# Overview of Zealandia and its subduction record

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GNS SCIENCE
TE PŪ AO

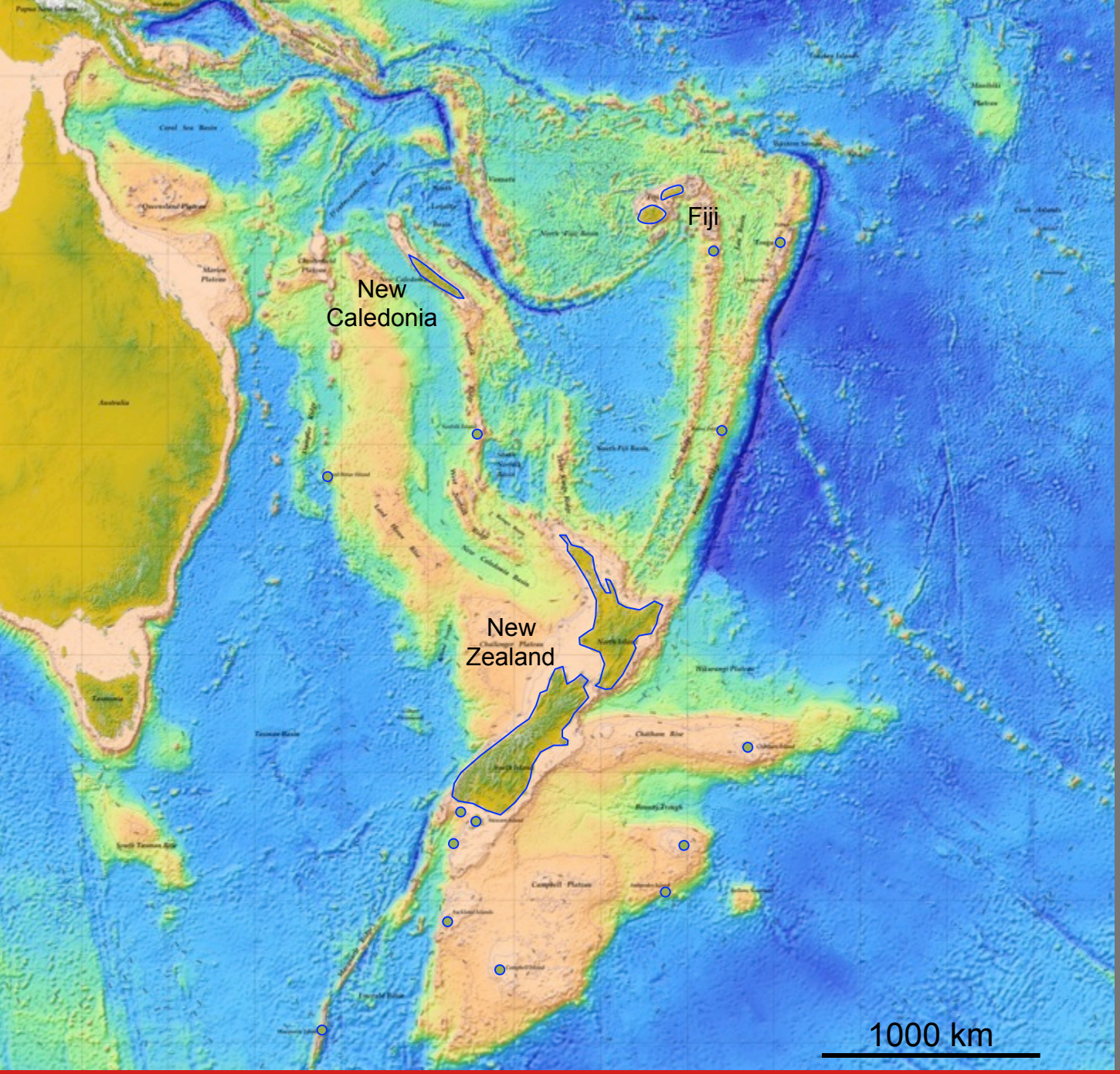

# SW Pacific geography

Scattered, remote islands

4 million people

Near Australia

# SW Pacific bathymetry

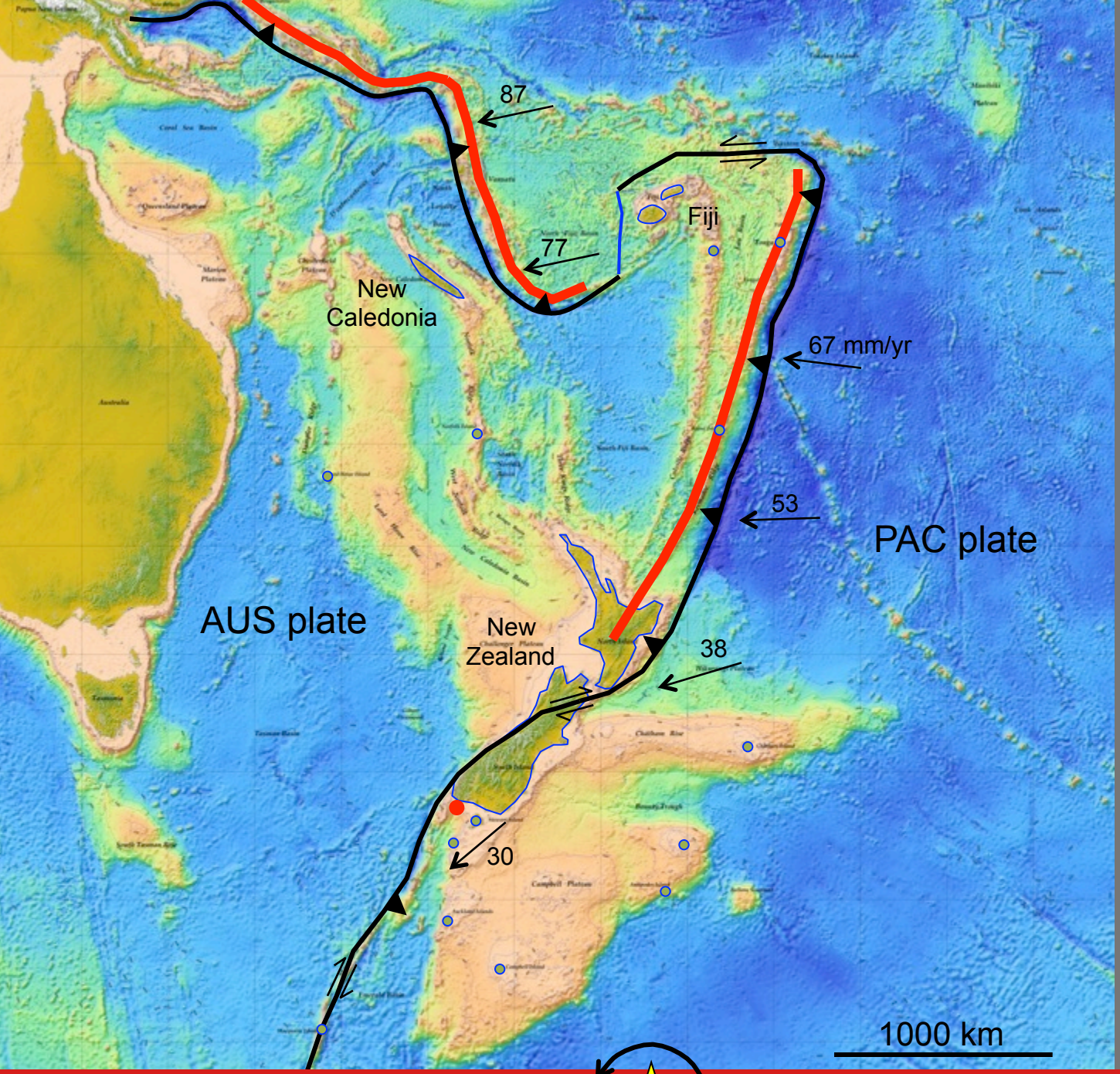



Based on satellite gravity

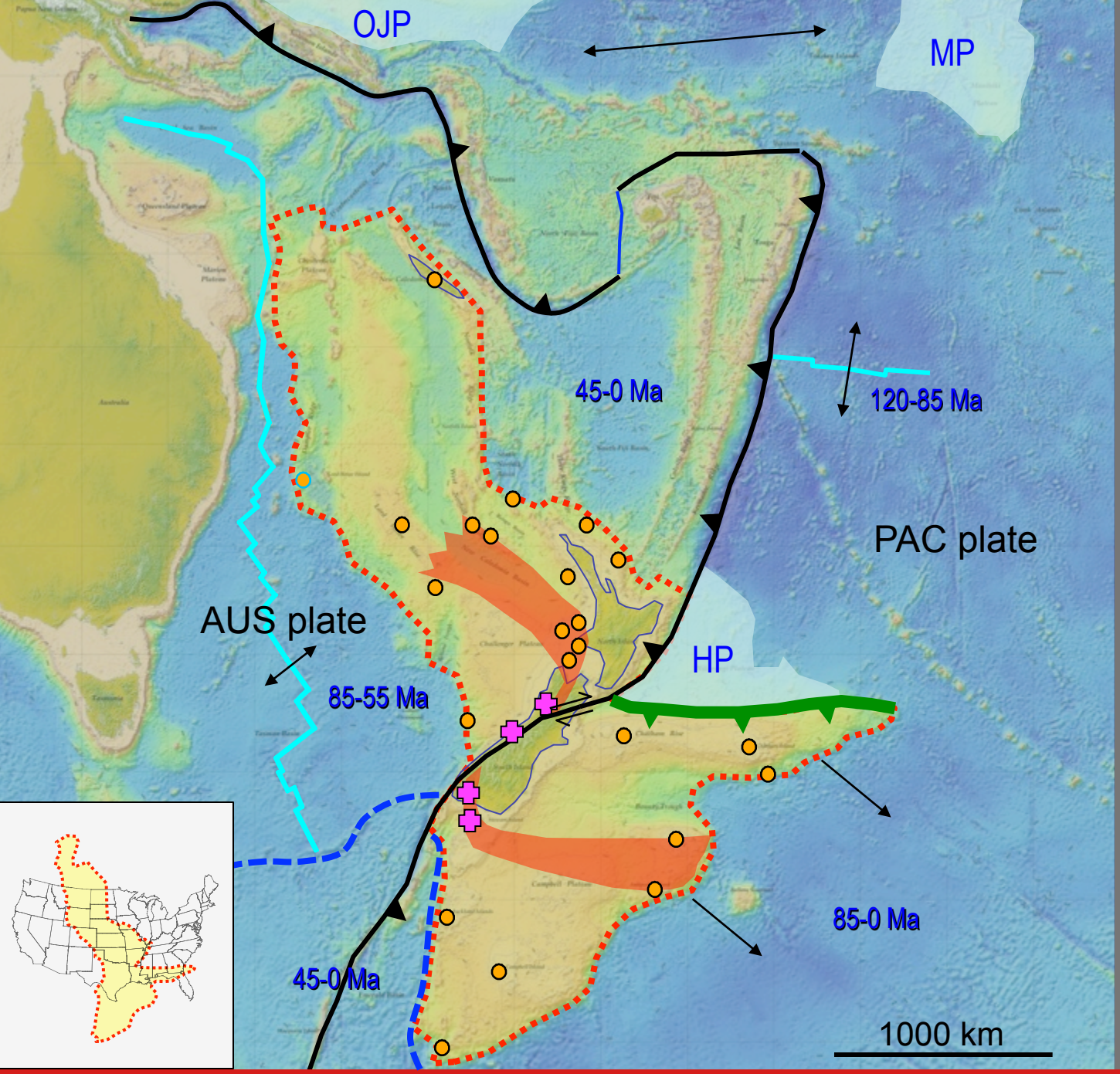
Broad plateaus and ridges 1-2 km water depth

Sandwell & Smith (1997), Stagpoole (2002)

# SW Pacific present day tectonics




- Pacific and Australian plates
- nearby pole of rotation ★
- convergence variably oblique
- subduction polarity changes




