COMPARISON OF NATURAL AND PREDICTED EARTHQUAKE OCCURRENCE IN SEISMOLOGICALLY ACTIVE AREAS FOR DETERMINATION OF STATISTICAL SIGNIFICANCE

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A Thesis

Submitted to the Graduate College of Bowling Green
State University in partial fulfillment of
the requirements for the degree of

MASTER OF SCIENCE

August 2008

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ABSTRACT

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Qiang et al. (2001) successfully predicted 100 earthquakes in the Western Pacific Rim including China, Japan, Taiwan, and Philippine, using a temperature anomaly method. Their model is based on a predicted increase of ground temperatures in the lower atmosphere from 2 to 8 days before an earthquake of with a Richter Scale magnitude of 5 or greater. Mixed gases, such as CO_2 and CH_4, in different ratios under the action of a transient electric field, cause the temperature of the lower atmosphere to increase up to 6 °C, while solar radiation only increases temperature by 3 °C. The authors detected the thermal anomalies using ground-based evidence and thermal infrared anomalies in METEOSAT thermal infrared image data. Despite their apparent success at predicting the earthquakes, they did not compare their prediction with the natural rate of occurrence in the area, which experiences an earthquake of Richter magnitude greater than 4 every week.

In order to evaluate the apparent success of Qiang et al's. (2001) method, a study was undertaken to compare their predictions to the natural occurrence of earthquakes within the region. Qiang et al's. (2001) predictions were compared to earthquakes in the Chinese and United States Geological Survey earthquake database using a specific area, magnitude and time (SMT) analysis. The Chinese database shows 81% of the predicted earthquake epicenters occurred out of SMT window whereas, the USGS earthquake database shows 88% of the predicted earthquake epicenters occurred out of the SMT window. The expected value and Poisson probability of the 12% (occurred in the SMT window) of the earthquake predictions show 75% of those are significant (0-10% expected and 0-0.1 Poisson probability value)

significant, and 25% (25-50% expected and 0.1 to 0.25 Poisson probability value) are moderately significant. It is clearly seen that more than 80% earthquakes occurred outside the predicted window. Thus, the ability of Qiang et al’s. (2007) method to predict earthquake epicenters can be called into question.

ACKNOWLEDGMENTS

I am very thankful to Dr. Robert K. Vincent for his time, continual encouragement, invaluable advice, and guidance during this thesis. Similarly, I am very thankful to Dr. Charles M. Onasch and Dr. Joseph P. Frizado for their insightful comments, and suggestions throughout the work. I am also thankful to the Department of Geology for providing me A Geophysical Research scholarship that was very worthy to make the thesis in the present form. I would especially like to thank my friends Deepti Bhatt and pukar hamal for encouraging and supporting ME. My final acknowledgement must be to my parents for their endless support and encouragement. At last but not least, I would like to thank you all who helped me in someway for the completion of this work.

Ganesh P. Neupane

Bowling Green, 2008

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1. INTRODUCTION

Earthquake prediction is one of the most challenging tasks in the history of science. Because it is considered one of the most desirable achievements in human society, scientists are constantly trying to explore the mystery of earthquakes. Some predictions have been very useful in minimizing social and economical loss in the past. In spite of the challenging tasks associated with earthquake prediction, recent studies have shown that numerous geophysical parameters are closely associated with the earthquakes (Knopoff, 1996). Commonly used precursors for the prediction of earthquakes are foreshocks, electromagnetics (ground and air resistivity), cloud formations, infrared temperature, well water composition and level, and animal behavior (Stark, 2006). Among these, thermal infrared radiation associated with ground temperature anomalies has been used to predict earthquakes (Qiang et al., l991, 1993).

Qiang Zuji and Dian Changgong (1993), from the Institute of Geology and the Satellite Meteorological Center, People's Republic of China, reported there is significant change of ground temperatures and electric field in the lower atmosphere from 2 to 8 days before an earthquake of with a Richter Scale magnitude of five or greater. The authors predicted earthquakes based on ground-based evidence and thermal infrared anomalies in METEOSAT thermal infrared image data. METEOSAT, a European Space Agency weather satellite, contains two infrared spectral bands with 5 km spatial resolution in the 10.5- 12.5µm and 5.7- 7.1 µm wavelength regions and a visible/reflective IR panchromatic band in the 0.4 – 1.1 µm wavelength region, with 23 km spatial resolution (Vincent, 1997). They identified large area thermal

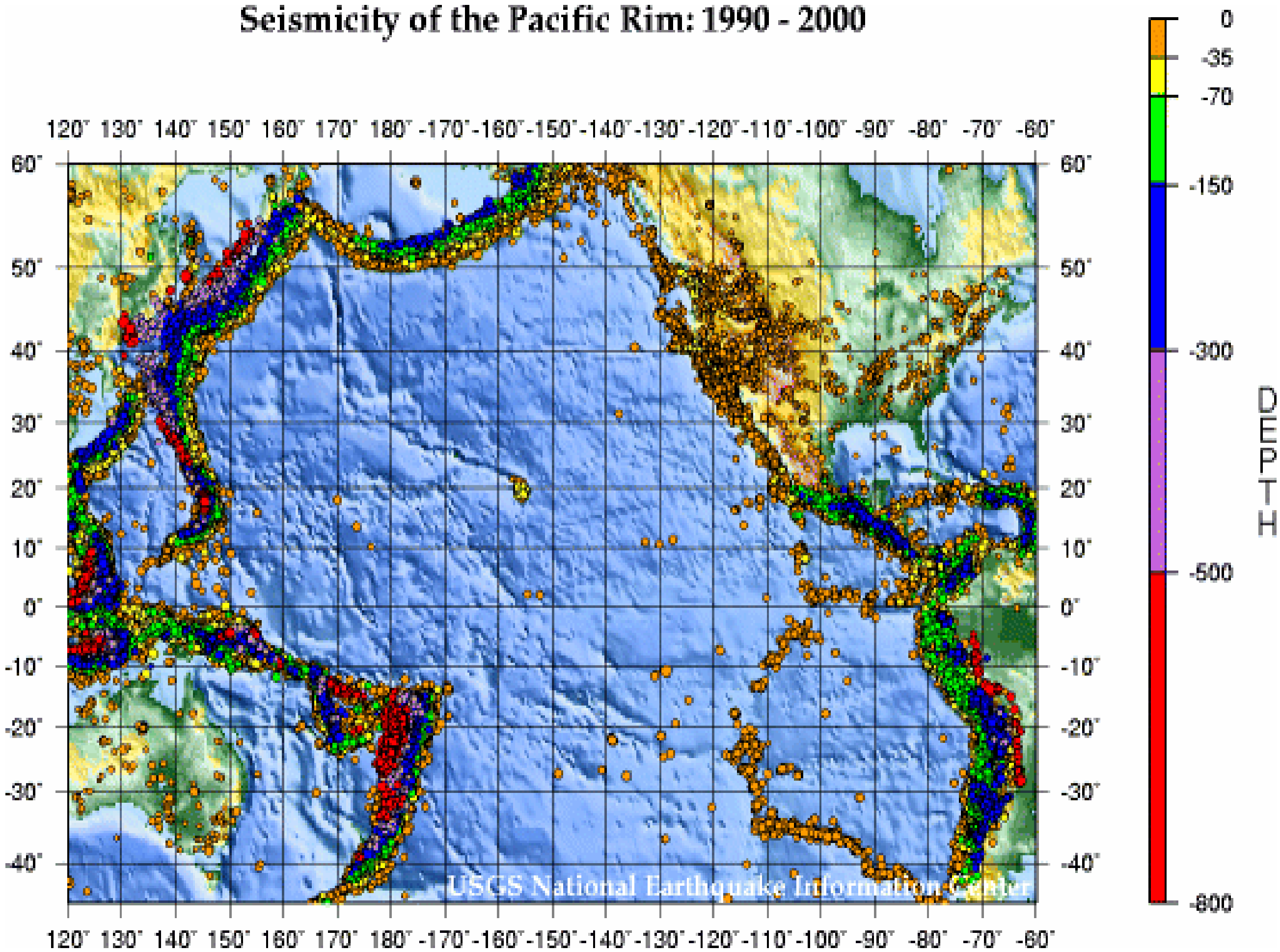

Fig .1 Seismicity of the Pacific Rim (USGS)

anomalies from Meteosat color-composite images before large earthquakes with epicenters in the area from China to the Philippines islands.

Qiang et al. (2001) stated four features that characterize the abrupt temperature increase that they believe were precursors to impending earthquakes:

- A thermal anomaly is 3 to 5 °C warmer than its surrounding area
- The dimension of the thermal anomaly varies with time
- The most common time interval between the appearance of a thermal anomaly precursor and its impending earthquake is 5 – 7 days

- There are two types of thermal anomalies: Stable and Pulse. A stable anomaly is characterized by a constant rise of temperature prior to a big earthquake. On the other hand, a pulse anomaly fluctuates between rise and fall of temperature.

The authors offered an explanation for the temperature and electric field anomalies of the lower atmosphere prior to a big earthquake. They stated that mixed gases, such as CO_2 and CH_4, in different ratios under the action of a transient electric field may cause the temperature of the lower atmosphere to increase up to 6 °C, while solar radiation only increases temperature by 3 °C. They further stated that the increase in thermal infrared brightness temperature in the lower atmosphere is caused by paroxysmal release of greenhouse gases and a sudden change in the lower atmosphere electric field. The release of such gases prior to an earthquake is related to moderately large to large magnitude earthquakes because of associated high stress and deformation in fault zones. The temperature of rocks drops at the beginning of loading (stress) because the gases are released from the rock; then as stress increases, the temperature increases until rocks rupture.

Table 1. The Meteosat temperature anomalies numerical data on March 7 -9, 1991 (Qiang et al. 1993)

Locality	Temperature of March 7	Temperature of March 8	Temp. of March 9	The temperature Anomaly
Tainan City	29º C	30º C	34º C	+5º C
Gaoxinong	29º C	31º C	34º C	+5º C
Taiwan Strait	23º C	21-22º C	24-25º C	+3º C
Bashi Strait	22-23º C	21-22º C	24-25º C	+3º C
Balingtang Strait	23-24º C	20-21º C	25-27º C	+5-6º C

Table 1 shows the temperature increase before a large earthquake of a magnitude 6 east Tainan City in March, 1991. The table also shows the significant increase of temperature from March 7, 8, and peak temperature on March 9. Finally, an earthquake of 6.3 magnitude occurred on March 12. It is not known what weather fronts occurred on or about these days that could have been partially or completely the cause of these temperature increases.

Using the above mentioned theory, Qiang et al. (2001) reported 100 "successful" earthquake predictions that were made from 1990 to 2000. Even a stopped clock is right twice a day and almost any method for predicting earthquakes will succeed occasionally, whether the method has merit or not. Furthermore, they did not compare the prediction with the natural rate of occurrence in a specified area. Additionally, the authors did not state how many earthquake predictions were unsuccessful. Furthermore, those 100 earthquakes were predicted in very active seismological areas, where earthquakes of magnitude ≥5 are frequent. Subduction zones, especially China, Japan, and Taiwan, are zones of intense seismic activity (Fig, 1.1). Thus, this study focuses on the significance of those predicted earthquakes, based on the natural rate of occurrence. Furthermore, this study compares the predicted range, magnitude and area with the United States Geological Survey database.

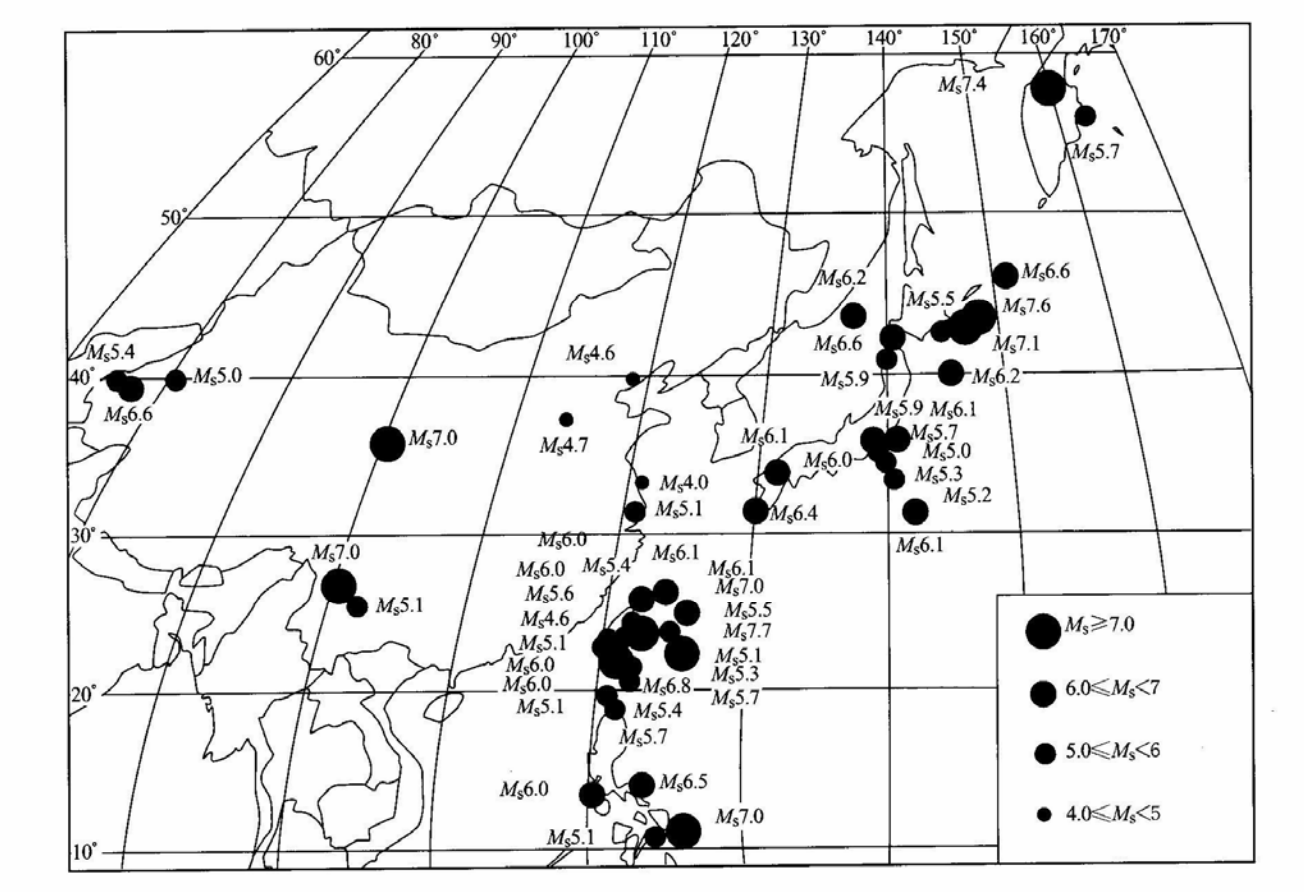

Figure 2. Location of the 100 earthquakes, Qiang et al. (2001). Some of the earthquakes occurred on the same locations more than one times, so the dots are overlapped.

2. STUDY AREA

Qiang et al. (2001) reported 100 successful earthquake predictions. However, they were predicted mainly in the Pacific Margin which is one of the most seismologically active regions of the world (Fig.1 and 2). Their predictions range geographically from S7 º to N 161 º longitude and 11º to 60 º latitude. The authors predicted 31 earthquakes in Taiwan, 29 earthquakes in Japan, 22 earthquakes in China, 9 earthquake in the Philippines, and 9 in the Kamchatka Peninsula of Russian. The tectonic histories of some of the areas are described below.

