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# Geochemistry of deep Manihiki Plateau crust: Implications for compositional diversity of large igneous provinces in the Western Pacific and their genetic link

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ABSTRACT

Geochemical studies revealed two major (high- and low-Ti) magmatic series composing the Manihiki Plateau in the Western Pacific. Here we report new geochemical data (major and trace element and Sr-Nd-Pb isotope compositions) of the Manihiki rocks. The rocks belong to the previously rarely sampled high-Ti Manihiki series and represent a section of deep crust of the plateau. The rocks were collected by remotely operated vehicle ROV Kiel 6000 during R/V SONNE SO225 expedition from a tectonic block at a stretched and faulted boundary between the Northern and Western Manihiki sub-plateaus. Additional data is presented on samples obtained by dredging during the same cruise. Judging from the age of stratigraphically higher lavas, most samples must be ≥125 Ma old. They comprise fully crystalline microdolerites, aphyric and *Ol-Px-Pl*-phyric basalts and breccias metamorphosed under greenschist to amphibolite facies with peak metamorphic temperatures of 636–677 °C and pressures of 2.0–2.7 kbar. A single sample of hornblende gabbro was also recovered and likely represents a late stage intrusion. Despite strong metamorphism, the samples from the ROV profile reveal only minor to moderate chemical alteration and their initial compositions are well preserved. The rocks are relatively primitive with MgO up to 13 wt%, range from enriched to depleted in LREE ($La_N/Sm_N$ = 0.7–1.1), exhibit variable but mostly depleted Nb contents (Nb/Nb* = 0.8–1.3) and display only a narrow range in isotope compositions with strong EM1 characteristics (εNd (t) = 1.8–3.6, $^{206}Pb/^{204}Pb$ (t) = 17.9–18.1, $^{207}Pb/^{204}Pb$ (t) = 15.49–15.53, $^{208}Pb/^{204}Pb$ (t) = 38.08–38.42). The parental magmas are interpreted to originate from a thermochemical plume with a potential mantle temperature > 1460 °C. The trace element and isotope EM1 signature of the high-Ti rocks reflects the presence of recycled lower continental crust material or re-fertilized subcontinental lithospheric mantle in the plume source. A highly refractory mantle was the primary source of the low-Ti basalts and could also contribute to the origin of high-Ti basalts. On average a more depleted mantle source for the Manihiki rocks can explain ~30% lower crustal thickness of this plateau compared to Ontong Java Plateau, which was mainly formed by melting of similarly hot but more fertile mantle. The presently available data suggest that the sources of Ontong Java and Manihiki Plateaus were compositionally different and could represent two large domains of a single plume or two contemporaneous but separate plumes.

## 1. Introduction

The Ontong Java, Manihiki and Hikurangi Plateaus in the Western Pacific, together covering > 1% of the earth's surface, are thought to be emplaced at c. 125 Ma as one single Ontong Java Nui “super” plateau and thus are likely to represent the largest magmatic event in the Phanerozoic (Taylor, 2006; Davy et al., 2008; Hoernle et al., 2010; Timm et al., 2011; Chandler et al., 2012; Hochmuth et al., 2015). The origin of the magmatic event is still controversial. The prevailing hypothesis invokes mantle plume head melting (Mahoney and Spencer, 1991; Larson, 1991a, b, 1997; Hoernle et al., 2010). Impact origin (Rogers, 1982; Ingle and Coffin, 2004) and melting of eclogite under a super-fast spreading ridge (Korenaga, 2005) have also been proposed. The key evidence for the former existence of a single plateau, before it

