Intraplate Deformation Adjacent to the Macquarie Ridge South of New Zealand - The Tectonic Evolution of a Complex Plate Boundary

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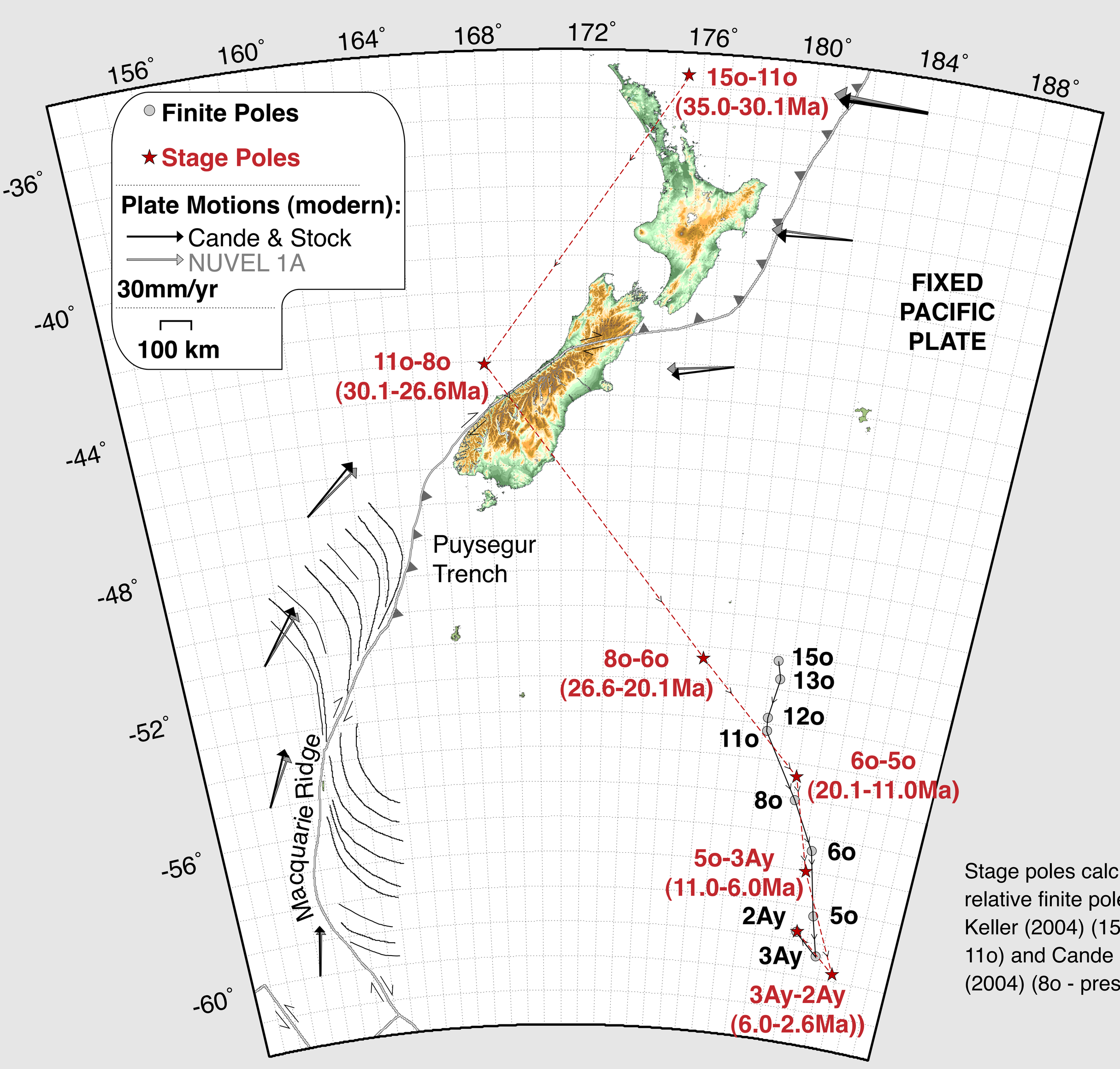
1 INTRODUCTION

The response of lithospheric plate boundaries to rapid changes in plate motions provide constraints used to determine the manner in which transitions in plate motions and plate boundary configurations can occur. In the case of the Australia – Pacific plate boundary in the Macquarie Ridge region south of New Zealand a substantial change in plate motions has occurred since the Oligocene. Over a period of less than 15Ma, this boundary changed from mid-ocean ridge spreading to simple translation, the record of which is recorded in the fabric and fracture zones of the oceanic lithosphere.

