Geochemistry Geophysics Geosystems

Supporting Information for

Assessing origins of end-Triassic tholeiites from Eastern North America using hafnium isotopes

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Table S4 (Mantle Wedge Calculator model)
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Introduction

The Supporting Information for this manuscript includes supporting figures showing trace element and isotope compositions for samples from this study. It also includes three supporting tables with modeling parameters for all of the calculations and models described in the main text. An additional supporting table, Table S4, is the metasomatized mantle evolution model calculator from this study, provided as a user-enabled spreadsheet.

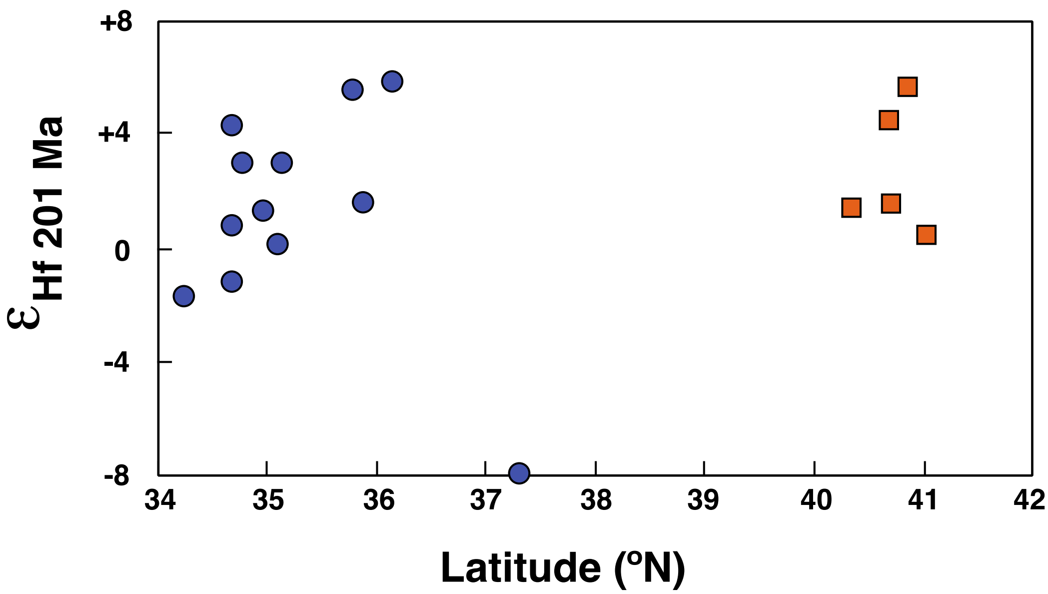

Figure S1. Age-corrected ε_{Hf} vs. latitude for ENA tholeiites from this study, including samples from the southern ENA region and the northern Newark basin. All symbols as in Figure 2.

