## SAMPLE SELECTION AND PREPARATION, AND ANALYTICAL METHODS

For the lherzolites, all analyses were performed at the Pheasant Memorial Laboratory, Okayama University at Misasa following Nakamura et al. (2003). We selected 11 spinel lherzolites (out of 54 spinel peridotite samples in our collection, including spinel harzburgites) using the following criteria: (1) no texturally equilibrated amphibole was present; (2) clinopyroxene displayed a systematic depletion in light REE; and (3) REE heterogeneity within clinopyroxene grains was slight, on the basis of *in situ* analyses with an ion-microprobe using the techniques described in Nakamura and Kushiro (1998). Homogeneous clinopyroxene from a spinel lherzolite xenolith from Kilbourne Hole Crater in New Mexico (KLB-1) was used as a standard material.

Concentration and isotopic measurements were performed on clinopyroxene separates (~20 mg) handpicked from the crushed lherzolite xenoliths. Prior to dissolution, the separates were sequentially acid-leached with 6 N HCl (overnight), 0.5 N HNO3 (~1 hr.) and 0.5 N HF (~15 min.) to remove contamination and alteration. REE concentrations, except for Sm and Nd, were determined by solution ICP-MS (inductively coupled plasma – mass spectrometry) using an external-standard technique (Makishima and Nakamura, 1997), whereas Sr and Nd isotopic ratios and Sr, Rb, Nd, and Sm abundances were determined on the remaining aliquot of the same solution by thermal ionization mass spectrometry and isotope dilution, following Nakamura et al. (2003). Concentrations of the REE in the lherzolite clinopyroxene separates are similar to averaged values of *in situ* analyses (Table DR1), indicating that (a) leaching to remove contamination did not significantly affect the REE, and (b) the grains were well-homogenized with respect to the REE.

For the gabbro, all analyses were performed at the University of Hawaii. Handpicked clinopyroxene and plagioclase separates were leached twice in an ultrasonic bath with hot 6 N HCl (1 hr. for the clinopyroxene and 15 min. for the plagioclase) and once in 0.2 N HF + HNO3 (10 min.), following which the clinopyroxene was subjected to an additional HCl step. Also, a split of the coarsely powdered bulk rock was subjected to multi-step acid leaching similar to that described by Mahoney (1987). As with the lherzolite clinopyroxenes, isotopic and parent-daughter ratios were determined by thermal ionization mass spectrometry and isotope dilution.

Table DR1. Rare-earth element abundances of clinopyroxenes (ppm)

