Liquefaction and Paleo-liquefaction in Christchurch, New Zealand

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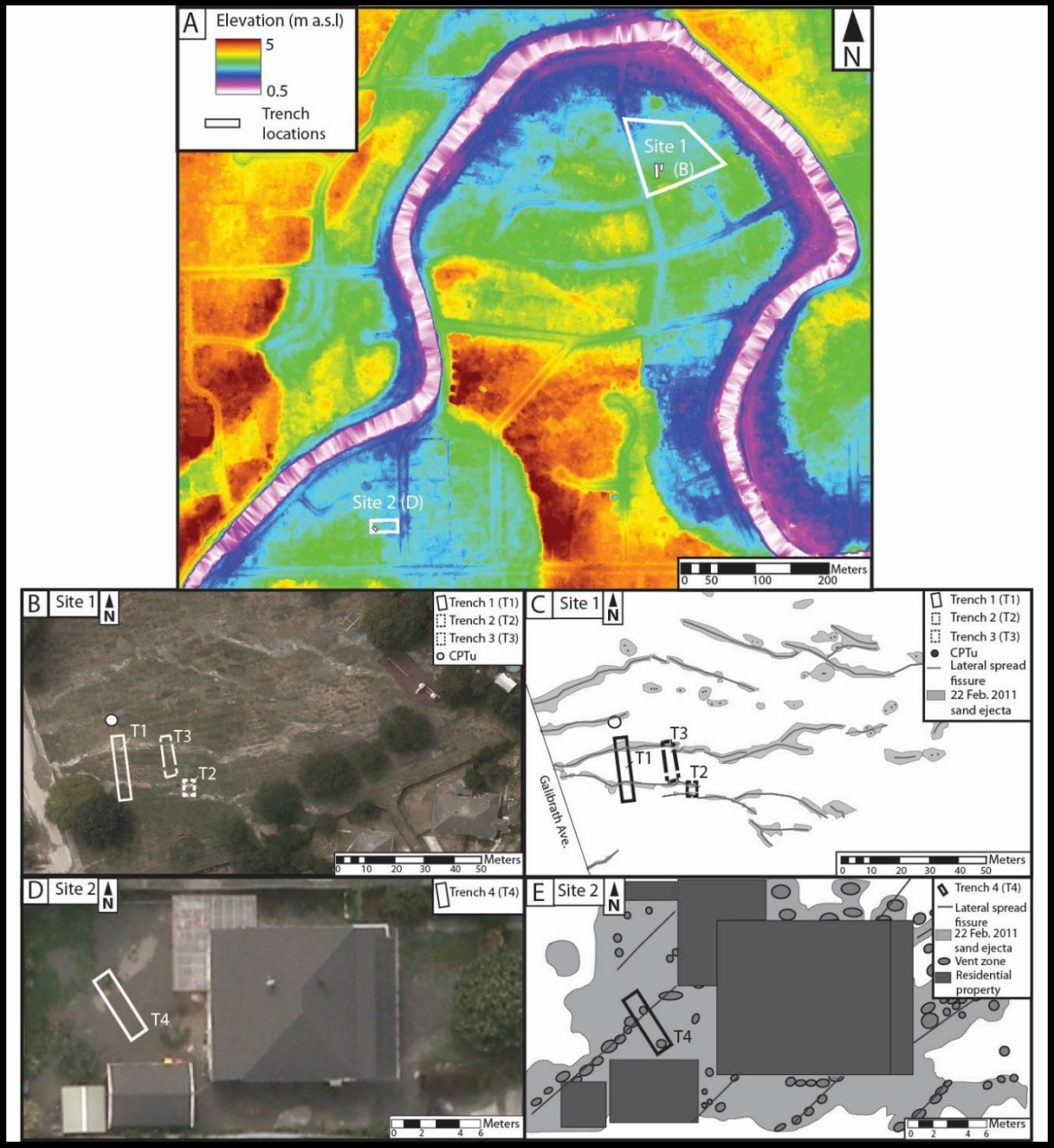
Liquefaction during the CES

- > 10 episodes of CES liquefaction; >7000 homes ‘red zoned’
- Can it be recognised in the geologic record? Has this area previously liquefied?
- Determine geological and geomorphic influences on liquefaction/ lateral spreading

