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Geodynamics of the SW Pacific: a brief review and relations with New Caledonian geology

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Abstract :

The SW Pacific region consists of a succession of ridges and basins that were created by the fragmentation of Gondwana and the evolution of subduction zones since Mesozoic times. This complex geodynamic evolution shaped the geology of New Caledonia, which lies in the northern part of the Zealandia continent. Alternative tectonic models have been postulated. Most models agree that New Caledonia was situated on an active plate margin of eastern Gondwana during the Mesozoic. Extension affected the region from the Late Cretaceous to the Paleocene and models for this period vary in the location and nature of the plate boundary between the Pacific and Australian plates. Eocene regional tectonic contraction included the obduction of a mantle-derived Peridotite Nappe in New Caledonia. In one class of model, this contractional phase was controlled by an east-dipping subduction zone into which the Norfolk Ridge jammed, whereas in a second class of model this phase corresponds to the initiation of the west-dipping Tonga–Kermadec subduction zone. Neogene tectonics of the region near New Caledonia was dominated by the eastwards retreat of Tonga–Kermadec subduction, leading to the opening of a back-arc basin east of New Caledonia, and the initiation and southwestwards advance of the New Hebrides–Vanuatu subduction zone towards New Caledonia.

Geological structures of the southwest Pacific

New Caledonia sits at the northeastern extremity of the Australian Plate, close to the Pacific-Australia plate boundary. Its onland and offshore geology provides important information on the geodynamic evolution of the southwest Pacific (Fig. 1 and fold out geological map, this memoir). Present day physiography and geology of the region has resulted from fragmentation of eastern Gondwana since the Mesozoic by successive basin openings and closures associated with the evolution of subduction zones. Basin closures led in some places to folding, faulting and obduction of nappes during the Cenozoic, including nappes containing ophiolitic material in Papua New Guinea, New Caledonia, and New Zealand.

Central to describing and understanding the bathymetry and geology of the southwest Pacific is the 94% submerged continent of Zealandia [Mortimer *et al.*, 2017]. Zealandia is composed of a succession of continental ridges (from west to east): the Dampier Ridge, Lord Howe Rise, Fairway Ridge and Norfolk Ridge. Each ridge and intervening trough has a clear expression on the free air gravity anomaly map (Fig. 1). New Caledonia is located at the northern end of Norfolk Ridge. The continental ridges are separated from each other by basins (of probable continental type). From west to east these are the Middleton Basin, Fairway-Aotea Basin, and New Caledonia Trough. Crustal thicknesses vary from ca. 25 km beneath ridges to 10-15 km in the basins [Klingelhoefer *et al.*, 2007]. Water-depths of Zealandia are typically 1000-1500 m for the ridges, down to 2000 m in the Fairway Basin, and ca. 3500 m in the New Caledonia Trough near New Caledonia.

Zealandia is surrounded by oceanic basins, back-arc basins and subduction-related volcanic ridges of various ages. Between Zealandia and Australia are the Tasman and Coral seas, two 2000 km wide Late Cretaceous to early Eocene ocean basins containing central spreading centres and sets of continuous distinct oceanic fracture zones (Fig. 2). The area to the east of Zealandia is predominantly composed of Cenozoic volcanic ridges that, with exception to the New Hebrides-Vanuatu arc, are generally younger to the east: Loyalty Ridge, Three Kings Ridge, Lau-Colville Ridge, Tonga-Kermadec Ridge and the New Hebrides-Vanuatu arc. The latter two, although resulting from oppositely-dipping subduction zones, are active with subduction-related volcanic arcs. Between the ridges are back-arc basins: Norfolk, South Fiji, Lau-Havre, and North Fiji basins. In contrast to the Tasman and Coral Sea basins, these back-arc basins contain short-segment, poorly-organised spreading centres and have few prominent fracture zones (Figs. 2 and 3).

Other prominent features of the southwest Pacific are three age-progressive volcanic 'hotspot' tracks that may approximate motion of the Pacific and Australian plates relative to the mantle during the Cenozoic [Knesel *et al.*, 2008; McDougall and Duncan, 1988; McDougall *et al.*, 1981; Missègue and Collot, 1987; Mortimer *et al.*, 2018]. The Louisville chain is on the Pacific Plate and the Tasmantid and Lord Howe chains are on the Australian plate (Fig. 1).

Geodynamics

Present day geodynamics

The southwest Pacific is tectonically active with very rapid motion between two opposite subduction zones, and active back-arc extension. The Mesozoic Pacific plate is subducted at the Tonga-Kermadec trench at rates that increase northward. At 16°S the convergence rate reaches 24 cm/year, which is

the fastest convergence rate on Earth [Bevis *et al.*, 1995; Pelletier and Louat, 1989; Pelletier *et al.*, 1998]. The convergence rate corresponds to the sum of the Australia-Pacific relative plate motion rate and the Lau basin spreading rate, which is a measure of the rate of trench retreat (see Heuret and Lallemand [2005] for more details). The Australian plate moves NNE at a rate of 7 cm/year relative to Antarctica [Pettersen *et al.*, 1999] and is subducted along the New Hebrides-Vanuatu trench beneath the Pacific Plate at a rate of up to 17 cm/year [Bergeot *et al.*, 2009; Calmant *et al.*, 2003; Dubois *et al.*, 1977; Pelletier *et al.*, 1998]. The Fiji Fracture Zone (see location on Fig. 2 and 3), combined with a complex system of spreading ridges and transform faults in the North-Fiji Basin, accommodates motion between the Australian and Pacific plates [Pelletier *et al.*, 1998; Pelletier *et al.*, 2001] (Fig. 2 and 3). The northeastern part of the Australian plate is being subducted along the New Hebrides-Vanuatu trench. South of New Zealand, the Pacific-Australian plate boundary has a dextral strike-slip rate of c. 3 cm/yr, and has evolved from extension to compression since the Eocene, with oblique subduction of the Australian plate initiating at the Puysegur Trench during the Miocene [Collot *et al.*, 1995; Lamarche and Lebrun, 2000; Sutherland *et al.*, 2000; Sutherland *et al.*, 2009].

