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Geochemistry, Geophysics, Geosystems
December 2009 ; Volume 10 (12) : Pages 1-24
http://dx.doi.org/10.1029/2009GC002612
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An edited version of this paper was published by AGU.

Mesozoic history of the Fairway-Aotea Basin: Implications for the early stages of Gondwana fragmentation

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Abstract:

The Fairway Ridge is a buried continental structure that separates the Fairway Basin from the New Caledonia Basin. The proposed Cretaceous age of the Fairway Basin has remained highly hypothetical to date. Deep offshore petroleum exploration wells revealed well-dated Mesozoic carbonaceous sedimentary rocks in the Taranaki Basin at the southern end of the Aotea Basin. In this paper we use geophysical data to confirm the continuity of the 2000 km long Fairway-Aotea Basin connecting New Caledonia to New Zealand and prove its early Late Cretaceous age. Analysis of seismic reflection profiles together with newly compiled gravity and magnetic maps reveals Late Cretaceous NE–SW trending lineaments projecting northeastward from major Tasman Sea fracture zones and the Bellona Trough, which demonstrate that the opening of the Fairway-Aotea Basin predates the opening of the Tasman Sea. This result combined with observations of the Mesozoic regional geology suggests that the Lord Howe, Fairway, and Norfolk ridges are part of a remnant late Early Cretaceous continental arc, which was fragmented into three pieces by the late Early to early Late Cretaceous. This event might be contemporaneous with a plate motion change between the Gondwana and Pacific plates and/or the arrival of the Hikurangi plateau in the subduction zone around 105 Ma, which caused the cessation of subduction along this plate boundary. We interpret either of those two events as being possible trigger events for the post–Early Cretaceous fragmentation of the eastern Gondwana margin in a slab retreat process.

Keywords: southwest Pacific; Fairway Basin; Aotea Basin.

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1. Introduction

[2] The SW Pacific basin and ridge system is the result of the fragmentation of the Gondwana eastern margin mainly through a trench rollback/back-arc extension process [Cluzel et al., 2001; Crawford et al., 2003; Schellart et al., 2006; Symonds et al., 1996] resulting in the formation of successive back-arc basins, continental fragments and remnant volcanic arcs. In this system, the age of most basins are reasonably well constrained thanks to magnetic anomalies and/or dredge samples [Auzende, 1988; Cande and Stock, 2004; Gaina et al., 1998, 1999; Mortimer, 1998; Mortimer et al., 2007; Sdrolias et al., 2003]. This is not the case for the Fairway and New Caledonia basins (see Figure 1 for location). Although the nature of the crust of the Fairway Basin (FB) and New Caledonia Basin (NCB) is well known as described by Klingelhoefer et al. [2007] and Lafoy et al. [2005c], their ages and processes of formation remain poorly constrained. They are thought to be of Cretaceous age, based on rifting evidence in the Taranaki Basin located more than 1500 km further south [Lafoy et al., 2005c], and of Early Paleocene age as mid-Paleocene ooze was found in the DSDP 206 drill hole [Burns et al., 1973c; Collot et al., 1987; Lafoy et al., 2005a; Mignot, 1984; Ravenne et al., 1977; Uruski and Wood, 1991; Willcox et al., 2001]. Understanding their origin and their tectonic history is essential to understanding the relationship that links New Caledonia to the

Lord Howe Rise (LHR), and knowing whether these basins opened prior to, synchronously or after the Tasman Sea is a key element in building regional kinematic models of the early stage of the fragmentation of the eastern Gondwana margin.

Using Faust-3 reflection seismic data which cross-cuts the NCB from east to west, *Exon et al.* [2007] showed that the bathymetric NCB, which extends from New Caledonia to New Zealand, is in fact divided by the Fairway Ridge (FR) into two sub-parallel north-trending structural basins extending south to 31°S (from west to east : the structural Fairway and New Caledonia Basins). This division was previously noted by others [*Dupont et al.*, 1975; *Eade*, 1988; *Lafoy et al.*, 2005a; *Ravenne et al.*, 1977]. *Klingelhoefer et al.* [2007] showed that the Fairway Basin crust is of continental type whereas the NCB crust is of backarc oceanic type in its central part and of atypical type in its northern part. This makes these basins structurally very different. *Collot et al.* [2008] showed that their tectonic history and sedimentary infills are very distinct: the Fairway Basin has a thick pre-Oligocene sedimentary cover (2.5 seconds two-way travel time (s twt)) resulting from the erosion of the LHR whereas the NCB has a thick post Oligocene sedimentary cover (3.5 s twt) in its northern part, resulting from the erosion of the newly emerged post-Eocene New Caledonia, and relatively thinner sedimentary cover elsewhere (1 s twt). On the basis of reflection seismic data, *Lafoy et al.* [1998; 2005a] identify the West New Caledonia Basin on the western flank of the Norfolk Ridge (NR) as a perched basin which is the eastern conjugate of the Fairway Basin.

South of 31°S the Fairway Ridge (also called the northern West Norfolk Ridge by *Exon et al.* [2007]) connects with the West Norfolk Ridge (WNR) [*Exon et al.*, 2007], the Fairway Basin connects with the Aotea Basin (AB) in New Zealand and the NCB dies between the WNR and the Norfolk Ridge. For the sake of clarity, we here point out that the name of Aotea Basin was chosen by New Zealand and Australian experts [*Exon et al.*, 2007] to define the structural basin extending northward from the Taranaki Basin, off New Zealand's northern margin.

Before this, the basin was referred to as the “Deepwater Taranaki Basin” (e.g. [*Baillie and Uruski*, 2004]) or “Greater Taranaki Basin” (e.g. [*Uruski and Baillie*, 2004]). According to *Baillie and Uruski* [2004], the Aotea Basin is a rifted Cretaceous basin based on Tane-1 well information. *Zhu and Symonds* [1994] showed from gravity modelling the continental nature of the West Norfolk Ridge and the stretched continental nature of the Aotea and Reinga basins.

Here we use a set of reflection seismic data from New Zealand (NZ), Australia and New Caledonia (NC) to connect the well constrained Cretaceous stratigraphy from the Aotea Basin at 43°S to the Fairway Basin at 20°S and shed light on the Cretaceous age of this 2000 km long basin that connects NC to NZ. We also present a magnetic anomaly map, which we combine with free air gravity anomalies and seismic data to produce a detailed structural synthesis map of the structures linking NC to NZ. The structures to the east of the West Norfolk Ridge (i.e. The Wanganella Ridge, Wanganella Basin, the Reinga and Norfolk Basins) are not considered in this study because their structure was strongly affected during the Miocene by the Veining Meinesz Fracture Zone. The southern extension of the New Caledonia Basin into the Reinga Basin is therefore not discussed in this paper.

On the basis of these results we propose a model for the breakup of the eastern Gondwana margin.

II Cretaceous seismic stratigraphy of the basins linking NZ to NC

A The Aotea Basin (AB)

Stretching from the western flank of the New Zealand continental platform to the Fairway Basin, the Aotea Basin is the deep offshore continuation of the shallow and widely drilled Taranaki Basin. Wells Tane-1, Wainui-1 and Wakanui-1 [*Milne and Quick*, 1999; *Shell et al.*, 1976, 1981] were drilled just on the edge of the platform (see location on Figure 1). Unlike most DSDP drillholes, aimed at reaching a shallow basement, these deep petroleum wells have the advantage of penetrating thick strata, enabling reliable seismic reflector ties to be made. Moreover, these holes reach Cretaceous and Jurassic (in the case of Wakanui-1) sedimentary strata. The Aotea Basin also has fairly good coverage of seismic data. We use two seismic lines, Astrolabe-40 [*TGS-NOPEC*, 2001] and UNCLOS TL-1 [*Uruski*, 1997], and three petroleum wells Wakanui-1, Tane-1 and Wainui-1 [*Milne and Quick*, 1999; *Shell et al.*, 1976, 1981] to tie the seismic data (Figure 1).

Well information is listed below and synthesized in Figure 2:

- No Cretaceous rocks were found at Wakanui-1 [*Milne and Quick*, 1999]; instead a thick marine mudstone of Paleocene age overlies a Middle Jurassic coal-measure succession dated radiometrically by a 158 Ma intrusive sill and by pollen [*Folland*, 1999].
- At well Tane-1 [*Shell et al.*, 1976], the Oligocene sequence is very thin (30 m) and lies on mudstones and siltstones of Eocene age. Much of the 500 metre thick Paleocene succession consists of siltstone facies. The Top Cretaceous was encountered at 3462 m, with sandstones overlying coal-measure units. Granitic basement was drilled at 4290 m. It correlates with the Separation Point Granite of the northern South Island and is dated at between 110 and 120 Ma.
- Very little Oligocene is found at Wainui-1 (91 m) [*Shell et al.*, 1981]. The underlying 400 metre thick Eocene sequence is shale dominated and overlies 275 m of Paleocene marine mudstones. The Top Cretaceous was drilled at 3703 m. It includes typical coastal plain Upper Cretaceous coal-measure facies and ranges from fully terrestrial to shallow marine. Schistose basement rocks are found at 3864 m and are similar to outcrops in northern South Island, believed to be of Early Paleozoic age.

Seismic line TL-1 is tied at its southern end by well Wainui-1 [*Baillie and Uruski*, 2004], which reached Cretaceous strata (Figure 3). It continues northwards (Figure 1) in the axis of the Aotea Basin to DSDP 206 [*Burns et al.*, 1973c] (Figure 3), where the regional Eocene Oligocene unconformity (reflector RN) is identified. Seismic line Astrolabe-40 crosses TL-1 at CDP 3890 (Figure 1) and is tied at either end by wells Wakanui-1 and Tane-1 (Figure 4), which both reach Mesozoic strata (Jurassic strata for Wakanui-1 and Lower Cretaceous for Tane-1, see Figure 2) [*Uruski et al.*, 2002; *Uruski et al.*, 2003]. Top Cretaceous (C1) and Lower Cretaceous (C2) reflectors are identified at well Tane-1 and are followed with confidence along Astrolabe-40 to the intersection with seismic line TL-1 (Figure 5). According to *Uruski and Baillie* [2004], the basal seismic unit imaged by the Astrolabe survey in the Deepwater Taranaki Basin at the head of the Aotea Basin consists of sedimentary rocks of Jurassic age. It is worth noting that even though Jurassic sediments are recognized in the basal units of the Aotea Basin, the structural continuity of the reflector (J1) along profile Astrolabe-40 from well Wakanui-1 towards the southern end of the profile cannot be demonstrated because J1 is too deep and close to basement (light blue reflector on Figure 5).

From Wainui-1, the Top Cretaceous reflector (C1) is followed northwards along TL-1 and its position confirmed at the intersection with profile Astrolabe-40 (CDP 2163 on Figure 6). C2 cannot be extrapolated very far northwards, but on the edge of the Taranaki platform, 1.5 s twt of pre-C2 sequences are encountered. C1 is characterized by a negative phase – high amplitude reflector located at 2-2.2 s twt beneath seafloor and overlying a 1.2 s twt, (or thicker) disrupted channel-like sequence. As C1 is followed further north along TL-1, a few narrow diffractive intrusions interfere with the continuity of this high amplitude reflector, which can lead, in some places, to uncertainty in the interpretation of C1's position. The question mark on Figure 6 illustrates this particular case. It is nevertheless noteworthy that neither position drastically changes the interpretation of the relative thickness of the pre-C1 sediments further north along TL-1. In fact, once CDP 9900 is reached (see Figure 6), the characteristics of C1 are again clear. At CDP 16775, TL-1 crosses seismic line RS114-4 along which early Upper Cretaceous - Cenomanian carbonaceous rocks were dredged on the western flank of the West Norfolk Ridge (dredge RE9302-5, see dredge location on Figure 1 and Figure 7) [*Herzer et al.*, 1999]. These dredge samples are not used as seismic markers but confirm the nearby presence of Cretaceous rocks at this latitude of the basin.

At the northern end of TL-1, DSDP 206 reaches Paleocene oozes. This site is located on a basement high in the middle of the Aotea Basin. The edge of this basement high reveals 1.2-1.5 s twt thick pre-C1 sedimentary layers. The thickness of the pre-C1 strata in the Aotea Basin varies from 2.5 s twt on the edge of the Taranaki Platform (Figure 5 and Figure 6) to an average thickness of 1.3 s twt farther north (Figure 6). This indicates that as far as DSDP 206, the Aotea Basin includes thick Upper Cretaceous sedimentary layers, with evidence for Cenomanian rocks (dredge RE9302-5, see dredge location on Figure 1 and Figure 7) [*Herzer et al.*, 1999].

A 100 km wide, highly faulted zone identified on profile TL-1 affects dominantly pre-C1 deposits (see highlighted zone on Figure 1 and Figure 6). The fault zone correlates with large-scale NNE-trending lineaments characterized by their gravimetric, magnetic and bathymetric signatures (see section III for more details on structural map, Figure 8 and Figure 9). These lineaments align with the Bellona Trough (Figure 1, andFigure 9) and cut through the West Norfolk Ridge around 168°E, 37°S). According to *Gaina et al.* [1998b] the Bellona Trough would have formed during the early stage of opening of the Tasman Sea. The earliest identified Tasman Sea magnetic anomaly being chron 34 [*Cande and Stock*, 2004; *Gaina et al.*, 1998b; *Hayes Dennis and Ringis*, 1973] rifting of the Bellona Trough would have occurred around 90-83 Ma during the Senonian [*Gaina et al.*, 1998b].

The fault zone we identify in the Aotea Basin sealed by post-Cretaceous deposits (see inset Figure 6), indicates that faulting ceased by the end of the Cretaceous. It appears to be structurally related to the Bellona Trough (Figure 1 andFigure 9) and we interpret it as a faulted zone inherited from the early stage of Tasman Sea opening, ie as being early Senonian. As the pre-C1 strata of the Aotea Basin are affected by this Senonian lineament, the basin must have existed prior to the Senonian.

B The Fairway Basin

The Fairway Basin extends northward from DSDP 206 to 21°S and is separated from the NCB by the Fairway Ridge (Figure 1). The only modern digital seismic reflection data available between DSDP 206 and the New Caledonia EEZ is the FAUST-3 (S232) survey which zig-zags northwards up the basin between the LHR and the Norfolk Ridge. The orientation of these profiles does not allow C1 to be followed continuously. We therefore propose an interpretation based on stratal thicknesses and seismic reflector identification.

