A PRELIMINARY INVESTIGATION
OF THE COSEISMIC SURFACE-RUPTURES for WENCHUAN EARTHQUAKE of 12 MAY 2008, SICHUAN, CHINA

Ken Xian-Sheng Hao[1], Hongjun Si[2] and Hiroyuki Fujiwara[1]

[1] *Researcher, National Research Institute for Earth Science & Disaster Prevention (NIED), Japan*
[2] *Researcher, Kozo Keikaku Engineering Inc., Japan*
Email: hao@bosai.go.jp

ABSTRACT

On the field investigation we found coseismic surface ruptures over a length of 140km faults; of them the maximum deformation reached 4.6m in vertical, near Leigu-zhen, Beichuan County. The uplifting displacements dominated in the southwestern segment of the rupture. Moreover, the northwest-striking left-lateral fault was found with the maximum displacements of 2.8m in horizontal, and 1.5m in vertical as well, in Xiaoyudong, Pengzhou City. The left-lateral fault, inversely under the controlled movement of right-lateral fault in the area, showed the complexity of the fault movements. The field results showed the detail ruptures and the SAR interferogram let us understand the whole faults movements.

KEYWORDS: Wenchuan earthquake, coseismic ruptures, field investigation, PALSAR, interferogram

1. INTRODUCTION

On 12 May 2008, an M_w 7.9 earthquake occurred beneath the steep eastern margin of the Tibetan plateau in Sichuan, China. The ruptures possibly occurred over a length of 285 km along the northeast striking Longmen Shan (LMS) thrust belt by analysis. Over 86,592 people were dead or missing, 374159 injured.

