Age and geochemistry of lithospheric mantle underlying Marie Byrd Land, Antarctica

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I. Introduction

The study of upper lithospheric mantle peridotite xenoliths entrained in alkaline magmas from the West Antarctic Rift System has produced information on the composition and processes within the upper mantle and lower crust. Rhenium-Osmium isotopic systematics can potentially constrain the time of melt depletion events in the peridotites using Os model ages (Rudnick and Walker, 2009). This method operates under the assumption that lithosphere formation happens concurrently with melt depletion.

Dating melt depletion events recorded in peridotites from the lithospheric mantle and, hence, the formation of the lithospheric mantle is important for understanding the relationship between the lithospheric mantle and overlying crust, and their associated dynamics. The prevailing theories for the lithosphere under Marie Bird Land, Antarctica are 1) the overlying crustal block may have tectonically overridden lithosphere of the East Antarctic Craton (Handler et al. 2003), 2) that the lithosphere beneath it is a fragment of continental lithospheric mantle that originated in the oceanic lithosphere during rifting and break up of Rodinia where the piece of mantle lithosphere delaminated off another piece and accreted to the Antarctic margin (Hassler and Shimizu, 1998) . The older lithosphere could possibly have come from eastern Antarctica as well (Handler et al. 2003). These theories are based on what happened to the lithospheric mantle during continental break up, subduction and accretion processes, and convection within the mantle.

In this study, the Hannuoba region in the North China Craton (NCC) is used for comparison of what happened to the lithospheric mantle. In the case of the NCC the lithospheric mantle was found to not have the same age as the crust. The crust was formed in the Archean and the results of the Liu et al. (2012) Study suggested that there was lithospheric mantle removal and replacement during the Paleoproterozoic. Also this study will be compared to Handler et al. (2003) study, which concluded that the lithospheric mantle underneath Marie Byrd Land co-formed with the overlying crust, and both are relatively similar in model ages of 1.1-1.3 Ga and 1.1-1.5 Ga (Pankhurst et al. 1998) respectively.

II. Objectives

Samples of this study will be compared to

- Assess whether crust-lithospheric mantle relationship is normal (same-age) or modified (like North China Craton)
- To study the melt depletion history of lithospheric mantle underlying Marie Byrd Land

III. Hypothesis

The lithospheric mantle underlying Marie Byrd Land Antarctica is the same age as the overlying crust (1.1-1.3 Ga (Handler et al. 2003)) and that it has been temporally linked to the present day crust and consistent with co-formation.

IV. Analytical Methods

Analysis	Instruments	Location
Whole-rock: Major/minor elements	*Phillips 2404 X-Ray* fluorescence(XRF) mass	Franklin & Marshall College
Olivine grains Major/minor elements	*JEOL JXA-8900R* electron probe microanalyzer(EPMA)	University of Maryland
Os measurements	*VG Sector 54 thermal ionization* mass spectrometer(TIMS) & *NBS* TIMS	University of Maryland
Re measurements	Nu Plasma ICP-MS	University of Maryland

- The uncertainties of the XRF data is typically better than 1%(1σ) for the major elements of concentrations greater than 1% and better than 5% (1σ) for the remaining major elements.
- The uncertainties of the major elements for olivine, from the EPMA, are typically under 1% (2σ).
- The uncertainties of the $^{187}Os/^{188}Os$ data are typically .1%.

V. Samples

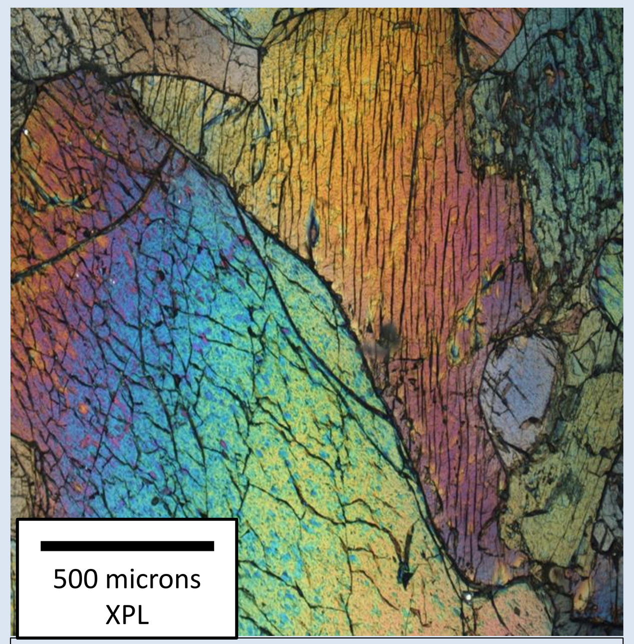

Figure 1. Optical photomicrograph of selected thin section from sample 11.1. from Demas Bluff in the Fosdick Mountains.

