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Editorial

The 2008 Wenchuan earthquake and active tectonics of Asia

1. Introduction

The great Wenchuan earthquake (Mw 7.9 or Ms 8.0), struck western Sichuan at 14:28 Beijing time on 12 May, 2008. It is the worst event in China since the Tangshan earthquake in 1976, killed more than 88,000 people and displaced millions. It is one of the largest continental thrusting events in the world. The nucleation point of this long rupture was defined by an epicenter at 103.4°E and 31.0°N, with a focal depth of 15–20 km. A first-motion solution was reported to be striking N50°E, dipping 32°NW with an average rake of 118° (Wang et al., 2008). The event was officially named after the nearest county Wenchuan by the China Earthquake Administration (CEA). Early studies indicated that the NE-trending Yingxiu–Beichuan and Guanxian–Anxian faults in the Longmen Shan fault zone were responsible for this great earthquake. The principal surface rupture zones are totally longer than 300 km in length, mainly distributed along the pre-existing Yingxiu–Beichuan and Guanxian–Anxian fault zones (Fu et al., 2008; Li et al., 2008; Xu et al., 2009). The surface deformation is characterized by oblique reverse faulting with the maximum vertical displacement of ca. 10 m occurred around the Beichuan. The geological disasters were linearly distributed along the surface rupture zones and the river valleys.

This special issue arises from a special session on the 2008 Wenchuan earthquake during the 13th Gondwana Conference in Dali city (Yunnan Province, SW China) 3–5 September 2008 and presents a broad range of papers on the 2008 Wenchuan earthquake and active tectonics of Asia. Scientifically, this special issue collects a total of 18 papers mainly dealing with the earthquakes, geodynamics, geophysics and tectonics around the Tibetan Plateau, especially around the Longmen Shan region in the eastern Tibetan Plateau.

2. Active tectonics of Asia

The actively deforming parts of Asia display some of the most diverse and complicated patterns of active deformation on Earth (e.g., Molnar and Tapponnier, 1975, 1978; Molnar and Deng, 1984; Avouac and Tapponnier, 1993; England and Molnar, 1997; Tapponnier et al., 2001; Van der Woerd et al., 2002; Yin, 2010). The late Cenozoic to the present tectonic deformation of Asia is mainly controlled by relative movements and interactions of tectonic plates, such as the Arabian, Indian, Eurasian, Pacific, Okhotsk, Philippine Sea and Australian plates (Fig. 1). Asia constitutes three broad active deformation zones: the Arabia–Eurasia convergence zone in the west, the India–Asia convergence zone in the central, and the East–Southeast Asia convergence zone caused by the Indian, Australian, Sunda, Philippine Sea and Pacific subductions in the east (Fig. 1).

Asia is the largest region of intense intracontinental deformation. Continental deformation measured by regional Global Positioning System (GPS) networks reflects the geologic and tectonic variability across the region (Fig. 1; Bilham et al., 1997; King et al., 1997; Bendick et al., 2000; Wang et al., 2001; Sella et al., 2002; Vernant et al., 2004; Zhang et al., 2004; Calais et al., 2006; Reilinger et al., 2006; Socquet et al., 2006; Allmendinger et al., 2007; Meade, 2007; Vergnolle et al., 2007).

A regional GPS network across Iran suggests that a total of 20–25 mm/yr of NNE–SSW shortening occurs within the Arabia–Eurasia collision zone (Vernant et al., 2004; Reilinger et al., 2006; Fig. 1). The continuous convergent process has led both to the uplift of high mountain ranges and the formation of the high-plateau system of Iran and Anatolia. The kinematics of faulting in the eastern and western parts of the Arabia–Eurasia collision zone is very different. In the east, convergence is accommodated by north–south continental shortening within Iran, whereas in the west the North and East Anatolian Fault Zones allow the lateral expulsion of Turkey (e.g., Allen et al., 2006).

Wang et al. (2001) and Zhang et al. (2004) estimate that the equivalent of 40–50 mm/yr of convergence is currently accumulating as strain across the India–Asia collision zone; with ca. 20 mm/yr of shortening directly distributed along the Himalaya that is presumed to be caused by locking on the main frontal thrust (Cattin and Avouac, 2000). Regional GPS measurements show that the current motion of Australian Plate with respect to the Sunda Plate is at rate of 60 mm/yr. The relative motions of the Pacific Plate and Philipine Sea Plate with respect to the Eurasia Plate are at rate of 70 mm/yr and 86 mm/yr, respectively (Fig. 1; Calais et al., 2006, Vergnolle et al., 2007).