Mesozoic and Cenozoic geodynamics

Various conceptual geodynamic and tectonic models have attempted to explain the formation and development of the southwest Pacific in time and space, e.g. [Ballance *et al.*, 1982; Cluzel *et al.*, 2001; Crawford *et al.*, 2003a; Hall, 2002; Karig, 1971; Kroenke, 1984; Müller *et al.*, 2000; Schellart *et al.*, 2006; Sdrolias *et al.*, 2003; Veevers, 2000; Yan and Kroenke, 1993]. Most geodynamic models of the southwest Pacific follow the model of Karig [1971], which, based on examples from the western Pacific region, introduced the concept that roll-back of a subducted slab may induce oceanward retreat of the subduction trench, extension behind the arc, and associated formation of a series of remnant arcs and back-arc basins.

Magnetic anomalies of the Tasman and Coral seas show that oceanic crust formed from the Late Cretaceous to Early Eocene (Figs. 2 & 3) [Gaina *et al.*, 1998; Hayes and Ringis, 1973]. The New Caledonia Trough, Fairway and Norfolk basins have a more contentious origin and may be underlain by oceanic crust, continental crust, thinned continental crust, or exposed/denuded mantle. Their ages are more difficult to constrain. Moreover, the long history of subduction in the region has led to the recycling of large swaths of lithosphere into the mantle, thus obliterating much of the geological record (e.g. magnetic anomalies, age and nature of crust and extent of the basin) in some areas. As a result, elements of the geodynamic evolution of the southwest Pacific remain poorly controlled and several alternative conceptual models exist. We review below some of the alternate models.

Mesozoic Gondwana subduction

The belt-like distribution of deformed Permian to Early Cretaceous trench-slope and fore-arc basin sedimentary rocks, arc volcanic and intrusive rocks in New Caledonia and New Zealand (eastern Zealandia) shows that a Pacific basin subducting slab dipped southwest beneath the eastern margin of Gondwana throughout much of the 260-110 Ma interval ([Bradshaw, 1981; Cluzel *et al.*, 2010b; Mortimer *et al.*, 2008; Mortimer *et al.*, 2009; Sdrolias *et al.*, 2003]. Some geodynamic models propose that this was complicated by opening and closing of marginal basins and involved local changes in trench location and/or periods with opposite subduction vergence [Adams *et al.*, 2009; Li *et al.*, 2012] and chapter 3 this memoir. Evidence for existence of a Mesozoic volcanic arc along the paleo-

margin of Gondwana comes from the accumulation of Mesozoic volcanoclastic sediments of considerable thickness in the Otway and Gippsland basins (located between Australia and Tasmania), the Great Artesian Basin (located in the middle of the Australian continent), in New Zealand, and in New Caledonia (cf. Chapter 3, this memoir). More directly, Mortimer et al. [2008; 2002; 1999] show that roots of the Mesozoic continental arc are exposed as the Median Batholith in New Zealand, as well as equivalents in Marie Byrd Land, Antarctica, Queensland, and dredged rocks from offshore Zealandia (e.g. West Norfolk Ridge). Late Mesozoic subduction at the Gondwana margin correspond to the long-lived subduction that runs from northeast of Australia to South America, and that subsequently died adjacent to Zealandia and Antarctica, but remains active today beneath South America (Fig. 4).

Late Cretaceous – Palaeocene extension

At c. 110-100 Ma (end Early Cretaceous), the regional tectonic regime along the Pacific margin of Gondwana changed from convergent to extensional. An episode of intracontinental rifting lasted until at least c. 85 Ma along much of the Gondwana margin, at which time Zealandia began to separate from Gondwana. As well as the termination of deformation and metamorphism in accretionary subduction complexes, there was a switch from subduction-type to rift-type magmatism in New Zealand and New Caledonia in the Early to early Late Cretaceous [Cluzel et al., 2010b; Mortimer, 2004; Muir et al., 1995; Tulloch et al., 2009]. Widespread sedimentary basins associated with normal faulting during the interval c. 105-80 Ma are found throughout Zealandia (in New Caledonia (cf. Chapter 4, this memoir), Lord Howe Rise, New Zealand, Campbell Plateau) and in West Antarctica [Bache et al., 2013; Carter et al., 1992; Herzer et al., 1997; Laird, 1992; Luyendyk et al., 2003; Luyendyk et al., 2001; Rouillard et al., 2017; Van der Lingen et al., 1973]. It has been suggested that a fundamental cause of this tectonic change from subduction to rifting was due to jamming of subduction by the Hikurangi Plateau at c. 105 Ma [Collot et al., 2009; Davy et al., 2008]. An alternative is waning subduction associated with the interaction of the trench with adjacent spreading ridges [Matthews et al., 2012]. Initial breakup of Zealandia from Gondwana is dated at 83-79 Ma (chron 33r), based on marine magnetic anomalies adjacent to much of Zealandia in the Tasman Sea, and propagated towards the North until 57 Ma (chron 26) [Gaina et al., 1998]. Initial break-up may have occurred slightly earlier at the southern extremity of the Tasman Sea (chron 34) [Gaina et al., 1998; Sutherland, 1999]. The Tasman Sea spreading centre was active until 52 Ma (chron 24), and the resulting oceanic seafloor provides a record of relative plate motions between Gondwana and Zealandia [Gaina et al., 1998].

Tectonic models of Late Cretaceous to Early Eocene plate kinematics in the southwest Pacific vary in the nature of plate boundary east of Zealandia. Options include an east-dipping subduction zone, a west-dipping subduction zone, a strike-slip boundary, or no boundary at all.