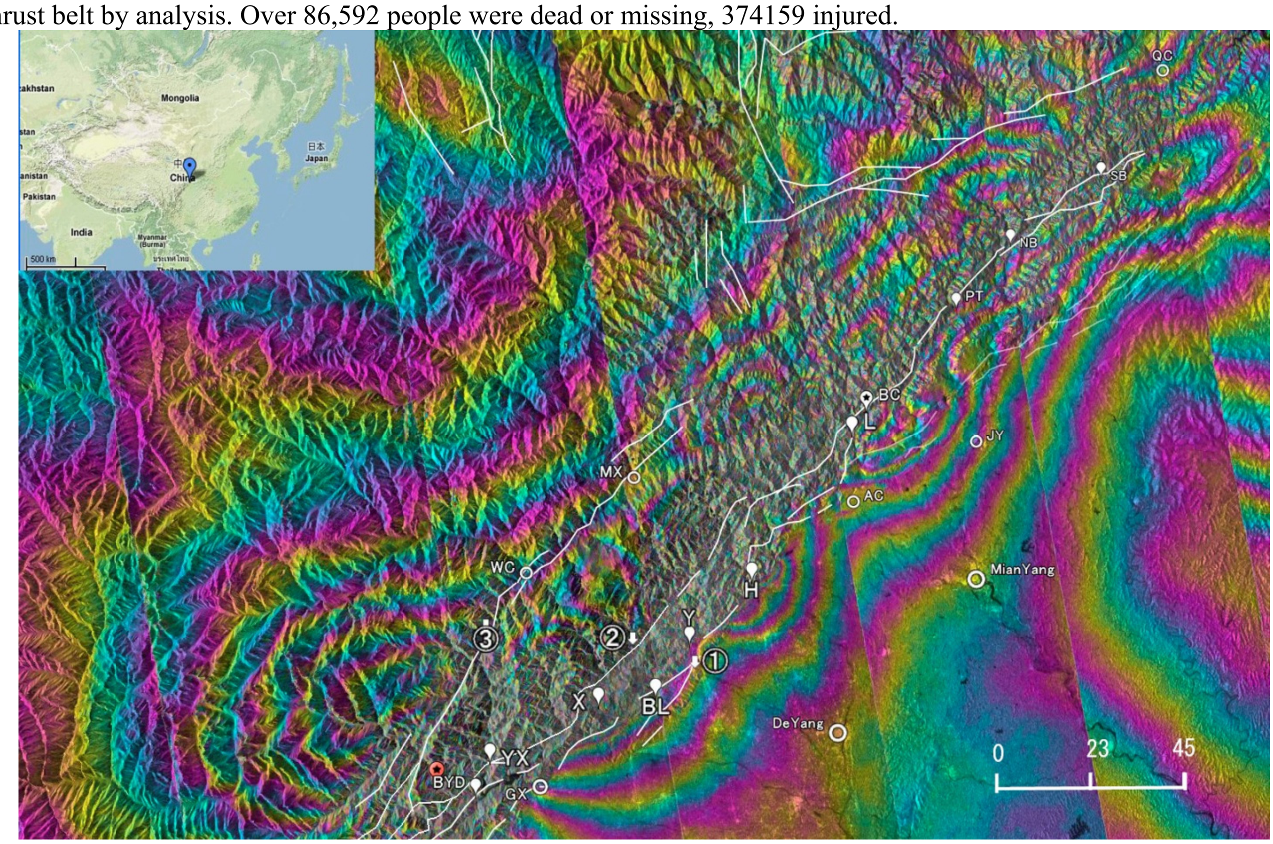

Figure 1 The coseismic faults based on field investigation indicate with letters L(Leigu-zhen), H(Hanwang), Y(Yinghua), BL(Bailu), X(Xiaoyudong), and BYD(Baiyunding). For details see text, Table and Figures. Major active faults are shown in white, while those in thin gray (east of BC) are known to be Mesozoic in age (Kirby *et al.,* 2003). As a complementation, whole ruptured LMS faults are super-positioned by SAR interferometry using ALOS/PALSAR data, ©METI/JAXA, analyzed by NIED (2008).

In order to study the fault ruptures, active faults related and relationships with the damages caused by the earthquake, we conducted a field investigation during 4-15 June, 2008, covered about 140km length of the Longmen Shan(LMS) faults, including Beichuan, Anxian, Mianzhu, Shifang, Pengzhou, GX(Dujiangyan), and Wenchuan. We found coseismic faults as indicated with letters L (Leigu-zhen), H (Hanwang), Y (Yinghua), BL (Bailu), X (Xiaoyudong), and BYD (Baiyunding) in Figure 1. Coseismic faults at PT (Pingtong), NB (Nanba) and SB (Shiba) were based other information (e.g., Zhang, 2008) in the LMS north segment. In Figure 1, red star indicates epicenter of Mw=7.9, and city abbreviation is given as YX-Yingxiu, WC-Wenchuan, MX-Maoxian, BC-Beichuan, AC-Anxian, JY-Jangyou and QC-Qingchuan.

2. COSEISMIC SURFACE FAULTS FROM FIELD INVESTIGATION

The so-called Longmen Shan (LMS) faults usually include three main faults, Guanxian-Anxian fault, Yingxiu-Beichuan fault, and Wenchuan-Maoxian fault as denoted①,②, and ③ in Figure 1. Our target was to find which faults were ruptured during the Wenchuan earthquake although there were synthetic results based on the far-field P waves (Ji, 2008; Nishimura and Yagi, 2008). We investigated the coseismic faults along several measure profiles perpendicular to the LMS faults. Coseismic-fault points we discovered on fields are mainly at Leigu-zhen, Hanwang, Yinghua, Bailu, Xiaoyudong, and Baiyunding, as summarized at Figure 1 and Table 2.1. Of them the maximum deformation reached 4.6m in vertical, near Leigu-zhen, Beichuan County (Hao *et al.,* 2008). The uplifting displacements dominated in the southwestern portion of the rupture. Moreover, the northwest-striking left-lateral fault was found with the maximum displacements of 2.8m in horizontal, and 1.5m in vertical as well, in Xiaoyudong, Pengzhou City. The left-lateral fault, inversely under the controlled movement of right-lateral fault in the LMS area (Tang *et al.,* 1993, 1995; Burchfiel *et al.,* 1995, 2008), showed the complexity of the fault movements. In this session, we describe the each coseismic fault with pictures as following sessions from 2.1 to 2.6, and these measured fault parameters on field are summarized in Table 2.1 for detail.

2.1. Leigu-zhen, Beichuan County

Figure 2 Looking west against the N00E-striking thrust fault with maximum deformation reached 4.6m in vertical, as the offset of two red lines shown, near Leigu-zhen, Beichuan County (Figure 1, Table 2.1). Over 2km length of the fault was traced on riverbed, both riversides, strath terrace, and until mountain sides.

