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Some Characteristics of Seismicity Before Strong Earthquake Chi-Chi (Mw = 7.6), 1999, Taiwan

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Abstract

The purpose of this paper is an analysis of features of the seismic regime before one of the strongest earthquake Taiwan in the twentieth century (Chi-Chi, 21.09.1999, Mw = 7.6). According to data for 1990-1999 variations of three parameters of the seismic regime were studied retrospectively: total annual number of earthquakes N_Σ in the range of magnitudes of M_L = 2.5-5.5, total annual quantity of released seismic energy ΣE, J and angular coefficient b of graphs of recurrence of earthquakes. There were chosen two obvious sub-periods in course the seismic regime – quiescence in 1990-1996 and activation in 1997-1999. Earthquake of Chi-Chi occurred on a maximum of seismic activity. The prevalence of weak earthquakes during of preparation the Chi-Chi earthquake caused an overestimation of coefficient b graphs of earthquake recurrence (-1.16 on average).

Keywords: seismicity, strong earthquake, seismic regime

1. Introduction

The retrospective analysis of the seismic regime is widely used in seismological research. Many programs of prediction of strong earthquakes as global (see, for example, CALIFORNIA-NEVADA-CN (Keilis-Borok et al., 1980), MAGNITUDE 8 (Keilis-Borok & Kossobokov, 1986; Healy et al., 1992), SCENARIO MENDOCINO-MSc (Kossobokov et al., 1990) and regional character – RTL (briefly: radius of area, time of research, and length of source fracture, Sobolev, 1993), Algorithm MEE (Map of expected earthquakes, Zavyalov, 2002) are known.

Forecast algorithms included in the global programs are based on recognition of patterns of the situations, characterized by the set of descriptions that is statistically related to preparation of strong earthquakes and the possibility of their origin. At the output of algorithms the list of zones or territories is given, where possible occurrence strong earthquakes as well as the periods of time during which these earthquakes can occure within the particular seismic active region. In more recent regional programs RTL (Sobolev, 1993) and the Algorithm MEE (Zavyalov, 2002) along with statistics the physical precursors of strong earthquakes (density of seismogenic fractures, slope of the recurrence graphs of earthquakes, number of earthquakes per unit time, released seismic energy) were taken into account. As a forecast of strong earthquakes is not an objective of research, a discussion of the mentioned programs is beyond of the scope of this paper. Nevertheless choice of spatial-temporal frameworks at retrospective analysis of seismic regime before the Chi-Chi earthquake is also actual. Therefore we have considered some examples of choice of periods of time and dimensions of the studied area, and also available documents, in the fulfilling of present work.

In the analysis the above-mentioned programs have been established that specific rules for choosing the period of retrospective research of seismic regime does not quantified. For example, to test the algorithm M 8 on data for seismic areas of Central Asia, Central America and some arcs (Kurile-Kamchatka) were chosen periods 8 years and for Pacific up to 15 years (Romashkova & Kossobokov, 2002). But for the algorithm California-Nevada (CN) the duration of retrospective studies of seismic regime recommended by a document (Long-Term forecast of…, 1986) for earthquakes with M = 6.4-7.5 within the same regions makes up to 17 years.

Thus, according to available data the periods in the analysis seismicity before strong earthquakes varies between 8-17 years.

At the same tume the dimension of regions at the retrospective study of the seismic regime varies in wider range than the temporal factor. So, research of the seismic regime in the Pacific seismic belt in the forecasting of earthquakes with M=8 were carried out in the circles of radius 427 km from the center on axis of belt or in the overlapping quadrangles with sides 12º in latitude and longitude (Keilis-Borok & Kossobokov, 1986; Healy et al., 1992). On territory of the Russian Federation research on predictive program RTL (Sobolev, 1993) for earthquakes with M=8 carried out in circles by a radius 100 km the center in an epicenter. According to a document (Long-Term forecast of …, 1986) for determination of linear dimensions of the study area is recommended equation:

$$log\ L= log\ exp\ (M-5.6) \quad (1)$$

where L is determined in the degrees of arc of a great circle. The equation enable to determine value L for earthquakes of different M. In case M = 8 value L is 10º and for M=7.5 is equal to 6º. It follows that at moderate duration of period of research the linear dimensions the studied area according to Equation (1) are very large.

A retrospective analysis of peculiarities of the seismic regime Taiwan region before the destructive earthquake of Chi-Chi (Mw = 7.6) in September 1999 was carried out in this paper. The accumulation of information on the known strong earthquakes in a perspective can assist to increase the effectiveness of forecasting programs taking into account tectonics of specific regions and typifying of source mechanisms of strong earthquakes.

