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Discovery of Continental Stretching and Oceanic Spreading in the Tasman Sea

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A deep seismic survey conducted within the western part of New Caledonia's Exclusive Economic Zone (EEZ) (Figure 1) from 8 September–5 October 2004 revealed for the first time the thinned continental and oceanic natures of the crust beneath the eastern Tasman Sea.

The survey, which was conducted by an international group of scientists aboard the Institut Français de Recherche pour l'Exploitation de la MER (Ifremer) R/V *L'Atalante*, aimed at improving the understanding of the geological framework, crustal characteristics, and evolution of the submarine basin and ridge system located west of New Caledonia's mainland. The study area, located east of both Australia and the oceanic Tasman Sea Basin, is composed of continental fragments: the Lord Howe Rise and the Norfolk Ridge, which are separated by the New Caledonia and Fairway basins.

Due to the lack of seismic refraction data, the nature of the basins remained controversial until completion of the ZoNéCo 11 survey, the sixth geophysical cruise of the ZoNéCo (Zone Économique de Nouvelle-Calédonie) program that aims at assessing the marine resources of New Caledonia's EEZ. The ZoNéCo 11 wide-angle and magnetic data reveal for the first time the thinned continental nature of the Fairway Ridge and Basin system and the oceanic origin of the New Caledonia Basin N-S central segment.

Moreover, magnetic data show that the N-S trending New Caledonia Basin's crust was produced during the seafloor spreading phase of the basin. The weak amplitude of these anomalies can be explained by either magmatic accretion at a very slow spreading ridge during the Upper Cretaceous quiet time or by emplacement of serpentinized upper mantle.

Since the Cretaceous period, the geodynamic history of the southwest Pacific region has been dominated by the dismembering of Gondwanaland. From circa 120 to 52 Ma, an extensional episode led to fragmentation of continental crust to form three subparallel marginal basins, namely, from west to east, the Tasman Sea Basin, the New Caledonia Basin, and the Loyalty Basin (Figure 1). This fragmentation phase isolated two main aseismic microcontinental fragments, the Lord Howe Rise and the New Caledonia-Norfolk Ridge [*Shor et al.*, 1971; *Hayes and Ringis*, 1973; *Weissel and Hayes*, 1977; *Gaina et al.*, 1998; *Auzende et al.*, 2000; *Crawford et al.*, 2002; *Lafoy et al.*, 2005].

The Tasman Sea Basin, which opened between the Cretaceous and Paleocene, is floored with oceanic crust (chron 33 to 24, 84–52 Ma). The age of the New Caledonia Basin, located west of New Caledonia, is unclear. Its opening is either contemporary with the Tasman Sea or it occurred during Early Cretaceous time. However, due to the lack of identifiable magnetic anomalies and the absence of convincing evidence that the basin ever reached the stage of rupturing and accretion of oceanic-type crust, the New Caledonia Basin's extension may have begun in the Early Cretaceous with stretched continental lithosphere underlying the basin.

In a recent analysis of multichannel seismic, magnetic, and gravity data, *Lafoy et al.* [2005] distinguished a northern NW-SE trending, thinned continental segment of the basin from a southern N-S trending segment of oceanic origin.

Necessary Further Studies

Due to the lack of wide-angle seismic data available in the Fairway Basin, the Fairway Ridge, and the New Caledonia Basin, the nature and origin of these key features still remained controversial.

Since 1993, French scientists have been studying the area between the Lord Howe Rise and New Caledonia, within the framework of the ZoNéCo program that aims at assessing the non-living and living resources of New Caledonia EEZ. The ZoNéCo 11 deep seismic survey aimed at acquiring seismic refraction and reflection data to unveil the origin and deep structure of the geological units located

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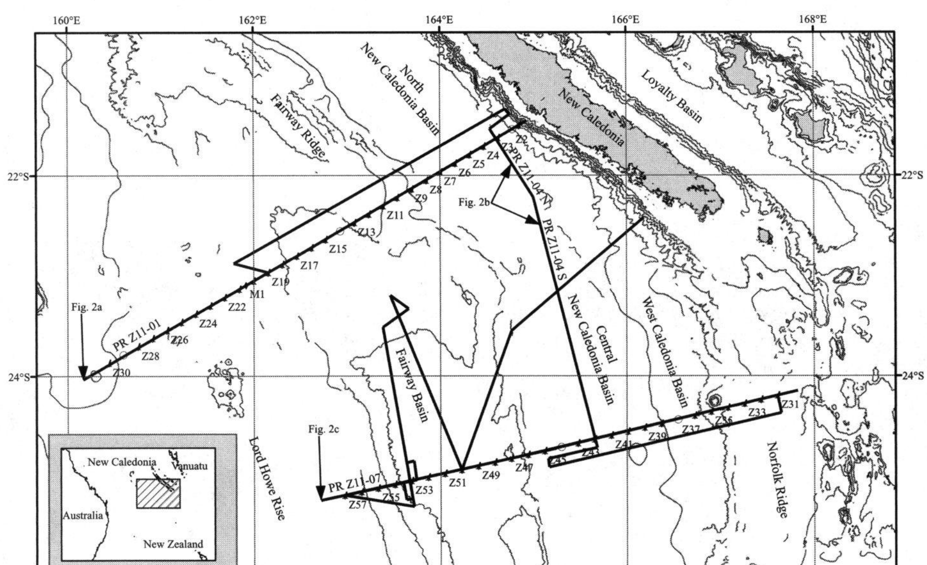

