Scenario earthquake- Link of Probabilistic and Deterministic SHA's

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Why combine the two

- Engineering seismic hazard assessment, so called PSHA, is now widely adopted in zoning maps at national, regional and city level in the world.
- In probabilistic seismic hazard assessment, ground motion from earthquake with magnitude in interval M_j and in k^{th} potential area is estimated by means of attenuation relationship.
- The attenuation relation is a kind of simplification, taking magnitude for source mechanism, distance for path of wave propagation, and the source is considered as a point.
- Ground motion at the near field of large earthquake must be overestimated or underestimated, since the energy from a quite large source (rupture plane) is concentrated on a point (hypocenter).

Why combine the two (cont. 1)

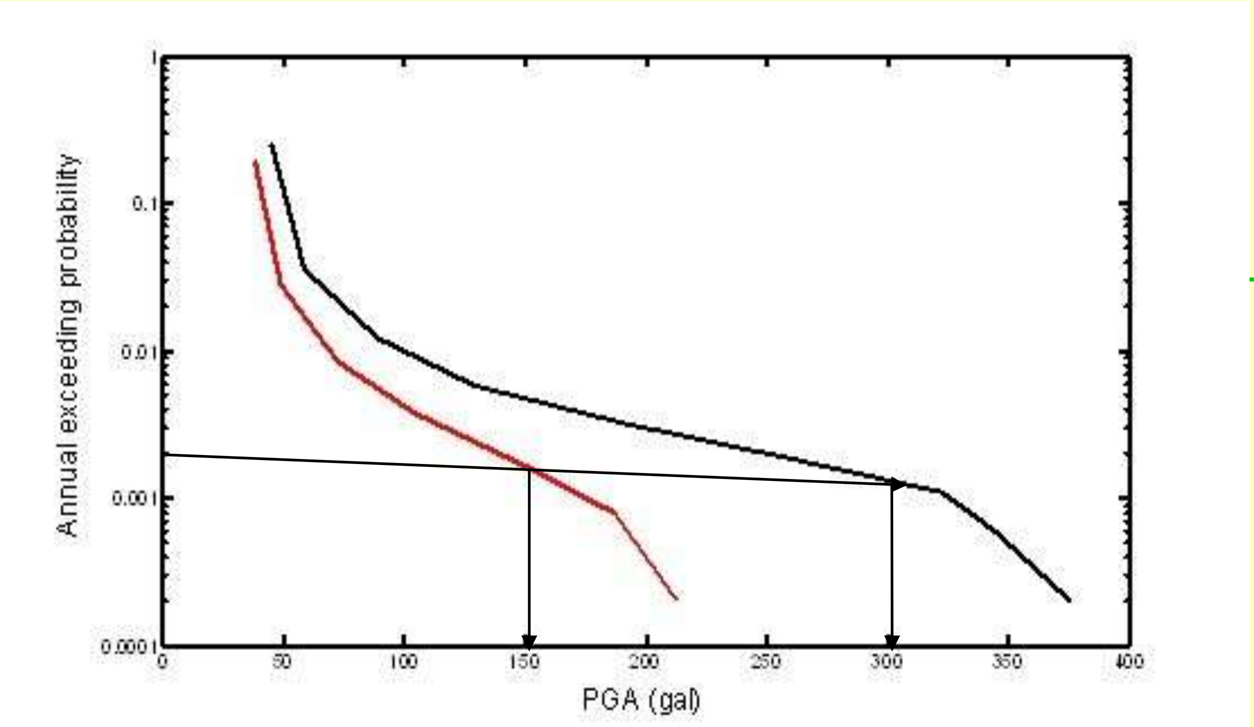
- Strong ground motion at near field is well known complicated since it is governed by the source predominately and the source of large earthquake is quite complicated in general.
- In that case, a rupture plane is needed to characterize the source, for otherwise the ground motion tends to be overestimated, and the near fault effect cannot be simulated.
- Finite fault model is currently adopted in strong ground motion simulation to describe near-fault rupture directivity effect and hanging wall effect which strongly influence the distribution of ground motion amplitudes on rock sites in the near fault region.

Why combine the two (cont. 2)

- A new idea is proposed to combine the two approaches, the key step is how to establish a link between the two.
- Benefit of seismic zoning map is mainly from mitigation of loss and casualty in cities in large earthquake.
- To describe the probabilistic seismic hazard of a city, scenario earthquake is widely adopted, with some strong queries, since the difference between hazard from an earthquake and that from earthquakes with various magnitudes in many areas.

How to build a link

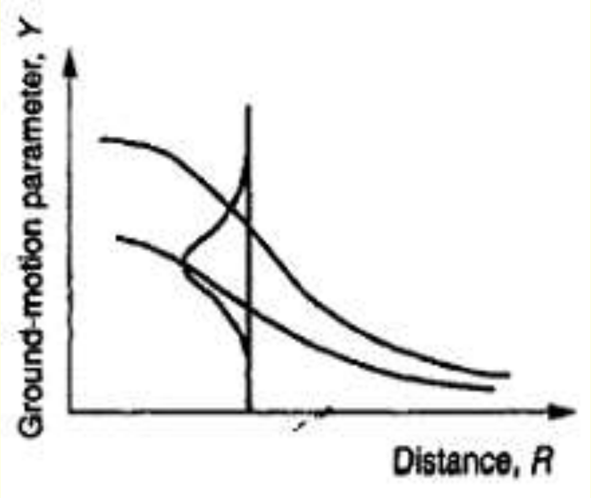
- The way to deal with a scenario earthquake is the key step to build a link between PSHA and DSHA.
- This is seismic hazard curves of a city in case study by PSHA



Uncertainty correction of seismic hazard

$$P(Y_C > y) = \int_{-3\sigma}^{3\sigma} P(Y > y \cdot e^{-\varepsilon}) \cdot f(\varepsilon) d\varepsilon$$

$$\lg Y = C_o + C_1 M + C_2 M^2 + C_3 \lg(R + C_4 e^{C_5 M}) + C_6 R + \varepsilon$$



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3	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
4	0.0058	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
5	0.0011	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
6	0.0165	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
7	0.0065	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
9	0.0015	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
10	0.0017	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
12	0.0081	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
13	0.0083	0.0018	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
14	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
15	0.0120	0.0024	0.0005	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
16	0.0121	0.0009	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
17	0.0060	0.0005	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
19	0.0024	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
20	0.0627	0.0159	0.0068	0.0034	0.0017	0.0008	0.0002	0.0000	0.0000	0.0000
21	0.0200	0.0027	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
22	0.0033	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
24	0.0021	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
25	0.0210	0.0040	0.0008	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
26	0.0028	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
27	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
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30	0.0038	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
31	0.0006	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
32	0.0010	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
33	0.0005	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
34	0.0066	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
36	0.0008	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
37	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

