



# Greywacke

**the world's most boring rock**

... though it isn't really because it's got some fascinating stories to tell

# Sources

**Heather Nicholson, MSc (1953) PhD (2003)**

*The New Zealand Greywackes. A study of associated geological concepts*



**With thanks, also, to Mike Johnston**

# Etymology

**German:**

**Grau = grey**

**+**

**Wacke = rock**



**First identified in Harz district of Germany in late 18th century**

Variously spelt as grauenwacke, grauwacke, grauwacke, grau-wakke, grauwacke, grauwacke, greywacké, grey-wacké, grey wakke, grey-wacce, and graywacke ...

# Definition

## As a rock:

- hard, grey sandstone consisting mainly of quartz and feldspar minerals and rock fragments cemented together by finer 'matrix'
- particles/fragments usually sub-rounded to sub-angular, and range from silt to pebbles

## As a rock unit:

- an association of interbedded sandstone and laminated shale/mudstone/argillite
- beds may show size grading from coarse (below) to finer (above)
- usually unfossiliferous
- beds often distorted by faults and folds and veined by quartz

# Greywacke, Port Waikato



# Greywacke in hand specimen



# Greywacke in this section

Plane polarized light



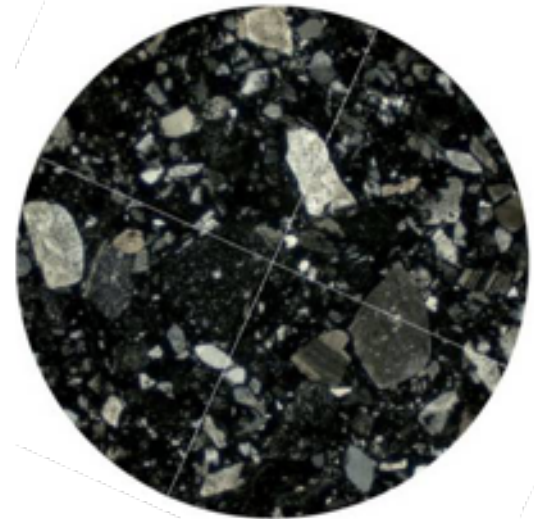
**Greywacke,  
Cumbria, UK**

Plane polarized light



**Greywacke,  
Galway, Ireland**

Between crossed polars



# Abraham Gottlob Werner



*Kurze Klassifikation (1787)*

## 1. Primitive formation



Crystalline rocks (e.g. granite, gneiss) precipitate out in a calm, global ocean.

## 2. Transition formation



Sea level falls; waves erode the emergent rocks and deposit slates and greywackes.

## 3. Flötz formation

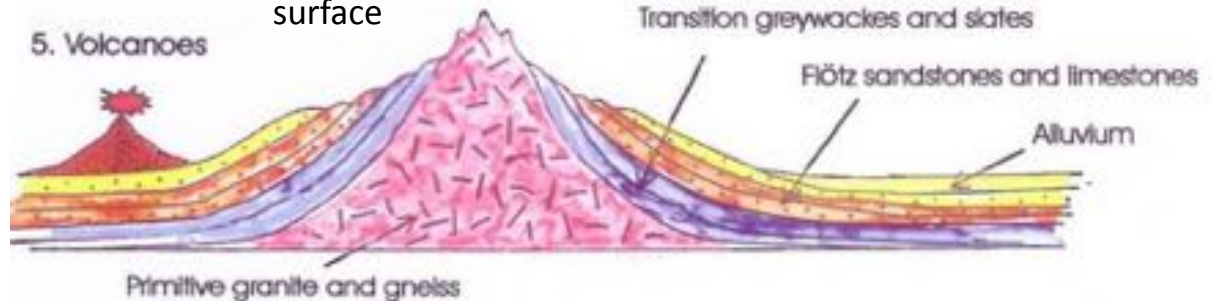


In alternating calm and more turbulent conditions, as sea-levels rise and fall, limestones and sandstones are laid down

## 4. Alluvium

Volcanic activity and more recent deposition adorn the surface

## 5. Volcanoes

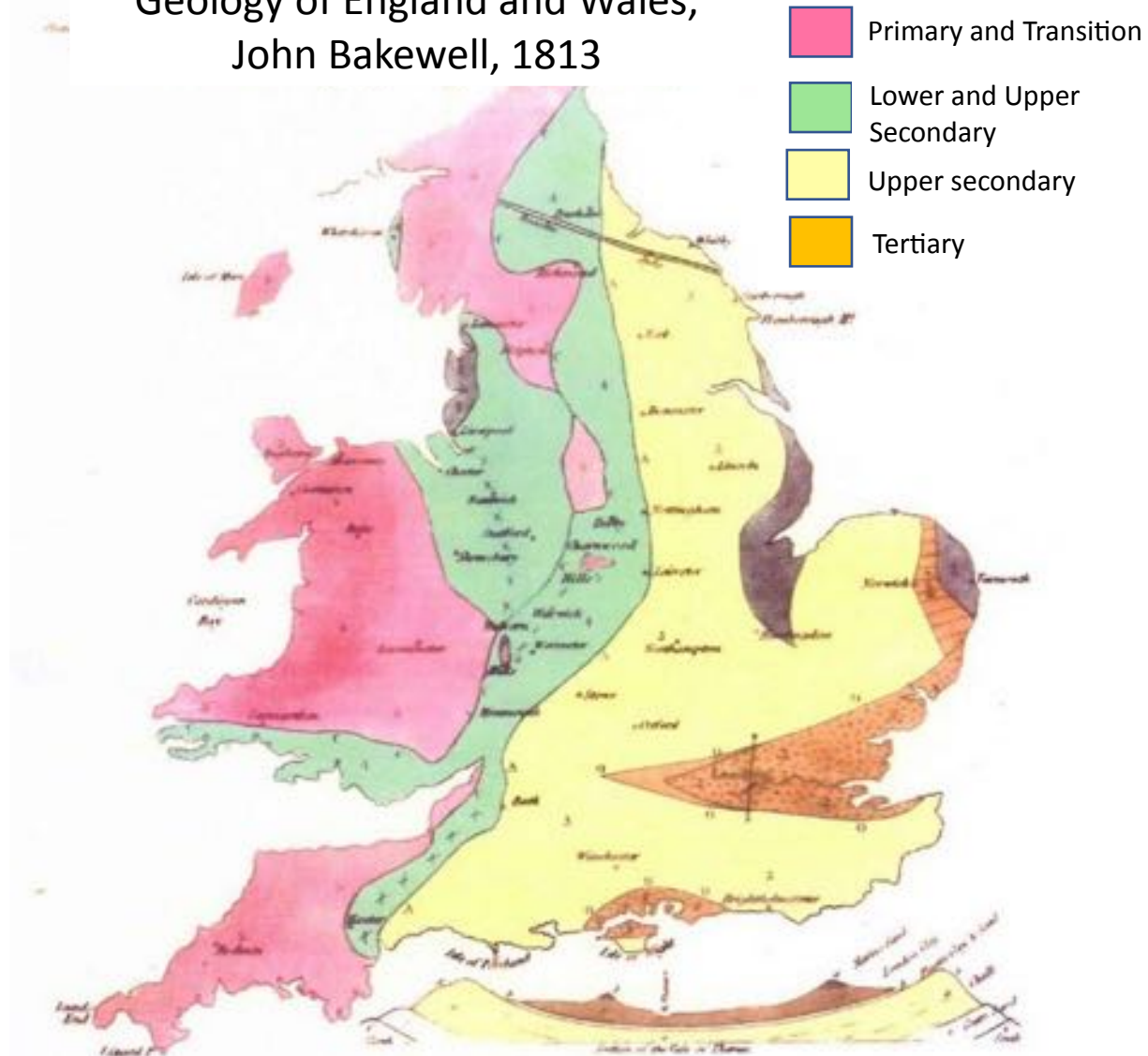




# British interpretations

- Werner's ideas spread to Britain, where similar geological categories were identified
- Greywacke was shown to cover much of western Britain

Geology of England and Wales,  
John Bakewell, 1813



# The British Protagonists



Roderick  
Murchison



Adam  
Sedgwick

Over 50+ years of mapping, Murchison, Sedgwick, and later Lapworth:

- Divided the greywacke into an upper and lower member, then further divided these into 6, then 3, then 8 members
- Showed that the 'greywacke' was a series of different strata covering the Cambrian, Ordovician, Silurian and Devonian periods
- Concluded that: *as the term has done much disservice to geology, by inducing observers to merge, under an unmeaning name, deposits belonging to distinct periods in history ... we hope that the term may henceforth be discarded*
- Fell out with each other and called each other names instead!



