Understanding magma genesis through analysis of melt inclusions: application of innovative micro-sampling techniques

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UNDERSTANDING MAGMA GENESIS THROUGH ANALYSIS OF MELT INCLUSIONS: APPLICATION OF INNOVATIVE MICRO-SAMPLING TECHNIQUES

APPENDIX VOLUME

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TABLE OF CONTENTS

Appendix D: Relates to Chapter 4

Appendix D1: Sr isotope data collected on sub-ng NBS 987 loads by TIMS during BIP MI study

Appendix D2: Standard trace element data collected during ICPMS BIP MI study

Appendix D3: TPB associated wit the BIP MI study

Appendix D4: Standard and TPB data collected by ICPMS during BIP whole-rock study

Appendix D5: Sr isotope data collected by MC-ICPMS during BIP whole-rock study

Appendix D6: BIP - isotope, major and element data

Appendix D7: Selected crustal rocks of Baffin Island – Sr isotope and element data

Appendix D8: Olivine phenocryst of the BIP – major element data

Appendix D9: Normalized MI trace element concentrations to 100 μm-sized MI

Appendix E: Ph.D. abstracts, posters and papers

Appendix E1: Conference abstracts

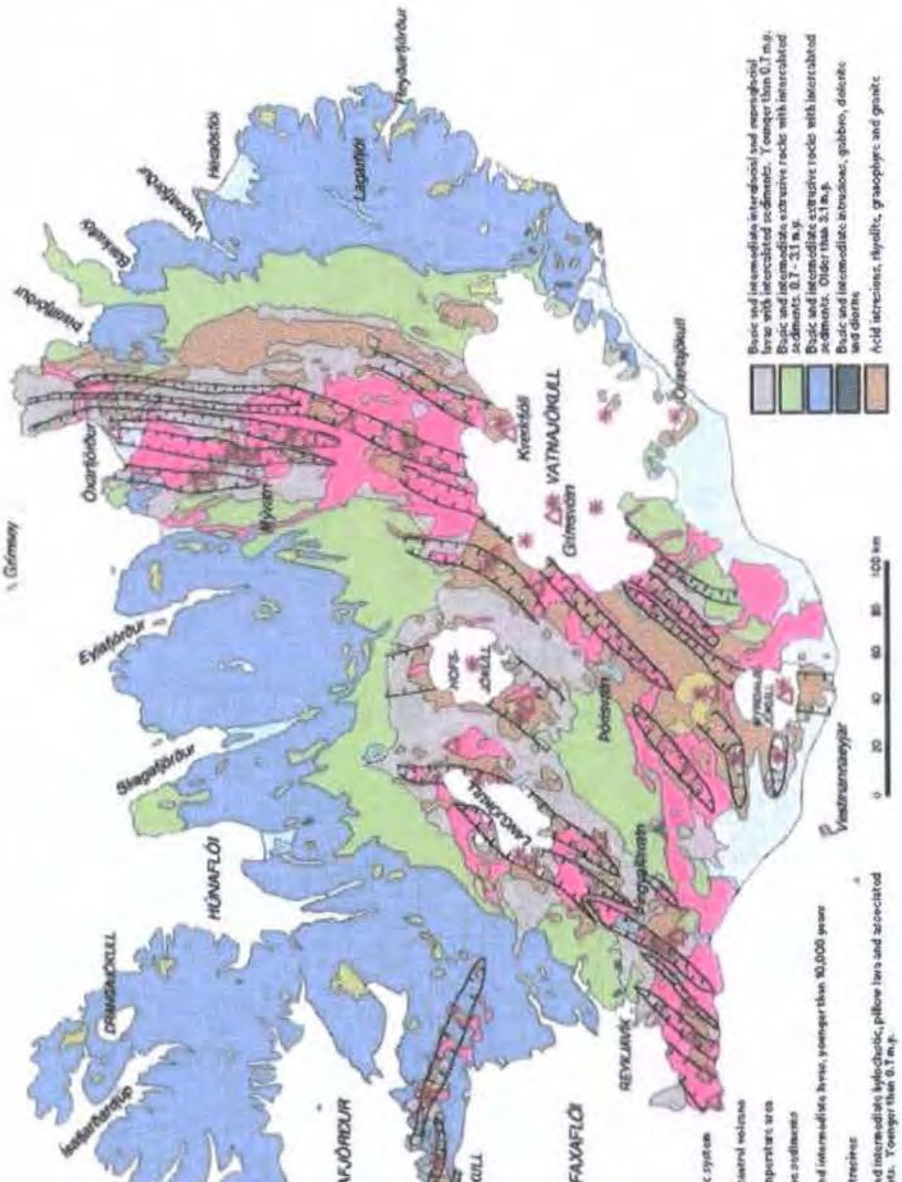
Appendix E2: Conference posters

Appendix E3: Scientific papers in press or in preparation

APPENDIX A

Contents of Appendix A:

Appendix A1: Detailed geological map of Iceland



Geological map of Iceland (http://www.geophysik.uni-frankfurt.de/iceland/geologyl.gif)

Appendix A2: Experimental homogenization of olivine-hosted MIs

Homogenization of the melt inclusions (MIs) is necessary when MIs have crystallized after being entrapped. The MIs are preserved as glass inclusions under rapid cooling, however if cooling of the system is slow crystallization of the MIs may occur due to the physical and chemical changes. Heterogeneous or crystallized MIs may be spotted by the presence of tiny daughter crystal and shrinkage/fluid bubbles (e.g. Figure 2.2b). Less obvious are the crystallization of the host crystal phase on the wall of the MIs. The crystallization of the host mineral and other daughter phases within the MIs can be experimentally reversed by homogenization during heating experiments (details in Danyushevsky et al., 2000). Care must be taken to ensure that the MIs are not over heated or under heated, as this will affect the relationship between the MI composition and the host mineral phase (e.g. Nielsen et al., 1998; Danyushevsky et al., 2000). If under heated, the daughter crystals and olivine rim grown on the inclusion wall may fail to melt completely. Over heating may result in an over-contribution of the host olivine to the melt, but it may also result in degassing. In particular, MgO, FeO, and Ni are affected by over- and under-heating, since these elements are strongly compatible in olivine. However, based on the assumption that the MI is in equilibrium with its host olivine at the time of entrapment it is possible to recalculate the original composition by using the FeO-MgO exchange between melt and olivine (Danyushevsky et al., 2000). The problem is less serious for the incompatible elements as their concentrations are controlled by dilution of the liquid by major constituents, and thus the trace/trace element ratios should remain unaffected. In general, only primary well-preserved MIs should be chosen for analytical work. Nevertheless, it is a difficult microscoping task to see whether or not MIs have breached or degassed. However, these can be screened out from electron microprobe measurement of their volatile content e.g. monitoring of the Cl and S content.

The homogenization of the MIs in olivine during this study was done using a vertical furnace at the Department of Geography and Geology - Geology Section (University of Copenhagen). Handpicked olivine phenocrysts hosting MIs and free of adhering groundmass glass were put in a carbon crucible mixed with fine grained carbon powder. Carbon is used in order to maintain reducing conditions during heating, and hereby ensures a non-oxidizing atmosphere. At first preliminary heating experiments are carried out to establish an approximate liquidus temperature of the entrapped melts, and to establish the length of the heating period needed to homogenize the MIs. Heating experiments were carried out over a temperature range of 1200°C to 1280°C.

'***Homogenization experiments by the batch***' as described here - where multiple olivine grains hosting MIs are heated in '*one go*' ensures a large number of homogenous MIs. A different approach for homogenization experiments is the use of a heating stage where individual olivine grains are homogenized one by one. Using a '***heating stage on a microscope***' entails the visual monitoring of individual MIs during heating, and that heating can be stopped as the liquidus temperature is reached. However, it is a very time consuming procedure to prepare a larger number of MIs for analytical work, as it also requires a great deal of sample preparation (see details in Nielsen et al., 1998).

Procedure for homogenization of olivine-hosted MIs '*by the batch*'

- The furnace is pre-heated to the desired temperature, and wait until the temperature is stable.
- The crucible i preheated for approximately 10 minutes
- The sample material (olivine grains) are mixed with fine-grained carbon powder in a glass disc.
- The mixture of sample material and carbon powder is transferred to the crucible, and placed in the furnace
- The crucible is heated for 15-30 minutes
- The crucible is swiftly taken out of the furnace, and the sample-carbon powder mixture is quickly cooled, by pouring onto a clean metal plate.
- Once cooled down, the olivine crystals are removed from the carbon powder by hand picking or sieving.
- After cleaning of the olivine grains by ultrasonic baths in dilute acid and MQ-water, they are ready for mounting.

References:

Danyushevsky, L. V., McNeill, A. W. & Sobolev, A. V. (2002): Experimental and petrological studies of melt inclusions in phenocrysts from mantle-derived magmas: an overview of techniques, advantages and complications. Chemical Geology, 183: 5-24.

Nielsen, R. L., Michael, P. J., & Sours-Page, R. (1998): Chemical and physical indicators of compromised melt inclusions. Geochimica et Cosmochimica Acta, 62(5): 831-839.

Appendix A3: Preparation of 25 mm epoxy grain mounts for MI micro-sampling work

Equipment for making grain mounts

- Hot plate
- Balance
- Vaseline
- SpeciFix Resin
- SpeciFix-40
- Disposable paper cups
- 25 mm mounting ring plus plate
- Tweezers
- Wooden stick (lolly stick)
- Gloves
- Safety glasses

Equipment for polishing grain mounts

- Rotating polishing table equipped with running water supply
- Silicon-carbide paper for wet grinding e.g. Struers SiC-paper #320, #500, #1200, and #4000
- Struers AP-A powder (a 0.3 μm Alumina, agglomerated powder)

Procedure for making epoxy grain mounts

1. Put on safety glasses and gloves.

2. Put a thin layer of Vaseline on the inside of the mounting ring plus plate. Vaseline will prevent the epoxy from sticking to the mounting cup. If not Vaseline is applied the mounting cup will easily brake as you try to get your mount out!

3. Place the pre-cleaned crystals on the mounting plate using a tweezer - approximately 5 mm from the edge. Try to place the crystals with the largest leveled crystal-surface facing down; doing this will prevent displacement of the sample material, as epoxy is pure over. Place the mounting ring on the plate, and make sure that it fits tightly.

4. Mix exactly 10 g SpeciFix Resin with exactly 4 g of SpeciFix-40 curing agent in a paper cup. This is enough epoxy for 3 grain mounts. It is important to mix the resin and curing agent in the appropriate amount, if not in these proportions the mounts do not cure. Stir the epoxy mixture carefully for 3 minutes using a wooden stick, and place the epoxy mixture on the 80°C hot plate for 2 minutes to help release the air bubbles.

5. Pour the epoxy mixture carefully over the crystals, by letting the epoxy mixture flow down along wooden stick hold against the wall of the mounting ring. Do it slowly - to prevent the sample material to move!

6. Place the grain mounting cups on the heating plate for 3 to 4 hours at 80°C to cure.

7. Leave the grain mounts to cool down to room temperature. Tap the bottom of the mounting cup gentle with a hammer and remove the bottom plate. Tap the ring gently on the side whereby the epoxy loosens from the mounting cup, and the grain mount can be taken out. Please be careful not to break the mounting cups!

8. Hereafter the grain mounts are ready for polishing. This is best done using a rotating polishing plate equipped with running water supply and on silicon carbide paper. Start by using coarse grinding paper (e.g. #320 Struers SiC-paper for wet grinding). Importantly, the grain mount should frequently be expected under the microscope, once a level is reached which has multiple melt inclusions (MIs) close to the surface, proceed to grinding paper (e.g. #500, #1200, and # 4000). Again the grain should be frequently inspected so MIs are not lost. The final polished of the mount is done using Stuers AP-A powder (0.3 μm Alumina, Agglomerated powder). The polishing steep is very important, and the better the polishing is done the easier it is to spot the MIs. It does take time – so remember to be patient!

9. A detailed photographic map is generated of each grain mount to be used for navigation during analytical work. The grains are examined under the microscope, and each MI is inspected in detail. Only primary MIs are map out for analysis.

Appendix A4: LA-ICPMS instrumentation

Instrumentation: (after Kent et al., 2004)	
ICPMS	VG Elemental Excell quadrupole ICPMS
LA	NewWave DUV 193nm ArF Excimer laser

Analyzer conditions:	
Aerosol carrier gas flow	0.75 l/min (He)
Nebulizer gas flow	0.95 l/min (Ar)
Outer (cool)gas flow	13.00 l/min (Ar)
Detector mode	Dual (pulse counting and analogue)
RF power	1350 W
Vacuum pressure	8.0x10-7 mbar (analyzer)
	1.6 mbar (expansion chamber)
Mass table	^{43}Ca, ^{45}Sc, ^{47}Ti, ^{85}Rb, ^{88}Sr, ^{89}Y, ^{90}Zr, ^{93}Nb, ^{133}Cs, ^{137}Ba, ^{139}La, ^{140}Ce, ^{141}Pr, ^{146}Nd, ^{147}Sm, ^{153}Eu, ^{157}Gd, ^{163}Dy, ^{166}Er, ^{172}Yb, ^{178}Hf, ^{181}Ta, ^{208}Pb, ^{232}Th, and ^{238}U
Dwell time/mass/scan	10 ms
Total scan time	~300 ms

Laser conditions:	
Wavelength	193 nm
Frequency	3 Hz
Pulse duration	15 ns
Spot diameter	50 μm (melt inclusions and BHVO-2)
	70 μm (BCR-2)
Lateral translation rate	5 μm (total distance ~225 μm)
Ablation duration	45 s
Output energy	200 mJ at 193 nm (~15 J/cm^2)

Standardization:	
Internal standard	^{43}Ca
Calibration standard	BCR-2 standard glass
Secondary standard	BHVO-2 standard glass

Appendix A5: Electron microprobe major, trace, and volatile element data collected on standard glasses

Standard ID: BHVO-2

Unprocessed electron microprobe data (oxide wt.%)

Oxide	Al_2O_3	MnO	K_2O	Cl	Na_2O	SiO_2	FeO	CaO	S	MgO	NiO	TiO_2	Cr_2O_3	P_2O_5	Total
n	148	148	148	148	148	148	148	148	148	148	135	148	148	13	148
$wt.\%_{Ave}$	**13.55**	**0.17**	**0.51**	*0.01*	**2.35**	**50.10**	**10.96**	**11.44**	*0.00*	**7.30**	**0.02**	**2.77**	**0.05**	**0.26**	**99.24**
±2SD	0.48	0.10	0.05	*0.01*	0.15	1.45	0.47	0.36	*0.01*	0.31	0.05	0.13	0.05	0.05	-
±2SD (%)	3.55	58.47	9.51	*110.15*	6.42	2.89	4.27	3.17	*300.33*	4.28	252.40	4.64	106.81	20.85	-
$BHVO\text{-}2_{Rec}$	13.50	0.17	0.52	-	2.22	49.90	11.07	11.14	-	7.23	0.02	2.73	0.05	0.27	-
Δ%	0.35	-0.11	-2.07	-	5.77	0.40	-1.01	2.73	-	0.97	22.74	1.62	-11.22	-3.22	-

Processed electron microprobe data - recalculated to 100 wt.%

Oxide	Al_2O_3	MnO	K_2O	Cl	Na_2O	SiO_2	FeO	CaO	S	MgO	NiO	TiO_2	Cr_2O_3	P_2O_5	Total
n	148	148	148	148	148	148	148	148	148	148	135	148	148	13	148
$wt.\%_{Ave}$	**13.65**	**0.17**	**0.51**	*0.01*	**2.37**	**50.48**	**11.04**	**11.53**	*0.00*	**7.36**	**0.02**	**2.80**	**0.05**	**0.26**	**100.00**
±2SD	0.41	0.10	0.05	*0.01*	0.15	0.85	0.42	0.36	*0.01*	0.31	0.05	0.13	0.05	0.06	-
±2SD (%)	3.04	58.46	9.68	*110.18*	6.45	1.68	3.84	3.13	*301.58*	4.15	252.06	4.60	107.40	21.23	-
$BHVO\text{-}2_{Rec}$	13.50	0.17	0.52	-	2.22	49.90	11.07	11.14	-	7.23	0.02	2.73	0.05	0.27	-
Δ%	1.13	0.51	-1.25	-	6.58	1.16	-0.28	3.52	-	1.74	25.03	2.43	-10.71	-3.20	-

Table A5.1a: Electron microprobe data collected on USGS standard glass BHVO-2 using the JEOL JXA-8200 Superprobe at the Department of Geography and Geology - Geology Section (University of Copenhagen) and the Cameca SX-50 at Oregon State University. 'n' denotes number of analyses, $wt.\%_{Ave}$ the average wt.% obtained, ±2SD is the 2SD error on $wt.\%_{Ave}$, $BHVO\text{-}2_{Rec}$ is the recommended values for BHVO-2 given by USGS (http://minerals.cr.usgs.gov/geo_chem_stand/basaltbhvo2.html). Δ% gives the difference in percent between $BHVO\text{-}2_{Rec}$ and $wt.\%_{Ave}$ obtained.

Appendix A5: Continued

Standard ID: BCR-2

Unprocessed electron microprobe data (oxide wt.%)

Oxide	Al_2O_3	MnO	K_2O	Cl	Na_2O	SiO_2	FeO	CaO	S	MgO	NiO	TiO_2	Cr_2O_3	P_2O_3	Total
n	146	146	146	*146*	146	146	146	146	*146*	146	*133*	146	*146*	13	146
wt.%$_{Ave}$	**13.46**	**0.19**	**1.76**	*0.01*	**3.20**	**54.41**	**12.17**	**7.17**	*0.01*	**3.69**	*0.01*	**2.30**	*0.01*	**0.36**	**98.43**
±2SD	0.62	0.09	0.30	*0.02*	0.50	2.64	0.62	0.97	*0.05*	1.05	*0.03*	0.15	*0.04*	0.06	-
±2SD (%)	4.58	48.19	17.11	*277.60*	15.77	4.84	5.11	13.51	*432.96*	28.56	*306.43*	6.49	*277.49*	16.43	-
BCR-2$_{Rec}$	14	0.20	1.79	-	3.16	54.10	12.47	7.12	-	3.59	-	2.26	-	0.35	-
Δ%	-0.30	-4.38	-1.52	-	1.23	0.57	-2.41	0.76	-	2.72	-	1.97	-	1.64	-

Processed electron microprobe data - recalculated to 100 wt.%

Oxide	Al_2O_3	MnO	K_2O	Cl	Na_2O	SiO_2	FeO	CaO	S	MgO	NiO	TiO_2	Cr_2O_3	P_2O_3	Total
n	146	146	146	*146*	146	146	146	146	*146*	146	*133*	146	*146*	13	146
wt.%$_{Ave}$	**13.67**	**0.19**	**1.79**	*0.01*	**3.25**	**55.28**	**12.36**	**7.29**	*0.01*	**3.75**	*0.01*	**2.34**	*0.01*	**0.36**	**100.00**
±2SD	0.44	0.09	0.31	*0.02*	0.52	1.48	0.60	1.00	*0.05*	1.08	*0.03*	0.15	*0.04*	0.06	-
±2SD (%)	3.23	47.49	17.23	*279.95*	15.93	2.68	4.82	13.75	*436.15*	28.81	*326.61*	6.33	*278.17*	17.26	-
BCR-2$_{Rec}$	13.50	0.20	1.79	-	3.16	54.10	12.47	7.12	-	3.59	-	2.26	-	0.35	-
Δ%	1.30	-2.93	0.07	-	2.87	2.17	-0.84	2.39	-	4.38	-	3.61	-	1.97	-

Table A5.1b: Electron microprobe data collected on USGS standard glass BCR-2 using the JEOL JXA-8200 Superprobe at the Department of Geography and Geology - Geology Section (University of Copenhagen) and the Cameca SX-50 at Oregon State University. 'n' denotes number of analyses, wt.%$_{Ave}$ the average measured wt.% obtained, ±2SD is the 2SD error on wt.%$_{Ave}$. BCR-2$_{Rec}$ is the recommended values for BCR-2 given by USGS (http://minerals.cr.usgs.gov/geo_chem_stand/basaltbcr2.html). Δ% gives the difference in percent between BCR-2$_{Rec}$ and wt.%$_{Ave}$ obtained.

Appendix A5: Continued

Standard ID: LO-02-04

Unprocessed electron microprobe data (oxide wt.%)

Oxide	Al_2O_3	MnO	K_2O	Cl	Na_2O	SiO_2	FeO	CaO	S	MgO	NiO	TiO_2	Cr_2O_3	P_2O_3	Total
n	140	140	140	140	140	140	140	140	140	140	*128*	140	140	12	140
wt.%$_{Ave}$	**12.04**	**0.17**	**0.55**	**0.14**	**2.52**	**48.51**	**10.87**	**10.91**	**0.11**	**8.85**	*0.02*	**2.41**	**0.07**	**0.26**	**98.43**
±2SD	0.50	0.09	0.05	0.01	0.31	2.64	0.48	0.38	0.04	0.43	*0.05*	0.13	0.07	0.05	-
±2SD (%)	4.19	50.96	8.47	7.54	12.36	5.43	4.46	3.52	33.64	4.90	*205.82*	5.34	96.62	18.71	-
LO-02-04$_{Rec}$	12.17	0.16	0.56	0.14	2.48	49.30	10.84	10.53	0.07	9.03	-	2.24	0.07	0.30	-
Δ%	-1.07	4.48	-2.55	-2.05	1.44	-1.60	0.27	3.65	57.46	-2.01	-	7.37	2.66	-11.91	-

Processed electron microprobe data (oxide wt.%)

Oxide	Al_2O_3	MnO	K_2O	Cl	Na_2O	SiO_2	FeO	CaO	S	MgO	NiO	TiO_2	Cr_2O_3	P_2O_3	Total
n	140	140	140	140	140	140	140	140	140	140	*140*	140	140	12	140
wt.%$_{Ave}$	**12.24**	**0.17**	**0.55**	**0.14**	**2.56**	**49.31**	**11.05**	**11.09**	**0.11**	**8.99**	*0.02*	**2.44**	**0.07**	**0.27**	**100.00**
±2SD	0.52	0.09	0.05	0.01	0.31	2.67	0.44	0.35	0.04	0.41	*0.05*	0.13	0.07	0.05	-
±2SD (%)	4.27	50.99	8.92	7.53	12.24	5.41	3.96	3.15	33.71	4.58	*223.72*	5.32	96.57	18.02	-
LO-02-04$_{Rec}$	2.17	0.16	0.56	0.14	2.48	49.30	10.84	10.53	0.07	9.03	-	2.24	0.07	0.30	-
Δ%	0.57	6.21	-0.93	-0.42	3.11	0.03	1.92	5.37	60.08	-0.39	-	9.15	4.35	-10.59	-

Table A5.1c: Electron microprobe data collected on standard glass LO-02-04 using the JEOL JXA-8200 Superprobe at the Department of Geography and Geology - Geology Section (University of Copenhagen) and the Cameca SX-50 at Oregon State University. 'n' denotes number of analyses, wt.%$_{Ave}$ the average measured wt.% obtained, ±2SD is the 2SD error on wt.%$_{Ave}$, LO-02-04$_{Rec}$ is the recommended values for LO-02-04 given by Kent et al. (1999). Δ% gives the difference in percent between LO-02-04$_{Rec}$ and wt.%$_{Ave}$ obtained.

References

Kent, A. J. R., Norman, M. D., Hutcheon, I. D., & Stolper, E. M. (1999): Assimilation of seawater-derived components in an oceanic volcano: evidence from glasses and glass inclusions from Loihi seamount, Hawaii. Chemical Geology, 156, 299-319.

Appendix A6: LA-ICPMS trace element data collected on standard glasses

Standard ID: BCR-2

Element	n	$BCR\text{-}2_{Ave}$	±2SD	±2SD%	$BCR\text{-}2_{Rec}$	Δ%
Sc	81	**34.31**	0.93	2.70	34.30	0.02
Ti	81	**13503.87**	214.27	1.59	13500.00	0.03
Rb	81	**48.05**	1.94	4.03	48.00	0.11
Sr	81	**346.92**	12.24	3.53	346.00	0.27
Y	81	**37.18**	1.83	4.93	37.00	0.50
Zr	81	**188.85**	8.19	4.34	188.00	0.45
Nb	81	**13.61**	0.54	4.00	13.60	0.05
Cs	81	**1.17**	0.12	10.65	1.18	-0.65
Ba	81	**672.08**	23.89	3.56	674.00	-0.29
La	81	**25.23**	0.80	3.19	25.26	-0.12
Ce	81	**53.56**	2.01	3.76	53.75	-0.35
Pr	81	**6.84**	0.40	5.78	6.88	-0.60
Nd	81	**28.56**	2.04	7.13	28.82	-0.91
Sm	81	**6.51**	0.63	9.74	6.57	-0.93
Eu	81	**1.93**	0.19	9.73	1.95	-1.14
Gd	81	**6.70**	0.81	12.10	6.79	-1.22
Dy	81	**6.35**	0.80	12.54	6.45	-1.51
Er	81	**3.67**	0.41	11.10	3.72	-1.37
Yb	81	**3.29**	0.45	13.54	3.34	-1.53
Hf	81	**4.73**	0.55	11.70	4.80	-1.36
Ta	81	**0.85**	0.14	16.51	0.86	-1.87
Pb	81	**10.70**	2.31	21.58	11.00	-2.72
Th	81	**6.06**	1.00	16.59	6.20	-2.28
U	81	**1.65**	0.30	17.94	1.69	-2.25

Table A6.1a: LA-ICPMS trace element data collected BCR-2 using the VG Element Excell quadrupole ICPMS fitted with a New Wave DUV 193nm ARF Excimer laser at Oregon State University. 'n' denotes number of analyses, $BCR\text{-}2_{Ave}$ is the average measured trace element content given in ppm, ±2SD is the 2SD error on $BCR\text{-}2_{Ave}$, $BCR\text{-}2_{Rec}$ is the recommended values for BCR-2 given by USGS (http://minerals.cr.usgs.gov/geo_chem_stand/basaltbcr2.html). Δ% gives the difference in percent between $BCR\text{-}2_{Rec}$ and $BCR\text{-}2_{Ave}$ obtained.

Standard ID: BHVO-2						
Element	**n**	**BHVO-2$_{Ave}$**	**±2SD**	**±2SD%**	**BHVO-2$_{Rec.}$**	**Δ%**
Sc	23	**30.59**	2.50	8.17	30.80	-0.67
Ti	23	**16458.80**	431.94	2.62	16300.00	0.97
Rb	23	**9.89**	0.96	9.71	9.80	0.93
Sr	23	**402.68**	31.34	7.78	389.00	3.52
Y	23	**23.78**	1.90	7.98	26.00	-8.54
Zr	23	**155.81**	10.61	6.81	172.00	-9.41
Nb	23	**19.64**	1.73	8.81	19.20	2.29
Cs	-	-	-	-	0.10	-
Ba	23	**133.66**	8.36	6.25	129.00	3.61
La	23	**14.65**	0.81	5.52	15.28	-4.12
Ce	23	**39.05**	1.78	4.55	37.91	3.01
Pr	23	**5.28**	0.33	6.26	5.34	-0.99
Nd	23	**23.16**	1.79	7.72	24.40	-5.09
Sm	21	**5.56**	0.69	12.41	6.03	-7.77
Eu	23	**1.99**	0.27	13.46	2.04	-2.13
Gd	18	**5.45**	0.80	14.58	6.23	*-12.45*
Dy	20	**4.73**	0.63	13.35	5.31	*-10.84*
Er	19	**2.28**	0.38	16.53	2.55	*-10.45*
Yb	20	**1.82**	0.39	21.44	1.96	-6.93
Hf	22	**3.87**	0.80	20.75	4.10	-5.52
Ta	23	**1.13**	0.21	18.58	1.19	-5.26
Pb	20	**1.83**	0.26	14.05	1.66	10.00
Th	21	**1.16**	0.22	19.04	1.20	-3.29
U	17	**0.42**	0.08	18.75	0.41	2.12

Table A6.1b: LA-ICPMS trace element data collected BHVO-2 using the VG Element Excell quadrupole ICPMS fitted with a New Wave DUV 193nm ARF Excimer laser at Oregon State University. 'n' denotes number of analyses, BHVO-2$_{Ave}$ is the average measured trace element content in ppm obtained, ±2SD is the 2SD error on BHVO-2$_{Ave}$, BHVO-2$_{Rec}$ is the recommended values for BHVO-2 given by USGS (http://minerals.cr.usgs.gov/geo_chem_stand/basaltbhvo2.html). Δ% gives the difference in percent between BHVO-2$_{Rec}$ and obtained BHVO-2$_{Ave}$. Concentrations, which were not obtained within 10% of the recommended values, are marked in grey italic.

Appendix A7: Vestfirdir ankaramites – whole rock data

Sample ID	408611	408624	408772	SEL97
Rock type	*Ankaramite*	*Ankaramite*	*Ankaramite*	*Ankaramite*
Latitude	65.85	66.06	65.7646	-
Longitude	-23.25	-23.30	-24.0419	-
Location	*Lambadalur*	*Burfell*	*Selardalur*	*Selardalur*
Major element concentrations (oxide wt.%)				
SiO_2	44.94	47.08	45.13	45.94
TiO_2	0.63	1.07	0.90	1.19
Al_2O_3	9.87	9.61	7.70	9.72
MgO	25.17	18.89	25.66	18.74
CaO	7.35	10.85	7.54	10.15
Fe_2O_3	2.07	2.03	2.16	-
FeO	8.23	8.46	9.154	-
Cr_2O_3	0.39	0.27	0.44	0.51
NiO	0.13	0.08	0.13	0.10
MnO	0.17	0.17	0.17	0.15
Na_2O	0.81	1.29	0.87	1.18
K_2O	0.13	0.12	0.05	0.05
P_2O_5	0.11	0.10	0.09	0.06
Total	100	100	100	-
Mg#	84.0	79.4	82.9	77.3
FeO_{total}	10.09	10.29	11.10	11.53
K_2O+Na_2O	0.94	1.40	0.92	1.23
Selected PM normalized trace element ratios				
$(Ce/Sm)_N$	1.43	1.12	1.44	1.36
$(La/Y)_N$	2.00	2.02	2.95	2.18
$(Rb/Sr)_N$	1.14	0.23	0.09	0.48
$(Sr/Nd)_N$	1.06	1.26	1.16	2.12
$(Ti/Zr)_N$	0.63	0.95	0.99	0.82
$(Sm/Nd)_N$	0.89	0.88	0.84	0.88
$(Ba/Zr)_N$	0.70	0.66	0.58	0.71
ΔNb	0.03	-0.02	0.11	0.13

Table A7.1: Major and trace element compositions of the Vestfirdir ankaramites - samples 408611, 408624, and 408772 (Breddam et al., in prep). All data reported on SEL97 is from Hilton et al. (1999). The selected trace element data is normalized to primitive mantle (PM) using values from McDonough & Sun (1995). For details on the ΔNb notation see Fitton et al. (1997).

Sample ID	408611	408624	408772	SEL97
Trace element concentrations (ppm)				
Cr	1287	902	1496	1728
Ni	998	593	982	759
Rb	3.044	1.155	0.318	2.7
Sr	88.65	165.34	118.00	185
Cs	0.009	-	0.014	-
Ba	21.5	24.0	17.0	33
Th	0.206	0.256	0.351	-
U	0.081	0.086	0.070	-
Pb	0.247	0.455	0.323	-
Nb	3.60	3.70	4.52	10
Ta	0.30	0.27	0.34	-
Zr	49.0	58.1	46.6	75
Hf	1.12	1.45	1.27	-
Y	11.7	14.3	10.0	12
La	3.55	4.37	4.47	3.95
Ce	8.89	10.88	10.31	8.8
Pr	1.22	1.65	1.40	-
Nd	5.35	8.43	6.51	5.61
Sm	1.56	2.43	1.78	1.62
Eu	0.59	0.85	0.65	0.84
Gd	1.83	2.77	2.03	1.94
Tb	0.32	0.44	0.33	-
Dy	1.90	2.49	1.94	1.82
Ho	0.42	0.51	0.38	-
Er	1.12	1.28	0.99	-
Tm	0.16	0.18	0.14	-
Yb	1.09	1.11	0.85	0.84
Lu	0.17	0.17	0.12	0.12

Table A7.1: Continued

Appendix A7: Continued

References

Breddam, K., Stecher, O., Harlou, R., Peate, D. W., & Kurz, M. D. (in prep): Miocene high-$^3He/^4He$ ankaramites in NW-Iceland: Trace element constraints on the common component in mantle plumes.

Fitton, J. G., Saunders, A. D., Norry, M. J., Hardarson, B. S.; & Taylor, R. N. (1997): Thermal and chemical structure of the Iceland plum. Earth and Planetary Science Letters, 153: 197-208.

Hilton, D. R., Gronvold, K., Macpherson, C. G., & Castillo, P.R. (1999): Extreme $^3He/^4He$ ratios in northwest Iceland: constraining the common component in mantle plumes. Earth and Planetary Science Letters, 173: 53-60.

McDonough, W. F. & Sun, S. -s. (1995): The composition of the Earth. Chemical Geology, 120: 223-253.

Olivine phenocryst major element compositions of 408611 expressed as wt.% oxides (n=62)

Ol. ID	Al_2O_3	MnO	K_2O	Na_2O	SiO_2	FeO	CaO	SO_3	MgO	NiO	TiO_2	Cr_2O_3	Total	Ni ppm	Fo%	FeO/MgO
408611Bol4	0.02	0.23	0.01	0.01	39.15	16.11	0.22	-	44.02	0.17	0.04	0.01	100	1322	83.0	0.37
408611Bol5	0.02	0.20	-	0.01	39.45	14.81	0.24	-	44.97	0.22	0.02	0.05	100	1699	84.4	0.33
408611Bol6	0.03	0.21	-	0.00	39.16	15.57	0.20	-	44.61	0.17	0.01	0.03	100	1337	83.6	0.35
408611Bol7	0.05	0.15	-	0.02	40.29	10.52	0.28	-	48.31	0.30	0.01	0.06	100	2347	89.1	0.22
408611Bol8	0.03	0.23	-	0.01	39.49	14.16	0.22	-	45.58	0.23	0.02	0.02	100	1817	85.2	0.31
408611Col6	0.03	0.29	0.01	-	39.35	14.71	0.26	-	45.07	0.25	0.01	0.02	100	1981	84.5	0.33
408611Eol1	0.04	0.24	-	0.01	39.01	17.04	0.22	-	43.26	0.14	0.01	0.02	100	1070	81.9	0.39
408611Fol1	0.06	0.28	-	0.01	39.54	16.89	0.20	0.01	42.69	0.27	0.02	0.03	100	2111	81.8	0.40
408611Iol11	0.12	0.10	-	-	39.02	11.24	0.29	-	48.87	0.31	0.01	0.05	100	2426	88.6	0.23
408611Iol5	0.08	0.21	-	-	38.17	15.76	0.27	-	45.18	0.27	0.04	0.01	100	2124	83.6	0.35
408611Iol7	0.06	0.20	-	-	38.18	15.20	0.27	-	45.76	0.27	0.02	0.03	100	2107	84.3	0.33
408611Jol1	0.11	0.15	-	-	38.55	12.80	0.32	-	47.64	0.35	0.02	0.06	100	2765	86.9	0.27
408611Jol1	0.01	0.25	-	0.01	37.25	14.42	0.31	-	47.38	0.33	0.01	0.04	100	2580	85.4	0.30
408611Jol7	0.06	0.23	-	-	37.80	16.87	0.33	-	44.45	0.21	0.03	0.01	100	1647	82.4	0.38
408611Jol8	0.08	0.24	-	-	37.82	17.51	0.19	-	43.89	0.23	0.03	-	100	1797	81.7	0.40
408611Jol9	0.07	0.14	-	-	39.20	10.35	0.25	-	49.55	0.38	0.02	0.05	100	3008	89.5	0.21
408611Lol3	0.07	0.18	-	-	38.63	14.64	0.26	-	45.88	0.28	0.03	0.02	100	2202	84.8	0.32
408611Lol4	0.08	0.21	-	-	38.11	17.33	0.21	-	43.76	0.26	0.04	0.01	100	2059	81.8	0.40
408611Aol1	0.03	0.24	-	0.01	39.27	15.05	0.20	-	44.88	0.26	0.02	0.03	100	2081	84.2	0.34
408611Aol10	0.07	0.23	0.01	0.02	40.18	11.26	0.28	-	47.51	0.36	0.01	0.07	100	2846	88.3	0.24

Table A8.1: Olivine (Ol.) phenocryst compositions from ankaramite 408611 (expressed as wt.% oxides) obtained by electron microprobe using the JEOL JXA-8200 Superprobe at the Department of Geography and Geology - Geology Section (University of Copenhagen) and the Cameca SX-50 at Oregon State University. 'n' denotes number of ol. analyzed, each analysis represents an average of 3.

Appendix A8: Continued

Ol. ID	Al_2O_3	MnO	K_2O	Na_2O	SiO_2	FeO	CaO	SO_3	MgO	NiO	TiO_2	Cr_2O_3	Total	Ni ppm	Fo%	FeO/MgO
408611Aol11	0.07	0.21	-	-	40.00	11.14	0.27	-	47.93	0.31	0.01	0.06	100	2459	88.5	0.23
408611Aol12	0.06	0.20	-	0.02	40.03	12.82	0.29	-	46.16	0.33	0.01	0.07	100	2611	86.5	0.28
408611Aol13	0.07	0.20	-	-	39.29	16.15	0.26	-	43.82	0.19	-	0.02	100	1499	82.9	0.37
408611Aol2	0.07	0.22	-	-	40.31	10.64	0.26	-	48.04	0.37	0.02	0.07	100	2906	88.9	0.22
408611Aol3	0.06	0.10	0.01	0.01	39.97	9.77	0.24	0.01	49.35	0.36	0.05	0.08	100	2828	90.0	0.20
408611Aol4	0.05	0.28	-	-	39.33	16.30	0.23	-	43.62	0.18	-	-	100	1384	82.7	0.37
408611Aol5	0.05	0.17	0.01	-	40.45	9.38	0.26	0.01	49.24	0.37	0.03	0.03	100	2932	90.3	0.19
408611Aol6	0.04	0.22	-	0.01	39.16	15.70	0.22	0.01	44.32	0.26	0.02	0.03	100	2081	83.4	0.35
408611Aol7	0.04	0.32	-	-	38.87	17.76	0.21	-	42.55	0.19	0.03	0.02	100	1497	81.0	0.42
408611Aol8	0.04	0.14	-	-	40.42	9.99	0.23	-	48.77	0.33	0.03	0.06	100	2574	89.7	0.20
408611Aol9	0.09	0.29	-	-	39.27	18.04	0.19	-	41.87	0.20	0.02	0.03	100	1567	80.5	0.43
408611Bol1	0.04	0.25	-	0.02	39.08	16.20	0.27	-	43.82	0.25	0.03	0.04	100	1942	82.8	0.37
408611Bol2	0.07	0.14	0.01	-	39.22	13.25	0.30	-	46.60	0.31	0.02	0.07	100	2431	86.2	0.28
408611Bol3	0.03	0.23	-	-	39.00	16.01	0.20	0.01	44.27	0.21	0.02	0.02	100	1645	83.1	0.36
408611Col1	0.05	0.16	0.01	0.01	40.26	10.23	0.29	-	48.53	0.41	0.00	0.06	100	3224	89.4	0.21
408611Col2	0.04	0.26	0.01	0.00	39.52	14.05	0.23	-	45.55	0.26	0.03	0.04	100	2036	85.2	0.31
408611Col3	0.04	0.16	-	0.01	40.11	12.40	0.25	-	46.66	0.29	0.01	0.06	100	2296	87.0	0.27
408611Col4	0.01	0.17	-	0.01	39.51	14.61	0.26	-	45.15	0.23	0.01	0.03	100	1823	84.6	0.32
408611Col5	0.05	0.19	-	0.02	39.42	14.05	0.30	-	45.55	0.35	-	0.06	100	2731	85.2	0.31
408611Col7	0.09	0.31	-	0.01	39.74	14.33	0.26	0.01	44.81	0.32	0.02	0.09	100	2530	84.8	0.32
408611Col8	0.10	0.22	-	-	39.56	14.55	0.27	-	44.88	0.33	0.03	0.07	100	2599	84.6	0.32
408611Col9	0.03	0.20	-	-	39.93	12.33	0.30	-	46.79	0.33	0.02	0.05	100	2612	87.1	0.26
408611Eol2	0.03	0.23	-	0.01	39.16	15.04	0.22	0.01	44.99	0.26	0.03	0.02	100	2025	84.2	0.33
408611Eol3	0.09	0.24	-	0.02	39.39	15.42	0.27	0.01	44.24	0.28	-	0.04	100	2163	83.6	0.35
408611Eol4	0.02	0.25	0.00	0.00	39.47	14.94	0.28	0.01	44.68	0.28	0.02	0.05	100	2214	84.2	0.33

Table A8.1: Continued

Appendix A8: Continued

Ol. ID	Al_2O_3	MnO	K_2O	Na_2O	SiO_2	FeO	CaO	SO_3	MgO	NiO	TiO_2	Cr_2O_3	Total	Ni ppm	F0%	FeO/MgO
408611Fol2	0.02	0.18	0.01	-	40.26	16.04	0.20	0.01	43.07	0.19	0.01	0.01	100	1481	82.7	0.37
408611Fol3	0.03	0.24	0.00	0.01	39.76	15.30	0.24	-	44.13	0.24	0.01	0.03	100	1865	83.7	0.35
408611G+ol1	0.04	0.18	-	-	38.72	13.92	0.33	-	46.49	0.29	-	0.03	100	2273	85.6	0.30
408611Gol1	0.04	0.14	-	0.03	40.41	11.23	0.28	0.01	47.39	0.39	0.02	0.07	100	3054	88.3	0.24
408611Gol2	0.03	0.30	0.01	-	39.42	16.44	0.25	0.01	43.29	0.17	0.02	0.04	100	1349	82.4	0.38
408611Hol1	0.03	0.26	-	0.01	37.94	16.51	0.28	-	44.69	0.24	0.01	0.04	100	1855	82.8	0.37
408611Hol2	0.22	0.30	-	0.01	37.27	19.08	0.24	-	42.62	0.22	0.03	0.02	100	1726	79.9	0.45
408611Hol3	0.16	0.27	-	0.01	37.60	18.84	0.31	-	42.55	0.24	-	0.04	100	1850	80.1	0.44
408611Hol3	0.16	0.27	-	0.01	37.60	18.84	0.31	-	42.55	0.24	-	0.04	100	1850	80.1	0.44
408611Hol3	0.16	0.27	-	0.01	37.60	18.84	0.31	-	42.55	0.24	-	0.04	100	1850	80.1	0.44
408611Hol3	0.16	0.27	-	0.01	37.60	18.84	0.31	-	42.55	0.24	-	0.04	100	1850	80.1	0.44
408611Hol4	0.21	0.21	-	0.01	38.46	14.87	0.29	-	45.66	0.28	0.01	0.01	100	2162	84.6	0.33
408611Iol7a	0.06	0.19	-	-	38.44	14.61	0.27	-	46.16	0.24	0.02	0.01	100	1894	84.9	0.32
408611Lol3	0.07	0.18	-	-	38.63	14.64	0.26	-	45.88	0.28	0.03	0.02	100	2202	84.8	0.32
408611Lol3	0.07	0.18	-	-	38.63	14.64	0.26	-	45.88	0.28	0.03	0.02	100	2202	84.8	0.32
408611Lol3	0.07	0.18	-	-	38.63	14.64	0.26	-	45.88	0.28	0.03	0.02	100	2202	84.8	0.32
408611Lol6	0.12	0.11	-	-	39.30	10.21	0.30	-	49.48	0.42	0.02	0.04	100	3277	89.6	0.21

Table A8.1: Continued

Olivine phenocryst major element compositions of 408624 expressed as wt.% oxides (n=33)

Ol. ID	Al_2O_3	MnO	K_2O	Na_2O	SiO_2	FeO	CaO	SO_3	MgO	NiO	TiO_2	Cr_2O_3	Total	Ni ppm	Fo%	FeO/MgO
408624Aol2	0.04	0.16	-	0.01	40.09	12.48	0.28	-	46.61	0.28	0.01	0.04	100	2209	86.9	0.27
408624Aol3	0.03	0.17	-	0.01	40.06	13.14	0.32	-	45.96	0.24	0.01	0.05	100	1911	86.2	0.29
408624Bol2	0.05	0.22	-	-	40.39	12.72	0.27	-	46.05	0.27	-	0.02	100	2100	86.6	0.28
408624Dol2a	0.06	0.16	-	0.00	39.31	12.22	0.35	-	47.55	0.27	-	0.07	100	2115	87.4	0.26
408624Dol2b	0.05	0.15	-	0.02	38.91	12.32	0.32	-	47.89	0.28	-	0.06	100	2189	87.4	0.26
408624Dol3	0.06	0.16	-	0.01	39.14	13.09	0.32	-	46.88	0.27	-	0.07	100	2101	86.5	0.28
408624Fol1.1	0.05	0.18	-	-	38.61	13.76	0.32	-	46.74	0.27	0.02	0.04	100	2158	85.8	0.29
408624Fol7.1	0.04	0.21	-	-	38.54	13.58	0.32	-	46.97	0.28	0.01	0.06	100	2215	86.0	0.29
408624Fol2a.1	0.07	0.16	-	-	38.65	14.03	0.36	-	46.37	0.28	0.01	0.07	100	2180	85.5	0.30
408624Gol3.1	0.04	0.17	-	-	39.24	12.77	0.29	-	47.21	0.23	-	0.03	100	1820	86.8	0.27
408624Gol6a.1	0.03	0.16	-	-	39.76	12.21	0.31	-	47.25	0.24	-	0.04	100	1858	87.3	0.26
408624Hol7.1	0.18	0.18	-	-	38.56	13.43	0.29	-	47.09	0.26	-	0.01	100	2008	86.2	0.29
408624Hol4.1	0.04	0.19	-	-	38.39	14.66	0.31	-	46.10	0.24	-	0.06	100	1909	84.9	0.32
408624Hol2.1	0.03	0.17	-	-	39.49	11.58	0.28	-	48.08	0.32	0.01	0.05	100	2509	88.1	0.24
408624Hol1.1	0.05	0.15	-	-	39.04	11.44	0.27	-	48.65	0.33	-	0.07	100	2604	88.3	0.24
408624Hol1a.1	0.04	0.13	-	-	39.18	11.57	0.27	-	48.36	0.33	0.02	0.10	100	2576	88.2	0.24
408624Aol1	0.04	0.16	0.01	-	40.34	11.89	0.30	-	46.95	0.22	0.01	0.06	100	1744	87.6	0.25
408624Bol3	0.05	0.18	0.01	0.01	40.20	12.54	0.32	-	46.35	0.29	0.01	0.04	100	2314	86.8	0.27
408624Bol4	0.03	0.19	-	0.01	40.07	12.86	0.30	0.01	46.21	0.25	0.03	0.06	100	1930	86.5	0.28
408624Col1	0.02	0.17	0.01	0.01	39.46	12.05	0.28	-	47.64	0.28	-	0.08	100	2182	87.6	0.25

Table A8.2: Olivine (Ol.) phenocryst compositions from ankaramite 408624 (expressed as wt.% oxides) obtained by electron microprobe using the JEOL JXA-8200 Superprobe at the Department of Geography and Geology - Geology Section (University of Copenhagen) and the Cameca SX-50 at Oregon State University. 'n' denotes number of ol. analyzed, each analysis represents an average of 3.