2. Seismicity of Taiwan Region and Material Studied

Taiwan is an area of high seismic activity. According to (Taiwan tectonics…, 2005) during last century in the area of island about 30 earthquakes with M=6.5-7.4 occurred. The epicenters of majority from them are situated under the bottom of the Philippine Sea (island slope), and also in the underwater Luson ridge. Several epicenters were also in the south-west flank of the Ryukyu arc. Number of earthquakes occurring on a coast of the island and in the hinterland, is no more one third of total quantity.

Most often earthquakes occur at depth of up 50 km, and only in backarc region Ryukyu focal depth increases to 80-200 km. In the hinterland of island are known three strong earthquakes: Meyshan, 1906, M = 7.1, Chihu, 1935, M = 7.0, Sinhua, 1946, M = 6.8, and without the name at eastern coast earthquakes in 1951, M = 7.1 and in 1991, M = 7.3 (Figure 1).

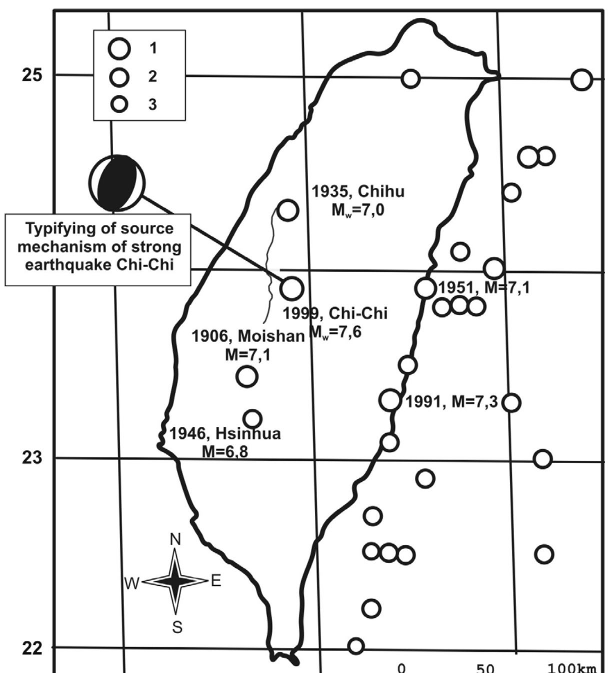

Figure 1. The Taiwan earthquakes with M > 6.0 in XX century according to (Taiwan tectonics…, 2005)

Magnitudes, M: 1. 7.1-7.5; 2. 6.6-7.0; 3. 6.1-6.5.

The development of network of the stations of the Central Weather Bureau (CWB) since early 70-ies of the last century in the Taiwan was made possible recording of earthquakes with $M_L \geq 1.5$, however to 90-ies are registered with gaps of earthquakes with $M_L \sim 2.5$. Most hypocenters of weak and moderate earthquake are concentrated in the earth's crust and adjacent part of the mantle near the boundaries of the Philippine plate, and in the coastal zone of the island. Besides they are attached to numerous tectonic faults in the montaneous part of the island and under the bottom of Philippine Sea. These earthquakes are caused by collision of the Eurasian and Philippine plates (more detail see section 3, Figure 2). The same process has caused occurrence of strongest earthquake of last century Chi-Chi in 1999 (Mw = 7.6). Epicenter of this earthquake was attached to Chelungpu thrust in the fold-and-thrust zone of the Western Foothills. At the time of earthquake within it epicentral zone originated fracturing of suture surface for 70 km. Amplitudes of the vertical motions were 12 m in the central part of the fault, and 10 m in the northern flank, the horizontal motions were 4 m in the center and 9 m on the northern flank correspondingly. The area of maximum shaking was approximately 8000 km^2 (length of 160 km and a width of 30-70 km), the values of acceleration reached 8 m/s^2. The earthquake caused numerous victims (number of losts has reached 2400), and great destructions of residential buildings and constructions: school stadium in Vufeng, bridge Pifeng and dam Shikang (Chu, 2007).

2.1 Material Studied

As an initial material for retrospective study of the seismic regime before Chi-Chi earthquake catalogs of CWB have been used for 1990-1999. The choice of spatial-temporal parameters of the study area for forming initial sample of earthquakes described below (see Section 4) because it has methodological character. In this case were chosen two stages of research. In the first stage (qualitative analysis of seismicity) the features of the spatial distribution of earthquakes with $M_L \geq 1.5$ in the vicinity of the epicenter of Chi-Chi were considered. The sample size of earthquakes with magnitudes 1.5-5.5 in this stage was 10500 events. The prevailing number of earthquakes had a magnitude $M_L < 2.5$ (their total number reaches 7200). In some years earthquakes have higher magnitudes: in 1997-1998 M_L = 3.5-4.0, in 1992-1995 – 4.0-4.5 and in 1990-1991, 1999 – 5.0-5.5. It does not into account few aftershocks (60) earthquakes with M=5.0-5.5, which can not influence the course of graphs N (t).