James Hector  
1834-1907



Frederick Wollaston Hutton  
1836-1905

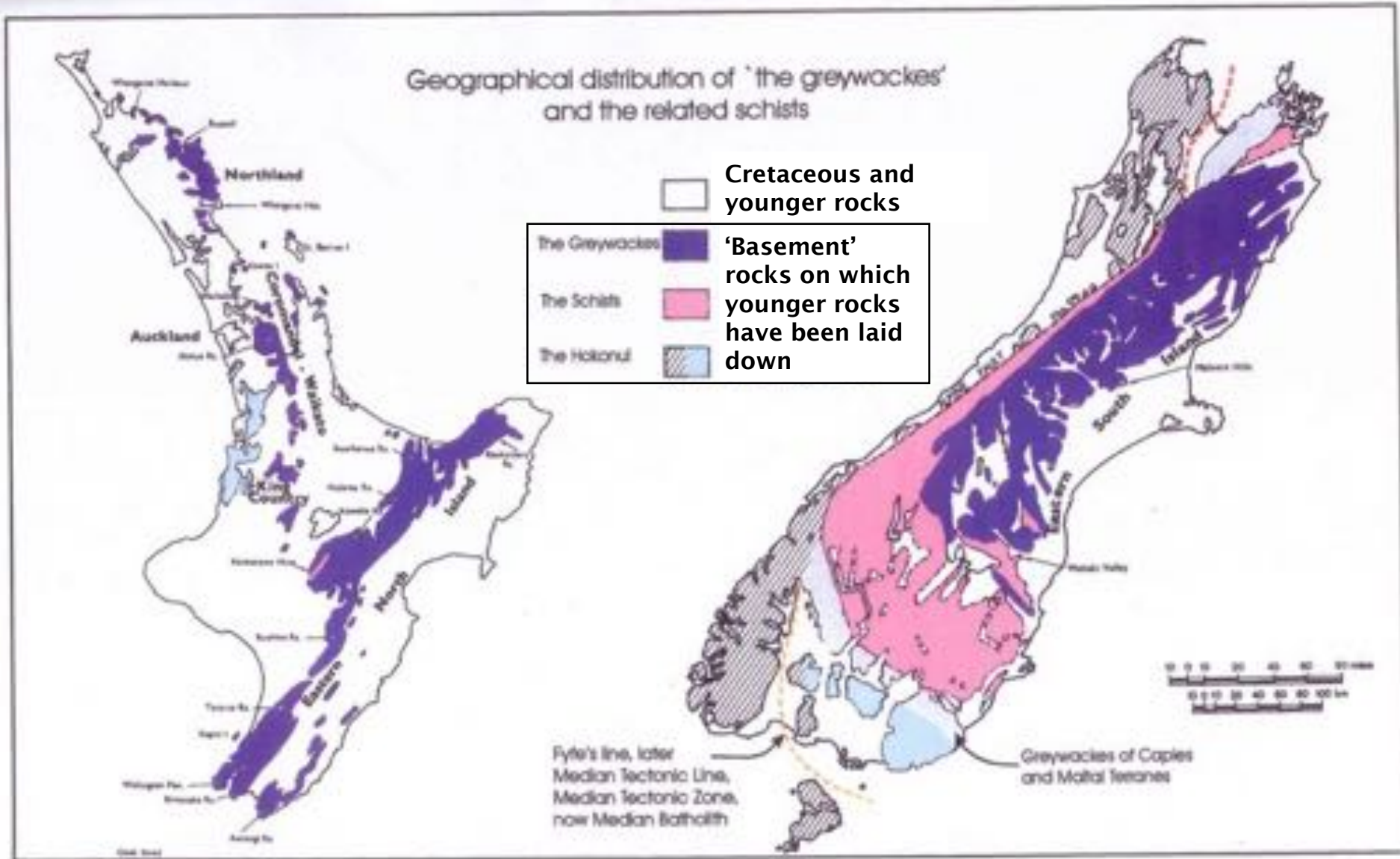
Julius Haast  
1822-1887



Alexander McKay  
1841-1917

# The early greywacke-ologists in New Zealand

# Greywacke in New Zealand



# Dating the Greywacke, 1860-1920

In Britain, it had been shown that the greywacke was Palaeozoic in age (Ordovician – Devonian). Initially, it was assumed that the same would be true here.

Year →

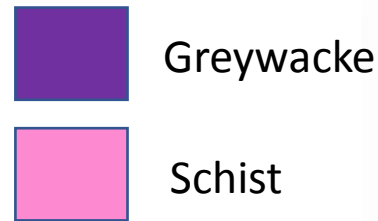


But even that wasn't then end . . .

# The difficulties

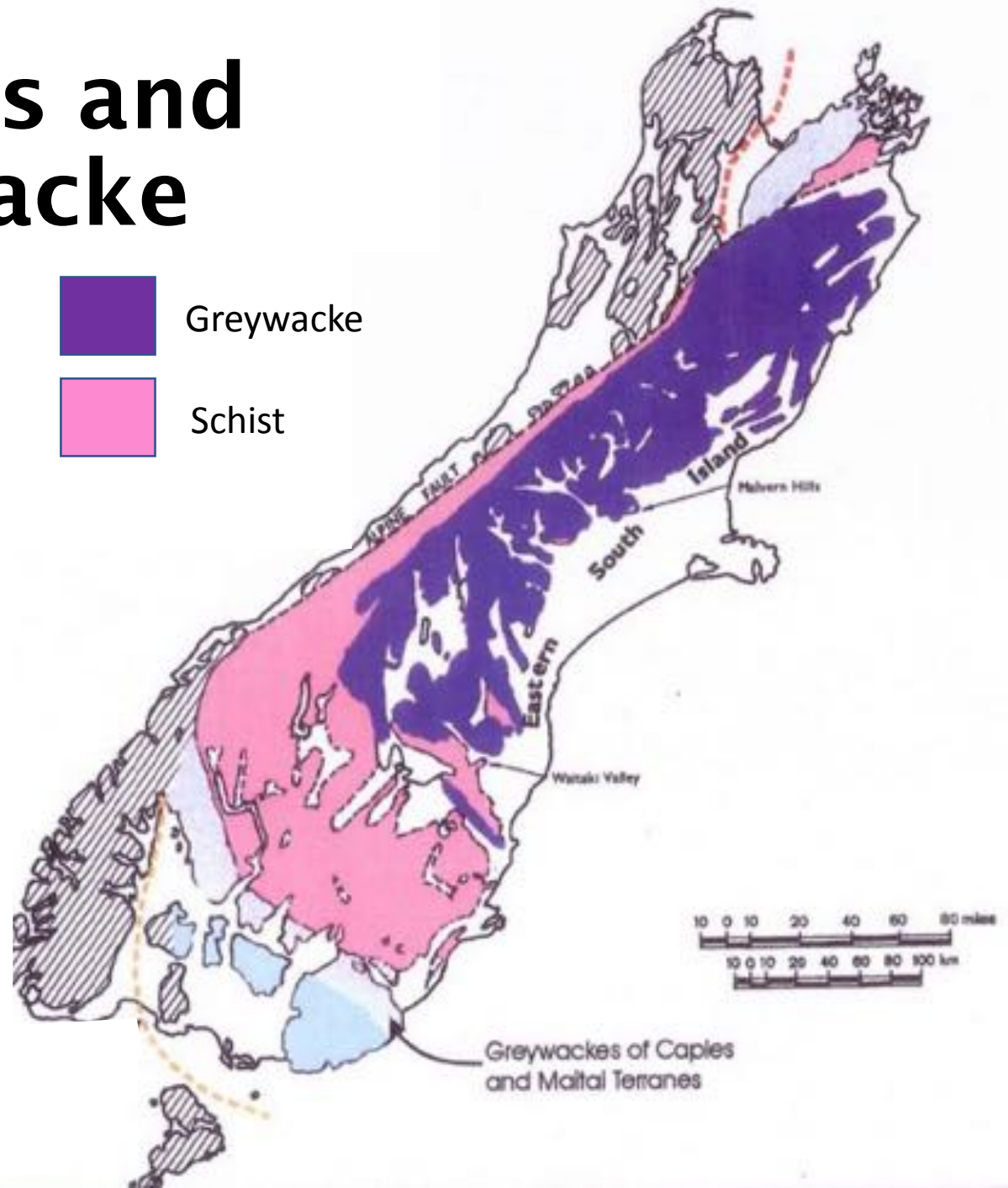
- Limited access and lack of exposures
- Very few geologists – with strong views!
- Limited and confusing fossil evidence
- Uncertain stratigraphic framework
- Assumption that greywackes in NZ should be similar age to those in UK (and coal = Carboniferous)
- Disturbed condition of greywackes
- Poor understanding of faults
- Problem of identifying greywackes and agreeing what they actually were

