Aspects of New Zealand Sedimentation and Tectonics

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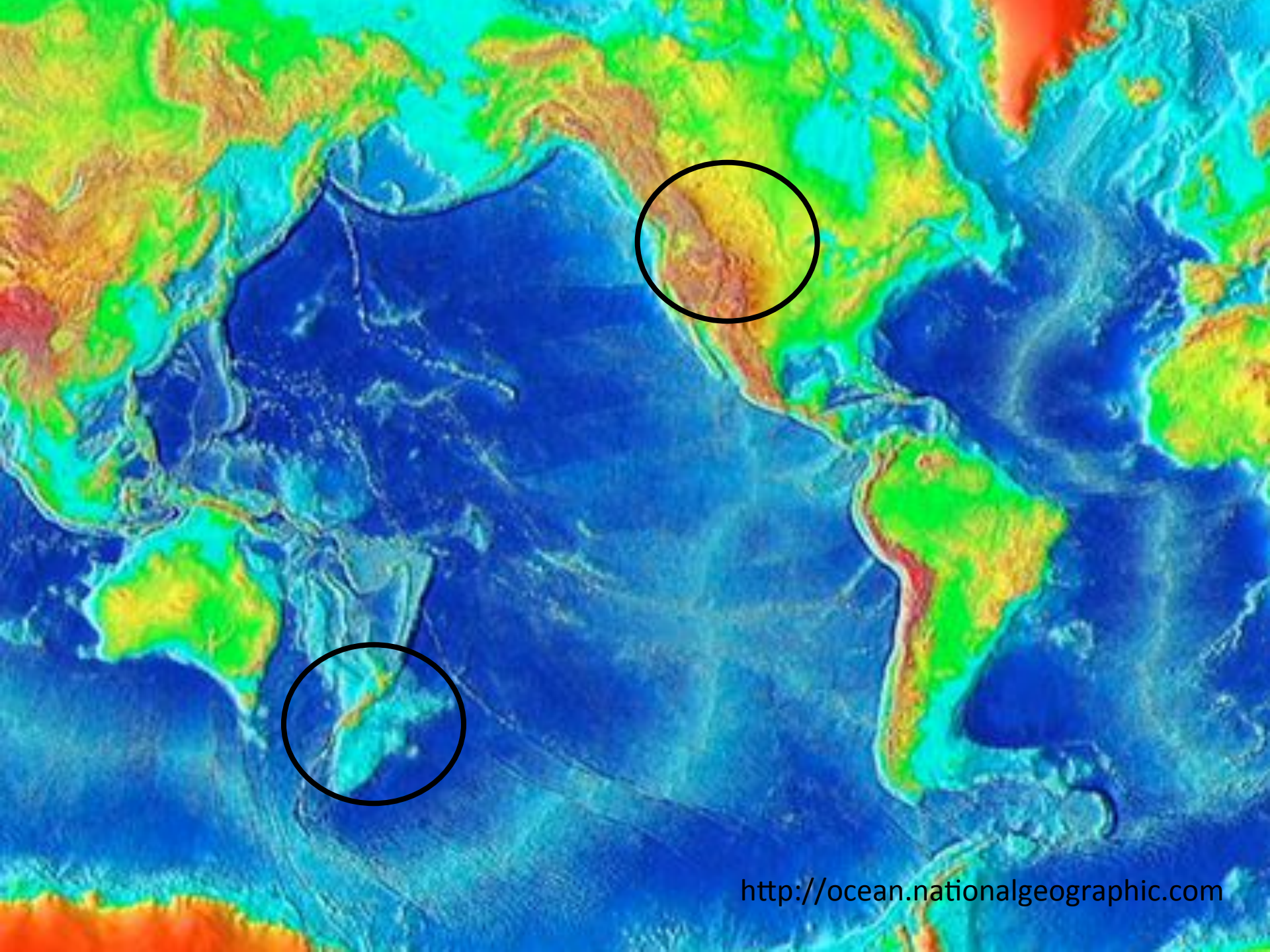

http://ocean.nationalgeographic.com

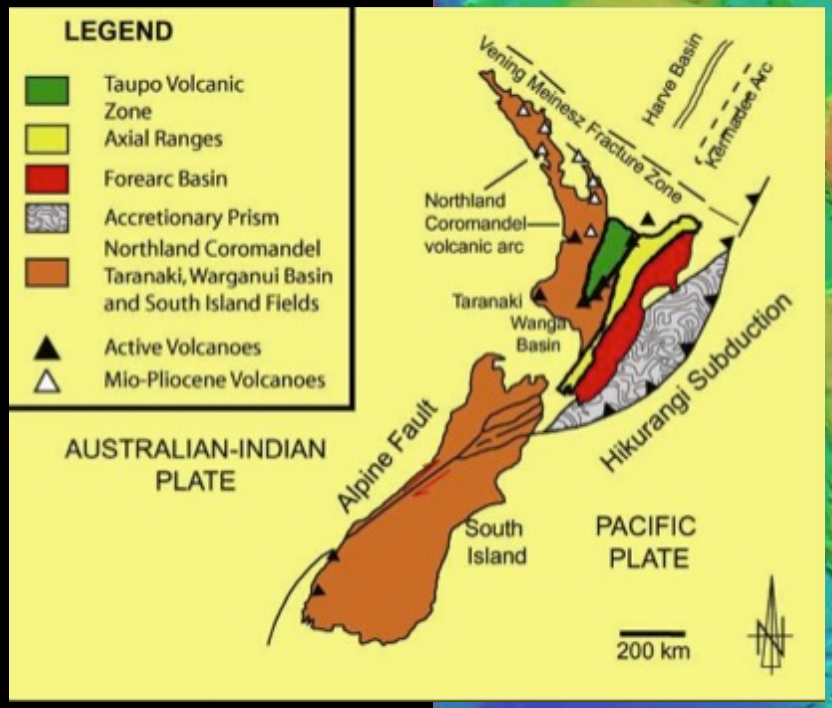


Image from CANZ (1996)

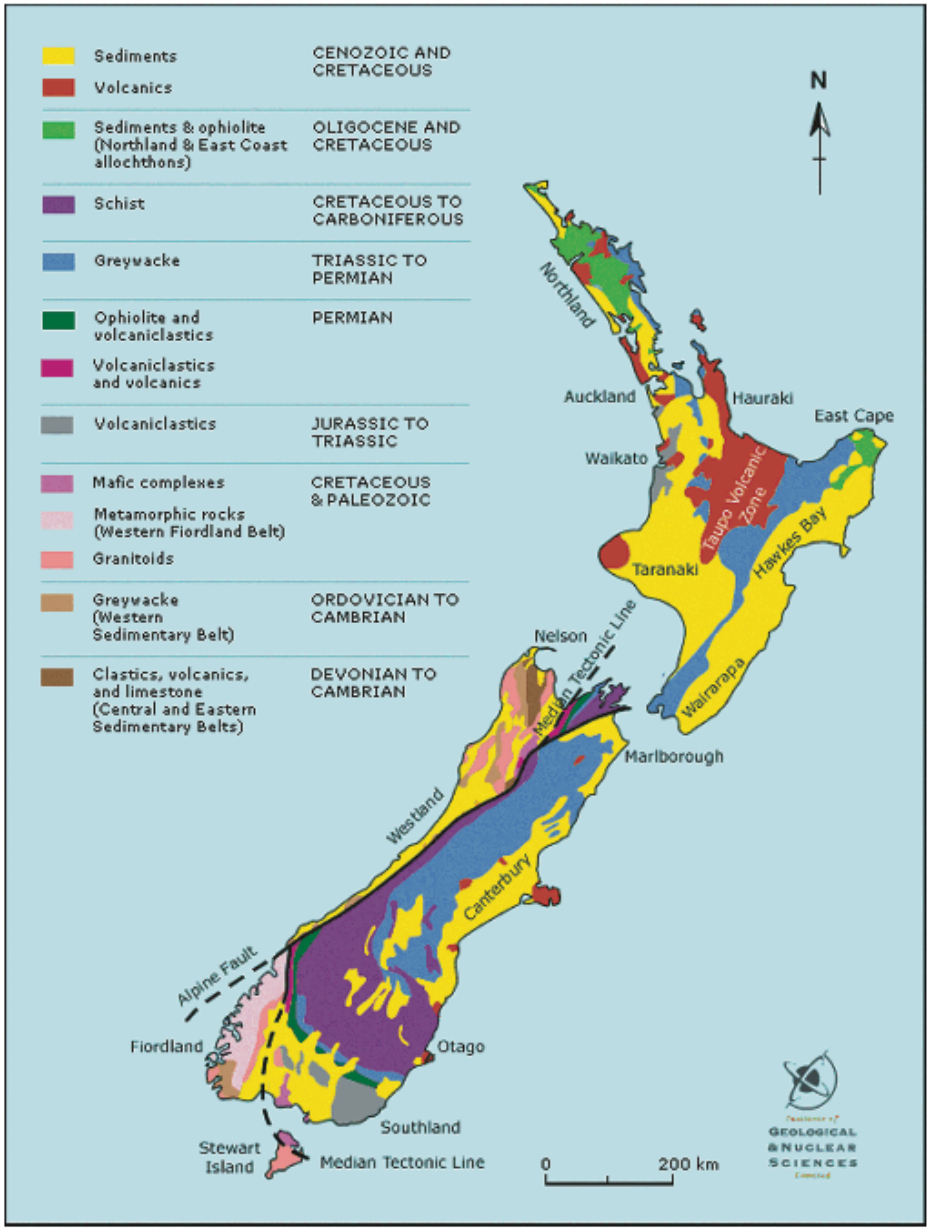
New Zealand
vs.
"Zealandia"

(see Mortimer, 2004; Gondwana Research)

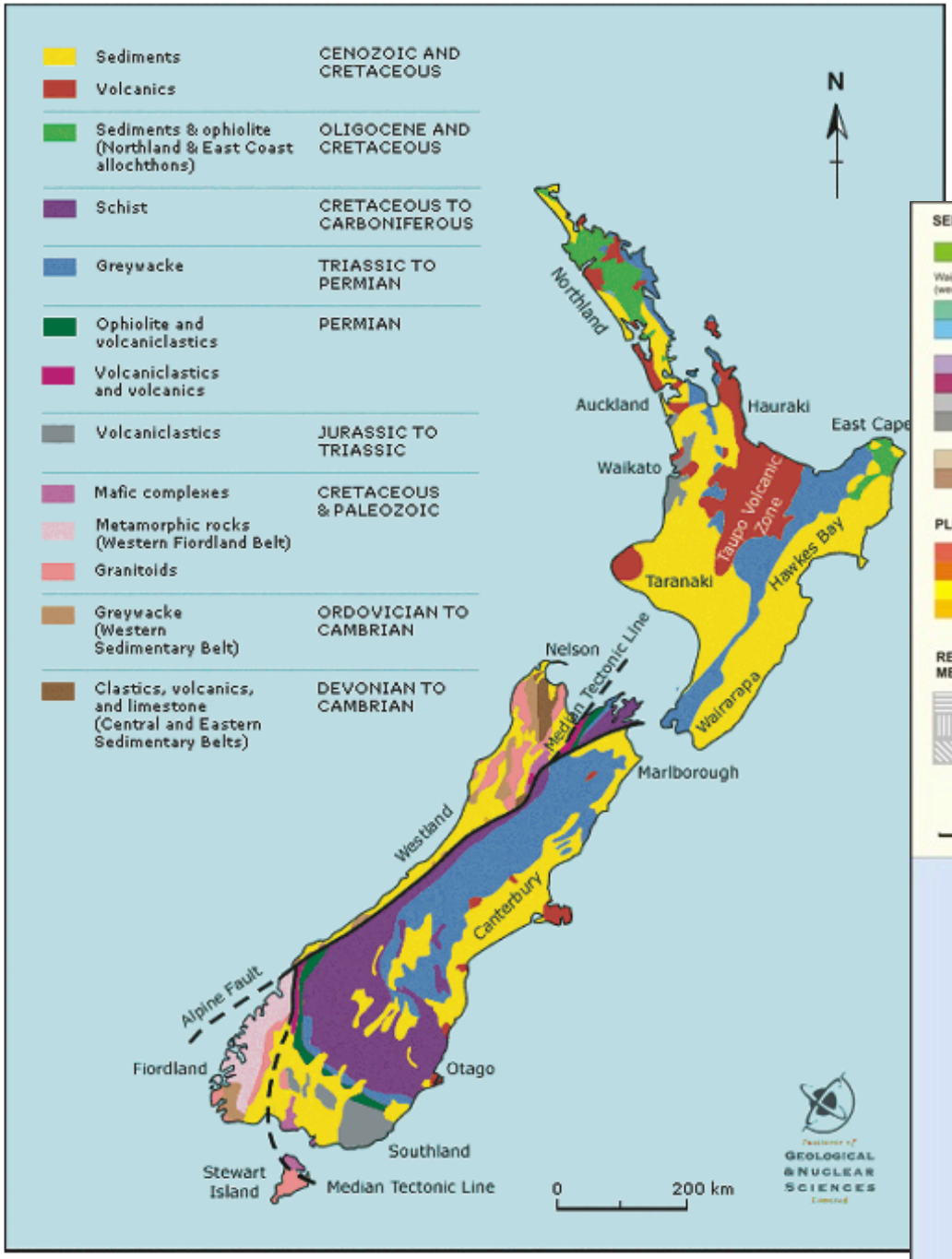
OVERVIEW of TALK

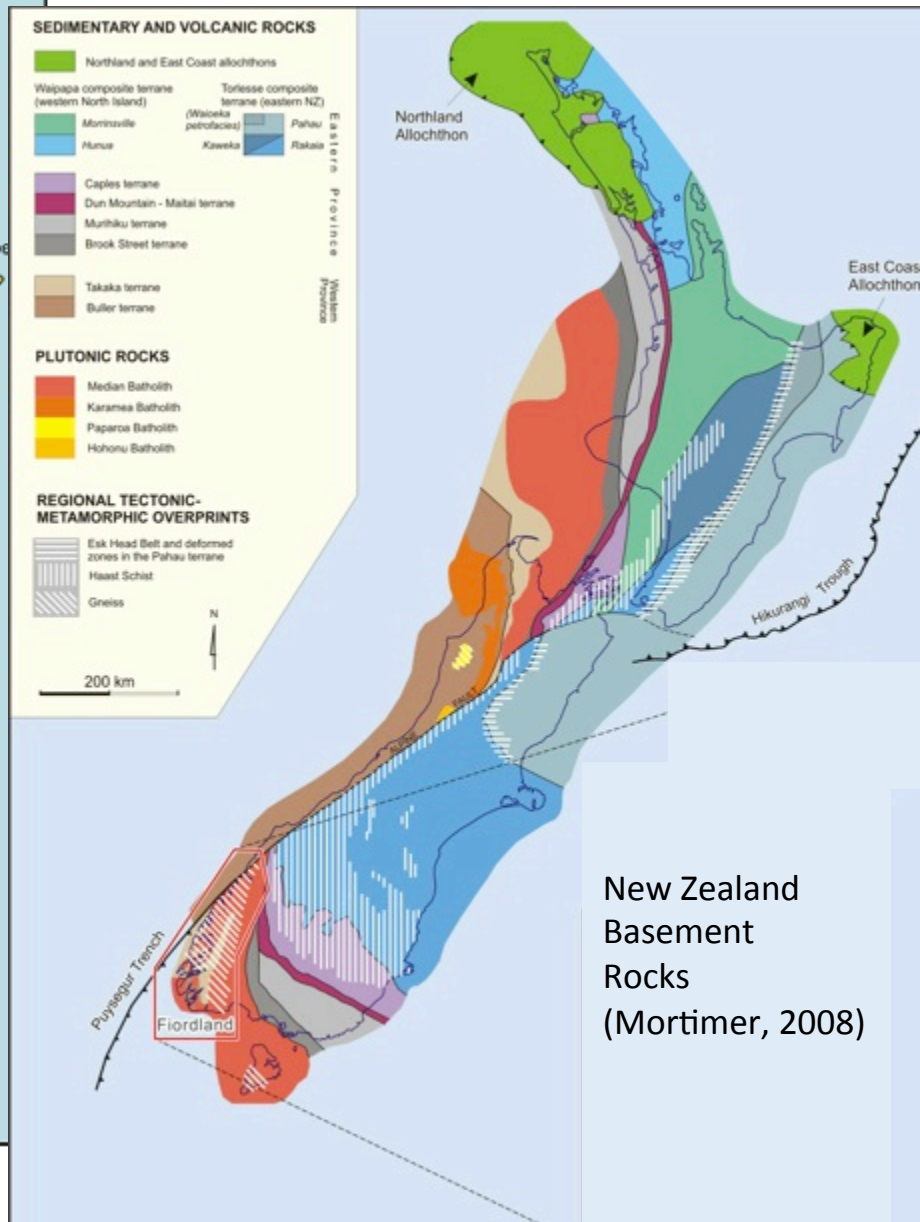
- *General overview of NZ Paleozoic to Cenozoic(meta)sedimentary units emphasizing convergent margin history*

- *North Island Cenozoic – sedimentary record of Oligo-Miocene subduction inception and Hikurangi margin development*



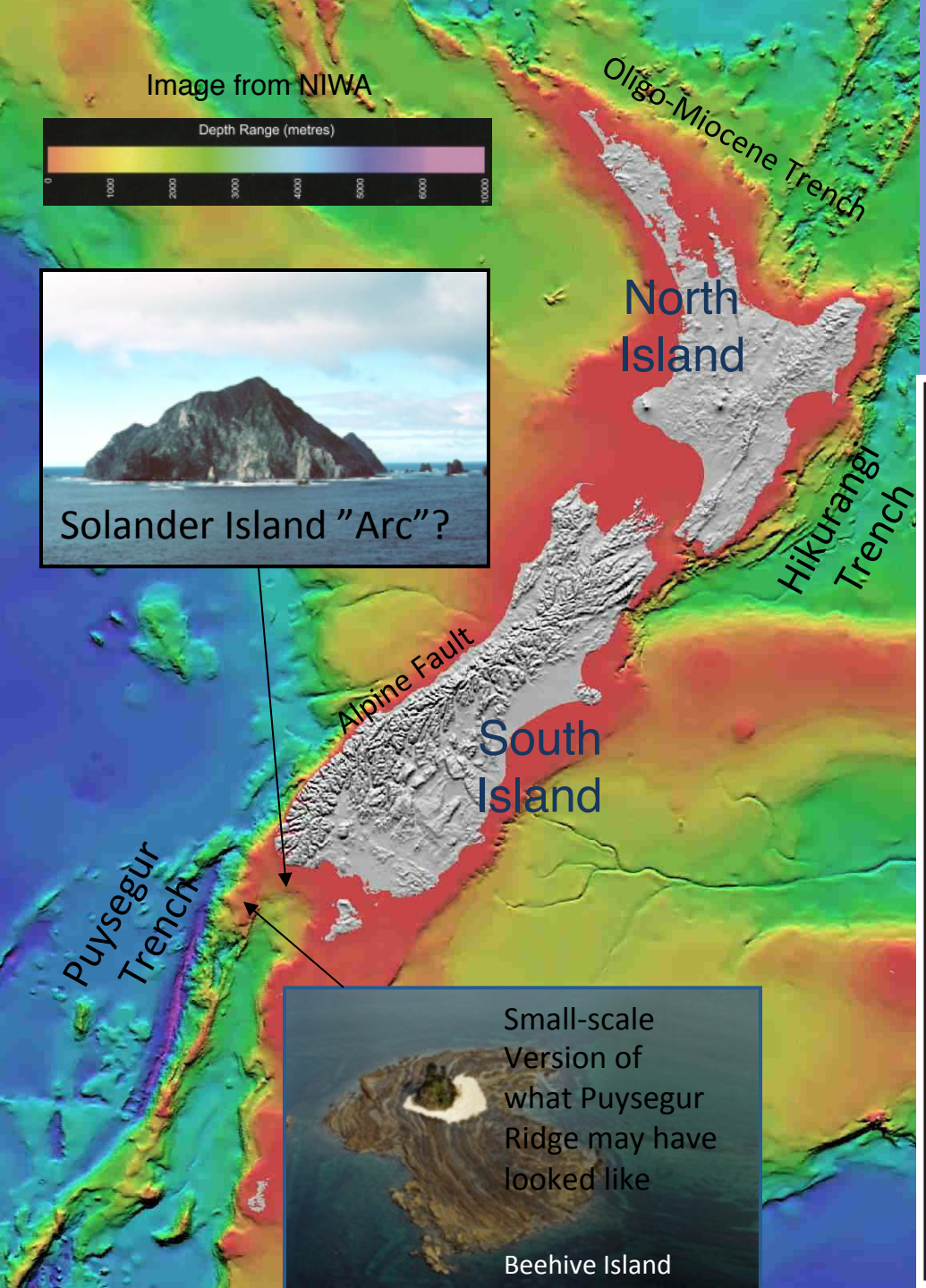
Youngest sediments and oldest sedimentary rocks related to subduction

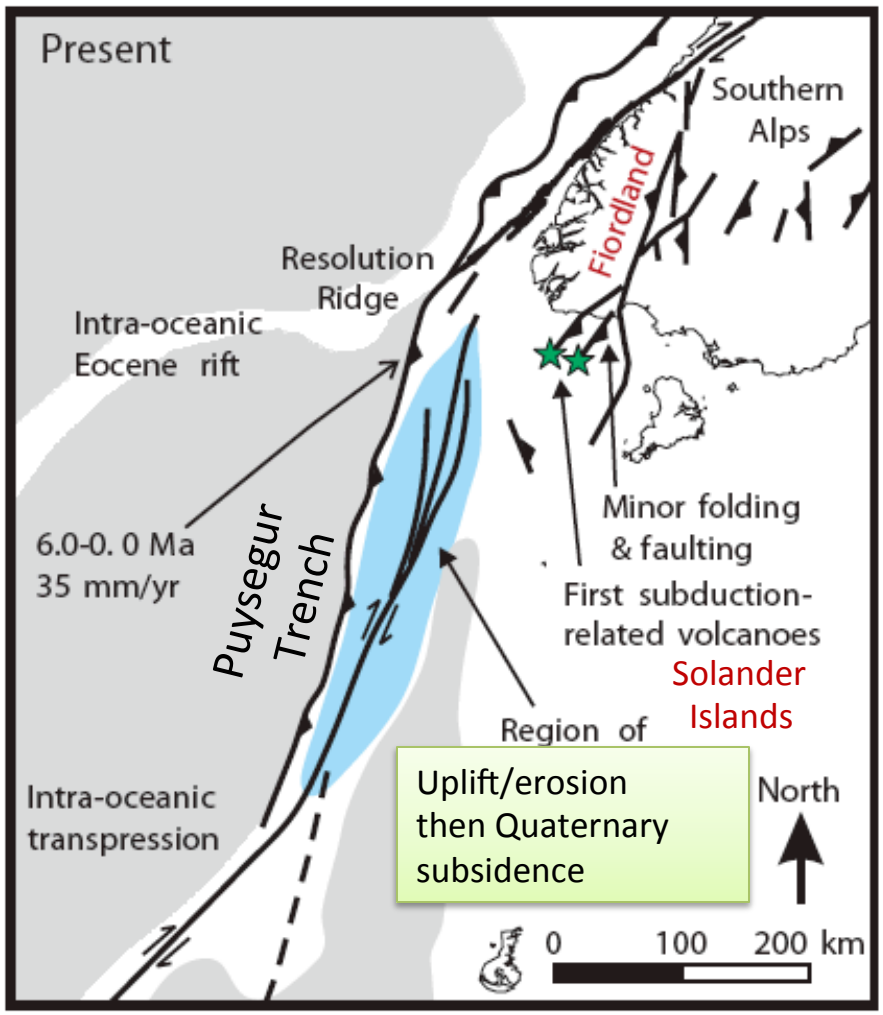


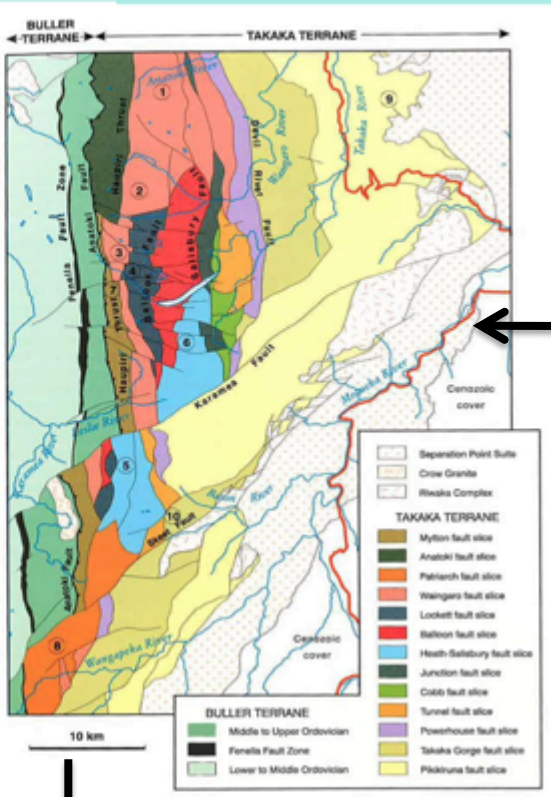


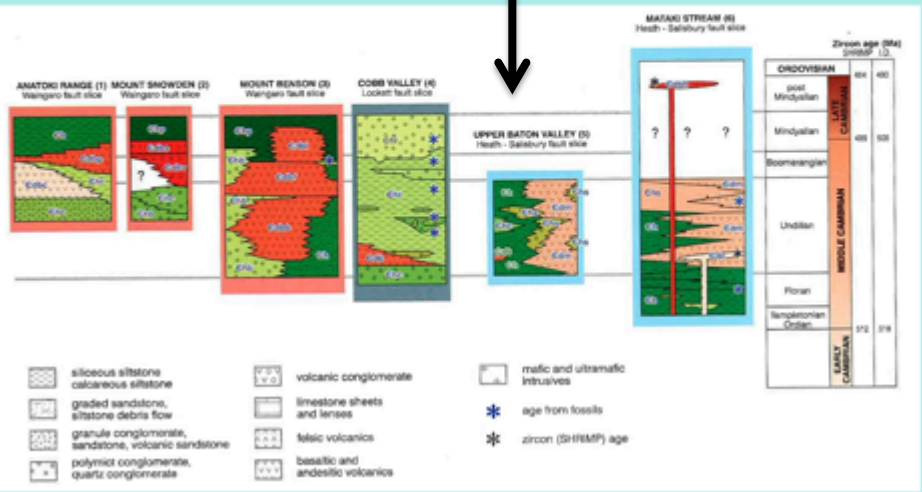
New Zealand Basement Rocks (Mortimer, 2008)

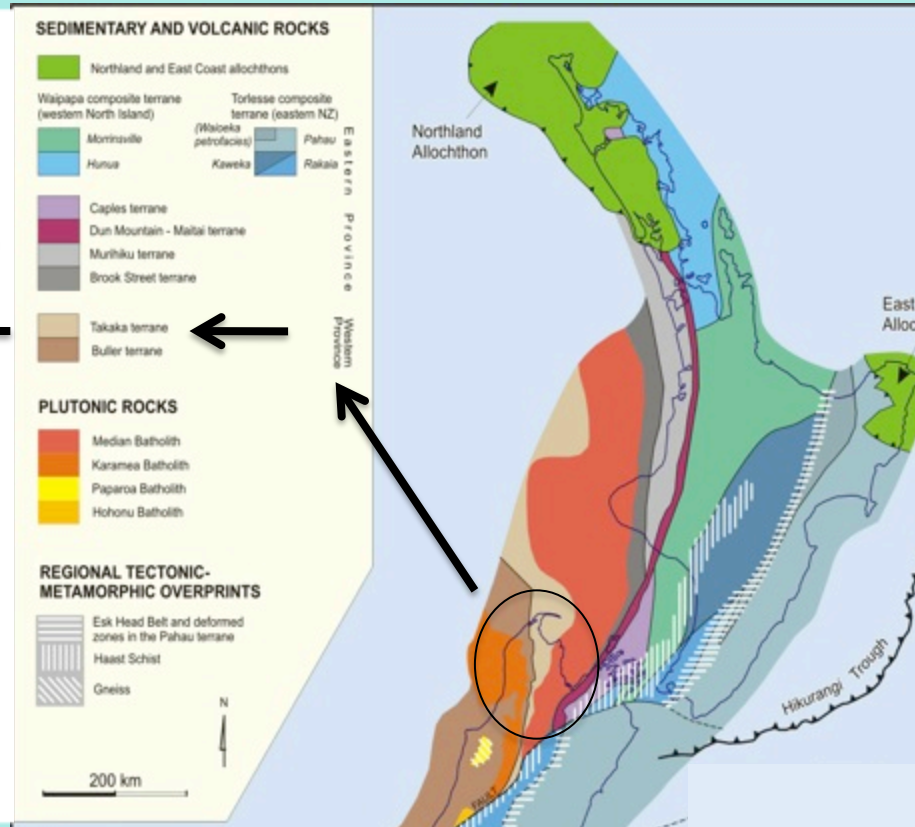
Modern Continental Margin Example of Subduction Inception South Island, NZ (Sutherland et al., 2006)







