Bulk Rock Isotopic Analysis of Lamprophyre Dikes and Mantle Xenoliths from Westerly, Rhode Island

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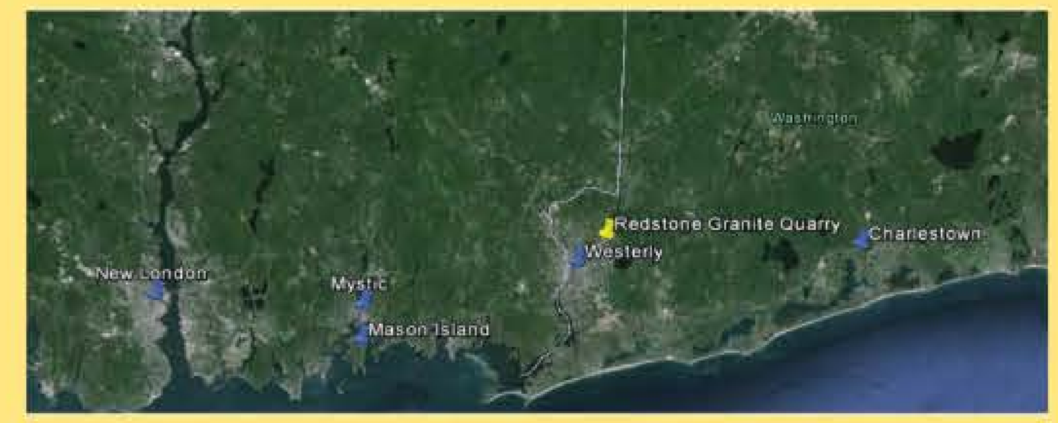
Abstract

The goal of this study is to understand the state of the sub-continental lithospheric mantle and its dynamics during late-stage rifting of Pangea. Jurassic aged (175 Ma) lamprophyre dikes hosted in the Westerly and Naragansett Pier Granites were sampled from the Cherenzia quarry in Westerly, Rhode Island. Lamprophyres are alkali-rich (K, Na), volatile-rich (H_2O, CO_2) silica-poor ultramafic igneous rocks derived from direct melting of the Earth's mantle. During the violent ascent of these magma, chunks of the surrounding and overlying mantle (up to 4 cm in diameter) were incorporated in the mix when they were then emplaced in the Earth's crust. These pristine chunks of the mantle or "mantle xenoliths" are of upmost importance to understanding the chemical composition and nature of the Earth's mantle, and in this case the state of the mantle during late-stage rifting of the last supercontinent – Pangea. Bulk rock Sr, Nd, Pb and Hf isotopic ratios were measured via Multi-collector Inductively Coupled Mass Spectrometry (MC-ICPMS) on the host lamprophyres and the lherzolite mantle xenoliths to understand the metasomatic history and mantle source of these rocks. In addition, bulk rock geochemistry was measured via X-Ray Fluorescence (XRF) of both the lamprophyres and two of the different types of xenoliths to further constrain the geochemical signatures of this region of the mantle during rifting. Combining both the geochemical and isotopic analyses provide valuable information of the mantle and allow a greater understanding about the deep-seated tectonic activity during the end of rifting of Pangea.

Methodology

- Ultramafic lamprophyres were sampled from the Cherenzia quarry in Westerly, Rhode Island. Isotopic ratios were measured at Brown University (courtesy of Soumen Mallick) using a Multi-collector Inductively Coupled Mass Spectrometry (MC-ICPMS). Bulk rock geochemistry were measured by Acme Labs using X-Ray Fluorescence (XRF).



