# Propagating rifts in the North Fiji Basin (southwest Pacific)

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## ABSTRACT

**The accretion system in the North Fiji marginal basin currently consists of four major, differently oriented axes. Multibeam bathymetry, recently acquired over the central north-south axis between 18° and 21°S, reveals a peculiar tectonic framework. Fanned patterns of the sea-floor topography at the northern and southern tips of this segment are the general shape of a rugby ball. These data, and the interpretation of magnetic anomalies, indicate that this central sector of the ridge has lengthened northward at the expense of the axis aligned N15°E. Both spreading and propagation rates are about 70–80 mm/yr. A southward propagation is also envisaged on the basis of the similar morphotectonic framework observed at the southern tip of the north-south ridge.**

## INTRODUCTION

The North Fiji Basin is a triangular-shaped marginal basin located at the convergent boundary between the Pacific and the Indo-Australian plates (Fig. 1). The opening of the basin, beginning in the late Miocene, is the result of the clockwise rotation of the New Hebrides arc and the counterclockwise rotation of the Fiji Islands (Chase, 1971; Gill and Gorton, 1973). These movements have required a permanent reorientation of the spreading axis during the past 10 m.y. After 3 Ma, a roughly north-south accretion system developed in the central and southern part of the basin, superimposing 030°-oriented lineations interpreted as ancient fracture zones guiding the rotation of the New Hebrides arc (Auzende et al., 1988b).

The accretion system currently consists of four first-order, differently oriented segments, two of which converge with a fracture zone having left-lateral motion to form a triple junction (Auzende et al., 1988a, 1988b; Lafoy et al., 1990) (Fig. 1): (1) the N160° ridge from about 14°30′S to the 16°40′S triple junction, (2) the N15° ridge from the triple junction to 18°10′S, (3) the north-south ridge from 18°10′S to 21°S, and (4) the southernmost north-south ridge, south of 21°S and offset by 80 km to the east from the north-south ridge through a 045°-oriented feature.

In this paper we present an unpublished bathymetric map of the central north-south ridge between 18° and 21°S, covering an area of 120 by 300 km. Multibeam bathymetry and magnetic profiles, acquired during the Japanese-French Yokosuka 1990 and 1991 cruises, provided the data set used for the study. We focused attention on the intersection of the north-south and N15° axes where a relevant propagating system appears.

