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Evaluation of Liquefaction Case Histories from the 2010-2011 Canterbury Earthquakes using Advanced Effective Stress Analysis

UC University of Canterbury
The University of Auckland New Zealand
Resilient Organisations
GNS Science
Massey University
Te Whare Wānanga o te Upoko o te Ika a Maui Victoria University of Wellington
The University of Waikato Te Whare Wānanga o Waikato
BRANZ

Publications

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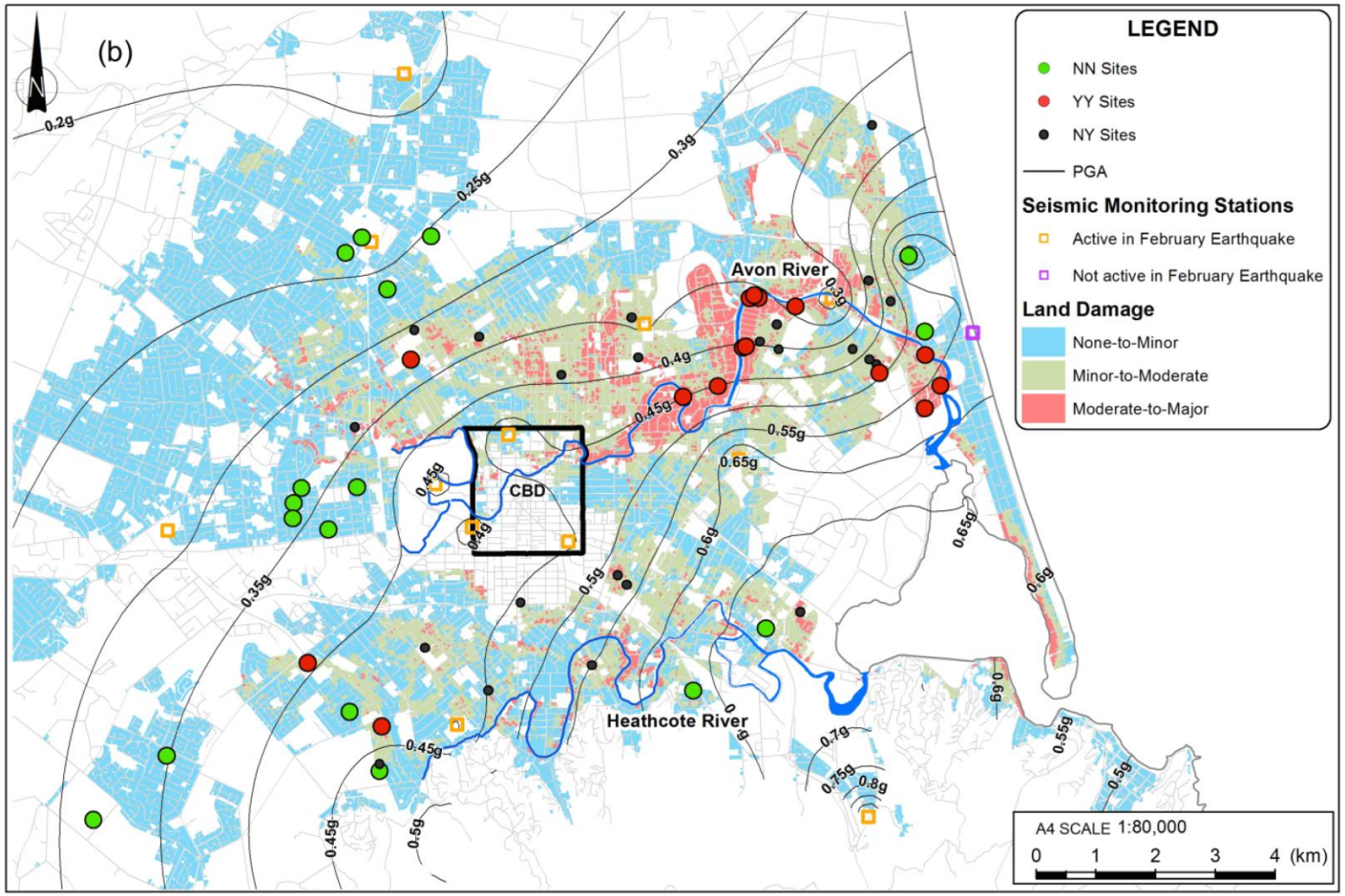
(1) Cubrinovski, M., Rhodes, A., Ntritsos, N. & van Ballegooy S. (2017). "**System response of liquefiable deposits**." *PBDIII Earthquake Geotechnical Engineering*, Vancouver, Canada.

(2) Cubrinovski, M., Rhodes, A., Ntritsos, N. & van Ballegooy S. (2017). "**System response of liquefiable deposits**." *Soil Dynamics and Earthquake Engineering* (submitted).

(3) Ntritsos, N., Cubrinovski, M. & Rhodes A. (2018). "**Evaluation of liquefaction case histories from the 2010-2011 Canterbury earthquakes using advanced effective stress analysis**." *5th GEESD Conf.*, Austin, Texas (accepted).

(4) Ntritsos, N. & Cubrinovski, M. (2018). "**A probabilistic framework for assessing liquefaction damage in urban areas: application to Christchurch (NZ)**." *16th European Conf. on Earthquake Eng.*, Thessaloniki, Greece (accepted).

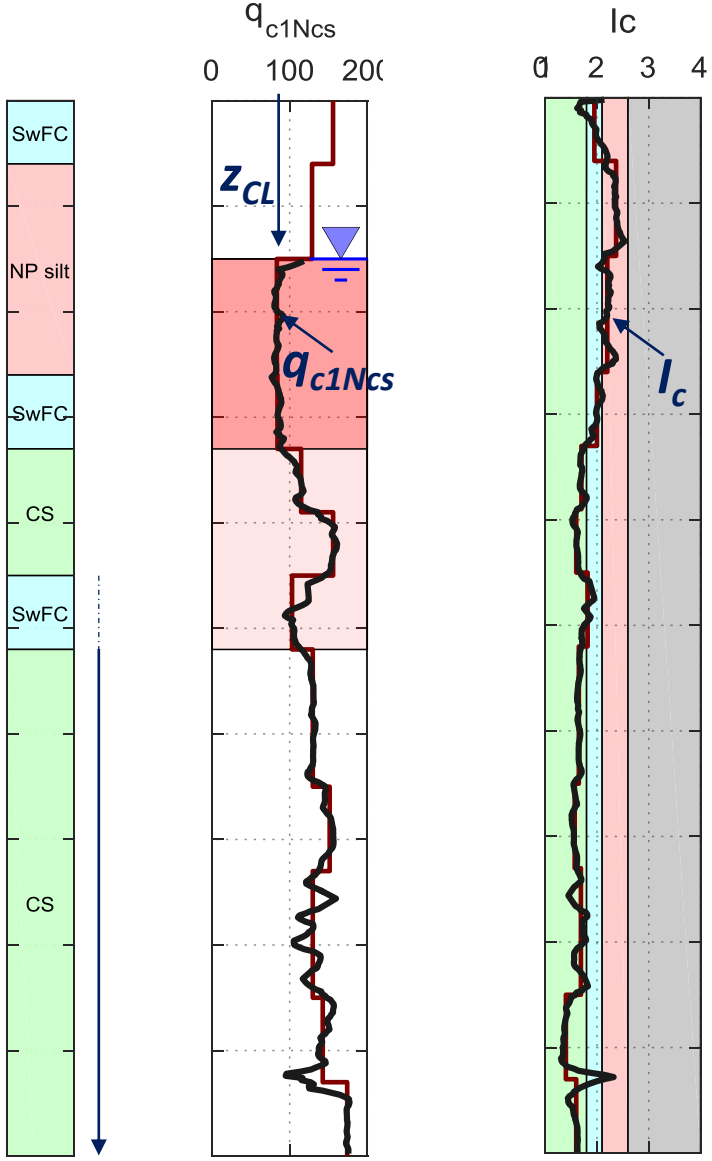
55 Christchurch sites

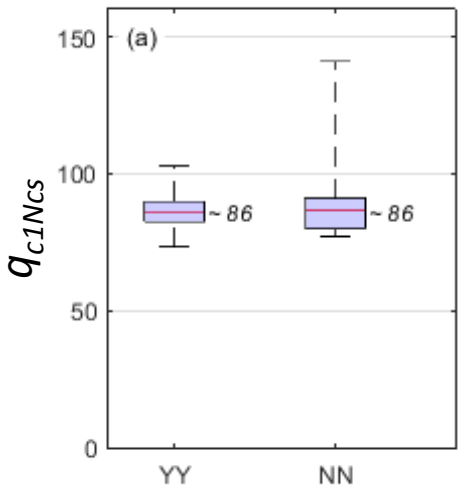


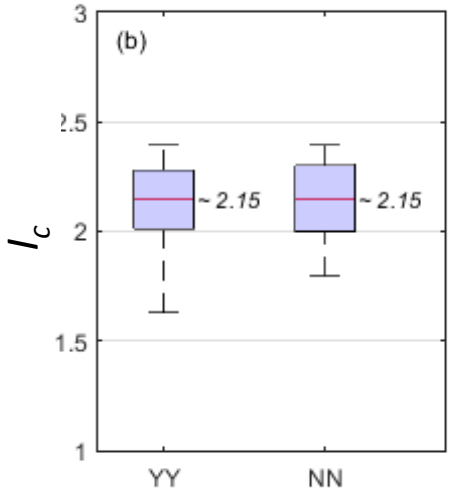
Liquefaction manifestation	Earthquake	
	4SEP2010	4FEB2011
YY (15 sites)	Yes	Yes
NY (23 sites)	No	Yes
NN (17 sites)	No	No