| Sample | SAS4 | SAS6 | SAS32 | SAS34 | SAS68 | SAS35 | SAS42 | SAS61 | SAS43 | SAS52 | SAS41 | JB-2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| mineral separates (ICP-MS, ID-TIMS) | | | | | | | | | | | | |
| La | 0.897 | 0.571 | 0.626 | 1.13 | 0.286 | 0.303 | 0.209 | 0.140 | 0.169 | 0.137 | 0.097 | 2.19 |
| Ce | 2.82 | 1.86 | 1.48 | 2.42 | 1.19 | 0.927 | 0.442 | 0.400 | 0.415 | 0.355 | 0.246 | 6.43 |
| Pr | 0.552 | 0.415 | 0.387 | 0.468 | 0.328 | 0.272 | 0.137 | 0.121 | 0.150 | 0.145 | 0.116 | 1.13 |
| Nd* | 3.736 | 3.056 | 3.023 | 3.129 | 2.595 | 2.083 | 1.530 | 1.364 | 1.543 | 1.479 | 1.345 | 6.39 |
| Sm* | 1.710 | 1.563 | 1.529 | 1.591 | 1.427 | 1.260 | 1.105 | 1.019 | 1.124 | 1.107 | 0.966 | 2.27 |
| Eu | 0.725 | 0.669 | 0.656 | 0.648 | 0.635 | 0.562 | 0.487 | 0.438 | 0.514 | 0.547 | 0.394 | 0.86 |
| Gd | 2.61 | 2.33 | 2.37 | 2.51 | 2.43 | 2.45 | 2.00 | 1.85 | 2.05 | 2.16 | 1.75 | 3.12 |
| Tb | 0.513 | 0.465 | 0.469 | 0.545 | 0.498 | 0.458 | 0.414 | 0.394 | 0.431 | 0.461 | 0.377 | 0.592 |
| Dy | 3.62 | 3.37 | 3.42 | 3.88 | 3.62 | 3.42 | 3.06 | 2.89 | 3.18 | 3.44 | 2.84 | 4.13 |
| Ho | 0.783 | 0.746 | 0.754 | 0.841 | 0.771 | 0.794 | 0.702 | 0.669 | 0.716 | 0.754 | 0.661 | 0.898 |
| Er | 2.07 | 1.99 | 2.11 | 2.29 | 2.15 | 2.11 | 1.95 | 1.85 | 1.98 | 2.10 | 1.84 | 2.47 |
| Tm | 0.319 | 0.317 | 0.314 | 0.374 | 0.340 | 0.324 | 0.299 | 0.288 | 0.315 | 0.347 | 0.302 | 0.392 |
| Yb | 2.02 | 2.10 | 2.01 | 2.35 | 2.20 | 2.25 | 1.92 | 1.83 | 2.00 | 2.14 | 1.88 | 2.60 |
| Lu | 0.285 | 0.297 | 0.299 | 0.340 | 0.308 | 0.313 | 0.288 | 0.274 | 0.291 | 0.310 | 0.289 | 0.397 |
| In situ analyses (SIMS) | | | | | | | | | | | | |
| spots | 14 | 11 | 14 | 7 | 7 | 7 | 6 | 5 | 6 | 9 | 5 | KLB-1 |
| La | 0.652 | 0.356 | 0.301 | 0.369 | 0.214 | 0.372 | 0.082 | 0.037 | 0.078 | 0.072 | 0.071 | 0.229 |
| Ce | 2.02 | 1.08 | 0.927 | 0.894 | 0.954 | 0.991 | 0.157 | 0.163 | 0.201 | 0.181 | 0.172 | 1.76 |
| Pr | 0.457 | 0.331 | 0.314 | 0.237 | 0.269 | 0.258 | 0.119 | 0.112 | 0.110 | 0.117 | 0.116 | 0.487 |
| Nd | 3.24 | 2.54 | 2.61 | 2.10 | 2.76 | 2.05 | 1.13 | 1.31 | 1.42 | 1.41 | 1.35 | 3.59 |
| Sm | 1.47 | 1.44 | 1.29 | 1.21 | 1.53 | 1.33 | 1.09 | 1.16 | 1.23 | 1.11 | 0.970 | 1.72 |
| Eu | 0.651 | 0.691 | 0.570 | 0.566 | 0.612 | 0.632 | 0.501 | 0.576 | 0.601 | 0.535 | 0.499 | 0.707 |
| Gd | 2.45 | 2.41 | 2.09 | 2.28 | 2.37 | 2.27 | 1.96 | 1.89 | 2.23 | 2.08 | 1.78 | 2.59 |
| Dy | 3.31 | 3.46 | 2.92 | 3.30 | 3.02 | 3.57 | 3.23 | 3.43 | 3.26 | 3.60 | 3.11 | 3.67 |
| Er | 2.01 | 2.41 | 1.81 | 2.15 | 1.92 | 2.34 | 2.20 | 2.40 | 2.21 | 2.43 | 2.29 | 2.23 |
| Yb | 1.73 | 2.12 | 1.65 | 1.96 | 1.88 | 2.18 | 1.89 | 2.25 | 2.15 | 2.07 | 2.14 | 2.12 |
| EPMA analyses (from Ishikawa et al. 2004) | | | | | | | | | | | | |
| $Na_2O$ (wt% | 1.79 | 1.70 | 1.70 | 1.46 | 1.69 | 1.47 | 1.41 | 1.32 | 1.35 | 1.37 | 1.59 | |
| $TiO_2$ (wt%) | 0.50 | 0.49 | 0.45 | 0.48 | 0.46 | 0.47 | 0.39 | 0.46 | 0.41 | 0.38 | 0.30 | |

*Nd and Sm compositions were determined by ID-TIMS, other elements were determined with solution ICP-MS using an external standard (JB-2). Analytical errors for the ICP-MS analyses are typically <5%. Data for in situ analyses with an ion microprobe are represented as average values of multiple spot analyses. Homogeneous clinopyroxene in a spinel lherzolite xenolith (KLB-1) was used as standard. The accuracy of the data is typically <15%.

Table DR2. Nd, Sr and Pb isotopic ratios and isotope-dilution abundances (ppm)