We use Plate reconstructions of this plate boundary system coupled with analyses of modern seismicity to isolate deformation that has occurred within the oceanic crust of the Australian since this transition occurred. The persistence of this deformation through time indicates a link with the evolution of subduction of the Australian Plate further north at the Puysegur Trench over the same time period, and may be a result of stress build-up within the plate as a consequence of resistance to that subduction.

2 PLATE MOTIONS



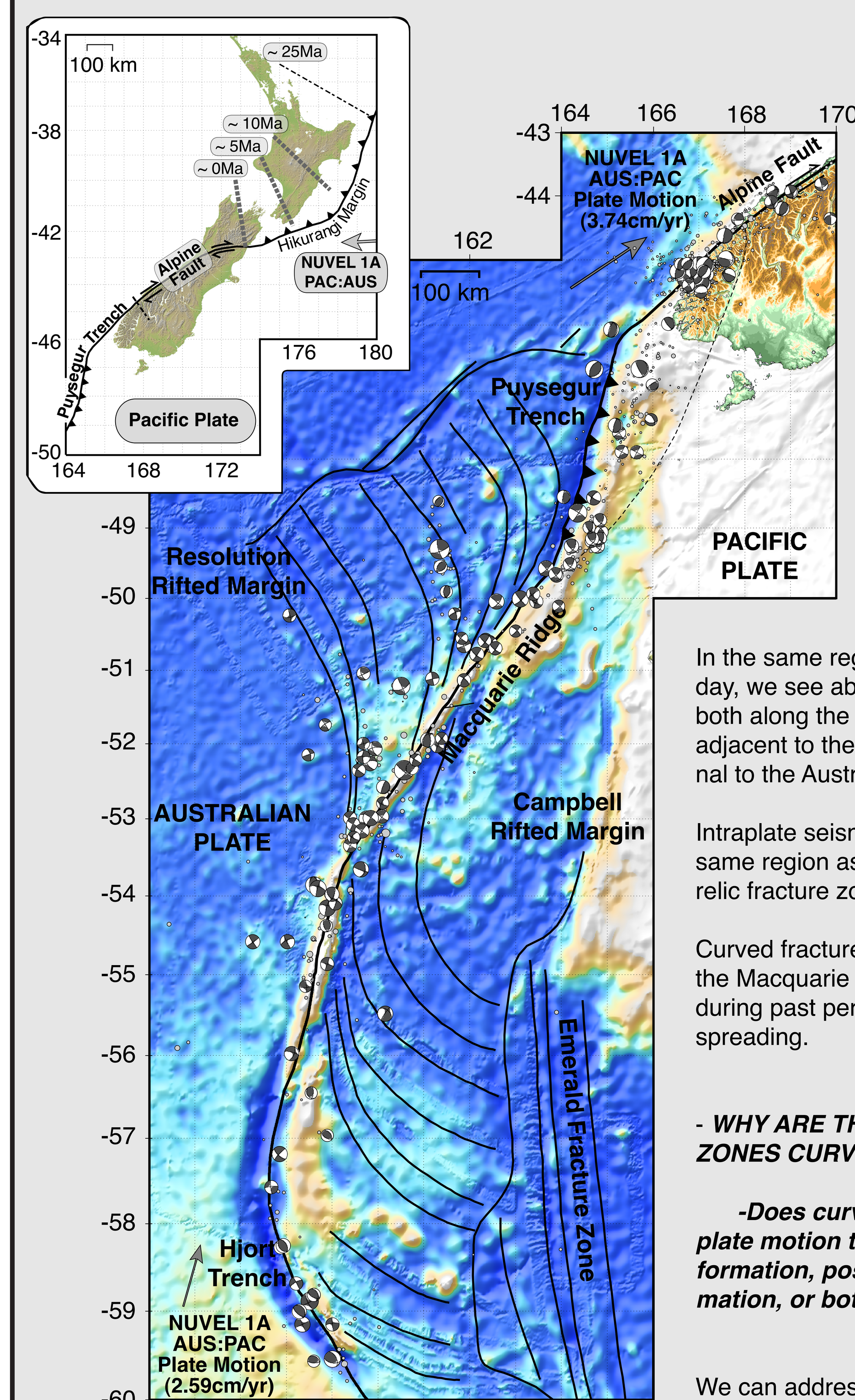
Stage poles calculated by relative finite poles of Keller (2004) (15o and 11o) and Cande and Stock (2004) (8o - present).

