Twin active spreading ridges in the North Fiji Basin (southwest Pacific)

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ABSTRACT

Recent work on the North Fiji Basin axial spreading ridge and on the active propagating ridge located west of the Fiji Islands has established the existence of two active spreading ridges that have been functioning synchronously in the basin since at least 1 or 1.5 Ma. This hypothesis is tested and the kinematics of the twin active ridges are refined further on the basis of analysis of bathymetric and magnetic data.

INTRODUCTION

Since Chase's (1971) work, the existence of an active spreading-ridge axis in the central part of the North Fiji Basin has been well documented (Malahoff et al., 1982; Maillet et al., 1986; Auzende et al., 1988). The first direct evidence of the presence of an accretionary ridge arose from the multibeam bathymetric survey carried out by the R/V *Jean Charcot* (Auzende et al., 1986). The central spreading ridge of the North Fiji Basin has been studied extensively, and Figure 1 shows the extent of the full multibeam coverage obtained during the Seapso III (Seabeam, southwest Pacific) and Starmer (Sci-

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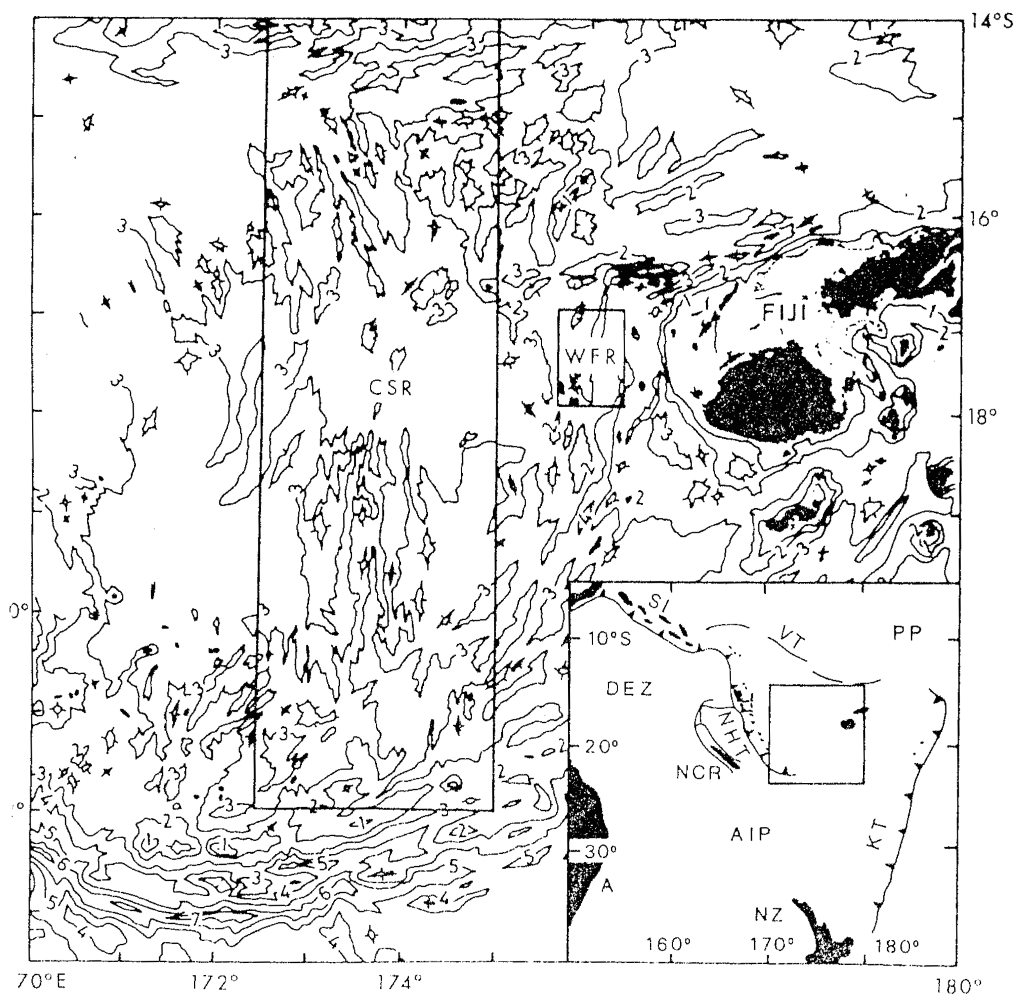