Fig. 1. Inset: Location of the ZoNéCo 11 survey within the southwest Pacific region. Ship tracks of the ZoNéCo 11 deep seismic survey. Numbers represent ocean bottom seismometers deployed along seismic refraction lines Z11-01 and Z11-07 shown on Figures 2a and 2c, respectively. Bathymetric contours are 500 m.

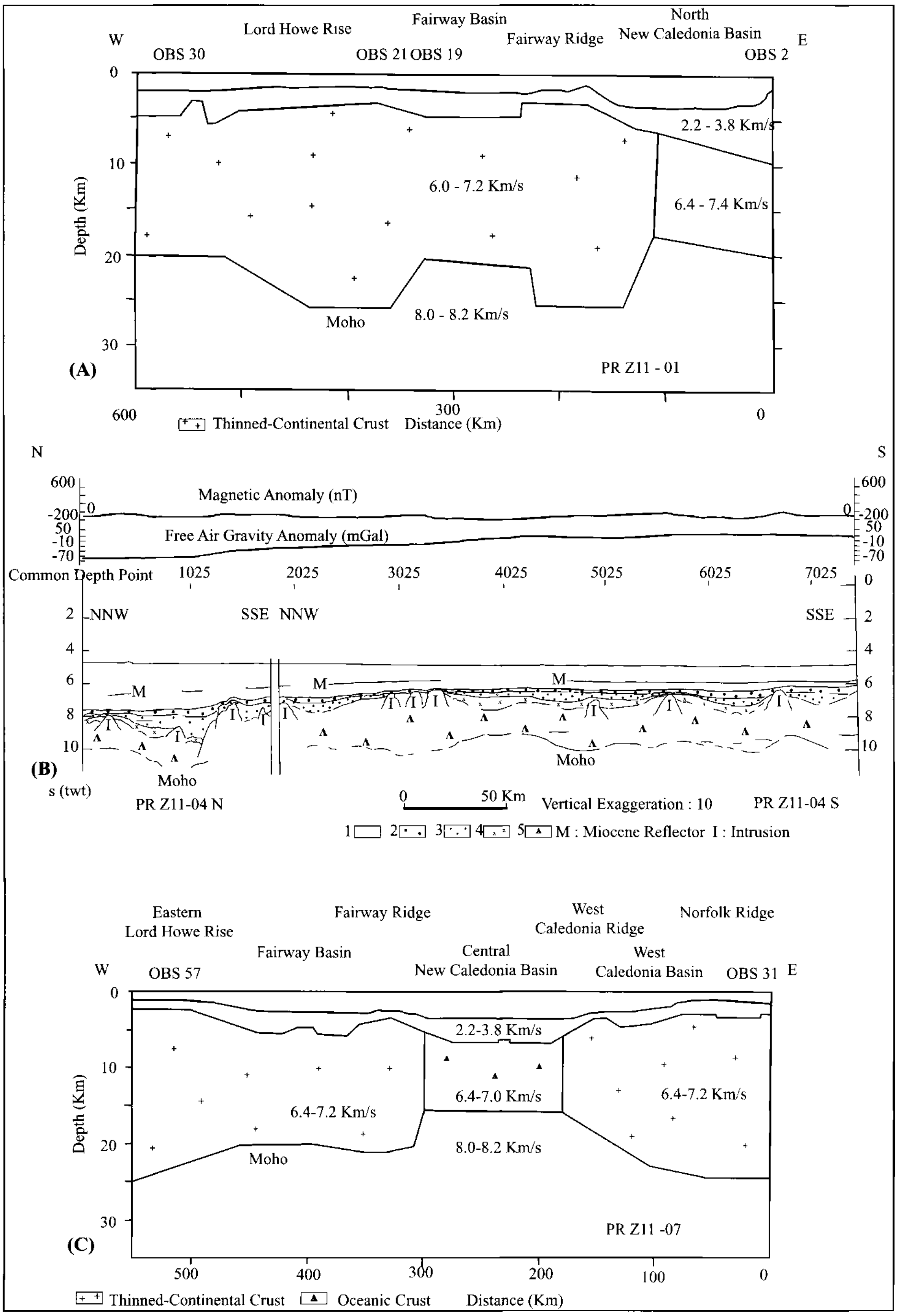

Fig. 2. (a) Preliminary modeling with velocity analysis of seismic refraction line Z11-01. See location on Figure 1. (b) Multichannel seismic reflection tie line Z11-04 and associated gravity and magnetic anomalies. See location on Figure 1. Definitions are M, Miocene reflector; 1: Post-Oligocene; 2: Paleocene; 3: Upper Cretaceous; 4: Ante-Cretaceous Series; 5: Oceanic Crust; I, intrusions; s (twt), seconds two-way time. (c) Preliminary modeling of seismic refraction line Z11-07. See location on Figure 1.

between the Lord Howe Rise and Norfolk Ridge continental ribbons, i.e., from west to east, the Fairway Basin, the Fairway Ridge, and the New Caledonia Basin (Figure 1).

The ZoNéCo 11 survey involved scientists from New Caledonia (Direction de l'Industrie, des Mines et de l'Energie) and France (Ifremer, Institut Français du Pétrole, Institut de Physique du Globe, and Institut Universitaire Européen de la Mer), and acquired 2500 km of deep seismic reflection and 600 km of wide-angle seismic data within the western part of New Caledonia's EEZ (Figure 1).

All shots from the 8000 cubic inch air gun array used to enhance the low frequencies were recorded by Ifremer's 4.5 km (360 channels) digital streamer and 15 ocean bottom seismometers. Additionally, a high-resolution seismic experiment was carried out in the Fairway Basin, using a high-frequency source consisting of six Sodera-GI (Generator-Injector) airguns.

Onboard interpretation of the ZoNéCo 11 seismic reflection and preliminary modeling of wide-angle data confirm the continental nature of the Lord Howe Rise and the Norfolk Ridge, corroborating *Shor et al.* [1971]. Seismic refraction data also reveal for the first time the continental-type seismic velocities and crustal thicknesses of the Fairway Ridge and Basin system (Figures 2a and 2c).