Past positions of the AUS:PAC relative rotation poles (fixed Pacific) show that the modern translational regime at the Macquarie Ridge has dominated for the past 10-20Ma.

Before ~20Ma, there was a rapid southward migration of the stage pole that caused a transition in plate motions from dominantly divergent prior to 20Ma, such that a mid-ocean spreading ridge occupied the plate boundary in the Macquarie Ridge region, forming the system of fracture zones still evident as relic features adjacent to the plate boundary today.

This transition from divergence to translational motion also drove the initiation of convergence at the Puysegur Trench immediately south of New Zealand, and subduction of the Australian Plate began.

3 TECTONIC SETTING



In the same region at the present-day, we see abundant seismicity both along the Macquarie Ridge and adjacent to the plate boundary internal to the Australian Plate.

Intraplate seismicity occurs in the same region as we find curvature to relic fracture zones.

Curved fracture zones adjacent to the Macquarie Ridge were formed during past periods of sea-floor spreading.

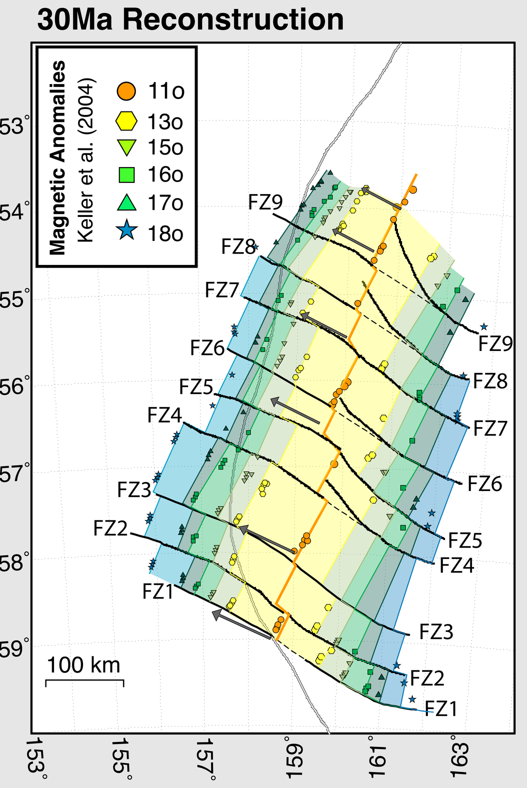
- WHY ARE THESE FRACTURE ZONES CURVED?

-Does curvature represent plate motion transitions during formation, post-formation deformation, or both?

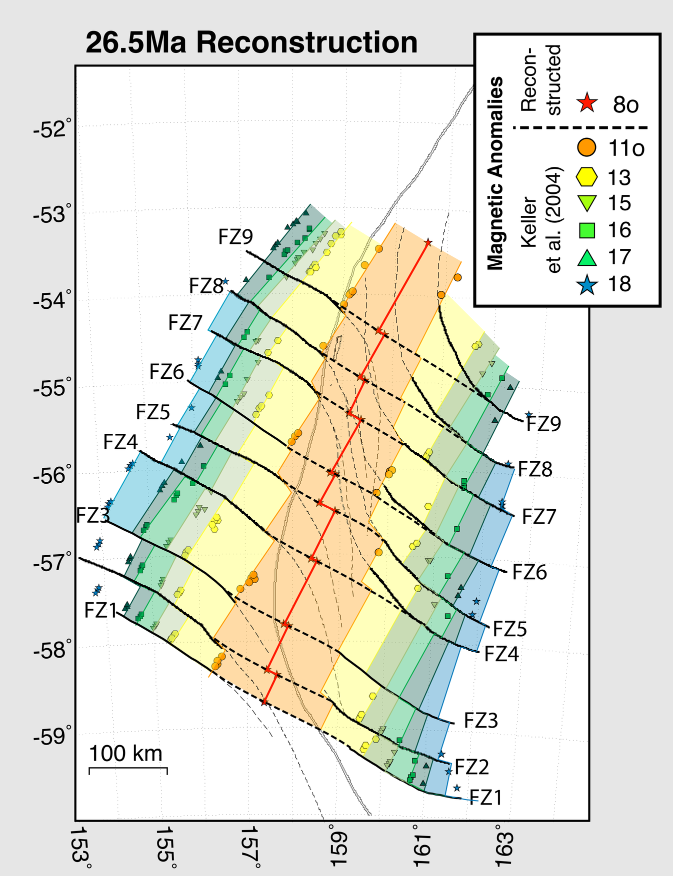
We can address these questions using plate reconstructions through the time of fracture zone formation.

