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Issues associated with setback distance from active faults in China: What we have learned from recent earthquakes

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Outline

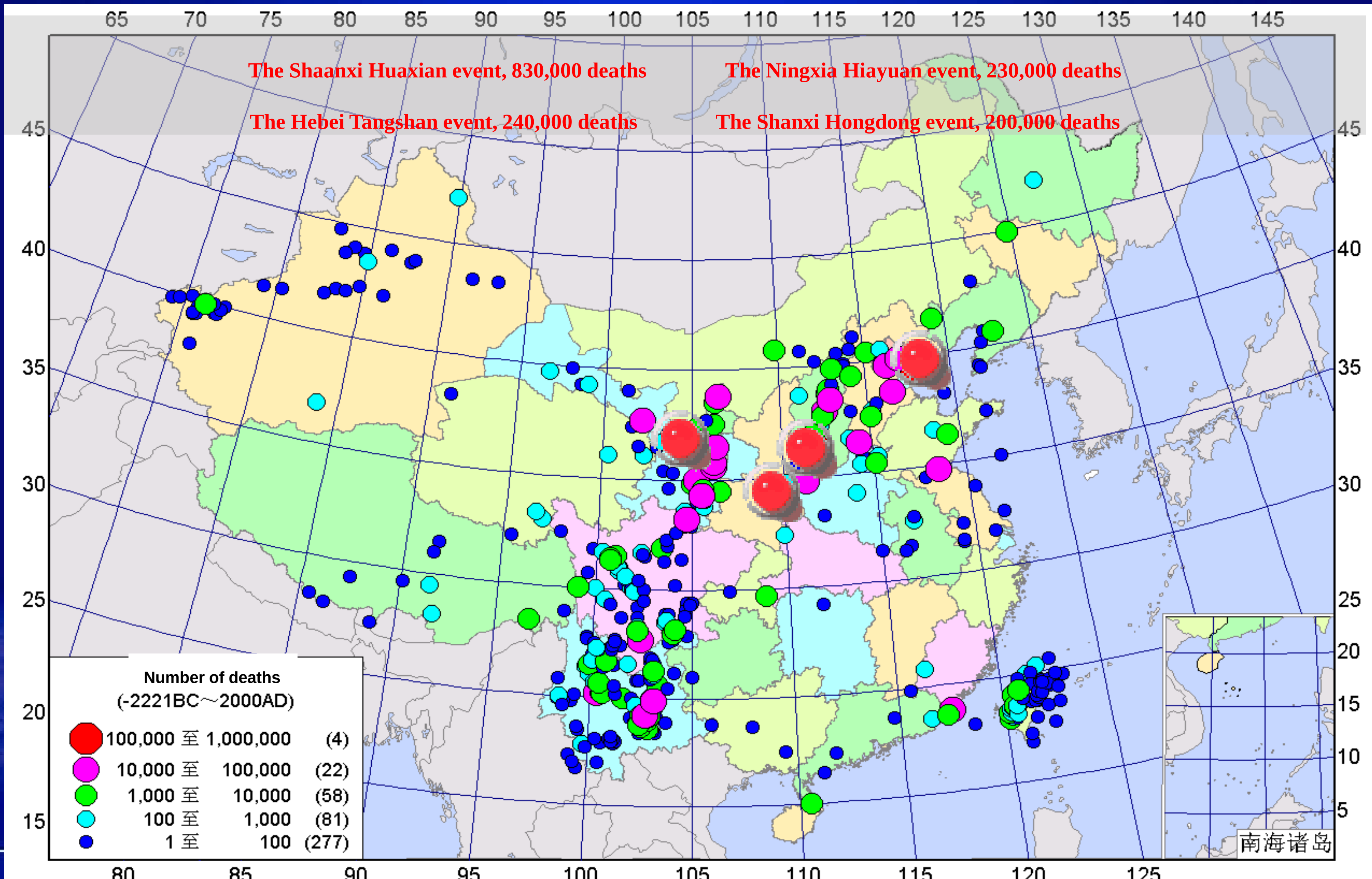
- **Problems we have been facing**
- **Observation facts: Rupture localization**

  Kokoxili Earthquake (strike-slip F)

  Yutian Earthquake (normal F)

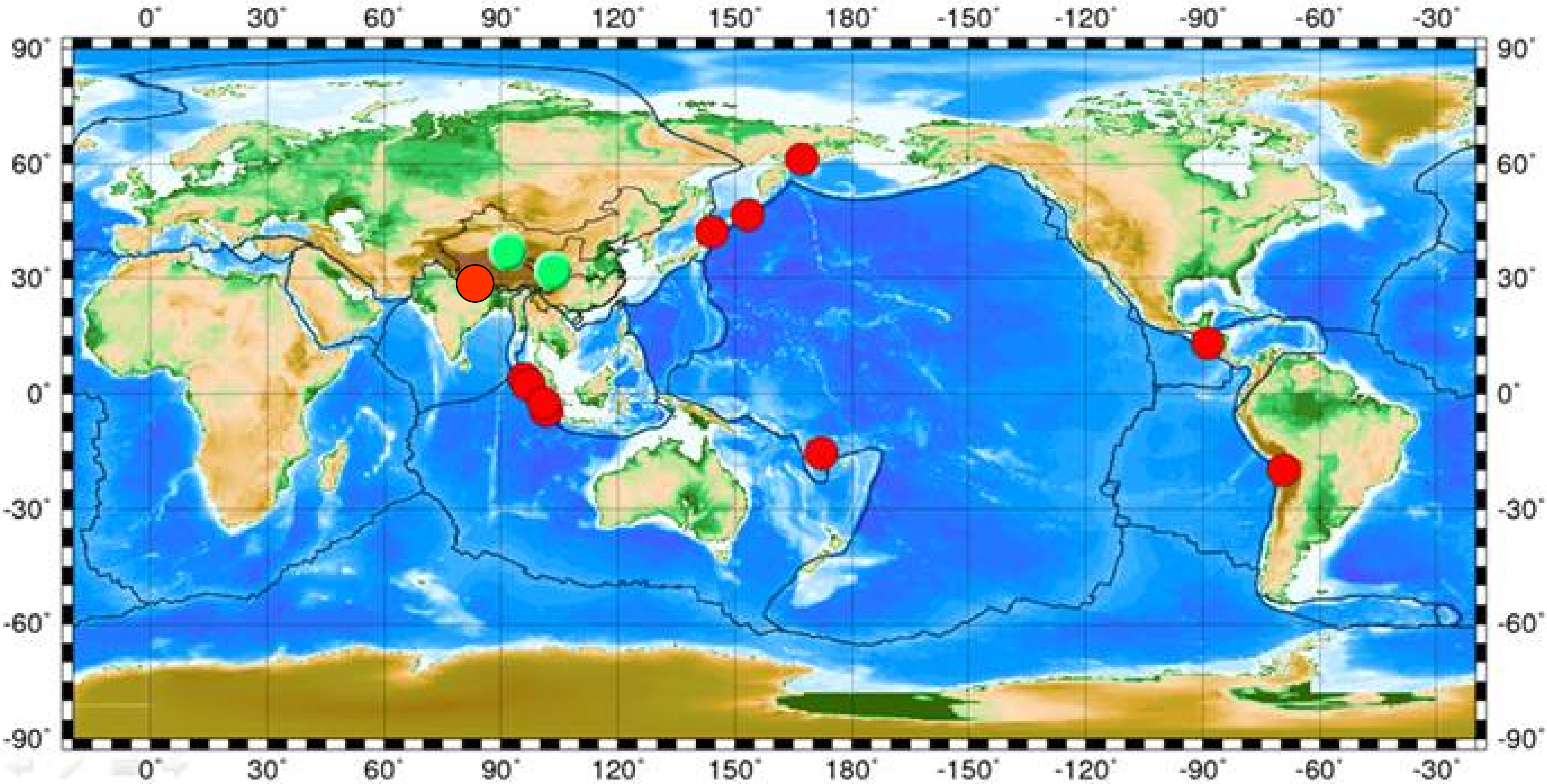
  Wenchuan Earthquake (Reverse F)
- **Hazard distribution associated fault-slip**
- **Discussion on setback distance**

Distribution of casualties caused by earthquakes



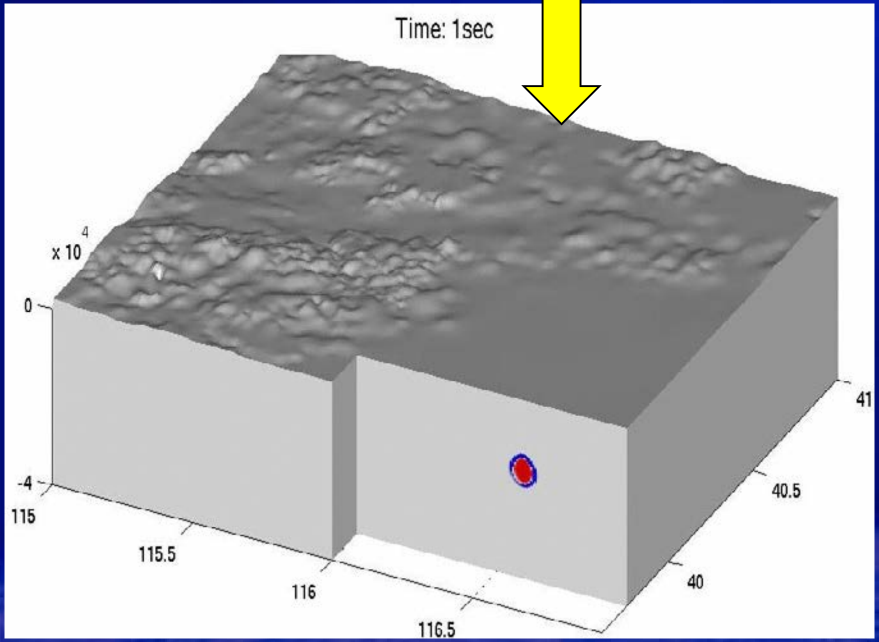
Living with earthquake disaster in China

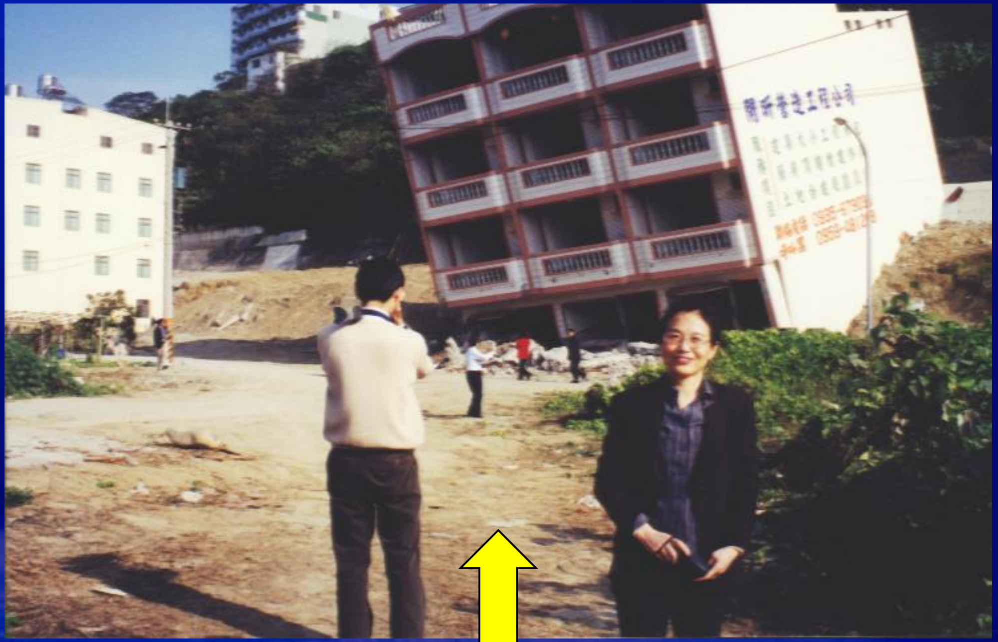
Among 14 earthquakes magnitude larger than 8.0 since 2000 AD, most of them occurred along the plate boundaries, but two of them in China Continent



Two factors cause earthquake disaster

① Strong ground motion





② Coseismic surface-faulting

However, how to effective mitigate their related disasters?

① Strong ground motion

- To meet fortification standards, reasonable design

② Coseismic surface-faulting

- To avoid an active fault

Problems we face

①How to avoid different types of active faults?
②How far to keep away can ensure safety of a building?
③How to regulate avoidance behavior for single or institution?