# The schists and the greywacke

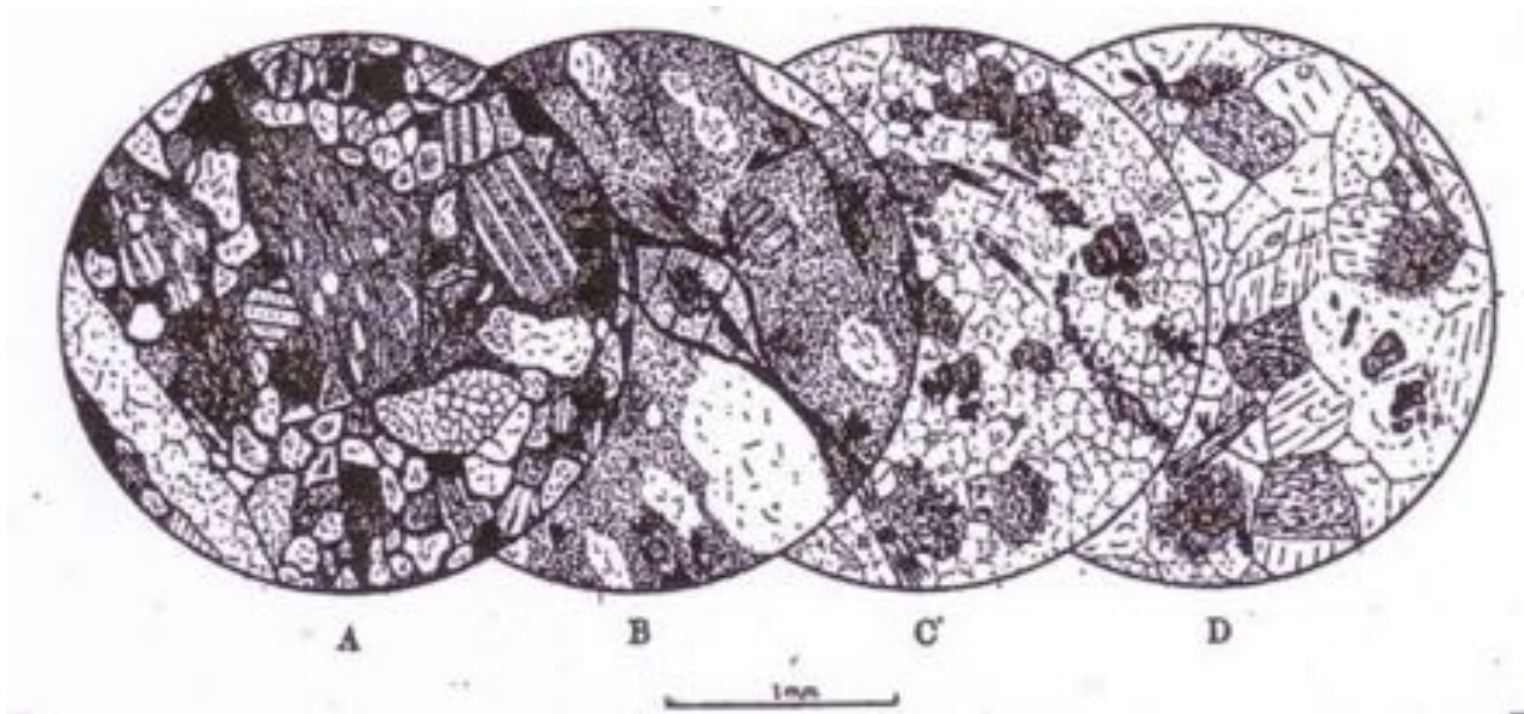


## Problems:

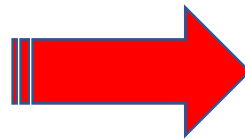
- Difficult to distinguish boundary between schist and greywacke
- Schist considered to be an older rock, by definition of its compaction and mineralogy



# Chlorite Zones



**Less metamorphosed:**  
contains rock fragments and  
mineral grains in a fine matrix



**More metamorphosed:**  
Completely crystallised  
– quartz, albite, epidote,  
chlorite, muscovite

Mineralogical studies eventually showed that the was the protolith of the schist and graded 'insensibly' into it.



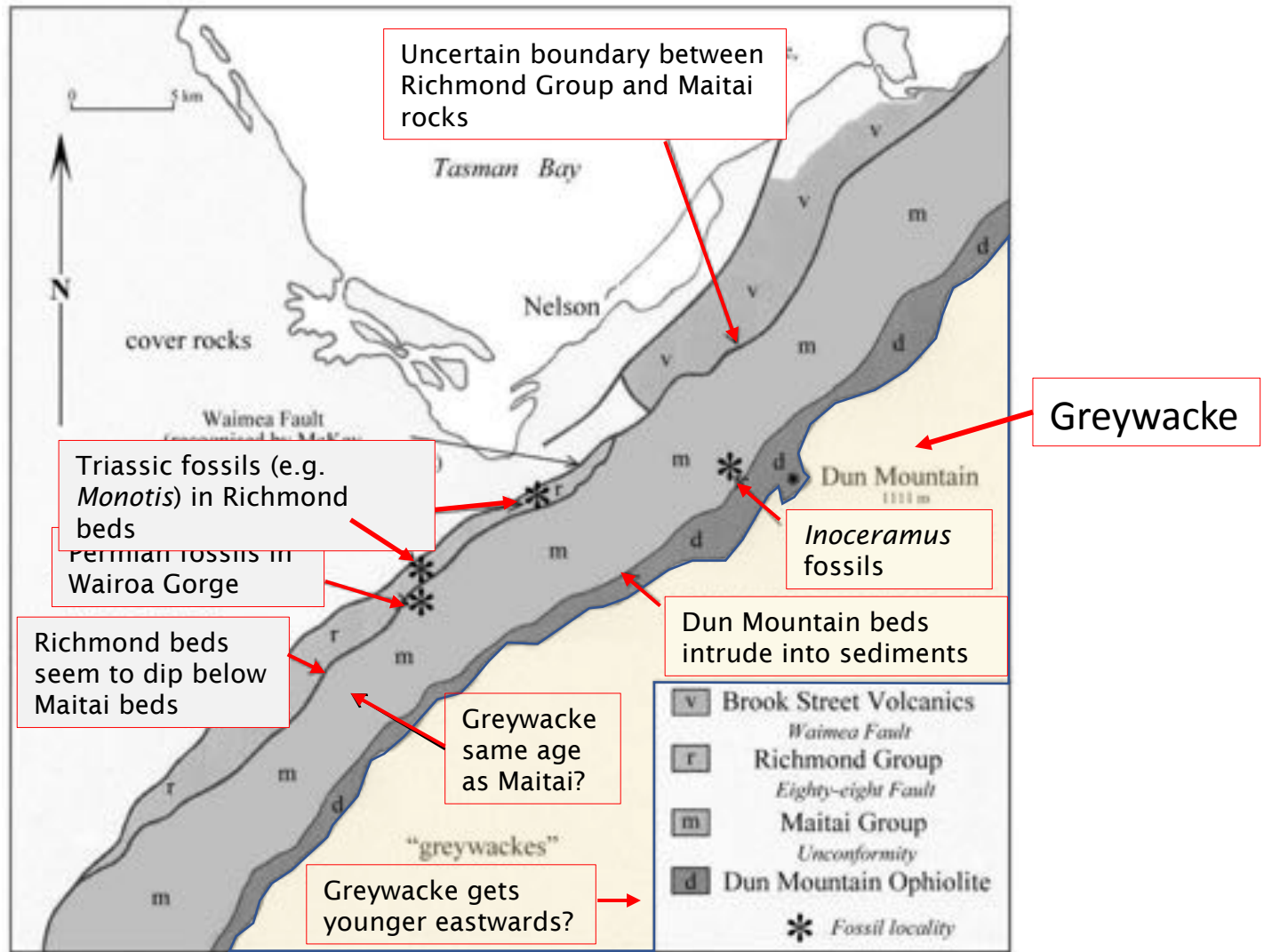
## A key problem was the age of the Maitai Beds



In the Wakefield area the Maitai Beds met and seemed to overlie beds containing Triassic fossils