2.1 China

In China, the authors predicted 22 earthquakes located around active faults and subduction zones, such as Tibet and Hebei provinces (Table 3, Appendix A.). The Tibetan Plateau holds particular interest among geologists and geophysicists because it is in the Himalaya Range. The Himalaya is a very active seismic zone where the authors predicted many earthquakes at different times (Fig. 3). The Himalaya Range is an excellence example of continent- continent collision. East and southeast of the Plateau, the crustal block removes towards the southeast. However the north and northeast of the Plateau, the crustal block body removes itself towards the northeast, which is a margin on the seismic activity in this zone (Gao et.al. 2000). There are four active thrusts: Main Frontal Thrust (MFT), Main Boundary Thrust (MBT), Main Central Thrust (MBT), and South Tethys Detachment System (STDS). Among them, MBT and STDS are active. Qiang et al. (2006) predicted 3 earthquakes in these regions and 17 in the midland area of China and Hebei province.

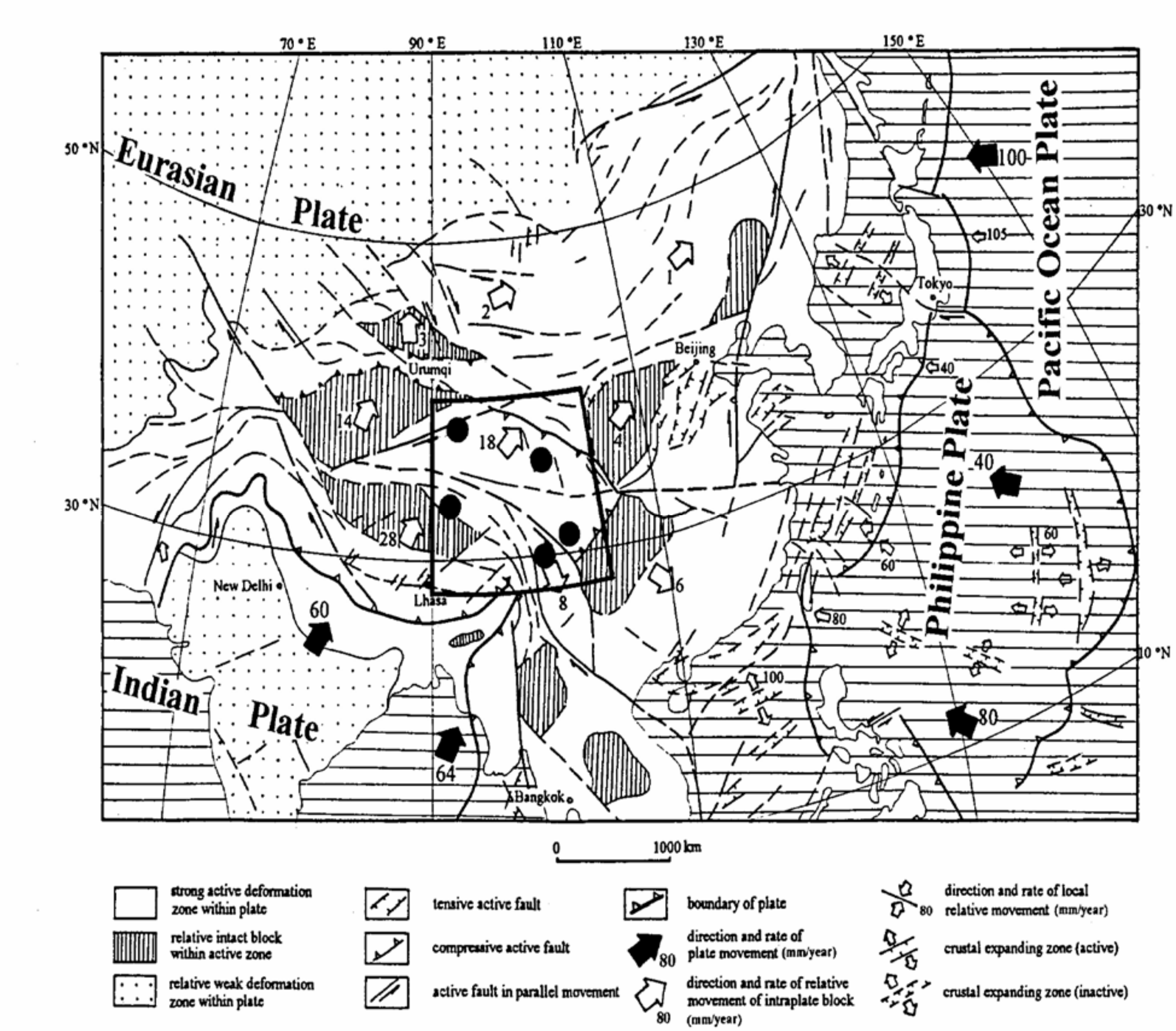

Figure 3. Tectonics of Himalayan. Distribution of earthquakes (black dots) of more than 6.0 magnitude in Tibet (Geo et al., 2000).

Hebei Province is associated with very active faults and a good example of ocean-continent collision between the Eurasian and Philippine Sea plates.

2.2 Taiwan

Qiang et al. (2001) predicted 31 earthquakes in Taiwan. The Taiwan mountain belt is one of the youngest orogenic belt in the world (Appendix: A). Taiwan is a result of the collision of the Luzon arc with the Eurasian (EU) margin. In northeastern Taiwan, the relative motion between the Philippine Sea plate and the Eurasian plate is in a northwest direction with an estimated rate of 8.2cm/year (Yu et al., 1997). The Luzon arc is an intra-oceanic volcanic arc belonging to the Philippine (PH) Sea plate. It crops out in the Coastal Range and contacts the EU margin in the Longitudinal Valley.

The tectonics are still unclear concerning the lithospheric collision between the Luzon arc and the EU lithosphere. Davis et al. (1983) and Suppe (1984) demonstrated that the collision was propagating southward slightly faster than that of the convergence rate, which means that moving south 90 km along the collision is analogous to viewing development of the collision 1 Ma earlier. Thus, most authors (e.g. Teng, 1990; Malavieille et al., 2002) suggest that the evolution through time of Taiwan mountain building is a continuum represented by a series of cross sections from the present-day Manila subduction system to the south (before collision), through middle Taiwan (collision) and northeast of Taiwan, to post-collision features across the southern Okinawa Trough and the Ryukyu subduction system (Fig. 4) (Sibuet and Hsu, 2003).

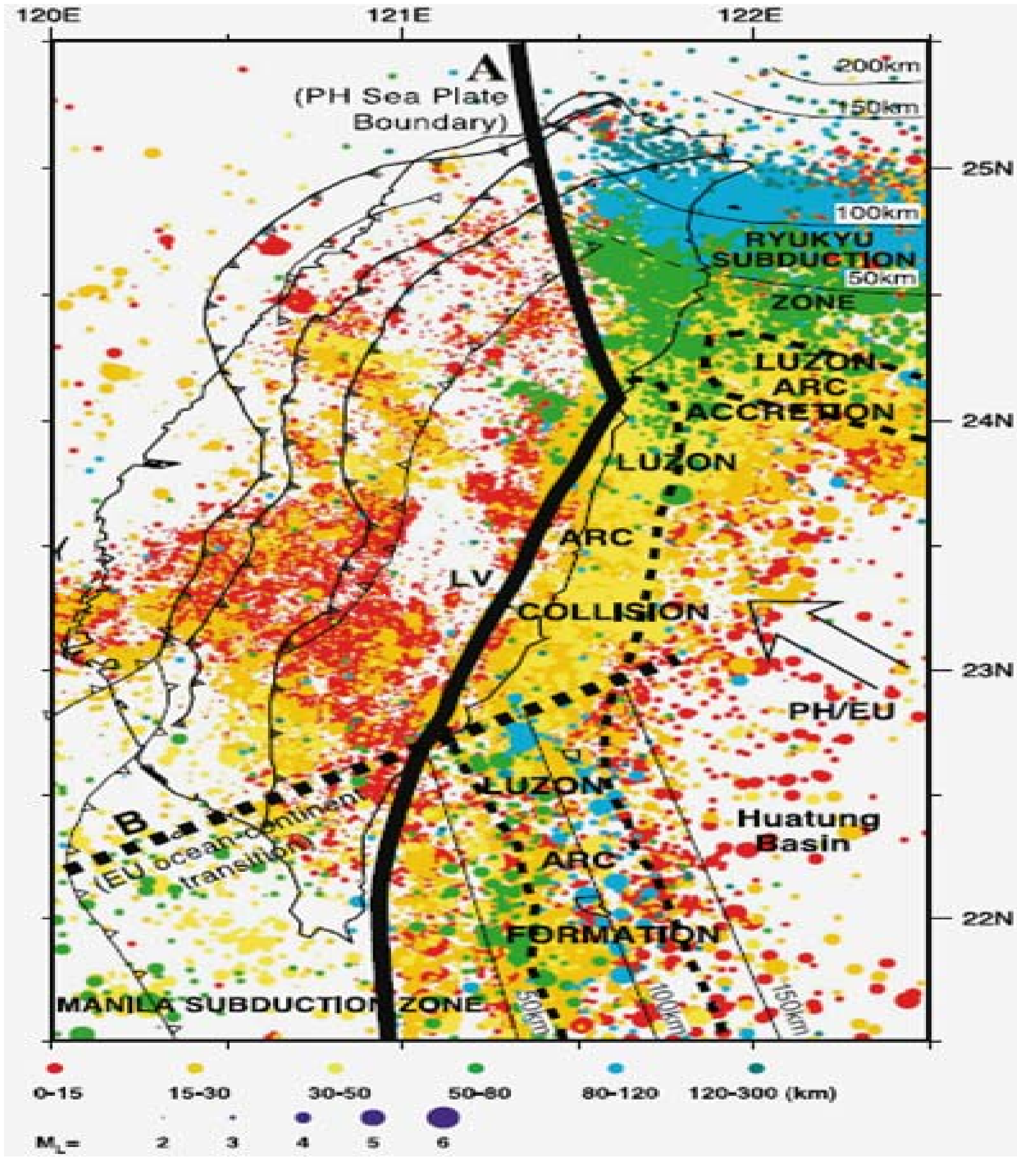

Figure 4. Seismicity map of Taiwan with earthquakes recorded during the 1991– 1997 period by the Central Weather Bureau in Taiwan. Deeper earthquakes are plotted above shallower earthquakes in order to underline the Ryukyu and Manila slabs. A (solid black line) is the western boundary of the PH Sea plate and B is the ocean– continent transition zone within the EU subducted slab. Isobaths of subducted slabs are every 50 km. South of B, the Luzon arc is forming; between A and B, the Luzon arc is colliding with the Eurasia margin. There are only a few deep slab events east of the Longitudinal Valley (LV); East of A, the upper portion of the Luzon arc is probably accreted against the Ryukyu forearc (Sibuet and Hsu, 2003).

2.3 Japan

The Japanese island arcs are an arc-trench system in the western Pacific. The arcs consist of four segments: the western Kuril, Honshu, Ryukyu, and Izu-Bonin arcs (Fig. 5c). The main part of the Japanese arc system contains four big islands: Hokkaido, Honshu, Shikoku, and Kyushu (Fig. 5b) where the authors predicted 29 earthquakes (Appendix A). The current tectonics of the Japanese arc system can be explained by the interaction of five plates: the Eurasia, Amur, Okhotsk, Pacific, and Philippine Sea plates (Wei & Seno 1998; Fig. 4a). Subduction of the Pacific plate at the Kuril arc is oblique, which causes westward migration of the Kuril forearc (Fig. 5c). The westward motion of the Kuril forearc resulted in formation of a collision zone (Hidaka collision zone) in the central Hokkaido. The subduction of the Pacific plate continues at the Japan trench and Izu-Bonin trench. In addition to subduction of the Pacific plate beneath northeastern (NE) Honshu, the plate tectonic model shows that east-west directed convergence between NE Japan (Okhotsk plate) and the Amur plate has initiated an incipient subduction zone on the eastern margin of the Japan Sea (Nakamura 1983, Tamaki & Honza 1985). Northwestward subduction of the Philippine Sea plate, which is oblique to both the Nankai trough and to the collision zone between the Izu-Bonin oceanic island arc and the Honshu arc (Izu collision zone), results in the westward migration of a forearc sliver (Fitch 1972).

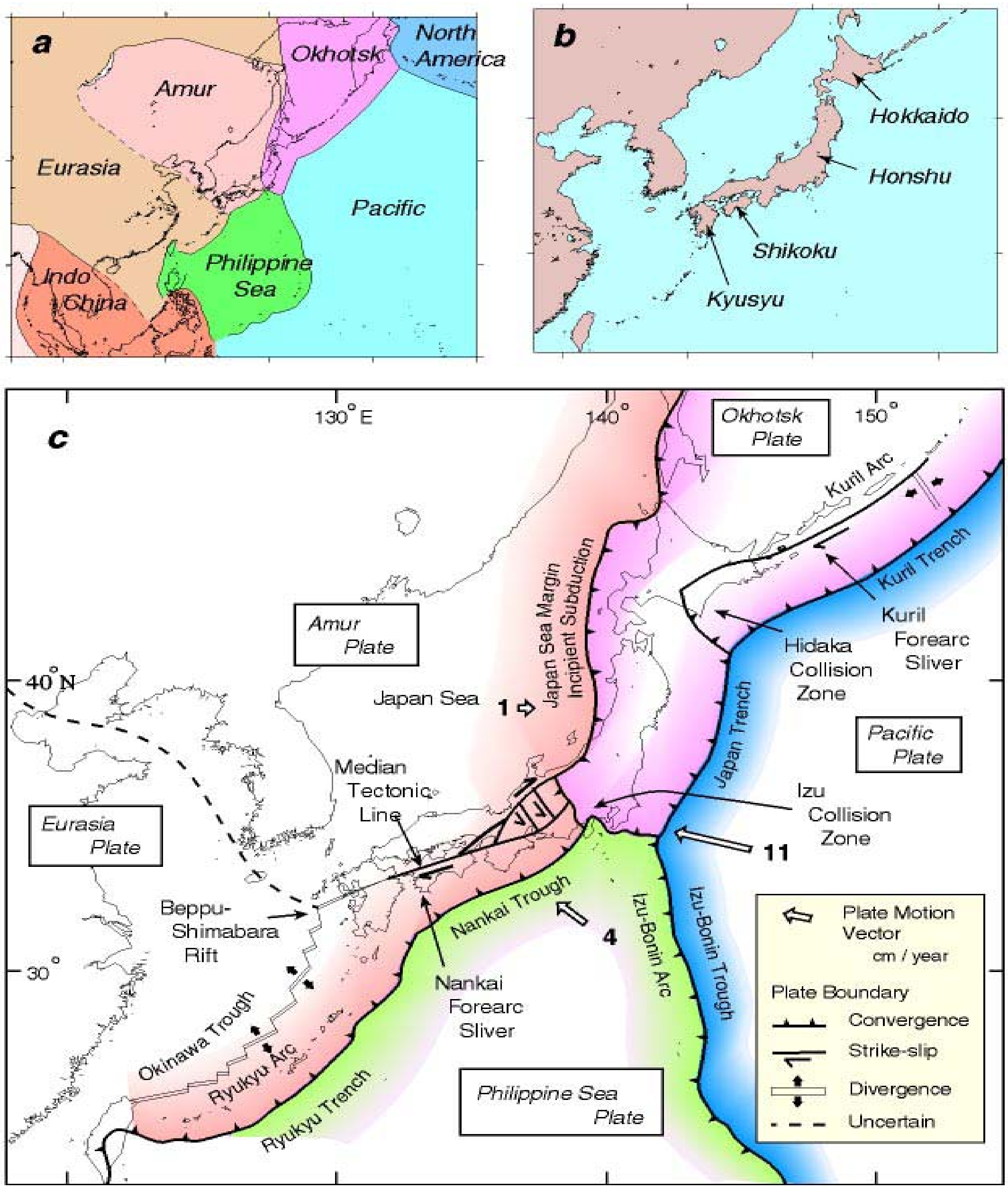

Figure 5. Plate tectonics of the Japanese arc system. (a) Plate tectonic framework of northeastern Asia (modified after Wei & Seno 1998). (b) Main part of the Japanese arc system, showing the distribution of the four big islands. (c) Plate boundaries of the Japanese arc system. Note that central Honshu shows complex microplate tectonics dominated by the median tectonic line (MTL), right-lateral motion, and bookshelf-type rotation tectonics. (Modified after Taira et al 2000.)

