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# Sheared continent–ocean margins: an overview

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**Abstract** Continent–ocean fracture zones are the fossil transform offsets located along passive rifted continental margins. Kinematic models identify at least two principal stages in their evolution. During the first stage as rifting proceeds, continent–continent shearing dominates a narrow region in which the transform fault will eventually rupture. High-standing continental marginal ridges 50–100 km wide and bounding deep sedimentary basins, are derived in such settings. In stage two as sea-floor spreading proceeds, the younger oceanic block slides along the active transform, heating the older continental block, and possibly induces thermal uplift and accompanying denudation. Magnetic injection into the continental block at depth may also induce an isostatic uplift. After ridge–transform intersection time, mechanical coupling between the continental and oceanic blocks may influence the stratigraphy and structure of these margins.

## Introduction

This special issue of *Geo-Marine Letters* reflects the marine geological and geophysical community's growing interest in sheared continent–ocean boundaries. The aim of this issue is to present the latest developments in the study of this topic, while also providing a broad overview of certain fracture zone margins for newcomers to the field. Although most of the papers emphasize Atlantic passive sheared margins, one study does focus on an active transpressional Pacific continent–ocean sheared margin.

Continent–ocean fracture zones are the fossil transform offsets located along passive rifted continental margins. These zones are responsible for the kinked appearance of some present-day continental margins. During continental collisional events, margins with sharp offsets created by continent–ocean fracture zones can then confer that kinked appearance to orogenic belts (Thomas 1977). Although the existence of transform faults has been acknowledged for over 30 years (Wilson 1965), few deep seismic soundings have been conducted across such margins (Fig. 1). Only recently, in January and February of 1995, was a marginal fracture ridge along a continent–ocean fracture zone drilled for the first time. The Ocean Drilling Program Leg 159 focused on the Ivory Coast–Ghana margin (Mascle et al. this issue).

In the following papers, the terms fracture zone and transform (fault) are used interchangeably although, strictly speaking, the term transform fault refers only to active boundaries. The cause of this ambiguous usage may reflect the fact that the well-defined topography of oceanic fracture zones can become obscured along continental margins where fracture zones are buried under heavily sedimented continent–ocean boundaries (Le Pichon and Hayes 1971). In purely oceanic settings fracture zones were initially defined to include transform segments (e.g., Heezen 1964). However, other workers have limited the definition of a fracture zone to include only the inactive trace of transform faults (e.g., Detrick et al. 1993). Figure 2 reflects the latter definition. Fracture zones extend beyond the junction of sea-floor spreading centers and transforms, known as the ridge–transform intersection (RTI) (Kastens 1987).

Kinematic models identify at least two principal stages in the evolution of continent–ocean fracture zones developed during continental breakup (Scrutton 1979; Mascle and Blarez 1987). The articles in this issue address the fossil evidence for each of these stages (Fig. 2). During stage one, continent–continent shearing (e.g., Benkhelil et al. and Lamarche et al. this issue) is the dominant process controlling the tectonic development of the long, narrow region in which the transform fault will eventually rupture. Often high-standing continental marginal ridges (50–100 km wide), bounding deep sedimentary basins, are

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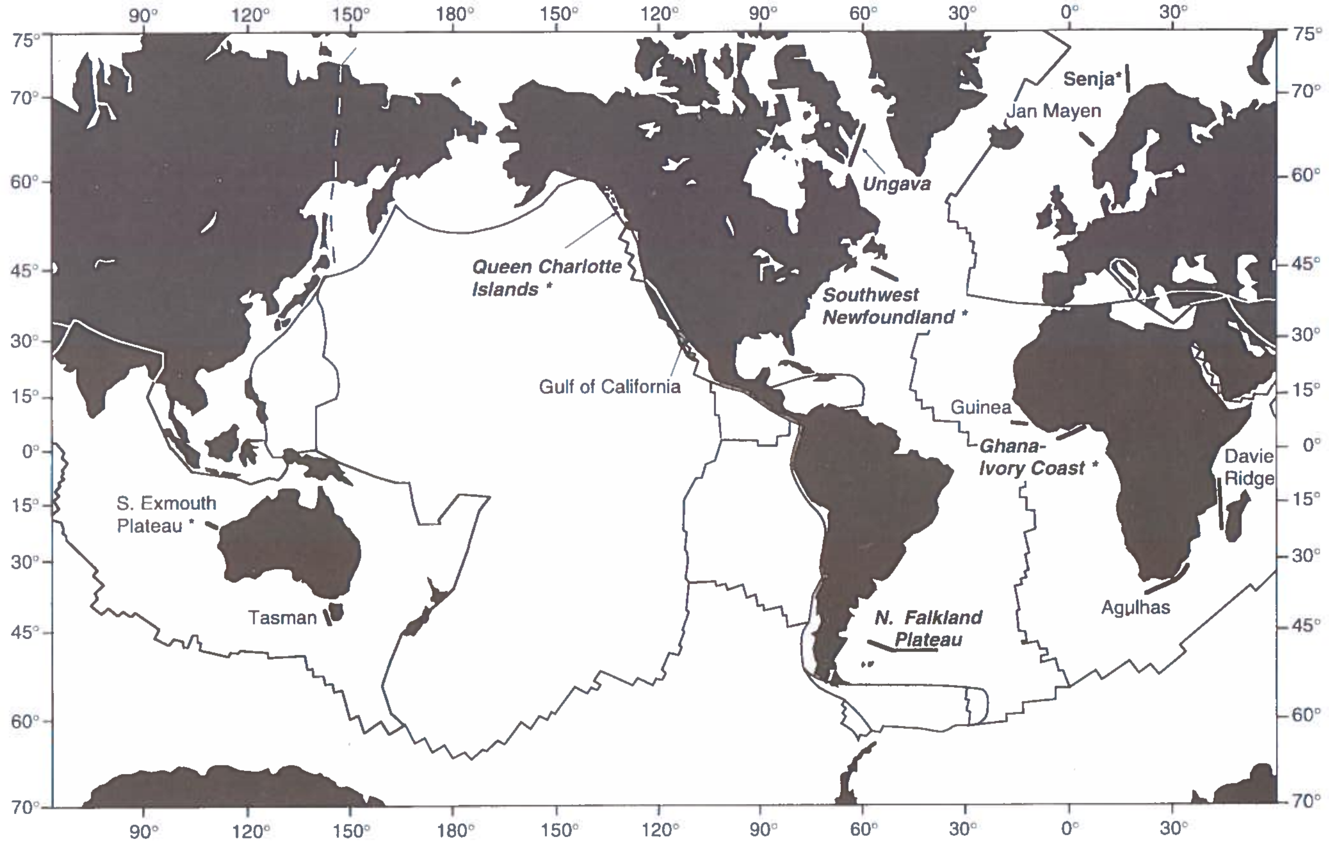