| Rock type | Peridotite | Peridotite | Peridotite | Peridotite | Peridotite | Peridotite | Peridotite | Peridotite | Peridotite | Peridotite | Peridotite | Gabbro | Gabbro | Gabbro |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Phase | Cpx | Cpx | Cpx | Cpx | Cpx | Cpx | Cpx | Cpx | Cpx | Cpx | Cpx | Pl | Cpx | W.R. |
| Sample | SAS4 | SAS6 | SAS32 | SAS34 | SAS68 | SAS35 | SAS42 | SAS61 | SAS43 | SAS52 | SAS41 | 5843 | 5843 | 5843 |
| Sm | 1.71 | 1.563 | 1.529 | 1.591 | 1.427 | 1.260 | 1.105 | 1.019 | 1.124 | 1.107 | 0.966 | 0.1300 | 2.192 | 1.691 |
| Nd | 3.736 | 3.056 | 3.023 | 3.129 | 2.595 | 2.083 | 1.530 | 1.364 | 1.543 | 1.479 | 1.345 | 0.6050 | 4.250 | 3.833 |
| $^{147}Sm/^{144}Nd$ | 0.2768 | 0.3092 | 0.3058 | 0.3073 | 0.3325 | 0.3659 | 0.4369 | 0.4517 | 0.4402 | 0.4527 | 0.4342 | 0.1299 | 0.3119 | 0.2667 |
| $^{143}Nd/^{144}Nd$ | 0.513125(5) | 0.513154(5) | 0.513129(6) | 0.513150(8) | 0.513208(8) | 0.513219(5) | 0.513285(7) | 0.513326(7) | 0.513276(4) | 0.513298(5) | 0.513728(4) | 0.512997(8) | 0.513187(6) | 0.513149(8) |
| $\varepsilon Nd_{(0Ma)}$ | 9.5 | 10.0 | 9.5 | 10.0 | 11.1 | 11.3 | 12.6 | 13.4 | 12.4 | 12.8 | 21.2 | 7.0 | 10.7 | 9.9 |
| $^{143}Nd/^{144}Nd_{(34Ma)}$ | 0.513064 | 0.513085 | 0.513061 | 0.513082 | 0.513134 | 0.513137 | 0.513188 | 0.513225 | 0.513178 | 0.513197 | 0.513631 | 0.512968 | 0.513118 | 0.513090 |
| $\varepsilon Nd_{(34Ma)}$ | 9.1 | 9.5 | 9.1 | 9.5 | 10.5 | 10.6 | 11.5 | 12.3 | 11.4 | 11.7 | 20.2 | 7.3 | 10.2 | 9.6 |
| $^{143}Nd/^{144}Nd_{(160Ma)}$ | 0.512835 | 0.512830 | 0.512808 | 0.512828 | 0.512860 | 0.512835 | 0.512827 | 0.512853 | 0.512815 | 0.512824 | 0.513273 | 0.512861 | 0.512861 | 0.512870 |
| $\varepsilon Nd_{(160Ma)}$ | 7.8 | 7.7 | 7.3 | 7.7 | 8.3 | 7.8 | 7.7 | 8.2 | 7.4 | 7.6 | 16.4 | 8.3 | 8.3 | 8.5 |
| Rb | 0.002 | 0.005 | 0.001 | 0.007 | 0.003 | 0.000 | 0.004 | 0.002 | 0.001 | 0.002 | 0.000 | 2.29 | 0.577 | - |
| Sr | 35.82 | 21.11 | 23.10 | 26.22 | 20.05 | 14.35 | 5.217 | 4.684 | 4.587 | 4.181 | 7.020 | 305.2 | 29.33 | - |
| $^{87}Rb/^{86}Sr$ | 0.0002 | 0.0007 | 0.0001 | 0.0008 | 0.0004 | 0.0001 | 0.0021 | 0.0013 | 0.0008 | 0.0015 | 0.0001 | 0.0217 | 0.0569 | - |
| $^{87}Sr/^{86}Sr$ | 0.702618(7) | 0.702802(9) | 0.702877(8) | 0.702665(8) | 0.702368(9) | 0.702489(12) | 0.703106(8) | 0.702888(8) | 0.702934(8) | 0.702830(9) | 0.702497(10) | 0.702940(14) | 0.703260(14) | - |
| $^{87}Sr/^{86}Sr_{(34Ma)}$ | 0.702618 | 0.702802 | 0.702877 | 0.702664 | 0.702368 | 0.702489 | 0.703105 | 0.702888 | 0.702933 | 0.702829 | 0.702497 | 0.702930 | 0.703233 | - |
| $^{87}Sr/^{86}Sr_{(160Ma)}$ | 0.702618 | 0.702800 | 0.702877 | 0.702663 | 0.702367 | 0.702489 | 0.703102 | 0.702885 | 0.702932 | 0.702827 | 0.702497 | 0.702891 | 0.703131 | - |
| Th | - | - | - | - | - | - | - | - | - | - | - | - | 0.0153 | - |
| U | - | - | - | - | - | - | - | - | - | - | - | - | 0.0094 | - |
| Pb | - | - | - | - | - | - | - | - | - | - | - | - | 0.0270 | - |
| $^{238}U/^{204}Pb$ | - | - | - | - | - | - | - | - | - | - | - | - | 25.5 | - |
| $^{232}Th/^{204}Pb$ | - | - | - | - | - | - | - | - | - | - | - | - | 41.5 | - |
| $^{206}Pb/^{204}Pb$ | - | - | - | - | - | - | - | - | - | - | - | - | 18.798 | - |
| $^{207}Pb/^{204}Pb$ | - | - | - | - | - | - | - | - | - | - | - | - | 15.531 | - |
| $^{208}Pb/^{204}Pb$ | - | - | - | - | - | - | - | - | - | - | - | - | 38.139 | - |
| $^{206}Pb/^{204}Pb_{(160Ma)}$ | - | - | - | - | - | - | - | - | - | - | - | - | 18.16 | - |
| $^{207}Pb/^{204}Pb_{(160Ma)}$ | - | - | - | - | - | - | - | - | - | - | - | - | 15.50 | - |
| $^{208}Pb/^{204}Pb_{(160Ma)}$ | - | - | - | - | - | - | - | - | - | - | - | - | 37.81 | - |