2.4 Philippine Islands

The Philippine Islands are the results of the collision between the Eurasian plate and the Pacific plate. In Figure 6, the lines with black triangles are active subduction zones with teeth on the over-riding plate, whereas white triangles denote passive subduction zones (Fig. 5). The major Philippine fault zone is shown as a black line with arrows showing the movement direction. The rate of subduction of the Eurasian Plate is >0.3 cm per year in the Luzon and Mindoro area. Qiang et al. (2001) predicted 9 earthquakes (1990 – 2000) in this area. The Philippine fault zone decouples the northwestward motion of the Pacific with the southwestward motion of the Eurasian Plate, which moves along the active faults and is responsible for the present-day high seismicity of the Philippine Islands (Fig. 7). For the last 35 years, the Philippines have been affected by 10 earthquakes with magnitude greater than 7.0.

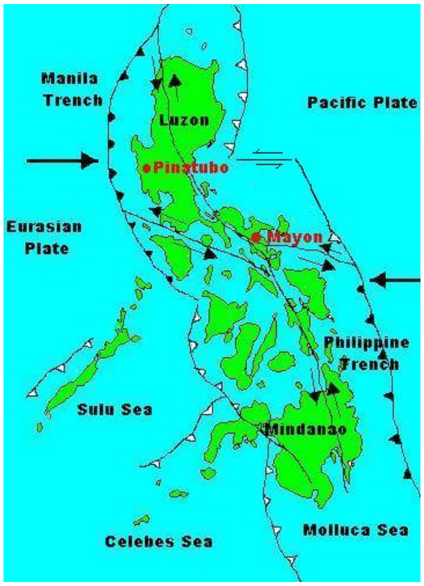

Figure 6. Tectonics of the Philippine Islands. Pinatubo and Mayon are shown as red dots. (http://whatonearth.olehnielsen.dk/philippines.asp)

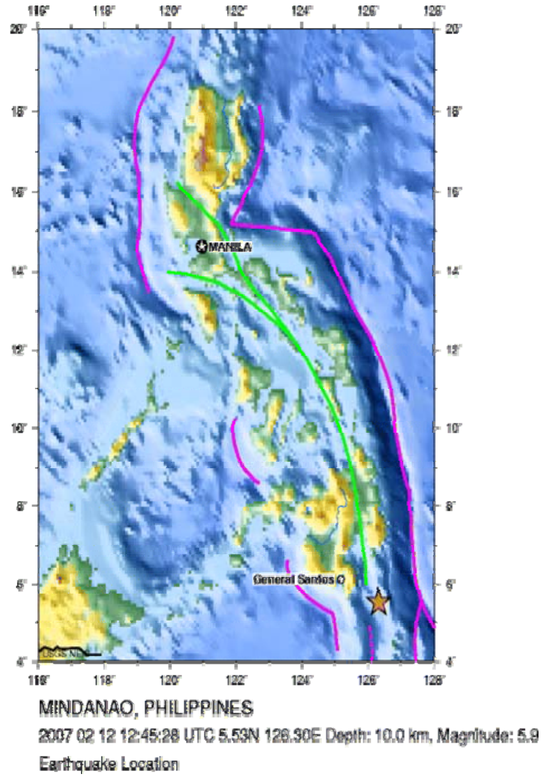

Figure 7. Map of Philippine Plate from USGS, marking one of the many earthquakes in the area. Major Tectonic Boundaries: subduction zones -purple and transform faults –green. (Source: http://whatonearth.olehnielsen.dk/philippines.asp)

2.5 Others

Qiang et al. (2001) predicted 9 earthquakes in the other different parts of world such as Kamchatka-Russia, Indonesia, Myanmar, and Kyrgyzstan. Kamcharka is seismological located near to east Japan and lies on the western Pacific rim. Additionally, Myanmar and Indonesia lie on the Pacific Rim. However, Indonesia is famous for its large volcanic eruptions but volcanism always related to earthquake events.

3. METHODOLOGY

3.1 Previous methods of statistical analysis of earthquake prediction

A common strategy for statistically evaluating earthquake predictions is to compare the success of the predictions on the observed seismicity with the success of the same predictions based on random seismicity. There are two approaches for predicting an earthquake: deterministic and probabilistic models (Stark, 2006). Deterministic earthquake prediction involves specification in advance of the time interval, region, and magnitude range in which a future earthquake will occur. Probabilistic forecasting is defined as estimating the probability of occurrence of an earthquake within a specified time, place, and magnitude window. Many researchers have used these models as well as geophysical methods to test the predictions. Some of them are characterized below (Stark, 2006).

Hypothesis testing and earthquake prediction

Jackson (1996) explains both deterministic and probabilistic prediction testing methods. The deterministic prediction method is based on a probability distribution for the number of successful predictions. Although his null hypothesis is that seismicity follows a Poisson process with rates equal to the historical rates, Jackson does not say how to find these probabilities. Jackson advocates estimating the p-value by simulating the distribution of the sum of independent Bernoulli variables, and mentions the Poisson approximation as an alternative.

Probabilistic approach to earthquake prediction

Console (2001) assumes both deterministic and probabilistic predictions. In deterministic predictions he uses several statistics for comparing alternative sets of predictions. In probabilistic forecasts, he employs the likelihood approach. The likelihood function assumes that predictions succeed independently, with known probabilities. He defines null hypothesis as a seismicity having a Poisson distribution. His model does not determine the significance level or power of such tests. His test rejects the null hypothesis if more events occur during alarms than are expected on the assumption that seismicity has a homogeneous Poisson distribution with true rate equal to the observed rate. Console also addresses selecting prediction methods on the basis of a risk function. The loss function Console contemplates is linear in the number of earthquakes and the number of successful and unsuccessful predictions, all of which are treated as random. He does not address estimating the risk from data, but it seems that any estimate must involve stochastic assumptions.

Chinese earthquake evaluation

Shi, et al. (2001) investigated Chinese earthquake predictions for earthquakes with a magnitude of ≥5 over the 1990–1998 period. They divided the study region into 3,743 small cells in space and years of time. In a given cell and in a given year, either an earthquake is predicted to occur, or not occur in that cell during that year. They define the R-score as

$$R = \frac{\text{cells in which earthquakes are successfully predicted}}{\text{cells in which earthquakes occur}} - \frac{\text{cells with false alarms}}{\text{aseismic cells}}$$

R measures predictions of occurrence and of non-occurrence. For R-score, they first decluster the catalog using Keilis-Borok method. Their hypothesis tests use the R-score as the test statistic.

This model does not explain the relationship between the natural rate of occurrence and predicted earthquakes.

Qiang et al., (2001) prediction error

Qiang et al., (2001) introduced an approach to rate the earthquake prediction errors. They considered that the time, space and magnitude have different degrees of difficulty; the rating standards take the median value of each parameter.

Prediction error is:

$\Delta M = |M - M0|$, $\Delta T = |T - T0|$, $\Delta A = |A - A0|$

They divided each (M, T, and R) parameter starting from 30 to 100 points, with five-point intervals. Earthquake magnitudes are classified into three group 5.0-5.9; 6.0-6.9; 7.0-8.0. For each group, the difference between "prediction realization" and the medium value of the prediction range is computed. ΔT is given as days for the impending earthquake prediction and ΔA has units of kilometers. Due to different degrees of difficulty, the final prediction result is rated according to the sum. Furthermore, a difficulty factor is used in the final sum, that is, 0.20 for M, 0.35 for T and 0.45 for A. The rating formula is:

$$P = AmPm + AtPt + ArPr.$$

Where, P= Prediction

A= Difficulty factor

3.2 Data collection

The location, magnitude, and time of each and every predicted earthquake have been searched from the National Earthquakes Information Center, a branch of United States Geological Survey (USGS) and the Chinese earthquake database. The USGS database contains worldwide earthquake records starting in 1973 to the present. The National Earthquakes Information Center operates a 24-hour-a-day service to determine the location and magnitude of significant earthquakes in the United States and around the world as rapidly and accurately as possible. The total earthquakes that occurred from 1973 to 2007 were used to calculate the natural rate of occurrence. Qiang et al. (2001) reported the location, magnitude and time of the predicted earthquakes based on the Chinese earthquake database. There was no public excess to the Chinese earthquake database. Thus, the expected value and the Poisson probability of the successful earthquakes were not calculated. To collect the number of earthquakes based on USGS database, the geographical coordinates and lower magnitude ranges predicted by the authors for each earthquake were used.

3.3 Deterministic Model (Expected value)

The first task in analyzing the data set is to find out the how many earthquakes occurred within the SMT window. The SMT window is defined as the occurrence of earthquakes with the predicted area, magnitude range, and time frame.

The second task is to find out the expected value and probability of a predicted earthquake in term of successfully predicted occurrence. For the calculation, two major approaches were used to achieve this goal: deterministic and probabilistic models. Earthquake data are very complex in terms of magnitude, time and geography. First, the weekly rate of natural earthquake occurrence over a given geographical area was calculated according to the total number of earthquakes (lower range of predicted earthquake magnitude) and the total time in days of the United States Geological Survey (USGS) database. Additionally, I also calculated the natural rate of occurrence at the lower range of 4 and 5 magnitudes was calculated to determine the degree of seismicity of the areas. The USGS database contains 35 years of worldwide earthquake records starting in 1973 to the present. The total earthquakes that occurred from 1973 to 2007 were used to calculate the natural rate of occurrence. Then, this natural frequency of occurrence will be multiplied by the number of days over which the prediction is made, and the result is the average number of earthquake epicenters that are expected (by the normal rate) to occur over the time window of the prediction.

$$\text{Natural rate of occurrence per week (R)} = \frac{\text{total Number of earthquakes in the predicted area (N)}}{\text{Total Number of weeks (1973-2007)}}$$

$$\text{Expected Value (EX)} = \frac{R*T}{7}$$

Where, T is the predicted time window in days

If the expected earthquake occurrence over the region, magnitude range, and time range of the prediction is 0.5 or greater, there is at least a 50% a chance of an earthquake happening by the natural occurrence rate in that geographical area during the time range of the prediction, and the prediction is not significant. If the expected value is between 0.0 and 0.24, it I is marked as a significant earthquake prediction, because the probability is less than one in four that the earthquake would have occurred according to historical records (what is called natural occurrence). If it is between 0.25 and 0.49, then the prediction is marked as moderately significant.

3.4 Probabilistic Model (Poisson Probability)

For the probability of occurrence of an earthquake in the predicted SMT window the probability of earthquake occurrence using the Poisson distribution were calculated. The Poisson distribution is an appropriate model for count data, such as earthquake occurrence, that has a low rate of occurrence. Therefore, the Poisson distribution was applied only to those areas where the rate of natural frequency is less than 0.15 per week. If the probability is more than 0.15, only the expected number of earthquakes in the predicted SMT window was calculated. The Poisson distribution is a mathematical rule that assigns probabilities to the number of occurrences. The probability density function of the Poisson variable is given by

$$\Pr(Y = y) = \frac{e^{-\mu}\mu^{y}}{y!}$$

Where, μ = average number of occurrences in the predicted SMT window (expected number)

y = Number of earthquakes predictions (0, 1, 2, 3 …n) corresponding to number of earthquake occurrences of interest. The authors predicted one earthquake in a specific SMT (Space, Magnitude, and Time) window.

Therefore, y = 1.

Hence the equation becomes,

$\Pr (Y= y) = e^{-\mu} * \mu$

When $e^{-\mu} \longrightarrow 1$ (Very small)

Then, μ = Expected Number

Hence, if the probability of occurrence is very small, the prediction model has some merits. A predicted earthquake occurrence was assigned as a significant prediction if the probability of an earthquake from historical records over the predicted range of parameters is between 0.0 and 0.09. If it is between 0.1 and 0.25, it is called a moderately significant earthquake prediction. If the natural occurrence probability is more than 0.25, then it is called an insignificant earthquake prediction. Furthermore, if an earthquake is insignificant by expected value and significant by Poisson probability, then the earthquake is classified as an insignificant earthquake.

4. STATISTICAL ANALYSIS OF THE PREDICTED EARTHQUAKES

One hundred successful predictions are reported by Qiang et al., (2001) from 1990 to 2000 (Appendix A). However, the authors did not mention unsuccessful predictions, only the successful ones. Thus, this research is limited to statistical analysis that compares the natural occurrence and Poisson probability of the successfully predicted earthquakes with the occurrence within the SMT window.

Primary analysis shows 85 of those 100 earthquakes that were not reported within predicted SMT window in the USGS database (Appendix B), 2 of those earthquakes were reported without magnitude range by the authors (Appendix B: No. 61, and 64), and one earthquake of those was reported with incomplete latitude (Appendix A: No. 11). Magnitude range should be reported because the statistical calculations are based on the predicted magnitude range of the predicted earthquakes. Thus, 88 out of the 100 successfully predicted earthquakes are not suitable for the further statistical calculations (SMT window analysis, Expected value and Poisson probability).The expected value and Poisson probability of occurrence of the reported 12 successful earthquakes are given in Appendix C and D. Additionally, the detailed statistics of the earthquakes are described below according to the countries where the authors made predictions. According to the Chinese earthquake database, reported by the authors, 81 of 100 earthquakes were considered for statistical calculation because of 78 of 100 earthquakes were not reported within the predicted SMT window in the Chinese database and 3 of 100 earthquakes were reported with incomplete information (Appendix A and B).

4.1. China

Qiang et al. (2001) reported 22 “successful” predictions in China from 1990 to 2000 (Fig. 8, and Appendix: A). According to the USGS database, only 9 earthquakes were reported in the predicted areas, only 6 earthquakes occurred in the predicted magnitude ranges, and 12 earthquakes occurred in the predicted time frame (Fig. 8 and Appendix A). Figure 9 shows that only 4 earthquakes occurred in the predicted area and magnitude, 7 earthquakes occurred in the predicted area and time, and 6 earthquakes occurred in the predicted time and magnitude. Altogether, only 4 of 22 predicted earthquakes occurred in the SMT window (included in Fig. 12). This means that 82 % of the reported “successful” earthquakes are outside the SMT (Space, Magnitude, and Time) window in China. Based on the USGS database, the expected and Poisson probabilities of natural occurrence of 4 successful earthquakes were calculated (Appendix C. No’s. 1, 6, 59, and 64). Three of those are significant and one of those is moderately significant (Appendix C and D).