As demonstrated in the previous paragraph, Top Cretaceous (C1) and Top Eocene (RN) reflectors are well identified along the northern part of TL-1. By comparing the structural styles, relative stratal thicknesses and seismic characters of profile TL-1 with profiles Mobil72-145 and FAUST3-10 (see inset in Figure 1 for location), we identify C1 and RN along these profiles (see Figure 10 which shows at similar scales, seismic lines Mobil72-145, FAUST3-10 and TL-1 northern end, all located near DSDP 206). On the flanks of the basin, C1 is generally located at an average depth of 5.5 s twt and around 6-6.5 s twt in its center (Figure 6,Figure 7 andFigure 10). The basin stratigraphy is uniform northwards, allowing confident extrapolation of C1 and RN as far as seismic line FAUST-232-5 (Figure 11). Thick, black, dashed lines on Figure 1 indicate the location of the seismic sections that were not shown in this paper but that were used to correlate the stratigraphy from one profile to another. Once C1 was identified along profile FAUST-232-5, seismic line ZoNeCo5-6A located in the axis of the Fairway Basin (Figure 1) was used to follow the reflectors to line FAUST-S206-1 (Figure 12). From the seismic interpretation of RN [*Collot et al.*, 2008; *Nouzé et al.*, 2007], we confirm the position of the Eocene-Oligocene unconformity in the Northern Fairway Basin. Figure 11 and Figure 12 reveal that in the Fairway Basin, the pre-C1 strata are about 1.3 s twt thick. Although the Fairway Basin is separated from New Caledonia by the Fairway Ridge and the New Caledonia Basin, it is important here to notice that Senonian coals are encountered in Cretaceous basins located all along the west coast of New Caledonia [*Pomeyrol*, 1951; *Vially and Mascle*, 1994; *Vially et al.*, 2003]. This observation is not used to correlate any seismic reflectors, but the presence of Cretaceous coals 200 km to the east of the northern end of the Fairway Basin supports our interpretation of Cretaceous deposits being possibly coals in the Fairway Basin.

It is also noteworthy that as we go further north, domes embedded by C1 appear in the sedimentary sequence (Figure 12). These domes have been described by *Auzende et al.* [2000a; 2000b] as salt domes or mud diapirs. Other larger domes could well be of volcanic origin [*Exon et al.*, 2007; *Lafoy et al.*, 1994; *Lafoy et al.*, 1998].

Exon et al. [2007], *Gaina* [1998], *Gaina et al.* [1998a], *Lafoy et al.* [2005b] and *Stagg* [1999] identified the Barcoo-Elizabeth-Fracture-Lineament (BEFL), which crosscuts the LHR, Fairway Basin, Fairway Ridge and NCB, as being a faulted zone inherited from the change of spreading rate of the Tasman Sea around chron 33. We provide a detailed structural map of this feature in the Fairway and New Caledonia basins (section III). The map shows that the Fairway Ridge is displaced 60 km laterally by the BEFL (Figure 9). The Fairway Basin, the Fairway Ridge and the New Caledonia Basin are offset by this 85 Ma old lineament, which implies that they must have existed prior to 85 Ma. Note that this shift is barely distinguishable on the magnetic anomaly map (Figure 8) because of the lack of data coverage in this area.

C The Central New Caledonia Basin

The Central New Caledonia Basin has a thinner sedimentary cover than the Fairway Basin, its seafloor is deeper and its crust is of oceanic type [*Klingelhoefer et al.*, 2007]. The position of C1 is not identified in this basin, the reflectors identified in the Fairway-Aotea Basin (FAB) being truncated by the Fairway Ridge. Its deeper seafloor and thinner sedimentary cover suggest a younger age than that of the FAB.

III Structural synthesis map

In order to observe the N-S extensions of the Fairway-Aotea basin (FAB) and its relation with the neighbouring LHR and Norfolk Ridge, we compiled a structural synthesis map combining information from seismic, gravity, magnetic, drilling and bathymetric data (Figure 9).

Magnetic map

The magnetic anomaly map was compiled using the New Caledonia database (Geological Survey of New Caledonia) and the New Zealand data base (GNS Science / NIWA). For the New Caledonia area, the data incorporates all available shipboard data from 97 surveys between 1967 and 2004. *Champollion* [2001] compiled all the data from 1967 to 2000 and computed the magnetic anomaly using the IGRF 1995 (7th generation), which is definitive for the pre-1990 data. We therefore reprocessed all post-1990 data, incorporating the new post-2000 data, using the IGRF 2005 (10th generation) and recompiled the data set. The IGRF 2005 is not definitive for the computation of the magnetic anomaly of the 2004 surveys, it will therefore be necessary to reprocess them in 2010 with the IGRF 2010. Table 1 and Table 2 show the statistics of the cross-over points.

For the New Zealand area, the compilation was done using all shipboard data from the GNS database kindly provided by Dr Bryan Davy (GNS Science).

A reduction to the pole was then applied to the whole data set taking a magnetic declination of -48° which corresponds to the declination of the IGRF field at 167°E, –22°S. This reduction to the pole allows the magnetic anomaly to be centred on the structures. Figure 8 presents the magnetic anomaly map with brief interpretations showing the structural continuity of the Fairway Ridge toward the WNR.

Gravity and Bathymetric data

The gravity map of NC combines satellite and shipboard data (Lalancette et al, in prep); the bathymetry of NC is a compilation of multibeam and predicted satellite altimetry data. The gravity of NZ is satellite-derived [*Sandwell and Smith*, 1997] and the bathymetry is a combination of NIWA-compiled multibeam data and predicted satellite altimetry data.

Structural information

We identify, via the geophysical dataset, a series of faults confirming and defining the structure of the well documented BEFL and identifying a new fault zone: the Bellona-Aotea Lineament described in section IIA.

Together these data reveal the structure of the LHR. The eastern limit of the LHR with the Fairway Basin is shown on Figure 9-A (grey shaded line) and consists almost continuously from north to south of pre-Oligocene prograding sequences [*Collot et al.*, 2008] extending from the top of the LHR platform towards the western edge of the Fairway Basin (Figure 11 andFigure 12). The platform consists of highly eroded and flattened basement, overlain by a thin transparent post-Eocene sedimentary cover [*Collot et al.*, 2008] and intruded by recent volcanics [*Van de Beuque et al.*, 1998]. To the west is a rifted margin composed of a half-graben and horst system (also known in literature as the Capel and Faust Basins [*Exon et al.*, 2005; *Stagg*, 1999; *Van de Beuque*, 2003]). The structural style of this system is known in detail between -24°S and -28°S. In this area, dense seismic data coverage allows this system to be mapped by correlating horsts with gravity highs and grabens with gravity lows. The southern prolongation of this rifted margin is poorly documented because of a lack of seismic data. Nevertheless the gravity and magnetic data suggest that the rifted margin propagates down to the Challenger Plateau (see Figure 9-B). No wells have penetrated deep enough in these grabens to date the rifting phase.

IV Discussion

A Age of the Fairway-Aotea Basin (FAB)

As previously demonstrated from chronostratigraphy in section II, the basement of the FAB from New Zealand to New Caledonia is overlain by a 1.2 to 2.6 s twt thick pre-Cenozoic sedimentary cover with its top approximately 2.2 s twt beneath seafloor. An interval velocity of approximately 2300m/s makes this sequence about 1.3-3 km thick. This great thickness combined with the presence of (i) Lower Cretaceous strata (in well Tane-1 and along the southern ends of profiles Astrolabe-40 and TL-1), (ii) Jurassic strata in well Wakanui-1 and (iii) early Upper Cretaceous rocks in dredge RE9302-5 leads us to propose that the oldest sediments present in the basin are at least early Upper Cretaceous (Cenomanian). Moreover, this hypothesis corroborates the presence of Senonian coals encountered all along the western margin of New Caledonia.

Two NE-trending fault zones related to the early stages of Tasman Sea opening (the BEFL and the newly identified Bellona-Aotea Lineament) affect the Cretaceous sediments of the LHR, the FAB, the Fairway Ridge and the NCB, which confirms that extension in these basins predates the Tasman Sea, as suggested by *Lafoy et al.* [2005c]. Therefore, the history of these basins is as old as early Late Cretaceous (Cenomanian) or older.

The mafic allochthon that crops out over more than 150 km along the west coast of NC (the Poya Terrane), and extends further north beneath the Belep Islands [*Collot et al.*, 1987] is evidence of the South Loyalty Basin. On micropaleontological and geochemical evidence, the South Loyalty Basin is an oceanic basin interpreted to have formed from the Campanian to the earliest Eocene in a backarc setting [*Aitchison et al.*, 1995; *Cluzel et al.*, 2001], which post-dates the proposed age of the opening of the FAB (Cenomanian or older).

All other basins located between the Australian margin and the Tonga-Kermandec trench (with the exception of the oceanic Tasman Basin, which started to form at 80 Ma in the Campanian) are post-Cretaceous [*Auzende*, 1988; *Crawford et al.*, 2002; *Gaina et al.*, 1998b; *Mortimer et al.*, 2007; *Schellart et al.*, 2006; *Sdrolias et al.*, 2003; *Sdrolias*, 2004; *Whattam et al.*, 2008]. The FAB is accordingly the oldest (Cenomanian) existing basin system of the region.

All known pre-Cenozoic samples of the Fairway-Aotea Basin (in wells Wakanui-1, Tane-1, Wainui-1 and dredge RE9302-5) are siliciclastic and carbonaceous, which testifies to shallow depositional conditions in a coastal to shelf environment, close to an emergent continental source. These Cretaceous strata were deposited during the rifting phase of continental break-up [*King and Thrasher*, 1996; *King*, 2000; *Laird*, 1993] and we suggest that this applies to the rest of the FAB. Approximately 50 to 60 Ma later, during Eocene and Oligocene, a major subsidence phase of 2-4 km amplitude affected the basin, giving it its present day physiography [*Sutherland et al.*, 2009]. These combined results seem to show that the FAB underwent a two phase history: a Mesozoic aborted rift phase and a Cenozoic subsidence phase. This paper focuses on the rifting phase.

B Implications for the early stage of Gondwana fragmentation

As shown from seismic stratigraphy and structural interpretations, the Fairway-Aotea Basin is an early Late Cretaceous (Cenomanian) or older basin, which makes it the oldest preserved basin of the Southwest Pacific. Here, we describe the geology and paleogeography of the eastern Gondawana margin during that period in order to discuss and propose a geodynamic model integrating the extension of the FAB.

New Zealand basement geology

Onshore, in NZ, three main provinces make up the basement geology: the Eastern Province, the Median Batholith (also called the Median Tectonic Zone) and the Western Province [*Mortimer*, 2003]. Based on geological evidence and on a deep reflection seismic profile, *Mortimer et al.* [2002] identify the Eastern Province as an extended Paleozoic-Mesozoic convergent orogen composed of, from east to west (Figure 13):

i. The Caples and Torlesse Terranes which are Permian-Cretaceous tectonically imbricated, weakly metamorphosed sequences of marine volcaniclastics, oceanic crust substrate interpreted as an accretionary prism of the long-lived west-dipping Gondwana subduction zone

ii. The Otago Schist Belt which is a greenschist facies that has overprinted the Caples and Torlesse Terranes and represents the maximum exhumation of the Jurassic-Cretaceous Caples-Torlesse accretionary prism

iii. The Dun Mountain-Maitai Terrane which consists of Permian ophiolites and cover sediments, unconformably overlain by western provinces most probably in a near arc setting

iv. The Murihiku Terrane which is an upper Permian to Upper Jurassic volcaniclastic succession interpreted to be a long lived forearc basin

v. The Brook Street Terrane which is a Permian subduction-related volcanic pile and volcanicalastic apron considered to be an allochthonous part of the Median Batholith

The Median Batholith, in NZ, is a long lived, composite, cordilleran batholith composed of Devonian to Early Cretaceous gabbroic – granitic subalkaline, I-type plutons which correspond to igneous products of subduction at the Gondwana Margin in the interval 375-

110 Ma [*Mortimer et al.*, 2002]. The youngest plutons (110 Ma) found in this terrane are the Separation Point Suite Plutons, which are also encountered in the bottom of hole Tane-1. This Median Batholith / Eastern Province system is described by *Mortimer et al.* [2002] as the Mesozoic arc / forearc region of the Gondwana margin west-dipping subduction zone, with an accretionary prism, an exhumed accretionary prism, a forearc buttress/basin and an arc. The Eastern Province, forming the forearc, broadly correlates with the New Caledonia autochthon geology.

New Caledonia basement geology

In New Caledonia four main pre-Late Cretaceous terranes are described (east to west):

i. the Boghen Terrane which is formed of deep-sea fan sediments, arc-related volcaniclastic and volcanic rocks and sheared oceanic crust, accreted during the Jurassic in a forearc area, which underwent HP-LT metamorphism by plunging into the west-dipping subduction zone [*Cluzel and Meffre*, 2002]. This terrane correlates with the Otago Schist Belt in NZ although the metamorphic facies is not the same (personnal communication P. Maurizot).

ii. the Koh Terrane, a dismembered upper Carboniferous forearc ophiolite [*Cluzel and Meffre*, 2002] which is the equivalent of the Dun Mountain-Maitai Terrane in NZ [*Maurizot et al.*, since 2005].

iii. the mid-Triassic to Jurassic Central Chain Terrane, composed of more distal volcaniclastic arc sediments and a few arc tholeiite lava flows [*Cluzel and Meffre*, 2002], which correlates with the Murihiku Terrane [*Maurizot et al.*, since 2005].

iv. the Permian-late Jurassic Teremba proximal arc-related terrane [*Cluzel and Meffre*, 2002], which correlates with the lower Jurassic part of the Murihiku Terrane and Brook Street Terranes [*Spandler et al.*, 2005].

This comparison of NC and NZ basement geology shows that the exhumed part of the accretionary prism is found both in NC and NZ. In contrast, the arc and the accretionary prism are absent in New Caledonia; mainly because of the narrowness of the island (average of 80 km) and of the Eocene obduction which overrode and buried most of the Mesozoic outcrops. Figure 13 [after *Mortimer* [2008] shows the relationships between the Mesozoic geology of NC, NZ and Australia.

Mesozoic subduction system

From magnetic data [*Sutherland*, 1999], geochemical and zircon analyses in the New England Fold Belt, Queensland, and Marie Bird Land, Antarctica, *Mortimer* [2004, 2008] and *Mortimer et al.* [2008] have identified a Mesozoic volcanic continental arc (the Median Batholith) that was active or intermittently active from Permian to Cretaceous time along the eastern Gondwana Margin. The reconstruction in Figure 14-A illustrates this active margin [*Eagles et al.*, 2004; *Gaina*, 1998; *Sutherland*, 1999].

Seismic profiles beneath the Chatham Rise show paleo-slab relics of this same Mesozoic west-dipping subduction zone [*Davy et al.*, 2008]. The paleo-distance, observed on the reconstruction of Figure 14-A [*Eagles et al.*, 2004; *Gaina*, 1998; *Sutherland*, 1999], between Queensland and the eastern margin of NC (300-400 km) fits with the arc-trench distance of a low-angle subduction beneath a continent. This configuration indicates that the paleogeography of the eastern margin of Gondwana was probably analogous to that of the present day Cordilleran orogenic belt along the western margin of South America as suggested by *Veevers* [1991], with a forearc region, possibly comprising a coastal cordillera, a forearc basin and a continental arc.