Figure 1. Simplified bathymetric map of North Fiji Basin. Boxes indicate multibeam full-coverage areas. CSR = central spreading ridge; WFR = west Fiji ridge. Bathymetric contour interval = 1 km. Inset shows geodynamic setting of North Fiji Basin. Box represents surface covered by bathymetric map. SI = Solomon Islands; VT = Vityaz Trench; PP = Pacific plate; KT = Kermadec-Tonga Trench; NZ = New Zealand; AIP = Australia-India plate; NCR = New Caledonia; NHT = New Hebrides Trench; DEZ = D'Entrecasteaux zone; A = Australia.

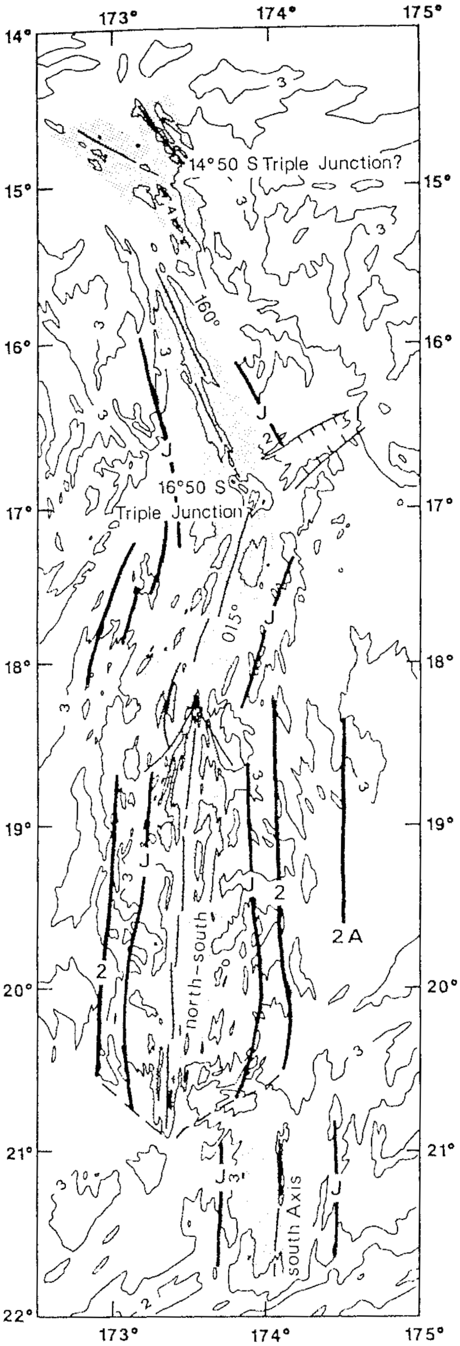


Figure 2. Simplified bathymetry (contour interval = 1 km) and magnetic lineations along central spreading ridge (from Auzende et al., 1990). Shading represents anomaly 1. J—Jaramillo anomaly (1 Ma); 2—anomaly 2 (1.98 Ma); 2A—anomaly 2A (3 Ma). Ages of anomalies are after Cande and Kent (1992).