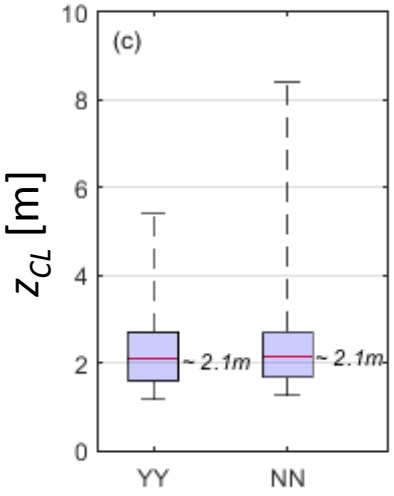
Locations of 55 investigated sites and land damage caused by the 22 February 2011 earthquake

“Critical layer” characteristics









“YY” vs “NN” typical profiles

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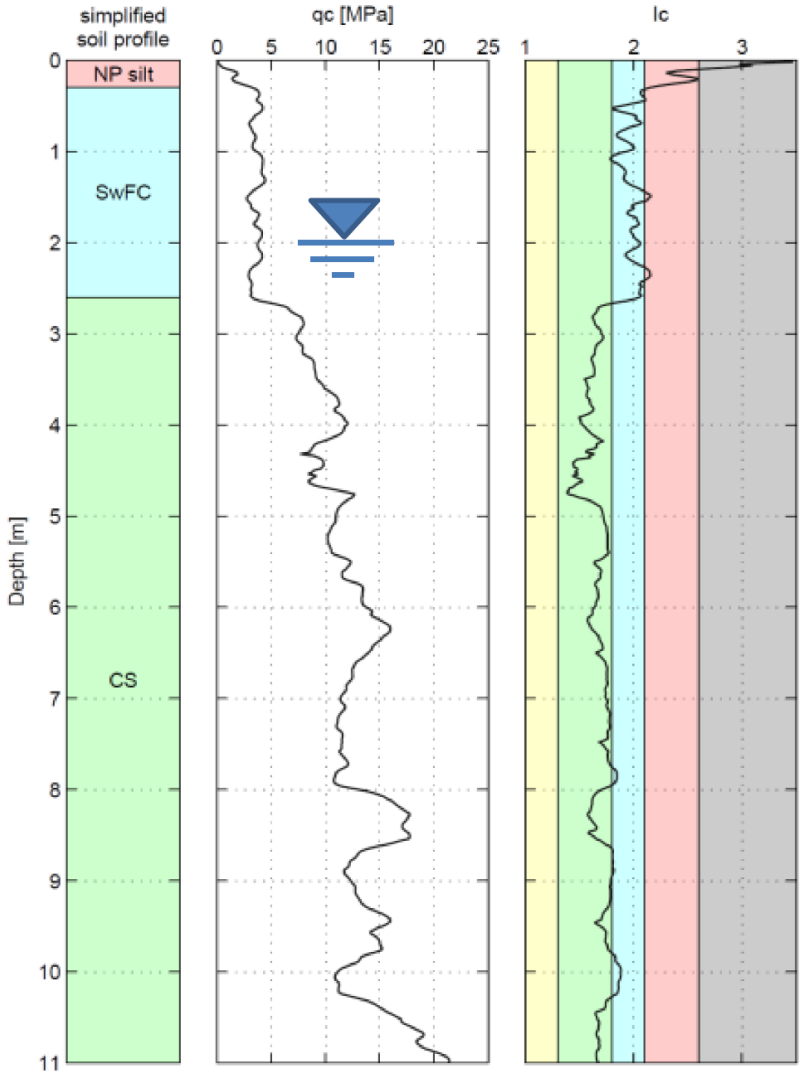
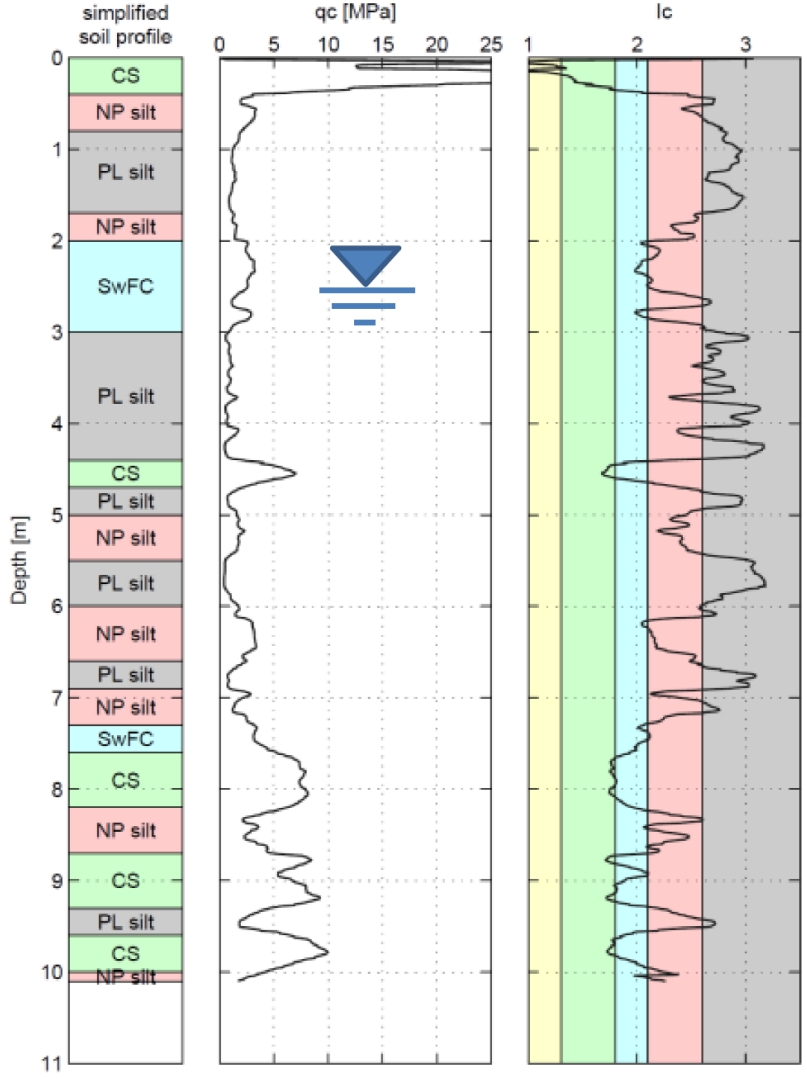
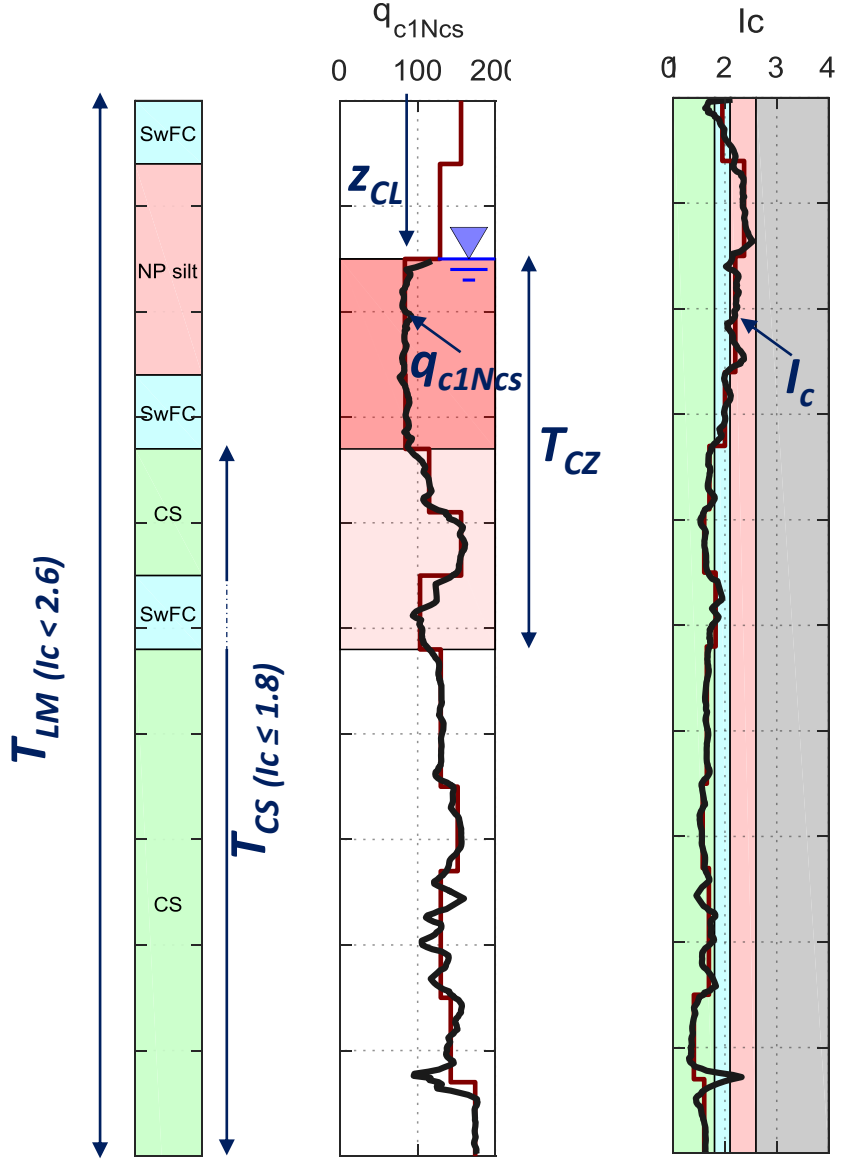
YY - Manifested liquefaction in both earthquakes

