Fault Avoidance Zones and planning for the next rupture of the Alpine Fault in Franz Josef

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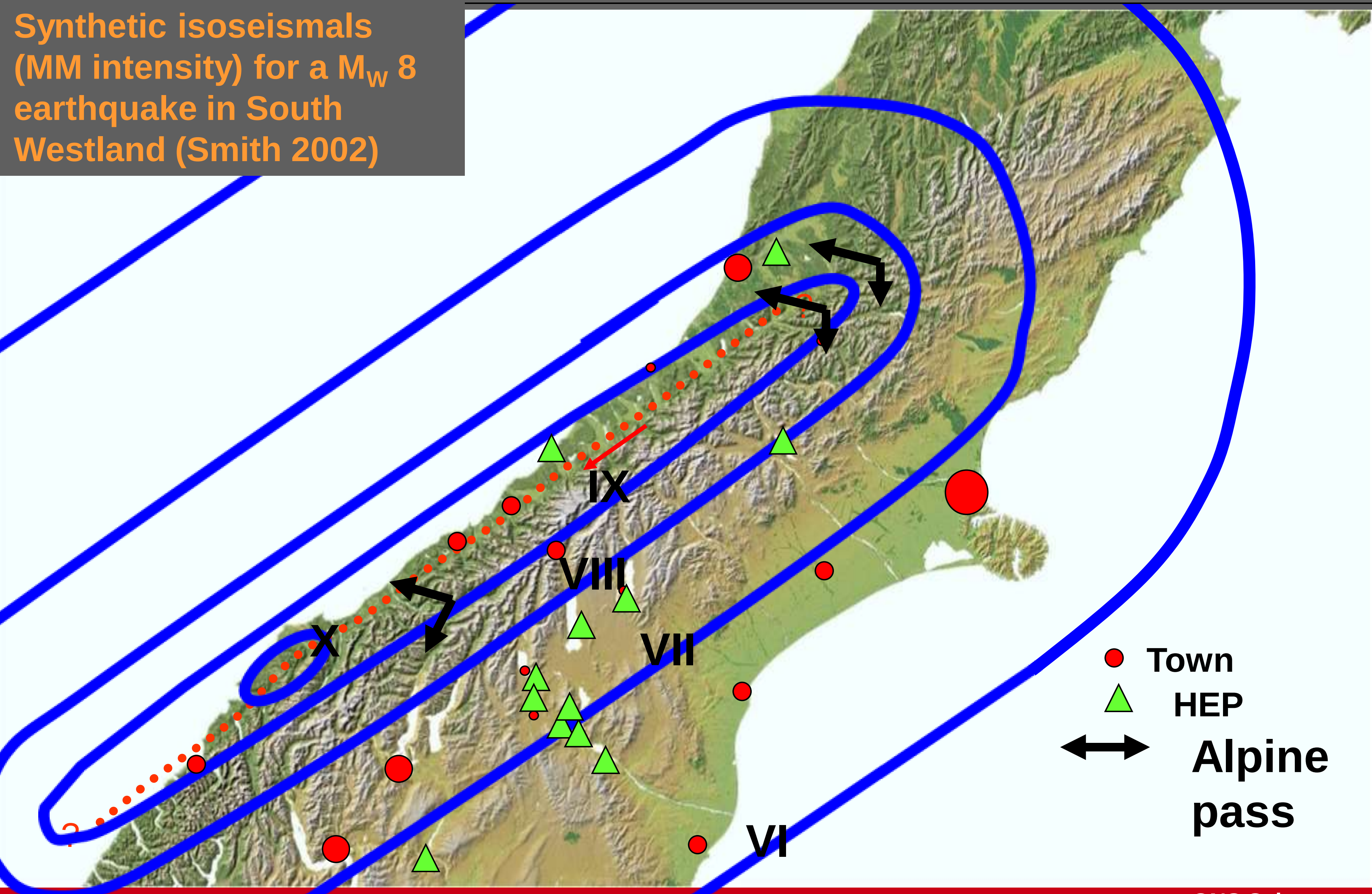
Franz Josef community, February 29th 2012.

The next Great Alpine Fault Earthquake

Synthetic isoseismals (MM intensity) for a M_W 8 earthquake in South Westland (Smith 2002)



Talk plan

- Introduction
- Quick tour of your town
- The Alpine Fault – its geology
- Applications of the MfE Guidelines and FAZ's in New Zealand
- FAZ map for the entire Alpine Fault
- Advances from LiDAR swath mapping in the Franz Josef area
- FAZ map for the Franz Josef area
- Planning responsibilities surrounding the future of Franz
- Response by WDC to the recommendations of the GNS study
- Questions ?

Franz Josef – a quick tour

- Fault scarp in Highway 6 through town

Franz Josef – a quick tour
- Fault scarp in Cron Street

- Hotel built into Fault scarp on Cron/ Condon Streets

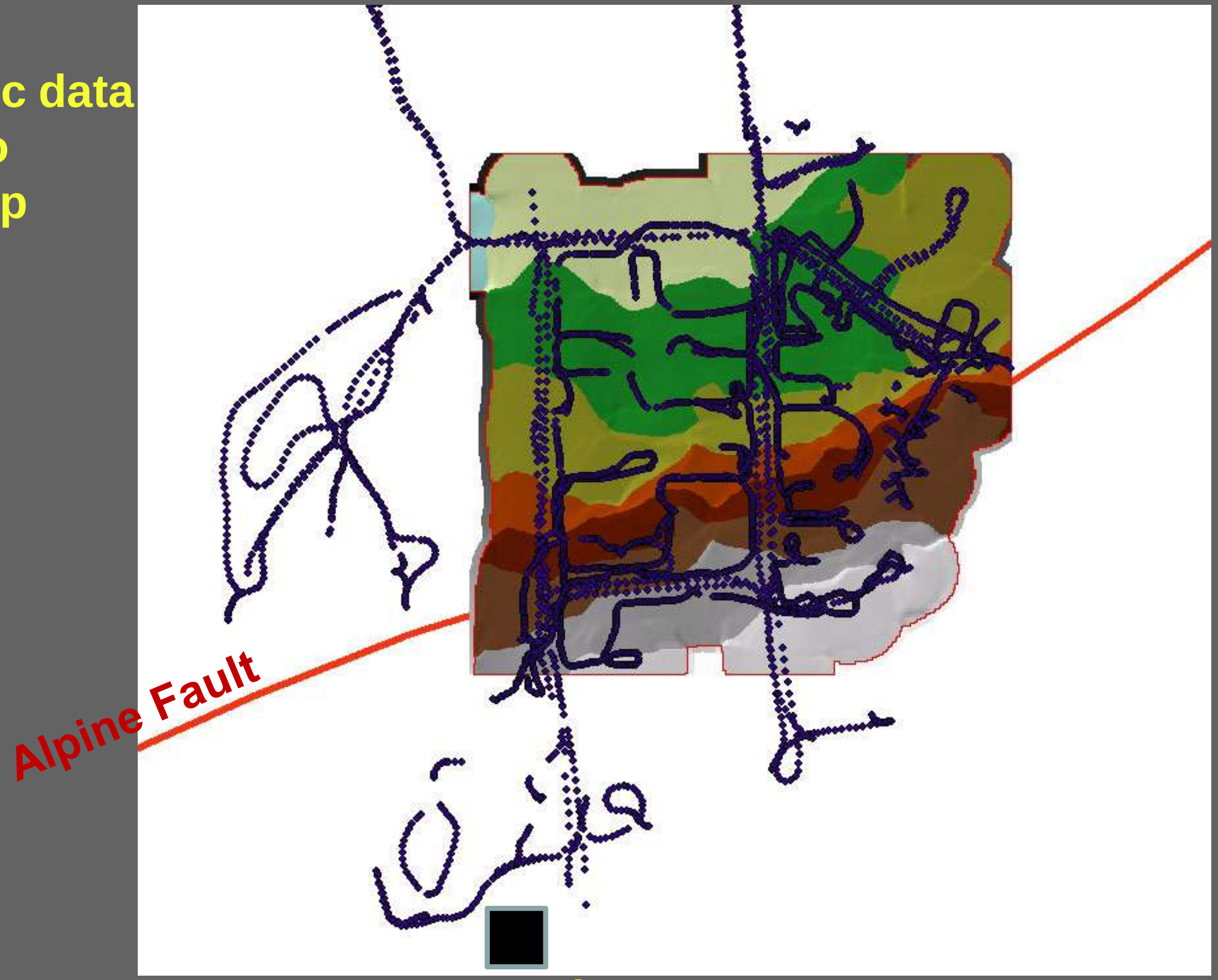
Franz Josef – a quick tour
- Fault scarp in Condon Street

- Petrol station straddling Fault scarp on Condon Street

Franz Josef – a quick tour
- Waiho River bridge on Highway 6

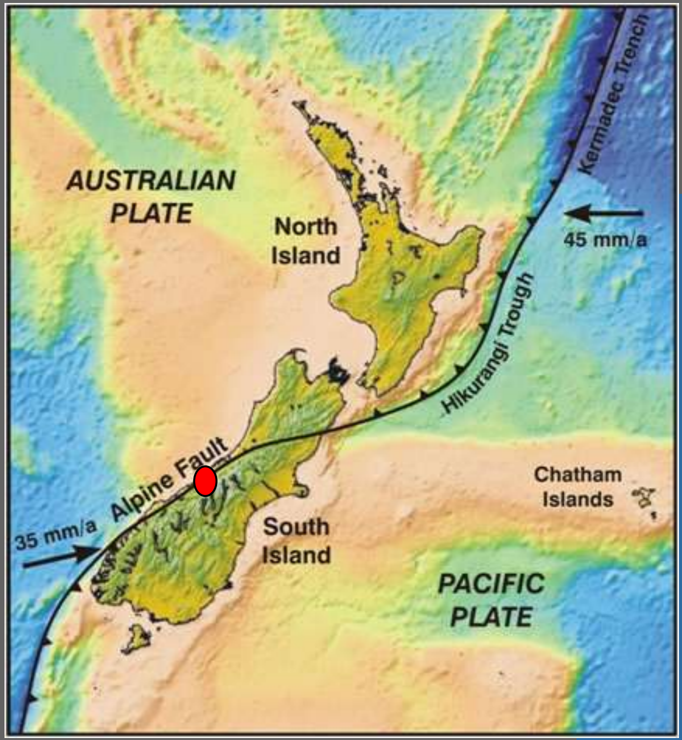
Franz Josef – street plan

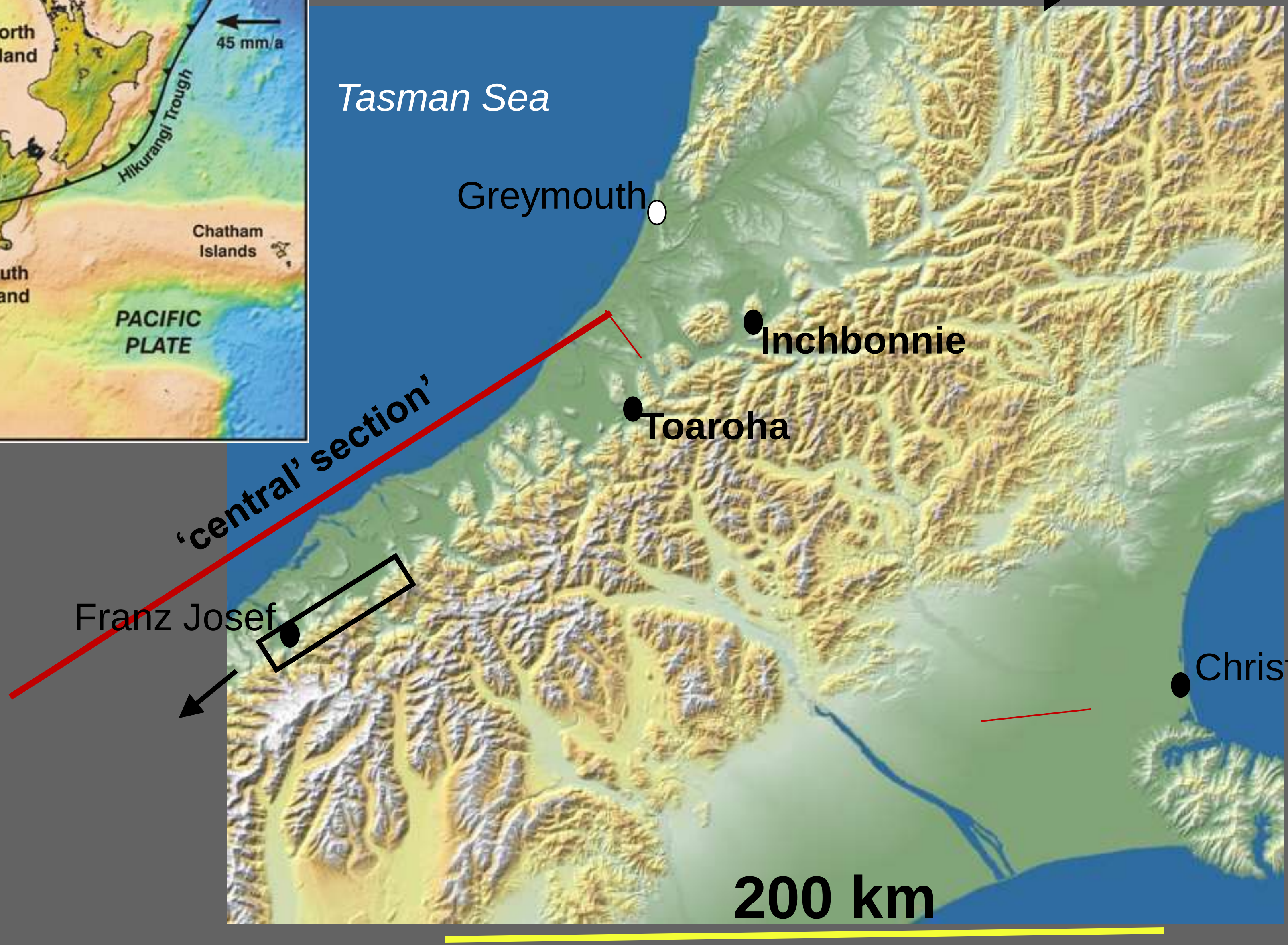
A lack of good topographic data through the town led us to Survey in a basic topo map Using our GPS-RTK



You are here

Alpine Fault
- Franz to Whataroa LiDAR run



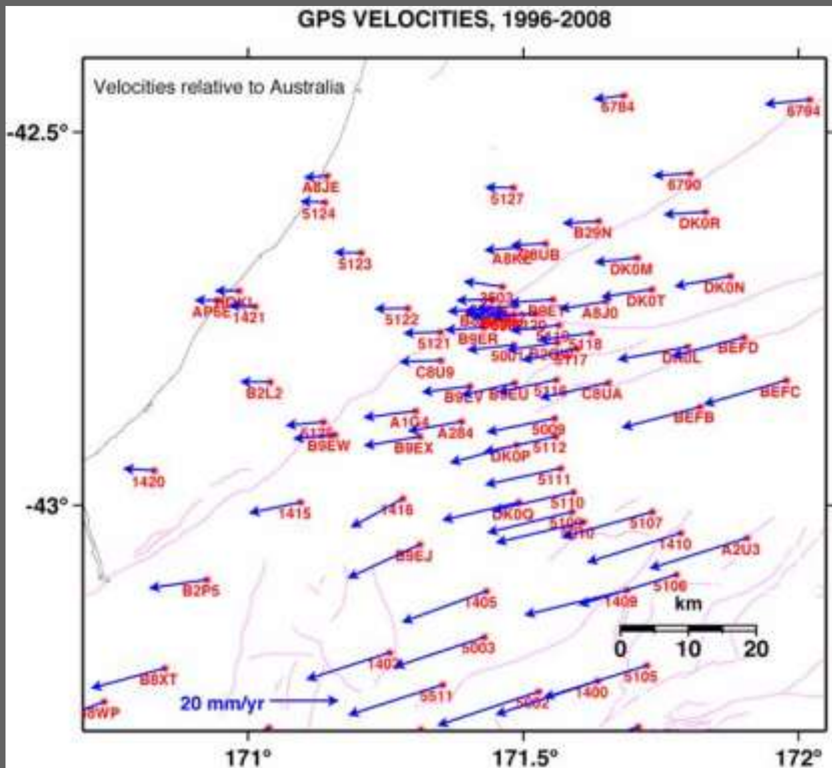


The Alpine Fault
- poses challenges

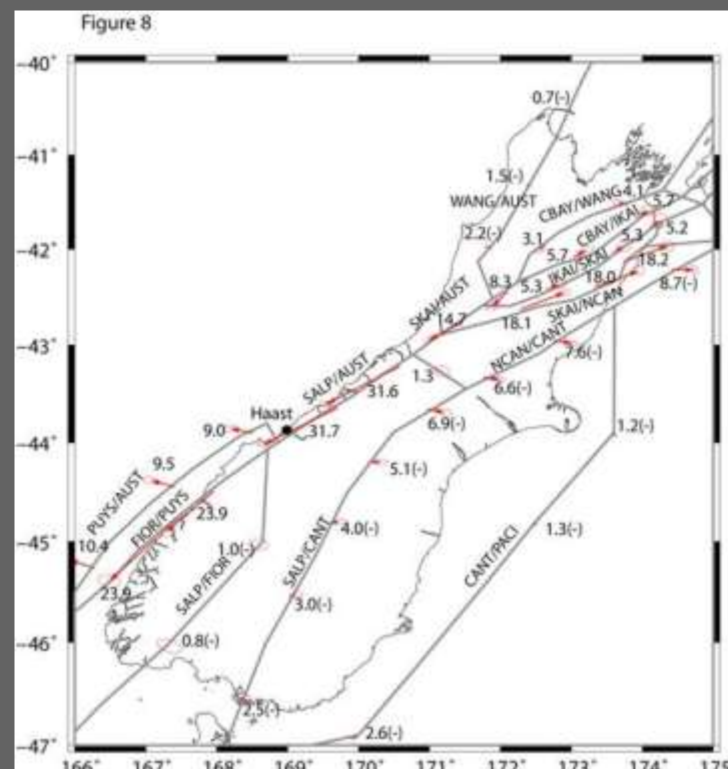
- oblique slip fault
- c. 25 mm/yr dextral
- c. 10 mm/yr reverse-slip
- 6-8 metres annual rainfall !