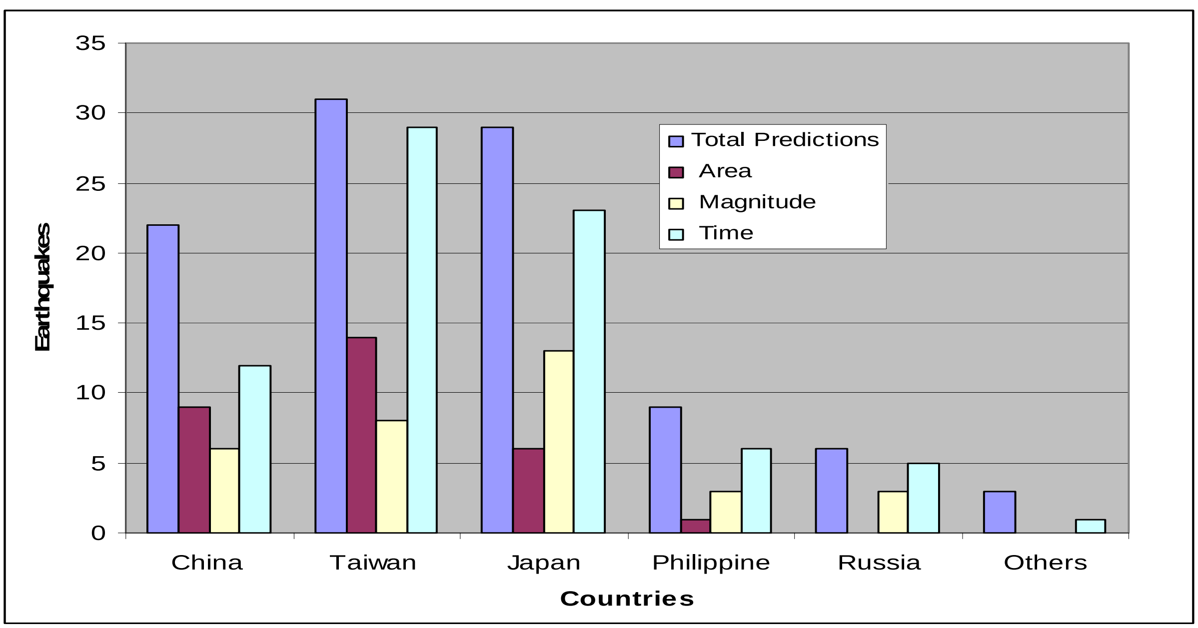

Figure 8. Number of earthquake occurrences within the predicted Area, Magnitude, and Time individually (USGS database).

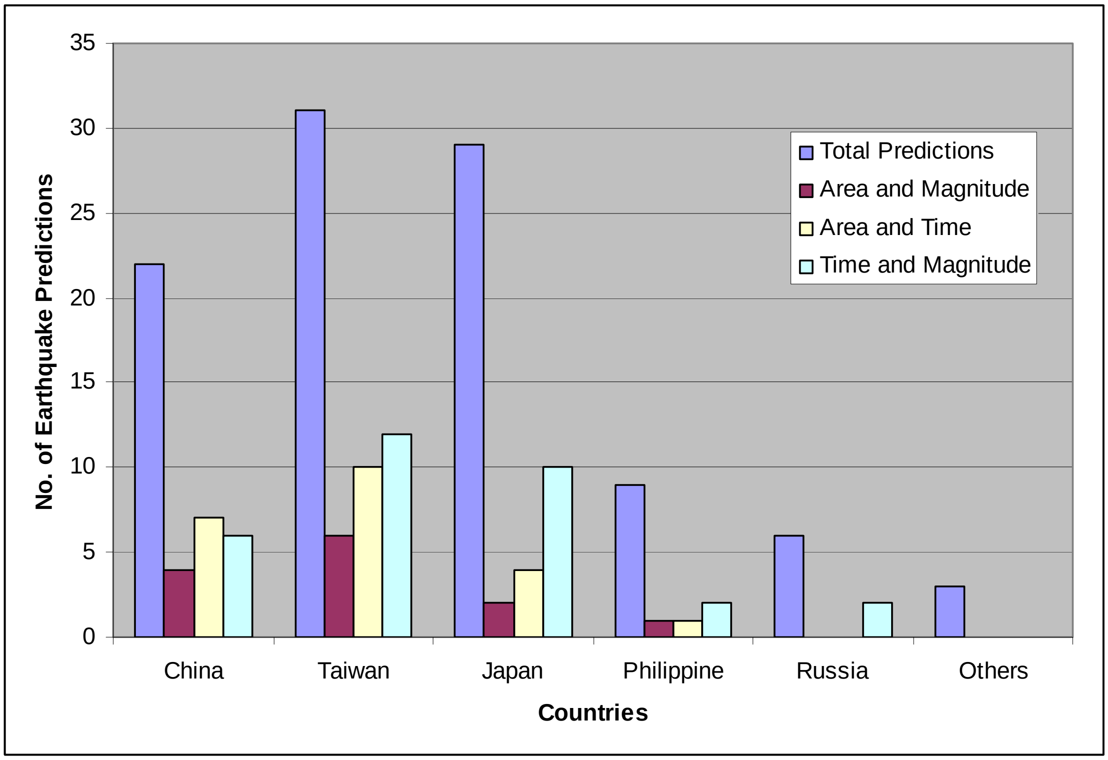

Figure 9. Number of earthquake occurrences within the predicted area and magnitude, area and time, and time and magnitude respectively (USGS database).

According to the Chinese earthquake database, 13 of 22 earthquakes were reported in the predicted areas, 10 of 22 earthquakes occurred in the predicted magnitude ranges, and 15 of those earthquakes occurred in the predicted time frame (Appendix A and Fig. 10). Figure 11 shows that only 6 earthquakes occurred in the predicted area and magnitude, 8 earthquakes occurred in the predicted area and time, and 5 earthquakes occurred in the predicted time and magnitude. Altogether, only 4 of 20 predicted earthquakes occurred in the predicted area and magnitude ranges (Tables. 3 and included in Fig. 12). This means that 82 % of the reported "successful" earthquakes are outside the SMT window in the Chinese database.

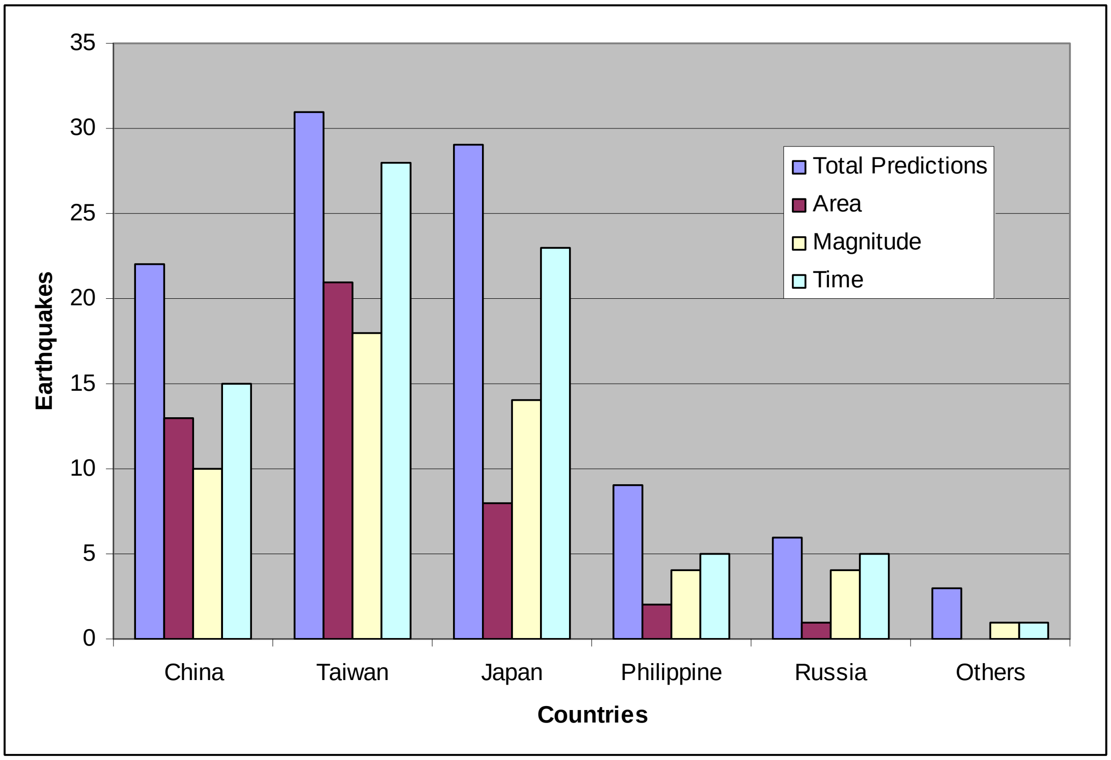

Figure 10. Number of earthquake occurrences within the predicted Space, Magnitude, and Time frame individually (Chinese database).

4.2. Taiwan

Taiwan is one of the most seismically active areas of the world and Qiang et al. (2001) predicted the highest number of earthquakes in Taiwan. They reported 31 "successful" earthquake predictions from 1990 to 2000 in the region (Fig. 8, and Appendix B). Of these earthquakes, 25 were not reported in the predicted SMT window in the USGS database (Appendix B). So, only 6 earthquakes were taken into account for statistical analysis. Furthermore, the authors reported more earthquakes to verify the prediction in a particular time and area of one predicted earthquake (Appendix A and B: No, 67, 71, 97). All of these earthquakes were analyzed, but for the purpose of calculation, only the earthquake that occurred nearest to the SMT window was taken into account (Appendix C). According to STM window analysis, 14 earthquakes were reported in the predicted area, yet only 10 earthquakes occurred in the predicted magnitude range and 29 earthquakes occurred in the predicted time frame (Fig. 8, Table 2 and Appendix B). Figure 9 shows that only 6 earthquakes occurred in the predicted area and magnitude, 10 earthquakes occurred in the predicted area and time, and 12 earthquakes occurred in the predicted time and magnitude. There are only 6 earthquakes that occurred within the SMT (included in Fig. 12, Table. 2, and Appendix B). This means that 79.3 % of the reported "successful" earthquakes were outside the SMT (Space, Magnitude, and Time) window. From the USGS database, the statistical analysis based on expected and Poisson probabilities of the natural occurrence of the 6 successful earthquakes shows that 4 are significant (< 10% probability of occurrence) and 2 earthquakes are moderately significant (< 10% - 25% probability of occurrence) (Appendix C and D).

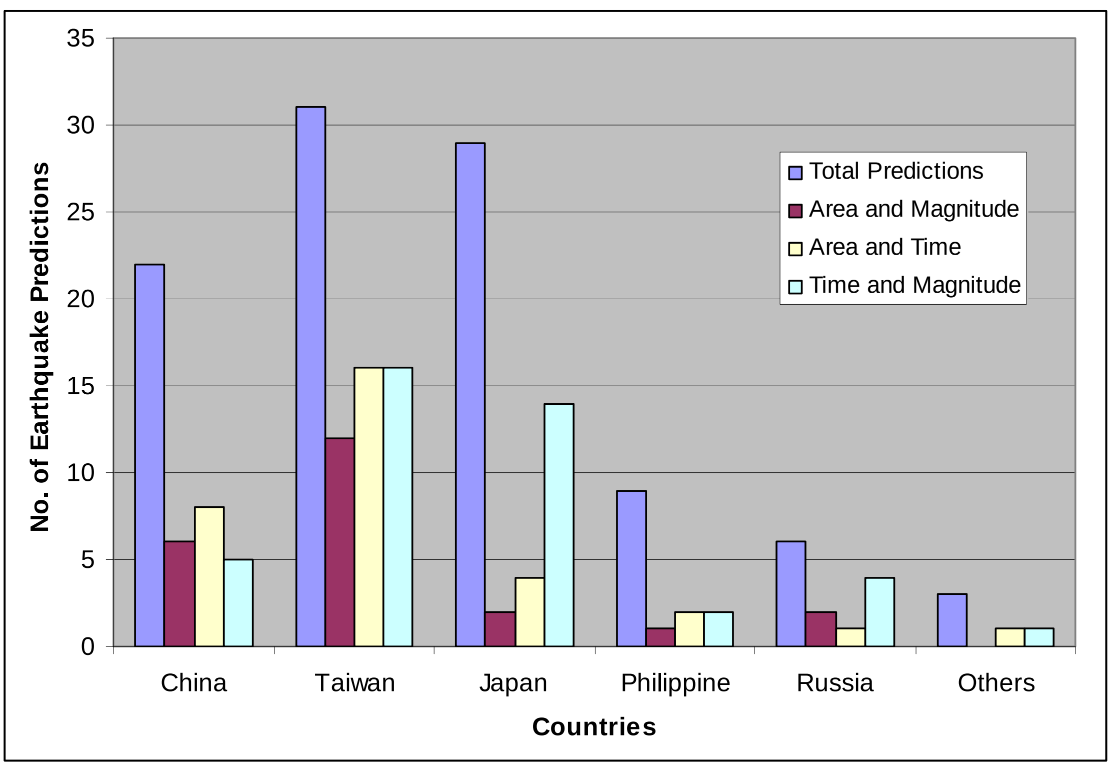

Figure 9. Number of earthquake occurrences within the predicted area and magnitude, area and time, and time and magnitude respectively (Chinese earthquake database).

According to the Chinese earthquake database, 21 of 31 earthquakes were reported in the predicted areas, 18 of 31 earthquakes occurred in the predicted magnitude ranges, and 28 of 31 earthquakes occurred in the predicted time frame. Figure 11 shows that 12 earthquakes occurred in the predicted area and magnitude, 16 earthquakes occurred in the predicted area and time, and 16 earthquakes occurred in the predicted time and magnitude. Altogether, 11 of 31 predicted earthquakes occurred in the predicted area and magnitude ranges (Table 3 and Fig. 12). This means that 64.5 % of the reported "successful" earthquakes were outside the SMT window in the database.

4.3. Japan

Qiang et al. (2001) reported 29 successful earthquake predictions from 1990 to 2000 in Japan (Fig. 8). The authors reported two and more than two earthquakes in many regions. However, an earthquake occurring geographically nearest to the predicted SMT window was taken into statistical analysis, when they were within the M and T windows of prediction. For example, the Izu Island earthquake of Japan that occurred on 30 July, 2000 was included because it is nearer to the predicted SMT window than other reported earthquakes at the time (Appendix B: No. 96). A similar methodology is applied to the Hokkaido earthquake on 26 August 2000 and the Miyake Island earthquake on 23 August 2000, where the authors reported 3 and 2 earthquakes, respectively (Appendix A: No. 98 and 99). The USGS database shows that 6 of those earthquakes occurred in the predicted area, 13 earthquakes occurred in the predicted magnitude range, and 23 earthquakes occurred in the predicted time span (Appendix B). Figure 9 shows that only 2 earthquakes occurred in the predicted area and magnitude, 4 earthquakes occurred in the predicted area and time, and 10 earthquakes occurred in the predicted time and magnitude. Altogether, only one earthquake occurred within the predicted STM window

(Appendix B: No. 45, and included in Fig. 12.). Thus, 96.5 % of the reported "successful" earthquakes were outside the SMT window in Japan. Based on the USGS database, the expected value and Poisson probabilities of the natural occurrence of earthquakes shows that only one earthquakes successfully predicted for this region is significant (< 10% probability of occurrence).