4 PLATE RECONSTRUCTIONS

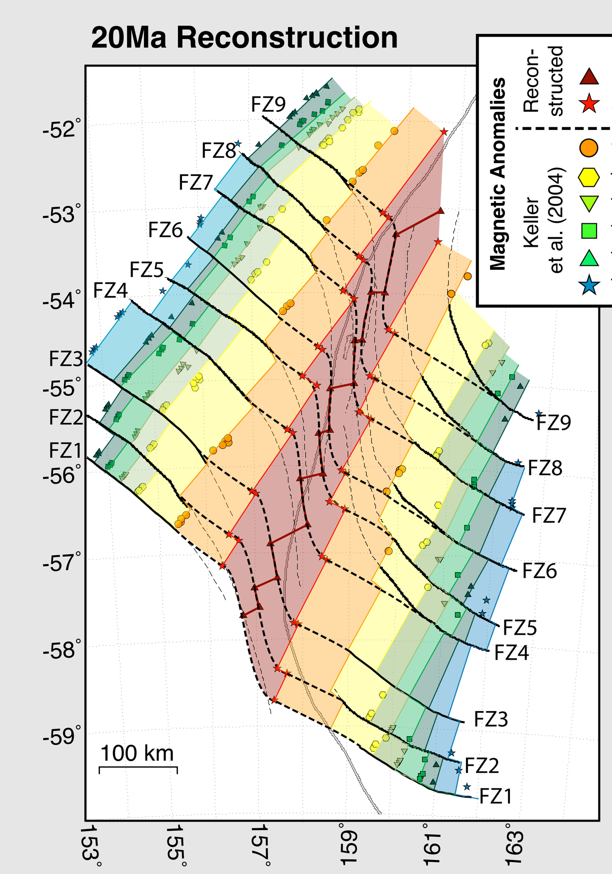
30Ma Reconstruction



26.5Ma Reconstruction



20Ma Reconstruction



Magnetic anomalies and modern fracture zone locations from Keller (2004).
Finite poles from Keller (2004) (chron 11o, 30Ma) and Cande and Stock (2004) (chrons 8o and 6o, 26.5Ma and 20Ma).

These figures describe the plate configuration at each magnetic chron time, constructed using the following rules:

Australian Plate rotated relative to a fixed Pacific Plate.

At 30Ma, reconstructed magnetic anomaly positions dictate the location of the spreading ridge. Plate motion directions (derived from stage pole locations) dictate the orientation of the ridge.

Fracture zones (FZ's) form perpendicular to the ridge, parallel to plate motion. Any mismatch is thus an artifact of deformation since formation or of FZ misidentification.

At 30Ma, FZ's align across the ridge with few exceptions, providing a good 'original' framework for subsequent reconstructions. This also implies little/no deformation to this lithosphere since 30Ma.

At 26.5Ma and 20Ma, modern FZ's (dashed) do not align across the reconstructed ridge positions. FZ's are restored according to rules above.