Photo: P. Almond, 2010

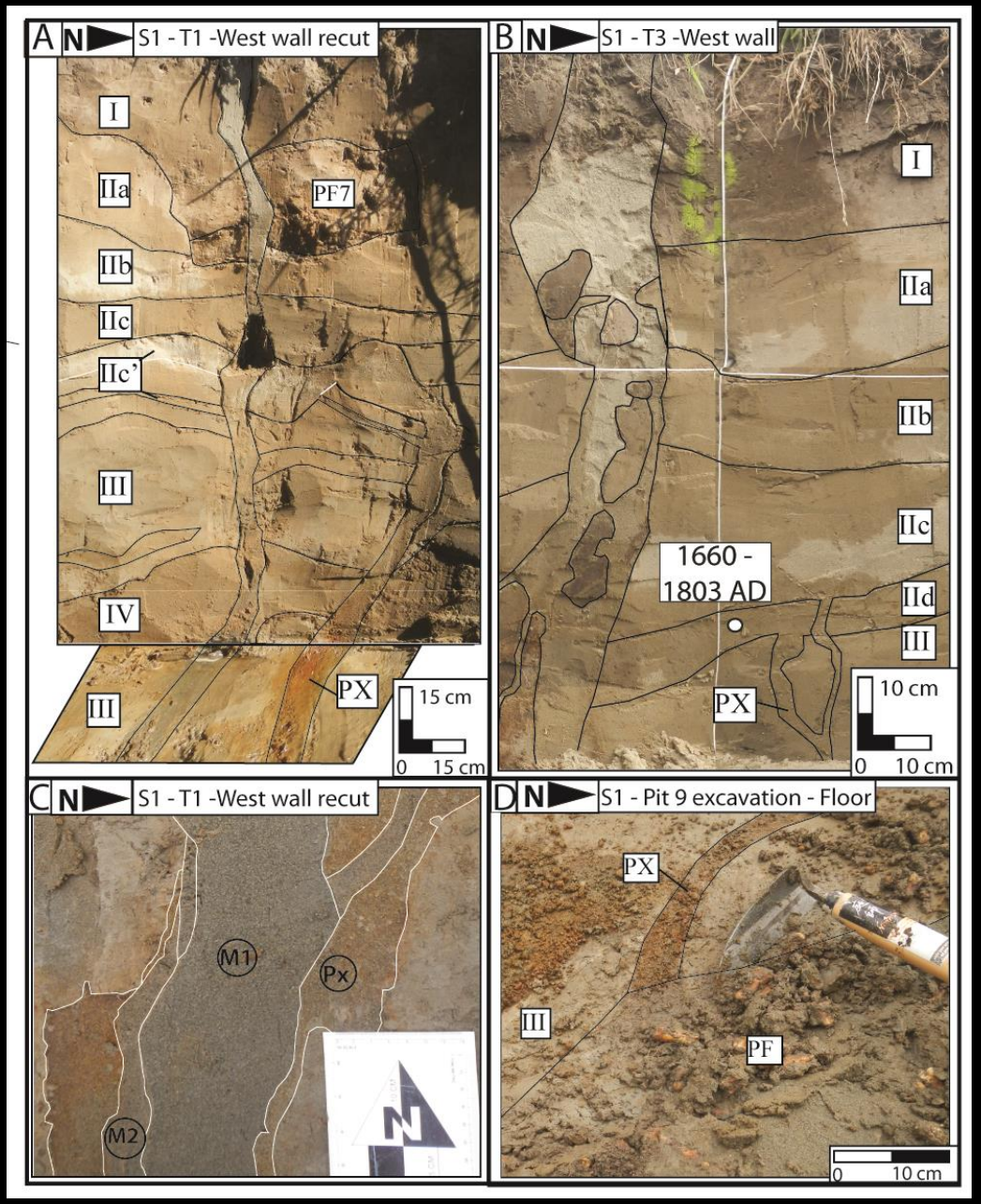
Paleo-liquefaction in Avonside



Bastin et al. 2015

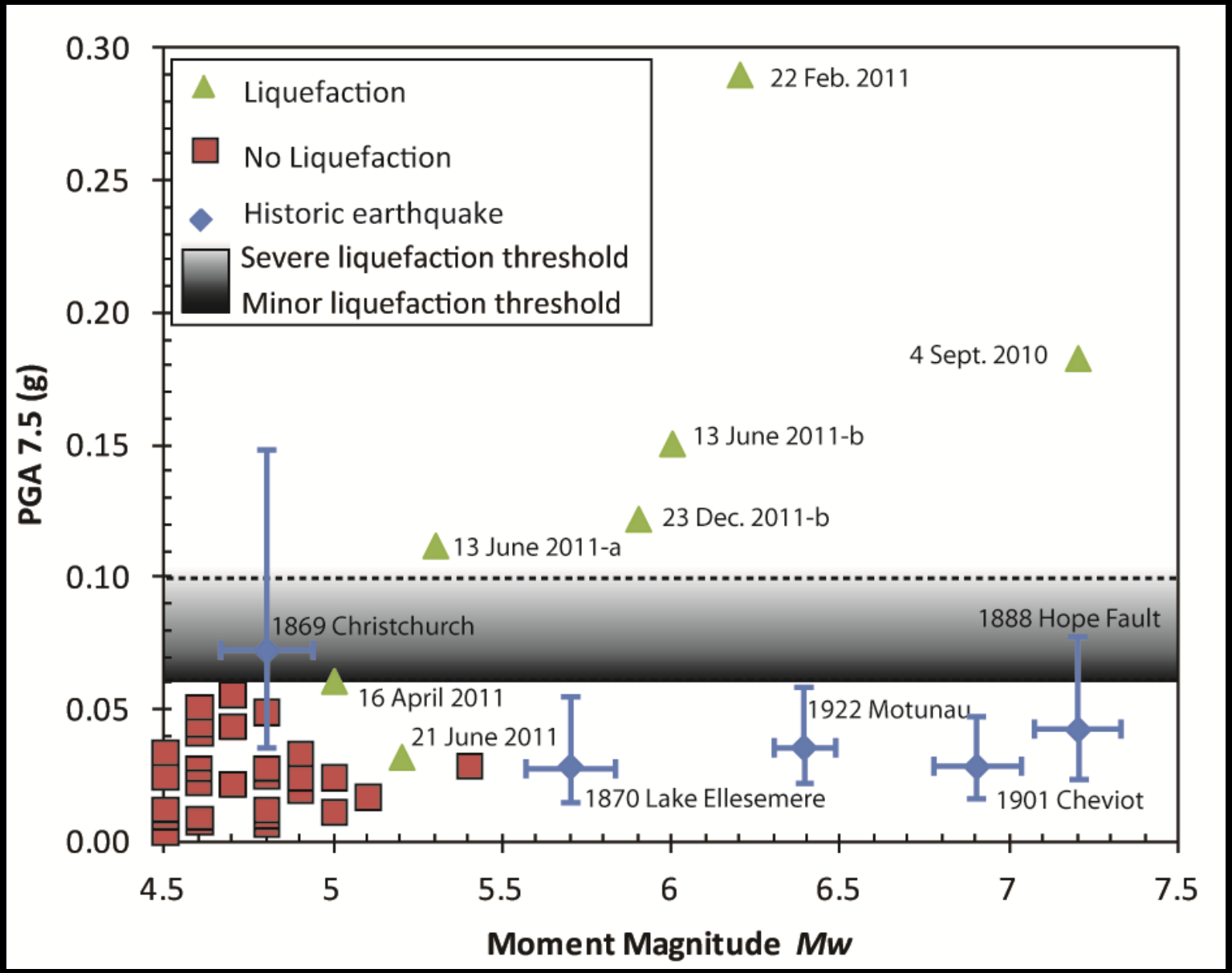
Avonside: Paleo-liquefaction

- Liquefaction dikes and sills increase in width and grain size with depth
- CES dikes cross-cut and align with paleo-liquefaction features
- Site 1: Paleo-liquefaction dike likely formed post 1660 and pre ca. 1905
- Site 2: bulbous injection feature



Bastin et al. 2015

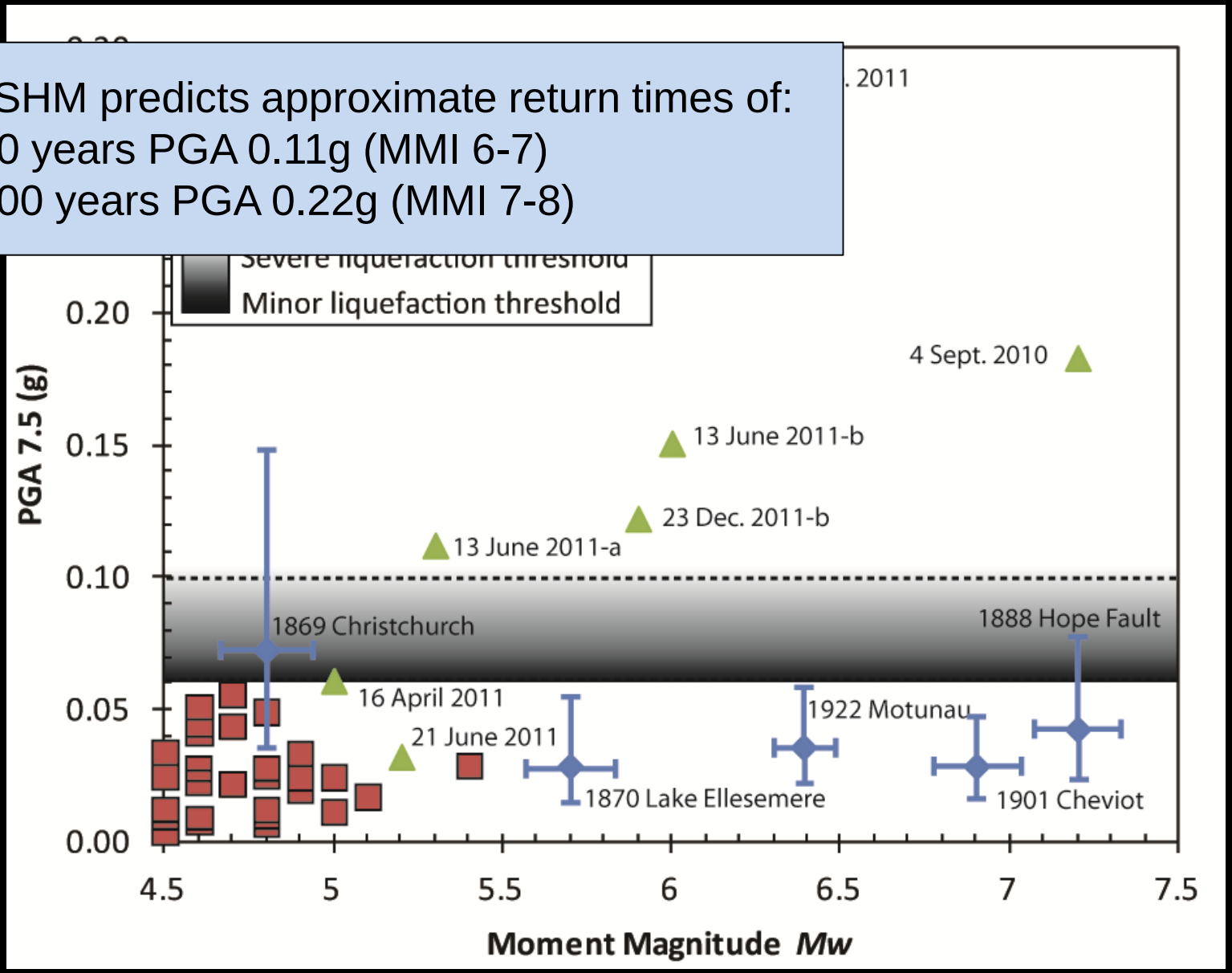
Possible Seismic Source



Bastin et al. 2015

Possible Seismic Source

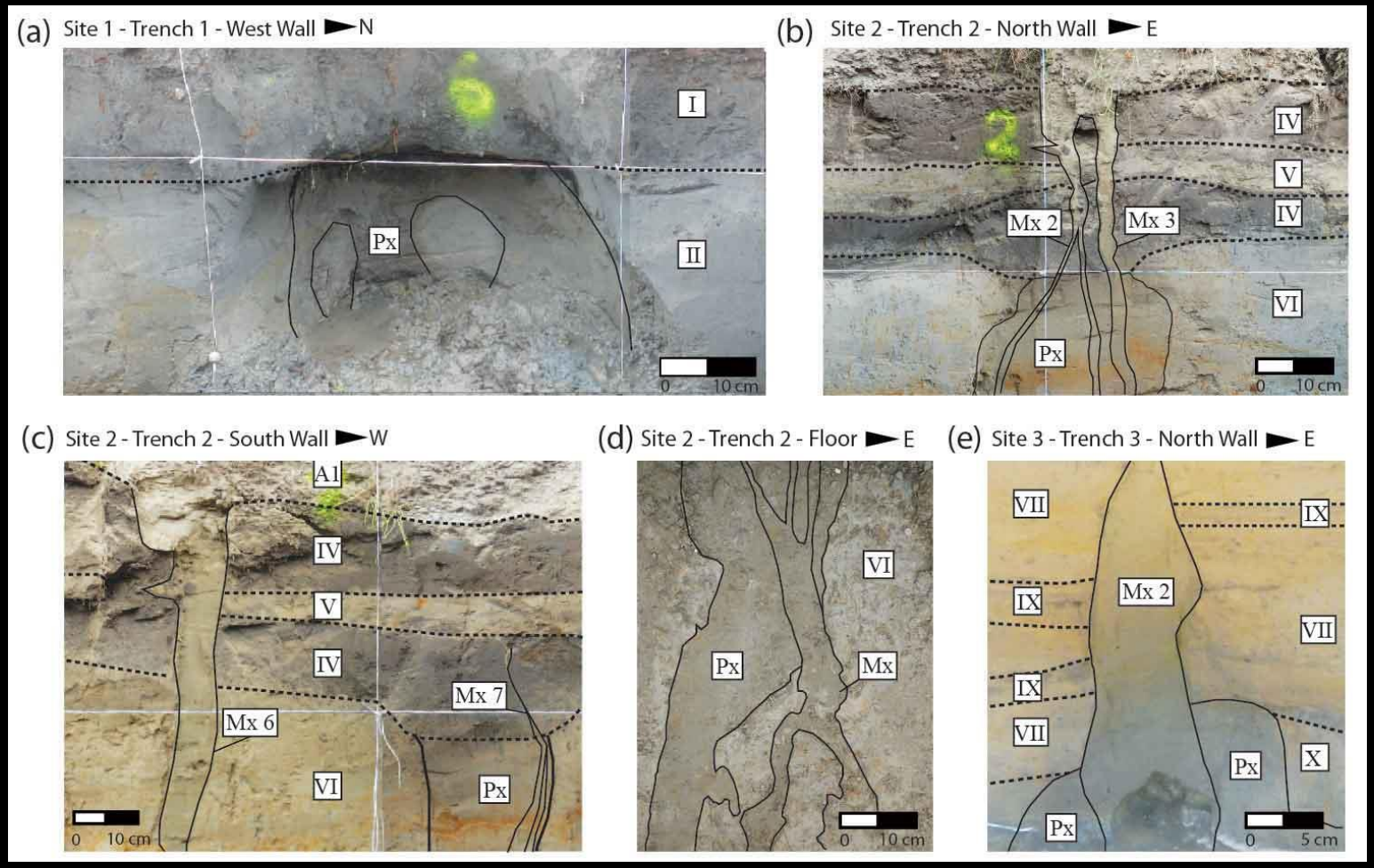
NZSHM predicts approximate return times of:
~50 years PGA 0.11g (MMI 6-7)
~200 years PGA 0.22g (MMI 7-8)