Eastern Gondwana margin fragmentation

In the Mesozoic configuration, summarized in Figure 14-A, the northern LH and Fairway Ridges are located between the observed continental arc in Queensland (the Median Batholith) and the observed forearc in New Caledonia. To this day the only sampled geological elements to identify their origin are in the Teremba Terrane (NZ Brook Street Terrane equivalent, see Figure 13) found in the Bay of St Vincent [*Cluzel et al.*, 1998; *Cluzel and Meffre*, 2002; *Paris*, 1981; *Spandler et al.*, 2005] on the western edge of New Caledonia. These are proximal arc-related deposits, suggesting that the LHR and the Fairway Ridge may have once been in an arc position. The strong parallel N-to-NNW magnetic trends (>250 nTesla) currently associated with the eastern flank of the LHR, the Fairway Ridge and the Norfolk Ridge (Figure 8) and magnetic modelling of the basal crust of the LHR [*Schreckenberger et al.*, 1992] support this hypothesis. These arguments lead us to propose that the arc, originally located in Queensland throughout the Paleozoic and Mesozoic (the Median Batholith), may have finally migrated towards the LHR and the Fairway Ridge. The early Late Cretaceous (Cenomanian) age of the FAB gives an age window for the dislocation of the LHR-FR.

Farther south, the Hikurangi Plateau large igneous province arrived at the Chatham Rise subduction trench around 105 Ma (late Early Cretaceous) and was jammed into that part of the west-dipping subduction zone [*Davy et al.*, 2008]. The subduction of oceanic plateaus, which contain unusually thick basaltic crust, is an important factor in current models of plate motion [*Gaina and Müller*, 2007; *Hall*, 2002; *Knesel et al.*, 2008; *Wessel and Kroenke*, 2000, 2007] which could provide a potential mechanism for triggering plate reorganization according to some previous authors (e.g. [*Cloos*, 1993]). Moreover, the recent model of *Wallace et al.* [2009] shows that the entry of buoyant features into subduction zones is a fundamental mechanism for the generation of fore-arc block rotations and tectonic escape in subduction systems. These authors present a wide selection of modern-day and ancient examples where there are close spatial and temporal associations between subduction jamming and surrounding fore-arc block rotations. Thus, we propose that the jamming by the Hikurangi Plateau locally locked the subduction process, which may have resulted in tectonic escape of the surrounding slab during the Early Cretaceous (~105 Ma).

Based on plate kinematic data, *Müller et al.* [1993; 2000] show that between 132 and 99 Ma, the plate boundary between the Gondwana supercontinent and the Pacific plate progressively evolved from a convergent west-dipping subduction zone to a major sinistral strike-slip shear zone. From their model, cessation of subduction along the eastern Gondwana margin occurred between 132 Ma and 99 Ma.

From the predicted hotspot lineaments of *Duncan and Clague* [1985], *Veevers* [2000a] corroborates *Müller et al.'s* [1993; 2000] model by identifying a 58° swing to the northwest and an acceleration from 46 to 70 mm/year of the Pacific Plate at 99 Ma which the author correlates with the major mid-Cretaceous (99 Ma) tectono-sedimentary change of the Australian plate (full stratigraphic details can be found in *Veevers* [2000b]). From these obervations *Veevers* [2000a] establishes a correspondence between the change in azimuth of the stress from the Pacific Plate and the change along the eastern margin of Gondwana from head-on subduction collision to sinistral sidewipe or transtension, as pointed out by *Jones and Veevers* [1983]. Thus, this main 99 Ma change in the kinematics of the Pacific Plate led to cessation of subduction along the Gondwana-Pacific plate boundary, which may have resulted in the sinking and retreat of the Pacific slab.

The plate kinematic reorganization and the jamming of the Hikurangi Plateau may be causally related but the present-day data does not allow cause to be distinguished from effect. Nevertheless it seems obvious that on the strength of it, a kinematic change of major tectonic plates, such as the Gondwana and Pacific plates, would have had a greater impact on a long-lived, thousand-kilometer long subduction zone than the jamming of an oceanic plateau. In any case, this tectonic sequence led to the modification of the subduction process along the eastern margin of the Gondwana continent during the Early Cretaceous – early Late Cretaceous.

We suggest that this modification of the dynamics of the subduction zone triggered a gradual increase in the dip angle which had a two step impact on the evolution of the subduction process: 1) the gradual seaward migration of the arc axis originally located in Queensland towards the LHR-FR-Northern Norfolk Ridge (Figure 14-B) during late Early Cretaceous and 2) the progressive roll back of the trench leading to intra-arc extension and to the opening of the FAB as an intra-arc basin during the Cenomanian (Figure 14-C). The modification of the slab dynamics is therefore responsible for the migration of the arc and the incipient rifting of the FAB.

The present day N-S parallel geophysical signatures of the LHR, Fairway Ridge and Norfolk Ridge are inherited from this arc migration / break up which overprinted the initial Median Batholith arc configuration. During late Mesozoic and early Cenozoic time the opening of the Tasman Sea and Middleton Basin further dislocated the trace of the Median Batholith.

A discussion of whether or not subduction continued along the newly fragmented margin after the mid-Cretaceous and throughout the Cenozoic is beyond the scope of this paper.

Present day analogue

The Fairway-Aotea Basin is a continental intra-arc basin, which resulted from the dislocation of an active continental margin. The break up of this margin led an active continental margin to evolve towards an intra-oceanic island arc system.

This type of event, where intra-arc extension occurs in an active continental margin, exists in the East China Sea where the Philippine plate is subducting in a trench roll-back process beneath the continental East Eurasian plate [*Sibuet*, 1987]. Since the end of the Mesozoic, this slab retreat produced a series of narrow ~100 km wide basins (the Ouijang Depression, the Taibei Depression, the Jilong Depression and the Okinawa Trough) and rifted ridges (the Zhemin Belt, the Yandang Belt, the Yushan Belt, the Taiwan-Sinzi Belt and the present-day Ryukyu Arc) parallel to the margin, which display high magnetic signatures and have continental arc origins from borehole data [*Hsu et al.*, 2001]. The ages of these basins and belts increase, with proximity to the Chinese margin. The southernmost limit of this basin and ridge system is the active Ryukyu Arc and Okinawa Trough backarc basin [*Sibuet*, 1987]. This pattern is interpreted to be the record of a continental arc migrating from the continent towards the trench. It is a good analogue of the arc migration that we propose occurred from the Gondwana margin towards the Pacific trench during the early Late Cretaceous. The similarity of the LHR-FAB-FR-NCB-NR basin and ridge system to the East China Sea basin and belt system extends to its magnetic signature (400 nT peak to peak amplitude), elongated shape (100 km wide by a ~1000 km long), orientation (parallel to the subduction trench), and crustal thickness - 12-15 km for the Aotea Basin [*Klingelhoefer et al.*, 2007; *Zhu and Symonds*, 1994], compared to 10 km for the Okinawa Trough [*Klingelhöefer et al.*, 2008; *Sibuet et al.*, 1995] .

CONCLUSION

With ties to New Zealand petroleum well data, it is possible to confidently correlate Mesozoic seismic sequences throughout the Aotea Basin. This correlation, combined with a detailed structural synthesis, utilising gravity, magnetic, bathymetric and seismic data, confirms that Cretaceous strata extend all the way to the Fairway Basin and thus prove the existence of a Cretaceous, pre-Tasman-Sea-seafloor-spreading, 2000 km-long structural Fairway-Aotea Basin. This makes the Fairway-Aotea Basin the oldest extant basin of the Southwest Pacific.

This result, combined with 1) the basement geology of New Zealand, New Caledonia and Australia, and 2) major north-oriented magnetic lineaments, leads us to outline a model of fragmentation of the eastern margin of the Gondwana continent. We propose that a change in the dynamics of the west-dipping eastern Gondwana subduction zone led the slab to progressively retreat and cause the Mesozoic arc, originally located in Queensland, to migrate to the present LHR-FR-NR margin. In this process, the migrating arc split in two (the LHR and the Fairway Ridge) and formed the FAB as an intra-continental-arc basin. This change of slab dynamics could be due either to a kinematic change between the Gondwana and Pacific plates causing the cessation of subduction along this plate boundary or to jamming by the Hikurangi Plateau, implying a tectonic escape process.

Acknowledgements

We thank Mrs Typhaine Biard-Hamon and Marleen van Roosmalen of the Cultural and Scientific Service of the French Embassy in New Zealand, who enabled via an agreement between GNS Science, the French Ministry of Foreign Affairs and the French Agency of Development (GNS-MAE-AFD 2007), funding of the seismic data exchange between the New Caledonia Geological Survey (SGNC) and GNS Science. This work is the product of ongoing Southwest Pacific scientific collaboration between New Zealand, France and New Caledonia. We also thank Dr B. Davy (GNS Science), Dr G. Lamarche (NIWA) for the New Zealand magnetic and bathymetric data, and Dr G. Logan from Geoscience Australia for the FAUST3 (s232) seismic survey. We are also very grateful to Dr Marie-Françoise Lalancette and Didier Rouxel from the French Hydrographic and Oceanographic Office of the Navy (EPSHOM) for the magnetic data processing tools and their knowledge. Many thanks to the Agency of Economic Development of New Caledonia (ADECAL) for funding the lead author’s PhD work. Special thanks to Myriam Vendé-Leclerc (SGNC) for the GIS tips and to Dr P. Maurizot (BRGM) for his great knowledge of New Caledonian and New Zealand geology. Maps were produced with the Generic Mapping Tool 4.2.1 (http://gmt.soest.hawaii.edu), ESRI Inc. - ArcGis 9.2 and magnetic data processed with Geosoft Inc. - Oasis Montaj and IFREMER inhouse Caraïbes software. We would also like to express our gratitude to Dr N. Exon and Dr D. Müller, as reviewers, for their great contribution to this paper.

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FIGURE CAPTIONS

Figure 1

Bathymetric location map showing drill holes, dredge samples and seismic data used in this study. Thick black dashed lines indicate the profiles that were used in this study but not shown in this paper. The faulted zone identified from profile TL-1 (see Figure 6) is highlighted. Thin dashed line shows the connection between the Fairway Ridge and the West Norfolk Ridge (WNR). Inset shows a zoom around DSDP 206 to display the seismic lines used to correlate the reflectors from the Aotea Basin to the Fairway Basin (see Figure 10). Bathymetry is from *Smith and Sandwell* [1997] (v10.1).

Figure 2

Diagram modified from *Collot et al.* [2008] synthesizing the borehole data of the study zone : DSDP boreholes [*Burns et al.*, 1973a, b, c] and three New Zealand petroleum boreholes [*Milne and Quick,* 1999; *Shell et al.*, 1976, 1981]. Note that all Mesozoic sedimentary strata in the petroleum wells are coal measures. See Figure 1 for well locations.

Figure 3

Correlation of seismic line TL-1 with borehole WAINUI-1 (modified from *Baillie and Uruski* [2004] and *Uruski and Baillie* [2004]) and with DSDP 206 (modified from *Burns et al.* [1973c]). Acoustic basement is in orange, Top Cretaceous in dark green (C1), Top Eocene in purple (RN) and Top Miocene in pink.

Figure 4

Correlation of seimic line ASTROLABE-40 with boreholes TANE-1 (modified from *Uruski et al.* [2002] and *Uruski et al.* [2003]) and WAKANUI-1 (modified from *Milne and Quick*

[1999] and *Uruski and Baillie* [2004]). Acoustic basement is in orange, Top Jurassic in light blue (J1), Lower Cretaceous in yellow (C2), Top Cretaceous in dark green (C1), Top Paleocene in dark maroon and Top Miocene in pink.

Lower Cretaceous granites, identified at the southern end of Astrolabe-40, are correlated with the Separation Point Granite found in the northern South Island, NZ [*Shell et al.*, 1976].

Figure 5

Seismic profile ASTROLABE-40 modified from *TGS-NOPEC* [2001]. Colour code is the same as in Figure 4. Red lines mark main faults. Reflectors C1 and C2 are strongly tied to the southern end of Astrolabe-40 and can be followed up to the intersection with TL-1. Jurassic strata are found at the profile's northern end.

Figure 6

Seismic profile UNCLOS TL-1 modified from *Uruski* [1997]. Acoustic basement is in orange, Lower Cretaceous in yellow (C2), Top Cretaceous in dark green (C1), Top Eocene in purple (RN) and Top Miocene in pink. Red lines mark main faults.

Inset shows a highly faulted zone which is mapped on Figure 1 and geophysically related to magnetic, gravimetric and bathymetric Bellona-Aotea lineament shown on Figure 9, trending from the Bellona Trough. C1 is followed continuously from south to north except where basement highs truncate the reflector, in which case the negative-phase high amplitude of the reflector overlying a 1.2 s twt disrupted channel-like sequence is used as a correlation indicator. Dashed frame at the northern end of the profile indicates the location of the enlargement shown in Figure 10.

Figure 7

Seismic profile Rig Seismic 114-4 modified from *Marshall et al.* [1994]. Acoustic basement is in orange, Top Cretaceous in dark green (C1), Top Eocene in purple (RN) and Top Miocene in pink. Red lines mark main faults.

Early Upper Cretaceous carbonaceous sandstone was dredged on the western flank of the West Norfolk Ridge (WNR) (dredge RE9302-5) confirming the presence of Cretaceous rocks at this latitude of the basin. LHR : Lord Howe Rise.

Figure 8

Magnetic anomaly map reduced to the pole. This map merges data from the New Caledonia Geological Survey, GNS Science (NZ) and NIWA (NZ) and is realized in collaboration with the SHOM (Hydrographic and Oceanographic Service of the French Navy). Dashed lines indicate first order magnetic trends. The magnetic signature of the Fairway Ridge (FR) is here clearly seen trending southerly towards the West Norfolk Ridge (WNR). NCB: New Caledonia Basin, FB: Fairway Basin, WNC: West New Caledonia Basin.

Figure 9

Structural maps of the geological elements linking New Zealand to New Caledonia: A- structural synthesis map. Structures and geological features are identified by cross-cutting their magnetic, gravity, bathymetric and seismic signatures. B- Map of the structural provinces, combining the age and nature of basement. Poster-size full-map is also available for the Southwest Pacific region (140 190°E / -55 -10°S) in electronic form in “Additional Material” of *Collot et al.* [2009].

Figure 10

Seismic profiles Mobil-1972-145, FAUST3-S232-10 and the northern end of UNCLOS-TL-1, at similar scales, respectively modified from *Mobil* [1979], *Exon et al.* [2004] and *Uruski* [1997]. Vertical scale is in s twt. See insets in Figure 1 for location. Basement is in orange, Top Cretaceous in dark green, Top Eocene in purple (RN). Top Cretaceous on TL-1 is extrapolated from New Zealand deep exploration wells located on the flank of the Taranaki Basin. Structural similarities, relative thicknesses and seismic character enables us to locate Top Cretaceous and Top Eocene reflectors in the Fairway Basin on profile FAUST-3-10.

Figure 11

Seismic profiles FAUST3-S232-5 and FAUST3-S232-9 (survey S232) modified from *Exon et al.* [2004]. Acoustic basement is in orange, Top Cretaceous in dark green (C1), Top Eocene in purple (RN). Red line marks a main fault. Reflectors are identified using intermediate seismic profiles FAUST-232-10 to FAUST-232-5, which can be located by thick black dashed line on Figure 1.