Data

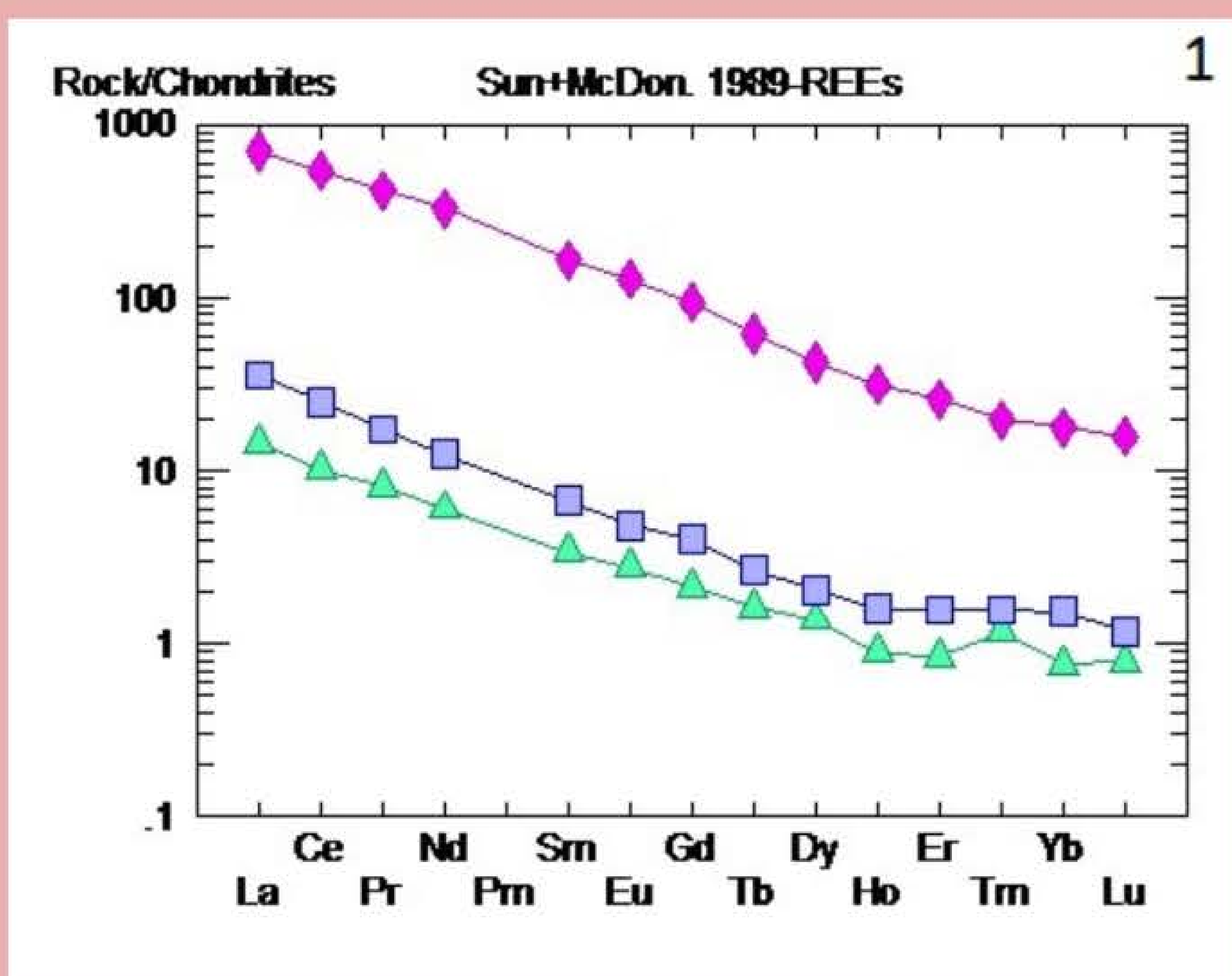


Figure 1: Rare Earth Element Geochemistry

