Appendix material online:

Three models of radioactive "in-growth" melting processes have been proposed: 1) reactive porous flow (RPF) (Spiegelman and Elliott, 1993;); 2) dynamic melting (DM) (McKenzie, 1985;); and 3) flux melting (Thomas et al., 2002). In the Spiegelman and Elliott (1993) model, melt moves through and continuously equilibrates with the solid as it ascends. In the dynamic melting model, different residence times are created by different extraction rates of elements into melt channels; once in channels, melt no longer interacts with solid. These two models were developed for decompression melting but are applicable to any melting whereby melt moves relative to residual peridotite. The flux melting model is similar to dynamic melting except that a hydrous fluid (containing U and Th) is added to the mantle wedge during the melting process (Thomas et al., 2002).

Melting rate can be defined as the mass of melt produced per unit time per volume of peridotite entering the melting zone. Thus, $\Gamma = M / tV$ where Γ is the melting rate, M is the mass of melt produced, t is the duration of melting, and V is the volume of mantle that becomes partially molten. If $M=F\rho_s V$, where F is the degree of melting and ρ_s is the density of mantle peridotite and $t= d/v_s$, where v_s is subduction rate and d is the amount of convergence in units of length, then the relationship between subduction rate and melting rate can be described as $\Gamma = F\rho_s v_s / d$ (equation. 1).

In all in-growth melting models, the source mineralogy is kept constant with 53% olivine, 27% orthopyroxene, 17% clinopyroxene, and 3% spinel. This leads to bulk partition coefficients for U, Th, Pa, and Ra of 0.0052, 0.0044, 2.1×10^{-6}, and 8.9×10^{-7}, respectively, based on the partition coefficients given in Blundy and Wood (2003). However, because of the high oxygen fugacity in the overriding mantle wedge (Parkinson and Arculus, 1999), we also assess the use of a ${}^{solid/melt}D_U$ of 0.0026 (half that of Blundy and Wood's value). The melting rates used in three models are calculated from equation (1). The equilibrium porous flow model uses equation (1) in (Spiegelman and Elliott, 1993). The dynamic melting model uses equation (A1)-(A4) given in Bourdon and Sims (2003). For simplicity, the porosity is fixed as 0.002; this could underestimate the 231Pa excess produced in equilibrium porous flow and dynamic melting models. The flux melting model is that given in Thomas et al. (2002) using a spreadsheet generously provided by Marc Hirschmann with a slight difference in the degree of melting in this study (15%). The (^{231}Pa)/(^{235}U) and (^{230}Th)/(^{238}U) assumed for the fluid is 0.75. The parameters used for this model are summarized in online appendix Table DR2.

Appendix Table DR1. U-series data of the Kick'em Jenny submarine volcano

Samples	SiO_2 (wt.%)	U (ppm)	(^{234}U)/(^{238}U)	Th (ppm)	U/Th	Pa (fg/g)	(^{231}Pa)/(^{235}U)
RB07	55.53	0.98	0.995	2.52	0.390	833	2.61
RB07*						834	2.61
RB07*						863	2.70
RB47	52.28	4.88	0.993	10.78	0.452	2975	1.88
RB47*						2975	1.88
RB51b	51.17	1.81	0.989	3.86	0.469	1343	2.28
RB64	52.31	2.18	0.998	5.12	0.427	1679	2.36
RB65	53.11	2.01	0.987	5.30	0.379	1724	2.64
RB79	47.57	0.54	0.996	1.25	0.427	271	1.56
RB82	47.20	0.93	0.998	1.83	0.508	704	2.33
KEJ100	51.74	1.57	0.998	3.14	0.501	1123	2.21
KEJ101	48.56	1.01	1.005	2.00	0.507	755	2.29
KEJ103	53.85	3.15	0.998	6.74	0.467	2106	2.06
KEJ899	52.35	1.69	0.989	3.37	0.502	1266	2.30
KEJ1976	-	1.17	0.992	2.36	0.497	878	2.29
BCR-2	-	1.70	-	-	-	551±17	1.00±0.03
KEJ100-G+W**	57	1.84	1.00	3.09	0.595	1292	2.15

*, Duplicate analysis. **, SiO_2 and U-Th data of KEJ100-G+W are from Gill and Williams (1990) and Pa data are from Pickett and Murrell (1997). U-Th-Pa data were analyzed by MC-ICP-MS. The ^{233}Pa spike was milked from ^{237}Np following procedures described in Regelous et al. (2004). The ^{233}Pa spike was calibrated by five analyses of rock standard BCR-2 and six more BCR-2 were measured as unknown. (^{231}Pa)/(^{235}U) of BCR-2 is calculated based on U content of 1.70 ppm. Error of Pa content and (^{231}Pa)/(^{235}U) of BCR-2 are one standard deviation from six analyses of BCR-2. Duplicate analyses of standards and KEJ samples indicate reproducibility of +/- 2.5% on ^{231}Pa.

Appendix Table DR2. Parameters in melting models.

Name	Value	units
melting rate (Γ)	-	$kg/m^3/y$
melting degree (F)	0.15	-
density of mantle peridotite (ρ_s)	3340	kg/m^3
density of melt (ρ_l)	2800	kg/m^3
Subduction rate (v_s)	-	cm/y
Amount of convergence (d)	90	km
Porosity	0.002	-

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