

Earthquake Risk Management in China: Lessons learned from the Wenchuan Earthquake

**Report prepared for Training Course on
“Recent Developments in Geo-Hazard Disaster Management; focusing on
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1.INTRODUCTION

China is one of the most severe seismic disaster countries in the world. The Chinese government pays much attention to the monitoring and forecasting of earthquake, to the seismic fortification criterion of building, and to urban seismic safety. This report provides a brief introduction to the integrated management system of natural disasters and the emergencies response system of China, the impacts of the recent Wenchuan Earthquake, the geologic active tectonic context, the intensity maps from USGS and China Earthquake Administration, and the results of loss evaluation of the Wenchuan Earthquake. An analysis of the causes for heavy casualties and serious damages of buildings is presented. The disaster region is mountainous and streamy, leading to the creation of many landslides, mudflows, and dammed lakes following the earthquake. These secondary disasters increase the difficulties of disaster relief and rescue. Finally, the report provides some key lessons and policy recommendations.

2. EARTHQUAKE RISK MANAGEMENT IN CHINA

2.1 EARTHQUAKE IN CHINA

China lays in the south-east margin of Eurasia, in the east of which lies Pacific-round seismic zone, and in the south-west of which lies Mediterranean-Himalayan seismic zone. The two seismic zones are the most important active tectonic zones in the world, the former lies at the common boundary between the Pacific Plate and Eurasia Plate, and the latter lies at the common boundary between the Eurasia Plate and Indian Ocean Plate. Due to its particular geologic location, there are a number of seismic active zones in China. Risks of earthquakes are characterized by high frequency, large magnitude, shallow hypocenter, and widespread distribution spatially. Figure 2.1.1 shows the historical earthquakes with a magnitude larger than 4.0 from 2300 B.C. to 2000 A.D.

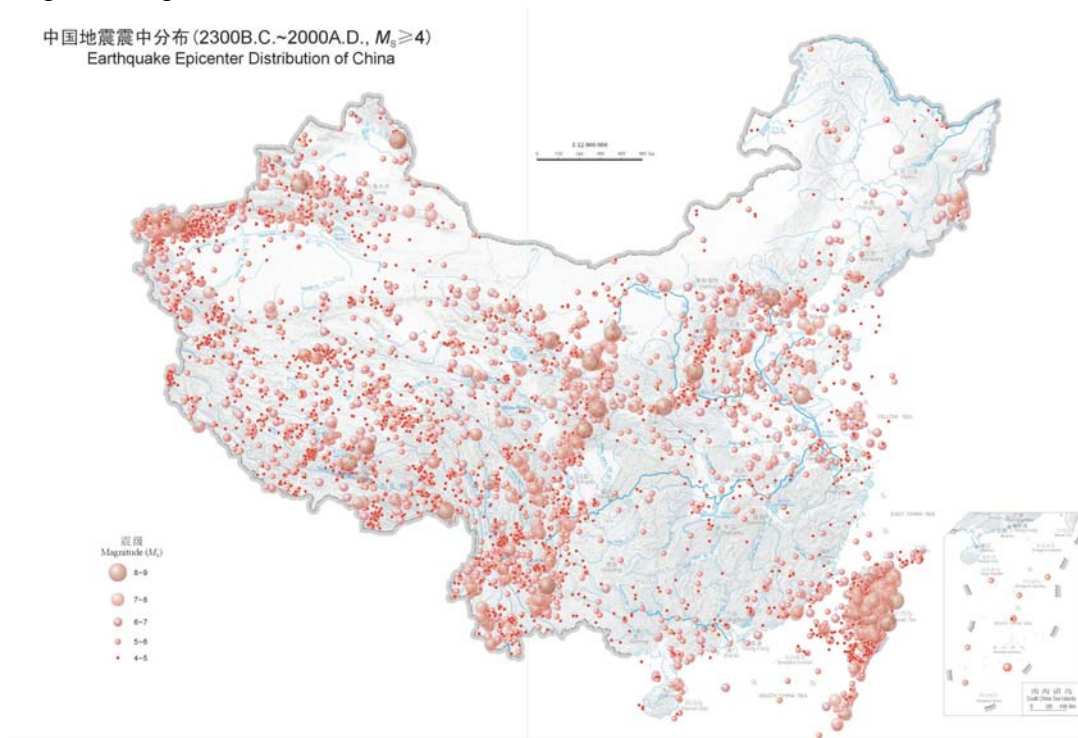


Fig. 2.1.1 the distribution of earthquake epicenter in China (from 2300B.C. to 2000 A.D, $M_s \geq 4.0$)

China is one of the most severe seismic disaster countries in the world. According to the historical records, from the 20th century on, the dead toll caused by earthquakes amounts to 600 thousand, not including the dead in Wenchuan Earthquake, and account for 42 percent of the dead toll in the world in the corresponding period. During the 20th century, five earthquakes claimed over ten thousand lives. The Chinese government pays much attention to the monitoring and forecasting of earthquake, and has forecast some massive earthquake successfully and has done much work on the seismic fortification of building and on urban seismic safety. Since the establishment of P. R. China, the government has issued four versions of seismic fortification intensity zone map successively. The majority of mega-middle cities have carried on the seismic damage prediction, and compiled the emergency plans of earthquake. At present, the seismic risk evaluation in different districts has started to be performed. So far, the Chinese government has issued four successful forecasts of earthquake. They are as follows:

(1) Haicheng Earthquake in Liaoning Province

On February 4, 1975, an M 7.3 earthquake occurred in Haicheng, a densely populated and industrialized city. The Earthquake is the largest earthquake in the region in history, and the meizoseismal area amounts to 760 square kilometers. Before the occurrence, the earthquake department of China made an immediate forecast, and local government adopted some measures of protection against earthquake and disasters mitigation, the seismic damage is lightened obviously. Besides the damage of buildings and constructions in different status, the dead toll is reduced considerably since most evacuated from their residential buildings when the quake struck the area. The casualty was about 29,579, and account for 0.32 percent of the total population, including the dead toll which was about 2,041, and accounted for 0.02 percent of total population.

It is only one successful forecast admitted by the international community.

(2) Songpan-Pingwu Earthquake in Sichuan Province

On Aug. 16, 1976, a 7.5 Magnitude earthquake occurred at the boundary between Songpan and Pingwu. After main shock, an M 6.7 aftershock occurred in 22 and another M 7.2 aftershock occurred in 23. The seismic type was swarm. The semi diameter of feeling range is about 1150 kilometers. After quakes, a successive rainstorm resulted in numerous landslides and mudflows. Many plantations, roads and riverbeds were seriously damaged. The communication was also interrupted.

These earthquakes occurred in mountainous region where is underpopulated, and before quake an immediate forecast is issued by local seismic department, so an evacuation measure was adopted. Consequently, the total casualty is about over 800, including the light injured about 600 plus.

(3) Longling Earthquake in Yunnan Province

On May 29, 1976, two massive earthquakes occurred at Longling County in the west of Yuannan Province. The first massive earthquake of 7.3 magnitude occurred at 20:23, the second of magnitude 7.4 occurred at 22:00. The seismic type was swarm. The two earthquakes claimed 98 lives, the severe injured are 451, and the slight injured were 1,991. The landslides caused by the quakes aggravated the building and road damage and property loss. Middle-term and immediate earthquake forecasts are made and issued by local seismic department, and some protections against earthquake and disasters mitigations were adopted before quakes, so the dead toll was reduced obviously.

(4) Menglian Earthquake in Yunnan Province

On July 12, 1995, an M 7.3 earthquake occurred at the border of China- Myanmar in Menglian County. Before the earthquake, an M 5.5 earthquake and an M 6.2 earthquake were occurred in the same region. After the main-shock, 197 aftershocks more than M 3.0 occurred. During these earthquakes, the dead toll is 11, the injured are 136, including the severe injured which were about 26, and the homeless people was about several thousand. The local earthquake department forecast all the three earthquakes in long-middle-immediate term, whose magnitude was 5.5, 6.2 and 7.3 respectively. These successful forecasts provided a basis on measures of protections and mitigations which was adopted by local government to reduce the disaster loss.

