Morphostructure of an incipient subduction zone along a transform plate boundary: Puysegur Ridge and Trench

Jean-Yves Collot, Geoffroy Lamarche — L'Institut Français de Recherche Scientifique pour le Développement en Coopération, B.P. 48, Villefranche sur mer 06230, France
Ray A. Wood — Institute of Geological and Nuclear Sciences, P.O. Box 30368, Lower Hutt, New Zealand
Jean Delteil, Marc Sosson, Jean-Frédéric Lebrun — Institut de Géodynamique, rue A. Einstein 06560, Sophia Antipolis, Valbonne, France
Mike F. Coffin — Institute for Geophysics, University of Texas, 8701 North Mopac Expressway, Austin, Texas 78759-8397

ABSTRACT

Multibeam bathymetric and geophysical data reveal a major strike-slip fault that extends along the summit of the Puysegur Ridge east of the Puysegur Trench. The northward structural development of this ridge-trench system illustrates the evolution of an incipient subduction zone along a transform plate boundary that has been subjected to increasing transverse shortening during the past 10 m.y. At the southern end of the trench, where subduction has not yet started, the Puysegur Ridge has a narrow (<50 km) steep-sided cross section, and the axial strike-slip fault separates a shallow (125–625 m), flat-topped eastern crest from a deeper (400–1600 m) western crest; these characteristics indicate differential uplift during the initial stage of shortening. On the lower plate an incipient, 5.2-km-deep trench developed in conjunction with normal and reverse faults, suggesting strong interplate coupling across the trench. Northward, the ridge broadens linearly to 80 km wide, its western flank has locally collapsed, and the ridge summit has subsided, possibly by 1.5 km, suggesting that the interplate coupling decreases and that a Benioff zone is being formed. Concomitant to the northward ridge evolution, the trench deepens to 6.2 km and normal fault throws increase along its outer wall, indicating greater flexure of the downgoing plate.

INTRODUCTION

The mechanisms that govern the initiation and development of subduction are not well understood, in part because of a lack of morphostructural observations. The Macquarie Ridge complex, part of the Pacific-Australian intraoceanic plate boundary south of New Zealand (Fig. 1), was interpreted by Ruff et al. (1989) as a possible incipient subduction zone propagating south along a transform plate boundary in conjunction with the southwestward migration of the Pacific-Australian rotation pole since about 10 m.y. (Walcott, 1984).

The northern segment of the Macquarie Ridge complex, between lat 51°S and 47°S, is the 3–5-km-high Puysegur Ridge, flanked to the west by the 6-km-deep Puysegur Trench and to the east by the sedimented 3.5-km-deep Solander Trough (Summerhayes, 1967; Van der Linden and Hayes, 1972). In this region, the NUVEL-1 model predicts a 3.2–3.5 cm/yr relative plate motion trending N52°–59°E, oblique to the N15°–20° trending trench (De Mets et al., 1990). According to Ruff et al. (1989), the oblique convergence at 49°–50°S is accommodated by a dual-rupture mode of relatively small (4.5 < M < 5.1) thrust earthquakes on shallowly dipping faults followed by a greater (M > 7) strike-slip earthquake on a subvertical fault.

We acquired multibeam bathymetry (Fig. 1), side-scan sonar imagery, and seismic reflection and geopotential data during the Geodynz-sud cruise of the R.V. *L'Atalante* along the Puysegur Ridge, Puysegur Trench, and adjacent Australian plate between 49°45′ and 47°S. This cruise was designed to investigate the structure and dynamics of this immature subduction margin.

MORPHOSTRUCTURE OF THE AUSTRALIAN PLATE AND PUYSEGUR TRENCH

The sea floor of the Australian plate shows a complex primary oceanic fabric with a structural grain that rotates from N120°E in the southern part of the survey area to N60°E in the north. Near 49°S, this pattern is cut perpendicularly by a ridge that trends N20°–30°E, which we interpret as a fracture zone (l'Atalante fracture zone; Fig. 2). Similar fractures zones may have played a significant role in the development of the plate boundary.

Extension related to flexure of the plate as it descends into the trench has affected the Australian plate within 10 km of the trench. Trench-parallel normal faults developed north of 49°15′S. The throws increase and the trench deepens from 5250 to 6250 m to the north, indicating that the plate flexure also increases to the north.

Reverse faults with small throws appear to deform the Australian sea floor as far as 65 km west of the trench near 47°S, indicating that primary oceanic structures were recently reactivated by shortening. Near 48°30′–49°S, reverse faults may indicate transpression along a trench-parallel zone, suggesting relatively strong interplate coupling.

MORPHOSTRUCTURE OF THE PUYSEGUR RIDGE

The Puysegur Ridge widens and deepens from south to north. It can be divided near lat 48°30′S into a linear, N30°E-trending southern half, with a subsymmetrical cross section, and a more complex, asymmetrical, N15°E-trending northern half. The southern half widens from less than 50 km to more than 75 km wide and is sheared along its summit by a sharply localized fault zone. The northern half is 80 km wide and shows a complex set of northward-diverging faults. We first discuss the data from the ridge apex that are critical to locating the strike-slip fault zone and to understanding the nature of the ridge basement. We then examine the ridge flanks, which show structural features relevant to the development of the subduction zone.

Puysegur Ridge Summit

The summit of the Puysegur Ridge, between 48°40′ and 49°40′S, is bisected by a linear, N26°E-trending axial valley, 800–2500 m deep and 2–4 km wide. The valley is 18–30 km east of the trench and separates a massive, 15–20-km-wide, shallow (125–625 m), flat-topped eastern crest from a less developed, 400–1600-m-deep, 2–6-km-wide western crest. Immediately north of 49°S the valley consists of two parallel, narrow troughs that overlap along the strike of the ridge, isolating an axial crest. Both axial and western crests have narrow (2–6 km), 10–25-km-long, stretched tectonic lenses, suggesting strike-slip deformation along a fault zone within the axial valley (Fig. 2). North of 48°S, this fault zone shifts farther from the trench and splits into a fan-shaped set of locally sinuous faults, ridges, and troughs