Magnetotelluric evidence for thick-skinned tectonics in central Taiwan

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ABSTRACT

Taiwan is the type example of an arc-continent collision. Numerous tectonic models have been proposed for this orogen, and include both thin-skinned and thick-skinned lithospheric deformation. These models predict very different structures at middle and lower crustal depths, but insufficient geophysical data exist to unequivocally distinguish between them. Long-period magnetotelluric (MT) data were collected in central Taiwan in 2006–2007 to constrain the crustal resistivity structure. A two-dimensional inversion of these MT data revealed a prominent electrical conductor that extends across the décollement predicted by the thin-skinned model. This feature is interpreted to be due to 1%–2% saline fluids, and is inconsistent with the thin-skinned model. In contrast, the thick-skinned model predicts this feature since fluids are generated in the crustal root through metamorphism. Quantitative correlation of the resistivity and seismic velocity models supports small-volume, high-salinity fluids in a thickened crust as the cause of this conductor.

INTRODUCTION

Arc-continent collisions are a fundamental tectonic process and contribute to continental growth. In ancient collisions, postorogenic geological events obscure the orogenic processes, thus studies of active collisions are needed. The oblique convergence between the Luzon Volcanic Arc and the passive margin of the Eurasian plate represents the best example of an active arc-continent collision. Since the late Miocene, convergence has produced a mature orogen in northern Taiwan, the collision becoming younger to the south (Byrne and Liu, 2002). Several models have been proposed to explain the collision tectonics of central Taiwan, and these models form a spectrum between two end members: (1) thin-skinned tectonics, and (2) thick-skinned lithospheric deformation.

In the thin-skinned model, a shallow décollement dips east within the upper continental crust. Deformation is localized above this surface while the Eurasian continental lithosphere subducts below. The thin-skinned model was motivated by geological and shallow seismic exploration in the Western Foothills fold-and-thrust belt (Suppe, 1981). Near-surface deformation in the Western Foothills (Yue et al., 2005) and surface heat flow (Bahr and Dahlen, 1990) are consistent with predictions from critical wedge theory employing a shallow décollement. In addition, earthquake hypocenters have been moved under certain assumptions to infer that a band of seismicity exists at 8–10 km depth from the Western Foothills to the Coastal Range, which is interpreted to be the décollement (Carena et al., 2002).

In contrast, the thick-skinned model predicts continuous deformation throughout the lithosphere, with prograde metamorphism occurring within a thickened crust beneath the Central Ranges (Wu et al., 1997). This model is supported by observation of a crustal root in seismic tomography models (Wu et al., 2007) and by precisely relocated hypocenters (Wu et al., 2004). Receiver function analysis (Kim et al., 2004), TAICRUST active source seismic data (McIntosh et al., 2005), shear wave splitting (Rau et al., 2000), and gravity data (Yen et al., 1998) also support the thick-skinned model.

Existing geophysical data could not distinguish between these end-member models beneath the Central Ranges, thus additional data were needed. As part of the Taiwan Integrated Geodynamics Research (TAIGER) project, the first long-period (10–10000 s) MT data were collected in Taiwan. MT measurements image subsurface electrical resistivity and can provide constraints on lithospheric composition and strength (Unsworth et al., 2005). This paper describes the collection and interpretation of the TAIGER MT data in central Taiwan.

MAGNETOTELLURIC DATA COLLECTION AND ANALYSIS

MT measurements use natural electromagnetic (EM) fields to image subsurface resistivity structure. The penetration depth of these signals increases with period (Simpson and Bahr, 2005). In 2006–2007, long-period MT data were recorded at 21 stations in central Taiwan and at a remote reference station on the Penghu archipelago to reduce cultural EM noise (Fig. 1). The study area is located in a region of complex geology and
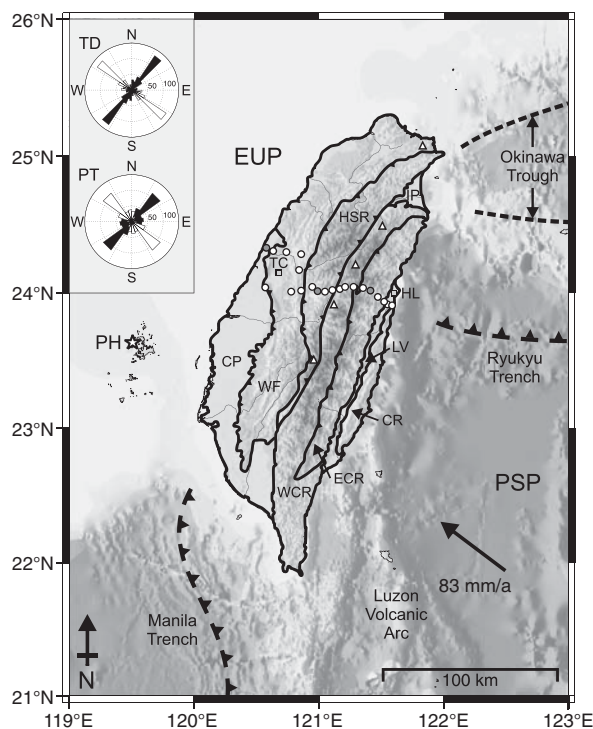

Figure 1. Regional geologic and tectonic map of Taiwan. White circles denote long-period magnetotelluric stations; gray circles indicate where only magnetic field data were analyzed; white triangles show locations of Au-Cu deposits. Star marks remote reference station on Penghu (PH) archipelago. EUP—Eurasian plate; PSP—Philippine Sea plate. Geological provinces: CP—Coastal Plain; WF—Western Foothills; HSR—Hseuhshan Range; WCR—West Central Range; ECR—East Central Range; LV—Longitudinal Valley; CR—Coastal Range; IP—Ilan Plain. Cities: TC—Taichung; HL—Hualien. Rose diagrams show geoelectric strike direction computed from tensor decomposition (TD) and phase tensor (PT) analysis for periods 10–3000 s. Black and white sectors are equivalent, as there is inherent 90° ambiguity in strike direction determined by these methods.