A plume origin for the Ontong Java Plateau?

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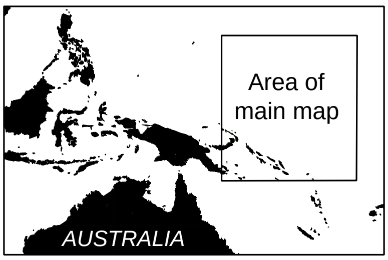
The submarine Ontong Java Plateau (OJP) is the most voluminous of the Earth’s large igneous provinces (Coffin & Eldholm 1994). The plateau, defined mostly by the 4000-m bathymetric contour (Fig. 1), covers an area of 2×10^6 km^3 (comparable in size with Western Europe), but OJP-related volcanism extends over a considerably larger area into the adjacent Nauru and East Mariana basins. Collision with the Solomon arc has resulted in folding and uplift of the southern margin of the OJP in the last 6 m.y., exposing thick (up to ~3.5 km) sections of basaltic rocks on land in the Solomon Islands, notably in Malaita, Santa Isabel, and San Cristobal (e.g. Petterson 1999). OJP basaltic basement rocks have also been sampled at ten Deep Sea Drilling Project (DSDP) and Ocean Drilling Program (ODP) drill sites on and around the plateau (Fig. 1).



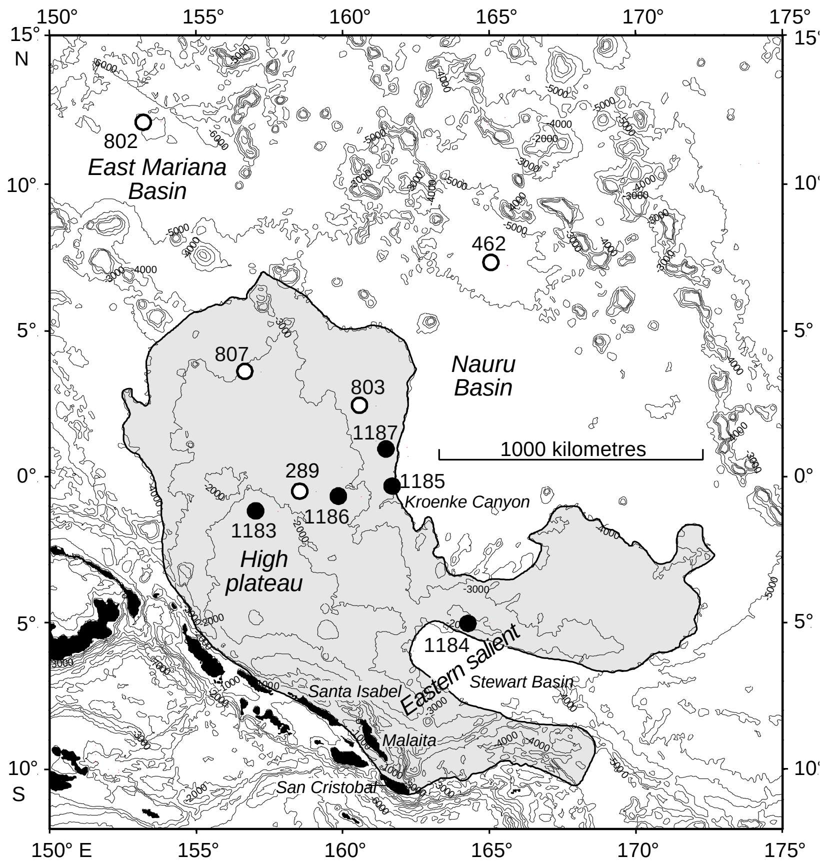


Figure 1.
Predicted bathymetry (after Smith & Sandwell 1997) of the Ontong Java Plateau and surrounding areas showing the location of DSDP and ODP basement drill sites. ODP Leg 192 drill sites are marked by black circles; open circles represent pre-Leg 192 drill sites.

With an average thickness of crust beneath the plateau of 30-35 km (Gladczenko et al. 1997; Richardson et al. 2000), the volume of igneous rock forming the plateau may be as high as 6×10^7 km^3. The OJP seems to have been emplaced rapidly at around 120 Ma (e.g. Mahoney et al., 1993; Tejada et al., 1996, 2002; Chambers et al. 2002; Parkinson et al. 2002) and the peak magma production rate may have exceeded that on the entire global mid-ocean ridge system at the time (e.g. Coffin & Eldholm, 1994).

