Determining the Ni Content in St. Helena Olivines

William A. Millard: W.T. Moore Elementary School, Tallahassee, FL
Dr. Vincent Salters: Department of Geochemistry, National High Magnetic Field Laboratory

Abstract:

Olivine is magnesium-iron silicate, $(Mg,Fe)_2SiO_4$, a common mineral in basalt and other mafic igneous rocks that make up the oceanic crust. It is found in all compositions between pure magnesium silicate (forsterite) and pure iron silicate (fayalite), and olivine composition is often given as a number from zero to 100, where Fa100 is pure fayalite. Forsterite is white and fayalite is dark brown, but olivine is usually green.

Sobolev in determining the composition of olivines stated that his data "show that the unusually high nickel and silicon contents of most parental Hawaiian magmas are inconsistent with a deep olivine-bearing source, because this mineral together with pyroxene buffers both nickel and silicon at lower levels (Sobolev, et al., 2005, p.590)".

The purpose of this project is to determine the amount of Ni in olivines from St. Helena, a small island in the south Atlantic Ocean. If Sobolev's hypothesis is correct, then there should be high Ni content in the samples from St. Helena's.

Compositions of Olivines from Mantle-derived Rocks

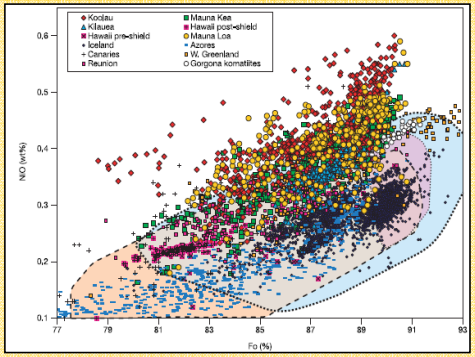

Figure 1 (Sobolev, et al. 2005, p.591)

Background:

This is the third set of samples analyzed as a part of the RET program during the Summer of 2007. Previously, we measured the isotopic composition of samples from the Mid Ocean Ridge and samples collected from the AHA-Nemo cruise of 2000. The samples were analyzed using laser ablation and inductively coupled plasma mass spectrometry. Data was recorded in counts per second and translated to parts per million.

St. Helena's Island

Hypothesis:

The prevalent mineralogy of the mantle contains approximately 50% olivine. Nickel partitions strongly into the olivine. Melts derived from an olivine bearing source and the olivines that crystallize from those melts will thus have relatively low Ni content.

Olivines from Hawaiian magmas have relatively high Ni contents suggesting that the magma source is devoid of olivine. Sobolev et al (2005) suggests that the Hawaiian magma source is recycled oceanic crust which is devoid of olivine.

It has long been recognized based on their isotopic composition that the source of the basalts from St. Helena (Atlantic Ocean) have a large recycled crust component (larger than Hawaii).

If Sobolev's assertion of an olivine free recycled oceanic crust is correct for Hawaii, then this signature of high Ni content should be even stronger at St. Helena.

Method:

Nine samples from St. Helena Island were placed in an aluminum mount. They were then ground and polished. The mount was placed in a laser ablation device to be analyzed. The St. Helena samples were ablated using a UP-213 Laser Ablation System. The Laser was set to a spot size of 80 um, a rep rate of 10 Hz and an energy level of 50%. The ablated materials were carried from the laser to the Element Finnegan 1 High Resolution Inductively Coupled Plasma Mass Spectrometer on a flow of Ar and He.

Inductively Coupled Plasma Mass Spectrometry is a type of mass spectrometry that is highly sensitive and capable of the determination of a range of metals and several non-metals at concentrations below one part in 10^{12}. Material carried into the plasma by the Argon stream is first ionized, then separated by mass through a magnetic field and the ions of an individual mass are counted with an electron multiplier.

Olivine

Ablation of Olivine

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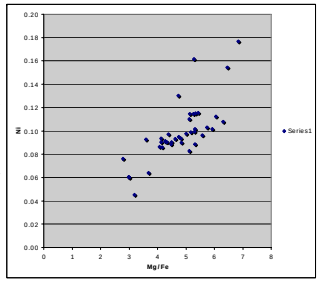
National High Magnetic Field Laboratory

Data Collected:

	Mg25(LR)	Si29(LR)	Ca43(LR)	Ti47(LR)	Cr53(LR)	Mn55(LR)	Fe57(LR)	Co59(LR)	Ni60(LR)	Cu63(LR)	Zn66(LR)	Sr86(LR)	Y89(LR)	Zr90(LR)
H 13	340,436.00	0.40	0.00	119.03	108.40	1,859.50	308,279.50	199.40	1,498.00	4.16	107.01	0.47	0.14	0.23
H 28	317,519.00	0.40	0.00	117.68	128.30	2,068.71	345,515.10	197.10	1,321.00	1.60	134.40	0.17	0.14	0.07
H 38	336,496.00	0.40	0.00	97.20	129.30	1,801.69	227,194.10	183.70	1,511.00	2.47	98.39	0.28	0.12	0.04
H 64	323,919.00	0.40	0.00	101.43	51.90	2,312.43	357,152.30	202.50	1,343.00	15.39	134.30	0.19	0.15	0.06
H 68	324,802.00	0.40	0.00	106.92	173.80	2,126.40	317,534.70	187.30	1,375.00	1.57	122.79	0.03	0.15	0.06
H 74	328,620.00	0.40	0.00	96.81	202.70	1,997.90	328,496.00	185.40	1,914.00	1.86	152.38	0.37	0.15	0.11
H 75	298,979.00	0.40	0.00	153.44	15.70	3,133.77	471,870.40	215.10	887.00	1.31	195.18	0.14	0.21	0.11
H 86	336,886.00	0.40	0.00	97.63	110.30	1,843.32	297,809.70	187.10	1,689.00	3.20	110.01	0.14	0.13	0.06
H 125	306,813.00	0.40	0.00	117.00	73.00	2,055.69	339,181.40	185.90	1,334.00	1.78	147.90	8.67	0.16	0.06
Average	323,830.00	0.40	0.00	111.90	110.38	2,133.27	332,559.24	193.72	1,430.22	3.70	133.60	1.16	0.15	0.09

Interpretation:

The figure on the right shows the variation of the NI counts with the Mg/Fe ratio. The decrease in Ni with decreasing Mg/Fe indicates the olivines belong to a regular crystallization sequences with the high Mg/Fe ratio olivines being the early crystallites. Olivines with the high Mg/Fe count ratio correspond to olivines with forsterite contents between 89-85%. Analysis of the a standard (NIST 612) allows conversion of the Ni counts to concentrations. The high-Mg/Fe-St. Helena olivines contain at most 0.2 weight % NiO. This is significantly lower than the Hawaiian olivines.



Conclusions:

Our data show a relatively low content of Ni in the St. Helena samples. Therefore, our data obtained on samples that are the type locality for recycled oceanic crust do not support a olivine free magma source. Therefore, our data does not support the inferences made by Sobolev et al (2005).

Aluminum Mount

Placing the sample in the UP-213 Laser Ablation System

UP-213 Laser Ablation System

Plasma of the ICP-MS

Analyzing the Data

References:

Sobolev, A.; Hoffman, A; Sobolev, S; Nikogosian, I. (2005). An olivine-free mantle source of Hawaiian shield basalts. *Nature*. v434. p.590-597

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