Present Legislation

- Article 67, in Law on Earthquake Preparedness and Disaster Mitigation, People' s Republic of China, requires that new towns and villages of post-earthquake recovery and reconstruction should avoid earthquake fault, but there is no any rule to distance for avoiding.

- Code for Seismic Design of Buildings(GB50011-2010) requires that the setback distance from active faults may be at least 100m in the area where the fortification intensity reaches **Ⅷ degree, and 200m where** the fortification intensity reaches **degree.**

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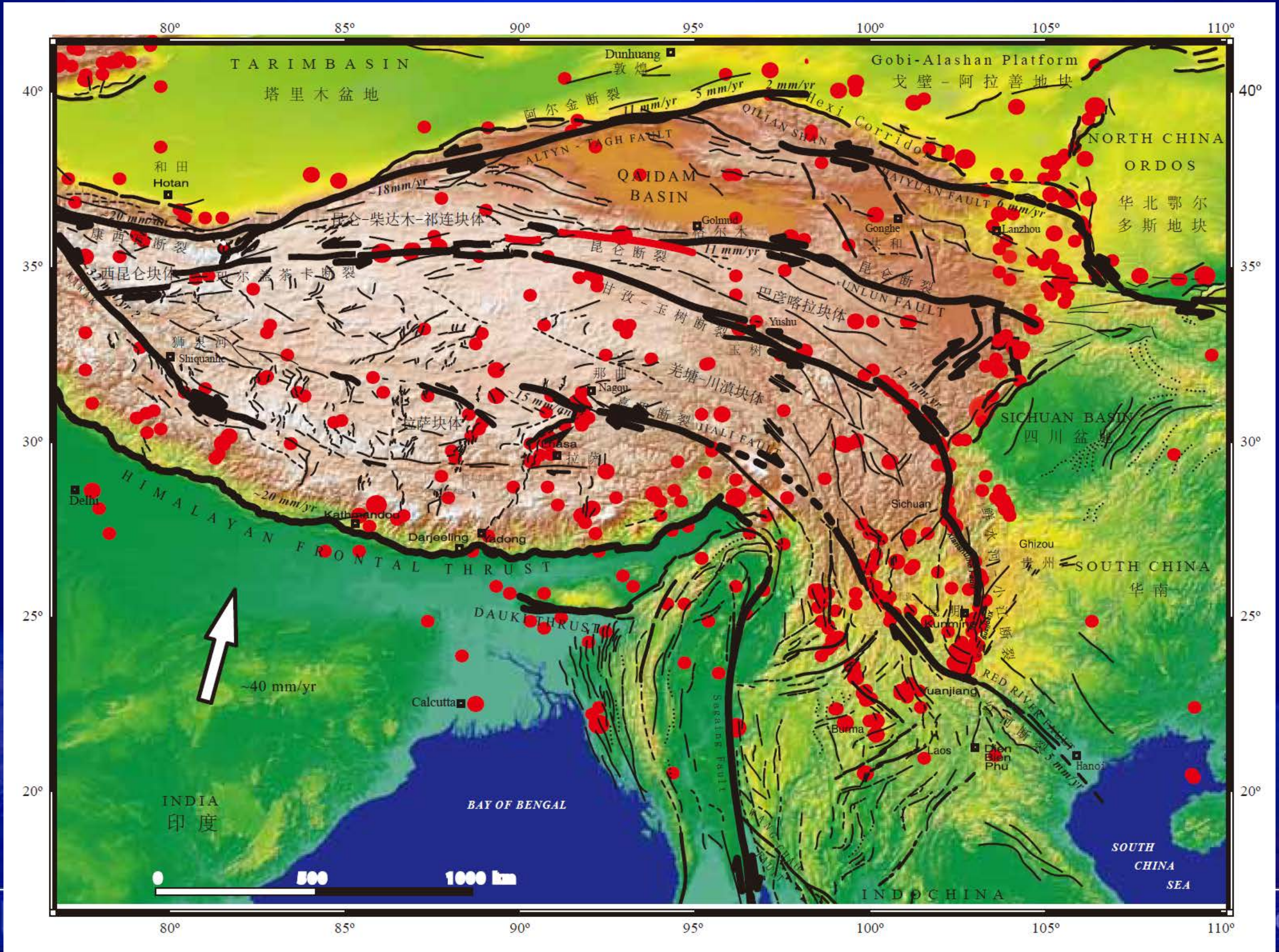
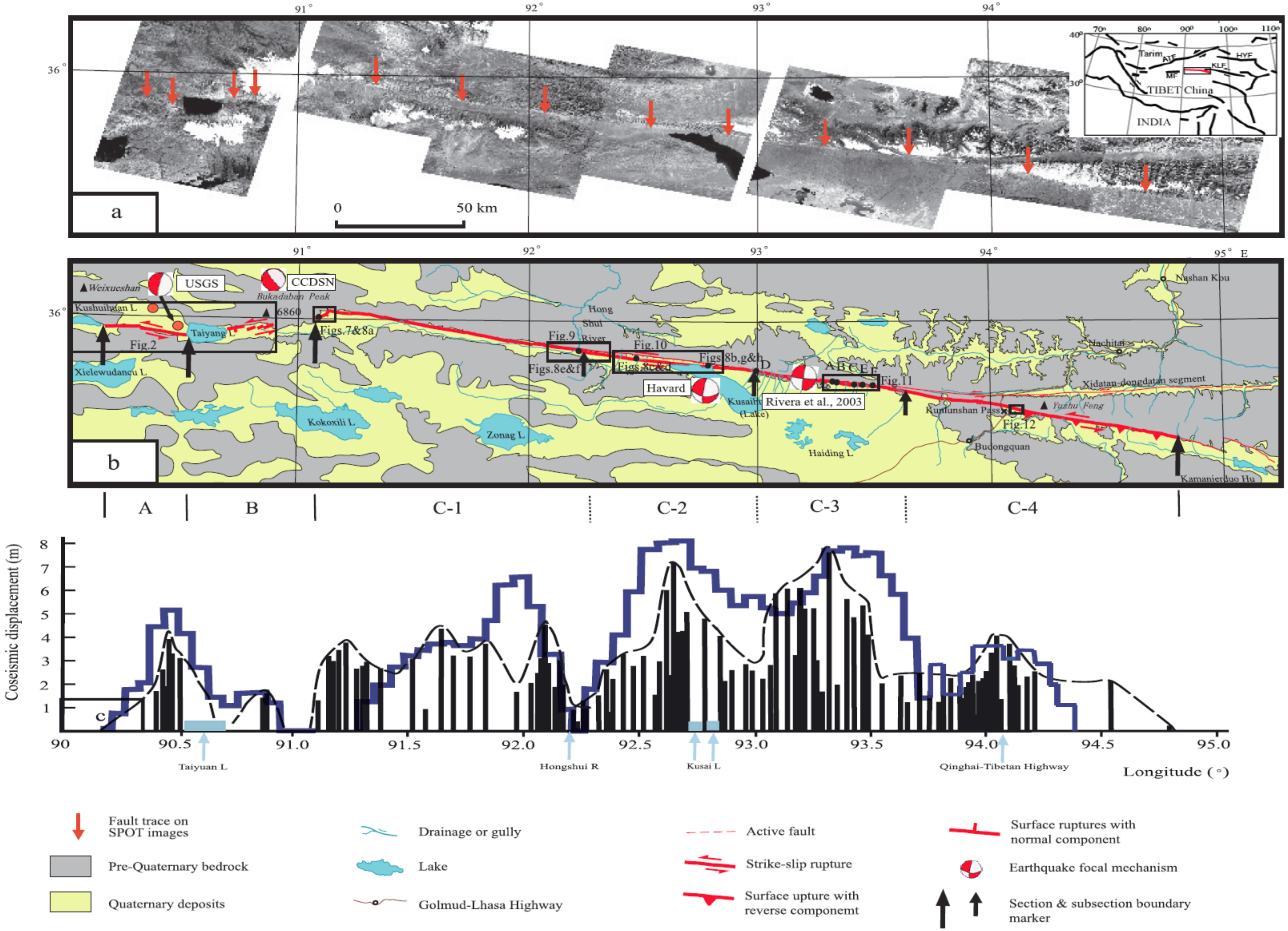
- Conclusions

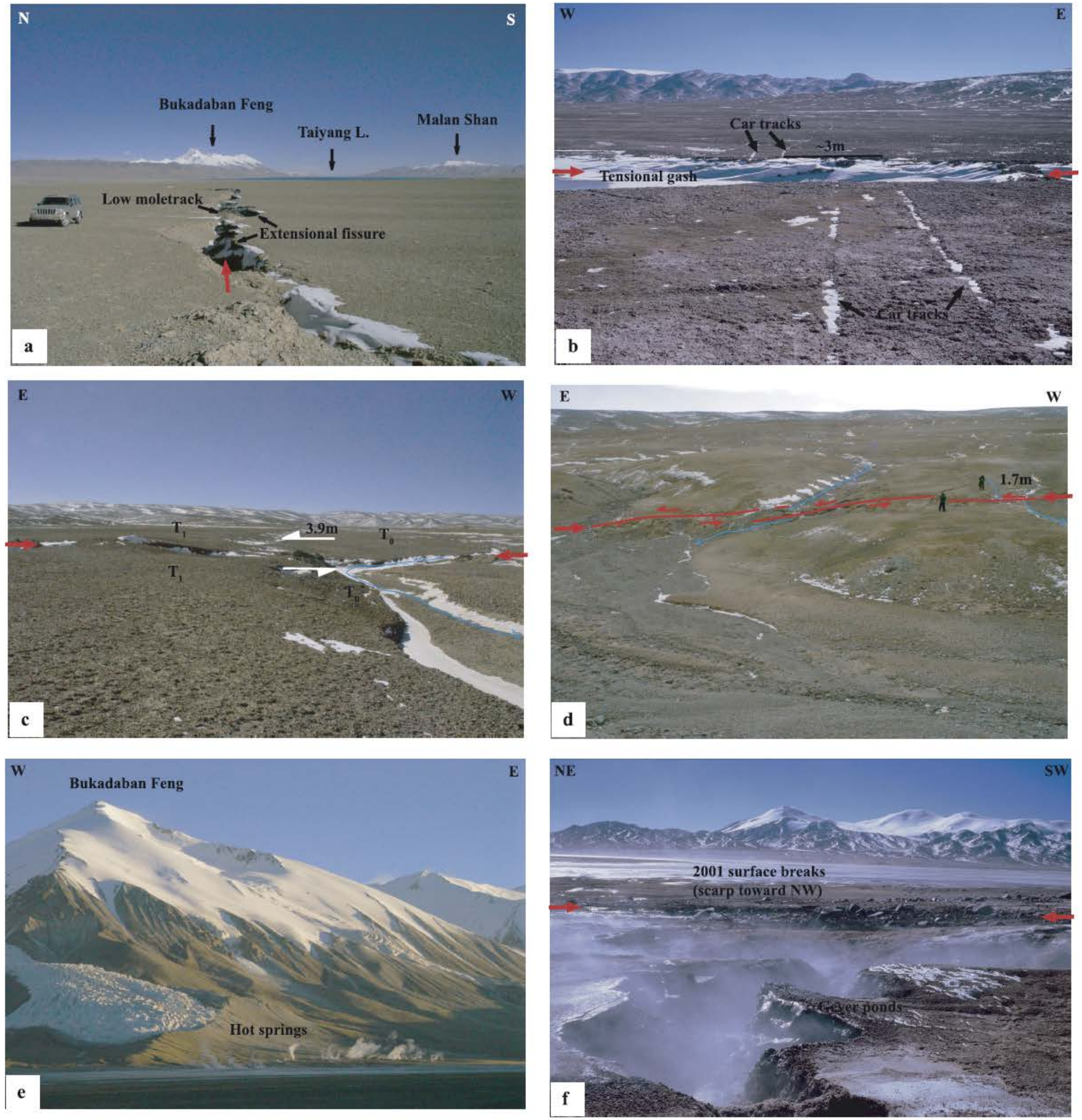
2001 Kokoxili *M*w7.8 earthquake surface ruptures