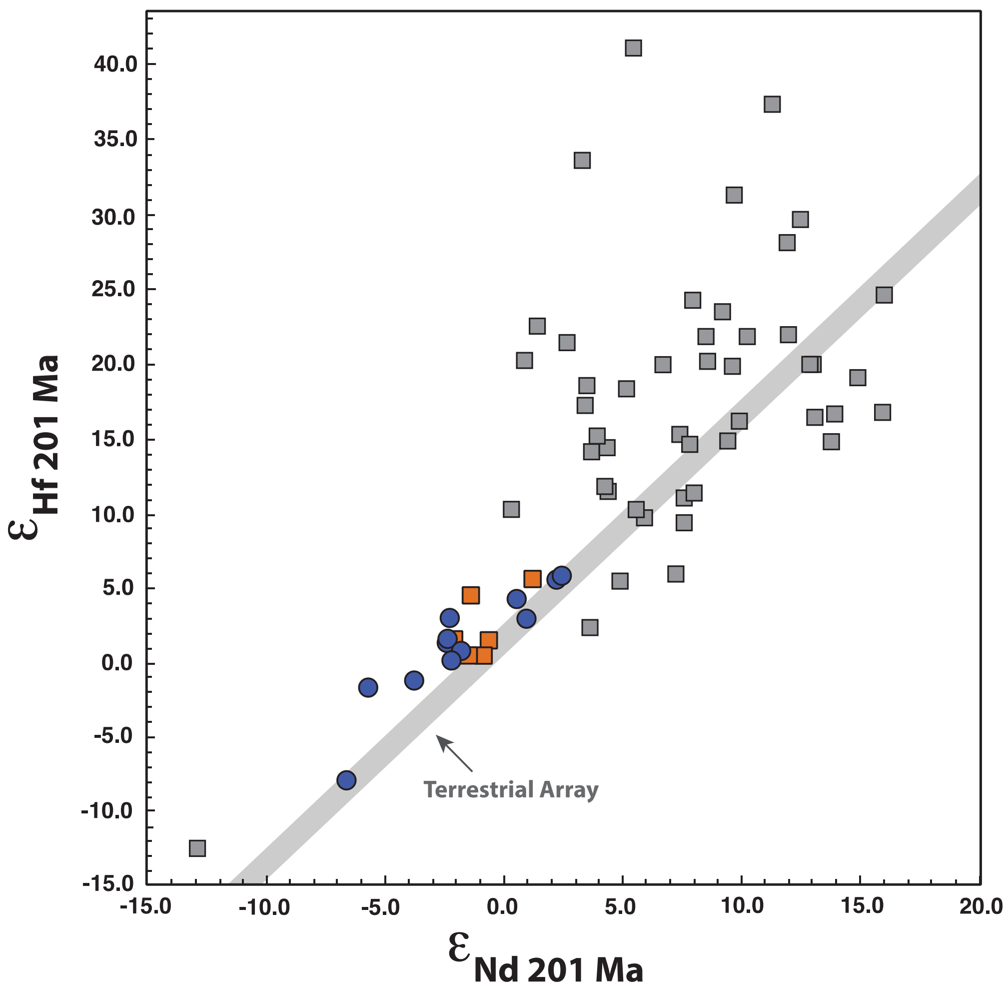

Figure S2. ε_{Hf} vs. ε_{Nd} showing samples from this study (symbols as in Figure 2) with globally representative SCLM-derived xenolith samples from Jordan, China, Morocco, and France (Choi et al., 2008; Shaw et al., 2007; Wittig et al., 2010) (gray squares).

	Lu (ppm)	Hf (ppm)	Sm (ppm)	Nd (ppm)	U (ppm)	Pb (ppm)	ϵ_{Hf}	$\epsilon_{Hf,201\ Ma}$ [a]	ϵ_{Nd}	$\epsilon_{Nd,201\ Ma}$ [b]	$^{206}Pb/^{204}Pb$	$^{206}Pb/^{204}Pb_{201\ Ma}$ [c]	$^{207}Pb/^{204}Pb$	$^{207}Pb/^{204}Pb_{201\ Ma}$ [d]	References
DMM solid source	0.63	0.20	0.27	0.71	0.005	0.023	+18.2	+16.7	+9.4	+8.5	-	-	-	-	Salters & Stracke, 2004; Klein et al., 2004
DMM partial melt (MORB)	-	2.9	-	6.1	-	0.2	+18.2	+16.7	+9.4	+8.5	-	-	-	-	
DMM alternate composition							+16.8	+14.3	+9.8	+8.4	18.28	17.93	15.49	15.47	Workman & Hart, 2005
EM1 solid source	0.1	0.4	0.54	1.67	0.04	0.23	-5.8	-5.7	-5.8	-5.8	17.77	17.34	15.49	15.47	Eisele et al., 2002; Jackson & Dasgupta, 2008; Willbold & Stracke, 2006; Woodhead & Devey, 1993
EM1 partial melt	-	9.3	-	60.0	-	5.5	-5.8	-5.7	-5.8	-5.8	17.77	17.34	15.49	15.47	
EM2 solid source	0.1	0.4	0.53	1.55	0.02	0.1	-5.9	-6.1	-6.6	-6.9	19.56	19.17	15.66	15.64	Jackson & Dasgupta, 2008; Jackson et al., 2007; Salters et al., 2011; Willbold & Stracke, 2006; Workman et al., 2004
EM2 partial melt	-	5.6	-	42.3	-	6.6	-5.9	-6.1	-6.6	-6.9	19.56	19.17	15.66	15.64	
Upper continental crust:															
Carolina terrane	-	2.0	-	65.0	-	25.9	-	-8.6 [e]	-	-6.3	-	17.4	-	15.6	Whalen et al., 2015, and references therein
Lower continental crust:															
Michigan mafic granulite	0.27	1.2	2.1	9.0	0.12	3.3	-0.2	+0.14	-13.0	-11.4	17.74	17.67	15.71	15.70	Zartman et al., 2013
Markt mafic granulite	-	-	-	-	0.5	2.5	-	-	-	-	16.9	16.5	15.4	15.3	Huang et al., 1995
Intermediate granulite	0.79	20.0	33.4	131.0	-	-	-21.5	-17.0	-13.0	-7.1	-	-	-	-	Schmitz et al., 2004
Average subducted sediment [f] (GLOSS)	0.41	4.06	5.80	27.0	1.68	19.9	+2.0	-0.07	-8.8	-9.67	18.91	19.1	15.67	15.68	Plank and Langmuir, 1998; Chauvel et al., 2008