In one class of geodynamic model (model A, Fig. 5 and 6), the Tasman Sea, New Caledonia Trough and South Loyalty Basin are inferred to be back-arc basins, with extension driven by a west-dipping subduction zone retreating towards the Pacific via a rollback process [Cluzel et al., 2012a; Crawford et al., 2003a; Gaina et al., 1998; Hall and Spakman, 2002; Schellart et al., 2006; Sdrolias et al., 2001; 2003]. The South Loyalty Basin would once have been much wider with its back-arc basin oceanic crust now telescoped and obducted in allochthons of the Poya Terrane (cf. chapter 5, this memoir) in New Caledonia [Aitchison et al., 1995; Cluzel et al., 2001; Cluzel et al., 2018; Eissen et al., 1998] and

of the Tangihua and Makatoa Volcanics in New Zealand [Cluzel *et al.*, 2010a; Nicholson *et al.*, 2000a; Nicholson *et al.*, 2000b]. It is notable that arc volcanic rocks for this period have not been conclusively discovered [Mortimer *et al.*, 2018; Pelletier, 2007].

An alternative class of model has eastern Gondwana subduction cessation followed by divergent plate motions (initially intracontinental, then at spreading ridges) that led to rifting of Gondwana, breakup, and then opening of the Southern Ocean and Tasman Sea [Gaina *et al.*, 1998; Norvick *et al.*, 2008; Sdrolias *et al.*, 2001; 2003; van der Meer *et al.*, 2016; Williams *et al.*, 2011]. In this class of model (model B, Fig. 5 and 6), the Late Cretaceous plate boundary between Zealandia and the Pacific Plate is either thought to be inactive [Pirard and Spandler, 2017; Steinberger *et al.*, 2004], or to be a transform boundary [Müller *et al.*, 2000; Richards and Lithgow-Bertelloni, 1996]. In this class of model, the South Loyalty Basin could be a relic of the Pacific Plate, or could be connected with Coral Sea spreading.

Eocene contraction

Most authors agree that a phase of regional tectonic contraction started during the latest Palaeocene or Eocene (cf. Chapter 4 and 5, this memoir), though the precise magnitude, extent, timing and duration of this phase remains debated [Ballance, 1999; Ballance *et al.*, 1982; Cluzel *et al.*, 2001; Crawford *et al.*, 2003a; Dallanave *et al.*, 2018; Kroenke, 1984; Maurizot, 2012; Schellart *et al.*, 2006; Sdrolias *et al.*, 2003; Sutherland *et al.*, 2010; Sutherland *et al.*, 2017; Whattam *et al.*, 2008]. In New Caledonia, this phase culminates with obduction of the Peridotite Nappe during the latest Eocene. Lower strain regional Eocene contraction is observed on seismic-reflection data across Zealandia and in eastern Australia [Bache *et al.*, 2012; Etienne *et al.*, 2017; Lafoy *et al.*, 1994; Rouillard *et al.*, 2017; Sutherland *et al.*, 2010; Sutherland *et al.*, 2017].

The first class of model (Model A, Fig. 5 and 6) proposes that a new east-dipping subduction zone initiated in the South Loyalty Basin, possibly near a spreading ridge at c. 56 Ma [Cluzel *et al.*, 2006; Cluzel *et al.*, 2012b; Cluzel *et al.*, 2016; Ulrich *et al.*, 2010]; and then retreated towards the west until c. 34 Ma, when the Norfolk Ridge arrived at the trench and blocked it [Aitchison *et al.*, 1995]. In this class of model, the South Loyalty Basin is almost entirely consumed by the second east-dipping subduction zone. The change in subduction polarity at c. 56 Ma (subduction flip from westward to eastward slab dip) is invoked to explain southward propagation of Eocene foreland basins and emplacement of nappes (cf. Chapter 4, this memoir), supra-subduction features within the allochthons, and eclogite-blueschist (high-pressure low-temperature) metamorphism in northern New Caledonia (cf. Chapter 5, this memoir).

In a second class of model (Model B, Fig. 5 and 6), the west-dipping Gondwana subduction zone that died at the start of the Late Cretaceous re-initiated at c. 50 Ma [Gurnis *et al.*, 2004; Steinberger *et al.*, 2004]. In this class of model, new subduction zones initiated throughout the western Pacific during the Eocene (see Miles *et al.* [2016]) and are associated with changes in Pacific Plate motion manifest as the Emperor-Hawaii seamount bend [O'Connor *et al.*, 2013; Steinberger *et al.*, 2004].

Although the first class of model can explain the Cenozoic geology of New Caledonia, latest Cretaceous, Palaeocene, or Eocene volcanic arc material related to the proposed subduction zone have yet to be found in the southwest Pacific [Matthews *et al.*, 2015; Mortimer *et al.*, 2018]. The exception is arc material recovered from Bougainville Seamount near the New Hebrides-Vanuatu

trench (see Fig. 1 for location), which was dated as Late Eocene [Collot *et al.*, 1992; Greene *et al.*, 1994] and along the D'Entrecasteaux Ridge [Maillet *et al.*, 1983; Mortimer *et al.*, 2014]. However, the relationship between the Bougainville Seamount, D'Entrecasteaux Ridge, Loyalty Ridge and an eastward-dipping subduction system is not clear (cf. Chapter 6, this memoir). The second model does not provide a simple explanation for the mechanisms of emplacement of ophiolites in New Caledonia (in the context of southwest-dipping subduction). However, Spörli *et al.* [1992] and Mortimer *et al.* [2003] have suggested 'flake tectonic' emplacement of the Northland Allochthon in this configuration. For more details on the geodynamic evolution of this time period, Matthews *et al.* [2015] give a comprehensive analysis and discussion of the available geological and kinematic data.

Oligocene to present-day Tonga-Kermadec subduction

There are an increasing number of dredged rock samples from marginal basins and ridges between the Norfolk Ridge and the Tonga-Kermadec trench. They reveal an overall history of west-to-east Tonga-Kermadec subduction roll-back to its present-day position, although locally uncertainties of subduction polarity exist during the Oligocene.

In one class of model (Model A, Fig. 5 and 6), the jamming of east-dipping South Loyalty subduction occurs during the latest Eocene in New Caledonia, and propagates to New Zealand throughout the Oligocene [Whattam *et al.*, 2008]. This propagation explains diachronous ophiolite emplacement: Eocene in New Caledonia (cf. Chapter 5, this memoir), to Oligocene in Northland, New Zealand [Ballance and Sporli, 1979; Malpas *et al.*, 1992; Ruohong *et al.*, 2014]. In this model, west-dipping Tonga Kermadec subduction initiates during or just following this jamming, as a subduction flip.