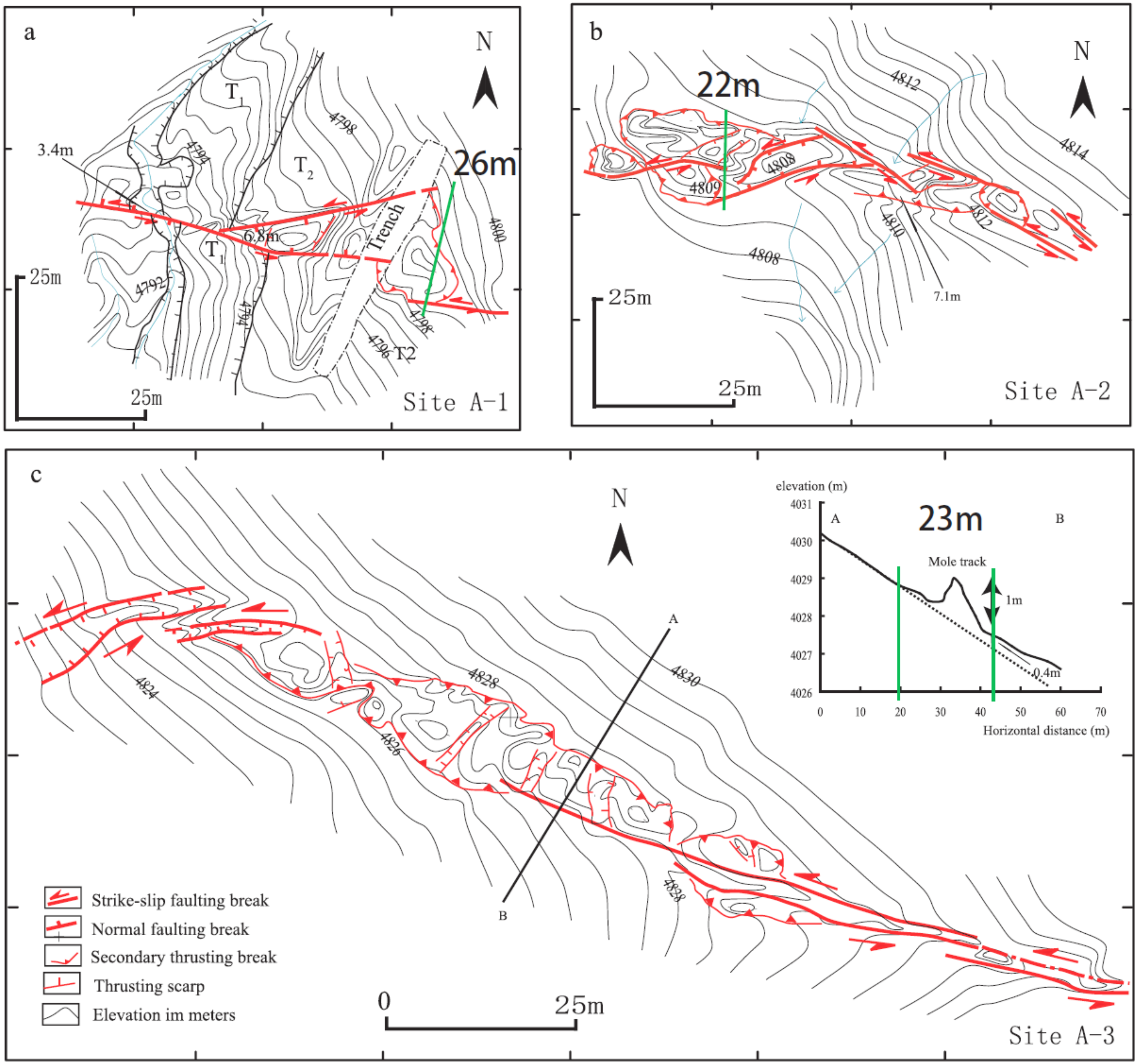


Simplified map of the 2001 Kunlunshan earthquake surface rupture zone on the preexisting fault traces of the westernmost segments of the Kunlun Fault.

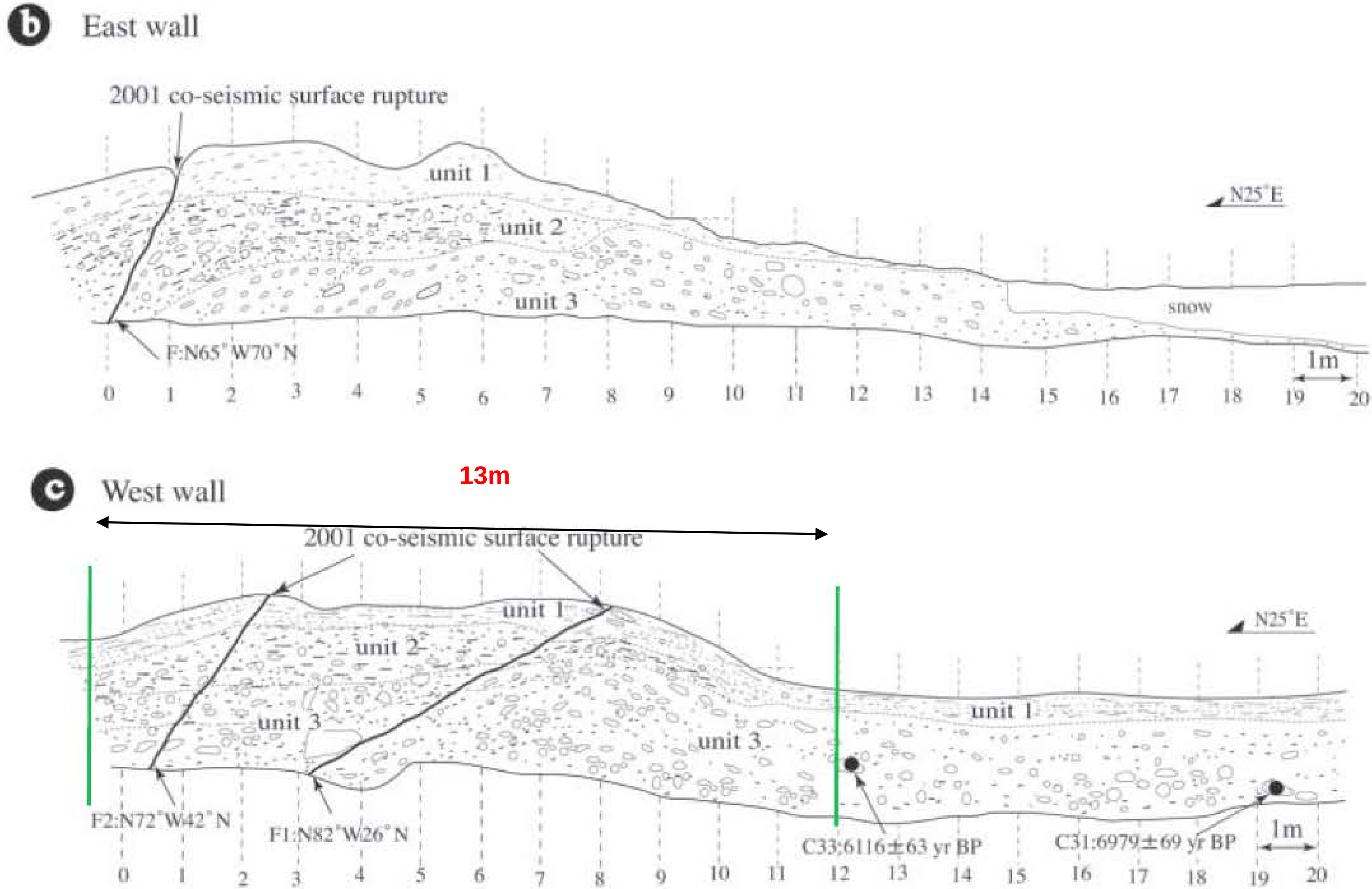
Citation: Xu, X., G. Yu, Y. Klinger, P. Tapponnier, and J. Van Der Woerd (2006), Reevaluation of surface rupture parameters and faulting segmentation of the 2001 Kunlunshan earthquake (M_w7.8), northern Tibetan Plateau, China, *J. Geophys. Res.*, *111*, B05316, doi:10.1029/2004JB003488.



Typical surface breaks on the western strike-slip and transtensional sections



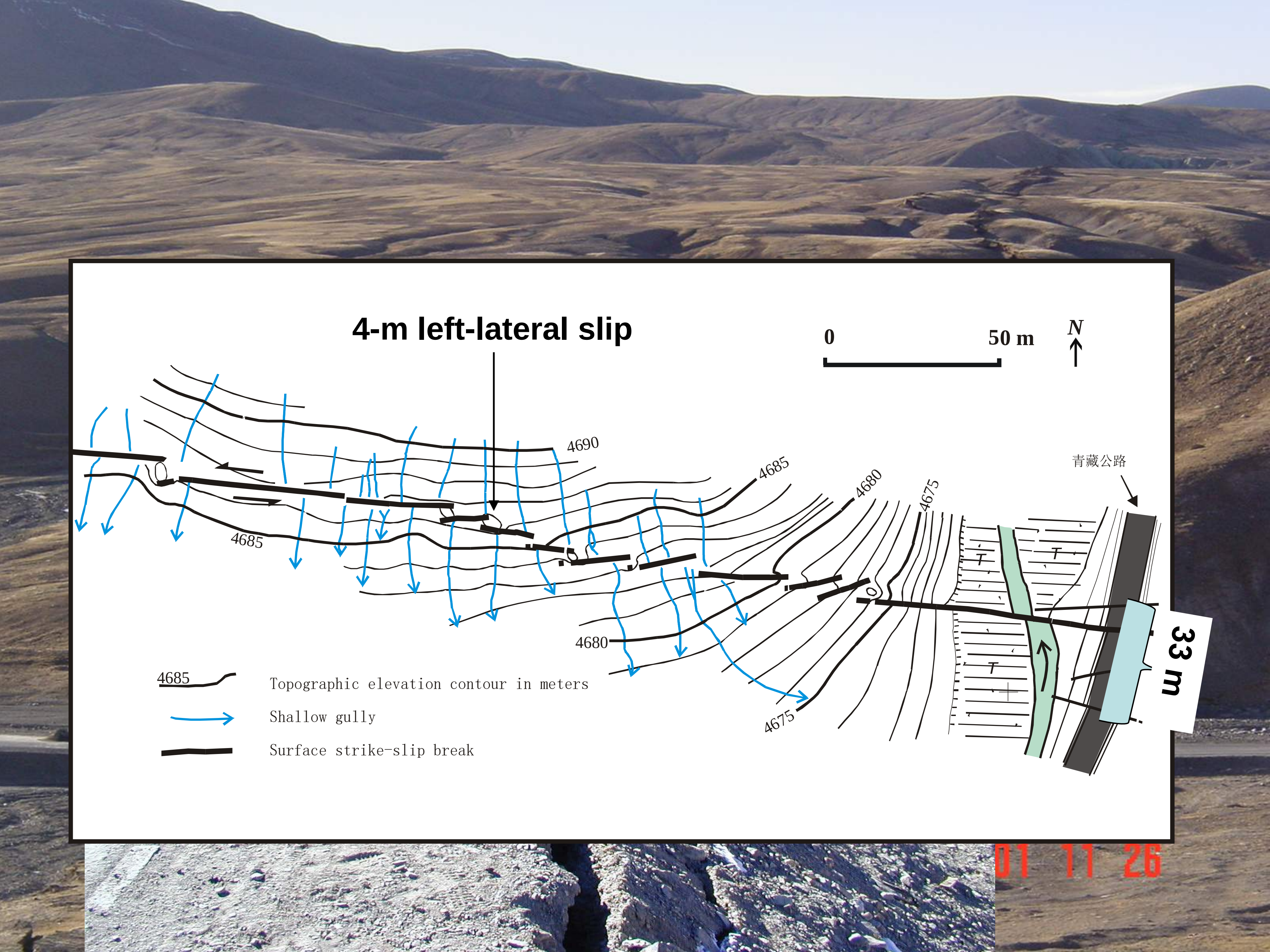
a
N
T1
T2
3.4m
6.8m
26m
Trench
4792
4794
4798
4800
4796 T2
25m
25m
Site A-1
b
N
22m
4812
4814
4808
4809
4810
7.1m
25m
25m
Site A-2
c
N
A
B
4824
4826
4828
4830
elevation (m)
4031
4030
4029
4028
4027
4026
23m
Mole track
1m
0.4m
0 10 20 30 40 50 60 70
Horizontal distance (m)
Strike-slip faulting break
Normal faulting break
Secondary thrusting break
Thrusting scarp
Elevation im meters
0
25m
Site A-3



Bulletin of the Seismological Society of America, Vol. 96, No. 5, pp. 1597–1611, October 2006, doi: 10.1785/0120050051

