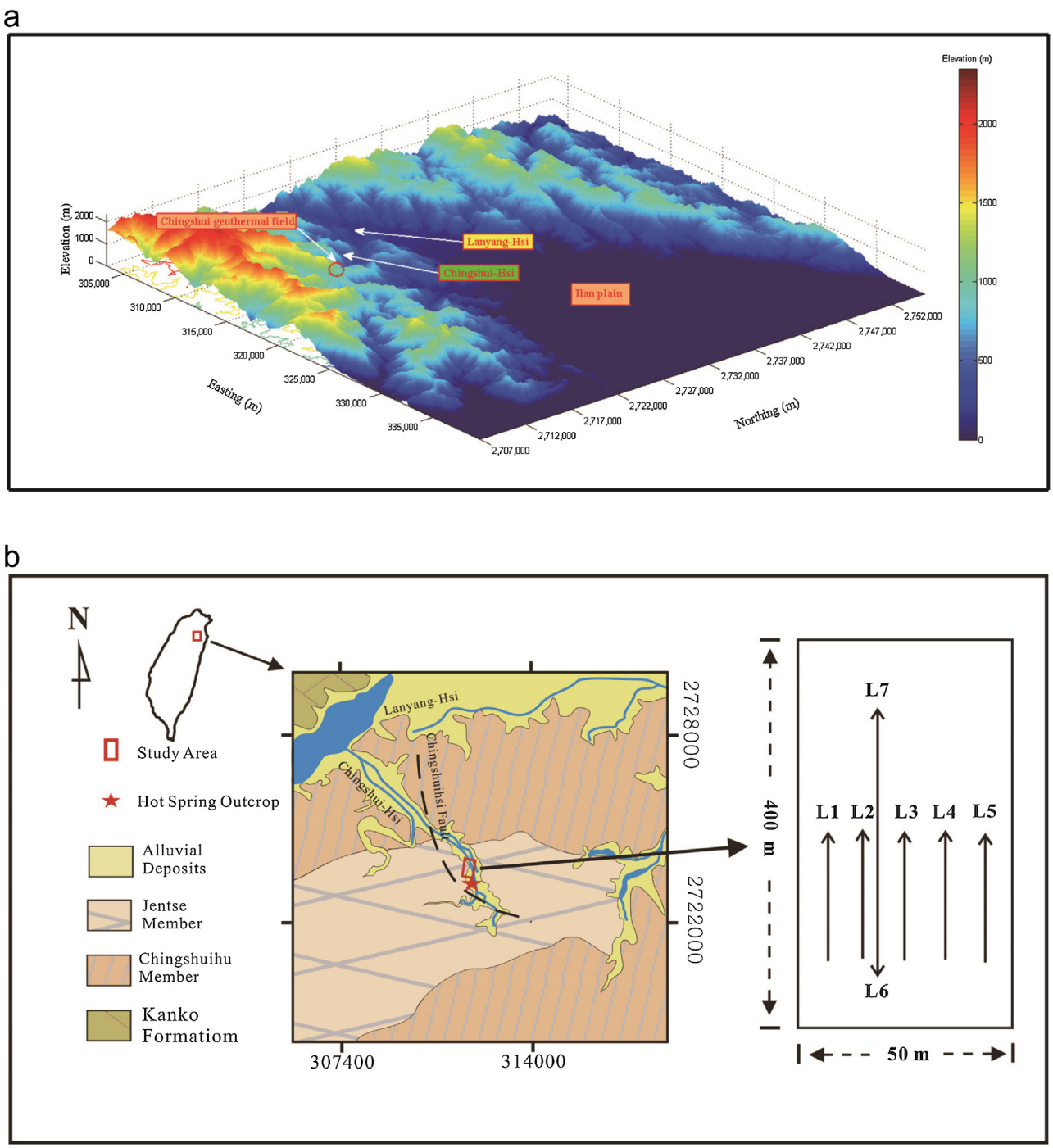

Fig. 1. Chingshui geothermal field and the survey site. (a) Shaded topographic map showing a part of northeast Taiwan and the Chingshui geothermal field. The study site is located in the valley of Chingshui-Hsi. (b) Detailed map (modified from Lin and Lin, 1995) showing locations of the hot spring outcrop and the GPR survey site. The map is a Transverse Mercator 2° projection (TM2) with scale in meters. A map view sketch of GPR survey lines is shown on the right.

scale deposits of silica and calcium carbonates which drastically dropped the geothermal fluids deliverability in the first three years after operation (Mao and Chan, 2006) and no re-injection of spent geothermal fluids (geothermal steam, gases, and liquid) was undertaken (Bronicki, 1991; Fan et al., 2005).

Influenced by the growing public opinion on developing alternative energy sources rather than expanding conventional and nuclear energy, the Chingshui experimental geothermal power plant was restored in 2005 and rehabilitated as a small 50 KW community geothermal power plant waiting for further development. At the same time geothermal exploration in the Chingshui area was initiated in accordance for assessing the reservoir storativity and the construction of new geothermal power plants. To evaluate the geological safety and environmental compliance for building up a substantial geothermal power plant, the near-surface structures are as important as the deep structures. However, an extensive environmental investigation has not been undertaken before, and the shallow structure is not well characterized because of the complexity of the geology in this area.

In this study, we demonstrate an example of using a near-surface geophysical survey, ground penetrating radar (GPR), to investigate a site in the Chingshui geothermal field where the geology and

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