rangefront at Omoeroa River

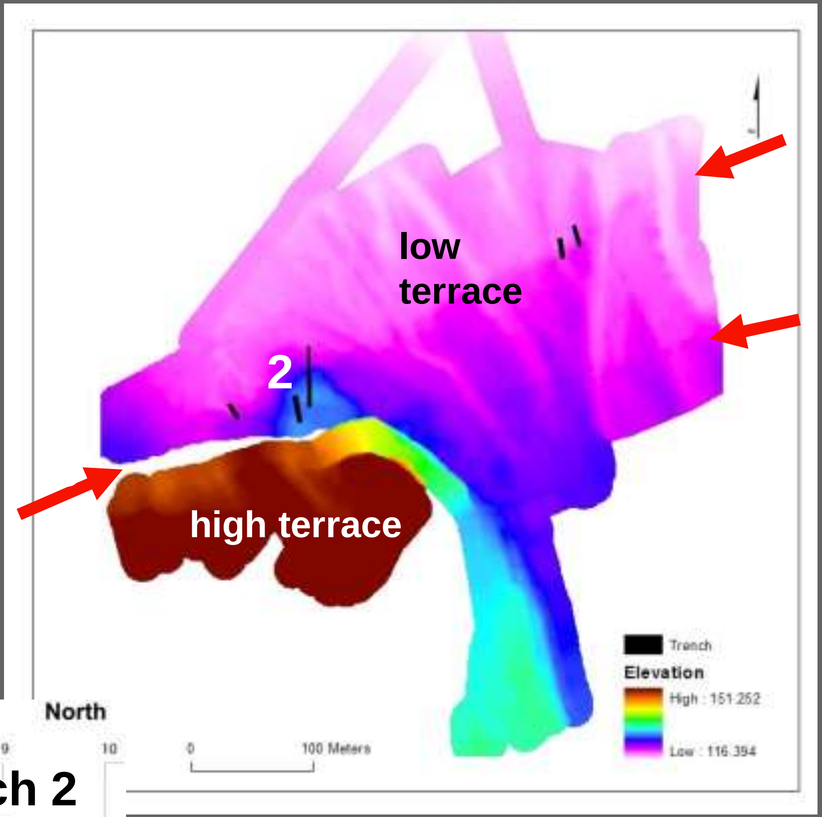
GPS block models and resolution of strain

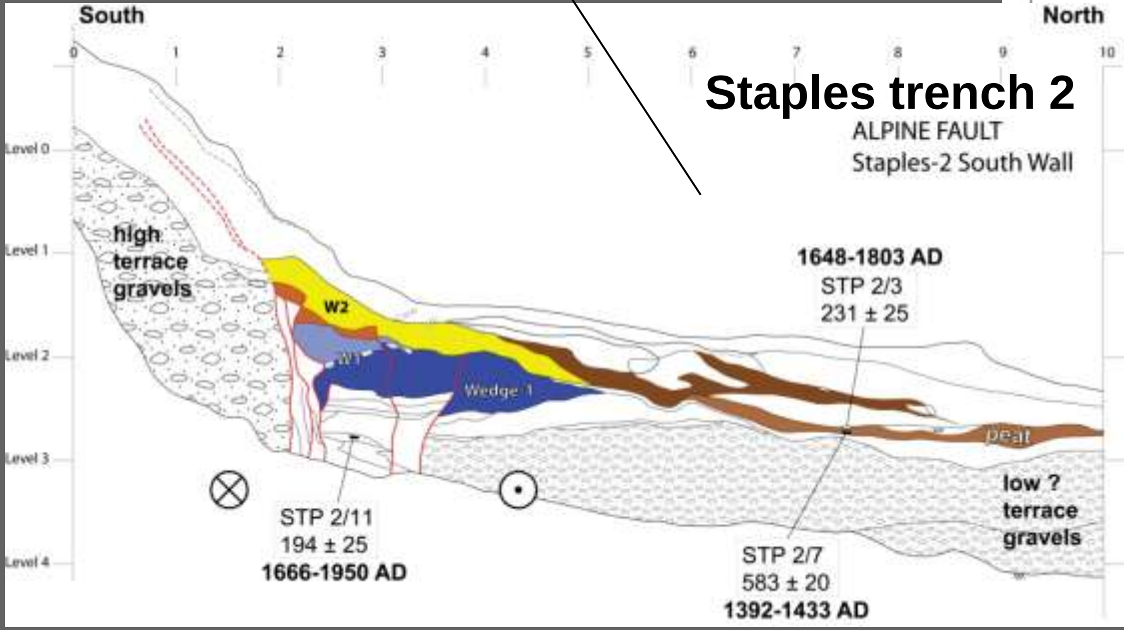


(*Sources*: J. Beavan; Wallace et al., 2007)



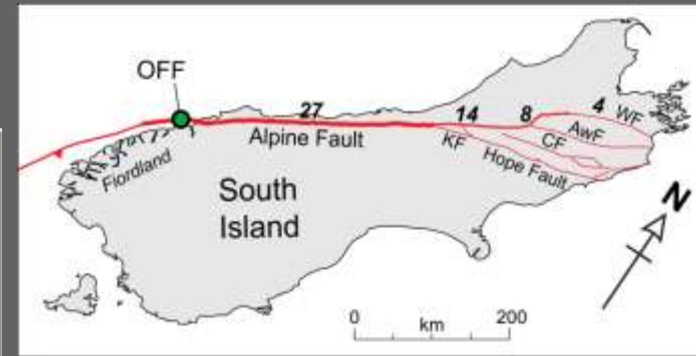
Paleoseismic studies

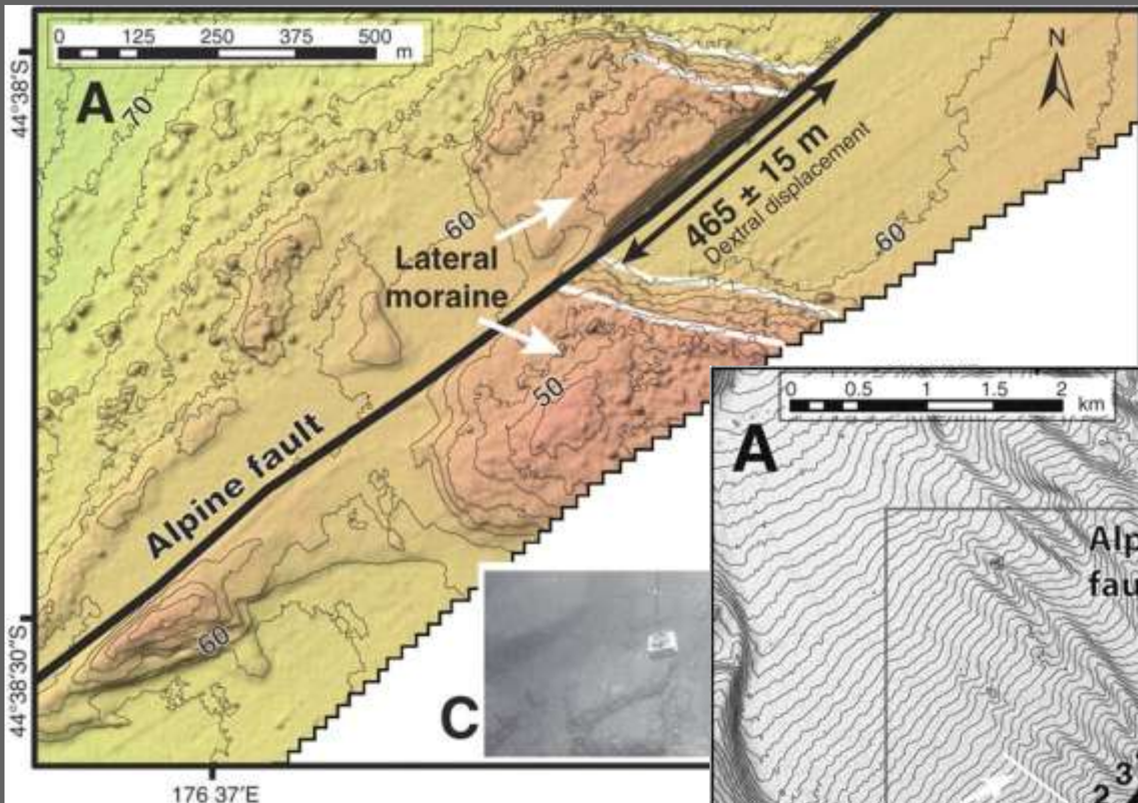


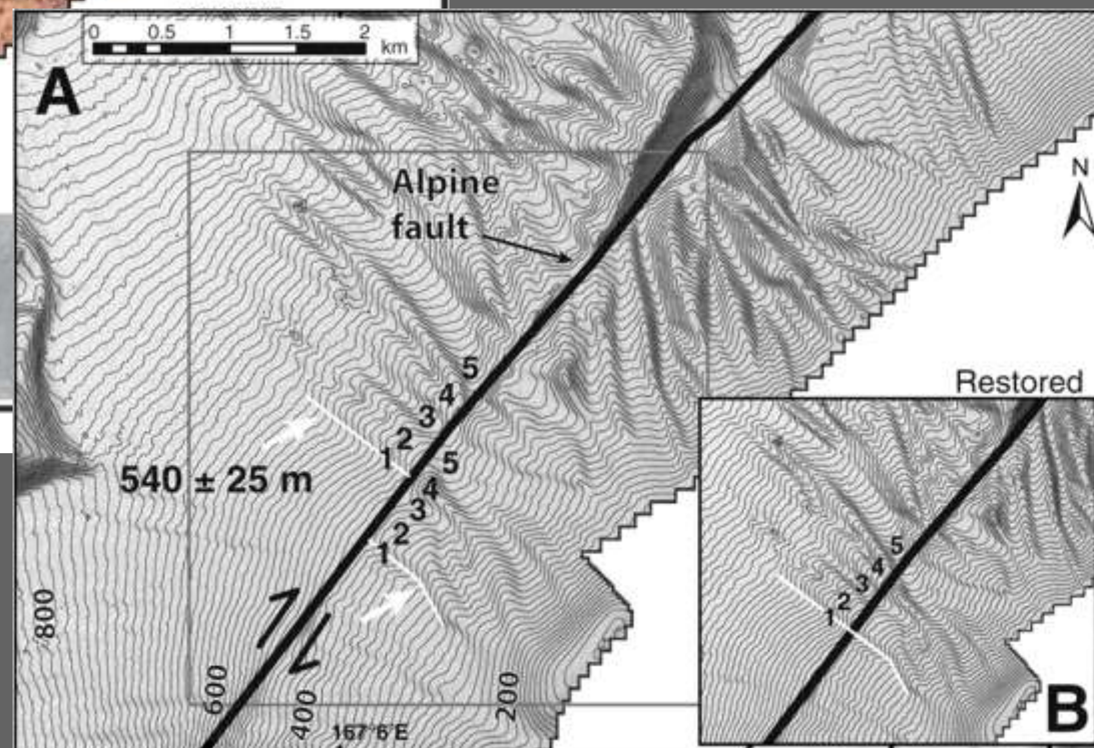


Toaroha River

Fault slip rate studies





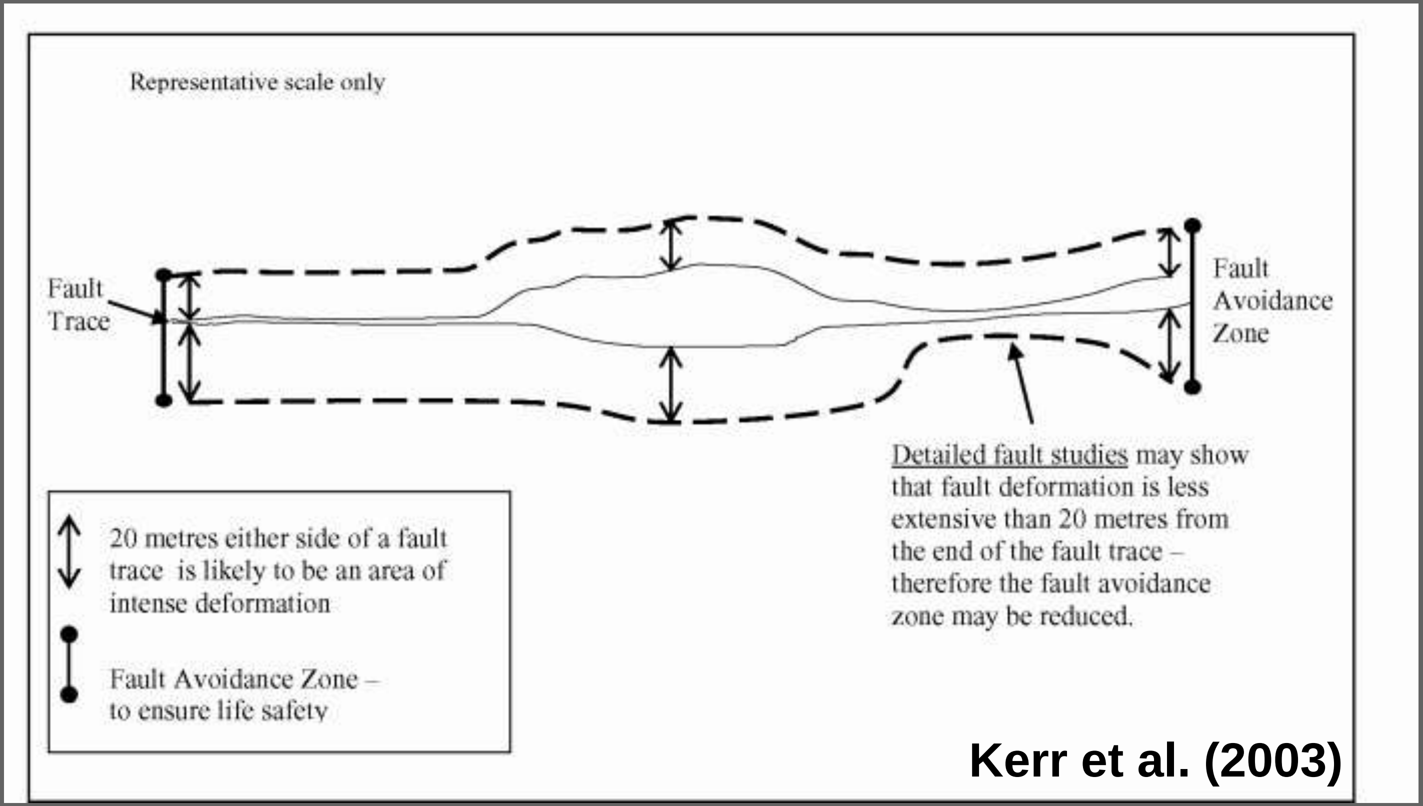


Marine geology by NIWA
P. Barnes (2009) in Geology

Offshore of Fiordland

Aim of this study

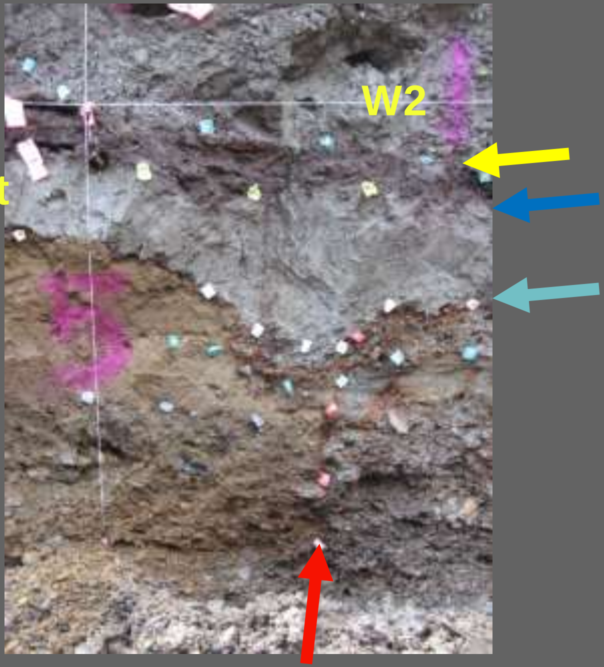
- to develop a Fault Avoidance Zone strategy for Franz Josef
-to give the WDC some advice/ direction on how to implement or cope with such a FAZ strategy



Kerr et al. (2003)

Ministry for the Environment Guidelines

- MfE Guidelines formulated by joint study group of
  - Geological Society of New Zealand
  - New Zealand Society for Earthquake Engineering
- Aim to assist planners with development near active faults
- Life-safety is the key driver
- Promote a risk-based approach
  - Type of proposed development (Building Importance Category)
  - Existing site usage (Greenfield vs. developed site)
  - Fault activity (Recurrence Interval Class)
  - Location & complexity of fault rupture (Fault Avoidance Zones)

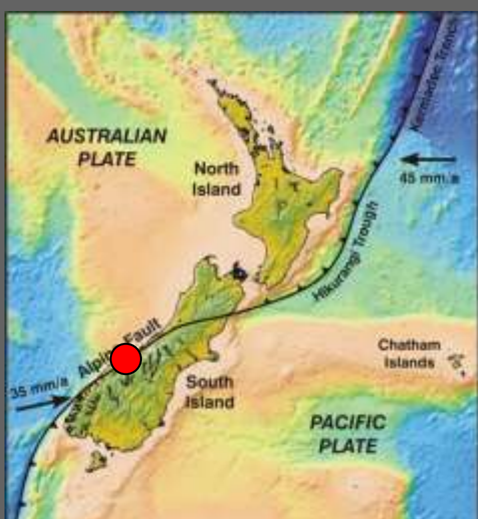


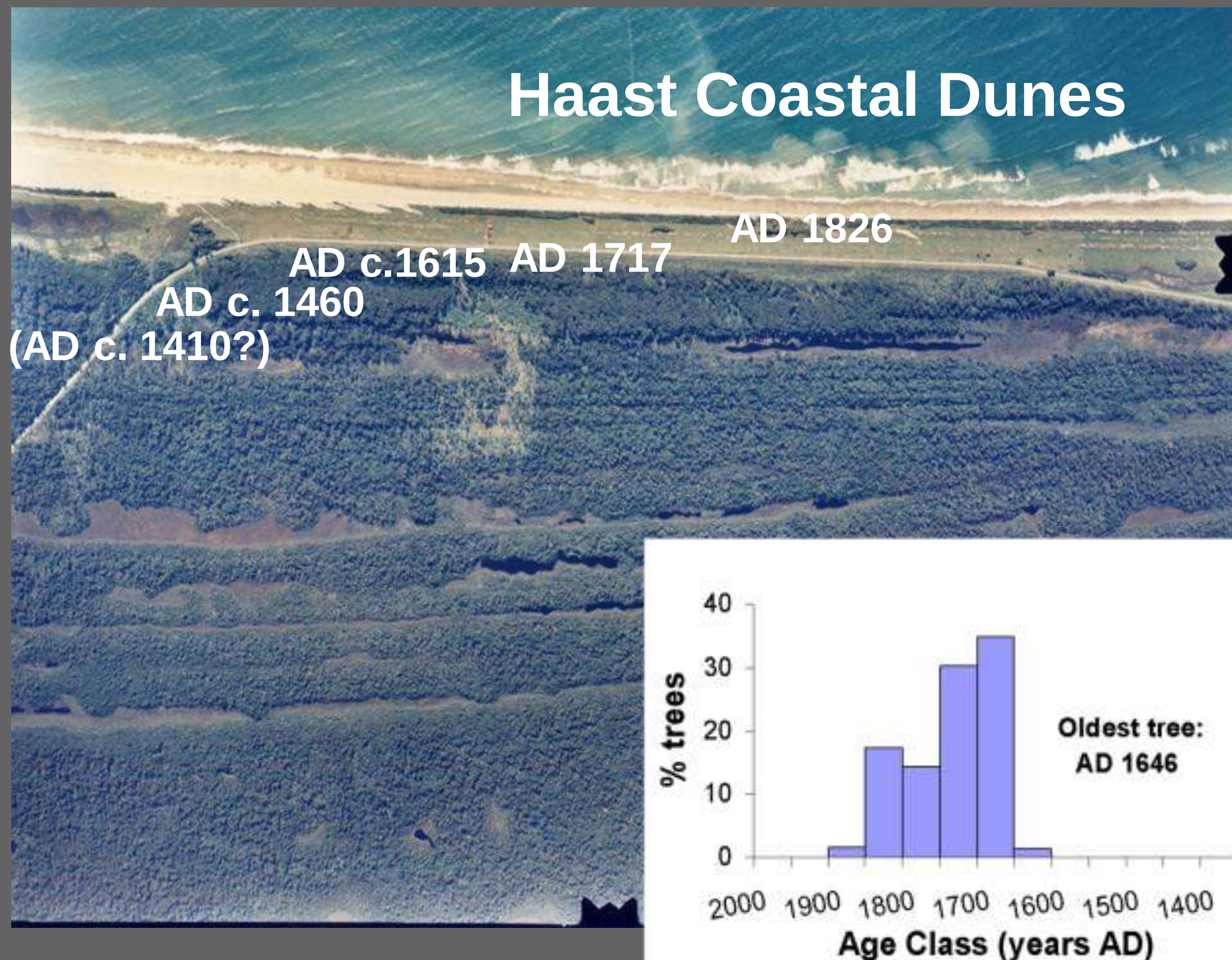
Recurrence Interval Class (RI Class)