At the second stage of the research quantitative analysis of parameters of seismic regime was carried out: total annual number of earthquakes N_Σ, total annual quantity of the released seismic energy ΣE in Joules and angular coefficient of the recurrence graphs of earthquakes b (b = d log N/dM). To eliminate the influence of gaps of weak earthquakes in 1990-1993 on variations of the seismic regime the level of the minimum magnitude was upgraded to 2.5. As a result the sample size was reduced to 3300 events.

3. **Area Descriptions**

Taiwan is northern part of the Philippine-Taiwan arc that offset en-echelon to west of the northern flank of Philippine islands. Within this area parallel to Taiwan are stretched out two underwater heights–the Huatung ridge and the northern part of Luson volcanic arc. They are separated by a narrow deep depression–Manila trench depth of 3000-4000 m. In terms of plate tectonics Taiwan is located on the Eurasian plate near its boundary with the Philippine Sea plate. This boundary has a complex character. To the south of 22.5º N there is observed absorption of the oceanic crust of the South China Sea which led to a collision between China continental margin and Luson arc. It began 6.6 Ma ago and continues to this day (Ho. 1986). Because of oblique contact of the Philippine and Eurasian plates mature zone collision exists between 22.5 and 24.5º N. To the north of 24.5º N collision fades and is replaced by subduction of opposite polarity, i.e. take place sinking of the Philippine plate under Eurasian. The process of collision promoted to formation of mountain ranges of Taiwan.

The island Taiwan is anticlinorium northeast strike formed rocks of the Paleozoic, Mesozoic and Tertiary ages. It is characterized by scaly structure due to numerous thrusts in which motions along the rupture planes are oriented from east to west. Geodynamic situation in Taiwan region and its tectonic structure is illustrated by Figure 2 (Hu et al., 2002; Taiwan tectonics…, 2005).

A characteristic feature of the structure of mountain belt of Taiwan is considerable change strike ridges at latitude 24.5º N from NNE to NEE. Turning angle is 55º (Hu et al., 2002). Reason for such turn is a change in direction of subduction because of opening of trough Okinawa (Dan, 1996; Taiwan tectonics…, 2005). It is assumed that north-eastern part of Taiwan was involved in post collision process and included in the system of the Ryukyu arc with change of polarity of subduction. Confirmation of this later evolution is the strike of Quaternary structures in northern part of island (Li & Wang, 1988). As a result process compression tectonics which caused the growth of Taiwan orogen changed on tectonics of tension under influence of the opening of trough Okinava (Teng, 1996).

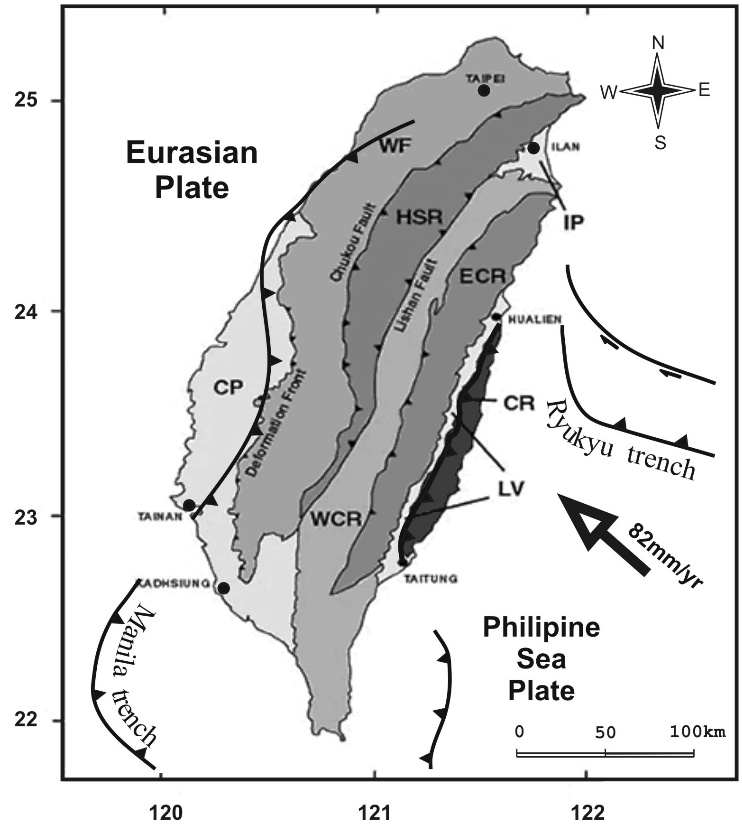

Figure 2. Tectonic position of Taiwan and geological structure (Biq, 1989; Taiwan tectonics…, 2005)

Structures: CR–Coastal Range; LV–Longitudinal Valley; ECR–East Central Range or Tananao Schist complex; WCR–West Central Range or Backbone Range; HSR – Hsűeshan Range; WF–Western Foothills; CP–Coast Plain.