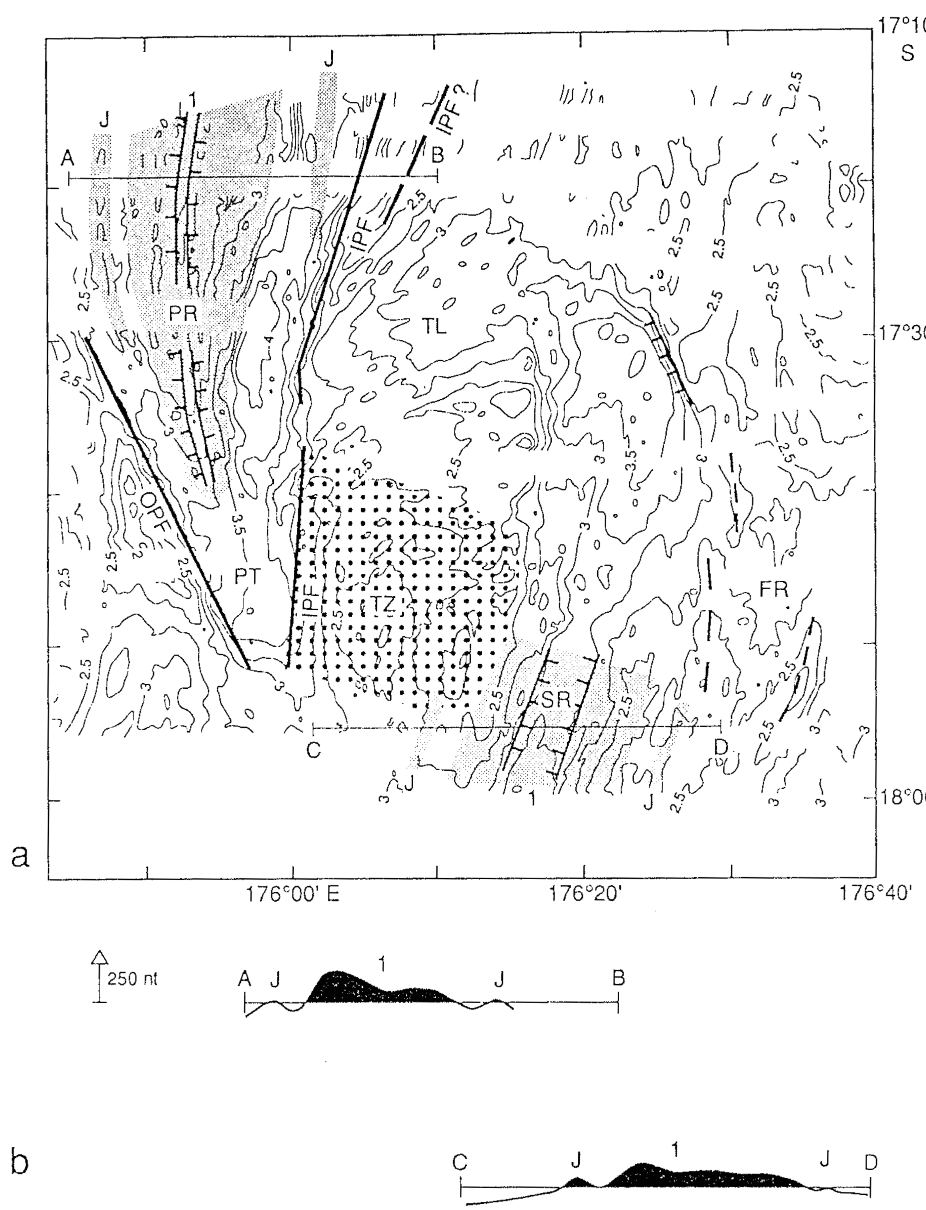


Figure 3. a: Simplified bathymetric map of west Fiji propagating ridge. Contour interval = 250 m. Depth values every 0.5 km. PR = propagating rift axis; SR = southern rift; FR = failed rift; PT = propagating tip; TZ = transform zone; TL = transferred lithosphere; IPF = inner pseudofault; OPF = outer pseudofault. AB and CD = magnetic profiles shown in b. Stipple indicates anomaly 1; J = Jaramillo. Random stipples represent transform zone. b: Magnetic profiles across west Fiji ridge.

ence and Technology Agency of Japan and IFREMER) projects. On the basis of seismological data, other authors proposed that the present-day accretion is distributed on the central ridge and an axis located immediately west of the Fiji archipelago (Chase, 1971; Pelletier and Louat, 1989). These hypotheses were not well supported by previous morphologic data.