In total, 18 samples from 4 separate volcanic centers in the Fosdick Mountains in Marie Byrd Land, Antarctica. These samples were compared to mantle xenoliths from the Hannuoba region in the North China Craton(NCC) in Liu et al.(2012) study.

Samples were mantle peridotite xenoliths entrained in a alkaline magmas from the West Antarctic Rift System.

VI. Whole Rock & Olivine Comparison

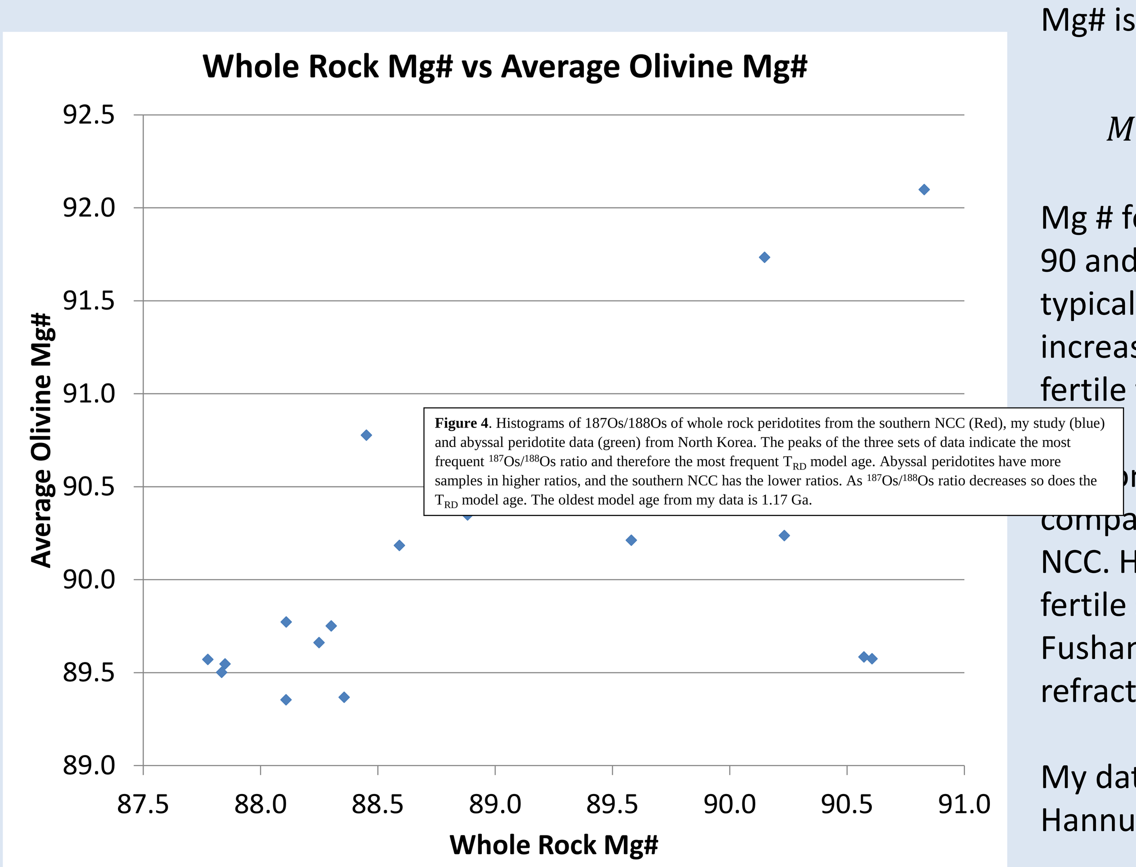

Figure 2: My Study is from Marie Byrd Land
Liu et al. (2011) concluded that Hannuoba has younger lithospheric mantle relative to the overlying crust.

Mg# is found by using:

$$Mg\# = \frac{molar\ Mg}{Mg + Fe^{2+}} \times 100$$

Mg # for unmelted mantle is around 90 and removal of basaltic melt typically increases Mg#. Also as it increases it changes from being fertile to more refractory.

mparison, my data is compared to two examples in the NCC. Hannuoba, which has more fertile samples, shown in red, and Fushan and Hebi which are the more refractory samples in green.