4. Method

Research on the retrospective analysis of seismic regime before earthquake Chi-Chi can not be successful without a clear formulation of temporal and spatial conditions for solution the problem. It should be noted two undesirable consequences of wrong choice of duration of period of research. In case of overestimation an excessive number of data is used complicating the analysis of initial information. Underestimation the duration entails a risk of gap of one the stages of seismic regime – quiescence or activation. As a consequence the wrong interpretation of nature of the seismic process before a strong earthquake is possible. In literature are known errors of both types in papers (Kuzin et al., 2011; Wu & Chiao, 2006) accordingly.

We could not accept observational period of 17 years according to the document (Long-Term forecast of …, 1986), because of the gaps microearthquakes (M_L = 1.5-2.5) and of a weak earthquakes (M_L =2.5-3.0) before 1990 the homogeneity of initial sample was disrupted. Therefore in first approximation we used following equation:

$$log\ T = 0.74\ M - 4.6 \tag{2}$$

where T is defined in years. The equation is obtained by analyzing data of numerous earthquakes-precursors of different magnitudes (Myachkin & Zubkov, 1973; Rikitake, 1979). In essence in this case the precursors are foreshocks of strong earthquake. For earthquake Chi-Chi (Mw =7.6) the value of T is 10 years, that is less 1.7 than according to (Long-term forecast of…, 1986) and is comparable with estimate of work (Romashkova & Kossobokov, 2002). So for retrospective analysis of the data before earthquake catalogues of CWB during 1990-1999 were used.

On the basis of equation (1) from (Long-Term forecast of…, 1986) the linear extent of the investigated area to earthquake of Chi-Chi (Mw = 7.6) is 6º (666 km). The use of this estimation in our case is inexpedient because it is about 2 times more the length of the island Taiwan with adjoining to it Ryukyu arc to the northeast and Luson in the south. The existence of different tectonic areas complicates seismotectonics of region and as a consequence analysis of the spatial distribution of seismicity. Taking into consideration this circumstance, we chose the size of region on the basis of length of source fracture of Chi-Chi earthquake. According to (Ulomov et al., 1997) the length of source fracture for earthquakes with M > 6.5 is determined by equation:

$$log\ L = 0.6\ M - 2.5 \quad (3)$$

where L is in km. Hence, for the Chi-Chi earthquake (Mw = 7.6), we have L = 115 km. By analogy to (Mogi, 1979) the studied area in form of two rectangles was adopted - large, having sides 222 km or ± 1º from epicenter and sizes 42200 km^2, and small having sides 111 km or ± 0.5º from epicenter, size 12300 km^2. Within these areas detailed study of peculiarities of spatial distribution of microearthquakes (M_L = 1.5-2.5) and weak earthquakes (M_L = 3-5) was carried out.

Determination of the spatial-temporal frameworks of retrospective studies of seismic regime allowed us to reveal the variations of its quantitative characteristics. They are: the total annual number of earthquakes N_Σ, the total quantity of releasing energy ΣE and angular coefficient b graphs of recurrence of earthquakes. The described approach is analogous to the one used the paper (Kuzin et al., 2011) in a retrospective analysis of seismic regime before destructive Kronotsky earthquake (M = 7.9) in area of Kamchatka.

5. Results

The study of seismic regime before Chi-Chi earthquake was based on a retrospective analysis of CWB catalogs for 1990-1999. In the first stage there were considered qualitatively peculiarities of distribution of earthquakes with $M_L \geq 1.5$ within the large and small areas in the vicinity of the Chi-Chi epicenter. The similarity of these schemes for full observation period was established. This testifies to the absence of great spatial fluctuations of earthquakes in magnitude range 1.5-5.5.

The general notion of the nature of seismicity can make schemes for the beginning of the observational period (1990) Figure 3a, and at its end (1999), Figure 3b. The first Figure shows diffuse seismicity near epicenter of the Chi-Chi. A prevalence of the number of earthquakes having M_L > 1.5 within the small area is observed. In a large area there are two groups of earthquakes to the east and north-east of epicenter of the Chi-Chi. Before the occurrence of this earthquake in 1999 seismic activity has increased. Most earthquakes occurred to south of the epicenter of the Chi-Chi. Within the small area the number shocks with M_L = 1.5-2.5 has increased approximately by 1.5 orders. Much weaker seismic activity was manifested to east and north of epicenter of Chi-Chi. Within the large area of two groups earthquakes to east and north-east epicenter of the Chi-Chi noted in Figure 4a are united in common zone of north-eastern orientation (Figure 3b).