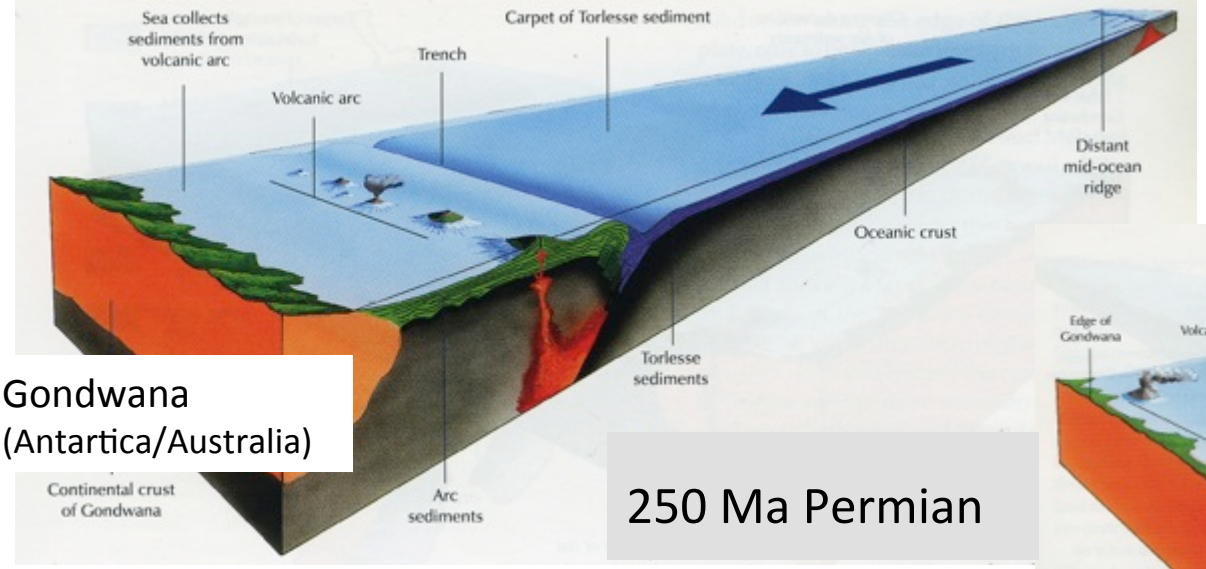




New Zealand Basement Rocks (Mortimer, 2008)

Nelson Q-map by Rattenbury et al. (1998)

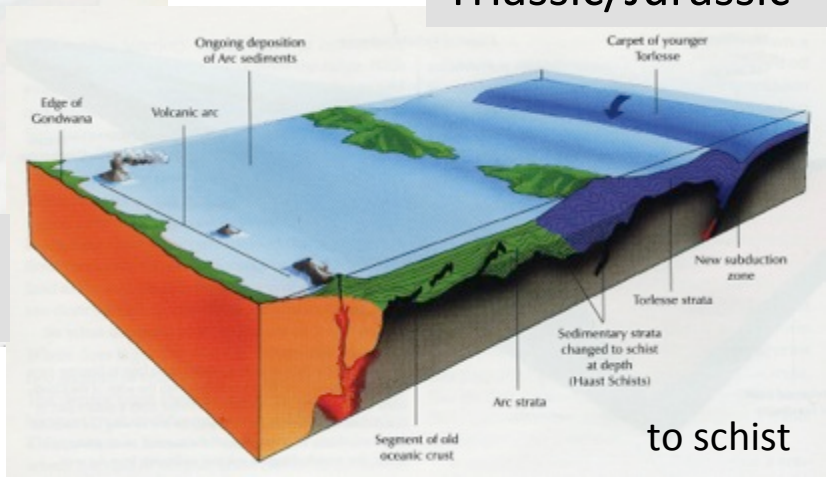
See GeoPRISMS White Paper by Pound et al. on Takaka Terrane



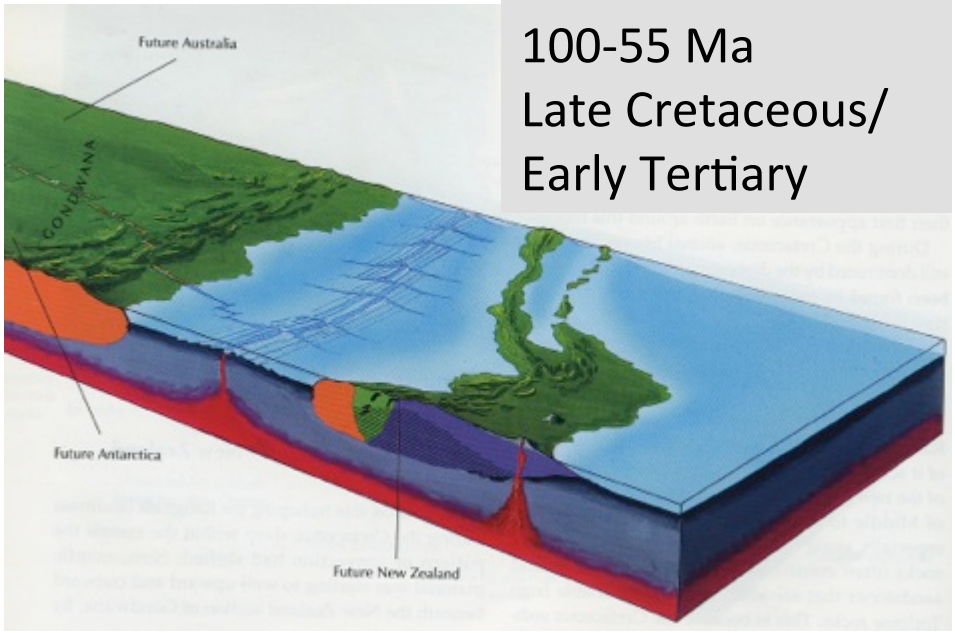
Gondwana
(Antartica/Australia)

250 Ma Permian

200 Ma
Triassic/Jurassic



to schist

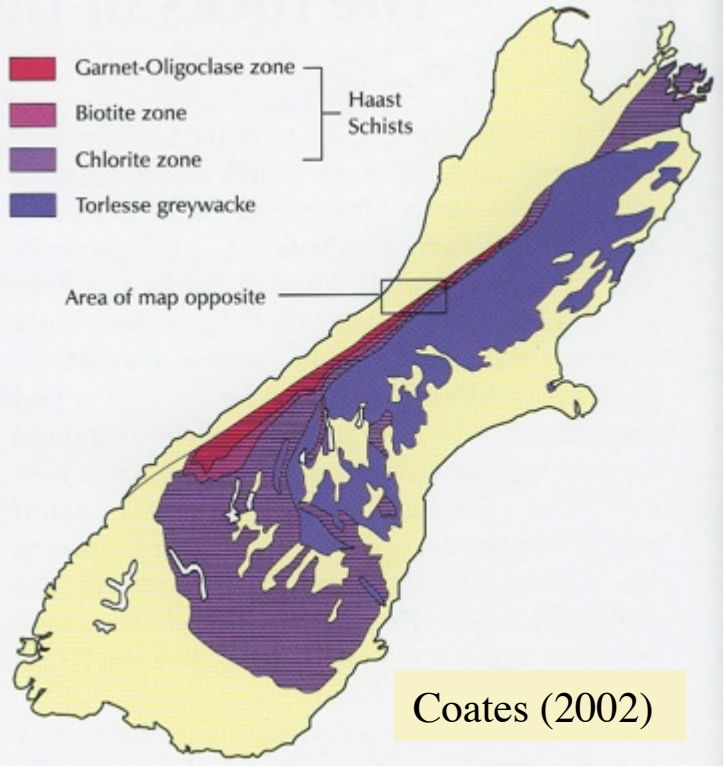


100-55 Ma
Late Cretaceous/
Early Tertiary

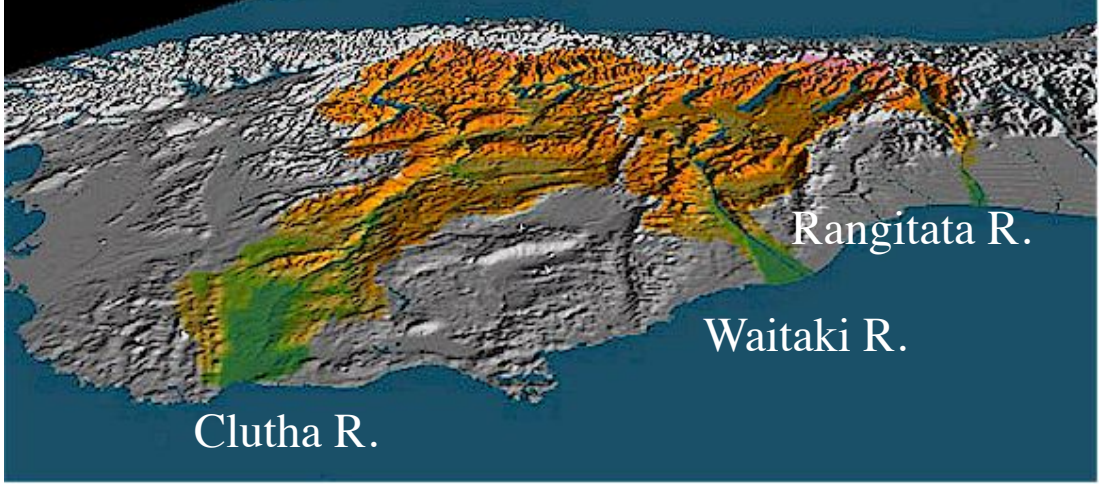
Illustrations by G. Cox from Coates (2002)
The Rise and Fall of the Southern Alps

Zealandia Tectonic History

- **Active-margin subduction in Permian (older?)**
- **Followed by rifting and passive-margin formation in Cretaceous**
- **Active (subduction and transform) margin in Cenozoic (complex evolution)**



Coates (2002)



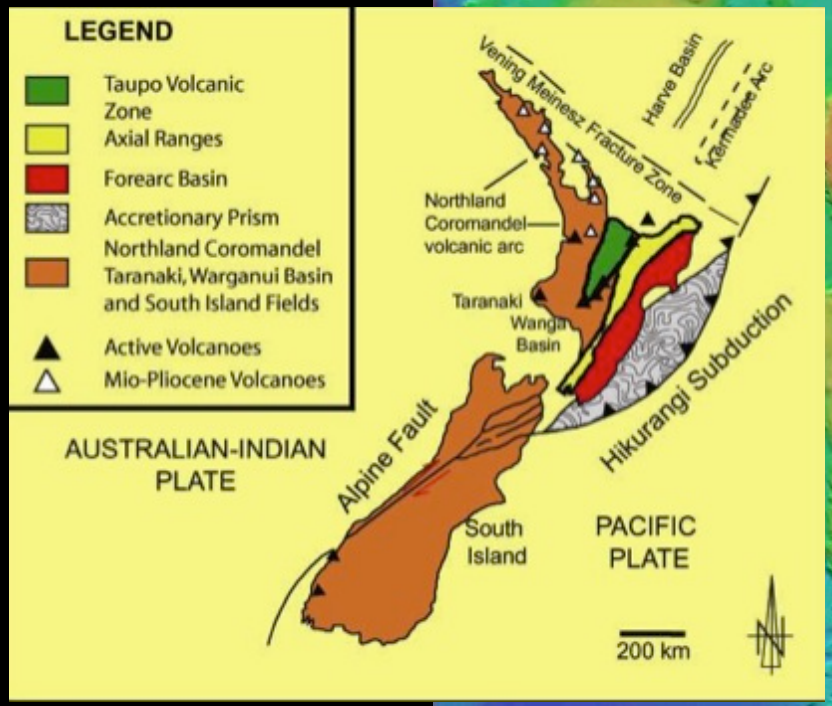
Bounty/Canterbury Sedimentary System: SOURCE

The Southern Alps consist of sandstone, and schist formed when the sandstone has been metamorphosed. The samples shown are 25 centimetres long.

Torlesse sandstone (greywacke) — Sand-sized grains embedded in a silty matrix. Originally deposited as loose sand in the sea, the sediment has since been cemented together during rock formation.

Pressure + Heat = Metamorphism

Haast Schist — Schist is made up of new minerals that have grown within the rock in fine layers perpendicular to the direction of pressure. The light-coloured layers consist of the minerals quartz and feldspar, and the dark layers are biotite. The original sand grains have been completely recrystallised.



Alpine Fault

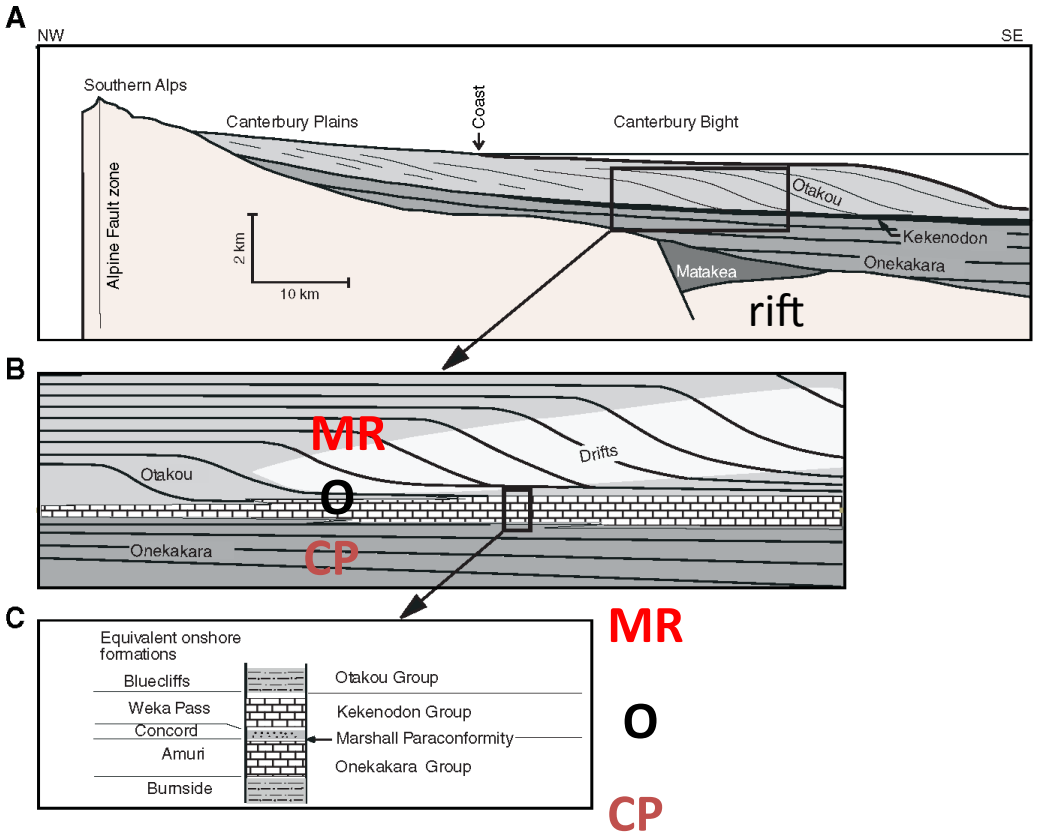
CM

BT

Passive Margin History preserved in Bounty Trough (BT)and Canterbury Margin (CM) but with Alpine Fault Influence

Canterbury Stratigraphy:

Post-rift, Cretaceous to Recent first-order, tectonically-controlled, transgressive-regressive cycle.



Summary from C. Fulthorpe

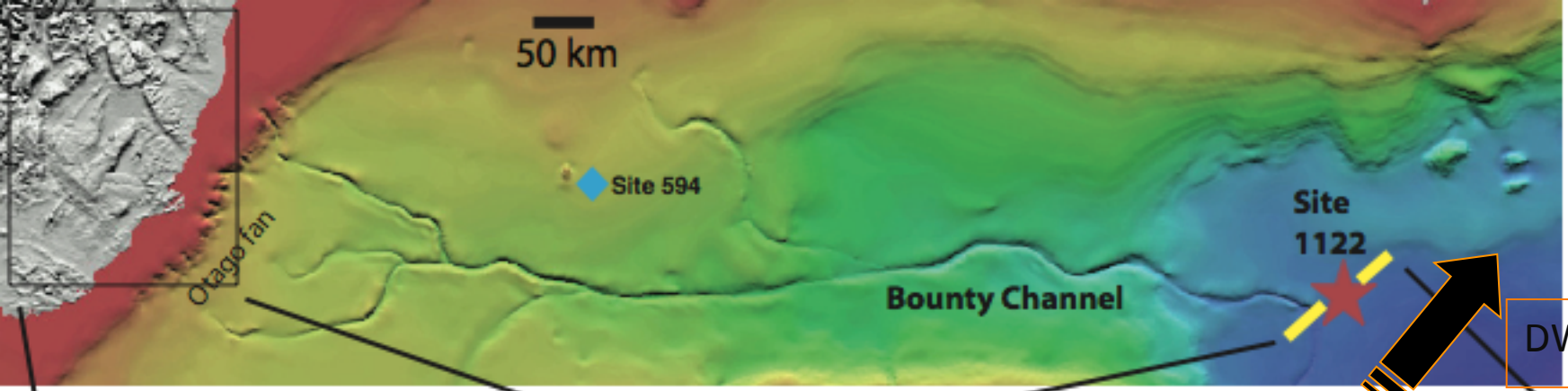
3. Miocene - Recent (MR) Regression

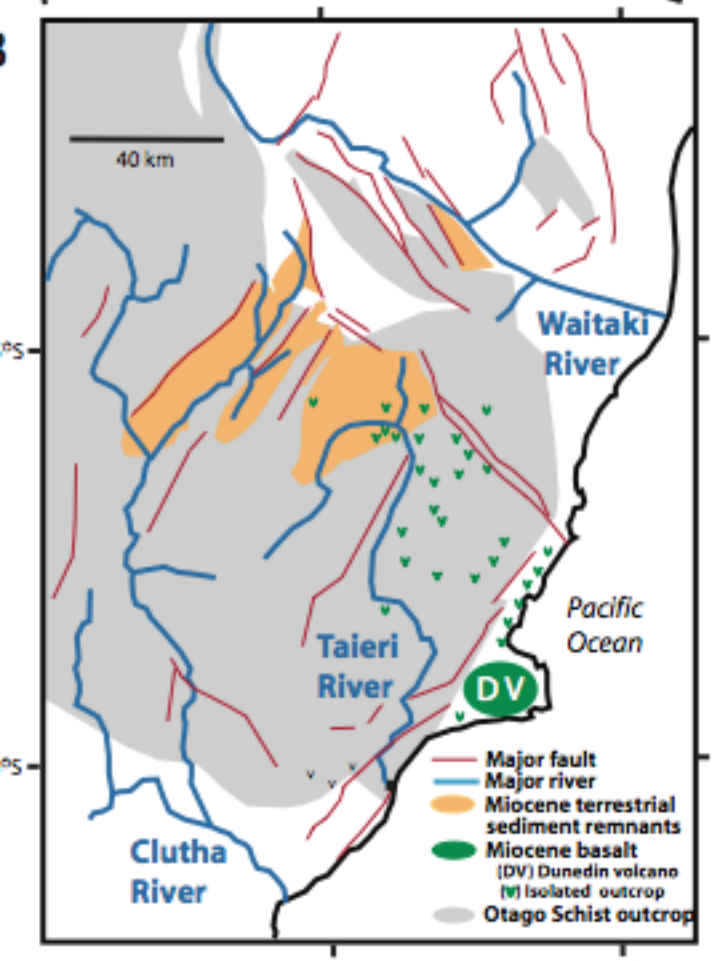
- Regression in late Oligocene or early Miocene: initiation of Alpine Fault movement increased sediment supply.
- Uplift of the Southern Alps accelerated at ~8-5 Ma or ~10-8 Ma indicating an increased component of convergence.
- This transpression led to a further increase in sediment supply to the offshore basin.

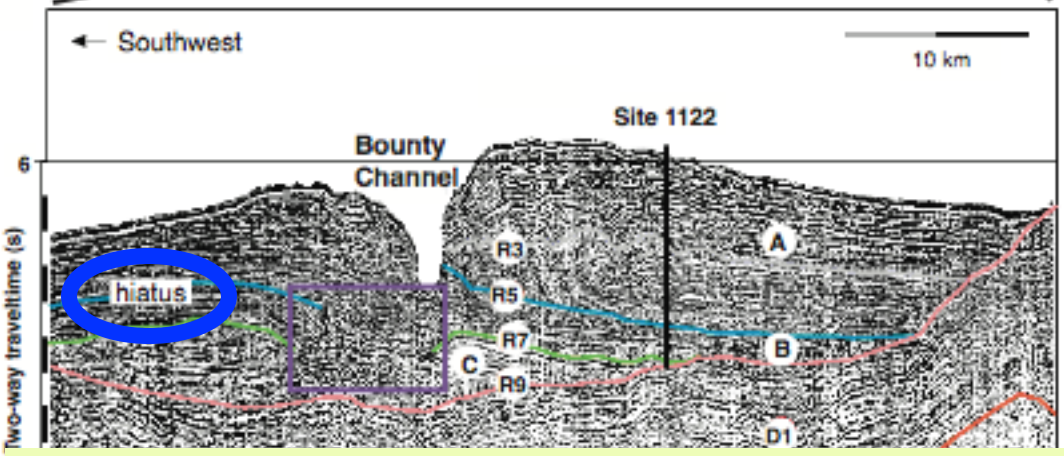
2. Oligocene Highstand (O)

Marshall Paraconformity
Initiation of strong ocean currents

1. Cret.-Paleogene (CP) Transgression



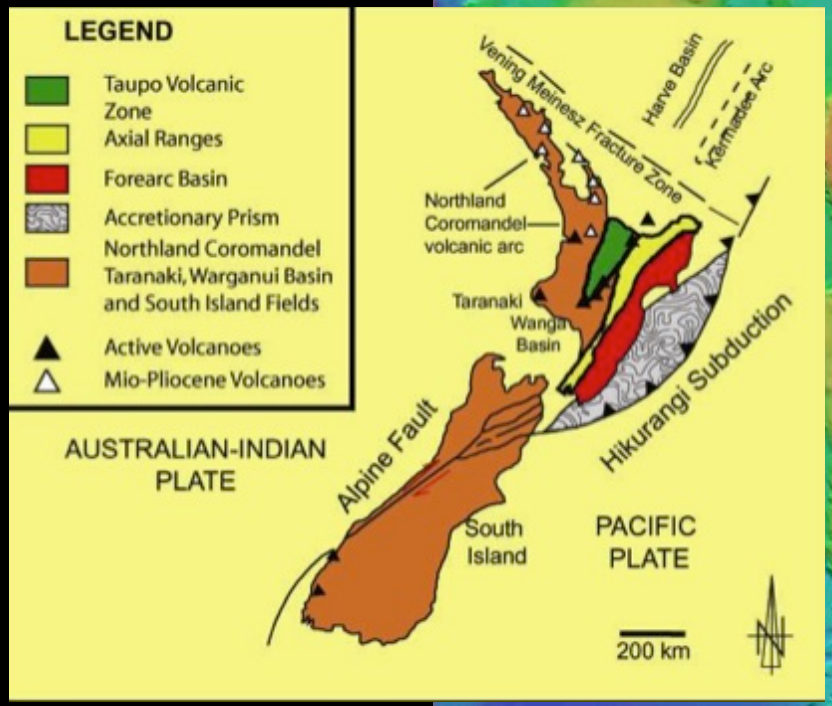




11.0-3.5 Ma hiatus at Site 1122 during time of Alpine uplift and sealevel lowstand

Cause(s)? Submarine erosion (DWBC) & decrease in sediment input owing to onshore fluvial drainage disruption and LAKE formation

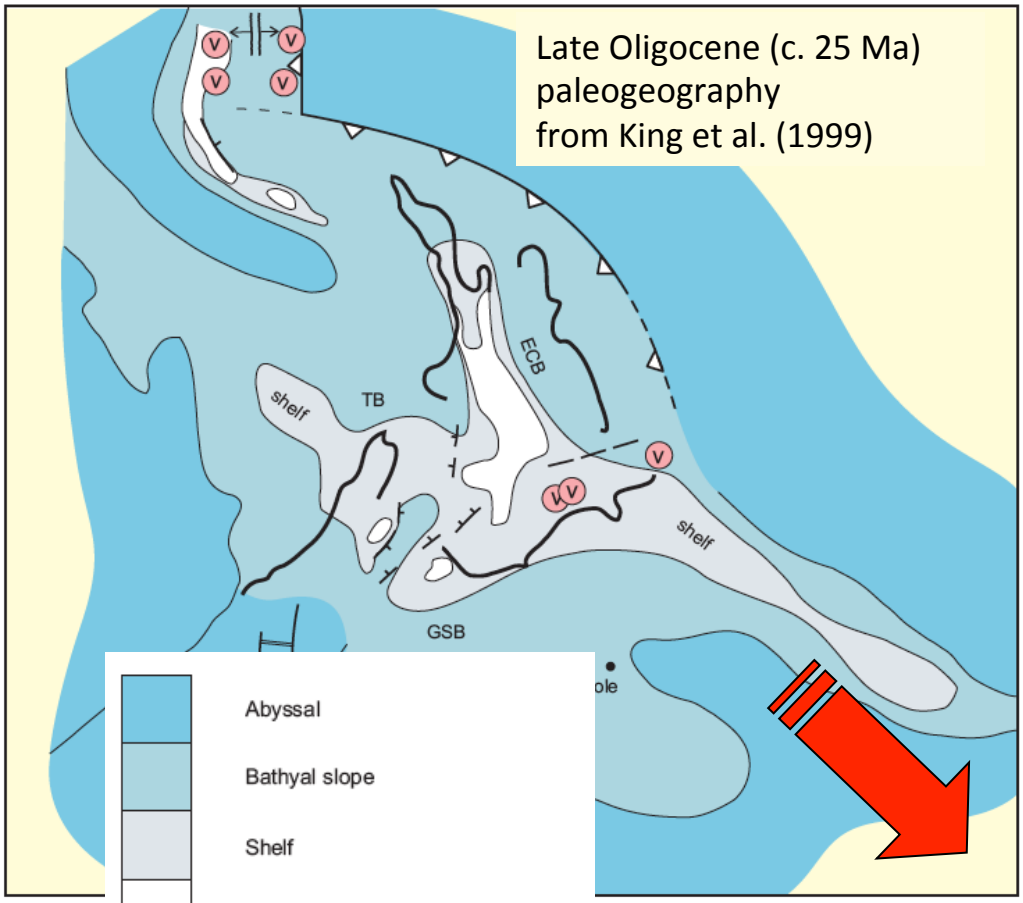
Marsaglia et al. (2011; Geosphere)