[a] $^{176}Hf/^{177}Hf$ isotope ratios corrected to an age of 201 Ma using a ^{176}Lu decay constant of $1.867 \times 10^{-11}\ a^{-1}$ (Söderland et al., 2004). ϵ_{Hf} values were determined using an age-corrected CHUR value of $^{176}Hf/^{177}Hf = 0.282659$, calculated using present-day CHUR values of $^{176}Hf/^{177}Hf = 0.282785$ and $^{176}Lu/^{177}Hf = 0.0336$ (Bouvier et al., 2008).

[b] $^{143}Nd/^{144}Nd$ isotope ratios corrected to an age of 201 Ma using a ^{147}Sm decay constant of $6.539 \times 10^{-12}\ a^{-1}$ (Begemann et al., 2001). ϵ_{Nd} values were determined using an age-corrected CHUR value of $^{143}Nd/^{144}Nd = 0.512374$, calculated using present-day values of $^{143}Nd/^{144}Nd = 0.51263$ and $^{147}Sm/^{144}Nd = 0.196$ (Bouvier et al., 2008).

[c] $^{206}Pb/^{204}Pb$ isotope ratios corrected to 201 Ma using a ^{238}U decay constant of $1.551 \times 10^{-10}\ a^{-1}$ (Jaffey et al., 1971).

[d] $^{207}Pb/^{204}Pb$ isotope ratios corrected to 201 Ma using a ^{235}U decay constant of $9.8485 \times 10^{-10}\ a^{-1}$ (Jaffey et al., 1971).

[e] ϵ_{Hf} for Carolina terrane upper crust was calculated using the age-corrected ϵ_{Nd} value shown and the average terrestrial array best fit relationship after Vervoort et al. (2011).

[f] Subducted sediment isotope values determined using average subducted sediment compositions (GLOSS) with a calculated age of 170 Ma, chosen to represent subducted Paleozoic sediments in the CAMP melt region (i.e., sediments subducted around 370 Ma and later sampled by CAMP melting at 201 Ma), after Merle et al. (2011).

Table S1. Composition of source reservoirs and partial melts used for mixing and EC-AFC calculations.

Parameter [a]	Magma	Mafic LCC	Intermediate LCC	UCC	Units
$T_{liquidus}$	1380	1100	1000	1000	ºC
$T_{initial}$	1380	600	600	300	ºC
$T_{solidus}$	-	950	850	700	ºC
$T_{equilibrium}$	1100	1100	1100	1100	ºC
C_p	1484	1388	1380	1370	J/kg K
$H_{crystallization}$	396,000	-	-	-	J/kg
H_{fusion}	-	350,000	300,000	270,000	J/kg
D_{Hf} [b,c,d]	0.05	0.14	1.23	0.05	
D_{Nd}	0.04	0.14	0.17	0.09	
D_{Pb}	0.002	0.14	0.14	0.2	

[a] Liquidus and solidus temperatures, specific heat (C_p) values, and enthalpies estimated using values after Callegaro et al. (2017), Heinonen et al. (2016), and Bohrson and Spera (2001).

[b] Magmatic partition coefficients were determined using mineral/melt partition coefficients by McKenzie and O'Nions (1991) and fertile spinel peridotite modes of 60% olivine, 20% clinopyroxene, and 20% orthopyroxene.