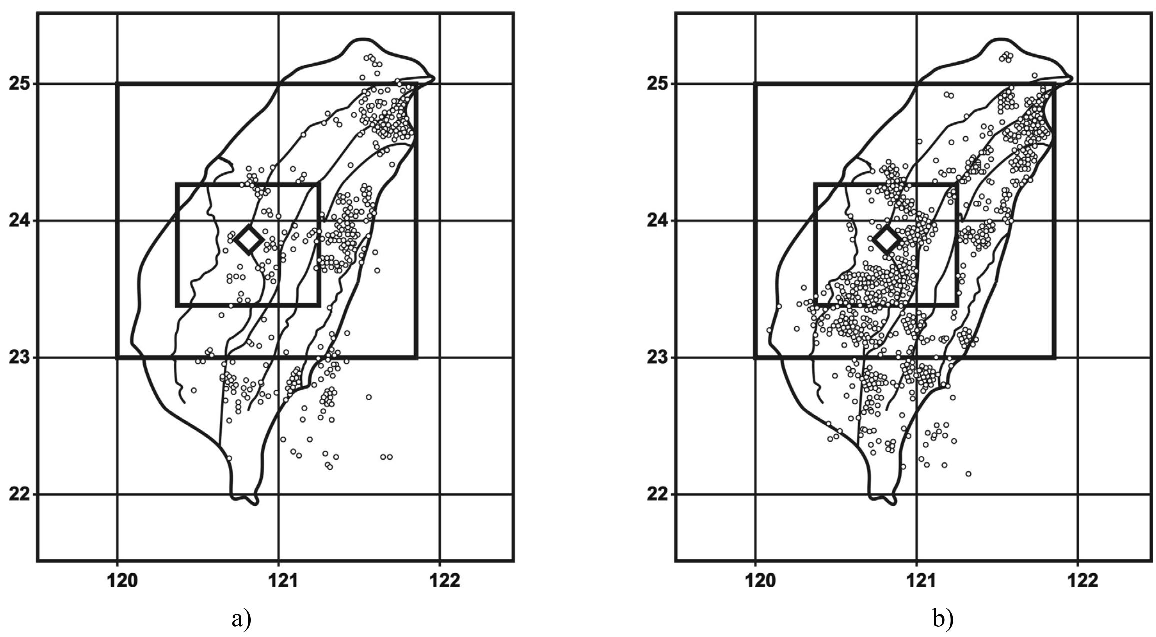

Figure 3. a) Seismicity of Taiwan for 1990, M_L > 1.5. Large rectangle – area within ± 1º around epicenter of Chi-Chi; small rectangle – the area of ± 0.5 º; b) the same for January 1 to September 21, 1999

The concentration of microearthquakes (M_L = 1.5-2.5), as well as of weak earthquakes (M_L = 2.5-4.5) within a small area (Figures 3a & 3b) is not typical for more strong earthquakes (M_L > 4.5) which migrate into the large area. This situation resembles the definition of seismic gap 2-nd kind (Mogi, 1979), when near epicenter of the future strong earthquake predominantly weak earthquakes occur. The difference between large and small areas in Figures 4a and 4b of the scheme in paper (Mogi, 1979) is that they have a rectangular rather circular shape.

The main conclusion of the consideration of seismicity in the first stage is prevalence of microearthquakes (M_L = 1.5-2.5), compared to number of weak and moderate earthquakes (M_L = 2.5-5.0) in the vicinity of the Chi-Chi epicenter (7200 microshocks against 3300 weak and moderate shocks in a large area). In a small area number of more strong earthquakes in 5.6 times less than in a large (590 and 3300 events respectively). These data can be interpreted as a sign of seismic quiescence by (Mogi, 1979). At the same time, a sharp increase in the number of microshocks just before the Chi-Chi earthquake (approximately 1.5 orders of magnitude in 1999) testify seismic activity in the final stage of its preparation. However, the absence of certain parameters and their changes in time does not allow estimate the variations of seismic regime before the Chi-Chi earthquake. This could be done only on the basis of quantitative parameters N_Σ, ΣE and coefficient b as it was mentioned above.

In the next stage the analysis of variations of seismic regime before the earthquake Chi-Chi changes annual values of N_Σ and ΣE on data of earthquakes with M_L = 2.5-5.5 were considered. Figure 5 shows the change of the N_Σ (t) for large (a) and small (b) areas around the epicenter of the earthquake Chi-Chi. The first graph characterizes a smooth decrease of N_Σ (a decrease in the flow rate of seismic events) in 1990-1994. However in 1995-1996 unusual behavior of graph N_Σ was observed. First, in 1995, the number of earthquakes has increased by 16%, and in 1996 there was a sharp fall (at 42%) compared to the previous year. The result was absolute minimum of N_Σ. Decrease in N_Σ during 1990-1996 by 1.9 times corresponds to the seismic quiescence complicated by a sign-variable variation in 1995-1996. An increase of N_Σ by 1.4 times in 1997-1999 signifies activation of seismic regime before the earthquake Chi-Chi. It is necessary to note, that similar phenomena during the period of quiescence were observed before the strong Kronotsky earthquake (M = 7.9) near the Kamchatka. They should be considered supposedly as a result of irregularity in the seismic process within large area having complex tectonics (see Figure 2).