Appendix A8: Continued

Ol. ID	Al_2O_3	MnO	K_2O	Na_2O	SiO_2	FeO	CaO	SO_3	MgO	NiO	TiO_2	Cr_2O_3	Total	Ni ppm	Fo%	FeO/MgO
408624Dol1	0.03	0.16	0.01	0.01	39.97	13.72	0.28	-	45.49	0.28	0.01	0.03	100	2193	85.5	0.30
408624Dol4a	0.12	0.17	-	0.02	38.70	12.82	0.34	-	47.54	0.21	0.01	0.07	100	1659	86.9	0.27
408624Dol4b	0.54	0.20	-	0.01	38.84	12.90	0.36	-	46.84	0.23	0.01	0.08	100	1805	86.6	0.28
408624Iol1	0.10	0.22	-	-	37.83	18.59	0.21	-	42.82	0.20	-	0.01	100	1566	80.4	0.43
408624Iol2a	0.06	0.16	-	0.01	38.81	12.96	0.33	-	47.40	0.24	0.01	0.04	100	1901	86.7	0.27
408624Iol2b	0.08	0.16	-	-	38.99	12.93	0.34	-	47.22	0.24	-	0.05	100	1866	86.7	0.27
408624Iol3	0.86	0.21	-	0.10	37.95	19.39	0.71	-	40.42	0.19	0.14	0.04	100	1473	78.8	0.48
408624Iol4.1	3.69	0.19	-	0.15	36.47	17.06	1.86	-	40.39	0.17	-	0.01	100	1328	80.8	0.42
408624Iol4.2	0.05	0.23	-	-	37.95	19.14	0.22	-	42.23	0.16	0.01	-	100	1260	79.7	0.45
408624Iol5a	0.04	0.15	-	0.01	38.99	11.90	0.30	-	48.27	0.30	-	0.04	100	2338	87.9	0.25
408624Iol5b	0.08	0.15	-	0.01	38.74	13.20	0.27	-	47.18	0.28	0.01	0.07	100	2227	86.4	0.28
408624Eol1	0.02	0.31	0.01	-	38.62	20.25	0.29	-	40.29	0.17	0.01	0.03	100	1341	78.0	0.50
408624Eol2	0.05	0.17	-	0.01	40.04	12.95	0.27	-	46.19	0.25	0.02	0.05	100	1955	86.4	0.28

Table A8.2: Continued

Olivine phenocryst major element compositions of 408772 expressed as wt.% oxides (n=73)

Ol. ID	Al_2O_3	MnO	K_2O	Na_2O	SiO_2	FeO	CaO	SO_3	MgO	NiO	TiO_2	Cr_2O_3	Total	Ni ppm	Fo%	FeO/MgO
208772A2o6a	0.08	0.16	-	0.00	38.44	13.98	0.30	-	46.75	0.26	-	0.02	100.00	2012	85.6	0.29
208772A2ol1	0.05	0.18	-	0.01	38.52	14.69	0.29	-	45.98	0.26	0.01	-	100.00	2076	84.8	0.30
208772A2ol11	0.05	0.16	-	0.00	38.44	14.52	0.29	-	46.29	0.24	-	0.01	100.00	1872	85.0	0.32
208772A2ol2a	0.05	0.19	-	0.01	38.30	16.29	0.29	-	44.65	0.22	0.01	-	100.00	1761	83.0	0.31
208772A2ol2b	0.06	0.25	-	0.01	37.93	16.28	0.29	-	44.95	0.22	-	-	100.00	1761	83.1	0.36
208772A2ol3	0.05	0.18	-	0.01	38.37	14.91	0.28	-	45.94	0.24	-	0.02	100.00	1897	84.6	0.36
208772A2ol4a	0.04	0.18	-	0.01	38.40	14.92	0.29	-	45.95	0.21	0.01	-	100.00	1682	84.6	0.32
208772B2ol10	0.10	0.16	-	0.01	38.53	13.82	0.29	-	46.80	0.26	-	0.02	100.00	2058	85.8	0.32
208772B2ol3a	0.06	0.16	-	0.01	38.29	14.05	0.28	-	46.86	0.26	-	0.02	100.00	2064	85.6	0.30
208772B2ol3b	0.05	0.15	-	0.01	38.63	13.97	0.27	-	46.62	0.29	-	0.01	100.00	2276	85.6	0.30
208772B2ol5a	0.06	0.18	-	0.01	38.98	13.86	0.30	-	46.31	0.26	0.01	0.03	100.00	2023	85.6	0.30
208772B2ol7a	0.07	0.16	-	0.01	38.79	13.92	0.29	-	46.45	0.28	-	0.02	100.00	2224	85.6	0.30
208772B2ol7b	0.08	0.18	-	0.01	38.46	14.45	0.33	-	46.22	0.24	-	0.04	100.00	1869	85.1	0.30
408772Aol1	0.04	0.24	-	-	40.26	13.80	0.29	-	45.07	0.23	0.02	0.04	100.00	1833	85.3	0.31
408772Aol1	0.03	0.20	0.01	-	39.58	11.23	0.26	0.01	48.24	0.29	0.04	0.12	100.00	2284	88.5	0.31
408772Aol2	0.03	0.23	-	-	39.60	15.72	0.28	-	43.89	0.22	-	0.02	100.00	1702	83.3	0.23
408772Aol2	0.09	0.15	-	0.02	39.25	12.33	0.26	-	47.47	0.33	0.01	0.07	100.00	2590	87.3	0.36
408772Aol3	0.06	0.15	-	0.01	40.10	14.23	0.32	-	44.87	0.20	0.01	0.04	100.00	1588	84.9	0.26
408772Bol4	0.05	0.17	0.01	-	39.96	13.05	0.28	-	46.13	0.28	0.03	0.03	100.00	2223	86.3	0.32
408772Bol7	0.05	0.22	-	0.01	40.10	13.16	0.32	-	45.83	0.26	0.01	0.03	100.00	2068	86.1	0.28

Table A8.3: Olivine (Ol.) phenocryst compositions from ankaramite 408772 (expressed as wt.% oxides) obtained by electron microprobe using the JEOL JXA-8200 Superprobe at the Department of Geography and Geology - Geology Section (University of Copenhagen) and the Cameca SX-50 at Oregon State University. 'n' denotes number of ol. analyzed, each analysis represents an average of 3.

Appendix A8: Continued

Ol. ID	Al_2O_3	MnO	K_2O	Na_2O	SiO_2	FeO	CaO	SO_3	MgO	NiO	TiO_2	Cr_2O_3	Total	Ni ppm	Fo%	FeO/MgO
408772Col3	0.03	0.21	-	-	39.64	13.72	0.28	0.01	45.79	0.24	0.03	0.05	100.00	1917	85.6	0.29
408772Dol1	0.05	0.25	0.01	0.01	39.73	14.05	0.25	0.01	45.34	0.26	0.02	0.02	100.00	2012	85.2	0.30
408772Dol5	0.04	0.21	0.01	0.01	39.71	13.67	0.28	-	45.77	0.27	-	0.04	100.00	2085	85.6	0.31
408772Dol7	0.07	0.17	0.01	0.01	39.68	13.05	0.26	-	46.42	0.26	0.01	0.08	100.00	2024	86.4	0.30
408772Dol8	0.03	0.21	-	0.02	39.69	13.59	0.28	-	45.85	0.26	0.02	0.04	100.00	2060	85.7	0.28
408772Dol10	0.04	0.19	0.01	0.02	39.60	13.44	0.27	-	46.15	0.25	0.01	0.02	100.00	1971	86.0	0.30
408772Gol1	0.04	0.27	-	0.01	40.32	14.09	0.28	0.01	44.68	0.25	0.01	0.03	100.00	1992	85.0	0.29
408772Gol3	0.02	0.14	-	-	40.57	13.31	0.30	0.01	45.37	0.23	0.02	0.04	100.00	1800	85.9	0.32
408772Gol5	0.03	0.09	-	0.02	40.48	12.67	0.29	-	46.00	0.31	0.03	0.07	100.00	2458	86.6	0.29
408772Gol8	0.08	0.20	0.01	0.01	40.28	13.62	0.30	0.01	45.13	0.28	0.03	0.06	100.00	2162	85.5	0.28
408772Bol1	0.05	0.12	0.01	0.02	40.71	10.67	0.25	-	47.70	0.37	-	0.10	100.00	2926	88.9	0.30
408772Bol2	0.05	0.14	-	0.02	39.94	14.04	0.28	-	45.26	0.22	0.02	0.03	100.00	1713	85.2	0.22
408772Bol3	0.05	0.21	-	0.01	40.04	12.96	0.30	-	46.11	0.26	0.01	0.06	100.00	2070	86.4	0.31
408772Bol5	0.06	0.17	-	-	40.13	13.83	0.29	0.01	45.20	0.24	0.02	0.03	100.00	1913	85.3	0.28
408772Bol6	0.05	0.20	0.02	-	39.86	14.02	0.31	-	45.21	0.24	0.05	0.04	100.00	1891	85.2	0.31
408772Bol8	0.06	0.23	0.00	0.01	40.12	12.99	0.26	-	46.03	0.26	-	0.05	100.00	2024	86.3	0.31
408772Col1	0.03	0.24	0.01	-	39.55	13.50	0.30	-	46.04	0.29	-	0.04	100.00	2260	85.9	0.28
408772Col2	0.06	0.19	-	-	39.80	13.63	0.29	-	45.70	0.28	0.01	0.03	100.00	2227	85.7	0.29
408772Dol2	0.06	0.15	-	-	39.80	13.46	0.29	-	45.91	0.24	0.01	0.06	100.00	1897	85.9	0.30
408772Dol3	0.05	0.19	-	-	39.83	13.26	0.28	0.01	46.06	0.29	-	0.02	100.00	2277	86.1	0.29
408772Dol4	0.06	0.20	-	-	39.54	13.74	0.30	-	45.84	0.27	0.01	0.02	100.00	2152	85.6	0.29
408772Dol6	0.10	0.20	0.01	-	39.97	12.71	0.29	-	46.39	0.29	0.01	0.04	100.00	2246	86.7	0.30
408772Dol9	0.11	0.21	0.01	0.01	39.84	13.68	0.27	-	45.53	0.28	0.01	0.05	100.00	2229	85.6	0.27
408772Eol1	0.06	0.23	-	0.02	39.51	13.71	0.30	0.01	45.91	0.22	-	0.04	100.00	1758	85.7	0.30
408772Eol2	0.04	0.20	0.01	0.02	40.09	12.14	0.26	0.01	46.94	0.25	-	0.04	100.00	1933	87.3	0.30

Table A8.3: Continued

Appendix A8: Continued

Ol. ID	Al_2O_3	MnO	K_2O	Na_2O	SiO_2	FeO	CaO	SO_3	MgO	NiO	TiO_2	Cr_2O_3	Total	Ni ppm	Fo%	FeO/MgO
408772Eol3	0.06	0.24	-	0.01	39.93	12.76	0.30	-	46.32	0.29	0.03	0.05	100.00	2288	86.6	0.26
408772Eol4	0.05	0.19	-	-	39.37	13.64	0.28	0.01	46.20	0.23	0.02	0.02	100.00	1803	85.8	0.28
408772Eol5	0.06	0.17	0.01	-	40.01	13.22	0.28	0.01	45.88	0.27	0.03	0.05	100.00	2109	86.1	0.30
408772Eol6	0.06	0.12	-	0.01	40.40	10.05	0.20	-	48.65	0.40	0.03	0.09	100.00	3104	89.6	0.29
408772Eol7	0.05	0.13	0.02	-	39.81	13.07	0.29	0.01	46.30	0.25	0.03	0.03	100.00	1929	86.3	0.21
408772Eol8	0.06	0.18	-	0.01	39.57	13.60	0.30	-	45.99	0.24	-	0.04	100.00	1857	85.8	0.28
408772Eol9	0.07	0.19	-	-	39.70	13.63	0.27	-	45.82	0.26	0.01	0.03	100.00	2076	85.7	0.30
408772Gol4	0.04	0.28	-	-	40.51	13.46	0.31	-	45.08	0.26	0.01	0.03	100.00	2038	85.7	0.30
408772Gol2	0.04	0.19	-	-	40.54	13.89	0.28	-	44.77	0.24	-	0.05	100.00	1862	85.2	0.30
408772iol1	0.08	0.19	-	0.01	39.61	14.13	0.28	0.01	45.39	0.23	0.02	0.04	100.00	1847	85.1	0.31
408772iol2	0.05	0.21	0.01	0.01	40.14	13.17	0.27	-	45.82	0.25	0.02	0.05	100.00	1973	86.1	0.31
408772iol3	0.03	0.21	-	-	39.54	14.30	0.20	-	45.43	0.23	0.01	0.04	100.00	1806	85.0	0.29
208772A2o4b	0.11	0.18	-	-	38.19	14.75	0.29	-	46.22	0.22	0.01	0.01	100.00	1714	84.8	0.31
208772A2ol12	0.11	0.16	-	-	38.79	12.97	0.30	-	47.32	0.32	0.01	0.01	100.00	2553	86.7	0.32
208772A2ol13	0.06	0.16	-	0.02	38.59	13.81	0.29	-	46.77	0.28	-	0.02	100.00	2183	85.8	0.27
208772A2o6b	0.06	0.16	-	0.01	38.40	13.96	0.30	-	46.78	0.29	-	0.02	100.00	2306	85.7	0.30
208772A2ol7	0.06	0.18	-	0.01	39.01	14.08	0.29	-	46.11	0.24	-	0.02	100.00	1897	85.4	0.30
208772Abol2.1	0.05	0.16	-	0.01	38.37	14.34	0.28	-	46.48	0.28	0.01	0.01	100.00	2211	85.2	0.31
208772B2ol6	0.08	0.16	-	-	38.66	13.80	0.30	-	46.72	0.26	-	0.01	100.00	2020	85.8	0.31
208772B2ol3c	0.05	0.15	-	0.01	38.62	13.49	0.28	-	47.04	0.28	-	0.07	100.00	2212	86.1	0.30
208772B2ol11	0.04	0.18	-	0.01	38.94	13.58	0.29	-	46.72	0.23	-	-	100.00	1842	86.0	0.29
208772B2ol1a	0.05	0.17	-	0.01	38.47	14.47	0.30	-	46.26	0.24	-	0.03	100.00	1915	85.1	0.29
208772B2ol1b	0.06	0.19	-	0.01	38.44	14.63	0.28	-	46.11	0.27	-	-	100.00	2143	84.9	0.31
208772B2ol4	0.05	0.17	-	0.01	38.85	14.10	0.30	-	46.24	0.26	0.01	0.02	100.00	2009	85.4	0.32
408772A2ol8	0.06	0.17	-	0.02	38.73	12.98	0.34	-	47.40	0.24	0.01	0.07	100.00	1877	86.7	0.31
408772A2ol14	0.05	0.17	-	-	38.65	13.34	0.27	-	47.16	0.30	0.01	0.04	100.00	2342	86.3	0.27
408772Gol6	0.07	0.19	0.01	-	39.92	14.08	0.30	-	45.13	0.25	0.02	0.04	100.00	1941	85.1	0.28
408772Gol7	0.05	0.23	0.01	0.01	40.47	13.45	0.27	-	45.20	0.24	0.01	0.07	100.00	1869	85.7	0.31

Table A8.3: Continued

Average olivine phenocryst composition of 408611 (n=62)

	Al_2O_3	MnO	K_2O	Na_2O	SiO_2	FeO	CaO	SO_3	MgO	NiO	TiO_2	Cr_2O_3	Total	Ni ppm	Fo%	FeO/MgO
Average	0.07	0.21	0.00	0.01	39.10	14.60	0.26	0.00	45.42	0.27	0.02	0.04	100.00	2147	84.7	0.32
±2SD	0.09	0.10	0.01	0.01	1.69	5.07	0.07	0.01	4.04	0.13	0.02	0.04	0.00	1007	5.59	0.14
Max wt.%	0.22	0.32	0.01	0.03	40.45	19.08	0.33	0.01	49.55	0.42	0.05	0.09	100.00	3277	90.34	0.45
Min wt.%	0.01	0.10	0.00	0.00	37.25	9.38	0.19	0.00	41.87	0.14	0.00	0.00	100.00	1070	79.93	0.19

Average olivine phenocryst composition of 408624 (n=33)

	Al_2O_3	MnO	K_2O	Na_2O	SiO_2	FeO	CaO	SO_3	MgO	NiO	TiO_2	Cr_2O_3	Total	Ni ppm	Fo%	FeO/MgO
Average	0.20	0.18	0.00	0.01	39.07	13.70	0.30	0.00	46.16	0.25	0.01	0.05	100.00	1986	85.68	0.30
±2SD	1.30	0.07	0.01	0.06	1.70	4.75	0.07	0.00	4.55	0.09	0.05	0.05	0.00	682	5.54	0.14
Max wt.%	3.69	0.31	0.01	0.15	40.39	20.25	0.36	0.01	48.65	0.33	0.14	0.10	100.00	2604	88.35	0.50
Min wt.%	0.02	0.13	0.00	0.00	36.47	11.44	0.21	0.00	40.29	0.16	0.00	0.00	100.00	1260	78.01	0.24

Average olivine phenocryst composition of 408772 (n=73)

	Al_2O_3	MnO	K_2O	Na_2O	SiO_2	FeO	CaO	SO_3	MgO	NiO	TiO_2	Cr_2O_3	Total	Ni ppm	Fo%	FeO/MgO
Average	0.06	0.19	0.00	0.01	39.41	13.67	0.29	0.00	46.08	0.26	0.01	0.04	100.00	2052	85.7	0.30
±2SD	0.04	0.07	0.01	0.01	1.49	1.94	0.04	0.01	1.65	0.07	0.02	0.05	0.00	523	2.04	0.05
Max wt.%	0.11	0.28	0.02	0.02	40.71	16.29	0.34	0.01	48.65	0.40	0.05	0.12	100.00	3104	89.61	0.36
Min wt.%	0.02	0.09	0.00	0.00	37.93	10.05	0.20	0.00	43.89	0.20	0.00	0.00	100.00	1588	83.01	0.21

Table A8.4: Summary table of average olivine phenocryst compositions of each of the three Vestfirdir ankaramites (408611, 408624, and 408772) presented in Table A8.1, A8.2, and A8.3, respectively. 'n' gives the number of olivine phenocrysts analyzed. Average wt.% is given, and the ±2SD standard error on each of the three ol. averages. The compositional range is given by the maximum (Max. wt.%) and minimum (Min. wt.%) wt.% of the each elements analyzed.

Appendix A8: Continued

Major element concentrations (oxide wt.%) of clinopyroxene phenocrysts of the Vestfirdir ankaramites (n=21)

Cpx. ID	Al_2O_3	MnO	K_2O	Cl	Na_2O	SiO_2	FeO	CaO	SO_3	MgO	NiO	TiO_2	Cr_2O_3	Total	Mg#	Ni ppm	CaO/Al_2O
408407-a	3.74	0.15	-	-	0.29	51.89	5.31	20.72	-	16.82		0.47	0.62	100	85.0	-	5.54
408407-b	3.90	0.05	-	-	0.28	51.50	5.13	21.19	0.01	16.95	0.01	0.46	0.53	100	85.5	63	5.43
408407-c	3.81	0.17	-	-	0.30	51.71	5.02	20.88	-	16.85	0.06	0.53	0.68	100	85.7	454	5.47
408407-d	3.74	0.09	0.01	0.01	0.33	51.66	5.24	20.86	-	16.80	0.10	0.50	0.66	100	85.1	794	5.58
408407-e	3.63	0.09	-	-	0.26	51.68	4.51	21.29	0.02	16.66	0.03	0.62	1.20	100	86.8	258	5.87
408407-f	2.74	0.14	-	0.01	0.22	52.43	4.40	21.19	-	17.83	0.02	0.43	0.58	100	87.8	164	7.73
408407-g	3.11	0.17	-	-	0.21	52.32	4.49	21.25	0.02	17.37		0.53	0.53	100	87.3	-	6.82
408407-h	2.96	0.14	-	-	0.22	52.70	4.51	20.55	-	17.96	0.06	0.34	0.57	100	87.7	453	6.94
408407-i	2.78	0.13	0.01	0.01	0.22	52.23	5.61	20.94	0.02	17.11	0.02	0.70	0.26	100	84.5	126	7.54
408407-j	3.48	0.06	-	-	0.24	52.32	4.88	20.33	-	17.60	0.06	0.44	0.60	100	86.5	454	5.85
408407-k	3.59	0.16	-	-	0.28	52.06	4.70	20.45	0.01	17.70		0.43	0.63	100	87.0	-	5.70
408407-l	3.48	0.10	-	-	0.22	52.19	4.68	20.51	0.01	17.66	0.09	0.51	0.55	100	87.1	714	5.90
408407-n	3.87	0.23	0.01	-	0.22	51.12	4.40	21.65	0.03	16.51	0.06	0.67	1.24	100	87.0	486	5.60
408407-o	3.14	0.18	-	-	0.20	51.85	5.90	21.03	0.02	16.65		0.85	0.19	100	83.4	-	6.70
408419-a	5.17	0.15	-	0.01	0.32	50.74	4.61	20.74	-	16.56	0.05	0.58	1.06	100	86.5	383	4.01
408419-b	5.11	0.15	-	-	0.31	50.42	4.77	20.79	-	16.63	0.04	0.58	1.20	100	86.2	288	4.06
408419-c	4.59	0.14	-	-	0.29	50.86	4.79	20.93	-	17.07	0.03	0.57	0.73	100	86.4	257	4.56
408419-d	4.97	0.08	-	-	0.28	50.84	4.82	20.67	-	16.68	0.02	0.58	1.06	100	86.0	133	4.16
408419-e	5.32	0.07	-	-	0.33	50.31	5.02	20.59	-	16.59	0.05	0.57	1.15	100	85.5	418	3.87

Ave. Cpx.	Al_2O_3	MnO	K_2O	Cl	Na_2O	SiO_2	FeO	CaO	SO_3	MgO	NiO	TiO_2	Cr_2O_3	Total	Mg#	Ni ppm	CaO/Al2
Ave.	3.85	0.13	0.00	0.01	0.26	51.62	4.88	20.87	0.01	17.05	0.05	0.54	0.74	100	86.16	287	5.65
±2SD	1.63	0.09	0.00	0.01	0.09	1.43	0.82	0.67	0.02	0.96	0.05	0.23	0.64	-	2.29	480	2.32
Max	5.32	0.23	0.01	0.01	0.33	52.70	5.90	21.65	0.03	17.96	0.10	0.85	1.24	100	87.83	794	7.73
Min wt.%	2.74	0.05	-	-	0.20	50.31	4.40	20.33	-	16.51	0.01	0.34	0.19	100	83.42	63	3.87

Table A8.5: Clinopyroxene (Cpx.) phenocryst compositions of ankaramite 408772 (expressed as wt.% oxides) obtained by electron microprobe using the JEOL JXA-8200 Superprobe at the Department of Geography and Geology - Geology Section (University of Copenhagen) and the Cameca SX-50 at Oregon State University.

Appendix A8: Continued

Trace element concentrations of clinopyroxene phenocryst cores (ppm), (n=17)

Cpx. ID	408624-1	408624-2	408624-3	408624-4	408624-5	408624-6	408772-1	408772-2	408772-3	408772-4	408772-5	408772-6	408611-1	408611-2	408611-3	408611-4	408611-5
Sc	77.69	90.75	82.26	79.27	95.75	72.90	79.36	81.03	97.70	81.17	75.83	84.25	107.29	87.58	113.35	104.93	98.45
Ti	3357	3417	3049	2658	3496	2831	2918	2753	3909	3277	2719	3295	3200	2234	3338	3355	2706
Sr	22.62	18.26	18.57	19.86	19.45	20.09	20.49	18.82	18.47	21.05	20.42	23.20	15.50	12.99	13.98	15.25	13.81
Y	9.30	8.71	8.94	7.52	10.16	7.89	8.26	7.48	12.60	8.90	7.23	8.60	11.26	8.57	12.69	12.56	10.15
Zr	10.12	9.42	8.18	8.18	10.47	8.39	8.90	7.78	11.65	10.56	7.90	9.81	13.05	7.27	13.74	12.99	10.77
Nb	0.17	-	-	0.04	-	-	0.04	0.05	-	-	-	0.04	0.05	-	0.04	0.04	-
La	0.41	0.36	0.29	0.27	0.34	0.29	0.35	0.28	0.53	0.36	0.31	0.48	0.59	0.34	0.51	0.62	0.49
Ce	1.87	1.61	1.42	1.20	1.68	1.45	1.67	1.35	2.53	1.60	1.47	2.19	2.98	2.00	2.93	3.02	2.38
Pr	0.42	0.39	0.37	0.31	0.41	0.35	0.37	0.30	0.59	0.38	0.37	0.48	0.58	0.41	0.59	0.61	0.46
Nd	2.77	2.49	2.43	1.92	2.81	2.40	2.48	2.08	3.64	2.43	2.25	3.11	3.42	2.39	3.45	3.50	2.75
Sm	1.13	1.01	0.97	0.94	1.18	1.01	1.20	0.99	1.53	1.17	0.93	1.22	1.19	1.05	1.34	1.32	1.14
Eu	0.43	0.41	0.37	0.36	0.45	0.39	0.37	0.35	0.56	0.43	0.36	0.46	0.56	0.35	0.61	0.55	0.43
Gd	1.63	1.63	1.60	1.54	1.62	1.61	1.47	1.49	2.47	1.67	1.43	1.59	1.91	1.65	2.12	2.15	1.79
Dy	1.79	1.69	1.90	1.56	2.28	1.50	1.59	1.53	2.46	1.74	1.47	1.74	2.11	1.64	2.30	2.47	1.91
Er	0.91	0.78	0.89	0.72	1.02	0.84	0.86	0.73	1.30	0.93	0.70	0.88	1.28	0.89	1.43	1.24	1.09
Yb	0.77	0.67	0.80	0.65	0.80	0.58	0.54	0.67	0.92	0.70	0.45	0.67	1.00	0.68	1.08	1.08	0.85
Hf	0.37	0.39	0.35	0.42	0.41	0.41	0.42	0.39	0.53	0.47	0.34	0.53	0.63	0.35	0.52	0.63	0.54

Table A8.6a: Trace element compositions (ppm) of clinopyroxene phenocryst cores of the Vestfirdir ankaramites obtained by LA-ICPMS using the VG Element Excell quadrupole ICPMS fitted with a NewWave DUV 193nm ARF Excimer laser at Oregon State University.

Appendix A8: Continued

Trace element concentration of clinopyroxene phenocryst rims (ppm), (n=17)

Cpx. ID	408624-1	408624-2	408624-3	408624-4	408624-5	408624-6	408772-1	408772-2	408772-3	408772-4	408772-5	408772-6	408611-1	408611-2	408611-3	408611-4	408611-5
Sc	76.05	81.63	87.25	79.27	80.32	77.49	80.17	79.81	112.30	82.10	85.40	73.41	108.31	85.29	112.60	112.53	92.81
Ti	2825	3137	3246	2833	2775	3151	3047	2388	4872	3339	3134	2771	4200	2214	3376	3871	3080
Sr	19.21	19.44	19.65	20.75	17.40	21.00	21.05	16.85	20.08	21.45	19.94	20.67	16.50	13.07	14.10	14.83	14.48
Y	8.08	8.32	9.88	8.03	7.83	9.08	8.18	7.41	14.62	9.30	8.82	7.05	16.81	8.74	12.46	16.00	13.45
Zr	7.15	7.99	10.75	9.21	6.36	8.90	9.61	6.27	16.17	10.65	9.39	8.05	15.63	6.95	13.72	14.59	9.13
Nb	-	0.02	0.03	-	-	0.04	0.04	-	-	-	-	0.04	0.05	-	0.06	0.05	-
La	0.24	0.30	0.33	0.27	0.28	0.33	0.40	0.21	0.66	0.33	0.34	0.35	0.81	0.36	0.60	0.76	0.61
Ce	1.33	1.50	1.59	1.43	1.40	1.71	1.73	1.05	3.17	1.72	1.77	1.67	4.28	1.93	3.05	3.62	2.93
Pr	0.33	0.32	0.39	0.33	0.33	0.42	0.38	0.24	0.71	0.40	0.43	0.36	0.84	0.40	0.60	0.69	0.59
Nd	2.06	2.15	2.76	2.16	2.13	2.69	2.46	1.68	4.58	3.00	2.66	2.50	4.92	2.34	3.47	4.14	3.71
Sm	0.94	0.98	1.13	0.96	1.02	1.12	1.02	0.78	1.87	1.12	1.17	0.92	1.86	1.04	1.31	1.76	1.44
Eu	0.38	0.42	0.43	0.40	0.38	0.48	0.40	0.31	0.63	0.44	0.42	0.34	0.63	0.38	0.57	0.62	0.49
Gd	1.33	1.47	1.77	1.63	1.35	1.53	1.55	1.32	2.62	1.94	1.68	1.16	2.75	1.49	2.15	2.65	2.38
Dy	1.59	1.67	2.03	1.62	1.58	1.86	1.47	1.49	2.91	2.04	1.65	1.43	3.26	1.67	2.41	3.09	2.72
Er	0.74	0.84	0.96	0.82	0.86	0.94	0.77	0.80	1.44	0.93	0.89	0.75	1.69	0.88	1.32	1.68	1.40
Yb	0.60	0.71	0.70	0.61	0.49	0.68	0.57	0.56	1.27	0.75	0.75	0.43	1.38	0.79	1.12	1.31	1.13
Hf	0.36	0.31	0.53	0.36	0.29	0.50	0.38	0.35	0.69	0.47	0.42	0.33	0.78	0.36	0.69	0.68	0.43

Table A8.6a: Continued. Trace element compositions (ppm) of clinopyroxene phenocryst rims of the Vestfirdir ankaramites obtained by LA-ICPMS using the VG Element Excell quadrupole ICPMS fitted with a New Wave DUV 193nm ARF Excimer laser at Oregon State University.

Average clinopyroxene core composition				
n=17	$Core_{Ave}$	±2SD	Max	Min
Trace element concentrations (ppm)				
Sc	88.80	24.17	113.35	72.90
Ti	3089	814	3909	2234
Sr	18.40	6.14	23.20	12.99
Y	9.46	3.65	12.69	7.23
Zr	9.95	3.99	13.74	7.27
Nb	0.06	0.09	0.17	0.04
La	0.40	0.23	0.62	0.27
Ce	1.96	1.21	3.02	1.20
Pr	0.44	0.20	0.61	0.30
Nd	2.72	1.05	3.64	1.92
Sm	1.14	0.32	1.53	0.93
Eu	0.44	0.17	0.61	0.35
Gd	1.73	0.56	2.47	1.43
Dy	1.86	0.68	2.47	1.47
Er	0.97	0.44	1.43	0.70
Yb	0.76	0.36	1.08	0.45
Hf	0.45	0.19	0.63	0.34

Average clinopyroxene rim composition				
n=17	Rim_{Ave}	±2SD	Max	Min
Trace element concentrations (ppm)				
Sc	88.63	27.60	112.60	73.41
Ti	3192	1286	4872	2214
Sr	18.26	5.57	21.45	13.07
Y	10.24	6.30	16.81	7.05
Zr	10.03	6.35	16.17	6.27
Nb	0.04	0.03	0.06	0.02
La	0.42	0.38	0.81	0.21
Ce	2.11	1.86	4.28	1.05
Pr	0.46	0.33	0.84	0.24
Nd	2.91	1.88	4.92	1.68
Sm	1.20	0.67	1.87	0.78
Eu	0.45	0.20	0.63	0.31
Gd	1.81	1.03	2.75	1.16
Dy	2.03	1.22	3.26	1.43
Er	1.04	0.65	1.69	0.74
Yb	0.81	0.61	1.38	0.43
Hf	0.47	0.31	0.78	0.29

Table A8.6c: Summary table of average core and rim compositions of the Vestfirdir clinopyroxene phenocryst compositions presented in Table A8.6a and A8.6b. 'n' gives the number of clinopyroxene phenocrysts analyzed. Average ppm is given, and the ±2SD standard error on the core and rim averages. The compositional range is given by the maximum (Max. ppm) and minimum (Min. ppm) ppm of the each elements analyzed.

Appendix A9: Vestfirdir ankaramites – olivine-hosted MI data

MI ID	Ami14	Bmi4	Bmi5	Cmi6	Emi1	F+mi1	G+mi1	Imi11	Imi5	Imi7	Jmi1.2	Jmi3	Jmi7	Jmi8	Jmi9	Lmi3	Lmi4	Lmi6
Rock ID	408611	408611	408611	408611	408611	408611	408611	408611	408611	408611	408611	408611	408611	408611	408611	408611	408611	408611
Major element concentrations (oxide wt.%)																		
Al_2O_3	14.59	18.30	13.08	13.82	15.22	12.18	13.61	15.64	13.93	12.51	14.14	12.32	15.08	16.28	13.10	14.41	13.15	15.63
MnO	0.18	0.13	0.11	0.16	0.21	0.11	0.16	0.07	0.16	0.21	0.13	0.17	0.17	0.15	0.16	0.17	0.21	0.09
K_2O	0.13	0.15	0.42	0.09	0.18	0.09	0.08	0.08	0.38	0.20	0.09	0.51	0.20	0.48	0.15	0.48	0.02	0.24
Cl	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.00	0.01	0.00	0.02	0.00	0.02	0.00	0.01
Na_2O	2.29	2.67	3.40	2.19	1.89	2.79	1.97	2.04	2.04	1.45	2.01	1.94	1.80	1.67	1.81	1.84	1.47	1.75
SiO_2	49.07	48.63	51.52	49.55	47.56	50.94	48.65	50.36	49.58	49.27	52.75	49.94	50.03	48.53	52.78	52.08	46.21	51.83
FeO	9.21	8.22	9.32	9.08	12.53	10.08	10.49	6.79	11.59	12.00	9.34	11.39	10.35	11.90	7.89	8.89	14.01	6.01
CaO	12.49	12.07	10.13	12.35	10.31	10.83	11.96	12.04	9.22	12.05	12.81	9.92	11.94	9.51	10.73	10.15	8.61	13.07
SO_3	0.07	0.04	0.09	0.07	0.07	0.05	0.07	0.09	0.10	0.04	0.05	0.07	0.08	0.13	0.07	0.07	0.07	0.06
MgO	10.52	8.86	9.14	11.22	10.43	11.78	11.91	11.66	10.76	10.69	7.55	10.89	8.82	7.70	10.88	9.01	13.40	9.09
NiO	0.01	0.03	0.01	0.01	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TiO_2	1.14	0.76	2.71	1.20	1.55	0.86	0.90	1.04	1.73	1.31	0.93	2.35	1.33	2.93	1.95	2.27	1.60	1.51
Cr_2O_3	0.30	0.14	0.06	0.23	0.02	0.18	0.12	0.09	0.03	0.16	0.12	0.07	0.01	0.03	0.22	0.13	0.07	0.17
P_2O_5	0.00	0.00	0.00	0.00	0.00	0.10	0.06	0.10	0.48	0.10	0.08	0.43	0.20	0.66	0.25	0.50	1.18	0.54
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
±Ol.	-11.00	-9.60	-5.70	-12.80	-7.50	-7.30	-9.30	-12.00	-7.00	-4.80	4.30	-4.40	-5.80	0.00	-3.30	-5.50	-14.50	-4.60

Table A9.1: Major, trace, and volatile element archive of olivine-hosted MIs of 408611 (Vestfirdir ankaramite). Major and volatile (S and Cl) are obtained by electron microprobe using the JEOL JXA-8200 Superprobe at the Department of Geography and Geology – Geology Section (University of Copenhagen) and the Cameca SX-50 at Oregon State University. Trace element composite ons are obtained by LA-ICPMS using the VG element Excell quadrupole ICPMS fitted with a New Wave DUV 193nm ARF Excimer laser at Oregon State University. PM normalization is after McDonough & Sun (1995). For details on the ΔNb terminology and boundaries see Fitton et al. (1997), [$\Delta Nb = 1.74 + \log(Nb/Y) - 1.92\log(Zr/Y)$].