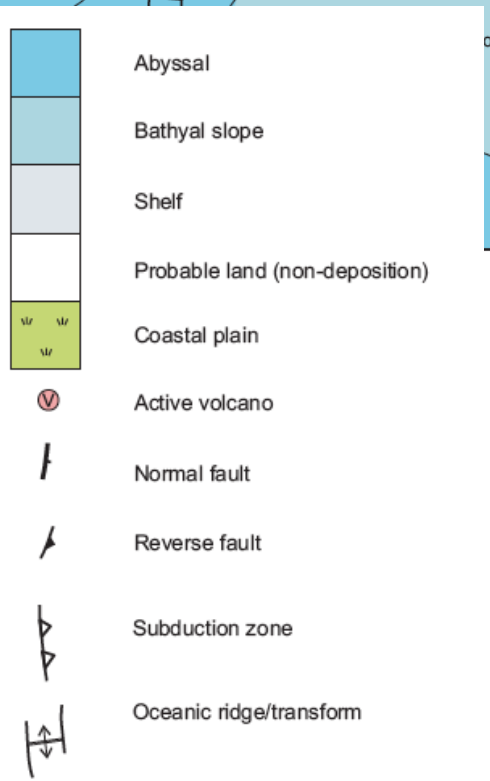


Subduction initiation in Oligocene/ Miocene in Northern North Island ultimately evolving into modern Hikurangi Subduction Zone

Image from CANZ (1996)

Late Oligocene (c. 25 Ma) paleogeography from King et al. (1999)

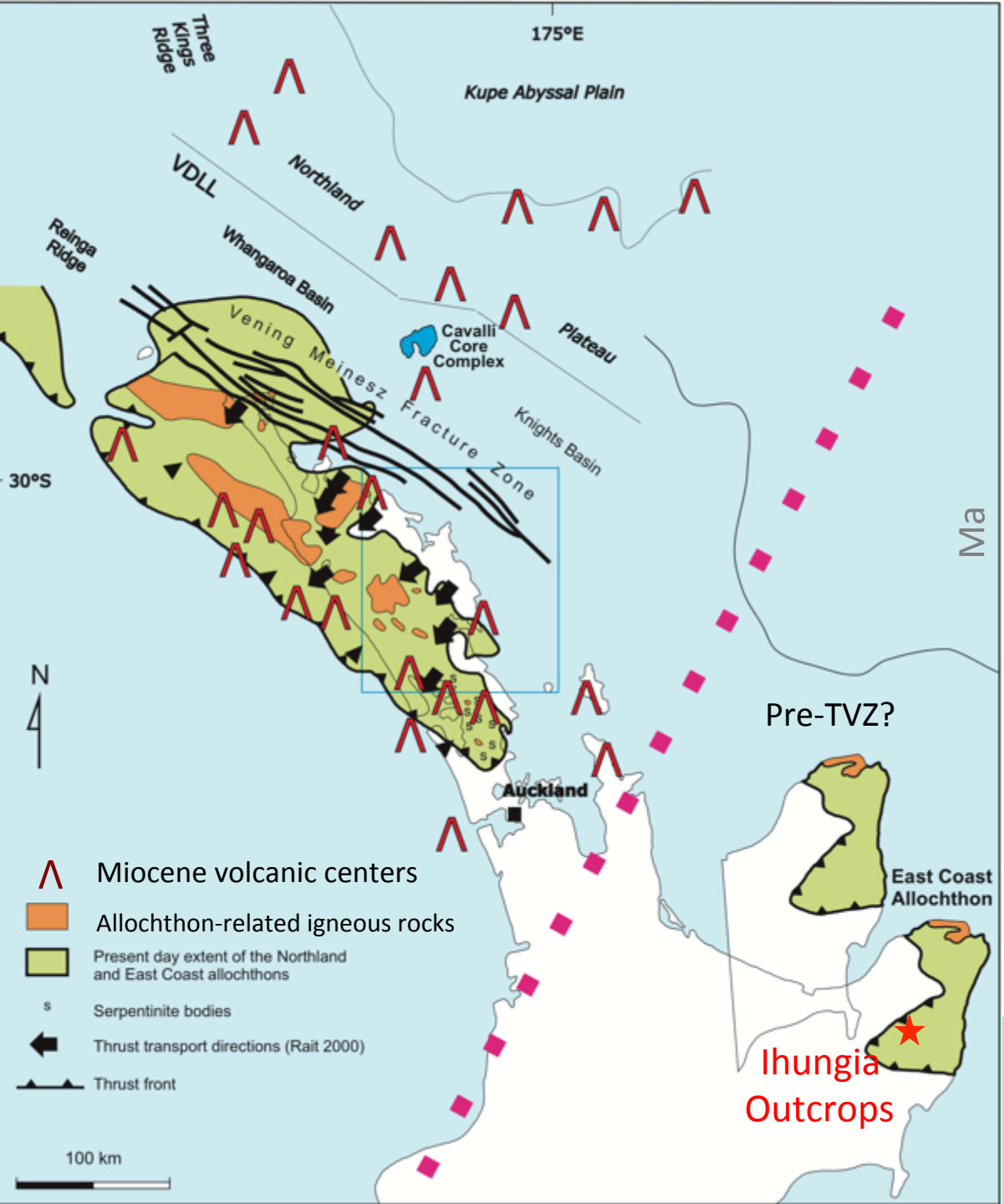


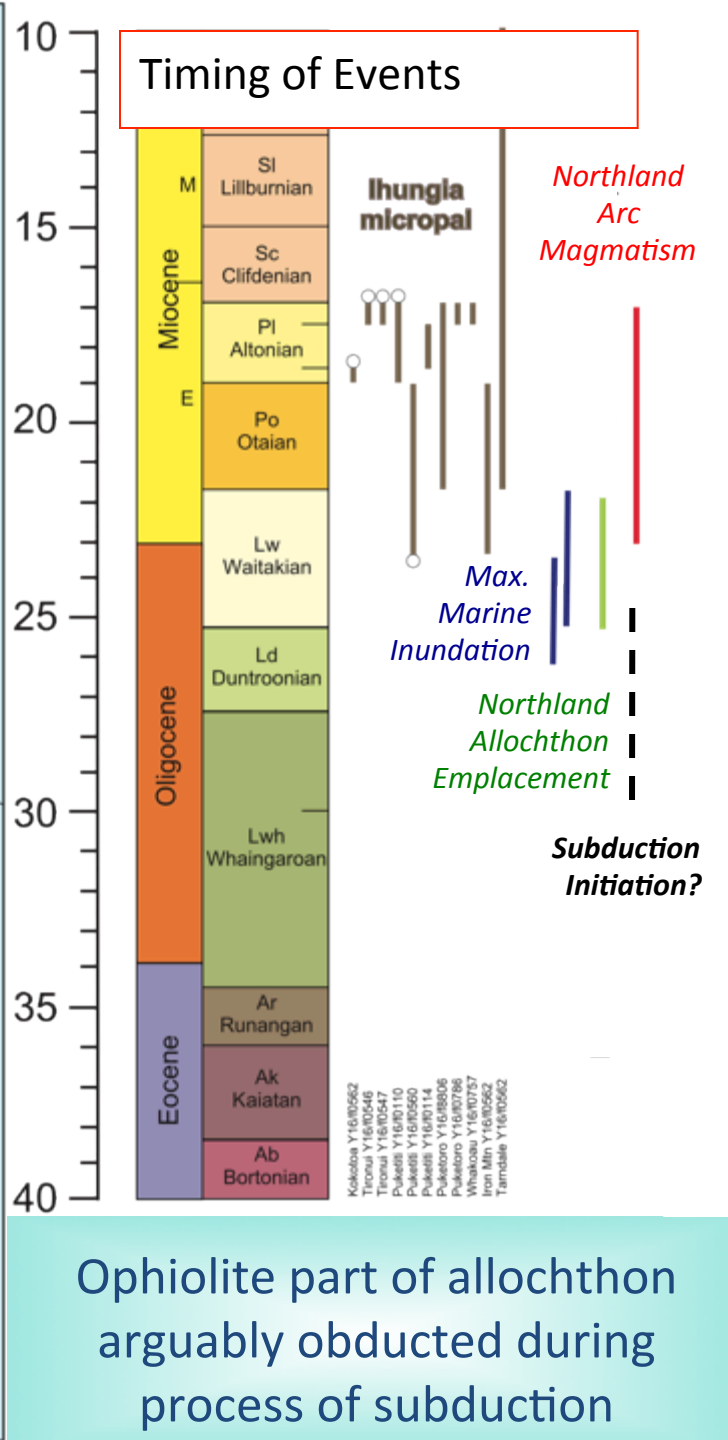


Evidence for uplift and exposure (islands)…

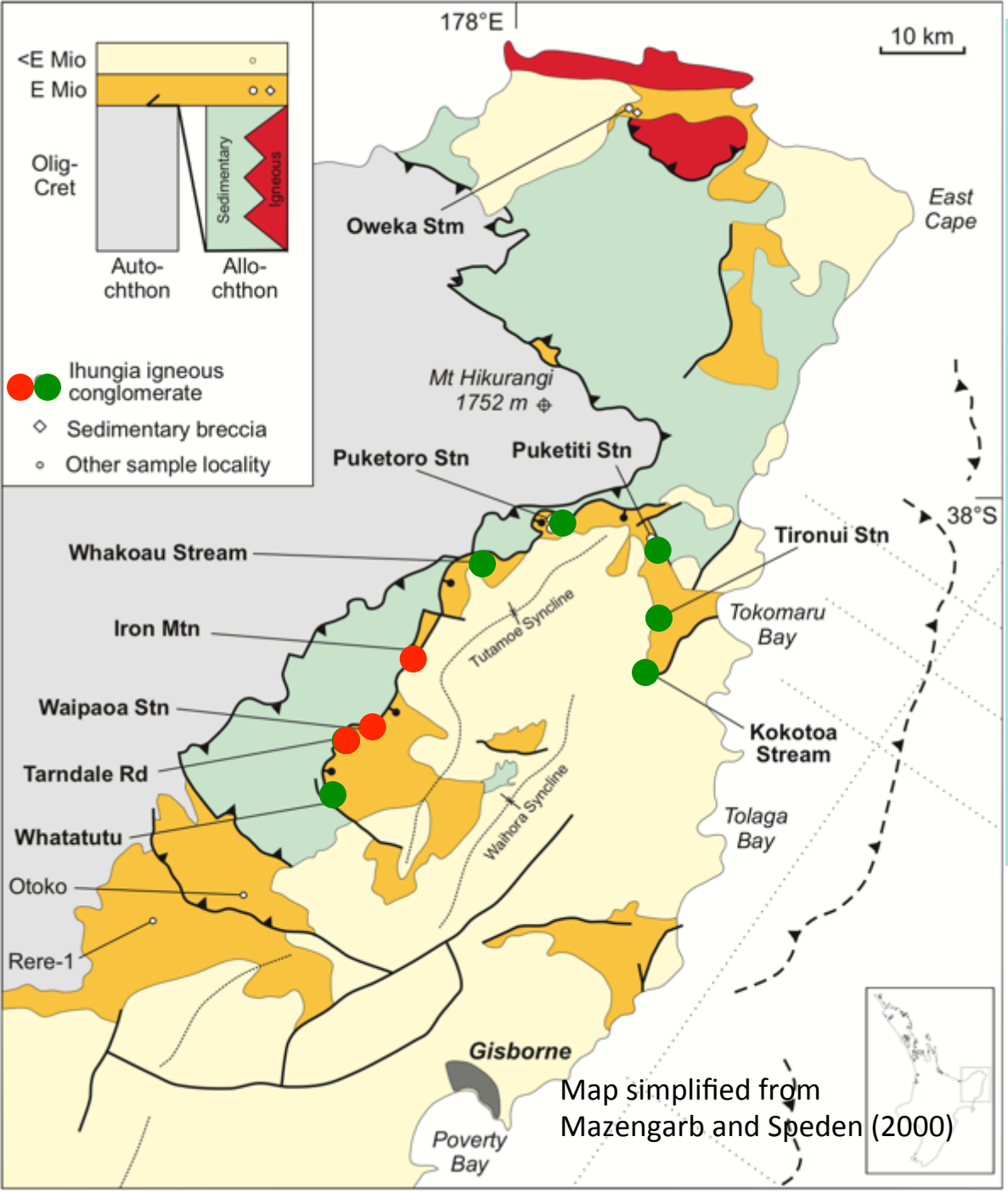
1) During subduction initiation?
   Unknown?
2) During allochthon emplacement?
   Ihungia Igneous Conglomerate?

Alternate view
No land area during Late Oligocene



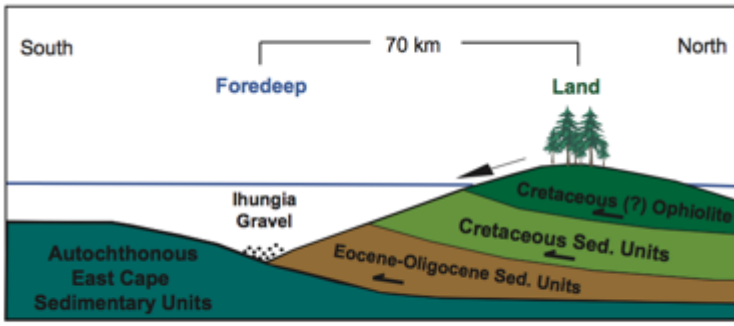


Ophiolite part of allochthon arguably obducted during process of subduction

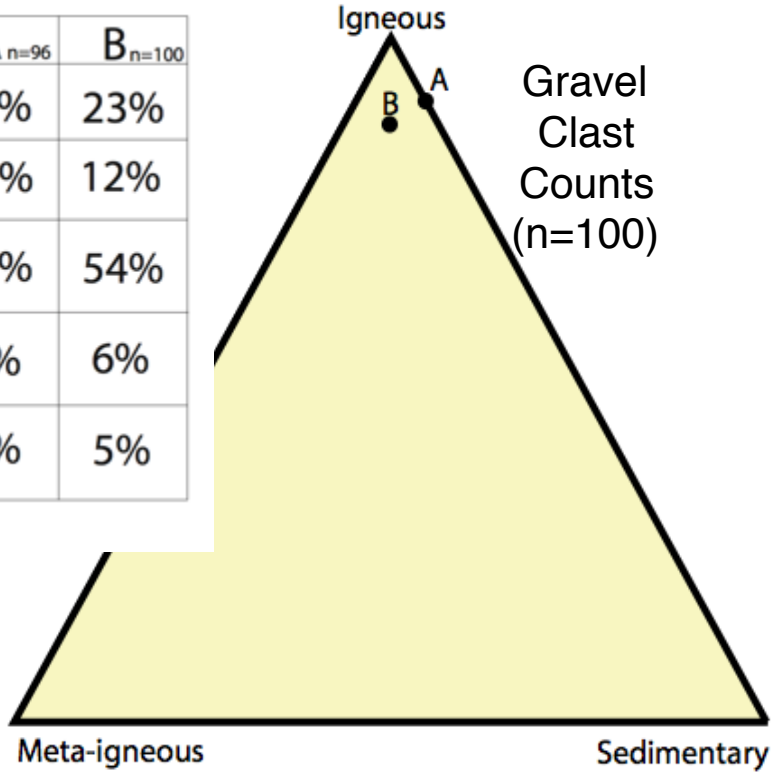


Observations of Ihungia igneous conglomerate:

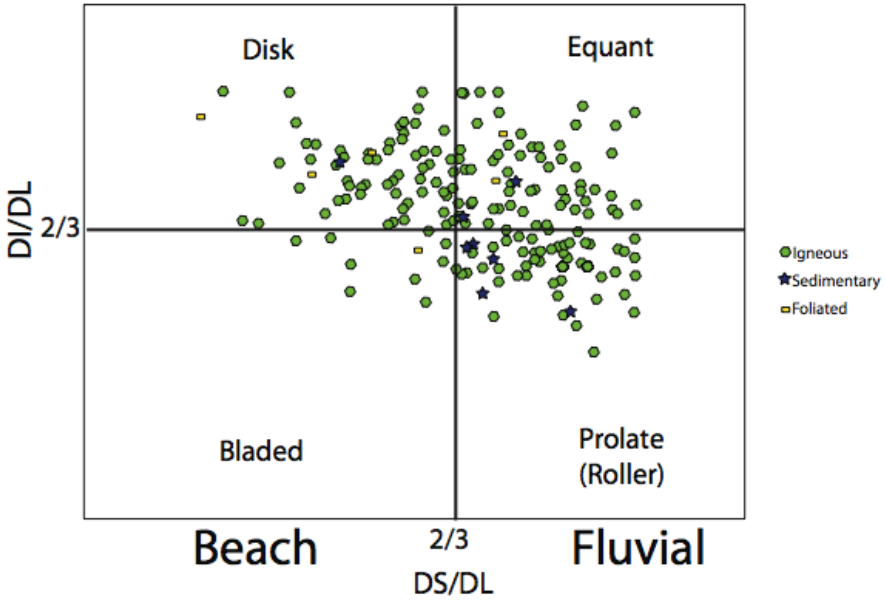
- In Lower Tolaga Group
- Occurs as isolated, small outcrops (<1km^2)
- Adjacent to faulted(?) contacts with allochthon
- 10-15m thick conglomeratic intervals
- Outer shelf to slope deposits
- Channelized, discontinuous
- Normal grading, NW source
- Wood and plant debris
- Associated with mélange, debris flows & sedimentary breccia



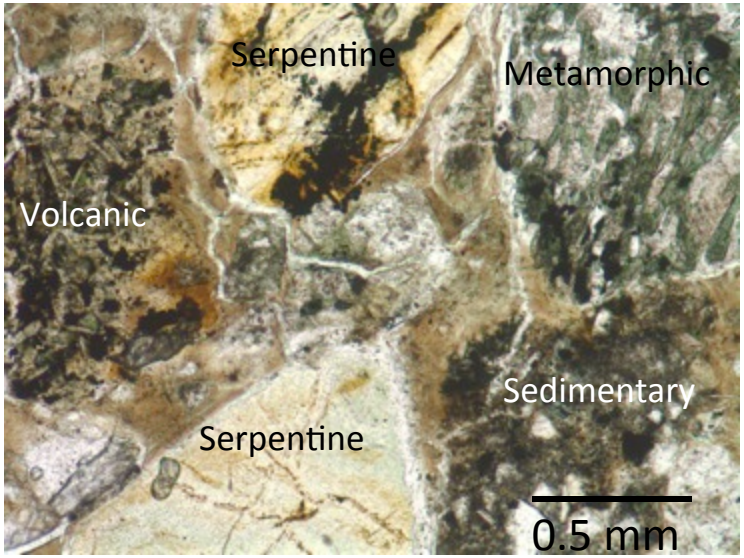
Clast type	A n=96	B n=100
Plutonic	17%	23%
Hypabyssal	29%	12%
Volcanic	50%	54%
Foliated Igneous	0%	6%
Sedimentary	4%	5%

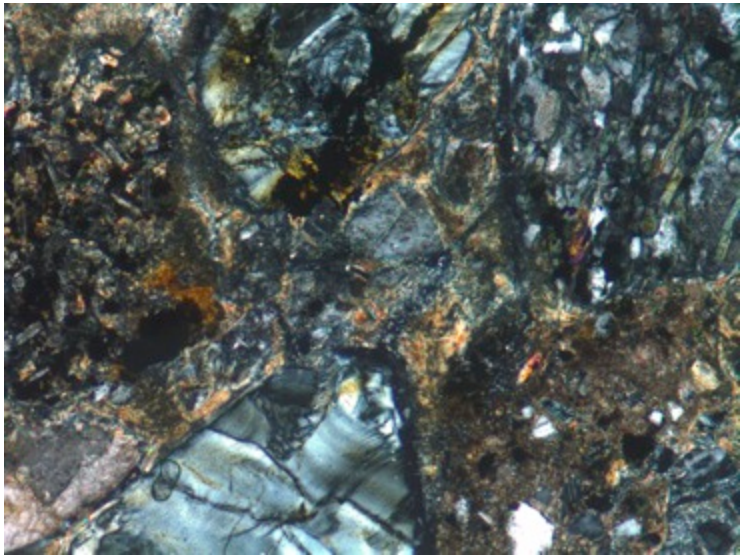


Gravel Clast Counts (n=100)



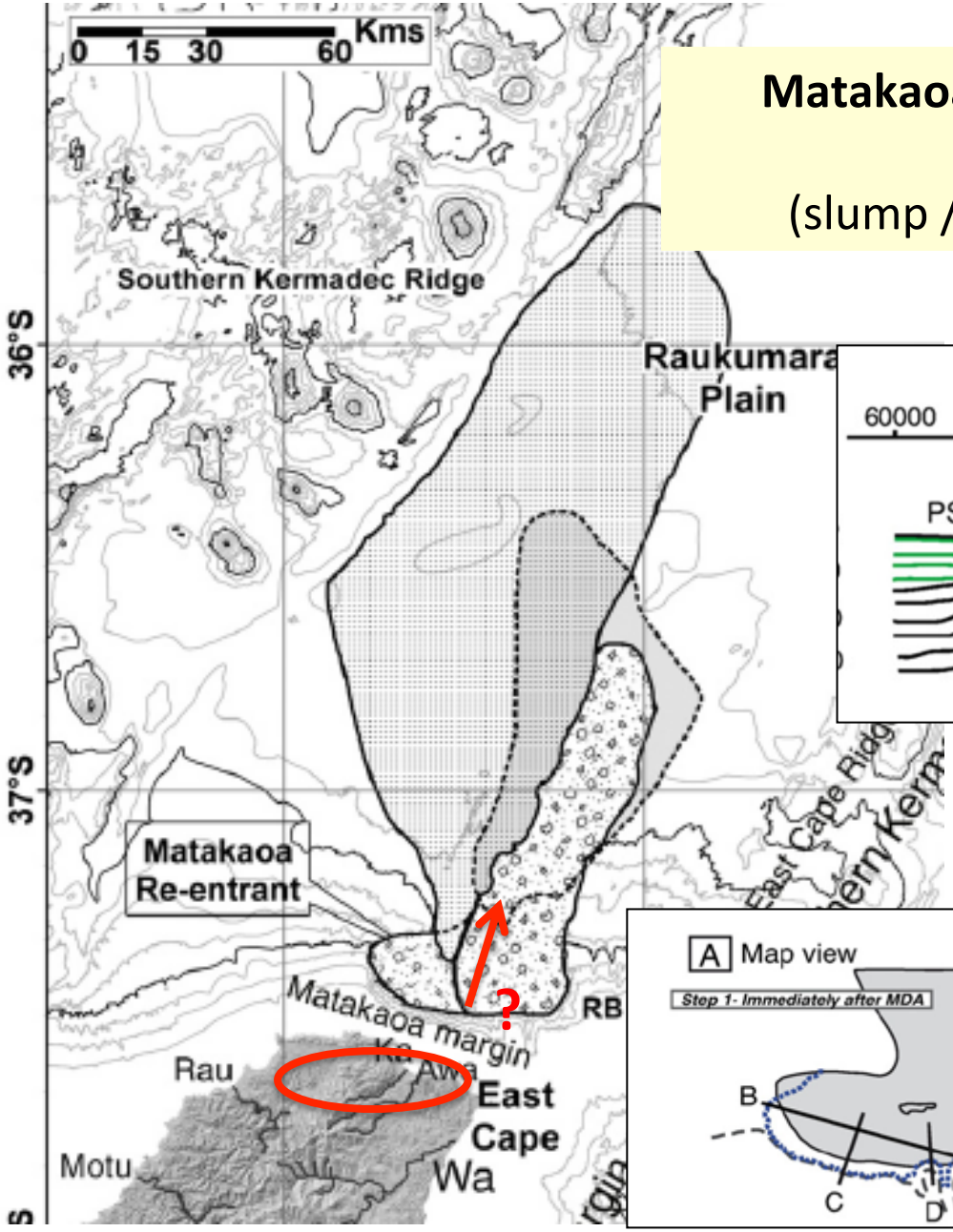
DS short axis
DI intermediate axis
DL long axis



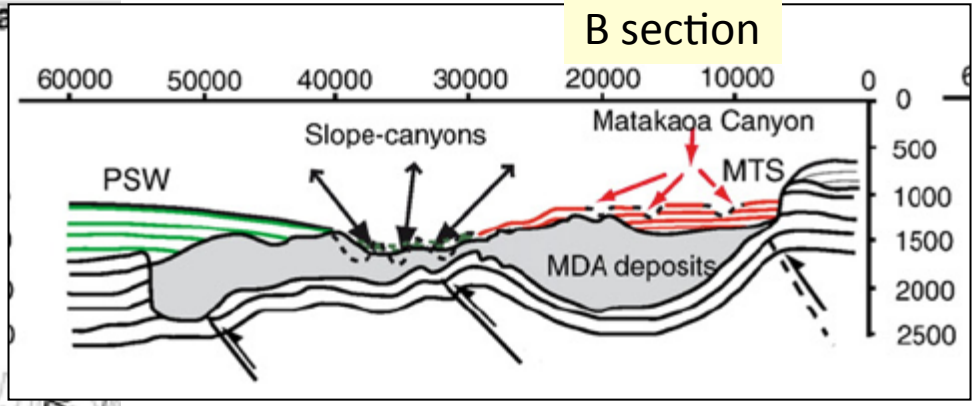


Sandstones Contain Serpentinite Clasts!