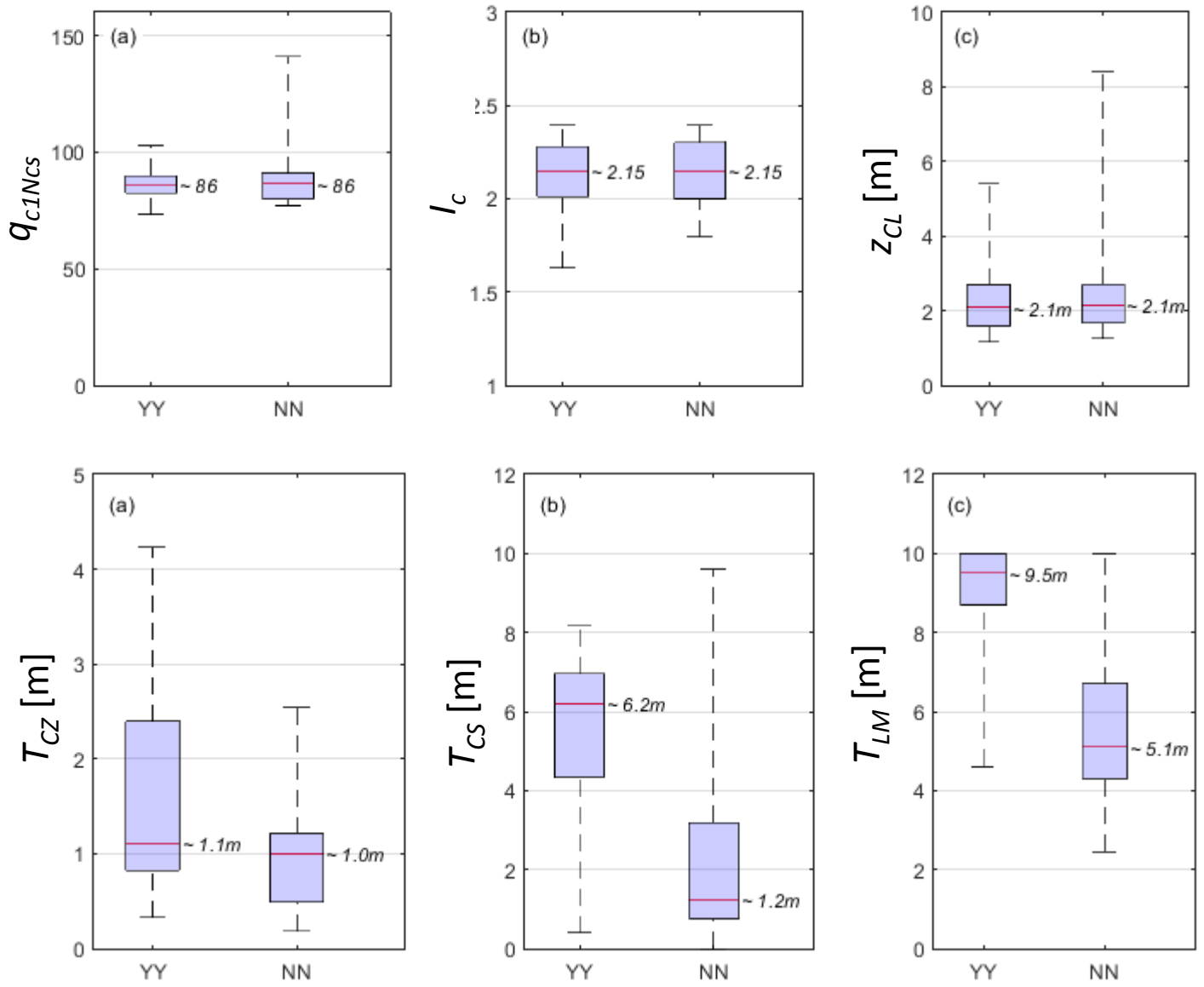


NN - Did not manifest liquefaction in either event

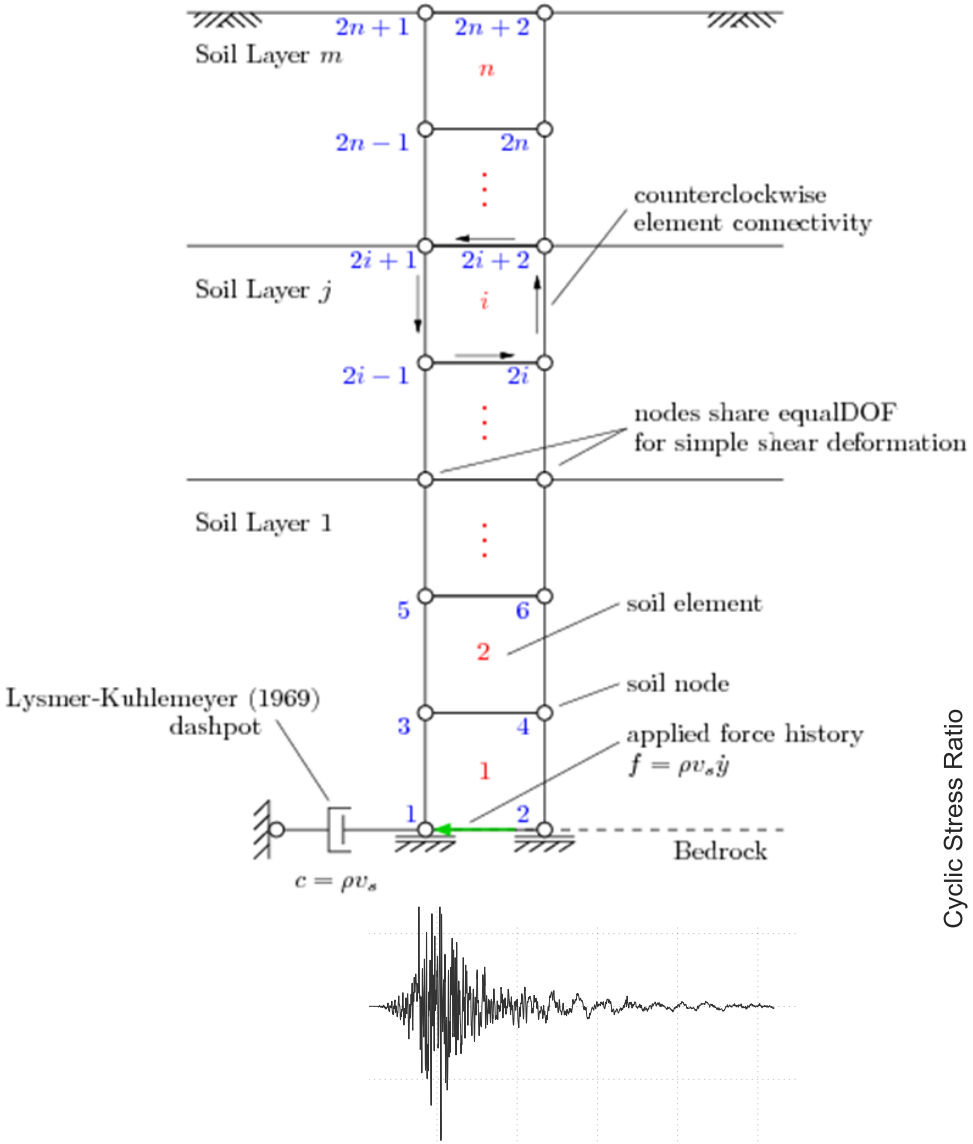


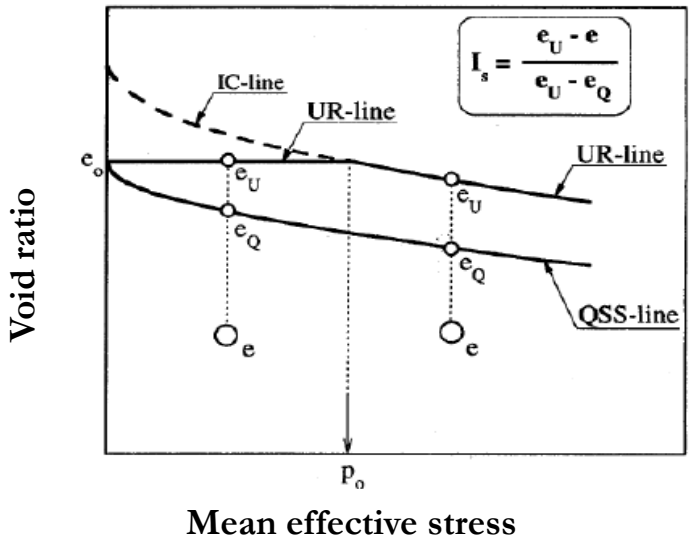
“Critical layer” vs Deposit characteristics

