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The initiation and evolution of the transpressional Straight River shear zone, central Fiordland, New Zealand

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Abstract

Structural data and U/Pb geochronology on zircon from central Fiordland, New Zealand show the role of pre-existing structural heterogeneities in the kinematic evolution of a newly discovered zone of transpression. The Straight River shear zone consists of steep zones of high strain that are superimposed onto older fabrics across a 10×80 km region. The older foliation formed during two periods of tectonism: contraction and magmatism of mostly Carboniferous ($\sim$312–306 Ma) age and Early Cretaceous batholith emplacement ending by 113.4 ± 1.7 Ma followed by extension that ceased by 88.4 ± 1.2 Ma. The primary mechanism for the formation of steep shear zone foliations was the folding of these older fabrics. Conjugate crenulation cleavages associated with the folding record shortening at high angles to the shear zone boundaries. Fold axial surfaces and axial planar cleavages strike parallel to the shear zone with increasing strain as they progressively steepened to subvertical. In most areas, shear sense flips from oblique-sinistral (east-side-down component) to oblique-dextral (west-side-down) across zones of intermediate and high strain. High strain zones display subvertical mineral lineations, steep strike-slip faults and shear sense indicators that record strike-slip motion across the steep lineations. These patterns reflect triclinic transpression characterized by narrow zones of mostly strike-slip deformation and wide zones of mostly contraction. Zones of high strain align with offshore traces of late Tertiary strike-slip faults, suggesting that a previously undocumented component of late Tertiary shortening and strike-slip motion is accommodated within Fiordland.

Keywords: Transpression; Shear zone; Strain partitioning; U/Pb geochronology

1. Introduction

Transpression refers to deformation that accommodates simultaneous flattening and shearing and is commonly observed at oblique plate margins (Harland, 1971). One of the first three-dimensional kinematic models for transpression was introduced by Sanderson and Marchini (1984), and many subsequent studies have modified this model and its boundary conditions to explore the complex three-dimensional strain patterns that are possible with transpression (e.g. Fossen and Tikoff, 1993; Jones et al., 1997, 2004; Robin and Cruden, 1994; Jiang et al., 2001). These and most other mathematical models generally assume homogeneous deformation within the block being deformed. However, zones of continental deformation typically are characterized by heterogeneous strain patterns, including displacements that are distributed non-uniformly across large areas. Kinematic partitioning, where components of strike-slip and dip-slip motion occur in different places and on separate structures, is especially common in zones of oblique convergence and has been documented in many orogens and continental transforms

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(e.g. Mount and Suppe, 1987; McCaffrey, 1992; Goodwin and Williams, 1996; Butler et al., 1998; Norris and Cooper, 2001; Bhattacharyya and Hudleston, 2001; Claypool et al., 2002; Fuis et al., 2003; Holdsworth et al., 2002; Czeck and Hudleston, 2003; Barnes et al., 2005; Sutherland et al., 2006). Previous work has shown that the controls on kinematic partitioning, and the evolution of obliquely convergent zones in general, can include far-field plate boundary conditions (e.g. Teyssier et al., 1995; Jiang et al., 2001; Tikoff et al., 2002), rheological contrasts in the crust (e.g. Coke et al., 2003; Marcotte et al., 2005), and the presence of mechanical heterogeneities such as old faults and shear zones (e.g. Mount and Suppe, 1987; Vauchez et al., 1998; Tavarnelli et al., 2004). Determining which of these factors exerts the dominant control on zones of oblique convergence, and at which scale, is important for understanding how orogenic belts develop in different settings.

Variations in the style or degree of strike-slip partitioning commonly occur along the strike of major fault zones such as the Alpine fault, which has accommodated at least 460 km of dextral movement since 20–25 Ma (Wellman, 1953; Sutherland, 1999). Oblique-slip on the central section of the Alpine fault (Fig. 1a) provides an example of a system characterized by a low degree of strike-slip partitioning (Norris et al., 1990; Berryman et al., 1992; Teyssier et al., 1995; Little, 1996; Norris and Cooper, 1995, 2001). Along this segment, the Alpine fault strikes to the northeast (55°), dips moderately to the southeast and displays a slip direction that plunges ∼22°. The remaining motion is distributed on thrust and oblique-slip faults in a >100 km-wide zone located mostly east of the Alpine fault. In contrast, the Fiordland (southernmost) segment of the Alpine fault is nearly vertical and accommodates almost pure strike-slip motion (Barnes et al., 2001, 2005). Folds and reverse faults west and east of the Alpine fault accommodate contraction, indicating that this part of the Alpine fault system is strike-slip partitioned (Norris et al., 1990; Markley and Norris, 1999; Claypool et al., 2002; Barnes et al., 2001, 2005). However, the amount of shortening accommodated by these structures has been difficult to quantify (Norris and Cooper, 2001).

