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Rifting to spreading in the southern Lau Basin: Variations within the transition zone

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ABSTRACT

The Lau Basin and Havre Trough are back-arc basins related to Pacific–Australian plate convergence. Seafloor spreading occurs in the Lau Basin whereas the Havre Trough is in a rifting stage. At present, the spreading propagator's tip lies at the southern end of the Valu Fa Ridge (VFR) at 22°40′S. Studying this propagation process provides an opportunity to characterize the evolution of rifting to the initiation of seafloor spreading which is fundamental to back-arc basin development.

New geophysical data of the southern Lau Basin reveals that as spreading propagates south, it evolves in a discrete style south of 22°40′S. The propagation axis lies along the eastern margin of the basin, where the well defined, linear VFR loses its identifying morphology. Topography in this eastern zone is characterized by grabens separated by short narrow ridges. High backscatter intensity indicates tectonic and magmatic activity in this eastern area. Mantle Bouguer anomalies (MBA) increase southwards from the VFR to form an elevated MBA area extending west from the currently active area. This indicates eastward migration of active rifting, during which the arc crust was extremely thinned. High magnetization is observed in a left-stepping pattern south of the VFR. We interpret this pattern as discrete segments that characterize the initiation of the spreading stage. There is no evidence of a single, continuous spreading axis like that which characterizes the central and northern Lau Basin. The magnetization highs are discrete and are observed in areas where deformation and magmatism are focused. They are offset relative to the VFR, though they generally follow the same north–south trend as the VFR.

1. Introduction

The transition from arc crust rifting to initial seafloor spreading is one of the key aspects of back-arc evolution. Rifting and seafloor spreading propagate rather than occurring simultaneously along the strike of the basin, and form a continuous back-arc system with different tectonic stages. The two-stage opening, rifting and seafloor spreading (producing oceanic crust), has been observed in several active back-arc basins (e.g., Parson and Wright, 1996; Yamazaki et al., 2003). The transition between these two stages provides insights into the initiation of seafloor spreading and has been studied in many rift systems of both continental and back-arc settings (e.g. Cochran and Martinez, 1988; Taylor et al., 1999; Keranen et al., 2004).

The southernmost area of Lau Basin presents an ideal setting to examine the transition zone between arc crust rifting and seafloor spreading. Lau Basin is located in the northern part of a continuous back-arc system behind the Tonga subduction zone. The southern part of the back-arc system is considered to be in a rifting stage (Delteil et al., 2002; Fujiwara et al., 2001; Martinez et al., 2006; Parson and Wright, 1996; Ruellan et al., 2003) and is called the Havre Trough (Fig. 1).

Lau Basin is currently in a seafloor spreading stage opening at two spreading centers; the East Lau Spreading Center (ELSC) and the Central Lau Spreading Center (CLSC) (Parson and Hawkins, 1994). The spreading rate at these spreading centers is well determined by magnetic anomaly lineation patterns (Zellmer and Taylor, 2001). The CLSC propagates into oceanic crust generated at ELSC, whereas the ELSC propagates into rifted arc crust at a southern terminus called the Valu Fa Ridge (VFR) (Fig. 2a). The VFR is a well defined linear feature where an intermediate spreading rate of 60–70 mm/yr (full rate) has been estimated from magnetic anomalies. Narrowing of the Brunhes anomaly width has been observed at the off-axis of VFR (Morton and Pohl, 1990; Zellmer and Taylor, 2001).This indicates the southward propagation of this spreading axis.

Organized seafloor spreading has only been suggested to the topographic limit at 22°40′S of the VFR. South of the VFR, indications of tectonic activity and magmatic extrusion have been documented (Delteil et al., 2002; Fujiwara et al., 2001; Parson and Wright, 1996; Ruellan et al., 2003; Martinez and Taylor, 2006). For example, basaltic rock samples with glassy rinds have been sampled in a graben located in the northernmost Havre Trough (Fujiwara et al., 2001). Although,