2.2 INSTITUTIONAL FRAMEWORK FOR DISASTER (EARTHQUAKE) MANAGEMENT

The Chinese Government pays much attention to seismic disaster management, and takes disaster prevention and reduction as ways and means to ensure the sustainable development of the society and economy of China. In order to reduce the damage and loss resulted from natural disasters, China has established an integrated management system of natural disasters. Roles and responsibilities are distributed among different government bodies.

The different governments formulate and implement laws and administrative regulations, various policies and plans, and instruct, supervise and coordinate various measures on disaster management. The **State Council** leads the disaster management work of the central government grade, while the work at provincial, city and county grades is led by their own governments. The **central government** is responsible for the decision-making management of huge disasters. **Local governments** are responsible for regional disaster management in local regions. Based on the scale of disasters, the duties of various governments have been defined.

With regard to China's integrated mechanism of coordination for disaster management, the State Council exercises unified leadership and has established **China International Disaster Reduction Committee** composed of 34 main sections. All these sections must perform their respective duties and cooperate closely. The staff, funds and materials of the relevant departments together provide a solid guarantee for disaster management. These coordination agencies provide decision-making services for the governments at different levels in disaster management and ensure the timely implementation of the decisions of the governments at different levels on disaster management.

2.2.1 The Ministry of Civil Affairs

The office of China International Disaster Reduction Committee and the National Office for Overall Disaster Control and Relief Coordination are established in the Ministry of Civil Affairs. And Ministry of Civil Affairs is responsible for (1) the comprehensive coordination of overall disaster control and relief work in China; (2) the statistics and reporting of the injured and dead toll, homeless population and economic loss; (3) the preparedness and send-out of relief materials;

2.2.2 China Earthquake Administration

China Earthquake Administration is responsible for (1) Monitoring and forecasting the earthquake; (2) reporting the occurrence of earthquake and the corresponding seismic parameters rapidly; (3) organizing to investigate and assess seismic disaster; (4) rescuing the people trapped in debris and ruins.

2.2.3 The Ministry of Housing and Urban-rural Development

The Ministry of Housing and Urban-rural Development is responsible for (1) the assessment of building damage status, and giving the process means; (2) choosing and planning temporary resettlement sites; (3) planning and reconstruction of disaster region.

2.2.4 The Ministry of Land and Resource

The Ministry of Land and Resource is responsible for (1) mapping in disaster region, and providing the newest atlas of disaster regions; (2) the prevention of the geological disaster; (3) evaluating and zoning the hazard of the geologic disaster;

2.2.5 The Ministry of Health

The Ministry of Health is responsible for (1) providing medical rescue service; (2) monitoring sanitation conditions, preventing any epidemic from spreading in the aftermath of a natural disaster; (3) ensuring food and drinking water safety.

2.2.6 The Ministry of Water Resources

The Ministry of Water Resources is responsible for (1) evaluating the safety status of dams and reservoir in disaster region; (2) assessing the hazard of dammed lakes, and processing hazardous dammed lake; (3) monitoring and forecasting floodwater;

2.2.7 The Ministry of Transport

The Ministry of Transport is responsible for (1) repairing road and restoring traffic; (2) ensuring transportation of relief materials, rescue personnel, and victims; (3) traffic controlling in disastrous region.

2.2.8 The Ministry of Industry and Information Technology

The Ministry of Industry and Information Technology is responsible for (1) repairing the damage communication equipments; (2) providing the emergency and temporary communication measurement;

2.2.9 The Ministry of Public Security

The Ministry of Public Security is responsible for (1) ensuring the public security in disaster region; (2) rescuing the people trapped in debris and ruins;

2.2.10 the Ministry of Defense

The Ministry of Defense is responsible for organizing all kinds of forces to carry out the disaster relief including the People's Liberation Army if needed.

2.3 DISASTER PREPAREDNESS PLANS FOR EARTHQUAKES

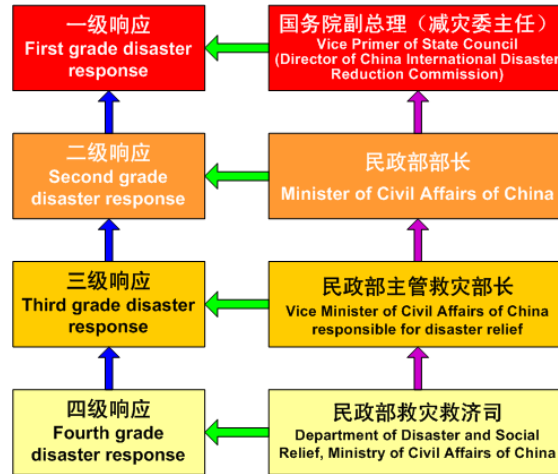


Fig.2.3.1 Four grades of disaster emergency response mechanism

In order to improve the emergency relief capacities, the Ministry of Civil Affairs has promoted the establishment of a **national planning system for emergency relief** in recent years (see fig.2.3.1). China is currently establishing this system.

In 2004, the Ministry of Civil Affairs has established **four grades of disaster emergency response mechanism**. The intensity of disasters is based on key indices such as toll number, the number of collapsed buildings, the number of people needed emergency evacuation and so on. Different institutions are responsible for different grades of disaster emergency responses. For example, Department of Disaster and Social Relief of Ministry of Civil Affairs is responsible for the fourth grade while the vice Primer of the State Council of China is responsible for the first grade.

After the disaster response mechanism is activated, many measures are implemented, including:

- (1) Collecting, assessing and releasing the disaster information rapidly and continuously;
- (2) Dispatching work groups to the affected area to instruct and supervise the implementation of the measures of the local governments in disaster relief;
- (3) If needed, organizing all kinds of forces to carry out the disaster relief including the People's Liberation Army (PLA);
- (4) Launching the emergency evacuation and establishing the temporary shelters;
- (5) Allocating emergency relief funds and materials to the affected areas; and
- (6) Carrying out timely disaster relief donations to mobilize social forces for disaster relief.

The **contingency plan** is one of the priorities of the emergency response system of the Chinese government. The objectives are: (1) to improve the governmental capabilities of maintaining the public security and dealing with the public emergency event, (2) to prevent and lessen maximally the emergency public affairs and the losses they caused, (3) to protect the human lives and property security and maintain the national security and social stability, and (4) to promote the holistic, harmonious and sustained development of economy and society.

The State Council passed the **Holistic Contingency Plan for Public Emergency** in April, 2005, and the **National Contingency Plan for Natural Disaster Relief** in May 2005. The enforcement of those plans started in January 2006. The content of the contingency plan consists of the following aspects: the purposes of the compilation, the work principles, the bases of compilation, the enforcement scope, the conditions to start the plan, the measures of relief, the duties and responsibilities of the coordinating bodies of the emergency dealing and the related administrative branches, the preparation for emergency including the funding, materials and resources, communication and information, the equipment of relief, human resources, social mobilization and media, education and training etc., the early warning and forecast of disaster information management on the disaster situation.

2.4 THE SEISMIC FORTIFICATION CODE OF CHINA

2.4.1 THE GROUND-MOTION PARAMETER ZONE MAP

The ground-motion parameter zone map includes two zone maps: 1) the peak ground acceleration zone map, and 2) the characteristic period zone map. **The peak ground acceleration zone map** provides a design basic acceleration of ground motion, which is defined as the PGA value corresponding to its probability of exceedance equal to 10% within a design reference period of 50 years. **The characteristic period zone map** considering the distance of probable earthquake from the site provides a design characteristic period on the II-type site. The real design characteristic period value must be modified according to the site classification. Combined the PGA with the characteristic period of site, a designed responding spectra can be defined. The aseismic capacity of the buildings must be checked by the designed responding spectra.

