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A variably enriched mantle wedge and contrasting melt types during arc stages following subduction initiation in Fiji and Tonga, southwest Pacific

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ABSTRACT

The earliest subaerially exposed magmatic products of the Fiji–Tonga–Kermadec (FTK) arc are preserved in the Yavuna Group of Viti Levu, Fiji, and cobbles from 'Eua, Tonga. They are similar in age and magma types to the earliest rocks of the Izu–Bonin–Mariana (IBM) arc. In Fiji they include typical island arc tholeiitic (IAT), boninitic (BON), and MORB-like early arc tholeiitic (EAT) pillow lavas that are interpreted as products of flux- and decompression-melting which occurred simultaneously during subduction initiation. Although the oldest rocks in the southwest Pacific (FTK) and the northwest Pacific (IBM) arcs are generally similar, they differ in two important respects. First, all magma types erupted simultaneously in the SW Pacific whereas a similar assemblage may have erupted sequentially in IBM. Second, the primary mantle wedge was "Pacific" in isotopic character in the SW Pacific, but "Indian" in the NW Pacific.

1. Introduction

Studies of Fijian volcanic rocks have contributed to the understanding of subduction-zone petrology and the evolution of oceanic arc stages, including infancy (Gill, 1970, 1987; Wharton et al., 1995), break-up (Gill and Whelan, 1989b; Gill, 1976a; Hathway, 1993; Rodda et al., 1984), and post-arc (Gill, 1976b, 1984; Gill and Whelan, 1989a). These studies have additional significance because subduction initiation may have happened simultaneously throughout the western Pacific (e.g., Koppers et al., 2004; Whittaker et al., 2007). New high-resolution geochemical and geochronological evidence for the Izu–Bonin–Mariana (IBM) arcs has led to a detailed model of magmatism during and following subduction initiation (Ishizuka et al., 2006; Reagan et al., 2008, 2010). This study focuses on the initial arc volcanism in Fiji and Tonga and compares it to IBM. Similarities and contrasts between the two arcs, formed at the same plate margin at around the same time, provide new insights into the associations of lava types produced during subduction initiation and arc infancy.

2. Regional setting and geological history

The modern Fiji–Tonga–Kermadec (FTK) arc extends for ~2500 km from New Zealand to Tonga due to westward subduction of the Pacific Plate beneath the Australian Plate (Fig. 1). This paper focuses on its initial arc volcanism, with special attention to rocks from southwest Viti Levu that have the most extensive stratigraphic record in the SW Pacific. We assume that Fiji and Tonga were part of the same arc at its inception that this early arc extended from north of Australia to south of Tonga, and that it developed on intra-oceanic crust due to inception of west-dipping subduction of the Pacific Plate. These assumptions are shared by most regional tectonic syntheses (Hall, 2002; Sdrolias et al., 2003; Crawford et al., 2003; Schellart et al., 2006), but there are relatively few constraints. It is clear, however, that no pre-Cenozoic continental crust underlies Fiji (Drewes et al., 2009) and that Eocene arc basement extends to at least 24°S (ODP Site 841), so Fiji and Tonga share the same history prior to opening of the Lau Basin. This initial arc, prior to breaking into western (New Britain to Vanuatu) and eastern (FTK) arms, is called the Vitiaz Arc (Gill and Gorton, 1973). The crust on which it was constructed is sometimes inferred to be the North Loyalty Basin (e.g., Crawford et al., 2003). However, we consider that inference unlikely because mantle from which the Vitiaz Arc was drawn is isotopically 'Pacific' (see below) whereas the one available sample of North Loyalty Basin crust is 'Indian' (Pearce et al., 2007).

