Chapter 5

Conclusions

Differ from previously discovered repeating events that occurred on the plate boundary interface such as the SAF and Japan subduction zone, we have found repeating earthquakes on a thrust fault zone in the arc-continent collision boundary of eastern Taiwan. This fault zone slips at the surface with a high rate of 1-3 cm/yr and slips in large earthquakes (ten $M > 7+$ earthquake since 1900). To improve seismic hazard assessment, it is important to know how the slip rate observed at the surface is related to the fault slip rate at depth. The recently discovered repeating earthquakes in eastern Taiwan offer a new insight into deep fault behavior.

In eastern Taiwan, two major RESs clusters are found near the north and south ends of the LVF, with highly variable recurrence patterns. The 25 M 2.3 - 4.6 RESs at the northern LVF region, the Hualien area, are widely distributed along the fault strike over a distance of 45 km, whereas in the southern LVF, the Chihshang fault zone, we found 30 M 2.2-3.4 RESs with three times shorter along-strike extent. The RESs on the Chihshang fault are confined to the north half of the 30-km-long Chihshang fault, where they occurred at 7-23 km depth with 3 cm/yr average deep slip rate consistent with surface creep rate. This suggests that the creeping section is probably extended from near surface to the depth of 23 km in the northern Chihshang fault zone. We infer a contrasting deep fault slip behavior from north to south of the Chihshang fault. The northern half of the Chihshang fault is creeping and southern half is probably locked with higher earthquake potential. The RESs in the Hualien area are widely distributed along the entire length of the fault zone, with focal depths of 10-22 km. The average deep slip rate is inferred to be 2.4-10.9 cm/yr with an average of 3.4 cm/yr, suggesting that localized deep aseismic slip is taking place at the deeper portion of the Hualien area. Compared with GPS surface slip rates, the slip deficit rate accumulated at the shallow portion of the fault reaches 3 cm/yr at maximum.

The variability of repeating earthquakes behavior in the two regions of eastern Taiwan shows that while the Hualien RESs zone produces $M > 3.8$ and $M > 4.6$ RESs, the Chihshang fault zone only has RESs of $M < 3.5$. The $M > 3.8$ RESs are characterized by regular recurrence time and uniform rupture size. By calculating the number and relative size of the neighboring earthquakes around each RES we found that the $M >
3.8, quasi-periodic RESs are surrounded by a small number of earthquakes with larger size than their own. The periodicity and size uniformity of these $M \geq 3.8$ RESs, therefore, can be explained by less interaction with nearby earthquakes, where the interaction degree is assumed to be controlled by the separation distance and relative size with respect to the RESs. The common features in fault loading rate and frequency-size distribution of background seismicity between two fault zones imply that the absence of $M \geq 3.8$ RESs on the Chihshang fault is due to neither the relative lack of comparable size of earthquakes nor the slow loading rate of the fault. With the 3 times shorter spatial extent of repeating events (15 km along-strike) in the Chihshang fault zone, the limited range of creeping area with respect to RES’s size is referred as a possible mechanism for the lacking $M \geq 3.8$ RESs. A well-resolved fault model to further evaluate the relative fraction of creeping areas and its relation to the spatial extent of RESs is expected. One implication of variable size limit to RES magnitudes on faults is that fault property and seismic hazard may vary from one segment to the other. The variable features of RESs add to the growing knowledge of segmentation and deep fault slip behavior along the LVF.

In this study, we also pay particular attention to the proper identification scheme because that the noise level of the seismic data and station coverage in this area could have significant contribution on the repeating earthquake identification. We propose a relatively objective method, composite selection criteria, to identify repeating sequences. Considering the criteria in both S minus P differential time and waveform similarity, this method provides an independent check on repeating events decomposition. The repeating sequence identification using composite selection criteria has an obvious advantage when poor station coverage and low signal to noise level are present.

The analysis of recurrence properties of small repeating earthquakes in eastern Taiwan reveals a weak variation in recurrence interval ($T_r$) with seismic moment ($M_o$). Compared to the scaling of $T_r$ with $M_o$ from repeating earthquake data near Parkfield in California, the repeating data from eastern Taiwan has recurrence intervals that are 2 times shorter. Also in northeastern Japan, $T_r$ of repeating quakes are ~4 times shorter than those expected from the Parkfield scaling law. When adjusted to account for differences in the geodetically derived slip rates for the three fault zones, however, the $T_r-M_o$ scaling is remarkably consistent among the three regions. It suggests that the tectonic loading rate is likely the most important factor that controls the repeat time. It also suggests that there seems to exist a universal rule on recurrence interval scaling of repeating earthquakes in diverse tectonic settings. These findings offer useful constraints for further study of the factors controlling the earthquake renewal process, the physics of earthquakes and faulting and associated
applications to earthquake forecasting and hazard estimation.