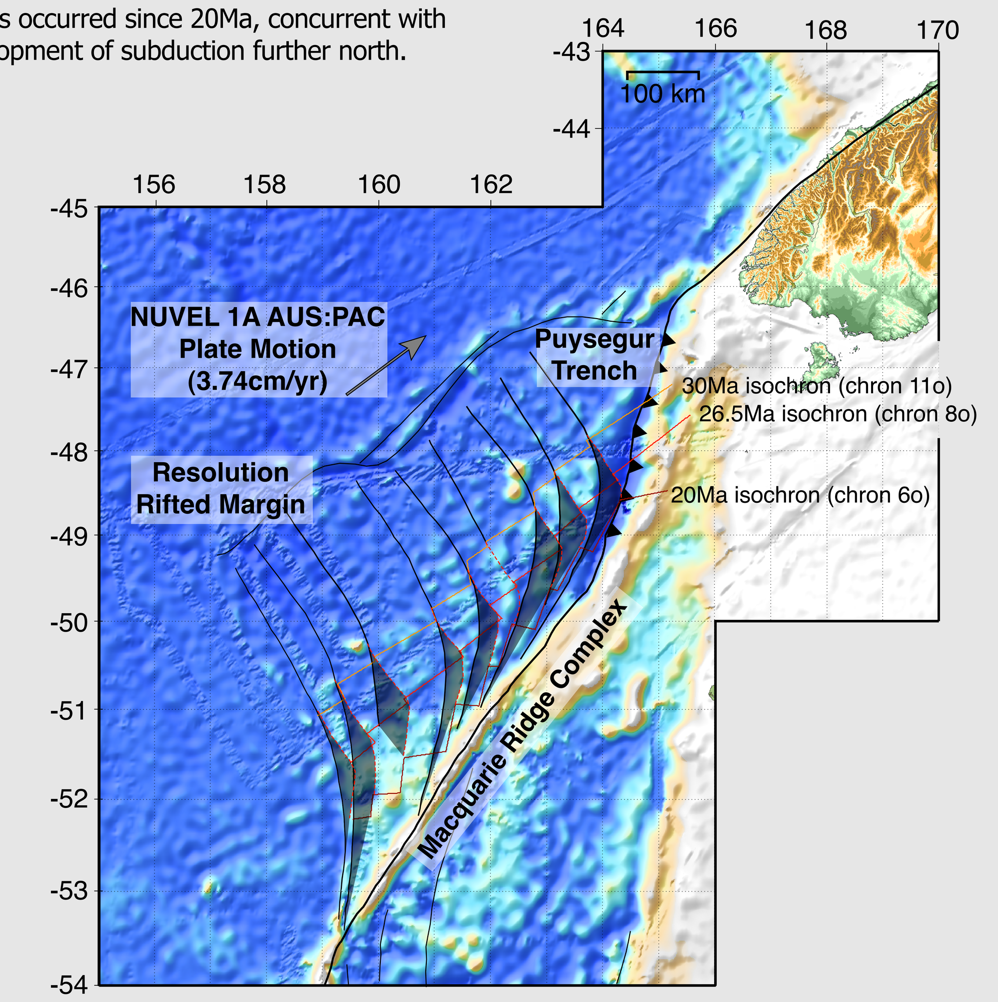
Mismatch between modern and restored FZ's results from deformation since the time of FZ formation.

5 GEOLOGICALLY OBSERVED DEFORMATION

Gray shading highlights the inferred deformation derived from comparison of restored 20Ma and modern fracture zones.

This implies substantial deformation has occurred within the Australian Plate adjacent to the Macquarie Ridge, up to 150km from the plate boundary.

This deformation has occurred since 20Ma, concurrent with the onset and development of subduction further north.