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12	0.0081							
13	0.0083	0.0018						
14	0.0003							
15	0.0120	0.0024	0.0005	0.0001				
16	0.0121	0.0009	0.0001					
17	0.0060	0.0005						
19	0.0024	0.0000						
20	0.0627	0.0159	0.0068	0.0034	0.0017	0.0008	0.0002	
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26	0.0028							
27	0.0007							
28	0.0025							
29	0.0040	0.0002	0.0000	0.0000				
30	0.0038							
31	0.0006							
32	0.0010							
33	0.0005							
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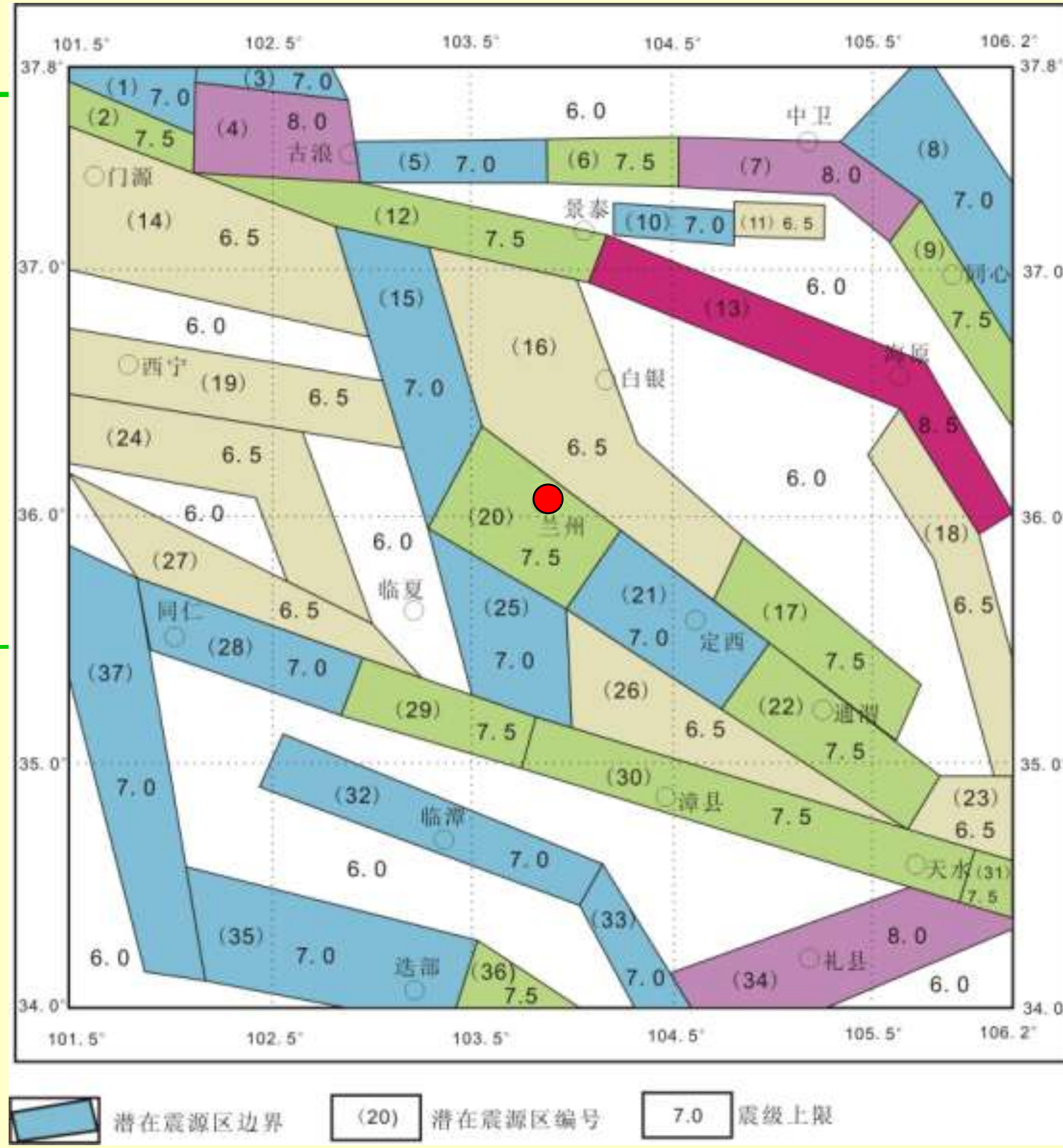
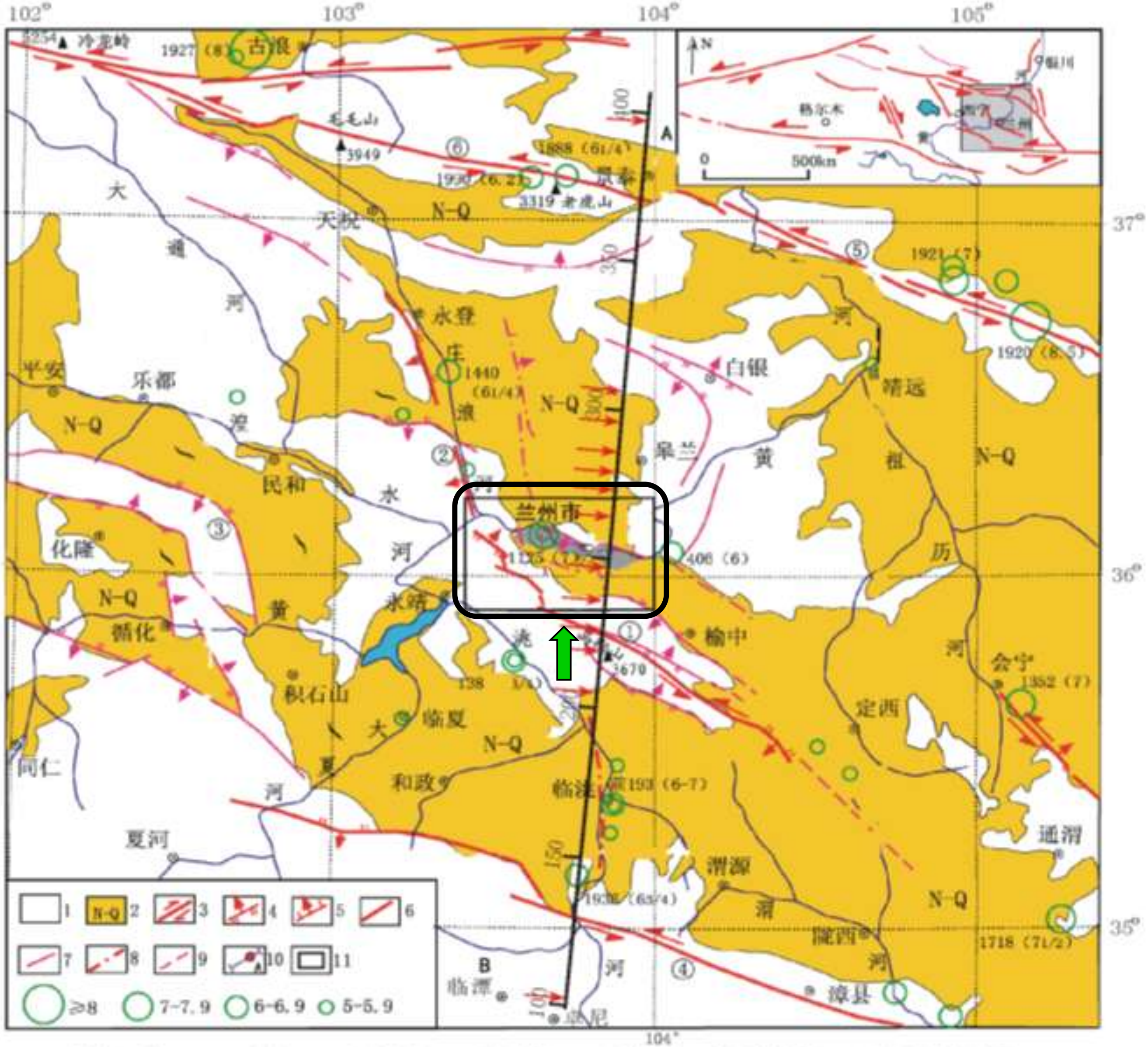
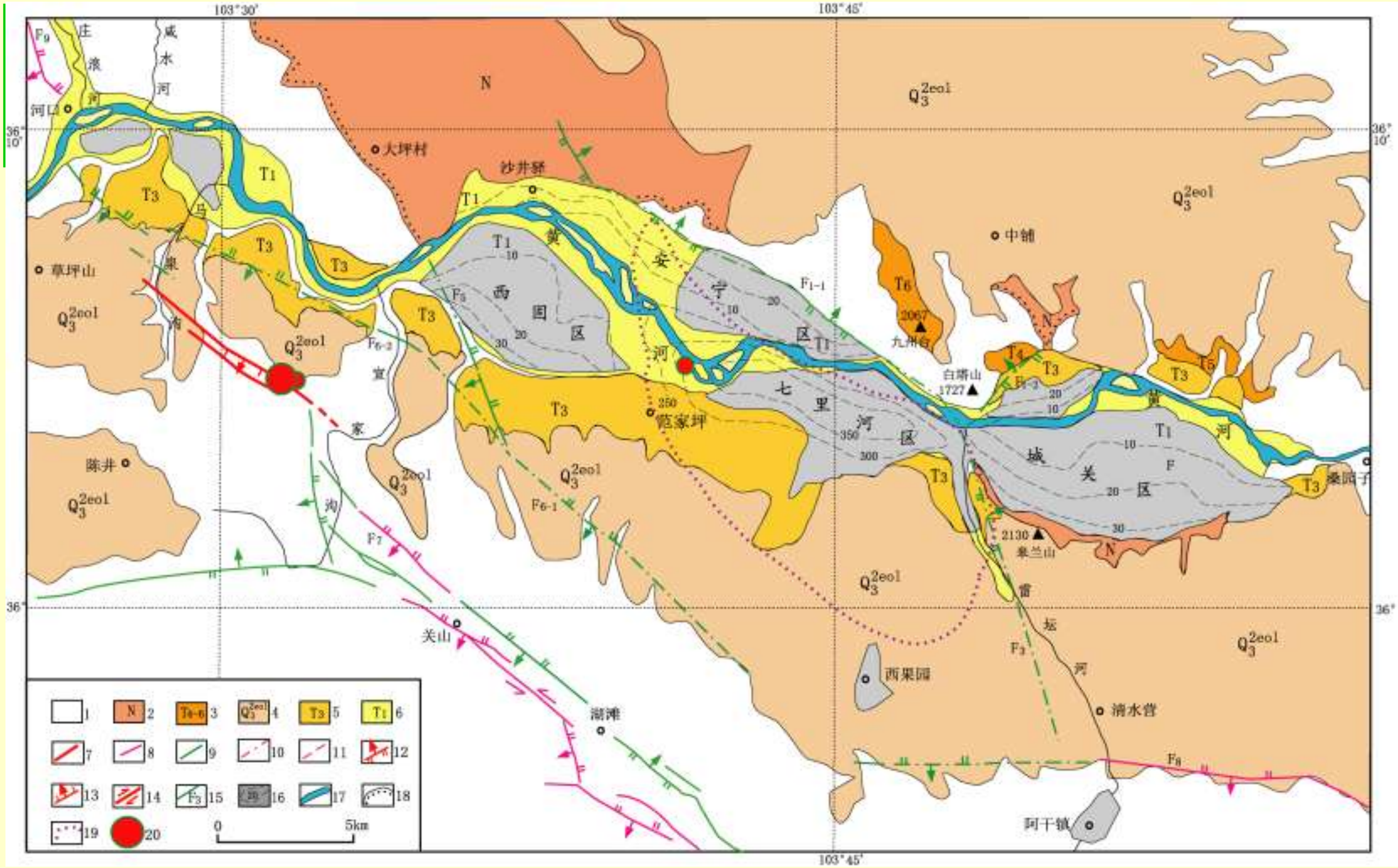
16	0.0009	0.0001				
17	0.0005					
19	0.0000					
20	0.0159	0.0068	0.0034	0.0017	0.0008	0.0002
21	0.0027	0.0003				
22	0.0001					
24	0.0000					
25	0.0040	0.0008	0.0002			
29	0.0002	0.0000	0.0000			