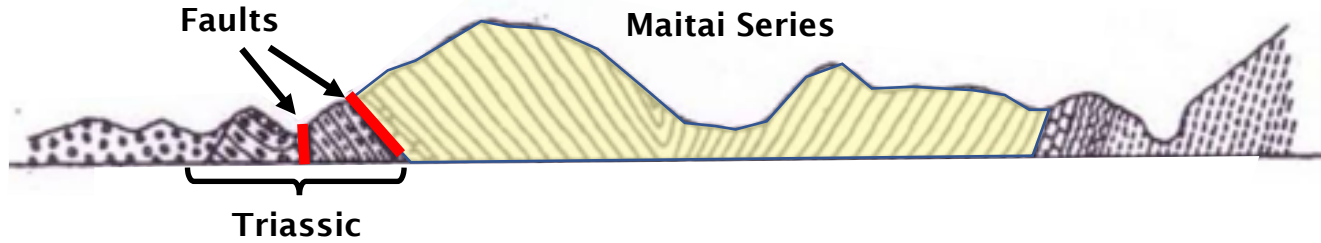


# The Maitai Problem

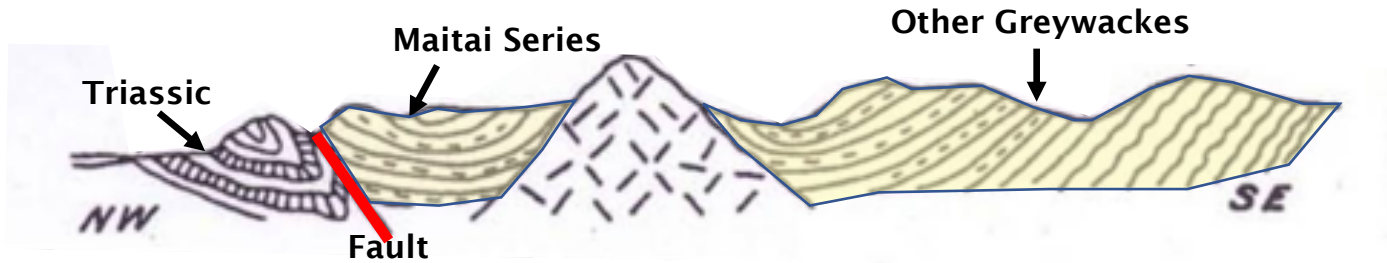


# Cross-sections of the Maitai

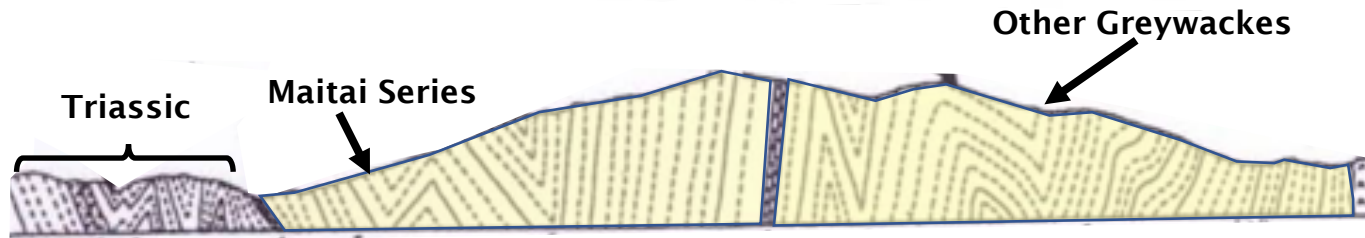
McKay  
1879



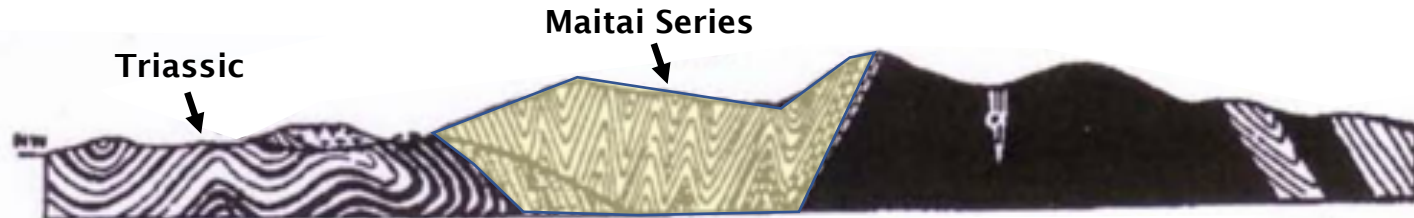
Park  
1909



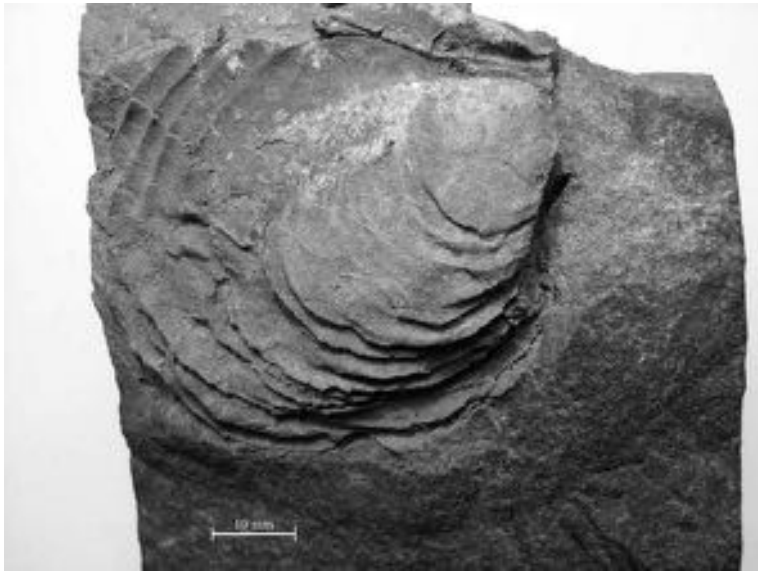
Marshall  
1911



Benson  
1921



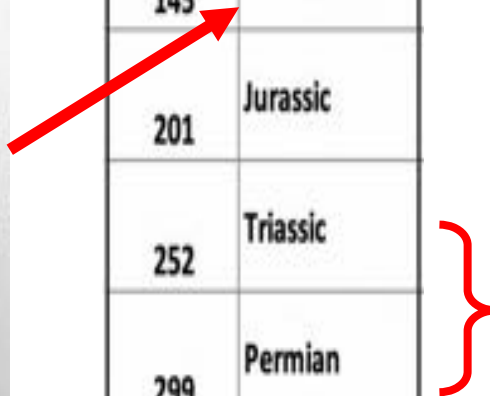
# The Fossil Problem



Supposed Cretaceous *Inoceramus* from Wairoa Gorge

What made it even more confusing was that the Triassic ammonites seemed to be stratigraphically above the *Inoceramus* beds

Mybp	Period
145	Cretaceous
201	Jurassic
252	Triassic
299	Permian
359	Carboniferous
419	Devonian
464	Silurian
485	Ordovician
	Cambrian and older



Triassic or Permian ammonites from the Wairoa Gorge



# Solving the Maitai Problem

Inferred age of greywacke

1858: Hochstetter identifies the Triassic *Monotis* beds in Richmond and declares the Maitai beds as older - Paleozoic

1865: Hector identifies the Jurassic/Cretaceous bivalve *Inoceramus* in the Maitai beds of the Wairoa Gorge, which he thinks are older than greywacke

1878: McKay and Hector identify Carboniferous fossils in the Maitai rocks and suggests that the sequence is overturned

1911: Geological Survey define Maitai beds as Triassic/ Jurassic, based on fossils (*Monotis* and *Inoceramus*)

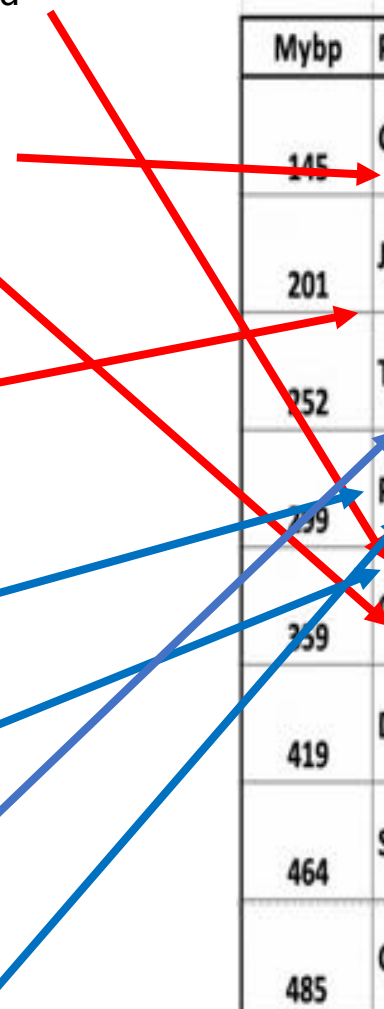
1915: Trechmann reclassifies *Inoceramus* as *Atomodesma* (Permian), identifies 88 Fault below Triassic beds, implying sequence is not continuous; also describes Permian fossils from an upper limestone bed in the Maitai sequence