According to the Chinese earthquake database, 8 of 31 earthquakes were reported in the predicted areas, 14 of those earthquakes occurred in the predicted magnitude ranges, and 23 of those earthquakes occurred in the predicted time frame. Figure 11 shows that only 2 earthquakes occurred in the predicted area and magnitude, 4 earthquakes occurred in the predicted area and time, and 14 earthquakes occurred in the predicted time and magnitude. Altogether, 2 of 29 earthquakes occurred in the predicted SMT window (Appendix A: No. 27 and 45). This means that 93 % of the reported "successful" earthquakes in Taiwan were outside the SMT window, according to the Chinese earthquake database (Fig. 12).

4.4. Philippines

Qiang et al. (2001) reported 9 successful earthquake predictions from 1990 to 2000 in the Philippines Island (Fig. 8 and Appendix A). However, only one earthquake occurred in the predicted areas and only 3 earthquakes occurred within the predicted magnitude range and 6 earthquakes occurred in the predicted time span, according to the USGS database. Figure 9 shows that only 1 of 9 earthquakes occurred in the predicted area and magnitude, 1 of those earthquakes occurred in the predicted area and time, and 2 of those earthquakes occurred in the predicted time and magnitude. Thus, only one earthquake occurred in the predicted SMT window. The expected and Poisson probability of natural occurrence of the one successful earthquake shows that it is significant.

According to the Chinese earthquake database, 2 of 9 earthquakes were reported in the predicted areas, 4 of those earthquakes occurred in the predicted magnitude ranges, and 5 of those earthquakes occurred in the predicted time frame. Figure 11 shows that only 1 earthquake occurred in the predicted area and magnitude, 2 earthquakes occurred in the predicted area and time, and 2 earthquakes occurred in the predicted time and magnitude. Altogether, only one earthquake occurred in the predicted SMT window (Appendix A: No. 29). This means that 89 % of the reported "successful" earthquakes were outside the SMT window, according to the Chinese earthquake database.

4.5. Kamchatka, Russia

Qiang et al. (2001) reported 6 successful earthquake predictions from 1990 to 2000 in Japan (Appendix A). The authors reported 5 earthquakes for Kamchatka-Kuriskie Island from 15th April to 6th May in 1999 at a time (Appendix A: No 69). However, an earthquake that occurred on 8th May is taken into statistical consideration because it is near the predicted SMT window (Appendix B: No. 69). The USGS database shows no earthquake occurred in the predicted area, 3 earthquakes occurred in the predicted magnitude range, and 5 earthquakes occurred in the predicted time span (Table. 3). Figure 9 shows that no earthquakes occurred in the predicted area and magnitude, no earthquakes occurred in the predicted area and time, and 2 earthquakes occurred in the predicted time and magnitude. Therefore, no earthquakes occurred in the predicted SMT window in Kamchatka, Russia.

According to the Chinese earthquake database, 1 of 6 earthquakes were reported in the predicted areas, 4 of those earthquakes occurred in the predicted magnitude ranges, and 5 of those earthquakes occurred in the predicted time frame. Figure 11 shows that only 2 earthquakes occurred in the predicted area and magnitude, 1 earthquake occurred in the predicted area and time, and 4 earthquakes occurred in the predicted time and magnitude. Altogether, only one occurred in the predicted SMT window (Table 12 and Appendix A: No. 29). This means that 83 % of the reported "successful" earthquakes were outside the SMT window in the Chinese earthquake database.

4.6. Others

Qiang et al. (2001) reported 3 successful earthquake predictions from 1990 to 2000 in different parts of the worlds other than the above mentioned (Appendix A). They reported 1 earthquake in Kyrgyzstan, 1 earthquake in the northern part of Myanmar, and 1 earthquake in Merapi volcano of Indonesia. However, the earthquake reported in Merapi was reported without magnitude; so, it was excluded in the calculation (Appendix A: No. 61). Therefore, only 2 earthquakes were taken into account for statistical analysis. Furthermore, two remaining earthquakes did not occur in the predicted area and magnitude range, but one of them occurred in the predicted time span. Figure 9 shows that no earthquakes occurred in the predicted area and magnitude, area and time, and time and magnitude. Thus, no earthquakes occurred in the predicted SMT window.

According to the Chinese earthquake database, no earthquakes were reported in the predicted areas, one of those earthquakes occurred in the predicted magnitude ranges, and one of those earthquakes occurred in the predicted time frame (Fig. 10). Figure 11 shows that no earthquakes occurred in the predicted area and magnitude, 1 earthquake occurred in the predicted area and time, and 1 earthquake occurred in the predicted time and magnitude. Thus, no earthquakes occurred in the predicted SMT window, according to the Chinese database.

5. DISCUSSION

The phenomena associated with earthquakes are complex and difficult to predict with respect to time, geography, and magnitude. Earthquake predictions are controversial, and pessimistic attitudes seem to be in vogue in seismology. Furthermore, Bak and Tang (1989) stated that earthquakes are a self-organized critical phenomenon and Geller et, al. (1997) declared that earthquakes cannot be predicted. Scientists have proposed different physical and statistical models with which to test their success, but it is very difficult to test physical models statistically. Physical models work in many different ways and might or might not have statistical significance.

Qiang et al. (1992,1993, and 1997) proposed a model in which there are significant changes in ground temperature and electric field of the lower atmosphere preceding large earthquakes. They stated that mixed gases, such as CO_2 and CH_4 in different ratios under the action of a transient electric field, may cause temperatures to increase up to 6 °C, from 2 to 8 days before an earthquake with a Scale magnitude ≥ 5.0, whereas solar radiation could increase temperature by only 3 °C. The authors predicted 100 earthquakes in the seismologically very active areas of Taiwan, China, Japan, Philippine, and Kamchatka-Russia from 1990 to 2000 based on ground-based evidence and thermal infrared anomalies in METEOSAT image data. It seems the predictions are biased by the precursor of large earthquakes because the anomalies are generally noticed a week before the large earthquakes occur and precursors are common before a big earthquake. There are other areas of doubt raised by their predictions. For instance, 25% of the total reported earthquakes were predicted in the Pacific Ocean (Appendix A). How is it possible to notice the change of temperature in the water having a depth of 5 to 10 km? It is difficult to explain such changes in local water temperature if the increase is due to the release of heat and gases from active faults on the sea floor. The effectiveness of heat transport to the surface will be negligible for water of 5-10 km depth. Also, cannot temperature anomalies at sea or over land be caused by a weather front? More than 90% of the total predictions reported occurred on the Pacific Rim, which clearly shows that the authors predicted the earthquakes in the tectonically active areas of the such as Japan, Taiwan, China etc (Fig. 1 and 2). Sixty-five of 100 earthquakes occurred in areas where an earthquake of $\geq$ 4 magnitude occurs naturally every week (USGS database, and Appendix C). The depths of the earthquake foci range from 5 to 300 km.

The first approach used to validate the predictions of by Qiang et al. (2001) was to count the total number of earthquake epicenters recorded in the United states Geological survey and Chinese earthquake database that occurred in the SMT (space, magnitude , and time) window. These results are summarized for both archived data sets in Figure 13, which shows that only 12% of 100 predicted earthquakes listed in the USGS database had epicenters that occurred in the SMT window for all 6 regions listed and only 19 % of 100 earthquakes listed in the Chinese database actually had an epicenter that occurred in the SMT window for these same regions (Fig. 12, Table 2 and 3). Over 80% of the time, the epicenters of the predicted earthquakes were reported outside the predicted SMT window, according to either database. This clearly shows that the authors' method failed to predict epicenters in the predicted SMT window.

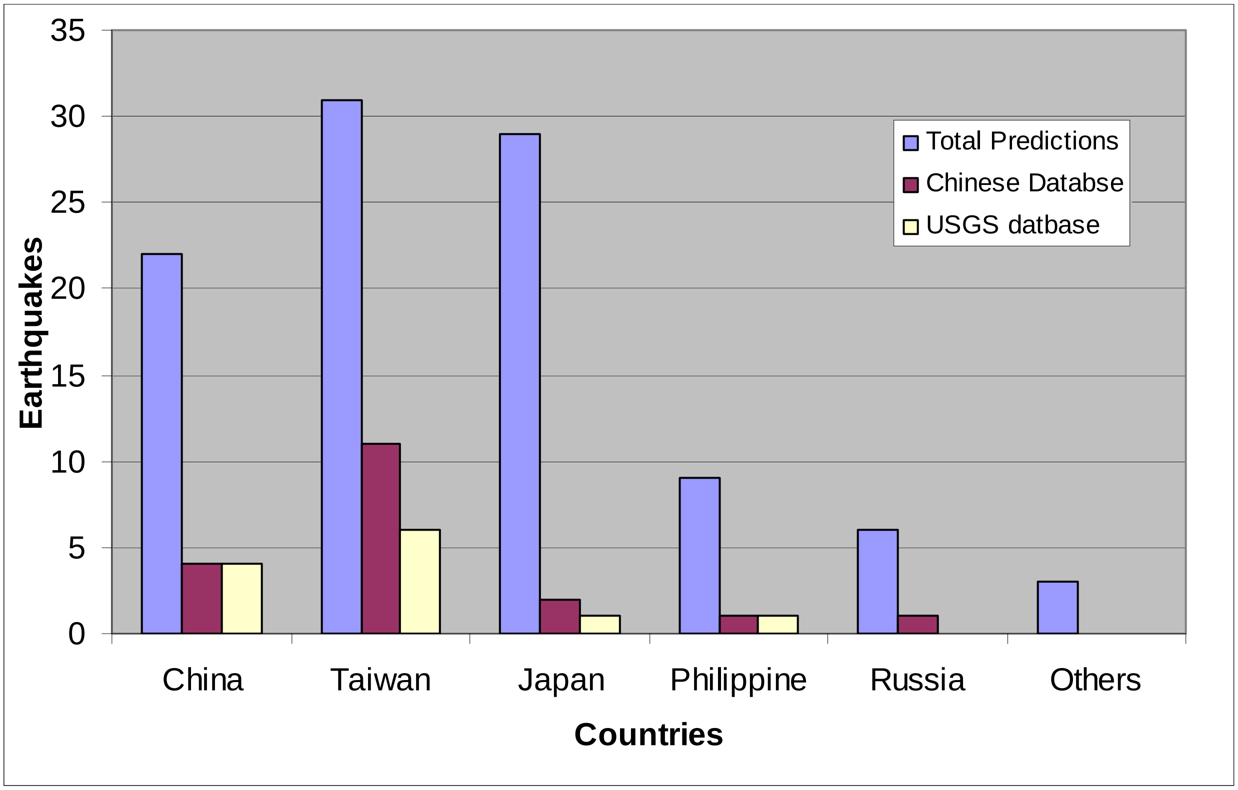

Figure 12. Number occurrences within SMT window on the Chinese database versus the USGS database with compare to total predictions.

The second approach is to calculate the expected natural rate of occurrence and Poisson probability for the 12 earthquakes that actually occurred within the predicted SMT window, as reported in the USGS database only. The expected value and Poisson probability of the natural occurrences of the 12 earthquakes in the USGS data base that occurred within the SMT window shows that 9 of them were significant (natural occurrence probability was less than 25%) and 3 of them were moderately significant (natural occurrence probability was 25-50%) (Fig.13). Remaining 80 earthquakes are worthless for statistical analysis because the authors predicting epicenters, not earthquakes. We can say that an earthquake occurs in Texas even when the epicenter is in California, because you can observe energy even at a long distance. However, mere earthquake prediction (with no epicenter prediction) would be almost meaningless for warning purposes, because most of the damage occurs near the epicenter. Therefore, this second approach is really not a good indicator of their success. The most important conclusion, then, is that labeling as "successful" the 80 earthquakes that had epicenter occurrences outside the SMT window is highly inaccurate reporting by Qiang et al. (2001).

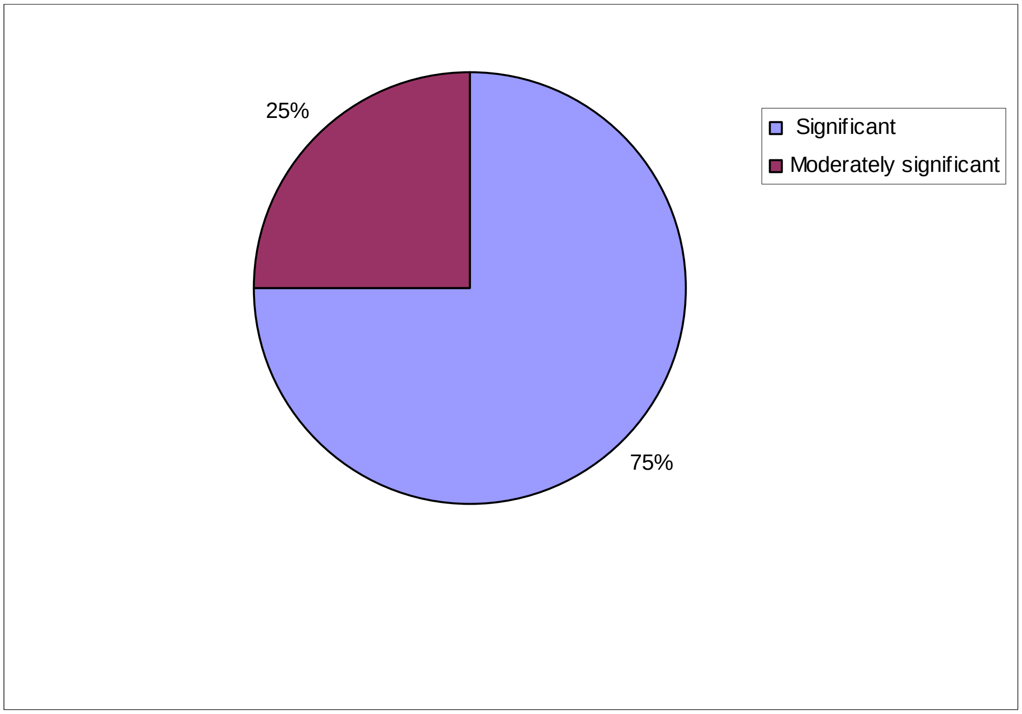

Figure 13. Statistical significance of 12 successful earthquakes

(Within SMT window, USGS database)

Qiang et al. (2001) also did not report how many unsuccessful earthquake predictions they made; they only mentioned successful predictions. Therefore, it is impossible to determine how many significant earthquakes were successfully predicted from all of their predictions. In all, the predictions by Qiang et al. (2001) have not proved too inaccurate to justify acceptance of their method by seismologists. It shows earthquake prediction is a very challenging task in the field of science.

Table 2. SMT window statistics based on the USGS database.

Country	Number of earthquakes reported	Epicenter Within the Area	Epicenter Within the Magnitude	Epicenter Within the Time frame	Epicenter Within Time, Area, and Magnitude window
China	22	9	6	12	4
Taiwan	31	14	8	29	6
Japan	29	6	13	23	1
Philippine	9	1	3	6	1
Russia	6	0	3	5	0
Others	3	0	0	1	0
Total	100	30	33	76	12

Table 3. SMT window statistics based on the Chinese earthquake database.

Country	Number of earthquakes reported	Epicenter Within the Area	Epicenter Within the Magnitude	Epicenter Within the Time frame	Epicenter Within Time, Area, and Magnitude window
China	22	13	10	15	4
Taiwan	31	21	18	28	11
Japan	29	8	14	23	2
Philippine	9	2	4	5	1
Russia	6	1	4	5	1
Others	3	0	1	1	0
Total	100	46	51	77	19

6. CONCLUSIONS

1. Qiang et al. (2001) did not report how many of their predictions were unsuccessful.

2. Based on the Chinese earthquake database, 81% of earthquake epicenters reported as "successful" predictions occurred outside of their predicted SMT window.