Average Slip Rate and Recurrence Interval of Large-Magnitude Earthquakes on the Western Segment of the Strike-Slip Kunlun Fault, Northern Tibet

by Aiming Lin, Jianming Guo, Ken-ichi Kano, and Yasuo Awata


4-m left-lateral slip
0
50 m
N
4690
4685
4685
4680
4680
4675
4675
青藏公路
33 m
4685
Topographic elevation contour in meters
Shallow gully
Surface strike-slip break
01 11 26

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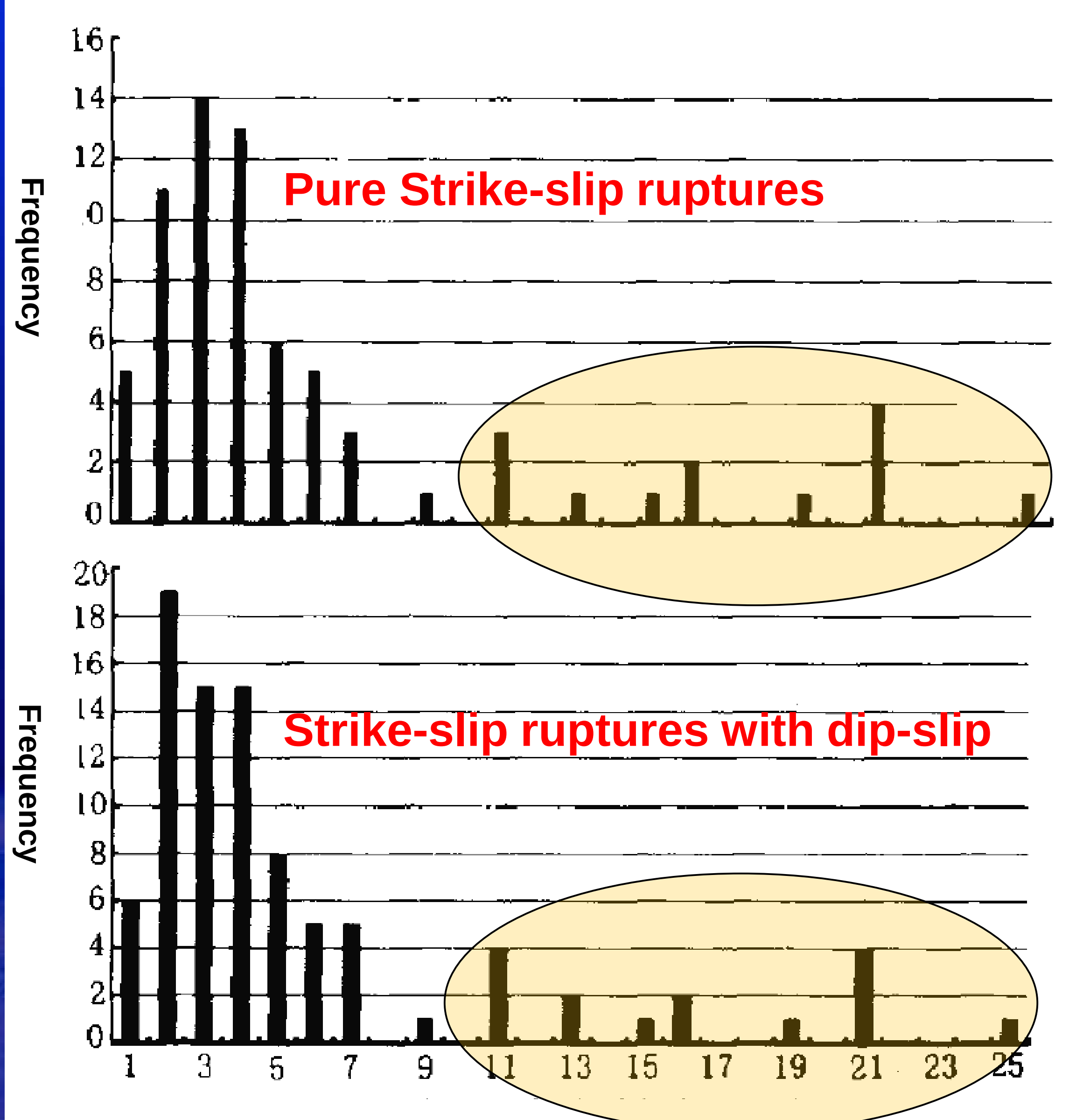
Statistic Width for Strike-slip faulting

Data Sources

2001 AD Kokoxili EQ
1999AD Izmit EQ
1976AD Tangshan EQ
1975AD Haicheng EQ
1932AD Changma EQ
(Strike-slip with Reverse)
1833AD Songming EQ
(Strike-slip with Reverse)
1515AD Yongsheng EQ
(Strike-slip with Normal)

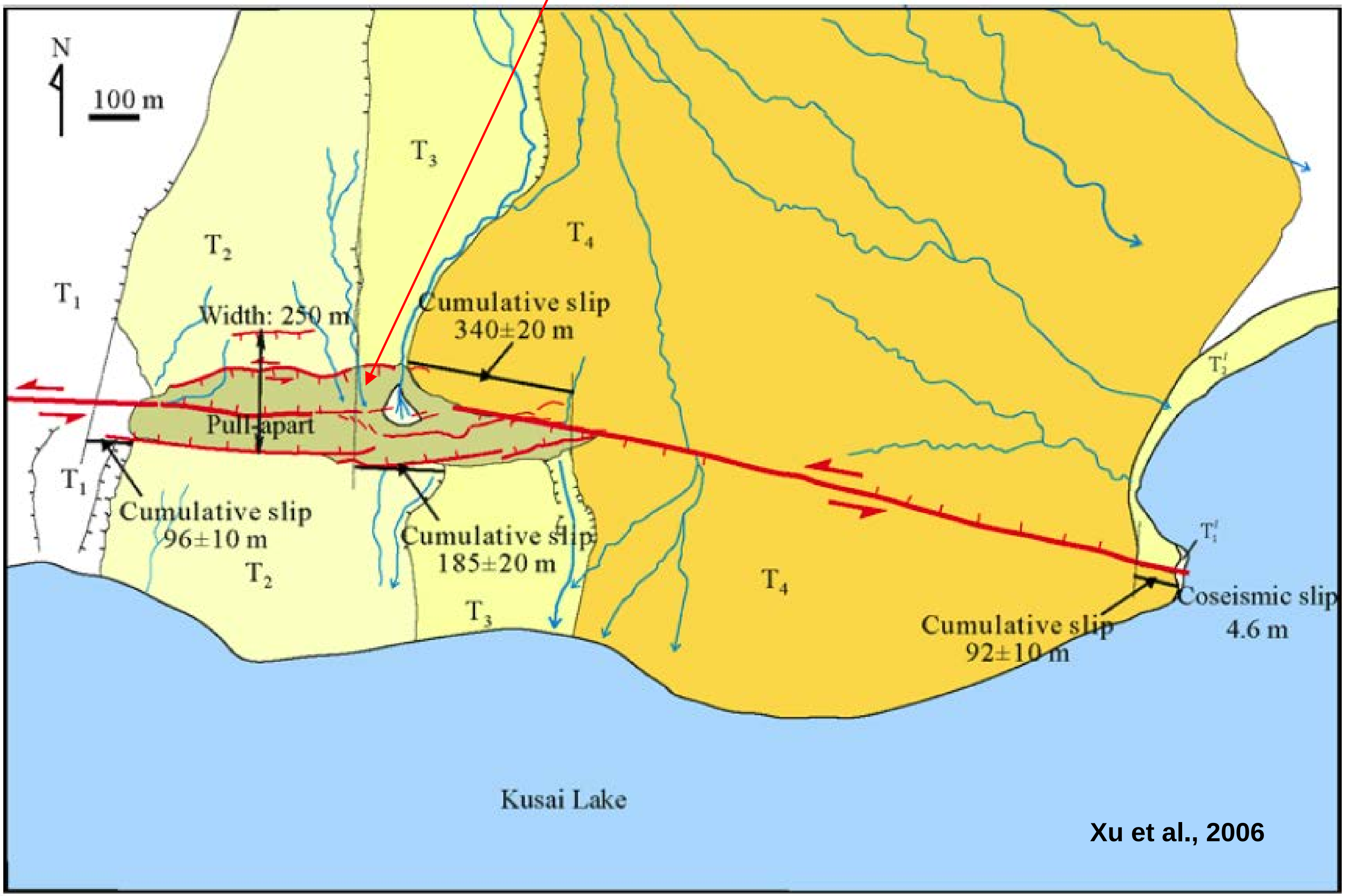
$\mu = 12.5m$
$\sigma = 8.5m$

$\mu + 2\sigma \approx 30m$



Histogram of Widths of Surface rupture zones × 5m

Wider surface ruptures are related to geometric structures: pull-apart basins and pressure ridges. For example, a pull apart basin is located at the north of the Kusai Lake and the rupture zone is measured to be 259m