In the second class of model (Model B, Fig. 5 and 6), west-dipping Tonga Kermadec subduction initiates along Zealandia's eastern margin during the Eocene, and then retreats towards the east from Eocene to present-day. The pole of rotation describing motion across the retreating trench is inferred to have been close to New Zealand. Deformation continued from the Eocene to present-day in the south (New Zealand), but was restricted to a pulse of Eocene deformation in the north, as trench retreat towards the east isolated New Caledonia.

For the Neogene, all models are similar. As Tonga Kermadec subduction retreated towards the east, it preserved a series of remnant volcanic arcs and back arc basins on the overriding plate.

Models predict that the North Loyalty Basin formed during the Eocene and Oligocene [Mortimer *et al.*, 2014; Sdrolias *et al.*, 2003], and the South Fiji Basin formed during the Oligocene to early Miocene [Davey, 1982; Herzer *et al.*, 2011; Malahoff *et al.*, 1982; Mortimer *et al.*, 2007; Watts *et al.*, 1977]. The Loyalty-Three Kings volcanic arc and Norfolk basin formed in the Oligocene and Miocene. [Mortimer *et al.*, 1998; Nicholson *et al.*, 2008].

Arc volcanism in Fiji started in the latest Eocene or Oligocene [Gill, 1987]. Subduction-related lavas of Oligocene age have been found on the Three Kings Ridge [Mortimer *et al.*, 2007]. Medium-K and high-K lavas of late Oligocene age on the northern Norfolk Ridge and early Miocene age near Three Kings Ridge are interpreted as an additional magmatic response to rapid Tonga-Kermadec subduction retreat [Mauffret *et al.*, 2002; Mortimer *et al.*, 2014]. The Lau-Colville volcanic arc is presumed to have been active during the Miocene [Ballance *et al.*, 1982; Hawkins, 1995] but is sparsely sampled

compared with other ridges in the region. Its activity appears to be coeval with formation of the South Fiji Basin, and cessation of Colville arc activity is interpreted to have resulted from intra-arc tearing associated with slab roll-back and creation of the Lau Basin in the north and the Havre Trough in the south. This isolated the active Tonga Kermadec arc [Hawkins, 1995]. The oldest rocks dated in ODP 841 drill hole in the Tonga fore-arc cluster around 45 Ma, with the oldest being 46 Ma [McDougall *et al.*, 1994]. A similar age range has been found from 'Eua, an island on the Tonga platform [Duncan *et al.*, 1985]. Studies of the Tonga fore-arc have dredged ultramafic and subduction-related volcanic rocks as old as 52-48 Ma [Bloomer *et al.*, 1995; Meffre *et al.*, 2012]. The Lau Basin and Havre Trough formed since the late Miocene or Pliocene [Malahoff *et al.*, 1982; Parson and Wright, 1996; Sdrolias *et al.*, 2003; Taylor *et al.*, 1996]. These active basins have been extensively studied, with particular emphasis on their petrological and geochemical signatures. Oceanic accretion occurs along two major spreading ridges that are propagating south: the Valu Fa Ridge and the Lau Ridge [Hawkins, 1995]. Ocean floor consists of MORB-type basalts, except in the west of the basin, where a mixture of MORB is found along with transitional rocks and volcanic arc basalts (arc tholeiites). Seismic-refraction data shows that the western basin consists of ~100 km width of thinned crust, probably stretched arc, and the eastern basin contains a ~200 km width of 8-9 km-thick oceanic crust [Crawford *et al.*, 2003b]. Spreading rates of 4-9.5 cm/year are comparable with those at the East Pacific Rise [Bevis *et al.*, 1995].

The area north of New Caledonia remains poorly studied. Geophysical and dredge sample data have identified the South Rennell Trough and Santa Cruz Basin as an early Oligocene fossil spreading ridge [Mortimer *et al.*, 2014; Seton *et al.*, 2016], with the age of the flanking D'Entrecasteaux Basin largely unconstrained.

Miocene to present-day New Hebrides-Vanuatu subduction initiation and retreat

At the end of the Middle Miocene, the northeast-dipping New Hebrides-Vanuatu subduction zone initiated along the Vitiaz lineament, possibly in relation to a subduction flip induced by collision of the Ontong Java and Melanesian Border plateaus with the Vitiaz subduction zone [Auzende *et al.*, 1988b; Brocher, 1985; Chase, 1971; Falvey, 1975; Pelletier and Auzende, 1996]. The reconfigured subduction zone then formed the Solomon-Vanuatu arc and rolled back towards the south and southwest, leading to opening of the North Fiji Basin [Auzende *et al.*, 1995a; Auzende *et al.*, 1988a; Auzende *et al.*, 1995b]. Zircons found within the arc suggest that part of the Vanuatu basement comprises old continental material that was rifted and transported thousands of kilometres from northeastern Australia prior to the Cenozoic [Buys *et al.*, 2014]. The d'Entrecasteaux and Loyalty ridges entered the subduction zone before 2 Ma, and resulted in local and regional deformation. The collision of the d'Entrecasteaux Ridge is thought to be responsible for large vertical motions in the central New Hebrides arc [Taylor *et al.*, 1987], as well as initiation of compression in the back-arc area [Collot *et al.*, 1985]. At the southern extremity, the eastern edge of the Loyalty Ridge (cf. Chapter 6, this memoir) entered the subduction zone, which resulted in local flexural uplift of the Loyalty Ridge and southern part of Grande Terre of New Caledonia (cf. Chapter 7, this memoir and Dubois *et al.* [1974]). This collision is thought to be responsible for initiation of the Matthew Hunter subduction zone along the southern edge of the North Fiji Basin [Monzier *et al.*, 1990; Patriat *et al.*, 2015].