2.4.2 THE SEISMIC FORTIFICATION CRITERION OF BUILDINGS

In China, the buildings are classified four classes according their importance.

The first class refers to the most important buildings, such as nuclear station. A special seismic safety evaluation must be done, and provides the seismic fortification parameters, which should be larger than the design basic intensity plus 1 degree.

The second class refers to the public buildings, such as schoolhouses and hospital buildings. The fortification criterion of the class buildings should increase one degree on the basis of the basic design acceleration value.

The third class refers to ordinary buildings, such as residential buildings. The fortification criterion should not be less than the basic design acceleration value.

The fourth class refers to other buildings, such as some storehouses. The fortification criterion of these buildings may reduce one degree than the design basic acceleration value.

From the building code of China, the majority of residential building in rural area is under-designed. Particularly some school buildings are not designed and constructed according to the seismic safety standard of the second class building.

3. CASE STUDY: WENCHUAN EARTHQUAKE

3.1 IMPACTS OF THE EARTHQUAKE

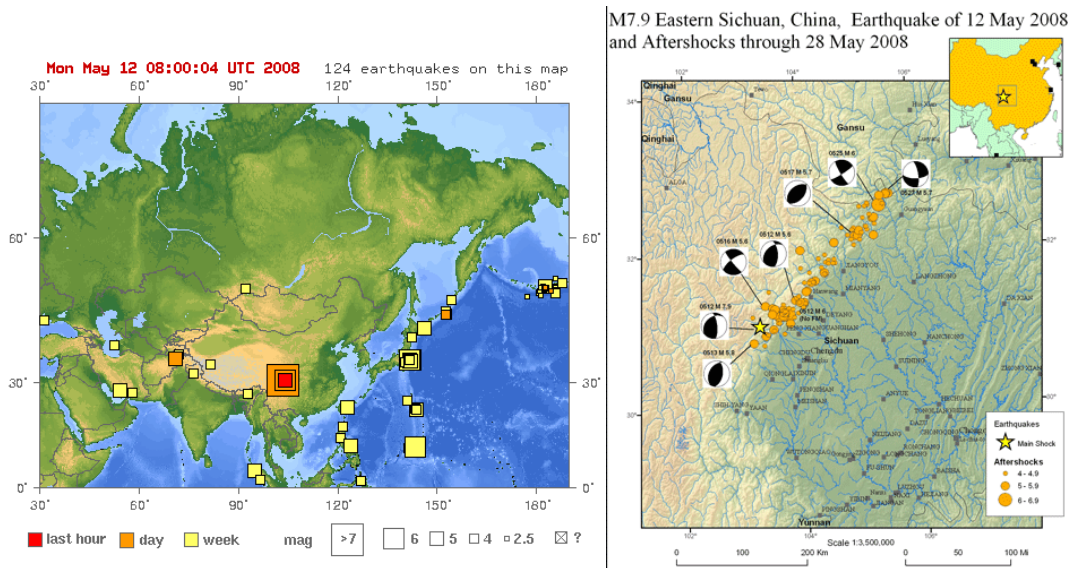


Fig.3.1.1 The main earthquake and its aftershocks as of May 28 (From USGS)

On May 12, 2008 at 14:28 pm (local time), a massive M 8.0 earthquake shook Wenchuan County in Sichuan Province. The epicenter was at latitude 31.0° N and longitude 103.4° E and the hypocenter was about 14 kilometers deep. The massive earthquake was a rare and catastrophic natural disaster, and has resulted in tremendous loss of lives and properties. This was the most destructive earthquake in China's recorded history and rescue was most difficult than that of any earthquake else since the establishment of P.R. China.

The earthquake affected area is a famous touristic region. Wenchuan is also home to the Wolong Nature Reserve, China's leading research and breeding base for endangered giant pandas. The stricken area has some factories and cities for heavy- and nuclear- industry, such as Dongfang Steam Turbine Works in Hangwang Town of Deyang City, which is one of three largest electric equipment manufacturers in China, while MianYan City is famous for its war-industry and nuclear research.

3.2 THE LOSS CAUSED BY WENCHUAN EARTHQUAKE

The death toll froze at **69,207** nationwide as of 12:00 pm. July 31, Beijing time. **374,216** people were injured and **18,194** missing. The number of homeless people amounts to over 15.1 million. The percentage of homeless people was over 90% in some disastrous counties, such as Beichuan County and Qingquan County.

Over 7.78 million houses collapsed, and 24.59 million houses were reported damaged. Some villages and towns, such as Beichuan County and Yingxiou Town in Wenchuan County, have totally disappeared. The infrastructures, such as road, electric supply, gas and communication, were destroyed completely in

disastrous districts. The social and economic activities of industry, commerce, education, etc. have stopped.

Statistics for the economic loss caused by the Earthquake have not yet been publicized. According to the estimation of some insurance companies, the economic loss in Sichuan Province may reach the amount of 500 billion yuan RMB (73.5 billion dollars), including the infrastructures, which equals to about 3 percent of GDP in China.

The public information shows that the GDP of Sichuan Province is 4.2 percent of that of the whole country, while the production value of industry is only 2.5 percent of that of the whole country. Consequently, some economists prognosticate that the impact of the earthquake on Chinese economy is not significant and temporary.

3.3 THE ACTIVE TECTONIC BACKGROUND OF WENCHUAN EARTHQUAKE

The massive M 8.0 Wenchuan Earthquake was caused by the movement of the NE-directional active rift zone of the Longmen Mountains, which is the middle part of the Chinese South-north Seismic Active Tectonic Zone. The active tectonic zone of the Longmen Mountains is over 530 km long, and about 40 to 50 km wide. Their strike is NE, and dip angle is about 30-70 degree. The active rift zone consists of three bare faults and a concealed fault. The three bare faults are Maowen-Wenchuan fault, Beichuan-Yingxiu fault (earthquake fault), and Guanxian-Jiangyou fault (rupture fault). The newest activity characteristics are mainly thrust as well as dextral strike-slip. The active rift zone was divided into two parts at Jiangyou: the west-south part is Holocene active fault, while the east-north part is early-middle Pleistocene active fault. The M 8.0 earthquake just occurred at the west-south part of the active rift of Longmen Mountains.

The activity of the rift zone of the Longmen Mountains was not violent before the M 8.0 earthquake happened. Since earthquakes have been recorded in Chinese history, more than M 7.0 earthquake caused by the movement of Longmen mountains rift zone never occurred. M 6.0-6.9 earthquakes happened about four times. **Before the massive M 8.0 earthquake, the Longmen Mountain rift zone was classified ordinary active rift zone, and drew little attention. However, this was controversial and some researchers had argued that this zone was misclassified.**

Some researchers argue that the Longmen Mountain rift zone should draw more attention according to the geological tectonics (Jiang Liangwen, 2005). In the region, there are three active rift zones: the NE-directional rift zone of Longmen Mountain, the south margin of the EW-directional rift zone of West Qinling Mountain, and the SN-directional active rift zone of Minshan Mountain which consist of the Minjiang River fault and Huya fault. The three active rift zones constitute an A-type active tectonic system controlling the occurrence of earthquakes. On the drive of a strong tectonic stress field, some researchers argued that earthquakes of larger than Magnitude 7.0 may happen repeatedly and transfer from south to north regularly and vice versa.

