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Fault-Zone Seismic Monitoring by the Borehole Seismometer Arrays in Taiwan

Yen-Yu Lin
National Central University, Taiwan

The Mw 7.6 Chi-Chi earthquake occurred at the Chi-Chi Township, Nantou County in central Taiwan in 1999. The main rupture fault of the earthquake was the Chelungpu fault with an 80-km-length surface rupture. The maximum coseismic slip was approximately 12 m in the northern part of the Chelungpu fault near the Shigang Township, Taichung County. Such large coseismic slips seriously damaged buildings, structures, and life-support systems resulting in two thousand people died, ten thousand injured, as well as economic losses over three hundred and sixty billion New Taiwan dollars. After the earthquake, a research group, including National Central University, National Taiwan University, Academia Sinica, and other international institutes, initiated a scientific drilling project, called the Taiwan Chelungpu-fault Drilling Project (TCDP), that drilled through the main rupture fault at a depth of 1111 m at the Dakeng Town in the northern part of Chelungpu fault (Figure 1). The fault gouges from the main slip zone are only 2 cm on the bottom of a 12-cm facture zone (Figure 1c) implying that earthquakes similar to the Chi-Chi event keep repeating with a temporal interval of ~400 years (Ma et al., 2006). After the drilling, the group deployed a seven-level borehole seismometer array at depths from 946 to 1274 m to monitor seismic activity on the Chelungpu fault during an interseismic period (Figure 2). The results indicate that no microearthquakes occurred near the main fault zone, suggesting that the Chelungpu fault is fully locked due to a complete stress release process on the fault in the Chi-Chi earthquake (Lin et al., 2012). In the meanwhile, the research group discovered a special kind of earthquakes which has P wave only, called “isotropic event”. They conclude that the occurrence of the events can be explained by overpressurized fluid flow below the recent slipped zone, which is capped by the impermeable slip zone. (Ma et al., 2012). Moreover, the fault zone structures (i.e., attenuation and anisotropic) were studied based on the seismic records from the borehole seismometer array (Wang et al., 2012; Hung et al., 2022). The TCDP borehole seismometer array indeed had great contribution in the fault-zone monitoring and benefited earthquake research society in the past two decades. Based on the experience from the TCDP borehole seismometer array, we deployed a new generation system for monitoring another active fault, the Milun fault near Hualien City, slipped in the 2018 M 6.3 Hualien earthquake. The system contains not only borehole seismometer arrays, but a distributed acoustic sensing system with high spatial resolution of 4 m (Figure 3). We believe the combined systems are able to discover new and special seismic and fault-zone observations occurring on/near an active fault.