Alpine Fault

Recurrence Interval Class	Average Recurrence Interval of Surface Rupture
I	≤2000 years
II	>2000 years to ≤3500 years
III	>3500 years to ≤5000 years
IV	>5000 years to ≤10,000 years
V	>10,000 years to ≤20,000 years
VI	>20,000 years to ≤125,000 years

The Alpine Fault is definitely an RI Class I fault



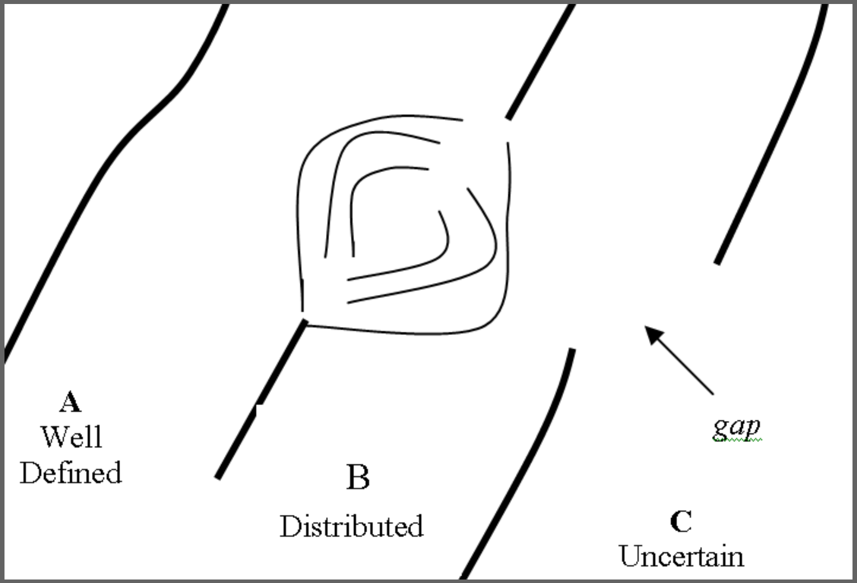


A. Wells and J. Goff (2007)

Classifying Fault Complexity

(a function of hazard & risk)

- Well defined
- Distributed
- Uncertain



In this study, rather than treat the Uncertainty about the fault based on its Complexity,

...we have considered the quality of the map data, i.e. its Uncertainty, as a better means of understanding where the next rupture will be along the length of the fault

MfE Guidelines: Building Importance Categories

(Van Dissen & Heron, 2003)

Building Importance Category	Description	Examples
1	**Temporary structures** with low hazard to life and other property	• Structures with a floor area of <30 m^2 • Farm buildings, fences • Towers in rural situations
2a	**Timber-framed residential construction**	• Timber framed single-story dwellings
2b	**Normal structures** and structures not in other categories	• Timber framed houses with area >300 m^2 • Multi-occupancy buildings accommodating <5000 people and <10,000 m^2 • Public assembly buildings, theatres and cinemas <1000 m^2
3	**Important structures** that may contain people in crowds or contents of high value to the community or pose risks to people in crowds	• Emergency medical and other emergency facilities not designated as critical post disaster facilities • Airport terminals, principal railway stations, schools • Structures accommodating >5000 people • Public assembly buildings >1000 m^2
4	**Critical structures** with special post disaster functions	• Major infrastructure facilities • Air traffic control installations • Designated civilian emergency centres, medical emergency facilities, emergency vehicle garages, fire and police stations

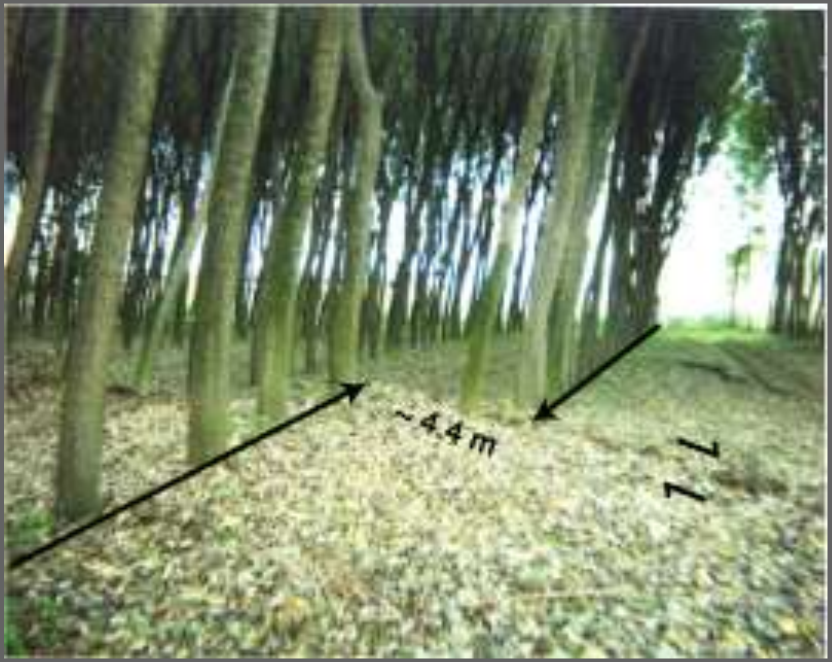
MfE Guidelines: Planning & Consent Table

Recurrence Interval Class and Building Importance Categories

Recurrence Interval Class	Average Recurrence Interval of Surface Rupture	Building Importance (BI) Category Limitations **(allowable buildings)**	
		Previously subdivided or developed sites	Greenfield sites
I	**≤2000 years**	BI Category 1 **Temporary structures only**	BI Category 1 **Temporary structures only**
II	**>2000 years to ≤3500 years**	BI Category 1& 2a **Temporary & Timber-framed residential structures only**	
III	**>3500 years to ≤5000 years**	BI Category 1, 2a, & 2b **Temporary & Normal structures only**	BI Category 1& 2a **Temporary & Timber-framed residential structures only**
IV	**>5000 years to ≤10,000 years**	BI Category 1, 2a, 2b & 3 **Temporary, Normal & Important structures only**	BI Category 1, 2a, & 2b **Temporary & Normal structures only**
V	**>10,000 years to ≤20,000 years**		BI Category 1, 2a, 2b & 3 **Temporary, Normal & Important structures only**
VI	**>20,000 years to ≤125,000 years**	BI Category 1, 2a, 2b, 3 & 4 **Critical structures with post-disaster requirements cannot be built across an active fault with a recurrence interval ≤20,000 years**	
Note: Faults with average recurrence intervals >125,000 years are not considered active			

Some examples of historic surface ruptures

3-4 metres of right-lateral movement at this site over a distributed zone (c. 40 m wide)
- stepping zone of fault traces



August 17, 1999 (Turkey) M_w 7.4 Izmit earthquake

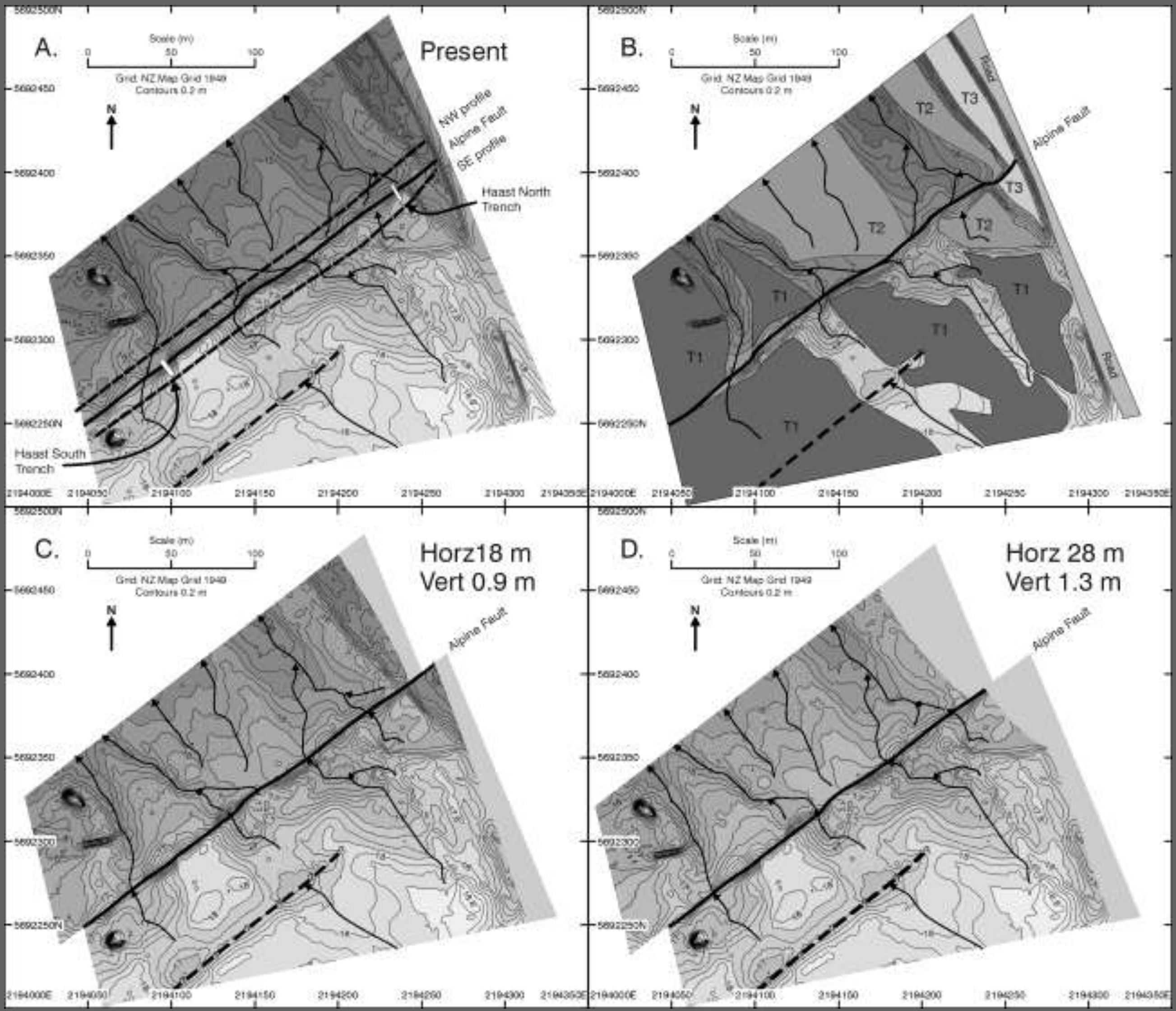
September 1999 (Taiwan) M_w 7.4 Chi-chi earthquake

Alpine Fault displacements at Haast River

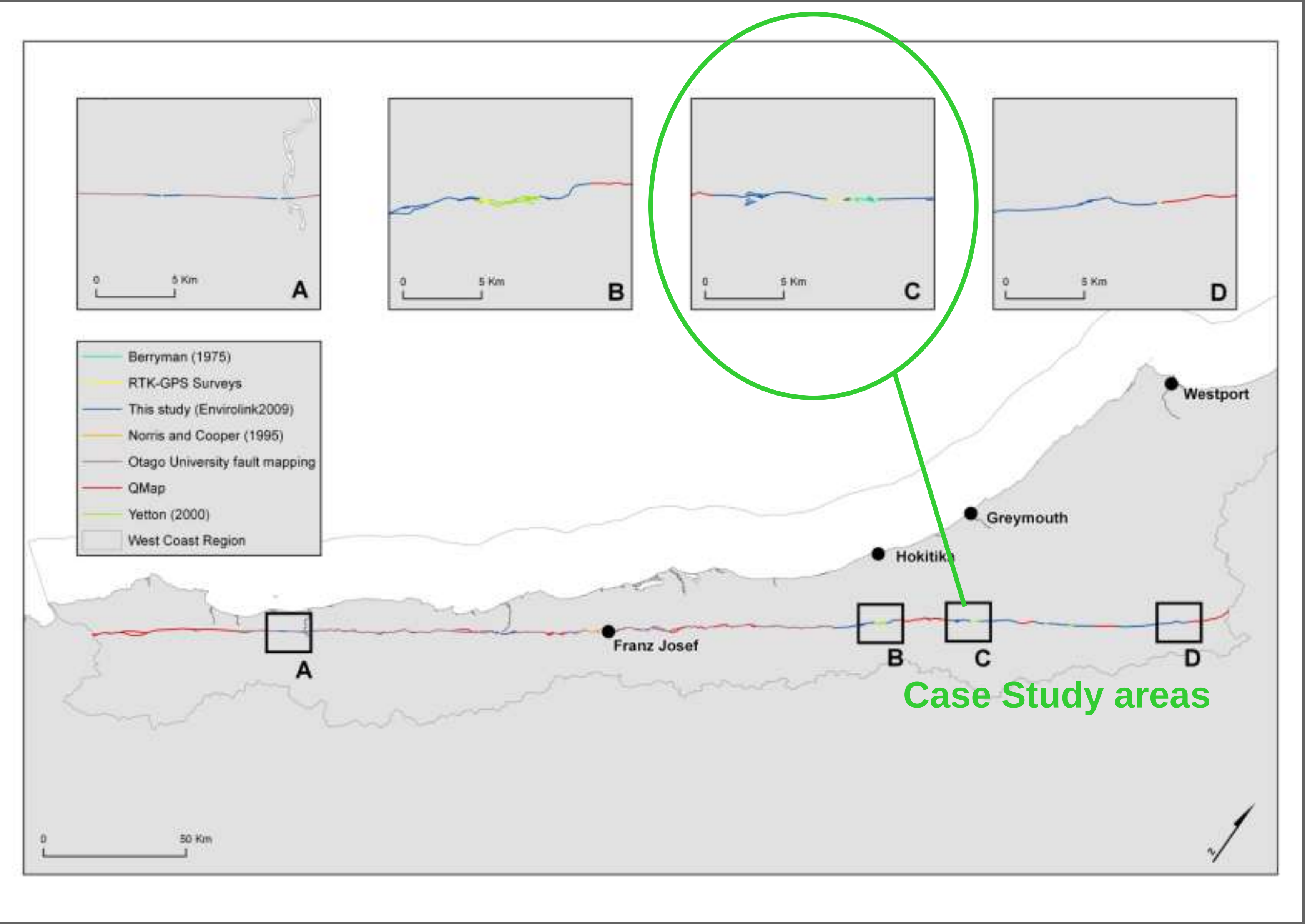
Berryman et al , in press

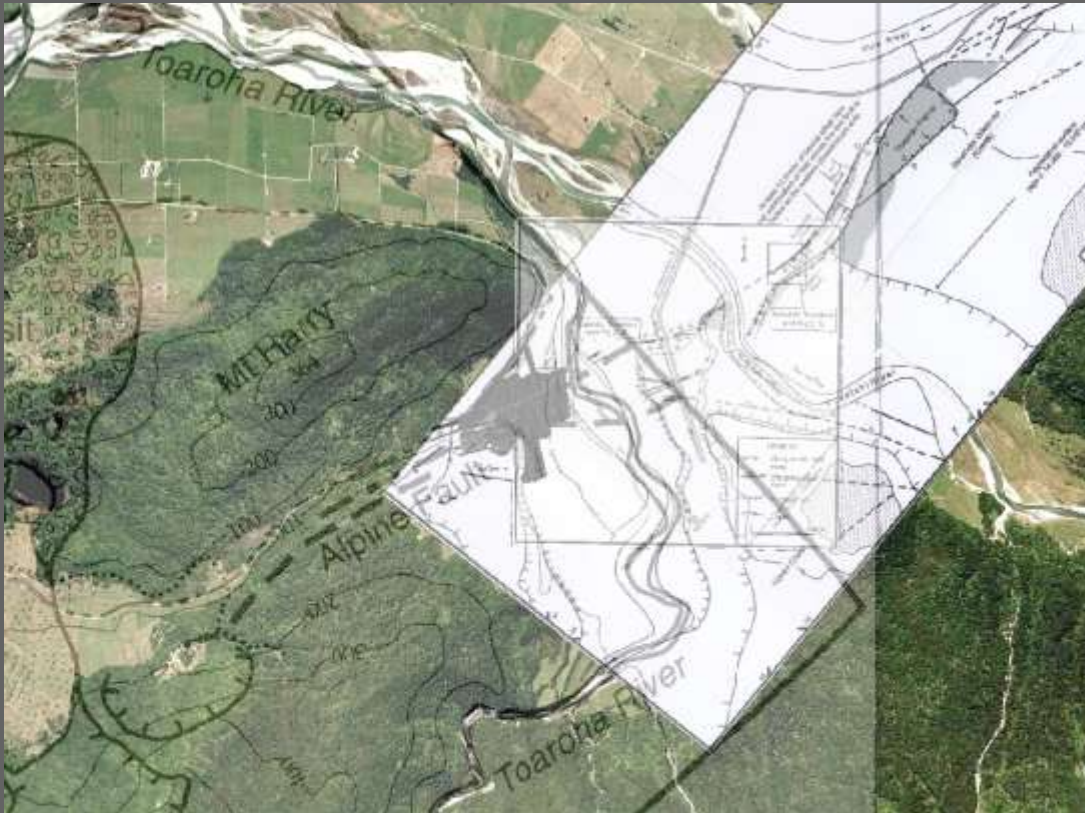
matching up displaced channels

multiples of c. 9 m

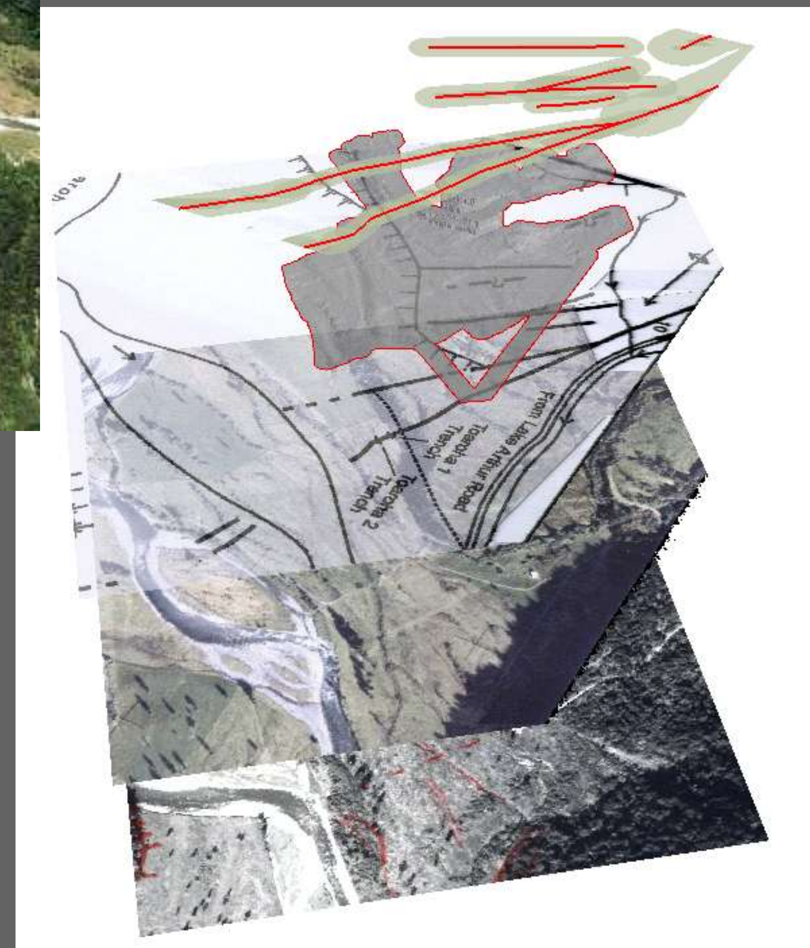


Scope of the original WCRC study





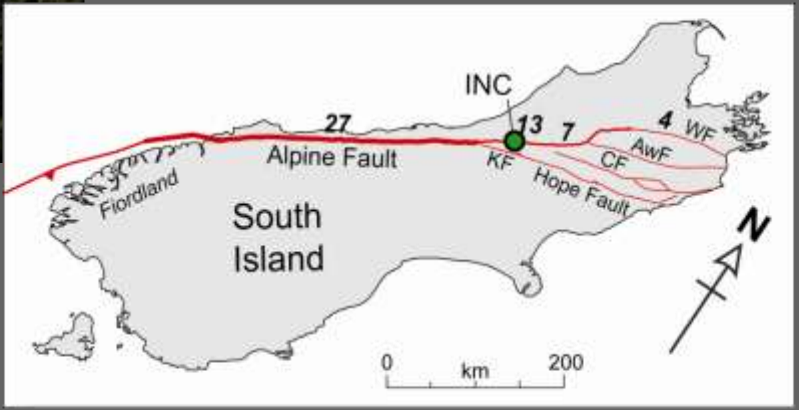
What's in the GIS ? (2-D vs. 3-D layering)



Different layers are accumulated within the GIS.