Appendix A9: Continued

MI ID	Ami14	Bmi4	Bmi5	Cmi6	Emi1	F+mi1	G+mi1	Imi11	Imi5	Imi7	Jmi1.2	Jmi3	Jmi7	Jmi8	Jmi9	Lmi3	Lmi4	Lmi6
Rock ID	408611	408611	408611	408611	408611	408611	408611	408611	408611	408611	408611	408611	408611	408611	408611	408611	408611	408611
Trace element concentrations (ppm)																		
Sc	35.55	33.37	50.38	32.70	43.23	70.88	45.18	26.85	31.18	-	-	37.52	33.71	23.77	48.66	32.59	54.72	24.87
Ti	6574	4735	15820	6658	9823	5275	5371	5928	10509	-	-	13904	8471	18078	11545	14033	9763	9027
Rb	2.65	-	4.90	1.39	2.16	-	1.01	1.43	5.13	-	-	7.96	2.69	8.77	2.10	8.03	-	3.40
Sr	221.67	614.80	542.81	207.28	388.49	132.76	137.81	142.96	238.92	-	-	247.01	216.08	271.52	221.67	334.04	253.41	258.56
Y	23.21	13.06	30.99	27.46	23.46	19.94	19.65	20.77	24.13	-	-	27.67	23.46	31.15	24.59	24.40	19.98	22.13
Zr	65.94	68.16	296.97	62.69	93.61	64.91	49.71	51.77	175.09	-	-	189.16	78.48	345.13	132.73	203.81	145.51	156.88
Nb	6.15	4.69	26.70	6.16	9.90	6.31	4.45	5.86	15.73	-	-	27.98	8.18	48.95	7.49	31.70	8.81	13.71
Ba	29.71	37.31	114.26	19.38	34.44	17.07	13.57	12.82	66.29	-	-	106.00	33.72	87.56	34.54	95.08	-	54.42
La	5.89	4.75	28.09	5.38	8.18	5.06	3.02	4.62	14.77	-	-	17.74	7.36	23.52	11.92	21.56	13.20	15.10
Ce	15.71	15.29	67.05	14.88	20.80	13.95	11.89	13.61	36.36	-	-	44.08	19.99	65.30	30.18	58.60	42.49	42.17
Pr	2.17	1.68	8.08	2.08	3.01	1.79	1.45	1.63	4.65	-	-	5.30	2.56	7.55	3.49	6.56	4.62	5.43
Nd	10.22	8.07	36.17	10.32	11.47	7.75	5.99	7.12	18.89	-	-	23.46	11.72	30.16	15.91	28.34	19.46	19.81
Sm	2.18	-	6.85	3.50	-	-	1.84	2.05	4.93	-	-	4.92	2.83	6.48	3.70	6.36	-	2.64
Eu	1.05	-	2.33	1.06	1.37	-	0.79	0.71	1.50	-	-	1.71	1.09	1.73	1.45	1.84	1.62	1.47
Gd	3.26	-	7.83	4.06	4.50	-	2.04	2.25	5.12	-	-	4.02	3.60	5.47	4.22	5.22	-	3.09
Dy	4.27	-	6.47	5.09	4.18	-	3.42	3.31	4.09	-	-	4.24	4.02	5.86	3.69	4.99	-	4.25
Er	2.41	-	3.06	2.87	2.65	-	1.82	2.02	2.07	-	-	2.67	2.27	3.32	2.61	2.30	-	2.33
Yb	2.42	-	-	2.96	-	-	1.97	1.56	1.71	-	-	1.65	2.27	2.28	-	2.25	-	1.88
Hf	1.85	-	6.53	1.76	-	-	1.47	1.09	3.46	-	-	4.35	2.62	7.41	2.99	5.37	-	3.53
Ta	0.46	-	1.61	0.41	-	-	-	0.35	1.00	-	-	1.51	0.44	2.44	-	1.97	-	-
Pb	3.35	-	1.74	0.61	1.43	-	0.28	0.26	1.07	-	-	1.39	0.66	1.67	-	1.53	-	1.11
Th	-	-	-	-	-	-	-	-	0.93	-	-	1.52	-	2.60	-	1.38	-	-
U	-	-	-	-	-	-	-	-	0.34	-	-	-	-	0.98	-	0.39	-	-

Table A9.1: continued

Appendix A9: Continued

MI ID	Ami14	Bmi4	Bmi5	Cmi6	Emi1	F+mi1	G+mi1	Imi11	Imi5	Imi7	Jmi1.2	Jmi3	Jmi7	Jmi8	Jmi9	Lmi3	Lmi4	Lmi6
Rock ID	408611	408611	408611	408611	408611	408611	408611	408611	408611	408611	408611	408611	408611	408611	408611	408611	408611	408611
Selected PM-normalized trace element ratios and ΔNb																		
Ce/Sm	1.81	-	2.45	1.06	-	-	1.62	1.66	1.84	-	-	2.24	1.77	2.52	2.04	2.30	-	4.00
La/Y	1.68	2.41	6.00	1.30	2.31	1.68	1.02	1.47	4.05	-	-	4.25	2.08	5.00	3.21	5.85	4.37	4.52
Rb/Sr	0.40	-	0.30	0.22	0.18	-	0.24	0.33	0.71	-	-	1.07	0.41	1.07	0.31	0.80	-	0.44
Sr/Nd	1.39	4.89	0.96	1.29	2.17	1.10	1.48	1.29	0.81	-	-	0.68	1.18	0.58	0.89	0.76	0.84	0.84
Ti/Zr	0.86	0.60	0.46	0.92	0.90	0.70	0.93	0.99	0.52	-	-	0.63	0.93	0.45	0.75	0.59	0.58	0.50
Sm/Nd	0.65	-	0.58	1.03	-	-	0.94	0.88	0.80	-	-	0.64	0.73	0.66	0.71	0.68	-	0.41
Ba/Zr	2.05	4.58	5.91	1.13	2.35	1.37	1.11	0.99	4.40	-	-	6.14	2.30	4.50	2.25	6.25	-	3.94
ΔNb	0.29	-0.08	-0.21	0.40	0.21	0.26	0.32	0.43	-0.10	-	-	0.14	0.28	-0.07	-0.18	0.08	-0.27	-0.10

Table A9.1: continued

MI ID	Ami2	Ami2b	Ami2c	Ami2d	Ami3	Bmi2	Dmi2b	Dmi3	Emi1	Emi2	Emi2a	Fmi1	Fmi1+	Fmi2a	Fmi5.1	Fmi5a	Fmi7a	Emi2a
Rock ID	408624	408624	408624	408624	408624	408624	408624	408624	408624	408624	408624	408624	408624	408624	408624	408624	408624	408624
Major element concentrations (wt.%)																		
Al_2O_3	14.75	14.96	15.11	7.67	7.17	7.52	14.31	15.70	12.75	14.21	16.39	13.48	13.48	14.05	13.95	13.88	14.74	16.39
MnO	0.11	0.13	0.13	0.15	0.18	0.18	0.12	0.13	0.24	0.10	0.16	0.16	0.16	0.15	0.14	0.14	0.12	0.16
K_2O	0.18	0.12	0.11	0.05	0.09	0.08	0.18	0.18	0.23	0.24	0.22	0.31	0.31	0.18	0.19	0.24	0.15	0.22
Cl	0.00	0.01	0.01	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.03	0.03	0.01	0.01	0.01	0.00	0.01
Na_2O	2.09	2.13	2.13	1.08	0.89	0.94	1.92	1.73	2.32	2.02	2.13	1.93	1.93	1.71	1.70	2.03	1.80	2.13
SiO_2	49.11	49.10	48.97	44.48	44.57	44.72	49.16	49.16	49.00	49.47	50.06	48.59	48.59	47.52	48.16	49.26	49.08	50.06
FeO	8.18	8.13	8.33	10.42	11.34	10.59	7.23	8.49	11.81	7.37	7.94	9.85	9.85	10.33	9.95	8.24	9.28	7.94
CaO	12.78	13.16	13.19	6.82	6.94	6.64	13.49	13.26	10.51	12.54	13.57	11.64	11.64	12.31	11.83	11.45	11.26	13.57
SO_3	0.12	0.12	0.12	0.06	0.05	0.08	0.06	0.06	0.16	0.11	0.11	0.11	0.11	0.10	0.10	0.11	0.06	0.11
MgO	10.93	10.37	10.07	28.17	27.74	28.24	11.36	8.77	10.97	11.81	7.43	11.87	11.87	11.84	12.05	12.62	11.80	7.43
NiO	0.02	0.02	0.04	0.17	0.13	0.15	0.00	0.00	0.02	0.05	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.03
TiO_2	1.55	1.59	1.61	0.83	0.77	0.81	1.76	1.73	1.97	1.95	1.90	1.62	1.62	1.51	1.66	1.68	1.43	1.90
Cr_2O_3	0.17	0.15	0.17	0.10	0.13	0.04	0.24	0.29	0.01	0.13	0.06	0.15	0.15	0.08	0.13	0.05	0.15	0.06
P_2O_5	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.49	0.00	0.00	0.00	0.25	0.25	0.20	0.15	0.27	0.13	0.00
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
±OL	-9.50	-8.00	-6.50	-74.70	-72.20	-76.10	-12.60	-3.10	-16.60	-14.70	0.20	-6.70	-9.90	-9.90	-10.60	-17.00	-11.10	0.20

Table A9.2: Major, trace, and volatile element archive of olivine-hosted MIs of 408624 (Vestfirdir ankaramite). Major and volatile (S and Cl) are obtained by electron microprobe using the JEOL JXA-8200 Superprobe at the Department of Geography and Geology – Geology Section (University of Copenhagen) and the Cameca SX-50 at Oregon State University. Trace element compositions are obtained by LA-ICPMS using the VG element Excell quadrupole ICPMS fitted with a New Wave DUV 193nm ARF Excimer laser at Oregon State University. PM normalization is after McDonough & Sun (1995). For details on the ΔNb terminology and boundaries see Fitton et al. (1997), [$\Delta Nb = 1.74+\log(Nb/Y)-1.92\log(Zr/Y)$].

Appendix A9: Continued

MI ID	Ami2	Ami2b	Ami2c	Ami2d	Ami3	Bmi2	Dmi2b	Dmi3	Emi1	Emi2	Emi2a	Fmi1	Fmi1+	Fmi2a	Fmi5.1	Fmi5a	Fmi7a	Emi2a
Rock ID	408624	408624	408624	408624	408624	408624	408624	408624	408624	408624	408624	408624	408624	408624	408624	408624	408624	408624
Trace element concentrations (ppm)																		
Sc	51.82	28.59	30.35	15.27	21.94	25.68	33.70	-	30.30	30.62	-	-	-	27.91	51.51	32.67	29.51	-
Ti	9666	9540	9571	5279	5010	8346	10517	-	11339	10947	-	-	-	10083	8696	9088	8279	-
Rb	1.57	2.29	1.83	1.84	1.50	2.49	2.64	-	3.83	3.15	-	-	-	2.07	2.50	3.39	1.44	-
Sr	205.19	266.25	258.74	147.28	134.11	206.94	267.35	-	267.38	257.89	-	-	-	244.13	245.33	242.80	197.94	-
Y	19.53	18.18	18.79	9.72	10.01	15.06	19.85	-	23.76	17.25	-	-	-	17.91	19.06	16.47	17.80	-
Zr	82.10	79.43	80.67	45.10	46.27	65.03	93.32	-	104.61	106.56	-	-	-	77.19	84.74	90.65	81.05	-
Nb	4.95	5.46	4.74	3.84	4.05	5.45	8.40	-	9.05	9.23	-	-	-	7.58	7.34	8.80	5.50	-
Ba	21.53	22.98	21.45	15.83	21.35	29.91	28.63	-	42.26	40.92	-	-	-	29.91	26.45	39.56	19.16	-
La	4.24	5.34	5.25	3.20	3.28	4.72	6.48	-	7.96	8.17	-	-	-	6.21	5.81	7.75	4.96	-
Ce	15.15	18.23	17.44	9.83	10.79	14.66	20.73	-	24.18	24.47	-	-	-	17.09	18.04	19.74	16.61	-
Pr	2.29	2.60	2.50	1.48	1.45	1.67	2.86	-	3.60	3.16	-	-	-	2.32	2.81	2.67	2.32	-
Nd	10.45	12.64	11.38	6.41	5.50	10.11	13.85	-	14.71	15.13	-	-	-	10.82	9.62	11.95	10.56	-
Sm	4.21	3.94	4.14	2.04	2.12	-	3.51	-	4.48	3.38	-	-	-	2.61	-	3.49	2.81	-
Eu	1.24	1.29	1.42	0.79	1.04	0.95	1.45	-	1.82	1.71	-	-	-	1.11	0.95	1.18	1.06	-
Gd	-	5.02	3.32	1.86	-	-	3.97	-	4.47	4.39	-	-	-	3.67	-	3.47	3.87	-
Dy	3.74	3.91	4.12	1.92	2.24	3.58	3.81	-	4.77	4.07	-	-	-	3.28	3.73	2.96	3.42	-
Er	-	1.62	1.65	0.89	-	-	2.06	-	2.60	1.52	-	-	-	1.41	-	1.63	1.82	-
Yb	-	1.86	-	-	-	-	1.48	-	1.91	1.23	-	-	-	1.44	-	1.24	1.35	-
Hf	-	1.88	1.77	1.34	-	-	2.43	-	2.62	2.74	-	-	-	2.09	-	2.62	2.07	-
Ta	-	-	-	-	-	-	0.52	-	0.37	0.54	-	-	-	0.48	-	0.62	-	-
Pb	-	-	-	-	-	-	0.51	-	0.52	0.74	-	-	-	0.45	-	0.76	-	-
Th	-	-	-	-	-	-	0.49	-			-	-	-		-	0.69	-	-
U	-	-	-	-	-	-		-			-	-	-		-		-	-

Table A9.2: Continued

Appendix A9: Continued

MI ID	Ami2	Ami2b	Ami2c	Ami2d	Ami3	Bmi2	Dmi2b	Dmi3	Emi1	Emi2	Emi2a	Fmi1	Fmi1+	Fmi2a	Fmi5.1	Fmi5a	Fmi7a	Emi2a
Rock ID	408624	408624	408624	408624	408624	408624	408624	408624	408624	408624	408624	408624	408624	408624	408624	408624	408624	408624
Selected PM-normalized trace element ratios and ΔNb																		
Ce/Sm	0.90	1.16	1.05	1.20	1.28	-	1.48	-	1.35	1.81	-	-	-	1.64	-	1.42	1.48	-
La/Y	1.44	1.95	1.85	2.18	2.17	2.07	2.16	-	2.22	3.14	-	-	-	2.30	2.02	3.12	1.85	-
Rb/Sr	0.25	0.29	0.23	0.42	0.37	0.40	0.33	-	0.48	0.41	-	-	-	0.28	0.34	0.46	0.24	-
Sr/Nd	1.26	1.35	1.46	1.48	1.56	1.31	1.24	-	1.17	1.09	-	-	-	1.45	1.64	1.30	1.20	-
Ti/Zr	1.01	1.03	1.02	1.01	0.93	1.11	0.97	-	0.93	0.89	-	-	-	1.13	0.88	0.86	0.88	-
Sm/Nd	1.23	0.95	1.11	0.97	1.17	-	0.77	-	0.93	0.68	-	-	-	0.73		0.89	0.81	-
Ba/Zr	1.77	2.03	1.83	2.61	3.42	3.18	2.31	-	2.85	3.80	-	-	-	2.68	2.22	3.85	1.73	-
ΔNb	-0.05	-0.01	-0.07	0.06	0.07	0.08	0.08	-	0.08	-0.05	-	-	-	0.15	0.08	0.05	-0.03	-

Table A9.2: Continued

MI ID	Gmi3	Gmi6a	Hmi1	Hmi1a	Hmi2	Hmi4a	Hmi7	Imi2a	Imi5a
Rock ID	408624	408624	408624	408624	408624	408624	408624	408624	408624
Major element concentrations (wt.%)									
Al_2O_3	13.66	13.87	12.13	12.91	13.46	9.85	14.89	13.23	13.29
MnO	0.13	0.12	0.19	0.07	0.12	0.23	0.12	0.11	0.09
K_2O	0.19	0.09	0.10	0.24	0.22	0.11	0.22	0.19	0.27
Cl	0.01	0.01	0.00	0.01	0.01	0.00	0.01	0.01	0.01
Na_2O	1.77	1.51	1.45	1.88	1.97	1.36	1.73	1.55	1.71
SiO_2	49.28	50.21	48.29	50.60	49.90	45.72	48.00	48.37	49.10
FeO	9.05	9.42	8.94	7.01	6.98	13.54	9.71	9.13	8.09
CaO	11.55	11.08	8.86	12.11	12.91	7.93	11.67	12.63	12.77
SO_3	0.09	0.04	0.05	0.07	0.08	0.04	0.09	0.09	0.08
MgO	12.51	11.86	18.60	12.91	12.11	20.17	11.94	12.99	12.37
NiO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TiO_2	1.47	1.60	1.17	1.84	1.91	0.84	1.40	1.46	1.79
Cr_2O_3	0.10	0.10	0.13	0.13	0.17	0.12	0.05	0.10	0.22
P_2O_5	0.18	0.08	0.08	0.23	0.16	0.08	0.16	0.15	0.21
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
±OL	-11.90	-7.30	-27.80	-15.70	-13.50	-32.60	-9.90	-13.90	-12.10

Table A9.2: Continued

Appendix A9: Continued

MI ID	Gmi3	Gmi6a	Hmi1	Hmi1a	Hmi2	Hmi4a	Hmi7	Imi2a	Imi5a
Rock ID	408624	408624	408624	408624	408624	408624	408624	408624	408624
Trace element concentrations (ppm)									
Sc	36.51	43.74	-	-	-	-	-	35.85	30.94
Ti	9115	8881	-	-	-	-	-	8451	10807
Rb	-	-	-	-	-	-	-	2.55	4.62
Sr	431.64	324.36	-	-	-	-	-	243.74	287.03
Y	17.54	15.20	-	-	-	-	-	19.18	19.44
Zr	73.53	51.14	-	-	-	-	-	74.98	89.61
Nb	2.43	2.33	-	-	-	-	-	5.65	9.27
Ba	11.48	19.56	-	-	-	-	-	30.41	39.71
La	3.26	2.54	-	-	-	-	-	5.37	7.22
Ce	14.07	11.25	-	-	-	-	-	17.32	22.00
Pr	2.52	1.56	-	-	-	-	-	2.53	2.90
Nd	11.54	7.44	-	-	-	-	-	10.12	14.50
Sm	3.26	-	-	-	-	-	-	3.01	4.25
Eu	0.82	0.69	-	-	-	-	-	1.55	1.35
Gd	2.59	3.80	-	-	-	-	-	3.46	4.32
Dy	2.99	2.78	-	-	-	-	-	3.49	4.15
Er	1.63	-	-	-	-	-	-	1.69	2.19
Yb	-	-	-	-	-	-	-	1.24	1.48
Hf	1.95	-	-	-	-	-	-	2.14	2.88
Ta	-	-	-	-	-	-	-	0.49	0.78
Pb	-	-	-	-	-	-	-	0.59	0.67
U	-	-	-	-	-	-	-	-	-

Table A9.2: Continued

Appendix A9: Continued

MI ID	Gmi3	Gmi6a	Hmi1	Hmi1a	Hmi2	Hmi4a	Hmi7	Imi2a	Imi5a
Rock ID	408624	408624	408624	408624	408624	408624	408624	408624	408624
Selected PM-normalized trace element ratios and ΔNb									
Ce/Sm	1.08	-	-	-	-	-	-	1.44	1.30
La/Y	1.23	1.11	-	-	-	-	-	1.86	2.46
Rb/Sr	-	-	-	-	-	-	-	0.35	0.54
Sr/Nd	2.40	2.80	-	-	-	-	-	1.55	1.27
Ti/Zr	1.07	1.50	-	-	-	-	-	0.97	1.04
Sm/Nd	0.86	-	-	-	-	-	-	0.91	0.89
Ba/Zr	1.05	2.06	-	-	-	-	-	2.54	3.27
ΔNb	-0.31	-0.09	-	-	-	-	-	0.07	0.14

Table A9.2: Continued

Appendix A9: Continued

MI ID	A2mi1	A2mi11	A2mi2a	A2mi2b	A2mi4a	A2mi6a	A2mi9	Ami1	Ami2	Ami3	B2mi10	B2mi1a	B2mi1b	B2mi3a	B2mi3b	B2mi5a	B2mi7a	B2mi7b	Bmi4
Rock ID	408772	408772	408772	408772	408772	408772	408772	408772	408772	408772	408772	408772	408772	408772	408772	408772	408772	408772	408772
Major element concentrations (wt.%)																			
Al_2O_3	14.33	10.79	11.34	12.64	15.08	16.17	14.78	14.33	13.86	14.81	14.85	14.36	14.24	16.21	15.23	15.14	14.71	15.02	15.06
MnO	0.21	0.19	0.18	0.14	0.18	0.19	0.12	0.13	0.14	0.18	0.19	0.12	0.14	0.15	0.18	0.15	0.15	0.10	0.21
K_2O	0.32	0.16	0.23	0.25	0.26	0.25	0.12	0.28	0.25	0.16	0.28	0.34	0.33	0.16	0.19	0.30	0.22	0.27	0.22
Cl	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01
Na_2O	1.99	1.43	1.86	1.94	1.86	2.30	1.77	2.32	2.35	2.34	1.97	2.08	2.07	1.72	1.88	1.95	2.06	2.17	1.50
SiO_2	48.81	45.34	46.10	46.58	46.67	49.27	48.33	48.88	49.32	49.02	48.45	48.37	48.25	48.58	48.62	46.88	46.70	48.03	47.16
FeO	9.62	10.20	11.45	11.15	10.91	8.47	8.66	9.67	10.63	9.81	9.09	9.43	9.42	8.72	9.08	9.53	9.61	9.35	10.15
CaO	13.47	8.59	7.67	8.97	13.29	13.86	13.15	12.70	10.95	13.37	12.72	13.61	13.07	14.21	13.13	13.49	13.83	13.41	14.18
SO_3	0.08	0.04	0.05	0.07	0.14	0.07	0.06	0.18	0.19	0.12	0.09	0.09	0.08	0.07	0.06	0.07	0.09	0.08	0.22
MgO	8.53	21.78	19.68	16.72	9.13	7.43	11.39	9.31	10.55	8.18	10.61	9.01	10.12	8.03	9.73	9.59	9.47	9.39	9.01
NiO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.02	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06
TiO_2	2.21	1.36	1.20	1.33	2.21	1.64	1.46	2.12	1.68	1.94	1.52	2.19	1.90	1.91	1.63	2.37	1.76	1.75	2.15
Cr_2O_3	0.03	0.01	0.08	0.01	0.00	0.06	0.03	0.03	0.05	0.03	0.04	0.06	0.06	0.15	0.09	0.25	1.23	0.25	0.07
P_2O_5	0.39	0.11	0.16	0.20	0.25	0.28	0.12	0.00	0.00	0.00	0.19	0.34	0.30	0.10	0.17	0.27	0.16	0.18	0.00
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
±Ol.	-2.80	-48.60	-41.30	-29.80	-2.00	-0.60	-12.00	-3.70	-9.40	-0.60	-8.50	-4.20	-8.00	-2.00	-6.20	-4.80	-4.30	-5.60	0.30

Table A9.3: Major, trace, and volatile element archive of olivine-hosted MIs of 408772 (Vestfirdir ankaramite). Major and volatile (S and Cl) are obtained by electron microprobe using the JEOL JXA-8200 Superprobe at the Department of Geography and Geology – Geology Section (University of Copenhagen) and the Cameca SX-50 at Oregon State University. Trace element compositions are obtained by LA-ICPMS using the VG element Excell quadrupole ICPMS fitted with a New Wave DUV 193nm ARF Excimer laser at Oregon State University. PM normalization is after McDonough & Sun (1995). For details on the ΔNb terminology and boundaries see Fitton et al. (1997), [$\Delta Nb = 1.74 + \log(Nb/Y) - 1.92\log(Zr/Y)$].

Appendix A9: Continued

MI ID	A2mi1	A2mi11	A2mi2a	A2mi2b	A2mi4a	A2mi6a	A2mi9	Ami1	Ami2	Ami3	B2mi10	B2mi1a	B2mi1b	B2mi3a	B2mi3b	B2mi5a	B2mi7a	B2mi7b	Bmi4
Rock ID	408772	408772	408772	408772	408772	408772	408772	408772	408772	408772	408772	408772	408772	408772	408772	408772	408772	408772	408772
Trace element concentrations (ppm)																			
Sc	67.15	-	57.19	55.40	-	95.62	37.76	37.41	33.15	37.41	36.14	39.82	39.21	-	-	55.95	45.94	-	40.78
Ti	13086	-	5936	7339	-	10306	9146	11951	10014	11951	9225	12737	11983	-	-	15311	12789	-	12930
Rb	4.58	-	2.64	3.81	-	3.59	1.77	5.94	4.38	5.94	4.77	6.41	6.58	-	-	3.40	3.26	-	4.31
Sr	375.91	-	147.71	184.08	-	303.55	265.38	336.99	256.59	336.99	294.14	206.28	209.95	-	-	1003.58	284.61	-	262.13
Y	25.75	-	13.75	16.45	-	22.39	18.84	23.27	21.31	23.27	20.61	22.54	22.03	-	-	26.65	20.18	-	20.18
Zr	109.11	-	58.35	71.06	-	111.65	83.22	112.83	104.20	112.83	98.81	98.02	93.50	-	-	135.19	95.42	-	117.05
Nb	11.93	-	7.23	9.12	-	11.74	4.94	15.87	11.95	15.87	15.28	16.68	17.94	-	-	9.37	8.41	-	13.70
Ba	54.01	-	28.61	29.73	-	41.84	16.51	59.43	40.77	59.43	49.36	58.27	61.75	-	-	58.38	33.44	-	52.73
La	8.13	-	5.07	6.71	-	8.75	6.57	10.50	9.49	10.50	10.68	10.71	11.82	-	-	9.85	8.03	-	9.00
Ce	28.21	-	13.78	16.75	-	26.47	23.51	29.32	26.50	29.32	25.67	26.16	27.08	-	-	28.18	24.07	-	27.66
Pr	3.59	-	1.55	2.25	-	2.71	2.88	3.96	3.57	3.96	3.13	3.18	3.22	-	-	4.04	3.20	-	3.50
Nd	14.86	-	7.15	10.65	-	11.61	13.82	18.96	14.36	18.96	14.69	15.80	14.81	-	-	22.72	14.38	-	17.67
Sm	-	-	-	-	-	-	3.47	5.09	3.89	5.09	3.87	3.98	4.68	-	-	5.85	4.24	-	4.00
Eu	1.61	-	0.66	-	-	-	1.26	1.57	1.40	1.57	1.46	1.54	1.31	-	-	1.94	1.53	-	1.54
Gd	-	-	2.41	-	-	-	2.16	4.37	3.37	4.37	3.60	4.06	4.10	-	-	6.24	3.82	-	4.81
Dy	5.06	-	2.37	-	-	-	3.59	4.42	3.67	4.42	4.06	4.16	3.52	-	-	4.81	3.74	-	4.20
Er	-	-	-	-	-	-	2.07	2.83	2.14	2.83	1.92	2.23	1.74	-	-	2.62	1.76	-	1.77
Yb	-	-	-	-	-	-	1.60	2.38	1.79	2.38	1.63	2.16	2.00	-	-	2.18	1.58	-	2.09
Hf	-	-	-	-	-	-	2.41	3.21	2.51	3.21	2.61	2.30	2.50	-	-	3.22	2.40	-	2.78
Ta	-	-	-	-	-	-		0.95	0.64	0.95	1.05	1.21	1.22	-	-	0.72	0.62	-	0.90
Pb	-	-	-	-	-	-	0.43	2.80	0.79	2.80	0.82	1.02	1.18	-	-	0.97	-	-	1.26
U	-	-	-	-	-	-	-	-	-	-	0.86	0.89	0.84	-	-	-	-	-	-

Table A9.3: Continued

MI ID	A2mi1	A2mi11	A2mi2a	A2mi2b	A2mi4a	A2mi6a	A2mi9	Ami1	Ami2	Ami3	B2mi10	B2mi1a	B2mi1b	B2mi3a	B2mi3b	B2mi5a	B2mi7a	B2mi7b	Bmi4
Rock ID	408772	408772	408772	408772	408772	408772	408772	408772	408772	408772	408772	408772	408772	408772	408772	408772	408772	408772	408772
Selected PM-normalized trace element ratios and ΔNb																			
Ce/Sm	-	-	-	-	-	-	1.69	1.44	1.70	1.44	1.66	1.65	1.45	-	-	1.20	1.42	-	1.73
La/Y	2.09	-	2.44	2.70	-	2.59	2.31	2.99	2.95	2.99	3.43	3.15	3.55	-	-	2.45	2.64	-	2.95
Rb/Sr	0.40	-	0.59	0.69	-	0.39	0.22	0.59	0.57	0.59	0.54	1.03	1.04	-	-	0.11	0.38	-	0.55
Sr/Nd	1.62	-	1.32	1.11	-	1.68	1.23	1.14	1.15	1.14	1.28	0.84	0.91	-	-	2.83	1.27	-	0.95
Ti/Zr	1.03	-	0.88	0.89	-	0.80	0.95	0.91	0.83	0.91	0.80	1.12	1.10	-	-	0.98	1.15	-	0.95
Sm/Nd	-	-	-	-	-	-	0.77	0.82	0.83	0.82	0.80	0.77	0.96	-	-	0.79	0.90	-	0.69
Ba/Zr	3.36	-	3.33	2.90	-	2.99	1.40	4.09	3.07	4.09	3.84	4.14	4.49	-	-	3.51	2.66	-	4.19
ΔNb	0.20	-	0.26	0.26	-	0.12	-0.08	0.26	0.17	0.26	0.30	0.38	0.45	-	-	-0.07	0.06	-	0.11

Table A9.3: Continued

MI ID	Bmi7	Cmi3b	Cmi3c	Dim8a	Dmi1	Dmi10	Dmi5a	Dmi5b	Dmi5d	Dmi7	Gmi1	Gmi3	Gmi5	Gmi6	Gmi7	Gmi8a
Rock ID	408772	408772	408772	408772	408772	408772	408772	408772	408772	408772	408772	408772	408772	408772	408772	408772
Major element concentrations (wt.%)																
Al_2O_3	15.02	14.54	14.40	14.43	15.32	14.29	15.37	14.75	15.03	14.13	15.01	14.90	13.65	15.15	14.60	16.68
MnO	0.16	0.10	0.20	0.22	0.15	0.16	0.16	0.22	0.17	0.22	0.19	0.18	0.14	0.09	0.14	0.19
K_2O	0.26	0.20	0.16	0.28	0.28	0.23	0.24	0.20	0.14	0.28	0.25	0.27	0.28	0.19	0.20	0.06
Cl	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Na_2O	2.18	1.82	1.87	2.13	2.47	2.09	2.53	2.32	1.60	2.10	2.13	2.06	2.14	1.14	2.06	0.57
SiO_2	49.15	47.89	47.91	48.13	48.74	48.47	49.10	48.40	47.48	48.27	49.62	48.73	49.36	47.06	48.93	49.21
FeO	8.96	9.19	9.37	9.55	9.30	9.41	8.93	9.47	9.87	9.51	9.65	10.19	8.91	10.79	9.39	8.42
CaO	12.46	12.92	12.93	12.34	12.37	12.23	12.12	12.24	12.09	12.17	12.12	13.23	12.92	12.73	12.86	11.43
SO_3	0.17	0.17	0.17	0.16	0.16	0.19	0.17	0.16	0.16	0.15	0.13	0.15	0.14	0.15	0.16	0.05
MgO	10.16	11.07	11.06	11.04	9.30	10.86	9.63	10.56	11.63	11.36	9.17	8.40	10.08	10.77	10.04	11.44
NiO	0.02	0.04	0.03	0.05	0.02	0.02	0.03	0.03	0.04	0.05	0.01	0.03	0.03	0.03	0.02	0.03
TiO_2	1.42	1.96	1.82	1.66	1.84	2.00	1.68	1.59	1.76	1.69	1.69	1.80	1.95	1.87	1.55	1.83
Cr_2O_3	0.05	0.10	0.07	0.02	0.03	0.05	0.03	0.05	0.04	0.06	0.02	0.05	0.38	0.02	0.04	0.09
P_2O_5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
±Ol.	-6.70	-10.20	-9.70	-8.80	-5.10	-8.10	-6.10	-7.70	-10.10	-8.50	-4.40	0.90	-5.90	-6.30	-6.40	-13.00

Table A9.3: Continued

Appendix A9: Continued

MI ID	Bmi7	Cmi3b	Cmi3c	Dim8a	Dmi1	Dmi10	Dmi5a	Dmi5b	Dmi5d	Dmi7	Gmi1	Gmi3	Gmi5	Gmi6	Gmi7	Gmi8a
Rock ID	408772	408772	408772	408772	408772	408772	408772	408772	408772	408772	408772	408772	408772	408772	408772	408772
Trace element concentrations (ppm)																
Sc	29.08	46.74	42.15	29.79	50.45	33.87	60.85	33.81	39.89	36.74	34.95	-	33.11	33.76	31.36	-
Ti	8526	11396	13960	10347	11274	11807	9629	9845	12374	10414	9763	-	11780	11564	8469	-
Rb	5.07	4.73	5.51	5.81	6.82	3.54	3.65	2.98	1.73	6.23	4.54	-	5.93	3.51	2.80	-
Sr	248.25	330.27	348.33	244.99	283.33	304.48	314.95	329.81	91.62	208.20	286.22	-	348.36	220.13	263.59	-
Y	16.83	26.17	26.57	19.41	23.32	23.12	25.07	24.85	25.12	20.13	19.84	-	20.85	19.39	18.81	-
Zr	82.77	136.63	128.83	99.43	114.30	113.61	118.85	103.69	117.80	102.84	100.89	-	147.54	111.99	87.57	-
Nb	11.34	16.61	19.11	13.77	12.25	9.52	12.78	12.59	13.87	17.74	12.78	-	18.71	14.04	7.72	-
Ba	46.93	72.13	67.00	60.74	61.39	39.28	39.36	38.27	36.74	55.98	50.35	-	68.14	56.77	31.40	-
La	8.11	14.79	16.52	11.09	8.07	8.37	10.30	10.41	2.99	11.49	9.13	-	12.80	7.17	7.46	-
Ce	22.26	30.75	32.73	31.23	28.32	25.67	24.21	26.05	9.74	29.52	25.25	--	36.27	21.68	19.85	-
Pr	2.86	4.29	4.75	3.55	3.48	3.69	2.71	3.30	1.76	3.32	3.11	-	4.77	2.77	2.50	-
Nd	14.01	18.25	21.05	15.21	16.49	18.33	14.30	16.77	9.99	14.53	15.02	-	21.84	13.08	12.77	-
Sm	2.81	4.98	4.52	4.42	-	4.12	-	4.19	3.03	3.51	2.98	-	4.48	2.95	2.88	-
Eu	1.27	1.65	1.74	1.54	-	1.79	-	1.51	1.02	1.39	1.29	-	1.21	1.16	1.08	-
Gd	3.75	5.11	5.97	4.42	-	4.67	-	4.20	4.87	3.96	3.53	-	4.77	3.27	3.22	-
Dy	3.22	4.33	4.63	3.40	-	4.23	-	4.77	5.18	4.04	2.89	-	3.36	3.72	3.10	-
Er	1.52	2.93	3.08	1.64	-	2.08	-	2.11	2.47	2.19	1.85	-	2.37	2.01	2.26	-
Yb	1.65	-	2.68	1.61	-	1.74	-	2.15	1.75	1.98	-	-	2.24	1.62	1.45	-
Hf	1.85	4.03	3.54	2.25	-	2.94	-	2.67	3.31	3.01	1.57	-	3.34	3.10	2.18	-
Ta	0.69	0.83	1.09	1.12	-	0.84	-	0.80	1.00	1.68	0.64	-	0.84	0.67	0.43	-
Pb	1.09	-	-	1.36	-	0.81	-	0.86	-	0.99	-	-	0.86	-	0.81	-
U	-	-	-	-	-	-	-	-	-	1.36	-	-	-	-	-	-

Table A9.3: Continued

Appendix A9: Continued

MI ID	Bmi7	Cmi3b	Cmi3c	Dim8a	Dmi1	Dmi10	Dmi5a	Dmi5b	Dmi5d	Dmi7	Gmi1	Gmi3	Gmi5	Gmi6	Gmi7	Gmi8a
Rock ID	408772	408772	408772	408772	408772	408772	408772	408772	408772	408772	408772	408772	408772	408772	408772	408772
Selected PM-normalized trace element ratios and ΔNb																
Ce/Sm	1.98	1.54	1.81	1.77	-	1.56	-	1.55	0.80	2.10	2.12	-	2.03	1.84	1.72	-
La/Y	3.19	3.74	4.12	3.78	2.29	2.40	2.72	2.77	0.79	3.78	3.05	-	4.07	2.45	2.63	-
Rb/Sr	0.68	0.48	0.53	0.79	0.80	0.39	0.39	0.30	0.63	0.99	0.53	-	0.57	0.53	0.35	-
Sr/Nd	1.14	1.16	1.06	1.03	1.10	1.07	1.41	1.26	0.59	0.92	1.22	-	1.02	1.08	1.32	-
Ti/Zr	0.89	0.72	0.93	0.90	0.85	0.90	0.70	0.82	0.90	0.87	0.83	-	0.69	0.89	0.83	-
Sm/Nd	0.61	0.83	0.65	0.89	-	0.69	-	0.76	0.92	0.74	0.60	-	0.63	0.69	0.69	-
Ba/Zr	4.47	4.42	4.04	5.01	4.22	2.72	2.52	2.47	2.34	4.46	4.07	-	5.24	4.69	2.67	-
ΔNb	0.24	0.16	0.28	0.23	0.13	0.03	0.15	0.25	0.19	0.33	0.19	-	0.06	0.14	0.07	-

Table A9.3: Continued

Reference:

Fitton, J. G., Saunders, A. D., Norry, M. J., Hardarson, B. S., & Taylor, R. N. (1997): Thermal and chemical structure of the Iceland plum. Earth and Planetary Science Letters, 153: 197-208.

McDonough, W. F. & Sun, S. -s. (1995): The composition of the Earth. Chemical Geology, 120: 223-253.

Sun, S. -s. & McDonough, W. F. (1989): Chemical and isotopic systematics of oceanic basalts: implications for mantle composition and processes. Geological Society Special Publication, No. 42: 313-345.

APPENDIX B

Contents of Appendix B

Appendix B1: Micro Sr dissolution and column chemistry

Dissolution	**Single MI**	**Single grain**	**Multiple grains**
29M HF + 16M HNO_3 • Dissolve overnight on hotplate • Dry to paste	100 μL + 30 μL	200 μL + 50 μL	750 μL + 250 μL
6M HCl • Dissolve overnight on hotplate • Dry to paste	100 μL	200 μL	500 μL
16M HNO_3 • Dissolve overnight on hotplate • Dry to paste, do not over dry!	100 μL	200 μL	500 μL
3M HNO_3 • Dissolve on hotplate	200 μL	200 μL	200 μL
Centrifugation	No	Yes	Yes
Aliquoting			
10% for ICPMS analysis	20 μL	20 μL	20 μL
90% for TIMS analysis	180 μL	180 μL	180 μL
Column setup			
Rinse clean columns with MQ H_2O thoroughly inside and out before being placed in the column rack			
Rinse the pre-cleaned columns with MQ H_2O	3 CV	3 CV	3 CV
Add pre-cleaned Sr spec resin	60 μL	60 μL	60 μL
Remove bubbles using a 1 mL pipette			
Rinse of resin with 6M HCl	1 CV	1 CV	1 CV
Rinse of resin with MQ H_2O	3 CV	3 CV	3 CV

Table B1: Flow sheet for micro Sr sample dissolution and column chemistry aimed at olivine-hosted MIs. 'Single MI' procedure is used for MIs sampled by micro-milling, 'Single grain' for single olivine grains hosting several MIs, and 'Multiple grains' for when multiple olivine grains hosting MIs are pooled. The total volume of MQ H_2O used for Sr elution depends on the latest column calibration see example in Appendix B2. CV equals a column volume. Temperatures used for the hotplate range between and 60-120°C. Aliquoting is double checked by weighing.

Appendix B1: Continued

Pre-condition			
3M HNO_3	2x100 μL	2x100 μL	2x100 μL
Load sample dissolved in 3M HNO_3 • Collect in to beaker and reload	180 μL	180 μL	180 μL
Add 250 μL 6M HCL to empty beaker and let it sweat on the hot plate			
Wash on 3M HNO_3	50 μL	50 μL	50 μL
Wash on 3M HNO_3	100 μL	100 μL	100 μL
Wash on 3M HNO_3	2x150 μL	2x150 μL	2x150 μL
Sr Elution*			
Recover beaker from hotplate and rinse out with MQ H_2O, use for collection			
Sr elution by MQ H_2O	2x50 μL	2x50 μL	2x50 μL
Continued elution by MQ H_2O	200 μL	200 μL	200 μL
Dry down, and ready for loading			

Table B1: Continued

Appendix B2: Sr and Sr-Pb column calibrations

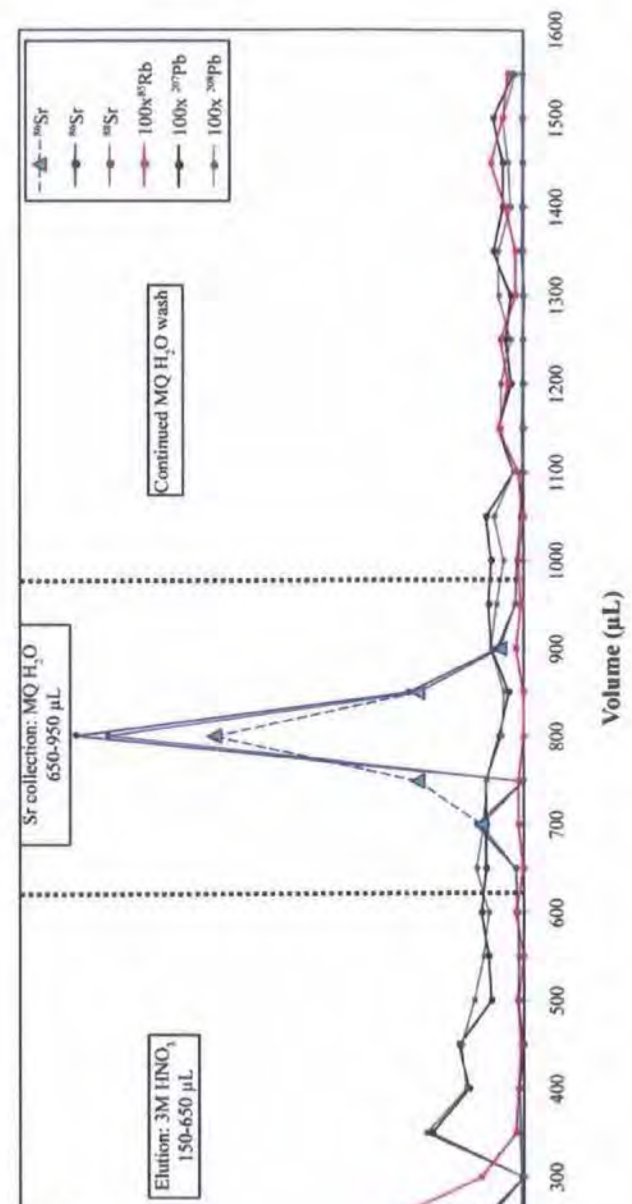


Figure B2.1: Sr column calibration. Sample is loaded in 3M HNO_3. Elution of Rb happens within the fist 350 µL of 3M HNO_3. Also Ca, Al, and Nd are washed off within the first 350 µL (see Figure B2.2b). Sr collections in MQ H_2O begins at 650 µL and finish at 950 µL.

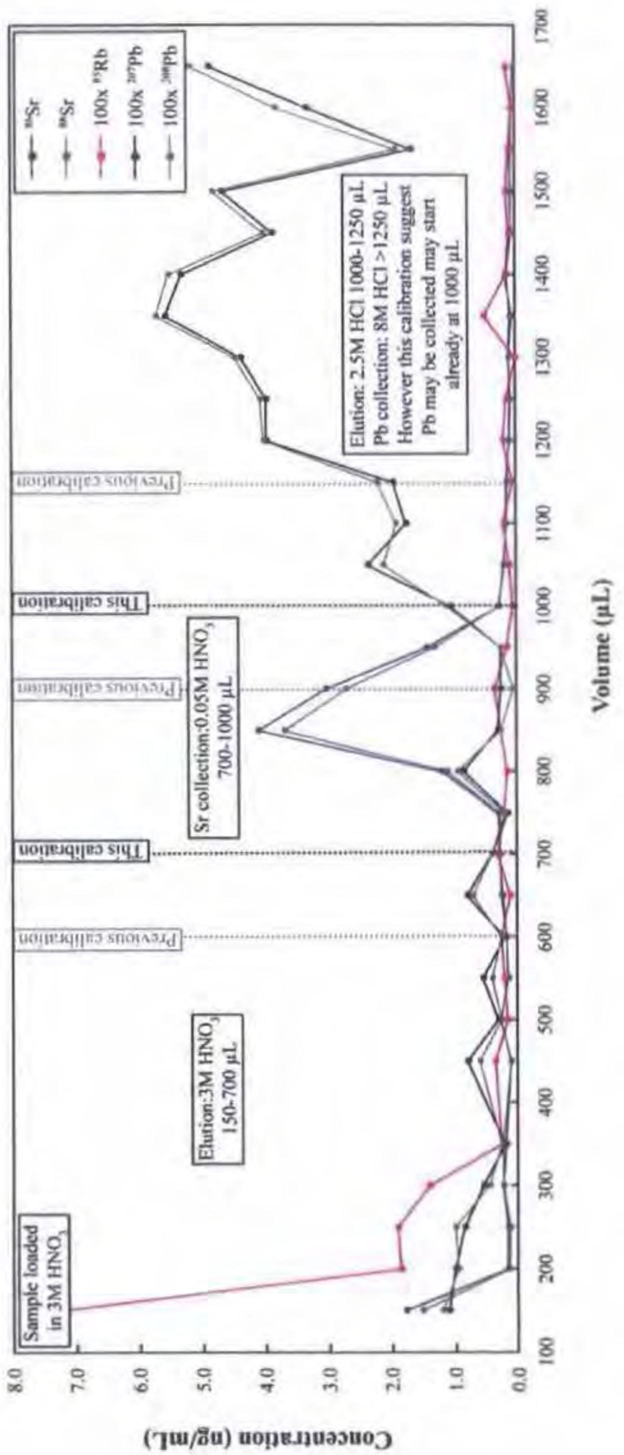


Figure B2.2a: Sr-Pb column calibration. Sample is loaded in 3M HNO_3, and Rb is washed off during the elution with 150-700 µL. Sr is collected in 0.05M HNO_3 in the interval between 700 and 1000 µL. Previous column calibrations suggest the Sr collection is followed by 250 µL 2.5M HCl elution, which is followed by collection of Pb in 8M HCl. However, this calibration shows that Pb may be collected straight after the Sr collection.