3. Based on the USGS earthquake database, 88% of earthquake epicenters reported by Qiang et al. (2001) as "successful" predictions occurred outside of their predicted SMT window. Hence, only 12% of those epicenters occurred within the predicted SMT window. However, 75% of those 12% were significant, and 25% were moderately significant predictions, when compared to natural earthquake epicenter occurrences in those SMT windows

4. The method used by Qiang et al. (2001) is unable to reliably predict earthquake epicenters within their SMT windows with reasonable accuracy, according to both the USGS and Chinese earthquake epicenter databases

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APPENDICES

Appendix A: Statistical analysis of the SMT window of the predicted earthquakes,

*** indicates the earthquakes out of the predicted time frame.**

(Chinese earthquake database)

No.	Earthquake	Ms	Date	Latitude	Longitude	Prediction			Occurrence within	
						Date	Area	Magnitude	Area	Magnitude
1	East of Changshu,Jiangsu province	5.1	1990 Feb.10	31.6	121.0	1990 Feb.6-Feb.21	N31-32 E120-121.5	5-6	Yes	Yes
2	Gonghe,Qinghai province	7.0	Apr.26*	36.1	100.3	Apr.17-Apr.25	N36-38 E99-101	6.5-6.9	Yes	Yes
3	SW sea area of Taiwan Island	5.1	May 23	20.1	120.7	May 21-May 31	N20-21 E119.5-121	5.0-5.5	Yes	Yes
4	East sea side of Taiwan	5.4	July 4	25.2	126.2	June 30-July 10	N25-24 E123-124	5.0-5.5	No	Yes
5	East of Taiwan Riukyu Island	5.5	Oct.1	24.0	124.6	Sept.22-Oct.3	N24-25 E122-123	5.0-5.5	No	Yes
6	Artux, Xinjiang province	5.4	1991 March 7	40.0	75.5	1991 Feb.28-March 20	N31-41 E74-76	5.0-5.5	Yes	Yes
7	East to Taiwan Island	6.0	March 12	23.0	120.3	March 7-March 17	N22-23 E120-121	5-6	Yes	Yes
8	Awat, Xinjiang province	5.6	Apr.3	40.1	80.4	March 27-Apr.10	N39-41 E78-80	6.0	No	No
9	Ryukyu Island, east to Hualian,Taiwan Island	6.0 5.0	Apr.14 Apr.26	26.2 23.9	122.4 122.6	Apr.14-Apr.29	N24-25 E121-122	5-6	No	Yes
10	Tangshan,Hebei province	4.7 5.1	May 29* May 30*	39.7 39.5	118.3 118.2	Apr.20-May 5	N39-40 E118-119	5.0-5.5	Yes	Yes
11	Luan Xian,Hebei province	4.6	July 29	39.9	118.7	July 25-Aug.5	N39-40 E118-119	5.0	Yes	No
12	Longyao,Xingtai ,Hebei province	4.7 4.6	Aug.28 Aug.29	37.4 37.5	114.1 114.9	Aug.18-Aug.29	N37-38 E114-11	5.0	Incomplete	No
13	Luzon,Bashi Channel	5.4 5.2	1992 Feb.10 Feb.18	21.0 22.0	122.0 119.0	1992 Jan.30-Feb.25	N21-22 E120-122	5.0	Yes	Yes
14	Sea area,east to Hualian,Taiwan Island	6.8	Apr.20	23.8	121.7	Apr.17-Apr.27	N23-24 E121-122.5	6.0-6.5	Yes	Yes
15	Sea area,east to Hualian,Taiwan Island	4.6 4.5	May 1 May 4	23.8 23.0	121.4 122.3	Apr.30-May 10	N23-24 E121-122	6.0	Yes	No
16	Kyrgyzstan	7.5	Aug.18	42.1	73.8	Aug.4-Aug.24	N41-43 E74-76	7.0	No	Yes
17	Dongsha Island,Southern Sea	5.9	Sept.14 *	21.6	117.8	Aug.19-Sept.9	N21-22 E117-119	6.0	Yes	No
18	Lazhi,Tibet	6.6	1993 March 20	29.5	88	1993 Feb.23-March 26	N28-30 E86-87	6.0	No	Yes
19	East of	6.6	Aug.8*	42.4	140.6	July 18-Aug.7	N41-43	7.0	No	No

	Hokaido,Japan Sea						E139-140			
20	Hachijojima,Japan	6.1	Sept.1	31.5	142.2	Aug.12-Sept.5	N32-34 E140-142	6.0-6.5	No	Yes
21	Outer sea of Hualian,Taiwan Island	5.6	1994 Jan.20	24.2	122.0	Jan.18-Feb.10	N24-25.5 E122-124	6.0-6.5	Yes	No
22	Northern part of Myanmar	6.2	Apr.6*	26.3	97.0	March 26-March 15	N25-26 E95-97	7.0	No	No
23	Southeastern sea area to Taiwan Island	5.7	Apr.13	21.9	122.2	Apr.3-Apr.23	N21-23 E121-122	6.0-6.5	No	No
24	East to Luzon Island,Philippine	6.0	Apr.27*	13.8	120.3	Apr.13-Apr.23	N11-13 E118-120	6.0-6.5	No	Yes
25	Outer sea of Hualian,Taiwan Island	6.3 5.6 6.2 7.0	May 23 May 23 May 23 May 24	24.5 24.5 24.4 24.1	122.2 122.1 122.5 122.5	May 13-May 28	N23-24 E122-123	5.0-6.0	No	Yes
26	Outer sea of Hualian,Taiwan Island	4.9	July 1	24.5	121.8	June 10-July 1	N22-23 E121-123	6.0	No	No
27	East of KuriLskije Island, Japan	7.6 6.9	Oct.9 Oct.16	43.8 43.8	148.2 148.2	Oct.9-Oct.29	N42-44 E148-150	7.0	Yes	Yes
28	Eastern of Yilan,Taiwan Island	6.0	1995 Apr.3*	24.5	122.0	1995 March 17-Apr. 2	N24-25 E121-123	6.0-6.5	Yes	Yes
29	Sama Island, Philippine	7.0 7.2 7.5 7.2 7.0 7.1	Apr.21 Apr.21 Apr.21 Apr.21 Apr.23 May 5	11.7 11.7 11.7 11.7 12.8 12.8	126.5 126.5 126.5 126.5 125.5 125.5	Apr. 16-May 5	N11-13 E126-127	6.0-6.5	Yes	Yes
30	Southernwestern of Zhanghua, Taiwan	5.1	Nov.1	23.6	120.2	Oct.21-Nov.10	N21-23 E120-122	6.0-6.5	No	No
31	Wuding,Yunnan province	5.1	Nov.1	25.7	102.2	Oct.27-Nov.18	N25-26 E101.5-102.5	6.0-6.5	Yes	No
32	Lijiang,Yunnan province	7.0	1996 Feb.3*	27.2	100.3	1995 Dec.16, -1996 Jan.5	N25-27 E101-103	6.5-6.9	No	Yes
33	Kamchatka,Russia	7.4	July 16	58.15	160.05	July 14-Aug.5	N57-59 E159-161	7.0	Yes	Yes
34	Dadanvis Island, Philippine	6.5	Nov.7	14.5	123.6	Oct.28-Nov.17	N13-15 E122-123	6.0	No	Yes
35	Western side of Hokkaido Island,Japan	6.2	Dec.22*	43.9	137.2	Oct.31-Dec.15	N42-44 E139-141	7.0	No	No
36	South part of Yellow Sea	4.0	Nov.17	33.28	121.15	Nov.13-Dec.3	N32-33 E121-122	5.0	No	No
37	South part of Ibaraki, Japan	6.0	Dec.21	36.04	139.04	Dec.13-Dec.28	N34-36 E139-141	6.0-6.5	No	Yes
38	Izu Pen.Swarm Earthquake,Japan	5.7	1997 March 4	35.5	139.04	1997 Feb.26-March 10	N35-36 E139-140	6.0	Yes	No
39	Hachijojima, Japan	5.2	Apr.9	33.5	140.6	Apr. 3-Apr.18	N32-33 E140-141	5.0	No	Yes
40	Kagoshima,Kyushu,Japan	6.4	May 13	31.60	130.20	Apr.19-May 11	N30-31 E131-132	6.0	No	Yes
41	Jashi,Xinjiang,P.R.China	5.4	May 17	39.60	77.00	Apr.19-May 21	N38-40 E76-78	5.5-6.5	Yes	No

42	Balintown, Phillipine	5.7	May 22	19.1	121.3	May 18-June 10	N13.5-15 E123-124.5	6.0	No	No
43	Iwakum Honshu Island, Japan	6.1	June 25	34	131.5	June 1-June 26	N31-33 E130-132	6.5-6.9	No	No
44	Taidong, Taiwan Island	5.1	July 5*	22.7	121.4	May 5-June 4	N23-24 E121-123	6.0	No	No
45	Ryukyu Island, Japan	6.1	Aug.13	25.3	125.7	Aug.13-Aug.28	N25-26 E125-126	6.0-6.5	Yes	Yes
46	Tokyo bay, Japan	5.9	Sept.8	35.5	139.7	Aug.13-Sept.21	N34-36 E140-142	6.5	No	No
47	The south side sea of Hokkaido,Japan	6.2 5.1 6.1	Oct.23 Oct.27 Nov.15	40.2 39.57 43.7	145.4 140.31 145	Oct.18-Nov.25	N41-43 E142-144	6.2	No	yes
48	Hokkaido,Japan	5.0 5.2 5.3 5.5	1998 Feb.27 March 3 Apr.8 Apr.9	42.36 42.64 41.79 42.74	145.7 144.1 141.88 144.9	1998 Feb.27-Apr.10	N41-43 E144-146	7.0	Yes	No
49	Tangshan,Hebei province	4.7	Apr.14	39.7	118.3	March 30-Apr.17	N39-40 E118-119	5.0	Yes	No
50	Hachijojima,Japan	5.3 5.1 4.7 5.3 4.8	Apr.26 Apr.26 Apr.26 May 2 May 3	34.51 30.75 32.9 32.51 34.83	140.0 141.89 141.19 137.7 138.9	Apr.7-Apr.27	N31-32 E140-141	5.0-5.5	No	Yes
51	Okinawa Island,Japan	5.3 7.7	May 2*	24.63 22.7	122.39 125.6	Apr.9-Apr.29	N25-26 E122-124	6.0	No	No
52	Luzon Island,Philippine	5.6	July 7*	20.13	121.35	May 29-June 29	N19-20 E120-121	6.0	No	No
53	Halomai Island,Japan	5.0	July 3*	42.0	146.2	May 29-June 29	N41-42 E143-144	5.5-6.0	No	No
54	Central part of Honshu Island,Japan	5.2	June 24	36.19	139.84	June 4-June 24	N33-34 E138-139	5.0-5.5	No	Yes
55	Mindanao Island. Philippine	6.1	June 27*	9.3	124.2	June 4-June 24	N10-12 E124-125	6.0-6.5	No	Yes
56	Kamchatka, Russia	4.3 5.0	July 26 Aug.5	54.6 56.6	161.9 163.34 163.22	June 14-Aug.12	N56-58 E160-161	7.0	No	No

		5.7 5.6	Aug.5 Aug.5	56.22 56.3	162.8					
57	Zhang-Bei, Hebei province	4.4	July 14*	41.0	114.33	June 16-July 10	N41-42 E114-115.5	5.0	Yes	No
58	East of Taiwan Island,south of Ryukyu	6.2	July 7*	23.27	122.83	June 16-July 6	N23-24 E122-123	6.0	Yes	Yes
59	Jiashi, Xinjiang province	6.6	Aug.27	39.9	77.9	Aug.14-Sept.5	N39-40 E77-78	6.0	Yes	Yes
60	Honshu, Japan	5.4 6.1	Aug.15 Aug.16	36.2 36.1	137.9 140.8	Aug.14-Sept.3	N35-36 E138-139	5.5-6.0	No	Yes
61	Merapi Volcano, Indonesia	5.9	Aug.17	-7.4	107	Aug.14-Sept.3	S7-8 E106-107		Yes	Not given
62	East of Hualian,Taidong ,Taiwan	5.0 5.0	Sept.4 Sept.28	21.5 25	121.5 124	Aug.18-Sept.9	N22-23 E121.5-122.5	6.0	No	No
63	Zhangbei-Huailai,Hebei province	4.3	Sept.26	41.05	114.32	Aug.26-Sept.26	N41-42 E113-114	5.0	No	No
64	Ninrang Yunnan, province	5.0	1999 Jan.3*	27.2	101.00	Nov.30-Dec.30	N26-27 E101-102		No	Not given
65	Zhangbei,Hebei province	5.6	March 11	41.2	114.6	1999 March 10-March 30	N41-42 E114-115	5.0-5.5	Yes	Yes
66	Zhangbei,Hebei province	4.0	Apr.23	41.2	114.5	Apr.6-Apr.26	N41-42 E114-115	5.0	Yes	No
67	North sea side of Hualian, Taiwan	5.0 4.5 5.4	Apr.10 May 6 May 7	24.2 22.1 24.7	121.6 121.6 122.2	Apr.8-May 8	N23-24 E121-122.5	6.0	Yes	No
68	South sea side of Hokkaido,Japan	6.3	Apr.25	37.9	139.3	Apr.16-May 6	N48-49 E150-151	6.0-6.5	No	Yes
69	Kamchatka-Kurilskie Island, Russia	Mb =5.0 >6.6 mb =6.1 mb =5.6 4.2	Apr.28 May 7 Apr.19 Apr.21 Apr.26	49.6 46.3 53.5 51.2 53.7	150.3 151.2 157.9 163.2 159.4	Apr.16-May 6	N48-49 E150-151	6.0-6.5	No	yes
70	Sakhalin Island,Russia	6.6	May 12*	45.5	145.1	Apr.20-May 10	N45-46 E145-146	6.5-6.9	Yes	Yes
71	Taiwan Island	5.3 4.9	June 25 July 7	24 23.5	122.8 120.6	June 16-July 6	N23-24 E122-123	6.0	Yes	No
72	The eastern sea side of	6.5	July 7	52.6	156.4	June 23-July 17	N50-51 E155-156	6.5-6.9	No	Yes