To the east, wide-angle and seismic reflection data show the oceanic nature of the New Caledonia Basin N-S central segment (Figures 2b and 2c) characterized by a shallow Mohorovicic discontinuity (16 km deep), typical oceanic-like velocities, average crustal thickness (8 km), and basement's wavelength segmentation (60 km).

Moreover, magnetic data indicate that the N-S trending New Caledonia Basin's crust was produced during the seafloor spreading phase of the basin. Furthermore, seismic reflection data indicate that the basin's crust is overlain by thick post-Upper Cretaceous deposits (Figure 2b). The weak amplitude of these anomalies can be explained by either magmatic accretion at a very slow spreading ridge during the Upper Cretaceous quiet time (anomalies M0 to 34, i.e. 114–83 Ma) or by amagmatic opening with emplacement of weakly magnetized upper mantle material.

With the preliminary results of the ZoNéCo 11 deep seismic survey enabling the completion of previous works [*Gaina et al.*, 1998; *Auzende et al.*, 2000], the following history for the formation of the study area is proposed.

The thinned continental Fairway Basin originates from the splitting of the continental Lord Howe Rise and Fairway Ridge, with a rifting stage that ended near the end of the Cretaceous. To the east, the New Caledonia Basin opened during Late Cretaceous times (Figure 3a).

If the weak anomalies observed are confirmed to be from the Magnetic Quiet zone, it would imply that the New Caledonia Basin opened earlier than previously thought, predating the Tasman Sea Basin (Figure 3b). Emplacement of oceanic crust within the New Caledonia Basin is interpreted to have been contemporaneous with the end of the continental stretching within the Fairway and West Caledonia basins.

Spreading along the New Caledonia Basin resulted in both accelerated subsidence within the basin and separation of the thinned continental Fairway and West Caledonia basins. Late Cretaceous, E-W spreading of the New Caledonia Basin isolated the Gondwana block (comprising the Lord Howe Rise and the thinned continental Fairway Basin and Ridge) to the west from the Norfolk Block (comprising thinned continental West Caledonia Basin and the Norfolk Ridge) to the east, with the two blocks drifting away along a series of SW-NE trending crustal-scale lineaments (Figure 3).