1948: Wellman shows that Maitai beds unconformably overlies Dun Mountain ophiolite, implying time-gap in sequence

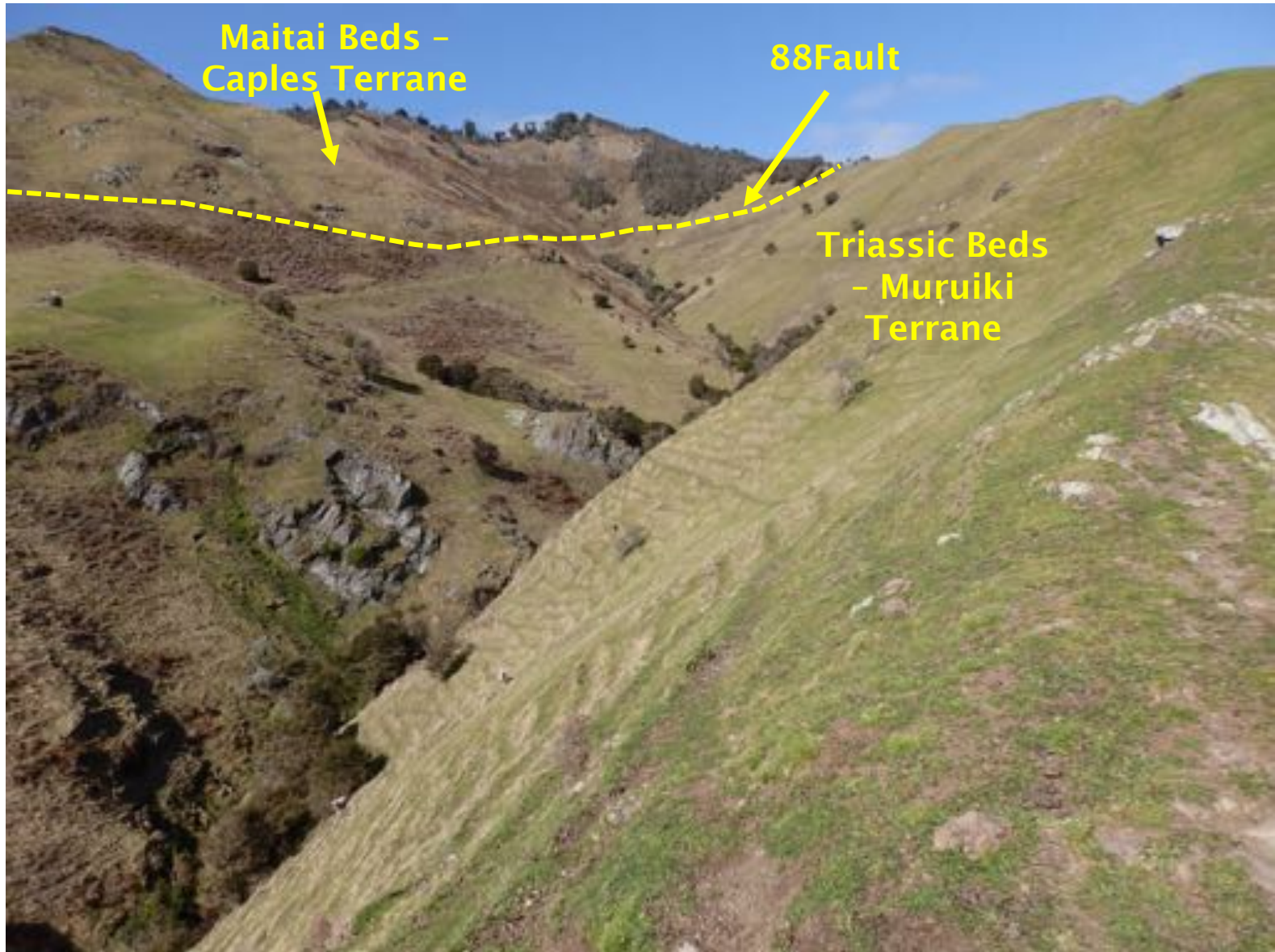
1985: Ammonites found in lower Maitai beds on d'Urville Island. Initially described as Permian, then reclassified as Triassic, creating clash with Trechman's Permian fossils

1992: Owen shows that upper limestone bed within the Maitai rocks is an olistostrome - blocks of Permian material slumped into Triassic beds during deposition

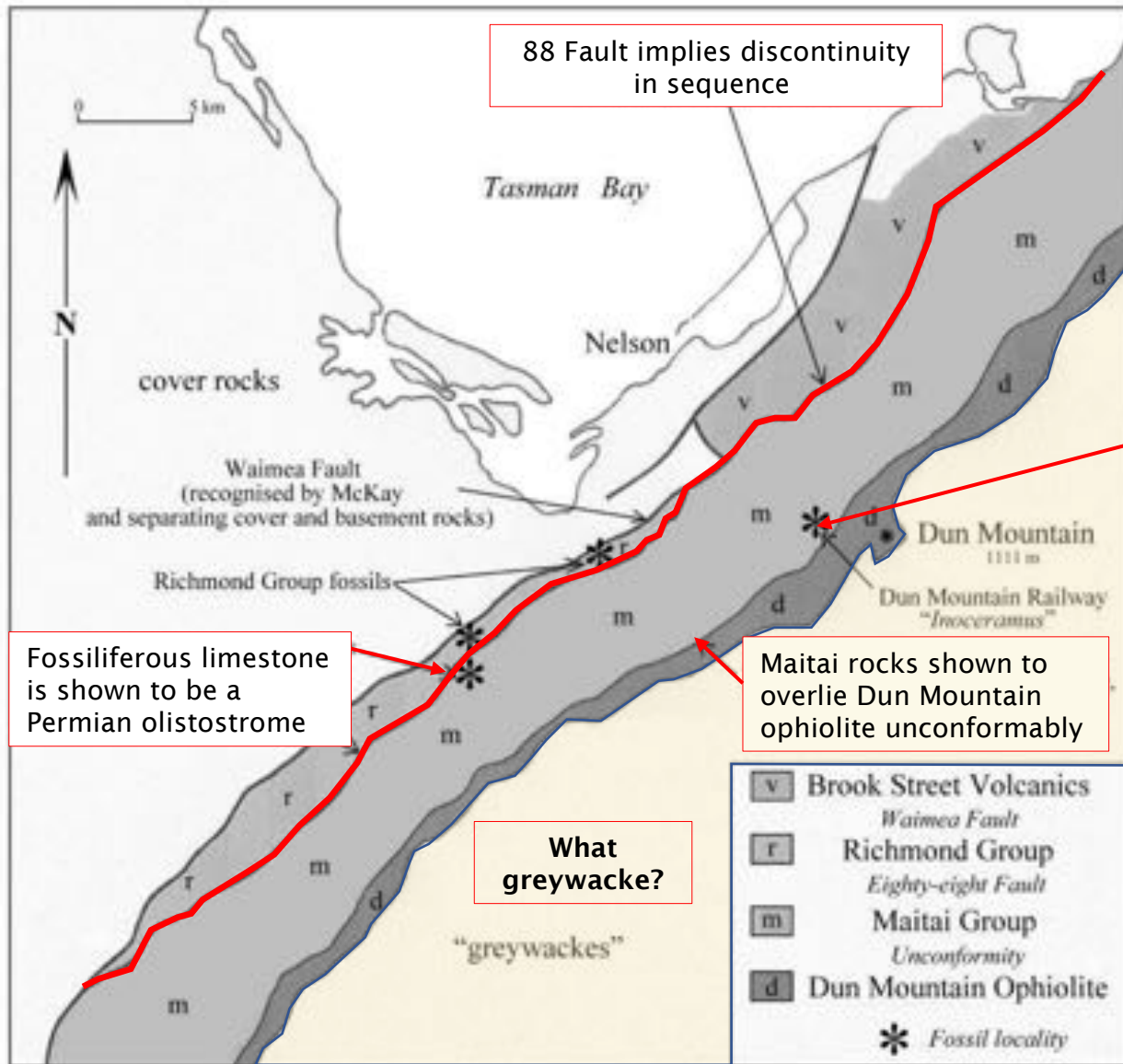
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# The 88 Fault



# Solving the Maitai Problem



88 Fault implies discontinuity in sequence

'Inoceramus' shown to be Permian bivalve *Atomodesma*

Fossiliferous limestone is shown to be a Permian olistostrome

Maitai rocks shown to overlie Dun Mountain ophiolite unconformably

What greywacke?