# Zealandia

- continent that is 95% submerged
- rifted internally and on most margins
- now on two plates
- Hikurangi Plateau adjacent

continental rock samples

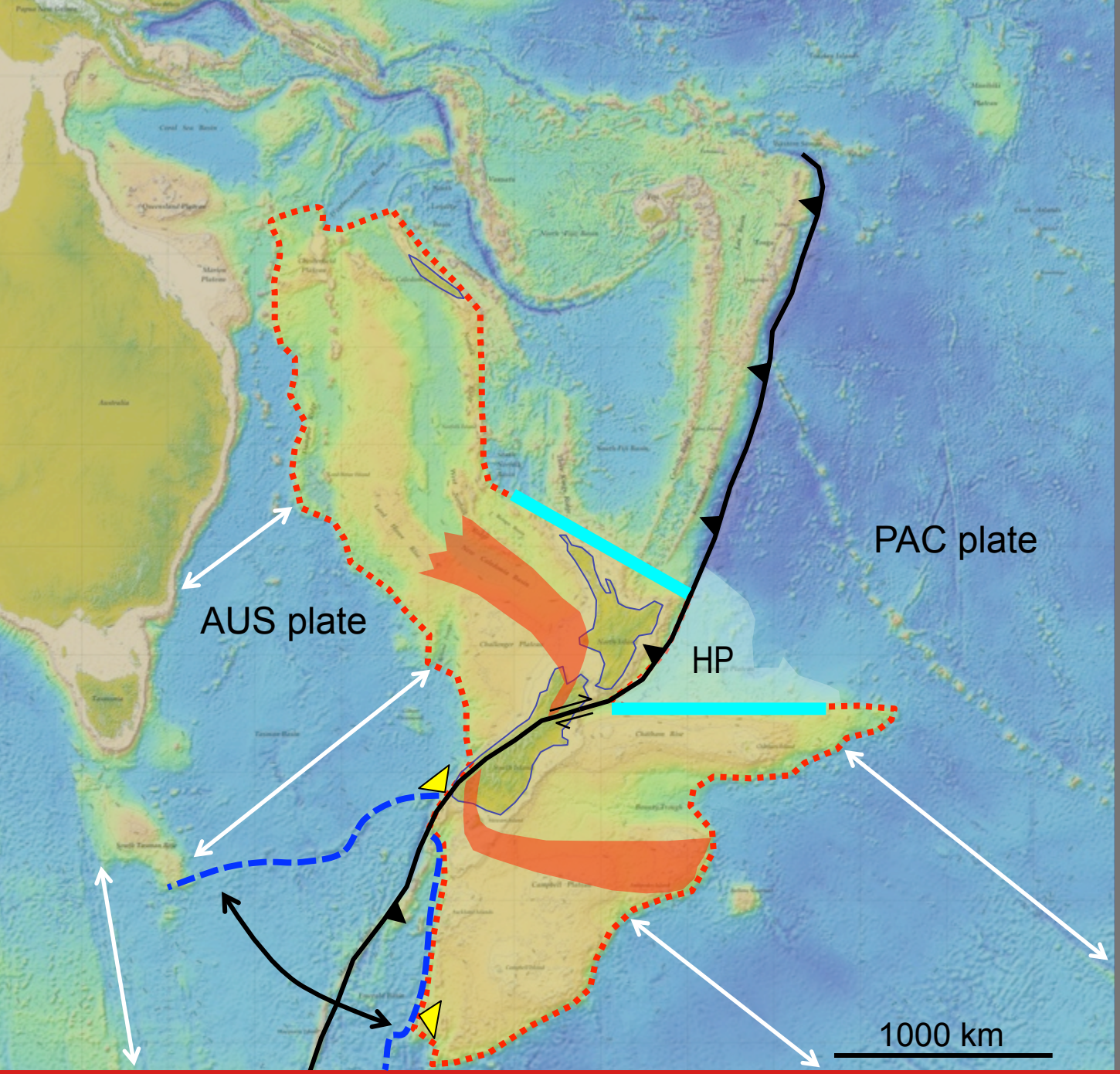
Median Batholith (Cambrian-Cret)

Late Cret. MCCs

Early Cret LIPs

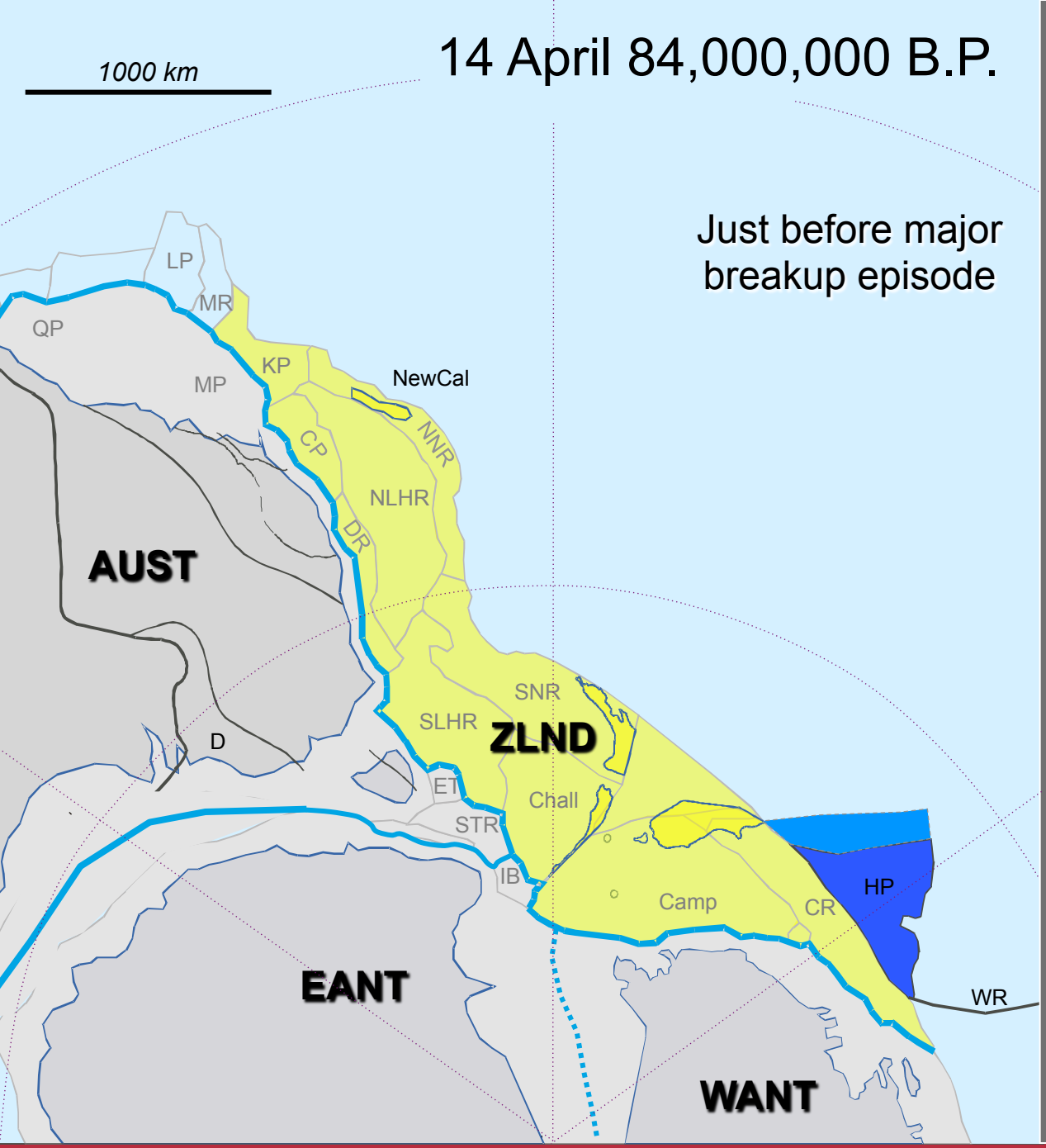
Preserved E Cret subduction zone

# Zealandia and Gondwana




- ZLD on PAC and AUS plates
- match piercing points
- track fracture zones
- rotation and translation

Sutherland (1995, 1999)




# Gondwana reconstruction

Continental crust

Oceanic crust

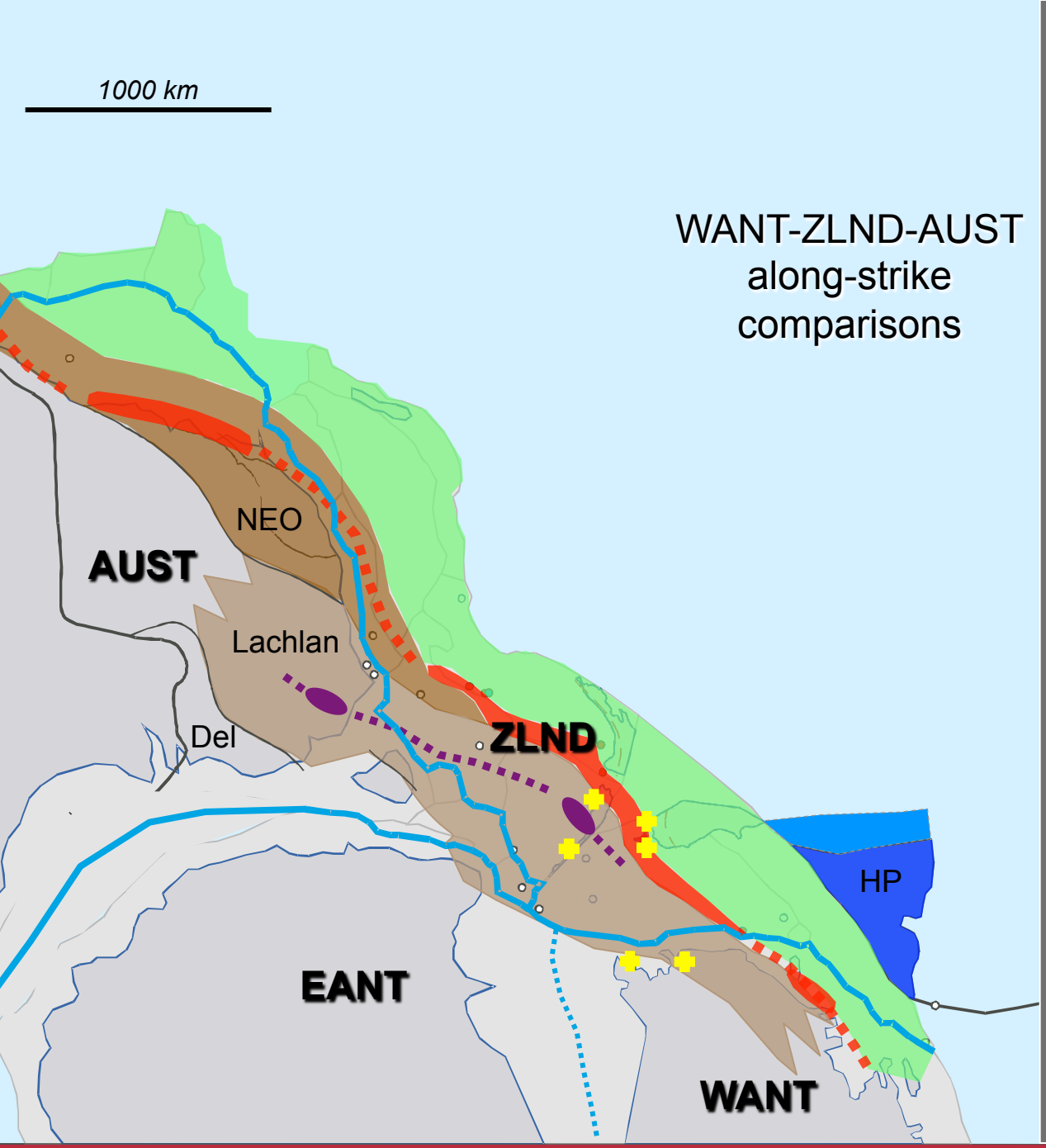
Hikurangi LIP

<85 Ma continental breakup lines

- **Zealandia was a ribbon continent**

After Gaina et al. (1998,1999), Sutherland (1999), Eagles et al. (2004)

