

Chapter 2

The Field Investigation of the Earthquake

Abstract Organized by the China Earthquake Administration (CEA), Field Investigation was conducted after the Lushan earthquake. The Field Investigation can be divided into two stages: the stage of emergency, and the post-emergency stage.

Keywords The field investigation · The earthquake emergency · The southern Longmenshan fault zone

2.1 Scientific Issues Related to the Field Investigation

In the context of the significant earthquakes in China (see Fig. 1.1), the April 20, 2013, Lushan earthquake occurred in the central-China north-south seismic zone, along the southern Longmenshan fault zone. The middle and north segment of the Longmenshan fault zone was ruptured by the 2008 Wenchuan earthquake. When speaking the Longmenshan fault ‘zone’, the four nearly parallelly-striking faults have to be accounted for, namely, from the west to the east, the Houshan fault (the back range fault, in Chinese Hou = back, Shan = mountain), the Zhongyang fault (the central fault, in Chinese Zhongyang = central), the Qianshan fault (the front range fault, in Chinese Qian = front, Shan = mountain), and the Shanqian fault (the range front fault). The first question about the Lushan earthquake, therefore, is which fault, or another unknown fault, is responsible for this earthquake.

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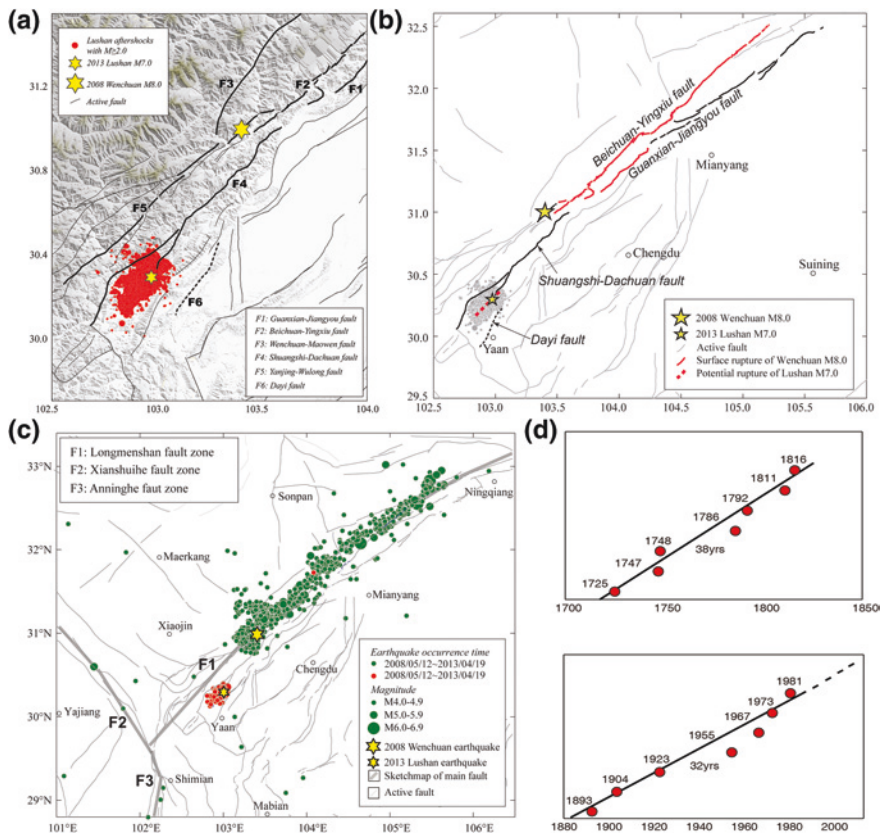