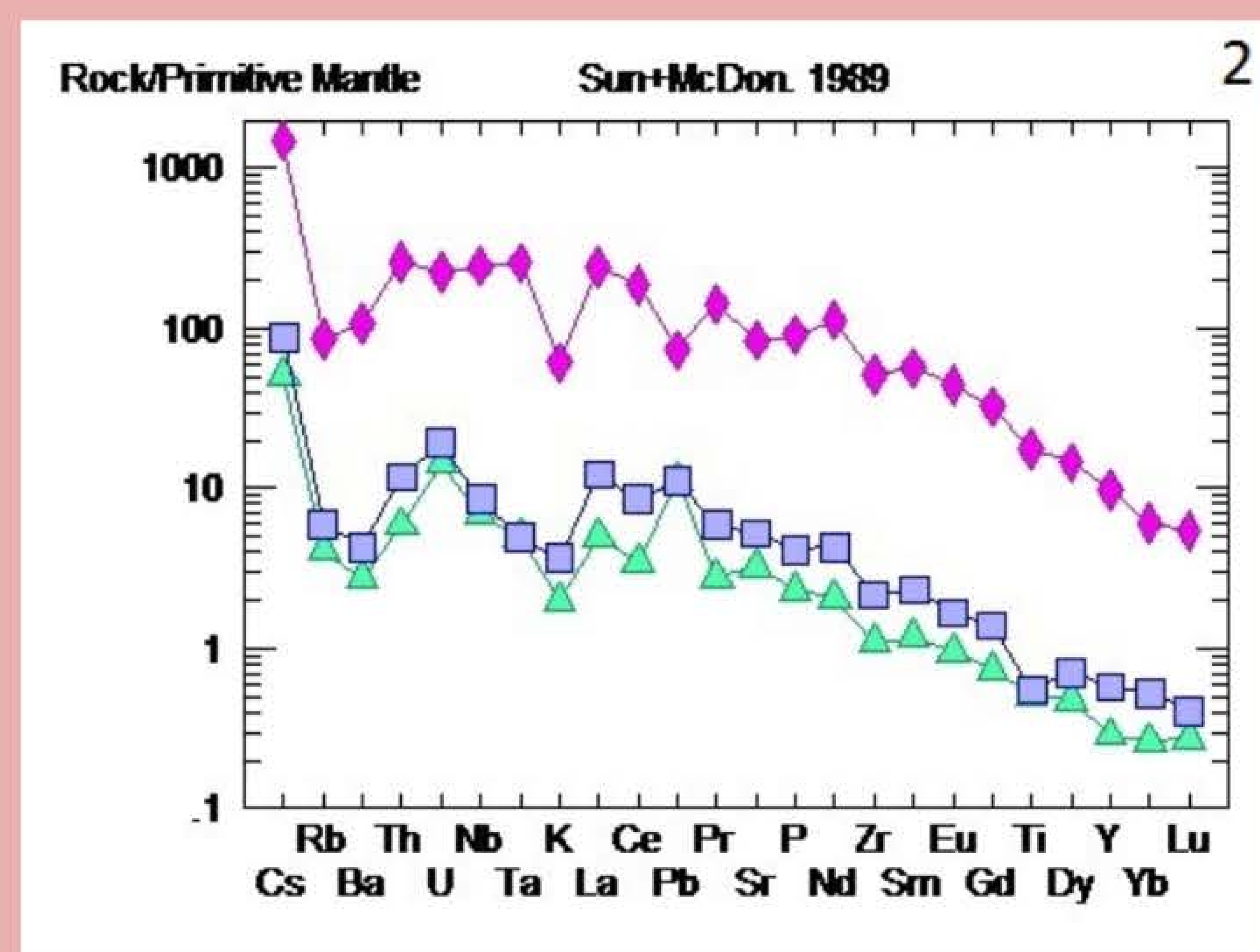


Figure 2: Trace Element Geochemistry

Lherzolite
Wehrlite
Lamprophyre