My data shows more similarity to the Hannuoba samples.

The majority of my data have lower Mg#s, which indicate that less melt depletion has occurred and the samples are more fertile.

VI. Al_2O_3 vs $^{187}Os/^{188}Os$

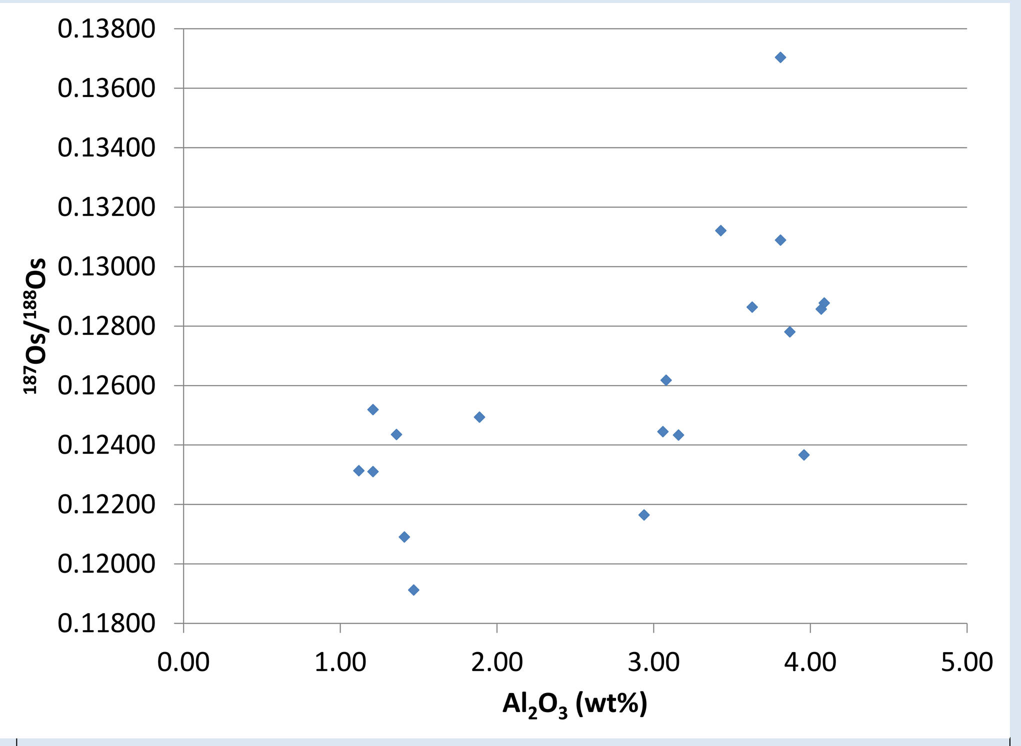

Figure 3: As partial melting increases Al_2O_3 weight percentage will decrease. These data show a poor-moderate positive correlation. The data with the lower Al_2O_3 weight percentage is older than that with higher percentage.

Al_2O_3 and $^{187}Os/^{188}Os$ are shown in Figure 3 with a positive correlation. This may indicate that the samples have undergone partial melting. A higher degree of partial melting is usually accompanied by lower $^{187}Os/^{188}Os$ and Al_2O_3.

Al_2O_3 can be used as an index of melt depetion. Al_2O_3 is often used as a proxy for Re since it has a similar bulk partition coefficient.

Partial melting is essential to the Re-Os isochron to be reliable. If there were not enough partial melting, there may have been too much retention of significant Re after melting for T_{RD} model ages to remain useful.