3.4 EVALUATION OF THE EFFECT RANGE AND SEISMIC INTENSITY

3.4.1 The Data from USGS

Soon after the Wenchuan Earthquake occurred, US Geological Survey (USGS) released three versions of the seismic parameters and experiential intensity maps of the Earthquake during several hours. In the first and second version, the earthquake is reduced to a point epicenter which appears to be inconsistent with the reality. Several hours following the occurrence of the Earthquake, the third version of the Earthquake's parameters was issued, reducing the Earthquake to a rupture-line model. This third version appears to be realistic. On May 12, USGS released a preliminary intensity map of Wenchuan Earthquake. From then on, the intensity map had been modified many times by USGS. After June 3, the intensity map is invariable basically. **Despite this iterative process, USGS managed to provide a faster evaluation of the effect range and seismic intensity of the Earthquake than the Chinese government.**

On May 12, USGS also released the number of people living in different intensity zones (see table 3.4.1). The table shows that about 603 thousand people were in the intensity X degree zone, and about 692 thousand people in the intensity IX degree zone, meaning that a huge number of people were injured and died in the disastrous Earthquake.

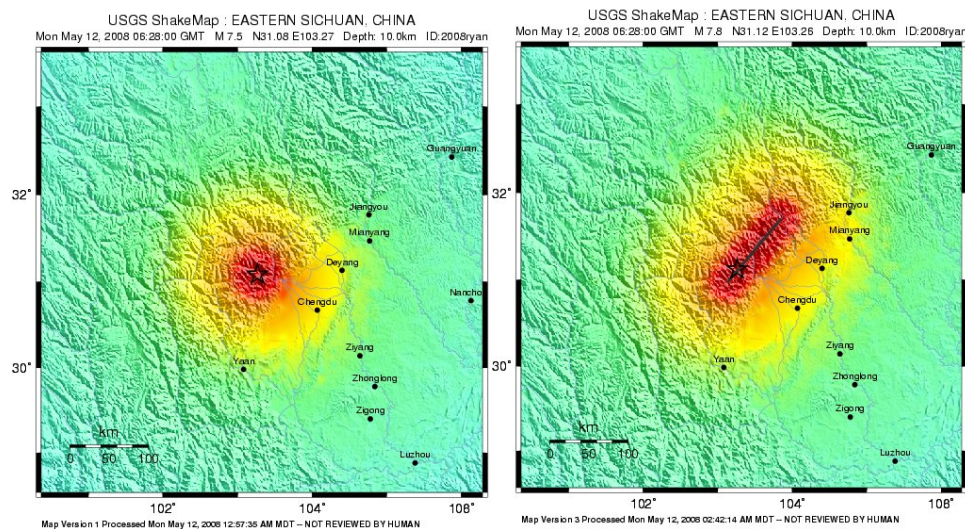
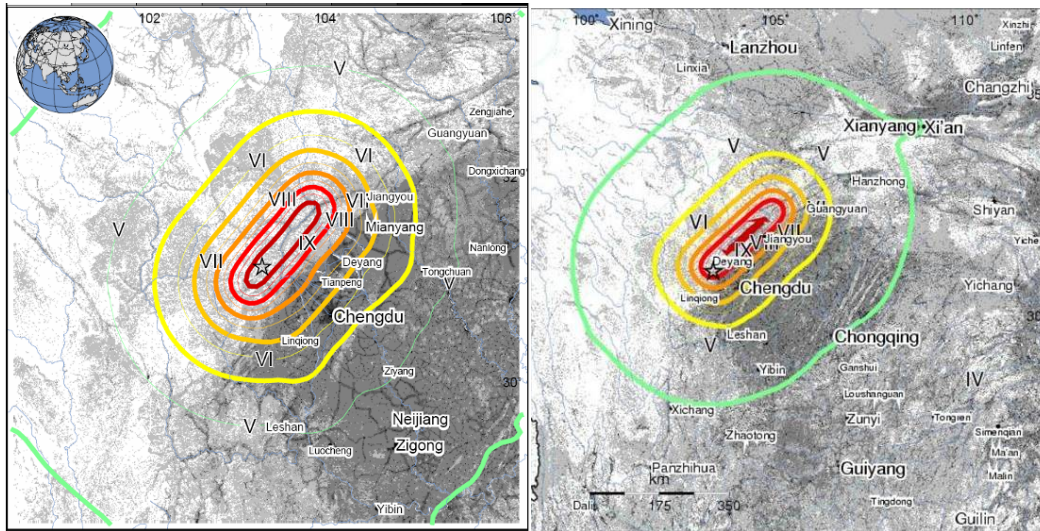


Fig.3.4.1 Three version of epicenter parameters of Wenchuan Earthquake publicized by USGS on May 12 between 12:47 AM and 02:42 AM



(a) issued on May 12 (b) issued on June 3

Fig. 3.4.2 the intensity map of Wenchuan Earthquake by USGS

Table 3.4.1 Estimated population exposed to every intensity zone in the Earthquake shaking

Est. Modified Mercalli Intensity	Est. Population Exposure ($k = \times 1000$)	Perceived Shaking	Potential Structure Damage	
			Resistant	Vulnerable
X	603k	Extreme	V. Heavy	V. Heavy
IX	692k	Violent	Heavy	V. Heavy
VIII	4,301k	Severe	Moderate/Heavy	Heavy
VII	12,396k	Very Strong	Moderate	Moderate/Heavy
VI	15,484k	Strong	Light	Moderate
V	89,480k	Moderate	V. Light	Light
IV	192,012k*	Light	None	None
II-III	--*	Weak	None	None
I	--*	Not Felt	None	None

3.4.2 The Data from Chinese Government

After the Wenchuan Earthquake, the Chinese government made the same error as USGS did in terms of estimation of the effect range and intensity. The Earthquake was also initially reduced to a point epicenter. Three days after the Wenchuan Earthquake occurrence, China Earthquake Administration delivered a correct description of the epicenter model and intensity attenuation map. After the occurrence of the Wenchuan Earthquake, the majority of technologist and professionals of China Earthquake Administration were dispatched to investigate the losses in the disaster region. Based on this field observation, several versions of intensity map were issued successively.

The south part of the fault plane is mainly thrust as well as dextral strike-slip, while the north part of fault plane is mainly dextral strike-slip as well as thrust, which based on the focal mechanism solutions provided by several research institutions. The fault plane is ruptured from Wenchuan epicenter, and then extended along with the N-E 49 degree direction to Beichuan County. The rupture line is about 300 km long, the duration time is close to 120 seconds, and the majority of energy was released out at the beginning of 80 seconds. The max displacement of fault amounts to 9 m.

3.4.3 A Post-Earthquake rapid Loss Assessment by Author

(1) Exposure Population

The Wenchuan Earthquake intensity chart from the Chinese Earthquake Administration provides the exposure population in the different intensity zone, see Table 3.4.2. The assessment result shows that in the meizoseismal area (earthquake intensity is bigger than and equal to X degree) the exposure population will be over 420,000, while in the IX degree intensity zone the exposure population will be over 910,000, demonstrating that the casualty caused by the Wenchuan Earthquake will be quite serious.

Table 3.4.2 the number of exposure people in every intensity zone of Wenchuan Earthquake

MMI	XI	X	IX	VIII	VII	VI
Exposure Population($\times 10^4$)	18.9402	23.3910	91.3595	432.7313	1969.6491	7110.0670

(2) Homeless Population and Residential Building Loss

Based on the number of villages and towns in different earthquake intensity zone and the damage matrix of the different residential buildings, a post-earthquake fast loss assessment was carried on. The economic loss and homeless population of 6 counties, whose economic loss is largest among all the counties, are listed in table 3.4.3. In comparison, the per-capita economic loss and the homeless population per ten thousand people of 6 counties, whose per-capita economic loss is largest among all the counties, are listed in table 3.4.4.

The space distribution of economic loss of every county is demonstrated in Fig.3.4.4, and that of the per capita economic loss of every county is demonstrated in Fig.3.4.5. According to the *total loss index* (i.e., the total economic loss or homeless population), Jiangyou Shi, Santai Xian, An Xian, Dujiangyan Shi, Mianzhu Shi and Zhongjiang Xian are the 6 most affected counties. But according to the *per-capita loss index* (i.e., the per-capita economic loss or homeless population per ten thousand people), Beichuan Xian, An Xian, Wenchuan Xian, Pingwu Xian, Mianzhu Shi, and Qingchuan Xian are the six most affected counties.