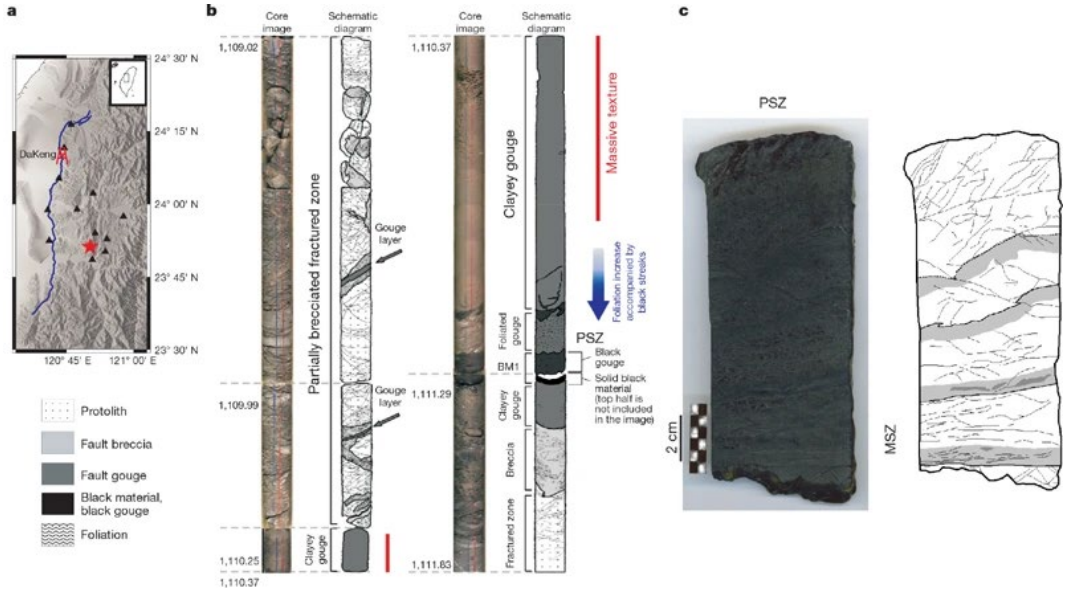

Figure 1. (a) The location of the drill site at the town DaKeng and the ruptured Chelungpu fault (bold blue line). (b) The core image and schematic diagram of hole A with descriptive comments. (c) An enlarged photo of the splitting and polishing slab of the 12-cm principal slip zone with its schematic. The bottom layer with the less-deformed slip zone is the major slip zone related to the 1999 Chi-Chi earthquake. (Ma et al., 2006)

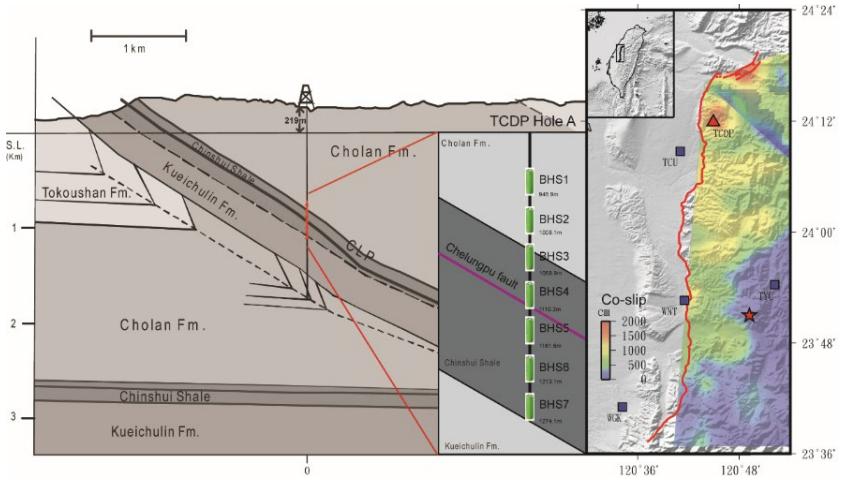

Figure 2. The layout of the TCDP borehole seismometer array. It is located close to the surface trace of the Chelungpu-fault (red line) and in the region with largest coseismic slip of 12 m. The seven sensors are located in a depth from 946 to 1274m with 50–60-m-depth intervals. (Lin et al., 2012)

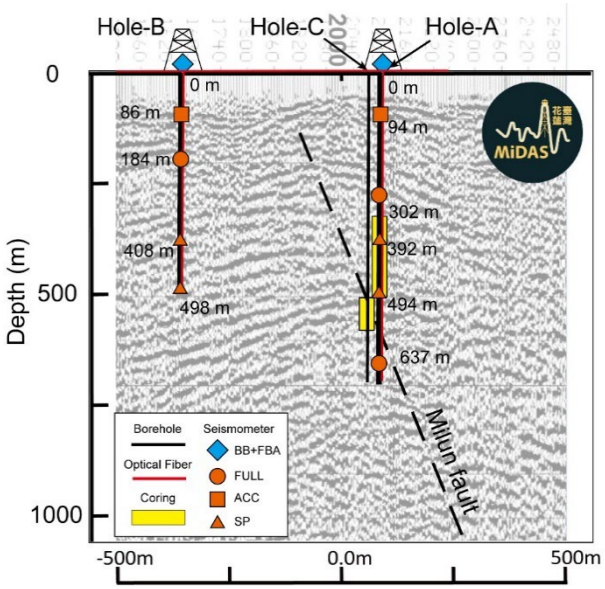

Figure 3. The layout of the combination of two borehole seismometer arrays and a distributed acoustic sensing system for monitoring seismic activities in the Milun fault in Hualien.

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