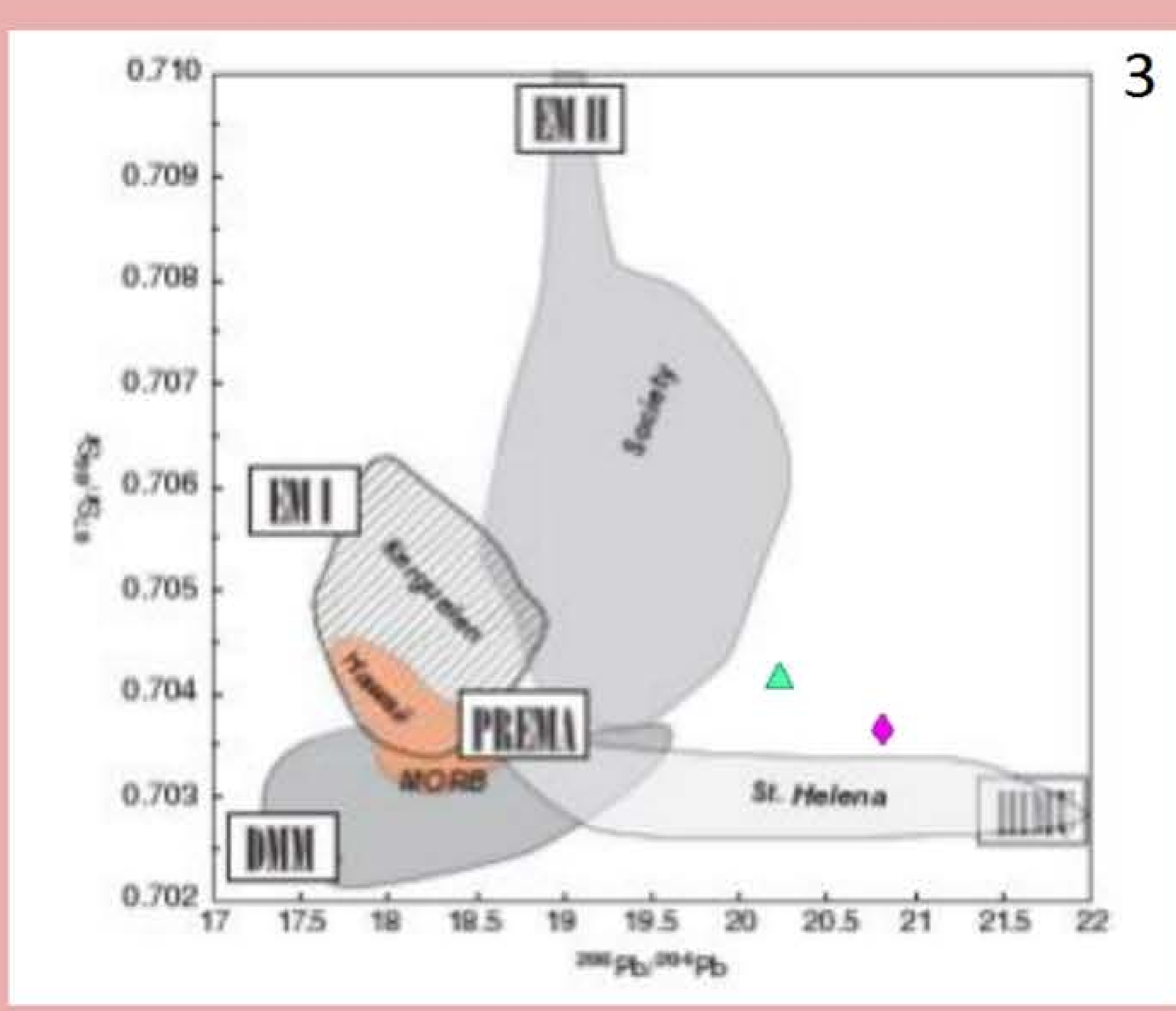


Figure 3: Modified Isotopic Ratio Diagram from White (2013)