	Kamchatka									
73	Nantou,Taiwan	7.6 7.0	Sept.21	23.7	121.1	Sept.12-Oct.2	N24-25 E121-122	6.5	Yes	Yes
74	Nantou, Taiwan	7.1	Sept.26	23.9	121.1	Sept.23- Oct.13	N23.5-24.5 E120.5-121.5	7.0	Yes	Yes
75	Philippine	4.9	Oct.7	12.7	125.2	Oct.2-Oct.22	N12-13 E125-126	6.0	Yes	No
76	Nantou, Taiwan	6.9	Nov.2	23.43	121.63	Oct.13-Nov.3	N23.5-24.5 E121.5-122.5	7.0	Yes	No
77	The eastern side of Honshu Island, Japan	5.6	Oct.25	32.1	142.4	Oct.23- Nov.13	N36-37 E142-143	6.0	No	No
78	Nantou, Taiwan	7.1	Sept.26	23.9	121.1	Sept.23- Oct.13	N23.5-24.5 E121-122.5	7.0	No	No
79	Philippine	4.9	Oct.7*	12.7	125.2	Sept.12-Oct.2	N21-22 E125-126	6.0	No	No
80	Jiayi, Taiwan	6.7	Nov.2	23.43	121.63	Oct.13-Nov.3	N23.5-24.5 E121-122.5	6.5	No	No
81	South side of Honshu Island, Japan	5.6	10.25	32.1	142.4	Oct.23- Nov.13	N34-35 E141-142	6.0	No	No
82	Yaoan, Yunnan province	6.5	2000 Jan.15	25.5	101.1	Dec.30- 2000 Jan.30	N24-25 E102-103	6.0	No	No
83	Quibi-Mileo, Yunnan province	5.5	Jan.27	24.2	103.6	Jan.19-Feb.8	N24-25 E102-103	6.0	No	No
84	The eastern sea side of Hualian,Taiwan	6.1	Jan.28	26.3	124.6	Jan.28-Feb.17	N24-25 E124-125	6.0	No	Yes
85	Hokkaido,Japan	6.8	Jan.28	42.0	143.5	Jan.28-Feb.17	N41-42 E142-143	7.0	No	No
86	Kamchataka, Russia	7.1 Mb 5.3 Mb 5.7	Jan.28 Jan.29 Jan.29	43.1 55.2 54.5	146.9 156.2 157.2	Jan.28-Feb.17	N52-53 E156-157	6.0	No	Yes
87	Honshu Island, Japan	4.8	Feb.14	31.6	141.8	Feb.13-March 3	N30-31 E131-132	6.0	No	No
88	Jiayi,Taiwan	5.2	Mach 16	23.5	120.8	March 15- March 31	N23.5-24.5 E120.5-121.5	5.5-6.0	No	Yes
89	Honshu,Japan	Mb 5.8	Apr.21	34.8	139.7	Apr.7-Apr.27	N32-33 E139-141	5.5	No	Yes
90	North part of Honshu,Japan	5.7	Apr.26	40.5	143.2	Apr.24-May 16	N35-36 E141-142	5.5	No	Yes
91	Chiba of Honshu,Japan	5.8	June 3*	35.6	140.4	May 3-May 23	N35-36 E140-141	6.0	Yes	No
92	Central part of Luzon Island, Philippine	5.1	May 8	11.1	124.7	May 3-May 23	N12-13 E123-124	7.0	No	No
93	Nantou,Taiwan	6.1	May 17	24	121.1	May 17-June 7	N24-25 E121-122	6.0	Yes	Yes
94	Nantou,Taiwan	6.8	June 11	23.8	121.1	June 5-June 25	N23-24 E121-122	6.0	Yes	Yes
95	Nantou-Jiayi,Taiwan	6.2	July 29	23.7	120.7	June 27-July 27	N23-24 E120.5-121.5	6.5	Yes	Yes
96	Izu Island,Japan	7.0 5.9	July 30 Aug.3	33.8 32.8	140 137.8	July 19-Aug.8	N32-33 E139-140	6.2	No	Yes
97	Jiayi-Hualian,Taiwan	4.4 5.1	Aug.20 Aug.20	23.2 23.4	120.9 120.7	Aug.18-Sept.8	N23-24.5 E121-123	6.8	No	No

		5.2 5.9 6.1	Aug.23 Sept.10 Sept.10	23.7 24.5 26.5	121.5 121.7 124.0				
98	Hokkaido,Japan	4.4 5.7 Mb 5.9	Aug.26 Aug.25 Aug.27	42.8 43.9 41	142.4 144.2 140	Aug.18-Sept.8	N42-43 E142-143	6.5	Yes	No
99	Miyake Island volcanic e Ruption, Japan	5.0	Aug.23 Aug.28	35	139.5	Aug.21- Aug.31	N35-36 E139-141	6.0	Yes	No
100	Hualian,Taiwan	6.2	Sept.10	24.4	121.1	Sept.5-Sept.25	N24-25 E121-122	5.5	Yes	Yes

Appendix B. Statistical analysis of the SMT window of the predicted earthquakes, USGS database.

*** indicates earthquakes out of the predicted time frame.**

No.	Earthquakes	Ms	Date	Longitude / Latitude	Prediction			Occurrence	
					Date	Area	Magnitude	Within area	Within Magnitude
1	East of Changshu, Jiangsu province	5.1	1990 Feb.9	31.68 121.03	1990 Feb.6-Feb.21	N31-32 E120-121.5	5-6	Yes	Yes
2	Gonghe,Qinghai province	6.3	Apr.26*	36.24 100.25	Apr.17-Apr.25	N36-38 E99-101	6.5-6.9	Yes	No
3	SW sea area of Taiwan Island	5.5	May 23	20.63 120.89	May 21-May 31	N20-21 E119.5-121	5.0-5.5	Yes	Yes
4	East sea side of Taiwan	5.6	July 4	25.37 124.47	June 30-July 10	N25-24 E123-124	5.0-5.5	No	Yes
5	East of Taiwan Riukyu Island	6.2	Sep 30	24.25 125.21	Sept.22-Oct.3	N24-25 E122-123	5.0-5.5	No	Yes
6	Artux, Xinjiang province	5.0	1991 March 7	39.93 75.71	1991 Feb.28-March 20	N31-41 E74-76	5.0-5.5	Yes	Yes
7	East to Taiwan Island	5.6	March 12	23.16 120.05	March 7-March 17	N22-23 E120-121	5-6	No	Yes
8	Awat, Xinjiang province	5.2	Apr. 2	40.1 80.4	March 27-Apr.10	N39-41 E78-80	6.0	No	No
9	Ryukyu Island, east to Hualian,Taiwan Island	4.7	Apr.26	24.01 122.54	Apr.14-Apr.29	N24-25 E121-122	5-6	No	No
10	Tangshan,Hebei province	4.9	May 29	39.61 118.38	Apr.20-May 5	N39-40 E118-119	5.0-5.5	Yes	No
11	Luan Xian,Hebei province	4.6	July 29	39.9 118.7	July 25-Aug.5	N39-40 E118-119	5.0	No	No
12	Longyao,Xingtai,Hebei province	4.7 4.6	Aug.28 Aug.29	37.4 114.1 37.5 114.9	Aug.18-Aug.29	N37-38 E114-11	5.0	Incomplete Longitude	
13	Luzon,Bashi Channel	5.3	1992 Feb.10	21.17 121.90	1992 Jan.30-Feb.25	N21-22 E120-122	5.0	Yes	Yes
14	Sea area,east to Hualian,Taiwan Island	6.2	Apr. 19	23.86 121.59	Apr.17-Apr.27	N23-24 E121-122.5	6.0-6.5	Yes	Yes
15	Sea area,east to Hualian,Taiwan Island	4.5 4.8	May 1 May 3	24.5 120.79 23.99 122.49	Apr.30- May 10	N23-24 E121-122	6.0	No	No
16	Kyrgyzstan	6.6	Aug.19	42.1 73.24	Aug.4-Aug.24	N41-43 E74-76	7.0	No	No

17	Dongsha Island,Southern Sea	5.5	Sep.14*	21.39 117.77	Aug.19-Sept.9	N21-22 E117-119	6.0	Yes	No
18	Lazhi,Tibet	6.2	1993 March 20	29.08 87.33	1993 Feb.23-March 26	N28-30 E86-87	6.0	No	Yes
19	East of Hokaido,Japan Sea	6.6	Aug.8*	41.99 139.84	July 18-Aug.7	N41-43 E139-140	7.0	Yes	No
20	Hachijojima, Japan	5.9	Sept.1	31.71 141.61	Aug.12-Sept.5	N32-34 E140-142	6.0-6.5	No	No
21	Outer sea of Hualian,Taiwan Island	5.5	1994 Jan.20	23.98 121.81	Jan.18-Feb.10	N24-25.5 E122-124	6.0-6.5	No	No
22	Northern part of Myanmar	6.2	Apr.6*	26.19 96.87	March 26-March 15	N25-26 E95-97	7.0	No	No
23	Southeastern sea area to Taiwan Island	5.8	Apr.13	22.77 123.63	Apr.3-Apr.23	N21-23 E121-122	6.0-6.5	No	No
24	East to Luzon Island,Philippine	6.0	Apr.27 *	113.07 119.54	Apr.13-Apr.23	N11-13 E118-120	6.0-6.5	No	Yes
25	Outer sea of Hualian,Taiwan Island	6.7	May 24	23.96 122.45	May 13-May 28	N23-24 E122-123	5.0-6.0	Yes	Yes
26	Outer sea of Hualian,Taiwan Island	4.5	June 17	23.93 121.83	June 10-July 1	N22-23 E121-123	6.0	No	No
27	East of KuriLskije Island, Japan	7.3	Oct.9	43.9 147.92	Oct.9-Oct.29	N42-44 E148-150	7.0	No	Yes
28	Eastern of Yilan,Taiwan Island	5.7	1995 Apr.3	24.07 122.29	1995 March 17-Apr. 2	N24-25 E121-123	6.0-6.5	No	No
29	Sama Island, Philippine	7.3	Apr.21	12.06 125.58	Apr. 16-May 5	N11-13 E126-127	6.0-6.5	No	Yes
30	Southernwestern of Zhanghua, Taiwan	4.9	Oct. 31	23.2 120.5	Oct.21-Nov.10	N21-23 E120-122	6.0-6.5	No	No
31	Wuding,Yunnan province	4.8	Nov.1	25.87 102.34	Oct.27-Nov.18	N25-26 E101.5-102.5	6.0-6.5	No	Yes
32	Lijiang,Yunnan province	6.6	1996 Feb.3*	27.29 100.28	1995 Dec.16, -1996 Jan.5	N25-27 E101-103	6.5-6.9	No	No
33	Kamchatka,Russia	6.6	July 16	56.08 165.0	July 14-Aug.5	N57-59 E159-161	7.0	No	No
34	Dadanvis Island, Philippine	4.6	Nov. 5	13.75 124.11	Oct.28-Nov.17	N13-15 E122-123	6.0	No	No
35	Western side of Hokkaido Island,Japan	6.5	Dec.22 *	43.21 138.92	Oct.31-Dec.15	N42-44 E139-141	7.0	No	No
36	South part of Yellow Sea	4.0	Nov.17	33.28 121.15	Nov.13-Dec.3	N32-33 E121-122	5.0	Not reported in USGS	
37	South part of Ibaraki, Japan	5.7	Dec.21	36.03 139.77	Dec.13-Dec.28	N34-36 E139-141	6.0-6.5	No	No
38	Izu Pen.Swarm Earthquake,Japan	5.6	1997 March 3	34.89 139.04	1997 Feb.26-March 10	N35-36 E139-140	6.0	No	No

39	Hachijojima, Japan	5.1	Apr.9	33.04 140.42	Apr. 3-Apr.18	N32-33 E140-141	5.0	No	Yes
40	Kagoshima,Kyushu,Japan	6.1	May 13*	31.82 130.28	Apr.19-May 11	N30-31 E131-132	6.0	No	Yes
41	Jashi,Xinjiang, P.R.China	4.9	May 17	39.53 76.97	Apr.19-May 21	N38-40 E76-78	5.5-6.5	Yes	No
42	Balintown, Phillipine	6.1	May 22	18.92 121.34	May 18-June 10	N13.5-15 E123-124.5	6.0	No	Yes
43	Iwakum Honshu Island, Japan	5.9	June 25	34.4 131.6	June 1-June 26	N31-33 E130-132	6.5-6.9	Yes	No
44	Taidong, Taiwan Island	5.1	July 4	22.97 120.93	May 5-June 4	N23-24 E121-123	6.0	No	No
45	Ryukyu Island, Japan	6.2	Aug.13	25.03 125.77	Aug.13-Aug.28	N25-26 E125-126	6.0-6.5	Yes	Yes
46	Tokyo bay, Japan	5.9	Sept. 7	35.44 139.77	Aug.13-Sept.21	N34-36 E140-142	6.5	No	No
47	The south side sea of Hokkaido, Japan	6.1	Nov.15	43.81 145.02	Oct.18-Nov.25	N41-43 E142-144	6.2	No	Yes
48	Hokkaido, Japan	5.1	1998 Apr.9	42.81 144.94	1998 Feb.27-Apr.10	N41-43 E144-146	7.0	Yes	No
49	Tangshan, Hebei province	4.6	Apr.14	39.69 118.65	March 30-Apr.17	N39-40 E118-119	5.0	Yes	No
50	Hachijojima,Japan	5.6	May 3*	34.87 138.98	Apr.7-Apr.27	N31-32 E140-141	5.0-5.5	No	Yes
51	Okinawa Island,Japan	7.9	May 3	22.31 125.31	Apr.9-Apr.29	N25-26 E122-124	6.0	No	Yes
52	Luzon Island,Philippine	5.3	July 7	19.89 121.36	May 29-June 29	N19-20 E120-121	6.0	No	No
53	Halomai Island,Japan	5.1	July 3*	43.36 147.1	May 29-June 29	N41-42 E143-144	5.5-6.0	No	No
54	Central part of Honshu Island,Japan	4.6	June 24	34.19 139.07	June 4-June 24	N33-34 E138-139	5.0-5.5	No	No
55	Mindanao Island. Philippine	5.3	June 27*	9.33 124.2	June 4-June 24	N10-12 E124-125	6.0-6.5	No	No
56	Kamchatka, Russia	4.6	Aug.5	56.28 163.18	June 14-Aug.12	N56-58 E160-161	7.0	No	No

57	Zhang-Bei, Hebei province	4.4	July 14	41.0 114.33	June 16-July 10	N41-42 E114-115.5	5.0	Not found in USGS database	
58	East of Taiwan Island,south of Ryukyu	6.2	July 7*	23.27 122.83	June 16-July 6	N23-24 E122-123	6.0		
59	Jiashi, Xinjiang province	6.3	Aug.27	39.61 77.34	Aug.14-Sept.5	N39-40 E77-78	6.0	Yes	Yes
60	Honshu, Japan	5.5	Aug.15	36.27 137.64	Aug.14-Sept.3	N35-36 E138-139	5.5-6.0	No	No
61	Merapi Volcano, Indonesia	5.4	Aug.17	-7.58 107.2	Aug.14-Sept.3	S7-8 E106-107	Magnitude range is not given		
62	East of Hualian, Taidong, Taiwan	4.7	Sept.4	23.77 121.5	Aug.18-Sept.9	N22-23 E121.5-122.5	6.0	No	No
63	Zhangbei-Huailai,Hebei province	4.7	Sept.26	41.15 114.52	Aug.26-Sept.26	N41-42 E113-114	5.0	No	Yes
64	Ninrang Yunnan, province	4.5	1999 Jan.3*	27.28 101.05	Nov.30-Dec.30	N26-27 E101-102	Magnitude range is not given		
65	Zhangbei,Hebei province	5.3	March 11	41.13 114.66	1999 March 10-March 30	N41-42 E114-115	5.0-5.5	Yes	Yes
66	Zhangbei,Hebei province	4.0	Apr.23	41.2 114.5	Apr.6-Apr.26	N41-42 E114-115	5.0	Not found in USGS database	
67	North sea side of Hualian, Taiwan	4.8 4.4 5.2	Apr.10 May 6 May 7	24.04 121.83 22.23 121.94 24.16 121.86	Apr.8-May 8	N23-24 E121-122.5	6.0	No No No	No No No
68	South sea side of Hokkaido,Japan	5.3	Apr.25	36.44 140.47	Apr.16-May 6	N48-49 E150-151	6.0-6.5	No	No
69	Kamchatka-Kurilskie Island, Russia	4.9 6.2 5.4 4.8 4.8	Apr.28 May 8* Apr.19 Apr.21 Apr.26	45.25 150.59 45.45 151.63 50.89 156.42 53.67 160.54 53.97 159.19	Apr.16-May 6	N48-49 E150-151	6.0-6.5	No No No No	No Yes No No