The Tibetan Plateau, the largest and highest plateau on Earth, is the result of the collision of the Indian continent with Asia since ca. 50–60 Ma. Active deformation and seismicity within the Tibetan Plateau represent an important component of the active intracontinental tectonics of Asia (Fig. 2). The great elevation of the Tibetan plateau results from crustal thickening, and the active tectonics of the high plateau are now characterized by a mixture of strike-slip and normal faulting in the interior of plateau and active thrust-and-folding deformation around the margins of plateau accommodating convergence, extension and extrusion. The active deformation in Asia has been extensively studied over the past 30 years (e.g., Molnar and Tapponnier, 1975; Tapponnier and Molnar, 1979; Burchfiel et al., 1989, 1995; Tapponnier et al., 2001; Taylor and Yin, 2009; Yin and Harrison, 2000; Yin, 2010). It is now well established that current deformation is distributed over a broad

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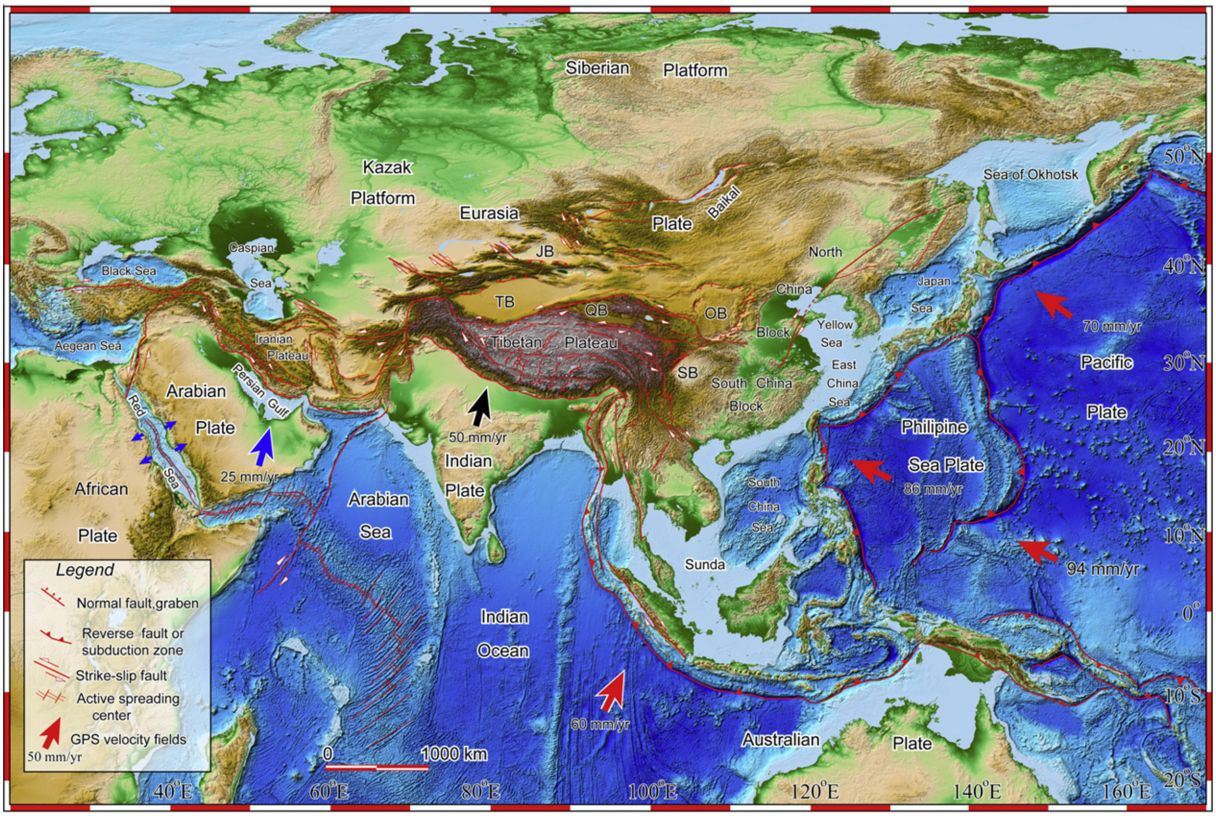

Fig. 1. A color-shaded relief map with simplified active tectonic map of Asia and surrounding regions. The main faults are compiled from listed here (i.e., Armijo et al., 1986, 1989; Avouac and Tapponnier, 1993; Burchfiel et al., 1995; Fu et al., 2004; Peltzer and Tapponnier, 1988; Walker and Jackson, 2004; Tapponnier and Molnar, 1979; Tapponnier et al., 2001; Taylor and Yin, 2009; Yin, 2010), and are also interpreted by our own data. GPS data showing relative plate motions with respect to Eurasia Plate from Wang et al. (2001), Sella et al. (2002), Zhang et al. (2004), Allmendinger et al. (2007) and Vergnolle et al. (2007). JB: Jungar Basin, QB: Qaidam Basin, SB: Sichuan Basin, TB: Tarim Basin. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

area extending from the Himalayas in the south to the Baikal rift to the north, and from the Pamir–Tian Shan to the west (Fig. 2). However, the nature of deformation within the actively deforming Asia continent has long been debated.