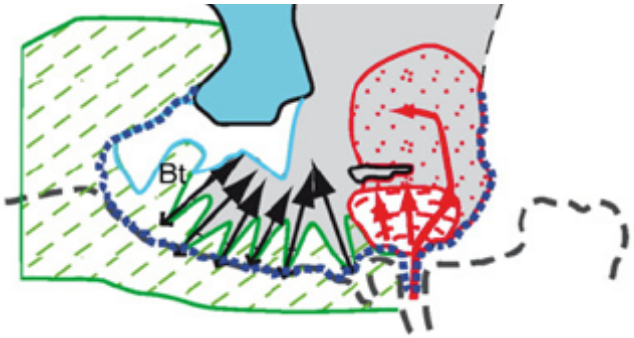
Matakaoa Submarine Instability Complex
Joanne et al. (2010)
(slump / debris avalanche / debris flow)

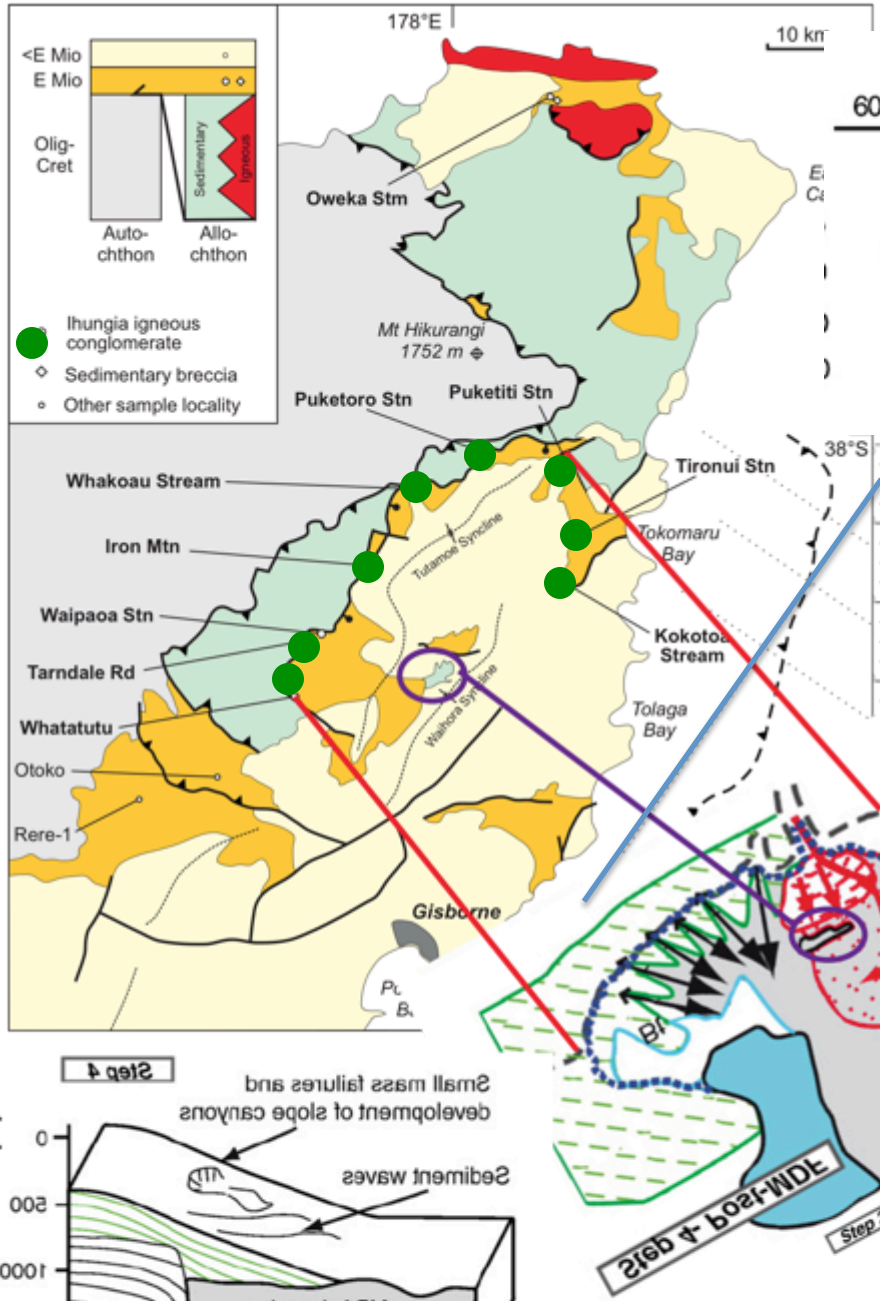


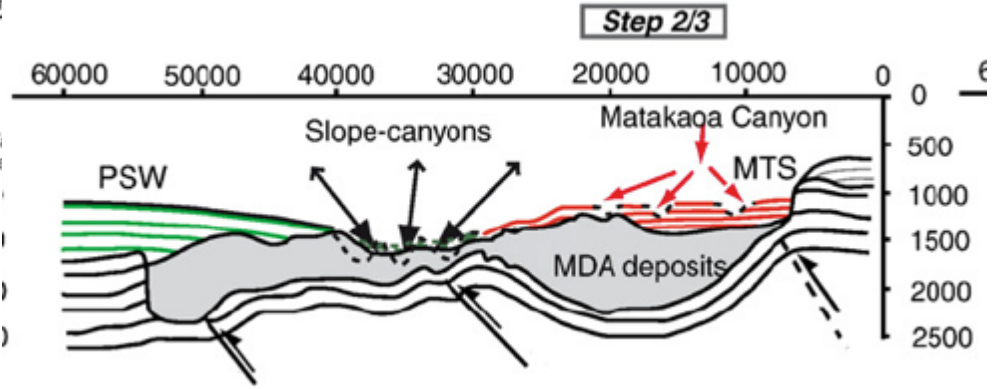
B section

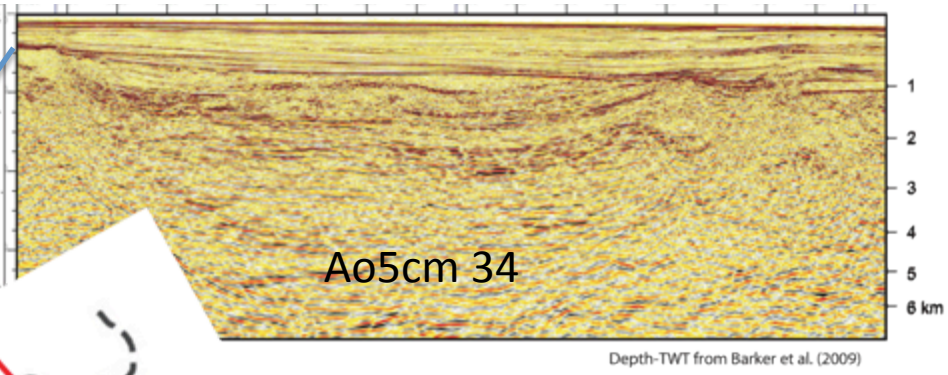


MDA = Matakoa Debris Avalanche





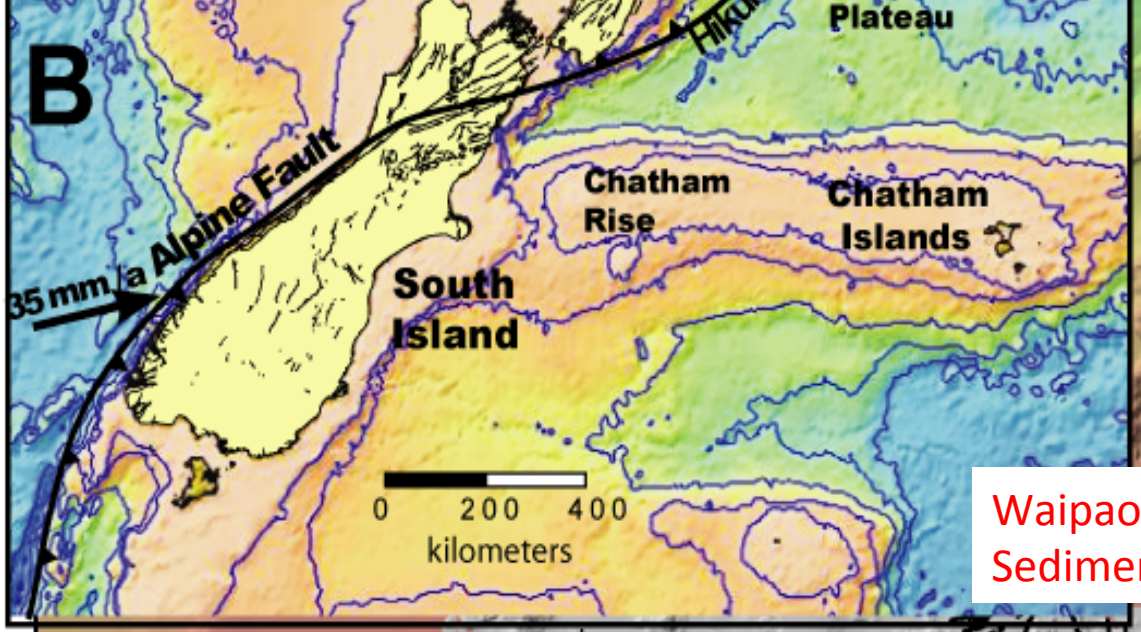




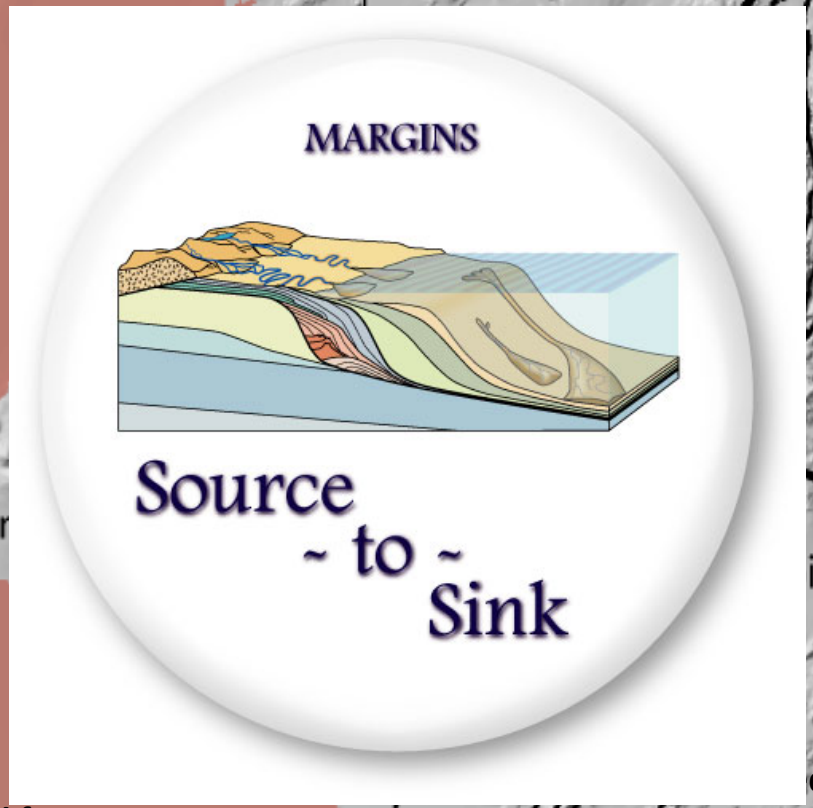
Depth-TWT from Barker et al. (2009)

Ihungia re-entrant explains:

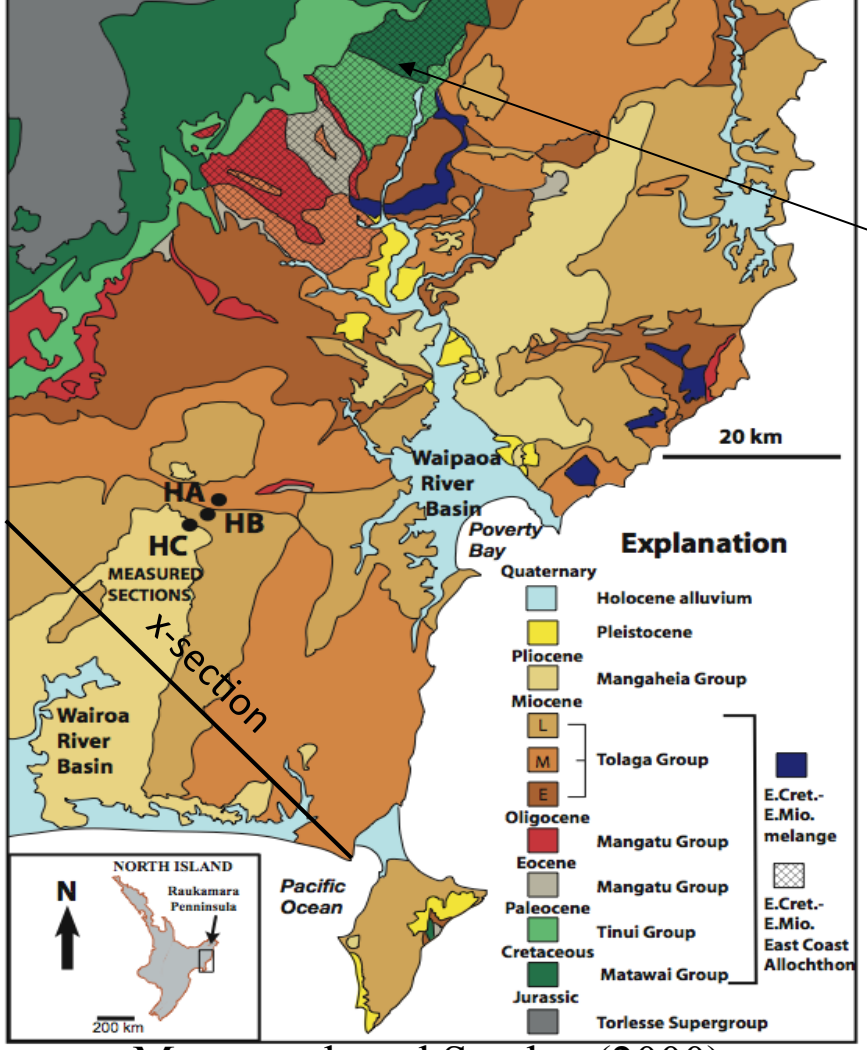
> Nature of contact
> Distribution of gravel
> Debris flows / breccia beds
> Distribution of mélange
> Large block of allochthon
> Offshore seismic character
> Distribution of Miocene seep imestones in this basin



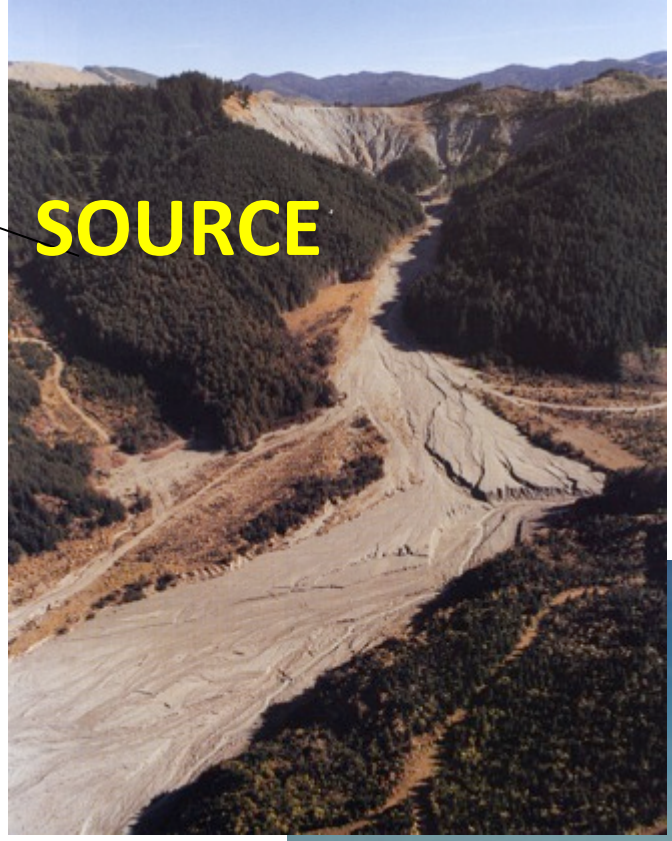
Waipaoa River Sedimentary System



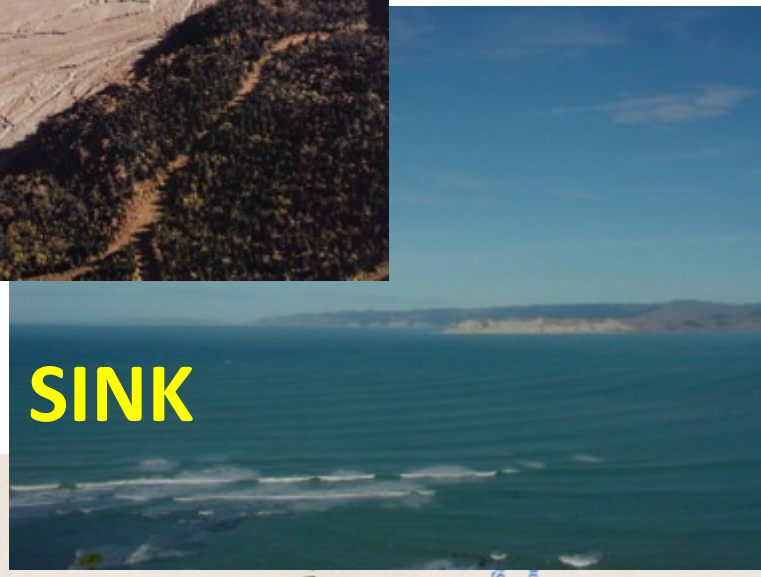
d from Barnes et al. (2010)

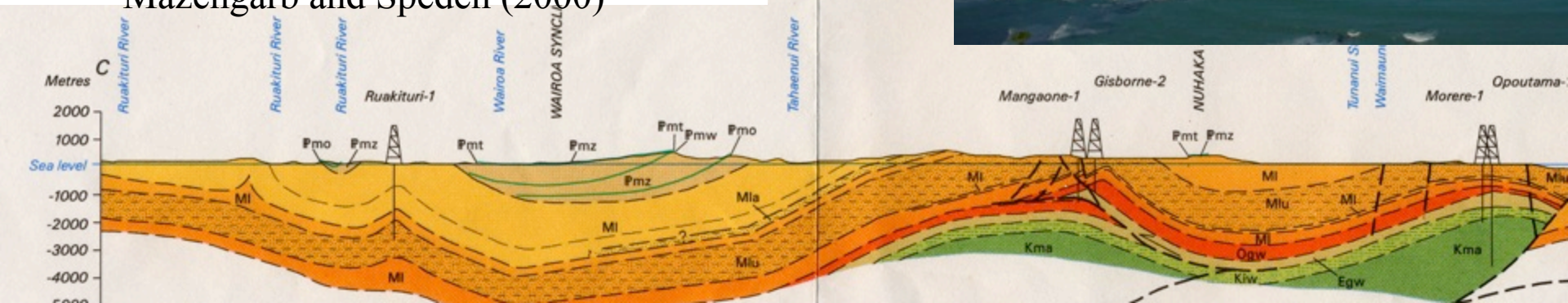


Mazengarb and Speden (2000)

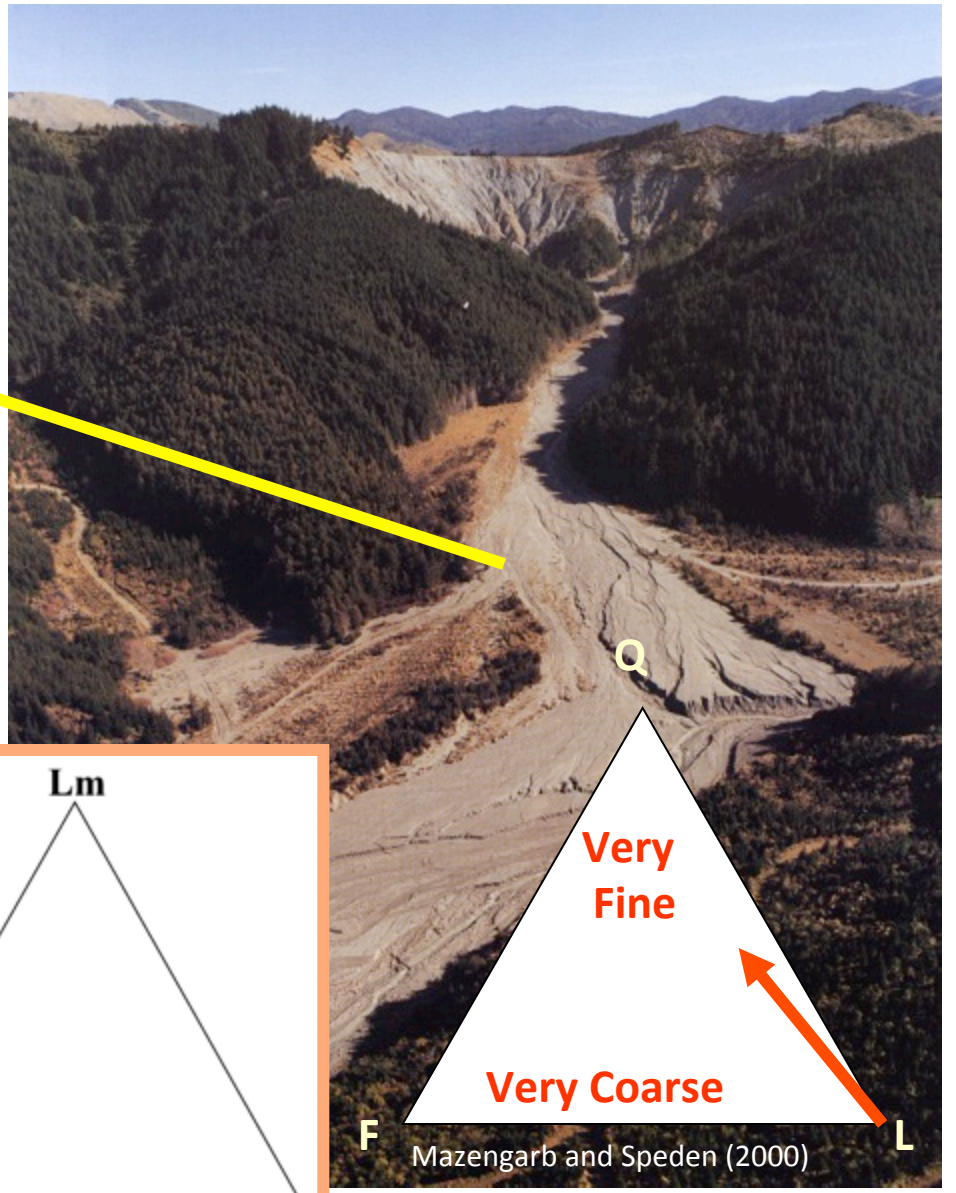


Waipaoa Sedimentary System

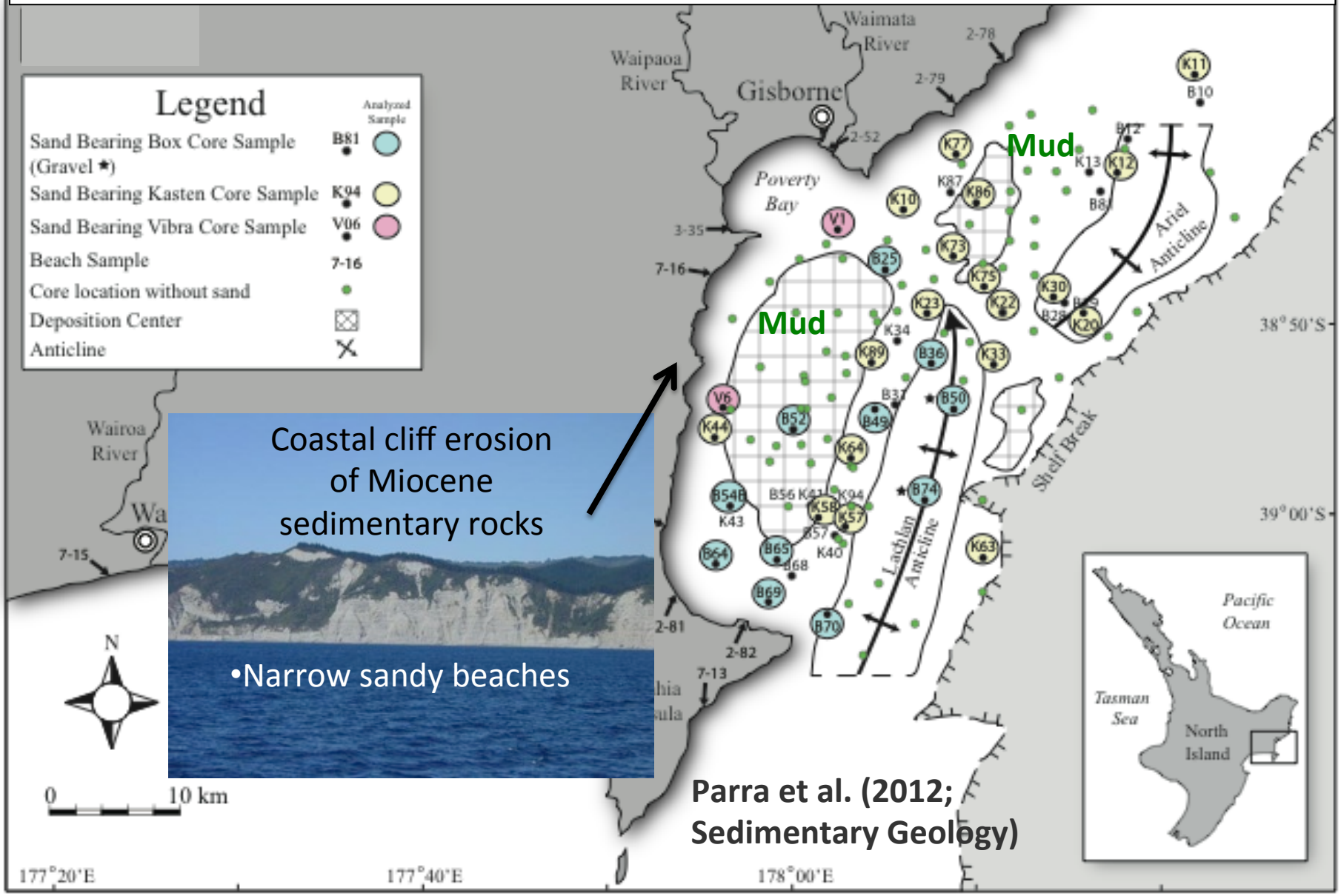




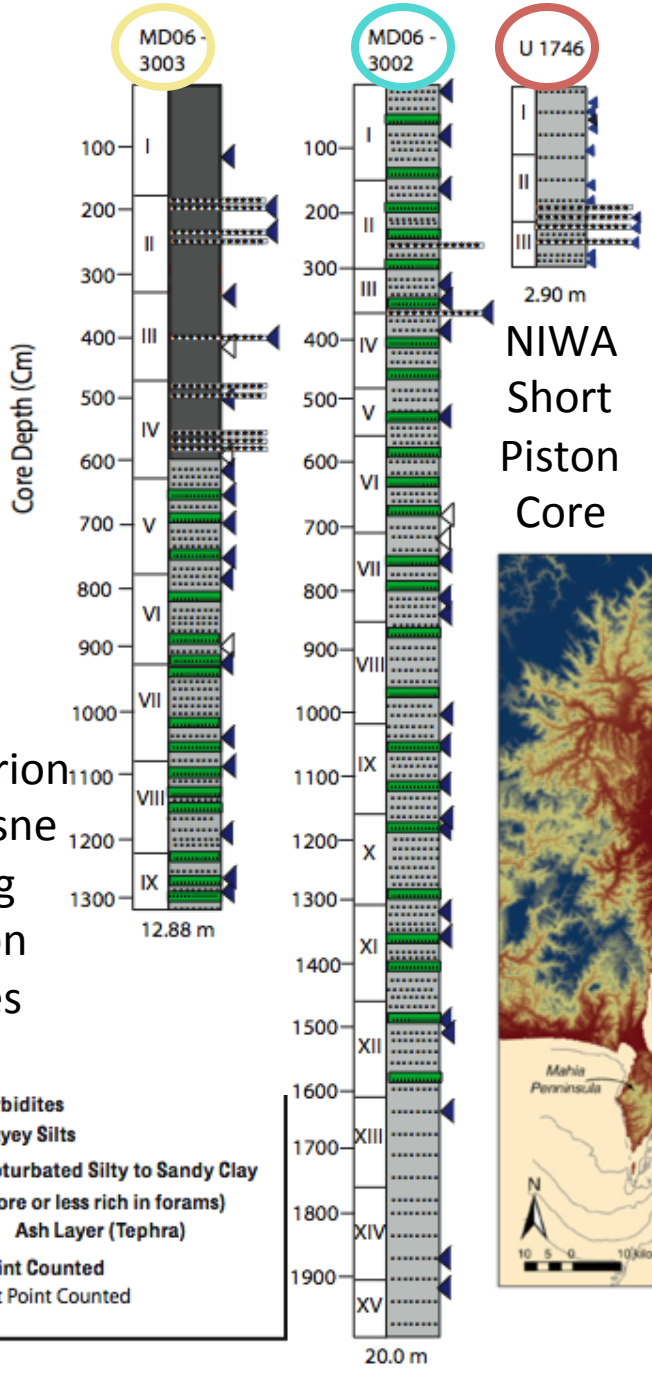
TARNDALE SLIP



Poverty Shelf - Sink/Source/Transfer zone? *mud, sand, and gravel*

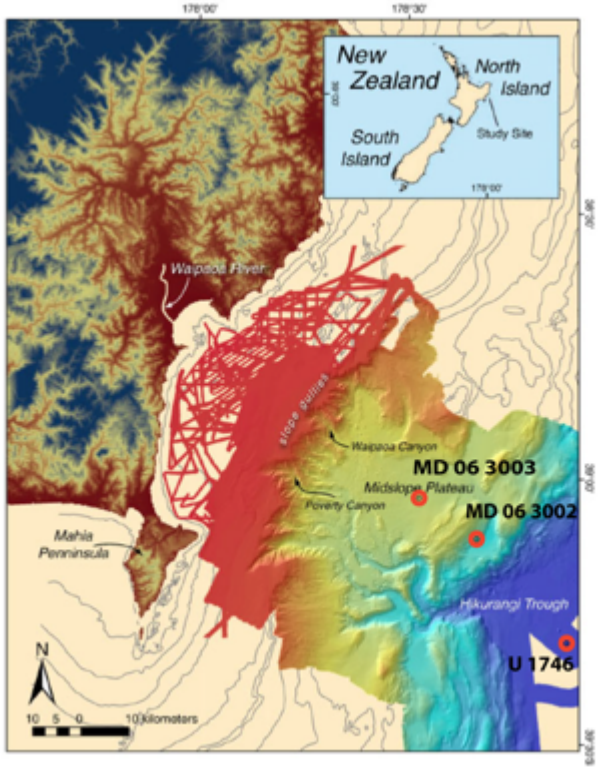


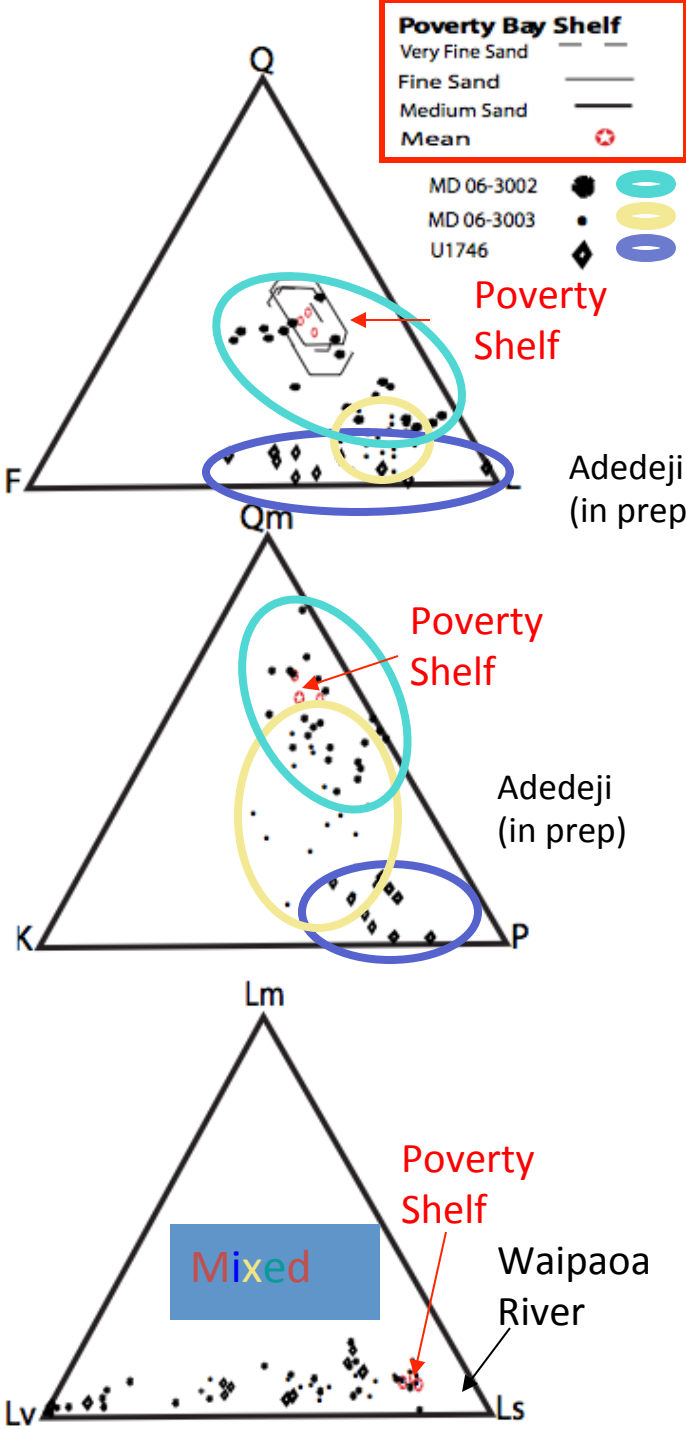
Poverty Slope & Hikurangi Trough: WSS SINK