Figure 12

Seismic profile FAUST1-S206-1, modified from *Lafoy et al.* [1998]. Colour code is the same as in Figure 3. Red lines mark main faults. Reflectors are extrapolated from line FAUST-232-5 using profile ZoNéCo5-6A, which extends down the axis of the basin (see Figure 1 for location).

Figure 13

Map modified from *Mortimer* [2008] and *Sutherland* [1999] showing the continuiry of the Mesozoic geological foundations in the Southwest Pacific and the correspondance between the Mesozoic terranes observed in the Southwest Pacific. The Caples, Torlesse and Dun Mountain-Maitai Terrane are not shown here; their location is available in Figure 2 and from associated poster of *Mortimer* [2003].

Figure 14

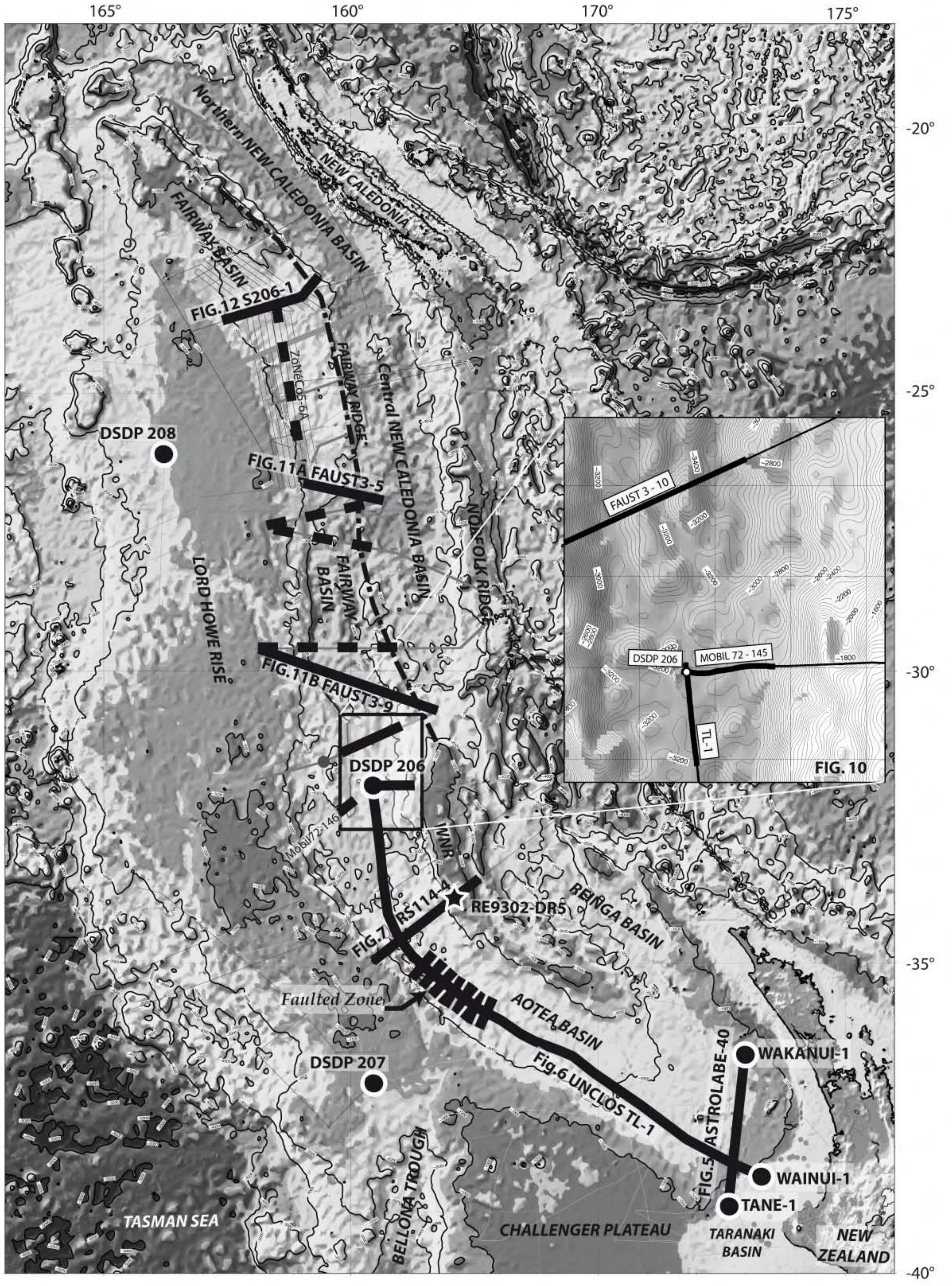
Geodynamic model of the fragmentation of the eastern Gondwana margin. Acronyms are NC: New Caledonia, NNR: Northern Norfolk Ridge, SNR: Southern Norfolk Ridge, NLHR:

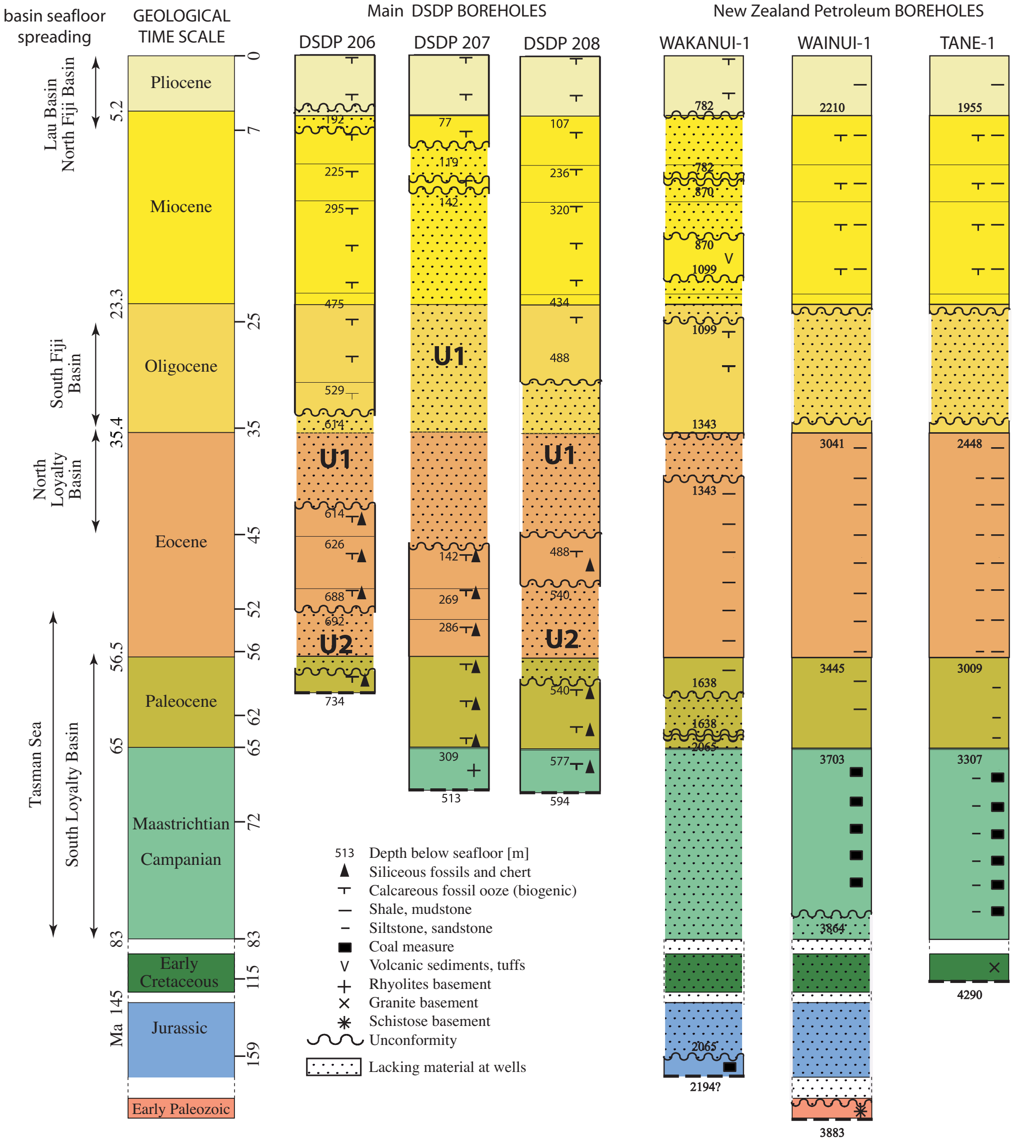
Northern Lord Howe Rise, SLHR: Southern Lord Howe Rise, Chall: Challenger Plateau, ETR: East Tasman Rise, STR: South Tasman Rise, Camp: Campbell Plateau, HP: Hikurangi Plateau, CR: Chatham Rise, LP: Louisiade Plateau, MR: Mellish Rise, KP: Kenn Plateau, MP: Marion Plateau, QP: Queensland Plateau, NG: New Guinea, WP: Western Province, EP: Eastern Province, AUST: Australia, EANT, East Antarctica, WANT: West Antarctica, IB: Iselin Bank.

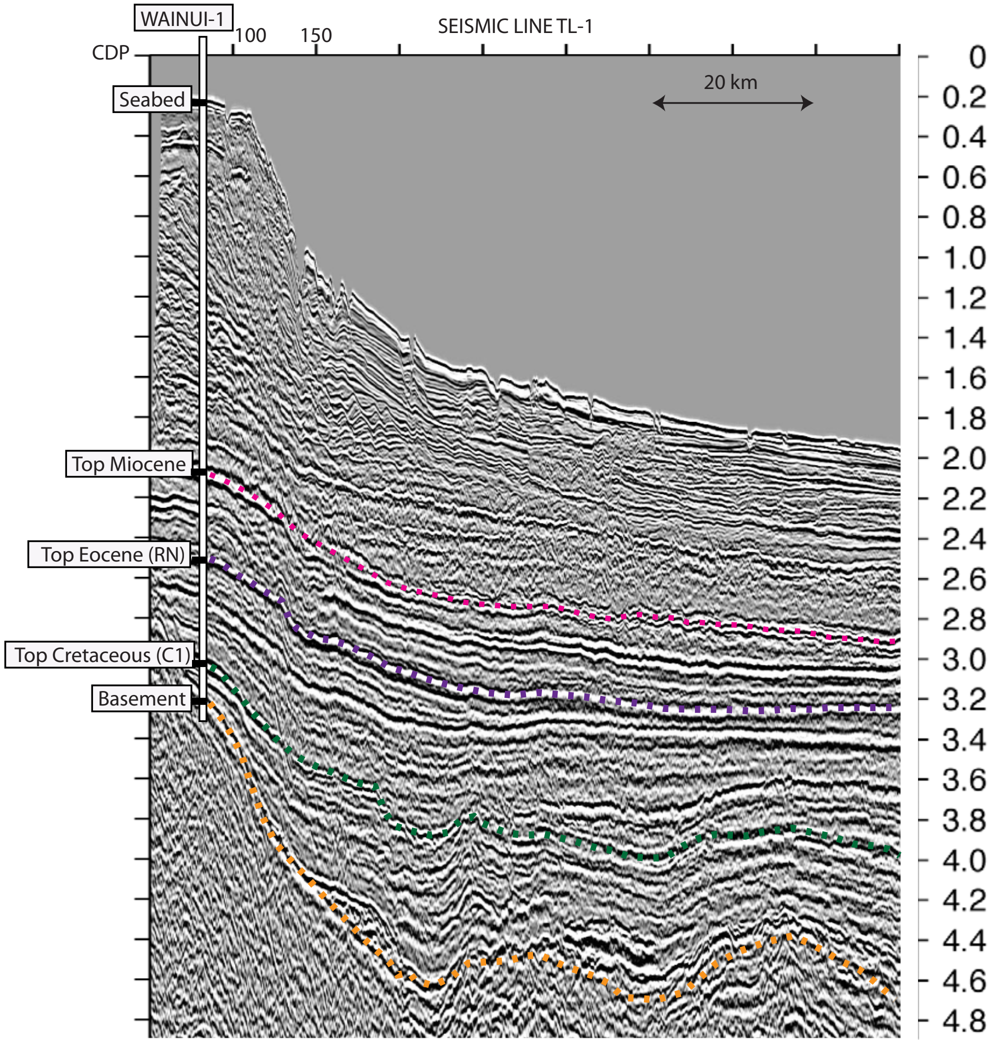
TABLES

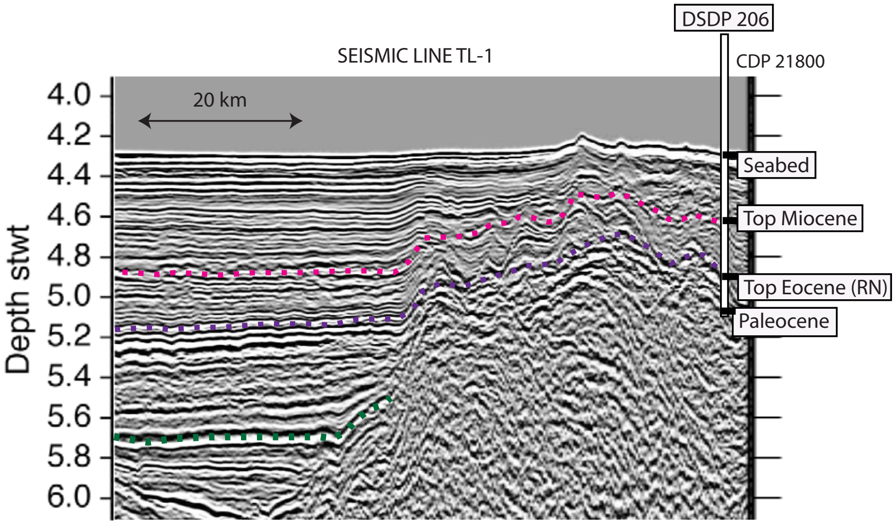
Table 1 Statistics of the cross-over points of the shipboard magnetic anomaly in the New Caledonia dataset, New Caledonia Geological Survey data source.