Tectonic impacts on New Caledonian geology

The geology and present-day shape and structure of New Caledonia are intimately related to the geodynamic evolution of the southwest Pacific. Mesozoic basement terranes, described in Chapter 3 of this memoir, (e.g. Teremba, Boghen and Koh-Central terranes) were deposited and emplaced in the forearc context of the peri-Gondwana subduction zone. Cretaceous to Palaeocene breakup and seafloor spreading between Gondwana and Zealandia resulted in deposition of syn- and post-rift sedimentary cover described in Chapter 4 of this memoir (e.g. Formation à charbon, Black Cherts). Eocene sedimentary rocks found in New Caledonia (e.g. Bourail Group turbidites) along with high-pressure low-temperature metamorphic rocks record the reconfiguration of subduction and regional contraction across Zealandia [Sutherland *et al.*, 2017]. Nappe emplacement described in Chapter 5 of this memoir (e.g. Montagnes Blanches Nappe, Poya Nappe and Peridotite Nappe) was associated with the culmination of this tectonic event. Neogene tectonic quiescence reflects Tonga-Kermadec subduction roll-back and isolation of New Caledonia by back-arc basins. During this period, northward motion of the Australian Plate moved New Caledonia to lower latitudes and tropical conditions. These favoured the development of carbonate platforms and deep weathering of exposed rocks described in Chapter 7 of this memoir, notably laterite development on the Peridotite Nappe and formation of supergene nickel ore (cf. Chapter 10, this memoir). Since 2 Ma, the southern tip of Grande Terre and the Loyalty Islands, described in Chapter 6 of this memoir, were uplifted by lithospheric flexure associated with subduction at the New Hebrides-Vanuatu trench.

Conclusions

The southwest Pacific contains a diverse assemblage of continents, volcanic arcs, hotspot tracks, large igneous provinces, and oceanic basins. The geodynamic evolution was controlled by the dynamics of subduction zone death, reversal, initiation, and roll-back. This led to the final dispersal of Gondwanaland and formation of the continent of Zealandia. Two classes of plate kinematic model have been proposed to explain development of features since 100 Ma. In one class of model, subduction evolution was complex, but nearly continuous throughout the entire period. In the other class of model, subduction ceased in the Late Cretaceous and then re-initiated in the Eocene. The main unresolved plate tectonic issues revolve around arc longevity and polarity in the interval 85-25 Ma that may be better understood by future sampling and analysis in the southwest Pacific.

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FIGURE CAPTIONS

Figure 1. (a) New Caledonia in the Southwest Pacific. (b) Bathymetric map of the southwest Pacific [Smith and Sandwell, 1997]. Dashed red line is outline of the Zealandia continent [Mortimer et al., 2017]. (c) Free air gravity anomaly map of the southwest Pacific [Sandwell and Smith, 1997]. Acronyms: Bougainville Seamount (BS); D'Entrecasteaux Ridge (DER); South Rennel Trough (SRT).

Figure 2. Basement geological map of the southwest Pacific, modified after [Collot et al., 2012]

Figure 3. Age of formation of basement of the southwest Pacific, modified after [Collot et al., 2012]. See Figure 2 for legend.

Figure 4. Early Cretaceous plate kinematic reconstruction of Gondwana. Age grids and reconstructions are based on [Müller et al., 2016]. Projection is orthographic, centred on 120°/-90°.

Figure 5. Cross sections of two classes of models for the geodynamic evolution of the southwest Pacific. See Fig. 6 for location of cross section.

Figure 6. Map reconstructions of two classes of models for the geodynamic evolution of the southwest Pacific. Paleolatitudes are based on a hotspot reference frame. Red triangles: active volcanic arc. Blue lines: active spreading center. Acronyms: Median Batholith (MB); Loyalty Ridge – Three Kings Ridge (LR-3KR); Lau Basin (LB); Lau Colville Ridge (LCR); Tonga Kermadec Ridge (TKR); New Hebrides-Vanuatu arc (NH), North Fiji Basin (NFB). Dashed line indicates location of cross section of Fig. 5. Maps generated with Gplates.

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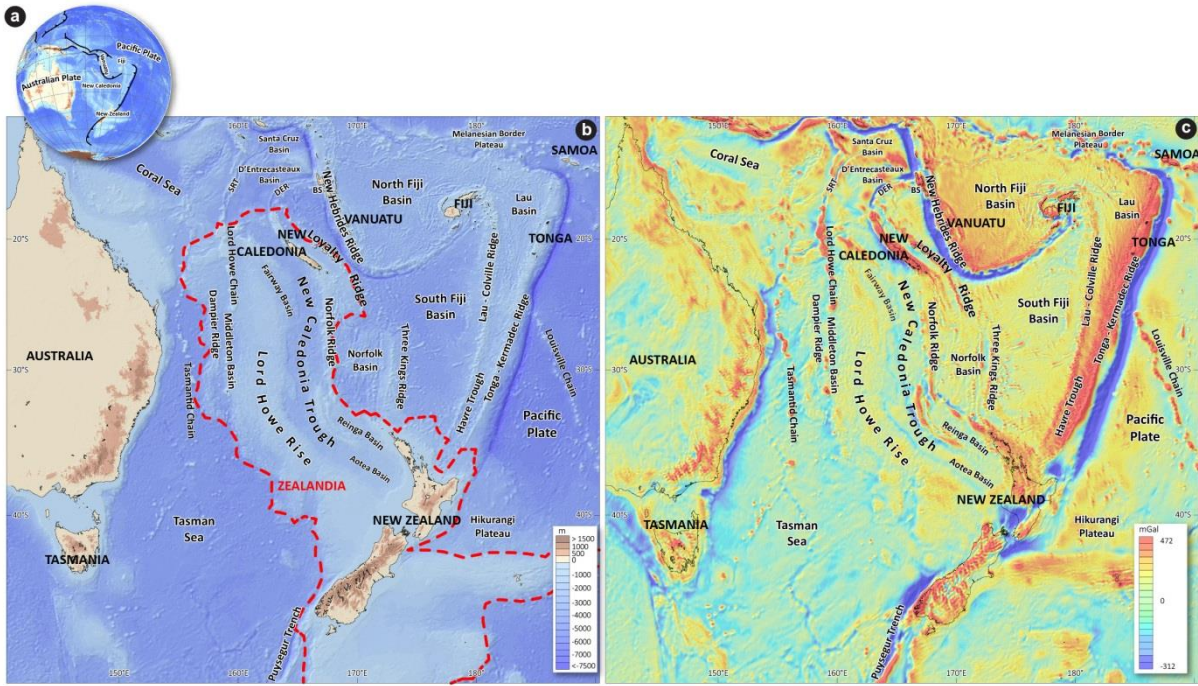