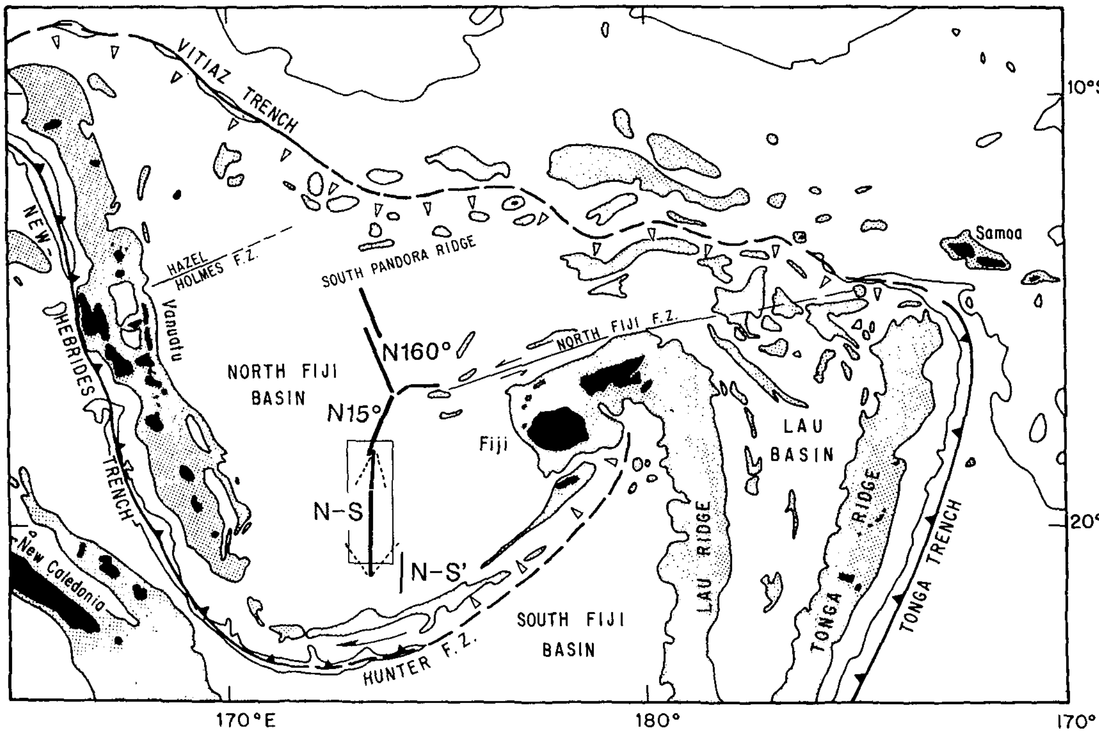

**Figure 1. Location map of North Fiji Basin ridge; box indicates full multibeam covered area of Figure 2. Heavy lines denote north-south, N15°, and N160° main segments of ridge axis; dashed lines are pseudofaults indicating double propagation. F. Z.—fracture zone.**

## N15° AND NORTH-SOUTH RIDGES

The N15° axis extends for at least 140 km from lat 17°00′S, where a large volcanic edifice is present in the triple-junction area, to the intersection with the north-south axis around 18°S. All the 015°–025° morphological lineations relative to the N15° axis are concentrated in a 50- to 60-km-wide belt that appears superimposed on the external, older north-south pattern. A tentative evaluation of the spreading rate, based on the width of two axial (Brunhes) anomalies at 17°10′S (south of the triple junction) gives a range of 40 to 50 mm/yr. This suggests a crustal age in the N15° belt of about 1.2–1 Ma.