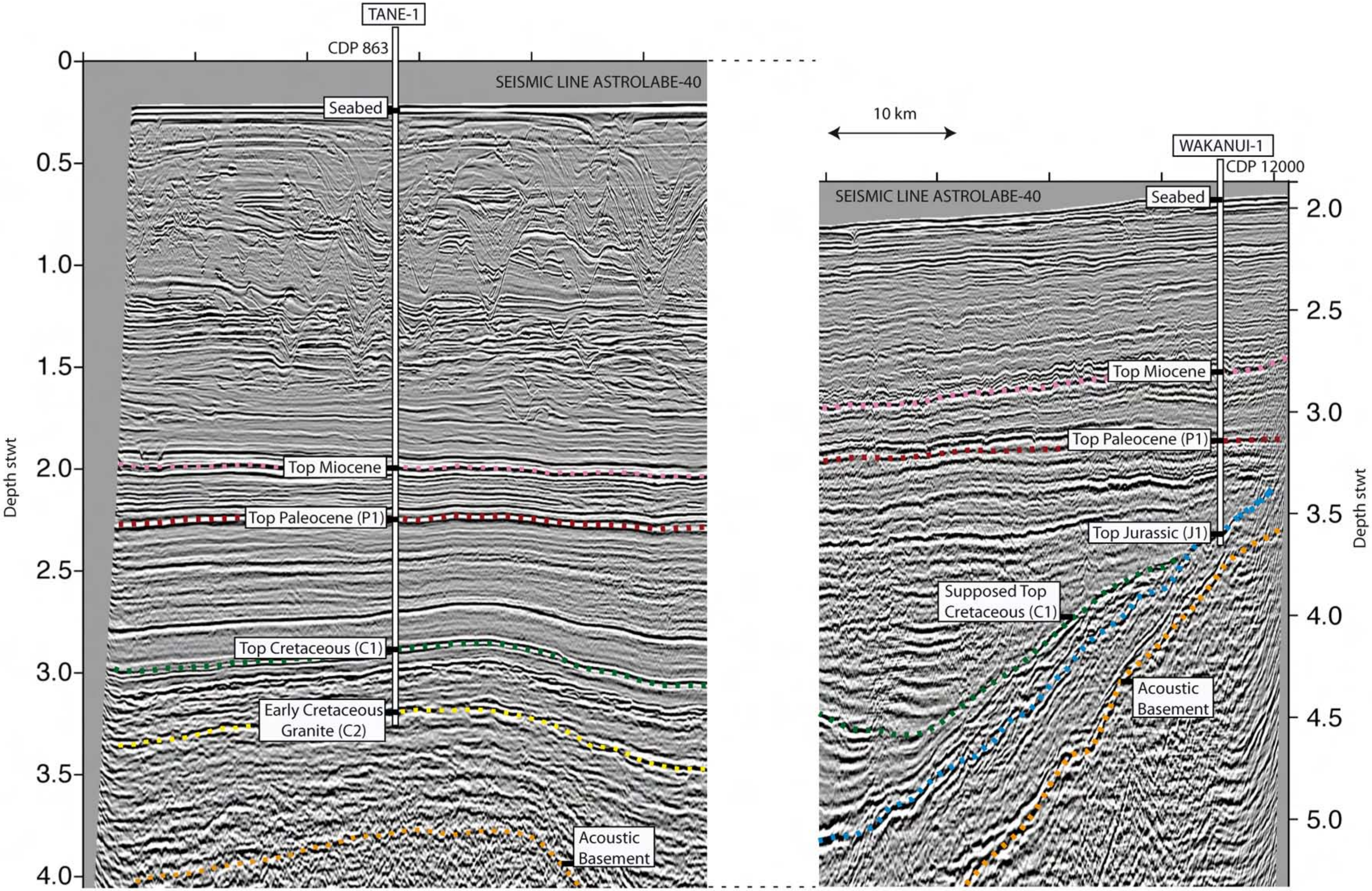
Table 2 Statistics of the cross-over points of the shipboard magnetic anomaly in the New Zealand dataset, GNS Science - NIWA data source.

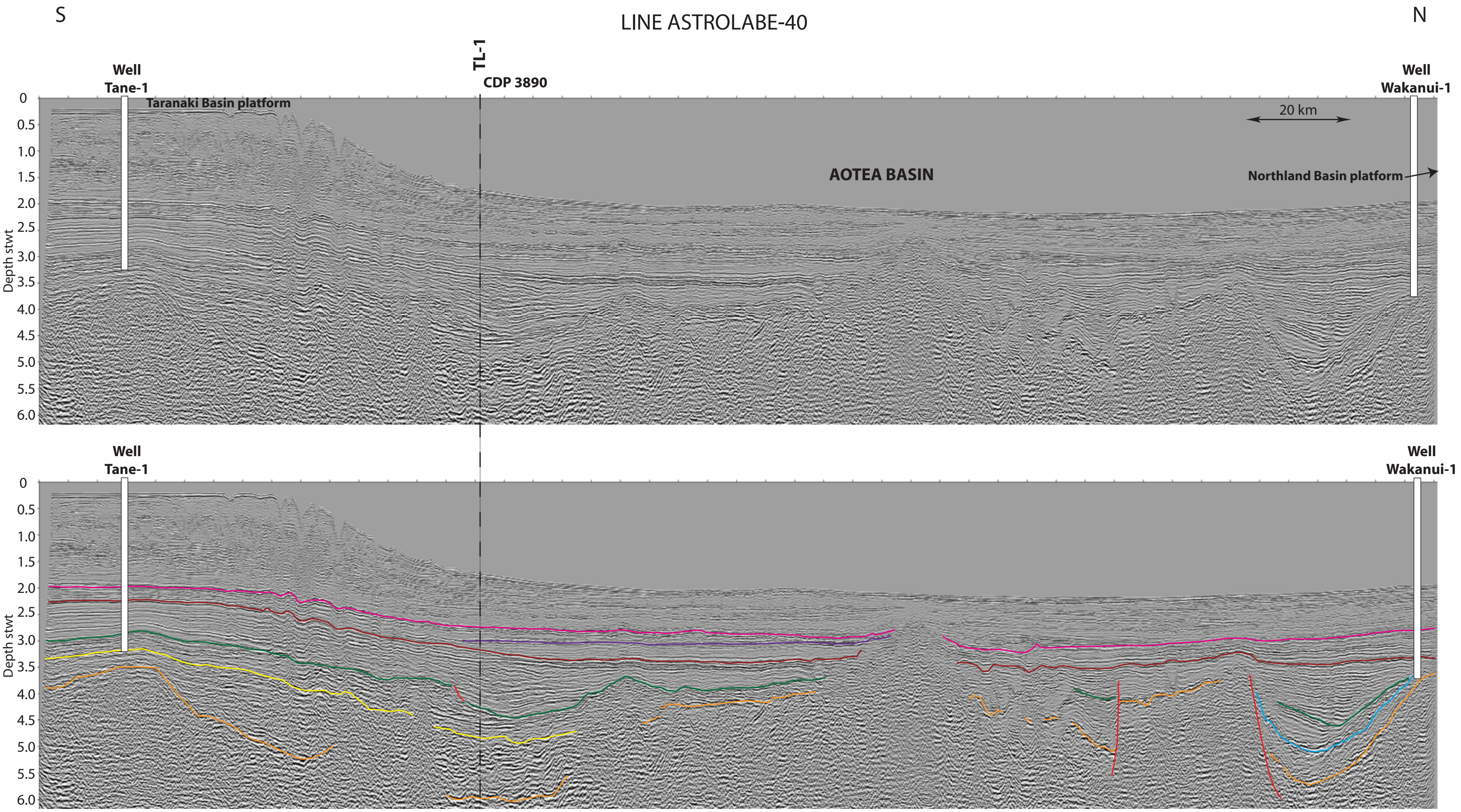

165°
160°
170°
175°
-20°
-25°
-30°
-35°
-40°
Northern NEW CALEDONIA BASIN
NEW CALEDONIA
FAIRWAY BASIN
FIG.12 S206-1
ZoNéCo-6A
FAIRWAY RIDGE
Central NEW CALEDONIA BASIN
DSDP 208
FIG.11A FAUST3-5
NORFOLK RIDGE
LORD HOWE RISE
FAIRWAY BASIN
FIG.11B FAUST3-9
DSDP 206
Mobil72-146
IMNR
RS114-4
RE9302-DR5
REINGA BASIN
FIG.7
Faulted Zone
AOTEA BASIN
DSDP 207
Fig.6 UNCLOS TL-1
FIG.5 ASTROLABE-40
WAKANUI-1
WAINUI-1
TANE-1
BELLONA TROUGH
TASMAN SEA
CHALLENGER PLATEAU
TARANAKI BASIN
NEW ZEALAND
FAUST 3 - 10
DSDP 206
MOBIL 72 - 145
TL-1
FIG. 10
-3400
-2800
-3200
-3000
-2600
-2400
-2200
-2000
-1600
-1800

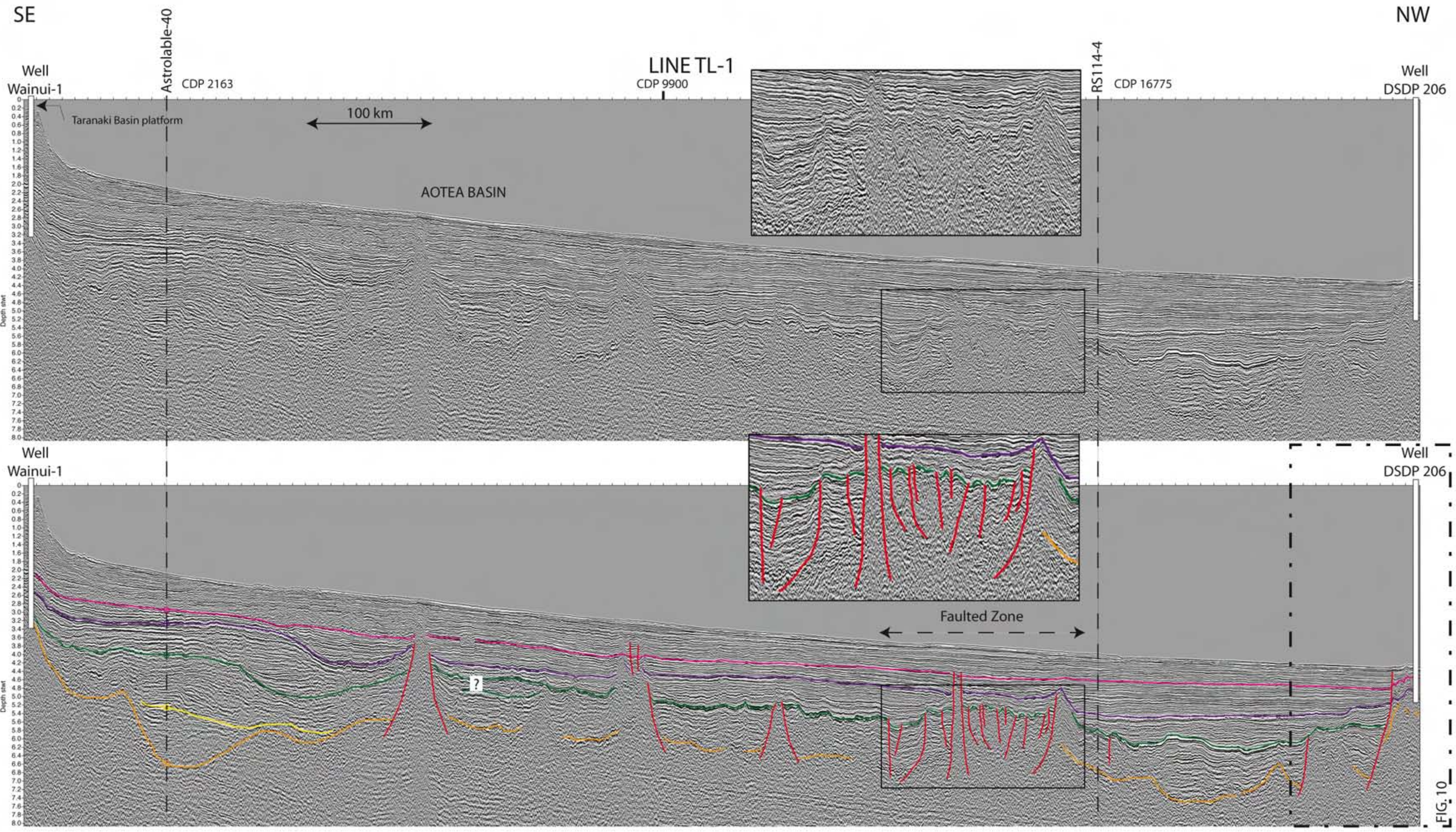

basin seafloor spreading
GEOLOGICAL TIME SCALE
Main DSDP BOREHOLES
New Zealand Petroleum BOREHOLES
DSDP 206
DSDP 207
DSDP 208
WAKANUI-1
WAINUI-1
TANE-1
Lau Basin
North Fiji Basin
South Fiji Basin
North Loyalty Basin
Tasman Sea
South Loyalty Basin
Pliocene
Miocene
Oligocene
Eocene
Paleocene
Maastrichtian
Campanian
Early Cretaceous
Jurassic
Early Paleozoic
Ma
0
5.2
7
23.3
25
35
35.4
45
52
56
56.5
62
65
72
83
115
145
159
U1
U2
734
513
594
2194?
3883
4290
513 Depth below seafloor [m]
Siliceous fossils and chert
Calcareous fossil ooze (biogenic)
Shale, mudstone
Siltstone, sandstone
Coal measure
Volcanic sediments, tuffs
Rhyolites basement
Granite basement
Schistose basement
Unconformity
Lacking material at wells

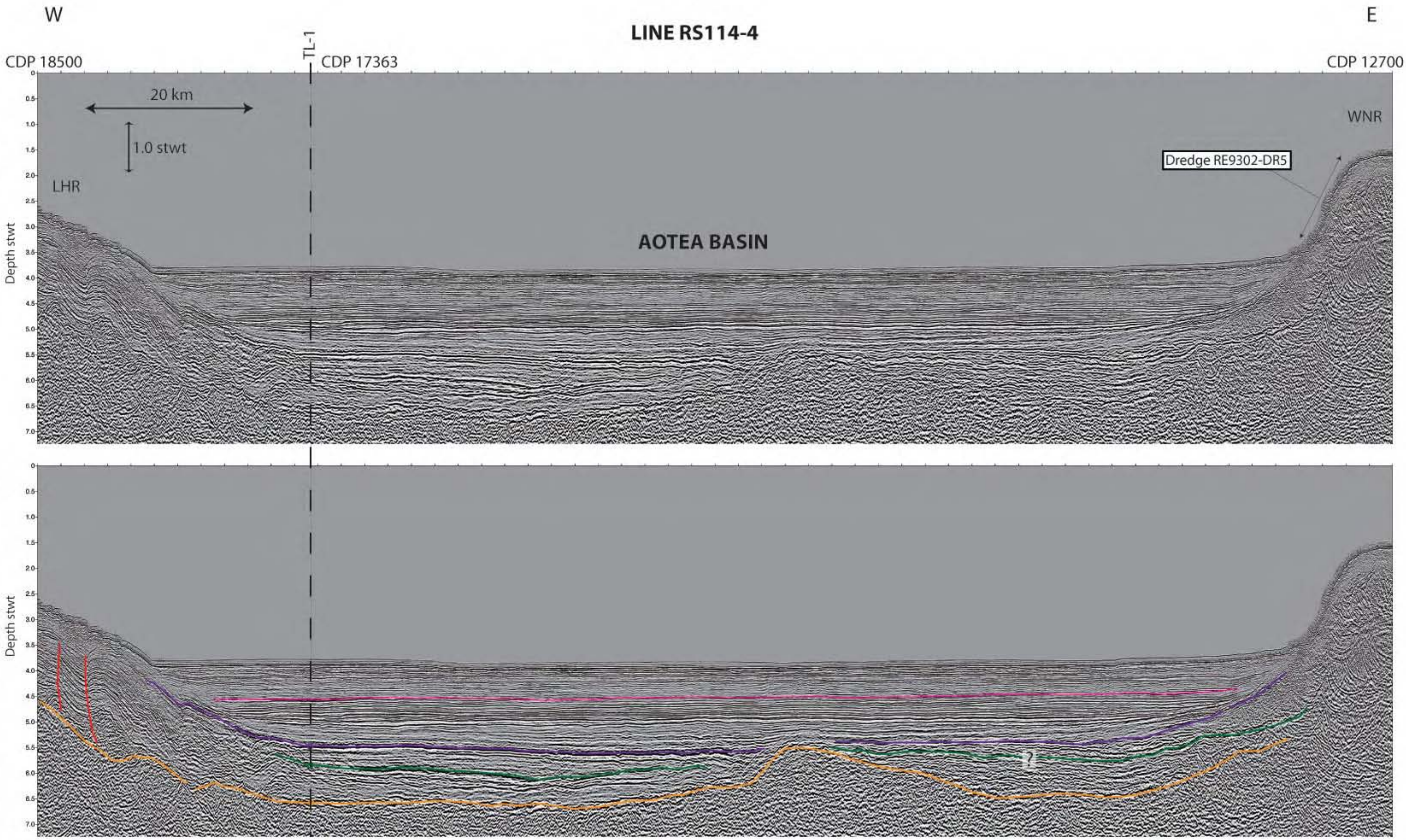

WAINUI-1
CDP
100
150
SEISMIC LINE TL-1
20 km
Seabed
Top Miocene
Top Eocene (RN)
Top Cretaceous (C1)
Basement
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0
4.2
4.4
4.6
4.8

