Characteristics of Taiwan's Seismicity

Tsui-Yu Chang¹⁾, Fabrice Cotton²⁾, Yi-Ben Tsai¹⁾ and Jacques Angelier³⁾

1) College of Earth Sciences, National Central University, 320 Taiwan.

2) LGIT, Observatoire de Grenoble, Maison Des Géosciences, 38041 Grenoble, France.

3) Laboratoire Tectonique Quantitative, U. P&M CURIE, 75252 Cedex Paris, France.

Abstract: In Taiwan area, the instrumental observation of earthquakes has been initiated since 1898, and up to 2000, about 180,000 earthquakes have been accumulated in the synthetic catalog organized by the Central Weather Bureau of Taiwan (abbr. CWB). In this study, we aim to have a systematical comprehension from preliminary statistical analysis of seismicity in terms of Taiwan's seismotectonics. We firstly applied a completeness test for the CWB seismicity catalog for determining the reliable records which can be considered to correspond with Taiwan's tectonic activity. Afterward, *b*-value and *z*-value have been realized after such reliable records. The *b*-value analysis has extracted the relationship between the seismic behaviors and tectonic setting. The application of the *z*-test demonstrated a series of rate changes before and after the Chi-Chi earthquake.

1. General Seismotectonics of Taiwan

The geodynamic setting of the island of Taiwan, at the convergent boundary between the Philippine Sea Plate and Eurasia, is well known and does not deserves presentation herein. Two Wadati-Benioff seismic zones occur south and east of Taiwan (Manila-Luzon and Ryukyu arc-and-trench systems respectively). Between these opposite-verging subduction systems, active collision occurs on Taiwan, with a high density of crustal seismicity. During the last hundred years, more than 85 disastrous earthquakes in and around Taiwan have been reported; some produced important damage, like the Chichi earthquake of September 21st, 1999.

The progress in seismotectonic studies in Taiwan, which corresponds to the evolution of local seismographic instrumentation and networks, can be roughly divided into 4 eras (e.g. Tsai et al., 1977; Tsai, 1986; Cheng et al., 1996; Wang and Shin, 1998). The first era began when Japanese installed the first seismometer in Taiwan at the end of 19th century. The second one corresponds to the period when the Taiwan Telemetered Seismographic Network (TTSN, functioned from 1973 to 1991) served as the main observation facility in the region (Tsai et al., 1977). The merge of TTSN and the seismic network operated by the Central Weather Bureau (CWB) into a densely distributed Taiwan Seismic Network (TaiSeiN/CWBSeN, since 1992) with real-time monitoring capability marks the arrival of the third one. Finally, the establishment of the Broadband Array in Taiwan for Seismology (BATS, since 1995), the completion of Taiwan

Strong Motion Instrumentation Program (TSMIP), and the build-up of digital seismic arrays for temporal deployment in mid-1990's jointly open the latest era. A clear trend of improvement, both on quality and quantity of data, is evident over the years and can be self-explanatory in the seismic rate figure and earthquake number histogram.

In this study, we aim to have a systematical comprehension from preliminary statistical analysis of Taiwan's seismicity. We firstly applied a completeness test for the CWB seismicity catalog for determining the reliable records that can be considered to correspond with Taiwan's tectonic activity. Afterward, b -value and z -value have been realized after such reliable records. A computer program, *ZMAP*, distributed free by the Stefan Wiemer (2001), has been efficiently used in this study.

2. Magnitude of Completeness of the CWB Catalogue

The magnitude of completeness (M_c), from such magnitude at which the Gutenberg-Richter law can depart from linearity, is the index value to examine whether the seismic catalogue cover an exhaustive record or not for a specific area. It is well known that M_c changes with time in most catalogs, because the number of seismographs increases and the methods of analysis improve. In this study, we determine firstly the M_c value of the CWB catalogue as the function of time sequence from 1900 to 2002. It shows that M_c decreases to about 2.0 at the year about 1994 and lasts stable with this small value to the present, except the higher M_c around the period of the Chi-Chi earthquake. We can therefore account the CWB catalogue complete since 1994.

The difference of M_c as a function of space is generally ignored, although it is known that M_c is variant from different catalogues recording seismicity of divergent geological setting. Here we develop some spatial mappings of the frequency-magnitude distribution and application of a localized M_c in accordance with the distinct seismogenic zones. It shows that M_c is generally one-to-two unit of magnitude higher in the offshore areas than onshore. This result consists with the study of Wiemer & Wyss (2000). Four vertical profiles of M_c perpendicular to the subduction trenches of Taiwan and across the dense seismicity area were derived for the variation of M_c along the depth. The higher M_c are observed for the onshore seismicity with deeper focal depth or for some typical structures, e.g. subduction zone, and transfer fault zone, etc.

3. b -value of the Taiwan Area

In order to quantifying the relationship between the degree of seismic activity and the tectonic setting, the b value of Gutenberg-Richter's magnitude-frequency law (Gutenberg and Richter, 1956) has been applied for all Taiwan region with seismicity recorded in the period between 1994 and 1999.5 (before the Chi-Chi earthquake) and a limit of magnitude is considered

as 2.0, just following the previous result of completeness test. Furthermore, because we are interested especially in the shallow seismic activity, which can be related to the deformation within collisional mechanism, only such events with a focal depth less than 50 kilometers are taken into account.

Generally speaking, the b values are smaller offshore than on land. This difference may be due to different crustal properties: principal division into oceanic-type crust and orogenic-type crust. In the central Taiwan, large b values with a peak of about 1 at the southern part indicate infrequent occurrence of moderate to large earthquake. With consideration the geothermal and tomographic studying, deeper crustal deformation and metamorphism of rock must play an important role for this area.

4. Space–Time Variation of z -value before and after the Chi-Chi Earthquake

A sequence of seismic rate change, z -value, has been mapping for the whole Taiwan area with each time window of 0.5 years. The goal of this analysis is to find out significant rate change pattern related to the Chi-Chi earthquake. In considering to the completeness of seismicity catalogue, we use the data recorded from the period of 1994 to 1999.5, and also from 2000.5 to 2002.5 (unit in year). A critical focal depth is defined as 50 km, just with the same consideration in b -value study.

The resultant z -value maps reveal that the seismic rate change is spatially random for the years between 1994.5 and 1999.5. However, the seismic rate change has a linear extending of augmentation for the western Taiwan with a spatial scale about 200 km in the time window of 1998.5~1999. After the Chi-Chi earthquake, the z -value map shows again that the seismic stress diffuse randomly in space.

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