101.5°
102.5°
103.5°
104.5°
105.5°
106.2°
37.8°
37.0°
36.0°
35.0°
34.0°
中卫
古浪
门源
景泰
同心
海原
西宁
白银
兰州
临夏
同仁
定西
通渭
漳县
临潭
天水
迭部
礼县
潜在震源区边界
(20) 潜在震源区编号
7.0 震级上限



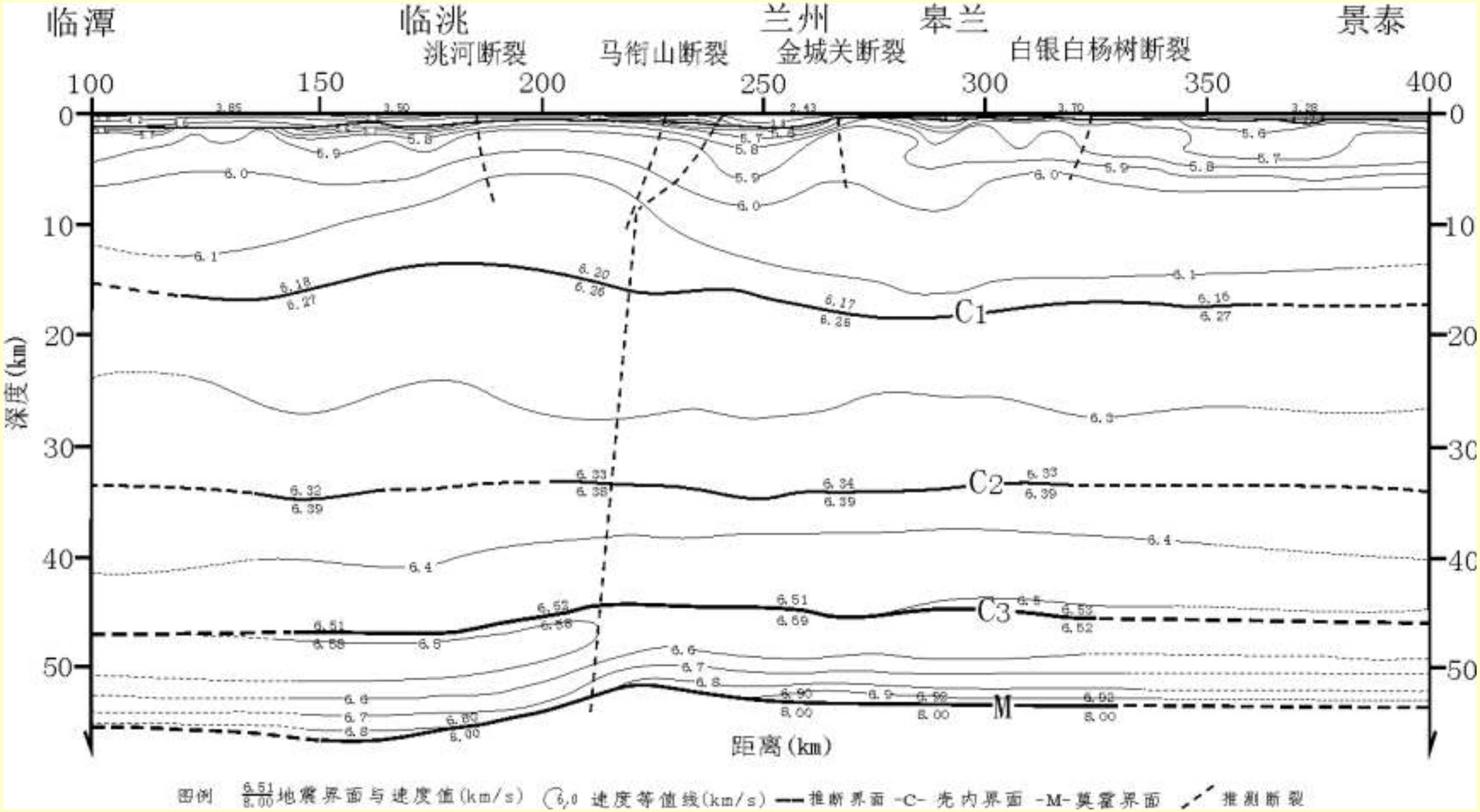
1. 前第三系； 2. N-Q盆地；3. 走滑断裂； 4. 逆断裂； 5. 正断裂 6. 全新世断裂； 7. 晚更新世断裂；
8. 隐伏断裂；9. 推测断裂； 10. 人工地震折射剖面及炮点位置； 11. 兰州市放大图.
①马衔山断裂； ②庄浪河断裂；③拉脊山断裂；④西秦岭北缘断裂；⑤海原断裂；⑥老虎山-毛毛山断裂.



103°30′
103°45′
36° 10′
36°
N
大坪村
沙井驿
中铺
草坪山
陈井
关山
湖滩
西果园
清水营
阿干镇
范家坪
桑园子
白塔山 1727
九州台 2067
皋兰山 2130
西 固 区
安 宁 区
七 里 河 区
城 关 区
黄 河
庄 浪 河
咸 水 河
宣 家 沟
雷 坛 河
河口
T1
T3
T4
T5
T6
F9
F5
F1-1
F1-2
F6-1
F6-2
F7
F3
F8
0 5km