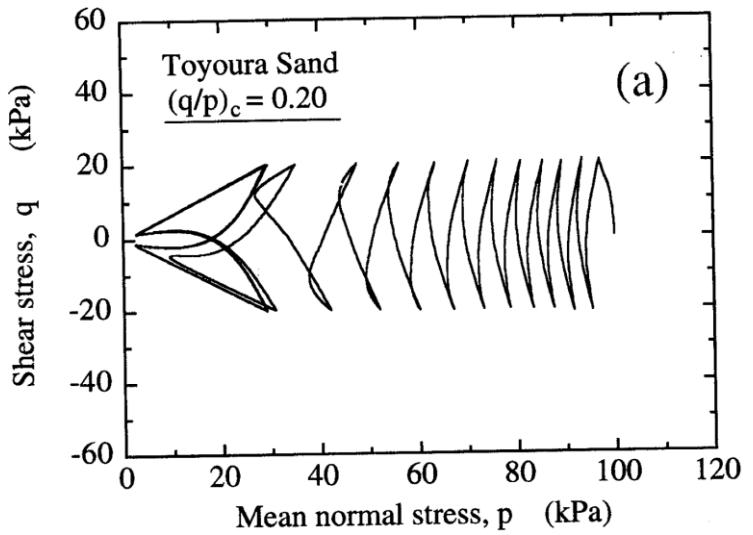


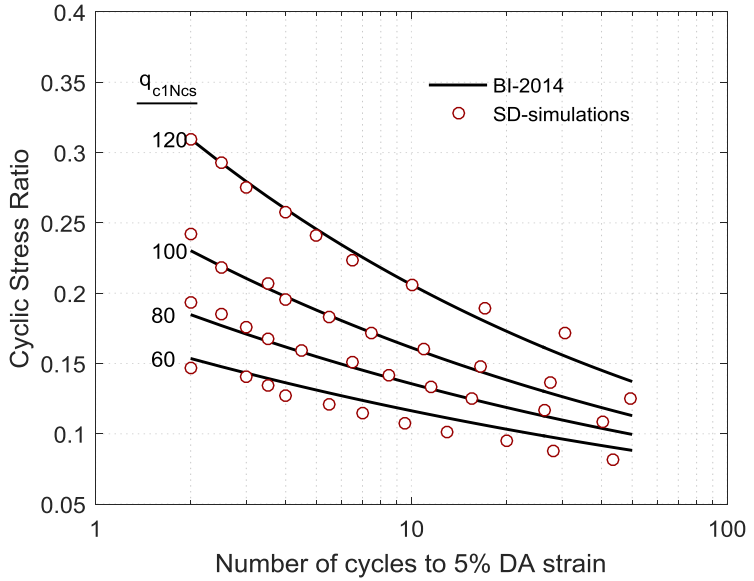


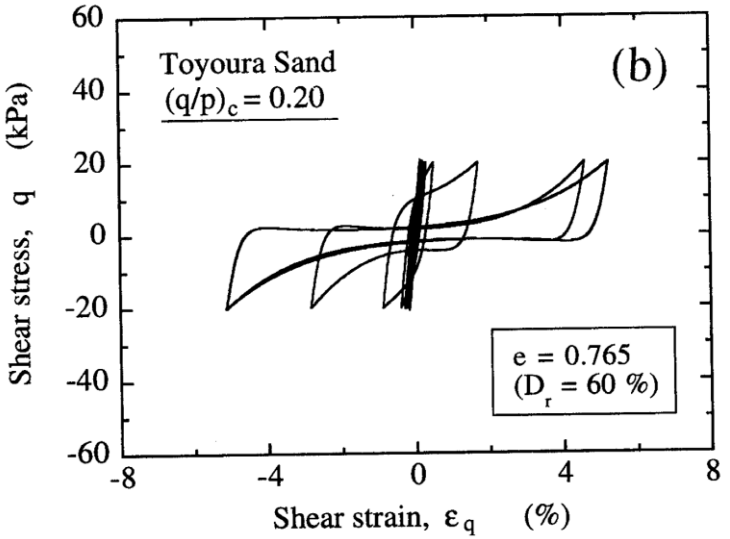
Seismic Effective Stress Analysis











System response of YY- deposits

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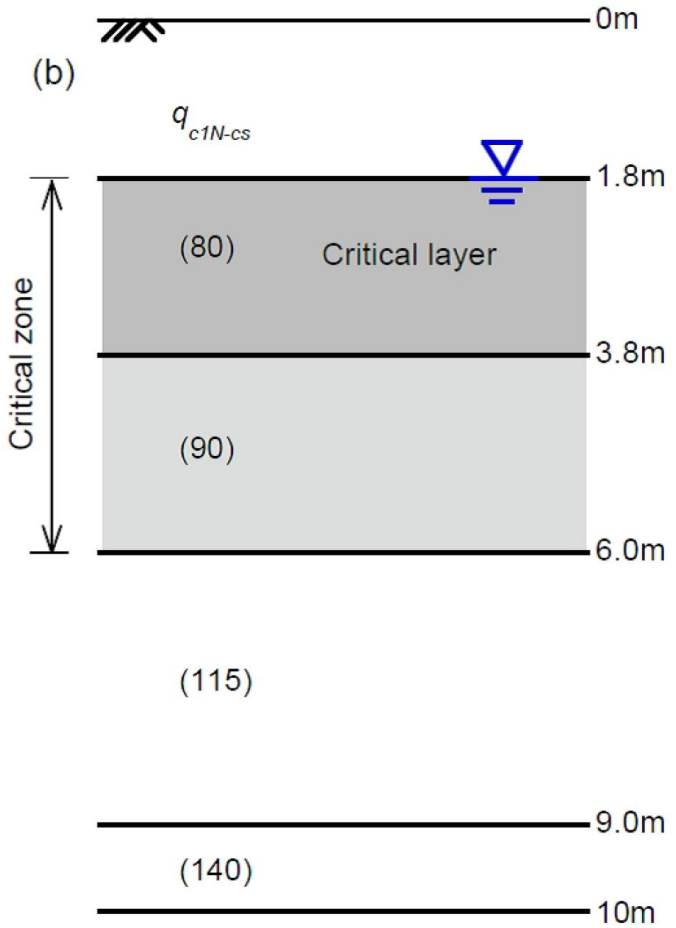
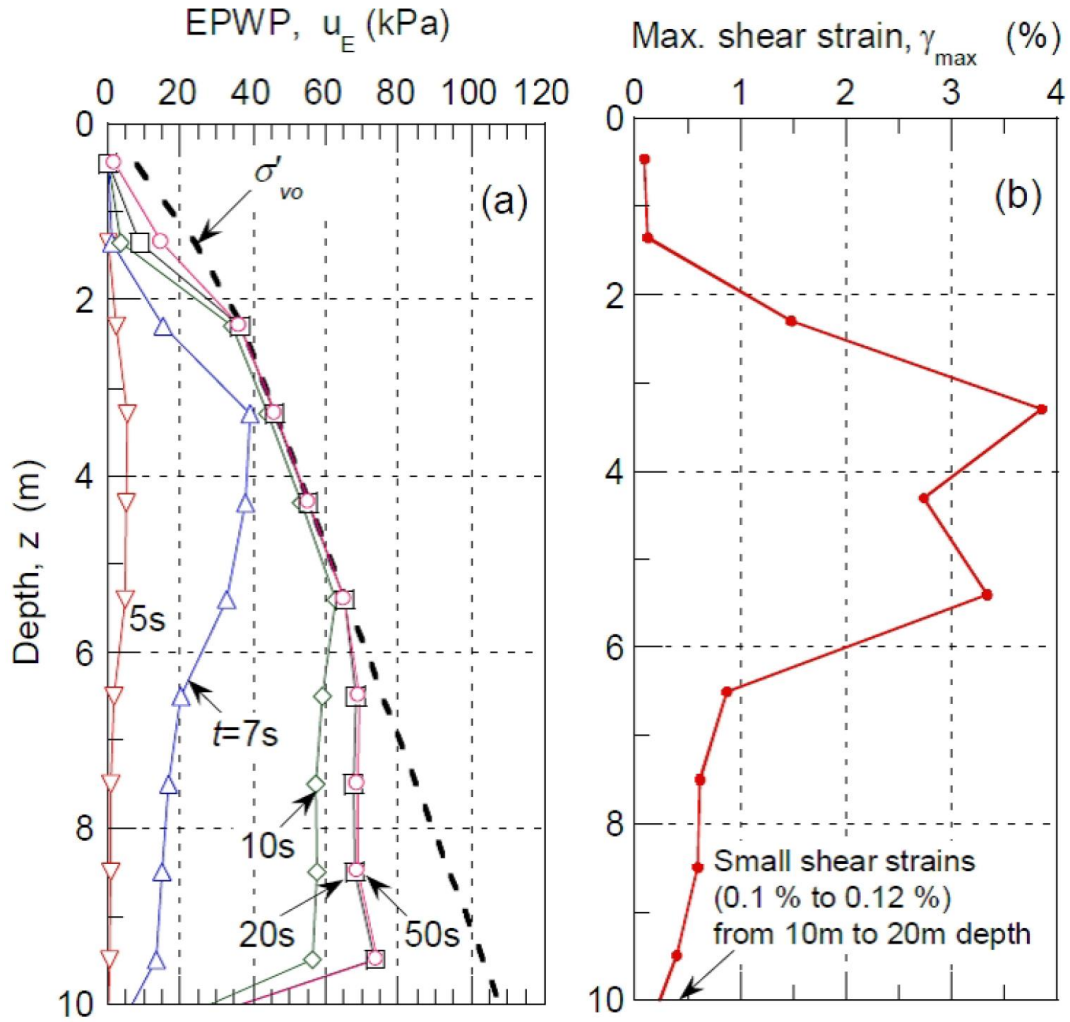
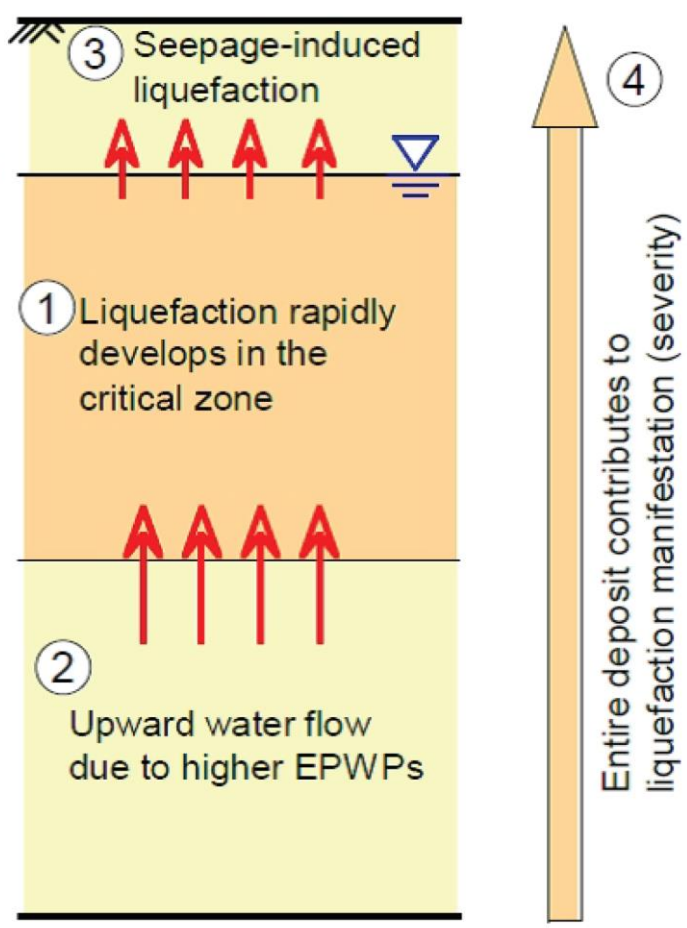
Typical YY profile