2.2. Hanwang, Mianzhu City

Figure 3 Looking northeast along the N40E-thrust fault with the maximum displacements of 1.5m in vertical, in Hanwang, Mianzhu City (Figure 1, Table 2.1). The 2km length of the fault was traced on riverbed, both riversides, strath terrace, and until mountain sides H1 and H2.

2.3. Yinghua zhen, Shifang City

Figure 4 Looking northwest against the N30E-thrust fault. The vertical displacement of 2m, above first author's height, shows the offset of two red lines. The maximum displacements at nearby is 2.3m with 30 degree angle and 4.7m ramp, in Yinghua zhen, Shifang City(Figure 1, Table 2.1). The old offset between old man and woman was about 1.3m, supposedly the coseismic fault ruptured historically. About 1km length of the fault was traced on riverbed, riversides, strath terrace, and until mountain sides.

2.4. Bailu zhen, Pengzhou City

Figure 5 Looking north along the N00E-thrust fault with the maximum displacements over 2m in vertical, at Bailu zhen, Pengzhou City(Figure 1, Table 2.1). The new building W on hanging wall of the fault found no damages, while the old building E on foot wall of the fault suffered shear-stress cracks in X-shape.

2.5. Xiaoyudong, Pengzhou City

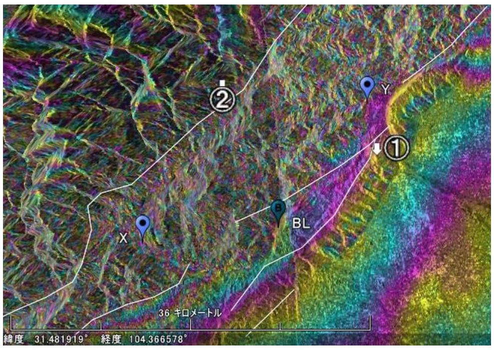

Figure 6 The N20W left-lateral strike-slip fault with dip-slip cut and uplifted irrigation canal with the maximum displacements of 2.8m in horizontal, and 1.5m in vertical(point B, left), in X(Xiaoyudong, left top), Pengzhou City. The length of the NW surface fault was identified over 2 km on both riversides, strath terrace. It broken down the Xiaoyudong bridge (Bridge), cut throughout the cone and vegetable farmlands, and destroyed the buildings and roads. By SAR interferogram, the NW left-lateral fault with about 10km length between LMS faults ① and②, and ~4 km width. See text in detail.

2.6. ***Baiyunding, Wenchuan county***

Figure 6 Coseismic fault with vertical displacement 0.5m inside tunnel BYD (middle), where located at intersection of the road in right front (bottom). The river and valley are along the NE fault near BYD as the map shown. Many land sliding occurred along steep mountains.

Table 2.1 Coseismic-fault parameters measured on fields

Loc.	Latitude	Longitude	Alt	Code	Strike	Dip-Slip	Strike-Slip	Memo
L	31.781501	104.420717	724	H15	N00E	2.3m	0	Liulin, Leigu
L	31.779574	104.421462	726	S22	N00E	Max4.6	0	Shiyan, Leigu
H	31.461577	104.165467	695	H21	N40E	1.5m	0	Hanwang
Y	31.319623	104.001537	769	H43	N30E	Max2.3m	0	Yinghua
X	31.188821	103.762426	948	H59	N20W	1.85m	2.8m	Xiaoyudong
B	31.20834	103.91646	-	G01	N00E	>2m	-	Bailu
BYD	30.987522	103.45435		I01		0.5m		By T. Inokuchi

3. CRUST DEFORMATION COMPLEMENTED FROM SAR INTERFEROGRAM

The surface rupture investigation discovered the coseismic fault traces with detail information as discussed previously chapter. It concludes impliedly that the causative active fault of the earthquake may include parts of the Yingxiu-Beichuan faults and the Guanxian-Jiangyou faults. For the unavailable investigation areas, including mountains and the blocked areas where people cannot access, we used the interferogram as a complementation.