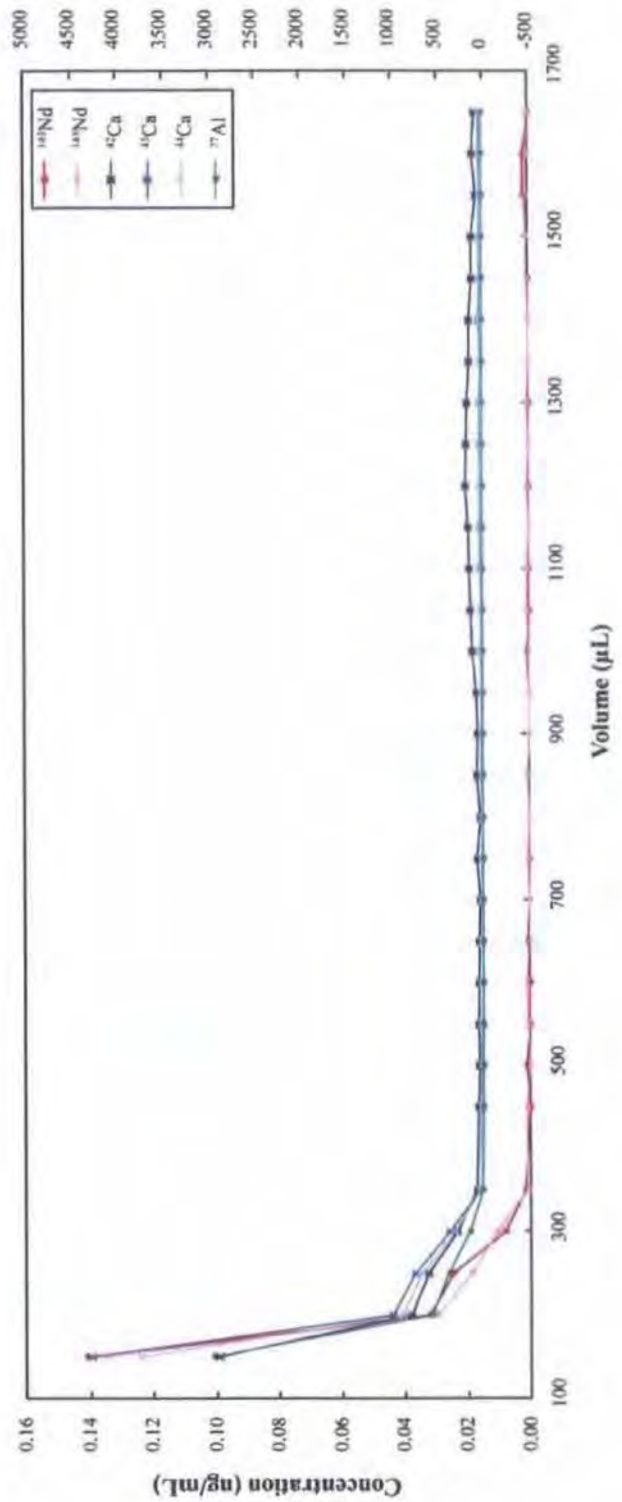


Figure B2.2b: Sr-Pb column calibration. This diagram nicely demonstrates that Ca, Al, and Nd are washed of during the 3M HNO_3 elution. This particular example is from the Sr-Pb column calibration example in Figure B2.2a.

Appendix B3: Loading of sub-ng Sr loads on Re filaments

- Two strips of Parafilm is melted onto the surface of the Re filaments leaving a 1 mm loading gab free in the center of the filament. This is done by running a 1.0-1.2 A current through the filament, while gently touching the filament with the Parafilm. The current is here after turned off.

- Both for standards (NBS 987) and samples 0.5 µL TaF_5 activator is used. The activator is pipette into the gab on the filament.

- The filaments are loaded one by one! When ready to load the standard the filament is heated by sending 1A current through the filament. The appropriate volume (no more then 1-2 µL) of standard NBS 987 dissolved in concentrated UpA HNO_3 is loaded onto the droplet of activator. The current that is send through the filament ensures that the activator is well mixed with the standard solution. The current is turned off as the droplet dries out.

- Samples are loaded in a similar manner. However, the dried down Sr cut is picked up from the 3 mL Teflon beaker by pipetting 1 µL concentrated UpA HNO_3 into the beaker. Move the droplet around with the tip of the pipette to make sure that the total sample mass is picked up. Hereafter the procedure for loading is as described above.

- Finally, the current is slowly increased from 0 A to about 1.8 A at which stage the Parafilm burns off. As all the Parafilm is burn off the current is further increased to about 2.2-2.4 A this causes the filament to glow orange/red and the current is kept at this level for a few seconds, where after the current is slowly turn off. The loaded filament is now ready to be mounted in the magazine.

Appendix B4: Oxide production check on the ELEMENT2

Element	1 ppb solution (Cps)	Blank (Cps)	Δ (1 ppb-blank)	Interference (%)
Ba	138799	2123.7	136675.3	0.046
Eu	81	18.5	62.5	
La	1086135	237	1085898	0.008
Gd	93.6	10.7	82.9	
Ce	1043758.5	338.3	1043420.2	0.024
Gd	258	10.7	247.3	
Pr	1390277.8	45.4	1390232.4	2.122
Gd	29501.7	7.3	29494.4	
Nd	163080.1	26.6	163053.5	1.530
Dy	2497.8	3.8	2494	
Nd	163080.1	26.6	163053.5	1.042
Er	1702.7	4.2	1698.5	
Sm	193728.3	17.4	193710.9	0.148
Er	291.1	4.2	286.9	
Gd	178100.2	7.3	178092.9	1.367
Yb	2436.9	2.7	2434.2	

Table B4: Interferences due to oxide production during low concentration trace element analysis on the Thermo ELEMENT2 (double focusing magnetic sector field ICPMS) at *AHIGL* (Department of Earth Sciences, Durham University) Oxygen have the 3 isotopes ^{16}O, ^{17}O, and ^{18}O, which in combination with the isotopes of the elements listed *italic* generates certain interferences, on the element listed below. This means that e.g. 0.046% of the Eu signal is due to Ba oxides ($^{135}Ba^{16}O$, $^{134}Ba^{17}O$, $^{137}Ba^{16}O$, $^{136}Ba^{17}O$, and $^{135}Ba^{18}O$). This was accounted for incorporation of simple corrections algorithms into the analytical method.

Appendix B5: ELEMENT2 method file A

			Time per Pass [min:sec:ms]	Time per Res. [h:min:sec]
Runs/Passes (Meas.) :	3 * 3 + 0 * 0 + 0 * 0	Low	00 : 02 : 286	00 : 00 : 21
Runs/Passes (Eval.) :	3 * 3 + 0 * 0 + 0 * 0	Med.	00 : 00 : 000	00 : 00 : 00
Res. Switch Delay [s] :	2	High	00 : 00 : 000	00 : 00 : 00
			Total Time	00 : 00 : 21

Entry	Locked	Isotope	Calib Threshold	Accurate Mass	Method Mass Offset	Mass Window	Mass Range	Magnet Mass	Settling Time	Sample Time	Samples per Peak	Segment Duration	Search Window	Integration Window	Scan Type	Detection Mode	Integration Type
Low																	
1	No	Rb85	0	84.9113	0.0000	20	84.883 - 84.940	82.914	0.001	0.0100	50	0.100	60	80	EScan	Both	Average
2	No	Rb87	0	86.9086	0.0000	20	86.880 - 86.938	82.914	0.001	0.0100	50	0.100	60	80	EScan	Both	Average
3	No	Sr86	0	85.9087	0.0000	20	85.880 - 85.937	82.914	0.001	0.0100	50	0.100	60	80	EScan	Both	Average
4	No	Sr87	0	86.9084	0.0000	20	86.879 - 86.937	82.914	0.001	0.0100	50	0.100	60	80	EScan	Both	Average
5	No	Sr88	0	87.9051	0.0000	20	87.876 - 87.934	82.914	0.001	0.0100	50	0.100	60	80	EScan	Both	Average
6	No	Nd143	0	142.9093	0.0000	20	142.862 - 142.957	142.909	0.041	0.0100	50	0.100	60	80	EScan	Both	Average
7	No	Nd145	0	144.9120	0.0000	20	144.864 - 144.960	142.909	0.001	0.0100	50	0.100	60	80	EScan	Both	Average
8	No	Nd146	0	145.9126	0.0000	20	145.864 - 145.961	142.909	0.001	0.0100	50	0.100	60	80	EScan	Both	Average
9	No	Hf177	0	176.9427	0.0000	20	176.884 - 177.002	176.943	0.019	0.0100	50	0.100	60	80	EScan	Both	Average
10	No	Hf178	0	177.9432	0.0000	20	177.884 - 178.002	176.943	0.001	0.0100	50	0.100	60	80	EScan	Both	Average
11	No	Hf179	0	178.9453	0.0000	20	178.886 - 179.005	176.943	0.001	0.0100	50	0.100	60	80	EScan	Both	Average
12	No	Pb206	0	205.9739	0.0000	20	205.905 - 206.043	205.974	0.018	0.0100	50	0.100	60	80	EScan	Both	Average
13	No	Pb207	0	206.9753	0.0000	20	206.906 - 207.044	205.974	0.001	0.0100	50	0.100	60	80	EScan	Both	Average
14	No	Pb208	0	207.9761	0.0000	20	207.907 - 208.045	205.974	0.001	0.0100	50	0.100	60	80	EScan	Both	Average
15	No	Kr83	0	82.9136	0.0000	20	82.886 - 82.941	82.914	0.300	0.0100	50	0.100	60	80	EScan	Both	Average

Entry	Locked	Isotope	IS Index	IS Name	Regression Type	Programmed Equation	Correction Equation	Appended for Correction	Equation Active	QC Active	Correlation Coeff. (-) Limit	QC Int.Std. (-) %	QC Int.Std. (+) %	Detection Limit	Shift Peak Center [u]	Min. Resolution
Low																
1	No	Rb85			Linear			use	Yes	No	0.000000	0.000000	0.000000	0.000000	0.000000	0
2	No	Rb87			Linear	Sr	-0.0848*Sr88		Yes	No	0.000000	0.000000	0.000000	0.000000	0.000000	0
3	No	Sr86			Linear	Kr	-1.5043*Kr83		Yes	No	0.000000	0.000000	0.000000	0.000000	0.000000	0
4	No	Sr87			Linear	Rb	-0.3857*Rb85		Yes	No	0.000000	0.000000	0.000000	0.000000	0.000000	0
5	No	Sr88			Linear			use	Yes	No	0.000000	0.000000	0.000000	0.000000	0.000000	0
6	No	Nd143			Linear				Yes	No	0.000000	0.000000	0.000000	0.000000	0.000000	0
7	No	Nd145			Linear				Yes	No	0.000000	0.000000	0.000000	0.000000	0.000000	0
8	No	Nd146			Linear				Yes	No	0.000000	0.000000	0.000000	0.000000	0.000000	0
9	No	Hf177			Linear				Yes	No	0.000000	0.000000	0.000000	0.000000	0.000000	0
10	No	Hf178			Linear				Yes	No	0.000000	0.000000	0.000000	0.000000	0.000000	0
11	No	Hf179			Linear				Yes	Yes	0.000000	0.000000	0.000000	0.000000	0.000000	0
12	No	Pb206			Linear				Yes	Yes	0.000000	0.000000	0.000000	0.000000	0.000000	0
13	No	Pb207			Linear				Yes	Yes	0.000000	0.000000	0.000000	0.000000	0.000000	0
14	No	Pb208			Linear				Yes	Yes	0.000000	0.000000	0.000000	0.000000	0.000000	0
15	No	Kr83			Linear			app	Yes	Yes	0.000000	0.000000	0.000000	0.000000	0.000000	0

Appendix B5: ELEMENT2 method file B

			Time per Pass [min:sec:ms]	Time per Res. [h:min:sec]
		Low	00 : 04 : 387	00 : 00 : 52
		Med.	00 : 00 : 000	00 : 00 : 00
Runs/Passes (Meas.) :	4 * 3 + 0 * 0 + 0 * 0	High	00 : 00 : 000	00 : 00 : 06
Runs/Passes (Eval.) :	4 * 3 + 0 * 0 + 0 * 0			
Res. Switch Delay [s] :	1		Total Time	00 : 00 : 52

Entry	Locked	Isotope	Calib Threshold	Accurate Mass	Method Mass Offset	Mass Window	Mass Range	Magnet Mass	Settling Time	Sample Time	Samples per Peak	Segment Duration	Search Window	Integration Window	Scan Type	Calib Threshold	Accurate Mass
Low																	
1	No	Ti49	0	48.9473	0.0003	60	48.898 - 48.996	48.947	0.300	0.0100	20	0.120	80	40	EScan	0	48.9473
2	No	Rb85	0	84.9113	0.0031	60	84.826 - 84.996	84.911	0.034	0.0300	20	0.360	80	40	EScan	0	84.9113
3	No	Sr88	0	87.9051	0.0050	60	87.817 - 87.993	84.911	0.001	0.0300	20	0.360	80	40	EScan	0	87.9051
4	No	Y89	0	88.9053	0.0033	60	88.816 - 88.994	84.911	0.001	0.0100	20	0.120	80	40	EScan	0	88.9053
5	No	Zr90	0	89.9042	0.0032	60	89.814 - 89.994	84.911	0.001	0.0150	20	0.180	80	40	EScan	0	89.9042
6	No	Nb93	0	92.9058	0.0040	60	92.813 - 92.999	84.911	0.001	0.0300	20	0.360	80	40	EScan	0	92.9058
7	No	Ba137	0	136.9053	0.0104	60	136.768 - 137.042	136.905	0.036	0.0150	20	0.180	80	40	EScan	0	136.9053
8	No	La139	0	138.9058	0.0088	60	138.767 - 139.045	136.905	0.001	0.0150	20	0.180	80	40	EScan	0	138.9058
9	No	Ce140	0	139.9049	0.0083	60	139.765 - 140.045	136.905	0.001	0.0150	20	0.180	80	40	EScan	0	139.9049
10	No	Pr141	0	140.9071	-0.0033	5	140.895 - 140.919	136.905	0.001	0.0100	50	0.030	80	40	EScan	0	140.9071
11	No	Nd143	0	142.9093	0.0095	60	142.766 - 143.052	136.905	0.001	0.0150	20	0.180	80	40	EScan	0	142.9093
12	No	Sm147	0	146.9144	0.0116	60	146.767 - 147.061	136.905	0.001	0.0150	20	0.180	80	40	EScan	0	146.9144
13	No	Eu151	0	150.9193	0.0116	60	150.768 - 151.070	136.905	0.001	0.0150	20	0.180	80	40	EScan	0	150.9193
14	No	Gd157	0	156.9234	0.0115	60	156.767 - 157.080	136.905	0.001	0.0200	20	0.240	80	40	EScan	0	156.9234
15	No	Dy161	0	160.9264	0.0055	60	160.765 - 161.087	160.926	0.014	0.0200	20	0.240	80	40	EScan	0	160.9264
16	No	Er166	0	165.9298	0.0068	60	165.764 - 166.096	160.926	0.001	0.0200	20	0.240	80	40	EScan	0	165.9298
17	No	Yb172	0	171.9359	0.0087	60	171.764 - 172.108	160.926	0.001	0.0200	20	0.240	80	40	EScan	0	171.9359

Entry	Locked	Isotope	Method Mass Offset	Mass Window	Mass Range	Magnet Mass	Settling Time	Sample Time	Samples per Peak	Segment Duration	Search Window	Integration Window	Scan Type	Detection Mode	Integration Type	Regression Type	Programmed Equation
Low																	
1	No	Ti49	0.0003	60	48.898 - 48.996	48.947	0.300	0.0100	20	0.120	80	40	EScan	Both	Average	Thru Zero	
2	No	Rb85	0.0031	60	84.826 - 84.996	84.911	0.034	0.0300	20	0.360	80	40	EScan	Both	Average	Thru Zero	
3	No	Sr88	0.0050	60	87.817 - 87.993	84.911	0.001	0.0300	20	0.360	80	40	EScan	Both	Average	Thru Zero	
4	No	Y89	0.0033	60	88.816 - 88.994	84.911	0.001	0.0100	20	0.120	80	40	EScan	Both	Average	Thru Zero	
5	No	Zr90	0.0032	60	89.814 - 89.994	84.911	0.001	0.0150	20	0.180	80	40	EScan	Both	Average	Thru Zero	
6	No	Nb93	0.0040	60	92.813 - 92.999	84.911	0.001	0.0300	20	0.360	80	40	EScan	Both	Average	Thru Zero	
7	No	Ba137	0.0104	60	136.768 - 137.042	136.905	0.036	0.0150	20	0.180	80	40	EScan	Both	Average	Thru Zero	
8	No	La139	0.0086	60	138.767 - 139.045	136.905	0.001	0.0150	20	0.180	80	40	EScan	Both	Average	Thru Zero	
9	No	Ce140	0.0083	60	139.765 - 140.045	136.905	0.001	0.0150	20	0.180	80	40	EScan	Both	Average	Thru Zero	
10	No	Pr141	-0.0033	5	140.895 - 140.919	136.905	0.001	0.0100	50	0.030	80	40	EScan	Both	Average	Thru Zero	
11	No	Nd143	0.0095	60	142.766 - 143.052	136.905	0.001	0.0150	20	0.180	80	40	EScan	Both	Average	Thru Zero	
12	No	Sm147	0.0116	60	146.767 - 147.061	136.905	0.001	0.0150	20	0.180	80	40	EScan	Both	Average	Thru Zero	
13	No	Eu151	0.0116	60	150.768 - 151.070	136.905	0.001	0.0150	20	0.180	80	40	EScan	Both	Average	Thru Zero	Ba
14	No	Gd157	0.0115	60	156.767 - 157.080	136.905	0.001	0.0200	20	0.240	80	40	EScan	Both	Average	Thru Zero	La,Ce,Pr
15	No	Dy161	0.0055	60	160.765 - 161.087	160.926	0.014	0.0200	20	0.240	80	40	EScan	Both	Average	Thru Zero	Nd
16	No	Er166	0.0068	60	165.764 - 166.096	160.926	0.001	0.0200	20	0.240	80	40	EScan	Both	Average	Thru Zero	Nd,Sm
17	No	Yb172	0.0087	60	171.764 - 172.108	160.926	0.001	0.0200	20	0.240	80	40	EScan	Both	Average	Thru Zero	Gd(La,Ce,Pr)

Appendix B5: ELEMENT2 method file B continued

Entry	Locked	Isotope	Correction Equation	Appended for Correction	Equation Active	QC Active	Correlation Coeff. (-) Limit	QC Int.Std. (-) %	QC Int.Std. (+) %	Detection Limit	Shift Peak Center [u]	Min. Resolution
Low												
1	No	Ti49			No	Yes	0.000000	0.000000	0.000000	0.000000	0.000000	0
2	No	Rb85			No	Yes	0.000000	0.000000	0.000000	0.000000	0.000000	0
3	No	Sr88			No	Yes	0.000000	0.000000	0.000000	0.000000	0.000000	0
4	No	Y89			No	No	0.000000	0.000000	0.000000	0.000000	0.000000	0
5	No	Zr90			No	No	0.000000	0.000000	0.000000	0.000000	0.000000	0
6	No	Nb93			No	Yes	0.000000	0.000000	0.000000	0.000000	0.000000	0
7	No	Ba137		use	No	Yes	0.000000	0.000000	0.000000	0.000000	0.000000	0
8	No	La139		use	No	Yes	0.000000	0.000000	0.000000	0.000000	0.000000	0
9	No	Ce140		use	No	Yes	0.000000	0.000000	0.000000	0.000000	0.000000	0
10	No	Pr141		use	No	No	0.000000	0.000000	0.000000	0.000000	0.000000	0
11	No	Nd143		use	No	Yes	0.000000	0.000000	0.000000	0.000000	0.000000	0
12	No	Sm147		use	No	Yes	0.000000	0.000000	0.000000	0.000000	0.000000	0
13	No	Eu151	-0.0007*Ba137		Yes	Yes	0.000000	0.000000	0.000000	0.000000	0.000000	0
14	No	Gd157	-0.000042*La139 -0.00058*Ce140 -0.02165*Pr141	use	Yes	Yes	0.000000	0.000000	0.000000	0.000000	0.000000	0
15	No	Dy161	-0.018*Nd143		Yes	Yes	0.000000	0.000000	0.000000	0.000000	0.000000	0
16	No	Er166	-0.01137*Nd143 -0.00194*Sm147		Yes	Yes	0.000000	0.000000	0.000000	0.000000	0.000000	0
17	No	Yb172	-0.01698*Gd157		Yes	Yes	0.000000	0.000000	0.000000	0.000000	0.000000	0

Two ELEMENT2 method files are shown in this appendix. ***Method file A*** (first page) is used for routine analysis of reagent blanks where concentration of the following elements are of interest: Rb, Sr, Nd, Hf, Pb, and K. ***Method file B*** (last two pages) is used of MI work where a larger spectrum of elements are analyzed: Ti, Rb, Sr, Y, Xr, Nb, Ba, La, Ce, Pr, Nd, Sm, Eu, Gd, Dy, Er, And Yb.

Appendix B6: USGS rock standards

USGS rock standards used for calibration on the Thermo ELEMENT2 at *AHIGL* (Department of Earth Sciences, Durham University). Concentrations are given in ppm with one exception - TiO_2 is given in wt.%. The recommended values for each of the three USGS rock standard can be find via the webpages listed below. The concentrations of the elements of each of the rock standards of interest for this work are listed in the table below.

Standard ID	W2	BHVO-1	AGV-1
TiO_2	1.1	2.71	1.06
Rb	20.36	9.6	67
Sr	193.31	403	662
Y	21.36	27.6	21
Zr	92.87	179	225
Nb	7.76	19.5	14.4
Ba	167.08	139	1221
La	10.61	15.8	38
Ce	23.03	39	66
Pr	2.94	5.7	6.5
Nd	13.22	25.2	34
Sm	3.36	6.2	5.9
Eu	1.12	2.06	1.66
Gd	3.63	6.4	5.2
Dy	3.71	5.2	3.8
Er	2.23	2.4	1.61
Yb	2.03	2.02	1.67
Rb/Sr	0.105	0.024	0.101

W2: http://minerals.cr.usgs.gov/geo_chem_stand/diabase.html

BHVO-1: http://minerals.cr.usgs.gov/geo_chem_stand/basaltbhvo1.html

AGV-1: http://minerals.cr.usgs.gov/geo_chem_stand/andesite1.html

Appendix B7: Standard data collected during MI sessions on the ELEMENT2

Rock standard ID: 25 ppb AGV-1 (n=9)

Isotope	I	II	III	IV	V	VI	VII	VIII	IX	Average	±2SD	$AGV\text{-}1_{Rec}$	Δ%
Ti	0.19	0.19	0.18	0.22	0.23	0.23	0.23	0.22	0.22	0.21	0.04	0.21	0.58
Rb	14.71	13.93	13.80	14.22	14.59	14.74	14.39	14.06	13.84	14.25	0.74	13.40	6.35
Sr	146.02	138.58	135.62	156.47	160.55	162.69	158.63	158.63	156.48	152.63	19.95	132.40	*15.28*
Y	4.52	4.25	3.96	4.75	4.77	4.88	4.83	4.91	4.75	4.62	0.65	4.20	*10.06*
Zr	48.35	47.82	46.62	53.21	52.85	53.88	53.74	54.05	53.44	51.55	6.04	45.00	*14.55*
Nb	3.04	3.03	2.89	3.46	3.48	3.40	3.58	3.53	3.53	3.33	0.53	2.88	*15.47*
Ba	276.36	251.82	245.85	271.22	288.02	289.35	280.55	282.35	286.77	274.70	31.63	244.20	*12.49*
La	8.54	7.98	8.35	8.69	8.90	8.98	8.98	8.68	8.63	8.64	0.64	7.60	*13.65*
Ce	14.82	13.75	15.69	15.85	16.06	16.05	16.08	16.18	15.82	15.59	1.60	13.20	*18.10*
Pr	1.91	1.75	2.04	1.92	2.13	2.00	1.87	1.94	1.92	1.94	0.22	1.30	*49.44*
Nd	8.00	7.23	9.77	7.91	8.64	8.57	8.27	8.41	7.80	8.29	1.42	6.80	*21.87*
Sm	1.30	1.16	1.50	1.54	1.54	1.33	1.47	1.35	1.51	1.41	0.26	1.18	*19.47*
Eu	0.42	0.32	0.37	0.42	0.41	0.43	0.41	0.43	0.46	0.41	0.08	0.33	*23.03*
Gd	1.25	0.97	1.02	1.31	1.22	1.60	1.33	1.34	1.50	1.28	0.40	1.04	*23.41*
Dy	0.99	0.68	0.77	0.89	1.01	0.76	1.01	0.83	0.86	0.87	0.24	0.76	*13.99*
Er	0.36	0.31	0.32	0.41	0.51	0.40	0.41	0.41	0.48	0.40	0.13	0.32	*24.71*
Yb	0.49	0.40	0.39	0.40	0.43	0.43	0.45	0.46	0.49	0.44	0.08	0.33	*30.81*
Rb/Sr	0.101	0.101	0.102	0.091	0.091	0.091	0.091	0.089	0.088	0.094	0.011	0.101	-7.449

Table B7.1: Standard data collected on AGV-1 using the Thermo ELEMENT2 at *AHIGL* (Department of Earth Sciences, Durham University). The AGV-1 reference values are marked in solid grey, however recalculated accordingly to degree of dilution of each solution (either 25, 50, 250, or 500 ppb). The undiluted reference values are listed in Appendix B6. Marked in light grey are the average concentrations of Rb and Sr plus the average Rb/Sr ratio obtained for each analysis. Also marked in light grey is the average difference in % between the average obtained concentrations and average Rb/Sr ratios and the reference values (Δ%).

Rock standard ID: 50 ppb AGV-1 (n=7)											
Isotope	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**Average**	**±2SD**	**AGV-1$_{Rec}$**	**Δ%**
Ti	0.44	0.43	0.41	0.45	0.42	0.40	0.40	0.42	0.04	0.42	-0.76
Rb	27.42	26.61	26.44	29.62	26.45	25.19	27.91	27.09	2.81	26.80	1.08
Sr	268.97	264.82	260.00	282.38	254.79	248.58	246.40	260.85	25.06	264.80	-1.49
Y	7.37	7.87	7.22	8.31	7.80	7.37	7.10	7.58	0.86	8.40	-9.77
Zr	94.69	95.49	89.67	96.65	88.50	87.70	83.23	90.85	9.82	90.00	0.94
Nb	6.41	6.32	6.14	6.62	6.81	7.13	6.53	6.56	0.66	5.76	*13.95*
Ba	500.68	499.25	485.15	522.65	482.82	467.59	449.33	486.78	47.78	488.40	-0.33
La	15.89	15.33	15.60	16.21	15.32	14.51	14.23	15.30	1.42	15.20	0.64
Ce	28.00	27.29	27.41	29.02	27.21	26.27	25.18	27.20	2.44	26.40	3.03
Pr	3.07	3.31	2.91	3.35	3.32	3.18	2.99	3.16	0.35	2.60	*21.59*
Nd	12.91	12.25	12.12	13.98	12.83	12.94	11.57	12.66	1.54	13.60	-6.93
Sm	2.44	1.95	2.12	2.18	2.48	1.82	1.95	2.13	0.51	2.36	-9.54
Eu	0.61	0.57	0.61	0.61	0.68	0.60	0.58	0.61	0.07	0.66	-8.31
Gd	1.93	1.43	1.58	1.54	1.82	1.79	1.72	1.69	0.36	2.08	*-18.87*
Dy	1.27	1.36	1.22	1.32	1.28	1.39	1.39	1.32	0.13	1.52	*-13.31*
Er	0.72	0.64	0.67	0.72	0.68	0.66	0.60	0.67	0.09	0.64	3.95
Yb	0.69	0.53	0.54	0.65	0.56	0.65	0.60	0.60	0.12	0.67	*-10.05*
Rb/Sr	0.102	0.100	0.102	0.105	0.104	0.101	0.113	0.10	0.01	0.10	2.676

Table B7.1: Continued

Rock standard ID: 250 ppb AGV-1 (n=6)

Isotope	I	II	III	IV	V	VI	Average	±2SD	$AGV\text{-}1_{Rec}$	Δ%
Ti	1.96	2.12	2.11	1.82	1.69	2.11	1.97	0.36	2.12	-7.15
Rb	124.54	150.27	149.30	139.64	123.88	150.34	139.66	25.25	134.00	4.23
Sr	1217.72	1541.92	1534.67	1383.60	1261.06	1531.07	1411.67	293.18	1324.00	6.62
Y	37.94	46.27	45.71	41.50	38.42	45.80	42.61	7.68	42.00	1.44
Zr	404.62	508.79	506.04	452.50	422.22	506.23	466.73	93.45	450.00	3.72
Nb	26.90	32.72	32.79	29.26	27.67	32.78	30.35	5.49	28.80	5.39
Ba	2278.01	2791.57	2766.63	2621.43	2396.16	2786.58	2606.73	442.44	2442.00	6.75
La	70.74	84.97	84.94	79.32	74.94	85.12	80.00	12.23	76.00	5.27
Ce	123.01	152.34	151.81	139.77	132.03	153.27	142.04	25.22	132.00	7.60
Pr	14.61	19.31	18.91	17.49	16.46	19.94	17.79	4.02	13.00	*36.82*
Nd	62.23	80.86	79.64	75.45	68.95	78.79	74.32	14.63	68.00	9.29
Sm	11.88	14.71	14.67	13.34	12.04	14.31	13.49	2.58	11.80	*14.33*
Eu	3.28	4.23	4.18	3.78	3.57	3.94	3.83	0.74	3.32	*15.36*
Gd	9.83	12.81	12.87	12.46	11.33	12.40	11.95	2.35	10.40	*14.91*
Dy	7.76	8.78	8.55	8.21	7.45	8.31	8.18	0.99	7.60	7.58
Er	2.08	4.33	4.18	3.75	3.47	4.24	3.67	1.69	3.22	*14.08*
Yb	2.67	4.42	4.15	4.00	3.80	4.28	3.89	1.27	3.34	*16.42*
Rb/Sr	0.102	0.097	0.097	0.101	0.098	0.098	0.099	0.004	0.101	-2.121

Table B7.1: Continued

Rock standard ID: 500 ppb AGV-1 (n=5)									
Isotope	**I**	**II**	**III**	**IV**	**V**	**Average**	**±2SD**	**AGV-1$_{Rec}$**	**Δ%**
Ti	4.40	4.19	4.23	4.34	4.54	4.34	0.28	4.24	2.41
Rb	297.36	262.47	264.19	276.78	296.45	279.45	33.73	268.00	4.27
Sr	2832.87	2573.03	2603.11	2639.41	2774.31	2684.54	226.19	2648.00	1.38
Y	82.79	77.13	77.26	79.97	82.28	79.88	5.35	84.00	-4.90
Zr	992.63	952.44	964.58	1010.88	980.63	980.23	45.94	900.00	8.91
Nb	64.56	62.14	73.57	71.26	69.56	68.22	9.49	57.60	*18.43*
Ba	5200.80	4901.82	4803.69	4814.14	4980.64	4940.22	324.88	4884.00	1.15
La	162.93	150.76	150.57	156.37	156.94	155.51	10.24	152.00	2.31
Ce	284.54	268.89	266.90	272.34	275.08	273.55	13.80	264.00	3.62
Pr	34.72	31.06	30.72	29.83	31.45	31.56	3.74	26.00	*21.38*
Nd	137.98	130.55	130.61	129.45	135.33	132.78	7.37	136.00	-2.37
Sm	22.69	22.39	22.90	24.68	23.78	23.29	1.87	23.60	-1.33
Eu	7.14	5.91	6.61	6.72	6.67	6.61	0.88	6.64	-0.47
Gd	19.84	18.52	19.34	20.08	20.07	19.57	1.32	20.80	-5.91
Dy	13.98	14.40	14.06	14.41	14.25	14.22	0.39	15.20	-6.44
Er	7.34	6.10	6.66	6.93	7.13	6.83	0.96	6.44	6.10
Yb	6.99	6.38	6.17	6.78	6.61	6.59	0.65	6.68	-1.41
Rb/Sr	0.105	0.102	0.101	0.105	0.107	0.10	0.00	0.10	2.794

Table B7.1: Continued

Rock standard ID: 25 ppb BHVO-1 (n=4)								
Element	**I**	**II**	**III**	**IV**	**Average**	**±2SD**	**BHVO-1$_{Rec}$**	**Δ%**
Ti	0.44	0.51	0.47	0.46	0.47	0.06	0.54	*-12.87*
Rb	1.91	1.91	2.15	2.14	2.03	0.27	1.92	5.65
Sr	78.83	73.93	83.26	80.48	79.13	7.83	80.60	-1.83
Y	5.58	5.67	6.01	5.85	5.78	0.39	5.52	4.66
Zr	33.23	33.05	35.91	35.51	34.42	2.99	35.80	-3.85
Nb	3.66	3.64	3.78	3.71	3.70	0.13	3.90	-5.18
Ba	27.76	25.42	29.05	27.01	27.31	3.03	27.80	-1.77
La	3.07	2.95	3.25	3.17	3.11	0.26	3.16	-1.62
Ce	7.36	7.00	7.72	7.42	7.37	0.59	7.80	-5.47
Pr	1.18	1.00	1.03	1.10	1.08	0.16	1.14	-5.45
Nd	5.74	4.91	5.84	5.63	5.53	0.84	5.04	9.70
Sm	1.43	1.05	1.38	1.38	1.31	0.35	1.24	5.58
Eu	0.50	0.42	0.48	0.42	0.46	0.08	0.41	*10.60*
Gd	1.35	1.34	1.53	1.52	1.44	0.21	1.28	*12.15*
Dy	1.25	1.18	1.29	1.19	1.23	0.10	1.04	*17.99*
Er	0.49	0.28	0.43	0.51	0.43	0.20	0.48	*-10.73*
Yb	0.51	0.34	0.53	0.45	0.46	0.17	0.40	*12.89*
Rb/Sr	0.024	0.026	0.026	0.027	0.026	0.002	0.024	7.60

Table B7.2: Standard data collected on BHVO-1 using the Thermo ELEMENT2 at *AHIGL* (Department of Earth Sciences, Durham University). The BHVO-1 reference values are marked in solid grey, however recalculated accordingly to degree of dilution of each solution (either 25, 50, 250, or 500 ppb). The undiluted reference values are listed in Appendix B6. Marked in light grey are the concentrations of Rb and Sr plus the Rb/Sr ratio obtained for each analysis. Also marked in light grey is the average difference in % between the average obtained concentrations and the average Rb/Sr ratios and the reference values (Δ%).

Rock standard ID: 50 ppb BHVO-1 (n=8)												
Elemen	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**Average**	**±2SD**	**BHVO-1$_{Rec}$**	**Δ%**
Ti	1.16	1.08	1.13	1.04	1.09	1.05	1.12	1.02	1.08	0.09	1.08	0.09
Rb	4.33	3.73	3.03	2.93	2.72	3.68	3.85	5.37	3.71	1.72	3.84	-3.45
Sr	168.02	154.02	158.26	146.43	154.28	146.34	155.83	143.79	153.37	15.77	161.20	-4.86
Y	11.59	10.77	10.52	10.05	10.80	10.67	10.90	10.06	10.67	0.99	11.04	-3.35
Zr	71.18	67.41	69.78	66.24	70.31	63.68	69.10	60.64	67.29	7.25	71.60	-6.01
Nb	8.40	8.04	8.25	7.80	8.14	8.50	9.34	8.12	8.32	0.93	7.80	6.71
Ba	55.55	53.36	52.70	51.01	49.66	48.35	52.01	47.56	51.27	5.36	55.60	-7.78
La	6.60	6.19	6.14	5.76	6.08	5.86	6.30	5.71	6.08	0.60	6.32	-3.82
Ce	16.24	15.43	15.28	14.61	14.74	14.38	14.99	13.59	14.91	1.57	15.60	-4.45
Pr	2.32	2.17	2.22	1.83	1.95	2.02	1.89	2.03	2.05	0.34	2.28	-9.90
Nd	11.58	9.71	9.44	9.31	9.71	10.32	10.73	9.67	10.06	1.54	10.08	-0.20
Sm	2.87	2.11	2.73	2.28	2.58	2.23	2.38	2.15	2.42	0.56	2.48	-2.56
Eu	0.85	0.92	0.79	0.71	0.88	0.76	0.79	0.79	0.81	0.14	0.82	-1.70
Gd	2.75	2.22	2.02	1.92	2.27	2.54	2.18	2.15	2.26	0.54	2.56	*-11.86*
Dy	2.48	2.08	2.31	1.86	1.94	2.14	2.20	1.96	2.12	0.41	2.08	1.91
Er	1.06	0.90	0.96	0.92	0.84	0.83	0.93	0.81	0.91	0.16	0.96	-5.54
Yb	0.88	0.75	0.77	0.81	0.80	0.76	0.79	0.73	0.79	0.09	0.81	-2.81
Rb/Sr	0.026	0.024	0.019	0.020	0.018	0.025	0.025	0.037	0.02	0.01	0.02	1.85

Table B7.2: Continued

Rock standard ID: 500 ppb BHVO-1 (n=4)								
Element	**I**	**II**	**III**	**IV**	**Average**	**±2SD**	**BHVO-1$_{Rec}$**	**Δ%**
Ti	11.18	11.71	10.92	11.52	11.33	0.71	10.84	4.54
Rb	37.40	37.58	37.28	40.90	38.29	3.49	38.40	-0.29
Sr	1565.21	1602.45	1502.51	1601.75	1567.98	93.97	1612.00	-2.73
Y	107.66	112.57	106.36	109.86	109.11	5.44	110.40	-1.17
Zr	741.04	746.17	718.82	722.49	732.13	27.00	716.00	2.25
Nb	79.17	85.13	90.78	87.67	85.69	9.85	78.00	9.86
Ba	540.79	543.86	504.00	531.89	530.13	36.30	556.00	-4.65
La	61.46	63.80	60.40	61.73	61.85	2.84	63.20	-2.14
Ce	149.78	153.46	146.38	149.27	149.72	5.81	156.00	-4.02
Pr	19.87	19.93	19.82	19.65	19.82	0.24	22.80	*-13.08*
Nd	100.25	106.40	101.26	102.57	102.62	5.39	100.80	1.80
Sm	22.77	24.46	24.80	24.55	24.15	1.85	24.80	-2.63
Eu	8.41	8.18	8.50	8.20	8.32	0.31	8.24	1.02
Gd	23.90	25.88	26.16	25.88	25.46	2.09	25.60	-0.56
Dy	20.94	21.46	20.96	21.37	21.18	0.54	20.80	1.84
Er	9.35	9.45	9.13	9.70	9.41	0.47	9.60	-2.01
Yb	7.51	7.63	8.31	8.13	7.89	0.77	8.08	-2.29
Rb/Sr	0.024	0.023	0.025	0.026	0.024	0.002	0.02	2.52

Table B7.2: Continued

Rock standard ID: 25 ppb W2 (n=2)

Isotope	I	II	Average	±2SD	$W2_{Rec}$	Δ%
Ti	0.18	0.17	0.17	0.03	0.22	*-20.91*
Rb	4.43	4.09	4.26	0.49	4.07	4.67
Sr	44.42	40.32	42.37	5.80	38.66	9.59
Y	5.20	4.87	5.03	0.47	4.27	*17.80*
Zr	20.25	18.80	19.52	2.06	18.57	5.11
Nb	1.58	1.47	1.53	0.16	1.55	-1.71
Ba	36.66	33.89	35.28	3.93	33.42	5.56
La	2.36	2.19	2.27	0.23	2.12	7.12
Ce	5.03	4.62	4.82	0.57	4.61	4.73
Pr	0.63	0.66	0.64	0.05	0.59	9.35
Nd	3.23	3.15	3.19	0.12	2.64	*20.67*
Sm	0.91	0.83	0.87	0.12	0.67	*29.32*
Eu	0.24	0.23	0.24	0.02	0.22	5.80
Gd	0.96	0.73	0.85	0.32	0.73	*16.39*
Dy	0.86	0.80	0.83	0.08	0.74	*11.86*
Er	0.49	0.49	0.49	0.00	0.45	*10.09*
Yb	0.49	0.50	0.49	0.01	0.41	*21.80*
Rb/Sr	0.100	0.101	0.101	0.002	0.105	-4.459

Table B7.3: Standard data collected on W2 using the Thermo ELEMENT2 at *AHIGL* (Department of Earth Sciences, Durham University). The W2 reference values are marked in solid grey, however recalculated accordingly to degree of dilution of each solution (either 25, 50, 250, or 500 ppb). The undiluted reference values are listed in Appendix B6. Marked in light grey are the concentrations of Rb and Sr plus the Rb/Sr ratio obtained for each analysis. Also marked in light grey is the average difference in % between the average obtained concentrations and the average Rb/Sr ratios and the reference values(Δ%).

Rock standard ID: 50 ppb W2 (n=9)													
Isotope	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**Average**	**±2SD**	**$W2_{Rec}$**	**Δ%**
Ti	0.40	0.44	0.43	0.39	0.39	0.44	0.41	0.40	0.43	0.41	0.04	0.44	-5.94
Rb	7.93	8.18	7.54	6.86	6.69	8.30	7.64	7.85	8.20	7.69	1.15	8.14	-5.61
Sr	74.96	84.07	80.56	75.64	75.92	84.68	79.11	77.75	82.00	79.41	7.30	77.32	2.70
Y	8.46	9.32	8.93	8.48	8.47	8.95	9.18	8.56	9.34	8.86	0.74	8.54	3.65
Zr	33.83	38.11	36.81	35.80	34.93	36.94	34.03	35.39	37.35	35.91	2.99	37.15	-3.33
Nb	2.80	3.23	3.15	2.97	2.79	3.35	3.22	3.55	3.57	3.18	0.58	3.10	2.50
Ba	65.50	74.93	67.65	65.43	65.79	73.22	71.65	67.06	71.80	69.23	7.35	66.83	3.58
La	3.80	4.56	4.39	4.19	4.01	4.45	4.31	3.97	4.21	4.21	0.50	4.24	-0.78
Ce	8.45	9.40	9.30	8.62	9.12	9.30	9.16	8.81	9.27	9.05	0.68	9.21	-1.78
Pr	0.94	1.25	0.98	0.96	0.94	1.27	1.03	1.05	1.23	1.07	0.28	1.18	-8.85
Nd	4.83	5.68	5.18	5.20	4.31	5.55	5.34	5.06	5.70	5.20	0.88	5.29	-1.58
Sm	1.39	1.46	1.41	1.21	1.25	1.22	1.27	1.16	1.39	1.31	0.21	1.34	-2.83
Eu	0.32	0.46	0.42	0.40	0.34	0.53	0.44	0.44	0.50	0.43	0.14	0.45	-4.69
Gd	1.23	1.43	1.39	1.18	1.10	1.39	1.77	1.32	1.37	1.35	0.39	1.45	-6.72
Dy	1.50	1.59	1.41	1.54	1.58	1.55	1.60	1.59	1.43	1.53	0.14	1.48	3.21
Er	0.68	0.92	0.76	0.78	0.83	1.01	0.87	0.82	0.83	0.83	0.19	0.89	-6.54
Yb	0.67	0.96	0.87	0.86	0.70	0.76	1.00	0.71	0.81	0.82	0.23	0.81	0.44
Rb/Sr	0.106	0.097	0.094	0.091	0.088	0.098	0.097	0.101	0.100	0.097	0.011	0.105	-8.112

Table B7.3: Continued

Appendix B7: Continued

Rock standard ID: 250 ppb W2 (n=2)						
Isotope	**I**	**II**	**Average**	**±2SD**	**$W2_{Rec}$**	**Δ%**
Ti	1.78	1.87	1.83	0.13	2.20	*-16.98*
Rb	39.57	41.30	40.44	2.45	40.72	-0.69
Sr	395.58	412.06	403.82	23.30	386.62	4.45
Y	44.71	46.37	45.54	2.35	42.72	6.60
Zr	173.21	178.69	175.95	7.76	185.74	-5.27
Nb	14.72	15.20	14.96	0.67	15.52	-3.61
Ba	353.82	364.69	359.25	15.38	334.16	7.51
La	21.19	22.04	21.61	1.21	21.22	1.85
Ce	46.18	46.86	46.52	0.96	46.06	0.99
Pr	6.10	6.21	6.15	0.14	5.88	4.66
Nd	29.76	30.62	30.19	1.22	26.44	*14.19*
Sm	7.28	7.24	7.26	0.06	6.72	8.02
Eu	2.52	2.59	2.56	0.10	2.24	*14.08*
Gd	8.80	9.51	9.16	1.00	7.26	*26.11*
Dy	8.62	9.27	8.94	0.92	7.42	*20.53*
Er	4.46	4.61	4.54	0.21	4.46	1.70
Yb	4.99	4.98	4.99	0.01	4.06	*22.80*
Rb/Sr	0.10	0.10	0.10	0.00	0.11	-4.923

Table B7.3: Continued

Rock standard ID: 500 ppbW2 (n=3)							
Isotope	**I**	**II**	**III**	**Average**	**±2SD**	**$W2_{Rec}$**	**Δ%**
Ti	4.17	4.44	4.27	4.29	0.28	4.40	-2.42
Rb	74.93	81.04	82.06	79.35	7.71	81.44	-2.57
Sr	741.46	784.95	761.95	762.79	43.52	773.24	-1.35
Y	84.71	90.54	87.55	87.60	5.83	85.44	2.53
Zr	357.73	386.99	359.82	368.18	32.65	371.48	-0.89
Nb	30.43	36.29	32.94	33.22	5.88	31.04	7.02
Ba	669.70	677.61	657.11	668.14	20.68	668.32	-0.03
La	41.19	43.00	40.96	41.71	2.24	42.44	-1.71
Ce	87.95	90.95	88.66	89.19	3.14	92.12	-3.18
Pr	10.88	10.35	10.72	10.65	0.55	11.76	-9.40
Nd	53.65	54.05	50.87	52.86	3.46	52.88	-0.05
Sm	12.40	13.30	13.49	13.06	1.17	13.44	-2.82
Eu	4.06	4.53	4.24	4.27	0.47	4.48	-4.60
Gd	12.83	15.85	14.65	14.44	3.05	14.52	-0.52
Dy	14.78	15.51	15.16	15.15	0.73	14.84	2.09
Er	8.01	8.69	8.52	8.41	0.71	8.92	-5.71
Yb	8.31	8.26	8.20	8.26	0.11	8.12	1.72
Rb/Sr	0.101	0.103	0.108	0.104	0.007	0.105	-1.253

Table B7.3: Continued

Synthetic 1:10 Rb-Sr solution (n=3)							
Element	**I**	**II**	**II**	**Average**	**±2SD**	**Rec**	**Δ%**
Rb	1.01	0.91	0.94	0.96	0.11	1.00	-4.49
Sr	12.39	10.51	11.16	11.36	1.91	10.00	13.56
Rb/Sr	0.082	0.086	0.085	0.084	0.005	0.100	-15.77

Table B7.4:

Synthetic 5:50 Rb-Sr solution (n=1)					
Element	**I**	**Average**	**±2SD**	**Rec**	**Δ%**
Rb	4.73	-	-	5.00	-5.46
Sr	45.59	-	-	50.00	-8.82
Rb/Sr	0.104	-	-	0.100	3.68

Table B7.4: Continued

Synthetic 20:200 Rb-Sr solution (n=4)								
Element	**I**	**II**	**III**	**IV**	**Average**	**±2SD**	**Rec**	**Δ%**
Rb	19.12	18.75	16.59	18.98	18.36	2.39	20.00	-8.20
Sr	177.21	184.81	168.62	184.82	178.86	15.43	200.00	-10.57
Rb/Sr	0.108	0.101	0.098	0.103	0.103	0.008	0.100	2.61

Table B7.4: Standard data collected on synthetic Rb-Sr solutions by TIMS at *AHIGL* (Department of Earth Sciences, Durham University). Listed are the concentrations of Rb and Sr plus the Rb/Sr ratio obtained for each analysis. Also listed is the average difference in % between the average obtained concentrations and the average Rb/Sr ratios and the reference values (Δ%).