Bastin et al. 2015

Paleo-liquefaction in Avondale

Paleo-liquefaction in Avondale



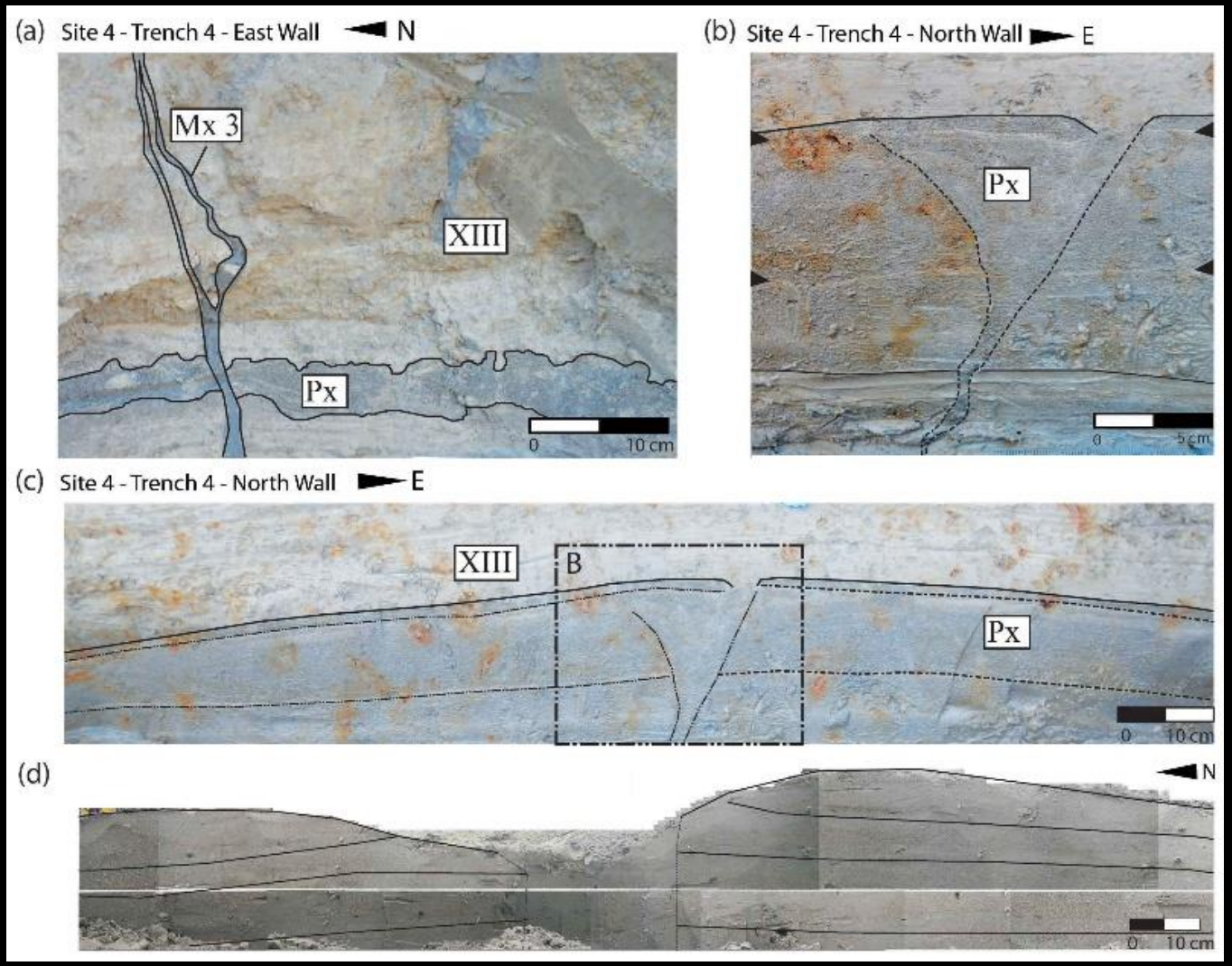
Bastin et al. (in review)

- CES dikes cross-cut and align with paleo-liquefaction features
- Likely post-AD 1398 and pre-1960

Paleo-liquefaction in Kaiapoi

Sewell Street Liquefaction

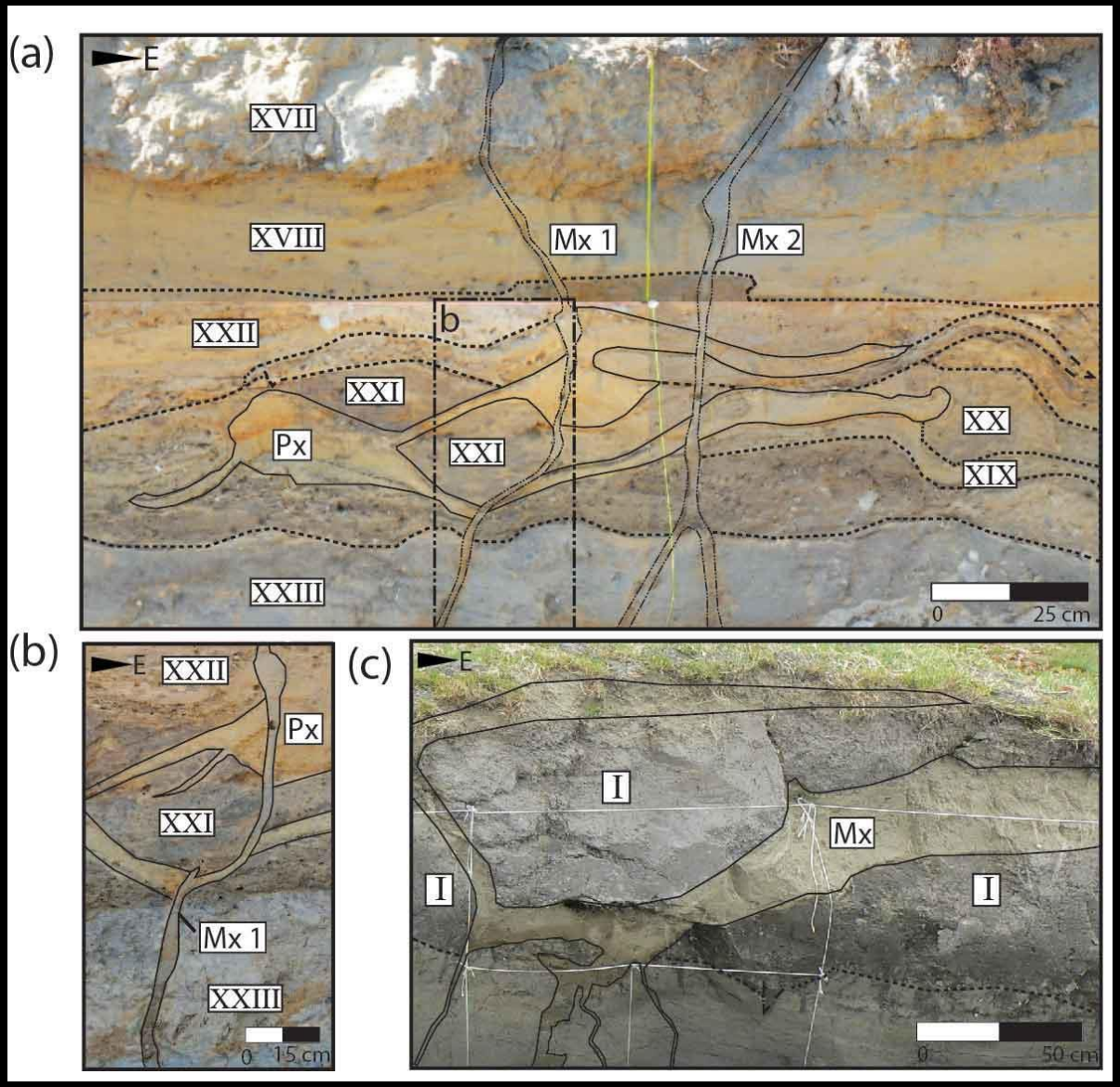
- CES dike cross-cuts paleo-sill likely 1901 liquefaction
- Inter-bedded compound paleo-sand blow dated as pre-1458
- Evidence for pre-historic earthquake clustering