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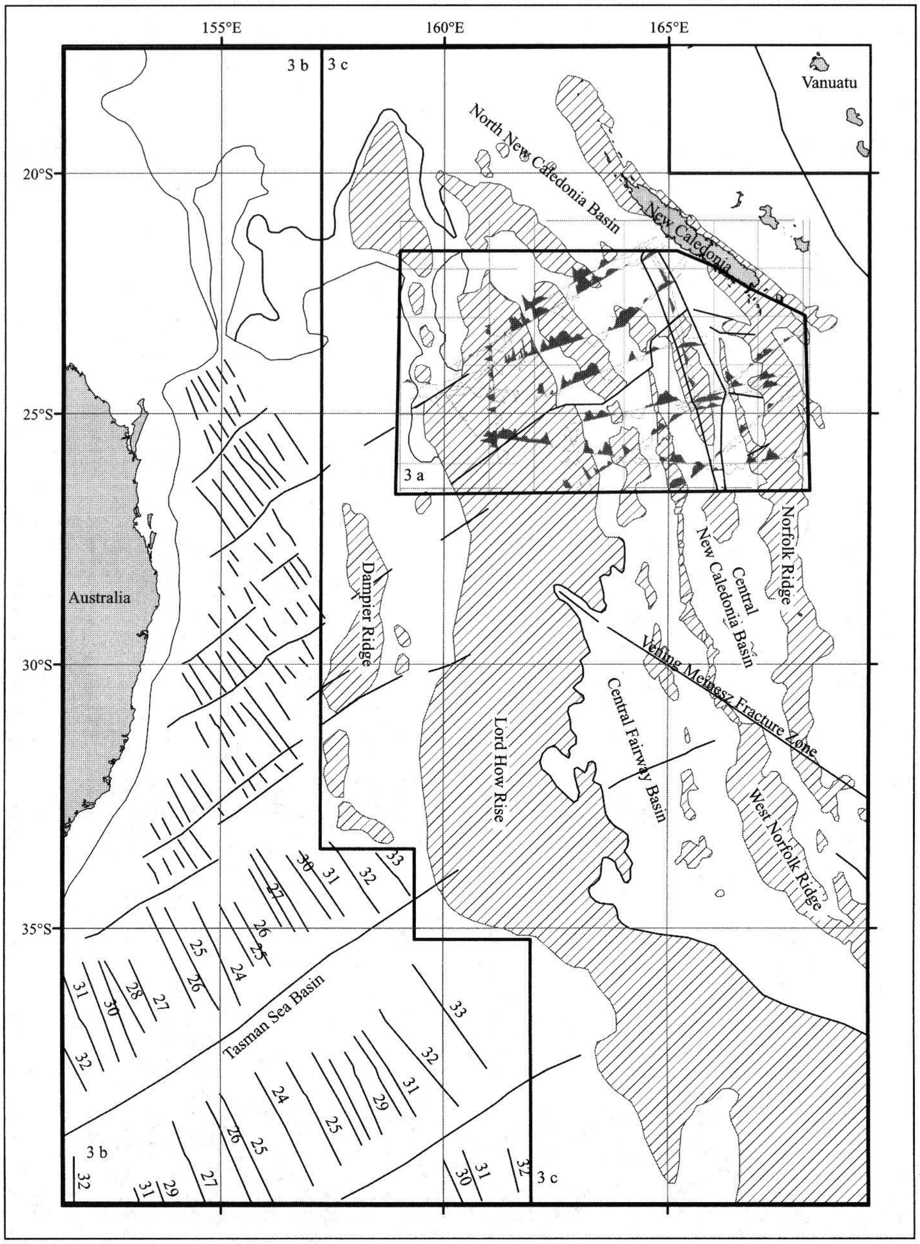

*Fig. 3. (a) Magnetic anomalies map superimposed on satellite gravity anomalies (Figure 3c). Compilation from the ZoNéCo 11 [*Lafoy et al.*, 2005], NOUCAPLAC 2 (a survey conducted within the framework of the French continental shelf extension program (the national extraplac program), in the western part of New Caledonia's EEZ)* (B. Loubrieu et al., *manuscript in preparation, 2005), and FAUST 1 (deep seismic survey, which was the first research cruise of the French-Australian Seismic Transect (FAUST) Program (1998–2001)] [*Lafoy et al.*, 1998] magnetic surveys. Thick curvilinear contour indicates weak positive amplitude anomalies within the central New Caledonia Basin. Thick lines indicate eastern extension of Tasman Sea crustal scale lineaments. (b) Seafloor spreading anomalies within the Tasman Sea [from* Stagg et al.*, 2000]. Numbers indicate dated anomalies. (c) Southern extensions of the Fairway and New Caledonia basins based on satellite gravity anomalies (modified from* Lafoy et al. *[2005]). Shaded areas indicate gravity highs.*

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