The assessment result shows that the economic loss can reach 212.32 billion yuan RMB, 28.01 billion yuan RMB and 21.45 billion yuan RMB in Sichuan, Gansu and Shanxi Province respectively, and the number of homeless people can reach 10.037 million, 3.070 million and 1.206 million respectively.

Table 3.4.3 The homeless population and economic loss of 6 of the largest economic loss counties

Number	Postcode	City	County	Homeless population (10,000 people)	Economic Loss (10,000 Yuan RMB)
1	510781	Mianyang	Jiangyou Shi	42.8317	684585.9486
2	510722	Mianyang	Santai Xian	29.1091	666072.1020
3	510724	Mianyang	An Xian	30.1238	634374.9598
4	510181	Chengdu	Dujiangyan Shi	28.6696	541400.8339
5	510683	Deyang	Mianzhu Shi	34.1217	523510.8130
6	510623	Deyang	Zhongjiang Xian	30.6786	499299.8653

Table 3.4.4 the homeless population per ten thousand people and the economic loss per person of 6 of the largest economic loss per person counties

Number	postcode	City	County	Homeless population per 10,000 people	Economic loss per person (Yuan RMB)
1	510726	Mianyang	Beichuan Xian	7928	13495
2	510724	Mianyang	An Xian	5906	12438
3	513221	Aba	Wenchuan Xian	7908	11254
4	510727	Mianyang	Pingwu Xian	6027	10231
5	510683	Deyang	Mianzhu Shi	6643	10192
6	510822	Guangyuan	Qingchuan Xian	7075	9970

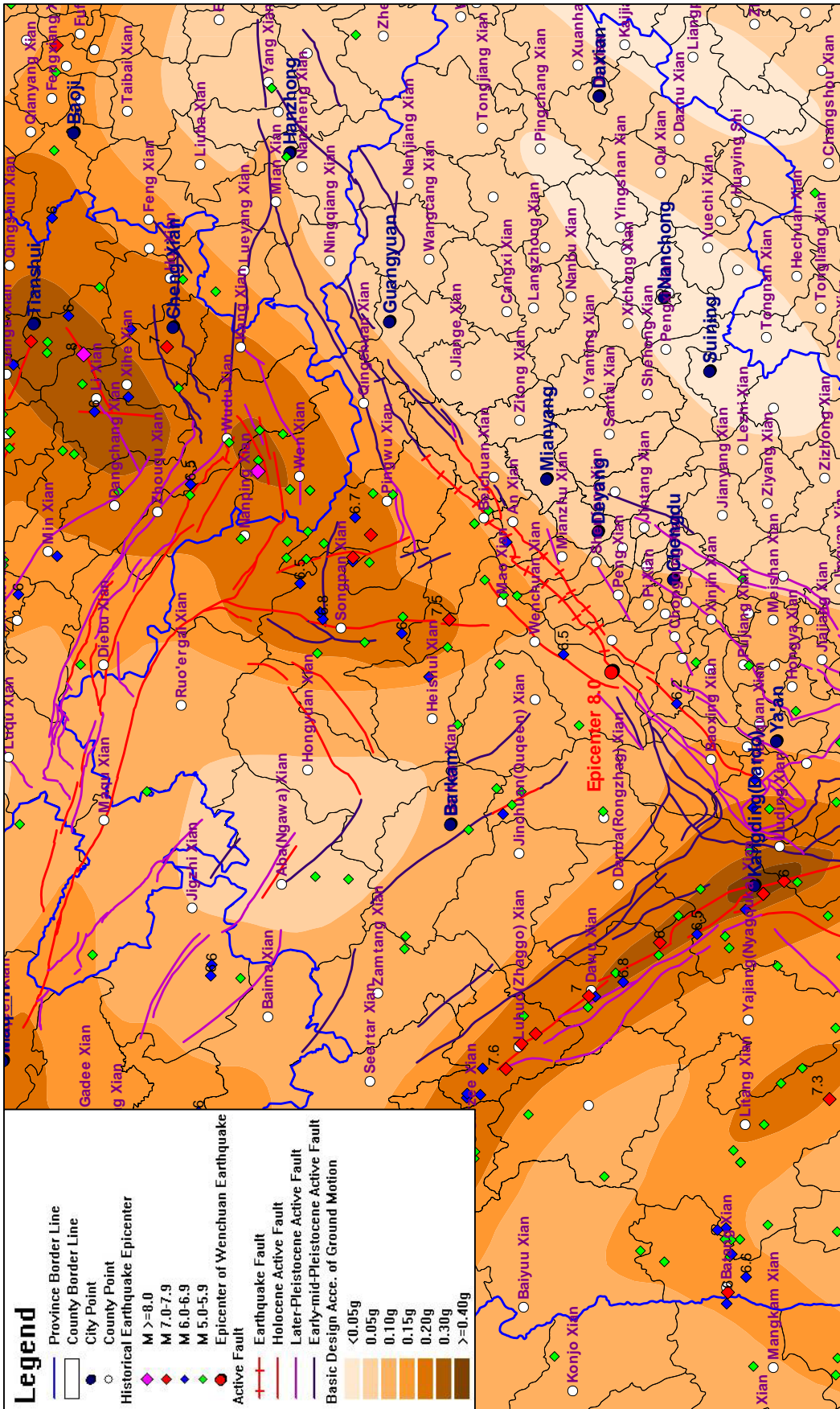


Fig.3.4.3 the active tectonic and the basic design acceleration zone map of ground motion in the circumjacent area affected by the M 8.0 Earthquake