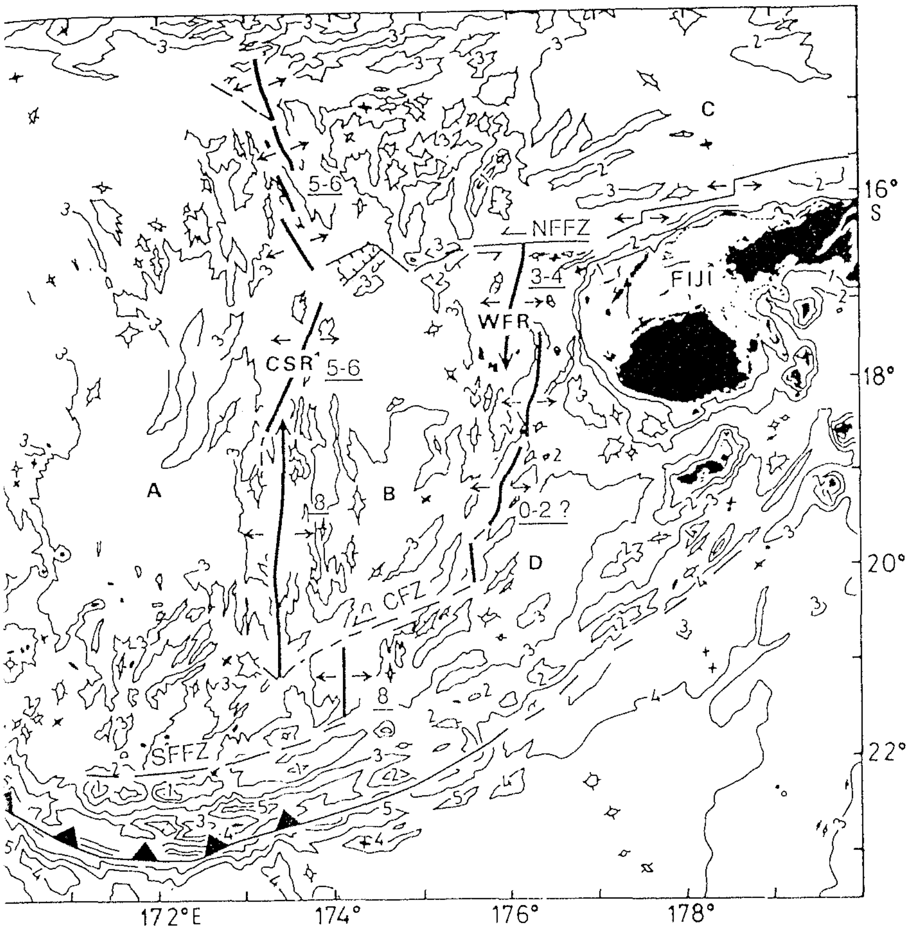
In this paper we propose the existence of twin active ridges in the North Fiji Basin on the basis of morphological and magnetic evidence and discuss the implications of such a dual system.

CENTRAL SPREADING RIDGE

The central spreading ridge is mapped by multibeam over an area of more than 1° of longitude and 8° of latitude (Fig. 1), and can be divided into four major segments (Fig. 2).

1. Between lat 22°S and 20°30'S, the active spreading axis is defined only by the identification of the axial magnetic anomaly (Maillet et al., 1986). The morphology of this segment is similar to that of slow spreading ridges; there is a central graben >3000 m deep bounded by 2500-m-high ridges oriented 005°.

2. Between lat 21°00'S and 18°10'S, the north-south segment is offset ~80 km to the west from the southernmost segment, and its morphology is typical of fast-spreading ridges (Macdonald, 1982), with an 8-km-wide, 200–300-m-high axial dome. This dome is cut locally in its middle by a 50–500-m-wide and 20–50-m-deep graben. The axial dome is bounded on both sides by north-trending abyssal hills representative of an east-west spreading direction. This



ʒure 4. Kinematic sketch of twin ridges. NFFZ = north Fiji fracture zone; CFZ = central Fiji frac-re zone; SFFZ = south Fiji fracture zone; CSR = central spreading ridge; WFR = west Fiji ridge; 6 = spreading rate (in cm/yr) calculated from magnetic data; 0–2? = inferred spreading rate ı cm/yr). Arrows at tips of ridge segments indicate direction of propagation. Contour interval = ‹m. A = western North Fiji Basin plate; B = intermediate microplate; C = north Fiji (Pacific?) plate; = southeast Fiji (Australian?) plate.