Fig. 2.1 a Active faults associated with the 2008 Wenchuan earthquake and the 2013 Lushan earthquake. Yellow star and red star show the epicenters of the Wenchuan earthquake and the Lushan earthquake, respectively. The aftershocks of the Lushan earthquake are also shown in the figure. Aftershock data from April 20 to June 14, 2013 with magnitude no less than $M_L 2.0$, are from the CENC (<http://10.5.202.22/bianmu/index.jsp>). Active fault data is provided by the National Center for Active Fault Studies (NCAFS). b Epicenter and surface rupture in deep of the 2008 Wenchuan earthquake, and deduced earthquake rupture in deep of the 2013 Lushan earthquake, together with the related faults. Data of surface fault of the Wenchuan earthquake is from Xu et al. (2008), in which the central fault is the Beichuan-Yingxiu fault, and the front range fault is the Guanxian-Jiangyou fault in the mid Longmenshan fault zone and the Shuangshi-Dachuan fault in the southern Longmenshan fault zone. c Aftershocks of the 2008 Wenchuan earthquake and the 2013 Lushan earthquake, together with the Xianshuihe fault zone, the Longmenshan fault zone, and the Anninghe fault zone, highlighting the ‘seismic gap’ between the Wenchuan aftershocks and the Lushan aftershocks, and between the Lushan aftershocks and the ‘triple junction’. d Strong earthquakes with magnitude larger than 6.5 along the Xianshuihe fault. Top the active period between 1725 and 1816; Bottom the active period since 1893

Figure 2.1a shows this situation. Answering this question is, to much extent, an interdisciplinary endeavor which needs to overcome the limitation of seismology by reducing the uncertainty of the of the earthquake location, to overcome the limitation of geology (which investigates the faults and paleo-earthquakes on a

point-by-point basis, and sometimes cannot provide an accurate location of the faults) by organizing a comprehensive field investigation, and to overcome the limitation of geophysics by enhancing the resolution of geophysical mapping.

For the Lushan earthquake, the relation with the Wenchuan earthquake is another key issue to be considered. Figure 2.1b shows the locations of the Wenchuan earthquake sequence and the Lushan earthquake sequence. In between of the Lushan sequence and the Wenchuan sequence, the southern Longmenshan fault zone left a 45 km ‘seismic gap’. Between the Lushan sequence and the ‘triple junction’ among the Xianshuihe, Anninghe, and Longmenshan fault zone there is another ‘seismic gap’ with comparable size (see Fig. 2.1c). The two ‘seismic gaps’ make the debate about the relation between the Lushan earthquake and the Wenchuan earthquake of practical implication to regional seismic hazard assessment. It has to be noticed that the Wenchuan earthquake was not a simple rupture. Rather it ruptured the central fault (in Fig. 2.1b the Beichuan-Yingxiu fault) and the front range fault (in Fig. 2.1b the Guanxian-Jiangyou fault), with surface ruptures 240 and 70 km, respectively. It was suspected that the Lushan earthquake occurred along the front range fault (in Fig. 2.1b the Shuangshi-Dachuan fault), or the Dayi fault, or ‘another’ unknown fault. These fault associations provide different models for both the seismogenesis of the Lushan earthquake and the seismic hazard in the southern Longmenshan fault zone.

Figure 2.1c shows the sketch of the two ‘seismic gaps’ along the southern Longmenshan fault zone. In the ‘north gap’ there was the record of a magnitude 6.2 earthquake in Dayi on February 24, 1970, approximately along the Dayi fault (as shown in Fig. 2.1a). In the ‘south gap’ there were the records of a magnitude 6 earthquake in Luding-Tianquan on June 12, 1941, and a magnitude 6 earthquake in Tianquan in September 1327. Problem is that the accurate locations of these two historical earthquakes could not be determined using historical recordings, with the uncertainty of up to 100–200 km.

The region of the ‘triple junction’ is even more complicated at the present time considering another famous fault, the Xianshuihe strike-slip fault. Figure 2.1d shows the strong earthquakes with magnitude larger than 6.5 along the Xianshuihe fault. Two active periods are shown in the figure, namely the active period between 1725 and 1816, and the active period since 1893. Note that till 2013 there has been 32 years since the last strong earthquake in 1981, in the active period since 1893 the maximum inter-seismic duration is 32 years, but the duration between the recent two active periods is 77 years, the seismic hazard along the Xianshuihe fault is not a simple picture.