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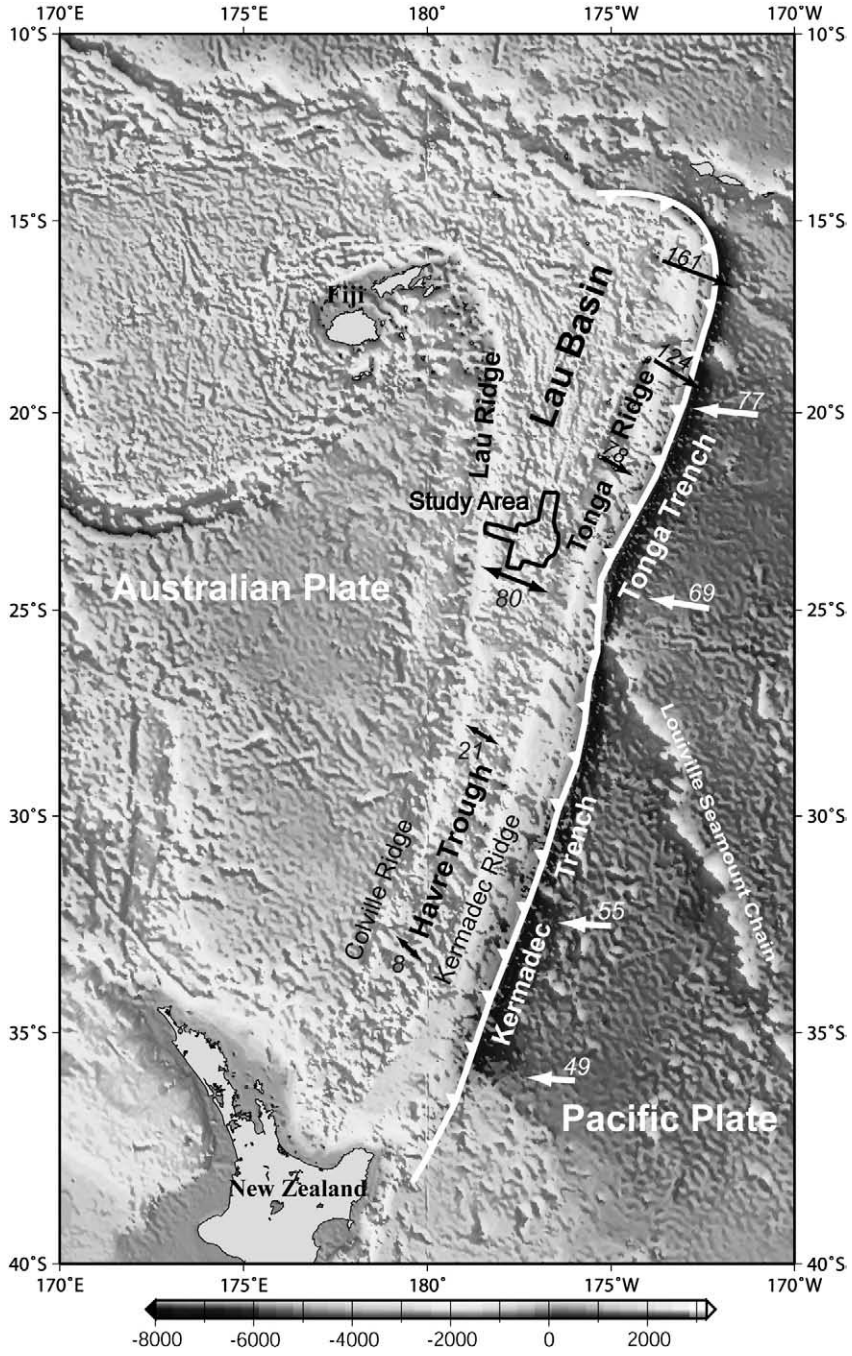

Fig. 1. Regional bathymetry of the Lau–Havre back-arc system, derived by satellite altimetry (Smith and Sandwell, 1997). The polygon shows the study area. The Pacific plate motion relative to the Australian plate (Demets et al., 1994) is shown in white arrows. Black arrows show geodetically determined motion (mm/yr) of the Tonga arc in an Australian plate fixed reference frame (Bevis et al., 1995). Divergent arrows indicate the rate of Havre Trough opening (Pelletier and Louat, 1989).

indications of intrusive or extrusive volcanism have been observed, a single axis of spreading has not been identified.

The southern Lau Basin, immediately south of the VFR, provides insights into the final stage of arc crust rifting which progressively evolves into organized seafloor spreading. A detailed survey of this area can lead to clarify how the transition occurs, and thus finding out the mechanism of spreading propagation in a back-arc setting. The objective of this study is to clarify the specific details of the area previously known as a diffuse volcanic–tectonic zone of opening south of a propagating spreading center (Martinez et al., 2006; Martinez and Taylor, 2006).

In this paper, we focus on the nascent seafloor spreading stage in the area ahead of organized spreading. Results of bathymetry, gravity and magnetic anomaly measurements are presented to examine the characteristics of the volcanic and extensional tectonic activity.

2. Data collection and analysis

From September 23rd to October 20th 2004, a geophysical survey in the southernmost Lau Basin was conducted during the YK04-09 cruise of *R/V Yokosuka* (Fig. 1). Bathymetric, magnetic and gravity data were obtained along the tracks.

Survey tracks cover the area between 21°30′S and 23°30′S and are spaced at 5 NM. They are designed to cross the general trend of the spreading centers in the northern and central Lau Basin. Tracks between 22°30′S and 23°S cover the entire width of the basin.