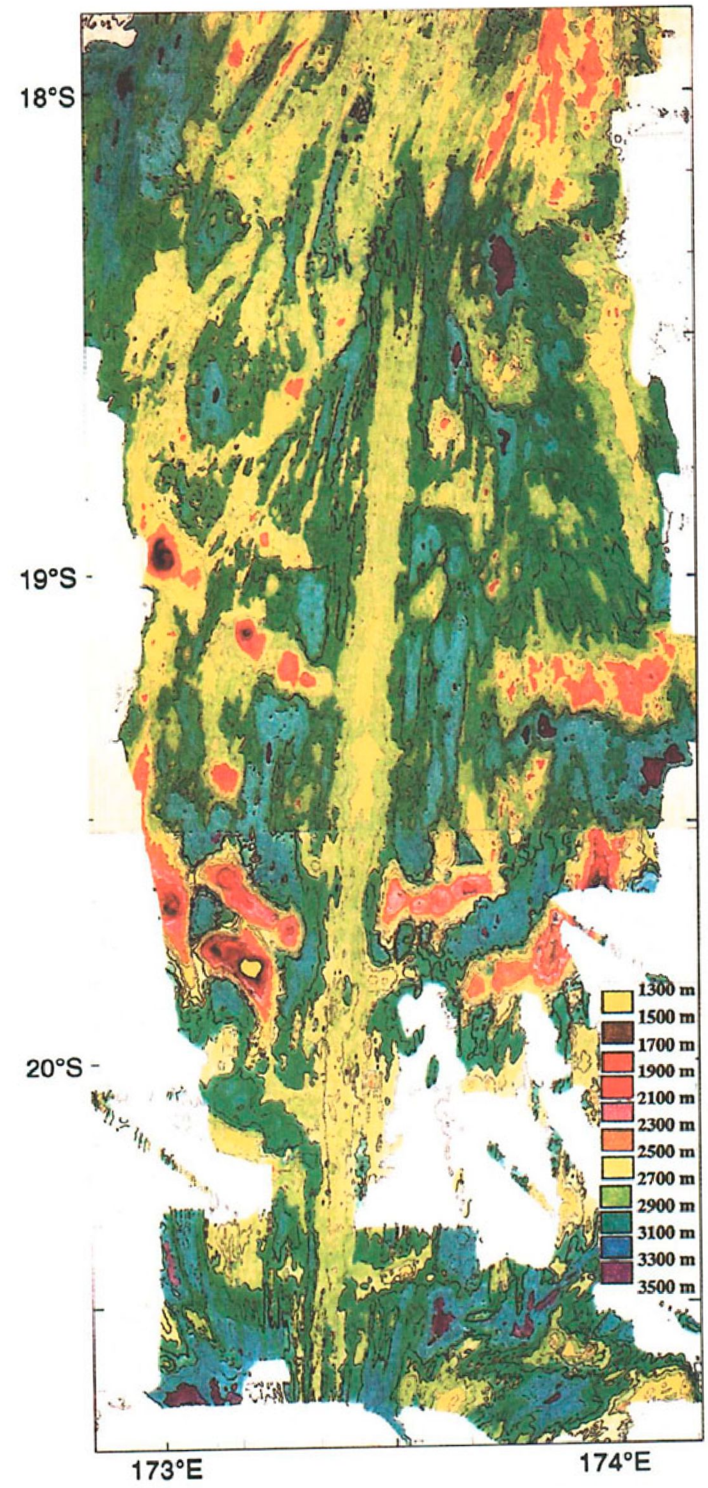

**Figure 2. Detailed multibeam bathymetry of ridge between 18° and 21°S. Contour lines represent depth below sea level. Contour interval is 100 m. General tectonic fabric is shaped like rugby ball. North of 19°10′S and south of 20°20′S, fan-shaped lineations converge northward and southward, respectively. Central sector is characterized by prevailing north-south pattern parallel to present-day axis and relevant punctiform volcanism located mainly off axial domain.**

The approximate length of the north-south axis is 300 km from 18°10′ to 21°S, its orientation changing slightly from 000° at 21°S to 005° at 18°S. From south to north the axis is gradually displaced eastward by 15–20 km. The total displacement is accommodated through minor dextral offsets ranging from a few hundred metres to 2–3 km; some of these show overlapping morphologies (Auzende et al., 1988a). The magnetic lineations have been identified up to anomaly 2A (3.5 Ma). The total spreading rate, measured from anomalies J (Jaramillo) and 2, gives a range of 70–80 mm/yr at 19°S (see Fig. 4). The morphology of the north-south ridge is typical of an intermediate- to fast-spreading accretion system. Along-axis bathymetry shows a very flat general topography except for an axial rise of 100–200 m and about 50 km long, centered at 19°30′S approximately at the middle of the segment. The axial domain deepens to 300 m near the intersection with the N15° axis (Fig. 2).

The central part of the ridge domain, between 19° and 20°S, is characterized by the presence of numerous off-axis volcanoes disposed along oblique alignments. They rise above the abyssal plain by 500 to 1300 m; some of them present caldera depressions (as much as 1–2 km in diameter) indicating foundering magmatic chambers (Batiza and Vanko, 1983).

North of 19°S the overall tectonic fabric of the north-south axial domain differs strongly from the central sector. The most striking feature is the presence of a broad, V-shaped region trending to the north. West of the V-shaped region between 18°30′ and 18°00′S, a 40-km-long ridge rises some 300 m above the abyssal plain. Its curved shape recalls the morphology of an overlapping spreading-center volcanic tip (C in Fig. 3). Two other features similar to overlapping spreading centers, although less evident, can be identified to the southwest (A and B in Fig. 3); the westernmost (and older) overlapping spreading center relict is partially incorporated by a large volcanic complex at 19°S.

