Seismogenic Structures in Chiayi: Deduced from 1999 M_L 6.4 Earthquake Sequences

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ABSTRACT

There were 475 earthquakes including the main shock and aftershocks in ten days since the Chiayi earthquake that happened on October 22nd 1999. For the purpose of understanding the regional structure framework this study analyzed not only this earthquake sequence but also the background seismicities from 1990 to 2004. All above-mentioned earthquakes are processed by the Double difference (hypoDD) method and then used GOCAD (3-D modeling software) to identify the seismogenic structures, and then create the regional structure model. Focal mechanisms of larger earthquakes (ML > 4) are used to recognize the faulting behavior. On the other hand, we separately reconstruct structural model based on available subsurface and surface geological data. By comparison, we found the seismogenic faults are closely related to the previously reported active faults including the blind ones.

Three major fault planes (FP1, FP2, and FP3) are presented in the study area. Eight earthquakes, i.e., the main shock and seven aftershocks (ML > 4) located on the first fault plane (FP1), all show focal mechanisms of reverse faulting and a nodal plane parallel to the fault plane. The aftershocks distributed in the northern study area allow us further identify another nearly vertical fault plane (FP2), in which five focal solutions indicate pure strike-slip. Since the main shock is located at the bottom of the FP1, we therefore interpret that the main shock caused by rupturing on the FP1 and simultaneously triggered not only aftershocks on the FP1, but also the other strike-slip fault (FP2) in the north. By the background seismicities we further allocate two detachments in the study area. The 1999 main shock just occurred on the lower detachment, and the earthquake sequence extends upward to the upper
detachment. Judging from the spatial relationships of the subsurface structures the Hsiaomei Anticline may be related to the fault-bend developed on the upper detachment, which is caused by the actions of FP1 and FP3.

INTRODUCTION

Taiwan is located at the boundary between the Eurasian plate and the Philippine Sea plate. Since 5-6 Myr ago, the mountain ranges of central Taiwan started to form as a result of the collision that the underplating Luzon arc is carried by the Philippine Sea plate and collided with the eastern margin the Eurasian plate. Plate convergence presently is still moving at a rate of ~80 mm/yr along an azimuth close to 306° and keeping producing intense strain in the Taiwan island as shown by GPS geodetic measurements. The structure of the entire mountain range has long been recognized as a crustal scale accretionary prism composed of major east dipping thrust faults. Active deformation is partly accommodated by thrusting along the fold-and-thrust belt that forms the Western Foothills of western Taiwan and by strike-slip and thrust faulting along the Longitudinal Valley fault, in the eastern of Taiwan. Settings mentioned above bring dense and frequent earthquakes to the island. Because of the predominance of thrust faults, shallow-sourced earthquakes are common in western Taiwan, generating severe disasters once an earthquake strikes.

Although large earthquakes are always dangers to everyone and everything, they sometimes let us understand more about the subsurface geology. In general, large earthquake usually occurs at a transformation point of the geologic structures. By surface observation and shallow seismic profile, scientists only can reconstruct structures in the upper crust, usually <5 km in depth. To the deeper depth, utilizing the seismicities record is one of the possible ways, which can help us extend the shallow structures and comprehend the mechanism of the surface deformation, especially in a fold-and-thrust belt. Actually, this study combines the results from background seismicities as well as the Chiayi earthquake sequence. There are two major seismicity clusters are identified in the Chiayi earthquake sequence. One is the already known strike-slip fault (FP2), which may be the subsurface extension of the 1906 Meishan earthquake rupture. Another one is a completely unexpected reverse fault (FP1) dipping westward. The background seismicites further present three fault planes: FP3, DT1, and DT2. DT1 and DT2 denote lower and upper regional detachments respectively. FP3 is located above the DT2 also dipping to the west. Although its sense and orientation are both similar to the FP1 but in fact no seismic cluster connects FP1 and FP3. In between DT1 and DT2 the seismicities are dominated by the earthquakes created by the strike-slip FP2, which is located in the northern boundary of the study area. However, we still interpret the bend developed
on DT2 is caused by mass brought up by FP1 and further generated FP3 from DT2 upwards. Spatially the FP3 is responsible to the development of Hsiaomei anticline.

Before 1999 Chiayi earthquake, scientists thought that there are only one EW strike-slip fault (i.e., MSF) and two NS thrust faults (i.e., CCKF and CKF) as major seismogenic sources where large earthquake could occur. This study presents more possibilities: The back-thrust system (FP1 and FP3) and their related detachment bends (on DT1 and DT2) are all seismogenic asperities in the entire fault network. We believe other hidden sources will be found out if we could retrieve more information of subsurface geology related to the upper thrust system and the burial pre-existing normal fault system from nature earthquake or new geophysical exploration.

References


Figure 1
The green star is the mainshock of the Chiayi earthquake sequence. (A) Epicenter distribution of the 1999 Chiayi earthquake sequence. (B) Relocated distribution after Double difference (hypoDD) method with beach ball showing the focal mechanisms of larger earthquakes. (C) E-W profile showing the hypocenter distribution in depth. (D) E-W profile showing relocated (hypoDD) hypocenters.
Figure 2
(a) AA’ profile from Figure 1 shows the upper crust geological structures reconstructed by the surface and subsurface geology (CPC, 1982; Yang et al., 2001), and also shown are the identified fault planes (FP1, FP2, and FP3, DT1, and DT2).
(b) E-W profile shows the relocated background seismicities. FP1, FP3, DT1, and DT2 can be clearly identified by clusters.