The course graph N_Σ for small area is similar to that for a large area but without eject of N_Σ in 1995. The other difference is in a slower decrease the number of earthquakes in the period of quiescence (the lower flow rate of events) and comparable increase during activation. Figure 4 shows that the graph N_Σ (t) in this case as well as for large area consists of two parts, a 7-year quiescence (1990-1996) and 3-year activation (1997-1999). Chi-Chi earthquake occurred on high level of seismic activity.

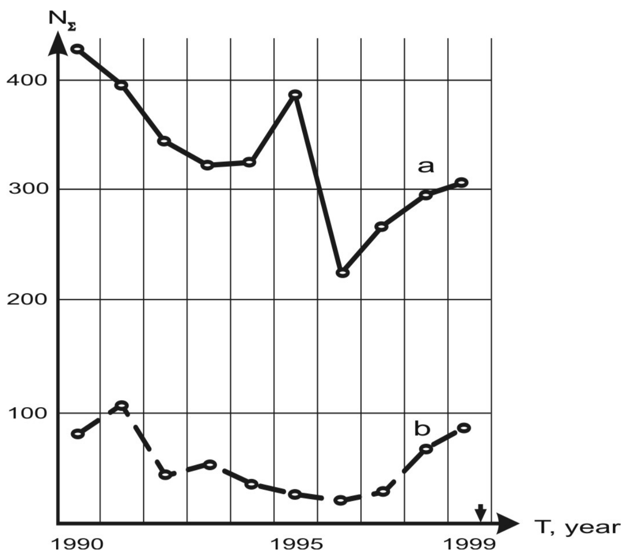

Figure 4. Variations of annual numbers of earthquakes N_Σ with magnitudes M_L = 2.5-5.5 for a large (a) and small (b) areas around of an epicenter of earthquake Chi-Chi for1990-1999

Figure 5 shows graphs of the quantity of the released seismic energy ΣE, J for large and small areas. They are also similar, both among themselves and graphs N_Σ (with the exception of ejection value of N_Σ for large area).

Character of the graphs ΣE for large (a) and small (b) areas is defined by distribution of earthquakes of different magnitudes. The maxima ΣE on graph (a) in 1990-1991 and in 1999 and as well as on graph (b) in 1991 and 1999 are correspondent to earthquakes with M = 5.0-5.5. Secondary maximum in 1993 is conditioned by earthquakes with M = 4.0-4.5, the remaining values correspond to shocks with M < 4.0 (see section 2, page 3). The observed peculiarities of distribution of magnitudes defined division of graphs ΣE (t) for large and small areas into three parts: a) sharp decrease of ΣE in the beginning of quiescence (1992) in comparison with 1991(by 1.6 order for large area and by almost 3 of the order of small area); b) the slow decrease of ΣE in the period of quiescence in 1992-1996 (only in 5 times for a large area and 2.9 times for small); at the beginning of activation in 1997-1998 it was comparable growth of ΣE (1.9 times for large area and 8.6 times to small); c) the rapid increase of ΣE in 1999 compared to 1998 (by 2.2 order for a large area and 2.7 order for the small). It is necessary to note, that course of graph (a) on Figure 5 has not so dramatic in 1995-1996 , as observed on graph 4 (a) for N_{Σ}. Absence of ejection for ΣE in 1995 suggests that local maximum N_{Σ} is formed by weak earthquakes.

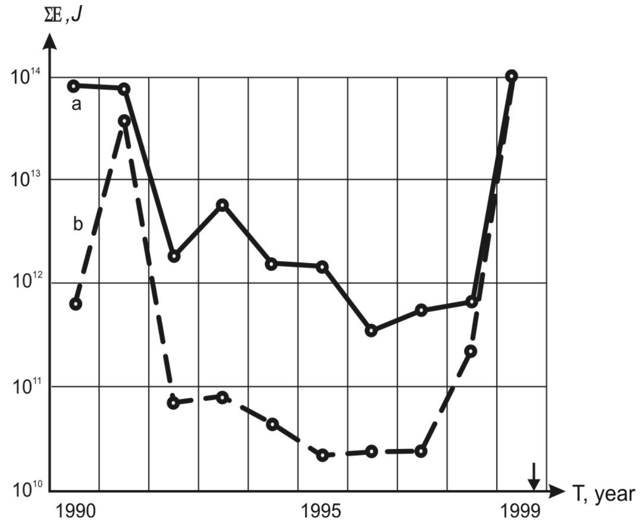

Figure 5. Variations of annual quantity of released seismic energy ΣE, J for magnitudes M_L = 2.5-5.5, 1990-1999; curves (a) and (b) are correspondent to seismic energy for the large and small areas

In general, total released energy for 1990-1999, within a large area is ($2.7 \cdot 10^{14}$ J) or 5% of energy for the Chi-Chi ($5.6 \cdot 10^{15}$ J), and for a small area 3% ($1.7 \cdot 10^{14}$ J).