# Gondwana geology




## CONVERGENT OROGENS

### MESOZOIC

- Sed-volc-met
- Plutonic

### PALEOZOIC

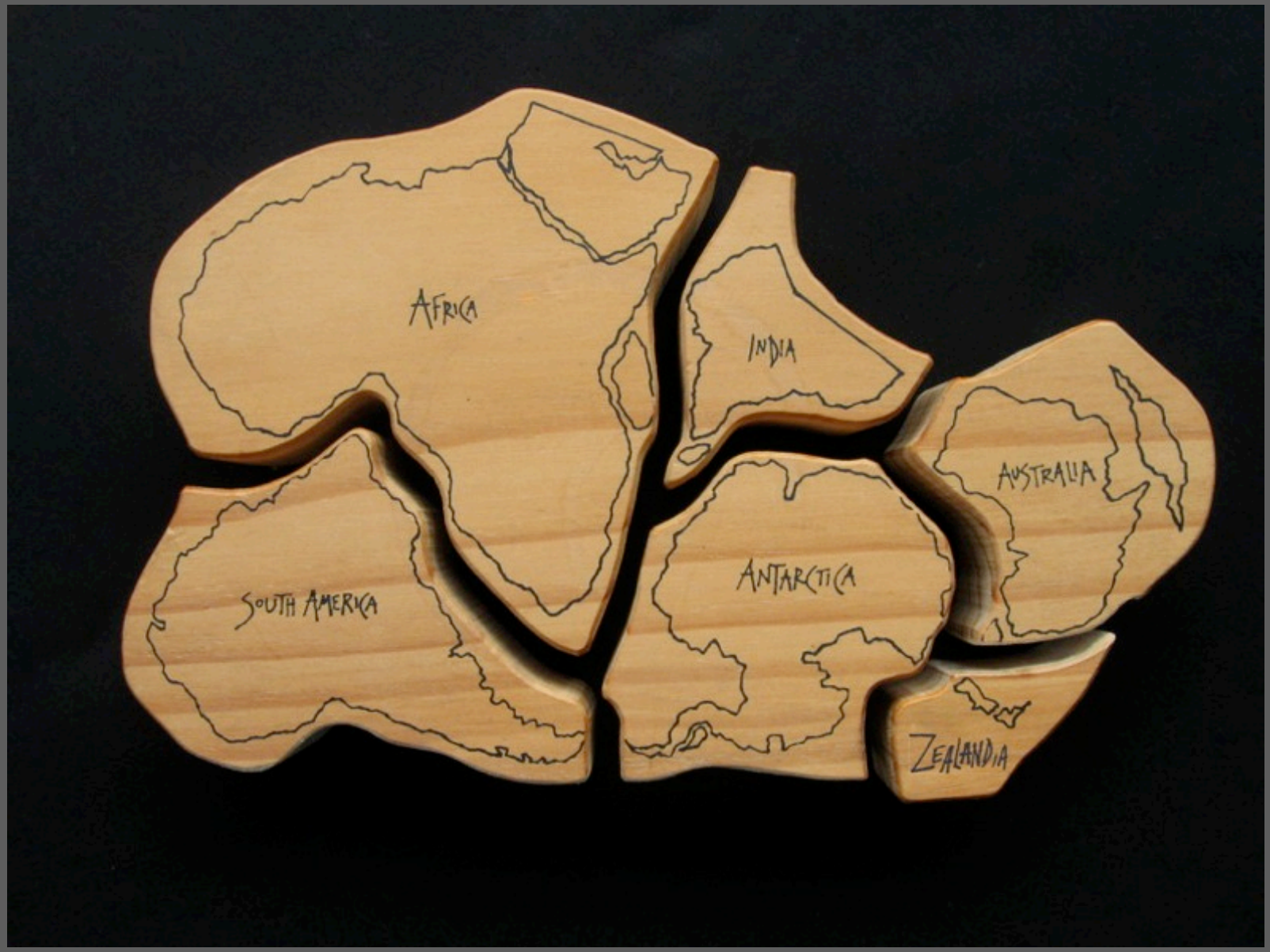
- Sed-volc-met
- Plutonic

## EXTENSIONAL OROGEN

### CRETACEOUS

- pre-breakup MCCs

*Rifting, thin crust, breakup, cooling, subsidence, submergence: Zealandia*

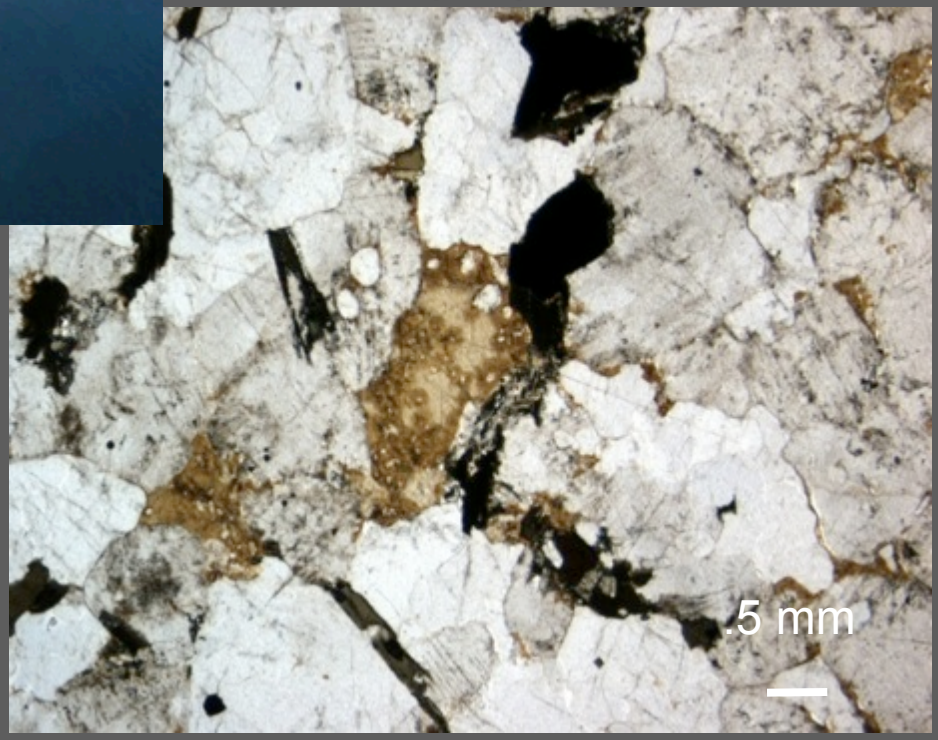

AFRICA
INDIA
AUSTRALIA
SOUTH AMERICA
ANTARCTICA
ZEALANDIA

# New Zealand's subduction history

Cambrian to Now

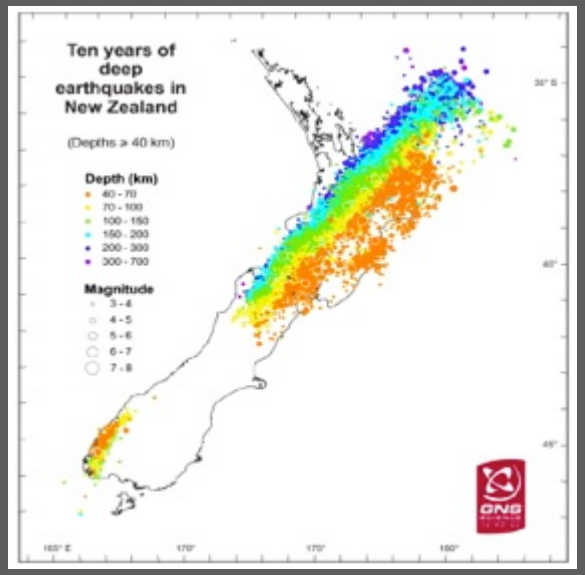
*White Island, August 2012*

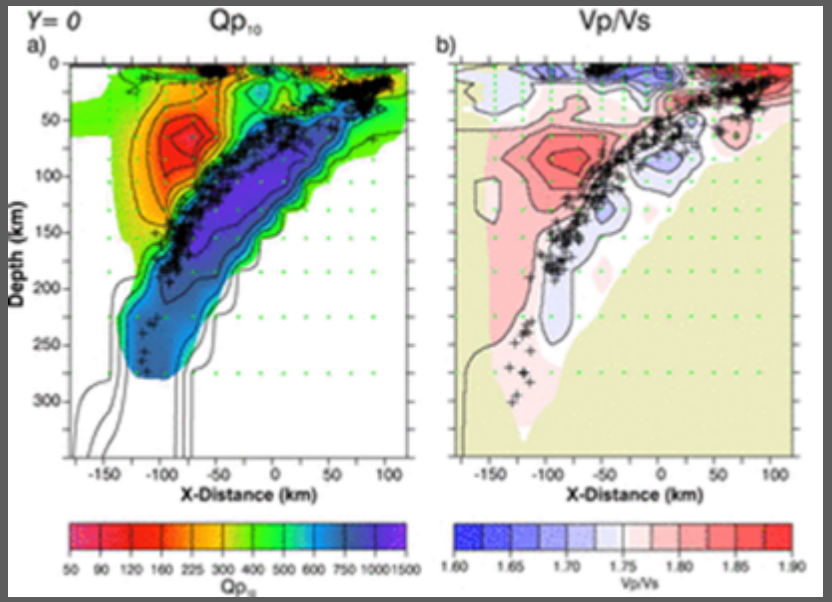
*500 Ma Jaquiery Granite, Fiordland*

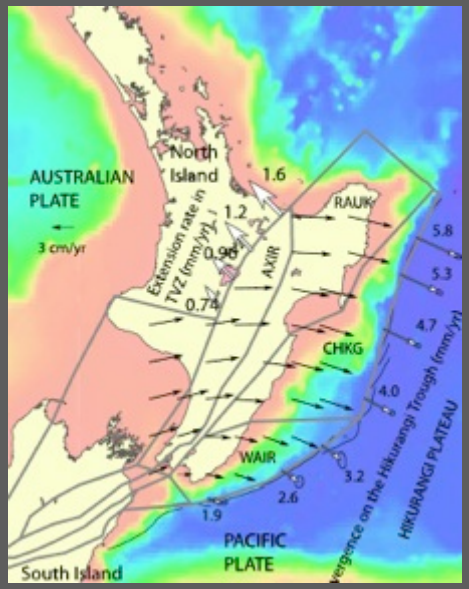


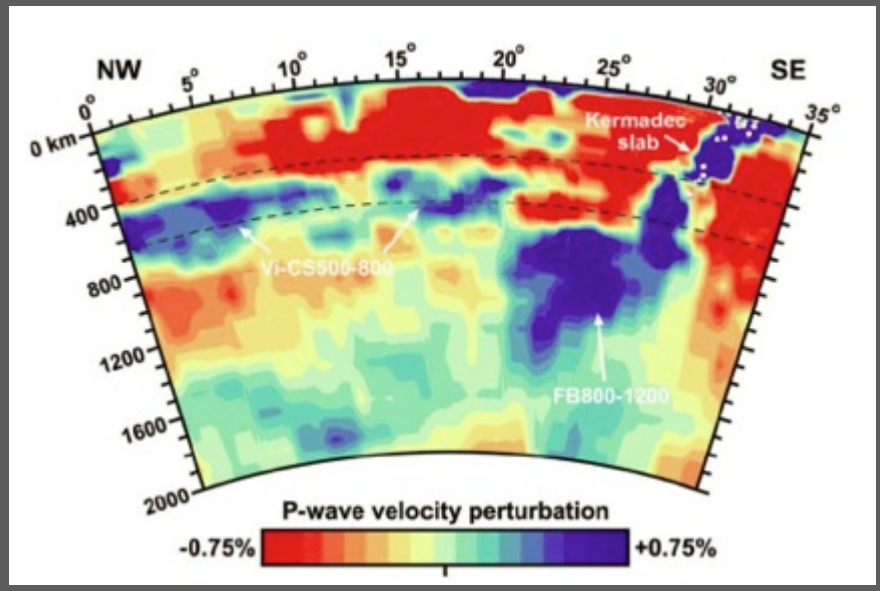

Expressions of subduction:

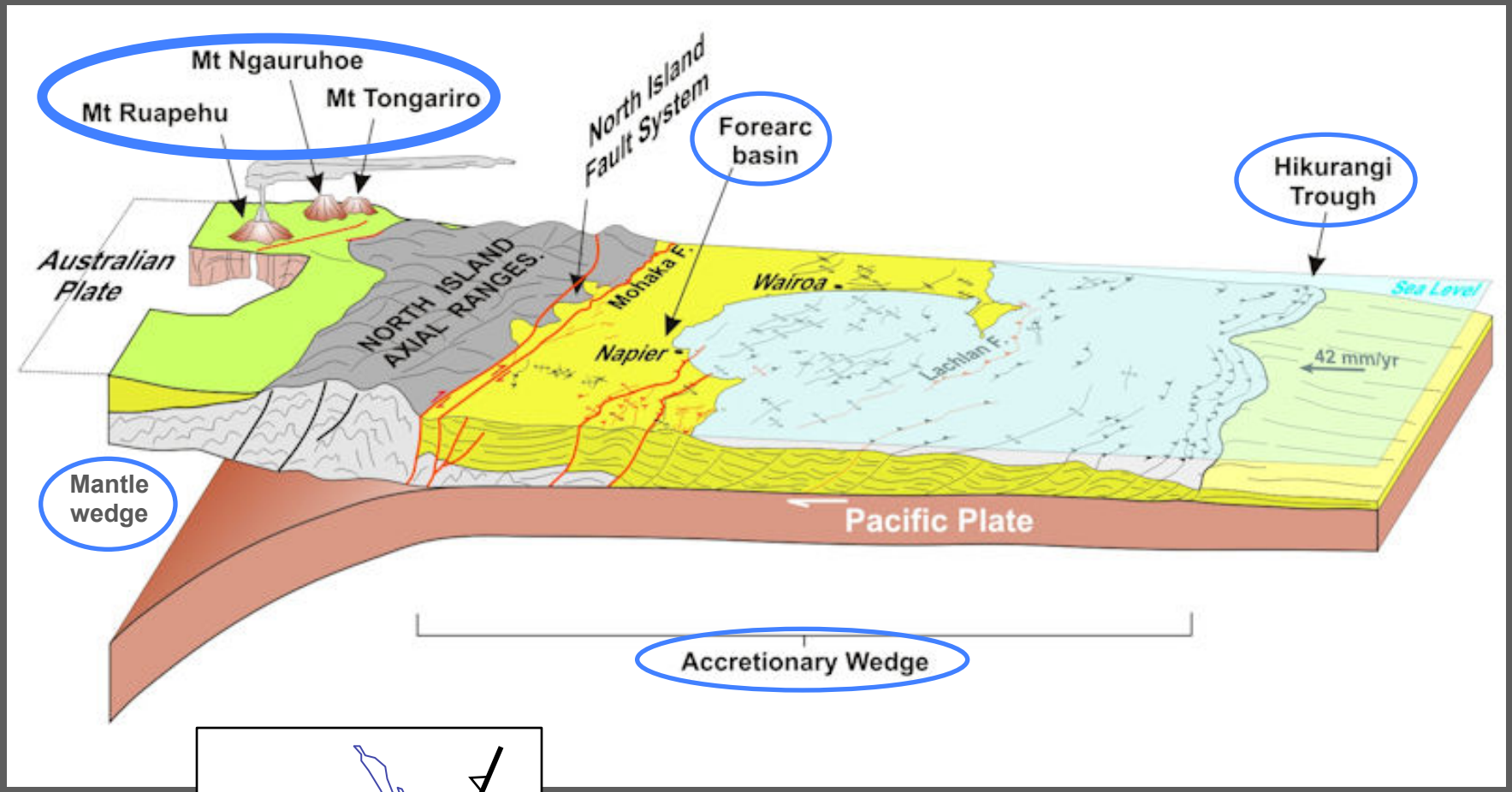
plate convergence, Benioff zone EQs, magmatic arc with distinct petrochemistry, fore-arc basin, back-arc basin, accretionary wedge