VII. $^{187}Os/^{188}Os$ data

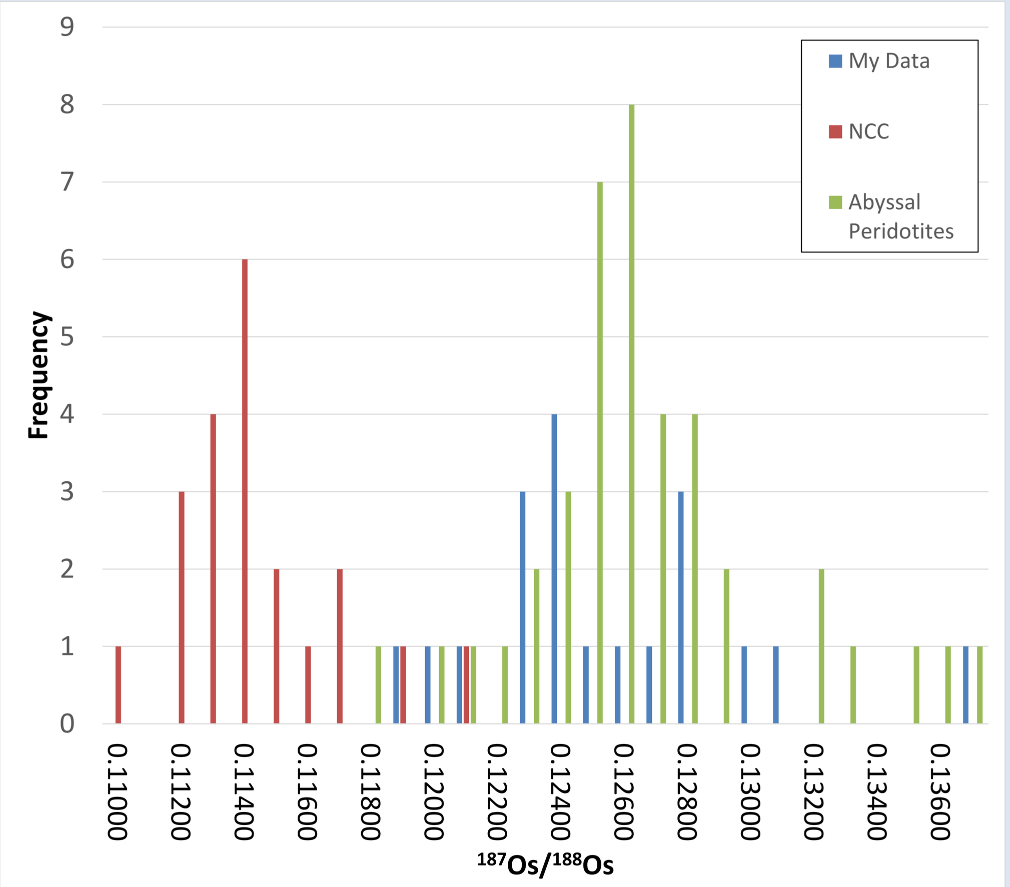

Figure 4: Histograms of 187Os/188Os of whole rock peridotites from the Hannuoba in the NCC (Red), my study (blue) and abyssal peridotite data (green) from North Korea. The peaks of the three sets of data indicate the most frequent $^{187}Os/^{188}Os$ ratio and therefore the most frequent T_{RD} model age. Abyssal peridotites have more samples in higher ratios, and the southern NCC has the lower ratios. As $^{187}Os/^{188}Os$ ratio decreases so does the T_{RD} model age. The oldest model age from my data is 1.17 Ga.

The peaks of the three sets of data indicate the most frequent $^{187}Os/^{188}Os$ ratio and therefore the most frequent T_{RD} model age.

The results found by Handler et al. (2003) suggested that the lithospheric mantle had a model age of 1.1-1.3 Ga underneath Marie Byrd Land. This study has evidence agreeing that there was possibly a melt depletion event occurred at the model age of .9 Ga-1.17 Ga in the lithospheric mantle underneath Marie Byrd Land. This is derived from $^{187}Os/^{188}Os$ data peaks on Figure 4 between .118 and .12, which correspond with 1.17 Ga and .9 Ga model ages respectively. These data are further supported by data with younger model ages in Figure 4, where the peak distribution is more in line with the peak distribution of abyssal peridotites, instead of being closer to the much older Archean aged peridotites from the southern NCC.

These data support a much younger age than the exposed crust(1.0-1.2 Ga) for the lithospheric mantle which supports my hypothesis.

VIII. Conclusions

These data indicate that the lithospheric mantle underneath Marie Byrd Land underwent a melt depletion event near within the same model age range as the overlying crust (1.1-1.5 Ga). Furthermore, this would suggest that the both the crust and lithospheric mantle present today were co-formed, that the lithospheric mantle that formed during the formation of the crust has since been removed.

The TRD model ages may be a good indicator of the lithospheric mantle currently under the Fosdick Mountains, due to the positive correlation of Al_2O_3 weight percent and $^{187}Os/^{188}Os$, which indicates melt depletion has occurred. This is essential for the model to work, as enough melt depletion is needed to mobilize Re into a leaving residue. These data are within the uncertainties of the Handler et al. (2003) study to suggest a similar model age for the lithospheric mantle beneath Marie Byrd Land. This indicates co-formation of the mantle lithosphere and the overlying crust and therefore supporting my hypothesis.

References

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