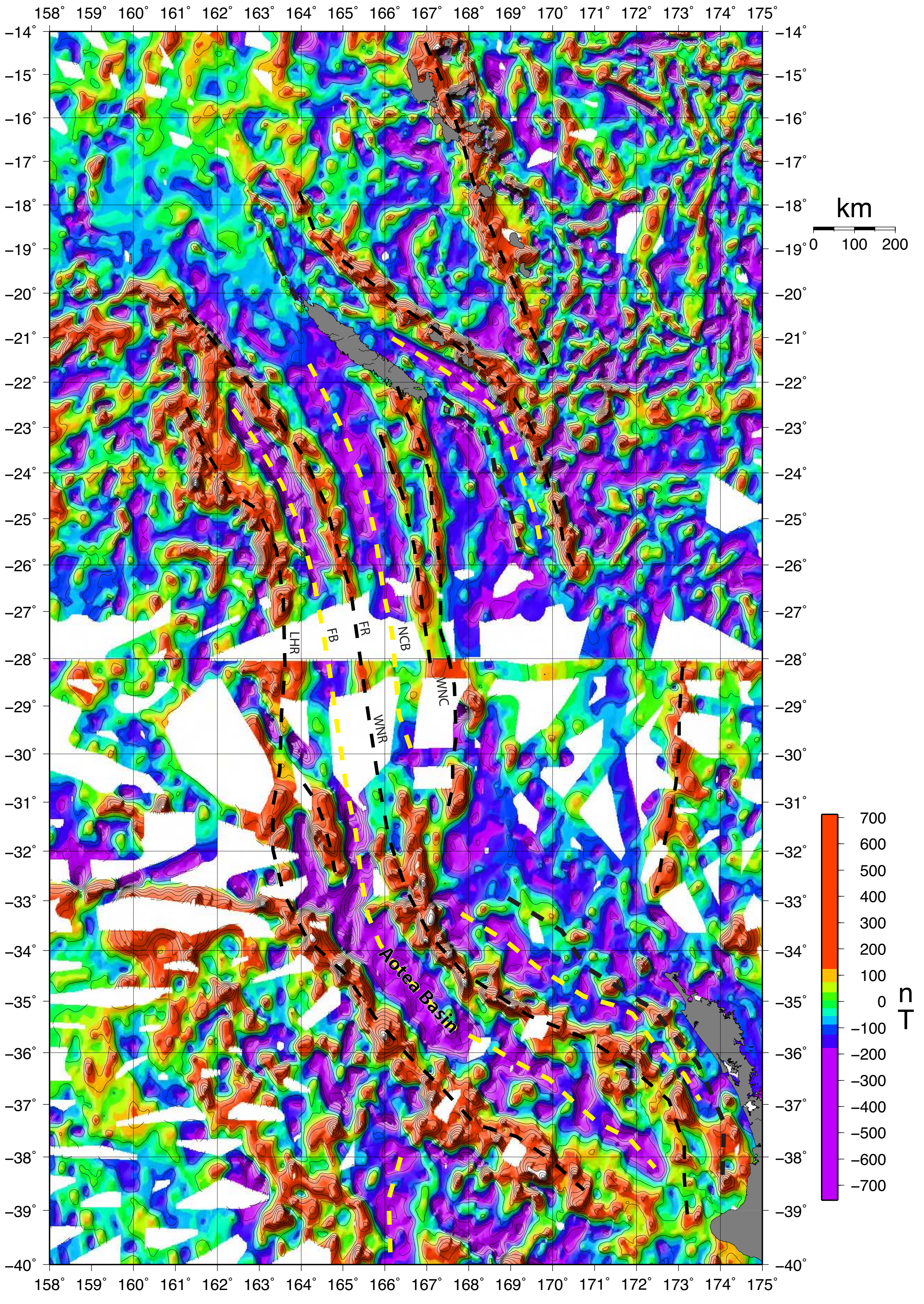

DSDP 206
SEISMIC LINE TL-1
CDP 21800
20 km
Depth stwt
4.0
4.2
4.4
4.6
4.8
5.0
5.2
5.4
5.6
5.8
6.0
Seabed
Top Miocene
Top Eocene (RN)
Paleocene

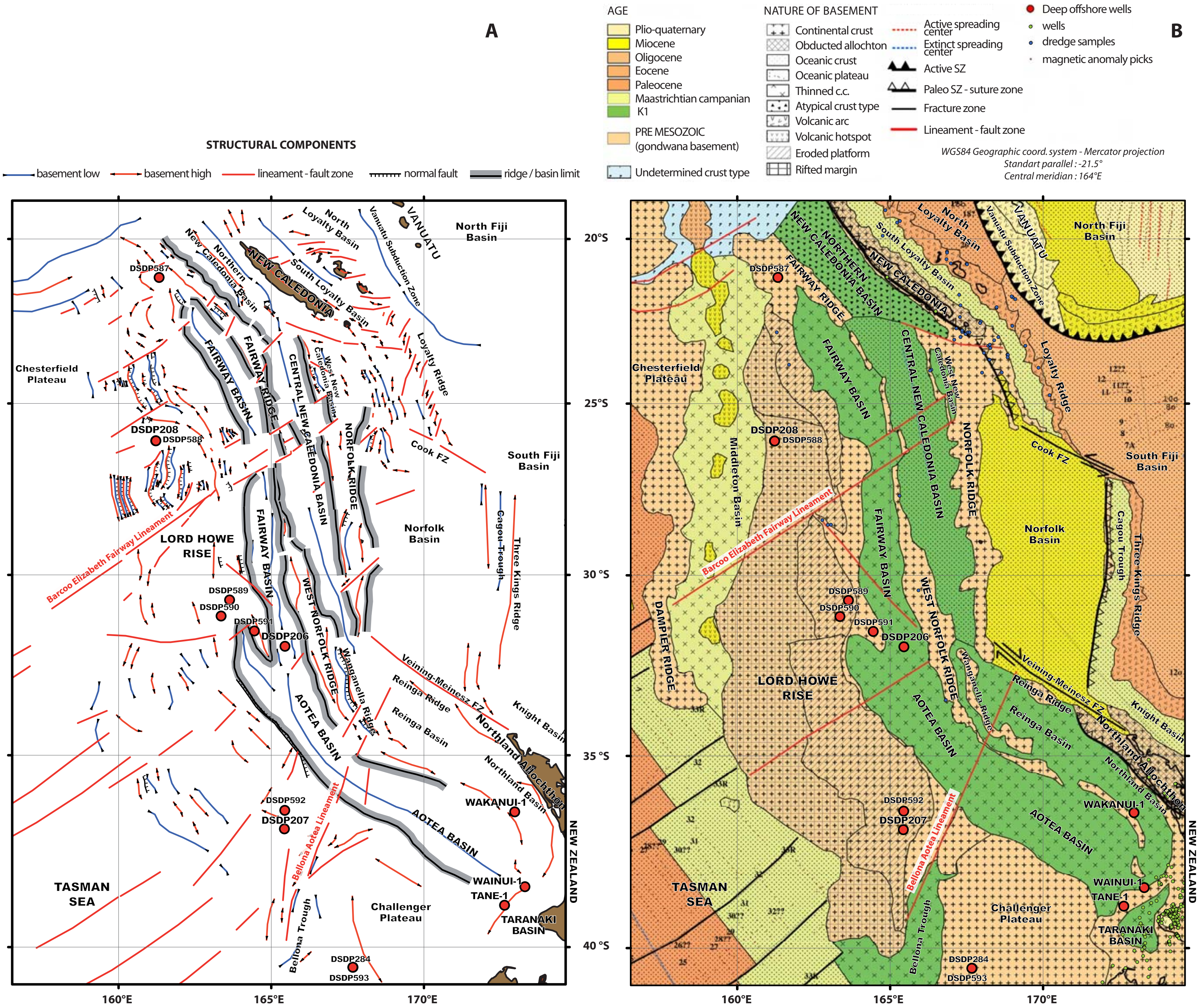

TANE-1
CDP 863
SEISMIC LINE ASTROLABE-40
Seabed
Top Miocene
Top Paleocene (P1)
Top Cretaceous (C1)
Early Cretaceous Granite (C2)
Acoustic Basement
Depth stwt
0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
10 km
WAKANUI-1
CDP 12000
SEISMIC LINE ASTROLABE-40
Seabed
Top Miocene
Top Paleocene (P1)
Top Jurassic (J1)
Supposed Top Cretaceous (C1)
Acoustic Basement
Depth stwt
2.0
2.5
3.0
3.5
4.0
4.5
5.0

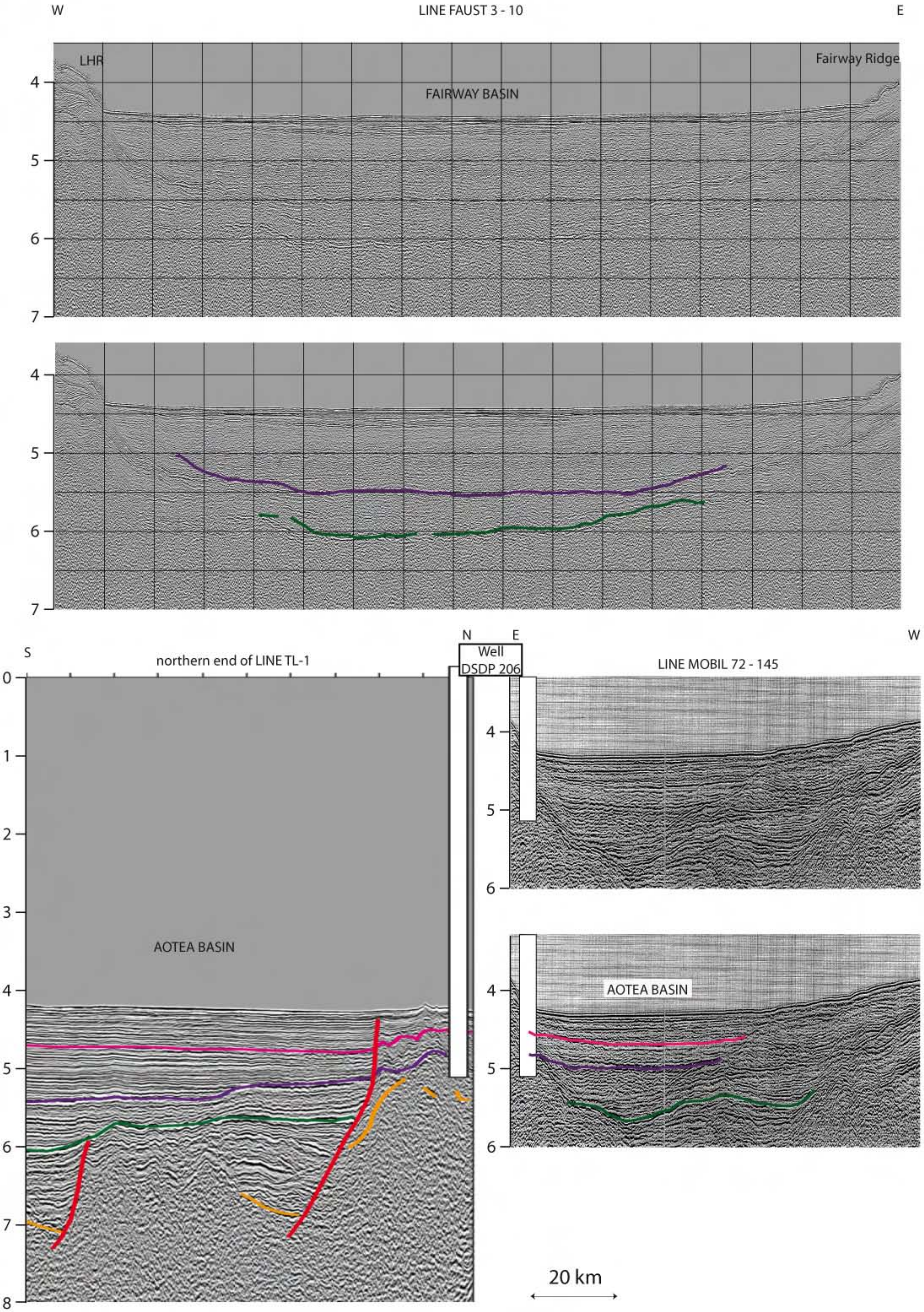

S
LINE ASTROLABE-40
N
TL-1
Well
Tane-1
CDP 3890
Well
Wakanui-1
Taranaki Basin platform
20 km
AOTEA BASIN
Northland Basin platform
Depth stwt
0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
Well
Tane-1
Well
Wakanui-1
Depth stwt
0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0


SE
NW
LINE TL-1
Well
Wainui-1
Astrolable-40
CDP 2163
CDP 9900
RS114-4
CDP 16775
Well
DSDP 206
Taranaki Basin platform
100 km
AOTEA BASIN
Depth stwt
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0
4.2
4.4
4.6
4.8
5.0
5.2
5.4
5.6
5.8
6.0
6.2
6.4
6.6
6.8
7.0
7.2
7.4
7.6
7.8
8.0
?
Faulted Zone
FIG. 10