·gment is propagating northward, as dem-ıstrated by Alteris et al. (1993).

3. Between lat 18°10′S and the 16°50′S tri-e junction (Lafoy et al., 1990), the spread-g ridge trends 015°. In the northern part, it characterized by a high double ridge cul-inating at <2500 m depth, bounding a 1–2-n-wide, 100-m-deep graben. The axis is :gmented about every 30 km by transverse ructures.

4. North of the 16°50′S triple junction, the ›reading ridge consists of a succession of ırec 3500–4000-m-deep grabens aligned on 160° direction. This morphology is typical f slow spreading ridges (Macdonald, 1982), ˈthough the spreading rate calculated from ıagnetic lineation analysis is 50 to 60 km/ ı.y. The northern tip of the 160° axis con-sts of a triple junction connected to the ›rthern and northwestern spreading cen-·rs of the North Fiji Basin.

The magnetic lineations (Fig. 2) have been ıapped all along the central ridge of the ba-n (Auzende et al., 1990). The central mag-netic anomaly is present and well defined along the entire axis; the J (Jaramillo) anomaly definitely exists on the two southern segments and probably on the 015° segment and on the southern part of the 160° segment. The 2 and 2A anomalies are clearly defined all along the central north-south segment. The calculated average spreading rates, calculated with a 070° spreading trend, vary from 50 km/m.y. on the 160° and the 015° segments to 80 km/m.y. on the central and southernmost segments (Auzende et al., 1990).

WEST FIJI PROPAGATING RIDGE

The west Fiji propagating ridge was mapped during the Seapso III cruise of the R/V *Jean Charcot* (December 1985) (Figs. 1 and 3a). It is associated with significant shallow seismicity (Hamburger and Isacks, 1988; Pelletier and Louat, 1989). The focal mechanisms are normal or strike-slip faulting solutions. Previously interpreted as a strike-slip deformation zone, the ridge has been reinterpreted as a propagating rift (Auzende et al., 1993).

Morphostructural Units

The propagating ridge (Fig. 3a) is located in the western part and consists of a central ridge bounded by two grabens. The eastern graben is well developed, and has a constant 10 km width and 4000 m depth. The western graben is narrower (2 to 3 km) and shallower (3000 m). The central ridge is 7–8 km wide and 2750 m deep. Its north-south to 005° trend changes to 155° at its southern tip. The width of crust inside the pseudofaults varies from 40 km in the north to 8 km in the south. South of 17°44′S, the ridge disappears and is replaced by a 3000-m-deep propagating tip (Hey et al., 1986) within converging pseudofaults.

The outer pseudofault corresponds to a 155°-trending fault that bounds the crust formed by the propagating ridge. This fault separates the propagating ridge from the oceanic bottom grain, which trends 015°–020°. North of 17°35′S, the inner pseudofault trends 015° and converges with the outer pseudofault at a 40° angle; south of 17°35′S, the 005° inner pseudofault converges with the outer pseudofault at a 20° angle. A less well marked scarp east of the main inner pseudofault could be a secondary pseudofault that converges at a 55° angle with the outer pseudofault.

The southern ridge (Fig. 4) is characterized by a 3000-m-deep, 7-km-wide axial rift valley trending 010°. In the eastern part of the domain the failed rift is composed of a succession of 010°–015° ridges abutting a 150° fault. These ridges are 2–3 km wide and 2750 m deep, and are probably the old spreading axis, shut down when the western active rift propagated south.

The junction between the propagating rift and the southern ridge is composed of a wide zone of arcuate small ridges interpreted as a transform zone as defined by Hey et al. (1986). Transferred lithosphere is located north of the transform zone in the central area, and comprises fan-shaped structures that are as deep as 3000 m in the northern part.