Effective stress analysis results



System–response mechanisms



System response of NN- deposits

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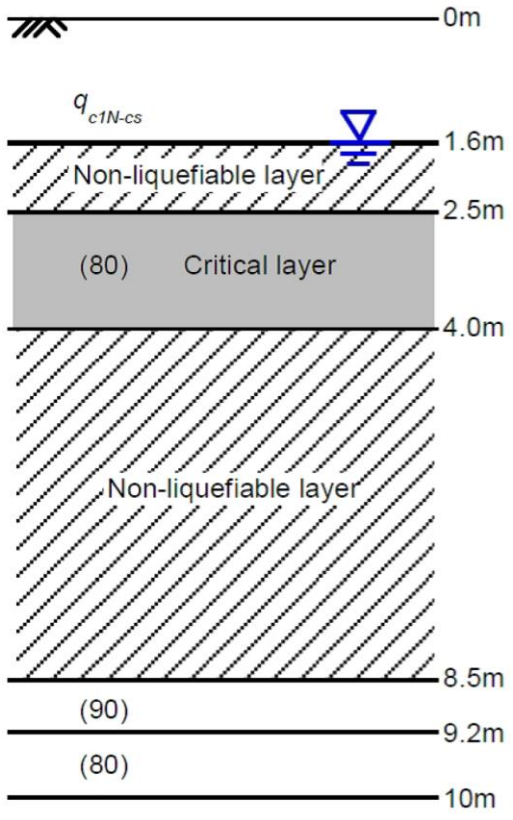
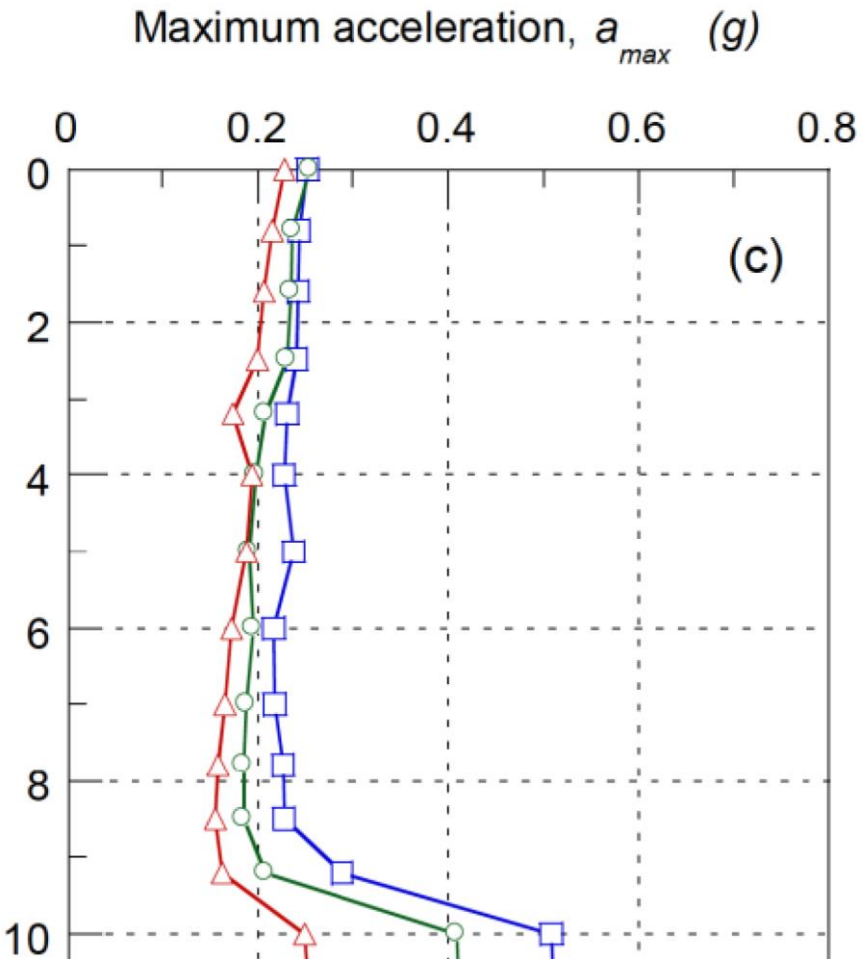
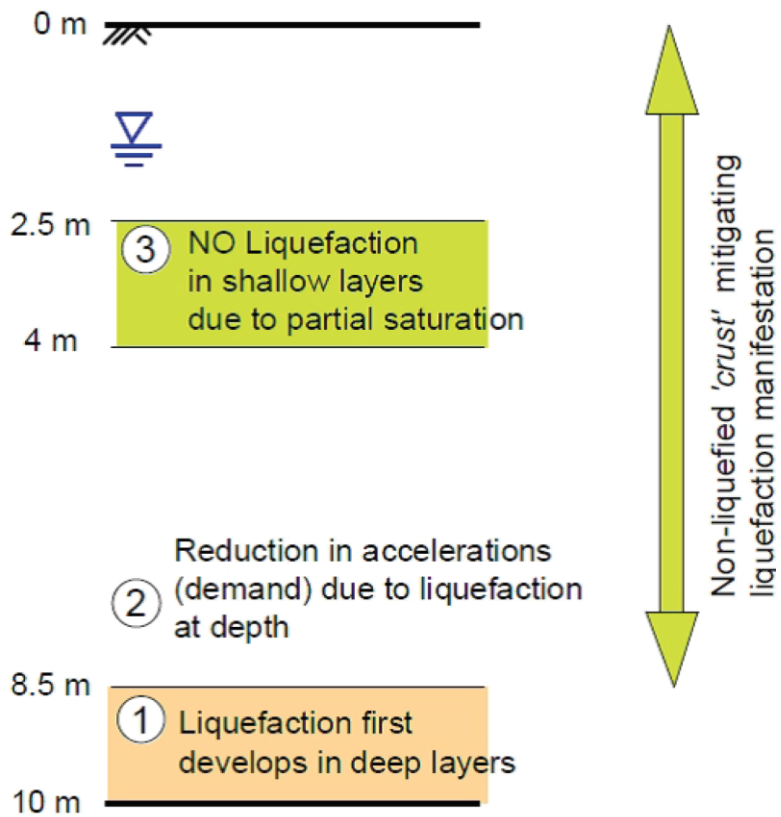
Typical NN profile