Among the scientific problems associated with the Lushan earthquake, the fault association, the relation with the Wenchuan earthquake, and the seismic hazard of the southern Longmenshan fault zone are of special concern not only in earthquake science but also in the public. Responding to this concern, after the earthquake, organized by the China Earthquake Administration (CEA), the Field Investigation of the 2013 Lushan Earthquake was organized, participating in by the institutions in the CEA, with the assistance of the Earthquake Administration of Sichuan Province. Figure 2.2 shows the scientific targets of the

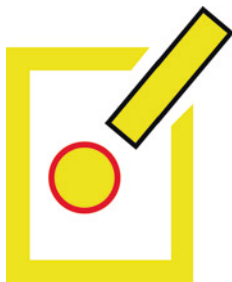


Fig. 2.2 Logo of the field investigation highlighting the scientific goals (Designed by Wu ZL, team leader of the field investigation of the 2013 Lushan earthquake.). In the logo the *black box* shows the rupture zone of the 2008 Wenchuan earthquake, and the *red circle* shows the after-shock zone of the 2013 Lushan earthquake. The *exclamation mark* consists of the Wenchuan earthquake and the Lushan earthquake, as shown in the logo, indicating a warning of the future seismic hazard

Field Investigation by its logo, which shows the Lushan earthquake, the Wenchuan earthquake rupture zone, and the Longmenshan fault zone. The yellow box is similar to the National Geographic, indicating the nature of the activity. The exclamation mark consisting of the Wenchuan earthquake and the Lushan earthquake indicates a warning of the future seismic hazard.

2.2 The Field Investigation of the 2013 Lushan Earthquake

2.2.1 *Field Investigation in the Stage of Earthquake Emergency*

The Field Investigation started almost at the same time when the earthquake stroke. As a matter of fact, institutions of the CEA had prepared a plan for the earthquake field investigation and the design of the organization. Generally, after an earthquake, the field investigation includes engineering and damage investigation, mobile seismic observation of aftershocks, seismo-tectonic field work, and geophysical explorations of the structure of seismic source. After many of the earthquakes, field investigation of the precursor-like anomalies is also organized.

Figure 2.3a shows the intensity distribution map officially released by the CEA in the emergency response stage. This map is to be revised and refined due to its emergency response nature. Figure 2.3b shows the working sites of the engineering group of the Field Investigation. Figure 2.3c shows structural engineers working in the disastrous region. These works are to much extent connected to the field work for earthquake emergency. In the CEA, the earthquake emergency includes two fronts: network-based seismological information service to the public and the government (see Chap. 6 of this Brief), and field work. The field work includes three components: rescue and relief actions, field investigation of damage and