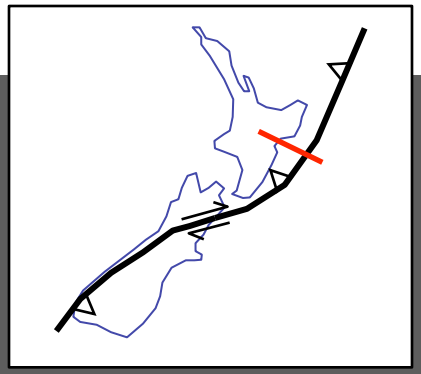

Ten years of deep earthquakes in New Zealand
(Depths ≥ 40 km)
Depth (km)
40 - 70
70 - 100
100 - 150
150 - 200
200 - 300
300 - 700
Magnitude
3 - 4
4 - 5
5 - 6
6 - 7
7 - 8
GNS


Y= 0
Qp10
Vp/Vs
a)
b)
Depth (km)
X-Distance (km)
X-Distance (km)
50 90 120 160 225 300 400 500 600 750 1000 1500
Qp10
1.60 1.65 1.70 1.75 1.80 1.85 1.90
Vp/Vs


AUSTRALIAN PLATE
3 cm/yr
North Island
1.6
1.2
0.98
0.74
Extension rate in TVZ (mm/yr)
RAUK
AXIR
CHKG
WAIR
5.8
5.3
4.7
4.0
3.2
2.6
1.9
Convergence on the Hikurangi Trough (mm/yr)
HIKURANGI PLATEAU
PACIFIC PLATE
South Island

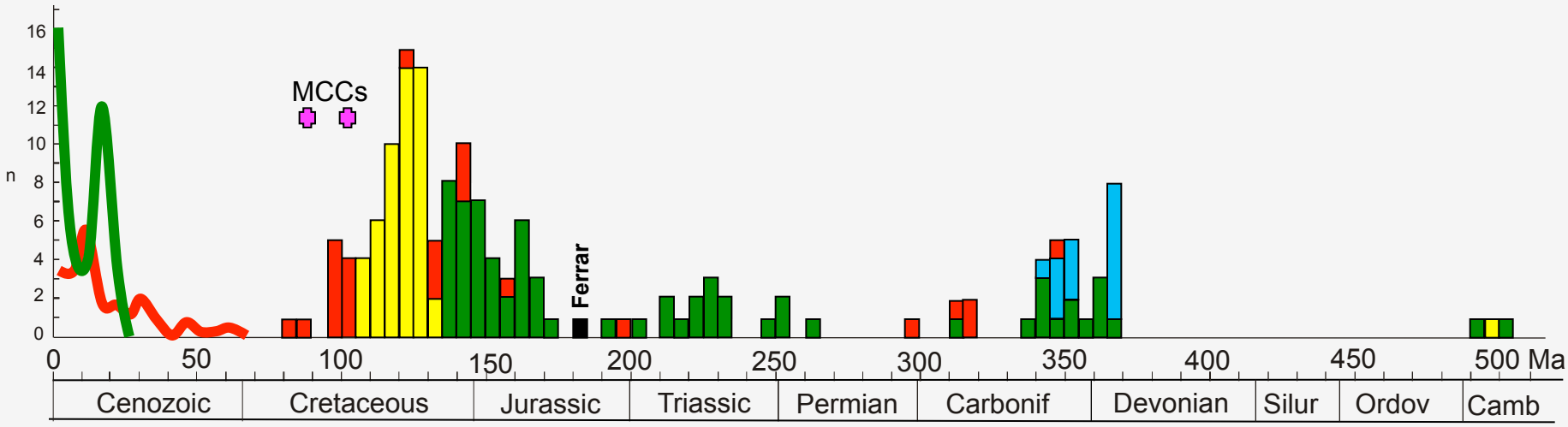

NW
SE
0°
5°
10°
15°
20°
25°
30°
35°
0 km
400
800
1200
1600
2000
Kermadec slab
Vi-CS500-800
FB800-1200
P-wave velocity perturbation
-0.75%
+0.75%


Mt Ngauruhoe
Mt Ruapehu
Mt Tongariro
North Island Fault System
Forearc basin
Hikurangi Trough
Australian Plate
NORTH ISLAND AXIAL RANGES
Mohaka F.
Wairoa
Napier
Lachlan F.
Sea Level
42 mm/yr
Mantle wedge
Pacific Plate
Accretionary Wedge



# New Zealand's igneous rock record

**Interpreted subduction episodes**




**SUBDUCTION?** Yes Maybe No

**Cz VOLCANICS** (K-Ar, Ar-Ar)

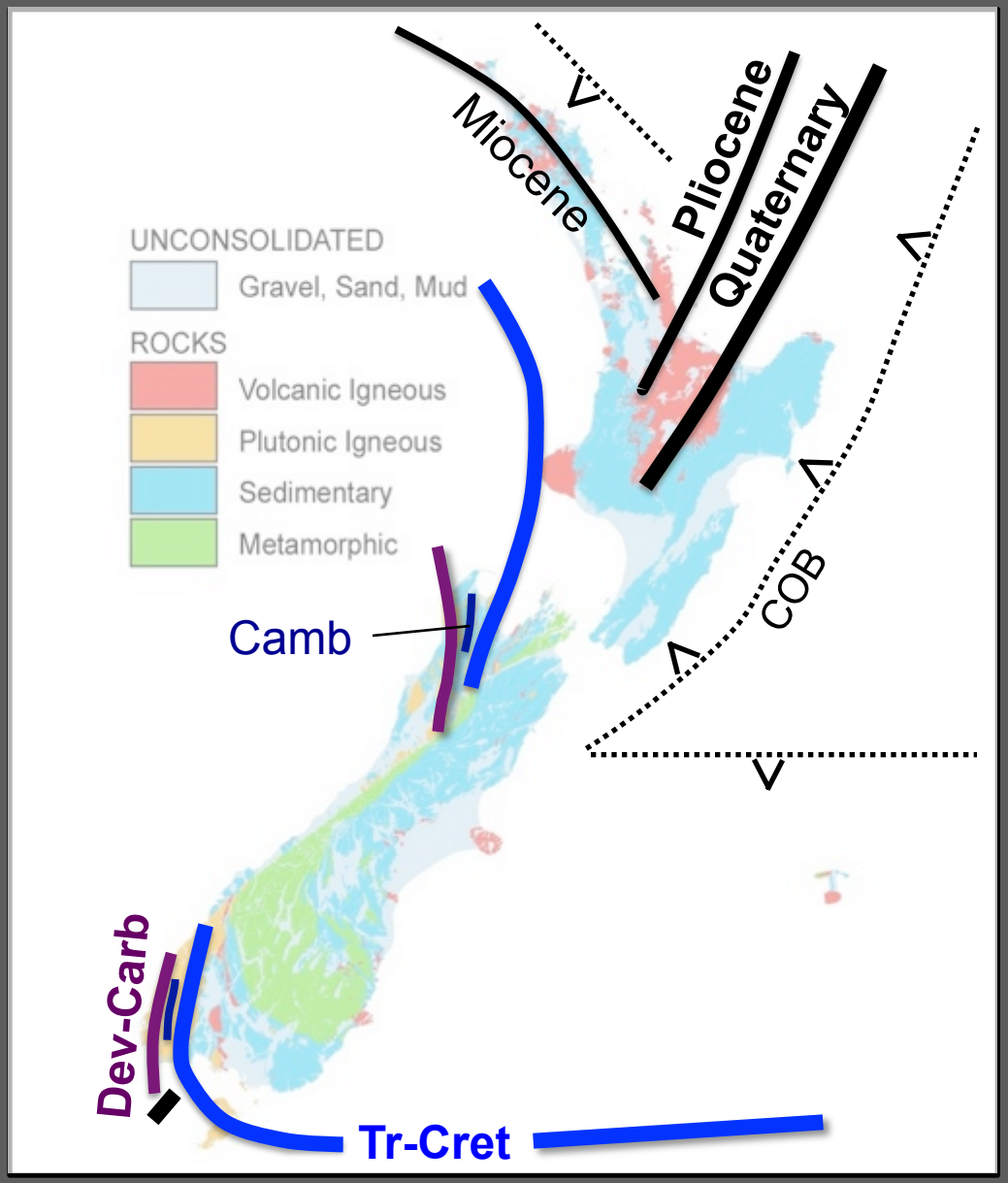
- Subduction-related
- Intraplate

**Mz-Pz BATHOLITH SUITES** (U-Pb zc)

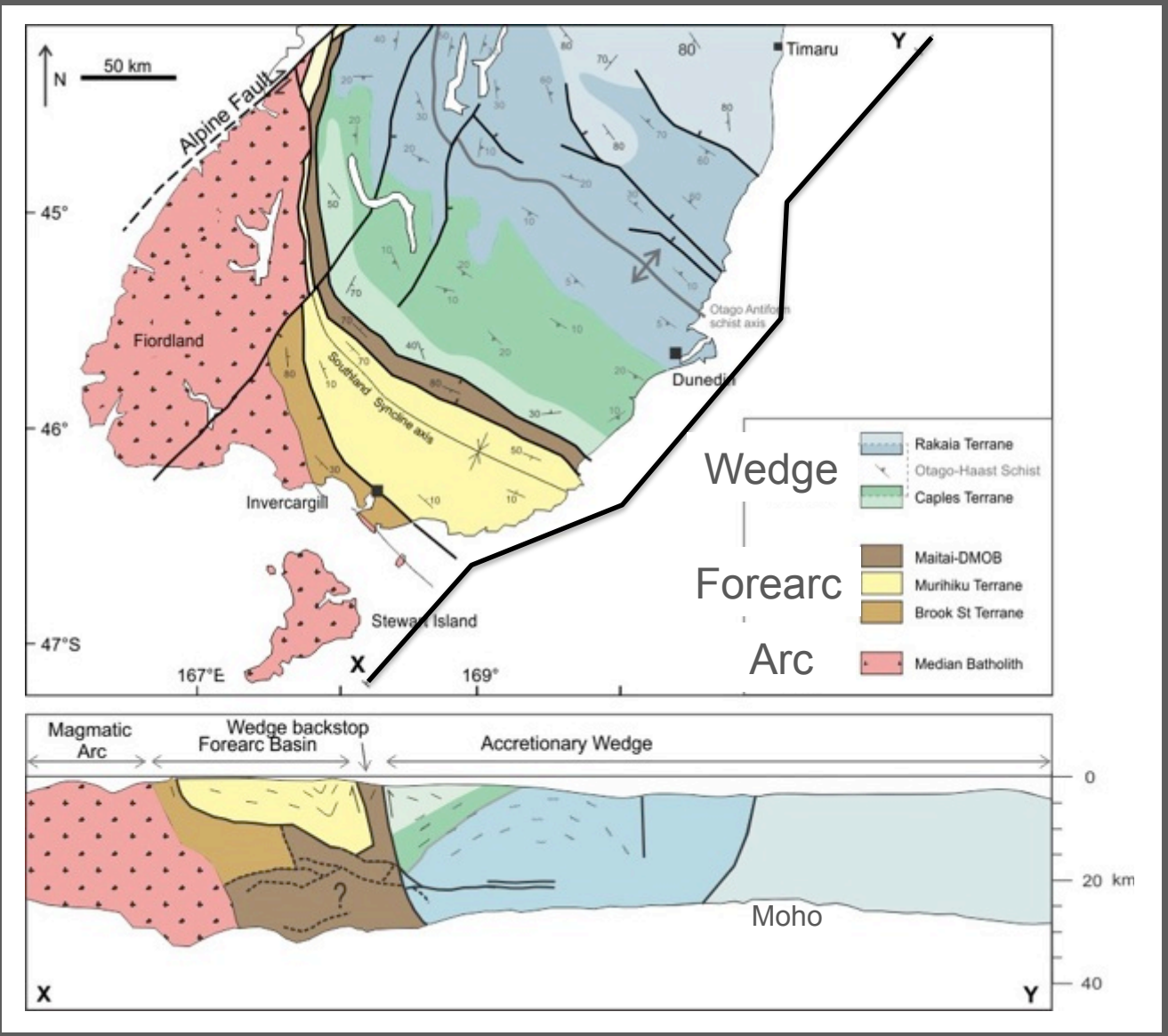
| I-type | S & IS-type | A-type |
|---|---|---|
| Low Sr/Y | Low Sr/Y | |
| High Sr/Y | | |

