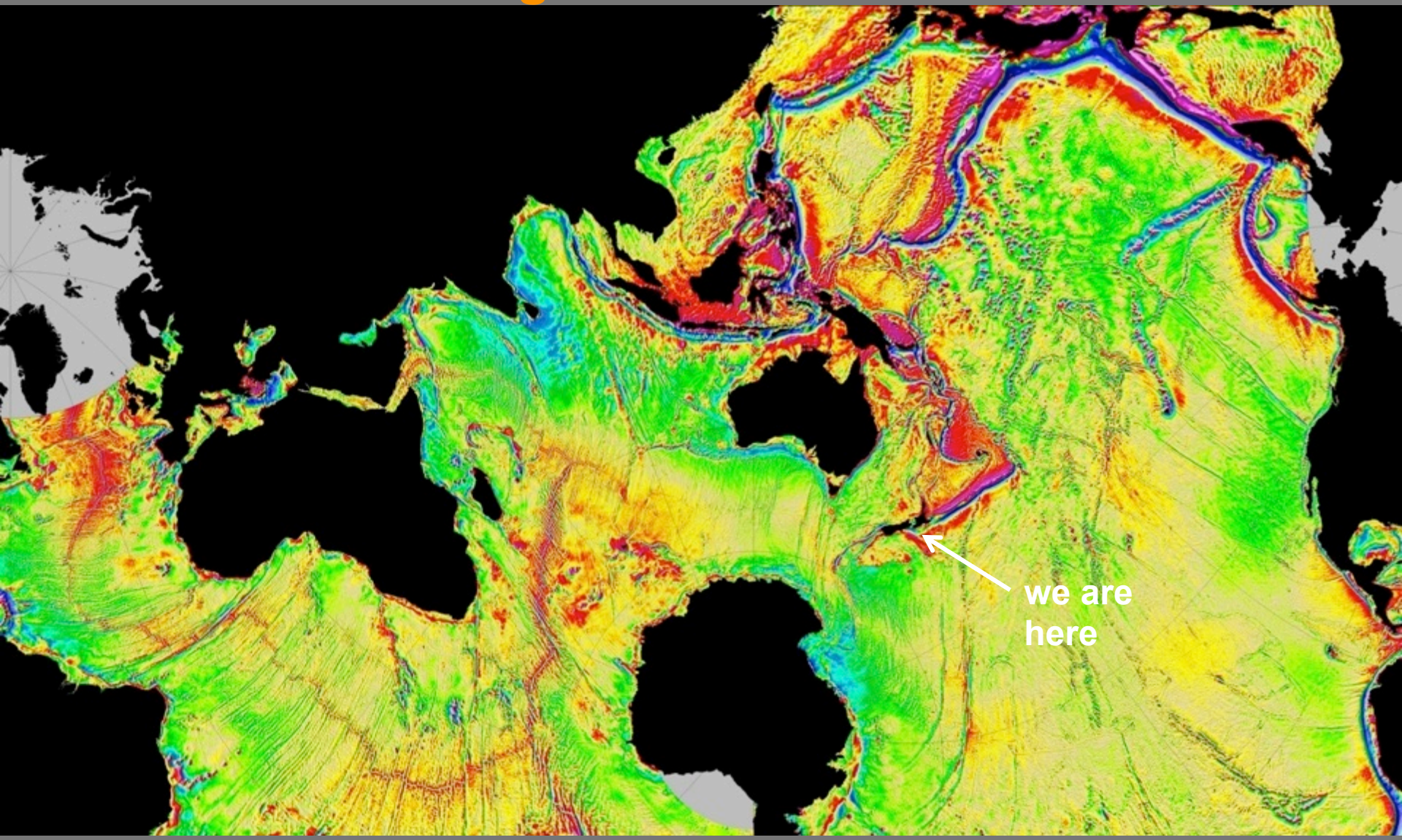
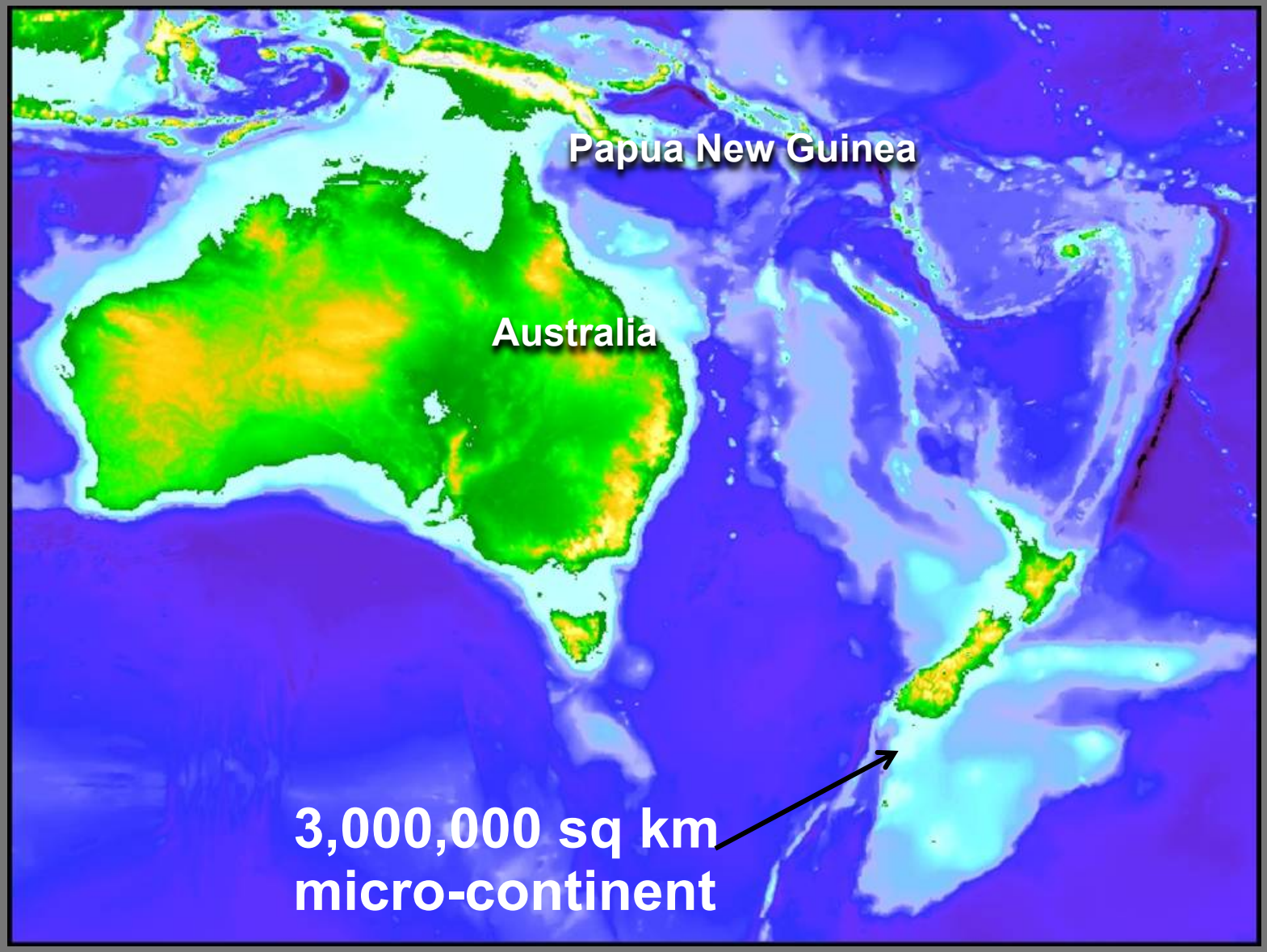
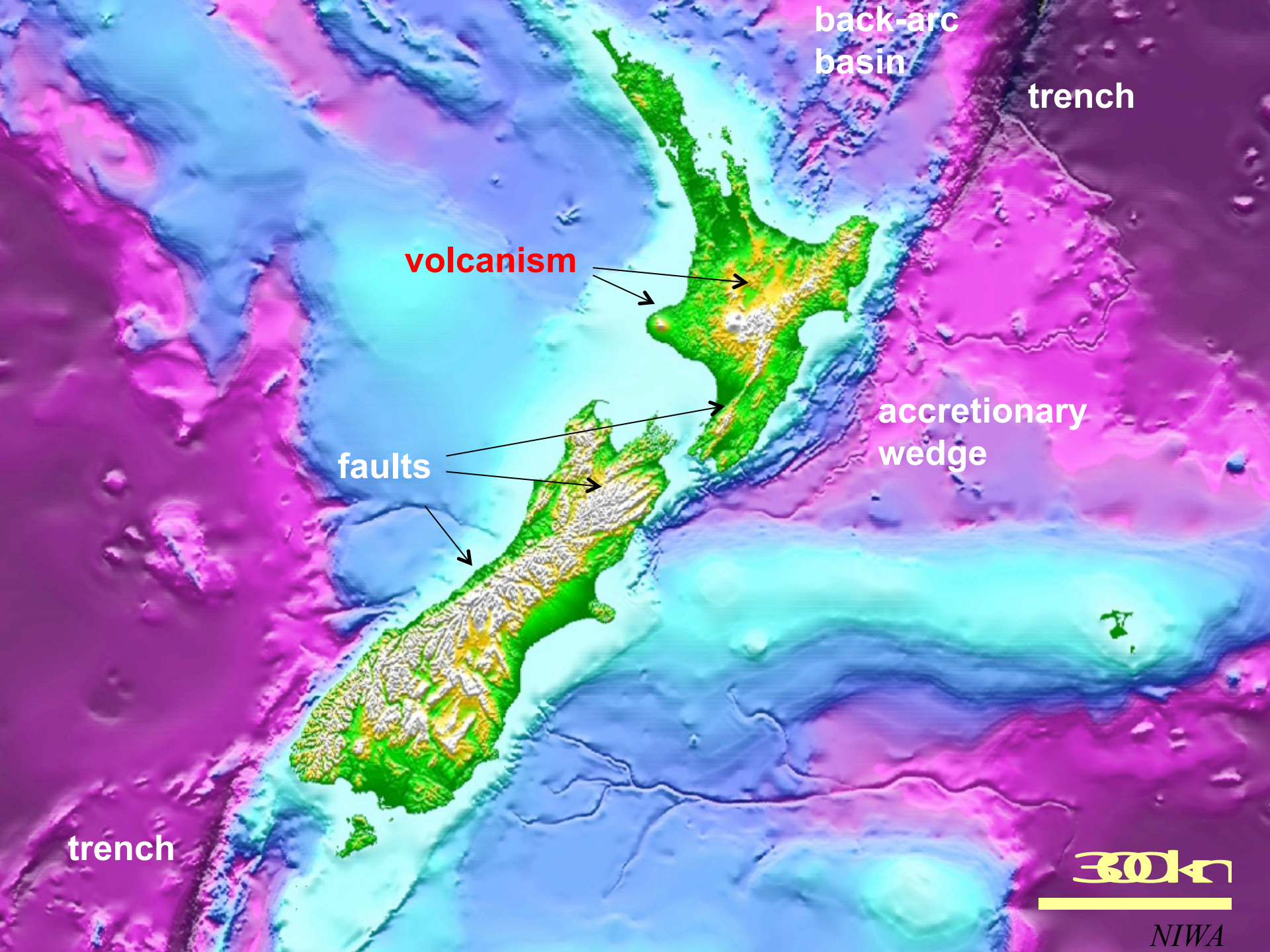
The Tectonic Setting of New Zealand