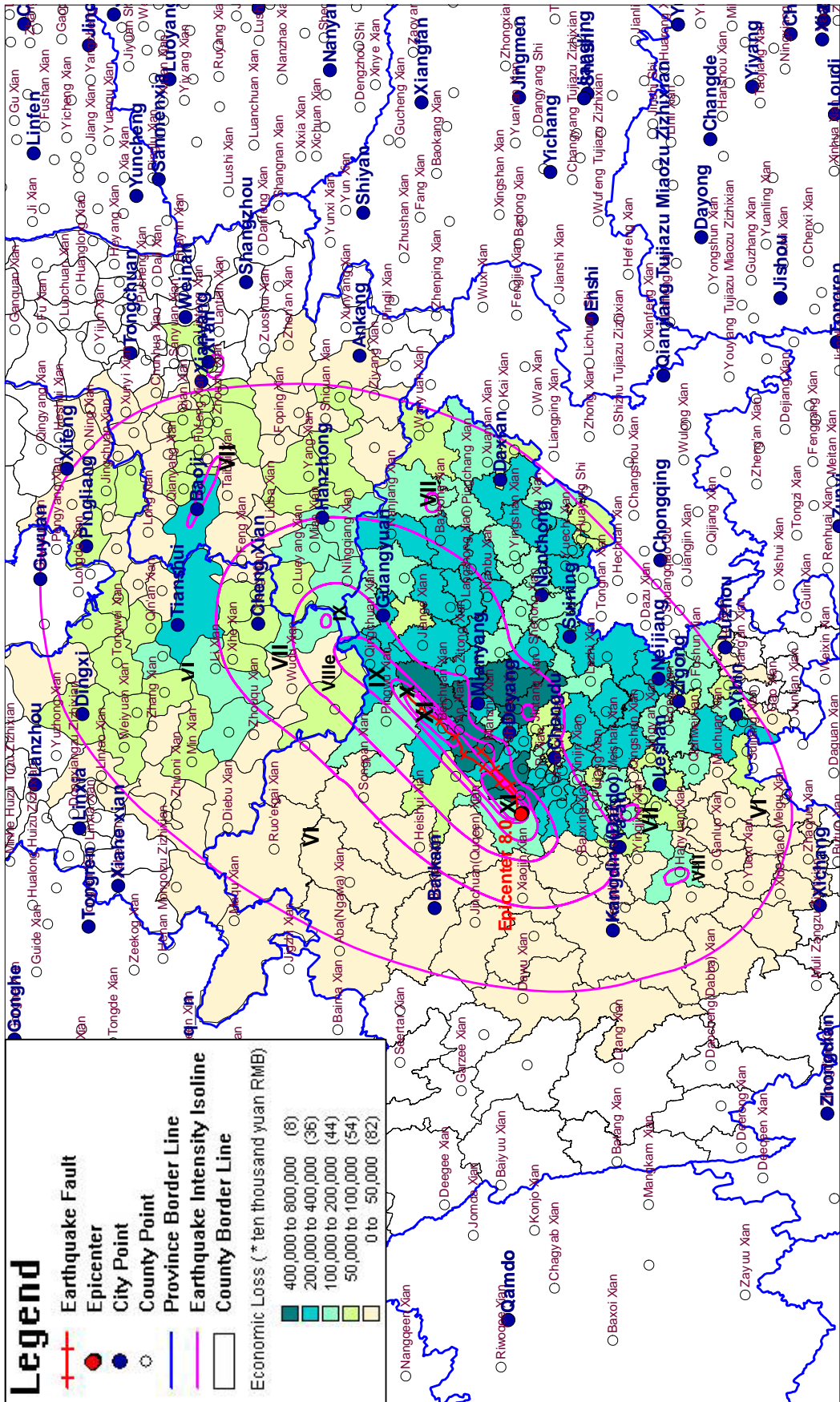


Fig.3.4.4 the loss assessment map of residential building in every county caused by the M 8.0 Wenchuan Earthquake

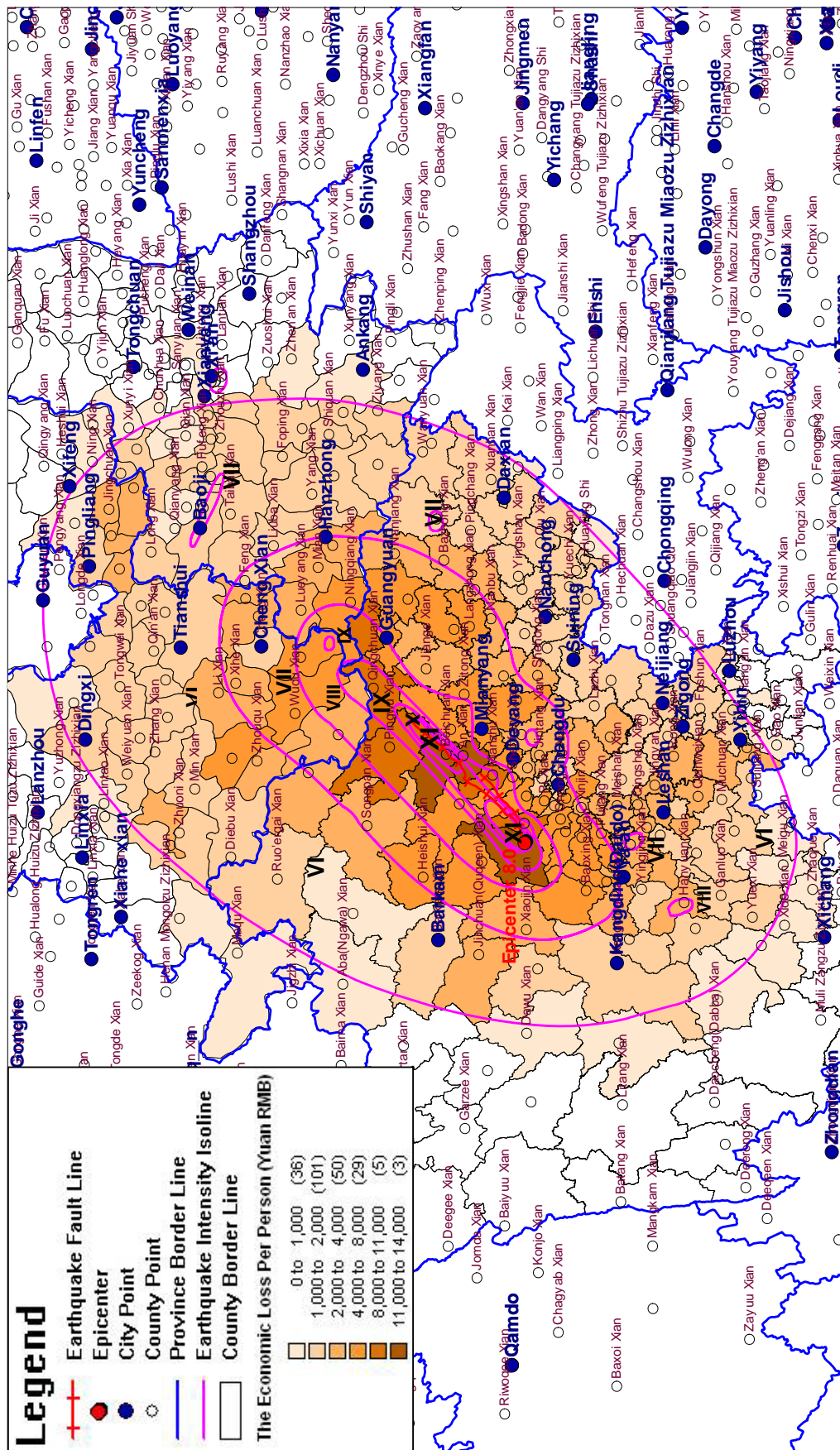


Fig.3.4.5 The per-capita loss assessment map of residential building in every county caused by the M 8.0 Wenhuan Earthquake

3.4.4. Discussion on the Intensity Map

In this section, the author shares some views on the shape of seismic intensity isograms. First, the major axis direction is the same as the fault rupture, and the curvature radius of intensity isograms in the west-south end of the rupture should be larger than that of intensity isograms in the east-north end of the rupture. Second, considering the hanging wall effect, the Longmen Mountain Middle Fault's hanging wall thrust to the footwall in the west-south part of rupture, and transform to strike-slip gradually in the east-north part of rupture. Consequently, the area of certain intensity zone in the hanging wall should be larger than that of the same intensity zone in the footwall. Third, it took about 80 seconds to finish the fault rupture process from Yinxu in the west-south end of rupture to Beichuan in the east-north end of rupture. If the Doppler Effect is considered, the curvature radius of intensity isograms in the east-north end of rupture may become smaller, and the intensity isograms in the east-north end may extend to the east-north direction slightly.

So, the author suggests that the shape of Wenchuan Earthquake intensity isograms may look like an "egg". The big end of "egg" lie in the west-south end of rupture, and the small end of "egg" in the east-north end of rupture. The intensity isograms in the hanging wall should be plump, while those in the footwall should be thin. The same intensity isoline in the east-north end should extend more than in the west-south end. **These characteristics highlighted here are different than the Wenchuan Intensity Map issued by China Earthquake Administration.**

3.5 THE DAMAGE OF SCHOOL BUILDING

During the Earthquake, many schoolhouses collapsed, and children and students had heavy casualties. Only in Sichuan province, according to the statistic data by May 14, 6,898 schoolhouses collapsed, not including the data of the disastrous counties of Beichuan and Wenchuan . The majority of school buildings in disaster districts were not up to the national standard. The qualities of school buildings which collapsed during the Earthquake were very low. This aspect needs serious examination.

3.6 SECONDARY DISASTER

3.6.1 Landslide and Debris Flow

Wenchuan is a mountain region with narrow valleys in the west of Sichuan Province. The seismic tremor caused countless landslides, rock-falls and mudflow, disrupting all road access to the disastrous regions. Statistics from the Ministry of Public Security showed that all the roads from Songpan and Hongyuan counties to counties of Maoxian, Lixian and Wenchuan, were completely blocked or crumpled. Roads linking towns in the western part of Sichuan were totally destroyed.