From this we can decide upon the quality or accuracy of the data sources, and use the best available to make our fault map

Case Study I –
Inchbonnie/ Lake Poerua



Case Study I –
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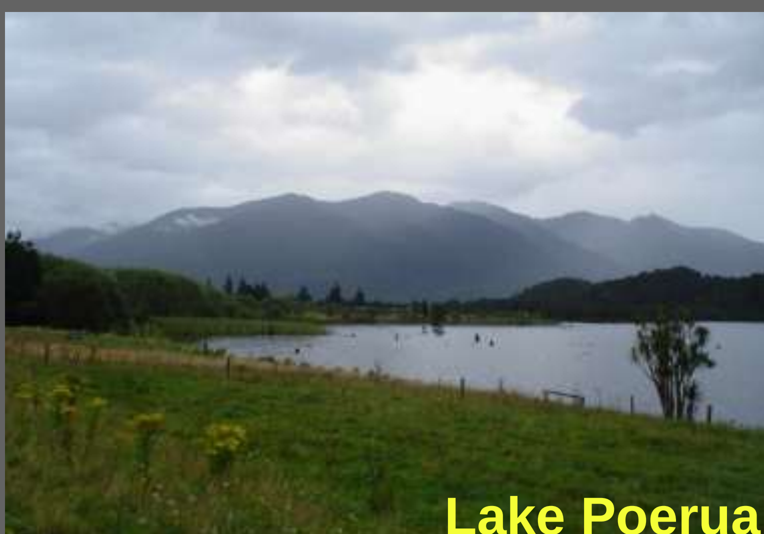
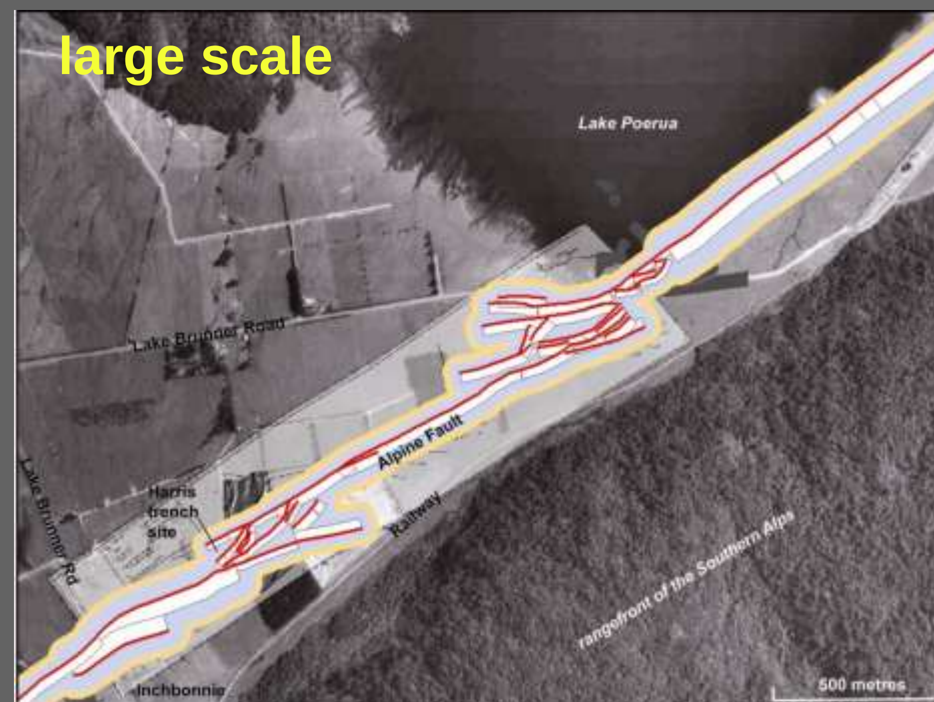
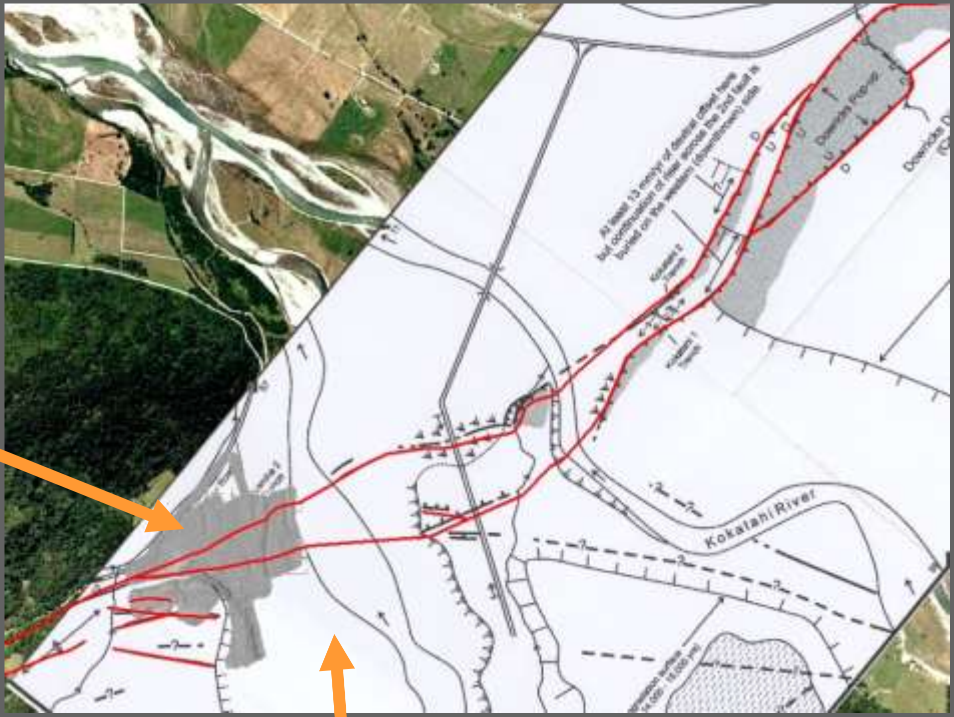




Case Study II – Toaroha River

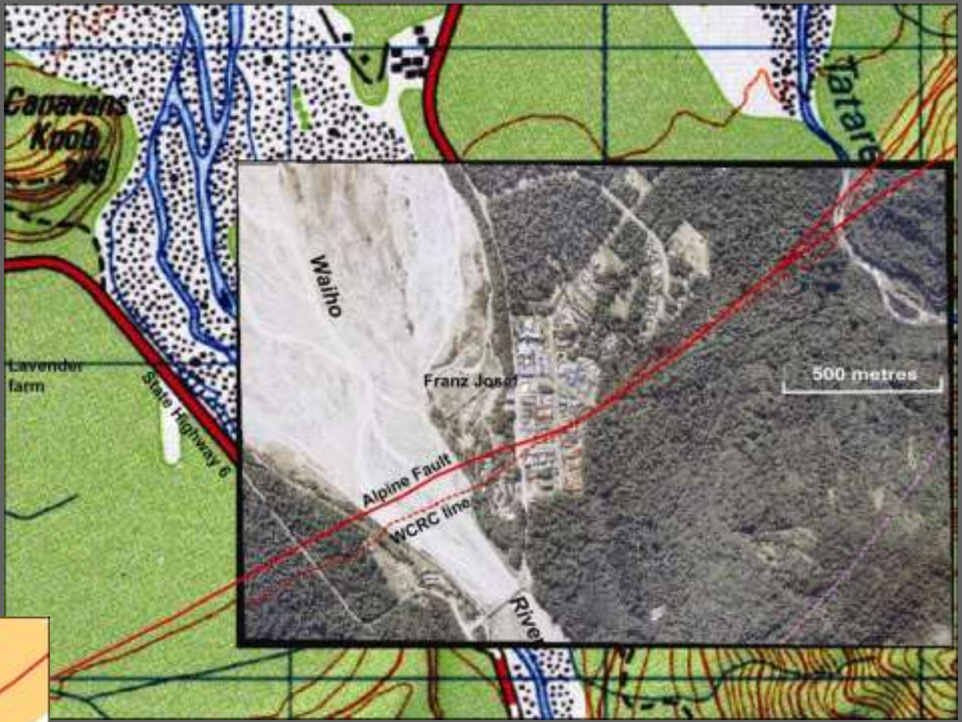
our RTK-GPS map



Yetton (2000) sketch map

Sketches are Geo-referenced to Ortho-Photographs; while an RTK map is Geo-referenced to the LINZ geodetic network

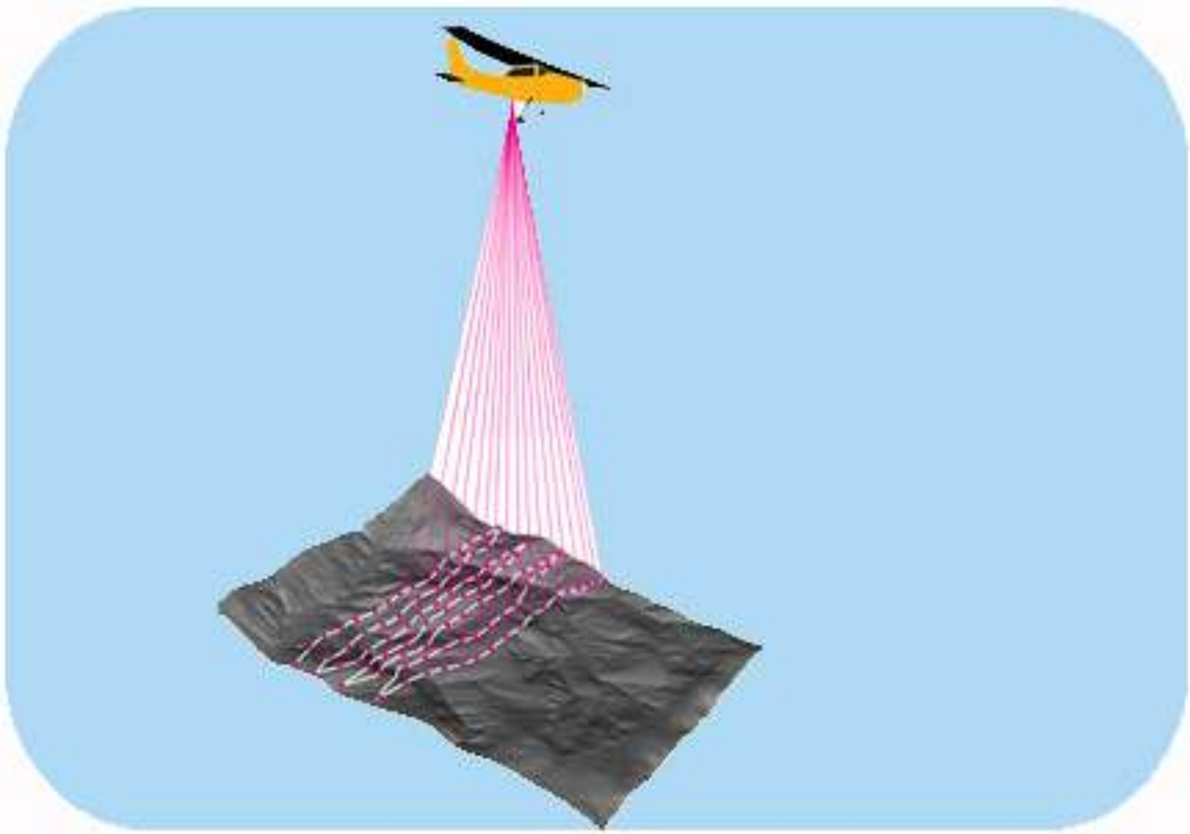
Case Study III – Franz Josef



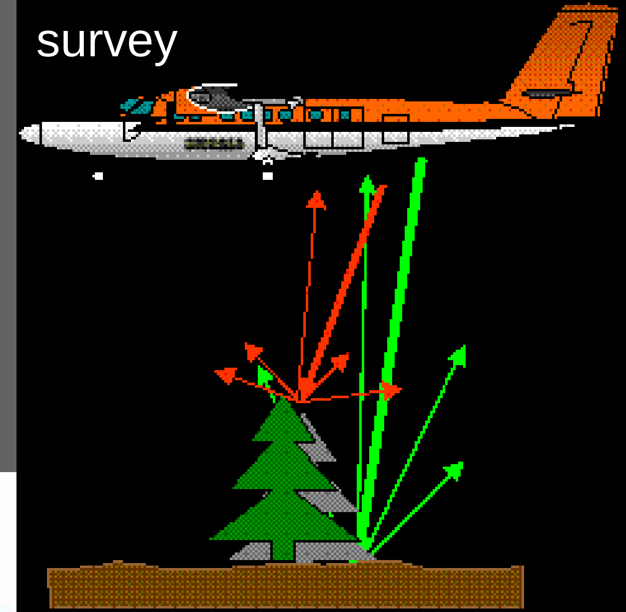
this is arguably the most vital Case Study along the fault, however...

...the original WCRC study did not do this issue enough justice

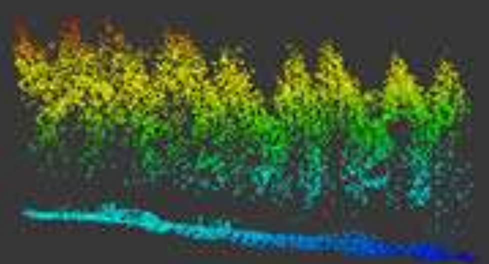
How Airborne **L**ight **D**etection **A**nd **R**anging (**lidar**) Works