Despite its size, the OJP's basaltic crust appears to be remarkably homogeneous in composition (Fitton & Godard, in press; Tejada et al., in press). The most abundant rock type is a uniform low-K tholeiite, represented by the Kwaimbaita Formation on Malaita and found at all but one of the DSDP and ODP drill sites on the plateau and in the adjacent basins. Kwaimbaita-type basalt is capped by a thin and impersistent veneer of a slightly more incompatible-element-rich tholeiite (the Singgalo Formation on Malaita, some flows in Santa Isabel, and the upper unit of flows at ODP Site 807). Singgalo-type basalt has lower $^{206}Pb/^{204}Pb$ and $^{143}Nd/^{144}Nd$, and higher $^{87}Sr/^{86}Sr$ than does Kwaimbaita-type basalt.

A third magma type is represented by high-Mg (Kroenke-type) basalt found in thick (>100 m) successions of lava flows at two drill sites (ODP Sites 1185 and 1187) 146 km apart on the eastern flank of the plateau (Fig. 1). The high-Mg basalt is isotopically indistinguishable from Kwaimbaita-type basalt and may therefore represent the parental magma for the bulk of the OJP. Low-pressure fractional crystallisation of olivine followed by olivine+augite+plagioclase can explain the compositional range from high-Mg Kroenke-type to Kwaimbaita-type basalt. The Singgalo-type basalt probably represents slightly smaller-degree, late-stage melting of an isotopically distinct component in the mantle source.

Identification of a parental magma type allows the primary-magma composition to be estimated by incremental addition of equilibrium olivine until the residual mantle olivine composition is reached. Taking residual olivine compositions ranging from Fo_{90} to Fo_{92} gives primary magma with MgO ranging from 15.6 to 20.4 wt.%, respectively. Incompatible-element contents in the calculated primary magma, coupled with radiogenic isotope ratios, are consistent with a mantle source consisting of primitive mantle depleted through the extraction of 1% by mass of average continental crust (Fitton & Godard, in press; Tejada et al., in press). The degree of melting required to produce the primary magma from this source ranges from 27% (in equilibrium with Fo_{90}) to 31% (Fo_{92}). Independent estimates of residual olivine composition and degree of melting can be obtained from the major-element composition of primitive basalt through the combined forward- and inverse-modelling method of Herzberg & O'Hara (2002). Applying this method to Kroenke-type basalt and a fertile mantle source gives 25% melt with residual $Fo_{90.4}$ for perfect fractional melting, and 30% melting with $Fo_{91.6}$ for equilibrium melting. The remarkable agreement in the results of trace- and major-element modelling provides compelling evidence that the OJP had a fertile peridotite mantle source.

Peridotite mantle with a potential temperature >1500ºC will melt to a *maximum* of around 30% if decompressed to shallow levels (i.e. at or close to a spreading centre). To achieve an *average* of 30% melting requires that the mantle is actively and rapidly fed into the melt zone, and a start-up mantle plume provides the most obvious mechanism. This should have caused uplift well above sea level, but the abundance of essentially non-vesicular pillow lava and the absence of any basalt showing signs of subaerial weathering show that the OJP was emplaced below sea level (e.g. Neal et al., 1997; Mahoney et al., 2001). Volatile concentrations in quenched pillow-rim glasses suggest eruption depths ranging from 1100 m at Site 1183 to 2570 m at Site 1187 (Roberge et al., in press).

We have not yet been able to resolve the paradox of apparent high mantle potential temperature coupled with submarine emplacement. An eclogitic source does not provide a solution because the high-Mg parental magma would require almost total melting, and consequently a very high potential temperature would be needed to provide the latent heat of fusion. We can also rule out a hydrous mantle source because the magmas have very low H_2O contents (Michael, 1999; Roberge et al., 2002, in press). Widespread melting of the mantle following the impact of an asteroid provides an attractive means of avoiding uplift, but the magma would be generated entirely within the upper mantle and would have the chemical and isotopic characteristics of NMORB. OJP basalt is isotopically (Tejada et al., in press) and chemically (Fitton & Godard, in press) distinct from NMORB and seems to have a lower mantle source.

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