Bastin et al. in review

Kirk St Reserve Liquefaction

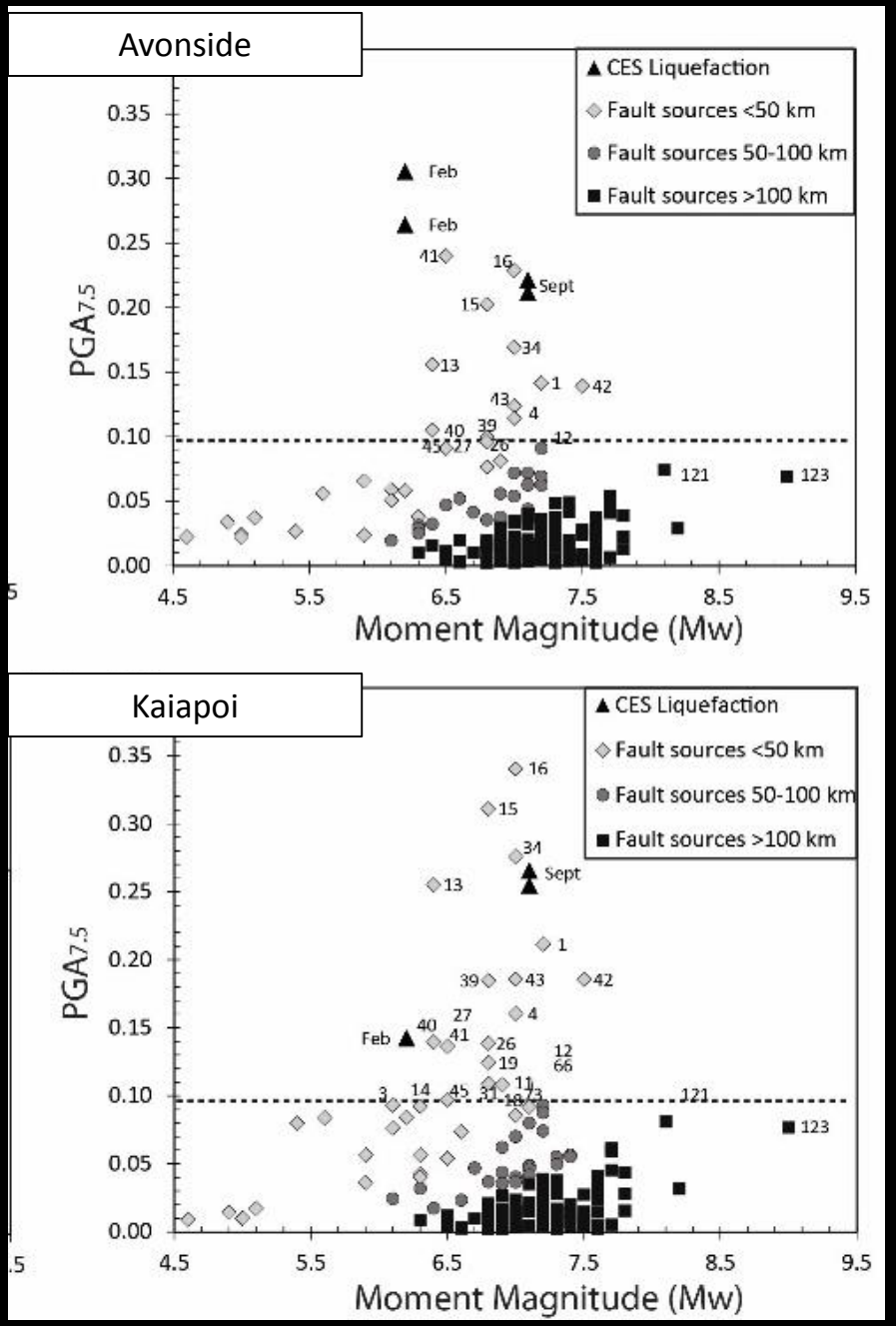
- Convolute bedding indicating deformation event (earthquake)
- Paleo-liquefaction inter-fingers stratigraphy and intrudes paleo-soil
- Consistent with CES surface blister
- Oxidised margin surrounding dike
- Dated at post-AD 1297 pre-1901 (?)



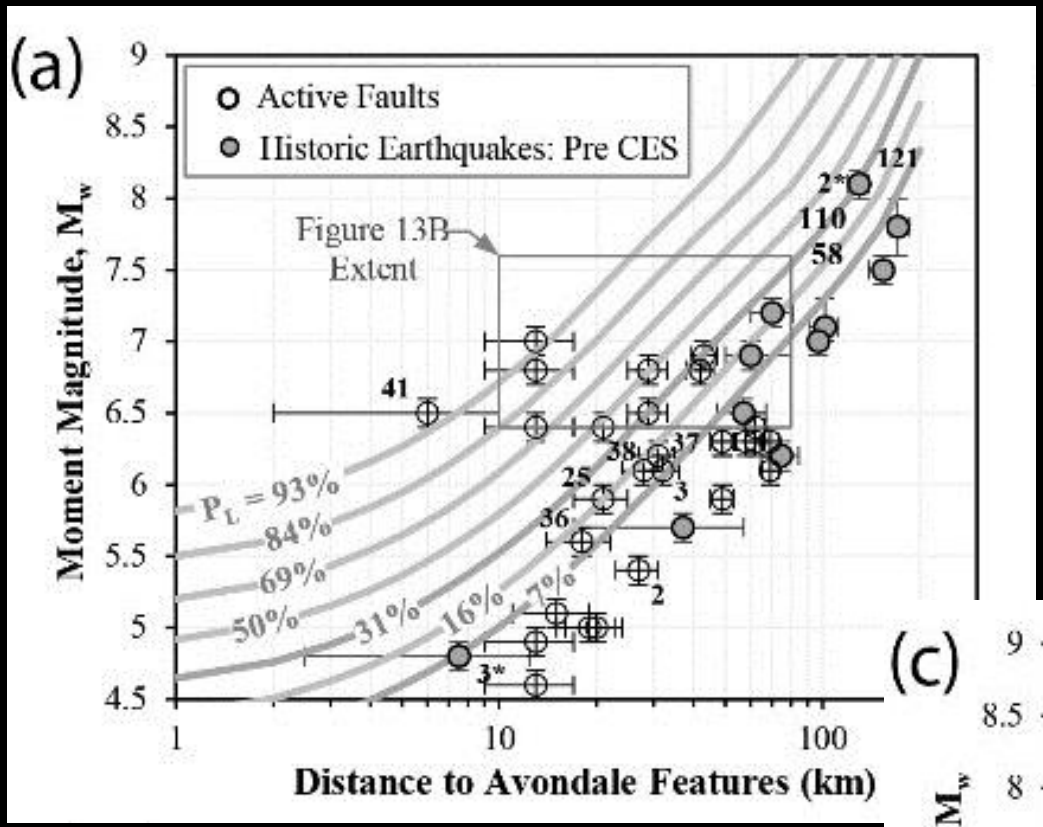
Bastin et al. in review

Possible Seismic Source

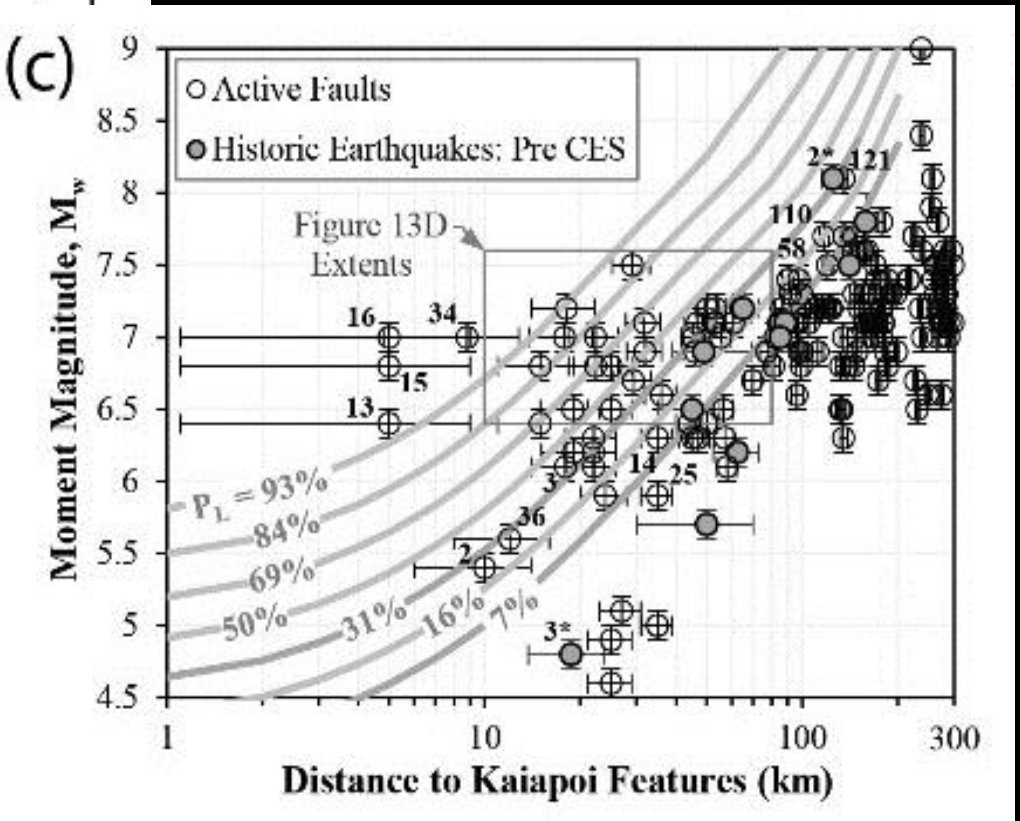
- Active faults within 50 km of Avondale & generate M_w >6.5 earthquakes likely to trigger widespread liquefaction
- North Canterbury and offshore faults within 50 km of Kaiapoi & generate M_w >5.5 earthquakes likely to trigger liquefaction
- Offshore Kaiapoi (15), Kaiapoi and Pegasus combined (16), Kaiapoi offshore (13) and Pegasus (34) faults all exceed the $PGA_{7.5}$ of the September 2010 earthquake in Kaiapoi