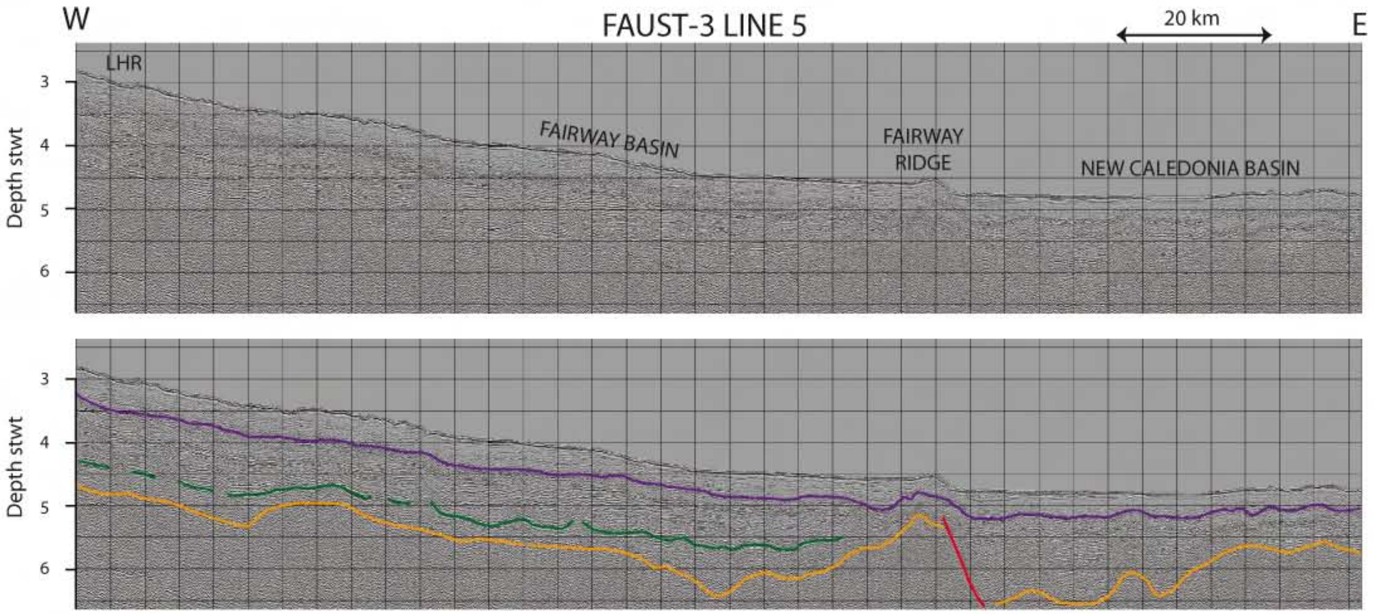

W
E
LINE RS114-4
TL-1
CDP 18500
CDP 17363
CDP 12700
20 km
1.0 stwt
LHR
WNR
Dredge RE9302-DR5
AOTEA BASIN
Depth stwt
0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
Depth stwt
?


158° 159° 160° 161° 162° 163° 164° 165° 166° 167° 168° 169° 170° 171° 172° 173° 174° 175°
−14° −15° −16° −17° −18° −19° −20° −21° −22° −23° −24° −25° −26° −27° −28° −29° −30° −31° −32° −33° −34° −35° −36° −37° −38° −39° −40°
km
0 100 200
LHR
FB
FR
NCB
WNC
WNR
Aotea Basin
700 600 500 400 300 200 100 0 −100 −200 −300 −400 −500 −600 −700
nT

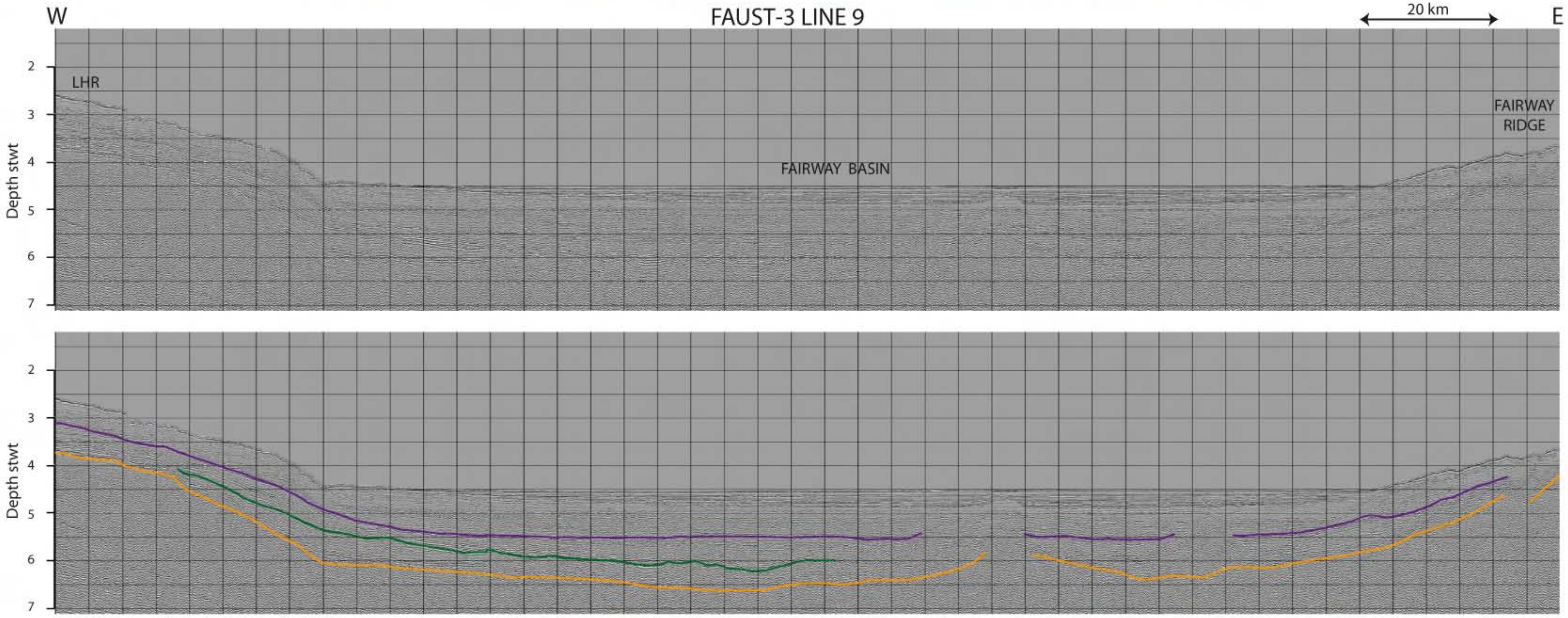

A
STRUCTURAL COMPONENTS
basement low
basement high
lineament - fault zone
normal fault
ridge / basin limit
B
AGE
Plio-quaternary
Miocene
Oligocene
Eocene
Paleocene
Maastrichtian campanian
K1
PRE MESOZOIC (gondwana basement)
Undetermined crust type
NATURE OF BASEMENT
Continental crust
Obducted allochton
Oceanic crust
Oceanic plateau
Thinned c.c.
Atypical crust type
Volcanic arc
Volcanic hotspot
Eroded platform
Rifted margin
Active spreading center
Extinct spreading center
Active SZ
Paleo SZ - suture zone
Fracture zone
Lineament - fault zone
Deep offshore wells
wells
dredge samples
magnetic anomaly picks
WGS84 Geographic coord. system - Mercator projection
Standart parallel : -21.5°
Central meridian : 164°E
20 °S
25 °S
30 °S
35 °S
40 °S
160°E
165°E
170°E
VANUATU
North Fiji Basin
North Loyalty Basin
Vanuatu Subduction Zone
NEW CALEDONIA
South Loyalty Basin
Northern New Caledonia Basin
DSDP587
Chesterfield Plateau
FAIRWAY RIDGE
FAIRWAY BASIN
CENTRAL NEW CALEDONIA BASIN
West New Caledonia Basin
Loyalty Ridge
NORFOLK RIDGE
Cook FZ
South Fiji Basin
DSDP208
DSDP588
Middleton Basin
LORD HOWE RISE
Barcoo Elizabeth Fairway Lineament
Norfolk Basin
Cagou Trough
Three Kings Ridge
DAMPIER RIDGE
DSDP589
DSDP590
DSDP591
DSDP206
WEST NORFOLK RIDGE
Wanganella Ridge
Vening-Meinesz FZ
Reinga Ridge
Reinga Basin
Knight Basin
Northland Allochthon
Northland Basin
AOTEA BASIN
DSDP592
DSDP207
WAKANUI-1
Bellona Aotea Lineament
TASMAN SEA
Challenger Plateau
WAINUI-1
TANE-1
TARANAKI BASIN
Bellona Trough
DSDP284
DSDP593
NEW ZEALAND

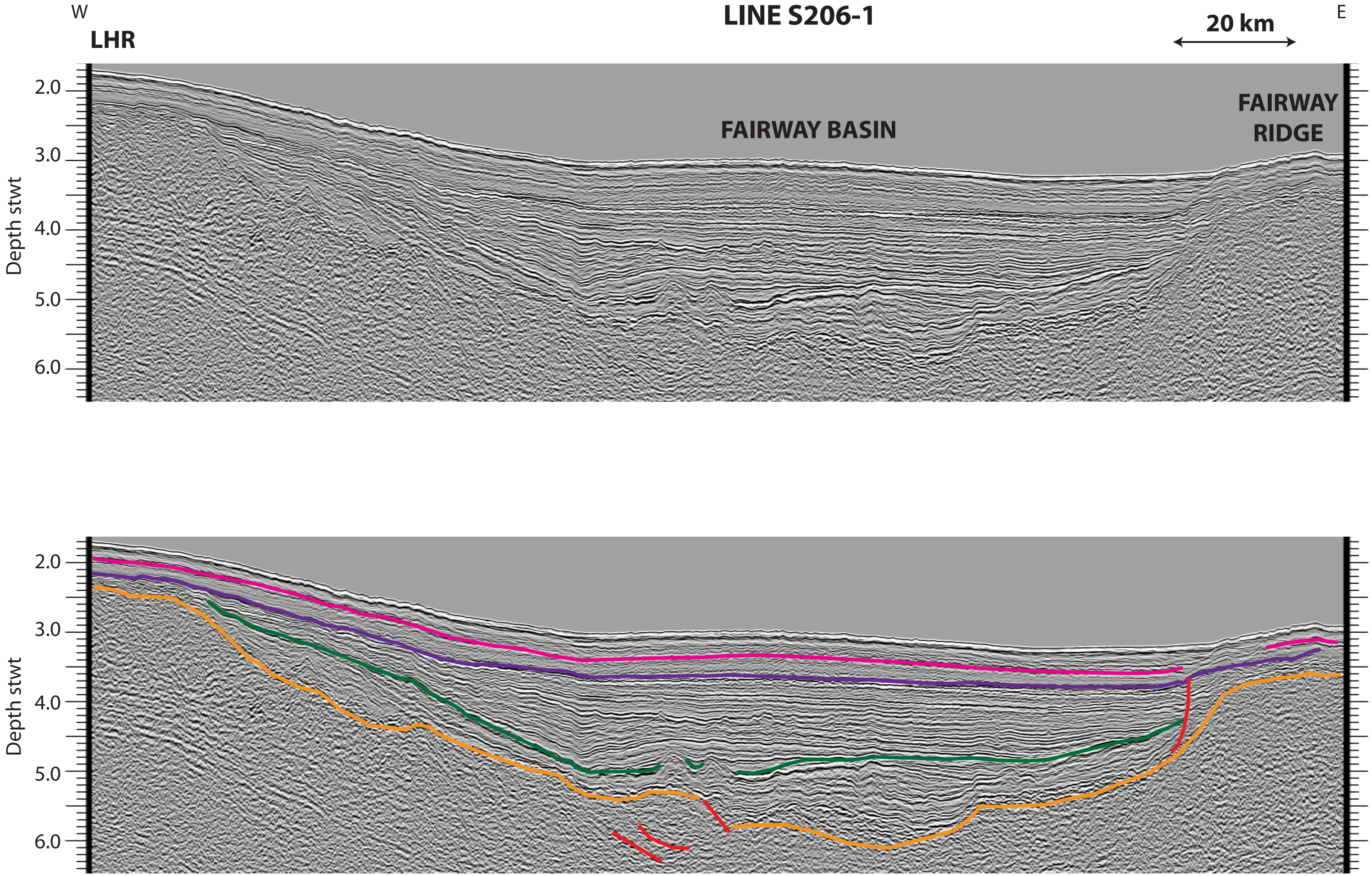

W
LINE FAUST 3 - 10
E
LHR
Fairway Ridge
FAIRWAY BASIN
4
5
6
7
4
5
6
7
S
northern end of LINE TL-1
N
E
Well
DSDP 206
W
LINE MOBIL 72 - 145
0
1
2
3
4
5
6
7
8
AOTEA BASIN
4
5
6
4
5
6
AOTEA BASIN
20 km