Figure 1

Nature of basement

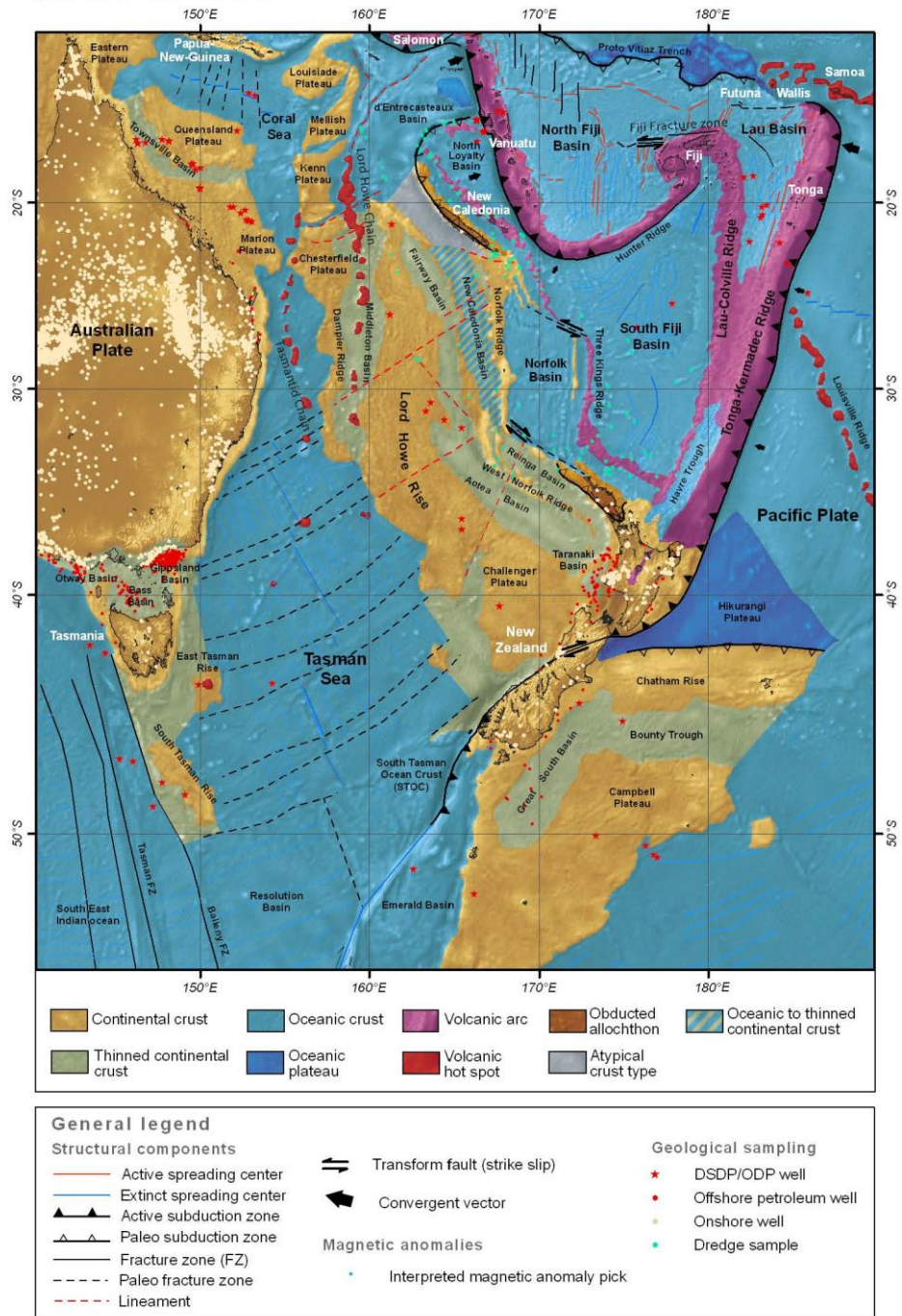


Figure 2

Age of formation