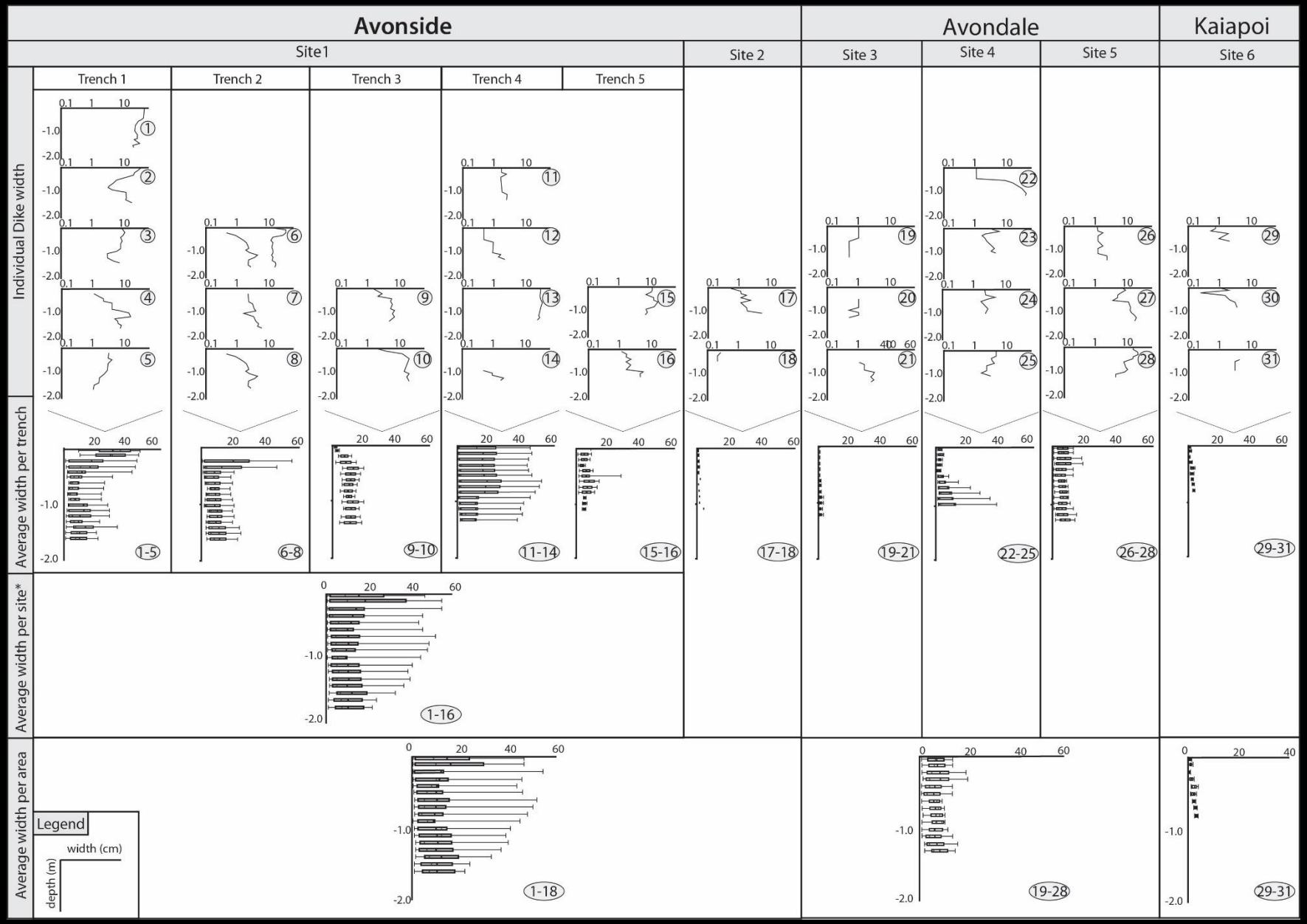
Bastin et al. in review



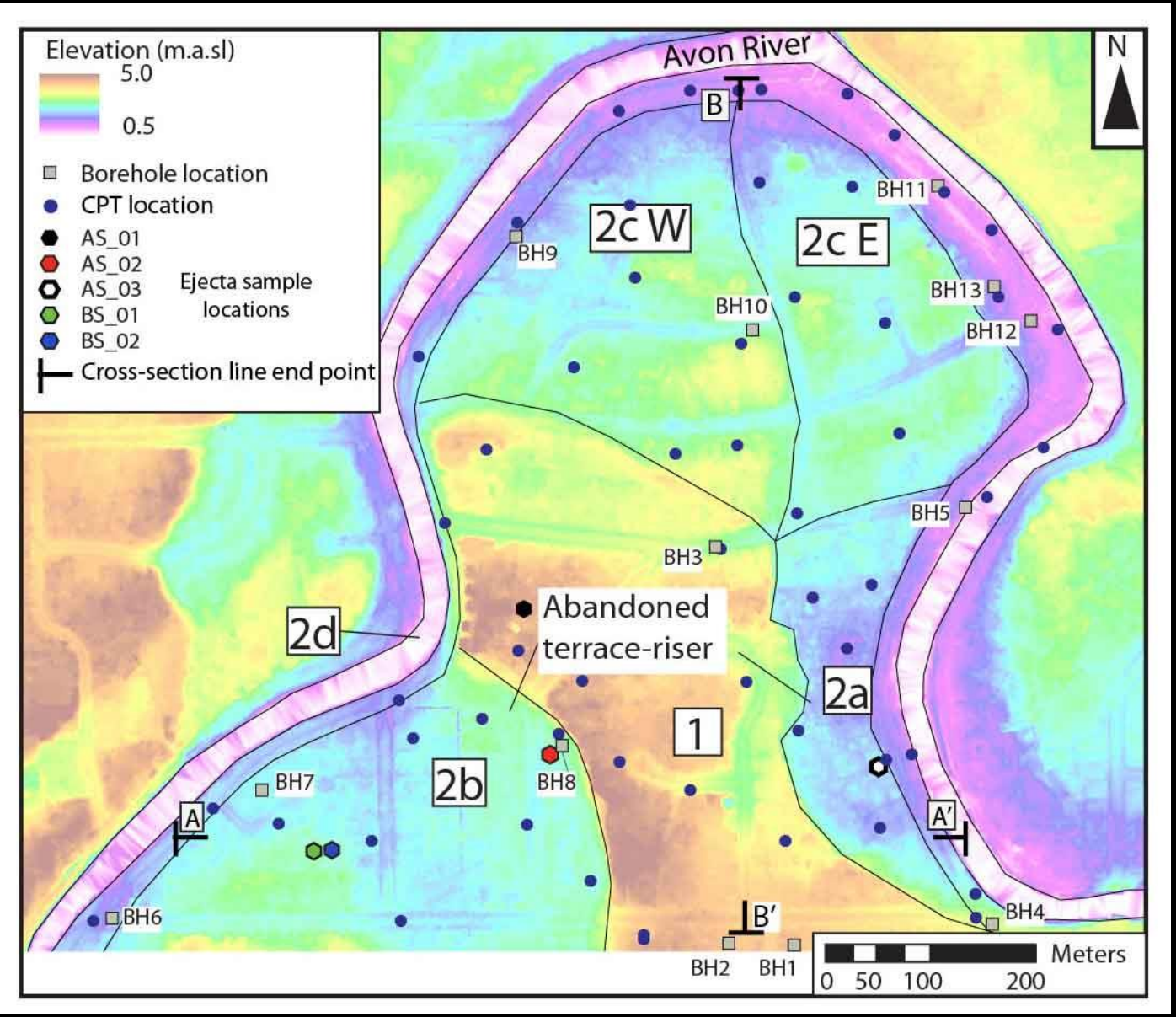
- Pegasus, Kaiapoi, and Ashley Faults likely to trigger widespread liquefaction in Avondale $P_L > 70\%$