Rock standard ID	AGV-1	BHVO-1	W2	Rb-Sr
n	27	16	17	8
Elements (Δ%)				
Ti	-1.15	-2.04	-8.90	-
Rb	4.13	-0.39	-3.49	-6.47
Sr	6.43	-3.57	3.19	-1.30
Y	0.23	-0.80	5.81	-
Zr	7.57	-3.41	-2.27	-
Nb	*13.38*	4.52	2.22	-
Ba	5.79	-5.49	3.87	-
La	6.31	-2.85	0.31	-
Ce	9.18	-4.60	-0.99	-
Pr	*34.22*	-9.58	-5.54	-
Nd	7.12	2.77	3.36	-
Sm	6.96	-0.54	2.37	-
Eu	8.85	2.06	-1.31	-
Gd	5.13	-3.03	1.01	-
Dy	1.71	5.91	6.45	-
Er	*13.52*	-5.96	-3.69	-
Yb	*11.05*	1.25	6.17	-
Rb/Sr	-1.74	3.46	-6.48	-4.15

Table B7.5: Summary table giving the average difference in percent (Δ %) for each element between the obtained concentrations and the recommended values (listed in Appendix B6). Notice, that these values are weighted average according to the number (n) of each different dissolutions were analyzed.

Appendix B8: Sr isotope data collected on sub-ng NBS 987 standard loads by TIMS

For Sr isotope standard, we used NBS 987 (equals to SRM 987), which is a strontium carbonate standard citified by the National Institute of Standards and technology *(http://www.nist.gov.srm)*.

Run order	Load (ng)	MI Session	$^{87}Sr/^{86}Sr$	±2SE
1	0.6	Vestfirdir	0.710267	0.000053
2	0.6	Vestfirdir	0.710242	0.000042
3	0.6	Vestfirdir	0.710240	0.000043
4	0.6	Vestfirdir	0.710293	0.000048
5	0.6	Vestfirdir	0.710258	0.000022
6	0.6	Vestfirdir	0.710272	0.000022
7	0.6	Vestfirdir	0.710243	0.000019
8	0.6	Vestfirdir	0.710249	0.000033
9	0.6	Vestfirdir	0.710260	0.000029
10	0.6	Vestfirdir	0.710257	0.000028
11	0.6	Vestfirdir	0.710293	0.000025
12	0.6	Vestfirdir	0.710225	0.000031
13	0.6	Vestfirdir	0.710257	0.000032
14	0.6	Vestfirdir	0.710255	0.000028
15	0.6	Vestfirdir	0.710265	0.000032
16	0.6	Vestfirdir	0.710239	0.000046
17	0.3	Vestfirdir	0.710245	0.000046
18	0.3	Vestfirdir	0.710254	0.000039
19	0.3	Vestfirdir	0.710272	0.000032
20	0.3	Vestfirdir	0.710298	0.000039
21	0.6	Vestfirdir	0.710256	0.000026
22	0.6	Vestfirdir	0.710267	0.000026
23	0.6	Vestfirdir	0.710268	0.000022
24	0.6	Vestfirdir	0.710212	0.000039
25	0.6	Vestfirdir	0.710281	0.000033
26	0.3	Vestfirdir	0.710295	0.000037
27	0.3	Vestfirdir	0.710219	0.000073
28	0.3	Vestfirdir	0.710279	0.000074
29	0.3	Vestfirdir	0.710265	0.000065
30	0.6	Vestfirdir	0.710290	0.000030
31	0.6	Vestfirdir	0.710251	0.000026
32	0.6	Vestfirdir	0.710279	0.000026
33	0.6	Vestfirdir	0.710265	0.000034
34	0.3	Vestfirdir	0.710269	0.000076
35	0.3	Vestfirdir	0.710245	0.000045

Table B8.1: Continues on the next two pages. See caption below the last part of the table.

Run order	Load (ng)	MI Session	$^{87}Sr/^{86}Sr$	±2SE
36	0.3	Vestfirdir	0.710252	0.000041
37	0.3	Vestfirdir	0.710280	0.000055
38	0.3	Vestfirdir	0.710261	0.000077
39	0.3	Vestfirdir	0.710299	0.000131
40	0.1	Vestfirdir	0.710243	0.000134
41	0.1	Vestfirdir	0.710227	0.000154
42	0.3	Vestfirdir	0.710255	0.000079
43	0.3	Vestfirdir	0.710263	0.000066
44	0.3	Vestfirdir	0.710302	0.000097
45	0.6	Vestfirdir	0.710245	0.000025
46	0.6	Vestfirdir	0.710288	0.000028
47	0.3	Vestfirdir	0.710262	0.000054
48	0.3	Vestfirdir	0.710251	0.000056
49	0.3	Vestfirdir	0.710222	0.000070
50	0.1	Vestfirdir	0.710261	0.000100
51	0.1	Vestfirdir	0.710267	0.000089
52	0.3	Vestfirdir	0.710238	0.000091
53	0.3	Vestfirdir	0.710245	0.000077
54	0.6	Vestfirdir	0.710245	0.000049
55	0.6	Vestfirdir	0.710261	0.000092
56	0.3	Vestfirdir	0.710313	0.000058
57	0.1	Vestfirdir	0.710299	0.000297
58	0.6	Vestfirdir	0.710263	0.000049
59	0.3	Vestfirdir	0.710276	0.000088
60	0.3	Vestfirdir	0.710250	0.000108
61	0.3	Vestfirdir	0.710243	0.000057
62	0.3	BIP	0.710258	0.000047
63	0.3	BIP	0.710280	0.000042
64	0.1	BIP	0.710266	0.000068
65	0.1	BIP	0.710267	0.000058
66	0.1	BIP	0.710272	0.000056
67	0.3	BIP	0.710279	0.000116
68	0.3	BIP	0.710298	0.000060
69	0.3	BIP	0.710237	0.000004
70	0.1	BIP	0.710269	0.000137
71	0.3	BIP	0.710291	0.000057
72	0.3	BIP	0.710278	0.000127
73	0.3	BIP	0.710269	0.000044
74	0.3	BIP	0.710265	0.000041
75	0.1	BIP	0.710255	0.000114

Table B8.1: Continued.

Run order	Load (ng)	MI Session	$^{87}Sr/^{86}Sr$	±2SE
76	0.3	BIP	0.710247	0.000025
77	0.3	BIP	0.710268	0.000027
78	0.3	BIP	0.710271	0.000033
79	0.3	BIP	0.710256	0.000036
80	0.1	BIP	0.710263	0.000063
81	0.3	BIP	0.710280	0.000072
82	0.3	BIP	0.710255	0.000039
83	0.1	BIP	0.710268	0.000111
84	0.1	BIP	0.710235	0.000098
85	0.1	BIP	0.710243	0.000147
86	0.3	BIP	0.710246	0.000042
87	0.3	BIP	0.710240	0.000051
88	0.3	BIP	0.710245	0.000037
89	0.3	BIP	0.710214	0.000038
90	0.3	BIP	0.710244	0.000042
91	0.1	BIP	0.710289	0.000063

Table B8.1: Table including 91 NBS 987 sub-ng loads analyzed in association with MI work presented in this Ph.D. thesis. Data is ordered in accordance with the run order. The first 61 standards were analyzed in association with the Vestfirdir MIs (*Chapter 3*), and the following 30 analyses with the BIP MIs (*Chapter 4*). The data was colleted using the ThermoFinnigan TIMS at *AHIGL* (Department of Earth Sciences, Durham University).

Load size	0.1 ng	0.3 ng	0.6 ng
n	15	46	30
$^{87}Sr/^{86}Sr_{Ave}$	0.710262	0.710262	0.710260
±2SD	0.000038	0.000045	0.000039
±2SD	43	63	54

Sub-ng	Long term	Vestfirdir MI	Baffin Island MI
n	91	61	30
Interval	1 through 91	1 through 61	62 through 91
$^{87}Sr/^{86}Sr_{Ave}$	0.710261	0.710261	0.710262
±2SD	0.000042	0.000044	0.000038
±2SD	58	61	53

Table B8.2: Statistic overview of the NBS 987 Sr isotope data collected over a 9 month period using the ThermoFinnigan TIMS at *AHIGL* (Department of Earth Sciences, Durham University). These standards were analyzed in connection with the Vestfirdir and BIP MI work presented in the Ph.D. thesis. 'n' gives the number of analyses.

Test Session	Statistics	Load (ng)	$^{87}Sr/^{86}Sr$	±2SE
$^{87}Sr/^{86}Sr_{Ave}$	0.710205	0.01	0.710195	0.000441
±2SD	0.000041	0.01	0.710228	0.000821
±2SD (ppm)	57	0.01	0.710191	0.001422
n	3			

Test Session	Statistics	Load (ng)	$^{87}Sr/^{86}Sr$	±2SE
$^{87}Sr/^{86}Sr_{Ave}$	0.709908	0.025	0.710204	0.000104
±2SD	0.000531	0.025	0.709691	0.000068
±2SD (ppm)	747	0.025	0.70983	0.000131
n	3			

Table B8.3: A few test were done to run 0.025 ng and 0.010 ng NBS 987 standard loads on the ThermoFinnigan TIMS at *AHGIL* (Department of Earth Sciences, Durham University).

Appendix B9: TPB archive

Trace element concentrations of 12 individual TPBs (pg)

Element	M14-43	M14-44	M14-45	M14-46	M14-47	M14-48	M14-49	M14-50	M14-51	M14-52	M14-53	M14-54	TPB_{M14}	±2SD
Ti	0.27	0.35	0.50	0.11	0.19	0.18	0.18	0.31	0.68	0.27	0.25	0.59	0.32	0.35
Rb	0.41	4.36	4.62	0.71	-0.19	1.22	4.02	0.87	2.25	2.40	2.54	2.50	1.41	2.06
Sr	0.55	22.60	13.70	0.86	4.18	8.98	11.50	3.37	6.50	8.04	6.23	4.86	4.84	5.87
Y	-0.32	0.39	1.31	-0.41	-0.45	-0.25	0.40	-0.55	-0.16	0.25	0.69	0.32	0.10	1.11
Zr	36.65	96.89	323.93	33.05	123.17	71.38	63.49	118.33	116.72	86.82	64.11	75.90	80.59	62.32
Nb	6.52	5.53	15.26	11.12	21.20	4.21	53.89	12.51	9.04	9.55	4.42	6.45	9.62	10.38
Ba	33.99	29.95	4.39	8.81	9.01	9.93	26.61	7.24	12.30	14.41	9.59	11.73	9.71	5.86
La	0.31	0.91	5.69	0.38	0.35	1.15	2.18	0.38	1.36	1.32	0.60	1.80	0.86	1.28
Ce	0.66	1.86	9.23	0.42	0.38	0.74	2.21	0.68	2.29	3.13	1.24	1.43	1.37	1.81
Pr	0.05	0.13	0.79	-0.11	0.03	0.13	0.21	-0.02	0.08	0.10	0.17	0.40	0.16	0.47
Nd	-0.21	0.28	3.87	0.08	-0.28	0.20	0.69	0.17	0.56	1.18	0.35	0.96	0.36	0.91
Sm	-0.24	-0.08	0.38	0.02	0.00	0.01	0.06	0.10	0.06	0.06	0.09	-0.05	0.00	0.20
Eu	-0.18	-0.14	-0.09	-0.07	-0.06	-0.10	-0.12	-0.07	-0.12	-0.04	0.04	0.11	-0.07	0.16
Gd	-0.83	-0.83	-0.27	-0.85	-0.83	-0.69	-0.94	-0.71	-0.74	-0.51	-0.05	0.08	-0.60	0.68
Dy	-0.10	0.03	0.29	-0.15	-0.11	0.02	-0.07	-0.03	0.00	0.10	0.19	0.05	0.02	0.26
Er	-0.03	-0.04	0.12	-0.04	-0.02	-0.07	-0.04	0.00	0.00	0.00	0.02	0.03	-0.01	0.10
Yb	0.02	0.01	0.18	-0.06	-0.01	0.00	0.03	0.02	0.02	-0.04	0.09	0.06	0.03	0.13

Table B9.1: Trace element data collected on 12 individual total procedural blanks (TPB) processed in association with the BIP MIs data set presented in *Chapter 4*. The data is collected using the Thermo ELEMENT2 at *AHIGL* (Department of Earth Sciences, Durham University).The average TPB composition or the TPB-M14 is the composition used for blank correction of the data presented in *Chapter 4* in combination with the Sr isotope composition of TPB60 (Table 2.6). Data in grey is rejected.

Trace element concentrations of 8 individual TPBs

	M14-55 19	M14-56 21	M14-57 23	M14-61 32	M14-62 34	M14-64 51	M14-65 53	M14-66 55	TPB_{14-55}	±2SD
Ti	0.13	0.17	0.29	0.12	0.19	0.16	0.09	0.12	0.16	0.12
Rb	1.88	2.01	1.70	2.03	2.04	1.41	1.09	0.79	1.62	0.95
Sr	6.39	4.98	6.16	6.14	5.91	5.12	3.53	1.77	5.00	3.21
Y	0.14	0.00	0.23	0.28	0.43	0.04	0.30	0.07	0.19	0.30
Zr	9.39	99.41	253.99	159.52	15.06	9.62	16.26	79.50	80.34	177.58
Nb	1.59	6.66	2.02	3.41	2.88	2.94	2.56	3.47	3.19	3.09
Ba	35.83	2.88	6.63	11.19	7.15	2.56	7.43	3.65	9.67	21.91
La	2.03	0.09	0.12	0.23	0.07	0.42	0.05	0.12	0.39	1.35
Ce	0.64	0.14	0.27	0.45	0.27	0.15	0.16	0.13	0.28	0.36
Pr	0.21	0.00	0.10	0.06	0.00	0.13	-0.03	-0.03	0.06	0.18
Nd	0.72	0.23	0.30	0.26	0.35	0.26	0.28	0.55	0.37	0.35
Sm	-0.03	-0.18	-0.04	-0.12	-0.20	-0.11	-0.11	-0.16	-0.12	0.12
Eu	-0.03	0.02	0.01	0.01	0.04	0.04	0.01	-0.01	0.01	0.04
Gd	-0.17	-0.02	-0.03	-0.02	-0.14	-0.21	0.00	-0.03	-0.08	0.16
Dy	0.10	0.05	-0.01	0.00	0.06	0.00	-0.01	-0.04	0.02	0.09
Er	-0.03	-0.02	-0.02	-0.03	-0.04	-0.05	-0.03	0.00	-0.03	0.03
Yb	0.00	0.00	0.04	0.00	0.04	-0.01	0.00	0.00	0.01	0.04

Table B9.2: Another example of TPB compositions collected in association with MI work using the Thermo ELEMENT2 at *AHIGL* (Department of Earth Sciences, Durham University).

Trace element compositions of TPBs associated with MI work

TPB ID	TPB_{M14}	TPB_{M11}	TPB_{14-55}	TPB_{Ave}	±2SD	LOD
n	9	12	8	29		10
Ti	0.31	0.11	0.16	0.20	0.22	0.01
Rb	1.41	0.94	1.62	1.32	0.69	0.41
Sr	4.84	4.75	5.00	4.86	0.26	0.73
Y	0.10	0.19	0.19	0.16	0.10	0.40
Zr	80.59	48.01	80.34	69.65	37.47	0.41
Nb	9.62	3.64	3.19	5.48	7.17	0.15
Ba	9.71	9.64	9.67	9.09	1.97	2.06
La	0.86	0.84	0.39	0.73	0.59	0.10
Ce	1.37	1.00	0.28	0.98	1.39	0.11
Pr	0.16	0.10	0.06	0.11	0.10	0.15
Nd	0.36	0.34	0.37	0.36	0.03	0.32
Sm	0.00	0.00	-0.12	-0.04	0.14	0.29
Eu	-0.07	0.00	0.01	-0.02	0.09	0.09
Gd	-0.60	-0.13	-0.08	-0.27	0.57	0.26
Dy	0.02	0.03	0.02	0.02	0.02	0.11
Er	-0.01	0.00	-0.03	-0.01	0.03	0.05
Yb	0.03	0.02	0.01	0.02	0.02	0.07
Rb/Sr	0.292	0.198	0.324	0.271	0.130	

Table B9.3: Summary table of TPB collected in association with MI work using the Thermo ELEMENT2 at AHIGL (Department of Earth Sciences, Durham University). LOD gives the limit of detection (See Table B9.4b)

Trace element concentrations of 10 analyte blanks (3% UpA HNO_3) analyzed with the BIP MIs (pg/mL)										Average (n=10)
Element	Blank 1	Blank 2	Blank 3	Blank 4	Blank 5	Blank 6	Blank 7	Blank 8	Blank 9	Blank 10	$Blank_{ave}$
Ti	0.00	0.01	0.00	0.00	-0.01	-0.01	0.00	0.00	0.00	0.02	0.00
Rb	1.21	0.24	-0.13	-0.66	-0.67	-0.84	-0.01	-0.03	0.00	2.22	0.13
Sr	-0.19	0.58	-0.21	0.69	-0.84	-1.09	0.29	-0.06	1.23	3.78	0.42
Y	-0.17	0.13	-0.15	-0.26	-0.32	-0.31	0.04	0.05	-0.07	0.10	-0.10
Zr	0.54	0.60	0.11	0.30	0.02	-0.28	-0.24	-0.24	-0.14	-0.25	0.04
Nb	0.04	-0.03	-0.03	0.06	-0.13	-0.14	-0.07	-0.05	-0.03	-0.03	-0.04
Ba	0.62	0.35	1.85	2.35	0.29	0.84	0.17	0.49	0.52	1.11	0.86
La	-0.01	0.05	0.00	0.08	0.03	0.07	0.00	-0.02	0.02	0.05	0.03
Ce	0.07	0.06	0.01	0.03	0.03	-0.01	0.01	-0.01	0.07	0.24	0.05
Pr	0.00	-0.06	-0.02	0.04	0.00	-0.03	0.00	-0.02	-0.02	0.10	0.00
Nd	-0.28	-0.28	-0.26	-0.15	-0.25	-0.24	-0.04	-0.05	-0.01	0.19	-0.14
Sm	-0.09	-0.05	-0.10	-0.07	-0.07	-0.01	-0.11	-0.08	-0.16	-0.06	-0.08
Eu	-0.05	0.01	-0.04	-0.04	-0.05	-0.07	0.00	0.00	-0.02	0.01	-0.03
Gd	-0.28	-0.27	-0.29	-0.34	-0.31	-0.33	0.02	-0.05	-0.05	0.03	-0.19
Dy	-0.05	-0.03	-0.03	0.00	-0.04	-0.04	0.01	-0.02	-0.01	0.00	-0.02
Er	-0.02	-0.03	-0.04	-0.02	-0.05	-0.04	-0.01	-0.01	-0.01	0.01	-0.02
Yb	0.02	-0.04	-0.03	0.00	-0.03	-0.01	0.01	0.00	-0.02	0.00	-0.01

Table B9.4a: Trace element compositions of 10 analyte blanks (3% UpA HNO3) analyzed by double focusing magnetic sector field ICPMS (Thermo ELEMENT2) at *AHIGL* (Department of Earth Sciences, Durham University) in association with MI work. Concentrations are given in pg/mL. Marked in light grey is the average composition of 10 analyte blanks.

Appendix B9: Continued

Internal precision (1SE) on the 10 analyses of analyte blanks (3% UpA HNO_3) analyzed with the BIP MIs												
											(n=10)	
Element	Blank 1	Blank 2	Blank 3	Blank 4	Blank 5	Blank 6	Blank 7	Blank 8	Blank 9	Blank 10	1SD	LOD
Ti	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Rb	0.19	0.23	0.09	0.18	0.13	0.09	0.11	0.07	0.03	0.26	0.14	0.41
Sr	0.27	0.18	0.12	*2.95*	0.39	0.47	0.20	0.14	0.36	0.05	0.24	0.73
Y	0.17	0.16	0.14	0.15	0.12	0.18	0.10	0.09	0.11	0.11	0.13	0.40
Zr	0.25	0.25	0.13	0.23	0.03	0.09	0.10	0.09	0.09	0.11	0.14	0.41
Nb	0.02	0.05	0.06	0.14	0.03	0.05	0.02	0.07	0.03	0.05	0.05	0.15
Ba	0.17	0.76	1.10	2.13	0.92	0.88	0.46	0.24	0.07	0.15	0.69	2.06
La	0.03	0.01	0.05	0.07	0.05	0.04	0.02	0.02	0.02	0.02	0.03	0.10
Ce	0.01	0.05	0.05	0.08	0.02	0.01	0.05	0.03	0.02	0.04	0.04	0.11
Pr	0.05	0.02	0.05	0.09	0.08	0.03	0.04	0.01	0.02	0.11	0.05	0.15
Nd	0.07	0.14	0.11	0.22	0.16	0.17	0.04	0.03	0.04	0.07	0.11	0.32
Sm	0.10	0.09	0.08	0.09	0.17	0.17	0.05	0.07	0.06	0.08	0.10	0.29
Eu	0.05	0.02	0.03	0.03	0.04	0.02	0.02	0.03	0.02	0.04	0.03	0.09
Gd	0.09	0.17	0.05	0.11	0.08	0.11	0.10	0.07	0.03	0.05	0.09	0.26
Dy	0.03	0.05	0.07	0.06	0.05	0.03	0.03	0.01	0.01	0.03	0.04	0.11
Er	0.03	0.03	0.00	0.03	0.01	0.02	0.01	0.01	0.02	0.01	0.02	0.05
Yb	0.03	0.02	0.03	0.03	0.02	0.01	0.04	0.02	0.03	0.02	0.02	0.07

Table B9.4b: Internal precision (1SE) for each of the 10 analyte blanks in pg/mL presented in Table B5.4a. The reproducibility (1SD) of the analyte blanks equals the average of the internal precision (1SE) of the 10 blanks. Marked in light grey is the lower detection limit (LOD) for each element calculated as 3 times the average standard deviation (1SD).

APPENDIX C

Contents of Appendix C

Appendix C1: Standard ICPMS data collected during Vestfirdir MI session

Standard ID: 25 ppb AGV-1 (n=9)

Trace element composition (pg/mL)

No.	I	II	III	IV	V	VI	VII	VIII	IX	$AGV\text{-}1_{Ref}$	$AGV\text{-}1_{Ave}$	±2SD	Δ%
Ti	0.19	0.19	0.20	0.21	0.21	0.21	0.21	0.22	0.22	**0.21**	0.21	0.02	-2.78
Rb	15.34	15.20	14.13	13.08	12.78	12.59	12.93	13.27	13.41	**13.40**	13.64	2.05	1.77
Sr	140.18	137.22	140.90	127.25	127.24	125.52	125.52	128.78	130.50	**132.40**	131.46	12.50	-0.71
Y	4.28	3.98	4.50	4.18	4.25	4.11	4.11	4.13	4.22	**4.20**	4.20	0.29	-0.07
Zr	49.56	48.36	50.14	44.47	44.73	44.22	44.04	43.74	44.59	**45.00**	45.98	5.17	2.18
Nb	3.08	2.94	3.10	2.91	2.87	2.87	2.81	2.83	2.76	**2.88**	2.91	0.23	0.96
Ba	286.12	280.15	304.06	234.90	236.40	240.10	227.08	241.15	242.27	**244.20**	254.69	55.28	4.30
La	8.34	8.70	8.90	7.58	7.33	7.29	7.34	7.52	7.59	**7.60**	7.84	1.26	3.18
Ce	14.37	16.31	15.43	12.87	12.95	12.66	12.68	12.86	12.85	**13.20**	13.66	2.74	3.51
Pr	1.77	2.07	1.95	1.38	1.43	1.41	1.42	1.57	1.47	**1.58**	1.61	0.52	1.80
Nd	7.37	9.91	8.06	6.42	6.53	6.05	6.14	6.71	6.65	**6.80**	7.09	2.46	4.33
Sm	1.15	1.48	1.26	1.14	1.04	1.16	1.19	1.19	1.03	**1.18**	1.18	0.27	0.18
Eu	0.33	0.38	0.40	0.30	0.31	0.34	0.31	0.30	0.32	**0.33**	0.33	0.07	-0.09
Gd	0.97	1.02	1.23	0.91	0.92	1.03	0.90	0.84	1.10	**1.04**	0.99	0.24	-4.76
Dy	0.67	0.76	0.97	0.86	0.70	0.73	0.75	0.85	0.64	**0.76**	0.77	0.21	1.09
Er	0.31	0.33	0.37	*0.04*	*0.04*	*0.05*	*0.04*	*0.05*	*0.04*	**0.23**	0.14	0.30	*-39.30*
Yb	0.39	0.39	0.47	0.32	0.32	0.34	0.28	0.30	0.30	**0.33**	0.35	0.12	3.58
Rb/Sr	0.109	0.111	0.100	0.103	0.101	0.100	0.103	0.103	0.103	**0.101**	0.104	0.01	2.50

Table C1.1a: Standard data collected on AGV-1 using the Thermo ELEMENT2 at *AHIGL* (Department of Earth Sciences, Durham University). The AGV-1 reference values are marked in solid grey, however recalculated accordingly to degree of dilution of each solution (either 25, 50, 250, or 500 ppb). The undiluted reference values are listed in Appendix B6. Marked in light grey are the concentrations of Rb and Sr plus the Rb/Sr ratio obtained for each analysis. Also marked in light grey is the average difference in % between the average obtained concentrations and average Rb/Sr ratios and the reference values (Δ%).

Appendix C1: Continued

Standard ID: 250 ppb AGV-1 (n=6)

Trace element composition (pg/mL)

No.	I	II	III	IV	V	VI	AGV-1$_{Ref}$	AGV-1$_{Ave}$	±2SD	Δ%
Ti	1.94	1.69	1.84	1.99	1.99	1.99	**2.12**	1.91	0.24	*-10.07*
Rb	111.69	123.88	139.07	136.68	135.79	136.73	**134.00**	130.64	21.46	-2.51
Sr	1203.29	1261.06	1378.48	1236.86	1231.04	1228.15	**1324.00**	1256.48	125.12	-5.10
Y	37.71	38.42	41.48	40.07	39.58	39.66	**42.00**	39.49	2.63	-5.98
Zr	389.47	422.22	454.29	421.07	418.80	418.96	**450.00**	420.80	41.12	-6.49
Nb	26.43	27.67	29.31	26.61	26.66	26.66	**28.80**	27.22	2.23	-5.49
Ba	1972.11	2396.16	2649.14	2337.29	2316.40	2333.11	**2442.00**	2334.03	433.09	-4.42
La	67.63	74.94	79.68	71.76	71.72	71.88	**76.00**	72.94	8.08	-4.03
Ce	117.54	132.03	140.38	121.92	121.49	122.66	**132.00**	126.00	17.04	-4.54
Pr	14.33	16.46	17.52	14.23	13.93	14.70	**15.80**	15.20	2.90	-3.82
Nd	60.91	68.95	75.52	62.78	61.83	61.17	**68.00**	65.19	11.74	-4.13
Sm	12.04	12.04	13.30	11.37	11.34	11.06	**11.80**	11.86	1.63	0.48
Eu	3.18	3.57	3.76	3.09	3.05	2.87	**3.32**	3.25	0.68	-2.00
Gd	9.84	11.33	12.44	8.78	8.83	8.50	**10.40**	9.96	3.20	-4.27
Dy	7.87	7.45	8.19	7.41	7.21	7.01	**7.60**	7.52	0.87	-1.02
Er	2.00	3.47	3.76	*0.42*	*0.41*	*0.42*	**2.32**	1.75	3.15	*-24.73*
Yb	2.71	3.80	3.99	3.10	2.91	3.00	**3.34**	3.25	1.04	-2.66
Rb/Sr	0.093	0.098	0.101	0.111	0.110	0.111	**0.101**	0.10	0.02	2.77

Table C1.1a: Continued

Standard ID: 25 ppb BHVO-1 (n=4)

Trace element composition (pg/mL)

No.	I	II	III	IV	BHVO-1_{Ref}	BHVO-1_{Ave}	±2SD	Δ%
Ti	0.51	0.47	0.46	0.49	**0.54**	0.48	0.05	*-11.10*
Rb	2.49	1.68	1.40	1.57	**1.92**	1.78	0.97	-7.08
Sr	74.01	75.92	73.64	78.14	**80.60**	75.43	4.13	-6.42
Y	5.65	5.87	5.58	6.00	**5.52**	5.77	0.39	4.58
Zr	33.25	37.18	35.07	37.70	**35.80**	35.80	4.09	-0.01
Nb	3.61	3.74	3.75	3.83	**3.90**	3.73	0.19	-4.28
Ba	*46.08*	*54.31*	*55.14*	*56.75*	**27.80**	53.07	9.54	*90.90*
La	3.14	3.52	3.41	3.61	**3.16**	3.42	0.41	8.30
Ce	7.22	8.05	7.96	8.33	**7.80**	7.89	0.95	1.15
Pr	1.01	1.13	1.21	1.06	**1.14**	1.10	0.17	-3.25
Nd	4.90	5.73	5.83	5.90	**5.04**	5.59	0.93	*10.92*
Sm	1.09	1.33	1.39	1.35	**1.24**	1.29	0.27	3.94
Eu	0.42	0.40	0.47	0.46	**0.41**	0.44	0.06	6.35
Gd	1.34	1.49	1.32	1.51	**1.28**	1.41	0.20	*10.35*
Dy	1.18	1.18	1.25	1.27	**1.04**	1.22	0.09	*17.52*
Er	0.28	0.52	0.50	0.44	**0.48**	0.43	0.22	-9.47
Yb	*0.34*	*0.45*	*0.50*	*0.51*	**1.04**	0.45	0.16	*-56.69*
Rb/Sr	0.034	0.022	0.019	0.020	**0.024**	0.02	0.01	-0.49

Table C1.1b: Standard data collected on BHVO-1 using the Thermo ELEMENT2 at *AHIGL* (Department of Earth Sciences, Durham University). The BHVO-1 reference values are marked in solid grey, however recalculated accordingly to degree of dilution of each solution (either 25, 50, 250, or 500 ppb). The undiluted reference values are listed in Appendix B6. Marked in light grey are the concentrations of Rb and Sr plus the Rb/Sr ratio obtained for each analysis. Also marked in light grey is the average difference in % between the average obtained concentrations and Rb/Sr ratios and the reference values (Δ%).

Standard ID: 25 ppb ppt W2 (n=2)						
Trace element composition (pg/mL)						
No.	I	II	**$W2_{Ref}$**	**$W2_{Ave}$**	**±2SD**	**Δ%**
Ti	0.18	0.20	**0.22**	0.19	0.02	*-14.70*
Rb	3.43	3.86	**4.07**	3.65	0.60	*-10.43*
Sr	35.23	39.30	**38.66**	37.26	5.76	**-3.62**
Y	4.85	5.18	**4.27**	5.02	0.48	*17.42*
Zr	20.41	22.04	**18.57**	21.23	2.31	*14.28*
Nb	1.51	1.63	**1.55**	1.57	0.18	**1.08**
Ba	61.18	64.37	**33.42**	62.77	4.51	*87.85*
La	2.54	2.71	**2.12**	2.63	0.24	*23.89*
Ce	5.24	5.64	**4.61**	5.44	0.56	*18.06*
Pr	0.68	0.66	**0.59**	0.67	0.03	*14.34*
Nd	3.22	3.30	**2.64**	3.26	0.12	*23.25*
Sm	0.82	0.87	**0.67**	0.85	0.08	*26.02*
Eu	0.20	0.22	**0.22**	0.21	0.04	**-6.32**
Gd	0.69	0.93	**0.73**	0.81	0.34	*11.91*
Dy	0.79	0.84	**0.74**	0.81	0.07	**9.68**
Er	0.50	0.50	**0.45**	0.50	0.00	*11.96*
Yb	0.50	0.48	**0.41**	0.49	0.03	*19.62*
Rb/Sr	0.098	0.098	**0.105**	0.10	0.00	**-7.09**

Table C1.1b: Continued

Standard ID: 250 ppb W2 (n=2)						
Trace element composition (pg/mL)						
No.	**I**	**II**	**$W2_{Ref}$**	**$W2_{Ave}$**	**±2SD**	**Δ%**
Ti	1.80	1.88	**2.20**	1.84	0.13	-16.36
Rb	39.06	40.73	**40.72**	39.89	2.36	-2.03
Sr	390.38	406.94	**386.62**	398.66	23.41	3.11
Y	44.71	46.35	**42.72**	45.53	2.33	6.58
Zr	175.05	180.48	**185.74**	177.76	7.68	-4.29
Nb	14.82	15.25	**15.52**	15.03	0.61	-3.15
Ba	381.20	392.40	**334.16**	386.80	15.83	15.75
La	21.53	22.40	**21.22**	21.97	1.22	3.52
Ce	46.78	47.47	**46.06**	47.13	0.97	2.31
Pr	6.13	6.24	**5.88**	6.19	0.15	5.20
Nd	29.85	30.69	**26.44**	30.27	1.19	14.48
Sm	7.24	7.20	**6.72**	7.22	0.05	7.43
Eu	2.49	2.57	**2.24**	2.53	0.11	12.92
Gd	8.77	9.48	**7.26**	9.13	1.01	*25.71*
Dy	8.62	9.25	**7.42**	8.93	0.89	*20.42*
Er	4.47	4.62	**4.46**	4.54	0.21	1.90
Yb	4.98	4.97	**4.06**	4.98	0.02	22.54
Rb/Sr	0.100	0.100	**0.105**	0.10	0.00	-4.99

Table C1.1c: Standard data collected on W2 using the Thermo ELEMENT2 at *AHIGL* (Department of Earth Sciences, Durham University). The W2 reference values are marked in solid grey, however recalculated accordingly to degree of dilution of each solution (either 25, 50, 250, or 500 ppb). The undiluted reference values are listed in Appendix B6. Marked in light grey are the concentrations of Rb and Sr plus the Rb/Sr ratio obtained for each analysis. Also marked in light grey is the average difference in % between the average obtained concentrations and Rb/Sr ratios and the reference values (Δ%).

Appendix C2: TPB associated with the Vestfirdir MI study

Trace element content of TPB_{MI1}		
n	12	
TPB ID	TPB_{MI1}	±2SE
Ti	0.11	0.01
Rb	0.94	0.15
Sr	4.75	0.59
Y	0.19	0.08
Zr	48.01	5.23
Nb	3.64	0.09
Ba	9.64	0.33
La	0.84	0.09
Ce	1.00	0.16
Pr	0.10	0.05
Nd	0.34	0.03
Sm	0.00	0.05
Eu	0.00	0.02
Gd	-0.13	0.05
Dy	0.03	0.07
Er	0.00	0.03
Yb	0.02	0.07
Rb/Sr	0.198	

Table C2.1: Trace element composition (pg/sample) of TPB_{MI1} obtained by double focusing magnetic sector field ICPMS using the Thermo ELEMENT2 at *AHIGL* (Department of Earth Sciences, Durham University). The trace element composition of TPB_{MI1} and the Sr isotope composition of TPB60 (Appendix B9) was used for the blank correction of the Vestfirdir MI data set.

Blank ID: UpA 3% HNO_3 (n=20)

Trace element composition (pg/mL)

No.	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	XVI	XVII	XVIII	XIX	XX	$Blank_{Ave}$	±2SD
Ti	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
Rb	0.84	0.75	0.77	1.59	-	-	-	-	-	1.51	1.47	1.65	1.35	-	-	-	0.28	0.47	0.54	0.67	0.99	0.49
Sr	1.01	1.09	0.95	1.69	-	-	-	-	-	2.13	1.90	1.95	1.94	0.59	0.56	0.37	-	-	-	-	1.29	0.65
Y	0.02	0.03	0.02	0.03	0.03	0.00	-	0.00	-	0.04	0.05	0.03	0.02	0.08	0.07	0.07	-	-	0.01	0.02	0.03	0.02
Zr	1.60	1.51	1.57	1.68	1.66	1.62	1.68	1.72	1.67	1.11	0.47	0.53	0.30	8.94	8.92	8.97	1.33	1.02	0.98	0.79	2.40	2.85
Nb	0.05	0.03	0.03	0.05	0.03	0.03	0.04	0.09	0.05	-	-	-	-	-	-	-	0.01	0.00	-	0.03	0.04	0.02
Ba	24.41	24.33	24.29	1.59	16.20	16.23	11.95	13.85	14.01	6.74	6.13	6.44	6.90	2.13	0.34	-	-	-	-	-	11.70	8.28
La	0.33	0.33	0.33	0.31	0.33	0.32	0.34	0.30	0.31	0.23	0.07	0.05	0.07	6.41	6.43	6.35	-	-	-	-	1.41	2.48
Ce	0.56	0.55	0.56	0.60	0.59	0.59	0.60	0.54	0.54	0.14	0.06	0.04	0.07	3.45	3.51	3.58	-	-	-	-	1.00	1.27
Pr	0.03	0.02	0.03	0.03	0.03	0.03	0.02	0.03	0.03	-	0.04	0.00	-	0.55	0.64	0.74	-	-	0.00	-	0.15	0.26
Nd	0.12	0.09	0.09	0.12	0.11	0.07	0.06	0.07	0.05	0.11	-	-	-	1.65	1.33	1.59	-	-	-	-	0.42	0.63
Sm	0.07	0.01	0.01	-	-	-	-	-	-	-	-	-	-	0.06	0.06	0.08	-	0.00	-	-	0.04	0.03
Eu	0.01	0.01	0.02	0.01	-	-	-	-	-	0.02	0.00	0.03	0.03	0.01	0.01	0.03	0.00	0.01	0.00	0.03	0.02	0.01
Gd	0.00	0.00	-	0.00	-	-	-	-	-	0.09	0.05	0.05	0.01	0.48	0.53	0.52	0.02	0.01	0.01	0.00	0.13	0.21
Dy	-	-	-	-	-	-	-	0.00	-	0.00	0.02	0.02	0.01	0.05	0.04	0.04	-	0.00	0.03	-	0.02	0.02
Er	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Yb	0.00	0.00	-	-	0.00	0.00	0.00	0.00	-	0.01	0.01	0.02	0.00	0.01	0.02	0.02	0.00	0.01	0.01	0.00	0.01	0.01

Table C2.2a: Trace element compositions of 20 analyte blanks (3% UpA HNO3) analyzed by double focusing magnetic sector field ICPMS (Thermo ELEMENT2) at *AHIGL* (Department of Earth Sciences, Durham University) in association with MI work. Concentrations are given in pg/mL.

Appendix C2: Continued

Blank ID: UpA 3% HNO_3 (n=20)

1 SE on trace element composition (pg/mL)

No.	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	XVI	XVII	XVIII	XIX	XX	LOD
Ti	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rb	0.08	0.09	0.09	0.16	0.05	0.12	0.12	0.05	0.03	0.19	0.12	0.07	0.13	0.19	0.13	0.10	0.16	0.26	0.11	0.07	0.17
Sr	0.15	0.16	0.10	0.15	0.03	0.10	0.10	0.04	0.02	0.37	0.25	0.14	0.16	0.12	0.24	0.15	0.07	0.13	0.22	0.34	0.28
Y	0.02	0.01	0.01	0.02	0.02	0.01	0.01	0.02	0.01	0.05	0.03	0.02	0.04	0.03	0.03	0.05	0.03	0.05	0.06	0.01	0.05
Zr	0.04	0.04	0.03	0.14	0.06	0.07	0.10	0.07	0.08	1.02	0.29	0.16	0.23	0.42	0.30	0.64	0.37	0.07	0.14	0.24	0.73
Nb	0.04	0.01	0.01	0.03	0.02	0.01	0.03	0.02	0.04	0.01	0.02	0.03	0.02	0.02	0.02	0.02	0.01	0.02	0.02	0.03	0.02
Ba	0.24	0.25	0.26	0.04	0.17	0.31	0.11	0.16	0.08	1.67	1.41	2.03	0.50	1.73	0.92	0.96	3.79	0.80	0.35	1.91	2.87
La	0.02	0.02	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.32	0.02	0.02	0.03	0.11	0.10	0.30	0.08	0.01	0.03	0.02	0.28
Ce	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.00	0.01	0.14	0.05	0.03	0.03	0.06	0.17	0.14	0.08	0.03	0.04	0.06	0.15
Pr	0.01	0.00	0.02	0.01	0.01	0.01	0.00	0.01	0.01	0.02	0.05	0.04	0.01	0.13	0.13	0.26	0.02	0.02	0.06	0.03	0.19
Nd	0.04	0.02	0.05	0.04	0.02	0.01	0.01	0.02	0.03	0.19	0.08	0.05	0.07	0.11	0.20	0.26	0.06	0.04	0.03	0.05	0.21
Sm	0.06	0.02	0.02	0.02	0.01	0.04	0.03	0.03	0.01	0.01	0.05	0.11	0.06	0.03	0.09	0.05	0.07	0.07	0.03	0.03	0.08
Eu	0.02	0.01	0.01	0.02	0.02	0.01	0.01	0.00	0.01	0.04	0.02	0.03	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Gd	0.03	0.03	0.01	0.03	0.01	0.01	0.01	0.02	0.02	0.08	0.04	0.06	0.03	0.08	0.14	0.16	0.03	0.01	0.02	0.03	0.13
Dy	0.02	0.01	0.01	0.01	0.01	0.02	0.00	0.02	0.00	0.01	0.01	0.02	0.02	0.03	0.02	0.03	0.01	0.02	0.01	0.01	0.02
Er	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Yb	0.00	0.01	0.01	0.03	0.01	0.01	0.01	0.02	0.00	0.02	0.01	0.01	0.00	0.02	0.03	0.02	0.01	0.01	0.02	0.01	0.02

Table C2.2b: Internal precision (1SE) for each of the 20 analyte blanks in pg/mL presented in Table C2.2a. The reproducibility (1SD) of the analyte blanks equals the average of the internal precision (1SE) of the 10 blanks. Marked in light grey is the limit of detection (LOD) for each element calculated as 3 times the average standard deviation (1SD).