There are two opposing conceptual models explaining continental deformation in Tibetan Plateau. Edge-driven block models suggest that boundary stresses due to the India–Eurasia collision are responsible for the eastward extrusion of rigid lithospheric blocks bounded by fast slipping lithospheric-scale fault zones (e.g., Tapponnier et al., 1982; Peltzer and Saucier, 1996). On the other hand, thin sheet models treat the deformation as pervasive throughout the continent such that fault zones play a minor role. In that view, deformation is driven for a large part by buoyancy forces resulting from crustal thickening or thinning in response to the India–Asia collision (England and Houseman, 1986; Houseman and England, 1993; England and Molnar, 1997).

The widespread availability of GPS data provides a significant new perspective on the instantaneous state of strain in continental plateaus. The past decade has seen a rapid increase in geodetic results for the Tibetan Plateau (e.g., Bilham et al., 1997; King et al., 1997; Bendick et al., 2000; Wang et al., 2001; Sella et al., 2002; Wright et al., 2004; Zhang et al., 2004; Calais et al., 2006; Socquet et al., 2006; Vergnolle et al., 2007). For instance, GPS and interferometric synthetic aperture radar data show that the central and western parts of the Altyn Tagh fault accumulate strain at a rate of 9 mm/yr (Bendick et al., 2000; Wright et al., 2004), inconsistent with edge-driven block models that require slip rates at least a factor of two larger (Peltzer and Saucier, 1996). On the other hand, geodetic measurements of the eastward velocity of south China at 8–10 mm/yr (e.g., Wang et al., 2001) match block models and continuous deformation models equally well (Peltzer and Saucier, 1996) but are inconsistent with early models of extrusion that required at least 10–15 mm/yr of eastward motion of south China (Avouac and Tapponnier, 1993). Therefore, even though it is now accepted that only 20–30% of India–Eurasia convergence is accommodated by lateral extrusion of continental blocks (e.g., Peltzer and Saucier, 1996; England and Molnar, 1997), no consensus has yet been reached on the processes and relative importance of the forces that drive present-day continental deformation in Asia. India still moves northward with respect to Asia at a rate of ca. 40–50 mm per year, maintaining the high elevations of both the Himalayas and the Tibetan Plateau (Figs. 1 and 2).

Seismicity within Tibet is widespread and most large earthquakes occur at known active fault zones. A number of large events have struck Tibet during the 21st century, such as the 2001 Mw 7.8 Kunlun earthquakes in the east Kunlun fault zone (Lin et al., 2002; Fu et al., 2005), the 2008 Mw 7.9 Wenchuan earthquake in the Longmen Shan, and more recently, a Mw 7.0 event at Yushu in the Ganze–Yushu fault zone occurred on April 14, 2010 (Fig. 2). Geological, seismological, and geodetic investigations of these recent earthquakes can also provide clues about the complex intracontinental active deformation ongoing in the Tibetan Plateau (Fig. 2).

3. Overview of the different papers

Most of papers in this special issue address the following aspects:

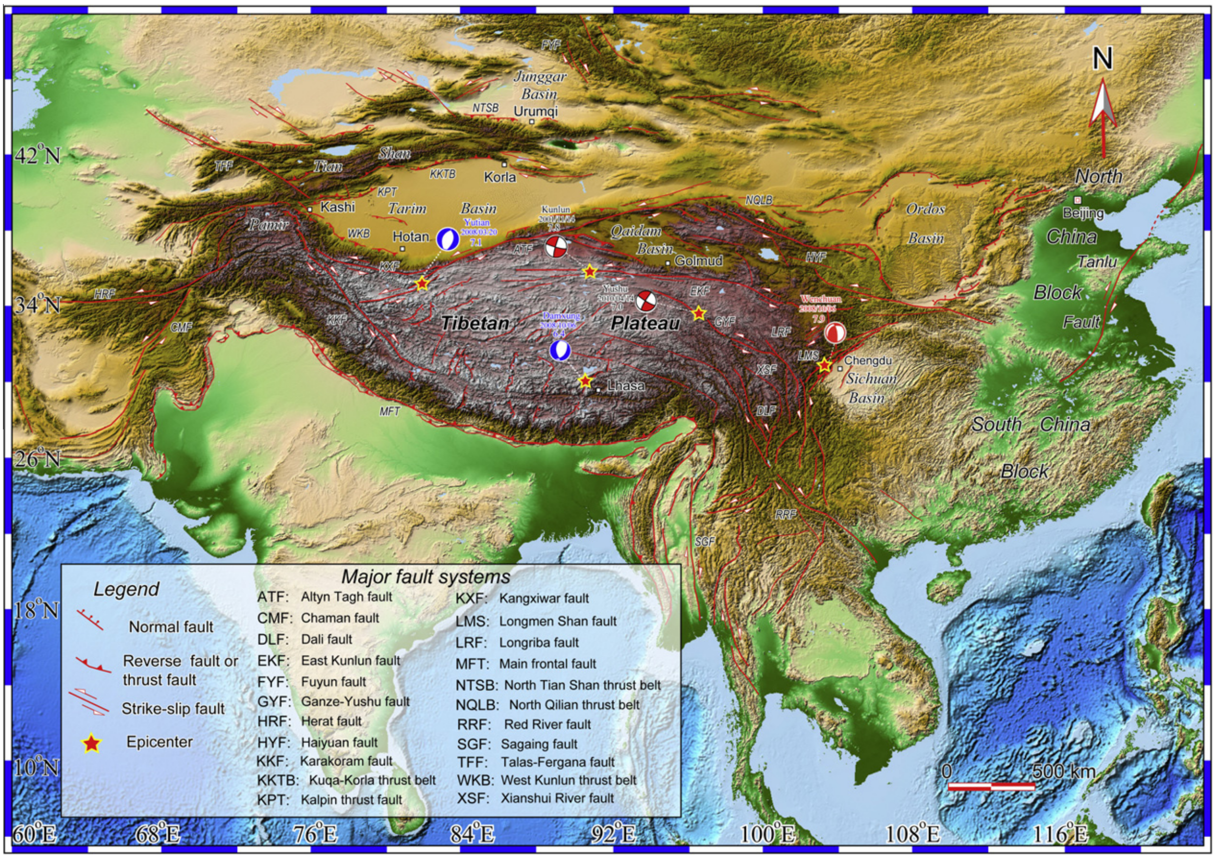

Fig. 2. Simplified active tectonic map of the Tibetan Plateau and surrounding region. The major active fault zones are represented on the DEM image. The five recent large earthquakes in Tibet are marked by the GCMT focal mechanisms (five-pointed stars showing their epicenters), with the name, date (yy/mm/dd) and moment magnitude (Mw). The names of major active fault zones are indicated in the legend.

(1) Coseismic surface deformation, seismology and geological disasters related to the 2008 Wenchuan earthquake.
(2) Active tectonics, geomorphology and paleoearthquakes in the Longmen Shan, east Tibet.
(3) Active faulting, seismicity and deep structures of Asia.

Six articles focus on the coseismic surface deformation, active tectonics, paleoearthquake, geomorphic features and deep structure in the Longmen Shan fold-and-thrust zone, east Tibetan Plateau, where is a perfect nature laboratory to understand intense intracontinental active deformation, seismicity and geomorphic growth.

To begin with, Fu et al. (2011) give an overview of the surface deformation caused by the 2008 Wenchuan earthquake from the field investigations as well as interpretation of remote sensing images. They investigated the geometry, geomorphology, and kinematics of coseismic surface ruptures, as well as seismic and geologic hazards along the Longmen Shan fold-and-thrust belt. Their results indicate that the Wenchuan earthquake occurred along the NE–SW-trending Yingxiu–Beichuan and Guanxian–Anxian faults in the Longmen Shan fold-and-thrust belt. The main surface rupture zones along the Yingxiu–Beichuan and Guanxian–Anxian fault zones are approximately 235 and 72 km in length, respectively. These sub-parallel ruptures may merge at depth. The Yingxiu–Donghekou surface rupture zone can be divided into four segments separated by discontinuities that appear as step-overs or bends in map view. Surface deformation is characterized by oblique reverse faulting with a maximum vertical displacement of approximately 10 m in areas around Beichuan County. Furthermore, rapid erosion within the Longmen Shan fold-and-thrust belt occurs along deep valleys and rupture zones following the occurrence of large-scale landslides caused by earthquakes. Consequently, they suggest that crustal shortening related to repeated great seismic events, together with isostatic rebound induced by rapid erosion-related unloading, is a key component of the geodynamics that drive ongoing mountain building on the eastern Tibetan Plateau.