## 18°S PROPAGATING SYSTEM

Nontransform discontinuities, such as propagating rifts and overlapping spreading centers, are commonly found at intermediate- to fast-spreading ocean ridges (Shih and Molnar, 1975; Hey, 1977; Macdonald and Fox, 1983). They are generally interpreted as transient phenomena related to a geometric rearrangement of the ridge-axis segmentation through time (Menard and Atwater, 1968, 1969; Hey et al., 1988).

Recently, several propagating rifts have been documented among the nontransform offsets of the East Pacific Rise (Lonsdale, 1989; Macdonald, 1989; Naar and Hey, 1991), and propagating "ridges" have also been described in back-arc basins such as the Lau Basin (Parson et al., 1990). However, the only propagator studied in great detail is still that at 95.5°W on the Colòn Ridge (Hey et al., 1986; Kleinrock and Hey, 1989). An interesting question arising from these observations concerns the dynamics of the ocean lithosphere in the zone between the propagating and failing axes, i.e., in the zone where the spreading motion is transferred from one plate to another. Hey et al. (1986) and McKenzie (1986) formulated a propagation model by considering a broad zone of lithospheric shear between the propagating and the failing axis, which fit well with the curved sea-floor fabric observed at the 95.5°W propagator (Hey et al., 1986); later, Acton et al. (1988) demonstrated that the curved sea-floor patterns could be achieved by other mechanisms that did not deviate from purely rigid plate tectonics, such as (1) variations in the propagation and/or spreading rate and (2) variations in the direction of propagation.

The basic observations on sea-floor topography at the intersection between the north-south and N15° axes in the North Fiji Basin, as discussed above, confirm the hypothesis of an active propagation system between 18°S and 19°S (Auzende et al., 1988a). The propagation system has been produced by the northward migration of the transform offset between the north-south and N15° axes. Currently, the tip of the propagator is located at 18°10′S, 173°30′E (Figs. 2, 3). A tentative evaluation of the propagation rate gives a range of 70–80 km/m.y. obtained by taking into account the extent of the Brunhes magnetic anomaly at the propagator tip (Fig. 4); this rate is comparable with other values in the literature (Acton et al., 1988; Kleinrock and Hey, 1989). Moreover, it has the same order of magnitude as the spreading rate inferred at 19°S. Other evidence corroborates the hypothesis of a very recent to present-day propagation at 18°S: (1) clusters of earthquakes concentrated in the proximity of the propagator tip, as evidenced by the distribution of shallow seismicity (Hamburger and Isacks, 1988), which suggests mechanisms such as the propagation of cracks occurring when axial segments lengthen through preexisting lithosphere (Macdonald et al., 1991); (2) the high amplitude of the magnetic axial anomaly found in correspondence with the propagator tip (Hey and Vogt, 1977; Miller and Hey, 1986) (Fig. 4); and (3) the anomalously deep region at the extremity of the north-south ridge (Phipps Morgan and Parmentier, 1985).

The overlap and the offset between the axes are ~40 km and ~15 km, respectively, assuming that the curved tip of the N15° axis (C in Fig. 3) is an active spreading center. These parameters differ considerably from those of the 95.5°W Galapagos propagator (15–20 km overlap and 35–40 km offset according to Hey et al., 1992) and give an overlap to offset ratio of ~3, closer to the ratio evidenced by the overlapping spreading centers on the East Pacific Rise (Macdonald and Fox, 1983; Naar and Hey, 1991). Moreover the orientation of the propagation vector with respect to the failing axis in the North Fiji Basin differs slightly from that of 95.5°W. Another unusual feature of the 18°S propagator is represented by the fan-shaped, clearly asymmetric lineations inside the V-shaped domain (Fig. 3). Most of the oblique lineations described in the literature are related to the two pseudofaults (Hey, 1977) that offset different magnetic patterns or, on a smaller scale, refer to the pseudofaults inferred from detailed bathymetry, as in the case of the 95.5°W propagator tip (Kleinrock and Hey, 1989). The lineations of the topography are generally quite parallel inside the V-shaped domain bordered by the pseudofaults whereas, in the case of our propagator, the abyssal-hill fabric clearly appears fanned in the V-shaped region (see discussion in Fig. 3 caption). In the zone of overlap between the growing and the failing axes, i.e., the zone of transferred lithosphere (Hey et al., 1980), curved abyssal-hill patterns appear (Fig. 3). The definition of the transfer zone is based on the assumption that the curved high at 18°30′S (C in Fig. 3), opposite to the curve-shaped deep of the propagating rift, is the spreading center tip of the failing N15° axis. The adoption of a shear-zone model (Hey et al., 1986) rather than a rigid-plate model (Acton et al., 1988) to match the observed sea-floor fabric necessarily requires further detailed knowledge of the transfer zone. In any case an original configuration of the intersection of north-south and N15° axes can be envisaged: the two ridge tips are curved, like an overlapping spreading center, but one tip (the failing one) is represented by a positive feature, and the other tip (the propagating one) is represented by a negative feature. This is partly in agreement with the observation that propagating rifts are magmatically starved and severely tectonized, whereas the failing rifts are magmatically robust, having only modest tectonic deformation (Macdonald, 1989; Kleinrock and Hey, 1989).