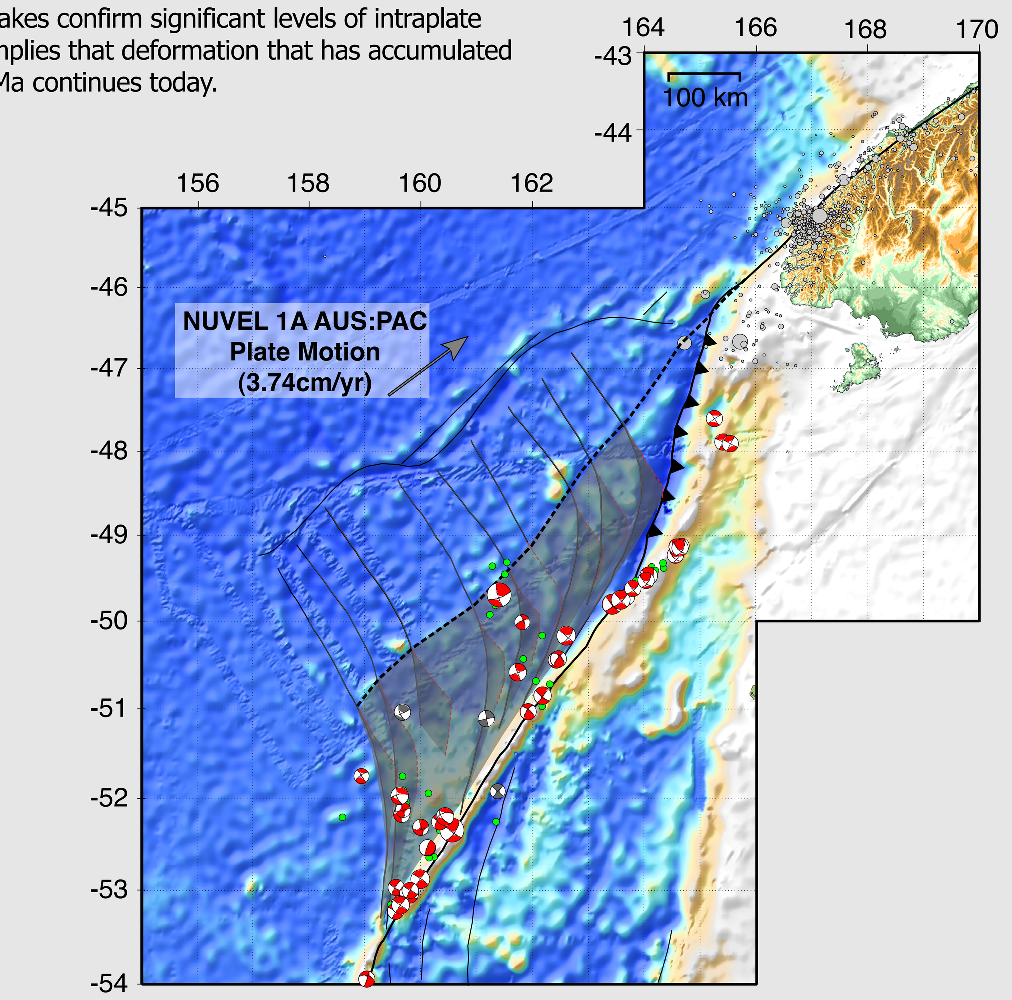


6 SEISMICALLY OBSERVED DEFORMATION

The same region that demonstrates intraplate deformation in the geologic record also exhibits high levels of intraplate seismicity. This may indicate deformation continues at present.

To confirm this hypothesis, we relocate earthquakes along the Macquarie Ridge and within the Australian Plate using the surface wave double-difference code written by Charles Ammon at Penn State.

Relocate earthquakes confirm significant levels of intraplate seismicity. This implies that deformation that has accumulated over the past 20Ma continues today.