The roads to Wenchuan failed to be reopened soon because logistics made it extremely difficult to repair. Most roads to Wenchuan are narrow and run through tight valleys, many alongside rivers. These roads are already risky to travel on given the 4000-meter-altitude in normal days. These conditions often allows only one relief vehicle to operate at a time. Steep topography, landslides and mudflows triggered by frequent aftershocks made it harder for the quake relief and rescue teams to reach the most severely

affected areas. The only way in was by military helicopters transferring rescue personnel and relief supplies to the trapped victims. Since hundreds of thousands of survivors were still trapped in Wenchuan and only two locations were suitable for parachutes to land, it was also not easy to depend on aircraft to transport relief supplies and injured people. The relief workers therefore decided to restore all the four roads leading to Wenchuan and Maoxian simultaneously.

Late on May 15, rescuers announced that the Lixian-Wenchuan Highway was finally reopened. It was the first repaired road leading to Wenchuan County at the epicenter of the Earthquake in May 12, which allowed rescue equipment and relief materials to arrive in Wenchuan by land.

3.6.2 Dammed Lake

Volcano lava flow, glacial till, or massive rock and soil of landslides caused by the seismic activity got down and blocked off the mountain valley or river bed, and stored water to form what is called dammed lakes. Thirty four dammed lakes were formed because of landslides and mudflows caused by the massive Wenchuan Earthquake, and threaten the lives and properties of downstream regions. **The Ministry of Water Resources monitored every dammed lake round-the-clock.** In case of a dam break risk, the alarm would have been sent out and the downstream people would have been evacuated quickly.

Tangjiashan dammed lake is the largest and most dangerous one among all dammed lakes. The length of the dam alone the river is about 803 meters, and the width cross the river is about 611 meter, and the area of top dam is about 300 thousand square meters. The dam consists of rock and hillside-rotten soil. As of May 21, 5 p.m, the capacity of Tangjiashan dammed lake is about 100 million cube meters, and the water-head between the upstream and the downstream is about 52 meters.

Since May 27, the Ministry of Water Resources started to drained the dangerous dammed lake. As of June 2, the capacity of the dammed lake is about 200 million cube meters. On June 7 at 7a.m., the dam began to release water from the dammed lake. On June 10, 17, the danger relieved basically.

3.6.3 Epidemic Prevention

The Ministry of Health immediately launched the first-level sanitation emergency response mechanism. A leading disaster relief team was formed and medical rescue workers were mobilized to go to the disaster-stricken areas in order to reduce the death toll and prevent epidemics. The ministry mobilized an emergency medical team of 700, prepared 10,350 CC of blood, 20,000 blood plasma bags, and 15 tons of first aid kits and drugs overnight, and sent them to disaster-stricken area on May 13. The ministry sent another team of 1,000 medical personnel and 504 ambulances to Sichuan on May 14, and on the night of the same day, the ministry organized a third medical aid team of 3,000.

3.7 BRIEF SUMMARY

In earthquake risk management, it is difficult, generally impossible, to identify an imminent massive earthquake. So, after the occurrence of a massive earthquake, it is very important to give a reasonable focal mechanism solution, a rational intensity zone map, and a proper fast assessment result as soon as

possible, which are basis on the determination of disastrous district, on the disposition of the rescue manpower, and on the supplement of the relief materials.

After the Earthquake, China Earthquake Administration could not quickly provide a rational focal mechanism and a realistic intensity map. As a result, disaster evaluation did not match with the realistic situation. Because of these errors from China Earthquake Administration, some disastrous counties and towns drew little attentions in early stage of relief and rescue.

In seismic risk management, if the aseismic standard of buildings is low, or aseismic measures in structure system are not adopted, the risk and expected loss will increase. The Earthquake caused heavy casualties and properties loss. There are three main subjective reasons for this:

- **First**, because the Longmen Mountain active rift zone is classified into ordinary active rift zone, the basic design acceleration value in the majority of disastrous region is 0.10g (by the seismic parameter zone map of China issued in 2001). China is a developing country, and the aseismic standard is inferior to that of developed country for similar seismic hazard region.
- **Secondly**, not all the buildings are designed and constructed by the aseismic code. In rural area, the majority of buildings did not adopt aseismic measures, so the seismic risk was high. In China, the building's aseismic code is not mandatory for private residential buildings. The private residential buildings are seldom designed and constructed in conformity to the building code. Moreover, the majorities of people in rural region do not know how to construct aseismic buildings, and can not acquire some instructions freely from government, sometimes they can not afford to construct aseismic buildings. In urban district, the aseismic capability of some buildings constructed before 2000 is inferior to the present aseismic code. Consequently, the damage of buildings is high and prevalent in the intensity region more than VIII degree.
- **Finally**, the construction of some public buildings, such as schools and hospitals, did not meet the standard. During the Earthquake, many school buildings collapsed completely, and many children were buried under the debris of buildings. After the Earthquake, the Ministry of Housing and Urban-rural Development and local governments started to check the seismic performance of public buildings, particularly in the highly seismic hazard regions. For these public buildings inferior to the seismic safety standard some retrofitting measures should be adopted to ensure their seismic safety.

In many situations, the secondary disasters may not only aggravate the disaster, but also increase the disaster relief difficulties. Sometimes the loss caused by the secondary disasters is greater than that caused by the original disaster. Due to the mountainous terrain of the disaster region and its numerous streams and rivers, the earthquake induced a lot of landslides, mudflows, and dammed lakes. Fortunately, so far, big epidemic incidents in the disaster regions did not occur because of the efficient and timely response of medical personnel.

4. THE POST-DISASTER EMERGENCY RESPONSE AND DISASTER RELIEF

Soon after the earthquake occurred, President Hu Jintao ordered personnel to rescue and save the injured as soon as possible in order to ensure people's safety in the disaster area. Premier Wen Jiabao flew to the disaster area on the same day the quake struck, acting as the chief commander of relief

efforts. He pledged to save lives at any cost. The national contingency plan was implemented, and the forces and local governments plunged into the rescue and disaster reduction according to the emergencies response arrangement.

During his investigation tour to Mianyang on May 16, President Hu emphasized, “Although the ‘golden relief time, [referring to the 72 hours after an earthquake occurs], has already passed, saving lives is still the top priority of our work.”

From the occurrence of the Earthquake to the seismic information issue, to the contingency plan startup, to the deployment of rescue and disaster reduction, all the decision and work had been doing during two hours, which show a most powerful capability of mobilization of China government.

4.1 DISASTER RELIEF

The death toll from the May 12 earthquake in Sichuan Province and its neighboring region stood at 69,222 as of Aug. 7 Thursday noon. The number of people listed as missing and injured reached 18,176 and 374,638 respectively.

Among the 96,525 hospitalized for injury, 91,923 have been discharged.

About 1.58 million tents, 4.87 million quilts, 14.1 million garments, 2.73 million tons of fuel and 5.83 million tons of coal had been sent to the quake-hit areas. A total of 321,982 tons of grain and 9,401 tons of edible oil have been allocated to the quake zones from central reserves as of Aug. 6, Wednesday.

As of Aug. 7 Thursday noon, a total of 1.48 million quake-affected people had been relocated. As of Wednesday, relief workers had built 612,400 temporary houses and another 6,700 were being installed, with 39,500 to be built.

The government spending on disaster relief and reconstruction has topped 64.39 billion yuan (about US\$9.39 billion), including 57.41 billion yuan from the central budget and 6.976 billion yuan from the local budget.

According to the Ministry of Civil Affairs, domestic and foreign donations had reached 59.26 billion yuan in cash and goods by Monday noon. Of this, 23.81 billion yuan had been forwarded to quake-hit areas.