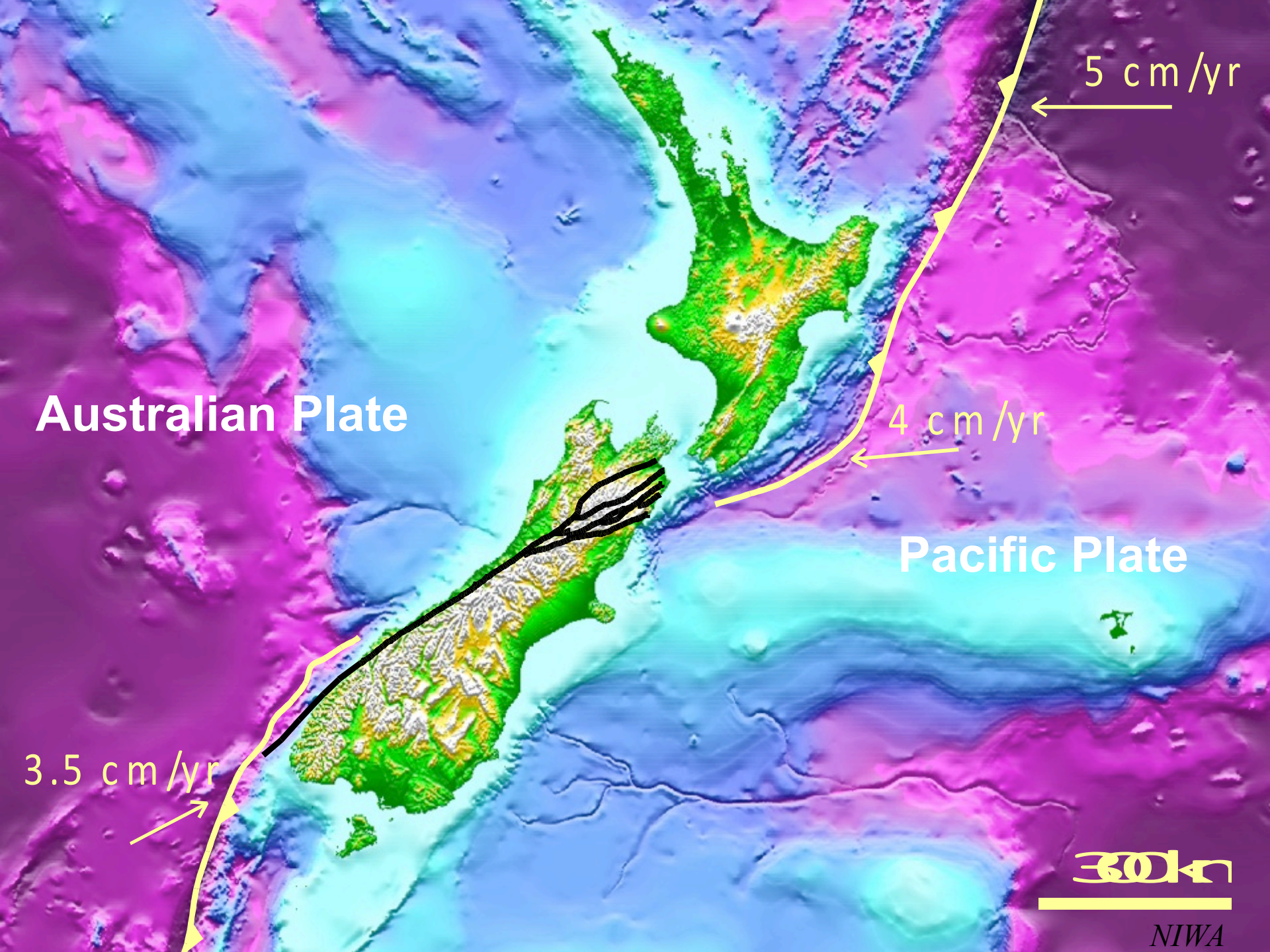


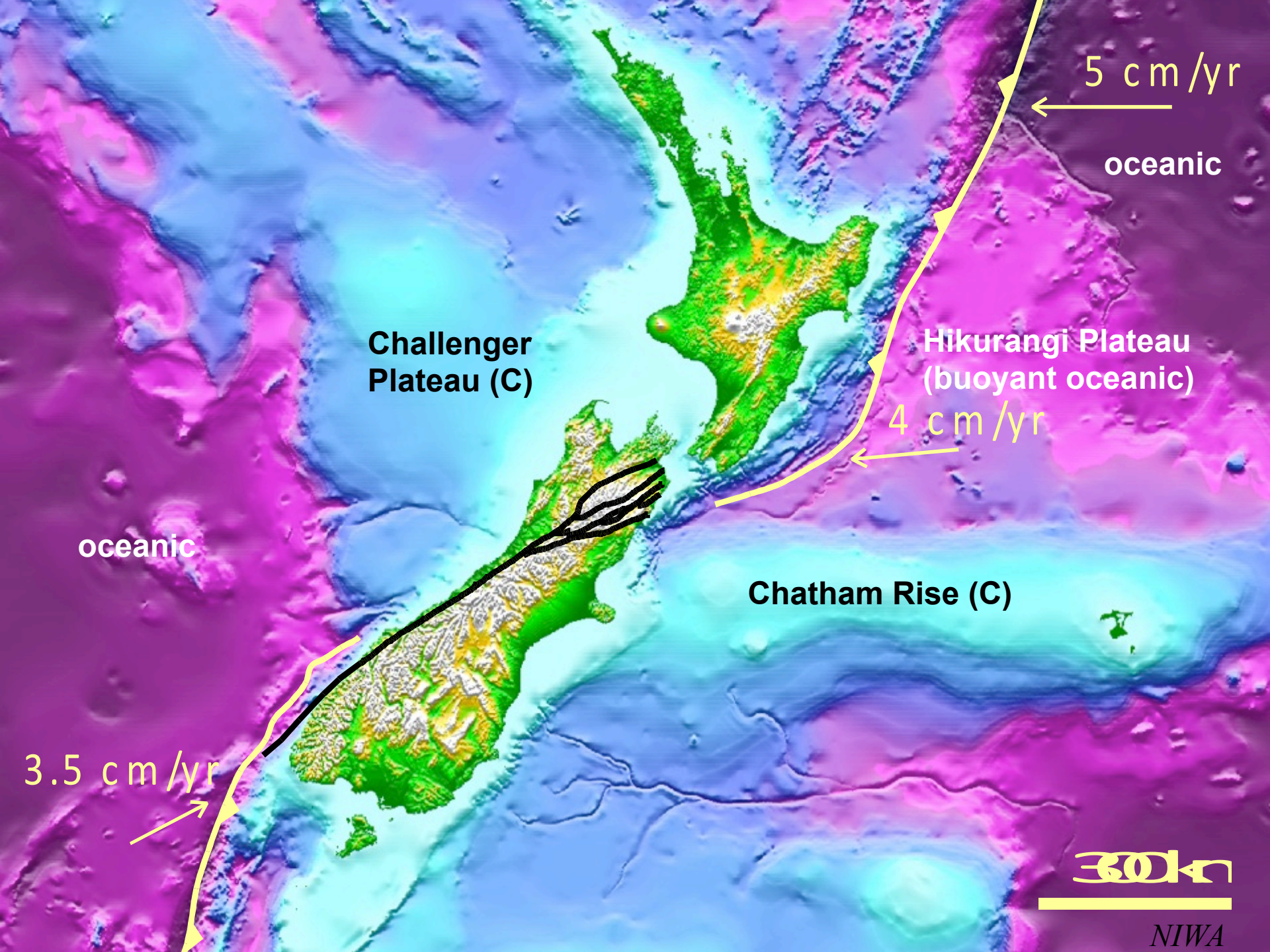
"Subduction-driven" tectonics

The New Zealand continent

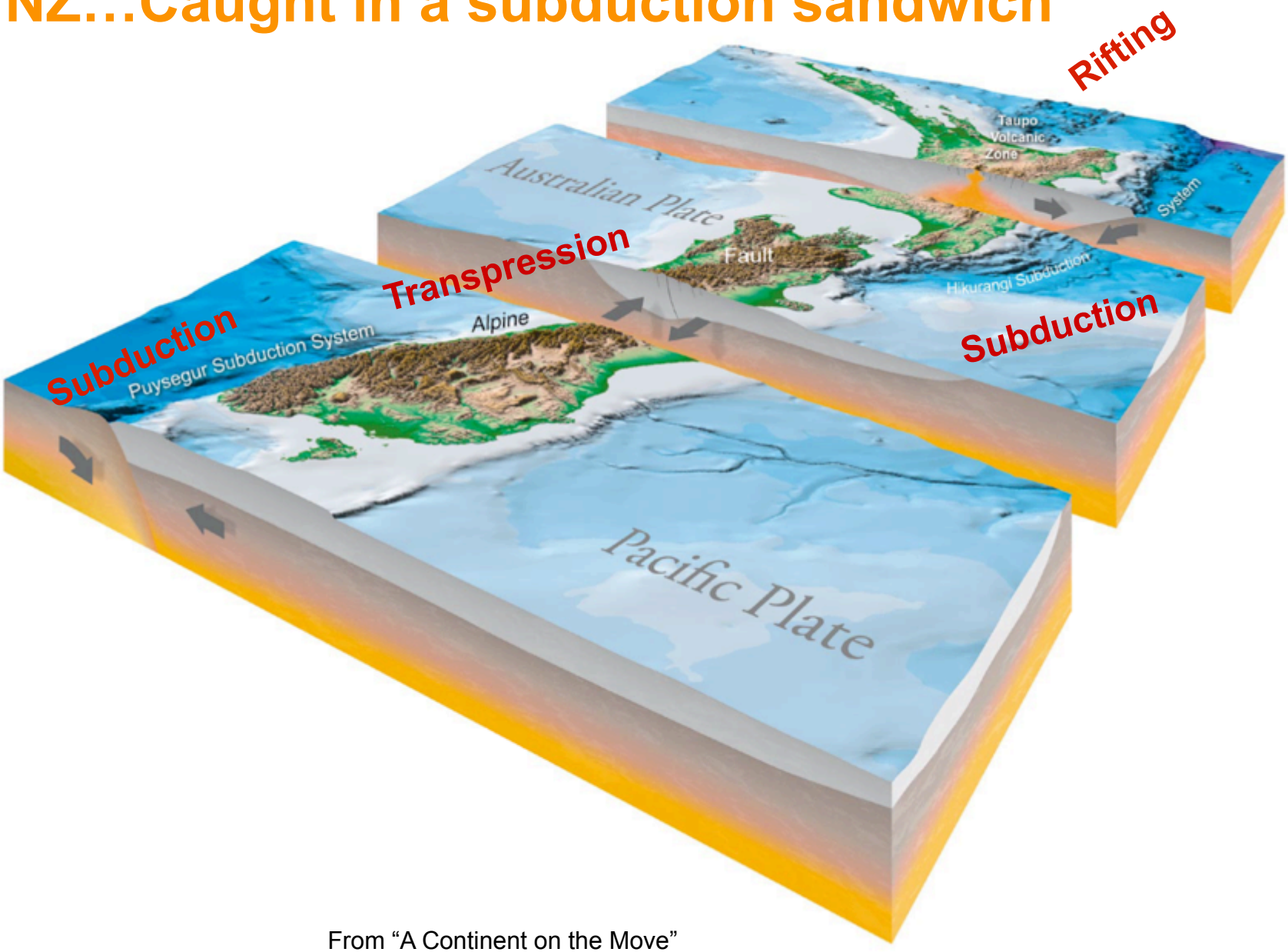



back-arc
basin
trench
volcanism
accretionary
wedge
faults
trench
300 km
NIWA


5 cm/yr
Australian Plate
4 cm/yr
Pacific Plate
3.5 cm/yr
300 km
NIWA

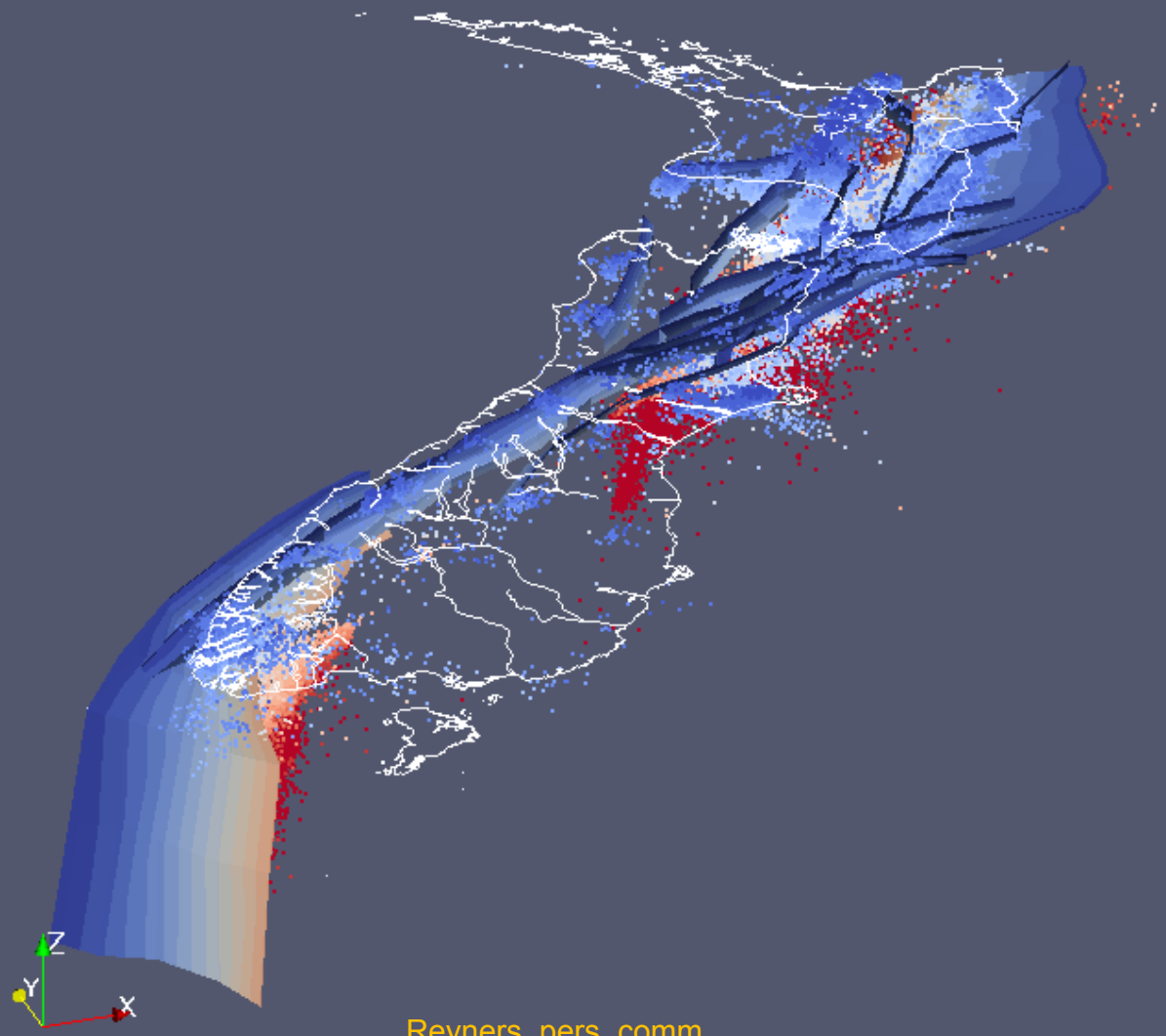

5 cm/yr
oceanic
Challenger
Plateau (C)
Hikurangi Plateau
(buoyant oceanic)
4 cm/yr
oceanic
Chatham Rise (C)
3.5 cm/yr
300 km
NIWA

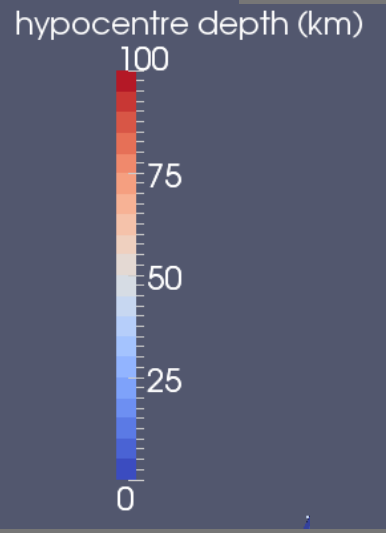
NZ…Caught in a subduction sandwich



From “A Continent on the Move”