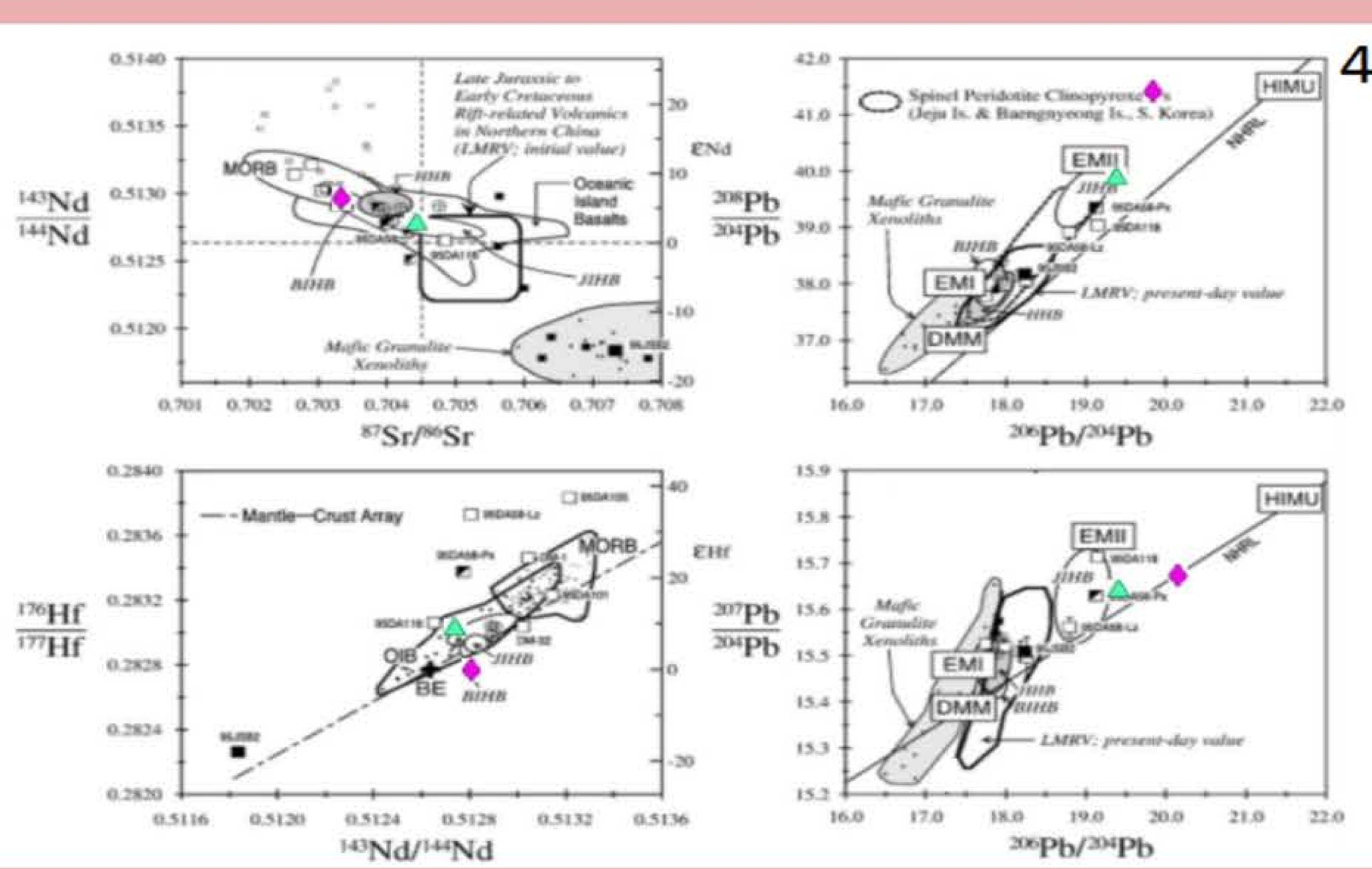


Figure 4: Modified Isotopic Ratio Diagrams from Choi, et al. (2008)

Conclusions

The geochemistry and the isotopic data show distinct differences between the lamprophyres and two types of xenoliths (lherzolite and wehrlite). The data clearly displays that these are all unrelated and the lamprophyre cannot possibly be formed via crystal fractionation of either type of xenolith. The REE diagrams all show negative slopes from LREE to HREE and display characteristics of mantle derived rocks above the spinel-garnet transition zone (30-70 km) indicating a source from the subcontinental lithospheric mantle. The lamprophyres do not have a Nb-Ta-Ti anomaly indicating that no subduction signature is present. On the contrary, Nb-Ta-Ti anomalies are seen in both types of the xenoliths indicating a subduction signature due to depletion of these HFSE. The subduction signature are likely preserved from events like the Taconic (450-440 Ma) or Acadian (400-350 Ma) Orogenies when island arcs collided into proto-North America (Laurentia). The lamprophyres show higher-than-normal $^{208}Pb/^{204}Pb$ and $^{206}Pb/^{204}Pb$ values and low $^{87}Sr/^{86}Sr$ showing characteristics towards a high uranium/lead (HIMU) mantle component. The lamprophyres show both enrichment in LREE and heavier Pb isotopes indicating an overall enriched and old mantle reservoir. A likely candidate for this extreme enrichment may be due to metasomatism of this region of the mantle by partial melts from a subducting slab (Hanyu, et al., 2011). The lherzolitic xenoliths show high $^{207}Pb/^{204}Pb$ and $^{208}Pb/^{204}$ Pb and lower $^{143}Nd/^{144}Nd$ values which indicate either Enriched Mantle 1 (EMI) or Enriched Mantle 2 (EMII) components. These isotopic signatures may be due to a number of things including: continentally derived sediment, delamination of the subcontinental lithosphere, or mantle metasomatism (White, 2014). The Nb-Ta-Ti anomaly as well as the EMI or EMII signature indicate this region of the mantle sampled by the xenoliths are showing geochemical fingerprints of continentally derived sediments and metasomatism from a paleo-subduction zone. Brand new research of Ni-in-Ol barometer (Pu. et al, 2017) may shed insight on the exact pressures and therefore depths at which the lamprophyres and xenoliths were generated, with continued work expected during the upcoming summer.

Aknowlegdements

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