4.2 PSYCHOLOGICAL RESCUES

The homeland was destroyed in a moment, the family member went away forever, and the sudden disaster brought the bodily wound, which will also cause the damage to the people psychology as well as the bodily injure. To the victims in the Earthquake, the psychological rescue and the life salvage are equally important. Some psychologists analyzed that in the disaster area there are three kinds of high-risk groups which require the most psychological aid.

The first high-risk group is children, including the orphans who lost their family member, teachers,

classmates; also including the children of physical disabilities. Most of them need a long-term special treatment of psychological adjustment and counseling.

The second group needing psychological rescues is the old persons and the parents who lost their children. In China, this may mean that at least 6 adults (parents, paternal grandfather and grandmother, maternal grandfather and grandmother), who lost their only child, were heavily hurt in their hearts. This disaster had claimed many children's lives, in some schools the death toll of students was more than 1000.

The third group needed psychological rescues are the relief personnel, including the medical care personnel, the People's Liberation Army officers and soldiers. They fights and rush bravely to the frontier of saving from the impending death, rescuing the injured, dealing with large numbers of corpses, witnessing the massive sanguinary scenes, similarly need specialized psychology aid.

The psychological rescue is a relatively long-term task, and the heavy demand of psychology rescue in disaster regions should be about three months after a disaster, namely in July and August. The Ministry of Education has readjusted the teacher's training plan this summer, by strengthening teacher's training on psychological rescue. According to the plan, teachers in disaster regions will be trained in steps and arrangements will be made to support all the students in disaster region to access qualified psychological rescue support.

The role of the Ministry of Education is to standardized the activity of psychological rescue and makes the psychological rescue a long-term activity.

4.3 INTERNATIONAL RESCUES

After the earthquake occurs, the international society mobilized itself to support the Chinese government. Many countries and districts have provided aids and rescues in their power to China.

The Japanese Government dispatched a 60-person specialized rescue crew on May 16. In Chinese history this is first time that a foreign specialized rescue groups participated in the disaster relief. The Japanese rescue groups are also the first groups arriving at the disaster regions after the Wenchuan Earthquake.

On May 14, the Russian Emergency Department dispatched a transport aircrafts to ships the second batch of relief materials to China. It is reported that on May 15 and 16 there will be 2 airplanes from Russian to ship the humanitarianism relief goods to China.

The German Government provided a mobile hospital which have 120 beds, and can treat 250,000 patients for the earthquake disaster area.

On May 29 morning, two medical rescue crews from Indonesian and Pakistan, including 50 members, carried on medical rescue service in Wen County and the Wudu County in Gansu Province.

4.4 BRIEF SUMMARY

After the Wenchuan earthquake occurs, the Chinese government's activities in rescue deployment and emergency response and the disaster relief, were quickly carried out, mobilizing the maximum manpower and resources of the whole society with support from Chinese people and the international community. In the disaster relief process, the Chinese government paid much attention to the victims who required psychological aid. Carrying on the psychological aid timely to the disaster victims has not only the advantages of smoothing the heart wound of victims, making the victims live in normal life as soon as possible, but also the advantages of eliminating the social unstable factors, maintaining social long-term stability. At the same time, the Chinese government accepted the disaster aid from international societies, publicizes the disaster information, and widely develops the international exchange and cooperation of disaster reduction.

5. CONCLUSION: SOME LESSONS AND POLICY RECOMMENDATIONS

(1) Establishment and perfection of an efficient post-disaster rescue and relief system

During the Earthquake, the Chinese Government manages to mobilize the resources of the whole country for rescue work shortly after a natural disaster. This has also been recognized by the international community. The shortcoming of China's system is that it is expensive, with far higher costs than in Western countries. Another shortcoming of the system is that none but central government can make all the departments cooperate and coordinate; sometimes the relief leader must be President or Prime Minister. Therefore, a catastrophe disaster and its corresponding rescue activity may impact heavily on the normal orders of the economy and society.

(2) Need for planning some emergent landing stations for helicopters in valley and mountainous region

In valley and mountainous region, disasters such as the massive earthquake or rainstorm, can result in secondary disasters, such as landslide, mudflow, or floodwater. These secondary disasters may destroy roads and interrupt the traffic from outside to the disaster region rendering the transportation of rescue personnel and relief materials into the disaster region extremely difficult. Some landing stations for helicopter should be planned in the future to facilitate the transportation of manpower and materials into the disaster region by aircraft, and in order to ensure timely rescue and help to the victims.

(3) Enhance the aseismic performance of public buildings, such as school and hospital

After the Earthquake, some school buildings were destroyed severely, and numbers of students died or were seriously injured. This issue has also gained the attentions of the international community. Any new building should respect the seismic fortification codes and strictly respond to national standards, the aseismic level of the public buildings should be enhanced. For existing public building, we should check the aseismic capability of the buildings particularly in the region of high seismic hazard. If the aseismic performance of the public buildings is inferior to the code, some reinforcement measures should be adopted.

(4) Informing the rural community on how to construct aseismic residential buildings,

In rural area, the government should provide the rural residents with some technical and economic supports for constructing aseismic residential buildings, considering the knowledge and income conditions of the residents. **Technical aids, such as guidance manuals and construction drawing should be provided freely.**

(5) Compiling a comprehensive treatment handbook for medical personnel

Some medical personnel may not be familiar with the first-aid procedure for the injured who may be buried under gravel for a long time. For example, in the rescue processing, some trapped victims was extricated from debris, but went out of this world soon. The reason may result from the extrusion syndrome when a person is pressed more than two hours by collapsed building. If the heavy materials are removed from the person, the pressed muscle would send out a lot of harmful compound, which may result in heart or kidney exhausted. The correct rescue procedure is that firstly injecting the normal saline before the heavy materials are removed.

(6) Equipping the relief personnel with the indispensable instruments for rescue

On TV, the rescue soldiers were only equipped with shovel and pickaxe, which makes it difficult to save lives buried by ruins. Equipping them with some simple machines, such as jack, big clamps, block and tackle, and hoist chain should be promoted. Jack can shift heavy things, block and tackle can change the direction of force, if cooperated with hoist chain, can suspend up heavy materials , and the big clamps can snip steel bar. Equipped with these simple machines, the rescue team can be more efficient.

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7. ANNEX I: EARTHQUAKE DAMAGE PHOTOS



Photo 1: A school building in Shifang City. The intensity at this place was about 7.5 MMI. The right side building is a reinforced concrete structure built in 2005 and it had minor damaged. The left school building was brick masonry with ring beams, columns and prefabricated slabs as floor built in 2000. It was heavily damaged, but did not collapse and no students were injured. The left side school building was dismantled later.



Photo2: Prefabricated floor slab referred in Photo 1



Photo 3: Hanwang middle school in Mianzhu City, VIII MMI scale, with slight damage. Two students were killed because of the collapse of brick parapet in 3rd storey



Photo 4: Jiulong elementary school, Jiulong Town, Mianzhu City. Among 200 students only 30 could survived. This photo shows only the mourning signs (made of white paper) placed above the collapsed building.



Photo 5: 3-storey brick building, heavily damaged during the Earthquake. The intensity was about 7.5 MMI. The quality of masonry construction was not good: (1) the strength of mortar was not sufficient, and it could be cracked by hand; (2) the joints were not staggered.



Photo 6: Tall brick tower, built during Ming Dynasty, about five hundred years ago, in the Dujiangyan City. The intensity was VIII MMI and it was moderately damaged in the upper part. Compared with present building, the masonry quality is considerably fine.



Photo 7 and 8: Temporary shelters in Dujiangyan City. It has drainage system, learning room, playing room, common kitchen, temporary clinic, and bathroom.



Photo 9: A volunteer is providing psychological support to the survived children.



Photo 10: A band from Hong Kong is acting in Jiulong Village, Mianzhu City. This also contributes to re-comfort the victims.