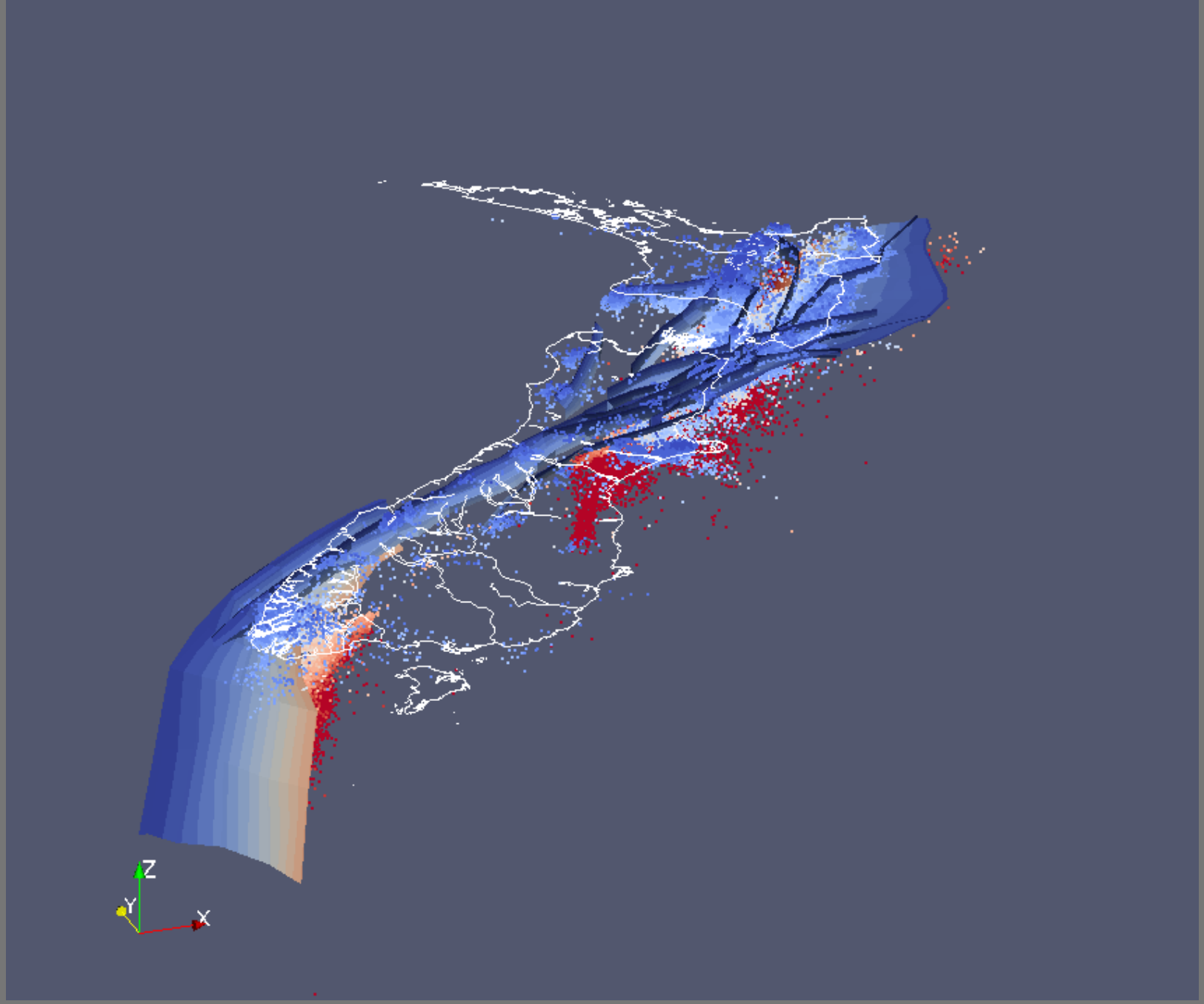
Relocated seismicity 2001-2011

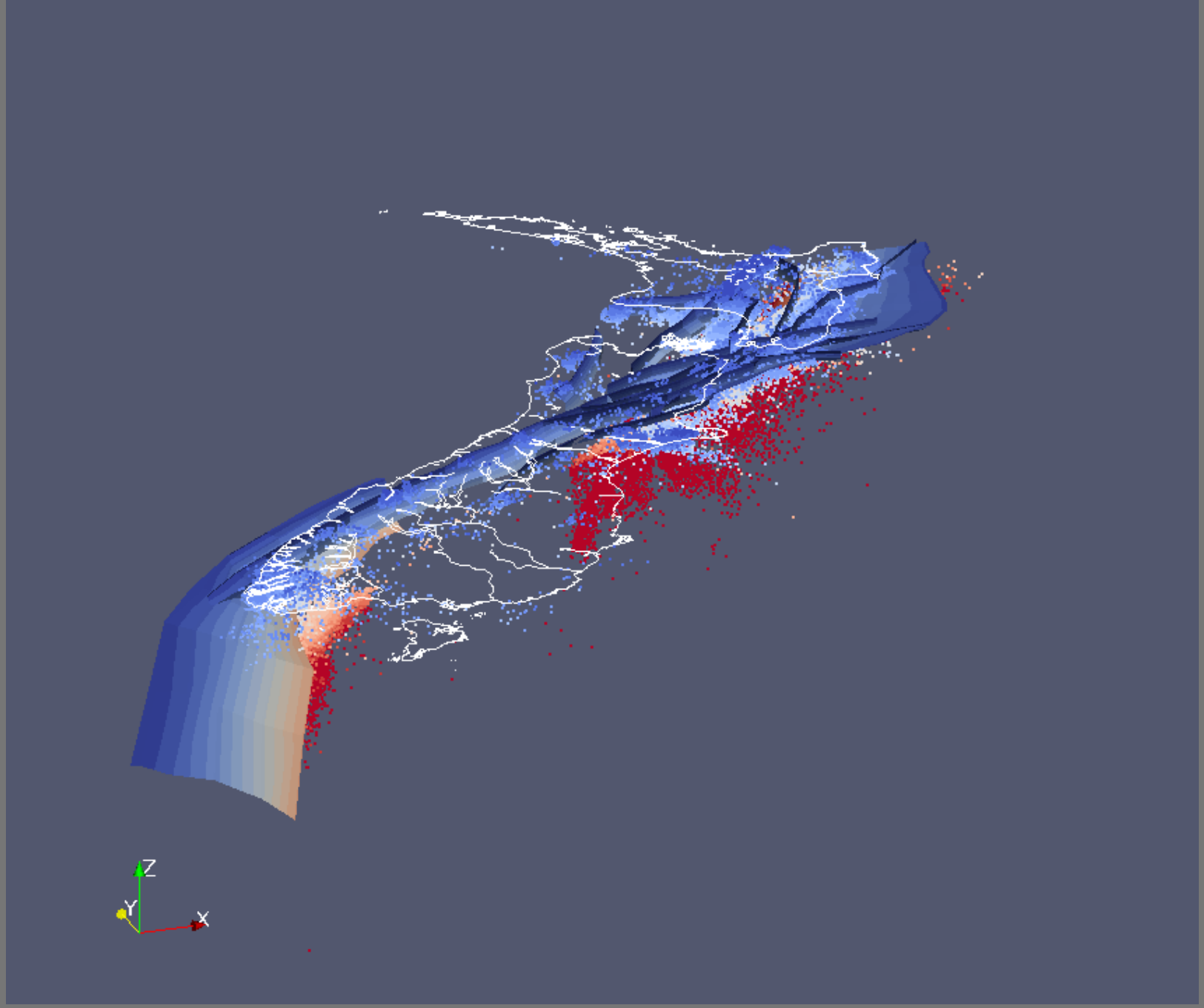




Reyners, pers. comm

Main fault boundaries also shown


Z
Y
X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Y
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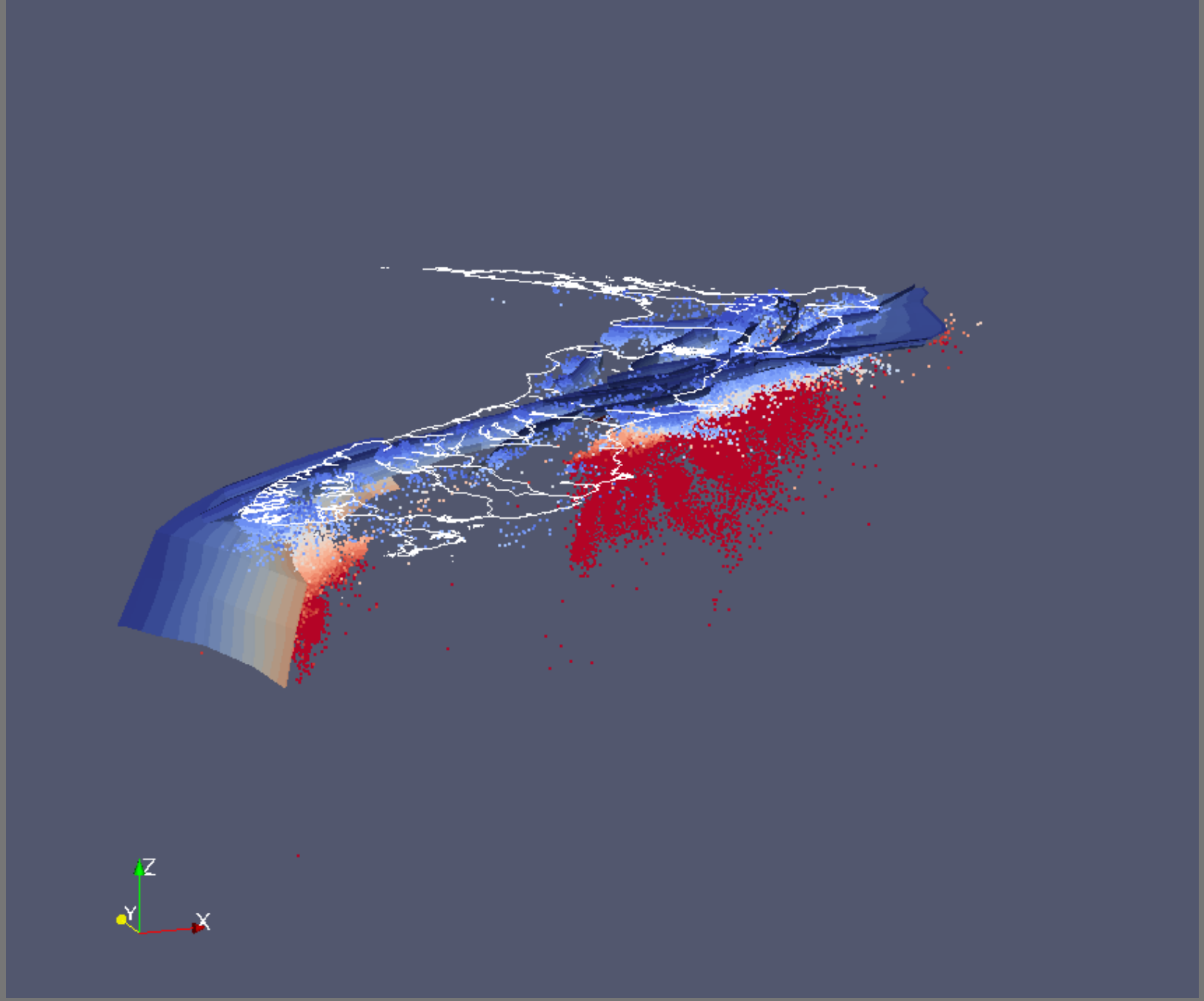
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Y
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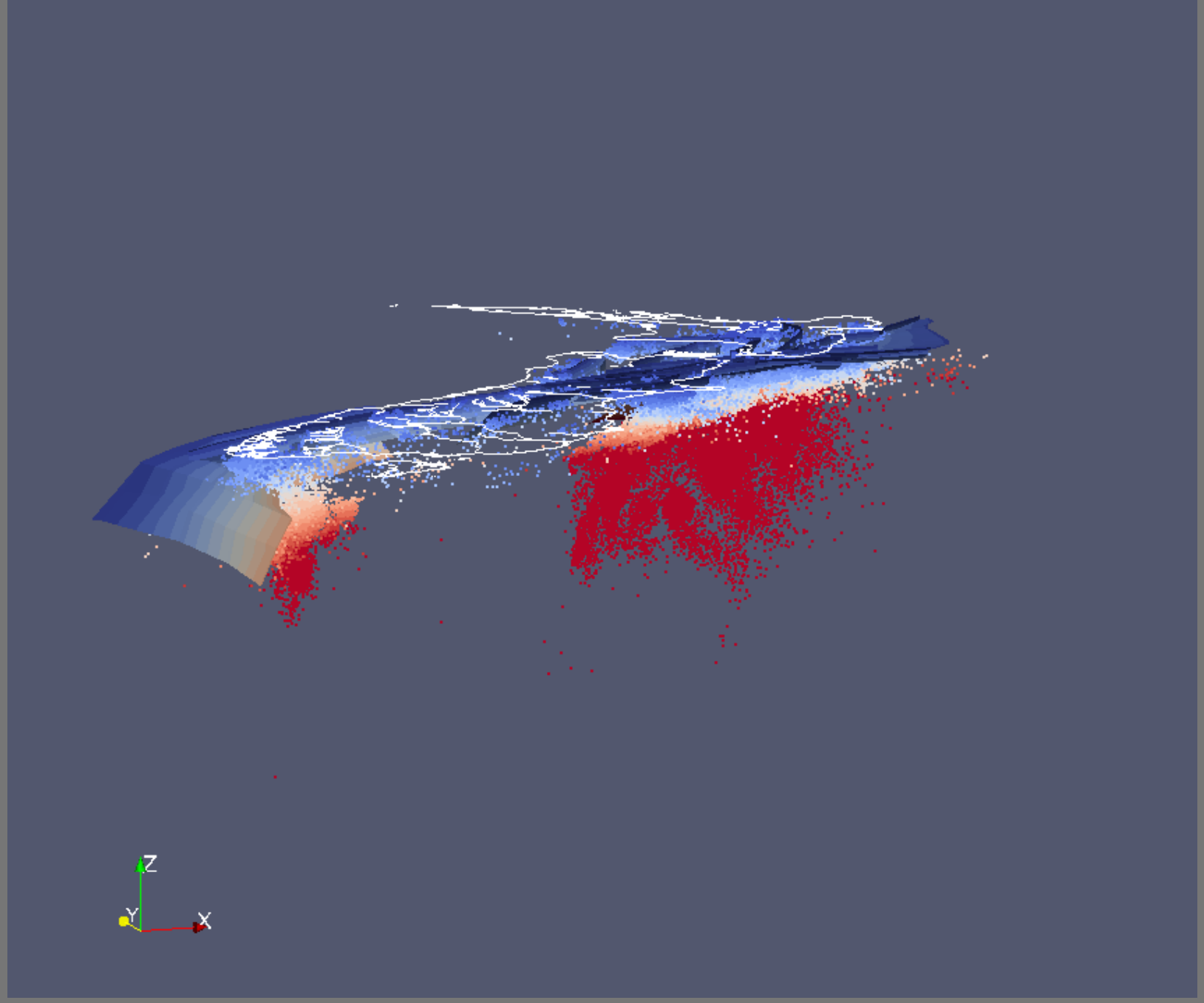
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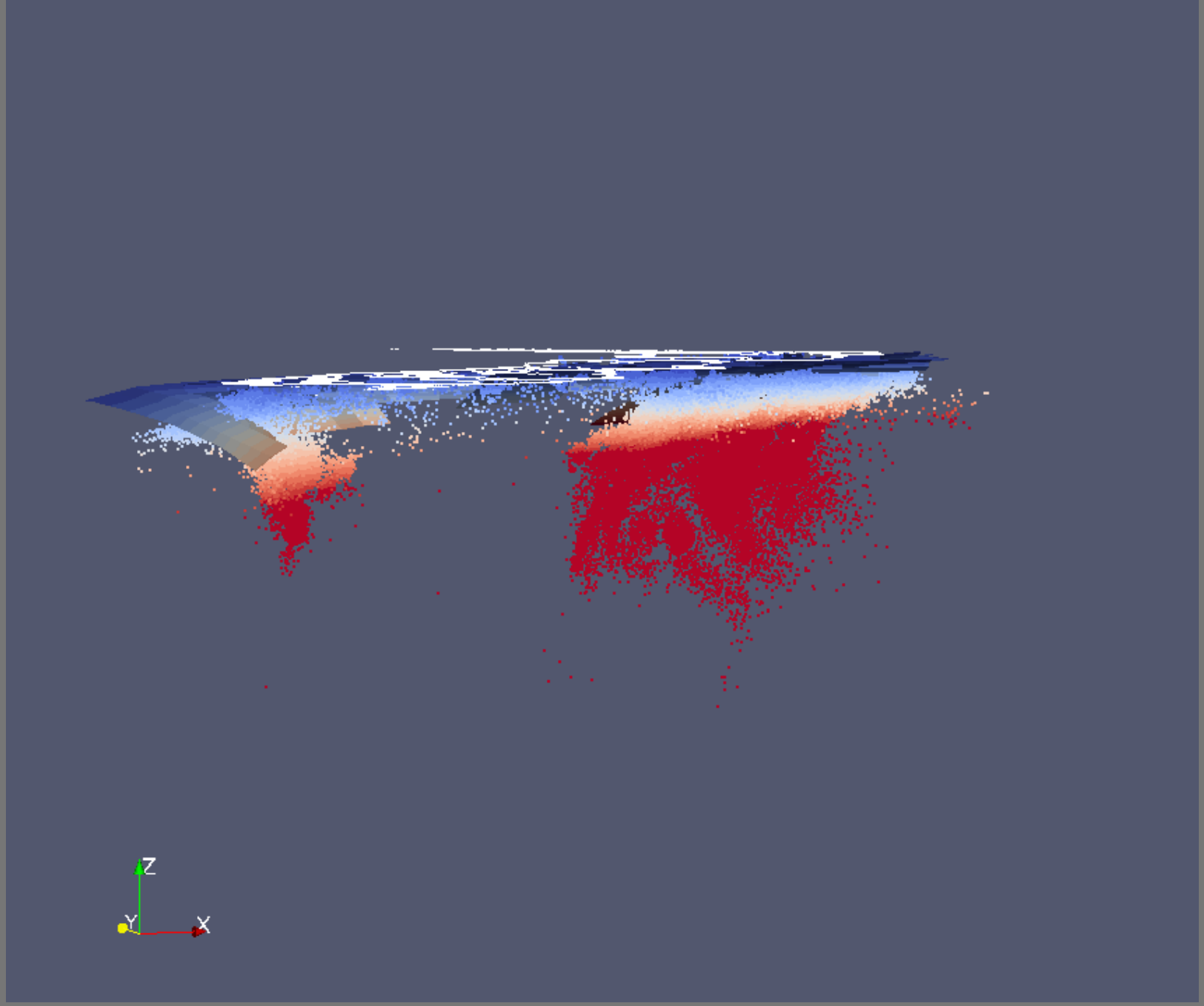
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Y
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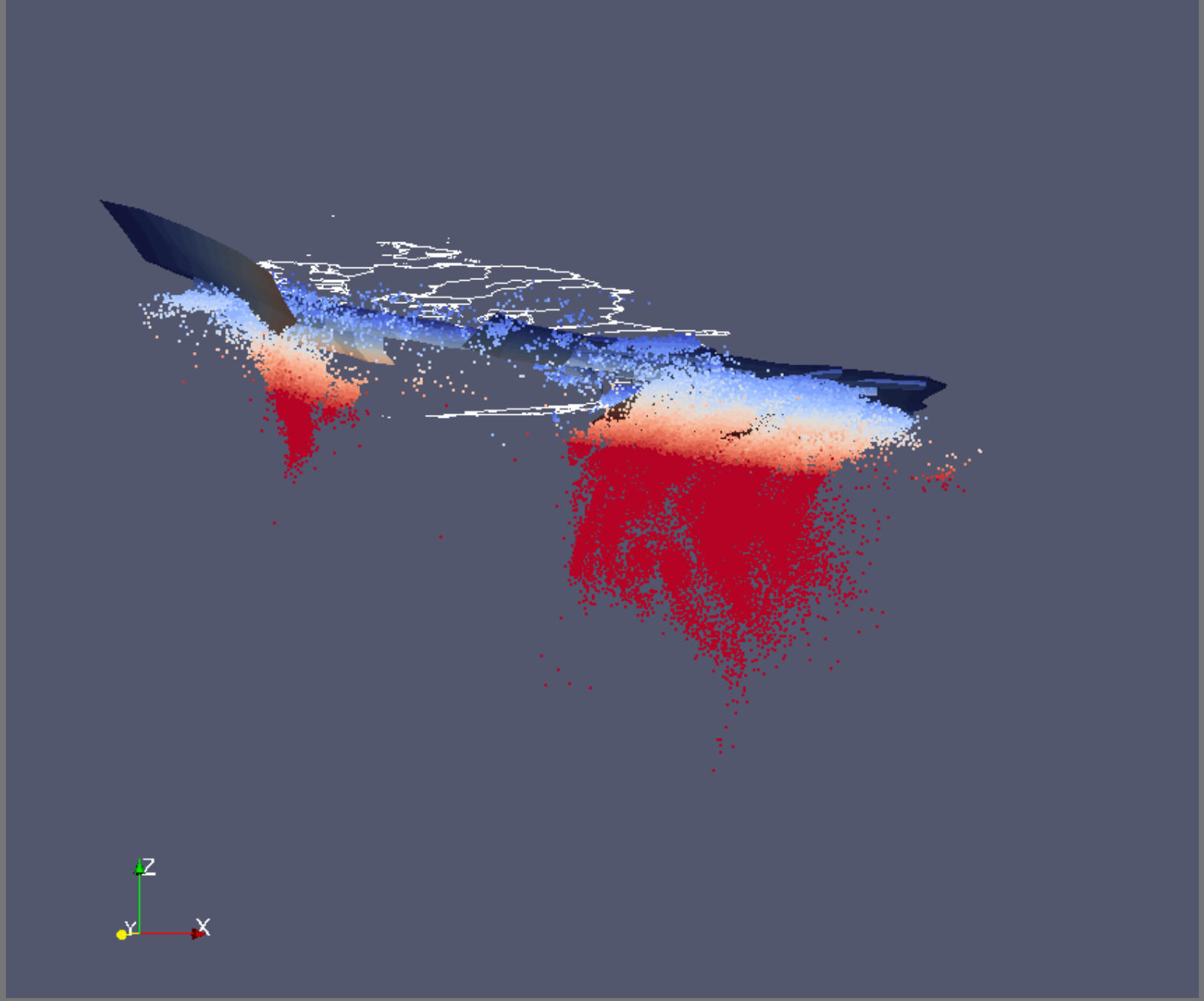
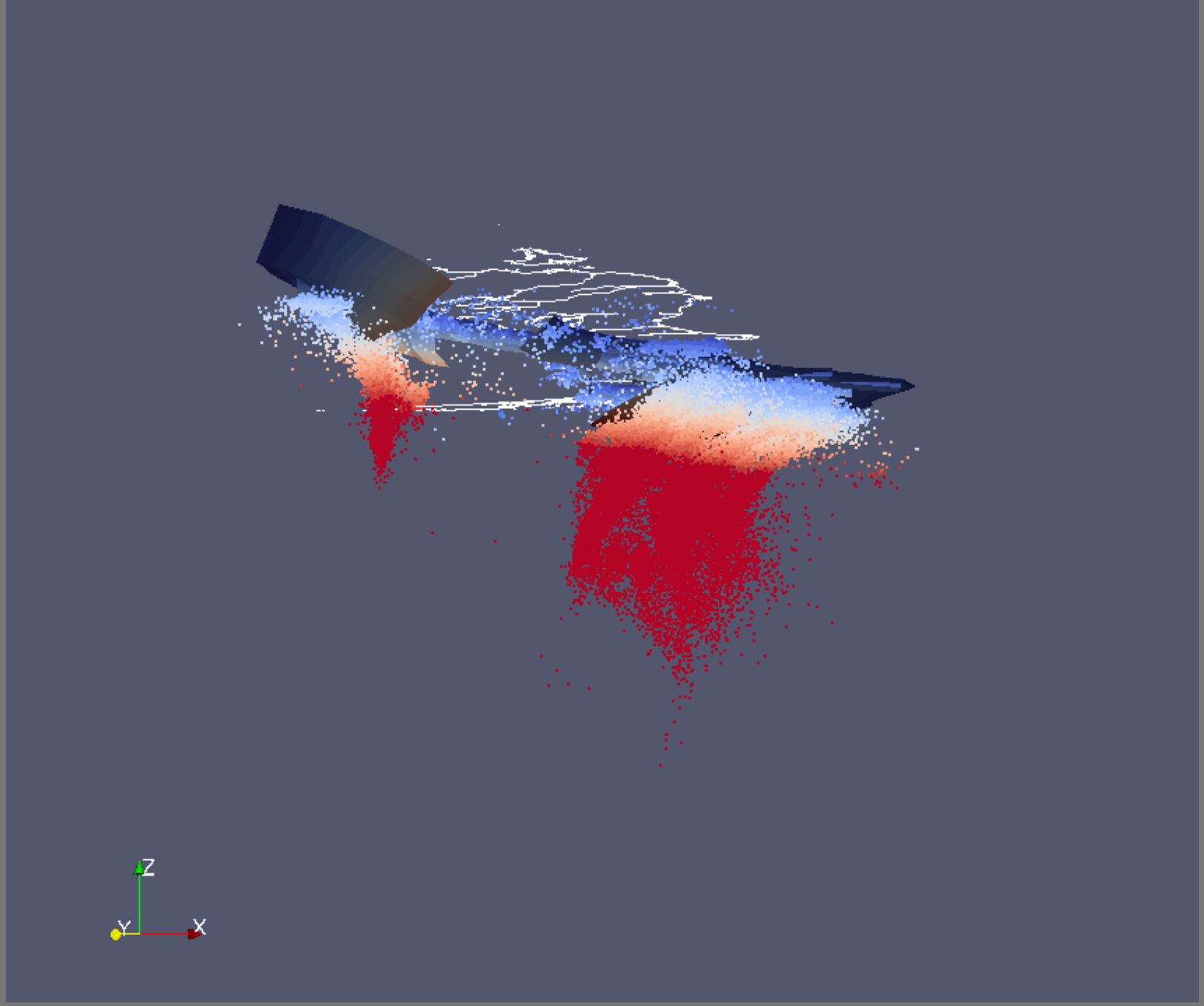
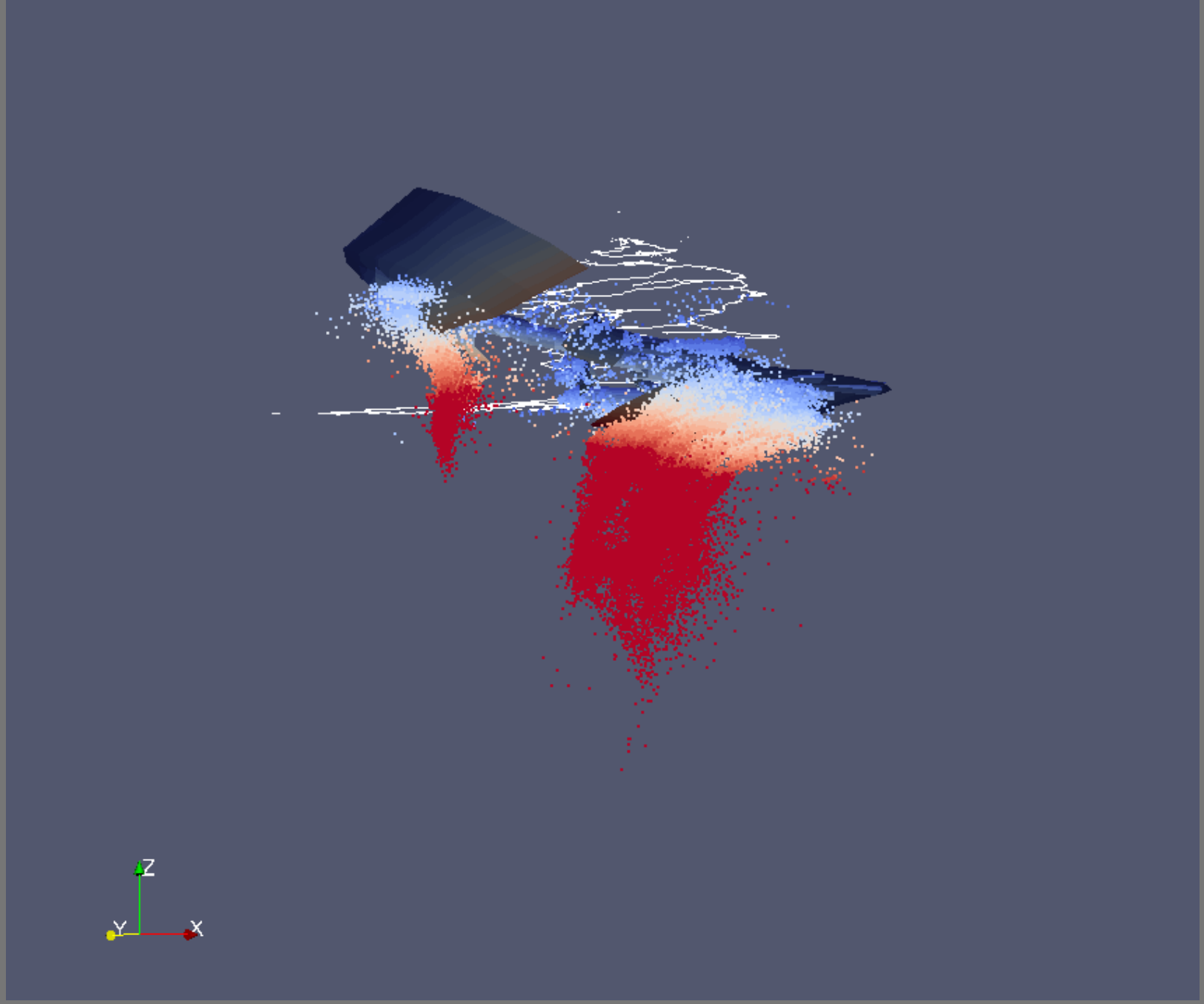
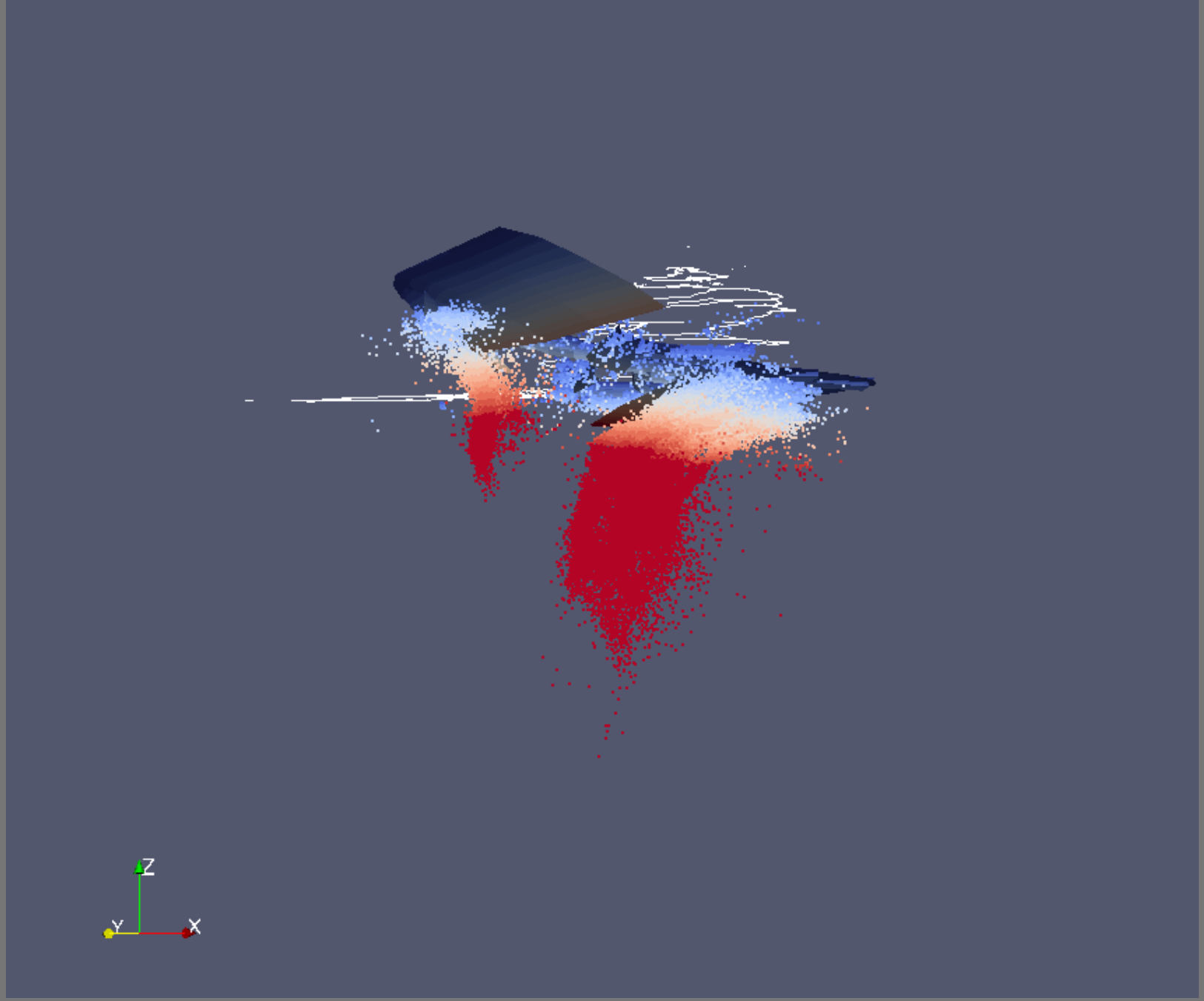