Li et al. (2011) report the trenching excavation across the 2008 earthquake rupture across the Yingxiu–Bichuan fault on three representative sites as well as the ^{14}C and OSL dating data. They suggest that the 2008 earthquake is a characteristic earthquake along the Yingxiu–Beichuan fault. The interval of reoccurrence of large earthquake events on this fault can be inferred to be about 11,000 years. Styles of coseismic deformation along the 2008 earthquake rupture at these three sites represent three models of deformation along a thrust fault. Two of the three trench exposures reveal one pre-2008 earthquake event, which is coincident with the pre-existing scarps. It is indicated that the deformation is absorbed mainly not by shortening, but by uplift along the rupture during the 2008 earthquake.

To better understand the potential for the Zipingpu Reservoir in triggering the 2008 Wenchuan earthquake, Lei X.L. (2011) carried out detailed analysis of numerical results and local seismicity, the author suggests that the Zipingpu Reservoir may have played some role in triggering the Wenchuan earthquake. It is not proper to rule out the possibility of the Wenchuan earthquake being a reservoir-triggered earthquake (RTS) based on very limited knowledge obtained from a few cases of historical RTS. In risk assessment concerning dam construction, forecasting the probability and location of damaging earthquakes in the future is an important task.

The Longmen Shan on the eastern Tibetan Plateau possesses the steepest topographic gradient on the margins of the Tibetan Plateau. Zhang H.P. et al. (2011) reveal first-order topographic variations from high-elevation and low-relief within the interior of the plateau to the relatively low elevation, high-relief plateau margins in eastern Tibet based on regional topographic and geomorphic analyses. Their field observation along the 2008 surface rupture zone motivates a more careful examination of topographic features along the Longmen Shan to explore the connection between the seismic cycle and mountain building. Analyses of topographic relief, hillslope gradient, and channel gradient indices reveal significant geomorphic differences along the Longmen Shan mountain front. The central part of the range exhibits the highest slope, relief and steepness of river longitudinal profiles. Whereas the southern Longmen Shan exhibits only subtle differences associated with slightly lower hillslope and channel gradients, the northern Longmen Shan is characterized by topography of significantly lower relief, lessened hillslope gradients, and low-gradient channels. They suggest two possible explanations for these topographic differences; one of them may reflect different stages of an evolutionary history. Alternatively, these may reflect differences in the rate of differential rock uplift relative to the stable Sichuan Basin.

Wang P. et al. (2011) report multiple levels of well-preserved soft-sediment deformation structures (seismites) in sediments of paleo-dammed lakes in the upper part of the Minjiang River. These deformation structures include liquefied convolute deformation, water-escape structures, flame structures, pseudonodules, ball-and-pillow structures, sedimentary dykes, mud lenses, and large-scale folds. Several kilometers from the barrier bar of the Diexi paleo-dammed lakes, seven deformed structural layers were identified at different heights in late Quaternary stratigraphic sequences near Shawan Village, Maoxian County. Analyses of the deformation structures, landforms, and the structural environment indicate that these deformation structures were caused by earthquakes, slumps, and landslides. Optical stimulated luminescence (OSL) and ^{14}C dating of soft-sediment layers from the Shawan site indicate that intense earthquakes occurred during the period 25–20 ka B.P. Therefore, accurate geological dating of deformed features in dammed lake deposits in high mountains and canyons enables the record of moderate- to large-magnitude earthquakes to be extended to the late Pleistocene–Holocene upon the eastern Tibetan Plateau.

Bai et al. (2011) reconstruct the upper mantle velocity structure through a passive seismic experiment across the Longmen Shan (LMS) fault belt which was conducted between August 2006 and July 2007 for the understanding of geodynamic process between the Eastern Tibet and Sichuan basin. Their results show that the depth of the Lithosphere–Asthenosphere boundary (LAB) changes from 70 km beneath Eastern Tibet to about 110 km beneath Longquan Shan, West Sichuan Basin, which is consistent with the receiver function imaging results. The very thin mantle part of the lithosphere beneath Eastern Tibet may suggest delamination of the lithosphere due to strong interaction between the Tibetan eastward escaping flow and the rigid resisting Sichuan basin, which can be further supported by the existences of two high-velocity anomalies beneath LAB in our imaging result. They also found two related low-velocity anomalies beneath the LMS fault belt, which may imply magmatic upwelling from lithosphere delamination and might account for the origin of the tremendous energy needed by the devastating Wenchuan earthquake.

Five papers involve the geological disasters and mitigation of disasters related to the 2008 Wenchuan earthquake.