Hayward et al. (1994), Mortimer et al. (1999), Tulloch et al. (2009), Hoernle et al. (2006) Timm et al. (2010)

# New Zealand's magmatic arcs



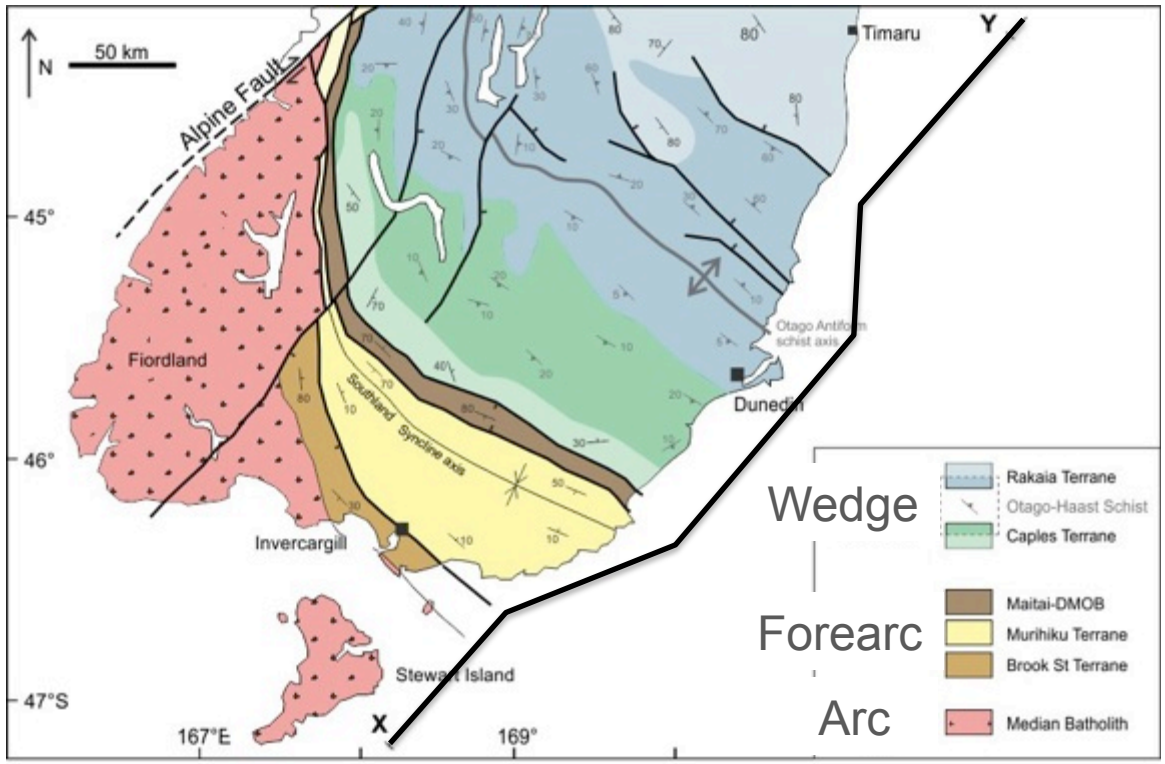

- different arcs give insights into different arc processes
- only some have associated FABs, accretionary wedges
- Cenozoic arcs founded on Mesozoic accretionary wedge
- ignore Pz, just talk about Mz, Cz subduction

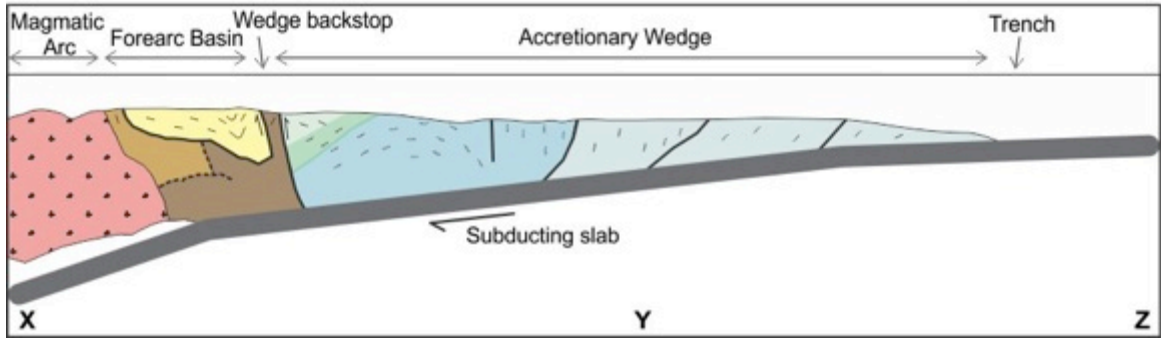



# Mesozoic orogen

- Mz arc, forearc, wedge elements all in position
- crustal thickness affected by widespread extension

Mortimer et al. (2002)



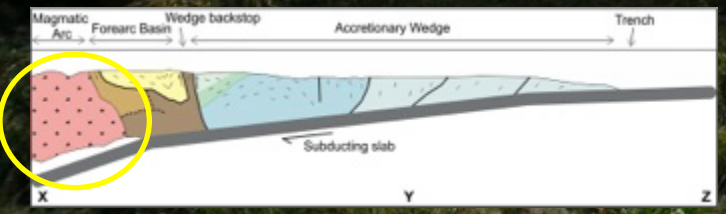




# Mesozoic orogen

- preserved long-lived, convergent margin
- variably exhumed, so can study shallow and deep levels

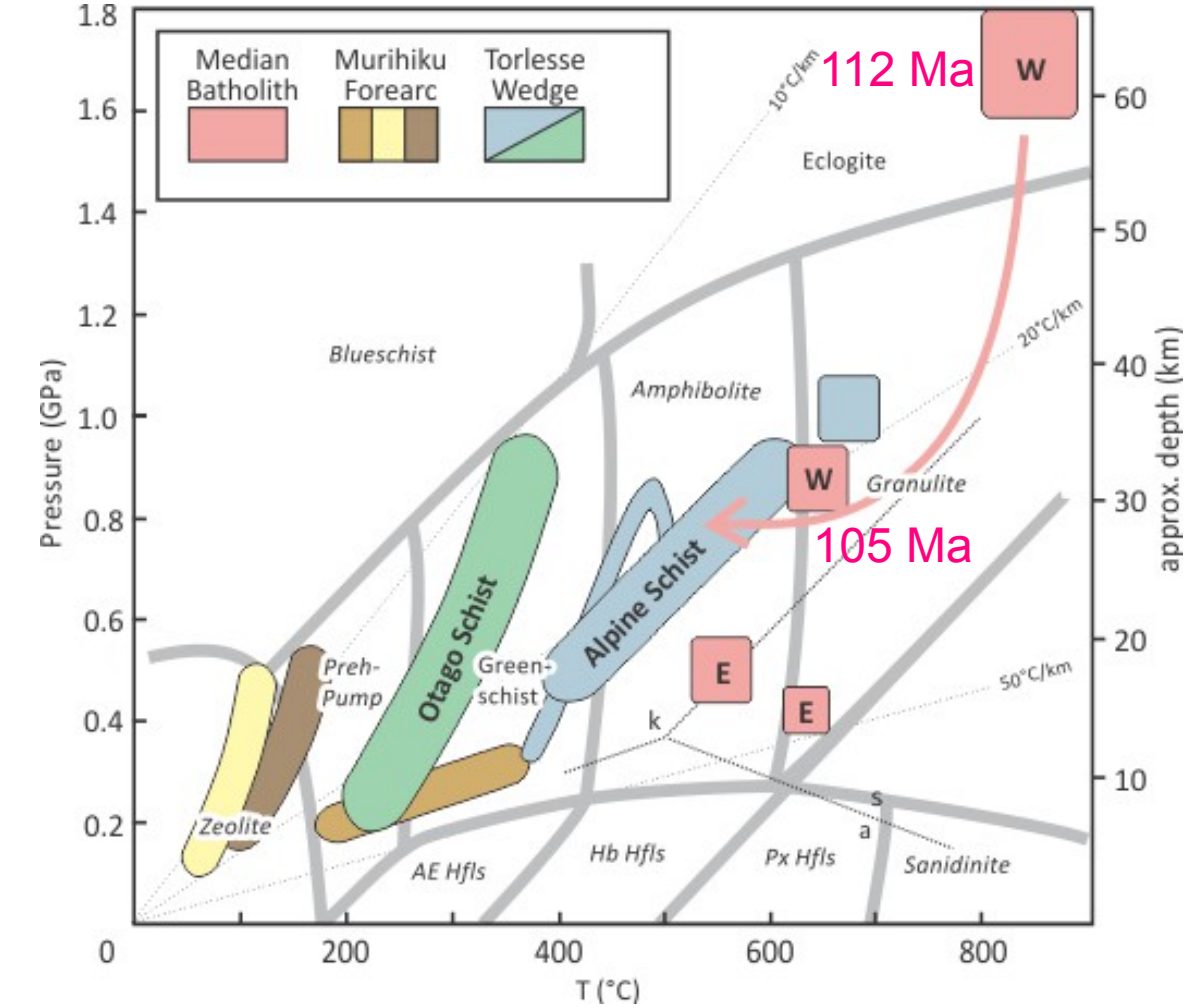
**Arc Forearc Wedge**

# The Mesozoic Arc




**Median Batholith = site of most NZ Phanerozoic magmatism**

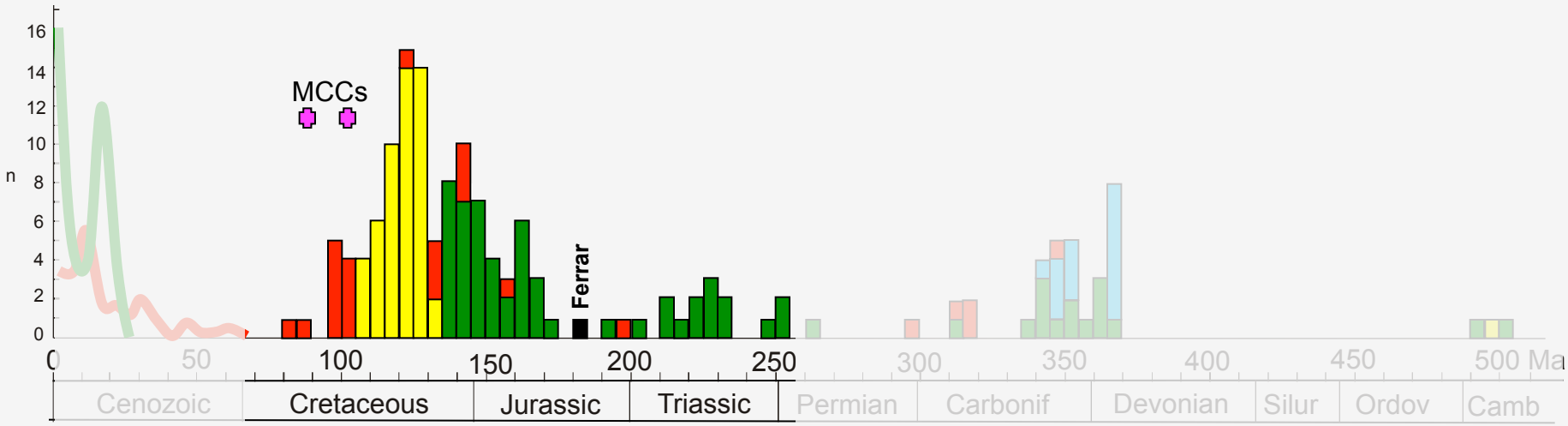
# Thermobarometry




Mortimer (2000), Flowers (2005), DePaoli et al. (2011)