Xu et al., 2006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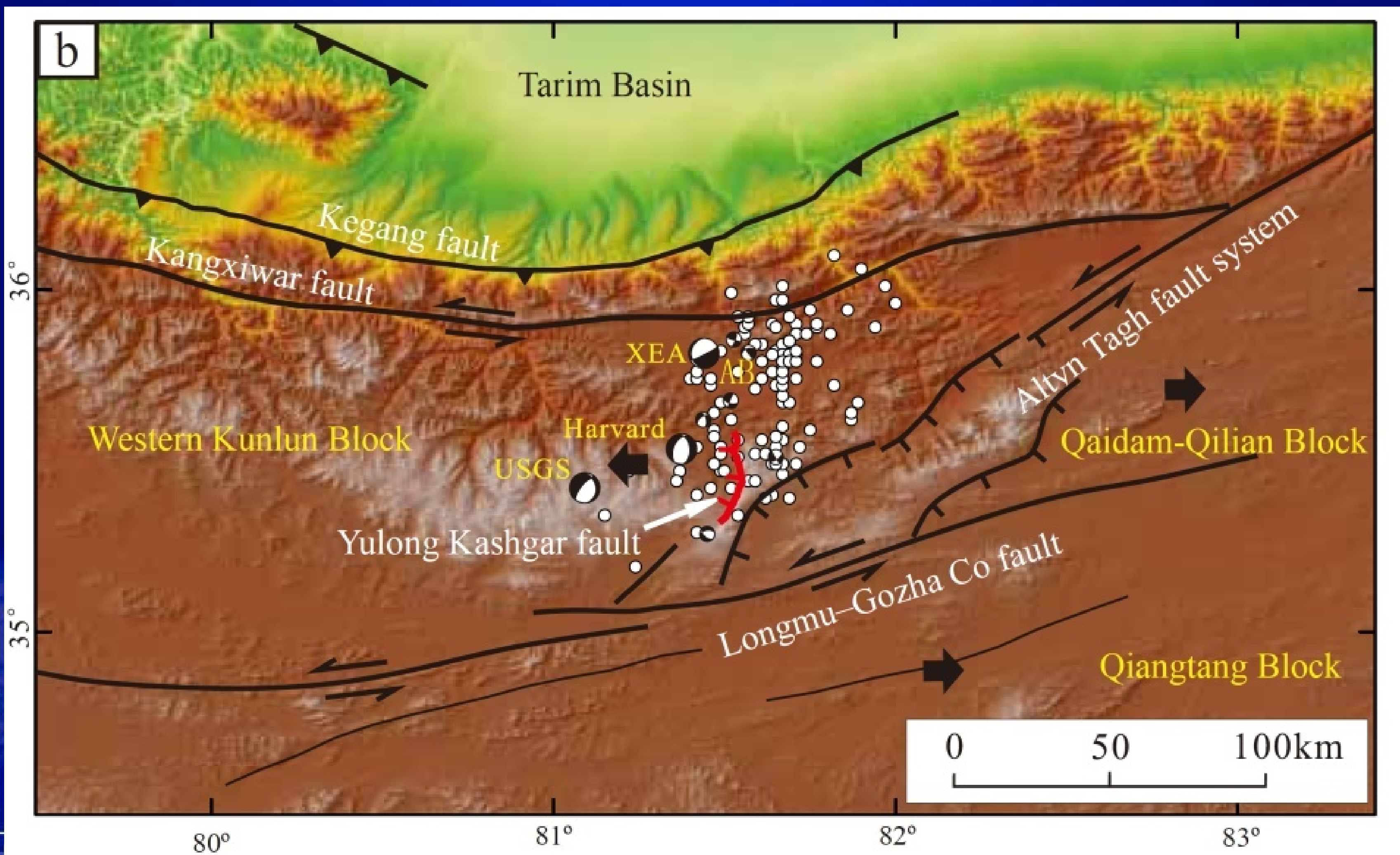
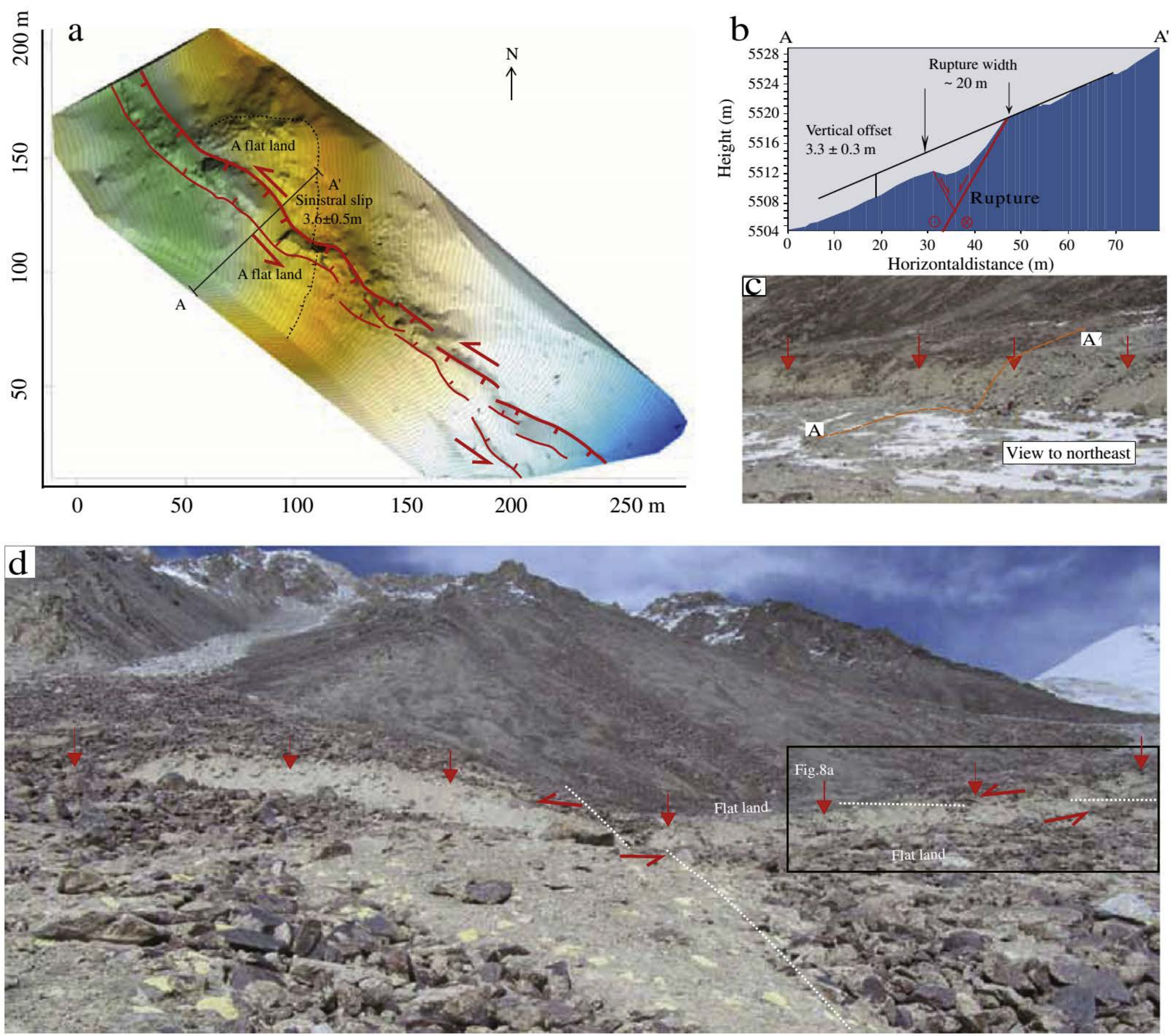
Contents lists available at SciVerse ScienceDirect
Tectonophysics
journal homepage: www.elsevier.com/locate/tecto

Normal- and oblique-slip of the 2008 Yutian earthquake: Evidence for eastward block motion, northern Tibetan Plateau

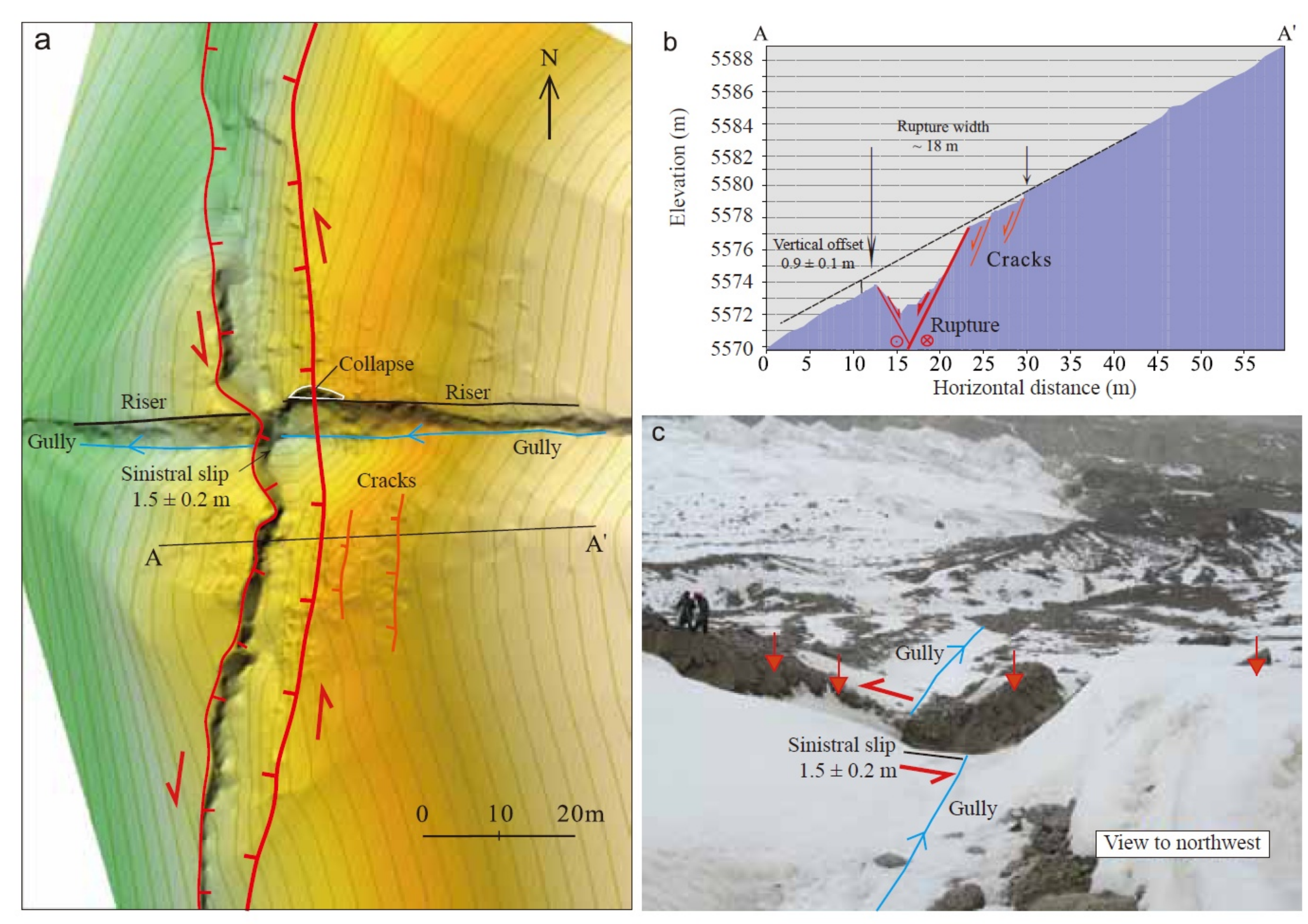
Xiwei Xu [a,*], Xibin Tan [a], Guihua Yu [a], Guodong Wu [b], Wei Fang [b], Jianbo Chen [b], Heping Song [b], Jun Shen [b]

2008 Yutian 7.1 earthquake surface ruptures




a
200 m
150
100
50
0
50
100
150
200
250 m
N
A flat land
A'
Sinistral slip
3.6±0.5m
A flat land
A
b
A
A'
5528
5524
5520
5516
5512
5508
5504
Height (m)
Rupture width
~ 20 m
Vertical offset
3.3 ± 0.3 m
Rupture
0
10
20
30
40
50
60
70
Horizontaldistance (m)
c
A
A'
View to northeast
d
Fig.8a
Flat land
Flat land

中 国 … tration


a
N
Collapse
Riser
Riser
Gully
Gully
Sinistral slip
1.5 ± 0.2 m
Cracks
A
A'
0 10 20m
b
A
A'
Elevation (m)
5588
5586
5584
5582
5580
5578
5576
5574
5572
5570
Rupture width
~ 18 m
Vertical offset
0.9 ± 0.1 m
Cracks
Rupture
0 5 10 15 20 25 30 35 40 45 50 55
Horizontal distance (m)
c
Gully
Sinistral slip
1.5 ± 0.2 m
Gully
View to northwest