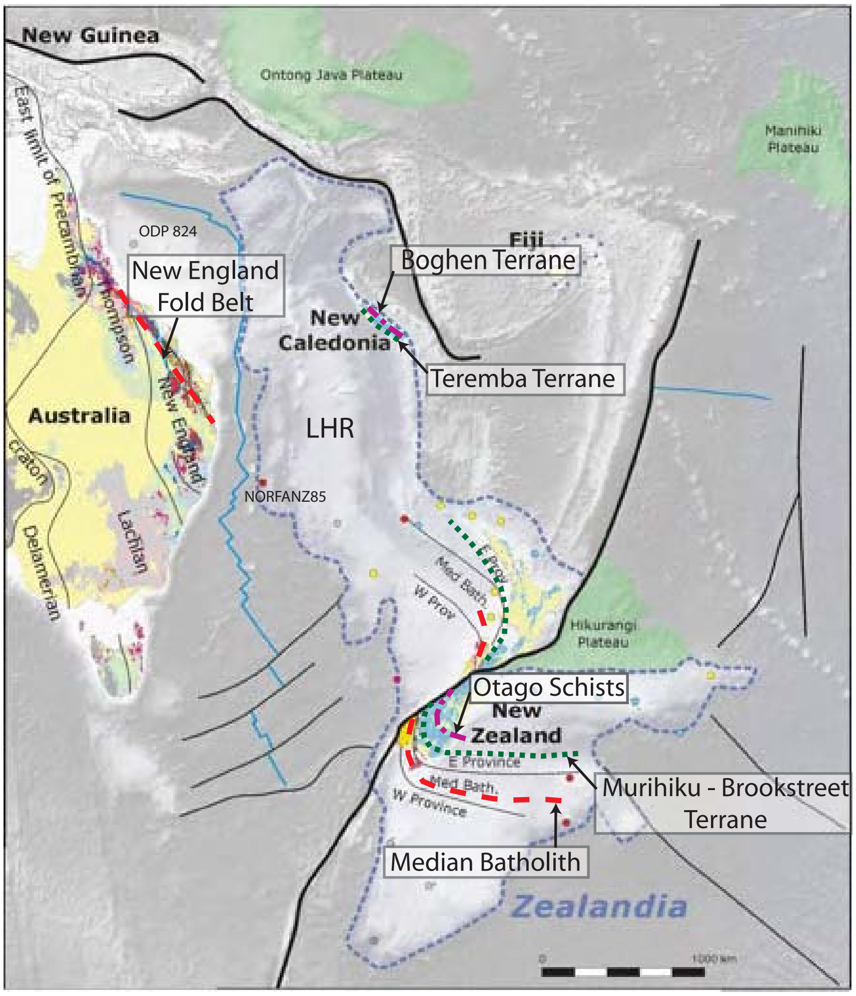
FAUST-3 LINE 5

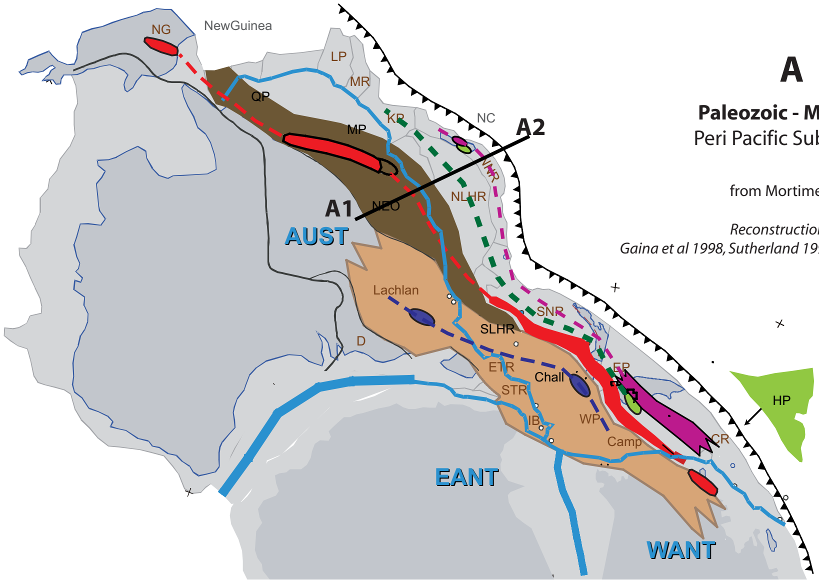


FAUST-3 LINE 9




W
LINE S206-1
E
LHR
20 km
FAIRWAY BASIN
FAIRWAY
RIDGE
Depth stwt
2.0
3.0
4.0
5.0
6.0
Depth stwt
2.0
3.0
4.0
5.0
6.0


New Guinea
Ontong Java Plateau
Manihiki Plateau
East limit of Precambrian
Thompson
ODP 824
New England Fold Belt
Fiji
Boghen Terrane
New Caledonia
Teremba Terrane
Australia
New England
Craton
Delamerian
Lachlan
LHR
NORFANZ85
E Prov
Med Bath.
W Prov
Hikurangi Plateau
Otago Schists
New Zealand
E Province
Med Bath.
W Province
Murihiku - Brookstreet Terrane
Median Batholith
Zealandia
0
1000 km

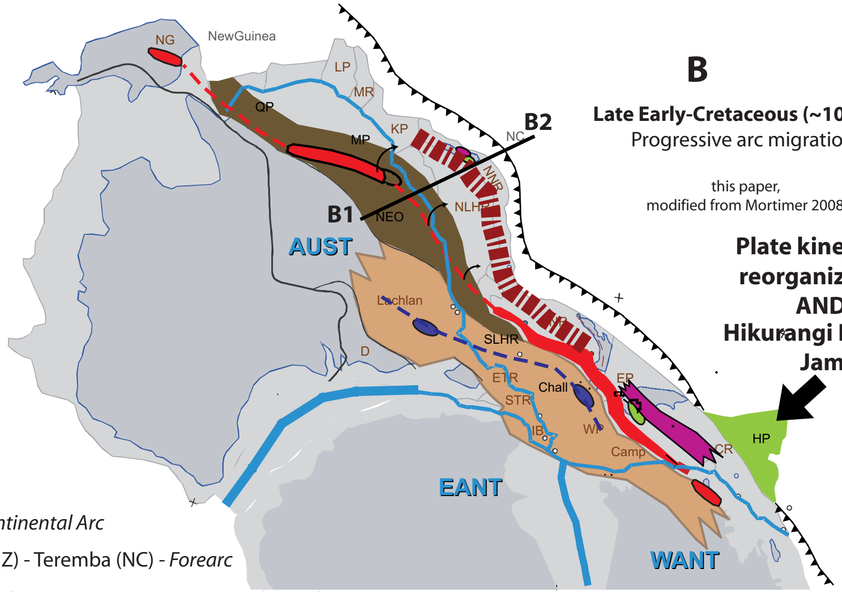


A

Paleozoic - Mesozoic
Peri Pacific Subduction

from Mortimer 2008

Reconstruction from
Gaina et al 1998, Sutherland 1999 and Eagles et al 2004



B

Late Early-Cretaceous (~105 Ma)
Progressive arc migration

this paper,
modified from Mortimer 2008

Plate kinematic
reorganization
AND
Hikurangi Plateau
Jam

🟥 Median Batholith - *Continental Arc*

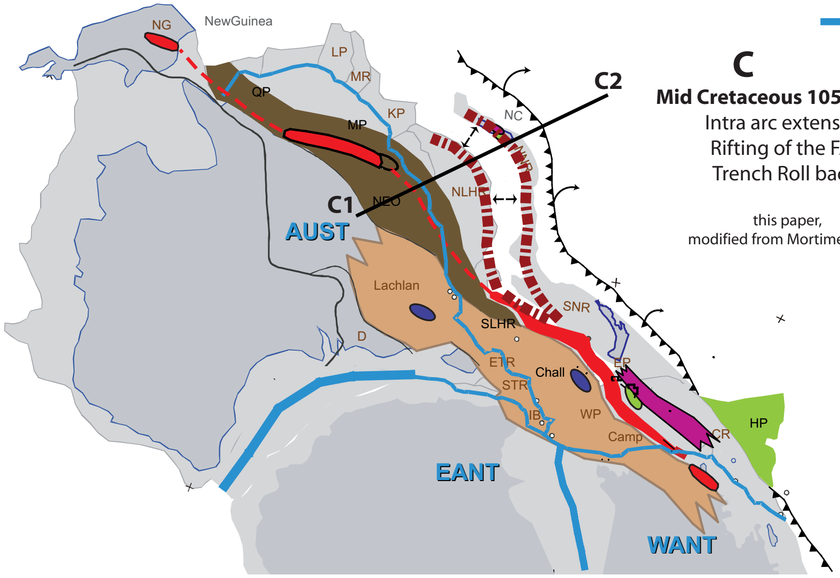
▪▪ Brookstreet Terrane (NZ) - Teremba (NC) - *Forearc*

🟪 Otago Schist (NZ) - Boghen Terrane (NC) - *Forearc Exhumed prism*

🟦 Lachlan Orogen

▮▮▮ Mid Cretaceous migrated arc

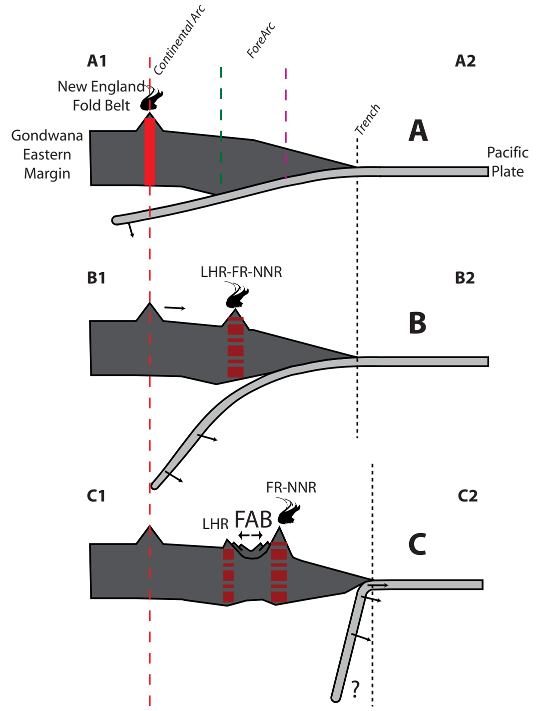
— Futur (< 85 Ma) spreading center axis (Coral Sea, Tasman Sea, South East Indian Rise, East Pacific Rise)



C

Mid Cretaceous 105-100 Ma
Intra arc extension
Rifting of the FAB
Trench Roll back

this paper,
modified from Mortimer 2008



Paleozoic - Mesozoic
Peri Pacific Subduction

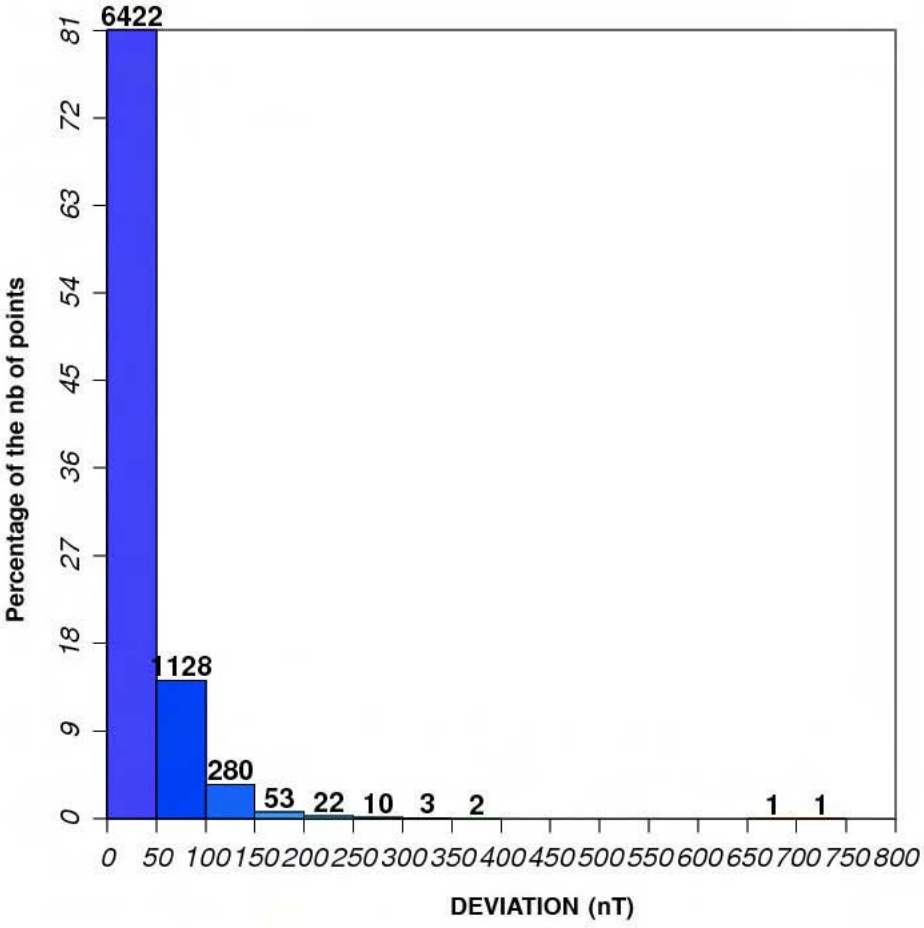
from Mortimer 2008

Late Early-Cretaceous (~105 Ma)
Progressive arc migration

this paper,
modified
from Mortimer 2008

Mid Cretaceous 105-100 Ma
Intra arc extension
Rifting of the FAB
Trench Roll back

this paper,
modified
from Mortimer 2008



MIN : 0

MAX : 710.44

MEAN : 31.9496

ABS. DEV. : 23.492

VARIANCE : 1251.98

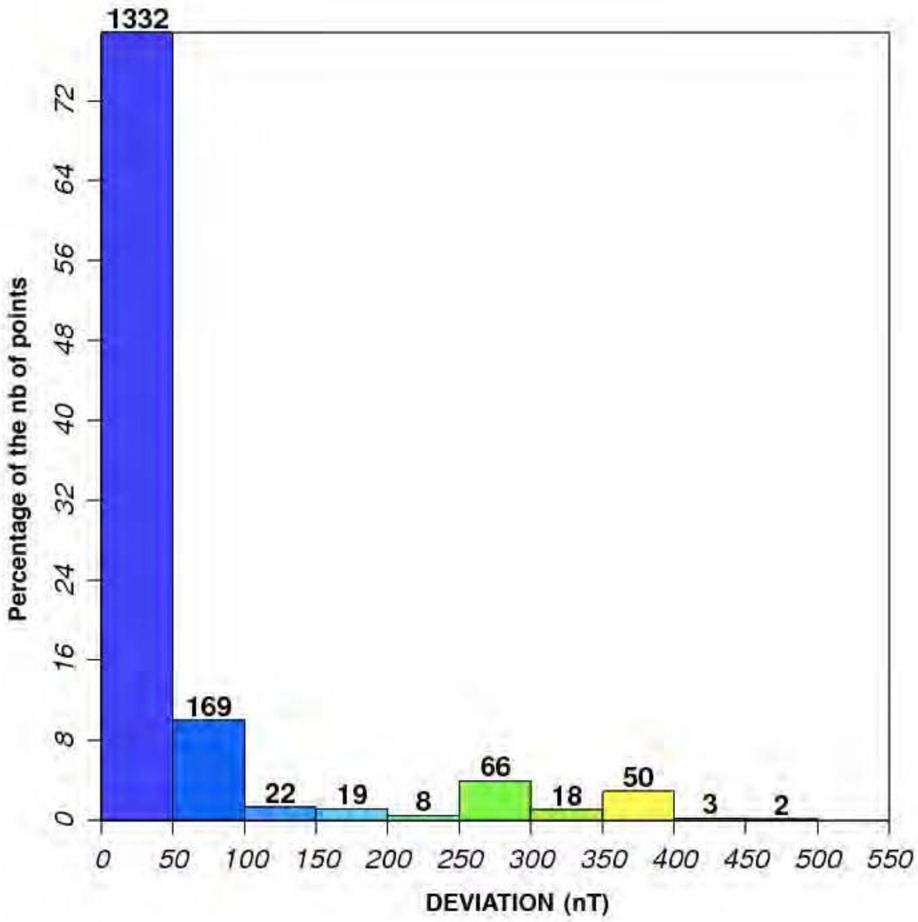
STAND. DEV. : 35.3834

ASSYM : 3.96862

KURTOSIS : 39.4454

GAUSS. STAND. DEV. : 12.5

NB OF POINTS : 7922



MIN : 0

MAX : 496.82

MEAN : 50.9227

ABS. DEV. : 53.8465

VARIANCE : 7701.41

STAND. DEV. : 87.7577

ASSYM : 2.66552

KURTOSIS : 6.10886

GAUSS. STAND. DEV. : 62.5

NB OF POINTS : 1689