In this paper, we examine how lithologic heterogeneity and pre-existing mechanical anisotropies controlled the initiation and evolution of a large transpressional shear zone of apparent late Tertiary age in Fiordland, New Zealand. The Straight River shear zone (Fig. 1), which is located southeast of the southernmost segment of the Alpine fault, was first identified by Oliver and Coggon (1979) as the Straight River [thrust] fault and is interpreted here as a transpressional structure on the basis of new data. This reinterpretation shows the existence of a previously undocumented component of contraction

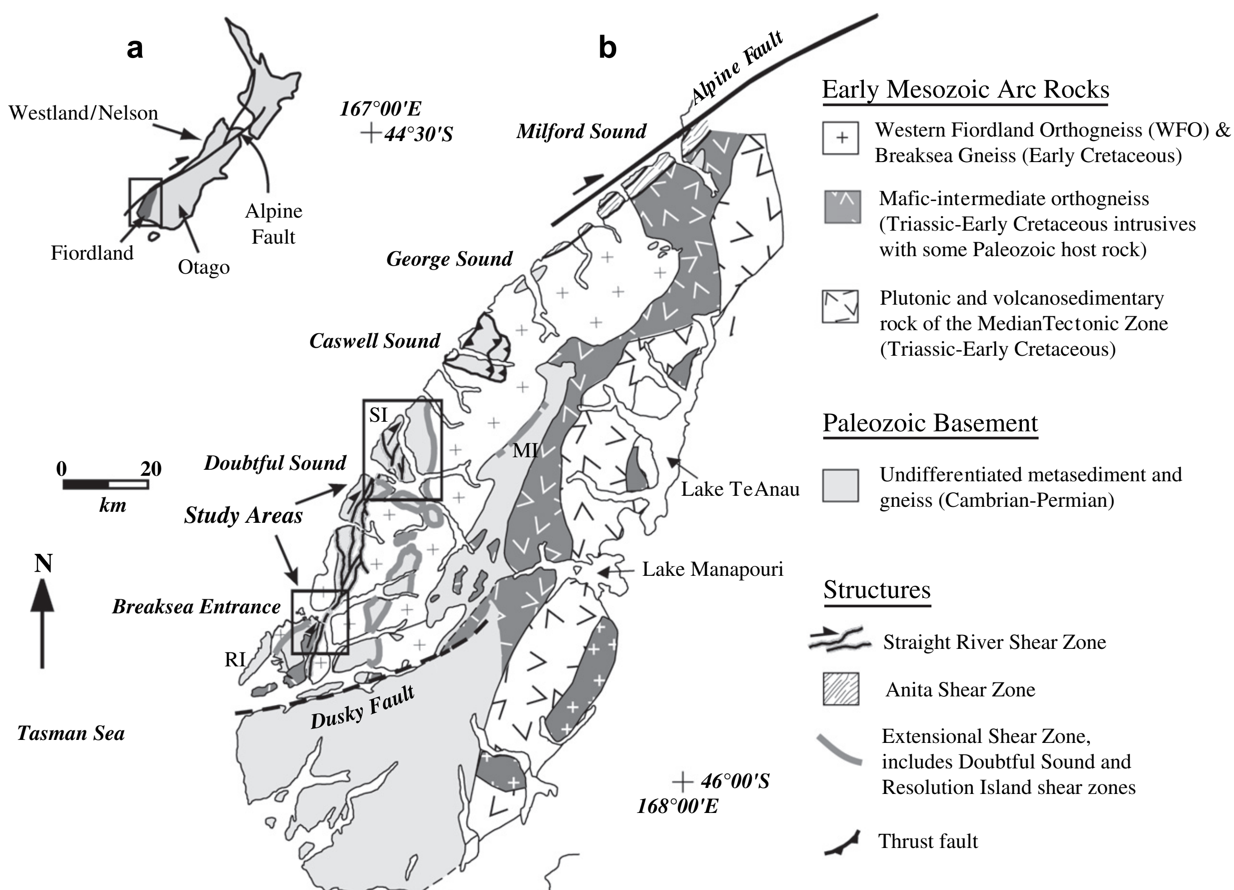

Fig. 1. (a) Sketch map showing location of Fiordland and Westland–Nelson regions. (b) Geological map of Fiordland (after Bradshaw, 1990). SI – Secretary Island; RI – Resolution Island; MI – Mt. Irene.