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Imaging the ramp–décollement geometry of the Chelungpu fault using coseismic GPS displacements from the 1999 Chi-Chi, Taiwan earthquake

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Abstract

We use coseismic GPS data from the 1999 Chi-Chi, Taiwan earthquake to estimate the subsurface shape of the Chelungpu fault that ruptured during the earthquake. Studies prior to the earthquake suggest a ramp–décollement geometry for the Chelungpu fault, yet many finite source inversions using GPS and seismic data assume slip occurred on the down-dip extension of the Chelungpu ramp, rather than on a sub-horizontal décollement. We test whether slip occurred on the décollement or the down-dip extension of the ramp using well-established methods of inverting GPS data for geometry and slip on faults represented as elastic dislocations. We find that a significant portion of the coseismic slip did indeed occur on a sub-horizontal décollement located at f 8 km depth. The slip on the décollement contributes 21% of the total modeled moment release. We estimate the fault geometry assuming several different models for the distribution of elastic properties in the earth: homogeneous, layered, and layered with lateral material contrast across the fault. It is shown, however, that heterogeneity has little influence on our estimated fault geometry. We also investigate several competing interpretations of deformation within the E/W trending rupture zone at the northern end of the 1999 ground ruptures. We demonstrate that the GPS data require a 22- to 35-km-long lateral ramp at the northern end, contradicting other investigations that propose deformation is concentrated within 10 km of the Chelungpu fault. Lastly, we propose a simple tectonic model for the development of the lateral ramp.

Keywords: Décollement; GPS; Taiwan; Geodetic inversion; Fault slip

1. Introduction

The 1999 Chi-Chi, Taiwan earthquake ($M_w = 7.6$) nucleated at 8–10 km depth and propagated to the surface generating 100 km of ground rupture, extending 80 km north/south from Chushan to Fengyuan and 20 km east/west from Fengyuan to Shuangchi (Fig. 1; Kao et al., 2000). The 80-km Chushan–Fengyuan section ruptured part of the previously recognized Chelungpu fault. Surface features such as ground ruptures and folding along this segment are consistent with reverse/left-lateral fault dipping f 30j east. The ground ruptures deviate from the trend of the Chelungpu fault at the northern end in the east/west Fengyuan–Shuangchi section where rupture occurred in a 3-km-wide zone consisting of six segments of north and south dipping reverse faults.

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