The earthquake triggered tens of thousands of landslides over a broad area, including shallow, disrupted landslides, rock falls, deep-seated landslides, and rock avalanches, some of which buried some towns and dammed the rivers. Dai et al. (2011) investigate correlations between the occurrence of landslides with geologic and geomorphologic conditions, and seismic parameters. They mapped over 56,000 landslides using aerial photographs and satellite images. The main types of landslides include shallow, disrupted landslides, rock falls, deep-seated landslides, and rock avalanches. Most of the landslides occurred along the major surface rupture, and were concentrated on the hanging wall of the rupture. Landslide concentration has a positive correlation with slope angle, distance from the major surface rupture, and seismic intensity. The correlation of landslide concentration with lithology shows that slopes composed of Pre-Sinian schist, or Cambrian sandstone and siltstone intercalated with slate are most susceptible to earthquake-triggered failure.

Qi et al. (2011) report the most destructive landslides triggered by this seismic event. They found that most of the long runout rock avalanches have source areas with high relief and steep inclination, causing the debris in the travel courses to accelerate. Comparison studies indicate that saturated Holocene loose deposits in the travel courses could be the most important factor for the causes of the long runout characteristic of the rock avalanches especially when they traveled over gentle or even flat ground surfaces. Furthermore, the relationships among the relief slope gradient, runout and covered area are investigated, and a threshold line for predicting the maximum horizontal runout distance under certain change in elevation is presented.

Bad weather conditions usually limit the acquisition of optical remote sensing images, while all day and all weather synthetic aperture radar (SAR) shows the ability of providing timely remote sensing data for emergency response and rescue works after earthquake. Dong et al. (2011) extract geological disasters and building damage information associated with the Ms. 8.0 Wenchuan earthquake based on ALOS PALSAR data with 10 m ground resolution and TerraSAR-X data with 1 m ground resolution acquired before and post-earthquake. This study demonstrates that SAR remote sensing data can provide earthquake damage information at early emergency stage and assist the field surveying, further damage assessment and post-earthquake reconstruction.

Wang Z.Y. et al. (2011) present observations of the newly exposed rocks uncovered by the Wenchuan earthquake, which are undergoing continual intensive erosion in the form of detachment and movement of individual grains. Grain erosion causes flying stones, injuring humans, and resulting in numerous slope debris flows. The process of grain erosion and strategies to limit the erosion were studied by field investigations and field experiments. According to these field investigations and field studies, the most serious grain erosion occurs in the dry spring and early summer seasons. Rocks are broken down to grains under the action of insolation and temperature change. Then, wind blows the grains from the bare rock down slope. Their experimental results showed that the amount of grains blown down by wind per area of rock surface per unit time is proportional to the fourth power of the wind speed. However, the size of the grains blows down by wind increases linearly with wind speed. Their experiment also proved that grain erosion can be controlled with two moss species, which germinated on the rock surface in one month and green the bare rocks in two months. The moss layer protected the rocks from insolation and mitigated the effects of temperature change, thus effectively mitigated grain erosion.

Liu et al. (2011) summarized several principles that underlie the selection of emergency shelter sites for a disastrous earthquake based on field investigations and analyses of remote sensing imagery for distribution of active faults and the locations of coseismic surface rupture zones in which buildings are at risk of intensive damage. They recognized that site-selection process requires an interdisciplinary approach involving seismologists, engineers, environmental and social scientists, emergency management personnel, and government officials.

Three papers discuss the earthquake in the Tibetan Plateau and northern China.

Before the 2008 Wenchuan earthquake, a large earthquake (Ms. 7.3) occurred at Yutian County, Xinjiang Uygur Autonomous Region, in the west end of the Songpan–Ganze block (Fig. 2). Shan et al. (2011) carried out analysis and interpretation to high-resolution satellite (Quickbird) images as well as D-InSAR data from the satellite Envisat ASAR, in conjunction with the analysis of seismicity, focal mechanism solutions and active tectonics in this region. The result shows that the 22 km long, nearly NS trending surface rupture zone by this event lies on a range-front alluvial platform in the Qira County. It is characterized by distinct linear traces and a simple structure with 1–3 m-wide individual seams and maximum 6.5 m width of a collapse fracture. Along the rupture zone are seen many secondary fractures and fault-bounded blocks by collapse, exhibiting remarkable extension. The coseismic deformation affected a big range 100 km $\times$ 40 km. D-InSAR analysis indicates that the interferometric deformation field is dominated by extensional faulting with a small strike-slip component. Along the causative fault, the western wall side was downdropped and the eastern block, rose up, both with westerly vergence. The maximum subsidence displacement is 2.6 m in the LOS, and the maximum uplift is 1.2 m. The maximum relative vertical dislocation reaches 4.1 m, which is 10 km distant from the starting rupture point to south. The 42 km-long seismogenic fault in the subsurface extends in NS direction as an arc, and it dipping angle changes from 70° near the surface to 52° at a depth of 10 km. The slip on the fault plane is concentrated in the depth range 0–8 km, forming a belt of length 30 km along strike on the fault plane. There are three areas of slip concentration, in which the largest slip is 10.5 m located at the area 10 km distant from the initial point of the rupture.