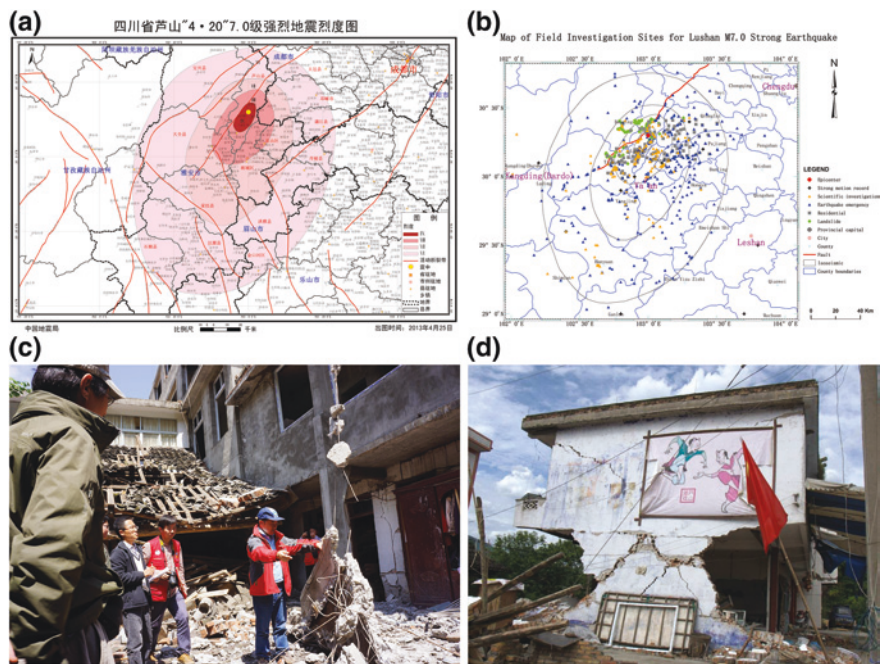


Fig. 2.3 **a** Intensity distribution of the Lushan earthquake, officially released by the CEA in the emergency response stage (From: <http://www.cea.gov.cn/publish/dizhenj/464/478/20130425153642550719811/index.html>), with the Chinese characters on the top ‘The intensity distribution map of the April 20 Lushan, Sichuan Province magnitude 7.0 earthquake’, subject to revision based on field investigation and study. See Fig. 2.3b. **b** Field investigation of engineering damages and disasters: Map used for the field investigation of the task force (unpublished, courtesy of Prof. Dai JW). *Blue triangle* sites of field investigation of engineering damage; *Black cross* strong ground motion recording stations; *Green dots* sites for remote sensing interpretation of landslides; *Gray squares* residential sites for remote sensing interpretation of damages. The epicenter (*red dot*), the Shuangshi-Dachuan fault (*red line*), and the (revised) iso-seismal (*black thin line*) are also marked on the map. **c** Structural engineers in the field. Shown in the figure is Li XJ (the first on the *right*), associate team leader of the Field investigation of the 2013 Lushan earthquake, in the disastrous region in the days after the earthquake. Photo by the engineering group of the field investigation of the 2013 Lushan earthquake. **d** A typical ‘standing ruin’. Photo by Guo X, Institute of Disaster Prevention

disaster assessment, and scientific works including mobile field observations of aftershocks and geophysical fields and field survey of seismo-tectonics.

It has to be noticed that field work has the unique role which cannot be replaced by remote sensing. Figure 2.3d shows a special kind of seismic destruction in the epicentral region, the ‘standing ruin’. In the remote sensing picture, this ruin is hard to recognize if there is not special data processing added.

Before the Lushan earthquake, in connection to the post-Wenchuan earthquake field work, several continuous GPS stations were deployed in the Lushan region. These GPS stations were named as LS#, with # stands for numbers of different

stations. Therefore some people thought that there must be some ‘forecasts’ before the Lushan earthquake. But actually LS is a Chinese abbreviation Lin-Shi (temporary) and has nothing to do with Lushan. And this misunderstanding just reflects a good hope of people to solve the problem of earthquake forecast.

Started from April 20, mobile seismic stations were deployed in the epicentral region, monitoring the aftershock activity. Up to April 25, 15 mobile seismic stations were deployed and networked. These near source observation stations, together with the local and regional seismic stations, well-constrained the aftershock distribution.

2.2.2 Post-Earthquake Field Investigation and Studies

Field investigation for surface faults and geological disasters were also organized in the emergency response stage, and lasted after the ending of the emergency. In the later field investigation, besides the systematic investigation of active faults, geological trenches and near-ground-surface geophysical exploration were conducted to search for the traces of the past earthquakes (Fig. 2.4), including the immediately passed earthquake (the Lushan earthquake). Field investigation obtained a ‘zero result’ that there was no surface rupture observed. What had been claimed to be the ‘seismic surface faults’ (e.g., Liu et al. 2014a) were all proved to be the secondary geological effects. It is worth mentioning that, like a detective searching and collecting evidences, or like Thomas Edison excluded the materials which could not be used in the electric lamp, such ‘zero result’ in the field investigation plays an equivalently important role for the scientific understanding of the earthquake as the discovered surface faults and historical earthquakes.