- v Brook Street Volcanics
- r Richmond Group
- m Maitai Group
- d Dun Mountain Ophiolite
- \* Fossil locality

# The sequence in the Nelson area

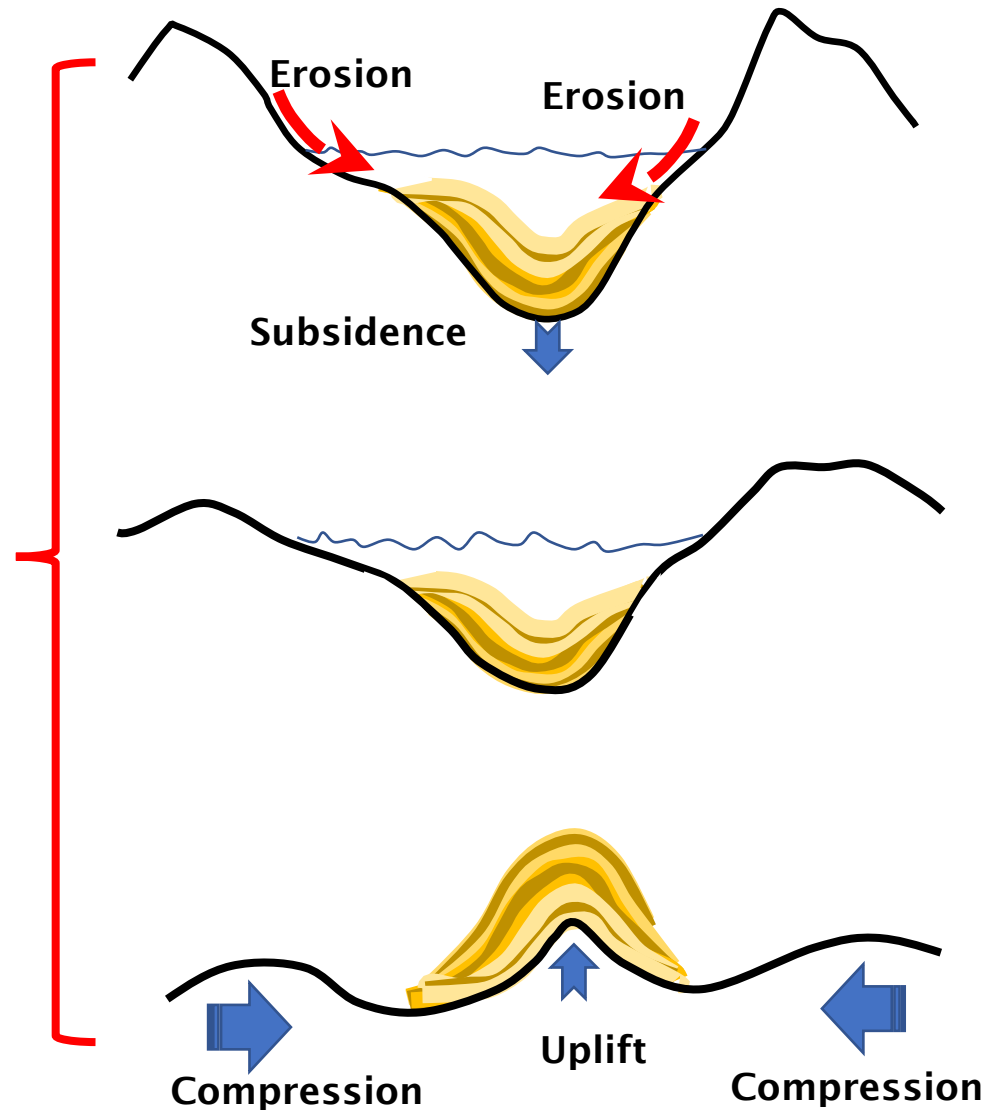
Late Triassic	Richmond Group	e.g. Highfield Farm
88 Fault	-----	
	Stephens Group*	Ammonites
Early-Mid Triassic	Waiua Formation	↑
	Greville Formation	⋮
	Little Ben Sandstone	'Greywacke'?
Permian/Triassic Boundary	.....	
	Tramway Sandstone	↑
	Wooded Peak Limestone	<i>Atomodesma</i>
Permian	Dun Mountain Ophiolite	
	Patuki Melange	
	Ward Formation	'Greywacke'?

\* Including Permian limestone olistostromes

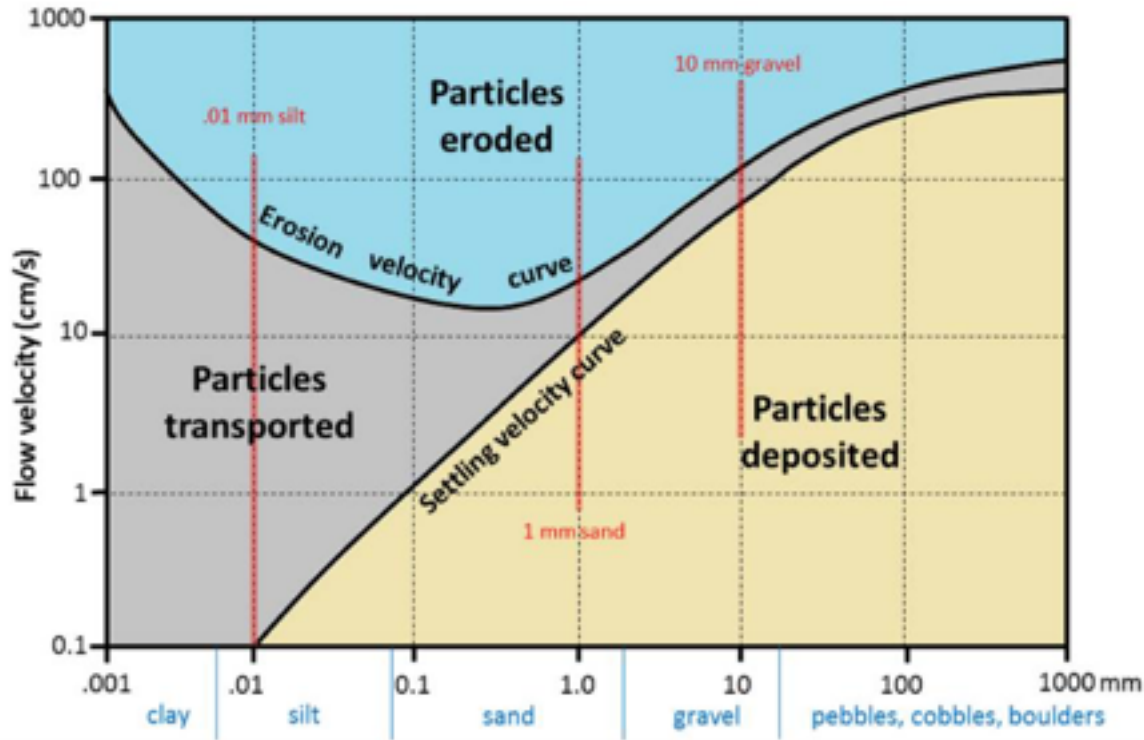


# Mode of formation

1. Early ideas were that greywackes were shallow water deposits, laid down in near-shore areas by streams.
2. Later, theory of diastrophism led to belief that they were associated with *geosynclines* (deep subsiding basins), which then were uplifted by compressive forces to create new mountain ranges.
3. But new theories on mountain-building discredited the idea of geosynclines and diastrophism.