After the 2008 Wenchuan earthquake, the Mw 6.3 Damxung earthquake occurred on October 6, 2008 in southern Damxung County within the N–S trending Yangyi graben, which forms the northern section of the Yadong–Gulu rift of south-central Tibet (Fig. 2). Wu et al. (2011) report field observations and focal mechanism solutions related to the October 6 2008 Mw 6.3 Damxung earthquake. Their results show normal fault movement occurred along the NNE-trending western boundary fault of the Yangyi graben, in agreement with the felt epicenter, pattern of the isoseismal contours, and distribution of aftershocks. The Damxung earthquake is one of several prominent events that occurred on normal and strike-slip faults in Tibet before and after the 2008 Mw 7.9 Wenchuan earthquake. The subsequent renewal of extensional deformational events in central Tibet appears related to some drag effect due to the crustal shortening of the 2008 Wenchuan event.

Lei J.S. et al. (2011) investigate the temporal variations of the crustal structure by using a number of P and PmP (Moho reflected) wave arrival times recorded by 107 digital seismic stations from earthquakes that occurred separately in 2002, 2003, 2004, and 2005–2006 to determine P-wave velocity structures in and around the source area of the Wen-An earthquake (4 July 2006, M5.1) in different periods. Their results suggest that the occurrence of the Wen-An earthquake is not only related to the long-term influence of fluids that decrease the effective normal stress on the fault plane, but also closely associated with the drastic increase of such influence. It is necessary to improve the resolution of crustal tomography to the size of the rupture zone and utilize identical seismic ray paths from the same pairs of sources and receivers in order to detect any temporal variations of the crust structure in the source area of a large earthquake.

Three papers review the deep structures and geomorphic evolution of the Tibetan Plateau and China.

The Tibetan Plateau is a natural laboratory for understanding intense intracontinental deformation and crustal thickening. Since the pioneering wide-angle seismic profile along the Yadong–Gulu rift acquired in 1974 by the ex-Institute of Geophysics, Chinese Academy of Sciences (CAS), several research programs have aimed at deep geophysical imaging, performed thanks to the participation of Chinese national and international institutions. These programs, which have been developed during the last 35 years have included, 23 wide-angle seismic profiles with a total length of about 6000 km. These profiles are unevenly distributed, most of them in eastern Tibet and few profiles in western Tibet.

Zhang Z.J. et al. (2011) make a summarized presentation of all these wide-angle seismic profiles and provide an overall view of the seismic velocity structure of the crust beneath the broad Tibetan plateau. Different patterns of crustal thickness variation related to the tectonic blocks and along suture zones of the region are displayed. The crust thickness is confirmed to be about 70–75 km under southern Tibet, and 60–65 km under northern, northeastern and southeastern Tibet. The leading edge of the subducted lithosphere reaches the northern margin of the plateau and directly contacts with Tarim Basin. Westward of the 90°E boundary, the Indian crust is moving towards the northern edge of the plateau and collides with Tarim Basin at 80°E while reach the Bangong–Nujiang suture belt at 88°E; eastward of the 90°E boundary, the northern edge of the crust should be at 50–100 km south of Bangong–Nujiang suture. The results supply helpful constrains to understand the mechanism of the continent–continent collision and its consequences in the plateau and adjacent areas.

Lu et al. (2011) investigate strong earthquakes that occurred in the Chinese continent, which are usually characterized by group activity, long-distance jumping migration, and different main activity areas formed in different times. In this study, a new 3-D finite element model was set up by involving the surface topography, the main active faults, and the initial stress field. They present two new results: (1) In the Earth's crust where there is always initial stress field, the regions where the strong earthquakes occurred have no ability to load (killed element groups in the simulation) and can cause large-scale adjustment of the stress fields in a magnitude of MPa. This may be one of the main factors for the long-distance jumping migration of the follow-up strong-earthquakes. (2) It is difficult to accurately predict the location of the follow-up strong earthquakes because it is affected by many factors such as the loading manner, geological structure, active faults, and the initial stress field as well as the sequence of strong earthquakes, but in an active period of earthquakes the main activity area (killed element group) and its migration of strong earthquakes in China.