Appendix C3: Sr isotope composition of sub-ng NBS 987 loads analyzed by TIMS

Run order	Load (ng)	MI Session	$^{87}Sr/^{86}Sr$	±2SE
1	0.6	Vestfirdir	0.710267	0.000053
2	0.6	Vestfirdir	0.710242	0.000042
3	0.6	Vestfirdir	0.710240	0.000043
4	0.6	Vestfirdir	0.710293	0.000048
5	0.6	Vestfirdir	0.710258	0.000022
6	0.6	Vestfirdir	0.710272	0.000022
7	0.6	Vestfirdir	0.710243	0.000019
8	0.6	Vestfirdir	0.710249	0.000033
9	0.6	Vestfirdir	0.710260	0.000029
10	0.6	Vestfirdir	0.710257	0.000028
11	0.6	Vestfirdir	0.710293	0.000025
12	0.6	Vestfirdir	0.710225	0.000031
13	0.6	Vestfirdir	0.710257	0.000032
14	0.6	Vestfirdir	0.710255	0.000028
15	0.6	Vestfirdir	0.710265	0.000032
16	0.6	Vestfirdir	0.710239	0.000046
17	0.3	Vestfirdir	0.710245	0.000046
18	0.3	Vestfirdir	0.710254	0.000039
19	0.3	Vestfirdir	0.710272	0.000032
20	0.3	Vestfirdir	0.710298	0.000039
21	0.6	Vestfirdir	0.710256	0.000026
22	0.6	Vestfirdir	0.710267	0.000026
23	0.6	Vestfirdir	0.710268	0.000022
24	0.6	Vestfirdir	0.710212	0.000039
25	0.6	Vestfirdir	0.710281	0.000033
26	0.3	Vestfirdir	0.710295	0.000037
27	0.3	Vestfirdir	0.710219	0.000073
28	0.3	Vestfirdir	0.710279	0.000074
29	0.3	Vestfirdir	0.710265	0.000065
30	0.6	Vestfirdir	0.710290	0.000030
31	0.6	Vestfirdir	0.710251	0.000026
32	0.6	Vestfirdir	0.710279	0.000026
33	0.6	Vestfirdir	0.710265	0.000034
34	0.3	Vestfirdir	0.710269	0.000076
35	0.3	Vestfirdir	0.710245	0.000045
36	0.3	Vestfirdir	0.710252	0.000041
37	0.3	Vestfirdir	0.710280	0.000055
38	0.3	Vestfirdir	0.710261	0.000077
39	0.3	Vestfirdir	0.710299	0.000131
40	0.1	Vestfirdir	0.710243	0.000134

Table C3.1a: See caption on next page.

Run order	Load (ng)	MI Session	$^{87}Sr/^{86}Sr$	±2SE
41	0.1	Vestfirdir	0.710227	0.000154
42	0.3	Vestfirdir	0.710255	0.000079
43	0.3	Vestfirdir	0.710263	0.000066
44	0.3	Vestfirdir	0.710302	0.000097
45	0.6	Vestfirdir	0.710245	0.000025
46	0.6	Vestfirdir	0.710288	0.000028
47	0.3	Vestfirdir	0.710262	0.000054
48	0.3	Vestfirdir	0.710251	0.000056
49	0.3	Vestfirdir	0.710222	0.000070
50	0.1	Vestfirdir	0.710261	0.000100
51	0.1	Vestfirdir	0.710267	0.000089
52	0.3	Vestfirdir	0.710238	0.000091
53	0.3	Vestfirdir	0.710245	0.000077
54	0.6	Vestfirdir	0.710245	0.000049
55	0.6	Vestfirdir	0.710261	0.000092
56	0.3	Vestfirdir	0.710313	0.000058
57	0.1	Vestfirdir	0.710299	0.000297
58	0.6	Vestfirdir	0.710263	0.000049
59	0.3	Vestfirdir	0.710276	0.000088
60	0.3	Vestfirdir	0.710250	0.000108
61	0.3	Vestfirdir	0.710243	0.000057

Table C3.1a: Table including 61 NBS 987 sub-ng loads analyzed in association with the Vestfirdir MI work presented in *Chapter 3*. Data is ordered in accordance with the run order. The data was colleted using the ThermoFinnigan TIMS at *AGHIL* (Department of Earth Sciences, Durham University).

n	Load size (pg)	$^{87}Sr/^{86}Sr_{Ave}$	±2SD	±2SD (ppm)
5	0.1	0.710259	0.00005	76
26	0.3	0.710264	0.00004	68
30	0.6	0.710260	0.00003	54
61	Total	0.710261	0.00004	61

Table C3.1b: Statistical summary of the NBS 987 standard data collected on sub-ng (0.1, 0.3, and 0.6 ng) load sizes presented in Table C3.1a. 'n' denotes number of analyzes. See also Figure 2.8 (*Chapter 2*).

Appendix C4: BIP MIs - normalized trace element content to a 100 μm-sized MI

MI ID	M11-1	M11-2	M11-3	M11-4	M11-5	M11-20	M11-21
Sample ID	408611	408611	408611	408611	408611	408611	408611
Trace element content normalized to a 100 μm-sized MI (pg)							
Ti (ppm)	10987.14	4484.28	3741.42	2263.30	4188.15	3938.35	3036.42
Rb	13.21	2.09	3.25	1.46	2.78	1.82	2.46
Sr	985.70	41.07	66.97	24.19	38.09	35.34	19.36
Y	44.24	6.98	4.47	5.49	6.58	3.34	6.19
Zr	140.82	18.30	82.49	7.17	47.91	195.35	38.79
Nb	2.42	0.14	-0.27	-	-	1.33	-
Ba	2.68	34.94	104.16	159.09	37.58	29.17	31.01
La	9.13	2.16	2.26	2.10	2.42	0.74	1.86
Ce	19.84	6.54	7.42	3.91	6.35	3.05	4.84
Pr	2.77	0.86	0.56	0.42	0.66	0.17	0.46
Nd	11.30	3.90	3.02	1.82	2.79	1.45	1.69
Sm	104.92	1.12	1.64	0.61	0.76	0.67	0.64
Eu	2.12	0.31	0.26	0.16	0.19	0.12	0.19
Gd	4.13	1.37	0.72	0.70	0.77	0.62	0.74
Dy	5.67	1.12	0.70	0.89	0.96	0.59	0.85
Er	4.69	0.53	0.35	0.47	0.59	0.34	0.53
Yb	11.20	1.06	0.59	0.77	0.93	0.36	1.08

Table C4.1: BIP MIs - normalized trace element content to a 100 μm-sized MI. Concentrations obtained by double focusing magnetic sector field ICPMS at *AHIGL* (Department of Earth Sciences, Durham University).

Appendix C4: Continued

MI ID	M11-6	M11-7	M11-8	M11-9	M11-15	M11-16
Sample ID	408624	408624	408624	408624	408624	408624
Trace element content normalized to a 100 μm-sized MI (pg)						
Ti (ppm)	18709.07	53920.43	10637.52	8820.89	7884.37	5562.67
Rb	10.52	4.11	5.04	4.75	2.88	5.15
Sr	135.48	342.57	92.59	144.66	382.09	126.40
Y	20.10	83.19	8.90	14.19	9.70	2.48
Zr	167.29	394.30	98.56	59.80	31.83	46.26
Nb	5.22	12.40	11.86	2.57	-	-
Ba	129.65	191.50	399.40	267.05	33.67	47.78
La	8.21	12.59	4.07	3.02	1.73	1.25
Ce	14.94	41.49	10.93	8.75	5.67	5.49
Pr	2.06	7.33	1.21	1.18	0.69	0.38
Nd	9.15	44.15	4.07	5.74	4.04	2.11
Sm	3.78	13.54	1.62	1.99	1.67	0.66
Eu	0.61	5.04	0.41	0.64	0.52	0.20
Gd	2.76	18.14	1.74	2.41	1.89	0.57
Dy	3.06	16.59	1.55	2.62	1.70	0.57
Er	1.68	5.54	0.69	1.03	1.11	0.26
Yb	2.95	6.48	0.92	1.38	1.45	0.29

Table C4.1: Continued

Appendix C4: Continued

MI ID	M11-10	M11-11	M11-12	M11-13	M11-14	M11-17
Sample ID	408772	408772	408772	408772	408772	408772
Trace element content normalized to a 100 μm-sized MI (pg)						
Ti (ppm)	2648.24	22500.53	8586.84	16345.74	16138.68	3213.53
Rb	1.17	9.48	2.02	6.54	10.06	3.37
Sr	30.78	481.35	201.32	303.95	344.51	73.67
Y	3.03	31.88	11.71	25.52	28.20	4.31
Zr	16.08	170.30	141.92	168.76	154.59	15.10
Nb	2.48	0.99	2.76	4.76	14.74	-
Ba	27.75	55.49	27.78	46.78	107.26	41.48
La	0.57	13.01	3.77	10.76	11.40	1.73
Ce	4.04	37.33	10.28	29.97	26.66	4.57
Pr	0.18	4.22	1.30	3.53	3.80	0.35
Nd	1.15	18.76	5.41	17.33	16.08	1.69
Sm	0.47	5.51	1.58	4.91	4.20	0.49
Eu	0.08	1.84	0.48	1.46	1.44	0.11
Gd	0.57	6.26	1.76	5.25	4.58	0.54
Dy	0.67	5.45	2.02	4.24	4.28	0.52
Er	0.24	3.09	1.25	2.55	2.75	0.56
Yb	0.40	4.14	1.63	3.30	3.89	0.95

Table C4.1: Continued

Appendix C5: Parameters used in the modelling of Figure 3.8

End-members	$^3He/^4He$	$^{87}Sr/^{86}Sr$	$^{143}Nd/^{144}Nd$	Sr (ppm)	Nd (ppm)	Sample ID
$DM_{low\ 3He/4He}$	8	0.70275	0.513184	90	7.3	ID1
$DM_{high\ 3He/4He}$	60	0.70275	0.513184	90	7.3	-
REM_a	5	0.70854	0.512188	30.34	4.25	GP101
REM_b	5	0.70417	0.512614	46.35	9.35	GP33
HRDM	52	<0.70320	0.51312			-
$PRIM_{high\ 3He/4He}$	60	0.70475	0.51265	19.9	1.25	-

Table C5.1a: He-Sr-Nd isotope ratios and Sr-Nd concentrations of end-members used in the modeling in Figure 3.8. The Sr-Nd isotope composition of the low $^3He/^4He$ depleted mantle (DM) is from Thirlwall et al. (2004), which is also used for the high $^3He/^4He$ DM, while the Sr-Nd concentrations of PM and DM are from McDonough & Sun (1995). Sr-Nd isotope compositions of the high $^3He/^4He$ primordial mantle (PRIM) is from Hofmann (1997). Proxies for low $^3He/^4He$ recycled, enriched mantle (or subducted oceanic lithosphere) components are pyroxenites #GP101 (REM_a) and #GP33 (REM_b) from Pearson et al. (1993). HRDM (*He-recharged* DM) is from Ellam & Stuart (2004).

Label	K1	K2	$[He]_X/[He]_Y$
A	100	129.78	22.22
B	50	64.89	11.11
C	10	13.74	2.35

Table C5.1b: Parameters used the modeling HRDM by binary mixing between $DM_{low\ 3He/4He}$ (x) and PRIM (y) (Figure 3.8a-b). Both endmembers have Sr/Nd equal to 1. $K1=([He]_x/[Sr]_x)/([He]_y/[Sr]_y)$ and $K2=([He]_x/[Nd]_x)/([He]_y/[Nd]_y)$. $[He]_x$ is calculated using the equation for K1 and the values listed in Table C5.1a for $[Nd]_X$, $[Nd]_Y$, and $[He]_Y$ is calculated. Following K2 is calculated. Values calculated are rounded off to two decimal places. See Ellam & Stuart (2004) for modeling details on HRDM.

Label	K1	K2	$[He]_X/[He]_Y$
A	100	248.70	194.17
B	50	124.35	97.09
C	10	24.87	19.42
D	1	2.49	1.94
E	0.2	0.50	0.39
F	0.01	0.02	0.02

Table C5.1c: Parameters used for the modeling of binary mixing between $DM_{high\ 3He/4He}$ (x) and REM_a (y) in Figure 3.8c-d). $K1=([He]_x/[Sr]_x)/([He]_y/[Sr]_y)$ and $K2=([He]_x/[Nd]_x)/([He]_y/[Nd]_y)$ Values calculated are rounded off to two decimal places. Calculations as described in Table C5.1b.

Appendix C5: Continued

Label	K1	K2	$[He]_X/[He]_Y$
A	100	172.74	296.64
B	50	86.37	148.32
C	10	17.27	29.66
D	1	1.73	2.97
E	0.2	0.35	0.59
F	0.01	0.02	0.03

Table C5.1d: Parameters used for the modeling of binary mixing between $DM_{high\ 3He/4He}$ (x) and REM_b (y) (Figure 3.8e-f). $K1=([He]_x/[Sr]_x)/([He]_y/[Sr]_y)$ and $K2=([He]_x/[Nd]_x)/([He]_y/[Nd]_y)$ Values calculated are rounded off to two decimal places. Calculations as described in Table C5.1b.

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APPENDIX D

Contents of Appendix D

Appendix D1: Sr isotope data collected on sub-ng NBS 987 loads by TIMS during BIP MI study

Load (ng)	$^{87}Sr/^{86}Sr$	±2SE	±2SE (ppm)
0.1	0.710266	0.000068	96
0.1	0.710272	0.000056	79
0.1	0.710267	0.000058	82
0.1	0.710269	0.000137	193
0.1	0.710255	0.000114	161
0.1	0.710263	0.000063	88
0.1	0.710268	0.000111	157
0.1	0.710235	0.000098	139
0.1	0.710243	0.000147	208
0.1	0.710289	0.000063	88

Load (ng)	$^{87}Sr/^{86}Sr$	±2SE	±2SE (ppm)
0.3	0.710258	0.000047	66
0.3	0.710280	0.000042	59
0.3	0.710279	0.000116	163
0.3	0.710298	0.000060	84
0.3	0.710237	0.000004	6
0.3	0.710291	0.000057	80
0.3	0.710278	0.000127	179
0.3	0.710269	0.000044	62
0.3	0.710265	0.000041	57
0.3	0.710247	0.000025	35
0.3	0.710268	0.000027	38
0.3	0.710271	0.000033	46
0.3	0.710256	0.000036	51
0.3	0.710280	0.000072	102
0.3	0.710255	0.000039	55
0.3	0.710240	0.000051	71
0.3	0.710245	0.000037	52
0.3	0.710246	0.000042	59
0.3	0.710214	0.000038	53
0.3	0.710244	0.000042	59

Table D1.1a: Sr isotope composition 0.1 and 0.3 ng NBS987 standards analyzed by TIMS (Thermo-Electron Triton) together with the olivine-hosted MIs of BIP at *AHIGL* (Department of Earth Sciences, Durham University).

Load (ng)	n	$^{87}Sr/^{86}Sr$	±2SD	ppm
0.1	10	0.710263	0.000030	42.9
0.3	20	0.710261	0.000041	58.1
Total	30	0.710262	0.000038	52.8

Table D1.1b: Statistical overview of the sub-ng NBS 987 loads run on the *AGHIL* TIMS listed in Table D.1a.

Appendix D2: Standard trace element data collected during ICPMS BIP MI study

Std. ID	$AGV\text{-}1_{Rec}$	$AGV\text{-}1_1$	$AGV\text{-}1_2$	$AGV\text{-}1_3$	$AGV\text{-}1_4$	$AGV\text{-}1_5$	$AGV\text{-}1_{Ave}$ (n=5)	±2SD	Δ%
500 ppb AGV-1: Trace element concentrations (ppm)									
Ti	4.24	4.34	4.54	4.19	4.23	4.40	4.34	0.25	2.41
Rb	268.00	276.78	296.45	262.47	264.19	297.36	279.45	30.17	4.27
Sr	2648.00	2639.41	2774.31	2573.03	2603.11	2832.87	2684.54	202.31	1.38
Y	84.00	79.97	82.28	77.13	77.26	82.79	79.88	4.79	-4.90
Zr	900.00	1010.88	980.63	952.44	964.58	992.63	980.23	41.09	8.91
Nb	57.60	71.26	69.56	62.14	73.57	64.56	68.22	8.49	*18.43*
Ba	4884.00	4814.14	4980.64	4901.82	4803.69	5200.80	4940.22	290.58	1.15
La	152.00	156.37	156.94	150.76	150.57	162.93	155.51	9.16	2.31
Ce	264.00	272.34	275.08	268.89	266.90	284.54	273.55	12.34	3.62
Pr	26.00	29.83	31.45	31.06	30.72	34.72	31.56	3.34	*21.38*
Nd	136.00	129.45	135.33	130.55	130.61	137.98	132.78	6.59	-2.37
Sm	23.60	24.68	23.78	22.39	22.90	22.69	23.29	1.67	-1.33
Eu	6.64	6.72	6.67	5.91	6.61	7.14	6.61	0.79	-0.47
Gd	20.80	20.08	20.07	18.52	19.34	19.84	19.57	1.18	-5.91
Dy	15.20	14.41	14.25	14.40	14.06	13.98	14.22	0.35	-6.44
Er	6.44	6.93	7.13	6.10	6.66	7.34	6.83	0.86	6.10
Yb	6.68	6.78	6.61	6.38	6.17	6.99	6.59	0.58	-1.41
Rb/Sr	0.101	0.105	0.107	0.102	0.101	0.105	0.104	0.004	2.79

Table D2.1: AGV-1 data collected by double focusing magnetic sector field ICPMS (Thermo ELEMENT2) during low concentration BIP MIs session at *AHIGL* (Department of Earth Sciences, Durham University) The solid grey column lists the recommended concentrations the rock standard. The recommended concentration values for AGV-1 can be found on the following webpage: http://minerals.cr.usgs.gov/geo_chem_stand/andesite1.html. The average, 2SD reproducibility, and the difference in percentage (Δ%) from the recommended value are given.

Appendix D2: Continued

Std. ID	$AGV\text{-}1_{Rec}$	$AGV\text{-}1_6$	$AGV\text{-}1_7$	$AGV\text{-}1_8$	$AGV\text{-}1_9$	$AGV\text{-}1_{10}$	$AGV\text{-}1_{11}$	$AGV\text{-}1_{12}$	$AGV\text{-}1_{Ave}$ (n=7)	±2SD	Δ%
50 ppb AGV-1: Trace element concentrations (ppm)											
Ti	0.42	0.44	0.40	0.43	0.41	0.42	0.45	0.40	0.42	0.03	-0.76
Rb	26.80	27.42	27.91	26.61	26.44	26.45	29.62	25.19	27.09	2.60	1.08
Sr	264.80	268.97	246.40	264.82	260.00	254.79	282.38	248.58	260.85	23.20	-1.49
Y	8.40	7.37	7.10	7.87	7.22	7.80	8.31	7.37	7.58	0.80	-9.77
Zr	90.00	94.69	83.23	95.49	89.67	88.50	96.65	87.70	90.85	9.10	0.94
Nb	5.76	6.41	6.53	6.32	6.14	6.81	6.62	7.13	6.56	0.61	*13.95*
Ba	488.40	500.68	449.33	499.25	485.15	482.82	522.65	467.59	486.78	44.24	-0.33
La	15.20	15.89	14.23	15.33	15.60	15.32	16.21	14.51	15.30	1.32	0.64
Ce	26.40	28.00	25.18	27.29	27.41	27.21	29.02	26.27	27.20	2.26	3.03
Pr	2.60	3.07	2.99	3.31	2.91	3.32	3.35	3.18	3.16	0.32	*21.59*
Nd	13.60	12.91	11.57	12.25	12.12	12.83	13.98	12.94	12.66	1.42	-6.93
Sm	2.36	2.44	1.95	1.95	2.12	2.48	2.18	1.82	2.13	0.47	-9.54
Eu	0.66	0.61	0.58	0.57	0.61	0.68	0.61	0.60	0.61	0.06	-8.31
Gd	2.08	1.93	1.72	1.43	1.58	1.82	1.54	1.79	1.69	0.33	*-18.87*
Dy	1.52	1.27	1.39	1.36	1.22	1.28	1.32	1.39	1.32	0.12	*-13.31*
Er	0.64	0.72	0.60	0.64	0.67	0.68	0.72	0.66	0.67	0.08	3.95
Yb	0.67	0.69	0.60	0.53	0.54	0.56	0.65	0.65	0.60	0.11	-10.05
Rb/Sr	0.101	0.102	0.113	0.100	0.102	0.104	0.105	0.101	0.104	0.008	2.68

Table D2.1: Continued

Appendix D2: Continued

Std. ID	$BHVO\text{-}1_{Rec}$	$BHVO\text{-}1_1$	$BHVO\text{-}1_2$	$BHVO\text{-}1_3$	$BHVO\text{-}1_4$	$BHVO\text{-}1_{Ave}$ (n=4)	±2SD	Δ%
500 ppb BHVO-1: Trace element concentrations (ppm)								
Ti	10.84	10.92	11.18	11.71	11.52	11.33	0.61	4.54
Rb	38.40	37.28	37.40	37.58	40.90	38.29	3.03	-0.29
Sr	1612.00	1502.51	1565.21	1602.45	1601.75	1567.98	81.38	-2.73
Y	110.40	106.36	107.66	112.57	109.86	109.11	4.71	-1.17
Zr	716.00	718.82	741.04	746.17	722.49	732.13	23.38	2.25
Nb	78.00	90.78	79.17	85.13	87.67	85.69	8.53	9.86
Ba	556.00	504.00	540.79	543.86	531.89	530.13	31.44	-4.65
La	63.20	60.40	61.46	63.80	61.73	61.85	2.46	-2.14
Ce	156.00	146.38	149.78	153.46	149.27	149.72	5.03	-4.02
Pr	22.80	19.82	19.87	19.93	19.65	19.82	0.20	*-13.08*
Nd	100.80	101.26	100.25	106.40	102.57	102.62	4.67	1.80
Sm	24.80	24.80	22.77	24.46	24.55	24.15	1.61	-2.63
Eu	8.24	8.50	8.41	8.18	8.20	8.32	0.27	1.02
Gd	25.60	26.16	23.90	25.88	25.88	25.46	1.81	-0.56
Dy	20.80	20.96	20.94	21.46	21.37	21.18	0.47	1.84
Er	9.60	9.13	9.35	9.45	9.70	9.41	0.41	-2.01
Yb	8.08	8.31	7.51	7.63	8.13	7.89	0.66	-2.29
Rb/Sr	0.024	0.025	0.024	0.023	0.026	0.024	0.002	2.52

Table D2.2: BHVO-1 data collected by double focusing magnetic sector field ICPMS (Thermo ELEMENT2) during low concentration BIP MIs session at *AHIGL* (Department of Earth Sciences, Durham University). The solid grey column lists the recommended concentrations the rock standard. The recommended concentration values for BHVO-1 can be found on the following webpage: http://minerals.cr.usgs.gov/geo_chem_stand/basaltbhvo1.html. The average, 2SD reproducibility, and the difference in percentage (Δ%) from the recommended value are given.

Std. ID	BHVO-1$_{Rec}$	BHVO-1$_5$	BHVO-1$_6$	BHVO-1$_7$	BHVO-1$_8$	BHVO-1$_9$	BHVO-1$_{10}$	BHVO-1$_{11}$	BHVO-1$_{12}$	BHVO-1$_{Ave}$ (n=8)	±2SD	Δ%
50 ppb BHVO-1: Trace element concentrations (ppm)												
Ti	1.08	1.13	1.02	1.04	1.09	1.05	1.08	1.12	1.16	1.08	0.09	0.09
Rb	3.84	3.03	5.37	2.93	2.72	3.68	3.73	3.85	4.33	3.71	1.72	-3.45
Sr	161.20	158.26	143.79	146.43	154.28	146.34	154.02	155.83	168.02	153.37	15.77	-4.86
Y	11.04	10.52	10.06	10.05	10.80	10.67	10.77	10.90	11.59	10.67	0.99	-3.35
Zr	71.60	69.78	60.64	66.24	70.31	63.68	67.41	69.10	71.18	67.29	7.25	-6.01
Nb	7.80	8.25	8.12	7.80	8.14	8.50	8.04	9.34	8.40	8.32	0.93	6.71
Ba	55.60	52.70	47.56	51.01	49.66	48.35	53.36	52.01	55.55	51.27	5.36	-7.78
La	6.32	6.14	5.71	5.76	6.08	5.86	6.19	6.30	6.60	6.08	0.60	-3.82
Ce	15.60	15.28	13.59	14.61	14.74	14.38	15.43	14.99	16.24	14.91	1.57	-4.45
Pr	2.28	2.22	2.03	1.83	1.95	2.02	2.17	1.89	2.32	2.05	0.34	-9.90
Nd	10.08	9.44	9.67	9.31	9.71	10.32	9.71	10.73	11.58	10.06	1.54	-0.20
Sm	2.48	2.73	2.15	2.28	2.58	2.23	2.11	2.38	2.87	2.42	0.56	-2.56
Eu	0.82	0.79	0.79	0.71	0.88	0.76	0.92	0.79	0.85	0.81	0.14	-1.70
Gd	2.56	2.02	2.15	1.92	2.27	2.54	2.22	2.18	2.75	2.26	0.54	*-11.86*
Dy	2.08	2.31	1.96	1.86	1.94	2.14	2.08	2.20	2.48	2.12	0.41	1.91
Er	0.96	0.96	0.81	0.92	0.84	0.83	0.90	0.93	1.06	0.91	0.16	-5.54
Yb	0.81	0.77	0.73	0.81	0.80	0.76	0.75	0.79	0.88	0.79	0.09	-2.81
Rb/Sr	0.024	0.019	0.037	0.020	0.018	0.025	0.024	0.025	0.026	0.024	0.012	1.85

Table D2.2: Continued

Std. ID	$W2_{Rec}$	$W2_1$	$W2_2$	$W2_3$	$W2_4$	$W2_{Ave}$ (n=4)	±2SD	Δ%
500 ppb W2: Trace element concentrations (ppm)								
Ti	4.40	4.44	4.27	4.17	4.24	4.28	0.20	-2.70
Rb	81.44	81.04	82.06	74.93	82.18	80.05	5.98	-1.70
Sr	773.24	784.95	761.95	741.46	775.45	765.95	32.67	-0.94
Y	85.44	90.54	87.55	84.71	88.19	87.75	4.15	2.70
Zr	371.48	386.99	359.82	357.73	375.73	370.06	24.00	-0.38
Nb	31.04	36.29	32.94	30.43	31.82	32.87	4.33	5.90
Ba	668.32	677.61	657.11	669.70	681.79	671.55	18.80	0.48
La	42.44	43.00	40.96	41.19	42.47	41.90	1.71	-1.27
Ce	92.12	90.95	88.66	87.95	90.30	89.46	2.42	-2.88
Pr	11.76	10.35	10.72	10.88	11.12	10.77	0.56	-8.41
Nd	52.88	54.05	50.87	53.65	53.09	52.91	2.46	0.06
Sm	13.44	13.30	13.49	12.40	12.93	13.03	0.83	-3.08
Eu	4.48	4.53	4.24	4.06	4.90	4.43	0.64	-1.08
Gd	14.52	15.85	14.65	12.83	14.42	14.44	2.15	-0.56
Dy	14.84	15.51	15.16	14.78	15.07	15.13	0.52	1.95
Er	8.92	8.69	8.52	8.01	8.20	8.36	0.53	-6.31
Yb	8.12	8.26	8.20	8.31	8.35	8.28	0.11	2.00
Rb/Sr	0.105	0.103	0.108	0.101	0.106	0.104	0.005	-0.79

Table D2.3: W2 data collected by double focusing magnetic sector field ICPMS (Thermo ELEMENT2) during low concentration BIP MIs session at *AHIGL* (Department of Earth Sciences, Durham University). The solid grey column lists the recommended concentrations the rock standard. The recommended concentration values for W2 can be found on the following webpage: http://minerals.cr.usgs.gov/geo_chem_stand/diabase.html. The average, 2SD reproducibility, and the difference in percentage (Δ%) from the recommended value are given.

Appendix D2: Continued

Std. ID	$W2_{Rec}$	$W2_5$	$W2_6$	$W2_7$	$W2_8$	$W2_9$	$W2_{10}$	$W2_{11}$	$W2_{12}$	$W2_{13}$	$W2_{Ave}$ (n=9)	±2SD	Δ%
50 ppb W2: Trace element concentrations (ppm)													
Ti	0.44	0.43	0.43	0.39	0.44	0.39	0.41	0.44	0.40	0.40	0.41	0.04	-5.94
Rb	8.14	8.20	7.54	6.86	8.30	6.69	7.64	8.18	7.85	7.93	7.69	1.15	-5.61
Sr	77.32	82.00	80.56	75.64	84.68	75.92	79.11	84.07	77.75	74.96	79.41	7.30	2.70
Y	8.54	9.34	8.93	8.48	8.95	8.47	9.18	9.32	8.56	8.46	8.86	0.74	3.65
Zr	37.15	37.35	36.81	35.80	36.94	34.93	34.03	38.11	35.39	33.83	35.91	2.99	-3.33
Nb	3.10	3.57	3.15	2.97	3.35	2.79	3.22	3.23	3.55	2.80	3.18	0.58	2.50
Ba	66.83	71.80	67.65	65.43	73.22	65.79	71.65	74.93	67.06	65.50	69.23	7.35	3.58
La	4.24	4.21	4.39	4.19	4.45	4.01	4.31	4.56	3.97	3.80	4.21	0.50	-0.78
Ce	9.21	9.27	9.30	8.62	9.30	9.12	9.16	9.40	8.81	8.45	9.05	0.68	-1.78
Pr	1.18	1.23	0.98	0.96	1.27	0.94	1.03	1.25	1.05	0.94	1.07	0.28	-8.85
Nd	5.29	5.70	5.18	5.20	5.55	4.31	5.34	5.68	5.06	4.83	5.20	0.88	-1.58
Sm	1.34	1.39	1.41	1.21	1.22	1.25	1.27	1.46	1.16	1.39	1.31	0.21	-2.83
Eu	0.45	0.50	0.42	0.40	0.53	0.34	0.44	0.46	0.44	0.32	0.43	0.14	-4.69
Gd	1.45	1.37	1.39	1.18	1.39	1.10	1.77	1.43	1.32	1.23	1.35	0.39	-6.72
Dy	1.48	1.43	1.41	1.54	1.55	1.58	1.60	1.59	1.59	1.50	1.53	0.14	3.21
Er	0.89	0.83	0.76	0.78	1.01	0.83	0.87	0.92	0.82	0.68	0.83	0.19	-6.54
Yb	0.81	0.81	0.87	0.86	0.76	0.70	1.00	0.96	0.71	0.67	0.82	0.23	0.44
Rb/Sr	0.105	0.100	0.094	0.091	0.098	0.088	0.097	0.097	0.101	0.106	0.097	0.011	-8.11

Table D2.3: Continued

Rb-Sr solution	Std. 2_1	Std. 2_2	Std. 2_3	Std. 2_4	Std. 2_5	Std. 2_6	Std.$_{Ave}$ (n=6)	±2SD	Δ%
Trace element concentrations (ppm)									
Ti	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-
Rb	0.89	1.12	1.04	1.18	0.82	0.75	0.97	0.34	-3.48
Sr	12.05	11.77	11.41	12.39	10.42	11.06	11.52	1.42	15.18
Y	0.02	-0.07	0.01	0.09	-0.18	-0.09	-0.04	0.19	-
Zr	-0.13	-0.25	-0.22	0.00	-0.93	-1.33	-0.48	1.06	-
Nb	-2.01	0.01	-0.23	-1.19	-1.83	-2.54	-1.30	2.04	-
Ba	0.33	0.80	-0.68	0.53	-0.91	-1.01	-0.16	1.59	-
La	0.03	0.00	0.04	-0.01	0.00	-0.02	0.01	0.04	-
Ce	-0.01	-0.03	-0.01	0.00	0.00	-0.02	-0.01	0.02	-
Pr	0.07	-0.03	-0.03	-0.01	0.05	-0.01	0.01	0.09	-
Nd	-0.06	-0.02	-0.08	0.13	0.00	0.09	0.01	0.17	-
Sm	-0.01	0.11	0.03	0.04	-0.02	0.05	0.03	0.09	-
Eu	0.05	-0.02	0.03	0.02	-0.01	0.00	0.01	0.05	-
Gd	0.03	0.03	0.05	0.02	0.09	-0.06	0.03	0.10	-
Dy	0.00	-0.02	-0.01	0.02	0.02	-0.02	0.00	0.03	-
Er	0.02	-0.02	0.01	0.01	0.02	0.00	0.00	0.03	-
Yb	-0.01	0.00	-0.04	0.00	0.00	0.01	-0.01	0.03	-
Rb/Sr	0.074	0.095	0.091	0.095	0.079	0.068	0.08	0.02	-16.44

Table D2.4: Synthetic Rb-Sr solution data colleted by double focusing magnetic sector field ICPMS (Thermo ELEMENT2) during low concentration BIP MIs session at *AHIGL* (Department of Earth Sciences, Durham University). Three synthetic 1:10 Rb-Sr solutions were made respectively Std. 2 (1:100), Std. 3 (5:50) and std. 5 (20:200). For each standard the average, 2SD reproducibility, and the difference in percentage (Δ%) from the '*recommended*' value are given.

Rb-Sr solution	Std. 3_1	Δ%
	(n=1)	
Trace element concentrations (ppm)		
Ti	0.00	-
Rb	4.73	-5.46
Sr	45.59	-8.82
Y	0.48	-
Zr	-0.31	-
Nb	-0.01	-
Ba	1.04	-
La	-0.05	-
Ce	-0.05	-
Pr	-0.01	-
Nd	-0.04	-
Sm	-0.10	-
Eu	-0.02	-
Gd	-0.06	-
Dy	0.04	-
Er	-0.03	-
Yb	0.00	-
Rb/Sr	0.104	3.68

Rb-Sr solution	Std. 5_1	Std. 5_2	Std. 5_3	Std. 5_4	Std. 5_{Ave}	±2SD	Δ%
					(n=4)		
Trace element concentrations (ppm)							
Ti	0.01	0.00	0.00	0.00	0.00	0.01	-
Rb	19.12	18.75	16.59	18.98	18.36	2.39	-8.20
Sr	177.21	184.81	168.62	184.82	178.86	15.43	-10.57
Y	1.96	1.81	1.60	2.00	1.84	0.36	-
Zr	0.30	0.11	0.15	0.08	0.16	0.20	-
Nb	0.14	0.14	-0.02	0.13	0.10	0.16	-
Ba	1.84	0.18	-0.20	0.00	0.46	1.87	-
La	0.04	0.01	-0.05	-0.02	-0.01	0.07	-
Ce	-0.02	-0.06	-0.11	-0.06	-0.06	0.08	-
Pr	-0.03	-0.06	-0.02	-0.03	-0.03	0.03	-
Nd	-0.15	-0.26	-0.32	0.13	-0.15	0.40	-
Sm	0.00	0.05	-0.15	-0.07	-0.04	0.17	-
Eu	0.10	-0.05	-0.04	0.01	0.00	0.14	-
Gd	-0.11	-0.39	-0.33	-0.04	-0.22	0.34	-
Dy	0.14	0.08	0.09	0.12	0.11	0.05	-
Er	0.01	-0.05	-0.04	0.00	-0.02	0.05	-
Yb	-0.03	-0.04	-0.03	-0.01	-0.02	0.03	-
Rb/Sr	0.108	0.101	0.098	0.103	0.103	0.008	2.61

Table D2.4: Continued

Appendix D3: TPB associated with the BIP MI study

Trace element concentrations of 12 individual TPBs analyzed with the MIs of BIP (pg)													Average	
													(n=12)	(n=9)
Element	M14-43	M14-44	M14-45	M14-46	M14-47	M14-48	M14-49	M14-50	M14-51	M14-52	M14-53	M14-54	TPB_{ave}	TPB_{M14}
Ti	0.27	0.35	0.50	0.11	0.19	0.18	0.18	0.31	0.68	0.27	0.25	0.59	0.32	0.32
Rb	0.41	4.36	4.62	0.71	-0.19	1.22	4.02	0.87	2.25	2.40	2.54	2.50	2.14	1.41
Sr	0.55	22.60	13.70	0.86	4.18	8.98	11.50	3.37	6.50	8.04	6.23	4.86	7.61	4.84
Y	-0.32	0.39	1.31	-0.41	-0.45	-0.25	0.40	-0.55	-0.16	0.25	0.69	0.32	0.10	0.10
Zr	36.65	96.89	323.93	33.05	123.17	71.38	63.49	118.33	116.72	86.82	64.11	75.90	100.87	80.59
Nb	6.52	5.53	15.26	11.12	21.20	4.21	53.89	12.51	9.04	9.55	4.42	6.45	13.31	9.62
Ba	33.99	29.95	4.39	8.81	9.01	9.93	26.61	7.24	12.30	14.41	9.59	11.73	14.83	9.71
La	0.31	0.91	5.69	0.38	0.35	1.15	2.18	0.38	1.36	1.32	0.60	1.80	1.37	0.86
Ce	0.66	1.86	9.23	0.42	0.38	0.74	2.21	0.68	2.29	3.13	1.24	1.43	2.02	1.37
Pr	0.05	0.13	0.79	-0.11	0.03	0.13	0.21	-0.02	0.08	0.10	0.17	0.40	0.16	0.16
Nd	-0.21	0.28	3.87	0.08	-0.28	0.20	0.69	0.17	0.56	1.18	0.35	0.96	0.65	0.36
Sm	-0.24	-0.08	0.38	0.02	0.00	0.01	0.06	0.10	0.06	0.06	0.09	-0.05	0.03	0.00
Eu	-0.18	-0.14	-0.09	-0.07	-0.06	-0.10	-0.12	-0.07	-0.12	-0.04	0.04	0.11	-0.07	-0.07
Gd	-0.83	-0.83	-0.27	-0.85	-0.83	-0.69	-0.94	-0.71	-0.74	-0.51	-0.05	0.08	-0.60	-0.60
Dy	-0.10	0.03	0.29	-0.15	-0.11	0.02	-0.07	-0.03	0.00	0.10	0.19	0.05	0.02	0.02
Er	-0.03	-0.04	0.12	-0.04	-0.02	-0.07	-0.04	0.00	0.00	0.00	0.02	0.03	-0.01	-0.01
Yb	0.02	0.01	0.18	-0.06	-0.01	0.00	0.03	0.02	0.02	-0.04	0.09	0.06	0.03	0.03

Table D3.1a: Trace element composition of 12 TPB determined by double focusing magnetic field ICPMS (ELEMENT 2) at *AHIGL* (Department of Earth Sciences, Durham University) during the BIP MIs session. Average TPB_{M14} is used for the blank correction of the BIP MI data set in combination with TPB60 (see Chapter 2, Appendix B9). Values in grey are rejected.

Appendix D3: Continued

Trace element concentrations of 10 analyte blanks (3% UpA HNO_3) analyzed with the BIP MIs (pg/mL)										Average (n=10)
Element	Blank 1	Blank 2	Blank 3	Blank 4	Blank 5	Blank 6	Blank 7	Blank 8	Blank 9	Blank 10	$Blank_{Ave}$
Ti	0.00	0.01	0.00	0.00	-0.01	-0.01	0.00	0.00	0.00	0.02	0.00
Rb	1.21	0.24	-0.13	-0.66	-0.67	-0.84	-0.01	-0.03	0.00	2.22	0.13
Sr	-0.19	0.58	-0.21	0.69	-0.84	-1.09	0.29	-0.06	1.23	3.78	0.42
Y	-0.17	0.13	-0.15	-0.26	-0.32	-0.31	0.04	0.05	-0.07	0.10	-0.10
Zr	0.54	0.60	0.11	0.30	0.02	-0.28	-0.24	-0.24	-0.14	-0.25	0.04
Nb	0.04	-0.03	-0.03	0.06	-0.13	-0.14	-0.07	-0.05	-0.03	-0.03	-0.04
Ba	0.62	0.35	1.85	2.35	0.29	0.84	0.17	0.49	0.52	1.11	0.86
La	-0.01	0.05	0.00	0.08	0.03	0.07	0.00	-0.02	0.02	0.05	0.03
Ce	0.07	0.06	0.01	0.03	0.03	-0.01	0.01	-0.01	0.07	0.24	0.05
Pr	0.00	-0.06	-0.02	0.04	0.00	-0.03	0.00	-0.02	-0.02	0.10	0.00
Nd	-0.28	-0.28	-0.26	-0.15	-0.25	-0.24	-0.04	-0.05	-0.01	0.19	-0.14
Sm	-0.09	-0.05	-0.10	-0.07	-0.07	-0.01	-0.11	-0.08	-0.16	-0.06	-0.08
Eu	-0.05	0.01	-0.04	-0.04	-0.05	-0.07	0.00	0.00	-0.02	0.01	-0.03
Gd	-0.28	-0.27	-0.29	-0.34	-0.31	-0.33	0.02	-0.05	-0.05	0.03	-0.19
Dy	-0.05	-0.03	-0.03	0.00	-0.04	-0.04	0.01	-0.02	-0.01	0.00	-0.02
Er	-0.02	-0.03	-0.04	-0.02	-0.05	-0.04	-0.01	-0.01	-0.01	0.01	-0.02
Yb	0.02	-0.04	-0.03	0.00	-0.03	-0.01	0.01	0.00	-0.02	0.00	-0.01

Table D3.1b: Trace element compositions of 10 analyte blanks (3% UpA HNO3) analyzed double focusing magnetic field ICPMS (ELEMENT 2) at *AHIGL* (Department of Earth Sciences, Durham University) with the BIP MIs. Concentrations are given in pg/mL.

