Supporting Information for

"Quantifying Asthenospheric and Lithospheric Controls on Mafic Magmatism and Uplift Across North Africa"

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1. Database

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Analytical Procedures

The database published as part of this paper was collected and analyzed over a ten year period by the authors. It is a compilation of three individual suites of XRF, ICP-MS and Sr-Nd-Pb-He isotopic analyses. Samples that were analyzed using different protocols and procedures are identified by names of authors who carried out the analyses (i.e. Ball, Nixon, Masoud).

0.1 Ball

0.1.1 XRF Analysis

Powdered samples were analyzed by XRF on an analytical PW2404 wavelength-dispersive sequential X-ray spectrometer at the School of GeoSciences, University of Edinburgh, following the analytical technique outlined by *Fitton et al.* [1998].

0.1.2 ICP-MS Analysis

Powdered samples were analyzed for trace element concentrations on a PerkinElmer SCIEX Elan DRC II quadrupole ICP-MS machine at the Department of Earth Sciences, University of Cambridge (with the exception of Tibesti samples which were analyzed on a PerkinElmer Nexion 350D ICP-MS machine). Procedures are similar to those described by *Eggins et al.* [1997], who used matrix-matched calibration of international rock standards. A control containing 10 ppb Re, Rh and In in a 1% HNO_3 solution was analyzed between each run of 10 samples as a drift monitor. Under the conditions used, instrumental drift was $< 5\%$ measured for the internal standard intensity during the entire analytical run (40 or more solutions per batch). Solutions were analyzed using a Micromist nebulizer (FM05, Glass Expansion, Australia) and a quartz cyclonic baffled spray chamber with platinum sampler and skimmer cones. ICP-MS sensitivity for this configuration was 5×10^4 cps/ppb In with CeO/Ce ratio of 2%. Appropriate corrections were made using oxide/metal correction factors calculated by analyzing pure single-element standard solutions. Internationally recognised United States Geologic Survey (USGS) rock standards: BIR-1, BHVO-2, BCR-1, AGV-2 and BOB-1 were analyzed using identical procedures. Results were compared to values from GEOREM database (version 9, 2009; `http://georem.mpch-mainz.gwdg.de`). Concentrations were calculated on a spreadsheet where raw intensities were blank subtracted, internal standard normalized, and Rare

Earth oxide corrected. Calibration method was a simple linear calibration curve fitted to calculated slopes and intercept was set at zero. All results (i.e., standards, unknowns) were accurately corrected for dilution by mass.

Each sample was prepared by digesting 0.1 g of finely ground rock powder in 4 ml HF and 1 ml HNO_3 in a sealed perfluoralkoxy vial. Acids used were ppb grade, which were further distilled in-house using Teflon or quartz stills. An Evapoclean (Analab, France) system consisting of a temperature-controlled Teflon-covered graphite block was used for digestions and evaporations within a closed, clean perfluoralkoxy environment, thus avoiding the need for sample preparation to be carried out in a clean laboratory. Additional blank samples were prepared alongside actual samples and standards. Total procedural blanks returned low concentrations for all elements that were negligible when compared to sample intensities. External reproducibility compared to USGS samples is low (i.e. $< 5\%$) for all elements.

0.2 Nixon

0.2.1 XRF and ICP-MS Analysis

Techniques used for XRF and ICP-MS analysis were identical as those used and described by Ball. The ICP-MS analysis was conducted on a PerkinElmer SCIEX Elan DRC II quadrupole ICP-MS machine at Department of Earth Sciences, University of Cambridge. Results from analyzing BHVO-2 for XRF and BHVO-2 and BOB-1 for ICP-MS yielded results for all elements that were within 5% of published values from *Jochum and Nohl* [2008].

0.2.2 Sr-Nd-Pb Isotopic Analysis

0.2 ± 0.01 g of powdered or chipped samples and reference materials were prepared for analysis where exact weight of sample used was determined by ICP-MS analysis to contain ~ 2 ppm of Pb. Samples were leached for 1 hour at $150°C$ in ~ 0.8 ml of HNO_3. Cooled samples were rinsed five times and left to dry overnight at $50°C$ and then reweighed to establish any sample loss during leaching process. Weight loss ranged from 0.0174–0.0554 g leaving sample weights for dissolution ranging from 0.1413–0.1954 g. Finally, samples were digested and evaporated in a mixture of HF and HNO_3 to produce samples for column chemistry in order to establish Sr-Nd-Pb isotopic values.