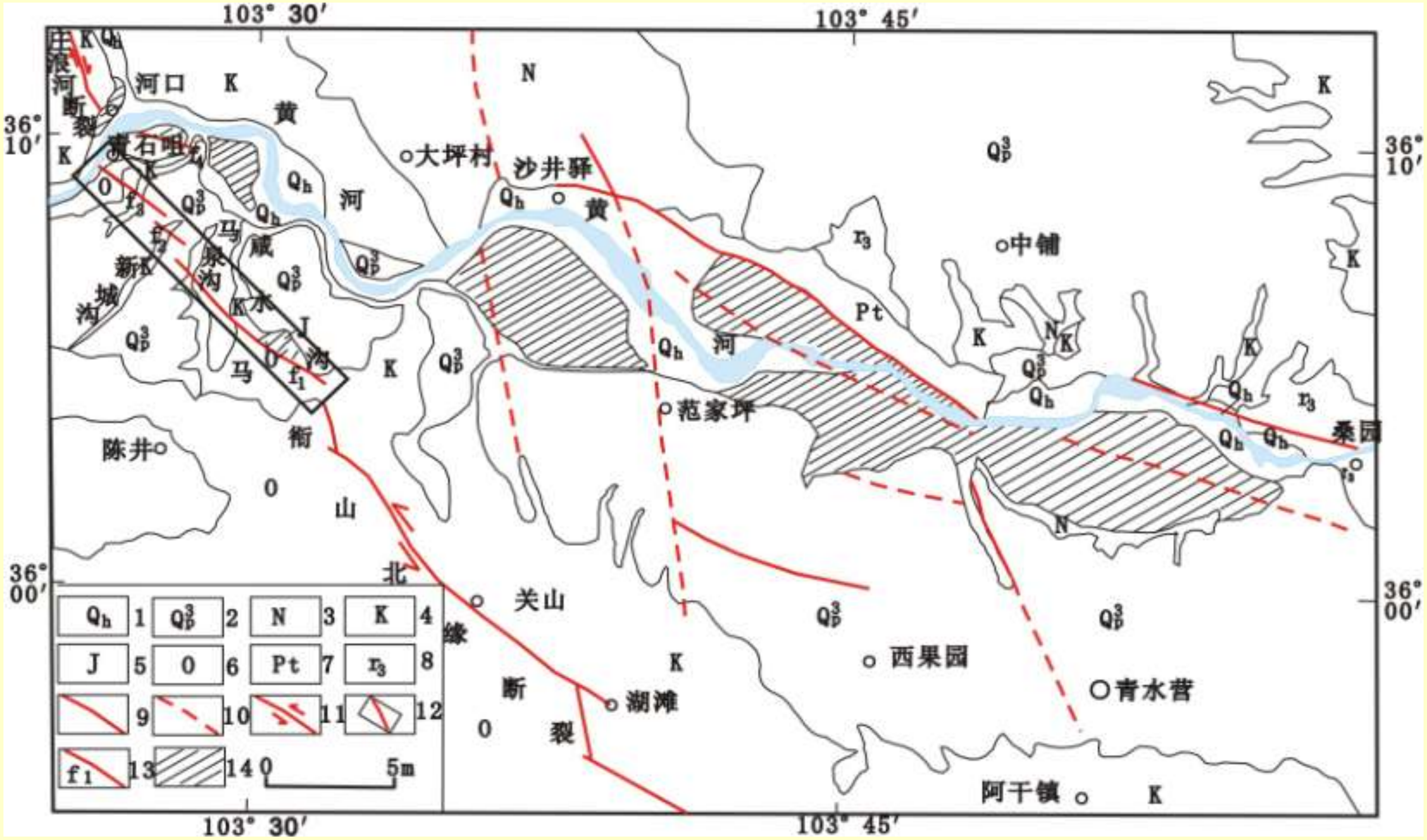
Exceeding Probability	63% in 50 years	10% in 50 years	2% in 50 years
PGA （gal）	59	192	345
Magnitude	5.7	6.5	7.0
Distance （km）	30	21	16
Causative fault	Maxianshan North Fault	Western segment of Maxianshan North Fault	Midele and Eastern segments of Maxianshan North Fault

Parameter	Magnitude 6.5	Mean value
Rupture area S	$\log S = M_w - 4.0$	136 km^2
Rupture width W	$\log W = 0.5 M_w - 2.125$	8 km
Rupture length L	$L = S/W$	17 km
Average slip on the rupture $\overline{D}$	$\log \overline{D} = 0.5 M_w - 1.45$	146 cm



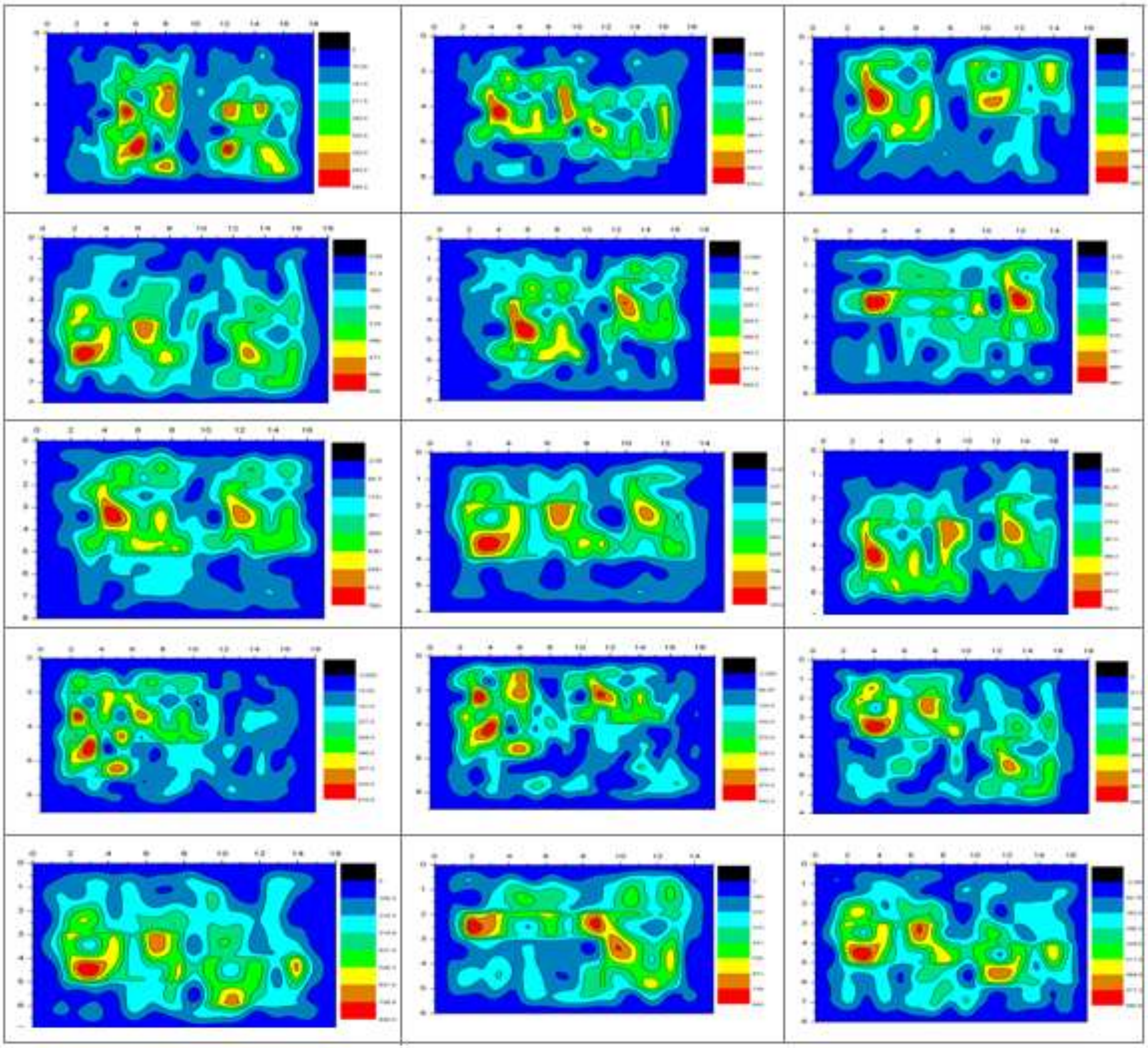
临潭
临洮
兰州
皋兰
景泰
洮河断裂
马衔山断裂
金城关断裂
白银白杨树断裂
100 150 200 250 300 350 400
0 10 20 30 40 50
深度(km)
距离(km)
C1
C2
C3
M
图例 6.51/8.00 地震界面与速度值(km/s) 6.0 速度等值线(km/s) 推断界面 -C- 壳内界面 -M- 莫霍界面 推测断裂