								No	No
70	Sakhalin Island,Russia	6.5	May 12	43.03 143.84	Apr.20-May 10	N45-46 E145-146	6.5-6.9	No	Yes
71	Taiwan Island	4.6 4.5	June 25 July 8	25.56 122.35 24.15 122.46	June 16-July 6	N23-24 E122-123	6.0	No No	No No
72	The eastern sea side of Kamchatka	6.1	July 7	49.23 155.56	June 23-July 17	N50-51 E155-156	6.5-6.9	No	No
73	Nantou,Taiwan	7.7 6.3	Sept.21	23.77 120.98	Sept.12-Oct.2	N24-25 E121-122	6.5	No	No
74	Nantou, Taiwan	6.5	Sept.25	23.74 121.16	Sept.23-Oct.13	N23.5-24.5 E120.5-121.5	7.0	Yes	No
75	Philippine	5.3	Oct.7	13.69 125.17	Oct.2-Oct.22	N12-13 E125-126	6.0	No	No
76	Nantou, Taiwan	6.3	Nov.2	23.38 121.52	Oct.13-Nov.3	N23.5-24.5 E121.5-122.5	7.0	Yes	No
77	The eastern side of Honshu Island, Japan	5.8	Oct.25	31.97 142.25	Oct.23-Nov.13	N36-37 E142-143	6.0	No	No
78	Nantou, Taiwan	6.5	Sept.25	23.74 121.16	Sept.23-Oct.13	N23.5-24.5 E121-122.5	7.0	Yes	No
79	Philippine	5.3	Oct.7*	13.69 125.17	Sept.12-Oct.2	N21-22 E125-126	6.0	No	No
80	Jiayi, Taiwan	6.3	Nov.1	23.38 121.52	Oct.13-Nov.3	N23.5-24.5 E121-122.5	6.5	No	No
81	South side of Honshu Island, Japan	5.8	10.25	31.97 142.25	Oct.23-Nov.13	N34-35 E141-142	6.0	No	No
82	Yaoan, Yunnan province	5.9	2000 Jan.14	25.61 101.06	Dec.30-2000 Jan.30	N24-25 E102-103	6.0	No	No
83	Quibi-Mileo, Yunnan province	4.9	Jan.26	24.26 103.8	Jan.19-Feb.8	N24-25 E102-103	6.0	No	No
84	The eastern sea side of Hualian,Taiwan	6.1	Jan.28	26.08 124.5	Jan.28-Feb.17	N24-25 E124-125	6.0	No	Yes
85	Hokkaido,Japan	6.8	Jan.28	43.05 146.84	Jan.28-Feb.17	N41-42 E142-143	7.0	No	No
86	Kamchataka, Russia	6.8	Jan.28	43.05 146.84	Jan.28-Feb.17	N52-53 E156-157	6.0	No	Yes
87	Honshu Island, Japan	5.3	Feb.14	31.04 141.62	Feb.13-March 3	N30-31 E131-132	6.0	No	Yes
88	Jiayi,Taiwan	4.8	March 16	23.25 120.88	March 15-March 31	N23.5-24.5 E120.5-121.5	5.5-6.0	No	No
89	Honshu,Jap	5.5	Apr.26	35.67	Apr.7-Apr.27	N32-33	5.5	No	Yes

	an			135.49		E139-141			
90	North part of Honshu,Japan	5.6	Apr.26	40.5 143.2	Apr.24-May 16	N35-36 E141-142	5.5	No	Yes
91	Chiba of Honshu,Japan	6.2	June 3*	35.55 140.46	May 3-May 23	N35-36 E140-141	6.0	Yes	Yes
92	Central part of Luzon Island, Philippine	5.6	May 8	11.05 124.73	May 3-May 23	N12-13 E123-124	7.0	No	No
93	Nantou,Taiwan	5.4	May 17	24.22 121.06	May 17-June 7	N24-25 E121-122	6.0	Yes	No
94	Nantou,Taiwan	6.4	June 10	23.84 121.22	June 5-June 25	N23-24 E121-122	6.0	Yes	Yes
95	Nantou-Jiayi,Taiwan	5.7	July 28	23.36 120.92	June 27-July 27	N23-24 E120.5-121.5	6.5	Yes	No
96	Izu Island,Japan	7.1 4.8	July 30 Aug.3	33.9 139.38 33.94 139.42	July 19-Aug.8	N32-33 E139-140	6.2	No	Yes
97	Jiayi-Hualian,Taiwan	4.8 5.7 5.8	Aug.20 Aug.23 Sept.10	23.07 120.76 23.62 121.47 21.01 121.53	Aug.18-Sept.8	N23-24.5 E121-123	6.8	No Yes No	No No No
98	Hokkaido,Japan	5.1 4.8 5	Aug.26 Aug.25 Aug.28	42.23 142.49 43 144.75 37.81 142.1	Aug.18-Sept.8	N42-43 E142-143	6.5	Yes No No	No No No
99	Miyake Island volcanic e Ruption, Japan	5.4 5.2	Aug.23 Aug.28	34.07 139.45 34.3 139.11	Aug.21-Aug.31	N35-36 E139-141	6.0	No No	No No
100	Hualian,Taiwan	5.8	Sept.10	24.01 121.53	Sept.5-Sept.25	N24-25 E121-122	5.5	Yes	Yes

Appendix C: Expected values and Poisson probabilities of 12 successful earthquakes with respect to reported earthquake Number (USGS database).

No.	Earthquakes	Ms	Date	Longitude/ Latitude	Prediction			Occurrence (based on USGS database)	
					Date	Area	Magnitude	Expected V.	Poisson P.
1	East of Changshu, Jiangsu province	5.1	1990 Feb.9	31.68 121.03	1990 Feb.6-Feb.21	N31-32 E120-121.5	5-6	0.001	0.001
3	SW sea area of Taiwan Island	5.5	May 23	20.63 120.89	May 21-May 31	N20-21 E119.5-121	5.0-5.5	0.026	0.025
6	Artux, Xinjiang province	5.0	1991 March 7	39.93 75.71	1991 Feb.28-March 20	N31-41 E74-76	5.0-5.5	0.135	0.117
13	Luzon,Bashi Channel	5.3	1992 Feb.10	21.17 121.90	1992 Jan.30-Feb.25	N21-22 E120-122	5.0	0.112	0.101
14	Sea area,east to Hualian,Taiwan Island	6.2	Apr. 19	23.86 121.59	Apr.17-Apr.27	N23-24 E121-122.5	6.0-6.5	0.017	0.017
25	Outer sea of Hualian,Taiwan Island	6.7	May 24	23.96 122.45	May 13-May 28	N23-24 E122-123	5.0-6.0	0.181	0.151
45	Ryukyu Island, Japan	6.2	Aug.13	25.03 125.77	Aug.13-Aug.28	N25-26 E125-126	6.0-6.5	0.005	0.005
59	Jiashi, Xinjiang province	6.3	Aug.27	39.61 77.34	Aug.14-Sept.5	N39-40 E77-78	6.0	0.003	0.003
65	Zhangbei,Hebei province	5.3	March 11	41.13 114.66	1999 March 10-March 30	N41-42 E114-115	5.0-5.5	0.005	0.005
91	Chiba of Honshu,Japan	6.2	June 3	35.55 140.46	May 3-May 23	N35-36 E140-141	6.0	0.015	0.015
94	Nantou,Taiwan	6.4	June 10	23.84 121.22	June 5-June 25	N23-24 E121-122	6.0	0.03	0.029
100	Hualian,Taiwan	5.8	Sept.10	24.01 121.53	Sept.5-Sept.25	N24-25 E121-122	5.5	0.015	0.146

Appendix D. Expected value and Poisson probability calculations of 12 earthquakes with respected to earthquake number reported by the authors. (USGS Database).

1	Location of epicenter :-	East Changshu, Jiangsu province, China
	Latitude/Longitude predicted :-	N31-32/E120-121.5
	Latitude/Longitude occurred:-	N 31.68/121.03
	Date of occurrence :-	Feb. 9, 1990
	Magnitude predicted :-	5
	Magnitude occurred :-	5

Magnitude	> 4	> 5
Total Number of years	35	35
Total No of earthquakes	1	1
Natural rate of occurrence per week (λ)	0.0006	0.0006
Predicted time span (days)	16	16
Expected value of occurrence	0.0013	0.0013
Probability of occurrence (%)	0.1268	0.1268

3	Location of Epicenter :-	SW sea area of Taiwan Island
	Latitude/Longitude predicted :-	N20-21/E119.5-121
	Latitude/Longitude occurred :-	N 20.63/120.89
	Date of occurrence :-	May. 23. 1990
	Magnitude predicted :-	5
	Magnitude occurred :-	5.5

Magnitude	> 4	> 5
Total Number of years	35	35
Total No of earthquakes	158	31
Natural rate of occurrence per week (λ)	0.0866	0.0170
Predicted time span (days)	11	11
Expected value of occurrence	0.1360	0.0267
Probability of occurrence (%)	11.8742	2.5990

6 Location of Epicenter :- Artus Xinjiang province
Latitude/Longitude predicted :- N31-41/E74-76
Latitude/Longitude :- N 39.93/75.71
Date of occurrence :- Mar. 7. 1991
Magnitude Predicted :- 5
Magnitude Occurred :- 5

Magnitude	> 4	> 5
Total Number of years	35	35
Total No of earthquakes	603	82
Natural rate of occurrence per week (λ)	0.3304	0.04493
Predicted time span (days)	21	21
Expected value of occurrence	0.9912	0.1348
Probability of occurrence (%)	-	11.7796

13 Location of Epicenter :- Luzon, Bashi Channel
Latitude/Longitude predicted :- N21-22/E120-121
Latitude/Longitude :- N 21.17/121.9
Date of occurrence :- Feb. 10. 1992
Magnitude Predicted (LR) :- 5
Magnitude Occurred :- 5.3

Magnitude	> 4	> 5
Total Number of years	35	35
Total No of earthquakes	350	55
Natural rate of occurrence per week (λ)	0.1918	0.0301
Predicted time span (days)	26	26
Expected value of occurrence	0.7123	0.1119
Probability of occurrence (%)	34.9398	10.0083

14 Location of Epicenter :- Sea area, east to Hualian, Taiwan Island
Lattitude/Longitude predicted :- N23-24/E121-122
Lattitude/Longitude occurred :- N 21.17/121.9
Date of occurrence :- Apr. 19. 1992
Magnitude Predicted (LR) :- 6
Magnitude Occurred :- 6.2

Magnitude	> 4	> 5	> 6.0
Total Number of years	35	35	35
Total No of earthquakes	669	166	20
Natural rate of occurrence per week (λ)	0.3666	0.0910	0.0110
Predicted time span (days)	11	11	11
Expected value of occurrence	0.5760	0.1429	0.0172
Probability of occurrence (%)	32.3805	12.3898	1.6927

25 Location of Epicenter :- Outer Sea of Hualian, Taiwan Island
Latitude/Longitude predicted :- N23-24/E122-123
Latitude/Longitude occurred :- N 23.96/122.45
Date of occurrence :- May.24.1994
Magnitude Predicted (LR) :- 5
Magnitude Occurred :- 6.7

Magnitude	> 4	> 5
Total Number of years	35	35
Total No of earthquakes	699	154
Natural rate of occurrence per week (λ)	0.3830	0.0844
Predicted time span (days)	16	15
Expected value of occurrence	0.8755	0.1808
Probability of occurrence (%)	36.4778	15.0911

45 Location of epicenter :- Ryukyu Island, Japan
Latitude/Longitude predicted :- N25-26/E125-126
Latitude/Longitude occurred:- N25.03/125.77
Date of occurrence :- Aug.13.1997
Magnitude predicted :- 6
Magnitude occurred :- 6.2

Magnitude	> 4	> 5	> 6.0
Total Number of years	35	35	35
Total No of earthquakes	102	23	4
Natural rate of occurrence per week (λ)	0.0567	0.0128	0.0022
Predicted time span (days)	16	16	16
Expected value of occurrence	0.1295	0.0292	0.0051
Probability of occurrence (%)	11.3788	2.8366	0.5054

59 Location of epicenter :- Jiashi, Xinjiang province
Latitude/Longitude predicted :- N39 - 40/E77- 78
Latitude/Longitude occurred:- N39.66/77.34
Date of occurrence :- Aug.27.1998
Magnitude predicted :- 6
Magnitude occurred :- 6.3

Magnitude	> 4	> 5	> 6
Total Number of years	35	35	35
Total No of earthquakes	142	21	2
Natural rate of occurrence per week (λ)	0.0778	0.0115	0.0011
Predicted time span (days)	22	22	22
Expected value of occurrence	0.2445	0.0362	0.0034
Probability of occurrence (%)	19.1491	3.4880	0.3432

65 Location of epicenter :- Zhangbei, Hebei province,China
Latitude/Longitude predicted :- N41-42/E114-115
Latitude/Longitude occurred:- N41.13/114.66
Date of occurrence :- Mar.11.1999
Magnitude predicted :- 5
Magnitude occurred :- 5.3

Magnitude	> 4	> 5
Total Number of years	35	35
Total No of earthquakes	8	2
Natural rate of occurrence per week (λ)	0.0044	0.0011
Predicted time span (days)	21	21
Expected value of occurrence	0.0330	0.0051
Probability of occurrence (%)	3.1944	0.5054

91 Location of epicenter :- Chiba of Honshu, Japan
Latitude/Longitude predicted :- N35-36/E140-141
Latitude/Longitude occurred:- N35.55/140.46
Date of occurrence :- Jun.3.2000
Magnitude predicted :- 6
Magnitude occurred :- 6.2

Magnitude	> 4	> 5	> 6
Total Number of years	35	35	35
Total No of earthquakes	470	72	6
Natural rate of occurrence per week (λ)	0.2575	0.0395	0.0033
Predicted time span (days)	32	32	32
Expected value of occurrence	1.1773	0.1804	0.0150
Probability of occurrence (%)	36.2737	15.0590	1.4805

94 Location of epicenter :- Nantou, Taiwan
Latitude/Longitude predicted :- N23-24/E121-122
Latitude/Longitude occurred:- N23.84/121.22
Date of occurrence :- Jun.10.2000
Magnitude predicted :- 6
Magnitude occurred :- 6.4

Magnitude	> 4	> 5	> 6
Total Number of years	35	35	35
Total No of earthquakes	580	151	18
Natural rate of occurrence per week (λ)	0.3178	0.0827	0.0099
Predicted time span (days)	21	21	21
Expected value of occurrence	0.9534	0.2482	0.0296
Probability of occurrence (%)	36.7468	19.3658	2.8726

100 Location of epicenter :- Hualian, Taiwan
Latitude/Longitude predicted :- N24-25/E121-122
Latitude/Longitude occurred:- N24.01/121.53
Date of occurrence :- Sep.10.2000
Magnitude predicted :- 6
Magnitude occurred :- 5.8

Magnitude	> 4	> 5	> 5.8
Total Number of years	35	35	35
Total No of earthquakes	383	72	9
Natural rate of occurrence per week (λ)	0.2099	0.0395	0.0049
Predicted time span (days)	21	11	21
Expected value of occurrence	0.6296	0.0620	0.0148
Probability of occurrence (%)	33.5452	5.8269	1.4577