The spreading rate of the west Fiji ridge was estimated to be 30 km/m.y. (Pelletier and Louat, 1989), taking into account the kinematics of the junction between the North Fiji and Lau basins. The magnetic anomaly lineations and profiles in Figure 3 (a and b) also support the existence of an active spreading axis. In the northwestern part of the survey there is a well-defined anomaly corresponding to the propagating rift system; the anomaly is interpreted as anomaly 1, and its width decreases from north to south. On both sides, especially in the west, a magnetic lineation could be identified as anomaly J (Jaramillo, 1 Ma) (Fig. 3, a and b). The magnetic pattern coincides well with the structural interpretation (Fig. 3a). Anomaly 1, and possibly anomaly J, exists in the south-central part of the survey, coinciding with the southern rift. Between both axes a large transverse east-west negative magnetic lineation can be interpreted as the transform zone between the propagating rift and the southern rift. The spreading rate of the west Fiji ridge, given by the magnetic data interpretation, is 35 km/m.y. on both the propagating and southern rifts. Considering the 40° and 20° angles between the outer and inner pseudofaults, the calculated propagating velocity obtained using the formula of Hey et al. (1986) is 42 km/m.y., and increases up to 96 km/m.y. for the southern tip.

DISCUSSION AND CONCLUSIONS

The compilation of the structural and magnetic data allows us to confirm the existence in the North Fiji Basin of two parallel, synchronously active spreading ridges. The magnetic lineation analysis demonstrates the generation of the central spreading ridge to its present-day position from 3 Ma, at an average spreading rate of 60 km/m.y. The identification of the J (Jaramillo) anomaly on both sides of the west Fiji ridge implies that propagation began at least 1 Ma, and was related to the left-lateral strike-slip motion of the north Fiji fracture zone (Lafoy et al., 1990).

The southern termination of the west Fiji ridge (Fig. 4) is formed by an oblique feature trending 060°, the central Fiji fracture zone (Pelletier and Louat, 1989), which could be interpreted as a transform zone between both the central spreading ridge and west Fiji ridge axes. If we assume that the spreading rate in the North Fiji Basin is constant south of the north Fiji fracture zone, the sum of the rates of the central spreading ridge and the west Fiji ridge north of the central Fiji fracture zone must be equivalent all along their length. Taking into account the spreading rates deduced from magnetic anomaly identifications, a rate of 0 to 20 km/m.y. is inferred for the southernmost part of the west Fiji ridge. This low rate is compatible with the near absence of seismicity along this southern part. Following this scheme, spreading rates increase to the south along the central spreading ridge segments and to the north along the west Fiji ridge. These characteristics can be compared directly to those observed at a smaller scale on overlapping spreading centers (Macdonald, 1982) and propagating rifts (Hey, 1977) or at the same scale on the East Pacific Rise in the area of the Easter (Searle et al., 1989; Naar et al., 1991) and Juan Fernandez (Francheteau et al., 1987; Larson et al., 1992) microplates. This implies that the central spreading ridge and west Fiji ridge are propagating in opposite sense. The result is the individualization of a microplate between both ridges since the generation of the west Fiji ridge, 1 or 1.5 Ma.

Other examples of twin ridge systems, although not yet very well documented, can be found in the southwest Pacific marginal basins, e.g., in the northern Lau Basin, where the Peggy ridge and the 175°W ridge are active (Pelletier and Louat, 1989), and in the Manus Basin (Taylor et al., 1992), where the accretion could also be located on at least two active spreading centers.

ACKNOWLEDGMENTS

We thank anonymous reviewers for their constructive comments, and the scientists involved in the Seapso and Starmer cruises.

REFERENCES CITED

Alteris, G. de, and eight others, 1993, Propagating rifts in the North Fiji Basin (southwest Pacific): Geology, v. 21, p. 583–586.

Auzende, J.M., Lagabrielle, Y., Schaaf, A., Gente, P., and Eissen, J.P., 1986, Tectonique intra-océanique décrochante à l'ouest des îles Fidji (Bassin Nord Fidjien). Campagne SEAPSO III du N.O. *Jean Charcot*: Paris, Académie des Sciences Comptes Rendus, v. 303, p. 241–246.