Internal precision (1SE) on the 10 analyses of analyte blanks (3% UpA HNO_3) analyzed with the BIP MIs (pg/mL)											
Element	Blank 1	Blank 2	Blank 3	Blank 4	Blank 5	Blank 6	Blank 7	Blank 8	Blank 9	Blank 10	1SD	(n=10) LOD
Ti	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Rb	0.19	0.23	0.09	0.18	0.13	0.09	0.11	0.07	0.03	0.26	0.14	0.41
Sr	0.27	0.18	0.12	*2.95*	0.39	0.47	0.20	0.14	0.36	0.05	0.24	0.73
Y	0.17	0.16	0.14	0.15	0.12	0.18	0.10	0.09	0.11	0.11	0.13	0.40
Zr	0.25	0.25	0.13	0.23	0.03	0.09	0.10	0.09	0.09	0.11	0.14	0.41
Nb	0.02	0.05	0.06	0.14	0.03	0.05	0.02	0.07	0.03	0.05	0.05	0.15
Ba	0.17	0.76	1.10	2.13	0.92	0.88	0.46	0.24	0.07	0.15	0.69	2.06
La	0.03	0.01	0.05	0.07	0.05	0.04	0.02	0.02	0.02	0.02	0.03	0.10
Ce	0.01	0.05	0.05	0.08	0.02	0.01	0.05	0.03	0.02	0.04	0.04	0.11
Pr	0.05	0.02	0.05	0.09	0.08	0.03	0.04	0.01	0.02	0.11	0.05	0.15
Nd	0.07	0.14	0.11	0.22	0.16	0.17	0.04	0.03	0.04	0.07	0.11	0.32
Sm	0.10	0.09	0.08	0.09	0.17	0.17	0.05	0.07	0.06	0.08	0.10	0.29
Eu	0.05	0.02	0.03	0.03	0.04	0.02	0.02	0.03	0.02	0.04	0.03	0.09
Gd	0.09	0.17	0.05	0.11	0.08	0.11	0.10	0.07	0.03	0.05	0.09	0.26
Dy	0.03	0.05	0.07	0.06	0.05	0.03	0.03	0.01	0.01	0.03	0.04	0.11
Er	0.03	0.03	0.00	0.03	0.01	0.02	0.01	0.01	0.02	0.01	0.02	0.05
Yb	0.03	0.02	0.03	0.03	0.02	0.01	0.04	0.02	0.03	0.02	0.02	0.07

Table D3.1c: Internal precision (1SE) for each of the 10 analyte blanks in pg/mL presented in Table D3.1b. The reproducibility (1SD) of the analyte blanks equals the average of the internal precision (1SE) of the 10 blanks. Marked in light grey is the limit of detection (LOD) for each element calculated as 3 times the average standard deviation (1SD).

Appendix D4: Standard and TPB data collected by ICPMS during BIP whole-rock study

Standard ID	GP13			W2			BHVO-1		
n	7			3			3		
Element	Ave.	±2SD	Δ%	Ave.	±2SD	Δ%	Ave.	±2SD	Δ%
Sc	14.98	0.80	5.99	35.45	1.60	0.18	30.65	1.42	-3.61
Ti	741.13	18.05	5.70	6382.55	135.61	-3.18	16300.96	16.95	0.37
V	69.50	1.26	4.78	267.06	0.88	1.11	315.46	2.35	-0.49
Cr	2537.08	41.12	4.84	90.97	0.70	-8.57	294.58	6.90	1.93
Mn	0.11	0.00	-11.34	0.17	0.00	1.18	0.18	0.00	3.24
Co	98.41	2.19	0.51	45.42	0.88	-0.10	45.23	0.29	0.50
Ni	1989.52	27.05	-1.99	81.47	1.15	-16.47	134.33	1.61	11.01
Cu	24.90	0.86	6.45	104.24	0.67	-1.42	137.05	1.11	0.77
Zn	40.41	1.05	0.00	73.77	0.52	-4.53	109.63	0.55	4.41
Ga	2.68	0.10	6.92	17.19	0.29	-1.91	20.80	0.24	-0.94
Rb	0.32	0.02	-1.58	19.54	0.31	-4.03	9.20	0.05	-4.14
Sr	10.71	0.56	-4.52	187.53	6.02	-2.99	371.45	4.86	-7.83
Y	3.38	0.08	2.21	22.45	0.20	5.11	27.37	0.07	-0.83
Zr	5.66	0.18	5.86	87.44	0.50	-5.85	172.39	1.23	-3.69
Nb	0.12	0.01	-13.57	7.53	0.02	-3.02	19.14	0.12	-1.84
Cs	0.07	0.01	15.00	0.90	0.02	3.56	0.10	0.01	827.27
Ba	0.72	0.11	0.00	174.39	5.15	4.37	134.99	0.73	-2.89
La	0.19	0.01	2.73	10.62	0.57	0.12	15.42	0.33	-2.43
Ce	0.58	0.02	-2.22	22.75	0.98	-1.22	37.13	0.51	-4.79
Pr	0.11	0.00	0.44	3.14	0.12	6.73	5.59	0.03	-1.98
Nd	0.67	0.03	2.78	13.83	0.12	4.59	26.06	0.17	3.40
Sm	0.25	0.02	0.94	3.39	0.02	0.86	6.31	0.09	1.73
Eu	0.10	0.00	-0.32	1.12	0.00	-0.40	2.10	0.03	2.01
Gd	0.41	0.03	2.87	3.89	0.21	7.07	6.47	0.08	1.11
Tb	0.08	0.00	-0.88	0.65	0.02	4.44	0.98	0.01	1.61
Dy	0.50	0.01	-2.31	3.84	0.01	3.54	5.31	0.01	2.06
Ho	0.11	0.00	0.15	0.80	0.01	7.84	0.98	0.00	-1.26
Er	0.33	0.01	-0.25	2.14	0.03	-4.16	2.39	0.00	-0.31
Tm	0.05	0.00	3.85	0.33	0.00	-3.38	0.34	0.00	3.18
Yb	0.35	0.01	-0.63	2.06	0.02	1.34	2.00	0.01	-0.88
Lu	0.06	0.00	2.59	0.33	0.00	-0.15	0.30	0.00	3.45
Hf	0.17	0.01	2.12	2.38	0.03	-4.59	4.45	0.03	1.51
Ta	0.01	0.01	-46.83	0.49	0.01	-10.09	1.25	0.02	1.87

Table D.1a: Average trace element compositions of an *in-house* (GP13) and five USGS rock standards (W2, BHVO-1, AGV-1, BE-N, SRM688, and BIR-1) analyzed during ICPMS (Perkin Elmer Sciex Elan 6000) BIP whole rock session at *AHIGL* (Department of Earth Sciences, Durham University). Listed is the 2SD error for each rock standard plus the deviation in % from the recommended values are available from USGS, NIST, and Ottley et al. (2003). 'n' denotes number of analyses.

Appendix D4: Continued

Standard ID	AGV-1			BE-N			SRM688		
n	3			3			3		
Element	Ave.	±2SD	Δ%	Ave.	±2SD	Δ%	Ave.	±2SD	Δ%
Sc	11.61	0.99	-4.08	22.27	1.11	1.20	36.08	1.19	-5.06
Ti	6268.68	237.31	-1.32	15551.84	169.51	-0.57	6945.89	84.75	-0.94
V	120.99	3.34	-1.63	232.73	0.62	-0.97	249.62	1.09	3.15
Cr	8.94	0.29	-25.53	360.50	4.16	0.14	323.40	2.99	-2.59
Mn	0.09	0.00	-10.94	0.20	0.00	1.75	0.17	0.00	0.90
Co	15.63	0.52	3.48	61.80	1.91	1.30	49.17	0.54	0.34
Ni	20.56	0.34	20.95	290.50	5.61	8.80	178.10	2.53	12.72
Cu	58.00	2.70	-3.34	71.84	0.80	-0.22	88.01	1.29	-8.32
Zn	84.74	1.17	-3.70	123.67	1.97	3.06	71.75	0.04	-14.58
Ga	20.32	0.51	1.59	17.84	0.10	4.95	15.72	0.09	-7.55
Rb	67.23	0.32	0.34	47.92	1.61	1.96	1.91	0.06	0.24
Sr	678.02	18.51	2.42	1446.97	51.77	5.62	162.26	2.88	-4.10
Y	20.20	0.26	-3.81	30.90	0.40	3.01	21.01	0.03	23.57
Zr	230.44	5.07	2.42	272.68	2.77	2.90	55.18	0.72	-9.54
Nb	14.86	0.27	3.16	118.18	0.21	18.18	4.66	0.05	-6.75
Cs	1.26	0.04	-0.20	0.76	0.02	-5.44	0.04	0.00	-84.38
Ba	1229.63	26.74	0.71	1035.40	3.58	1.01	171.32	2.18	-14.34
La	38.19	0.38	0.49	80.91	1.31	-1.33	5.09	0.04	-4.00
Ce	67.34	1.03	2.03	145.87	3.63	-4.03	11.56	0.05	-11.11
Pr	8.78	0.21	35.01	17.91	0.07	5.99	1.79	0.01	-25.23
Nd	33.63	1.34	-1.08	69.57	0.46	-0.62	8.77	0.04	-8.69
Sm	5.91	0.31	0.19	12.39	0.16	3.25	2.44	0.12	-2.43
Eu	1.64	0.06	-0.93	3.71	0.04	3.01	0.99	0.07	-2.28
Gd	4.89	0.12	-5.97	10.01	0.16	11.17	3.14	0.01	-1.75
Tb	0.67	0.02	-5.21	1.31	0.01	0.96	0.54	0.02	3.17
Dy	3.56	0.13	-6.19	6.29	0.04	0.01	3.37	0.03	-0.90
Ho	0.69	0.02	-5.68	1.07	0.01	4.13	0.73	0.00	-9.81
Er	1.75	0.05	8.77	2.41	0.05	-2.66	2.04	0.03	-3.07
Tm	0.26	0.00	-17.97	0.33	0.01	-12.03	0.33	0.01	12.07
Yb	1.67	0.05	-0.12	1.85	0.02	2.61	2.08	0.06	1.24
Lu	0.27	0.01	-3.75	0.26	0.01	9.38	0.34	0.00	-2.14
Hf	5.17	0.17	1.46	5.72	0.02	5.94	1.48	0.03	-4.34
Ta	0.91	0.01	-0.65	6.10	0.05	10.99	0.29	0.01	-5.32

Table D.4.1a: Continued

Standard ID	BIR-1		
n	3		
Element	Ave.	±2SD	Δ%
Sc	42.39	2.38	-3.65
Ti	5753.28	118.66	0.00
V	324.41	9.97	3.65
Cr	396.86	4.67	3.89
Mn	0.18	0.00	4.09
Co	54.38	0.35	5.81
Ni	196.23	4.04	18.21
Cu	120.55	1.09	-4.33
Zn	67.84	4.47	-4.45
Ga	15.06	0.33	-5.90
Rb	0.21	0.01	-24.07
Sr	105.70	1.11	-2.13
Y	16.45	0.12	2.83
Zr	14.74	0.19	-33.01
Nb	0.65	0.01	-67.50
Cs	0.01	0.01	-97.67
Ba	6.81	0.07	-11.51
La	0.62	0.00	-29.38
Ce	1.88	0.02	-24.82
Pr	0.39	0.01	-22.60
Nd	2.55	0.10	1.94
Sm	1.14	0.03	5.21
Eu	0.53	0.01	-1.76
Gd	2.00	0.03	5.47
Tb	0.39	0.02	-5.98
Dy	2.59	0.08	7.79
Ho	0.58	0.02	15.20
Er	1.64	0.02	-9.10
Tm	0.26	0.01	-4.81
Yb	1.67	0.03	-1.90
Lu	0.27	0.01	5.58
Hf	0.58	0.01	-0.39
Ta	0.04	0.00	-30.65

Table D4.1a: Continued

Appendix D4: Continued

TPB ID	TPB 1		TPB 2		TPB 3		TPB 4		Average TPB	
n	6		2		2		3		13	
Element	Ave.	±2SD	Ave.	±2SD	Ave.	±2SD	Ave.	±2SD	TPB	LOD
Sc	0.14	0.26	-0.07	0.58	-0.16	0.57	-0.23	0.64	-0.08	0.77
Ti	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
V	-0.02	0.08	-0.05	0.15	-0.07	0.14	-0.05	0.15	-0.05	0.19
Cr	1.12	0.20	0.03	0.20	-0.06	0.35	-0.15	0.43	0.23	0.44
Mn	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Co	0.02	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.01	0.01
Ni	1.79	0.14	-0.33	0.10	-0.32	0.01	-0.14	0.40	0.25	0.24
Cu	0.00	0.62	-0.21	0.98	-0.30	0.93	-0.30	0.84	-0.20	1.26
Zn	0.67	0.12	-0.27	0.43	-0.23	0.16	0.01	0.02	0.05	0.27
Ga	0.01	0.02	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.01
Rb	0.00	0.02	-0.01	0.01	-0.01	0.00	0.00	0.00	0.00	0.01
Sr	0.02	0.02	0.01	0.00	0.01	0.02	0.00	0.01	0.01	0.02
Y	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Zr	0.00	0.02	0.00	0.00	-0.01	0.01	0.00	0.00	0.00	0.01
Nb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cs	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.01
Ba	0.02	0.04	0.01	0.06	0.12	0.14	0.02	0.05	0.04	0.11
La	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ce	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sm	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Eu	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tb	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dy	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ho	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Er	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tm	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Yb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lu	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hf	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ta	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table D4.1b: Trace element compositions of 4 different TPBs analyzed 'n' times during ICPMS (Perkin Elmer Sciex Elan 6000) BIP whole rock session at *AHIGL* (Department of Earth Sciences, Durham University). Listed is the 2SD error on the average of each TPB, and also the limit of detection (LOD equals 3 times SD). Negative values and zero values indicate concentrations near the LOD.

Appendix D5: Sr isotope data collected by MC-ICPMS during BIP whole-rock study

No.	$^{87}Sr/^{86}Sr$	±2SE
1	0.710255	0.000010
2	0.710260	0.000010
3	0.710249	0.000011
4	0.710259	0.000010
5	0.710258	0.000011
6	0.710257	0.000011
7	0.710252	0.000010
8	0.710257	0.000010
9	0.710261	0.000011
10	0.710253	0.000011
11	0.710262	0.000012
12	0.710267	0.000011
13	0.710264	0.000012

Standard ID	n	$^{87}Sr/^{86}Sr$	±2SD	±2SD (ppm)
NBS 987	13	0.710258	0.000011	15

Table D5.1a: Sr isotope data collected on NBS 987 during whole-rock Sr isotope MC-ICPMS session on the *AHIGL* Neptune (Department of Earth Sciences, Durham University).

No.	$^{87}Sr/^{86}Sr$	±2SE
1	0.703491	0.000014
2	0.703505	0.000020
3	0.703495	0.000013
4	0.703494	0.000014
5	0.703478	0.000010
6	0.703485	0.000014

Standard ID	n	$^{87}Sr/^{86}Sr$	±2SD	±2SD (ppm)
BHVO-1	6	0.710491	0.000014	20

Table D5.1b: Sr isotope data collected on BHVO-1 during whole-rock Sr isotope MC-ICPMS session on the *AHIGL* Neptune (Department of Earth Sciences, Durham University).

Appendix D6: BIP - isotope, major and element data

Sample ID	Pd3	Pd6	Pd12	Pd23	Pd26	Pd66
Rock	*Picrite*	*Picrite*	*Picrite*	*Picrite*	*Picrite*	*Picrite*
Type	*E-type*	*N-type*	*N-type*	*E-type*	*E-type*	*E-type*
$^{87}Sr/^{86}Sr$ isotope ratios						
$^{87}Sr/^{86}Sr_{meas}$	0.703287	0.703129	0.703097	0.703309	0.703300	0.703689
$^{87}Sr/^{86}Sr_{norm}$	0.703269	0.703111	0.703079	0.703291	0.703282	0.703671
$^{87}Sr/^{86}Sr_{i}$	0.703266	0.703104	0.703075	0.703286	0.703278	0.703662
±2SE	0.000012	0.000012	0.000015	0.000013	0.000012	0.000013
Major elements in wt.% from Yaxley et al. (2004)						
SiO_2	45.95	45.46	45.87	46.38	47.13	-
TiO_2	0.90	0.77	0.82	1.06	1.03	-
Al_2O_3	12.04	10.83	11.40	13.55	13.35	-
MgO	18.16	21.36	19.83	14.02	14.56	-
FeO_{total}	10.68	10.59	10.64	10.83	10.78	-
MnO	0.18	0.17	0.17	0.18	0.18	-
CaO	10.32	9.12	9.83	11.55	11.34	-
Na_2O	1.16	1.01	1.09	1.42	1.41	-
K_2O	0.02	0.02	0.02	0.03	0.04	-
P_2O_5	0.07	0.06	0.06	0.09	0.09	-
LOI	0.53	0.82	0.24	0.43	0.31	-
Total	100.01	100.21	99.97	99.54	100.22	-
Mg#	74.87	77.95	76.56	69.41	70.30	-
Primitive mantle normalized trace element ratios						
$(La/Sm)_N$	0.95	0.57	0.58	0.97	0.94	1.09
$(La/Y)_N$	1.23	0.66	0.69	1.14	1.25	1.20
$(La/Yb)_N$	1.28	0.66	0.70	1.27	1.30	1.31
$(Rb/Sr)_N$	0.04	0.10	0.05	0.06	0.05	0.12
$(Sr/Nd)_N$	1.01	1.03	1.08	0.92	1.00	1.09
$(Ba/Y)_N$	0.54	0.34	0.27	0.53	0.71	1.08
$(Zr/Y)_N$	1.24	1.07	1.14	1.12	1.23	1.07

Table D6.1: See caption on next page

Appendix D6: Continued

Sample ID	Pd3	Pd6	Pd12	Pd23	Pd26	Pd66
Rock	*Picrite*	*Picrite*	*Picrite*	*Picrite*	*Picrite*	*Picrite*
Type	E-type	*N-type*	*N-type*	*E-type*	*E-type*	*E-type*
Trace element composition (ppm)						
Sc	45.10	38.70	42.40	40.78	45.90	37.28
Ti*	5394.59	4615.37	4915.07	6353.63	6173.81	5435.65
V	278.00	229.00	258.00	291.61	284.00	253.83
Cr	575.00	741.00	678.00	889.15	626.00	927.89
Mn*	1394.02	1316.58	1316.58	1394.02	1394.02	1394.02
Co	72.40	89.50	49.80	64.87	71.40	63.53
Ni	484.00	1087.00	836.00	402.22	400.00	418.28
Cu	139.00	101.00	119.00	133.41	141.00	100.11
Zn	89.30	84.20	84.90	82.57	89.20	76.86
Ga	15.30	12.10	13.90	14.12	15.40	13.80
Rb	0.14	0.23	0.15	0.21	0.20	0.40
Sr	118.00	77.10	94.00	115.00	125.00	112.13
Y	19.40	15.50	17.20	21.50	20.20	18.90
Zr	58.90	40.40	47.90	59.01	60.70	49.37
Nb	3.67	1.21	1.58	3.85	3.73	4.56
Cs	-	-	-	-	-	0.01
Ba	16.00	8.12	7.23	17.65	22.10	31.26
La	3.61	1.53	1.80	3.70	3.77	3.41
Ce	9.21	4.84	5.84	9.05	9.57	8.13
Pr	1.39	0.81	0.94	1.52	1.49	1.28
Nd	7.37	4.68	5.45	7.81	7.89	6.44
Sm	2.37	1.69	1.96	2.39	2.52	1.97
Eu	0.85	0.63	0.72	0.90	0.90	0.76
Gd	2.96	2.26	2.52	3.21	3.04	2.72
Tb	0.55	0.43	0.48	0.56	0.57	0.48
Dy	3.46	2.77	3.04	3.47	3.63	3.00
Ho	0.76	0.61	0.68	0.74	0.78	0.64
Er	2.04	1.66	1.84	2.00	2.19	1.81
Tm	-	-	-	0.32	-	0.29
Yb	1.92	1.57	1.74	1.98	1.97	1.77
Lu	0.28	0.24	0.26	0.33	0.30	0.29
Hf	1.52	1.09	1.28	1.61	1.63	1.33
Ta	0.21	0.08	0.10	0.24	0.22	0.26
Pb	-	-	-	1.41	-	1.16
Th	0.28	0.08	0.11	0.31	0.28	0.31
U	0.04	0.02	0.02	0.05	0.04	0.06

Table D6.1: $^{87}Sr/^{86}Sr$ isotope, major and trace element composition of the Baffin Island picrites. Sr isotope ratios are obtained by MC-ICPMS, and trace element concentrations by ICPMS at *AHIGL* (Department of Earth Sciences, Durham University) Major element compositions are from Yaxley et al. (2004). Ti* and Mn* are calculated from wt.% except for Pd66. Subscribed i indicates initial or the formation age, which for the BIP are 61 Ma.

Appendix D7: Selected crustal rocks of Baffin Island – Sr isotope and element data

Sample ID	JD70-250	JD70-272-1	JD70-E256	JD70-214-1	JDC70-280	JDC70-E418
Rock	*Charnockite*	*Charnockite*	*Charnockite*	*Gneisses*	*Gneisses*	*Gneisses*
Trace elements (ppm)						
Sc	7.91	12.93	14.36	11.88	0.87	1.16
Ti	3206	3919	7863	1912	264	797
V	37.27	64.62	91.73	28.28	7.11	13.45
Cr	33.41	39.25	11.87	8.33	1.82	17.67
Mn	0.03	0.07	0.09	0.08	0.01	0.01
Co	4.54	9.49	14.97	8.23	0.81	3.24
Ni	10.35	14.00	13.58	10.67	3.00	10.58
Cu	11.01	22.66	15.38	5.77	1.74	6.20
Zn	47.98	74.06	99.55	53.30	10.60	17.71
Ga	20.65	19.79	23.40	21.53	14.59	13.95
Rb	249.78	249.69	57.16	33.63	165.12	171.28
Sr	140.15	126.68	484.24	286.80	362.43	276.37
Y	42.75	54.12	29.63	46.77	0.51	0.65
Zr	346.18	310.25	180.90	59.43	57.47	38.58
Nb	18.81	17.35	22.55	9.31	0.44	1.83
Cs	8.56	3.78	0.32	0.02	0.50	1.27
Ba	1045	953	1689	356	1474	1847
La	59.05	58.97	83.65	37.71	3.29	2.78
Ce	117.35	121.59	181.31	75.66	9.93	4.97
Pr	14.30	15.41	22.46	10.27	0.60	0.47
Nd	51.89	56.93	85.27	40.86	1.86	1.59
Sm	9.17	10.40	13.23	8.66	0.28	0.26
Eu	1.27	1.37	2.85	1.46	0.36	0.42
Gd	7.39	8.70	8.81	7.90	0.19	0.19
Tb	1.17	1.41	1.16	1.29	0.02	0.02
Dy	6.61	8.16	5.68	7.21	0.09	0.11
Ho	1.34	1.66	1.00	1.41	0.01	0.02
Er	3.53	4.43	2.39	3.72	0.04	0.05
Tm	0.55	0.69	0.34	0.56	0.01	0.01
Yb	3.40	4.30	1.97	3.32	0.04	0.05
Lu	0.53	0.67	0.30	0.50	0.01	0.01
Hf	8.63	7.38	4.24	1.40	1.61	1.10
Ta	1.53	1.16	0.96	0.35	0.02	0.11
Pb	34.56	41.30	19.92	13.34	27.63	41.24
Th	28.64	27.48	4.09	0.64	1.72	0.54
U	3.93	2.61	0.78	0.15	0.29	0.21

Table D7.1: $^{87}Sr/^{86}Sr$ isotope and trace element composition of selected crustal rocks of Baffin Island. Sr isotope ratios are obtained by MC-ICPMS, and trace element concentrations by ICPMS at *AHIGL* (Department of Earth Sciences, Durham University) Subscribed i indicates the initial or the formation age (61 Ma), which the possible age for the interaction between the crustal rocks and the BIP.

Appendix D7: Continued

Sample ID	JD70-197-2	JD70-318-2	JDC70-304	JD70-D239-2
Rock	*Granitoid*	*Granitoid*	*Granitoid*	*Mafic*
Trace elements (ppm)				
Sc	4.19	4.51	8.85	17.57
Ti	1650	2421	2721	4357
V	22.75	18.67	35.53	124.75
Cr	11.22	11.09	23.86	151.88
Mn	0.02	0.01	0.03	0.07
Co	3.59	13.67	6.24	18.81
Ni	5.02	28.84	9.76	64.15
Cu	3.20	29.17	10.03	14.74
Zn	32.52	16.89	48.32	109.67
Ga	16.45	16.10	19.22	21.72
Rb	143.27	142.58	142.03	158.56
Sr	177.29	121.87	163.20	160.86
Y	13.82	20.35	17.91	21.94
Zr	107.55	229.32	183.61	140.10
Nb	11.04	11.53	13.43	12.95
Cs	0.59	0.29	3.42	11.91
Ba	521	927	624.42	593.96
La	28.29	17.61	34.34	33.64
Ce	52.58	32.67	77.42	66.50
Pr	6.08	4.03	8.35	8.48
Nd	20.91	16.02	30.28	32.79
Sm	3.74	3.47	5.04	6.00
Eu	0.73	0.92	0.93	1.28
Gd	2.79	3.42	3.56	4.83
Tb	0.44	0.55	0.53	0.71
Dy	2.40	3.16	2.92	3.93
Ho	0.43	0.63	0.57	0.76
Er	0.95	1.62	1.41	2.04
Tm	0.11	0.24	0.21	0.32
Yb	0.59	1.41	1.21	2.09
Lu	0.09	0.22	0.19	0.33
Hf	3.25	5.98	4.66	3.86
Ta	0.57	0.85	1.41	1.04
Pb	61.61	13.67	22.46	28.80
Th	20.24	7.24	13.32	11.84
U	4.26	1.71	1.34	3.69

Appendix D7: Continued

Sample ID	JD70-258-1	JD70-294-2	JD70-303-2	JD70-304-1	JD70-E236-1	JD70-E294-1
Rock	*Metasediment*	*Metasediment*	*Metasediment*	*Metasediment*	*Metasediment*	*Metasediment*
Trace elements (ppm)						
Sc	4.21	0.61	4.04	18.80	10.88	10.69
Ti	2421	473	2985	4213	3506	3020
V	31.95	1.34	31.56	135.26	89.89	68.12
Cr	2.38	0.30	8.87	219.40	120.12	73.04
Mn	0.01	0.01	0.03	0.08	0.03	0.03
Co	4.13	0.52	5.77	16.01	13.53	10.73
Ni	2.89	0.34	7.00	49.51	56.31	32.65
Cu	5.90	1.95	6.53	32.20	43.95	3.53
Zn	30.97	11.04	48.73	130.32	127.88	71.12
Ga	18.11	14.79	20.96	17.61	16.63	19.24
Rb	157.95	178.31	115.97	126.07	176.37	185.67
Sr	486.86	88.91	336.22	77.14	134.31	50.57
Y	3.84	3.62	8.31	21.26	25.45	19.54
Zr	285.14	77.13	113.63	159.41	205.83	156.92
Nb	4.62	1.73	5.68	10.22	11.79	11.70
Cs	0.55	1.32	0.78	9.93	3.39	8.06
Ba	4717.55	381.01	1266.90	429.17	212.56	652.42
La	154.10	42.70	26.73	23.31	34.00	37.94
Ce	247.18	77.28	175.85	45.85	67.78	68.84
Pr	24.78	8.26	7.09	5.80	8.57	8.49
Nd	72.70	26.03	22.78	22.04	32.38	30.75
Sm	6.17	2.84	3.58	4.05	6.53	5.39
Eu	1.88	0.71	0.92	0.85	0.83	1.07
Gd	1.63	1.05	2.02	3.37	5.59	4.11
Tb	0.17	0.12	0.31	0.53	0.86	0.63
Dy	0.77	0.60	1.63	3.21	4.54	3.26
Ho	0.13	0.11	0.30	0.69	0.84	0.63
Er	0.28	0.24	0.69	2.04	2.00	1.67
Tm	0.04	0.03	0.09	0.35	0.28	0.26
Yb	0.28	0.18	0.51	2.35	1.59	1.66
Lu	0.05	0.03	0.08	0.38	0.24	0.27
Hf	6.13	2.26	2.70	4.21	5.31	4.26
Ta	0.12	0.07	0.15	0.81	0.85	1.02
Pb (total)	35.92	44.15	28.69	20.80	16.47	17.71
Th	32.21	23.00	31.65	8.29	12.82	10.74
U	0.65	2.48	0.59	2.13	2.62	2.45

Tabel D7.1: Continued

Appendix D7: Continued

Sample ID	JD70-250	JD70-272-1	JD70-E256	JD70-214-1	JDC70-280	JDC70-E418
Rock type	*Charnockite*	*Charnockite*	*Charnockite*	*Gneisses*	*Gneisses*	*Gneisses*
Map unit	*Pcc*	*Pcc*	*Pcc*	*Agn*	*Agn*	*Agn*
$^{87}Sr/^{86}Sr_{meas}$	0.841779	0.855917	0.715122	0.728072	0.748264	0.760999
$^{87}Sr/^{86}Sr_{norm}$	0.841761	0.855899	0.715104	0.728054	0.748246	0.760981
$^{87}Sr/^{86}Sr_{61\ Ma}$	0.837234	0.850885	0.714808	0.727759	0.747099	0.759419
±2SE	0.000011	0.000016	0.000017	0.000011	0.000010	0.000011
Selected PM normalized trace element ratios						
$(La/Sm)_N$	4.03	3.55	3.96	2.73	7.43	6.68
$(La/Y)_N$	9.17	7.23	18.73	5.35	42.76	28.40
$(La/Yb)_N$	11.81	9.34	28.86	7.72	51.52	34.69
$(Rb/Sr)_N$	59.11	65.37	3.91	3.89	15.11	20.56
$(Sr/Nd)_N$	0.17	0.14	0.36	0.44	12.23	10.90
$(Ba/Y)_N$	15.92	11.47	37.13	4.97	1879.73	1854.57
$(Zr/Y)_N$	3.32	2.35	2.50	0.52	46.05	24.34

Table D7.1: Continued

Sample ID	JD70-197-2*	JD70-318-2	JDC70-304	JD70-D239-2
Rock type	*Granitoid*	*Granitoid*	*Granitoid*	*Mafic*
Map unit			*Pcgl*	*PHB*
$^{87}Sr/^{86}Sr_{meas}$	0.774056	0.771383	0.794484	0.777997
$^{87}Sr/^{86}Sr_{norm}$	0.774038	0.771365	0.794466	0.777979
$^{87}Sr/^{86}Sr_{61\ Ma}$	0.771999	0.768413	0.792265	0.775491
±2SE	0.000011	0.000010	0.000013	0.000011
Selected PM normalized trace element ratios				
$(La/Sm)_N$	4.74	3.18	4.27	3.51
$(La/Y)_N$	13.59	5.74	12.72	10.18
$(La/Yb)_N$	32.38	8.50	19.32	10.96
$(Rb/Sr)_N$	26.80	38.80	28.86	32.69
$(Sr/Nd)_N$	0.53	0.48	0.34	0.31
$(Ba/Y)_N$	24.58	29.68	22.71	17.64
$(Zr/Y)_N$	3.19	4.62	4.20	2.62

Table D7.1: Continued

Sample ID	JD70-258-1	JD70-294-2	JD70-303-2	JD70-304-1	JD70-E236-1	JD70-E294-1
Rock type	*Metasediment*	*Metasediment*	*Metasediment*	*Metasediment*	*Metasediment*	*Metasediment*
Map unit	*PHmb*	*PHmb*	*PHmb*	*PHma*	*PHma*	*PHma*
$^{87}Sr/^{86}Sr_{meas}$	0.730154	0.901624	0.743830	0.820062	0.800911	0.978878
$^{87}Sr/^{86}Sr_{norm}$	0.730136	0.901606	0.743812	0.820044	0.800893	0.978860
$^{87}Sr/^{86}Sr_{61Ma}$	0.729321	0.896482	0.742944	0.815901	0.797571	0.969410
±2SE	0.000016	0.000015	0.000010	0.000013	0.000013	0.000012

Selected PM normalized trace element ratios

$(La/Sm)_N$	15.65	9.43	4.67	3.61	3.26	4.41
$(La/Y)_N$	266.57	78.34	21.35	7.28	8.86	12.89
$(La/Yb)_N$	368.61	157.94	35.88	6.76	14.58	15.53
$(Rb/Sr)_N$	10.76	66.52	11.44	54.20	43.55	121.77
$(Sr/Nd)_N$	0.42	0.21	0.93	0.22	0.26	0.10
$(Ba/Y)_N$	801.24	68.63	99.34	13.15	5.44	21.76
$(Zr/Y)_N$	30.44	8.73	5.60	3.07	3.31	3.29

Table D7.1: Continued

Appendix D8: Olivine phenocryst of the BIP – major element data

Olivine ID	Pd6-4 (E)	Pd6-4 (C)	Pd6-2 (E)	Pd6-1 (E)	Pd6-1 (C)	Ave. $_{Ol-Pd6}$	n=15
MIs contained	M14-3	M14-3	M14-12,13,14	M14-1	M14-1	-	±2SD
Major elements (wt.%)							
Al_2O_3	*0.06*	*0.06*	*0.06*	*0.09*	*0.05*	*0.06*	*0.03*
MnO	*0.16*	*0.18*	*0.19*	*0.19*	*0.17*	*0.18*	*0.03*
TiO_2	*0.00*	*0.01*	*0.01*	*0.00*	*0.00*	*0.01*	*0.01*
Cr_2O_3	*0.07*	0.09	*0.08*	*0.10*	*0.08*	*0.08*	*0.03*
MgO	*48.33*	*48.27*	*48.13*	*47.54*	*47.77*	*48.01*	*0.68*
SiO_2	*40.44*	*40.66*	*40.76*	*40.78*	*40.77*	*40.68*	*0.29*
FeO	*11.37*	*11.17*	*11.29*	*11.16*	*11.17*	*11.23*	*0.19*
CaO	*0.31*	*0.30*	*0.33*	*0.32*	*0.29*	*0.31*	*0.03*
NiO	*0.35*	*0.37*	*0.34*	*0.35*	*0.38*	*0.36*	*0.03*
Na_2O	*0.00*	*0.00*	*0.01*	*0.00*	*0.00*	*0.00*	*0.00*
K_2O	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Total	*101.10*	*101.10*	*101.20*	*100.54*	*100.67*	*100.92*	*0.59*
Al_2O_3	0.06	0.06	0.06	0.09	0.05	0.06	0.03
MnO	0.15	0.18	0.19	0.19	0.16	0.18	0.03
TiO_2	0.00	0.01	0.01	0.00	0.00	0.00	0.01
Cr_2O_3	0.07	0.09	0.08	0.10	0.07	0.08	0.03
MgO	47.81	47.74	47.56	47.28	47.45	47.57	0.43
SiO_2	40.00	40.21	40.28	40.56	40.50	40.31	0.45
FeO	11.24	11.04	11.16	11.10	11.09	11.13	0.15
CaO	0.31	0.29	0.32	0.32	0.29	0.31	0.03
NiO	0.35	0.37	0.34	0.35	0.38	0.36	0.03
Na_2O	0.00	0.00	0.01	0.00	0.00	0.00	0.00
K_2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	100.00	100.00	100.00	100.00	100.00	100.00	0.00
Fo	88.2	88.3	88.2	88.2	88.2	88.2	0.14

Table D8.1a: Major element composition of olivine phenocrysts from the BIP, which contained the MIs that were sampled by micro-milling are presented in Table D8.1a through D8.1e.. Concentrations are determined by electron microprobe at the Department of Geography and Geology – Geology section (University of Copenhagen) and are given in wt.%. Concentrations in italic are the untreated data, while the concentrations in regular are normalized to a 100 wt.%. Each analysis represents an average of three analyses. The *E*, *C*, and *P* in parentheses after the '*Olivine ID*' denotes that the olivine was probed at the edge, centre, or near the mill pit. '*MIs contained*' refer to which MIs was sampled at each particular grain. '*Fo*' is the fosterite content of the olivine. The two columns to the right list the average composition of '*n*' olivine phenocrysts analyzed, and the 2SD error on the average concentration.

Appendix D8: Continued

Olivine ID	Pd12-1 (P)	Pd12-1 (E)	Pd12-1 (C)	Pd12-2 (E)	Pd12-2 (C)	Pd12-3 (C)
MIs_{hosted}	M14-4	M14-4	M14-4	M14-5	M14-5	M14-30,31
Major elements (wt.%)						
Al_2O_3	*0.29*	*0.07*	*0.07*	*0.09*	*0.09*	*0.07*
MnO	*0.22*	*0.19*	*0.21*	*0.18*	*0.16*	*0.15*
TiO_2	*0.02*	*0.00*	*0.00*	*0.00*	*0.00*	*0.01*
Cr_2O_3	*0.10*	*0.07*	*0.07*	*0.10*	*0.11*	*0.14*
MgO	*47.67*	*47.78*	*48.21*	*46.94*	*48.31*	*47.82*
SiO_2	*40.36*	*40.55*	*40.59*	*40.49*	*40.56*	*40.07*
FeO	*11.41*	*11.51*	*10.96*	*11.46*	*10.51*	*11.60*
CaO	*0.32*	*0.32*	*0.31*	*0.29*	*0.29*	*0.30*
NiO	*0.36*	*0.38*	*0.41*	*0.35*	*0.42*	*0.38*
Na_2O	*0.01*	*0.01*	*0.02*	*0.00*	*0.01*	*0.01*
K_2O	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Total	*100.75*	*100.87*	*100.85*	*99.92*	*100.47*	*100.53*
Al_2O_3	0.29	0.07	0.07	0.09	0.09	0.07
MnO	0.22	0.19	0.20	0.18	0.16	0.15
TiO_2	0.02	0.00	0.00	0.00	0.00	0.01
Cr_2O_3	0.10	0.07	0.07	0.10	0.11	0.14
MgO	47.31	47.37	47.80	46.98	48.08	47.57
SiO_2	40.05	40.20	40.25	40.52	40.37	39.85
FeO	11.32	11.41	10.87	11.47	10.46	11.53
CaO	0.31	0.32	0.31	0.29	0.29	0.30
NiO	0.36	0.37	0.41	0.35	0.41	0.38
Na_2O	0.01	0.01	0.02	0.00	0.01	0.01
K_2O	0.00	0.00	0.00	0.00	0.00	0.00
Total	100.00	100.00	100.00	100.00	100.00	100.00
Fo	88.0	87.9	88.5	87.8	89.0	87.9

Table D8.1b: Continues on next page.