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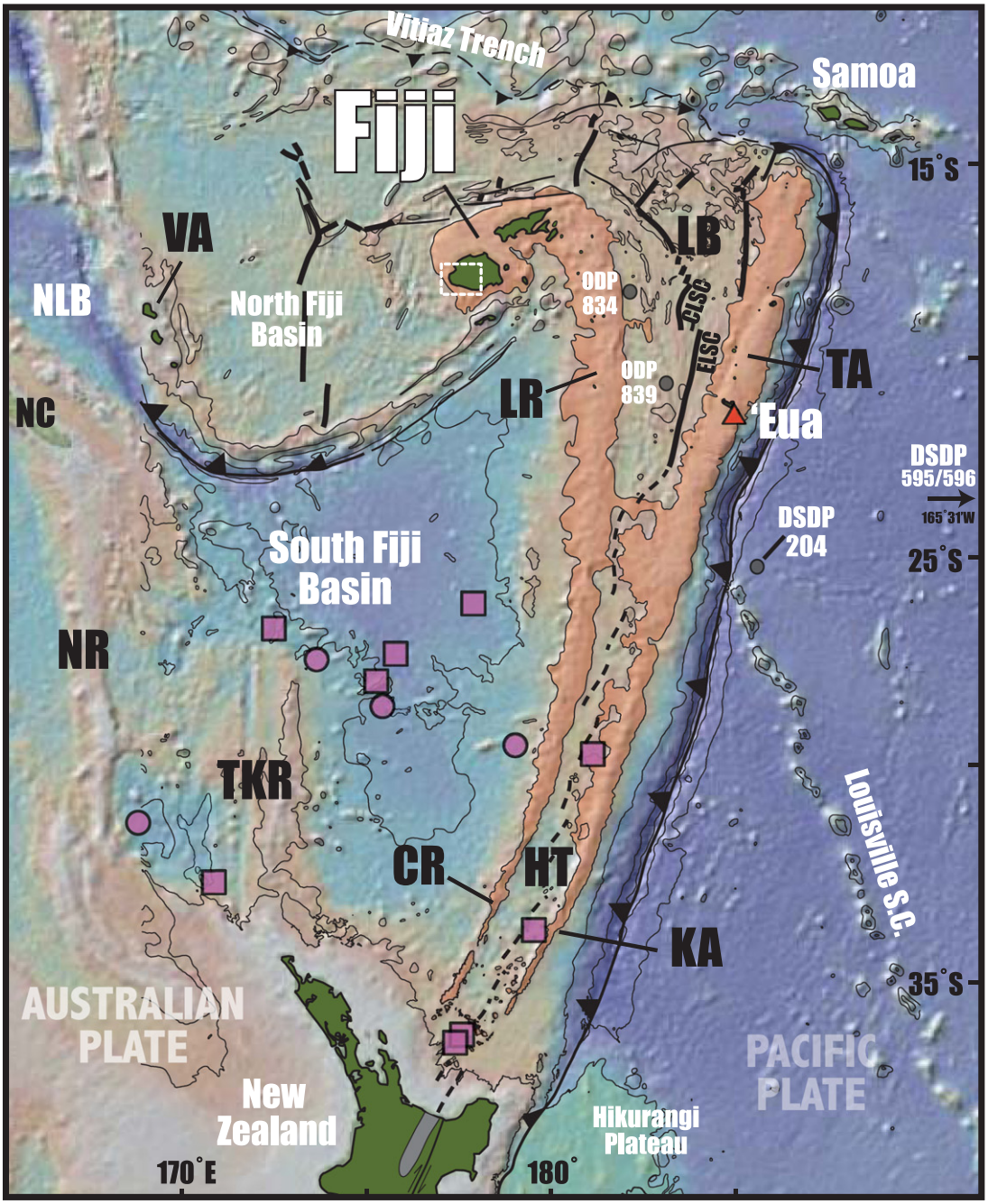

Fig. 1. Regional map showing Fiji, the Kermadec (KA) and Tonga (TA) arcs, the Havre Trough (HT), Lau Basin (LB), and South Fiji Basin backarcs, and the Colville (CR) and Lau (LR) remnant arcs. Also shown are New Caledonia (NC), Vanuatu (VA), Norfolk Ridge (NR), Three Kings Rise (TKR), and North Loyalty Basin (NLB). The location of 'Eua, Tonga is indicated by the red triangle. The locations of samples from Viti Levu, Fiji are shown in greater detail in Fig. 2, within the region indicated by the dashed white box. Locations of South Fiji Basin and Havre Trough backarc samples discussed in this study are shown by pink symbols (squares, BABB-like; circles, OIB-like) (Todd et al., 2011). The solid black lines indicate spreading axes, whereas dashed black indicate backarc rifting. Also shown are the locations of Lau Basin ODP holes 834 and 839 and locations of sediments sampled by drilling at DSDP 204 (black circles). DSDP holes 595/596 are located east of this field of view (~ 165°31′W). Figure was modified from Todd et al. (2010). (For interpretation of the references to color in this figure caption, the reader is referred to the web version of this article.)

Therefore, although the pre-arc plate configuration is unknown, subduction may have initiated along an intra-Pacific fracture zone.

Subduction in both the northwestern and southwestern Pacific has long been thought to have begun around the same time because the oldest volcanic rocks in the IBM and Vitiaz arcs have Middle to Upper Eocene Ar–Ar ages (Ewart et al., 1977; Cosca et al., 1998) and are associated with limestones that have similar Middle to Upper Eocene fauna (e.g., Cole, 1960; Milner, 1992). The east side of 'Eua island, Tonga, has the oldest exposed igneous rocks of the Tonga Ridge (Ewart and Bryan, 1972). They include cobbles of gabbro and volcanic rocks in a basal conglomerate, plus overlying altered lavas and tuffs cut by dikes. The clasts are embedded in a Middle Eocene shallow water limestone (Letter Stage Ta3; Plankton Zone P.14; Tappin and Ballance, 1994) that is overlain by Upper Eocene limestone (Letter Stage Tb) similar to that described below from Fiji and lacking igneous clasts.