3.1. PALSAR/InSAR data

Crustal deformation associated with the earthquake was detected by the Synthetic Aperture Radar (SAR) sensor on ALOS satellite. The interferometry SAR(InSAR) technique was used from the ALOS/PALSAR data (NIED, 2008). Whole LMS fault rupture zone of the earthquake were superpositioned by interferogram of seven satellite tracks (Figure 1), which were acquired before and after the Wenchuan earthquake. Observation dates for these interferometric pairs are shown in Table 3.1. The offnadir angle was 34.3 degree. A phase difference of 2 π radian corresponds with displacement of 11.8 cm in the line-of-sight (LOS) direction component. In another simple word, deformation of each color cycle (blue-purple- yellow-blue) on the interferogram equaled roughly 11.8 cm, half of the wavelength of the radar.

Table 3.1 Observation dates

Path	before EQ	after EQ
471	2008/2/29	2008/5/31
472	2007/1/28	2008/6/17
473	2008/2/17	2008/5/19
474	2008/3/5	2008/6/5
475	2007/6/20	2008/6/22
476	2008/4/8	2008/5/24
477	2008/4/25	2008/6/10

3.2. Coseismic Faults

Whole crust deformation and fault rupture zone was surrounded by the sets of color cycles in N57E, measured from the link-line of the two centers of the color cycles, as shown in Figure 1. The outer color cycles express the continuous deformation under the NNW-SSE main stress pressing in general. In inner color cycles, surface coseismic faults either cut the color cycles clearly, or broke the color cycles pieces. The maximum deformation of crust are dependent locally on the rock-rupture limitation allowed before ruptured.

The core deformation zones with dark grey were eventually residual deformation accompanied with ruptured coseismic faults, land sliding and displaced mountains, rivers and everything.

The deformation zone with a width of ~30 km in southwestern segment, and of ~10km in northeastern segment, cut through the color cycles in the range of N43~48E. We put on the LMS faults (Kirby *et al.,* 2003) with white lines on the deformation zone in Figure 1, to compare differences between the known active faults and the coseismic surface faults. The deformation zone was mostly within the active faults①,② and ③ in southwestern segment, and within① and /or over②, from X to Anxian, and fit the fault ② from BC to PT, NB, SB and QC in a narrow zone.

Guanxian-Anxian fault①: The coseismic surface faults along the Guanxian-Anxian fault ①, cut the color cycles at GX(Guanxian), BL(Bailu), Y(Yinghua), H(Hanwang), and Anxian. Most of them were investigated on field as described at section before. The faults in thin grey lines at east of Beichuan(Figure 1), known to be Mesozoic in age did not cut the color cycle, remaining inactive as mentioned by Kirby *et al.*, (2003).

From the enlarged SAR interferogram in Figure 6, we can identify the clear color boundary which passing throughout the BL fault, along the NE direction of LMS fault①. The east side of the boundary has continuous color cycle orders which mean crust continuous deformation occurred from Chengdu plain until the LMS fault①. The west side of the boundary has the broken color pieces even through over the LMS fault②, which mean the discontinuous deformations occurred in this area.

Yingxiu-Beichuan fault②: There were no color cycles identified from Xiaoyudong to Beichuan along the Yingxiu-Beichuan fault belts, where submerged mostly by the crust deformations, such as fault ruptures, land sliding. It remains unknown area where most of them are mountain areas we could not go to on fields investigation.

By the SAR interferogram, we also can identify the coseismic surface fault changed the LMS fault① direction at Anxian to N20E, left the Mesozoic faults un-ruptured. Then, coseismic faults passed L(Leigu) to BC(Beichuan), jumped to Yingxiu-Beichuan fault②, final went through PT(Pingtong), B(Nanba), SB(Shiba) (Zhang, 2008), and Qingchuan in the LMS north segment.

Wenchuan-Maoxian fault③: The coseismic surface faults along the WC(Wenchuan)-MX(Maoxian) faults did not ruptured, that was proofed by remaining the color cycles continuous of the SAR interferogram, while the southwestern segment was submerged by the crust deformations, from WC(Wenchuan) to YX(Yingxiu), end after several kilometers of the epicenter.