Active deformation of the Tibetan Plateau is not only expressed by the intensive seismicity, but also can influence the long-term regional geomorphic evolution. Generally, the incision of rivers across orogenic belts often leads to the exposure of deeply seated old rocks, such as metamorphic and igneous rocks. However, the Yellow River system, the largest river system in northern China, flows northeasterly through a series of linear mountain belts in the northeastern margin of the Tibetan Plateau, the youngest of which are the Laji–Jishi Shan and Riyue Shan ranges within the northeastern margin of the Tibetan plateau is in contrast underlain by young unmetamorphosed rocks that range from early Cretaceous to Pliocene in age. Wang E.C. et al. (2011) revealed that the topographic feature of the Laji Shan belt is largely dominated by the differential deformation, which shielded these young rocks from erosion. Their mapping shows that the variation in deformation along this mountain belt formed two structural saddles with relative low elevation in late Cenozoic time, through which the Yellow and Yaoshui Rivers cut into the plateau and drained a series of the Tertiary basins. These two saddles, featured by topographic and structural low, were formed in the middle or late Miocene, and facilitated the headward propagation of the Yellow and Yaoshui Rivers, which initiated in early and middle Pleistocene time, respectively.

Finally, one paper addresses the active tectonics of Iranian plateau in the Arabia-Eurasia collision zone. Jamali et al. (2011) attempts to constrain active structural deformation in the Kashan region of central Iran based on the interpretation of high-resolution images and field investigations, in conjunction with seismic reflection data. Their results at Kashan indicate that deformation occurs within central Iran: a region that is often considered to behave as a non-deforming block within the Arabia–Eurasia collision zone. They show that the active Qom-Zefreh strike-slip fault, and parallel active blind thrust faults and folds, together accommodate the motion of Arabia with respect to Eurasia by partitioning of strike-slip and dip-slip onto separate structures.

4. Summary and perspectives

Most of the papers presented this special issue on the 2008 Wenchuan earthquake provide a good opportunity to better understand the geodynamics and active tectonics of Asia, particularly for the active deformation and tectonics of the Longmen Shan mountain building belt, eastern margin of Tibetan Plateau.

Clearly, this special issue marks only the beginning of research topics investigating the details related to the 2008 Wenchuan earthquake. The quake-hit regions were rocked again this summer by landslides and flooding events that proved catastrophic for rehabilitation efforts and caused huge economic losses. It is therefore of critical importance to mitigate the natural disasters induced by the 2008 Wenchaun earthquake in the quake-hit mountainous region.

Investigations of geometry and kinematics of active structures, deep lithospheric deformation, surface geomorphic response and their relationships with earthquakes in Asia are very important from the viewpoints of both scientific research and mitigation of natural hazards. There are still several places needed to be explored in the near future.

For example, the active deformation and Cenozoic tectonic evolution of the eastern part of the Tibetan Plateau, from the Songpan–Ganze block in the west to the Sichuan Basin in the east near the Longmen Shan, are not very clear (Burchfiel et al., 2008). The interactions of adjacent active fault zones in the eastern Tibetan Plateau is especially important in the sense that it may generate large earthquakes along the southwestern segment of Longmen Shan fold-and-thrust zone and Xianshui River fault zone. On the other hand, the active structures near southeast of the plateau in Yunnan province are not clear either. This region is related to the tectonic reversion of the Red River fault zone in the Late Miocene and Early Pliocene (Tapponnier, 1990; Leloup et al., 2001) and is associated with the eastern Himalayan syntaxis.

In the north, the northwestern margin of the Tibetan Plateau and the Pamir–Tian Shan convergence zone obviously demand more attention, especially the active slip partitioning among the strike-slip faulting and thrust-and-fold deformation related to the northwestern extrusion of India–Asia collision zone.

In this broad region of Asia, large earthquakes have occurred frequently within the 21st century. These earthquakes have caused heavy casualties and significant damages to human society, such as the 2003 Mw 6.6 Bam earthquake in southeastern Iran, the 2005 Mw 7.6 Kashmir earthquake in the Pakistan, the 2008 Mw 7.9 (Ms. 8.0) Wenchuan earthquake and the 2010 Mw 6.9 (Ms. 7.1) Yushu earthquake in the eastern Tibet. To clarify the mechanisms of earthquake generation and active tectonics, scientific co-operation through bilateral or multiple countries become more and more important. The joint studies are especially significant for the Tian Shan and Himalayan regions where active tectonics and earthquakes are overlapped by different countries.

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