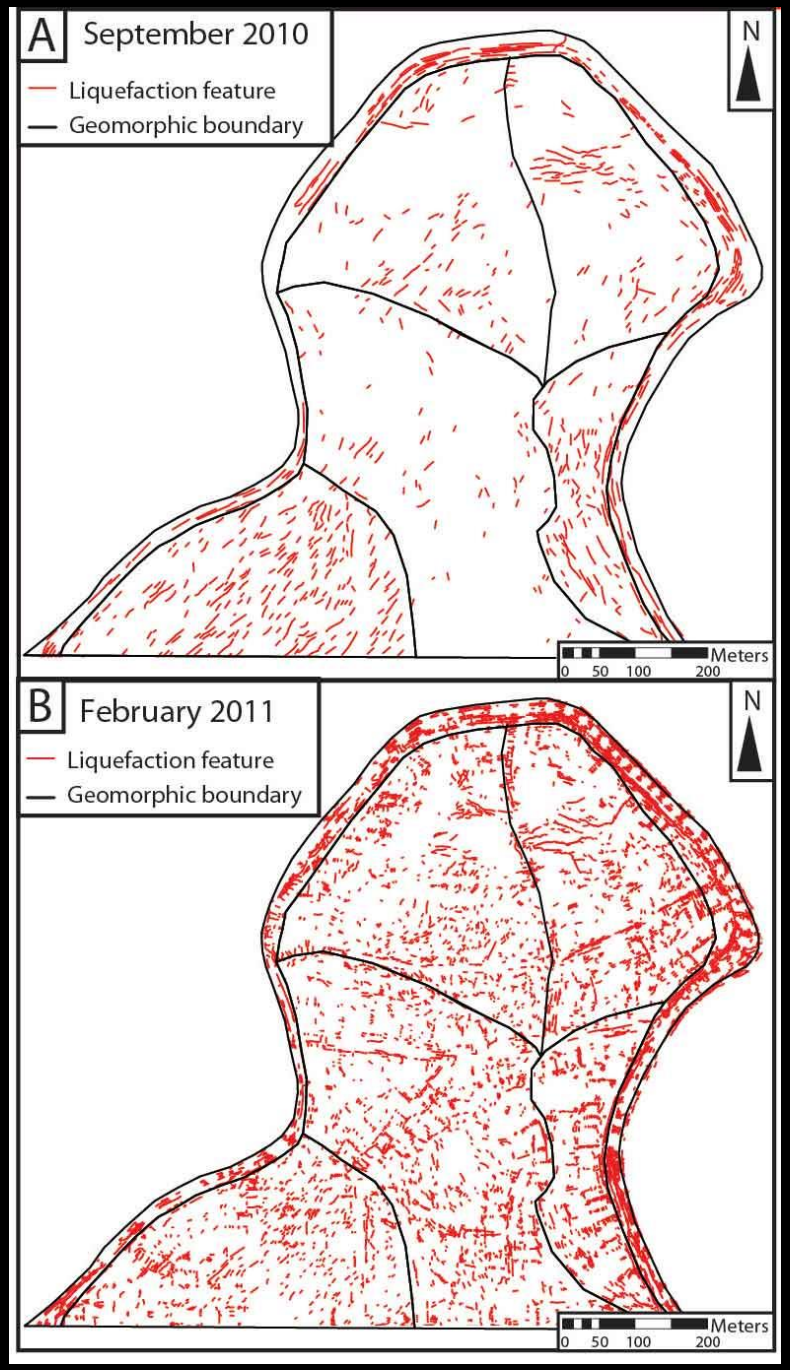
- Pegasus, Kaiapoi, Springbank, Porter's Pass, Ashley, and Cust Faults likely to trigger liquefaction in Kaiapoi ($P_L > 70\%$)

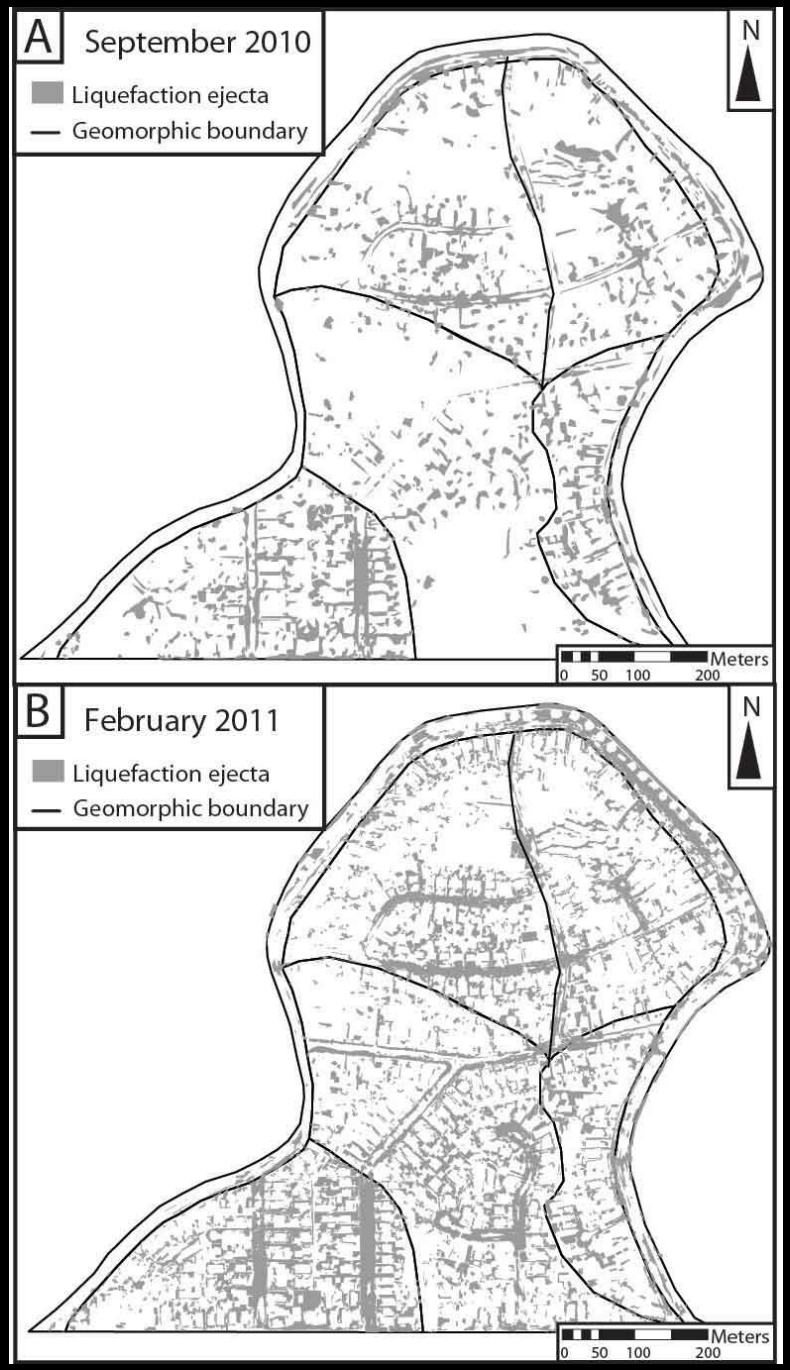

Avonside
Avondale
Kaiapoi
Site1
Site 2
Site 3
Site 4
Site 5
Site 6
Trench 1
Trench 2
Trench 3
Trench 4
Trench 5
Individual Dike width
Average width per trench
Average width per site*
Average width per area
1-5
6-8
9-10
11-14
15-16
17-18
19-21
22-25
26-28
29-31
1-16
1-18
19-28
29-31
Legend
width (cm)
depth (m)