Z
Y
X


Z
Y
X


Z
Y
X


Z
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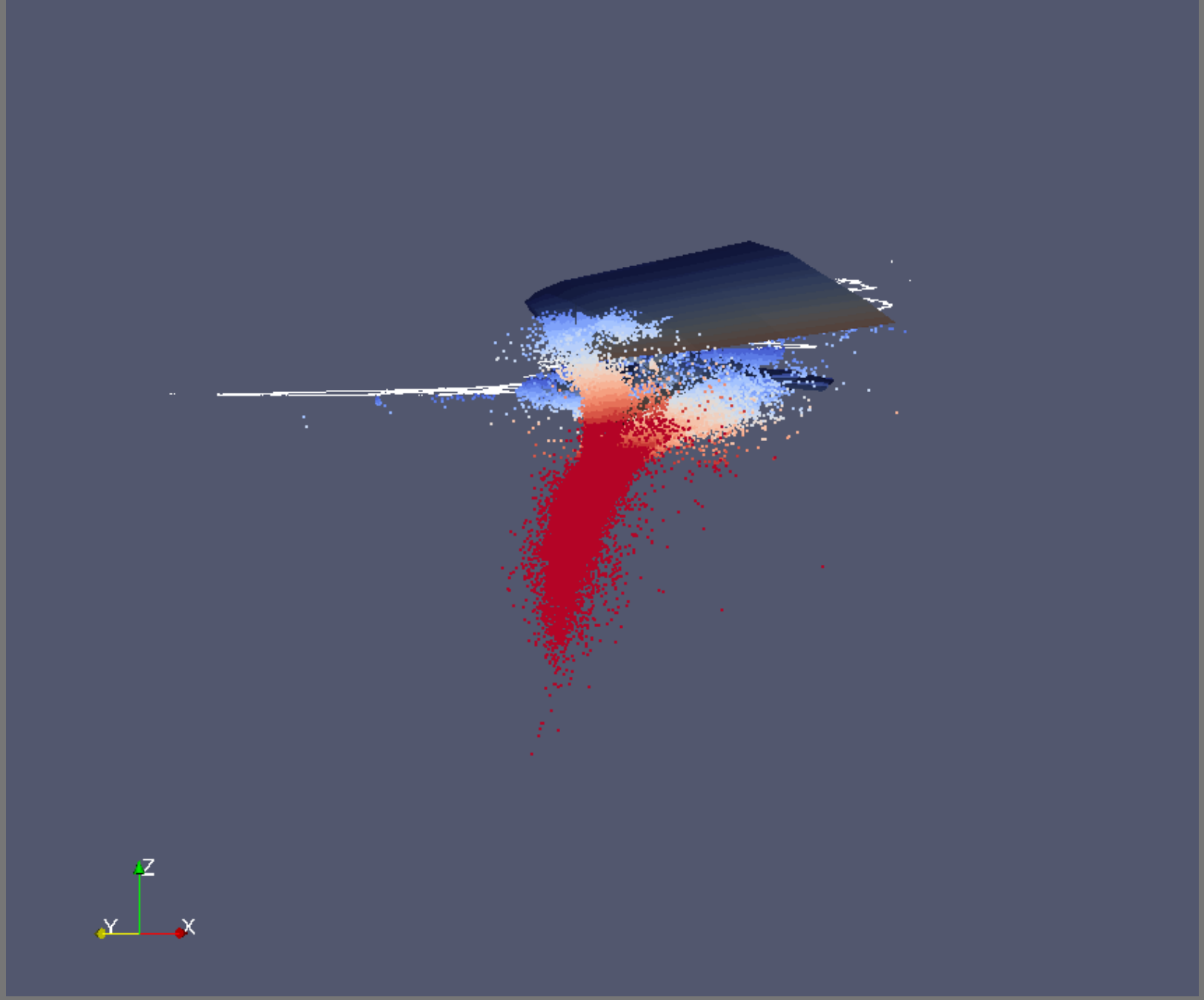
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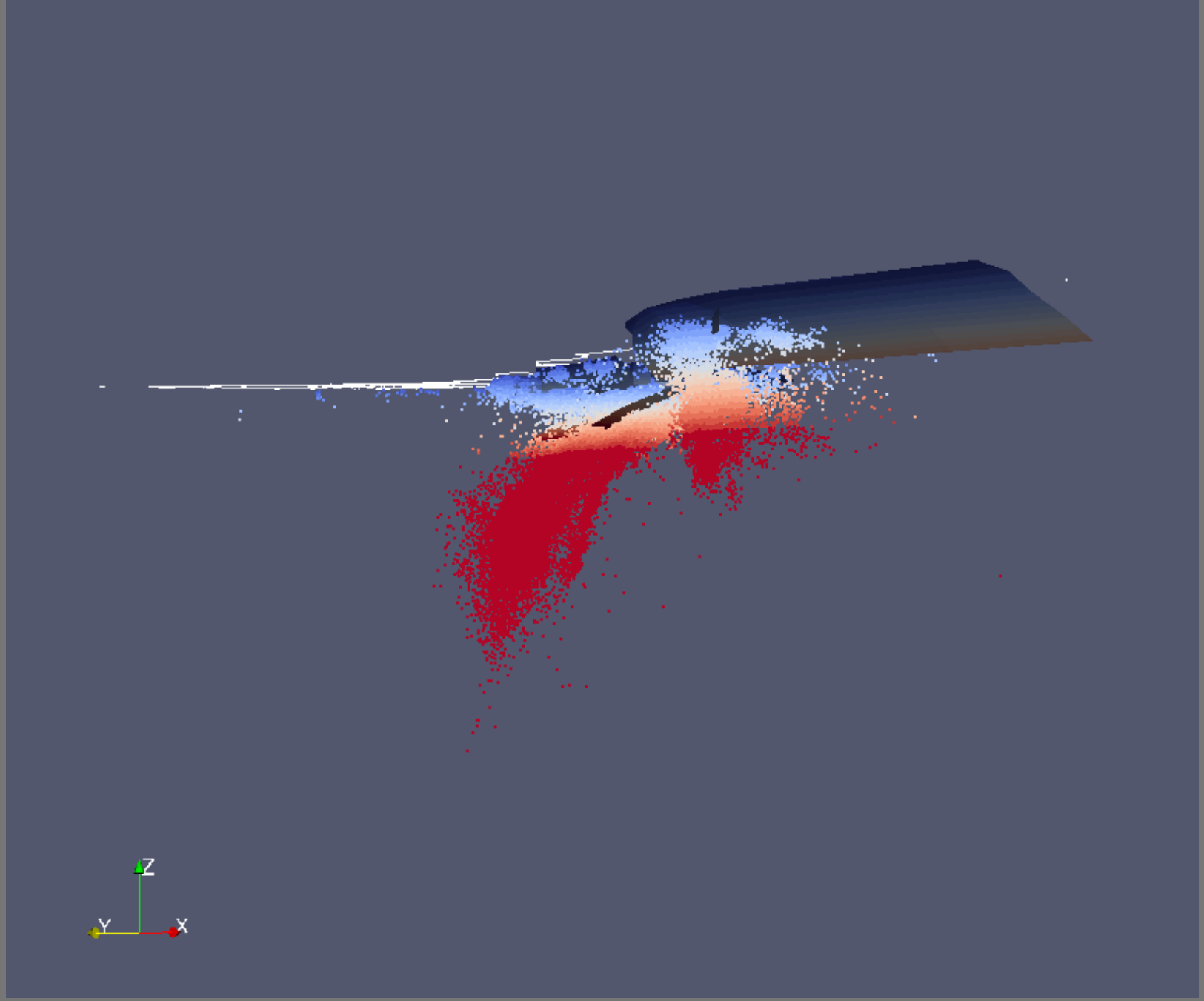
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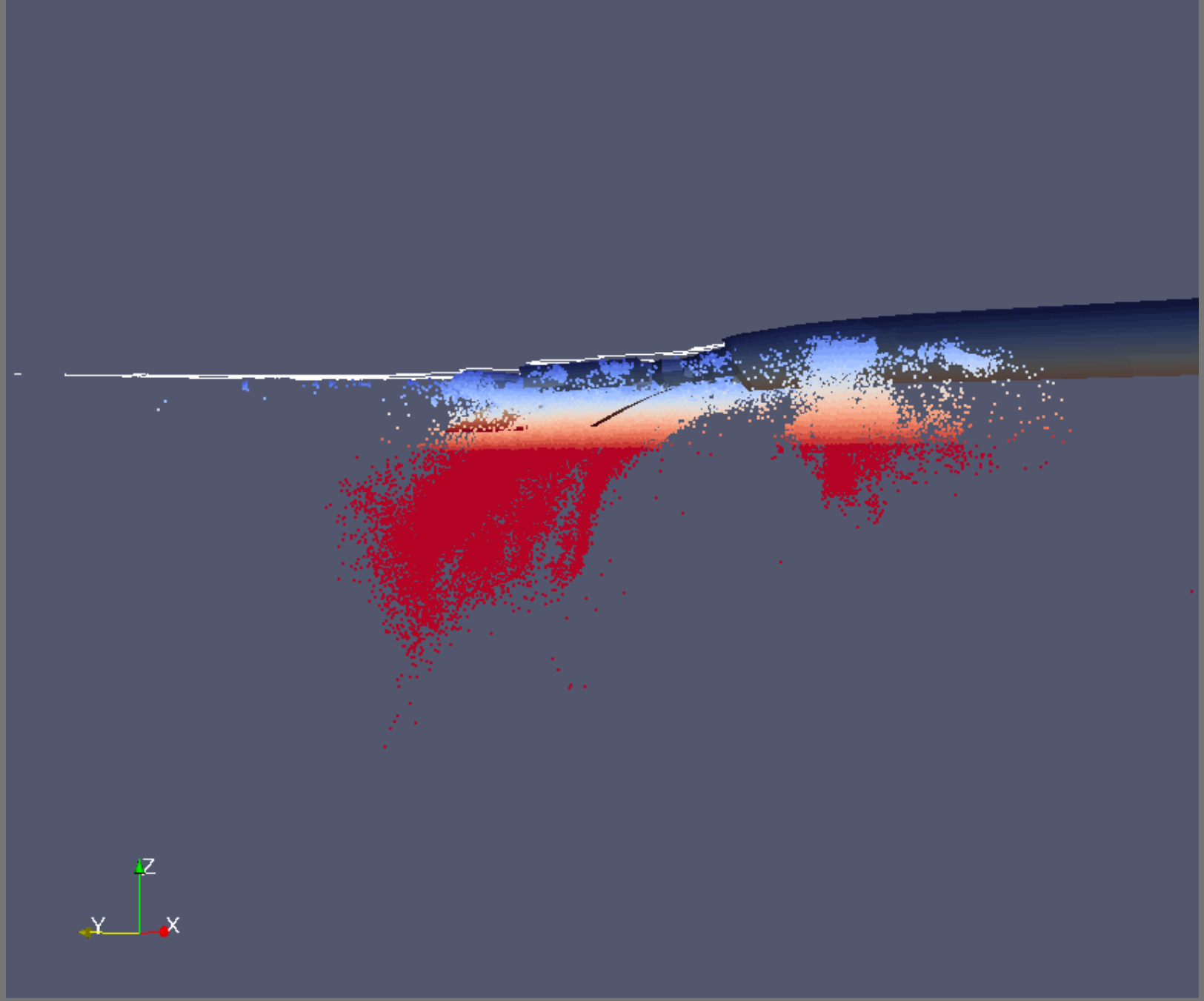
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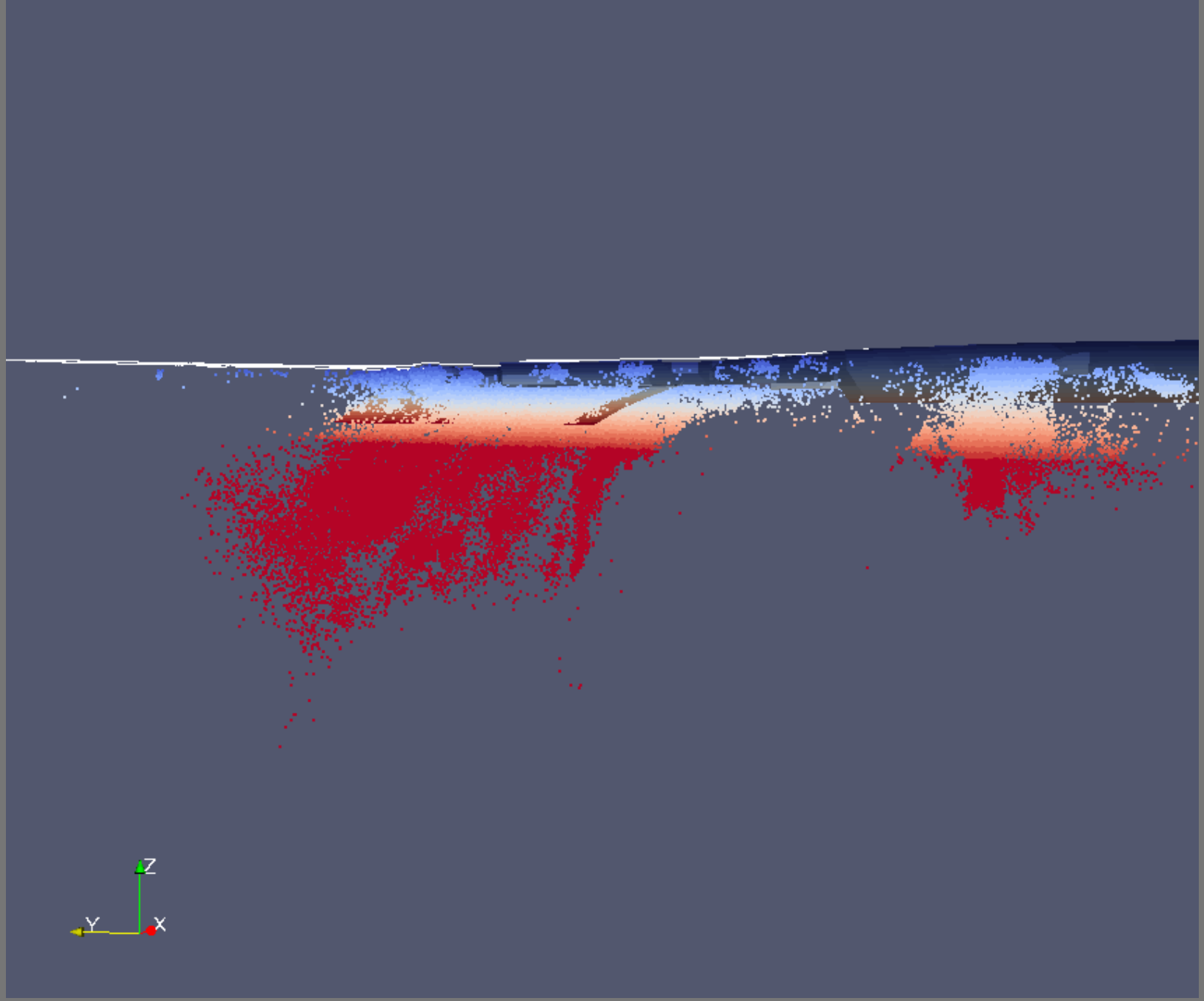
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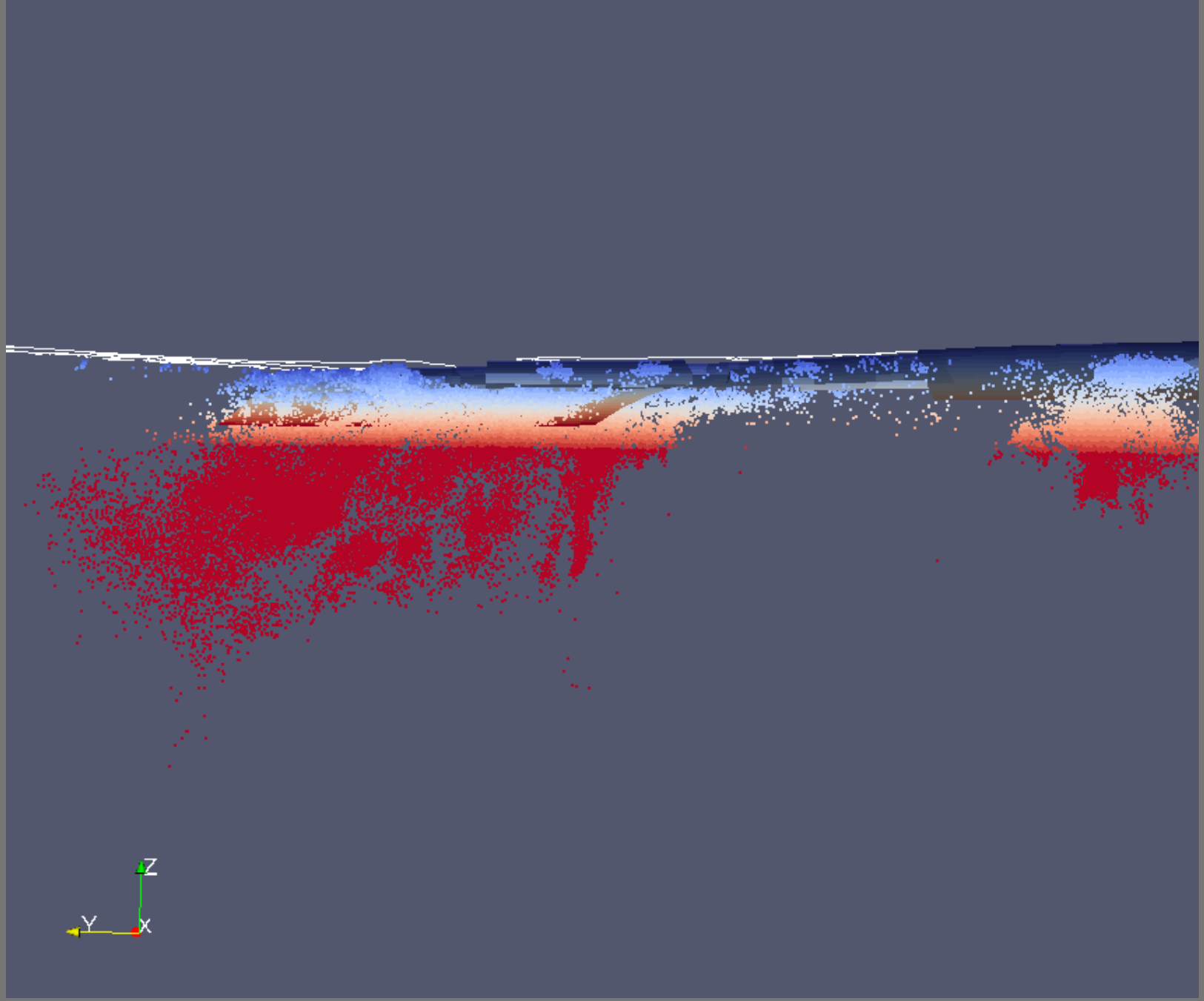
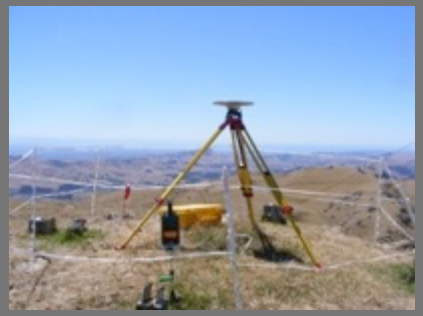