With the emergency response stage finalized, more mobile seismic stations were deployed and joined in the network. Seismologists from the Institute of Geophysics, CEA, and the Earthquake Administration of Sichuan Province learnt from IRIS the improvement of the site condition to enhance the quality of observation (Fig. 2.5a). By combing the mobile seismic stations, the reservoir seismic stations, the public/industry seismic stations, the local seismic stations operated by the Earthquake Administration of Sichuan Province, and the regional seismic stations operated by neighboring provinces such as Chongqing (Fig. 2.5b), the seismic network carried out a real-time monitoring of the Lushan sequence. Double difference (DD) relocation was conducted to the aftershock sequence (see Chap. 4 of this Brief). The aftershock sequence was also ‘predictively monitored’ by the ETAS model which estimates the expected earthquake rate.

Supported by, and in collaboration with, other existing projects, the Field Investigation of the 2013 Lushan earthquake also carried out geophysical mapping such as MT sounding, geomagnetic mapping, and gravity mapping, as well as leveling measurement for ground deformation. A wide-angle reflection profile, crossing the Longmenshan fault zone, was planned to map the structure of the seismic source. Such collaborative mechanism was also valid for the works of engineering damage investigation, seismo-tectonics and paleo-earthquakes, and seismological



Fig. 2.4 Geological trench to detect the earthquake fault, in Shuangshi Town, over the co-seismic liquefaction zone. Picture by the Seismo-tectonics group of the field investigation of the 2013 Lushan earthquake

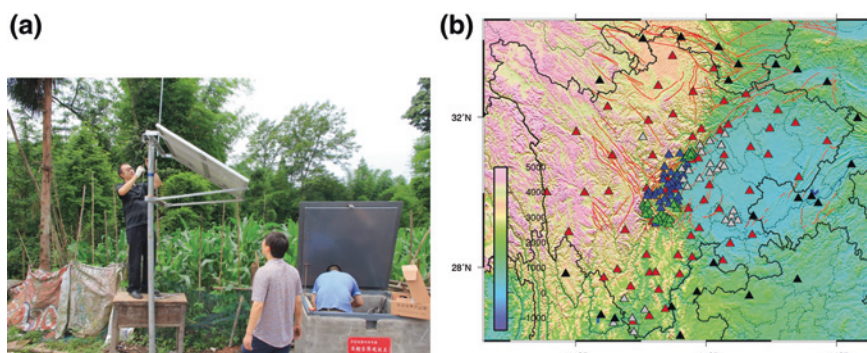


Fig. 2.5 **a** Installation of the temporal seismic stations. From the picture the vault for seismic sensors (*right*) and the solar power panel (*left*) can be seen. Picture by the Portable seismic array group of the field investigation of the 2013 Lushan earthquake. **b** Joint observation and monitoring by the 35 temporal seismic stations (in *blue*), the 60 local and regional seismic stations of Sichuan Province (in *red*), the 32 reservoir seismic stations (in *green*), the 33 public/industry seismic stations (in *gray*), and the 40 seismic stations sharing data with neighboring provinces (in *black*). The data was transmitted in real time to the data center of the earthquake administration of Sichuan Province. Courtesy of Su JR (Earthquake Administration of Sichuan Province)

monitoring. Partly due to this collaborative nature, it might be interesting to notice that in the publications by the team members of the Field Investigation, only a few were acknowledged that the work was supported by the Field Investigation. This, together with the fast and numerous publications mentioned in [Chap. 1](#) and [Appendix A1](#) of this Brief, reflects one side of the characteristics of earthquake science and technology in China, that funding condition seemed good for scientific researches, albeit how to make full use of this unprecedented opportunity to enhance the quality of scientific researches so that such funding state may be sustainable remains a question to be seriously considered by the Chinese institutions.