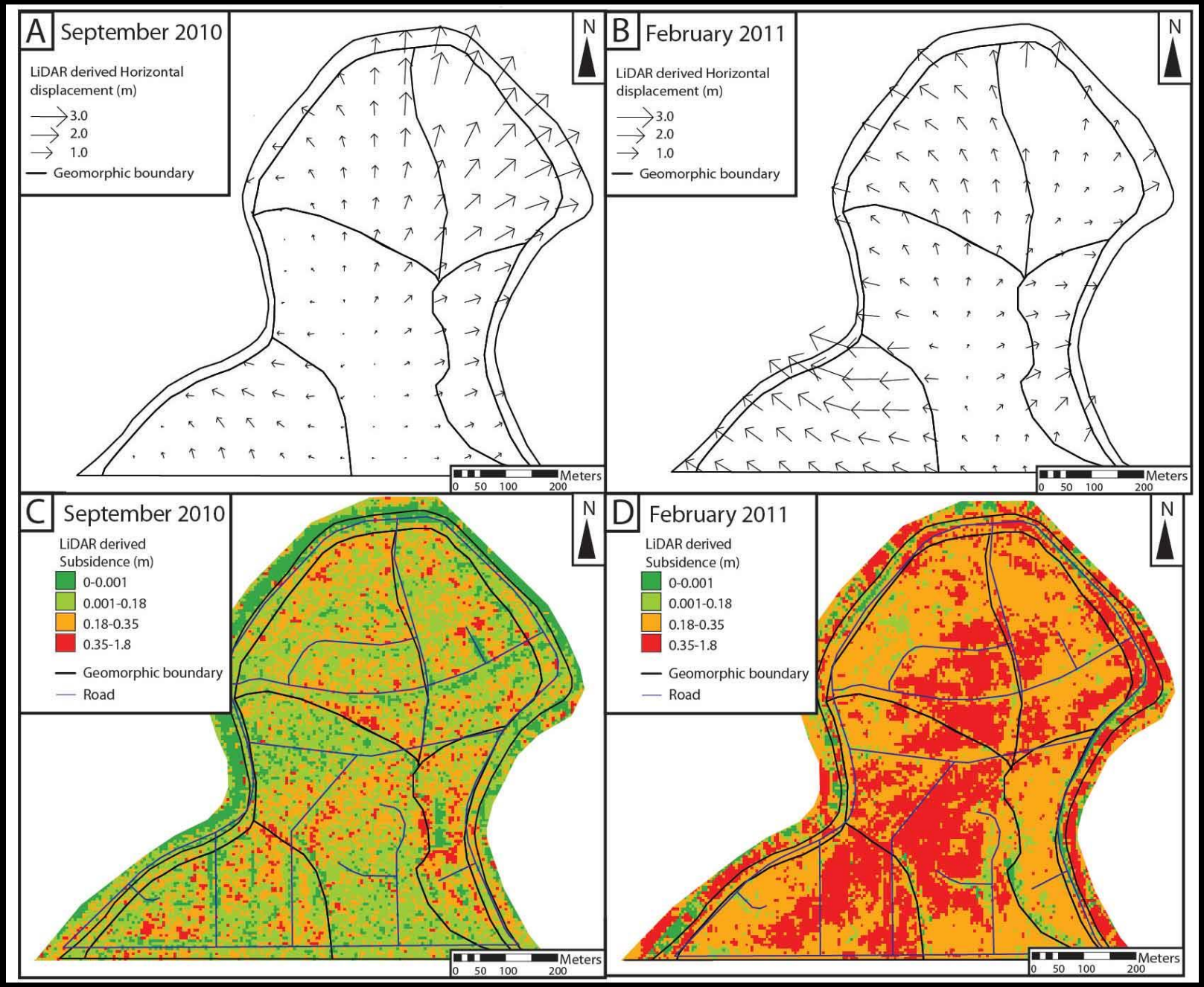
Geomorphic influences on liquefaction

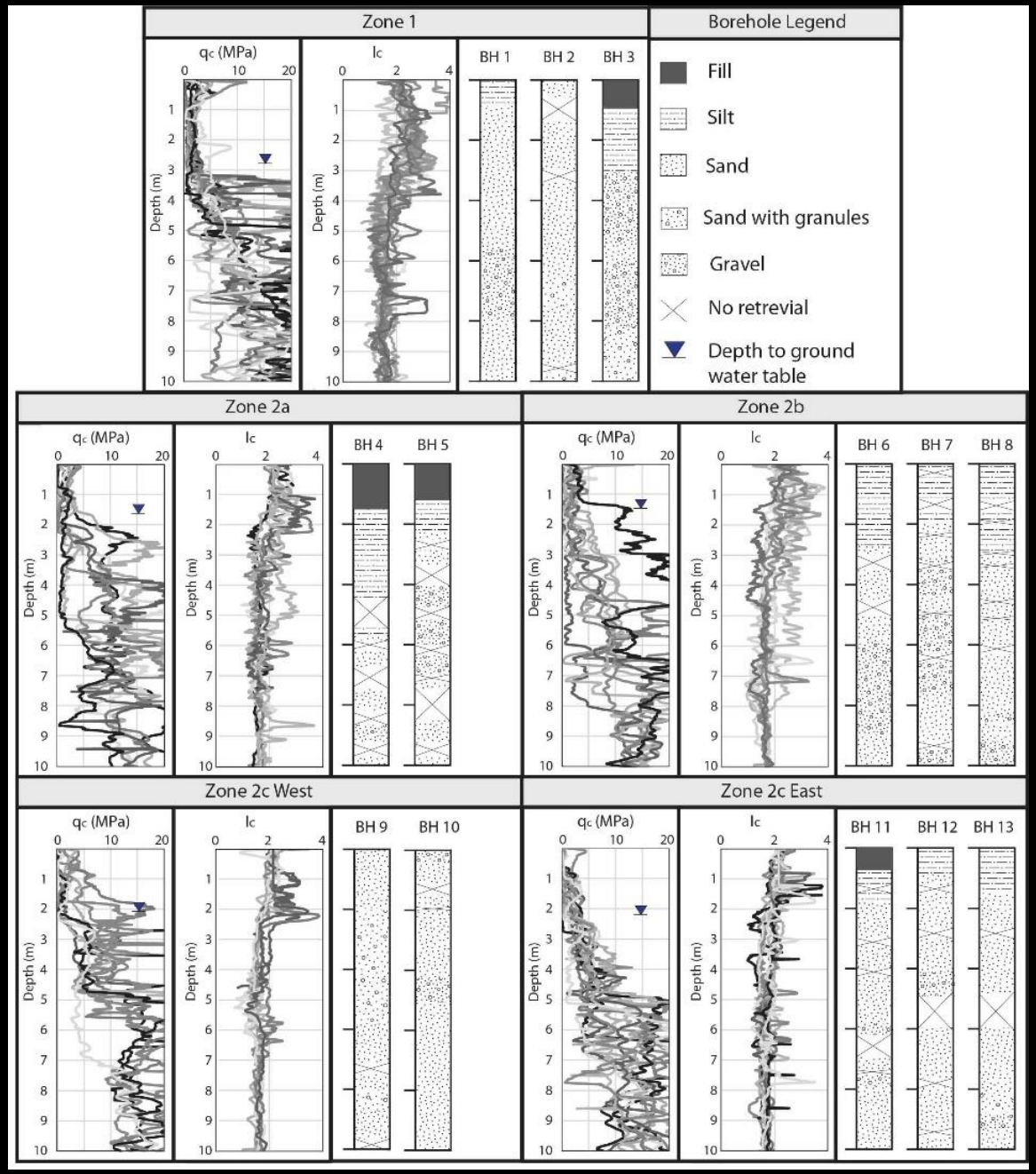


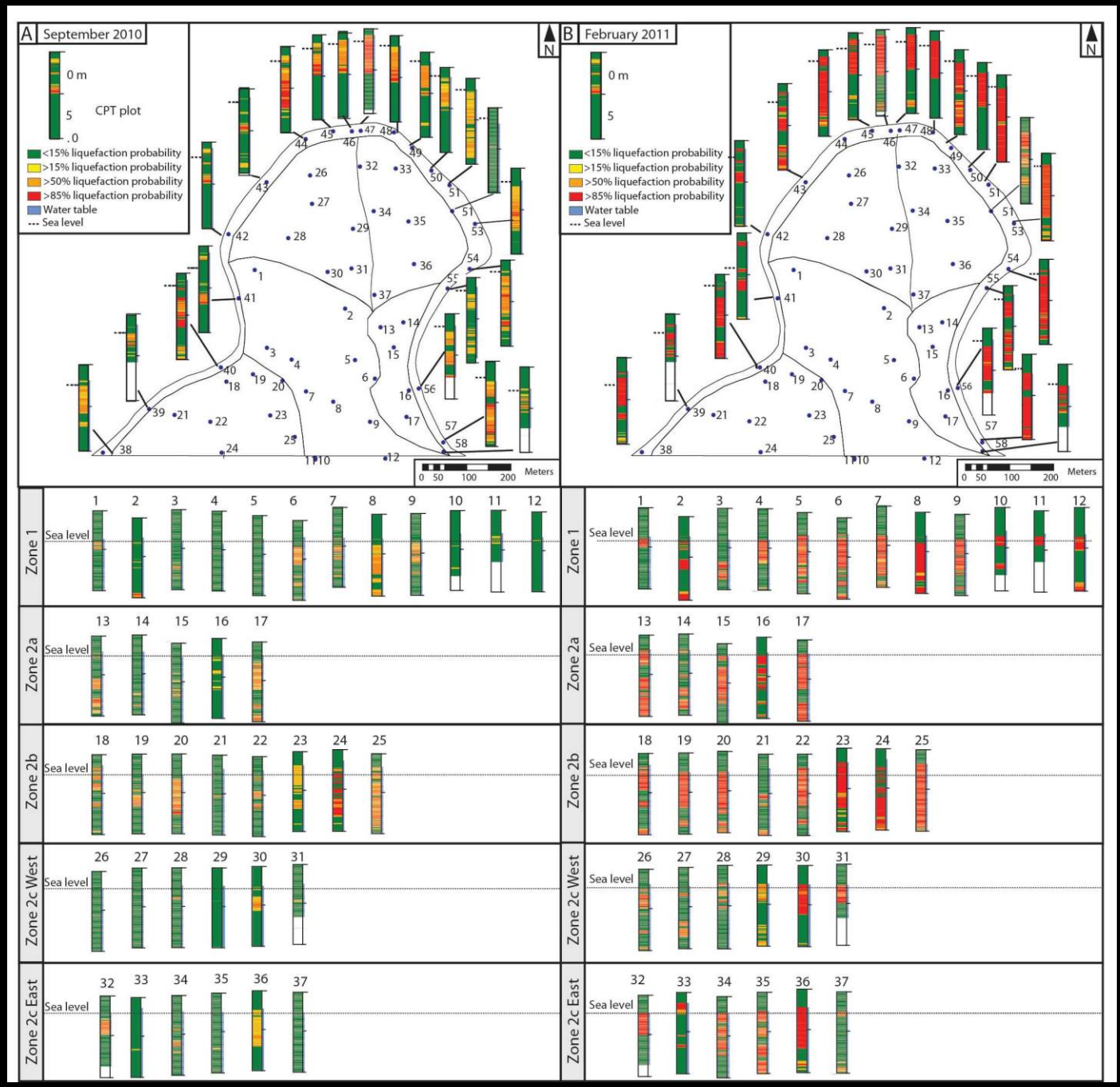
Bastin et al., in prep

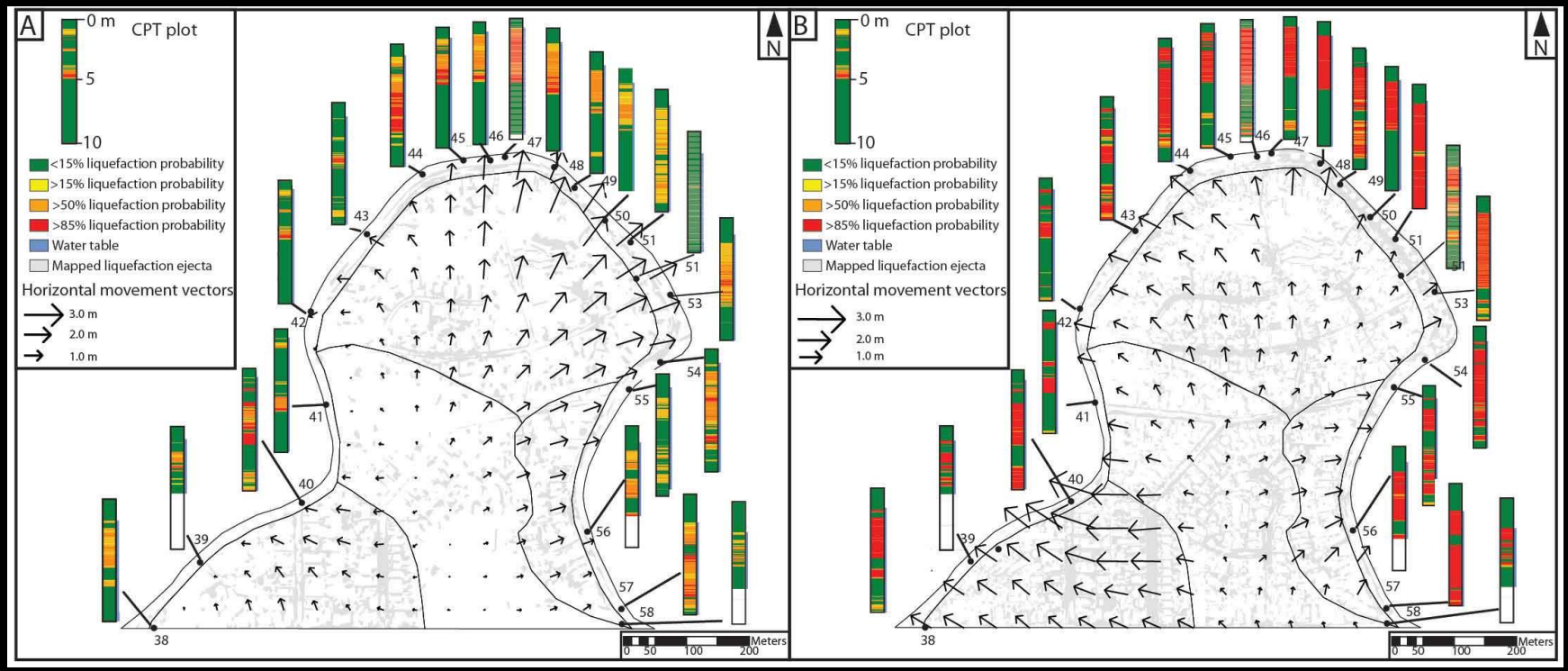

A
September 2010
Liquefaction feature
Geomorphic boundary
N
Meters
0 50 100 200
B
February 2011
Liquefaction feature
Geomorphic boundary
N
Meters
0 50 100 200


A
September 2010
Liquefaction ejecta
Geomorphic boundary
N
Meters
0 50 100 200
B
February 2011
Liquefaction ejecta
Geomorphic boundary
N
Meters
0 50 100 200

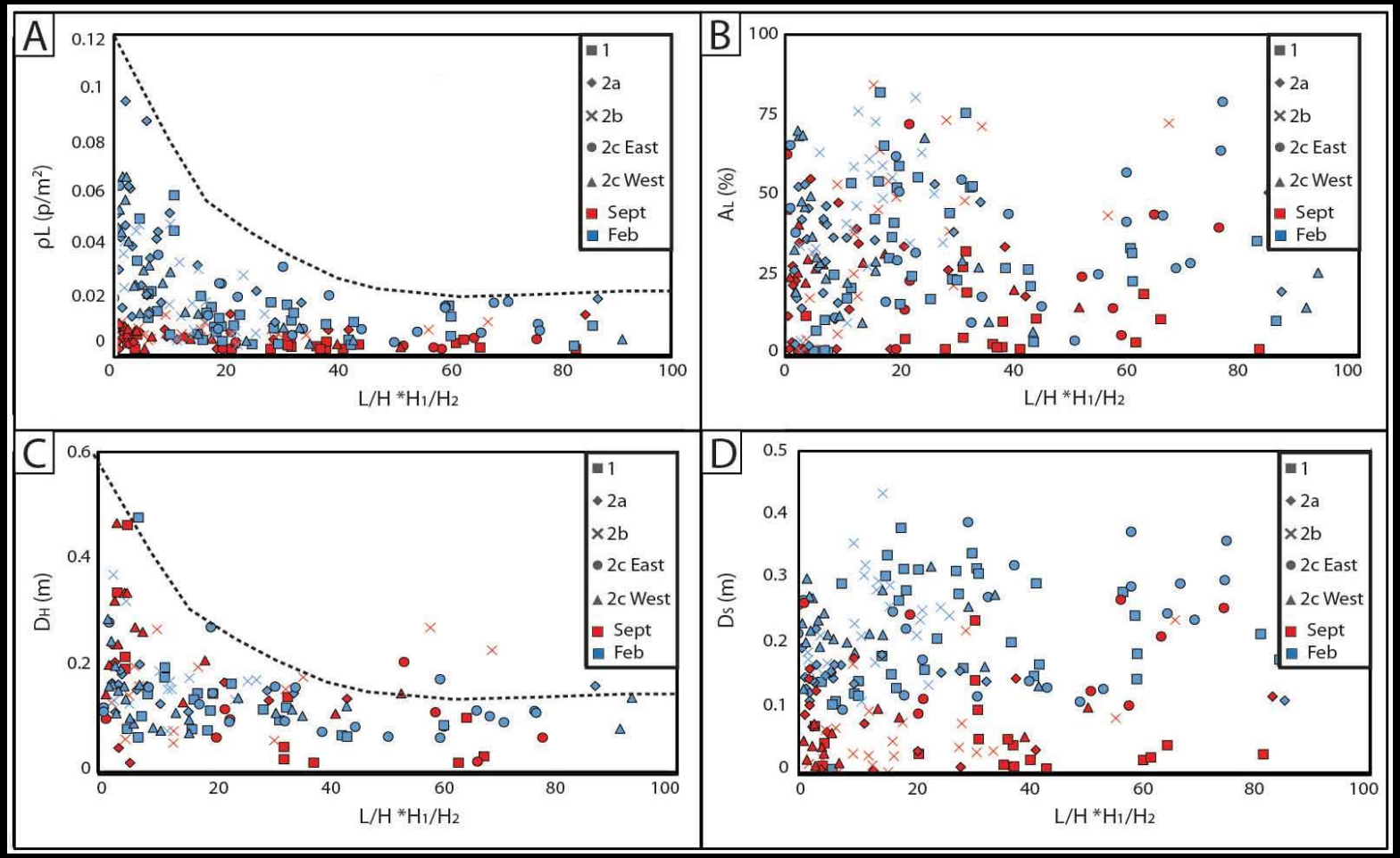

A
September 2010
LiDAR derived Horizontal displacement (m)
3.0
2.0
1.0
Geomorphic boundary
N
Meters
0 50 100 200
B
February 2011
LiDAR derived Horizontal displacement (m)
3.0
2.0
1.0
Geomorphic boundary
N
Meters
0 50 100 200
C
September 2010
LiDAR derived Subsidence (m)
0-0.001
0.001-0.18
0.18-0.35
0.35-1.8
Geomorphic boundary
Road
N
Meters
0 50 100 200
D
February 2011
LiDAR derived Subsidence (m)
0-0.001
0.001-0.18
0.18-0.35
0.35-1.8
Geomorphic boundary
Road
N
Meters
0 50 100 200


Zone 1
Borehole Legend
qc (MPa)
Ic
Depth (m)
BH 1
BH 2
BH 3
Fill
Silt
Sand
Sand with granules
Gravel
No retrevial
Depth to ground water table
Zone 2a
BH 4
BH 5
Zone 2b
BH 6
BH 7
BH 8
Zone 2c West
BH 9
BH 10
Zone 2c East
BH 11
BH 12
BH 13


A September 2010
0 m
5
CPT plot
.0
<15% liquefaction probability
>15% liquefaction probability
>50% liquefaction probability