Z
Y
X

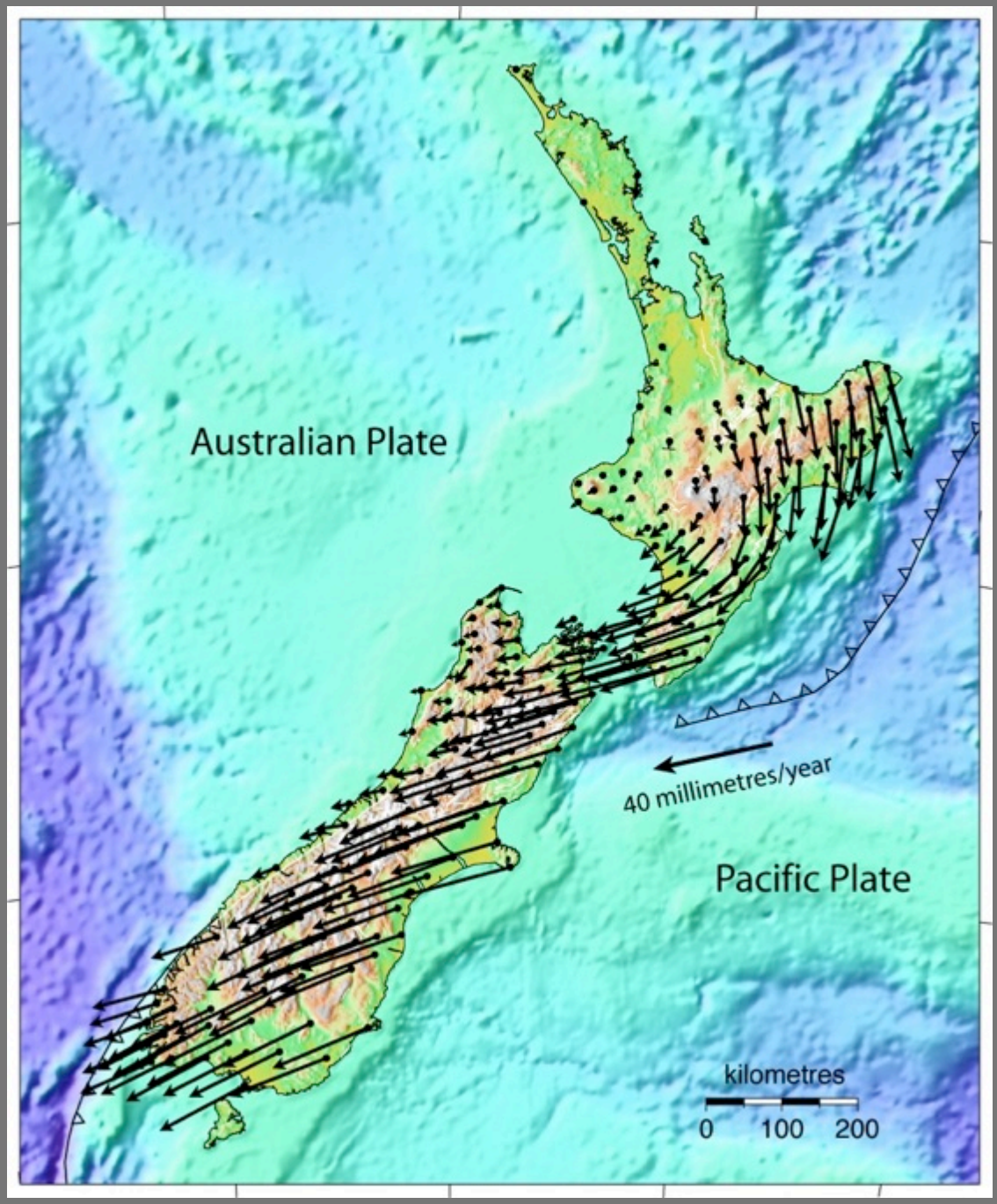
Present-day accumulating strain (strain-rate):

Surface velocities relative to Australian Plate from 1991-2005 GPS campaigns

- Approx 200 points plotted out of >800 measured



Updated from Beavan and Haines (2001)

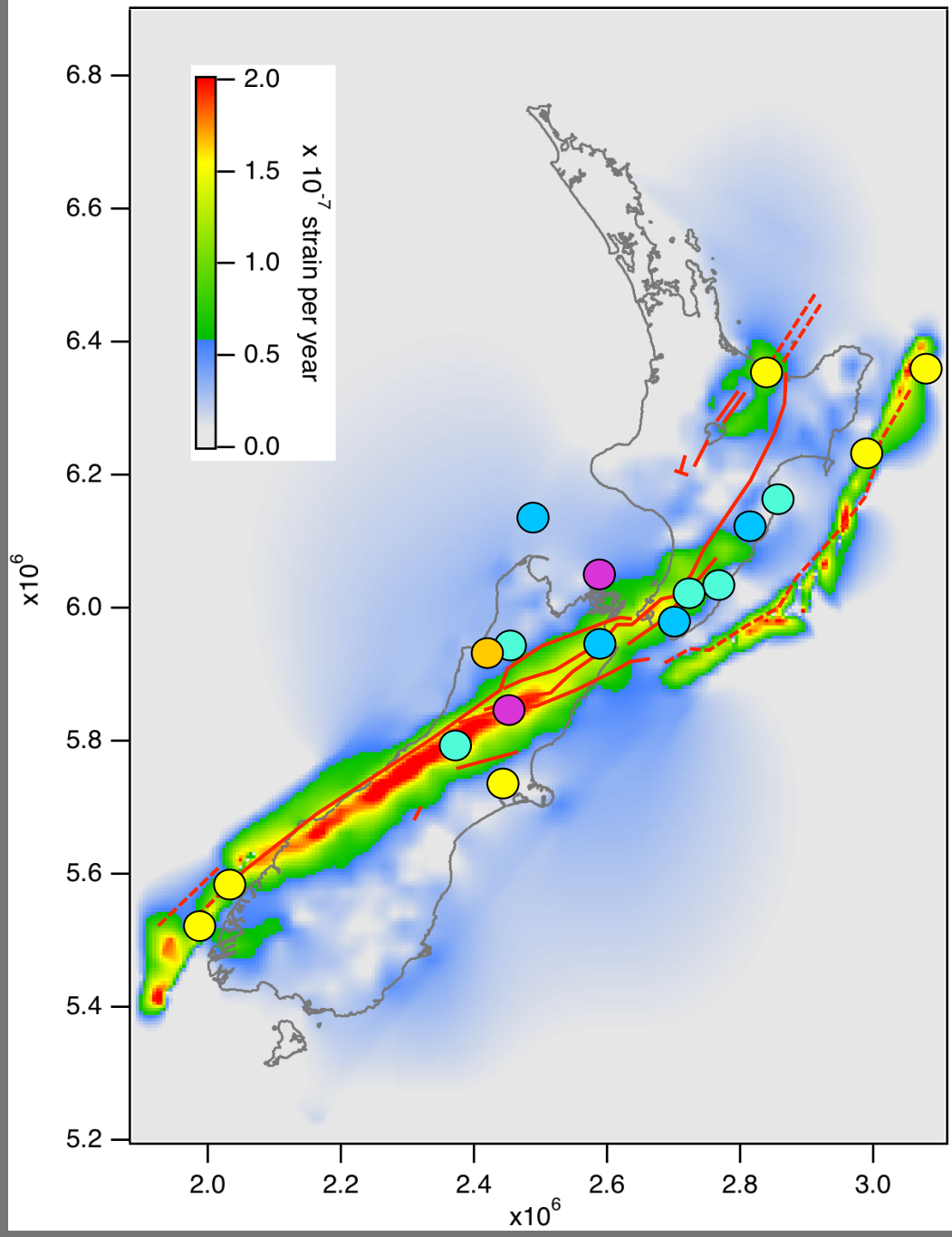


Maximum shear strain-rate (1996-2008 GPS data)

Main active faults with <2000 years recurrence interval

Shallow large NZ earthquakes since 1848

- 1848-1868
- 1888-1893
- 1929-1942
- 1968
- 1987-present



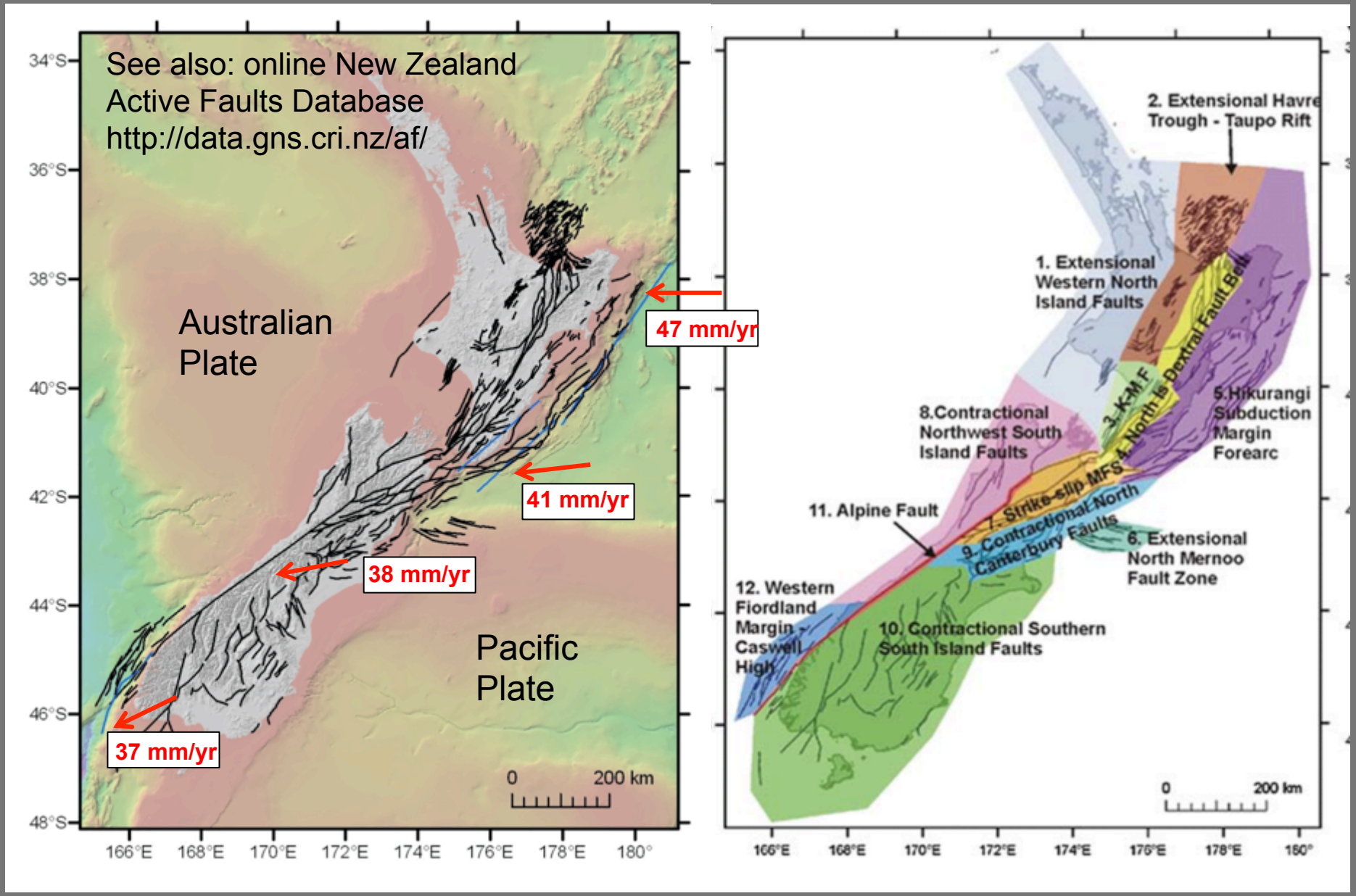
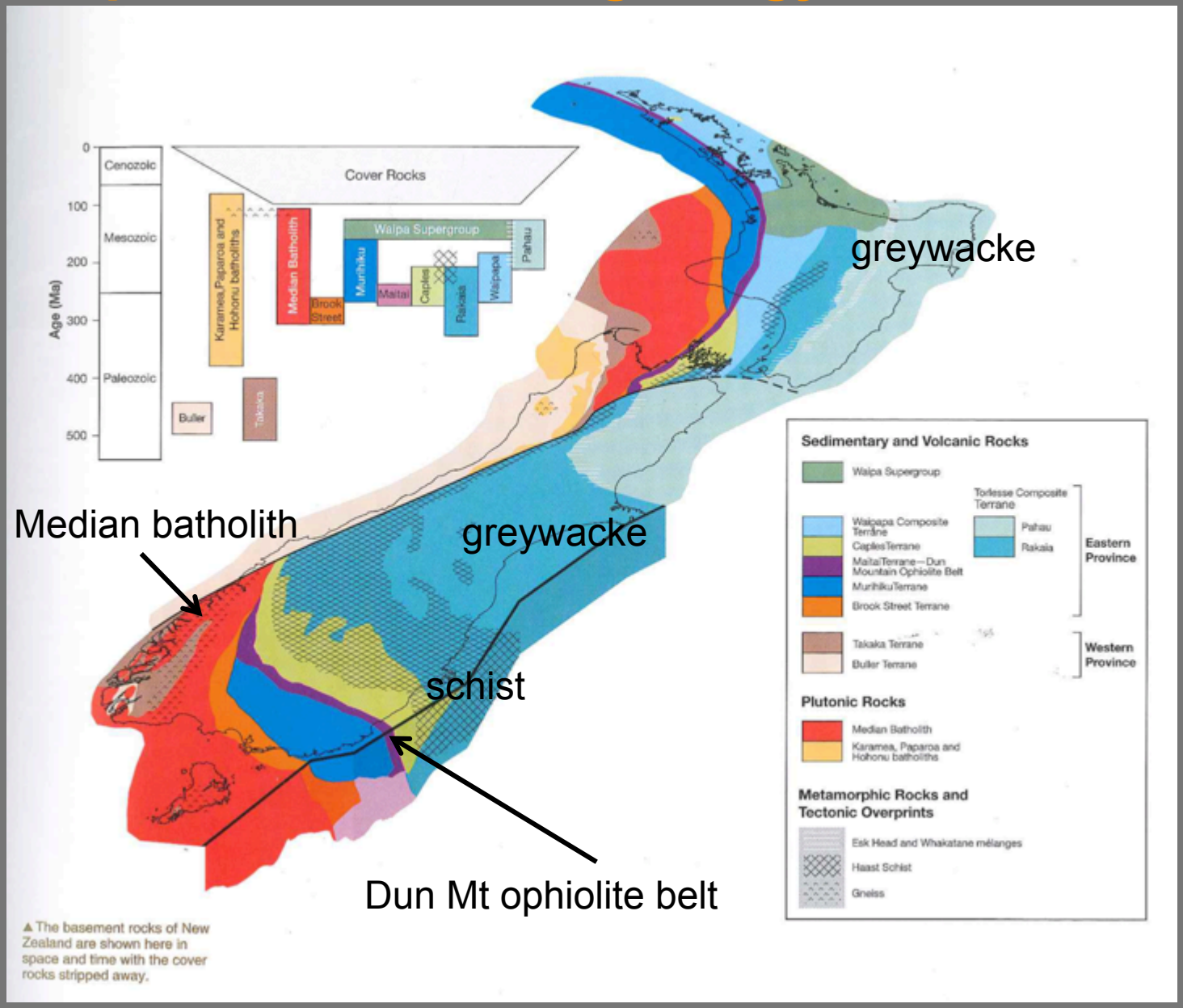


