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Response of seismicity to Coulomb stress triggers and shadows of the 1999 $M_w = 7.6$ Chi-Chi, Taiwan, earthquake

Kuo-Fong Ma and Chung-Han Chan
Institute of Geophysics, National Central University, Chung-Li, Taiwan

Ross S. Stein
U.S. Geological Survey, Menlo Park, California, USA

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[1] The correlation between static Coulomb stress increases and aftershocks has thus far provided the strongest evidence that stress changes promote seismicity, a correlation that the Chi-Chi earthquake well exhibits. Several studies have deepened the argument by resolving stress changes on aftershock focal mechanisms, which removes the assumption that the aftershocks are optimally oriented for failure. Here one compares the percentage of planes on which failure is promoted after the main shock relative to the percentage beforehand. For Chi-Chi we find a 28% increase for thrust and an 18% increase for strike-slip mechanisms, commensurate with increases reported for other large main shocks. However, perhaps the chief criticism of static stress triggering is the difficulty in observing predicted seismicity rate decreases in the stress shadows, or sites of Coulomb stress decrease. Detection of sustained drops in seismicity rate demands a long catalog with a low magnitude of completeness and a high seismicity rate, conditions that are met at Chi-Chi. We find four lobes with statistically significant seismicity rate declines of 40–90% for 50 months, and they coincide with the stress shadows calculated for strike-slip faults, the dominant faulting mechanism. The rate drops are evident in uniform cell calculations, 100-month time series, and by visual inspection of the M 3 seismicity. An additional reason why detection of such declines has proven so rare emerges from this study: there is a widespread increase in seismicity rate during the first 3 months after Chi-Chi, and perhaps many other main shocks, that might be associated with a different mechanism.

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1. Introduction

[2] Advocates of static stress transfer argue that aftershocks and subsequent main shocks often occur in regions that experienced an increase in Coulomb stress caused by the main shock, and that earthquakes become less prevalent than before the main shock in regions subject to a Coulomb stress drop (see reviews by Harris [1998], Stein [1999], and King and Cocco [2001]). Most work on this hypothesis has concentrated on strike-slip main shocks, whose stress change does not vary greatly with depth. For thrust faulting, the stress change is depth-dependent [Lin and Stein, 2004], and thus the downdip geometry and slip of the source fault, and the depth of aftershocks become essential to Coulomb analysis. The 20 September 1999 $M_w = 7.6$ Chi-Chi, Taiwan, earthquake on the Chelungpu fault is probably the world's best recorded continental thrust event, with well determined spatial slip models from seismic, strong motion, and geodetic data. Equally important for this study, background seismicity and aftershock sequence are also recorded in unprecedented detail (Figure 1), making it ideal for investigation.

[3] Several studies [e.g., Ma et al., 2001; Zeng and Chen, 2001; Chi et al., 2001; Ji et al., 2003] have illuminated the kinematics of the Chi-Chi rupture process. Results of these studies show consistent features, with high slip in the northern portion of the fault. Aftershocks, recorded by the Central Weather Bureau Seismographic Network (CWBSN), are widely distributed over central Taiwan. During the first month after the main shock, nine $M > 6.0$ aftershocks occurred near the source region of the main shock, yielding more disastrous damage, and providing a further data set for stress transfer analysis.

[4] Using the detailed spatial slip distribution of the Chi-Chi earthquake source, we calculated the Coulomb stress changes following Toda et al. [1998], which we compare to the seismicity rate changes derived from the 100-month seismic record centered on the main shock. We place particular emphasis on the response of seismicity to the broad lobes of calculated stress increase (the trigger zones), and stress decrease (the stress shadows), and on whether the

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