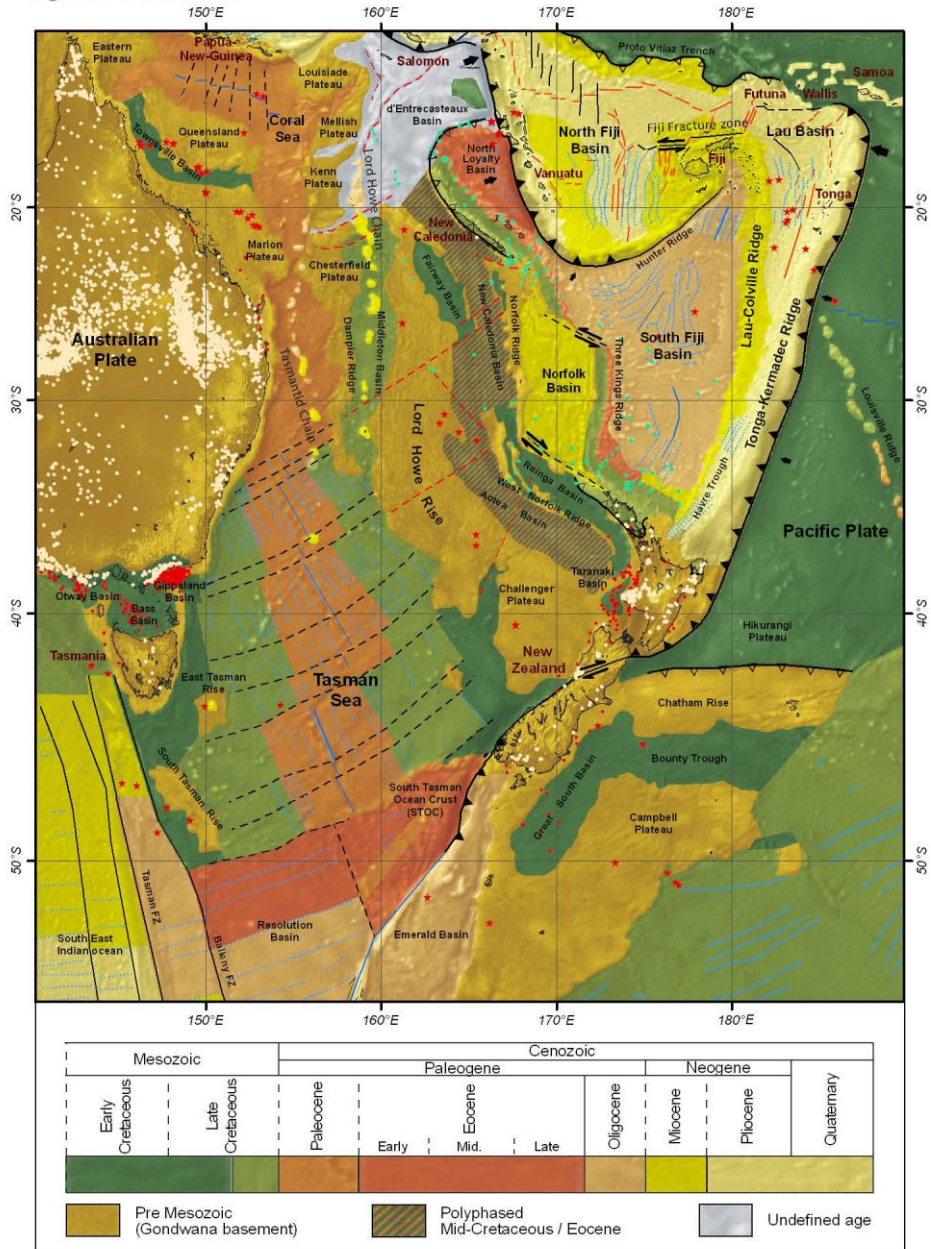


Figure 3

140 Ma

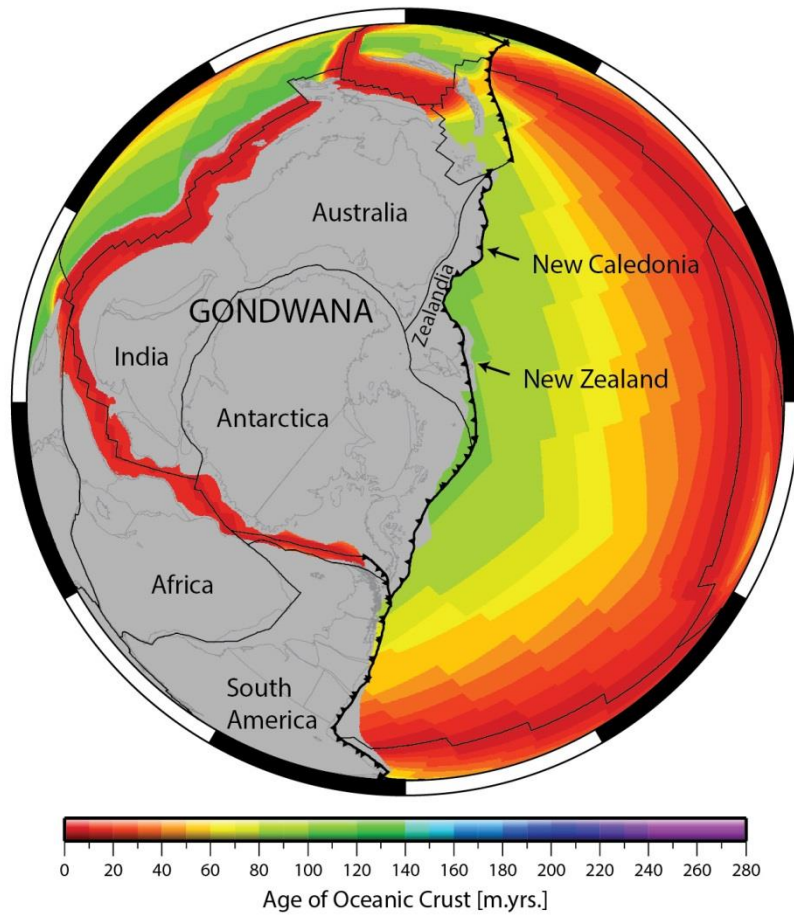


Figure 4