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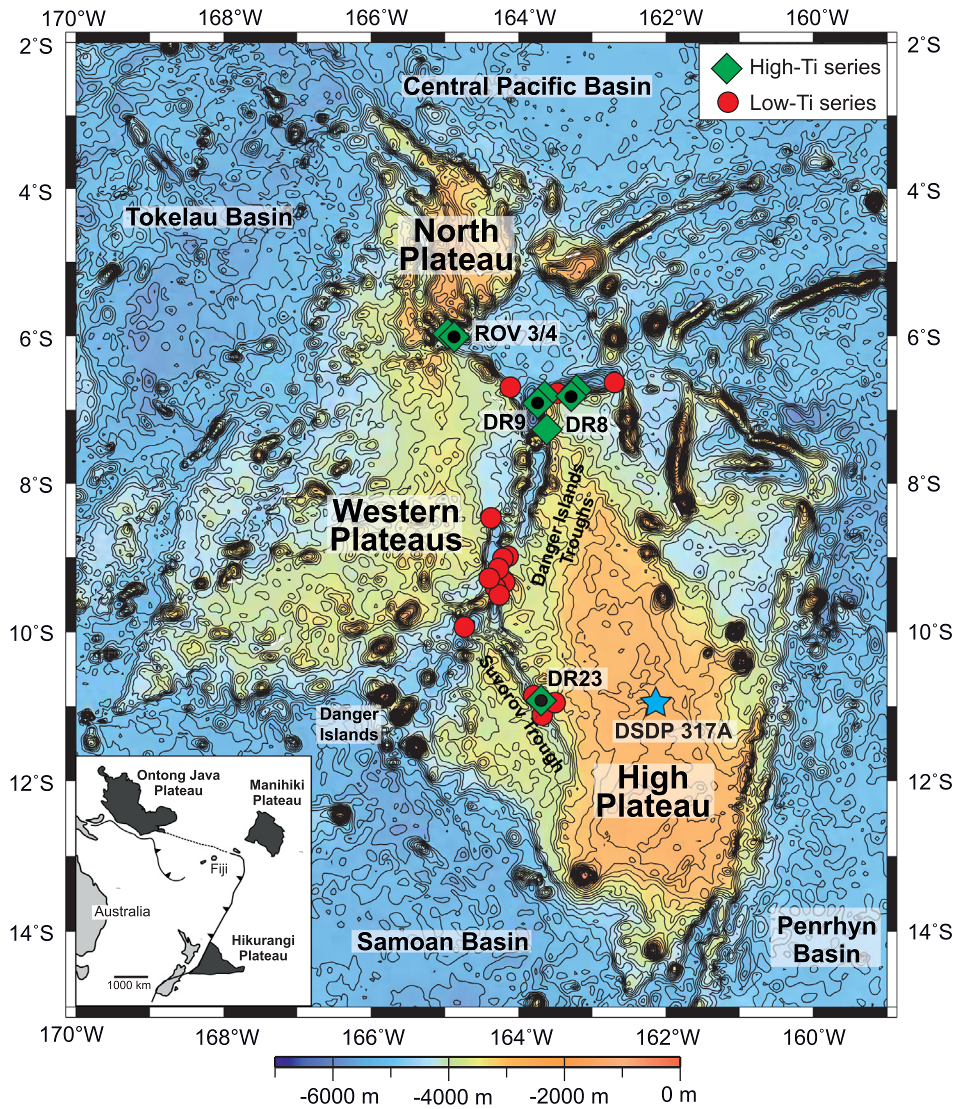


**Fig. 1.** Bathymetric map of the Manihiki Plateau and sample locations.
Green diamonds denote locations at which high-Ti rock series and red circles low-Ti rock series were sampled from the Manihiki plateau basement (Clague et al., 1976; Ingle et al., 2007; Hoernle et al., 2010; Timm et al., 2011; Golowin et al., 2017a, b; this study). Locations of samples from this study are marked with black dot. Predicted global bathymetry is after Smith and Sandwell (1997). Inset map is after Timm et al. (2011). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

was broken apart and dispersed by plate movements, comes from palaeo-tectonic reconstructions (Taylor, 2006; Chandler et al., 2012), geophysical data (Hochmuth et al., 2015), and ages and compositions of volcanic rocks comprising these plateaus (Hoernle et al., 2010; Timm et al., 2011). Whereas the joint origin of the Manihiki and Hikurangi Plateaus and their later separation by the spreading at the Osborn Trough is well justified by the Western Pacific plate kinematics (Billen and Stock, 2000; Davy et al., 2008), the tectonic relationships between the Ontong Java and Manihiki Plateaus are less certain (Larson, 1997; Taylor, 2006; Chandler et al., 2012; Hochmuth et al., 2015).

Although the similarity of rock compositions and their ages is commonly cited to advocate the conjunctive origin of the Ontong Java, Manihiki and Hikurangi plateaus, the existing data indicate significant heterogeneity of the rock compositions within each plateau and likely a significant time interval for their formation. The compositions of the Ontong Java rocks have been studied through deep-sea drilling at 10 sites in the plateau and neighbouring Nauru and East Mariana basins and extensive sampling of subaerially exposed rocks on Malaita and Santa Isabel, Solomon Islands (Mahoney et al., 1993; Tejada et al., 1996, 2004, 2002; Fitton and Godard, 2004). The Ontong Java Plateau rocks have been divided into three groups based on their major and trace element compositions: Kwaimbaita evolved tholeiites, dominant rock group; Kroenke primitive tholeiites with similar Sr-Nd-Pb isotopic composition to Kwaimbaita lavas; and Singgalo enriched tholeiites with enriched incompatible element contents and more enriched Sr-Nd-Pb isotopic compositions than the Kwaimbaita and Kroenke groups (e.g., Mahoney et al., 1993; Tejada et al., 2002, 2004; Fitton and Godard, 2004). A distinctive feature of the Ontong Java rocks is the relatively narrow range of Sr-Nd-Pb isotope compositions of the Kwaimbaita-Kroenke and Singgalo groups. The ages of Ontong Java rocks indicate a major volcanic pulse at ~122 Ma followed by a less volumetric event at ~90 Ma (e.g. Tejada et al., 2002). Scarce data of Hikurangi basement rocks indicate ages scattering from 96 to 118 Ma, broadly between the two magmatic pulses at Ontong Java, but trace element and Sr-Nd-Pb isotopic compositions are very similar to the Kwaimbaita group (Hoernle et al., 2010). Reported ages of Manihiki plateau basement rocks range from 116 to 125 Ma (Ingle et al., 2007; Hoernle et al., 2010; Timm et al., 2011) and thus span the earliest stage of both Ontong Java