**Fig. 1** Location and names of continent–ocean fracture zones and active sheared continent–ocean margins across which acoustic images have been collected. Asterisks mark positions where seismic reflection and refraction analyses have revealed the nature of both the lower continental and oceanic crust and upper mantle. Names of areas examined in the accompanying papers are in bold. Useful references for the areas not covered by papers in this issue are: (1) Agulhas Fracture (Scrutton et al. 1973; Robson and Dingle 1986), (2) Davies Ridge (Mascle et al. 1987), Guinea (Mascle et al. 1987), Gulf of California (Lonsdale 1985) Jan Mayen (Skogseid and Eldholm 1987), Southern Exmouth Plateau (Lorenzo et al. 1991), Tasman (Exon et al. 1995)

**Fig. 2** Idealized two-stage development of continent–ocean fracture zones across continental margins during rifting (**A**) and drifting (**B1** and **B2**). During early drifting, the young oceanic block slides against the older continental block possibly inducing thermal uplift. After the passing of a ridge when the transform becomes inactive, mechanical coupling across the fracture zone is possible. As a result, the faster subsiding oceanic lithosphere may bow down the surface of the continental block. RTI: ridge–transform intersection, FZ: fracture zone, TF: transform fault. Vertical black arrow implies thermally induced uplift on continental block. See text for explanation

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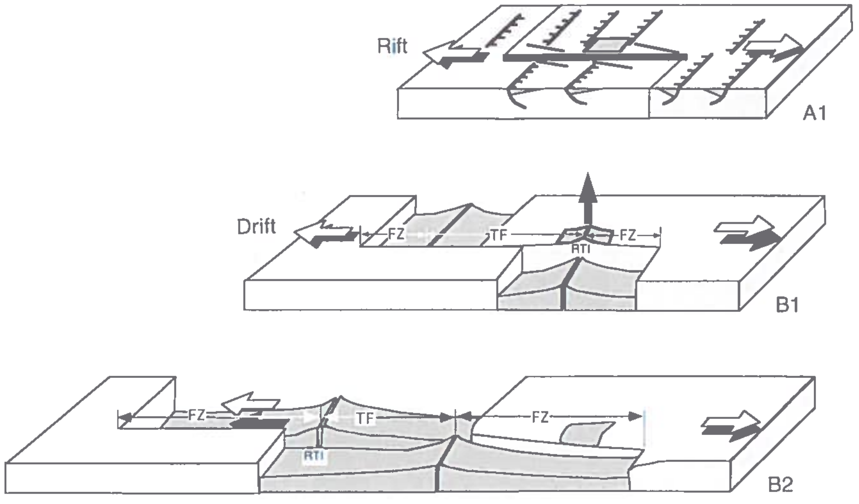

derived in such settings (Scrutton 1979; Guiraud et al. this issue). Analogous high-standing ridges have been previously identified in modern extensional settings at zones of accommodation between large half-graben rift basins systems (e.g., Rosendahl 1987).

In stage two as sea-floor spreading proceeds, the younger oceanic block slides along the active transform, heating the older continental block, and possibly inducing thermal uplift (Bouillin et al. 1997; Mascle et al. 1977) and accompanying denudation (Vågnes this issue). Magmatic injection into the continental block at depth may also result (Lorenzo et al. 1991). Early thermal–rheological models assumed that the oceanic and continental blocks had no mechanical strength and either remained uncoupled mechanically at all times or weakly coupled during only the active transform stage. The potential influence of coupled flexure on the stratigraphy and structure of these margins is addressed for the first time here (Gadd and Scrutton, and Lorenzo and Wessel this issue).

Future research on continent–ocean fracture zones could benefit greatly by considering geological and geophysical models of ocean–ocean fracture zones and actively shearing plate margins. At ocean–ocean fracture zones (Detrick et al. 1993), as at continent–ocean fracture zones (Edwards et al. this issue), oceanic crustal structure is highly variable, possibly as a result of large thermal contrasts across the RTI. Continent–ocean fracture zones would be expected to display even greater thermal gradients and structural variability. The degree of shortening or extension across transform margins during strike-slip faulting may alter crustal structure across continent–ocean fracture zones (Sage et al. this issue). The Queen Charlotte Fracture Zone (Prims et al. this issue), an active strike-slip margin, has experienced significant shortening that has resulted in significant crustal underthrusting. The articles in this issue should provide the groundwork for these future lines of research.

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