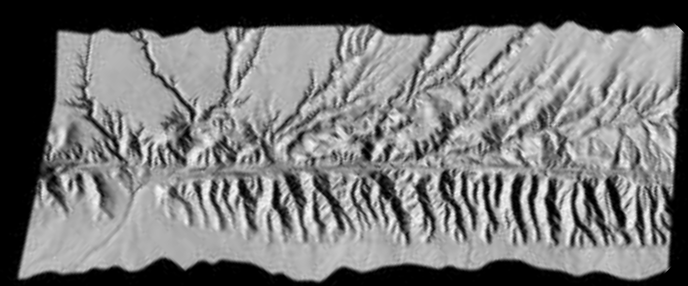
survey



point cloud



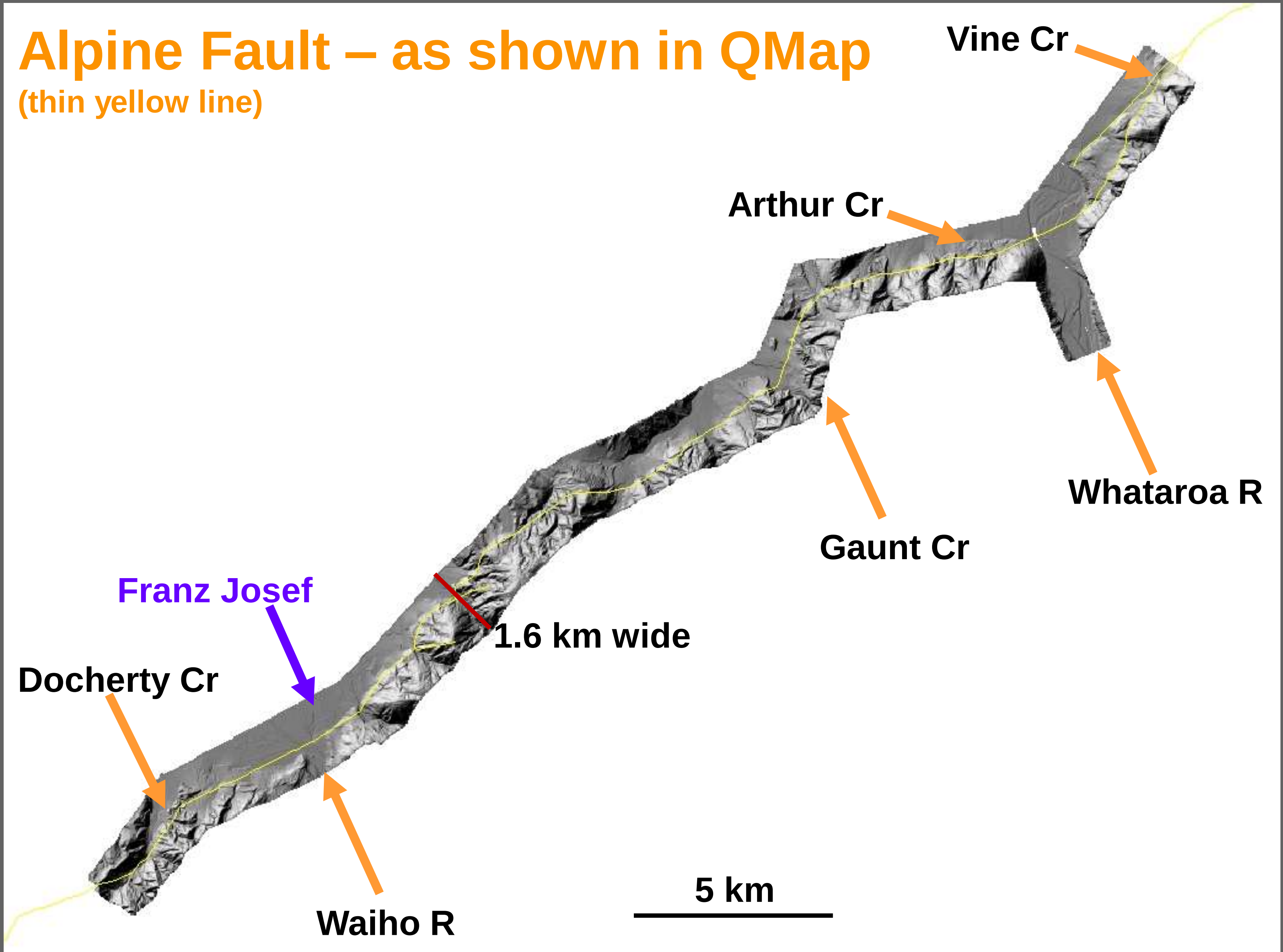
surface model



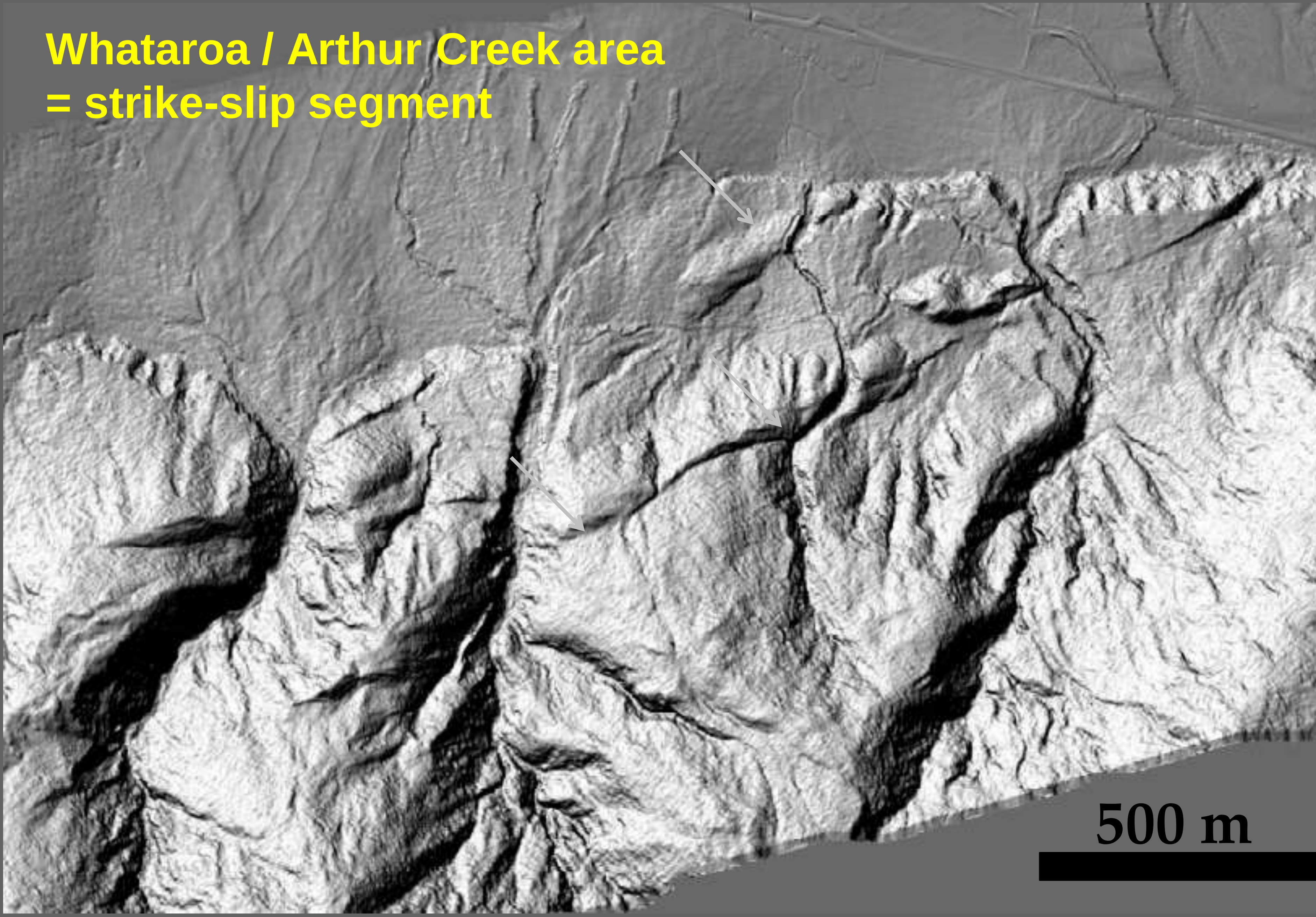
images from Forestry Tasmania, US Forest Service, Live Science

Alpine Fault – as shown in QMap

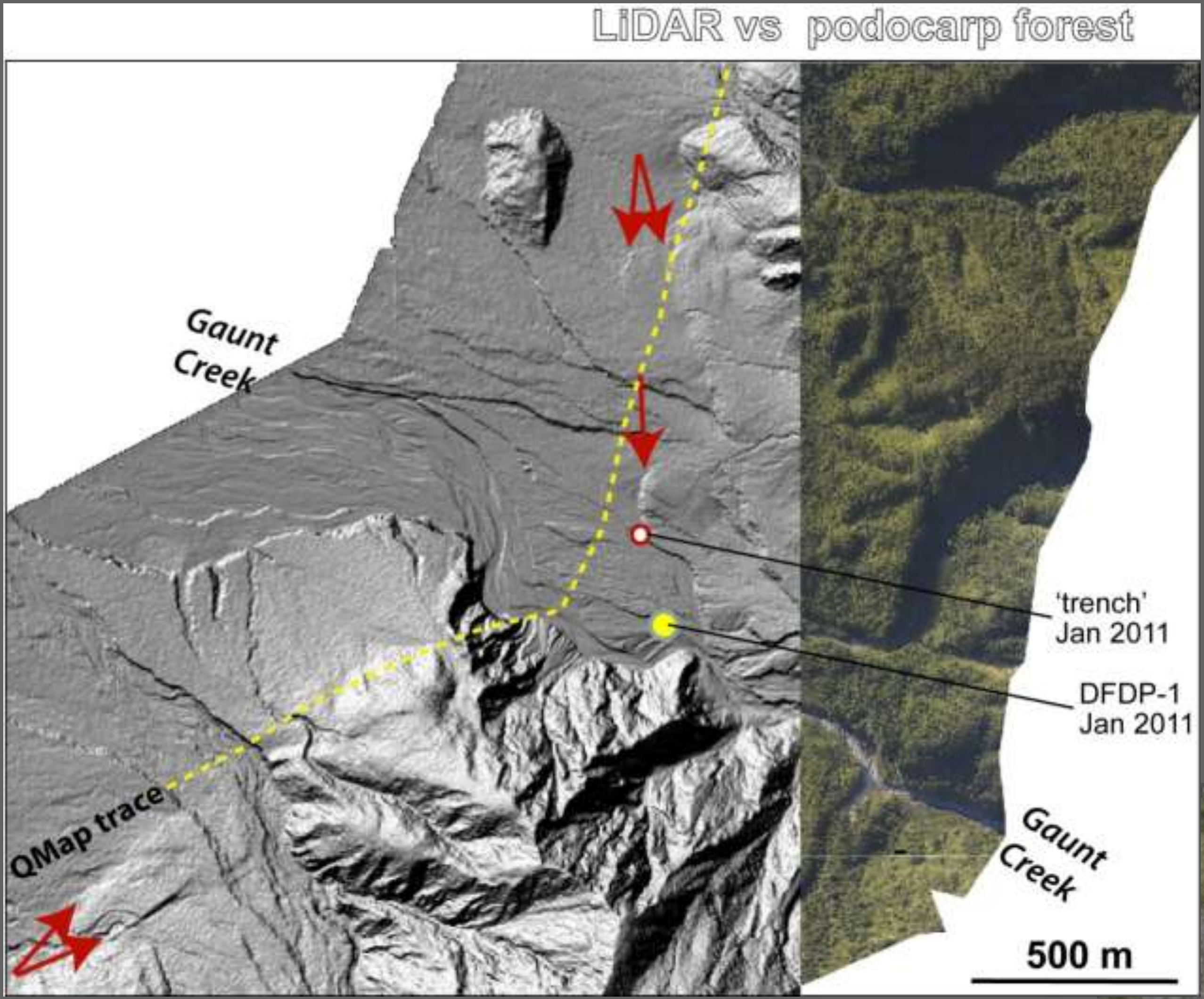
(thin yellow line)



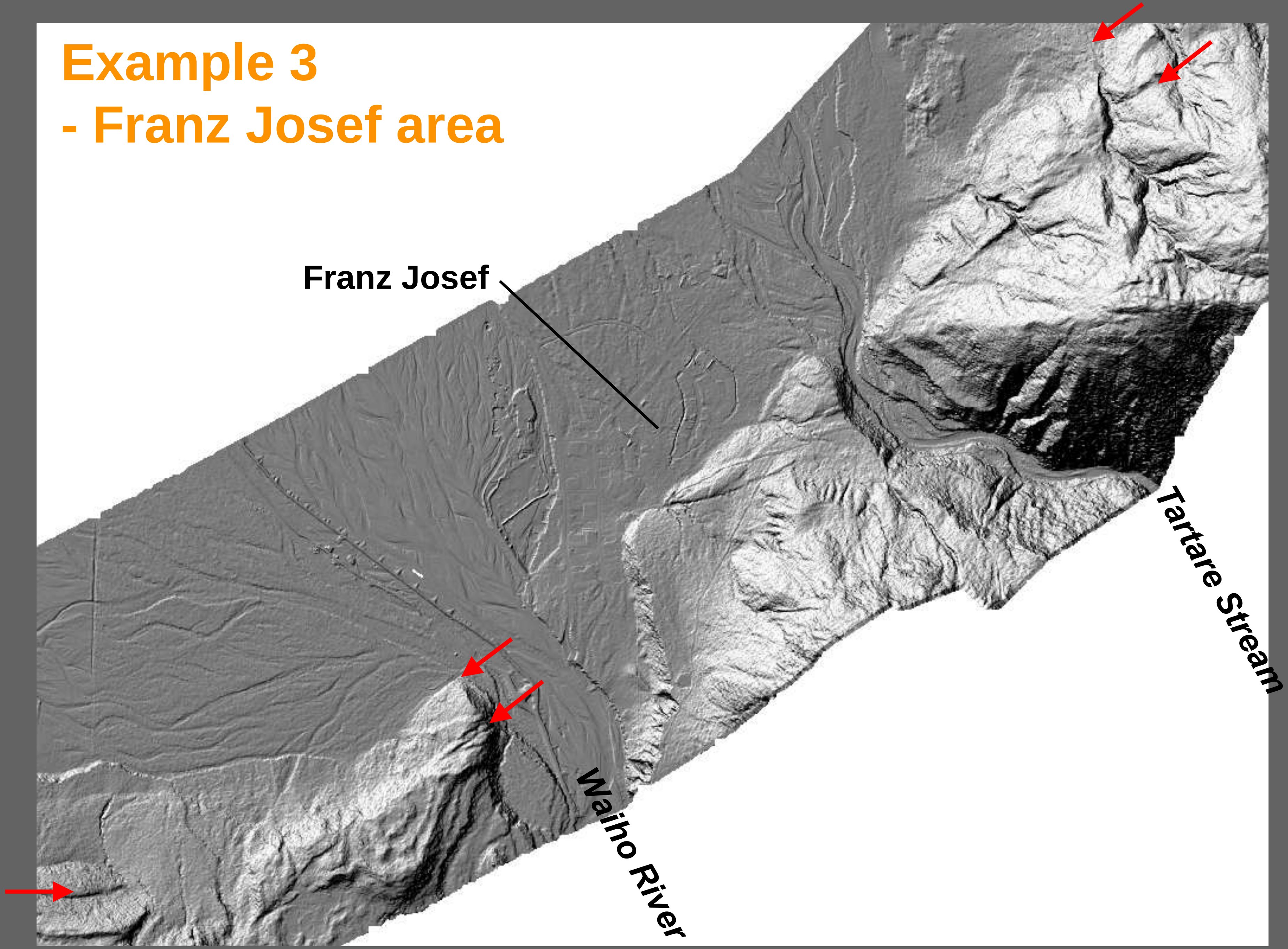
Whataroa / Arthur Creek area
= strike-slip segment

