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STUDIES OF FAULT FABRICS AND EARTHQUAKE MECHANICS FROM PRECISE RELATIVE LOCATIONS OF MICROEARTHQUAKES

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TECHNICAL ABSTRACT

Using a waveform cross-correlation technique, we obtained precise relative locations for over 10,000 microearthquakes from central California. The relocated catalogs were used as the primary data sources for studies of both fault structure and earthquake interaction. In the study of fault structure, 2700 earthquakes (primarily aftershocks) in the vicinity of the 1986 M=5.7 Mt. Lewis, California earthquake were relocated. While the aftershocks appear to be concentrated along the north-south extension of this right-lateral mainshock, the relocation demonstrates that they actually define "wedge-shaped" regions (narrower near the ends of the mainshock) of closely-spaced, east-west left-lateral "bookshelf" faults. We interpret these faults as comprising the "process zone" of the Mt. Lewis mainshock fault as it grows along strike. The rough symmetry of these bookshelf faults across the Mt. Lewis mainshock fault is suggestive of moderate-to-low friction values, providing a counter-example to the claim that immature faults have high friction. This study also highlights the importance of knowing which nodal plane of the focal mechanism solution corresponds to the actual fault plane, when conducting studies of fault stress transfer. In the study of earthquake interaction, we stacked the aftershock sequences of the microearthquakes in the relocated catalogs to compute a "composite" aftershock sequence, to compare aftershock rates in various distance ranges (normalized by mainshock magnitude) to the predictions of rate-and-state fault friction models. The resulting seismicity rates show many of the expected features, including a nearly constant value at long time intervals, a roughly 1/time decay for the bulk of the aftershock sequence, an aftershock duration that is independent of stress step (normalized distance from the mainshock), and a peak rate at early times that increases with stress step. Along the San Andreas fault the microearthquake aftershock duration is roughly 100 days. By projecting the aftershocks onto the fault plane, it is found that the typical mainshock is elongate in the slip-parallel (mode-II) direction by several tens of percent, a result that can be rationalized by the larger stresses beyond the mode-II ends of a static circular shear crack. An important component of this work was to improve location accuracy by obtaining time-dependent station corrections for roughly 75 NCSN stations. Most of the largest changes appear to be due to changing station electronics. These time-dependent corrections will be made available to anyone who requests them.

NON-TECHNICAL ABSTRACT

Small earthquakes that have similar focal mechanisms and locations produce ground displacements at a given seismic station that appear very similar. By cross-correlating the seismic waveforms of such similar events, it is possible to obtain relative earthquake locations with errors that are only meters to tens of meters for events separated by tens to hundreds of meters. These errors are between 10 and 100 times smaller than those typical of the original catalog. The precise locations enable one to observe fine-scale details of fault-zone structure that were previously obscured by location error. In addition, because the errors in relative location are considerably smaller than the event sizes (more than tens of meters for magnitude >1 earthquakes), one can use large relocated earthquake catalogs to study earthquake interaction, a process of importance to earthquake forecasting. By relocating aftershocks of the 1986 magnitude 5.7 Mt. Lewis, California, earthquake, we find that rather than lying along the extension of the mainshock fault plane, the earthquakes define wedge-shape regions of narrowly-spaced faults perpendicular to the mainshock. We interpret this structure as a "snapshot" during the growth of the fault that produced the Mt. Lewis mainshock. By stacking the aftershock sequences of thousands of microearthquakes along the San Andreas fault, we find that typical microearthquakes are elongate in the direction of slip, a result that can be compared to models of earthquake rupture. In addition, we find that the microearthquake aftershock rates are generally consistent with current models of aftershock production, but show important differences between faults that may reflect differences in the underlying physical properties of the faults. Such results are important because it is difficult to measure fault properties outside of the laboratory. Finally, we have improved the relocation technique by accounting for small changes in seismic station operation asociated with changing the station electronics. Such changes become visible only because of the increased accuracy afforded by the cross-correlation technique, a result with important lessons for future network operation.