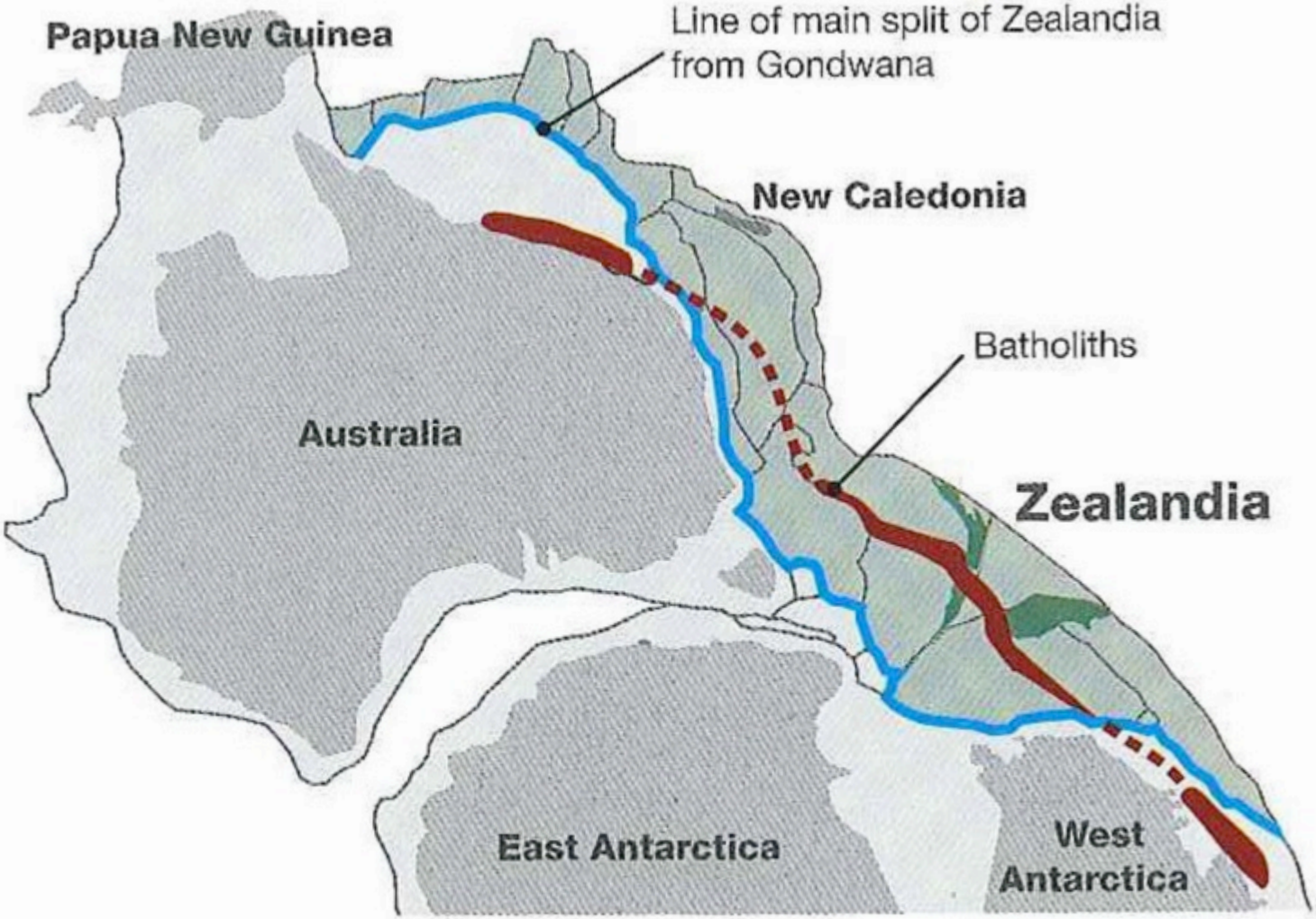
Figure after Stirling et al., 2012

Simplified basement geology



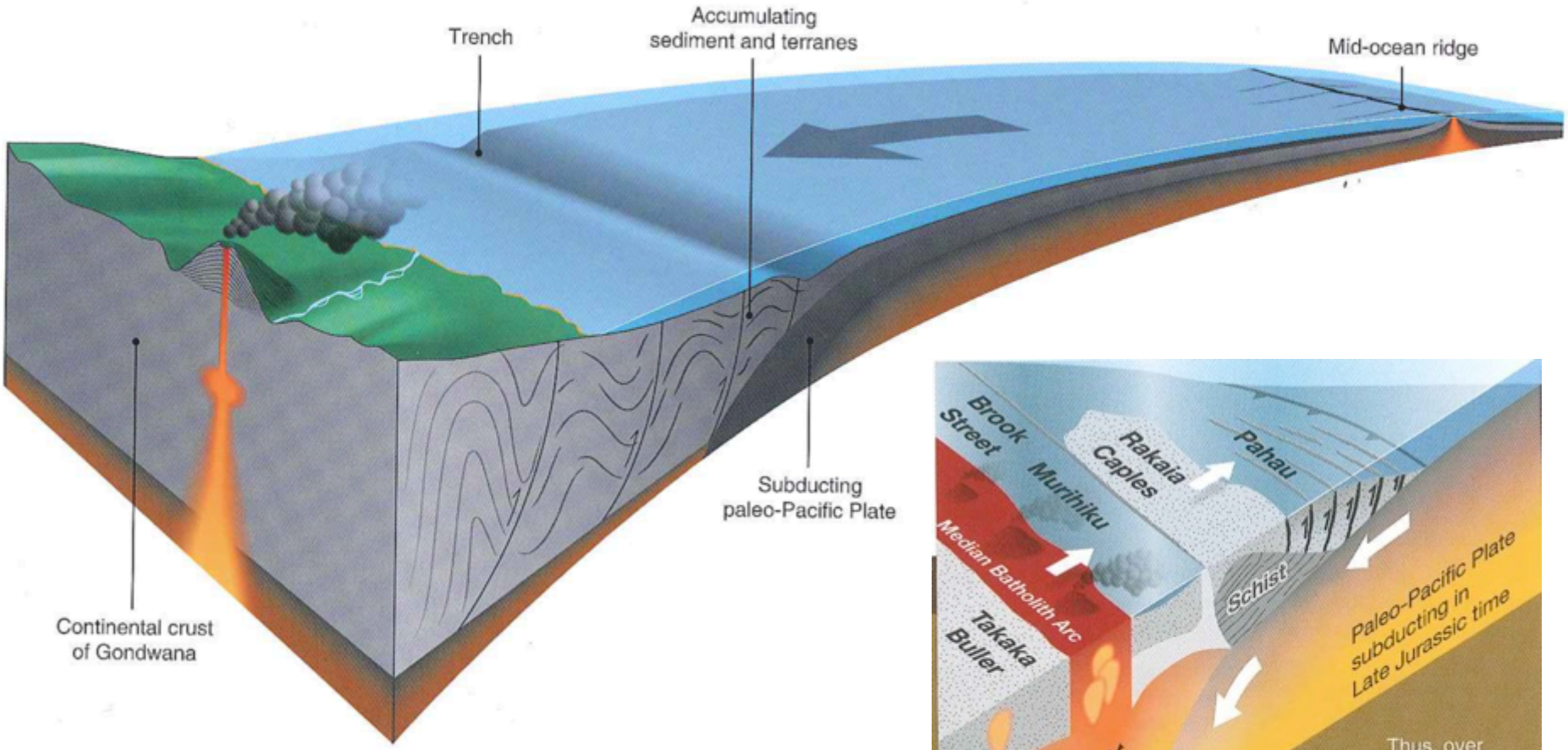
▲ The basement rocks of New Zealand are shown here in space and time with the cover rocks stripped away.

Greywacke + schist make up ca. 40% of NZ basement rocks!



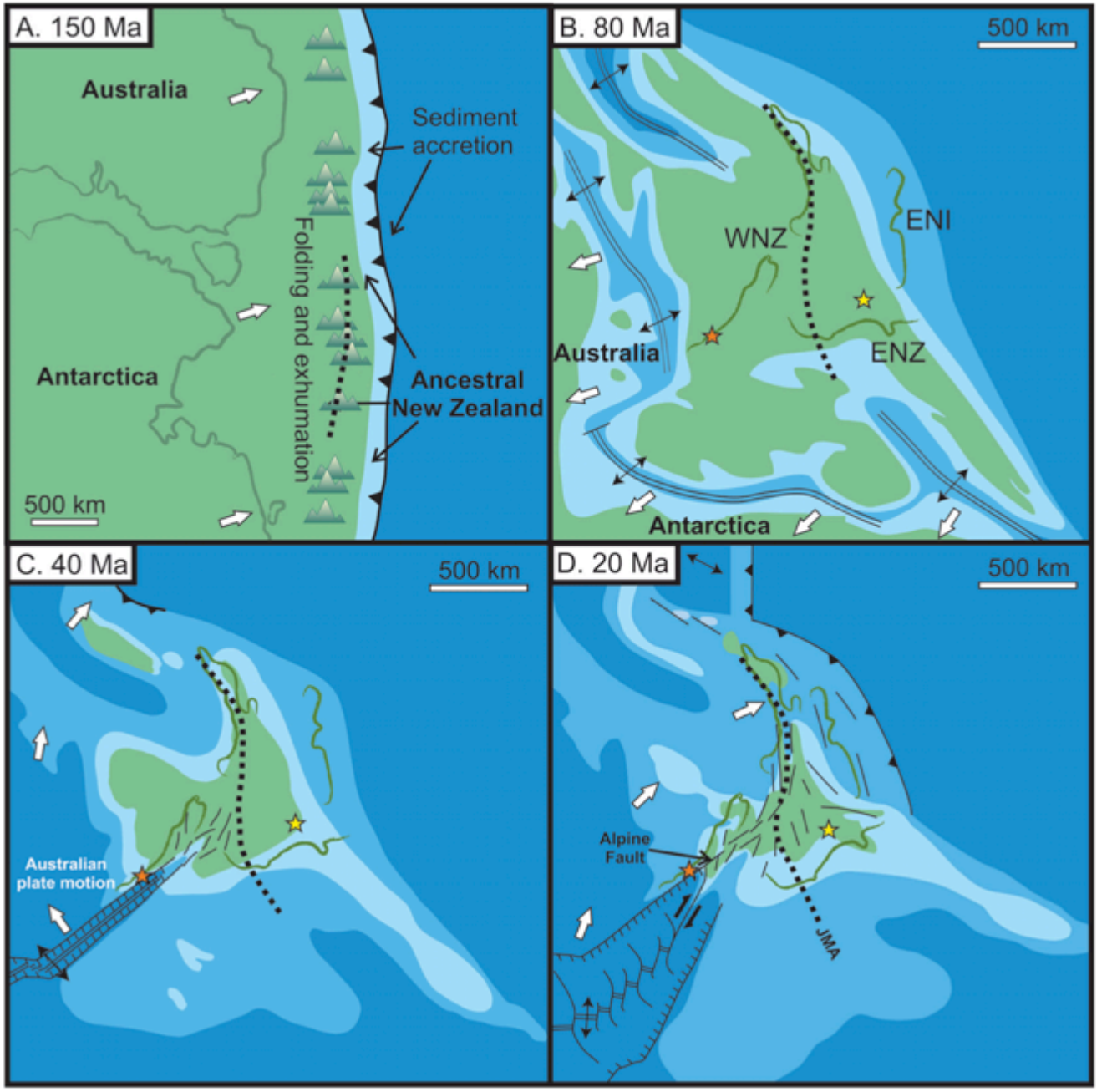
▲ The continent of Zealandia, restored to its former position in Gondwana 90 million years ago, is seen to contain geological features common to Australia and Antarctica.

▼Gondwana grew sideways as terranes were scraped off progressively from the subducting paleo-Pacific Plate, and upwards as magma rose in the crust and erupted from volcanoes.



Diagrams from “A Continent on the Move”

Ca. 150 Ma



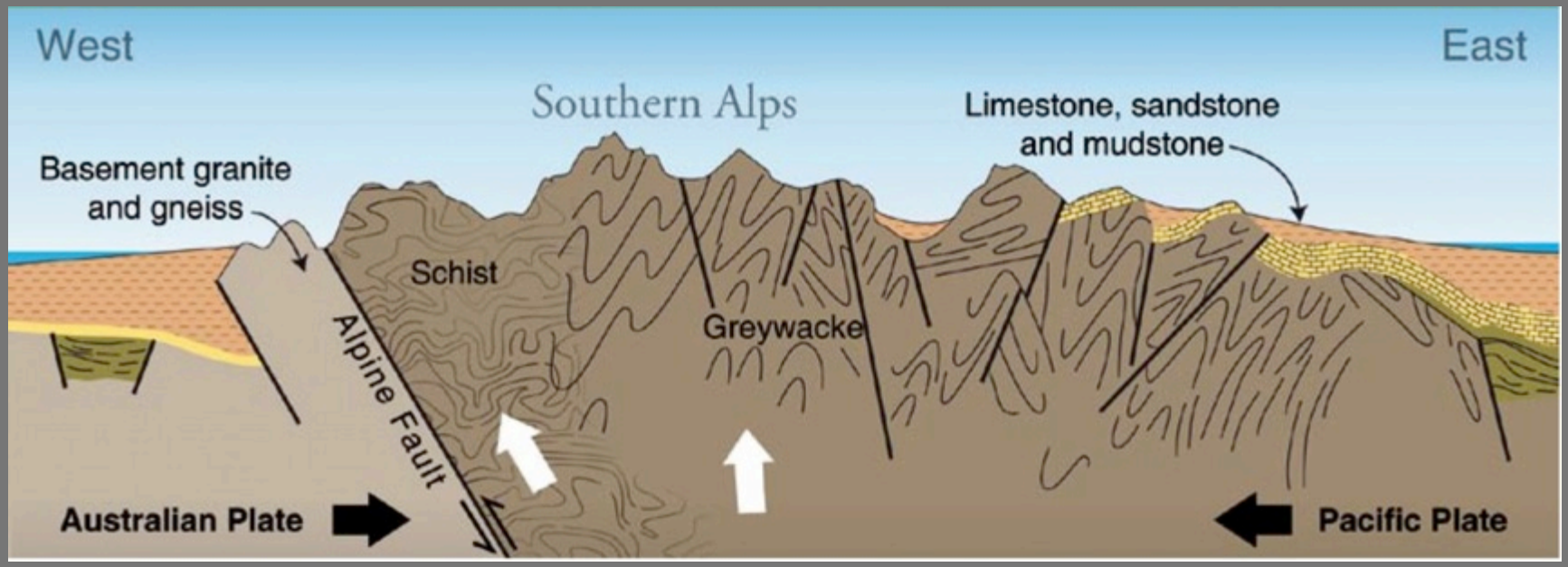
Cox & Sutherland 2007
AGU Monograph 20

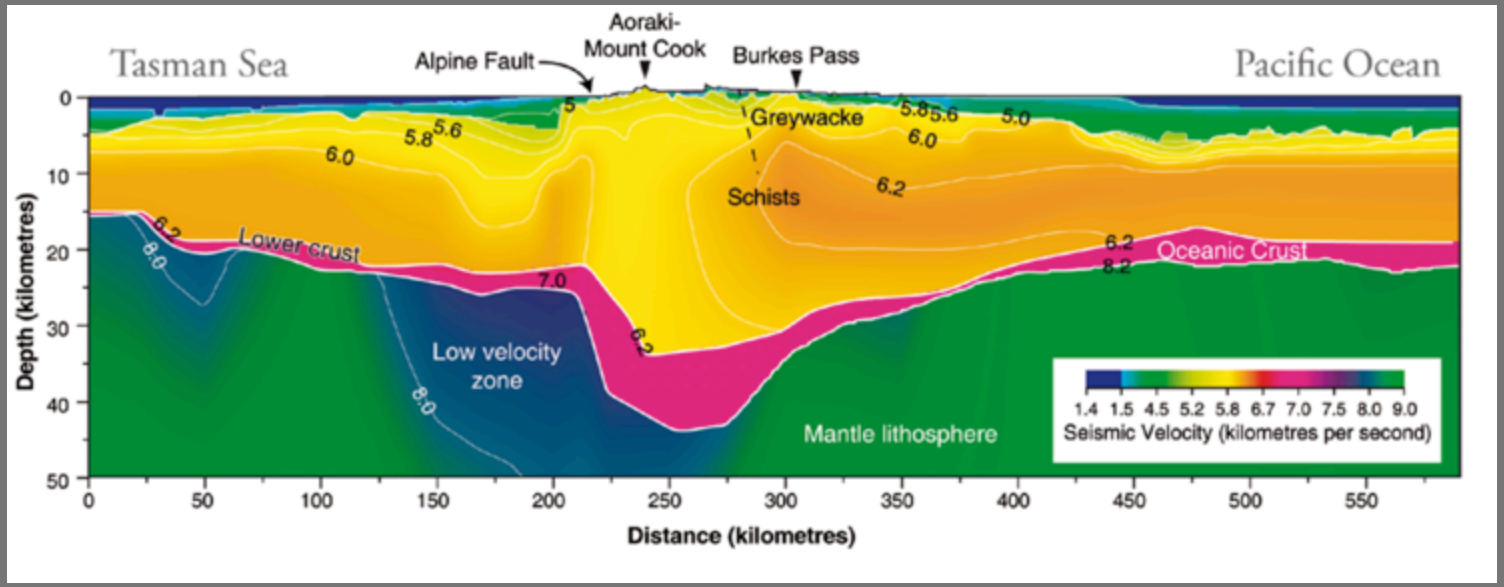
Alpine Fault

23-27 mm/yr; no surface creep: episodic slip

8 m offsets suggest large or great EQs

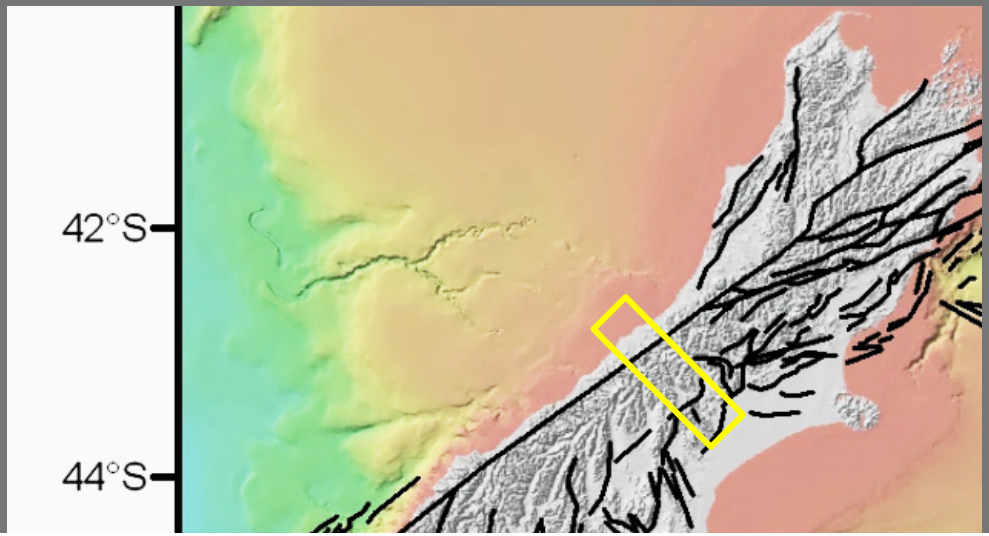
Pre-historic ruptures: 1717 (7.9 ± 0.3),
1620 (7.6 ± 0.3), and 1440 A.D. (7.9 ± 0.4)





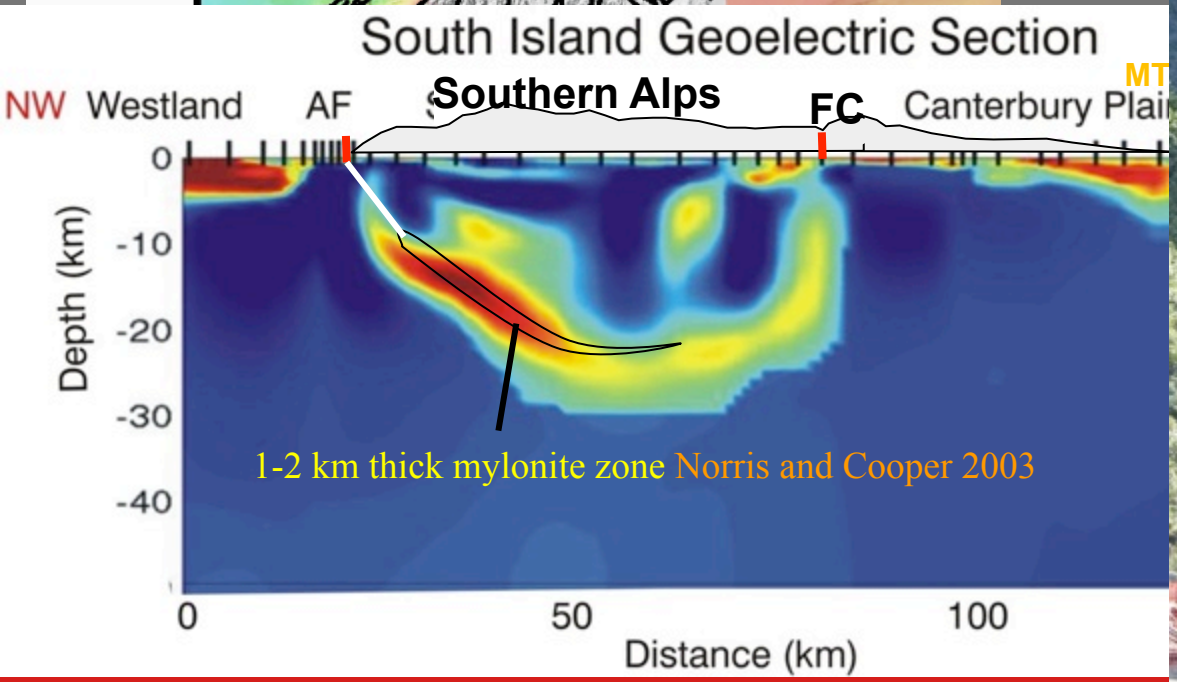
SIGHT geophysical transect (1990s)