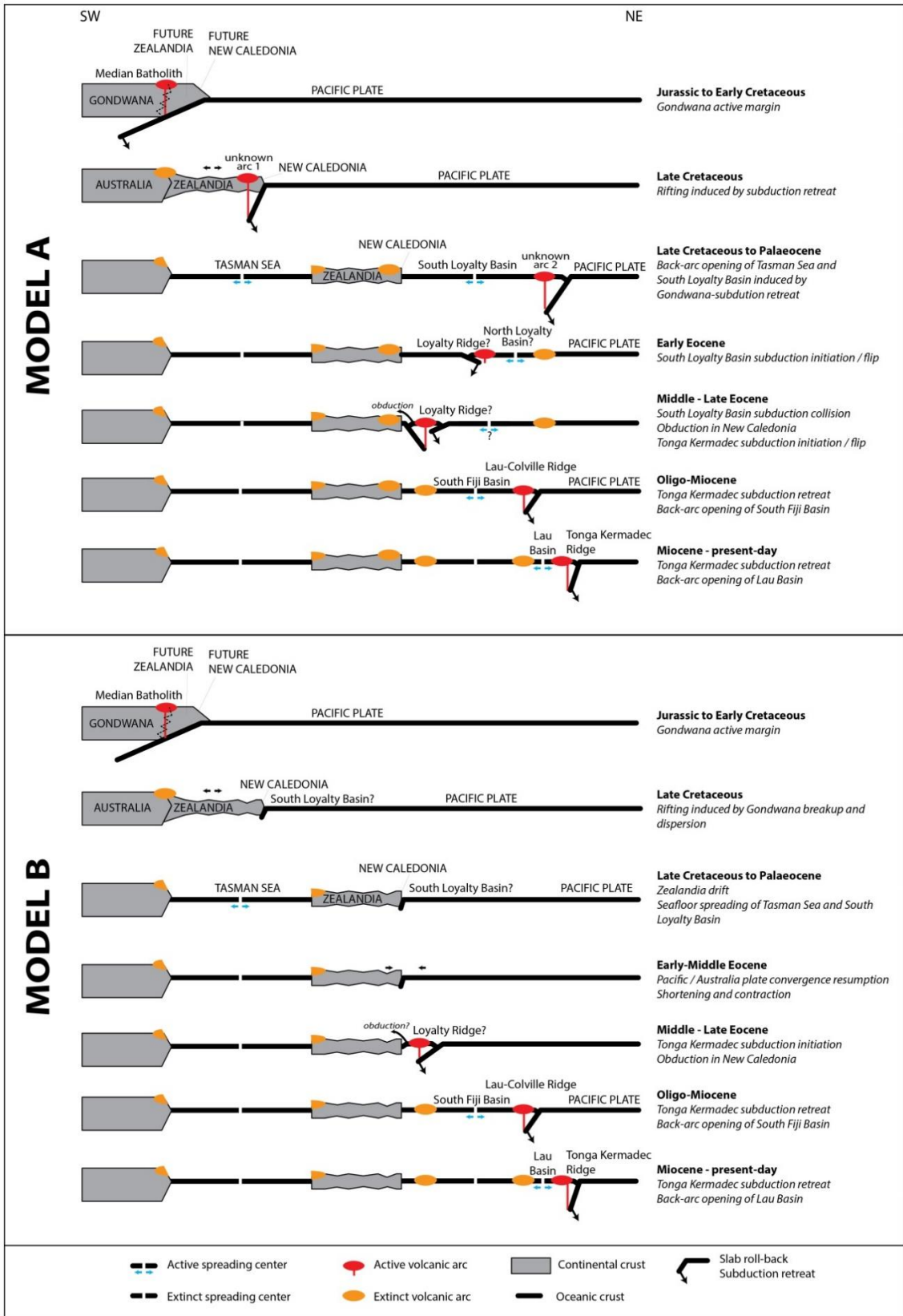


Figure 5

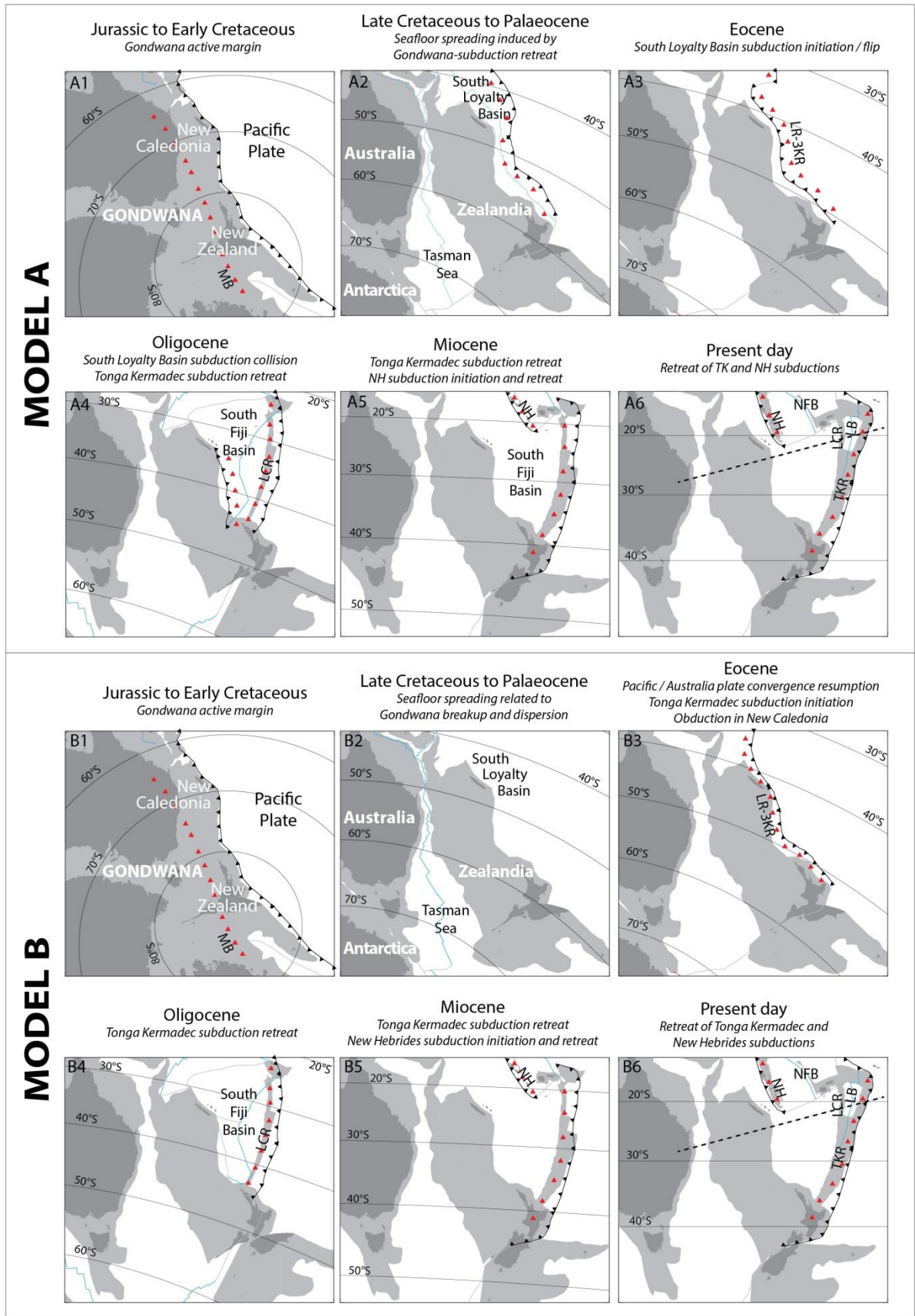


Figure 6