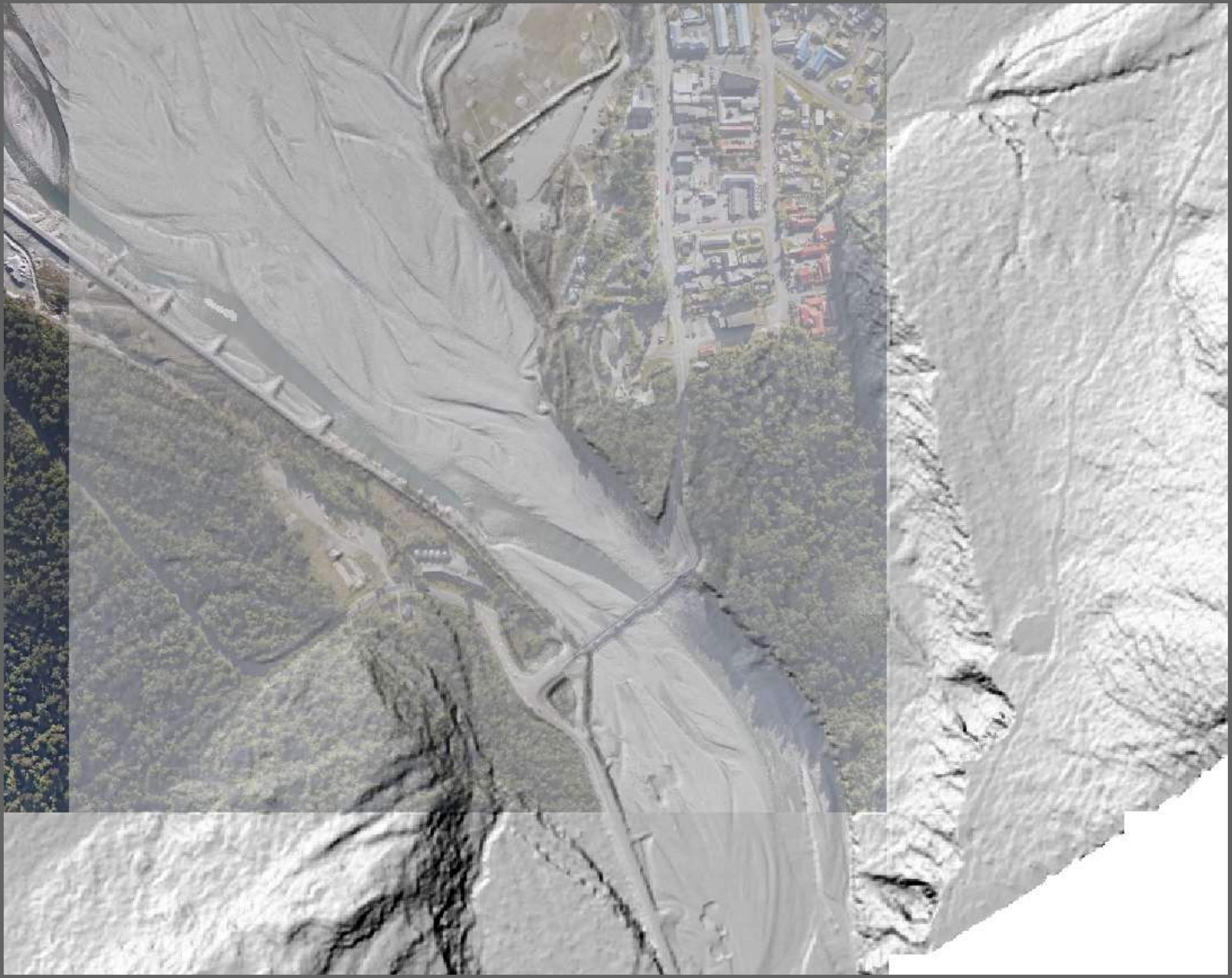


Example 2 - Gaunt Creek

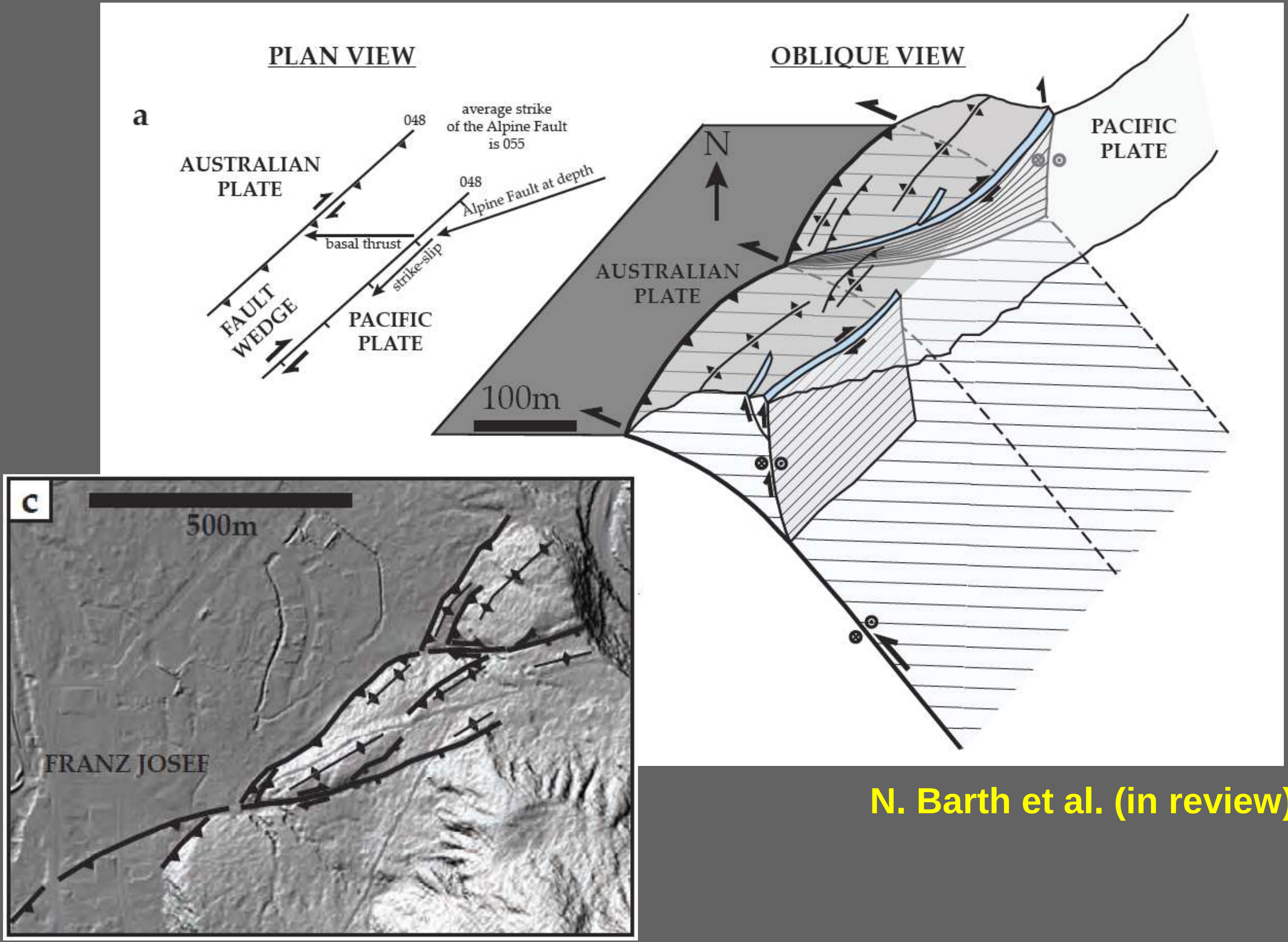


Example 3
- Franz Josef area



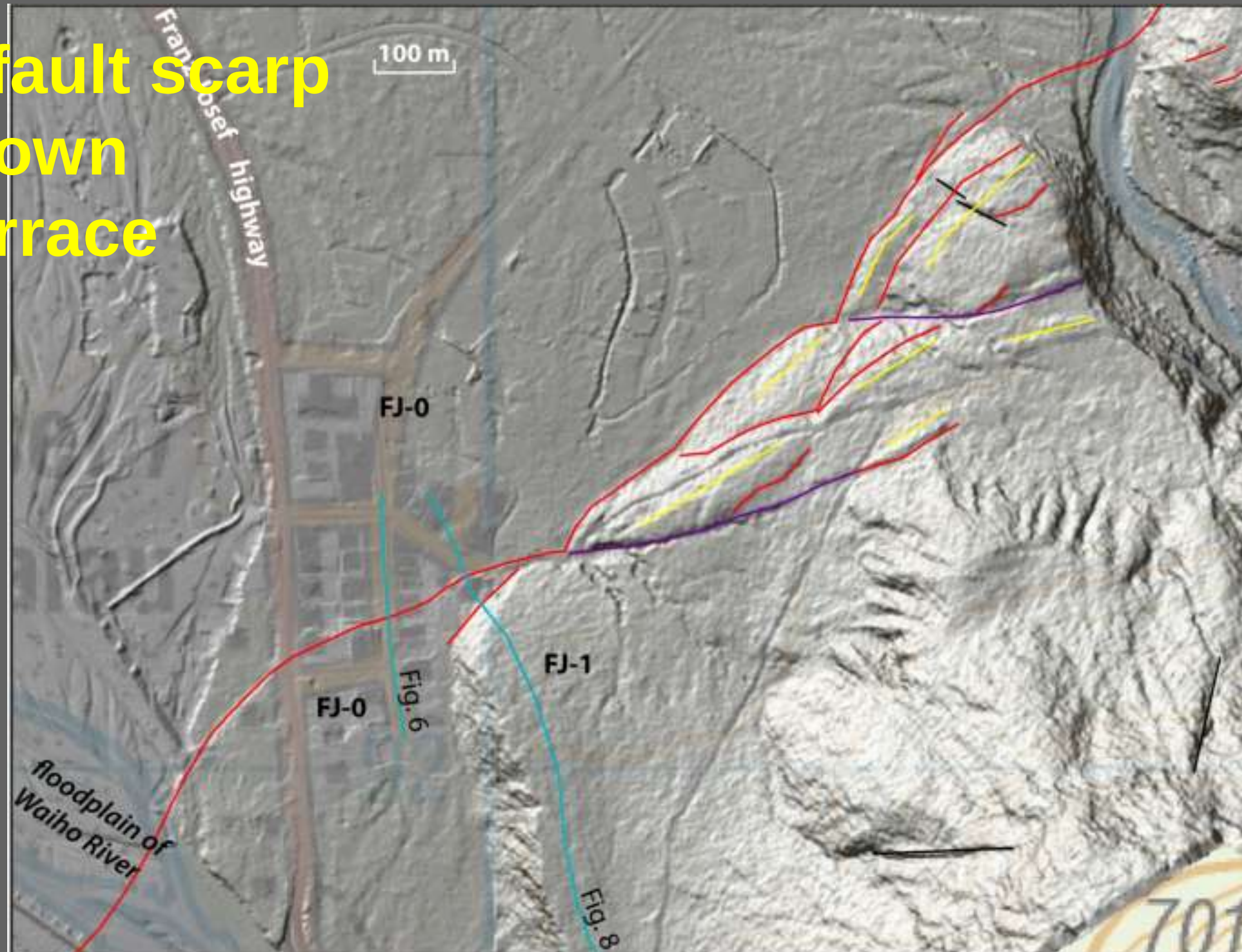


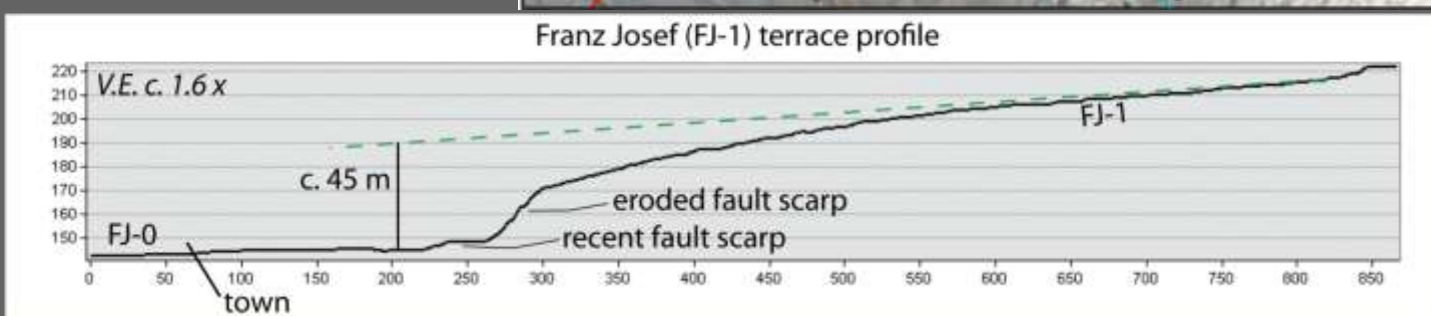
Shape of the fault in 3-D



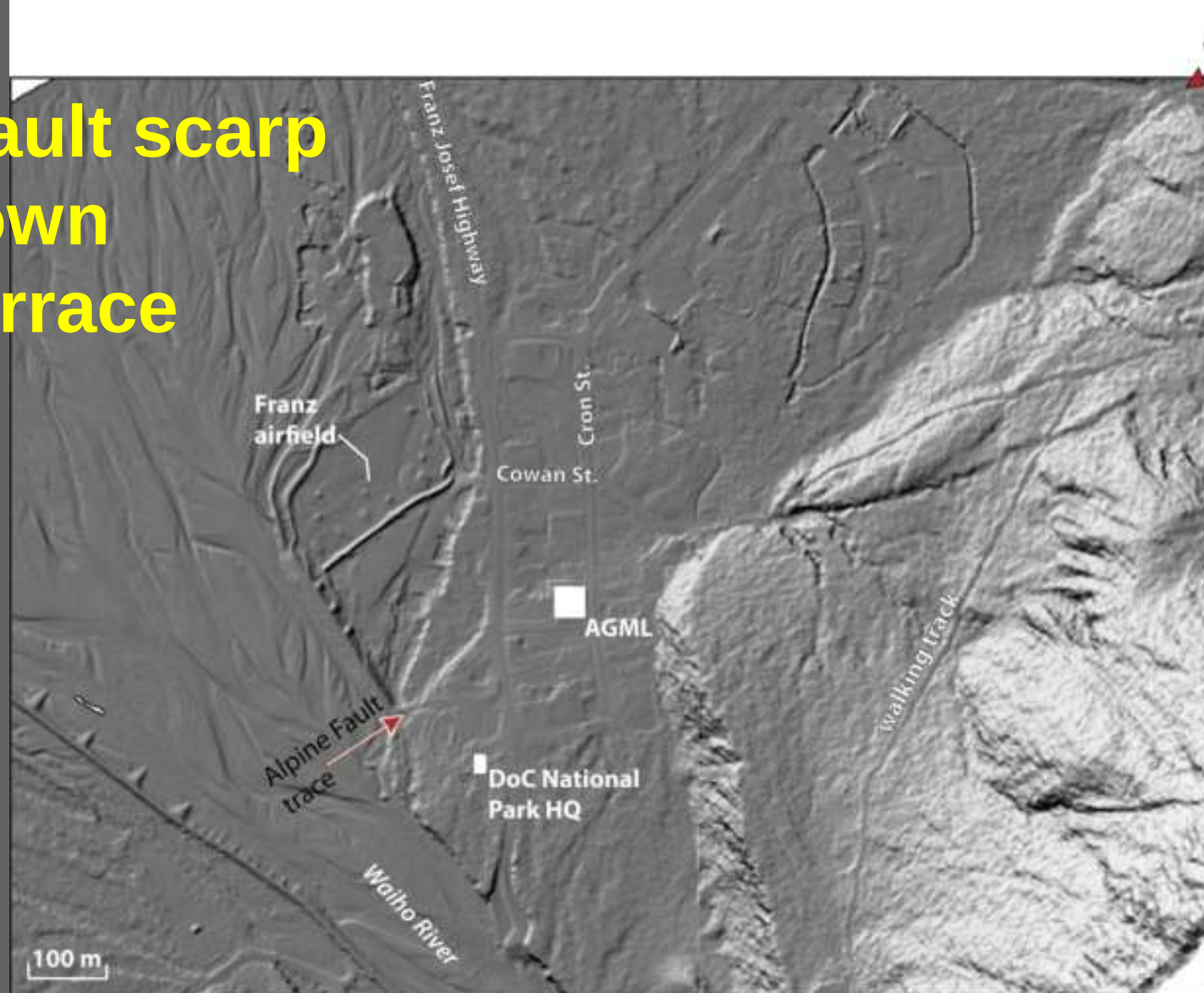
N. Barth et al. (in review)

Profiling the fault scarp through the town
1. the high terrace

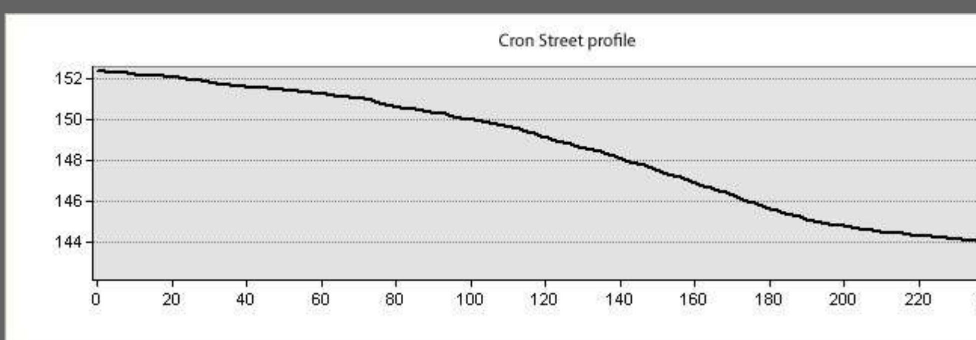




Profiling the fault scarp through the town
2. the Town terrace

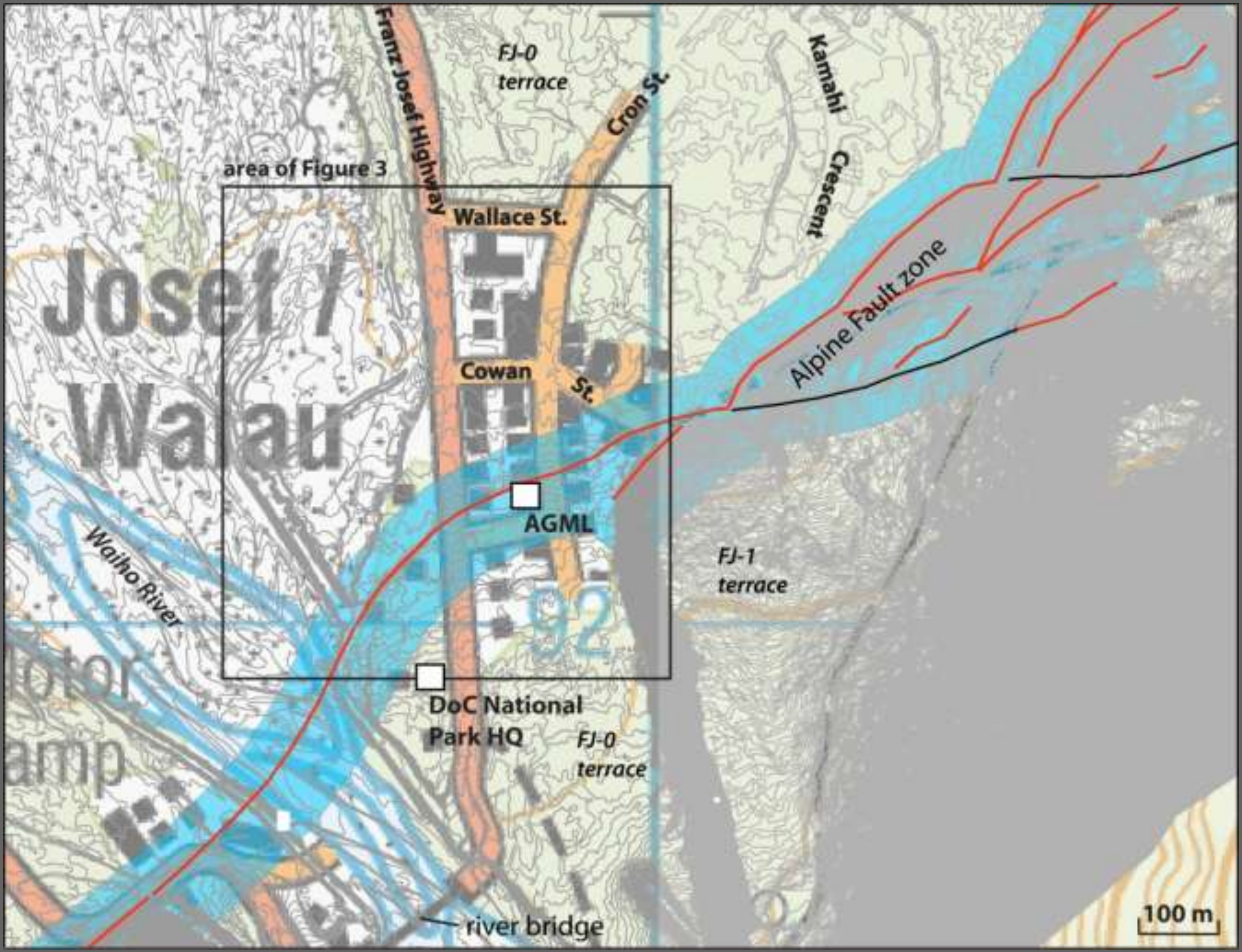


7 m high scarp over width of 120 m

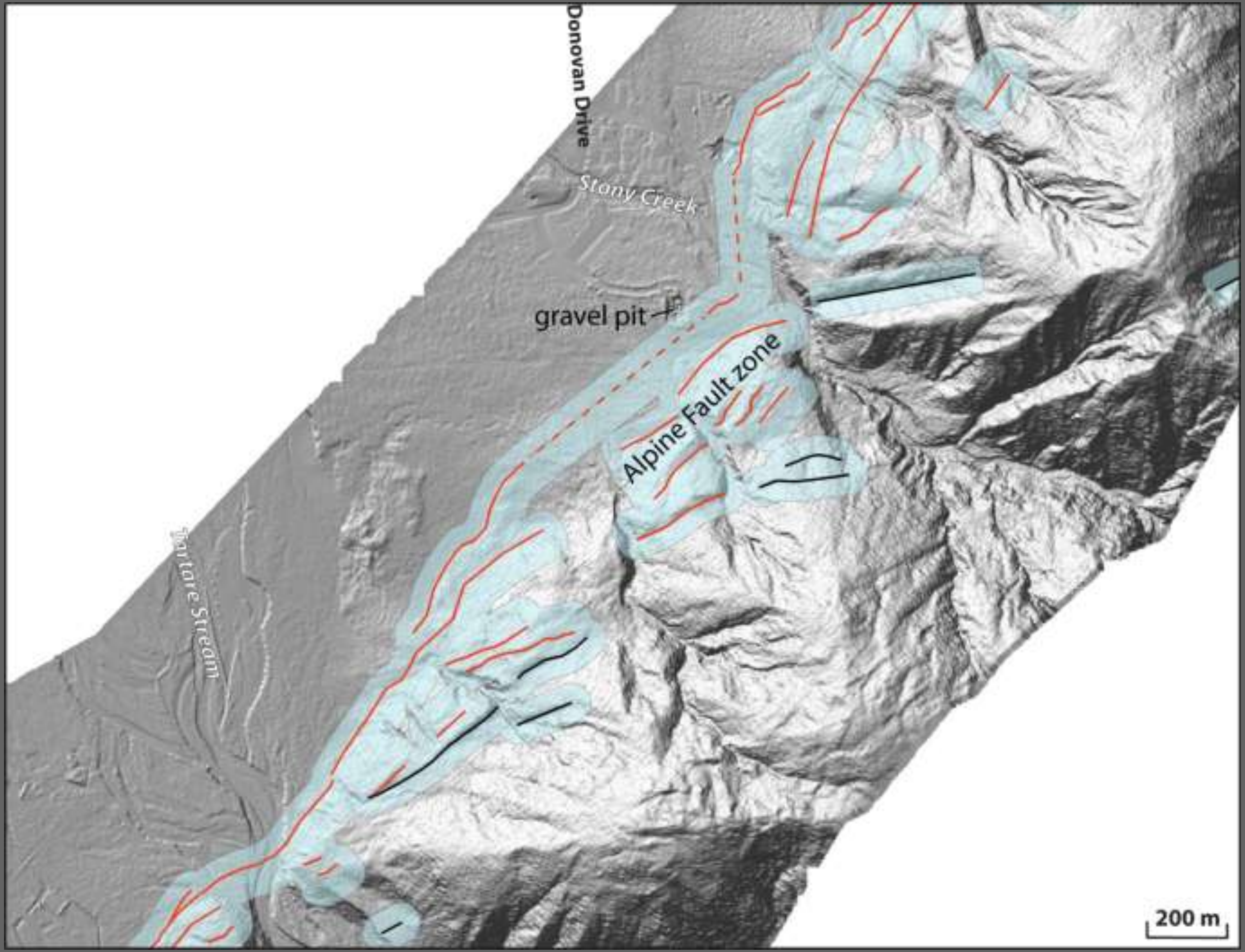


Profile of FJ-0 terrace in Franz Josef

END RESULT:
A Fault Avoidance Zone for Franz Josef



Similarly, we can construct a map for developing areas NE of Franz Josef (Tartare to Stony Cr)



Planning and Preparedness section

(perhaps not my *forte* !)

matching Severity of an event against its Likelihood of happening

Statute	Implication for natural hazard management
Resource Management Act 1991	• Health and safety issue must be addressed. • Local authorities are required to avoid or mitigate the effects of natural hazards, not their occurrence (*Canterbury RC v Banks Peninsula DC, 1995).* • S106 allows for Councils to consider the potential erosion, falling debris and flooding effects which could affect a subdivision (not landuse development). It should be noted that S106 does not allow for the consideration of all natural hazards as defined under the RMA (in particular fault rupture and tsunami which can be associated with an earthquake). • The ability to develop National Policy Statements of National Environmental Standards to address natural hazards (none currently exist).
Building Act 2004	• Requires all buildings are 'safe from all reasonably foreseeable actions during the life of the building' • Reference is made to the joint Australian/New Zealand loading standard AS/NZS1170. Within table 3.1 of part 0 the acceptable annual probability of exceedence for wind and earthquake loads are identified. These relate to the return period for an event (being 1/500, 1/1000 and 1/2500) and the building importance categories of II (ordinary) (Important) and IV (Critical). The more important the building, the longer the return period of an event is the structure required to be designed for. • These annual probabilities of exceedence correspond to a 10%, 5% and 2% probability within the nominal 50 year life of the building. • The ability to resist actions from other hazards is specified in the Building Code (a regulation that accompanies the Building Act) but no acceptable intensity of action or recurrence interval is prescribed either in the Code or in the Loading Standard (except for snow which has a nominal annual probability of exceedence of 1/150 years). • Sections 72 – 74 of the Building Act identify the process that Councils must follow when considering a building consent on a site subject to 1 or more natural hazards. The Building Act allows for Council to decline a building consent if, by granting the consent, the development would worsen or accelerate the effects from a natural hazard. Alternatively, building consent can be granted if : i) adequate provision has been or will be made to protect the land, building work, or other property from the natural hazard or hazards; or ii) restore any damage to that land or other property as a result of the building work. • The definition of natural hazards under the Building Act is limited and does not include tsunami or fault rupture
CDEM Act 2002	• 4R (readiness, reduction, response and recovery) philosophy – risk reduction is assumed to be managed under the RMA (refer Saunders et al 2007). • Encourage and enable communities to achieve acceptable levels of risk. • Readiness and response driven.
Local Government Act 2002	• Financial planning for risk reduction activities. • Take into account the foreseeable needs of future generations.
Local Government Official Information & Meetings Act 1987	• Provides for natural hazard information to be included in LIMs. • If the natural hazard is identified within the District Plan, this information is not required to be provided within a LIM (S44A(2)(a)(ii).