In the emergency stage, partly due to the lessons and experiences of the Wenchuan earthquake, many scientists and engineers from different agencies and institutions rushed to the disastrous region. However, because the Wenchuan earthquake, with magnitude 8.0 according to the Chinese surface wave magnitude, belongs to the case of ‘up-scaling’ which showed the insufficient task forces comparing to the natural disasters, the lessons and experiences of this earthquake was not valid to the Lushan earthquake. As a matter of fact, the second day after the earthquake, the CEA, as well as other agencies responsible for the emergency field work, had to announce that without special ratification going to the field was no more permitted. Reason? Transportation bogged by landslides, rock bursts, and, more importantly, traffic jam because of the unbalance between the carry-on capability of the road and the transportation load. This lesson taught people that meeting the challenge of an earthquake, it is better to have a well designed, organized, and well prepared plan for the field work, even if it is not directly the rescue and relief action.

In the emergency stage, the scientific field investigation was mainly coordinated by the headquarter commanding the rescue and relief actions. With the emergency stage completed, the Field Investigation established its own headquarter coordinating the field works and the communication with local authorities. Transportation was shown to be the first difficulty to be overcome, because after the earthquake there were many rock bursts and/or landslides destroying or threatening the transportation. In some regions the local authority had special emergency traffic control for the safety of the travelers along the roads. Rainfall and flood were another threatening factor to be cautioned during the field investigation. Dealing with this special condition, the headquarter of the Field Investigation established hotline communication with the local weather agencies. The headquarter also kept good communication with local government, traffic administrative agencies, and the public. For the quality control purposes, some of the field works were video framed with interview with the investigators, which serves both as a technical archive and as the raw materials for further public outreach.

Time-dependent seismic hazard of the southern Longmenshan fault zone kept to be the main scientific concern of the Field Investigation. Coping with this complex problem, the Field Investigation organized several academic exchanges discussing on the seismic hazard in the Lushan region. In the 8th International Workshop on Statistical Seismology (Statsei8, Beijing), a special session on the Lushan earthquake, together with a panel discussion, was organized. The on-going progresses of the Field Investigation were also introduced at the East-Asia Earthquake Seminar 2013 (Changbaishan, Jilin, by keynote presentation), the Joint China-India Workshop on Earthquake Disaster Mitigation (Shanghai, by special session), and the Cross-Taiwan-Strait Workshop on Earthquake Prediction Experiment Site (Dali, Yunnan, by invited presentation), as well as the Annual Meeting of the Chinese Geophysical Society (Kunming, Yunnan, by co-organized session).

2.3 Concluding Remarks

To understand the scientific problems associated with the Lushan earthquake, namely the seismogenic fault of the Lushan earthquake, the relation between the Lushan earthquake and the Wenchuan earthquake, and the time-dependent seismic hazard of the southern Longmenshan fault zone as well as its surrounding regions, a Field Investigation was organized by the CEA. This Brief is just organized by the Team for the Field Investigation, based on part of the results of the Field Investigation. Preliminary results of the Field Investigation deal with the relocation and depth of aftershocks (Fang et al. 2013; Xu et al. 2013a; Sun et al. 2014; Zhang et al. 2014), discussion on the relation between the Lushan earthquake and the Wenchuan earthquake based on the ETAS model (Jia et al. 2014) and seismogenic structure (Qi et al. 2013; Wang et al. 2013; Wen et al. 2013a; Xiong et al. 2013; Xu et al. 2013b; Ye et al. 2013a, 2013b; Zhang et al. 2013; Chen et al. 2014), gravity anomaly in the seismic source region (Shi et al. 2013), engineering damage of the earthquake (Dai et al. 2013; Sun et al. 2013), earthquake induced landslides (Xu 2013), and seismic hazard assessments (Liu et al. 2014). For the Field Investigation itself, not only scientific results but also the lessons and experiences of the Field Investigation, its design, planning, and organization, are all useful materials for further study.

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Earthquake Phenomenology from the Field

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