Effective stress analysis results



System–response mechanisms

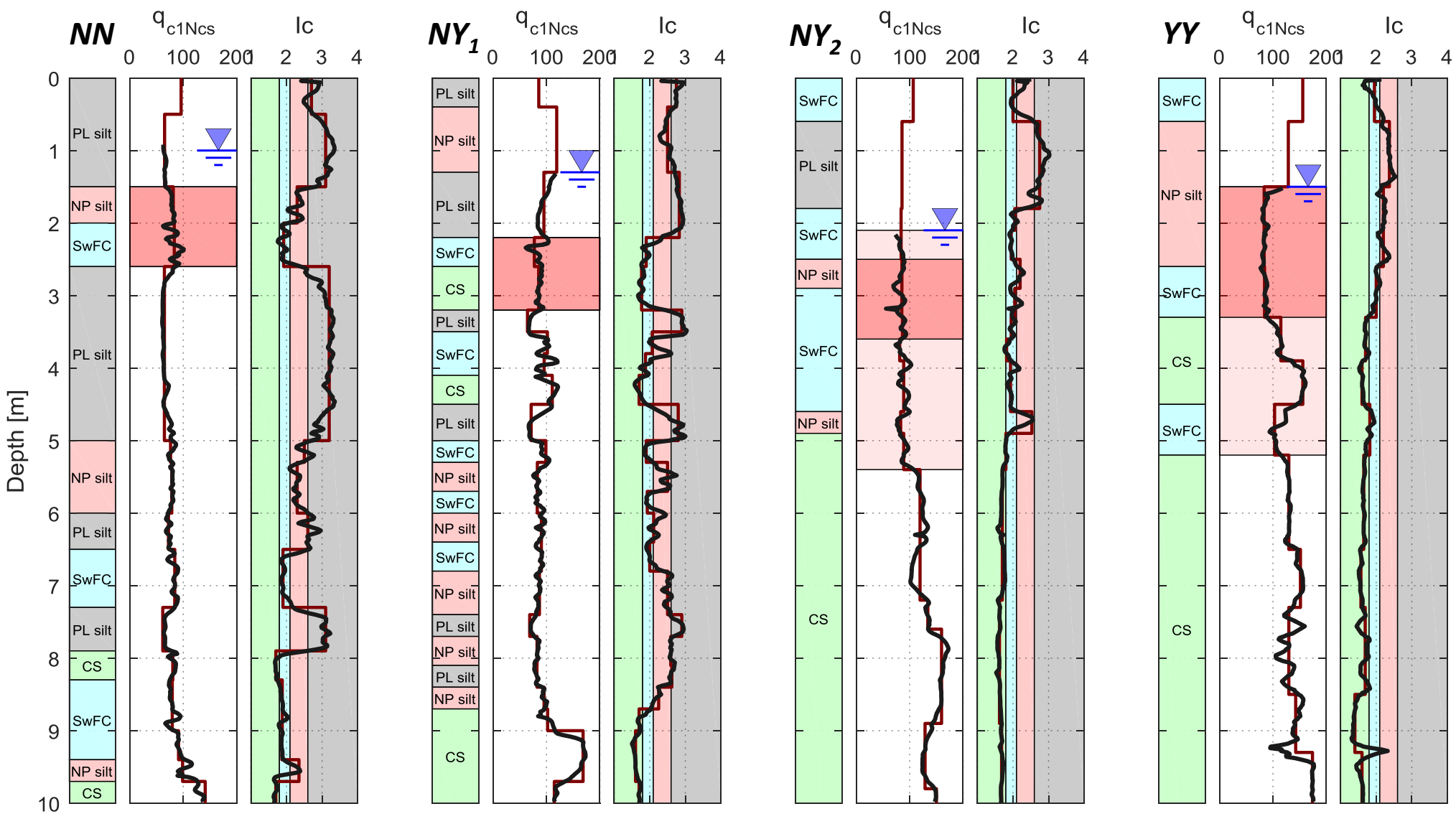


Series of Analyses

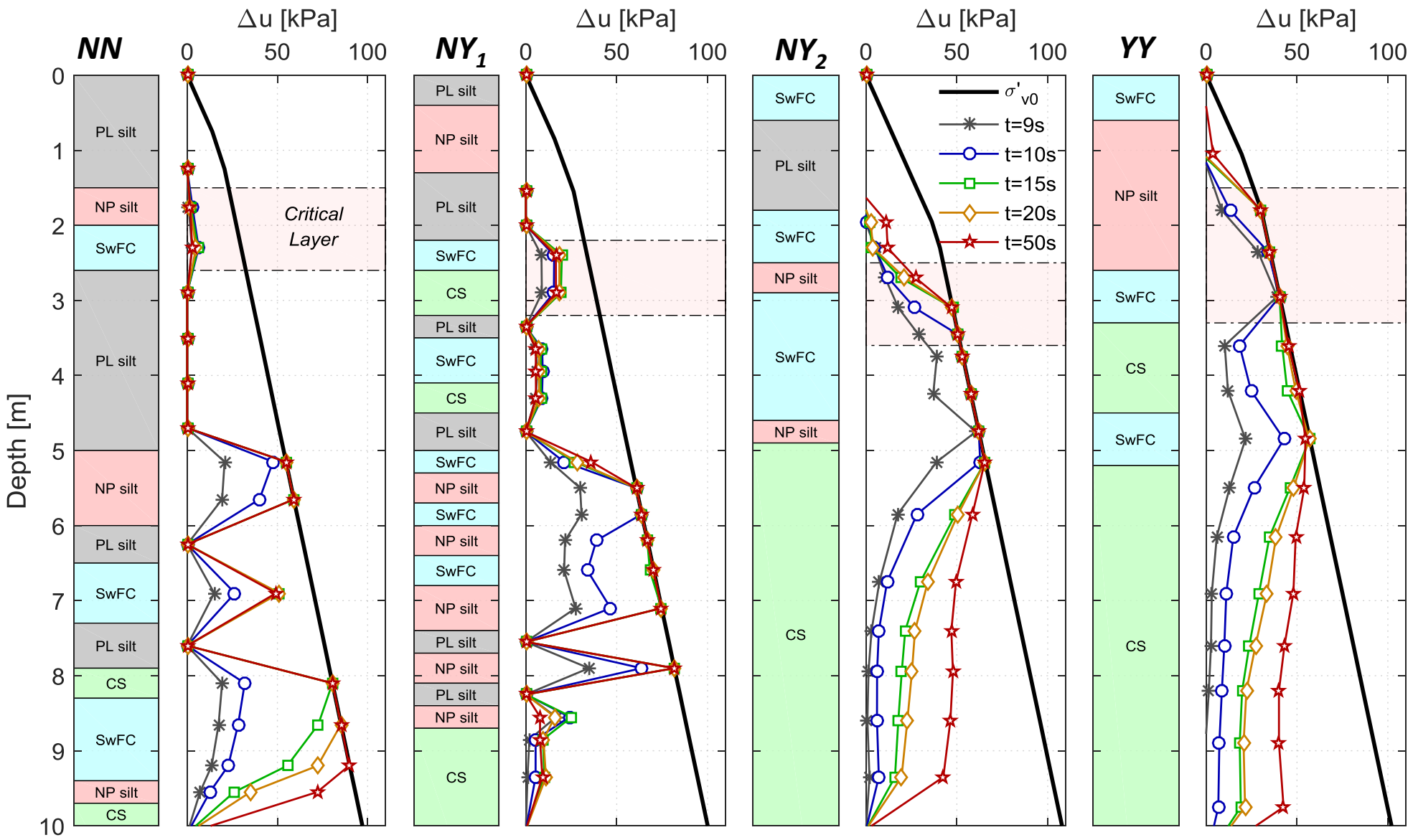
1. ***STEP 1: IDENTIFICATION OF KEY SYSTEM-RESPONSE MECHANISMS (DA of 4 profiles representative of YY sites (based on 10 sites) and 2 NN profiles (2 sites)***

2. ***STEP 2: APPLICATION OF SYSTEM-RESPONSE CONCEPT (DA of 4 profiles: 1 YY site, 2 NY sites, and 1 NN site***

Typical NN-, NY- and YY- sites



ESA on typical NN-, NY- and YY- sites



Depth – Thickness – Severity of liquefaction

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Site	Depth [m] to top of liquefied zone	Thickness [m] of liquefied zone	γ_{max} [%] within liquefied zone	Vertical Continuity	Manifestation (22FEB2011)
NN (Papanui)	5.0	1.0	4.6	No	None
NY_1 (St. Albans)	5.3	2.5	4.8	No	Minor
NY_2 (Avondale)	2.9	2.5	6.8	Yes	Moderate
YY (Avondale)	1.5	3.7	6.2	Yes	Moderate-Severe

Series of Analyses

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1. ***STEP 1: IDENTIFICATION OF KEY SYSTEM-RESPONSE MECHANISMS (DA of 4 profiles representative of YY sites (based on 10 sites) and 2 NN profiles (2 sites)***