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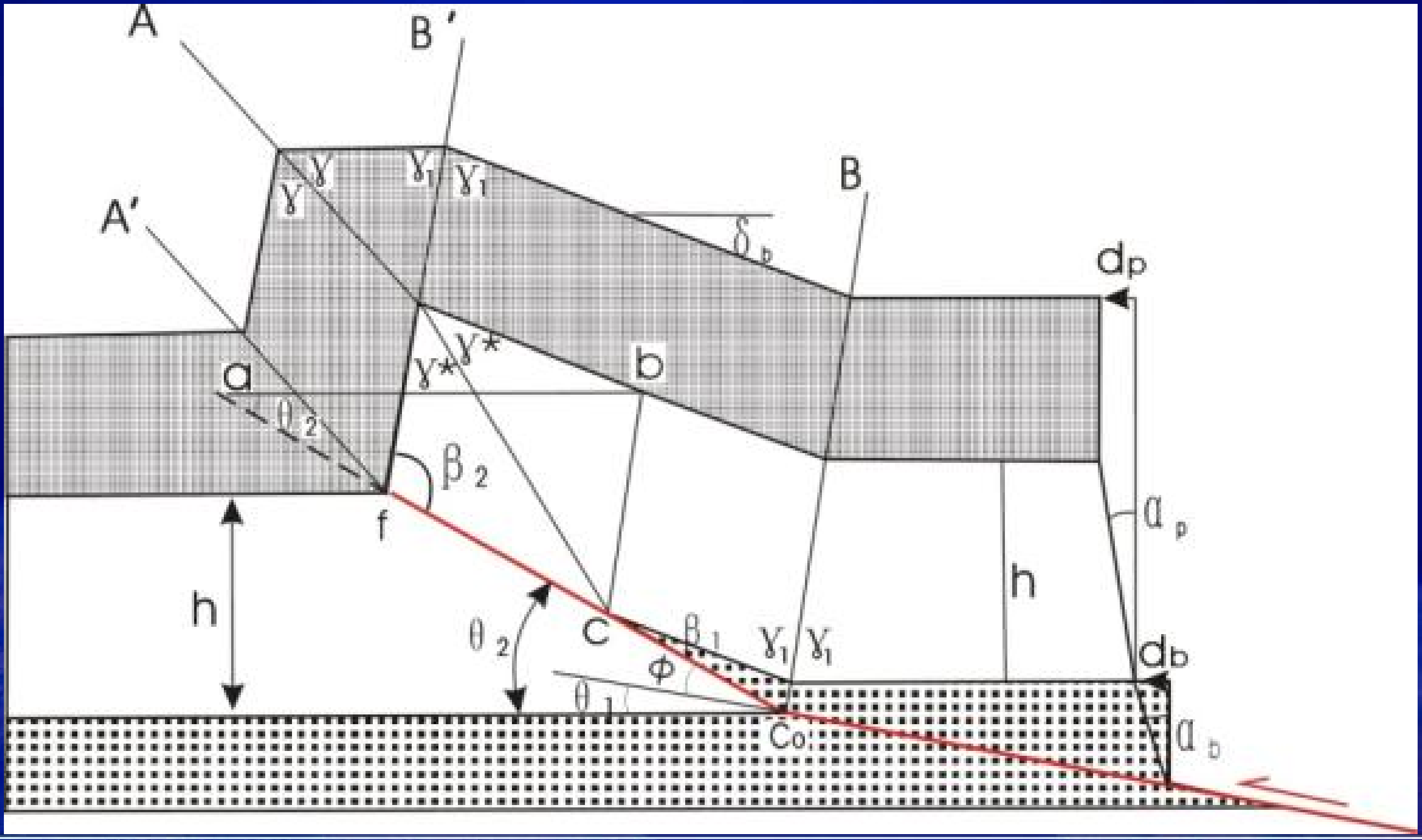
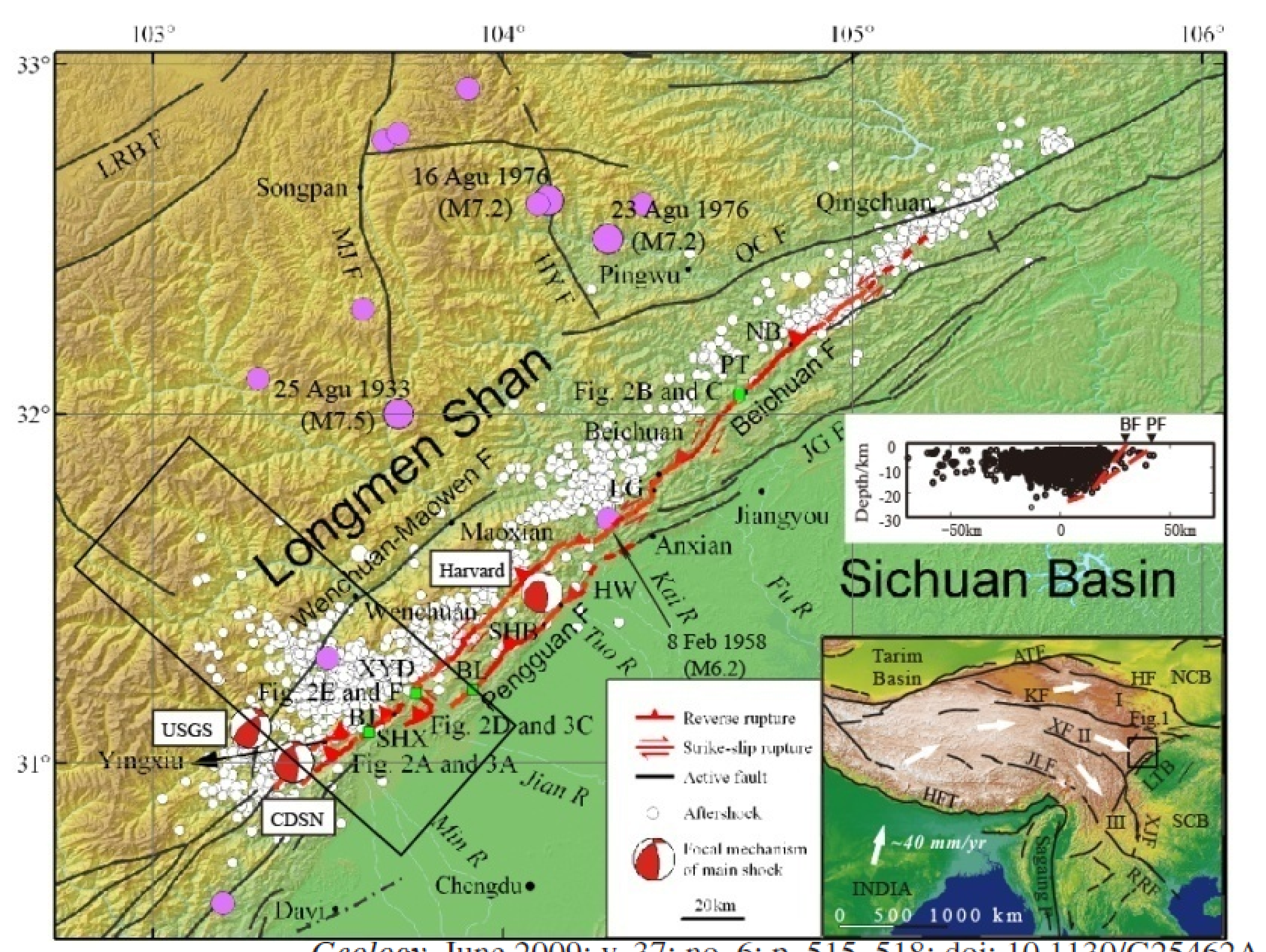
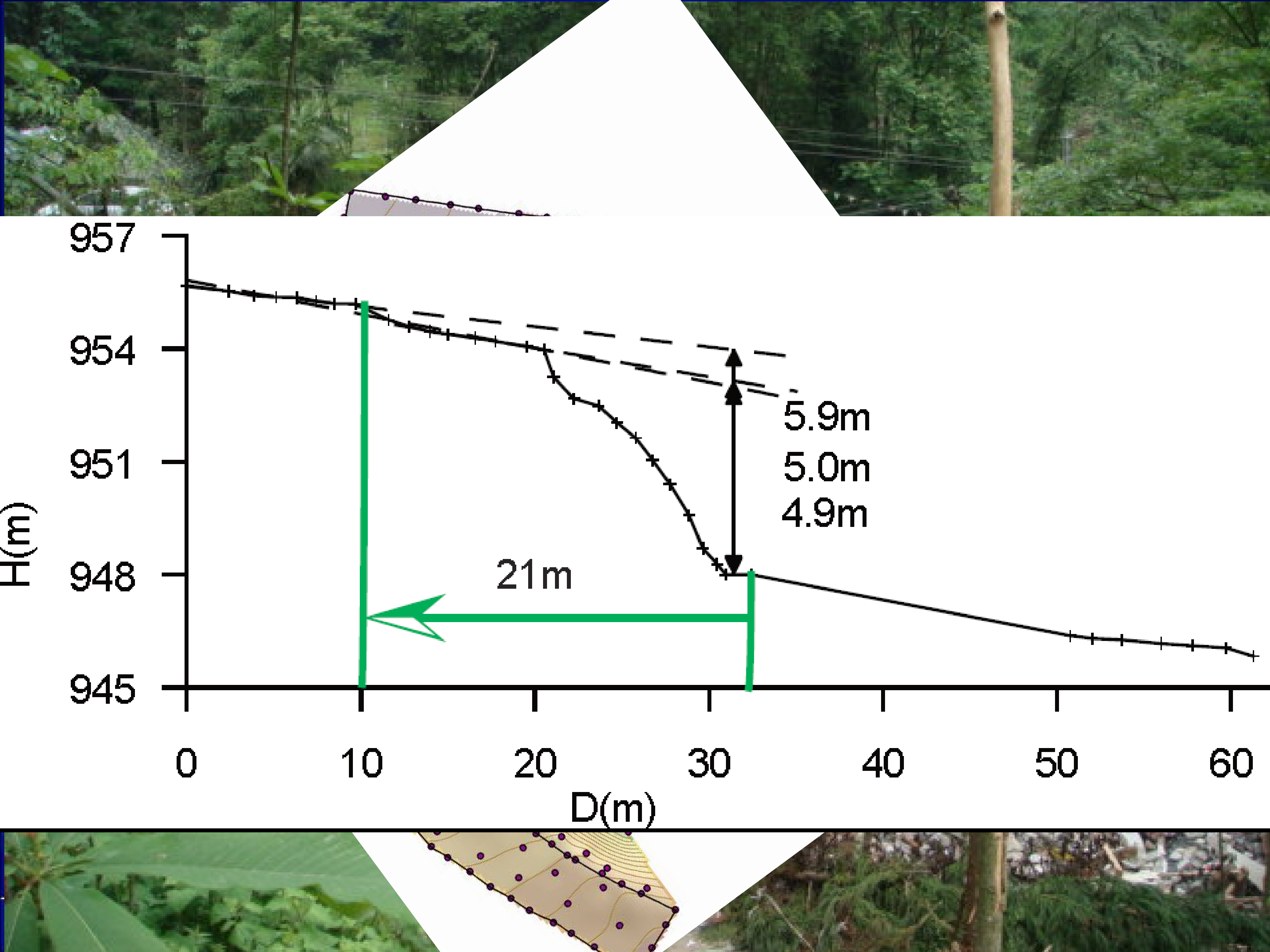
But dip-slip faults are quite different with hanging-wall effect

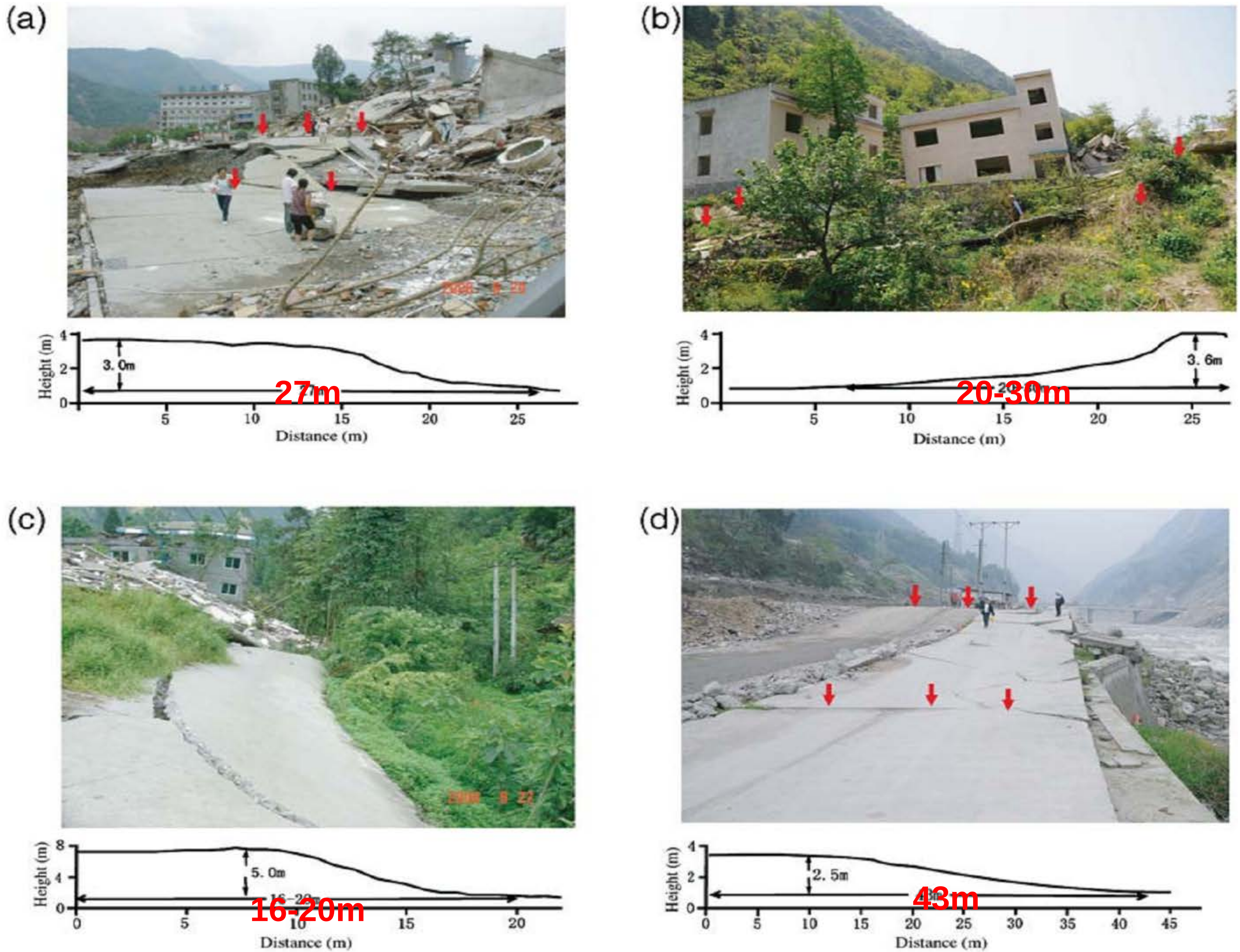


2008 AD Wenchuan Earthquake



Geology, June 2009; v. 37; no. 6; p. 515–518; doi: 10.1130/G25462A.1


957
954
951
948
945
H(m)
0
10
20
30
40
50
60
D(m)
5.9m
5.0m
4.9m
21m



(a)
Height (m)
3.0m
27m
Distance (m)
(b)
Height (m)
3.6m
20-30m
Distance (m)
(c)
Height (m)
5.0m
16-20m
Distance (m)
(d)
Height (m)
2.5m
43m
Distance (m)