>85% liquefaction probability
Water table
Sea level
N
0 50 100 200 Meters
B February 2011
0 m
5
<15% liquefaction probability
>15% liquefaction probability
>50% liquefaction probability
>85% liquefaction probability
Water table
Sea level
N
0 50 100 200 Meters
Zone 1
Sea level
1 2 3 4 5 6 7 8 9 10 11 12
Zone 2a
Sea level
13 14 15 16 17
Zone 2b
Sea level
18 19 20 21 22 23 24 25
Zone 2c West
Sea level
26 27 28 29 30 31
Zone 2c East
Sea level
32 33 34 35 36 37


A
0 m
5
10
CPT plot
<15% liquefaction probability
>15% liquefaction probability
>50% liquefaction probability
>85% liquefaction probability
Water table
Mapped liquefaction ejecta
Horizontal movement vectors
3.0 m
2.0 m
1.0 m
N
38
39
40
41
42
43
44
45
46
47
48
49
50
51
51
53
54
55
56
57
58
0 50 100 200
Meters
B
0 m
5
10
CPT plot
<15% liquefaction probability
>15% liquefaction probability
>50% liquefaction probability
>85% liquefaction probability
Water table
Mapped liquefaction ejecta
Horizontal movement vectors
3.0 m
2.0 m
1.0 m
N
38
39
40
41
42
43
44
45
46
47
48
49
50
51
51
53
54
55
56
57
58
0 50 100 200
Meters

Geomorphic influences on liquefaction



Overall Conclusions

- Eastern Christchurch has previously liquefied
- Modelling of PGA and back-calculated magnitude-bound curves indicates many faults capable of triggering liquefaction at highly susceptible sites
- Geologic and geomorphic variability significantly influences liquefaction susceptibility and observed ground damage