## RIDGE REARRANGEMENT IN THE PAST 1.7 M.Y.

The North Fiji Basin accretion system between 16°40′S and 21°S currently consists of two segments of different lengths and ori-

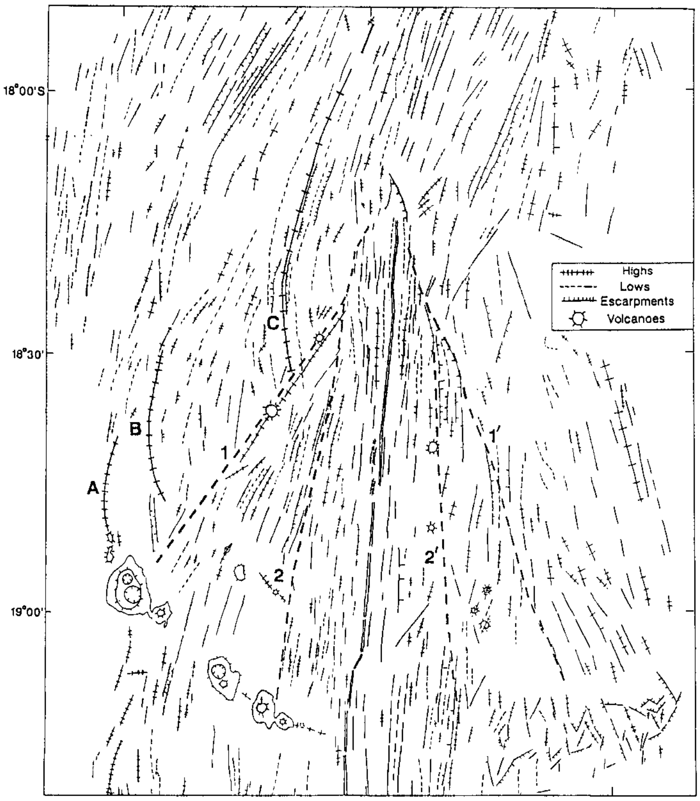

**Figure 3. Main morphostructural features in area of 18°S propagating rift; A and B are abandoned tips of N15° ridge, C is present tip. Four domains, defined by iso-oriented lineations are: (1) N15°–N20° domain related to present N15° axis (west of line 1); (2) "fan-shaped" domain, located inside V-shaped region west of north-south axis (between lines 1 and 2); (3) north-south domain with lineations mainly parallel to north-south axis, inside V-shaped region east and west of axis (between lines 2 and 1′); (4) fan-shaped external domain east of V-shaped region (east of line 1′). In assumed zone of transferred lithosphere (between C and propagator tip), slightly curved lineations appear. Lines 1 and 1′ may represent, respectively, inner and outer pseudofaults of previous phase of propagation; subsequently, another phase of propagation (and of accretion) characterized by different velocity (Acton et al., 1988) has developed inside V-shaped region; it is bounded by lines 2 and 2′ that define roughly parallel patterns of abyssal-hill fabric. Another interpretation, closer to existing model (Hey et al., 1986), is that line 1 may represent failed rift trace. This alternative would require adoption of line 2 as inner pseudofault; consequently, area between lines 1 and 2 could be wake of transferred lithosphere. In this case, clearly convergent lineations between lines 1 and 2 could be considered as sets of failed rifts and pseudofaults.**