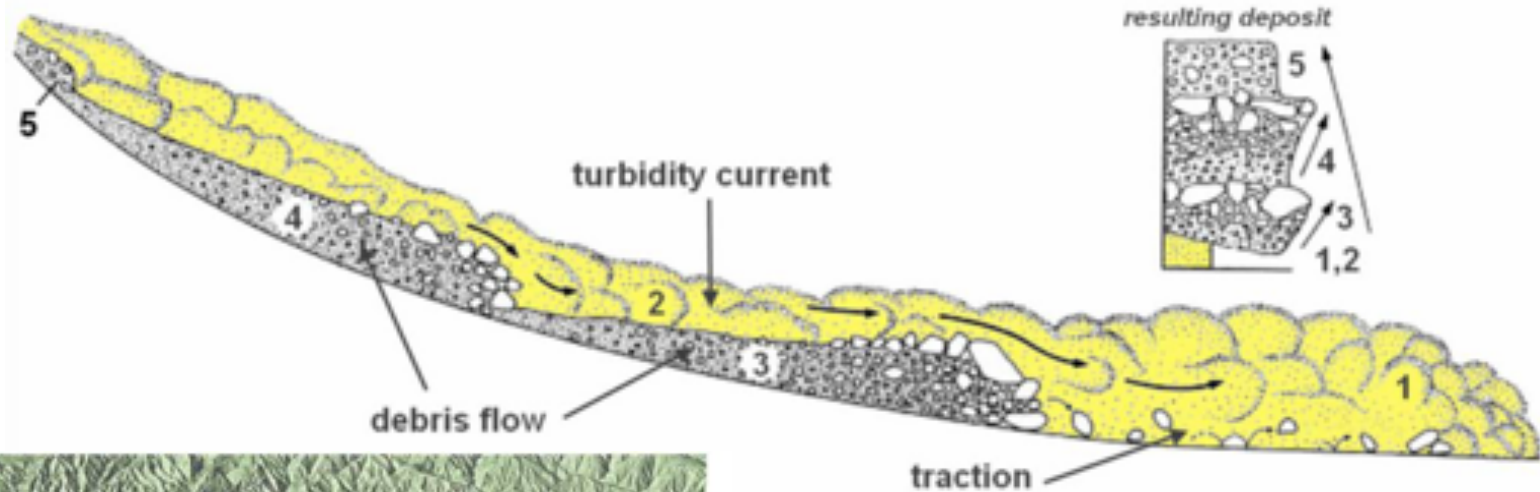
# The particle size problem



Greywackes composed of a mix of clay and sand or coarser particles/

But hydraulic studies show that sand and clay are entrained and deposited at different velocities – so how could they be deposited together?

# Greywackes are turbidites



Turbidites form from sediments swept through (or out of) deep channels in the continental shelf

New Zealand's greywackes are turbidites, laid down by turbidity currents at the edge of the continental shelf.

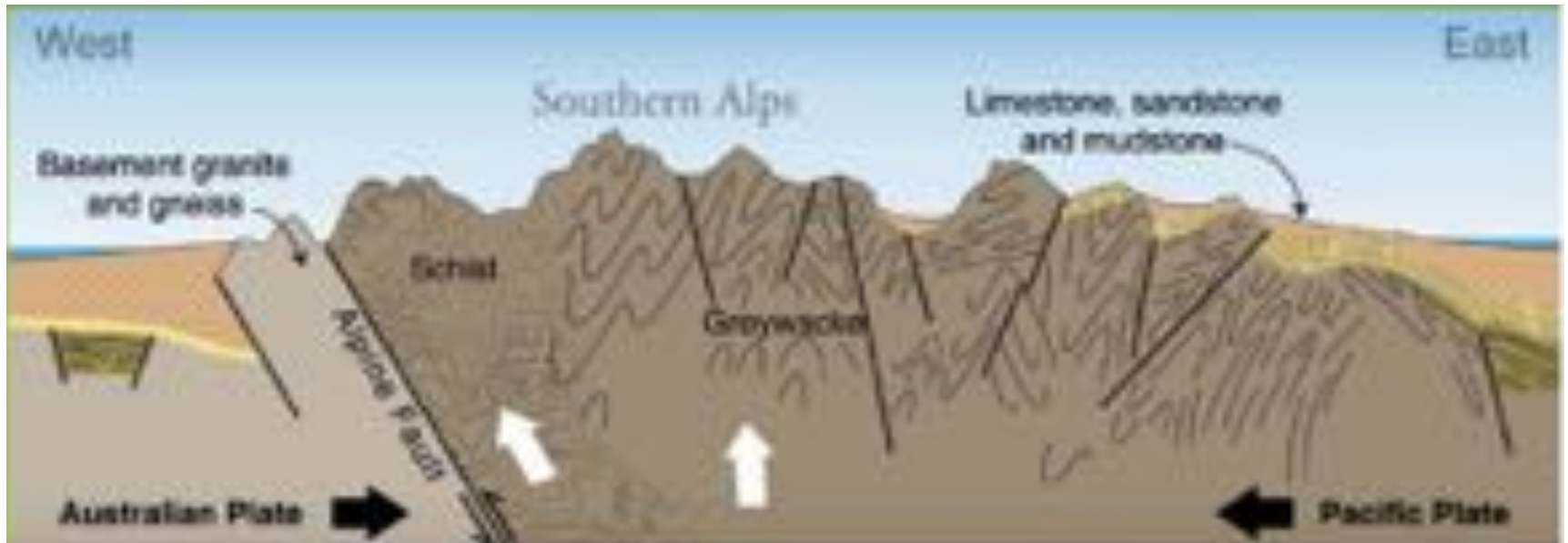


Pause (k)

0:00 / 2:20



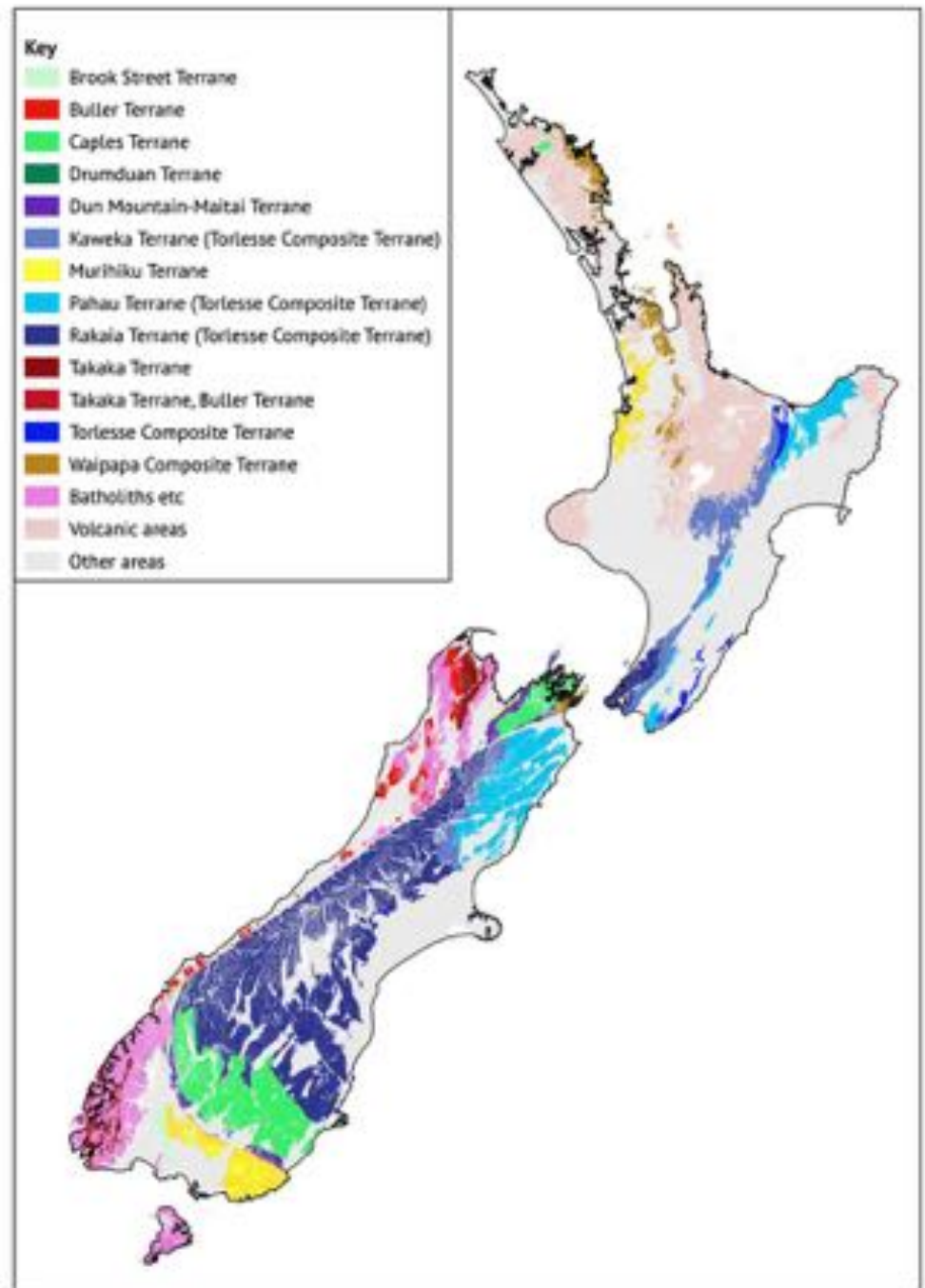
# Plate Tectonics and the Greywacke



# Terranes

A terrane is a fault-bounded package or rock sequence of regional extent with distinctive geologic history.