Appendix D8: Continued

Olivine ID	Pd12-3 (E)	Pd12-4 (E)	Pd12-4 (C)	Pd12-4 (P)	$Ave_{Ol-Pd12}$	n=30
MIs_{hosted}	M14-30,31	M14-20,21	M14-20,21	M14-20,21	-	±2SD
Major elements (wt.%)						
Al_2O_3	*0.15*	*0.07*	*0.05*	*0.08*	*0.10*	*0.14*
MnO	*0.16*	*0.18*	*0.16*	*0.16*	*0.18*	*0.04*
TiO_2	*0.01*	*0.00*	*0.00*	*0.00*	*0.00*	*0.01*
Cr_2O_3	*0.11*	*0.08*	*0.12*	*0.10*	*0.10*	*0.04*
MgO	*48.49*	*47.63*	*47.71*	*47.65*	*47.82*	*0.88*
SiO_2	*41.02*	*40.65*	*40.51*	*41.21*	*40.60*	*0.64*
FeO	*10.61*	*11.47*	*11.88*	*11.31*	*11.27*	*0.88*
CaO	*0.30*	*0.31*	*0.30*	*0.33*	*0.31*	*0.03*
NiO	*0.39*	*0.35*	*0.38*	*0.36*	*0.38*	*0.05*
Na_2O	*0.01*	*0.01*	*0.00*	*0.01*	*0.01*	*0.01*
K_2O	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Total	*101.26*	*100.75*	*101.09*	*101.21*	*100.77*	*0.80*
Al_2O_3	0.15	0.07	0.05	0.08	0.10	0.14
MnO	0.16	0.18	0.16	0.16	0.18	0.04
TiO_2	0.01	0.00	0.00	0.00	0.00	0.01
Cr_2O_3	0.11	0.08	0.12	0.10	0.10	0.04
MgO	47.89	47.28	47.19	47.08	47.45	0.74
SiO_2	40.51	40.34	40.07	40.72	40.29	0.52
FeO	10.48	11.38	11.75	11.17	11.18	0.88
CaO	0.29	0.31	0.29	0.33	0.30	0.02
NiO	0.39	0.34	0.37	0.36	0.37	0.05
Na_2O	0.01	0.01	0.00	0.01	0.01	0.01
K_2O	0.00	0.00	0.00	0.00	0.00	0.00
Total	100.00	100.00	100.00	100.00	100.00	0.00
Fo	88.9	87.9	87.6	88.0	88.1	0.96

Table D8.1b: Continued

Appendix D8: Continued

Olivine ID	Pd23-3 (P)	Pd23-3 (C)	Pd23-3 (E)	Pd23-2 (P)	Pd23-2 (C)	Pd23-2 (E)	Pd23-1 (E)
MIs_{hosted}	M14-11	M14-11	M14-11	M14-8,9,10	M14-8,9,10	M14-8,9,10	M14-6,7
Major elements (wt.%)							
Al_2O_3	*0.07*	*0.06*	*0.07*	*0.07*	*0.06*	*0.06*	*0.07*
MnO	*0.19*	*0.20*	*0.16*	*0.16*	*0.19*	*0.23*	*0.18*
TiO_2	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.00*	*0.01*
Cr_2O_3	*0.06*	*0.06*	*0.07*	*0.06*	*0.08*	*0.08*	*0.06*
MgO	*46.93*	*47.11*	*46.16*	*46.99*	*47.33*	*47.25*	*46.60*
SiO_2	*40.15*	*40.82*	*40.28*	*40.14*	*39.75*	*39.81*	*40.08*
FeO	*12.23*	*12.00*	*12.53*	*12.01*	*11.99*	*12.21*	*13.33*
CaO	*0.30*	*0.30*	*0.32*	*0.30*	*0.31*	*0.32*	*0.33*
NiO	*0.34*	*0.31*	*0.34*	*0.34*	*0.32*	*0.32*	*0.28*
Na_2O	*0.01*	*0.00*	*0.01*	*0.00*	*0.01*	*0.00*	*0.00*
K_2O	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Total	*100.28*	*100.88*	*99.94*	*100.08*	*100.05*	*100.28*	*100.94*
Al_2O_3	0.07	0.06	0.07	0.07	0.06	0.06	0.07
MnO	0.19	0.20	0.16	0.16	0.19	0.23	0.18
TiO_2	0.00	0.01	0.01	0.01	0.01	0.00	0.01
Cr_2O_3	0.06	0.06	0.07	0.06	0.08	0.08	0.06
MgO	46.80	46.70	46.19	46.95	47.31	47.12	46.17
SiO_2	40.04	40.46	40.30	40.11	39.73	39.69	39.70
FeO	12.19	11.89	12.54	12.00	11.98	12.18	13.20
CaO	0.30	0.30	0.32	0.30	0.31	0.32	0.32
NiO	0.34	0.31	0.34	0.34	0.32	0.32	0.28
Na_2O	0.00	0.00	0.01	0.00	0.01	0.00	0.00
K_2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Fo	87.0	87.3	86.6	87.3	87.4	87.2	86.0

Table D8.1c:

Appendix D8: Continued

Olivine ID	$Ave_{Ol-Pd23}$	n=21
MIs_{hosted}	-	±2SD
Al_2O_3	*0.07*	*0.01*
MnO	*0.19*	*0.05*
TiO_2	*0.01*	*0.01*
Cr_2O_3	*0.07*	*0.02*
MgO	*46.91*	*0.82*
SiO_2	*40.14*	*0.70*
FeO	*12.33*	*0.96*
CaO	*0.31*	*0.02*
NiO	*0.32*	*0.04*
Na_2O	*0.01*	*0.01*
K_2O	*0.00*	*0.00*
Total	*100.35*	*0.81*
Al_2O_3	0.07	0.01
MnO	0.19	0.05
TiO_2	0.01	0.01
Cr_2O_3	0.07	0.02
MgO	46.75	0.87
SiO_2	40.01	0.62
FeO	12.28	0.92
CaO	0.31	0.02
NiO	0.32	0.04
Na_2O	0.01	0.01
K_2O	0.00	0.00
Total	100.00	0.00
Fo	87.0	1.02

Table D8.1e: Continued

Appendix D8: Continued

Olivine ID	Pd26-1 (E)	Pd26-1 (C)	Pd26-2 (C)	Pd26-2 (E)	Pd26-3 (E)	Pd26-3 (C)	$Ave._{Ol-Pd26}$	n=18
MIs_{hosted}	M14-22,23	M14-22,23	M14-24,25	M14-24,25	M14-32,33,34	M14-32,33,34	-	±2SD
Major elements (wt.%)								
Al_2O_3	*0.06*	*0.05*	*0.07*	*0.08*	*0.11*	*0.05*	*0.07*	*0.04*
MnO	*0.20*	*0.18*	*0.19*	*0.22*	*0.18*	*0.19*	*0.19*	*0.03*
TiO_2	*0.01*	*0.01*	*0.01*	*0.02*	*0.01*	*0.01*	*0.01*	*0.01*
Cr_2O_3	*0.07*	*0.08*	*0.06*	*0.07*	*0.08*	*0.05*	*0.07*	*0.02*
MgO	*46.82*	*47.62*	*46.94*	*46.59*	*46.68*	*47.57*	*47.04*	*0.90*
SiO_2	*40.67*	*40.75*	*40.97*	*40.64*	*40.97*	*40.48*	*40.75*	*0.39*
FeO	*12.59*	*12.08*	*12.32*	*13.00*	*12.02*	*12.16*	*12.36*	*0.75*
CaO	*0.32*	*0.32*	*0.30*	*0.31*	*0.33*	*0.32*	*0.32*	*0.02*
NiO	*0.32*	*0.33*	*0.31*	*0.31*	*0.31*	*0.33*	*0.32*	*0.02*
Na_2O	*0.00*	*0.00*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*
K_2O	*0.00*	*0.00*	*0.00*	*0.01*	*0.00*	*0.00*	*0.00*	*0.00*
Total	*101.06*	*101.41*	*101.17*	*101.25*	*100.70*	*101.17*	*101.13*	*0.48*
Al_2O_3	0.06	0.05	0.07	0.08	0.11	0.05	0.07	0.04
MnO	0.19	0.18	0.19	0.21	0.18	0.19	0.19	0.03
TiO_2	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01
Cr_2O_3	0.07	0.08	0.06	0.07	0.08	0.05	0.07	0.02
MgO	46.32	46.95	46.39	46.02	46.35	47.02	46.51	0.79
SiO_2	40.25	40.18	40.49	40.13	40.69	40.01	40.29	0.50
FeO	12.46	11.91	12.18	12.84	11.94	12.01	12.22	0.72
CaO	0.32	0.31	0.30	0.30	0.32	0.31	0.31	0.02
NiO	0.31	0.33	0.30	0.30	0.31	0.33	0.31	0.02
Na_2O	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01
K_2O	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	0.00
Fo	86.7	87.4	87.0	86.3	87.2	87.3	87.0	0.83

Table D8.1d:

Appendix D8: Continued

Olivine ID	PD66-3 (E)	PD66-3 (E)	PD66-2 (E)	PD66-1 (E)	$Ave_{Ol-Pd66}$	n=12
MIs_{hosted}	M14-28,29	M14-28,29	M14-35,36,37	M14-26	-	±2SD
Major elements (wt.%)						
Al_2O_3	*0.06*	*0.05*	*0.15*	*0.08*	*0.08*	*0.09*
MnO	*0.22*	*0.23*	*0.23*	*0.23*	*0.23*	*0.01*
TiO_2	*0.01*	*0.02*	*0.01*	*0.00*	*0.01*	*0.01*
Cr_2O_3	*0.05*	*0.07*	*0.06*	*0.07*	*0.06*	*0.02*
MgO	*46.55*	*45.42*	*44.21*	*45.56*	*45.43*	*1.92*
SiO_2	*39.50*	*41.18*	*40.71*	*40.16*	*40.39*	*1.42*
FeO	*14.43*	*14.65*	*14.42*	*14.41*	*14.48*	*0.23*
CaO	*0.33*	*0.33*	*0.34*	*0.36*	*0.34*	*0.03*
NiO	*0.23*	*0.23*	*0.24*	*0.21*	*0.23*	*0.02*
Na_2O	*0.00*	*0.00*	*0.01*	*0.01*	*0.00*	*0.01*
K_2O	*0.00*	*0.00*	*0.01*	*0.01*	*0.00*	*0.01*
Total	*101.37*	*102.18*	*100.37*	*101.11*	*101.26*	*1.49*
Al_2O_3	0.06	0.05	0.15	0.08	0.08	0.09
MnO	0.22	0.22	0.23	0.23	0.23	0.01
TiO_2	0.01	0.01	0.01	0.00	0.01	0.01
Cr_2O_3	0.05	0.07	0.06	0.07	0.06	0.02
MgO	45.92	44.45	44.04	45.06	44.87	1.63
SiO_2	38.97	40.31	40.56	39.72	39.89	1.41
FeO	14.24	14.34	14.37	14.25	14.30	0.13
CaO	0.32	0.33	0.34	0.35	0.34	0.03
NiO	0.23	0.22	0.24	0.21	0.22	0.03
Na_2O	0.00	0.00	0.01	0.01	0.00	0.01
K_2O	0.00	0.00	0.01	0.01	0.00	0.01
Total	100.00	100.00	100.00	100.00	100.00	0.00
Fo	85.0	84.5	84.3	84.7	84.6	0.58

Table D8.1e:

Appendix D9: Normalized MI trace element concentrations to 100 μm-sized MI

MI ID$_{M14}$	M14-1	M14-12	M14-13	M14-14	M14-2	M14-3	M14-4	M14-5
Host Rock	Pd6	Pd6	Pd6	Pd6	Pd6	Pd6	Pd12	Pd12
Size (μm)	100x50	100x80	100x80	75	80	125	75	125x150
n	1	1	1	1	1	1	1	1
Type	N (I)	E (II)	N (II)	E (II)	N (II)	N(I)	N (II)	N (I)
Trace element content normalized to 100 μm-sized MI (pg)								
Ti	13238.90	2139.90	3411.02	536.92	14752.50	4728.06	56175.99	15299.03
Rb	4.68	2.09	3.80	1.79	3.35	2.39	25.38	8.81
Sr	181.27	17.91	47.30	17.43	176.53	77.42	675.32	204.97
Y	40.44	3.39	6.84	2.87	43.09	17.89	148.41	43.13
Zr	128.91	19.22	19.89	42.41	152.17	43.83	481.24	117.17
Nb	-	4.52	4.42	16.10	-	-	9.77	-
Ba	119.58	26.47	52.62	26.67	79.83	62.57	127.90	906.33
La	4.19	1.05	0.79	0.94	4.51	1.44	16.19	3.91
Ce	12.16	2.38	1.77	2.57	13.03	4.60	64.72	13.43
Pr	2.01	0.36	0.24	0.04	2.21	0.60	7.61	2.58
Nd	11.14	1.18	2.25	0.79	10.76	4.46	45.68	10.87
Sm	3.99	0.28	0.59	0.12	3.82	1.77	13.91	3.54
Eu	1.73	0.24	0.25	0.10	1.62	0.62	6.09	1.63
Gd	5.15	0.50	0.75	-0.01	5.40	1.77	19.07	4.81
Dy	6.18	0.40	1.04	0.39	6.11	2.45	22.79	6.54
Er	4.03	0.30	0.63	0.34	4.44	2.02	15.03	4.72
Yb	5.21	0.32	0.83	0.62	5.50	2.43	17.24	5.76

Table D9.1: Trace element concentrations are obtained by double focusing magnetic sector field ICPMS at AHIGL (Department of Earth Sciences, Durham University). Here the concentrations are normalized to a 100 μm-sized MI (pg). See also Table 4.10.

Appendix D9: Continued

MI ID_{M14}	M14-31	M14-21	M14-20	M14-6	M14-7	M14-8	M14-9	M14-10
Host rock	Pd12	Pd12	Pd12	Pd23	Pd23	Pd23	Pd23	Pd23
Size (μm)	Zone	Zone	Zone	40x80	40x80	100x80	100	50x70
Number of	M	M	M	1	1	1	1	1
Type	N (II)	N (II)	N(I)	E (I)	E (I)	E (II)	N (II)	E (?)
Trace element content normalized to 100 μm-sized MI (pg)								
Ti	1763.36	1764.57	1219.55	11975.51	12590.68	4112.52	2869.47	4273.58
Rb	0.85	5.41	-0.29	3.85	5.54	6.79	3.19	3.25
Sr	20.61	47.98	11.14	157.21	127.86	91.35	11.51	38.68
Y	6.82	7.46	3.91	28.74	22.56	11.23	3.68	4.77
Zr	17.33	22.67	-	67.54	88.38	48.04	2.95	-
Nb	2.94	9.56	7.72	-	2.71	17.03	13.08	4.09
Ba	28.58	34.91	9.34	79.72	39.88	75.43	13.54	43.69
La	0.60	1.03	0.48	4.82	4.07	2.96	0.29	0.97
Ce	1.44	2.46	0.05	13.63	18.05	6.75	1.30	4.91
Pr	0.36	0.24	0.03	1.52	1.33	0.84	0.08	0.27
Nd	1.24	1.40	0.42	10.78	6.90	4.24	1.00	1.90
Sm	1.06	0.83	0.10	2.53	2.21	1.43	0.40	0.48
Eu	0.04	0.19	0.13	1.01	1.06	0.66	0.15	0.17
Gd	0.25	0.43	0.12	3.80	2.75	1.47	0.46	0.54
Dy	0.92	1.01	0.57	4.22	3.80	1.63	0.18	0.74
Er	0.73	0.74	0.40	2.92	2.58	1.13	0.34	0.54
Yb	1.31	1.31	0.86	3.27	2.65	1.20	0.75	0.74

Table D9.1: Continued

Appendix D9: Continued

MI ID_{M14}	M14-11	M14-23	M14-22	M14-25	M14-24	M14-34	M14-32	M14-33
Host rock	Pd23	Pd26	Pb26	Pd26	Pd26	Pd26	Pd26	Pd26
Size (µm)	75	60	40	Zone	70	Zone	75	70
Number of	1	1	3	M	1	M	1	1
Type	E (II)	N (II)	N (II)	E (I)	E (II)	N (II)	N (II)	N (II)
Trace element content normalized to 100 µm-sized MI (pg)								
Ti	722.58	1328.78	4797.14	41488.85	2239.99	8138.22	1465.62	1096.16
Rb	1.39	0.67	0.64	5.29	0.45	3.41	0.70	0.23
Sr	23.29	16.70	11.39	561.68	35.58	66.89	30.35	19.67
Y	2.99	4.11	4.03	109.45	5.47	14.71	4.32	1.33
Zr	14.60	26.36	1.29	389.68	9.11	95.43	-	-
Nb	9.76	-	19.27	34.13	12.37	6.72	6.90	8.14
Ba	28.64	35.77	29.22	210.86	24.38	36.16	12.45	12.29
La	0.73	0.81	0.24	21.57	1.46	2.91	25.14	0.01
Ce	5.07	8.35	0.70	51.25	3.22	3.82	5.45	0.75
Pr	0.25	0.13	0.24	6.50	0.35	0.68	2.75	-
Nd	1.25	1.31	0.85	37.49	1.89	2.88	7.23	0.22
Sm	0.45	0.72	0.23	10.87	1.13	1.20	0.87	0.60
Eu	0.18	0.15	0.11	4.43	0.25	0.35	0.23	0.05
Gd	0.24	0.42	0.23	14.68	0.72	0.88	0.51	0.08
Dy	0.36	0.55	0.58	16.98	0.96	1.99	0.72	0.16
Er	0.27	0.35	0.43	10.88	0.46	1.63	0.52	0.16
Yb	0.30	0.48	0.69	12.21	0.74	2.82	0.50	0.23

Table D9.1: Continued

Appendix D9: Continued

MI ID$_{M14}$	M14-26	M14-35	M14-36	M14-29	M14-37	M14-38
Host rock ID	Pd66-1	Pd66-2	Pd66-2B	Pd66-3	Pd66-2	Pd66-3
Size (μm)	160	60	60	225	Zone	Zone
n	1	2	2	1	M	M
Type	E (I)	N (I)	N (II)	E (I)	E (I)	E (I)
Trace element content in ppm recalculated to 100 μm sized MI						
Ti	22858	2422	1516	31436	535885	26195
Rb	9.04	1.71	0.86	13.84	3.54	1.48
Sr	337.78	47.81	44.51	430.11	791.23	513.48
Y	71.95	6.68	7.90	52.02	121.47	80.00
Zr	203.80	4.58	29.80	264.00	432.83	236.49
Nb	10.57	6.69	4.49	22.50	3.43	14.69
Ba	168.53	20.24	24.21	152.17	193.73	108.73
La	14.60	1.17	1.02	11.34	23.43	16.29
Ce	34.76	2.67	4.93	31.74	59.43	34.76
Pr	4.73	0.38	0.59	3.63	7.52	4.81
Nd	24.16	2.18	1.76	17.32	38.14	24.98
Sm	7.37	1.26	0.86	5.44	11.21	7.44
Eu	2.75	0.19	0.22	2.18	4.60	2.91
Gd	9.53	0.56	0.76	6.95	15.77	10.15
Dy	11.27	0.85	0.85	7.75	19.28	12.35
Er	6.90	0.69	0.73	4.85	11.44	6.79
Yb	7.70	0.80	1.04	5.22	12.21	7.43

APPENDIX E

Contents of Appendix E

Appendix E1: Conference abstracts

Kent, A. J. R., **Harlou, R.** & Peate, D. W. (2003): Volatile-rich slab-derived fluxes in back-arcs: Insights from melt inclusions and glasses from the Valu Fa ridge, Lau Basin. (SOTA 2003 Conference abstract, http://terra.rice.edu/sota/sotaabstracts.html)

Harlou, R., Kent, A. J. R., Breddam, K., Davidson, J. P. & Pearson, D. G. (2003): Origin Of Extreme $^3He/^4He$ Signatures In Icelandic Lavas: Insights From Melt Inclusion Studies. Eos Trans. AGU, 84(46), Fall Meet. Suppl., Abstract V32A-1006. (**See poster I in Appendix E2**)

Harlou, R., Bernstein, S., Brooks, C. K., Pearson, D. G. & Davidson, J. P. (2004): The origin of the extreme Ti-rich melilitites and nephelinites of the Nunatak Region ~ 74°N in Northeast Greenland: Preliminary insights from melt inclusions. (Kent Brooks symposium 2004 abstract)

Harlou, R., Kent, A. J. R., Breddam, K., Davidson, J. P. & Pearson, D. G (2004): Origin Of Extreme $^3He/^4He$ Signatures In Icelandic Lavas: Insights From Melt Inclusion Studies. Geochim. Cosmochim. Acta, 68 11S, A579.

Harlou, R., Pearson, D. G., Nowell, G. M, Davidson, J. P. & Kent, A. J. R. (2005): Sr isotope studies of melt inclusions by TIMS. Geochim. Cosmochim Acta vol 69/10S, A380. (**See poster II in Appendix E2**)

Davidson, J., Morgan, D., Chertkoff, D., Font, L., Jerram, D., **Harlou, R.** & Martin, V. (2006): New perspectives in understanding magma sources and differentiation. (VMGS abstract 2006)

Harlou, R., Pearson, D. G., Davidson, J. P., Kamenetsky, V. S. and Yaxley, G. M. (2006): Source variability and crustal contamination of the Baffin Island picrites – coupled Sr isotope and trace element study of individual melt inclusions. Geochimica et Cosmochimica Acta Supplement 1, Vol. 70, Issue 18, supplement 1, page 11.

Volatile-rich components in back-arcs: Insights from melt inclusions and glasses from the Valu Fa ridge, Lau Basin

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We present the results of an ongoing investigation of volatile, major and trace element abundances in melt inclusions and matrix glass from primitive lavas erupted along the Valu Fa Ridge, southern Lau Basin. The chemical and isotopic compositions of back arc lavas provide important information regarding the role of slab-derived fluxes in convergent margins and the evolution of slab and mantle source components during subduction. Many back arc magmas are also erupted in submarine environments at higher confining pressures than subaerial lavas from arc fronts, and thus may be particularly useful for investigating volatile element fluxes and for elucidating the important roles these elements play in mass transfer and arc magma genesis (e.g. Stolper and Newman, 1994; Kent et al., 2002). The study of melt inclusions provides a useful extension of this work. Melt inclusions in early-formed phenocryst phases are typically less affected by low pressure fractionation and/or crustal assimilation, and preserve more primitive magma compositions than erupted lavas. Inclusions may also trap melts before final melt aggregation and thus preserve a broader range of primitive melt compositions, including those that are petrologically interesting, but may have relatively poor preservation potential during aggregation. Finally, even though they are erupted underwater, many volatile-rich back arc magmas are still volatile-saturated at the pressures of eruption (Newman et al., 2000). Melt inclusions trapped at higher confining pressures may preserve abundances of volatile elements closer to primitive, pre-degassing levels. The Lau Basin, and in particular the Valu Fa Ridge, is recognized as an excellent natural laboratory for studying the relationship between subduction and back arc magmatism, although much of the previous work has been conducted on whole rock or matrix glass compositions.

Olivine- and clinopyroxene-hosted melt inclusions from three lavas from the Valu Fa Ridge were analyzed by EMPA, SIMS and LA-ICP-MS for major, volatile (H_2O, CO_2, Cl, S, F) and trace element compositions (LILE, HFSE, REE). The chemical and isotopic composition of the host lava samples are well known from previous studies (e.g. Peate et al., 2001; Kent et al., 2002). All lava samples have relatively high matrix glass MgO contents (>7 wt.%) and compositions consistent with significant contributions from a slab-derived fluid component (e.g. Ba/Nb 130-355; H_2O 1.2 – 1.3 wt.%, Cl ~ 700 ppm). Olivine and clinopyroxene phenocrysts that host inclusions have Mg# between 0.82 – 0.88, suggesting that they preserve melts trapped at the relatively early stages of magmatic differentiation (host glasses are in equilibrium with olivine with Mg# ~ 0.79 – 0.83). Melt inclusions in olivine phenocrysts range in size from ~30 - > 200 μm, are naturally glassy, and are characterized by an unusual absence of shrinkage bubbles. Clinopyroxene-hosted inclusions typically contain shrinkage bubbles (occupying ~10-20 volume% of the inclusion) and plagioclase daughter crystals.

Appendix E1: Continued

Melt inclusions from Valu Fa lavas are more primitive than host lavas, with MgO contents (corrected for host crystallization) of 8-12 wt.%. Inclusions also show considerable variation in volatile element and LILE abundances (e.g. Cl 600-4500 ppm, S 200-1600 ppm, K_2O 0.1-0.4 wt.%). Using a simple flux melting model the calculated Cl/K_2O slab (the Cl/K_2O ratios of slab-derived material added to the mantle wedge) varies from 0.2-0.7 for melts trapped in inclusions (Fig. 1). Large variations in this ratio are also evident in inclusions from other arc and back-arc suites, suggesting that the composition of slab-derived inputs to arc and back arc magma systems not only vary within and between different arc and back-arc systems, but also within individual arc melting systems. We also note that even larger compositional variations are observed in inclusions from Valu Fa seamounts (Kamenetsky et al., 1997) compared to samples from this study taken from the ridge, mirroring the large compositional diversity observed at off-axis seamounts along mid-ocean ridges. Overall the inferred slab-fluid heterogeneity may reflect: (1) changes in the composition of the slab flux over short spatial or temporal scales (heterogeneity must occur on scales smaller than the melting region, but large enough to be manifest in individual melt batches); and/or (2) variations in fluid composition induced during fluid transport within the mantle wedge.

References: Kamenetsky, V. S. et al. 1997 EPSL 151, 203-233; Kent, A.J.R. et al. 2002 EPSL 361-377; Newman, S. et al. 2000 GGG 1 1999GC000027; Peate, D.W. 2001, J. Pet. 42, 1449-1470; Stolper, E.M. & Newman, S. 1984 EPSL 121, 293-325.

The origin of the extreme Ti-rich melilitites and nephelinites of the Nunatak Region ~ 74°N in Northeast Greenland: Preliminary insights from melt inclusions

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Melt inclusions represent droplets of melt entrapped during the growth of a crystal, and thus provide samples of the melt compositions present during the growth of the particular crystal phase. In this study we report analyses of the major, volatile (Cl, S) and trace element compositions of melt inclusions hosted in olivine phenocrysts from Tertiary alkaline ultrabasic lavas from the Nunatak Region at ~74°N in Northeast Greenland. The Nunatak lavas are highly alkaline and range from melilitite, nepehelinite to basanite - notable are extreme melilitite compositions with up to 8.8 wt% TiO_2. The compositions of melt inclusions provide new insights into the origin of such extreme compositions. Inclusions were examined from two olivine phyric lavas - a Ti-rich melilitite and a nephelinite. These two lavas represent two of the major melt types present within the Nunatak lavas. Melt inclusions compositions advocate the existences of an additional enriched component in the source region of these lavas, such as a packet of recycled oceanic lithosphere.

Previous studies of the Nunatak lavas show that:

- These lavas formed during a short magmatic event at 50 Ma shortly after the continental breakup and the formation of the East Greenland flood basalts. Eruption of the Nunatak lavas occurred some 200-300 km west of the line of continental breakup.

- Lavas types range from melilitites through nephelinites and basanites to more evolved composition such as basalts, trachybasalts and basaltic trachyandesites. The melilitites are dominantly olivine phyric, the nephelinites contain olivine plus clinopyroxene, whereas more evolved lavas contain olivine, clinopyroxene, ±plagioclase, and ±amphibole. The groundmass assemblages are dominated by clinopyroxene plus microlites of oxides and plagioclase is present in the groundmass of the more evolved lavas. In addition phlogopite is also abundant in the melilitites and some nephelinites, whereas perovskite is only observed in the meliltites.

Appendix E1: Continued

- Whole rock major and trace element data show large chemical variation. Overall, the chemistry of the Nunatak lavas is distinctly different from the East Greenland flood basalts by at a given MgO-content having much lower SiO_2 and Al_2O_3 significantly higher FeO_{total} and TiO_2, and also higher CaO, K_2O, and Na_2O. These lavas also have extremely high levels of incompatible elements. Primitive mantle normalized multi element diagrams are characterized by depletion of the most incompatible elements Cs, Rb, Ba, Th, U, and K relative to the more compatible elements such as Nb, La, and Ce. Also Pb, Sr and P are depleted compared to the neighboring REE, and some lavas have positive Ti-anomalies whereas others have negative Zr-anomalies.

- Corrections for olivine (±clinopyroxene) fractionation to melt compositions in equilibrium with residual mantle olivine with 3500 ppm Ni suggests there were several different primary melt types among the Nunatak lavas. Examination of melt modifying processes suggests that these do not explain the overall chemical variation observed among these lavas. These contrasts are more likely due to heterogeneities in the source region rather than variation in the melting systematic.

Insights from melt inclusions:

The range of compositions of olivine phenocrysts from the nephelinite and Ti-melilitite samples are distinctly different. The olivine from the nephelinite sample ranges widely from Fo75 to Fo89, whereas the melilitite shows a narrower range from $Fo_{83.4}$ to $Fo_{86.5}$. Overall, the major element compositions of the melt inclusions overlap those of the whole rocks, but also extend to more extreme compositions. The TiO_2-content of the melt inclusions from the melilitite are as high as 13.5 wt% (about twice as high as the whole rock), whereas inclusions from the nephelinite have TiO_2-contents lower than 6 wt%. The melilitite melt inclusions also have lower FeO_{total} at a given MgO-content compared to the nephelinite population, but much higher K_2O and Na_2O. S and Cl are typically quite high in these melt inclusions – up to 5300 ppm and 3500 ppm in melilitite and nephelinite hosted inclusions.

The trace element concentrations of the melt inclusions are also typically higher than their respective host lavas, and the melilitite inclusions sample the most enriched compositions. The REE-patterns and primitive mantle normalized multi element diagrams of melt inclusions from the two samples are similar to their host lava, though shifted towards higher values. The lower concentrations of incompatible trace elements in the host lavas can be explained by accumulation of olivine in the host lava. Variations within the melt inclusion populations could also reflect various degree of olivine fractionation from a primary melt.

The major and trace element systematic suggests that the lavas are generated by low degree of melting within the stability field of garnet - thus indicating a high pressured mantle melting regime. The concentrations of incompatible elements in the Nunatak lavas are higher by an order of magnitude than melts produced by aggregated melting of a garnet peridotite with a primitive mantle signature. This suggests the existence of an additional enriched component in the source region of these alkaline lavas, such as recycled oceanic lithosphere. It is suggested that the alkaline Nunatak lavas were generated by melting of packets of recycled oceanic lithosphere present in the ancestral Iceland mantle plume, and variation of melting conditions resulted in a spectrum of different alkaline melt types – such as Ti-rich melilitite, melilitite, and nephelinite. It is further suggested that the small degree alkaline melts rapidly ascended through existing weaknesses in the lithosphere, perhaps aided by low viscosity and/or high volatile contents. Rapid ascent is consistent with the low observed degree of contamination by crustal rocks.

Origin of Extreme $^3He/^4He$ Signatures in Icelandic Lavas: Insights from Melt Inclusion Studies

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Helium isotopes are considered a powerful tool for tracking different mantle domains. Yet, the origin of He isotope variations in many basaltic suites remains enigmatic and often difficult to link with more lithophile chemical and isotopic tracers. One problem is that He isotope ratios are measured from crushed olivines and thus reflect prior fluid and melt fluxes trapped in inclusions within the olivine grains, whereas the lithophile elements mainly reflect the host lava. In an attempt to link He and lithophile element variations, we have characterized the major and trace element composition including volatile elements, of olivine-hosted melt inclusions from three ankaramitic lavas from Vestfirdir, NW-Iceland.

Previous studies have reported extreme $^3He/^4He$ ratios from NW-Iceland and one ankaramite (SEL97) has been suggested to provide the most precise estimate of the radiogenic (Sr-Nd-Pb) isotopic composition of a relatively undegassed (high $^3He/^4He$) mantle component (C or FOZO) common to several ocean islands (Hilton et al. 1999, EPSL 173, 53-60). The samples investigated here exhibit amongst the highest $^3He/^4He$ ratios observed in terrestrial rocks (42.9 and 34.8 R/R_a). A detailed account of the trace element signature of melt inclusions in these samples may thus help explain the origin of FOZO. One sample of similar composition to these, has a lower He content and a relatively poorly defined He isotope composition of 8.15 +/- 5.1 R/R_a (Breddam & Kurz, 2001, EOS, 82, F1315).

In terms of major elements, the whole rock data reflect olivine accumulation, whereas the melt inclusion data reflect ol + cpx fractionation. The melt inclusions are generally basaltic (Mg#: 52-62), with primitive mantle normalised trace element concentrations that are broadly parallel the host lavas. There is little compositional difference between melt inclusion populations from high and low $^3He/^4He$ lavas, although inclusions of the low $^3He/^4He$ lava have lower S and moderately lower Cl. The observed range of trace element ratios: $[La/Sm]_N$ 1-4, $[La/Yb]_N$ 1-5, Sr/Nd 14-24, Ba/Rb 9-23, and Ce/Pb 5-46, covers much of the range observed in Icelandic alkali basalts.

The compositional similarities between inclusions and host lavas suggest that bulk rock compositions are petrogenetically related to the melts sampled by melt inclusions. If He predominantly resides in these inclusions, it suggests that the whole rock composition is an aggregate derived from the same melts that contain the measured He.

Origin of Extreme $^3He/^4He$ Signatures in Icelandic Lavas: Insights from Melt Inclusion Studies

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The variation in He-isotopes in many basaltic suites remains enigmatic and often difficult to link with lithophile chemical and isotopic tracers. One problem is that He-isotopes, commonly measured from crushing olivine separates, reflect the composition of fluids and melts trapped within the olivine grains, while the lithophile elements measured in glass or bulk rock reflect the composition of the host lava. Previous studies from NW-Iceland have reported extreme $^3He/^4He$ [1], [2]. SEL97 (ankaramite) is suggested to provide the most precise estimate of the Sr-Nd-Pb isotopic ratios of a relatively undegassed (high $^3He/^4He$) mantle component (FOZO) [1]. To link He-isotope and lithophile element variations, we characterize major, volatile and trace element compositions of olivine-hosted melt inclusions from 3 ankaramitic lavas from Vestfirdir, NW-Iceland. These samples exhibit amongst the highest $^3He/^4He$ observed in terrestrial rocks (42.9 and 34.8 R/R_a). Host lavas and melt inclusions are basaltic (Mg# 52-62). Melt inclusions have higher trace element concentrations than host lavas but parallel REE-patterns. ΔNb of the melt inclusions from a single lava span a large range from -0.08 to 0.45 (most >0) with $(La/Sm)_N$ from 0.65 to 2.65. This contrasts with negative ΔNb and $(La/Sm)_N$ <1 for the high $^3He/^4He$ Baffin Island basalts [3]. Major and trace element systematics suggest that each melt inclusion population and their host lavas are related by a combination of accumulation and fractionation of olivine and clinopyroxene. Variations in incompatible trace element ratios within each melt inclusion population reflect variations in the degree and depth of melting. Lack of fluid inclusions in the olivine phenocrysts suggests that these melt inclusions are the major host of He, suggesting that the trace element signatures and He-isotopes in these lavas derive from the same mantle source. Strong links between melt inclusion and whole rock chemistry could also imply that the extremely high $^3He/^4He$ and FOZO-like Sr-Nd-Pb isotopic compositions originate in the same lower mantle source.

References

[1] Hilton D.R., Gronvold K., Macpherson K., and Castillo P.R. (1999). EPSL 173, 53-60.

[2] Breddam K. and Kurz M.D. (2001) EOS 82, F1315.

[3] Stuart F.M., Lass-Evans S., Fitton, J.G., and Ellam R.M. (2003) NATURE 424, 57-59.

Sr isotope studies of melt inclusions by TIMS

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In-situ measurements by SIMS have revealed considerable variation in the Pb isotope compositions of melt inclusions from single magmas (Saal et al. 1998). Variations among such inclusions have important implications for melt aggregation processes and source variations. To examine further the potential for isotopic studies on melt inclusions we focus on Sr isotope compositions of olivine hosted melt inclusions found in the extreme (high) $^{3}He/^{4}He$ picrites of Vestfirdir (NW Iceland).

Our previous study of the major, trace, and volatile element systematics of these melt inclusions and their picritic host lavas suggests that melt inclusions and lavas are related by a combination of accumulation and fractionation of olivine and clinopyroxene. Furthermore, the variations in incompatible trace element ratios within each melt inclusion population reflect either (1) variations in the degree and depth of melting or (2) originate from a heterogeneous mantle source. We aim to test these alternative hypotheses using high precision Sr isotope analyses on the melt inclusions.

Melt inclusions hosted in the olivine phenocrysts range in size between 50 and 150 μm and have Sr concentrations (by LA-ICPMS) of 200 to 700 ppm. Such melt inclusions should have total Sr contents of 0.04 to 4 ng. Preliminary experiments carried out on whole olivine grains containing visible melt inclusions show the potential for analyzing single grain and possibly single melt inclusions for high precision $^{87}Sr/^{86}Sr$ (50 to 100 ppm 2-sigma internal errors).

Using miniaturized micro-Sr chemistry techniques based around Sr spec resin (Charlier et al., in prep.), this technique gives total procedural blanks as low as 3 pg, enabling the analysis of sub- 0.5 ng samples. Samples are run using a TaF5 activator using a Triton TIMS.

A.E. Saal, S.R. Hart, N. Shimizu, E.H. Hauri, and G.D. Layne (1998), Science Vol. 282 pages 1481-1484.

New perspectives in understanding magma sources and differentiation

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Geochemists, petrologists and volcanologists all want to know how magma systems work. For the most part our approach involves interrogating the rocks that are formed by igneous processes, using a diverse array of analytical tools. Elemental and mineralogical studies can be used to constrain processes of differentiation – most of which involve the effects of crystallisation and separation or aggregation of crystals and liquids. Isotope ratios serve as a sort of rock "DNA" enabling us to determine the sources of magmas, such as different mantle or crustal domains. In-situ element data used to inform diffusive models, along with short-lived isotope data, are now shedding light on the timescales of magmatic processes. Integration of all of these approaches is helping us to understand where magmas come from, by what processes they are generated and evolve, and over what timescales. At Durham, this principle underpins the research focus of TiMAG (Textural and Isotopic Micro Analysis Group).

Recent analytical advances have enabled us to determine in-situ isotope ratios, in the context of textural features in individual crystals. A surprising result is that considerable isotopic heterogeneity has been identified among and even within crystals from a single rock. This calls into question the utility of whole rock isotopic data in identifying mantle sources. Core-rim isotopic variation in crystals records the changing composition of the magma as the crystal grew. Processes such as contamination and recharge can be identified – the latter commonly associated with textural features such as resorption horizons. The rims of crystals can be used to ascertain the degree to which crystals have equilibrated with the magma in which they have erupted, which itself is a function of time. An overall view is developing of multi-level open system processing, at least among arc magmas.

Source variability and crustal contamination of the Baffin Island picrites – coupled Sr isotope and trace element study of individual melt inclusions

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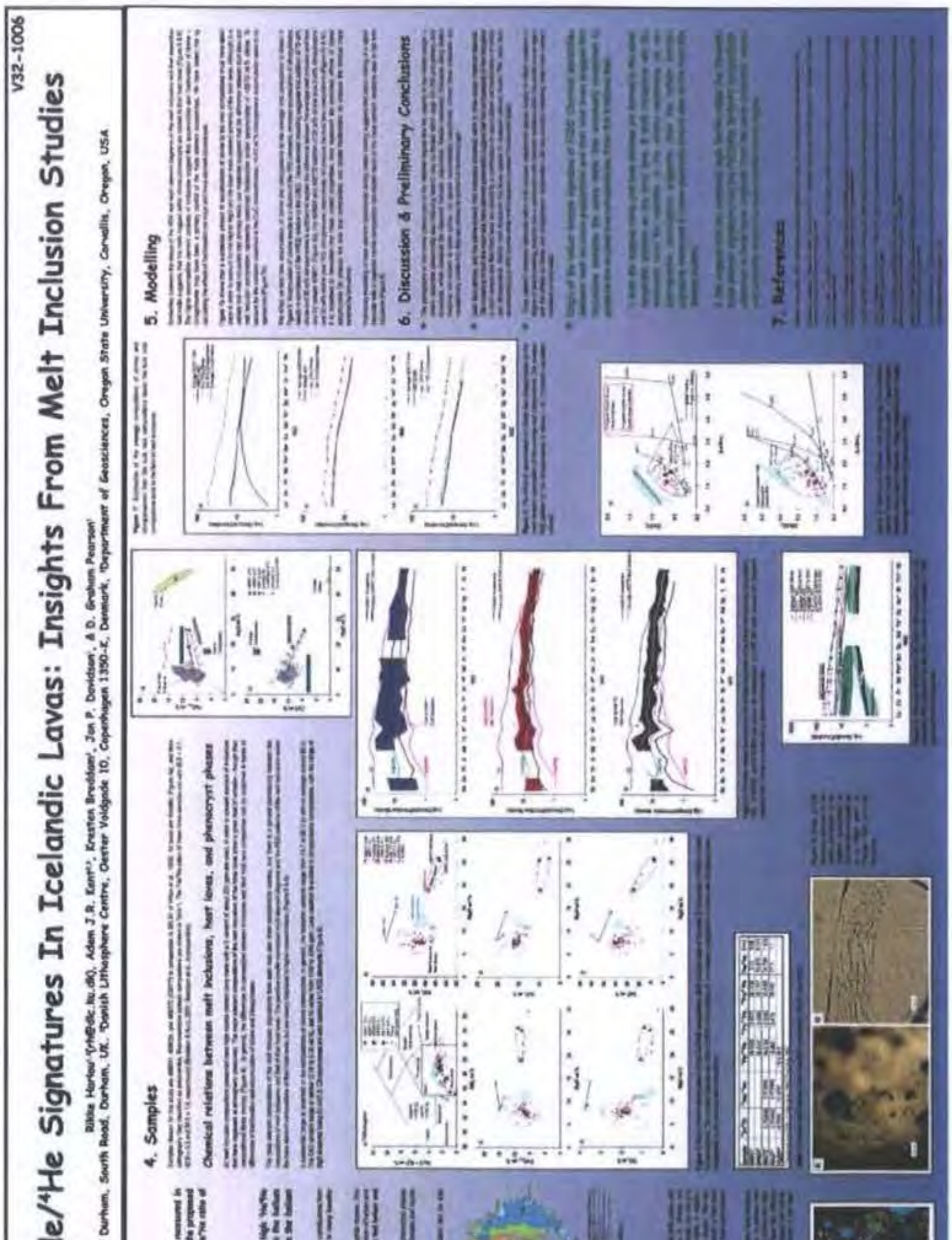
Baffin Island picrites are among the most primitive post-Archean magmas erupted and are thought to have escaped major melt-modifying processes en route to the surface. Recent whole rock geochemical studies show remarkable coherence between radiogenic and He isotopes that infer varying contributions from mantle reservoirs ranging from a high 3He primordial endmember, through "primitive-enriched" material to depleted MORB source mantle [1]. Early-formed olivine-hosted melt inclusions (MIs) may sample undiluted melt fractions from these components prior to melt aggregation and mixing. Sr isotope and trace element measurements of single MIs [2] may thus provide a higher resolution picture of these source contributions. 30 individual olivine-hosted MIs from 5 picrites reveal substantial Sr isotope variations (0.7031-0.7103), which contrast the narrow range of the host picrites (0.7031-0.7037). REE fractionation of MIs [$(La/Sm)_N$ 0.36-2.38] is comparable to the picrites [$(La/Sm)_N$ 0.57-1.09], but $(Rb/Sr)_N$ of the MIs extend to more extreme values (0.1-9.19 vs. 0.04-0.12). Mixing of mantle-derived melts fails to reproduce such elemental and isotopic variations. This suggests, that the Baffin Island MIs witness an overprint of crust that masks the source variations. We derive a model involving interaction of magma with various crustal endmembers to produce a complex spectrum of MI isotopic compositions. This agrees with the model based on trace elements [3]. The extensive nature and complexity of this high level interaction of olivine-hosted MIs suggests that caution should be applied to the interpretation of Sr and Pb isotope variations in oceanic magmas as being solely of mantle origin.

[1] Ellam, R., Stuart, F.. (2004) EPSL 228, 511-523.

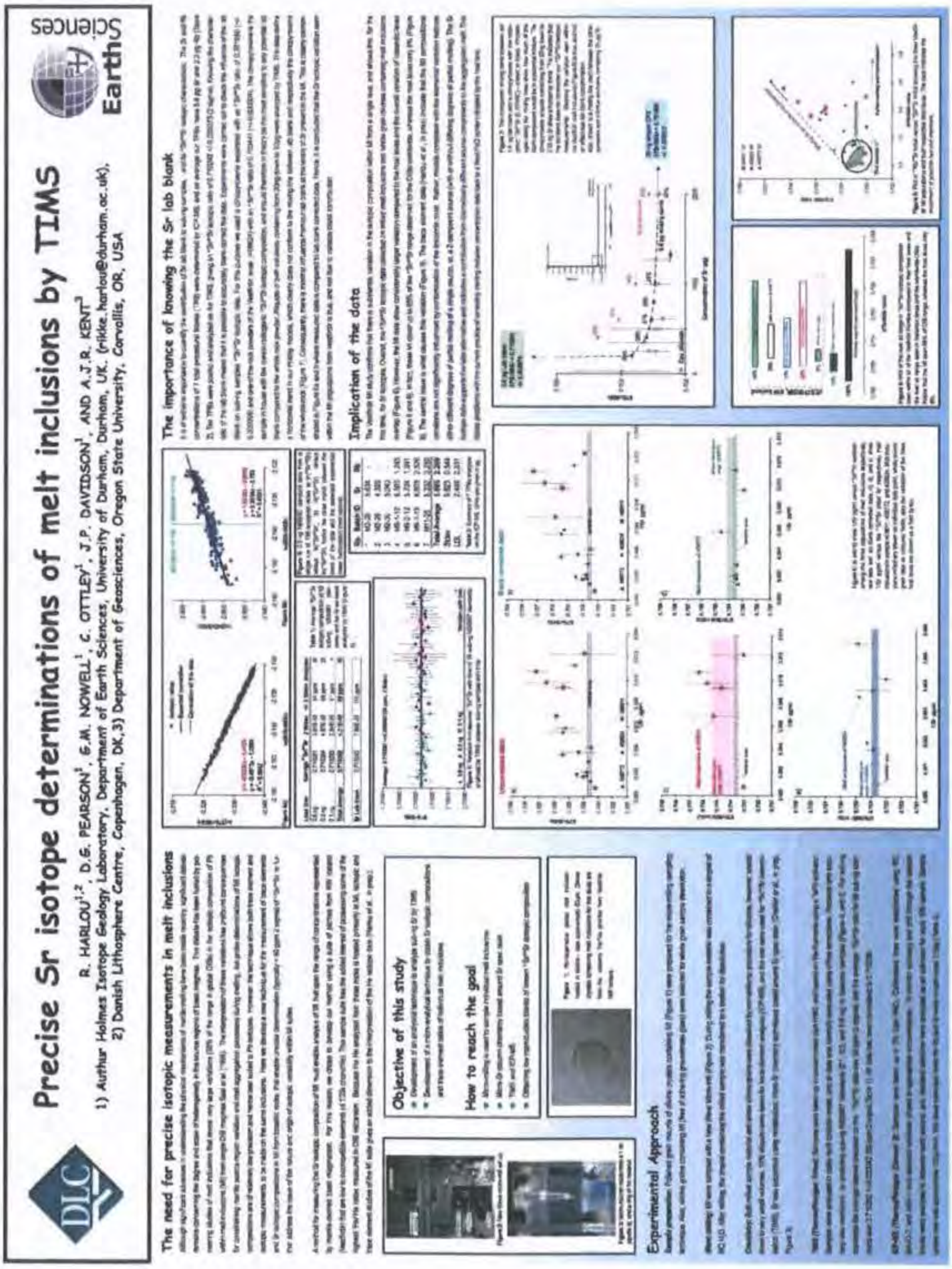
[2] Harlou, R., et al. (2005) GCA, 69/10S, A380.

[3] Yaxley, G., et al. (2004) Contrib Mineral Petrol, 148. 426-442.

Appendix E1: Conference poster I



Appendix E1: Conference poster II



Appendix E3: Scientific papers in press and in preparation

Breddam, K, Stecher, O., **Harlou, R.**, Peate, D.W. & Kurz, M.D. (paper in prep): Miocene high-^{3}He/^{4}He ankaramites in NW-Iceland: Trace element constraints on the common component in mantle plumes.

Davidson, J. P., Morgan, D. J., Charlier, B. L. A., **Harlou, R.**, and Hora, J. M. (in press): Microsampling and isotopic analysis of ignous rocks: Implications for the study of magmatic systems. Annual Review of Earth and Planetary Sciences, 35.

Harlou, R., Kent, A. J. R., Pearson, D. G., Davidson, J. P. & Breddam, K. (in prep): Origin of Extreme ^{3}He/^{4}He Signatures in Icelandic Lavas: Insights from Melt Inclusion Studies.

Harlou, R., Pearson, D. G., Nowell, G. M., Ottley, C. J., & Davidson, J. P. (in prep): Precise and accurate Sr isotope and trace element analysis of melt inclusions at sub-ng levels using micro-milling and TIMS and ICPMS

Harlou, R., Pearson, D. G., Kamenetsky, V. S., Yaxley, G. M., Davidson, J. P., & Jackson, G. (in prep): Source variability and crustal contamination of the Baffin Island picrites – coupled Sr isotope and trace element study of individual melt inclusions.

Harlou, R., Pearson, D. G., Davidson, J. P., Kent, A. J. R. (in prep): Substantial Sr isotope heterogeneity revealed by olivine-hosted melt inclusions from NW Iceland.