The observed similarity of graphs N_{Σ} (t) and ΣE(t) indicate a certain coherent change parameters both a decrease during seismic quiescence and increase during activation. At the stage of quiescence reduced the number of earthquakes (with exception of single deviation for large area in 1995) and the quantity of released energy reduced and vice versa they consistently increase during activation. Such consistent behavior of the considered parameters a priori is not clear.

The existent prevalence of weak earthquakes in period of preparation of earthquake Chi-Chi has led to overestimation of value of angular coefficient b of recurrence graph of earthquakes (-1.16 in average). At the same time according to available data a typical value of this coefficient for crustal earthquakes does not exceed -0.9 (Bune & Gorshkov, 1980).

Thus, it should be emphasized that most important result of this work is the revelation of two distinct sub-periods in course of seismic regime before earthquake Chi-Chi – quiescence in 1990-1996 and activation in 1997-1999. Assuming the existence of relation of seismicity with the stress state of medium it can be considered characteristic accumulation of stresses during period of quiescence and their discharge in the period of activation.

6. Discussion

Commenting on the remark about the possible undesirable consequence of wrong choice of period duration in retrospective researches of seismic regime, it is necessary to note the following. In the paper (Kuzin et al., 2011) overestimated duration of the period (36 years) before Kronotsky earthquake in Kamchatka region was used. This value is more 2 times higher than recommended documents (Long-Term forecast of…, 1986), i.e. 17 years. In practice, however the quiescence before occurrence of this earthquake in 1997 began in 1987, i.e. for 11 years earlier. Therefore, the information in the preceding 19-25 years was excessive and useless for research.

As an example of underestimation the duration of research period is work (Wu & Chiao, 2006). In it had been allowed deviation from recommendations of the document (Long-Term forecast of…, 1986) in choosing of the research period before the earthquake Chi-Chi (6 years instead of 17).

The evaluation of the linear extent of researched area is close to recommended above mentioned document (4º against 6º). However, it was not taken into account the existence of heterogeneous tectonic areas Taiwan region (the island itself and two arcs – Ryukyu in north-east and Luson at south).

To evaluate the influence of initial conditions in paper (Wu & Chiao, 2006). on results of the studies necessary a brief discussion of its content. The quiescence before the earthquake Chi-Chi in the paper was determined on the basis of formalized approach to analysis of seismic information. As the algorithm it was used the so-called z-mapping software (Wimer & Wyss, 1994), based on consideration of period of observation and the flow rate of seismic events (parameter z(t)). Values of this parameter were calculated on the sites of 20 x 20 km (400 km^2) with the subsequent summation. A positive value z(t) corresponds to a decrease of seismic activity (quiescence), the negative value of its increase (activation). Energy characteristics of the seismic regime were not taken into account at all. The research was based on sample of 66090 earthquakes with $M_L > 2$ for 1994-1999.

Boundaries of studied region are defined by coordinates φ = 21.5-25.5º N, λ = 119.5-122.5º, i.e. 4º in latitude and 3º in longitude, total area is 146 900 km^2. The region includes the tectonic elements with different types of geodynamics – zone of collision of Philippine and Eurasian plates (Central Taiwan), and zones of subduction of Philippine plate under Eurasian in the north-east of Taiwan and Eurasian under Philippine near of its southern flank.

The following results on base of research in the above–mentioned space-time frameworks by (Wu & Chiao, 2006) were obtained. It was established the existence of seismic quiescence for 9 month before the Chi-Chi earthquake only (January 1999), but the signs of activation could not be found. Comparing this conclusion with the results of present paper, it should be noted that the beginning of the seismic quiescence late almost 9 years. As a consequence, it is superimposed on activation (1997-1999) and the course of seismic regime according to (Wu & Chiao, 2006) was opposite phase character.

Some possible reasons for this discrepancy in the evaluation of course of the seismic regime before the Chi-Chi earthquake can be noted. First of all, this is a great difference in spatial distribution of earthquakes in the vicinity of epicenter of the Chi-Chi earthquake on the one hand and within the Taiwan region on the whole on the other hand. Figure 6 shows high concentration of earthquakes in the eastern coastal area of Taiwan and the adjoining island arcs. The epicenter of Chi-Chi earthquake is located on the periphery of seismic active area of the region.