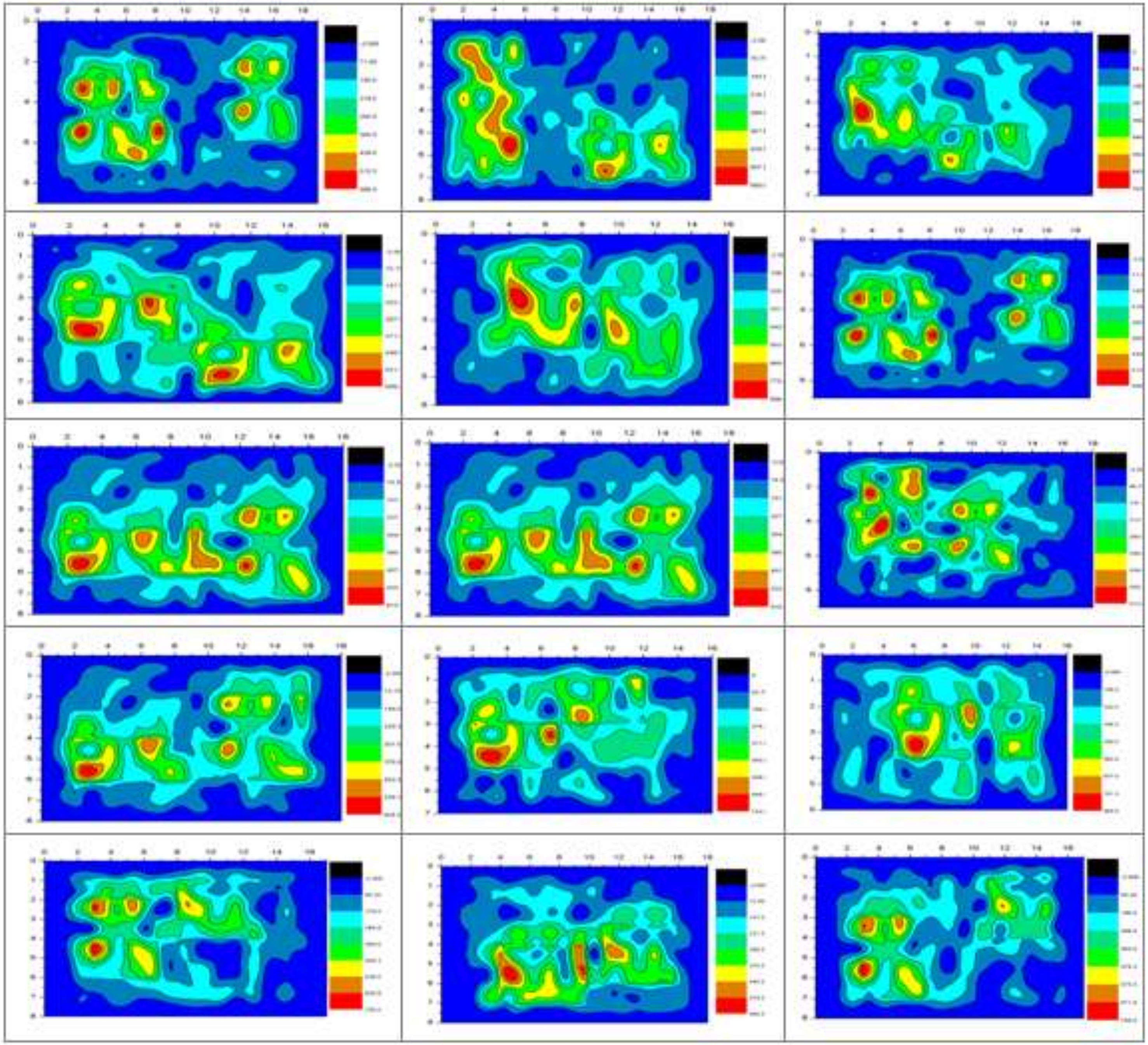
Parameter	Max. Asperity	Other Asperity
Asperity area (km^2)	$\log S_{am} = \log S - 0.92$	$\log S_a = \log S - 0.65$ $S_{ao} = S_a - S_{am}$
Asperity length (km)	$\log L_{am} = 0.5L - 2.31$	$L_{ao} = S_{ao} / W_{ao}$
Asperity width (km)	$W_{am} = S_{am} / L_{am}$	$W_{ao} = \xi_W \sqrt{S_{ao}}$
X coordinate of Asperity center (km)	$\log x_{am} = \log L - 0.72$	$X_{ao} = \xi_X (L - X_2)$
Y coordinate of Asperity center (km)	$\log y_{am} = \log W - 0.28$	$Y_{ao} = \xi_W \times W + W_{ao} / 2$
Average slip of Asperity (cm)	$\log \overline{D}_{am} = \log \overline{D} + 0.39$	$\log \overline{D}_{ao} = \mathrm{M}_w + 0.31$

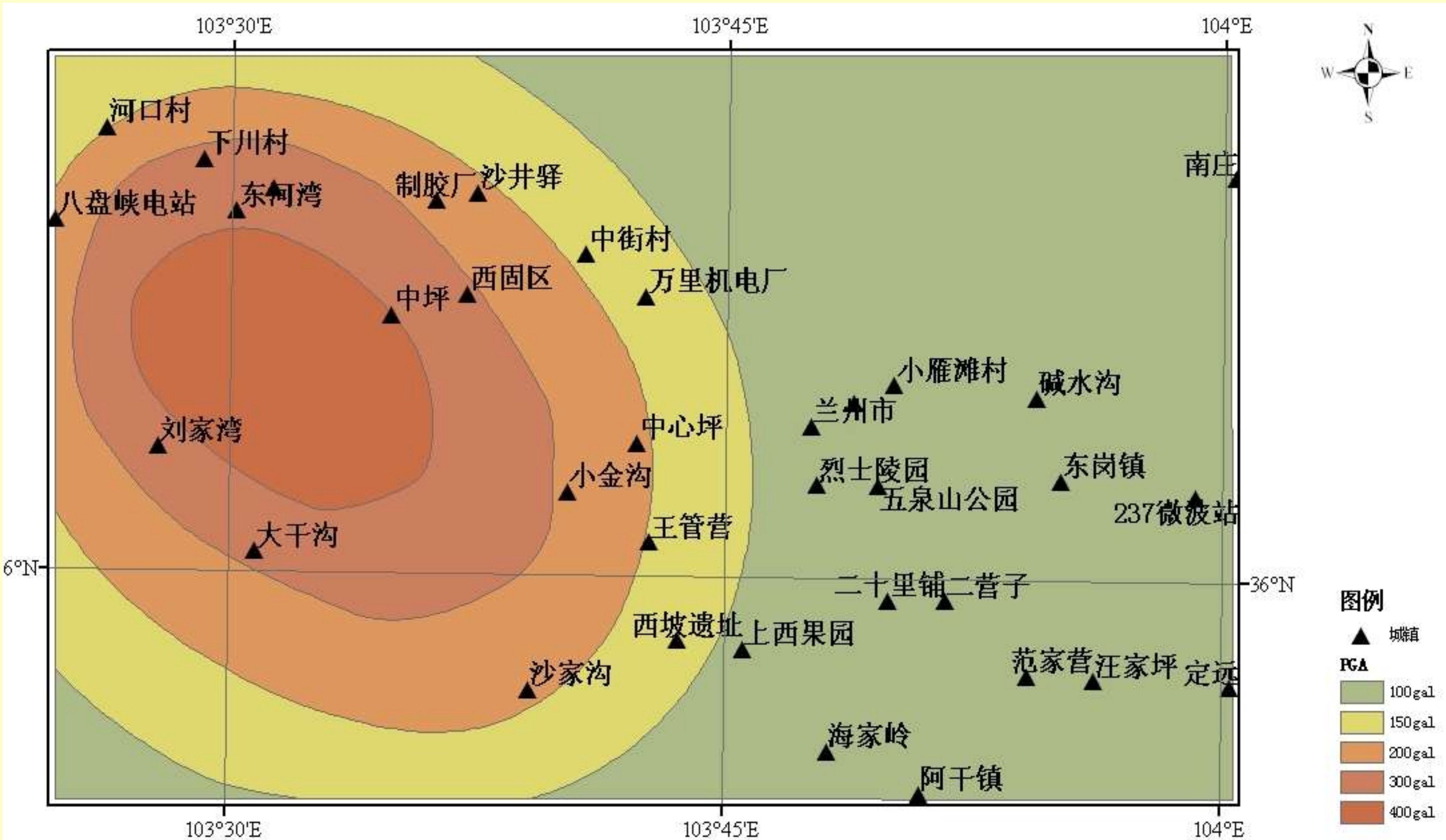

103° 30′
103° 45′
36° 10′
36° 00′
河口
黄
河
大坪村
沙井驿
中铺
范家坪
陈井
山
北
缘
断
裂
关山
湖滩
西果园
青水营
阿干镇
桑园
庄浪河断裂
黄石咀
马咸水沟
泉沟
新城沟
马
衔
Qh 1
Qp3 2
N 3
K 4
J 5
O 6
Pt 7
r3 8
9
10
11
12
13
14
0 5m