Auzende, J.M., Lafoy, Y., and Marsset, B., 1988, Recent geodynamic evolution of the North Fiji Basin (southwest Pacific): Geology, v. 16, p. 925–929.

Auzende, J.M., and 29 others, 1990, Active spreading and hydrothermalism in North Fiji Basin (southwest Pacific). Results of Japanese-French cruise Kaiyo 87: Marine Geophysical Research, v. 12, p. 269–283.

Auzende, J.M., Hey, R.N., Pelletier, B., and Lafoy, Y., 1993, Propagation d'une zone d'accrétion à l'est de la dorsale du bassin Nord Fidjien: Paris, Académie des Sciences Comptes Rendus, sér. 2, p. 1546–1552.

Cande, S.C., and Kent, D.V., 1992, A new geomagnetic polarity time scale for the Late Cretaceous and Cenozoic: Journal of Geophysical Research, v. 97, p. 13,917–13,951.

Chase, C.G., 1971, Tectonic history of the Fiji Plateau: Geological Society of America Bulletin, v. 82, p. 3087–3110.

Francheteau, J., Yelles-Chaouche, A., and Craig, H., 1987, The Juan Fernandez microplate north of the Nazca-Pacific-Antarctic plate junction at 35°S: Earth and Planetary Science Letters, v. 86, p. 253–286.

Hamburger, M.W., and Isacks, B.L., 1988, Diffuse back-arc deformation in the southwestern Pacific: Nature, v. 332, p. 599–604.

Hey, R.N., 1977, A new class of pseudo-faults and their bearing on plate tectonics: A propagating rift model: Earth and Planetary Science Letters, v. 37, p. 321–325.

Hey, R.N., Kleinrock, M.C., Miller, S.P., Atwater, T.M., and Searle, R.C., 1986, Sea Beam/deep-tow investigation of an active oceanic propagating rift system, Galapagos 95.5°W: Journal of Geophysical Research, v. 91, p. 3369–3393.

Lafoy, Y., Auzende, J.M., Ruellan, E., Huchon, P., and Honza, E., 1990, The 16°40S triple junction in the North Fiji Basin (SW Pacific): Marine Geophysical Research, v. 12, p. 285–296.

Larson, R.L., and eight others, 1992, Roller-bearing tectonic evolution of the Juan Fernandez microplate: Nature, v. 356, p. 571–576.

Macdonald, K.C., 1982, Mid-ocean ridges: Fine scale tectonic, volcanic and hydrothermal processes within the plate boundary zone: Earth and Planetary Science Letters, v. 167, p. 155–190.

Maillet, P., Eissen, J.P., Lapouille, A., Monzier, M., Baleivanualala, V., Butscher, J., Gallois, F., and Lardy, M., 1986, La dorsale active du bassin Nord-Fidjien entre 20°00'S et 20°53'S; signature magnétique et morphologie: Paris, Académie des Sciences Comptes Rendus, sér. 2, v. 302, p. 135–140.

Malahoff, A., Feden, R.H., and Fleming, H.F., 1982, Magnetic anomalies and tectonic fabric of marginal basins north of New Zealand: Journal of Geophysical Research, v. 87, p. 4109–4125.

Naar, D.F., Martinez, F., Hey, R.N., Reed, T.B., and Stein, S., 1991, Pito rift: How a large-offset rift propagates: Marine Geophysical Research, v. 13, p. 287–309.

Pelletier, B., and Louat, R., 1989, Mouvement relatif des plaques dans le Sud-Ouest Pacifique: Paris, Académie des Sciences Comptes Rendus, sér. 2, v. 308, p. 123–130.

Searle, R.C., and eight others, 1989, Comprehensive sonar imaging of the Easter microplate: Nature, v. 341, p. 701–705.

Taylor, B., Crook, K.A.W., Sinton, J.M., and Petersen, L., 1992, Manus Basin, Papua New Guinea, *in* Pacific seafloor atlas, SOPAC region: IUG Sheets 1–7.

Manuscript received July 6, 1993
Revised manuscript received October 6, 1993
Manuscript accepted October 12, 1993