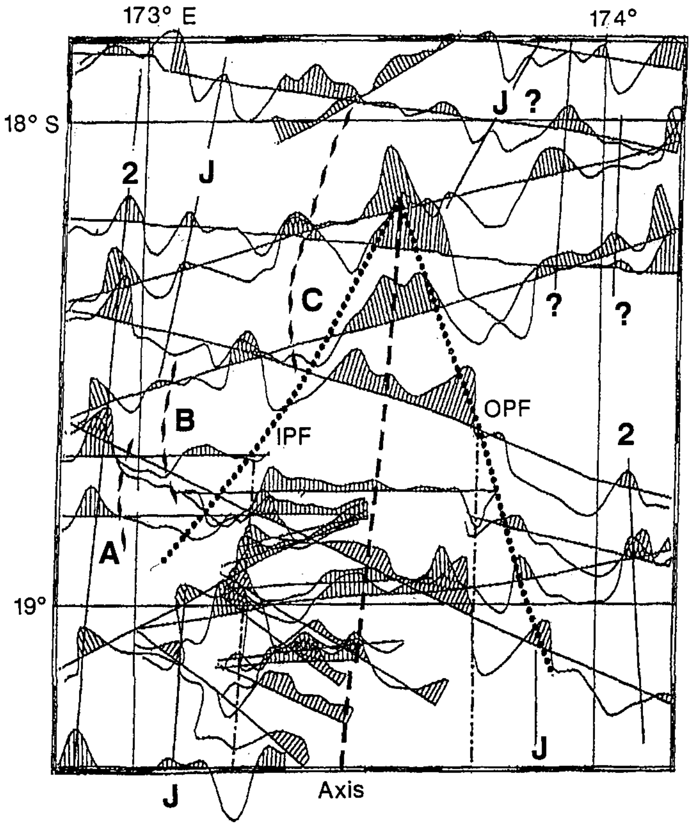

**Figure 4. Magnetic profiles across north-south and N15° axes intersection. A, B, and C are same as in Figure 3; IPF and OPF (inner and outer pseudofaults) correspond to lines 1 and 1′ in Figure 3. Obliquity of magnetic lineations with respect to anomaly 2 (1.7 Ma) suggests that overall process of axis reorientation occurred at 1.7 Ma; Jaramillo anomaly (J; 0.97 Ma) is not easy to identify on N15° ridge. Its position as interpreted here pushes back date of N15° axis to 1 Ma; moreover, it extends to 18°40′S (latitude of B, abandoned tip of N15° axis), indicating that propagation began at least 1 Ma. Note general asymmetry of magnetic anomalies and their high amplitude at propagator tip.**

entations. An abrupt change from a roughly north-south accretion system to a double segmented ridge occurred after anomaly 2 (1.7 Ma) and is suggested by discordant sea-floor and magnetic lineations between the N15° belt and the surrounding north-south patterns. The ridge segmentation, induced by reorientation of the stress field in the basin, resulted in the northward propagation of the probably longer segment (north-south) in order to reach a more stable configuration (Parson et al., 1990). This tentative restoration appears confirmed by the tracks left by the N15° failing ridge (A and B in Fig. 3). These old, abandoned, overlapping spreading-center tips testify that the N15° segment was longer in the past: it probably extended up to 19°S (latitude of A, Fig. 3). Similar fossil trails left by failing ridges have been observed on the East Pacific Rise (Lonsdale, 1989; Macdonald, 1989). A southward propagation, although not confirmed by magnetic data, may be envisaged at the southern tip of the ridge (Fig. 2).

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