As the result it is observed a significant difference in sample sizes of earthquakes for mentioned areas. In a large area in the vicinity of the Chi-Chi epicenter (S = 42200 km^2) sampling of earthquakes with Ml > 2 for 1990-1999 contains 7200 events, while for Taiwan region with adjacent arcs on the whole (S = 146900 km^2) sample size is 66090 events in 1994-1999. Consequently the influence of the variability of seismicity around of the Chi-Chi epicenter on character of its variation in the region on the whole will be very weak and does not affect the course of seismic regime within it. Taking into account these considerations, it can be assumed that the results of a retrospective analysis of seismic regime before the Chi-Chi earthquake in paper (Wu & Chiao, 2006) indicate the wrong interpretation of it course during preparation of this earthquake.

Thus, the discussion of results in spatial-temporal analysis of the seismic regime before Chi-Chi earthquake leads to conclusion about necessity taking into account features geodynamics of the studied region in estimation the spatial factor research.

7. Conclusion

In accordance with existing concepts of construction of algorithms known prognostic programs a retrospective research of the seismic regime before destructive earthquake in Taiwan in 1999 (Chi-Chi, Mw = 7.6) was carried out by catalogs CWB (Central Weather Bureau of Taiwan). However estimation of the periods of research and the sizes of the studied area according to document recommendations (The long-term forecast of... 1986) were overestimated for a case of an earthquake of Chi-Chi. Therefore they were corrected on the basis of known relations in literature for a waiting time of precursors of a strong earthquake and an estimation of the linear dimensions of the studied area on base of length of a source fracture. Elaboration of a new method of retrospective analysis of the seismic regime is an important result of present paper. Its advantages are the accounting of geodynamics of studied region (combination of collision and subduction processes) and its influence on the distribution of earthquakes.

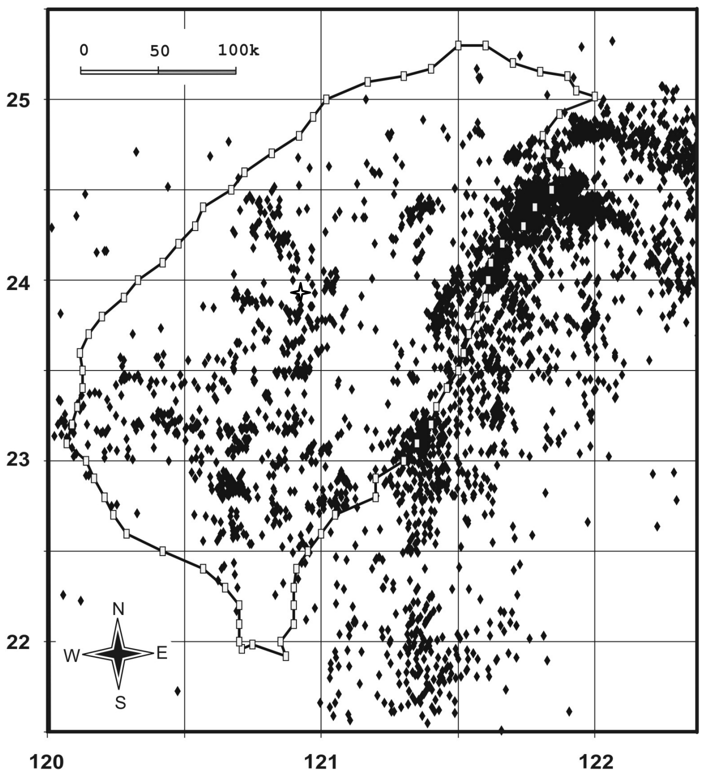

Figure 6. Map of microearthquakes (M_L =2-4) for Taiwan region in the first half of 1997 according to CWB data

Symbol ✢ indicates the position of epicenter of earthquake Chi-Chi.

The other results of a paper are the following:

1) Application of modified approach to retrospective analysis of seismic regime on the example of an earthquake of Chi-Chi (M_B = 7.6) allowed to reveal two sub periods in a course the seismic regime before this earthquake – quiescence in 1990-1996 and activation in 1997-1999. The result is the main inference in the present work. However for an estimate of its efficiency it is necessary statistical check on enough wide range of examples.
2) Similarity of graphs of N_Σ and of ΣE for the large (on the whole) and small areas around of an epicenter of earthquake Chi-Chi was revealed. Along with that it was observed certain coherence of graphs N_Σ (t) and of $\Sigma E(t)$, i.e. simultaneous decrease and increase of values of the parameters. The marked feature cannot be a priory.
3) The prevalence of weak earthquakes before the Chi-Chi event caused overestimate value of angular coefficient b of recurrence graphs of earthquakes.
4) Discussion of the results confirmed the importance of estimation both the duration of study period, and the seismotectonics of the studied region in a retrospective analysis of the seismic regime.

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