2. ***STEP 2: APPLICATION OF SYSTEM-RESPONSE CONCEPT (DA of 4 profiles: 1 YY site, 2 NY sites, and 1 NN site***

3. ***STEP 3: Probabilistic analyses for two Christchurch areas typical for YY and NN sites***

Probabilistic modelling of soil profiles

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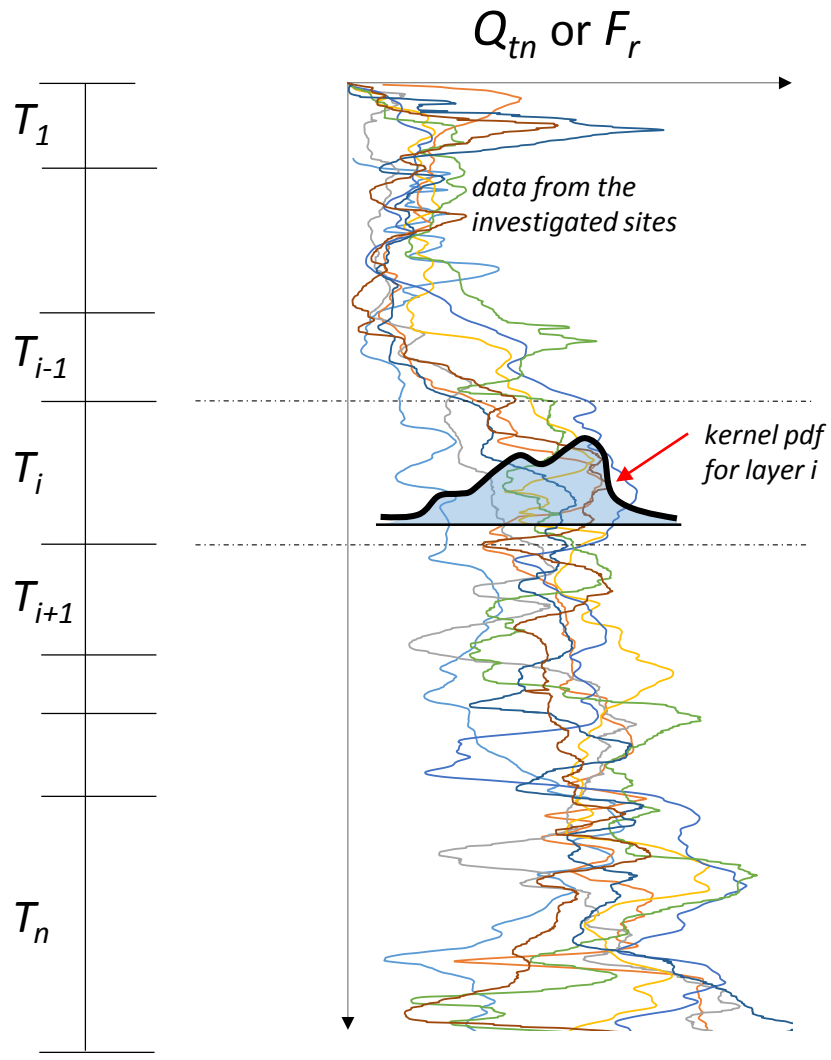
Two main elements:

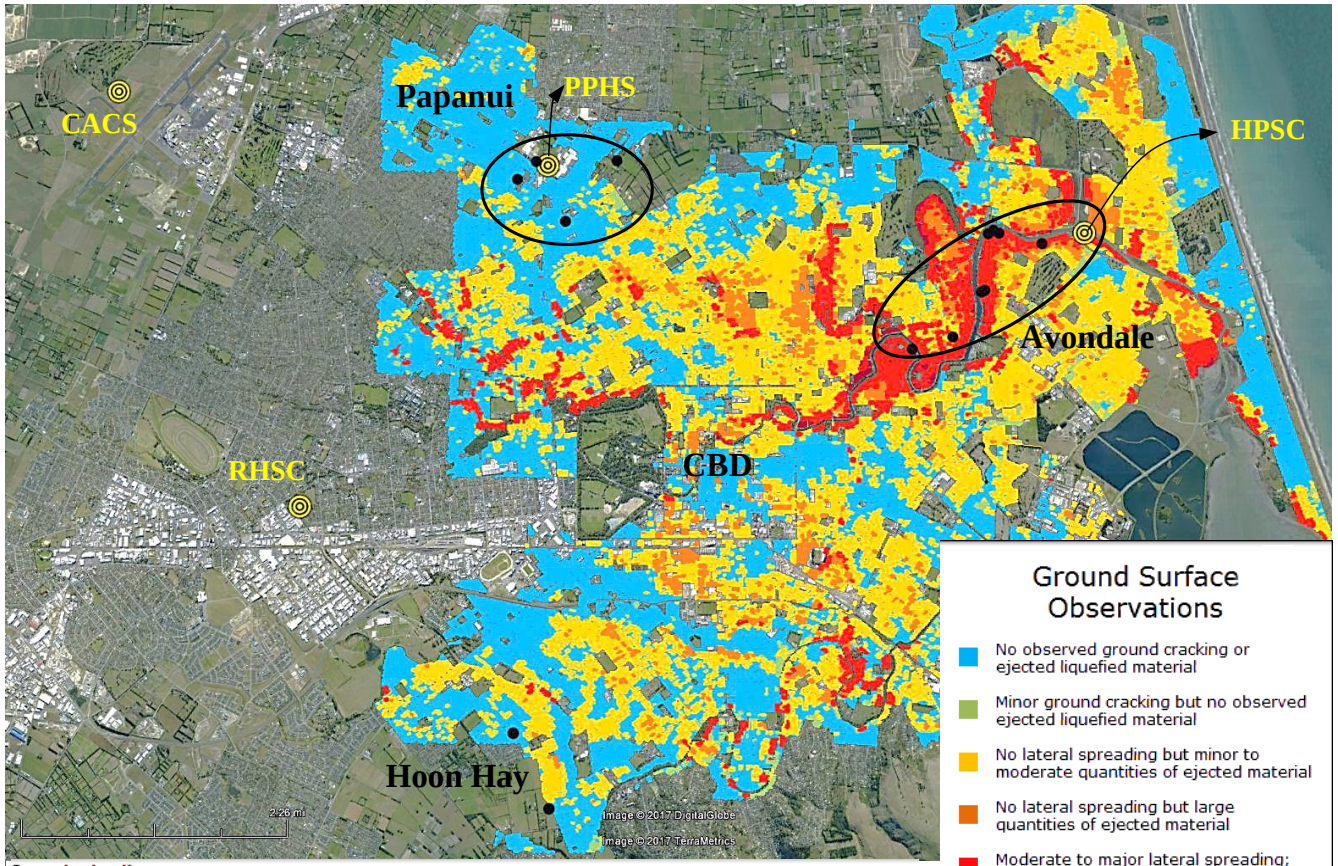
1. ***Layering simulation:*** Layer thicknesses T_i (or locations of layer boundaries/interfaces) are generated through a non-homogeneous Poisson process (i.e. *mean rate of layer boundary occurrence varies with depth*).

2. ***Definition of soil layer properties:*** Nonparametric kernel distributions are used to describe the variation of Q_{tn} and F_r within each layer.

   *The **correlation between Q_{tn} and F_r** within each layer is taken into account by combining the marginal Q_{tn} and F_r distributions into a bivariate Gaussian copula.*