Width Distribution of Surface Rupture Zones Produced by the Wenchuan Earthquake

Surface Rupture Zone	Fault	Site	Displacement (m) Horizontal	Displacement (m) Vertical	Width (m)	Strike	Source*
S1	BCF	Maioziwan, Nanba	1.4	1.2	4-5	55°	1
S2		Daai Primary School		2.7	>27	55°	1
S3		Pintong	3.7	3.66	36	60°	2
S4		Chenjiaba	2.1	2.2–2.4	30	25–30°	4
S5		Chaping, Beichuan		3–4	20–30	50–60°	
S6		Highway in Beichuan	2.6	3.0	27		
S7	BCF	1st Group,Shiyan, Leigu		3.24	41		2
S8		Shiyan, Leigu	1.88	3.69	39		2
S9		East of Quansuicun,Gaochuan		2.2	59	60°	
S10		South of Quansuicun,Gaochuan		3.19	30	65°	2
S11		Longmen Shan	1.0–2.5	0.8–2.0	10–20		
S12		Shenxigou, Hongkou, Dujiangyan		5.0–6.2	16–20	60°	
S13		Yinxiu,Wenchuan		2.5	43	70°	
S14	PGF	Hanwang,Quanxincun		0.94	6		3
S15		Hanwang,Dongqi		2.1	16	50°	
S16		Bailu Middle School, Penzhou	2	2.0	18	55°	
S17		Guangou, Bailu		3.65	25.8	50°	
S18		Wangjiakan, Bailu		2.2	19.8	55°	
S19		Shuangyang , Tongji		2.8	12.9	70°	
S20	XF	Xiaoyudong, Penzhou	2.3	1.1	30	320°	

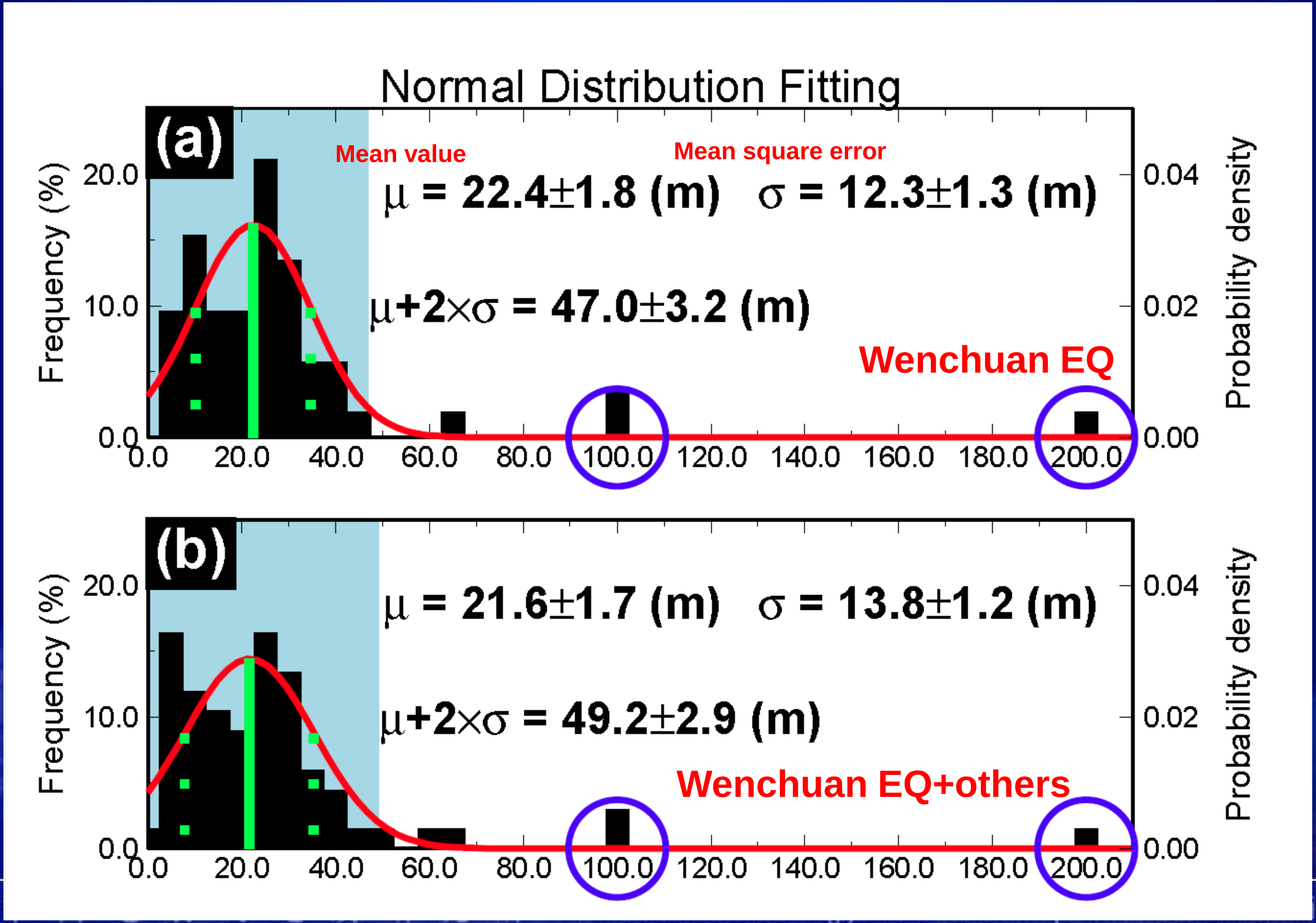
*1, Zheng *et al.*, 2008; 2, Chen, Xu *et al.*, 2008; 3, Chen, Li *et al.*, 2008; 4, Li *et al.*, 2008.

Table 2. Width distribution of surface ruptures from historical large earthquakes in China

No.	Site	Displacement (m) Horizontal	Displacement (m) Vertical	Width of surface rupture zone (m)	Width of single rupture (m)	Strike	Source
	The 1927 Gulang Earthquake (M 8)						
1	Xiafangzai-Sierta		0.6～1.5		10～20	290°	
2	Huangchen－Taerzhuang-Shuangta		2～4	500	7～15	300°	Inst. of Geol. et al. CSB, 1993
3	Mozuizi-Zhongba		2～4		6	340°	
4	Gulang-Suangta			500		340°	
	The 1999 Chi Chi Earthquake (Mw 7.6)						
5	Wufeng	3.3 (h.v.)	2.2	60	20～30	30°	Lee et al., 2001
6	Experimental Vineyard Site, Wufeng		2.2		30	55°	Kelson et al., 2001
7	Kuang Fu Middle School	5 (h.v.)	2.8		30-35	NW	
	The 2001 Kusaihu Earthquake (Mw 7.8)						
8	Tibet Highway 2894 Landmark	3.5-4 (l.l))		32.5	8-15	NW	
9	3 5 .932°N, 9 0 .469°E	4.5 (l.l.)			7	NW	Xu et al., 2008a
10	3 5 .9 2 5°N, 9 0 .5 1°E	2.9-3.2 (l.l.)			15	NW	
11	35 .848°N, 93 .513°E (Yuxi Feng subsection)	16.3 (l.l.)		550		100°	Xu et al., 2006

Note: h.v. = horizontal shortening; l.l. = left-lateral.

Statistic value of surface rupture width



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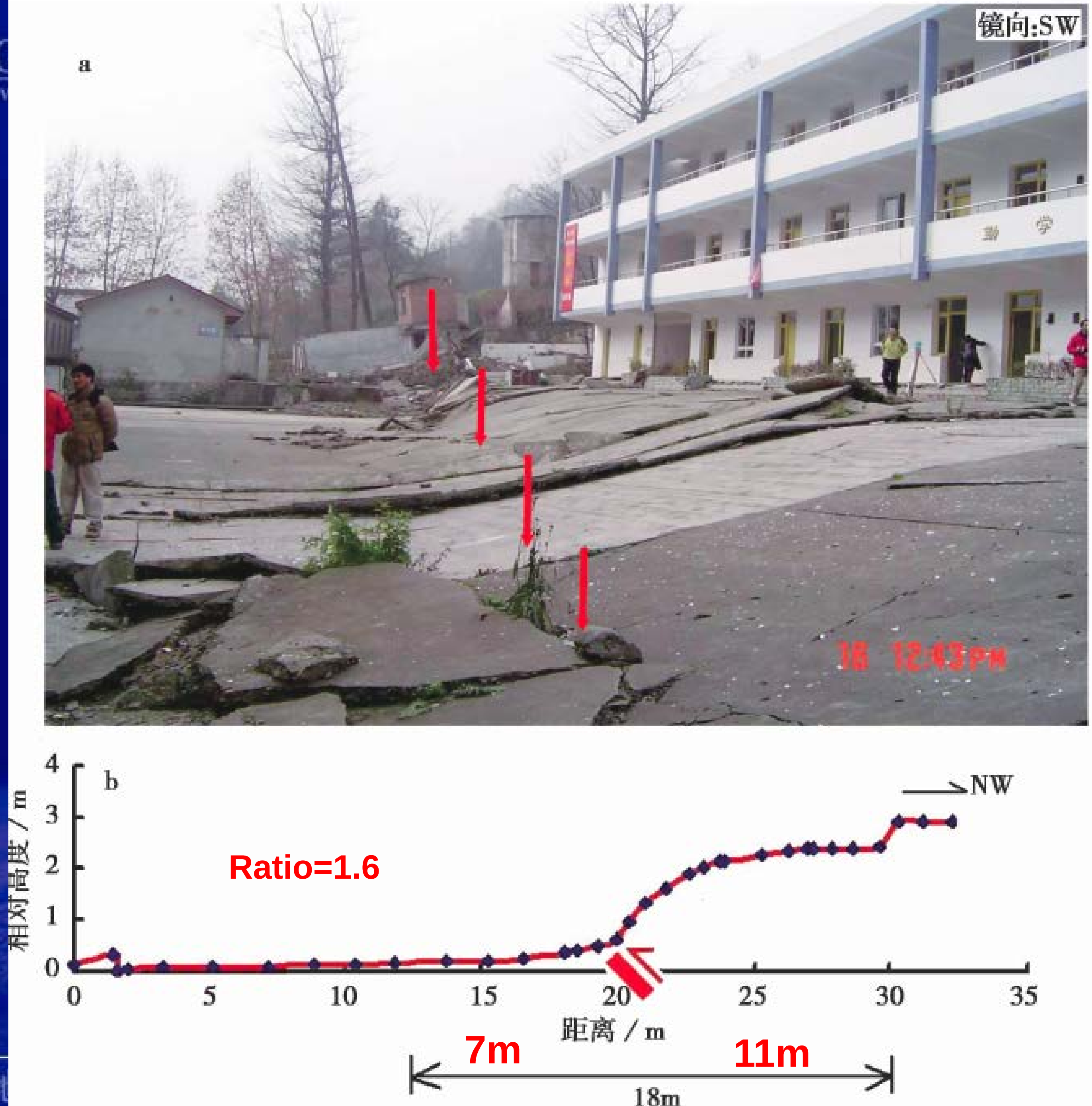
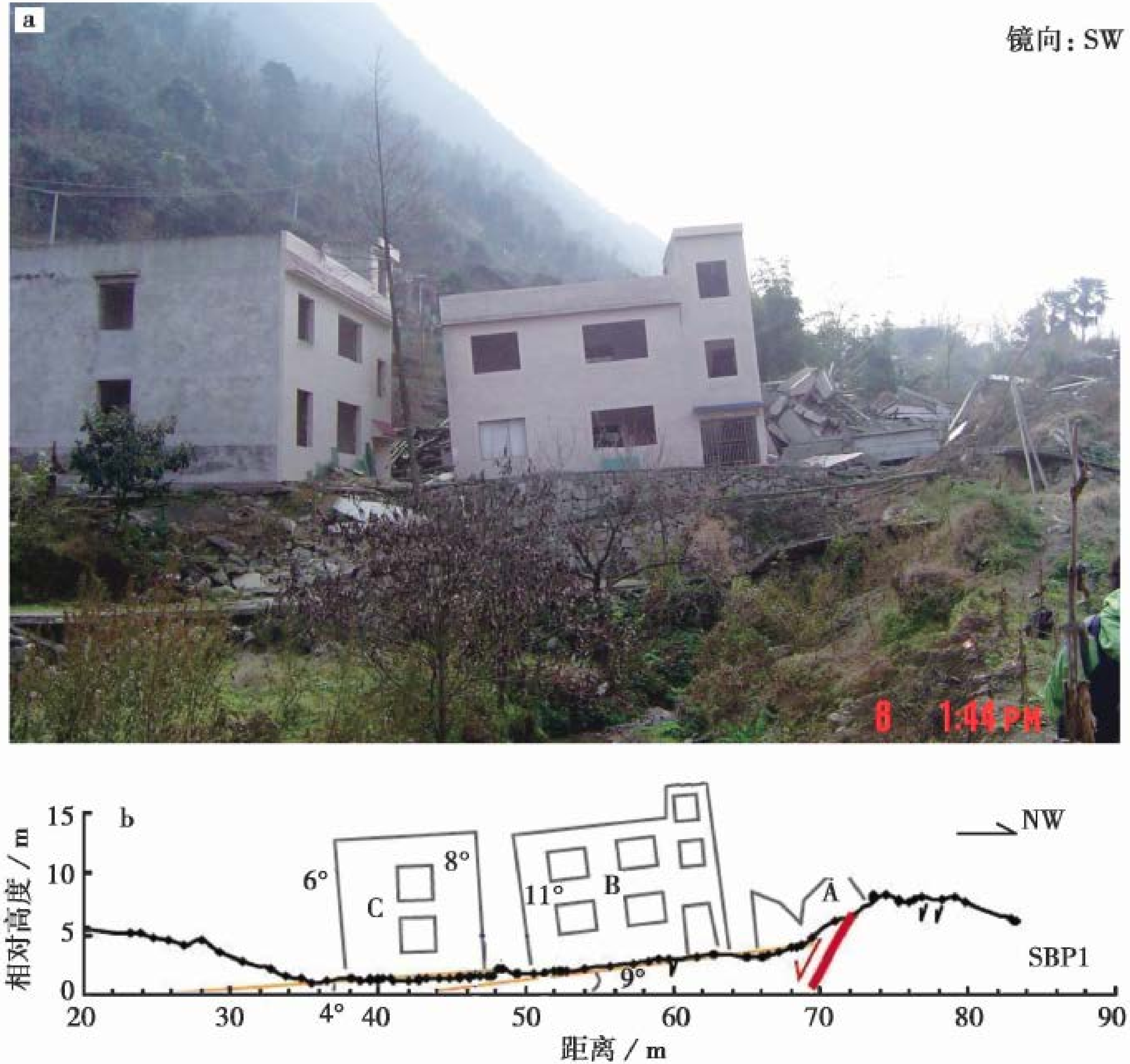
Building damages related to distance from the surface rupture zone (active fault)