# Mesozoic plutonic record

**Interpreted subduction episodes**

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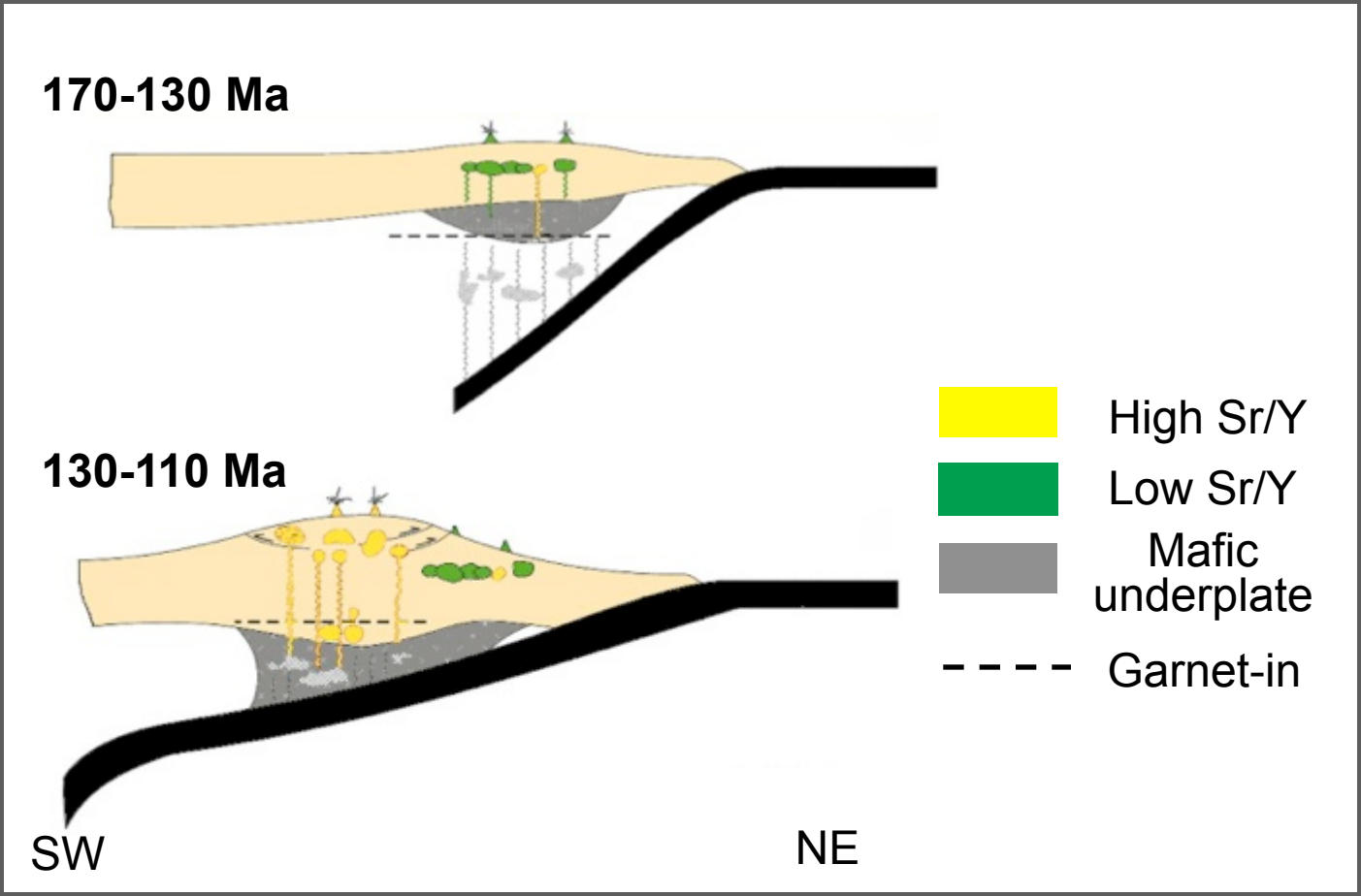
# Major change in Zealandia arc at c. 130 Ma

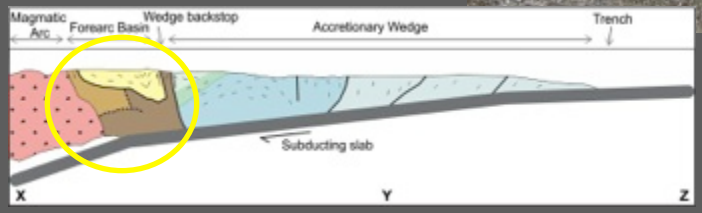



- **thickening crust in maturing arc and/or flat slab subduction**

# Mesozoic fore-arc basin

*Monotis*
205-212 Ma

Curio Bay, 160 Ma
fossil forest

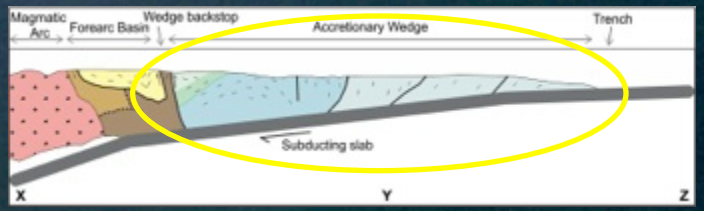



- at least 13 km Murihiku Terrane strata over 120 m.y.
- marine and non-marine fossils
- zeolite facies

# Mesozoic fore-arc basin

- in New Caledonia as well as New Zealand
- structurally simple
- provenance links to Median Batholith arc

# Mesozoic accretionary wedge



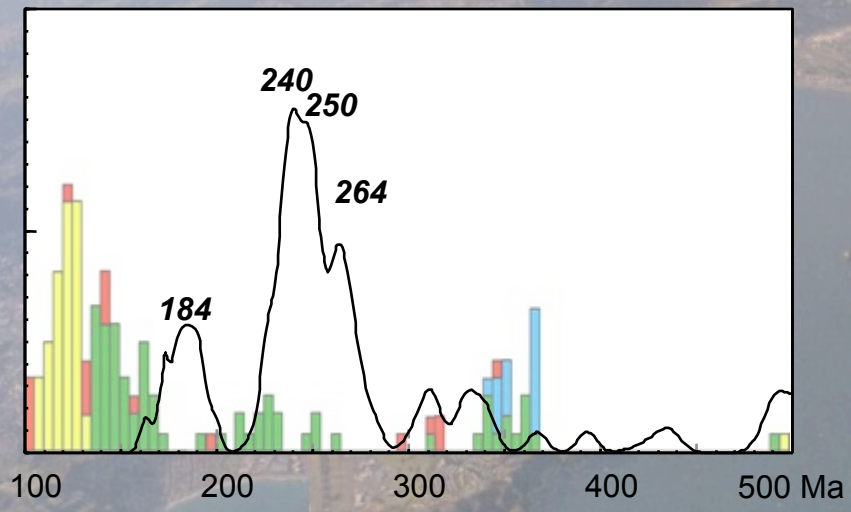
# Mesozoic accretionary wedge

- first cycle sandstones
- different Perm-Cret basins accreted in wedge
- frontal accretion and underplating
- polyphase Jura-Cret schist overprint

Mackinnon (1983)

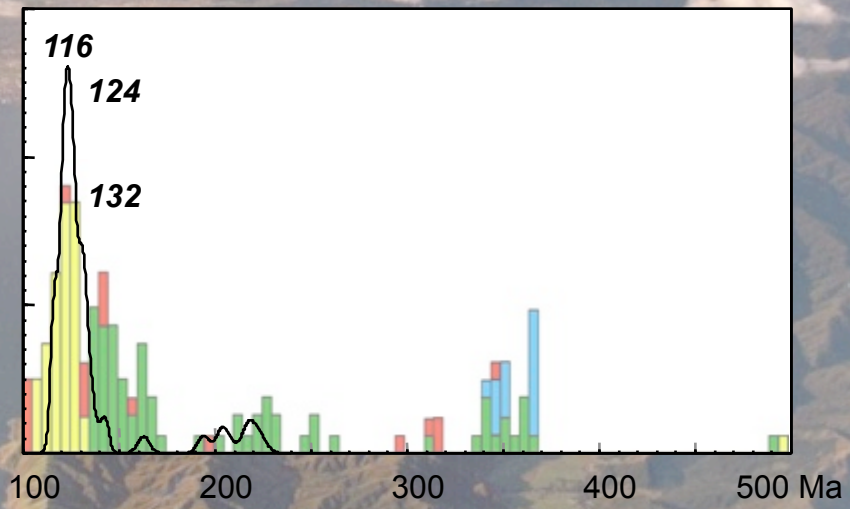
# Exotic vs local provenance

## Older Jura-Trias wedge




- detrital zircon peaks don't match NZ pluton chronology
- northern Queensland source

## Younger Cretaceous wedge




- detrital zircon peaks do match NZ pluton chronology
- local Median Batholith source
- constrain time of wedge cessation

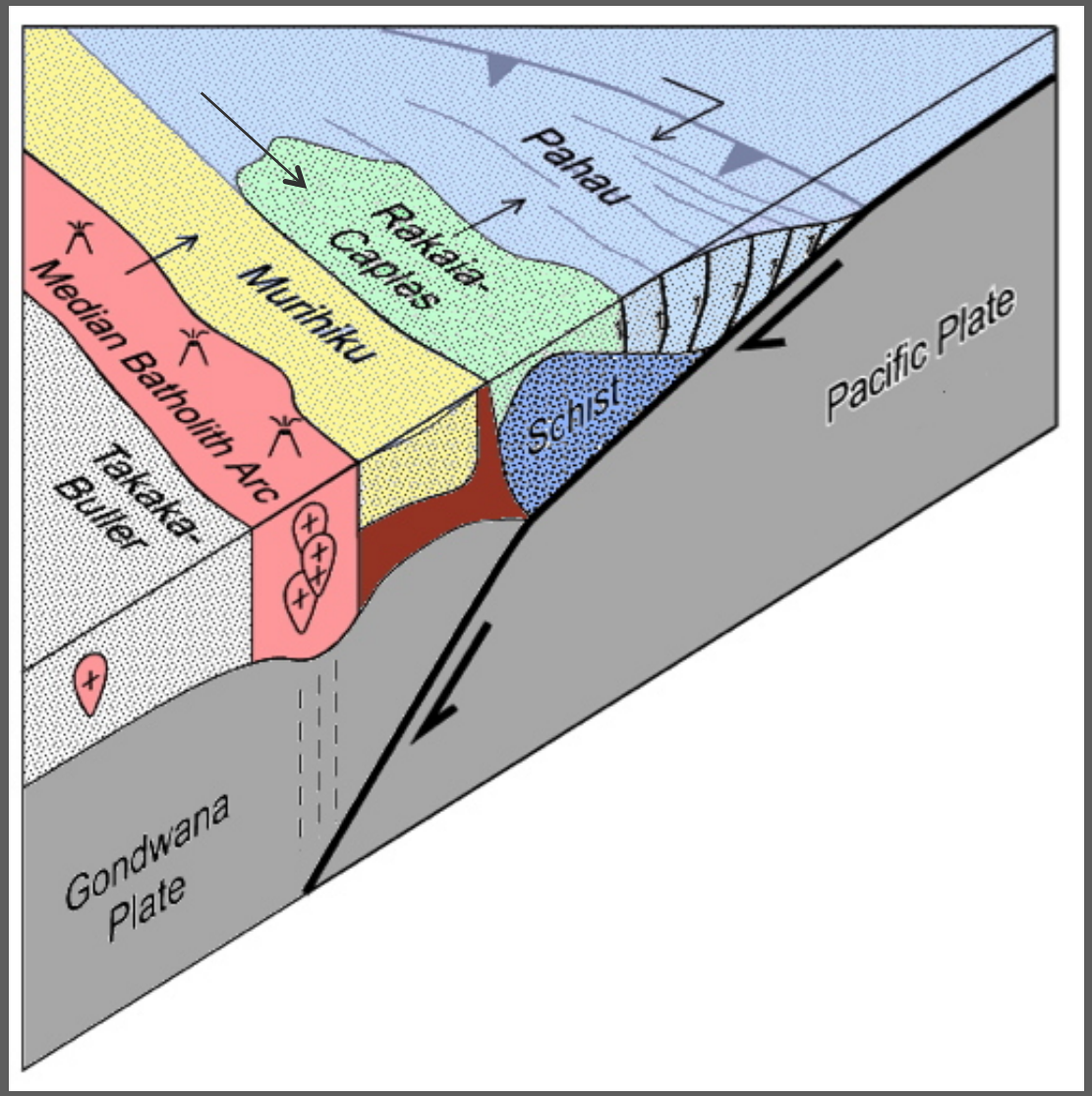
- **detrital zircon studies of Mesozoic accretionary wedge**

Wandres et al. (2004), Adams et al. (2008, 2009)

