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Characterization of slip zone associated with the 1999 Taiwan Chi-Chi earthquake: X-ray CT image analyses and microstructural observations of the Taiwan Chelungpu fault

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Abstract

To characterize the fault-related rocks within the Chelungpu fault, we performed X-ray computed tomography (CT) image analyses and microstructural observations of Hole B core samples from the Taiwan Chelungpu-fault Drilling Project. We identified the slip zone associated with the 1999 Chi-Chi earthquake, within the black gouge zone in the shallowest major fault zone, by comparison with previous reports. The slip zone was characterized by low CT number, cataclastic (or ultracataclastic) texture, and high possibility to have experienced a mechanically fluidized state. Taking these characteristics and previous reports of frictional heating in the slip zone into consideration, we suggested that thermal pressurization was the most likely dynamic weakening mechanism during the earthquake.

Keywords: Chelungpu fault; Chi-Chi earthquake; X-ray CT; Microstructure; Fault zone

1. Introduction

The Taiwan Chi-Chi earthquake (Mw 7.6; epicenter, 23.853 °N, 120.816 °E; focal depth, 8 km) occurred on 21 September 1999 (Ma et al., 1999) (Fig. 1). The earthquake initiated on the southern Chelungpu fault and ruptured both upward and laterally northward (Chen et al., 2001; Kikuchi et al., 2000; Ma et al., 2000). This earthquake was well recorded by a dense seismic observatory network (Taiwan Strong Motion Network) operated by the Central Weather Bureau (Shin et al., 2000). The stations near the northern end of the Chelungpu fault recorded the largest ground velocities and displacements, up to 3 m/s and 8 m, respectively (Shin and Teng, 2001). In contrast, ground accelerations were higher along the southern part of the fault, even though the ground velocities and fault displacements there were less than in the north. Ma et al. (2003) attributed the low level of high-frequency radiation to an elasto-hydrodynamic lubrication-type slip mechanism, in which increased lubrication pressure widened the gap between the fault surfaces, thereby reducing the areas of asperities in contact and decreasing the level of high-frequency radiations. Andrews (2005), however, proposed that the high slip velocity and large

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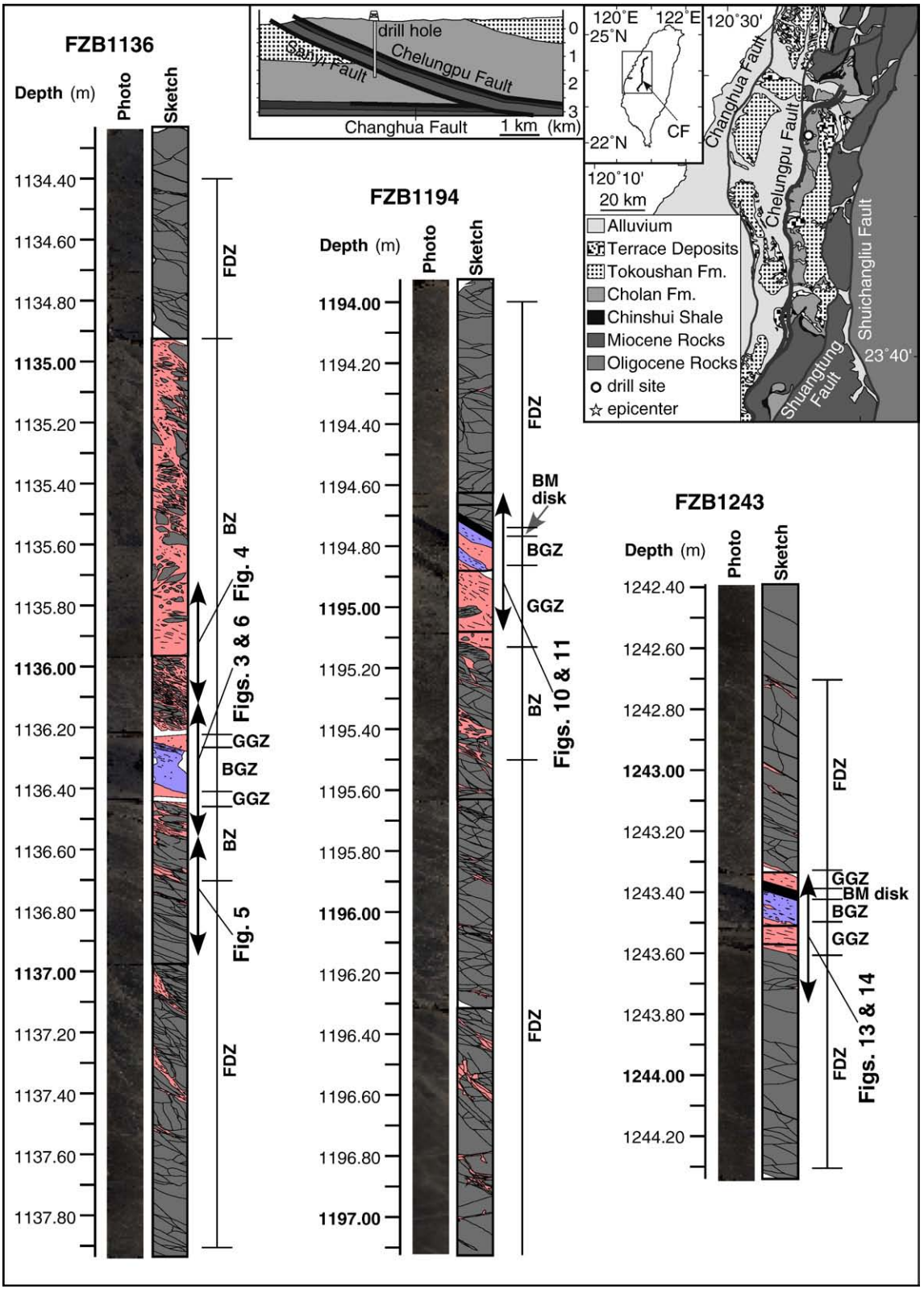

Fig. 1. Location of the Chelungpu fault with geological map, an E–W cross section through drilling site location, and fault zone architectures of three major fault zones (FZB1136, FZB1194, and FZB1243) in TCDP Hole B. CF, Chelungpu Fault; FDZ, fracture-damaged zone; BZ, breccia zone; GGZ, gray gouge zone; BGZ, black gouge zone; BM disk, disk-shaped black material.

displacement resulted from thermal pressurization, by means of which fluid pressure generated by shear-related heating reduced the fault strength during seismic slip.

The 2002 Taiwan Chelungpu-fault Drilling Project (TCDP) was undertaken to investigate the faulting mechanism of the 1999 Chi-Chi earthquake. One of the main aims of TCDP was