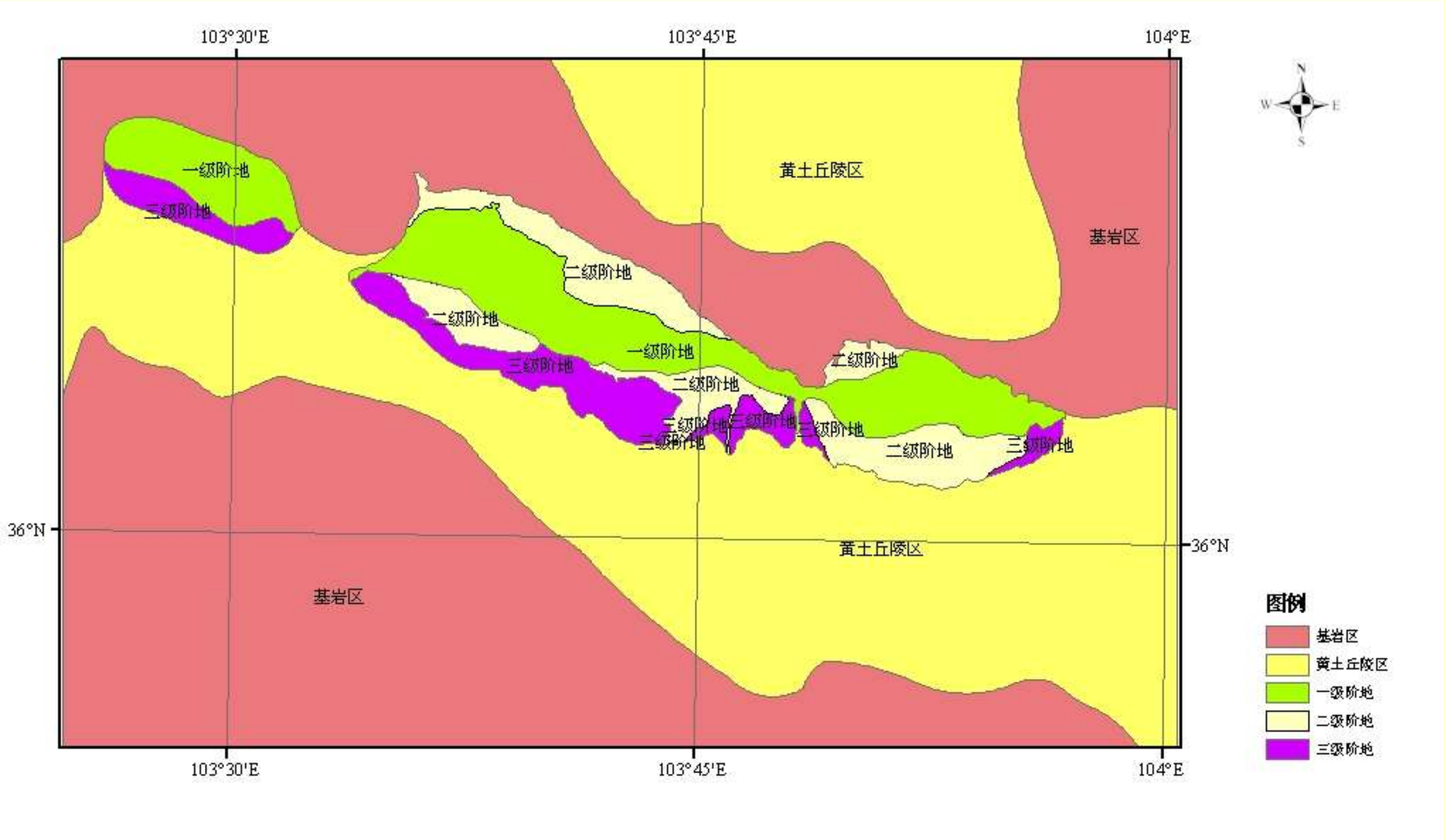
Magnitude 6.5	Mean value
$\log k_{cx} = 1.89 - 0.5M_w$	0.0437
$\log k_{cy} = 2.09 - 0.5M_w$	0.0692

$$D(k_x, k_y) = \frac{\overline{D} \cdot L \cdot W}{\sqrt{1 + \left(\left(\frac{k_x}{k_{cx}} \right)^2 + \left(\frac{k_y}{k_{cy}} \right)^2 \right)^2}} e^{i\Phi(k_x, k_y)}$$