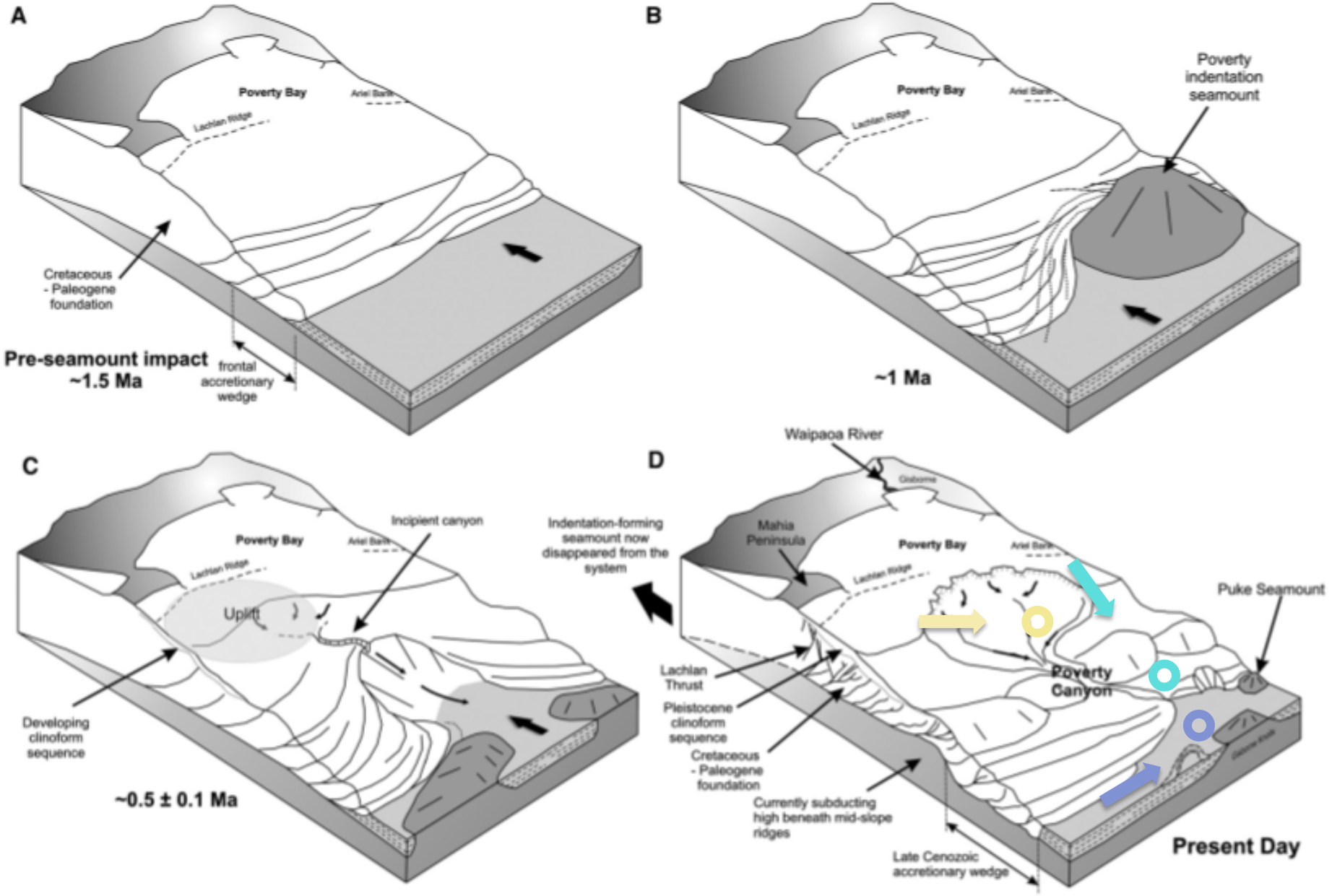
RV Marion Dufresne Long Piston Cores

NIWA Short Piston Core

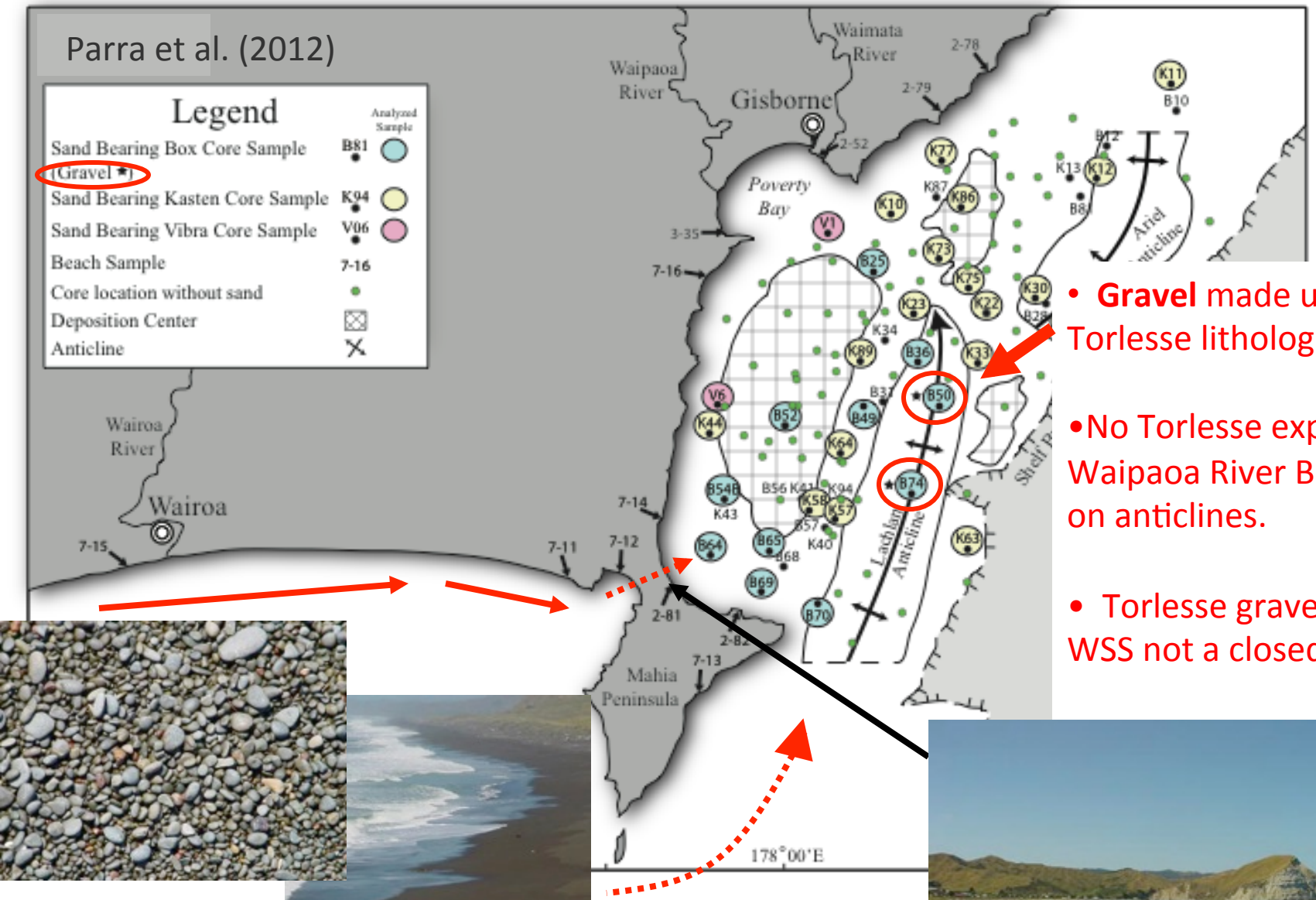




Effects of Seamount Subduction - Seismic Interpretation by Pedley et al. (2010)



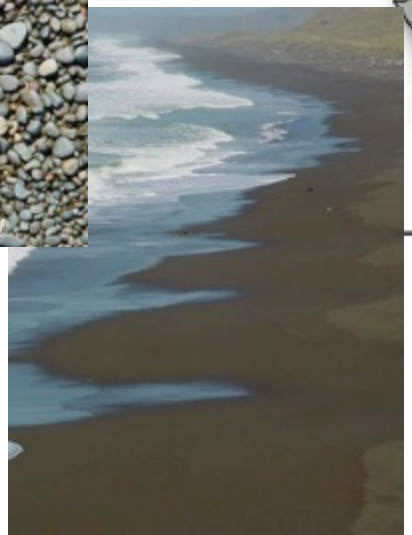
Parra et al. (2012)



- **Gravel** made up of Torlesse lithologies.

- No Torlesse exposed in Waipaoa River Basin or on anticlines.

- Torlesse gravel implies WSS not a closed system

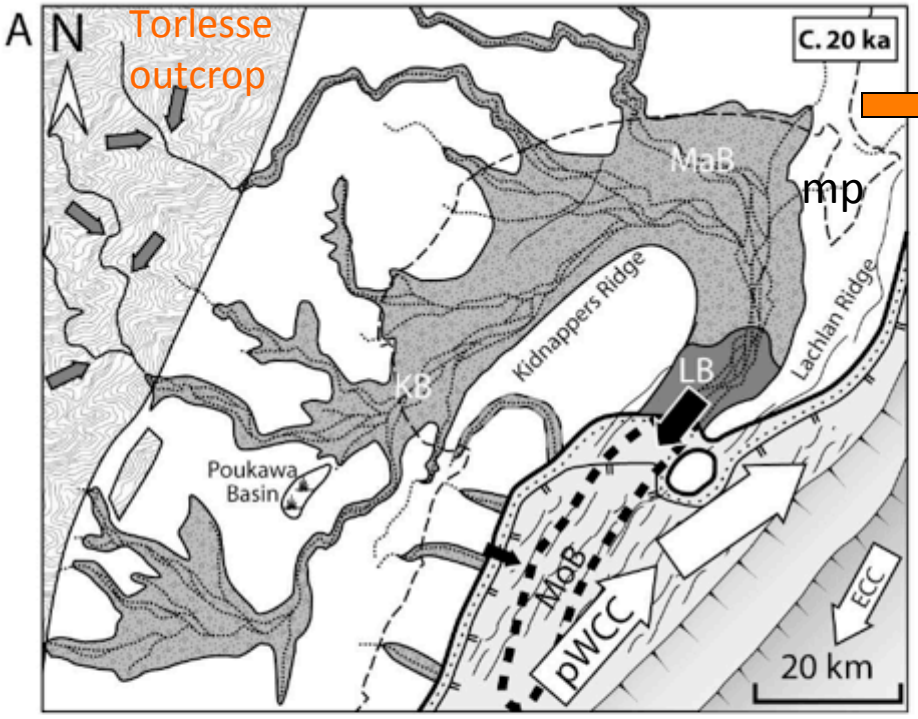


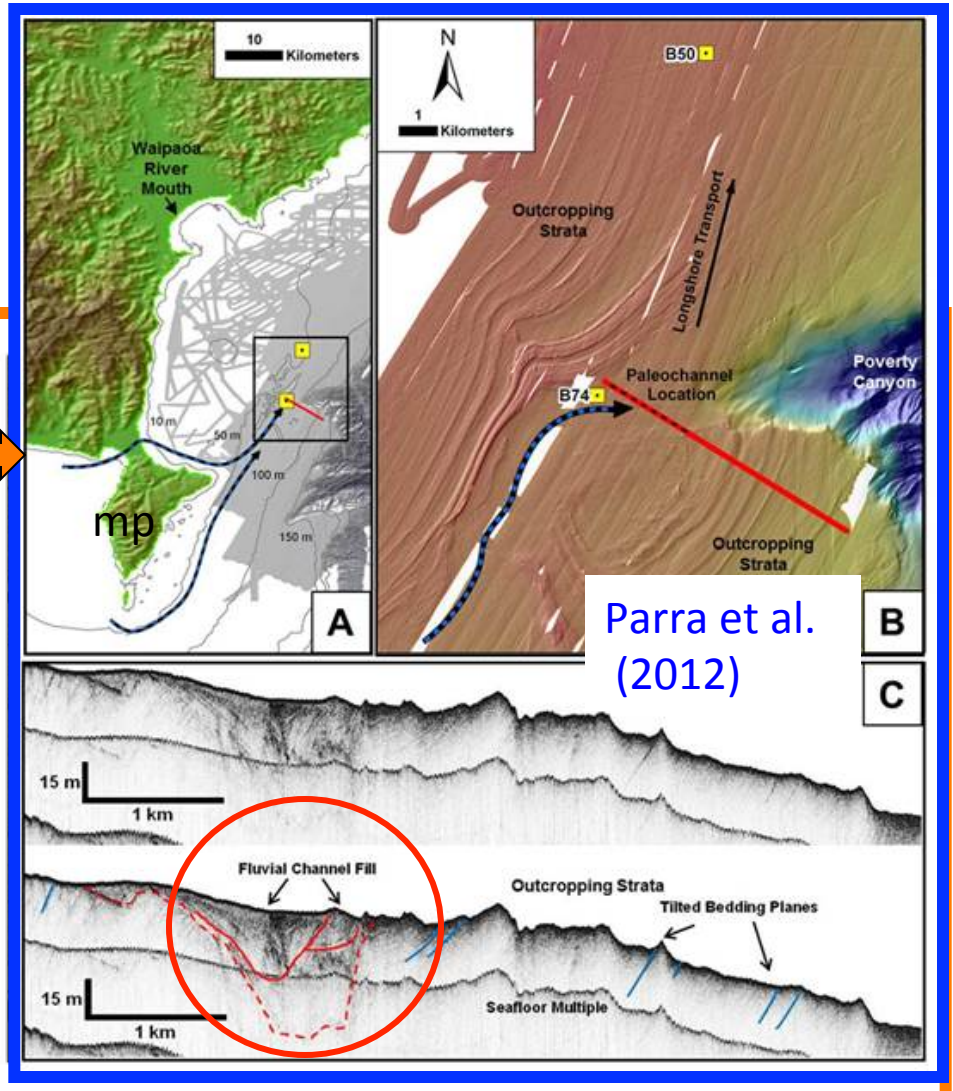
Torlesse gravel on beaches in Hawke's Bay

Sandy low tombolo connecting Mahia Peninsula to mainland

Oblate
Equant
Bladed
Prolate
1
2/3
0
Di/DI
Ds/Di
Hawke Bay
Torlesse
Beach
Gravel
Parra et al. (2012)
Legend
KM-B-74
KM-B-50
NZ-07-15
Ngaruroro River
Mid-Canterbury Rivers
Poverty
Shelf
Box-core
Gravel

Did lowstand river system extend from Hawke Bay across or around Mahia Peninsula to Poverty Shelf? Probably… System not closed!

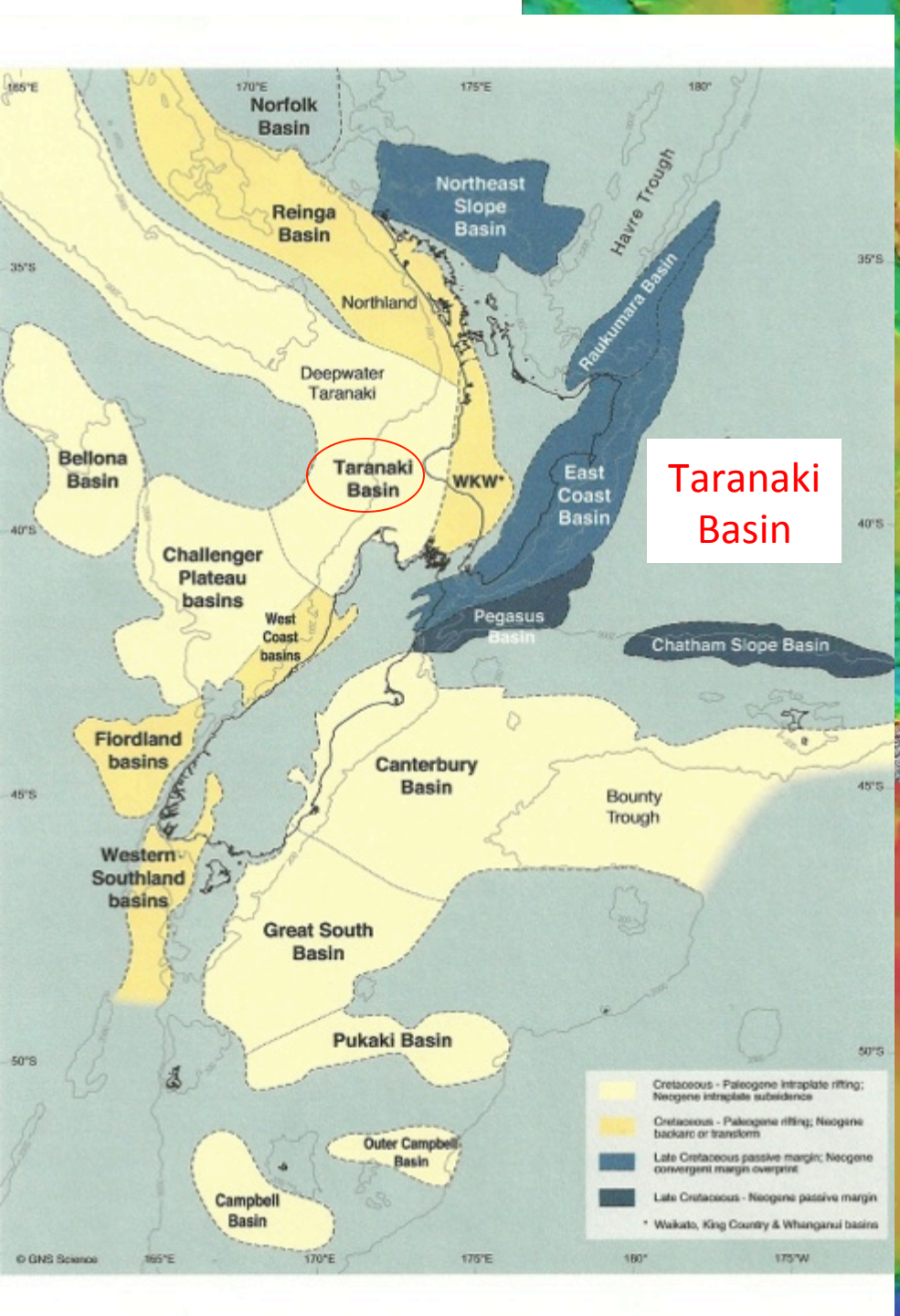




Parra et al. (2012)

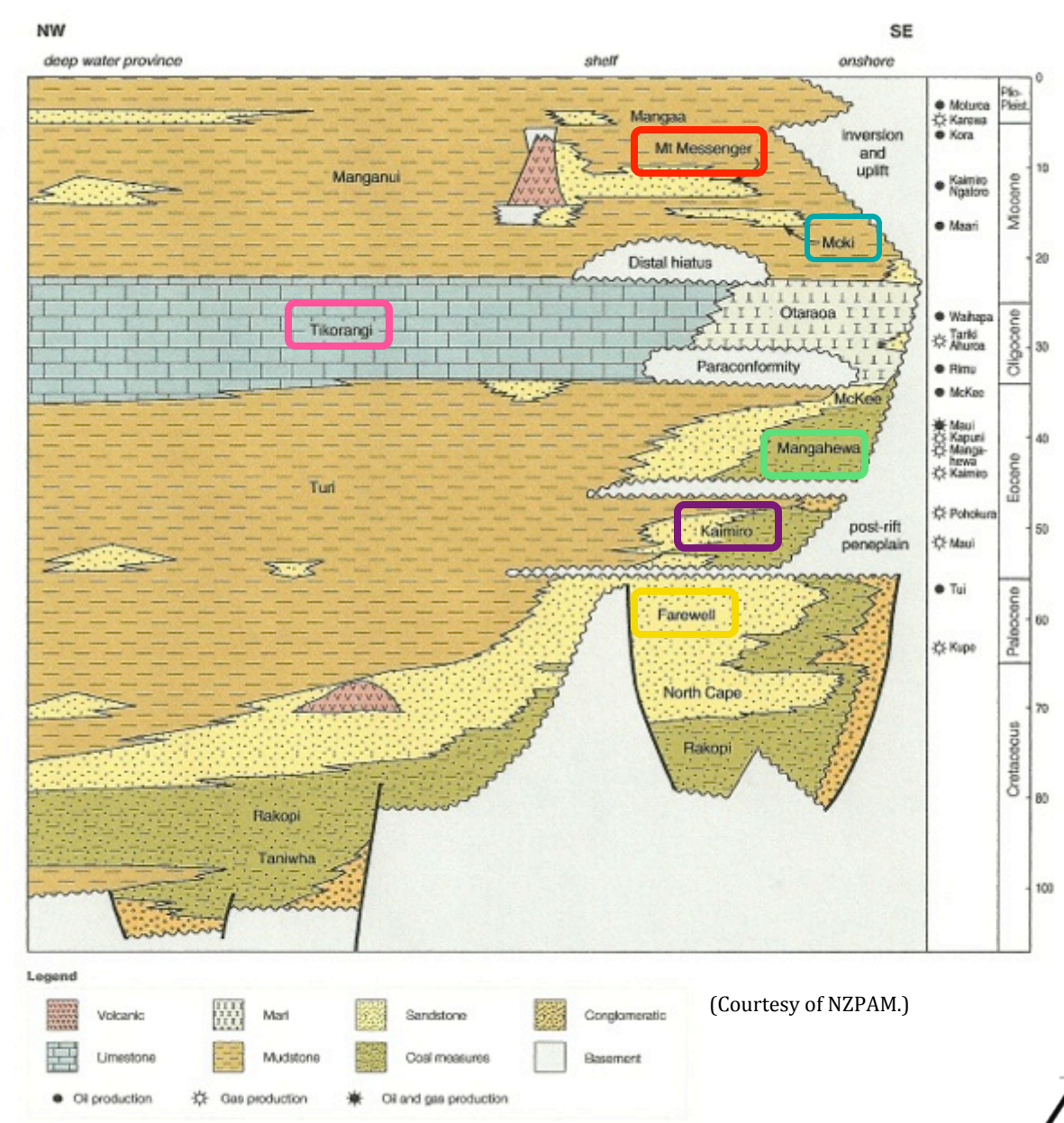
Axial ranges
Foothills and coastal ranges
Braided river and flood plains
Coastal plain
Submerged areas with no deposition
Submarine area with sedimentation
Active / inactive sediment waves
Lagoon and/or estuary
Lake and/or peat
Shoreface
Shelf edge
Last Glacial or Holocene Maximum Shoreline
Increased erosion
Sediment supply
Observed modern water circulation
surface circulation
WCC Wairarapa Coastal Current
pWCC proto-Wairarapa Coastal Current
ECC East Cape Current
Depocenter

Paquet et al. 2009

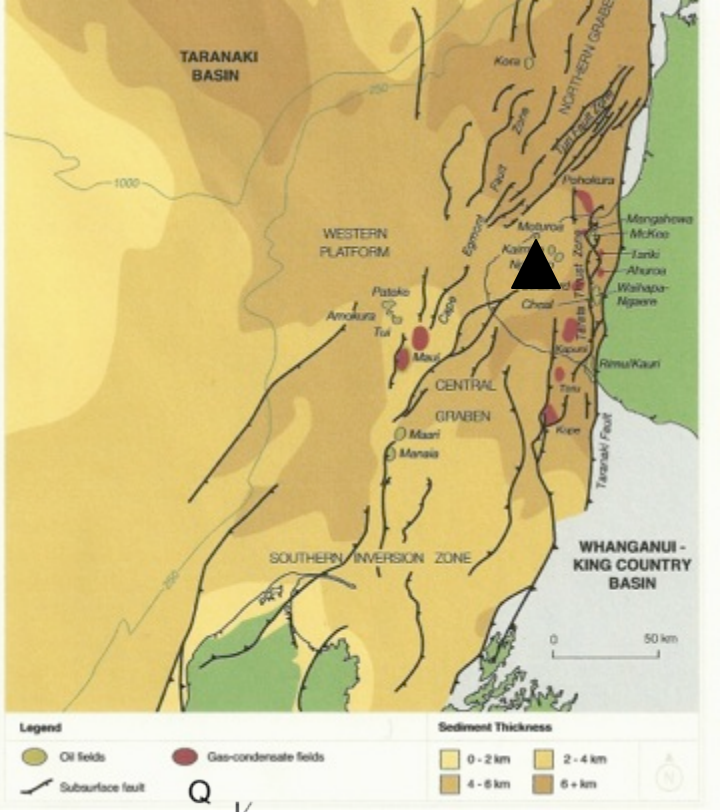


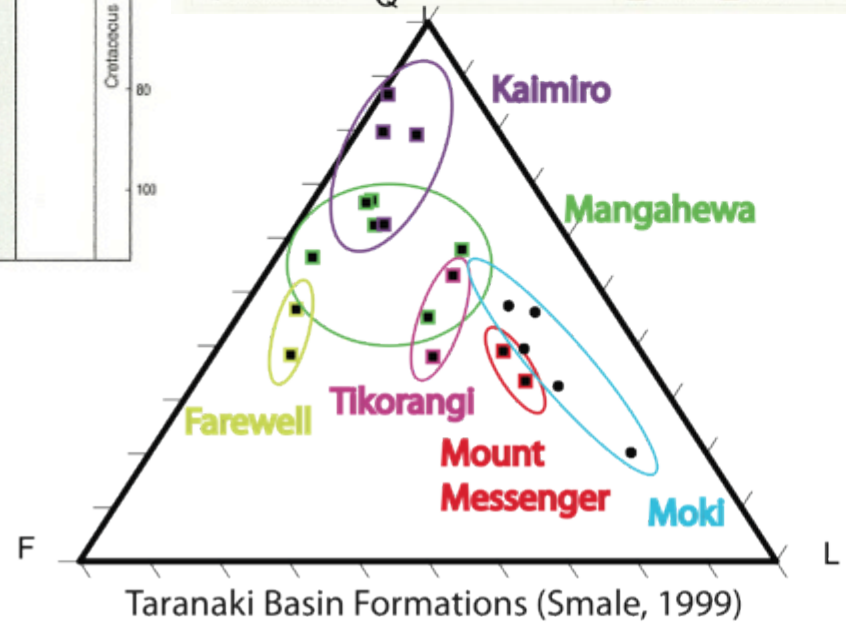
Taranaki Basin

Image from CANZ (1996)



(Courtesy of NZPAM.)