a
镜向:SW
b
NW
相对高度 / m
0
1
2
3
4
距离 / m
0
5
10
15
20
25
30
35
Ratio=1.6
7m
11m
18m


a
镜向：SW
8 1:44 PM
b
相对高度 / m
15
10
5
0
20
30
40
50
60
70
80
90
距离 / m
6°
8°
C
11°
B
A
9°
4°
NW
SBP1

Ratio≈3

36m

①Earthquake surface rupture zone directly controls spacial distribution of serious hazards or building collapse

② Dip-slip fault has obvious hanging-wall effect: The width of both surface ruptures and building collapse on the hanging wall is 2 or 3 times larger than its foot-wall.

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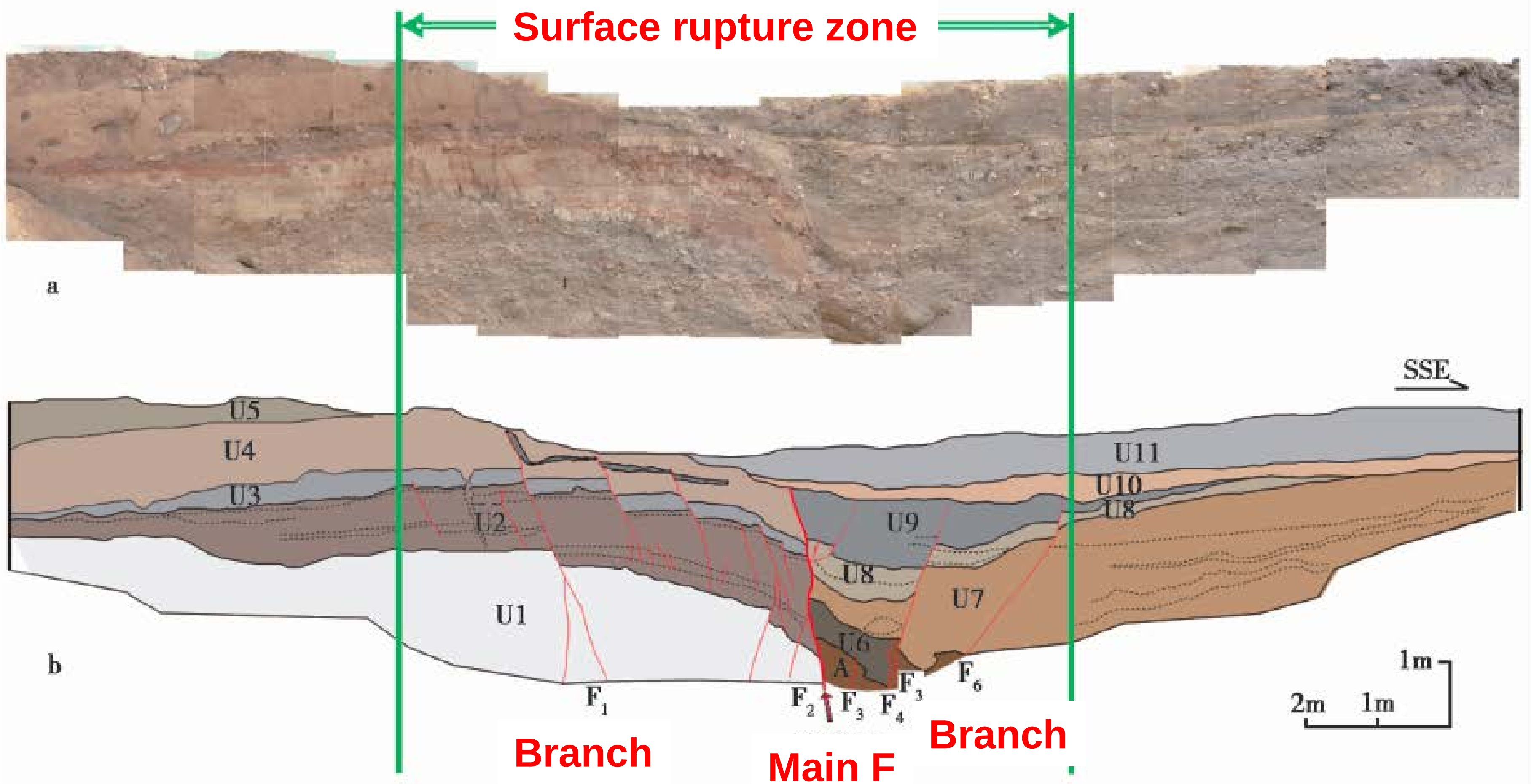
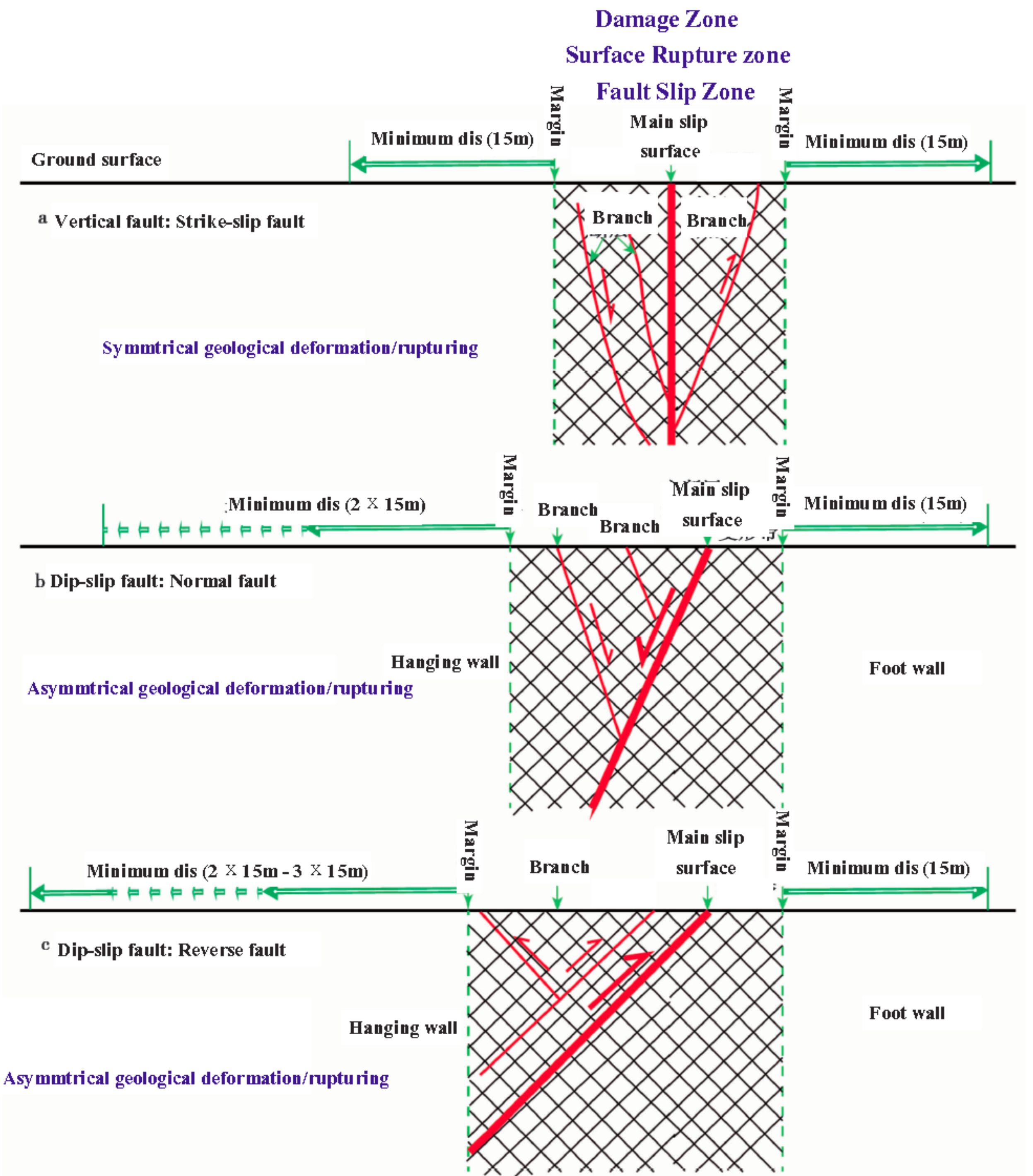
- **Conclusions**


Surface rupture zone
a
b
SSE
U1
U2
U3
U4
U5
U6
U7
U8
U9
U10
U11
A
F1
F2
F3
F4
F6
1m
2m
1m
Branch
Main F
Branch


Damage Zone
Surface Rupture zone
Fault Slip Zone
Margin
Main slip surface
Margin
Minimum dis (15m)
Minimum dis (15m)
Ground surface
Branch
Branch
a Vertical fault: Strike-slip fault
Symmtrical geological deformation/rupturing
Margin
Margin
Minimum dis (2 X 15m)
Branch
Branch
Main slip surface
Minimum dis (15m)
b Dip-slip fault: Normal fault
Hanging wall
Foot wall
Asymmtrical geological deformation/rupturing
Margin
Margin
Main slip surface
Branch
Minimum dis (2 X 15m - 3 X 15m)
Minimum dis (15m)
c Dip-slip fault: Reverse fault
Hanging wall
Foot wall
Asymmtrical geological deformation/rupturing

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Conclusions

① Earthquake surface ruptures are localized with a statistic width less than 30 m in most cases for strike-slip fault and they are symmetrically distribution along the fault trace. Its minimum setback distance is about 15 m from their margin of the deformation zone.

② Earthquake surface ruptures are localized with a statistic width up to 49 m in most cases for dip-slip fault and are asymmetrically distribution along the fault trace. In general, the width on its hanging wall is two times larger than on tis foot-wall for from their margin of the deformation zone. normal fault, and is three time larger than its foot-wall. The minimum setback distance then is about 30m up to 45 m on the hanging wall, while is 15 m on its foot-wall


谢谢！
Thanks for your attention