MT resistivity anomaly and other geophysical anomalies below Alpine Fault



Drilling for answers

- Rock cores
- Downhole geophysics
- Fault zone observatory



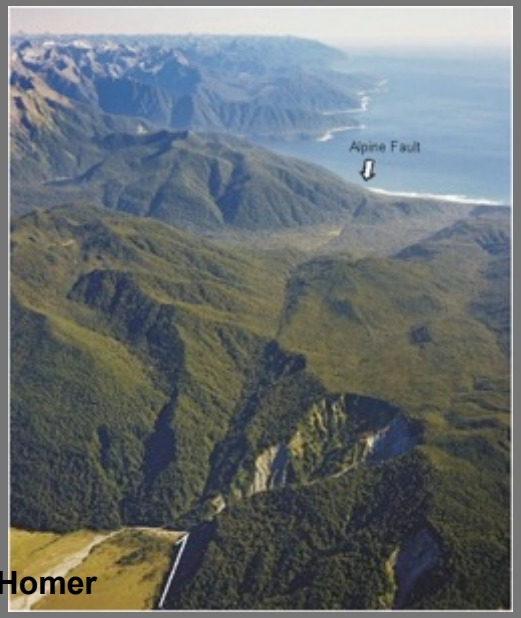
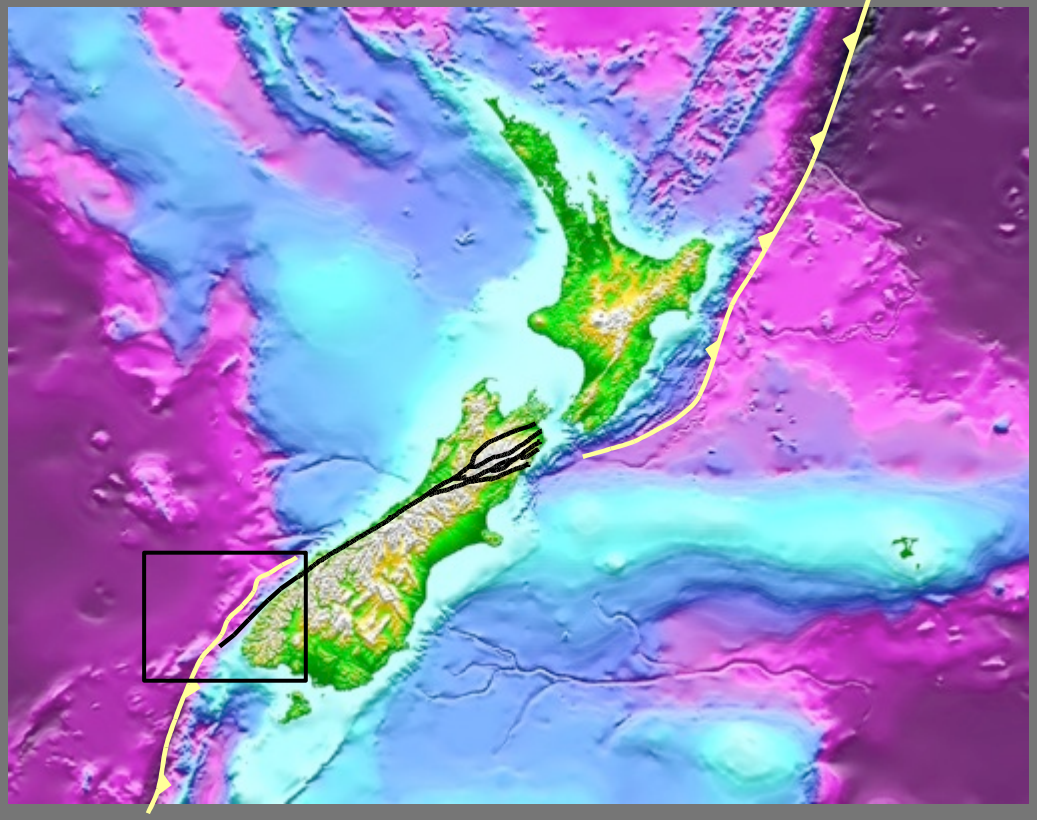
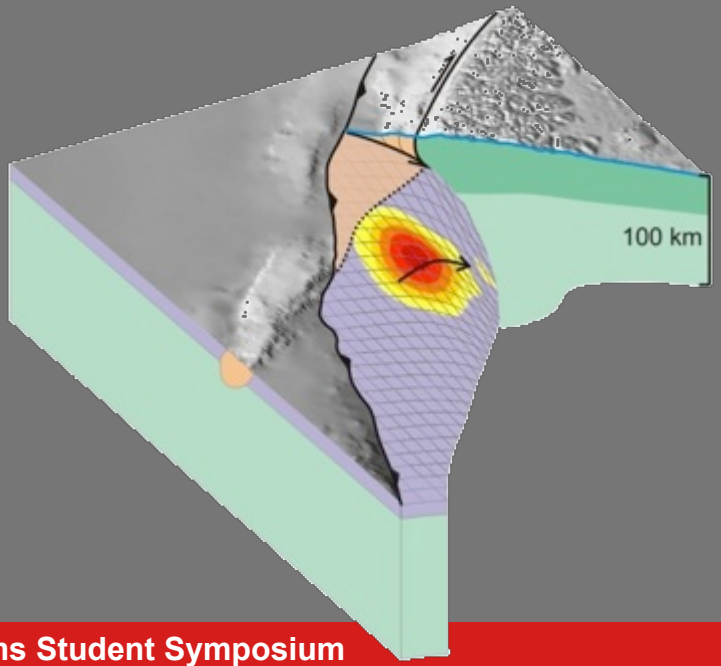


Photo: D.L. Homer

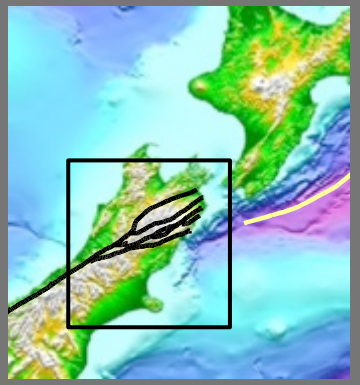


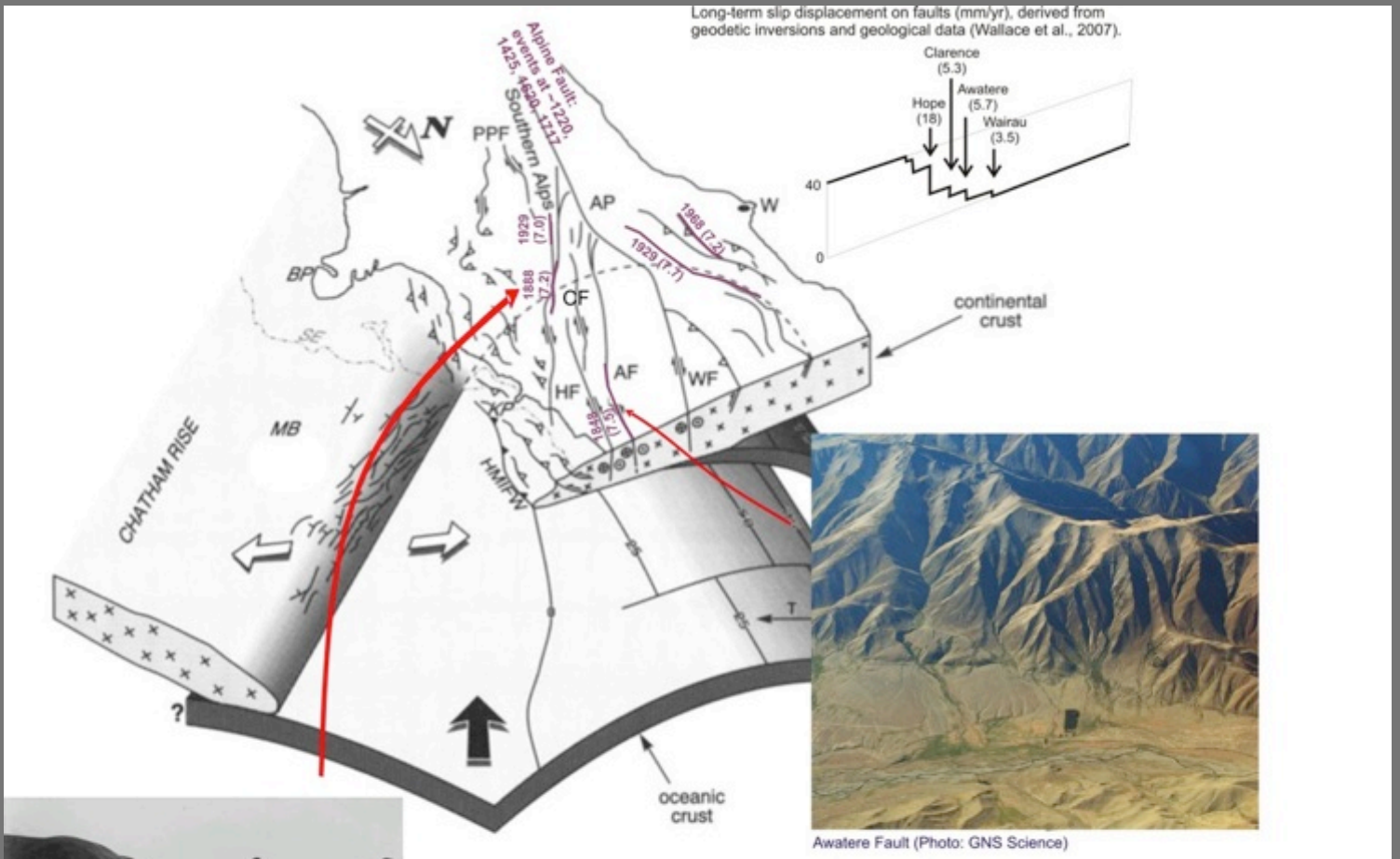
July 2009 M7.8 Dusky Sd. earthquake



Steep slab, has not subducted very deep
Partitioning between A.F. and interface
Highly oblique

Marlborough Fault System: transition collision to subduction



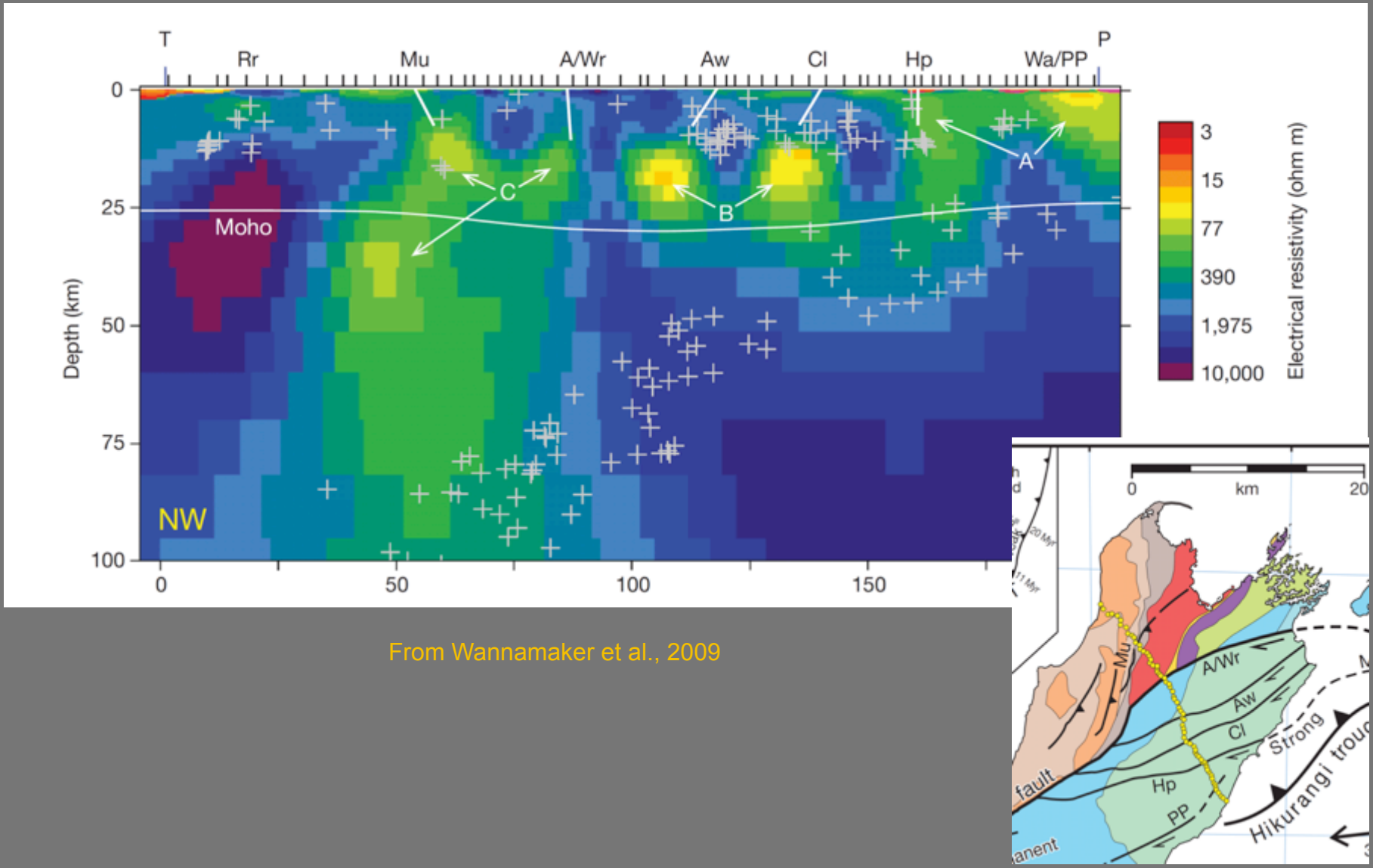


Awatere Fault (Photo: GNS Science)

Fenceline displaced in 1888 Hope Fault earthquake (Photo: A. McKay, courtesy of the Te Ara encyclopedia)

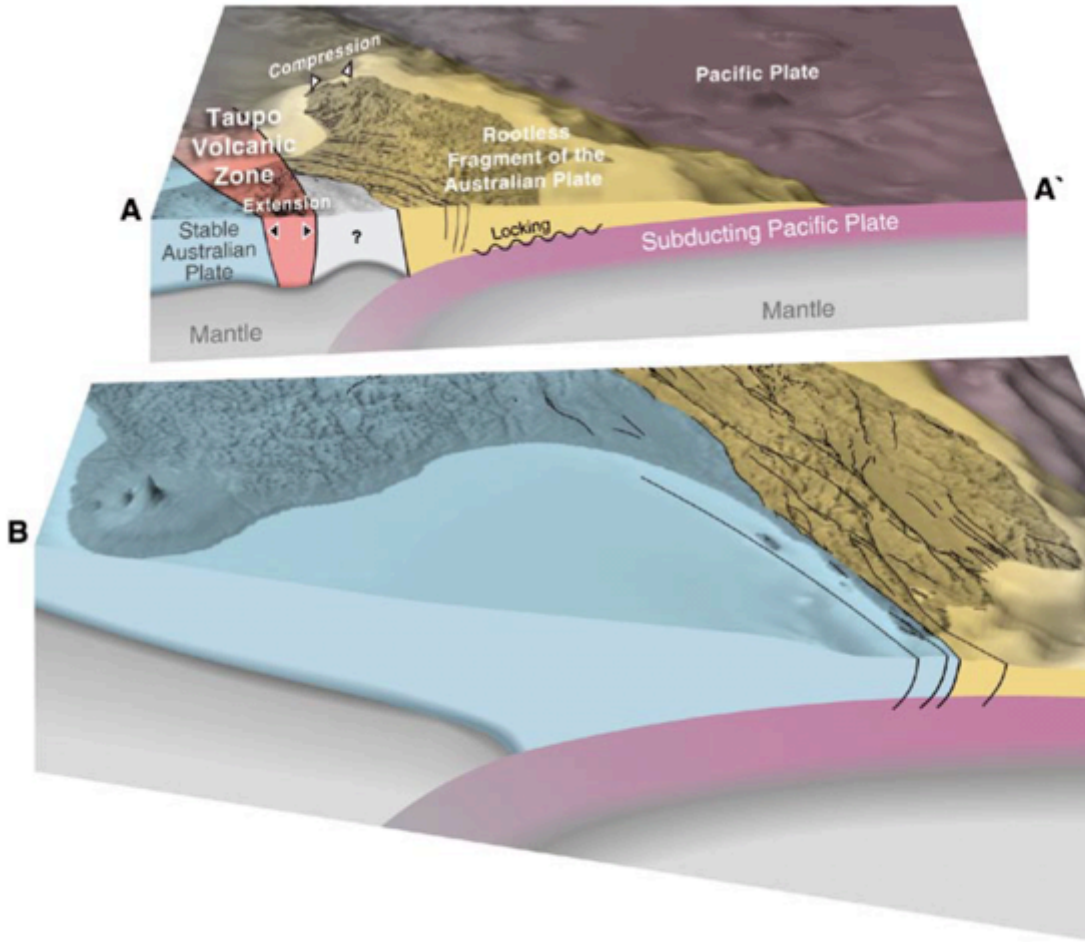
Background image from Phil Barnes (NIWA)