Taranaki Basin Formations (Smale, 1999)

Clastic provenance reflects change from Cretaceous rifted margin to Miocene/ Recent retroarc foreland basin

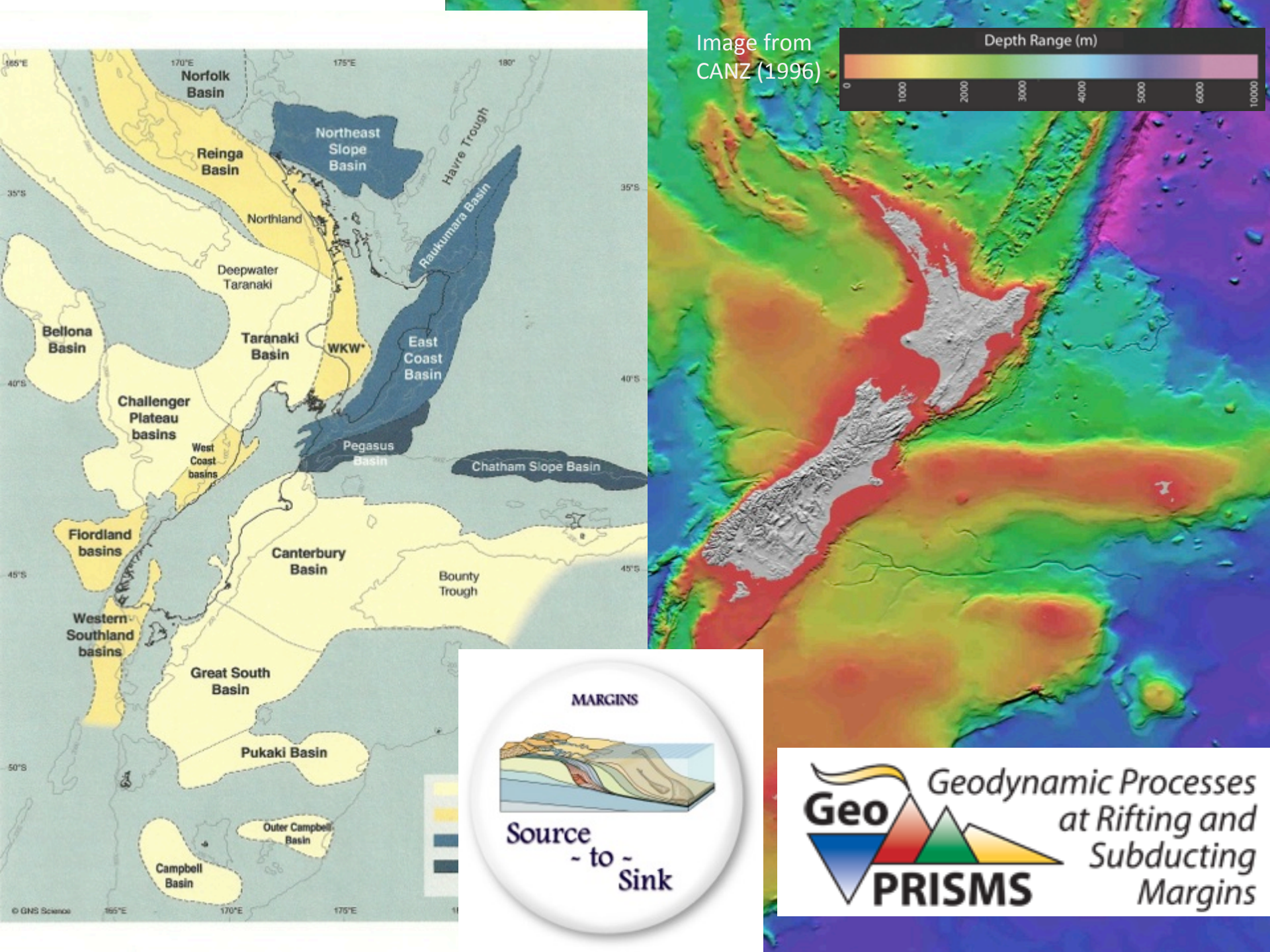


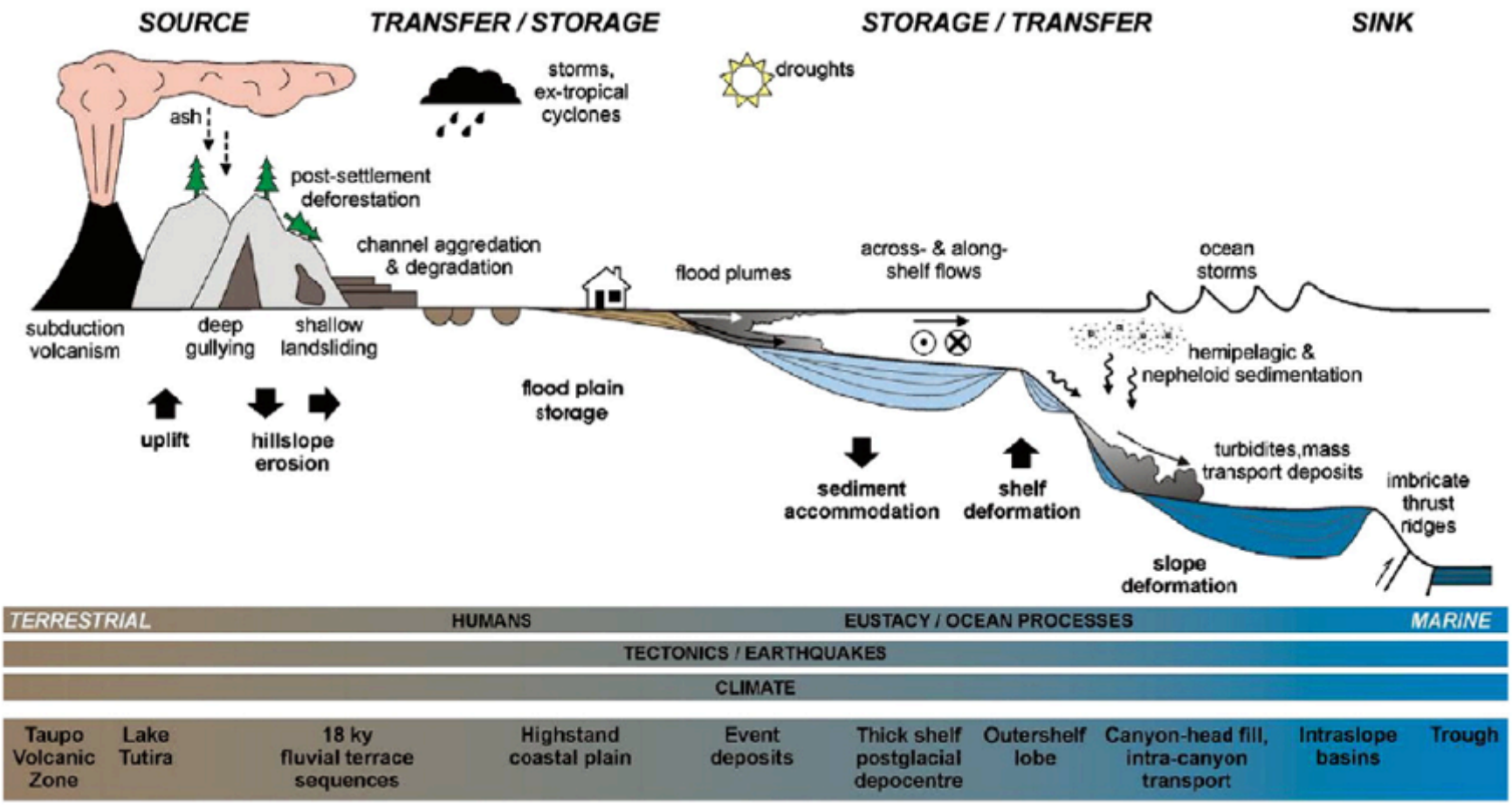
Image from
CANZ (1996)
Depth Range (m)
0
1000
2000
3000
4000
5000
6000
10000
Norfolk Basin
Reinga Basin
Northeast Slope Basin
Havre Trough
Northland
Raukumara Basin
Deepwater Taranaki
Bellona Basin
Taranaki Basin
WKW*
East Coast Basin
Challenger Plateau basins
West Coast basins
Pegasus Basin
Chatham Slope Basin
Fiordland basins
Canterbury Basin
Bounty Trough
Western Southland basins
Great South Basin
Pukaki Basin
Outer Campbell Basin
Campbell Basin
170°E
175°E
180°
35°S
40°S
45°S
50°S
© GNS Science
MARGINS
Source - to - Sink
Geo PRISMS
Geodynamic Processes at Rifting and Subducting Margins


Thank you for your attention
Questions?

Waipaoa Sedimentary System:

Drivers, processes and responses

(Carter et al., 2010, Marine Geology v.270)



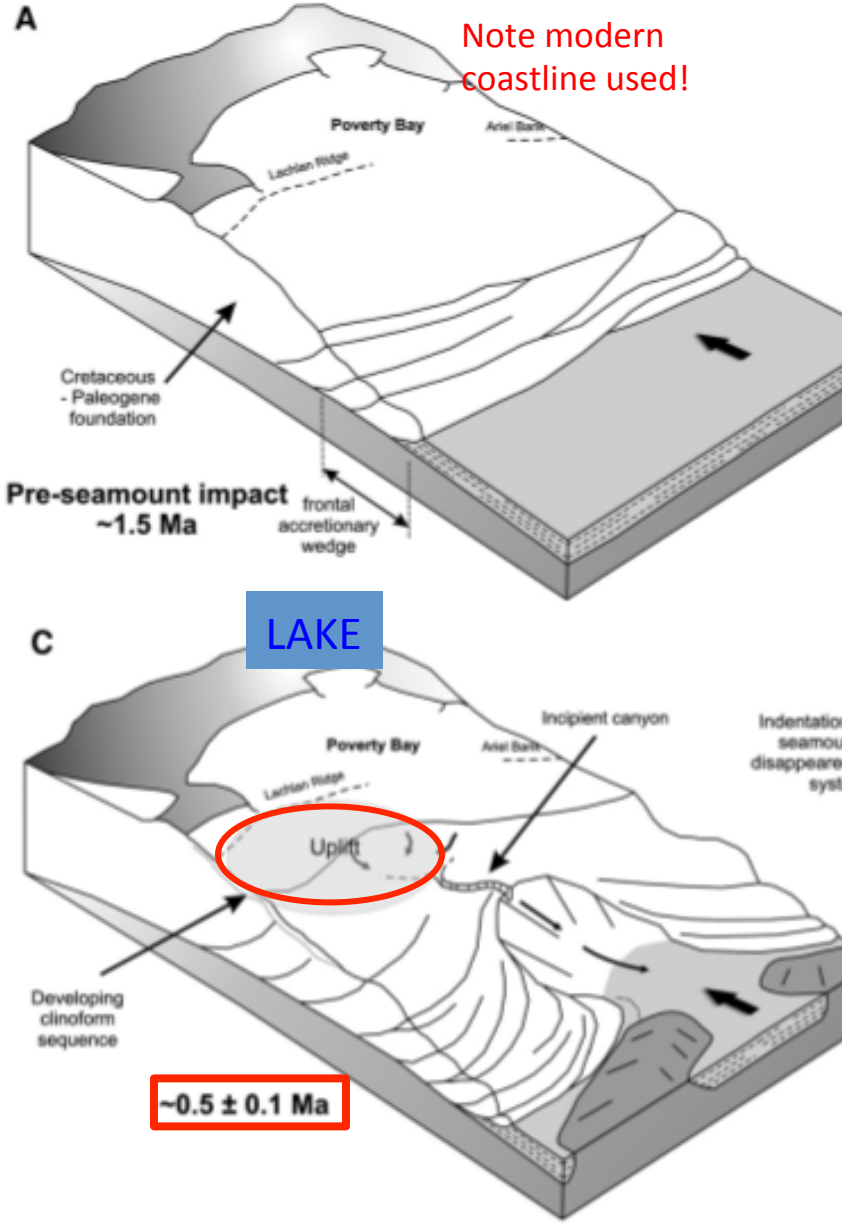
Taupo Magmatic arc

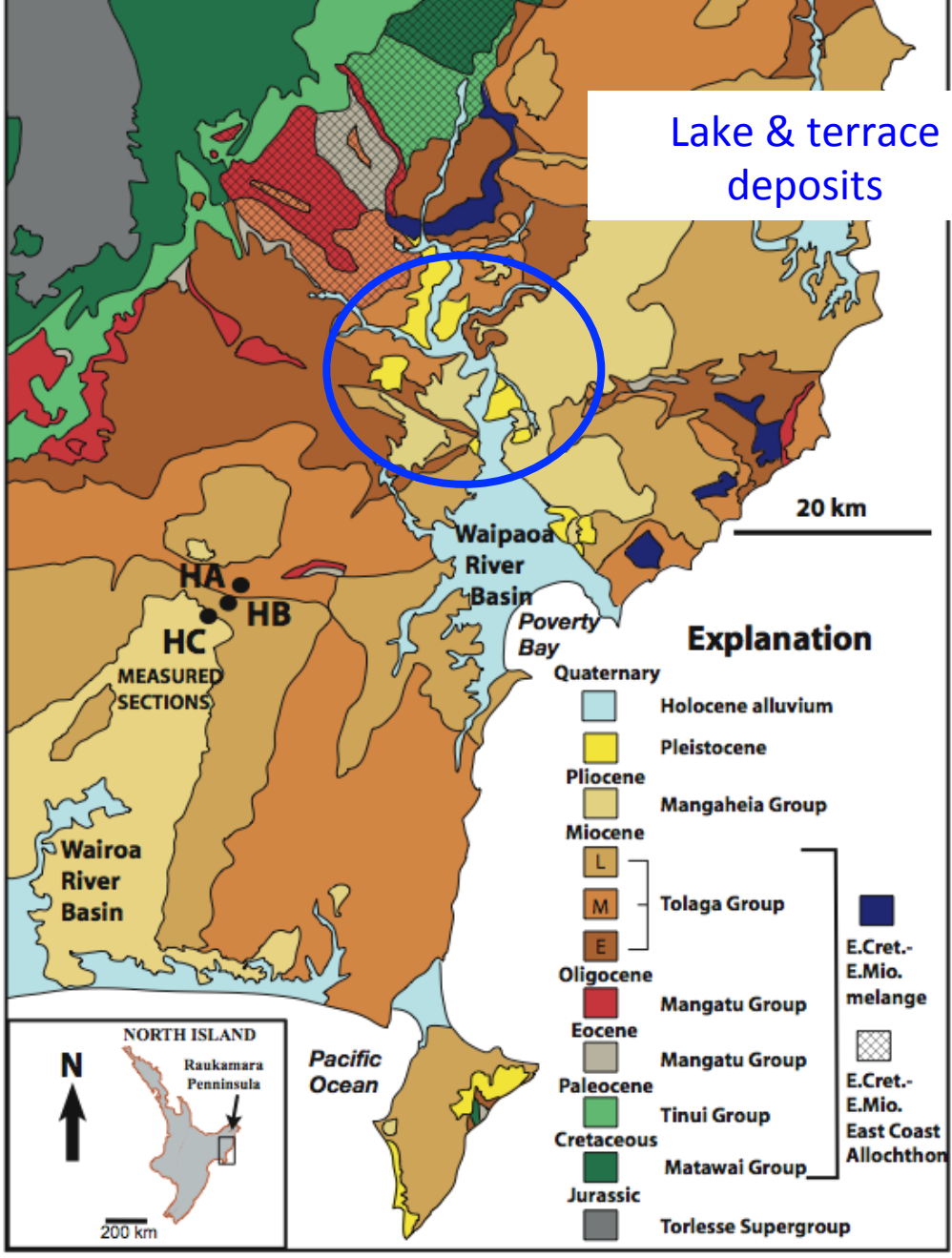
Waipaoa River

Poverty Bay, Shelf, Slope

Hikurangi Trench

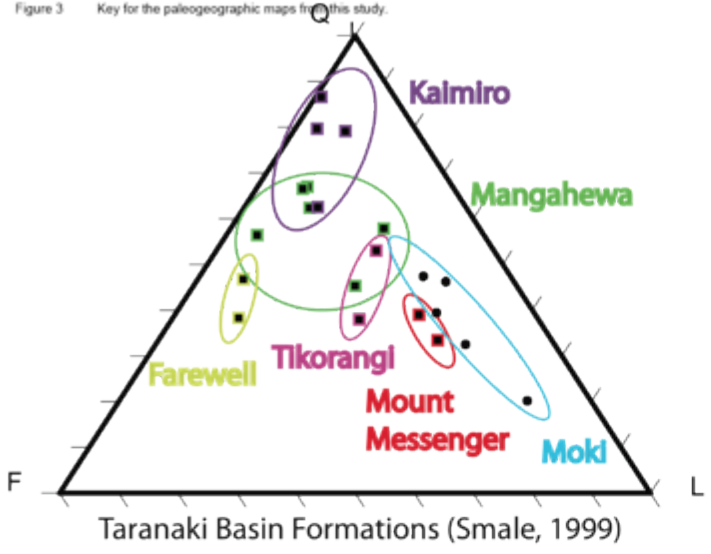
Pedley et al. (2010)





Offshore implications: sediment derived from uplift, decrease river input, lake outflow deposit(s)?

Figure 3 Key for the paleogeographic maps from this study.



Taranaki Basin Formations (Smale, 1999)

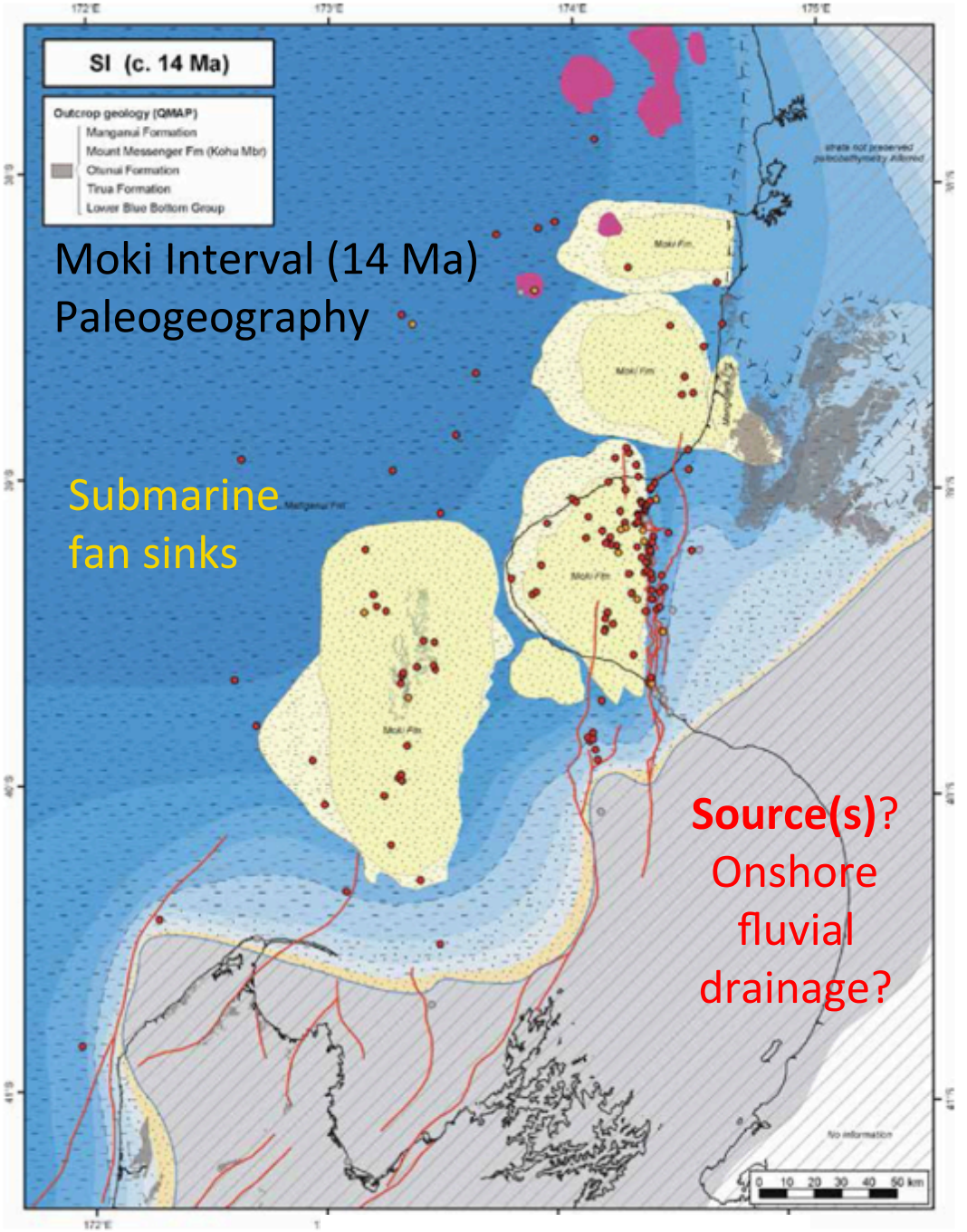
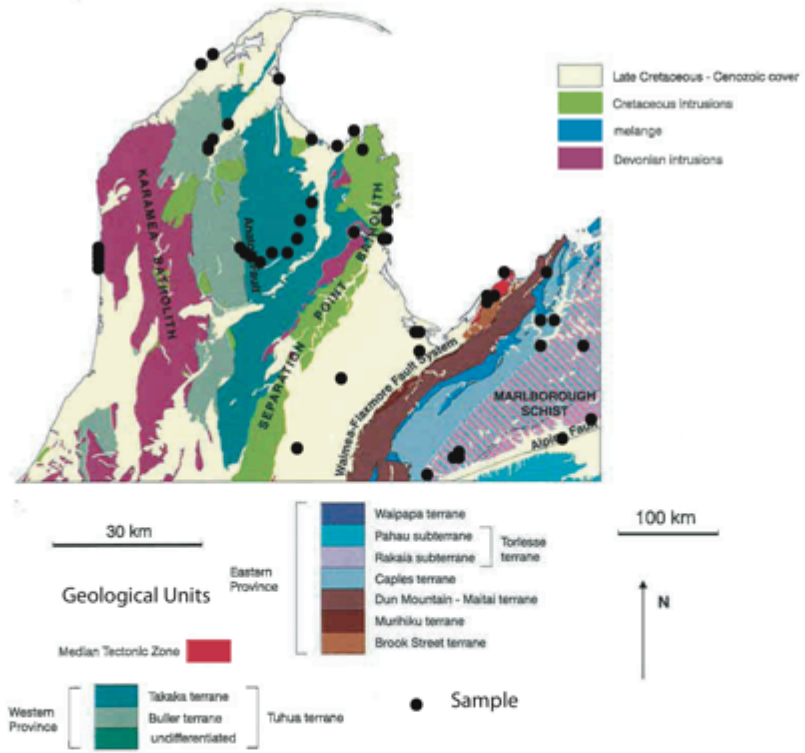


Figure 25 Paleogeographic map for (courtesy of P. King, GNS)

Doran (in prep.)



Adapted from Rattenbury, 1998, and GNS Science, 2010.