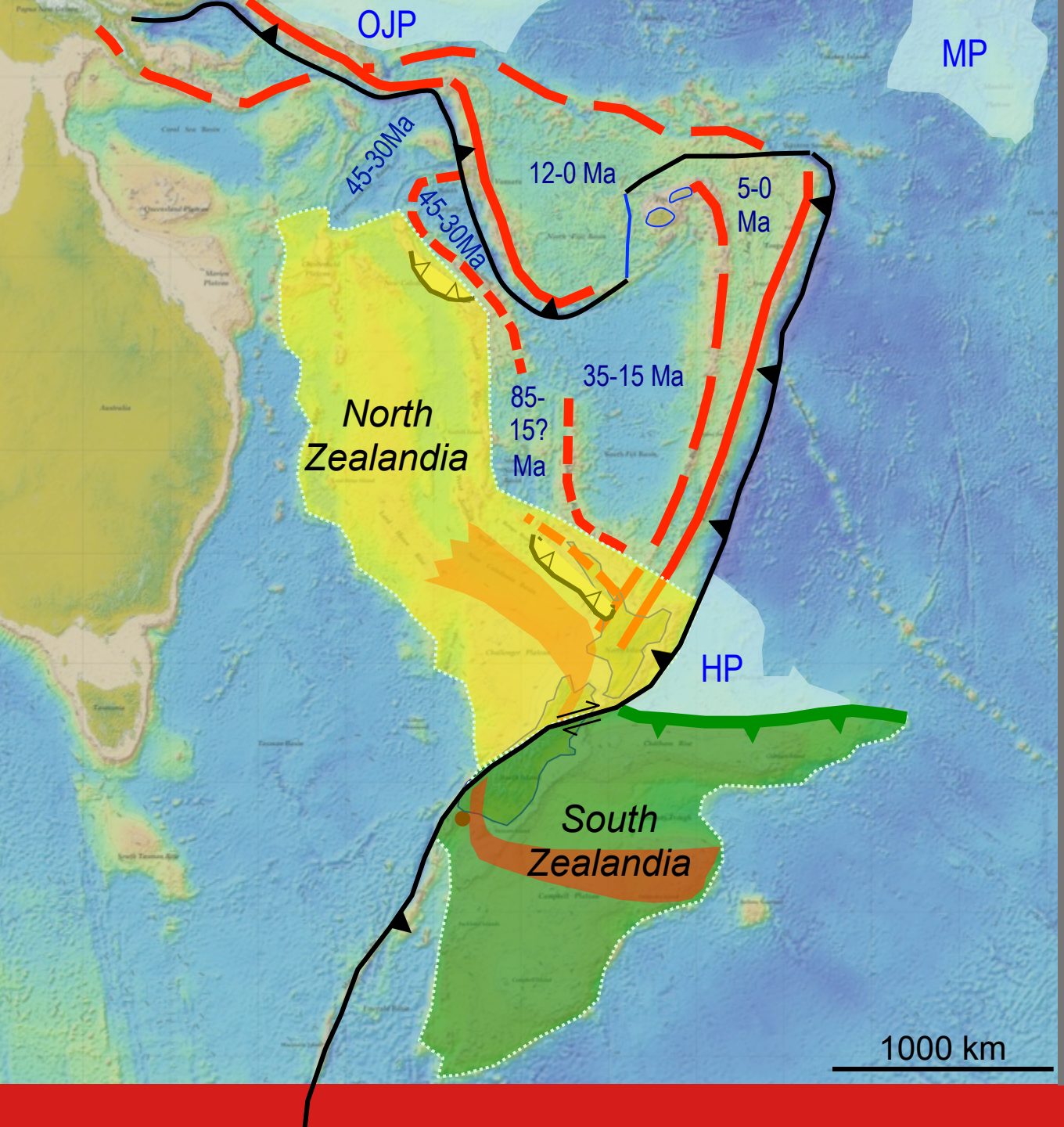
# Haast Schist: an exhumed accretionary wedge

quartz veins, fluids, mass balance, Ar-Ar, thermochronology, PTt paths, c. 135 Ma exhumation & mesothermal Au-W

# Subduction termination

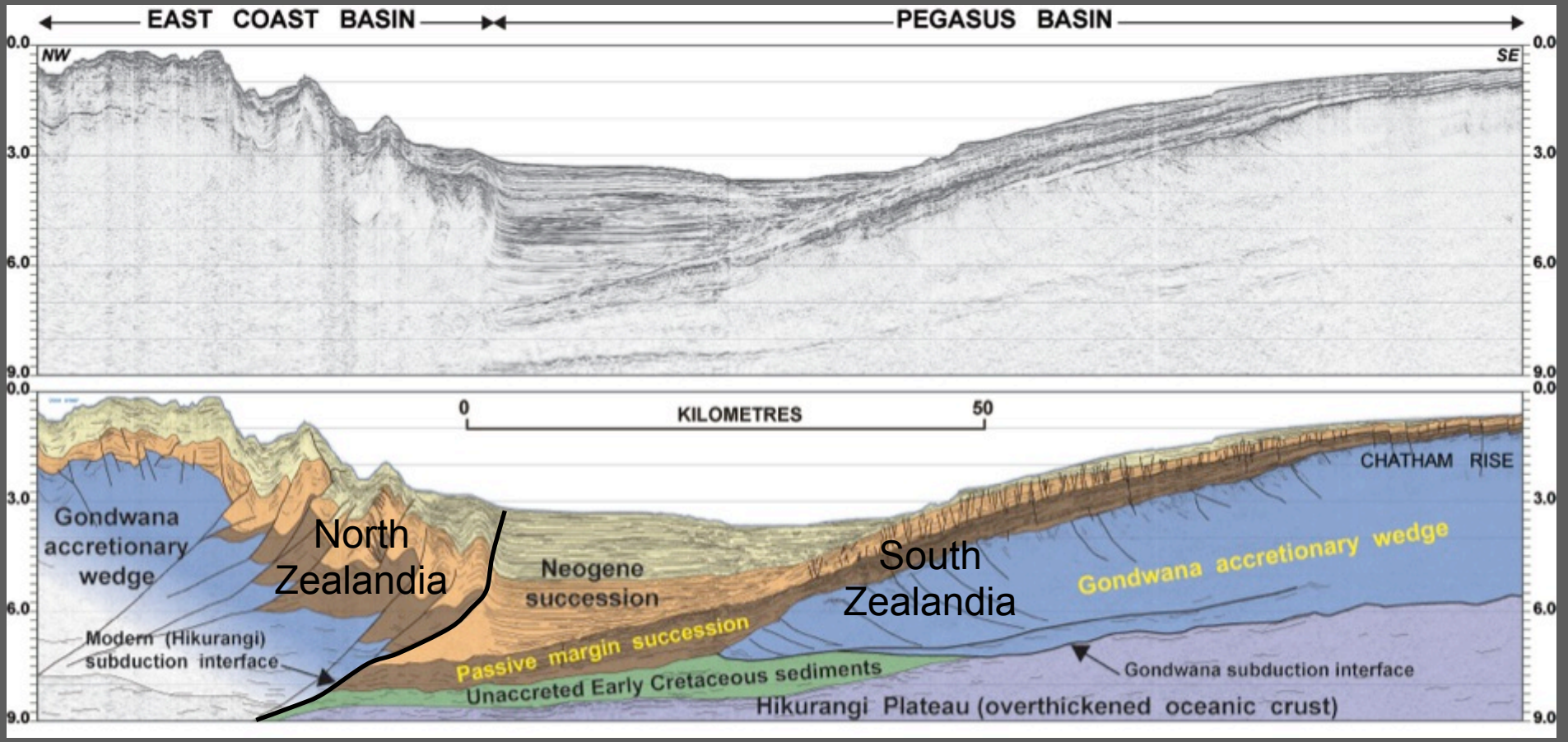


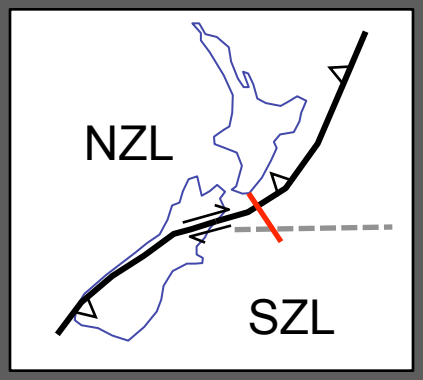

- 130, 105, 85 Ma?
- youngest rocks in arc and wedge c. 110 Ma
- oldest Zealandia intraplate c. 97 Ma
- reason = Hikurangi Plateau collision. Other models
- BUT – did it ever really stop to the north?




# North vs South Zealandia

- Cenozoic arcs
- Cz allochthons with back-arc basin ophiolitic basalts
- 12-0 Ma — Age of back arc basin



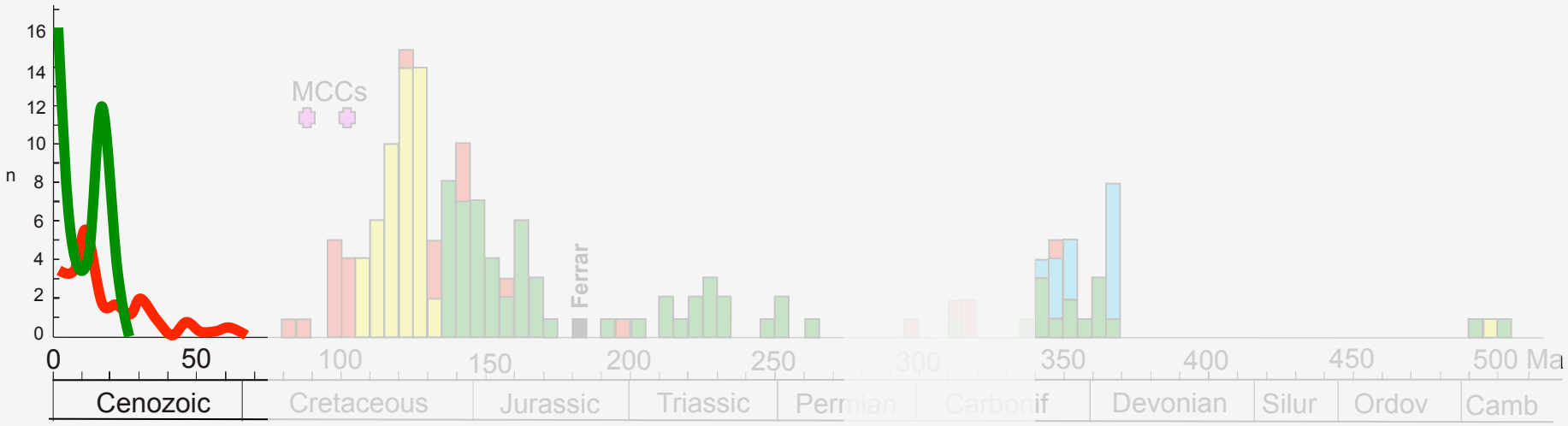




SOUTH ZEALANDIA
Subsiding, simple, passive, on Pacific Plate since 84 Ma

NORTH ZEALANDIA
Subsiding, but complex: arcs, back-arc basins, allochthons, ophiolites, (re) captured by Australian Plate

# Cenozoic volcanic record

**Interpreted subduction episodes**




**SUBDUCTION?** Yes Maybe No

**Cz VOLCANICS** (K-Ar, Ar-Ar)

Subduction-related = NORTH
Intraplate = SOUTH

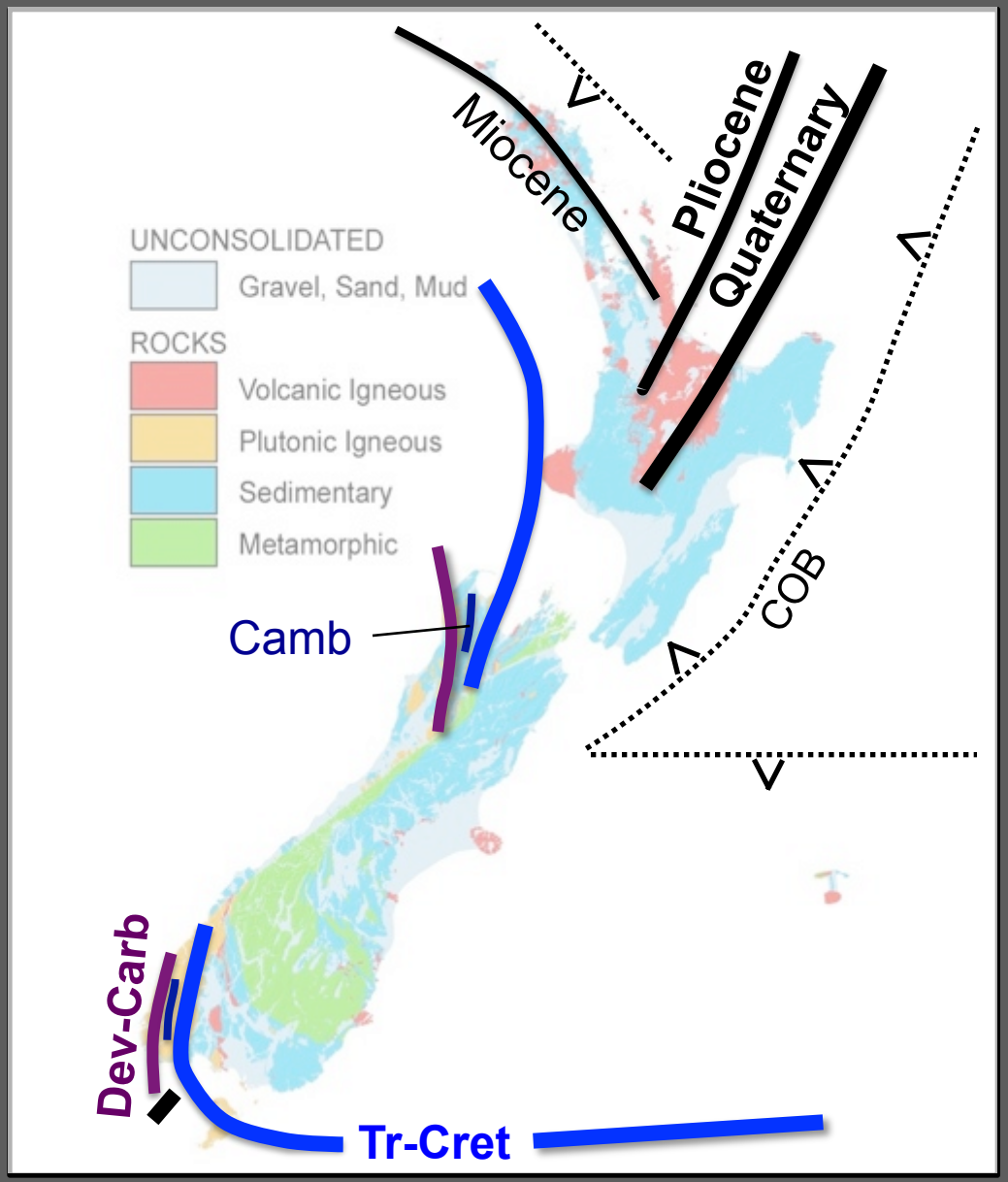
**Mz-Pz BATHOLITH SUITES** (U-Pb zc)