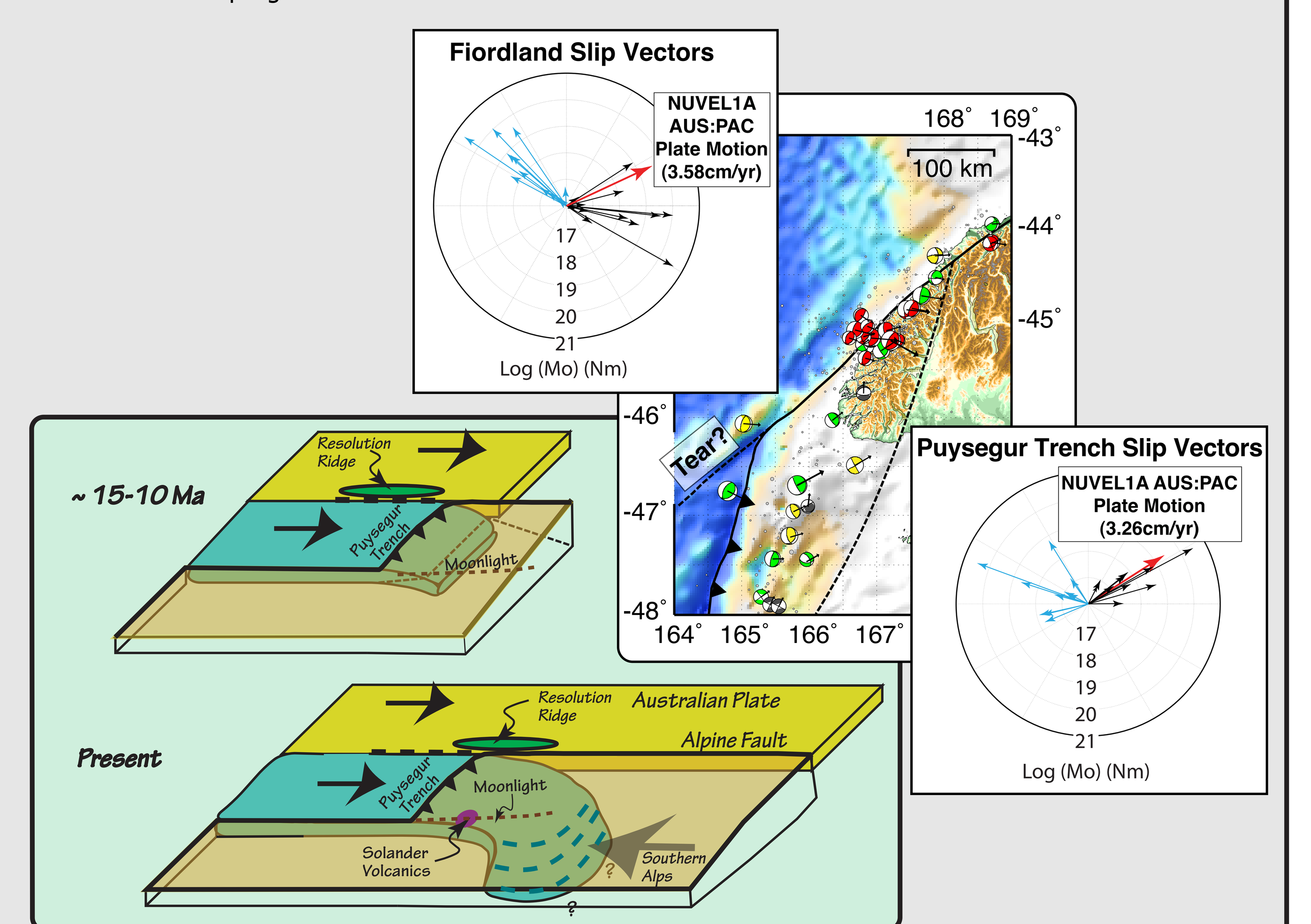
7 THE FIORDLAND SUBDUCTION PARADOX

Schematic below shows the inferred development of subduction following initiation at the Puysegur Trench at ~20Ma.

Present-day geometry requires that the subducted part of the Australian Plate be decoupled from that part translating past the Pacific Plate along the Alpine Fault.

In the Puysegur Trench (subduction interface south of ~-46°), earthquake slip vectors align with plate motion.

In Fiordland, the majority of earthquake slip vectors are highly oblique to plate motion. We infer these to represent Australian Plate decoupling events.