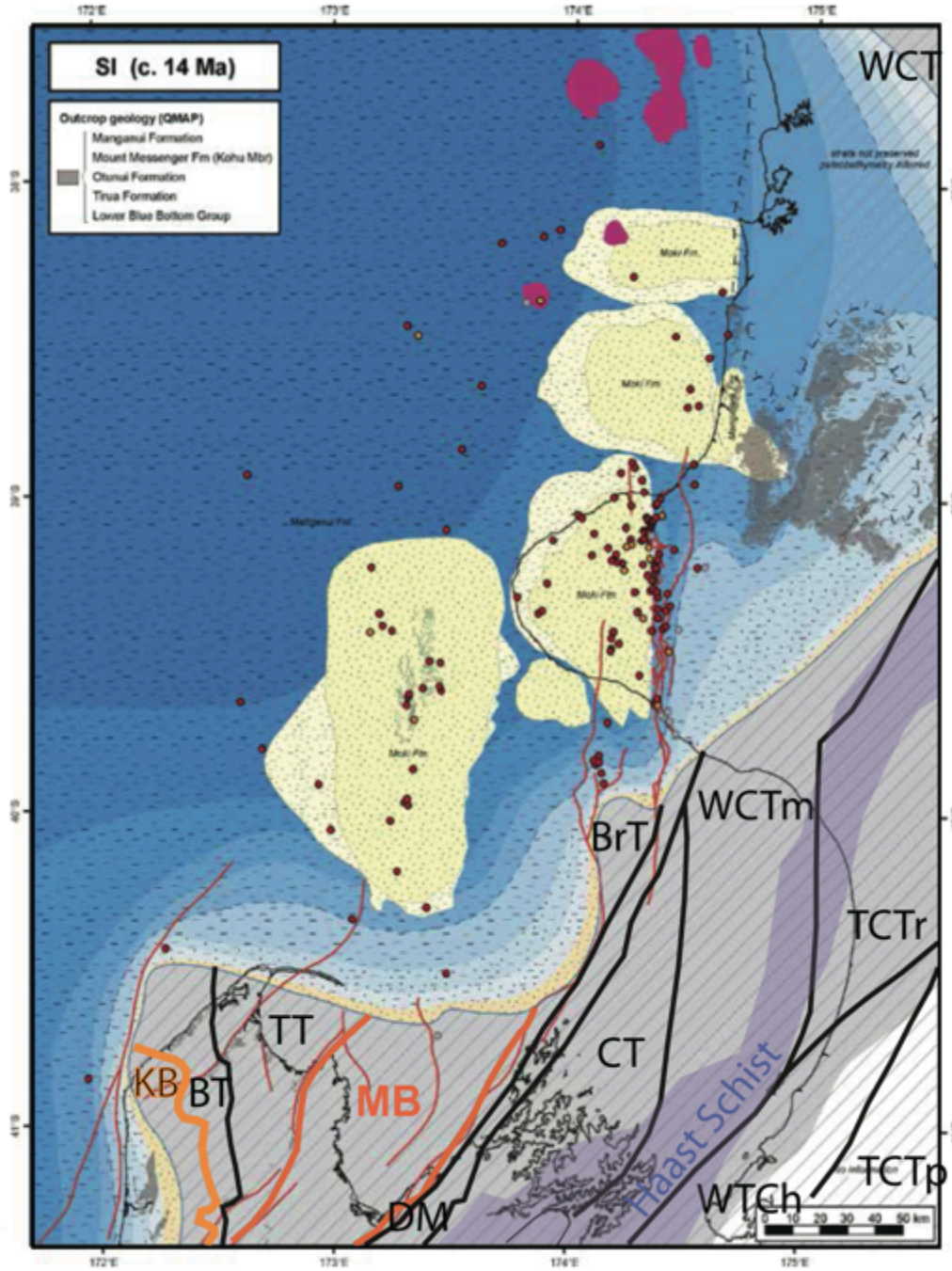
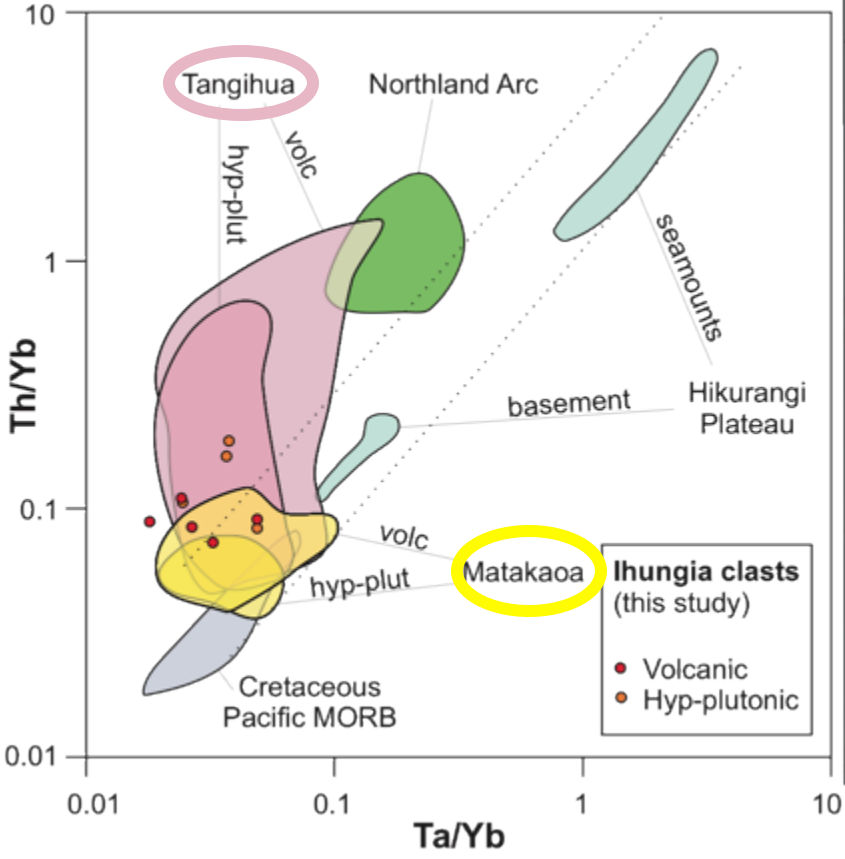
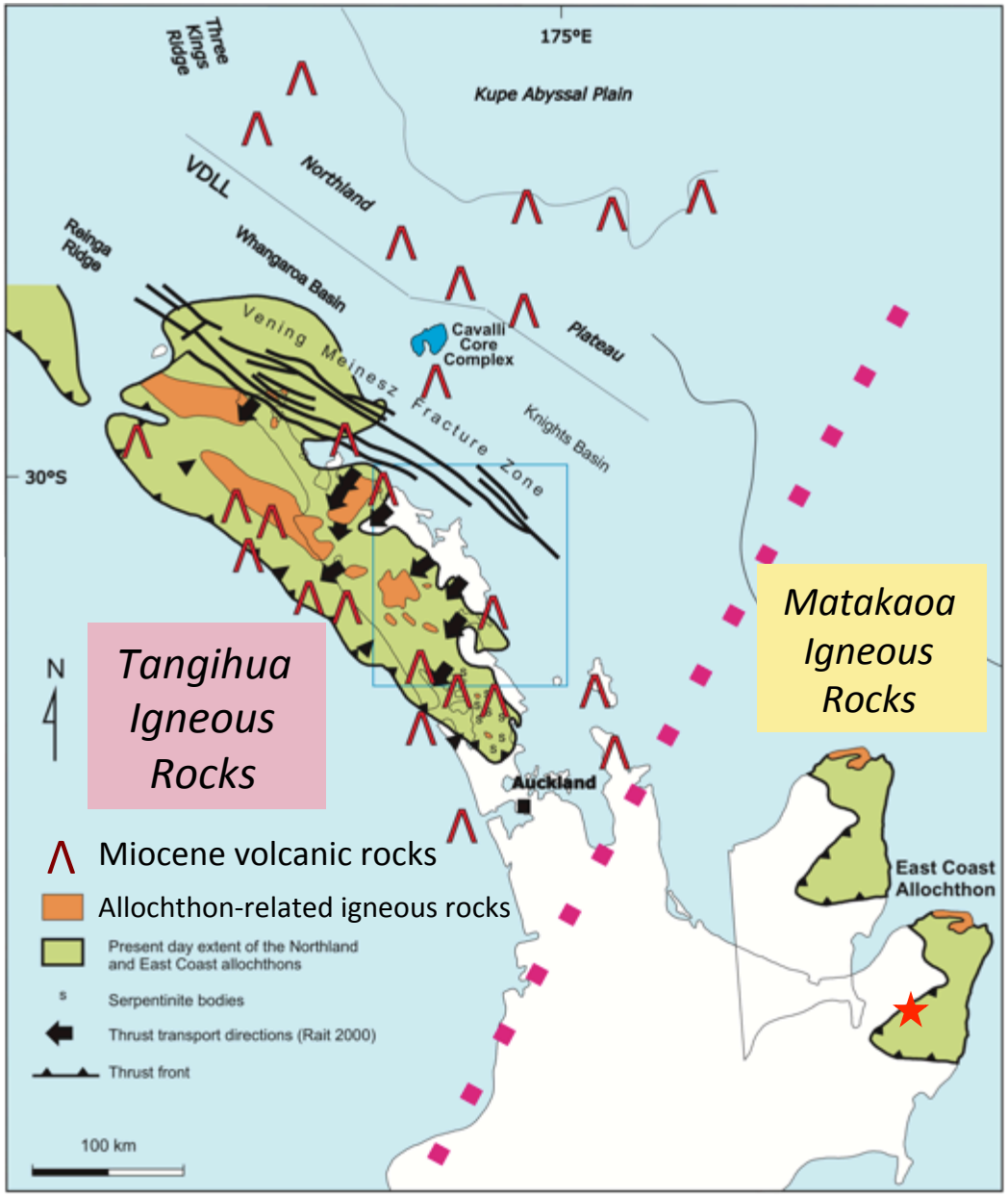


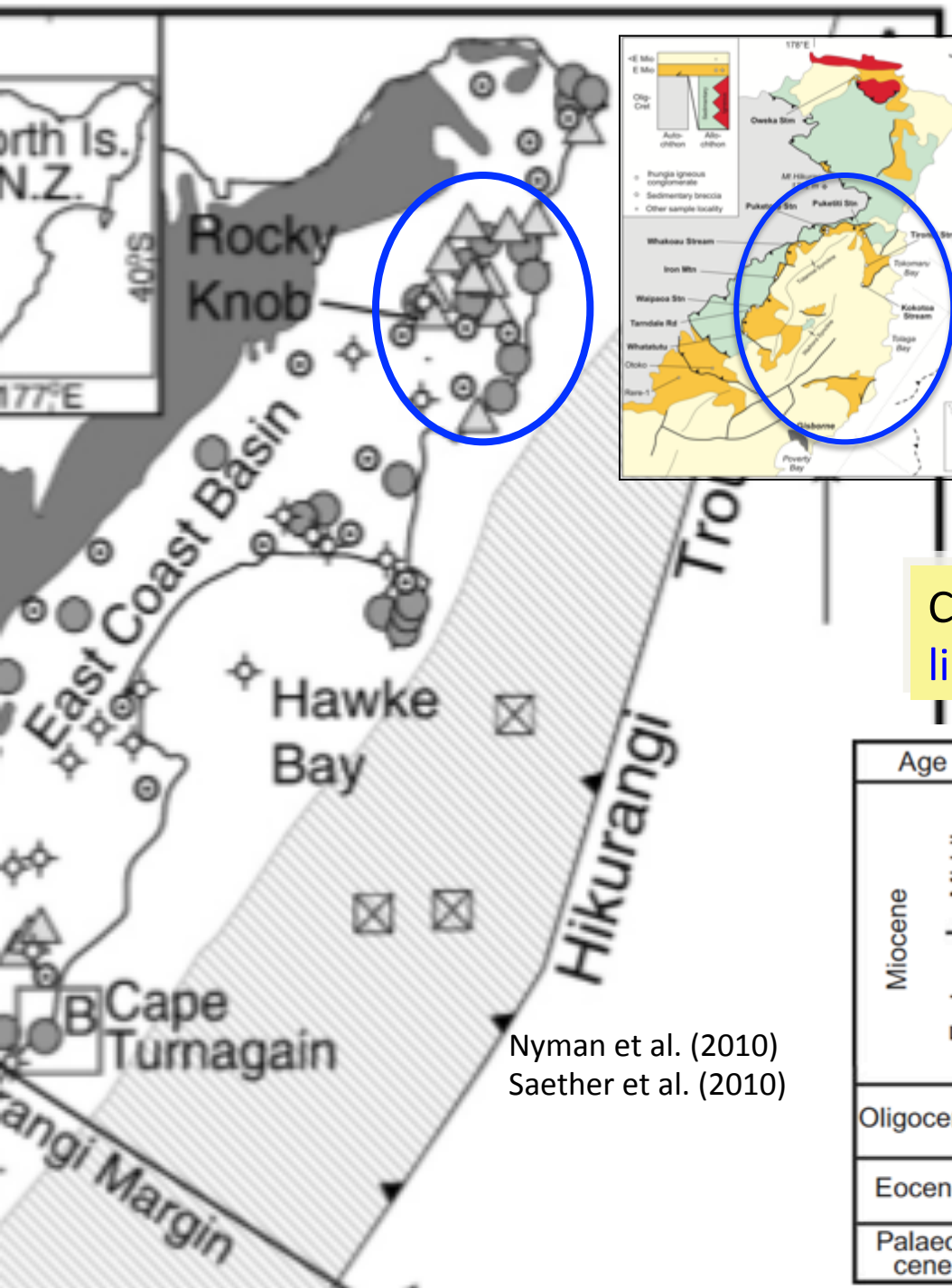
Figure 25 Paleogeographic map for 14 Ma (Lillburnian).

Ihungia Clast Geochemistry

> Basaltic andesite to gabbro
> Mainly tholeiitic & subalkalic
> Trace element composition:
  a) intermediate between MORB & arc basalt with mild slab fluid signature
  b) unlike Hikurangi Plateau, Cret. MORB and Northland Arc
  c) similar to Tangihua & Matakaoa Ign.



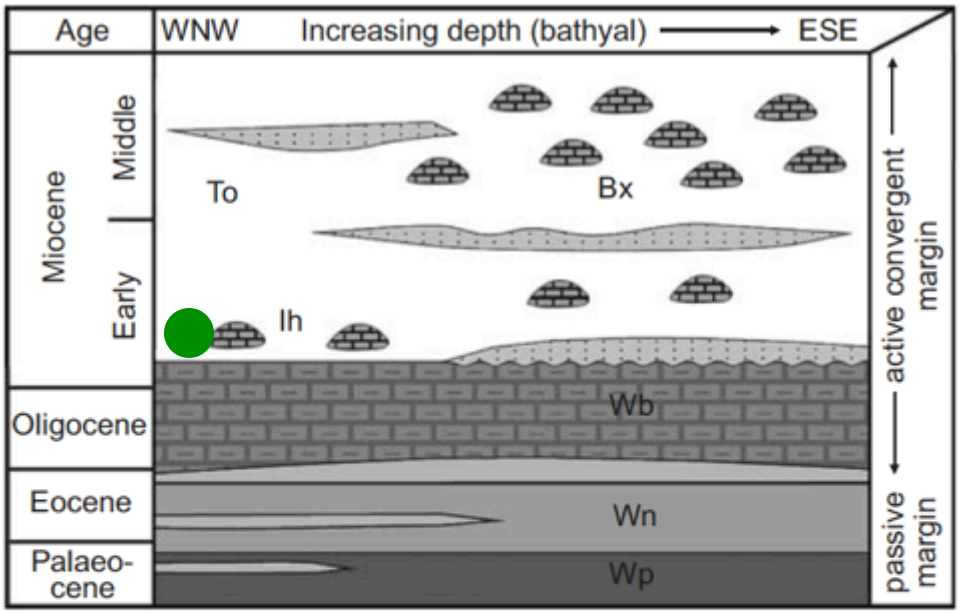


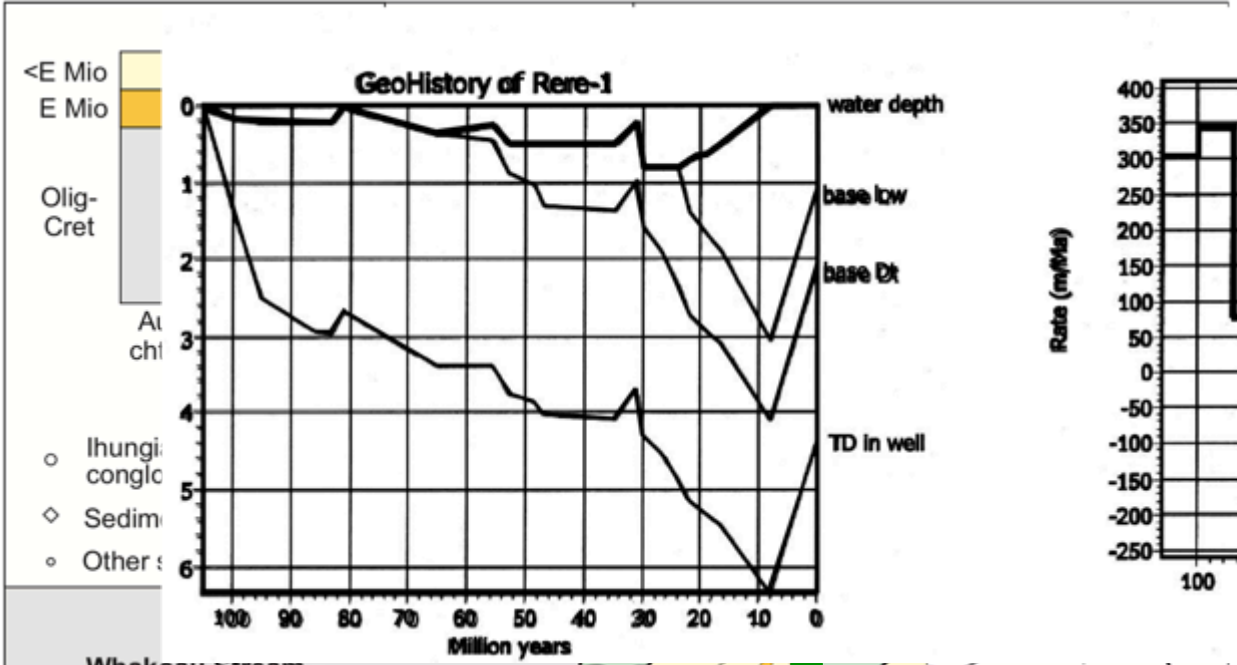


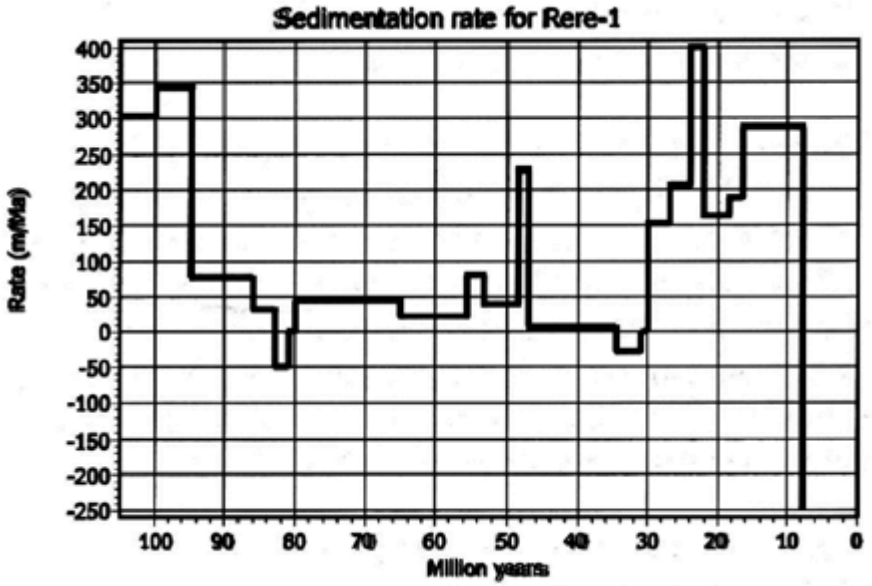
- Neogene tubular carbonate concretion localities
- Miocene seep limestone localities
- Mesozoic basement rocks
- Known bottom simulating reflector (BSR)
- Modern seep carbonates ± concretions
- Well locations
- Active oil and gas seeps

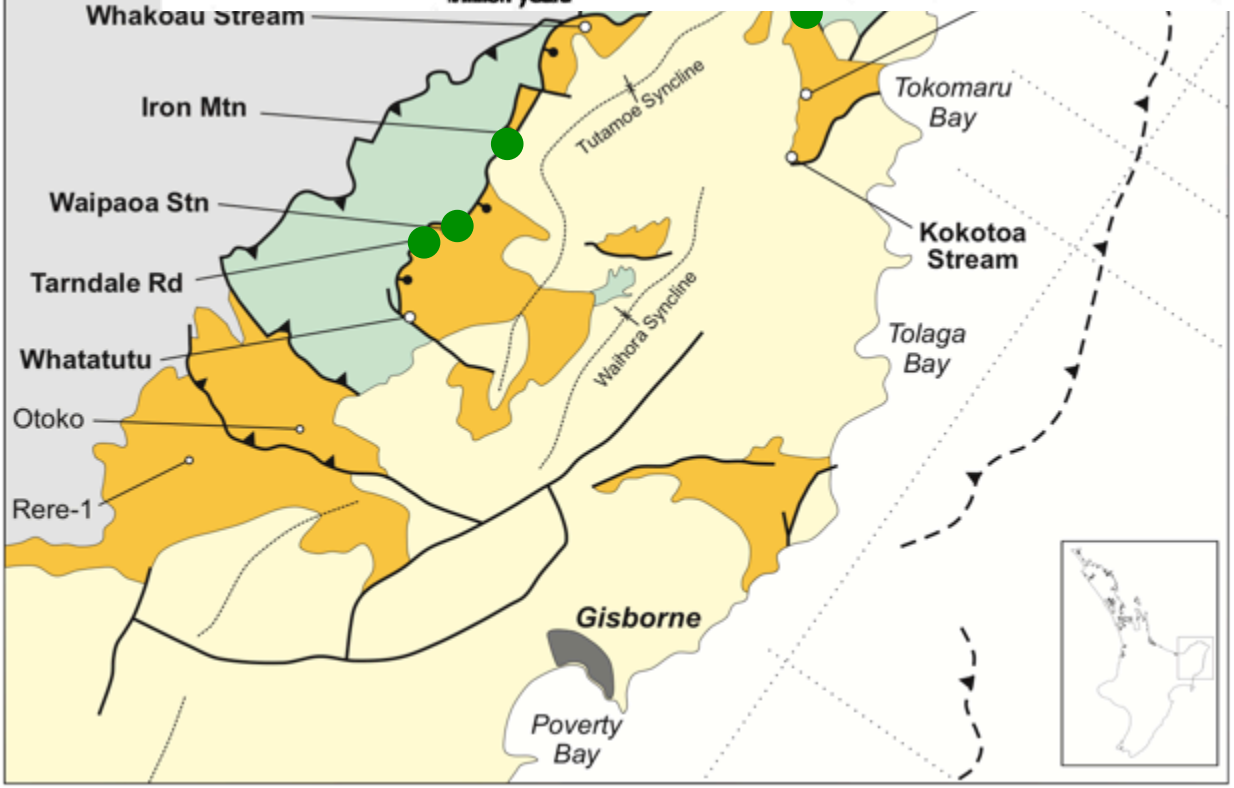
Concentration of Miocene seep limestones in Ihungia 'basin'

Nyman et al. (2010)
Saether et al. (2010)

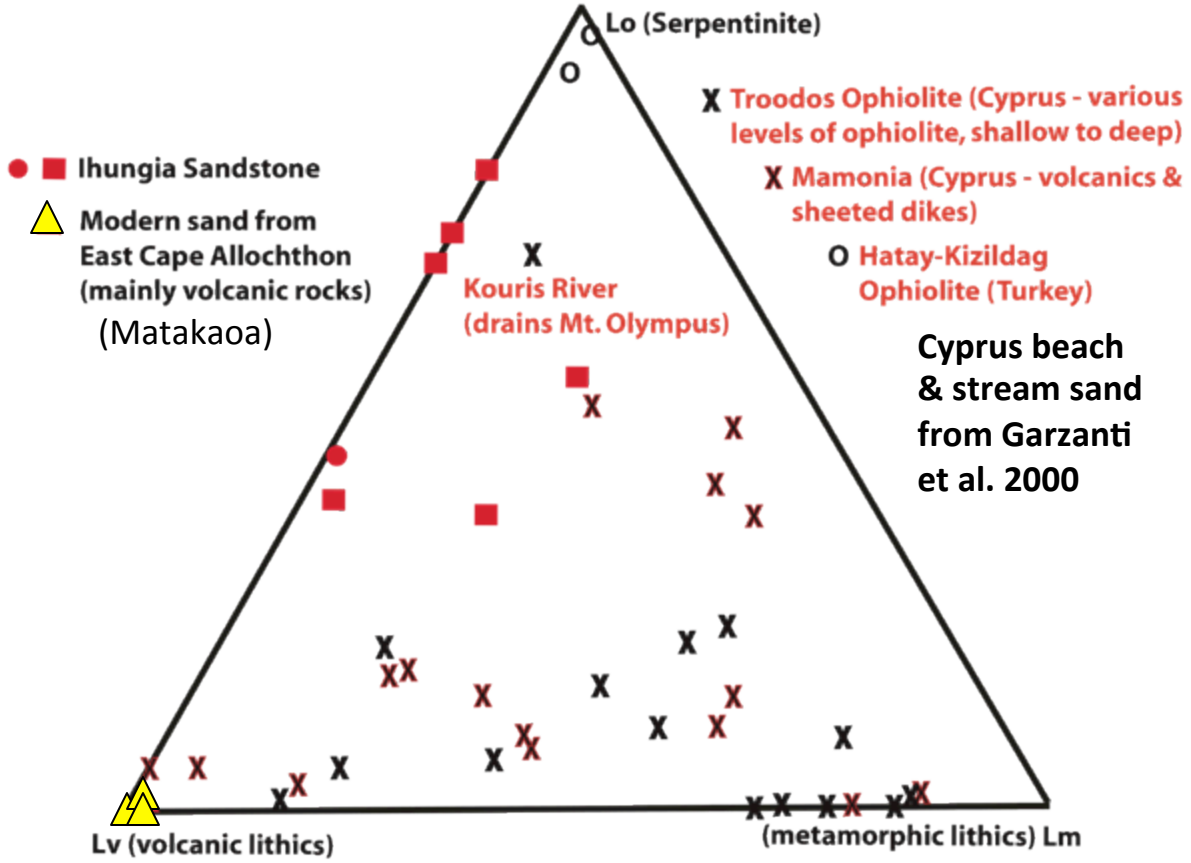



<E Mio
E Mio
Olig-
Cret
GeoHistory of Rere-1
water depth
base low
base Dt
TD in well
Million years
Ihungi
Sedim
Other

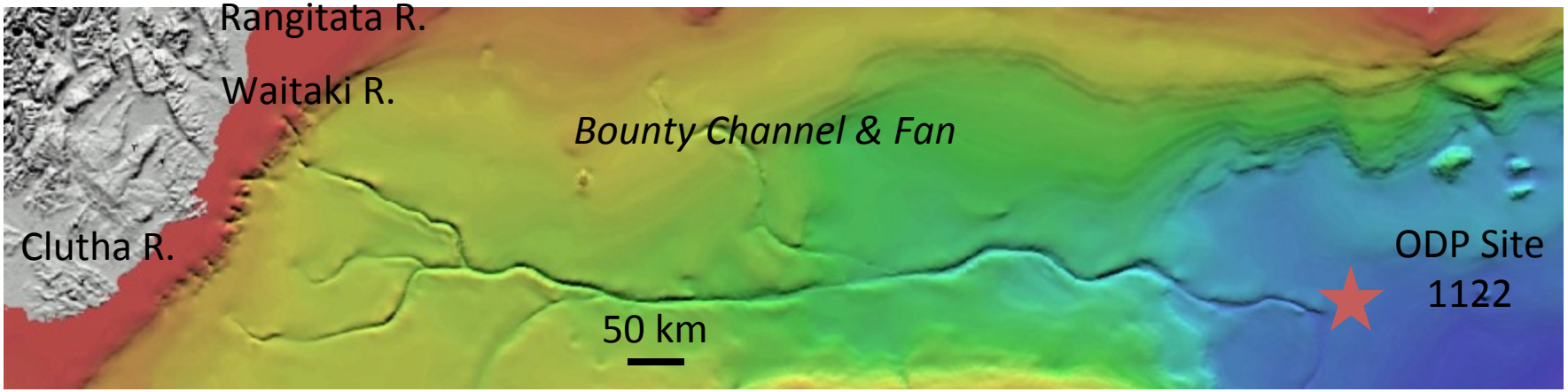

Sedimentation rate for Rere-1
Rate (m/Ma)
Million years


Whakoau Stream
Iron Mtn
Waipaoa Stn
Tarndale Rd
Whatatutu
Otoko
Rere-1
Tutamoe Syncline
Waihora Syncline
Tokomaru Bay
Kokotoa Stream
Tolaga Bay
Gisborne
Poverty Bay

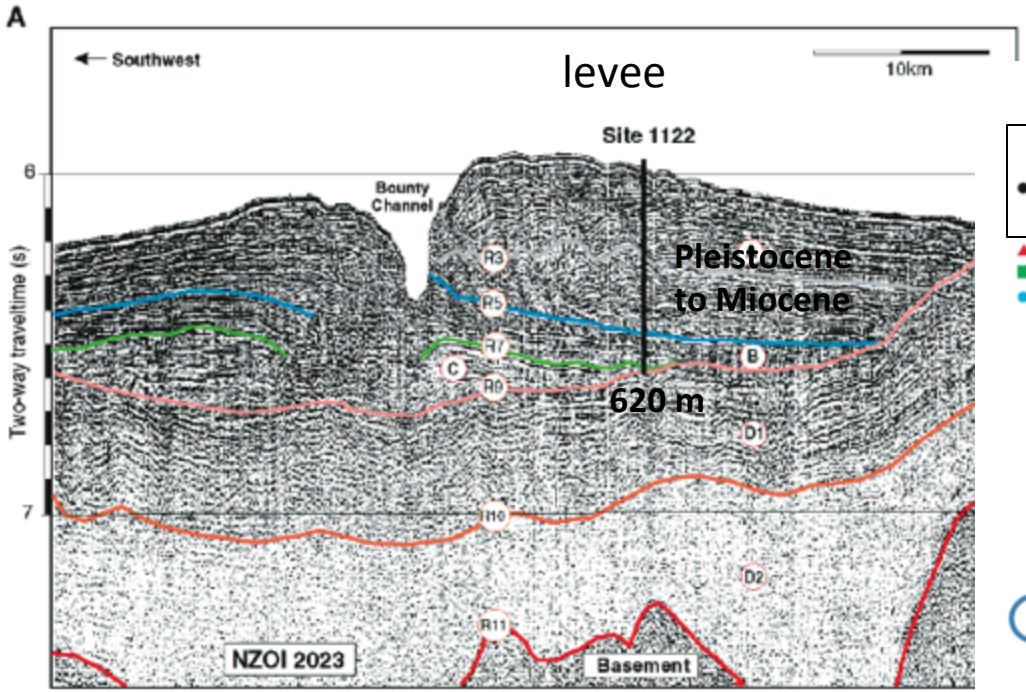
Sand/Sandstone Detrital Modes
Similar to those from Cyprus!