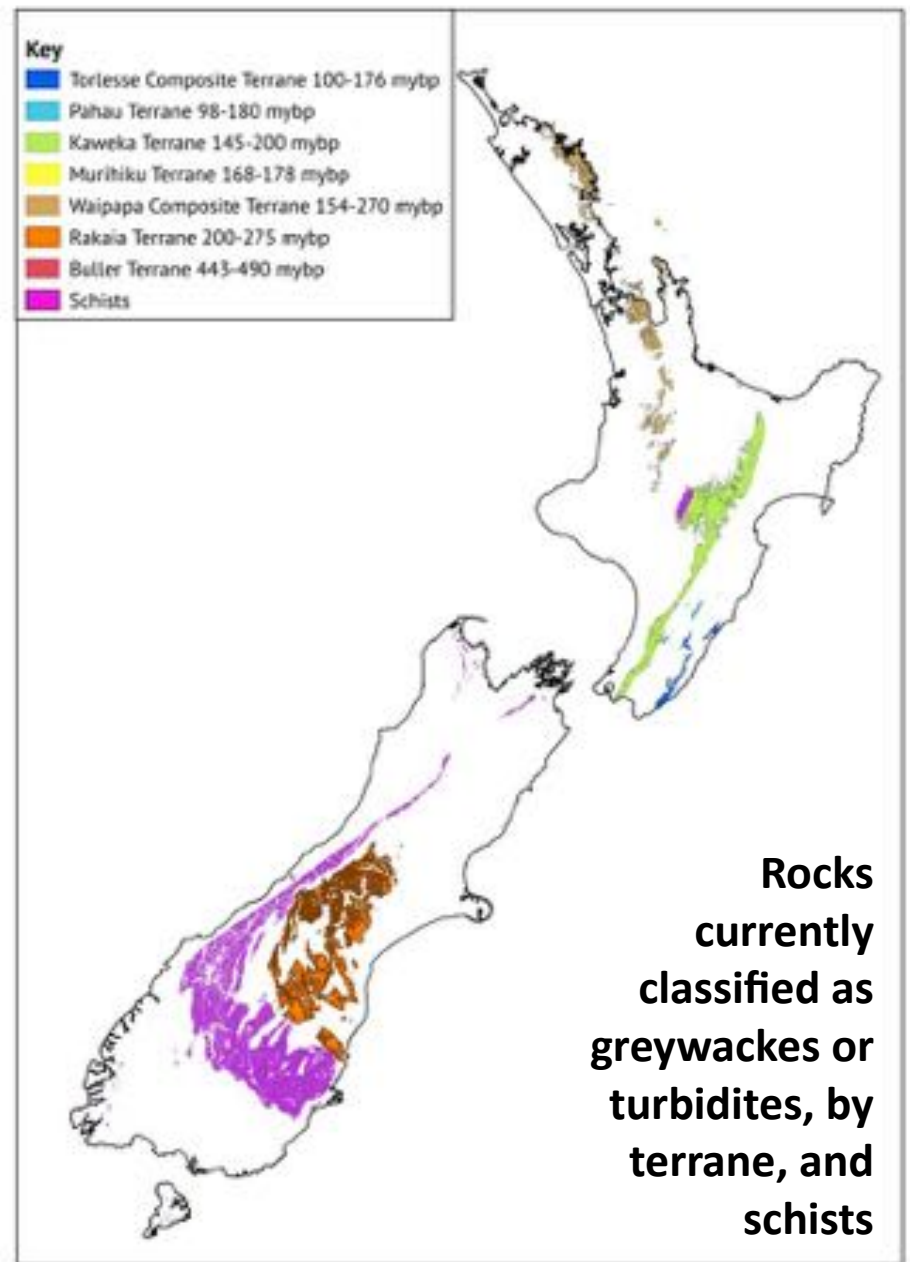
The mainland of New Zealand comprises ca. 12 major terranes, dating back to the Archean period ca, 3.4 billion years BP. The terranes have been brought together through faulting and other tectonic processes.



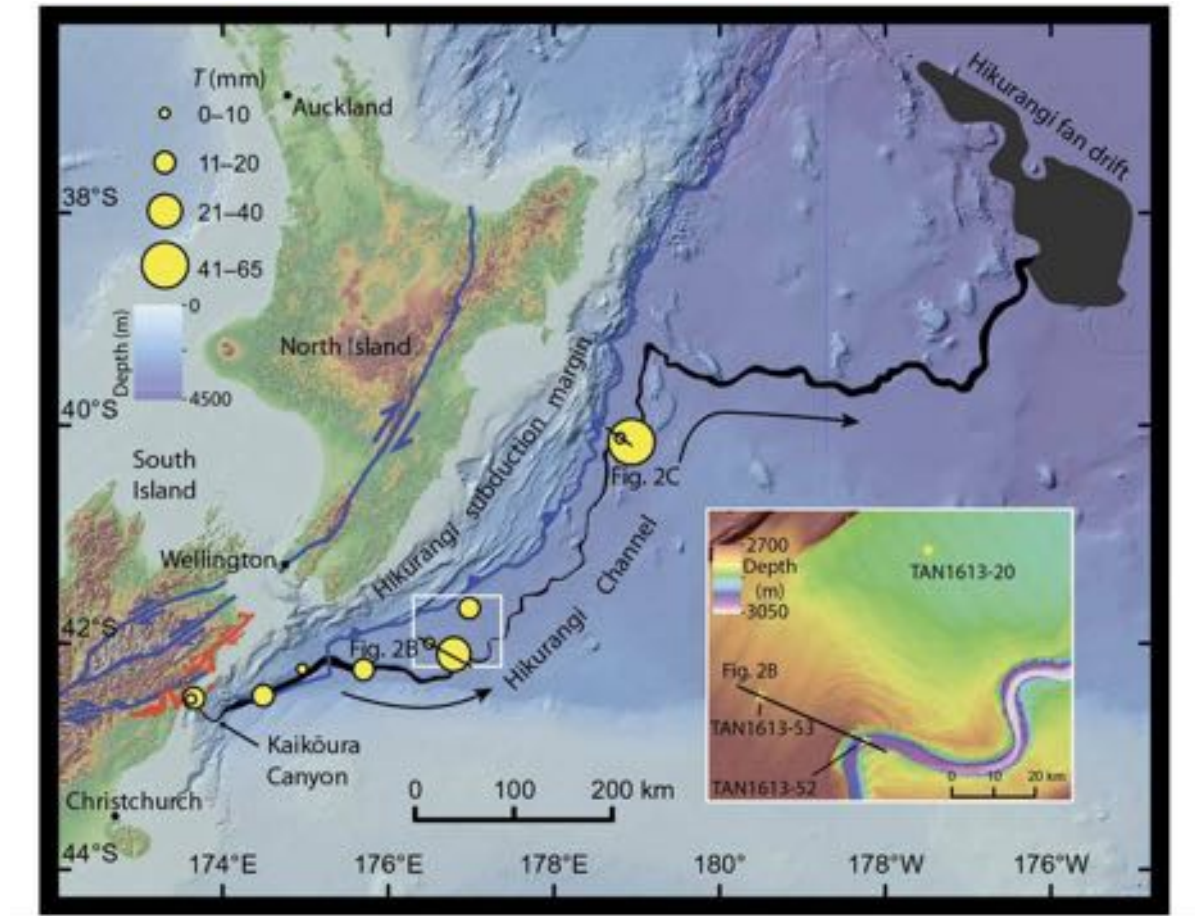
# So how old are the greywackes?

Mybp	Period	Terrane
145	Cretaceous	
201	Jurassic	
251	Triassic	
299	Permian	
359	Carboniferous	
419	Devonian	
454	Silurian	
485	Ordovician	
	Cambrian	

... and note how much more restricted the greywackes are now...



# Tectonics and turbidites



The Kaikōura earthquake stripped >850 million tonnes of sediment from the Kaikōura Canyon, which travelled > 680km northeast along the Hikurangi Channel.



# Conclusions?

Greywackes aren't boring

It's just the name that's a problem