Cpx, clinopyroxene; Pl, plagioclase; W.R., leached whole rock. Values in parentheses are internal precisions for isotope data (2 σ mean; refer to least significant digits). External uncertainty on measured $^{143}Nd/^{144}Nd$ is ± 0.000020 for Cpx from peridotite and ± 0.000011 for sample 5843. Uncertainty on $^{147}Sm/^{144}Nd$ is 0.42% for Cpx from peridotite and 0.2% for sample 5843. The $\varepsilon_{Nd}$ values are calculated assuming that $\varepsilon_{Nd}$ = 0 today corresponds to $^{143}Nd/^{144}Nd$ = 0.51264, and bulk-earth $^{147}Sm/^{144}Nd$ = 0.1967. Numbers on $^{143}Nd/^{144}Nd$ and $^{87}Sr/^{86}Sr$ are relative to 0.511850 for La Jolla Nd and 0.71024 for NBS987 Sr, respectively. External uncertainty on measured $^{87}Sr/^{86}Sr$ is ± 0.000020 for Cpx from peridotite and ± 0.000018 for sample 5843. Pb isotopes ( $^{206}Pb/^{204}Pb$, $^{207}Pb/^{204}Pb$, and $^{208}Pb/^{204}Pb$) were measured with an ion-counting Daly detector; values are relative to those of Todt et al. (1996) for NBS981 Pb; external uncertainties on measured values are ± 0.028, 0.025, 0.08 on $^{206}Pb/^{204}Pb$, $^{207}Pb/^{204}Pb$, and $^{208}Pb/^{204}Pb$, respectively.

Table DR3. Nd isotope and parent-daughter ratios for calculated whole rocks

| | SAS4 | SAS6 | SAS32 | SAS34 | SAS68 | SAS35 | SAS42 | SAS61 | SAS43 | SAS52 |
|---|---|---|---|---|---|---|---|---|---|---|
| $^{147}Sm/^{144}Nd$ | 0.2823 | 0.3154 | 0.3119 | 0.3135 | 0.3392 | 0.3733 | 0.4456 | 0.4607 | 0.4490 | 0.4617 |
| error | 0.008 | 0.009 | 0.009 | 0.009 | 0.009 | 0.010 | 0.012 | 0.013 | 0.013 | 0.013 |
| $^{143}Nd/^{144}Nd$ | 0.513126 | 0.513155 | 0.513130 | 0.513152 | 0.513210 | 0.513220 | 0.513287 | 0.513328 | 0.513278 | 0.513300 |
| error | 0.000020 | 0.000020 | 0.000020 | 0.000020 | 0.000020 | 0.000020 | 0.000020 | 0.000020 | 0.000020 | 0.000020 |

Whole rock $^{147}Sm/^{144}Nd$ and $^{143}Nd/^{144}Nd$ ratios were estimated by mass-balance, assuming that (1) the individual xenoliths were chemically and isotopically equilibrated at the time of host eruption (34 Ma); (2) Sm and Nd concentrations in olivine and spinel are negligible; (3) the orthopyroxene/clinopyroxene ratio for all samples is fixed as 3.4 (average of the spinel lherzolite xenoliths studied here) with 50% errors; (4) the orthopyroxene/clinopyroxene partition coefficients for Sm and Nd are 0.012 and 0.006 with 50% errors. It should be emphasized that the partitioning data were selected from the study of a representative spinel lherzolite xenolith from Kilbourne Hole Crater in New Mexico (KLB-1) rather than the experimental values in melt-bearing systems, which are approximately one order of magnitude higher than the selected values (e.g. Salters et al., 2002).

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