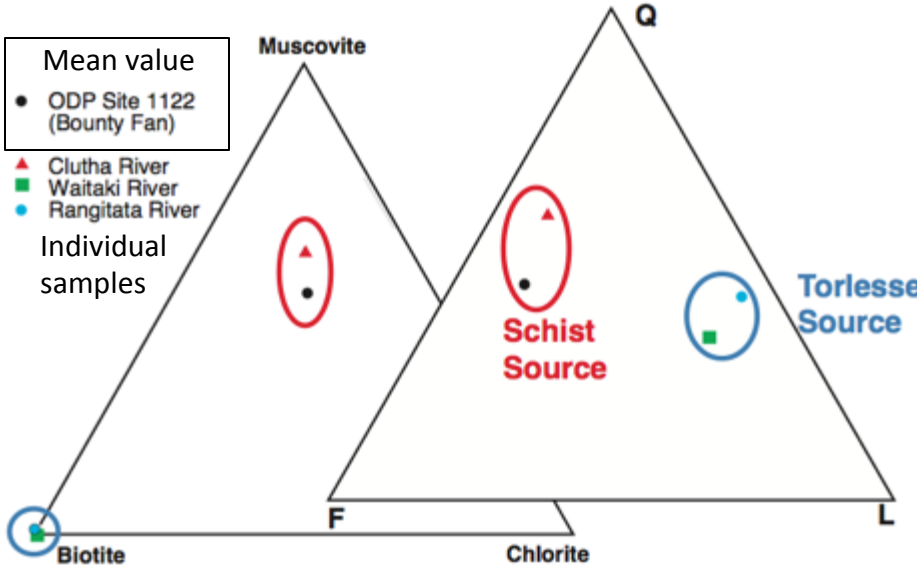


Geological Map of Cyprus
Geological Survey Dept., Cyprus (1995)



~4500 m water depth

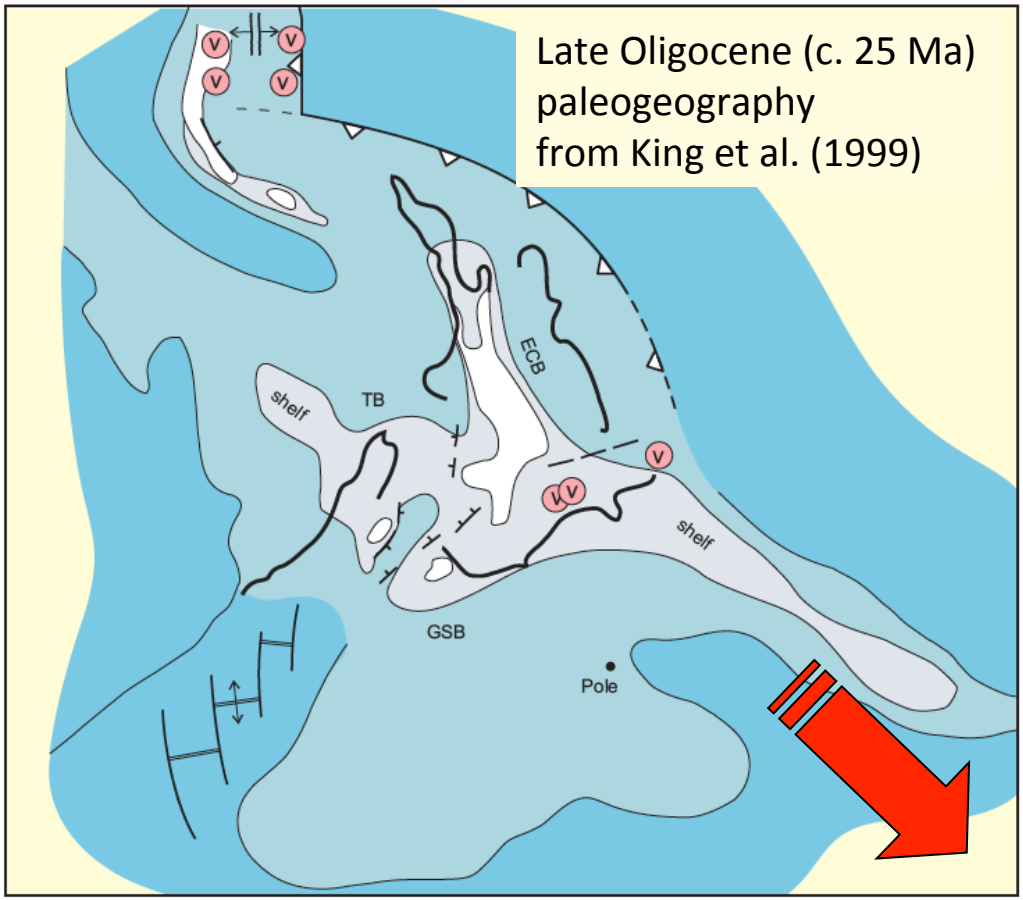


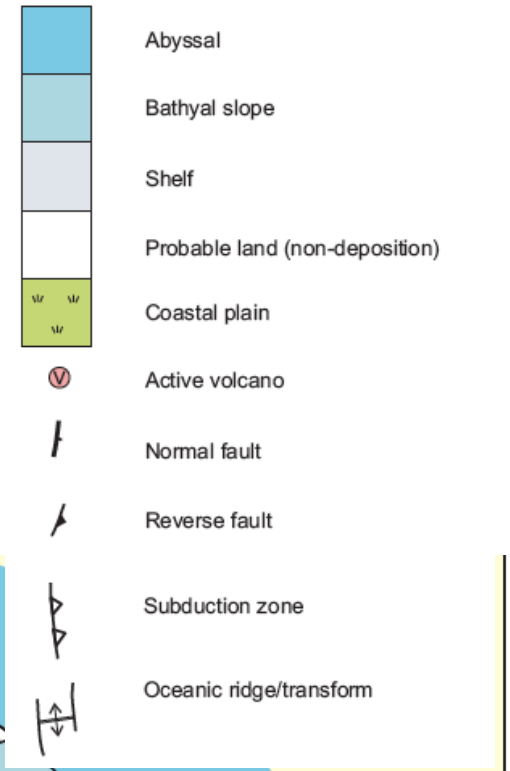


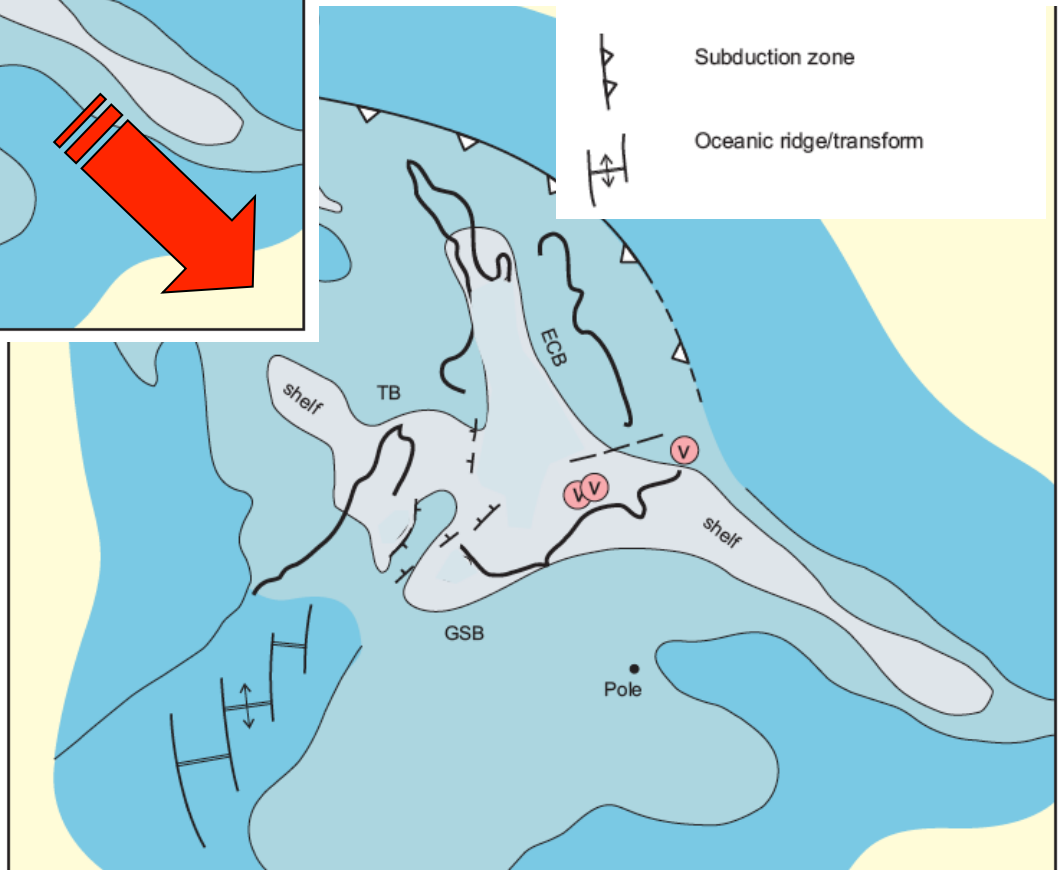
Shapiro et al. (2007)
GSA Spec. Pap. 420

Conclusion:

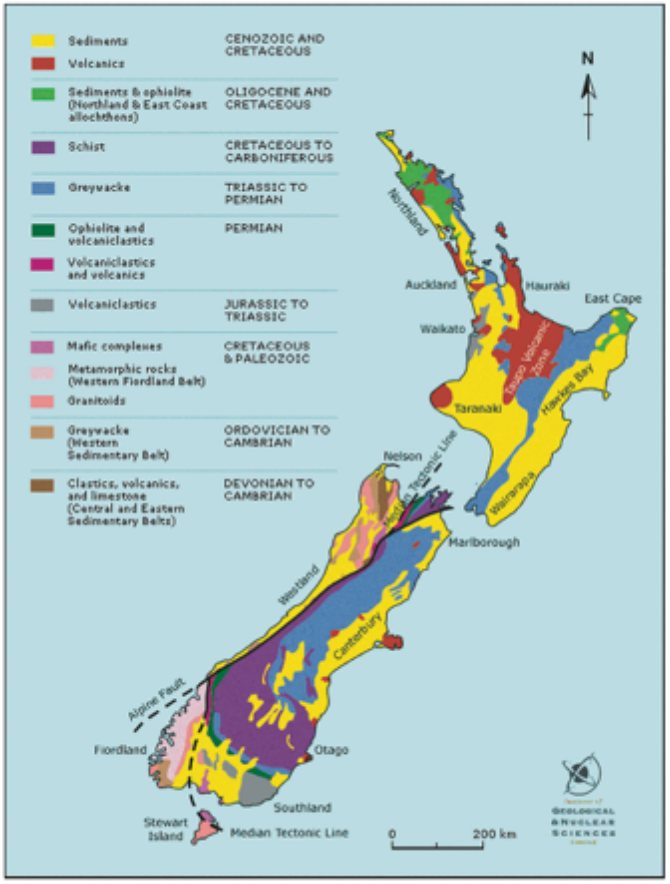
Clutha River is the main source of sand delivered to Bounty Fan

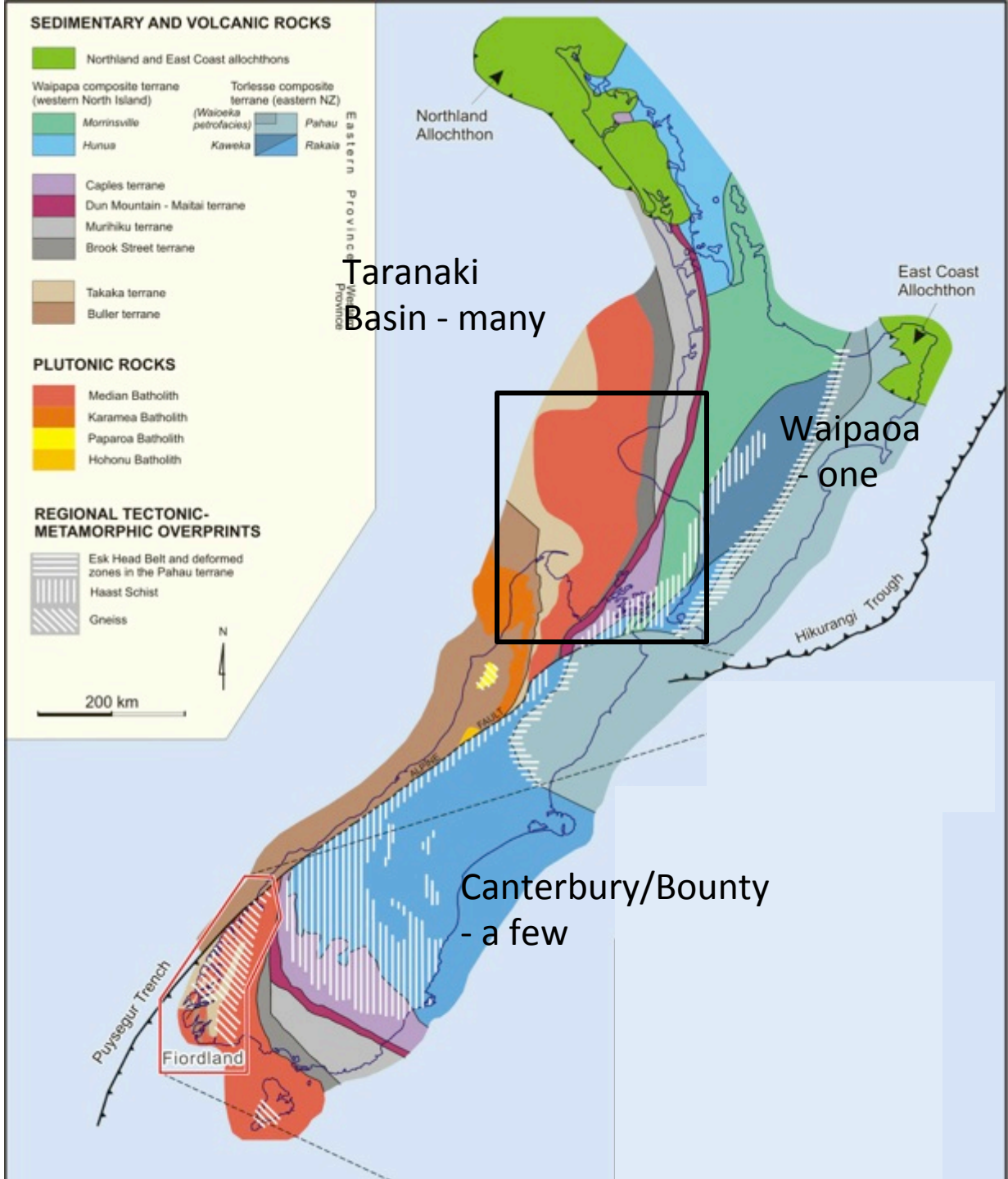


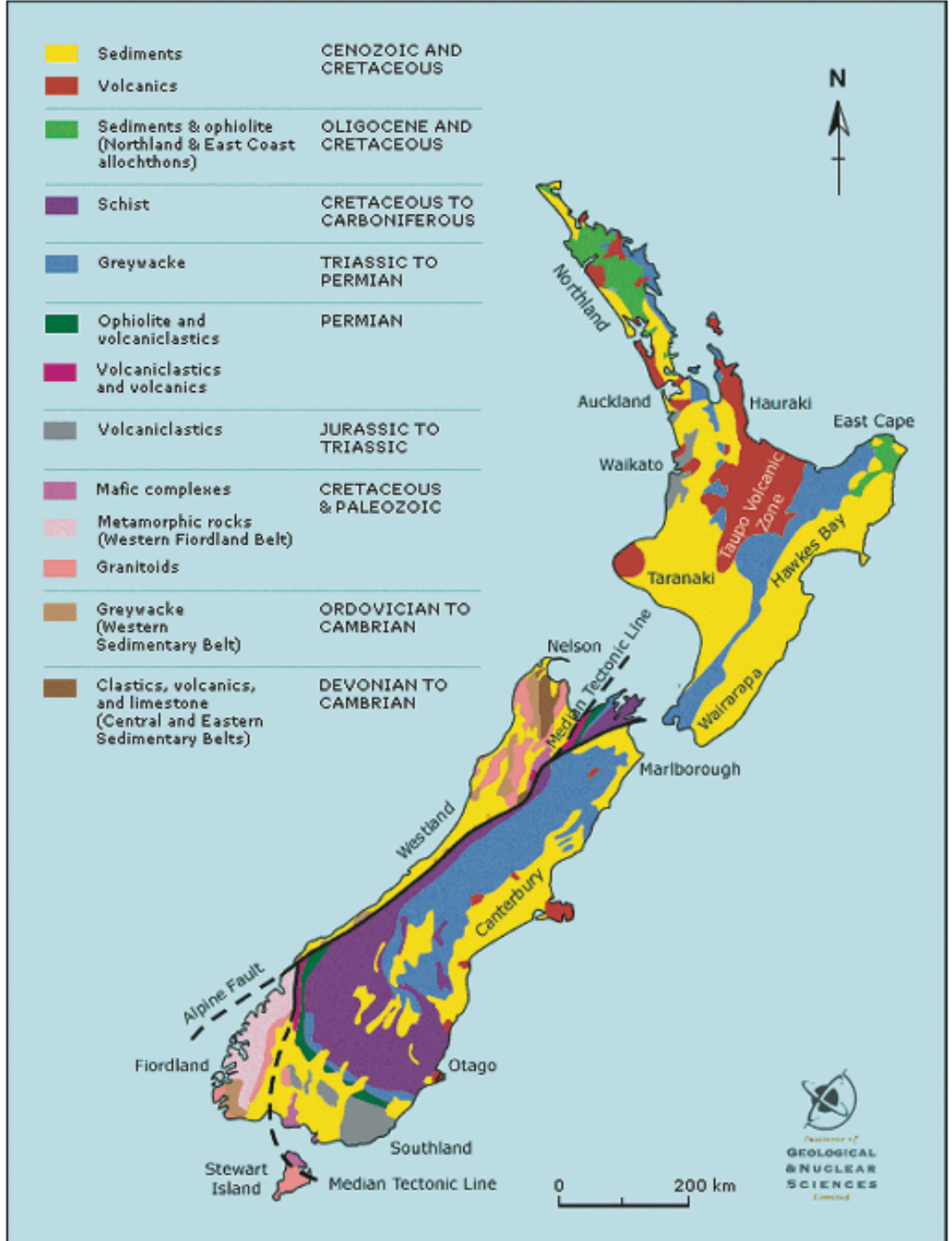




Alternate view:
No land area during Late Oligocene


Sediments
Volcanics
Sediments & ophiolite (Northland & East Coast allochthons)
Schist
Greywacke
Ophiolite and volcaniclastics
Volcaniclastics and volcanics
Volcaniclastics
Mafic complexes
Metamorphic rocks (Western Fiordland Belt)
Granitoids
Greywacke (Western Sedimentary Belt)
Clastics, volcanics, and limestone (Central and Eastern Sedimentary Belts)
CENOZOIC AND CRETACEOUS
OLIGOCENE AND CRETACEOUS
CRETACEOUS TO CARBONIFEROUS
TRIASSIC TO PERMIAN
PERMIAN
JURASSIC TO TRIASSIC
CRETACEOUS & PALEOZOIC
ORDOVICIAN TO CAMBRIAN
DEVONIAN TO CAMBRIAN
N
Northland
Auckland
Hauraki
East Cape
Waikato
Taupo Volcanic Zone
Taranaki
Hawke Bay
Nelson
Alpine Fault
Wairarapa
Marlborough
Westland
Canterbury
Fiordland
Otago
Southland
Stewart Island
Median Tectonic Line
0
200 km


SEDIMENTARY AND VOLCANIC ROCKS
Northland and East Coast allochthons
Waipapa composite terrane (western North Island)
Morrinsville
Hunua
Torlesse composite terrane (eastern NZ)
(Waioeka petrofacies)
Kaweka
Pahau
Rakaia
Eastern Province
Western Province
Caples terrane
Dun Mountain - Maitai terrane
Murihiku terrane
Brook Street terrane
Takaka terrane
Buller terrane
PLUTONIC ROCKS
Median Batholith
Karamea Batholith
Paparoa Batholith
Hohonu Batholith
REGIONAL TECTONIC-METAMORPHIC OVERPRINTS
Esk Head Belt and deformed zones in the Pahau terrane
Haast Schist
Gneiss
N
200 km
Northland Allochthon
Taranaki Basin - many
East Coast Allochthon
Waipaoa - one
Hikurangi Trough
ALPINE FAULT
Puysegur Trench
Fiordland
Canterbury/Bounty - a few


Sediments
Volcanics
CENOZOIC AND CRETACEOUS
Sediments & ophiolite (Northland & East Coast allochthons)
OLIGOCENE AND CRETACEOUS
Schist
CRETACEOUS TO CARBONIFEROUS
Greywacke
TRIASSIC TO PERMIAN
Ophiolite and volcaniclastics
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DEVONIAN TO CAMBRIAN
N
Northland
Auckland
Hauraki
East Cape
Waikato
Taupo Volcanic Zone
Hawkes Bay
Taranaki
Wairarapa
Nelson
Median Tectonic Line
Marlborough
Westland
Canterbury
Alpine Fault
Fiordland
Otago
Southland
Stewart Island
Median Tectonic Line
0
200 km
GEOLOGICAL & NUCLEAR SCIENCES

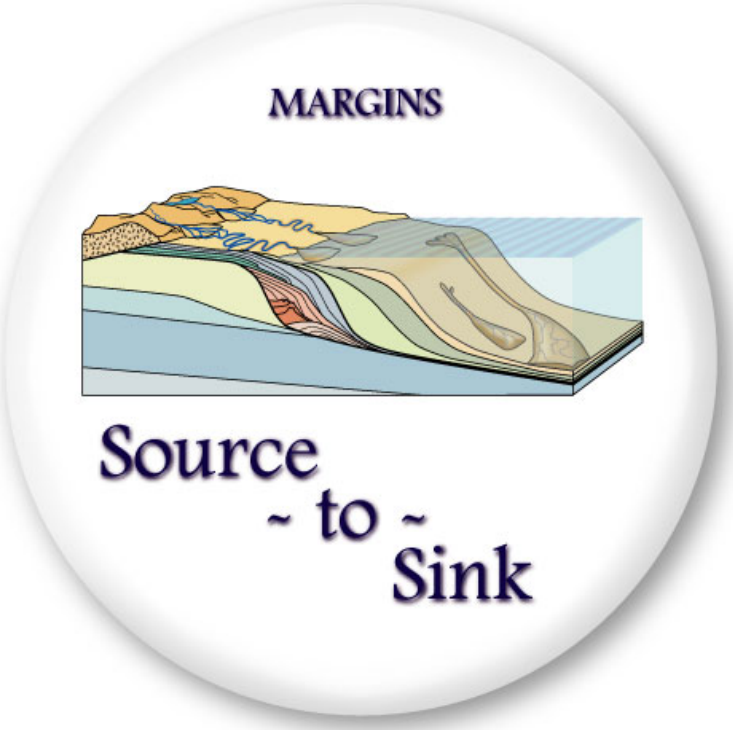
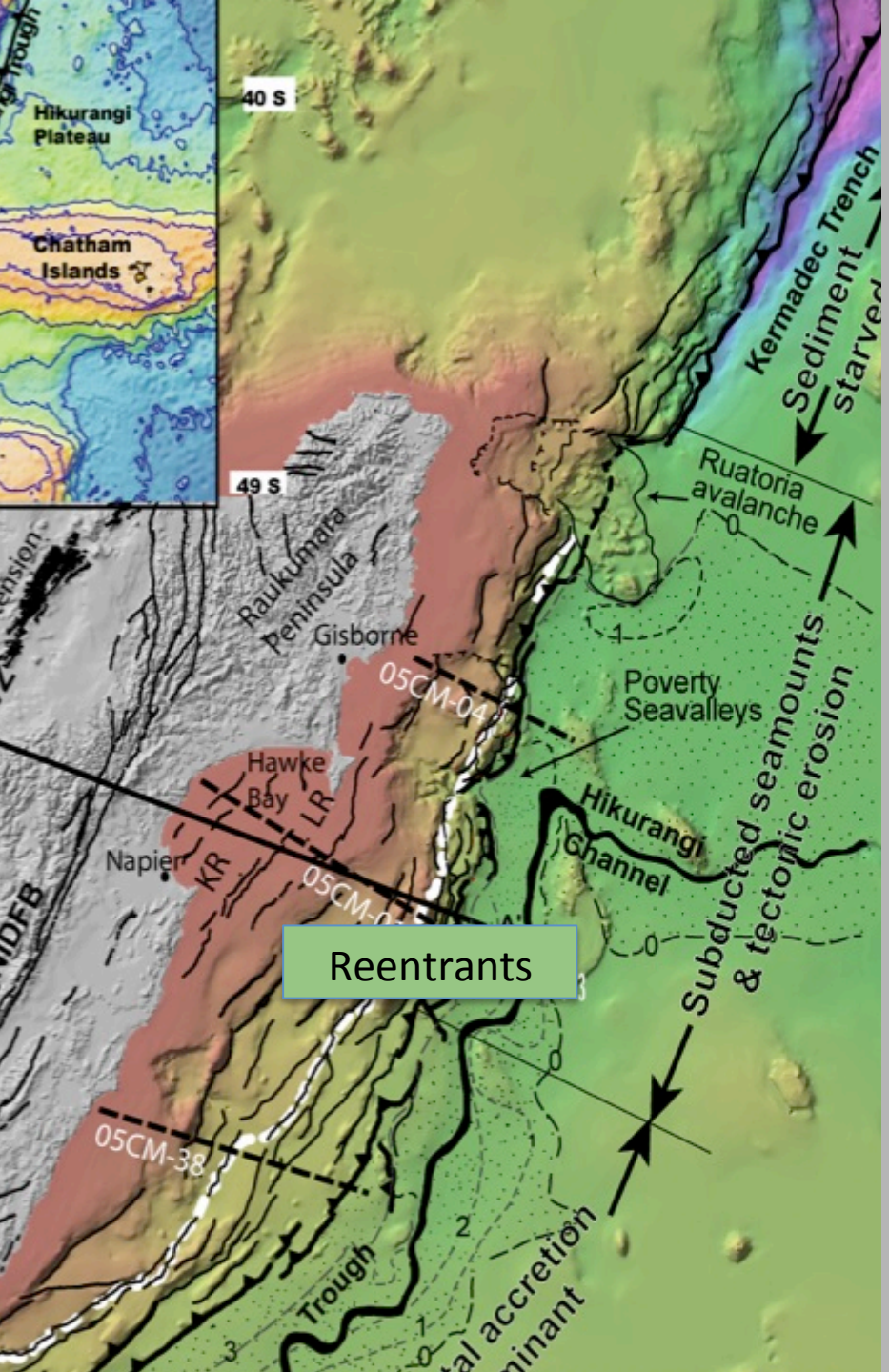


Image from CANZ (1996)

Waipaoa SS Focus Site (actively deforming forearc)

New paradigm for modeling sediment production, transport & deposition; closed systems allow for sediment budget calculations. *Embraced by the Petroleum Indus.*



HIKURANKI REENTRANT STUDIES

1) Source-to Sink in Poverty Reentrant

Modern Waipaoa Sedimentary System (WSS)

Source (River) to Sink (Poverty re-entrant & Hikurangi Trench)

2) Ihungia Miocene Reentrant

Miocene Subduction & Forearc Development

Ihungia Conglomerate

3) IODP Drilling Proposal

Seamount subduction. slow-slip events, reentrant sedimentation and tectonics

Depositional model must explain:

> Subaerial indicators (clast shape, wood debris)

> Limited sedimentary structures

> Northwestern(?) source from deeper (mantle?) levels

> Association with mélange, debris flows & sedimentary breccia

> Gravel-sized clasts in deep water

> Limited occurrence

> Contact with allochthon (normal fault, sheared, vs. unconformity)