I-type
Low Sr/Y
High Sr/Y

S & IS-type
Low Sr/Y

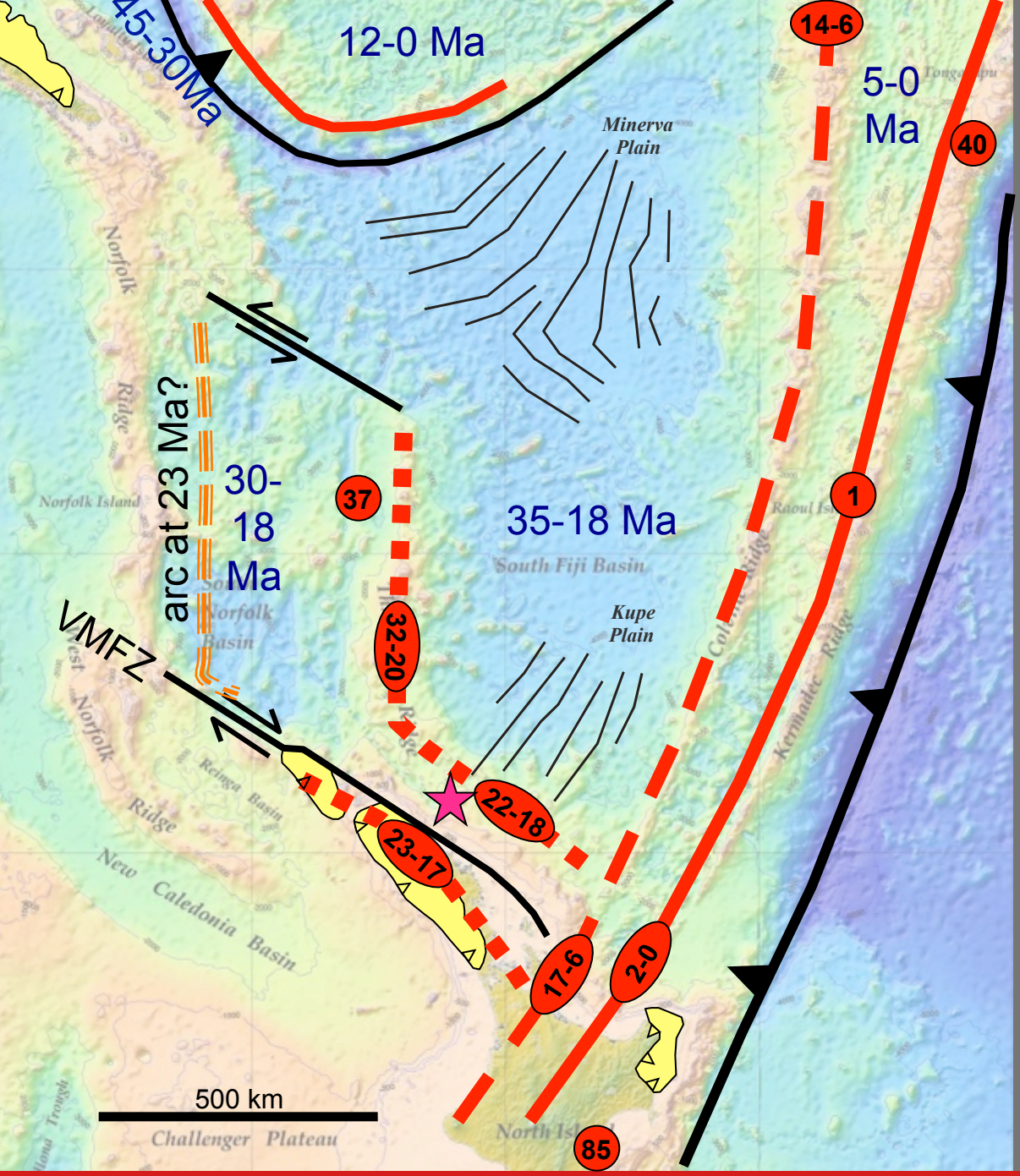
A-type

Hayward et al. (1994), Mortimer et al. (1999), Tulloch et al. (2009), Hoernle et al. (2006) Timm et al. (2010)




# Onland Cenozoic arc footprint

- volcanic levels exposed onland
- migration in space and time
- age and cause of inception near NZ is speculative

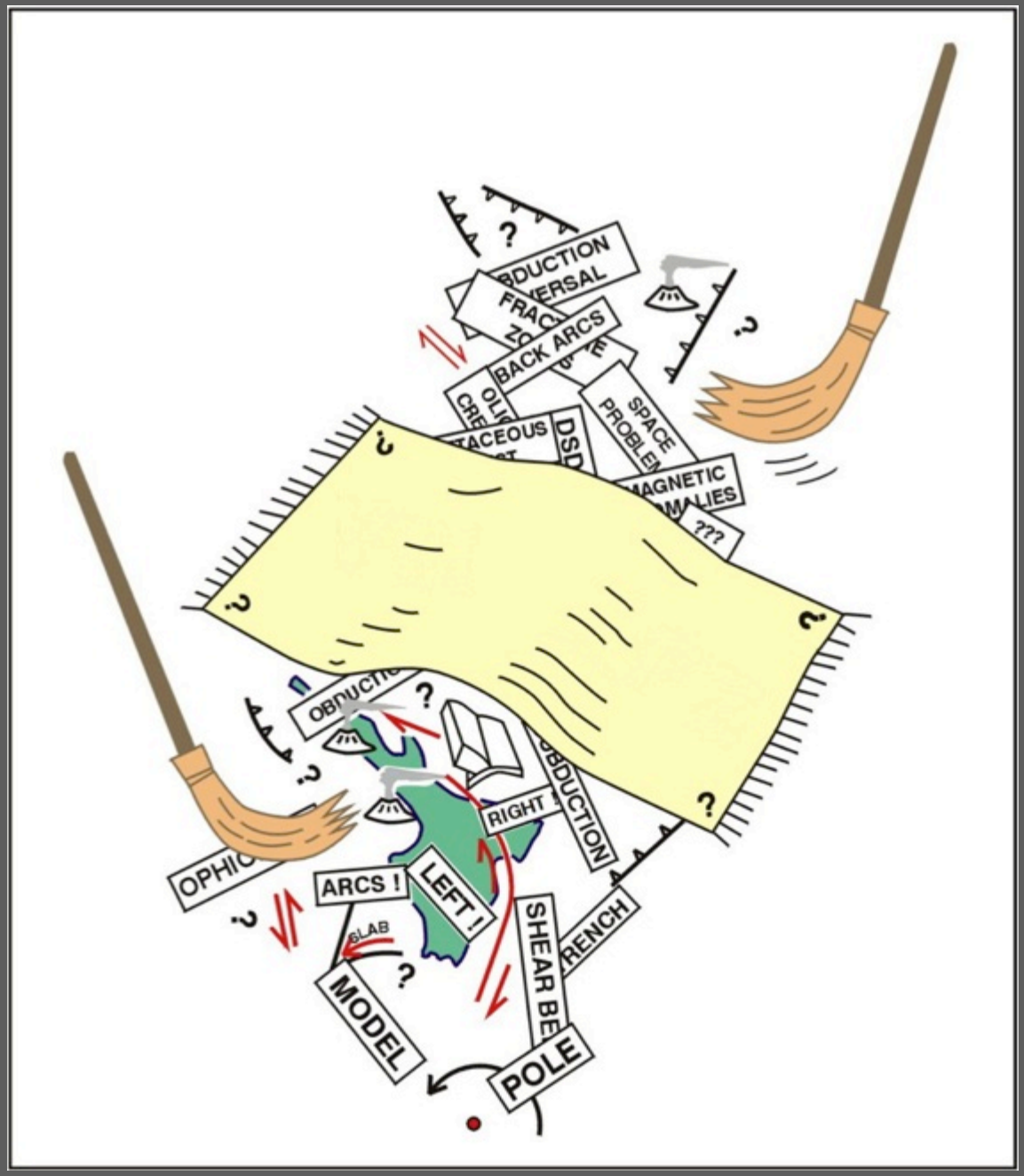



# Arc footprints offshore

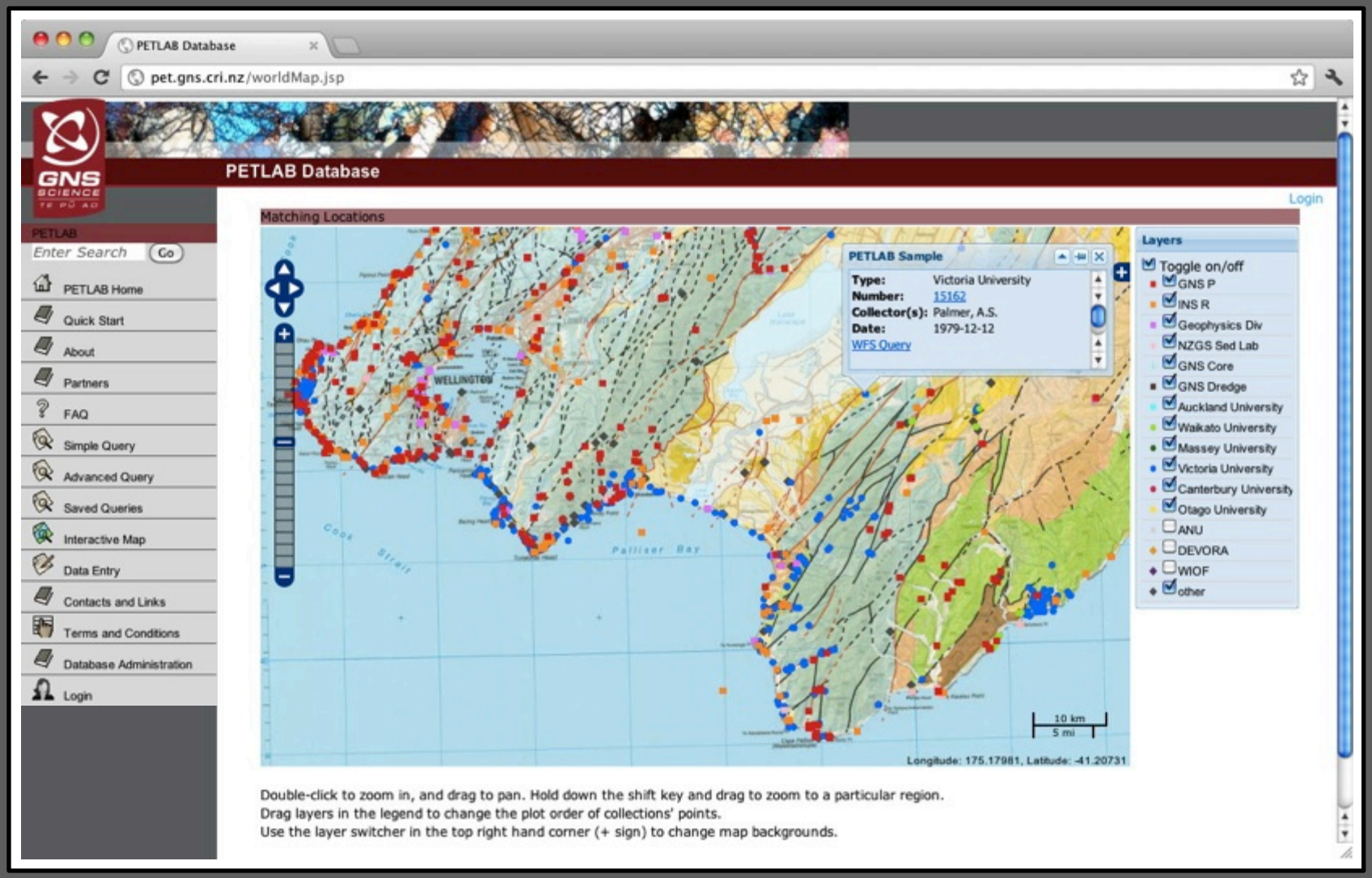
- 0-2 Ma
- 6-17 Ma
- 17-23 Ma
- 20 Ma MCC
- Ophiolite allochthon emplaced 25 Ma

- 23-18 Ma = rapid trench rollback to east
- pre-23Ma initiation = uncertain time and mechanism

Mortimer et al. (2007, 2010), Herzer et al. (2011)


BACK ARCS
SPACE PROBLEM
???
RIGHT
ARCS !
LEFT !
SLAB
MODEL
POLE

# New Zealand National Databases




**QMAP** data.gns.cri.nz/geology
1:250K geol map data

**PETLAB** pet.gns.cri.nz
Rocks, analyses

**FRED** fred.org.nz
Fossils

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**Guest Editors:** J Townend, P Villamor and M Quigley

# Zealandia and its subduction history

520-100 Ma
Gondwanaland

100-0 Ma
Pacific Rim