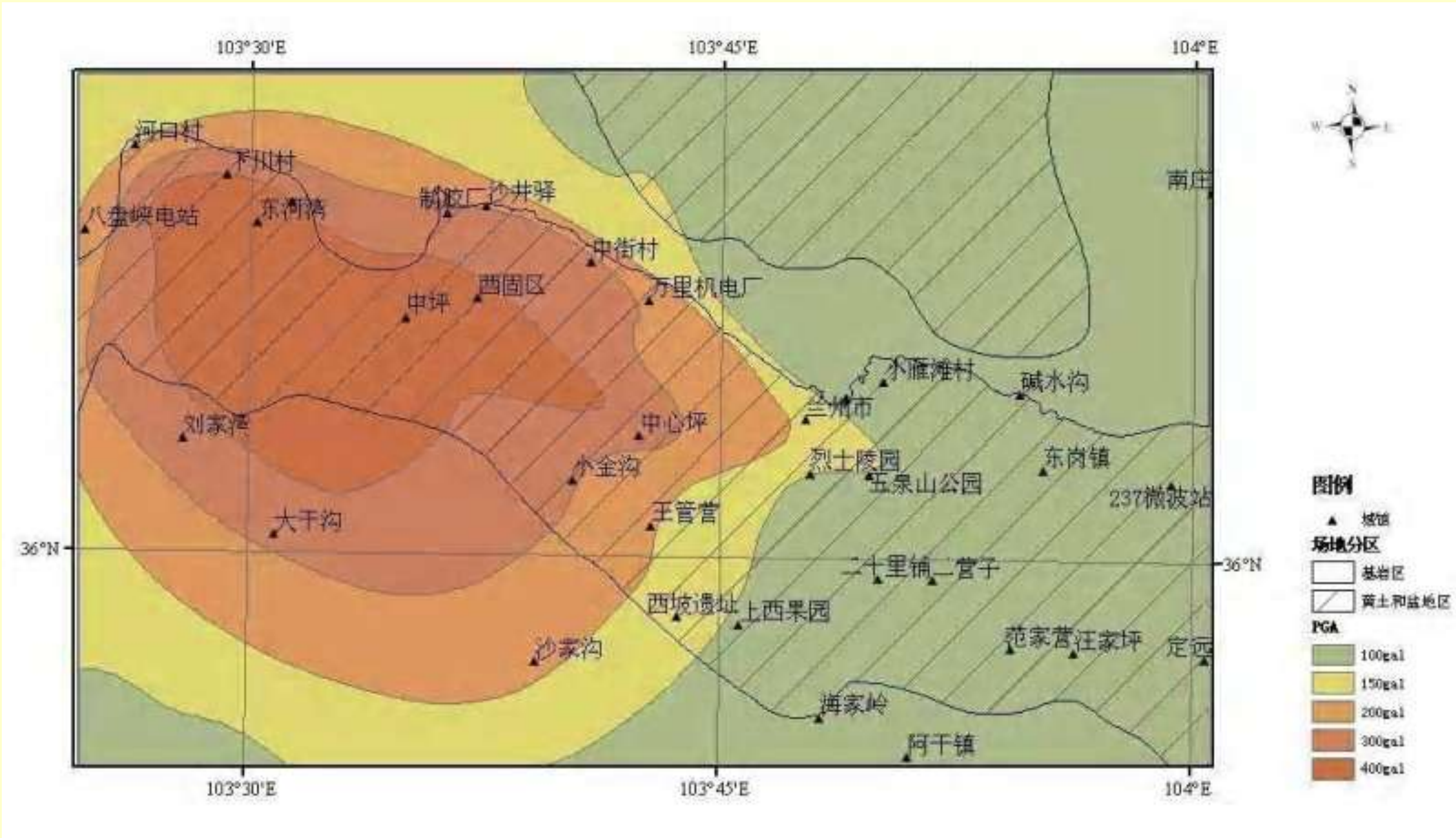




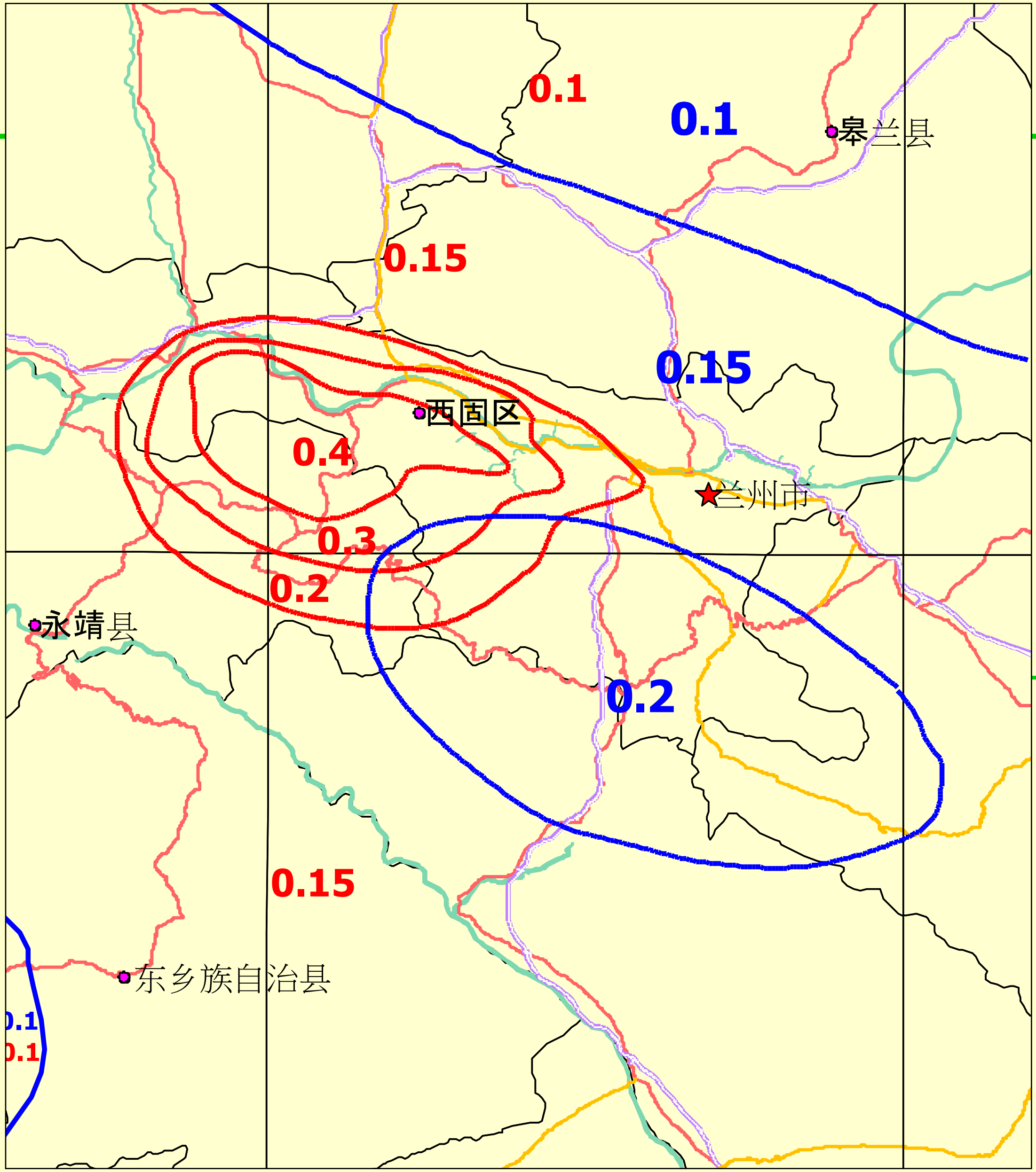

103°30'E
103°45'E
104°E
N
W
E
S
河口村
下川村
八盘峡电站
东河湾
制胶厂
沙井驿
中街村
西固区
中坪
万里机电厂
南庄
小雁滩村
碱水沟
兰州市
刘家湾
中心坪
小金沟
烈士陵园
五泉山公园
东岗镇
237微波站
大干沟
王管营
6°N
36°N
二十里铺
二营子
西坡遗址
上西果园
沙家沟
范家营
汪家坪
定远
海家岭
阿干镇
图例
城镇
PGA
100gal
150gal
200gal
300gal
400gal

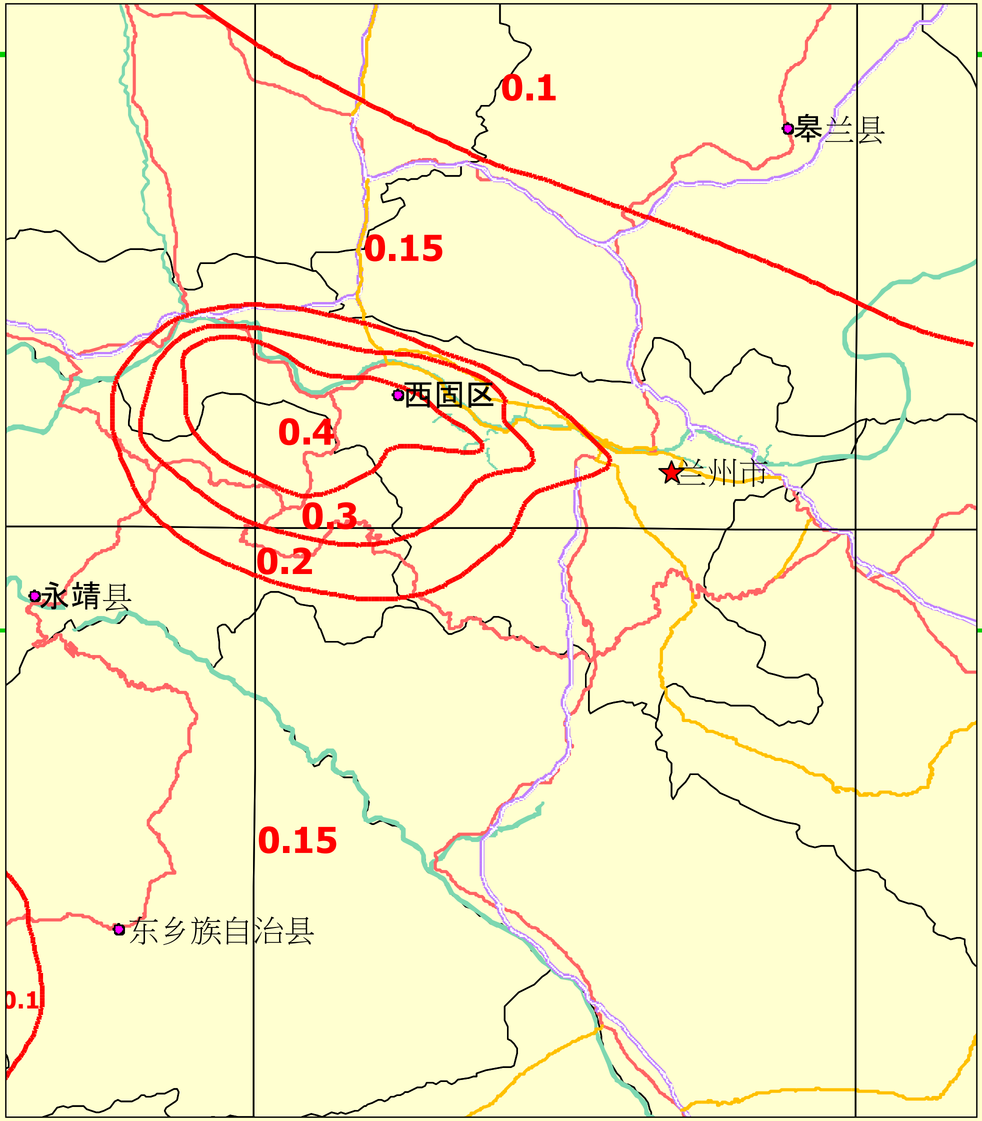


103°30'E
103°45'E
104°E
N
W
E
S
一级阶地
三级阶地
黄土丘陵区
基岩区
二级阶地
二级阶地
一级阶地
二级阶地
三级阶地
二级阶地
三级阶地
三级阶地
三级阶地
三级阶地
二级阶地
三级阶地
36°N
36°N
黄土丘陵区
基岩区
图例
基岩区
黄土丘陵区
一级阶地
二级阶地
三级阶地
103°30'E
103°45'E
104°E



103°30'E
103°45'E
104°E
36°N
河口村
下川村
八盘峡电站
东洲湾
制胶厂
沙井驿
中街村
西固区
中坪
万里机电厂
小雁滩村
碱水沟
兰州市
南庄
刘家湾
中心坪
小金沟
烈士陵园
五泉山公园
东岗镇
237微波站
大干沟
王管营
二十里铺
二营子
西坡遗址
上西果园
沙家沟
范家营
汪家坪
定远
海家岭
阿干镇
图例
城镇
场地分区
基岩区
黄土和盐地区
PGA
100gal
150gal
200gal
300gal
400gal


0.1
0.1
皋兰县
0.15
0.15
西固区
0.4
兰州市
0.3
0.2
永靖县
0.2
0.15
东乡族自治县
0.1
0.1



0.1
皋兰县
0.15
西固区
0.4
兰州市
0.3
0.2
永靖县
0.15
东乡族自治县
0.1

Conclusion

- A new idea is proposed to combine the PSHA and DSHA approaches for the next generation map.
- Scenario earthquake is emphasized as the key step to establish a link between the two.
- From a case study, the detail hazard result by mean attenuation relation is examined, and the most potential source area is acquired for a given exceeding probability.
- A distance range is then fixed from the segmentation of the main active fault in the source area, and the corresponding magnitude is calculated from the PGA by PSHA by the mean attenuation law.
- The magnitude is checked from the upper bond magnitude of the potential area.

Conclusion (cont.1)

- Finite fault source model is built from the checked magnitude with the fault data as much as possible.
- 30 source models are presented to take into account uncertainty on global and local parameters.
- The ground motions at near field are synthesized, and average PGA is assigned to each rock site, and soil site as well by taking site condition into account further.
- The isoseismials constructed from the synthesized motion field is overlaid on that from PSHA, and the two are merged together as the final map by replacing the PSHA result at near field by the synthesized one.