A scale of Severity (S) of an event

Scale of impact	Description of consequences				Severity of Consequence
	Health & safety	Social	Economic	Environmental	
Major	Multiple fatalities, or significant irreversible effects to >50 persons.	On-going serious social issues. Significant damage to structures and items of cultural significance	Severe i.e. over $10 million -or- more than 50 % of assets	Severe, long-term environmental impairment of ecosystem functions	VI
Severe	Single fatalities and / or severe permanent disability (>30%) to one or more people.	On-going serious social issues. Significant damage to structures and items of cultural significance	Major i.e. between $1 million and $10 million -or- 10-50 % assets	Very serious, long-term environmental impairment of ecosystem functions	V
Moderate	Moderate irreversible disability or impairment (<30%) to one or more persons.	On-going social issues, permanent damage to buildings and items of cultural significance	Moderate i.e. between $100,000 and $1million -or- 10 % of assets	Moderate, short term effects by not affecting ecosystem functions	IV
Minor	Reversible injury possibly requiring hospitalisation.	On-going social issues, temporary damage to buildings and items of cultural significance	Minor i.e. between $10,000 and $100,000 -or- 1 % of assets	Minor effects on physical environment	III
		Medium-term social issues, minor damage to dwellings	Minor i.e. between $10,000 and $100,000 -or- 0.1% of assets		II
Negligible	Minor first aid or no medical treatment required.	Negligible short -term social impacts on local population, mostly repairable	Small i.e. less than $10,000 -or- 0.01% of assets	Insignificant effects on physical environment	I

A scale of Likelihood (L) of an event

Level	Descriptor	Description	Indicative Frequency (expected to occur)	AEP*
7	Almost certain	The event will occur on an annual basis	Once a year or more frequently	1
6	Likely	The event has occurred several times or more in your career	Once every three years	0.3
5	Possible	The event might occur once in your career	Once every ten years	0.1
4	Unlikely	The event does occur somewhere from time to time	Once every thirty years	0.03
3	Rare	Heard of something like this occurring elsewhere	Once every 100 years	0.01
2	Very rare	Have never heard of this happening	One in 1000 years	0.001
1	Almost incredible	Theoretically possible but not expected to occur	One in 10,000 years	0.0001

A matrix of L x S for an event

7	14	21	28	35	42
6	12	18	24	30	36
5	10	15	20	25	30
4	8	12	16	20	24
3	6	9	12	15	18
2	4	6	8	10	12
1	2	3	4	5	6

Response by WDC so far (positive !)

- **Accepting the mapping and FAZ strategy undertaken for Alpine Fault**

- **Future inclusion of fault line and FAZ's into the District Plan**

- **Goal of deterring further development within the Franz Josef FAZ**

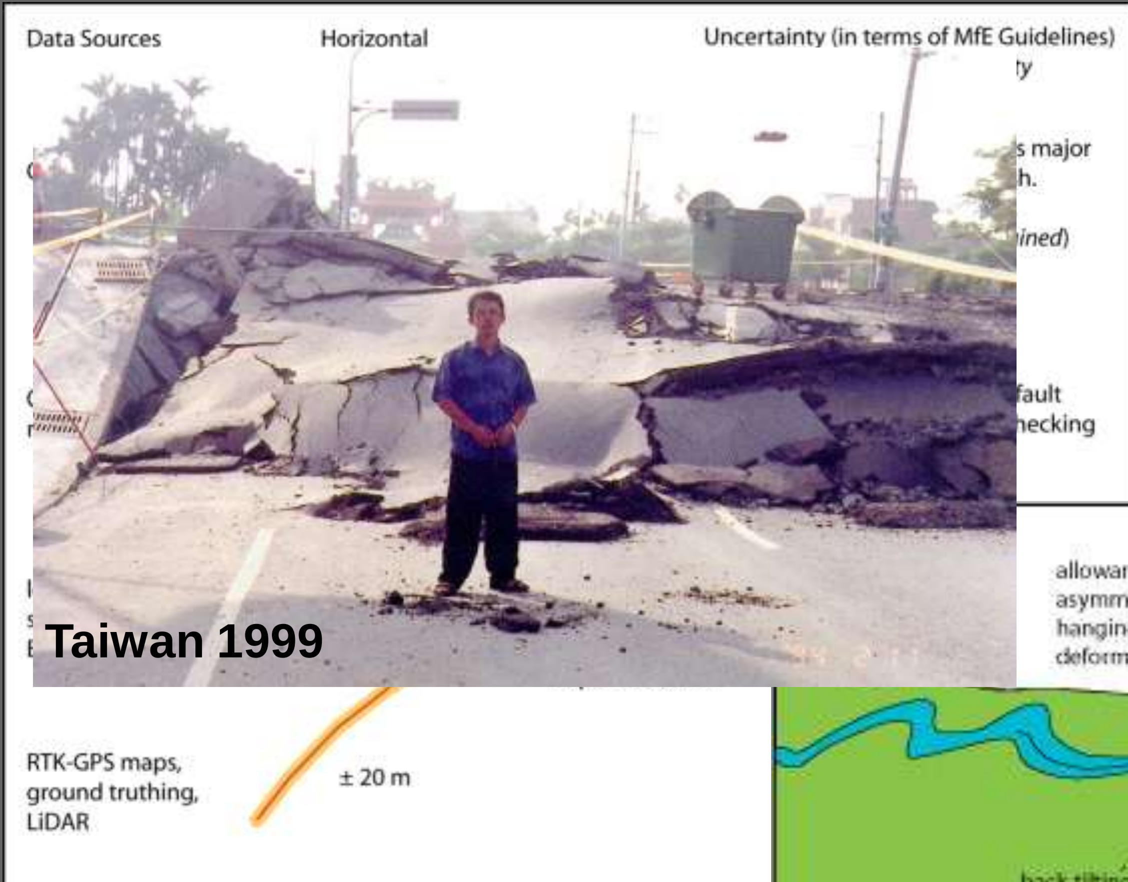
- **Therefore, developing a revised plan of how the town should develop**

- **In future, WDC may look to de-commission parts of the town as the Annual Exceedance of Probability for the Alpine Fault event gets very high**

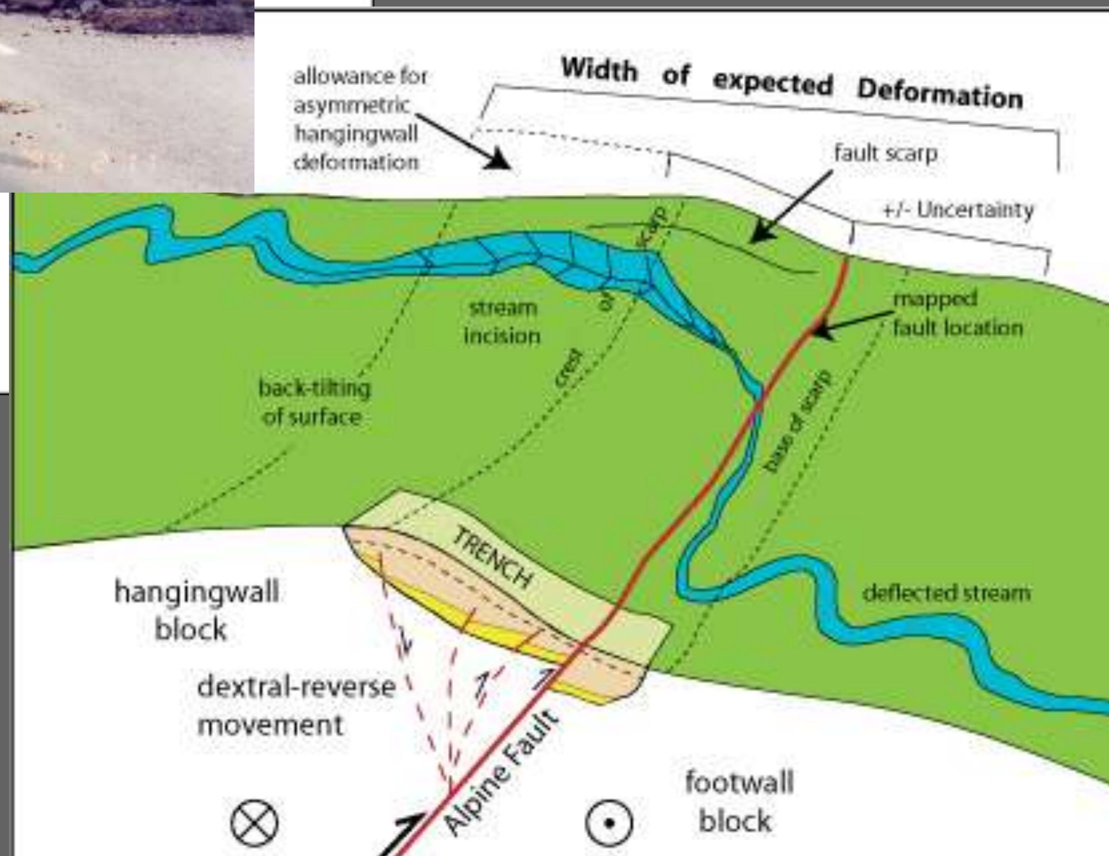
Questions, please....

Fault Avoidance Zones and planning for the next rupture of the Alpine Fault in Franz Josef

Dr. Robert Langridge
GNS Science,
Wellington, NZ

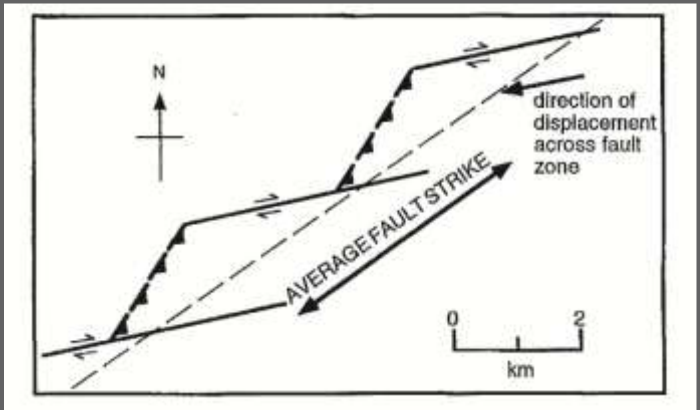


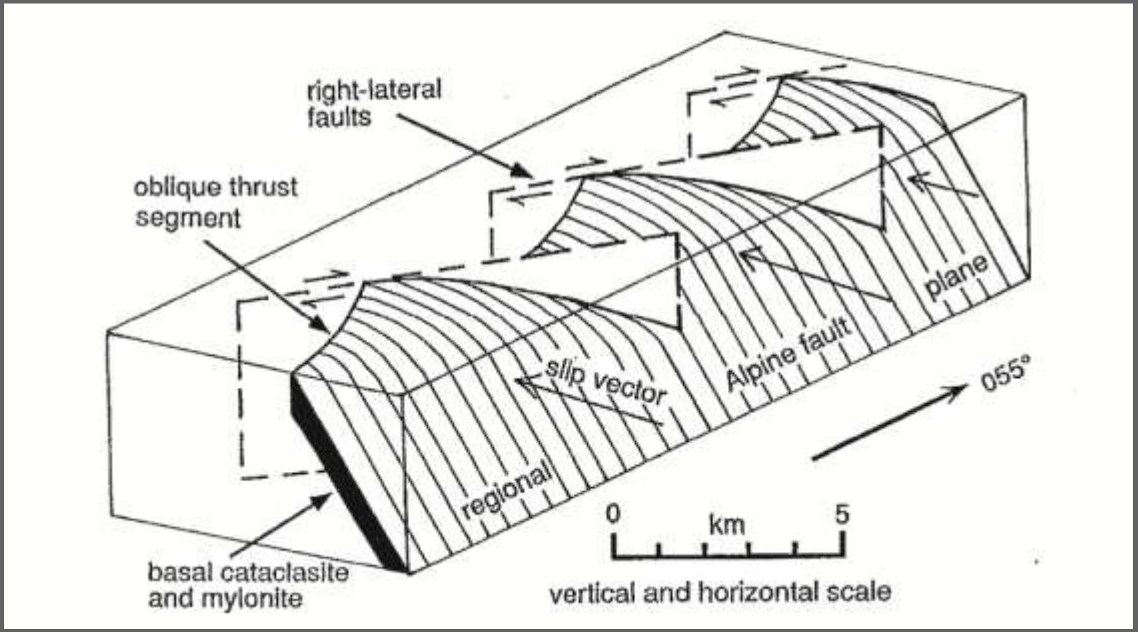
Data Sources
Horizontal
Uncertainty (in terms of MfE Guidelines)
Taiwan 1999
RTK-GPS maps, ground truthing, LiDAR
± 20 m



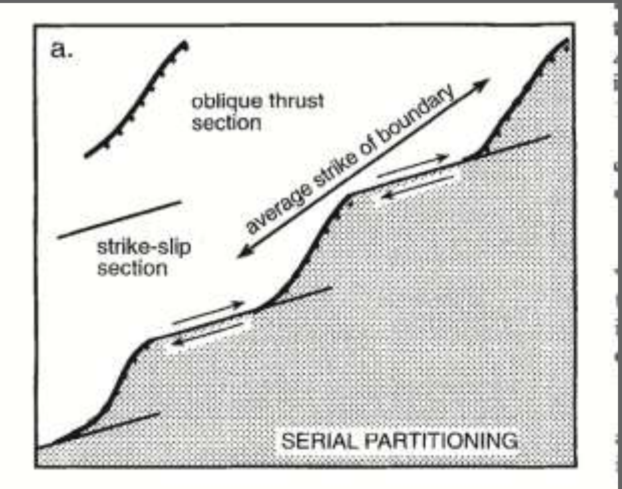
allowance for asymmetric hangingwall deformation
Width of expected Deformation
fault scarp
+/- Uncertainty
stream incision
mapped fault location
back-tilting of surface
crest
base of scarp
TRENCH
hangingwall block
dextral-reverse movement
Alpine Fault
deflected stream
footwall block

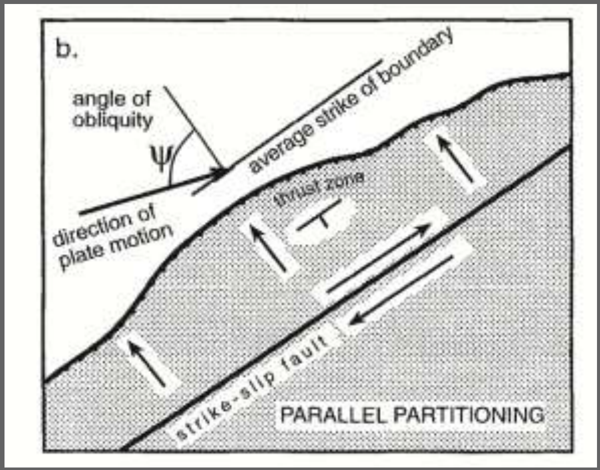
Models of shallow Alpine Fault structure





serial partitioning



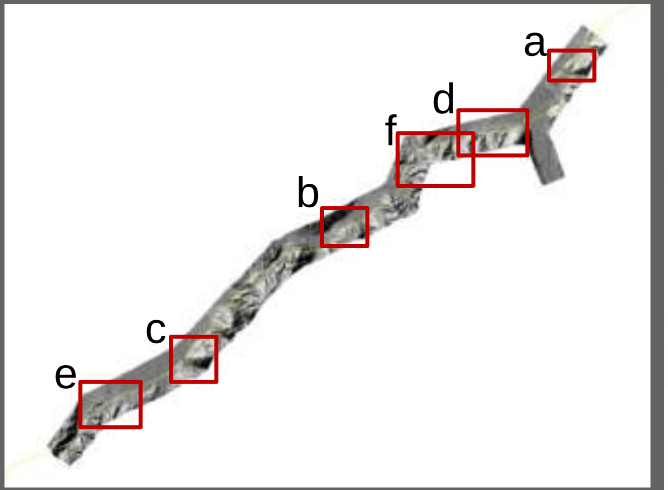


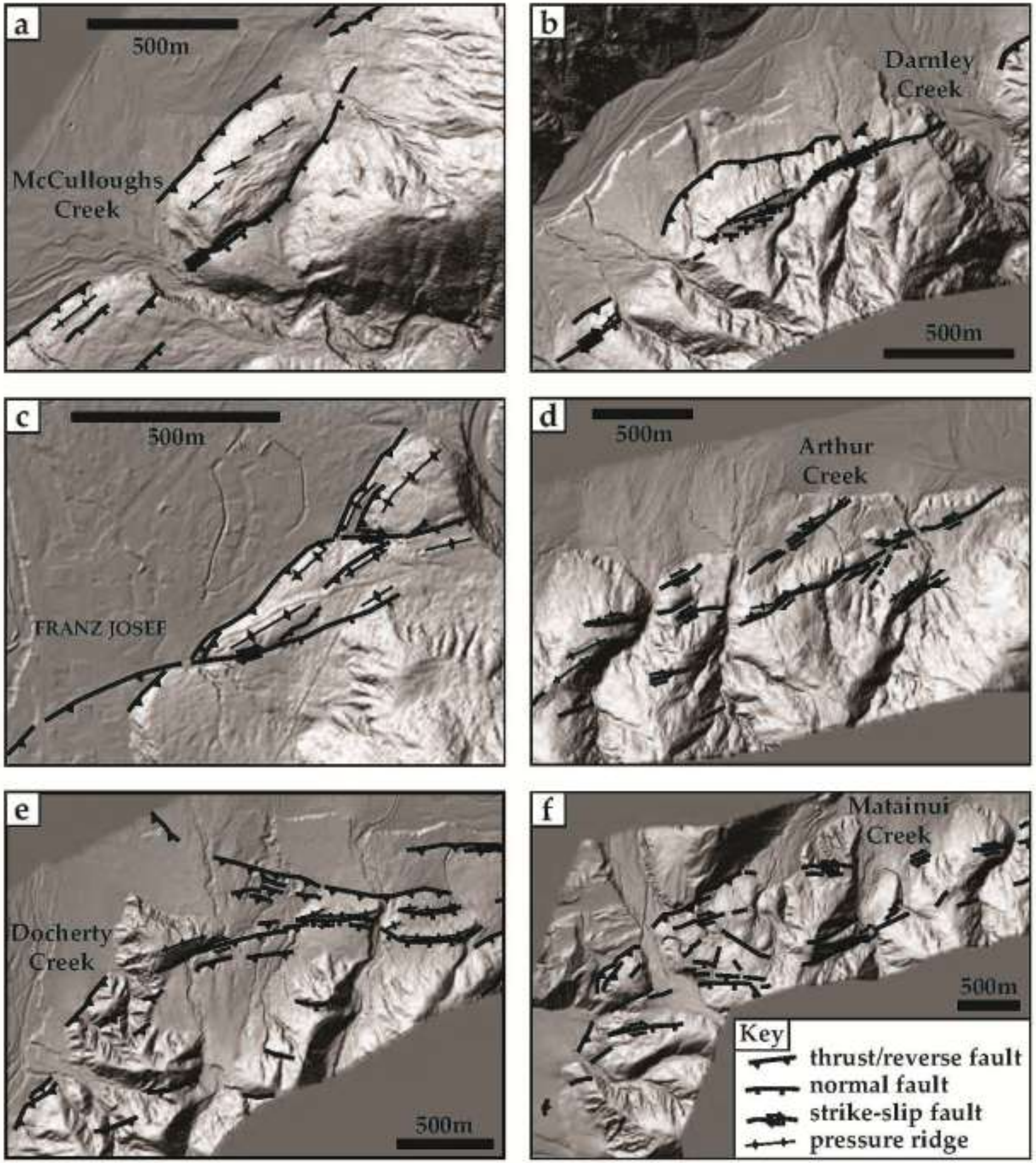
parallel partitioning

Norris & Cooper (2005; 2007)