4. DISCUSSION AND SUMMARY

In the field investigation, we found several coseismic surface ruptures; of them the maximum deformation reached 4.6m in vertical, near Leigu-zhen, Beichuan County. The uplifting displacements dominated in the southwestern portion of the rupture. The field results showed the details rupture mechanism and the SAR interferogram let us understand the whole faults movements and the land sliding disasters.

Xiaoyudong fault: As session ***2.5*** mentioned, we found The N20W left-lateral strike-slip fault with dip-slip component of the maximum displacements of 2.8m in horizontal, and 1.5m in vertical as well, in Xiaoyudong, Pengzhou City. But the right-lateral fault is the predominant system in the LMS fault zone (Tang *et al.,* 1993, 1995; Burchfiel *et al.,* 1995, 2008).
On the other hand, from the SAR interferogram in Figure 6, we can also identify the clear fringe color cycle in NW direction at X(Xiaoyudong), with about 10km length, and ~4 km width. This isolated color cycle was disturbed totally on southwest side, bounded by X(Xiaoyudong) fault. The left-lateral fault along the northwest direction has about 10km length by the interferogram, and it is the fault where the coseismic faults supposedly shifted along with. To southern LMS fault segment, the coseismic surface faults ruptured along the Yingxiu-Beichuan faults②, and to northeastern LMS fault segment, ruptured along the Guanxian-Anxian faults①.

Acknowledgement
We thank to Taku Ozawa (NIED) for data and discussions of SAR interferogram, also to Takeshi Inokuchi (NIED) for BYD information. Thanks also go to Eric Kirby for the active fault information. The ownership of PALSAR (L-band SAR sensor on the ALOS satellite) data belongs to METI (Ministry of Economy, Trade and Industry) and JAXA (Japan Aerospace Exploration Agency).
Finally authors offer deepest condolences for the more than 86,592 people who lost their lives in the tragedy Wenchuan Earthquake.

REFERENCES

Burchfiel, B. C., Chen, Z., Liu,Y., and Royden, L. H., 1995, Tectonics of the Longmen Shan and adjacent regions: International Geology Review, 37, 661_735.
Burchfiel, B.C., L.H. Royden, R.D. vander Hilst, B.H. Hager, Z. Chen, R.W. King, C. Li, J. Lü, H. Yao and E. Kirby (2008), A geological and geophysical context for the Wenchuan earthquake of 12 May 2008, Sichuan, People's Republic of China, *GSA Today*, **18**.
Hao, Ken X-S., H. Fujiwara and H. Si(2008), A report on field investigation for the 2008 Wenchuan earthquake, china, *NIED News*, 2008 Summer, **164**, 12-17, http://www.bosai.go.jp/library/k_news_img/k_news164.pdf, in Japanese.
Ji C. 2008. Preliminary result of the May 12, 2008 M_W 7.9 eastern Sichuan, China earthquake, May 12, 2008: http://www.geol.ucsb.edu/faculty/ji/big_earthquakes/2008/05/12/ShiChuan.html.
Kirby, E., K., X. Whipple, W. Tang, and Z. Chen (2003). Distribution of active rock uplift along the eastern margin of the Tibetan Plateau: Inferences from bedrock channel longitudinal profiles, *J. Geophys. Res.*, **108**(B4), 2217.
Nishimura N. and Y. Yagi (2008), Rupture Process for May 12, 2008 Sichuan Earthquake, http://www.geol.tsukuba.ac.jp/~nisimura/20080512
National Research Institute for Earth Science and Disaster Prevention (NIED) (2008), Crustal deformation associated with Wenchuan Earthquake by PALSAR/InSAR analysis (Preliminary result), Documents for Earthquake Research Committee of Japan, in Japanese.
Tang R.C., Z. Huang, S. Ma, Y. Gong and R. Zou (1995) Basic characteristics of active fault zones in Sichuan province, *Seismology and Geology*, **4**, 390-396, in Chinese.
Tang R.C. and W., Han (1993). Active faults and earthquakes in Sichuan province, Earthquake publishing house, pp1-360, in Chinese.
Zhang, peizhen(2008), Report on the 2008 Wenchuan earthquake, China, at the National People's Congress (NPC) of the People's Republic of China, http://www.sciencenet.cn/htmlnews/2008/6/208446.html