8 AN EVOLVING PLATE BOUNDARY

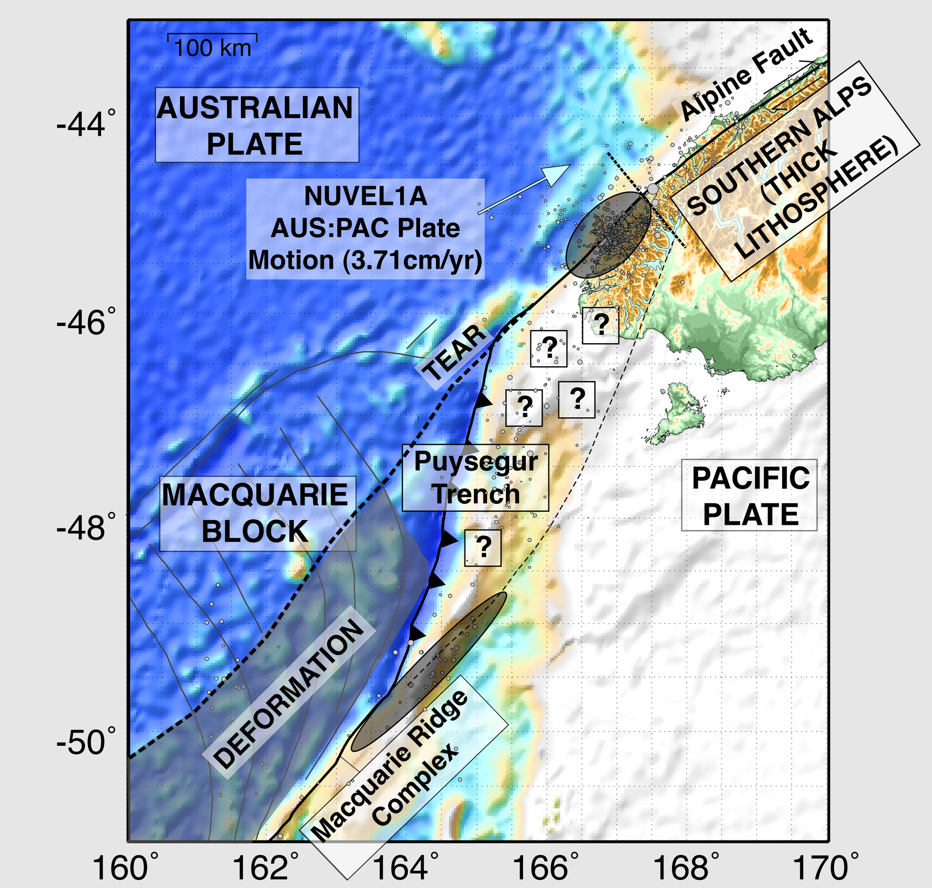


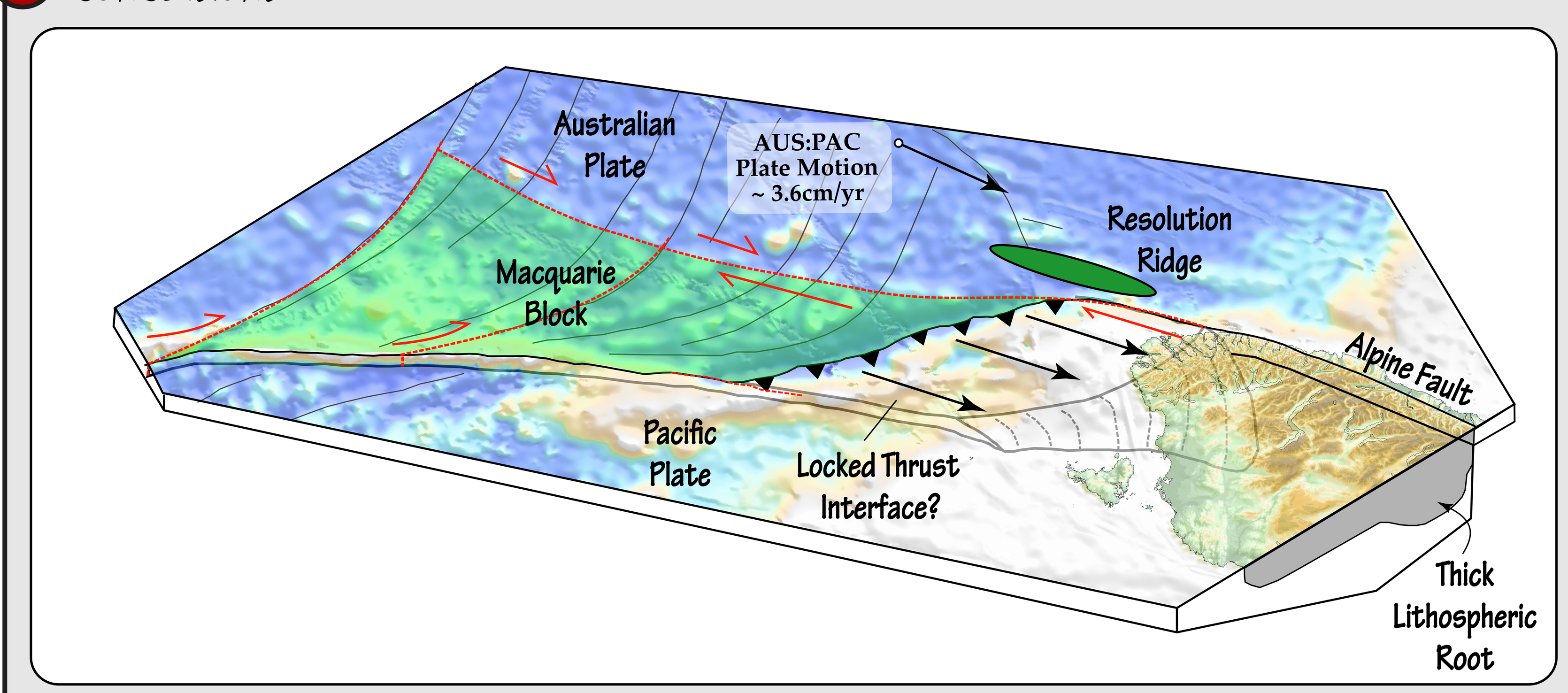
Plate reconstructions and modern seismicity identify deformation internal to the Australian Plate, restricted to an area within ~150km of the AUS:PAC plate boundary. We call this area the Macquarie Block.

This area coincides in spatial extent with that part of the Australian Plate subducting at the Puysegur Trench, and has occurred since and during the time of subduction initiation and development.

Thrusting earthquakes in Fiordland are likely associated with decoupling of the Australian Plate. This feature aligns with the westward extent of deformation in the Macquarie Block.

The temporal and spatial coincidence of these features suggests that Macquarie Block deformation is related to the resistance to subduction of the Australian Plate at the Puysegur Trench.

9 CONCLUSIONS



Our analyses reveal a highly stressed Macquarie Block, caused by a resistance to subduction of the Australian Plate.

Potential mechanisms for this resistance are:

i) the collision of the Australian slab with the thickened lithospheric root of New Zealand's Southern Alps.

ii) prolonged locking of the low-angle, large area shallow subduction thrust interface.

The lack of subduction-related seismicity within the trench today suggests this interface is presently locked. Persistence of deformation through time implies stress build-up must be at least partially caused by a more constant source than the temporal stick-slip pattern of a locked interface. Could both mechanisms have led to the deformation pattern seen today?