[c] Mafic lower crust assimilant partition coefficients were determined using lower crustal granulite mineral modes after Zartman et al. (2013) and mineral/melt partition coefficients estimated from ranges compiled in the GERM Earthref catalog. Intermediate lower crust assimilant partition coefficients were determined for a granulite with 14% quartz, 42% garnet, 34% plagioclase, 3% clinopyroxene, 0.1% apatite, 0.1% zircon, and 1% rutile. This composition is comparable to intermediate granulite xenoliths measured by Schmitz et al. (2004) and Zartman et al. (2013). In the absence of accessory minerals, D_{Hf} = 0.12, D_{Nd} = 0.10, and D_{Pb} = 0.13.

[d] Upper crust assimilant partition coefficients were determined using average upper crust compositions after Taylor and Maclennan (1995) and Wedepohl (1995), which were used to calculate a stable upper crustal assemblage of 21% clinopyroxene, 38% quartz, 4% muscovite, 9% orthoclase, and 28% plagoclase; and mineral/melt partition coefficients estimated from ranges compiled in the GERM Earthref catalog.

Table S2. Model parameters used for EC-AFC calculations, after Bohrson and Spera (2001) and Spera and Bohrson (2001).

Table S3. Model parameters used for calculating the composition of residual metasomatized mantle (see Table S4).

	U	Th	Pb	Rb	Sr	Sm	Nd	Lu	Hf	References
DMM	0.005	0.01	0.02	0.09	9.8	0.3	0.7	0.06	0.2	Salters & Stracke, 2004
GLOSS	1.7	6.9	19.9	57.2	327	5.8	27	0.4	4.1	Plank & Langmuir, 1998
Altered Ocean Crust (AOC)	0.3	0.01	0.7	13	180	2.6	6.7	0.4	1.9	Staudigel et al., 1996
Partition coefficients, D_i:										
Bulk peridotite/melt [a]	0.0065	0.0044	0.0012	0.0012	0.0071	0.041	0.020	0.61	0.065	McKenzie & O'Nions, 1991; Salters et al., 2002
Bulk sediment/melt [b]	1.0	1.2	1.0	1.1	0.6	2.9	3.0	5.5	2.4	Johnson & Plank, 2000
Bulk sediment/fluid [c]	3.1	4.5	0.8	1.7	0.7	2.0	2.4	2.5	2.1	Johnson & Plank, 2000
AOC Mobility coefficients [d]	0.3	0.4	0.9	0.6	0.4	0.1	0.31	0.01	0.01	Kogiso et al., 1997

	$^{206}Pb/^{204}Pb$	$^{207}Pb/^{204}Pb$	$^{207}Pb/^{204}Pb$	$^{87}Sr/^{86}Sr$	$^{143}Nd/^{144}Nd$	$^{176}Hf/^{177}Hf$	References
DMM	18.4	15.5	37.8	0.70254	0.51315	0.28317	Salters & Stracke, 2004
GLOSS	18.9	15.7	38.9	0.7173	0.51218	0.2824	Plank & Langmuir, 1998
Altered Ocean Crust (AOC) [e]	18.4	15.5	37.8	0.70458	0.51308	0.28320	Salters & Stracke, 2004; Staudigel et al., 1996

[a] Peridotite/melt partition coefficients were calculated using a fertile garnet peridotite composition with 59% olivine, 8% clinopyroxene, 21% orthopyroxene, and 12% garnet. Mineral/melt partition coefficients were drawn from experiments RD1097-1 and RD1097-5 of Salters et al. (2002) and calculated values of McKenzie and O'Nions (1991).

[b] Sediment/melt partition coefficients are averaged from experiments PC 36 and PC 39 of Johnson and Plank (2000).

[c] Sediment/fluid partition coefficients are averaged from experiments PC 38 and PC 47 of Johnson and Plank (2000).

[d] Mobility coefficients for AOC are shown as percent mobilities, after Kogiso et al (1997).

[e] Trace element concentrations for AOC are derived from Atlantic drilling site 417/418 (Staudigel et al., 1996).

Table S4. Metasomatized mantle evolution calculator (download as .xlsx file).