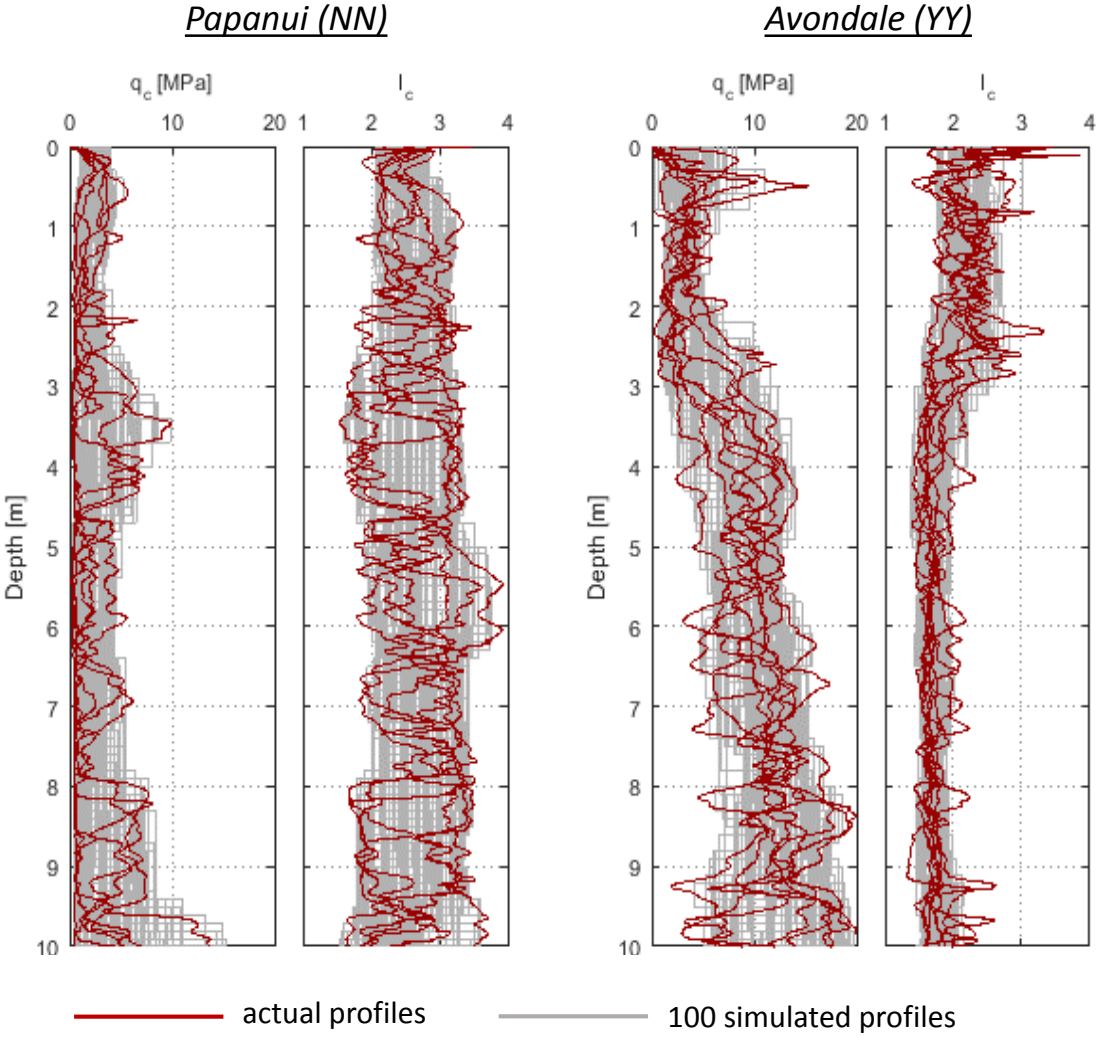


Application to two Christchurch subregions



Ground Surface Observations

- No observed ground cracking or ejected liquefied material
- Minor ground cracking but no observed ejected liquefied material
- No lateral spreading but minor to moderate quantities of ejected material
- No lateral spreading but large quantities of ejected material
- Moderate to major lateral spreading; ejected material often observed
- Severe lateral spreading; ejected material often observed
- No observations (uncoloured)



Probabilistic analysis results

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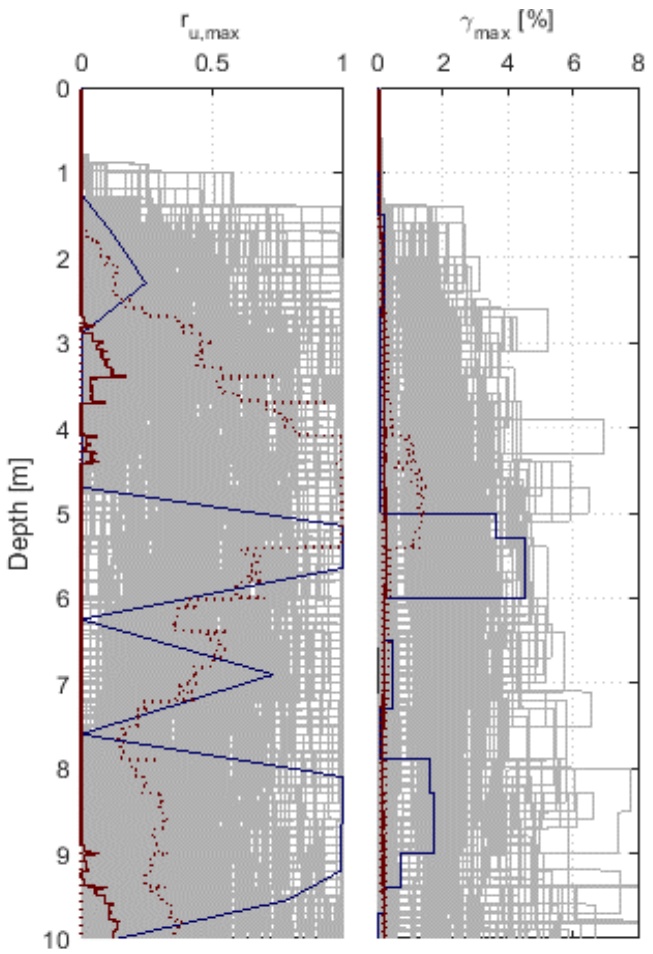
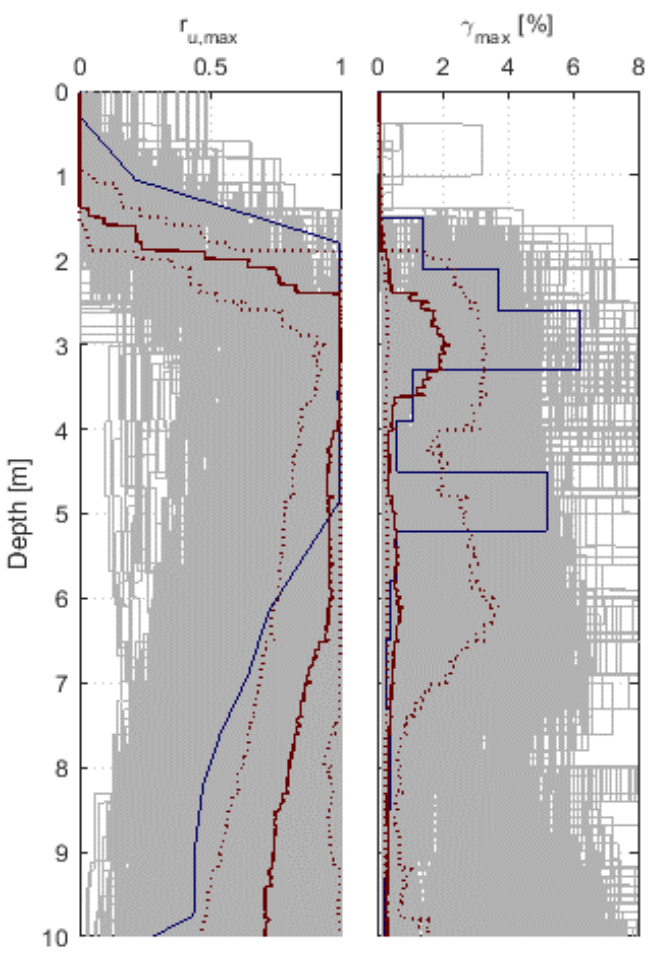
Papanui (NN)

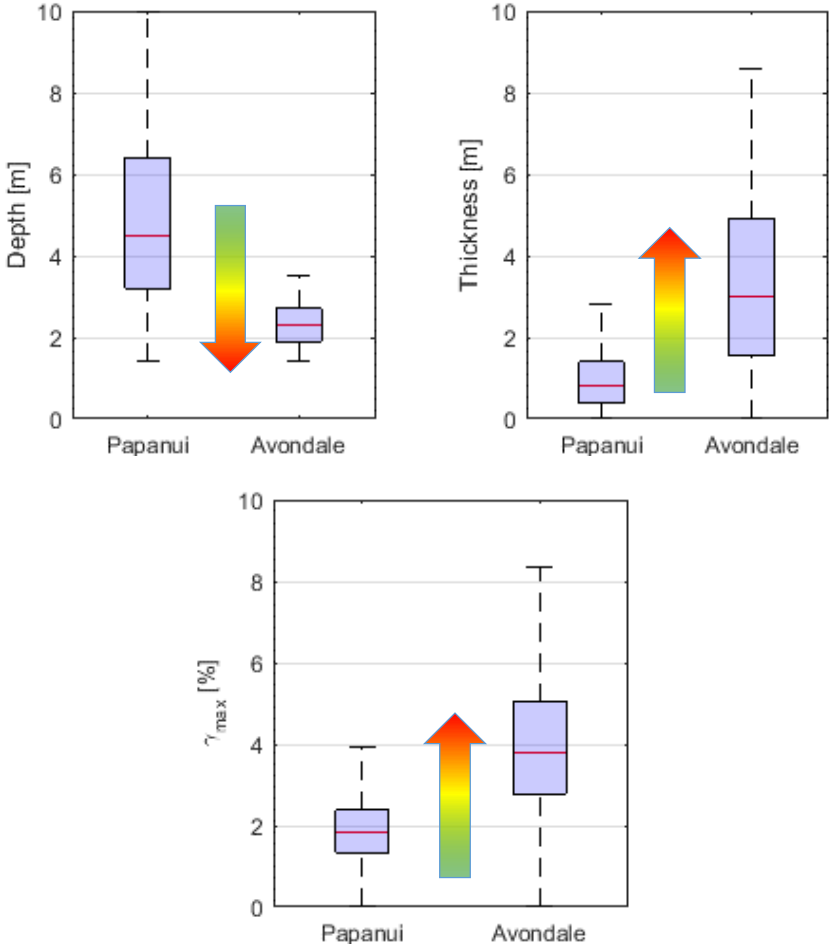


Avondale (YY)



Deterministic analysis
Probabilistic analysis
Median response
25th and 75th percentile

*Variation in **depth** and **thickness** of the liquefied zone and **severity** of liquefaction (γ_{max})*



Future work: *Quantification* of system-response