Marlborough Fault System: localised shear or fluids beneath faults



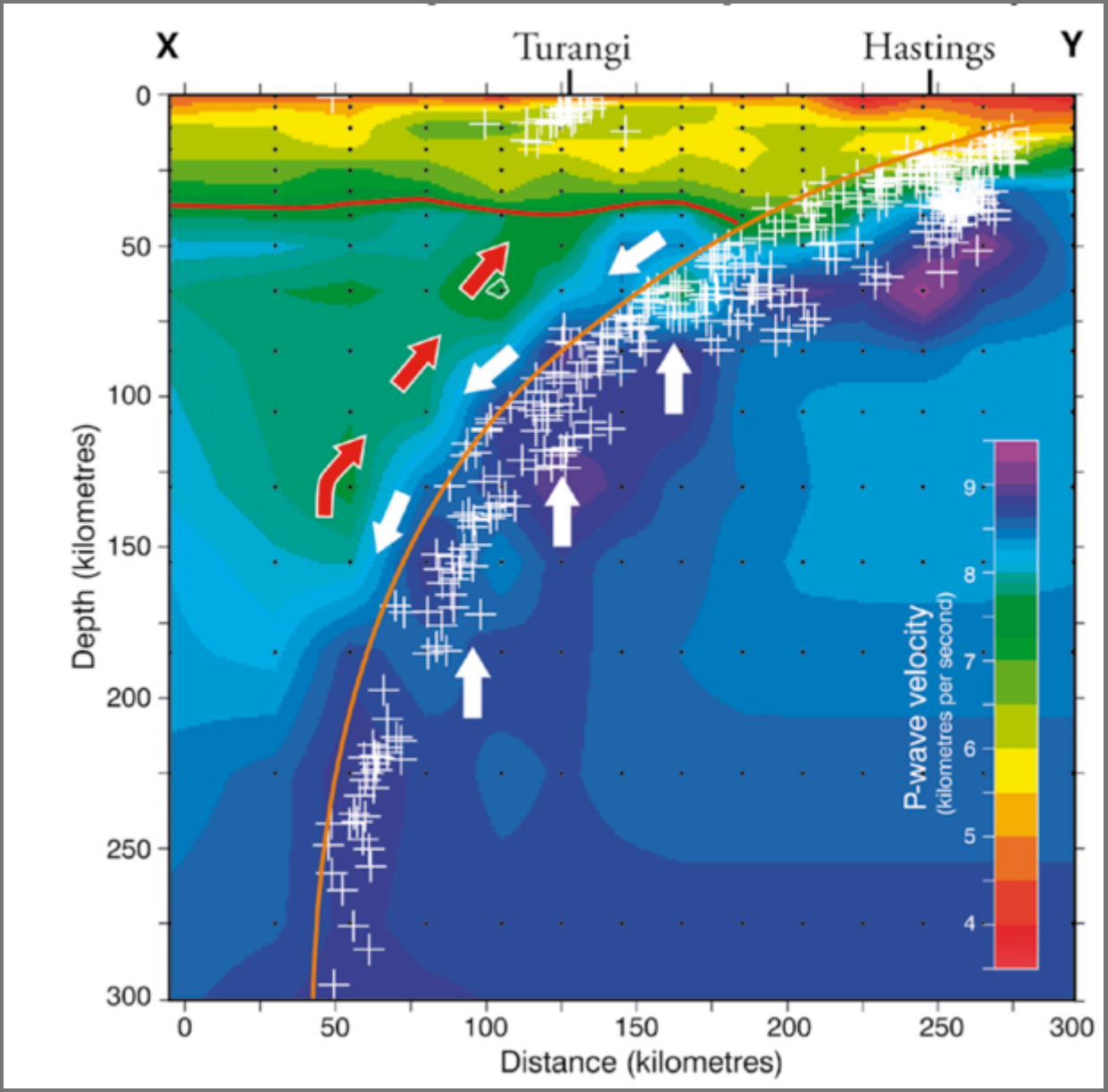
From Wannamaker et al., 2009

Photo: D.J. Homer



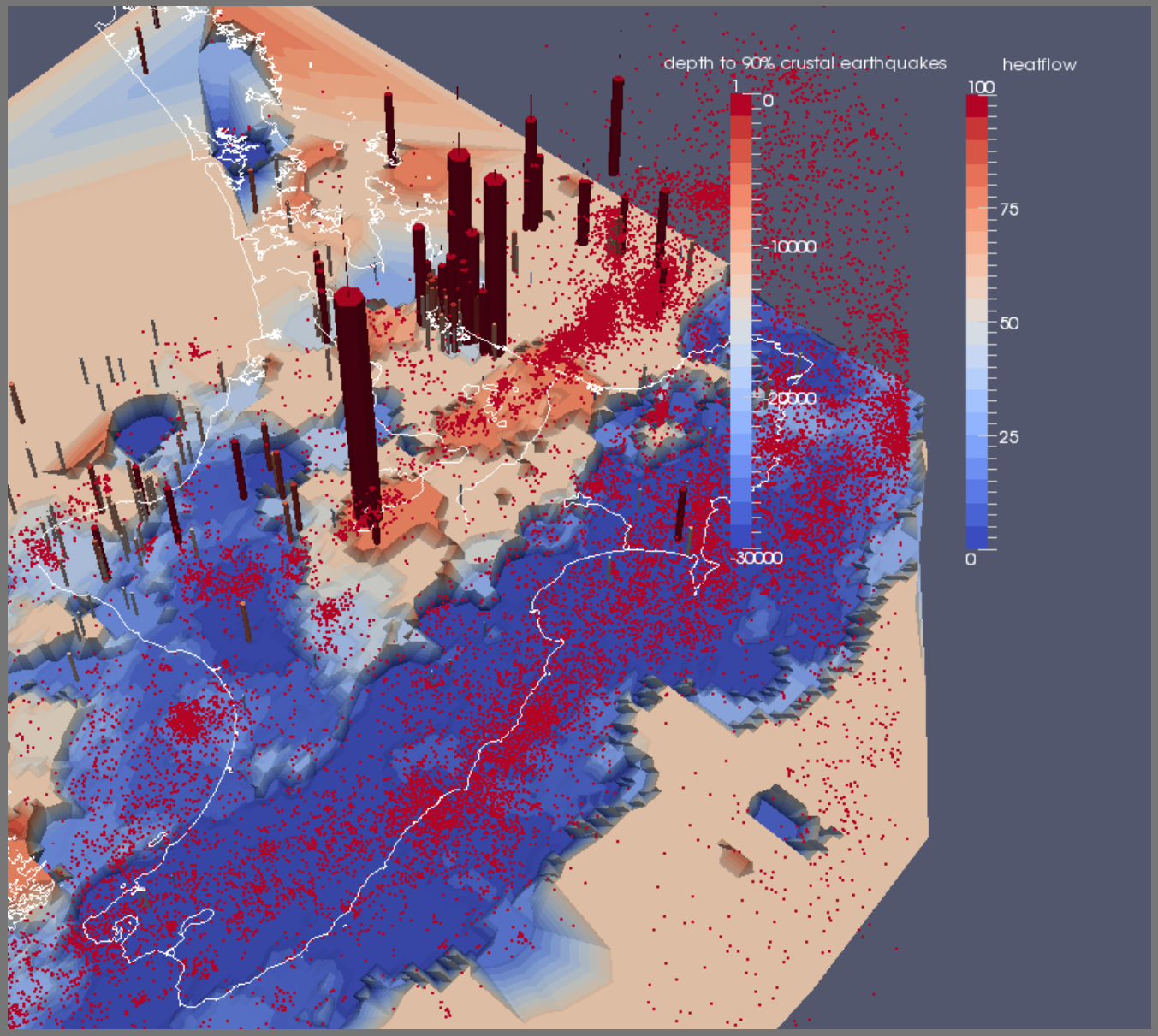
Block diagrams through northern Hawke's Bay (A-A') and Cook Strait (B-B') illustrate the relationship of the North Island Fault system to the Australian-Pacific plate margin. In the south, the Wellington Fault cuts through the Australian Plate and may touch the subduction interface. In the north, the fault system lies between the Taupo Volcanic Zone, where the crust is extending, and the axial ranges, where the crust is being compressed and uplifted.

Subduction-generated magmatism and its influence on tectonics



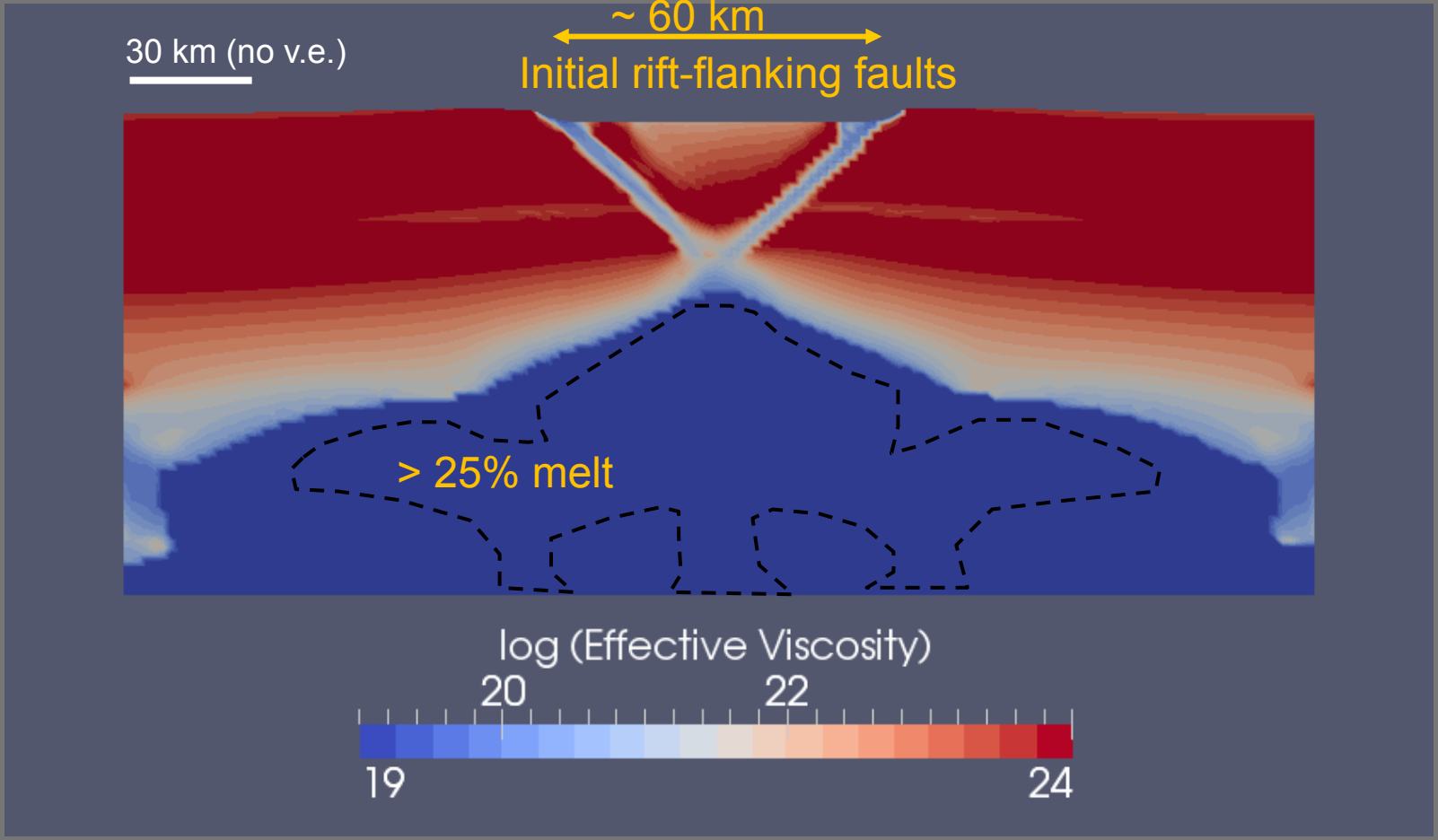
After Reyners et al., 2006

Contoured depth to D90 (90% cutoff depth of seismicity) highlighting the shallowing of the seismogenic zone beneath the TVZ

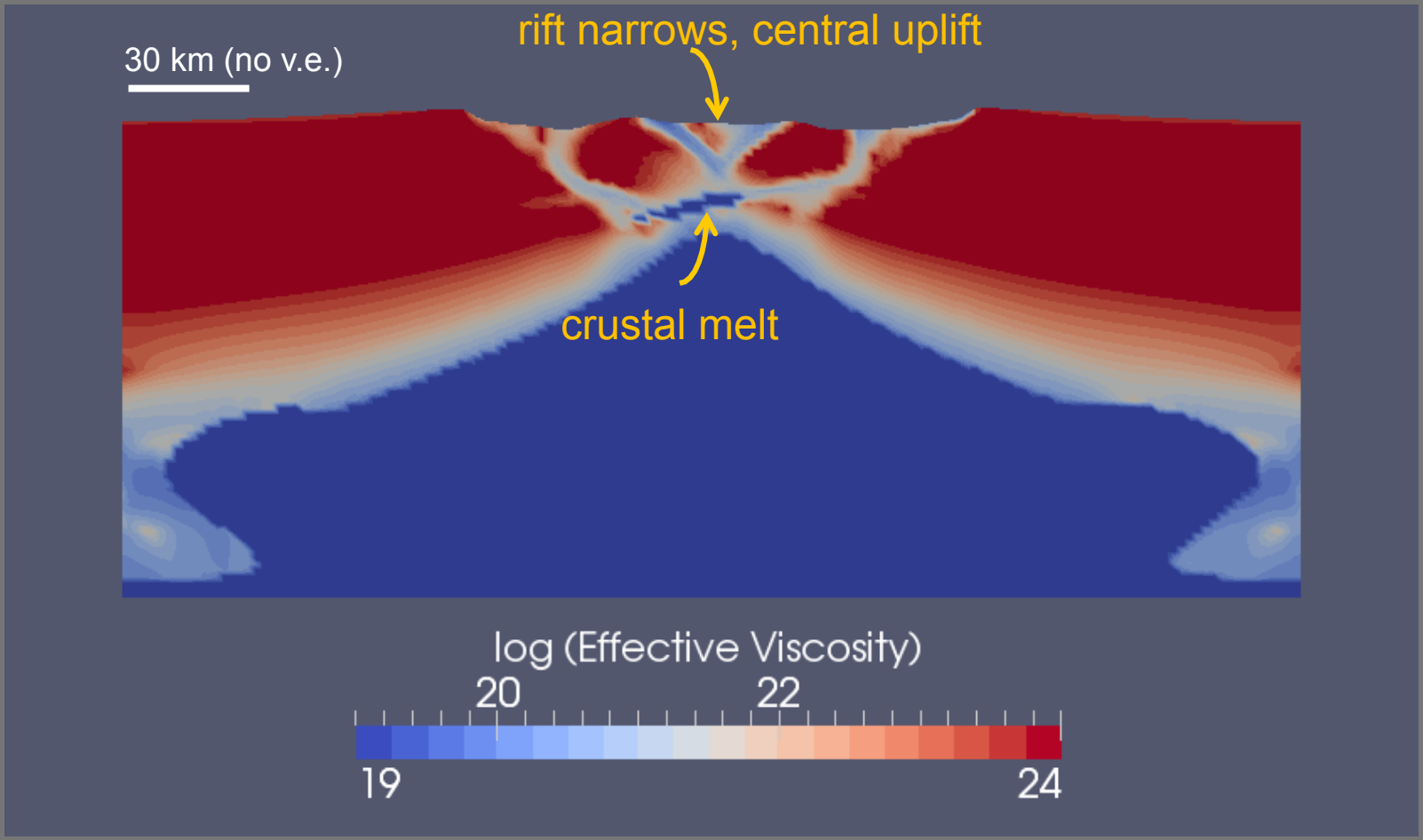


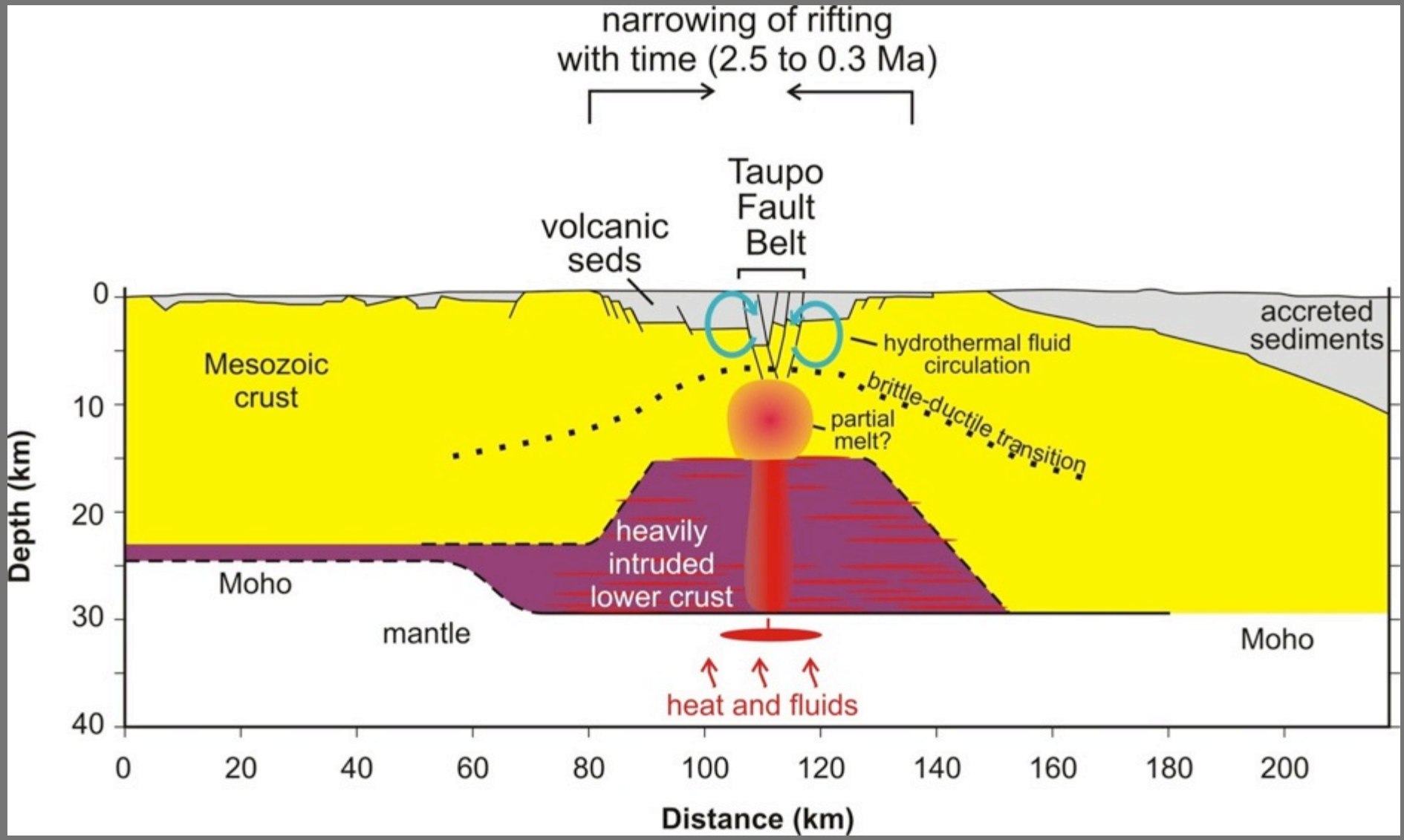
Effect of melt on rift tectonics in Taupo Volcanic Zone

Extension has caused rift to become established (faults are low strength (blue) as is ductile zone of partial melt in mantle) (3 M.y. ago)



Rift narrows as crustal melt develops above zone of mantle melt. Presence of melt buoys up centre of rift (present-day)




narrowing of rifting
with time (2.5 to 0.3 Ma)
Taupo
Fault
Belt
volcanic
seds
accreted
sediments
hydrothermal fluid
circulation
Mesozoic
crust
brittle-ductile transition
partial
melt?
heavily
intruded
lower crust
Moho
mantle
Moho
heat and fluids
Depth (km)
0
10
20
30
40
0
20
40
60
80
100
120
140
160
180
200
Distance (km)

Conclusions

- NZ: born of Gondwanan subduction
- Now caught in a subduction sandwich
- Almost every type of tectonic environment found here- great natural laboratory

Ongoing work

- Alpine Fault drilling project: nature of stress cycling, fluids, rock deformation at > 1 km depth
- Mantle deformation beneath NZ
- Estimating hazard from Hikurangi subduction zone (see next talk)
- Connection of Hikurangi subduction zone to Tonga-Kermadec system, timing of subduction initiation (IODP proposal, see Rupert's talk later at Geoprisms)
- Southern North Island active source + MT transect (SAHKE)
- Degree of localisation of deformation beneath faults
- Stress transfer between faults (e.g., Canterbury earthquakes)