Chemical separation of Sr, Nd and Pb was performed using routine action-exchange column techniques. Nd and Pb isotopic compositions were determined using a Nu Plasma HR multi-collector mass spectrometer (MC-ICPMS) at the University of Cambridge, fitted with an Edwards high-capacity rotary pump for the expansion chamber and Nu DSN100 desolvating nebulizer. Nd samples were normalized to $^{146}Nd/^{144}Nd = 0.7219$ and each sample was bracketed by analysis of Jndi-1 100 ppb Nd isotopic standard [*Tanaka et al.*, 2000]. Bracketing standards had an average external reproducibility of ± 0.000015 for $^{143}Nd/^{144}Nd$. The value recorded for BCR-2 was within error of the value reported by *Jochum and Nohl* [2008]. Pb samples were bracketed with runs of the standard NIST 981 with a Pb concentration ranging from $40 - 66$ ppb Pb and $20 - 33$ ppb Tl. A correction was made to the standard runs using published value of NIST 981 taken from *Galer and Abouchami* [1998]. Total procedural planks were negligible at < 44 pg. The USGS standard BCR-2 values were found to be within error of published values. $^{87}Sr/^{86}Sr$ values were obtained using a VG Sector 54 multi-collector thermal ionisation mass spectrometer (TIMS) at the Department of Earth Sciences, University of Cambridge. Sr isotopes were analysed in dynamic mode with on-line corrections for interferences, mass fractionation and error calculations built into the VG software. International standard NBS 987 was used to monitor precision and accuracy [0.712048; *Jochum and Nohl*, 2008]. Repeat analyses gave a mean of $^{87}Sr/^{86}Sr$ 0.710267 ± 0.000011 (2σ, $n = 7$). Blank samples gave Sr values of < 1 ng, which is negligible compared with the typical amount present within each sample.

0.2.3 He Isotopic Analysis

Olivine crystals were separated by hand from crushed samples and cleaned in 40% HNO_3 to remove adhered volcanic glass and glass-free olivines were identified and picked for analysis. He ratios and concentrations were determined using the MAP 215-50 mass spectrometer at the Scottish Universities Environmental Research Council (SUERC). Gas clean-up and mass spectrometric techniques are described by *Williams et al.* [2005]. ^{3}He and ^{4}He blanks analyzed did not exceed 1% of crush released gas content with the exception of samples 22.5A (11%), 2.2 (38%), 2.10U (6%) and 1.2 (2%), which yielded low concentrations of He. Analytical uncertainties reported are propagated from uncertainties in the ^{3}He and ^{4}He concentrations and standard calibration measurements.

0.3 Masoud

0.3.1 XRF and ICP-MS Analysis

XRF analyses were performed using the same equipment and procedures as those used and described by Ball and Nixon. Powdered samples and reference materials were analyzed for trace element concentrations by ICP-MS at SUERC. Approximately 100 mg of powdered rock samples and reference materials were weighed into 15 ml flat bottom Teflon (PFA) screw cap vials for dissolution. 5 ml of HF and 2 ml of HNO_3 were added and closed vials were left on a hotplate at 160°C for 12 hours. After subsequent evaporation to dryness, 5 ml of HNO_3 were added, once again leaving capped vials for 12 hours on a hotplate at 160°C, before dry-down. The third step consisted of adding 5 ml of HCl, closing the vial, and gently swirling it. evaporation to dryness was carried out immediately and repeated once. Samples were picked up in 2.5 ml of (16 mol) HNO_3, transferred to volumetric flasks, and diluted to 100 ml with de-ionised H_2O. They were decanted into polythene bottles for storage [*Olive et al.*, 2001]. ICP-MS procedures followed the techniques outlined by *Olive et al.* [2001].

Caption for Database

Inventory of major, trace element and isotopic analyses for Libyan and Chadian samples. Each sheet of attached spreadsheet represents each of three suites of analyses.

Caption for input file of INVMEL **routine**

Input file that was used to generate inverse modeling result for Haruj-P2 volcanic field using INVMEL routine