N. Barth et al., in prep.

Shallow transpressional segmentation and partitioning revealed by LiDAR data, central Alpine Fault, New Zealand





Franz Josef

MM 9+ shaking / surface rupture

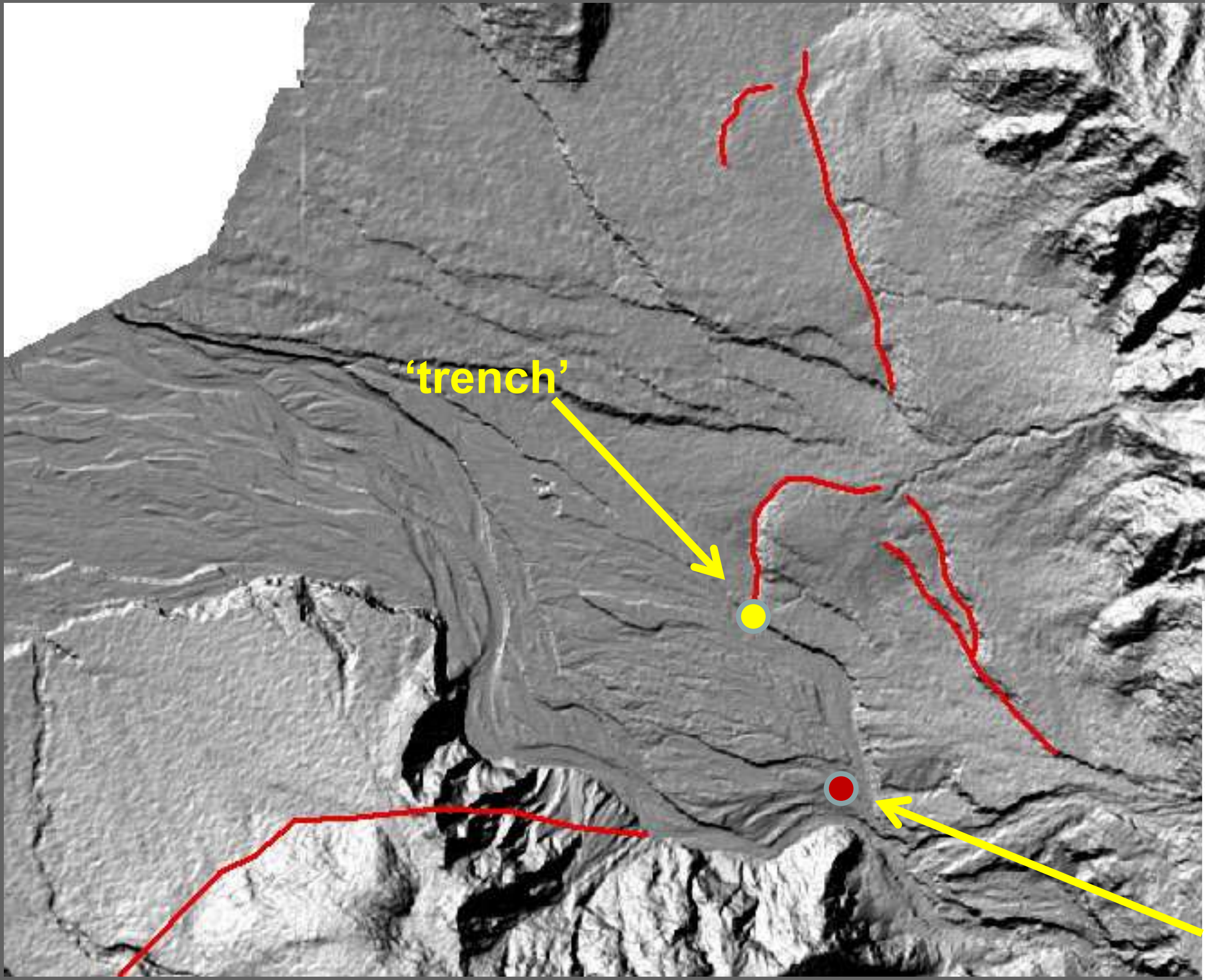
- Some buildings collapse
- Pre 1970-1980 buildings damaged
- Houses not secured to foundations move off
- Brick veneers fall and expose framing
- Fault rupture destroys houses, and facilities such as the petrol station and transport routes.
-Land-sliding in the mountains dams streams and blocks off roads.


Waiho River Bridge

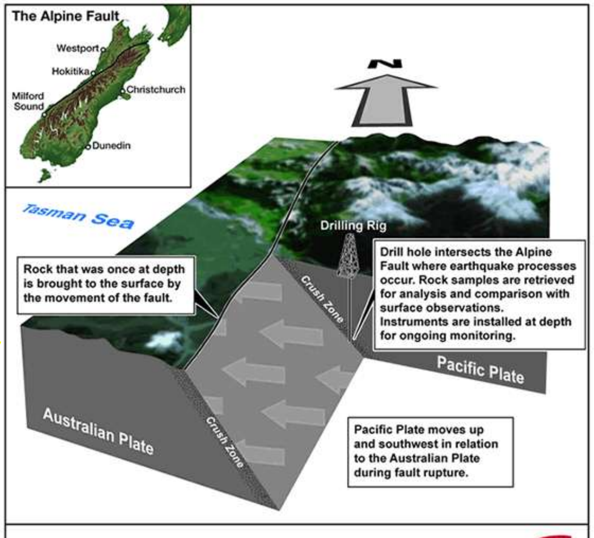

Franz Josef


petrol station…after?

Gaunt Creek



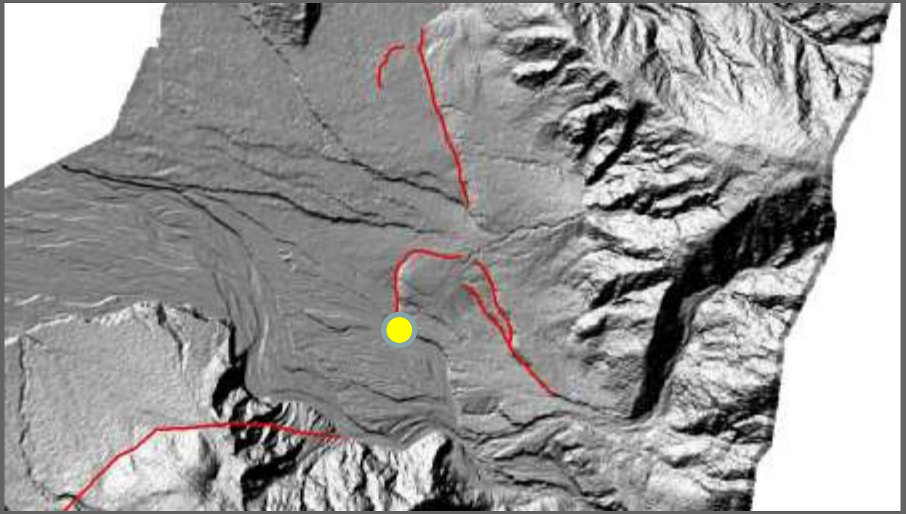
AF DFDP-1
January 2011

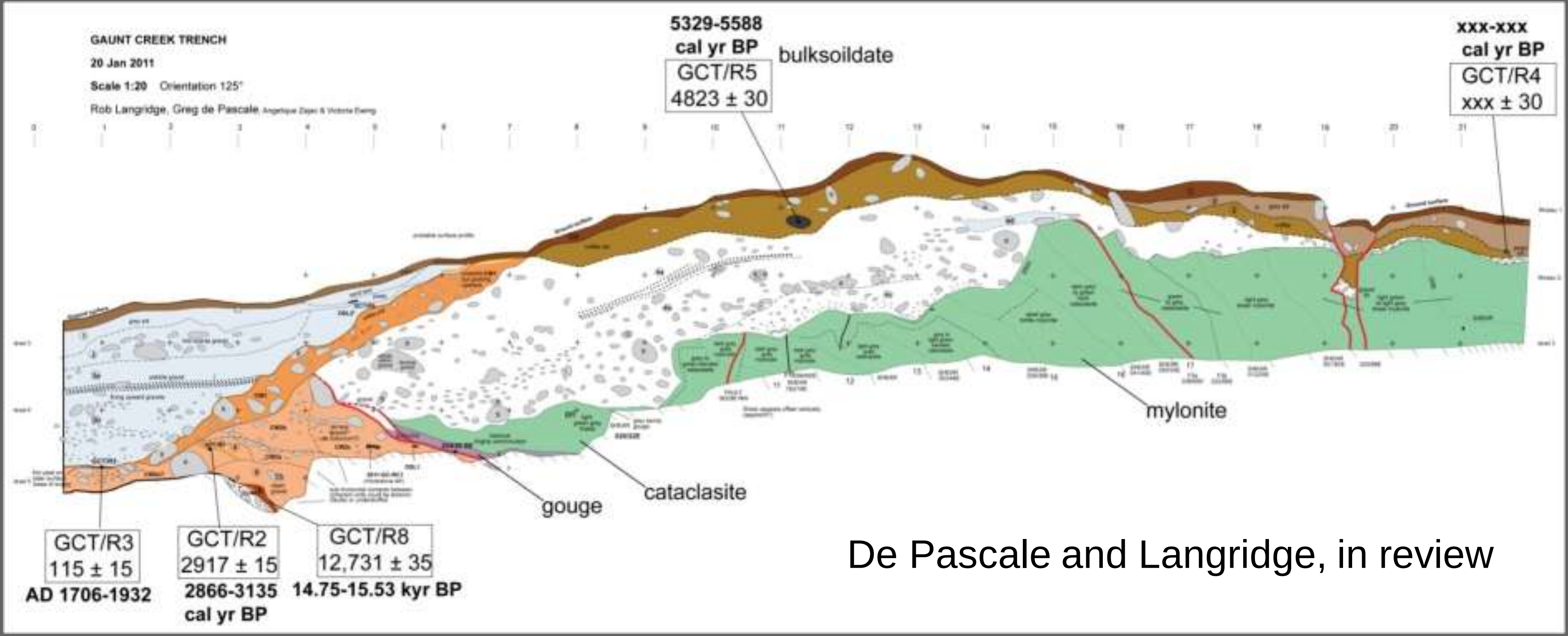


Schematic illustration of how a deep fault drilling project would operate on the Alpine Fault.

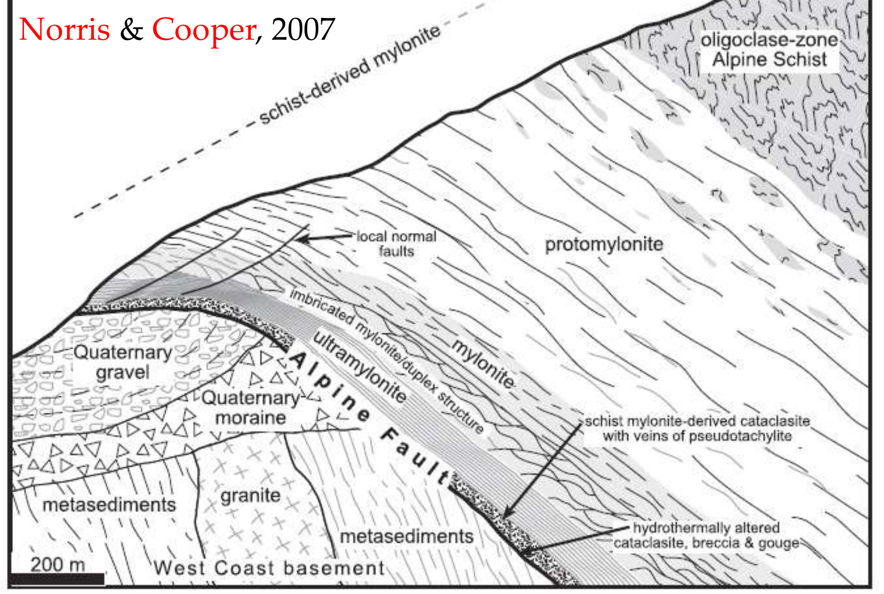
fault looks N- to NNW-striking ?

Gaunt Creek trench

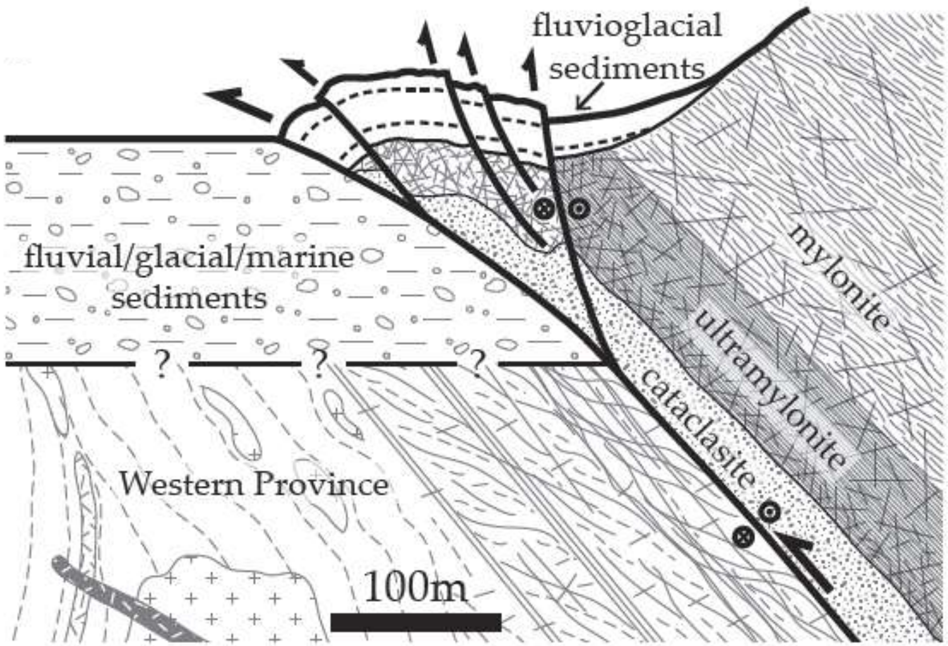


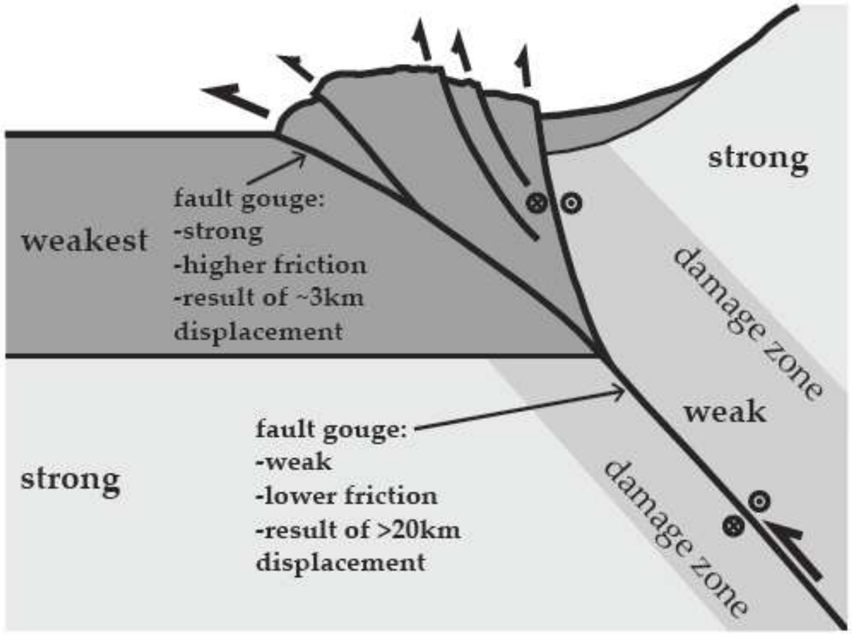


De Pascale and Langridge, in review



Cross sections

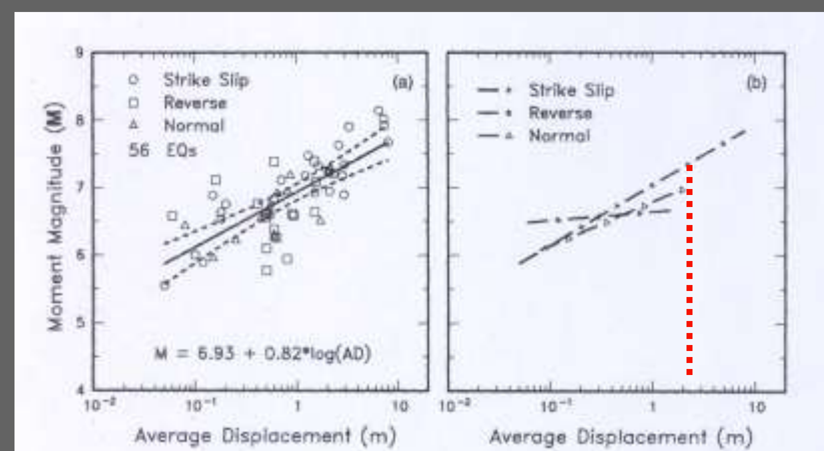




1888 M 7.1 North Canterbury earthquake – first documented strike-slip movement

Cowan – 1888 earthquake in North Canterbury 3

Fig. 2 – Regional isoseismal map and locations of inferred Modified Mercalli intensities for the September 1, 1888, North Canterbury earthquake, from data in Appendix 1.



South Island tectonics

- transpressional boundary between the Pacific and Australian plates

- dominant provinces are: Alpine Fault, Puysegur subduction Zone, Marlborough Fault System

- minor provinces are: Porters Pass FZ, Otago Range & Basin, NW Nelson faults

- dominantly a dextral-slip system