Conclusion (cont.2)

- By this way, the scenario is the maximum confidential, from seismotectonic condition, the corresponding PGA by mean attenuation relation is the same as the PSHA result by the same relation.
- In this meaning, the isoseismals from the scenarion could be considered with that exceeding probabilitty of the PSHA result, and can merged with that together.
- The uncertinty on source model has been taken into account, and that on attenuation could also be taken into account by the same way to synthesize more motion fields from each source model with different values of random error term in attenuation law.
- The hign intensity area on the map is shifted now westwards reasonably as an improvement.
- The number of synthesis is determined by the stability of the mean PGA.

Thank you!

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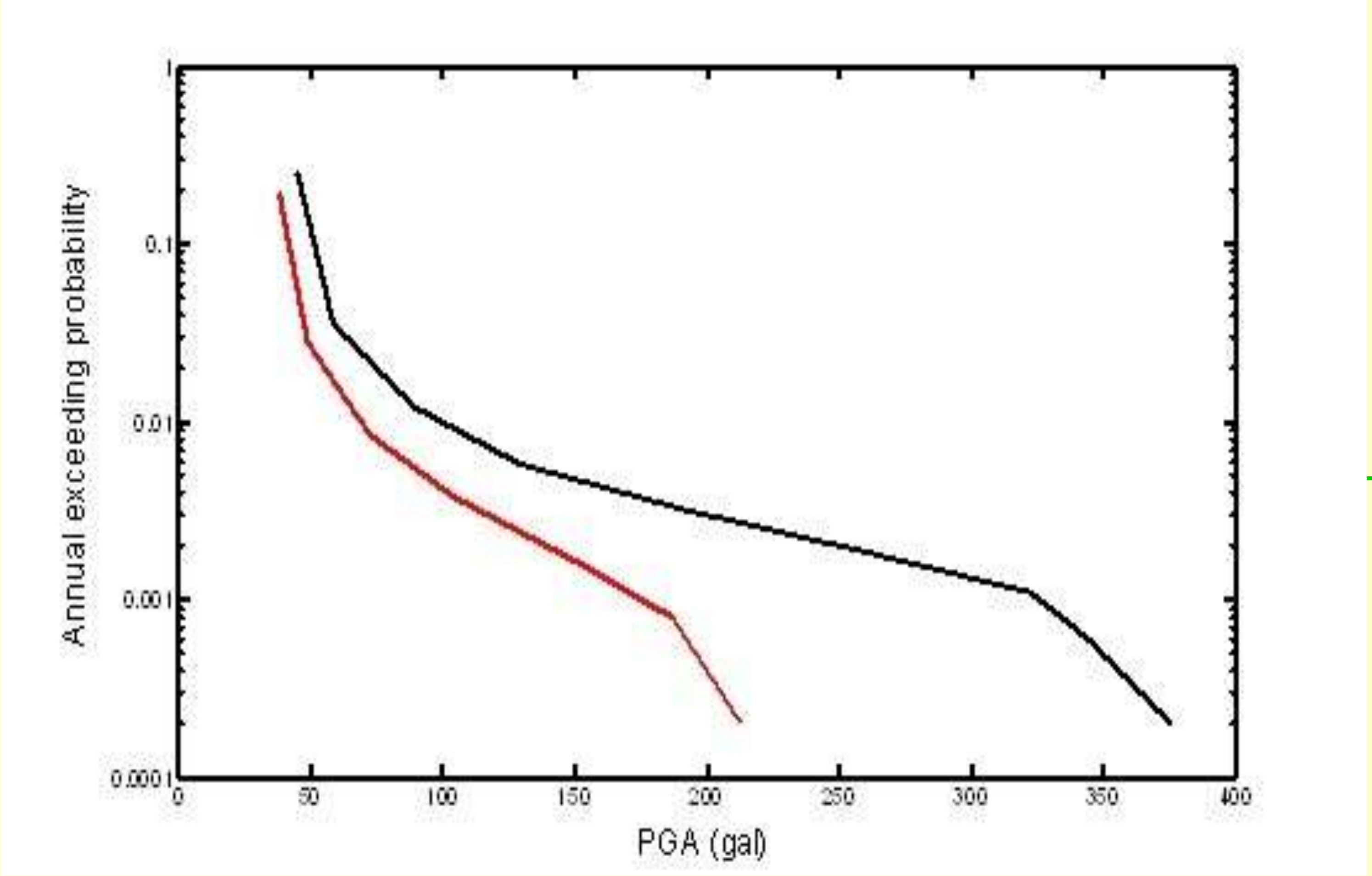
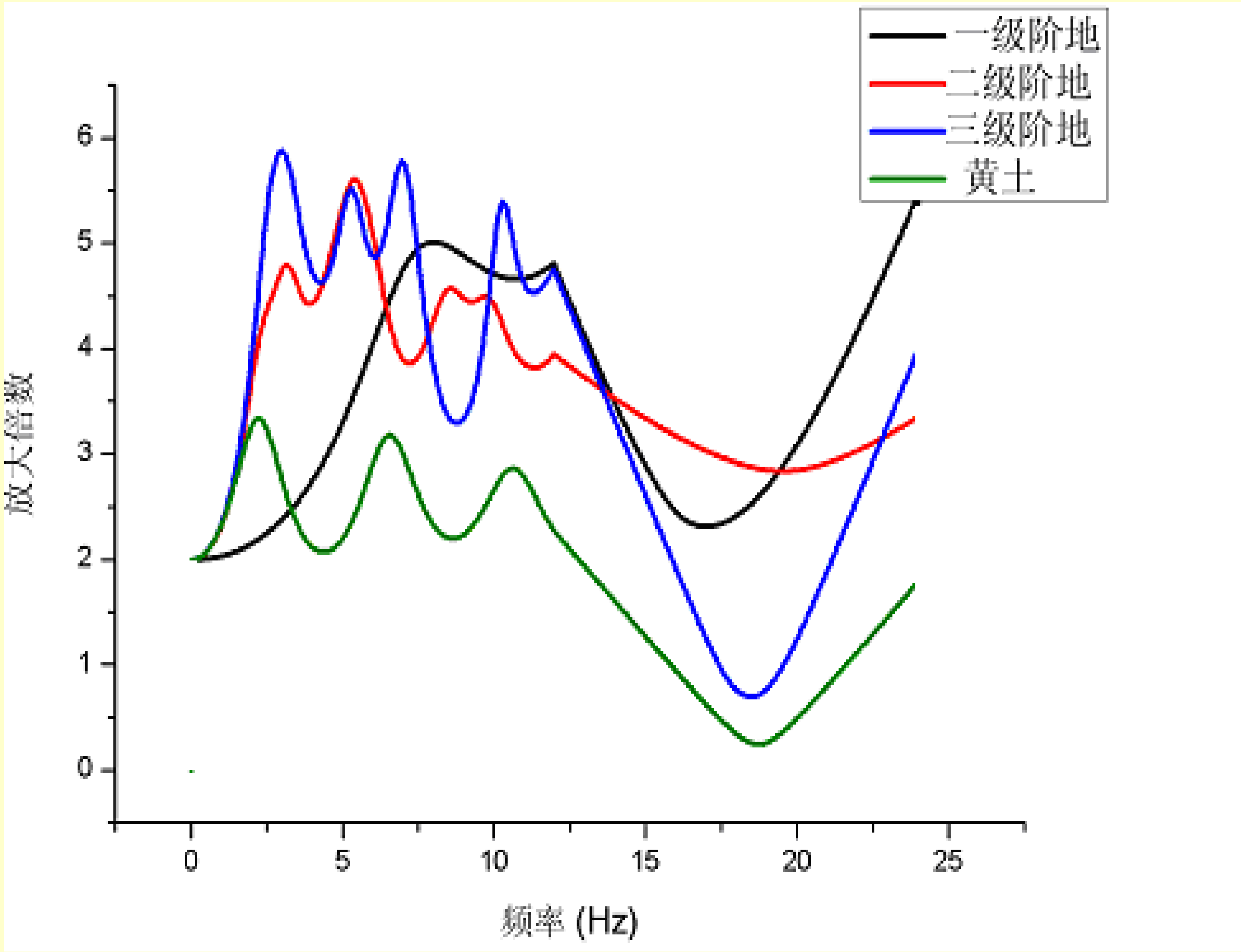
Seismic hazard of a city by PSHA




一级阶地
二级阶地
三级阶地
黄土
放大倍数
0
1
2
3
4
5
6
0
5
10
15
20
25
频率 (Hz)